TANK CAR THERMAL ANALYSIS, VOLUME II, TECHNICAL DOCUMENTATION REPORT FOR ANALYSIS PROGRAM

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M. R. JOHNSON
IIT Research Institute
Chicago, IL 60616

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Tank Car Thermal Analysis,
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Author(s)

Milton R. Johnson

Performing Organization Name and Address

IIT Research Institute
10 W. 35th Street
Chicago, IL 60646

Abstract

The computer program AFFTAC is described. The program can be used to analyze the behavior of railroad tank cars when subjected to fire. It is designed to perform the analyses which are required to determine if a tank car meets the requirements of the Code of Federal Regulations, Title 49, Part 179, Section 179.18. The conditions associated with two types of fires are built into the program, the pool fire environment, where the car is fully engulfed by flame, and the torch fire environment, where only a small area of the tank is subjected to a high intensity flame. Other fire conditions can also be analyzed. A wide variety of tank car types can also be considered including cars equipped with a safety relief valve or a safety vent closed with a frangible disc. The program is described in two volumes. This volume describes the assumptions and procedures used in the analysis. Four main conditions must be considered, an upright car orientation where vapor is vented, an overturned car condition where liquid is vented, a shell full condition where the tank contains only product in the liquid phase, and the condition where the tank contains only product in the vapor phase. The source codes of the main program and the subroutines are presented in a series of appendices.

Key Words

railroad tank car, tank car failure, hazardous material release, fire effects

Distribution Statement

PREFACE

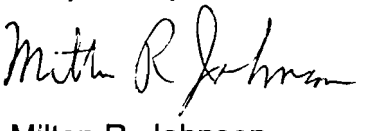
The work described in this report was conducted by IIT Research Institute (IITRI) under authorization of Federal Railroad Administration (FRA) Contract No. DTFR53-90-C-00042, Task Order No. 6, and DTFR53-97-P-00325.

The work was directed at the further development of a program to analyze the effects of fire on a tank car and the product contained in the tank. The final report on this project is presented in two volumes. This volume, Volume II, describes the technical background for the analysis program. A second volume, Volume I, is the user's manual for the program.

The first period of performance was from September 1994 to March 1995. The program was then distributed to selected users for comment. The FRA reviewed these comments and requested several changes be made in the program and the documentation. Authorization to proceed with the work was received in May 1997. A test version of the software and the draft of the final report was delivered in October 1997. Authorization to deliver the final software and report was received in September 1998.

Dr. Milton R. Johnson was the IITRI Project Manager for this work. Mr. Jose Pena was the FRA Technical Monitor for this project. Mr. Garold R. Thomas was the FRA Contracting Officer's Technical Representative. The contributions of these individuals throughout the course of the work are gratefully acknowledged.

Respectfully submitted,



Milton R. Johnson

EXECUTIVE SUMMARY

This report describes the technical background for the computer program AFFTAC (Analysis of Fire eFfects on TAnk Cars) which can be used to analyze the behavior of tank cars and the products they contain when subjected to fire. The assumptions and procedures used in the analysis are described in this report and the source codes of the main program and subroutines are presented in a series of appendices.

The first version of the program was developed for the Federal Railroad Administration in 1984. Since that time certain features have been added to the program such as the thermal properties of additional commodities and the ability to consider a tank with a safety vent as well as the safety relief valve. The thermal properties of 16 commodities are now contained in the program.

Originally, the program accepted entry of input variables at the monitor. This has been modified so that input data can be read from a file or entered in an interactive way at the monitor. The interactive process at the monitor has been expanded with prompts added to provide added instructions for the entry of data.

Another feature that has been added in this version of the program is the entry of thermal property data. Now one can enter thermal property data for products by creating and reading a file of data or by entering the data at the keyboard of the monitor following the instructions given by a series of prompts on the screen.

Several different conditions must be recognized when analyzing the effects of fire on a tank car. First, the car may be in the upright position venting vapor. Most of the heat is conducted into the car through the wetted area of the tank. The properties of the thermal shield (insulation system) determine the rate of heat transfer into the liquid product. Some heat is also conducted through the thermal shield over the vapor space which increases the temperature of the liquid product, increasing as its temperature increases. The presence of a pad of inert gas must be considered for cars containing certain commodities.

The analysis considers whether the car is equipped with a safety relief valve or a safety vent with a frangible disc. If the car is equipped with a safety relief valve the valve opens allowing the vapor to exhaust from the car when the pressure within the tank

exceeds the start-to-discharge pressure of the valve. A slight rise in the pressure above this value causes the valve to move to the fully open position. If the valve flow capacity is adequate, the liquid will tend to remain at a nearly constant temperature as it is vaporized and exhausted from the tank. If the valve flow capacity is not large enough, the pressure in the tank will rise allowing the temperature of the liquid to increase and also resulting in a somewhat larger mass flow rate through the valve. If the car is equipped with a safety vent, the vent opens and stays open for the remainder of the calculation when the rupture pressure of the frangible disc is reached.

Another condition is the overturned car case. The car is assumed to be partially rolled over so that when the safety relief device opens it will vent liquid instead of vapor. The volumetric flow rate for liquid discharge is less than for the vapor case at any given pressure, but the mass flow rate may be larger because of the greater density of the fluid. Liquid flow is calculated assuming homogenous isentropic two-phase flow (liquid and vapor). Two-phase effects are significant only when the product has a high vapor pressure.

Still another condition is where the tank is "shell full" (of liquid) and for all practical purposes there is no vapor space left within the tank. This occurs when the car is initially filled with only a small empty volume (outage) above the liquid surface. When the car is exposed to the fire, the temperature of the product rises and its specific volume increases so that eventually all of the tank is filled with liquid. When the car becomes shell full, any further increase in temperature of the product will cause liquid flow through the safety relief device. If the capacity of the device is small and the rate of increase in the specific volume of the liquid is large, very high pressures can be developed.

A fourth condition is where all the liquid has been vaporized. This condition is also associated with the case where the critical temperature of the product is exceeded before all the liquid is vaporized so that the vapor state is the only phase in which the product can exist. The temperature of the vapor will increase at a fairly rapid rate because heat is both convected and radiated to the product and because the mass of the product within the tank is relatively small. The tank wall temperature also increases fairly rapidly because there is no cooling effect from the vaporization of liquid product within the tank.

For each of these four conditions, the burst pressure of the tank is estimated as a function of the wall temperature over the vapor space. When the tank is no longer capable of containing the pressure within the tank, failure is assumed causing the sudden release of the remaining product within the car.

The program has been written in FORTRAN using Microsoft Version 5.0 FORTRAN and is intended for use on a personal computer. It has been compiled using the /Fi option which does not require the use of a 8087/80287/80387 math coprocessor to perform floating point operations, but will use it if present in the computer. The program is designed for interactive use with a monitor. The results can be displayed at the monitor or written to a report file.

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TECHNICAL DOCUMENTATION REPORT FOR PROGRAM AFFTAC

1. INTRODUCTION

This report describes the technical details for the computer program AFFTAC (Analysis of Fire eFfects on TAnk Cars). The program is used to analyze the behavior of tank cars and the products they contain when subjected to fire. The assumptions and procedures used in the analysis are described in this report and the source codes of the main program and subroutines are presented in a series of appendices.

2. BACKGROUND

In 1984, IIT Research Institute (IITRI) developed a computer program for analytic procedure which could be used to calculate the effects of fire on a railroad tank car. The work was sponsored by the Federal Railroad Administration (FRA). The procedure was developed so that the consequences of using different conductances of thermal insulation systems on the tank and different flow capacities of the safety relief valve could be determined. It was used to predict various effects of the fire, such as the time to tank failure, the amount of product remaining in the tank at the time of failure, the maximum pressure in the tank, the time to reach certain pressure levels, etc. Both upright and overturned car cases were considered. Tank cars containing the following products were analyzed: ethylene oxide, propane, propylene, 1,3-butadiene, vinyl chloride, monomethylamine, and propylene oxide. A report describing the procedure and presenting the source code of the computer program was published in 1984 by the FRA (Ref. 1).

In subsequent years IITRI modified the procedure to include additional commodities and different conditions, such as the use of safety vents closed by frangible discs instead of safety relief valves, the use of linings in the tank, the expansion of the tank due to internal pressure, etc. This was done so that it could be used to analyze different situations where tank cars are engulfed by fire.

The thermal properties of other commodities were also entered into the program. Some of these commodities were solutions, such as hydrochloric acid, where consideration had to be given to a change in the concentration of the solution as vaporization and venting of the product takes place.

In November 1992 a project was initiated with the Association of American Railroads (AAR) to make the computer program more accessible to the tank car industry. The purpose of this project was to document the changes and describe the operation of the program so that it could be used by others. The work included modification of the program to run on a personal computer.

The results of this work were published in April 1993 in a draft report. The executable program was distributed to selected users by the AAR for evaluation. Comments on the program were not transmitted to IITRI until October 1994. The program was revised and resubmitted to the AAR in November 1994 (Ref. 2).

As mentioned in the Preface to this report, the present efforts to expand the capabilities of the analysis program were initiated in September 1994.

3. GENERAL CONSIDERATIONS

The analytic procedure allows the conditions within the tank to be determined as a function of time for different initial conditions, which include characteristics of the tank, product contained in the tank, the safety relief device, thermal insulation and fire. The computer program has been written in FORTRAN using Microsoft Version 5.0 FORTRAN and is intended for use on a personal computer. It has been compiled using the /Fpi option which does not require the use of a 8087/80287/80387 math coprocessor to perform floating point operations, but will use it if present in the computer. The program is designed for interactive use with a monitor. The results can be displayed at the monitor or written to a file.

3.1 DESCRIPTION OF PHENOMENA

Fig. 3.1 illustrates the basic phenomena which must be taken into consideration. Four different conditions are recognized. The first is where the car is in the upright position venting vapor. Most of the heat is conducted into the car through the wetted area of the tank. The properties of the thermal shield (insulation system) determine the rate of heat transfer into the liquid product. Some heat is also conducted through the thermal shield over the vapor space which increases the temperature of the tank wall. As the temperature rises, heat is radiated from the wall to the liquid below. The amount of radiated heat depends on both the radiation surface configuration factor of the surface of the liquid and the temperatures of the wall and liquid.

The burst pressure of the tank is estimated as a function of the wall temperature over the vapor space. When the tank is no longer capable of containing the pressure within the tank, failure is assumed causing the sudden release of the remaining product within the car.

The pressure within the tank is a function of the temperature of the liquid product, increasing as its temperature increases. The presence of a pad of inert gas, must be considered for cars containing certain commodities.

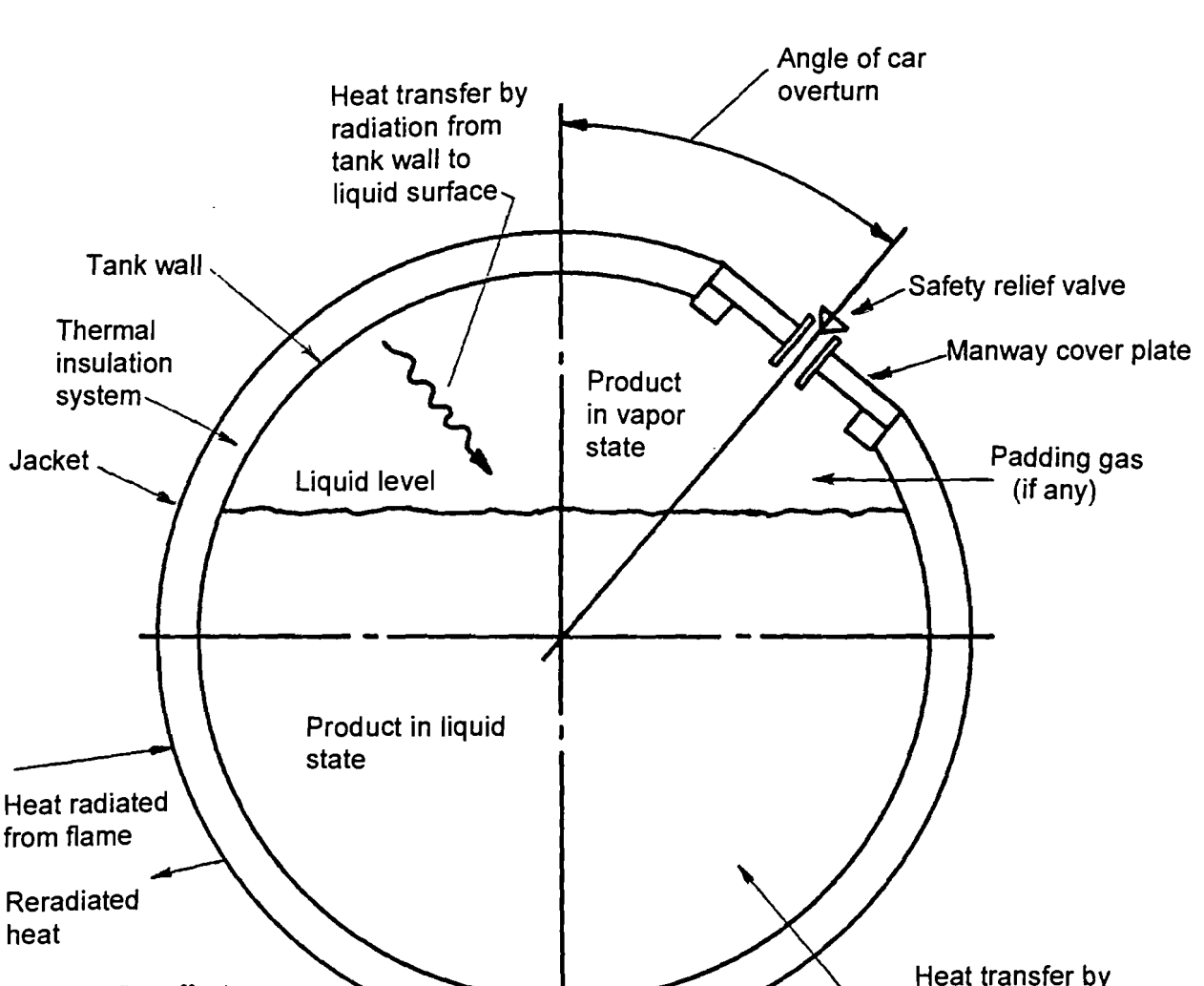

FIG. 3.1 CONDITIONS CONSIDERED IN THE ANALYLSIS OF TANK CARS SUBJECTED TO FIRE

The calculation considers whether the car is equipped with a safety relief valve or a safety vent with a frangible disc. If the car is equipped with a safety relief valve the valve opens allowing the vapor to exhaust from the car when the pressure within the tank exceeds the start-to-discharge pressure of the valve. A slight rise in the pressure above this value causes the valve to move to the fully open position. If the valve flow capacity is adequate, the liquid will tend to remain at a nearly constant temperature as it is vaporized and is exhausted from the tank. If the valve flow capacity is not large enough, the pressure in the tank will rise allowing the temperature of the liquid to increase and also resulting in a somewhat larger mass flow rate through the valve. If the car is equipped with a safety vent, the vent opens and stays open for the remainder of the calculation when the rupture pressure of the frangible disc is reached.

The second condition is the overturned car case. The car is assumed to be partially rolled over so that when the safety relief device opens it will vent liquid instead of vapor. The volumetric flow rate for liquid discharge is less than for the vapor case at any given pressure, but the mass flow rate may be larger because of the greater density of the fluid. Liquid flow is calculated assuming homogenous isentropic two-phase flow (liquid and vapor). Two-phase effects are significant only when the product has a high vapor pressure.

The third condition is where the tank is "shell full" (of liquid) and for all practical purposes there is no vapor space left within the tank. This condition is more likely to occur when the car is initially filled with only a small empty volume (outage) above the liquid surface. When the car is exposed to the fire, the temperature of the product rises and its specific volume increases so that eventually all of the tank is filled with liquid. When the car becomes shell full, any further increase in temperature of the product will cause liquid flow through the safety relief device. If the capacity of the device is small and the rate of increase in the specific volume of the liquid is large, very high pressures can be developed.

The fourth condition is where all the liquid has been vaporized. This condition is also associated with the case where the critical temperature* of the product is exceeded before all the liquid is vaporized so that the vapor state is the only phase in which the product can exist. The temperature of the vapor will increase at a fairly rapid rate because heat is both convected and radiated to the product and because the mass of the product within the tank is relatively small. Under almost all conditions, the safety relief device is capable of relieving any increases in pressure as the vapor becomes hotter. For a valve, the pressure would be maintained near the valve closing pressure. The tank wall temperature also increases fairly rapidly because there is no cooling effect from the vaporization of liquid product within the tank.

The calculational procedure assumes that each of the parameters remains constant over a given time step. The parameters are then updated at the end of the time step. An integration time step of 0.1 minutes has been found to be adequate for the calculations.

3.2 STANDARD FIRE CONDITIONS

Two standard fire conditions are built into the analytic procedure. They are the pool fire condition and the torch fire condition. They are based on the requirements of Appendix B to Part 179 of the Code of Federal Regulations (CFR).

The pool fire simulation test described in the CFR calls for a sample insulation system to be subjected to a 1600 °F ± 100 °F flame. Analysis of the full scale fire tests on tank cars containing propane indicated that the effects of the fire could be represented by complete engulfment of the car in a fire with approximate flame teemperature 1500 °F. (See Refs. 1 and 4.)

A torch fire is defined as a high intensity flame that will heat and weaken the tank wall in a localized area. The effect will be much more pronounced if the flame impinges on the tank wall over the vapor space because the cooling effect of the liquid product will not be present. It will have a minimal effect, when compared to a pool fire, in raising

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* This critical temperature has a different meaning than the "critical temperature" entered into the program. "critical temperature" here refers to the maximum temperature at which the product can exist in the liquid state.

the temperature of the contents of the tank, because heat is transmitted into the tank only in a localized area.

The heat input used to analyze the effects of a torch fire on a tank car is based on the requirements for a simulated torch fire test which are also given in Appendix B to Part 179 of the CFR. The requirements state that the flame shall have a temperature of 2200 ± 100 °F and shall be directed at the test specimen at a velocity of 40 ± 10 mph. The intensity of the heat input from this flame is to be verified by directing it at a 4 by 4 ft steel plate 5/8 in. thick, which is initially between 32 and 100 °F. When the flame is directed at the plate, the plate is to reach a temperature of 800 °F in 4.0 ± 0.5 minutes.

Torch fire simulation test has been analyzed to determine the heat input required to raise the temperature of the plate to 800 °F in four minutes. The result is a thermal input of approximately 37,000 BTU/hr-ft^2 to a cold plate surface. This equivalent to the radiant energy from a flame with a temperature of 2200 °F, but with a factor of 0.536 to account for the fact that the flame does not completely surround the plate. In the analytic procedure a flame with this intensity is directed at the outer surface of the tank wall (for a bare uninsulated tank) or the jacket of an insulated tank. The heat input to the tank will be reduced, as the surface temperature is raised.

The above calculated value of thermal input has been used in the tank car torch fire analysis. It is assumed to be applied to a 4 ft square section of the surface of the tank adjacent to the liquid for the calculation of heat input to the tank. For purposes of determining the reduction of in burst pressure of the tank, it is assumed that the heat input is directed at the tank wall adjacent to the vapor space.

The assumption is made for the purpose of analysis that all of the heat is transferred to the surface of the tank by radiation. Under actual test conditions, heat transfer by convection would also be present because of the 40 mph flow velocity specified for the flame. However, there is no way to separate out the relative effects of the two mechanisms of heat transfer. Assuming the heat transfer is by radiation is a conservative assumption because it results a significant level of heat transfer even when there is only a small difference in temperature between the flame and the outside surface of the tank.

3.3 USE OF SUBROUTINES

The computer program is named AFFTAC and makes use of subroutines which are listed as follows:

ENTRDAT permits entry of variables used in the analysis interactively at the computer terminal,

SURFACET calculates the surface temperature of the outside of the tank insulation system,

AVFLOW calculates the liquid flow through a safety relief device, and

TSHIELD calculates the effective conductance of an insulation system, where temperature dependent conductivity is assumed.

Two different subroutines are used for the entry of thermal property data. These are:

SBSENTR for the entry of thermal property data for a substance, and

SLNENTR for the entry of thermal property data for a solution.

The analysis requires establishing the current values for the thermal properties of the product at various steps through the calculations. The values are found by calling one of four subroutines. Two subroutines, FPRPSBS and FPRPSLV, are used to obtain data for products where the thermal properties are stored in the program. FPRPSBS contains data for products which are substances. FPRPSLV contains data for products which are solutions. The other two subroutines are used for cases where the property data are entered into the program either by reading a file or by entering at the monitor. One of these subroutines, SBSPROP, is used for products which are substances. The other, SLNPROP, is used for products which are solutions.

The subroutine ANLYRPT is used to prepare a file describing the analysis conditions for any given run of the program.

3.4 VARIABLES USED TO DESCRIBE CONDITIONS OF THE ANALYSIS

The following variables are entered into the program to establish the conditions of the analysis.

Tank Characteristics

Capacity of Tank (gal)
Inside Tank Diameter (ins.)
Tank Wall Thickness (ins.)
Tank Material Type
Tensile Strength of Tank Material (psi)
Nominal Burst Pressure (psig)
Tank Orientation with Respect to Vertical (deg)

Product Characteristics

Type of Product in Tank: Substance or Solution
Procedure for Entry of Thermal Property Data
Name of Product
Fraction of Tank Filled with Product
Initial Temperature of Product (deg F)
Concentration of Product (if solution)
Padding Gas Pressure (if present, psig)

Safety Relief Device Characteristics

Type of Safety Relief Device; Valve or Vent
Discharge Area for Vent (if used, in^2)
Frangible Disc Rupture Pressure for Vent (if used, psig)
Flow Capacity of Safety Relief Valve (if used, SCFM)
Flow Rating Pressure of Safety Relief Valve (if used, psig)
Start-to-Discharge Pressure of Safety Relief Valve (if used, psig)
Vapor Discharge Coefficient
Liquid Discharge Coefficient

Thermal Insulation System Characteristics

Type of Thermal Insulation System
Initial Conductance of Thermal Insulation (BTU/hr-ft^2-°F)
Final Conductance of Thermal Insulation (BTU/hr-ft^2-°F)
Time Interval for Change from Initial to Final Conductance (if any, min)
Thickness of Thermal Insulation (only for temperature dependent conductivity cases, ins.)
Constants Defining Thermal Conductivity (only for temperature dependent conductivity cases)
Effect of Discontinuities Increasing Heat Transfer (if any)
Type of Lining (if any)

Fire Characteristics

Type of Fire (pool, torch, or special conditions)
Flame Temperature (deg F)
Fraction of Tank Surface Subjected to Fire
Emissivity/Absorptivity of Tank Surface

Analysis Conditions

Time Increment Used in Analysis (min)
Number of Time Increments Between Display of Output Data
Time Limit Analysis (min)

The manner in which these data are entered into the program is described in the User's Manual.

3.5 EXCEEDENCE OF TEMPERATURE OR CONCENTRATION LIMITS

During the operation of the program the temperature and concentration (if the product is a solution) are checked to determine if certain limits are exceeded. If the temperature range for which thermal property data are entered into the program is exceeded during the analysis, the following statement will appear on the terminal screen and written to the output file:

OUTSIDE TEMPERATURE RANGE OF THERMAL PROPERTY DATA

The calculations will continue, but will be based on extrapolated, rather than interpolated thermal property data.

If the concentration range for which thermal property data for a solution are entered into the program is exceeded during the analysis, the following statement will appear on the terminal screen and be written to the output file:

OUTSIDE CONCENTRATION RANGE OF THERMAL PROPERTY DATA

The calculations will continue, but will be based on extrapolated, rather than interpolated thermal property data.

3.6 LIMITATIONS OF ANALYSIS

Several assumptions are made in the analytic procedure which limit the scope of the types of situations that can be considered. First, it is assumed that the liquid product within the tank is at a uniform temperature. This implies that the liquid product has a low viscosity because this would lead to rapid mixing of the liquid as heat is transferred to it through the tank wall and insulation. Rapid mixing would not take place if the liquid had a high viscosity and this would lead to a nonuniform temperature which would influence the effects of the fire on the tank and the product within the tank.

While the present version of the analytic procedure allows one to consider products which are solutions, it is limited to two-component solutions. Entry of thermal property data for a two-component solution involves considerably more effort than for a substance. Entry of thermal property data for a solution with additional constituents would require considerably greater effort.

A third limitation is that the present analytic procedure does not permit consideration of chemical reactions or changes in phase within the product which would result in the liberation or absorption of heat (except, of course, for the vaporization of the product). As certain products are heated beyond a temperature limit, they may undergo a reaction which liberates heat. This would tend to increase the rate of increase of temperature and pressure within the tank.

The analytic procedure considers the effect of discontinuities such as the manway nozzle, jacket spacers, and body bolsters when computing the total heat flow into the tank, but it does not predict the temperature of the tank wall at these locations. The effect of heat flow through discontinuities might lead to local "hot spots" at these locations particularly if the discontinuity were in the vapor space region of the tank, and could be of concern with commodities where a chemical reaction may be initiated if they are raised to a certain temperature.

4. ANALYTICAL PROCEDURE

The program is initiated by entering the command: AFFTAC.* The steps in the analysis are described in this section. Additional explanatory notes are contained in the listing of the source code, which is presented in Appendix A. A flow chart for the program is presented in Fig. 4.1.

4.1 INITIALIZATION

The first part of the program deals with the entry of data.

4.1.1 Data Entry

Fig. 4.2 presents a flow chart showing the options and logic for the entry of data. There are two parts to this process, the first dealing with the entry of the variables describing the initial conditions of the analysis and the second dealing with the entry of thermal property data.

The first decision point is whether the initial values are to be entered at the monitor or from an existing computer file. If a file is used, the name of the file must be entered. If the values are to be entered, one at a time, at the terminal, subroutine ENTRDAT.FOR is called. See the User's Manual, Section 2, for a detailed description of this part of the program. The source code for subroutine ENTRDAT.FOR is presented in Appendix B of this report. A report of the initial data is prepared by subroutine ANLYRPT.FOR. The source code for this subroutine is presented in Appendix C of this report.

The next step in the program is the entry of the thermal property data. As indicated by the flow chart this can be done by entering the property data at the monitor, reading a previously developed file or property data, or by using the property data for one of the commodities which are stored in the program. Two types of commodities are considered, substances and two-component solutions. The procedures for entering thermal property at the monitor are described in Section 3 of the User's Manual. The source codes for the two subroutines for the entry of thermal property data, SBSENTR.FOR and SLNENTR.FOR are presented in Appendices D and E of this report.

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* The program can be run from Windows 95 by using Windows Explorer to find the AFFTAC icon and then double clicking this icon.

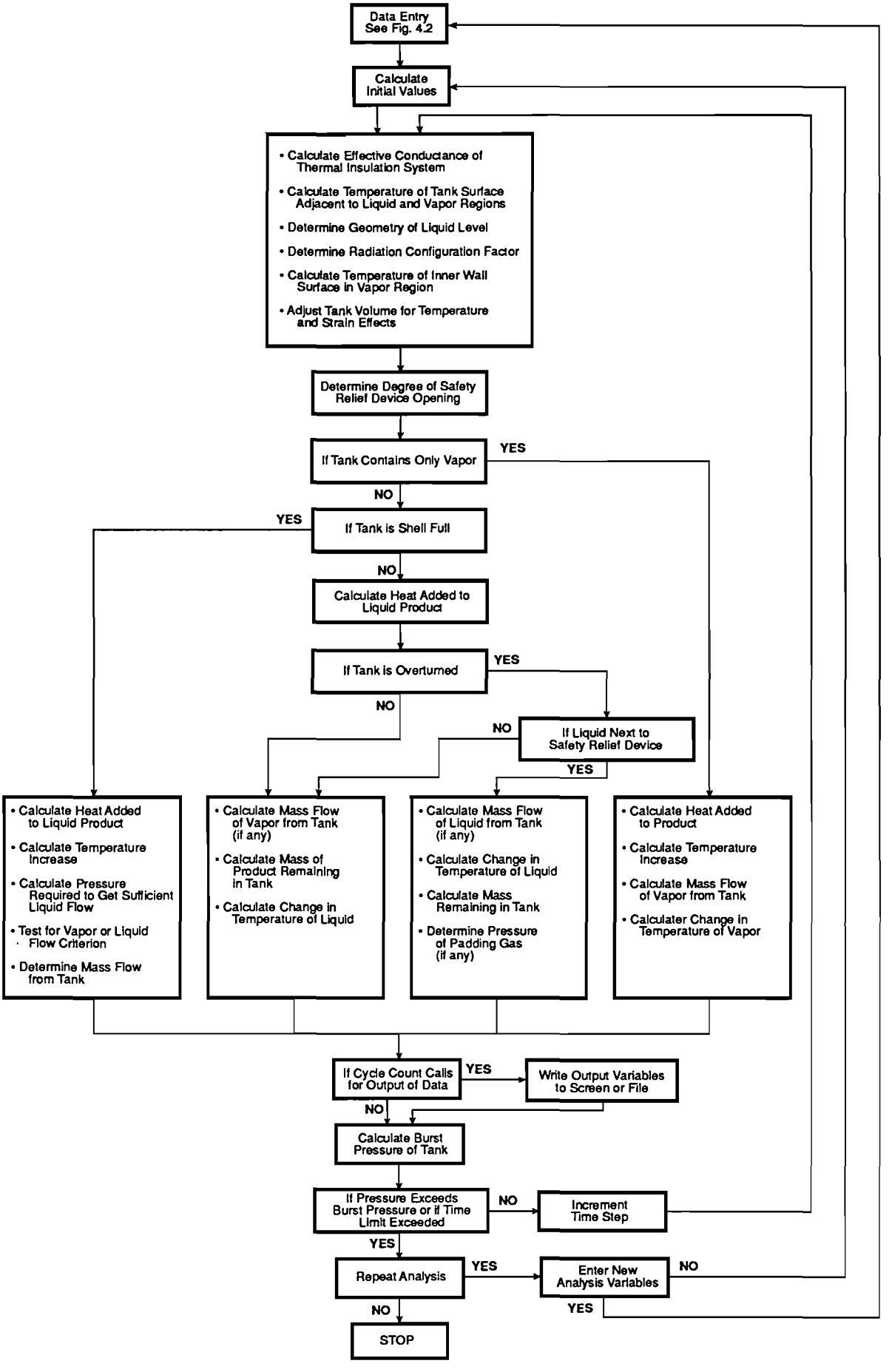

FIG. 4.1 FLOW CHART FOR PROGRAM 'AFFTAC'

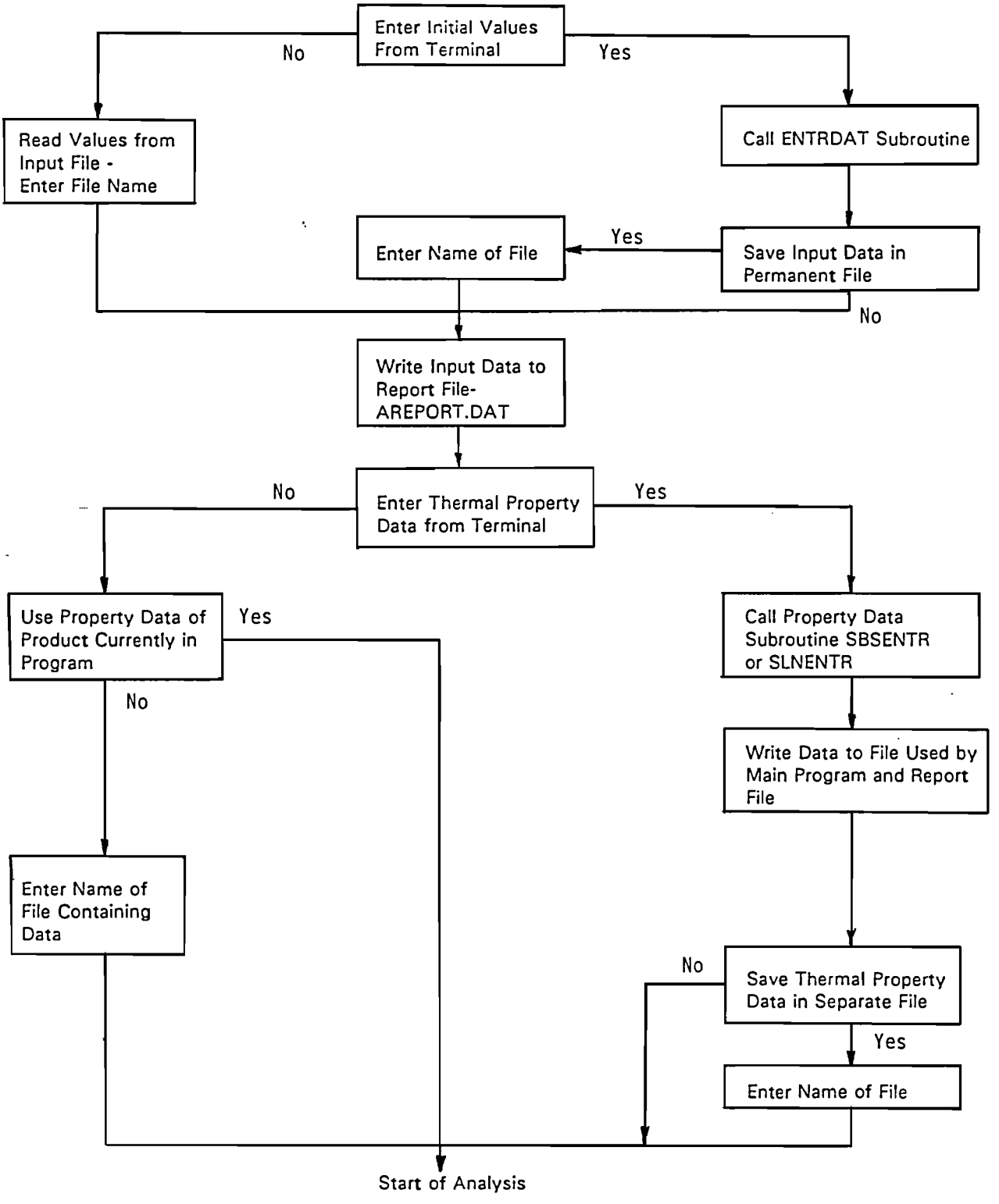

FIG. 4.2 FLOW CHART OF DATA ENTRY FOR PROGRAM 'AFFTAC'

A statement then appears on the screen asking definition of the type of data output desired. The alternatives are data written to the monitor screen, data written to a file, or both. If data is to be written to a file, a statement appears on the screen asking the name of the output file. Type in the name of the file and press the return key.

4.1.2 Calculate Other Initial Values

After the entry of initial analysis and thermal property data the program then proceeds with the calculation of other parameters.

First, conductances are calculated for the tank wall and the tank wall in combination with a film coefficient between the liquid and tank wall. The thermal resistance offered by the film coefficient is difficult to estimate. Conductances ranging from several hundred to several thousand are reported in the literature depending on the properties of the liquid, whether or not boiling is present at the interface, and the geometry of the interface (e.g., see Ref. 3). An indication of a representative value to use for this parameter can be inferred from the results* of the full scale fire test on a tank car filled with propane (Ref. 4). A value of 1000 BTU/hr-ft^2-°F is recommended as a conservative representative value of the film coefficient.

Next, other parameters, such as the volume of the tank, tank length, tank surface area, weight of tank shell, initial weight of liquid product, initial weight of padding gas, if any, weight of product in the vapor space, etc., are determined. The appropriate product subroutine is called to get the product data for these calculations. Pressures related to the safety relief valve are converted to absolute values. Pressures defining the degree of opening of a safety relief valve are also established.

If a safety relief valve is used, its cross sectional area is calculated from the standard equation for compressible gas flow through a nozzle:

$$w = 144 C_d A_v P \sqrt{\frac{g\gamma}{ZRT}\left[\frac{2}{\gamma+1}\right]^{\left[\frac{\gamma+1}{\gamma-1}\right]}} \qquad (1)$$

* The results of this test indicated that the average conductance over the surface of the car was 300 BTU/hr-ft^2-°F. The conductance of the 5/8 in. thick steel wall can be estimated at approximately 500 BTU/hr-ft^2-°F, which implies that the conductance o the film coefficient would be about 750 BTU/hr-ft^2-°F.

where : w is mass flow rate (lbs/sec),
A_v is minimum cross sectional area of valve (ft^2),
C_d is the valve discharge coefficient,
P is upstream gas pressure (psia),
T is upstream gas temperature (absolute temperature, °R*),
g is the gravitational constant (ft/sec^2),
Z is the gas compressibility factor,
R is the gas constant, equal to 1545/(molecular weight)(ft/°R), and
γ is the ratio of specific heats.

For air it is assumed that Z equals 1.0, γ equals 1.4, and R equals 53.3. T is assumed to be 519.7 or 60 °F.

Equation (1) then becomes:

$$w = 3.3958\ PC_dA_v \tag{2}$$

The density of air at standard conditions (60° F and 14.7 psia) is 0.0763 lbs/ft^3. Substituting and rearranging terms, the minimum cross sectional area of the valve can be expressed as follows:

$$A_v = (SCFM) / (C_dP_s2644) \tag{3}$$

where: SCFM is the rated flow capacity (ft^3/min), and
P_s is the valve flow rating pressure (psia).

If a safety relief valve is used, constants related to the equation for vapor flow through a valve (VLPCON), are calculated so that they can be used later in the analysis when vapor mass flow through the valve is determined. The constants are calculated, as appropriate, for vapor flow of the substance, solvent and padding gas as follows:

$$VLPCON = 144\sqrt{\frac{g\gamma}{R}\left[\frac{2}{\gamma+1}\right]^{\left[\frac{\gamma+1}{\gamma-1}\right]}} \tag{4}$$

* The notation °R is used to refer to absolute temperature in degrees Rankine.

4.2 PRELIMINARY CALCULATIONS OF FIRE EFFECTS

4.2.1 Determine Effective Conductance of Thermal Insulation and Thermal Protection System(s)

Once all the initial value calculations have been completed, the program begins the analysis of the effects of the fire on the tank car. The first step in this process is to integrate the effects of any linings, if present, into the conductance's previously determined for the tank wall and the tank wall combined with the film coefficient. This calculation also takes into account any deterioration in the thermal resistance afforded by the lining which may take place over time. This option is provided in the entry of data (see Section 2.3.4 in the User's Manual). Two options are provided, the use of a rubber liner or an organic coating.

Rubber liners are used on some acid cars. They would initially offer a high value of insulation. A typical value for the conductivity of rubber is 0.1 BTU/hr-ft-°F. This would imply a conductance of 6.4 BTU/hr-ft^2-°F for a 3/16 in. thick rubber liner, which would provide a high degree of resistance to heat flow into the tank. It is likely, however, that the effectiveness of the rubber as a thermal insulator would soon be destroyed on cars which do not have any exterior insulation because the adjacent steel tank wall would soon be heated to over 1000 °F which would melt the surface of the rubber in contact with it. Therefore, in an analysis of this condition, it is recommended that the rubber liner be considered to have an initial conductance of 6.4 BTU/hr-ft^2-°F, but that this would be degraded linearly over a 15 minute period. The rubber liner on an insulated car is likely to remain effective for a much longer time because the exterior insulation would keep the tank wall at a moderate temperature.

Some cars have an organic coating on the inside of the tank. It would offer less resistance to heat flow than a rubber liner because of its small thickness. An estimate of its conductivity is 0.25 BTU/hr-ft-°F which implies a thermal conductance of 500 BTU/hr-ft^2-°F for a 6 mil thickness. Its effectiveness would be expected to be retained for a fairly long period of time because, its conductance is high, which means the temperature of the inside of the tank wall would be close to the temperature of the product within the tank. Thus, it is less likely to be damaged by high temperature.

The overall value for the conductance of the tank (CNDLQ in liquid region or CNDVD in vapor region) is determined from the conductances of the component parts by the following formula:

$$\frac{1}{\text{CNDLQ or CNDVD}} = \sum \frac{1}{C_i} \qquad (5)$$

where: C_i is the conductance of a component of the system (e.g., tank wall, insulation, etc.)

4.2.2 Calculate Temperature of Tank Surface Outside of Liquid Region

Next, the temperature of the outer surface of the tank in the liquid region is calculated. This calculation is carried out in subroutine SURFACET. (See Appendix J.) It is assumed that a quasi-steady temperature distribution exists through the tank wall thermal insulation system and that the inside wall temperature maintains the value which has been established in the last calculational cycle. The heat input to the outside surface is assumed to be the radiant energy from the flame at the flame temperature. The radiation surface configuration factor is assumed to be unity except in the case of a torch fire where it is assumed to be 0.536. The surface emissivity factor is as entered with the input paraameters. A heat balance then exists between the heat radiated to the outside surface of the shell, the heat that is being conducted through the insulation, and the heat being radiated away back to the fire from the outside surface of the tank. The solution for the temperature of the outside wall is carried out in an iterative manner to find the heat balance under these conditions.

4.2.3 Calculate Temperature of Tank Surface Outside of Vapor Region

The calculation of the temperature of the outer wall surface in the vapor region is also made using subroutine SURFACET. The conservative assumption is made, if a padding gas was initially present, that even when the tank is shell full, there is a small volume of vapor between the top of the shell and the surface of the liquid so that the tank wall is not cooled by contact with the liquid product. This allows for the fact that the tank might not be completely level allowing a small region of vapor at the high end of the tank.

