Applications of Local Post Weld Heat Treatment in Manufacturing Oil Field Equipment

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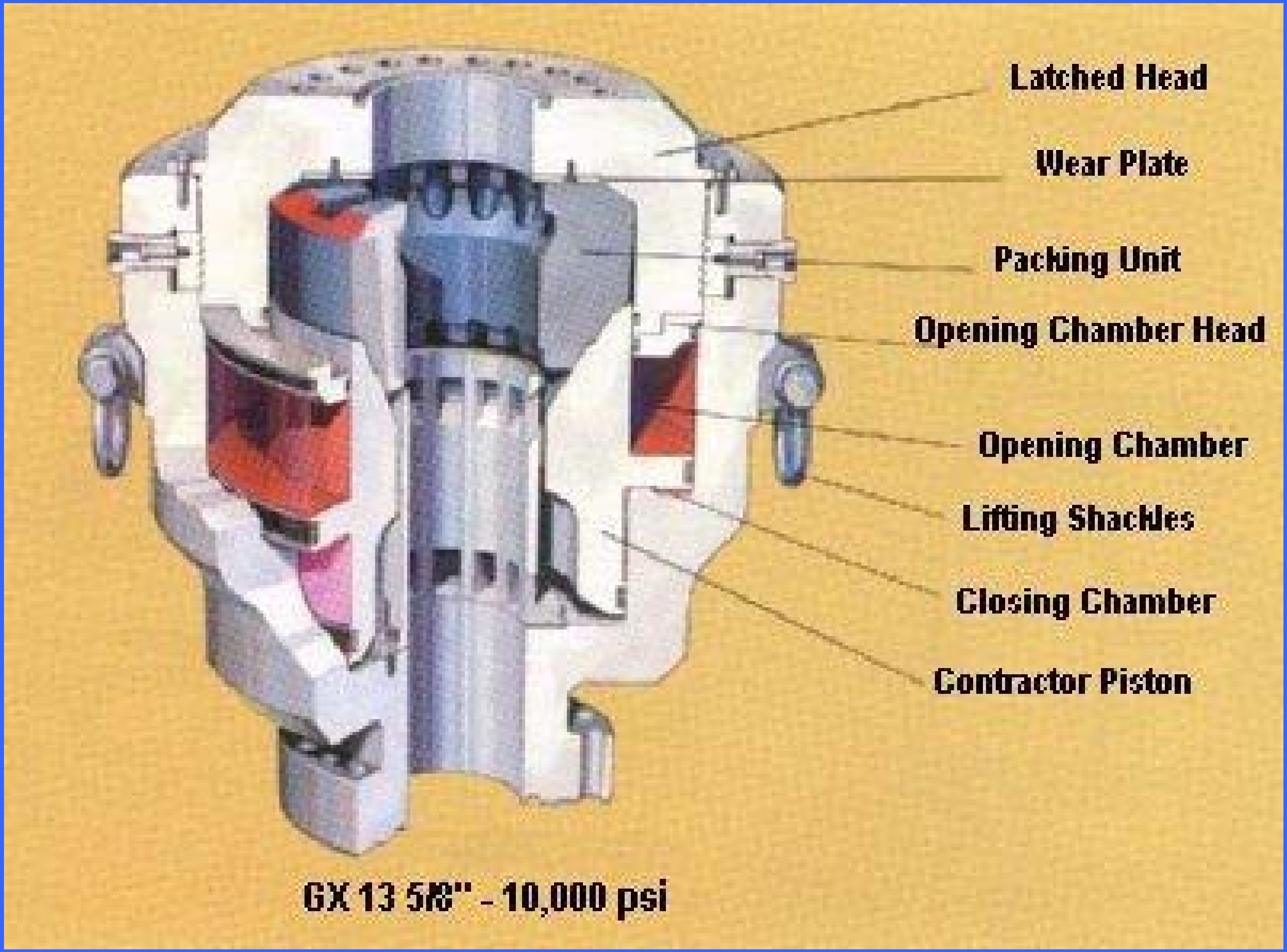
Typical Oil Patch Weldments Produced by Hydril

- Valves, & Blow out preventers manufactured in accordance with API 6A & API 16A
- Diverters manufactured in accordance with NACE MR0175
- Subsea Controls, Piping, Skids manufactured in accordance with API 16D
- ASME Pressure Vessels manufactured in accordance with ASME VIII

Hydril Choke Valve

Hydril Annular BOP



Hydril Double Ram BOP

Hydril Pulsation Dampeners

What is postweld heat treatment (PWHT)?

