



A METALLURGIST LOOKS AT REVERSE ENGINEERING

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REVERSE ENGINEERING A UNIVERSAL CONCEPT



- **CORPORATIONS OFTEN BENCHMARK OWN PRODUCTS VS THOSE OF COMPETITION**
 - **TEAR DOWN COMPETITOR'S PRODUCT**
 - **USE INFORMATION TO OWN ENDS**
- **SOUNDS LIKE REVERSE ENGINEERING?- IT IS**
- **FAA APPLICANTS PRODUCE REPLACEMENTS TO TYPE-CERTIFICATED PARTS, USING REVERSE ENGINEERING**
- **APPLICANTS STRIVE TO DEMONSTRATE SIMILARITY / IDENTICALITY TO CERTIFICATED PARTS**
 - **REDUCE TEST, COMPUTATION & ANALYSIS**
 - **COST SAVINGS TO APPLICANT**

ISSUE



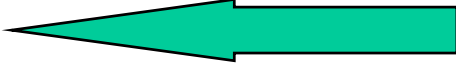
- **PART MANUFACTURER APPROVAL PROCEDURES, ORDER 8110.42 Rev. A (31 MARCH 1999) STATES:**

“ WHILE APPLICANT COULD ESTABLISH THE USE OF IDENTICAL MATERIALS AND DIMENSIONS, IT IS UNLIKELY THAT A SHOWING COULD BE MADE THAT TOLERANCES, PROCESSES AND MANUFACTURING SPECIFICATIONS WERE IDENTICAL ”

- **PURPOSE OF BRIEFING: CHECK VALIDITY OF STATEMENT**

AGENDA



- **ANATOMY OF TYPE DESIGN** 
- **THE AFTER-MARKET APPLICANT**
- **CHEMICAL ANALYSES**
- **MECHANICAL TESTING**
- **APPLICANT SCORE SHEET**
- **CONCLUSIONS**

ANATOMY OF TYPE DESIGN



- **FORM, FIT & FUNCTION**
- **MATERIALS & PROCESSES**
- **SUPPLIER INFORMATION**
- **OEM MATERIAL & PROCESS SELECTION CRITERIA**

FORM, FIT & FUNCTION



FORM & FIT

- **DEPICTED ON DRAWING (DIMENSIONS, TOLERANCES, ETC.)**

FUNCTION

- **FUNCTIONAL / PERFORMANCE REQUIREMENTS**
 - **MECHANICAL, PHYSICAL, ENVIRONMENTAL**
- **SPECIFIED ON DRAWING OR REFERENCED SPECS**
- **SOMETIMES**
 - **SPECIFIED ON HIGHER ASSEMBLY OR NOT SPECIFIED ANYWHERE (CORPORATE MEMORY)**

MATERIALS



CALLED OUT IN MATERIAL BLOCK AND / OR GENERAL NOTES OF DRAWING

- **MATERIAL TYPE AND FORM (AISI 4130 PLATE; ETC.)**
- **STOCK CONDITION (ANNEALED; ROLLED; ETC.)**
- **STOCK SIZE**
- **MATERIAL SPECIFICATION**
 - **COMPOSITION LIMITS, MELTING PRACTICE, INSPECTION & TEST REQUIREMENTS, ETC.**
- **MATERIAL SUBSTITUTION INFORMATION**

PROCESSES



CALLED OUT IN GENERAL NOTES SECTION

- **FABRICATION OPERATIONS**: HEAT TREAT, WELDING, BRAZING, FORGING, ETC.
- **SURFACE TREATMENTS**: COATINGS, SHOT PEENING, ETC.
- **AUXILIARY PROCESSES**: STRESS RELIEF, ANNEAL, ETC.
- **INSPECTION**: PENETRANT, MAGNETIC PARTICLE, ETC.
- **PROCESS SEQUENCE**: HEAT TREAT AFTER WELDING; INSPECT AFTER WELDING AND AFTER HEAT TREAT; ETC.
- **TOOLING**: FIXTURES, TEMPLATES, ETC.