4.2.4 Establish Geometry of Liquid Levels

The calculation requires the establishment of the angle from the horizontal (THET), in radians, of a radial line to the liquid level at the surface of the tank. The angle THET is a function of the fraction of tank volume occupied by the liquid, which is defined as FRAC. The determination of THET requires an iterative solution of the equation:

$$FRAC = 1/\pi \, [\pi/2 + THET + \sin(THET) \cos(THET)] \qquad (6)$$

4.2.5 Radiation Surface Configuration Factor

First, the area of the surface of the liquid (AREALQ) within the tank is calculated. Next, the radiation surface configuration factor for the transfer of radiant energy from the tank wall over the vapor space to the surface of the liquid is established. The view factor is estimated from the relationship:

$$A_1 F_{12} = A_2 F_{21} \qquad (7)$$

where: F_{ij} is the radiation surface configuration factor for a gray body.

F_{12} can be calculated taking into account the emmissivities of the two surfaces by using the following equation:

$$F_{12} = \frac{1}{1/f_{12} + (1/\varepsilon_1 - 1) + (A_1/A_2)(1/\varepsilon_2 - 1)} \qquad (8)$$

where: f_{12} is the radiation surface configuration factor for a black body, and
ε_1 and ε_2 are emmissivities of surfaces 1 and 2.

In using this equation it is assumed that $f_{liq,tk} = 1$ since the liquid surface sees only the tank wall.

The radiation surface configuration factor for the liquid to the tank is designated FLQT, and the factor for the tank to the liquid is designated FTLQ. FTLQ is calculated from FLQT using the reciprocal relationship. The emissivity of the inside tank wall is assumed to be 0.8. The emissivity of the liquid surface is assumed to be 0.9.

These equations are used with the assumption that the conditions are uniform on the inside surface of the tank. This is not strictly correct because the temperature of the inner wall surface would be cooler for regions closer to the surface of the liquid. The temperature would depend on the length of time the wall has been exposed to the vapor and also the amount of radiant energy that has been received from the hotter part of the wall. Uniform conditions will be closely approached when the liquid level is near the top of the tank, because a slight drop in the liquid level will expose a large area of the inner surface of the tank. Uniform conditions will also be approached when the level of the liquid is low. Although the transient differences may be larger when the liquid level is near the center of the tank, calculations show that they would only have a small effect on the total heat transfer.

4.2.6 Calculate Temperature of Inner Wall Surface in Vapor Region

The next step is to calculate the temperature of the tank wall in the vapor region. This is done by taking the value for the outer tank wall surface temperature previously computed, and establishing a heat balance on the inside surface between the heat that is being conducted through the tank wall and insulation system, and the heat that is being lost by convection and radiation to the inside of the tank. The calculation also considers that there is small amount of convected heat loss. Various values for the convection coefficient are assumed depending on the orientation of the car, the fraction of tank volume occupied by liquid and the flow rate through the safety relief device. This characteristic has been deduced, in part, from the full scale fire tests.

4.2.7 Adjust Tank Size for Temperature and Strain Effects

Next, the size of the tank is adjusted for temperature and strain effects. The temperature of the tank adjacent to the liquid is used to determine the expansion of the volume of the tank due to its rise in temperature. The use of the liquid temperature is a reasonable assumption because the effect is only significant when the product is near the shell full condition. Calculation of the expansion of the tank is based on the following equation:

$$l_1 = l_0 [\, 1 + \alpha\, (T_1 - T_2)] \qquad (9)$$

where: l_1 is length dimension at temperature T_1 (1/°F),
l_0 is length dimension at temperature T_0 (1/°F), and
α is a constant, which depends on the type of material (1/°F).

The ratio of any dimension on the tank at elevated temperature to the original dimension is then:

$$\frac{1 + \alpha T_2}{1 + \alpha T_1} \qquad (10)$$

where: T_2 is the elevated temperature of the tank, and
T_1 is the initial temperature of the tank.

Since this ratio applies to each of the three spatial dimensions, the ratio of volume expansion would be the cube of the ratio.

The size of the tank is also adjusted to account for the membrane stresses in the tank caused by the circumferential and axial stresses.

The circumferential and axial strains associated with these stress are given as follows:

$$\varepsilon_c = \sigma_c/E - \mu(\sigma_a/E) \qquad (11)$$

$$\varepsilon_a = \sigma_a/E - \mu(\sigma_c/E) \qquad (12)$$

where: ε_c is the circumferential strain,
ε_a is the axial strain,
E is the Modulous of Elasticity of tank material (psi),
μ is Poisson's ratio assumed to be 0.3 for all tank materials,
σ_c is circumferential stress, equal to pd/2t (psi),
σ_a is the axial stress, equal to pd/4t (psi),
p is the internal pressure (psig),
d is the tank inside diameter (ins.), and
t is tank wall thickness (ins.).

Substituting the values for stresses in the strain equations leads to the following relationships:

$$\varepsilon_c = 0.425 \frac{pd}{E\,t}$$

$$\varepsilon_a = 0.100 \frac{pd}{E\,t} \qquad (13)$$

The cross sectional area of the tank would increase by a factor $(1 + \varepsilon_c)^2$. The volume of the tank would then increase by the following factor:

$$[\,(1 + \varepsilon_c)^2\,(1 + \varepsilon_a)\,] \qquad (14)$$

4.2.8 Determine Vent Opening or Degree of Valve Opening

The next step in the calculation is to determine the degree to which the safety relief valve has opened, when this type of device is used. Three pressure levels are defined with reference to the start-to-discharge pressure. These are the fully opened pressure, which is assumed to be 103 percent of the start-to-discharge pressure, the valve closing pressure, which is assumed to be 82 percent of the start-to-discharge pressure, and a reference pressure on the closing stroke of the valve which is 88 percent of the start-to-discharge pressure. The degree to which the valve is opened depends on whether the pressure is increasing or decreasing. The relationship between the degree of valve opening and the pressure is shown in Fig. 4.3. Note that an alternate closing path is shown, which represents the condition where the valve starts to close before it has fully opened.

4.2.9 Determine Conditions in the Tank

The next step in the calculation is to determine which of the four conditions exist within the tank. These have been previously defined as:

- Liquid and vapor within the tank with vapor adjacent to safety relief device,
- Liquid and vapor within the tank with liquid adjacent to safety relief device,
- Shell full of liquid product, and
- Containing only product in the vapor phase.

The calculational procedure is divided at this point so that each of these cases is considered separately. The general procedure is the same in each case, the major difference being associated with the determination of the mass flow rate of the product through the valve or vent.

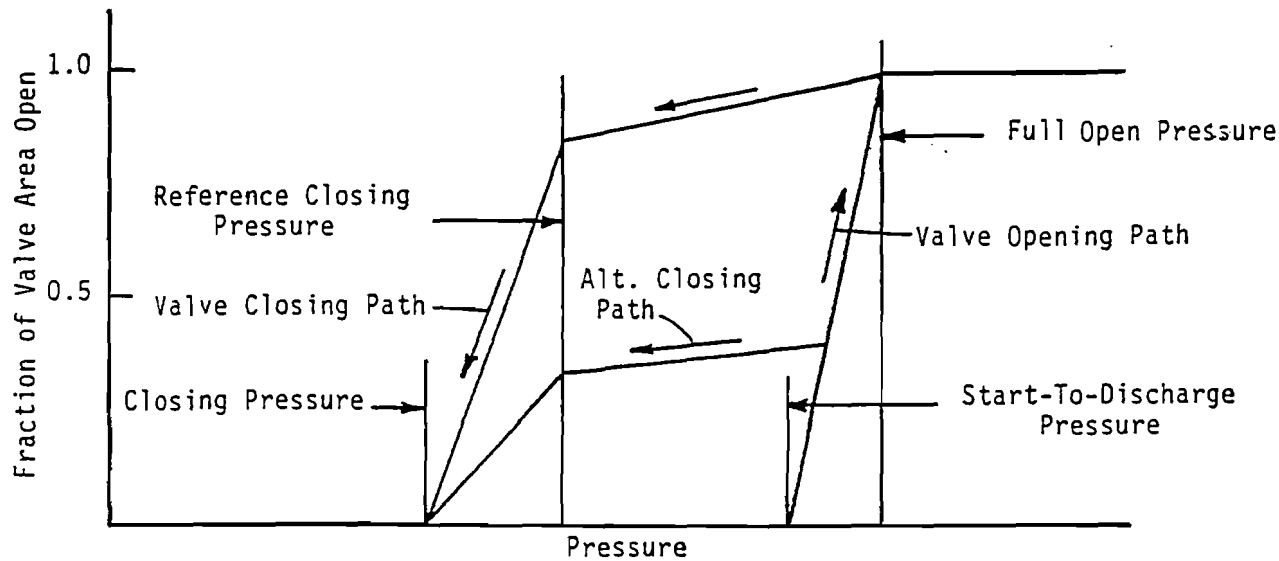

FIG. 4.3 RELATIONSHIP BETWEEN DEGREE OF VALVE OPENING AND PRESSURE

4.3 CALCULATION OF EFFECTS WITH LIQUID AND VAPOR WITHIN TANK WITH VAPOR ADJACENT TO SAFETY RELIEF DEVICE

4.3.1 Calculate Heat Transfer to Liquid Product

If the type of fire is not a torch fire, the heat transfer to the liquid product is determined by calculating the heat conducted through the portion of the tank shell which is in contact with the liquid and by estimating the radiant heat transfer to the surface of the liquid from the tank wall above the liquid. In the calculation of the heat conducted through the wetted area of the shell, it is assumed that the heat transfer in the circumferential direction is negligible, a quasi-steady situation exists (transient effects are neglected), and that the heat capacity of a jacket, if present, and insulation materials can be neglected. If the effect of discontinuities on heat transfer is considered, the heat transfer through these discontinuities is added to the heat input calculated for the insulated part of the tank.

If the type of fire is a torch fire the heat input is calculated for a 16 ft^2 portion of the tank wall adjacent to the liquid. The effect of discontinuities are not included.

The radiant exchange of energy between the tank shell above the liquid and the liquid surface has been discussed in Section 4.2.5.

4.3.2 Calculate Mass Flow Rate Through Safety Relief Device

The mass flow rate through the safety relief device is computed for vapor flow, if the pressure is sufficient to open the valve or to have ruptured the frangible disc. The calculation is first made by using the standard compressible gas flow equation, for flow through a nozzle, which was previously given in Equation 1. The calculation makes use of the VLPCON constants calculated at the beginning of the analysis. The formula for the mass flow rate becomes.

$$W = (VLPCON)\, C_d A P \sqrt{\frac{1}{ZT}} \qquad (15)$$

Where there is more than one component in the vapor, such as a padding gas, or vapor from the solvent of a commodity that is in solution, it is assumed that the mass flow of each component is proportional to the partial pressure of each gas. The effect of the padding gas on the mass flow rate becomes negligible after a short period of time,

because its mass in relation to the mass of the product is quite small. Examination of the logic in the calculation will show that the out-flows are arbitrarily reduced if the resulting pressure would be less than atmospheric in the case of a vent, or less than the valve closing pressure in the case of a safety relief valve. This compensates for the consequences of using a finite time step which may not be sufficiently accurate for rapidly changing conditions. The effect is significant only as the shell full condition is approached.

If the total pressure within the tank is greater than atmospheric pressure (14.7 psia), but less than 27.0 psia, the calculated outflow of vapor is reduced because a critical flow condition would not be reached at the minimum area cross section of the valve or vent.

If less than 2.5 percent of the tank is filled with liquid, rapid changes in the outflow are limited by adding one-half of the newly calculated outflow to one-half of the outflow calculated in the previous step.

After these calculations are completed, additional checks are made, if a padding gas was initially present, to determine if the outflow is such that the pressure within the tank would be below atmospheric pressure in the case of a vent or below the closing pressure in the case of a relief valve. It the pressure is below the appropriate limit, the calculated outflow of vapor is reduced further to keep the vapor pressure in the tank at the limit.

4.3.3 Calculate Change in Mass of Product

The next step in the calculation is to determine the change in the mass of product within the tank and its apportionment between the liquid and vapor.

4.3.4 Calculate Temperature Rise of Liquid

The temperature rise of the liquid product is calculated by determining the net heat flow into the liquid product which is the difference between the total heat flow to the product and the heat absorbed by the vaporization of the product.

4.4 CALCULATION OF LIQUID AND VAPOR WITHIN TANK WITH LIQUID ADJACENT TO SAFETY RELIEF DEVICE

This case represents the overturned car condition.

4.4.1 Calculate Heat Input to Liquid Product

The heat transferred to the liquid product within the time increment is determined by calculating the heat conducted through the wetted area of the tank and the heat radiated to the surface of the liquid from the inner tank shell surface over the vapor space.

4.4.2 Calculate Liquid Flow Rate Through Safety Relief Device

The liquid flow rate through the safety relief device, if it is open is calculated using subroutine AVFLOW, (see Appendix K) which assumes homogenous, isentropic, two-phase flow (liquid and vapor). Two-phase flow effects will be a significant factor only if the product has a high vapor pressure.

4.4.3 Calculate Change in Temperature

The change in temperature of the liquid of the product over the time increment is calculated by considering the heat added to the liquid product, the amount of liquid that is vaporized within the time increment, and the work done in expelling the fluid from the tank.

4.4.4 Determine New Properties

The properties of the product at the new temperature are determined by calling the appropriate property subroutine.

4.4.5 Calculate Remaining Mass of Product and Padding Gas

The remaining mass of the product within the tank, and its division between liquid and vapor states, is recalculated under the new temperature and pressure conditions.

The following assumptions are made for the cases where a padding gas is used. First, it is assumed that initially the padding gas in the vapor space is in equilibrium with the gas dissolved in the liquid product. Because of the small outage volume in which the gas is contained, there may be more gas dissolved in the product than present in the vapor phase. It is also assumed that there is no exchange between the padding gas dissolved in the fluid and the gas in the vapor phase during the course of the exposure to the fire environment. If equilibrium were to be maintained between the padding a gas in the vapor phase and the gas dissolved in the product, there would first be an increase in the amount of the dissolved gas and a corresponding decrease in the amount of padding gas vapor. This would be caused by the increase in pressure, when the outage volume is diminished by the expansion of the product as it is heated.

This would mean the pressure of the padding gas would be less than that predicted by the assumption of no exchange between the vapor and the dissolved state. After the safety relief device opens and the product starts to flow from the car, the outage volume would increase and the corresponding decrease in the vapor pressure would cause more padding gas to be liberated from the fluid. Also, as the liquid product is heated, more of the padding gas would be liberated from the fluid. Thus, there would be a tendency to maintain the partial pressure of the gas above that predicted by the assumption of no exchange between the vapor and the dissolved states. The assumption that equilibrium is maintained would delay slightly the time at which the safety relief device is first opened, but increase the pressure after the product starts to flow through the valve. These effects would counteract one another. In any event, when the outage gets to approximately 10 percent, the effect of the padding gas becomes insignificant on the prediction of flow through the relief device.

The major reason that the exchange of padding gas between the vapor state and the dissolved state is not included in the analysis is that one would expect that equilibrium conditions would not be attained during the course of the phenomena predicted by the fire environment. There would not be sufficient time for the effect of the partial pressure of the padding gas in the vapor state to be communicated to all portions of the liquid within the tank and for gas to be absorbed in the early phases of the predicted effects. Similarly, the effect of the decrease in the partial pressure of the padding gas once the device is opened, would not be immediately communicated to all portions of the liquid in the tank so a non-equilibrium condition would likely exist. Consequently, the assumption that there is no exchange of the padding gas from the vapor phase to the dissolved state is believed to have minimal significance in the predicted events associated with the flow of the product from the tank car.

4.5 CALCULATION OF EFFECTS WITH SHELL FULL CONDITIONS

This case considers the condition where the tank is completely filled with liquid.

4.5.1 Calculate Heat Transferred to Liquid Product

The total heat transmitted to the liquid product of the tank in the time increment is calculated.

4.5.2 Calculate Change in Temperature

The change in temperature of the liquid product is established from the heat transferred into the tank.

4.5.3 Determine New Properties

The new properties of the product at the higher temperature are determined by calling the appropriate property subroutine.

4.5.4 Calculate Required Volume of Flow

The volume that must be discharged through the safety relief device in the time increment is determined by calculating the change in the specific volume of the product over the time increment.

4.5.5 Calculate Pressure Required to Generate Sufficient Flow

The pressure that must be developed within the tank so that the required volume will be discharged through the valve is calculated. This pressure is calculated by assuming that the pressure difference driving the fluid out through the device will have as the lower pressure the maximum of the saturated vapor pressure or atmospheric pressure. This is a conservative assumption. Consideration of two-phase flow effects for high vapor pressure products might result in a slightly lower tank pressure, but the difference would be small. The following formula is utilized:

$$w = C_d A \rho \sqrt{(2g/\rho)(p_c - p_s)} \qquad (16)$$

where: w is the mass flow rate, (lbs/sec),
C_d is the liquid discharge coefficient of the valve,
A is the cross sectional area of the valve (ft^2),
ρ is the density of the liquid (lbs/ft^3),
p_c is the upstream fluid pressure (lbs/ft^2), and
p_s is the saturated vapor pressure at the temperature of the fluid, or atmospheric pressure, whichever is greater (lbs/ft^2).

If the vapor pressure is less than atmospheric pressure, in the case of a vent, or less than the valve closing pressure, in the case of a valve, the pressure is reset to one of these values. The tank remains full.

If sufficient vapor flow can be generated with the pressure at saturated conditions, in the case of an upright car, enough product may be passed through the

relief device so that the tank will not be shell full the next time through the calculational cycle. The liquid flow calculation is made using subroutine AVFLOW so that two-phase flow effects are considered. If these calculations indicate that the mass flow is less than the minimum required for the shell full condition, an index is set so that a shell full condition will be recognized the next time through the calculational cycle. If the calculations show that the mass flow is greater than the minimum required for the shell full condition, the index is set so that a non-shell full condition will be recognized.

4.5.6 Calculate Mass of Product Remaining in Tank

The remaining mass in the tank is calculated. The mass flow from the tank will be the larger of the mass flow required to accommodate the increase in specific volume of the product or the mass flow calculated from saturated vapor flow for an upright car or liquid flow for an overturned car.

4.6 CALCULATION OF EFFECTS WITH VAPOR PHASE ONLY WITHIN TANK

This condition occurs after the critical temperature* is reached (a condition obtained only at high temperatures for the products: propane, ethylene oxide, propylene, or propylene oxide, which have their properties contained in the program) or after the vaporization of all of the liquid within the tank. The temperature of the remaining product within the tank will increase at a fairly rapid rate during this phase because of the relatively low mass of product and the fact that there is no heat absorbed by the vaporization of the liquid. During this condition the pressure within the tank may increase due to the increased pressure of the product, but the increased pressure will be relieved by flow through the safety valve closing pressure.

4.6.1 Calculate Heat Transfer to Vapor Product

The first step in the calculation of this case is to determine the heat transfer to the vapor product. This is estimated by assuming that there is a convection coefficient of 1.0 (BTU/hr-ft^2-°F) between the vapor and the inner wall of the tank.

4.6.2 Calculate Change in Pressure

The change in pressure of the vapor within the tank is calculated using the ideal gas law considering the change in temperature from the beginning of the time increment.

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* See note on page 8.

4.6.3 Calculate Mass Flow Out

The mass out through the safety relief device is calculated using the equation previously presented for vapor flow (Equation 1). A compressibility factor of 0.7 is assumed for all commodities except for propane where it is represented as a function of the total pressure within the tank, the temperature and specific volume.

4.6.4 Calculate Change in Tank Temperature

The change in the temperature of the product within the tank over the time increment is calculated considering the heat transferred to the product and the work done in expelling the gas from the tank.

4.7 OUTPUT DATA

The program provides two different types of format for displaying the results of the calculations. The first format writes data to a file at selected time intervals during the course of analysis. The interval is selectable as a multiple of the time increments used during the analysis. The second format displays a more limited set of data on the monitor screen at selected intervals. The output variables displayed at the monitor are: time, the pressure within the tank, the burst pressure of the tank, the temperature of the product, the fraction of the tank filled with liquid, the fraction of the original mass of product remaining in the tank, and the rate of product out-flow through the safety relief device. The output to the monitor pauses after 20 lines of data have been displayed on the screen. The calculation can be restarted by pressing the ENTER key.

The output variables which are written to the computer file include all of the above along with the temperature of the tank over the vapor space. The rate of product out-flow that is displayed in each of these cases is the average out-flow over the number of time increments between the display of data.

If during the course of the analysis the temperature of the product exceeds the temperature for which thermal property data have been entered into the program, the following message will appear in the output data:

OUTSIDE TEMPERATURE RANGE OF THERMAL PROPERTY DATA

The analysis program will still run if a temperature limit is exceeded, but reduced accuracy should be anticipated because the property values would be determined by extrapolation rather than by interpolation.

If during the course of the analysis of a solution, the concentration of the solution goes outside the range for which thermal property data have been entered into the program, the following message will appear in the output data:

OUTSIDE CONCENTRATION RANGE OF THERMAL PROPERTY DATA

The analysis program will still run if the concentration range has been exceeded, but reduced accuracy should be anticipated because the property values would be determined by extrapolation rather than interpolation.

If a critical temperature has been entered into the program, the program will terminate the analysis if the critical temperature is exceeded. A message will appear in the output data stating:

CRITICAL TEMPERATURE EXCEEDED

4.8 COMPARE TANK BURSTING PRESSURE AND INTERNAL PRESSURE

The final step in the calculation is to compare the internal pressure in the tank with its bursting pressure. The bursting pressure is determined from the tensile strength of the tank material, which is a function of its maximum temperature. If the internal pressure exceeds the burst pressure it is assumed that the tank will fail and the calculation is stopped. The burst pressure is calculated by substituting the tensile strength in the formula for the membrane circumferential stress in the tank as follows:

$$P_b = 2\sigma_t t / d \qquad (17)$$

where: P_b is the burst pressure (psig),
σ_t is the tensile strength (psi),
t is the tank wall thickness (ins.), and
d is the inside diameter of the tank (ins.).

A number of functions are contained in the program which define the reduction in strength of tank materials with increasing temperature. These functions reduce the value of the tensile strength of the tank material, which is entered into the program at the beginning of the analysis, as the temperature of the tank increases. The reduced strength is then used to calculate the burst pressure. One function is used for carbon

steel. It is based on data for TC128 steel given in Ref. 14. Two functions are used for stainless steel. They are based on data in Refs. 15 and 16. Three functions are used for aluminum alloys. They are based on data in Ref. 13. The program uses the identification number for the tank material, IMT, to select the appropriate function.

4.9 CHECK FOR TIME LIMIT

If the burst pressure has not been exceeded, a check is made to determine if the time limit has been exceeded. If so, the calculation is halted. Otherwise, the time is incremented and the calculation returns to the point where the effective conductance of the thermal shield is determined (see Section 4.2.1).

4.10 PROGRAM TERMINATION OR RESTART

After the analysis has been completed an option is provided to terminate the operation of the program or conduct a repeat analysis. If a repeat analysis is desired, an option is provided to begin the analysis using the same initial conditions and thermal properties as the preceding analysis, or to change the initial conditions.

4.1.1 PROGRAM LISTINGS

The source code for the main program AFFTAC.FOR is presented in Appendix A. The source codes for the subroutines are presented in Appendices B through L.