- heating a weldment to a specified temperature at a specified rate,
- holding the weldment at temperature for a specified period,
- cooling the weldment from holding or soak temperature at a specified rate
- See HEMPS 11.100, Sections 4.12, 5.5, 5.6, & 9.

What purpose does PWHT serve?

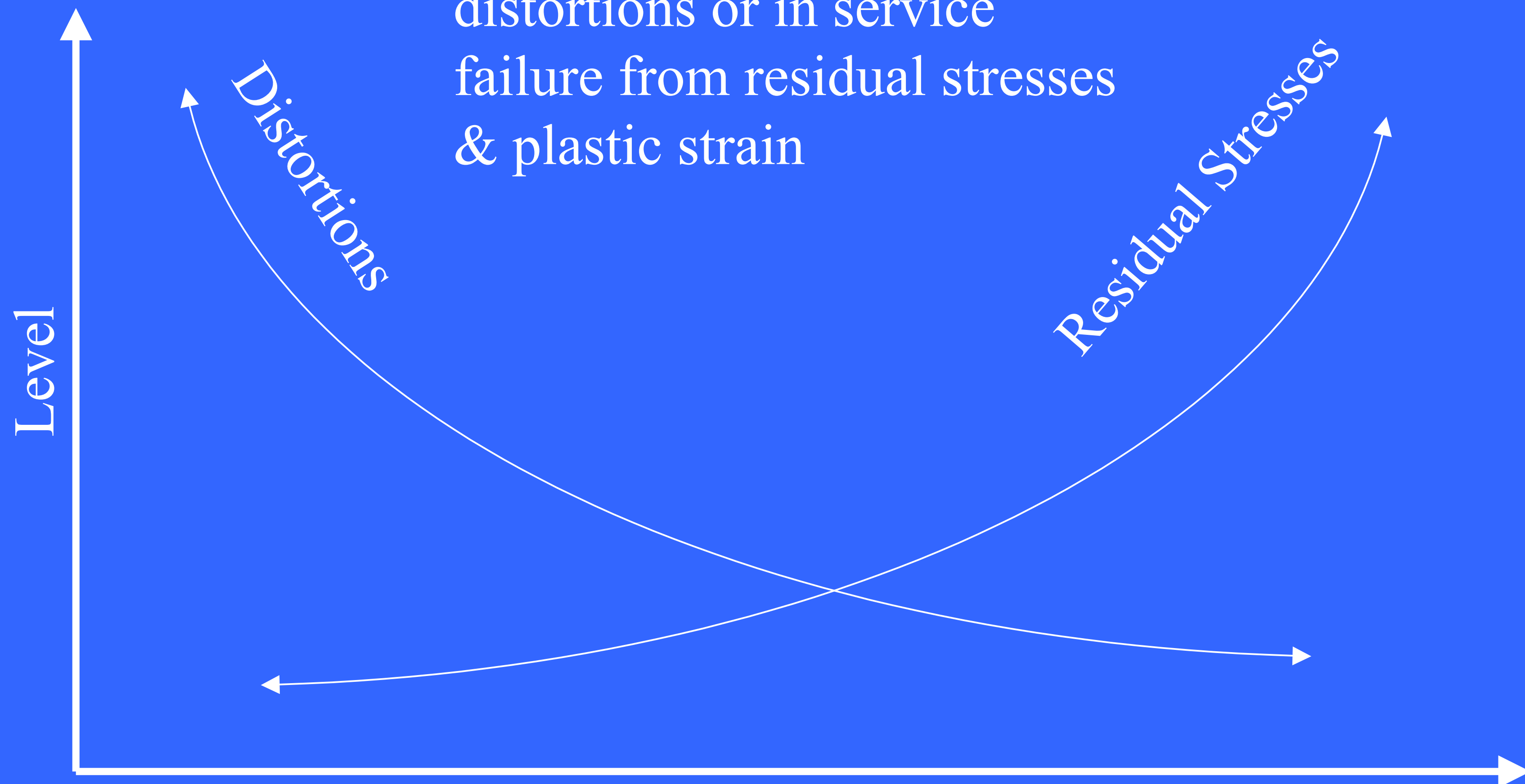
- soften base metal heat-affected zone (HAZ) produced by welding ***hardenable materials***
- remove hydrogen & relieve residual welding & machining stresses in ***hardenable & non-hardenable materials***
- to reduce susceptibility of sulfide stress cracking in sour service per NACE MR0175
- meet requirements of NACE MR0175 & API 6A & 16A
- meet requirements of Welding Specification