SUPPLIER INFORMATION



PREFERRED SUPPLIERS MAY BE CALLED OUT ON DRAWING OR SPECIFICATIONS

- **SPECIALIZED PROCESSING**
 - **CASTING, BRAZING, PLATING ON ALUMINUM OR TITANIUM, STRAIGHTENING, ETC.**
- **INTRICATE / SPECIALIZED COMPONENTS**
 - **BALL BEARINGS, GEARS, ETC.**
- **DIFFICULT TO PROCURE MATERIALS**
 - **VACUUM MELTED 4340 OR 440, 17-4 PH SHEET OR PLATE, ETC.**

OEM MATERIAL & PROCESS SELECTION CRITERIA

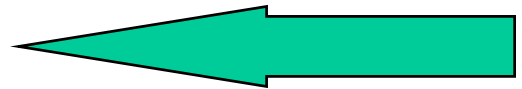


- **DESIGN REQUIREMENTS**
 - MECHANICAL, PHYSICAL, ENVIRONMENTAL
- **FABRICATION CONSIDERATIONS**
 - FORMING, DEPTH OF HARDENING, WELDING, ETC.
- **THE ECONOMY FACTOR**
 - COST & AVAILABILITY OF MATERIALS & PROCESSES
- **MATERIAL COST VS PROCESSING ECONOMY**
- **COST = MATERIAL + FABRICATION + INSPECTION + FINISHING + REWORK**

AGENDA



- ANATOMY OF TYPE DESIGN
- THE AFTER-MARKET APPLICANT
- CHEMICAL ANALYSES
- MECHANICAL TESTING
- APPLICANT SCORE SHEET
- CONCLUSIONS



THE AFTER - MARKET APPLICANT



- **TYPE DESIGN DATA NOT AVAILABLE TO APPLICANT**
 - **MUST RELY ON REVERSE ENGINEERING**
 - ☹ **USING OEM PARTS ON THE MARKET**
- **CONFIGURATION**
 - **BY MEASURING PART DIMENSIONS**
- **MATERIAL & PROCESS REQUIREMENTS**
 - **ALLOY TYPE: BY CHEMICAL ANALYSES**
 - **HEAT TREAT: BY MECHANICAL TESTING**

***APPLICANT FEELS DESIGN REQUIREMENTS
SUFFICIENTLY IDENTIFIED***

AGENDA



- ANATOMY OF TYPE DESIGN
- THE AFTER-MARKET APPLICANT
- CHEMICAL ANALYSES
 - CHEMICAL ANALYSIS METHODS
 - WHAT APPLICANT SHOULD DO
- MECHANICAL TESTING
- APPLICANT SCORE SHEET
- CONCLUSIONS



CHEMICAL ANALYSES METHODS



- **CLASSICAL WET ANALYTICAL CHEMISTRY (DIRECT)**
 - ACCURATE, TIME CONSUMING & EXPENSIVE
- **INSTRUMENTAL METHODS (INDIRECT)**
 - ONLY COMPARATIVE- NOT ABSOLUTE
 - ☹️ **MUST HAVE ADEQUATE STANDARDS**
 - FAST & FAIRLY INEXPENSIVE
- **ARC / SPARK OES (OPTICAL EMISSION SPECTROSCOPY)**
 - MOST ACCEPTED METHOD
- **EDS (ENERGY DISPERSIVE X-RAY SPECTROMETRY)**
 - FREQUENTLY USED BY APPLICANTS

OES CONSIDERATIONS / LIMITATIONS



- **EXIT SLITS SET BY MANUFACTURER**
 - **SUITABLE FOR ONLY SOME ALLOY GROUPS**
- **RESULTS CAN VARY FROM LAB TO LAB**
 - **SPECTROMETER, STANDARDS & LINES USED**
 - **MONOCHROMATOR FOR A TRUE UNKNOWN**
- **NOT FOR ALL ELEMENTS**
 - **OLDER AIR-PASS SPECTROMETERS- NO C, S OR P**
 - **OES NOT YET ACCEPTED FOR H, O OR N**

EDS LIMITATIONS



- **ONLY SMALL VOLUME ANALYZED**
 - NOT REPRESENTATIVE OF BULK CHEMISTRY
- **MANY SYSTEMS CANNOT DETECT O, C, N, Be, Li, B**
- **SOME ENERGY PEAKS COINCIDE**
 - DIFFICULT TO IDENTIFY GENERATING ELEMENT
- **QUANTITATIVE ANALYSES REQUIRE STANDARDS**
 - EVEN WITH STANDARDS
 - ☹ **METHOD NOT ACCEPTED AS OES**
 - ☹ **SUPPLEMENT BY OTHER METHODS**