5. REFERENCES

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APPENDIX A

SOURCE CODE FOR MAIN PROGRAM: AFFTAC

```
C   AFFTAC.FOR IS A PROGRAM FOR THE ANALYSIS OF TANK CARS IN THE
C   POOL OR TORCH FIRE ENVIRONMENTS VENTING LIQUID OR VAPOR.    THE
C   PROGRAM USES SUBROUTINES FPRPSBS, FPRPSLV, AVFLOW, ASETUP, SURFACET,
C   TSHIELD, ENTRDAT, ALYRPT, SBSENTR, SLNENTR, SBSPROP, AND SLNPROP.
C.....................................Version 3.0, November 11, 1998
      REAL CNDLQ,CNDVP,TWAL,TWAV,ATEM,WLET
      REAL NETQ,LENG,KWALL,WOUT,CONC,TEMP,CINTV,FLFAC
      REAL LINTV,MLWSBS,MLWSLV,SCFM,CNDD,ERAD,TFLA
      REAL THIC,A1,A2,A3,TTNK,TTNV,CDJNT,CNDWL
      REAL WOUT2,DELT,CVLQ,PNIT,TIME
      INTEGER*4 NTIME
      INTEGER*2 INTYPE,OTYPE,NALYSS,IPFST
      INTEGER*2 IMT,IPTYP,ISBSL,IPR,ICR,IPAD,IVLTYP
      INTEGER*2 INS,KINDX,IDSC,LLNG,ILN,ILD,IFRTYP,INTV
      CHARACTER*1 RESPNS
      CHARACTER*12 FNAME,ANAME,PNAME
      CHARACTER*30 QNAME,CPRD(21)
      DIMENSION CDLIN(2)
C
      COMMON/TANK/SIZE,DIAI,WTKI
      COMMON/MATL/IMT,TNSRTH,PNBRS,PCBRS
      COMMON/PRDCT1/IPTYP,ISBSL,IPR,ICR,TCRIT
      COMMON/PRDCT2/FRAT,TEMC,CONC,IPAD,PPID
      COMMON/SRELF1/IVLTYP,AVENT,VGTD,SCFM
      COMMON/SRELF2/PGSD,PGTD,CVAD,CVLQ,TILT
      COMMON/THRML1/INS,CNDD,KINDX,CNDI,CINTV
      COMMON/THRML2/THIC,A1,A2,A3
      COMMON/THRML3/IDSC,USUM,LLNG,ILN,ILD,LINTV
      COMMON/FIRE/IFRTYP,TEMF,CFRA,CATR,ERAD
      COMMON/ITIME/TLIMIT,DELT,INTV
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
      COMMON/NAME/CPRD
C
       WRITE (*,*)
     1  'VERSION 3.0 OF PROGRAM AFFTAC, November 11, 1998'
      WRITE (*,*) '   '
       WRITE (*,*) '    Press Enter to Proceed'
      READ (*,*)
      WRITE (*,*) '   '
C
      NALYSS=0     ! identifier for repeat analysis
      QNAME='BLANK'
      WRITE (*,*)
     1 'ENTER CODE DESIGNATING PROCEDURE FOR ENTERING ANALYSIS DATA'
      WRITE (*,*) '  (enter integer number):'
      WRITE (*,*) '  1 - Data entry at monitor'
      WRITE (*,*) '  2 - Data read from existing file'
      READ(*,*) INTYPE
403   CONTINUE
       IF (INTYPE.EQ.1) CALL ENTRDAT(QNAME,NALYSS)
       IF (INTYPE.EQ.2) THEN
         WRITE (*,*) 'ENTER NAME OF FILE CONTAINING ANALYSIS DATA'
         WRITE (*,*) '  (Maximum of 12 Characters):'
         READ (*,519) ANAME
         OPEN(UNIT=11,FILE=ANAME,STATUS='OLD')
         READ (11,501) SIZE,DIAI,WTKI
```

```
            READ (11,502) IMT,TNSRTH,PNBRS,PCBRS
            READ (11,503) IPTYP,ISBSL,IPR,ICR,TCRIT
            READ (11,504) FRAT,TEMC,CONC,IPAD,PPID
            READ (11,505) IVLTYP,AVENT,VGTD,SCFM
            READ (11,507) PGSD,PGTD,CVAD,CVLQ,TILT
            READ (11,509) INS,CNDD,KINDX,CNDI,CINTV
            READ (11,511) THIC,A1,A2,A3
            READ (11,513) IDSC,USUM,LLNG,ILN,ILD,LINTV
            READ (11,515) IFRTYP,TEMF,CFRA,CATR,ERAD
            READ (11,517) TLIMIT,DELT,INTV
          ENDIF
501       FORMAT (F8.0,F8.2,F8.4)
502       FORMAT (I8,F8.0,2F8.1)
503       FORMAT (4I8,F8.2)
504       FORMAT (F8.3,F8.2,F8.3,I8,F8.3)
505       FORMAT (I8,2F8.2,F8.0)
507       FORMAT (5F8.2)
509       FORMAT (I8,F8.2,I8,2F8.2)
511       FORMAT (F8.2,3F8.3)
513       FORMAT (I8,F8.2,3I8,F8.2)
515       FORMAT (I8,F8.1,3F8.2)
517       FORMAT (2F8.2,I8)
519       FORMAT (A12)
521       FORMAT (A30)
          AVHOLD=AVENT
          CNHOLD=CONC
          IPHOLD=IPAD
C
          IF (INTYPE.EQ.2.AND.IPR.GT.16) THEN
            WRITE (*,*)
     1         'ENTER NAME OF PRODUCT (Maximum of 30 Characters):'
            READ (*,521) QNAME
          ENDIF
C.....Write input data to a report file.....
C
          CALL ANLYRPT (QNAME)
C
C.....Select method for entering thermal property data.....
C
          IF (NALYSS.EQ.0.AND.IPTYP.EQ.2) THEN
            IF (ISBSL.EQ.1) THEN
              OPEN (UNIT=16,FILE='NEWSBS.DAT',STATUS='NEW')
               CALL SBSENTR (QNAME)
            ENDIF
            IF (ISBSL.EQ.2) THEN
              OPEN (UNIT=16,FILE='NEWSLN.DAT',STATUS='NEW')
               CALL SLNENTR (QNAME)
            ENDIF
          ENDIF
          IF (NALYSS.EQ.0.AND.IPTYP.EQ.3) THEN
            WRITE (*,*)
     1       'ENTER NAME OF FILE CONTAINING THERMAL PROPERTY DATA'
            WRITE (*,*) '  (File must be in proper format; see'
            WRITE (*,*) '   Users Manual; maximum of 12 characters)'
            READ (*,519) PNAME
            OPEN (UNIT=13,FILE=PNAME,STATUS='OLD')
          ENDIF
C
405       CONTINUE
          WRITE(*,*)
```

```
     1    'ENTER CODE FOR DESIGNATION OF TYPE OF DATA OUTPUT'
          WRITE(*,*)'  1 - for data display at monitor'
          WRITE(*,*)'  2 - for writing data to file'
          WRITE(*,*)'  3 - for both types of output'
          READ(*,*) OTYPE
          IF (OTYPE.EQ.2.OR.OTYPE.EQ.3) THEN
            WRITE(*,*)'ENTER OUTPUT FILE NAME maximum 12 characters'
            READ(*,519) FNAME
            OPEN(UNIT=19,FILE=FNAME,STATUS='NEW')
          ENDIF
C.....Set up conductances for tank wall and film coefficient.....
          IF (IMT.LE.15) KWALL=26.0     ! conductivity of carbon steel
          IF(IMT.GE.16.AND.IMT.LE.19)KWALL=10.0 ! cond. of stainless steel
          IF (IMT.GE.20) KWALL=100.0    ! conductivity of aluminum
          CWALI=12.0*KWALL/WTKI
          CFILM=1000.0
          CJNTI=CWALI*CFILM/(CWALI+CFILM)
          CDLIN(1)=500.0
          CDLIN(2)=6.4
C
          IPAD=IPHOLD
          CONC=CNHOLD
          AVENT=AVHOLD
          WSBOUT=0.0
          WSVOUT=0.0
          PASD=PGSD+14.7
          PATD=PGTD+14.7
          DHTK=DIAI/12.0
          ITEMP=0          ! index for temperature range message
          ICONC=0          ! index for concentration range message
          IFRAC=0          ! index for shell full (1 is shell full)
          IF (FRAT.GE.(1.0)) THEN
            FRAT=1.0                    ! Vs 3.0
            IFRAC=1                     ! Vs 3.0
          ENDIF
          NVLV=0           ! valve opening index (0 is closed)
          NFRST=0          ! index for first time valve opens
          NTIME=0          ! time counting index
          IPFST=0          ! changed first time thru property SUBROUTINE
          NREFTM=INT(100.0*DELT+0.0001)
          TEMP=TEMC
          WAVOUT=0.0       ! average product outflow for data output
C
C....INITIALIZATION OF THERMAL PROPERTIES AT START OF ANALYSIS
C
        IF (IPTYP.EQ.1) THEN
          IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
          IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
        ENDIF
        IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
            IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
            IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
        ENDIF
        SZGL=SIZE/7.48                      ! size in cubic feet
        TPSZGL=SZGL                         ! size adjusted for expansion
        LENG=SZGL/(0.7854*DHTK*DHTK)        ! length of tank (ft)
        AREA=3.1416*DHTK*(LENG+0.5*DHTK)    ! surface area of tank (sq ft)
        WTWL=WTKI*0.283*144.0               ! weight of tank wall (lbs/sq-ft)
C
         IF (IPAD.EQ.1) PPAD=14.7-PSBS-PSLV
```

```
      IF (IPAD.EQ.2) PPAD=0.0
      IF (IPAD.EQ.3) PPAD=PPID+14.7-PSBS-PSLV
      IF (IPAD.EQ.1.AND.PPAD.LE.(0.0)) PPAD=0.0
      IF (IPAD.EQ.3.AND.PPAD.LE.(0.0)) THEN
        IPAD=2
        PPAD=0.0
      ENDIF
      WGNT=(1.0-FRAT)*SZGL*2.61*PPAD/   ! weight of padding gas
     1      (460.0+TEMC)                 ! at start of analysis (lbs)
      WPAD=WGNT
      WLIQ=SZGL*FRAT/SPLQ             ! weight of liquid prdct in tank (lbs)
      WVAP=(1.0-FRAT)*SZGL/VVAP       ! wght of prdct vap in tank (lbs)
      WGHT=WLIQ+WVAP                  ! weight of product (lbs)
      WSBS=WGHT*CONC
      WSLV=WGHT*(1.0-CONC)
      AVLV=SCFM/(CVAD*PASD*2644.0)      ! discharge area of safety
C                                       ! relief valve (sq ft)
      KDCNT=0
      FRAC=FRAT
      TIME=0.0
      WOUT=0.0
      AVENT=AVENT/144.0                 ! convert to square feet
      ATEM=0.0                          ! vent or valve closed
      FMSS=WGHT
      PNIT=PPAD
      PTOT=PSBS+PSLV+PNIT
      PSIG=PTOT-14.7
      CNDLQ=CNDI
      CNDVP=CNDI
      CLINT=A1*12.0/THIC                ! initialization
      CVINT=A1*12.0/THIC                !   for INS=6
      TEMH=TEMC
      FMAT=1.0
      KCNT=INTV                           ! count for display interval
      KPAGE=0
      KCNTRL=21
      WOLST=0.0
      RQLST=0.0
      TCLST=0.0          ! value of TCFM from prior time step; TCFM
C                        ! is flow capacity of partially open valve.
      TFLA=(TEMF+460.0)/1000.0       ! flame temperature (0.001 deg R)
      TTNK=(TEMC+460.0)/1000.0       ! inner tank wall temp. next to
C                                    !   liquid (0.001 deg R)
      TNKHLD=TTNK                    ! hold initial value of TTNK
      TTNV=(TEMC+460.0)/1000.0       ! inner tank wall temp. next to
C                                    !   vapor space (0.001 deg R)
      TWAL=TFLA-0.001                ! outer jacket (or tank) surface temp.
C                                    !   next to liquid (0.001 deg R)
      TWAV=TFLA-0.001                ! outer jacket (or tank) surface temp.
C                                    !   next to vapor (0.001 deg R)
      TMIV=TTNV+0.25*(TWAV-TTNV)     ! initialization for INS=6
      TMIL=TTNK+0.25*(TWAL-TTNK)     ! initialization for INS=6
      PLST=0.0                       ! value of PTOT from prior time step
      POPN=1.03*PGTD+14.7            ! valve fully open pressure (psia)
      PRTN=0.88*PGTD+14.7            ! valve 85% open closing press (psia)
      PCLS=0.82*PGTD+14.7            ! valve closed pressure (psia)
      TEMP=TEMC
      PCOM=0.0
      REQL=0.0
      TRLT=3.1416*(0.5-TILT/180.0)   ! angle (rad) with ref. to horz.
```

```
        KIDN=0                        ! analysis type, e.g. shell full, etc.
        VLPPCN=75.31                     ! padding gas (air)
        ZPAD=0.98                        ! compressibility, air
C
        IF (INS.EQ.5) THEN               ! initialization needed when
          CNDLQ=0.2                      !   considering variable
          CNDVP=0.2                      !   conductivity
        ENDIF
C
        IF (IFRTYP.EQ.2) THEN            ! view factor for
          FLFAC=0.536                    ! torch fire
        ELSE
          FLFAC=1.00
        ENDIF
C
C................BEGINNING OF CALCULATIONS.............................
        IF (NTIME.EQ.0) GO TO 153
211     CONTINUE
        NTIME=NTIME+1
C
C..........following is calculation of valve flow constants..............
        GSBFCT=GAMSBS*((2.0/(GAMSBS+1.0))**((GAMSBS+1.0)/(GAMSBS-1.0)))
        GSLFCT=GAMSLV*((2.0/(GAMSLV+1.0))**((GAMSLV+1.0)/(GAMSLV-1.0)))
        VLSBCN=144.0*SQRT(32.2*MLWSBS*GSBFCT/1545.0)
        VLSLCN=144.0*SQRT(32.2*MLWSLV*GSLFCT/1545.0)
C................Calculation of Effective Conductance.................
C.....Make adjustments in wall conductances to account for linings.....
        CNDWL=CWALI
        CDJNT=CJNTI
        IF (LLNG.EQ.2) THEN
          IF (ILD.EQ.2.AND.TIME.LT.LINTV) THEN
            CTEMPJ=CDLIN(ILN)*CJNTI/(CDLIN(ILN)+CJNTI)
            CTEMPW=CDLIN(ILN)*CWALI/(CDLIN(ILN)+CWALI)
            CNDWL=CTEMPW-(CTEMPW-CWALI)*TIME/LINTV
            CDJNT=CTEMPJ-(CTEMPJ-CJNTI)*TIME/LINTV
          ENDIF
        ENDIF
C.........Consider Effects of Various Thermal Insulation Options....
C.............Bare uninsulated tank case.............................
        IF (INS.EQ.1) THEN
          CNDLQ=CDJNT
          CNDVP=CNDWL
        ENDIF
C..............Constant conductance high temperature insulation........
        IF (INS.EQ.2) THEN
          CNDLQ=CNDD*CDJNT/(CNDD+CDJNT)
          CNDVP=CNDD*CNDWL/(CNDD+CNDWL)
        ENDIF
C........Determine outer surface temperatures for jacket only case.
        IF (INS.EQ.3) THEN
          CTMPVP=40.0*CNDWL/(40.0+CNDWL)
          CTMPLQ=40.0*CDJNT/(40.0+CDJNT)
          IF (TIME.LT.CINTV) THEN
            CNDVP=CNDI+(CTMPVP-CNDI)*(TIME/CINTV)
            CNDLQ=CNDI+(CTMPLQ-CNDI)*(TIME/CINTV)
          ELSEIF (TIME.GE.CINTV) THEN
            CNDVP=CTMPVP
            CNDLQ=CTMPLQ
          ENDIF
        ENDIF
```

```
C.................Non-temperature dependent conductivity.................
        IF (INS.EQ.4) THEN
          IF (KINDX.EQ.1) THEN
            CNDVP=CNDI+(CNDD-CNDI)*(TIME/CINTV)
            CNDVP=CNDVP*CNDWL/(CNDVP+CNDWL)
            CNDLQ=CNDI+(CNDD-CNDI)*(TIME/CINTV)
            CNDLQ=CNDLQ*CDJNT/(CNDVP+CDJNT)
          ENDIF
          IF (KINDX.NE.1) THEN
            CNDLQ=CNDD*CDJNT/(CNDD+CDJNT)
            CNDVP=CNDD*CNDWL/(CNDD+CNDWL)
          ENDIF
        ENDIF
C.........Establish effective conductance adjacent to vapor and liquid
C.............for temperature dependent conductivity
C
        IF (INS.EQ.5) THEN
          CALL TSHIELD(TWAL,TTNK,CNDLQ,THIC,A1,A2,A3,CDJNT)
          CALL TSHIELD(TWAV,TTNV,CNDVP,THIC,A1,A2,A3,CNDWL)
        ENDIF
C
        IF (INS.EQ.6) THEN
          IF (TIME.LT.CINTV) THEN
            CNDVP=CNDI+(CNDD-CNDI)*(TIME/CINTV)
            CNDLQ=CNDI+(CNDD-CNDI)*(TIME/CINTV)
          ELSEIF (TIME.GE.CINTV) THEN
            CNDVP=CNDD
            CNDLQ=CNDD
          ENDIF
C
          CALL TSHIELD(TMIL,TTNK,CLINT,THIC,A1,A2,A3,CDJNT)
          CALL TSHIELD(TMIV,TTNV,CVINT,THIC,A1,A2,A3,CNDWL)
C
          CVTEMP=CNDVP
          CLTEMP=CNDLQ
          CNDLQ=(CNDLQ*CLINT)/(CNDLQ+CLINT)
          CNDVP=(CNDVP*CVINT)/(CNDVP+CVINT)
          TMIL=(TWAL*CLTEMP+TTNK*CLINT)/(CLINT+CLTEMP)
          TMIV=(TWAV*CVTEMP+TTNV*CVINT)/(CVINT+CVTEMP)
        ENDIF
C
C-----------------------------------------------------------------------
C..Determine effective outer surface temps; adjacent to the liquid:
        CALL SURFACET(TWAL,TTNK,ERAD,CNDLQ,TFLA,INS,TIME,CINTV,FLFAC)
C.........adjacent to vapor space:
        CALL SURFACET(TWAV,TTNV,ERAD,CNDVP,TFLA,INS,TIME,CINTV,FLFAC)
C-----------------------------------------------------------------------
C.....Determine angle THET (radians) between horizontal reference line
C......through center of tank and radius line to surface of liquid at
C......tank wall; use iterative solution for THET as function of FRAC.
        THOU=0.10
        THEM=1.5708
        IF (FRAC.LE.0.0001) THEN
          THET=-1.5708
        ELSE
222       CONTINUE
          FTST=(1.5708+THEM+COS(THEM)*SIN(THEM))/3.1416
          IF (ABS(FTST-FRAC).LT.0.0001) THEN
            THET=THEM
          ELSE
```

```
            IF (FTST.LT.FRAC) GO TO 224
            THEM=THEM-THOU
            IF (THEM.LE.(-1.5708)) GO TO 224
            GO TO 222
224         CONTINUE
            THEM=THEM+0.8*THOU
            THOU=THOU/5.0
            GO TO 222
          ENDIF
        ENDIF
C-------------------------------------------------------------------------
C       Determine radiation surface configuration factor.
C
        AREALQ=DHTK*COS(THET)*LENG+1.0          ! area liquid surface
        ATANK=LENG*DHTK*(1.5708-THET)
     1    +1.5708*(1.0-FRAC)*DHTK*DHTK+1.0      ! tank area over vapor
        IF (ATANK.LE.0.0) THEN
          FLTQ=0.9
          GO TO 369
        ENDIF
        FLQT=1.0/(1.10+0.25*(AREALQ/ATANK))
        FTLQ=FLQT*AREALQ/ATANK
369     CONTINUE
C-------------------------------------------------------------------------
C       Readjust vapor tank temperatures for shell full condition.
C
        IF (WGNT.LT.(0.1).AND.IFRAC.EQ.1) THEN
          TTNV=TTNK
          TWAV=TWAL
          GO TO 371
        ENDIF
C-------------------------------------------------------------------------
C       Determine inner wall temperature next to vapor space.
C
        HCNV=0.0
        IF (KIDN.EQ.2.OR.KIDN.EQ.3) THEN
          IF (FRAC.GT.0.99) HCNV=2.0
          IF (FRAC.GT.0.95.AND.FRAC.LE.0.99) HCNV=0.5
        ENDIF
        IF (KIDN.EQ.1) THEN
          IF(WOUTDL.GT.1500.0) THEN
            IF (FRAC.GT.0.9) HCNV=6.0
            IF (FRAC.GT.0.4.AND.FRAC.LE.0.9) HCNV=1.5
          ELSEIF (WOUTDL.GT.200.0.AND.WOUTDL.LE.1500.0) THEN
            IF (FRAC.GT.0.9) HCNV=2.0
            IF (FRAC.GT.0.6.AND.FRAC.LE.0.9) HCNV=0.50
            IF (FRAC.GT.0.4.AND.FRAC.LE.0.6) HCNV=0.25
          ENDIF
        ENDIF
C
C......Heat radiated and convected from tank wall to liquid surface.
        QOUT=0.48*FTLQ*(TTNV**4-TTNK**4)+HCNV*(TTNV-TTNK)/3.6
C......Heat conducted through insulation to tank wall (BTU/sq.ft-sec).....
C.............Calculate temperature of tank wall over vapor space.........
        NETQ=(TWAV-TTNV)*(CNDVP/3.6)-QOUT  ! Net heat input to wall
        TDEL=(NETQ/WTWL)*(60.0/125.0)*DELT ! Incremental temperature increase
        TTNV=TTNV+TDEL
371     CONTINUE
C-------------------------------------------------------------------------
C.......Adjust volume of tank for temperature and stress effects..........
```

```
        TPSLST=TPSZGL
        IF (IMT.GE.20) THEN
          EMOD=10.0*(10.0**6.0)              ! aluminum
        ELSE
          EMOD=30.0*(10.0**6.0)              ! steel
        ENDIF
        IF (IMT.LE.15) ALPHA=6.0/(10.0**6.0)
        IF (IMT.GE.16.AND.IMT.LE.19) ALPHA=10.0/(10.0**6.0)
        IF (IMT.GE.20) ALPHA=13.0/(10.0**6.0)
        RATIO=(1.0+ALPHA*TEMP)/(1.0+ALPHA*TEMC)
        STRN=(0.5*(PTOT-14.7)*DHTK*12.0)/(WTKI*EMOD)
        TPSZGL=0.33*(SZGL*((1.0+0.850*STRN)**2.0)*(1.0+0.200*STRN)
     1     *(RATIO**3.0))+0.67*TPSLST
C-------------------------------------------------------------------------
C.......Determine the degree of safety relief device opening.............
        IF (IVLTYP.EQ.2) GO TO 322
C.......Calculation for valve, first determine valve opening index number....
        IF (NVLV.EQ.0.AND.PTOT.GT.PATD) THEN
          NFRST=1
          IF (PTOT.LT.POPN) NVLV=1
          IF (PTOT.GE.POPN) NVLV=2
          GO TO 320
        ENDIF
        IF (NVLV.EQ.1.AND.PTOT.LT.PCLS) THEN
          NVLV=0
          GO TO 320
        ENDIF
        IF (NVLV.EQ.1.AND.PTOT.LT.PLST) THEN
          PKEEP=PLST
          NVLV=4
          GO TO 320
        ENDIF
        IF (NVLV.EQ.1.AND.PTOT.GE.PLST) THEN
          IF (PTOT.GE.POPN) NVLV=2           ! NVLV stays at 1 if PTOT<POPN
          GO TO 320
        ENDIF
        IF (NVLV.EQ.2) THEN
          IF (PTOT.LT.POPN.AND.PTOT.GT.PCLS) NVLV=3
          IF (PTOT.LE.PCLS) NVLV=0
          GO TO 320
        ENDIF
        IF (NVLV.EQ.3) THEN
          IF (PTOT.GE.POPN) NVLV=2
          IF (PTOT.LE.PCLS) NVLV=0
          GO TO 320
        ENDIF
        IF (NVLV.EQ.4) THEN
          IF (PTOT.LT.POPN.AND.PTOT.GE.PKEEP) NVLV=1
          IF (PTOT.GE.POPN) NVLV=2
          IF (PTOT.LE.PCLS) NVLV=0
          GO TO 320
        ENDIF
320     CONTINUE
C.........determine flow rate based on valve opening index.........
        IF (NVLV.EQ.0) TCFM=0
        IF (NVLV.EQ.1) TCFM=SCFM*(PTOT-PATD)/(POPN-PATD)
        IF (NVLV.EQ.2) TCFM=SCFM
        IF (NVLV.EQ.3.AND.PTOT.GE.PRTN) THEN
          TCFM=SCFM*(0.85+0.15*(PTOT-PRTN)/(POPN-PRTN))
        ENDIF
```

```
        IF (NVLV.EQ.3.AND.PTOT.LT.PRTN) THEN
          TCFM=SCFM*0.85*(PTOT-PCLS)/(PRTN-PCLS)
        ENDIF
        IF (NVLV.EQ.4.AND.PTOT.GE.PRTN) THEN
          TCFM=SCFM*(0.85+0.15*(PTOT-PRTN)/(POPN-PRTN))
     1         *((PKEEP-PATD)/(POPN-PATD))
        ENDIF
        IF (NVLV.EQ.4.AND.PTOT.LT.PRTN) THEN
          TCFM=SCFM*0.85*((PTOT-PCLS)/(PRTN-PCLS))
     1         *((PKEEP-PATD)/(POPN-PATD))
        ENDIF
C
        TCLST=TCFM
        ATEM=AVLV*TCFM/SCFM
322     CONTINUE
        IF (IVLTYP.EQ.2) THEN
          IF (NVLV.EQ.0.AND.PTOT.GT.VGTD) THEN
            ATEM=AVENT
            NVLV=5
            NFRST=1
          ENDIF
        ENDIF
C-------------------------------------------------------------------------
C       Sort out conditions in the tank.
C...If contents are above critical temperature, analyze as vapor in tank.
        IF (TTNK.GT.0.6659.AND.IPR.EQ.2) GO TO 430   ! temperature greater
        IF (TTNK.GT.0.830.AND.IPR.EQ.3) GO TO 430    ! than critical temp.
        IF (TTNK.GT.0.6567.AND.IPR.EQ.4) GO TO 430   ! for
        IF (TTNK.GT.0.8681.AND.IPR.EQ.8) GO TO 430   ! product
        IF (FRAC.LT.0.0005) GO TO 430              ! no liquid left in tank
        IF (IFRAC.EQ.1) GO TO 410                  ! tank filled with liquid
C-------------------------------------------------------------------------
C       Both liquid and vapor within tank. . . . . .
C       Determine heat in through wetted area and radiated to surface.
C
        THEA=0.0
        IF(THET.LT.(-1.0))THEA=0.10
C
        IF (IFRTYP.NE.2) HTINR=(0.48*FLQT*((TTNV)**4-(TTNK)**4)+
     1    (TTNV-TTNK)*HCNV/3.6)*AREALQ*DELT*60.0
        IF (IFRTYP.EQ.2) HTINR=(0.48*1.0*((TTNV)**4-(TTNK)**4)+
     1    (TTNV-TTNK)*HCNV/3.6)*16.0*DELT*60.0  ! Note 16.0 put in
C
        STDA=AREA*(1.5708+THEA+THET)/3.1416
        IF (IFRTYP.EQ.2) THEN
           HTIN=HTINR                                ! No heat to liquid
        ELSE                                         ! because torch over vap
          HTIN=CFRA*((TWAL-TTNK)*CNDLQ*STDA*DELT*60.0/3.6+HTINR)
          IF (IDSC.EQ.2)  HTIN=HTIN+USUM*(TWAL-TTNK)*DELT*
     1              (60.0/3.6)*(0.5+THET/3.1416)
        ENDIF
C
        THRML=SPEC*WLIQ+0.125*WTWL*STDA
        TLST=TTNK
        SLST=VVAP
        PLST=PTOT
        IF (THET.LE.TRLT) GO TO 420
C*************************************************************************
C       Liquid and vapor in tank, venting liquid..(KIDN=2). . . . . .
C       .........Calculate mass flow out through valve.................
```

```
C
      PTOT=PSBS+PSLV+PNIT
      IF (NVLV.NE.0) CALL AVFLOW(TTNK,WOUT,ATEM,DELT,CVLQ,PNIT,
     1       CONC,IPR,IPFST,ISBSL,IPTYP,TIME)
C
      IF (IPTYP.EQ.1) THEN
       IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
       IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
      ENDIF
      IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
         IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
         IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
       ENDIF
C
      WSBOUT=WOUT*CONC
      WSVOUT=(1.0-CONC)*WOUT
      QWRK=WOUT*SPLQ*PTOT*144.0/778.0
C
C     ..............Determine temperature increase.....................
C
      TELT=(HTIN-QWRK-WOUT*SPLQ*HFLV/VVAP)/THRML
      TTNK=TTNK+TELT/1000.0
C
C     .................Calculate mass remaining in tank...............
C
      FMSS=FMSS-WOUT
      WSBS=WSBS-WSBOUT
      WSLV=WSLV-WSVOUT
      TEMP=(TTNK-0.46)*1000.0
C
      IF (IPTYP.EQ.1) THEN
       IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
       IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
      ENDIF
      IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
         IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
         IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
       ENDIF
C
      PTOT=PSBS+PSLV+PNIT
      WLIQ=(FMSS-TPSZGL/VVAP)/(1.0-SPLQ/VVAP)
      WVAP=FMSS-WLIQ
      VLIQ=WLIQ*SPLQ
      FRAC=VLIQ/TPSZGL
      IF(VLIQ.GE.TPSZGL.AND.PPAD.LT.(0.001)) THEN
        FRAC=1.0
        IFRAC=1
      ELSE
        IFRAC=0
      ENDIF
      IF(VLIQ.GE.TPSZGL.AND.PPAD.LT.(0.001)) THEN
        PNIT=1.1*PNIT
        VLIQ=TPSZGL-0.01
        GO TO 329
      ENDIF
C
      IF(VLIQ.LE.0.0)FRAC=0.0
C
C     ..........Determine pressure of padding gas (if present).........
C
```

```
        IF (IFRAC.EQ.0) PNIT=
     1        PPAD*(TTNK/TNKHLD)*(1.0-FRAT)*(SZGL/TPSZGL)/(1.0-FRAC)
C
329     CONTINUE
        PTOT=PSBS+PSLV+PNIT
        IF (NVLV.LE.1.AND.WGNT.GT.(0.0)) THEN
          IF (PTOT.GT.POPN) PNIT=POPN-PSBS-PSLV
          IF (PNIT.LT.(0.0)) PNIT=0.0
        ENDIF
        PTOT=PSBS+PSLV+PNIT
        IF (PTOT.LT.14.7) PTOT=14.7
        KIDN=2
        GO TO 153
C*********************************************************************
C       Shell full case......( KIDN=3 ). . . . . . . . . . . . . . . .
C.................Calculate heat in and change in temperature.........
C
410     CONTINUE
        IF (IFRTYP.EQ.2) THEN
          HTIN=CATR*(TWAL-TTNK)*CNDLQ*DELT*60.0/3.6
        ELSE
          HTIN=(TWAL-TTNK)*CFRA*CNDLQ*AREA*DELT*60.0/3.6
          IF (IDSC.EQ.2) HTIN=HTIN+USUM*(TWAL-TTNK)*DELT*60.0/3.6
        ENDIF
        TELT=HTIN/(SPEC*WLIQ*1000.0+125.0*WTWL*AREA)
        TLST=TTNK
        SLST=VVAP
        PLST=PTOT
        TTNK=TTNK+TELT
        IPAD=0
        NFRST=1
C
        TEMP=(TTNK-0.46)*1000.0
C
        IF (IPTYP.EQ.1) THEN
         IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
         IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
        ENDIF
        IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
           IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
           IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
         ENDIF
C.............Calculate pressure required to get sufficient flow........
        REQL=0.5*REQL+0.5*(FMSS*SPLQ-TPSZGL)/DELT
        IF (REQL.LT.0.0) REQL=0.0
        WOUT1=REQL*DELT/SPLQ
C
        IF (IVLTYP.EQ.1) AREQ=AVLV
        IF (IVLTYP.EQ.2) AREQ=AVENT
        PTOT=PSBS+PSLV
        PMIN=AMAX1(PTOT,(14.7))
        PCOM=PMIN+((REQL/(720.0*CVLQ*AREQ))**2)/(64.4*SPLQ)
C
        IF (IVLTYP.EQ.1.AND.PTOT.LT.PCLS) THEN
          PTOT=AMAX1(PCLS,PCOM)
          WOUT=WOUT1
          FMSS=FMSS-WOUT
          FRAC=1.0
          IFRAC=1
          GO TO 416
```

```
        ENDIF
        IF (IVLTYP.EQ.2.AND.PTOT.LT.(14.7)) THEN
          PTOT=PCOM
          WOUT=WOUT1
          FMSS=FMSS-WOUT
          FRAC=1.0
          IFRAC=1
          GO TO 416
        ENDIF
C
        IF (TILT.GE.10.0) GO TO 411
        TEMPR=1000.0*TTNK
        WSBOUT=PSBS*ATEM*CVAD*VLSBCN*60.0*DELT/SQRT(TEMPR*ZSBS)
        WSVOUT=PSLV*ATEM*CVAD*VLSLCN*60.0*DELT/SQRT(TEMPR*ZSLV)
        IF (PTOT.LT.(27.0)) THEN
          WSBOUT=WSBOUT*(PTOT-14.7)/12.3
          WSVOUT=WSVOUT*(PTOT-14.7)/12.3
        ENDIF
        IF (WSBOUT.LT.0.0) WSBOUT=0.0
        IF (WSVOUT.LT.0.0) WSVOUT=0.0
        WOUT2=WSBOUT+WSVOUT
        GO TO 413
411     CONTINUE
        CALL AVFLOW(TTNK,WOUT2,ATEM,DELT,CVLQ,PNIT,
     1  CONC,IPR,IPFST,ISBSL,IPTYP,TIME)
C
        IF (IPTYP.EQ.1) THEN
         IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
         IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
        ENDIF
        IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
           IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
           IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
         ENDIF
C
413     CONTINUE
C
        IF (WOUT2.GT.WOUT1) THEN
          WOUT=WOUT2
          FMSS=FMSS-WOUT
          FRAC=FMSS*SPLQ/TPSZGL
          IF (FRAC.GT.1.000)FRAC=0.9999  ! v3.0 rev
          IFRAC=0
          GO TO 416
        ENDIF
C
        PTOT=PCOM
        WOUT=WOUT1
        FMSS=FMSS-WOUT
        FRAC=1.0
        IFRAC=1
C
416     CONTINUE
        VLIQ=FMSS*SPLQ
        WVAP=0.0
        IF (IPR.NE.1) THEN
          WSBOUT=WOUT*CONC
          WSVOUT=WOUT*(1.0-CONC)
        ELSEIF (IPR.EQ.1) THEN
          WSBOUT=0.0
```

```
          WSVOUT=WOUT
        ENDIF
        WNTOUT=0.0
        PNIT=0.0
        WPAD=0.0
        WLIQ=FMSS
        WSBS=FMSS*CONC
        WSLV=FMSS*(1.0-CONC)
        SLST=TPSZGL/FMSS
C
        KIDN=3
        GO TO 153
C*****************************************************************
C       Liquid and vapor in car, but venting vapor..( KIDN=1) . . .
C       ..........Calculate mass flow rate through valve...........
C
420     CONTINUE
        IF (IFRAC.EQ.0.AND.WGNT.NE.(0.0)) THEN
          PNIT=((1.0-FRAT)/(1.0-FRAC))*PPAD*(TTNK/TNKHLD)*WPAD/WGNT
        ELSE
          PNIT=0.0
        ENDIF
C
        PTOT=PSBS+PSLV+PNIT
        IF (IVLTYP.EQ.1.AND.NVLV.LE.1.AND.WGNT.GT.(0.0)) THEN
          IF (PTOT.GT.POPN) PNIT=POPN-PSBS-PSLV
          IF (PNIT.LT.(0.0)) PNIT=0.0
        ENDIF
        PTOT=PSBS+PSLV+PNIT
C
        IF (NFRST.EQ.0) GO TO 424
        WSBOLD=WSBOUT
        WTROLD=WSVOUT
        WNTOLD=WNTOUT
        TEMPR=1000.0*TTNK
        WSBOUT=PSBS*ATEM*CVAD*VLSBCN*60.0*DELT/SQRT(TEMPR*ZSBS)
        WSVOUT=PSLV*ATEM*CVAD*VLSLCN*60.0*DELT/SQRT(TEMPR*ZSLV)
        WNTOUT=PNIT*ATEM*CVAD*VLPPCN*60.0*DELT/SQRT(TEMPR*ZPAD)
        IF (PTOT.GT.(14.7).AND.PTOT.LT.(27.0)) THEN
          WSBOUT=WSBOUT*(PTOT-14.7)/12.3
          WSVOUT=WSVOUT*(PTOT-14.7)/12.3
          WNTOUT=WNTOUT*(PTOT-14.7)/12.3
        ENDIF
        IF (FRAC.LE.0.040) THEN
             WSBOUT=0.5*(WSBOUT+WSBOLD)
             WSVOUT=0.5*(WSVOUT+WTROLD)
             WNTOUT=0.5*(WNTOUT+WNTOLD)
        ENDIF
C
        IF (IPAD.EQ.0) GO TO 424
        WNTHLD=WPAD
        PNTHLD=PNIT
        WPAD=WPAD-WNTOUT
        IF (WPAD.LT.(0.0)) WPAD=0.0
        PTOT=PSBS+PSLV+PNIT
        IF (IVLTYP.EQ.2.AND.PTOT.LT.14.7) THEN
          PNIT=14.71-PSBS-PSLV
          IF (PNTHLD.LE.(0.0)) THEN
            WPAD=0.0
          ELSE
```

```
            WPAD=WNTHLD*PNIT/PNTHLD
          ENDIF
          IF (WNTOUT.LE.(0.0)) THEN
            RATIO=1.0
          ELSE
            RATIO=(WNTHLD-WPAD)/WNTOUT
            IF(RATIO.LE.0.0)RATIO=0.1      !  v3.0 rev
          ENDIF
          WNTOUT=WNTHLD-WPAD
          IF (WNTOUT.LT.(0.0)) WNTOUT=0.0   !  v3.0 rev
          WSVOUT=WSVOUT*RATIO
          WSBOUT=WSBOUT*RATIO
        ENDIF
        IF (IVLTYP.EQ.1.AND.PTOT.LT.PCLS) THEN
          PNIT=PCLS-PSBS-PSLV+1.0
          IF (PNTHLD.LE.(0.0)) THEN
            WPAD=0.0
          ELSE
            WPAD=WNTHLD*PNIT/PNTHLD
          ENDIF
          IF (WNTOUT.LE.(0.0)) THEN
            RATIO=1.0
          ELSE
            RATIO=(WNTHLD-WPAD)/WNTOUT
            IF (RATIO.LE.0.0) RATIO=0.1
          ENDIF
          WNTOUT=WNTHLD-WPAD
          WSVOUT=WSVOUT*RATIO
          WSBOUT=WSBOUT*RATIO
        ENDIF
        PTOT=PSBS+PSLV+PNIT
424     CONTINUE
C
        FMSS=FMSS-WSVOUT-WSBOUT
C
C       Calculate change in temperature.
C
        QVAL=(WSBOUT+WSVOUT)*HFLV
        TELT=(HTIN-QVAL)/(THRML*1000.0)
        TLST=TTNK
        TTNK=TTNK+TELT
        IF(FRAC.LT.0.025)TTNK=0.2*TTNK+0.8*TLST
C
        TEMP=(TTNK-0.46)*1000.0
C
        IF (IPTYP.EQ.1) THEN
         IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,TEMP)
         IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,TEMP)
        ENDIF
        IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
           IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,TEMP)
          IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,TEMP)
         ENDIF
C
        WLIQ=(FMSS-TPSZGL/VVAP)/(1.0-SPLQ/VVAP)
        WVAP=FMSS-WLIQ
        VLIQ=WLIQ*SPLQ
        FRAC=VLIQ/TPSZGL
        SLST=TPSZGL/FMSS
        IF(VLIQ.GE.TPSZGL) THEN
```

```
            FRAC=1.0
            IFRAC=1
          ELSE
            IFRAC=0
          ENDIF
          IF(VLIQ.LE.0.0)FRAC=0.0
C
          WSBS=WSBS-WSBOUT
          WSLV=WSLV-WSVOUT
          CONC=WSBS/(WSBS+WSLV)
C
          KIDN=1
          GO TO 153
C*******************************************************************************
C         Tank filled only with vapor (nitrogen pad neglected)...( KIDN=4)...
C
430       CONTINUE
          IF (IFRTYP.EQ.2) THEN
            HTIN=(TTNV-TTNK)*CATR*1000.0*1.0*DELT/60.0
          ELSE
            HTIN=(TTNV-TTNK)*AREA*1000.0*1.0*DELT/60.0
          ENDIF
          PLST=PTOT
          ZSBS=0.7
          PNIT=0.0
          IPAD=0
          SVLV=TPSZGL/FMSS
          PTOT=(PLST*SLST/SVLV*TTNK/TLST)*0.3+0.7*PLST
          SLST=SVLV
          IF(IVLTYP.EQ.1.AND.PTOT.LE.PCLS)PTOT=PCLS+0.001
          TEMPR=1000.0*TTNK
          WSBOUT=PSBS*ATEM*CVAD*VLSBCN*60.0*DELT/SQRT(TEMPR*ZSBS)
          WSVOUT=PSLV*ATEM*CVAD*VLSLCN*60.0*DELT/SQRT(TEMPR*ZSLV)
          IF (PTOT.LT.(27.0)) THEN
            WSBOUT=WSBOUT*(PTOT-14.7)/12.3
            WSVOUT=WSVOUT*(PTOT-14.7)/12.3
          ENDIF
          WLET=WOUT
          WOUT=WSBOUT+WSVOUT
          IF ((FMSS/WGHT).LE.0.0100) THEN
            ALFA=0.5
            IF(SCFM.GT.15000.0)ALFA=0.05
            WOUT=WOUT*ALFA+WLET*(1.0-ALFA)
          ENDIF
          QWRK=WOUT*SVLV*PTOT*144.0/778.0
C
C         Calculate change in temperature.
C
          TELT=(HTIN-QWRK)/(FMSS*0.40*1000.0)
          TLST=TTNK
          TTNK=TTNK+TELT
          FMSS=FMSS-WOUT
          WLIQ=0.0
          WVAP=FMSS
          FRAC=0.000
          IFRAC=0
          IF ((FMSS/WGHT).LT.(0.0005)) GO TO 470
          KIDN=4
          GO TO 153
C*******************************************************************************
```

```
C       .............Burst strength of tank.............................
C
153     CONTINUE
        FCTR=1.0
C.......................Carbon Steels.....................................
        IF (IMT.GE.1.AND.IMT.LE.15) THEN
          IF(TTNV.LT.(1.260)) FCTR=1.0-(0.54)*(TTNV-0.460)**4
          IF(TTNV.GE.(1.260)) FCTR=1.74-1.17*(TTNV-0.460)
          IF(TTNV.GE.(1.947)) FCTR=0.0
        ENDIF
C.......................Stainless Steels..................................
        IF (IMT.EQ.16.OR.IMT.EQ.17) THEN
          IF (TTNV.GE.(0.860).AND.TTNV.LT.(1.760))
     1      FCTR=1.0-0.45*(TTNV-0.86)/0.90
          IF (TTNV.GE.(1.760).AND.TTNV.LT.(2.160))
     1      FCTR=0.55-0.55*(TTNV-1.76)/0.40
          IF (TTNV.GE.(2.160)) FCTR=0.0
        ENDIF
        IF (IMT.EQ.18.OR.IMT.EQ.19) THEN
          IF (TTNV.GE.(0.860).AND.TTNV.LT.(1.760))
     1      FCTR=1.0-0.55*(TTNV-0.86)/0.90
          IF (TTNV.GE.(1.760).AND.TTNV.LT.(2.160))
     1      FCTR=0.45-0.45*(TTNV-1.76)/0.40
          IF (TTNV.GE.(2.160)) FCTR=0.0
        ENDIF
C.......................Aluminum Alloys...................................
        IF (IMT.GE.20.AND.IMT.EQ.25) THEN
          IF (TTNV.GE.(0.610).AND.TTNV.LT.(1.260))
     1      FCTR=1.0-(TTNV-0.61)/0.65
          IF (TTNV.GE.(1.260)) FCTR=0.0
        ENDIF
        IF (IMT.EQ.26) THEN
          IF (TTNV.GE.(0.610).AND.TTNV.LT.(0.860))
     1      FCTR=1.0-0.48*(TTNV-0.61)/0.25
          IF (TTNV.GE.(0.860).AND.TTNV.LT.(1.260))
     1      FCTR=0.52-0.52*(TTNV-0.86)/0.40
          IF (TTNV.GE.(0.860)) FCTR=0.0
        ENDIF
        IF (IMT.EQ.27) THEN
          IF (TTNV.GE.(0.610).AND.TTNV.LT.(0.960))
     1      FCTR=1.0-0.83*(TTNV-0.61)/0.35
          IF (TTNV.GE.(0.960).AND.TTNV.LT.(1.260))
     1      FCTR=0.17-0.17*(TTNV-0.96)/0.30
          IF (TTNV.GE.(0.860)) FCTR=0.0
        ENDIF
C
        PBRS=PCBRS*FCTR
C
C.....................Set output parameters.............................
C
        PSIG=PTOT-14.7
        TEMP=1000.0*TTNK-460.0
        TEMW=1000.0*TWAL-460.0
        TEMH=1000.0*TTNV-460.0
        FMAT=FMSS/WGHT
        FRCLQ=WLIQ/WGHT
        KCNT=KCNT+1
C
        TIME=(FLOAT(NTIME*NREFTM))/100.0
C
```

```
155     CONTINUE
C
C       HEADINGS FOR OUTPUTS
C
        IF(PBRS.LT.PSIG)GO TO 470
        IF (NTIME.GT.0.OR.OTYPE.EQ.1) GO TO 465
        IF(IPR.EQ.1)WRITE(19,57)'PRODUCT: WATER'
        IF(IPR.EQ.2)WRITE(19,57)'PRODUCT: PROPANE'
        IF(IPR.EQ.3)WRITE(19,57)'PRODUCT: ETHLYENE OXIDE'
        IF(IPR.EQ.4)WRITE(19,57)'PRODUCT: PROPYLENE'
        IF(IPR.EQ.5)WRITE(19,57)'PRODUCT: 1,3-BUTADIENE'
        IF(IPR.EQ.6)WRITE(19,57)'PRODUCT: VINYL CHLORIDE'
        IF(IPR.EQ.7)WRITE(19,57)'PRODUCT: MONOMETHYLAMINE'
        IF(IPR.EQ.8)WRITE(19,57)'PRODUCT: PROPYLENE OXIDE'
        IF(IPR.EQ.9)WRITE(19,57)'PRODUCT: ANHYDROUS AMMONIA'
        IF(IPR.EQ.10)WRITE(19,57)'PRODUCT: SULFURIC ACID'
        IF(IPR.EQ.11)WRITE(19,57)'PRODUCT: HYDROCHLORIC ACID'
        IF(IPR.EQ.12)WRITE(19,57)'PRODUCT: SODIUM HYDROXIDE'
        IF(IPR.EQ.13)WRITE(19,57)'PRODUCT: PHOSPHORIC ACID (75%)'
        IF(IPR.EQ.14)WRITE(19,57)'PRODUCT: SUPERPHOSPHORIC ACID'
        IF(IPR.EQ.15)WRITE(19,57)'PRODUCT: POTASSIUM HYDROXIDE'
        IF(IPR.EQ.16)WRITE(19,57)'PRODUCT: HYDROGEN PEROXIDE SOLUTION'
C
        IF (IPR.EQ.20.OR.IPR.EQ.21)
     1    WRITE(19,59)'PRODUCT:',QNAME
C
57      FORMAT(T8,A/)
59      FORMAT(T8,A,T18,A/)
        WRITE(19,73)' TIME   TEMPERATURES     PRESSURES',
     1   'MASS   FILLED  RATE OF'
        WRITE(19,73)'(min.)     (deg F)     WITHIN  BURST',
     1   'FRACT. FRACT.  PRODUCT '
        WRITE(19,73)'          LIQ.  TANK     TANK    STR.',
     1   ' IN     OF     RELEASE '
        WRITE(19,73)'          PROD. VAPOR   (psi)   (psi)',
     1   'TANK   TANK   (lbs/min) '
        WRITE (19,971) '        '
73      FORMAT(T8,A,T47,A)
465      CONTINUE
C
C....Outside temperature range of thermal property data message.......
       IF (ITEMP.EQ.1) GO TO 466
       IF (TEMP.GT.(TLMTMX+0.01).OR.TEMP.LT.(TLMTMN-0.01)) THEN
         IF (OTYPE.EQ.1.OR.OTYPE.EQ.3) WRITE (*,577)
     1       'OUTSIDE TEMPERATURE RANGE OF THERMAL PROPERTY DATA'
         IF (OTYPE.EQ.2.OR.OTYPE.EQ.3) WRITE (19,577)
     1       'OUTSIDE TEMPERATURE RANGE OF THERMAL PROPERTY DATA'
         ITEMP=1
       ENDIF
466    CONTINUE
C
C....Outside concentration range of thermal property data message.......
       IF (ICONC.NE.0) GO TO 467
       IF (ISBSL.NE.2) GO TO 467       ! corrected 11/1/97 was NE.0
       IF (CONC.GT.(CNCMAX+0.001).OR.CONC.LT.(CNCMIN-0.001)) THEN
         IF (OTYPE.EQ.1.OR.OTYPE.EQ.3) WRITE (*,577)
     1       'OUTSIDE CONCENTRATION RANGE OF THERMAL PROPERTY DATA'
         IF (OTYPE.EQ.2.OR.OTYPE.EQ.3) WRITE (19,577)
     1       'OUTSIDE CONCENTRATION RANGE OF THERMAL PROPERTY DATA'
         ICONC=1
```

```
      ENDIF
467   CONTINUE
577    FORMAT (/T3,A/)
C
C.............Outside range of critical temperature message.............
        IF (ICR.EQ.2.AND.TEMP.GE.TCRIT) THEN
          IF (OTYPE.EQ.2.OR.OTYPE.EQ.3)
     1     WRITE (19,577)  'CRITICAL TEMPERATURE EXCEEDED'
          IF (OTYPE.EQ.1.OR.OTYPE.EQ.3)
     1     WRITE (*,577)  'CRITICAL TEMPERATURE EXCEEDED'
          GO TO 470
        ENDIF
C
        WOUTDL=WSBOUT+WSVOUT+WNTOUT     !  used for control on HCNV
        WAVOUT=WAVOUT+WOUTDL            !  cummulate
        WOUTDL=WOUTDL/DELT              !  change to rate
C
        IF (KCNT.LT.INTV.AND.TIME.LT.TLIMIT) GO TO 211
        IF (TIME.GE.TLIMIT) GO TO 470
C
        WAVOUT=WAVOUT/(FLOAT(INTV)*DELT)
        IF (OTYPE.EQ.2.OR.OTYPE.EQ.3) WRITE(19,980)TIME,TEMP,
     1     TEMH,PSIG,PBRS,FMAT,FRAC,WAVOUT
C
980     FORMAT(F12.1,F8.1,F7.1,2F8.1,F8.3,F7.3,F8.1)
C.........................write to monitor.............................
C
        IF (OTYPE.EQ.2) GO TO 917
        KDCNT=KDCNT+1
        IF (KDCNT.EQ.1) WRITE(*,969)' TIME   TEMP   PRESSURE',
     1   'TANK BURST    LIQUID     MASS     OUT-FLOW'
        IF (KDCNT.EQ.1) WRITE(*,969)'(min.) (deg F)   (psi)',
     1   ' PRESSURE    FRACTION  FRACTION   (lbs/min)'
        WRITE(*,967)TIME,TEMP,PSIG,PBRS,FRAC,FMAT,WAVOUT
        IF (KDCNT.EQ.KCNTRL) THEN
          WRITE (*,*) 'Type "ENTER" to proceed'
          READ(*,*)
          KDCNT=0
          KPAGE=KPAGE+1
          IF (KPAGE.GE.1) KCNTRL=20
        ENDIF
967     FORMAT(F8.2,F8.1,F9.1,F11.1,F11.3,F11.3,F11.1)
969     FORMAT(T4,A,T29,A)
        KCNT=0
917     CONTINUE
        WAVOUT=0.0
        IF (TIME.LT.TLIMIT) GO TO 211
C
470     CONTINUE
C
        PENDT=PSIG
        PENDB=PBRS
        IF (KCNT.NE.0) WAVOUT=WAVOUT/(FLOAT(KCNT)*DELT)
        IF (PSIG.GT.PBRS) PENDT=AMIN1(PSIG,PBRS)
        IF (PSIG.GT.PBRS) PENDB=AMIN1(PSIG,PBRS)
        IF (OTYPE.EQ.2.OR.OTYPE.EQ.3) WRITE(19,980)TIME,TEMP,TEMH,
     1     PENDT,PENDB,FMAT,FRAC,WAVOUT
        IF(OTYPE.EQ.1.OR.OTYPE.EQ.3)
     1    WRITE(*,967)TIME,TEMP,PENDT,PENDB,FRAC,FMAT,WAVOUT
977     FORMAT(F8.2,F8.1,F9.1,F11.1,F11.3,F11.3,F11.1,F5.2)
```

```
C
      WRITE (*,971)
     1  'DO YOU WISH TO TERMINATE OPERATION OF PROGRAM ?'
      WRITE (*,971) '  (Enter Y or N):'
      READ (*,973) RESPNS
      IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 473
C
      IF (IPTYP.EQ.3) REWIND 13    ! old file of thermal property data
      IF (IPTYP.EQ.2) REWIND 16    ! new file of thermal property data
      WRITE (*,971)
     1  'DO YOU WISH TO CHANGE INITIAL ANALYSIS CONDITIONS?'
      WRITE (*,971) '  (Enter Y or N):'
      READ (*,973) RESPNS
      IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') THEN
        NALYSS=1
        INTYPE=1
        GO TO 403
      ELSE
        GO TO 405
      ENDIF
C
473   CONTINUE
      IF (IPTYP.EQ.2) CLOSE (16, STATUS='DELETE')
971   FORMAT (T3,A)
973   FORMAT (A1)
      STOP
      END
```

APPENDIX B

SUBROUTINE ENTRDAT

Subroutine ENTRDAT.FOR is used to enter the initial analysis data into the program. See the User's Manual for a detailed description for the use of this subroutine. After all of the data have been entered, the program presents the option of storing the data in a separate file, which can be sued for data input, if desired, on succeeding analyses.