What are the consequences of inadequate or improper PWHT?

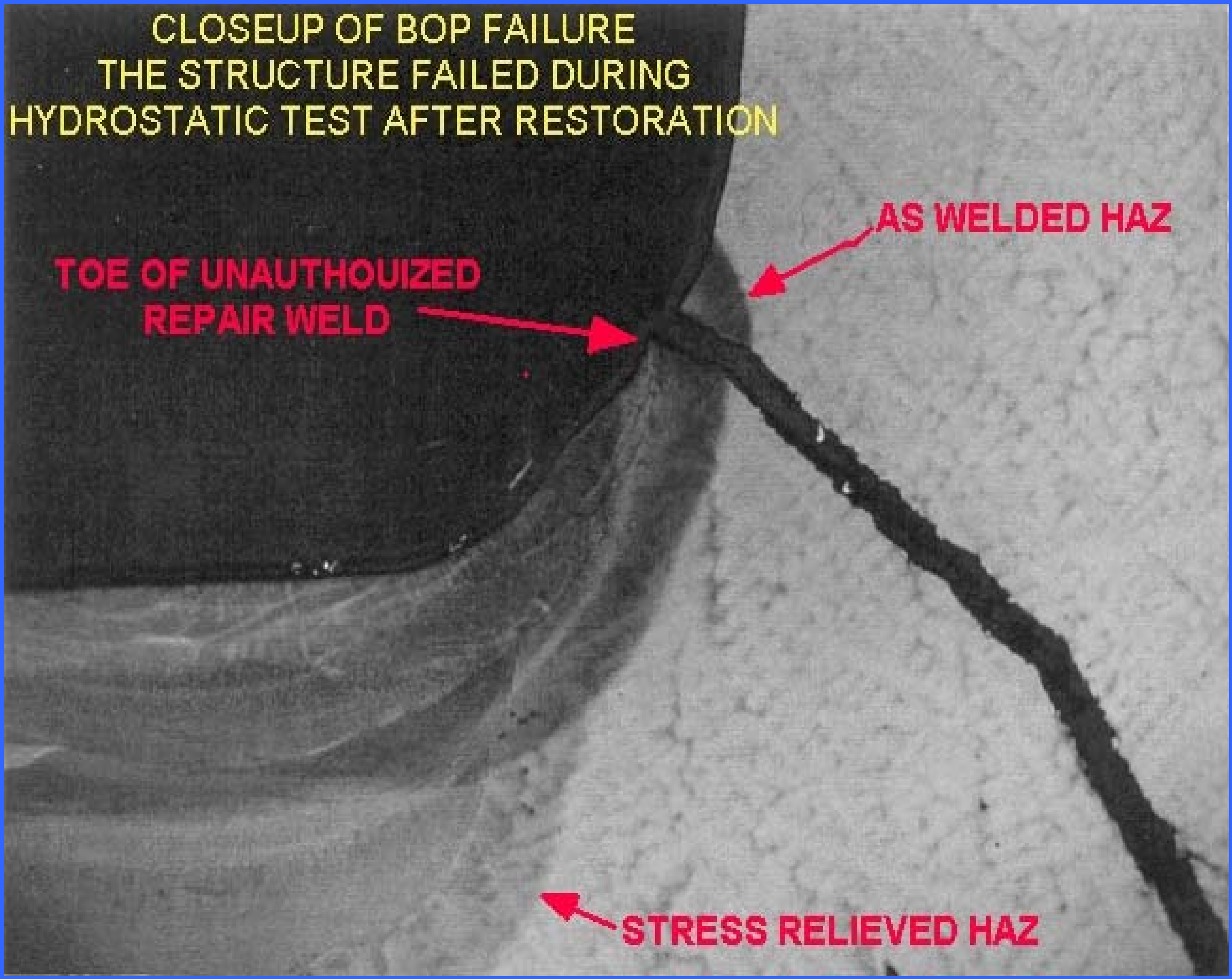
- hard zones & attendant susceptibility to hydrogen induced cold-cracking
- hard zones & attendant susceptibility to hydrogen sulfide stress cracking
- unacceptable distortion after finish machining
- unacceptable strength levels