CHEMICAL ANALYSIS

WHAT APPLICANT SHOULD DO



SHOULD "INTERROGATE" LAB

- **METHOD USED & ITS SUITABILITY FOR ELEMENTS PRESENT; CONCENTRATIONS IN STANDARDS ; SUPPLEMENTAL METHODS USED; ETC.**
- **IF EDS WAS USED, REQUEST ANOTHER METHOD**

SHOULD CONSULT

- **WITH A CHEMIST**
 - **SUITABILITY & ACCURACY OF METHOD(S) USED**
- **WITH MILLS, CONSULTANTS, CSTA-METALLURGY**
 - **SELECTIONS IN SIMILAR APPLICATIONS IN INDUSTRY**

CHEMICAL ANALYSIS

WHAT APPLICANT SHOULD DO



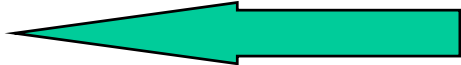
SHOULD VALIDATE RESULTS IF IN DOUBT

- **GET SAMPLE OF ALLOY PROPOSED BY LAB**
- **SUBMIT SAMPLE + OEM MATERIAL TO DIFFERENT LAB**
 - **FOR COMPARISON**
- **REMEMBER**
 - **MANY ALLOYS CLOSE IN CHEMISTRY**
 - ☺ **SUPERALLOYS; CRES STEELS; 4340 & 300M;**
OTHERS
 - **BUT NOT IN PERFORMANCE**

INCORRECT ANALYSIS ⇒ PROBLEMS LATER ON

AGENDA



- **ANATOMY OF TYPE DESIGN**
- **THE AFTER-MARKET APPLICANT**
- **CHEMICAL ANALYSES**
- **MECHANICAL TESTING** 
 - **HARDNESS**
 - **HARDNESS & CONDUCTIVITY**
 - **TENSILE**
 - **ISSUES IN MECHANICAL TESTING**
- **APPLICANT SCORE SHEET**
- **CONCLUSIONS**

MECHANICAL TESTING



- **PERFORMED TO**
 - **DETERMINE ALLOY HEAT TREAT / TEMPER**
- **TWO APPROACHES EXIST**
 - **INDIRECT METHODS**
 - ☹ **HARDNESS**
 - ☹ **HARDNESS AND CONDUCTIVITY**
 - **THE DIRECT METHOD**
 - ☹ **TENSILE TESTING**
- **APPLICANTS PREFER INDIRECT METHODS**
 - **NONDESTRUCTIVE**
 - **LESS EXPENSIVE**

INDIRECT METHODS HARDNESS TESTING



- **HARDNESS SENSITIVE MEASURE OF HEAT TREATMENT**
 - FOR MANY STEELS (41XX, 43XX, 300M, 440, ETC.)
- **HARDNESS-STRENGTH RELATIONSHIPS EXIST**
 - CONSISTENT & REPRODUCIBLE (ASTM A370)
- **TO DETERMINE STEEL HEAT TREATMENT**
 - MEASURE HARDNESS & CONVERT TO STRENGTH
 - FIND CORRESPONDING HEAT TREAT DETAILS
 - ☺ FROM AMS 2759, OTHER SPECS, DATA SHEETS, ETC.
- **OFTEN, NO NEED TO CONVERT TO STRENGTH**
 - HEAT TREAT RELATED DIRECTLY TO HARDNESS

HARDNESS TEST LIMITATIONS



- **HARDNESS GENERALLY NOT SENSITIVE MEASURE OF HEAT TREATMENT / TEMPER**
 - **FOR NONFERROUS ALLOYS**
 - **FOR AUSTENITIC & PH CRES STEELS**
 - **MARAGING STEELS**
- **NO HARDNESS-STRENGTH RELATIONSHIPS**
- **∴ HARDNESS CANNOT BE USED TO DETERMINE HEAT TREAT DETAILS**

INDIRECT METHODS ALUMINUM ALLOYS



- **VARIOUS (T) AND (O) TEMPERS IDENTIFIED BY**
 - **MEASURING HARDNESS & CONDUCTIVITY**
 - ☺ **AMS 2658**
- **TEMPER FOR PARTICULAR ALLOY IDENTIFIED WHEN**
 - **HARNESS WITHIN SPECIFIED RANGE**
 - AND**
 - **CONDUCTIVITY WITHIN SPECIFIED RANGE**
- **METHOD NOT APPLICABLE TO**
 - **STRAIN HARDENED (H) TEMPERS**
 - **CASTINGS**