The source code for the subroutine is presented on the following pages.

```
C.......Subroutine ENTRDAT.FOR is developed for the entry of data.
C..........All entered data is placed in COMMON.
C.....................................Version 3.0, November 11, 1998
C
      SUBROUTINE ENTRDAT(QNAME,NALYSS)
C
      CHARACTER*30 CPRD(21),QNAME
      CHARACTER*12 BNAME
      CHARACTER*1 RESPNS,LRESP
      REAL LINTV
      INTEGER*2 IMT,IPTYP,ISBSL,IPR,ICR,IPAD,IVLTYP,NALYSS
      INTEGER*2 INS,KINDX,IDSC,LLNG,ILN,ILD
      INTEGER*2 IFRTYP,INTV
C.....................................................................
      COMMON/TANK/SIZE,DIAI,WTKI
      COMMON/MATL/IMT,TNSRTH,PNBRS,PCBRS
      COMMON/PRDCT1/IPTYP,ISBSL,IPR,ICR,TCRIT
      COMMON/PRDCT2/FRAT,TEMC,CONC,IPAD,PPID
      COMMON/SRELF1/IVLTYP,AVENT,VGTD,SCFM
      COMMON/SRELF2/PGSD,PGTD,CVAD,CVLQ,TILT
      COMMON/THRML1/INS,CNDD,KINDX,CNDI,CINTV
      COMMON/THRML2/THIC,A1,A2,A3
      COMMON/THRML3/IDSC,USUM,LLNG,ILN,ILD,LINTV
      COMMON/FIRE/IFRTYP,TEMF,CFRA,CATR,ERAD
      COMMON/ITIME/TLIMIT,DELT,INTV
C
      CPRD(1)='WATER'
      CPRD(2)='PROPANE'
      CPRD(3)='ETHYLENE OXIDE'
      CPRD(4)='PROPYLENE'
      CPRD(5)='1,3 BUTADIENE'
      CPRD(6)='VINYL CHLORIDE'
      CPRD(7)='MONOMETHYLAMINE'
      CPRD(8)='PROPYLENE OXIDE'
      CPRD(9)='ANHYDROUS AMMONIA'
      CPRD(10)='SULFURIC ACID'
      CPRD(11)='HYDROCHLORIC ACID'
      CPRD(12)='SODIUM HYDROXIDE'
      CPRD(13)='PHOSPHORIC ACID (75%)'
      CPRD(14)='SUPERPHOSPHORIC ACID'
      CPRD(15)='POTASSIUM HYDROXIDE'
      CPRD(16)='HYDROGEN PEROXIDE SOLUTION'
      CPRD(17)='BLANK'
      CPRD(18)='BLANK'
      CPRD(19)='BLANK'
C
C...............TANK PARAMETERS.................................
C
      WRITE(*,*)
     1   'ENTER NOMINAL CAPACITY OF TANK (decimal number, gallons):'
      READ(*,*) SIZE
C
      WRITE(*,*)
     1   'ENTER INSIDE TANK DIAMETER (decimal number, inches):'
      READ(*,*) DIAI
C
      WRITE(*,*)
     1   'ENTER TANK WALL THICKNESS (decimal number, inches):'
      READ(*,*) WTKI
C
```

```
      WRITE(*,*)
     1   'ENTER FOLLOWING CODE NUMBER FOR TYPE OF MATERIAL'
      WRITE(*,*)
     1   '(integer number):'
      WRITE(*,*)
     1   '    1 - Carbon Steel or Carbon Steel Alloys'
      WRITE(*,*)
     1   '    2 - Stainless Steel'
      WRITE(*,*)
     1   '    3 - Aluminum'
      READ(*,*) MCLASS
C
      IF (MCLASS.EQ.1) THEN
        WRITE(*,*)
     1  '  CODE            SPECIFICATION            MINIMUM TENSILE'
        WRITE(*,*)
     1  ' NUMBER                NUMBER                STRENGTH (psi)'
        WRITE(*,*)
     1  '    1          ASTM A 515-70, Gr. 55            55,000'
        WRITE(*,*)
     1  '    2          ASTM A 515-70, Gr. 60            60,000'
        WRITE(*,*)
     1  '    3          ASTM A 515-70, Gr. 65            65,000'
        WRITE(*,*)
     1  '    4          ASTM A 515-70, Gr. 70            70,000'
        WRITE(*,*)
     1  '    5          ASTM A 285-70a, Gr. A            45,000'
        WRITE(*,*)
     1  '    6          ASTM A 285-70a, Gr. B            50,000'
        WRITE(*,*)
     1  '    7          ASTM A 286-70a, Gr. C            55,000'
        WRITE(*,*)
     1  '    8          ASTM A 516-70a, Gr. 55           55,000'
        WRITE(*,*)
     1  '    9          ASTM A 516-70a, Gr. 60           60,000'
        WRITE(*,*)
     1  '   10          ASTM A 516-70a, Gr. 65           65,000'
        WRITE(*,*)
     1  '   11          ASTM A 516-70a, Gr. 70           70,000'
        WRITE(*,*)
     1  '   12          AAR TC128-70, Grs. A & B         81,000'
        WRITE (*,*) '     '
        WRITE(*,*)
     1  '          Low Alloy Manganese Carbon Steels'
        WRITE (*,*) '     '
        WRITE(*,*)
     1  '   13          ASTM A 537-80, Class 1           70,000'
        WRITE(*,*)
     1  '   14          ASTM A 302-69a, Gr. B            80,000'
        WRITE(*,*)
     1  '   15          ASTM A 302-70a, Gr. B            80,000'
        WRITE(*,*)
     1  'ENTER CODE NUMBER FOR SPECIFIC TYPE OF STEEL'
        WRITE(*,*)
     1  '(integer number):'
        READ(*,*)IMT
      ENDIF
C
      IF (MCLASS.EQ.2) THEN
        WRITE(*,*)
```

```
     1    '  CODE            SPECIFICATION            MINIMUM TENSILE'
          WRITE(*,*)
     1    ' NUMBER                NUMBER              STRENGTH (psi)'
          WRITE(*,*)
     1    '    16         ASTM A 240-70, Type 304         75,000'
          WRITE(*,*)
     1    '    17         ASTM A 240-70, Type 304L        70,000'
          WRITE(*,*)
     1    '    18         ASTM A 240-70, Type 316         75,000'
          WRITE(*,*)
     1    '    19         ASTM A 240-70, Type 316L        70,000'
          WRITE(*,*)
     1  'ENTER CODE NUMBER FOR SPECIFIC TYPE OF STAINLESS STEEL'
        WRITE(*,*)
     1  '(integer number):'
          READ(*,*)IMT
        ENDIF
C
        IF (MCLASS.EQ.3) THEN
          WRITE(*,*)
     1    '  CODE            SPECIFICATION            MINIMUM TENSILE'
          WRITE(*,*)
     1    ' NUMBER                NUMBER              STRENGTH (psi)'
          WRITE(*,*)
     1    '    20         ASTM B 209-70, Alloy 5052       25,000'
          WRITE(*,*)
     1    '    21         ASTM B 209-70, Alloy 5083       38,000'
          WRITE(*,*)
     1    '    22         ASTM B 209-70, Alloy 5086       35,000'
          WRITE(*,*)
     1    '    23         ASTM B 209-70, Alloy 5154       30,000'
          WRITE(*,*)
     1    '    24         ASTM B 209-70, Alloy 5254       30,000'
          WRITE(*,*)
     1    '    25         ASTM B 209-70, Alloy 5454       31,000'
          WRITE(*,*)
     1    '    26         ASTM B 209-70, Alloy 5652       25,000'
          WRITE(*,*)
     1    '    27         ASTM B 209-70, Alloy 6061       24,000'
          WRITE(*,*)
     1  'ENTER CODE NUMBER FOR SPECIFIC TYPE OF ALUMINUM'
        WRITE(*,*)
     1  '(integer number):'
          READ(*,*)IMT
        ENDIF
C
        IF(IMT.EQ.1.OR.IMT.EQ.7.OR.IMT.EQ.8)TNSRTH=55000.0
        IF(IMT.EQ.2.OR.IMT.EQ.9)TNSRTH=60000.0
        IF(IMT.EQ.3.OR.IMT.EQ.10)TNSRTH=65000.0
        IF(IMT.EQ.4.OR.IMT.EQ.11.OR.IMT.EQ.13)TNSRTH=70000.0
        IF(IMT.EQ.17.OR.IMT.EQ.19)TNSRTH=70000.0
        IF(IMT.EQ.5)TNSRTH=45000.0
        IF(IMT.EQ.6)TNSRTH=50000.0
        IF(IMT.EQ.12)TNSRTH=81000.0
        IF(IMT.EQ.14.OR.IMT.EQ.15)TNSRTH=60000.0
        IF(IMT.EQ.16.OR.IMT.EQ.18)TNSRTH=75000.0
        IF(IMT.EQ.20.OR.IMT.EQ.26)TNSRTH=75000.0
        IF(IMT.EQ.21)TNSRTH=38000.0
        IF(IMT.EQ.22)TNSRTH=35000.0
        IF(IMT.EQ.23.OR.IMT.EQ.24)TNSRTH=30000.0
```

```
      IF(IMT.EQ.25)TNSRTH=31000.0
      IF(IMT.EQ.27)TNSRTH=34000.0
C
C.................Determine Calculated Burst Strength.............
      PCBRS=2.0*TNSRTH*WTKI/DIAI
C
      WRITE(*,*)'ENTER NOMINAL TANK BURSTING STRENGTH'
      WRITE(*,*)'  (decimal number, psig):'
      READ(*,*) PNBRS
C
      IF (PNBRS.GT.PCBRS) WRITE(*,*)
     1         'INCONSISTENT BURST PRESSURE'
C
C.................PRODUCT DATA....................................
C
      IF (NALYSS.NE.0) GO TO 101
      WRITE (*,*)
     1       'ENTER CODE FOR METHOD OF ENTRY OF THERMAL PROPERTY'
      WRITE (*,*) '  DATA OF PRODUCT (enter integer number):'
      WRITE (*,*) '     (1) Use product property data'
      WRITE (*,*) '         contained in program'
      WRITE (*,*) '     (2) Enter new property data at monitor'
      WRITE (*,*) '     (3) Read property data from existing'
      WRITE (*,*) '         separate file'
      READ (*,*) IPTYP
C
      IF (IPTYP.EQ.1) THEN
        WRITE(*,*)'     SELECT PRODUCT FROM FOLLOWING LIST'
        WRITE(*,*)
        WRITE(*,*)'1-WATER                9 -ANHYDROUS AMMONIA'
        WRITE(*,*)'2-PROPANE              10-SULFURIC ACID'
        WRITE(*,*)'3-ETHYLENE OXIDE       11-HYDROCHLORIC ACID'
        WRITE(*,*)'4-PROPYLENE            12-SODIUM HYDROXIDE'
        WRITE(*,*)'5-1,3 BUTADIENE        13-PHOSPHORIC ACID (75%)'
        WRITE(*,*)'6-VINYL CHLORIDE       14-SUPERPHOSPHORIC ACID'
        WRITE(*,*)'7-MONOMETHYLAMINE      15-POTASSIUM HYDROXIDE'
        WRITE(*,*)'8-PROPYLENE OXIDE      16-HYDROGEN PEROXIDE SOLUTION'
        WRITE(*,*)'  '
        WRITE(*,*)'  ENTER PRODUCT NUMBER (integer number):'
        READ(*,*) IPR
        CPRD(20)='BLANK'
        CPRD(21)='BLANK'
        IF (IPR.LE.9) ISBSL=1
        IF (IPR.GE.10.AND.IPR.LE.16) ISBSL=2
      ELSEIF (IPTYP.EQ.2) THEN    ! keyboard entry of property data
        IPR=20
        WRITE (*,*) 'ENTER NAME OF PRODUCT:'
        WRITE (*,*) '  (Maximum of 30 Characters)'
        READ (*,201) CPRD(20)
      ELSEIF (IPTYP.EQ.3) THEN    ! read file of property data
        IPR=21
        WRITE (*,*) 'ENTER NAME OF PRODUCT:'
        WRITE (*,*) '  (Maximum of 30 Characters)'
        READ (*,201) CPRD(21)
      ENDIF
      QNAME=CPRD(IPR)
C
      IF (IPTYP.NE.1) THEN
        WRITE (*,*)
     1    'ENTER CODE FOR TYPE OF PRODUCT (integer number):'
```

```
          WRITE (*,*) '   (1) for substance'
          WRITE (*,*) '   (2) for solution'
          READ (*,*) ISBSL
        ENDIF
C
        IF (IPR.GE.1.AND.IPR.LE.16) THEN
          ICR=1
          TCRIT=1.0
        ENDIF
C
        IF(IPR.GT.16) THEN
          WRITE (*,*)
     1       'DOES PRODUCT HAVE A CRITICAL TEMPERATURE?'
          WRITE (*,*) '  ENTER Y or N (for yes or no):'
          READ (*,205) LRESP
          IF (LRESP.EQ.'Y') THEN
            ICR=2
            WRITE (*,*)
     1      'ENTER CRITICAL TEMPERATURE (decimal number, deg F):'
            READ (*,*) TCRIT
          ELSE
            ICR=1
            TCRIT=1.0
          ENDIF
        ENDIF
C
101     CONTINUE
C
        WRITE(*,*)
     1   'ENTER INITIAL FRACTION OF TANK FILLED (decimal fraction):'
        READ(*,*) FRAT
C
        WRITE (*,*) 'ENTER INITIAL TEMPERATURE OF PRODUCT'
        WRITE (*,*) '   (decimal number, deg F):'
        READ (*,*) TEMC
C
        IF (ISBSL.EQ.2) THEN
          WRITE (*,*)
     1       'ENTER CONCENTRATION OF PRODUCT (decimal fraction):'
          READ(*,*) CONC
        ELSE
          CONC=1.0
        ENDIF
C
        WRITE (*,*) 'ENTER CODE FOR PRESENCE OF PADDING GAS'
        WRITE (*,*) '   (Enter integer number):'
        WRITE (*,*) '   (1) Padding gas used to bring internal tank'
        WRITE (*,*) '       pressure to atmospheric pressure if'
        WRITE (*,*) '       vapor pressure of product is'
        WRITE (*,*) '       below atmospheric pressure'
        WRITE (*,*) '   (2) No padding gas is used'
        WRITE (*,*) '   (3) Padding gas added to give specific'
        WRITE (*,*) '       gage pressure within tank '
        READ(*,*) IPAD
        IF (IPAD.EQ.1.OR.IPAD.EQ.2) THEN
          PPID=0.0       ! Pressure adjusted in main program for IPAD=1
        ELSE
          WRITE(*,*)
     1      'ENTER GAGE PRESSURE WITHIN TANK AFTER ADDITION OF'
          WRITE (*,*) 'PADDING GAS (decimal number, psig):'
```

```
          READ(*,*) PPID
        ENDIF
C
C.....................SAFETY RELIEF DEVICE PARAMETERS.....................
C
        WRITE (*,*)
     1   'ENTER CODE FOR TYPE OF SAFETY RELIEF DEVICE'
        WRITE (*,*) '  (integer number):'
        WRITE (*,*) '  (1) Safety relief valve'
        WRITE (*,*) '  (2) Safety vent with rupture disc'
        READ(*,*) IVLTYP
C
        IF (IVLTYP.EQ.2) THEN
          WRITE (*,*) 'ENTER DISCHARGE AREA OF VENT'
          WRITE (*,*) '  (decimal number, square inches):'
          READ(*,*) AVENT
          WRITE (*,*) 'ENTER FRANGIBLE DISC RUPTURE PRESSURE'
          WRITE (*,*) '  (decimal number, psig):'
          READ (*,*) VGTD
          SCFM=1.0
          PGSD=1.0
          PGTD=1.0
        ENDIF
C
        IF (IVLTYP.EQ.1) THEN
          WRITE (*,*)
     1      'ENTER SAFETY VALVE RATED FLOW CAPACITY'
          WRITE (*,*) '  (decimal number, SCFM of air):'
          READ(*,*) SCFM
          WRITE (*,*)
     1      'ENTER SAFETY VALVE FLOW RATING PRESSURE'
          WRITE (*,*) '  (decimal number, psig):'
          READ (*,*) PGSD
          WRITE (*,*) 'ENTER SAFETY VALVE START-TO-DISCHARGE PRESSURE'
          WRITE (*,*) '  (decimal number, psig):'
          READ (*,*) PGTD
          AVENT=1.0
          VGTD=1.0
        ENDIF
C
        WRITE (*,*) 'ENTER SAFETY RELIEF DEVICE DISCHARGE COEFFICIENTS'
        WRITE (*,*) '  (as decimal fractions),'
        WRITE (*,*) '  VAPOR DISCHARGE COEFFICIENT:'
        READ (*,*) CVAD
        WRITE (*,*) '  LIQUID DISCHARGE COEFFICIENT:'
        READ (*,*) CVLQ
C
        WRITE (*,*) 'ENTER ROLLOVER ORIENTATION ANGLE OF TANK CAR'
        WRITE (*,*)
     1  '  WITH RESPECT TO VERTICAL (decimal number, deg):'
        READ (*,*) TILT
C
C.....THERMAL PROTECTION SYSTEM CHARACTERISTICS.....................
C
        WRITE (*,*)
     1        'ENTER CODE FOR TYPE OF THERMAL INSULATION SYSTEM'
        WRITE (*,*) '  (integer number):'
        WRITE (*,*) '   (1) Bare, Uninsulated Tank'
        WRITE (*,*)
     1  '   (2) Approved High Temperature Insulation System'
```

```
      WRITE (*,*)
     1  '   (3) Jacketed Insulation System Not Resistant to High'
      WRITE (*,*) '       Temperature Effects'
      WRITE (*,*)
     1  '   (4) Other Systems, Conductivity Independent of Temperature'
      WRITE (*,*) '   (5) Other Systems, Conductivity is a'
      WRITE (*,*) '       Function of Temperature'
      WRITE (*,*) '   (6) Jacketed, Two Component Insulation with'
      WRITE (*,*) '       Conductivity a Function of Temperature'
      WRITE (*,*) '       for Insulation Adjacent to Tank Wall'
      READ (*,*) INS
C
        CNDD=1.0
        KINDX=2
        CNDI=1.0
        CINTV=1.0
        THIC=1.0
        A1=1.0
        A2=1.0
        A3=1.0
C
      IF (INS.EQ.2) THEN
        CNDD=4.0
        CNDI=4.0
      ENDIF
C
      IF (INS.EQ.3) THEN
        WRITE (*,*)
     1  'ENTER INITIAL CONDUCTANCE OF THERMAL INSULATION'
        WRITE (*,*) '  (decimal number, BTU/hr-sqft-degF):'
        READ (*,*) CNDI
        CNDD=CNDI
        WRITE (*,*)
     1  'ENTER TIME INTERVAL FOR CHANGE IN CONDUCTANCE'
        WRITE (*,*) '  (decimal number, minutes):'
        READ (*,*) CINTV
      ENDIF
C
      IF (INS.EQ.4) THEN
        WRITE (*,*)
     1    'ENTER CODE FOR CONSTANT CONDUCTANCE OR LINEAR CHANGE'
        WRITE (*,*)
     1    '  WITH TIME FROM INITIAL VALUE TO FINAL VALUE'
        WRITE (*,*) '  (integer number):'
        WRITE (*,*) '   (1) Conductance changes with time'
        WRITE (*,*) '   (2) Conductance constant with time'
        READ(*,*) KINDX
C
        WRITE (*,*)
     1    'ENTER THERMAL INSULATION FINAL CONDUCTANCE'
        WRITE (*,*) '  (decimal number, BTU/hr-sq.ft-deg F):'
        READ (*,*) CNDD
        CNDI=CNDD
C
        IF (KINDX.EQ.1) THEN
          WRITE (*,*) 'ENTER INITIAL CONDUCTANCE'
          WRITE (*,*) '  (decimal number, BTU/hr-sqft-DegF):'
          READ (*,*) CNDI
          WRITE (*,*)
     1    'ENTER TIME INTERVAL FOR CHANGE IN CONDUCTANCE'
```

```
            WRITE (*,*) '  (decimal number, minutes):'
            READ (*,*) CINTV
          ENDIF
        ENDIF
C
        IF (INS.EQ.5) THEN
          WRITE (*,*)
     1    'ENTER THICKNESS OF INSULATION (decimal number, inches):'
          READ (*,*) THIC
          WRITE (*,*)
     1      'ENTER FIRST CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A1
          WRITE (*,*)
     1      'ENTER SECOND CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A2
          WRITE (*,*)
     1      'ENTER THIRD CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A3
          TEMPC=TEMC/1000.0
          CNDD=12.0*(A1+A2*TEMPC+A3*TEMPC*TEMPC)/THIC
          CNDI=CNDD
        ENDIF
C
        IF (INS.EQ.6) THEN
          WRITE (*,*)
     1     'ENTER INITIAL CONDUCTANCE OF OUTER INSULATION LAYER'
          WRITE (*,*) '  (decimal number, BTU/hr-sqft-DegF):'
          READ (*,*) CNDI
          CNDD=CNDI
C
          WRITE (*,*)
     1      'ENTER CODE FOR CONSTANT CONDUCTANCE OR LINEAR CHANGE'
          WRITE (*,*)
     1      '  OF CONDUCTANCE OF OUTER LAYER OF INSULATION WITH'
          WRITE (*,*)
     1      '  TIME FROM INITIAL VALUE TO FINAL VALUE'
          WRITE (*,*) '  (integer number):'
          WRITE (*,*)
     1      '    (1) Conductance of outer layer changes with time'
          WRITE (*,*)
     1      '    (2) Conductance of outer layer constant with time'
          READ(*,*) KINDX
C
          IF (KINDX.EQ.1) THEN
            WRITE (*,*)
     1      'ENTER TIME INTERVAL FOR CHANGE IN CONDUCTANCE'
            WRITE (*,*) '  (decimal number, minutes):'
            READ (*,*) CINTV
            WRITE (*,*)
     1      'DOES OUTER INSULATION LAYER MAINTAIN FINAL STEADY STATE'
            WRITE (*,*) '  VALUE AFTER LINEAR CHANGE (Y OR N)?'
            READ (*,205) RESPNS
            IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') THEN
              WRITE (*,*)
     1        'ENTER FINAL CONDUCTANCE OF OUTER LAYER OF INSULATION'
              WRITE (*,*) '  (decimal number, BTU/hr-sq.ft-deg F):'
              READ (*,*) CNDD
            ELSE
              CNDD=40.0
            ENDIF
```

```
          ENDIF
C
          WRITE (*,*)
     1      'ENTER THICKNESS OF INNER LAYER OF INSULATION'
          WRITE (*,*) '(decimal number, inches):'
          READ (*,*) THIC
          WRITE (*,*)
     1      'ENTER FIRST CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A1
          WRITE (*,*)
     1      'ENTER SECOND CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A2
          WRITE (*,*)
     1      'ENTER THIRD CONDUCTIVITY PARAMETER (decimal number):'
          READ (*,*) A3
        ENDIF
C
C.................Heat transfer through discontinuities.................
C
        WRITE (*,*) 'ENTER CODE FOR CONSIDERATION OF HEAT TRANSFER'
        WRITE (*,*) '  THROUGH DISCONTINUITIES (integer number):'
        WRITE (*,*) '  (1) Discontinuities not considered in analysis'
        WRITE (*,*) '  (2) Discontinuties considered in analysis'
        READ(*,*) IDSC
        IF (IDSC.EQ.2) THEN
          WRITE (*,*)
     1     'ENTER SUM TOTAL OF "U" FACTORS (Overall heat transfer'
          WRITE (*,*) '  coefficient, decimal number, BTU/hr-deg F):'
          READ (*,*) USUM
        ELSE
          USUM=1.0
        ENDIF
C
C.................Use of tank linings.................................
C
        WRITE (*,*)
     1   'ENTER CODE FOR CONSIDERATION OF TANK LININGS'
        WRITE (*,*) '  (integer number):'
        WRITE (*,*) '   (1) Tank linings not considered in analysis'
        WRITE (*,*) '   (2) Tank linings considered in analysis'
        READ(*,*) LLNG
        IF (LLNG.EQ.2) THEN
          WRITE (*,*) 'ENTER CODE FOR TYPE OF LINING (integer number):'
          WRITE (*,*) '  (1) Six (6) mil organic liner'
          WRITE (*,*) '  (2) 3/16 inch thick rubber liner'
          READ (*,*) ILN
          WRITE (*,*)
     1       'DOES LINING DETERIORATE OVER FIXED TIME PERIOD?'
          WRITE (*,*) '  ENTER Y or N (for yes or no):'
          READ (*,205) LRESP
          IF (LRESP.EQ.'Y') THEN
            ILD=2
            WRITE (*,*)
     1        'ENTER TIME INTERVAL FOR DETERIORATION OF LINING'
            WRITE (*,*) '  (decimal number, minutes):'
            READ (*,*) LINTV
          ELSE
            ILD=1
            LINTV=1.0
          ENDIF
```

```
        ELSE
          ILN=0
          ILD=1
          LINTV=1.0
        ENDIF
C
C.................FIRE CONDITIONS.....................................
C
        WRITE (*,*)
     1    'ENTER CODE FOR TYPE OF FIRE ANALYSIS (integer number):'
        WRITE (*,*) '  (1) Standard Pool Fire Analysis'
        WRITE (*,*) '  (2) Standard Torch Fire Analysis'
        WRITE (*,*) '  (3) Special Conditions Fire Analysis'
        READ(*,*) IFRTYP
C
        IF (IFRTYP.EQ.1) THEN
          TEMF=1500.0
          CFRA=1.0
          CATR=1.0              ! Dummy value
        ELSEIF (IFRTYP.EQ.2) THEN
          TEMF=2200.0
          CFRA=1.0              ! Dummy value
          CATR=16.0
        ELSEIF (IFRTYP.EQ.3) THEN
          WRITE (*,*) 'ENTER FLAME TEMPERATURE (decimal number, deg F):'
          READ (*,*) TEMF
          WRITE (*,*)
     1       'ENTER FRACTION OF TANK SURFACE SUBJECTED TO FIRE'
          WRITE (*,*) '   (decimal fraction):'
          READ (*,*) CFRA
          CATR=1.0              ! Dummy value
        ENDIF
C
        WRITE (*,*) 'ENTER EMISSIVITY/ABSORPTIVITY OF TANK SURFACE'
        WRITE (*,*) '  (decimal fraction):'
        READ (*,*) ERAD
C
C.........................ANALYSIS CONDITIONS.........................
C
        WRITE (*,*) 'ENTER TIME INCREMENT (must be given in tenths of'
        WRITE (*,*) '  a minute as a decimal number, minimum value is'
        WRITE (*,*) '  0.01, recommended value is 0.1):'
        READ (*,*) DELT
C
        WRITE (*,*)
     1    'ENTER NUMBER OF TIME INCREMENTS BETWEEN DISPLAY'
        WRITE (*,*) '  OF OUTPUT DATA (integer number):'
        READ (*,*) INTV
C
        WRITE (*,*)
     1    'ENTER TIME LIMIT OF ANALYSIS (decimal number, minutes):'
        READ (*,*) TLIMIT
C
        WRITE (*,*)
     1 'DO YOU WISH TO WRITE ANALYSIS DATA TO A NEW FILE? (Y or N)'
        READ (*,205) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') THEN
          WRITE (*,*)
     1         'ENTER NAME OF FILE (Maximum of 12 Characters)'
          READ (*,203) BNAME
```

```
            OPEN(UNIT=14,FILE=BNAME,STATUS='NEW')
C
            WRITE (14,501) SIZE,DIAI,WTKI
            WRITE (14,502) IMT,TNSRTH,PNBRS,PCBRS
            WRITE (14,503) IPTYP,ISBSL,IPR,ICR,TCRIT
            WRITE (14,504) FRAT,TEMC,CONC,IPAD,PPID
            WRITE (14,505) IVLTYP,AVENT,VGTD,SCFM
            WRITE (14,507) PGSD,PGTD,CVAD,CVLQ,TILT
            WRITE (14,509) INS,CNDD,KINDX,CNDI,CINTV
            WRITE (14,511) THIC,A1,A2,A3
            WRITE (14,513) IDSC,USUM,LLNG,ILN,ILD,LINTV
            WRITE (14,515) IFRTYP,TEMF,CFRA,CATR,ERAD
            WRITE (14,517) TLIMIT,DELT,INTV
          ENDIF
C
201       FORMAT (A30)
203       FORMAT (A12)
205       FORMAT (A1)
501       FORMAT (F8.0,F8.2,F8.4)
502       FORMAT (I8,F8.0,2F8.1)
503       FORMAT (4I8,F8.2)
504       FORMAT (F8.3,F8.2,F8.3,I8,F8.3)
505       FORMAT (I8,2F8.2,F8.0)
507       FORMAT (5F8.2)
509       FORMAT (I8,F8.2,I8,2F8.2)
511       FORMAT (F8.2,3F8.3)
513       FORMAT (I8,F8.2,3I8,F8.2)
515       FORMAT (I8,F8.1,3F8.2)
517       FORMAT (2F8.2,I8)
C
          RETURN
          END
```

APPENDIX C

SUBROUTINE ANLYRPT

Subroutine ANLYRPT.FOR is used to prepare a report of the initial analysis data entered into the program. The report describes the nature and value of each variable required by the conditions of the analysis. The report is contained in a file which is named by the user. It may be printed to provide a permanent record.

The source code for this subroutine is presented on the following pages.

```
C......ANLYRPT.FOR prepares a report of the data entered into
C.......the program describing the conditions of the analysis.
C.......(Version 1.0, April 4, 1995) Modified to add thermal
C.......properties from FPRPSBS, FPRPSLV, SBSENTR, and SLNENTR.
C.......Version 3.0, November 11, 1998
C
      SUBROUTINE ANLYRPT(QNAME)
C
      REAL LINTV,MLWSBS,MLWSLV,SCFM,CNDD
      INTEGER*2 IMT,IPTYP,ISBSL,IPR,ICR,IPAD,IVLTYP,INS
      INTEGER*2 KINDX,IDSC,LLNG,ILN,ILD,IFRTYP,INTV
      CHARACTER*13 BNAME
      CHARACTER*30 CPRD(21),CMATYP(15),CLNTYP(10),QNAME
      CHARACTER*40 CINTYP(10)
C
      COMMON/TANK/SIZE,DIAI,WTKI
      COMMON/MATL/IMT,TNSRTH,PNBRS,PCBRS
      COMMON/PRDCT1/IPTYP,ISBSL,IPR,ICR,TCRIT
      COMMON/PRDCT2/FRAT,TEMC,CONC,IPAD,PPID
      COMMON/SRELF1/IVLTYP,AVENT,VGTD,SCFM
      COMMON/SRELF2/PGSD,PGTD,CVAD,CVLQ,TILT
      COMMON/THRML1/INS,CNDD,KINDX,CNDI,CINTV
      COMMON/THRML2/THIC,A1,A2,A3
      COMMON/THRML3/IDSC,USUM,LLNG,ILN,ILD,LINTV
      COMMON/FIRE/IFRTYP,TEMF,CFRA,CATR,ERAD
      COMMON/ITIME/TLIMIT,DELT,INTV
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
      COMMON/NAME/CPRD
C
      WRITE (*,*)
     1   'Enter Name of File Which is Used to Present Analsis Data,'
      WRITE (*,*)
     1   '  Maximum of 12 Characters Including ".DAT" Extension,'
      WRITE (*,*)
     1   '  For Example: REPORT.DAT'
      READ (*,447) BNAME
      OPEN (UNIT=12,FILE=BNAME,STATUS='NEW')
C
C.........Initialization of Character Variables.................
      CPRD(1)='WATER'
      CPRD(2)='PROPANE'
      CPRD(3)='ETHLYENE OXIDE'
      CPRD(4)='PROPYLENE'
      CPRD(5)='1,3-BUTADIENE'
      CPRD(6)='VINYL CHLORIDE'
      CPRD(7)='MONOMETHYLAMINE'
      CPRD(8)='PROPYLENE OXIDE'
      CPRD(9)='ANHYDROUS AMMONIA'
      CPRD(10)='SULFURIC ACID'
      CPRD(11)='HYDROCHLORIC ACID'
      CPRD(12)='SODIUM HYDROXIDE'
      CPRD(13)='PHOSPHORIC ACID (75%)'
      CPRD(14)='SUPERPHOSPHORIC ACID'
      CPRD(15)='POTASSIUM HYDROXIDE'
      CPRD(16)='HYDROGEN PEROXIDE SOLUTION'
      CPRD(17)='BLANK'
```

```
      CPRD(18)='BLANK'
      CPRD(19)='BLANK'
C
      CLNTYP(1)='6 mil ORGANIC LINER'
      CLNTYP(2)='3/16 in. RUBBER LINER'
C
      CMATYP(1)='CARBON STEEL'
      CMATYP(2)='STAINLESS STEEL'
      CMATYP(3)='ALUMINUM ALLOY'
C
      CINTYP(1)='Bare Uninsulated Tank'
      CINTYP(2)='"J" (DOT Approved High Temperature)'
      CINTYP(3)='Jacketed, Non-High Temperature'
      CINTYP(4)='Conductivity Independent of Temperature'
      CINTYP(5)='Conductivity Function of Temperature'
      CINTYP(6)='Jacketed, Two Component Insulation'
C
      WRITE (12,305)
     1   'DATA ENTERED INTO AFFTAC PROGRAM FOR ANALYSIS'
      WRITE (12,305) '  Program Version 3.0, November 11, 1998'
      WRITE (12,303) '   '
C
      WRITE (12,301) 'TANK PARAMETERS'
      WRITE (12,303) '   '
      WRITE (12,323) 'Capacity (gal):',SIZE
      WRITE (12,331) 'Inside Diameter (ins.):',DIAI
      WRITE (12,329) 'Wall Thickness (ins.):',WTKI
      IF (IMT.GE.1.AND.IMT.LE.15) IWRIT=1
      IF (IMT.GE.16.AND.IMT.LE.19) IWRIT=2
      IF (IMT.GE.20.AND.IMT.LE.27) IWRIT=3
      WRITE (12,383) 'Tank Material Type:',CMATYP(IWRIT)
      WRITE (12,346)
     1   'Tensile Strength of Tank Material (psi):',TNSRTH
      WRITE (12,345) 'Nominal Burst Strength (psig):',PNBRS
      WRITE (12,345) 'Calculated Burst Strength (psig):',PCBRS
      WRITE (12,363)
     1       'Tank Car Orientation with Respect'
      WRITE (12,367) 'to Vertical (deg):',TILT
      WRITE (12,303) '   '
C
      WRITE (12,301) 'PRODUCT DATA'
      WRITE (12,303) '   '
      IF (IPTYP.EQ.1) WRITE (12,303)
     1       'Product Thermal Property Data Contained in Program'
      IF (IPTYP.EQ.2) WRITE (12,303)
     1       'Product Thermal Property Data Entered in Program'
      IF (IPTYP.EQ.3) WRITE (12,303)
     1       'Product Thermal Property Data Read from File'
      IF (IPR.EQ.20.OR.IPR.EQ.21)
     1       WRITE (12,381) 'Product Name:',QNAME
      IF (IPR.GE.1.AND.IPR.LE.16)
     1       WRITE (12,381) 'Product Name:',CPRD(IPR)
      IF (ISBSL.EQ.1) WRITE (12,303) 'Product Type: Substance'
      IF (ISBSL.EQ.2) WRITE (12,303) 'Product Type: Solution'
      IF (ICR.EQ.2) WRITE (12,355)
     1   'Product Has Critical Temperature (deg F):',TCRIT
      WRITE (12,343) 'Initial Fraction of Tank Filled:',FRAT
      WRITE (12,341) 'Initial Temperature of Product:',TEMC
      IF (ISBSL.EQ.2) WRITE (12,321) 'Concentration:',CONC
      IF (IPAD.EQ.1.OR.IPAD.EQ.3)
```

```
     1          WRITE (12,303) 'Padding Gas Used'
        IF (IPAD.EQ.1) WRITE (12,303)
     1   'Atmospheric Pressure in Tank at Beginning of Analysis'
        IF (IPAD.EQ.3) WRITE (12,303)
     1  'Target Gage Pressure Within Tank'
        IF (IPAD.EQ.3) WRITE (12,337)
     1   'After Addition of Padding Gas (psig):',PPID
        IF (IPAD.EQ.3) WRITE (12,337)
     1   '(Note: Padding gas pressure will be 0.0 if target gage'
        IF (IPAD.EQ.3) WRITE (12,337)
     1   '  pressure is less than initial product vapor pressure.)'
        IF (IPAD.EQ.2) WRITE (12,303) 'No Padding Gas Used'
        WRITE (12,303) '   '
C
        WRITE (12,301) 'SAFETY RELIEF DEVICE PARAMETERS'
        WRITE (12,303) '   '
        IF (IVLTYP.EQ.2) THEN
          WRITE (12,303) 'Safety Vent Used'
          WRITE (12,341) 'Cross Sectional Area (sq.ins.):',AVENT
          WRITE (12,351)
     1      'Frangible Disc Rupture Pressure (psig):',VGTD
        ENDIF
C
        IF (IVLTYP.EQ.1) THEN
          WRITE (12,303) 'Safety Relief Valve Used'
          WRITE (12,333) 'Rated Flow Capacity (SCFM):',SCFM
          WRITE (12,335) 'Flow Rating Pressure (psig):',PGSD
          WRITE (12,349) 'Start-to-Discharge Pressure (psig):',PGTD
        ENDIF
        WRITE (12,359)
     1       'Vent or Valve Vapor Flow Discharge Coefficient:',CVAD
        WRITE (12,363)
     1       'Vent or Valve Liquid Flow Discharge Coefficient:',CVLQ
        WRITE (12,303) '   '
C
        WRITE (12,301) 'THERMAL PROTECTION SYSTEM CHARACTERISTICS'
        WRITE (12,303) '   '
C
        IF (INS.EQ.1) THEN
          WRITE (12,303) 'Bare, Uninsulated Tank'
          WRITE (12,303) '   '
        ENDIF
C
        IF (INS.EQ.2) THEN
          WRITE (12,303)
     1      '"J" Type Insulation, Approved High Temperature System'
          WRITE (12,357)
     1      'Steady State Conductance (BTU/hr-sq.ft-deg F):',CNDD
          WRITE (12,303) '   '
        ENDIF
C
        IF (INS.EQ.3) THEN
          WRITE (12,303) 'Jacketed Insulation System Not Resistant'
          WRITE (12,303) '  to High Temperature Effects'
          WRITE (12,355)
     1      'Initial Conductance (BTU/hr-sq.ft-deg F):',CNDI
          WRITE (12,303)
     1      'Time Interval for Linear Change from Initial Conductance'
          WRITE (12,369) 'to Final Conductance (min):',CINTV
          WRITE (12,303) '   '
```

```
      ENDIF
C
      IF (INS.EQ.4) THEN
        WRITE (12,303) 'Other Insulation System, Conductivity'
        WRITE (12,303) '  Independent of Temperature'
        WRITE (12,357)
     1    'Final Conductance (BTU/hr-sq.ft-deg F):',CNDD
        IF (KINDX.EQ.1) THEN
          WRITE (12,303)
     1      'Change from Initial to Final Conductance'
          WRITE (12,355)
     1      'Initial Conductance (BTU/hr-sq.ft-deg F):',CNDI
          WRITE (12,303)
     1    'Time Interval for Linear Change from Initial Conductance'
          WRITE (12,369) 'to Final Conductance (min):',CINTV
        ENDIF
        WRITE (12,303) '   '
      ENDIF
C
      IF (INS.EQ.5) THEN
        WRITE (12,303) 'Other Insulation System, Conductivity'
        WRITE (12,303) '  is a Function of Temperature'
        WRITE (12,341) 'Thickness of Insulation (ins.):',THIC
        WRITE (12,337) 'First Conductivity Parameter:',A1
        WRITE (12,339) 'Second Conductivity Parameter:',A2
        WRITE (12,337) 'Third Conductivity Parameter:',A3
        WRITE (12,303) '   '
      ENDIF
C
      IF (INS.EQ.6) THEN
        WRITE (12,303)
     1   'Jacketed, Two Component Insulation System, where '
        WRITE (12,303)
     1   '  Conductivity of Inner Layer is a'
        WRITE  (12,303) '  Function of Temperature'
        WRITE (12,303)
     1    'Initial Conductance of Outer Layer'
        WRITE (12,331) '  (BTU/hr-sq.ft-deg F):',CNDI
        IF (KINDX.EQ.1) THEN
          WRITE (12,303)
     1    'Change from Initial to Final Conductance of Outer Layer'
          WRITE (12,303)
     1    'Time Interval for Linear Change from Initial Conductance'
          WRITE (12,369) 'to Final Conductance (min):',CINTV
          WRITE (12,303)
     1    'Final Conductance of Outer Layer'
          WRITE (12,331) '  (BTU/hr-sq.ft-deg F):',CNDD
        ENDIF
        IF (KINDX.EQ.2) WRITE(12,303)
     1    'Conductance of Outer Layer Stays Constant'
        WRITE (12,357)
     1    'Thickness of Inner Layer of Insulation (ins.):',THIC
        WRITE (12,337) 'First Conductivity Parameter:',A1
        WRITE (12,339) 'Second Conductivity Parameter:',A2
        WRITE (12,337) 'Third Conductivity Parameter:',A3
        WRITE (12,303) '   '
        WRITE (12,303) '   '
      ENDIF
C
      IF (IDSC.EQ.1) WRITE (12,303)
```

```
     1     'Discontinuities in Insulation Not Considered'
           IF (IDSC.EQ.2) THEN
              WRITE (12,303)
     1     'Discontinuities Considered in Insulation'
              WRITE (12,351)
     1     'Sum Total of "U" Factors (BTU/deg F):',USUM
           ENDIF
           WRITE (12,303) '   '
C
           IF (LLNG.EQ.2) THEN
             WRITE (12,303) 'Tank Lining Used'
             WRITE (12,385) 'Type of Lining:',CLNTYP(ILN)
             IF (ILD.EQ.2) WRITE (12,345)
     1          'Lining Deterioration Time (min):',LINTV
             IF (ILD.EQ.1) WRITE (12,303)
     1          'Lining Does Not Deteriorate'
           ENDIF
           IF (LLNG.EQ.1) WRITE (12,303) 'No Tank Lining Used'
           WRITE (12,303) '   '
C
           WRITE (12,301) 'FIRE CONDITIONS'
           WRITE (12,303) '   '
           IF (IFRTYP.EQ.1) WRITE (12,303)
     1          'Standard Pool Fire Simulation Analysis'
           IF (IFRTYP.EQ.2) WRITE (12,303)
     1          'Standard Torch Fire Simulation Analysis'
           IF (IFRTYP.EQ.3) WRITE (12,303)
     1          'Special Fire Simulation Analysis'
           WRITE (12,327) 'Flame Temperature (deg F):',TEMF
           IF (IFRTYP.EQ.1.OR.IFRTYP.EQ.3) WRITE (12,359)
     1          'Fraction of Tank Surface Subject to Heat Input:',CFRA
           IF (IFRTYP.EQ.2) WRITE (12,365)
     1     'Area of Tank Surface Subject to Heat Input (sq.ft):',CATR
           WRITE (12,351) 'Tank Radiation Emissivity Coefficient:',ERAD
           WRITE (12,303) '   '
C
           WRITE (12,301) 'ANALYSIS CONDITIONS'
           WRITE (12,303) '   '
           WRITE (12,325) 'Time Limit (min):',TLIMIT
           WRITE (12,347) 'Time Increment for Analysis (min):',DELT
           WRITE (12,361)
     1          'Time Increments Between Display of Output Data:',INTV
C
301        FORMAT (T6,A)
303        FORMAT (T8,A)
305        FORMAT (T20,A)
321        FORMAT (T8,A,T23,F8.3)
323        FORMAT (T8,A,T24,F8.0)
325        FORMAT (T8,A,T26,F8.2)
327        FORMAT (T8,A,T35,F8.1)
329        FORMAT (T8,A,T31,F8.4)
331        FORMAT (T8,A,T32,F8.2)
333        FORMAT (T8,A,T36,F8.0)
335        FORMAT (T8,A,T37,F8.2)
337        FORMAT (T8,A,T38,F8.3)
339        FORMAT (T8,A,T39,F8.3)
341        FORMAT (T8,A,T40,F8.2)
343        FORMAT (T8,A,T41,F8.3)
345        FORMAT (T8,A,T42,F8.1)
346        FORMAT (T8,A,T49,F8.0)
```

```
347     FORMAT (T8,A,T43,F8.2)
349     FORMAT (T8,A,T44,F8.2)
351     FORMAT (T8,A,T48,F8.2)
355     FORMAT (T8,A,T50,F8.2)
357     FORMAT (T8,A,T55,F8.2)
359     FORMAT (T8,A,T56,F8.2)
361     FORMAT (T8,A,T56,I8)
363     FORMAT (T8,A,T57,F8.2)
365     FORMAT (T8,A,T60,F8.2)
367     FORMAT (T10,A,T29,F8.2)
369     FORMAT (T10,A,T39,F8.2)
381     FORMAT (T8,A,T22,A30)
383     FORMAT (T8,A,T30,A30)
385     FORMAT (T8,A,T24,A30)
443     FORMAT (A12)
445     FORMAT (A1)
447     FORMAT (A13)
C*************************************************************************
        IF (IPTYP.NE.1) GO TO 999
        IF (IPR.GE.10) GO TO 131
C.............Thermal Property Data for Substances.....................
        WRITE (12,715) '      '
        WRITE (12,301)
     1  'THERMAL PROPERTY DATA CONTAINED IN PROGRAM'
        WRITE (12,719)
     1  'FOR',CPRD(IPR)
        WRITE (12,715) '      '
        WRITE (12,711)
     1  'Temperature (degrees F), Vapor Pressure (psia), Specific'
        WRITE (12,711)
     1  'Heat (BTU/lb-deg F), Specific Volume (cu. ft/lb), Heat of'
        WRITE (12,711)
     1  'Vaporization (BTU/lb), Compressibility Factor of Vapor,'
        WRITE (12,711) 'and Ratio of Specific Heats of Vapor'
        WRITE (12,711) '      '
        WRITE (12,711)
     1 '                                                    Vapor'
        WRITE (12,711)
     1 '                                            Vapor  Ratio of'
        WRITE (12,711)
     1 '        Vapor    Spec.   Spec.   Heat of   Comp.   Spec.'
        WRITE (12,711)
     1 'Temp.   Pres.    Heat    Volume    Vap.    Fact.   Heats'
        WRITE (12,711) '      '
C
        IF (IPR.NE.1.OR.IPR.NE.9) DGRF=0.0
        IF (IPR.EQ.1) DGRF=40.0
        IF (IPR.EQ.9) DGRF=-20.0
        DSTEP=20.0
        IF (IPR.EQ.1) NTEMP=24
        IF (IPR.EQ.2) NTEMP=11
        IF (IPR.EQ.3) NTEMP=17
        IF (IPR.EQ.4.OR.IPR.EQ.9) NTEMP=10
        IF (IPR.EQ.5) NTEMP=15
        IF (IPR.EQ.6) NTEMP=14
        IF (IPR.EQ.7) NTEMP=13
        IF (IPR.EQ.8) NTEMP=20
        DO I=1,NTEMP
          CALL FPRPSBS (IPR,DGRF)
          WRITE (12,713) DGRF,PSBS,SPEC,SPLQ,HFLV,ZSBS,GAMSBS
```

```
            DGRF=DGRF+DSTEP
          ENDDO
          WRITE (12,711) '      '
          WRITE (12,717) 'MOLECULAR WEIGHT:',MLWSBS
          GO TO 999
C*************************************************************************
C.....................Thermal Property Data for Solutions.....................
131       CONTINUE
          WRITE (12,715) '      '
          WRITE (12,301) 'THERMAL PROPERTY DATA CONTAINED IN PROGRAM'
          WRITE (12,719) 'FOR',CPRD(IPR)
          WRITE (12,715) '      '
          WRITE (12,711)
     1    'Temperature (degrees F), Specific Heat of Solution'
          WRITE (12,711)
     1    '(BTU/lb-deg F), Specific Volume of Solution (cu. ft/lb),'
          WRITE (12,711)
     1    'Heat of Vaporization of Solution (BTU/lb), Vapor Pressure of'
          WRITE (12,711)
     1    'Substance (psia), Vapor Pressure of Solvent (psia),'
          WRITE (12,711)
     1    'Compressibility Factor for Substance Vapor, Compressibility'
          WRITE (12,711)
     1    'Factor for Solvent Vapor, Ratio of Specific Heats for'
          WRITE (12,711)
     1    'Substance Vapor, and Ratio of Specific Heats for'
          WRITE (12,711)
     1    'Solvent Vapor'
          WRITE (12,715) '      '
729       FORMAT (T1,A,T44,A)
C
          NUMBCNC=2
          IF (IPR.EQ.11) NUMBCNC=4
          IF (IPR.EQ.16) NUMBCNC=3
          DO I=1,NUMBCNC
            DGRF=0.0
            DSTEP=20.0
            WRITE (12,715) '      '
            IF (IPR.EQ.10.AND.I.EQ.1) CONC=0.92
            IF (IPR.EQ.10.AND.I.EQ.2) CONC=0.94
            IF (IPR.EQ.11.AND.I.EQ.1) CONC=0.32
            IF (IPR.EQ.11.AND.I.EQ.2) CONC=0.34
            IF (IPR.EQ.11.AND.I.EQ.3) CONC=0.36
            IF (IPR.EQ.11.AND.I.EQ.4) CONC=0.38
            IF (IPR.EQ.12.AND.I.EQ.1) CONC=0.50
            IF (IPR.EQ.12.AND.I.EQ.2) CONC=0.60
            IF (IPR.EQ.13.AND.I.EQ.1) CONC=0.75
            IF (IPR.EQ.13.AND.I.EQ.2) CONC=0.85
            IF (IPR.EQ.14.AND.I.EQ.1) CONC=0.755
            IF (IPR.EQ.14.AND.I.EQ.2) CONC=0.765
            IF (IPR.EQ.15.AND.I.EQ.1) CONC=0.44
            IF (IPR.EQ.15.AND.I.EQ.2) CONC=0.50
            IF (IPR.EQ.16.AND.I.EQ.1) CONC=0.82
            IF (IPR.EQ.16.AND.I.EQ.2) CONC=0.74
            IF (IPR.EQ.16.AND.I.EQ.3) CONC=0.65
            WRITE (12,735) 'CONCENTRATION:',CONC
            WRITE (12,711) '      '
            WRITE (12,729)
     1  '          Solution Properties     Vapor     ',
     2  '  Compress.      Ratio of Spec.'
```

```
          WRITE (12,729)
     1 '          Spec. Spec.  Heat of   Pressures  ',
     2 '  Fact. of Vap.  Heats of Vap.'
          WRITE (12,729)
     1 ' Temp.   Heat  Volume   Vap.   Sbs.   Solv.',
     2 '  Sbs.   Solv.    Sbs.  Solv. '
          WRITE (12,711) '       '
          IF (IPR.EQ.10.OR.IPR.EQ.13) NTEMP=23
          IF (IPR.EQ.11) NTEMP=11
          IF (IPR.EQ.12) NTEMP=16
          IF (IPR.EQ.14.OR.IPR.EQ.15) NTEMP=18
          IF (IPR.EQ.16) NTEMP=13
          DO J=1,NTEMP
            CALL FPRPSLV (IPR,CONC,DGRF)
            WRITE (12,733) DGRF,SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,
     1      ZSLV,GAMSBS,GAMSLV
            DGRF=DGRF+DSTEP
          ENDDO
        ENDDO
        WRITE (12,715) '       '
        WRITE (12,727) 'MOLECULAR WEIGHT OF SUBSTANCE:',MLWSBS
        WRITE (12,727) 'MOLECULAR WEIGHT OF SOLVENT:',MLWSLV
C*****************************************************************************
733     FORMAT(F7.2,F7.4,F7.5,F7.0,2F7.2,F7.2,F6.2,F9.2,F7.2)
735     FORMAT (T6,A,T21,F6.2)
711     FORMAT (T8,A)
715     FORMAT (/T8,A)
717     FORMAT (T8,A,T26,F6.2)
719     FORMAT (T6,A,T11,A)
713     FORMAT (F12.2,F9.2,F8.4,F9.5,F8.1,2F8.2)
727     FORMAT (T8,A,T38,F6.2)
C*****************************************************************************
999     CONTINUE
        RETURN
        END
```

