Post Weld Heat Treatments for New and In Service Coke Drums

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Welding Issue

- When weld is applied it is molten metal and thermally expanded when filling a groove.
- When weld metal cools, it will shrink a lot. Yield Strength is low for much of the cooling range.
- Surrounding metal that was not heated to molten temperatures will constrain or keep the weld from shrinking as it cools.
- Internal forces and moments are self equilibrating to keep the weld and welded parts together when cold.

What is PWHT?

- Post Weld Heat Treatment is a procedure to reduce residual stress, temper the HAZ, and remove hydrogen from the weld region after a seam weld is made.
- Can be Global (entire vessel) or…
- Can be Local (weld seam and surrounding metal only)
- Weld and HAZ heated below the transition temperature for several hours and then gradually allowed to cool.

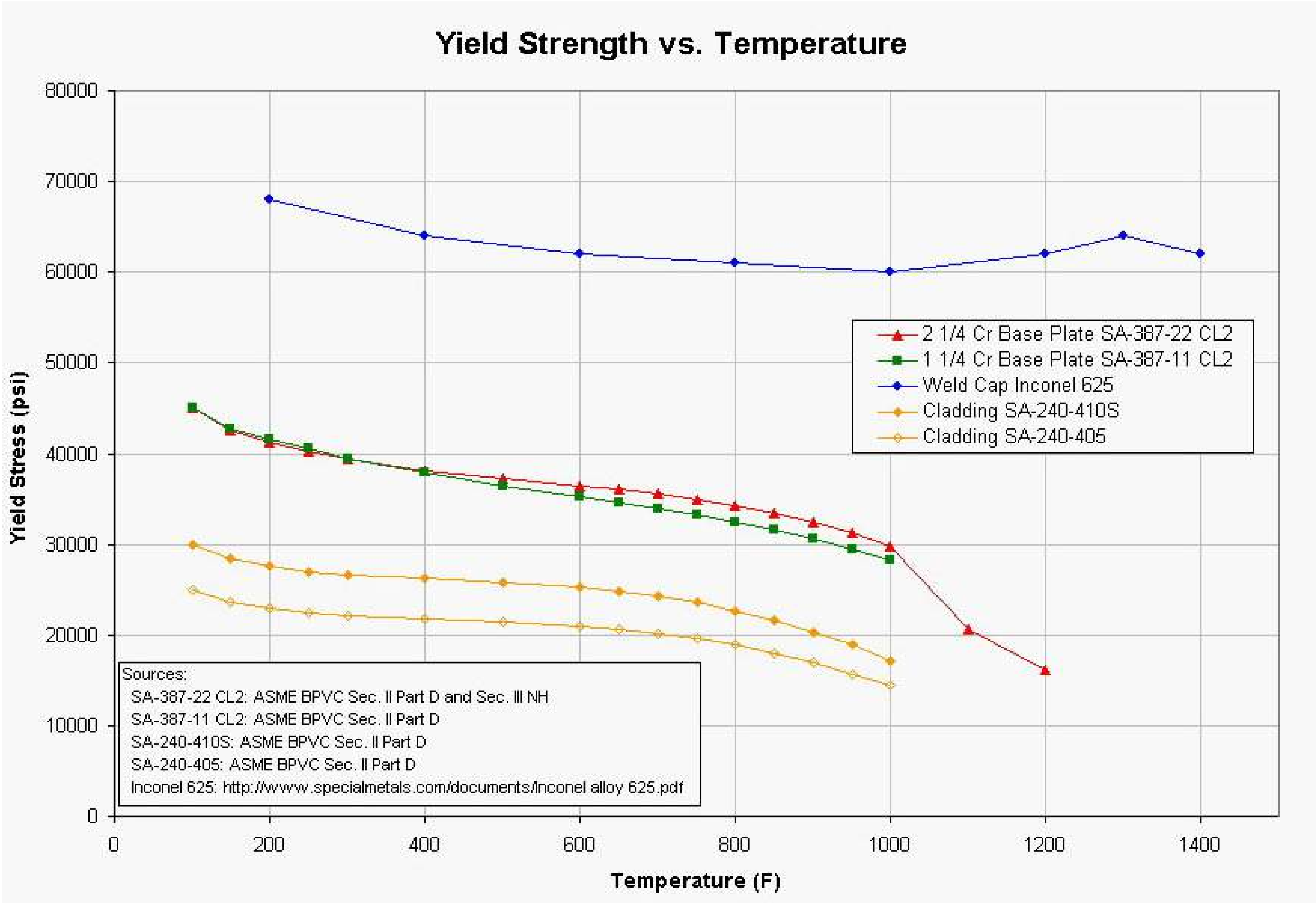
Why PWHT ?

