Appendix E

Heat Pipe Performance Uncertainty Analyses

McCoy, D. C., "Milliken Station Heat Pipe Air Heater Performance Uncertainty Analysis," CONSOL R&D Report to NYSEG, New York State Electric & Gas Corporation, Binghamton, New York, June 1995.

Maskew, J. T., "Milliken Station Heat Pipe Air Heater Performance Uncertainty Analysis of "Totally Corrected Gas Temperature Leaving The Air Heater"", CONSOL R&D Report to NYSEG, New York State Electric & Gas Corporation, Binghamton, New York, April 1996.

MILLIKEN STATION HEAT PIPE AIR HEATER PERFORMANCE UNCERTAINTY ANALYSIS

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Milliken Station Heat Pipe Air Heater
Performance Uncertainty Analysis

This report documents the heat pipe performance uncertainty analyses done by CONSOL R&D. The uncertainty analyses were requested by ABB Air Preheater Inc., ABB API, and New York State Electric & Gas Corporation, NYSEG, as part of the performance testing program. The results indicate that for the two areas of most concern, i.e., the flue gas outlet temperature measurement and the percent air leakage, the measurement errors will be small. For the heat pipe operating at the design outlet temperature of 253 °F, the measured outlet temperature uncertainty is likely to be less than about 2.6 °F. The air leak uncertainty is likely to be less than 1.6 wt %.

Uncertainty Calculations ABB API requested that overall uncertainty analyses be calculated for:

1. Weighted average temperature for each traverse plane
2. Air and gas flows
3. Air-to-gas leakage rate.

The analysis is to develop performance test tolerance criteria which can be agreed to by NYSEG and ABB API.

The uncertainty analysis is a method of estimating the potential error in a result caused by errors in measured parameters. Errors fall into two catagories, bias or fixed errors and random errors. Bias errors remain constant during a test and cannot be reduced by repeated measurement of a parameter. However, if the cause of the bias is known, the bias can sometimes be accounted for and eliminated. Instrument signal off set is one type of bias error which can be eliminated by calibration.

Random errors are errors which can be reduced by repeated measurement. Measurement fluctuations due to changes in personnel, environmental fluctuations, instrument noise etc. represent types of random errors.

The ASME procedure for calculating uncertainty recommends that sources and levels of bias and random errors be identified.[1] These errors are propagated separately through the calculation procedure to the final result. The error propagation is calculated by Taylor Series expansion of the result function. In general, if $r = f(x_1,...x_i,....x_n)$ then the error statistics, S_r, for bias and random errors are each calculated separately by applying:[2]

$$S_r = \left(\sum_{i,j=1}^{n} \frac{\partial f}{\partial x_i} \frac{\partial f}{\partial x_j} \sigma_{x_j} \sigma_{x_i} \right)^{1/2} \tag{1}$$

Where:

$\frac{\partial f}{\partial x_i}, \frac{\partial f}{\partial x_j}$ = *Partial Derivatives of f With Respect to x_i and x_j*

$\sigma_{x_i}, \sigma_{x_j}$ = *Error Standard Deviations*

When parameters are independent only the i = j terms are significant. The cross product terms i ≠ j are zero. However, when parameters are not independent (i.e. are linked or correlated) the cross product terms must be considered. An example would be the use of a single thermocouple to measure all temperatures in a traverse plane. The bias associated with the measurements is the same for all points, therefore, there is a 1:1 correlation. Here the cross product terms must be evaluated to obtain the proper bias error statistic.

Depending upon the desired range of coverage (level of confidence) the uncertainty is calculated by:

$$U = \left(B^2 + (tS)^2\right)^{1/2} \qquad (2)$$

Where:

U = *Uncertainty Interval*

B = *Overall Bias Error Statistic*

S = *Overall Random Error Statistic*

t = *Percentile Point For Student t Distribution*

Normally t is selected for 95% coverage. If the random error standard deviations for the primary measurements can be taken to represent the result of a large number of repeated measurments, then t is 1.96 or for simplicity assumed to be 2.0.

Temperature Traverse Uncertainty Calculations The following is a calculation example for uncertainty calculations. Except for the secondary air inlet temperature, which will be obtained by a straight average of 4 thermocouples, all flue gas and air inlet/outlet temperatures will be obtained by pitot/temperature traverses of the ductwork. The average temperatures will be calculated using the formula:

$$T_{avg} = \frac{\sum_{i=1}^{n} A_i V_i \rho_i T_i}{\sum_{i=1}^{n} A_i V_i \rho_i} \qquad (3)$$

Where:

A_i = *Cross Section i Area*, ft^2

i = *Traverse Point Number*

T_i = *Temperature in Center of Area* A_i, °F

V_i = *Gas Velocity in Area* A_i, *fps*

ρ_i = *Gas Density in Area* A_i, lb/ft^3

The gas velocity in each area section, A_i is obtained by:

$$V_i = 85.49CP_i\left(\frac{DP_iT_i}{P_{si}M_i}\right)^{1/2} \tag{4}$$

Where:

CP_i = *Pitot Tube Flow Rate Coefficient, Dimensionless*

DP_i = *Velocity Head In Area* A_i, *In. WC*

P_{si} = *Static Pressure In Area* A_i, *In. Hg Absolute*

M_i = *Gas Mol Wt. In Area* A_i, *lbs/lb-mol*

and the gas density by:

$$\rho_i = \frac{0.04578M_iP_{si}}{T_i} \tag{5}$$

Combining Equations 3, 4, and 5 gives:

$$T_{avg} = \frac{\sum_{i=1}^{n} CP_iA_i(DP_iM_iP_{si}T_i)^{1/2}}{\sum_{i=1}^{n} CP_iA_i\left(\frac{DP_iM_iP_{si}}{T_i}\right)^{1/2}} \tag{6}$$

To obtain sensitivities for the uncertainty calculations, Equation 6 is differentiated with respect to each variable. If we let the SUM1 equal the denominator of Equation 6 and SUM2 the numerator, then the derivatives are:

$$\frac{\partial T_{avg}}{\partial A_i} = \frac{CP_i SUM1 (DP_i M_i P_{si} T_i)^{1/2} - CP_i SUM2 \left(\frac{DP_i M_i P_{si}}{T_i} \right)^{1/2}}{SUM1^2} \tag{7}$$

$$\frac{\partial T_{avg}}{\partial CP_i} = \frac{A_i SUM1 (DP_i M_i P_{si} T_i)^{1/2} - A_i SUM2 \left(\frac{DP_i M_i P_{si}}{T_i} \right)^{1/2}}{SUM1^2} \tag{8}$$

$$\frac{\partial T_{avg}}{\partial DP_i} = \frac{A_i CP_i SUM1 (M_i P_{si} T_i)^{1/2} DP_i^{-1/2} - A_i CP_i SUM2 \left(\frac{M_i P_{si}}{T_i} \right)^{1/2} DP_i^{-1/2}}{2SUM1^2} \tag{9}$$

$$\frac{\partial T_{avg}}{\partial M_i} = \frac{A_i CP_i SUM1 (DP_i P_{si} T_i)^{1/2} M_i^{-1/2} - A_i CP_i SUM2 \left(\frac{DP_i P_{si}}{T_i} \right)^{1/2} M_i^{-1/2}}{2SUM1^2} \tag{10}$$

$$\frac{\partial T_{avg}}{\partial P_{si}} = \frac{A_i CP_i SUM1 (DP_i M_i T_i)^{1/2} P_{si}^{-1/2} - A_i CP_i SUM2 \left(\frac{DP_i M_i}{T_i} \right)^{1/2} P_{si}^{-1/2}}{2SUM1^2} \tag{11}$$

$$\frac{\partial T_{avg}}{\partial T_i} = \frac{A_i CP_i SUM1 (DP_i M_i P_{si})^{1/2} T_i^{-1/2} + A_i CP_i SUM2 (DP_i M_i P_{si})^{1/2} T_i^{-3/2}}{2SUM1^2} \tag{12}$$

To evaluate Equation 1 we must now determine the biases and precision indices (random errors) associated with the measurements. These errors are determined from experiments, literature sources, and experience. Errors and sources are presented in Table 1. Most of the errors were taken from literature sources or were based on experience. The likely bias and sampling errors for the coal

Table 1

Summary of Bias Limits and Precision Indices For Uncertainty Calculations

Parameter	Bias Limit	Random Error (Precision) (1 Standard Deviation)	Comments
Dimensions			
Width	0.5" (0.042')	0.5" (0.042')	Assumed.
Length	0.5" (0.042')	0.5" (0.042')	Assumed.
Temperature	1% of °F Reading	1/2% of deg F Reading	Bias - Typical for Type K TC's; Actual Insturment Accuracy Is 0.1% Of Reading +/- 0.8 deg F; Precision - Typical Error Based on Experience (From ASME PTC 4.1).
Pressure			
Barometric	0.04" Hg	0.04" Hg	Calibrated Aneroid Barometer Readability.
Static	0.05" WC	0.05" WC (0.0037" Hg)	Water Manometer with 0.1" Scale, Readable to 0.05".
Velocity Head, DP	2% of Avg Reading	0.00005" WC	Bias - Instrument Design Specifications; Precision or Random Error - 1/2 Insturment Resolution.
Pitot Factor, CP	0.01	0.0	Calibration Accuracy.
Coal Analysis			
Moisture, Mf	3.9% of Mf	(0.20+0.012*Mf)/(2*1.414)	Bias - Assumed Same As For Ash; Precision - ASTM Analysis Repeatability.
C	3.9% of C	(0.64)/(2*1.414)	Bias - Assumed Same As For Ash; Precision - ASTM Analysis Repeatability.
H	3.9% of H	(0.16)/(2*1.414)	Bias - Assumed Same As For Ash; Precision - ASTM Analysis Repeatability.
N	3.9% of N	(0.11)/(2*1.414)	Bias - Assumed Same As For Ash; Precision - ASTM Analysis Repeatability.
S	1.9% of S	(0.06+0.035*S)/(2*1.414)	Bias - From Washability Data; Precision - ASTM Analysis Repeatability.
Ash	3.9% of Ash	(0.07+0.02*Ash)/(2*1.414)	Bias - From Washability Data; Precision - ASTM Analysis Repeatability.
Carbon In Ash	25% of Ash Carbon	10% of Ash Carbon	Bias - From Unit 2 LOI Data; Precision - Assumed.
Coal Rate, Wfe	5.0% of Wfe	0.25% of Wfe	Bias - Assumed; Precision - Typical Value for Calibrated Scales Based on Experience (Form PCT 4.1).
Gas Analyses			
O2	0.05% Absolute	0.05% Absolute	Bias - Cal. Gas Spec.; Precision - Low O2 Calibration.
CO	20 ppm (0.002%)	10 ppm (0.001%)	Insturment Design Specification.
CO2	0.1% Absolute	3% of Measurement	Bias - Burette Scale Division Readability; Precision - Orsat Error Based on Experience (From PCT 4.1).
Air Moisture	10% of Humidity	20% of Humidity	Bias - Estimate Based on 1 deg F Error In Measured T; Precision - Estimate Based on 2 deg F Error In Wet Bulb.
MW			
Flue Gas	0.05	0.07	Bias & Precision - Uncertainty Analysis Results Based On Composition Bias Limits and Precision Indices for Coal, Ash, and Flue Gas.
Air	0.025	0.05	Bias & Precision - Uncertainty Analysis Results Based On Bias and Precision Errors for Air Humidity.

sulfur and ash analyses were determined from coal washability data based on a method by Gy[3] and illustrated in Bilonick.[4] The method requires ash and sulfur measurements for various size and density fractions. This information was taken from the results of a coal washability study on coal from CONSOL's Bailey Mine which was performed on January 16, 1993. The coal top-size was assumed to be 3/4 inch to be consistant with the Milliken Station sample size. The calculations were performed for sample sizes of 1 lb and 4 lbs. Data were not available to calculate bias errors for the coal moisture (m_f), C, H, and N; so as a conservative estimate, the bias error for these components was assumed to be the same as for the ash. Also to be conservative, large bias errors were assumed for the refuse carbon (carbon in the ash relative 25%) analysis and for the coal feed rate (relative 5%).

Equation 1 can now be evaluated using the biases and random errors listed in Table 1, and Equations 7 to 12 to calculate sensitivitives. A spreadsheet program was developed. The results of this program were later checked using the MAPLE™ relational math computer program. The results of the two programs were essentially identical; indicating that the explicit partial derivatives used in the spreadsheet program were properly evaluated.

The results of the average temperature uncertainty calculations are presented in Appendix A. Bias and random errors in each traverse plane (primary air inlet/outlet, secondary air inlet/outlet, and flue gas inlet/outlet) are included. The traverse bias evaluation includes cross product terms for measured parameters (i.e. T_i with T_j, A_i with A_j, DP_i with DP_j, etc., where $i \neq j$). This accounts for the use of the same equipment to obtain measurements for each point in a traverse. Normally, only one thermocouple will be used for all temperature measurements in a traverse plane; one pressure transducer for all velocity head measurements; one gas analyzer for all gas compositions etc. Therefore, the bias errors associated with the readings are correlated 1:1 for each traverse point. Cross product terms between parameters, such as between temperature and gas composition, or temperature and velocity head, are not included since these parameters are independent of each other.

Table 2 summarizes the uncertainty analysis results for the average flue gas and air stream temperatures around the heat pipe. The major contribution to the uncertainties in the average inlet/outlet temperatures is the bias error of the temperature measuring system. Bias and random errors in the other measured parameters do not contribute to the uncertainty. For the calculations, the bias error is assumed to be 1% of the thermocouple reading in °F. This is based on typical errors cited in the literature.[5] The uncertainty analysis indicates that the estimate of the average flue gas outlet temperature will be only about ±2.6 °F for 95% coverage if the heat pipe operates at the design 253 °F outlet. To reduce this error further, the temperature measuring equipment will be calibrated before testing against a National Institute of Standards and Technology (NIST) traceable thermocouple and potentiometer. The calibration will cover the expected operating range for heat pipe testing.

The input data shown in Appendix A Tables A-1 through A-12 are dummy values for design case conditions. Except for an assumed temperature spacial bias, input data values are constant for each parameter (i.e. A_i, CP_i, DP_i, M_i, Ps_i). A comparison of Tables A-1 with A-13 and A-7 with A-14

Table 2 **Uncertainty Estimates for Average Duct Temperatures Based on Multi-Point Traverses**					
Location	No. of Traverse Points	Operating Temp. °F	Bias Error °F	Random Error °F	Uncertainty °F (1)
Primary Air Inlet	12	80	0.80	0.12	0.84
Primary Air Outlet	20	644	6.44	0.74	6.61
Secondary Air Inlet	4	80	0.80	0.20	0.89
Secondary Air Outlet	24	616	6.16	0.70	6.32
Flue Gas Inlet	20	680	6.81	0.81	6.99
Flue Gas Outlet	24	253	2.53	0.35	2.63
(1) Calculated by Equation 2.					

shows the effect of non-uniform input data on the bias and precision errors respectively. For the weighted averages, the weighting does not significantly affect the overall bias and precision errors of the average result. Because the weighting terms are in the numerator and denominator of the result function and the errors tend to cancel. This shows that use of actual data will have little effect on the estimated uncertainties.

Primary Air Flow Rate Uncertainty Calculations The proposed heat pipe performance test procedure requires direct measurement of the primary air flows exiting each air heater. The flow rates will be determined using the following equation:

$$W_{air} = 14088 CP \sum_{i=1}^{n} A_i \left(\frac{P_{st} M_i DP_i}{T_i} \right)^{1/2} \qquad (13)$$

Since terms A_i, CP, P_{si}, and M_i will be essentially constant for each traverse point, single values can be used for these parameters and Equation 13 can be simplified to:

$$W_{air} = 14088 \cdot A \cdot CP \cdot (P_s M)^{1/2} \sum_{i=1}^{n} \left(\frac{DP_i}{T_i} \right)^{1/2} \qquad (14)$$

Where:

A_i = *Cross Section i Area, ft^2*

CP = *Pitot Tube Flow Coefficient, Dimensionless*

DP_i = *Velocity Head in Center of Area A_i, in. WC*

i = *Traverse Point Number*

M_i = *Air Mol Weight (wet) in Area A_i, lbs/mol*

P_{si} = *Static Pressure in Duct, in. Hg*

T_i = *Temperature in Center of Area A_i, °R*

W_{air} = *Primary Air Outlet Flow, lb/hr*

For test purposes, it is assumed that the primary air inlet flow is equal to the measured outlet flow. However, for the uncertainty evaluation presented here, Equation 14 was evaluated for both the inlet and outlet flows. The inlet flow is through a rectangular duct (3.28'x17.5') while the outlet flow is through a 4' diameter round duct. For these calculations the Maple relational math computer program was used. The program listings and calculated results are presented in Appendices B-1 to B-4.

Table 3 summarizes the 95% coverage uncertainty estimates. The uncertainties for the inlet and outlet primary air flow rates should not exceed about 7% and 5%, respectively. These are conservative results, the actual uncertainty may well be less. In Appendix B the individual contributions due to errors associated with the air humidity, pitot factor, velocity head, temperature, pressure, and traverse area are listed. The largest contributors to the air flow rate uncertainties are the bias and random errors associated with flow area terms. Throughout this analysis, a 1/2" standard deviation was assumed for length, width, and diameter terms associated with the incremental traverse areas. This assumption, when propogated through the incremental area calculations, results in relatively large, conservative, standard deviations for the calculated bias and random errors associated with the traverse areas.

Realistic average pitot velocity heads were assumed for the uncertainty calculations. The slight difference in the inlet and outlet flow rates is a consequence of not adjusting the velocity heads exactly to achieve identical flow rates. This has no effect on the calculated uncertainties.

Table 3 Uncertainty Estimates for Primary Air Streams							
		Bias Error		Random Error		Uncertainty 95% Interval	
Stream	Value lbs/hr	Abs lbs/hr	Rel %	Abs lbs/hr	Rel %	Abs lbs/hr	Rel %
Air In	62300	2060	3.31	1820	2.93	4190	6.72
Air Out	62500	1640	2.61	1300	2.08	3075	4.92

Flue Gas Flow Rate Uncertainty Calculations The flue gas flow to each heat pipe is determined in the following manner:

(1) The inlet flue gas ducts to each heat pipe are pitot tube traversed to obtain temperature, velocity, and gas composition data.
(2) Carbon flow rates as SCFH CO_2 to each heat pipe are calculated from the pitot data.
(3) The carbon burn split to each heat pipe is calculated from the CO_2 flow rates (needed since flue gas flow is calculated as lbs gas/lb AF coal).
(4) Average inlet flue gas compositions to each heat pipe (i.e. $\overline{CO}$, $\overline{CO_2}$, and $\overline{O_2}$) are calculated from pitot probe gas analysis data).
(5) The combustion air rate required to produce the flue gas to each heat pipe is calculated from the coal analysis, ambient air moisture, and dry flue gas analyses.
(6) The flue gas moisture content is calculated from the coal analysis and calculated combustion air rate.
(7) The flue gas rate is then calculated from the coal analysis, average dry gas analysis, flue gas moisture content, coal feed rate, and carbon burn split.

The above procedure is discussed below and appropriate equations presented. Outlet flue gas flows are calculated in the same fashion.

The CO_2 flow rates at standard conditions to each heat pipe are calculated from gas analyse, temperature, static pressure, and velocity traverse data by:

$$FA_{CO_2} = 53{,}488 \sum_{i=1}^{20} A_{FGIi} CP \left(\frac{DP_i P_{si}}{T_i M_i} \right)^{1/2} (1 - M_{FGIi}) CO_{2i} \qquad (15)$$

and

$$FB_{CO_2} = 53{,}488 \sum_{i=1}^{20} A_{FGIi} CP \left(\frac{DP_i P_{si}}{T_i M_i} \right)^{1/2} (1 - M_{FGIi}) CO_{2i} \tag{16}$$

Where:

A_{FGIi} = *Flue Gas Inlet Duct Area For Traverse Point i*, ft^2

CO_{2i} = CO_2 *Concentration In Area* A_{FGIi}, *Vol %*

CP = *Pitot Tube Flow Coefficient, Dimensionless*

DP_i = *Velocity Head In Area* A_{FGIi}, *in. WC*

FA_{CO_2}, FB_{CO_2} = CO_2 *Flow To "A" & "B" Heat Pipes Respectively, SCFH*

i = *Traverse Point Number*

M_i = *Flue Gas Mol Weight (wet) In Area* A_{FGIi}, *lbs/mol*

M_{FGIi} = *Flue Gas Moisture In Area* A_{FGIi}, *Mol Fraction*

P_{si} = *Duct Static Pressure In Area* A_{FGIi}, *in. Hg*

T_i = *Temperature In Area* A_{FGIi}, $^\circ R$

The flow split is then determined by:

$$SA = \frac{FA_{CO_2}}{(FA_{CO_2} + FB_{CO_2})} \tag{17}$$

$$SB = 1.0 - SA \tag{18}$$

Where:

SA = *Flow Split To "A" Side Air Heater, Fraction*

SB = *Flow Split To "B" Side Air Heater, Fraction*

For the uncertainty calculations, the assumption is made that 90% of the fly ash goes overhead in the boiler and that the bottom ash has one-third the carbon level of the overhead. The carbon in the refuse is therefore:

$$C_R = \frac{A \times OVHD \times C_a}{1 - C_a} + \frac{A \times (1.0 - OVHD) \times \frac{C_a}{3}}{1.0 - \frac{C_a}{3}} \tag{19}$$

$$C_b = C - C_R \tag{20}$$

Where:

A = *Coal Ash Content, lbs/lb As Fired (AF) Coal*
C = *Coal Carbon Content, lbs/lb AF Coal*
C_a = *Carbon In Fly Ash, lbs/lb*
C_b = *Coal Carbon Burned, lbs/lb AF Coal*
$OVHD$ = *Fraction Fly Ash To Overhead,* (0.9 *For Calculations*)

The average dry gas compositions to each heat pipe are determined by:

$$\overline{CO} = \frac{\sum_{i=1}^{20} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})CO_i}{\sum_{i=1}^{n} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})} \tag{21}$$

$$\overline{CO_2} = \frac{\sum_{i=1}^{20} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})CO_{2i}}{\sum_{i=1}^{n} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})} \tag{22}$$

$$\overline{O_2} = \frac{\sum_{i=1}^{20} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})O_{2i}}{\sum_{i=1}^{n} A_{FGIi}\left(\frac{DP_i P_{si}}{M_i T_i}\right)^{1/2}(1 - M_{FGIi})} \tag{23}$$

The flue gas moisture mol fraction, M_{FGIi}, and the wet mol weight, M_i, are:

$$M_{FGIi} = \frac{0.055506K_{4i}}{0.055506K_{4i} + 100K_{3i}} \quad (24)$$

$$M_i = \frac{18.016K_{4i} + K_{3i}(288.08CO_{2i} + 71.70O_{2i} + 50481)}{K_{4i} + 1801.6K_{3i}} \quad (25)$$

Where:

$$K_{3i} = \frac{C_b + \frac{12.01S}{32.07}}{12.01(CO_{2i} + CO_i)} \quad (26)$$

$$K_{4i} = 8.936H + Wma\left[\frac{28.02(100 - CO_i - CO_{2i} - O_{2i})K_{3i} - N}{0.7685}\right] + m_f \quad (27)$$

and:

H = *Coal Hydrogen, lbs/lb AF Coal*

K_{3i} = *Constant Equivalent To mols Flue Gas /lb AF Coal/100*

K_{4i} = *Flue Gas Moisture In Area A_{FGIi}, lbs/lb AF Coal*

m_f = *Coal Moisture, lbs/lb AF Coal*

N = *Coal Nitrogen, lbs/lb AF Coal*

S = *Coal Sulfur, lbs/lb AF Coal*

Wma = *Air Humidity, lbs/lb Bone Dry Air*

CO_i = *Flue Gas Carbon Monoxide Level In Area A_{FGIi}, Vol %*

CO_{2i} = *Flue Gas Carbon Dioxide Level In Area A_{FGIi}, Vol %*

O_{2i} = *Flue Gas Oxygen Level In Area A_{FGIi}, Vol %*

To obtain the average flue gas moisture, $\overline{M_{FGI}}$, Equations 26, 27, and 24 are evaluated replacing CO_i, CO_{2i}, and O_{2i} with $\overline{CO}$, $\overline{CO}_2$, and $\overline{O}_2$. Once average values are obtained for the flue gas composition, the amount of combustion air and the moisture in the flue gases are calculated by:

$$W_{AI} = \frac{\dfrac{28.02(100 - \overline{CO} - \overline{CO_2} - \overline{O_2})}{12.01(\overline{CO} + \overline{CO_2})}\left(C_b + \dfrac{12.01S}{32.07}\right) - N}{0.7685} \tag{28}$$

and

$$W_{MGI} = 8.936H + (Wma \times W_{AI}) + m_f \tag{29}$$

Where:

W_{AI} = *Combustion Air Requirement, lbs/lb AF Coal*

W_{MGI} = *Inlet Flue Gas Moisture, lbs/lb AF Coal*

The flue gas inlet rate can be calculated using Equation (30):

$$W_{GI} = \frac{\left(44.01\overline{CO_2} + 32.02\overline{O_2} + 28.01\overline{CO} + 28.02\overline{N_2}\right)\left(C_b + \dfrac{12.01S}{32.07}\right)}{12.01(\overline{CO} + \overline{CO_2})} + W_{MGI} \tag{30}$$

Where:

$\overline{N_2}$ = *Flue Gas Average Nitrogen Level* $(100 - \overline{CO} - \overline{CO_2} - \overline{O_2})$, *Dry Vol %*

W_{GI} = *Flue Gas Inlet Rate (Wet), lbs/lb AF Coal*

In a sumilar fashion, the outlet flue gas rate from each heat pipe is calculated. The Power Test Code[5] (para. 5.4) recommends that the flue gas rates be calculated from the fuel analysis and flue gas composition as shown above. The method yields the pounds of flue gas produced per pound of as-fired fuel. The total flue gas rate is then determined from the product of this calculation and the measured fuel feed rate. Rates in lbs/hr to and from the "A" side heat pipe are:

$$W_{TFGI} = W_{GI} \times W_{fe} \times SA \tag{31}$$

$$W_{TFGO} = W_{GO} \times W_{fe} \times SA \tag{32}$$

Where:

W_{GI} = *Flue Gas Inlet Rate Based On "A" Side Conditions, lbs/lb AF Coal*

W_{GO} = *Flue Gas Outlet Rate Based On "A" Side Conditions, lbs/lb AF Coal*

W_{fe} = *As Fired Coal Rate, lbs/hr*

SA = *Flue Gas Flow Split To "A" Side, Fraction*

Based on the above, the flue gas flow rate calculation is complicated, involving several steps and depending upon a large number of variables. To expidite the uncertainty calculations, the Maple relational math computer program was used. The program input is the series of equations leading to the desired final result. The program then generates a single equation from the series of equations. The single equation is differentiated to obtain the sensitivities. Parameter variances are then separately propogated to obtain the result term bias and random errors. Additionally, for the bias calculations, the program is set up to include covarances for dependent variables.

The computer outputs for the flue gas flow rate uncertainty estimates are presented in Appendices C through H. The reader is cautioned that some printouts contain extraneous calculations which are not needed for the calculation of the specific result shown. For example, the primary air flow and air leak results are shown in the flue gas inlet flow bias error calculation (Appendix G-1). These calculations are superfluous to the flue gas rate calculation. The reason is that program files were copied and modified to suit specific calculation needs. Frequently, not all unrelated calculations were eliminated from a modified file. The reader should be aware that only lines with a right facing carrot (>) are executed by the program. Otherwise, the statement is assumed to be a comment by the program. On some print outs comments have been "penciled in" to help with interpertation.

Some problems exceeded the memory of the PC used (i.e. > 40 Megabytes RAM and 60 Megabytes virtual memory). Examples are the bias and random error calculations for average dry gas compositions where pitot traverses contain more than about 10 or 12 data points. The problem was overcome by extrapolating program results for a small number of traverse points. The bias errors were found to be independent of the number of traverse points and the random errors varied inversely with the square root of the number of data points (a result expected based on the statistics of averaging several measurements[(1)]).

To reduce the complexity of calculating flue gas flow rate bias and random errors, the bias and random errors for the average dry gas compositions were first calculated and then used via error propogation. This was done because of machine memory limitations as mensioned above. Appendix C-1 contains the bias error associated with the average $\overline{CO_2}$ concentration at the inlet of a heat pipe, based on pitot traverses. Two calculations are presented for 2 point and 4 point traverse data. The results show that the bias is independent of the number of traverse points and is equal to the input bias shown in Table 1. Therefore, the biases for $\overline{CO}$ and $\overline{O_2}$ are the same as shown in Table 1.

The random errors associated with the calculation of the average inlet dry flue gas compositions are shown in Appendices D-1 through D-3, and for the outlet compositions in Appendices E-1 through E-3. Appendix D-1 shows the random error associated with the calculation of the inlet dry CO_2 concentration for 8 point and 12 point traverses. Direct calculation of the results for 20 point traverses was not possible because of computer memory limitations. However, as shown in the D-1 Appendix results, extrapolation of the 8 point and 12 point travese results to 20 point, gives the same result.

Appendices F-1 and F-2 present the bias and random errors respectively for the flue gas inlet flows. Appendices G-1 through G-4 are the bias and random error calculations for the flue gas outlet flows. Two cases are presented. Case 1 is for zero air leak into the flue gas, Case 2 is for nominal air leak of 6.9 wt %. Appendices H-1 and H-2 show the bias and random errors associated with the estimate of the flue gas flow split between the heat pipes. The split calculation is included here since it is needed to properly estimate the absolute flow rate to each heat pipe (see Equation 31).

The results of the flue gas flow rate uncertainty calculations are summarized in Table 4. For the flue gas inlet flows, conditions were selected which provided approximately the design flue gas rate of 750,000 lb/hr to each heat pipe. For the flow split calculation, conditions were selected which provided different gas compositions to each heat pipe and approximately a 50/50 gas split between the two heat pipes. The results indicate that the uncertainty in the flue gas flows is less than 6.5% relative and the uncertainty in the flow split is less than 1 % relative.

Table 4
Uncertainty Estimates for Flue Flow Rates
and Inlet Flow Split Between Heat Pipes

		Bias Error		Random Error		Uncertainty 95% Interval	
Stream	Value lbs/hr	Abs lbs/hr	Rel %	Abs lbs/hr	Rel %	Abs lbs/hr	Rel %
Flue Gas In	754,800	47,400	6.28	5,680	0.75	48,700	6.46
Flue Gas Out No Leak	754,800	47,200	6.25	3,460	0.46	47,700	6.32
Flue Gas Out With Leak	806,592	50,458	6.26	3,708	0.46	51,000	6.32
Flow Split to 'A' Side (SA)	51.7%	0.2214%	0.43	0.2175%	0.49	0.49%	0.94

Secondary Air Flow Rate Uncertainty Calculations The primary air flows from the heat pipes will be measured by pitot traverses of the outlet ducts. The secondary air rates will be calculated from a heat balances around the heat pipes. For either heat pipe the secondary air rate is determined by the following equation:

$$W_{SAI} = \frac{W_{FGI}[C_{PFG}(T_{FGI}-T_{FGO})-(AL)C_{PAL}(T_{FGO}-T_{ALI})]-W_{PAO}C_{PPA}(T_{PAO}-T_{PAI})}{C_{PSA}(T_{SAO}-T_{SAI})} \tag{33}$$

Where:

AL = *Fraction Air Leakage, Pounds Air Leak Per Pound Entering Flue Gas*

C_{PAL} = *Leaked Air Specific Heat From* T_{ALI} *To* T_{FGO}*, Btu/Lb-°F*

C_{PFG} = *Flue Gas Specific Heat From* T_{FGI} *To* T_{FGO}*, Btu/lb-°F*

C_{PPA} = *Primary Air Specific Heat From* T_{PAI} *To* T_{PAO}*, Btu/lb-°F*

C_{PSA} = *Secondary Air Specific Heat From* T_{SAI} *To* T_{SAO}*, Btu/lb-°F*

W_{FGI} = *Flue Gas Flow In, lb/lb A.F. Coal*

W_{PAO} = *Primary Air Flow In, lb/lb A.F. Coal*

W_{SAI} = *Secondary Air Flow In, lb/lb A.F. Coal*

T_{FGI}, T_{FGO} = *Flue Gas In, Out Temperature Respectively, °F*

T_{PAI}, T_{PAO} = *Primary Air In, Out Temperature Respectively, °F*

T_{SAI}, T_{SAO} = *Secondary Air In, Out Temperature Respectively, °F*

T_{ALI} = *Air Leak In Temperature (Same As* T_{SAI}*), °F*

Bias and random error calculations for the secondary air flows are shown in Appendices I-1 through I-4. Appendices I-1 and I-2 are for a zero leak case while Appendices I-3 and I-4 are for a 6.9 wt % leak case. Table 5 summarizes the results.

Comparing Tables 3, 4, and Table 5 shows that the relative uncertainty in the secondary air rate is somewhat less than for the primary air inlet and the flue gas inlet and outlet rates.

Air Leak Uncertainty Calculations The leak from air side to the flue gas side within the air heater is calculated from the difference between the inlet and outlet flue gas flow rates by:

$$AL' = \frac{W_{GO} - W_{GI}}{W_{GI}} \times 100 \qquad (34)$$

Equation 34 represents the air leak as a weight percentage of the inlet flue gas flow rate.

Table 5

Uncertainty Estimates for Secondary Air Flow Rates

Stream	Value lbs/hr	Bias Error Abs lbs/hr	Bias Error Rel %	Random Error Abs lbs/hr	Random Error Rel %	Uncertainty 95% Interval Abs lbs/hr	Uncertainty 95% Interval Rel %
2nd Air In/Out (Zero Air Leak Case)	573,700	28,800	5.02	3,890	0.68	29,900	5.20
2nd Air In/Out (6.9 wt % Air Leak)	557,400	28,000	5.02	3,830	0.69	29,000	5.21

The uncertainty in the air leak calculation is summarized in Table 6. Calculations are presented in Appendices J-1 to J-4 for a zero leak case and a case with air leak. For the zero leak case, the inlet and outlet dry flue gas O_2 concentrations were both assumed to be 3.8 vol %. For the air leak case, a 5.0 vol % average outlet O_2 concentration was assumed. This resulted in a 6.9 wt % calculated air leak. The 95 % coverage uncertainties are similar for the two cases, i.e., 1.56 wt % for zero leak, and 1.73 wt % for 6.9 wt % air leak. Since the heat pipe air heaters are designed for zero air leak, the 6.9 w. % leak case indicates a significant mechanical failure. This level of air leakage should be readily detected since the difference between inlet and outlet average O_2 levels is 1.2 vol. % (i.e., 5.0% - 3.8%) and the accuracy of the oxygen analyzer is 0.05 vol. % absolute.

The air leak uncertainties upon first inspection appear to be rather large. The relative uncertainty for the zero leak case is infinity (or not defined) and is +25% for the 6.9 wt % leak case. However, the absolute uncertainties actually translate into relatively small differences between inlet and outlet average O_2 concentrations i.e., 0.29 and 0.32 vol. % for the no leak and with leak cases, respectively. Again, this level of difference should be readily identified by inlet/outlet traverses and oxygen analyzer readings.

Establishing that an absolute zero air leak is achieved will be time consuming and expensive since a large number of tests would likely be required. Based on the uncertainty results, one would expect that for a zero leak rate, the test results would vary between ±1.56 wt %. Therefore, CONSOL proposes that a zero leak be considered demonstrated if the calculated leak rate (after correction for sootblower seal and vent valve leaks) is 1.6 wt % or less for two full load boiler tests.

Table 6

Uncertainty Estimate for Air Leak

Case	Value	Bias Error		Random Error		Uncertainty 95% Interval	
	wt %	Abs wt %	Rel %	Abs wt %	Rel %	Abs wt %	Rel %
Zero Air Leak	0.0	0.020	ND	0.782	ND	1.56	ND
Air Leak Case	6.87	0.058	0.85	0.866	12.60	1.73	25.21

ND -- Not Defined

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Appendix A
Bias and Random Error Calculations
Air and Flue Gas Stream Temperatures

Table A-1
Bias Error Calculation -- Primary Air Inlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
Duct Size				
Width, ft	3.28	0.042	1.27%	
Length, ft	17.5	0.042	0.24%	
# of Points	12			
Widthwise	2			
Lengthwise	6			
Sector Width, ft	1.64	0.042	2.54%	
Sector Length, ft	2.92	0.042	1.43%	
A, Sector Area ft^2	4.78	0.139	2.91%	
T, deg F	80	0.800	1.00%	
T, deg R	540	0.800	0.15%	
Special Bias, deg F	10		2.00	deg F/Length Increment Special Bias
DP, In WC	0.005069	0.0001	2.00%	
M, lb/mol	28.85	0.025	0.09%	
Amb Pres, In. Hg	29.50			
Duct Pres, In. WC	48.00			
Ps, In. Hg Absolute	31.23	0.040	0.13%	
CP, Pitot Fact	0.84	0.0100	1.19%	
Nominal Vel, fps	3.96	ACFM= 13631	SCFM= 13702	lb/hr= 62500

Input Data

Point	Ai	CPi	DPi	Mi	Pai	Ti	(1)	(2)
1	4.78	0.84	0.005069	28.85	31.23	535.0	0.371	198.6
2	4.78	0.84	0.005069	28.85	31.23	537.0	0.371	199.0
3	4.78	0.84	0.005069	28.85	31.23	539.0	0.370	199.4
4	4.78	0.84	0.005069	28.85	31.23	541.0	0.369	199.7
5	4.78	0.84	0.005069	28.85	31.23	543.0	0.369	200.1
6	4.78	0.84	0.005069	28.85	31.23	545.0	0.368	200.5
7	4.78	0.84	0.005069	28.85	31.23	535.0	0.371	198.6
8	4.78	0.84	0.005069	28.85	31.23	537.0	0.371	199.0
9	4.78	0.84	0.005069	28.85	31.23	539.0	0.370	199.4
10	4.78	0.84	0.005069	28.85	31.23	541.0	0.369	199.7
11	4.78	0.84	0.005069	28.85	31.23	543.0	0.369	200.1
12	4.78	0.84	0.005069	28.85	31.23	545.0	0.368	200.5
	Temperature -- Simple Average					540.00	Sum1	Sum2
	Temperature -- Weighted Average					539.99	4.434	2394.6

Derivatives, dTa/dX

Point	dTa/dTi	dTa/Ai	dTa/CPi	dTa/dDPi	dTa/dMi	dTa/dPai
1	8.41E-02	-8.73E-02	-4.97E-01	-4.1E+01	-7.2E-03	-6.7E-03
2	8.38E-02	-5.22E-02	-2.97E-01	-2.5E+01	-4.3E-03	-4.0E-03
3	8.35E-02	-1.72E-02	-9.82E-02	-8.1E+00	-1.4E-03	-1.3E-03
4	8.32E-02	1.76E-02	1.00E-01	8.30E+00	1.46E-03	1.35E-03
5	8.29E-02	5.23E-02	2.98E-01	2.47E+01	4.34E-03	4.01E-03
6	8.26E-02	8.69E-02	4.95E-01	4.10E+01	7.20E-03	6.65E-03
7	8.41E-02	-8.73E-02	-4.97E-01	-4.1E+01	-7.2E-03	-6.7E-03
8	8.38E-02	-5.22E-02	-2.97E-01	-2.5E+01	-4.3E-03	-4.0E-03
9	8.35E-02	-1.72E-02	-9.82E-02	-8.1E+00	-1.4E-03	-1.3E-03
10	8.32E-02	1.76E-02	1.00E-01	8.30E+00	1.46E-03	1.35E-03
11	8.29E-02	5.23E-02	2.98E-01	2.47E+01	4.34E-03	4.01E-03
12	8.26E-02	8.69E-02	4.95E-01	4.10E+01	7.20E-03	6.65E-03

(dTa/dX*Sigma)^2

Point	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SM	d/dPai*SPa
1	4.53E-03	1.48E-04	2.47E-05	1.74E-05	3.28E-08	7.21E-08
2	4.49E-03	5.30E-05	8.84E-06	6.24E-06	1.17E-08	2.58E-08
3	4.46E-03	5.78E-06	9.65E-07	6.81E-07	1.28E-09	2.82E-09
4	4.43E-03	6.02E-06	1.00E-06	7.08E-07	1.33E-09	2.93E-09
5	4.40E-03	5.32E-05	8.87E-06	6.26E-06	1.18E-08	2.59E-08
6	4.36E-03	1.47E-04	2.45E-05	1.73E-05	3.24E-08	7.14E-08
7	4.53E-03	1.48E-04	2.47E-05	1.74E-05	3.28E-08	7.21E-08
8	4.49E-03	5.30E-05	8.84E-06	6.24E-06	1.17E-08	2.58E-08
9	4.46E-03	5.78E-06	9.65E-07	6.81E-07	1.28E-09	2.82E-09
10	4.43E-03	6.02E-06	1.00E-06	7.08E-07	1.33E-09	2.93E-09
11	4.40E-03	5.32E-05	8.87E-06	6.26E-06	1.18E-08	2.59E-08
12	4.36E-03	1.47E-04	2.45E-05	1.73E-05	3.24E-08	7.14E-08
	T	A	CP	DP	M	Ps
Contributions (3)	6.40E-01	8.47E-20	-8.47E-21	-2.03E-20	2.81E-23	-8.27E-24
			Total Sigma^2		0.64	
			Tavg Sigma		0.80	deg F

(1) Ai*CPi(DPi*Mi*Pai/Ti)^0.5

(2) Ai*CPi(DPi*Mi*Pai*Ti)^0.5

(3) Contributions Include Cross Product Terms

Table A-1 (Continued)
Cross Product Terms

d/dTi*d/dTj*STi*STj

	4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03	4.53E-03	4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03
4.51E-03		4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03	4.43E-03
4.49E-03	4.48E-03		4.44E-03	4.43E-03	4.41E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03
4.48E-03	4.46E-03	4.44E-03		4.41E-03	4.40E-03	4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03	4.40E-03
4.46E-03	4.44E-03	4.43E-03	4.41E-03		4.38E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03
4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03		4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03	4.36E-03
4.53E-03	4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03		4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03
4.51E-03	4.49E-03	4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.51E-03		4.48E-03	4.46E-03	4.44E-03	4.43E-03
4.49E-03	4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03	4.49E-03	4.48E-03		4.44E-03	4.43E-03	4.41E-03
4.48E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.48E-03	4.46E-03	4.44E-03		4.41E-03	4.40E-03
4.46E-03	4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03	4.46E-03	4.44E-03	4.43E-03	4.41E-03		4.38E-03
4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03	4.36E-03	4.44E-03	4.43E-03	4.41E-03	4.40E-03	4.38E-03	
4.93E-02	4.91E-02	4.90E-02	4.88E-02	4.86E-02	4.85E-02	4.93E-02	4.91E-02	4.90E-02	4.88E-02	4.86E-02	4.85E-02

d/dDPi*d/dDPj*SDPi*SDPj

	1.04E-05	3.45E-06	-3.52E-06	-1.05E-05	-1.74E-05	1.74E-05	1.04E-05	3.45E-06	-3.52E-06	-1.05E-05	-1.74E-05
1.04E-05		2.06E-06	-2.10E-06	-6.25E-06	-1.04E-05	1.04E-05	6.24E-06	2.06E-06	-2.10E-06	-6.25E-06	-1.04E-05
3.45E-06	2.06E-06		-6.94E-07	-2.06E-06	-3.43E-06	3.45E-06	2.06E-06	6.81E-07	-6.94E-07	-2.06E-06	-3.43E-06
-3.52E-06	-2.10E-06	-6.94E-07		2.11E-06	3.50E-06	-3.52E-06	-2.10E-06	-6.94E-07	7.08E-07	2.11E-06	3.50E-06
-1.05E-05	-6.25E-06	-2.06E-06	2.11E-06		1.04E-05	-1.05E-05	-6.25E-06	-2.06E-06	2.11E-06	6.26E-06	1.04E-05
-1.74E-05	-1.04E-05	-3.43E-06	3.50E-06	1.04E-05		-1.74E-05	-1.04E-05	-3.43E-06	3.50E-06	1.04E-05	1.73E-05
1.74E-05	1.04E-05	3.45E-06	-3.52E-06	-1.05E-05	-1.74E-05		1.04E-05	3.45E-06	-3.52E-06	-1.05E-05	-1.74E-05
1.04E-05	6.24E-06	2.06E-06	-2.10E-06	-6.25E-06	-1.04E-05	1.04E-05		2.06E-06	-2.10E-06	-6.25E-06	-1.04E-05
3.45E-06	2.06E-06	6.81E-07	-6.94E-07	-2.06E-06	-3.43E-06	3.45E-06	2.06E-06		-6.94E-07	-2.06E-06	-3.43E-06
-3.52E-06	-2.10E-06	-6.94E-07	7.08E-07	2.11E-06	3.50E-06	-3.52E-06	-2.10E-06	-6.94E-07		2.11E-06	3.50E-06
-1.05E-05	-6.25E-06	-2.06E-06	2.11E-06	6.26E-06	1.04E-05	-1.05E-05	-6.25E-06	-2.06E-06	2.11E-06		1.04E-05
-1.74E-05	-1.04E-05	-3.43E-06	3.50E-06	1.04E-05	1.73E-05	-1.74E-05	-1.04E-05	-3.43E-06	3.50E-06	1.04E-05	
-1.74E-05	-6.24E-06	-6.81E-07	-7.08E-07	-6.26E-06	-1.73E-05	-1.74E-05	-6.24E-06	-6.81E-07	-7.08E-07	-6.26E-06	-1.73E-05

d/dMi*d/dMj*SMi*SMj

	1.96E-08	6.47E-09	-6.60E-09	-1.96E-08	-3.26E-08	3.28E-08	1.96E-08	6.47E-09	-6.60E-09	-1.96E-08	-3.26E-08
1.96E-08		3.87E-09	-3.95E-09	-1.17E-08	-1.95E-08	1.96E-08	1.17E-08	3.87E-09	-3.95E-09	-1.17E-08	-1.95E-08
6.47E-09	3.87E-09		-1.30E-09	-3.88E-09	-6.44E-09	6.47E-09	3.87E-09	1.28E-09	-1.30E-09	-3.88E-09	-6.44E-09
-6.60E-09	-3.95E-09	-1.30E-09		3.95E-09	6.57E-09	-6.60E-09	-3.95E-09	-1.30E-09	1.33E-09	3.95E-09	6.57E-09
-1.96E-08	-1.17E-08	-3.88E-09	3.95E-09		1.95E-08	-1.96E-08	-1.17E-08	-3.88E-09	3.95E-09	1.18E-08	1.95E-08
-3.26E-08	-1.95E-08	-6.44E-09	6.57E-09	1.95E-08		-3.26E-08	-1.95E-08	-6.44E-09	6.57E-09	1.95E-08	3.24E-08
3.28E-08	1.96E-08	6.47E-09	-6.60E-09	-1.96E-08	-3.26E-08		1.96E-08	6.47E-09	-6.60E-09	-1.96E-08	-3.26E-08
1.96E-08	1.17E-08	3.87E-09	-3.95E-09	-1.17E-08	-1.95E-08	1.96E-08		3.87E-09	-3.95E-09	-1.17E-08	-1.95E-08
6.47E-09	3.87E-09	1.28E-09	-1.30E-09	-3.88E-09	-6.44E-09	6.47E-09	3.87E-09		-1.30E-09	-3.88E-09	-6.44E-09
-6.60E-09	-3.95E-09	-1.30E-09	1.33E-09	3.95E-09	6.57E-09	-6.60E-09	-3.95E-09	-1.30E-09		3.95E-09	6.57E-09
-1.96E-08	-1.17E-08	-3.88E-09	3.95E-09	1.18E-08	1.95E-08	-1.96E-08	-1.17E-08	-3.88E-09	3.95E-09		1.95E-08
-3.26E-08	-1.95E-08	-6.44E-09	6.57E-09	1.95E-08	3.24E-08	-3.26E-08	-1.95E-08	-6.44E-09	6.57E-09	1.95E-08	
-3.28E-08	-1.17E-08	-1.28E-09	-1.33E-09	-1.18E-08	-3.24E-08	-3.28E-08	-1.17E-08	-1.28E-09	-1.33E-09	-1.18E-08	-3.24E-08

Table A-1 (Continued)
Cross Product Terms

d/dPsi*d/dPsj*SPsi*SPsj

	4.31E-08	1.43E-08	-1.45E-08	-4.32E-08	-7.18E-08	7.21E-08	4.31E-08	1.43E-08	-1.45E-08	-4.32E-08	-7.18E-08
4.31E-08		8.52E-09	-8.69E-09	-2.58E-08	-4.29E-08	4.31E-08	2.58E-08	8.52E-09	-8.69E-09	-2.58E-08	-4.29E-08
1.43E-08	8.52E-09		-2.87E-09	-8.54E-09	-1.42E-08	1.43E-08	8.52E-09	2.82E-09	-2.87E-09	-8.54E-09	-1.42E-08
-1.45E-08	-8.69E-09	-2.87E-09		8.71E-09	1.45E-08	-1.45E-08	-8.69E-09	-2.87E-09	2.93E-09	8.71E-09	1.45E-08
-4.32E-08	-2.58E-08	-8.54E-09	8.71E-09		4.30E-08	-4.32E-08	-2.58E-08	-8.54E-09	8.71E-09	2.59E-08	4.30E-08
-7.18E-08	-4.29E-08	-1.42E-08	1.45E-08	4.30E-08		-7.18E-08	-4.29E-08	-1.42E-08	1.45E-08	4.30E-08	7.14E-08
7.21E-08	4.31E-08	1.43E-08	-1.45E-08	-4.32E-08	-7.18E-08		4.31E-08	1.43E-08	-1.45E-08	-4.32E-08	-7.18E-08
4.31E-08	2.58E-08	8.52E-09	-8.69E-09	-2.58E-08	-4.29E-08	4.31E-08		8.52E-09	-8.69E-09	-2.58E-08	-4.29E-08
1.43E-08	8.52E-09	2.82E-09	-2.87E-09	-8.54E-09	-1.42E-08	1.43E-08	8.52E-09		-2.87E-09	-8.54E-09	-1.42E-08
-1.45E-08	-8.69E-09	-2.87E-09	2.93E-09	8.71E-09	1.45E-08	-1.45E-08	-8.69E-09	-2.87E-09		8.71E-09	1.45E-08
-4.32E-08	-2.58E-08	-8.54E-09	8.71E-09	2.59E-08	4.30E-08	-4.32E-08	-2.58E-08	-8.54E-09	8.71E-09		4.30E-08
-7.18E-08	-4.29E-08	-1.42E-08	1.45E-08	4.30E-08	7.14E-08	-7.18E-08	-4.29E-08	-1.42E-08	1.45E-08	4.30E-08	
-7.21E-08	-2.58E-08	-2.82E-09	-2.93E-09	-2.59E-08	-7.14E-08	-7.21E-08	-2.58E-08	-2.82E-09	-2.93E-09	-2.59E-08	-7.14E-08

d/dCPi*d/dCPj*SCPi*SCPj

	1.48E-05	4.88E-06	-4.98E-06	-1.48E-05	-2.46E-05	2.47E-05	1.48E-05	4.88E-06	-4.98E-06	-1.48E-05	-2.46E-05
1.48E-05		2.92E-06	-2.98E-06	-8.86E-06	-1.47E-05	1.48E-05	8.84E-06	2.92E-06	-2.98E-06	-8.86E-06	-1.47E-05
4.88E-06	2.92E-06		-9.84E-07	-2.93E-06	-4.86E-06	4.88E-06	2.92E-06	9.65E-07	-9.84E-07	-2.93E-06	-4.86E-06
-4.98E-06	-2.98E-06	-9.84E-07		2.98E-06	4.96E-06	-4.98E-06	-2.98E-06	-9.84E-07	1.00E-06	2.98E-06	4.96E-06
-1.48E-05	-8.86E-06	-2.93E-06	2.98E-06		1.47E-05	-1.48E-05	-8.86E-06	-2.93E-06	2.98E-06	8.87E-06	1.47E-05
-2.46E-05	-1.47E-05	-4.86E-06	4.96E-06	1.47E-05		-2.46E-05	-1.47E-05	-4.86E-06	4.96E-06	1.47E-05	2.45E-05
2.47E-05	1.48E-05	4.88E-06	-4.98E-06	-1.48E-05	-2.46E-05		1.48E-05	4.88E-06	-4.98E-06	-1.48E-05	-2.46E-05
1.48E-05	8.84E-06	2.92E-06	-2.98E-06	-8.86E-06	-1.47E-05	1.48E-05		2.92E-06	-2.98E-06	-8.86E-06	-1.47E-05
4.88E-06	2.92E-06	9.65E-07	-9.84E-07	-2.93E-06	-4.86E-06	4.88E-06	2.92E-06		-9.84E-07	-2.93E-06	-4.86E-06
-4.98E-06	-2.98E-06	-9.84E-07	1.00E-06	2.98E-06	4.96E-06	-4.98E-06	-2.98E-06	-9.84E-07		2.98E-06	4.96E-06
-1.48E-05	-8.86E-06	-2.93E-06	2.98E-06	8.87E-06	1.47E-05	-1.48E-05	-8.86E-06	-2.93E-06	2.98E-06		1.47E-05
-2.46E-05	-1.47E-05	-4.86E-06	4.96E-06	1.47E-05	2.45E-05	-2.46E-05	-1.47E-05	-4.86E-06	4.96E-06	1.47E-05	
-2.47E-05	-8.84E-06	-9.65E-07	-1.00E-06	-8.87E-06	-2.45E-05	-2.47E-05	-8.84E-06	-9.65E-07	-1.00E-06	-8.87E-06	-2.45E-05

d/dAi*d/dAj*SAi*SAj

	8.86E-05	2.93E-05	-2.99E-05	-8.88E-05	-1.47E-04	1.48E-04	8.86E-05	2.93E-05	-2.99E-05	-8.88E-05	-1.47E-04
8.86E-05		1.75E-05	-1.79E-05	-5.31E-05	-8.82E-05	8.86E-05	5.30E-05	1.75E-05	-1.79E-05	-5.31E-05	-8.82E-05
2.93E-05	1.75E-05		-5.90E-06	-1.75E-05	-2.91E-05	2.93E-05	1.75E-05	5.78E-06	-5.90E-06	-1.75E-05	-2.91E-05
-2.99E-05	-1.79E-05	-5.90E-06		1.79E-05	2.97E-05	-2.99E-05	-1.79E-05	-5.90E-06	6.02E-06	1.79E-05	2.97E-05
-8.88E-05	-5.31E-05	-1.75E-05	1.79E-05		8.84E-05	-8.88E-05	-5.31E-05	-1.75E-05	1.79E-05	5.32E-05	8.84E-05
-1.47E-04	-8.82E-05	-2.91E-05	2.97E-05	8.84E-05		-1.47E-04	-8.82E-05	-2.91E-05	2.97E-05	8.84E-05	1.47E-04
1.48E-04	8.86E-05	2.93E-05	-2.99E-05	-8.88E-05	-1.47E-04		8.86E-05	2.93E-05	-2.99E-05	-8.88E-05	-1.47E-04
8.86E-05	5.30E-05	1.75E-05	-1.79E-05	-5.31E-05	-8.82E-05	8.86E-05		1.75E-05	-1.79E-05	-5.31E-05	-8.82E-05
2.93E-05	1.75E-05	5.78E-06	-5.90E-06	-1.75E-05	-2.91E-05	2.93E-05	1.75E-05		-5.90E-06	-1.75E-05	-2.91E-05
-2.99E-05	-1.79E-05	-5.90E-06	6.02E-06	1.79E-05	2.97E-05	-2.99E-05	-1.79E-05	-5.90E-06		1.79E-05	2.97E-05
-8.88E-05	-5.31E-05	-1.75E-05	1.79E-05	5.32E-05	8.84E-05	-8.88E-05	-5.31E-05	-1.75E-05	1.79E-05		8.84E-05
-1.47E-04	-8.82E-05	-2.91E-05	2.97E-05	8.84E-05	1.47E-04	-1.47E-04	-8.82E-05	-2.91E-05	2.97E-05	8.84E-05	
-1.48E-04	-5.30E-05	-5.78E-06	-6.02E-06	-5.32E-05	-1.47E-04	-1.48E-04	-5.30E-05	-5.78E-06	-6.02E-06	-5.32E-05	-1.47E-04

Table A-2
Bias Error Calculation – Primary Air Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
ɹct Size				
ɔia. ft	4	0.042	1.04%	
ɹength, ft				
# of Points	20			
ɔia. #1	10			
ɔia. #2	10			
A, Sector Area ft^2	0.63	0.013	2.06%	
deg F	644	6.440	1.00%	
deg R	1104	6.440	0.58%	
ɪmp Bias, deg F	100		11.11	deg F/Length Increment Special Bias
P, in WC	0.2171	0.0043	2.00%	
, lb/mol	28.85	0.025	0.09%	
ɱb Pres, in. Hg	29.50			
ɹct Pres, in. WC	44.50			
ɪ, in. Hg Absolute	31.11	0.040	0.13%	
P, Pitot Fact	0.84	0.0100	1.19%	
ɔminal Vel, fps	37.11	ACFM= 27982	SCFM= 13702	lb/hr= 62500

Point	Input Data: Ai	CPi	DPi	Mi	Psi	Ti	(1)	(2)
1	0.63	0.84	0.2171	28.85	31.11	1054.0	0.227	239.2
2	0.63	0.84	0.2171	28.85	31.11	1065.1	0.226	240.4
3	0.63	0.84	0.2171	28.85	31.11	1076.2	0.225	241.7
4	0.63	0.84	0.2171	28.85	31.11	1087.3	0.223	242.9
5	0.63	0.84	0.2171	28.85	31.11	1098.4	0.222	244.2
6	0.63	0.84	0.2171	28.85	31.11	1109.6	0.221	245.4
7	0.63	0.84	0.2171	28.85	31.11	1120.7	0.220	246.6
8	0.63	0.84	0.2171	28.85	31.11	1131.8	0.219	247.8
9	0.63	0.84	0.2171	28.85	31.11	1142.9	0.218	249.1
10	0.63	0.84	0.2171	28.85	31.11	1154.0	0.217	250.3
11	0.63	0.84	0.2171	28.85	31.11	1054.0	0.227	239.2
12	0.63	0.84	0.2171	28.85	31.11	1065.1	0.226	240.4
13	0.63	0.84	0.2171	28.85	31.11	1076.2	0.225	241.7
14	0.63	0.84	0.2171	28.85	31.11	1087.3	0.223	242.9
15	0.63	0.84	0.2171	28.85	31.11	1098.4	0.222	244.2
16	0.63	0.84	0.2171	28.85	31.11	1109.6	0.221	245.4
17	0.63	0.84	0.2171	28.85	31.11	1120.7	0.220	246.6
18	0.63	0.84	0.2171	28.85	31.11	1131.8	0.219	247.8
19	0.63	0.84	0.2171	28.85	31.11	1142.9	0.218	249.1
20	0.63	0.84	0.2171	28.85	31.11	1154.0	0.217	250.3
	Temperature -- Simple Average					1104.0	Sum1	Sum2
	Temperature -- Weighted Average					1103.5	4.436	4695.0

Point	Derivatives, dTa/dX: dTa/dTi	dTa/dAi	dTa/dCPi	dTa/dDPi	dTa/dMi	dTa/dPsi
1	5.236E-02	-4.03E+00	-3.02E+00	-5.84E+00	-4.39E-02	-4.07E-02
2	5.18E-02	-3.11E+00	-2.33E+00	-4.50E+00	-3.39E-02	-3.14E-02
3	5.13E-02	-2.20E+00	-1.65E+00	-3.18E+00	-2.40E-02	-2.22E-02
4	5.07E-02	-1.30E+00	-9.72E-01	-1.88E+00	-1.41E-02	-1.31E-02
5	5.02E-02	-4.06E-01	-3.04E-01	-5.88E-01	-4.42E-03	-4.10E-03
6	4.97E-02	4.77E-01	3.57E-01	6.91E-01	5.20E-03	4.82E-03
7	4.92E-02	1.35E+00	1.01E+00	1.96E+00	1.47E-02	1.37E-02
8	4.88E-02	2.22E+00	1.66E+00	3.21E+00	2.42E-02	2.24E-02
9	4.83E-02	3.08E+00	2.30E+00	4.45E+00	3.35E-02	3.11E-02
10	4.78E-02	3.93E+00	2.94E+00	5.68E+00	4.28E-02	3.97E-02
11	5.24E-02	-4.03E+00	-3.02E+00	-5.84E+00	-4.39E-02	-4.07E-02
12	5.18E-02	-3.11E+00	-2.33E+00	-4.50E+00	-3.39E-02	-3.14E-02
13	5.13E-02	-2.20E+00	-1.65E+00	-3.18E+00	-2.40E-02	-2.22E-02
14	5.07E-02	-1.30E+00	-9.72E-01	-1.88E+00	-1.41E-02	-1.31E-02
15	5.02E-02	-4.06E-01	-3.04E-01	-5.88E-01	-4.42E-03	-4.10E-03
16	4.97E-02	4.77E-01	3.57E-01	6.91E-01	5.20E-03	4.82E-03
17	4.92E-02	1.35E+00	1.01E+00	1.96E+00	1.47E-02	1.37E-02
18	4.88E-02	2.22E+00	1.66E+00	3.21E+00	2.42E-02	2.24E-02
19	4.83E-02	3.08E+00	2.30E+00	4.45E+00	3.35E-02	3.11E-02
20	4.78E-02	3.926E+00	2.94E+00	5.68E+00	4.28E-02	3.97E-02

Point	(dTa/dX*Sigma)^2: d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPsi*SPsi
1	1.14E-01	2.79E-03	9.10E-04	6.42E-04	1.21E-06	2.68E-06
2	1.11E-01	1.66E-03	5.42E-04	3.82E-04	7.18E-07	1.59E-06
3	1.09E-01	8.30E-04	2.71E-04	1.91E-04	3.59E-07	7.97E-07
4	1.07E-01	2.89E-04	9.44E-05	6.66E-05	1.25E-07	2.78E-07
5	1.05E-01	2.83E-05	9.23E-06	6.52E-06	1.22E-08	2.72E-08
6	1.03E-01	3.91E-05	1.28E-05	9.00E-06	1.69E-08	3.75E-08
7	1.01E-01	3.13E-04	1.02E-04	7.22E-05	1.36E-07	3.01E-07
8	9.86E-02	8.44E-04	2.75E-04	1.94E-04	3.65E-07	8.10E-07
9	9.67E-02	1.62E-03	5.30E-04	3.74E-04	7.02E-07	1.56E-06
10	9.48E-02	2.64E-03	8.63E-04	6.09E-04	1.14E-06	2.54E-06
11	1.14E-01	2.79E-03	9.10E-04	6.42E-04	1.21E-06	2.68E-06
12	1.11E-01	1.66E-03	5.42E-04	3.82E-04	7.18E-07	1.59E-06
13	1.09E-01	8.30E-04	2.71E-04	1.91E-04	3.59E-07	7.97E-07
14	1.07E-01	2.89E-04	9.44E-05	6.66E-05	1.25E-07	2.78E-07
15	1.05E-01	2.83E-05	9.23E-06	6.52E-06	1.22E-08	2.72E-08
16	1.03E-01	3.91E-05	1.28E-05	9.00E-06	1.69E-08	3.75E-08
17	1.01E-01	3.13E-04	1.02E-04	7.22E-05	1.36E-07	3.01E-07
18	9.86E-02	8.44E-04	2.75E-04	1.94E-04	3.65E-07	8.10E-07
19	9.67E-02	1.62E-03	5.30E-04	3.74E-04	7.02E-07	1.56E-06
20	9.48E-02	2.64E-03	8.63E-04	6.09E-04	1.14E-06	2.54E-06
	T	A	CP	DP	M	Ps
Contributions (3)	4.15E+01	1.02E-18	1.76E-19	-5.69E-19	-1.0E-21	1.85E-22
			Total Sigma^2		41.51	
			Tavg Sigma		6.44	deg F

1) Ai*CPi(DPi*Mi*Psi/Ti)^0.5
2) Ai*CPi(DPi*Mi*Psi*Ti)^0.5
3) Contributions Include Cross Product Terms

Table A-2 (Continued)
Cross Product Terms

/dTI*d/dTj*STI*STj	1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.14E-01	1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01
1.12E-01		1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01
1.11E-01	1.10E-01		1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01
1.10E-01	1.09E-01	1.08E-01		1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01
1.09E-01	1.08E-01	1.07E-01	1.06E-01		1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02
1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01		1.02E-01	1.01E-01	9.96E-02	9.86E-02	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02
1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01		9.95E-02	9.86E-02	9.76E-02	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02	9.86E-02	9.76E-02
1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02		9.76E-02	9.67E-02	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02	9.86E-02	9.76E-02	9.67E-02
1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02		9.58E-02	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02
1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02		1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02	9.48E-02
1.14E-01	1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01		1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01
1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.12E-01		1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01
1.11E-01	1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.11E-01	1.10E-01		1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01
1.10E-01	1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	1.10E-01	1.09E-01	1.08E-01		1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01
1.09E-01	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	1.09E-01	1.08E-01	1.07E-01	1.06E-01		1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02
1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	1.08E-01	1.07E-01	1.06E-01	1.05E-01	1.04E-01		1.02E-01	1.01E-01	9.96E-02	9.86E-02
1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02	9.86E-02	9.76E-02	1.07E-01	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01		9.95E-02	9.86E-02	9.76E-02
1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02	9.86E-02	9.76E-02	9.67E-02	1.06E-01	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.95E-02		9.76E-02	9.67E-02
1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02	1.05E-01	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02		9.58E-02
1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02	9.48E-02	1.04E-01	1.03E-01	1.02E-01	1.01E-01	9.96E-02	9.86E-02	9.76E-02	9.67E-02	9.58E-02	
2.06E+00	2.04E+00	2.02E+00	2.00E+00	1.98E+00	1.96E+00	1.94E+00	1.92E+00	1.91E+00	1.89E+00	2.06E+00	2.04E+00	2.02E+00	2.00E+00	1.98E+00	1.96E+00	1.94E+00	1.92E+00	1.91E+00	1.89E+00

/dDPI*d/dDPj*SDPI*SDPj	4.96E-04	3.50E-04	2.07E-04	6.47E-05	-7.6E-05	-2.2E-04	-3.5E-04	-4.9E-04	-6.25E-04	6.42E-04	4.96E-04	3.50E-04	2.07E-04	6.47E-05	-7.6E-05	-2.15E-04	-3.53E-04	-4.90E-04	-6.25E-04
4.96E-04		2.70E-04	1.60E-04	4.99E-05	-5.9E-05	-1.7E-04	-2.7E-04	-3.8E-04	-4.82E-04	4.96E-04	3.82E-04	2.70E-04	1.60E-04	4.99E-05	-5.9E-05	-1.66E-04	-2.73E-04	-3.78E-04	-4.82E-04
3.50E-04	2.70E-04		1.13E-04	3.53E-05	-4.1E-05	-1.2E-04	-1.9E-04	-2.7E-04	-3.41E-04	3.50E-04	2.70E-04	1.91E-04	1.13E-04	3.53E-05	-4.1E-05	-1.18E-04	-1.93E-04	-2.67E-04	-3.41E-04
2.07E-04	1.60E-04	1.13E-04		2.08E-05	-2.4E-05	-6.9E-05	-1.1E-04	-1.6E-04	-2.01E-04	2.07E-04	1.60E-04	1.13E-04	6.66E-05	2.08E-05	-2.4E-05	-6.94E-05	-1.14E-04	-1.58E-04	-2.01E-04
6.47E-05	4.99E-05	3.53E-05	2.08E-05		-7.7E-06	-2.2E-05	-3.6E-05	-4.9E-05	-6.30E-05	6.47E-05	4.99E-05	3.53E-05	2.08E-05	6.52E-06	-7.7E-06	-2.17E-05	-3.56E-05	-4.93E-05	-6.30E-05
-7.60E-05	-5.9E-05	-4.1E-05	-2.4E-05	-7.7E-06		2.55E-05	4.18E-05	5.80E-05	7.40E-05	-7.60E-05	-5.87E-05	-4.15E-05	-2.45E-05	-7.66E-06	9.00E-06	2.55E-05	4.18E-05	5.80E-05	7.40E-05
-2.15E-04	-1.7E-04	-1.2E-04	-6.9E-05	-2.2E-05	2.55E-05		1.18E-04	1.64E-04	2.10E-04	-2.15E-04	-1.66E-04	-1.18E-04	-6.94E-05	-2.17E-05	2.55E-05	7.22E-05	1.18E-04	1.64E-04	2.10E-04
-3.53E-04	-2.7E-04	-1.9E-04	-1.1E-04	-3.6E-05	4.18E-05	1.18E-04		2.69E-04	3.44E-04	-3.53E-04	-2.73E-04	-1.93E-04	-1.14E-04	-3.56E-05	4.18E-05	1.18E-04	1.94E-04	2.69E-04	3.44E-04
-4.90E-04	-3.8E-04	-2.7E-04	-1.6E-04	-4.9E-05	5.80E-05	1.64E-04	2.69E-04		4.77E-04	-4.90E-04	-3.78E-04	-2.67E-04	-1.58E-04	-4.93E-05	5.80E-05	1.64E-04	2.69E-04	3.74E-04	4.77E-04
-6.25E-04	-4.8E-04	-3.4E-04	-2.0E-04	-6.3E-05	7.40E-05	2.10E-04	3.44E-04	4.77E-04		-6.25E-04	-4.82E-04	-3.41E-04	-2.01E-04	-6.30E-05	7.40E-05	2.10E-04	3.44E-04	4.77E-04	6.09E-04
6.42E-04	4.96E-04	3.50E-04	2.07E-04	6.47E-05	-7.6E-05	-2.2E-04	-3.5E-04	-4.9E-04	-6.25E-04		4.96E-04	3.50E-04	2.07E-04	6.47E-05	-7.6E-05	-2.15E-04	-3.53E-04	-4.90E-04	-6.25E-04
4.96E-04	3.82E-04	2.70E-04	1.60E-04	4.99E-05	-5.9E-05	-1.7E-04	-2.7E-04	-3.8E-04	-4.82E-04	4.96E-04		2.70E-04	1.60E-04	4.99E-05	-5.9E-05	-1.66E-04	-2.73E-04	-3.78E-04	-4.82E-04
3.50E-04	2.70E-04	1.91E-04	1.13E-04	3.53E-05	-4.1E-05	-1.2E-04	-1.9E-04	-2.7E-04	-3.41E-04	3.50E-04	2.70E-04		1.13E-04	3.53E-05	-4.1E-05	-1.18E-04	-1.93E-04	-2.67E-04	-3.41E-04
2.07E-04	1.60E-04	1.13E-04	6.66E-05	2.08E-05	-2.4E-05	-6.9E-05	-1.1E-04	-1.6E-04	-2.01E-04	2.07E-04	1.60E-04	1.13E-04		2.08E-05	-2.4E-05	-6.94E-05	-1.14E-04	-1.58E-04	-2.01E-04
6.47E-05	4.99E-05	3.53E-05	2.08E-05	6.52E-06	-7.7E-06	-2.2E-05	-3.6E-05	-4.9E-05	-6.30E-05	6.47E-05	4.99E-05	3.53E-05	2.08E-05		-7.7E-06	-2.17E-05	-3.56E-05	-4.93E-05	-6.30E-05
-7.60E-05	-5.9E-05	-4.1E-05	-2.4E-05	-7.7E-06	9.00E-06	2.55E-05	4.18E-05	5.80E-05	7.40E-05	-7.60E-05	-5.87E-05	-4.15E-05	-2.45E-05	-7.66E-06		2.55E-05	4.18E-05	5.80E-05	7.40E-05
-2.15E-04	-1.7E-04	-1.2E-04	-6.9E-05	-2.2E-05	2.55E-05	7.22E-05	1.18E-04	1.64E-04	2.10E-04	-2.15E-04	-1.66E-04	-1.18E-04	-6.94E-05	-2.17E-05	2.55E-05		1.18E-04	1.64E-04	2.10E-04
-3.53E-04	-2.7E-04	-1.9E-04	-1.1E-04	-3.6E-05	4.18E-05	1.18E-04	1.94E-04	2.69E-04	3.44E-04	-3.53E-04	-2.73E-04	-1.93E-04	-1.14E-04	-3.56E-05	4.18E-05	1.18E-04		2.69E-04	3.44E-04
-4.90E-04	-3.8E-04	-2.7E-04	-1.6E-04	-4.9E-05	5.80E-05	1.64E-04	2.69E-04	3.74E-04	4.77E-04	-4.90E-04	-3.78E-04	-2.67E-04	-1.58E-04	-4.93E-05	5.80E-05	1.64E-04	2.69E-04		4.77E-04
-6.25E-04	-4.8E-04	-3.4E-04	-2.0E-04	-6.3E-05	7.40E-05	2.10E-04	3.44E-04	4.77E-04	6.09E-04	-6.25E-04	-4.82E-04	-3.41E-04	-2.01E-04	-6.30E-05	7.40E-05	2.10E-04	3.44E-04	4.77E-04	
-6.42E-04	-3.8E-04	-1.9E-04	-6.7E-05	-6.5E-06	-9.0E-06	-7.2E-05	-1.9E-04	-3.7E-04	-6.09E-04	-6.42E-04	-3.82E-04	-1.91E-04	-6.66E-05	-6.52E-06	-9.0E-06	-7.22E-05	-1.94E-04	-3.74E-04	-6.09E-04

Table A-2 (Continued)
Cross Product Terms

d/dMi*d/dMj*SMi*SMj	9.30E-07	6.58E-07	3.88E-07	1.21E-07	-1.4E-07	-4.0E-07	-6.6E-07	-9.2E-07	-1.17E-06	1.21E-06	9.30E-07	6.58E-07	3.88E-07	1.21E-07	-1.4E-07	-4.04E-07	-6.63E-07	-9.20E-07	-1.17E-06
9.30E-07		5.08E-07	3.00E-07	9.37E-08	-1.1E-07	-3.1E-07	-5.1E-07	-7.1E-07	-9.06E-07	9.30E-07	7.18E-07	5.08E-07	3.00E-07	9.37E-08	-1.1E-07	-3.12E-07	-5.12E-07	-7.10E-07	-9.06E-07
6.58E-07	5.08E-07		2.12E-07	6.63E-08	-7.8E-08	-2.2E-07	-3.6E-07	-5.0E-07	-6.40E-07	6.58E-07	5.08E-07	3.59E-07	2.12E-07	6.63E-08	-7.8E-08	-2.21E-07	-3.62E-07	-5.02E-07	-6.40E-07
3.88E-07	3.00E-07	2.12E-07		3.91E-08	-4.6E-08	-1.3E-07	-2.1E-07	-3.0E-07	-3.78E-07	3.88E-07	3.00E-07	2.12E-07	1.25E-07	3.91E-08	-4.6E-08	-1.30E-07	-2.14E-07	-2.96E-07	-3.78E-07
1.21E-07	9.37E-08	6.63E-08	3.91E-08		-1.4E-08	-4.1E-08	-6.7E-08	-9.3E-08	-1.18E-07	1.21E-07	9.37E-08	6.63E-08	3.91E-08	1.22E-08	-1.4E-08	-4.07E-08	-6.68E-08	-9.26E-08	-1.18E-07
-1.43E-07	-1.1E-07	-7.8E-08	-4.6E-08	-1.4E-08		4.79E-08	7.85E-08	1.09E-07	1.39E-07	-1.43E-07	-1.10E-07	-7.79E-08	-4.60E-08	-1.44E-08	1.69E-08	4.79E-08	7.85E-08	1.09E-07	1.39E-07
-4.04E-07	-3.1E-07	-2.2E-07	-1.3E-07	-4.1E-08	4.79E-08		2.22E-07	3.08E-07	3.94E-07	-4.04E-07	-3.12E-07	-2.21E-07	-1.30E-07	-4.07E-08	4.79E-08	1.36E-07	2.22E-07	3.08E-07	3.94E-07
-6.63E-07	-5.1E-07	-3.6E-07	-2.1E-07	-6.7E-08	7.85E-08	2.22E-07		5.06E-07	6.46E-07	-6.63E-07	-5.12E-07	-3.62E-07	-2.14E-07	-6.68E-08	7.85E-08	2.22E-07	3.65E-07	5.06E-07	6.46E-07
-9.20E-07	-7.1E-07	-5.0E-07	-3.0E-07	-9.3E-08	1.09E-07	3.08E-07	5.06E-07		8.95E-07	-9.20E-07	-7.10E-07	-5.02E-07	-2.96E-07	-9.26E-08	1.09E-07	3.08E-07	5.06E-07	7.02E-07	8.95E-07
-1.17E-06	-9.1E-07	-6.4E-07	-3.8E-07	-1.2E-07	1.39E-07	3.94E-07	6.46E-07	8.95E-07		-1.17E-06	-9.06E-07	-6.40E-07	-3.78E-07	-1.18E-07	1.39E-07	3.94E-07	6.46E-07	8.95E-07	1.14E-06
1.21E-06	9.30E-07	6.58E-07	3.88E-07	1.21E-07	-1.4E-07	-4.0E-07	-6.6E-07	-9.2E-07	-1.17E-06		9.30E-07	6.58E-07	3.88E-07	1.21E-07	-1.4E-07	-4.04E-07	-6.63E-07	-9.20E-07	-1.17E-06
9.30E-07	7.18E-07	5.08E-07	3.00E-07	9.37E-08	-1.1E-07	-3.1E-07	-5.1E-07	-7.1E-07	-9.06E-07	9.30E-07		5.08E-07	3.00E-07	9.37E-08	-1.1E-07	-3.12E-07	-5.12E-07	-7.10E-07	-9.06E-07
6.58E-07	5.08E-07	3.59E-07	2.12E-07	6.63E-08	-7.8E-08	-2.2E-07	-3.6E-07	-5.0E-07	-6.40E-07	6.58E-07	5.08E-07		2.12E-07	6.63E-08	-7.8E-08	-2.21E-07	-3.62E-07	-5.02E-07	-6.40E-07
3.88E-07	3.00E-07	2.12E-07	1.25E-07	3.91E-08	-4.6E-08	-1.3E-07	-2.1E-07	-3.0E-07	-3.78E-07	3.88E-07	3.00E-07	2.12E-07		3.91E-08	-4.6E-08	-1.30E-07	-2.14E-07	-2.96E-07	-3.78E-07
1.21E-07	9.37E-08	6.63E-08	3.91E-08	1.22E-08	-1.4E-08	-4.1E-08	-6.7E-08	-9.3E-08	-1.18E-07	1.21E-07	9.37E-08	6.63E-08	3.91E-08		-1.4E-08	-4.07E-08	-6.68E-08	-9.26E-08	-1.18E-07
-1.43E-07	-1.1E-07	-7.8E-08	-4.6E-08	-1.4E-08	1.69E-08	4.79E-08	7.85E-08	1.09E-07	1.39E-07	-1.43E-07	-1.10E-07	-7.79E-08	-4.60E-08	-1.44E-08		4.79E-08	7.85E-08	1.09E-07	1.39E-07
-4.04E-07	-3.1E-07	-2.2E-07	-1.3E-07	-4.1E-08	4.79E-08	1.36E-07	2.22E-07	3.08E-07	3.94E-07	-4.04E-07	-3.12E-07	-2.21E-07	-1.30E-07	-4.07E-08	4.79E-08		2.22E-07	3.08E-07	3.94E-07
-6.63E-07	-5.1E-07	-3.6E-07	-2.1E-07	-6.7E-08	7.85E-08	2.22E-07	3.65E-07	5.06E-07	6.46E-07	-6.63E-07	-5.12E-07	-3.62E-07	-2.14E-07	-6.68E-08	7.85E-08	2.22E-07		5.06E-07	6.46E-07
-9.20E-07	-7.1E-07	-5.0E-07	-3.0E-07	-9.3E-08	1.09E-07	3.08E-07	5.06E-07	7.02E-07	8.95E-07	-9.20E-07	-7.10E-07	-5.02E-07	-2.96E-07	-9.26E-08	1.09E-07	3.08E-07	5.06E-07		8.95E-07
-1.17E-06	-9.1E-07	-6.4E-07	-3.8E-07	-1.2E-07	1.39E-07	3.94E-07	6.46E-07	8.95E-07	1.14E-06	-1.17E-06	-9.06E-07	-6.40E-07	-3.78E-07	-1.18E-07	1.39E-07	3.94E-07	6.46E-07	8.95E-07	
-1.21E-06	-7.2E-07	-3.6E-07	-1.3E-07	-1.2E-08	-1.7E-08	-1.4E-07	-3.6E-07	-7.0E-07	-1.14E-06	-1.21E-06	-7.18E-07	-3.59E-07	-1.25E-07	-1.22E-08	-1.7E-08	-1.36E-07	-3.65E-07	-7.02E-07	-1.14E-06

d/dPsi*d/dPsj*SPsi*SPsj	2.07E-06	1.46E-06	8.62E-07	2.70E-07	-3.2E-07	-9.0E-07	-1.5E-06	-2.0E-06	-2.61E-06	2.68E-06	2.07E-06	1.46E-06	8.62E-07	2.70E-07	-3.2E-07	-8.98E-07	-1.47E-06	-2.04E-06	-2.61E-06
2.07E-06		1.13E-06	6.65E-07	2.08E-07	-2.4E-07	-6.9E-07	-1.1E-06	-1.6E-06	-2.01E-06	2.07E-06	1.59E-06	1.13E-06	6.65E-07	2.08E-07	-2.4E-07	-6.93E-07	-1.14E-06	-1.58E-06	-2.01E-06
1.46E-06	1.13E-06		4.71E-07	1.47E-07	-1.7E-07	-4.9E-07	-8.0E-07	-1.1E-06	-1.42E-06	1.46E-06	1.13E-06	7.97E-07	4.71E-07	1.47E-07	-1.7E-07	-4.90E-07	-8.04E-07	-1.11E-06	-1.42E-06
8.62E-07	6.65E-07	4.71E-07		8.69E-08	-1.0E-07	-2.9E-07	-4.7E-07	-6.6E-07	-8.39E-07	8.62E-07	6.65E-07	4.71E-07	2.78E-07	8.69E-08	-1.0E-07	-2.89E-07	-4.74E-07	-6.58E-07	-8.39E-07
2.70E-07	2.08E-07	1.47E-07	8.69E-08		-3.2E-08	-9.0E-08	-1.5E-07	-2.1E-07	-2.63E-07	2.70E-07	2.08E-07	1.47E-07	8.69E-08	2.72E-08	-3.2E-08	-9.04E-08	-1.48E-07	-2.06E-07	-2.63E-07
-3.17E-07	-2.4E-07	-1.7E-07	-1.0E-07	-3.2E-08		1.06E-07	1.74E-07	2.42E-07	3.09E-07	-3.17E-07	-2.45E-07	-1.73E-07	-1.02E-07	-3.19E-08	3.75E-08	1.06E-07	1.74E-07	2.42E-07	3.09E-07
-8.98E-07	-6.9E-07	-4.9E-07	-2.9E-07	-9.0E-08	1.06E-07		4.94E-07	6.85E-07	8.74E-07	-8.98E-07	-6.93E-07	-4.90E-07	-2.89E-07	-9.04E-08	1.06E-07	3.01E-07	4.94E-07	6.85E-07	8.74E-07
-1.47E-06	-1.1E-06	-8.0E-07	-4.7E-07	-1.5E-07	1.74E-07	4.94E-07		1.12E-06	1.43E-06	-1.47E-06	-1.14E-06	-8.04E-07	-4.74E-07	-1.48E-07	1.74E-07	4.94E-07	8.10E-07	1.12E-06	1.43E-06
-2.04E-06	-1.6E-06	-1.1E-06	-6.6E-07	-2.1E-07	2.42E-07	6.85E-07	1.12E-06		1.99E-06	-2.04E-06	-1.58E-06	-1.11E-06	-6.58E-07	-2.06E-07	2.42E-07	6.85E-07	1.12E-06	1.56E-06	1.99E-06
-2.61E-06	-2.0E-06	-1.4E-06	-8.4E-07	-2.6E-07	3.09E-07	8.74E-07	1.43E-06	1.99E-06		-2.61E-06	-2.01E-06	-1.42E-06	-8.39E-07	-2.63E-07	3.09E-07	8.74E-07	1.43E-06	1.99E-06	2.54E-06
2.68E-06	2.07E-06	1.46E-06	8.62E-07	2.70E-07	-3.2E-07	-9.0E-07	-1.5E-06	-2.0E-06	-2.61E-06		2.07E-06	1.46E-06	8.62E-07	2.70E-07	-3.2E-07	-8.98E-07	-1.47E-06	-2.04E-06	-2.61E-06
2.07E-06	1.59E-06	1.13E-06	6.65E-07	2.08E-07	-2.4E-07	-6.9E-07	-1.1E-06	-1.6E-06	-2.01E-06	2.07E-06		1.13E-06	6.65E-07	2.08E-07	-2.4E-07	-6.93E-07	-1.14E-06	-1.58E-06	-2.01E-06
1.46E-06	1.13E-06	7.97E-07	4.71E-07	1.47E-07	-1.7E-07	-4.9E-07	-8.0E-07	-1.1E-06	-1.42E-06	1.46E-06	1.13E-06		4.71E-07	1.47E-07	-1.7E-07	-4.90E-07	-8.04E-07	-1.11E-06	-1.42E-06
8.62E-07	6.65E-07	4.71E-07	2.78E-07	8.69E-08	-1.0E-07	-2.9E-07	-4.7E-07	-6.6E-07	-8.39E-07	8.62E-07	6.65E-07	4.71E-07		8.69E-08	-1.0E-07	-2.89E-07	-4.74E-07	-6.58E-07	-8.39E-07
2.70E-07	2.08E-07	1.47E-07	8.69E-08	2.72E-08	-3.2E-08	-9.0E-08	-1.5E-07	-2.1E-07	-2.63E-07	2.70E-07	2.08E-07	1.47E-07	8.69E-08		-3.2E-08	-9.04E-08	-1.48E-07	-2.06E-07	-2.63E-07
-3.17E-07	-2.4E-07	-1.7E-07	-1.0E-07	-3.2E-08	3.75E-08	1.06E-07	1.74E-07	2.42E-07	3.09E-07	-3.17E-07	-2.45E-07	-1.73E-07	-1.02E-07	-3.19E-08		1.06E-07	1.74E-07	2.42E-07	3.09E-07
-8.98E-07	-6.9E-07	-4.9E-07	-2.9E-07	-9.0E-08	1.06E-07	3.01E-07	4.94E-07	6.85E-07	8.74E-07	-8.98E-07	-6.93E-07	-4.90E-07	-2.89E-07	-9.04E-08	1.06E-07		4.94E-07	6.85E-07	8.74E-07
-1.47E-06	-1.1E-06	-8.0E-07	-4.7E-07	-1.5E-07	1.74E-07	4.94E-07	8.10E-07	1.12E-06	1.43E-06	-1.47E-06	-1.14E-06	-8.04E-07	-4.74E-07	-1.48E-07	1.74E-07	4.94E-07		1.12E-06	1.43E-06
-2.04E-06	-1.6E-06	-1.1E-06	-6.6E-07	-2.1E-07	2.42E-07	6.85E-07	1.12E-06	1.56E-06	1.99E-06	-2.04E-06	-1.58E-06	-1.11E-06	-6.58E-07	-2.06E-07	2.42E-07	6.85E-07	1.12E-06		1.99E-06
-2.61E-06	-2.0E-06	-1.4E-06	-8.4E-07	-2.6E-07	3.09E-07	8.74E-07	1.43E-06	1.99E-06	2.54E-06	-2.61E-06	-2.01E-06	-1.42E-06	-8.39E-07	-2.63E-07	3.09E-07	8.74E-07	1.43E-06	1.99E-06	
-2.68E-06	-1.6E-06	-8.0E-07	-2.8E-07	-2.7E-08	-3.8E-08	-3.0E-07	-8.1E-07	-1.6E-06	-2.54E-06	-2.68E-06	-1.59E-06	-7.97E-07	-2.78E-07	-2.72E-08	-3.8E-08	-3.01E-07	-8.10E-07	-1.56E-06	-2.54E-06