APPENDIX D

SUBROUTINE SBSENTR

Subroutine SBSENTR.FOR is used to enter thermal property data for a substance into the program. See the User's Manual for a detailed discussion of the use of this subroutine.

While the data is being entered into the program, the data is also written to the report file. This file may be printed to provide a permanent record.

After all of the data has been entered, the data is written to a file named NEWSBS.DAT. This file is read by the appropriate property subroutine to get the data into the main program.

Also, after all of the data has been entered, the program presents the option of storing the data in a separate file which can be used, if desired, for data input on succeeding analyses.

The variables used in this subroutine are defined as follows:

NSPEC	Number of data points for specific heat to be entered in program,
SPCTMP(I)	Temperature of the I'th data point for specific heat (°F),
ESPEC(I)	Value of specific heat at temperature of I'th data point (BTU/lb-°F),
NPSLQ	Number of data points for specific volume to be entered into program,
SPLTMP(I)	Temperature of the I'th data point for specific volume (°F),
ESPLQ(I)	Value of specific volume at temperature of I'th data point (ft^3/lb),
NHFLV	Number of data points for heat of vaporization to be entered into program,
HFLTMP(I)	Temperature of the I'th data point for heat of vaporization (°F),
EHFLV(I)	Value of heat of vaporization at temperature of I'th data point (BTU/lb),
NPSBS	Number of data points for vapor pressure to be entered into program,
PSBTMP(I)	Temperature of the I'th data point for vapor pressure (°F),
EPSBS(I)	Value of vapor pressure at temperature of I'th data point (psia),
NZPRO	Number of data points for compressibility factor of vapor to be entered into program,

ZPRTMP(I)	Temperature of the I'th data point for compressibility factor of vapor (°F),
EZPRO(I)	Value of compressibility factor of vapor at temperature of I'th data point,
NGMMP	Number of data points for ratio of specific heats of vapor to be entered into program,
GMPTMP(I)	Temperature of the I'th data point for ratio of specific heats of vapor (°F),
EGMMP(I)	Value of ratio of specific heats of vapor at temperature of I'th data point, and
MLWSBS	Molecular weight of vapor.

```
C.......SBSENTR.FOR is a subroutine developed
C.........for the entry of thermal property data for a substance
C.........by an interactive process at the computer terminal.
C.....................................Version 2.0, August 30, 1997
C
      SUBROUTINE SBSENTR(QNAME)
C
      DIMENSION ESPEC(8),ESPLQ(8),EHFLV(8),EPSBS(15)
      DIMENSION SPCTMP(8),SPLTMP(8),HFLTMP(8),PSBTMP(15)
      DIMENSION EZPRO(8),EGMMP(8),ZPRTMP(8),GMPTMP(8)
      REAL MLWSBS
      INTEGER*2 NSPEC,NSPLQ,NHFLV,NPSBS,NZPRO,NGMMP
      CHARACTER*1 RESPNS
      CHARACTER*12 FLNAME
      CHARACTER*30 QNAME
C
C.....................Initialize variables.........................
C
      DO I=1,8
         ESPEC(I)=0.0
         ESPLQ(I)=0.0
         EHFLV(I)=0.0
         EZPRO(I)=0.0
         EGMMP(I)=0.0
         SPCTMP(I)=0.0
         SPLTMP(I)=0.0
         HFLTMP(I)=0.0
         ZPRTMP(I)=0.0
         GMPTMP(I)=0.0
      ENDDO
      DO I=1,15
         EPSBS(15)=0.0
         PSBTMP(15)=0.0
      ENDDO
C
      WRITE (12,202) '    '
      WRITE (12,201) '     THERMAL PROPERTY DATA'
      WRITE (12,251) 'PRODUCT NAME:',QNAME
      WRITE (12,202) '    '
C
C*************** ENTRY OF THERMAL PROPERTY DATA ************************
111   CONTINUE
      WRITE (*,201)
     1    'Entry of data defining thermal properties of a substance'
      WRITE (*,202) '   as a function of temperature (deg F)'
      WRITE (*,202) '            GENERAL INSTRUCTIONS  '
      WRITE (*,201)
     1    'Property data is entered at specific temperatures. The'
      WRITE (*,202)
     1    '  order of entry must be for increasing temperatures.'
      WRITE (*,201) 'Temperatures and thermal property data should be'
      WRITE (*,201)
     1    '  entered as real numbers (i.e. with a decimal point).'
      WRITE (*,201)
     1    '  Temperatures (degs F) are normally entered to two decimal'
      WRITE (*,204) '  places (e.g. 70.50).'
C*********************************************************************
C.................Entry of SPECIFIC HEAT Data.........................
121   CONTINUE
      WRITE (*,202)
```

```
     1     'Entry of Property data for SPECIFIC HEAT of liquid'
           WRITE (*,201) 'SPECIFIC HEAT data (BTU/lb-deg F) is normally'
           WRITE (*,202) '  entered to four decimal places (e.g. 0.5432).'
           WRITE (*,201) 'Enter number of data points to be provided'
           WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
           READ (*,203) NSPEC
           DO I=1,NSPEC
             WRITE (*,205)
     1       'Enter TEMPERATURE and corresponding SPECIFIC HEAT'
             WRITE (*,315) '  (separated by a comma) for data point:',I
             READ (*,311) SPCTMP(I), ESPEC(I)
           ENDDO
C.....................Review of Data Entered .....................
           WRITE (*,202)
     1       '   DATA ENTERED IN PROGRAM FOR SPECIFIC HEAT'
           WRITE (*,202)
     1       ' Temperature (deg F)  Specific Heat (BTU/lb-deg F)'
           DO I=1,NSPEC
             WRITE (*,213) SPCTMP(I),ESPEC(I)
           ENDDO
           WRITE (*,202) '   '
C.................Check Acceptibility of Data Entered.............
           WRITE (*,*) 'Do you wish to reenter Specific Heat Data?'
           WRITE (*,*) '  (Enter Y for yes, or N for no):'
           READ (*,241) RESPNS
           IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 121
C.....................Write Data to Report File.....................
           WRITE (12,202)
     1       'DATA ENTERED IN PROGRAM FOR SPECIFIC HEAT'
           WRITE (12,202)
     1       ' Temperature (deg F)  Specific Heat (BTU/lb-deg F)'
           DO I=1,NSPEC
             WRITE (12,213) SPCTMP(I),ESPEC(I)
           ENDDO
           WRITE (12,202) '   '
C.....................................................................
311        FORMAT (F8.2,F8.4)
315        FORMAT (T3,A,T44,I3)
           WRITE(*,204) 'SPECIFIC HEAT data entry is completed.'
C*********************************************************************
C.................Entry of SPECIFIC VOLUME of Liquid Data.............
131        CONTINUE
           WRITE (*,202)
     1     'Entry of Property data for SPECIFIC VOLUME of liquid'
           WRITE (*,201) 'SPECIFIC VOLUME (cu. ft/lb) data is normally'
           WRITE (*,202) '  entered to five decimal places (e.g. 0.01120).'
           WRITE (*,201) 'Enter number of data points to be provided'
           WRITE (*,201) '  (integer number), minimum of 2, maximum of 8:'
           READ (*,203) NSPLQ
           DO I=1,NSPLQ
             WRITE (*,205)
     1        'Enter TEMPERATURE and corresponding SPECIFIC VOLUME'
             WRITE (*,315) '  (separated by a comma) for data point:',I
             READ (*,313) SPLTMP(I), ESPLQ(I)
           ENDDO
C.....................Review of Data Entered .....................
           WRITE (*,202)
     1       'DATA ENTERED IN PROGRAM FOR SPECIFIC VOLUME'
           WRITE (*,202)
     1       ' Temperature (deg F)  Specific Volume (cu.-ft/lb)'
```

```
        DO I=1,NSPLQ
          WRITE (*,214) SPLTMP(I),ESPLQ(I)
        ENDDO
        WRITE (*,202) '   '
C.................Check Acceptibility of Data Entered.................
        WRITE (*,*) 'Do you wish to reenter Specific Volume Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 131
C.....................Write Data to Report File.....................
        WRITE (12,202)
     1      'DATA ENTERED IN PROGRAM FOR SPECIFIC VOLUME'
        WRITE (12,202)
     1      ' Temperature (deg F)  Specific Volume (cu.-ft/lb)'
        DO I=1,NSPLQ
          WRITE (12,214) SPLTMP(I),ESPLQ(I)
        ENDDO
        WRITE (12,202) '   '
C.....................................................................
        WRITE(*,204) 'SPECIFIC VOLUME data entry is completed.'
313     FORMAT (F8.2,F8.5)
C*********************************************************************
C.................Entry of HEAT OF VAPORIZATION Data.................
141     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for HEAT OF VAPORIZATION'
        WRITE (*,201) 'HEAT OF VAPORIZARION data (BTU/lb) is normally'
        WRITE (*,202) '  entered to one decimal place (e.g. 1010.1).'
        WRITE (*,201) 'Enter number of data points to be provided'
        WRITE (*,201) '  (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NHFLV
        DO I=1,NHFLV
          WRITE (*,205)
     1     'Enter TEMPERATURE and corresponding HEAT OF VAPORIZATION'
          WRITE (*,315) '  (separated by a comma) for data point',I
          READ (*,317) HFLTMP(I),EHFLV(I)
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,202)
     1   'DATA ENTERED IN PROGRAM FOR HEAT OF VAPORIZATION'
        WRITE (*,202)
     1      ' Temperature (deg F)  Heat of Vaporization (BTU/lb)'
        DO I=1,NHFLV
          WRITE (*,219) HFLTMP(I),EHFLV(I)
        ENDDO
        WRITE (*,202) '   '
C.................Check Acceptibility of Data Entered.................
        WRITE (*,*) 'Do you wish to reenter Heat of Vaporization Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 141
C.....................Write Data to Report File.....................
        WRITE (12,202)
     1   'DATA ENTERED IN PROGRAM FOR HEAT OF VAPORIZATION'
        WRITE (12,202)
     1      ' Temperature (deg F)  Heat of Vaporization (BTU/lb)'
        DO I=1,NHFLV
          WRITE (12,219) HFLTMP(I),EHFLV(I)
        ENDDO
        WRITE (12,202) '   '
```

```
C.....................................................................
      WRITE(*,204)
     1      'HEAT OF VAPORIZATION data entry is completed.'
317   FORMAT (F8.2,F8.1)
C*********************************************************************
C.................Entry VAPOR PRESSURE OF SUBSTANCE Data...............
151   CONTINUE
      WRITE (*,202)
     1   'Entry of Property data for VAPOR PRESSURE OF SUBSTANCE'
      WRITE (*,201)
     1        'VAPOR PRESSURE OF SUBSTANCE data (psia) is normally'
      WRITE (*,202) '  entered to two decimal places (e.g. 60.55).'
      WRITE (*,201) 'Enter number of data points to be provided'
      WRITE (*,201) '  (integer number); must be an odd number of'
      WRITE (*,201) '  points, minimum of 3, maximum of 15:'
      READ (*,203) NPSBS
      DO I=1,NPSBS
        WRITE (*,205)
     1    'Enter TEMPERATURE and corresponding VAPOR PRESSURE'
        WRITE (*,315) '  (separated by a comma) for data point',I
        READ (*,319) PSBTMP(I),EPSBS(I)
      ENDDO
C.....................Review of Data Entered .......................
      WRITE (*,202)
     1  'DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SUBSTANCE'
      WRITE (*,202)
     1      ' Temperature (deg F)      Vapor Pressure (psia)'
      DO I=1,NPSBS
        WRITE (*,221) PSBTMP(I),EPSBS(I)
      ENDDO
      WRITE (*,202) '   '
C..................Check Acceptibility of Data Entered................
      WRITE (*,*) 'Do you wish to reenter Vapor Pressure Data?'
      WRITE (*,*) '  (Enter Y for yes, or N for no):'
      READ (*,241) RESPNS
      IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 151
C.....................Write Data to Report File.....................
      WRITE (12,202)
     1  'DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SUBSTANCE'
      WRITE (12,202)
     1      ' Temperature (deg F)      Vapor Pressure (psia)'
      DO I=1,NPSBS
        WRITE (12,221) PSBTMP(I),EPSBS(I)
      ENDDO
      WRITE (12,202) '   '
C.....................................................................
319   FORMAT(2F8.2)
      WRITE(*,204) 'VAPOR PRESSURE data entry is completed.'
C*********************************************************************
C.........Entry of COMPRESSIBILITY FACTOR OF SUBSTANCE VAPOR Data.......
161   CONTINUE
      WRITE (*,202)
     1   'Property data for COMPRESSIBILITY FACTOR OF SUBSTANCE VAPOR'
      WRITE (*,201)
     1   'COMPRESSIBILITY FACTOR  data is normally entered to two'
      WRITE (*,202) '  decimal places (e.g. 0.97).'
      WRITE (*,201) 'Enter number of data points to be provided'
      WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
      READ (*,203) NZPRO
      DO I=1,NZPRO
```

```
          WRITE (*,205)
     1   'Enter TEMPERATURE and corresponding COMPRESSIBILITY FACTOR'
          WRITE (*,315) '  (separated by a comma) for data point',I
          READ (*,319) ZPRTMP(I), EZPRO(I)
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,201)
     1        'DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY FACTOR'
        WRITE (*,202)
     1        '              OF SUBSTANCE VAPOR'
        WRITE (*,202)
     1      ' Temperature (deg F)    Compressibility Factor'
        DO I=1,NZPRO
          WRITE (*,221) ZPRTMP(I),EZPRO(I)
        ENDDO
        WRITE (*,202) '   '
C..................Check Acceptibility of Data Entered.................
        WRITE (*,*) 'Do you wish to reenter Compresibility Factor Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 161
C.....................Write Data to Report File.....................
        WRITE (12,201)
     1        'DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY FACTOR'
        WRITE (12,202)
     1        '              OF SUBSTANCE VAPOR'
        WRITE (12,202)
     1      ' Temperature (deg F)    Compressibility Factor'
        DO I=1,NZPRO
          WRITE (12,221) ZPRTMP(I),EZPRO(I)
        ENDDO
        WRITE (12,202) '   '
C.....................................................................
        WRITE(*,204)
     1        'COMPRESSIBILITY FACTOR data entry is completed.'
C*********************************************************************
C.........Entry of RATIO OF SPECIFIC HEATS OF SUBSTANCE VAPOR Data.........
171     CONTINUE
        WRITE (*,202)
     1   'Property data for RATIO OF SPECIFIC HEATS OF SUBSTANCE VAPOR'
        WRITE (*,201)
     1    'RATIO OF SPECIFIC HEATS data is normally entered to two'
        WRITE (*,202) '  decimal places (e.g. 1.37).'
        WRITE (*,201) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NGMMP
        WRITE (*,201) '   '
        DO I=1,NGMMP
          WRITE (*,205)
     1   'Enter TEMPERATURE and corresponding SPECIFIC HEAT RATIO'
          WRITE (*,315) '  (separated by a comma) for data point',I
          READ (*,319) GMPTMP(I), EGMMP(I)
          WRITE (*,201) '   '
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,201)
     1    'DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC HEATS'
        WRITE (*,201)
     1    '              OF SUBSTANCE VAPOR'
        WRITE (*,201)
```

```
     1      ' Temperature (deg F)    Ratio of specific heats'
            WRITE (*,201) '   '
            DO I=1,NGMMP
              WRITE (*,221) GMPTMP(I),EGMMP(I)
            ENDDO
            WRITE (*,202) '   '
C.....Check Acceptibility of Data Entered.....
            WRITE (*,*) 'Do you wish to reenter Specific Heat Ratio Data?'
            WRITE (*,*) '  (Enter Y for yes, or N for no):'
            READ (*,241) RESPNS
            IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 171
C.....Write Data to Report File.....
            WRITE (12,201)
     1    'DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC HEATS'
            WRITE (12,201)
     1    '              OF SUBSTANCE VAPOR'
            WRITE (12,201)
     1      ' Temperature (deg F)    Ratio of specific heats'
            WRITE (12,201) '   '
            DO I=1,NGMMP
              WRITE (12,221) GMPTMP(I),EGMMP(I)
            ENDDO
            WRITE (12,202) '   '
C.....
            WRITE(*,204)
     1        'RATIO OF SPECIFIC HEATS data entry is completed.'
C*****************************************************************
C.....Entry of MOLLECULAR WEIGHT OF SUBSTANCE VAPOR Data.....
181         CONTINUE
            WRITE (*,201)
     1    'Property data for MOLLECULAR WEIGHT OF SUBSTANCE VAPOR'
            WRITE (*,201) 'MOLLECULAR WEIGHT data is normally entered'
            WRITE (*,201) '  to two decimal places (e.g. 18.00).'
            WRITE (*,201) '   '
            WRITE (*,201) 'Enter Mollecular Weight:'
            READ (*,209) MLWSBS
            WRITE (*,201) '   '
C.....Review of Data Entered .....
            WRITE (*,201)
     1    'DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT'
            WRITE (*,202)
     1    '              OF SUBSTANCE VAPOR'
            WRITE (*,245) MLWSBS
            WRITE (*,202) '   '
C.....Check Acceptibility of Data Entered.....
            WRITE (*,*) 'Do you wish to reenter Mollecular Weight Data?'
            WRITE (*,*) '  (Enter Y for yes, or N for no):'
            READ (*,241) RESPNS
            IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 181
C.....Write Data to Report File.....
            WRITE (12,201)
     1    'DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT'
            WRITE (12,202)
     1    '              OF SUBSTANCE VAPOR'
            WRITE (12,245) MLWSBS
            WRITE (12,202) '   '
C.....
            WRITE(*,204)
     1        'MOLLECULAR WEIGHT OF VAPOR data entry is completed.'
C*****************************************************************
```

```
C.....If desired, save thermal property data by writing it......
C.................to a separate file.............................
C
        ISTART=16
        WRITE (*,*) 'Do you want to save Thermal Property Data in'
        WRITE (*,*) '  a separate file?  (Enter Y or N):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') THEN
          WRITE (*,*) 'Enter name of file (maximum of 12 characters):'
          READ (*,243) FLNAME
          OPEN ( UNIT=17,FILE=FLNAME,STATUS='NEW')
          ISTART=17
        ENDIF
C
C........Write data to NEWSBS.DAT file (and above optional file).........
C
        DO I=16,ISTART
          WRITE (I,223) NSPEC
          DO J=1,NSPEC
            WRITE (I,225) SPCTMP(J),ESPEC(J)
          ENDDO
          WRITE (I,223) NSPLQ
          DO J=1,NSPLQ
            WRITE (I,226) SPLTMP(J),ESPLQ(J)
          ENDDO
          WRITE (I,223) NHFLV
          DO J=1,NHFLV
            WRITE (I,227) HFLTMP(J),EHFLV(J)
          ENDDO
          WRITE (I,223) NPSBS
          DO J=1,NPSBS
            WRITE (I,229) PSBTMP(J),EPSBS(J)
          ENDDO
          WRITE (I,223) NZPRO
          DO J=1,NZPRO
            WRITE (I,229) ZPRTMP(J),EZPRO(J)
          ENDDO
          WRITE (I,223) NGMMP
          DO J=1,NGMMP
            WRITE (I,229) GMPTMP(J),EGMMP(J)
          ENDDO
          WRITE (I,247) MLWSBS
        ENDDO
        REWIND 16
411     CONTINUE
C*************************************************************************
201     FORMAT (T3,A)
202     FORMAT (T3,A/)
203     FORMAT (I8)
204     FORMAT (T3,A//)
205     FORMAT (/T3,A)
209     FORMAT (F8.2)
212     FORMAT (F10.5)
213     FORMAT (T10,F8.2,T27,F10.4)
214     FORMAT (T10,F8.2,T27,F10.5)
219     FORMAT (T10,F8.2,T27,F10.1)
221     FORMAT (T10,F8.2,T27,F10.2)
223     FORMAT (I10)
225     FORMAT (F10.2,F10.4)
226     FORMAT (F10.2,F10.5)
```

```
227      FORMAT (F10.2,F10.1)
229      FORMAT (2F10.2)
241      FORMAT (A1)
243      FORMAT (A12)
245      FORMAT (T10,F8.2)
247      FORMAT (F10.2)
251      FORMAT (T10,A,T25,A)
C
         RETURN
         END
```

APPENDIX E

SUBROUTINE SLNENTR

Subroutine SLNENTR.FOR is used to enter thermal property data for a solution into the program. See the User's Manual for a detailed discussion of the use of this subroutine.

While the data is being entered into the program, the data is written to the report file. This file may be printed to provide a permanent record.

After all of the data has been entered, the data is written to a file named NEWSLN.DAT. This file is read by the appropriate property subroutine to get the data into the main program.

Also, after all of the data has been entered, the program presents the option of storing the data in a separate file which can be used, if desired, for data input on succeeding analyses.

The variables used in this subroutine are defined as follows:

NSPEC	Number of data points for specific heat to be entered in program,
SPCTMP(I,J)	Temperature of the J'th data point for specific heat of liquid at I'th value of concentration (°F),
ESPEC(I,J)	Value of specific heat of liquid at temperature of J'th data point for the I'th value of concentration (BTU/lb-°F),
NPSLQ	Number of data points for specific volume of liquid to be entered into program,
SPLTMP(I)	Temperature of the J'th data point for specific volume of liquid at the I'th value of concentration (°F),
ESPLQ(I,J)	Value of specific volume of liquid at temperature of J'th data point for the I'th value of concentration (ft^3/lb),
NHFLV	Number of data points for heat of vaporization to be entered into program,
HFLTMP(I,J)	Temperature of the J'th data point for heat of vaporization at the I'th value of concentration (°F),
EHFLV(I,J)	Value of heat of vaporization at temperature of J'th data point for the I'th value of concentration (BTU/lb),

NPSLT	Number of data points for vapor pressure to be entered into program,
PSTTMP(I,J)	Temperature of the J'th data point for vapor pressure of solute at the I'th value of concentration (°F),
EPSLT(I,J)	Value of vapor pressure of solute at temperature of J'th data point for the I'th value of concentration (psia),
NPSLV	Number of data points for vapor pressure of solvent to be entered into program,
PSVTMP(I,J)	Temperature of the J'th data point for vapor pressure of solvent at the I'th value of concentration (°F)
EPSLV(I,J)	Value of vapor pressure of solvent at temperature of J'th data point for the I'th value of concentration (psia),
NZSLT	Number of data points for compressibility factor of solute vapor to be entered into program,
ZSTTMP(I)	Temperature of the I'th data point for compressibility factor of solute vapor (°F),
EZSLT(I)	Value of compressibility factor of solute vapor at temperature of I'th data point,
NZSLV	Number of data points for compressibility factor of solvent vapor to be entered into program,
ZSVTMP(I)	Temperature of the I'th data point for compressibility factor of solvent vapor (°F),
EZSLV(I)	Value of compressibility factor of solvent vapor at temperature of I'th data point,
NGSLT	Number of data points for ratio of specific heats of solute vapor to be entered into program,
GSTTMP(I)	Temperature of the I'th data point for ratio of specific heats of solute vapor (°F),
EGSLT(I)	Value of ratio of specific heat of solute vapor at temperature of I'th data point,
NGSLV	Number data points for ratio of specific heats of solvent vapor to be entered into the program,