- PWHT requires reheating to allow weld metal to yield and comply with the distortions, forces, and moments previously trapped and held by the weld.
- Likelihood of later cracking reduces with lower residual tension stress.
- Hydrogen gas is removed to prevent later cracking.
- At best, the residual tensile stress is reduced from yield to 1/3 of yield strength, but never to zero.

Issues for PWHT

- High temperature during PWHT and usage creates lower yield stress in components :
  - base metal
  - weld metal
  - weld cap
  - cladding
- Components have different yield strengths and thermal expansions
- Free expansion creates no stress
- Constrained expansion creates stress
- Non uniform temperatures creates constraint

Plate Component Yield Strengths



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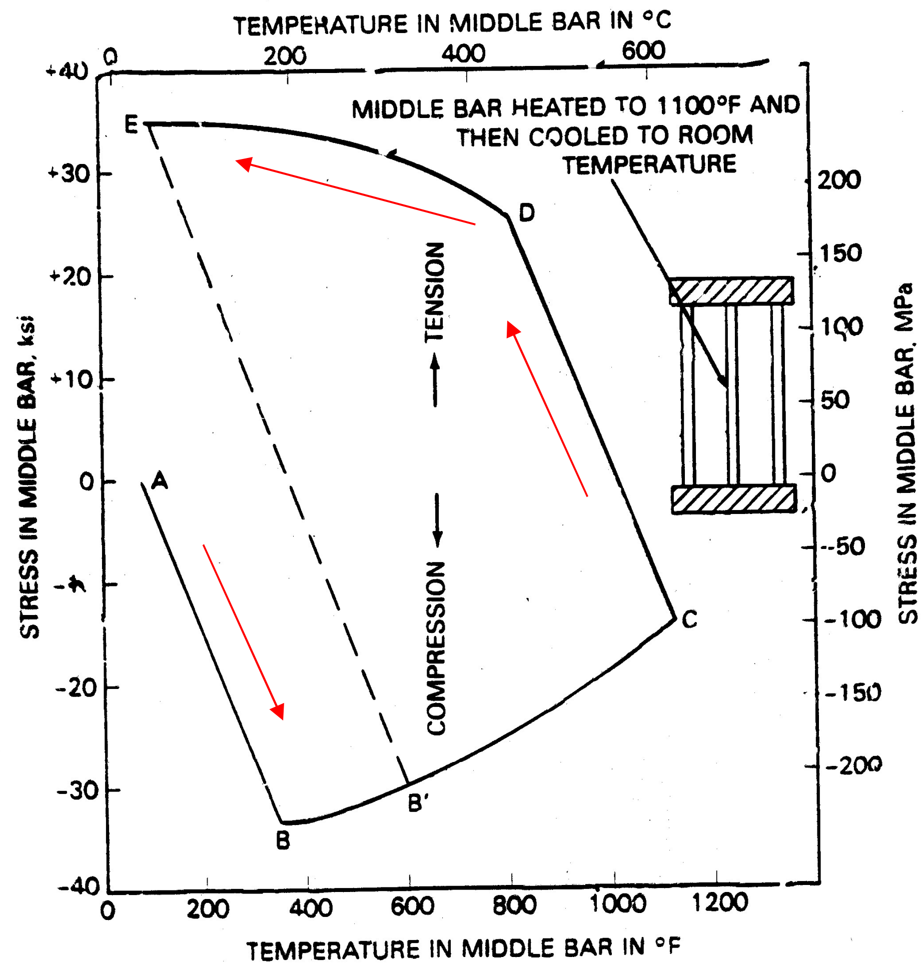
Conceptual Constraint Model