Table A-2 (Continued)
Cross Product Terms

dCPI*d/dCPJ*8CPI*8CPJ

	7.02E-04	4.97E-04	2.93E-04	9.17E-05	-1.1E-04	-3.1E-04	-5.0E-04	-6.9E-04	-8.86E-04	9.10E-04	7.02E-04	4.97E-04	2.93E-04	9.17E-05	-1.1E-04	-3.05E-04	-5.01E-04	-6.94E-04	-8.86E-04
7.02E-04		3.83E-04	2.26E-04	7.07E-05	-8.3E-05	-2.4E-04	-3.9E-04	-5.4E-04	-6.84E-04	7.02E-04	5.42E-04	3.83E-04	2.26E-04	7.07E-05	-8.3E-05	-2.36E-04	-3.86E-04	-5.36E-04	-6.84E-04
4.97E-04	3.83E-04		1.60E-04	5.00E-05	-5.9E-05	-1.7E-04	-2.7E-04	-3.8E-04	-4.84E-04	4.97E-04	3.83E-04	2.71E-04	1.60E-04	5.00E-05	-5.9E-05	-1.67E-04	-2.73E-04	-3.79E-04	-4.84E-04
2.93E-04	2.26E-04	1.60E-04		2.95E-05	-3.5E-05	-9.8E-05	-1.6E-04	-2.2E-04	-2.85E-04	2.93E-04	2.26E-04	1.60E-04	9.44E-05	2.95E-05	-3.5E-05	-9.83E-05	-1.61E-04	-2.24E-04	-2.85E-04
9.17E-05	7.07E-05	5.00E-05	2.95E-05		-1.1E-05	-3.1E-05	-5.0E-05	-7.0E-05	-8.92E-05	9.17E-05	7.07E-05	5.00E-05	2.95E-05	9.23E-06	-1.1E-05	-3.07E-05	-5.04E-05	-6.99E-05	-8.92E-05
-1.08E-04	-8.3E-05	-5.9E-05	-3.5E-05	-1.1E-05		3.61E-05	5.93E-05	8.22E-05	1.05E-04	-1.08E-04	-8.31E-05	-5.88E-05	-3.47E-05	-1.09E-05	1.28E-05	3.61E-05	5.93E-05	8.22E-05	1.05E-04
-3.05E-04	-2.4E-04	-1.7E-04	-9.8E-05	-3.1E-05	3.61E-05		1.68E-04	2.33E-04	2.97E-04	-3.05E-04	-2.36E-04	-1.67E-04	-9.83E-05	-3.07E-05	3.61E-05	1.02E-04	1.68E-04	2.33E-04	2.97E-04
-5.01E-04	-3.9E-04	-2.7E-04	-1.6E-04	-5.0E-05	5.93E-05	1.68E-04		3.82E-04	4.87E-04	-5.01E-04	-3.86E-04	-2.73E-04	-1.61E-04	-5.04E-05	5.93E-05	1.68E-04	2.75E-04	3.82E-04	4.87E-04
-6.94E-04	-5.4E-04	-3.8E-04	-2.2E-04	-7.0E-05	8.22E-05	2.33E-04	3.82E-04		6.76E-04	-6.94E-04	-5.36E-04	-3.79E-04	-2.24E-04	-6.99E-05	8.22E-05	2.33E-04	3.82E-04	5.30E-04	6.76E-04
-8.86E-04	-6.8E-04	-4.8E-04	-2.9E-04	-8.9E-05	1.05E-04	2.97E-04	4.87E-04	6.76E-04		-8.86E-04	-6.84E-04	-4.84E-04	-2.85E-04	-8.92E-05	1.05E-04	2.97E-04	4.87E-04	6.76E-04	8.63E-04
9.10E-04	7.02E-04	4.97E-04	2.93E-04	9.17E-05	-1.1E-04	-3.1E-04	-5.0E-04	-6.9E-04	-8.86E-04		7.02E-04	4.97E-04	2.93E-04	9.17E-05	-1.1E-04	-3.05E-04	-5.01E-04	-6.94E-04	-8.86E-04
7.02E-04	5.42E-04	3.83E-04	2.26E-04	7.07E-05	-8.3E-05	-2.4E-04	-3.9E-04	-5.4E-04	-6.84E-04	7.02E-04		3.83E-04	2.26E-04	7.07E-05	-8.3E-05	-2.36E-04	-3.86E-04	-5.36E-04	-6.84E-04
4.97E-04	3.83E-04	2.71E-04	1.60E-04	5.00E-05	-5.9E-05	-1.7E-04	-2.7E-04	-3.8E-04	-4.84E-04	4.97E-04	3.83E-04		1.60E-04	5.00E-05	-5.9E-05	-1.67E-04	-2.73E-04	-3.79E-04	-4.84E-04
2.93E-04	2.26E-04	1.60E-04	9.44E-05	2.95E-05	-3.5E-05	-9.8E-05	-1.6E-04	-2.2E-04	-2.85E-04	2.93E-04	2.26E-04	1.60E-04		2.95E-05	-3.5E-05	-9.83E-05	-1.61E-04	-2.24E-04	-2.85E-04
9.17E-05	7.07E-05	5.00E-05	2.95E-05	9.23E-06	-1.1E-05	-3.1E-05	-5.0E-05	-7.0E-05	-8.92E-05	9.17E-05	7.07E-05	5.00E-05	2.95E-05		-1.1E-05	-3.07E-05	-5.04E-05	-6.99E-05	-8.92E-05
-1.08E-04	-8.3E-05	-5.9E-05	-3.5E-05	-1.1E-05	1.28E-05	3.61E-05	5.93E-05	8.22E-05	1.05E-04	-1.08E-04	-8.31E-05	-5.88E-05	-3.47E-05	-1.09E-05		3.61E-05	5.93E-05	8.22E-05	1.05E-04
-3.05E-04	-2.4E-04	-1.7E-04	-9.8E-05	-3.1E-05	3.61E-05	1.02E-04	1.68E-04	2.33E-04	2.97E-04	-3.05E-04	-2.36E-04	-1.67E-04	-9.83E-05	-3.07E-05	3.61E-05		1.68E-04	2.33E-04	2.97E-04
-5.01E-04	-3.9E-04	-2.7E-04	-1.6E-04	-5.0E-05	5.93E-05	1.68E-04	2.75E-04	3.82E-04	4.87E-04	-5.01E-04	-3.86E-04	-2.73E-04	-1.61E-04	-5.04E-05	5.93E-05	1.68E-04		3.82E-04	4.87E-04
-6.94E-04	-5.4E-04	-3.8E-04	-2.2E-04	-7.0E-05	8.22E-05	2.33E-04	3.82E-04	5.30E-04	6.76E-04	-6.94E-04	-5.36E-04	-3.79E-04	-2.24E-04	-6.99E-05	8.22E-05	2.33E-04	3.82E-04		6.76E-04
-8.86E-04	-6.8E-04	-4.8E-04	-2.9E-04	-8.9E-05	1.05E-04	2.97E-04	4.87E-04	6.76E-04	8.63E-04	-8.86E-04	-6.84E-04	-4.84E-04	-2.85E-04	-8.92E-05	1.05E-04	2.97E-04	4.87E-04	6.76E-04	
-9.10E-04	-5.4E-04	-2.7E-04	-9.4E-05	-9.2E-06	-1.3E-05	-1.0E-04	-2.8E-04	-5.3E-04	-8.63E-04	-9.10E-04	-5.42E-04	-2.71E-04	-9.44E-05	-9.23E-06	-1.3E-05	-1.02E-04	-2.75E-04	-5.30E-04	-8.63E-04

dAI*d/dAJ*8AI*8AJ

	2.15E-03	1.52E 03	8.98E-04	2.81E-04	-3.3E-04	-9.3E-04	-1.5E-03	-2.1E-03	-2.71E-03	2.79E-03	2.15E-03	1.52E-03	8.98E-04	2.81E-04	-3.3E-04	-9.35E-04	-1.53E-03	-2.13E-03	-2.71E-03
2.15E-03		1.17E-03	6.93E-04	2.17E-04	-2.5E-04	-7.2E-04	-1.2E-03	-1.6E-03	-2.09E-03	2.15E-03	1.66E-03	1.17E-03	6.93E-04	2.17E-04	-2.5E-04	-7.21E-04	-1.18E-03	-1.64E-03	-2.09E-03
1.52E-03	1.17E-03		4.90E-04	1.53E-04	-1.8E-04	-5.1E-04	-8.4E-04	-1.2E-03	-1.48E-03	1.52E-03	1.17E-03	8.30E-04	4.90E-04	1.53E-04	-1.8E-04	-5.10E-04	-8.37E-04	-1.16E-03	-1.48E-03
8.98E-04	6.93E-04	4.90E-04		9.04E-05	-1.1E-04	-3.0E-04	-4.9E-04	-6.8E-04	-8.74E-04	8.98E-04	6.93E-04	4.90E-04	2.89E-04	9.04E-05	-1.1E-04	-3.01E-04	-4.94E-04	-6.85E-04	-8.74E-04
2.81E-04	2.17E-04	1.53E-04	9.04E-05		-3.3E-05	-9.4E-05	-1.5E-04	-2.1E-04	-2.73E-04	2.81E-04	2.17E-04	1.53E-04	9.04E-05	2.83E-05	-3.3E-05	-9.41E-05	-1.54E-04	-2.14E-04	-2.73E-04
-3.30E-04	-2.5E-04	-1.8E-04	-1.1E-04	-3.3E-05		1.11E-04	1.82E-04	2.52E-04	3.21E-04	-3.30E-04	-2.55E-04	-1.80E-04	-1.06E-04	-3.32E-05	3.91E-05	1.11E-04	1.82E-04	2.52E-04	3.21E-04
-9.35E-04	-7.2E-04	-5.1E-04	-3.0E-04	-9.4E-05	1.11E-04		5.14E-04	7.13E-04	9.10E-04	-9.35E-04	-7.21E-04	-5.10E-04	-3.01E-04	-9.41E-05	1.11E-04	3.13E-04	5.14E-04	7.13E-04	9.10E-04
-1.53E-03	-1.2E-03	-8.4E-04	-4.9E-04	-1.5E-04	1.82E-04	5.14E-04		1.17E-03	1.49E-03	-1.53E-03	-1.18E-03	-8.37E-04	-4.94E-04	-1.54E-04	1.82E-04	5.14E-04	8.44E-04	1.17E-03	1.49E-03
-2.13E-03	-1.6E-03	-1.2E-03	-6.8E-04	-2.1E-04	2.52E-04	7.13E-04	1.17E-03		2.07E-03	-2.13E-03	-1.64E-03	-1.16E-03	-6.85E-04	-2.14E-04	2.52E-04	7.13E-04	1.17E-03	1.62E-03	2.07E-03
-2.71E-03	-2.1E-03	-1.5E-03	-8.7E-04	-2.7E-04	3.21E-04	9.10E-04	1.49E-03	2.07E-03		-2.71E-03	-2.09E-03	-1.48E-03	-8.74E-04	-2.73E-04	3.21E-04	9.10E-04	1.49E-03	2.07E-03	2.64E-03
2.79E-03	2.15E-03	1.52E-03	8.98E-04	2.81E-04	-3.3E-04	-9.3E-04	-1.5E-03	-2.1E-03	-2.71E-03		2.15E-03	1.52E-03	8.98E-04	2.81E-04	-3.3E-04	-9.35E-04	-1.53E-03	-2.13E-03	-2.71E-03
2.15E-03	1.66E-03	1.17E-03	6.93E-04	2.17E-04	-2.5E-04	-7.2E-04	-1.2E-03	-1.6E-03	-2.09E-03	2.15E-03		1.17E-03	6.93E-04	2.17E-04	-2.5E-04	-7.21E-04	-1.18E-03	-1.64E-03	-2.09E-03
1.52E-03	1.17E-03	8.30E-04	4.90E-04	1.53E-04	-1.8E-04	-5.1E-04	-8.4E-04	-1.2E-03	-1.48E-03	1.52E-03	1.17E-03		4.90E-04	1.53E-04	-1.8E-04	-5.10E-04	-8.37E-04	-1.16E-03	-1.48E-03
8.98E-04	6.93E-04	4.90E-04	2.89E-04	9.04E-05	-1.1E-04	-3.0E-04	-4.9E-04	-6.8E-04	-8.74E-04	8.98E-04	6.93E-04	4.90E-04		9.04E-05	-1.1E-04	-3.01E-04	-4.94E-04	-6.85E-04	-8.74E-04
2.81E-04	2.17E-04	1.53E-04	9.04E-05	2.83E-05	-3.3E-05	-9.4E-05	-1.5E-04	-2.1E-04	-2.73E-04	2.81E-04	2.17E-04	1.53E-04	9.04E-05		-3.3E-05	-9.41E-05	-1.54E-04	-2.14E-04	-2.73E-04
-3.30E-04	-2.5E-04	-1.8E-04	-1.1E-04	-3.3E-05	3.91E-05	1.11E-04	1.82E-04	2.52E-04	3.21E-04	-3.30E-04	-2.55E-04	-1.80E-04	-1.06E-04	-3.32E-05		1.11E-04	1.82E-04	2.52E-04	3.21E-04
-9.35E-04	-7.2E-04	-5.1E-04	-3.0E-04	-9.4E-05	1.11E-04	3.13E-04	5.14E-04	7.13E-04	9.10E-04	-9.35E-04	-7.21E-04	-5.10E-04	-3.01E-04	-9.41E-05	1.11E-04		5.14E-04	7.13E-04	9.10E-04
-1.53E-03	-1.2E-03	-8.4E-04	-4.9E-04	-1.5E-04	1.82E-04	5.14E-04	8.44E-04	1.17E-03	1.49E-03	-1.53E-03	-1.18E-03	-8.37E-04	-4.94E-04	-1.54E-04	1.82E-04	5.14E-04		1.17E-03	1.49E-03
-2.13E-03	-1.6E-03	-1.2E-03	-6.8E-04	-2.1E-04	2.52E-04	7.13E-04	1.17E-03	1.62E-03	2.07E-03	-2.13E-03	-1.64E-03	-1.16E-03	-6.85E-04	-2.14E-04	2.52E-04	7.13E-04	1.17E-03		2.07E-03
-2.71E-03	-2.1E-03	-1.5E-03	-8.7E-04	-2.7E-04	3.21E-04	9.10E-04	1.49E-03	2.07E-03	2.64E-03	-2.71E-03	-2.09E-03	-1.48E-03	-8.74E-04	-2.73E-04	3.21E-04	9.10E-04	1.49E-03	2.07E-03	
-2.79E-03	-1.7E-03	-8.3E-04	-2.9E-04	-2.8E-05	-3.9E-05	-3.1E-04	-8.4E-04	-1.6E-03	-2.64E-03	-2.79E-03	-1.66E-03	-8.30E-04	-2.89E-04	-2.83E-05	-3.9E-05	-3.13E-04	-8.44E-04	-1.62E-03	-2.64E-03

Table A-3
Bias Error Calculation -- Secondary Air Inlet
Milliken Heat Pipe Air Preheater

# of Points	4		
T, deg F	80	0.800	1.00%
T, deg R	540	0.800	0.15%

Input Data		Derivatives		(dTa/dX*Sigma)^2 (1)	Cross Product Terms			
Point	Ti	dTa/DTi		dTa/dTi	d/dTi*d/dTj*STi*STj			
1	80.0	0.25		4.00E-02		4.00E-02	4.00E-02	4.00E-02
2	80.0	0.25		4.00E-02	4.00E-02		4.00E-02	4.00E-02
3	80.0	0.25		4.00E-02	4.00E-02	4.00E-02		4.00E-02
4	80.0	0.25		4.00E-02	4.00E-02	4.00E-02	4.00E-02	
			Totals	1.60E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01

	T	
Contributions (2)	6.40E-01	
Total Sigma^2	0.64	
Tavg Sigma	0.80	deg F

(1) Ta = (T1 + T2 + T3 + T4)/4

(2) Contributions Include Cross Product Terms

Table A-4
Bias Error Calculation -- Secondary Air Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
uct Size				
Width, ft	9	0.042	0.46%	
ength, ft	6	0 042	0.69%	
# of Points	24			
Widthwise	6			
engthwise	4			
Sector Width, ft	1.50	0.042	2.78%	
Sector Length, ft	1.50	0.042	2.78%	
A, Sector Area ft^2	2.25	0.088	3.93%	
deg F	616	6.160	1.00%	
deg R	1076	6.160	0.57%	
mp Bias, deg F	100		33.33	deg F/Length Increment Spacial Bias
P, In WC	0.972035	0.0194	2.00%	
, lb/mol	28.85	0.025	0.09%	
mb Pres, In. Hg	29.50			
uct Pres, In. WC	5.60			
, In. Hg Absolute	29.70	0.040	0.14%	
P, Pitot Fact	0.84	0.0100	1.19%	
ominal Vel, fps	79.34	ACFM= 257051	SCFM= 123321	lb/hr= 562500

Input Data									Derivatives, dTa/dX							(dTa/dX*Sigma)^2					
Point	Ai	CPi	DPi	Mi	Pai	Ti	(1)	(2)	dTa/dTi	dTa/dAi	dTa/dCPi	dTa/dDPi	dTa/dMi	dTa/dPai		d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPai*SPai
1	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
2	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
3	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
4	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
5	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
6	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
7	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
8	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
9	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
10	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
11	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
12	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
13	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
14	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
15	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
16	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
17	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
18	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
19	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
20	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
21	2.25	0.84	0.9720	28.85	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02		7.24E-02	6.84E-03	6.26E-04	4.43E-04	8.32E-07	2.03E-06
22	2.25	0.84	0.9720	28.85	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02		6.79E-02	6.98E-04	6.41E-05	4.52E-05	8.49E-08	2.07E-07
23	2.25	0.84	0.9720	28.85	29.70	1092.7	1.650	1803.1	4.10E-02	3.16E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02		6.38E-02	7.90E-04	7.26E-05	5.12E-05	9.61E-08	2.34E-07
24	2.25	0.84	0.9720	28.85	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02		6.01E-02	6.56E-03	6.03E-04	4.25E-04	7.96E-07	1.94E-06
Temperature -- Simple Average						1076.0	SUM1	SUM2								T	A	CP	DP	M	Pa
Temperature -- Weighted Average						1075.4	39.927	42936.0							Contributions (3)	3.80E+01	7.61E-18	3.74E-18	4.88E-19	-4.76E-22	6.99E-21
																		Total Sigma^2		37.99	
																		Tavg Sigma		6.16	deg F

) Ai*CPi(DPi*Mi*Pai/Ti)^0.5

) Ai*CPi(DPi*Mi*Pai*Ti)^0.5

) Contributions Include Cross Product Terms

Table A-4 (Continued)

Cross Product Terms

d/dTI*d/dTj*STI*STj	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02
7.01E-02		6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02
6.80E-02	6.58E-02		6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02
6.60E-02	6.39E-02	6.19E-02		6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02
7.24E-02	7.01E-02	6.80E-02	6.60E-02		7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02
7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02		6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02
6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02		6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02
6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02		6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02
7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02		7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02
7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02		6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02
6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02		6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02
6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02		6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02
7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02		7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02
7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02		6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02
6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02		6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02
6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02		6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02
7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02		7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02
7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02		6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02
6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02		6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02
6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02		6.60E-02	6.39E-02	6.19E-02	6.01E-02
7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02	7.24E-02	7.01E-02	6.80E-02	6.60E-02		7.01E-02	6.80E-02	6.60E-02
7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02	6.79E-02	6.58E-02	6.39E-02	7.01E-02		6.58E-02	6.39E-02
6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02	6.38E-02	6.19E-02	6.80E-02	6.58E-02		6.19E-02
6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	6.01E-02	6.60E-02	6.39E-02	6.19E-02	
1.59E+00	1.54E+00	1.49E+00	1.45E+00	1.59E+00	1.54E+00	1.49E+00	1.45E+00	1.59E+00	1.54E+00	1.49E+00	1.45E+00	1.59E+00	1.54E+00	1.49E+00	1.45E+00	1.59E+00	1.54E+00	1.49E+00	1.45E+00	1.59E+00	1.54E+00	1.49E+00	1.45E+00

d/dDPI*d/dDPj*SDPI*SDPj	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.51E-04	-4.34E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.81E-05	-1.39E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05		1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.81E-05	5.12E-05	1.48E-04
-4.34E-04	-1.4E-04	1.48E-04		-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.39E-04	1.48E-04	4.25E-04
4.43E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.51E-04	-4.34E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.81E-05	-1.39E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05		1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.81E-05	5.12E-05	1.48E-04
-4.34E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04		-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.39E-04	1.48E-04	4.25E-04
4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.51E-04	-4.34E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.81E-05	-1.39E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05		1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.81E-05	5.12E-05	1.48E-04
-4.34E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04		-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.39E-04	1.48E-04	4.25E-04
4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.51E-04	-4.34E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.81E-05	-1.39E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05		1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.81E-05	5.12E-05	1.48E-04
-4.34E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04		-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.39E-04	1.48E-04	4.25E-04
4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.51E-04	-4.34E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.81E-05	-1.39E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05		1.48E-04	-1.5E-04	-4.81E-05	5.12E-05	1.48E-04
-4.34E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04		-4.3E-04	-1.39E-04	1.48E-04	4.25E-04
4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.5E-04	-4.3E-04	4.43E-04	1.42E-04	-1.51E-04	-4.34E-04		1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.8E-05	-1.4E-04	1.42E-04	4.52E-05	-4.81E-05	-1.39E-04	1.42E-04		-4.8E-05	-1.4E-04
-1.51E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.8E-05	5.12E-05	1.48E-04	-1.5E-04	-4.81E-05		1.48E-04
-4.34E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.4E-04	1.48E-04	4.25E-04	-4.3E-04	-1.39E-04	1.48E-04	
-4.43E-04	-4.5E-05	-5.1E-05	-4.3E-04	-4.4E-04	-4.5E-05	-5.1E-05	-4.3E-04	-4.4E-04	-4.5E-05	-5.1E-05	-4.3E-04	-4.4E-04	-4.5E-05	-5.1E-05	-4.3E-04	-4.4E-04	-4.5E-05	-5.12E-05	-4.25E-04	-4.4E-04	-4.52E-05	-5.1E-05	-4.3E-04

Table A-4 (Continued)

Cross Product Terms

d/dMl*d/dMj*SMl*SMj

	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.83E-07	-6.15E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07
2.66E-07		-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.03E-08	-2.60E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08		2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.03E-08	9.61E-08	2.77E-07
-6.15E-07	-2.6E-07	2.77E-07		-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.60E-07	2.77E-07	7.96E-07
6.32E-07	2.66E-07	-2.8E-07	-6.1E-07		2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.83E-07	-6.15E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07
2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07		-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.03E-08	-2.60E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08		2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.03E-08	9.61E-08	2.77E-07
-6.15E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07		-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.60E-07	2.77E-07	7.96E-07
6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07		2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.83E-07	-6.15E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07
2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07		-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.03E-08	-2.60E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08		2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.03E-08	9.61E-08	2.77E-07
-6.15E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07		-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.60E-07	2.77E-07	7.96E-07
6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07		2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.83E-07	-6.15E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07
2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07		-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.03E-08	-2.60E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08		2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.03E-08	9.61E-08	2.77E-07
-6.15E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07		-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.60E-07	2.77E-07	7.96E-07
6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07		2.66E-07	-2.83E-07	-6.15E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07
2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07		-9.03E-08	-2.60E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08		2.77E-07	-2.8E-07	-9.03E-08	9.61E-08	2.77E-07
-6.15E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07		-6.1E-07	-2.60E-07	2.77E-07	7.96E-07
6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.8E-07	-6.1E-07	6.32E-07	2.66E-07	-2.83E-07	-6.15E-07		2.66E-07	-2.8E-07	-6.1E-07
2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.0E-08	-2.6E-07	2.66E-07	6.49E-08	-9.03E-08	-2.60E-07	2.66E-07		-9.0E-08	-2.6E-07
-2.83E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.0E-08	9.61E-08	2.77E-07	-2.8E-07	-9.03E-08		2.77E-07
-6.15E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.6E-07	2.77E-07	7.96E-07	-6.1E-07	-2.60E-07	2.77E-07	
-6.32E-07	-6.5E-08	-9.6E-08	-6.0E-07	-6.3E-07	-6.5E-08	-9.6E-08	-6.0E-07	-6.3E-07	-6.5E-08	-9.6E-08	-6.0E-07	-6.3E-07	-6.5E-08	-9.6E-08	-6.0E-07	-6.3E-07	-6.5E-08	-9.61E-08	-7.96E-07	-6.3E-07	-6.49E-08	-9.6E-08	-6.0E-07

d/dPel*d/dPej*SPel*SPej

	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.89E-07	-1.96E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06
6.47E-07		-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.20E-07	-6.34E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07		6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.20E-07	2.34E-07	6.75E-07
-1.96E-06	-6.3E-07	6.75E-07		-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.34E-07	6.75E-07	1.94E-06
2.03E-06	6.47E-07	-6.9E-07	-2.0E-06		6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.89E-07	-1.96E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06
6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07		-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.20E-07	-6.34E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07		6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.20E-07	2.34E-07	6.75E-07
-1.96E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07		-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.34E-07	6.75E-07	1.94E-06
2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06		6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.89E-07	-1.96E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06
6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07		-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.20E-07	-6.34E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07		6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.20E-07	2.34E-07	6.75E-07
-1.96E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07		-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.34E-07	6.75E-07	1.94E-06
2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06		6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.89E-07	-1.96E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06
6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07		-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.20E-07	-6.34E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07		6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.20E-07	2.34E-07	6.75E-07
-1.96E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07		-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.34E-07	6.75E-07	1.94E-06
2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06		6.47E-07	-6.89E-07	-1.96E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06
6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07		-2.20E-07	-6.34E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07		6.75E-07	-6.9E-07	-2.20E-07	2.34E-07	6.75E-07
-1.96E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07		-2.0E-06	-6.34E-07	6.75E-07	1.94E-06
2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.9E-07	-2.0E-06	2.03E-06	6.47E-07	-6.89E-07	-1.96E-06		6.47E-07	-6.9E-07	-2.0E-06
6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.2E-07	-6.3E-07	6.47E-07	2.07E-07	-2.20E-07	-6.34E-07	6.47E-07		-2.2E-07	-6.3E-07
-6.89E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.2E-07	2.34E-07	6.75E-07	-6.9E-07	-2.20E-07		6.75E-07
-1.96E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.3E-07	6.75E-07	1.94E-06	-2.0E-06	-6.34E-07	6.75E-07	
-2.03E-06	-2.1E-07	-2.3E-07	-1.9E-06	-2.0E-06	-2.1E-07	-2.3E-07	-1.9E-06	-2.0E-06	-2.1E-07	-2.3E-07	-1.9E-06	-2.0E-06	-2.1E-07	-2.3E-07	-1.9E-06	-2.0E-06	-2.1E-07	-2.34E-07	-1.94E-06	-2.0E-06	-2.07E-07	-2.3E-07	-1.9E-06

Table A-4 (Continued)

Cross Product Terms

dCP*d/dCP|*SCPI*SCP|

	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.13E-04	-6.15E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04
2.01E-04		-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.82E-05	-1.97E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05		2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.82E-05	7.28E-05	2.09E-04
-6.15E-04	-2.0E-04	2.09E-04		-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-1.97E-04	2.09E-04	6.03E-04
6.28E-04	2.01E-04	-2.1E-04	-6.2E-04		2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.13E-04	-6.15E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04
2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04		-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.82E-05	-1.97E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05		2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.82E-05	7.28E-05	2.09E-04
-6.15E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04		-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-1.97E-04	2.09E-04	6.03E-04
6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04		2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.13E-04	-6.15E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04
2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04		-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.82E-05	-1.97E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05		2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.82E-05	7.28E-05	2.09E-04
-6.15E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04		-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-1.97E-04	2.09E-04	6.03E-04
6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04		2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.13E-04	-6.15E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04
2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04		-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.82E-05	-1.97E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05		2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.82E-05	7.28E-05	2.09E-04
-6.15E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04		-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-1.97E-04	2.09E-04	6.03E-04
6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04		2.01E-04	-2.13E-04	-6.15E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04
2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04		-6.82E-05	-1.97E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05		2.09E-04	-2.1E-04	-6.82E-05	7.28E-05	2.09E-04
-6.15E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04		-6.2E-04	-1.97E-04	2.09E-04	6.03E-04
6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.1E-04	-6.2E-04	6.28E-04	2.01E-04	-2.13E-04	-6.15E-04		2.01E-04	-2.1E-04	-6.2E-04
2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.8E-05	-2.0E-04	2.01E-04	6.41E-05	-6.82E-05	-1.97E-04	2.01E-04		-6.8E-05	-2.0E-04
-2.13E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.8E-05	7.28E-05	2.09E-04	-2.1E-04	-6.82E-05		2.09E-04
-6.15E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-2.0E-04	2.09E-04	6.03E-04	-6.2E-04	-1.97E-04	2.09E-04	
-6.28E-04	-6.4E-05	-7.3E-05	-6.0E-04	-6.3E-04	-6.4E-05	-7.3E-05	-6.0E-04	-6.3E-04	-6.4E-05	-7.3E-05	-6.0E-04	-6.3E-04	-6.4E-05	-7.3E-05	-6.0E-04	-6.3E-04	-6.4E-05	-7.28E-05	-6.03E-04	-6.3E-04	-6.41E-05	-7.3E-05	-6.0E-04

l/dA*d/dA|*SAI*SA|

	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.32E-03	-6.70E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03
2.18E-03		-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.43E-04	-2.14E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03
-2.32E-03	-7.4E-04		2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.43E-04	7.90E-04	2.28E-03
-6.70E-03	-2.1E-03	2.28E-03		-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.14E-03	2.28E-03	6.56E-03
6.84E-03	2.18E-03	-2.3E-03	-6.7E-03		2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.32E-03	-6.70E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03
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-2.32E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04		2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.43E-04	7.90E-04	2.28E-03
-6.70E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03		-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.14E-03	2.28E-03	6.56E-03
6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03		2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.32E-03	-6.70E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03
2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03		-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.43E-04	-2.14E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03
-2.32E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04		2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.43E-04	7.90E-04	2.28E-03
-6.70E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03		-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.14E-03	2.28E-03	6.56E-03
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-2.32E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04		2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.43E-04	7.90E-04	2.28E-03
-6.70E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03		-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.14E-03	2.28E-03	6.56E-03
6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03		2.18E-03	-2.32E-03	-6.70E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03
2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03		-7.43E-04	-2.14E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03
-2.32E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04		2.28E-03	-2.3E-03	-7.43E-04	7.90E-04	2.28E-03
-6.70E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03		-6.7E-03	-2.14E-03	2.28E-03	6.56E-03
6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.3E-03	-6.7E-03	6.84E-03	2.18E-03	-2.32E-03	-6.70E-03		2.18E-03	-2.3E-03	-6.7E-03
2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.4E-04	-2.1E-03	2.18E-03	6.98E-04	-7.43E-04	-2.14E-03	2.18E-03		-7.4E-04	-2.1E-03
-2.32E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.4E-04	7.90E-04	2.28E-03	-2.3E-03	-7.43E-04		2.28E-03
-6.70E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.1E-03	2.28E-03	6.56E-03	-6.7E-03	-2.14E-03	2.28E-03	
-6.84E-03	-7.0E-04	-7.9E-04	-6.6E-03	-6.8E-03	-7.0E-04	-7.9E-04	-6.6E-03	-6.8E-03	-7.0E-04	-7.9E-04	-6.6E-03	-6.8E-03	-7.0E-04	-7.9E-04	-6.6E-03	-6.8E-03	-7.0E-04	-7.90E-04	-6.56E-03	-6.8E-03	-6.98E-04	-7.9E-04	-6.6E-03

Table A-5
Bias Error Calculation -- Flue Gas Inlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative					
uct Size								
Width, ft	5.5	0.042	0.76%					
Length, ft	14.5	0.042	0.29%					
# of Points	20							
Widthwise	4							
Lengthwise	5							
Sector Width, ft	1.38	0.042	3.03%					
Sector Length, ft	2.90	0.042	1.44%					
A, Sector Area ft^2	3.99	0.134	3.35%					
, deg F	680	6.800	1.00%					
, deg R	1140	6.800	0.60%					
emp Bias, deg F	100		25.00	deg F/Length Increment Special Bias				
P, In WC	0.82831	0.0166	2.00%					
, lb/mol	29.71	0.050	0.17%					
mb Pres, In. Hg	29.50							
uct Pres, In. WC	-7.50							
s, In. Hg Absolute	29.23	0.040	0.14%					
P, Pitot Fact	0.84	0.0100	1.19%					
ominal Vel, fps	74.88	ACFM=	358315	SCFM=	159669	lb/hr=	750001	

	Input Data								Derivatives, dTa/dX					
Point	Ai	Cpi	DPi	Mi	Psi	Ti	(1)	(2)	dTa/dTi	dTa/dAi	dTa/dCP	dTa/dDPi	dTa/dMi	dTa/dPsi
1	3.99	0.84	0.82831	29.71	29.23	1090.0	2.721	2965.9	5.51E-02	-1.5E+00	-6.9E+00	-3.5E+00	-9.7E-02	-9.9E-02
2	3.99	0.84	0.82831	29.71	29.23	1115.0	2.690	2999.7	5.38E-02	-1.1E+00	-5.3E+00	-2.7E+00	-7.4E-02	-7.6E-02
3	3.99	0.84	0.82831	29.71	29.23	1140.0	2.661	3033.1	5.26E-02	-7.6E-01	-3.7E+00	-1.9E+00	-5.2E-02	-5.3E-02
4	3.99	0.84	0.82831	29.71	29.23	1165.0	2.632	3066.2	5.15E-02	-4.5E-01	-2.1E+00	-1.1E+00	-3.0E-02	-3.1E-02
5	3.99	0.84	0.82831	29.71	29.23	1190.0	2.604	3098.9	5.04E-02	-1.3E-01	-6.2E-01	-3.1E-01	-8.7E-03	-8.9E-03
6	3.99	0.84	0.82831	29.71	29.23	1215.0	2.577	3131.3	4.94E-02	1.63E-01	8.66E-01	4.39E-01	1.22E-02	1.24E-02
7	3.99	0.84	0.82831	29.71	29.23	1240.0	2.551	3163.4	4.84E-02	4.89E-01	2.32E+00	1.18E+00	3.28E-02	3.34E-02
8	3.99	0.84	0.82831	29.71	29.23	1265.0	2.526	3195.1	4.74E-02	7.89E-01	3.75E+00	1.90E+00	5.30E-02	5.38E-02
9	3.99	0.84	0.82831	29.71	29.23	1290.0	2.501	3226.5	4.65E-02	1.08E+00	5.15E+00	2.61E+00	7.27E-02	7.39E-02
10	3.99	0.84	0.82831	29.71	29.23	1315.0	2.477	3257.6	4.57E-02	1.37E+00	6.52E+00	3.30E+00	9.21E-02	9.36E-02
11	3.99	0.84	0.82831	29.71	29.23	1090.0	2.721	2965.9	5.51E-02	-1.5E+00	-6.9E+00	-3.5E+00	-9.7E-02	-9.9E-02
12	3.99	0.84	0.82831	29.71	29.23	1115.0	2.690	2999.7	5.38E-02	-1.1E+00	-5.3E+00	-2.7E+00	-7.4E-02	-7.6E-02
13	3.99	0.84	0.82831	29.71	29.23	1140.0	2.661	3033.1	5.26E-02	-7.6E-01	-3.7E+00	-1.9E+00	-5.2E-02	-5.3E-02
14	3.99	0.84	0.82831	29.71	29.23	1165.0	2.632	3066.2	5.15E-02	-4.5E-01	-2.1E+00	-1.1E+00	-3.0E-02	-3.1E-02
15	3.99	0.84	0.82831	29.71	29.23	1190.0	2.604	3098.9	5.04E-02	-1.3E-01	-6.2E-01	-3.1E-01	-8.7E-03	-8.9E-03
16	3.99	0.84	0.82831	29.71	29.23	1215.0	2.577	3131.3	4.94E-02	1.63E-01	8.66E-01	4.39E-01	1.22E-02	1.24E-02
17	3.99	0.84	0.82831	29.71	29.23	1240.0	2.551	3163.4	4.84E-02	4.89E-01	2.32E+00	1.18E+00	3.28E-02	3.34E-02
18	3.99	0.84	0.82831	29.71	29.23	1265.0	2.526	3195.1	4.74E-02	7.89E-01	3.75E+00	1.90E+00	5.30E-02	5.38E-02
19	3.99	0.84	0.82831	29.71	29.23	1290.0	2.501	3226.5	4.65E-02	1.08E+00	5.15E+00	2.61E+00	7.27E-02	7.39E-02
20	3.99	0.84	0.82831	29.71	29.23	1315.0	2.477	3257.6	4.57E-02	1.37E+00	6.52E+00	3.30E+00	9.21E-02	9.36E-02
		Temperature -- Simple Average				1202.5	SUM1	SUM2						
		Temperature -- Weighted Average				1200.4	51.881	62275.2						Contributions (3)

	(dTa/dX*Sigma)^2					
Point	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPsi*SPsi
1	1.40E-01	3.77E-02	4.75E-03	3.35E-03	2.37E-05	1.58E-05
2	1.34E-01	2.20E-02	2.78E-03	1.96E-03	1.39E-05	9.25E-06
3	1.28E-01	1.08E-02	1.36E-03	9.58E-04	6.78E-06	4.52E-06
4	1.23E-01	3.62E-03	4.56E-04	3.22E-04	2.28E-06	1.52E-06
5	1.18E-01	3.04E-04	3.83E-05	2.70E-05	1.91E-07	1.27E-07
6	1.13E-01	5.96E-04	7.51E-05	5.30E-05	3.75E-07	2.50E-07
7	1.08E-01	4.28E-03	5.39E-04	3.80E-04	2.69E-06	1.79E-06
8	1.04E-01	1.11E-02	1.40E-03	9.91E-04	7.01E-06	4.66E-06
9	1.00E-01	2.10E-02	2.65E-03	1.87E-03	1.32E-05	8.82E-06
10	9.64E-02	3.37E-02	4.25E-03	3.00E-03	2.12E-05	1.42E-05
11	1.40E-01	3.77E-02	4.75E-03	3.35E-03	2.37E-05	1.58E-05
12	1.34E-01	2.20E-02	2.78E-03	1.96E-03	1.39E-05	9.25E-06
13	1.28E-01	1.08E-02	1.36E-03	9.58E-04	6.78E-06	4.52E-06
14	1.23E-01	3.62E-03	4.56E-04	3.22E-04	2.28E-06	1.52E-06
15	1.18E-01	3.04E-04	3.83E-05	2.70E-05	1.91E-07	1.27E-07
16	1.13E-01	5.96E-04	7.51E-05	5.30E-05	3.75E-07	2.50E-07
17	1.08E-01	4.28E-03	5.39E-04	3.80E-04	2.69E-06	1.79E-06
18	1.04E-01	1.11E-02	1.40E-03	9.91E-04	7.01E-06	4.66E-06
19	1.00E-01	2.10E-02	2.65E-03	1.87E-03	1.32E-05	8.82E-06
20	9.64E-02	3.37E-02	4.25E-03	3.00E-03	2.12E-05	1.42E-05
	T	A	CP	DP	M	Ps
	4.64E+01	-2.17E-17	6.37E-18	1.07E-18	2.75E-20	2.62E-20
			Total Sigma^2		46.41	
			Tavg Sigma		6.81	deg F

1) Ai*CPi(DPi*Mi*Psi/Ti)^0.5

2) Ai*CPi(DPi*Mi*Psi*Ti)^0.5

Table A-5 (Continued)
Cross Product Terms

d/dTI*d/dTJ*STI*STJ

	1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.21E-01	1.19E-01	1.16E-01	1.40E-01	1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.21E-01	1.19E-01	1.16E-01
1.37E-01		1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.16E-01	1.14E-01	1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.16E-01	1.14E-01
1.34E-01	1.31E-01		1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.34E-01	1.31E-01	1.28E-01	1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01
1.31E-01	1.28E-01	1.25E-01		1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.09E-01	1.31E-01	1.28E-01	1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.09E-01
1.28E-01	1.26E-01	1.23E-01	1.20E-01		1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01
1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01		1.10E-01	1.08E-01	1.06E-01	1.04E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01	1.08E-01	1.06E-01	1.04E-01
1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01		1.06E-01	1.04E-01	1.02E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01
1.21E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01		1.02E-01	1.00E-01	1.21E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01
1.19E-01	1.16E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01		9.83E-02	1.19E-01	1.16E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02
1.16E-01	1.14E-01	1.11E-01	1.09E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02		1.16E-01	1.14E-01	1.11E-01	1.09E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02	9.64E-02
1.40E-01	1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.21E-01	1.19E-01	1.16E-01		1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.21E-01	1.19E-01	1.16E-01
1.37E-01	1.34E-01	1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.16E-01	1.14E-01	1.37E-01		1.31E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.16E-01	1.14E-01
1.34E-01	1.31E-01	1.28E-01	1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.34E-01	1.31E-01		1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01
1.31E-01	1.28E-01	1.25E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.09E-01	1.31E-01	1.28E-01	1.25E-01		1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.09E-01
1.28E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.28E-01	1.26E-01	1.23E-01	1.20E-01		1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01
1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01	1.08E-01	1.06E-01	1.04E-01	1.26E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01		1.10E-01	1.08E-01	1.06E-01	1.04E-01
1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01	1.23E-01	1.20E-01	1.18E-01	1.15E-01	1.13E-01	1.10E-01		1.06E-01	1.04E-01	1.02E-01
1.21E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	1.21E-01	1.18E-01	1.15E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01		1.02E-01	1.00E-01
1.19E-01	1.16E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02	1.19E-01	1.16E-01	1.13E-01	1.11E-01	1.08E-01	1.06E-01	1.04E-01	1.02E-01		9.83E-02
1.16E-01	1.14E-01	1.11E-01	1.09E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02	9.64E-02	1.16E-01	1.14E-01	1.11E-01	1.09E-01	1.06E-01	1.04E-01	1.02E-01	1.00E-01	9.83E-02	
2.41E+00	2.36E+00	2.31E+00	2.26E+00	2.22E+00	2.17E+00	2.13E+00	2.09E+00	2.06E+00	2.02E+00	2.41E+00	2.36E+00	2.31E+00	2.26E+00	2.22E+00	2.17E+00	2.13E+00	2.09E+00	2.06E+00	2.02E+00

d/dDPI*d/dDPJ*SDPI*SDPJ

	2.56E-03	1.79E-03	1.04E-03	3.01E-04	-4.2E-04	-1.1E-03	-1.8E-03	-2.5E-03	-3.2E-03	3.35E-03	2.56E-03	1.79E-03	1.04E-03	3.01E-04	-4.2E-04	-1.13E-03	-1.82E-03	-2.50E-03	-3.17E-03
2.56E-03		1.37E-03	7.94E-04	2.30E-04	-3.2E-04	-8.6E-04	-1.4E-03	-1.9E-03	-2.4E-03	2.56E-03	1.96E-03	1.37E-03	7.94E-04	2.30E-04	-3.2E-04	-8.63E-04	-1.39E-03	-1.91E-03	-2.42E-03
1.79E-03	1.37E-03		5.55E-04	1.61E-04	-2.3E-04	-6.0E-04	-9.7E-04	-1.3E-03	-1.7E-03	1.79E-03	1.37E-03	9.58E-04	5.55E-04	1.61E-04	-2.3E-04	-6.03E-04	-9.74E-04	-1.34E-03	-1.69E-03
1.04E-03	7.94E-04	5.55E-04		9.32E-05	-1.3E-04	-3.5E-04	-5.6E-04	-7.8E-04	-9.8E-04	1.04E-03	7.94E-04	5.55E-04	3.22E-04	9.32E-05	-1.3E-04	-3.50E-04	-5.64E-04	-7.75E-04	-9.82E-04
3.01E-04	2.30E-04	1.61E-04	9.32E-05		-3.8E-05	-1.0E-04	-1.6E-04	-2.2E-04	-2.8E-04	3.01E-04	2.30E-04	1.61E-04	9.32E-05	2.70E-05	-3.8E-05	-1.01E-04	-1.64E-04	-2.25E-04	-2.84E-04
-4.21E-04	-3.2E-04	-2.3E-04	-1.3E-04	-3.8E-05		1.42E-04	2.29E-04	3.15E-04	3.98E-04	-4.2E-04	-3.2E-04	-2.3E-04	-1.3E-04	-3.8E-05	5.30E-05	1.42E-04	2.29E-04	3.15E-04	3.98E-04
-1.13E-03	-8.6E-04	-6.0E-04	-3.5E-04	-1.0E-04	1.42E-04		6.14E-04	8.43E-04	1.07E-03	-1.1E-03	-8.6E-04	-6.0E-04	-3.5E-04	-1.0E-04	1.42E-04	3.80E-04	6.14E-04	8.43E-04	1.07E-03
-1.82E-03	-1.4E-03	-9.7E-04	-5.6E-04	-1.6E-04	2.29E-04	6.14E-04		1.36E-03	1.72E-03	-1.8E-03	-1.4E-03	-9.7E-04	-5.6E-04	-1.6E-04	2.29E-04	6.14E-04	9.91E-04	1.36E-03	1.72E-03
-2.50E-03	-1.9E-03	-1.3E-03	-7.8E-04	-2.2E-04	3.15E-04	8.43E-04	1.36E-03		2.37E-03	-2.5E-03	-1.9E-03	-1.3E-03	-7.8E-04	-2.2E-04	3.15E-04	8.43E-04	1.36E-03	1.87E-03	2.37E-03
-3.17E-03	-2.4E-03	-1.7E-03	-9.8E-04	-2.8E-04	3.98E-04	1.07E-03	1.72E-03	2.37E-03		-3.2E-03	-2.4E-03	-1.7E-03	-9.8E-04	-2.8E-04	3.98E-04	1.07E-03	1.72E-03	2.37E-03	3.00E-03
3.35E-03	2.56E-03	1.79E-03	1.04E-03	3.01E-04	-4.2E-04	-1.1E-03	-1.8E-03	-2.5E-03	-3.2E-03		2.56E-03	1.79E-03	1.04E-03	3.01E-04	-4.2E-04	-1.13E-03	-1.82E-03	-2.50E-03	-3.17E-03
2.56E-03	1.96E-03	1.37E-03	7.94E-04	2.30E-04	-3.2E-04	-8.6E-04	-1.4E-03	-1.9E-03	-2.4E-03	2.56E-03		1.37E-03	7.94E-04	2.30E-04	-3.2E-04	-8.63E-04	-1.39E-03	-1.91E-03	-2.42E-03
1.79E-03	1.37E-03	9.58E-04	5.55E-04	1.61E-04	-2.3E-04	-6.0E-04	-9.7E-04	-1.3E-03	-1.7E-03	1.79E-03	1.37E-03		5.55E-04	1.61E-04	-2.3E-04	-6.03E-04	-9.74E-04	-1.34E-03	-1.69E-03
1.04E-03	7.94E-04	5.55E-04	3.22E-04	9.32E-05	-1.3E-04	-3.5E-04	-5.6E-04	-7.8E-04	-9.8E-04	1.04E-03	7.94E-04	5.55E-04		9.32E-05	-1.3E-04	-3.50E-04	-5.64E-04	-7.75E-04	-9.82E-04
3.01E-04	2.30E-04	1.61E-04	9.32E-05	2.70E-05	-3.8E-05	-1.0E-04	-1.6E-04	-2.2E-04	-2.8E-04	3.01E-04	2.30E-04	1.61E-04	9.32E-05		-3.8E-05	-1.01E-04	-1.64E-04	-2.25E-04	-2.84E-04
-4.21E-04	-3.2E-04	-2.3E-04	-1.3E-04	-3.8E-05	5.30E-05	1.42E-04	2.29E-04	3.15E-04	3.98E-04	-4.2E-04	-3.2E-04	-2.3E-04	-1.3E-04	-3.8E-05		1.42E-04	2.29E-04	3.15E-04	3.98E-04
-1.13E-03	-8.6E-04	-6.0E-04	-3.5E-04	-1.0E-04	1.42E-04	3.80E-04	6.14E-04	8.43E-04	1.07E-03	-1.1E-03	-8.6E-04	-6.0E-04	-3.5E-04	-1.0E-04	1.42E-04		6.14E-04	8.43E-04	1.07E-03
-1.82E-03	-1.4E-03	-9.7E-04	-5.6E-04	-1.6E-04	2.29E-04	6.14E-04	9.91E-04	1.36E-03	1.72E-03	-1.8E-03	-1.4E-03	-9.7E-04	-5.6E-04	-1.6E-04	2.29E-04	6.14E-04		1.36E-03	1.72E-03
-2.50E-03	-1.9E-03	-1.3E-03	-7.8E-04	-2.2E-04	3.15E-04	8.43E-04	1.36E-03	1.87E-03	2.37E-03	-2.5E-03	-1.9E-03	-1.3E-03	-7.8E-04	-2.2E-04	3.15E-04	8.43E-04	1.36E-03		2.37E-03
-3.17E-03	-2.4E-03	-1.7E-03	-9.8E-04	-2.8E-04	3.98E-04	1.07E-03	1.72E-03	2.37E-03	3.00E-03	-3.2E-03	-2.4E-03	-1.7E-03	-9.8E-04	-2.8E-04	3.98E-04	1.07E-03	1.72E-03	2.37E-03	
-3.35E-03	-2.0E-03	-9.6E-04	-3.2E-04	-2.7E-05	-5.3E-05	-3.8E-04	-9.9E-04	-1.9E-03	-3.0E-03	-3.3E-03	-2.0E-03	-9.6E-04	-3.2E-04	-2.7E-05	-5.3E-05	-3.80E-04	-9.91E-04	-1.87E-03	-3.00E-03

Table A-5 (Continued)
Cross Product Terms

d/dMi*d/dMj*δMi*δMj

	1.81E-05	1.27E-05	7.35E-06	2.13E-06	-3.0E-06	-8.0E-06	-1.3E-05	-1.8E-05	-2.2E-05	2.37E-05	1.81E-05	1.27E-05	7.35E-06	2.13E-06	-3.0E-06	-7.99E-06	-1.29E-05	-1.77E-05	-2.24E-05
1.81E-05		9.70E-06	5.62E-06	1.63E-06	-2.3E-06	-6.1E-06	-9.9E-06	-1.4E-05	-1.7E-05	1.81E-05	1.39E-05	9.70E-06	5.62E-06	1.63E-06	-2.3E-06	-6.11E-06	-9.86E-06	-1.35E-05	-1.72E-05
1.27E-05	9.70E-06		3.93E-06	1.14E-06	-1.6E-06	-4.3E-06	-6.9E-06	-9.5E-06	-1.2E-05	1.27E-05	9.70E-06	6.78E-06	3.93E-06	1.14E-06	-1.6E-06	-4.27E-06	-6.90E-06	-9.47E-06	-1.20E-05
7.35E-06	5.62E-06	3.93E-06		6.60E-07	-9.2E-07	-2.5E-06	-4.0E-06	-5.5E-06	-7.0E-06	7.35E-06	5.62E-06	3.93E-06	2.28E-06	6.60E-07	-9.2E-07	-2.48E-06	-4.00E-06	-5.49E-06	-6.95E-06
2.13E-06	1.63E-06	1.14E-06	6.60E-07		-2.7E-07	-7.2E-07	-1.2E-06	-1.6E-06	-2.0E-06	2.13E-06	1.63E-06	1.14E-06	6.60E-07	1.91E-07	-2.7E-07	-7.17E-07	-1.16E-06	-1.59E-06	-2.01E-06
-2.98E-06	-2.3E-06	-1.6E-06	-9.2E-07	-2.7E-07		1.00E-06	1.62E-06	2.23E-06	2.82E-06	-3.0E-06	-2.3E-06	-1.6E-06	-9.2E-07	-2.7E-07	3.75E-07	1.00E-06	1.62E-06	2.23E-06	2.82E-06
-7.99E-06	-6.1E-06	-4.3E-06	-2.5E-06	-7.2E-07	1.00E-06		4.34E-06	5.97E-06	7.56E-06	-8.0E-06	-6.1E-06	-4.3E-06	-2.5E-06	-7.2E-07	1.00E-06	2.69E-06	4.34E-06	5.97E-06	7.56E-06
-1.29E-05	-9.9E-06	-6.9E-06	-4.0E-06	-1.2E-06	1.62E-06	4.34E-06		9.63E-06	1.22E-05	-1.3E-05	-9.9E-06	-6.9E-06	-4.0E-06	-1.2E-06	1.62E-06	4.34E-06	7.01E-06	9.63E-06	1.22E-05
-1.77E-05	-1.4E-05	-9.5E-06	-5.5E-06	-1.6E-06	2.23E-06	5.97E-06	9.63E-06		1.68E-05	-1.8E-05	-1.4E-05	-9.5E-06	-5.5E-06	-1.6E-06	2.23E-06	5.97E-06	9.63E-06	1.32E-05	1.68E-05
-2.24E-05	-1.7E-05	-1.2E-05	-7.0E-06	-2.0E-06	2.82E-06	7.56E-06	1.22E-05	1.68E-05		-2.2E-05	-1.7E-05	-1.2E-05	-7.0E-06	-2.0E-06	2.82E-06	7.56E-06	1.22E-05	1.68E-05	2.12E-05
2.37E-05	1.81E-05	1.27E-05	7.35E-06	2.13E-06	-3.0E-06	-8.0E-06	-1.3E-05	-1.8E-05	-2.2E-05		1.81E-05	1.27E-05	7.35E-06	2.13E-06	-3.0E-06	-7.99E-06	-1.29E-05	-1.77E-05	-2.24E-05
1.81E-05	1.39E-05	9.70E-06	5.62E-06	1.63E-06	-2.3E-06	-6.1E-06	-9.9E-06	-1.4E-05	-1.7E-05	1.81E-05		9.70E-06	5.62E-06	1.63E-06	-2.3E-06	-6.11E-06	-9.86E-06	-1.35E-05	-1.72E-05
1.27E-05	9.70E-06	6.78E-06	3.93E-06	1.14E-06	-1.6E-06	-4.3E-06	-6.9E-06	-9.5E-06	-1.2E-05	1.27E-05	9.70E-06		3.93E-06	1.14E-06	-1.6E-06	-4.27E-06	-6.90E-06	-9.47E-06	-1.20E-05
7.35E-06	5.62E-06	3.93E-06	2.28E-06	6.60E-07	-9.2E-07	-2.5E-06	-4.0E-06	-5.5E-06	-7.0E-06	7.35E-06	5.62E-06	3.93E-06		6.60E-07	-9.2E-07	-2.48E-06	-4.00E-06	-5.49E-06	-6.95E-06
2.13E-06	1.63E-06	1.14E-06	6.60E-07	1.91E-07	-2.7E-07	-7.2E-07	-1.2E-06	-1.6E-06	-2.0E-06	2.13E-06	1.63E-06	1.14E-06	6.60E-07		-2.7E-07	-7.17E-07	-1.16E-06	-1.59E-06	-2.01E-06
-2.98E-06	-2.3E-06	-1.6E-06	-9.2E-07	-2.7E-07	3.75E-07	1.00E-06	1.62E-06	2.23E-06	2.82E-06	-3.0E-06	-2.3E-06	-1.6E-06	-9.2E-07	-2.7E-07		1.00E-06	1.62E-06	2.23E-06	2.82E-06
-7.99E-06	-6.1E-06	-4.3E-06	-2.5E-06	-7.2E-07	1.00E-06	2.69E-06	4.34E-06	5.97E-06	7.56E-06	-8.0E-06	-6.1E-06	-4.3E-06	-2.5E-06	-7.2E-07	1.00E-06		4.34E-06	5.97E-06	7.56E-06
-1.29E-05	-9.9E-06	-6.9E-06	-4.0E-06	-1.2E-06	1.62E-06	4.34E-06	7.01E-06	9.63E-06	1.22E-05	-1.3E-05	-9.9E-06	-6.9E-06	-4.0E-06	-1.2E-06	1.62E-06	4.34E-06		9.63E-06	1.22E-05
-1.77E-05	-1.4E-05	-9.5E-06	-5.5E-06	-1.6E-06	2.23E-06	5.97E-06	9.63E-06	1.32E-05	1.68E-05	-1.8E-05	-1.4E-05	-9.5E-06	-5.5E-06	-1.6E-06	2.23E-06	5.97E-06	9.63E-06		1.68E-05
-2.24E-05	-1.7E-05	-1.2E-05	-7.0E-06	-2.0E-06	2.82E-06	7.56E-06	1.22E-05	1.68E-05	2.12E-05	-2.2E-05	-1.7E-05	-1.2E-05	-7.0E-06	-2.0E-06	2.82E-06	7.56E-06	1.22E-05	1.68E-05	
-2.37E-05	-1.4E-05	-6.8E-06	-2.3E-06	-1.9E-07	-3.7E-07	-2.7E-06	-7.0E-06	-1.3E-05	-2.1E-05	-2.4E-05	-1.4E-05	-6.8E-06	-2.3E-06	-1.9E-07	-3.7E-07	-2.69E-06	-7.01E-06	-1.32E-05	-2.12E-05

d/dPei*d/dPej*δPei*δPej

	1.21E-05	8.46E-06	4.90E-06	1.42E-06	-2.0E-06	-5.3E-06	-8.6E-06	-1.2E-05	-1.5E-05	1.58E-05	1.21E-05	8.46E-06	4.90E-06	1.42E-06	-2.0E-06	-5.33E-06	-8.60E-06	-1.18E-05	-1.50E-05
1.21E-05		6.47E-06	3.75E-06	1.09E-06	-1.5E-06	-4.1E-06	-6.6E-06	-9.0E-06	-1.1E-05	1.21E-05	9.25E-06	6.47E-06	3.75E-06	1.09E-06	-1.5E-06	-4.07E-06	-6.58E-06	-9.03E-06	-1.14E-05
8.46E-06	6.47E-06		2.62E-06	7.59E-07	-1.1E-06	-2.8E-06	-4.6E-06	-6.3E-06	-8.0E-06	8.46E-06	6.47E-06	4.52E-06	2.62E-06	7.59E-07	-1.1E-06	-2.85E-06	-4.60E-06	-6.32E-06	-8.00E-06
4.90E-06	3.75E-06	2.62E-06		4.40E-07	-6.2E-07	-1.7E-06	-2.7E-06	-3.7E-06	-4.6E-06	4.90E-06	3.75E-06	2.62E-06	1.52E-06	4.40E-07	-6.2E-07	-1.65E-06	-2.66E-06	-3.66E-06	-4.64E-06
1.42E-06	1.09E-06	7.59E-07	4.40E-07		-1.8E-07	-4.8E-07	-7.7E-07	-1.1E-06	-1.3E-06	1.42E-06	1.09E-06	7.59E-07	4.40E-07	1.27E-07	-1.8E-07	-4.78E-07	-7.72E-07	-1.06E-06	-1.34E-06
-1.99E-06	-1.5E-06	-1.1E-06	-6.2E-07	-1.8E-07		6.70E-07	1.08E-06	1.49E-06	1.88E-06	-2.0E-06	-1.5E-06	-1.1E-06	-6.2E-07	-1.8E-07	2.50E-07	6.70E-07	1.08E-06	1.49E-06	1.88E-06
-5.33E-06	-4.1E-06	-2.8E-06	-1.7E-06	-4.8E-07	6.70E-07		2.90E-06	3.98E-06	5.04E-06	-5.3E-06	-4.1E-06	-2.8E-06	-1.7E-06	-4.8E-07	6.70E-07	1.79E-06	2.90E-06	3.98E-06	5.04E-06
-8.60E-06	-6.6E-06	-4.6E-06	-2.7E-06	-7.7E-07	1.08E-06	2.90E-06		6.42E-06	8.14E-06	-8.6E-06	-6.6E-06	-4.6E-06	-2.7E-06	-7.7E-07	1.08E-06	2.90E-06	4.68E-06	6.42E-06	8.14E-06
-1.18E-05	-9.0E-06	-6.3E-06	-3.7E-06	-1.1E-06	1.49E-06	3.98E-06	6.42E-06		1.12E-05	-1.2E-05	-9.0E-06	-6.3E-06	-3.7E-06	-1.1E-06	1.49E-06	3.98E-06	6.42E-06	8.82E-06	1.12E-05
-1.50E-05	-1.1E-05	-8.0E-06	-4.6E-06	-1.3E-06	1.88E-06	5.04E-06	8.14E-06	1.12E-05		-1.5E-05	-1.1E-05	-8.0E-06	-4.6E-06	-1.3E-06	1.88E-06	5.04E-06	8.14E-06	1.12E-05	1.42E-05
1.58E-05	1.21E-05	8.46E-06	4.90E-06	1.42E-06	-2.0E-06	-5.3E-06	-8.6E-06	-1.2E-05	-1.5E-05		1.21E-05	8.46E-06	4.90E-06	1.42E-06	-2.0E-06	-5.33E-06	-8.60E-06	-1.18E-05	-1.50E-05
1.21E-05	9.25E-06	6.47E-06	3.75E-06	1.09E-06	-1.5E-06	-4.1E-06	-6.6E-06	-9.0E-06	-1.1E-05	1.21E-05		6.47E-06	3.75E-06	1.09E-06	-1.5E-06	-4.07E-06	-6.58E-06	-9.03E-06	-1.14E-05
8.46E-06	6.47E-06	4.52E-06	2.62E-06	7.59E-07	-1.1E-06	-2.8E-06	-4.6E-06	-6.3E-06	-8.0E-06	8.46E-06	6.47E-06		2.62E-06	7.59E-07	-1.1E-06	-2.85E-06	-4.60E-06	-6.32E-06	-8.00E-06
4.90E-06	3.75E-06	2.62E-06	1.52E-06	4.40E-07	-6.2E-07	-1.7E-06	-2.7E-06	-3.7E-06	-4.6E-06	4.90E-06	3.75E-06	2.62E-06		4.40E-07	-6.2E-07	-1.65E-06	-2.66E-06	-3.66E-06	-4.64E-06
1.42E-06	1.09E-06	7.59E-07	4.40E-07	1.27E-07	-1.8E-07	-4.8E-07	-7.7E-07	-1.1E-06	-1.3E-06	1.42E-06	1.09E-06	7.59E-07	4.40E-07		-1.8E-07	-4.78E-07	-7.72E-07	-1.06E-06	-1.34E-06
-1.99E-06	-1.5E-06	-1.1E-06	-6.2E-07	-1.8E-07	2.50E-07	6.70E-07	1.08E-06	1.49E-06	1.88E-06	-2.0E-06	-1.5E-06	-1.1E-06	-6.2E-07	-1.8E-07		6.70E-07	1.08E-06	1.49E-06	1.88E-06
-5.33E-06	-4.1E-06	-2.8E-06	-1.7E-06	-4.8E-07	6.70E-07	1.79E-06	2.90E-06	3.98E-06	5.04E-06	-5.3E-06	-4.1E-06	-2.8E-06	-1.7E-06	-4.8E-07	6.70E-07		2.90E-06	3.98E-06	5.04E-06
-8.60E-06	-6.6E-06	-4.6E-06	-2.7E-06	-7.7E-07	1.08E-06	2.90E-06	4.68E-06	6.42E-06	8.14E-06	-8.6E-06	-6.6E-06	-4.6E-06	-2.7E-06	-7.7E-07	1.08E-06	2.90E-06		6.42E-06	8.14E-06
-1.18E-05	-9.0E-06	-6.3E-06	-3.7E-06	-1.1E-06	1.49E-06	3.98E-06	6.42E-06	8.82E-06	1.12E-05	-1.2E-05	-9.0E-06	-6.3E-06	-3.7E-06	-1.1E-06	1.49E-06	3.98E-06	6.42E-06		1.12E-05
-1.50E-05	-1.1E-05	-8.0E-06	-4.6E-06	-1.3E-06	1.88E-06	5.04E-06	8.14E-06	1.12E-05	1.42E-05	-1.5E-05	-1.1E-05	-8.0E-06	-4.6E-06	-1.3E-06	1.88E-06	5.04E-06	8.14E-06	1.12E-05	
-1.58E-05	-9.2E-06	-4.5E-06	-1.5E-06	-1.3E-07	-2.5E-07	-1.6E-06	-4.7E-06	-8.8E-06	-1.4E-05	-1.6E-05	-9.2E-06	-4.5E-06	-1.5E-06	-1.3E-07	-2.5E-07	-1.79E-06	-4.68E-06	-8.82E-06	-1.42E-05

Table A-5 (Continued)
Cross Product Terms

d/dCPI*d/dCPJ*SCPI*SCPJ	3.63E-03	2.54E-03	1.47E-03	4.26E-04	-6.0E-04	-1.6E-03	-2.6E-03	-3.5E-03	-4.5E-03	4.75E-03	3.63E-03	2.54E-03	1.47E-03	4.26E-04	-6.0E-04	-1.60E-03	-2.58E-03	-3.54E-03	-4.49E-03
3.63E-03		1.94E-03	1.12E-03	3.26E-04	-4.6E-04	-1.2E-03	-2.0E-03	-2.7E-03	-3.4E-03	3.63E-03	2.78E-03	1.94E-03	1.12E-03	3.26E-04	-4.6E-04	-1.22E-03	-1.97E-03	-2.71E-03	-3.43E-03
2.54E-03	1.94E-03		7.87E-04	2.28E-04	-3.2E-04	-8.6E-04	-1.4E-03	-1.9E-03	-2.4E-03	2.54E-03	1.94E-03	1.36E-03	7.87E-04	2.28E-04	-3.2E-04	-8.55E-04	-1.38E-03	-1.90E-03	-2.40E-03
1.47E-03	1.12E-03	7.87E-04		1.32E-04	-1.8E-04	-5.0E-04	-8.0E-04	-1.1E-03	-1.4E-03	1.47E-03	1.12E-03	7.87E-04	4.56E-04	1.32E-04	-1.8E-04	-4.96E-04	-8.00E-04	-1.10E-03	-1.39E-03
4.26E-04	3.26E-04	2.28E-04	1.32E-04		-5.4E-05	-1.4E-04	-2.3E-04	-3.2E-04	-4.0E-04	4.26E-04	3.26E-04	2.28E-04	1.32E-04	3.83E-05	-5.4E-05	-1.44E-04	-2.32E-04	-3.18E-04	-4.03E-04
-5.97E-04	-4.6E-04	-3.2E-04	-1.8E-04	-5.4E-05		2.01E-04	3.25E-04	4.46E-04	5.65E-04	-6.0E-04	-4.6E-04	-3.2E-04	-1.8E-04	-5.4E-05	7.51E-05	2.01E-04	3.25E-04	4.46E-04	5.65E-04
-1.60E-03	-1.2E-03	-8.6E-04	-5.0E-04	-1.4E-04	2.01E-04		8.70E-04	1.19E-03	1.51E-03	-1.6E-03	-1.2E-03	-8.6E-04	-5.0E-04	-1.4E-04	2.01E-04	5.39E-04	8.70E-04	1.19E-03	1.51E-03
-2.58E-03	-2.0E-03	-1.4E-03	-8.0E-04	-2.3E-04	3.25E-04	8.70E-04		1.93E-03	2.44E-03	-2.6E-03	-2.0E-03	-1.4E-03	-8.0E-04	-2.3E-04	3.25E-04	8.70E-04	1.40E-03	1.93E-03	2.44E-03
-3.54E-03	-2.7E-03	-1.9E-03	-1.1E-03	-3.2E-04	4.46E-04	1.19E-03	1.93E-03		3.35E-03	-3.5E-03	-2.7E-03	-1.9E-03	-1.1E-03	-3.2E-04	4.46E-04	1.19E-03	1.93E-03	2.65E-03	3.35E-03
-4.49E-03	-3.4E-03	-2.4E-03	-1.4E-03	-4.0E-04	5.65E-04	1.51E-03	2.44E-03	3.35E-03		-4.5E-03	-3.4E-03	-2.4E-03	-1.4E-03	-4.0E-04	5.65E-04	1.51E-03	2.44E-03	3.35E-03	4.25E-03
4.75E-03	3.63E-03	2.54E-03	1.47E-03	4.26E-04	-6.0E-04	-1.6E-03	-2.6E-03	-3.5E-03	-4.5E-03		3.63E-03	2.54E-03	1.47E-03	4.26E-04	-6.0E-04	-1.60E-03	-2.58E-03	-3.54E-03	-4.49E-03
3.63E-03	2.78E-03	1.94E-03	1.12E-03	3.26E-04	-4.6E-04	-1.2E-03	-2.0E-03	-2.7E-03	-3.4E-03	3.63E-03		1.94E-03	1.12E-03	3.26E-04	-4.6E-04	-1.22E-03	-1.97E-03	-2.71E-03	-3.43E-03
2.54E-03	1.94E-03	1.36E-03	7.87E-04	2.28E-04	-3.2E-04	-8.6E-04	-1.4E-03	-1.9E-03	-2.4E-03	2.54E-03	1.94E-03		7.87E-04	2.28E-04	-3.2E-04	-8.55E-04	-1.38E-03	-1.90E-03	-2.40E-03
1.47E-03	1.12E-03	7.87E-04	4.56E-04	1.32E-04	-1.8E-04	-5.0E-04	-8.0E-04	-1.1E-03	-1.4E-03	1.47E-03	1.12E-03	7.87E-04		1.32E-04	-1.8E-04	-4.96E-04	-8.00E-04	-1.10E-03	-1.39E-03
4.26E-04	3.26E-04	2.28E-04	1.32E-04	3.83E-05	-5.4E-05	-1.4E-04	-2.3E-04	-3.2E-04	-4.0E-04	4.26E-04	3.26E-04	2.28E-04	1.32E-04		-5.4E-05	-1.44E-04	-2.32E-04	-3.18E-04	-4.03E-04
-5.97E-04	-4.6E-04	-3.2E-04	-1.8E-04	-5.4E-05	7.51E-05	2.01E-04	3.25E-04	4.46E-04	5.65E-04	-6.0E-04	-4.6E-04	-3.2E-04	-1.8E-04	-5.4E-05		2.01E-04	3.25E-04	4.46E-04	5.65E-04
-1.60E-03	-1.2E-03	-8.6E-04	-5.0E-04	-1.4E-04	2.01E-04	5.39E-04	8.70E-04	1.19E-03	1.51E-03	-1.6E-03	-1.2E-03	-8.6E-04	-5.0E-04	-1.4E-04	2.01E-04		8.70E-04	1.19E-03	1.51E-03
-2.58E-03	-2.0E-03	-1.4E-03	-8.0E-04	-2.3E-04	3.25E-04	8.70E-04	1.40E-03	1.93E-03	2.44E-03	-2.6E-03	-2.0E-03	-1.4E-03	-8.0E-04	-2.3E-04	3.25E-04	8.70E-04		1.93E-03	2.44E-03
-3.54E-03	-2.7E-03	-1.9E-03	-1.1E-03	-3.2E-04	4.46E-04	1.19E-03	1.93E-03	2.65E-03	3.35E-03	-3.5E-03	-2.7E-03	-1.9E-03	-1.1E-03	-3.2E-04	4.46E-04	1.19E-03	1.93E-03		3.35E-03
-4.49E-03	-3.4E-03	-2.4E-03	-1.4E-03	-4.0E-04	5.65E-04	1.51E-03	2.44E-03	3.35E-03	4.25E-03	-4.5E-03	-3.4E-03	-2.4E-03	-1.4E-03	-4.0E-04	5.65E-04	1.51E-03	2.44E-03	3.35E-03	
-4.75E-03	-2.8E-03	-1.4E-03	-4.6E-04	-3.8E-05	-7.5E-05	-5.4E-04	-1.4E-03	-2.6E-03	-4.2E-03	-4.7E-03	-2.8E-03	-1.4E-03	-4.6E-04	-3.8E-05	-7.5E-05	-5.39E-04	-1.40E-03	-2.65E-03	-4.25E-03

d/dAI*d/dAJ*SAI*SAJ	2.88E-02	2.01E-02	1.17E-02	3.38E-03	-4.7E-03	-1.3E-02	-2.0E-02	-2.8E-02	-3.6E-02	3.77E-02	2.88E-02	2.01E-02	1.17E-02	3.38E-03	-4.7E-03	-1.27E-02	-2.05E-02	-2.81E-02	-3.56E-02
2.88E-02		1.54E-02	8.93E-03	2.59E-03	-3.6E-03	-9.7E-03	-1.6E-02	-2.2E-02	-2.7E-02	2.88E-02	2.20E-02	1.54E-02	8.93E-03	2.59E-03	-3.6E-03	-9.70E-03	-1.57E-02	-2.15E-02	-2.73E-02
2.01E-02	1.54E-02		6.24E-03	1.81E-03	-2.5E-03	-6.8E-03	-1.1E-02	-1.5E-02	-1.9E-02	2.01E-02	1.54E-02	1.08E-02	6.24E-03	1.81E-03	-2.5E-03	-6.79E-03	-1.10E-02	-1.50E-02	-1.91E-02
1.17E-02	8.93E-03	6.24E-03		1.05E-03	-1.5E-03	-3.9E-03	-6.3E-03	-8.7E-03	-1.1E-02	1.17E-02	8.93E-03	6.24E-03	3.62E-03	1.05E-03	-1.5E-03	-3.93E-03	-6.35E-03	-8.72E-03	-1.10E-02
3.38E-03	2.59E-03	1.81E-03	1.05E-03		-4.3E-04	-1.1E-03	-1.8E-03	-2.5E-03	-3.2E-03	3.38E-03	2.59E-03	1.81E-03	1.05E-03	3.04E-04	-4.3E-04	-1.14E-03	-1.84E-03	-2.53E-03	-3.20E-03
-4.74E-03	-3.6E-03	-2.5E-03	-1.5E-03	-4.3E-04		1.60E-03	2.58E-03	3.54E-03	4.48E-03	-4.7E-03	-3.6E-03	-2.5E-03	-1.5E-03	-4.3E-04	5.96E-04	1.60E-03	2.58E-03	3.54E-03	4.48E-03
-1.27E-02	-9.7E-03	-6.8E-03	-3.9E-03	-1.1E-03	1.60E-03		6.90E-03	9.48E-03	1.20E-02	-1.3E-02	-9.7E-03	-6.8E-03	-3.9E-03	-1.1E-03	1.60E-03	4.28E-03	6.90E-03	9.48E-03	1.20E-02
-2.05E-02	-1.6E-02	-1.1E-02	-6.3E-03	-1.8E-03	2.58E-03	6.90E-03		1.53E-02	1.94E-02	-2.0E-02	-1.6E-02	-1.1E-02	-6.3E-03	-1.8E-03	2.58E-03	6.90E-03	1.11E-02	1.53E-02	1.94E-02
-2.81E-02	-2.2E-02	-1.5E-02	-8.7E-03	-2.5E-03	3.54E-03	9.48E-03	1.53E-02		2.66E-02	-2.8E-02	-2.2E-02	-1.5E-02	-8.7E-03	-2.5E-03	3.54E-03	9.48E-03	1.53E-02	2.10E-02	2.66E-02
-3.56E-02	-2.7E-02	-1.9E-02	-1.1E-02	-3.2E-03	4.48E-03	1.20E-02	1.94E-02	2.66E-02		-3.6E-02	-2.7E-02	-1.9E-02	-1.1E-02	-3.2E-03	4.48E-03	1.20E-02	1.94E-02	2.66E-02	3.37E-02
3.77E-02	2.88E-02	2.01E-02	1.17E-02	3.38E-03	-4.7E-03	-1.3E-02	-2.0E-02	-2.8E-02	-3.6E-02		2.88E-02	2.01E-02	1.17E-02	3.38E-03	-4.7E-03	-1.27E-02	-2.05E-02	-2.81E-02	-3.56E-02
2.88E-02	2.20E-02	1.54E-02	8.93E-03	2.59E-03	-3.6E-03	-9.7E-03	-1.6E-02	-2.2E-02	-2.7E-02	2.88E-02		1.54E-02	8.93E-03	2.59E-03	-3.6E-03	-9.70E-03	-1.57E-02	-2.15E-02	-2.73E-02
2.01E-02	1.54E-02	1.08E-02	6.24E-03	1.81E-03	-2.5E-03	-6.8E-03	-1.1E-02	-1.5E-02	-1.9E-02	2.01E-02	1.54E-02		6.24E-03	1.81E-03	-2.5E-03	-6.79E-03	-1.10E-02	-1.50E-02	-1.91E-02
1.17E-02	8.93E-03	6.24E-03	3.62E-03	1.05E-03	-1.5E-03	-3.9E-03	-6.3E-03	-8.7E-03	-1.1E-02	1.17E-02	8.93E-03	6.24E-03		1.05E-03	-1.5E-03	-3.93E-03	-6.35E-03	-8.72E-03	-1.10E-02
3.38E-03	2.59E-03	1.81E-03	1.05E-03	3.04E-04	-4.3E-04	-1.1E-03	-1.8E-03	-2.5E-03	-3.2E-03	3.38E-03	2.59E-03	1.81E-03	1.05E-03		-4.3E-04	-1.14E-03	-1.84E-03	-2.53E-03	-3.20E-03
-4.74E-03	-3.6E-03	-2.5E-03	-1.5E-03	-4.3E-04	5.96E-04	1.60E-03	2.58E-03	3.54E-03	4.48E-03	-4.7E-03	-3.6E-03	-2.5E-03	-1.5E-03	-4.3E-04		1.60E-03	2.58E-03	3.54E-03	4.48E-03
-1.27E-02	-9.7E-03	-6.8E-03	-3.9E-03	-1.1E-03	1.60E-03	4.28E-03	6.90E-03	9.48E-03	1.20E-02	-1.3E-02	-9.7E-03	-6.8E-03	-3.9E-03	-1.1E-03	1.60E-03		6.90E-03	9.48E-03	1.20E-02
-2.05E-02	-1.6E-02	-1.1E-02	-6.3E-03	-1.8E-03	2.58E-03	6.90E-03	1.11E-02	1.53E-02	1.94E-02	-2.0E-02	-1.6E-02	-1.1E-02	-6.3E-03	-1.8E-03	2.58E-03	6.90E-03		1.53E-02	1.94E-02
-2.81E-02	-2.2E-02	-1.5E-02	-8.7E-03	-2.5E-03	3.54E-03	9.48E-03	1.53E-02	2.10E-02	2.66E-02	-2.8E-02	-2.2E-02	-1.5E-02	-8.7E-03	-2.5E-03	3.54E-03	9.48E-03	1.53E-02		2.66E-02
-3.56E-02	-2.7E-02	-1.9E-02	-1.1E-02	-3.2E-03	4.48E-03	1.20E-02	1.94E-02	2.66E-02	3.37E-02	-3.6E-02	-2.7E-02	-1.9E-02	-1.1E-02	-3.2E-03	4.48E-03	1.20E-02	1.94E-02	2.66E-02	
-3.77E-02	-2.2E-02	-1.1E-02	-3.6E-03	-3.0E-04	-6.0E-04	-4.3E-03	-1.1E-02	-2.1E-02	-3.4E-02	-3.8E-02	-2.2E-02	-1.1E-02	-3.6E-03	-3.0E-04	-6.0E-04	-4.28E-03	-1.11E-02	-2.10E-02	-3.37E-02

Table A-6
Bias Error Calculation -- Flue Gas Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative				
ct Size							
idth, ft	2.5	0.042	1.67%				
ength, ft	34	0.042	0.12%				
of Points	24						
idthwise	2						
engthwise	12						
ector Width, ft	1.25	0.042	3.33%				
ector Length, ft	2.83	0.042	1.47%				
, Sector Area ft^2	3.54	0.129	3.64%				
deg F	253	2.530	1.00%				
deg R	713	2.530	0.35%				
mp Bias, deg F	100		9.09	deg F/Length Increment Special Bias			
, in WC	0.45802	0.0092	2.00%				
V, lb/mol	29.71	0.050	0.17%				
b Pres, in. Hg	29.50						
ct Pres, in. WC	-11.00						
e Pres, in. Hg	29.10	0.040	0.14%				
ot Fact, Cp	0.84	0.0100	1.19%				
minal Vel, fps	44.13	ACFM=	225078	SCFM=	159669	lb/hr=	750003

	Input Data								Derivatives, dTa/dX					
Point	Ai	CPi	DPi	Mi	Pai	Ti	(1)	(2)	dTa/dTi	dTa/dAi	dTa/dCPi	dTa/dDPi	dTa/dMi	dTa/dPai
1	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
2	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
3	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
4	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
5	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
6	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
7	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
8	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
9	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
10	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
11	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
12	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
13	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
14	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
15	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
16	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
17	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
18	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
19	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
20	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
21	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524.4	4.25E-02	-1.6E-01	-6.8E-01	-6.2E-01	-9.6E-03	-9.8E-03
22	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1534.8	4.19E-02	-5.3E-02	-2.2E-01	-2.0E-01	-3.1E-03	-3.2E-03
23	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545.2	4.14E-02	5.42E-02	2.26E-01	2.10E-01	3.23E-03	3.30E-03
24	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555.5	4.06E-02	1.60E-01	6.73E-01	6.17E-01	9.52E-03	9.72E-03
	Temperature -- Simple Average						SUM1	SUM2						
	Temperature -- Weighted Average						54.626	36959.4						

	(dTa/dX*Sigma)^2					
Point	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPai*SPai
1	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
2	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
3	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
4	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
5	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
6	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
7	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
8	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
9	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
10	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
11	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
12	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
13	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
14	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
15	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
16	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
17	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
18	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
19	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
20	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
21	1.16E-02	4.32E-04	4.62E-05	3.26E-05	2.31E-07	1.55E-07
22	1.13E-02	4.63E-05	4.95E-06	3.49E-06	2.47E-08	1.66E-08
23	1.10E-02	4.89E-05	5.22E-06	3.66E-06	2.61E-08	1.75E-08
24	1.07E-02	4.25E-04	4.53E-05	3.20E-05	2.27E-07	1.52E-07
	T	A	CP	DP	M	Pa
Contributions (3)	6.40E+00	-9.76E-19	-2.24E-19	1.52E-19	3.57E-22	-3.18E-22
			Total Sigma^2		6.40	
			Tavg Sigma		2.53 deg F	

) Ai*CPi(DPi*Mi*Pai/Ti)^0.5

) Ai*CPi(DPi*Mi*Pai*Ti)^0.5

) Contributions Include Cross Product Terms

Table A-6 (Continued)

Cross Product Terms

d/dTI*d/dTj*STI*STj

	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02
1.14E-02		1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02
1.13E-02	1.11E-02		1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02
1.11E-02	1.10E-02	1.08E-02		1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02
1.16E-02	1.14E-02	1.13E-02	1.11E-02		1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02
1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02		1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02
1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02		1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02
1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02		1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02
1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02		1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02
1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02		1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02
1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02		1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02
1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02		1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02
1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02		1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02
1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02		1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02
1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02		1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02
1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02		1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02
1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02		1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02
1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02		1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02
1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02		1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02
1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02		1.11E-02	1.10E-02	1.08E-02	1.07E-02
1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02	1.16E-02	1.14E-02	1.13E-02	1.11E-02		1.14E-02	1.13E-02	1.11E-02
1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02	1.13E-02	1.11E-02	1.10E-02	1.14E-02		1.11E-02	1.10E-02
1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02	1.10E-02	1.08E-02	1.13E-02	1.11E-02		1.08E-02
1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	1.07E-02	1.11E-02	1.10E-02	1.08E-02	
2.61E-01	2.57E-01	2.54E-01	2.51E-01	2.61E-01	2.57E-01	2.54E-01	2.51E-01	2.61E-01	2.57E-01	2.54E-01	2.51E-01	2.61E-01	2.57E-01	2.54E-01	2.51E-01	2.61E-01	2.57E-01	2.54E-01	2.51E-01	2.61E-01	2.57E-01	2.54E-01	2.51E-01

d/dDPI*d/dDPj*SDPI*SDPj

	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.10E-05	-3.23E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05
1.07E-05		-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.59E-06	-1.06E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06		1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.10E-05	-3.59E-06	3.68E-06	1.09E-05	-1.1E-05	-3.59E-06	3.68E-06	1.09E-05
-3.23E-05	-1.1E-05	1.09E-05		-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.23E-05	-1.06E-05	1.09E-05	3.20E-05	-3.2E-05	-1.06E-05	1.09E-05	3.20E-05
3.26E-05	1.07E-05	-1.1E-05	-3.2E-05		1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.10E-05	-3.23E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05
1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05		-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.59E-06	-1.06E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06		1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.10E-05	-3.59E-06	3.68E-06	1.09E-05	-1.1E-05	-3.59E-06	3.68E-06	1.09E-05
-3.23E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05		-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.23E-05	-1.06E-05	1.09E-05	3.20E-05	-3.2E-05	-1.06E-05	1.09E-05	3.20E-05
3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05		1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.10E-05	-3.23E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05
1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05		-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.59E-06	-1.06E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06		1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.10E-05	-3.59E-06	3.68E-06	1.09E-05	-1.1E-05	-3.59E-06	3.68E-06	1.09E-05
-3.23E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05		-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.23E-05	-1.06E-05	1.09E-05	3.20E-05	-3.2E-05	-1.06E-05	1.09E-05	3.20E-05
3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05		1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.10E-05	-3.23E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05
1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05		-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.59E-06	-1.06E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06		1.09E-05	-1.10E-05	-3.59E-06	3.68E-06	1.09E-05	-1.1E-05	-3.59E-06	3.68E-06	1.09E-05
-3.23E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05		-3.23E-05	-1.06E-05	1.09E-05	3.20E-05	-3.2E-05	-1.06E-05	1.09E-05	3.20E-05
3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05		1.07E-05	-1.10E-05	-3.23E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05
1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05		-3.59E-06	-1.06E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.10E-05	-3.59E-06		1.09E-05	-1.1E-05	-3.59E-06	3.68E-06	1.09E-05
-3.23E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.23E-05	-1.06E-05	1.09E-05		-3.2E-05	-1.06E-05	1.09E-05	3.20E-05
3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.1E-05	-3.2E-05	3.26E-05	1.07E-05	-1.10E-05	-3.23E-05		1.07E-05	-1.1E-05	-3.2E-05
1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.6E-06	-1.1E-05	1.07E-05	3.49E-06	-3.59E-06	-1.06E-05	1.07E-05		-3.6E-06	-1.1E-05
-1.10E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.1E-05	-3.6E-06	3.68E-06	1.09E-05	-1.10E-05	-3.59E-06	3.68E-06	1.09E-05	-1.1E-05	-3.59E-06		1.09E-05
-3.23E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.2E-05	-1.1E-05	1.09E-05	3.20E-05	-3.23E-05	-1.06E-05	1.09E-05	3.20E-05	-3.2E-05	-1.06E-05	1.09E-05	
-3.26E-05	-3.5E-06	-3.7E-06	-3.2E-05	-3.3E-05	-3.5E-06	-3.7E-06	-3.2E-05	-3.3E-05	-3.5E-06	-3.7E-06	-3.2E-05	-3.3E-05	-3.5E-06	-3.7E-06	-3.2E-05	-3.26E-05	-3.49E-06	-3.68E-06	-3.20E-05	-3.3E-05	-3.49E-06	-3.7E-06	-3.2E-05

Table A-6 (Continued)