GSVTMP(I)	Temperature of the I'th data point for ratio of specific heats of solvent vapor (°F),
EGSLV(I)	Value of ratio of specific heats of solvent vapor at temperature of I'th data point,
MLWSBS	Molecular weight of solute vapor, and
MLWSLV	Molecular weight of solvent vapor.

```
C.......SLNENTR.FOR is a program developed
C..........for the entry of thermal property data for a two-component
C..........solution (solvent and solute) by an interactive process
C..........at the computer terminal.
C.....................................Version 2.0, August 30, 1997
C
      SUBROUTINE SLNENTR(QNAME)
C
      DIMENSION ESPEC(2,8),ESPLQ(2,8),EHFLV(2,8),EPSLT(2,15)
      DIMENSION EPSLV(2,15),EZSLT(8),EZSLV(8)
      DIMENSION EGSLT(8),EGSLV(8),CNCSLN(7,2)
      DIMENSION SPCTMP(2,8),SPLTMP(2,8),HFLTMP(2,8),PSTTMP(2,15)
      DIMENSION PSVTMP(2,15),ZSTTMP(8),ZSVTMP(8)
      DIMENSION GSTTMP(8),GSVTMP(8)
      REAL MLWSBS,MLWSLV
      INTEGER*2 NSPEC,NSPLQ,NHFLV,NPSLT,NPSLV
      INTEGER*2 NZSLT,NZSLV,NGSLT,NGSLV
      CHARACTER*1 RESPNS
      CHARACTER*12 FLNAME
      CHARACTER*30 QNAME
C
C.....................Initialize variables.........................
C
      DO I=1,2
        DO J=1,8
          ESPEC(I,J)=0.0
          ESPLQ(I,J)=0.0
          EHFLV(I,J)=0.0
          SPCTMP(I,J)=0.0
          SPLTMP(I,J)=0.0
          HFLTMP(I,J)=0.0
        ENDDO
      ENDDO
      DO I=1,2
        DO J=1,15
          EPSLT(I,J)=0.0
          PSTTMP(I,J)=0.0
          EPSLV(I,J)=0.0
          PSVTMP(I,J)=0.0
        ENDDO
      ENDDO
      DO I=1,5
        DO J=1,2
          CNCSLN(I,J)=1.000
        ENDDO
      ENDDO
      DO I=1,8
        EZSLT(I)=0.0
        EZSLV(I)=0.0
        EGSLT(I)=0.0
        EGSLV(I)=0.0
        ZSTTMP(I)=0.0
        ZSVTMP(I)=0.0
        GSTTMP(I)=0.0
        GSVTMP(I)=0.0
      ENDDO
C
      WRITE (12,202) '    '
      WRITE (12,201) '   THERMAL PROPERTY DATA'
      WRITE (12,259) 'PRODUCT NAME',QNAME
```

```
        WRITE (12,202) '    '
C
C*************** ENTRY OF THERMAL PROPERTY DATA ************************
        WRITE (*,201)
     1     'Entry of data defining thermal properties of a solution'
        WRITE (*,201) '   as a function of temperature (deg F)'
        WRITE (*,202) '            GENERAL INSTRUCTIONS  '
        WRITE (*,202)
     1    'Property data is entered at two levels of concentration'
        WRITE (*,201)
     1    '  of the solution for specific heat, specific volume,'
        WRITE (*,201)
     1    '  heat of vaporization, vapor pressure of solute, and'
        WRITE (*,201)
     1    '  vapor pressure of solvent data.'
        WRITE (*,202)
     1    'Property data is entered at specific temperatures. The'
        WRITE (*,201)
     1    '  order of entry must be for increasing temperatures.'
        WRITE (*,201)
     1    '  (Note: the same number of data points are to be provided'
        WRITE (*,201) '  at each concentration level.)'
        WRITE (*,201) 'Temperatures and thermal property data should be'
        WRITE (*,201)
     1    '  entered as real numbers (i.e. with a decimal point).'
        WRITE (*,201)
     1    '  Temperatures (degs F) are normally entered to two decimal'
        WRITE (*,201) '  places (e.g. 70.50).'
        WRITE (*,202) 'Press the ENTER key to proceed'
        READ (*,*)
C*********************************************************************
C.................Entry of SPECIFIC HEAT Data.........................
111     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for SPECIFIC HEAT of liquid'
        WRITE (*,201)
     1    '  at two levels of concentration of the solution.'
        WRITE (*,202) 'SPECIFIC HEAT data (BTU/lb-deg F) is normally'
        WRITE (*,201) '  entered to four decimal places (e.g. 0.5432).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NSPEC
C
        DO 115 I=1,2
117     CONTINUE
          WRITE (*,201) 'Property Data for SPECIFIC HEAT of liquid at'
        IF (I.EQ.1) THEN
          WRITE (*,201) '  Lower Concentration Level'
          WRITE (*,201)
     1      'Enter Lower Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(1,1)
        ENDIF
        IF (I.EQ.2) THEN
          WRITE (*,201) '  Upper Concentration Level'
          WRITE (*,201)
     1      'Enter Upper Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(1,2)
        ENDIF
C.....................................................................
        DO J=1,NSPEC
```

```
          WRITE (*,205)
     1      'Enter TEMPERATURE and corresponding SPECIFIC HEAT'
          WRITE (*,315) '  (separated by a comma) for data point:',J
          READ (*,311) SPCTMP(I,J), ESPEC(I,J)
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,202)
     1      '   DATA ENTERED IN PROGRAM FOR SPECIFIC HEAT'
        WRITE (*,252)'     AT CONCENTRATION OF:',CNCSLN(1,I)
        WRITE (*,202)
     1      ' Temperature (deg F)  Specific Heat (BTU/lb-deg F)'
        DO J=1,NSPEC
          WRITE (*,213) SPCTMP(I,J),ESPEC(I,J)
        ENDDO
        WRITE (*,201) '   '
C.................Check Acceptibility of Data Entered.................
        WRITE (*,*) 'Do you wish to reenter Specific Heat Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 117
115     CONTINUE
C.....................................................................
C.....................Write Data to Report File.....................
        DO 119 I=1,2
        WRITE (12,201)
     1      'DATA ENTERED IN PROGRAM FOR SPECIFIC HEAT OF LIQUID'
        IF (I.EQ.1) WRITE (12,253)
     1      '  AT FIRST CONCENTRATION:',CNCSLN(1,1)
        IF (I.EQ.2) WRITE (12,253)
     1      '  AT SECOND CONCENTRATION:',CNCSLN(1,2)
        WRITE (12,201) '   '
        WRITE (12,201)
     1      ' Temperature (deg F)  Specific Heat (BTU/lb-deg F)'
        WRITE (12,201) '   '
C
          DO J=1,NSPEC
C.....................Write Data to Report File.....................
            WRITE (12,213) SPCTMP(I,J),ESPEC(I,J)
          ENDDO
          IF (I.EQ.1) WRITE (12,201) '   '
119     CONTINUE
C
        WRITE (*,201) 'SPECIFIC HEAT data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C**********************************************************************
C.................Entry of SPECIFIC VOLUME of Liquid Data.............
121     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for SPECIFIC VOLUME of liquid'
        WRITE (*,201)
     1    '  at two levels of concentration of the solution.'
        WRITE (*,202)
     1   'SPECIFIC VOLUME data (cu.-ft/lb) is normally'
        WRITE (*,201) '  entered to five decimal places (e.g. 0.01234).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
```

```
      READ (*,203) NSPLQ
C
      DO 125 I=1,2
127   CONTINUE
        WRITE (*,201) 'Property Data for SPECIFIC VOLUME of liquid at'
      IF (I.EQ.1) THEN
        WRITE (*,201) '  Lower Concentration Level'
        WRITE (*,201)
     1    'Enter Lower Concentration Value (decimal fraction):'
        READ (*,249) CNCSLN(2,1)
      ENDIF
      IF (I.EQ.2) THEN
        WRITE (*,201) '  Upper Concentration Level'
        WRITE (*,201)
     1    'Enter Upper Concentration Value (decimal fraction):'
        READ (*,249) CNCSLN(2,2)
      ENDIF
C.....................................................................
      DO J=1,NSPLQ
        WRITE (*,205)
     1    'Enter TEMPERATURE and corresponding SPECIFIC VOLUME'
        WRITE (*,315) '  (separated by a comma) for data point:',J
        READ (*,313) SPLTMP(I,J), ESPLQ(I,J)
      ENDDO
C.....................Review of Data Entered .......................
      WRITE (*,202)
     1    '   DATA ENTERED IN PROGRAM FOR SPECIFIC VOLUME'
      WRITE (*,252)'     AT CONCENTRATION OF:',CNCSLN(2,I)
      WRITE (*,202)
     1    ' Temperature (deg F)  Specific Volume (cu.-ft/lb)'
      DO J=1,NSPLQ
        WRITE (*,214) SPLTMP(I,J),ESPLQ(I,J)
      ENDDO
      WRITE (*,201) '   '
C..................Check Acceptibility of Data Entered.................
      WRITE (*,*) 'Do you wish to reenter Specific Volume Data?'
      WRITE (*,*) '  (Enter Y for yes, or N for no):'
      READ (*,241) RESPNS
      IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 127
125   CONTINUE
C.....................................................................
C.....................Write Data to Report File.......................
      DO 129 I=1,2
      WRITE (12,201)
     1    'DATA ENTERED IN PROGRAM FOR SPECIFIC VOLUME OF LIQUID'
      IF (I.EQ.1) WRITE (12,253)
     1    '  AT FIRST CONCENTRATION:',CNCSLN(2,1)
      IF (I.EQ.2) WRITE (12,253)
     1    '  AT SECOND CONCENTRATION:',CNCSLN(2,2)
      WRITE (12,201) '   '
      WRITE (12,201)
     1    ' Temperature (deg F)  Specific Volume (cu.-ft/lb)'
      WRITE (12,201) '   '
C
        DO J=1,NSPLQ
C.....................Write Data to Report File.....................
          WRITE (12,214) SPLTMP(I,J),ESPLQ(I,J)
        ENDDO
        IF (I.EQ.1) WRITE (12,201) '   '
129   CONTINUE
```

```
C
        WRITE(*,201) 'SPECIFIC VOLUME data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C*********************************************************************
C.................Entry of HEAT OF VAPORIZATION Data.....................
131     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for HEAT OF VAPORIZATION'
        WRITE (*,201)
     1    '  at two levels of concentration of the solution.'
        WRITE (*,202)
     1   'HEAT OF VAPORIZATON data (BTU/lb) is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 345.67).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NHFLV
C
        DO 135 I=1,2
137     CONTINUE
          WRITE (*,201) 'Property Data for HEAT OF VAPORIZATION at'
        IF (I.EQ.1) THEN
          WRITE (*,201) '  Lower Concentration Level'
          WRITE (*,201)
     1      'Enter Lower Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(3,1)
        ENDIF
        IF (I.EQ.2) THEN
          WRITE (*,201) '  Upper Concentration Level'
          WRITE (*,201)
     1      'Enter Upper Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(3,2)
        ENDIF
C.....................................................................
        DO J=1,NHFLV
          WRITE (*,205)
     1    'Enter TEMPERATURE and corresponding HEAT OF VAPORIZATION'
          WRITE (*,315) '  (separated by a comma) for data point:',J
          READ (*,317) HFLTMP(I,J), EHFLV(I,J)
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,202)
     1      '   DATA ENTERED IN PROGRAM FOR HEAT OF VAPORIZATION'
        WRITE (*,252)'     AT CONCENTRATION OF:',CNCSLN(3,I)
        WRITE (*,202)
     1      ' Temperature (deg F)  Heat of Vaporization (BTU/lb)'
        DO J=1,NHFLV
          WRITE (*,219) HFLTMP(I,J),EHFLV(I,J)
        ENDDO
        WRITE (*,201) '   '
C.................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Heat of Vaporization Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 137
135     CONTINUE
```

```
C.....................................................................
C.....................Write Data to Report File.....................
        DO 139 I=1,2
        WRITE (12,201)
     1       'DATA ENTERED IN PROGRAM FOR HEAT OF VAPORIZATION'
        IF (I.EQ.1) WRITE (12,253)
     1       '  AT FIRST CONCENTRATION:',CNCSLN(3,1)
        IF (I.EQ.2) WRITE (12,253)
     1       '  AT SECOND CONCENTRATION:',CNCSLN(3,2)
        WRITE (12,201) '   '
        WRITE (12,201)
     1       ' Temperature (deg F)  Heat of Vaporization (BTU/lb)'
        WRITE (12,201) '   '
C
          DO J=1,NHFLV
C.....................Write Data to Report File.....................
            WRITE (12,219) HFLTMP(I,J),EHFLV(I,J)
          ENDDO
          IF (I.EQ.1) WRITE (12,201) '   '
139     CONTINUE
C
        WRITE(*,201)
     1     'HEAT OF VAPORIZATION data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C**********************************************************************
C..................Entry VAPOR PRESSURE OF SOLUTE Data................
141     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for VAPOR PRESURE OF SOLUTE'
        WRITE (*,201)
     1    '  at two levels of concentration of the solution.'
        WRITE (*,202)
     1   'VAPOR PRESSURE OF SOLUTE data (psia) is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 35.67).'
        WRITE (*,202) 'Enter number of data points to be provided,'
        WRITE (*,201) '  must be an odd number (integer number),'
        WRITE (*,201) '  minimum of 3, maximum of 15:'
        READ (*,203) NPSLT
C
        DO 145 I=1,2
147     CONTINUE
          WRITE (*,201) 'Property Data for VAPOR PRESSURE OF SOLUTE at'
        IF (I.EQ.1) THEN
          WRITE (*,201) '  Lower Concentration Level'
          WRITE (*,201)
     1      'Enter Lower Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(4,1)
        ENDIF
        IF (I.EQ.2) THEN
          WRITE (*,201) '  Upper Concentration Level'
          WRITE (*,201)
     1      'Enter Upper Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(4,2)
        ENDIF
C.....................................................................
        DO J=1,NPSLT
```

```
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding VAPOR PRESSURE OF SOLUTE'
          WRITE (*,315) '  (separated by a comma) for data point:',J
          READ (*,319) PSTTMP(I,J), EPSLT(I,J)
        ENDDO
C.....................Review of Data Entered .....................
        WRITE (*,202)
     1      '   DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SOLUTE'
        WRITE (*,252)'     AT CONCENTRATION OF:',CNCSLN(4,I)
        WRITE (*,202)
     1      ' Temperature (deg F)  Vapor Pressure of Solute (psia)'
        DO J=1,NPSLT
          WRITE (*,221) PSTTMP(I,J),EPSLT(I,J)
        ENDDO
        WRITE (*,201) '   '
C.....................Check Acceptibility of Data Entered.............
        WRITE (*,*)
     1    'Do you wish to reenter Vapor Pressure of Solute Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 147
145     CONTINUE
C.....................................................................
C.....................Write Data to Report File.....................
        DO 149 I=1,2
        WRITE (12,201)
     1      'DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SOLUTE'
        IF (I.EQ.1) WRITE (12,253)
     1      '  AT FIRST CONCENTRATION:',CNCSLN(4,1)
        IF (I.EQ.2) WRITE (12,253)
     1      '  AT SECOND CONCENTRATION:',CNCSLN(4,2)
        WRITE (12,201) '   '
        WRITE (12,201)
     1      ' Temperature (deg F)  Solute Vapor Pressure (psia)'
        WRITE (12,201) '   '
C
          DO J=1,NPSLT
C.....................Write Data to Report File.....................
            WRITE (12,221) PSTTMP(I,J),EPSLT(I,J)
          ENDDO
          IF (I.EQ.1) WRITE (12,201) '   '
149     CONTINUE
C
        WRITE(*,201)
     1     'VAPOR PRESSURE OF SOLUTE data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C**********************************************************************
C.....................Entry VAPOR PRESSURE OF SOLVENT Data.............
151     CONTINUE
        WRITE (*,202)
     1    'Entry of Property data for VAPOR PRESURE OF SOLVENT'
        WRITE (*,201)
     1    '  at two levels of concentration of the solution.'
        WRITE (*,202)
     1   'VAPOR PRESSURE OF SOLVENT data (psia) is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 35.67).'
```

```
        WRITE (*,202) 'Enter number of data points to be provided,'
        WRITE (*,201) '  must be an odd number (integer number),'
        WRITE (*,201) '  minimum of 3, maximum of 15:'
        READ (*,203) NPSLV
C
        DO 155 I=1,2
157     CONTINUE
          WRITE (*,201) 'Property Data for VAPOR PRESSURE OF SOLUTE at'
        IF (I.EQ.1) THEN
          WRITE (*,201) '  Lower Concentration Level'
          WRITE (*,201)
     1      'Enter Lower Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(5,1)
        ENDIF
        IF (I.EQ.2) THEN
          WRITE (*,201) '  Upper Concentration Level'
          WRITE (*,201)
     1      'Enter Upper Concentration Value (decimal fraction):'
          READ (*,249) CNCSLN(5,2)
        ENDIF
C.......................................................................
        DO J=1,NPSLV
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding VAPOR PRESSURE OF SOLVENT'
          WRITE (*,315) '  (separated by a comma) for data point:',J
          READ (*,319) PSVTMP(I,J), EPSLV(I,J)
        ENDDO
C.......................Review of Data Entered .........................
        WRITE (*,202)
     1      '   DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SOLUTE'
        WRITE (*,252)'     AT CONCENTRATION OF:',CNCSLN(5,I)
        WRITE (*,202)
     1      ' Temperature (deg F)  Vapor Pressure of Solvent (psia)'
        DO J=1,NPSLV
          WRITE (*,221) PSVTMP(I,J),EPSLV(I,J)
        ENDDO
        WRITE (*,201) '   '
C.....................Check Acceptibility of Data Entered................
        WRITE (*,*)
     1    'Do you wish to reenter Vapor Pressure of Solvent Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 157
155     CONTINUE
C.......................................................................
C.......................Write Data to Report File.......................
        DO 159 I=1,2
        WRITE (12,201)
     1      'DATA ENTERED IN PROGRAM FOR VAPOR PRESSURE OF SOLVENT'
        IF (I.EQ.1) WRITE (12,253)
     1      '  AT FIRST CONCENTRATION:',CNCSLN(5,1)
        IF (I.EQ.2) WRITE (12,253)
     1      '  AT SECOND CONCENTRATION:',CNCSLN(5,2)
        WRITE (12,201) '   '
        WRITE (12,201)
     1      ' Temperature (deg F)  Solvent Vapor Pressure (psia)'
        WRITE (12,201) '   '
C
          DO J=1,NPSLV
C.......................Write Data to Report File.....................
```

```
            WRITE (12,221) PSVTMP(I,J),EPSLV(I,J)
          ENDDO
          IF (I.EQ.1) WRITE (12,201) '    '
159     CONTINUE
C
        WRITE(*,201)
     1     'VAPOR PRESSURE OF SOLVENT data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '    '
        WRITE (12,202) '    '
C
C*****************************************************************************
C.......Entry of COMPRESSIBILITY FACTOR OF SOLUTE VAPOR Data........
161     CONTINUE
        WRITE (*,202) 'Entry of Property data for COMPRESSIBILITY'
        WRITE (*,201) '  FACTOR OF SOLUTE VAPOR'
        WRITE (*,202)
     1   'COMPRESSIBILITY FACTOR data is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 0.95).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '    (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NZSLT
C
167     CONTINUE
        WRITE (*,201)
     1  'Property Data for COMPRESSIBILITY FACTOR OF SOLUTE VAPOR'
C.....................................................................
        DO I=1,NZSLT
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding COMPRESSIBILITY FACTOR'
          WRITE (*,315) '  (separated by a comma) for data point:',I
          READ (*,319) ZSTTMP(I), EZSLT(I)
        ENDDO
C.........................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY'
        WRITE (*,201) '            FACTOR OF SOLUTE VAPOR'
        WRITE (*,202)
     1   ' Temperature (deg F)  Compresibility Factor of Solute Vapor'
        DO I=1,NZSLT
          WRITE (*,221) ZSTTMP(I), EZSLT(I)
        ENDDO
        WRITE (*,201) '    '
C...................Check Acceptibility of Data Entered................
        WRITE (*,*)
     1    'Do you wish to reenter Compressibility Factor Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 167
C.....................................................................
C.......................Write Data to Report File.....................
        WRITE (12,201) 'DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY'
        WRITE (12,201) '            FACTOR OF SOLUTE VAPOR'
        WRITE (12,201) '    '
        WRITE (12,201)
     1      ' Temperature (deg F)  Compressibility Factor'
        WRITE (12,201) '    '
C
        DO I=1,NZSLT
C.....................Write Data to Report File...................
```

```
          WRITE (12,221) ZSTTMP(I),EZSLT(I)
        ENDDO
        WRITE (12,201) '   '
C
        WRITE(*,201)  'COMPRESSIBILITY FACTOR OF SOLUTE VAPOR'
        WRITE(*,201)  '  data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C*********************************************************************
C.......Entry of COMPRESSIBILITY FACTOR OF SOLVENT VAPOR Data........
171     CONTINUE
        WRITE (*,202) 'Entry of Property data for COMPRESSIBILITY'
        WRITE (*,201) '  FACTOR OF SOLVENT VAPOR'
        WRITE (*,202)
     1   'COMPRESSIBILITY FACTOR data is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 0.95).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NZSLV
C
177     CONTINUE
        WRITE (*,201)
     1  'Property Data for COMPRESSIBILITY FACTOR OF SOLVENT VAPOR'
C.....................................................................
        DO I=1,NZSLV
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding COMPRESSIBILITY FACTOR'
          WRITE (*,315) '  (separated by a comma) for data point:',I
          READ (*,319) ZSVTMP(I), EZSLV(I)
        ENDDO
C.......................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY'
        WRITE (*,201) '           FACTOR OF SOLVENT VAPOR'
        WRITE (*,202)
     1   ' Temperature (deg F)  Compresibility Factor of Solvent Vapor'
        DO I=1,NZSLV
          WRITE (*,221) ZSVTMP(I), EZSLV(I)
        ENDDO
        WRITE (*,201) '   '
C..................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Compressibility Factor Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 177
C.....................................................................
C.......................Write Data to Report File.....................
        WRITE (12,201) 'DATA ENTERED IN PROGRAM FOR COMPRESSIBILITY'
        WRITE (12,201) '           FACTOR OF SOLVENT VAPOR'
        WRITE (12,201) '   '
        WRITE (12,201)
     1      ' Temperature (deg F)  Compressibility Factor'
        WRITE (12,201) '   '
C
        DO I=1,NZSLV
C.......................Write Data to Report File.....................
          WRITE (12,221) ZSVTMP(I),EZSLV(I)
```

```
        ENDDO
        WRITE (12,201) '   '
C
        WRITE(*,201)  'COMPRESSIBILITY FACTOR OF SOLVENT VAPOR'
        WRITE(*,201)  '  data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C*********************************************************************
C.........Entry of RATIO OF SPECIFIC HEATS OF SOLUTE VAPOR Data.........
181     CONTINUE
        WRITE (*,202) 'Entry of Property data for RATIO OF SPECIFIC'
        WRITE (*,201) '  HEATS OF SOLUTE VAPOR'
        WRITE (*,202)
     1   'RATIO OF SPECIFIC HEATS data is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 1.30).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NGSLT
C
187     CONTINUE
        WRITE (*,201)
     1  'Property Data for RATIO OF SPECIFIC HEATS OF SOLUTE VAPOR'
C.....................................................................
        DO I=1,NGSLT
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding RATIO OF SPECIFIC HEATS'
          WRITE (*,315) '  (separated by a comma) for data point:',I
          READ (*,319) GSTTMP(I), EGSLT(I)
        ENDDO
C.......................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC'
        WRITE (*,201) '             HEATS OF SOLUTE VAPOR'
        WRITE (*,202)
     1   ' Temperature (deg F)    Ratio of Specific Heats'
        DO I=1,NGSLT
          WRITE (*,221) GSTTMP(I), EGSLT(I)
        ENDDO
        WRITE (*,201) '   '
C.................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Ratio of Specific Heat Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 187
C.....................................................................
C.....................Write Data to Report File.......................
        WRITE (12,201) 'DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC'
        WRITE (12,201) '             HEATS OF SOLUTE VAPOR'
        WRITE (12,201) '   '
        WRITE (12,201)
     1      ' Temperature (deg F)  Ratio of Specific Heats'
        WRITE (12,201) '   '
C
        DO I=1,NGSLT
C.....................Write Data to Report File...................
          WRITE (12,221) GSTTMP(I),EGSLT(I)
        ENDDO
```

```
        WRITE (12,201) '    '
C
        WRITE(*,201)  'RATIO OF SPECIFIC HEATS OF SOLUTE VAPOR'
        WRITE(*,201)  '  data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '    '
        WRITE (12,202) '    '
C
C*********************************************************************
C.........Entry of RATIO OF SPECIFIC HEATS OF SOLVENT VAPOR Data........
191     CONTINUE
        WRITE (*,202) 'Entry of Property data for RATIO OF SPECIFIC'
        WRITE (*,201) '  HEATS OF SOLVENT VAPOR'
        WRITE (*,202)
     1   'RATIO OF SPECIFIC HEATS data is normally'
        WRITE (*,201) '  entered to two decimal places (e.g. 1.30).'
        WRITE (*,202) 'Enter number of data points to be provided'
        WRITE (*,201) '   (integer number), minimum of 2, maximum of 8:'
        READ (*,203) NGSLV
C
197     CONTINUE
        WRITE (*,201)
     1  'Property Data for RATIO OF SPECIFIC HEATS OF SOLVENT VAPOR'
C.....................................................................
        DO I=1,NGSLV
          WRITE (*,205)
     1  'Enter TEMPERATURE and corresponding RATIO OF SPECIFIC HEATS'
          WRITE (*,315) '  (separated by a comma) for data point:',I
          READ (*,319) GSVTMP(I), EGSLV(I)
        ENDDO
C.........................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC'
        WRITE (*,201) '             HEATS OF SOLVENT VAPOR'
        WRITE (*,202)
     1   ' Temperature (deg F)    Ratio of Specific Heats'
        DO I=1,NGSLV
          WRITE (*,221) GSVTMP(I), EGSLV(I)
        ENDDO
        WRITE (*,201) '    '
C...................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Ratio of Specific Heat Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 197
C.......................Write Data to Report File.......................
        WRITE (12,201) 'DATA ENTERED IN PROGRAM FOR RATIO OF SPECIFIC'
        WRITE (12,201) '             HEATS OF SOLVENT VAPOR'
        WRITE (12,201) '    '
        WRITE (12,201)
     1      ' Temperature (deg F)  Ratio of Specific Heats'
        WRITE (12,201) '    '
C
        DO I=1,NGSLV
C.......................Write Data to Report File.....................
          WRITE (12,221) GSVTMP(I),EGSLV(I)
        ENDDO
        WRITE (12,201) '    '
C
```

```
        WRITE(*,201)  'RATIO OF SPECIFIC HEATS OF SOLVENT VAPOR'
        WRITE(*,201)  '  data entry is completed.'
        WRITE (*,201) '  Type ENTER to proceed'
        READ  (*,*)
        WRITE (*,202) '   '
        WRITE (12,202) '   '
C
C*****************************************************************
C.........Entry of MOLLECULAR WEIGHT OF SOLUTE VAPOR Data.............
611     CONTINUE
        WRITE (*,201)
     1      'Property Data for MOLLECULAR WEIGHT OF SOLUTE VAPOR'
        WRITE (*,201) '   '
        WRITE (*,201) 'Enter MOLLECULAR WEIGHT data to two decimal'
        WRITE (*,201) '   places (e.g. 18.00)'
        WRITE (*,201) '   '
        WRITE (*,201) 'Enter Mollecular Weight:'
        READ (*,209) MLWSBS
        WRITE (*,201) '   '
C.......................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT'
        WRITE (*,201) '                OF SOLUTE VAPOR'
        WRITE (*,245) MLWSBS
        WRITE (*,202) '   '
C..................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Molecular Weight Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 611
C.....................Write Data to Report File...................
        WRITE (12,201)
     1  'DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT OF SOLUTE VAPOR'
        WRITE (12,201) '   '
        WRITE (12,245) MLWSBS
        WRITE (12,201) '   '
C
C*****************************************************************
C.........Entry of MOLLECULAR WEIGHT OF SOLVENT VAPOR Data.............
621     CONTINUE
        WRITE (*,201)
     1      'Property Data for MOLLECULAR WEIGHT OF SOLVENT VAPOR'
        WRITE (*,201) '   '
        WRITE (*,201) 'Enter MOLLECULAR WEIGHT data to two decimal'
        WRITE (*,201) '   places (e.g. 18.00)'
        WRITE (*,201) '   '
        WRITE (*,201) 'Enter Mollecular Weight:'
        READ (*,209) MLWSLV
        WRITE (*,201) '   '
C.......................Review of Data Entered .......................
        WRITE (*,202) ' DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT'
        WRITE (*,201) '                OF SOLVENT VAPOR'
        WRITE (*,245) MLWSLV
        WRITE (*,202) '   '
C..................Check Acceptibility of Data Entered.................
        WRITE (*,*)
     1    'Do you wish to reenter Molecular Weight Data?'
        WRITE (*,*) '  (Enter Y for yes, or N for no):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y'.OR.RESPNS.EQ.'y') GO TO 621
```

```
C.....................Write Data to Report File.....................
        WRITE (12,201)
     1  'DATA ENTERED IN PROGRAM FOR MOLECULAR WEIGHT OF SOLVENT VAPOR'
        WRITE (12,201) '    '
        WRITE (12,245) MLWSLV
C
        WRITE(*,201)
     1        'MOLLECULAR WEIGHT data entry is completed.'
        WRITE (*,201) '    '
        WRITE (*,201) '    '
        WRITE (12,201) '    '
        WRITE (12,201) '    '
C
C**********************************************************************
C.............If desired, save thermal property data by writing it......
C..................to a separate file..............................
C
        ISTART=16
        WRITE (*,*) 'Do you want to save Thermal Property Data in'
        WRITE (*,*) '  a separate file?  (Enter Y or N):'
        READ (*,241) RESPNS
        IF (RESPNS.EQ.'Y') THEN
          WRITE (*,*) 'Enter name of file (maximum of 12 characters):'
          READ (*,243) FLNAME
          OPEN ( UNIT=17,FILE=FLNAME,STATUS='NEW')
          ISTART=17
        ENDIF
C...........Write data to NEWSLN.DAT file (and above optional file)......
C
        DO I=16,ISTART
          WRITE (I,255) CNCSLN(1,1),CNCSLN(1,2)
          DO J=1,2
            WRITE (I,223) NSPEC
            DO K=1,NSPEC
              WRITE (I,225) SPCTMP(J,K),ESPEC(J,K)
            ENDDO
          ENDDO
           WRITE (I,255) CNCSLN(2,1),CNCSLN(2,2)
           DO J=1,2
             WRITE (I,223) NSPLQ
             DO K=1,NSPLQ
               WRITE (I,226) SPLTMP(J,K),ESPLQ(J,K)
             ENDDO
           ENDDO
           WRITE (I,255) CNCSLN(3,1),CNCSLN(3,2)
           DO J=1,2
             WRITE (I,223) NHFLV
             DO K=1,NHFLV
               WRITE (I,227) HFLTMP(J,K),EHFLV(J,K)
             ENDDO
           ENDDO
           WRITE (I,255) CNCSLN(4,1),CNCSLN(4,2)
           DO J=1,2
             WRITE (I,223) NPSLT
             DO K=1,NPSLT
               WRITE (I,229) PSTTMP(J,K),EPSLT(J,K)
             ENDDO
           ENDDO
           WRITE (I,255) CNCSLN(5,1),CNCSLN(5,2)
           DO J=1,2
```

```
              WRITE (I,223) NPSLV
              DO K=1,NPSLV
                WRITE (I,229) PSVTMP(J,K),EPSLV(J,K)
              ENDDO
            ENDDO
C
            WRITE (I,223) NZSLT
            DO J=1,NZSLT
              WRITE (I,229) ZSTTMP(J),EZSLT(J)
            ENDDO
            WRITE (I,223) NZSLV
            DO J=1,NZSLV
              WRITE (I,229) ZSVTMP(J),EZSLV(J)
            ENDDO
            WRITE (I,223) NGSLT
            DO J=1,NGSLT
              WRITE (I,229) GSTTMP(J),EGSLT(J)
            ENDDO
            WRITE (I,223) NGSLV
            DO J=1,NGSLV
              WRITE (I,229) GSVTMP(J),EGSLV(J)
            ENDDO
            WRITE (I,247) MLWSBS
            WRITE (I,247) MLWSLV
          ENDDO
          REWIND 16
C.....................................................................
201       FORMAT (T3,A)
202       FORMAT (/T3,A)
203       FORMAT (I8)
205       FORMAT (T3,A,T30,I3)
207       FORMAT (T3,A,T40,I3)
209       FORMAT (F8.2)
211       FORMAT (F10.4)
212       FORMAT (F10.5)
213       FORMAT (T10,F8.2,T27,F10.4)
214       FORMAT (T10,F8.2,T27,F10.5)
215       FORMAT (F10.1)
217       FORMAT (T3,A,T47,I3)
219       FORMAT (T10,F8.2,T27,F10.1)
221       FORMAT (T10,F8.2,T27,F10.2)
222       FORMAT (T10,F8.3,T27,F10.3)
223       FORMAT (I10)
225       FORMAT (F10.2,F10.4)
226       FORMAT (F10.2,F10.5)
227       FORMAT (F10.2,F10.1)
229       FORMAT (2F10.2)
241       FORMAT (A1)
243       FORMAT (A12)
245       FORMAT (T10,F8.2)
247       FORMAT (F10.2)
249       FORMAT (F10.3)
251       FORMAT (T3,A,T20,F8.3)
252       FORMAT (T3,A,T25,F7.3)
253       FORMAT (T3,A,T30,F6.3)
255       FORMAT (2F10.3)
257       FORMAT (T3,A,T45,F6.3)
259       FORMAT (T10,A,T25,A)
311       FORMAT (F8.2,F8.4)
313       FORMAT (F8.2,F8.5)
```

```
315     FORMAT (T3,A,T44,I3)
317     FORMAT (F8.2,F8.1)
319     FORMAT (2F8.2)
C
        RETURN
        END
```

APPENDIX F

SUBROUTINE SBSPROP

Subroutine SBSPROP.FOR is called by the main program to obtain the current thermal properties of a substance at a specific temperature. This is done by interpolating between values entered into the program. These values are read from the file NEWSBS.DAT on the first call of the subroutine. The variables in SBSPROP are the same as those listed for subroutine SBSENTR.

After all the data has been entered, the maximum and minimum temperature limits are established. The minimum value is established by determining the maximum temperature of the first data points entered for each of the properties. The maximum value is established by determining the minimum temperature of the final data points entered for each of the properties. The analysis program will still run if these limits are exceeded, but reduced accuracy should be anticipated because the values of the properties would be determined by extrapolation rather than by interpolation.

```
C........SBSPROP.FOR is a subroutine for obtaining the thermal properties
C..........of a SUBSTANCE at a given temperature from a generalized
C.......... file of data at specific temperatures.
C.....................................Version 2.0, October 20, 1997
C
      SUBROUTINE SBSPROP(IPFST,IPR,TEMP)
C
      REAL MLWSBS,MLWSLV,TEMP
      DIMENSION ESPEC(8),ESPLQ(8),EHFLV(8),EPSBS(15)
      DIMENSION SPCTMP(8),SPLTMP(8),HFLTMP(8),PSBTMP(15)
      DIMENSION EZPRO(8),EGMMP(8)
      DIMENSION ZPRTMP(8),GMPTMP(8)
      INTEGER*2 NSPEC,NSPLQ,NHFLV,NPSBS,NZPRO,NGMMP,IPR
      INTEGER*2 IPFST
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
      IF (IPFST.EQ.0) THEN
        IF (IPR.EQ.20) IP=16      ! keyboard entry of data
        IF (IPR.EQ.21) IP=13      ! read data in existing file
C
        READ (IP,223) NSPEC
        DO I=1,NSPEC
          READ (IP,225) SPCTMP(I),ESPEC(I)
        ENDDO
        READ (IP,223) NSPLQ
        DO I=1,NSPLQ
          READ (IP,226) SPLTMP(I),ESPLQ(I)
        ENDDO
        READ (IP,223) NHFLV
        DO I=1,NHFLV
          READ (IP,227) HFLTMP(I),EHFLV(I)
        ENDDO
        READ (IP,223) NPSBS
        DO I=1,NPSBS
          READ (IP,229) PSBTMP(I),EPSBS(I)
        ENDDO
        READ (IP,223) NZPRO
        DO I=1,NZPRO
          READ (IP,229) ZPRTMP(I),EZPRO(I)
        ENDDO
        READ (IP,223) NGMMP
        DO I=1,NGMMP
          READ (IP,229) GMPTMP(I),EGMMP(I)
        ENDDO
        READ (IP,247) MLWSBS
C.............Initialize variables not used with substance.............
        PSLV=0.0
        ZSLV=1.0
        CNCMIN=1.0
        CNCMAX=1.0
        GAMSLV=1.1
        MLWSLV=1.0
C...........Establish lower and upper temperature limits of data
C.......................entered into program............................
        TLMTMN=AMAX1 (SPCTMP(1),SPLTMP(1),HFLTMP(1),PSBTMP(1),
     1              ZPRTMP(1),GMPTMP(1))
        TLMTMX=AMIN1 (SPCTMP(NSPEC),SPLTMP(NSPLQ),HFLTMP(NHFLV),
```

```
     1            PSBTMP(NPSBS),ZPRTMP(NZPRO),GMPTMP(NGMMP))
C
          IPFST=1
        ENDIF
C.............CALCULATION OF PROPERTIES.....................
C.................Specific Heat.............................
C
        IF (TEMP.LT.SPCTMP(1)) THEN
          ISPCUP=2
          ISPCLW=1
          GO TO 111
        ENDIF
C
        DO I=2,NSPEC
        IF (TEMP.GE.SPCTMP(I-1).AND.TEMP.LT.SPCTMP(I)) THEN
          ISPCUP=I
          ISPCLW=I-1
          GO TO 111
        ENDIF
        ENDDO
C
        IF (TEMP.GE.SPCTMP(NSPEC)) THEN
          ISPCUP=NSPEC
          ISPCLW=NSPEC-1
          GO TO 111
        ENDIF
C
111     CONTINUE
        IF (SPCTMP(ISPCUP).EQ.SPCTMP(ISPCLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        SPEC=ESPEC(ISPCLW)+(ESPEC(ISPCUP)-ESPEC(ISPCLW))
     1         *(TEMP-SPCTMP(ISPCLW))/(SPCTMP(ISPCUP)-SPCTMP(ISPCLW))
C
C.................Specific Volume.............................
C
        IF (TEMP.LT.SPLTMP(1)) THEN
          ISPLUP=2
          ISPLLW=1
          GO TO 121
        ENDIF
C
        DO I=2,NSPLQ
        IF (TEMP.GE.SPLTMP(I-1).AND.TEMP.LT.SPLTMP(I)) THEN
          ISPLUP=I
          ISPLLW=I-1
          GO TO 121
        ENDIF
        ENDDO
C
        IF (TEMP.GE.SPLTMP(NSPEC)) THEN
          ISPCUP=NSPLQ
          ISPCLW=NSPLQ-1
          GO TO 121
        ENDIF
C
121     CONTINUE
        IF (SPLTMP(ISPLUP).EQ.SPLTMP(ISPLLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
```

```
          GO TO 399
        ENDIF
        SPLQ=ESPLQ(ISPLLW)+(ESPLQ(ISPLUP)-ESPLQ(ISPLLW))
     1         *(TEMP-SPLTMP(ISPLLW))/(SPLTMP(ISPLUP)-SPLTMP(ISPLLW))
C
C.....................Heat of Vaporization.......................
C
        IF (TEMP.LT.HFLTMP(1)) THEN
          IHFLUP=2
          IHFLLW=1
          GO TO 131
        ENDIF
C
        DO I=2,NHFLV
        IF (TEMP.GE.HFLTMP(I-1).AND.TEMP.LT.HFLTMP(I)) THEN
          IHFLUP=I
          IHFLLW=I-1
          GO TO 131
        ENDIF
        ENDDO
C
        IF (TEMP.GE.HFLTMP(NHFLV)) THEN
          IHFLUP=NHFLV
          IHFLLW=NHFLV-1
          GO TO 131
        ENDIF
C
131     CONTINUE
        IF (HFLTMP(IHFLUP).EQ.HFLTMP(IHFLLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        HFLV=EHFLV(IHFLLW)+(EHFLV(IHFLUP)-EHFLV(IHFLLW))
     1         *(TEMP-HFLTMP(IHFLLW))/(HFLTMP(IHFLUP)-HFLTMP(IHFLLW))
C
C.....................Vapor Pressure of Product...................
C
        IF (TEMP.LT.PSBTMP(1)) THEN
          IPSBUP=3
          IPSBMD=2
          IPSBLW=1
          GO TO 141
        ENDIF
C
        DO I=3,NPSBS,2
        IF (TEMP.GE.PSBTMP(I-2).AND.TEMP.LT.PSBTMP(I)) THEN
          IPSBUP=I
          IPSBMD=I-1
          IPSBLW=I-2
          GO TO 141
        ENDIF
        ENDDO
C
        IF (TEMP.GE.PSBTMP(NPSBS)) THEN
          IPSBUP=NPSBS
          IPSBMD=NPSBS-1
          IPSBLW=NPSBS-2
          GO TO 141
        ENDIF
C
```

```
141     CONTINUE
        DELT0=PSBTMP(IPSBMD)-PSBTMP(IPSBLW)
        DELT1=PSBTMP(IPSBUP)-PSBTMP(IPSBMD)
        DELT2=PSBTMP(IPSBUP)-PSBTMP(IPSBLW)
        IF (DELT0.EQ.0.OR.DELT1.EQ.0.OR.DELT2.EQ.0) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        BCON=(EPSBS(IPSBLW)*DELT1-EPSBS(IPSBMD)*DELT2
     1       +EPSBS(IPSBUP)*DELT0)/(DELT0*DELT1*DELT2)
        ACON=(EPSBS(IPSBMD)-EPSBS(IPSBLW))/DELT0-BCON*DELT0
        PSBS=EPSBS(IPSBLW)+ACON*(TEMP-PSBTMP(IPSBLW))
     1       +BCON*((TEMP-PSBTMP(IPSBLW))**2.0)
C
C.................Compressibility Factor.....................
C
        IF (TEMP.LT.ZPRTMP(1)) THEN
          IZPRUP=2
          IZPRLW=1
          GO TO 151
        ENDIF
C
        DO I=2,NZPRO
        IF (TEMP.GE.ZPRTMP(I-1).AND.TEMP.LT.ZPRTMP(I)) THEN
          IZPRUP=I
          IZPRLW=I-1
          GO TO 151
        ENDIF
        ENDDO
C
        IF (TEMP.GE.ZPRTMP(NZPRO)) THEN
          IZPRUP=NZPRO
          IZPRLW=NZPRO-1
          GO TO 151
        ENDIF
C
151     CONTINUE
        IF (ZPRTMP(IZPRUP).EQ.ZPRTMP(IZPRLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        ZSBS=EZPRO(IZPRLW)+(EZPRO(IZPRUP)-EZPRO(IZPRLW))
     1         *(TEMP-ZPRTMP(IZPRLW))/(ZPRTMP(IZPRUP)-ZPRTMP(IZPRLW))
C
C.............Ratio of Specific Heats for Vapor.....................
C
        IF (TEMP.LT.GMPTMP(1)) THEN
          IGMPUP=2
          IGMPLW=1
          GO TO 161
        ENDIF
C
        DO I=2,NGMMP
        IF (TEMP.GE.GMPTMP(I-1).AND.TEMP.LT.GMPTMP(I)) THEN
          IGMPUP=I
          IGMPLW=I-1
          GO TO 161
        ENDIF
        ENDDO
C
```

```
        IF (TEMP.GE.GMPTMP(NGMMP)) THEN
          IGMPUP=NGMMP
          IGMPLW=NGMMP-1
          GO TO 161
        ENDIF
C
161     CONTINUE
        IF (GMPTMP(IGMPUP).EQ.GMPTMP(IGMPLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        GAMSBS=EGMMP(IGMPLW)+(EGMMP(IGMPUP)-EGMMP(IGMPLW))
     1         *(TEMP-GMPTMP(IGMPLW))/(GMPTMP(IGMPUP)-GMPTMP(IGMPLW))
C
C.................Specific Volume of Substance Vapor.................
C
        VVAP=1545.4*ZSBS*(TEMP+460.0)/(144.0*PSBS*MLWSBS)
C
399     CONTINUE
C
223     FORMAT (I10)
225     FORMAT (F10.2,F10.4)
226     FORMAT (F10.2,F10.5)
227     FORMAT (F10.2,F10.1)
229     FORMAT (2F10.2)
247     FORMAT (F10.2)
251     FORMAT (A12)
C
        RETURN
        END
```

APPENDIX G

SUBROUTINE SLNPROP

Subroutine SLNPROP.FOR is called by the main program to obtain the current thermal properties of a solution at a specific temperature. This is done by interpolating between values entered into the program. These values are read from the file NEWSLN.DAT on the first call of the subroutine. The variables in SLNPROP are the same as those listed for subroutine SLNENTR.