- Outer bars and top/bottom plates represent the coke drum
- Inner bar represents weld metal, HAZ, and heated base metal
- Inner bar is heated and constrained by outer bars, and yields in compression,
- Final result is **residual tension** stress



-Effect of Heating Restrained Bar on the Residual Stresses

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Local Repairs for In Service Drums
WRC Bulletin 452 (June 2000)

- Local Post Weld Heat Treatment is for repair of vessels in service after fabrication.
- “For PWHT to be successful, it must be based upon engineering assessment and optimization of parameters to meet the desired objectives.”
- “As a result, engineering judgment, in addition to stated code requirements, is often necessary.”
- See Welding Research Council Bulletin 452.

PWHT for Older Drums in Service

- Coke Drums are Pressure Vessel Design Compliant, but are in cyclic service.
- Low Cycle Fatigue happens to coke drums, with base metal and weld seam stressed beyond Nominal Yield every cycle.
- Cracks will eventually occur in all coke drums.
- Through Wall Cracks will allow contents to leak and the result can be a fire during leakage or on the next cycle.
- Through Wall Cracking must be weld repaired as quickly and efficiently as possible to restore production.
- After Weld Repair, a **Local PWHT** is often applied to remove hydrogen, temper the HAZ, and reduce the residual stress. This can also be a global PWHT instead.

Temperature vs Time (ASME)

- Rate of heating and cooling specified.
- Maximum temperature specified.
- Testing of samples prior to PWHT will qualify the procedures for the application.
- Soak time to represent fabrication sequence and extra time for future repairs.

Temperature vs Length (WRC 452)

- Based upon the American Welding Society ANSI/AWS D10.10-90, Recommended Practices for Local Heating of Welds in Piping and Tubing.
- Gradient Control Band
  - controls axial temperature gradient
  - minimizes heat losses
  - $8(Rt)^{1/2}$ plus width of soak band
- Axial temperature gradient
  - control is important to limit thermal stress
  - protect vessel outside of band: “not harmful”
  - limit temperature to no less than 50% soak at distance of 2(Rt)1/2 from edge of soak band

PWHT of New or Old Drum on Site

- Gas Burners used inside of an insulated drum built on site.
- Also used when many repairs made at same time in existing drum.
- Concern for Collapse in skirt
- Not Commonly performed.

New Drum Construction PWHT

- All seams in a new drum must be PWHT before delivery
- The problem is that many new drum sizes no longer fit in fabrication furnaces, and drums are PWHT in pieces to assure the longitudinal seam receives full benefit as it is loaded in hoop stress by internal design pressure.

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New Drum Construction PWHT

- Once the Can Section pieces are PWHT they are assembled together and then exposed to another PWHT cycle.
- This is often performed with **Local PWHT** procedures that comply with Pressure Vessel Code specifications although the issues of WRC 452 are not addressed.
- Consequently, some material of the drum near the seam being treated undergoes multiple PWHT cycles and material is damaged more than intended.

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New Drum Specifications

- Fabrication Specifications usually attempt to protect the drum by requiring assurance that the material can undergo enough hours at PWHT temperature to address repeated cycles as well as possible repairs after many years of operation. This is required by ASME Section VIII Div 1 UCS-85 (c) for base material and in Section IX QW-407.2 for the PQRs (where impact is required)

- The number of hours at PWHT temperatures is important because of creep damage and material deterioration.

- It is important to assure the narrow range of the PWHT is complied with and not exceeded or not attained.

Conventional Coke Drum Fabrication Features LPWHT

- The following slides depict a typical and traditional coke drum assembled using pressure vessel procedures
- Smaller parts are sent to the stress relief furnace to assure the longitudinal seams are fully stress relieved.
- Eventually the assembly is too large for the oven and the **Local PWHT** are required.
- Final assembly is the Closure Seam with LPWHT.