Distortion Level vs. Restraint

Risks: rejects from large distortions or in service failure from residual stresses & plastic strain



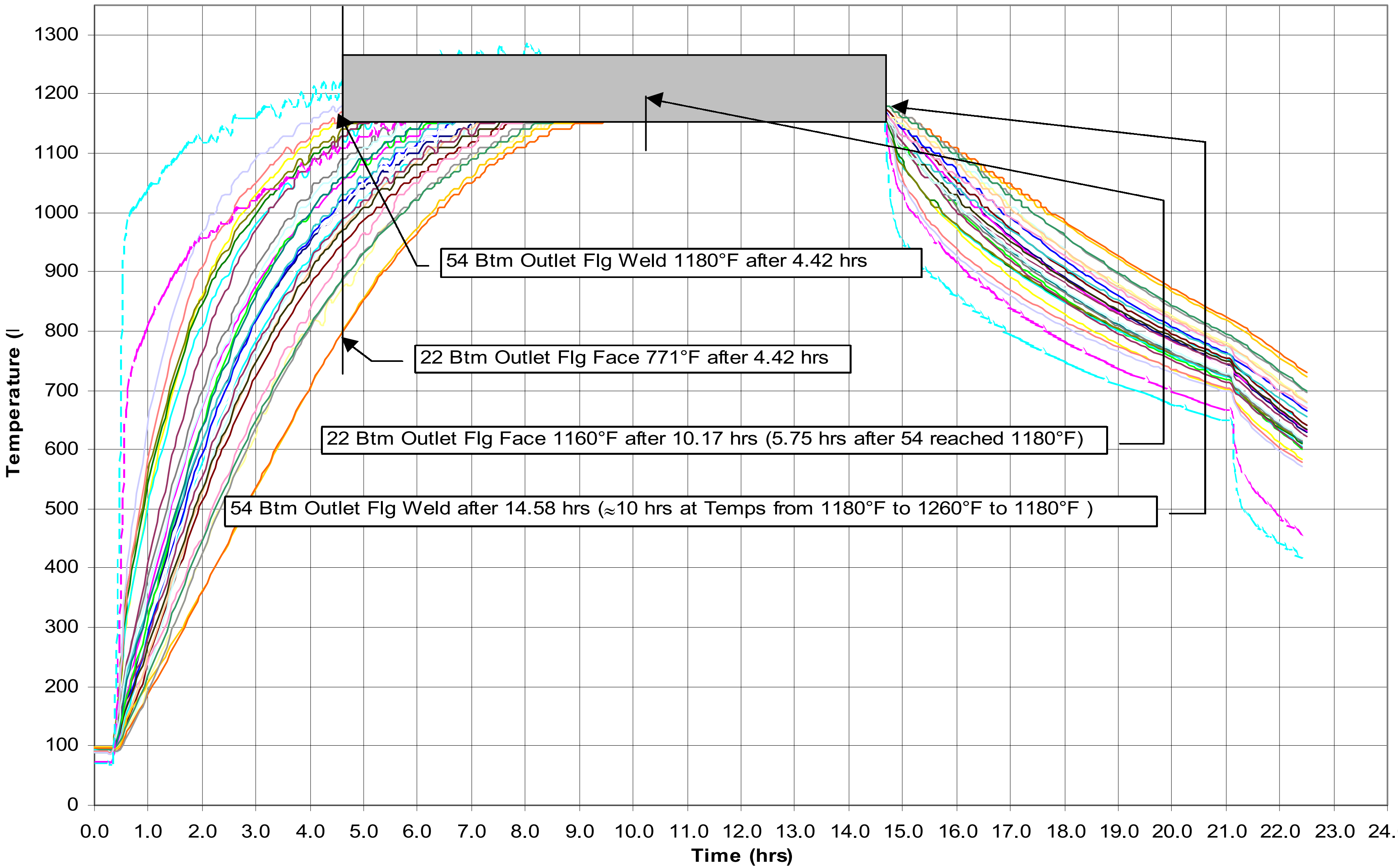
Failed During Hydro-Test


CLOSEUP OF BOP FAILURE