After all the data have been entered, the maximum and minimum temperature and concentration limits are established. The minimum temperature value is established by determining the maximum temperature of the first data points entered for each of the properties. The maximum value is established by determining the minimum temperature of the final data points entered for each of the properties. The minimum concentration is established by determining the maximum value of the lower level concentration for the properties and the maximum concentration is established by determining the minimum value of the upper level concentration for the properties. The analysis program will still run if these limits are exceeded, but reduced accuracy should be anticipated because the values of the properties would be determined by extrapolation rather than by interpolation.

```
C....SLNPROP.FOR is a routine for obtaining the thermal properties
C......of a SOLUTION, at a given temperature from a generalized
C......file of data, which defines the properties at specific points.
C.................................Version 2.0, October 20, 1997
C
      SUBROUTINE SLNPROP(IPFST,IPR,CONC,TEMP)
C
      DIMENSION ESPEC(2,8),ESPLQ(2,8),EHFLV(2,8),EPSLT(2,15)
      DIMENSION EPSLV(2,15),EZSLT(8),EZSLV(8)
      DIMENSION EGSLT(8),EGSLV(8)
      DIMENSION SPCTMP(2,8),SPLTMP(2,8),HFLTMP(2,8),PSTTMP(2,15)
      DIMENSION PSVTMP(2,15),ZSTTMP(8),ZSVTMP(8)
      DIMENSION GSTTMP(8),GSVTMP(8),CNCSLN(5,2)
      DIMENSION TSPEC(2),TSPLQ(2),THFLV(2),TPSLT(2),TPSLV(2)
      INTEGER*2 NSPEC(2),NSPLQ(2),NHFLV(2),NPSLT(2),NPSLV(2)
      INTEGER*2 NZSLT,NZSLV,NGSLT,NGSLV,IPR,IPFST
      REAL MLWSBS,MLWSLV,CONC,TEMP
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
      IF (IPFST.EQ.0) THEN
        IF (IPR.EQ.20) IP=16     ! keyboard entry of data
        IF (IPR.EQ.21) IP=13     ! read data in existing file
C
        READ (IP,255) CNCSLN(1,1),CNCSLN(1,2)
        DO I=1,2
          READ (IP,223) NSPEC(I)
          DO J=1,NSPEC(I)
            READ (IP,225) SPCTMP(I,J),ESPEC(I,J)
          ENDDO
        ENDDO
        READ (IP,255) CNCSLN(2,1),CNCSLN(2,2)
        DO I=1,2
          READ (IP,223) NSPLQ(I)
          DO J=1,NSPLQ(I)
            READ (IP,226) SPLTMP(I,J),ESPLQ(I,J)
          ENDDO
        ENDDO
        READ (IP,255) CNCSLN(3,1),CNCSLN(3,2)
        DO I=1,2
          READ (IP,223) NHFLV(I)
          DO J=1,NHFLV(I)
            READ (IP,227) HFLTMP(I,J),EHFLV(I,J)
          ENDDO
        ENDDO
        READ (IP,255) CNCSLN(4,1),CNCSLN(4,2)
        DO I=1,2
          READ (IP,223) NPSLT(I)
          DO J=1,NPSLT(I)
            READ (IP,229) PSTTMP(I,J),EPSLT(I,J)
          ENDDO
        ENDDO
        READ (IP,255) CNCSLN(5,1),CNCSLN(5,2)
        DO I=1,2
          READ (IP,223) NPSLV(I)
          DO J=1,NPSLV(I)
            READ (IP,229) PSVTMP(I,J),EPSLV(I,J)
          ENDDO
```

```
          ENDDO
C
            READ (IP,223) NZSLT
            DO I=1,NZSLT
              READ (IP,229) ZSTTMP(I),EZSLT(I)
            ENDDO
            READ (IP,223) NZSLV
            DO I=1,NZSLV
              READ (IP,229) ZSVTMP(I),EZSLV(I)
            ENDDO
            READ (IP,223) NGSLT
            DO I=1,NGSLT
              READ (IP,229) GSTTMP(I),EGSLT(I)
            ENDDO
            READ (IP,223) NGSLV
            DO I=1,NGSLV
              READ (IP,229) GSVTMP(I),EGSLV(I)
            ENDDO
          READ (IP,247) MLWSBS
          READ (IP,247) MLWSLV
C.....Establish lower and upper temperature and concentration
C             limits of data entered into program
          TLMTMN=AMAX1 (SPCTMP(1,1),SPLTMP(1,1),HFLTMP(1,1),
     1      PSTTMP(1,1),PSVTMP(1,1),ZSTTMP(1),ZSVTMP(1),
     1      GSTTMP(1),GSVTMP(1),SPCTMP(2,1),SPLTMP(2,1),
     1      HFLTMP(2,1),PSTTMP(2,1),PSVTMP(2,1))
          TLMTMX=AMIN1 (SPCTMP(1,NSPEC(1)),SPLTMP(1,NSPLQ(1)),
     1      HFLTMP(1,NHFLV(1)),PSTTMP(1,NPSLT(1)),PSVTMP(1,NPSLV(1)),
     1      ZSTTMP(NZSLT),ZSVTMP(NZSLV),GSTTMP(NGSLT),
     1      GSVTMP(NGSLV),SPCTMP(2,NSPEC(2)),SPLTMP(2,NSPLQ(2)),
     1      HFLTMP(2,NHFLV(2)),PSTTMP(2,NPSLT(2)),PSVTMP(2,NPSLV(2)))
C
          CNCMIN=AMAX1(CNCSLN(1,1),CNCSLN(2,1),CNCSLN(3,1),
     1           CNCSLN(4,1),CNCSLN(5,1))
          CNCMAX=AMIN1(CNCSLN(1,2),CNCSLN(2,2),CNCSLN(3,2),
     1           CNCSLN(4,2),CNCSLN(5,2))
C
          IPFST=1
        ENDIF
C
C.....................Specific Heat.............................
C
        DO 115 I=1,2
        IF (TEMP.LT.SPCTMP(I,1)) THEN
          JSPCUP=2
          JSPCLW=1
          GO TO 111
        ENDIF
C
        DO J=2,NSPEC(I)
        IF (TEMP.GE.SPCTMP(I,J-1).AND.TEMP.LT.SPCTMP(I,J)) THEN
          JSPCUP=J
          JSPCLW=J-1
          GO TO 111
        ENDIF
        ENDDO
C
        IF (TEMP.GE.SPCTMP(I,NSPEC(I))) THEN
          JSPCUP=NSPEC(I)
          JSPCLW=NSPEC(I)-1
```

```
          GO TO 111
        ENDIF
C
111     CONTINUE
        IF (SPCTMP(I,JSPCUP).EQ.SPCTMP(I,JSPCLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
C
        TSPEC(I)=ESPEC(I,JSPCLW)+(ESPEC(I,JSPCUP)-ESPEC(I,JSPCLW))
     1  *(TEMP-SPCTMP(I,JSPCLW))/(SPCTMP(I,JSPCUP)-SPCTMP(I,JSPCLW))
115     CONTINUE
C
        SPEC=TSPEC(1)+(TSPEC(2)-TSPEC(1))
     1        *(CONC-CNCSLN(1,1))/(CNCSLN(1,2)-CNCSLN(1,1))
C
C.....................Specific Volume.............................
C
        DO 125 I=1,2
        IF (TEMP.LT.SPLTMP(I,1)) THEN
          JSPLUP=2
          JSPLLW=1
          GO TO 121
        ENDIF
C
        DO J=2,NSPLQ(I)
        IF (TEMP.GE.SPLTMP(I,J-1).AND.TEMP.LT.SPLTMP(I,J)) THEN
          JSPLUP=J
          JSPLLW=J-1
          GO TO 121
        ENDIF
        ENDDO
C
        IF (TEMP.GE.SPLTMP(I,NSPEC(I))) THEN
          JSPCUP=NSPLQ(I)
          JSPCLW=NSPLQ(I)-1
          GO TO 121
        ENDIF
C
121     CONTINUE
        IF (SPLTMP(I,JSPLUP).EQ.SPLTMP(I,JSPLLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
C
        TSPLQ(I)=ESPLQ(I,JSPLLW)+(ESPLQ(I,JSPLUP)-ESPLQ(I,JSPLLW))
     1  *(TEMP-SPLTMP(I,JSPLLW))/(SPLTMP(I,JSPLUP)-SPLTMP(I,JSPLLW))
125     CONTINUE
C
        SPLQ=TSPLQ(1)+(TSPLQ(2)-TSPLQ(1))
     1       *(CONC-CNCSLN(2,1))/(CNCSLN(2,2)-CNCSLN(2,1))
C
C.....................Heat of Vaporization.......................
C
        DO 135 I=1,2
        IF (TEMP.LT.HFLTMP(I,1)) THEN
          JHFLUP=2
          JHFLLW=1
          GO TO 131
        ENDIF
```

```
C
        DO J=2,NHFLV(I)
        IF (TEMP.GE.HFLTMP(I,J-1).AND.TEMP.LT.HFLTMP(I,J)) THEN
          JHFLUP=J
          JHFLLW=J-1
          GO TO 131
        ENDIF
        ENDDO
C
        IF (TEMP.GE.HFLTMP(I,NHFLV(I))) THEN
          JHFLUP=NHFLV(I)
          JHFLLW=NHFLV(I)-1
          GO TO 131
        ENDIF
C
131     CONTINUE
        IF (HFLTMP(I,JHFLUP).EQ.HFLTMP(I,JHFLLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
C
        THFLV(I)=EHFLV(I,JHFLLW)+(EHFLV(I,JHFLUP)-EHFLV(I,JHFLLW))
     1  *(TEMP-HFLTMP(I,JHFLLW))/(HFLTMP(I,JHFLUP)-HFLTMP(I,JHFLLW))
135     CONTINUE
C
        HFLV=THFLV(1)+(THFLV(2)-THFLV(1))
     1       *(CONC-CNCSLN(3,1))/(CNCSLN(3,2)-CNCSLN(3,1))
C
C.....................Vapor Pressure of Solute.....................
C
        DO 145 I=1,2
        IF (TEMP.LT.PSTTMP(I,1)) THEN
          JPSBUP=3
          JPSBMD=2
          JPSBLW=1
          GO TO 141
        ENDIF
C
        DO J=3,NPSLT(I),2
        IF (TEMP.GE.PSTTMP(I,J-2).AND.TEMP.LT.PSTTMP(I,J)) THEN
          JPSBUP=J
          JPSBMD=J-1
          JPSBLW=J-2
          GO TO 141
        ENDIF
        ENDDO
C
        IF (TEMP.GE.PSTTMP(I,NPSLT(I))) THEN
          JPSBUP=NPSLT(I)
          JPSBMD=NPSLT(I)-1
          JPSBLW=NPSLT(I)-2
          GO TO 141
        ENDIF
C
141     CONTINUE
        DELT0=PSTTMP(I,JPSBMD)-PSTTMP(I,JPSBLW)
        DELT1=PSTTMP(I,JPSBUP)-PSTTMP(I,JPSBMD)
        DELT2=PSTTMP(I,JPSBUP)-PSTTMP(I,JPSBLW)
        IF (DELT0.EQ.0.OR.DELT1.EQ.0.OR.DELT2.EQ.0) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
```

```
          GO TO 399
        ENDIF
        BCON=(EPSLT(I,JPSBLW)*DELT1-EPSLT(I,JPSBMD)*DELT2
     1       +EPSLT(I,JPSBUP)*DELT0)/(DELT0*DELT1*DELT2)
        ACON=(EPSLT(I,JPSBMD)-EPSLT(I,JPSBLW))/DELT0-BCON*DELT0
        TPSLT(I)=EPSLT(I,JPSBLW)+ACON*(TEMP-PSTTMP(I,JPSBLW))
     1       +BCON*((TEMP-PSTTMP(I,JPSBLW))**2.0)
145     CONTINUE
C
        PSBS=TPSLT(1)+(TPSLT(2)-TPSLT(1))
     1       *(CONC-CNCSLN(4,1))/(CNCSLN(4,2)-CNCSLN(4,1))
C
C.....................Vapor Pressure of Solvent.....................
C
        DO 149 I=1,2
        IF (TEMP.LT.PSVTMP(I,1)) THEN
          JPSBUP=3
          JPSBMD=2
          JPSBLW=1
          GO TO 146
        ENDIF
C
        DO J=3,NPSLV(I),2
        IF (TEMP.GE.PSVTMP(I,J-2).AND.TEMP.LT.PSVTMP(I,J)) THEN
          JPSBUP=J
          JPSBMD=J-1
          JPSBLW=J-2
          GO TO 146
        ENDIF
        ENDDO
C
        IF (TEMP.GE.PSVTMP(I,NPSLV(I))) THEN
          JPSBUP=NPSLV(I)
          JPSBMD=NPSLV(I)-1
          JPSBLW=NPSLV(I)-2
          GO TO 146
        ENDIF
C
146     CONTINUE
        DELT0=PSVTMP(I,JPSBMD)-PSVTMP(I,JPSBLW)
        DELT1=PSVTMP(I,JPSBUP)-PSVTMP(I,JPSBMD)
        DELT2=PSVTMP(I,JPSBUP)-PSVTMP(I,JPSBLW)
        IF (DELT0.EQ.0.OR.DELT1.EQ.0.OR.DELT2.EQ.0) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        BCON=(EPSLV(I,JPSBLW)*DELT1-EPSLV(I,JPSBMD)*DELT2
     1       +EPSLV(I,JPSBUP)*DELT0)/(DELT0*DELT1*DELT2)
        ACON=(EPSLV(I,JPSBMD)-EPSLV(I,JPSBLW))/DELT0-BCON*DELT0
        TPSLV(I)=EPSLV(I,JPSBLW)+ACON*(TEMP-PSVTMP(I,JPSBLW))
     1       +BCON*((TEMP-PSVTMP(I,JPSBLW))**2.0)
149     CONTINUE
C
        PSLV=TPSLV(1)+(TPSLV(2)-TPSLV(1))
     1       *(CONC-CNCSLN(5,1))/(CNCSLN(5,2)-CNCSLN(5,1))
C
C.................Compressibility Factor of Solute Vapor.............
C
        IF (TEMP.LT.ZSTTMP(1)) THEN
          IZPRUP=2
```

```
          IZPRLW=1
          GO TO 151
        ENDIF
C
        DO I=2,NZSLT
          IF (TEMP.GE.ZSTTMP(I-1).AND.TEMP.LT.ZSTTMP(I)) THEN
            IZPRUP=I
            IZPRLW=I-1
            GO TO 151
          ENDIF
        ENDDO
C
        IF (TEMP.GE.ZSTTMP(I)) THEN
          IZPRUP=NZSLT
          IZPRLW=NZSLT-1
          GO TO 151
        ENDIF
C
151     CONTINUE
        IF (ZSTTMP(IZPRUP).EQ.ZSTTMP(IZPRLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        ZSBS=EZSLT(IZPRLW)+(EZSLT(IZPRUP)-EZSLT(IZPRLW))
     1    *(TEMP-ZSTTMP(IZPRLW))/(ZSTTMP(IZPRUP)-ZSTTMP(IZPRLW))
C
C.....................Compressibility Factor of Solvent Vapor..............
C
        IF (TEMP.LT.ZSVTMP(1)) THEN
          IZPRUP=2
          IZPRLW=1
          GO TO 156
        ENDIF
C
        DO I=2,NZSLV
          IF (TEMP.GE.ZSVTMP(I-1).AND.TEMP.LT.ZSVTMP(I)) THEN
            IZPRUP=I
            IZPRLW=I-1
            GO TO 156
          ENDIF
        ENDDO
C
        IF (TEMP.GE.ZSVTMP(NZSLV)) THEN
          IZPRUP=NZSLV
          IZPRLW=NZSLV-1
          GO TO 156
        ENDIF
C
156     CONTINUE
        IF (ZSVTMP(IZPRUP).EQ.ZSVTMP(IZPRLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        ZSLV=EZSLV(IZPRLW)+(EZSLV(IZPRUP)-EZSLV(IZPRLW))
     1  *(TEMP-ZSVTMP(IZPRLW))/(ZSVTMP(IZPRUP)-ZSVTMP(IZPRLW))
C
C.............Ratio of Specific Heats for Solute Vapor.............
C
        IF (TEMP.LT.GSTTMP(1)) THEN
          IGMPUP=2
```

```
          IGMPLW=1
          GO TO 161
        ENDIF
C
        DO I=2,NGSLT
          IF (TEMP.GE.GSTTMP(I-1).AND.TEMP.LT.GSTTMP(I)) THEN
            IGMPUP=I
            IGMPLW=I-1
            GO TO 161
          ENDIF
        ENDDO
C
        IF (TEMP.GE.GSTTMP(NGSLT)) THEN
          IGMPUP=NGSLT
          IGMPLW=NGSLT-1
          GO TO 161
        ENDIF
C
161     CONTINUE
        IF (GSTTMP(IGMPUP).EQ.GSTTMP(IGMPLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        GAMSBS=EGSLT(IGMPLW)+(EGSLT(IGMPUP)-EGSLT(IGMPLW))
     1  *(TEMP-GSTTMP(IGMPLW))/(GSTTMP(IGMPUP)-GSTTMP(IGMPLW))
C
C.............Ratio of Specific Heats for Solvent Vapor.............
C
        IF (TEMP.LT.GSVTMP(1)) THEN
          IGMPUP=2
          IGMPLW=1
          GO TO 166
        ENDIF
C
        DO I=2,NGSLV
          IF (TEMP.GE.GSVTMP(I-1).AND.TEMP.LT.GSVTMP(I)) THEN
            IGMPUP=I
            IGMPLW=I-1
            GO TO 166
          ENDIF
        ENDDO
C
        IF (TEMP.GE.GSVTMP(NGSLV)) THEN
          IGMPUP=NGSLV
          IGMPLW=NGSLV-1
          GO TO 166
        ENDIF
C
166     CONTINUE
        IF (GSVTMP(IGMPUP).EQ.GSVTMP(IGMPLW)) THEN
          WRITE(*,*) 'Bad temperature data; program run terminated'
          GO TO 399
        ENDIF
        GAMSLV=EGSLV(IGMPLW)+(EGSLV(IGMPUP)-EGSLV(IGMPLW))
     1  *(TEMP-GSVTMP(IGMPLW))/(GSVTMP(IGMPUP)-GSVTMP(IGMPLW))
C
C........Specific Volume of Combined Solute and Solvent Vapor.....
C
        VVAP=1545.4*(TEMP+459.7)/
     1           (144.0*(PSBS*MLWSBS/ZSBS+PSLV*MLWSLV/ZSLV))
```

```
C
399      CONTINUE
C.....................................................................
223      FORMAT (I10)
225      FORMAT (F10.2,F10.4)
226      FORMAT (F10.2,F10.5)
227      FORMAT (F10.2,F10.1)
229      FORMAT (2F10.2)
247      FORMAT (F10.2)
255      FORMAT (2F10.3)
C
         RETURN
         END
```

APPENDIX H

SUBROUTINE FPRPSBS

Subroutine FPRPSBS.FOR contains the thermal property data for the commodities available in the program. The following are input data to the subroutine.

KPRD — Identification number for commodity contained in tank. (See Section 2.3.2 of the User's Manual for product designations), and

TEMP — Temperature (°F).

The following properties of a product are then calculated at saturated vapor condition as a function of temperature:

PSBS — Vapor pressure of product (psia),

SPEC — Specific heat of the liquid (BTU/lb-°F),

SPLQ — Specific volume of liquid (ft^3/lb),

HFLV — Heat of vaporization (BTU/lb-°F),

GAMSBS — Ratio of specific heats of substance vapor,

ZSBS — Compressibility factor of substance vapor,

MLWSBS — Molecular weight of substance vapor, and

VVAP — Specific volume of vapor (ft^3/lb).

The thermal properties of the products listed in Section 2.3.2 of the User's Manual are contained in this subroutine.

The thermal property data are represented as quadratic functions of temperature within given temperature ranges. A sufficient number of temperature ranges are used with each commodity to give an accurate representation of the property data. The subroutine is called with a given value of temperature (TEMP) in °F.

The thermal property data are based on the following sources: propane (Ref. 5), ethylene oxide (Ref. 5), propylene (Ref. 5), 1,3-butadiene (Refs. 5 and 6), vinyl chloride (Refs. 5 and 6), monomethylamine (Refs. 5 and 7), and propylene oxide (Ref. 8).

```
C  THIS SUBROUTINE, FPRPSBS.FOR, CONTAINS THE THERMAL PROPERTIES OF
C     WATER(1), PROPANE(2), ETHYLENE OXIDE(3), PROPYLENE(4),
C     1,3-BUTADIENE(5), VINYL CHLORIDE(6), MONOMETHYLAMINE(7),
C     PROPYLENE OXIDE(8), AND ANHYDROUS AMMONIA(9), UNDER SATURATED
C     VAPOR CONDITIONS AS A FUNCTION OF TEMPERATURE. PROPERTIES ARE:
C             PSBS-VAPOR PRESSURE OF SUBSTANCE (PSIA)
C             SPEC-SPECIFIC HEAT OF LIQUID (BTU/LB-DEG F)
C             SPLQ-SPECIFIC VOLUME LIQUID (CU FT/LB)
C             HFLV-HEAT OF VAPORIZATION (BTU/LB)
C             VVAP-SPECIFIC VOLUME VAPOR (CU FT/LB)
C             ZSBS-COMPRESSIBILITY FACTOR OF SOLUTE VAPOR
C             GAMSBS-RATIO OF SPECIFIC HEATS OF SOLUTE
C             MLWSBS-MOLLECULAR WEIGHT OF SOLUTE VAPOR
C.........................Version 2.1, November 11, 1998
      SUBROUTINE FPRPSBS (KPRD,TEMP)
C
      REAL MLWSBS,MLWSLV
      INTEGER*2 KPRD
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
        PSLV=0.0
        ZSLV=1.0
        GAMSLV=1.1
        MLWSLV=1.0
        CNCMIN=1.0
        CNCMAX=1.0
      GO TO (101,102,103,104,105,106,107,108,109) KPRD
C
C.....PROPERTIES OF WATER.....................................
101   CONTINUE
      IF (TEMP.LE.100.0) PSBS=0.089+0.000706*(TEMP-32.0)
     1   +0.000176*((TEMP-32.0)**2.0)
      IF (TEMP.GT.100.0.AND.TEMP.LE.160.0) PSBS=0.949
     1   +0.021733*(TEMP-100.0)+0.000691*((TEMP-100.0)**2.0)
      IF (TEMP.GT.160.0.AND.TEMP.LE.280.0) THEN
        TDELT=TEMP-160.0
        PSBS=4.74+0.0459*TDELT+0.00269*TDELT*TDELT
      ENDIF
      IF (TEMP.GT.280.0.AND.TEMP.LE.400.0) THEN
        TDELT=TEMP-280.0
        PSBS=49.2+0.643*TDELT+0.00840*TDELT*TDELT
      ENDIF
      IF (TEMP.GT.400) THEN
        TDELT=TEMP-400.0
        PSBS=247.31+3.390*TDELT+0.01099*TDELT*TDELT
      ENDIF
C
      IF (TEMP.LE.300.0) SPEC=1.0+0.000112*(TEMP-32.0)
      IF (TEMP.GT.300.0) SPEC=1.03+0.000864*(TEMP-300.0)
      IF (TEMP.LE.300.0) SPLQ=0.01602+0.00000534*(TEMP-32.0)
      IF (TEMP.GT.300.0) SPLQ=0.01745+0.00001568*(TEMP-300.0)
      IF (TEMP.LE.300.0) HFLV=1075.8-0.618*(TEMP-32.0)
      IF (TEMP.GT.300.0) HFLV=910.1-1.0168*(TEMP-300.0)
      IF (TEMP.LE.300.0) GAMSBS=1.32-0.0000373*(TEMP-32.0)
      IF (TEMP.GT.300.0) GAMSBS=1.31-0.0001818*(TEMP-300.0)
      IF (TEMP.LE.300.0) ZSBS=0.998-0.000157*(TEMP-32.0)
      IF (TEMP.GT.300.0) ZSBS=0.956-0.000809*(TEMP-300.0)
```

```
        MLWSBS=18.0
        TLMTMN=32.0
        TLMTMX=520.0
        GO TO 999
C
C.............PROPERTIES OF PROPANE.....................................
102     CONTINUE
C
        IF(TEMP.LE.56.75) THEN
          PSBS=38.32+0.711*TEMP+0.00751*TEMP*TEMP
          SPLQ=0.029456+0.0000327*TEMP
          HFLV=170.38-0.3105*TEMP
        ENDIF
        IF (TEMP.GT.56.75.AND.TEMP.LE.81.12) THEN
          PSBS=44.809+0.47317*TEMP+0.0096905*TEMP*TEMP
          SPLQ=(31.312+
     1        .05029*(TEMP-56.75)+.0002*((TEMP-56.75)**2))/1000.
          HFLV=166.67-0.12991*TEMP-0.00203103*TEMP*TEMP
        ENDIF
        IF (TEMP.GT.81.12.AND.TEMP.LE.135.59)  THEN
          PSBS=63.705+0.026189*TEMP+0.012329*TEMP*TEMP
          SPLQ=(32.656+.05999*(TEMP-81.12)+.0003307*((TEMP-81.12)**2)
     1   )/1000.
          HFLV=164.54-0.10958*TEMP-0.00195787*TEMP*TEMP
        ENDIF
        IF (TEMP.GT.135.59.AND.TEMP.LE.172.54) THEN
          PSBS=123.25-0.8776297*TEMP+0.015756*TEMP*TEMP
          SPLQ=(36.905+.085936*(TEMP-135.59)+0.001399*((TEMP-135.59)**2)
     1    )/1000.
          HFLV=105.00+0.7376607*TEMP-0.00496746*TEMP*TEMP
        ENDIF
        IF (TEMP.GT.172.54.AND.TEMP.LE.201.25) THEN
          PSBS=193.32-1.723723*TEMP+0.0183058*TEMP*TEMP
          SPLQ=(41.991+.13595*(TEMP-172.54)+.00901*((TEMP-172.54)**2))
     1    /1000.
          IF (TEMP.LE.187.63) HFLV=84.39-(TEMP-172.54)*1.226
          IF (TEMP.GT.187.63) HFLV=65.88-(TEMP-187.63)*2.472
        ENDIF
        IF (TEMP.GT.201.25) THEN
          PSBS=587.84+6.0748*(TEMP-201.25)
          SPLQ=0.053324+(TEMP-201.25)*0.003496
          HFLV=32.21-(TEMP-201.25)*6.341
        ENDIF
C
        IF (TEMP.LE.40.0)
     1    SPEC=0.5539+0.00065*TEMP+0.0000035*(TEMP**2.0)
        IF (TEMP.GT.40.0.AND.TEMP.LE.80.0) SPEC=0.5855
     1    +0.000920*(TEMP-40.0)+0.00000675*((TEMP-40.0)**2.0)
        IF (TEMP.GT.80.0.AND.TEMP.LE.123.64) SPEC=0.6331
     1    +0.001207*(TEMP-80.0)+0.00002637*((TEMP-80.0)**2.0)
        IF (TEMP.GT.123.64.AND.TEMP.LE.163.975) THEN
          TDELT=TEMP-123.64
          SPEC=0.736+0.0019923*TDELT+0.00005325*(TDELT**2)
        ENDIF
        IF (TEMP.GT.163.975.AND.TEMP.LE.201.25) THEN
          TDELT=TEMP-163.975
          SPEC=0.903+0.00033931*TDELT+0.0006224*(TDELT**2)
        ENDIF
        IF (TEMP.GT.201.25) SPEC=3.976
C
```

```
      IF (TEMP.LT.80.0) THEN
        GAMSBS=1.21+0.00133*(TEMP-20.0)
        ZSBS=0.920-0.00105*TEMP-0.00000438*TEMP*TEMP
      ENDIF
      IF (TEMP.GE.80.0.AND.TEMP.LT.140.0) THEN
        GAMSBS=1.29+0.00383*(TEMP-80.0)
        ZSBS=0.810-0.002200*(TEMP-80.0)
      ENDIF
      IF (TEMP.GE.140.0.AND.TEMP.LT.196.0) THEN
        GAMSBS=1.52+0.00564*(TEMP-140.0)
        ZSBS=0.678-0.004107*(TEMP-140.0)
      ENDIF
      IF (TEMP.GE.196.0.AND.TEMP.LT.206.3) THEN
        GAMSBS=1.84                                    ! 2.1 rev
        ZSBS=0.448-0.0173*(TEMP-196.0)
      ENDIF
      IF (TEMP.GE.206.3) THEN
        GAMSBS=1.20+0.68*(10.0/(10.0+(603.0-PSBS)**2.0)) ! 2.1 rev
        ZSBS=0.700-0.252*(10.0/(10.0+(603.0-PSBS)**2.0))
      ENDIF
      MLWSBS=44.0
      TLMTMN=0.0
      TLMTMX=1000.0
      GO TO 999
C
C.............PROPERTIES OF ETHYLENE OXIDE.............................
103   CONTINUE
C
      IF(TEMP.LE.70.0) PSBS=3.73
     1  +0.0846*(TEMP+4.0)+0.002194*((TEMP+4.0)**2.0)
      IF(TEMP.GT.70.0.AND.TEMP.LE.130.0) PSBS=22.00
     1  +0.4135*(TEMP-70.0)+0.004650*((TEMP-70.0)**2.0)
      IF(TEMP.GT.130.0.AND.TEMP.LE.190.0) PSBS=63.55
     1  +0.9692*(TEMP-130.0)+0.007861*((TEMP-130.0)**2.0)
      IF(TEMP.GT.190.0.AND.TEMP.LE.250.0) PSBS=150.00
     1  +1.9145*(TEMP-190.0)+0.011506*((TEMP-190.0)**2.0)
      IF(TEMP.GT.250.0.AND.TEMP.LE.310.0) PSBS=306.29
     1  +3.3008*(TEMP-250.0)+0.015317*((TEMP-250.0)**2.0)
      IF(TEMP.GT.310.0.AND.TEMP.LE.370.0) PSBS=559.48
     1  +5.1473*(TEMP-310.0)+0.018989*((TEMP-310.0)**2.0)
      IF(TEMP.GT.370.0) PSBS=936.68+7.383*(TEMP-370.0)
C
      IF(TEMP.LT.85.0) SPEC=0.4560+0.000204*TEMP
      IF(TEMP.GT.85.0.AND.TEMP.LE.145.0) SPEC=0.4733
     1  +0.00067*(TEMP-85.0)+0.00000367*((TEMP-85.0)**2.0)
      IF(TEMP.GT.145.0.AND.TEMP.LE.205.0) SPEC=0.5267
     1  +0.001065*(TEMP-145.0)+0.00000539*((TEMP-145.0)**2.0)
      IF(TEMP.GT.205.0.AND.TEMP.LE.265.0) SPEC=0.6100
     1  +0.001610*(TEMP-205.0)+0.00000933*((TEMP-205.0)**2.0)
      IF(TEMP.GT.265.0.AND.TEMP.LE.325.0) SPEC=0.7402
     1  +0.002435*(TEMP-265.0)+0.00000383*((TEMP-265.0)**2.0)
      IF(TEMP.GT.325.0.AND.TEMP.LE.355.0) SPEC=
     1  0.9001+0.00010733*((TEMP-325.0)**2.0)
      IF(TEMP.GT.355.0.AND.TEMP.LE.375.0)
     1  SPEC=0.9967+0.13*(TEMP-355.0)
      IF(TEMP.GT.375.0) SPEC=2.7+4.4*(TEMP-375.0)
C
      IF (TEMP.LE.70.0) SPLQ=0.01744+0.00001086*TEMP
      IF (TEMP.GT.70.0.AND.TEMP.LE.130.0) SPLQ=
     1  (18.200+0.01195*(TEMP-70.)+0.0000672*(TEMP-70.)**2)/1000.0
```

```
      IF (TEMP.GT.130.0.AND.TEMP.LE.190.0) SPLQ=
     1  (19.159+0.02108*(TEMP-130.)+0.000065*(TEMP-130.)**2)/1000.0
      IF (TEMP.GT.190.0.AND.TEMP.LE.250.0) SPLQ=
     1  (20.658+0.02888*(TEMP-190.)+0.0000828*(TEMP-190.)**2)/1000.0
      IF (TEMP.GT.250.0.AND.TEMP.LE.310.0) SPLQ=
     1  (22.689+0.03543*(TEMP-250.)+0.000273*(TEMP-250.)**2)/1000.0
      IF (TEMP.GT.310.0.AND.TEMP.LE.370.0) SPLQ=
     1  (25.799+0.060*(TEMP-310.0)+0.001*(TEMP-310.0)**2)/1000.0
       IF (TEMP.GT.370.0)
     1   SPLQ=0.032999+0.0012499*(TEMP-370.0)
C
      IF (TEMP.LE.70.0) HFLV=261.4-0.2586*TEMP
      IF (TEMP.GT.70.0.AND.TEMP.LE.250.0)
     1   HFLV=261.04-0.2219*TEMP-0.000451*TEMP*TEMP
      IF (TEMP.GT.250.0.AND.TEMP.LE.310.0) HFLV=177.4
     1   -0.4474*(TEMP-250.0)-0.003182*((TEMP-250.0)**2.0)
      IF (TEMP.GT.310.0.AND.TEMP.LE.370.0) HFLV=139.1
     1   -0.7517*(TEMP-310.0)-0.003944*((TEMP-310.0)**2.0)
      IF (TEMP.GT.370.0)
     1   HFLV=79.8-5.542*(TEMP-370.0)
C
      IF (TEMP.LE.100.0) ZSBS=0.9522-0.00044167*TEMP
      IF (TEMP.GT.100.0.AND.TEMP.LE.220.0) ZSBS=0.908
     1   -0.00044167*(TEMP-100.0)-0.00000542*((TEMP-100.0)**2.0)
      IF (TEMP.GT.220.0.AND.TEMP.LE.340.0) ZSBS=0.777
     1   -0.00073327*(TEMP-220.0)-0.00000889*((TEMP-220.0)**2.0)
      IF (TEMP.GT.340.0.AND.TEMP.LE.370.0) ZSBS=0.561
     1   -0.002867*(TEMP-340.0)
      IF (TEMP.GT.370.0) ZSBS=0.475-0.017*(TEMP-370.0)
C
      GAMSBS=1.2
      MLWSBS=44.05
      TLMTMN=-20.0
      TLMTMX=1000.0
      GO TO 999
C
C.....PROPERTIES OF PROPYLENE.....
104   CONTINUE
C
      IF(TEMP.LE.40.0) THEN
        PSBS=47.97+1.2138*TEMP
        SPEC=0.5552+0.00046*TEMP+0.00000375*TEMP*TEMP
        SPLQ=0.028032+0.00004*TEMP
        HFLV=173.0-0.3225*TEMP
      ENDIF
      IF(TEMP.GT.40.0.AND.TEMP.LE.80.0) THEN
        F=TEMP-40.0
        PSBS=96.52+1.5303*F+0.0106*F*F
        SPEC=0.5796+0.000743*F+0.00000713*F*F
        SPLQ=(29633.0+60.13*F-0.2*F*F)/10.0**6
        HFLV=160.1-0.458250*F+0.000088*F*F
      ENDIF
      IF(TEMP.GT.80.0.AND.TEMP.LE.120.0) THEN
        F=TEMP-80.0
        PSBS=174.71+2.3750*F+0.01343*F*F
        SPEC=0.6207+0.001235*F+0.000018*F*F
        SPLQ=(31716.0+56.03*F+0.4*F*F)/10.0**6
        HFLV=141.91-0.475250*F-0.001263*F*F
      ENDIF
      IF (TEMP.GT.120.0.AND.TEMP.LE.160.0) THEN
```

```
            F=TEMP-120.0
            PSBS=291.19+3.4445*F+0.01750*F*F
            SPEC=0.6989+0.001870*F+0.0000945*F*F
            SPLQ=(34599.0+100.15*F+1.0*F*F)/10.0**6
            HFLV=120.88-0.479250*F-0.006388*F*F
          ENDIF
          IF (TEMP.GT.160.0.AND.TEMP.LE.180.0) THEN
            F=TEMP-160.0
            PSBS=456.97+4.8570*F+0.02160*F*F
            SPEC=0.9249+0.02555*F
            SPLQ=(40205.0+128.15*F+4.81*F*F)/10.0**6
            HFLV=91.49-1.038500*F-0.013550*F*F
          ENDIF
          IF (TEMP.GT.180.0.AND.TEMP.LE.190.0) THEN
            SPEC=1.4915+0.0237*((TEMP-180.0)**2.0)
            SPLQ=0.044690+0.0005126*(TEMP-180.0)
            HFLV=65.3-1.803*(TEMP-180.0)
          ENDIF
          IF (TEMP.GT.190.0) THEN
            SPEC=3.865
            SPLQ=0.049816+0.00319*(TEMP-190.0)
            HFLV=47.27-6.593*(TEMP-190.0)
          ENDIF
          IF (TEMP.GT.180.0) THEN
            F=TEMP-180.0
            PSBS=562.75+5.6680*F+0.03460*F*F
          ENDIF
C
          IF (TEMP.LE.100.0)
     1      ZSBS=0.805-0.00111*TEMP-0.0000038*TEMP*TEMP
          IF (TEMP.GT.100.0) ZSBS=0.656
     1      -0.0011375*(TEMP-100.0)-0.00002344*((TEMP-100.0)**2.0)
C
          IF (TEMP.LE.50.0) GAMSBS=1.32+0.0006*TEMP
          IF (TEMP.GT.50.0.AND.TEMP.LE.100.0)
     1      GAMSBS=1.35+0.0026*(TEMP-50.0)
          IF (TEMP.GT.100.0.AND.TEMP.LE.140.0)
     1      GAMSBS=1.48+0.0075*(TEMP-100.0)
          IF (TEMP.GT.140.0.AND.TEMP.LE.180.0)
     1      GAMSBS=1.78+0.0425*(TEMP-140.0)
          IF (TEMP.GT.180.0) GAMSBS=3.48+0.088*(TEMP-180.0)
          MLWSBS=42.08
          TLMTMN=0.0
          TLMTMX=1000.0
          GO TO 999
C
C.....................PROPERTIES OF 1,3-BUTADIENE.........................
105       CONTINUE
C
          IF (TEMP.LE.40.0) THEN
            PSBS=8.46+0.19825*TEMP+0.002563*TEMP*TEMP
            SPEC=0.5026+0.000485*TEMP
            SPLQ=0.024060+0.00002428*TEMP
            HFLV=184.0-0.22775*TEMP
          ENDIF
          IF (TEMP.GT.40.0.AND.TEMP.LE.80.0) THEN
            F=TEMP-40.0
            PSBS=20.49+0.403250*F+0.003888*F*F
            SPEC=0.522+0.000700*F
            SPLQ=(25030.0+26.25*F+0.0375*F*F)/10.0**6
```

```
          HFLV=174.89-0.22900*F-0.000525*F*F
        ENDIF
        IF (TEMP.GT.80.0.AND.TEMP.LE.120.0) THEN
          F=TEMP-80.0
          PSBS=42.84+0.71425*F+0.005438*F*F
          SPEC=0.550+0.000775*F+0.0000013*F*F
          SPLQ=(26140.0+30.75*F+0.0625*F*F)/10.0**6
          HFLV=164.89-0.25775*F-0.000613*F*F
        ENDIF
        IF (TEMP.GT.120.0.AND.TEMP.LE.160.0) THEN
          F=TEMP-120.0
          PSBS=80.11+1.14975*F+0.007063*F*F
          SPEC=0.583+0.000875*F+0.0000013*F*F
          SPLQ=(27470.0+35.50*F+0.1250*F*F)/10.0**6
          HFLV=153.60-0.30825*F-0.000613*F*F
        ENDIF
        IF (TEMP.GT.160.0.AND.TEMP.LE.200.0) THEN
          F=TEMP-160.0
          PSBS=137.40+1.72150*F+0.008900*F*F
          SPEC=0.620+0.001500*F
          SPLQ=(29090.0+45.00*F+0.2000*F*F)/10.0**6
          HFLV=140.29-0.36275*F-0.001113*F*F
        ENDIF
        IF (TEMP.GT.200.0.AND.TEMP.LE.240.0) THEN
          F=TEMP-200.0
          PSBS=220.50+2.51250*F+0.013125*F*F
          SPEC=0.680+0.001325*F+0.0000088*F*F
          SPLQ=(31210.0+52.25*F+0.3625*F*F)/10.0**6
          HFLV=124.00-0.25500*F-0.003850*F*F
        ENDIF
        IF (TEMP.GT.240.0) THEN
          F=TEMP-240.0
          PSBS=342.00+3.70000*F+0.007500*F*F
          SPEC=0.747+0.002550*F+0.0000175*F*F
          SPLQ=(33880.0+87.50*F+1.5000*F*F)/10.0**6
          HFLV=107.64-0.58050*F-0.008325*F*F
        ENDIF
        IF (TEMP.LE.100.0) ZSBS=1.00-0.00097*TEMP
        IF (TEMP.GT.100.0.AND.TEMP.LE.200.0)
     1    ZSBS=0.903-0.00151*(TEMP-100.0)
        IF (TEMP.GT.200.0) ZSBS=0.752-0.00274*(TEMP-200)
        MLWSBS=54.09
        GAMSBS=1.3
        TLMTMN=0.0
        TLMTMX=280.0
        GO TO 999
C
C.....................PROPERTIES OF VINYL CHLORIDE.....................
106     CONTINUE
C
        IF (TEMP.LE.40.0) THEN
          PSBS=12.2+0.25*TEMP+0.0045*TEMP*TEMP
          SPEC=0.276+0.000675*TEMP
          SPLQ=0.01666+0.000011*TEMP
          HFLV=142.3-0.16*TEMP
        ENDIF
        IF (TEMP.GT.40.0.AND.TEMP.LE.100.0) THEN
          F=TEMP-40.0
          PSBS=29.40+0.7100*F+0.002778*F*F
          SPEC=0.3034+0.000688*F
```

```
        SPLQ=(17100.0+14.33*F+0.0330*F*F)/10.0**6
        HFLV=135.9-0.2017*(TEMP-40.0)
      ENDIF
      IF (TEMP.GT.100.0.AND.TEMP.LE.140.0) THEN
        F=TEMP-100.0
        PSBS=82.00+0.92500*F+0.008750*F*F
        SPEC=0.3445+0.000678*F
        SPLQ=(18080.0+22.50*F+0.0250*F*F)/10.0**6
        HFLV=123.80-0.17500*F-0.001000*F*F
      ENDIF
      IF (TEMP.GT.140.0.AND.TEMP.LE.180.0) THEN
        F=TEMP-140.0
        PSBS=133.00+1.57500*F+0.008750*F*F
        SPEC=0.3718+0.000688*F
        SPLQ=(19020.0+23.25*F+0.1880*F*F)/10.0**6
        HFLV=115.20-0.25000*F-0.000500*F*F
      ENDIF
      IF (TEMP.GT.180.0.AND.TEMP.LE.220.0) THEN
        F=TEMP-180.0
        PSBS=210.00+2.32500*F+0.016250*F*F
        SPEC=0.3991+0.000685*F
        SPLQ=(20250.0+34.00*F+0.2250*F*F)/10.0**6
        HFLV=104.40-0.2950*F-0.001500*F*F
      ENDIF
      IF (TEMP.GT.220.0) THEN
        F=TEMP-220.0
        PSBS=329.00+3.52500*F+0.023750*F*F
        SPEC=0.4265+0.000678*F
        SPLQ=(21970.0+52.25*F+0.4130*F*F)/10.0**6
        HFLV=90.20-0.27500*F-0.004250*F*F
      ENDIF
      ZSBS=0.900-0.00146*TEMP
      MLWSBS=62.5
      GAMSBS=1.3
      TLMTMN=0.0
      TLMTMX=260.0
      GO TO 999
C
C.....PROPERTIES OF MONOMETHYLAMINE.....
107   CONTINUE
C
      IF(TEMP.LE.50.0) THEN
        PSBS=8.78+0.223*TEMP+0.003976*TEMP*TEMP
        SPEC=0.730+0.00084*TEMP
        SPLQ=0.02264+0.0000204*TEMP+0.00000003*TEMP*TEMP
        HFLV=367.8-0.416*TEMP
      ENDIF
      IF(TEMP.GT.50.0.AND.TEMP.LE.86.0) THEN
        F=TEMP-50.0
        PSBS=29.87+0.6372*F+0.006728*F*F
        SPEC=0.772+0.000806*F+0.0000077*F*F
        SPLQ=(23740.0+23.89*F+0.0310*F*F)/10.0**6
        HFLV=347.00-0.45830*F-0.000463*F*F
      ENDIF
      IF (TEMP.GT.86.0.AND.TEMP.LE.122.0) THEN
        F=TEMP-86.0
        PSBS=61.53+0.9669*F+0.013627*F*F
        SPEC=0.811+0.001167*F+0.0000031*F*F
        SPLQ=(24640.0+26.11*F+0.0620*F*F)/10.0**6
        HFLV=329.9-0.5083*F-0.000463*F*F
```

```
      ENDIF
      IF (TEMP.GT.122.0.AND.TEMP.LE.150.0) THEN
        F=TEMP-122.0
        PSBS=114.00+1.89250*F+0.009451*F*F
        SPEC=0.857+0.001132*F+0.0000016*F*F
        SPLQ=(25660.0+30.20*F+0.0440*F*F)/10.0**6
        HFLV=311.00-0.5516*F-0.003132*F*F
      ENDIF
      IF (TEMP.GT.150.0.AND.TEMP.LE.180.0) THEN
        F=TEMP-150.0
        PSBS=174.40+2.4267*F+0.015111*F*F
        SPEC=0.890+0.001467*F
        SPLQ=(26540.0+32.67*F+0.0440*F*F)/10.0**6
        HFLV=293.1-0.6933*F-0.003111*F*F
      ENDIF
      IF (TEMP.GT.180.0.AND.TEMP.LE.210.0) THEN
        F=TEMP-180.0
        PSBS=260.80+3.2867*F+0.016444*F*F
        SPEC=0.934+0.001367*F+0.0000022*F*F
        SPLQ=(27560.0+35.33*F+0.0440*F*F)/10.0**6
        HFLV=269.50-0.870*F-0.002000*F*F
      ENDIF
      IF (TEMP.GT.210.0) THEN
        F=TEMP-210.0
        PSBS=374.20+4.568*F+0.024960*F*F
        SPEC=0.977+0.001300*F+0.0000067*F*F
        SPLQ=(28660.0+32.67*F+0.4*F*F)/10.0**6
        HFLV=241.60-0.9667*F-0.001778*F*F
      ENDIF
      ZSBS=0.980-0.00041*TEMP
      GAMSBS=1.3
      TLMTMN=50.0
      TLMTMX=240.0
      MLWSBS=31.06
      GO TO 999
C
C.....................PROPERTIES OF PROPYLENE OXIDE.......................
108   CONTINUE
C
      IF (TEMP.LE.40.0) THEN
        PSBS=1.4+0.075*TEMP
        SPEC=0.442+0.001*TEMP
        SPLQ=0.01836+0.00001225*TEMP
        HFLV=223.0-0.175*TEMP
      ENDIF
      IF (TEMP.GT.40.0.AND.TEMP.LE.160.0) THEN
        F=TEMP-40.0
        PSBS=4.4+0.05667*F+0.002417*F*F
        SPEC=0.482+0.001167*F+0.0000017*F*F
        SPLQ=(18850.0+14.667*F+0.014*F*F)/10.0**6
        HFLV=216.0-0.24*F
      ENDIF
      IF (TEMP.GT.160.0.AND.TEMP.LE.280.0) THEN
        F=TEMP-160.0
        PSBS=46.0+0.55000*F+0.007500*F*F
        SPEC=0.646+0.0012583*F+0.0000135*F*F
        SPLQ=(20810.0+16.500*F+0.083*F*F)/10.0**6
        HFLV=187.2-0.24*F-0.000500*F*F
      ENDIF
      IF (TEMP.GT.280.0.AND.TEMP.LE.370.0) THEN
```

```
            F=TEMP-280.0
            PSBS=220.0+1.55556*F+0.018519*F*F
            SPEC=0.991+0.0021944*F+0.0000076*F*F
            SPLQ=(23990.0+11.556*F+0.752*F*F)/10.0**6
            HFLV=151.2-0.19*F-0.006333*F*F
          ENDIF
          IF (TEMP.GT.370.0) THEN
            IF (TEMP.LE.400.0) PSBS=510.0+4.667*(TEMP-370.0)
            IF (TEMP.GT.400.0) PSBS=650.0+7.529*(TEMP-370.0)
            SPEC=1.25+0.01*(TEMP-370.0)
            SPLQ=0.03112+0.000147*(TEMP-370.0)
     1        +0.0000061*((TEMP-370.0)**2.0)
            HFLV=82.8-2.151*(TEMP-370.0)
          ENDIF
C
          IF (TEMP.LE.100.0) ZSBS=0.9522-0.00044167*TEMP
          IF (TEMP.GT.100.0.AND.TEMP.LE.220.0) ZSBS=0.908
     1      -0.00044167*(TEMP-100.0)-0.00000542*((TEMP-100.0)**2.0)
          IF (TEMP.GT.220.0.AND.TEMP.LE.340.0) ZSBS=0.777
     1      -0.00073327*(TEMP-220.0)-0.00000889*((TEMP-220.0)**2.0)
          IF (TEMP.GT.340.0.AND.TEMP.LE.370.0) ZSBS=0.561
     1      -0.002867*(TEMP-340.0)
          IF (TEMP.GT.370.0) ZSBS=0.475-0.006415*(TEMP-370.0)
C
          TLMTMN=0.0
          TLMTMX=1000.0
          GAMSBS=1.3
          MLWSBS=58.08
          GO TO 999
C
C.................PROPERTIES OF ANHYDROUS AMMONIA.............................
109       CONTINUE
C
          IF (TEMP.LT.20.0) PSBS=18.30
     1        +0.46425*(TEMP+20.0)+0.007088*((TEMP+20.0)**2.0)
          IF (TEMP.GE.20.0.AND.TEMP.LT.60.0) PSBS=48.21
     1        +1.02625*(TEMP-20.0)+0.01146*((TEMP-20.0)**2.0)
          IF (TEMP.GE.60.0.AND.TEMP.LT.100.0) PSBS=107.6
     1        +1.93250*(TEMP-60.0)+0.01688*((TEMP-60.0)**2.0)
          IF (TEMP.GE.100.0.AND.TEMP.LT.140.0) PSBS=211.9
     1        +3.26975*(TEMP-100.0)+0.02276*((TEMP-100.0)**2.0)
          IF (TEMP.GE.140.0) PSBS=379.1+5.08861*(TEMP-140.0)
     1        +0.02995*((TEMP-140.0)**2.0)
C
          SPEC=1.100+0.001*(TEMP-20.0)
C
          IF (TEMP.LT.20.0) HFLV=583.6-0.7625*(TEMP+20.0)
          IF (TEMP.GE.20.0.AND.TEMP.LT.80.0) HFLV=553.1
     1        -0.8133*(TEMP-20.0)-0.001556*((TEMP-20.0)**2.0)
          IF (TEMP.GE.80.0) HFLV=498.7-0.9952*(TEMP-80.0)
     1        -0.002489*((TEMP-80.0)**2.0)
C
          IF (TEMP.LT.20.0) SPLQ=0.02369+0.00002625*(TEMP+20.0)
          IF (TEMP.GE.20.0.AND.TEMP.LT.80.0) SPLQ=0.02473
     1      +(28.2*(TEMP-20.0)+0.072*((TEMP-20.0)**2.0))/(10.0**6.0)
          IF (TEMP.GE.80.0) SPLQ=0.02668
     1      +(37.0*(TEMP-80.0)+0.125*((TEMP-80.0)**2.0))/(10.0**6.0)
C
          IF (TEMP.LT.50.0) ZSBS=0.967-0.000786*(TEMP+20.0)
          IF (TEMP.GE.50.0) ZSBS=0.912-0.00135*(TEMP-50.0)
```

```
        GAMSBS=1.32
        MLWSBS=17.0
        TLMTMN=-20.0
        TLMTMX=176.0
C
        GO TO 999
C.....................................................................
999     CONTINUE
        IF (PSBS.LE.(0.01)) THEN
          VVAP=20000.0
        ELSE
          VVAP=ZSBS*(1545.0/MLWSBS)*(TEMP+460.0)/(PSBS*144.0)
        ENDIF
        RETURN
        END
```

APPENDIX I

SUBROUTINE FPRPSLV

Subroutine FPRPSLV.FOR contains the thermal property data for the commodities available in the program which are solutions. The following are input data to the subroutine.