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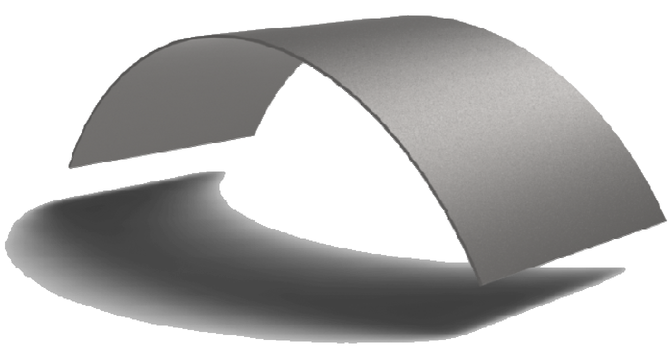
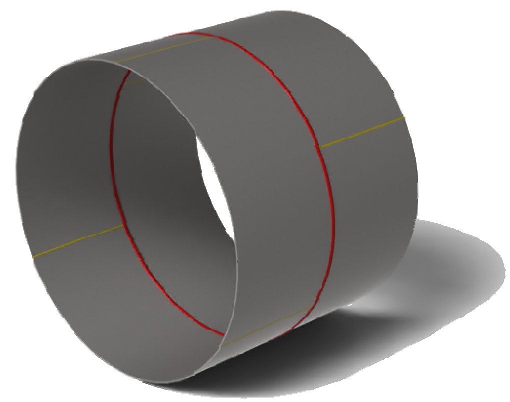
1. Clad Plate is Prepared

2. Clad Plate is Formed to Diameter

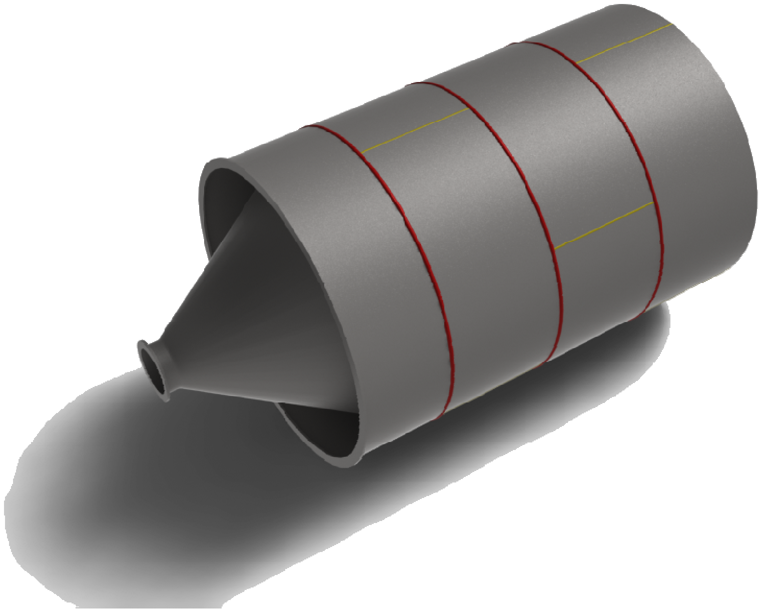


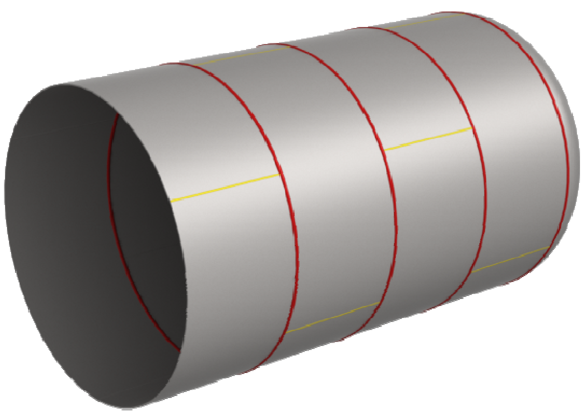
3. One or several plates assembled into a Cylindrical Can and may be Furnace Heat Treated (Long. Seams)