THE STRUCTURE FAILED DURING
HYDROSTATIC TEST AFTER RESTORATION
AS WELDED HAZ
TOE OF UNAUTHOUIZED
REPAIR WELD
STRESS RELIEVED HAZ

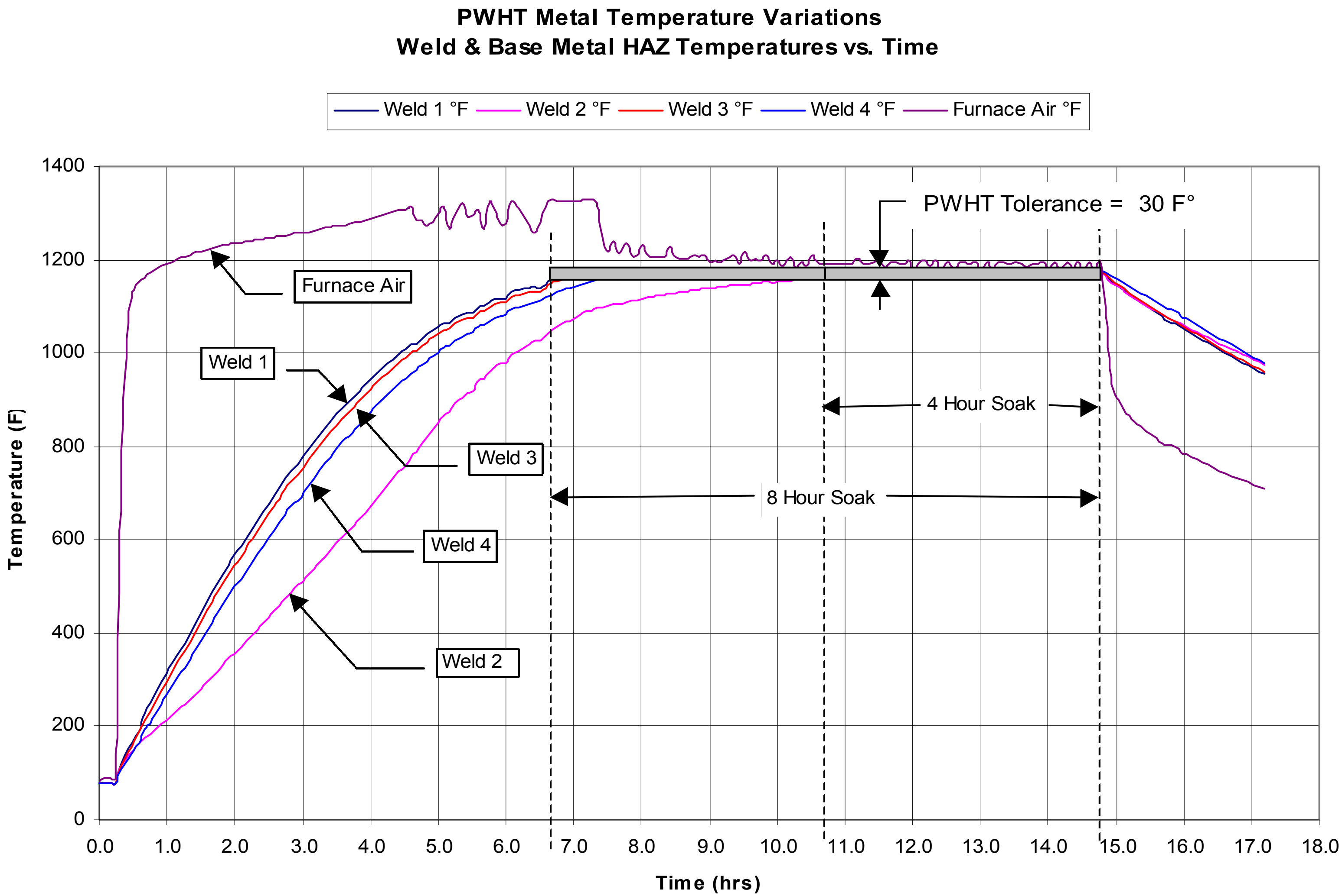
What does inadequate or improper PWHT mean?