Cross Product Terms

d/dMl*d/dMl*SMl*SMl	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.76E-08	-2.29E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07
7.55E-08		-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.54E-08	-7.48E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08		7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.76E-08	-2.54E-08	2.61E-08	7.69E-08	-7.8E-08	-2.54E-08	2.61E-08	7.69E-08
-2.29E-07	-7.5E-08	7.69E-08		-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.29E-07	-7.48E-08	7.69E-08	2.27E-07	-2.3E-07	-7.48E-08	7.69E-08	2.27E-07
2.31E-07	7.55E-08	-7.8E-08	-2.3E-07		7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.76E-08	-2.29E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07
7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08		-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.54E-08	-7.48E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08		7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.76E-08	-2.54E-08	2.61E-08	7.69E-08	-7.8E-08	-2.54E-08	2.61E-08	7.69E-08
-2.29E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08		-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.29E-07	-7.48E-08	7.69E-08	2.27E-07	-2.3E-07	-7.48E-08	7.69E-08	2.27E-07
2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07		7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.76E-08	-2.29E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07
7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08		-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.54E-08	-7.48E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08		7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.76E-08	-2.54E-08	2.61E-08	7.69E-08	-7.8E-08	-2.54E-08	2.61E-08	7.69E-08
-2.29E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08		-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.29E-07	-7.48E-08	7.69E-08	2.27E-07	-2.3E-07	-7.48E-08	7.69E-08	2.27E-07
2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07		7.56E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.76E-08	-2.29E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07
7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08		-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.54E-08	-7.48E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08		7.69E-08	-7.76E-08	-2.54E-08	2.61E-08	7.69E-08	-7.8E-08	-2.54E-08	2.61E-08	7.69E-08
-2.29E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08		-2.29E-07	-7.48E-08	7.69E-08	2.27E-07	-2.3E-07	-7.48E-08	7.69E-08	2.27E-07
2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07		7.55E-08	-7.76E-08	-2.29E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07
7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08		-2.54E-08	-7.48E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.76E-08	-2.54E-08		7.69E-08	-7.8E-08	-2.54E-08	2.61E-08	7.69E-08
-2.29E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.29E-07	-7.48E-08	7.69E-08		-2.3E-07	-7.48E-08	7.69E-08	2.27E-07
2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.8E-08	-2.3E-07	2.31E-07	7.55E-08	-7.76E-08	-2.29E-07		7.55E-08	-7.8E-08	-2.3E-07
7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.5E-08	-7.5E-08	7.55E-08	2.47E-08	-2.54E-08	-7.48E-08	7.55E-08		-2.5E-08	-7.5E-08
-7.76E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.8E-08	-2.5E-08	2.61E-08	7.69E-08	-7.76E-08	-2.54E-08	2.61E-08	7.69E-08	-7.8E-08	-2.54E-08		7.69E-08
-2.29E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.3E-07	-7.5E-08	7.69E-08	2.27E-07	-2.29E-07	-7.48E-08	7.69E-08	2.27E-07	-2.3E-07	-7.48E-08	7.69E-08	
-2.31E-07	-2.5E-08	-2.6E-08	-2.3E-07	-2.3E-07	-2.5E-08	-2.6E-08	-2.3E-07	-2.3E-07	-2.5E-08	-2.6E-08	-2.3E-07	-2.3E-07	-2.5E-08	-2.6E-08	-2.3E-07	-2.31E-07	-2.47E-08	-2.61E-08	-2.27E-07	-2.3E-07	-2.47E-08	-2.6E-08	-2.3E-07

d/dPel*d/dPel*SPel*SPel	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.22E-08	-1.54E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07
5.08E-08		-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.71E-08	-5.03E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08		5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.22E-08	-1.71E-08	1.75E-08	5.17E-08	-5.2E-08	-1.71E-08	1.75E-08	5.17E-08
-1.54E-07	-5.0E-08	5.17E-08		-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.54E-07	-5.03E-08	5.17E-08	1.52E-07	-1.5E-07	-5.03E-08	5.17E-08	1.52E-07
1.55E-07	5.08E-08	-5.2E-08	-1.5E-07		5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.22E-08	-1.54E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07
5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08		-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.71E-08	-5.03E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08		5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.22E-08	-1.71E-08	1.75E-08	5.17E-08	-5.2E-08	-1.71E-08	1.75E-08	5.17E-08
-1.54E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08		-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.54E-07	-5.03E-08	5.17E-08	1.52E-07	-1.5E-07	-5.03E-08	5.17E-08	1.52E-07
1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07		5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.22E-08	-1.54E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07
5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08		-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.71E-08	-5.03E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08		5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.22E-08	-1.71E-08	1.75E-08	5.17E-08	-5.2E-08	-1.71E-08	1.75E-08	5.17E-08
-1.54E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08		-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.54E-07	-5.03E-08	5.17E-08	1.52E-07	-1.5E-07	-5.03E-08	5.17E-08	1.52E-07
1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07		5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.22E-08	-1.54E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07
5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08		-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.71E-08	-5.03E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08		5.17E-08	-5.22E-08	-1.71E-08	1.75E-08	5.17E-08	-5.2E-08	-1.71E-08	1.75E-08	5.17E-08
-1.54E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08		-1.54E-07	-5.03E-08	5.17E-08	1.52E-07	-1.5E-07	-5.03E-08	5.17E-08	1.52E-07
1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07		5.08E-08	-5.22E-08	-1.54E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07
5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08		-1.71E-08	-5.03E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.22E-08	-1.71E-08		5.17E-08	-5.2E-08	-1.71E-08	1.75E-08	5.17E-08
-1.54E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.54E-07	-5.03E-08	5.17E-08		-1.5E-07	-5.03E-08	5.17E-08	1.52E-07
1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.2E-08	-1.5E-07	1.55E-07	5.08E-08	-5.22E-08	-1.54E-07		5.08E-08	-5.2E-08	-1.5E-07
5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.7E-08	-5.0E-08	5.08E-08	1.66E-08	-1.71E-08	-5.03E-08	5.08E-08		-1.7E-08	-5.0E-08
-5.22E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.2E-08	-1.7E-08	1.75E-08	5.17E-08	-5.22E-08	-1.71E-08	1.75E-08	5.17E-08	-5.2E-08	-1.71E-08		5.17E-08
-1.54E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.5E-07	-5.0E-08	5.17E-08	1.52E-07	-1.54E-07	-5.03E-08	5.17E-08	1.52E-07	-1.5E-07	-5.03E-08	5.17E-08	
-1.55E-07	-1.7E-08	-1.8E-08	-1.5E-07	-1.6E-07	-1.7E-08	-1.8E-08	-1.5E-07	-1.6E-07	-1.7E-08	-1.8E-08	-1.5E-07	-1.6E-07	-1.7E-08	-1.8E-08	-1.5E-07	-1.55E-07	-1.66E-08	-1.75E-08	-1.52E-07	-1.6E-07	-1.66E-08	-1.8E-08	-1.5E-07

Table A-6 (Continued)

Cross Product Terms

/dCP*d/dCP|*SCPI*SCP|

	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.55E-05	-4.58E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05
1.51E-05		-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.08E-06	-1.50E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06		1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.55E-05	-5.08E-06	5.22E-06	1.54E-05	-1.6E-05	-5.08E-06	5.22E-06	1.54E-05
-4.58E-05	-1.5E-05	1.54E-05		-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.58E-05	-1.50E-05	1.54E-05	4.53E-05	-4.6E-05	-1.50E-05	1.54E-05	4.53E-05
4.62E-05	1.51E-05	-1.6E-05	-4.6E-05		1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.55E-05	-4.58E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05
1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05		-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.08E-06	-1.50E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06		1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.55E-05	-5.08E-06	5.22E-06	1.54E-05	-1.6E-05	-5.08E-06	5.22E-06	1.54E-05
-4.58E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05		-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.58E-05	-1.50E-05	1.54E-05	4.53E-05	-4.6E-05	-1.50E-05	1.54E-05	4.53E-05
4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05		1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.55E-05	-4.58E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05
1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05		-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.08E-06	-1.50E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06		1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.55E-05	-5.08E-06	5.22E-06	1.54E-05	-1.6E-05	-5.08E-06	5.22E-06	1.54E-05
-4.58E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05		-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.58E-05	-1.50E-05	1.54E-05	4.53E-05	-4.6E-05	-1.50E-05	1.54E-05	4.53E-05
4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05		1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.55E-05	-4.58E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05
1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05		-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.08E-06	-1.50E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06		1.54E-05	-1.55E-05	-5.08E-06	5.22E-06	1.54E-05	-1.6E-05	-5.08E-06	5.22E-06	1.54E-05
-4.58E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05		-4.58E-05	-1.50E-05	1.54E-05	4.53E-05	-4.6E-05	-1.50E-05	1.54E-05	4.53E-05
4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05		1.51E-05	-1.55E-05	-4.58E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05
1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05		-5.08E-06	-1.50E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.55E-05	-5.08E-06		1.54E-05	-1.6E-05	-5.08E-06	5.22E-06	1.54E-05
-4.58E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.58E-05	-1.50E-05	1.54E-05		-4.6E-05	-1.50E-05	1.54E-05	4.53E-05
4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.6E-05	-4.6E-05	4.62E-05	1.51E-05	-1.55E-05	-4.58E-05		1.51E-05	-1.6E-05	-4.6E-05
1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.1E-06	-1.5E-05	1.51E-05	4.95E-06	-5.08E-06	-1.50E-05	1.51E-05		-5.1E-06	-1.5E-05
-1.55E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.6E-05	-5.1E-06	5.22E-06	1.54E-05	-1.55E-05	-5.08E-06	5.22E-06	1.54E-05	-1.6E-05	-5.08E-06		1.54E-05
-4.58E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.6E-05	-1.5E-05	1.54E-05	4.53E-05	-4.58E-05	-1.50E-05	1.54E-05	4.53E-05	-4.6E-05	-1.50E-05	1.54E-05	
-4.62E-05	-4.9E-06	-5.2E-06	-4.5E-05	-4.6E-05	-4.9E-06	-5.2E-06	-4.5E-05	-4.6E-05	-4.9E-06	-5.2E-06	-4.5E-05	-4.6E-05	-4.9E-06	-5.2E-06	-4.5E-05	-4.62E-05	-4.95E-06	-5.22E-06	-4.53E-05	-4.6E-05	-4.95E-06	-5.2E-06	-4.5E-05

d/Ap*d/dA|*SAI*SA|

	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.45E-04	-4.29E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.76E-05	-1.40E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05		1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.45E-04	-4.76E-05	4.89E-05	1.44E-04	-1.5E-04	-4.76E-05	4.89E-05	1.44E-04
-4.29E-04	-1.4E-04	1.44E-04		-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.29E-04	-1.40E-04	1.44E-04	4.25E-04	-4.3E-04	-1.40E-04	1.44E-04	4.25E-04
4.32E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.45E-04	-4.29E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.76E-05	-1.40E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05		1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.45E-04	-4.76E-05	4.89E-05	1.44E-04	-1.5E-04	-4.76E-05	4.89E-05	1.44E-04
-4.29E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04		-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.29E-04	-1.40E-04	1.44E-04	4.25E-04	-4.3E-04	-1.40E-04	1.44E-04	4.25E-04
4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.45E-04	-4.29E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.76E-05	-1.40E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05		1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.45E-04	-4.76E-05	4.89E-05	1.44E-04	-1.5E-04	-4.76E-05	4.89E-05	1.44E-04
-4.29E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04		-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.29E-04	-1.40E-04	1.44E-04	4.25E-04	-4.3E-04	-1.40E-04	1.44E-04	4.25E-04
4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.45E-04	-4.29E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.76E-05	-1.40E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05		1.44E-04	-1.45E-04	-4.76E-05	4.89E-05	1.44E-04	-1.5E-04	-4.76E-05	4.89E-05	1.44E-04
-4.29E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04		-4.29E-04	-1.40E-04	1.44E-04	4.25E-04	-4.3E-04	-1.40E-04	1.44E-04	4.25E-04
4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04		1.42E-04	-1.45E-04	-4.29E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04		-4.76E-05	-1.40E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.45E-04	-4.76E-05		1.44E-04	-1.5E-04	-4.76E-05	4.89E-05	1.44E-04
-4.29E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.29E-04	-1.40E-04	1.44E-04		-4.3E-04	-1.40E-04	1.44E-04	4.25E-04
4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.5E-04	-4.3E-04	4.32E-04	1.42E-04	-1.45E-04	-4.29E-04		1.42E-04	-1.5E-04	-4.3E-04
1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.8E-05	-1.4E-04	1.42E-04	4.63E-05	-4.76E-05	-1.40E-04	1.42E-04		-4.8E-05	-1.4E-04
-1.45E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.5E-04	-4.8E-05	4.89E-05	1.44E-04	-1.45E-04	-4.76E-05	4.89E-05	1.44E-04	-1.5E-04	-4.76E-05		1.44E-04
-4.29E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.3E-04	-1.4E-04	1.44E-04	4.25E-04	-4.29E-04	-1.40E-04	1.44E-04	4.25E-04	-4.3E-04	-1.40E-04	1.44E-04	
-4.32E-04	-4.6E-05	-4.9E-05	-4.2E-04	-4.3E-04	-4.6E-05	-4.9E-05	-4.2E-04	-4.3E-04	-4.6E-05	-4.9E-05	-4.2E-04	-4.3E-04	-4.6E-05	-4.9E-05	-4.2E-04	-4.32E-04	-4.63E-05	-4.89E-05	-4.25E-04	-4.3E-04	-4.63E-05	-4.9E-05	-4.2E-04

Table A-7
Random Error Calculation -- Primary Air Inlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative					
Duct Size								
Width, ft	3.28	0.042	1.27%					
Length, ft	17.5	0.042	0.24%					
# of Points	12							
Widthwise	2							
Lengthwise	6							
Sector Width, ft	1.64	0.042	2.54%					
Sector Length, ft	2.92	0.042	1.43%					
A, Sector Area ft^2	4.78	0.139	2.91%					
T, deg F	80	0.400	0.50%					
T, deg R	540	0.400	0.07%					
Temp Bias, deg F	10		2.00	deg F/Length Increment Special Bias				
DP, in WC	0.005069	0.00005	0.99%					
M, lb/mol	28.85	0.050	0.17%					
Amb Pres, in. Hg	29.50							
Duct Pres, in. WC	48.00							
Ps, in. Hg Absolute	31.23	0.040	0.13%					
CP, Pitot Fact	0.84	0.0000	0.00%					
Nominal Vel, fps	3.96	ACFM=	13631	SCFM=	13702	lb/hr=	62500	

Input Data									Derivatives, dTa/dX					
Point	Ai	CPi	DPi	Mi	Psi	Ti	(1)	(2)	dTa/dTi	dTa/Ai	dTa/CPi	dTa/dDPi	dTa/dMi	dTa/dPsi
1	4.78	0.84	0.0051	28.85	31.23	535.0	0.371	198.6	8.41E-02	-8.7E-02	-5.0E-01	-4.1E+01	-7.2E-03	-6.7E-03
2	4.78	0.84	0.0051	28.85	31.23	537.0	0.371	199.0	8.38E-02	-5.2E-02	-3.0E-01	-2.5E+01	-4.3E-03	-4.0E-03
3	4.78	0.84	0.0051	28.85	31.23	539.0	0.370	199.4	8.35E-02	-1.7E-02	-9.8E-02	-8.1E+00	-1.4E-03	-1.3E-03
4	4.78	0.84	0.0051	28.85	31.23	541.0	0.369	199.7	8.32E-02	1.76E-02	1.00E-01	8.30E+00	1.46E-03	1.35E-03
5	4.78	0.84	0.0051	28.85	31.23	543.0	0.369	200.1	8.29E-02	5.23E-02	2.98E-01	2.47E+01	4.34E-03	4.01E-03
6	4.78	0.84	0.0051	28.85	31.23	545.0	0.368	200.5	8.26E-02	8.69E-02	4.95E-01	4.10E+01	7.20E-03	6.65E-03
7	4.78	0.84	0.0051	28.85	31.23	535.0	0.371	198.6	8.41E-02	-8.7E-02	-5.0E-01	-4.1E+01	-7.2E-03	-6.7E-03
8	4.78	0.84	0.0051	28.85	31.23	537.0	0.371	199.0	8.38E-02	-5.2E-02	-3.0E-01	-2.5E+01	-4.3E-03	-4.0E-03
9	4.78	0.84	0.0051	28.85	31.23	539.0	0.370	199.4	8.35E-02	-1.7E-02	-9.8E-02	-8.1E+00	-1.4E-03	-1.3E-03
10	4.78	0.84	0.0051	28.85	31.23	541.0	0.369	199.7	8.32E-02	1.76E-02	1.00E-01	8.30E+00	1.46E-03	1.35E-03
11	4.78	0.84	0.0051	28.85	31.23	543.0	0.369	200.1	8.29E-02	5.23E-02	2.98E-01	2.47E+01	4.34E-03	4.01E-03
12	4.78	0.84	0.0051	28.85	31.23	545.0	0.368	200.5	8.26E-02	8.69E-02	4.95E-01	4.10E+01	7.20E-03	6.65E-03
							SUM1	SUM2						
							4.434	2394.6					Contributions	

Point	(dTa/dX*Sigma)^2					
	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPsi*SPs
1	1.13E-03	1.48E-04	0.00E+00	4.24E-06	1.31E-07	7.21E-08
2	1.12E-03	5.30E-05	0.00E+00	1.52E-06	4.69E-08	2.58E-08
3	1.12E-03	5.78E-06	0.00E+00	1.66E-07	5.11E-09	2.82E-09
4	1.11E-03	6.02E-06	0.00E+00	1.72E-07	5.32E-09	2.93E-09
5	1.10E-03	5.32E-05	0.00E+00	1.52E-06	4.70E-08	2.59E-08
6	1.09E-03	1.47E-04	0.00E+00	4.20E-06	1.30E-07	7.14E-08
7	1.13E-03	1.48E-04	0.00E+00	4.24E-06	1.31E-07	7.21E-08
8	1.12E-03	5.30E-05	0.00E+00	1.52E-06	4.69E-08	2.58E-08
9	1.12E-03	5.78E-06	0.00E+00	1.66E-07	5.11E-09	2.82E-09
10	1.11E-03	6.02E-06	0.00E+00	1.72E-07	5.32E-09	2.93E-09
11	1.10E-03	5.32E-05	0.00E+00	1.52E-06	4.70E-08	2.59E-08
12	1.09E-03	1.47E-04	0.00E+00	4.20E-06	1.30E-07	7.14E-08
	T	A	Cp	DP	M	Ps
Contributions	1.33E-02	8.26E-04	0.00E+00	2.36E-05	7.30E-07	4.02E-07
			Total Sigma^2		0.01	
			Tavg Sigma		0.12 deg F	

(1) Ai*CPi(DPi*Mi*Psi/Ti)^0.5

(2) Ai*CPi(DPi*Mi*Psi*Ti)^0.5

Table A-8
Random Error Calculation -- Primary Air Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
Duct Size				
Dia. ft	4	0.042	1.04%	
Length, ft				
# of Points	20			
Dia. #1	10			
Dia. #2	10			
A, Sector Area ft^2	0.63	0.013	2.08%	
T, deg F	644	3.220	0.50%	
T, deg R	1104	3.220	0.29%	
Temp Bias, deg F	100		11.11	deg F/Length Increment Special Bias
DP, in WC	0.2171	0.0043	2.00%	
M, lb/mol	28.85	0.025	0.09%	
Amb Pres, in. Hg	29.50			
Duct Pres, in. WC	44.50			
Ps, in. Hg Absolute	31.11	0.040	0.13%	
CP, Pitot Fact	0.84	0.0000	0.00%	
Nominal Vel, fps	37.11	ACFM= 27982	SCFM= 13702	lb/hr= 62500

	Input Data								Derivatives, dTa/dX						(dTa/dX*Sigma)^2					
Point	Ai	CPi	DPi	Mi	Psi	Ti	(1)	(2)	dTa/dTi	dTa/dAi	dTa/dCPi	dTa/dDPi	dTa/dMi	dTa/dPsi	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPsi*SPsi
1	0.63	0.84	0.2171	28.85	31.11	1054.0	0.227	239.2	5.24E-02	-4.03E+00	-3.02E+00	-5.84E+00	-4.39E-02	-4.07E-02	2.84E-02	2.79E-03	0.00E+00	6.42E-04	1.21E-06	2.68E-06
2	0.63	0.84	0.2171	28.85	31.11	1065.1	0.226	240.4	5.18E-02	-3.11E+00	-2.33E+00	-4.50E+00	-3.39E-02	-3.14E-02	2.78E-02	1.66E-03	0.00E+00	3.82E-04	7.18E-07	1.59E-06
3	0.63	0.84	0.2171	28.85	31.11	1076.2	0.225	241.7	5.13E-02	-2.20E+00	-1.65E+00	-3.18E+00	-2.40E-02	-2.22E-02	2.73E-02	8.30E-04	0.00E+00	1.91E-04	3.59E-07	7.97E-07
4	0.63	0.84	0.2171	28.85	31.11	1087.3	0.223	242.9	5.07E-02	-1.30E+00	-9.72E-01	-1.88E+00	-1.41E-02	-1.31E-02	2.67E-02	2.89E-04	0.00E+00	6.66E-05	1.25E-07	2.78E-07
5	0.63	0.84	0.2171	28.85	31.11	1098.4	0.222	244.2	5.02E-02	-4.06E-01	-3.04E-01	-5.88E-01	-4.42E-03	-4.10E-03	2.62E-02	2.83E-05	0.00E+00	6.52E-06	1.22E-08	2.72E-08
6	0.63	0.84	0.2171	28.85	31.11	1109.6	0.221	245.4	4.97E-02	4.77E-01	3.57E-01	6.91E-01	5.20E-03	4.82E-03	2.56E-02	3.91E-05	0.00E+00	9.00E-06	1.69E-08	3.75E-08
7	0.63	0.84	0.2171	28.85	31.11	1120.7	0.220	246.6	4.92E-02	1.35E+00	1.01E+00	1.96E+00	1.47E-02	1.37E-02	2.51E-02	3.13E-04	0.00E+00	7.22E-05	1.36E-07	3.01E-07
8	0.63	0.84	0.2171	28.85	31.11	1131.8	0.219	247.8	4.88E-02	2.22E+00	1.66E+00	3.21E+00	2.42E-02	2.24E-02	2.46E-02	8.44E-04	0.00E+00	1.94E-04	3.65E-07	8.10E-07
9	0.63	0.84	0.2171	28.85	31.11	1142.9	0.218	249.1	4.83E-02	3.08E+00	2.30E+00	4.45E+00	3.35E-02	3.11E-02	2.42E-02	1.62E-03	0.00E+00	3.74E-04	7.02E-07	1.56E-06
10	0.63	0.84	0.2171	28.85	31.11	1154.0	0.217	250.3	4.78E-02	3.93E+00	2.94E+00	5.66E+00	4.28E-02	3.97E-02	2.37E-02	2.64E-03	0.00E+00	6.09E-04	1.14E-06	2.54E-06
11	0.63	0.84	0.2171	28.85	31.11	1054.0	0.227	239.2	5.24E-02	-4.03E+00	-3.02E+00	-5.84E+00	-4.39E-02	-4.07E-02	2.84E-02	2.79E-03	0.00E+00	6.42E-04	1.21E-06	2.68E-06
12	0.63	0.84	0.2171	28.85	31.11	1065.1	0.226	240.4	5.18E-02	-3.11E+00	-2.33E+00	-4.50E+00	-3.39E-02	-3.14E-02	2.78E-02	1.66E-03	0.00E+00	3.82E-04	7.18E-07	1.59E-06
13	0.63	0.84	0.2171	28.85	31.11	1076.2	0.225	241.7	5.13E-02	-2.20E+00	-1.65E+00	-3.18E+00	-2.40E-02	-2.22E-02	2.73E-02	8.30E-04	0.00E+00	1.91E-04	3.59E-07	7.97E-07
14	0.63	0.84	0.2171	28.85	31.11	1087.3	0.223	242.9	5.07E-02	-1.30E+00	-9.72E-01	-1.88E+00	-1.41E-02	-1.31E-02	2.67E-02	2.89E-04	0.00E+00	6.66E-05	1.25E-07	2.78E-07
15	0.63	0.84	0.2171	28.85	31.11	1098.4	0.222	244.2	5.02E-02	-4.06E-01	-3.04E-01	-5.88E-01	-4.42E-03	-4.10E-03	2.62E-02	2.83E-05	0.00E+00	6.52E-06	1.22E-08	2.72E-08
16	0.63	0.84	0.2171	28.85	31.11	1109.6	0.221	245.4	4.97E-02	4.77E-01	3.57E-01	6.91E-01	5.20E-03	4.82E-03	2.56E-02	3.91E-05	0.00E+00	9.00E-06	1.69E-08	3.75E-08
17	0.63	0.84	0.2171	28.85	31.11	1120.7	0.220	246.6	4.92E-02	1.35E+00	1.01E+00	1.96E+00	1.47E-02	1.37E-02	2.51E-02	3.13E-04	0.00E+00	7.22E-05	1.36E-07	3.01E-07
18	0.63	0.84	0.2171	28.85	31.11	1131.8	0.219	247.8	4.88E-02	2.22E+00	1.66E+00	3.21E+00	2.42E-02	2.24E-02	2.46E-02	8.44E-04	0.00E+00	1.94E-04	3.65E-07	8.10E-07
19	0.63	0.84	0.2171	28.85	31.11	1142.9	0.218	249.1	4.83E-02	3.08E+00	2.30E+00	4.45E+00	3.35E-02	3.11E-02	2.42E-02	1.62E-03	0.00E+00	3.74E-04	7.02E-07	1.56E-06
20	0.63	0.84	0.2171	28.85	31.11	1154.0	0.217	250.3	4.78E-02	3.93E+00	2.94E+00	5.66E+00	4.28E-02	3.97E-02	2.37E-02	2.64E-03	0.00E+00	6.09E-04	1.14E-06	2.54E-06
		Temperature -- Simple Average				1104.0	Sum1	Sum2							T	A	CP	DP	M	Ps
		Temperature -- Weighted Average				1103.5	4.436	4695.0						Contributions (3)	5.19E-01	2.21E-02	0.00E+00	5.09E-03	9.56E-06	2.12E-05
																	Total Sigma^2		0.55	
																	Tavg Sigma		0.74	deg F

(1) Ai*CPi(DPi*Mi*Psi/Ti)^0.5

(2) Ai*CPi(DPi*Mi*Psi*Ti)^0.5

(3) Contributions Include Cross Product Terms

Table A-9
Random Error Calculation -- Secondary Air Inlet
Milliken Heat Pipe Air Preheater

# of Points	4		
T, deg F	80	0.400	0.50%
T, deg R	540	0.400	0.07%

Input Data		Derivatives		(dTa/dX*Sigma)^2 (1)
Point	Ti	dTa/DTi		dTa/dTi
1	80.0	0.25		1.00E-02
2	80.0	0.25		1.00E-02
3	80.0	0.25		1.00E-02
4	80.0	0.25		1.00E-02
			Totals	4.00E-02

	T	
Contributions (2)	4.00E-02	
Total Sigma^2	0.04	
Tavg Sigma	0.20	deg F

(1) Ta = (T1 + T2 + T3 + T4)/4

(2) Temperature Is Only Term Contributing -- Simple Average.

Table A-10
Random Error Calculation -- Secondary Air Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
ɪct Size				
Width, ft	9	0.042	0.46%	
ength, ft	6	0.042	0.69%	
of Points	24			
Widthwise	6			
engthwise	4			
Sector Width, ft	1.50	0.042	2.78%	
Sector Length, ft	1.50	0.042	2.78%	
A, Sector Area ft^2	2.25	0.088	3.93%	
deg F	616	3.060	0.50%	
deg R	1076	3.060	0.29%	
mp Bias, deg F	100		33.33	deg F/Length Increment Spacial Bias
P, In WC	0.972035	0.00006	0.01%	
, lb/mol	28.65	0.050	0.17%	
mb Pres, In. Hg	29.50			
uct Pres, In. WC	5.60			
s, In. Hg Absolute	29.70	0.040	0.14%	
P, Pitot Fact	0.84	0.0000	0.00%	
ominal Vel, fps	79.34	ACFM= 257051	SCFM= 123321	lb/hr= 562500

Input Data / Derivatives, dTa/dX

Point	AI	CPI	DPI	MI	PsI	TI	(1)	(2)	dTa/dTI	dTa/dAI	dTa/dCPI	dTa/dDPI	dTa/dMI	dTa/dPsI
1	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
2	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
3	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
4	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
5	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
6	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
7	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
8	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
9	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
10	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
11	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
12	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
13	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
14	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
15	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
16	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
17	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
18	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
19	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
20	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
21	2.25	0.84	0.9720	28.65	29.70	1026.0	1.703	1747.2	4.37E-02	-9.36E-01	-2.51E+00	-1.06E+00	-3.65E-02	-3.54E-02
22	2.25	0.84	0.9720	28.65	29.70	1059.3	1.676	1775.4	4.23E-02	-2.99E-01	-8.01E-01	-3.46E-01	-1.17E-02	-1.13E-02
23	2.25	0.84	0.9720	28.65	29.70	1092.7	1.650	1803.1	4.10E-02	3.18E-01	8.52E-01	3.66E-01	1.24E-02	1.20E-02
24	2.25	0.84	0.9720	28.65	29.70	1126.0	1.626	1830.4	3.96E-02	9.16E-01	2.45E+00	1.06E+00	3.57E-02	3.47E-02
							SUM1	SUM2						
							39.927	42936.0						

(dTa/dX*Sigma)^2

Point	d/dTI*STI	d/dAI*SAI	d/dCPI*SCPI	d/dDPI*SDPI	d/dMI*SMI	d/dPsI*SPsI
1	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
2	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
3	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
4	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
5	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
6	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
7	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
8	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
9	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
10	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
11	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
12	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
13	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
14	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
15	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
16	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
17	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
18	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
19	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
20	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
21	1.81E-02	6.64E-03	0.00E+00	2.93E-09	3.33E-06	2.03E-06
22	1.70E-02	6.96E-04	0.00E+00	2.99E-10	3.40E-07	2.07E-07
23	1.59E-02	7.90E-04	0.00E+00	3.39E-10	3.84E-07	2.34E-07
24	1.50E-02	6.56E-03	0.00E+00	2.81E-09	3.19E-06	1.94E-06
	T	A	Cp	DP	M	Ps
Contributions	3.96E-01	8.93E-02	0.00E+00	3.83E-08	4.35E-05	2.65E-05
			Total Sigma^2		0.49	
			Tavg Sigma		0.70 deg F	

(1) AI*CPI(DPI*MI*PsI/TI)^0.5
(2) AI*CPI(DPI*MI*PsI*TI)^0.5

5 / 2 / 5

Table A-11
Random Error Calculation -- Flue Gas Inlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
ct Size				
Vidth, ft	5.5	0.042	0.76%	
ength, ft	14.5	0.042	0.29%	
of Points	20			
Vidthwise	4			
engthwise	5			
ector Width, ft	1.38	0.042	3.03%	
ector Length, ft	2.90	0.042	1.44%	
, Sector Area ft^2	3.99	0.134	3.35%	
deg F	680	3.400	0.50%	
deg R	1140	3.400	0.30%	
mp Bias, deg F	100		25	deg F/Length Increment Special Bias
, In WC	0.82831	0.00005	0.01%	
, lb/mol	29.71	0.070	0.24%	
nb Pres, In. Hg	29.50			
ct Pres, In. WC	-7.50			
, In. Hg Absolute	29.23	0.040	0.14%	
, Pitot Fact	0.84	0.0000	0.00%	
minal Vel, fps	74.88	ACFM= 358315	SCFM= 159669	lb/hr= 750001

Input Data									Derivatives, dTa/dX					
Point	AI	CPI	DPI	MI	Pai	TI	(1)	(2)	dTa/dTI	dTa/dAI	dTa/dCPI	dTa/dDPI	dTa/dMI	dTa/dPai
1	3.99	0.84	0.8283	29.71	29.23	1090	2.721	2966	5.23E-02	-6.34E-01	-3.01E+00	-1.53E+00	-4.25E-02	-4.32E-02
2	3.99	0.84	0.8283	29.71	29.23	1115	2.690	3000	5.11E-02	-3.10E-01	-1.47E+00	-7.46E-01	-2.08E-02	-2.11E-02
3	3.99	0.84	0.8283	29.71	29.23	1140	2.661	3033	5.00E-02	6.86E-03	3.26E-02	1.66E-02	4.61E-04	4.69E-04
4	3.99	0.84	0.8283	29.71	29.23	1165	2.632	3066	4.89E-02	3.17E-01	1.50E+00	7.63E-01	2.13E-02	2.16E-02
5	3.99	0.84	0.8283	29.71	29.23	1190	2.604	3099	4.79E-02	6.20E-01	2.94E+00	1.49E+00	4.16E-02	4.23E-02
6	3.99	0.84	0.8283	29.71	29.23	1090	2.721	2966	5.23E-02	-6.34E-01	-3.01E+00	-1.53E+00	-4.25E-02	-4.32E-02
7	3.99	0.84	0.8283	29.71	29.23	1115	2.690	3000	5.11E-02	-3.10E-01	-1.47E+00	-7.46E-01	-2.08E-02	-2.11E-02
8	3.99	0.84	0.8283	29.71	29.23	1140	2.661	3033	5.00E-02	6.86E-03	3.26E-02	1.66E-02	4.61E-04	4.69E-04
9	3.99	0.84	0.8283	29.71	29.23	1165	2.632	3066	4.89E-02	3.17E-01	1.50E+00	7.63E-01	2.13E-02	2.16E-02
10	3.99	0.84	0.8283	29.71	29.23	1190	2.604	3099	4.79E-02	6.20E-01	2.94E+00	1.49E+00	4.16E-02	4.23E-02
11	3.99	0.84	0.8283	29.71	29.23	1090	2.721	2966	5.23E-02	-6.34E-01	-3.01E+00	-1.53E+00	-4.25E-02	-4.32E-02
12	3.99	0.84	0.8283	29.71	29.23	1115	2.690	3000	5.11E-02	-3.10E-01	-1.47E+00	-7.46E-01	-2.08E-02	-2.11E-02
13	3.99	0.84	0.8283	29.71	29.23	1140	2.661	3033	5.00E-02	6.86E-03	3.26E-02	1.66E-02	4.61E-04	4.69E-04
14	3.99	0.84	0.8283	29.71	29.23	1165	2.632	3066	4.89E-02	3.17E-01	1.50E+00	7.63E-01	2.13E-02	2.16E-02
15	3.99	0.84	0.8283	29.71	29.23	1190	2.604	3099	4.79E-02	6.20E-01	2.94E+00	1.49E+00	4.16E-02	4.23E-02
16	3.99	0.84	0.8283	29.71	29.23	1090	2.721	2966	5.23E-02	-6.34E-01	-3.01E+00	-1.53E+00	-4.25E-02	-4.32E-02
17	3.99	0.84	0.8283	29.71	29.23	1115	2.690	3000	5.11E-02	-3.10E-01	-1.47E+00	-7.46E-01	-2.08E-02	-2.11E-02
18	3.99	0.84	0.8283	29.71	29.23	1140	2.661	3033	5.00E-02	6.86E-03	3.26E-02	1.66E-02	4.61E-04	4.69E-04
19	3.99	0.84	0.8283	29.71	29.23	1165	2.632	3066	4.89E-02	3.17E-01	1.50E+00	7.63E-01	2.13E-02	2.16E-02
20	3.99	0.84	0.8283	29.71	29.23	1190	2.604	3099	4.79E-02	6.20E-01	2.94E+00	1.49E+00	4.16E-02	4.23E-02
							SUM1	SUM2						
							53.232	60655						Contributions

	(dTa/dX*Sigma)^2					
Point	d/dTI*STI	d/dAI*SAI	d/dCPI*SCPI	d/dDPI*SDPI	d/dMI*SMI	d/dPai*SPai
1	3.16E-02	7.19E-03	0.00E+00	5.82E-09	8.87E-06	3.02E-06
2	3.02E-02	1.72E-03	0.00E+00	1.39E-09	2.12E-06	7.21E-07
3	2.89E-02	8.46E-07	0.00E+00	6.85E-13	1.04E-09	3.55E-10
4	2.76E-02	1.79E-03	0.00E+00	1.45E-09	2.21E-06	7.53E-07
5	2.65E-02	6.88E-03	0.00E+00	5.57E-09	8.49E-06	2.89E-06
6	3.16E-02	7.19E-03	0.00E+00	5.82E-09	8.87E-06	3.02E-06
7	3.02E-02	1.72E-03	0.00E+00	1.39E-09	2.12E-06	7.21E-07
8	2.89E-02	8.46E-07	0.00E+00	6.85E-13	1.04E-09	3.55E-10
9	2.76E-02	1.79E-03	0.00E+00	1.45E-09	2.21E-06	7.53E-07
10	2.65E-02	6.88E-03	0.00E+00	5.57E-09	8.49E-06	2.89E-06
11	3.16E-02	7.19E-03	0.00E+00	5.82E-09	8.87E-06	3.02E-06
12	3.02E-02	1.72E-03	0.00E+00	1.39E-09	2.12E-06	7.21E-07
13	2.89E-02	8.46E-07	0.00E+00	6.85E-13	1.04E-09	3.55E-10
14	2.76E-02	1.79E-03	0.00E+00	1.45E-09	2.21E-06	7.53E-07
15	2.65E-02	6.88E-03	0.00E+00	5.57E-09	8.49E-06	2.89E-06
16	3.16E-02	7.19E-03	0.00E+00	5.82E-09	8.87E-06	3.02E-06
17	3.02E-02	1.72E-03	0.00E+00	1.39E-09	2.12E-06	7.21E-07
18	2.89E-02	8.46E-07	0.00E+00	6.85E-13	1.04E-09	3.55E-10
19	2.76E-02	1.79E-03	0.00E+00	1.45E-09	2.21E-06	7.53E-07
20	2.65E-02	6.88E-03	0.00E+00	5.57E-09	8.49E-06	2.89E-06
	T	A	CP	DP	M	Pa
Contributions	5.79E-01	7.03E-02	0.00E+00	5.69E-08	8.68E-05	2.95E-05
			Total Sigma^2		0.65	
			Tavg Sigma		0.81 deg F	

(1) AI*CPI(DPI*MI*Pai/TI)^0.5
(2) AI*CPI(DPI*MI*Pai*TI)^0.5

Table A-12
Random Error Calculation -- Flue Gas Outlet
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
Duct Size				
Width, ft	2.5	0.042	1.67%	
Length, ft	34	0.042	0.12%	
# of Points	24			
Widthwise	2			
Lengthwise	12			
Sector Width, ft	1.25	0.042	3.33%	
Sector Length, ft	2.83	0.042	1.47%	
A, Sector Area ft^2	3.54	0.129	3.64%	
T, deg F	253	1.265	0.50%	
T, deg R	713	1.265	0.18%	
Temp Bias, deg F	100		9.09	deg F/Length Increment Special Bias
DP, in WC	0.45802	0.00006	0.01%	
M, lb/mol	29.71	0.070	0.24%	
Amb Pres, in. Hg	29.50			
Duct Pres, in. WC	-11.00			
Ps, in. Hg Absolute	29.10	0.040	0.14%	
CP, Pitot Fact	0.84	0.0000	0.00%	
Nominal Vel, fps	44.13	ACFM= 225078	SCFM= 150669	lb/hr= 750003

Point	Ai	CPi	DPi	Mi	Psi	Ti	(1)	(2)
1	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524
2	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1535
3	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545
4	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555
5	3.54	0.84	0.4580	29.71	29.10	699.4	2.239	1566
6	3.54	0.84	0.4580	29.71	29.10	708.5	2.224	1576
7	3.54	0.84	0.4580	29.71	29.10	717.5	2.210	1586
8	3.54	0.84	0.4580	29.71	29.10	726.6	2.196	1596
9	3.54	0.84	0.4580	29.71	29.10	735.7	2.183	1606
10	3.54	0.84	0.4580	29.71	29.10	744.8	2.169	1616
11	3.54	0.84	0.4580	29.71	29.10	753.9	2.156	1626
12	3.54	0.84	0.4580	29.71	29.10	763.0	2.143	1635
13	3.54	0.84	0.4580	29.71	29.10	663.0	2.299	1524
14	3.54	0.84	0.4580	29.71	29.10	672.1	2.284	1535
15	3.54	0.84	0.4580	29.71	29.10	681.2	2.268	1545
16	3.54	0.84	0.4580	29.71	29.10	690.3	2.253	1555
17	3.54	0.84	0.4580	29.71	29.10	699.4	2.239	1566
18	3.54	0.84	0.4580	29.71	29.10	708.5	2.224	1576
19	3.54	0.84	0.4580	29.71	29.10	717.5	2.210	1586
20	3.54	0.84	0.4580	29.71	29.10	726.6	2.196	1596
21	3.54	0.84	0.4580	29.71	29.10	735.7	2.183	1606
22	3.54	0.84	0.4580	29.71	29.10	744.8	2.169	1616
23	3.54	0.84	0.4580	29.71	29.10	753.9	2.156	1626
24	3.54	0.84	0.4580	29.71	29.10	763.0	2.143	1635
							SUM1	SUM2
							53.251	37931

Derivatives, dTa/dX

Point	dTa/dTi	dTa/dAi	dTa/dCPi	dTa/dDPi	dTa/dMi	dTa/dPsi
1	4.48E-02	-6.01E-01	-2.53E+00	-2.32E+00	-3.58E-02	-3.66E-02
2	4.42E-02	-4.87E-01	-2.05E+00	-1.88E+00	-2.90E-02	-2.96E-02
3	4.36E-02	-3.74E-01	-1.58E+00	-1.45E+00	-2.23E-02	-2.28E-02
4	4.30E-02	-2.63E-01	-1.11E+00	-1.02E+00	-1.57E-02	-1.60E-02
5	4.24E-02	-1.54E-01	-6.48E-01	-5.94E-01	-9.16E-03	-9.35E-03
6	4.19E-02	-4.55E-02	-1.92E-01	-1.76E-01	-2.71E-03	-2.77E-03
7	4.14E-02	6.14E-02	2.59E-01	2.37E-01	3.66E-03	3.73E-03
8	4.08E-02	1.67E-01	7.04E-01	6.45E-01	9.95E-03	1.02E-02
9	4.03E-02	2.71E-01	1.14E+00	1.05E+00	1.62E-02	1.65E-02
10	3.98E-02	3.74E-01	1.58E+00	1.45E+00	2.23E-02	2.28E-02
11	3.94E-02	4.76E-01	2.01E+00	1.84E+00	2.83E-02	2.89E-02
12	3.89E-02	5.76E-01	2.43E+00	2.23E+00	3.43E-02	3.51E-02
13	4.48E-02	-6.01E-01	-2.53E+00	-2.32E+00	-3.58E-02	-3.66E-02
14	4.42E-02	-4.87E-01	-2.05E+00	-1.88E+00	-2.90E-02	-2.96E-02
15	4.36E-02	-3.74E-01	-1.58E+00	-1.45E+00	-2.23E-02	-2.28E-02
16	4.30E-02	-2.63E-01	-1.11E+00	-1.02E+00	-1.57E-02	-1.60E-02
17	4.24E-02	-1.54E-01	-6.48E-01	-5.94E-01	-9.16E-03	-9.35E-03
18	4.19E-02	-4.55E-02	-1.92E-01	-1.76E-01	-2.71E-03	-2.77E-03
19	4.14E-02	6.14E-02	2.59E-01	2.37E-01	3.66E-03	3.73E-03
20	4.08E-02	1.67E-01	7.04E-01	6.45E-01	9.95E-03	1.02E-02
21	4.03E-02	2.71E-01	1.14E+00	1.05E+00	1.62E-02	1.65E-02
22	3.98E-02	3.74E-01	1.58E+00	1.45E+00	2.23E-02	2.28E-02
23	3.94E-02	4.76E-01	2.01E+00	1.84E+00	2.83E-02	2.89E-02
24	3.89E-02	5.76E-01	2.43E+00	2.23E+00	3.43E-02	3.51E-02

(dTa/dX*Sigma)^2

Point	d/dTi*STi	d/dAi*SAi	d/dCPi*SCPi	d/dDPi*SDPi	d/dMi*SMi	d/dPsi*SPsi
1	3.21E-03	6.02E-03	0.00E+00	1.35E-08	6.29E-06	2.16E-06
2	3.12E-03	3.95E-03	0.00E+00	8.86E-09	4.13E-06	1.42E-06
3	3.04E-03	2.33E-03	0.00E+00	5.24E-09	2.44E-06	8.37E-07
4	2.96E-03	1.15E-03	0.00E+00	2.59E-09	1.21E-06	4.14E-07
5	2.88E-03	3.93E-04	0.00E+00	8.82E-10	4.11E-07	1.41E-07
6	2.81E-03	3.44E-05	0.00E+00	7.72E-11	3.60E-08	1.23E-08
7	2.74E-03	6.27E-05	0.00E+00	1.41E-10	6.56E-08	2.25E-08
8	2.67E-03	4.64E-04	0.00E+00	1.04E-09	4.85E-07	1.66E-07
9	2.60E-03	1.22E-03	0.00E+00	2.75E-09	1.28E-06	4.39E-07
10	2.54E-03	2.33E-03	0.00E+00	5.23E-09	2.43E-06	8.35E-07
11	2.48E-03	3.77E-03	0.00E+00	8.45E-09	3.94E-06	1.35E-06
12	2.42E-03	5.53E-03	0.00E+00	1.24E-08	5.78E-06	1.98E-06
13	3.21E-03	6.02E-03	0.00E+00	1.35E-08	6.29E-06	2.16E-06
14	3.12E-03	3.95E-03	0.00E+00	8.86E-09	4.13E-06	1.42E-06
15	3.04E-03	2.33E-03	0.00E+00	5.24E-09	2.44E-06	8.37E-07
16	2.96E-03	1.15E-03	0.00E+00	2.59E-09	1.21E-06	4.14E-07
17	2.88E-03	3.93E-04	0.00E+00	8.82E-10	4.11E-07	1.41E-07
18	2.81E-03	3.44E-05	0.00E+00	7.72E-11	3.60E-08	1.23E-08
19	2.74E-03	6.27E-05	0.00E+00	1.41E-10	6.56E-08	2.25E-08
20	2.67E-03	4.64E-04	0.00E+00	1.04E-09	4.85E-07	1.66E-07
21	2.60E-03	1.22E-03	0.00E+00	2.75E-09	1.28E-06	4.39E-07
22	2.54E-03	2.33E-03	0.00E+00	5.23E-09	2.43E-06	8.35E-07
23	2.48E-03	3.77E-03	0.00E+00	8.45E-09	3.94E-06	1.35E-06
24	2.42E-03	5.53E-03	0.00E+00	1.24E-08	5.78E-06	1.98E-06
	T	A	CP	DP	M	Ps
Contributions	6.694E-02	5.450E-02	0.000E+00	1.223E-07	5.696E-05	1.955E-05
			Total Sigma^2		0.12	
			Tavg Sigma		0.35 deg F	

(1) Ai*CPi(DPi*Mi*Psi/Ti)^0.5
(2) Ai*CPi(DPi*Mi*Psi*Ti)^0.5

Table A-13
Bias Error Calculation -- Primary Air Inlet
(Randomized Input Data Assumed)
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative	
uct Size				
Width, ft	3.28	0.042	1.27%	
Length, ft	17.5	0.042	0.24%	
# of Points	12			
Widthwise	2			
Lengthwise	6			
Sector Width, ft	1.64	0.042	2.54%	
Sector Length, ft	2.92	0.042	1.43%	
A, Sector Area ft^2	4.78	0.139	2.91%	
, deg F	80	0.800	1.00%	
, deg R	540	0.800	0.15%	
pecial Bias, deg F	10		2.00	deg F/Length Increment Special Bias
P, in WC	0.005069	0.0001	2.00%	
I, lb/mol	28.85	0.025	0.09%	
mb Pres, in. Hg	29.50			
uct Pres, in. WC	48.00			
's, in. Hg Absolute	31.23	0.040	0.13%	
P, Pitot Fact	0.84	0.0100	1.19%	
Nominal Vel, fps	3.96	ACFM= 13631	SCFM= 13702	lb/hr= 62500

	Input Data (1)							
Point	AI	CPI (2)	DPI	MI	Pal	TI	(3)	(4)
1	4.69	0.84	0.0005	28	30.00	535.0	0.111	59.4
2	4.97	0.84	0.0010	29	31.00	537.0	0.172	92.4
3	4.54	0.84	0.0015	28	32.00	539.0	0.185	99.7
4	4.31	0.84	0.0020	24	30.00	541.0	0.188	101.6
5	5.28	0.84	0.0025	28	28.00	543.0	0.267	145.2
6	4.78	0.84	0.0030	30	31.00	545.0	0.289	157.8
7	2.87	0.84	0.0051	32	30.00	535.0	0.230	123.0
8	3.83	0.84	0.0063	29	29.00	537.0	0.320	171.9
9	5.74	0.84	0.0076	28	28.00	539.0	0.507	273.3
10	5.98	0.84	0.0101	29	31.00	541.0	0.652	352.7
11	4.78	0.84	0.0089	28	29.00	543.0	0.446	242.1
12	4.07	0.84	0.0041	31	30.00	545.0	0.284	154.8
							Sum1	Sum2
							3.652	1974.0

	Derivatives, dTa/dX					
Point	dTa/dTI	dTa/AI	dTa/CPI	dTa/dDPI	dTa/dMI	dTa/dPal
1	3.06E-02	-3.60E-02	-2.01E-01	-1.66E+02	-3.01E-03	-2.81E-03
2	4.73E-02	-3.35E-02	-1.99E-01	-8.23E+01	-2.88E-03	-2.69E-03
3	5.07E-02	-1.72E-02	-9.29E-02	-2.56E+01	-1.50E-03	-1.22E-03
4	5.14E-02	5.49E-03	2.81E-02	5.83E+00	4.93E-04	3.94E-04
5	7.30E-02	3.42E-02	2.14E-01	3.55E+01	3.22E-03	3.22E-03
6	7.89E-02	7.39E-02	4.21E-01	5.81E+01	5.89E-03	5.70E-03
7	6.33E-02	-1.22E-01	-4.15E-01	-3.44E+01	-5.45E-03	-5.81E-03
8	8.60E-02	-8.11E-02	-3.70E-01	-2.45E+01	-5.35E-03	-5.35E-03
9	1.39E-01	-3.73E-02	-2.55E-01	-1.41E+01	-3.82E-03	-3.82E-03
10	1.76E-01	1.37E-02	9.77E-02	4.05E+00	1.41E-03	1.32E-03
11	1.22E-01	6.28E-02	3.58E-01	1.69E+01	5.78E-03	5.18E-03
12	7.75E-02	8.53E-02	4.13E-01	4.28E+01	5.60E-03	5.78E-03
					Contributions (5)	

	(dTa/dX*Sigma)^2					
Point	d/dTI*STI	d/dAI*SAI	d/dCPI*SCPI	d/dDPI*SDPI	d/dMI*SMI	d/dPal*SPa
1	5.98E-04	2.51E-05	4.03E-06	2.84E-04	5.66E-09	1.27E-08
2	1.43E-03	2.19E-05	3.95E-06	6.96E-05	5.17E-09	1.17E-08
3	1.65E-03	5.73E-06	8.62E-07	6.76E-06	1.41E-09	2.40E-09
4	1.69E-03	5.86E-07	7.92E-08	3.49E-07	1.52E-10	2.51E-10
5	3.41E-03	2.28E-05	4.60E-06	1.30E-05	6.48E-09	1.67E-08
6	3.99E-03	1.06E-04	1.77E-05	3.47E-05	2.17E-08	5.24E-08
7	2.56E-03	2.87E-04	1.72E-05	1.22E-05	1.86E-08	5.45E-08
8	4.95E-03	1.28E-04	1.37E-05	6.17E-06	1.79E-08	4.62E-08
9	1.24E-02	2.70E-05	6.48E-06	2.03E-06	9.12E-09	2.35E-08
10	2.04E-02	3.66E-06	9.54E-07	1.68E-07	1.25E-09	2.83E-09
11	9.50E-03	7.66E-05	1.28E-05	2.95E-06	2.09E-08	4.33E-08
12	3.84E-03	1.42E-04	1.71E-05	1.88E-05	1.96E-08	5.30E-08
	T	A	CP	DP	M	Pa
	6.40E-01	5.06E-05	-1.05E-20	3.48E-04	8.90E-11	1.92E-11
			Total Sigma^2		0.64	
			Tavg Sigma		0.80	deg F

(1) No Attempt Made to Make Average of Randomized Individual Terms Equal to Input Average Values.

(2) Not Varied Since Same Pitot Tube Used For All Measurements.

(3) AI*CPI(DPI*MI*Pal/TI)^0.5

(4) AI*CPI(DPI*MI*Pal*TI)^0.5

(5) Contributions Include Cross Product Terms

Table A-13 (Continued)
Cross Product Terms

d/dTi*d/dTj*STi*STj

	9.25E-04	9.92E-04	1.01E-03	1.43E-03	1.54E-03	1.24E-03	1.72E-03	2.72E-03	3.49E-03	2.38E-03	1.52E-03
9.25E-04		1.53E-03	1.56E-03	2.21E-03	2.39E-03	1.92E-03	2.66E-03	4.21E-03	5.40E-03	3.69E-03	2.35E-03
9.92E-04	1.53E-03		1.67E-03	2.37E-03	2.56E-03	2.05E-03	2.86E-03	4.51E-03	5.79E-03	3.95E-03	2.51E-03
1.01E-03	1.56E-03	1.67E-03		2.40E-03	2.60E-03	2.08E-03	2.89E-03	4.58E-03	5.87E-03	4.01E-03	2.55E-03
1.43E-03	2.21E-03	2.37E-03	2.40E-03		3.69E-03	2.96E-03	4.11E-03	6.50E-03	8.34E-03	5.70E-03	3.62E-03
1.54E-03	2.39E-03	2.56E-03	2.60E-03	3.69E-03		3.20E-03	4.44E-03	7.02E-03	9.01E-03	6.15E-03	3.91E-03
1.24E-03	1.92E-03	2.05E-03	2.08E-03	2.96E-03	3.20E-03		3.56E-03	5.63E-03	7.23E-03	4.93E-03	3.14E-03
1.72E-03	2.66E-03	2.86E-03	2.89E-03	4.11E-03	4.44E-03	3.56E-03		7.83E-03	1.00E-02	6.86E-03	4.36E-03
2.72E-03	4.21E-03	4.51E-03	4.58E-03	6.50E-03	7.02E-03	5.63E-03	7.83E-03		1.59E-02	1.08E-02	6.89E-03
3.49E-03	5.40E-03	5.79E-03	5.87E-03	8.34E-03	9.01E-03	7.23E-03	1.00E-02	1.59E-02		1.39E-02	8.85E-03
2.38E-03	3.69E-03	3.95E-03	4.01E-03	5.70E-03	6.15E-03	4.93E-03	6.86E-03	1.08E-02	1.39E-02		6.04E-03
1.52E-03	2.35E-03	2.51E-03	2.55E-03	3.62E-03	3.91E-03	3.14E-03	4.36E-03	6.89E-03	8.85E-03	6.04E-03	
1.90E-02	2.88E-02	3.08E-02	3.12E-02	4.33E-02	4.65E-02	3.79E-02	5.13E-02	7.66E-02	9.38E-02	6.85E-02	4.57E-02

d/dDPi*d/dDPj*SDPi*SDPj

	1.41E-04	4.38E-05	-9.96E-06	-6.07E-05	-9.93E-05	5.88E-05	4.19E-05	2.40E-05	-6.91E-06	-2.89E-05	-7.31E-05
1.41E-04		2.17E-05	-4.93E-06	-3.01E-05	-4.92E-05	2.91E-05	2.07E-05	1.19E-05	-3.42E-06	-1.43E-05	-3.62E-05
4.38E-05	2.17E-05		-1.54E-06	-9.36E-06	-1.53E-05	9.07E-06	6.46E-06	3.71E-06	-1.07E-06	-4.46E-06	-1.13E-05
-9.96E-06	-4.93E-06	-1.54E-06		2.13E-06	3.48E-06	-2.06E-06	-1.47E-06	-8.43E-07	2.42E-07	1.01E-06	2.56E-06
-6.07E-05	-3.01E-05	-9.36E-06	2.13E-06		2.12E-05	-1.26E-05	-8.94E-06	-5.14E-06	1.48E-06	6.18E-06	1.56E-05
-9.93E-05	-4.92E-05	-1.53E-05	3.48E-06	2.12E-05		-2.05E-05	-1.46E-05	-8.40E-06	2.42E-06	1.01E-05	2.55E-05
5.88E-05	2.91E-05	9.07E-06	-2.06E-06	-1.26E-05	-2.05E-05		8.66E-06	4.97E-06	-1.43E-06	-5.99E-06	-1.51E-05
4.19E-05	2.07E-05	6.46E-06	-1.47E-06	-8.94E-06	-1.46E-05	8.66E-06		3.54E-06	-1.02E-06	-4.26E-06	-1.08E-05
2.40E-05	1.19E-05	3.71E-06	-8.43E-07	-5.14E-06	-8.40E-06	4.97E-06	3.54E-06		-5.85E-07	-2.45E-06	-6.18E-06
-6.91E-06	-3.42E-06	-1.07E-06	2.42E-07	1.48E-06	2.42E-06	-1.43E-06	-1.02E-06	-5.85E-07		7.04E-07	1.78E-06
-2.89E-05	-1.43E-05	-4.46E-06	1.01E-06	6.18E-06	1.01E-05	-5.99E-06	-4.26E-06	-2.45E-06	7.04E-07		7.44E-06
-7.31E-05	-3.62E-05	-1.13E-05	2.56E-06	1.56E-05	2.55E-05	-1.51E-05	-1.08E-05	-6.18E-06	1.78E-06	7.44E-06	
3.02E-05	8.60E-05	4.17E-05	-1.14E-05	-8.01E-05	-1.45E-04	5.29E-05	4.01E-05	2.46E-05	-7.82E-06	-3.49E-05	-9.97E-05

d/dMi*d/dMj*SMi*SMj

	5.41E-09	2.82E-09	-9.26E-10	-6.05E-09	-1.11E-08	1.03E-08	1.01E-08	7.18E-09	-2.66E-09	-1.09E-08	-1.05E-08
5.41E-09		2.70E-09	-8.86E-10	-5.78E-09	-1.06E-08	9.80E-09	9.63E-09	6.87E-09	-2.54E-09	-1.04E-08	-1.01E-08
2.82E-09	2.70E-09		-4.62E-10	-3.01E-09	-5.52E-09	5.11E-09	5.02E-09	3.58E-09	-1.33E-09	-5.42E-09	-5.25E-09
-9.26E-10	-8.86E-10	-4.62E-10		9.90E-10	1.81E-09	-1.68E-09	-1.65E-09	-1.18E-09	4.35E-10	1.78E-09	1.72E-09
-6.05E-09	-5.78E-09	-3.01E-09	9.90E-10		1.18E-08	-1.10E-08	-1.08E-08	-7.68E-09	2.84E-09	1.16E-08	1.12E-08
-1.11E-08	-1.06E-08	-5.52E-09	1.81E-09	1.18E-08		-2.01E-08	-1.97E-08	-1.41E-08	5.21E-09	2.13E-08	2.06E-08
1.03E-08	9.80E-09	5.11E-09	-1.68E-09	-1.10E-08	-2.01E-08		1.82E-08	1.30E-08	-4.82E-09	-1.97E-08	-1.91E-08
1.01E-08	9.63E-09	5.02E-09	-1.65E-09	-1.08E-08	-1.97E-08	1.82E-08		1.28E-08	-4.73E-09	-1.93E-08	-1.87E-08
7.18E-09	6.87E-09	3.58E-09	-1.18E-09	-7.68E-09	-1.41E-08	1.30E-08	1.28E-08		-3.38E-09	-1.38E-08	-1.34E-08
-2.66E-09	-2.54E-09	-1.33E-09	4.35E-10	2.84E-09	5.21E-09	-4.82E-09	-4.73E-09	-3.38E-09		5.11E-09	4.95E-09
-1.09E-08	-1.04E-08	-5.42E-09	1.78E-09	1.16E-08	2.13E-08	-1.97E-08	-1.93E-08	-1.38E-08	5.11E-09		2.02E-08
-1.05E-08	-1.01E-08	-5.25E-09	1.72E-09	1.12E-08	2.06E-08	-1.91E-08	-1.87E-08	-1.34E-08	4.95E-09	2.02E-08	
-6.37E-09	-5.85E-09	-1.76E-09	-3.54E-11	-5.70E-09	-2.03E-08	-1.99E-08	-1.92E-08	-1.00E-08	-9.17E-10	-1.95E-08	-1.83E-08

Table A-13 (Continued)
Cross Product Terms

d/dPsi*d/dPsj*SPsi*SPsj

	1.22E-08	5.52E-09	-1.79E-09	-1.46E-08	-2.58E-08	2.63E-08	2.43E-08	1.73E-08	-6.00E-09	-2.35E-08	-2.62E-08
1.22E-08		5.29E-09	-1.71E-09	-1.40E-08	-2.48E-08	2.52E-08	2.32E-08	1.66E-08	-5.75E-09	-2.25E-08	-2.51E-08
5.52E-09	5.29E-09		-7.75E-10	-6.32E-09	-1.12E-08	1.14E-08	1.05E-08	7.51E-09	-2.60E-09	-1.02E-08	-1.14E-08
-1.79E-09	-1.71E-09	-7.75E-10		2.04E-09	3.62E-09	-3.70E-09	-3.40E-09	-2.43E-09	8.41E-10	3.29E-09	3.68E-09
-1.46E-08	-1.40E-08	-6.32E-09	2.04E-09		2.96E-08	-3.02E-08	-2.78E-08	-1.98E-08	6.87E-09	2.69E-08	3.00E-08
-2.58E-08	-2.48E-08	-1.12E-08	3.62E-09	2.96E-08		-5.35E-08	-4.92E-08	-3.51E-08	1.22E-08	4.76E-08	5.32E-08
2.63E-08	2.52E-08	1.14E-08	-3.70E-09	-3.02E-08	-5.35E-08		5.02E-08	3.58E-08	-1.24E-08	-4.86E-08	-5.42E-08
2.43E-08	2.32E-08	1.05E-08	-3.40E-09	-2.78E-08	-4.92E-08	5.02E-08		3.30E-08	-1.14E-08	-4.47E-08	-4.99E-08
1.73E-08	1.66E-08	7.51E-09	-2.43E-09	-1.98E-08	-3.51E-08	3.58E-08	3.30E-08		-8.15E-09	-3.19E-08	-3.56E-08
-6.00E-09	-5.75E-09	-2.60E-09	8.41E-10	6.87E-09	1.22E-08	-1.24E-08	-1.14E-08	-8.15E-09		1.11E-08	1.23E-08
-2.35E-08	-2.25E-08	-1.02E-08	3.29E-09	2.69E-08	4.76E-08	-4.86E-08	-4.47E-08	-3.19E-08	1.11E-08		4.83E-08
-2.62E-08	-2.51E-08	-1.14E-08	3.68E-09	3.00E-08	5.32E-08	-5.42E-08	-4.99E-08	-3.56E-08	1.23E-08	4.83E-08	
-1.22E-08	-1.12E-08	-2.18E-09	-3.20E-10	-1.73E-08	-5.35E-08	-5.35E-08	-4.53E-08	-2.29E-08	-3.06E-09	-4.42E-08	-5.50E-08

d/dCPi*d/dCPj*SCPi*SCPj

	3.99E-06	1.86E-06	-5.65E-07	-4.30E-06	-8.44E-06	8.33E-06	7.41E-06	5.11E-06	-1.96E-06	-7.17E-06	-8.29E-06
3.99E-06		1.84E-06	-5.59E-07	-4.26E-06	-8.36E-06	8.25E-06	7.34E-06	5.06E-06	-1.94E-06	-7.10E-06	-8.21E-06
1.86E-06	1.84E-06		-2.61E-07	-1.99E-06	-3.91E-06	3.86E-06	3.43E-06	2.36E-06	-9.07E-07	-3.32E-06	-3.84E-06
-5.65E-07	-5.59E-07	-2.61E-07		6.03E-07	1.18E-06	-1.17E-06	-1.04E-06	-7.17E-07	2.75E-07	1.01E-06	1.16E-06
-4.30E-06	-4.26E-06	-1.99E-06	6.03E-07		9.02E-06	-8.90E-06	-7.92E-06	-5.46E-06	2.09E-06	7.66E-06	8.85E-06
-8.44E-06	-8.36E-06	-3.91E-06	1.18E-06	9.02E-06		-1.75E-05	-1.56E-05	-1.07E-05	4.11E-06	1.50E-05	1.74E-05
8.33E-06	8.25E-06	3.86E-06	-1.17E-06	-8.90E-06	-1.75E-05		1.53E-05	1.06E-05	-4.06E-06	-1.48E-05	-1.72E-05
7.41E-06	7.34E-06	3.43E-06	-1.04E-06	-7.92E-06	-1.56E-05	1.53E-05		9.41E-06	-3.61E-06	-1.32E-05	-1.53E-05
5.11E-06	5.06E-06	2.36E-06	-7.17E-07	-5.46E-06	-1.07E-05	1.06E-05	9.41E-06		-2.49E-06	-9.10E-06	-1.05E-05
-1.96E-06	-1.94E-06	-9.07E-07	2.75E-07	2.09E-06	4.11E-06	-4.06E-06	-3.61E-06	-2.49E-06		3.49E-06	4.03E-06
-7.17E-06	-7.10E-06	-3.32E-06	1.01E-06	7.66E-06	1.50E-05	-1.48E-05	-1.32E-05	-9.10E-06	3.49E-06		1.48E-05
-8.29E-06	-8.21E-06	-3.84E-06	1.16E-06	8.85E-06	1.74E-05	-1.72E-05	-1.53E-05	-1.05E-05	4.03E-06	1.48E-05	
-4.03E-06	-3.95E-06	-8.62E-07	-7.92E-08	-4.60E-06	-1.77E-05	-1.72E-05	-1.37E-05	-6.48E-06	-9.54E-07	-1.28E-05	-1.71E-05

d/dAi*d/dAj*SAi*SAj

	2.34E-05	1.20E-05	-3.84E-06	-2.39E-05	-5.16E-05	8.49E-05	5.67E-05	2.60E-05	-9.59E-06	-4.39E-05	-5.96E-05
2.34E-05		1.12E-05	-3.58E-06	-2.23E-05	-4.82E-05	7.93E-05	5.29E-05	2.43E-05	-8.95E-06	-4.09E-05	-5.56E-05
1.20E-05	1.12E-05		-1.83E-06	-1.14E-05	-2.47E-05	4.06E-05	2.71E-05	1.24E-05	-4.58E-06	-2.10E-05	-2.85E-05
-3.84E-06	-3.58E-06	-1.83E-06		3.65E-06	7.89E-06	-1.30E-05	-8.66E-06	-3.98E-06	1.46E-06	6.70E-06	9.11E-06
-2.39E-05	-2.23E-05	-1.14E-05	3.65E-06		4.92E-05	-8.09E-05	-5.40E-05	-2.48E-05	9.13E-06	4.18E-05	5.68E-05
-5.16E-05	-4.82E-05	-2.47E-05	7.89E-06	4.92E-05		-1.75E-04	-1.17E-04	-5.35E-05	1.97E-05	9.02E-05	1.23E-04
8.49E-05	7.93E-05	4.06E-05	-1.30E-05	-8.09E-05	-1.75E-04		1.92E-04	8.80E-05	-3.24E-05	-1.48E-04	-2.02E-04
5.67E-05	5.29E-05	2.71E-05	-8.66E-06	-5.40E-05	-1.17E-04	1.92E-04		5.88E-05	-2.16E-05	-9.90E-05	-1.35E-04
2.60E-05	2.43E-05	1.24E-05	-3.98E-06	-2.48E-05	-5.35E-05	8.80E-05	5.88E-05		-9.94E-06	-4.55E-05	-6.18E-05
-9.59E-06	-8.95E-06	-4.58E-06	1.46E-06	9.13E-06	1.97E-05	-3.24E-05	-2.16E-05	-9.94E-06		1.67E-05	2.28E-05
-4.39E-05	-4.09E-05	-2.10E-05	6.70E-06	4.18E-05	9.02E-05	-1.48E-04	-9.90E-05	-4.55E-05	1.67E-05		1.04E-04
-5.96E-05	-5.56E-05	-2.85E-05	9.11E-06	5.68E-05	1.23E-04	-2.02E-04	-1.35E-04	-6.18E-05	2.28E-05	1.04E-04	
1.06E-05	1.15E-05	1.13E-05	-6.04E-06	-5.68E-05	-1.80E-04	-1.66E-04	-4.73E-05	1.00E-05	-1.73E-05	-1.39E-04	-2.26E-04

Table A-14
Random Error Calculation -- Primary Air Inlet
(Randomized Input Data Assumed)
Milliken Heat Pipe Air Preheater

	Average Value	Sigma Absolute	Sigma Relative		
Duct Size					
Width, ft	3.28	0.042	1.27%		
Length, ft	17.5	0.042	0.24%		
# of Points	12				
Widthwise	2				
Lengthwise	6				
Sector Width, ft	1.64	0.042	2.54%		
Sector Length, ft	2.92	0.042	1.43%		
A, Sector Area ft^2	4.78	0.139	2.91%		
T, deg F	80	0.400	0.50%		
T, deg R	540	0.400	0.07%		
Temp Bias, deg F	10		2.00	deg F/Length Increment Special Bias	
DP, in WC	0.005069	0.00005	0.90%		
M, lb/mol	28.85	0.050	0.17%		
Amb Pres, in. Hg	29.50				
Duct Pres, in. WC	48.00				
Ps, in. Hg Absolute	31.23	0.040	0.13%		
CP, Pitot Fact	0.84	0.0000	0.00%		
Nominal Vel, fps	3.96	ACFM= 13631		SCFM= 13702	lb/hr= 62500

Point	AI	CPI (2)	DPI	MI	PsI	TI	(3)	(4)
1	4.69	0.84	0.0005	28	30.00	535.0	0.111	59.4
2	4.97	0.84	0.0010	29	31.00	537.0	0.172	92.4
3	4.54	0.84	0.0015	28	32.00	539.0	0.185	99.7
4	4.31	0.84	0.0020	24	30.00	541.0	0.188	101.6
5	5.26	0.84	0.0025	28	28.00	543.0	0.267	145.2
6	4.78	0.84	0.0030	30	31.00	545.0	0.289	157.6
7	2.67	0.84	0.0051	32	30.00	535.0	0.230	123.0
8	3.83	0.84	0.0063	29	29.00	537.0	0.320	171.9
9	5.74	0.84	0.0076	28	28.00	539.0	0.507	273.3
10	5.98	0.84	0.0101	29	31.00	541.0	0.652	352.7
11	4.78	0.84	0.0089	28	29.00	543.0	0.446	242.1
12	4.07	0.84	0.0041	31	30.00	545.0	0.284	154.8
							SUM1	SUM2
							3.652	1974.0

Derivatives, dTa/dX

Point	dTa/dTI	dTa/AI	dTa/CPI	dTa/dDPI	dTa/dMI	dTa/dPsI
1	3.06E-02	-3.6E-02	-2.0E-01	-1.7E+02	-3.0E-03	-2.8E-03
2	4.73E-02	-3.4E-02	-2.0E-01	-8.2E+01	-2.9E-03	-2.7E-03
3	5.07E-02	-1.7E-02	-9.3E-02	-2.6E+01	-1.5E-03	-1.2E-03
4	5.14E-02	5.49E-03	2.61E-02	5.63E+00	4.93E-04	3.94E-04
5	7.30E-02	3.42E-02	2.14E-01	3.55E+01	3.22E-03	3.22E-03
6	7.69E-02	7.39E-02	4.21E-01	5.61E+01	5.89E-03	5.70E-03
7	6.33E-02	-1.2E-01	-4.2E-01	-3.4E+01	-5.5E-03	-5.6E-03
8	8.80E-02	-8.1E-02	-3.7E-01	-2.4E+01	-5.4E-03	-5.4E-03
9	1.39E-01	-3.7E-02	-2.5E-01	-1.4E+01	-3.8E-03	-3.8E-03
10	1.78E-01	1.37E-02	9.77E-02	4.05E+00	1.41E-03	1.32E-03
11	1.22E-01	6.28E-02	3.56E-01	1.69E+01	5.78E-03	5.18E-03
12	7.76E-02	8.53E-02	4.13E-01	4.28E+01	5.60E-03	5.78E-03

(dTa/dX*Sigma)^2

Point	d/dTI*STI	d/dAI*SAI	d/dCPI*SCPI	d/dDPI*SDPI	d/dMI*SMI	d/dPsI*SPs
1	1.50E-04	2.51E-05	0.00E+00	6.91E-05	2.26E-08	1.27E-08
2	3.58E-04	2.19E-05	0.00E+00	1.69E-05	2.07E-08	1.17E-08
3	4.11E-04	5.73E-06	0.00E+00	1.64E-06	5.63E-09	2.40E-09
4	4.23E-04	5.86E-07	0.00E+00	8.50E-08	6.07E-10	2.51E-10
5	8.54E-04	2.28E-05	0.00E+00	3.15E-06	2.59E-08	1.67E-08
6	9.97E-04	1.06E-04	0.00E+00	8.44E-06	8.66E-08	5.24E-08
7	6.41E-04	2.87E-04	0.00E+00	2.96E-06	7.43E-08	5.45E-08
8	1.24E-03	1.26E-04	0.00E+00	1.50E-06	7.16E-08	4.62E-08
9	3.09E-03	2.70E-05	0.00E+00	4.94E-07	3.65E-08	2.35E-08
10	5.09E-03	3.66E-06	0.00E+00	4.09E-08	5.00E-09	2.83E-09
11	2.37E-03	7.66E-05	0.00E+00	7.16E-07	8.34E-08	4.33E-08
12	9.60E-04	1.42E-04	0.00E+00	4.57E-06	7.83E-08	5.39E-08
	T	A	Cp	DP	M	Ps
Contributions	1.66E-02	8.46E-04	0.00E+00	1.10E-04	5.11E-07	3.21E-07
			Total Sigma^2		0.02	
			Tavg Sigma		0.13 deg F	

(1) No Attempt Made to Make Average of Randomized Individual Terms Equal to Input Average Values.
(2) Not Varied Since Same Pitot Tube Used For All Measurements.
(3) AI*CPI(DPI*MI*PsI/TI)^0.5
(4) AI*CPI(DPI*MI*PsI*TI)^0.5

Appendix B-1
Bias Calculation
Primary Air In

>

>

Error Propagation Calculations, Part B, PAFA

Set no. of sample points

```
> n := 12;
                    n := 12
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

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#13

m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

I := 'I';

$$i := i$$

#14 PRIMARY AIR FLOW – 'A' SIDE OF HEAT PIPE

PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} \right)$$

PRIMARY AIR FLOW – 'B' SIDE

PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} \right)$$

```
> sigmaPAFACP := sqrt(Diff(PAFA,CP)^2*varCP):
> sigmaPAFACP := value("):
> sigmaPAFAapa := sqrt(Diff(PAFA,apa)^2*varapa):
> sigmaPAFAapa := value("):
> sigmaPAFAPSpa := sqrt(Diff(PAFA,PSpa)^2*varPSpa):
> sigmaPAFAPSpa := value("):
> sigmaPAFAWma := sqrt(Diff(PAFA,Wma)^2*varWma):
> sigmaPAFAWma := value("):
>  sigmaPAFADPpa := sqrt(sum(sum(
>  Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFADPpa := value("):
> sigmaPAFATpa := sqrt(sum(sum(
>  Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFATpa := value("):
```

```
var := [.6400  .6400  .6400  .6400  .6400  .6400  .6400  .6400  .6400  .6400
  .6400  .6400]
> varTpa := make_array(var,n);
                                   varTpa := varcovar
```

Results

```
**************************************************************************
> evalf(PAFA);
                                   62313.28846   lb/HR   FLOW
> evalf(sigmaPAFA);
                                   2062.436394   BIAS
> evalf(100*sigmaPAFA/PAFA);                      BIAS CONTRIBUTIONS
                                   3.309785834
>
> evalf(sigmaPAFAWma);
                                   23.81299155
> evalf(sigmaPAFACP);
                                   741.8248627
>
> evalf(sigmaPAFADPpa);
                                   623.1328828
> evalf(sigmaPAFATpa);
                                   46.15799166
> evalf(sigmaPAFAPSpa);
                                   39.90604447
> evalf(sigmaPAFAapa);
                                   1819.548024
**************************************************************************
> i := 'i';
                                   i := i
```

#13 AIR MOL WT.

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                                   m := 28.74570417
```

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                                   PAFA := 62313.28846
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                                   PAFB := 62313.28846
>
```

```
sigmaPAFA := sqrt(
 Diff(PAFA,CP)^2*varCP +
 Diff(PAFA,apa)^2*varapa +
 Diff(PAFA,PSpa)^2*varPSpa +
 Diff(PAFA,Wma)^2*varWma +
 sum(sum(
  Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j] +
  Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
,j=1..n),i=1..n)):

sigmaPAFA := value("):
```

Constants

Averages and Variances from Part A

Pitot Coefficient

```
CP := 0.84;
                    CP := .84
varCP := (0.01)^2;
                    varCP := .0001
```

Pressure for primary air

```
PSpa := 31.23;
                    PSpa := 31.23
varPSpa := (0.04)^2;
                    varPSpa := .0016
```

Moisture (air)

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.1*Wma)^2;
                    varWma := .169 10^-3
```

Area for primary air AREA INCREMENT ft²

```
> apa := 4.78;
                    apa := 4.78
> varapa := (.0292*apa)^2;
                    varapa := .01948145978
```

VELOCITY HEAD " W.C.

```
> v := .005069;
                    v := .005069
> DPpa := array([seq(v,i=1..n)]);
  DPpa := [.005069  .005069  .005069  .005069  .005069  .005069  .005069  .00506
   .005069  .005069  .005069  .005069]
> u := (0.02*v)^2;
                    u := .102779044 10^-7
> var := array([seq(u,i=1..n)]);
  var := [.102779044 10^-7  .102779044 10^-7  .102779044 10^-7  .102779044 10^-7
   .102779044 10^-7  .102779044 10^-7  .102779044 10^-7  .102779044 10^-7
   .102779044 10^-7  .102779044 10^-7  .102779044 10^-7  .102779044 10^-7]
> varDPpa := make_array(var,n);
                    varDPpa := varcovar
```

INLET TEMPERATURE °F

```
> v := 540;
                    v := 540
> Tpa := array([seq(v,i=1..n)]);
  Tpa := [540  540  540  540  540  540  540  540  540  540  540  540]
> u := (0.01*(v - 460))^2;
                    u := .6400
> var := array([seq(u,i=1..n)]);
```

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Appendix B-2
Random Error Calculation
Primary Air In

```
>
>
```

Random Error Propagation Calculations, Part B, PAFA in

Set no. of sample points

```
> n := 12;
                                n := 12
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

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```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#13

> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

> i := 'i';

$$i := i$$

#14 PRIMARY AIR FLOW TO 'A' SIDE OF HEAT PIPE

> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}}\right)$$

PRIMARY AIR TO 'B' SIDE OF HEAT PIPE

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}}\right)$$

> sigmaPAFACP := sqrt(Diff(PAFA,CP)^2*varCP):

> sigmaPAFACP := value("):

> sigmaPAFAapa := sqrt(Diff(PAFA,apa)^2*varapa):

> sigmaPAFAapa := value("):

> sigmaPAFAPSpa := sqrt(Diff(PAFA,PSpa)^2*varPSpa):

> sigmaPAFAPSpa := value("):

> sigmaPAFAWma := sqrt(Diff(PAFA,Wma)^2*varWma):

> sigmaPAFAWma := value("):

> sigmaPAFADPpa := sqrt(sum(sum(

> Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j]

> ,j=1..n),i=1..n)):

> sigmaPAFADPpa := value("):

```
> sigmaPAFATpa := sqrt(sum(sum(
>  Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFATpa := value("):
```

```
> sigmaPAFA := sqrt(
>  Diff(PAFA,CP)^2*varCP +
>  Diff(PAFA,apa)^2*varapa +
>  Diff(PAFA,PSpa)^2*varPSpa +
>  Diff(PAFA,Wma)^2*varWma +
>  sum(sum(
>   Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j] +
>   Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):
```

```
> sigmaPAFA := value("):
```

Constants

Pitot Coefficient re

```
> CP := 0.84;
```

$CP := .84$

```
> varCP := 0^2;
```

$varCP := 0$

Area - Primary Air ~~Out~~ IN re

```
> apa := 4.78;
```

$apa := 4.78$

```
> varapa := (0.0292*apa)^2;
```

$varapa := .01948145978$

Primary Air Pressure ~~Out~~ IN re

```
> PSpa := 31.23;
```

$PSpa := 31.23$

```
> varPSpa := (0.04)^2;
```

$varPSpa := .0016$

Moisture (air) re

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.2*Wma)^2;
```

$varWma := .676\ 10^{-5}$

Velocity Head re

```
> v := 0.005069;
```

$v := .005069$

```
> DPpa := array([seq(v,i=1..n)]);
```

$DPpa := [.005069\ \ .005069\ \ .005069\ \ .005069\ \ .005069\ \ .005069\ \ .005069\ \ .00506$
$.005069\ \ .005069\ \ .005069\ \ .005069]$

```
> u := (0.00005)^2;
```

$u := .25\ 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```

$var := [.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

```
> varDPpa := make_array(var,n);
```

$varDPpa := varcovar$

Temperature Primary Air In re

```
> v := 540;
```

$v := 540$

```
> Tpa := array([seq(v,i=1..n)]);
```

$Tpa := [540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540\ \ 540]$

```
> u := (0.005*(v-460))^2;
```

$u := .160000$

```
> var := array([seq(u,i=1..n)]);
```

```
var := [.160000  .160000  .160000  .160000  .160000  .160000  .160000  .160000
  .160000  .160000  .160000  .160000]
> varTpa := make_array(var,n);
                    varTpa := varcovar

Results
*********************************************************************
> evalf(PAFA);
                    62313.28846   lb/HR   FLOW RATE
> evalf(sigmaPAFA);
                    1822.781079   RANDOM ERROR
> evalf(100*sigmaPAFA/PAFA);                CONTRIBUTIONS
                    2.925188389
>
> evalf(sigmaPAFAWma);
                    47.62598310
> evalf(sigmaPAFACP);
                    0
>
> evalf(sigmaPAFADPpa);
                    88.71718747
> evalf(sigmaPAFATpa);
                    6.662332196

> evalf(sigmaPAFAPSpa);
                    39.90604447
> evalf(sigmaPAFAapa);
                    1819.548024
*********************************************************************

> i := 'i';
                    i := i

#13   AIR MW.
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                    m := 28.74570417

#14
```

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFA := 62313.28846

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFB := 62313.28846
>
```

Appendix B-3
Bias Calculation
Primary Air Out

```
>

>

Error Propagation Calculations, Part B, PAFA out

Set no. of sample points
> n := 20;
                                   n := 20

procedure for creating variance-covariance matrix
> make_array := proc(var,n)

> varcovar := array(1..n,1..n);

> for j to n do

> for i to n do

> varcovar[i,j] := sqrt(var[i]*var[j])

> od

> od;

> varcovar;

> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end

#4
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

```
> i := 'i';
```

$$i := i$$

#14 PRIMARY AIR FLOW FROM 'A' SIDE OF HEAT PIPE

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} \right)$$

```
PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} \right)$$

```
> sigmaPAFACP := sqrt(Diff(PAFA,CP)^2*varCP):
> sigmaPAFACP := value("):
> sigmaPAFAapa := sqrt(Diff(PAFA,apa)^2*varapa):
> sigmaPAFAapa := value("):
> sigmaPAFAPSpa := sqrt(Diff(PAFA,PSpa)^2*varPSpa):
> sigmaPAFAPSpa := value("):
> sigmaPAFAWma := sqrt(Diff(PAFA,Wma)^2*varWma):
> sigmaPAFAWma := value("):
> sigmaPAFADPpa := sqrt(sum(sum(
> Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFADPpa := value("):
```

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```
> sigmaPAFATpa := sqrt(sum(sum(
>  Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFATpa := value("):

> sigmaPAFA := sqrt(
>  Diff(PAFA,CP)^2*varCP +
>  Diff(PAFA,apa)^2*varapa +
>  Diff(PAFA,PSpa)^2*varPSpa +
>  Diff(PAFA,Wma)^2*varWma +
> sum(sum(
>   Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j] +
>   Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):

> sigmaPAFA := value("):
```

Constants

Pitot Coefficient

```
> CP := 0.84;
```

$CP := .84$

```
> varCP := 0.01^2;
```

$varCP := .0001$

Area - Primary Air Out   AREA INCREMENT

```
> apa := 0.63;
```

$apa := .63$

```
> varapa := (0.0208*apa)^2;
```

$varapa := .000171714816$

Primary Air Pressure Out

```
> PSpa := 31.11;
```

$PSpa := 31.11$

```
> varPSpa := (0.04)^2;
```

$varPSpa := .0016$

Moisture (air)

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.1*Wma)^2;
```

$varWma := .169\ 10^{-5}$

Velocity Head re

```
> v := 0.2171;
```

$v := .2171$

```
> DPpa := array([seq(v,i=1..n)]);
```

DPpa := [.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171
.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171]

```
> u := (0.02*v)^2;
```

$u := .000018852964$

```
> var := array([seq(u,i=1..n)]);
```

var := [.000018852964 .000018852964 .000018852964 .000018852964
.000018852964 .000018852964 .000018852964 .000018852964 .000018852964
.000018852964 .000018852964 .000018852964 .000018852964 .000018852964
.000018852964 .000018852964 .000018852964 .000018852964 .000018852964
.000018852964]

```
> varDPpa := make_array(var,n);
```

varDPpa := varcovar

Temperature Primary Air Out re

```
> v := 1104;
```

$v := 1104$

```
> Tpa := array([seq(v,i=1..n)]);
```

Tpa := [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
1104 1104 1104 1104 1104 1104 1104 1104 1104]

```
> u := (0.01*(v-460))^2;
```

$u := 41.4736$

442

```
> var := array([seq(u,i=1..n)]);
    var := [41.4736  41.4736  41.4736  41.4736  41.4736  41.4736  41.4736  41.4736
      41.4736  41.4736  41.4736  41.4736  41.4736  41.4736  41.4736  41.4736
      41.4736  41.4736  41.4736  41.4736]
> varTpa := make_array(var,n);
                          varTpa := varcovar
```

Results

```
*********************************************************************
> evalf(PAFA);
                          62529.82254   lb/HR  FWW
> evalf(sigmaPAFA);
                          1634.685119   lb/HR  BIAS
> evalf(100*sigmaPAFA/PAFA);                  CONTRIBUTIONS
                          2.614248774
>
> evalf(sigmaPAFAWma);
                          23.89573991
> evalf(sigmaPAFACP);
                          744.4026492
>
> evalf(sigmaPAFADPpa);
                          625.2982312
> evalf(sigmaPAFATpa);
                          182.3786497
> evalf(sigmaPAFAPSpa);
                          40.19917875
> evalf(sigmaPAFAapa);
                          1300.620309
*********************************************************************
> i := 'i';
                          i := i
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                          m := 28.74570417
```

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                          PAFA := 62529.82254
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                          PAFB := 62529.82254
>
```

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Appendix B-4
Random Error Calculation
Primary Air Out

```
>
>
```

Random Error Propagation Calculations, Part B, PAFA out

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>  varcovar[i,j] := sqrt(var[i]*var[j])
> else
>  varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#13

m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

l := 'i';

$$i := i$$

#14 PRIMARY AIR FLOW FROM 'A' SIDE OF HEAT PIPE

PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),l=1..n);

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\ \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

AIR FLOW FROM 'B' SIDE

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),l=1..n);

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\ \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

> sigmaPAFACP := sqrt(Diff(PAFA,CP)^2*varCP):

> sigmaPAFACP := value("):

> sigmaPAFAapa := sqrt(Diff(PAFA,apa)^2*varapa):

> sigmaPAFAapa := value("):

> sigmaPAFAPSpa := sqrt(Diff(PAFA,PSpa)^2*varPSpa):

> sigmaPAFAPSpa := value("):

> sigmaPAFAWma := sqrt(Diff(PAFA,Wma)^2*varWma):

> sigmaPAFAWma := value("):

```
> sigmaPAFADPpa := sqrt(sum(sum(
> Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFADPpa := value("):

> sigmaPAFATpa := sqrt(sum(sum(
> Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):
> sigmaPAFATpa := value("):

> sigmaPAFA := sqrt(
>   Diff(PAFA,CP)^2*varCP +
>   Diff(PAFA,apa)^2*varapa +
>   Diff(PAFA,PSpa)^2*varPSpa +
>   Diff(PAFA,Wma)^2*varWma +
> sum(sum(
>   Diff(PAFA,DPpa[i])*Diff(PAFA,DPpa[j])*varDPpa[i,j] +
>   Diff(PAFA,Tpa[i])*Diff(PAFA,Tpa[j])*varTpa[i,j]
> ,j=1..n),i=1..n)):

> sigmaPAFA := value("):
```