KPRD	Identification number for commodity contained in tank. (See Section 2.3.2 of the User's Manual for product designations),
CONC	Product concentration, (decimal fraction), and
TEMP	Temperature (°F).

The following properties of a product are then calculated at saturated vapor condition as a function of temperature:

PSBS	Vapor pressure of product (psia),
PSLV	Vapor pressure of solvent (psia),
SPEC	Specific heat of the liquid (BTU/lb-°F),
SPLQ	Specific volume of liquid (ft^3/lb),
HFLV	Heat of vaporization (BTU/lb-°F),
GAMSBS	Ratio of specific heats of substance vapor,
GAMSLV	Ratio of specific heats of solvent vapor,
ZSBS	Compressibility factor of substance vapor,
MLWSBS	Molecular weight of substance vapor, and
VVAP	Specific volume of vapor (ft^3/lb).

The thermal properties of the products listed in Section 2.3.2 of the User's Manual are contained in this subroutine.

The thermal property data are represented as quadratic functions of temperature within given temperature ranges. A sufficient number of temperature ranges are used with each commodity to give an accurate representation of the property data. The subroutine is called with a given value of temperature (TEMP) in °F.

The thermal property data for the acids and caustic soda were obtained from various sources (Refs. 9 to 12). A listing of the subroutine is presented on the following pages.

```
C     THIS SUBROUTINE, FPRPSLV.FOR, CONTAINS THE THERMAL PROPERTIES
C         OF SULFURIC ACID(10), HYDROCHLORIC ACID(11), SODIUM
C         HYDROXIDE(12), PHOSPHORIC ACID-75%(13), SUPER
C         PHOSPHORIC ACID(14) POTASSIUM HYDROXIDE(15), AND HYDROGEN
C         PEROXIDE SOLUTIONS (16), UNDER SATURATED VAPOR
C         CONDITIONS AS A FUNCTION OF TEMPERATURE.
C         PROPERTIES ARE:
C              PSBS-VAPOR PRESSURE OF SUBSTANCE (PSIA)
C              PSLV-VAPOR PRESSURE OF WATER (FOR SOLUTIONS, PSIA)
C              SPEC-SPECIFIC HEAT OF LIQUID (BTU/LB-DEG F)
C              SPLQ-SPECIFIC VOLUME LIQUID (CU FT/LB)
C              HFLV-HEAT OF VAPORIZATION (BTU/LB)
C              VVAP-SPECIFIC VOLUME VAPOR (CU FT/LB)
C              ZSBS-COMPRESSIBILITY FACTOR OF SOLUTE VAPOR
C              ZSLV-COMPRESSIBILITY FACTOR OF SOLVENT VAPOR
C              GAMSBS-RATIO OF SPECIFIC HEATS OF SOLUTE
C              GAMSLV-RATIO OF SPECIFIC HEATS OF SOLVENT
C              MLWSBS-MOLLECULAR WEIGHT OF SOLUTE VAPOR
C              MLWSLV-MOLLECULAR WEIGHT OF SOLVENT VAPOR
C.....................................Version 2.1, November 11, 1998
      SUBROUTINE FPRPSLV (KPRD,CONC,TEMP)
C
      REAL MLWSBS,MLWSLV
      INTEGER*2 KPRD
C
      COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
      COMMON/PROP2/GAMSBS,GAMSLV,MLWSBS,MLWSLV
      COMMON/PROP3/TLMTMN,TLMTMX,CNCMIN,CNCMAX
C
      ZSLV=0.95
      GAMSLV=1.26
      TLMTMN=0.0
      MLWSLV=18.0
      JPRD=KPRD-9
C
      GO TO (101,102,103,104,105,106,107) JPRD
C.................PROPERTIES OF SULFURIC ACID.....................
101   CONTINUE
C
      IF (TEMP.LE.50.0) THEN
        PSLV=0.0
        PSBS=0.0
      ENDIF
      IF (TEMP.GT.50.0.AND.TEMP.LE.230.0) THEN
        TDELT=TEMP-50.0
        PWTR92=2.736*(TDELT**4.0)/(10.0**11.0)
        PWTR94=1.478*(TDELT**4.0)/(10.0**11.0)
        PSLF92=0.0
        PSLF94=0.0
        PSLV=PWTR92+(CONC-0.92)*(PWTR94-PWTR92)*50.0
        PSBS=PSLF92+(CONC-0.92)*(PSLF94-PSLF92)*50.0
      ENDIF
      IF (TEMP.GT.230.0.AND.TEMP.LE.410.0) THEN
        TD=TEMP-230.0
        PWTR92=0.02872+(9.0*TD*TD+0.3081*(TD**3.0))/(10.0**6.0)
        PWTR94=0.01552+(3.2*TD*TD+0.2020*(TD**3.0))/(10.0**6.0)
        PSLF92=1.015*(TD**3.0)/(10.0**8.0)
        PSLF94=1.219*(TD**3.0)/(10.0**8.0)
        PSLV=PWTR92+(CONC-0.92)*(PWTR94-PWTR92)*50.0
        PSBS=PSLF92+(CONC-0.92)*(PSLF94-PSLF92)*50.0
```

```
      ENDIF
      IF (TEMP.GT.410.0) THEN
        TD=TEMP-410.0
        PWTR92=2.1176+0.001127*TD+0.000863*(TD**2.0)
        PWTR94=1.2966+0.000561*TD+0.1302*(TD**2.0)/(10.0**6.0)
        PSLF92=0.0592+(27.5*TD*TD+0.09074*(TD**3.0))/(10.0**6.0)
        PSLF94=0.0711+(33.1*TD*TD+0.09000*(TD**3.0))/(10.0**6.0)
        PSLV=PWTR92+(CONC-0.92)*(PWTR94-PWTR92)*50.0
        PSBS=PSLF92+(CONC-0.92)*(PSLF94-PSLF92)*50.0
      ENDIF
C
      IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
        VVAP=40000.0
      ELSE
        VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8+PSBS/86.2))
      ENDIF
      HFLV=1550.0+(CONC-0.900)*4540.0
      SPLQ=0.0087+2.778*(TEMP-104.0)/(10.0**6.0)
      SPEC=0.36
      GAMSBS=1.2
      MLWSBS=98.0
      TLMTMX=450.0
      CNCMIN=0.920
      CNCMAX=0.940
      ZSBS=.950
C
      GO TO 999
C.....PROPERTIES OF HYDROCHLORIC ACID.....
102   CONTINUE
C
      SPEC=0.561+0.000573*(TEMP-32.0)
      SPLQ=0.0140*(1.0+0.000282*(TEMP-68.0))
      HFLV=1000.0
C
      EXPN=9.4670-2094.0/(255.38+TEMP/1.8)
      PHCL38=0.0193337*(10.0**EXPN)
      EXPN=9.5262-2229.0/(255.38+TEMP/1.8)
      PHCL36=0.0193337*(10.0**EXPN)
      EXPN=9.6061-2316.0/(255.38+TEMP/1.8)
      PHCL34=0.0193337*(10.0**EXPN)
      EXPN=9.7523-2457.0/(255.38+TEMP/1.8)
      PHCL32=0.0193337*(10.0**EXPN)
C
      EXPN=9.20783-2579.0/(255.38+TEMP/1.8)
      PH2O38=0.0193337*(10.0**EXPN)
      EXPN=9.11815-2526.0/(255.38+TEMP/1.8)
      PH2O36=0.0193337*(10.0**EXPN)
      EXPN=9.07143-2487.0/(255.38+TEMP/1.8)
      PH2O34=0.0193337*(10.0**EXPN)
      EXPN=9.03317-2453.0/(255.38+TEMP/1.8)
      PH2O32=0.0193337*(10.0**EXPN)
C
      IF(CONC.GE.(0.36)) THEN
        PSBS=PHCL36+(PHCL38-PHCL36)*(CONC-0.36)/(0.02)
        PSLV=PH2O36+(PH2O38-PH2O36)*(CONC-0.36)/(0.02)
      ENDIF
      IF (CONC.LE.(0.36).AND.CONC.GE.(0.34)) THEN
        PSBS=PHCL34+(PHCL36-PHCL34)*(CONC-0.34)/(0.02)
        PSLV=PH2O34+(PH2O36-PH2O34)*(CONC-0.34)/(0.02)
      ENDIF
```

```
          IF (CONC.LE.(0.34)) THEN
            PSBS=PHCL32+(PHCL34-PHCL32)*(CONC-0.32)/(0.02)
            PSLV=PH2O32+(PH2O34-PH2O32)*(CONC-0.32)/(0.02)
          ENDIF
C
          IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
            VVAP=20000.0
          ELSE
            VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8+PSBS/86.2))
          ENDIF
          GAMSBS=1.41
          MLWSBS=36.5
          ZSBS=0.95
          TLMTMX=200.0
          CNCMIN=0.320
          CNCMAX=0.380
C
          GO TO 999
C.....PROPERTIES OF SODIUM HYDROXIDE.....
103       CONTINUE
          PSBS=0.0
          IF (TEMP.LE.212.0) THEN
            EXPN=9.0349-2413.0/(255.2+TEMP/1.8)
            PH2O50=0.0193337*(10.0**EXPN)
            EXPN=9.1517-2492.9/(255.2+TEMP/1.8)
            PH2O60=0.0193337*(10.0**EXPN)
          ENDIF
          IF (TEMP.GT.212.0) THEN
            EXPN=8.7309-2299.6/(255.2+TEMP/1.8)
            PH2O50=0.0193337*(10.0**EXPN)
            EXPN=8.9058-2401.2/(255.2+TEMP/1.8)
            PH2O60=0.0193337*(10.0**EXPN)
          ENDIF
C
          PSLV=PH2O50+(PH2O60-PH2O50)*(CONC-0.50)/0.10
C
          IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
            VVAP=30000.0
          ELSE
            VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8))
          ENDIF
C
          SPLQ50=0.010326*(1.0+0.000252*TEMP)
          SPLQ60=0.009725*(1.0+0.000243*TEMP)
          SPLQ=SPLQ50+(SPLQ60-SPLQ50)*(CONC-0.50)/0.10
C
          SPEC=0.783
          HFLV=1071.3-0.64*(TEMP-40.0)
          ZSBS=0.900
          GAMSBS=1.2
          MLWSBS=40.0
          TLMTMX=300.0
          CNCMIN=0.500
          CNCMAX=0.600
          GO TO 999
C.....PROPERTIES OF 75% PHOSPHORIC ACID.....
104       CONTINUE
C
          PSBS=0.0
          IF (TEMP.LE.86.0) THEN
```

```
          EXPN=8.3798-2236.08/(255.2+TEMP/1.8)
          PH2O75=0.0193337*(10.0**EXPN)
          EXPN=8.3047-2335.554/(255.2+TEMP/1.8)
          PH2O85=0.0193337*(10.0**EXPN)
        ENDIF
        IF (TEMP.GT.86.0.AND.TEMP.LE.230.0) THEN
          EXPN=8.25245-2191.13/(255.2+TEMP/1.8)
          PH2O75=0.0193337*(10.0**EXPN)
          EXPN=8.2724-2324.161/(255.2+TEMP/1.8)
          PH2O85=0.0193337*(10.0**EXPN)
        ENDIF
        IF (TEMP.GT.230.0.AND.TEMP.LE.284.0) THEN
          EXPN=8.3176-2216.09/(255.2+TEMP/1.8)
          PH2O75=0.0193337*(10.0**EXPN)
          EXPN=8.3198-2342.314/(255.2+TEMP/1.8)
          PH2O85=0.0193337*(10.0**EXPN)
        ENDIF
        IF (TEMP.GT.284.0.AND.TEMP.LE.370.0) THEN
          EXPN=8.2067-2170.273/(255.2+TEMP/1.8)
          PH2O75=0.0193337*(10.0**EXPN)
          EXPN=7.8042-2129.348/(255.2+TEMP/1.8)
          PH2O85=0.0193337*(10.0**EXPN)
        ENDIF
        IF (TEMP.GT.370.0) THEN
          EXPN=7.8952-2026.744/(255.2+TEMP/1.8)
          PH2O75=0.0193337*(10.0**EXPN)
          EXPN=7.5828-2027.346/(255.2+TEMP/1.8)
          PH2O85=0.0193337*(10.0**EXPN)
        ENDIF
C
        PSLV=PH2O75+(PH2O85-PH2O75)*(CONC-0.75)/0.10
        IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
          VVAP=25000.0
        ELSE
          VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8))
        ENDIF
C
        HFLV=1071.3-0.64*(TEMP-40.0)
C
        SPC75=0.4844+0.000306*(TEMP-59.0)
        SPC85=0.4380+0.000267*(TEMP-59.0)
        SPEC=SPC75+(SPC85-SPC75)*(CONC-0.75)/0.10
C
        SPL75=0.01019+2.83*(TEMP-77.0)/(10.0**6.0)
        SPL85=0.00951+2.53*(TEMP-77.0)/(10.0**6.0)
        SPLQ=SPL75+(SPL85-SPL75)*(CONC-0.75)/0.10
C
        MLWSBS=142.0
        ZSBS=0.7
        GAMSBS=1.2
        TLMTMX=450.0
        CNCMIN=0.750
        CNCMAX=0.850
        GO TO 999
C.....................PROPERTIES OF SUPERPHOSPHORIC ACID..........
105     CONTINUE
C
        PSBS=0.0
        PSLV=0.0
        HFLV=1000.0
```

```
          SPEC=0.352+0.000197*TEMP
          SPLQ=0.00811*(1.0+0.000300*TEMP)
          MLWSBS=142.0
          TLMTMN=0.0
          TLMTMX=350.0
          CNCMIN=0.755
          CNCMAX=0.765
          ZSBS=0.7
          GAMSBS=1.2
          VVAP=20000.0
          GO TO 999
C.....................PROPERTIES OF POTASSIUM HYDROXIDE.............
106       CONTINUE
          PSBS=0.0
          EXPN=-1.0706+0.015264*(TEMP-68.0)-0.0000217*((TEMP-68.0)**2.0)
          PH2O44=10.0**EXPN
          EXPN=-1.3010+0.015405*(TEMP-68.0)-0.0000191*((TEMP-68.0)**2.0)
          PH2O50=10.0**EXPN
C
          PSLV=PH2O50+(PH2O50-PH2O44)*(CONC-0.50)/0.0556
C
          IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
            VVAP=25000.0
          ELSE
            VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8))
          ENDIF
C
          SPLQ50=0.01602*(0.6528+0.000132*TEMP)
          SPLQ44=0.01602*(0.6812+0.000150*TEMP)
          SPLQ=SPLQ50+(SPLQ50-SPLQ44)*(CONC-0.50)/0.0556
C
          SPEC50=0.6374
          SPEC44=0.6710
          SPEC=SPEC50+(SPEC50-SPEC44)*(CONC-0.50)/0.0556
C
          HFLV50=1066.0+.4694*TEMP
          HFLV44=1129.0-0.2389*TEMP
          HFLV=HFLV50+(HFLV50-HFLV44)*(CONC-0.50)/0.0556
          MLWSBS=56.11
          GAMSBS=1.2
          ZSBS=0.7
          TLMTMX=350.0
          CNCMIN=0.440
          CNCMAX=0.500
          GO TO 999
C
C.................PROPERTIES OF HYDROGEN PEROXIDE SOLUTIONS............
107       CONTINUE
C
          SPEC=0.757-0.065*(CONC-0.6)/0.2
          DENS=64.295+22.5*CONC-0.0134*TEMP+6.35*CONC*CONC-0.031*CONC*TEMP
          SPLQ=1.0/DENS
          HFLV=(828.0-83.0*(CONC-0.6)/0.2)*(1.0-0.0006*(TEMP-77.0))
C
          IF (TEMP.LT.158.0) THEN
            ATEMP=TEMP-68.0
            PH2O5=0.12+0.00544*ATEMP+1.50*(ATEMP**3.0)/(10.0**6.0)
            PH2O6=0.09+0.00262*ATEMP+1.52*(ATEMP**3.0)/(10.0**6.0)
            PH2O7=0.05+0.00269*ATEMP+0.73*(ATEMP**3.0)/(10.0**6.0)
            PH2O25=0.01+0.000650*ATEMP+0.22*(ATEMP**3.0)/(10.0**6.0)
```

```
          PH2O26=0.01+0.000792*ATEMP+0.30*(ATEMP**3.0)/(10.0**6.0)
          PH2O27=0.02+0.000646*ATEMP+0.41*(ATEMP**3.0)/(10.0**6.0)
          PH2O21=0.03+0.001213*ATEMP+0.60*(ATEMP**3.0)/(10.0**6.0)
        ENDIF
C
        IF (TEMP.GE.158.0.AND.TEMP.LT.230.0) THEN
          ATEMP=TEMP-158.0
          PH2O5=1.70+0.0333*ATEMP+0.000787*ATEMP*ATEMP
          PH2O6=1.23+0.0236*ATEMP+0.000586*ATEMP*ATEMP
          PH2O7=0.82+0.0156*ATEMP+0.000409*ATEMP*ATEMP
          PH2O25=0.23+0.00444*ATEMP+0.000177*ATEMP*ATEMP
          PH2O26=0.30+0.00611*ATEMP+0.000224*ATEMP*ATEMP
          PH2O27=0.38+0.00667*ATEMP+0.000285*ATEMP*ATEMP
          PH2O21=0.58+0.01080*ATEMP+0.000417*ATEMP*ATEMP
        ENDIF
C
        IF (TEMP.GE.230.0) THEN
          ATEMP=TEMP-230.0
          PH2O5=8.18+0.1396*ATEMP+0.001902*ATEMP*ATEMP
          PH2O6=5.97+0.1036*ATEMP+0.001420*ATEMP*ATEMP
          PH2O7=4.06+0.0711*ATEMP+0.000995*ATEMP*ATEMP
          PH2O25=1.47+0.0275*ATEMP+0.000540*ATEMP*ATEMP
          PH2O26=1.90+0.0353*ATEMP+0.000687*ATEMP*ATEMP
          PH2O27=2.34+0.0429*ATEMP+0.000837*ATEMP*ATEMP
          PH2O21=3.52+0.0661*ATEMP+0.001219*ATEMP*ATEMP
        ENDIF
C
        IF (CONC.GE.(0.815)) THEN
          PSBS=PH2O27+(PH2O21-PH2O27)*(CONC-0.815)/(0.185)
          PSLV=PH2O7+(0.0-PH2O7)*(CONC-0.815)/(0.185)
        ENDIF
        IF (CONC.GE.(0.739).AND.CONC.LT.(0.815)) THEN
          PSBS=PH2O26+(PH2O27-PH2O26)*(CONC-0.739)/(0.076)
          PSLV=PH2O6+(PH2O7-PH2O6)*(CONC-0.739)/(0.076)
        ENDIF
        IF (CONC.LT.(0.739)) THEN
          PSBS=PH2O25+(PH2O26-PH2O25)*(CONC-0.6537)/(0.0853)
          PSLV=PH2O5+(PH2O6-PH2O5)*(CONC-0.6537)/(0.0853)
        ENDIF
        IF (PSBS.LT.0.0)PSBS=0.0
        IF (PSLV.LT.0.0)PSLV=0.0
C
        IF (PSLV.LT.(0.01).AND.PSBS.LT.(0.01)) THEN
          VVAP=20000.0
        ELSE
          VVAP=0.95*(TEMP+459.0)/(144.0*(PSLV/85.8+PSBS/40.7))
        ENDIF
        GAMSBS=1.3
        MLWSBS=38.0
        ZSBS=0.95
        TLMTMX=250.0
        CNCMIN=0.654
        CNCMAX=0.815
C
        GO TO 999
C*********************************************************************
999     RETURN
        END
→
```

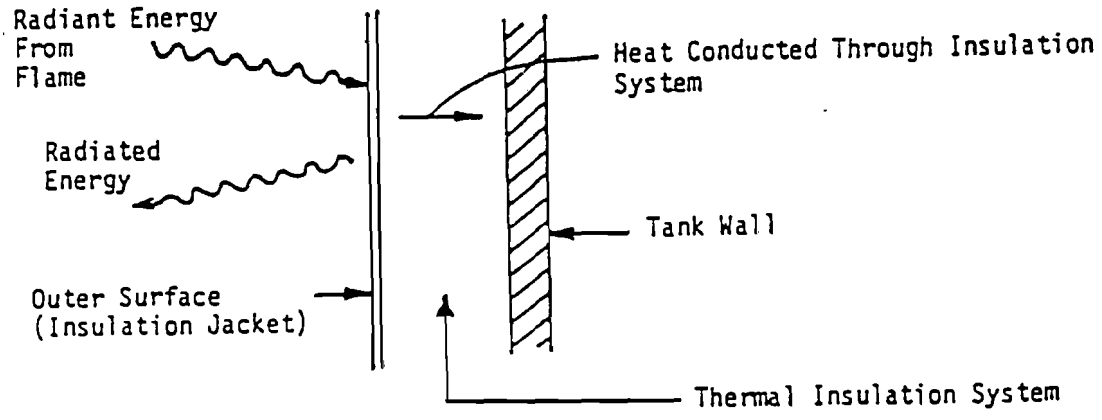
APPENDIX J

SUBROUTINE SURFACET

Subroutine SURFACET.FOR is used to calculate the surface temperature of the outside of the insulated tank which is engulfed in the fire. It is assumed that the dominant mechanism for the transfer of heat to the outer surface is by radiation from the flame. It is also assumed that a quasi-steady state condition exists for the transfer of heat from the outer surface of the insulation system to the steel wall of the tank. The subroutine uses an iterative solution of the equation defining a heat balance at the outer surface to determine the temperature of the surface.

There are two parts to the subroutine. The first set of calculations deals with the case where there is functioning insulation between the outer surface (or jacket) and the tank wall. This calculational procedure is used for the bare, uninsulated tank case by considering the conductivity of the tank wall itself as providing the thermal resistance. The second set of calculations deals with the case where there is a jacket, but where the insulation between the jacket and tank wall has lost its effectiveness because it is not capable of functioning at high temperature. In this case the jacket acts as a thermal radiation barrier and heat is transferred from the jacket to the tank wall by radiation.

The heat balance for the first set of calculations is illustrated as follows:

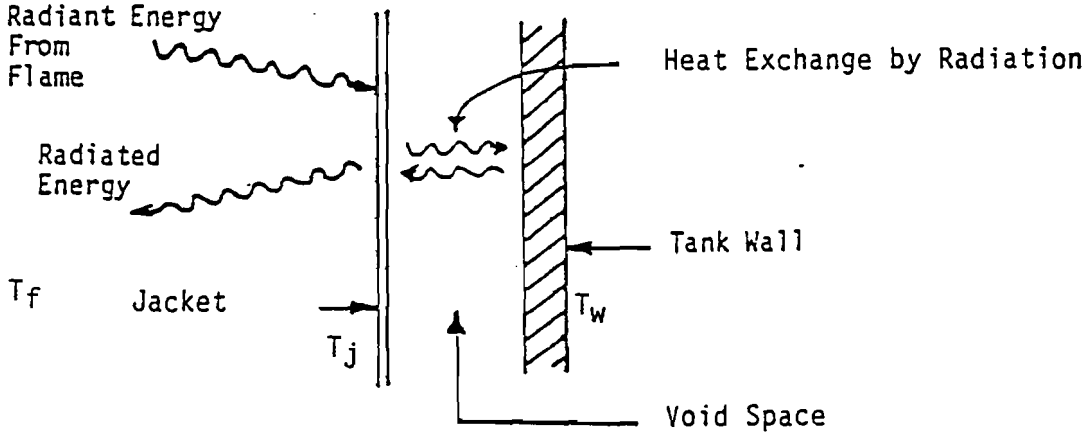


The following equation represents a heat balance at the outer surface of the insulation system.

$$0.48 [T_f^4 \varepsilon_r - T_s^4 \varepsilon_r] = [T_s - T_t] C_d / 3.6 \qquad (18)$$

where: T_f is flame temperature (°R/1000),
T_s is surface temperature (°R/1000),
T_t is tank wall temperature (°R/1000),
C is conductance of thermal shield (BTU/hr-ft^2°F), and
ε_r is the emmissivity/absorptivity of the outer surface.

The heat balance for the second set of calculations illustrated as follows:



The following equation represents a heat balance at the jacket:

$$0.48 [T_f^4 \varepsilon_r] - 0.48 [T_j^4 \varepsilon_r] = [\varepsilon_r / (2 - \varepsilon_r)] (0.48) (T_j^4 - T_w^4) \qquad (19)$$

where: T_j is the jacket temperature (°R/1000),
and other variables have the same definition as in Equation 18.

The subroutine calculates an effective value for the conductance of heat flow into the tank, which is returned to the main program for heat flow calculations.

When calculating the heat flow to the tank, it is assumed that the effective conductance changes from an initial value at the beginning of the fire exposure to a final value which only considers the thermal resistance of the jacket. The transition takes place over a time period which is an input variable to the main program. This accounts for the deterioration of a non high-temperature insulation. The final value of conductance includes an allowance for the residue of the charred insulation which is assumed to have a conductance of 40 BTU/hr- ft^2-°F).

The source code for this subroutine is presented on the following page.

The principal parameters used in the subroutine are defined as follows:

TFLA is flame temperature (°R/1000),

TCAL is surface temperature (°R/1000),

TINS is tank wall temperature (°R/1000),

COND is conductance of thermal shield (BTU/hr- ft^2-°F), and

ERAD is the emmissivity/absorptivity of outer surface.

```
      SUBROUTINE SURFACET(TSURF,TINSD,ERAD,
     1          COND,TFLA,INS,TIME,CINTV,FLFAC)
C
C     Determine the temperature of the outer surface of the
C        wall of the tank, TSURF, by an iterative
C        solution of the equation formed by taking a heat balance
C        at this point. Note, TINSD is inside wall temperature
C        at this location. TSURF is the outside surface
C        temperature which is calculated by the routine.
C.................................Version 3.1, November 11, 1998
C
      REAL TSURF,TINSD,ERAD,COND,TFLA,TIME,CINTV,FLFAC
      INTEGER*2 INS
C
      IF (INS.NE.3.OR.INS.NE.6) TFLA1=TFLA
C
C...........Jacket with only annular air space.....................
C             (original insulation destroyed by high temperrature)
      IF (INS.EQ.3.OR.INS.EQ.6) TFLA1=(((2.0-ERAD)*FLFAC
     1    *(TFLA**4)+(TINSD**4))/(3.0-ERAD))**0.25
C
C...........Iteration to Find Surface Temperature.................
50    CONTINUE
      TTEST=0.400
      IF (INS.NE.3.OR.INS.NE.6)
     1    REFT=FLFAC*(TFLA1**4)*0.48*ERAD+TINSD*COND/3.6
      IF (INS.EQ.3.OR.INS.EQ.6)
     1    REFT=(TFLA1**4)*0.48*ERAD/(2.0-ERAD)+TINSD*COND/3.6
      AFWD=0.100
35    TTEST=TTEST+AFWD
      IF (INS.NE.3.OR.INS.NE.6)
     1    GNCT=(TTEST**4)*0.48*ERAD+TTEST*COND/3.6
      IF (INS.EQ.3.OR.INS.EQ.6)
     1    GNCT=(TTEST**4)*0.48*ERAD/(2.0-ERAD)+TTEST*COND/3.6
      IF(ABS(REFT-GNCT).LT.0.0001)GO TO 39
      IF (GNCT.GT.REFT) THEN
        TTEST=TTEST-AFWD
        AFWD=AFWD/10.0
      ENDIF
      GO TO 35
39    CONTINUE
      TSURF=TTEST
C
100   CONTINUE
      RETURN
      END
```

APPENDIX K

SUBROUTINE AVFLOW

Subroutine AVFLOW.FOR is used to calculate the liquid flow through a safety relief valve. The liquid flow through the valve is calculated assuming homogenous isentropic two-phase flow (liquid and vapor). The calculation starts with the fluid conditions at the entry to the valve and integrates the conditions as the pressure and temperature drop when the fluid moves through the valve. The following equation is used:

$$V_1^2 - V_0^2 = 2g\int_0^1 dp/\rho \qquad (20)$$

where: V_1 is the flow velocity (ft/sec),
V_0 is the entry flow velocity at the valve (ft/sec),
p is pressure (lbs/ft^2),
ρ is fluid density (lbs/ft^2), and
g is the gravitational constant (ft/sec^2).

The integration is carried out along an isentropic path where an integration step equivalent to a ½ °F drop in temperature of the fluid is used. After each integration step the cross sectional area required to pass a unit mass flow rate is determined. When this area reaches a minimum value in the integration process it is assumed that the critical valve cross section has been reached. This area is related to the cross sectional area of the valve or vent to determine the mass flow rate.

The entropies of products in the liquid and vapor states are calculated by assuming that the entropy of the liquid under the initial saturated condition had a value of 1.0 and that the entropies at other conditions can be estimated from the following relationships:

$$SL_{t2} = SL_{t1} - CP\ (T_2 - T_1) / (T_2 + T_1) \quad (21)$$

$$SV_{t2} = SL_{t2} + 2\ (HFLV_{t2}) / (T_2 + T_1) \quad (22)$$

where: SL_{t2} is the entropy of the liquid at temperature 2 (BTU/lb-°R),
SL_{t1} is the entropy of the liquid at temperature 1 (BTU/lb-°R),
C_p is the average specific heat between temperatures T_1 and T_2 (BTU/lb-°R),
SV_{t2} is the entropy of the vapor at temperature 2,
HFLV is the heat of vaporization at temperature 2, and
T_1 and T_2 are temperatures (°R).

Where there is no padding gas present, the velocity, V_0, at the entry to the valve would be assumed to be zero. However, when there is padding gas pressure component, the saturated condition of the liquid flow through the valve will be reached after the fluid has been given some velocity. Under these conditions V_0, in Equation 12 will have a finite value which is estimated from the following formula:

$$V_0 = \sqrt{2gp/\rho} \quad (23)$$

where: ρ is the density of the liquid product (lbs/ft^3),
p is the padding gas pressure (lbs/ft^2), and
g is the gravitational constant (ft/sec^2).

A listing of the subroutine is presented on the following pages.

```
C.........THIS SUBROUTINE IS USED FOR THE ANALYSIS OF TWO-PHASE
C.........FLOW THROUGH A TANK CAR SAFETY VALVE OR VENT.............
      SUBROUTINE AVFLOW(TTNK,WOUT,ATEM,DELT,CDLQ,PNIT,
     1       CONC,IPR,IPFST,ISBSL,IPTYP,TIME)
C.....................................Version 3.0, October 20, 1997
C       This subroutine is used to calculate the liquid mass flow
C          rate through a safety relief valve. Homogeneous isentropic
C          flow is assumed. The presense of a nitrogen pad pressure
C          is also taken into account.
C
        REAL WOUT,TTNK,ATEM,DELT,CDLQ,PNIT,CONC,TIME
        INTEGER*2 IPR,ISBSL,IPTYP,IPFST
        COMMON/PROP1/SPEC,SPLQ,HFLV,PSBS,PSLV,ZSBS,ZSLV,VVAP
C
        DEGF=1000.0*TTNK-460.0
        TBEG=DEGF
        KCNT=0
C
        GO TO 896          ! get initial value of entropy
C
C       Start with initial conditions; drop temperature by 1/2 degree
C          and calculate the cross sectional valve area for a one
C          lb per sec mass flow rate.
C
898     KCNT=1
        SSTND=SLIQ
        VLONE=0.0
        ARONE=1000.0
        HTEST=0.0
C
        PTEST=PSBS+PSLV
        PTOT=PSBS+PSLV+PNIT
        IF (PTOT.LE.(14.7)) THEN
          WOUT=0.0
          GO TO 823
        ENDIF
        IF (PTEST.LE.(14.7)) THEN
          PDRV=PTOT-14.7
        ELSE
          PDRV=PNIT
        ENDIF
C
        IF (PDRV.LT.(0.001)) THEN
          VLONE=0.0
        ELSE
          VLONE=96.24*SQRT(SPLQ*PDRV)
          ARONE=SPLQ/VLONE
        ENDIF
C
        ATEST=ARONE
895     CONTINUE
        DEGF=DEGF-0.5
C
896     CONTINUE
C
        IF (IPTYP.EQ.1) THEN
          IF (IPR.GE.1.AND.IPR.LE.9) CALL FPRPSBS (IPR,DEGF)
          IF (IPR.GE.10.AND.IPR.LE.16) CALL FPRPSLV (IPR,CONC,DEGF)
        ENDIF
        IF (IPTYP.EQ.2.OR.IPTYP.EQ.3) THEN
```

```
          IF (ISBSL.EQ.1) CALL SBSPROP (IPFST,IPR,DEGF)
          IF (ISBSL.EQ.2) CALL SLNPROP (IPFST,IPR,CONC,DEGF)
        ENDIF
C
C.................Entropies of commodities.........................
        IF (KCNT.EQ.0) THEN
          SLIQ=1.000
          DGLST=TBEG
          GO TO 898
        ENDIF
C
        SLIQ=SLIQ+SPEC*(DEGF-DGLST)/((DGLST+DEGF)*0.5+459.6)
        SVAP=SLIQ+HFLV/(DEGF+459.6)
        DGLST=DEGF
C.....................................................................
        PREF=PSBS+PSLV
        IF (PREF.LE.(14.7)) GO TO 821
C
        X=(SSTND-SVAP)/(SLIQ-SVAP)
        VLTST=X*SPLQ+(1.0-X)*VVAP
        HTEST=HTEST+(PTEST-PREF)*144.0*VLTST*64.4
C
        VELOCB=SQRT(VLONE**2+HTEST)
        ARTWO=VLTST/VELOCB
        PTEST=PREF
C
        IF(ARTWO.LT.ATEST) THEN
          ATEST=ARTWO
          GO TO 895
        ENDIF
C
C       Repeat calculations until area becomes minimum; then calculate
C          mass flow rate.
C
821     CONTINUE
        WOUT=60.0*DELT*CDLQ*ATEM/ATEST
823     CONTINUE
C
        RETURN
        END
```

APPENDIX L

SUBROUTINE TSHIELD

Subroutine TSHIELD.FOR is used to determine the effective conductance of a thermal shield system which is constructed of a material with a conductivity which is a function of temperature. The subroutine assumes the following functional dependence of conductivity with temperature.

$$K = A_1 + A_2T + A_3T^2 \qquad (24)$$

where: A_1, A_2 and A_3 are constants,
K is conductivity (BTU/hr-ft^2)/(°F/ft), and
T is temperature (°F/1000).

The subroutine requires as input the thickness of the insulation under consideration (THIC), in inches, the outer and inner temperature of the insulation system (TOTSD and TINSD, respectively) and the value of the effective conductance that was calculated at the last time step (CNDCT). The output from the subroutine is a calculated value of effective conductance of the thermal shield system which reflects the current temperature distribution through the insulation material.

The subroutine divides the insulation into 50 layers. It then starts at the inside of the shell and using the last value of CNDCT and the heat flux that this implies, it goes through the insulation layer by layer to calculate the outside temperature of the insulation system. If the calculated temperature is not sufficiently close to TOTSD a new value for the heat flux is assumed and the calculation is repeated. When a sufficiently close value to TOTSD is achieved, it is assumed that the proper heat flux has been established through the insulation material and a new value of the effective conductance (CNDCT) is calculated using the temperature difference across the insulation system.

The principal parameters used in the subroutine are listed as follows:

TOTSD	Temperature of outside of insulation system (°R/1000),
CNDCT	Effective conductance of insulation system (BTU/hr-ft^2),
THIC	Thickness of insulation system (ins.),
CKND	Conductivity of thermal insulation material (BTU/hr-ft^2)/(°F/ft), and
QFLX	Heat flux through insulation system (BTU/hr-ft^2).

A listing of the subroutine is presented on the following pages.

```
      SUBROUTINE TSHIELD(TOTSD,TINSD,CNDCT,THIC,A1,A2,A3,CDAUX)
C
C     This subroutine calculates the effective conductance of a
C        given thickness of insulation where the conductivity of
C        the material is a quadratic function of temperature and the
C        inner and outer temperatures of the insulation are known.
C     Start with estimate of heat flux from last time step.
C.....................................Version 3.0, October 20, 1997
C
      REAL TOTSD,TINSD,CNDCT,THIC,A1,A2,A3,CDAUX
C
      QFLX=CNDCT*(TOTSD-TINSD)*1000.0
      KQT=0                    ! check for first pass through calculation
      TFINSD=TINSD*1000.0-460.0       ! convert to deg F
      TFOTSD=TOTSD*1000.0-460.0       ! convert to deg F
      TFLAST=TFOTSD
      DELX=THIC/(12.0*50.0)           ! Divide insulation into 50
C                                     ! layers and convert to feet.
C.....With the assumed heat flux, start with inside wall temperature
C       and determine temperature of outside wall.
100   CONTINUE
      TFTEMP=TFINSD+QFLX/CDAUX
      DO I=1,50
        TTEMP=TFTEMP/1000.0
        CKND=A1+A2*TTEMP+A3*TTEMP*TTEMP
        TFTEMP=TFTEMP+QFLX*DELX/CKND
      ENDDO
C
C.....Compare TFTEMP with TFOTSD, if too far off modify heat flux
C     and recalculate.
C
      IF(ABS(TFTEMP-TFOTSD).LT.(0.1))GO TO 103
C
C.....Calculate new QFLX on first pass through calculation.....
C
      IF (KQT.EQ.0) THEN
        QDELT=ABS(QFLX*(TFTEMP-TFOTSD)/TFTEMP)
        IF(TFTEMP.GT.TFOTSD)QFLX=QFLX-QDELT
        IF(TFTEMP.LT.TFOTSD)QFLX=QFLX+QDELT
        TFLAST=TFTEMP
        KQT=1
        GO TO 100
      ENDIF
C
C..........Calculate new QFLX on subsequent passes through calculation.
C
      IF(TFLAST.LT.TFOTSD.AND.TFTEMP.GT.TFOTSD)QDELT=QDELT/3.0
      IF(TFLAST.GT.TFOTSD.AND.TFTEMP.LT.TFOTSD)QDELT=QDELT/3.0
      IF(TFTEMP.GT.TFOTSD)QFLX=QFLX-QDELT
```

```
        IF(TFTEMP.LT.TFOTSD)QFLX=QFLX+QDELT
        TFLAST=TFTEMP
        GO TO 100
C
C.........Last step; new calculate effective conductance.
C
103     CONTINUE
        CNDCT=QFLX/((TOTSD-TINSD)*1000.0)
        RETURN
        END
→
```