- Production PWHT cycles that do not represent the PWHT used to qualify the welding procedure can result in inferior production weldments possessing:
- high HAZ hardness due to incomplete PWHT
- joint strength & toughness less than design requirements due to over tempering

Excessive Temperature Variations



PWHT Cycle Variations



When is Local PWHT Necessary?

- when weldments are too large to be postweld heat treated in a furnace
- when weldments exhibit excessive metal temperature variations in a furnace
- when different sections are held at times & temperatures different than qualified
- when local PWHT will preserve strength in non-welded areas of repaired weldments & thin and thick section welds

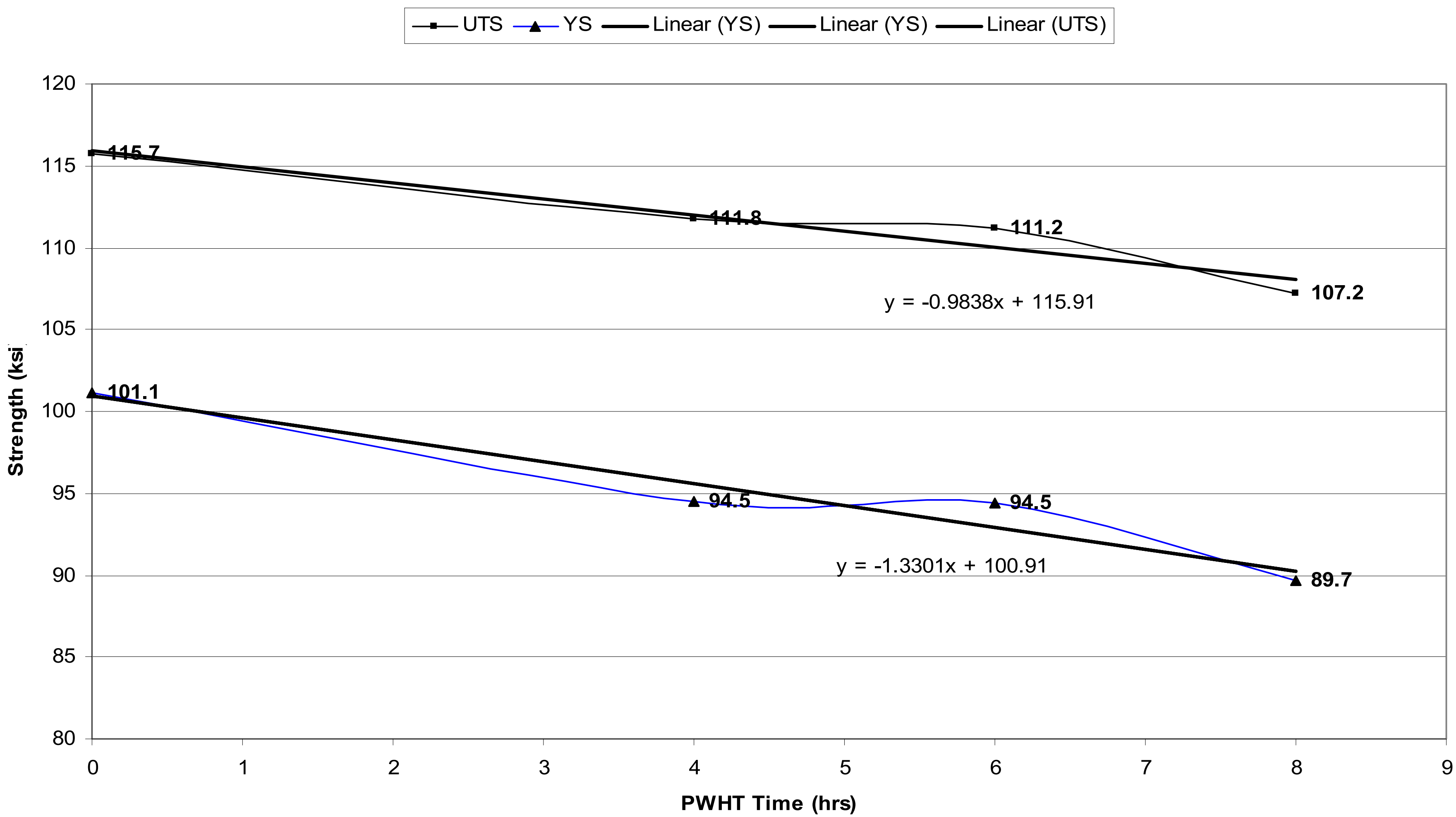
When are these issues a concern?