Constants

Pitot Coefficient re

```
> CP := 0.84;
```

$CP := .84$

```
> varCP := 0^2;
```

$varCP := 0$

Area - Primary Air Out re

```
> apa := 0.63;
```

$apa := .63$

```
> varapa := (0.0208*apa)^2;
```

$varapa := .000171714816$

Primary Air Pressure Out re

```
> PSpa := 31.11;
```

$PSpa := 31.11$

```
> varPSpa := (0.04)^2;
```

$varPSpa := .0016$

Moisture (air) re

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.2*Wma)^2;
```

$varWma := .676\ 10^{-5}$

Velocity Head re

```
> v := 0.2171;
```

$v := .2171$

```
> DPpa := array([seq(v,i=1..n)]);
```

$DPpa := [.2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171]$

```
> u := (0.00005)^2;
```

$u := .25\ 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```

$var := [.25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}$
$.25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 1C$
$.25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}\ .25\ 10^{-8}]$

```
> varDPpa := make_array(var,n);
```

$varDPpa := varcovar$

Temperature Primary Air Out re

```
> v := 1104;
                    v := 1104
> Tpa := array([seq(v,i=1..n)]);
   Tpa := [1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
    1104  1104  1104  1104  1104  1104  1104  1104  1104]
> u := (0.005*(v-460))^2;
                    u := 10.368400
> var := array([seq(u,i=1..n)]);
   var := [10.368400  10.368400  10.368400  10.368400  10.368400  10.368400
    10.368400  10.368400  10.368400  10.368400  10.368400  10.368400  10.368400
    10.368400  10.368400  10.368400  10.368400  10.368400  10.368400  10.368400]
> varTpa := make_array(var,n);
                    varTpa := varcovar
```

Results

```
*******************************************************************
> evalf(PAFA);
                    62529.82254   lb/hr   FLOW RATE
> evalf(sigmaPAFA);
                    1302.279372   RANDOM ERROR
> evalf(100*sigmaPAFA/PAFA);                CONTRIBUTIONS
                    2.082653235
>
> evalf(sigmaPAFAWma);
                    47.79147982
> evalf(sigmaPAFACP);
                    0
>
> evalf(sigmaPAFADPpa);
                    1.610098270
> evalf(sigmaPAFATpa);
                    20.39055286
> evalf(sigmaPAFAPSpa);
                    40.19917875
> evalf(sigmaPAFAapa);
                    1300.620309
*******************************************************************
> i := 'i';
                    i := i
#13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                    m := 28.74570417
#14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFA := 62529.82254
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFB := 62529.82254
>
```

Appendix C-1
Bias Error Calculation
Inlet Flue Gas Average CO_2 Concentration

```
>
>
```

Error Propagation Calculations, Part A, CO2i

Set no. of sample points

```
> n := 2;
```

$$n := 2$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

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```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
 Warning, `Cr` is implicitly declared local
 Warning, `Cb` is implicitly declared local
 Warning, `K3` is implicitly declared local
 Warning, `K4` is implicitly declared local
 Warning, `MFG` is implicitly declared local

 MFG :=

 proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
 local Cr,Cb,K3,K4,MFG;
     Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
     Cb := C-Cr;
     K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
     K4 :=
      8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
      ;
     MFG := .05550621670*K4/(.05550621670*K4+100*K3)
 end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
 Warning, `Cr` is implicitly declared local
 Warning, `Cb` is implicitly declared local
 Warning, `K3` is implicitly declared local
 Warning, `K4` is implicitly declared local
 Warning, `M` is implicitly declared local

 M :=

 proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
 local Cr,Cb,K3,K4,M;
     Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
     Cb := C-Cr;
     K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
     K4 :=
      8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
      ;
     M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
 end

> sigmaCO2avei := sqrt(

> Diff(CO2avei,A)^2*varA +

> Diff(CO2avei,OUHD)^2*varOUHD +

> Diff(CO2avei,Ca)^2*varCa +

> Diff(CO2avei,C)^2*varC +

> Diff(CO2avei,S)^2*varS +

> Diff(CO2avei,H)^2*varH +

> Diff(CO2avei,Wma)^2*varWma +

> Diff(CO2avei,N)^2*varN +

> Diff(CO2avei,Mf)^2*varMf +

> sum(sum(

> Diff(CO2avei,DPi[i])*Diff(CO2avei,DPi[j])*varDPi[i,j] +

> Diff(CO2avei,Ti[i])*Diff(CO2avei,Ti[j])*varTi[i,j] +

> Diff(CO2avei,COi[i])*Diff(CO2avei,COi[j])*varCOi[i,j] +

> Diff(CO2avei,CO2i[i])*Diff(CO2avei,CO2i[j])*varCO2i[i,j] +

> Diff(CO2avei,O2i[i])*Diff(CO2avei,O2i[j])*varO2i[i,j]

> ,j=1..n),i=1..n)):

> sigmaCO2avei := value("):
```

Constants

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
                    Wfe := 115839
> varWfe := (0.05*Wfe)^2;
                    varWfe := .3354668480 10^8
```

Area (square ft)

```
> Areai := 3.99;
                    Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                    varAreai := .01786633223
```

```
> Areao := 3.54;
                    Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                    varAreao := .01660386874
```

Pitot Coefficient

```
> CP := 0.84;
                    CP := .84
> varCP := (0.01)^2;
                    varCP := .0001
```

Pressure in Area

```
> PSi := 29.23;
                    PSi := 29.23
> varPSi := (0.04)^2;
                    varPSi := .0016
```

```
> PSo := 29.1;
                    PSo := 29.1
> varPSo := (0.04)^2;
                    varPSo := .0016
```

Velocity Head

```
> v := .45802;
                    v := .45802
> DPo := array([seq(v,i=1..n)]);
                    DPo := [.45802   .45802]
> u := (.02*v)^2;
                    u := .00008391292816
> var := array([seq(u,i=1..n)]);
                    var := [.00008391292816   .00008391292816]
> varDPo := make_array(var,n);
                    varDPo := varcovar
```

```
> v := .82831;
                    v := .82831
> DPi := array([seq(v,i=1..n)]);
                    DPi := [.82831   .82831]
> u := (.02*v)^2;
                    u := .0002744389824
> var := array([seq(u,i=1..n)]);
                    var := [.0002744389824   .0002744389824]
> varDPi := make_array(var,n);
                    varDPi := varcovar
```

Temperature (R)

```
> v := 713;
                    v := 713
> To := array([seq(v,i=1..n)]);
                    To := [713   713]
> u := (0.01*(v-460))^2;
                    u := 6.4009
```

```
> var := array([seq(u,i=1..n)]);
```
var := [6.4009   6.4009]

```
> varTo := make_array(var,n);
```
varTo := *varcovar*

```
> v := 1140;
```
v := 1140

```
> Ti:= array([seq(v,i=1..n)]);
```
Ti := [1140   1140]

```
> u := (0.01*(v-460))^2;
```
u := 46.2400

```
> var := array([seq(u,i=1..n)]);
```
var := [46.2400   46.2400]

```
> varTi := make_array(var,n);
```
varTi := *varcovar*

Moisture in Ash

```
> Mf :=0.06;
```
Mf := .06

```
> varMf := (0.039*Mf)^2;
```
$varMf := .54756\ 10^{-5}$

Ash

```
> A :=  0.0619;
```
A := .0619

```
> varA := ( 0.039*A)^2;
```
$varA := .582787881\ 10^{-5}$

Overhead

```
> OUHD :=  0.9;
```
OUHD := .9

```
> varOUHD :=  (0.1*OUHD)^2;
```
varOUHD := .0081

Carbon

```
> C := 0.7381;
```
C := .7381

```
> varC := (0.039*C)^2;
```
varC := .000828628038

Hydrogen

```
> H := 0.0482;
```
H := .0482

```
> varH := (0.039*H)^2;
```
$varH := .353364804\ 10^{-5}$

Nitrogen

```
> N := 0.0135;
```
N := .0135

```
> varN := (0.039*N)^2;
```
$varN := .27720225\ 10^{-6}$

Sulfur

```
> S := 0.0123;
```
S := .0123

```
> varS := (0.019*S)^2;
```
$varS := .5461569\ 10^{-7}$

CO2

```
> v := 14.145;
```
v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```
CO2o := [14.145   14.145]

```
> u := 0.1^2;
```
u := .01

```
> var := array([seq(u,i=1..n)]);
```
var := [.01   .01]

```
> varCO2o := make_array(var,n);
```
varCO2o := *varcovar*

```
> v := 15.2148;
```
v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```
CO2i := [15.2148   15.2148]

```
> u := (0.1)^2;
```
u := .01

```
> var := array([seq(u,i=1..n)]);
                var := [.01   .01]
> varCO2i := make_array(var,n);
                varCO2i := varcovar
```

O2

```
> v := 5;
                v := 5
> O2o := array([seq(v,i=1..n)]);
                O2o := [5   5]
> u := (0.05)^2;
                u := .0025
> var := array([seq(u,i=1..n)]);
                var := [.0025   .0025]
> varO2o := make_array(var,n);
                varO2o := varcovar
> v := 3.8;
                v := 3.8
> O2i := array([seq(v,i=1..n)]);
                O2i := [3.8   3.8]
> u := (0.05)^2;
                u := .0025
> var := array([seq(u,i=1..n)]);
                var := [.0025   .0025]
> varO2i := make_array(var,n);
                varO2i := varcovar
```

Moisture (air)

```
> Wma := 0.013;
                Wma := .013
> varWma := (.1*Wma)^2;
                varWma := .169 10^-5
```

CO

```
> v := 0.005;
                v := .005
> COo := array([seq(v,i=1..n)]);
                COo := [.005   .005]
> u := (0.002)^2;
                u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                var := [.4 10^-5   .4 10^-5]
> varCOo := make_array(var,n);
                varCOo := varcovar
> v := 0.005;
                v := .005
> COi := array([seq(v,i=1..n)]);
                COi := [.005   .005]
> u := (0.002)^2;
                u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                var := [.4 10^-5   .4 10^-5]
> varCOi := make_array(var,n);
                varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
                Ca := .0486
> varCa := (0.25*Ca)^2;
                varCa := .000147622500
```

Results

```
eval(sigmaO2avei);
> eval(CO2avei);
                15.21480000
> eval(sigmaCO2avei);
                .1000000000
> eval(100*sigmaCO2avei/CO2avei);
                .6572547782
```

```
>
>
```

Error Propagation Calculations, Part A, CO2i

Set no. of sample points

```
> n := 4;
                              n := 4
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
  Warning, `varcovar` is implicitly declared local
  Warning, `j` is implicitly declared local
  Warning, `i` is implicitly declared local

  make_array :=

      proc(var,n)
      local varcovar,j,i;
          varcovar := array(1 .. n,1 .. n);
          for j to n do
              for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
          od;
          varcovar
      end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*:
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
```

```
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*K3)
end
```

```
> CO2avel := sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/
> 2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i
> ]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,C
> a,C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n):
```

```
> sigmaCO2avel := sqrt(
> Diff(CO2avel,A)^2*varA +
> Diff(CO2avel,OUHD)^2*varOUHD +
> Diff(CO2avel,Ca)^2*varCa +
> Diff(CO2avel,C)^2*varC +
> Diff(CO2avel,S)^2*varS +
> Diff(CO2avel,H)^2*varH +
> Diff(CO2avel,Wma)^2*varWma +
> Diff(CO2avel,N)^2*varN +
> Diff(CO2avel,Mf)^2*varMf +
> sum(sum(
> Diff(CO2avel,DPi[i])*Diff(CO2avel,DPi[j])*varDPi[i,j] +
> Diff(CO2avel,Ti[i])*Diff(CO2avel,Ti[j])*varTi[i,j] +
> Diff(CO2avel,COi[i])*Diff(CO2avel,COi[j])*varCOi[i,j] +
> Diff(CO2avel,CO2i[i])*Diff(CO2avel,CO2i[j])*varCO2i[i,j] +
> Diff(CO2avel,O2i[i])*Diff(CO2avel,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):
```

```
> sigmaCO2avel := value("):
```

Constants

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```

Wfe := 115839

```
> varWfe := (0.05*Wfe)^2;
```

varWfe := $.3354668480\ 10^{8}$

Area (square ft)

```
> Areai := 3.99;
```

Areai := 3.99

```
> varAreai := (0.0335*Areai)^2;
```

varAreai := .01786633223

```
> Areao := 3.54;
```

Areao := 3.54

```
> varAreao := (0.0364*Areao)^2;
```

varAreao := .01660386874

Pitot Coefficient

```
> CP := 0.84;
```

CP := .84

```
> varCP := (0.01)^2;
```

varCP := .0001

Pressure in Area

```
> PSi := 29.23;
```

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```
                    PSi := 29.23
> varPSi := (0.04)^2;
                    varPSi := .0016

> PSo := 29.1;
                    PSo := 29.1
> varPSo := (0.04)^2;
                    varPSo := .0016
```

Velocity Head

```
> v := .45802;
                    v := .45802
> DPo := array([seq(v,i=1..n)]);
          DPo := [.45802   .45802   .45802   .45802]
> u := (.02*v)^2;
                    u := .00008391292816
> var := array([seq(u,i=1..n)]);
    var := [.00008391292816   .00008391292816   .00008391292816   .00008391292816]
> varDPo := make_array(var,n);
                    varDPo := varcovar

> v := .82831;
                    v := .82831
> DPi := array([seq(v,i=1..n)]);
          DPi := [.82831   .82831   .82831   .82831]
> u := (.02*v)^2;
                    u := .0002744389824
> var := array([seq(u,i=1..n)]);
    var := [.0002744389824   .0002744389824   .0002744389824   .0002744389824]
> varDPi := make_array(var,n);
                    varDPi := varcovar
```

Temperature (R)

```
> v := 713;
                    v := 713
> To := array([seq(v,i=1..n)]);
          To := [713   713   713   713]
> u := (0.01*(v-460))^2;
                    u := 6.4009
> var := array([seq(u,i=1..n)]);
          var := [6.4009   6.4009   6.4009   6.4009]
> varTo := make_array(var,n);
                    varTo := varcovar

> v := 1140;
                    v := 1140
> Ti:= array([seq(v,i=1..n)]);
          Ti := [1140   1140   1140   1140]
> u := (0.01*(v-460))^2;
                    u := 46.2400
> var := array([seq(u,i=1..n)]);
          var := [46.2400   46.2400   46.2400   46.2400]
> varTi := make_array(var,n);
                    varTi := varcovar
```

Moisture in Ash

```
> Mf :=0.06;
                    Mf := .06
> varMf := (0.039*Mf)^2;
                    varMf := .54756 10^-5
```

Ash

```
> A := 0.0619;
                    A := .0619
> varA := ( 0.039*A)^2;
                    varA := .582787881 10^-5
```

Overhead

```
> OUHD := 0.9;
                    OUHD := .9
> varOUHD := (0.1*OUHD)^2;
                    varOUHD := .0081
```

Carbon

```
> C := 0.7381;
                    C := .7381
```

```
> varC := (0.039*C)^2;
                    varC := .0008286280388
```

Hydrogen

```
> H := 0.0482;
                    H := .0482
> varH := (0.039*H)^2;
                    varH := .353364804 10^-5
```

Nitrogen

```
> N := 0.0135;
                    N := .0135
> varN := (0.039*N)^2;
                    varN := .27720225 10^-6
```

Sulfur

```
> S := 0.0123;
                    S := .0123
> varS := (0.019*S)^2;
                    varS := .5461569 10^-7
```

CO2

```
> v := 14.145;
                    v := 14.145
> CO2o := array([seq(v,i=1..n)]);
                    CO2o := [14.145  14.145  14.145  14.145]
> u := 0.1^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
                    var := [.01  .01  .01  .01]
> varCO2o := make_array(var,n);
                    varCO2o := varcovar

> v := 15.2148;
                    v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
                    CO2i := [15.2148  15.2148  15.2148  15.2148]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
                    var := [.01  .01  .01  .01]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar
```

O2

```
> v := 5;
                    v := 5
> O2o := array([seq(v,i=1..n)]);
                    O2o := [5  5  5  5]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                    varO2o := varcovar

> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
                    O2i := [3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air)

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.1*Wma)^2;
                    varWma := .169 10^-5
```

CO

```
> v := 0.005;
                    v := .005
```

```
> COo := array([seq(v,i=1..n)]);
                    COo := [.005   .005   .005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5   .4 10^-5   .4 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
                    COi := [.005   .005   .005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5   .4 10^-5   .4 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.25*Ca)^2;
                    varCa := .000147622500
```

****

Results

```
> eval(CO2avei);
                    15.21480000
> eval(sigmaCO2avei);
                    .1000000001
> eval(100*sigmaCO2avei/CO2avei);
                    .6572547789
```

****

```
>
```

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Appendix D-1
Random Error Calculation
Inlet Flue Gas Average CO_2 Concentration

```
>
>
```

Random Error Propagation Calculations, Part A, CO2i

Set no. of sample points

```
> n := 8;
                                n := 8
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for i to n do
> for j to n do
> if i = j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `i` is implicitly declared local
Warning, `j` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,i,j;
        varcovar := array(1 .. n,1 .. n);
        for i to n do
```

```
> Cb := C - Cr;
```

```
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
```

```
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
```

```
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
```

```
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*K3)
  end
```

```
                for j to n do
                    if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                    else varcovar[i,j] := 0
                    fi
                od
            od;
            varcovar
        end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

```
> Cb := C - Cr;
```

```
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
```

```
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
```

```
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
```

```
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

```
> CO2avei := sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/
> 2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i
> ]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,C
> a,C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n):
```

```
> sigmaCO2avei := sqrt(
> Diff(CO2avei,A)^2*varA +
> Diff(CO2avei,OUHD)^2*varOUHD +
> Diff(CO2avei,Ca)^2*varCa +
> Diff(CO2avei,C)^2*varC +
> Diff(CO2avei,S)^2*varS +
> Diff(CO2avei,H)^2*varH +
> Diff(CO2avei,Wma)^2*varWma +
> Diff(CO2avei,N)^2*varN +
> Diff(CO2avei,Mf)^2*varMf +
> sum(
> Diff(CO2avei,DPi[i])*Diff(CO2avei,DPi[i])*varDPi[i,i] +
> Diff(CO2avei,Ti[i])*Diff(CO2avei,Ti[i])*varTi[i,i] +
> Diff(CO2avei,COi[i])*Diff(CO2avei,COi[i])*varCOi[i,i] +
> Diff(CO2avei,CO2i[i])*Diff(CO2avei,CO2i[i])*varCO2i[i,i] +
> Diff(CO2avei,O2i[i])*Diff(CO2avei,O2i[i])*varO2i[i,i]
> ,i=1..n)):
```

```
> sigmaCO2avei := value("):
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                                   Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                              varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                                   Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                            varAreai := .01786633223
```

```
> Areao := 3.54;
                                   Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                            varAreao := .01660386874
```

```
tot Coefficient re
P := 0.84;
                    CP := .84
arCP := 0^2;
                    varCP := 0

ressure Ambient or Barometric re
Si := 29.23;
                    PSi := 29.23
arPSi := (0.04)^2;
                    varPSi := .0016

So := 29.1;
                    PSo := 29.1
arPSo := (0.04)^2;
                    varPSo := .0016

elocity Head DP re
:= .45802;
                    v := .45802
Po := array([seq(v,i=1..n)]);
    DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802]
:=.00005^2;
                    u := .25 10^-8
ar := array([seq(u,i=1..n)]);
var := [
 .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
 ]
arDPo := make_array(var,n);
                    varDPo := varcovar

:= .82831;
                    v := .82831
Pi := array([seq(v,i=1..n)]);
    DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831]
:= .00005^2;
                    u := .25 10^-8
> var := array([seq(u,i=1..n)]);
    var := [
    .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
    ]
> varDPi := make_array(var,n);
                    varDPi := varcovar

 Temperature (R) re
> v := 713;
                    v := 713
> To := array([seq(v,i=1..n)]);
          To := [713  713  713  713  713  713  713  713]
> u := (.005*(v-460))^2;
                    u := 1.600225
> var := array([seq(u,i=1..n)]);
    var := [
    1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225
    ]
> varTo := make_array(var,n);
                    varTo := varcovar

> v := 1140;
                    v := 1140
> Ti:= array([seq(v,i=1..n)]);
          Ti := [1140  1140  1140  1140  1140  1140  1140  1140]
> u := (.005*(v-460))^2;
                    u := 11.560000
> var := array([seq(u,i=1..n)]);
       var := [11.560000  11.560000  11.560000  11.560000  11.560000  11.560000
        11.560000  11.560000]
> varTi := make_array(var,n);
                    varTi := varcovar

 Moisture in Ash re
> Mf :=0.06;
                    Mf := .06
```

```
varMf := ((0.2+0.12*Mf)/(2*1.414))^2;
                    varMf := .005368101168

Ash re
A := 0.0619;
                    A := .0619
varA := (( 0.07+0.02*A)/(2*1.414))^2;
                    varA := .0006345482144

Overhead re
OUHD := 0.9;
                    OUHD := .9
varOUHD := (0.1*OUHD)^2;
                    varOUHD := .0081

Carbon re
C := 0.7381;
                    C := .7381
varC := (0.64/(2*1.414))^2;
                    varC := .05121546706

Hydrogen re
H := 0.0482;
                    H := .0482
varH := (0.16/(2*1.414))^2;
                    varH := .003200966692

Nitrogen re
N := 0.0135;
                    N := .0135
varN := (0.11/(2*1.414))^2;
                    varN := .001512956913

Sulfur re
S := 0.0123;
                    S := .0123
varS := ((0.06+0.035*S)/(2*1.414))^2;
                    varS := .0004566185652

CO2 re
> v := 14.145;
                    v := 14.145
> CO2o := array([seq(v,i=1..n)]);
      CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145]
> u := (0.03*v)^2;
                    u := .1800729225
> var := array([seq(u,i=1..n)]);
      var := [.1800729225  .1800729225  .1800729225  .1800729225  .1800729225
        .1800729225  .1800729225  .1800729225]
> varCO2o := make_array(var,n);
                    varCO2o := varcovar

> v := 15.2148;
                    v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
      CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                    u := .2083411251
> var := array([seq(u,i=1..n)]);
      var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
        .2083411251  .2083411251  .2083411251]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar

O2 re
> v := 5;
                    v := 5
> O2o := array([seq(v,i=1..n)]);
                    O2o := [5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
      var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                    varO2o := varcovar

> v := 3.8;
                    v := 3.8
```

```
O2i := array([seq(v,i=1..n)]);
                    O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
u := (0.05)^2;
                    u := .0025
var := array([seq(u,i=1..n)]);
          var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air) re

```
Wma := 0.013;
                    Wma := .013
varWma := (.2*Wma)^2;
                    varWma := .676 10^-5
```

CO re

```
v := 0.005;
                    v := .005
COo := array([seq(v,i=1..n)]);
          COo := [.005  .005  .005  .005  .005  .005  .005  .005]
u := (0.001)^2;
                    u := .1 10^-5
var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
varCOo := make_array(var,n);
                    varCOo := varcovar

v := 0.005;
                    v := .005
COi := array([seq(v,i=1..n)]);
          COi := [.005  .005  .005  .005  .005  .005  .005  .005]
u := (0.001)^2;
                    u := .1 10^-5
var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                    varCa := .0000236196
```

Results

```
eval(O2aveo);
eval(sigmaO2aveo);

eval(CO2aveo);
eval(sigmaCO2aveo);

eval(COaveo);
eval(sigmaCOaveo);

eval(O2avei);
eval(sigmaO2avei);

> eval(CO2avei);
                    15.21479999
> eval(sigmaCO2avei);
                    .1613773238   for n=20  x √(8/20) = 0.10206
> eval(100*sigmaCO2avei/CO2avei);
                    1.060660172

eval(COavei);
eval(sigmaCOavei);

>
```

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Random Error Propagation Calculations, Part A, CO2i

Set no. of sample points

```
n := 12;
```

$n := 12$

procedure for creating variance-covariance matrix

```
make_array := proc(var,n)
varcovar := array(1..n,1..n);
for i to n do
for j to n do
if i = j then
 varcovar[i,j] := sqrt(var[i]*var[j])
else
 varcovar[i,j] := 0
fi
od
od;
varcovar;
end;
Warning, `varcovar` is implicitly declared local
Warning, `i` is implicitly declared local
Warning, `j` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,i,j;
        varcovar := array(1 .. n,1 .. n);
        for i to n do
            for j to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

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6

```
> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
        8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
        ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*K3)
  end

> CO2avei := sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/
> 2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i
> ]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,C
> a,C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n):

> sigmaCO2avei := sqrt(

>  Diff(CO2avei,A)^2*varA +

>  Diff(CO2avei,OUHD)^2*varOUHD +

>  Diff(CO2avei,Ca)^2*varCa +

>  Diff(CO2avei,C)^2*varC +

>  Diff(CO2avei,S)^2*varS +

>  Diff(CO2avei,H)^2*varH +

>  Diff(CO2avei,Wma)^2*varWma +

>  Diff(CO2avei,N)^2*varN +

>  Diff(CO2avei,Mf)^2*varMf +

>  sum(

>  Diff(CO2avei,DPi[i])*Diff(CO2avei,DPi[i])*varDPi[i,i] +

>  Diff(CO2avei,Ti[i])*Diff(CO2avei,Ti[i])*varTi[i,i] +

>  Diff(CO2avei,COi[i])*Diff(CO2avei,COi[i])*varCOi[i,i] +

>  Diff(CO2avei,CO2i[i])*Diff(CO2avei,CO2i[i])*varCO2i[i,i] +

>  Diff(CO2avei,O2i[i])*Diff(CO2avei,O2i[i])*varO2i[i,i]

> ,i=1..n)):

> sigmaCO2avei := value("):
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                              Wfe := 115839

> varWfe := (0.0025*Wfe)^2;
                          varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                              Areai := 3.99

> varAreai := (0.0335*Areai)^2;
                         varAreai := .01786633223

> Areao := 3.54;
                              Areao := 3.54

> varAreao := (0.0364*Areao)^2;
                         varAreao := .01660386874
```

Pitot Coefficient re

> CP := 0.84;

CP := .84

> varCP := 0^2;

varCP := 0

Pressure Ambient or Barometric re

> PSi := 29.23;

PSi := 29.23

> varPSi := (0.04)^2;

varPSi := .0016

> PSo := 29.1;

PSo := 29.1

> varPSo := (0.04)^2;

varPSo := .0016

Velocity Head DP re

> v := .45802;

v := .45802

> DPo := array([seq(v,i=1..n)]);

DPo := [.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802]

> u := .00005^2;

u := $.25\ 10^{-8}$

> var := array([seq(u,i=1..n)]);

var := $[.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

> varDPo := make_array(var,n);

varDPo := *varcovar*

> v := .82831;

v := .82831

> DPi := array([seq(v,i=1..n)]);

DPi := [.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831]

> u := .00005^2;

u := $.25\ 10^{-8}$

> var := array([seq(u,i=1..n)]);

var := $[.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

> varDPi := make_array(var,n);

varDPi := *varcovar*

Temperature (R) re

> v := 713;

v := 713

> To := array([seq(v,i=1..n)]);

To := [713 713 713 713 713 713 713 713 713 713 713 713]

> u := (.005*(v-460))^2;

u := 1.600225

> var := array([seq(u,i=1..n)]);

var := [1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225]

> varTo := make_array(var,n);

varTo := *varcovar*

> v := 1140;

v := 1140

> Ti:= array([seq(v,i=1..n)]);

Ti :=
[1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140]

> u := (.005*(v-460))^2;

u := 11.560000

> var := array([seq(u,i=1..n)]);

var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000]

> varTi := make_array(var,n);

varTi := *varcovar*

Moisture in Ash re

> Mf :=0.06;

Mf := .06

> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;

varMf := .0001058319613

Ash re

```
> A := 0.0619;
```

A := .0619

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```

$varA := .4696223261\ 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```

OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon re

```
> C := 0.7381;
```

C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```

$varC := .5121546706\ 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```

H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```

$varH := .3200966692\ 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```

N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```

$varN := .1512956913\ 10^{-6}$

Sulfur re

```
> S := 0.0123;
```

S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```

$varS := .1327813813\ 10^{-6}$

CO2 re

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.1
14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```

u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```

var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729‑
.1800729225]

```
> varCO2o := make_array(var,n);
```

varCO2o := varcovar

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.21
15.2148 15.2148 15.2148 15.2148]

```
> u := (0.03*v)^2;
```

u := .2083411251

```
> var := array([seq(u,i=1..n)]);
```

var := [.2083411251 .2083411251 .2083411251 .2083411251 .2083411251
.2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411‑
.2083411251]

```
> varCO2i := make_array(var,n);
```

varCO2i := varcovar

O2 re

```
> v := 5;
```

v := 5

```
> O2o := array([seq(v,i=1..n)]);
```

O2o := [5 5 5 5 5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025]

```
> varO2o := make_array(var,n);
                    varO2o := varcovar

> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
        O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
        var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
         .0025  .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.2*Wma)^2;
                    varWma := .676 10^(-5)
```

CO re

```
> v := 0.005;
                    v := .005
> COo := array([seq(v,i=1..n)]);
        COo := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^(-5)
> var := array([seq(u,i=1..n)]);
        var := [.1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)
         .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
        COi := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^(-5)
> var := array([seq(u,i=1..n)]);
        var := [.1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-
         .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                    varCa := .0000236196
```

Results

```
eval(O2aveo);
eval(sigmaO2aveo);

eval(CO2aveo);
eval(sigmaCO2aveo);

eval(COaveo);
eval(sigmaCOaveo);

eval(O2avei);
eval(sigmaO2avei);

> eval(CO2avei);
                    15.21479999
> eval(sigmaCO2avei);
                    .1317640331     For n=20 × √(12/20) = 0.10206
> eval(100*sigmaCO2avei/CO2avei);

eval(COavei);
eval(sigmaCOavei);
```

Appendix D-2
Random Error Calculation
Inlet Flue Gas Average CO Concentration

```
>

>
```

Random Error Propagation Calculations, Part A, COi

Set no. of sample points

```
> n := 8;
```

$$n := 8$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i = j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
          for i to n do
              if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
              else varcovar[i,j] := 0
              fi
          od
      od;
      varcovar
  end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
      8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
      ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
      8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
      ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end

> COavei := sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2
> *(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*COi[i],i=1..n)/sum((DPi[i]/(
> Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,
> C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n):

> sigmaCOavei := sqrt(
> Diff(COavei,A)^2*varA +
> Diff(COavei,OUHD)^2*varOUHD +
> Diff(COavei,Ca)^2*varCa +
> Diff(COavei,C)^2*varC +
> Diff(COavei,S)^2*varS +
> Diff(COavei,H)^2*varH +
```

```
> Diff(COavei,Wma)^2*varWma +
> Diff(COavei,N)^2*varN +
> Diff(COavei,Mf)^2*varMf +
> sum(
> Diff(COavei,DPi[i])*Diff(COavei,DPi[i])*varDPi[i,i] +
> Diff(COavei,Ti[i])*Diff(COavei,Ti[i])*varTi[i,i] +
> Diff(COavei,COi[i])*Diff(COavei,COi[i])*varCOi[i,i] +
> Diff(COavei,CO2i[i])*Diff(COavei,CO2i[i])*varCO2i[i,i] +
> Diff(COavei,O2i[i])*Diff(COavei,O2i[i])*varO2i[i,i]
> ,i=1..n)):

> sigmaCOavei := value("):
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                         Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                         varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                         Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                         varAreai := .01786633223

> Areao := 3.54;
                         Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                         varAreao := .01660386874
```

Pitot Coefficient re

```
> CP := 0.84;
                         CP := .84
> varCP := 0^2;
                         varCP := 0
```

Pressure Ambient or Barometric re

```
> PSi := 29.23;
                         PSi := 29.23
> varPSi := (0.04)^2;
                         varPSi := .0016

> PSo := 29.1;
                         PSo := 29.1
> varPSo := (0.04)^2;
                         varPSo := .0016
```

Velocity Head DP re

```
> v := .45802;
                         v := .45802
> DPo := array([seq(v,i=1..n)]);
      DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802]
> u := .00005^2;
                         u := .25 10^-8
> var := array([seq(u,i=1..n)]);
   var := [
   .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10
   ]
> varDPo := make_array(var,n);
                         varDPo := varcovar

> v := .82831;
                         v := .82831
> DPi := array([seq(v,i=1..n)]);
      DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831]
> u := .00005^2;
```

$u := .25\ 10^{-8}$

> var := array([seq(u,l=1..n)]);

$var := [$
$.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$ $.25\ 10^{-8}$
$]$

> varDPi := make_array(var,n);

varDPi := *varcovar*

Temperature (R) re

> v := 713;

v := 713

> To := array([seq(v,l=1..n)]);

To := [713 713 713 713 713 713 713 713]

> u := (.005*(v-460))^2;

u := 1.600225

> var := array([seq(u,l=1..n)]);

var := [
1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225
]

> varTo := make_array(var,n);

varTo := *varcovar*

> v := 1140;

v := 1140

> Ti:= array([seq(v,l=1..n)]);

Ti := [1140 1140 1140 1140 1140 1140 1140 1140]

> u := (.005*(v-460))^2;

u := 11.560000

> var := array([seq(u,l=1..n)]);

var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000]

> varTi := make_array(var,n);

varTi := *varcovar*

Moisture in Ash re

> Mf :=0.06;

Mf := .06

> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;

varMf := .00001058319613

Ash re

> A := 0.0619;

A := .0619

> varA := ((0.07+0.02*A*100)/(2*1.414*100))^2;

$varA := .4696223261\ 10^{-6}$

Overhead re

> OUHD := 0.9;

OUHD := .9

> varOUHD := (0.1*OUHD)^2;

varOUHD := .0081

Carbon re

> C := 0.7381;

C := .7381

> varC := (0.64/(2*1.414*100))^2;

$varC := .5121546706\ 10^{-5}$

Hydrogen re

> H := 0.0482;

H := .0482

> varH := (0.16/(2*1.414*100))^2;

$varH := .3200966692\ 10^{-6}$

Nitrogen re

> N := 0.0135;

N := .0135

> varN := (0.11/(2*1.414*100))^2;

$varN := .1512956913\ 10^{-6}$

Sulfur re

> S := 0.0123;

S := .0123

> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;

$varS := .1327813813\ 10^{-6}$

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CO2 re

```
> v := 14.145;
                              v := 14.145
> CO2o := array([seq(v,i=1..n)]);
     CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145]
> u := (0.03*v)^2;
                              u := .1800729225
> var := array([seq(u,i=1..n)]);
     var := [.1800729225  .1800729225  .1800729225  .1800729225  .1800729225
       .1800729225  .1800729225  .1800729225]
> varCO2o := make_array(var,n);
                              varCO2o := varcovar
```

```
> v := 15.2148;
                              v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
  CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                              u := .2083411251
> var := array([seq(u,i=1..n)]);
     var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
       .2083411251  .2083411251  .2083411251]
> varCO2i := make_array(var,n);
                              varCO2i := varcovar
```

O2 re

```
> v := 5;
                              v := 5
> O2o := array([seq(v,i=1..n)]);
                    O2o := [5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
          var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                              varO2o := varcovar
```

```
> v := 3.8;
                              v := 3.8
> O2i := array([seq(v,i=1..n)]);
               O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
          var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                              varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                              Wma := .013
> varWma := (.2*Wma)^2;
                              varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                              v := .005
> COo := array([seq(v,i=1..n)]);
          COo := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                              u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5
> varCOo := make_array(var,n);
                              varCOo := varcovar
```

```
> v := 0.005;
                              v := .005
> COi := array([seq(v,i=1..n)]);
          COi := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                              u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5
```

```
> varCOi := make_array(var,n);
                                  varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                                  Ca := .0486
> varCa := (0.1*Ca)^2;
                                  varCa := .0000236196
```

Results

```
eval(O2aveo);
eval(sigmaO2aveo);

eval(CO2aveo);
eval(sigmaCO2aveo);

eval(COaveo);
eval(sigmaCOaveo);

eval(O2avei);
eval(sigmaO2avei);

eval(CO2avei);
eval(sigmaCO2avei);

> eval(COavei);
                                  .004999999996
> eval(sigmaCOavei);
                                  .0003535533905     FOR N:10   x √(8/10) = 0.000224
> eval(100*sigmaCOavei/COavei);
                                  7.071067810
>
```

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Appendix D-3
Random Error Calculation
Inlet Flue Gas Average O_2 Concentration

```
>
>
Random Error Propagation Calculations, Part A, O2i

Set no. of sample points
> n := 8;
                                n := 8

procedure for creating variance-covariance matrix
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i = j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+:
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*K:
end

> O2avei := sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)
> *(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(T
> i[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,
> S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n):
> sigmaO2avei := sqrt(
>  Diff(O2avei,A)^2*varA +
```

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```
> Diff(O2avei,OUHD)^2*varOUHD +
> Diff(O2avei,Ca)^2*varCa +
> Diff(O2avei,C)^2*varC +
> Diff(O2avei,S)^2*varS +
> Diff(O2avei,H)^2*varH +
> Diff(O2avei,Wma)^2*varWma +
> Diff(O2avei,N)^2*varN +
> Diff(O2avei,Mf)^2*varMf +
> sum(
> Diff(O2avei,DPi[i])*Diff(O2avei,DPi[i])*varDPi[i,i] +
> Diff(O2avei,Ti[i])*Diff(O2avei,Ti[i])*varTi[i,i] +
> Diff(O2avei,COi[i])*Diff(O2avei,COi[i])*varCOi[i,i] +
> Diff(O2avei,CO2i[i])*Diff(O2avei,CO2i[i])*varCO2i[i,i] +
> Diff(O2avei,O2i[i])*Diff(O2avei,O2i[i])*varO2i[i,i]
> ,i=1..n)):

> sigmaO2avei := value("):
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                    Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                    varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                    Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                    varAreai := .01786633223

> Areao := 3.54;
                    Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                    varAreao := .01660386874
```

Pitot Coefficient re

> CP := 0.84;

$CP := .84$

> varCP := 0^2;

$varCP := 0$

Pressure Ambient or Barometric re

> PSi := 29.23;

$PSi := 29.23$

> varPSi := (0.04)^2;

$varPSi := .0016$

> PSo := 29.1;

$PSo := 29.1$

> varPSo := (0.04)^2;

$varPSo := .0016$

Velocity Head DP re

> v := .45802;

$v := .45802$

> DPo := array([seq(v,i=1..n)]);

$DPo := [.45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802]$

> u := .00005^2;

$u := .25\ 10^{-8}$

> var := array([seq(u,i=1..n)]);

$var := [$

$.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}$

$]$

> varDPo := make_array(var,n);

$varDPo := varcovar$

> v := .82831;

$v := .82831$

> DPi := array([seq(v,i=1..n)]);

$DPi := [.82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831]$

> u := .00005^2;

$u := .25\ 10^{-8}$

> var := array([seq(u,i=1..n)]);

$var := [$

$.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10$

$]$

> varDPi := make_array(var,n);

$varDPi := varcovar$

Temperature (R) re

> v := 713;

$v := 713$

> To := array([seq(v,i=1..n)]);

$To := [713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713]$

> u := (.005*(v-460))^2;

$u := 1.600225$

> var := array([seq(u,i=1..n)]);

$var := [$

$1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.6002$

$]$

> varTo := make_array(var,n);

$varTo := varcovar$

> v := 1140;

$v := 1140$

> Ti:= array([seq(v,i=1..n)]);

$Ti := [1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140]$

> u := (.005*(v-460))^2;

$u := 11.560000$

> var := array([seq(u,i=1..n)]);

$var := [11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000$
$11.560000 \quad 11.560000]$

> varTi := make_array(var,n);

$varTi := varcovar$

Moisture in Ash re

> Mf :=0.06;

$Mf := .06$

```
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
```
varMf := .00001058319613

Ash re

```
> A := 0.0619;
```
A := .0619

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```
varA := $.4696223261\ 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```
OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```
varOUHD := .0081

Carbon re

```
> C := 0.7381;
```
C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```
varC := $.5121546706\ 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```
H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```
varH := $.3200966692\ 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```
N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```
varN := $.1512956913\ 10^{-6}$

Sulfur re

```
> S := 0.0123;
```
S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```
varS := $.1327813813\ 10^{-6}$

CO2 re

```
> v := 14.145;
```
v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```
CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```
u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```
var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225]

```
> varCO2o := make_array(var,n);
```
varCO2o := *varcovar*

```
> v := 15.2148;
```
v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```
CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148

```
> u := (0.03*v)^2;
```
u := .2083411251

```
> var := array([seq(u,i=1..n)]);
```
var := [.2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251]

```
> varCO2i := make_array(var,n);
```
varCO2i := *varcovar*

O2 re

```
> v := 5;
```
v := 5

```
> O2o := array([seq(v,i=1..n)]);
```
O2o := [5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```
u := .0025

```
> var := array([seq(u,i=1..n)]);
```
var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

```
> varO2o := make_array(var,n);
```
varO2o := *varcovar*

```
> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
          O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
     var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.2*Wma)^2;
                varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                    v := .005
> COo := array([seq(v,i=1..n)]);
     COo := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOo := make_array(var,n);
                varCOo := varcovar
> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
     COi := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOi := make_array(var,n);
                varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                varCa := .0000236196
```

Results

```
eval(O2aveo);
eval(sigmaO2aveo);

eval(CO2aveo);
eval(sigmaCO2aveo);

eval(COaveo);
eval(sigmaCOaveo);

> eval(O2avei);
                    3.800000000
> eval(sigmaO2avei);
                    .01767766953      FOR N:20  .017678 × √(8/20)
> eval(100*sigmaO2avei/O2avei);                  = 0.01118
                    .4652018297

eval(CO2avei);
eval(sigmaCO2avei);

eval(COavei);
eval(sigmaCOavei);

>
```

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Appendix E-1
Random Error Calculation
Outlet Flue Gas Average CO_2 Concentration

```
>

>

Random Error Propagation Calculations, Part A, CO2o

Set no. of sample points
> n := 8;
                                    n := 8

procedure for creating variance-covariance matrix
> make_array := proc(var,n)

> varcovar := array(1..n,1..n);

> for j to n do

> for i to n do

> if i = j then

>   varcovar[i,j] := sqrt(var[i]*var[j])

> else

>   varcovar[i,j] := 0

> fi

> od

> od;

> varcovar;

> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
            for i to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#7

```
> CO2aveo := sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))
> ^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/su
> m((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
> i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n):

> sigmaCO2aveo := sqrt(
> Diff(CO2aveo,A)^2*varA +
> Diff(CO2aveo,OUHD)^2*varOUHD +
> Diff(CO2aveo,Ca)^2*varCa +
> Diff(CO2aveo,C)^2*varC +
> Diff(CO2aveo,S)^2*varS +
```

```
Diff(CO2aveo,H)^2*varH +
Diff(CO2aveo,Wma)^2*varWma +
Diff(CO2aveo,N)^2*varN +
Diff(CO2aveo,Mf)^2*varMf +
sum(
Diff(CO2aveo,DPo[i])*Diff(CO2aveo,DPo[i])*varDPo[i,i] +
Diff(CO2aveo,To[i])*Diff(CO2aveo,To[i])*varTo[i,i] +
Diff(CO2aveo,COo[i])*Diff(CO2aveo,COo[i])*varCOo[i,i] +
Diff(CO2aveo,CO2o[i])*Diff(CO2aveo,CO2o[i])*varCO2o[i,i] +
Diff(CO2aveo,O2o[i])*Diff(CO2aveo,O2o[i])*varO2o[i,i]
i=1..n)):

sigmaCO2aveo := value("):
```

Constants

Coal Feed Rate (lbs/hr) re

```
Wfe := 115839;
```

$Wfe := 115839$

```
varWfe := (0.0025*Wfe)^2;
```

$varWfe := 83866.71200$

Area (square ft) re

```
Areai := 3.99;
```

$Areai := 3.99$

```
varAreai := (0.0335*Areai)^2;
```

$varAreai := .01786633223$

```
Areao := 3.54;
```

$Areao := 3.54$

```
> varAreao := (0.0364*Areao)^2;
```

$varAreao := .01660386874$

Pitot Coefficient re

```
> CP := 0.84;
```

$CP := .84$

```
> varCP := 0^2;
```

$varCP := 0$

Pressure Ambient or Barometric re

```
> PSI := 29.23;
```

$PSi := 29.23$

```
> varPSI := (0.04)^2;
```

$varPSi := .0016$

```
> PSo := 29.1;
```

$PSo := 29.1$

```
> varPSo := (0.04)^2;
```

$varPSo := .0016$

Velocity Head DP re

```
> v := .45802;
```

$v := .45802$

```
> DPo := array([seq(v,i=1..n)]);
```

$DPo := [\,.45802 \;\; .45802 \;\; .45802 \;\; .45802 \;\; .45802 \;\; .45802 \;\; .45802 \;\; .45802\,]$

```
> u := .00005^2;
```

$u := .25\ 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```

$var := [\,.25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8} \;\; .25\ 10^{-8}\,]$

```
> varDPo := make_array(var,n);
```

$varDPo := varcovar$

```
> v := .82831;
```

$v := .82831$

```
> DPi := array([seq(v,i=1..n)]);
```

$DPi := [\,.82831 \;\; .82831 \;\; .82831 \;\; .82831 \;\; .82831 \;\; .82831 \;\; .82831 \;\; .82831\,]$

```
:= .00005^2;
                    u := .25  10^-8
ır := array([seq(u,i=1..n)]);
var := [
 .25  10^-8  .25  10^-8  .25  10^-8  .25  10^-8  .25  10^-8  .25  10^-8  .25  10^-8  .25  10^-8
 ]
ırDPi := make_array(var,n);
                    varDPi := varcovar
```

:mperature (R) re

```
:= 713;
                    v := 713
ɔ := array([seq(v,i=1..n)]);
          To := [713   713   713   713   713   713   713   713]
:= (.005*(v-460))^2;
                    u := 1.600225
ır := array([seq(u,i=1..n)]);
var := [
 1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225
 ]
ırTo := make_array(var,n);
                    varTo := varcovar
```

```
:= 1140;
                    v := 1140
:= array([seq(v,i=1..n)]);
          Ti := [1140   1140   1140   1140   1140   1140   1140   1140]
:= (.005*(v-460))^2;
                    u := 11.560000
ar := array([seq(u,i=1..n)]);
   var := [11.560000  11.560000  11.560000  11.560000  11.560000  11.560000
      11.560000  11.560000]
arTi := make_array(var,n);
                    varTi := varcovar
```

loisture in Ash re

```
If :=0.06;
                    Mf := .06
> varMf := ((0.2+0.12*Mf)/(2*1.414))^2;
                    varMf := .005368101168
```

Ash re

```
> A := 0.0619;
                    A := .0619
> varA := (( 0.07+0.02*A)/(2*1.414))^2;
                    varA := .0006345482144
```

Overhead re

```
> OUHD := 0.9;
                    OUHD := .9
> varOUHD := (0.1*OUHD)^2;
                    varOUHD := .0081
```

Carbon re

```
> C := 0.7381;
                    C := .7381
> varC := (0.64/(2*1.414))^2;
                    varC := .05121546706
```

Hydrogen re

```
> H := 0.0482;
                    H := .0482
> varH := (0.16/(2*1.414))^2;
                    varH := .003200966692
```

Nitrogen re

```
> N := 0.0135;
                    N := .0135
> varN := (0.11/(2*1.414))^2;
                    varN := .001512956913
```

Sulfur re

```
> S := 0.0123;
                    S := .0123
> varS := ((0.06+0.035*S)/(2*1.414))^2;
                    varS := .0004566185652
```

CO2 re

```
v := 14.145;
                         v := 14.145
CO2o := array([seq(v,i=1..n)]);
    CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145]
u := (0.03*v)^2;
                         u := .1800729225
var := array([seq(u,i=1..n)]);
    var := [.1800729225  .1800729225  .1800729225  .1800729225  .1800729225
      .1800729225  .1800729225  .1800729225]
varCO2o := make_array(var,n);
                         varCO2o := varcovar

v := 15.2148;
                         v := 15.2148
CO2i := array([seq(v,i=1..n)]);
  CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148]
u := (0.03*v)^2;
                         u := .2083411251
var := array([seq(u,i=1..n)]);
    var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
      .2083411251  .2083411251  .2083411251]
varCO2i := make_array(var,n);
                         varCO2i := varcovar
```

O2 re

```
> v := 5;
                         v := 5
> O2o := array([seq(v,i=1..n)]);
                 O2o := [5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                         u := .0025
> var := array([seq(u,i=1..n)]);
      var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                         varO2o := varcovar

> v := 3.8;
                         v := 3.8
> O2i := array([seq(v,i=1..n)]);
            O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                         u := .0025
> var := array([seq(u,i=1..n)]);
      var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                         varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                         Wma := .013
> varWma := (.2*Wma)^2;
                         varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                         v := .005
> COo := array([seq(v,i=1..n)]);
      COo := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                         u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOo := make_array(var,n);
                         varCOo := varcovar

> v := 0.005;
                         v := .005
> COi := array([seq(v,i=1..n)]);
      COi := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                         u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
```

arCOi := make_array(var,n);

varCOi := *varcovar*

'arbon in Ash re

'a := 0.0486;

Ca := .0486

arCa := (0.1*Ca)^2;

varCa := .0000236196

'esults

val(CO2aveo);

14.14500000

val(sigmaCO2aveo);

.1500303812 For N=24 $X\sqrt{\frac{8}{24}}$ = .0866

val(100*sigmaCO2aveo/CO2aveo);

1.060660171

Appendix E-2
Random Error Calculation
Outlet Flue Gas Average CO Concentration

Random Error Propagation Calculations, Part A, COo

Set no. of sample points

```
> n := 8;
```

$n := 8$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i = j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
            for i to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*:
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end

> COaveo := sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))
> (1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*COo[i],i=1..n)/sum(
> DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A
> OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n):
```

```
> sigmaCOaveo := value("):
> sigmaCOaveo := sqrt(
> Diff(COaveo,A)*Diff(COaveo,A)*varA +
> Diff(COaveo,OUHD)*Diff(COaveo,OUHD)*varOUHD +
> Diff(COaveo,Ca)*Diff(COaveo,Ca)*varCa +
> Diff(COaveo,C)*Diff(COaveo,C)*varC +
> Diff(COaveo,S)*Diff(COaveo,S)*varS +
> Diff(COaveo,H)*Diff(COaveo,H)*varH +
> Diff(COaveo,Wma)*Diff(COaveo,Wma)*varWma +
> Diff(COaveo,N)*Diff(COaveo,N)*varN +
> Diff(COaveo,Mf)*Diff(COaveo,Mf)*varMf +
> sum(
> Diff(COaveo,DPo[i])*Diff(COaveo,DPo[i])*varDPo[i,i] +
> Diff(COaveo,To[i])*Diff(COaveo,To[i])*varTo[i,i] +
> Diff(COaveo,COo[i])*Diff(COaveo,COo[i])*varCOo[i,i] +
> Diff(COaveo,CO2o[i])*Diff(COaveo,CO2o[i])*varCO2o[i,i] +
> Diff(COaveo,O2o[i])*Diff(COaveo,O2o[i])*varO2o[i,i]
> ,i=1..n)):
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                              Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                              varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                              Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                              varAreai := .01786633223
> Areao := 3.54;
                              Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                              varAreao := .01660386874
```

Pitot Coefficient re

```
> CP := 0.84;
```
$CP := .84$

```
> varCP := 0^2;
```
$varCP := 0$

Pressure Ambient or Barometric re

```
> PSi := 29.23;
```
$PSi := 29.23$

```
> varPSi := (0.04)^2;
```
$varPSi := .0016$

```
> PSo := 29.1;
```
$PSo := 29.1$

```
> varPSo := (0.04)^2;
```
$varPSo := .0016$

Velocity Head DP re

```
> v := .45802;
```
$v := .45802$

```
> DPo := array([seq(v,i=1..n)]);
```
$DPo := [.45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802]$

```
> u := .00005^2;
```
$u := .25 \; 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```
$var := [.25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8}]$

```
> varDPo := make_array(var,n);
```
$varDPo := varcovar$

```
> v := .82831;
```
$v := .82831$

```
> DPi := array([seq(v,i=1..n)]);
```
$DPi := [.82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831]$

```
> u := .00005^2;
```
$u := .25 \; 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```
$var := [.25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 10^{-8} \quad .25 \; 1]$

```
> varDPi := make_array(var,n);
```
$varDPi := varcovar$

Temperature (R) re

```
> v := 713;
```
$v := 713$

```
> To := array([seq(v,i=1..n)]);
```
$To := [713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713]$

```
> u := (.005*(v-460))^2;
```
$u := 1.600225$

```
> var := array([seq(u,i=1..n)]);
```
$var := [1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600]$

```
> varTo := make_array(var,n);
```
$varTo := varcovar$

```
> v := 1140;
```
$v := 1140$

```
> Ti:= array([seq(v,i=1..n)]);
```
$Ti := [1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140]$

```
> u := (.005*(v-460))^2;
```
$u := 11.560000$

```
> var := array([seq(u,i=1..n)]);
```
$var := [11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000]$

```
> varTi := make_array(var,n);
```
$varTi := varcovar$

Moisture in Ash re

```
> Mf :=0.06;
```
$Mf := .06$

```
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
```
varMf := .00001058319613

Ash re

```
> A := 0.0619;
```
A := .0619

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```
varA := $.4696223261 \; 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```
OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```
varOUHD := .0081

Carbon re

```
> C := 0.7381;
```
C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```
varC := $.5121546706 \; 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```
H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```
varH := $.3200966692 \; 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```
N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```
varN := $.1512956913 \; 10^{-6}$

Sulfur re

```
> S := 0.0123;
```
S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```
varS := $.1327813813 \; 10^{-6}$

CO2 re

```
> v := 14.145;
```
v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```
CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```
u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```
var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225]

```
> varCO2o := make_array(var,n);
```
varCO2o := *varcovar*

```
> v := 15.2148;
```
v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```
CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.214

```
> u := (0.03*v)^2;
```
u := .2083411251

```
> var := array([seq(u,i=1..n)]);
```
var := [.2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251]

```
> varCO2i := make_array(var,n);
```
varCO2i := *varcovar*

O2 re

```
> v := 5;
```
v := 5

```
> O2o := array([seq(v,i=1..n)]);
```
O2o := [5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```
u := .0025

```
> var := array([seq(u,i=1..n)]);
```
var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

```
> varO2o := make_array(var,n);
```
varO2o := *varcovar*

```
> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
                    O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
     var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.2*Wma)^2;
                    varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                    v := .005
> COo := array([seq(v,i=1..n)]);
          COo := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
          COi := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                    varCa := .0000236196
```

Results

```
eval(O2aveo);
eval(sigmaO2aveo);

eval(CO2aveo);
eval(sigmaCO2aveo);

> eval(COaveo);
                    .005000000001
> eval(sigmaCOaveo);
                    .0003535533905   FOR N=14 x√(1/3) : .000204
> eval(100*sigmaCOaveo/COaveo);
                    7.071067809

eval(O2avei);
eval(sigmaO2avei);

eval(CO2avei);
eval(sigmaCO2avei);

eval(COavei);
eval(sigmaCOavei);

>
```

Appendix E-3
Random Error Calculation
Outlet Flue Gas Average O_2 Concentration

```
>
>
```

Random Error Propagation Calculations, Part A, O2o

Set no. of sample points

```
> n := 8;
```

$$n := 8$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i = j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

```
#4
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

```
#6
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
        8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
        ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

```
#5
> O2aveonum := sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,M
> f)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*O2o[i],i=1..n);
```

$$O2aveonum := \left(DPo_1 \left(8.936000000\ H + \%17 + Mf + 1801.600000\ \frac{\%2}{\%16} \right) \Big/ \left(To_1 \left(160.9909760\ H + 18.01600000\ \%17 + 18.01600000\ Mf + \frac{\%2 \left(288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000 \right)}{\%16} \right) \right) \right)^{1/2} \left(1. - .05550621670 \frac{8.936000000\ H + \%17 + Mf}{.4960035524\ H + .05550621670\ \%17 + .05550621670\ Mf + 100.\ \frac{\%2}{\%16}} \right.$$

$$\Big) O2o_1 + \Big(DPo_2 \Big(8.936000000\ H + \%15 + Mf + 1801.600000\ \frac{\%2}{\%14} \Big) \Big/ \Big(To_2 \Big($$

$$160.9909760\ H + 18.01600000\ \%15 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_2 + 71.70000000\ O2o_2 + 50480.80000\right)}{\%14} \Big)\Big)\Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%15 + Mf}{.4960035524\ H + .05550621670\ \%15 + .05550621670\ Mf + 100.\ \frac{\%2}{\%14}}$$

$$\Big) O2o_2 + \Big(DPo_3 \Big(8.936000000\ H + \%13 + Mf + 1801.600000\ \frac{\%2}{\%12} \Big) \Big/ \Big(To_3 \Big($$

$$160.9909760\ H + 18.01600000\ \%13 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_3 + 71.70000000\ O2o_3 + 50480.80000\right)}{\%12} \Big)\Big)\Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%13 + Mf}{.4960035524\ H + .05550621670\ \%13 + .05550621670\ Mf + 100.\ \frac{\%2}{\%12}}$$

$$\Big) O2o_3 + \Big(DPo_4 \Big(8.936000000\ H + \%11 + Mf + 1801.600000\ \frac{\%2}{\%10} \Big) \Big/ \Big(To_4 \Big($$

$$160.9909760\ H + 18.01600000\ \%11 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_4 + 71.70000000\ O2o_4 + 50480.80000\right)}{\%10} \Big)\Big)\Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%11 + Mf}{.4960035524\ H + .05550621670\ \%11 + .05550621670\ Mf + 100.\ \frac{\%2}{\%10}}$$

$$\Big) O2o_4 + \Big(DPo_5 \Big(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8} \Big) \Big/ \Big(To_5 \Big($$

$$160.9909760\ H + 18.01600000\ \%9 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_5 + 71.70000000\ O2o_5 + 50480.80000\right)}{\%8} \Big)\Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}}$$

$$\Big) O2o_5 + \Big(DPo_6 \Big(8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6} \Big) \Big/ \Big(To_6 \Big($$

$$160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_6 + 71.70000000\ O2o_6 + 50480.80000\right)}{\%6} \Big)\Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}}$$

$$\Big) O2o_6 + \Big(DPo_7 \Big(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4} \Big) \Big/ \Big(To_7 \Big($$

$$160.9909760\ H + 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_7 + 71.70000000\ O2o_7 + 50480.80000\right)}{\%4} \Big)\Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$\Big) O2o_7 + \Big(DPo_8 \Big(8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1} \Big) \Big/ \Big(To_8 \Big($$

$$160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_8 + 71.70000000\ O2o_8 + 50480.80000\right)}{\%1} \Big)\Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670 \frac{8.936000000\ H + \%3 + Mf}{.4960035524\ H + .05550621670\ \%3 + .05550621670\ Mf + 100.\ \frac{\%2}{\%1}}$$

$$\Big)\ O2o_8$$

$$\%1 := 12.01000000\ CO2o_8 + 12.01000000\ COo_8$$

$$\%2 := C - 1.\ \frac{A\ OUHD\ Ca}{1. - 1.\ Ca} - .3333333333\ \frac{A\ (1. - 1.\ OUHD)\ Ca}{1. - .3333333333\ Ca} + .3744932959\ S$$

$$\%3 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_8 - 1.\ CO2o_8 - 1.\ O2o_8)\ \%2}{\%1} - 1.301236174\ N \right)$$

$$\%4 := 12.01000000\ CO2o_7 + 12.01000000\ COo_7$$

$$\%5 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_7 - 1.\ CO2o_7 - 1.\ O2o_7)\ \%2}{\%4} - 1.301236174\ N \right)$$

$$\%6 := 12.01000000\ CO2o_6 + 12.01000000\ COo_6$$

$$\%7 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_6 - 1.\ CO2o_6 - 1.\ O2o_6)\ \%2}{\%6} - 1.301236174\ N \right)$$

$$\%8 := 12.01000000\ CO2o_5 + 12.01000000\ COo_5$$

$$\%9 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_5 - 1.\ CO2o_5 - 1.\ O2o_5)\ \%2}{\%8} - 1.301236174\ N \right)$$

$$\%10 := 12.01000000\ CO2o_4 + 12.01000000\ COo_4$$

$$\%11 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_4 - 1.\ CO2o_4 - 1.\ O2o_4)\ \%2}{\%10} - 1.301236174\ N \right)$$

$$\%12 := 12.01000000\ CO2o_3 + 12.01000000\ COo_3$$

$$\%13 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_3 - 1.\ CO2o_3 - 1.\ O2o_3)\ \%2}{\%12} - 1.301236174\ \ldots \right.$$

$$\%14 := 12.01000000\ CO2o_2 + 12.01000000\ COo_2$$

$$\%15 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_2 - 1.\ CO2o_2 - 1.\ O2o_2)\ \%2}{\%14} - 1.301236174\ \ldots \right.$$

$$\%16 := 12.01000000\ CO2o_1 + 12.01000000\ COo_1$$

$$\%17 := Wma \left(36.46063760\ \frac{(100. - 1.\ COo_1 - 1.\ CO2o_1 - 1.\ O2o_1)\ \%2}{\%16} - 1.301236174\ \ldots \right.$$

```
> O2aveoden := sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,M
> )))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n):

> O2aveo := O2aveonum/O2aveoden:

O2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A.
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO
H,Wma,O2i,N,Mf)),i=1..n):
#7
CO2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MF
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/sum((DPo[i]/(To[i]
M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C.
COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n):

CO2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i.
OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,
```

```
> ,i=1..n)):

> sigmaO2aveo := value("):

> sigmaO2aveo := sqrt(

>  Diff(O2aveo,A)^2*varA +

>  Diff(O2aveo,OUHD)^2*varOUHD +

>  Diff(O2aveo,Ca)^2*varCa +

>  Diff(O2aveo,C)^2*varC +

>  Diff(O2aveo,S)^2*varS +

>  Diff(O2aveo,H)^2*varH +

>  Diff(O2aveo,Wma)^2*varWma +

>  Diff(O2aveo,N)^2*varN +

>  Diff(O2aveo,Mf)^2*varMf +

>  sum(

>  Diff(O2aveo,DPo[i])*Diff(O2aveo,DPo[i])*varDPo[i,i] +

>  Diff(O2aveo,To[i])*Diff(O2aveo,To[i])*varTo[i,i] +

>  Diff(O2aveo,COo[i])*Diff(O2aveo,COo[i])*varCOo[i,i] +

>  Diff(O2aveo,CO2o[i])*Diff(O2aveo,CO2o[i])*varCO2o[i,i] +

>  Diff(O2aveo,O2o[i])*Diff(O2aveo,O2o[i])*varO2o[i,i]
```

Constants

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                    Wfe := 115839

> varWfe := (0.0025*Wfe)^2;
                    varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                    Areai := 3.99

> varAreai := (0.0335*Areai)^2;
                    varAreai := .01786633223

> Areao := 3.54;
                    Areao := 3.54

> varAreao := (0.0364*Areao)^2;
                    varAreao := .01660386874
```

Pitot Coefficient re

```
> CP := 0.84;
                    CP := .84

> varCP := 0^2;
                    varCP := 0
```

Pressure Ambient or Barometric re

\> PSi := 29.23;

$PSi := 29.23$

\> varPSi := (0.04)^2;

$varPSi := .0016$

\> PSo := 29.1;

$PSo := 29.1$

\> varPSo := (0.04)^2;

$varPSo := .0016$

Velocity Head DP re

\> v := .45802;

$v := .45802$

\> DPo := array([seq(v,i=1..n)]);

$DPo := [.45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802 \quad .45802]$

\> u := .00005^2;

$u := .25\ 10^{-8}$

\> var := array([seq(u,i=1..n)]);

$var := [.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}]$

\> varDPo := make_array(var,n);

$varDPo := varcovar$

\> v := .82831;

$v := .82831$

\> DPi := array([seq(v,i=1..n)]);

$DPi := [.82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831 \quad .82831]$

\> u := .00005^2;

$u := .25\ 10^{-8}$

\> var := array([seq(u,i=1..n)]);

$var := [.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}]$

\> varDPi := make_array(var,n);

$varDPi := varcovar$

Temperature (R) re

\> v := 713;

$v := 713$

\> To := array([seq(v,i=1..n)]);

$To := [713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713 \quad 713]$

\> u := (0.005*(v-460))^2;

$u := 1.600225$

\> var := array([seq(u,i=1..n)]);

$var := [1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600$

$]$

\> varTo := make_array(var,n);

$varTo := varcovar$

\> v := 1140;

$v := 1140$

\> Ti:= array([seq(v,i=1..n)]);

$Ti := [1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140 \quad 1140]$

\> u := (0.005*(v-460))^2;

$u := 11.560000$

\> var := array([seq(u,i=1..n)]);

$var := [11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000]$

\> varTi := make_array(var,n);

$varTi := varcovar$

Moisture in Ash re

\> Mf :=0.06;

$Mf := .06$

\> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;

$varMf := .00001058319613$

Ash re

\> A := 0.0619;

$A := .0619$

\> varA := ((0.07+0.02*A*100)/(2*1.414*100))^2;

varA := .4696223261 10^{-6}

Overhead re

```
> OUHD := 0.9;
```

OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon re

```
> C := 0.7381;
```

C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```

varC := .5121546706 10^{-5}

Hydrogen re

```
> H := 0.0482;
```

H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```

varH := .3200966692 10^{-6}

Nitrogen re

```
> N := 0.0135;
```

N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```

varN := .1512956913 10^{-6}

Sulfur re

```
> S := 0.0123;
```

S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```

varS := .1327813813 10^{-6}

CO2 re

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```

u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```

var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225]

```
> varCO2o := make_array(var,n);
```

varCO2o := varcovar

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.214·

```
> u := (0.03*v)^2;
```

u := .2083411251

```
> var := array([seq(u,i=1..n)]);
```

var := [.2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251 .2083411251]

```
> varCO2i := make_array(var,n);
```

varCO2i := varcovar

O2 re

```
> v := 5;
```

v := 5

```
> O2o := array([seq(v,i=1..n)]);
```

O2o := [5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

```
> varO2o := make_array(var,n);
```

varO2o := varcovar

```
> v := 3.8;
```

v := 3.8

```
> O2i := array([seq(v,i=1..n)]);
```

O2i := [3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

```
var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.2*Wma)^2;
                    varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                    v := .005
> COo := array([seq(v,i=1..n)]);
          COo := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
          COi := [.005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                    varCa := .0000236196
```

Results

```
> eval(O2aveo);
                    5.000000001
> eval(sigmaO2aveo);
                                     FOR N = 24
                    .01767766953     .0176776 * sqrt(8/24) = 0.0102[illegible]
> eval(100*sigmaO2aveo/O2aveo);
                    .3535533905

eval(CO2aveo);
```

5
0
93

Appendix F-1
Bias Error Calculation
Flue Gas Inlet Flow

```
>
>
```

Error Propagation Calculations, Part B, TFluegasINa

Set no. of sample points

```
> n := 2;
```

$$n := 2$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}}\right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
```

> O2i[i]/100,i=1..n):

#19

> SA := FA/(FA+FB);

$$SA := \frac{1}{2}$$

#20

> SB := FB/(FA+FB);

$$SB := \frac{1}{2}$$

#21

> WPAIA := PAFA/(Wfe*SA);

$$WPAIA := 28176.4 \frac{apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} \right)}{Wfe}$$

#22

> WPAIB := PAFB/(Wfe*SB);

$$WPAIB := 28176.4 \frac{apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} \right)}{Wfe}$$

#23

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> Cb := C - Cr;

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

> WMGi := 8.936*H + (Wma*WAi)+Mf;

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei)$$

#26

> WGi := WGpi + WMGi;

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (\right.$$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Big) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\ \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} + Wma\left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right) - \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} - Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right)\Bigg)\Bigg/\Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right) + Mf\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

```
> TFluegasINa := WGi*Wfe*SA;
```

$$TFluegasINa := \frac{1}{2}\ \Big((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$

$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}Ca}+.3744932959\ S\right)/($$

$$12.01\ CO2avei+12.01\ COavei)+8.936\ H+Wma\left(36.46063760\right.$$

$$(100-CO2avei-COavei-O2avei)$$

$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}Ca}+.3744932959\ S\right)/($$

$$\left.\left.12.01\ CO2avei+12.01\ COavei)-1.301236174\ N\right)+Mf\right)\ Wfe$$

```
> sigmaTFluegasINa := sqrt(
> Diff(TFluegasINa,CO2avei)^2*varCO2avei +
> Diff(TFluegasINa,COavei)^2*varCOavei +
> Diff(TFluegasINa,O2avei)^2*varO2avei +
> Diff(TFluegasINa,Wfe)^2*varWfe +
> Diff(TFluegasINa,Areai)^2*varAreai +
> Diff(TFluegasINa,CP)^2*varCP +
> Diff(TFluegasINa,PSi)^2*varPSi +
> Diff(TFluegasINa,A)^2*varA +
> Diff(TFluegasINa,OUHD)^2*varOUHD +
> Diff(TFluegasINa,Ca)^2*varCa +
> Diff(TFluegasINa,C)*Diff(TFluegasINa,C)*varC +
> Diff(TFluegasINa,S)*Diff(TFluegasINa,S)*varS +
> Diff(TFluegasINa,H)*Diff(TFluegasINa,H)*varH +
> Diff(TFluegasINa,Wma)*Diff(TFluegasINa,Wma)*varWma +
> Diff(TFluegasINa,N)*Diff(TFluegasINa,N)*varN +
> Diff(TFluegasINa,Mf)*Diff(TFluegasINa,Mf)*varMf +
> sum(sum(
> Diff(TFluegasINa,DPi[i])*Diff(TFluegasINa,DPi[j])*varDPi[i,j] +
> Diff(TFluegasINa,Ti[i])*Diff(TFluegasINa,Ti[j])*varTi[i,j] +
> Diff(TFluegasINa,COi[i])*Diff(TFluegasINa,COi[j])*varCOi[i,j] +
> Diff(TFluegasINa,CO2i[i])*Diff(TFluegasINa,CO2i[j])*varCO2i[i,j] +
> Diff(TFluegasINa,O2i[i])*Diff(TFluegasINa,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):

> sigmaTFluegasINa := value("):
```

Constants

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```

$$CO2avei := 15.2148$$

```
> varCO2avei := .1^2;
```

$$varCO2avei := .01$$

```
> COavei := .005;
```

$$COavei := .005$$

```
> varCOavei := .002^2;
```

$$varCOavei := .4\ 10^{-5}$$

```
> O2avei := 3.8;
```

$$O2avei := 3.8$$

```
> varO2avei := .05^2;
```

$$varO2avei := .0025$$

```
> CO2aveo := 14.145;
```

$$CO2aveo := 14.145$$

```
> varCO2aveo := .1^2;
```

```
varCO2aveo := .01
> COaveo := .005;
COaveo := .005
> varCOaveo := .002^2;
varCOaveo := .4 10^-5
> O2aveo := 5;
O2aveo := 5
> varO2aveo := .05^2;
varO2aveo := .0025
```

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
Wfe := 115839
> varWfe := (0.05*Wfe)^2;
varWfe := .3354668480 10^8
```

Area (square ft)

```
> Areai := 3.99;
Areai := 3.99
> varAreai := (0.0335*Areai)^2;
varAreai := .01786633223
> Areao := 3.54;
Areao := 3.54
> varAreao := (0.0364*Areao)^2;
varAreao := .01660386874
```

Pitot Coefficient

```
> CP := 0.84;
CP := .84
> varCP := (0.01)^2;
varCP := .0001
```

Pressure in Area

```
> PSi := 29.23;
PSi := 29.23
> varPSi := (0.04)^2;
varPSi := .0016
> PSo := 29.1;
PSo := 29.1
> varPSo := (0.04)^2;
varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
PSpa := 31.11
> varPSpa := (0.04)^2;
varPSpa := .0016
>
```

Velocity Head

```
> v := .45802;
v := .45802
> DPo := array([seq(v,i=1..n)]);
DPo := [.45802  .45802]
> u := (.02*v)^2;
u := .00008391292816
> var := array([seq(u,i=1..n)]);
var := [.00008391292816  .00008391292816]
> varDPo := make_array(var,n);
varDPo := varcovar
> v := .82831;
v := .82831
> DPi := array([seq(v,i=1..n)]);
DPi := [.82831  .82831]
> u := (.02*v)^2;
u := .0002744389824
> var := array([seq(u,i=1..n)]);
var := [.0002744389824  .0002744389824]
> varDPi := make_array(var,n);
varDPi := varcovar
```

Temperature (R)

```
> v := 713;
v := 713
```

```
> To := array([seq(v,i=1..n)]);
```
$To := [713 \quad 713]$

```
> u := (0.01*(v-460))^2;
```
$u := 6.4009$

```
> var := array([seq(u,i=1..n)]);
```
$var := [6.4009 \quad 6.4009]$

```
> varTo := make_array(var,n);
```
$varTo := varcovar$

```
> v := 1140;
```
$v := 1140$

```
> Ti:= array([seq(v,i=1..n)]);
```
$Ti := [1140 \quad 1140]$

```
> u := (0.01*(v-460))^2;
```
$u := 46.2400$

```
> var := array([seq(u,i=1..n)]);
```
$var := [46.2400 \quad 46.2400]$

```
> varTi := make_array(var,n);
```
$varTi := varcovar$

Moisture in Coal

```
> Mf :=0.06;
```
$Mf := .06$

```
> varMf := (0.039*Mf)^2;
```
$varMf := .54756 \; 10^{-5}$

Ash

```
> A :=  0.0619;
```
$A := .0619$

```
> varA := ( 0.039*A)^2;
```
$varA := .582787881 \; 10^{-5}$

Overhead

```
> OUHD :=  0.9;
```
$OUHD := .9$

```
> varOUHD :=  (0.1*OUHD)^2;
```
$varOUHD := .0081$

Carbon

```
> C := 0.7381;
```
$C := .7381$

```
> varC := (0.039*C)^2;
```
$varC := .0008286280388$

Hydrogen

```
> H := 0.0482;
```
$H := .0482$

```
> varH := (0.039*H)^2;
```
$varH := .353364804 \; 10^{-5}$

Nitrogen

```
> N := 0.0135;
```
$N := .0135$

```
> varN := (0.039*N)^2;
```
$varN := .27720225 \; 10^{-6}$

Sulfur

```
> S := 0.0123;
```
$S := .0123$

```
> varS := (0.019*S)^2;
```
$varS := .5461569 \; 10^{-7}$

CO2

```
> v := 14.145;
```
$v := 14.145$

```
> CO2o := array([seq(v,i=1..n)]);
```
$CO2o := [14.145 \quad 14.145]$

```
> u := (0.1)^2;
```
$u := .01$

```
> var := array([seq(u,i=1..n)]);
```
$var := [.01 \quad .01]$

```
> varCO2o := make_array(var,n);
```
$varCO2o := varcovar$

```
> v := 15.2148;
```
$v := 15.2148$

```
> CO2i := array([seq(v,i=1..n)]);
                    CO2i := [15.2148   15.2148]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
                    var := [.01   .01]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar
```

O2

```
> v := 5;
                    v := 5
> O2o := array([seq(v,i=1..n)]);
                    O2o := [5   5]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025   .0025]
> varO2o := make_array(var,n);
                    varO2o := varcovar

> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
                    O2i := [3.8   3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025   .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar
```

Moisture (air)

```
> Wma := 0.013;
                    Wma := .013
> varWma := (.1*Wma)^2;
                    varWma := .169 10^-5
```

CO

```
> v := 0.005;
                    v := .005
> COo := array([seq(v,i=1..n)]);
                    COo := [.005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
                    COi := [.005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.25*Ca)^2;
                    varCa := .000147622500
```

Area for primary air

```
> apa := .63;
                    apa := .63
> varapa := (.013)^2;
                    varapa := .000169

> v := .2171;
                    v := .2171
```

5
—
0

```
> DPpa := array([seq(v,i=1..n)]);
                    DPpa := [.2171   .2171]
> u := 0.02*v;
                    u := .004342
> var := array([seq(u,i=1..n)]);
                    var := [.004342   .004342]
> varDPpa := make_array(var,n);
                    varDPpa := varcovar

> v := 1104;
                    v := 1104
> Tpa := array([seq(v,i=1..n)]);
                    Tpa := [1104   1104]
> u := 0.01*(v - 460);
                    u := 6.44
> var := array([seq(u,i=1..n)]);
                    var := [6.44   6.44]
> varTpa := make_array(var,n);
                    varTpa := varcovar
```

Results

```
*******************************************************************************
> eval(TFluegasINa);
                    754792.2100
> eval(sigmaTFluegasINa);
                    47382.14935
> eval(100*sigmaTFluegasINa/TFluegasINa);
                    6.277509058
*******************************************************************************
```

Recalculate Other Results

```
> i := 'i';
                    i := i
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                    m := 28.74570417
```

```
>
>
```

Error Propagation Calculations, Part B, TFluegasINa

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

5/2

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

#5

```
O2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*O2o[i],i=1..n)/sum((DPo[i]/(To[i]*M(i
,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

O2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i
H,Wma,O2i,N,Mf)),i=1..n);
```

#7

```
CO2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/sum((DPo[i]/(To[i]*
M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,
COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

CO2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,
OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO
2i,H,Wma,O2i,N,Mf)),i=1..n);
```

#8

```
COaveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*COo[i],i=1..n)/sum((DPo[i]/(To[i]*M(
i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
COavei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*COi[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}}\right.$$

$$\left. + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) / Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} \right) \Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \Bigg) + Mf$$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COa
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \Bigg) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ ($$

5/5

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\right.$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$\left.12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\left(36.46063760\right.$$
$$(100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$\left.12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\left(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo}\right.$$
$$+ Wma\left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ :\right.$$
$$- \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2}$$
$$- Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ :\right.$$
$$\left.\right) / \left(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H\right.$$
$$+ Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ :\right.$$
$$\left. + Mf\right)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

```
> TFluegasINa := WGi*Wfe*SA;
```

$$TFluegasINa := \frac{1}{2}\left((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\right.$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\left(36.46063760\right.$$
$$(100 - CO2avei - COavei - O2avei)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

5/6

$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Big) + Mf\Big)\ Wfe$

```
TFluegasINb := WGi*Wfe*SB;

#33
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;

> sigmaTFluegasINa := sqrt(
> Diff(TFluegasINa,CO2avei)^2*varCO2avei +
> Diff(TFluegasINa,COavei)^2*varCOavei +
> Diff(TFluegasINa,O2avei)^2*varO2avei +
> Diff(TFluegasINa,Wfe)^2*varWfe +
> Diff(TFluegasINa,Areal)^2*varAreal +
> Diff(TFluegasINa,CP)^2*varCP +
> Diff(TFluegasINa,PSi)^2*varPSi +
> Diff(TFluegasINa,A)^2*varA +
> Diff(TFluegasINa,OUHD)^2*varOUHD +
> Diff(TFluegasINa,Ca)^2*varCa +
> Diff(TFluegasINa,C)*Diff(TFluegasINa,C)*varC +
> Diff(TFluegasINa,S)*Diff(TFluegasINa,S)*varS +
> Diff(TFluegasINa,H)*Diff(TFluegasINa,H)*varH +
> Diff(TFluegasINa,Wma)*Diff(TFluegasINa,Wma)*varWma +
> Diff(TFluegasINa,N)*Diff(TFluegasINa,N)*varN +
> Diff(TFluegasINa,Mf)*Diff(TFluegasINa,Mf)*varMf +
> sum(sum(
> Diff(TFluegasINa,DPi[i])*Diff(TFluegasINa,DPi[j])*varDPi[i,j] +
> Diff(TFluegasINa,Ti[i])*Diff(TFluegasINa,Ti[j])*varTi[i,j] +
> Diff(TFluegasINa,COi[i])*Diff(TFluegasINa,COi[j])*varCOi[i,j] +
> Diff(TFluegasINa,CO2i[i])*Diff(TFluegasINa,CO2i[j])*varCO2i[i,j] +
> Diff(TFluegasINa,O2i[i])*Diff(TFluegasINa,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):

> sigmaTFluegasINa := value("):
```

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Constants

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```

$CO2avei := 15.2148$

```
> varCO2avei := .1^2;
```

$varCO2avei := .01$

```
> COavei := .005;
```

$COavei := .005$

```
> varCOavei := .002^2;
```

$varCOavei := .4\ 10^{-5}$

```
> O2avei := 3.8;
```

$O2avei := 3.8$

```
> varO2avei := .05^2;
```

$varO2avei := .0025$

```
> CO2aveo := 14.145;
```

$CO2aveo := 14.145$

```
> varCO2aveo := .1^2;
```

$varCO2aveo := .01$

```
> COaveo := .004;
```

$COaveo := .004$

```
> varCOaveo := .002^2;
```

$varCOaveo := .4\ 10^{-5}$

```
> O2aveo := 5;
```

$O2aveo := 5$

```
> varO2aveo := .05^2;
```

$varO2aveo := .0025$

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```

$Wfe := 115839$

```
> varWfe := (0.05*Wfe)^2;
```

$varWfe := .3354668480\ 10^{8}$

Area (square ft)

```
> Areai := 3.99;
```

$Areai := 3.99$

```
> varAreai := (0.0335*Areai)^2;
```

$varAreai := .01786633223$

```
> Areao := 3.54;
```

$Areao := 3.54$

```
> varAreao := (0.0364*Areao)^2;
```

$varAreao := .01660386874$

Pitot Coefficient

```
> CP := 0.84;
```

$CP := .84$

```
> varCP := (0.01)^2;
```

$varCP := .0001$

Pressure in Area

```
> PSi := 29.23;
```

$PSi := 29.23$

```
> varPSi := (0.04)^2;
```

$varPSi := .0016$

```
> PSo := 29.1;
```

$PSo := 29.1$

```
> varPSo := (0.04)^2;
```

$varPSo := .0016$

Pressue for primary air

```
> PSpa := 31.11;
```

$PSpa := 31.11$

```
> varPSpa := (0.04)^2;
```

$varPSpa := .0016$

5/8

>

Velocity Head

> v := .45802;

v := .45802

> DPo := array([seq(v,i=1..n)]);

DPo := [.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802]

> u := (.02*v)^2;

u := .00008391292816

> var := array([seq(u,i=1..n)]);

var := [.00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816 .00008391292816]

> varDPo := make_array(var,n);

varDPo := varcovar

> v := .82831;

v := .82831

> DPi := array([seq(v,i=1..n)]);

DPi := [.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831]

> u := (.02*v)^2;

u := .0002744389824

> var := array([seq(u,i=1..n)]);

var := [.0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824 .0002744389824]

> varDPi := make_array(var,n);

varDPi := varcovar

Temperature (R)

> v := 713;

v := 713

> To := array([seq(v,i=1..n)]);

To := [713 713 713 713 713 713 713 713 713 713 713 713 713 7.
713 713 713 713 713 713]

> u := (0.01*(v-460))^2;

u := 6.4009

> var := array([seq(u,i=1..n)]);

var := [6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.400
6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.40
6.4009]

> varTo := make_array(var,n);

varTo := varcovar

> v := 1140;

v := 1140

> Ti:= array([seq(v,i=1..n)]);

Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140
1140 1140 1140 1140 1140 1140 1140 1140 1140]

> u := (0.01*(v-460))^2;

u := 46.2400

> var := array([seq(u,i=1..n)]);

var := [46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.24
46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400
46.2400 46.2400 46.2400 46.2400]

> varTi := make_array(var,n);

varTi := varcovar

Moisture in Coal

> Mf :=0.06;

Mf := .06

> varMf := (0.039*Mf)^2;

varMf := .54756 10^{-5}

Ash

> A := 0.0619;

A := .0619

> varA := (0.039*A)^2;

varA := .582787881 10^{-5}

Overhead

```
> OUHD :=  0.9;
                    OUHD := .9
> varOUHD :=  (0.1*OUHD)^2;
                    varOUHD := .0081
```

Carbon

```
> C := 0.7381;
                    C := .7381
> varC := (0.039*C)^2;
                    varC := .0008286280388
```

Hydrogen

```
> H := 0.0482;
                    H := .0482
> varH := (0.039*H)^2;
                    varH := .353364804  10^-5
```

Nitrogen

```
> N := 0.0135;
                    N := .0135
> varN := (0.039*N)^2;
                    varN := .27720225  10^-6
```

Sulfur

```
> S := 0.0123;
                    S := .0123
> varS := (0.019*S)^2;
                    varS := .5461569  10^-7
```

CO2

```
> v := 14.145;
                    v := 14.145
> CO2o := array([seq(v,i=1..n)]);
   CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
     14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
     14.145]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .0
     .01  .01  .01  .01  .01]
> varCO2o := make_array(var,n);
                    varCO2o := varcovar
```

```
> v := 15.2148;
                    v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
   CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.214
     15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
     15.2148  15.2148  15.2148  15.2148]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .0
     .01  .01  .01  .01  .01]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar
```

O2

```
> v := 5;
                    v := 5
> O2o := array([seq(v,i=1..n)]);
   O2o := [5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
   var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                    varO2o := varcovar
```

```
> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
```

O2i := [3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8]

> u := (0.05)^2;

u := .0025

> var := array([seq(u,i=1..n)]);

var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

> varO2i := make_array(var,n);

varO2i := *varcovar*

Moisture (air)

> Wma := 0.013;

Wma := .013

> varWma := (.1*Wma)^2;

varWma := $.169\ 10^{-5}$

CO

> v := 0.005;

v := .005

> COo := array([seq(v,i=1..n)]);

COo := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005]

> u := (0.002)^2;

u := $.4\ 10^{-5}$

> var := array([seq(u,i=1..n)]);

var := $[.4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}]$

> varCOo := make_array(var,n);

varCOo := *varcovar*

> v := 0.005;

v := .005

> COi := array([seq(v,i=1..n)]);

COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005]

> u := (0.002)^2;

u := $.4\ 10^{-5}$

> var := array([seq(u,i=1..n)]);

var := $[.4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}\ \ .4\ 10^{-5}]$

> varCOi := make_array(var,n);

varCOi := *varcovar*

Carbon in Ash

> Ca := 0.0486;

Ca := .0486

> varCa := (0.25*Ca)^2;

varCa := .000147622500

Area for primary air

> apa := .63;

apa := .63

> varapa := (.013)^2;

.0204 * apa

varapa := .000169

OK NOT USED THIS [illegible]

> v := .2171;

v := .2171

> DPpa := array([seq(v,i=1..n)]);

DPpa := [.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171]

> u := 0.02*v;

u := .004342

> varDPpa := array([seq(u,i=1..n)]);

varDPpa := [.004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342]

> varDPpa := make_array(var,n);

varDPpa := *varcovar*

> v := 1104;

v := 1104

> Tpa := array([seq(v,i=1..n)]);

```
Tpa := [1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
  1104  1104  1104  1104  1104  1104  1104  1104  1104]
> u := 0.01*(v - 460);
                              u := 6.44
> var := array([seq(u,i=1..n)]);
  var := [6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44
  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44]
> varTpa := make_array(var,n);
                              varTpa := varcovar
```

Results

```
*******************************************************************************
> eval(TFluegasINa);
                              754792.2100
> eval(sigmaTFluegasINa);
                              47382.14934
> eval(100*sigmaTFluegasINa/TFluegasINa);
                              6.277509056
*******************************************************************************

eval(TFluegasINb);
eval(sigmaTFluegasINb);

eval(TFluegasOUTa);
eval(sigmaTFluegasOUTa);

eval(TFluegasOUTb);
eval(sigmaTFluegasOUTb);
```

Recalculate Other Results

```
> i := 'i';
                              i := i

#13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                              m := 28.74570417

#14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

Appendix F-2
Random Error Calculation
Flue Gas Inlet Flow

```
>
>
```

Random Error Propagation Calculations, Part B, TFluegasINa

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

G 2 3

```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}}\right.$$

154

$$+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}$$
$$+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\Bigg)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}\right.$$
$$+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa_9}{Tpa_9}}$$
$$+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}$$
$$\left.+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}\right.$$
$$+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa}{Tpa}}$$
$$+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}$$
$$\left.+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)\Big/ Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}\right.$$
$$+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa}{Tpa}}$$
$$+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}$$
$$\left.+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)\Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \right.$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$\left. 12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma \left(36.46063760 \right.$$
$$(100 - CO2avei - COavei - O2avei)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$\left. 12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma \left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \right.$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$\left. 12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \right) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)/($$
$$12.01\ CO2aveo+12.01\ COaveo)$$