THE DIRECT METHOD TENSILE TESTING



- **USUALLY PERFORMED PER ASTM E 8**
 - **ON SAMPLES MACHINED FROM PART**
- **PART SIZE IMPOSES LIMITS ON**
 - **SAMPLE LENGTH**
 - ☹ **AFFECTS GRIP & GAGE LENGTHS**
 - **GAGE LENGTH ↓: STRENGTH ↓ & DUCTILITY ↑**
 - **NUMBER OF SAMPLES & CONFIDENCE LEVEL**
- **∴ SMALL PARTS CAN RENDER TEST IMPOSSIBLE**
 - **RELY ON INDIRECT METHODS**
 - ☹ **SUBJECT TO THEIR LIMITATIONS**

ISSUES IN MECHANICAL TESTING DRAWING CALLOUTS



- **DRAWINGS CALL OUT STRENGTH / HARDNESS**
 - AS A RANGE (e.g., HRC 50-54)
 - AS A MINIMUM (e.g., HRC 50 MIN.)

- **APPLICANT HAS NO ACCESS TO OEM DRAWING**

***HOW DO APPLICANT'S
RESULTS RELATE TO DRAWING CALLOUT?***

ISSUES IN MECHANICAL TESTING NON-EQUIVALENT SPECIFICATIONS



- **INCONEL 718 SHEET: AMS 5596 AND AMS 5597**
 - DIFFERENT HEAT TREATMENTS
 - DIFFERENT CREEP PROPERTIES
 - NEARLY IDENTICAL TENSILE PROPERTIES
- **AISI 4340 BAR : Mil-S-5000 (AIR MELTED) AND Mil-S-8844 (VACUUM MELTED)**
 - IDENTICAL TENSILE PROPERTIES & HARDNESS
 - MIL-S-8844 HAS SUPERIOR TOUGHNESS AND LOW TEMPERATURE PROPERTIES

***TENSILE (OR HARDNESS) TESTING
MAY NOT REVEAL ALL PROPERTY ASPECTS***

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APPLICANT SCORE SHEET FORM, FIT & FUNCTION



- **FORM**
 - FROM OEM PART DIMENSIONS
- **FIT**
 - DIMENSIONS FROM SMALL NUMBER OF PARTS
 - OEM TOLERANCES NOT KNOWN

WILL ALL PARTS FIT & BE INTERCHANGEABLE?

- **FUNCTION**
 - OEM FUNCTIONAL TESTS NOT KNOWN

***DID APPLICANT PERFORM RELEVANT FUNCTIONAL TESTS?
IF NOT, WILL PART PERFORM INTENDED FUNCTION?***

APPLICANT SCORE SHEET MATERIALS & PROCESSES



- MATERIAL TYPE DETERMINED
 - BY CHEMICAL ANALYSIS
 - ☹ SUBJECT TO LIMITATIONS
- HEAT TREAT / TEMPER DETERMINED
 - BY MECHANICAL TESTING
 - ☹ SUBJECT TO LIMITATIONS
- MELTING PRACTICE; INSPECTION; AUXILIARY PROCESSES; MANUFACTURING SPECIFICATIONS; PROCESS SEQUENCE
 - NOT ADDRESSED

***∴ MATERIAL & PROCESS
CHARACTERIZATION INCOMPLETE***

APPLICANT SCORE SHEET

OTHER FACETS OF TYPE DESIGN



- **SUPPLIER INFORMATION**
 - NOT AVAILABLE
 - ☹️ **WHAT IF OEM USED A SPECIAL SUPPLIER, SAY IN SWEDEN**
- **OEM MATERIAL & PROCESS SELECTION CRITERIA**
 - NOT AVAILABLE
 - ☹️ **WHAT IF OEM MATERIAL IS NOT AVAILABLE TO APPLICANT**
 - **ON WHAT BASIS CAN APPLICANT SELECT AN ALTERNATE MATERIAL?**

CONCLUSIONS



- **COMMONLY USED REVERSE ENGINEERING PRACTICES**
 - **DO NOT REVEAL MANY TYPE DESIGN FACETS**
- **THE STATEMENT CONTAINED IN ORDER 8110.42 REV. A (31 MARCH 1999) IS VALID**

“WHILE APPLICANT COULD ESTABLISH THE USE OF IDENTICAL MATERIALS AND DIMENSIONS, IT IS UNLIKELY THAT A SHOWING COULD BE MADE THAT TOLERANCES, PROCESSES AND MANUFACTURING SPECIFICATIONS WERE IDENTICAL”