- when the design requires materials of higher hardenability and strength for use in sour service e.g. reduction of weight to strength ratios requiring through thickness properties
- welding materials of higher hardenability has undesirable side effects:
- increases high HAZ hardness susceptibility
- strength degradation w/long/slow PWHT cycles

Effect of PWHT Variations?

- PWHT of PQR weldments not properly specified, properly controlled, or representative of production PWHT capability may result in:
- strength degradation in over heated sections
- high HAZ hardness in under heated sections
- toughness degradation in over heated sections
- mechanical properties of production weldment not representative of PQR weldment
- (See HEMPS 11.100, Appendix D, Sections 4-6.)

Multiple PWHT Strength Degradation



Multiple PWHT Strength Calculations

Weldment Material										
PWHT Temperature	Actual/Specified Minimum Tempering Temp (T)	Number of PWHT Cycles	Time at PWHT Temperature (°F)	Tempering Temp (T) minus PWHT Temp (°F)	BM CE_{IIW} (C + Mn/6 + (Cu + Ni)/15 +(Cr Mo + V)/5)	Yield strength (ksi) BFPWHT	Calculated Yield Strength (ksi) APWHT			
1180F	1215 / 1225°F	1st PWHT	8	35	0.9157	93.150	***88.496***			
1180F		1st PWHT	8	-25	0.9157	93.150	***86.172***			
1180F		2nd PWHT	8	35	0.9157	88.496	***84.258***			
1180F		2nd PWHT	8	-25	0.9157	86.172	***79.818***			

Possible Solutions to PWHT Issues

- quantify actual production PWHT cycle and capability of largest weldment (e.g. furnace survey)
- standardize PQR PWHT cycle based on production capability (e.g. actual heating/cooling rates; multiple cycle times) & differences in HAZ hardness from different welding processes (e.g. heat transfer efficiencies, f_1 SAW =1.0 while f_1 GTAW = 0.7) See HEMPS 11.100 Appendix D, Section 4.
- use local PWHT as necessary to ensure that production PWHT is representative of PQR PWHT
- "SYSWELD" welding & heat treatment simulation software by ESI Group (http://www.esi-group.com)

PWHT Objectives

- minimize catastrophic failures caused by hydrogen embrittlement & sulfide stress cracking,
- ensure that mechanical properties meet design requirements after all PWHT cycles
- ensure that joint hardness meets requirements
- NACE MR0175
- material specification
- welding specification

Questions?

- HYDRIL HEMPS 11.100
- Contact Ken Fordyce as follows:
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The NWHSS Webmaster has converted Ken's presentation to an Adobe file and added this slide of information about Ken. This presentation and the Hydril Document HEMPS_11.100_A1 have been provided with permission to distribute on the NWHSS website.