#30

> **WGo := WGpo + WMGo;**

$$WGo := (15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)$$
$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)/($$
$$12.01\ CO2aveo+12.01\ COaveo)+8.936\ H+Wma\ \Bigg(36.46063760$$
$$(100-CO2aveo-COaveo-O2aveo)$$
$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)/($$
$$12.01\ CO2aveo+12.01\ COaveo)-1.301236174\ N\Bigg)+Mf$$

#31

> **AL := ((WGo-WGi)/WGi)*100;**

$$AL := 100\ \Bigg(\frac{(15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}$$
$$+Wma\left(36.46063760\ \frac{(100-CO2aveo-COaveo-O2aveo)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}-1.301236174\ N\right)$$
$$-\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}$$
$$-Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ N\right)$$
$$\Bigg)\Bigg/\Bigg(\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}+8.936\ H$$
$$+Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ N\right)$$
$$+Mf\Bigg)$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

$$\%2 := 12.01\ CO2avei+12.01\ COavei$$

#32

> **TFluegasINa := WGi*Wfe*SA;**

$$TFluegasINa := \frac{1}{2}\ \Bigg((15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)$$
$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)/($$
$$12.01\ CO2avei+12.01\ COavei)+8.936\ H+Wma\ \Bigg(36.46063760$$
$$(100-CO2avei-COavei-O2avei)$$
$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)/($$
$$12.01\ CO2avei+12.01\ COavei)-1.301236174\ N\Bigg)+Mf\Bigg)\ Wfe$$

> **sigmaTFluegasINa := sqrt(**

> **Diff(TFluegasINa,CO2avei)^2*varCO2avei +**

> **Diff(TFluegasINa,COavei)^2*varCOavei +**

> **Diff(TFluegasINTa,O2avei)^2*varO2avei +**

> **Diff(TFluegasINa,Wfe)^2*varWfe +**

> **Diff(TFluegasINa,Areai)^2*varAreai +**

> **Diff(TFluegasINa,CP)^2*varCP +**

> **Diff(TFluegasINa,PSi)^2*varPSi +**

> **Diff(TFluegasINa,A)^2*varA +**

```
> Diff(TFluegasINa,OUHD)^2*varOUHD +
> Diff(TFluegasINa,Ca)^2*varCa +
> Diff(TFluegasINa,C)*Diff(TFluegasINa,C)*varC +
> Diff(TFluegasINa,S)*Diff(TFluegasINa,S)*varS +
> Diff(TFluegasINa,H)*Diff(TFluegasINa,H)*varH +
> Diff(TFluegasINa,Wma)*Diff(TFluegasINa,Wma)*varWma +
> Diff(TFluegasINa,N)*Diff(TFluegasINa,N)*varN +
> Diff(TFluegasINa,Mf)*Diff(TFluegasINa,Mf)*varMf +
> sum(
> Diff(TFluegasINa,DPI[i])*Diff(TFluegasINa,DPI[i])*varDPI[i,i] +
> Diff(TFluegasINa,Ti[i])*Diff(TFluegasINa,Ti[i])*varTi[i,i] +
> Diff(TFluegasINa,COi[i])*Diff(TFluegasINa,COi[i])*varCOi[i,i] +
> Diff(TFluegasINa,CO2i[i])*Diff(TFluegasINa,CO2i[i])*varCO2i[i,i] +
> Diff(TFluegasINa,O2i[i])*Diff(TFluegasINa,O2i[i])*varO2i[i,i]
> ,i=1..n)):

> sigmaTFluegasINa := value("):
```

Constants

Averages and Random Error Variances (Copied from Part A -- function of sample size n)

```
> CO2avei := 15.2148;
                    CO2avei := 15.2148
> varCO2avei := .102^2;
                    varCO2avei := .010404
> COavei := .005;
                    COavei := .005
> varCOavei := .0002^2;
                    varCOavei := .4 10^-7
> O2avei := 3.8;
                    O2avei := 3.8
> varO2avei := .01118^2;
                    varO2avei := .0001249924

> CO2aveo := 14.145;
                    CO2aveo := 14.145
> varCO2aveo := .0866^2;
                    varCO2aveo := .00749956
> COaveo := .005;
                    COaveo := .005
> varCOaveo := .000204^2;
                    varCOaveo := .41616 10^-7
> O2aveo := 5;
                    O2aveo := 5
> varO2aveo := .010206^2;
                    varO2aveo := .000104162436
```

Constants for Random Error Propagation

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                    Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                    varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                    Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                    varAreai := .01786633223

> Areao := 3.54;
                    Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                    varAreao := .01660386874
```

Pitot Coefficient re

```
> CP := 0.84;
                    CP := .84
> varCP := (0)^2;
                    varCP := 0
```

Pressure Ambient or Barometric re

```
> PSi := 29.23;
                    PSi := 29.23
> varPSi := (0.04)^2;
                    varPSi := .0016
> PSo := 29.1;
                    PSo := 29.1
> varPSo := (0.04)^2;
                    varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
                    PSpa := 31.11
> varPSpa := (0.04)^2;
                    varPSpa := .0016
>
```

Velocity Head DP re

```
> v := .45802;
                    v := .45802
> DPo := array([seq(v,i=1..n)]);
   DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
     .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
     .45802]
> u := .00005^2;
                    u := .25 10^-8
> var := array([seq(u,i=1..n)]);
   var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
> varDPo := make_array(var,n);
                    varDPo := varcovar
> v := .82831;
                    v := .82831
> DPi := array([seq(v,i=1..n)]);
   DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
     .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .828
     .82831]
> u := .00005^2;
                    u := .25 10^-8
> var := array([seq(u,i=1..n)]);
   var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
> varDPi := make_array(var,n);
                    varDPi := varcovar
>
> v := .2171;
                    v := .2171
> DPpa := array([seq(v,i=1..n)]);
   DPpa := [.2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171
     .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171]
> u := (0.00005)^2;
                    u := .25 10^-8
> var := array([seq(u,i=1..n)]);
   var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
> varDPpa := make_array(var,n);
                    varDPpa := varcovar
> v := 1104;
                    v := 1104
> Tpa := array([seq(v,i=1..n)]);
   Tpa := [1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
```

1104 1104 1104 1104 1104 1104 1104 1104 1104]

```
> u := (0.005*(v - 460))^2;
```

$u := 10.368400$

```
> var := array([seq(u,i=1..n)]);
```

var := [10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400]

```
> varTpa := make_array(var,n);
```

varTpa := *varcovar*

Temperature (R) re

```
> v := 713;
```

$v := 713$

```
> To := array([seq(v,i=1..n)]);
```

To := [713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713]

```
> u := (0.005*(v-460))^2;
```

$u := 1.600225$

```
> var := array([seq(u,i=1..n)]);
```

var := [1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225]

```
> varTo := make_array(var,n);
```

varTo := *varcovar*

```
> v := 1140;
```

$v := 1140$

```
> Ti:= array([seq(v,i=1..n)]);
```

Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140]

```
> u := (0.005*(v-460))^2;
```

$u := 11.560000$

```
> var := array([seq(u,i=1..n)]);
```

var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000]

```
> varTi := make_array(var,n);
```

varTi := *varcovar*

Moisture in Ash re

```
> Mf :=0.06;
```

$Mf := .06$

```
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
```

$varMf := .00001058319613$

Ash re

```
> A := 0.0619;
```

$A := .0619$

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```

$varA := .4696223261 \; 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon re

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.64/(2*1.414*100))^2;
```

$varC := .5121546706 \; 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.16/(2*1.414*100))^2;
```

$varH := .3200966692 \; 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.11/(2*1.414*100))^2;
```

$varN := .1512956913 \; 10^{-6}$

Sulfur re

```
> S := 0.0123;
                                S := .0123
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
                        varS := .1327813813 10^-6
```

CO2 re

```
> v := 14.145;
                                v := 14.145
> CO2o := array([seq(v,i=1..n)]);
  CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
    14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
    14.145]
> u := (0.03*v)^2;
                            u := .1800729225
> var := array([seq(u,i=1..n)]);
  var := [.1800729225  .1800729225  .1800729225  .1800729225  .1800729225
    .1800729225  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225
    .1800729225  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225
    .1800729225  .1800729225  .1800729225]
> varCO2o := make_array(var,n);
                          varCO2o := varcovar
```

```
> v := 15.2148;
                                v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
  CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                            u := .2083411251
> var := array([seq(u,i=1..n)]);
  var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251]
> varCO2i := make_array(var,n);
                          varCO2i := varcovar
```

O2 re

```
> v := 5;
                                v := 5
> O2o := array([seq(v,i=1..n)]);
    O2o := [5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                                u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
    .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                          varO2o := varcovar
```

```
> v := 3.8;
                                v := 3.8
> O2i := array([seq(v,i=1..n)]);
  O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.
    3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                                u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
    .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                          varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                                Wma := .013
> varWma := (.2*Wma)^2;
                          varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                                v := .005
> COo := array([seq(v,i=1..n)]);
  COo := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005
    .005  .005  .005  .005  .005  .005  .005  .005]
```

```
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
   .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
   .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
  COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
   .005 .005 .005 .005 .005 .005 .005 .005]
> u := (0.001)^2;
                    u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
   .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
   .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.1*Ca)^2;
                    varCa := .0000236196
```

Area for Primary Air re

```
> apa := 0.63;
                    apa := .63
> varapa := (0.0208*apa)^2;
                    varapa := .000171714816
```

Results

```
*************************************************************************
> evalf(TFluegasINa);
                    754792.2100
> evalf(sigmaTFluegasINa);
                    5676.235856
> evalf(100*sigmaTFluegasINa/TFluegasINa);
                    .7520262903
*************************************************************************
>
```

532

Appendix G-1
Bias Error Calculation
Flue Gas Outlet Flow -- Zero Leak Case

```
>
>
```

Error Propagation Calculations, Part B, TFluegasOUTa -- Zero Leakage

Set no. of sample points

```
> n := 24;
                                   n := 24
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) \Big/ Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) \Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> Cb := C - Cr;

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

> WMGi := 8.936*H + (Wma*WAi)+Mf;

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei)$$

#26

> WGi := WGpi + WMGi;

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#27

> WAo :=(((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

> WMGo := 8.936*H + (Wma*WAo) + Mf;

$$WMGo := 8.936\ H + Wma \left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \right) + Mf$$

#29

> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

536

$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/(12.01\ CO2aveo+12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/(12.01\ CO2aveo+12.01\ COaveo)+8.936\ H+Wma\Bigg(36.46063760\ (100-CO2aveo-COaveo-O2aveo)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/(12.01\ CO2aveo+12.01\ COaveo)-1.301236174\ N\Bigg)+Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\Bigg(\frac{(15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}+Wma\left(36.46063760\ \frac{(100-CO2aveo-COaveo-O2aveo)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}-1.301236174\ N\right)-\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}-Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ N\right)\Bigg)\Bigg/\Bigg(\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}+8.936\ H+Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ N\right)+Mf\Bigg)$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

$$\%2 := 12.01\ CO2avei+12.01\ COavei$$

#33

```
> TFluegasOUTa := WGo*Wfe*SA;
```

$$TFluegasOUTa := \frac{1}{2}\Bigg((15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/(12.01\ CO2aveo+12.01\ COaveo)+8.936\ H+Wma\Bigg(36.46063760\ (100-CO2aveo-COaveo-O2aveo)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/(12.01\ CO2aveo+12.01\ COaveo)-1.301236174\ N\Bigg)+Mf\Bigg)\ Wfe$$

```
> sigmaTFluegasOUTa := sqrt(
> Diff(TFluegasOUTa,CO2avei)^2*varCO2avei +
> Diff(TFluegasOUTa,COavei)^2*varCOavei +
> Diff(TFluegasOUTa,O2avei)^2*varO2avei +
> Diff(TFluegasOUTa,Wfe)^2*varWfe +
> Diff(TFluegasOUTa,Areai)^2*varAreai +
> Diff(TFluegasOUTa,CP)^2*varCP +
> Diff(TFluegasOUTa,PSi)^2*varPSi +
> Diff(TFluegasOUTa,A)^2*varA +
```

```
> Diff(TFluegasOUTa,OUHD)^2*varOUHD +
> Diff(TFluegasOUTa,Ca)^2*varCa +
> Diff(TFluegasOUTa,C)*Diff(TFluegasOUTa,C)*varC +
> Diff(TFluegasOUTa,S)*Diff(TFluegasOUTa,S)*varS +
> Diff(TFluegasOUTa,H)*Diff(TFluegasOUTa,H)*varH +
> Diff(TFluegasOUTa,Wma)*Diff(TFluegasOUTa,Wma)*varWma +
> Diff(TFluegasOUTa,N)*Diff(TFluegasOUTa,N)*varN +
> Diff(TFluegasOUTa,Mf)*Diff(TFluegasOUTa,Mf)*varMf +
> sum(sum(
> Diff(TFluegasOUTa,DPi[i])*Diff(TFluegasOUTa,DPi[j])*varDPi[i,j] +
> Diff(TFluegasOUTa,Ti[i])*Diff(TFluegasOUTa,Ti[j])*varTi[i,j] +
> Diff(TFluegasOUTa,COi[i])*Diff(TFluegasOUTa,COi[j])*varCOi[i,j] +
> Diff(TFluegasOUTa,CO2i[i])*Diff(TFluegasOUTa,CO2i[j])*varCO2i[i,j] +
> Diff(TFluegasOUTa,O2i[i])*Diff(TFluegasOUTa,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):

> sigmaTFluegasOUTa := value(");
```

$$sigmaTFluegasOUTa := \Bigg(\Big(\frac{1}{2}\,\frac{\%4\ \%1}{\%2} + 4.468000000\ H$$

$$+ \frac{1}{2}\ Wma \left(36.46063760\ \frac{\%3\ \%1}{\%2} - 1.301236174\ N \right) + \frac{1}{2}\ Mf \Big)^2\ varWfe + \frac{1}{4} \Bigg($$

$$\frac{\%4 \left(-\frac{OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{(1-OUHD)\ Ca}{1-\frac{1}{3}\,Ca} \right)}{\%2}$$

$$+ 36.46063760\ \frac{Wma\ \%3 \left(-\frac{OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{(1-OUHD)\ Ca}{1-\frac{1}{3}\,Ca} \right)}{\%2} \Bigg)^2\ Wfe^2\ varA + \frac{1}{4}$$

$$\Bigg(\frac{\%4 \left(-\frac{A\ Ca}{1-Ca} + \frac{1}{3}\,\frac{A\ Ca}{1-\frac{1}{3}\,Ca} \right)}{\%2}$$

$$+ 36.46063760\ \frac{Wma\ \%3 \left(-\frac{A\ Ca}{1-Ca} + \frac{1}{3}\,\frac{A\ Ca}{1-\frac{1}{3}\,Ca} \right)}{\%2} \Bigg)^2\ Wfe^2\ varOUHD + \frac{1}{4} \Bigg($$

$$\frac{\%4 \left(-\frac{A\ OUHD}{1-Ca} - \frac{A\ OUHD\ Ca}{(1-Ca)^2} - \frac{1}{3}\,\frac{A\ (1-OUHD)}{1-\frac{1}{3}\,Ca} - \frac{1}{9}\,\frac{A\ (1-OUHD)\ Ca}{\left(1-\frac{1}{3}\,Ca\right)^2} \right)}{\%2} +$$

$$36.46063760\ Wma\ \%3$$

$$\left(-\frac{A\ OUHD}{1-Ca} - \frac{A\ OUHD\ Ca}{(1-Ca)^2} - \frac{1}{3}\,\frac{A\ (1-OUHD)}{1-\frac{1}{3}\,Ca} - \frac{1}{9}\,\frac{A\ (1-OUHD)\ Ca}{\left(1-\frac{1}{3}\,Ca\right)^2} \right) \Big/ (\%2) \Bigg)^2$$

$$Wfe^2\ varCa + \frac{1}{4} \left(\frac{\%4}{\%2} + 36.46063760\ \frac{Wma\ \%3}{\%2} \right)^2\ Wfe^2\ varC$$

$$+ \frac{1}{4} \left(.3744932959\ \frac{\%4}{\%2} + 13.65426435\ \frac{Wma\ \%3}{\%2} \right)^2\ Wfe^2\ varS$$

$$+ 19.96302400\ Wfe^2\ varH$$

$$+\frac{1}{4}\left(36.46063760\ \frac{\%3\ \%1}{\%2}-1.301236174\ N\right)^2\ Wfe^2\ varWma$$

$$\left.+.4233038951\ Wma^2\ Wfe^2\ varN+\frac{1}{4}\ Wfe^2\ varMf\right)^{1/2}$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

$$\%2 := 12.01\ CO2aveo+12.01\ COaveo$$

$$\%3 := 100-CO2aveo-COaveo-O2aveo$$

$$\%4 := 15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00$$

Constants

Averages and Variances from Part A

> CO2avei := 15.2148;

$CO2avei := 15.2148$

> varCO2avei := .1^2;

$varCO2avei := .01$

> COavei := .005;

$COavei := .005$

> varCOavei := .002^2;

$varCOavei := .4\ 10^{-5}$

> O2avei := 3.8;

$O2avei := 3.8$

> varO2avei := .05^2;

$varO2avei := .0025$

> CO2aveo := 15.2148;

$CO2aveo := 15.2148$

> varCO2aveo := .1^2;

$varCO2aveo := .01$

> COaveo := .005;

$COaveo := .005$

> varCOaveo := .002^2;

$varCOaveo := .4\ 10^{-5}$

> O2aveo := 3.8;

$O2aveo := 3.8$

> varO2aveo := .05^2;

$varO2aveo := .0025$

Coal Feed Rate (lbs/hr)

> Wfe := 115839;

$Wfe := 115839$

> varWfe := (0.05*Wfe)^2;

$varWfe := .3354668480\ 10^8$

Area (square ft)

> Areai := 3.99;

$Areai := 3.99$

> varAreai := (0.0335*Areai)^2;

$varAreai := .01786633223$

> Areao := 3.54;

$Areao := 3.54$

> varAreao := (0.0364*Areao)^2;

$varAreao := .01660386874$

Pitot Coefficient

> CP := 0.84;

$CP := .84$

> varCP := (0.01)^2;

$varCP := .0001$

Pressure in Area

> PSI := 29.23;

$PSi := 29.23$

> varPSI := (0.04)^2;

$varPSi := .0016$

```
> PSo := 29.1;
                    PSo := 29.1
> varPSo := (0.04)^2;
                    varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
                    PSpa := 31.11
> varPSpa := (0.04)^2;
                    varPSpa := .0016
>
```

Velocity Head

```
> v := .45802;
                    v := .45802
> DPo := array([seq(v,i=1..n)]);
  DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
    .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
    .45802  .45802  .45802  .45802  .45802]
> u := (.02*v)^2;
                    u := .00008391292816
> var := array([seq(u,i=1..n)]);
  var := [.00008391292816  .00008391292816  .00008391292816  .00008391292816
    .00008391292816  .00008391292816  .00008391292816  .00008391292816
    .00008391292816  .00008391292816  .00008391292816  .00008391292816
    .00008391292816  .00008391292816  .00008391292816  .00008391292816
    .00008391292816  .00008391292816  .00008391292816  .00008391292816
    .00008391292816  .00008391292816  .00008391292816  .000C8391292816]
> varDPo := make_array(var,n);
                    varDPo := varcovar

> v := .82831;
                    v := .82831
> DPi := array([seq(v,i=1..n)]);
  DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
    .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
    .82831  .82831  .82831  .82831  .82831]
> u := (.02*v)^2;
                    u := .0002744389824
> var := array([seq(u,i=1..n)]);
  var := [.0002744389824  .0002744389824  .0002744389824  .0002744389824
    .0002744389824  .0002744389824  .0002744389824  .0002744389824
    .0002744389824  .0002744389824  .0002744389824  .0002744389824
    .0002744389824  .0002744389824  .0002744389824  .0002744389824
    .0002744389824  .0002744389824  .0002744389824  .0002744389824
    .0002744389824  .0002744389824  .0002744389824  .0002744389824]
> varDPi := make_array(var,n);
                    varDPi := varcovar
```

Temperature (R)

```
> v := 713;
                    v := 713
> To := array([seq(v,i=1..n)]);
  To := [713  713  713  713  713  713  713  713  713  713  713  713  713  71:
    713  713  713  713  713  713  713  713  713  713]
> u := (0.01*(v-460))^2;
                    u := 6.4009
> var := array([seq(u,i=1..n)]);
  var := [6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009
    6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.400
    6.4009  6.4009  6.4009  6.4009  6.4009]
> varTo := make_array(var,n);
                    varTo := varcovar

> v := 1140;
                    v := 1140
> Ti:= array([seq(v,i=1..n)]);
  Ti := [1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
    1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
    1140]
> u := (0.01*(v-460))^2;
                    u := 46.2400
> var := array([seq(u,i=1..n)]);
  var := [46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400
    46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400
    46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400]
> varTi := make_array(var,n);
```

540

varTi := *varcovar*

Moisture in Coal

```
> Mf :=0.06;
```

Mf := .06

```
> varMf := (0.039*Mf)^2;
```

varMf := .54756 10^{-5}

Ash

```
> A := 0.0619;
```

A := .0619

```
> varA := ( 0.039*A)^2;
```

varA := .582787881 10^{-5}

Overhead

```
> OUHD := 0.9;
```

OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon

```
> C := 0.7381;
```

C := .7381

```
> varC := (0.039*C)^2;
```

varC := .0008286280388

Hydrogen

```
> H := 0.0482;
```

H := .0482

```
> varH := (0.039*H)^2;
```

varH := .353364804 10^{-5}

Nitrogen

```
> N := 0.0135;
```

N := .0135

```
> varN := (0.039*N)^2;
```

varN := .27720225 10^{-6}

Sulfur

```
> S := 0.0123;
```

S := .0123

```
> varS := (0.019*S)^2;
```

varS := .5461569 10^{-7}

CO2

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145
14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.14
14.145 14.145 14.145 14.145 14.145]

```
> u := (0.1)^2;
```

u := .01

```
> var := array([seq(u,i=1..n)]);
```

var := [.01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .0
.01 .01 .01 .01 .01 .01 .01 .01 .01]

```
> varCO2o := make_array(var,n);
```

varCO2o := *varcovar*

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.214
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148]

```
> u := (0.1)^2;
```

u := .01

```
> var := array([seq(u,i=1..n)]);
```

var := [.01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .0
.01 .01 .01 .01 .01 .01 .01 .01 .01]

```
> varCO2i := make_array(var,n);
```

varCO2i := *varcovar*

O2

```
> v := 5;
```

v := 5

```
> O2o := array([seq(v,i=1..n)]);
O2o :=
[5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5]
> u := (0.05)^2;
u := .0025
> var := array([seq(u,i=1..n)]);
var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025]
> varO2o := make_array(var,n);
varO2o := varcovar
```

```
> v := 3.8;
v := 3.8
> O2i := array([seq(v,i=1..n)]);
O2i := [3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8
3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8]
> u := (0.05)^2;
u := .0025
> var := array([seq(u,i=1..n)]);
var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025]
> varO2i := make_array(var,n);
varO2i := varcovar
```

Moisture (air)

```
> Wma := 0.013;
Wma := .013
> varWma := (.1*Wma)^2;
varWma := .169 10^-5
```

CO

```
> v := 0.004;
v := .004
> COo := array([seq(v,i=1..n)]);
COo := [.004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004
.004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004]
```

```
> u := (0.002)^2;
u := .4 10^-5
> var := array([seq(u,i=1..n)]);
var := [.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5
.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5
.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5]
> varCOo := make_array(var,n);
varCOo := varcovar
```

```
> v := 0.005;
v := .005
> COi := array([seq(v,i=1..n)]);
COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005]
> u := (0.002)^2;
u := .4 10^-5
> var := array([seq(u,i=1..n)]);
var := [.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5
.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5
.4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5 .4 10^-5]
> varCOi := make_array(var,n);
varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
Ca := .0486
> varCa := (0.25*Ca)^2;
varCa := .000147622500
```

Area for primary air

```
> apa := .63;
apa := .63
> varapa := (.013)^2;
varapa := .000169
```

```
> v := .2171;
```

```
                          v := .2171
> DPpa := array([seq(v,i=1..n)]);
    DPpa := [.2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171
      .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171
      .2171  .2171  .2171]
> u := 0.02*v;
                          u := .004342
> varDPpa := array([seq(u,i=1..n)]);
    varDPpa := [.004342  .004342  .004342  .004342  .004342  .004342  .004342
      .004342  .004342  .004342  .004342  .004342  .004342  .004342  .004342
      .004342  .004342  .004342  .004342  .004342  .004342  .004342  .004342
      .004342]
> varDPpa := make_array(var,n);
                     varDPpa := varcovar

> v := 1104;
                          v := 1104
> Tpa := array([seq(v,i=1..n)]);
    Tpa := [1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
      1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
      1104]
> u := 0.01*(v - 460);
                          u := 6.44
> var := array([seq(u,i=1..n)]);
    var := [6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44
      6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44  6.44]
> varTpa := make_array(var,n);
                     varTpa := varcovar

Results
****************************************************************************
> eval(TFluegasOUTa);
                          754792.2100
> eval(sigmaTFluegasOUTa);
                          47176.46258
> eval(100*sigmaTFluegasOUTa/TFluegasOUTa);
                          6.250258277
****************************************************************************
```

```
> i := 'i';
                          i := i

#13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                          m := 28.74570417

#14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                          PAFA := 75035.78706

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                          PAFB := 75035.78706

#17
> FA := 5348840*Areal*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#18
> FB := 5348840*Areal*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#19
> SA := FA/(FA+FB);
                          SA := .5000000000

#20
> SB := FB/(FA+FB);
                          SB := .5000000000

#21
> WPAIA := PAFA/(Wfe*SA);
                          WPAIA := 1.295518557

#22
> WPAIB := PAFB/(Wfe*SB);
```

```
WPAIB := 1.295518557

#23
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
Cr := .002947741741

> Cb := C - Cr;
Cb := .7351522583

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
WAi := 11.93169660

#24
> WMGi := 8.936*H + (Wma*WAi)+Mf;
WMGi := .6458272558

#25
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
WGpi := 12.38591870

#26
> WGi := WGpi + WMGi;
WGi := 13.03174596

#27
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
WAo := 11.93169660

#28
> WMGo := 8.936*H + (Wma*WAo) + Mf;
WMGo := .6458272558

#29
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
WGpo := 12.38591870

#30
> WGo := WGpo + WMGo;
WGo := 13.03174596

#31
> AL := ((WGo-WGi)/WGi)*100;
AL := 0

#32
TFluegasINa := WGi*Wfe*SA;
TFluegasINb := WGi*Wfe*SB;

#33
> TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTa := 754792.2100

TFluegasOUTb := WGo*Wfe*SB;
>
```

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Appendix G-2
Random Error Calculation
Flue Gas Outlet Flow -- Zero Leak Case

```
>
>
```

Random Error Propagation Calculations, Part B, TFluegasOUTa Zero Leak

Set no. of sample points

```
> n := 24;
                              n := 24
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#5

```
O2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*O2o[i],i=1..n)/sum((DPo[i]/(To[i]*M(i
,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

O2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#7

```
CO2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/sum((DPo[i]/(To[i]*
M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,
COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
CO2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,
OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO
2i,H,Wma,O2i,N,Mf)),i=1..n);
```

#8

```
COaveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*COo[i],i=1..n)/sum((DPo[i]/(To[i]*M(
i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
COavei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*COi[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) \Big/ Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) \Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAI := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGI := 8.936*H + (Wma*WAI)+Mf;
```

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

```
> WGpI := ((44.01*CO2aveI+32.02*O2aveI+28.01*COaveI+28.02*(100-CO2aveI-COav
> eI-O2aveI))/(12.01*(CO2aveI+COaveI))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) \Big/ (12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpI + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$

$$\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2avei+12.01\ COavei\big)+8.936\ H+Wma\Big(36.46063760$$

$$(100-CO2avei-COavei-O2avei)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2avei+12.01\ COavei\big)-1.301236174\ N\Big)+Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100-CO2aveo-COaveo-O2aveo)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2aveo+12.01\ COaveo\big)-1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H+Wma\Big(36.46063760\ (100-CO2aveo-COaveo-O2aveo)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2aveo+12.01\ COaveo\big)-1.301236174\ N\Big)+Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2aveo+12.01\ COaveo\big)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2aveo+12.01\ COaveo\big)+8.936\ H+Wma\Big(36.46063760$$

$$(100-CO2aveo-COaveo-O2aveo)\left(C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S\right)\Big/\big(12.01\ CO2aveo+12.01\ COaveo\big)-1.301236174\ N\Big)+Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\Bigg(\frac{(15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}$$

$$+Wma\left(36.46063760\ \frac{(100-CO2aveo-COaveo-O2aveo)\ \%1}{12.01\ CO2aveo+12.01\ COaveo}-1.301236174\ \right.$$

$$-\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}$$

$$-Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ \right.$$

$$\Bigg)\Bigg/\Bigg(\frac{(15.99\ CO2avei+4.00\ O2avei-.01\ COavei+2802.00)\ \%1}{\%2}+8.936\ H$$

$$+Wma\left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \%1}{\%2}-1.301236174\ \right.$$

$$+Mf\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#33

```
> TFluegasOUTa := WGo*Wfe*SA;
```

$$TFluegasOUTa := \frac{1}{2}\left((15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\right.$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$
$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\left(36.46063760\right.$$
$$(100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$
$$\left.\left.12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf\right)\ Wfe$$

```
> sigmaTFluegasOUTa := sqrt(
> Diff(TFluegasOUTa,CO2avei)^2*varCO2avei +
> Diff(TFluegasOUTa,COavei)^2*varCOavei +
> Diff(TFluegasOUTa,O2avei)^2*varO2avei +
> Diff(TFluegasOUTa,Wfe)^2*varWfe +
> Diff(TFluegasOUTa,Areai)^2*varAreai +
> Diff(TFluegasOUTa,CP)^2*varCP +
> Diff(TFluegasOUTa,PSI)^2*varPSI +
> Diff(TFluegasOUTa,A)^2*varA +
> Diff(TFluegasOUTa,OUHD)^2*varOUHD +
> Diff(TFluegasOUTa,Ca)^2*varCa +
> Diff(TFluegasOUTa,C)*Diff(TFluegasOUTa,C)*varC +
> Diff(TFluegasOUTa,S)*Diff(TFluegasOUTa,S)*varS +
> Diff(TFluegasOUTa,H)*Diff(TFluegasOUTa,H)*varH +
> Diff(TFluegasOUTa,Wma)*Diff(TFluegasOUTa,Wma)*varWma +
> Diff(TFluegasOUTa,N)*Diff(TFluegasOUTa,N)*varN +
> Diff(TFluegasOUTa,Mf)*Diff(TFluegasOUTa,Mf)*varMf +
> sum(
> Diff(TFluegasOUTa,DPI[i])*Diff(TFluegasOUTa,DPI[i])*varDPI[i,i] +
> Diff(TFluegasOUTa,Ti[i])*Diff(TFluegasOUTa,Ti[i])*varTi[i,i] +
> Diff(TFluegasOUTa,COi[i])*Diff(TFluegasOUTa,COi[i])*varCOi[i,i] +
> Diff(TFluegasOUTa,CO2i[i])*Diff(TFluegasOUTa,CO2i[i])*varCO2i[i,i] +
> Diff(TFluegasOUTa,O2i[i])*Diff(TFluegasOUTa,O2i[i])*varO2i[i,i]
> ,i=1..n)):
```

```
> sigmaTFluegasOUTa := value("):
```

Constants

Averages and Random Error Variances (Copied from Part A -- function of sample size n)

```
> CO2avei := 15.2148;
```

$$CO2avei := 15.2148$$

```
> varCO2avei := .102^2;
```

$$varCO2avei := .010404$$

```
> COavei := .005;
```

$$COavei := .005$$

```
> varCOavei := .0002^2;
```
$varCOavei := .4\ 10^{-7}$

```
> O2avei := 3.8;
```
$O2avei := 3.8$

```
> varO2avei := .01118^2;
```
$varO2avei := .0001249924$

```
> CO2aveo := 15.2148;
```
$CO2aveo := 15.2148$

```
> varCO2aveo := .0866^2;
```
$varCO2aveo := .00749956$

```
> COaveo := .005;
```
$COaveo := .005$

```
> varCOaveo := .000204^2;
```
$varCOaveo := .41616\ 10^{-7}$

```
> O2aveo := 3.8;
```
$O2aveo := 3.8$

```
> varO2aveo := .010206^2;
```
$varO2aveo := .000104162436$

Constants for Random Error Propagation

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
```
$Wfe := 115839$

```
> varWfe := (0.0025*Wfe)^2;
```
$varWfe := 83866.71200$

Area (square ft) re

```
> Areai := 3.99;
```
$Areai := 3.99$

```
> varAreai := (0.0335*Areai)^2;
```
$varAreai := .01786633223$

```
> Areao := 3.54;
```
$Areao := 3.54$

```
> varAreao := (0.0364*Areao)^2;
```
$varAreao := .01660386874$

Pitot Coefficient re

```
> CP := 0.84;
```
$CP := .84$

```
> varCP := (0)^2;
```
$varCP := 0$

Pressure Ambient or Barometric re

```
> PSi := 29.23;
```
$PSi := 29.23$

```
> varPSi := (0.04)^2;
```
$varPSi := .0016$

```
> PSo := 29.1;
```
$PSo := 29.1$

```
> varPSo := (0.04)^2;
```
$varPSo := .0016$

Pressue for primary air

```
> PSpa := 31.11;
```
$PSpa := 31.11$

```
> varPSpa := (0.04)^2;
```
$varPSpa := .0016$

```
>
```

Velocity Head DP re

```
> v := .45802;
```
$v := .45802$

```
> DPo := array([seq(v,i=1..n)]);
```
$DPo := [.45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802$
$.45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802\ \ .458$
$.45802\ \ .45802\ \ .45802\ \ .45802\ \ .45802]$

```
> u := .00005^2;
```
$u := .25\ 10^{-8}$

```
> var := array([seq(u,i=1..n)]);
```
$var := [.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10$

```
      .25  10^(-8)]
> varDPo := make_array(var,n);
                              varDPo := varcovar

> v := .82831;
                              v := .82831
> DPi := array([seq(v,l=1..n)]);
   DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
     .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
     .82831  .82831  .82831  .82831  .82831]
> u := .00005^2;
                              u := .25  10^(-8)
> var := array([seq(u,l=1..n)]);
   var := [.25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)]
> varDPi := make_array(var,n);
                              varDPi := varcovar
>

> v := .2171;
                              v := .2171
> DPpa := array([seq(v,l=1..n)]);
    DPpa := [.2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171
      .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171
      .2171  .2171  .2171]
> u := (0.00005)^2;
                              u := .25  10^(-8)
> var := array([seq(u,l=1..n)]);
   var := [.25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)  .25 10^(-8)
     .25 10^(-8)]
> varDPpa := make_array(var,n);
                              varDPpa := varcovar

> v := 1104;
                              v := 1104
> Tpa := array([seq(v,l=1..n)]);
    Tpa := [1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
      1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104  1104
      1104]
> u := (0.005*(v - 460))^2;
                              u := 10.368400
> var := array([seq(u,l=1..n)]);
    var := [10.368400  10.368400  10.368400  10.368400  10.368400  10.368400
      10.368400  10.368400  10.368400  10.368400  10.368400  10.368400  10.368400
      10.368400  10.368400  10.368400  10.368400  10.368400  10.368400  10.368400
      10.368400  10.368400  10.368400  10.368400]
> varTpa := make_array(var,n);
                              varTpa := varcovar

Temperature (R) re
> v := 713;
                              v := 713
> To := array([seq(v,l=1..n)]);
    To := [713  713  713  713  713  713  713  713  713  713  713  713  713  71:
      713  713  713  713  713  713  713  713  713  713]
> u := (0.005*(v-460))^2;
                              u := 1.600225
> var := array([seq(u,l=1..n)]);
   var := [1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225
     1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.60022
     1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.60022
     1.600225]
> varTo := make_array(var,n);
                              varTo := varcovar

> v := 1140;
                              v := 1140
> Ti:= array([seq(v,l=1..n)]);
    Ti := [1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
      1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
```

1140]

```
> u := (0.005*(v-460))^2;
```

u := 11.560000

```
> var := array([seq(u,i=1..n)]);
```

var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000]

```
> varTi := make_array(var,n);
```

varTi := varcovar

Moisture in Ash re

```
> Mf :=0.06;
```

Mf := .06

```
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
```

varMf := .00001058319613

Ash re

```
> A := 0.0619;
```

A := .0619

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```

varA := $.4696223261 \; 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```

OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon re

```
> C := 0.7381;
```

C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```

varC := $.5121546706 \; 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```

H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```

varH := $.3200966692 \; 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```

N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```

varN := $.1512956913 \; 10^{-6}$

Sulfur re

```
> S := 0.0123;
```

S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```

varS := $.1327813813 \; 10^{-6}$

CO2 re

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145
14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.14
14.145 14.145 14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```

u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```

var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225]

```
> varCO2o := make_array(var,n);
```

varCO2o := varcovar

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148]

```
> u := (0.03*v)^2;
```

u := .2083411251

```
> var := array([seq(u,i=1..n)]);
```

var := [.2083411251 .2083411251]

```
> varCO2i := make_array(var,n);
```

varCO2i := varcovar

O2 re

```
> v := 5;
```

v := 5

```
> O2o := array([seq(v,i=1..n)]);
```

O2o :=
[5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025]

```
> varO2o := make_array(var,n);
```

varO2o := varcovar

```
> v := 3.8;
```

v := 3.8

```
> O2i := array([seq(v,i=1..n)]);
```

O2i := [3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025]

```
> varO2i := make_array(var,n);
```

varO2i := varcovar

Moisture (air) re

```
> Wma := 0.013;
```

Wma := .013

```
> varWma := (.2*Wma)^2;
```

varWma := $.676 \; 10^{-5}$

CO re

```
> v := 0.004;
```

v := .004

```
> COo := array([seq(v,i=1..n)]);
```

COo := [.004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004 .004]

```
> u := (0.001)^2;
```

u := $.1 \; 10^{-5}$

```
> var := array([seq(u,i=1..n)]);
```

var := [$.1\;10^{-5}$ $.1\;10^{-5}$]

```
> varCOo := make_array(var,n);
```

varCOo := varcovar

```
> v := 0.005;
```

v := .005

```
> COi := array([seq(v,i=1..n)]);
```

COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005]

```
> u := (0.001)^2;
```

u := $.1 \; 10^{-5}$

```
> var := array([seq(u,i=1..n)]);
```

var := [$.1\;10^{-5}$ $.1\;10^{-5}$]

```
> varCOi := make_array(var,n);
```

varCOi := varcovar

Carbon in Ash re

```
> Ca := 0.0486;
```

Ca := .0486

```
> varCa := (0.1*Ca)^2;
```

varCa := .0000236196

Area for Primary Air re

```
> apa := 0.63;
```

apa := .63

```
> varapa := (0.0208*apa)^2;
```

varapa := .000171714816

Results

****

```
> evalf(TFluegasOUTa);
```

754792.2100

```
> evalf(sigmaTFluegasOUTa);
```

3463.473784

```
> evalf(100*sigmaTFluegasOUTa/TFluegasOUTa);
```

.4588645376

****

```
>
```

555

Appendix G-3
Bias Error Calculation
Flue Gas Outlet Flow -- With Leak Case

```
>
>
```

Error Propagation Calculations, Part B, TFluegas~~INa~~ OUT

Set no. of sample points

```
> n := 24;
```

$n := 24$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

556

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right) / Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right) / Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
b := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
Ai := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

4

```
MGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \Bigg) + Mf$$

5

```
Gpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei)$$

6

```
Gi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \Bigg) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \Bigg) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S\right)/($$

$$12.01\ \ CO2aveo+12.01\ \ COaveo)$$

#30

WGo := WGpo + WMGo;

$$WGo := (15.99\ \ CO2aveo+4.00\ \ O2aveo-.01\ \ COaveo+2802.00)$$
$$\left(C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S\right)/($$
$$12.01\ \ CO2aveo+12.01\ \ COaveo)+8.936\ \ H+Wma\ \Bigg(36.46063760$$
$$(100-CO2aveo-COaveo-O2aveo)$$
$$\left(C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S\right)/($$
$$12.01\ \ CO2aveo+12.01\ \ COaveo)-1.301236174\ \ N\Bigg)+Mf$$

#31

AL := ((WGo-WGi)/WGi)*100;

$$AL := 100\ \Bigg(\frac{(15.99\ \ CO2aveo+4.00\ \ O2aveo-.01\ \ COaveo+2802.00)\ \ \%1}{12.01\ \ CO2aveo+12.01\ \ COaveo}$$
$$+\ Wma\ \left(36.46063760\ \frac{(100-CO2aveo-COaveo-O2aveo)\ \ \%1}{12.01\ \ CO2aveo+12.01\ \ COaveo}-1.301236174\ \ N\right)$$
$$-\frac{(15.99\ \ CO2avei+4.00\ \ O2avei-.01\ \ COavei+2802.00)\ \ \%1}{\%2}$$
$$-\ Wma\ \left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \ \%1}{\%2}-1.301236174\ \ N\right)$$
$$\Bigg)\Big/\Bigg(\frac{(15.99\ \ CO2avei+4.00\ \ O2avei-.01\ \ COavei+2802.00)\ \ \%1}{\%2}+8.936\ \ H$$
$$+\ Wma\ \left(36.46063760\ \frac{(100-CO2avei-COavei-O2avei)\ \ \%1}{\%2}-1.301236174\ \ N\right)$$
$$+\ Mf\Bigg)$$

$$\%1 := C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S$$

$$\%2 := 12.01\ \ CO2avei+12.01\ \ COavei$$

#33

> TFluegasOUTa := WGo*Wfe*SA;

$$TFluegasOUTa := \frac{1}{2}\ \Bigg((15.99\ \ CO2aveo+4.00\ \ O2aveo-.01\ \ COaveo+2802.00)$$
$$\left(C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S\right)/($$
$$12.01\ \ CO2aveo+12.01\ \ COaveo)+8.936\ \ H+Wma\ \Bigg(36.46063760$$
$$(100-CO2aveo-COaveo-O2aveo)$$
$$\left(C-\frac{A\ \ OUHD\ \ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ \ (1-OUHD)\ \ Ca}{1-\frac{1}{3}\ \ Ca}+.3744932959\ \ S\right)/($$
$$12.01\ \ CO2aveo+12.01\ \ COaveo)-1.301236174\ \ N\Bigg)+Mf\Bigg)\ \ Wfe$$

> sigmaTFluegasOUTa := sqrt(

> Diff(TFluegasOUTa,CO2avei)^2*varCO2avei +

> Diff(TFluegasOUTa,COavei)^2*varCOavei +

> Diff(TFluegasOUTa,O2avei)^2*varO2avei +

> Diff(TFluegasOUTa,Wfe)^2*varWfe +

> Diff(TFluegasOUTa,Areai)^2*varAreai +

> Diff(TFluegasOUTa,CP)^2*varCP +

> Diff(TFluegasOUTa,PSi)^2*varPSi +

> Diff(TFluegasOUTa,A)^2*varA +

```
ff(TFluegasOUTa,OUHD)^2*varOUHD +
ff(TFluegasOUTa,Ca)^2*varCa +
ff(TFluegasOUTa,C)*Diff(TFluegasOUTa,C)*varC +
ff(TFluegasOUTa,S)*Diff(TFluegasOUTa,S)*varS +
ff(TFluegasOUTa,H)*Diff(TFluegasOUTa,H)*varH +
ff(TFluegasOUTa,Wma)*Diff(TFluegasOUTa,Wma)*varWma +
ff(TFluegasOUTa,N)*Diff(TFluegasOUTa,N)*varN +
ff(TFluegasOUTa,Mf)*Diff(TFluegasOUTa,Mf)*varMf +
im(sum(
ff(TFluegasOUTa,DPi[i])*Diff(TFluegasOUTa,DPi[j])*varDPi[i,j] +
ff(TFluegasOUTa,Ti[i])*Diff(TFluegasOUTa,Ti[j])*varTi[i,j] +
iff(TFluegasOUTa,COi[i])*Diff(TFluegasOUTa,COi[j])*varCOi[i,j] +
iff(TFluegasOUTa,CO2i[i])*Diff(TFluegasOUTa,CO2i[j])*varCO2i[i,j] +
iff(TFluegasOUTa,O2i[i])*Diff(TFluegasOUTa,O2i[j])*varO2i[i,j]
1..n),i=1..n)):

jmaTFluegasOUTa := value(");
```

$$sigmaTFluegasOUTa := \Bigg(\Big(\frac{1}{2} \frac{\%4 \ \%1}{\%2} + 4.468000000 \ H + \frac{1}{2} \ Wma \left(36.46063760 \ \frac{\%3 \ \%1}{\%2} - 1.301236174 \ N \right) + \frac{1}{2} \ Mf \Big)^2 \ varWfe + \frac{1}{4} \Bigg($$

$$\frac{\%4 \left(-\frac{OUHD \ Ca}{1 - Ca} - \frac{1}{3} \frac{(1 - OUHD) \ Ca}{1 - \frac{1}{3} \ Ca} \right)}{\%2} + 36.46063760 \ \frac{Wma \ \%3 \left(-\frac{OUHD \ Ca}{1 - Ca} - \frac{1}{3} \frac{(1 - OUHD) \ Ca}{1 - \frac{1}{3} \ Ca} \right)}{\%2} \Bigg)^2 \ Wfe^2 \ varA + \frac{1}{4} \Bigg($$

$$\frac{\%4 \left(-\frac{A \ Ca}{1 - Ca} + \frac{1}{3} \frac{A \ Ca}{1 - \frac{1}{3} \ Ca} \right)}{\%2} + 36.46063760 \ \frac{Wma \ \%3 \left(-\frac{A \ Ca}{1 - Ca} + \frac{1}{3} \frac{A \ Ca}{1 - \frac{1}{3} \ Ca} \right)}{\%2} \Bigg)^2 \ Wfe^2 \ varOUHD + \frac{1}{4} \Bigg($$

$$\frac{\%4 \left(-\frac{A \ OUHD}{1 - Ca} - \frac{A \ OUHD \ Ca}{(1 - Ca)^2} - \frac{1}{3} \frac{A \ (1 - OUHD)}{1 - \frac{1}{3} \ Ca} - \frac{1}{9} \frac{A \ (1 - OUHD) \ Ca}{\left(1 - \frac{1}{3} \ Ca\right)^2} \right)}{\%2} +$$

$$36.46063760 \ Wma \ \%3 \left(-\frac{A \ OUHD}{1 - Ca} - \frac{A \ OUHD \ Ca}{(1 - Ca)^2} - \frac{1}{3} \frac{A \ (1 - OUHD)}{1 - \frac{1}{3} \ Ca} - \frac{1}{9} \frac{A \ (1 - OUHD) \ Ca}{\left(1 - \frac{1}{3} \ Ca\right)^2} \right) / (\%2) \Bigg)^2$$

$$Wfe^2 \ varCa + \frac{1}{4} \left(\frac{\%4}{\%2} + 36.46063760 \ \frac{Wma \ \%3}{\%2} \right)^2 \ Wfe^2 \ varC$$

$$+ \frac{1}{4} \left(.3744932959 \ \frac{\%4}{\%2} + 13.65426435 \ \frac{Wma \ \%3}{\%2} \right)^2 \ Wfe^2 \ varS$$

$$+ 19.96302400 \ Wfe^2 \ varH$$

$$+\frac{1}{4}\left(36.46063760\,\frac{\%3\ \%1}{\%2}-1.301236174\ N\right)^2\ Wfe^2\ varWma$$

$$\left.+.4233038951\ Wma^2\ Wfe^2\ varN+\frac{1}{4}\ Wfe^2\ varMf\right)^{1/2}$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

$$\%2 := 12.01\ CO2aveo+12.01\ COaveo$$

$$\%3 := 100-CO2aveo-COaveo-O2aveo$$

$$\%4 := 15.99\ CO2aveo+4.00\ O2aveo-.01\ COaveo+2802.00$$

onstants

verages and Variances from Part A

O2avei := 15.2148;

$CO2avei := 15.2148$

arCO2avei := .1^2;

$varCO2avei := .01$

Oavei := .005;

$COavei := .005$

arCOavei := .002^2;

$varCOavei := .4\ 10^{-5}$

2avei := 3.8;

$O2avei := 3.8$

arO2avei := .05^2;

$varO2avei := .0025$

O2aveo := 14.145;

$CO2aveo := 14.145$

arCO2aveo := .1^2;

$varCO2aveo := .01$

> COaveo := .005;

$COaveo := .005$

> varCOaveo := .002^2;

$varCOaveo := .4\ 10^{-5}$

> O2aveo := 5;

$O2aveo := 5$

> varO2aveo := .05^2;

$varO2aveo := .0025$

Coal Feed Rate (lbs/hr)

> Wfe := 115839;

$Wfe := 115839$

> varWfe := (0.05*Wfe)^2;

$varWfe := .3354668480\ 10^8$

Area (square ft)

> Areai := 3.99;

$Areai := 3.99$

> varAreai := (0.0335*Areai)^2;

$varAreai := .01786633223$

> Areao := 3.54;

$Areao := 3.54$

> varAreao := (0.0364*Areao)^2;

$varAreao := .01660386874$

Pitot Coefficient

> CP := 0.84;

$CP := .84$

> varCP := (0.01)^2;

$varCP := .0001$

Pressure in Area

> PSi := 29.23;

$PSi := 29.23$

> varPSi := (0.04)^2;

$varPSi := .0016$

```
o := 29.1;
                    PSo := 29.1
PSo := (0.04)^2;
                    varPSo := .0016

ssue for primary air
a := 31.11;
                    PSpa := 31.11
PSpa := (0.04)^2;
                    varPSpa := .0016

city Head
.45802;
                    v := .45802
 := array([seq(v,i=1..n)]);
Po := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
45802  .45802  .45802  .45802  .45802]
(.02*v)^2;
                    u := .00008391292816
= array([seq(u,i=1..n)]);
var := [.00008391292816  .00008391292816  .00008391292816  .00008391292816
  .00008391292816  .00008391292816  .00008391292816  .00008391292816
  .00008391292816  .00008391292816  .00008391292816  .00008391292816
  .00008391292816  .00008391292816  .00008391292816  .00008391292816
  .00008391292816  .00008391292816  .00008391292816  .00008391292816
  .00008391292816  .00008391292816  .00008391292816  .00008391292816]
Po := make_array(var,n);
                    varDPo := varcovar

.82831;
                    v := .82831
= array([seq(v,i=1..n)]);
i := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
2831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
2831  .82831  .82831  .82831  .82831]
.02*v)^2;
```

```
                    u := .0002744389824
> var := array([seq(u,i=1..n)]);
    var := [.0002744389824  .0002744389824  .0002744389824  .0002744389824
      .0002744389824  .0002744389824  .0002744389824  .0002744389824
      .0002744389824  .0002744389824  .0002744389824  .0002744389824
      .0002744389824  .0002744389824  .0002744389824  .0002744389824
      .0002744389824  .0002744389824  .0002744389824  .0002744389824
      .0002744389824  .0002744389824  .0002744389824  .0002744389824]
> varDPi := make_array(var,n);
                    varDPi := varcovar

Temperature (R)
> v := 713;
                    v := 713
> To := array([seq(v,i=1..n)]);
  To := [713  713  713  713  713  713  713  713  713  713  713  713  713  713
    713  713  713  713  713  713  713  713  713  713]
> u := (0.01*(v-460))^2;
                    u := 6.4009
> var := array([seq(u,i=1..n)]);
  var := [6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009
    6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009  6.4009
    6.4009  6.4009  6.4009  6.4009  6.4009]
> varTo := make_array(var,n);
                    varTo := varcovar

> v := 1140;
                    v := 1140
> Ti:= array([seq(v,I=1..n)]);
    Ti := [1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
      1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
      1140]
> u := (0.01*(v-460))^2;
                    u := 46.2400
> var := array([seq(u,i=1..n)]);
  var := [46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400
    46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400
    46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400  46.2400]
> varTi := make_array(var,n);
```

varTi := varcovar

Moisture in Coal

```
Mf :=0.06;
```

Mf := .06

```
varMf := (0.039*Mf)^2;
```

$varMf := .54756\ 10^{-5}$

Ash

```
A := 0.0619;
```

A := .0619

```
varA := ( 0.039*A)^2;
```

$varA := .582787881\ 10^{-5}$

Overhead

```
OUHD := 0.9;
```

OUHD := .9

```
varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon

```
C := 0.7381;
```

C := .7381

```
varC := (0.039*C)^2;
```

varC := .0008286280388

Hydrogen

```
H := 0.0482;
```

H := .0482

```
varH := (0.039*H)^2;
```

$varH := .353364804\ 10^{-5}$

Nitrogen

```
N := 0.0135;
```

N := .0135

```
varN := (0.039*N)^2;
```

$varN := .27720225\ 10^{-6}$

Sulfur

```
> S := 0.0123;
```

S := .0123

```
> varS := (0.019*S)^2;
```

$varS := .5461569\ 10^{-7}$

CO2

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145]

```
> u := (0.1)^2;
```

u := .01

```
> var := array([seq(u,i=1..n)]);
```

var := [.01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01]

```
> varCO2o := make_array(var,n);
```

varCO2o := varcovar

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148]

```
> u := (0.1)^2;
```

u := .01

```
> var := array([seq(u,i=1..n)]);
```

var := [.01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01 .01]

```
> varCO2i := make_array(var,n);
```

varCO2i := varcovar

O2

```
> v := 5;
```

v := 5

```
)2o := array([seq(v,i=1..n)]);
O2o :=
[5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]

:= (0.05)^2;
                    u := .0025

ar := array([seq(u,i=1..n)]);
var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025]

arO2o := make_array(var,n);
                    varO2o := varcovar

:= 3.8;
                    v := 3.8

2i := array([seq(v,i=1..n)]);
O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8
  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]

:= (0.05)^2;
                    u := .0025

ir := array([seq(u,i=1..n)]);
var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025]

irO2i := make_array(var,n);
                    varO2i := varcovar
```

oisture (air)

```
ma := 0.013;
                    Wma := .013

irWma := (.1*Wma)^2;
                    varWma := .169 10^-5
```

)

```
:= 0.004;
                    v := .004

)o := array([seq(v,i=1..n)]);
COo := [.004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004
  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004]
```

```
> u := (0.002)^2;
                    u := .4 10^-5

> var := array([seq(u,i=1..n)]);
var := [.4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5
  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5
  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5]

> varCOo := make_array(var,n);
                    varCOo := varcovar

> v := 0.005;
                    v := .005

> COi := array([seq(v,i=1..n)]);
COi := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005
  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005]

> u := (0.002)^2;
                    u := .4 10^-5

> var := array([seq(u,i=1..n)]);
var := [.4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5
  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5
  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5  .4 10^-5]

> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
                    Ca := .0486

> varCa := (0.25*Ca)^2;
                    varCa := .000147622500
```

Area for primary air

```
> apa := .63;
                    apa := .63

> varapa := (.013)^2;
                    varapa := .000169

> v := .2171;
```

```
v := .2171
DPpa := array([seq(v,i=1..n)]);
DPpa := [.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171
.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171
.2171 .2171 .2171]
u := 0.02*v;
u := .004342
varDPpa := array([seq(u,i=1..n)]);
varDPpa := [.004342 .004342 .004342 .004342 .004342 .004342 .004342
.004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342
.004342 .004342 .004342 .004342 .004342 .004342 .004342 .004342
.004342]
varDPpa := make_array(var,n);
varDPpa := varcovar

v := 1104;
v := 1104
Tpa := array([seq(v,i=1..n)]);
Tpa := [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
1104]
u := 0.01*(v - 460);
u := 6.44
var := array([seq(u,i=1..n)]);
var := [6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44
6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44 6.44]
varTpa := make_array(var,n);
varTpa := varcovar

Results

*****************************************************************************
eval(TFluegasINa);
eval(sigmaTFluegasINa);
eval(100*sigmaTFluegasINa/TFluegasINa);
*****************************************************************************

eval(TFluegasINb);
eval(sigmaTFluegasINb);

*****************************************************************************
> eval(TFluegasOUTa);
806591.6480
> eval(sigmaTFluegasOUTa);
50458.32200
> eval(100*sigmaTFluegasOUTa/TFluegasOUTa);
6.255745658
*****************************************************************************

eval(TFluegasOUTb);
eval(sigmaTFluegasOUTb);

Recalculate Other Results

> i := 'i';
i := i

#13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
m := 28.74570417

#14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
PAFA := 75035.78706

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
PAFB := 75035.78706

#17
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#18
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#19
```

```
;A := FA/(FA+FB);
                    SA := .5000000000

!20
;B := FB/(FA+FB);
                    SB := .5000000000

!21
VPAIA := PAFA/(Wfe*SA);
                    WPAIA := 1.295518557

!22
VPAIB := PAFB/(Wfe*SB);
                    WPAIB := 1.295518557

!23
:r := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
                    Cr := .002947741741
:b := C - Cr;
                    Cb := .7351522583
VAI := (28.02*(100-CO2avel-COavel-O2avel)/(12.01*(CO2avel+COavel))*(Cb+(12.0
I/32.07)*S)-N)/0.7685;
                    WAi := 11.93169660

!24
VMGI := 8.936*H + (Wma*WAI)+Mf;
                    WMGi := .6458272558

!25
VGpI := ((44.01*CO2avel+32.02*O2avel+28.01*COavel+28.02*(100-CO2avel-COav
el-O2avel))/(12.01*(CO2avel+COavel))*(Cb+(12.01/32.07)*S));
                    WGpi := 12.38591870

!26
WGI := WGpI + WMGI;
                    WGi := 13.03174596

!27
WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
b + (12.01/32.07)*S)-N)/0.7685;
                    WAo := 12.81444703

#28
> WMGo := 8.936*H + (Wma*WAo) + Mf;
                    WMGo := .6573030114

#29
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
                    WGpo := 13.26877798

#30
> WGo := WGpo + WMGo;
                    WGo := 13.92608099

#31
> AL := ((WGo-WGi)/WGi)*100;
                    AL := 6.862741437

#32
TFluegasINa := WGi*Wfe*SA;
TFluegasINb := WGi*Wfe*SB;

#33
> TFluegasOUTa := WGo*Wfe*SA;
                    TFluegasOUTa := 806591.6480
TFluegasOUTb := WGo*Wfe*SB;
>
```

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Appendix G-4
Random Error Calculation
Flue Gas Outlet Flow -- With Leak Case

```
>
>
```

Random Error Propagation Calculations, Part B, TFluegasOUTa

Set no. of sample points

```
> n := 24;
```

$$n := 24$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
```

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```
        for i to n do
            if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
            else varcovar[i,j] := 0
            fi
        od
    od;
    varcovar
end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\ \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\ \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}}\right)$$

#17

```
> FA := 5348840*Areal*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areal*CP*sqrt(PSI)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) / Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} + \sqrt{\frac{DPpa_{21}}{Tpa_{21}}} + \sqrt{\frac{DPpa_{22}}{Tpa_{22}}} + \sqrt{\frac{DPpa_{23}}{Tpa_{23}}} + \sqrt{\frac{DPpa_{24}}{Tpa_{24}}} \right) / Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / (12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\ \Bigg(36.46063760$$

$$(100 - CO2avei - COavei - O2avei)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Bigg) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\ \Bigg(36.46063760$$

$$(100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\ \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo}$$

$$+ Wma\ \left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ I\right.$$

$$- \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2}$$

$$- Wma\ \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ I\right.$$

$$\Bigg)/\Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H$$

$$+ Wma\ \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ I\right.$$

$$+ Mf\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#33

```
> TFluegasOUTa := WGo*Wfe*SA;
```

$$TFluegasOUTa := \frac{1}{2}\Bigg((15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\Bigg(36.46063760$$

$$(100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf\Bigg)\ Wfe$$

```
> sigmaTFluegasOUTa := sqrt(
> Diff(TFluegasOUTa,CO2avei)^2*varCO2avei +
> Diff(TFluegasOUTa,COavei)^2*varCOavei +
> Diff(TFluegasOUTa,O2avei)^2*varO2avei +
> Diff(TFluegasOUTa,Wfe)^2*varWfe +
> Diff(TFluegasOUTa,Areai)^2*varAreai +
> Diff(TFluegasOUTa,CP)^2*varCP +
> Diff(TFluegasOUTa,PSI)^2*varPSI +
> Diff(TFluegasOUTa,A)^2*varA +
> Diff(TFluegasOUTa,OUHD)^2*varOUHD +
> Diff(TFluegasOUTa,Ca)^2*varCa +
> Diff(TFluegasOUTa,C)*Diff(TFluegasOUTa,C)*varC +
> Diff(TFluegasOUTa,S)*Diff(TFluegasOUTa,S)*varS +
> Diff(TFluegasOUTa,H)*Diff(TFluegasOUTa,H)*varH +
> Diff(TFluegasOUTa,Wma)*Diff(TFluegasOUTa,Wma)*varWma +
> Diff(TFluegasOUTa,N)*Diff(TFluegasOUTa,N)*varN +
> Diff(TFluegasOUTa,Mf)*Diff(TFluegasOUTa,Mf)*varMf +
> sum(
> Diff(TFluegasOUTa,DPI[i])*Diff(TFluegasOUTa,DPI[i])*varDPI[i,i] +
> Diff(TFluegasOUTa,Ti[i])*Diff(TFluegasOUTa,Ti[i])*varTi[i,i] +
> Diff(TFluegasOUTa,COi[i])*Diff(TFluegasOUTa,COi[i])*varCOi[i,i] +
> Diff(TFluegasOUTa,CO2i[i])*Diff(TFluegasOUTa,CO2i[i])*varCO2i[i,i] +
> Diff(TFluegasOUTa,O2i[i])*Diff(TFluegasOUTa,O2i[i])*varO2i[i,i]
> ,i=1..n)):
```

```
> sigmaTFluegasOUTa := value("):
```

Constants

Averages and Random Error Variances (Copied from Part A -- function of sample size n)

```
> CO2avei := 15.2148;
```

$$CO2avei := 15.2148$$

```
> varCO2avei := .102^2;
```

$$varCO2avei := .010404$$

```
> COavei := .005;
```

$$COavei := .005$$

```
> varCOavei := .0002^2;
                    varCOavei := .4 10^-7
> O2avei := 3.8;
                    O2avei := 3.8
> varO2avei := .01118^2;
                    varO2avei := .0001249924

> CO2aveo := 14.145;
                    CO2aveo := 14.145
> varCO2aveo := .0866^2;
                    varCO2aveo := .00749956
> COaveo := .005;
                    COaveo := .005
> varCOaveo := .000204^2;
                    varCOaveo := .41616 10^-7
> O2aveo := 5;
                    O2aveo := 5
> varO2aveo := .010206^2;
                    varO2aveo := .000104162436
```

Constants for Random Error Propagation

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
                    Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
                    varWfe := 83866.71200
```

Area (square ft) re

```
> Areai := 3.99;
                    Areai := 3.99
> varAreai := (0.0335*Areai)^2;
                    varAreai := .01786633223

> Areao := 3.54;
                    Areao := 3.54
> varAreao := (0.0364*Areao)^2;
                    varAreao := .01660386874
```

Pitot Coefficient re

```
> CP := 0.84;
                    CP := .84
> varCP := (0)^2;
                    varCP := 0
```

Pressure Ambient or Barometric re

```
> PSi := 29.23;
                    PSi := 29.23
> varPSi := (0.04)^2;
                    varPSi := .0016

> PSo := 29.1;
                    PSo := 29.1
> varPSo := (0.04)^2;
                    varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
                    PSpa := 31.11
> varPSpa := (0.04)^2;
                    varPSpa := .0016
>
```

Velocity Head DP re

```
> v := .45802;
                    v := .45802
> DPo := array([seq(v,i=1..n)]);
   DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
     .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .458(
     .45802  .45802  .45802  .45802  .45802]
> u := .00005^2;
                    u := .25 10^-8
> var := array([seq(u,i=1..n)]);
   var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10
     .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10
```

```
.25 10^(-8)]

> varDPo := make_array(var,n);
                    varDPo := varcovar

> v := .82831;
                    v := .82831
> DPi := array([seq(v,I=1..n)]);
DPi := [.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831
 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831
 .82831 .82831 .82831 .82831 .82831]
> u := .00005^2;
                    u := .25 10^(-8)
> var := array([seq(u,I=1..n)]);
var := [.25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8)]
> varDPi := make_array(var,n);
                    varDPi := varcovar
>

> v := .2171;
                    v := .2171
> DPpa := array([seq(v,I=1..n)]);
DPpa := [.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171
 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171
 .2171 .2171 .2171]
> u := (0.00005)^2;
                    u := .25 10^(-8)
> var := array([seq(u,I=1..n)]);
var := [.25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8) .25 10^(-8)
 .25 10^(-8)]
> varDPpa := make_array(var,n);
                    varDPpa := varcovar

> v := 1104;
                    v := 1104
> Tpa := array([seq(v,I=1..n)]);
Tpa := [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
 1104]
> u := (0.005*(v - 460))^2;
                    u := 10.368400
> var := array([seq(u,I=1..n)]);
var := [10.368400 10.368400 10.368400 10.368400 10.368400 10.368400
 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400
 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400
 10.368400 10.368400 10.368400 10.368400]
> varTpa := make_array(var,n);
                    varTpa := varcovar

Temperature (R) re
> v := 713;
                    v := 713
> To := array([seq(v,I=1..n)]);
To := [713 713 713 713 713 713 713 713 713 713 713 713 713 71
 713 713 713 713 713 713 713 713 713 713]
> u := (0.005*(v-460))^2;
                    u := 1.600225
> var := array([seq(u,I=1..n)]);
var := [1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225
 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.60022
 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.60022
 1.600225]
> varTo := make_array(var,n);
                    varTo := varcovar

> v := 1140;
                    v := 1140
> Ti:= array([seq(v,I=1..n)]);
Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140
 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140
```

1140]

```
> u := (0.005*(v-460))^2;
```

u := 11.560000

```
> var := array([seq(u,i=1..n)]);
```

var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
11.560000 11.560000 11.560000 11.560000]

```
> varTi := make_array(var,n);
```

varTi := *varcovar*

Moisture in Ash re

```
> Mf :=0.06;
```

Mf := .06

```
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
```

varMf := .00001058319613

Ash re

```
> A := 0.0619;
```

A := .0619

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```

varA := $.4696223261 \; 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```

OUHD := .9

```
> varOUHD := (0.1*OUHD)^2;
```

varOUHD := .0081

Carbon re

```
> C := 0.7381;
```

C := .7381

```
> varC := (0.64/(2*1.414*100))^2;
```

varC := $.5121546706 \; 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```

H := .0482

```
> varH := (0.16/(2*1.414*100))^2;
```

varH := $.3200966692 \; 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```

N := .0135

```
> varN := (0.11/(2*1.414*100))^2;
```

varN := $.1512956913 \; 10^{-6}$

Sulfur re

```
> S := 0.0123;
```

S := .0123

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```

varS := $.1327813813 \; 10^{-6}$

CO2 re

```
> v := 14.145;
```

v := 14.145

```
> CO2o := array([seq(v,i=1..n)]);
```

CO2o := [14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145
14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.145 14.14
14.145 14.145 14.145 14.145 14.145]

```
> u := (0.03*v)^2;
```

u := .1800729225

```
> var := array([seq(u,i=1..n)]);
```

var := [.1800729225 .1800729225 .1800729225 .1800729225 .1800729225
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .180072922
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .180072922
.1800729225 .1800729225 .1800729225 .1800729225 .1800729225 .180072922
.1800729225]

```
> varCO2o := make_array(var,n);
```

varCO2o := *varcovar*

```
> v := 15.2148;
```

v := 15.2148

```
> CO2i := array([seq(v,i=1..n)]);
```

CO2i := [15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.214
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148
15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148 15.2148]

```
> u := (0.03*v)^2;
                              u := .2083411251
> var := array([seq(u,i=1..n)]);
    var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
     .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
     .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
     .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
     .2083411251]
> varCO2i := make_array(var,n);
                           varCO2i := varcovar

 O2 re
> v := 5;
                                  v := 5
> O2o := array([seq(v,i=1..n)]);
    O2o :=
     [5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                                u := .0025
> var := array([seq(u,i=1..n)]);
    var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025]
> varO2o := make_array(var,n);
                           varO2o := varcovar

> v := 3.8;
                                 v := 3.8
> O2i := array([seq(v,i=1..n)]);
    O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8
     3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                                u := .0025
> var := array([seq(u,i=1..n)]);
    var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025]
> varO2i := make_array(var,n);
                           varO2i := varcovar

 Moisture (air) re
> Wma := 0.013;
                                Wma := .013
> varWma := (.2*Wma)^2;
                          varWma := .676 10^(-5)

 CO re
> v := 0.004;
                                 v := .004
> COo := array([seq(v,i=1..n)]);
    COo := [.004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004
     .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004  .004]
> u := (0.001)^2;
                              u := .1 10^(-5)
> var := array([seq(u,i=1..n)]);
    var := [.1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)
     .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)
     .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)]
> varCOo := make_array(var,n);
                           varCOo := varcovar

> v := 0.005;
                                 v := .005
> COi := array([seq(v,i=1..n)]);
    COi := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005
     .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                              u := .1 10^(-5)
> var := array([seq(u,i=1..n)]);
    var := [.1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)
     .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)
     .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)  .1 10^(-5)]
> varCOi := make_array(var,n);
                           varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
```

$Ca := .0486$

```
> varCa := (0.1*Ca)^2;
```

$varCa := .0000236196$

Area for Primary Air re

```
> apa := 0.63;
```

$apa := .63$

```
> varapa := (0.0208*apa)^2;
```

$varapa := .000171714816$

Results

```
****************************************************************************
> evalf(TFluegasOUTa);
```

806591.6480

```
> evalf(sigmaTFluegasOUTa);
```

3707.782816

```
> evalf(100*sigmaTFluegasOUTa/TFluegasOUTa);
```

.4596852478

```
****************************************************************************
>
```

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Appendix H-1
Bias Error Calculation
Inlet Flue Gas Flow Split

>

>

Error Propagation Calculations, Part B, Split A (SA)

Set no. of sample points

```
> n := 2;
```

$$n := 2$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

#5

```
O2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*O2o[i],i=1..n)/sum((DPo[i]/(To[i]*M(i
,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

O2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#7

```
CO2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/sum((DPo[i]/(To[i]*
M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,
COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

CO2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,
OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO
2i,H,Wma,O2i,N,Mf)),i=1..n);
```

#8

```
COaveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*COo[i],i=1..n)/sum((DPo[i]/(To[i]*M(
i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
COavei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*COi[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} \right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} \right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

CALCULATION EXPEDIENT -- USED LEAK CASE FLUE GAS OUTLET COMPOSITIONS FOR GAS COMPOSITION TO 'B' SIDE HEAT PIPE. THIS JUST PROVIDES A SECOND GAS COMPOSITION FOR CALCULATING A FLOW SPLIT.

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COo,CO2o,H,
> Wma,O2o,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,M
> f))*CO2o[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := 5348840\ Areai\ CP \sqrt{PSi} \Bigg(.01000000000 \Bigg(DPi_1$$

$$\left(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8}\right) \Bigg/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%9 + 18.01600000\ Mf + \frac{\%2\ \left(288.0800000\ CO2i_1 + 71.70000000\ O2i_1 + 50480.80000\right)}{\%8} \Bigg) Ti_1 \Bigg) \Bigg)^{1/2} \Bigg(1. - .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}} \Bigg) CO2i_1 + .01000000000 \Bigg(DPi_2 \left(8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6}\right) \Bigg/$$

$$\Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf + \frac{\%2\ \left(288.0800000\ CO2i_2 + 71.70000000\ O2i_2 + 50480.80000\right)}{\%6} \Bigg) Ti_2 \Bigg) \Bigg)^{1/2} \Bigg(1. - .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}} \Bigg) CO2i_2 \Bigg) \Bigg/ \Bigg(5348840\ Areai\ CP \sqrt{PSi} \Bigg(.01000000000 \Bigg(DPi_1$$

$$\left(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8}\right) \Bigg/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%9 + 18.01600000\ Mf + \frac{\%2\ \left(288.0800000\ CO2i_1 + 71.70000000\ O2i_1 + 50480.80000\right)}{\%8} \Bigg) Ti_1 \Bigg) \Bigg)^{1/2} \Bigg(1. - .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}}$$

$$\Big) CO2i_1 + .01000000000 \Big(DPi_2 \Big(8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6} \Big) \Big/ \Big($$

$$\Big(160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2i_2 + 71.70000000\ O2i_2 + 50480.80000)}{\%6} \Big)\ Ti_2 \Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}}$$

$$\Big) CO2i_2 \Big) + 5348840\ Areai\ CP\ \sqrt{PSi}\ \Big(.01000000000 \Big(DPi_1$$

$$\Big(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4} \Big) \Big/ \Big(\Big(160.9909760\ H$$

$$+ 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000)}{\%4} \Big)\ Ti_1 \Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$\Big) CO2o_1 + .01000000000 \Big(DPi_2 \Big(8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1} \Big) \Big/ \Big($$

$$\Big(160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2o_2 + 71.70000000\ O2o_2 + 50480.80000)}{\%1} \Big)\ Ti_2 \Big)\Big)^{1/2} \Big(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%3 + Mf}{.4960035524\ H + .05550621670\ \%3 + .05550621670\ Mf + 100.\ \frac{\%2}{\%1}}$$

$$\Big) CO2o_2 \Big)\Big)$$

$$\%1 := 12.01000000\ CO2o_2 + 12.01000000\ COo_2$$

$$\%2 := C - 1.\ \frac{A\ OUHD\ Ca}{1. - 1.\ Ca} - .3333333333\ \frac{A\ (1. - 1.\ OUHD)\ Ca}{1. - .3333333333\ Ca} + .3744932959\ S$$

$$\%3 := Wma\ \Big(36.46063760\ \frac{(100. - 1.\ COo_2 - 1.\ CO2o_2 - 1.\ O2o_2)\ \%2}{\%1} - 1.301236174\ N \Big)$$

$$\%4 := 12.01000000\ CO2o_1 + 12.01000000\ COo_1$$

$$\%5 := Wma\ \Big(36.46063760\ \frac{(100. - 1.\ COo_1 - 1.\ CO2o_1 - 1.\ O2o_1)\ \%2}{\%4} - 1.301236174\ N \Big)$$

$$\%6 := 12.01000000\ CO2i_2 + 12.01000000\ COi_2$$

$$\%7 := Wma\ \Big(36.46063760\ \frac{(100. - 1.\ COi_2 - 1.\ CO2i_2 - 1.\ O2i_2)\ \%2}{\%6} - 1.301236174\ N \Big)$$

$$\%8 := 12.01000000\ CO2i_1 + 12.01000000\ COi_1$$

$$\%9 := Wma\ \Big(36.46063760\ \frac{(100. - 1.\ COi_1 - 1.\ CO2i_1 - 1.\ O2i_1)\ \%2}{\%8} - 1.301236174\ N \Big)$$

#20

> SB := FB/(FA+FB);

$$SB := 5348840\ Areai\ CP\ \sqrt{PSi}\ (.01000000000\ (DPi_1$$

$$(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4})/(((160.9909760\ H$$

$$+ 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000)}{\%4})\ Ti_1))^{1/2}\ (1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$)\ CO2o_1 + .01000000000\ (DPi_2\ (8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1})/($$

$$(160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2o_2 + 71.70000000\ O2o_2 + 50480.80000)}{\%1})\ Ti_2))^{1/2}\ (1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%3 + Mf}{.4960035524\ H + .05550621670\ \%3 + .05550621670\ Mf + 100.\ \frac{\%2}{\%1}}$$

$$)\ CO2o_2)/(5348840\ Areai\ CP\ \sqrt{PSi}\ (.01000000000\ (DPi_1$$

$$(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8})/(((160.9909760\ H$$

$$+ 18.01600000\ \%9 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2i_1 + 71.70000000\ O2i_1 + 50480.80000)}{\%8})\ Ti_1))^{1/2}\ (1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}}$$

$$)\ CO2i_1 + .01000000000\ (DPi_2\ (8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6})/$$

$$(160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2i_2 + 71.70000000\ O2i_2 + 50480.80000)}{\%6})\ Ti_2))^{1/2}\ (1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}}$$

$$)\ CO2i_2) + 5348840\ Areai\ CP\ \sqrt{PSi}\ (.01000000000\ (DPi_1$$

$$(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4})/(((160.9909760\ H$$

$$+ 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2\ (288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000)}{\%4})\ Ti_1))^{1/2}\ (1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$)\ CO2o_1 + .01000000000\ (DPi_2\ (8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1})/$$

$$(160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+\frac{\%2\left(288.0800000\ CO2o_2+71.70000000\ O2o_2+50480.80000\right)}{\%1}\Bigg)\ Ti_2\Bigg)\Bigg)^{1/2}\Bigg(1.$$

$$-.05550621670\ \frac{8.936000000\ H+\%3+Mf}{.4960035524\ H+.05550621670\ \%3+.05550621670\ Mf+100.\ \frac{\%2}{\%1}}$$

$$\Bigg)\ CO2o_2\Bigg)\Bigg)$$

$$\%1 := 12.01000000\ CO2o_2+12.01000000\ COo_2$$

$$\%2 := C-1.\ \frac{A\ OUHD\ Ca}{1.-1.\ Ca}-.3333333333\ \frac{A\ (1.-1.\ OUHD)\ Ca}{1.-.3333333333\ Ca}+.3744932959\ S$$

$$\%3 := Wma\left(36.46063760\ \frac{\left(100.-1.\ COo_2-1.\ CO2o_2-1.\ O2o_2\right)\ \%2}{\%1}-1.301236174\ N\right)$$

$$\%4 := 12.01000000\ CO2o_1+12.01000000\ COo_1$$

$$\%5 := Wma\left(36.46063760\ \frac{\left(100.-1.\ COo_1-1.\ CO2o_1-1.\ O2o_1\right)\ \%2}{\%4}-1.301236174\ N\right)$$

$$\%6 := 12.01000000\ CO2i_2+12.01000000\ COi_2$$

$$\%7 := Wma\left(36.46063760\ \frac{\left(100.-1.\ COi_2-1.\ CO2i_2-1.\ O2i_2\right)\ \%2}{\%6}-1.301236174\ N\right)$$

$$\%8 := 12.01000000\ CO2i_1+12.01000000\ COi_1$$

$$\%9 := Wma\left(36.46063760\ \frac{\left(100.-1.\ COi_1-1.\ CO2i_1-1.\ O2i_1\right)\ \%2}{\%8}-1.301236174\ N\right)$$

```
> sigmaSA := sqrt(
> Diff(SA,CO2avei)^2*varCO2avei +
> Diff(SA,COavei)^2*varCOavei +
> Diff(SA,O2avei)^2*varO2avei +
> Diff(SA,CO2aveo)^2*varCO2aveo +
> Diff(SA,COaveo)^2*varCOaveo +
> Diff(SA,O2aveo)^2*varO2aveo +
> Diff(SA,Wfe)^2*varWfe +
> Diff(SA,Areal)^2*varAreal +
> Diff(SA,CP)^2*varCP +
> Diff(SA,PSI)^2*varPSI +
> Diff(SA,A)^2*varA +
> Diff(SA,OUHD)^2*varOUHD +
> Diff(SA,Ca)^2*varCa +
> Diff(SA,C)*Diff(SA,C)*varC +
> Diff(SA,S)*Diff(SA,S)*varS +
> Diff(SA,H)*Diff(SA,H)*varH +
> Diff(SA,Wma)*Diff(SA,Wma)*varWma +
> Diff(SA,N)*Diff(SA,N)*varN +
> Diff(SA,Mf)*Diff(SA,Mf)*varMf +
> sum(sum(
> Diff(SA,DPi[i])*Diff(SA,DPi[j])*varDPi[i,j] +
> Diff(SA,Ti[i])*Diff(SA,Ti[j])*varTi[i,j] +
```

```
> Diff(SA,COo[i])*Diff(SA,COo[j])*varCOo[i,j] +
> Diff(SA,CO2o[i])*Diff(SA,CO2o[j])*varCO2o[i,j] +
> Diff(SA,O2o[i])*Diff(SA,O2o[j])*varO2o[i,j] +
> Diff(SA,COi[i])*Diff(SA,COi[j])*varCOi[i,j] +
> Diff(SA,CO2i[i])*Diff(SA,CO2i[j])*varCO2i[i,j] +
> Diff(SA,O2i[i])*Diff(SA,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):

> sigmaSA := value("):
```

Constants

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```
$CO2avei := 15.2148$

```
> varCO2avei := .1^2;
```
$varCO2avei := .01$

```
> COavei := .005;
```
$COavei := .005$

```
> varCOavei := .002^2;
```
$varCOavei := .4\ 10^{-5}$

```
> O2avei := 3.8;
```
$O2avei := 3.8$

```
> varO2avei := .05^2;
```
$varO2avei := .0025$

```
> CO2aveo := 14.145;
```
$CO2aveo := 14.145$

```
> varCO2aveo := .1^2;
```
$varCO2aveo := .01$

```
> COaveo := .005;
```
$COaveo := .005$

```
> varCOaveo := .002^2;
```
$varCOaveo := .4\ 10^{-5}$

```
> O2aveo := 5;
```
$O2aveo := 5$

```
> varO2aveo := .05^2;
```
$varO2aveo := .0025$

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```
$Wfe := 115839$

```
> varWfe := (0.05*Wfe)^2;
```
$varWfe := .3354668480\ 10^{8}$

Area (square ft)

```
> Areai := 3.99;
```
$Areai := 3.99$

```
> varAreai := (0.0335*Areai)^2;
```
$varAreai := .01786633223$

```
> Areao := 3.54;
```
$Areao := 3.54$

```
> varAreao := (0.0364*Areao)^2;
```
$varAreao := .01660386874$

Pitot Coefficient

```
> CP := 0.84;
```
$CP := .84$

```
> varCP := (0.01)^2;
```
$varCP := .0001$

Pressure in Area

```
> PSi := 29.23;
```
$PSi := 29.23$

```
> varPSi := (0.04)^2;
```
$varPSi := .0016$

```
> PSo := 29.1;
```
$PSo := 29.1$

```
> varPSo := (0.04)^2;
                              varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
                              PSpa := 31.11
> varPSpa := (0.04)^2;
                              varPSpa := .0016
>
```

Velocity Head

```
> v := .45802;
                              v := .45802
> DPo := array([seq(v,i=1..n)]);
                              DPo := [.45802   .45802]
> u := (.02*v)^2;
                              u := .00008391292816
> var := array([seq(u,i=1..n)]);
                              var := [.00008391292816   .00008391292816]
> varDPo := make_array(var,n);
                              varDPo := varcovar

> v := .82831;
                              v := .82831
> DPi := array([seq(v,i=1..n)]);
                              DPi := [.82831   .82831]
> u := (.02*v)^2;
                              u := .0002744389824
> var := array([seq(u,i=1..n)]);
                              var := [.0002744389824   .0002744389824]
> varDPi := make_array(var,n);
                              varDPi := varcovar
```

Temperature (R)

```
> v := 713;
                              v := 713
> To := array([seq(v,i=1..n)]);
                              To := [713   713]
> u := (0.01*(v-460))^2;
                              u := 6.4009
> var := array([seq(u,i=1..n)]);
                              var := [6.4009   6.4009]
> varTo := make_array(var,n);
                              varTo := varcovar

> v := 1140;
                              v := 1140
> Ti:= array([seq(v,i=1..n)]);
                              Ti := [1140   1140]
> u := (0.01*(v-460))^2;
                              u := 46.2400
> var := array([seq(u,i=1..n)]);
                              var := [46.2400   46.2400]
> varTi := make_array(var,n);
                              varTi := varcovar
```

Moisture in Coal

```
> Mf :=0.06;
                              Mf := .06
> varMf := (0.039*Mf)^2;
                              varMf := .54756 10^-5
```

Ash

```
> A :=  0.0619;
                              A := .0619
> varA := ( 0.039*A)^2;
                              varA := .582787881 10^-5
```

Overhead

```
> OUHD :=  0.9;
                              OUHD := .9
> varOUHD :=  (0.1*OUHD)^2;
                              varOUHD := .0081
```

Carbon

```
> C := 0.7381;
                              C := .7381
```

```
> varC := (0.039*C)^2;
                    varC := .0008286280388

Hydrogen
> H := 0.0482;
                    H := .0482
> varH := (0.039*H)^2;
                    varH := .353364804 10^(-5)

Nitrogen
> N := 0.0135;
                    N := .0135
> varN := (0.039*N)^2;
                    varN := .27720225 10^(-6)

Sulfur
> S := 0.0123;
                    S := .0123
> varS := (0.019*S)^2;
                    varS := .5461569 10^(-7)

CO2
> v := 14.145;
                    v := 14.145
> CO2o := array([seq(v,i=1..n)]);
                    CO2o := [14.145   14.145]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
                    var := [.01   .01]
> varCO2o := make_array(var,n);
                    varCO2o := varcovar

> v := 15.2148;
                    v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
                    CO2i := [15.2148   15.2148]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
                    var := [.01   .01]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar

O2
> v := 5;
                    v := 5
> O2o := array([seq(v,i=1..n)]);
                    O2o := [5   5]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025   .0025]
> varO2o := make_array(var,n);
                    varO2o := varcovar

> v := 3.8;
                    v := 3.8
> O2i := array([seq(v,i=1..n)]);
                    O2i := [3.8   3.8]
> u := (0.05)^2;
                    u := .0025
> var := array([seq(u,i=1..n)]);
                    var := [.0025   .0025]
> varO2i := make_array(var,n);
                    varO2i := varcovar

Moisture (air)
> Wma := 0.013;
                    Wma := .013
> varWma := (.1*Wma)^2;
                    varWma := .169 10^(-5)

CO
> v := 0.005;
                    v := .005
```

```
> COo := array([seq(v,i=1..n)]);
                    COo := [.005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5]
> varCOo := make_array(var,n);
                    varCOo := varcovar
```

```
> v := 0.005;
                    v := .005
> COi := array([seq(v,i=1..n)]);
                    COi := [.005   .005]
> u := (0.002)^2;
                    u := .4 10^-5
> var := array([seq(u,i=1..n)]);
                    var := [.4 10^-5   .4 10^-5]
> varCOi := make_array(var,n);
                    varCOi := varcovar
```

Carbon in Ash

```
> Ca := 0.0486;
                    Ca := .0486
> varCa := (0.25*Ca)^2;
                    varCa := .000147622500
```

Area for primary air

```
> apa := .63;
                    apa := .63
> varapa := (.013)^2;
                    varapa := .000169
```

```
> v := .2171;
                    v := .2171
> DPpa := array([seq(v,i=1..n)]);
                    DPpa := [.2171   .2171]
> u := 0.02*v;
                    u := .004342
> varDPpa := array([seq(u,i=1..n)]);
                    varDPpa := [.004342   .004342]
> varDPpa := make_array(var,n);
                    varDPpa := varcovar
```

```
> v := 1104;
                    v := 1104
> Tpa := array([seq(v,i=1..n)]);
                    Tpa := [1104   1104]
> u := 0.01*(v - 460);
                    u := 6.44
> var := array([seq(u,i=1..n)]);
                    var := [6.44   6.44]
> varTpa := make_array(var,n);
                    varTpa := varcovar
```

Results

```
**********************************************************************
> eval(SA);
                    .5168579433
> eval(sigmaSA);
                    .002214263857
> eval(100*sigmaSA/SA);
                    .4284085958
**********************************************************************
```

```
eval(TFluegasINb);
eval(sigmaTFluegasINb);

eval(TFluegasOUTa);
eval(sigmaTFluegasOUTa);

eval(TFluegasOUTb);
eval(sigmaTFluegasOUTb);
```

Recalculate Other Results

```
> i := 'i';
```

Appendix H-2
Random Error Calculation
Inlet Flue Gas Flow Split

```
>
>
```

Random Error Propagation Calculations, Part B, Split A (SA)

Set no. of sample points

```
> n := 4;
                                  n := 4
```

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if i=j then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
  Warning, `varcovar` is implicitly declared local
  Warning, `j` is implicitly declared local
  Warning, `i` is implicitly declared local

  . ·a_array :=

      proc(var,n)
      local varcovar,j,i;
          varcovar := array(1 .. n,1 .. n);
          for j to n do
```

```
            for i to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6*
end
```

#5

```
O2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*O2o[i],i=1..n)/sum((DPo[i]/(To[i]*M(i
,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,CO
o,CO2o,H,Wma,O2o,N,Mf)),i=1..n);

O2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,
A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*O2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,O
UHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,
H,Wma,O2i,N,Mf)),i=1..n);
```

#7

```
CO2aveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG
(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*CO2o[i],i=1..n)/sum((DPo[i]/(To[i]*
M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,
COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
CO2avei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*CO2i[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n);
```

#8

```
COaveo :=
sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf))*COo[i],i=1..n)/sum((DPo[i]/(To[i]*M(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,Mf)),i=1..n);
```

```
COavei :=
sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*COi[i],i=1..n)/sum((DPi[i]/(Ti[i]*M(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf)),i=1..n);
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} \right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} \right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

CALCULATION EXPEDIENT -- USED LEAK CASE FLUE GAS OUTLET COMP.
FOR GAS COMPOSITION TO 'B' SIDE HEAT PIPE, THIS JUST P...
A SECOND GAS COMPOSITION FOR CALCULATING A FLOW SPLIT.

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COo,CO2o,H,
> Wma,O2o,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COo,CO2o,H,Wma,O2o,N,M
> f))*CO2o[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := 5348840\ Areai\ CP \sqrt{PSi} \Bigg(.01000000000 \Bigg(DPi_1 \left(8.936000000\ H + \%17 + Mf + 1801.600000 \frac{\%2}{\%16}\right) \Bigg/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%17 + 18.01600000\ Mf + \frac{\%2 \left(288.0800000\ CO2i_1 + 71.70000000\ O2i_1 + 50480.80000\right)}{\%16} \Bigg) Ti_1 \Bigg) \Bigg)^{1/2} \Bigg(1. - .05550621670 \frac{8.936000000\ H + \%17 + Mf}{.4960035524\ H + .05550621670\ \%17 + .05550621670\ Mf + 100. \frac{\%2}{\%16}} \Bigg) CO2i_1 + .01000000000 \Bigg(DPi_2 \left(8.936000000\ H + \%15 + Mf + 1801.600000 \frac{\%2}{\%14}\right) \Bigg/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%15 + 18.01600000\ Mf + \frac{\%2 \left(288.0800000\ CO2i_2 + 71.70000000\ O2i_2 + 50480.80000\right)}{\%14} \Bigg) Ti_2 \Bigg) \Bigg)^{1/2} \Bigg(1. - .05550621670 \frac{8.936000000\ H + \%15 + Mf}{.4960035524\ H + .05550621670\ \%15 + .05550621670\ Mf + 100. \frac{\%2}{\%14}}$$

$$\Big) \mathit{CO2i}_2 + .01000000000 \Big(\mathit{DPi}_3 \Big(8.936000000\ H + \%13 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%12} \Big)$$

$$\Big/ \Big(\Big(160.9909760\ H + 18.01600000\ \%13 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_3 + 71.70000000\ \mathit{O2i}_3 + 50480.80000)}{\%12} \Big)\ \mathit{Ti}_3 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%13 + \mathit{Mf}}{.4960035524\ H + .05550621670\ \%13 + .05550621670\ \mathit{Mf} + 100.\ \frac{\%2}{\%12}}$$

$$\Big) \mathit{CO2i}_3 + .01000000000 \Big(\mathit{DPi}_4 \Big(8.936000000\ H + \%11 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%10} \Big)$$

$$\Big/ \Big(\Big(160.9909760\ H + 18.01600000\ \%11 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_4 + 71.70000000\ \mathit{O2i}_4 + 50480.80000)}{\%10} \Big)\ \mathit{Ti}_4 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%11 + \mathit{Mf}}{.4960035524\ H + .05550621670\ \%11 + .05550621670\ \mathit{Mf} + 100.\ \frac{\%2}{\%10}}$$

$$\Big) \mathit{CO2i}_4 \Big) \Big/ \Big(5348840\ \mathit{Areai}\ \mathit{CP}\ \sqrt{\mathit{PSi}} \Big(.01000000000 \Big(\mathit{DPi}_1$$

$$\Big(8.936000000\ H + \%17 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%16} \Big) \Big/ \Big(\Big(160.9909760\ H$$

$$+ 18.01600000\ \%17 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_1 + 71.70000000\ \mathit{O2i}_1 + 50480.80000)}{\%16} \Big)\ \mathit{Ti}_1 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%17 + \mathit{Mf}}{.4960035524\ H + .05550621670\ \%17 + .05550621670\ \mathit{Mf} + 100.\ \frac{\%2}{\%16}}$$

$$\Big) \mathit{CO2i}_1 + .01000000000 \Big(\mathit{DPi}_2 \Big(8.936000000\ H + \%15 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%14} \Big)$$

$$\Big/ \Big(\Big(160.9909760\ H + 18.01600000\ \%15 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_2 + 71.70000000\ \mathit{O2i}_2 + 50480.80000)}{\%14} \Big)\ \mathit{Ti}_2 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%15 + \mathit{Mf}}{.4960035524\ H + .05550621670\ \%15 + .05550621670\ \mathit{Mf} + 100.\ \frac{\%2}{\%14}}$$

$$\Big) \mathit{CO2i}_2 + .01000000000 \Big(\mathit{DPi}_3 \Big(8.936000000\ H + \%13 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%12} \Big)$$

$$\Big/ \Big(\Big(160.9909760\ H + 18.01600000\ \%13 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_3 + 71.70000000\ \mathit{O2i}_3 + 50480.80000)}{\%12} \Big)\ \mathit{Ti}_3 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H + \%13 + \mathit{Mf}}{.4960035524\ H + .05550621670\ \%13 + .05550621670\ \mathit{Mf} + 100.\ \frac{\%2}{\%12}}$$

$$\Big) \mathit{CO2i}_3 + .01000000000 \Big(\mathit{DPi}_4 \Big(8.936000000\ H + \%11 + \mathit{Mf} + 1801.600000\ \frac{\%2}{\%10} \Big)$$

$$\Big/ \Big(\Big(160.9909760\ H + 18.01600000\ \%11 + 18.01600000\ \mathit{Mf}$$

$$+ \frac{\%2\ (288.0800000\ \mathit{CO2i}_4 + 71.70000000\ \mathit{O2i}_4 + 50480.80000)}{\%10} \Big)\ \mathit{Ti}_4 \Big) \Big)^{1/2} \Big(1. -$$

$$.05550621670\ \frac{8.936000000\ H+\%11+Mf}{.4960035524\ H+.05550621670\ \%11+.05550621670\ Mf+100.\ \frac{\%2}{\%10}}$$

$$\Big)\ CO2i_4\Big)+5348840\ Areai\ CP\ \sqrt{PSi}\ \Big(.01000000000\ \Big(DPi_1$$

$$\Big(8.936000000\ H+\%9+Mf+1801.600000\ \frac{\%2}{\%8}\Big)\Big/\Big(\Big(\Big(160.9909760\ H$$

$$+18.01600000\ \%9+18.01600000\ Mf$$

$$+\frac{\%2\ (288.0800000\ CO2o_1+71.70000000\ O2o_1+50480.80000)}{\%8}\Big)\ Ti_1\Big)\Big)^{1/2}\ \Big(1.$$

$$-.05550621670\ \frac{8.936000000\ H+\%9+Mf}{.4960035524\ H+.05550621670\ \%9+.05550621670\ Mf+100.\ \frac{\%2}{\%8}}$$

$$\Big)\ CO2o_1+.01000000000\ \Big(DPi_2\ \Big(8.936000000\ H+\%7+Mf+1801.600000\ \frac{\%2}{\%6}\Big)\Big/\Big($$

$$\Big(160.9909760\ H+18.01600000\ \%7+18.01600000\ Mf$$

$$+\frac{\%2\ (288.0800000\ CO2o_2+71.70000000\ O2o_2+50480.80000)}{\%6}\Big)\ Ti_2\Big)\Big)^{1/2}\ \Big(1.$$

$$-.05550621670\ \frac{8.936000000\ H+\%7+Mf}{.4960035524\ H+.05550621670\ \%7+.05550621670\ Mf+100.\ \frac{\%2}{\%6}}$$

$$\Big)\ CO2o_2+.01000000000\ \Big(DPi_3\ \Big(8.936000000\ H+\%5+Mf+1801.600000\ \frac{\%2}{\%4}\Big)\Big/\Big($$

$$\Big(160.9909760\ H+18.01600000\ \%5+18.01600000\ Mf$$

$$+\frac{\%2\ (288.0800000\ CO2o_3+71.70000000\ O2o_3+50480.80000)}{\%4}\Big)\ Ti_3\Big)\Big)^{1/2}\ \Big(1.$$

$$-.05550621670\ \frac{8.936000000\ H+\%5+Mf}{.4960035524\ H+.05550621670\ \%5+.05550621670\ Mf+100.\ \frac{\%2}{\%4}}$$

$$\Big)\ CO2o_3+.01000000000\ \Big(DPi_4\ \Big(8.936000000\ H+\%3+Mf+1801.600000\ \frac{\%2}{\%1}\Big)\Big/\Big($$

$$\Big(160.9909760\ H+18.01600000\ \%3+18.01600000\ Mf$$

$$+\frac{\%2\ (288.0800000\ CO2o_4+71.70000000\ O2o_4+50480.80000)}{\%1}\Big)\ Ti_4\Big)\Big)^{1/2}\ \Big(1.$$

$$-.05550621670\ \frac{8.936000000\ H+\%3+Mf}{.4960035524\ H+.05550621670\ \%3+.05550621670\ Mf+100.\ \frac{\%2}{\%1}}$$

$$\Big)\ CO2o_4\Big)\Big)$$

$$\%1 := 12.01000000\ CO2o_4+12.01000000\ COo_4$$

$$\%2 := C-1.\ \frac{A\ OUHD\ Ca}{1.-1.\ Ca}-.3333333333\ \frac{A\ (1.-1.\ OUHD)\ Ca}{1.-.3333333333\ Ca}+.3744932959\ S$$

$$\%3 :=$$

$$Wma\ \Big(36.46063760\ \frac{(100.-1.\ COo_4-1.\ CO2o_4-1.\ O2o_4)\ \%2}{\%1}-1.301236174\ N\Big)$$

$$\%4 := 12.01000000\ CO2o_3+12.01000000\ COo_3$$

$$\%5 :=$$

$$Wma\ \Big(36.46063760\ \frac{(100.-1.\ COo_3-1.\ CO2o_3-1.\ O2o_3)\ \%2}{\%4}-1.301236174\ N\Big)$$

$$\%6 := 12.01000000\ CO2o_2 + 12.01000000\ COo_2$$

$$\%7 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COo_2 - 1.\ CO2o_2 - 1.\ O2o_2\right)\ \%2}{\%6} - 1.301236174\ N\right)$$

$$\%8 := 12.01000000\ CO2o_1 + 12.01000000\ COo_1$$

$$\%9 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COo_1 - 1.\ CO2o_1 - 1.\ O2o_1\right)\ \%2}{\%8} - 1.301236174\ N\right)$$

$$\%10 := 12.01000000\ CO2i_4 + 12.01000000\ COi_4$$

$$\%11 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COi_4 - 1.\ CO2i_4 - 1.\ O2i_4\right)\ \%2}{\%10} - 1.301236174\ N\right)$$

$$\%12 := 12.01000000\ CO2i_3 + 12.01000000\ COi_3$$

$$\%13 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COi_3 - 1.\ CO2i_3 - 1.\ O2i_3\right)\ \%2}{\%12} - 1.301236174\ N\right)$$

$$\%14 := 12.01000000\ CO2i_2 + 12.01000000\ COi_2$$

$$\%15 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COi_2 - 1.\ CO2i_2 - 1.\ O2i_2\right)\ \%2}{\%14} - 1.301236174\ N\right)$$

$$\%16 := 12.01000000\ CO2i_1 + 12.01000000\ COi_1$$

$$\%17 := Wma\left(36.46063760\ \frac{\left(100. - 1.\ COi_1 - 1.\ CO2i_1 - 1.\ O2i_1\right)\ \%2}{\%16} - 1.301236174\ N\right)$$

#20

SB := FB/(FA+FB);

$$SB := 5348840\ Areai\ CP\ \sqrt{PSi}\ \Bigg(.01000000000\ \Bigg(DPi_1$$

$$\left(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8}\right) \Bigg/ \Bigg(\Bigg(160.9909760\ H$$

$$+ 18.01600000\ \%9 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000\right)}{\%8}\Bigg)\ Ti_1\Bigg)\Bigg)^{1/2}\ \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}}$$

$$\Bigg)\ CO2o_1 + .01000000000\ \Bigg(DPi_2\ \left(8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6}\right) \Bigg/ \Bigg($$

$$\Bigg(160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_2 + 71.70000000\ O2o_2 + 50480.80000\right)}{\%6}\Bigg)\ Ti_2\Bigg)\Bigg)^{1/2}\ \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}}$$

$$\Bigg)\ CO2o_2 + .01000000000\ \Bigg(DPi_3\ \left(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4}\right) \Bigg/ \Bigg($$

$$\Bigg(160.9909760\ H + 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_3 + 71.70000000\ O2o_3 + 50480.80000\right)}{\%4}\Bigg)\ Ti_3\Bigg)\Bigg)^{1/2}\ \Bigg(1.$$

$$- .05550621670 \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$\Bigg) CO2o_3 + .01000000000 \left(DPi_4 \left(8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1} \right) \Big/ \Bigg(\right.\right.$$

$$\Bigg(160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2o_4 + 71.70000000\ O2o_4 + 50480.80000 \right)}{\%1} \Bigg) Ti_4 \Bigg) \Bigg)^{1/2} \Bigg(1.$$

$$- .05550621670 \frac{8.936000000\ H + \%3 + Mf}{.4960035524\ H + .05550621670\ \%3 + .05550621670\ Mf + 100.\ \frac{\%2}{\%1}}$$

$$\Bigg) CO2o_4 \Bigg) \Bigg/ \Bigg(5348840\ Areai\ CP \sqrt{PSi} \Bigg(.01000000000 \Bigg(DPi_1$$

$$\left(8.936000000\ H + \%17 + Mf + 1801.600000\ \frac{\%2}{\%16} \right) \Big/ \Bigg(\Bigg(160.9909760\ H$$

$$+ 18.01600000\ \%17 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2i_1 + 71.70000000\ O2i_1 + 50480.80000 \right)}{\%16} \Bigg) Ti_1 \Bigg) \Bigg)^{1/2} \Bigg(1. -$$

$$.05550621670 \frac{8.936000000\ H + \%17 + Mf}{.4960035524\ H + .05550621670\ \%17 + .05550621670\ Mf + 100.\ \frac{\%2}{\%16}}$$

$$\Bigg) CO2i_1 + .01000000000 \left(DPi_2 \left(8.936000000\ H + \%15 + Mf + 1801.600000\ \frac{\%2}{\%14} \right) \right.$$

$$\Big/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%15 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2i_2 + 71.70000000\ O2i_2 + 50480.80000 \right)}{\%14} \Bigg) Ti_2 \Bigg) \Bigg)^{1/2} \Bigg(1. -$$

$$.05550621670 \frac{8.936000000\ H + \%15 + Mf}{.4960035524\ H + .05550621670\ \%15 + .05550621670\ Mf + 100.\ \frac{\%2}{\%14}}$$

$$\Bigg) CO2i_2 + .01000000000 \left(DPi_3 \left(8.936000000\ H + \%13 + Mf + 1801.600000\ \frac{\%2}{\%12} \right) \right.$$

$$\Big/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%13 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2i_3 + 71.70000000\ O2i_3 + 50480.80000 \right)}{\%12} \Bigg) Ti_3 \Bigg) \Bigg)^{1/2} \Bigg(1. -$$

$$.05550621670 \frac{8.936000000\ H + \%13 + Mf}{.4960035524\ H + .05550621670\ \%13 + .05550621670\ Mf + 100.\ \frac{\%2}{\%12}}$$

$$\Bigg) CO2i_3 + .01000000000 \left(DPi_4 \left(8.936000000\ H + \%11 + Mf + 1801.600000\ \frac{\%2}{\%10} \right) \right.$$

$$\Big/ \Bigg(\Bigg(160.9909760\ H + 18.01600000\ \%11 + 18.01600000\ Mf$$

$$+ \frac{\%2 \left(288.0800000\ CO2i_4 + 71.70000000\ O2i_4 + 50480.80000 \right)}{\%10} \Bigg) Ti_4 \Bigg) \Bigg)^{1/2} \Bigg(1. -$$

$$.05550621670 \frac{8.936000000\ H + \%11 + Mf}{.4960035524\ H + .05550621670\ \%11 + .05550621670\ Mf + 100.\ \frac{\%2}{\%10}}$$

$$\Bigg) CO2i_4 \Bigg) + 5348840\ Areai\ CP \sqrt{PSi} \Bigg(.01000000000 \Bigg(DPi_1$$

$$\left(8.936000000\ H + \%9 + Mf + 1801.600000\ \frac{\%2}{\%8}\right) \bigg/ \Bigg(\Bigg(160.9909760\ H$$

$$+ 18.01600000\ \%9 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_1 + 71.70000000\ O2o_1 + 50480.80000\right)}{\%8}\Bigg)\ Ti_1\Bigg)\Bigg)^{1/2} \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%9 + Mf}{.4960035524\ H + .05550621670\ \%9 + .05550621670\ Mf + 100.\ \frac{\%2}{\%8}}$$

$$\Bigg)\ CO2o_1 + .01000000000\ \Bigg(DPi_2\ \left(8.936000000\ H + \%7 + Mf + 1801.600000\ \frac{\%2}{\%6}\right) \bigg/ \Bigg($$

$$\Bigg(160.9909760\ H + 18.01600000\ \%7 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_2 + 71.70000000\ O2o_2 + 50480.80000\right)}{\%6}\Bigg)\ Ti_2\Bigg)\Bigg)^{1/2} \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%7 + Mf}{.4960035524\ H + .05550621670\ \%7 + .05550621670\ Mf + 100.\ \frac{\%2}{\%6}}$$

$$\Bigg)\ CO2o_2 + .01000000000\ \Bigg(DPi_3\ \left(8.936000000\ H + \%5 + Mf + 1801.600000\ \frac{\%2}{\%4}\right) \bigg/ \Bigg($$

$$\Bigg(160.9909760\ H + 18.01600000\ \%5 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_3 + 71.70000000\ O2o_3 + 50480.80000\right)}{\%4}\Bigg)\ Ti_3\Bigg)\Bigg)^{1/2} \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%5 + Mf}{.4960035524\ H + .05550621670\ \%5 + .05550621670\ Mf + 100.\ \frac{\%2}{\%4}}$$

$$\Bigg)\ CO2o_3 + .01000000000\ \Bigg(DPi_4\ \left(8.936000000\ H + \%3 + Mf + 1801.600000\ \frac{\%2}{\%1}\right) \bigg/$$

$$\Bigg(160.9909760\ H + 18.01600000\ \%3 + 18.01600000\ Mf$$

$$+ \frac{\%2\ \left(288.0800000\ CO2o_4 + 71.70000000\ O2o_4 + 50480.80000\right)}{\%1}\Bigg)\ Ti_4\Bigg)\Bigg)^{1/2} \Bigg(1.$$

$$- .05550621670\ \frac{8.936000000\ H + \%3 + Mf}{.4960035524\ H + .05550621670\ \%3 + .05550621670\ Mf + 100.\ \frac{\%2}{\%1}}$$

$$\Bigg)\ CO2o_4\Bigg)\Bigg)$$

$$\%1 := 12.01000000\ CO2o_4 + 12.01000000\ COo_4$$

$$\%2 := C - 1.\ \frac{A\ OUHD\ Ca}{1. - 1.\ Ca} - .3333333333\ \frac{A\ (1. - 1.\ OUHD)\ Ca}{1. - .3333333333\ Ca} + .3744932959\ S$$

$$\%3 :=$$

$$Wma\ \left(36.46063760\ \frac{\left(100. - 1.\ COo_4 - 1.\ CO2o_4 - 1.\ O2o_4\right)\ \%2}{\%1} - 1.301236174\ N\right)$$

$$\%4 := 12.01000000\ CO2o_3 + 12.01000000\ COo_3$$

$$\%5 :=$$

$$Wma\ \left(36.46063760\ \frac{\left(100. - 1.\ COo_3 - 1.\ CO2o_3 - 1.\ O2o_3\right)\ \%2}{\%4} - 1.301236174\ N\right)$$

$$\%6 := 12.01000000\ CO2o_2 + 12.01000000\ COo_2$$

$$\%7 :=$$

$$Wma\ \left(36.46063760\ \frac{\left(100. - 1.\ COo_2 - 1.\ CO2o_2 - 1.\ O2o_2\right)\ \%2}{\%6} - 1.301236174\ N\right)$$

$$\%8 := 12.01000000\ CO2o_1 + 12.01000000\ COo_1$$

$$\%9 := Wma\left(36.46063760\ \frac{(100. - 1.\ COo_1 - 1.\ CO2o_1 - 1.\ O2o_1)\ \%2}{\%8} - 1.301236174\ N\right)$$

$$\%10 := 12.01000000\ CO2i_4 + 12.01000000\ COi_4$$

$$\%11 := Wma\left(36.46063760\ \frac{(100. - 1.\ COi_4 - 1.\ CO2i_4 - 1.\ O2i_4)\ \%2}{\%10} - 1.301236174\ N\right)$$

$$\%12 := 12.01000000\ CO2i_3 + 12.01000000\ COi_3$$

$$\%13 := Wma\left(36.46063760\ \frac{(100. - 1.\ COi_3 - 1.\ CO2i_3 - 1.\ O2i_3)\ \%2}{\%12} - 1.301236174\ N\right)$$

$$\%14 := 12.01000000\ CO2i_2 + 12.01000000\ COi_2$$

$$\%15 := Wma\left(36.46063760\ \frac{(100. - 1.\ COi_2 - 1.\ CO2i_2 - 1.\ O2i_2)\ \%2}{\%14} - 1.301236174\ N\right)$$

$$\%16 := 12.01000000\ CO2i_1 + 12.01000000\ COi_1$$

$$\%17 := Wma\left(36.46063760\ \frac{(100. - 1.\ COi_1 - 1.\ CO2i_1 - 1.\ O2i_1)\ \%2}{\%16} - 1.301236174\ N\right)$$

```
> sigmaSA := sqrt(
> Diff(SA,CO2avei)^2*varCO2avei +
> Diff(SA,COavei)^2*varCOavei +
> Diff(SA,O2avei)^2*varO2avei +
> Diff(SA,CO2aveo)^2*varCO2aveo +
> Diff(SA,COaveo)^2*varCOaveo +
> Diff(SA,O2aveo)^2*varO2aveo +
> Diff(SA,Wfe)^2*varWfe +
> Diff(SA,Areai)^2*varAreai +
> Diff(SA,CP)^2*varCP +
> Diff(SA,PSI)^2*varPSI +
> Diff(SA,A)^2*varA +
> Diff(SA,OUHD)^2*varOUHD +
> Diff(SA,Ca)^2*varCa +
> Diff(SA,C)*Diff(SA,C)*varC +
> Diff(SA,S)*Diff(SA,S)*varS +
> Diff(SA,H)*Diff(SA,H)*varH +
> Diff(SA,Wma)*Diff(SA,Wma)*varWma +
> Diff(SA,N)*Diff(SA,N)*varN +
> Diff(SA,Mf)*Diff(SA,Mf)*varMf +
> sum(
> Diff(SA,DPi[i])*Diff(SA,DPi[i])*varDPi[i,i] +
> Diff(SA,Ti[i])*Diff(SA,Ti[i])*varTi[i,i] +
> Diff(SA,COi[i])*Diff(SA,COi[i])*varCOi[i,i] +
> Diff(SA,CO2i[i])*Diff(SA,CO2i[i])*varCO2i[i,i] +
> Diff(SA,O2i[i])*Diff(SA,O2i[i])*varO2i[i,i] +
> Diff(SA,COo[i])*Diff(SA,COo[i])*varCOo[i,i] +
> Diff(SA,CO2o[i])*Diff(SA,CO2o[i])*varCO2o[i,i] +
```

```
> Diff(SA,O2o[i])*Diff(SA,O2o[i])*varO2o[i,i]
> ,i=1..n)):
> sigmaSA := value("):
```

Constants

Averages and Random Error Variances (Copied from Part A -- function of sample size n)

```
> CO2avei := 15.2148;
```
$CO2avei := 15.2148$
```
> varCO2avei := .102^2;
```
$varCO2avei := .010404$
```
> COavei := .005;
```
$COavei := .005$
```
> varCOavei := .0002^2;
```
$varCOavei := .4\ 10^{-7}$
```
> O2avei := 3.8;
```
$O2avei := 3.8$
```
> varO2avei := .01118^2;
```
$varO2avei := .0001249924$
```
> CO2aveo := 14.145;
```
$CO2aveo := 14.145$
```
> varCO2aveo := .0866^2;
```
$varCO2aveo := .00749956$
```
> COaveo := .005;
```
$COaveo := .005$
```
> varCOaveo := .000204^2;
```
$varCOaveo := .41616\ 10^{-7}$
```
> O2aveo := 5;
```
$O2aveo := 5$
```
> varO2aveo := .010206^2;
```
$varO2aveo := .000104162436$

Constants for Random Error Propagation

Coal Feed Rate (lbs/hr) re
```
> Wfe := 115839;
```
$Wfe := 115839$
```
> varWfe := (0.0025*Wfe)^2;
```
$varWfe := 83866.71200$

Area (square ft) re
```
> Areai := 3.99;
```
$Areai := 3.99$
```
> varAreai := (0.0335*Areai)^2;
```
$varAreai := .01786633223$
```
> Areao := 3.54;
```
$Areao := 3.54$
```
> varAreao := (0.0364*Areao)^2;
```
$varAreao := .01660386874$

Pitot Coefficient re
```
> CP := 0.84;
```
$CP := .84$
```
> varCP := (0)^2;
```
$varCP := 0$

Pressure Ambient or Barometric re
```
> PSi := 29.23;
```
$PSi := 29.23$
```
> varPSi := (0.04)^2;
```
$varPSi := .0016$
```
> PSo := 29.1;
```
$PSo := 29.1$
```
> varPSo := (0.04)^2;
```
$varPSo := .0016$

Pressue for primary air
```
> PSpa := 31.11;
```
$PSpa := 31.11$
```
> varPSpa := (0.04)^2;
```

$varPSpa := .0016$

Velocity Head DP re

v := .45802;

$v := .45802$

DPo := array([seq(v,i=1..n)]);

$DPo := [.45802 \quad .45802 \quad .45802 \quad .45802]$

u := .00005^2;

$u := .25\ 10^{-8}$

var := array([seq(u,i=1..n)]);

$var := [.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}]$

varDPo := make_array(var,n);

$varDPo := varcovar$

v := .82831;

$v := .82831$

DPi := array([seq(v,i=1..n)]);

$DPi := [.82831 \quad .82831 \quad .82831 \quad .82831]$

u := .00005^2;

$u := .25\ 10^{-8}$

var := array([seq(u,i=1..n)]);

$var := [.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}]$

varDPi := make_array(var,n);

$varDPi := varcovar$

v := .2171;

$v := .2171$

DPpa := array([seq(v,i=1..n)]);

$DPpa := [.2171 \quad .2171 \quad .2171 \quad .2171]$

u := (0.00005)^2;

$u := .25\ 10^{-8}$

varDPpa := array([seq(u,i=1..n)]);

$varDPpa := [.25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8} \quad .25\ 10^{-8}]$

v := 1104;

$v := 1104$

> Tpa := array([seq(v,i=1..n)]);

$Tpa := [1104 \quad 1104 \quad 1104 \quad 1104]$

> u := (0.005*(v - 460))^2;

$u := 10.368400$

> varTpa := array([seq(u,i=1..n)]);

$varTpa := [10.368400 \quad 10.368400 \quad 10.368400 \quad 10.368400]$

Temperature (R) re

> v := 713;

$v := 713$

> To := array([seq(v,i=1..n)]);

$To := [713 \quad 713 \quad 713 \quad 713]$

> u := (0.005*(v-460))^2;

$u := 1.600225$

> var := array([seq(u,i=1..n)]);

$var := [1.600225 \quad 1.600225 \quad 1.600225 \quad 1.600225]$

> varTo := make_array(var,n);

$varTo := varcovar$

> v := 1140;

$v := 1140$

> Ti:= array([seq(v,i=1..n)]);

$Ti := [1140 \quad 1140 \quad 1140 \quad 1140]$

> u := (0.005*(v-460))^2;

$u := 11.560000$

> var := array([seq(u,i=1..n)]);

$var := [11.560000 \quad 11.560000 \quad 11.560000 \quad 11.560000]$

> varTi := make_array(var,n);

$varTi := varcovar$

Moisture in Ash re

> Mf :=0.06;

$Mf := .06$

> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;

$varMf := .00001058319613$

Ash re

> A := 0.0619;

$A := .0619$

```
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
```

$varA := .4696223261\ 10^{-6}$

Overhead re

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon re

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.64/(2*1.414*100))^2;
```

$varC := .5121546706\ 10^{-5}$

Hydrogen re

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.16/(2*1.414*100))^2;
```

$varH := .3200966692\ 10^{-6}$

Nitrogen re

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.11/(2*1.414*100))^2;
```

$varN := .1512956913\ 10^{-6}$

Sulfur re

```
> S := 0.0123;
```

$S := .0123$

```
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
```

$varS := .1327813813\ 10^{-6}$

CO2 re

```
> v := 14.145;
```

$v := 14.145$

```
> CO2o := array([seq(v,i=1..n)]);
```

$CO2o := [14.145 \quad 14.145 \quad 14.145 \quad 14.145]$

```
> u := (0.03*v)^2;
```

$u := .1800729225$

```
> var := array([seq(u,i=1..n)]);
```

$var := [.1800729225 \quad .1800729225 \quad .1800729225 \quad .1800729225]$

```
> varCO2o := make_array(var,n);
```

$varCO2o := varcovar$

```
> v := 15.2148;
```

$v := 15.2148$

```
> CO2i := array([seq(v,i=1..n)]);
```

$CO2i := [15.2148 \quad 15.2148 \quad 15.2148 \quad 15.2148]$

```
> u := (0.03*v)^2;
```

$u := .2083411251$

```
> var := array([seq(u,i=1..n)]);
```

$var := [.2083411251 \quad .2083411251 \quad .2083411251 \quad .2083411251]$

```
> varCO2i := make_array(var,n);
```

$varCO2i := varcovar$

O2 re

```
> v := 5;
```

$v := 5$

```
> O2o := array([seq(v,i=1..n)]);
```

$O2o := [5 \quad 5 \quad 5 \quad 5]$

```
> u := (0.05)^2;
```

$u := .0025$

```
> var := array([seq(u,i=1..n)]);
```

$var := [.0025 \quad .0025 \quad .0025 \quad .0025]$

```
> varO2o := make_array(var,n);
```

$varO2o := varcovar$

```
> v := 3.8;
```

$v := 3.8$

```
> O2i := array([seq(v,i=1..n)]);
```

$O2i := [3.8 \quad 3.8 \quad 3.8 \quad 3.8]$

```
> u := (0.05)^2;
```

$u := .0025$

```
> var := array([seq(u,i=1..n)]);
```

```
var := [.0025   .0025   .0025   .0025]
> varO2i := make_array(var,n);
varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
Wma := .013
> varWma := (.2*Wma)^2;
varWma := .676 10^-5
```

CO re

```
> v := 0.005;
v := .005
> COo := array([seq(v,i=1..n)]);
COo := [.005   .005   .005   .005]
> u := (0.001)^2;
u := .1 10^-5
> var := array([seq(u,i=1..n)]);
var := [.1 10^-5   .1 10^-5   .1 10^-5   .1 10^-5]
> varCOo := make_array(var,n);
varCOo := varcovar

> v := 0.005;
v := .005
> COi := array([seq(v,i=1..n)]);
COi := [.005   .005   .005   .005]
> u := (0.001)^2;
u := .1 10^-5
> var := array([seq(u,i=1..n)]);
var := [.1 10^-5   .1 10^-5   .1 10^-5   .1 10^-5]
> varCOi := make_array(var,n);
varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
Ca := .0486
> varCa := (0.1*Ca)^2;
varCa := .0000236196
```

Area for Primary Air re

```
> apa := 0.63;
apa := .63
> varapa := (0.0208*apa)^2;
varapa := .000171714816
```

Results

```
**********************************************************************
> evalf(SA);
.5168579433
> eval(sigmaSA);
.004864108802
```

$\times\sqrt{\frac{4}{20}} = 0.002175$ ← for N=20

```
> eval(100*sigmaSA/SA);
.9410920089
**********************************************************************
>
```

Appendix I-1
Bias Error Calculation
Secondary Air Inlet Flow -- Zero Leak Case

Error Propagation Calculations, Part B, Secondary Airflow Wsai with No Leakage

#4

```
> MFG := proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2 + CO));
> K4 := 8.936*H + Wma*((28.02*(100-CO-CO2-O2)*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

   proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
   local Cr,Cb,K3,K4,MFG;
       Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
       Cb := C-Cr;
       K3 := (Cb+.3744932959*S)/(12.01*CO2+12.01*CO);
       K4 := 8.936*H+Wma*(36.46063760*(100-CO-CO2-O2)*K3-1.301236174*N
       MFG := .05550621670*K4/(.05550621670*K4+100*K3)
   end

> Mfg := MFG(A,OUHD,Ca,C,S,COavei,CO2avei,H,Wma,O2avei,N,Mf);
```

$$Mfg := .05550621670 \Bigg(8.936\ H + Wma \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174 \right. + Mf \Bigg) \Bigg/ \Big(.4960035524\ H + .05550621670$$

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$$Wma\left(36.46063760\,\frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$
$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p1 := CO2avei*(6.214*t2+(10.396/1000)*t2^2/2-(3.545/1000000)*t2^3/3-(6.214*t1+(1
> 0.396/1000)*t1^2/2-(3.545/1000000)*t1^3/3));
```

$$p1 := CO2avei\ \left(6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1 - .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3\right)$$

```
> p2 := COavei*(6.420*t2+(1.665/1000)*t2^2/2-(0.196/1000000)*t2^3/3-(6.420*t1+(1.66
> 5/1000)*t1^2/2-(0.196/1000000)*t1^3/3));
```

$$p2 := COavei\ \left(6.420\ t2 + .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2 + .6533333333\ 10^{-7}\ t1^3\right)$$

```
> p3 := O2avei*(6.148*t2+(3.102/1000)*t2^2/2-(0.923/1000000)*t2^3/3-(6.148*t1+(3.10
> 2/1000)*t1^2/2-(0.923/1000000)*t1^3/3));
```

$$p3 := O2avei\ \left(6.148\ t2 + .001551000000\ t2^2 - .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1^3\right)$$

```
> N2avei := 100 - CO2avei - COavei - O2avei;
```

$$N2avei := 100 - COavei - CO2avei - O2avei$$

```
> p4 := N2avei*(6.524*t2+(1.250/1000)*t2^2/2-(0.001/1000000)*t2^3/3-(6.524*t1+(1.25
> 0/1000)*t1^2/2-(0.001/1000000)*t1^3/3));
```

$$p4 := (100 - COavei - CO2avei - O2avei)\ \left(6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1 - .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3\right)$$

```
> p5 := Mfg*(7.256*t2+(2.298/1000)*t2^2/2+(0.283/1000000)*t2^3/3-(7.256*t1+(2.298/1
> 000)*t1^2/2+(0.283/1000000)*t1^3/3));
```

$$p5 := .05550621670\ \Bigg(8.936\ H + Wma\left(36.46063760\,\frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$
$$+ Mf\Bigg)\ \left(7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3 - 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3\right)\Big/\Bigg(.4960035524\ H + .05550621670$$
$$Wma\left(36.46063760\,\frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$
$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> Cpfg := (1/(t2-t1))*(((1-Mfg))*(p1+p2+p3+p4)+100*p5)/100;
```

$$Cpfg := \frac{1}{100}\Bigg(\Bigg(\Bigg(1 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}}$$
$$\Bigg)\Big(CO2avei\ \left(6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1 - .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3\right) + COavei\ \left(6.420\ t2 + .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2 + .6533333333\ 10^{-7}\ t1^3\right) + O2avei\ \left(6.148\ t2 + .001551000000\ t2^2 - .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1^3\right)$$
$$ + \%3\ \left(6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1 - .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3\right)\Big)\Bigg) + 5.550621670$$
$$(8.936\ H + \%4 + Mf)\ \left(7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3 - 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3\right)\Big/\Bigg($$

$$.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}\Bigg)\Bigg)\Big/(t2 - t1)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\left(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\right)$$

```
> p3 := 21*(6.148*t4+(3.102/1000)*t4^2/2-(0.923/1000000)*t4^3/3-(6.148*t3+(3.102/10
> 00)*t3^2/2-(0.923/1000000)*t3^3/3));
```

$$p3 := 129.108\ t4 + .03257100000\ t4^2 - .6460999999\ 10^{-5}\ t4^3 - 129.108\ t3 - .03257100000\ t3^2 + .6460999999\ 10^{-5}\ t3^3$$

```
> p4 := 79*(6.524*t4+(1.250/1000)*t4^2/2-(0.001/1000000)*t4^3/3-(6.524*t3+(1.250/10
> 00)*t3^2/2-(0.001/1000000)*t3^3/3));
```

$$p4 := 515.396\ t4 + .04937500000\ t4^2 - .2633333333\ 10^{-7}\ t4^3 - 515.396\ t3 - .04937500000\ t3^2 + .2633333333\ 10^{-7}\ t3^3$$

```
> amp := ((28.97*Wma*100)/18.015)/(28.97*Wma/18.015 +1);
```

$$amp := 160.8104357\ \frac{Wma}{1.608104357\ Wma + 1}$$

```
> p5 := amp*(7.256*t4+(2.298/1000)*t4^2/2+(0.283/1000000)*t4^3/3-(7.256*t3+(2.298/
> 1000)*t3^2/2+(0.283/1000000)*t3^3/3));
```

$$p5 := 160.8104357\ Wma\left(7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3\right)/(1.608104357\ Wma + 1)$$

```
> Cpal := (1/(t4-t3))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpal := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)\right.\right.\right.$$

$$\left.+ Mf\right)\Big/\Bigg(.4960035524\ H + .05550621670\ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Bigg)\Bigg)\Big(644.504\ t4 + .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2 + .6487333332\ 10^{-5}\ t3^3\Big) + 160.8104357\ Wma\left(7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3\right)/(1.608104357\ Wma + 1)\Big)\Big/(t4 - t3)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t8+(3.102/1000)*t8^2/2-(0.923/1000000)*t8^3/3-(6.148*t7+(3.102/10
> 00)*t7^2/2-(0.923/1000000)*t7^3/3));
```

$$p3 := 129.108\ t8 + .03257100000\ t8^2 - .6460999999\ 10^{-5}\ t8^3 - 129.108\ t7 - .03257100000\ t7^2 + .6460999999\ 10^{-5}\ t7^3$$

```
> p4 := 79*(6.524*t8+(1.250/1000)*t8^2/2-(0.001/1000000)*t8^3/3-(6.524*t7+(1.250/10
> 00)*t7^2/2-(0.001/1000000)*t7^3/3));
```

$$p4 := 515.396\ t8 + .04937500000\ t8^2 - .2633333333\ 10^{-7}\ t8^3 - 515.396\ t7 - .04937500000\ t7^2 + .2633333333\ 10^{-7}\ t7^3$$

```
> p5 := amp*(7.256*t8+(2.298/1000)*t8^2/2+(0.283/1000000)*t8^3/3-(7.256*t7+(2.298/
> 1000)*t7^2/2+(0.283/1000000)*t7^3/3));
```

$$p5 := 160.8104357\ Wma\left(7.256\ t8 + .001149000000\ t8^2 + .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3\right)/(1.608104357\ Wma + 1$$

```
> Cpsa := (1/(t8-t7))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpsa := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right.\right.\right.\right.$$

$$+ Mf\Big)\Big/\Big(.4960035524\ H + .05550621670\ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$
$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Big)\Big)\Big(644.504\ t8$$
$$+ .08194600000\ t8^2 - .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2$$
$$+ .6487333332\ 10^{-5}\ t7^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t8 + .001149000000\ t8^2$$
$$+ .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3$$
$$\Big)/(1.608104357\ Wma + 1)\Big)\Big/(t8 - t7)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t6+(3.102/1000)*t6^2/2-(0.923/1000000)*t6^3/3-(6.148*t5+(3.102/10
> 00)*t5^2/2-(0.923/1000000)*t5^3/3));
```

$$p3 := 129.108\ t6 + .03257100000\ t6^2 - .6460999999\ 10^{-5}\ t6^3 - 129.108\ t5$$
$$- .03257100000\ t5^2 + .6460999999\ 10^{-5}\ t5^3$$

```
> p4 := 79*(6.524*t6+(1.250/1000)*t6^2/2-(0.001/1000000)*t6^3/3-(6.524*t5+(1.250/10
> 00)*t5^2/2-(0.001/1000000)*t5^3/3));
```

$$p4 := 515.396\ t6 + .04937500000\ t6^2 - .2633333333\ 10^{-7}\ t6^3 - 515.396\ t5$$
$$- .04937500000\ t5^2 + .2633333333\ 10^{-7}\ t5^3$$

```
> p5 := amp*(7.256*t6+(2.298/1000)*t6^2/2+(0.283/1000000)*t6^3/3-(7.256*t5+(2.298/
> 1000)*t5^2/2+(0.283/1000000)*t5^3/3));
```

$$p5 := 160.8104357\ Wma\ \Big(7.256\ t6 + .001149000000\ t6^2 + .9433333332\ 10^{-7}\ t6^3$$
$$- 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3\Big)/(1.608104357\ Wma + 1)$$

```
> Cppa := (1/(t6-t5))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cppa := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\ \Big(8.936\ H\right.\right.$$
$$+ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ Mf\Big)\Big/\Big(.4960035524\ H + .05550621670$$
$$Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$
$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Big)\Big)\Big(644.504\ t6$$
$$+ .08194600000\ t6^2 - .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2$$
$$+ .6487333332\ 10^{-5}\ t5^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t6 + .001149000000\ t6^2$$
$$+ .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5 \ldots$$
$$\Big)/(1.608104357\ Wma + 1)\Big)\Big/(t6 - t5)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
>
```

```
> Wsai := (Wfgi*(Cpfg*(Tfgi-Tfgo) - AL*Cpal*(Tfgo-Tsai)) - Wpai*Cppa*(Tpao-Tsai))/
> (Cpsa*(Tsao-Tsal)*Wfe*SA);
```

$$Wsai := 100\left(Wfgi\left(\frac{1}{100}\left(\left(1 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\right)\Big(CO2avei\ \Big(\right.\right.\right.$$
$$6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1$$
$$- .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3\Big) + COavei\ \Big(6.420\ t2$$
$$+ .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2$$
$$+ .6533333333\ 10^{-7}\ t1^3\Big) + O2avei\ \Big(6.148\ t2 + .001551000000\ t2^2$$
$$- .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1 \ldots$$
$$\Big) + \%3\ \Big(6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1$$
$$- .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3\Big)\Big) + 5.550621670$$
$$(8.936\ H + \%4 + Mf)\ \Big(7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3$$
$$- 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3\Big)/(\%5)\Big)\ (Tfgi - Tfgo \ldots$$
$$/(t2 - t1) - \frac{1}{100}\ AL\ \left(\frac{1}{100}\left(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\right)\Big(644.504\ t \ldots\right.$$
$$+ .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2$$

$+ .6487333332\ 10^{-5}\ t3^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t4 + .001149000000\ t4^2$
$+ .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3$
$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tfgo - Tsai)/(t4 - t3)\Big) - \frac{1}{100}\ Wpai\ \Big(\frac{1}{100}$
$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t6 + .08194600000\ t6^2$
$- .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2$
$+ .6487333332\ 10^{-5}\ t5^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t6 + .001149000000\ t6^2$
$+ .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3$
$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tpao - Tsai)/(t6 - t5)\Big)\ (t8 - t7) \Big/ \Big(\Big(\Big(\frac{1}{100}$
$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t8 + .08194600000\ t8^2$
$- .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2$
$+ .6487333332\ 10^{-5}\ t7^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t8 + .001149000000\ t8^2$
$+ .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3$
$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tsao - Tsai)\ Wfe\ SA\Big)$

$\%1 := 12.01\ CO2avei + 12.01\ COavei$

$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$

$\%3 := 100 - COavei - CO2avei - O2avei$

$\%4 := Wma\ \Big(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\Big)$

$\%5 := .4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}$

```
>
> sigmaWsal := sqrt(
> Diff(Wsal,SA)^2*varSA +
> Diff(Wsal,CO2avei)^2*varCO2avei +
> Diff(Wsal,COavei)^2*varCOavei +
> Diff(Wsal,O2avei)^2*varO2avei +
> Diff(Wsal,Wfe)^2*varWfe +
> Diff(Wsal,A)^2*varA +
> Diff(Wsal,OUHD)^2*varOUHD +
> Diff(Wsal,Ca)^2*varCa +
> Diff(Wsal,C)*Diff(Wsal,C)*varC +
> Diff(Wsal,S)*Diff(Wsal,S)*varS +
> Diff(Wsal,H)*Diff(Wsal,H)*varH +
> Diff(Wsal,Wma)*Diff(Wsal,Wma)*varWma +
> Diff(Wsal,N)*Diff(Wsal,N)*varN +
> Diff(Wsal,Mf)*Diff(Wsal,Mf)*varMf
> ):

> sigmaWsal := value("):
```

Constants

SA - Split A

```
> SA := 0.5168;
```

$SA := .5168$

```
> varSA := 0.002214^2;
```

$varSA := .4901796\ 10^{-5}$

```
>
```

Weight of Flue Gas in

```
> Wfgi := 754952;
```

$Wfgi := 754952$

```
> varWfgi := 47382^2;
```

```
varWfgi := 2245053924

Weight of Primary Air in
> Wpai := 62530;
                    Wpai := 62530
> varWpai := 1635^2;
                    varWpai := 2673225

Air Leakage fraction
> AL := .0;
                    AL := 0
> varAL := .00058^2;
                    varAL := .3364 10^-6

> Tfgi := 680;
                    Tfgi := 680
> varTfgi := (0.01*Tfgi)^2;
                    varTfgi := 46.2400
> t2 := (Tfgi +460)/1.8;
                    t2 := 633.3333334
>
> Tfgo := 253;
                    Tfgo := 253
> varTfgo := (0.01*Tfgo)^2;
                    varTfgo := 6.4009
> t1 := (Tfgo+460)/1.8;
                    t1 := 396.1111112
>
> Tali := 80;
                    Tali := 80
> varTali := (0.01*Tali)^2;
                    varTali := .6400
> t3 := (Tali+460)/1.8;
                    t3 := 300.0000001
> t4 := t1;
                    t4 := 396.1111112
> Tpai := 80;
                    Tpai := 80
> varTpai := (0.01*Tpai)^2;
                    varTpai := .6400
> t5 := (Tpai+460)/1.8;
                    t5 := 300.0000001
> Tpao := 644;
                    Tpao := 644
> varTpao := (0.01*Tpao)^2;
                    varTpao := 41.4736
> t6 := (Tpao+460)/1.8;
                    t6 := 613.3333334

> Tsai := 80;
                    Tsai := 80
> varTsai := (0.01*Tsai)^2;
                    varTsai := .6400
> t7 := (Tsai+460)/1.8;
                    t7 := 300.0000001

> Tsao := 616;
                    Tsao := 616
> varTsao := (0.01*Tsao)^2;
                    varTsao := 37.9456
> t8 := (Tsao+460)/1.8;
                    t8 := 597.7777778

Averages and Variances from Part A
> CO2avei := 15.2148;
                    CO2avei := 15.2148
> varCO2avei := .1^2;
                    varCO2avei := .01
> COavei := .005;
                    COavei := .005
> varCOavei := .002^2;
                    varCOavei := .4 10^-5
> O2avei := 3.8;
                    O2avei := 3.8
> varO2avei := .05^2;
```

$varO2avei := .0025$

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```

$Wfe := 115839$

```
> varWfe := (0.05*Wfe)^2;
```

$varWfe := .3354668480 \; 10^{8}$

Moisture in Coal

```
> Mf :=0.06;
```

$Mf := .06$

```
> varMf := (0.039*Mf)^2;
```

$varMf := .54756 \; 10^{-5}$

Ash

```
> A := 0.0619;
```

$A := .0619$

```
> varA := ( 0.039*A)^2;
```

$varA := .582787881 \; 10^{-5}$

Overhead

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.039*C)^2;
```

$varC := .0008286280388$

Hydrogen

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.039*H)^2;
```

$varH := .353364804 \; 10^{-5}$

Nitrogen

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.039*N)^2;
```

$varN := .27720225 \; 10^{-6}$

Sulfur

```
> S := 0.0123;
```

$S := .0123$

```
> varS := (0.019*S)^2;
```

$varS := .5461569 \; 10^{-7}$

Moisture (air)

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.1*Wma)^2;
```

$varWma := .169 \; 10^{-5}$

Carbon in Ash

```
> Ca := 0.0486;
```

$Ca := .0486$

```
> varCa := (0.25*Ca)^2;
```

$varCa := .000147622500$

Results

****

```
> evalf(Mfg);
```

.08136935946

```
> evalf(Cpfg);
```

7.769387922

```
> evalf(Cpal);
```

7.151727411

```
> evalf(Cppa);
```

7.316810251

```
> evalf(Cpsa);
```

7.305185745

Wsai in lb/lb of AF Coal

```
> evalf(Wsai);
                                   9.583839808
> evalf(sigmaWsai);
                                   .4815015354
> evalf(100*sigmaWsai/Wsai);
                                   5.024098326
> evalf(Wsai*SA*Wfe);
                                   573742.2744
> evalf(sigmaWsai*SA*Wfe);
                                   28825.37601
>
```

****

```
>
```

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Appendix I-2
Random Error Calculation
Secondary Air Inlet Flow -- Zero Leak Case

>

>

Random Error Propagation Calculations, Part B, Secondary Airflow Wsai without Leakage

#4

```
> MFG := proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2 + CO));

> K4 := 8.936*H + Wma*((28.02*(100-CO-CO2-O2)*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

   proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
   local Cr,Cb,K3,K4,MFG;
       Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
       Cb := C-Cr;
       K3 := (Cb+.3744932959*S)/(12.01*CO2+12.01*CO);
       K4 := 8.936*H+Wma*(36.46063760*(100-CO-CO2-O2)*K3-1.301236174*N
       MFG := .05550621670*K4/(.05550621670*K4+100*K3)
   end

> Mfg := MFG(A,OUHD,Ca,C,S,COavei,CO2avei,H,Wma,O2avei,N,Mf);
```

$$Mfg := .05550621670 \Bigg(8.936\ H$$

$$+ Wma \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174 \right.$$

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$$+ Mf\Big) \Big/ \Big(.4960035524\ H + .05550621670\ Wma \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \right) + .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei} \Big)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p1 := CO2avei*(6.214*t2+(10.396/1000)*t2^2/2-(3.545/1000000)*t2^3/3-(6.214*t1+(1
> 0.396/1000)*t1^2/2-(3.545/1000000)*t1^3/3));
```

$$p1 := CO2avei\ (6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1 - .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3)$$

```
> p2 := COavei*(6.420*t2+(1.665/1000)*t2^2/2-(0.196/1000000)*t2^3/3-(6.420*t1+(1.66
> 5/1000)*t1^2/2-(0.196/1000000)*t1^3/3));
```

$$p2 := COavei\ (6.420\ t2 + .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2 + .6533333333\ 10^{-7}\ t1^3)$$

```
> p3 := O2avei*(6.148*t2+(3.102/1000)*t2^2/2-(0.923/1000000)*t2^3/3-(6.148*t1+(3.10
> 2/1000)*t1^2/2-(0.923/1000000)*t1^3/3));
```

$$p3 := O2avei\ (6.148\ t2 + .001551000000\ t2^2 - .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1^3)$$

```
> N2avei := 100 - CO2avei - COavei - O2avei;
```

$$N2avei := 100 - COavei - CO2avei - O2avei$$

```
> p4 := N2avei*(6.524*t2+(1.250/1000)*t2^2/2-(0.001/1000000)*t2^3/3-(6.524*t1+(1.25
> 0/1000)*t1^2/2-(0.001/1000000)*t1^3/3));
```

$$p4 := (100 - COavei - CO2avei - O2avei)\ (6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1 - .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3)$$

```
> p5 := Mfg*(7.256*t2+(2.298/1000)*t2^2/2+(0.283/1000000)*t2^3/3-(7.256*t1+(2.298/1
> 000)*t1^2/2+(0.283/1000000)*t1^3/3));
```

$$p5 := .05550621670\ \Big(8.936\ H + Wma \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \right) + Mf\Big)\ (7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3 - 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3) \Big/ \Big(.4960035524\ H + .05550621670\ Wma \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \right) + .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei} \Big)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> Cpfg := (1/(t2-t1))*(((1-Mfg))*(p1+p2+p3+p4)+100*p5)/100;
```

$$Cpfg := \frac{1}{100} \Bigg(\Bigg(\Bigg(1 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}} \Bigg) \Big(CO2avei\ (6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1 - .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3) + COavei\ (6.420\ t2 + .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2 + .6533333333\ 10^{-7}\ t1^3) + O2avei\ (6.148\ t2 + .001551000000\ t2^2 - .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1^3) + \%3\ (6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1 - .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3)\Big)\Bigg) + 5.550621670\ (8.936\ H + \%4 + Mf)\ (7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3 - 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3) \Big/ \Big($$

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$$.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}\Bigg)\Bigg)\Big/(t2 - t1)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\left(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\right)$$

```
> p3 := 21*(6.148*t4+(3.102/1000)*t4^2/2-(0.923/1000000)*t4^3/3-(6.148*t3+(3.102/10
> 00)*t3^2/2-(0.923/1000000)*t3^3/3));
```

$$p3 := 129.108\ t4 + .03257100000\ t4^2 - .6460999999\ 10^{-5}\ t4^3 - 129.108\ t3 - .03257100000\ t3^2 + .6460999999\ 10^{-5}\ t3^3$$

```
> p4 := 79*(6.524*t4+(1.250/1000)*t4^2/2-(0.001/1000000)*t4^3/3-(6.524*t3+(1.250/10
> 00)*t3^2/2-(0.001/1000000)*t3^3/3));
```

$$p4 := 515.396\ t4 + .04937500000\ t4^2 - .2633333333\ 10^{-7}\ t4^3 - 515.396\ t3 - .04937500000\ t3^2 + .2633333333\ 10^{-7}\ t3^3$$

```
> amp := ((28.97*Wma*100)/18.015)/(28.97*Wma/18.015 +1);
```

$$amp := 160.8104357\ \frac{Wma}{1.608104357\ Wma + 1}$$

```
> p5 := amp*(7.256*t4+(2.298/1000)*t4^2/2+(0.283/1000000)*t4^3/3-(7.256*t3+(2.298/
> 1000)*t3^2/2+(0.283/1000000)*t3^3/3));
```

$$p5 := 160.8104357\ Wma\ \big(7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3\big)/(1.608104357\ Wma + 1)$$

```
> Cpal := (1/(t4-t3))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpal := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)\right.\right.\right.$$

$$\left. + Mf\right)\Big/\Bigg(.4960035524\ H + .05550621670\ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Bigg)\Bigg)\big(644.504\ t4 + .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2$$

$$+ .6487333332\ 10^{-5}\ t3^3\big) + 160.8104357\ Wma\ \big(7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3$$

$$\big)/(1.608104357\ Wma + 1)\Big)\Big/(t4 - t3)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t8+(3.102/1000)*t8^2/2-(0.923/1000000)*t8^3/3-(6.148*t7+(3.102/10
> 00)*t7^2/2-(0.923/1000000)*t7^3/3));
```

$$p3 := 129.108\ t8 + .03257100000\ t8^2 - .6460999999\ 10^{-5}\ t8^3 - 129.108\ t7 - .03257100000\ t7^2 + .6460999999\ 10^{-5}\ t7^3$$

```
> p4 := 79*(6.524*t8+(1.250/1000)*t8^2/2-(0.001/1000000)*t8^3/3-(6.524*t7+(1.250/10
> 00)*t7^2/2-(0.001/1000000)*t7^3/3));
```

$$p4 := 515.396\ t8 + .04937500000\ t8^2 - .2633333333\ 10^{-7}\ t8^3 - 515.396\ t7 - .04937500000\ t7^2 + .2633333333\ 10^{-7}\ t7^3$$

```
> p5 := amp*(7.256*t8+(2.298/1000)*t8^2/2+(0.283/1000000)*t8^3/3-(7.256*t7+(2.298/
> 1000)*t7^2/2+(0.283/1000000)*t7^3/3));
```

$$p5 := 160.8104357\ Wma\ \big(7.256\ t8 + .001149000000\ t8^2 + .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3\big)/(1.608104357\ Wma + 1$$

```
> Cpsa := (1/(t8-t7))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpsa := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right.\right.\right.\right.$$

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$$+ Mf \Big) \Big/ \Big(.4960035524\ H + .05550621670$$
$$Wma \Big(36.46063760 \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \Big)$$
$$+ .05550621670\ Mf + 100 \frac{\%1}{12.01\ CO2avei + 12.01\ COavei} \Big) \Big) \Big(644.504\ t8$$
$$+ .08194600000\ t8^2 - .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2$$
$$+ .6487333332\ 10^{-5}\ t7^3 \Big) + 160.8104357\ Wma \Big(7.256\ t8 + .001149000000\ t8^2$$
$$+ .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3$$
$$\Big) / (1.608104357\ Wma + 1) \Big) / (t8 - t7)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t6+(3.102/1000)*t6^2/2-(0.923/1000000)*t6^3/3-(6.148*t5+(3.102/10
> 00)*t5^2/2-(0.923/1000000)*t5^3/3));
```

$$p3 := 129.108\ t6 + .03257100000\ t6^2 - .6460999999\ 10^{-5}\ t6^3 - 129.108\ t5$$
$$- .03257100000\ t5^2 + .6460999999\ 10^{-5}\ t5^3$$

```
> p4 := 79*(6.524*t6+(1.250/1000)*t6^2/2-(0.001/1000000)*t6^3/3-(6.524*t5+(1.250/10
> 00)*t5^2/2-(0.001/1000000)*t5^3/3));
```

$$p4 := 515.396\ t6 + .04937500000\ t6^2 - .2633333333\ 10^{-7}\ t6^3 - 515.396\ t5$$
$$- .04937500000\ t5^2 + .2633333333\ 10^{-7}\ t5^3$$

```
> p5 := amp*(7.256*t6+(2.298/1000)*t6^2/2+(0.283/1000000)*t6^3/3-(7.256*t5+(2.298/
> 1000)*t5^2/2+(0.283/1000000)*t5^3/3));
```

$$p5 := 160.8104357\ Wma \Big(7.256\ t6 + .001149000000\ t6^2 + .9433333332\ 10^{-7}\ t6^3$$
$$- 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3 \Big) / (1.608104357\ Wma + 1)$$

```
> Cppa := (1/(t6-t5))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cppa := \frac{1}{100} \Big(\frac{1}{100} \Big(100 - .05550621670 \Big(8.936\ H$$
$$+ Wma \Big(36.46063760 \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \Big)$$

$$+ Mf \Big) \Big/ \Big(.4960035524\ H + .05550621670$$
$$Wma \Big(36.46063760 \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N \Big)$$
$$+ .05550621670\ Mf + 100 \frac{\%1}{12.01\ CO2avei + 12.01\ COavei} \Big) \Big) \Big(644.504\ t6$$
$$+ .08194600000\ t6^2 - .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2$$
$$+ .6487333332\ 10^{-5}\ t5^3 \Big) + 160.8104357\ Wma \Big(7.256\ t6 + .001149000000\ t6^2$$
$$+ .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5$$
$$\Big) / (1.608104357\ Wma + 1) \Big) / (t6 - t5)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
>
```

```
> Wsai := (Wfgi*(Cpfg*(Tfgi-Tfgo) - AL*Cpal*(Tfgo-Tsai)) - Wpai*Cppa*(Tpao-Tsai))/
> (Cpsa*(Tsao-Tsai)*Wfe*SA);
```

$$Wsai := 100 \Big(Wfgi \Big(\frac{1}{100} \Big(\Big(1 - .05550621670 \frac{8.936\ H + \%4 + Mf}{\%5} \Big) \Big(CO2avei \Big($$
$$6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1$$
$$- .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3 \Big) + COavei \Big(6.420\ t2$$
$$+ .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2$$
$$+ .6533333333\ 10^{-7}\ t1^3 \Big) + O2avei \Big(6.148\ t2 + .001551000000\ t2^2$$
$$- .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1$$
$$\Big) + \%3 \Big(6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1$$
$$- .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3 \Big) \Big) + 5.550621670$$
$$(8.936\ H + \%4 + Mf) \Big(7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3$$
$$- 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3 \Big) / (\%5) \Big) (Tfgi - Tfgc$$
$$/ (t2 - t1) - \frac{1}{100}\ AL \Big(\frac{1}{100} \Big(100 - .05550621670 \frac{8.936\ H + \%4 + Mf}{\%5} \Big) \Big(644.504\ t$$
$$+ .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2$$

$$+ .6487333332\ 10^{-5}\ t3^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t4 + .001149000000\ t4^2$$
$$+ .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3$$
$$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tfgo - Tsai)/(t4 - t3)\Big) - \frac{1}{100}\ Wpai\ \Big(\frac{1}{100}$$
$$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t6 + .08194600000\ t6^2$$
$$- .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2$$
$$+ .6487333332\ 10^{-5}\ t5^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t6 + .001149000000\ t6^2$$
$$+ .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3$$
$$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tpao - Tsai)/(t6 - t5)\Big)\ (t8 - t7)\Big/\Big(\Big(\frac{1}{100}$$
$$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t8 + .08194600000\ t8^2$$
$$- .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2$$
$$+ .6487333332\ 10^{-5}\ t7^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t8 + .001149000000\ t8^2$$
$$+ .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3$$
$$\Big)/(1.608104357\ Wma + 1)\Big)\ (Tsao - Tsai)\ Wfe\ SA\Big)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\ \Big(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\Big)$$

$$\%5 := .4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}$$

```
>
> sigmaWsai := sqrt(
> Diff(Wsai,SA)^2*varSA +
> Diff(Wsai,CO2avei)^2*varCO2avei +
> Diff(Wsai,COavei)^2*varCOavei +
> Diff(Wsai,O2avei)^2*varO2avei +
> Diff(Wsai,Wfe)^2*varWfe +
> Diff(Wsai,A)^2*varA +
> Diff(Wsai,OUHD)^2*varOUHD +
> Diff(Wsai,Ca)^2*varCa +
> Diff(Wsai,C)*Diff(Wsai,C)*varC +
> Diff(Wsai,S)*Diff(Wsai,S)*varS +
> Diff(Wsai,H)*Diff(Wsai,H)*varH +
> Diff(Wsai,Wma)*Diff(Wsai,Wma)*varWma +
> Diff(Wsai,N)*Diff(Wsai,N)*varN +
> Diff(Wsai,Mf)*Diff(Wsai,Mf)*varMf
> ):

> sigmaWsai := value("):
```

Constants

SA - Split A

```
> SA := 0.5168;
```

$$SA := .5168$$

```
> varSA := 0.002175^2;
```

$$varSA := .4730625\ 10^{-5}$$

```
>
```

Weight of Flue Gas in

```
> Wfgi := 754952;
```

$$Wfgi := 754952$$

```
> varWfgi := 5676^2;
```

```
varWfgi := 32216976
```

Weight of Primary Air in

```
> Wpai := 62530;
                    Wpai := 62530
> varWpai := 1823^2;
                    varWpai := 3323329
```

Air Leakage fraction

```
> AL := .0;
                    AL := 0
> varAL := .00866^2;
                    varAL := .0000749956
> Tfgi := 680;
                    Tfgi := 680
> varTfgi := (0.0012*Tfgi)^2;
                    varTfgi := .66585600
> t2 := (Tfgi +460)/1.8;
                    t2 := 633.3333334
>
> Tfgo := 253;
                    Tfgo := 253
> varTfgo := (0.0035*Tfgo)^2;
                    varTfgo := .78411025
> t1 := (Tfgo+460)/1.8;
                    t1 := 396.1111112
>
> Tali := 80;
                    Tali := 80
> varTali := (0.0012*Tali)^2;
                    varTali := .00921600
> t3 := (Tali+460)/1.8;
                    t3 := 300.0000001
> t4 := t1;
                    t4 := 396.1111112
> Tpai := 80;
                    Tpai := 80
> varTpai := (0.0012*Tpai)^2;
                    varTpai := .00921600
> t5 := (Tpai+460)/1.8;
                    t5 := 300.0000001
> Tpao := 644;
                    Tpao := 644
> varTpao := (0.0074*Tpao)^2;
                    varTpao := 22.71094336
> t6 := (Tpao+460)/1.8;
                    t6 := 613.3333334
> Tsai := 80;
                    Tsai := 80
> varTsai := (0.002*Tsai)^2;
                    varTsai := .025600
> t7 := (Tsai+460)/1.8;
                    t7 := 300.0000001
> Tsao := 616;
                    Tsao := 616
> varTsao := (0.007*Tsao)^2;
                    varTsao := 18.593344
> t8 := (Tsao+460)/1.8;
                    t8 := 597.7777778
```

Averages and Variances from Part A

```
> CO2avei := 15.2148;
                    CO2avei := 15.2148
> varCO2avei := .10206^2;
                    varCO2avei := .0104162436
> COavei := .005;
                    COavei := .005
> varCOavei := .00022^2;
                    varCOavei := .484 10^-7
> O2avei := 3.8;
                    O2avei := 3.8
> varO2avei := .01118^2;
```

```
varO2avei := .0001249924
```

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
Wfe := 115839
> varWfe := (0.0025*Wfe)^2;
varWfe := 83866.71200
```

Moisture in Coal

```
> Mf :=0.06;
Mf := .06
> varMf := ((0.2+.012*Mf*100)/(100*2*1.414))^2;
varMf := .9250793742 10^-6
```

Ash re

```
> A := 0.0619;
A := .0619
> varA := ( (0.07+0.02*A*100)/(100*2*1.414))^2;
varA := .4696223261 10^-6
```

Overhead ?

```
> OUHD := 0.9;
OUHD := .9
> varOUHD := (0.1*OUHD)^2;
varOUHD := .0081
```

Carbon

```
> C := 0.7381;
C := .7381
> varC := (0.64/(100*2*1.414))^2;
varC := .5121546706 10^-5
```

Hydrogen

```
> H := 0.0482;
H := .0482
> varH := (0.16/(100*2*1.414))^2;
varH := .3200966692 10^-6
```

Nitrogen

```
> N := 0.0135;
N := .0135
> varN := (0.11/(100*2*1.414))^2;
varN := .1512956913 10^-6
```

Sulfur re

```
> S := 0.0123;
S := .0123
> varS := ((0.06+.035*S*100)/(100*2*1.414))^2;
varS := .1327813813 10^-6
```

Moisture (air) re

```
> Wma := 0.013;
Wma := .013
> varWma := (.2*Wma)^2;
varWma := .676 10^-5
```

Carbon in Ash re

```
> Ca := 0.0486;
Ca := .0486
> varCa := (0.10*Ca)^2;
varCa := .000023619600
```

Results

```
*********************************************************************
> evalf(Mfg);
.08136935946
> evalf(Cpfg);
7.769387922
> evalf(Cpal);
7.151727411
> evalf(Cppa);
7.316810251
> evalf(Cpsa);
7.305185745
```

Wsai in lb/lb of AF Coal

```
> evalf(Wsai);
                              9.583839808
> evalf(sigmaWsai);
                              .06491445524
> evalf(100*sigmaWsai/Wsai);
                              .6773324319
> evalf(Wsai*SA*Wfe);
                              573742.2744
> evalf(sigmaWsai*SA*Wfe);
                              3886.142500
>
```

****

```
>
```

Appendix I-3
Bias Error Calculation
Secondary Air Inlet Flow -- With Leak Case

>

>

Error Propagation Calculations, Part B, Secondary Airflow Wsai with Leakage

#4

```
> MFG := proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2 + CO));
> K4 := 8.936*H + Wma*((28.02*(100-CO-CO2-O2)*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

   proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
   local Cr,Cb,K3,K4,MFG;
       Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
       Cb := C-Cr;
       K3 := (Cb+.3744932959*S)/(12.01*CO2+12.01*CO);
       K4 := 8.936*H+Wma*(36.46063760*(100-CO-CO2-O2)*K3-1.301236174*N
       MFG := .05550621670*K4/(.05550621670*K4+100*K3)
   end

> Mfg := MFG(A,OUHD,Ca,C,S,COavei,CO2avei,H,Wma,O2avei,N,Mf);
```

$$Mfg := .05550621670 \Big(8.936\ H + Wma \Big(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174$$

$$+ Mf \Big) \Big/ \Big(.4960035524\ H + .05550621670$$

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—
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$$Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)$$
$$+.05550621670\ Mf+100\,\frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Bigg)$$

$$\%1:=C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
> p1 := CO2avei*(6.214*t2+(10.396/1000)*t2^2/2-(3.545/1000000)*t2^3/3-(6.214*t1+(1
> 0.396/1000)*t1^2/2-(3.545/1000000)*t1^3/3));
```

$$p1:=CO2avei\ \left(6.214\ t2+.005198000000\ t2^2-.1181666667\ 10^{-5}\ t2^3-6.214\ t1\right.$$
$$\left.-.005198000000\ t1^2+.1181666667\ 10^{-5}\ t1^3\right)$$

```
> p2 := COavei*(6.420*t2+(1.665/1000)*t2^2/2-(0.196/1000000)*t2^3/3-(6.420*t1+(1.66
> 5/1000)*t1^2/2-(0.196/1000000)*t1^3/3));
```

$$p2:=COavei\ \left(6.420\ t2+.0008325000000\ t2^2-.6533333333\ 10^{-7}\ t2^3-6.420\ t1\right.$$
$$\left.-.0008325000000\ t1^2+.6533333333\ 10^{-7}\ t1^3\right)$$

```
> p3 := O2avei*(6.148*t2+(3.102/1000)*t2^2/2-(0.923/1000000)*t2^3/3-(6.148*t1+(3.10
> 2/1000)*t1^2/2-(0.923/1000000)*t1^3/3));
```

$$p3:=O2avei\ \left(6.148\ t2+.001551000000\ t2^2-.3076666666\ 10^{-6}\ t2^3-6.148\ t1\right.$$
$$\left.-.001551000000\ t1^2+.3076666666\ 10^{-6}\ t1^3\right)$$

```
> N2avei := 100 - CO2avei - COavei - O2avei;
```

$$N2avei:=100-COavei-CO2avei-O2avei$$

```
> p4 := N2avei*(6.524*t2+(1.250/1000)*t2^2/2-(0.001/1000000)*t2^3/3-(6.524*t1+(1.25
> 0/1000)*t1^2/2-(0.001/1000000)*t1^3/3));
```

$$p4:=(100-COavei-CO2avei-O2avei)\ \left(6.524\ t2+.0006250000000\ t2^2\right.$$
$$-.3333333333\ 10^{-9}\ t2^3-6.524\ t1-.0006250000000\ t1^2$$
$$\left.+.3333333333\ 10^{-9}\ t1^3\right)$$

```
> p5 := Mfg*(7.256*t2+(2.298/1000)*t2^2/2+(0.283/1000000)*t2^3/3-(7.256*t1+(2.298/1
> 000)*t1^2/2+(0.283/1000000)*t1^3/3));
```

$$p5:=.05550621670\ \Bigg(8.936\ H$$
$$+Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right.$$
$$\left.+Mf\right)\ \left(7.256\ t2+.001149000000\ t2^2+.9433333332\ 10^{-7}\ t2^3-7.256\ t1\right.$$
$$\left.-.001149000000\ t1^2-.9433333332\ 10^{-7}\ t1^3\right)\Big/\Bigg(.4960035524\ H+.05550621670$$
$$Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)$$
$$+.05550621670\ Mf+100\,\frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Bigg)$$

$$\%1:=C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
> Cpfg := (1/(t2-t1))*(((1-Mfg))*(p1+p2+p3+p4)+100*p5)/100;
```

$$Cpfg:=\frac{1}{100}\Bigg(\Bigg(\Bigg($$
$$1-.05550621670\,\frac{8.936\ H+\%4+Mf}{.4960035524\ H+.05550621670\ \%4+.05550621670\ Mf+100\,\frac{\%2}{\%1}}$$
$$\Bigg)\Bigg(CO2avei\ \left(6.214\ t2+.005198000000\ t2^2-.1181666667\ 10^{-5}\ t2^3-6.214\ t1\right.$$
$$\left.-.005198000000\ t1^2+.1181666667\ 10^{-5}\ t1^3\right)+COavei\ \left(6.420\ t2\right.$$
$$+.0008325000000\ t2^2-.6533333333\ 10^{-7}\ t2^3-6.420\ t1-.0008325000000\ t1^2$$
$$\left.+.6533333333\ 10^{-7}\ t1^3\right)+O2avei\ \left(6.148\ t2+.001551000000\ t2^2\right.$$
$$-.3076666666\ 10^{-6}\ t2^3-6.148\ t1-.001551000000\ t1^2+.3076666666\ 10^{-6}\ t1^3$$
$$\Big)+\%3\ \left(6.524\ t2+.0006250000000\ t2^2-.3333333333\ 10^{-9}\ t2^3-6.524\ t1\right.$$
$$\left.-.0006250000000\ t1^2+.3333333333\ 10^{-9}\ t1^3\right)\Bigg)+5.550621670$$
$$(8.936\ H+\%4+Mf)\ \left(7.256\ t2+.001149000000\ t2^2+.9433333332\ 10^{-7}\ t2^3\right.$$
$$\left.-7.256\ t1-.001149000000\ t1^2-.9433333332\ 10^{-7}\ t1^3\right)\Big/\Big($$

620

$.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}\Big)\Big)/(t2 - t1)$

$\%1 := 12.01\ CO2avei + 12.01\ COavei$

$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$

$\%3 := 100 - COavei - CO2avei - O2avei$

$\%4 := Wma\ \left(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\right)$

```
> p3 := 21*(6.148*t4+(3.102/1000)*t4^2/2-(0.923/1000000)*t4^3/3-(6.148*t3+(3.102/10
> 00)*t3^2/2-(0.923/1000000)*t3^3/3));
```

$p3 := 129.108\ t4 + .03257100000\ t4^2 - .6460999999\ 10^{-5}\ t4^3 - 129.108\ t3 - .03257100000\ t3^2 + .6460999999\ 10^{-5}\ t3^3$

```
> p4 := 79*(6.524*t4+(1.250/1000)*t4^2/2-(0.001/1000000)*t4^3/3-(6.524*t3+(1.250/10
> 00)*t3^2/2-(0.001/1000000)*t3^3/3));
```

$p4 := 515.396\ t4 + .04937500000\ t4^2 - .2633333333\ 10^{-7}\ t4^3 - 515.396\ t3 - .04937500000\ t3^2 + .2633333333\ 10^{-7}\ t3^3$

```
> amp := ((28.97*Wma*100)/18.015)/(28.97*Wma/18.015 +1);
```

$amp := 160.8104357\ \frac{Wma}{1.608104357\ Wma + 1}$

```
> p5 := amp*(7.256*t4+(2.298/1000)*t4^2/2+(0.283/1000000)*t4^3/3-(7.256*t3+(2.298/
> 1000)*t3^2/2+(0.283/1000000)*t3^3/3));
```

$p5 := 160.8104357\ Wma\ (7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3)/(1.608104357\ Wma + 1)$

```
> Cpal := (1/(t4-t3))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$Cpal := \frac{1}{100}\ \Big(\frac{1}{100}\ \Big(100 - .05550621670\ \Big(8.936\ H + Wma\ \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$

$+ Mf\Big)\Big/\Big(.4960035524\ H + .05550621670\ Wma\ \left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right.$

$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Big)\Big)\ (644.504\ t4 + .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2 + .6487333332\ 10^{-5}\ t3^3) + 160.8104357\ Wma\ (7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t$

$)/(1.608104357\ Wma + 1)\Big)/(t4 - t3)$

$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$

```
> p3 := 21*(6.148*t8+(3.102/1000)*t8^2/2-(0.923/1000000)*t8^3/3-(6.148*t7+(3.102/10
> 00)*t7^2/2-(0.923/1000000)*t7^3/3));
```

$p3 := 129.108\ t8 + .03257100000\ t8^2 - .6460999999\ 10^{-5}\ t8^3 - 129.108\ t7 - .03257100000\ t7^2 + .6460999999\ 10^{-5}\ t7^3$

```
> p4 := 79*(6.524*t8+(1.250/1000)*t8^2/2-(0.001/1000000)*t8^3/3-(6.524*t7+(1.250/10
> 00)*t7^2/2-(0.001/1000000)*t7^3/3));
```

$p4 := 515.396\ t8 + .04937500000\ t8^2 - .2633333333\ 10^{-7}\ t8^3 - 515.396\ t7 - .04937500000\ t7^2 + .2633333333\ 10^{-7}\ t7^3$

```
> p5 := amp*(7.256*t8+(2.298/1000)*t8^2/2+(0.283/1000000)*t8^3/3-(7.256*t7+(2.298
> 1000)*t7^2/2+(0.283/1000000)*t7^3/3));
```

$p5 := 160.8104357\ Wma\ (7.256\ t8 + .001149000000\ t8^2 + .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3)/(1.608104357\ Wma +$

```
> Cpsa := (1/(t8-t7))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$Cpsa := \frac{1}{100}\ \Big(\frac{1}{100}\ \Big(100 - .05550621670\ \Big(8.936\ H + Wma\ \Big(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174$

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2

$$+ Mf\Big)\Big/\Big(.4960035524\ H + .05550621670$$

$$Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Big)\Big)\ \big(644.504\ t8$$

$$+ .08194600000\ t8^2 - .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2$$

$$+ .6487333332\ 10^{-5}\ t7^3\big) + 160.8104357\ Wma\ \big(7.256\ t8 + .001149000000\ t8^2$$

$$+ .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3$$

$$\big)/(1.608104357\ Wma + 1)\Big)/(t8 - t7)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t6+(3.102/1000)*t6^2/2-(0.923/1000000)*t6^3/3-(6.148*t5+(3.102/10
> 00)*t5^2/2-(0.923/1000000)*t5^3/3));
```

$$p3 := 129.108\ t6 + .03257100000\ t6^2 - .6460999999\ 10^{-5}\ t6^3 - 129.108\ t5$$
$$- .03257100000\ t5^2 + .6460999999\ 10^{-5}\ t5^3$$

```
> p4 := 79*(6.524*t6+(1.250/1000)*t6^2/2-(0.001/1000000)*t6^3/3-(6.524*t5+(1.250/10
> 00)*t5^2/2-(0.001/1000000)*t5^3/3));
```

$$p4 := 515.396\ t6 + .04937500000\ t6^2 - .2633333333\ 10^{-7}\ t6^3 - 515.396\ t5$$
$$- .04937500000\ t5^2 + .2633333333\ 10^{-7}\ t5^3$$

```
> p5 := amp*(7.256*t6+(2.298/1000)*t6^2/2+(0.283/1000000)*t6^3/3-(7.256*t5+(2.298/
> 1000)*t5^2/2+(0.283/1000000)*t5^3/3));
```

$$p5 := 160.8104357\ Wma\ \big(7.256\ t6 + .001149000000\ t6^2 + .9433333332\ 10^{-7}\ t6^3$$
$$- 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3\big)/(1.608104357\ Wma + 1)$$

```
> Cppa := (1/(t6-t5))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cppa := \frac{1}{100}\ \left(\frac{1}{100}\ \Big(100 - .05550621670\ \Big(8.936\ H\right.$$

$$+ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ Mf\Big)\Big/\Big(.4960035524\ H + .05550621670$$

$$Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Big)\Big)\ \big(644.504\ t6$$

$$+ .08194600000\ t6^2 - .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2$$

$$+ .6487333332\ 10^{-5}\ t5^3\big) + 160.8104357\ Wma\ \big(7.256\ t6 + .001149000000\ t6^2$$

$$+ .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5$$

$$\big)/(1.608104357\ Wma + 1)\Big)/(t6 - t5)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
>
```

```
> Wsal := (Wfgl*(Cpfg*(Tfgl-Tfgo) - AL*Cpal*(Tfgo-Tsal)) - Wpal*Cppa*(Tpao-Tsai))/
> (Cpsa*(Tsao-Tsal)*Wfe*SA);
```

$$Wsai := 100\ \left(Wfgi\ \left(\frac{1}{100}\ \left(\left(1 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\right)\ \Big(CO2avei\ \Big(\right.\right.\right.$$

$$6.214\ t2 + .005198000000\ t2^2 - .1181666667\ 10^{-5}\ t2^3 - 6.214\ t1$$

$$- .005198000000\ t1^2 + .1181666667\ 10^{-5}\ t1^3\Big) + COavei\ \big(6.420\ t2$$

$$+ .0008325000000\ t2^2 - .6533333333\ 10^{-7}\ t2^3 - 6.420\ t1 - .0008325000000\ t1^2$$

$$+ .6533333333\ 10^{-7}\ t1^3\big) + O2avei\ \big(6.148\ t2 + .001551000000\ t2^2$$

$$- .3076666666\ 10^{-6}\ t2^3 - 6.148\ t1 - .001551000000\ t1^2 + .3076666666\ 10^{-6}\ t1^3$$

$$\big) + \%3\ \big(6.524\ t2 + .0006250000000\ t2^2 - .3333333333\ 10^{-9}\ t2^3 - 6.524\ t1$$

$$- .0006250000000\ t1^2 + .3333333333\ 10^{-9}\ t1^3\big)\Big) + 5.550621670$$

$$(8.936\ H + \%4 + Mf)\ \big(7.256\ t2 + .001149000000\ t2^2 + .9433333332\ 10^{-7}\ t2^3$$

$$- 7.256\ t1 - .001149000000\ t1^2 - .9433333332\ 10^{-7}\ t1^3\big)/(\%5)\Big)\ (Tfgi - Tfgo$$

$$/(t2 - t1) - \frac{1}{100}\ AL\ \left(\frac{1}{100}\ \left(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\right)\ \big(644.504\ t\right.$$

$$+ .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2$$

$$+ .6487333332\ 10^{-5}\ t3^{3}) + 160.8104357\ Wma\ (7.256\ t4 + .001149000000\ t4^{2}$$
$$+ .9433333332\ 10^{-7}\ t4^{3} - 7.256\ t3 - .001149000000\ t3^{2} - .9433333332\ 10^{-7}\ t3^{3}$$
$$)/(1.608104357\ Wma + 1))\ (Tfgo - Tsai)/(t4 - t3)) - \frac{1}{100}\ Wpai\ (\frac{1}{100}$$
$$(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5})\ (644.504\ t6 + .08194600000\ t6^{2}$$
$$- .6487333332\ 10^{-5}\ t6^{3} - 644.504\ t5 - .08194600000\ t5^{2}$$
$$+ .6487333332\ 10^{-5}\ t5^{3}) + 160.8104357\ Wma\ (7.256\ t6 + .001149000000\ t6^{2}$$
$$+ .9433333332\ 10^{-7}\ t6^{3} - 7.256\ t5 - .001149000000\ t5^{2} - .9433333332\ 10^{-7}\ t5^{3}$$
$$)/(1.608104357\ Wma + 1))\ (Tpao - Tsai)/(t6 - t5))\ (t8 - t7) \Big/ (((\frac{1}{100}$$
$$(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5})\ (644.504\ t8 + .08194600000\ t8^{2}$$
$$- .6487333332\ 10^{-5}\ t8^{3} - 644.504\ t7 - .08194600000\ t7^{2}$$
$$+ .6487333332\ 10^{-5}\ t7^{3}) + 160.8104357\ Wma\ (7.256\ t8 + .001149000000\ t8^{2}$$
$$+ .9433333332\ 10^{-7}\ t8^{3} - 7.256\ t7 - .001149000000\ t7^{2} - .9433333332\ 10^{-7}\ t7^{3}$$
$$)/(1.608104357\ Wma + 1))\ (Tsao - Tsai)\ Wfe\ SA)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\ (36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N)$$

$$\%5 := .4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}$$

```
>
> sigmaWsai := sqrt(
> Diff(Wsai,SA)^2*varSA +
> Diff(Wsai,CO2avei)^2*varCO2avei +
```

623

```
> Diff(Wsal,COavei)^2*varCOavei +
> Diff(Wsal,O2avei)^2*varO2avei +
> Diff(Wsal,Wfe)^2*varWfe +
> Diff(Wsal,A)^2*varA +
> Diff(Wsal,OUHD)^2*varOUHD +
> Diff(Wsal,Ca)^2*varCa +
> Diff(Wsal,C)*Diff(Wsal,C)*varC +
> Diff(Wsal,S)*Diff(Wsal,S)*varS +
> Diff(Wsal,H)*Diff(Wsal,H)*varH +
> Diff(Wsal,Wma)*Diff(Wsal,Wma)*varWma +
> Diff(Wsal,N)*Diff(Wsal,N)*varN +
> Diff(Wsal,Mf)*Diff(Wsal,Mf)*varMf
> ):

> sigmaWsal := value("):
```

Constants

SA - Split A

```
> SA := 0.5168;
```

$SA := .5168$

```
> varSA := 0.002214^2;
```

$varSA := .4901796\ 10^{-5}$

```
>
```

Weight of Flue Gas in

```
> Wfgi := 754952;
```

$Wfgi := 754952$

```
> varWfgi := 47382^2;
```

$varWfgi := 2245053924$

Weight of Primary Air in

```
> Wpai := 62530;
```

$Wpai := 62530$

```
> varWpai := 1635^2;
```

$varWpai := 2673225$

Air Leakage fraction

```
> AL := .0687;
```

$AL := .0687$

```
> varAL := .00058^2;
```

$varAL := .3364\ 10^{-6}$

```
> Tfgi := 680;
```

$Tfgi := 680$

```
> varTfgi := (0.01*Tfgi)^2;
```

$varTfgi := 46.2400$

```
> t2 := (Tfgi +460)/1.8;
```

$t2 := 633.3333334$

```
>
> Tfgo := 253;
```

$Tfgo := 253$

```
> varTfgo := (0.01*Tfgo)^2;
```

$varTfgo := 6.4009$

```
> t1 := (Tfgo+460)/1.8;
```

$t1 := 396.1111112$

```
>
> Tali := 80;
```

$Tali := 80$

```
> varTali := (0.01*Tali)^2;
```

$varTali := .6400$

```
> t3 := (Tali+460)/1.8;
```

$t3 := 300.0000001$

```
> t4 := t1;
```

$t4 := 396.1111112$

```
> Tpai := 80;
```

$Tpai := 80$

```
> varTpai := (0.01*Tpai)^2;
```

$varTpai := .6400$

```
> t5 := (Tpai+460)/1.8;
```

$t5 := 300.0000001$

```
> Tpao := 644;
```

$Tpao := 644$

```
> varTpao := (0.01*Tpao)^2;
```

$varTpao := 41.4736$

```
> t6 := (Tpao+460)/1.8;
```

$t6 := 613.3333334$

```
> Tsai := 80;
```

$Tsai := 80$

```
> varTsai := (0.01*Tsai)^2;
```

$varTsai := .6400$

```
> t7 := (Tsai+460)/1.8;
```

$t7 := 300.0000001$

```
> Tsao := 616;
```

$Tsao := 616$

```
> varTsao := (0.01*Tsao)^2;
```

$varTsao := 37.9456$

```
> t8 := (Tsao+460)/1.8;
```

$t8 := 597.7777778$

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```

$CO2avei := 15.2148$

```
> varCO2avei := .1^2;
```

$varCO2avei := .01$

```
> COavei := .005;
```

$COavei := .005$

```
> varCOavei := .002^2;
```

$varCOavei := .4\ 10^{-5}$

```
> O2avei := 3.8;
```

$O2avei := 3.8$

```
> varO2avei := .05^2;
```

$varO2avei := .0025$

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```

$Wfe := 115839$

```
> varWfe := (0.05*Wfe)^2;
```

$varWfe := .3354668480\ 10^{8}$

Moisture in Coal