Ken Fordyce has worked in the field of welding and materials engineering for over 20 years. Ken currently works at the Hydril Company as a Sr. Welding Engineer. Previous positions include:

- Welding and Coatings Customer Representative, Elliott Company, Donora, PA
- Welding Engineer, American Welding Institute, Knoxville, TN
- Sr. Welding and Materials Consultant, Southwestern Laboratories, Houston, TX
- Field Engineer, N. L. Shaffer, Houston, TX
- Certification Manager of the AWS Certified Welding Inspectors Program, American Welding Society, Miami, FL

Formal Education: Bachelor of Science, B.Sc., Engineering Technology, Oklahoma State University

During his career, Ken has been engaged in welding, metallurgical, mechanical and quality engineering projects, as well as sales and marketing of products and services. Most of Ken's career included metallurgical evaluations of failures, welding code consultation, development and documentation of procedures for joining, overlaying, heat treating, machining, and coating various types of carbon, and low and high alloy steel components.

HEMPS 11.100

- Scope
- minimum requirements for joining & repairing
- minimum requirements for qualifying welding procedures
- applies to all entities welding for Hydril

IMPORTANT DEFINITIONS

- WPS as defined in 4.16
- Approved WPS as defined in 4.1
- PQR as defined in 4.11
- Qualified PWHT cycle as defined in 4.13

JOINT REQUIREMENTS

- Defined by the WS
- Joint must meet minimum requirements after PWHT (previous & current PWHT)

BASE MATERIAL REQUIREMENTS

- PQR test coupons must conform to HEMPS or other approved standard
- Equivalent P-Number metals not permitted
- ASME IX P-Number 1 Group 1 & 2 metals qualify other P-Numbers & S-Numbers in same group (but not vice-versa) except for two:
- ASTM A 105 & ASTM A 350 LF2 are limited by NACE MR0175 to 187 HB & 197 HB maximum, respectively.

FILLER METAL REQUIREMENTS

- NACE MR0175 limits filler metals to 1% Nickel
- ASME/AWS SAW flux classification not permitted on WPS for welding hardenable materials
- Deposited weld metal strength of non-prequalified filler metals shall be measured by all-weld metal tensile tests per Section 8.3
- Cross-weld measures of yield strength not valid

PQR PWHT Cycles

- First PQR PWHT cycle is to qualify WPSs for weldments not previously postweld heat treated
- Second PQR PWHT cycle is to qualify WPSs for weldments postweld heat treated one time previously
- Third & Subsequent PQR PWHT cycles are to qualify WPSs for weldments postweld heat treated more than twice previously

PWHT EXAMPLE No.1

- Given: Several repair welds in different areas of a part manufactured from 8” thick AISI 4130. The welds will be less than 5” thick & there has been no prior PWHT. The production PWHT cycle has been determined to be characteristic of that shown in Fig. D3 of HEMPS 11.100. The average hardness of the body is 215 HB. The repair weld is required to meet WS 11.101-DDD0II.
- Determine PQR test weld steps.

PWHT EXAMPLE No.2

- Given: Same conditions & assumptions as those in Example 1, except that the part contains an 8" thick groove weld that was postweld heat treated once previously for 8 hours @ 1210°F.
- Determine PQR test weld steps.

PWHT EXAMPLE No.3

- Given: Several repair welds in different areas of a part manufactured from 10” thick AISI 4130. The welds will be less than 5/8” thick & there was a prior PWHT of 4 hours @ 1210°F. The average hardness of the part is 215 HB. Production PWHT cycles have been observed to be characteristic of those shown in Fig. D4 of HEMPS 11.100.
- Determine PQR test weld steps.

PWHT EXAMPLE No.4

- Given: Same conditions & assumptions as those in Example 2, except that the number of prior postweld heat treatments is unknown. However, the average hardness of the 8” groove weld joining the bottom flange to the body is 190 HB & the average hardness of the body is 205 HB. All welds must meet WS 11.101-DDD0II.
- Determine PQR test weld steps.