```
> Mf :=0.06;
```

$Mf := .06$

```
> varMf := (0.039*Mf)^2;
```

$varMf := .54756\ 10^{-5}$

Ash

```
> A := 0.0619;
```

$A := .0619$

```
> varA := ( 0.039*A)^2;
```

$varA := .582787881\ 10^{-5}$

Overhead

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.039*C)^2;
```

$varC := .0008286280388$

Hydrogen

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.039*H)^2;
```

$varH := .353364804\ 10^{-5}$

Nitrogen

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.039*N)^2;
```

$varN := .27720225 \; 10^{-6}$

Sulfur

```
> S := 0.0123;
```

$S := .0123$

```
> varS := (0.019*S)^2;
```

$varS := .5461569 \; 10^{-7}$

Moisture (air)

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.1*Wma)^2;
```

$varWma := .169 \; 10^{-5}$

Carbon in Ash

```
> Ca := 0.0486;
```

$Ca := .0486$

```
> varCa := (0.25*Ca)^2;
```

$varCa := .000147622500$

Results

****

```
> evalf(Mfg);
```

.08136935946

```
> evalf(Cpfg);
```

7.769387922

```
> evalf(Cpai);
```

7.151727411

```
> evalf(Cppa);
```

7.316810251

```
> evalf(Cpsa);
```

7.305185745

Wsai in lb/lb of AF Coal

```
> evalf(Wsai);
```

9.310086250

```
> evalf(sigmaWsai);
```

.4677796756

```
> evalf(100*sigmaWsai/Wsai);
```

5.024439764

```
> evalf(Wsai*SA*Wfe);
```

557353.8547

```
> evalf(sigmaWsai*SA*Wfe);
```

28003.90871

```
>
```

****

```
>
```

Appendix I-4
Random Error Calculation
Secondary Air Inlet Flow -- With Leak Case

>

>

Random Error Propagation Calculations, Part B, Secondary Airflow Wsai with Leakag

#4

```
> MFG := proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2 + CO));

> K4 := 8.936*H + Wma*((28.02*(100-CO-CO2-O2)*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

     proc(A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
     local Cr,Cb,K3,K4,MFG;
         Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
         Cb := C-Cr;
         K3 := (Cb+.3744932959*S)/(12.01*CO2+12.01*CO);
         K4 := 8.936*H+Wma*(36.46063760*(100-CO-CO2-O2)*K3-1.301236174*I
         MFG := .05550621670*K4/(.05550621670*K4+100*K3)
     end

> Mfg := MFG(A,OUHD,Ca,C,S,COavei,CO2avei,H,Wma,O2avei,N,Mf);
```

$$Mfg := .05550621670 \Bigg(8.936\ H + Wma \left(36.46063760 \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.30123617 \right. $$

$$\left. + Mf \right) \Bigg/ \Bigg(.4960035524\ H + .05550621670$$

627

$$Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)$$
$$+.05550621670\ Mf+100\ \frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Bigg)$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
> p1 := CO2avei*(6.214*t2+(10.396/1000)*t2^2/2-(3.545/1000000)*t2^3/3-(6.214*t1+(1
> 0.396/1000)*t1^2/2-(3.545/1000000)*t1^3/3));
```

$$p1 := CO2avei\ \left(6.214\ t2+.005198000000\ t2^2-.1181666667\ 10^{-5}\ t2^3-6.214\ t1-.005198000000\ t1^2+.1181666667\ 10^{-5}\ t1^3\right)$$

```
> p2 := COavei*(6.420*t2+(1.665/1000)*t2^2/2-(0.196/1000000)*t2^3/3-(6.420*t1+(1.66
> 5/1000)*t1^2/2-(0.196/1000000)*t1^3/3));
```

$$p2 := COavei\ \left(6.420\ t2+.0008325000000\ t2^2-.6533333333\ 10^{-7}\ t2^3-6.420\ t1-.0008325000000\ t1^2+.6533333333\ 10^{-7}\ t1^3\right)$$

```
> p3 := O2avei*(6.148*t2+(3.102/1000)*t2^2/2-(0.923/1000000)*t2^3/3-(6.148*t1+(3.10
> 2/1000)*t1^2/2-(0.923/1000000)*t1^3/3));
```

$$p3 := O2avei\ \left(6.148\ t2+.001551000000\ t2^2-.3076666666\ 10^{-6}\ t2^3-6.148\ t1-.001551000000\ t1^2+.3076666666\ 10^{-6}\ t1^3\right)$$

```
> N2avei := 100 - CO2avei - COavei - O2avei;
```

$$N2avei := 100-COavei-CO2avei-O2avei$$

```
> p4 := N2avei*(6.524*t2+(1.250/1000)*t2^2/2-(0.001/1000000)*t2^3/3-(6.524*t1+(1.25
> 0/1000)*t1^2/2-(0.001/1000000)*t1^3/3));
```

$$p4 := (100-COavei-CO2avei-O2avei)\ \left(6.524\ t2+.0006250000000\ t2^2-.3333333333\ 10^{-9}\ t2^3-6.524\ t1-.0006250000000\ t1^2+.3333333333\ 10^{-9}\ t1^3\right)$$

```
> p5 := Mfg*(7.256*t2+(2.298/1000)*t2^2/2+(0.283/1000000)*t2^3/3-(7.256*t1+(2.298/1
> 000)*t1^2/2+(0.283/1000000)*t1^3/3));
```

$$p5 := .05550621670\ \Bigg(8.936\ H+Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ \text{:}\right.$$
$$\left.+Mf\right)\left(7.256\ t2+.001149000000\ t2^2+.9433333332\ 10^{-7}\ t2^3-7.256\ t1-.001149000000\ t1^2-.9433333332\ 10^{-7}\ t1^3\right)\Bigg/\Bigg(.4960035524\ H+.0555062167\text{(}$$
$$Wma\left(36.46063760\,\frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)$$
$$+.05550621670\ Mf+100\ \frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Bigg)$$

$$\%1 := C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
> Cpfg := (1/(t2-t1))*(((1-Mfg))*(p1+p2+p3+p4)+100*p5)/100;
```

$$Cpfg := \frac{1}{100}\Bigg(\Bigg(\Bigg(1-.05550621670\ \frac{8.936\ H+\%4+Mf}{.4960035524\ H+.05550621670\ \%4+.05550621670\ Mf+100\ \frac{\%\text{:}}{\%\text{:}}}$$
$$\Bigg)\Big(CO2avei\ \left(6.214\ t2+.005198000000\ t2^2-.1181666667\ 10^{-5}\ t2^3-6.214\ t\text{-}\right.$$
$$\left.-.005198000000\ t1^2+.1181666667\ 10^{-5}\ t1^3\right)+COavei\ \left(6.420\ t2\right.$$
$$+.0008325000000\ t2^2-.6533333333\ 10^{-7}\ t2^3-6.420\ t1-.0008325000000\ t1^{\text{:}}$$
$$\left.+.6533333333\ 10^{-7}\ t1^3\right)+O2avei\ \left(6.148\ t2+.001551000000\ t2^2\right.$$
$$-.3076666666\ 10^{-6}\ t2^3-6.148\ t1-.001551000000\ t1^2+.3076666666\ 10^{-6}\ t\text{:}$$
$$\Big)+\%3\ \left(6.524\ t2+.0006250000000\ t2^2-.3333333333\ 10^{-9}\ t2^3-6.524\ t1\right.$$
$$\left.-.0006250000000\ t1^2+.3333333333\ 10^{-9}\ t1^3\right)\Big)+5.550621670$$
$$(8.936\ H+\%4+Mf)\ \left(7.256\ t2+.001149000000\ t2^2+.9433333332\ 10^{-7}\ t2^3\right.$$
$$\left.-7.256\ t1-.001149000000\ t1^2-.9433333332\ 10^{-7}\ t1^3\right)\Big/\Big($$

$$.4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}\Bigg)\Bigg) \Big/ (t2 - t1)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\left(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\right)$$

```
> p3 := 21*(6.148*t4+(3.102/1000)*t4^2/2-(0.923/1000000)*t4^3/3-(6.148*t3+(3.102/10
> 00)*t3^2/2-(0.923/1000000)*t3^3/3));
```

$$p3 := 129.108\ t4 + .03257100000\ t4^2 - .6460999999\ 10^{-5}\ t4^3 - 129.108\ t3 - .03257100000\ t3^2 + .6460999999\ 10^{-5}\ t3^3$$

```
> p4 := 79*(6.524*t4+(1.250/1000)*t4^2/2-(0.001/1000000)*t4^3/3-(6.524*t3+(1.250/10
> 00)*t3^2/2-(0.001/1000000)*t3^3/3));
```

$$p4 := 515.396\ t4 + .04937500000\ t4^2 - .2633333333\ 10^{-7}\ t4^3 - 515.396\ t3 - .04937500000\ t3^2 + .2633333333\ 10^{-7}\ t3^3$$

```
> amp := ((28.97*Wma*100)/18.015)/(28.97*Wma/18.015 +1);
```

$$amp := 160.8104357\ \frac{Wma}{1.608104357\ Wma + 1}$$

```
> p5 := amp*(7.256*t4+(2.298/1000)*t4^2/2+(0.283/1000000)*t4^3/3-(7.256*t3+(2.298/
> 1000)*t3^2/2+(0.283/1000000)*t3^3/3));
```

$$p5 := 160.8104357\ Wma\ (7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3)/(1.608104357\ Wma + 1)$$

```
> Cpal := (1/(t4-t3))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpal := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)\right.\right.\right.$$

$$+ Mf\Bigg)\Bigg/\Bigg(.4960035524\ H + .05550621670\ Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right)$$

$$+ .05550621670\ Mf + 100\ \frac{\%1}{12.01\ CO2avei + 12.01\ COavei}\Bigg)\Bigg)\ (644.504\ t4 + .08194600000\ t4^2 - .6487333332\ 10^{-5}\ t4^3 - 644.504\ t3 - .08194600000\ t3^2$$

$$+ .6487333332\ 10^{-5}\ t3^3) + 160.8104357\ Wma\ (7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3$$

$$)/(1.608104357\ Wma + 1)\Big)\Big/(t4 - t3)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

```
> p3 := 21*(6.148*t8+(3.102/1000)*t8^2/2-(0.923/1000000)*t8^3/3-(6.148*t7+(3.102/10
> 00)*t7^2/2-(0.923/1000000)*t7^3/3));
```

$$p3 := 129.108\ t8 + .03257100000\ t8^2 - .6460999999\ 10^{-5}\ t8^3 - 129.108\ t7 - .03257100000\ t7^2 + .6460999999\ 10^{-5}\ t7^3$$

```
> p4 := 79*(6.524*t8+(1.250/1000)*t8^2/2-(0.001/1000000)*t8^3/3-(6.524*t7+(1.250/10
> 00)*t7^2/2-(0.001/1000000)*t7^3/3));
```

$$p4 := 515.396\ t8 + .04937500000\ t8^2 - .2633333333\ 10^{-7}\ t8^3 - 515.396\ t7 - .04937500000\ t7^2 + .2633333333\ 10^{-7}\ t7^3$$

```
> p5 := amp*(7.256*t8+(2.298/1000)*t8^2/2+(0.283/1000000)*t8^3/3-(7.256*t7+(2.298/
> 1000)*t7^2/2+(0.283/1000000)*t7^3/3));
```

$$p5 := 160.8104357\ Wma\ (7.256\ t8 + .001149000000\ t8^2 + .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3)/(1.608104357\ Wma + 1$$

```
> Cpsa := (1/(t8-t7))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cpsa := \frac{1}{100}\left(\frac{1}{100}\left(100 - .05550621670\left(8.936\ H + Wma\left(36.46063760\ \frac{(100 - COavei - CO2avei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\right.\right.\right.\right.$$

$$+Mf\Big)\Big/\Big(.4960035524\ H+.05550621670\ Wma\left(36.46063760\ \frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)+.05550621670\ Mf+100\ \frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Big)\Big)\Big(644.504\ t8+.08194600000\ t8^2-.6487333332\ 10^{-5}\ t8^3-644.504\ t7-.08194600000\ t7^2+.6487333332\ 10^{-5}\ t7^3\Big)+160.8104357\ Wma\ \big(7.256\ t8+.001149000000\ t8^2+.9433333332\ 10^{-7}\ t8^3-7.256\ t7-.001149000000\ t7^2-.9433333332\ 10^{-7}\ t7^3\big)/(1.608104357\ Wma+1)\Big)/(t8-t7)$$

$$\%1:=C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
> p3 := 21*(6.148*t6+(3.102/1000)*t6^2/2-(0.923/1000000)*t6^3/3-(6.148*t5+(3.102/10
> 00)*t5^2/2-(0.923/1000000)*t5^3/3));
```

$$p3:=129.108\ t6+.03257100000\ t6^2-.6460999999\ 10^{-5}\ t6^3-129.108\ t5-.03257100000\ t5^2+.6460999999\ 10^{-5}\ t5^3$$

```
> p4 := 79*(6.524*t6+(1.250/1000)*t6^2/2-(0.001/1000000)*t6^3/3-(6.524*t5+(1.250/10
> 00)*t5^2/2-(0.001/1000000)*t5^3/3));
```

$$p4:=515.396\ t6+.04937500000\ t6^2-.2633333333\ 10^{-7}\ t6^3-515.396\ t5-.04937500000\ t5^2+.2633333333\ 10^{-7}\ t5^3$$

```
> p5 := amp*(7.256*t6+(2.298/1000)*t6^2/2+(0.283/1000000)*t6^3/3-(7.256*t5+(2.298/
> 1000)*t5^2/2+(0.283/1000000)*t5^3/3));
```

$$p5:=160.8104357\ Wma\ \big(7.256\ t6+.001149000000\ t6^2+.9433333332\ 10^{-7}\ t6^3-7.256\ t5-.001149000000\ t5^2-.9433333332\ 10^{-7}\ t5^3\big)/(1.608104357\ Wma+1)$$

```
> Cppa := (1/(t6-t5))*(((100-Mfg)/100)*(p3+p4)+p5)/100;
```

$$Cppa:=\frac{1}{100}\left(\frac{1}{100}\left(100-.05550621670\ \Big(8.936\ H+Wma\left(36.46063760\ \frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)\right.\right.$$

$$+Mf\Big)\Big/\Big(.4960035524\ H+.05550621670\ Wma\left(36.46063760\ \frac{(100-COavei-CO2avei-O2avei)\ \%1}{12.01\ CO2avei+12.01\ COavei}-1.301236174\ N\right)+.05550621670\ Mf+100\ \frac{\%1}{12.01\ CO2avei+12.01\ COavei}\Big)\Big)\Big(644.504\ t6+.08194600000\ t6^2-.6487333332\ 10^{-5}\ t6^3-644.504\ t5-.08194600000\ t5^2+.6487333332\ 10^{-5}\ t5^3\Big)+160.8104357\ Wma\ \big(7.256\ t6+.001149000000\ t6^2+.9433333332\ 10^{-7}\ t6^3-7.256\ t5-.001149000000\ t5^2-.9433333332\ 10^{-7}\ t\big)/(1.608104357\ Wma+1)\Big)/(t6-t5)$$

$$\%1:=C-\frac{A\ OUHD\ Ca}{1-Ca}-\frac{1}{3}\ \frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca}+.3744932959\ S$$

```
>
```

```
> Wsai := (Wfgi*(Cpfg*(Tfgi-Tfgo) - AL*Cpal*(Tfgo-Tsai)) - Wpai*Cppa*(Tpao-Tsai))/
> (Cpsa*(Tsao-Tsai)*Wfe*SA);
```

$$Wsai:=100\ \Big(Wfgi\ \Big(\frac{1}{100}\Big(\Big(1-.05550621670\ \frac{8.936\ H+\%4+Mf}{\%5}\Big)\Big(CO2avei\ \big(6.214\ t2+.005198000000\ t2^2-.1181666667\ 10^{-5}\ t2^3-6.214\ t1-.005198000000\ t1^2+.1181666667\ 10^{-5}\ t1^3\big)+COavei\ \big(6.420\ t2+.0008325000000\ t2^2-.6533333333\ 10^{-7}\ t2^3-6.420\ t1-.0008325000000\ t1^2+.6533333333\ 10^{-7}\ t1^3\big)+O2avei\ \big(6.148\ t2+.001551000000\ t2^2-.3076666666\ 10^{-6}\ t2^3-6.148\ t1-.001551000000\ t1^2+.3076666666\ 10^{-6}\ t\big)+\%3\ \big(6.524\ t2+.0006250000000\ t2^2-.3333333333\ 10^{-9}\ t2^3-6.524\ t1-.0006250000000\ t1^2+.3333333333\ 10^{-9}\ t1^3\big)\Big)+5.550621670\ (8.936\ H+\%4+Mf)\ \big(7.256\ t2+.001149000000\ t2^2+.9433333332\ 10^{-7}\ t2^3-7.256\ t1-.001149000000\ t1^2-.9433333332\ 10^{-7}\ t1^3\big)/(\%5)\Big)\ (Tfgi-Tfg$$

$$/(t2-t1)-\frac{1}{100}\ AL\ \Big(\frac{1}{100}\Big(100-.05550621670\ \frac{8.936\ H+\%4+Mf}{\%5}\Big)\Big(644.504\ t4+.08194600000\ t4^2-.6487333332\ 10^{-5}\ t4^3-644.504\ t3-.08194600000\ t3^2$$

$$+ .6487333332\ 10^{-5}\ t3^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t4 + .001149000000\ t4^2 + .9433333332\ 10^{-7}\ t4^3 - 7.256\ t3 - .001149000000\ t3^2 - .9433333332\ 10^{-7}\ t3^3\Big)/(1.608104357\ Wma + 1)\Big)\ (Tfgo - Tsai)/(t4 - t3)\Big) - \frac{1}{100}\ Wpai\ \Big(\frac{1}{100}$$

$$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t6 + .08194600000\ t6^2 - .6487333332\ 10^{-5}\ t6^3 - 644.504\ t5 - .08194600000\ t5^2 + .6487333332\ 10^{-5}\ t5^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t6 + .001149000000\ t6^2 + .9433333332\ 10^{-7}\ t6^3 - 7.256\ t5 - .001149000000\ t5^2 - .9433333332\ 10^{-7}\ t5^3\Big)/(1.608104357\ Wma + 1)\Big)\ (Tpao - Tsai)/(t6 - t5)\Big)\ (t8 - t7)\Big/\Big(\Big(\frac{1}{100}$$

$$\Big(100 - .05550621670\ \frac{8.936\ H + \%4 + Mf}{\%5}\Big)\ \Big(644.504\ t8 + .08194600000\ t8^2 - .6487333332\ 10^{-5}\ t8^3 - 644.504\ t7 - .08194600000\ t7^2 + .6487333332\ 10^{-5}\ t7^3\Big) + 160.8104357\ Wma\ \Big(7.256\ t8 + .001149000000\ t8^2 + .9433333332\ 10^{-7}\ t8^3 - 7.256\ t7 - .001149000000\ t7^2 - .9433333332\ 10^{-7}\ t7^3\Big)/(1.608104357\ Wma + 1)\Big)\ (Tsao - Tsai)\ Wfe\ SA\Big)$$

$$\%1 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%2 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%3 := 100 - COavei - CO2avei - O2avei$$

$$\%4 := Wma\ \Big(36.46063760\ \frac{\%3\ \%2}{\%1} - 1.301236174\ N\Big)$$

$$\%5 := .4960035524\ H + .05550621670\ \%4 + .05550621670\ Mf + 100\ \frac{\%2}{\%1}$$

```
>
> sigmaWsai := sqrt(
> Diff(Wsai,SA)^2*varSA +
> Diff(Wsai,CO2avei)^2*varCO2avei +
> Diff(Wsai,COavei)^2*varCOavei +
> Diff(Wsai,O2avei)^2*varO2avei +
> Diff(Wsai,Wfe)^2*varWfe +
> Diff(Wsai,A)^2*varA +
> Diff(Wsai,OUHD)^2*varOUHD +
> Diff(Wsai,Ca)^2*varCa +
> Diff(Wsai,C)*Diff(Wsai,C)*varC +
> Diff(Wsai,S)*Diff(Wsai,S)*varS +
> Diff(Wsai,H)*Diff(Wsai,H)*varH +
> Diff(Wsai,Wma)*Diff(Wsai,Wma)*varWma +
> Diff(Wsai,N)*Diff(Wsai,N)*varN +
> Diff(Wsai,Mf)*Diff(Wsai,Mf)*varMf
> ):

> sigmaWsai := value("):
```

Constants

SA - Split A

```
> SA := 0.5168;
```

$$SA := .5168$$

```
> varSA := 0.002175^2;
```

$$varSA := .4730625\ 10^{-5}$$

```
>
```

Weight of Flue Gas in

```
> Wfgi := 754952;
```

$$Wfgi := 754952$$

```
> varWfgi := 5676^2;
```

$varWfgi := 32216976$

Weight of Primary Air in

```
> Wpai := 62530;
```

$Wpai := 62530$

```
> varWpai := 1823^2;
```

$varWpai := 3323329$

Air Leakage fraction

```
> AL := .0687;
```

$AL := .0687$

```
> varAL := .00866^2;
```

$varAL := .0000749956$

```
> Tfgi := 680;
```

$Tfgi := 680$

```
> varTfgi := (0.0012*Tfgi)^2;
```

$varTfgi := .66585600$

```
> t2 := (Tfgi +460)/1.8;
```

$t2 := 633.3333334$

```
>
```

```
> Tfgo := 253;
```

$Tfgo := 253$

```
> varTfgo := (0.0035*Tfgo)^2;
```

$varTfgo := .78411025$

```
> t1 := (Tfgo+460)/1.8;
```

$t1 := 396.1111112$

```
>
```

```
> Tali := 80;
```

$Tali := 80$

```
> varTali := (0.0012*Tali)^2;
```

$varTali := .00921600$

```
> t3 := (Tali+460)/1.8;
```

$t3 := 300.0000001$

```
> t4 := t1;
```

$t4 := 396.1111112$

```
> Tpai := 80;
```

$Tpai := 80$

```
> varTpai := (0.0012*Tpai)^2;
```

$varTpai := .00921600$

```
> t5 := (Tpai+460)/1.8;
```

$t5 := 300.0000001$

```
> Tpao := 644;
```

$Tpao := 644$

```
> varTpao := (0.0074*Tpao)^2;
```

$varTpao := 22.71094336$

```
> t6 := (Tpao+460)/1.8;
```

$t6 := 613.3333334$

```
> Tsai := 80;
```

$Tsai := 80$

```
> varTsai := (0.002*Tsai)^2;
```

$varTsai := .025600$

```
> t7 := (Tsai+460)/1.8;
```

$t7 := 300.0000001$

```
> Tsao := 616;
```

$Tsao := 616$

```
> varTsao := (0.007*Tsao)^2;
```

$varTsao := 18.593344$

```
> t8 := (Tsao+460)/1.8;
```

$t8 := 597.7777778$

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```

$CO2avei := 15.2148$

```
> varCO2avei := .10206^2;
```

$varCO2avei := .0104162436$

```
> COavei := .005;
```

$COavei := .005$

```
> varCOavei := .00022^2;
```

$varCOavei := .484\ 10^{-7}$

```
> O2avei := 3.8;
```

$O2avei := 3.8$

```
> varO2avei := .01118^2;
```

$varO2avei := .0001249924$

Coal Feed Rate (lbs/hr)

```
> Wfe := 115839;
```

$Wfe := 115839$

```
> varWfe := (0.0025*Wfe)^2;
```

$varWfe := 83866.71200$

Moisture in Coal

```
> Mf :=0.06;
```

$Mf := .06$

```
> varMf := ((0.2+.012*Mf*100)/(100*2*1.414))^2;
```

$varMf := .9250793742\ 10^{-6}$

Ash re

```
> A := 0.0619;
```

$A := .0619$

```
> varA := ( (0.07+0.02*A*100)/(100*2*1.414))^2;
```

$varA := .4696223261\ 10^{-6}$

Overhead ?

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.64/(100*2*1.414))^2;
```

$varC := .5121546706\ 10^{-5}$

Hydrogen

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.16/(100*2*1.414))^2;
```

$varH := .3200966692\ 10^{-6}$

Nitrogen

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.11/(100*2*1.414))^2;
```

$varN := .1512956913\ 10^{-6}$

Sulfur re

```
> S := 0.0123;
```

$S := .0123$

```
> varS := ((0.06+.035*S*100)/(100*2*1.414))^2;
```

$varS := .1327813813\ 10^{-6}$

Moisture (air) re

```
> Wma := 0.013;
```

$Wma := .013$

```
> varWma := (.2*Wma)^2;
```

$varWma := .676\ 10^{-5}$

Carbon in Ash re

```
> Ca := 0.0486;
```

$Ca := .0486$

```
> varCa := (0.10*Ca)^2;
```

$varCa := .000023619600$

Results

****

```
> evalf(Mfg);
```

.08136935946

```
> evalf(Cpfg);
```

7.769387922

```
> evalf(Cpal);
```

7.151727411

```
> evalf(Cppa);
```

7.316810251

```
> evalf(Cpsa);
```

7.305185745

633

Wsai in lb/lb of AF Coal

```
> evalf(Wsai);
                                  9.310086250
> evalf(sigmaWsai);
                                 .06394430072
> evalf(100*sigmaWsai/Wsai);
                                  .6868282313
> evalf(Wsai*SA*Wfe);
                                  557353.8547
> evalf(sigmaWsai*SA*Wfe);
                                  3828.063622
>
```

****

```
>
```

Appendix J-1
Bias Error Calculation
Air Leak Calculation -- Zero Leak Case

>

>

Error Propagation Calculations, Part B, AL

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

634

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

#13

> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

> i := 'i';

$$i := i$$

#14

> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,V
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*(
> O2i[i]/100,i=1..n):

#18

> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,V
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*(
> O2i[i]/100,i=1..n):

#19

> SA := FA/(FA+FB);

$$SA := \frac{1}{2}$$

#20

> SB := FB/(FA+FB);

$$SB := \frac{1}{2}$$

#21

> WPAIA := PAFA/(Wfe*SA);

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) \Big/ Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)\Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma\left(36.46063760\ (100 - CO2avei - COavei - O2avei)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\right) + Mf$$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-C(
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\left(36.46063760\ (100 - CO2avei - COavei - O2avei)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\right) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \Bigg) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma \Bigg(36.46063760$$
$$(100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \Bigg) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100 \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo}$$
$$+ Wma \left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174 \right.$$
$$- \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2}$$
$$- Wma \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174 \right.$$
$$\Bigg) \Bigg/ \Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H$$
$$+ Wma \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174 \right.$$
$$+ Mf \Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

```
> TFluegasINa := WGi*Wfe*SA;
```

$$TFluegasINa := \frac{1}{2} \Bigg((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma \Bigg(36.46063760$$
$$(100 - CO2avei - COavei - O2avei)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S \right) / ($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Big) + Mf\Big)\ Wfe$$

TFluegasINb := WGi*Wfe*SB;

#33
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;

> sigmaALCO2avei := sqrt(Diff(AL,CO2avei)^2*varCO2avei):

> sigmaALCO2avei := value(");

$$sigmaALCO2avei := \Bigg(\Bigg(100 \frac{-15.99 \frac{\%1}{\%2} + 12.01 \frac{\%4\ \%1}{\%2^2} - Wma\left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{\%3\ \%1}{\%2^2}\right)}{\frac{\%4\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right) + Mf}$$

$$- 100 \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo}$$

$$+ Wma\left(36.46063760 \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right)$$

$$- \frac{\%4\ \%1}{\%2} - Wma\left(36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right)\Bigg)$$

$$\left(15.99 \frac{\%1}{\%2} - 12.01 \frac{\%4\ \%1}{\%2^2} + Wma\left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{\%3\ \%1}{\%2^2}\right)\right)\Bigg)^2$$

$$\Bigg/\left(\frac{\%4\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right) + Mf\right)^2\Bigg)^{1/2}$$

$$varCO2avei\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%3 := 100 - CO2avei - COavei - O2avei$$

$$\%4 := 15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00$$

> sigmaALCOavei := sqrt(Diff(AL,COavei)^2*varCOavei):

> sigmaALCOavei := value("):

> sigmaALO2avei := sqrt(Diff(AL,O2avei)^2*varO2avei):

> sigmaALO2avei := value("):

> sigmaALCO2aveo := sqrt(Diff(AL,CO2aveo)^2*varCO2aveo):

> sigmaALCO2aveo := value(");

$$sigmaALCO2aveo := \sqrt{10000}\ \Bigg(\Bigg(15.99 \frac{\%1}{\%2}$$

$$- 12.01 \frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{\%2^2} + Wma$$

$$\left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{\%2^2}\right)\Bigg)^2$$

$$varCO2aveo \Bigg/ \Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{12.01\ CO2avei + 12.01\ COavei}$$

$$+ 8.936\ H$$

$$+ Wma\left(36.46063760 \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.30123617\right.$$

$$\left. + Mf\right)^2\Bigg)^{1/2}$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2aveo + 12.01\ COaveo$$

```
> sigmaALCOaveo := sqrt(Diff(AL,COaveo)^2*varCOaveo):

> sigmaALCOaveo := value("):

> sigmaALO2aveo := sqrt(Diff(AL,O2aveo)^2*varO2aveo):

> sigmaALO2aveo := value("):

> covarALCO2avelo :=  2*Diff(AL,CO2avei)*Diff(AL,CO2aveo)*sqrt(varCO2avei)*sqrt
> (varCO2aveo):

> covarALCO2avelo := value("):

> sigmaALAreai := sqrt(Diff(AL,Areai)^2*varAreai):

> sigmaALAreai := value("):

> sigmaALAreao := sqrt(Diff(AL,Areao)^2*varAreao):

> sigmaALAreao := value("):

> sigmaALCP := sqrt(Diff(AL,CP)^2*varCP):

> sigmaALCP := value("):

> sigmaALPSi := sqrt(Diff(AL,PSi)^2*varPSi):

> sigmaALPSi := value("):

> sigmaALPSo := sqrt(Diff(AL,PSo)^2*varPSo):

> sigmaALPSo := value("):

> sigmaALA := sqrt(Diff(AL,A)^2*varA):

> sigmaALA := value("):

> sigmaALOUHD := sqrt(Diff(AL,OUHD)^2*varOUHD):

> sigmaALOUHD := value("):

> sigmaALCa := sqrt(Diff(AL,Ca)^2*varCa):

> sigmaALCa := value("):

> sigmaALC := sqrt(Diff(AL,C)*Diff(AL,C)*varC):

> sigmaALC := value("):

> sigmaALS := sqrt(Diff(AL,S)*Diff(AL,S)*varS):

> sigmaALS := value("):

> sigmaALH := sqrt(Diff(AL,H)*Diff(AL,H)*varH):

> sigmaALH := value("):

> sigmaALWma := sqrt(Diff(AL,Wma)*Diff(AL,Wma)*varWma):

> sigmaALWma := value("):

> sigmaALN := sqrt(Diff(AL,N)*Diff(AL,N)*varN):

> sigmaALN := value("):

> sigmaALMf := sqrt(Diff(AL,Mf)*Diff(AL,Mf)*varMf):

> sigmaALMf := value("):

> sigmaALWfe := sqrt(Diff(AL,Wfe)^2*varWfe):

> sigmaALWfe := value("):

> sigmaALWma := sqrt(Diff(AL,Wma)*Diff(AL,Wma)*varWma):

> sigmaALWma := value("):

> sigmaALDPi := sqrt(sum(sum(

> Diff(AL,DPi[i])*Diff(AL,DPi[j])*varDPi[i,j]

> ,j=1..n),i=1..n)):

> sigmaALDPi := value("):

> sigmaALDPo := sqrt(sum(sum(

> Diff(AL,DPo[i])*Diff(AL,DPo[j])*varDPo[i,j]

> ,j=1..n),i=1..n)):

> sigmaALDPo := value("):
```

```
> sigmaALTi := sqrt(sum(sum(
>  Diff(AL,Ti[i])*Diff(AL,Ti[j])*varTi[i,j]
> ,j=1..n),i=1..n)):
> sigmaALTi := value("):

> sigmaALTo := sqrt(sum(sum(
>  Diff(AL,To[i])*Diff(AL,To[j])*varTo[i,j]
> ,j=1..n),i=1..n)):
> sigmaALTo := value("):

> sigmaALCOi := sqrt(sum(sum(
>  Diff(AL,COi[i])*Diff(AL,COi[j])*varCOi[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCOi := value("):

> sigmaALCOo := sqrt(sum(sum(
>  Diff(AL,COo[i])*Diff(AL,COo[j])*varCOo[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCOo := value("):

> sigmaALCO2i := sqrt(sum(sum(
>  Diff(AL,CO2i[i])*Diff(AL,CO2i[j])*varCO2i[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCO2i := value("):

> sigmaALCO2o := sqrt(sum(sum(
>  Diff(AL,CO2o[i])*Diff(AL,CO2o[j])*varCO2o[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCO2o := value("):

> sigmaALO2i := sqrt(sum(sum(
>  Diff(AL,O2i[i])*Diff(AL,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):
> sigmaALO2i := value("):

> sigmaALO2o := sqrt(sum(sum(
>  Diff(AL,O2o[i])*Diff(AL,O2o[j])*varO2o[i,j]
> ,j=1..n),i=1..n)):
> sigmaALO2o := value("):

> sigmaAL := sqrt(
>  Diff(AL,CO2avei)^2*varCO2avei +
>  Diff(AL,COavei)^2*varCOavei +
>  Diff(AL,O2avei)^2*varO2avei +
>  Diff(AL,CO2aveo)^2*varCO2aveo +
>  Diff(AL,COaveo)^2*varCOaveo +
>  Diff(AL,O2aveo)^2*varO2aveo +
>  2*Diff(AL,CO2avei)*Diff(AL,CO2aveo)*sqrt(varCO2avei)*sqrt(varCO2aveo) +
>  Diff(AL,Wfe)^2*varWfe +
>  Diff(AL,Areai)^2*varAreai +
```

```
> Diff(AL,Areao)^2*varAreao +
> Diff(AL,CP)^2*varCP +
> Diff(AL,PSi)^2*varPSi +
> Diff(AL,PSo)^2*varPSo +
> Diff(AL,A)^2*varA +
> Diff(AL,OUHD)^2*varOUHD +
> Diff(AL,Ca)^2*varCa +
> Diff(AL,C)*Diff(AL,C)*varC +
> Diff(AL,S)*Diff(AL,S)*varS +
> Diff(AL,H)*Diff(AL,H)*varH +
> Diff(AL,Wma)*Diff(AL,Wma)*varWma +
> Diff(AL,N)*Diff(AL,N)*varN +
> Diff(AL,Mf)*Diff(AL,Mf)*varMf +
> sum(sum(
> Diff(AL,DPi[i])*Diff(AL,DPi[j])*varDPi[i,j] +
> Diff(AL,Ti[i])*Diff(AL,Ti[j])*varTi[i,j] +
> Diff(AL,COi[i])*Diff(AL,COi[j])*varCOi[i,j] +
> Diff(AL,CO2i[i])*Diff(AL,CO2i[j])*varCO2i[i,j] +
> Diff(AL,O2i[i])*Diff(AL,O2i[j])*varO2i[i,j] +
> Diff(AL,DPo[i])*Diff(AL,DPo[j])*varDPo[i,j] +
> Diff(AL,To[i])*Diff(AL,To[j])*varTo[i,j] +
> Diff(AL,COo[i])*Diff(AL,COo[j])*varCOo[i,j] +
> Diff(AL,CO2o[i])*Diff(AL,CO2o[j])*varCO2o[i,j] +
> Diff(AL,O2o[i])*Diff(AL,O2o[j])*varO2o[i,j]
```

```
> ,j=1..n),i=1..n)):
```

```
> sigmaAL := value(");
```

$$sigmaAL := \left(\left(100\ \left(\right.\right.\right.$$

$$\frac{\%9\ \%15}{\%7} + 36.46063760\ \frac{Wma\ \%8\ \%15}{\%7} - \frac{\%5\ \%15}{\%2} - 36.46063760\ \frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)/(\%6) - 100\ \frac{\%10\left(\frac{\%5\ \%15}{\%2} + 36.46063760\ \frac{Wma\ \%3\ \%15}{\%2}\right)}{\%6^2}\Bigg)^2\ varA + \Bigg(100\ \Big($$

$$\frac{\%9\ \%14}{\%7} + 36.46063760\ \frac{Wma\ \%8\ \%14}{\%7} - \frac{\%5\ \%14}{\%2} - 36.46063760\ \frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)/(\%6) - 100\ \frac{\%10\left(\frac{\%5\ \%14}{\%2} + 36.46063760\ \frac{Wma\ \%3\ \%14}{\%2}\right)}{\%6^2}\Bigg)^2\ varOUHD + 20$$

$$\Bigg(100\ \frac{-15.99\ \frac{\%1}{\%2} + 12.01\ \frac{\%5\ \%1}{\%2^2} - \%11}{\%6}$$

$$- 100\ \frac{\%10\left(15.99\ \frac{\%1}{\%2} - 12.01\ \frac{\%5\ \%1}{\%2^2} + \%11\right)}{\%6^2}\Bigg)$$

$$\left(15.99\ \frac{\%1}{\%7} - 12.01\ \frac{\%9\ \%1}{\%7^2} + \%12\right)\sqrt{varCO2avei}\ \sqrt{varCO2aveo}/(\%6) + \Bigg(1$$

$$\Big($$

$$\frac{\%9\ \%13}{\%7} + 36.46063760\ \frac{Wma\ \%8\ \%13}{\%7} - \frac{\%5\ \%13}{\%2} - 36.46063760\ \frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)/(\%6) - 100\ \frac{\%10\left(\frac{\%5\ \%13}{\%2} + 36.46063760\ \frac{Wma\ \%3\ \%13}{\%2}\right)}{\%6^2}\Bigg)^2\ varCa + \Bigg($$

$$100 \frac{\frac{\%9}{\%7} + 36.46063760 \frac{Wma\ \%8}{\%7} - \frac{\%5}{\%2} - 36.46063760 \frac{Wma\ \%3}{\%2}}{\%6}$$

$$- 100 \frac{\%10 \left(\frac{\%5}{\%2} + 36.46063760 \frac{Wma\ \%3}{\%2}\right)}{\%6^2}\Bigg)^2 varC + \Bigg(100 \Big(.3744932959 \frac{\%9}{\%7}$$

$$+ 13.65426435 \frac{Wma\ \%8}{\%7} - .3744932959 \frac{\%5}{\%2} - 13.65426435 \frac{Wma\ \%3}{\%2}\Big)/(\%6)$$

$$- 100 \frac{\%10 \left(.3744932959 \frac{\%5}{\%2} + 13.65426435 \frac{Wma\ \%3}{\%2}\right)}{\%6^2}\Bigg)^2 varS$$

$$+ 798520.9600 \frac{\%10^2\ varH}{\%6^4} +$$

$$\left(100 \frac{36.46063760 \frac{\%8\ \%1}{\%7} - 36.46063760 \frac{\%3\ \%1}{\%2}}{\%6} - 100 \frac{\%10\ \%4}{\%6^2}\right)^2 varWma$$

$$+ 10000 \frac{\left(4.00 \frac{\%1}{\%7} - 36.46063760 \frac{Wma\ \%1}{\%7}\right)^2 varO2aveo}{\%6^2} + \Bigg($$

$$100 \frac{-4.00 \frac{\%1}{\%2} + 36.46063760 \frac{Wma\ \%1}{\%2}}{\%6}$$

$$- 100 \frac{\%10 \left(4.00 \frac{\%1}{\%2} - 36.46063760 \frac{Wma\ \%1}{\%2}\right)}{\%6^2}\Bigg)^2 varO2avei$$

$$+ 10000 \frac{\left(15.99 \frac{\%1}{\%7} - 12.01 \frac{\%9\ \%1}{\%7^2} + \%12\right)^2 varCO2aveo}{\%6^2}$$

$$+ 10000 \frac{\left(-.01 \frac{\%1}{\%7} - 12.01 \frac{\%9\ \%1}{\%7^2} + \%12\right)^2 varCOaveo}{\%6^2} + \Bigg($$

$$100 \frac{-15.99 \frac{\%1}{\%2} + 12.01 \frac{\%5\ \%1}{\%2^2} - \%11}{\%6}$$

$$- 100 \frac{\%10 \left(15.99 \frac{\%1}{\%2} - 12.01 \frac{\%5\ \%1}{\%2^2} + \%11\right)}{\%6^2}\Bigg)^2 varCO2avei + \Bigg($$

$$100 \frac{.01 \frac{\%1}{\%2} + 12.01 \frac{\%5\ \%1}{\%2^2} - \%11}{\%6}$$

$$- 100 \frac{\%10 \left(-.01 \frac{\%1}{\%2} - 12.01 \frac{\%5\ \%1}{\%2^2} + \%11\right)}{\%6^2}\Bigg)^2 varCOavei$$

$$+ 16932.15581 \frac{\%10^2\ Wma^2\ varN}{\%6^4} + 10000 \frac{\%10^2\ varMf}{\%6^4}\Bigg)^{1/2}$$

$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$

$\%2 := 12.01\ CO2avei + 12.01\ COavei$

$\%3 := 100 - CO2avei - COavei - O2avei$

$\%4 := 36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N$

$\%5 := 15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00$

$\%6 := \frac{\%5\ \%1}{\%2} + 8.936\ H + Wma\ \%4 + Mf$

$\%7 := 12.01\ CO2aveo + 12.01\ COaveo$

$\%8 := 100 - CO2aveo - COaveo - O2aveo$

$\%9 := 15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00$

$\%10 :=$

$$\frac{\%9\ \%1}{\%7} + Wma\left(36.46063760\ \frac{\%8\ \%1}{\%7} - 1.301236174\ N\right) - \frac{\%5\ \%1}{\%2} - Wma\ \%4$$

$$\%11 := Wma\left(-36.46063760\ \frac{\%1}{\%2} - 437.8922576\ \frac{\%3\ \%1}{\%2^2}\right)$$

$$\%12 := Wma\left(-36.46063760\ \frac{\%1}{\%7} - 437.8922576\ \frac{\%8\ \%1}{\%7^2}\right)$$

$$\%13 := -\frac{A\ OUHD}{1 - Ca} - \frac{A\ OUHD\ Ca}{(1 - Ca)^2} - \frac{1}{3}\,\frac{A\ (1 - OUHD)}{1 - \frac{1}{3}\ Ca} - \frac{1}{9}\,\frac{A\ (1 - OUHD)\ Ca}{\left(1 - \frac{1}{3}\ Ca\right)^2}$$

$$\%14 := -\frac{A\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ Ca}{1 - \frac{1}{3}\ Ca}$$

$$\%15 := -\frac{OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{(1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

Constants

Averages and Variances from Part A

```
> CO2avei := 15.2148;
```
$CO2avei := 15.2148$

```
> varCO2avei := .1^2;
```
$varCO2avei := .01$

```
> COavei := .005;
```
$COavei := .005$

```
> varCOavei := .002^2;
```
$varCOavei := .4\ 10^{-5}$

```
> O2avei := 3.8;
```
$O2avei := 3.8$

```
> varO2avei := .05^2;
```
$varO2avei := .0025$

```
> CO2aveo := 15.2148;
```
$CO2aveo := 15.2148$

```
> varCO2aveo := .1^2;
```
$varCO2aveo := .01$

```
> COaveo := .005;
```

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COaveo := .005

\> varCOaveo := .002^2;

varCOaveo := $.4\ 10^{-5}$

\> O2aveo := 3.8;

O2aveo := 3.8

\> varO2aveo := .05^2;

varO2aveo := .0025

Coal Feed Rate (lbs/hr)

\> Wfe := 115839;

Wfe := 115839

\> varWfe := (0.05*Wfe)^2;

varWfe := $.3354668480\ 10^{8}$

Area (square ft)

\> Areai := 3.99;

Areai := 3.99

\> varAreai := (0.0335*Areai)^2;

varAreai := .01786633223

\> Areao := 3.54;

Areao := 3.54

\> varAreao := (0.0364*Areao)^2;

varAreao := .01660386874

Pitot Coefficient

\> CP := 0.84;

CP := .84

\> varCP := (0.01)^2;

varCP := .0001

Pressure in Area

\> PSi := 29.23;

PSi := 29.23

\> varPSi := (0.04)^2;

varPSi := .0016

\> PSo := 29.1;

PSo := 29.1

\> varPSo := (0.04)^2;

varPSo := .0016

Pressue for primary air

\> PSpa := 31.11;

PSpa := 31.11

\> varPSpa := (0.04)^2;

varPSpa := .0016

\>

Velocity Head

\> v := .45802;

v := .45802

\> DPo := array([seq(v,i=1..n)]);

DPo := [.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .4580
.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45
.45802]

\> u := (.02*v)^2;

u := .0000839129281 6

\> var := array([seq(u,i=1..n)]);

var := [.00008391292816 .00008391292816 .00008391292816 .0000839129281
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816]

\> varDPo := make_array(var,n);

varDPo := varcovar

\> v := .82831;

v := .82831

\> DPi := array([seq(v,i=1..n)]);

DPi := [.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .828
.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82
.82831]

\> u := (.02*v)^2;

u := .0002744389824

\> var := array([seq(u,i=1..n)]);

var := [.0002744389824 .0002744389824 .0002744389824 .0002744389824

649

```
.0002744389824  .0002744389824  .0002744389824  .0002744389824
.0002744389824  .0002744389824  .0002744389824  .0002744389824
.0002744389824  .0002744389824  .0002744389824  .0002744389824
.0002744389824  .0002744389824  .0002744389824  .0002744389824]
```

```
> varDPi := make_array(var,n);
```

$varDPi := varcovar$

Temperature (R)

```
> v := 713;
```

$v := 713$

```
> To := array([seq(v,i=1..n)]);
```

To := [713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713 713]

```
> u := (0.01*(v-460))^2;
```

$u := 6.4009$

```
> var := array([seq(u,i=1..n)]);
```

var := [6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009]

```
> varTo := make_array(var,n);
```

$varTo := varcovar$

```
> v := 1140;
```

$v := 1140$

```
> Ti:= array([seq(v,i=1..n)]);
```

Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140]

```
> u := (0.01*(v-460))^2;
```

$u := 46.2400$

```
> var := array([seq(u,i=1..n)]);
```

var := [46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400]

```
> varTi := make_array(var,n);
```

$varTi := varcovar$

Moisture in Coal

```
> Mf :=0.06;
```

$Mf := .06$

```
> varMf := (0.039*Mf)^2;
```

$varMf := .54756 \; 10^{-5}$

Ash

```
> A := 0.0619;
```

$A := .0619$

```
> varA := ( 0.039*A)^2;
```

$varA := .582787881 \; 10^{-5}$

Overhead

```
> OUHD := 0.9;
```

$OUHD := .9$

```
> varOUHD := (0.1*OUHD)^2;
```

$varOUHD := .0081$

Carbon

```
> C := 0.7381;
```

$C := .7381$

```
> varC := (0.039*C)^2;
```

$varC := .0008286280388$

Hydrogen

```
> H := 0.0482;
```

$H := .0482$

```
> varH := (0.039*H)^2;
```

$varH := .353364804 \; 10^{-5}$

Nitrogen

```
> N := 0.0135;
```

$N := .0135$

```
> varN := (0.039*N)^2;
```

$varN := .27720225 \; 10^{-6}$

Sulfur

```
> S := 0.0123;
```

$S := .0123$

```
> varS := (0.019*S)^2;
```

$varS := .5461569 \; 10^{-7}$

CO2

```
> v := 14.145;
                              v := 14.145
> CO2o := array([seq(v,i=1..n)]);
   CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
     14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
     14.145]
> u := (0.1)^2;
                              u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
     .01  .01  .01  .01  .01]
> varCO2o := make_array(var,n);
                          varCO2o := varcovar
```

```
> v := 15.2148;
                              v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
   CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
     15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
     15.2148  15.2148  15.2148  15.2148]
> u := (0.1)^2;
                              u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01
     .01  .01  .01  .01  .01]
> varCO2i := make_array(var,n);
                          varCO2i := varcovar
```

O2

```
> v := 5;
                              v := 5
> O2o := array([seq(v,i=1..n)]);
        O2o := [5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
   var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                          varO2o := varcovar
```

```
> v := 3.8;
                              v := 3.8
> O2i := array([seq(v,i=1..n)]);
   O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3
     3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
   var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
     .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                          varO2i := varcovar
```

Moisture (air)

```
> Wma := 0.013;
                              Wma := .013
> varWma := (.1*Wma)^2;
                          varWma := .169 10^(-5)
```

CO

```
> v := 0.005;
                              v := .005
> COo := array([seq(v,i=1..n)]);
   COo := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .00
     .005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.002)^2;
                              u := .4 10^(-5)
> var := array([seq(u,i=1..n)]);
   var := [.4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10
     .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)
     .4 10^(-5)  .4 10^(-5)  .4 10^(-5)  .4 10^(-5)]
> varCOo := make_array(var,n);
                          varCOo := varcovar
```

> v := 0.005;

$v := .005$

> COi := array([seq(v,i=1..n)]);

$COi := [.005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005\ .005]$

> u := (0.002)^2;

$u := .4\ 10^{-5}$

> var := array([seq(u,i=1..n)]);

$var := [.4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}\ .4\ 10^{-5}]$

> varCOi := make_array(var,n);

$varCOi := varcovar$

Carbon in Ash

> Ca := 0.0486;

$Ca := .0486$

> varCa := (0.25*Ca)^2;

$varCa := .000147622500$

Area for primary air

> apa := .63;

$apa := .63$

> varapa := (.0208*apa)^2;

$varapa := .000171714816$

> v := .2171;

$v := .2171$

> DPpa := array([seq(v,i=1..n)]);

$DPpa := [.2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171\ .2171]$

> u := (0.02*v)^2;

$u := .000018852964$

> varDPPA := array([seq(u,i=1..n)]);

$varDPPA := [.000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964\ .000018852964]$

> v := 1104;

$v := 1104$

> Tpa := array([seq(v,i=1..n)]);

$Tpa := [1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104\ 1104]$

> u := (0.01*(v - 460))^2;

$u := 41.4736$

> varTpa := array([seq(u,i=1..n)]);

$varTpa := [41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736\ 41.4736]$

Results

****

> evalf(AL);

AIR LEAK $.3299634610\ 10^{-7}$ ≈ 0

> evalf(sigmaAL);

BIAS $.01952759709$ %

> evalf(100*sigmaAL/AL);

$.5918108942\ 10^{8}$ NOT SIGNIFICANT WHEN AL ≈ 0

> evalf(sigmaALWfe);

0

> evalf(sigmaALWma);

$.3927433122\ 10^{-10}$

> evalf(sigmaALCO2avei);

.5841239251

> evalf(sigmaALCOavei);

.01267624739

> evalf(sigmaALO2avei);

.005475063689

> evalf(sigmaALCO2aveo);

.5841239248

> evalf(sigmaALCOaveo);

```
                    .01267624739
> evalf(sigmaALO2aveo);
                    .005475063692
> evalf(covarALCO2aveio);
                    -.6824015194
> evalf(sigmaALAreai);
                    0
> evalf(sigmaALAreao);
                    0
> evalf(sigmaALCP);
                    0
> evalf(sigmaALPSi);
                    0
> evalf(sigmaALPSo);
                    0
> evalf(sigmaALA);
                    .4879213086 10^(-11)
> evalf(sigmaALOUHD);
                    .4893902538 10^(-11)
> evalf(sigmaALCa);
                    .1154095607 10^(-10)
> evalf(sigmaALC);
                    .1832051013 10^(-8)
> evalf(sigmaALS);
                    .3774725272 10^(-11)
> evalf(sigmaALH);
                    .4253221987 10^(-10)
> evalf(sigmaALN);
                    .2255075574 10^(-13)
> evalf(sigmaALMf);
                    .5924873774 10^(-11)
> evalf(sigmaALDPi);
                    0
> evalf(sigmaALTi);
                    0
> evalf(sigmaALCOi);
                    0
> evalf(sigmaALCO2i);
                    0
> evalf(sigmaALO2i);
                    0
> evalf(sigmaALDPo);
                    0
> evalf(sigmaALTo);
                    0
> evalf(sigmaALCOo);
                    0
> evalf(sigmaALCO2o);
                    0
> evalf(sigmaALO2o);
                    0
 *****************************************************************

> i := 'i';
                    i := i

 #13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                    m := 28.74570417

 #14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFA := 62529.82254

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                    PAFB := 62529.82254

 #17
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,\
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*
> O2i[i]/100,i=1..n):

 #18
```

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
                    SA := .5000000000
```

#20

```
> SB := FB/(FA+FB);
                    SB := .5000000000
```

#21

```
> WPAIA := PAFA/(Wfe*SA);
                    WPAIA := 1.079598797
```

#22

```
> WPAIB := PAFB/(Wfe*SB);
                    WPAIB := 1.079598797
```

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
                    Cr := .002947741741
> Cb := C - Cr;
                    Cb := .7351522583
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
                    WAi := 11.93169660
```

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
                    WMGi := .6458272558
```

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
                    WGpi := 12.38591870
```

#26

```
> WGi := WGpi + WMGi;
                    WGi := 13.03174596
```

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*((
> b + (12.01/32.07)*S)-N)/0.7685;
                    WAo := 11.93169660
```

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
                    WMGo := .6458272558
```

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
                    WGpo := 12.38591870
```

#30

```
> WGo := WGpo + WMGo;
                    WGo := 13.03174596
```

#31

```
> AL := ((WGo-WGi)/WGi)*100;
                    AL := 0
```

#32

```
> TFluegasINa := WGi*Wfe*SA;
                    TFluegasINa := 754792.2100
TFluegasINb := WGi*Wfe*SB;
```

#33

```
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;
>
```

Appendix J-2
Random Error Calculation
Air Leak Calculation -- Zero Leak Case

>

>

Random Error Propagation Calculations, Part B, AL (zero leakage, n=20 for flue gas in, n=24 for flue gas out)

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if  i = j  then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
```

652

```
        for j to n do
            for i to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> MFG := (K4/18.016)/((K4/18.016)+100*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `MFG` is implicitly declared local

  MFG :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,MFG;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
       ;
      MFG := .05550621670*K4/(.05550621670*K4+100*K3)
  end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

> Cb := C - Cr;

> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));

> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;

> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)

> end;
  Warning, `Cr` is implicitly declared local
  Warning, `Cb` is implicitly declared local
  Warning, `K3` is implicitly declared local
  Warning, `K4` is implicitly declared local
  Warning, `M` is implicitly declared local

  M :=

  proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
  local Cr,Cb,K3,K4,M;
      Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
      Cb := C-Cr;
      K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
      K4 :=
       8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
       ;
      M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
  end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} \right.$$

$$+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\Bigg)$$

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa_9}{Tpa_9}}+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#18

> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#19

> SA := FA/(FA+FB);

$$SA := \frac{1}{2}$$

#20

> SB := FB/(FA+FB);

$$SB := \frac{1}{2}$$

#21

> WPAIA := PAFA/(Wfe*SA);

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa_9}{Tpa_9}}+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)\Big/Wfe$$

#22

> WPAIB := PAFB/(Wfe*SB);

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma+28.97)}{1.608015098\ Wma+1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}}+\sqrt{\frac{DPpa_2}{Tpa_2}}+\sqrt{\frac{DPpa_3}{Tpa_3}}+\sqrt{\frac{DPpa_4}{Tpa_4}}+\sqrt{\frac{DPpa_5}{Tpa_5}}+\sqrt{\frac{DPpa_6}{Tpa_6}}+\sqrt{\frac{DPpa_7}{Tpa_7}}+\sqrt{\frac{DPpa_8}{Tpa_8}}+\sqrt{\frac{DPpa_9}{Tpa_9}}+\sqrt{\frac{DPpa_{10}}{Tpa_{10}}}+\sqrt{\frac{DPpa_{11}}{Tpa_{11}}}+\sqrt{\frac{DPpa_{12}}{Tpa_{12}}}+\sqrt{\frac{DPpa_{13}}{Tpa_{13}}}+\sqrt{\frac{DPpa_{14}}{Tpa_{14}}}+\sqrt{\frac{DPpa_{15}}{Tpa_{15}}}+\sqrt{\frac{DPpa_{16}}{Tpa_{16}}}+\sqrt{\frac{DPpa_{17}}{Tpa_{17}}}+\sqrt{\frac{DPpa_{18}}{Tpa_{18}}}+\sqrt{\frac{DPpa_{19}}{Tpa_{19}}}+\sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)\Big/Wfe$$

#23

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> Cb := C - Cr;

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

> WMGi := 8.936*H + (Wma*WAi)+Mf;

$$WMGi := 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#25

> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2avei + 12.01\ COavei)$$

#26

> WGi := WGpi + WMGi;

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma \left(36.46063760\ (100 - CO2avei - COavei - O2avei) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N \right) + Mf$$

#27

> WAo :=(((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

> WMGo := 8.936*H + (Wma*WAo) + Mf;

$$WMGo := 8.936\ H + Wma \left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo) \left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / (12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N \right) + Mf$$

#29

> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo)$$

#30

> WGo := WGpo + WMGo;

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\ \Big(36.46063760$$
$$(100 - CO2aveo - COaveo - O2aveo)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Big) + Mf$$

#31

> AL := ((WGo-WGi)/WGi)*100;

$$AL := 100\ \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo}$$
$$+ Wma\ \left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right)$$
$$- \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2}$$
$$- Wma\ \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right)$$
$$\Bigg) / \Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H$$
$$+ Wma\ \left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right)$$
$$+ Mf\Bigg)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

> TFluegasINa := WGi*Wfe*SA;

$$TFluegasINa := \frac{1}{2}\ \Bigg((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\ \Big(36.46063760$$
$$(100 - CO2avei - COavei - O2avei)$$
$$\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$
$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Big) + Mf\Bigg)\ Wfe$$

> sigmaAL := sqrt(

> Diff(AL,CO2avei)^2*varCO2avei +

> Diff(AL,COavei)^2*varCOavei +

> Diff(AL,O2avei)^2*varO2avei +

> Diff(AL,CO2aveo)^2*varCO2aveo +

> Diff(AL,COaveo)^2*varCOaveo +

> Diff(AL,O2aveo)^2*varO2aveo +

> Diff(AL,A)^2*varA +

> Diff(AL,OUHD)^2*varOUHD +

```
> Diff(AL,Ca)^2*varCa +
> Diff(AL,C)^2*varC +
> Diff(AL,S)^2*varS +
> Diff(AL,H)^2*varH +
> Diff(AL,Wma)^2*varWma +
> Diff(AL,N)^2*varN +
> Diff(AL,Mf)^2*varMf
> ):
> sigmaAL := value(");
```

$$sigmaAL := \left(\left(100\,\frac{-15.99\,\frac{\%1}{\%2}+12.01\,\frac{\%5\ \%1}{\%2^2}-\%14}{\%6}\right.\right.$$

$$\left.-100\,\frac{\%10\left(15.99\,\frac{\%1}{\%2}-12.01\,\frac{\%5\ \%1}{\%2^2}+\%14\right)}{\%6^2}\right)^2 varCO2avei+\Bigg($$

$$100\,\frac{.01\,\frac{\%1}{\%2}+12.01\,\frac{\%5\ \%1}{\%2^2}-\%14}{\%6}$$

$$\left.-100\,\frac{\%10\left(-.01\,\frac{\%1}{\%2}-12.01\,\frac{\%5\ \%1}{\%2^2}+\%14\right)}{\%6^2}\right)^2 varCOavei+\Bigg($$

$$100\,\frac{-4.00\,\frac{\%1}{\%2}+36.46063760\,\frac{Wma\ \%1}{\%2}}{\%6}$$

$$\left.-100\,\frac{\%10\left(4.00\,\frac{\%1}{\%2}-36.46063760\,\frac{Wma\ \%1}{\%2}\right)}{\%6^2}\right)^2 varO2avei+10000$$

$$\left(15.99\,\frac{\%1}{\%7}-12.01\,\frac{\%9\ \%1}{\%7^2}+Wma\left(-36.46063760\,\frac{\%1}{\%7}-437.8922576\,\frac{\%8\ \%1}{\%7^2}\right.\right.$$

$$2$$

$$varCO2aveo\Big/\%6^2+10000$$

$$\left(-.01\,\frac{\%1}{\%7}-12.01\,\frac{\%9\ \%1}{\%7^2}+Wma\left(-36.46063760\,\frac{\%1}{\%7}-437.8922576\,\frac{\%8\ \%1}{\%7^2}\right)\right.$$

$$varCOaveo\Big/\%6^2+10000\,\frac{\left(4.00\,\frac{\%1}{\%7}-36.46063760\,\frac{Wma\ \%1}{\%7}\right)^2 varO2aveo}{\%6^2}$$

$$100\Bigg($$

$$\frac{\%9\ \%13}{\%7}+36.46063760\,\frac{Wma\ \%8\ \%13}{\%7}-\frac{\%5\ \%13}{\%2}-36.46063760\,\frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)\Big/(\%6)-100\,\frac{\%10\left(\frac{\%5\ \%13}{\%2}+36.46063760\,\frac{Wma\ \%3\ \%13}{\%2}\right)}{\%6^2}\Bigg)^2 varA+\Bigg(100\,\Bigg($$

$$\frac{\%9\ \%12}{\%7}+36.46063760\,\frac{Wma\ \%8\ \%12}{\%7}-\frac{\%5\ \%12}{\%2}-36.46063760\,\frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)\Big/(\%6)-100\,\frac{\%10\left(\frac{\%5\ \%12}{\%2}+36.46063760\,\frac{Wma\ \%3\ \%12}{\%2}\right)}{\%6^2}\Bigg)^2 varOUHD+\Bigg(1$$

$$\Bigg($$

$$\frac{\%9\ \%11}{\%7}+36.46063760\,\frac{Wma\ \%8\ \%11}{\%7}-\frac{\%5\ \%11}{\%2}-36.46063760\,\frac{Wma\ \%3\ \%1}{\%2}$$

$$\Big)\Big/(\%6)-100\,\frac{\%10\left(\frac{\%5\ \%11}{\%2}+36.46063760\,\frac{Wma\ \%3\ \%11}{\%2}\right)}{\%6^2}\Bigg)^2 varCa+\Bigg($$

$$100\,\frac{\frac{\%9}{\%7}+36.46063760\,\frac{Wma\ \%8}{\%7}-\frac{\%5}{\%2}-36.46063760\,\frac{Wma\ \%3}{\%2}}{\%6}$$

$$- 100 \frac{\%10 \left(\frac{\%5}{\%2} + 36.46063760 \frac{Wma\ \%3}{\%2}\right)}{\%6^2}\Bigg)^2 varC + \Bigg(100 \Big(.3744932959 \frac{\%9}{\%7}$$

$$+ 13.65426435 \frac{Wma\ \%8}{\%7} - .3744932959 \frac{\%5}{\%2} - 13.65426435 \frac{Wma\ \%3}{\%2}\Big)/(\%6)$$

$$- 100 \frac{\%10 \left(.3744932959 \frac{\%5}{\%2} + 13.65426435 \frac{Wma\ \%3}{\%2}\right)}{\%6^2}\Bigg)^2 varS$$

$$+ 798520.9600 \frac{\%10^2\ varH}{\%6^4} +$$

$$\left(100 \frac{36.46063760 \frac{\%8\ \%1}{\%7} - 36.46063760 \frac{\%3\ \%1}{\%2}}{\%6} - 100 \frac{\%10\ \%4}{\%6^2}\right)^2 varWma$$

$$+ 16932.15581 \frac{\%10^2\ Wma^2\ varN}{\%6^4} + 10000 \frac{\%10^2\ varMf}{\%6^4}\Bigg)^{1/2}$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%3 := 100 - CO2avei - COavei - O2avei$$

$$\%4 := 36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N$$

$$\%5 := 15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00$$

$$\%6 := \frac{\%5\ \%1}{\%2} + 8.936\ H + Wma\ \%4 + Mf$$

$$\%7 := 12.01\ CO2aveo + 12.01\ COaveo$$

$$\%8 := 100 - CO2aveo - COaveo - O2aveo$$

$$\%9 := 15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00$$

$$\%10 := \frac{\%9\ \%1}{\%7} + Wma \left(36.46063760 \frac{\%8\ \%1}{\%7} - 1.301236174\ N\right) - \frac{\%5\ \%1}{\%2} - Wma\ \%4$$

$$\%11 := -\frac{A\ OUHD}{1 - Ca} - \frac{A\ OUHD\ Ca}{(1 - Ca)^2} - \frac{1}{3} \frac{A\ (1 - OUHD)}{1 - \frac{1}{3}\ Ca} - \frac{1}{9} \frac{A\ (1 - OUHD)\ Ca}{\left(1 - \frac{1}{3}\ Ca\right)^2}$$

$$\%12 := -\frac{A\ Ca}{1 - Ca} + \frac{1}{3} \frac{A\ Ca}{1 - \frac{1}{3}\ Ca}$$

$$\%13 := -\frac{OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{(1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

$$\%14 := Wma \left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{\%3\ \%1}{\%2^2}\right)$$

```
> sigmaALCO2avei := sqrt(Diff(AL,CO2avei)^2*varCO2avei):
> sigmaALCO2avei := value("):
> sigmaALCOavei := sqrt(Diff(AL,COavei)^2*varCOavei):
> sigmaALCOavei := value("):
> sigmaALO2avei := sqrt(Diff(AL,O2avei)^2*varO2avei):
> sigmaALO2avei := value("):
> sigmaALCO2aveo := sqrt(Diff(AL,CO2aveo)^2*varCO2aveo):
> sigmaALCO2aveo := value("):
> sigmaALCOaveo := sqrt(Diff(AL,COaveo)^2*varCOaveo):
> sigmaALCOaveo := value("):
> sigmaALO2aveo := sqrt(Diff(AL,O2aveo)^2*varO2aveo):
> sigmaALO2aveo := value("):
> sigmaALA := sqrt(Diff(AL,A)^2*varA):
```

```
> sigmaALA := value("):
> sigmaALOUHD := sqrt(Diff(AL,OUHD)^2*varOUHD):
> sigmaALOUHD := value("):
> sigmaALCa := sqrt(Diff(AL,Ca)^2*varCa):
> sigmaALCa := value("):
> sigmaALC := sqrt(Diff(AL,C)^2*varC):
> sigmaALC := value("):
> sigmaALS := sqrt(Diff(AL,S)^2*varS):
> sigmaALS := value("):
> sigmaALH := sqrt(Diff(AL,H)^2*varH):
> sigmaALH := value("):
> sigmaALWma := sqrt(Diff(AL,Wma)^2*varWma):
> sigmaALWma := value("):
> sigmaALN := sqrt(Diff(AL,N)^2*varN):
> sigmaALN := value("):
> sigmaALMf := sqrt(Diff(AL,Mf)^2*varMf):
> sigmaALMf := value("):
```

Constants

Averages and Random Error Variances from Part A (n=20 for in, n=24 for out)

```
> CO2avei := 15.2148;
```

$CO2avei := 15.2148$

```
> varCO2avei := .102^2;
```

$varCO2avei := .010404$

```
> COavei := .005;
```

$COavei := .005$

```
> varCOavei := .0002^2;
```

$varCOavei := .4\ 10^{-7}$

```
> O2avei := 3.8;
```

$O2avei := 3.8$

```
> varO2avei := .01118^2;
```

$varO2avei := .0001249924$

```
> CO2aveo := 15.2148;
```

$CO2aveo := 15.2148$

```
> varCO2aveo := .0866^2;
```

$varCO2aveo := .00749956$

```
> COaveo := .005;
```

$COaveo := .005$

```
> varCOaveo := .000204^2;
```

$varCOaveo := .41616\ 10^{-7}$

```
> O2aveo := 3.8;
```

$O2aveo := 3.8$

```
> varO2aveo := .010206^2;
```

$varO2aveo := .000104162436$

Coal Feed Rate (lbs/hr) re

```
> Wfe := 115839;
```

$Wfe := 115839$

```
> varWfe := (0.0025*Wfe)^2;
```

$varWfe := 83866.71200$

Area (square ft) re

```
> Areai := 3.99;
```

$Areai := 3.99$

```
> varAreai := (0.0335*Areai)^2;
```

$varAreai := .01786633223$

```
> Areao := 3.54;
```

$Areao := 3.54$

```
> varAreao := (0.0364*Areao)^2;
```

$varAreao := .01660386874$

Pitot Coefficient re

```
> CP := 0.84;
                              CP := .84
> varCP := (0)^2;
                              varCP := 0
```

Pressure Ambient or Barometric re

```
> PSi := 29.23;
                              PSi := 29.23
> varPSi := (0.04)^2;
                              varPSi := .0016
```

```
> PSo := 29.1;
                              PSo := 29.1
> varPSo := (0.04)^2;
                              varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
                              PSpa := 31.11
> varPSpa := (0.04)^2;
                              varPSpa := .0016
>
```

Velocity Head DP re

```
> v := .45802;
                              v := .45802
> DPo := array([seq(v,i=1..n)]);
    DPo := [.45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
      .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802  .45802
      .45802]
> u := .00005^2;
                              u := .25 10^-8
> var := array([seq(u,i=1..n)]);
    var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
> varDPo := make_array(var,n);
                              varDPo := varcovar
```

```
> v := .82831;
                              v := .82831
> DPi := array([seq(v,i=1..n)]);
    DPi := [.82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831
      .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82831  .82
      .82831]
> u := .00005^2;
                              u := .25 10^-8
> var := array([seq(u,i=1..n)]);
    var := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 1
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
> varDPi := make_array(var,n);
                              varDPi := varcovar
>
```

Area for primary air

```
> apa := .63;
                              apa := .63
> varapa := (.0208*apa)^2;
                              varapa := .000171714816
>
```

```
> v := .2171;
                              v := .2171
> DPpa := array([seq(v,i=1..n)]);
    DPpa := [.2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .217
      .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171  .2171]
> u := (0.00005)^2;
                              u := .25 10^-8
> varDPpa := array([seq(u,i=1..n)]);
    varDPpa := [.25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 1
      .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8  .25 10^-8]
```

```
> v := 1104;
                              v := 1104
> Tpa := array([seq(v,i=1..n)]);
    Tpa := [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104
        1104 1104 1104 1104 1104 1104 1104 1104 1104]
> u := (0.005*(v - 460))^2;
                              u := 10.368400
> varTpa := array([seq(u,i=1..n)]);
    varTpa := [10.368400 10.368400 10.368400 10.368400 10.368400 10.368400
      10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400
      10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400]
```

Temperature (R) re

```
> v := 713;
                              v := 713
> To := array([seq(v,i=1..n)]);
    To := [713 713 713 713 713 713 713 713 713 713 713 713 713 713
      713 713 713 713 713 713]
> u := (.005*(v-460))^2;
                              u := 1.600225
> var := array([seq(u,i=1..n)]);
    var := [1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225
      1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225 1.600225
      1.600225 1.600225 1.600225 1.600225 1.600225]
> varTo := make_array(var,n);
                              varTo := varcovar

> v := 1140;
                              v := 1140
> Ti:= array([seq(v,i=1..n)]);
    Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140
      1140 1140 1140 1140 1140 1140 1140 1140 1140]
> u := (.005*(v-460))^2;
                              u := 11.560000
> var := array([seq(u,i=1..n)]);
    var := [11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
      11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000
      11.560000 11.560000 11.560000 11.560000 11.560000 11.560000 11.560000]

> varTi := make_array(var,n);
                              varTi := varcovar
```

Moisture in Ash re

```
> Mf :=0.06;
                              Mf := .06
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
                              varMf := .0001058319613
```

Ash re

```
> A := 0.0619;
                              A := .0619
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
                              varA := .4696223261 10^-6
```

Overhead re

```
> OUHD := 0.9;
                              OUHD := .9
> varOUHD := (0.1*OUHD)^2;
                              varOUHD := .0081
```

Carbon re

```
> C := 0.7381;
                              C := .7381
> varC := (0.64/(2*1.414*100))^2;
                              varC := .5121546706 10^-5
```

Hydrogen re

```
> H := 0.0482;
                              H := .0482
> varH := (0.16/(2*1.414*100))^2;
                              varH := .3200966692 10^-6
```

Nitrogen re

```
> N := 0.0135;
                              N := .0135
> varN := (0.11/(2*1.414*100))^2;
                              varN := .1512956913 10^-6
```

Sulfur re

```
> S := 0.0123;
                              S := .0123
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
                         varS := .1327813813 10^-6
```

CO2 re

```
> v := 15.2148;
                              v := 15.2148
> CO2o := array([seq(v,i=1..n)]);
  CO2o := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                              u := .2083411251
> var := array([seq(u,i=1..n)]);
  var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251]
> varCO2o := make_array(var,n);
                         varCO2o := varcovar

> v := 15.2148;
                              v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
  CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
    15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                              u := .2083411251
> var := array([seq(u,i=1..n)]);
  var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
    .2083411251  .2083411251  .2083411251]
> varCO2i := make_array(var,n);
                         varCO2i := varcovar
```

O2 re

```
> v := 3.8;
                              v := 3.8
> O2o := array([seq(v,i=1..n)]);
  O2o := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3
    3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
    .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2o := make_array(var,n);
                         varO2o := varcovar

> v := 3.8;
                              v := 3.8
> O2i := array([seq(v,i=1..n)]);
  O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3
    3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                              u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
    .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                         varO2i := varcovar
```

Moisture (air) re

```
> Wma := 0.013;
                              Wma := .013
> varWma := (.2*Wma)^2;
                         varWma := .676 10^-5
```

CO re

```
> v := 0.005;
                              v := .005
```

```
> COo := array([seq(v,i=1..n)]);
      COo := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
        .005 .005 .005 .005 .005 .005 .005 .005]
> u := (0.001)^2;
                              u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
     .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
     .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5]
> varCOo := make_array(var,n);
                          varCOo := varcovar

> v := 0.005;
                              v := .005
> COi := array([seq(v,i=1..n)]);
      COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
        .005 .005 .005 .005 .005 .005 .005 .005]
> u := (0.001)^2;
                              u := .1 10^-5
> var := array([seq(u,i=1..n)]);
   var := [.1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
     .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5
     .1 10^-5 .1 10^-5 .1 10^-5 .1 10^-5]
> varCOi := make_array(var,n);
                          varCOi := varcovar
```

Carbon in Ash re

```
> Ca := 0.0486;
                              Ca := .0486
> varCa := (0.1*Ca)^2;
                          varCa := .0000236196
```

****

Results

```
> eval(AL);
                          .3299634610 10^-7        % LEAK
> eval(sigmaAL);
                          .7815861141    RANDOM ERROR
> eval(100*sigmaAL/AL);
                          .2368705043 10^10
                                              CONTRIBUTIONS
> evalf(sigmaALCO2avei);
                          .5958064036
> evalf(sigmaALCOavei);
                          .001267624739
> evalf(sigmaALO2avei);
                          .001224224241
> evalf(sigmaALCO2aveo);
                          .5058513189
> evalf(sigmaALCOaveo);
                          .001292977234
> evalf(sigmaALO2aveo);
                          .001117570000
> evalf(sigmaALA);
                          .1385060987 10^-11
> evalf(sigmaALOUHD);
                          .4893902538 10^-11
> evalf(sigmaALCa);
                          .4616382430 10^-11
> evalf(sigmaALC);
                          .1440317769 10^-9
> evalf(sigmaALS);
                          .5885660774 10^-11
> evalf(sigmaALH);
                          .1280109093 10^-10
> evalf(sigmaALWma);
                          .7854866245 10^-10
> evalf(sigmaALN);
```

6
8
3

RANDOM ERROR CONTRIBUTION

$.1666003868 \ 10^{-13}$

```
> evalf(sigmaALMf);
```

$.8237049338 \ 10^{-11}$

```
***************************************************************************
> i := 'i';
```

$i := i$

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$m := 28.74570417$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$PAFA := 62529.82254$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$PAFB := 62529.82254$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$SA := .5000000000$

#20

```
> SB := FB/(FA+FB);
```

$SB := .5000000000$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$WPAIA := 1.079598797$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$WPAIB := 1.079598797$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$Cr := .002947741741$

```
> Cb := C - Cr;
```

$Cb := .7351522583$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.(
> 1/32.07)*S)-N)/0.7685;
```

$WAi := 11.93169660$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$WMGi := .6458272558$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COa
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$WGpi := 12.38591870$

#26

```
> WGi := WGpi + WMGi;
```

$WGi := 13.03174596$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$WAo := 11.93169660$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$WMGo := .6458272558$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$WGpo := 12.38591870$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := 13.03174596$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 0$$

#32

```
> TFluegasINa := WGi*Wfe*SA;
```

$$TFluegasINa := 754792.2100$$

```
>
```

Appendix J-3
Bias Error Calculation
Air Leak Calculation -- With Leak Case

```
>
>
```

Error Propagation Calculations, Part B, AL (nonzero leak)

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> varcovar[i,j] := sqrt(var[i]*var[j])
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
        for j to n do
            for i to n do  varcovar[i,j] := sqrt(var[i]*var[j]) od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
```

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

```
#6
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

```
> i := 'i';
```

$$i := i$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) \Big/ Wfe$$

#22

> WPAIB := PAFB/(Wfe*SB);

$$WPAIB := 28176.4\; apa\; CP\; \sqrt{\frac{PSpa\;(28.97\;Wma + 28.97)}{1.608015098\;Wma + 1}}\left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) / Wfe$$

#23

> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);

$$Cr := \frac{A\;OUHD\;Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca}$$

> Cb := C - Cr;

$$Cb := C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca}$$

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;

$$WAi := 36.46063760\;(100 - CO2avei - COavei - O2avei)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/(12.01\;CO2avei + 12.01\;COavei) - 1.301236174\;N$$

#24

> WMGi := 8.936*H + (Wma*WAi)+Mf;

$$WMGi := 8.936\;H + Wma\left(36.46063760\;(100 - CO2avei - COavei - O2avei)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/(12.01\;CO2avei + 12.01\;COavei) - 1.301236174\;N\right) + Mf$$

#25

> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));

$$WGpi := (15.99\;CO2avei + 4.00\;O2avei - .01\;COavei + 2802.00)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/(12.01\;CO2avei + 12.01\;COavei)$$

#26

> WGi := WGpi + WMGi;

$$WGi := (15.99\;CO2avei + 4.00\;O2avei - .01\;COavei + 2802.00)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/(12.01\;CO2avei + 12.01\;COavei) + 8.936\;H + Wma\left(36.46063760\;(100 - CO2avei - COavei - O2avei)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/(12.01\;CO2avei + 12.01\;COavei) - 1.301236174\;N\right) + Mf$$

#27

> WAo :=(((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;

$$WAo := 36.46063760\;(100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\;OUHD\;Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\;(1 - OUHD)\;Ca}{1 - \frac{1}{3}\;Ca} + .3744932959\;S\right)/($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\left(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} + Wma\left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right) - \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} - Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right)\right)\Big/\left(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right) + Mf\right)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

```
> TFluegasINa := WGI*Wfe*SA;
```

$$TFluegasINa := \frac{1}{2}\Bigg((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/(12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)\Big/($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Big) + Mf\Big)\ Wfe$$

```
TFluegasINb := WGi*Wfe*SB;
```

```
#33
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;
```

> sigmaALCO2avei := sqrt(Diff(AL,CO2avei)^2*varCO2avei):

> sigmaALCO2avei := value(");

$$
\begin{aligned}
sigmaALCO2avei := \Bigg(\Bigg(\Bigg(& 100\ \frac{-15.99\ \frac{\%1}{\%2} + 12.01\ \frac{\%4\ \%1}{\%2^2} - Wma\left(-36.46063760\ \frac{\%1}{\%2} - 437.8922576\ \frac{\%3\ \%1}{\%2^2}\right)}{\frac{\%4\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760\ \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right) + Mf} \\
& - 100\ \Bigg(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} \\
& + Wma\left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right) \\
& - \frac{\%4\ \%1}{\%2} - Wma\left(36.46063760\ \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right)\Bigg) \\
& \left(15.99\ \frac{\%1}{\%2} - 12.01\ \frac{\%4\ \%1}{\%2^2} + Wma\left(-36.46063760\ \frac{\%1}{\%2} - 437.8922576\ \frac{\%3\ \%1}{\%2^2}\right)\right) \\
& \Bigg/ \left(\frac{\%4\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760\ \frac{\%3\ \%1}{\%2} - 1.301236174\ N\right) + Mf\right)^2\Bigg)^2 \\
& varCO2avei\Bigg)^{1/2}
\end{aligned}
$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%3 := 100 - CO2avei - COavei - O2avei$$

$$\%4 := 15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00$$

> sigmaALCOavei := sqrt(Diff(AL,COavei)^2*varCOavei):

> sigmaALCOavei := value("):

> sigmaALO2avei := sqrt(Diff(AL,O2avei)^2*varO2avei):

> sigmaALO2avei := value("):

> sigmaALCO2aveo := sqrt(Diff(AL,CO2aveo)^2*varCO2aveo):

> sigmaALCO2aveo := value(");

$$
\begin{aligned}
sigmaALCO2aveo := \sqrt{10000}\ \Bigg(\Bigg(& 15.99\ \frac{\%1}{\%2} \\
& - 12.01\ \frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{\%2^2} + Wma \\
& \left(-36.46063760\ \frac{\%1}{\%2} - 437.8922576\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{\%2^2}\right)\Bigg)^2 \\
& varCO2aveo \Bigg/ \Bigg(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{12.01\ CO2avei + 12.01\ COavei} \\
& + 8.936\ H \\
& + Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{12.01\ CO2avei + 12.01\ COavei} - 1.301236174\ N\right) \\
& + Mf\Bigg)^2\Bigg)^{1/2}
\end{aligned}
$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\ \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2aveo + 12.01\ COaveo$$

```
> sigmaALCOaveo := sqrt(Diff(AL,COaveo)^2*varCOaveo):
> sigmaALCOaveo := value("):
> sigmaALO2aveo := sqrt(Diff(AL,O2aveo)^2*varO2aveo):
> sigmaALO2aveo := value("):
> covarALCO2avelo := 2*Diff(AL,CO2avei)*Diff(AL,CO2aveo)*sqrt(varCO2avei)*sqrt
> (varCO2aveo):
> covarALCO2avelo := value("):
> sigmaALAreai := sqrt(Diff(AL,Areai)^2*varAreai):
> sigmaALAreai := value("):
> sigmaALAreao := sqrt(Diff(AL,Areao)^2*varAreao):
> sigmaALAreao := value("):
> sigmaALCP := sqrt(Diff(AL,CP)^2*varCP):
> sigmaALCP := value("):
> sigmaALPSi := sqrt(Diff(AL,PSi)^2*varPSi):
> sigmaALPSi := value("):
> sigmaALPSo := sqrt(Diff(AL,PSo)^2*varPSo):
> sigmaALPSo := value("):
> sigmaALA := sqrt(Diff(AL,A)^2*varA):
> sigmaALA := value("):
> sigmaALOUHD := sqrt(Diff(AL,OUHD)^2*varOUHD):
> sigmaALOUHD := value("):
> sigmaALCa := sqrt(Diff(AL,Ca)^2*varCa):
> sigmaALCa := value("):
> sigmaALC := sqrt(Diff(AL,C)*Diff(AL,C)*varC):
> sigmaALC := value("):
> sigmaALS := sqrt(Diff(AL,S)*Diff(AL,S)*varS):
> sigmaALS := value("):
> sigmaALH := sqrt(Diff(AL,H)*Diff(AL,H)*varH):
> sigmaALH := value("):
> sigmaALWma := sqrt(Diff(AL,Wma)*Diff(AL,Wma)*varWma):
> sigmaALWma := value("):
> sigmaALN := sqrt(Diff(AL,N)*Diff(AL,N)*varN):
> sigmaALN := value("):
> sigmaALMf := sqrt(Diff(AL,Mf)*Diff(AL,Mf)*varMf):
> sigmaALMf := value("):
> sigmaALWfe := sqrt(Diff(AL,Wfe)^2*varWfe):
> sigmaALWfe := value("):
> sigmaALWma := sqrt(Diff(AL,Wma)*Diff(AL,Wma)*varWma):
> sigmaALWma := value("):
>  sigmaALDPi := sqrt(sum(sum(
>  Diff(AL,DPi[i])*Diff(AL,DPi[j])*varDPi[i,j]
> ,j=1..n),i=1..n)):
> sigmaALDPi := value("):
>  sigmaALDPo := sqrt(sum(sum(
>  Diff(AL,DPo[i])*Diff(AL,DPo[j])*varDPo[i,j]
> ,j=1..n),i=1..n)):
> sigmaALDPo := value("):
```

```
> sigmaALTi := sqrt(sum(sum(
> Diff(AL,Ti[i])*Diff(AL,Ti[j])*varTi[i,j]
> ,j=1..n),i=1..n)):
> sigmaALTi := value("):

> sigmaALTo := sqrt(sum(sum(
> Diff(AL,To[i])*Diff(AL,To[j])*varTo[i,j]
> ,j=1..n),i=1..n)):
> sigmaALTo := value("):

> sigmaALCOi := sqrt(sum(sum(
> Diff(AL,COi[i])*Diff(AL,COi[j])*varCOi[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCOi := value("):

> sigmaALCOo := sqrt(sum(sum(
> Diff(AL,COo[i])*Diff(AL,COo[j])*varCOo[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCOo := value("):

> sigmaALCO2i := sqrt(sum(sum(
> Diff(AL,CO2i[i])*Diff(AL,CO2i[j])*varCO2i[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCO2i := value("):

> sigmaALCO2o := sqrt(sum(sum(
> Diff(AL,CO2o[i])*Diff(AL,CO2o[j])*varCO2o[i,j]
> ,j=1..n),i=1..n)):
> sigmaALCO2o := value("):

> sigmaALO2i := sqrt(sum(sum(
> Diff(AL,O2i[i])*Diff(AL,O2i[j])*varO2i[i,j]
> ,j=1..n),i=1..n)):
> sigmaALO2i := value("):

> sigmaALO2o := sqrt(sum(sum(
> Diff(AL,O2o[i])*Diff(AL,O2o[j])*varO2o[i,j]
> ,j=1..n),i=1..n)):
> sigmaALO2o := value("):

> sigmaAL := sqrt(
> Diff(AL,CO2avei)^2*varCO2avei +
> Diff(AL,COavei)^2*varCOavei +
> Diff(AL,O2avei)^2*varO2avei +
> Diff(AL,CO2aveo)^2*varCO2aveo +
> Diff(AL,COaveo)^2*varCOaveo +
> Diff(AL,O2aveo)^2*varO2aveo +
> 2*Diff(AL,CO2avei)*Diff(AL,CO2aveo)*sqrt(varCO2avei)*sqrt(varCO2aveo) +
> Diff(AL,Wfe)^2*varWfe +
> Diff(AL,Areai)^2*varAreai +
```

```
> Diff(AL,Areao)^2*varAreao +
> Diff(AL,CP)^2*varCP +
> Diff(AL,PSi)^2*varPSi +
> Diff(AL,PSo)^2*varPSo +
> Diff(AL,A)^2*varA +
> Diff(AL,OUHD)^2*varOUHD +
> Diff(AL,Ca)^2*varCa +
> Diff(AL,C)*Diff(AL,C)*varC +
> Diff(AL,S)*Diff(AL,S)*varS +
> Diff(AL,H)*Diff(AL,H)*varH +
> Diff(AL,Wma)*Diff(AL,Wma)*varWma +
> Diff(AL,N)*Diff(AL,N)*varN +
> Diff(AL,Mf)*Diff(AL,Mf)*varMf +
> sum(sum(
> Diff(AL,DPi[i])*Diff(AL,DPi[j])*varDPi[i,j] +
> Diff(AL,Ti[i])*Diff(AL,Ti[j])*varTi[i,j] +
> Diff(AL,COi[i])*Diff(AL,COi[j])*varCOi[i,j] +
> Diff(AL,CO2i[i])*Diff(AL,CO2i[j])*varCO2i[i,j] +
> Diff(AL,O2i[i])*Diff(AL,O2i[j])*varO2i[i,j] +
> Diff(AL,DPo[i])*Diff(AL,DPo[j])*varDPo[i,j] +
> Diff(AL,To[i])*Diff(AL,To[j])*varTo[i,j] +
> Diff(AL,COo[i])*Diff(AL,COo[j])*varCOo[i,j] +
> Diff(AL,CO2o[i])*Diff(AL,CO2o[j])*varCO2o[i,j] +
> Diff(AL,O2o[i])*Diff(AL,O2o[j])*varO2o[i,j]
```

```
> ,j=1..n),i=1..n)):
```

```
> sigmaAL := value(");
```

$$sigmaAL := \Bigg(\Bigg(100\,\frac{.01\,\frac{\%1}{\%2}+12.01\,\frac{\%5\ \%1}{\%2^2}-\%11}{\%6} - 100\,\frac{\%12\left(-.01\,\frac{\%1}{\%2}-12.01\,\frac{\%5\ \%1}{\%2^2}+\%11\right)}{\%6^2}\Bigg)^2 varCOavei + \Bigg(100\,\frac{-4.00\,\frac{\%1}{\%2}+36.46063760\,\frac{Wma\ \%1}{\%2}}{\%6} - 100\,\frac{\%12\left(4.00\,\frac{\%1}{\%2}-36.46063760\,\frac{Wma\ \%1}{\%2}\right)}{\%6^2}\Bigg)^2 varO2avei$$

$$+ 10000\,\frac{\left(15.99\,\frac{\%1}{\%7}-12.01\,\frac{\%10\ \%1}{\%7^2}+\%9\right)^2 varCO2aveo}{\%6^2} + 10000\,\frac{\left(-.01\,\frac{\%1}{\%7}-12.01\,\frac{\%10\ \%1}{\%7^2}+\%9\right)^2 varCOaveo}{\%6^2}$$

$$+ 10000\,\frac{\left(4.00\,\frac{\%1}{\%7}-36.46063760\,\frac{Wma\ \%1}{\%7}\right)^2 varO2aveo}{\%6^2} + \Bigg(100\,\frac{-15.99\,\frac{\%1}{\%2}+12.01\,\frac{\%5\ \%1}{\%2^2}-\%11}{\%6}$$

$$\left. - 100 \frac{\%12 \left(15.99 \frac{\%1}{\%2} - 12.01 \frac{\%5\ \%1}{\%2^2} + \%11\right)}{\%6^2}\right)^2 \mathit{varCO2avei}$$

$$+ 16932.15581 \frac{\%12^2\ \mathit{Wma}^2\ \mathit{varN}}{\%6^4} + 10000 \frac{\%12^2\ \mathit{varMf}}{\%6^4} +$$

$$\left(100 \frac{36.46063760 \frac{\%8\ \%1}{\%7} - 36.46063760 \frac{\%3\ \%1}{\%2}}{\%6} - 100 \frac{\%12\ \%4}{\%6^2}\right)^2 \mathit{varWma}$$

$$+ \left(100 \frac{\frac{\%10}{\%7} + 36.46063760 \frac{\mathit{Wma}\ \%8}{\%7} - \frac{\%5}{\%2} - 36.46063760 \frac{\mathit{Wma}\ \%3}{\%2}}{\%6}\right.$$

$$\left. - 100 \frac{\%12 \left(\frac{\%5}{\%2} + 36.46063760 \frac{\mathit{Wma}\ \%3}{\%2}\right)}{\%6^2}\right)^2 \mathit{varC} + \left(100 \left(.3744932959 \frac{\%10}{\%7}\right.\right.$$

$$\left. + 13.65426435 \frac{\mathit{Wma}\ \%8}{\%7} - .3744932959 \frac{\%5}{\%2} - 13.65426435 \frac{\mathit{Wma}\ \%3}{\%2}\right) / (\%6)$$

$$\left. - 100 \frac{\%12 \left(.3744932959 \frac{\%5}{\%2} + 13.65426435 \frac{\mathit{Wma}\ \%3}{\%2}\right)}{\%6^2}\right)^2 \mathit{varS}$$

$$+ 798520.9600 \frac{\%12^2\ \mathit{varH}}{\%6^4} + \left(100 \left(\frac{\%10\ \%15}{\%7} + 36.46063760 \frac{\mathit{Wma}\ \%8\ \%15}{\%7}\right.\right.$$

$$\left. - \frac{\%5\ \%15}{\%2} - 36.46063760 \frac{\mathit{Wma}\ \%3\ \%15}{\%2}\right) / (\%6)$$

$$\left. - 100 \frac{\%12 \left(\frac{\%5\ \%15}{\%2} + 36.46063760 \frac{\mathit{Wma}\ \%3\ \%15}{\%2}\right)}{\%6^2}\right)^2 \mathit{varCa} + \left(100 \left(\right.\right.$$

$$\frac{\%10\ \%14}{\%7} + 36.46063760 \frac{\mathit{Wma}\ \%8\ \%14}{\%7} - \frac{\%5\ \%14}{\%2}$$

$$\left. - 36.46063760 \frac{\mathit{Wma}\ \%3\ \%14}{\%2}\right) / (\%6)$$

$$\left. - 100 \frac{\%12 \left(\frac{\%5\ \%14}{\%2} + 36.46063760 \frac{\mathit{Wma}\ \%3\ \%14}{\%2}\right)}{\%6^2}\right)^2 \mathit{varA} + \left(100 \left(\right.\right.$$

$$\frac{\%10\ \%13}{\%7} + 36.46063760 \frac{\mathit{Wma}\ \%8\ \%13}{\%7} - \frac{\%5\ \%13}{\%2}$$

$$\left. - 36.46063760 \frac{\mathit{Wma}\ \%3\ \%13}{\%2}\right) / (\%6)$$

$$\left. - 100 \frac{\%12 \left(\frac{\%5\ \%13}{\%2} + 36.46063760 \frac{\mathit{Wma}\ \%3\ \%13}{\%2}\right)}{\%6^2}\right)^2 \mathit{varOUHD} + 200 \left(\right.$$

$$100 \frac{-15.99 \frac{\%1}{\%2} + 12.01 \frac{\%5\ \%1}{\%2^2} - \%11}{\%6}$$

$$\left. - 100 \frac{\%12 \left(15.99 \frac{\%1}{\%2} - 12.01 \frac{\%5\ \%1}{\%2^2} + \%11\right)}{\%6^2}\right)$$

$$\left.\left(15.99 \frac{\%1}{\%7} - 12.01 \frac{\%10\ \%1}{\%7^2} + \%9\right) \sqrt{\mathit{varCO2avei}}\ \sqrt{\mathit{varCO2aveo}} / (\%6)\right)^{1/2}$$

$$\%1 := C - \frac{A\ \mathit{OUHD}\ \mathit{Ca}}{1 - \mathit{Ca}} - \frac{1}{3} \frac{A\ (1 - \mathit{OUHD})\ \mathit{Ca}}{1 - \frac{1}{3}\ \mathit{Ca}} + .3744932959\ S$$

$$\%2 := 12.01\ \mathit{CO2avei} + 12.01\ \mathit{COavei}$$

$$\%3 := 100 - \mathit{CO2avei} - \mathit{COavei} - \mathit{O2avei}$$

$$\%4 := 36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N$$

$$\%5 := 15.99\ \mathit{CO2avei} + 4.00\ \mathit{O2avei} - .01\ \mathit{COavei} + 2802.00$$

$$\%6 := \frac{\%5\ \%1}{\%2} + 8.936\ H + \mathit{Wma}\ \%4 + \mathit{Mf}$$

$$\%7 := 12.01\ \mathit{CO2aveo} + 12.01\ \mathit{COaveo}$$

$\%8 := 100 - CO2aveo - COaveo - O2aveo$

$$\%9 := Wma \left(-36.46063760 \frac{\%1}{\%7} - 437.8922576 \frac{\%8\ \%1}{\%7^2} \right)$$

$\%10 := 15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00$

$$\%11 := Wma \left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{\%3\ \%1}{\%2^2} \right)$$

$\%12 :=$

$$\frac{\%10\ \%1}{\%7} + Wma \left(36.46063760 \frac{\%8\ \%1}{\%7} - 1.301236174\ N \right) - \frac{\%5\ \%1}{\%2} - Wma\ \%4$$

$$\%13 := -\frac{A\ Ca}{1 - Ca} + \frac{1}{3} \frac{A\ Ca}{1 - \frac{1}{3} Ca}$$

$$\%14 := -\frac{OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{(1 - OUHD)\ Ca}{1 - \frac{1}{3} Ca}$$

$$\%15 := -\frac{A\ OUHD}{1 - Ca} - \frac{A\ OUHD\ Ca}{(1 - Ca)^2} - \frac{1}{3} \frac{A\ (1 - OUHD)}{1 - \frac{1}{3} Ca} - \frac{1}{9} \frac{A\ (1 - OUHD)\ Ca}{\left(1 - \frac{1}{3} Ca\right)^2}$$

Constants

Averages and Variances from Part A

> CO2avei := 15.2148;

$CO2avei := 15.2148$

> varCO2avei := .1^2;

$varCO2avei := .01$

> COavei := .005;

$COavei := .005$

> varCOavei := .002^2;

$varCOavei := .4\ 10^{-5}$

> O2avei := 3.8;

$O2avei := 3.8$

> varO2avei := .05^2;

$varO2avei := .0025$

> CO2aveo := 14.145;

$CO2aveo := 14.145$

> varCO2aveo := .1^2;

$varCO2aveo := .01$

> COaveo := .004;

$COaveo := .004$

> varCOaveo := .002^2;

$varCOaveo := .4\ 10^{-5}$

> O2aveo := 5;

$O2aveo := 5$

> varO2aveo := .05^2;

$varO2aveo := .0025$

Coal Feed Rate (lbs/hr)

> Wfe := 115839;

$Wfe := 115839$

> varWfe := (0.05*Wfe)^2;

$varWfe := .3354668480\ 10^8$

Area (square ft)

> Areai := 3.99;

$Areai := 3.99$

> varAreai := (0.0335*Areai)^2;

$varAreai := .01786633223$

> Areao := 3.54;

$Areao := 3.54$

> varAreao := (0.0364*Areao)^2;

$varAreao := .01660386874$

Pitot Coefficient

> CP := 0.84;

$CP := .84$

> varCP := (0.01)^2;

$varCP := .0001$

Pressure in Area

> PSI := 29.23;

```
PSi := 29.23
> varPSI := (0.04)^2;
varPSi := .0016

> PSo := 29.1;
PSo := 29.1
> varPSo := (0.04)^2;
varPSo := .0016
```

Pressue for primary air

```
> PSpa := 31.11;
PSpa := 31.11
> varPSpa := (0.04)^2;
varPSpa := .0016
>
```

Velocity Head

```
> v := .45802;
v := .45802
> DPo := array([seq(v,i=1..n)]);
DPo := [.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802
.45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802 .45802
.45802]
> u := (.02*v)^2;
u := .00008391292816
> var := array([seq(u,i=1..n)]);
var := [.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816
.00008391292816 .00008391292816 .00008391292816 .00008391292816]
> varDPo := make_array(var,n);
varDPo := varcovar

> v := .82831;
v := .82831
> DPI := array([seq(v,i=1..n)]);
DPi := [.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831
.82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831 .82831
.82831]
> u := (.02*v)^2;
u := .0002744389824
> var := array([seq(u,i=1..n)]);
var := [.0002744389824 .0002744389824 .0002744389824 .0002744389824
.0002744389824 .0002744389824 .0002744389824 .0002744389824
.0002744389824 .0002744389824 .0002744389824 .0002744389824
.0002744389824 .0002744389824 .0002744389824 .0002744389824
.0002744389824 .0002744389824 .0002744389824 .0002744389824]
> varDPI := make_array(var,n);
varDPi := varcovar
```

Temperature (R)

```
> v := 713;
v := 713
> To := array([seq(v,I=1..n)]);
To := [713 713 713 713 713 713 713 713 713 713 713 713 713 7
713 713 713 713 713 713]
> u := (0.01*(v-460))^2;
u := 6.4009
> var := array([seq(u,i=1..n)]);
var := [6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.400
6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.4009 6.40
6.4009]
> varTo := make_array(var,n);
varTo := varcovar

> v := 1140;
v := 1140
> Ti:= array([seq(v,I=1..n)]);
Ti := [1140 1140 1140 1140 1140 1140 1140 1140 1140 1140 1140
1140 1140 1140 1140 1140 1140 1140 1140 1140]
> u := (0.01*(v-460))^2;
u := 46.2400
> var := array([seq(u,i=1..n)]);
var := [46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.24
46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400 46.2400
46.2400 46.2400 46.2400 46.2400]
```

```
> varTi := make_array(var,n);
                    varTi := varcovar
```

Moisture in Coal

```
> Mf :=0.06;
                    Mf := .06
> varMf := (0.039*Mf)^2;
                    varMf := .54756 10^-5
```

Ash

```
> A :=  0.0619;
                    A := .0619
> varA := ( 0.039*A)^2;
                    varA := .582787881 10^-5
```

Overhead

```
> OUHD :=  0.9;
                    OUHD := .9
> varOUHD :=  (0.1*OUHD)^2;
                    varOUHD := .0081
```

Carbon

```
> C := 0.7381;
                    C := .7381
> varC := (0.039*C)^2;
                    varC := .0008286280388
```

Hydrogen

```
> H := 0.0482;
                    H := .0482
> varH := (0.039*H)^2;
                    varH := .353364804 10^-5
```

Nitrogen

```
> N := 0.0135;
                    N := .0135
> varN := (0.039*N)^2;
                    varN := .27720225 10^-6
```

Sulfur

```
> S := 0.0123;
                    S := .0123
> varS := (0.019*S)^2;
                    varS := .5461569 10^-7
```

CO2

```
> v := 14.145;
                    v := 14.145
> CO2o := array([seq(v,i=1..n)]);
   CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.14
   14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.1
   14.145]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .0
   .01  .01  .01  .01  .01]
> varCO2o := make_array(var,n);
                    varCO2o := varcovar

> v := 15.2148;
                    v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
   CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.21
   15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
   15.2148  15.2148  15.2148  15.2148]
> u := (0.1)^2;
                    u := .01
> var := array([seq(u,i=1..n)]);
   var := [.01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .01  .
   .01  .01  .01  .01  .01]
> varCO2i := make_array(var,n);
                    varCO2i := varcovar
```

O2

```
> v := 5;
                    v := 5
```

678

```
> O2o := array([seq(v,i=1..n)]);
```

O2o := [5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

```
> varO2o := make_array(var,n);
```

varO2o := varcovar

```
> v := 3.8;
```

v := 3.8

```
> O2i := array([seq(v,i=1..n)]);
```

O2i := [3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8 3.8
3.8 3.8 3.8 3.8 3.8]

```
> u := (0.05)^2;
```

u := .0025

```
> var := array([seq(u,i=1..n)]);
```

var := [.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025
.0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025 .0025]

```
> varO2i := make_array(var,n);
```

varO2i := varcovar

Moisture (air)

```
> Wma := 0.013;
```

Wma := .013

```
> varWma := (.1*Wma)^2;
```

varWma := $.169\ 10^{-5}$

CO

```
> v := 0.005;
```

v := .005

```
> COo := array([seq(v,i=1..n)]);
```

COo := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
.005 .005 .005 .005 .005 .005 .005 .005]

```
> u := (0.002)^2;
```

u := $.4\ 10^{-5}$

```
> var := array([seq(u,i=1..n)]);
```

var := [$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$
$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$
$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$]

```
> varCOo := make_array(var,n);
```

varCOo := varcovar

```
> v := 0.005;
```

v := .005

```
> COi := array([seq(v,i=1..n)]);
```

COi := [.005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
.005 .005 .005 .005 .005 .005 .005 .005]

```
> u := (0.002)^2;
```

u := $.4\ 10^{-5}$

```
> var := array([seq(u,i=1..n)]);
```

var := [$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$
$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$
$.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$ $.4\ 10^{-5}$]

```
> varCOi := make_array(var,n);
```

varCOi := varcovar

Carbon in Ash

```
> Ca := 0.0486;
```

Ca := .0486

```
> varCa := (0.25*Ca)^2;
```

varCa := .000147622500

Area for primary air

```
> apa := .63;
```

apa := .63

```
> varapa := (.0208*apa)^2;
```

varapa := .000171714816

```
> v := .2171;
```

v := .2171

```
> DPpa := array([seq(v,i=1..n)]);
```

DPpa := [.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171

.2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171 .2171]

> u := (0.02*v)^2;

u := .000018852964

> varDPPA := array([seq(u,i=1..n)]);

varDPPA := [.000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964 .000018852964]

> v := 1104;

v := 1104

> Tpa := array([seq(v,i=1..n)]);

Tpa := [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104]

> u := (0.01*(v - 460))^2;

u := 41.4736

> varTpa := array([seq(u,i=1..n)]);

varTpa := [41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736 41.4736]

Results

****

> evalf(AL);

6.870044252 LEAK %

> evalf(sigmaAL);

.05846028139 BIAS %

> evalf(100*sigmaAL/AL);

.8509447573 RELATIVE ERROR

> evalf(sigmaALWfe);

0 CONTRIBUTIONS

> evalf(sigmaALWma);

.0006394708566

> evalf(sigmaALCO2avei);

.6242534970

> evalf(sigmaALCOavei);

.01354711120

CONTRIBUTIONS

> evalf(sigmaALO2avei);

.005851202990

> evalf(sigmaALCO2aveo);

.6768855565

> evalf(sigmaALCOaveo);

.01460668871

> evalf(sigmaALO2aveo);

.005889417936

> evalf(covarALCO2aveio);

-.8450963514

> evalf(sigmaALAreai);

0

> evalf(sigmaALAreao);

0

> evalf(sigmaALCP);

0

> evalf(sigmaALPSi);

0

> evalf(sigmaALPSo);

0

> evalf(sigmaALA);

.00004018356526

> evalf(sigmaALOUHD);

.00006740663400

> evalf(sigmaALCa);

.0002704368469

> evalf(sigmaALC);

.01006176701

> evalf(sigmaALS);

.00003059125007

> evalf(sigmaALH);

.008855472416

> evalf(sigmaALN);

$.4695207444\ 10^{-5}$

> evalf(sigmaALMf);

.001233595529

> evalf(sigmaALDPi);

080

```
                              0
> evalf(sigmaALTi);
                              0
> evalf(sigmaALCOi);
                              0
> evalf(sigmaALCO2i);
                              0
> evalf(sigmaALO2i);
                              0
> evalf(sigmaALDPo);
                              0
> evalf(sigmaALTo);
                              0
> evalf(sigmaALCOo);
                              0
> evalf(sigmaALCO2o);
                              0
> evalf(sigmaALO2o);
                              0
 *********************************************************************

> i := 'i';
                            i := i

 #13
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
                        m := 28.74570417

 #14
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                      PAFA := 62529.82254

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
                      PAFB := 62529.82254

 #17
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

 #18
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

 #19
> SA := FA/(FA+FB);
                        SA := .5000000000

 #20
> SB := FB/(FA+FB);
                        SB := .5000000000

 #21
> WPAIA := PAFA/(Wfe*SA);
                      WPAIA := 1.079598797

 #22
> WPAIB := PAFB/(Wfe*SB);
                      WPAIB := 1.079598797

 #23
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
                      Cr := .002947741741
> Cb := C - Cr;
                      Cb := .7351522583
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.
> 1/32.07)*S)-N)/0.7685;
                      WAi := 11.93169660

 #24
> WMGi := 8.936*H + (Wma*WAi)+Mf;
                      WMGi := .6458272558

 #25
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COa
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

```
WGpi := 12.38591870

#26
> WGi := WGpi + WMGi;
WGi := 13.03174596

#27
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
WAo := 12.81551267

#28
> WMGo := 8.936*H + (Wma*WAo) + Mf;
WMGo := .6573168647

#29
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
WGpo := 13.26971581

#30
> WGo := WGpo + WMGo;
WGo := 13.92703267

#31
> AL := ((WGo-WGi)/WGi)*100;
AL := 6.870044219

#32
> TFluegasINa := WGi*Wfe*SA;
TFluegasINa := 754792.2100
TFluegasINb := WGi*Wfe*SB;

#33
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;
>
```

Appendix J-4
Random Error Calculation
Air Leak Calculation -- With Leak Case

>

>

Random Error Propagation Calculations, Part B, AL (nonzero leakage, n=20 for flue gas in, n=24 for flue gas out)

Set no. of sample points

```
> n := 20;
```

$$n := 20$$

procedure for creating variance-covariance matrix

```
> make_array := proc(var,n)
> varcovar := array(1..n,1..n);
> for j to n do
> for i to n do
> if  i = j  then
>   varcovar[i,j] := sqrt(var[i]*var[j])
> else
>   varcovar[i,j] := 0
> fi;
> od
> od;
> varcovar;
> end;
Warning, `varcovar` is implicitly declared local
Warning, `j` is implicitly declared local
Warning, `i` is implicitly declared local

make_array :=

    proc(var,n)
    local varcovar,j,i;
        varcovar := array(1 .. n,1 .. n);
```

083

```
        for j to n do
            for i to n do
                if i = j then varcovar[i,j] := sqrt(var[i]*var[j])
                else varcovar[i,j] := 0
                fi
            od
        od;
        varcovar
    end
```

#4

```
> MFG := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> MFG := (K4/18.016)/((K4/18.016)+100*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `MFG` is implicitly declared local

MFG :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,MFG;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N)+Mf
     ;
    MFG := .05550621670*K4/(.05550621670*K4+100*K3)
end
```

#6

```
> M := proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
> Cb := C - Cr;
> K3 := (Cb+12.01*S/32.07)/(12.01*(CO2[x] + CO[x]));
> K4 := 8.936*H + Wma*((28.02*(100-CO[x]-CO2[x]-O2[x])*K3-N)/0.7685)+Mf;
> M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8))/(K4+1801.6*K3)
> end;
Warning, `Cr` is implicitly declared local
Warning, `Cb` is implicitly declared local
Warning, `K3` is implicitly declared local
Warning, `K4` is implicitly declared local
Warning, `M` is implicitly declared local

M :=

proc(x,A,OUHD,Ca,C,S,CO,CO2,H,Wma,O2,N,Mf)
local Cr,Cb,K3,K4,M;
    Cr := A*OUHD*Ca/(1-Ca)+1/3*A*(1-OUHD)*Ca/(1-1/3*Ca);
    Cb := C-Cr;
    K3 := (Cb+.3744932959*S)/(12.01*CO2[x]+12.01*CO[x]);
    K4 :=
     8.936*H+Wma*(36.46063760*(100-CO[x]-CO2[x]-O2[x])*K3-1.301236174*N
     ;
    M := (18.016*K4+K3*(288.08*CO2[x]+71.70*O2[x]+50480.8 ))/(K4+1801.6
end
```

#13

```
> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);
```

$$m := \frac{28.97\ Wma + 28.97}{1.608015098\ Wma + 1}$$

#14

```
> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFA := 14088.2\ apa\ CP \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}} \left(\sqrt{\frac{DPpa_1}{Tpa_1}} + \sqrt{\frac{DPpa_2}{Tpa_2}} + \sqrt{\frac{DPpa_3}{Tpa_3}} + \sqrt{\frac{DPpa_4}{Tpa_4}} + \sqrt{\frac{DPpa_5}{Tpa_5}} + \sqrt{\frac{DPpa_6}{Tpa_6}} + \sqrt{\frac{DPpa_7}{Tpa_7}} + \sqrt{\frac{DPpa_8}{Tpa_8}} + \sqrt{\frac{DPpa_9}{Tpa_9}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}} \right)$$

```
> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);
```

$$PAFB := 14088.2\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right)$$

#17

```
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#18

```
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):
```

#19

```
> SA := FA/(FA+FB);
```

$$SA := \frac{1}{2}$$

#20

```
> SB := FB/(FA+FB);
```

$$SB := \frac{1}{2}$$

#21

```
> WPAIA := PAFA/(Wfe*SA);
```

$$WPAIA := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) \Big/ Wfe$$

#22

```
> WPAIB := PAFB/(Wfe*SB);
```

$$WPAIB := 28176.4\ apa\ CP\ \sqrt{\frac{PSpa\ (28.97\ Wma + 28.97)}{1.608015098\ Wma + 1}}\left(\sqrt{\frac{DPpa_{1}}{Tpa_{1}}} + \sqrt{\frac{DPpa_{2}}{Tpa_{2}}} + \sqrt{\frac{DPpa_{3}}{Tpa_{3}}} + \sqrt{\frac{DPpa_{4}}{Tpa_{4}}} + \sqrt{\frac{DPpa_{5}}{Tpa_{5}}} + \sqrt{\frac{DPpa_{6}}{Tpa_{6}}} + \sqrt{\frac{DPpa_{7}}{Tpa_{7}}} + \sqrt{\frac{DPpa_{8}}{Tpa_{8}}} + \sqrt{\frac{DPpa_{9}}{Tpa_{9}}} + \sqrt{\frac{DPpa_{10}}{Tpa_{10}}} + \sqrt{\frac{DPpa_{11}}{Tpa_{11}}} + \sqrt{\frac{DPpa_{12}}{Tpa_{12}}} + \sqrt{\frac{DPpa_{13}}{Tpa_{13}}} + \sqrt{\frac{DPpa_{14}}{Tpa_{14}}} + \sqrt{\frac{DPpa_{15}}{Tpa_{15}}} + \sqrt{\frac{DPpa_{16}}{Tpa_{16}}} + \sqrt{\frac{DPpa_{17}}{Tpa_{17}}} + \sqrt{\frac{DPpa_{18}}{Tpa_{18}}} + \sqrt{\frac{DPpa_{19}}{Tpa_{19}}} + \sqrt{\frac{DPpa_{20}}{Tpa_{20}}}\right) \Big/ Wfe$$

#23

```
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
```

$$Cr := \frac{A\ OUHD\ Ca}{1 - Ca} + \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> Cb := C - Cr;
```

$$Cb := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\,\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

```
> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.C
> 1/32.07)*S)-N)/0.7685;
```

$$WAi := 36.46063760\ (100 - CO2avei - COavei - O2avei)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N$$

#24

```
> WMGi := 8.936*H + (Wma*WAi)+Mf;
```

$$WMGi := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2avei - COavei - O2avei)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Bigg) + Mf$$

#25

```
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
```

$$WGpi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2avei + 12.01\ COavei)$$

#26

```
> WGi := WGpi + WMGi;
```

$$WGi := (15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\ \Bigg(36.46063760$$

$$(100 - CO2avei - COavei - O2avei)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\Bigg) + Mf$$

#27

```
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
```

$$WAo := 36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N$$

#28

```
> WMGo := 8.936*H + (Wma*WAo) + Mf;
```

$$WMGo := 8.936\ H + Wma\ \Bigg(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\Bigg) + Mf$$

#29

```
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
```

$$WGpo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2aveo + 12.01\ COaveo)$$

#30

```
> WGo := WGpo + WMGo;
```

$$WGo := (15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)$$

$$\left(C - \frac{A\ OUHD\ Ca}{1-Ca} - \frac{1}{3}\,\frac{A\ (1-OUHD)\ Ca}{1-\frac{1}{3}\ Ca} + .3744932959\ S\right) / ($$

$$12.01\ CO2aveo + 12.01\ COaveo) + 8.936\ H + Wma\left(36.46063760\ (100 - CO2aveo - COaveo - O2aveo)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2aveo + 12.01\ COaveo) - 1.301236174\ N\right) + Mf$$

#31

```
> AL := ((WGo-WGi)/WGi)*100;
```

$$AL := 100\left(\frac{(15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} + Wma\left(36.46063760\ \frac{(100 - CO2aveo - COaveo - O2aveo)\ \%1}{12.01\ CO2aveo + 12.01\ COaveo} - 1.301236174\ N\right) - \frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} - Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right)\right)\Big/\left(\frac{(15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\ \%1}{\%2} + 8.936\ H + Wma\left(36.46063760\ \frac{(100 - CO2avei - COavei - O2avei)\ \%1}{\%2} - 1.301236174\ N\right) + Mf\right)$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

#32

```
> TFluegasINa := WGi*Wfe*SA;
```

$$TFluegasINa := \frac{1}{2}\left((15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2avei + 12.01\ COavei) + 8.936\ H + Wma\left(36.46063760\ (100 - CO2avei - COavei - O2avei)\left(C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3}\frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S\right)/(12.01\ CO2avei + 12.01\ COavei) - 1.301236174\ N\right) + Mf\right)\ Wfe$$

```
TFluegasINb := WGi*Wfe*SB;
```

#33

```
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;
```

```
> sigmaAL := sqrt(
> Diff(AL,CO2avei)^2*varCO2avei +
> Diff(AL,COavei)^2*varCOavei +
> Diff(AL,O2avei)^2*varO2avei +
> Diff(AL,CO2aveo)^2*varCO2aveo +
> Diff(AL,COaveo)^2*varCOaveo +
> Diff(AL,O2aveo)^2*varO2aveo +
> Diff(AL,A)^2*varA +
> Diff(AL,OUHD)^2*varOUHD +
> Diff(AL,Ca)^2*varCa +
> Diff(AL,C)^2*varC +
> Diff(AL,S)^2*varS +
> Diff(AL,H)^2*varH +
```

```
> Diff(AL,Wma)^2*varWma +
> Diff(AL,N)^2*varN +
> Diff(AL,Mf)^2*varMf
> );
> sigmaAL := value(");
```

$$sigmaAL := \left(\left(100\,\frac{-15.99\,\frac{\%1}{\%2} + 12.01\,\frac{\%5\ \%1}{\%2^2} - \%14}{\%6} - 100\,\frac{\%10\left(15.99\,\frac{\%1}{\%2} - 12.01\,\frac{\%5\ \%1}{\%2^2} + \%14\right)}{\%6^2}\right)^2 varCO2avei + \left(\right.\right.$$

$$100\,\frac{.01\,\frac{\%1}{\%2} + 12.01\,\frac{\%5\ \%1}{\%2^2} - \%14}{\%6} - 100\,\frac{\%10\left(-.01\,\frac{\%1}{\%2} - 12.01\,\frac{\%5\ \%1}{\%2^2} + \%14\right)}{\%6^2}\left.\right)^2 varCOavei + \left(\right.$$

$$100\,\frac{-4.00\,\frac{\%1}{\%2} + 36.46063760\,\frac{Wma\ \%1}{\%2}}{\%6} - 100\,\frac{\%10\left(4.00\,\frac{\%1}{\%2} - 36.46063760\,\frac{Wma\ \%1}{\%2}\right)}{\%6^2}\left.\right)^2 varO2avei + 10000$$

$$\left(15.99\,\frac{\%1}{\%7} - 12.01\,\frac{\%9\ \%1}{\%7^2} + Wma\left(-36.46063760\,\frac{\%1}{\%7} - 437.8922576\,\frac{\%8\ \%1}{\%7^2}\right)\right)^2 varCO2aveo\Big/\%6^2 + 10000$$

$$\left(-.01\,\frac{\%1}{\%7} - 12.01\,\frac{\%9\ \%1}{\%7^2} + Wma\left(-36.46063760\,\frac{\%1}{\%7} - 437.8922576\,\frac{\%8\ \%1}{\%7^2}\right)\right)^2$$

$$varCOaveo\Big/\%6^2 + 10000\,\frac{\left(4.00\,\frac{\%1}{\%7} - 36.46063760\,\frac{Wma\ \%1}{\%7}\right)^2 varO2aveo}{\%6^2} -$$

$$100\left(\frac{\%9\ \%13}{\%7} + 36.46063760\,\frac{Wma\ \%8\ \%13}{\%7} - \frac{\%5\ \%13}{\%2} - 36.46063760\,\frac{Wma\ \%3\ \%1}{\%2}\right.$$

$$\left.\Big)\Big/(\%6) - 100\,\frac{\%10\left(\frac{\%5\ \%13}{\%2} + 36.46063760\,\frac{Wma\ \%3\ \%13}{\%2}\right)}{\%6^2}\right)^2 varA + \left(100\right.$$

$$\frac{\%9\ \%12}{\%7} + 36.46063760\,\frac{Wma\ \%8\ \%12}{\%7} - \frac{\%5\ \%12}{\%2} - 36.46063760\,\frac{Wma\ \%3\ \%1.}{\%2}$$

$$\Big)\Big/(\%6) - 100\,\frac{\%10\left(\frac{\%5\ \%12}{\%2} + 36.46063760\,\frac{Wma\ \%3\ \%12}{\%2}\right)}{\%6^2}\left.\right)^2 varOUHD + \left(1\right.$$

$$\left(\frac{\%9\ \%11}{\%7} + 36.46063760\,\frac{Wma\ \%8\ \%11}{\%7} - \frac{\%5\ \%11}{\%2} - 36.46063760\,\frac{Wma\ \%3\ \%1}{\%2}\right.$$

$$\Big)\Big/(\%6) - 100\,\frac{\%10\left(\frac{\%5\ \%11}{\%2} + 36.46063760\,\frac{Wma\ \%3\ \%11}{\%2}\right)}{\%6^2}\left.\right)^2 varCa + \left(\right.$$

$$100\,\frac{\frac{\%9}{\%7} + 36.46063760\,\frac{Wma\ \%8}{\%7} - \frac{\%5}{\%2} - 36.46063760\,\frac{Wma\ \%3}{\%2}}{\%6}$$

$$-100\,\frac{\%10\left(\frac{\%5}{\%2} + 36.46063760\,\frac{Wma\ \%3}{\%2}\right)}{\%6^2}\left.\right)^2 varC + \left(100\left(.3744932959\,\frac{\%9}{\%7}\right.\right.$$

$$\left.+ 13.65426435\,\frac{Wma\ \%8}{\%7} - .3744932959\,\frac{\%5}{\%2} - 13.65426435\,\frac{Wma\ \%3}{\%2}\right)\Big/(\%6)$$

$$- 100 \frac{\%10 \left(.3744932959 \frac{\%5}{\%2} + 13.65426435 \frac{Wma\ \%3}{\%2} \right)}{\%6^2} \Bigg)^2 varS$$

$$+ 798520.9600 \frac{\%10^2\ varH}{\%6^4} +$$

$$\left(100 \frac{36.46063760 \frac{\%8\ \%1}{\%7} - 36.46063760 \frac{\%3\ \%1}{\%2}}{\%6} - 100 \frac{\%10\ \%4}{\%6^2} \right)^2 varWma$$

$$+ 16932.15581 \frac{\%10^2\ Wma^2\ varN}{\%6^4} + 10000 \frac{\%10^2\ varMf}{\%6^4} \Bigg)^{1/2}$$

$$\%1 := C - \frac{A\ OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{A\ (1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca} + .3744932959\ S$$

$$\%2 := 12.01\ CO2avei + 12.01\ COavei$$

$$\%3 := 100 - CO2avei - COavei - O2avei$$

$$\%4 := 36.46063760 \frac{\%3\ \%1}{\%2} - 1.301236174\ N$$

$$\%5 := 15.99\ CO2avei + 4.00\ O2avei - .01\ COavei + 2802.00$$

$$\%6 := \frac{\%5\ \%1}{\%2} + 8.936\ H + Wma\ \%4 + Mf$$

$$\%7 := 12.01\ CO2aveo + 12.01\ COaveo$$

$$\%8 := 100 - CO2aveo - COaveo - O2aveo$$

$$\%9 := 15.99\ CO2aveo + 4.00\ O2aveo - .01\ COaveo + 2802.00$$

$$\%10 := \frac{\%9\ \%1}{\%7} + Wma \left(36.46063760 \frac{\%8\ \%1}{\%7} - 1.301236174\ N \right) - \frac{\%5\ \%1}{\%2} - Wma\ \%4$$

$$\%11 := -\frac{A\ OUHD}{1 - Ca} - \frac{A\ OUHD\ Ca}{(1 - Ca)^2} - \frac{1}{3} \frac{A\ (1 - OUHD)}{1 - \frac{1}{3}\ Ca} - \frac{1}{9} \frac{A\ (1 - OUHD)\ Ca}{\left(1 - \frac{1}{3}\ Ca\right)^2}$$

$$\%12 := -\frac{A\ Ca}{1 - Ca} + \frac{1}{3} \frac{A\ Ca}{1 - \frac{1}{3}\ Ca}$$

$$\%13 := -\frac{OUHD\ Ca}{1 - Ca} - \frac{1}{3} \frac{(1 - OUHD)\ Ca}{1 - \frac{1}{3}\ Ca}$$

$$\%14 := Wma \left(-36.46063760 \frac{\%1}{\%2} - 437.8922576 \frac{\%3\ \%1}{\%2^2} \right)$$

```
> sigmaALCO2avei := sqrt(Diff(AL,CO2avei)^2*varCO2avei):
> sigmaALCO2avei := value("):
> sigmaALCOavei := sqrt(Diff(AL,COavei)^2*varCOavei):
> sigmaALCOavei := value("):
> sigmaALO2avei := sqrt(Diff(AL,O2avei)^2*varO2avei):
> sigmaALO2avei := value("):
> sigmaALCO2aveo := sqrt(Diff(AL,CO2aveo)^2*varCO2aveo):
> sigmaALCO2aveo := value("):
> sigmaALCOaveo := sqrt(Diff(AL,COaveo)^2*varCOaveo):
> sigmaALCOaveo := value("):
> sigmaALO2aveo := sqrt(Diff(AL,O2aveo)^2*varO2aveo):
> sigmaALO2aveo := value("):
> sigmaALA := sqrt(Diff(AL,A)^2*varA):
> sigmaALA := value("):
> sigmaALOUHD := sqrt(Diff(AL,OUHD)^2*varOUHD):
```

> sigmaALOUHD := value("):

> sigmaALCa := sqrt(Diff(AL,Ca)^2*varCa):

> sigmaALCa := value("):

> sigmaALC := sqrt(Diff(AL,C)^2*varC):

> sigmaALC := value("):

> sigmaALS := sqrt(Diff(AL,S)^2*varS):

> sigmaALS := value("):

> sigmaALH := sqrt(Diff(AL,H)^2*varH):

> sigmaALH := value("):

> sigmaALWma := sqrt(Diff(AL,Wma)^2*varWma):

> sigmaALWma := value("):

> sigmaALN := sqrt(Diff(AL,N)^2*varN):

> sigmaALN := value("):

> sigmaALMf := sqrt(Diff(AL,Mf)^2*varMf):

> sigmaALMf := value("):

Constants

Averages and Random Error Variances from Part A (n=20 for in, n=24 for out)

> CO2avei := 15.2148;

CO2avei := 15.2148

> varCO2avei := .102^2;

varCO2avei := .010404

> COavei := .005;

COavei := .005

> varCOavei := .0002^2;

varCOavei := $.4\ 10^{-7}$

> O2avei := 3.8;

O2avei := 3.8

> varO2avei := .01118^2;

varO2avei := .0001249924

> CO2aveo := 14.145;

CO2aveo := 14.145

> varCO2aveo := .0866^2;

varCO2aveo := .00749956

> COaveo := .004;

COaveo := .004

> varCOaveo := .000204^2;

varCOaveo := $.41616\ 10^{-7}$

> O2aveo := 5;

O2aveo := 5

> varO2aveo := .010206^2;

varO2aveo := .000104162436

Coal Feed Rate (lbs/hr) re

> Wfe := 115839;

Wfe := 115839

> varWfe := (0.0025*Wfe)^2;

varWfe := 83866.71200

Area (square ft) re

> Areai := 3.99;

Areai := 3.99

> varAreai := (0.0335*Areai)^2;

varAreai := .01786633223

> Areao := 3.54;

Areao := 3.54

> varAreao := (0.0364*Areao)^2;

varAreao := .01660386874

Pitot Coefficient re

> CP := 0.84;

CP := .84

> varCP := (0)^2;

varCP := 0

Pressure Ambient or Barometric re

> PSi := 29.23;

PSi := 29.23

> varPSi := (0.04)^2;

varPSi := .0016

> **PSo := 29.1;**

$PSo := 29.1$

> **varPSo := (0.04)^2;**

$varPSo := .0016$

Pressue for primary air

> **PSpa := 31.11;**

$PSpa := 31.11$

> **varPSpa := (0.04)^2;**

$varPSpa := .0016$

>

Velocity Head DP re

> **v := .45802;**

$v := .45802$

> **DPo := array([seq(v,i=1..n)]);**

$DPo :=$ [.45802]

> **u := .00005^2;**

$u := .25\ 10^{-8}$

> **var := array([seq(u,i=1..n)]);**

$var := [.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

> **varDPo := make_array(var,n);**

$varDPo := varcovar$

> **v := .82831;**

$v := .82831$

> **DPi := array([seq(v,i=1..n)]);**

$DPi :=$ [.82831]

> **u := .00005^2;**

$u := .25\ 10^{-8}$

> **var := array([seq(u,i=1..n)]);**

$var := [.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

> **varDPi := make_array(var,n);**

$varDPi := varcovar$

>

Area for primary air

> **apa := .63;**

$apa := .63$

> **varapa := (.0208*apa)^2;**

$varapa := .000171714816$

>

> **v := .2171;**

$v := .2171$

> **DPpa := array([seq(v,i=1..n)]);**

$DPpa :=$ [.2171]

> **u := (0.00005)^2;**

$u := .25\ 10^{-8}$

> **varDPpa := array([seq(u,i=1..n)]);**

$varDPpa := [.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10$
$.25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}\ \ .25\ 10^{-8}]$

> **v := 1104;**

$v := 1104$

> **Tpa := array([seq(v,i=1..n)]);**

$Tpa :=$ [1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104 1104]

> **u := (0.005*(v - 460))^2;**

$u := 10.368400$

> **varTpa := array([seq(u,i=1..n)]);**

$varTpa :=$ [10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400 10.368400

```
        10.368400   10.368400   10.368400   10.368400   10.368400   10.368400   10.368400]

 Temperature (R)  re
> v := 713;
                              v := 713
> To := array([seq(v,i=1..n)]);
    To := [713  713  713  713  713  713  713  713  713  713  713  713  713  713
      713  713  713  713  713  713]
> u := (.005*(v-460))^2;
                              u := 1.600225
> var := array([seq(u,i=1..n)]);
    var := [1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225
      1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225  1.600225
      1.600225  1.600225  1.600225  1.600225  1.600225]
> varTo := make_array(var,n);
                              varTo := varcovar

> v := 1140;
                              v := 1140
> Ti:= array([seq(v,i=1..n)]);
    Ti := [1140  1140  1140  1140  1140  1140  1140  1140  1140  1140  1140
      1140  1140  1140  1140  1140  1140  1140  1140  1140]
> u := (.005*(v-460))^2;
                              u := 11.560000
> var := array([seq(u,i=1..n)]);
    var := [11.560000  11.560000  11.560000  11.560000  11.560000  11.560000
      11.560000  11.560000  11.560000  11.560000  11.560000  11.560000  11.560000
      11.560000  11.560000  11.560000  11.560000  11.560000  11.560000  11.560000]
> varTi := make_array(var,n);
                              varTi := varcovar

 Moisture in Ash  re
> Mf :=0.06;
                              Mf := .06
> varMf := ((0.2+0.12*Mf*100)/(2*1.414*100))^2;
                              varMf := .00001058319613

 Ash  re
> A := 0.0619;
                              A := .0619
> varA := (( 0.07+0.02*A*100)/(2*1.414*100))^2;
                              varA := .4696223261 10^(-6)

 Overhead  re
> OUHD := 0.9;
                              OUHD := .9
> varOUHD := (0.1*OUHD)^2;
                              varOUHD := .0081

 Carbon  re
> C := 0.7381;
                              C := .7381
> varC := (0.64/(2*1.414*100))^2;
                              varC := .5121546706 10^(-5)

 Hydrogen  re
> H := 0.0482;
                              H := .0482
> varH := (0.16/(2*1.414*100))^2;
                              varH := .3200966692 10^(-6)

 Nitrogen  re
> N := 0.0135;
                              N := .0135
> varN := (0.11/(2*1.414*100))^2;
                              varN := .1512956913 10^(-6)

 Sulfur  re
> S := 0.0123;
                              S := .0123
> varS := ((0.06+0.035*S*100)/(2*1.414*100))^2;
                              varS := .1327813813 10^(-6)

 CO2  re
> v := 14.145;
                              v := 14.145
> CO2o := array([seq(v,i=1..n)]);
```

```
CO2o := [14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145  14.145
  14.145]
> u := (0.03*v)^2;
                         u := .1800729225
> var := array([seq(u,i=1..n)]);
  var := [.1800729225  .1800729225  .1800729225  .1800729225  .1800729225
  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225
  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225  .1800729225
  .1800729225  .1800729225  .1800729225]
> varCO2o := make_array(var,n);
                         varCO2o := varcovar

> v := 15.2148;
                         v := 15.2148
> CO2i := array([seq(v,i=1..n)]);
  CO2i := [15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148  15.2148
  15.2148  15.2148  15.2148  15.2148]
> u := (0.03*v)^2;
                         u := .2083411251
> var := array([seq(u,i=1..n)]);
  var := [.2083411251  .2083411251  .2083411251  .2083411251  .2083411251
  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251  .2083411251
  .2083411251  .2083411251  .2083411251]
> varCO2i := make_array(var,n);
                         varCO2i := varcovar

O2 re
> v := 5;
                         v := 5
> O2o := array([seq(v,i=1..n)]);
  O2o := [5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5]
> u := (0.05)^2;
                         u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
```

```
> varO2o := make_array(var,n);
                         varO2o := varcovar

> v := 3.8;
                         v := 3.8
> O2i := array([seq(v,i=1..n)]);
  O2i := [3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.8  3.
  3.8  3.8  3.8  3.8  3.8]
> u := (0.05)^2;
                         u := .0025
> var := array([seq(u,i=1..n)]);
  var := [.0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025
  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025  .0025]
> varO2i := make_array(var,n);
                         varO2i := varcovar

Moisture (air) re
> Wma := 0.013;
                         Wma := .013
> varWma := (.2*Wma)^2;
                         varWma := .676 10^-5

CO re
> v := 0.005;
                         v := .005
> COo := array([seq(v,i=1..n)]);
  COo := [.005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .005  .00
  .005  .005  .005  .005  .005  .005  .005  .005]
> u := (0.001)^2;
                         u := .1 10^-5
> var := array([seq(u,i=1..n)]);
  var := [.1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10
  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5
  .1 10^-5  .1 10^-5  .1 10^-5  .1 10^-5]
> varCOo := make_array(var,n);
                         varCOo := varcovar
```

> v := 0.005;

$v := .005$

> COi := array([seq(v,i=1..n)]);

$COi := [.005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005\ \ .005]$

> u := (0.001)^2;

$u := .1\ \ 10^{-5}$

> var := array([seq(u,i=1..n)]);

$var := [.1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}\ \ .1\ 10^{-5}]$

> varCOi := make_array(var,n);

$varCOi := varcovar$

Carbon in Ash re

> Ca := 0.0486;

$Ca := .0486$

> varCa := (0.1*Ca)^2;

$varCa := .0000236196$

Results

> eval(AL);

6.870044252

> eval(sigmaAL);

.8654859456

> eval(100*sigmaAL/AL);

12.59796755

> evalf(sigmaALCO2avei);

.6367385669

> evalf(sigmaALCOavei);

.001354711120

> evalf(sigmaALO2avei);

.001308328988

> evalf(sigmaALCO2aveo);

.5861828919

> evalf(sigmaALCOaveo);

.001489882249

> evalf(sigmaALO2aveo);

.001202147989

> evalf(sigmaALA);

.00001140689853

> evalf(sigmaALOUHD);

.00006740663400

> evalf(sigmaALCa);

.0001081747388

> evalf(sigmaALC);

.0007910337493

> evalf(sigmaALS);

.00004769876152

> evalf(sigmaALH);

.002665266661

> evalf(sigmaALWma);

.001278941713

> evalf(sigmaALN);

$.3468723555\ \ 10^{-5}$

> evalf(sigmaALMf);

.001715004846

> i := 'i';

$i := i$

#13

> m := (Wma * 28.97+28.97)/((Wma*28.97/18.016)+1);

$m := 28.74570417$

#14

> PAFA := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$PAFA := 62529.82254$

> PAFB := 14088.2*apa*CP*sqrt(PSpa*m)*sum((DPpa[i]/Tpa[i])^(1/2),i=1..n);

$PAFB := 62529.82254$

```
#17
> FA := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#18
> FB := 5348840*Areai*CP*sqrt(PSi)*sum((DPi[i]/(M(i,A,OUHD,Ca,C,S,COi,CO2i,H,W
> ma,O2i,N,Mf)*Ti[i]))^(1/2)*(1-MFG(i,A,OUHD,Ca,C,S,COi,CO2i,H,Wma,O2i,N,Mf))*C
> O2i[i]/100,i=1..n):

#19
> SA := FA/(FA+FB);
                    SA := .5000000000

#20
> SB := FB/(FA+FB);
                    SB := .5000000000

#21
> WPAIA := PAFA/(Wfe*SA);
                    WPAIA := 1.079598797

#22
> WPAIB := PAFB/(Wfe*SB);
                    WPAIB := 1.079598797

#23
> Cr := (A*OUHD*Ca)/(1-Ca) + (A*(1-OUHD)*Ca/3)/(1-Ca/3);
                    Cr := .002947741741

> Cb := C - Cr;
                    Cb := .7351522583

> WAi := (28.02*(100-CO2avei-COavei-O2avei)/(12.01*(CO2avei+COavei))*(Cb+(12.0
> 1/32.07)*S)-N)/0.7685;
                    WAi := 11.93169660

#24
> WMGi := 8.936*H + (Wma*WAi)+Mf;
                    WMGi := .6458272558

#25
> WGpi := ((44.01*CO2avei+32.02*O2avei+28.01*COavei+28.02*(100-CO2avei-COav
> ei-O2avei))/(12.01*(CO2avei+COavei))*(Cb+(12.01/32.07)*S));
                    WGpi := 12.38591870

#26
> WGi := WGpi + WMGi;
                    WGi := 13.03174596

#27
> WAo :=( ((28.02*(100-CO2aveo-COaveo-O2aveo))/(12.01*(CO2aveo+COaveo)))*(C
> b + (12.01/32.07)*S)-N)/0.7685;
                    WAo := 12.81551267

#28
> WMGo := 8.936*H + (Wma*WAo) + Mf;
                    WMGo := .6573168647

#29
> WGpo := ((44.01*CO2aveo+32.02*O2aveo+28.01*COaveo+28.02*(100-CO2aveo-C
> Oaveo-O2aveo))/(12.01*(CO2aveo+COaveo))*(Cb+(12.01/32.07)*S));
                    WGpo := 13.26971581

#30
> WGo := WGpo + WMGo;
                    WGo := 13.92703267

#31
> AL := ((WGo-WGi)/WGi)*100;
                    AL := 6.870044219

#32
> TFluegasINa := WGi*Wfe*SA;
                    TFluegasINa := 754792.2100
TFluegasINb := WGi*Wfe*SB;

#33
TFluegasOUTa := WGo*Wfe*SA;
TFluegasOUTb := WGo*Wfe*SB;
>
```

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MILLIKEN STATION HEAT PIPE AIR HEATER PERFORMANCE UNCERTAINTY ANALYSIS OF "TOTALLY CORRECTED GAS TEMPERATURE LEAVING THE AIR HEATER"

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April 1996 (Edition 2)

Milliken Station Heat Pipe Air Heater Performance Uncertainty Analysis of "Totally Corrected Gas Temperature Leaving the Air Heater"

This report documents the uncertainty analysis of the "totally corrected gas temperature leaving the air heater" as specified in the ASME performance code. The analysis was requested by ABB Air Preheater Inc. (ABB API) and New York State Electric & Gas Corporation (NYSEG) in support of the performance testing of the Milliken Station heat pipe air heater. This analysis estimates the uncertainty of the final, corrected gas outlet temperature for the flue gas leaving the primary air side as ±4.75 °F. For the flue gas leaving the secondary air side, the uncertainty is ±4.8 °F. The uncertainty for the combined flue gas stream is ±4.4 °F.

This following report discusses the procedures used and the sources of the values used in this calculation.

UNCERTAINTY CALCULATIONS

During a conference call with CONSOL R&D, held on March 5, 1996, ABB API raised additional questions concerning the measurements required to evaluate the performance of their heat pipe air heater. Specifically CONSOL was asked to extend their previously published analysis, *Milliken Station Heat Pipe Air Heater Performance Uncertainty Analysis*, McCoy, D. C. and Bilonick, R. A., June 1995. NYSEG agreed to extend the previous analysis to evaluate the uncertainty in the calculation of the totally corrected outlet temperature of the flue gas. Specifically, Equation 7.12 of the *Air Heaters -- Supplement to Performance Test Code for Steam Generating Units, PTC 4.1*; ASME PTC 4.3 -- 1974 will serve as the basis for this analysis. This analysis completes the uncertainty estimates for the heat pipe air heater performance testing.

A procedure similar to that detailed in the previous report (McCoy, 1995) was used to estimate these errors. Briefly, two categories of errors are present in measured values: biases (or fixed) errors and random errors. Biases are associated with the measuring equipment and cannot be minimized by repeat measurements. However, since many calculations present in the ASME performance code involve differences and ratios, the biases tend to compensate for one another. Random errors on the other hand are reduced by repeat measurements. For purposes of this analysis, only a single final evaluation was assumed. Repeating the test will reduce the random error portion of the uncertainty analysis estimated by this study.

Both error types propagate through the performance code calculations. The two types of errors are propagated separately with the final bias and random errors combined to yield the uncertainty in the result. In the previous study, partial derivatives of the function with respect to each parameter were determined. The errors are then propagated by a Taylor Series expansion of these derivatives.

The following formula was used to propagate the errors:

$$S_r = \left[\sum_{\substack{i=1 \\ j=1}}^{n} \frac{\partial f}{\partial x_i} \cdot \frac{\partial f}{\partial x_j} \cdot \sigma_{x_i} \cdot \sigma_{x_j} \right]^{\frac{1}{2}} \qquad (1)$$

where

$\frac{\partial f}{\partial x_i}$ = Partial derivative of the function f with respect to x_i,

$\frac{\partial f}{\partial x_j}$ = Partial derivative of the function f with respect to x_j,

σ_{x_i} = Error in i, and

σ_{x_j} = Error in j.

However, the applicability of Equation 1 to nonlinear equations is limited. Its estimate can become inaccurate for highly nonlinear equations. Then, the following equation should be used:

$$S_r = \left[\sum_{\substack{i=1 \\ j=1}}^{n} \frac{\Delta f}{\Delta x_i} \cdot \frac{\Delta f}{\Delta x_j} \cdot \sigma_{x_i} \cdot \sigma_{x_j} \right]^{\frac{1}{2}} \tag{2}$$

where

$\frac{\Delta f}{\Delta x_i}$ = Incremental change in the function f with respect to x_i, and

$\frac{\Delta f}{\Delta x_j}$ = Incremental change in the function f with respect to x_j.

Of course, in the limit, as Δ approaches zero, this equation is identical to Equation 1. The difference is that Equation 2 is a numerical approach to solving the uncertainty analysis. Carl James (James, 1995) used a similar procedure to evaluate the uncertainty in the design of a cross-flow heat exchanger.

Equation 2 approximates the actual function f surface as a linear segment parallel to the true functional relationship. Equation 1 is generally a more accurate estimate of the error limit for linear equations. For independent parameters, only the $i = j$ terms are non-zero. This is true for both relationships. Equation 1 will be evaluated initially. This was the equation used in the previous study. (McCoy, 1995.)

After evaluating the bias and random errors for the function separately, the uncertainty is calculated by:

$$U = \left[B^2 + (t \cdot S)^2 \right]^{\frac{1}{2}} \tag{3}$$

where

U = Uncertainty interval,
B = Overall bias error statistic,
S = Overall random error statistic, and
t = Appropriate Student t value.

For 95% significance, the value of Student t is approximately two.

CORRECTED FLUE GAS OUTLET TEMPERATURE

The totally corrected flue gas outlet temperature, $t_{G15\,\delta Total}$, shown in the ASME guide as Equation 7.12, is:

$$t_{G15\,\delta_{Total}} = t_{G15\,\delta_A} + t_{G15\,\delta_G} + t_{G15\,\delta_{XR}} + t_{G15\,\delta_\epsilon} - 3 \cdot t_{G15} \tag{4}$$

where

- $t_{G15\,\delta_A}$ = Flue gas temperature leaving the air heater corrected for the deviation from design of the entering air temperature, °F,
- $t_{G15\,\delta_G}$ = Flue gas temperature leaving the air heater corrected for deviation from design of the entering flue gas temperature, °F,
- $t_{G15\,\delta_{XR}}$ = Flue gas temperature leaving the air heater corrected for deviation from design of the X-ratio, °F,
- $t_{G15\,\delta_\epsilon}$ = Flue gas temperature leaving the air heater corrected for deviation from design of the entering gas flow, °F, and
- t_{G15} = Measured flue gas temperature leaving the air heater, °F.

The *ASME Performance Test Codes* provide definitions for two of the temperature corrections. The other corrections, $t_{G15\,\delta XR}$ and $t_{G15\,\delta\epsilon}$, are unique to the design of an air heater. ABB API supplied the X-ratio and gas flow correction factors for their heat pipe air heater.

For the flue gas temperature leaving the air heater corrected for deviation from the design entering air temperature, $t_{G15\,\delta A}$, this temperature correction is:

$$t_{G15\,\delta_A} = \frac{t_{A8D} \cdot (t_{G14} - t_{G15}) + t_{G14} \cdot (t_{G15} - t_{A8})}{(t_{G14} - t_{A8})} \tag{5}$$

where

- t_{A8D} = Design air temperature entering the air heater, °F,
- t_{G14} = Measured flue gas temperature entering the air heater, °F,
- t_{G15} = Measured flue gas temperature leaving the air heater, °F, and
- t_{A8} = Measured air temperature entering the air heater, °F.

Similarly, the correction of the flue gas temperature leaving the air heater, $t_{G15\,\delta G}$, for deviation from the design entering flue gas temperature, is:

$$t_{G15\,\delta_G} = \frac{t_{G14D} \cdot (t_{G15} - t_{A8}) + t_{A8} \cdot (t_{G14} - t_{G15})}{(t_{G14} - t_{A8})} \tag{6}$$

where

t_{G14D} = Design flue gas temperature entering the air heater, °F,
t_{G14} = Measured flue gas temperature entering the air heater, °F,
t_{G15} = Measured flue gas temperature leaving the air heater, °F, and
t_{A8} = Measured air temperature entering the air heater, °F.

The correction factors to the flue gas temperature for the deviation from the design X-ratio, $t_{G15\ \delta XR}$, and for the deviation from the design entering gas flow, $t_{G15\ \delta G}$, are obtained from performance equations developed by ABB API. Equipment specific correlation factors for these equations were provided graphically as functions of the X-ratio and the inlet flue gas flow. ABB API provided individual performance equations and plots for the primary air section and for the secondary air section of the air heater.

To be applicable to ASME Equation 7.12 -- Equation 4, above -- the performance equations must be rewritten in terms of the deviation from the original or design conditions rather than predicting the behavior at the current conditions. This requires calculation of the deviation from design conditions. The resulting delta is added to the current flue gas temperature leaving the air heater. This corrects for the deviation from design X-ratio and entering gas flow. The method will be discussed in detail below.

From the correction factor plots provided by ABB API, CONSOL derived mathematical correlations over the range of interest. ABB API's performance equation combined the correction parameters, X-ratio and flue gas flow, into a single equation for each section of the heat pipe. The individual correction factors for Equation 4 were derived by varying one parameter at a time in the performance equation, holding the other constant at the design conditions. In this fashion, separate correction factors were derived for the deviation from design X-ratio and for flue gas flow.

PRIMARY AIR SIDE

For the primary air side of the air heater, ABB API provided the following performance equation to NYSEG (Larkin, 1995). This performance equation combined the effects for the deviation from the design X-ratio, $t_{G14\ \delta XR}$, with that for the entering flue gas flow, $t_{G15\ \delta G}$, into a single equation. This equation predicts the no-leak gas temperature specific to the Milliken air heater, $t_{PG15\ Performance}^{NL}$ and is:

$$t_{PG15\ Performance}^{NL} = t_{G14} \cdot \left[1 - 0.6177 \cdot f_{pg} \cdot f_{px}\right] + t_{A8} \cdot 0.6177 \cdot f_{pg} \cdot f_{px} \tag{7}$$

where

f_{pg} = Primary gas flow parameter, and
f_{px} = X-ratio parameter for the primary gas flow.

At an air side effectiveness, E_{pa}, above a specified limiting value, this relationship changes. The air side effectiveness is defined as:

$$E_{pa} = \frac{(t_{PA9} - t_{A8})}{(t_{G14} - t_{A8})} \qquad (8)$$

For the primary air side of the heat pipe air heater, this limit is 0.9492. Above this value of the air side effectiveness, the air side effectiveness is fixed at 0.9492, and the primary-side flue gas X-ratio correction factor becomes:

$$f_{px} = \frac{[E_{pa} \cdot X_p]}{[0.6177 \cdot f_{pg}]} = \frac{[0.9492 \cdot X_p]}{[0.6177 \cdot f_{pg}]} \qquad (9)$$

where

X_p = X-ratio for the primary-side.

The air heater appears to be operating below this limit. Therefore, the uncertainty estimation will be conducted only on the correlations developed for the ABB API plotted curves.

The functional relationship for the parameter associated with deviations in the primary flue gas flow from the design value, f_{pg}, is:

$$f_{pg} \approx 1.063795 - 0.0003486 \cdot F_{PFG} \qquad (10)$$

where

F_{PFG} = Primary-side flue gas flow, 1,000 lb/hr.

Similarly, for the X-ratio, the parameter, f_{px}, is:

$$f_{px} \approx -0.20011 + 2.506607 \cdot X_P - 1.01786 \cdot X_P^2 \qquad (11)$$

The X-ratio for the primary air side, X_P, is:

$$X_P = \frac{(t_{G14} - t_{PG15}^{NL})}{(t_{PA9} - t_{A8})} \qquad (12)$$

where

t_{PA9} = Measured primary air temperature leaving the air heater, °F.

$$\frac{\partial t_{PG15\,\delta_{Total}}}{\partial t_{G14}} = \frac{t_{A8D} + \left(t_{PG15} - t_{A8}\right)}{\left(t_{G14} - t_{A8}\right)} - \frac{t_{A8D}\cdot\left(t_{G14} - t_{PG15}\right) + t_{G14}\cdot\left(t_{PG15} - t_{A8}\right)}{\left(t_{G14} - t_{A8}\right)^2}$$ **(23)**

$$+ \frac{t_{A8}}{\left(t_{G14} - t_{A8}\right)} - \frac{t_{G14D}\cdot\left(t_{PG15} - t_{A8}\right) + t_{A8}\cdot\left(t_{G14} - t_{PG15}\right)}{\left(t_{G14} - t_{A8}\right)^2}$$

$$+ \left\{ - t_{G14D}\cdot\left[- 0.6177\cdot f_{pgD}\cdot\left(\frac{2.506607}{\left(t_{PA9} - t_{A8}\right)} - 1.01786\cdot(2)\cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right)\right)}{\left(t_{PA9} - t_{A8}\right)^2}\right]\right)\right]\right.$$

$$\left. - t_{A8D}\cdot\left[0.6177\cdot f_{pgD}\cdot\left(\frac{2.506607}{\left(t_{PA9} - t_{A8}\right)} - 1.01786\cdot(2)\cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right)\right)}{\left(t_{PA9} - t_{A8}\right)^2}\right]\right)\right] + 0 \right\} + (0) + 0$$

This simplifies to yield:

$$\frac{\partial t_{PG15\,\delta_{Total}}}{\partial t_{G14}} = \frac{t_{A8D} + t_{PG15}}{\left(t_{G14} - t_{A8}\right)} - \frac{\left(t_{A8D} + t_{A8}\right)\cdot\left(t_{G14} - t_{PG15}\right) + \left(t_{G14D} + t_{G14}\right)\cdot\left(t_{PG15} - t_{A8}\right)}{\left(t_{G14} - t_{A8}\right)^2}$$ (24)

$$+ \left\{ \left(t_{G14D} - t_{A8D}\right)\cdot 0.6177\cdot f_{pgD}\cdot\left(\frac{2.506607}{\left(t_{PA9} - t_{A8}\right)} - 1.01786\cdot(2)\cdot\left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right)\right)}{\left(t_{PA9} - t_{A8}\right)^2}\right]\right)\right\}$$

Differentiating Equation 20 with respect to the primary-side flue gas outlet temperature, t_{PG15}, yields:

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$$\frac{\partial t_{PG15}\,\delta_{Total}}{\partial t_{PG15}} = \frac{-t_{A8D}+t_{G14}}{(t_{G14}-t_{A8})} + \frac{t_{G14D}-t_{A8}}{(t_{G14}-t_{A8})} + \Bigg\{1 - t_{G14D}\cdot\Bigg[-0.6177\cdot f_{pgD}\cdot \Bigg(\frac{-2.506607\cdot\left|1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right|}{(t_{PA9}-t_{A8})} + 1.01786\cdot(2)\cdot\left(1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right) \cdot\left[\frac{t_{G14}-t_{PG15}-\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot(t_{PG15}-t_{Amb})}{(t_{PA9}-t_{A8})^2}\right]\Bigg)\Bigg]$$

$$- t_{A8D}\cdot\Bigg[0.6177\cdot f_{pgD}\cdot\Bigg(\frac{-2.506607\cdot\left|1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right|}{(t_{PA9}-t_{A8})} + 1.01786\cdot(2)\cdot\left(1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right) \cdot\left[\frac{t_{G14}-t_{PG15}-\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot(t_{PG15}-t_{Amb})}{(t_{PA9}-t_{A8})^2}\right]\Bigg)\Bigg] + \left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\Bigg\} + \{1\} - 3 \qquad (25)$$

This is simplified to:

$$\frac{\partial t_{PG15}\,\delta_{Total}}{\partial t_{PG15}} = + \frac{(t_{G14D}+t_{G14})-(t_{A8D}+t_{A8})}{(t_{G14}-t_{A8})} + \Bigg\{(t_{G14D}-t_{A8D})\cdot\Bigg[0.6177\cdot f_{pgD}\cdot\Bigg(\frac{-2.506607\cdot\left|1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right|}{(t_{PA9}-t_{A8})} + 1.01786\cdot(2)\cdot\left(1+\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\right) \cdot\left[\frac{t_{G14}-t_{PG15}-\left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot(t_{PG15}-t_{Amb})}{(t_{PA9}-t_{A8})^2}\right]\Bigg)\Bigg] + \left[\frac{A_{\ell}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\Bigg\} - 1 \qquad (26)$$

Differentiating Equation 20 with respect to the air temperature leaving the primary-side of the air heater, t_{PA9}, yields the following equation:

$$
\begin{aligned}
\frac{\partial t_{PG15\,\delta_{Total}}}{\partial t_{PA9}} = {} & 0 + 0 + \Bigg\{ - t_{G14D} \cdot \Bigg[- 0.6177 \cdot f_{pgD} \cdot \\
& \Bigg(- 2.506607 \cdot \left[\frac{t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)}{\left(t_{PA9} - t_{A8}\right)^2} \right] \\
& + 1.01786 \cdot (2) \cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)\right)^2}{\left(t_{PA9} - t_{A8}\right)^3} \right] \Bigg) \Bigg] \\
& - t_{A8D} \cdot \Bigg[0.6177 \cdot f_{pgD} \cdot \Bigg(- 2.506607 \cdot \left[\frac{t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)}{\left(t_{PA9} - t_{A8}\right)^2} \right] \\
& + 1.01786 \cdot (2) \cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)\right)^2}{\left(t_{PA9} - t_{A8}\right)^3} \right] \Bigg) \Bigg] \Bigg\} + \{0\} + 0
\end{aligned}
\tag{27}
$$

which when rearranged and simplified yields:

$$
\begin{aligned}
\frac{\partial t_{PG15\,\delta_{Total}}}{\partial t_{PA9}} = {} & \left(t_{G15D} - t_{A8D}\right) \cdot \Bigg[0.6177 \cdot f_{pgD} \cdot \\
& \Bigg(- 2.506607 \cdot \left[\frac{t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)}{\left(t_{PA9} - t_{A8}\right)^2} \right] \\
& + 1.01786 \cdot (2) \cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100}\right] \cdot \left[\frac{c_{pA}}{c_{pG}}\right] \cdot \left(t_{PG15} - t_{Amb}\right)\right)^2}{\left(t_{PA9} - t_{A8}\right)^3} \right] \Bigg) \Bigg]
\end{aligned}
\tag{28}
$$

Differentiating Equation 20 with respect to the primary flue gas flow, F_{PA}, yields:

$$\frac{\partial t_{PG15\ \delta_{Total}}}{\partial F_{PFG}} = 0 + 0 + \{0\} + \Big\{ - t_{G14D} \cdot \left[0.6177 \cdot (0.0003486) \cdot f_{pxD} \right] + t_{A8D} \cdot \left[0.6177 \cdot (0.0003486) \cdot f_{pxD} \right] \Big\} + 0 \qquad (29)$$

The final parameter is the percent leak, $A_{\mathcal{L}}$. Differentiating with respect to percent leak yields:

$$\frac{\partial t_{PG15\ \delta_{Total}}}{\partial A_{\mathcal{L}}} = 0 + 0 + \Bigg\{ - t_{G14D} \cdot \Bigg[- 0.6177 \cdot f_{pgD} \cdot \left(- 2.506607 \cdot \left[\frac{\left(\left[\frac{1}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \right)}{\left(t_{PA9} - t_{A8} \right)} \right] + 1.01786 \cdot (2) \cdot \left[\frac{1}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \right)}{\left(t_{PA9} - t_{A8} \right)^2} \right] \right)$$

$$- t_{A8D} \cdot \Bigg[0.6177 \cdot f_{pgD} \cdot \left(- 2.506607 \cdot \left[\frac{\left(\left[\frac{1}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \right)}{\left(t_{PA9} - t_{A8} \right)} \right] + 1.01786 \cdot (2) \cdot \left[\frac{1}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \cdot \left[\frac{\left(t_{G14} - t_{PG15} - \left[\frac{A_{\mathcal{L}}}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \right)}{\left(t_{PA9} - t_{A8} \right)^2} \right] \right) \Bigg]$$

$$+ \left[\frac{1}{100} \right] \cdot \left[\frac{c_{pA}}{c_{pG}} \right] \cdot \left(t_{PG15} - t_{Amb} \right) \Bigg\} + \{0\} + 0 \qquad (30)$$

This can be simplified as follows:

$$\frac{\partial t_{PG15\,\delta_{Total}}}{\partial A_{\varphi}} = \left(t_{G14D} - t_{A8D}\right)\cdot\left[0.6177\cdot f_{pgD}\cdot\left(-2.506607\cdot\left[\frac{\left(\left[\frac{1}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right)\right)}{\left(t_{PA9} - t_{A8}\right)}\right] + 1.01786\cdot(2)\cdot\left[\frac{1}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right)\cdot\left[\frac{\left(t_{G14} - t_{FG15} - \left[\frac{A_{\varphi}}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{FG15} - t_{Amb}\right)\right)}{\left(t_{PA9} - t_{A8}\right)^2}\right]\right)\right] + \left[\frac{1}{100}\right]\cdot\left[\frac{c_{pA}}{c_{pG}}\right]\cdot\left(t_{PG15} - t_{Amb}\right) \qquad (31)$$

The equations presented above were used to propagate the errors presented in the previous work. (McCoy, 1995.) Unfortunately the nonlinearity of the equations results in an erroneous forecast. This can be seen in the table below.

Table I
Error Calculation Using Partial Differentiation

Parameter	Parameter Error, %		Corresponding Propagation Error, %	
	Bias Error	Random Error	Bias Error	Random Error
Air Temperature @ Inlet	1.00	0.15	1.96	0.29
Flue Gas Temperature @ Inlet	1.00	0.12	0.41	0.05
Primary-Side Flue Gas Temperature @ Outlet	1.00	0.11	0.16	0.02
Primary Air Temperature @ Outlet	1.00	0.11	0.51	0.06
Primary-Side Flue Gas Flow	6.25	0.46	0.81	0.06
Air Leak Into Primary-Side Flue Gas	0.85	12.60	0.38	5.64

The error forecast for the random portion of the air leak into the primary-side flue gas, the highlighted cell, is 6%, which corresponds to an uncertainty of approximately 34 °F. The effect of the entire 6 percent air leak on the results predicted by Equation 16, the X-ratio correction factor, is less than 2.5 °F. Therefore, it appears that Equation 20 is too nonlinear to be used to propagate the estimate of the errors rigorously via the partial differentiation technique.

Equation 2 was used to estimate the errors using the method detailed below. (Box, G. E. P., 1978.)

The function for the total corrected flue gas outlet temperature, $t_{G15\ \delta Total}$, can be approximated as a set of linear segments in the region of interest to yield:

$$t_{G15\ \delta_{Total}} \approx \Theta_0 + \sum_{i=1}^{n} \Theta_i \cdot x_i \qquad (32)$$

where

Θ_0 = Constant evaluated at center point for all parameters, and
Θ_i = Constants for each x_i.

These constants, Θ_i, are linear approximations of the actual function evaluated at the midpoint. The variance of this function is:

$$S_r = \sum_{i=1}^{n} \Theta_i^2 \cdot \sigma_i^2 + \sum_{\substack{i=1 \\ j=1 \\ i \neq j}}^{n} \Theta_i \cdot \Theta_j \cdot \sigma_i \cdot \sigma_j \qquad (33)$$

which, if the parameters are uncorrelated or independent, reduces to:

$$S_r = \sum_{i=1}^{n} \Theta_i^2 \cdot \sigma_i^2 \qquad (34)$$

The function f is evaluated at two points, α and β, about the center point for each parameter. These points are equal distances from the center point x_i. The distance is three σ_i. The constant is then defined as:

$$\Theta_i = \frac{f_\alpha - f_\beta}{6 \cdot \sigma_i} \qquad (35)$$

The following example shows the propagation of the bias for the entering air temperature through Equation 20. The entering air temperature is varied while all other parameters are held constant. The function, Equation 20, is evaluated for changes in this parameter, x_i, as shown below.

	Value of Parameter	Value of Function	Difference	Θ_i
$x_i + 3 \bullet \sigma$	103.00	312.31	-0.436	
x_i	100.00	312.74		-0.143
$x_i - 3 \bullet \sigma$	97.00	313.17	-0.422	

The results shown above are typical for the parameters presented in Table II. As shown, the difference values, in the fourth column, are very similar. This demonstrates that over the range of $\pm 3 \bullet \sigma$ the linear approximation is valid. The results of these calculations will be discussed below. Reducing the range did not affect the values of Θ_i.

SECONDARY AIR

For the secondary air side of the heat pipe air heater, ABB API provided the following equation:

$$t^{NL}_{SG15\ Performance} = t_{G14} \cdot [1 - 0.7265 \cdot f_{sg} \cdot f_{sx}] + t_{SA8} \cdot 0.7265 \cdot f_{sg} \cdot f_{sx} \tag{36}$$

where

$t^{NL}_{SG15\ Performance}$ = Temperature of the flue gas leaving the air heater at test conditions corrected for the air leak, i. e., the no-leak temperature,

f_{sg} = Secondary-side flue gas flow correction factor,

f_{sx} = X-ratio correction factor for secondary-side flue gas flow, and

t_{SA8} = Measured secondary-side air temperature entering the air heater,°F.

The derived functional relationship for the correction factor with respect to deviations in the secondary-side flue gas flow from its design value, f_{sg}, is:

$$f_{sg} \approx 1.088958 - 0.00006725 \cdot F_{SFG} \tag{37}$$

where

F_{SFG} = Secondary-side flue gas flow, 1,000 lb/hr.

Similarly, the X-ratio correction factor, f_{sx}, is:

$$f_{sx} \approx -0.16969 + 2.119151 \cdot X_S - 0.83539 \cdot X_S^2 \tag{38}$$

with the X-ratio for the secondary air side, X_S, defined as:

$$X_S = \frac{\left(t_{G14} - t_{SG15}^{NL}\right)}{\left(t_{SA9} - t_{SA8}\right)} \tag{39}$$

where

t_{SA9} = Measured secondary-side air temperature leaving the air heater, °F.

For the secondary-side of the air heater, the leak can be neglected and thus:

$$t_{SG15} = t_{SG15}^{NL} \tag{40}$$

As discussed for the primary-side of the air heater, the above equations are performance equations. Converting these equations to the required correction equations required by the ASME Equation 7.12 produce the following equations. For the deviation from design X-ratio, $t_{SG15\,\delta XR}$, this is:

$$\begin{aligned} t_{SG15\,\delta_{XR}} = t_{SG15} + \Bigg\| t_{SG15D} - t_{G14D} \cdot \Bigg[1 - 0.7265 \cdot f_{sgD} \cdot \Bigg\{ - 0.16969 + 2.119151 \cdot \\ \left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)} \right] - 0.83539 \cdot \left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)} \right]^2 \Bigg\} \Bigg] - t_{A8D} \cdot \Bigg[0.7265 \cdot f_{sgD} \cdot \Bigg\{ - 0.16969 + \\ + 2.119151 \cdot \left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)} \right] - 0.83539 \cdot \left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)} \right]^2 \Bigg\} \Bigg] \Bigg\| \end{aligned} \tag{41}$$

and for the deviation from design entering gas flow, this equation is:

$$\begin{aligned} t_{SG15\,\delta_{G}} = t_{SG15} + \Big\| t_{SG15D} - t_{G14D} \cdot \Big[1 - 0.7265 \cdot \left\{ 1.088958 - 0.00006725 \cdot F_{SFG} \right\} \cdot f_{sxD} \Big] \\ - t_{A8D} \cdot 0.7265 \cdot \left\{ 1.088958 - 0.00006725 \cdot F_{SFG} \right\} \cdot f_{sxD} \Big] \Big\| \end{aligned} \tag{42}$$

As with the primary air side, a break exists in this relationship. For a secondary air side effectiveness, E_{sa}, greater than 0.9300, the following relationship applies:

$$f_{sx} = \frac{\left[E_{sa} \cdot X_s\right]}{\left[0.7265 \cdot f_{sg}\right]} = \frac{\left[0.930 \cdot X_s\right]}{\left[0.7265 \cdot f_{sg}\right]} \tag{43}$$

The functional relationship for the secondary-side totally corrected flue gas temperature becomes:

$$
\begin{aligned}
t_{SG15\,\delta_{Total}} = {} & \frac{t_{A8D}\cdot\left(t_{G14} - t_{SG15}\right) + t_{G14}\cdot\left(t_{SG15} - t_{SA8}\right)}{\left(t_{G14} - t_{SA8}\right)} + \frac{t_{G14D}\cdot\left(t_{SG15} - t_{SA8}\right) + t_{SA8}\cdot\left(t_{G14} - t_{SG15}\right)}{\left(t_{G14} - t_{SA8}\right)} \\
& + \Big\{t_{SG15} + \Big\| \, t_{SG15D} - t_{G14D}\cdot\Big[1 - 0.7265\cdot f_{sgD}\cdot \\
& \left(-0.16969 + 2.119151\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)}\right] - 0.83539\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)}\right]^2\right)\Big] \\
& - t_{A8D}\cdot\Bigg[0.7265\cdot f_{sgD}\cdot\Bigg(-0.16969 + 2.119151\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)}\right] \\
& - 0.83539\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)}\right]^2\Bigg)\Bigg]\Big\|\Big\} + \Big\{t_{SG15} + \Big\| \, t_{SG15D} - t_{G14D}\cdot\Big[1 - 0.7265\cdot \\
& \left\{1.088958 - 0.00006725\cdot F_{PFG}\right\}\cdot f_{sxD}\Big] - t_{A8D}\cdot 0.7265\cdot\left\{1.088958 - 0.00006725\cdot F_{PFG}\right\} \\
& \cdot f_{sxD}\Big]\Big\|\Big\} - 3\cdot t_{SG15}
\end{aligned}
\qquad \textbf{(44)}
$$

These equations can be differentiated, similar to those of the primary-side, and simplified to yield the following equations.

Differentiating Equation 44 with respect to the inlet air temperature yields:

$$
\begin{aligned}
\frac{\partial t_{SG15\,\delta_{Total}}}{\partial t_{SA8}} = {} & \frac{-t_{G14D} - t_{SG15}}{\left(t_{G14} - t_{SA8}\right)} + \frac{\left(t_{G14D} + t_{G14}\right)\cdot\left(t_{SG15} - t_{SA8}\right) + \left(t_{SA8} + t_{A8D}\right)\cdot\left(t_{G14} - t_{SG15}\right)}{\left(t_{G14} - t_{SA8}\right)^2} \\
& + \left(t_{G14D} - t_{A8D}\right)\cdot\Big\| \, 0.7265\cdot f_{sgD}\cdot \\
& \left(2.119151\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)^2}\right] - 0.83539\cdot(2)\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)^2}{\left(t_{SA9} - t_{SA8}\right)^3}\right]\right)\Big\|
\end{aligned}
\qquad \textbf{(45)}
$$

With respect to the inlet gas temperature, t_{G14}, the result simplifies to:

$$\frac{\partial t_{SG15\,\delta_{Total}}}{\partial t_{G14}} = \frac{t_{A8D} + t_{SG15}}{\left(t_{G14} - t_{SA8}\right)} - \frac{\left(t_{A8D} + t_{SA8}\right)\cdot\left(t_{G14} - t_{SG15}\right) + \left(t_{G14D} + t_{G14}\right)\cdot\left(t_{SG15} - t_{SA8}\right)}{\left(t_{G14} - t_{SA8}\right)^2}$$
$$+ \left(t_{G14D} - t_{A8D}\right)\cdot \left\| 0.7265 \cdot f_{sgD} \cdot \left(\frac{2.119151}{\left(t_{SA9} - t_{SA8}\right)} - 0.83539\cdot(2)\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)^2}\right]\right)\right\| \tag{46}$$

Differentiating Equation 44 with respect to the flue gas outlet temperature, t_{SG15}, and simplifying yields:

$$\frac{\partial t_{SG15\,\delta_{Total}}}{\partial t_{SG15}} = \frac{\left(t_{G14D} + t_{G14}\right) - \left(t_{A8D} + t_{SA8}\right)}{\left(t_{G14} - t_{SA8}\right)} + \left\{1 + \left(t_{G14D} - t_{A8D}\right)\cdot \left\| 0.7265 \cdot f_{sgD} \cdot \left(- \frac{2.119151}{\left(t_{SA9} - t_{SA8}\right)} + 0.83539\cdot(2)\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)^2}\right]\right)\right\|\right\} + \{1\} - 3 \tag{47}$$

Differentiating with respect to the secondary-side outlet air temperature, t_{SA9}, this simplifies to:

$$\frac{\partial t_{SG15\,\delta_{Total}}}{\partial t_{SA9}} = \left(t_{G14D} - t_{A8D}\right)\cdot \left\| 0.7265 \cdot f_{sgD} \cdot \left(- 2.119151\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)}{\left(t_{SA9} - t_{SA8}\right)^2}\right] + 0.83539\cdot(2)\cdot\left[\frac{\left(t_{G14} - t_{SG15}\right)^2}{\left(t_{SA9} - t_{SA8}\right)^3}\right]\right)\right\| \tag{48}$$

With respect to the secondary flue gas flow, F_{SA}, this partial differentiation simplifies to:

$$\frac{\partial t_{SG15\,\delta_{Total}}}{\partial F_{SFG}} = - \left(t_{G14D} - t_{A8D}\right)\cdot \left\| 0.7265 \cdot (0.00006725) \cdot f_{sxD} \right\| \tag{49}$$

Besides the rigorous method presented above, the delta method, Equation 2, was also used to propagate the errors. Since the delta estimate resulted in a slightly larger error, it was used.

RESULTS

The resulting differentials were summed by the method presented in Equation 2 to provide the bias and the random errors for the "totally corrected flue gas temperatures leaving the primary and secondary sides of the heat pipe air heater." The parameters as shown in Table II were used to estimate the uncertainties. Table II also contains the bias and random error results of the initial study. As discussed, these error values were used in this study. These were combined via Equation 3 to produce the uncertainty in the "totally corrected flue gas exit temperature." These results are shown below in Table III.

Table II

Parameter Values and Associated Errors

Parameter	Unit	Value	Bias Error	Random Error
Air Temperature @ Primary Inlet	°F	100	1.00	0.15
Air Temperature @ Secondary Inlet	°F	80	0.80	0.12
Air Temperature @ Primary Outlet	°F	644	6.44	0.74
Air Temperature @ Secondary Outlet	°F	616	6.16	0.70
Flue Gas Temperature @ Inlet	°F	680	6.81	0.81
Flue Gas Temperature @ Primary Outlet	°F	285	2.85	0.35
Flue Gas Temperature @ Secondary Outlet	°F	244	2.44	0.35
Design Air Temperature @ Inlet	°F	80		
Design Flue Gas Temperature @ Inlet	°F	680		
Primary-Side Flue Gas Flow	1,000 lb/hr	157.00	9.82	0.72
Secondary-Side Flue Gas Flow	1,000 lb/hr	1342.60	83.96	6.16
Air Leak into Primary-Side Flue Gas Flow	Percent	6.0	0.05	0.77

Table III

Uncertainty Estimates for Totally Corrected Primary and Secondary Flue Gas Outlet Temperatures

Parameter	Unit	Bias Error	Random Error	Uncertainty
Primary Outlet	°F	4.57	0.66	±4.75
Secondary Outlet	°F	4.69	0.50	±4.80

EXTENDING UNCERTAINTY TO THE FINAL FLUE GAS TEMPERATURE

The uncertainties estimated above may be extended to the bulk temperature of the combined flue gas stream. Since an equipment specific correction factor for the combined primary and secondary heat pipe air heaters is not available, the ASME equation cannot be used. That is, a correction for the $t_{G15\,\delta XR}$ and $t_{G15\,\delta C}$ factors for the combined flue gas flow is required for Equation 7.12 of the ASME air heater performance code. Therefore, the errors must be propagated through the algebraic summation of primary and secondary flue gas temperatures leaving the air heater, t_{PG15} and t_{SG15}, respectively. This equation is:

$$t_{Final} = \frac{t_{PG15\,\delta_{Total}} \cdot F_{PFG} + t_{SG15\,\delta_{Total}} \cdot F_{SFG}}{F_{PFG} + F_{SFG}} \quad (50)$$

where

t_{Final} = Temperature of the combined flue gas leaving the air heater.

Equation 49 is partially differentiated as discussed above to yield the following four equations:

$$\frac{\partial t_{Final}}{\partial t_{PG15\,\delta_{Total}}} = \frac{F_{PFG}}{F_{PFG} + F_{SFG}} \quad (51)$$

$$\frac{\partial t_{Final}}{\partial t_{SG15\,\delta_{Total}}} = \frac{F_{SFG}}{F_{PFG} + F_{SFG}} \quad (52)$$

$$\frac{\partial t_{Final}}{\partial F_{PFG}} = \frac{t_{PG15}\,\delta_{Total}}{F_{PFG} + F_{SFG}} - \frac{t_{PG15}\,\delta_{Total} \cdot F_{PFG} + t_{SG15}\,\delta_{Total} \cdot F_{SFG}}{F_{PFG} + F_{SFG}} \tag{53}$$

and:

$$\frac{\partial t_{Final}}{\partial F_{SFG}} = \frac{t_{SG15}\,\delta_{Total}}{F_{PFG} + F_{SFG}} - \frac{t_{PG15}\,\delta_{Total} \cdot F_{PFG} + t_{SG15}\,\delta_{Total} \cdot F_{SFG}}{\left(F_{PFG} + F_{SFG}\right)^2} \tag{54}$$

As with the primary and secondary flue gas temperatures leaving the air heater, the bias and random errors are propagated individually and summed as shown in Equations 1 and 3. The values and errors for the temperatures and flue gas rates are the results calculated previously, as listed in Table III. The results of propagating the errors through these partial differentials, Equations 50 through 53, are listed below in Table IV.

Table IV

Uncertainty Estimates in the Combined Flue Gas Temperature

Parameter	Unit	Bias Error	Random Error	Uncertainty
Combined Flue Gas Temperature	°F	4.27	0.46	±4.36

Uncertainty in the temperature of the combined flue gas is in the same range as the uncertainty in the primary and secondary flue gas temperatures. The uncertainty in the combined flue gas flow is estimated to be ±4.4°F. This is less than that of the primary and secondary-side exit flue gas temperatures due to the nature of the error propagation calculations. The uncertainty of the flue gas temperatures leaving the heat pipe air heater is ±4.75°F for the flue gas leaving the primary air side of the air heater and ±4.80°F for that leaving the secondary air side, as shown in Table III.

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