4. Cans are combined and stress relieved in furnace as singles or pairs of cans (Long. and Circ seams)



5. Lower half of drum is assembled and becomes too big for furnace so LPWHT is used for connecting Seams





6. Upper half of drum is assembled and becomes too big for furnace so LPWHT is used for connecting seams

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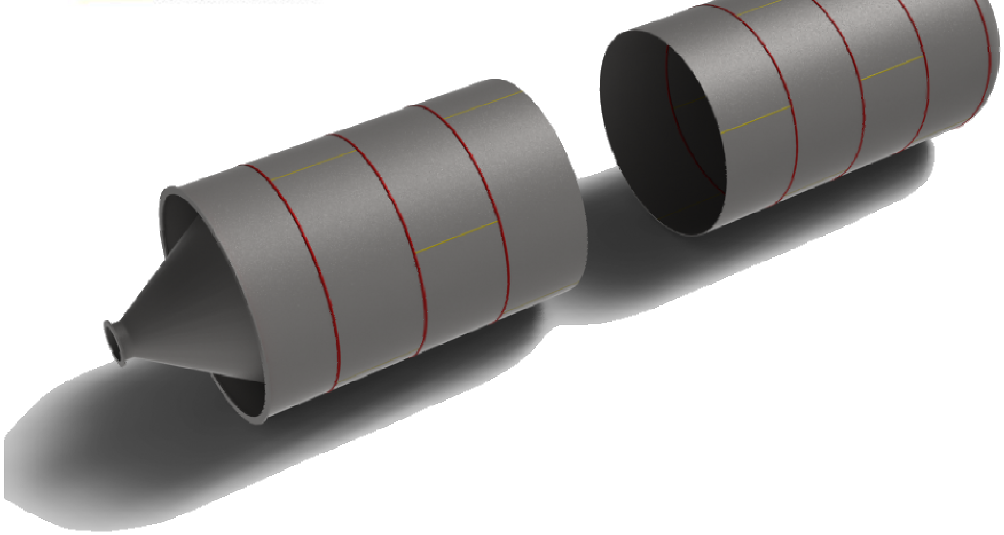
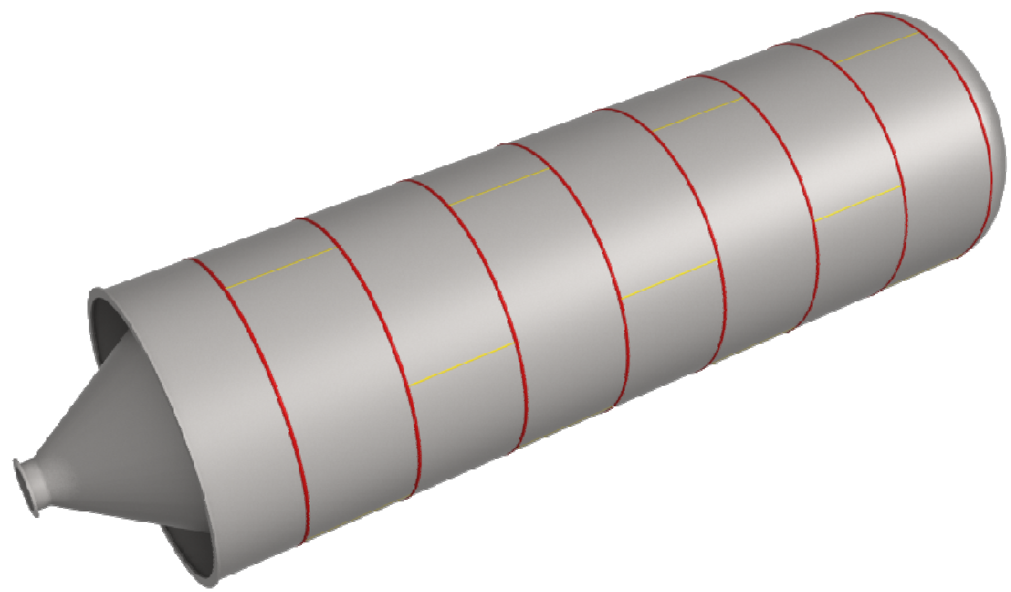


7. Two halves ready for Closure Seam Weld

8. Two halves are joined together



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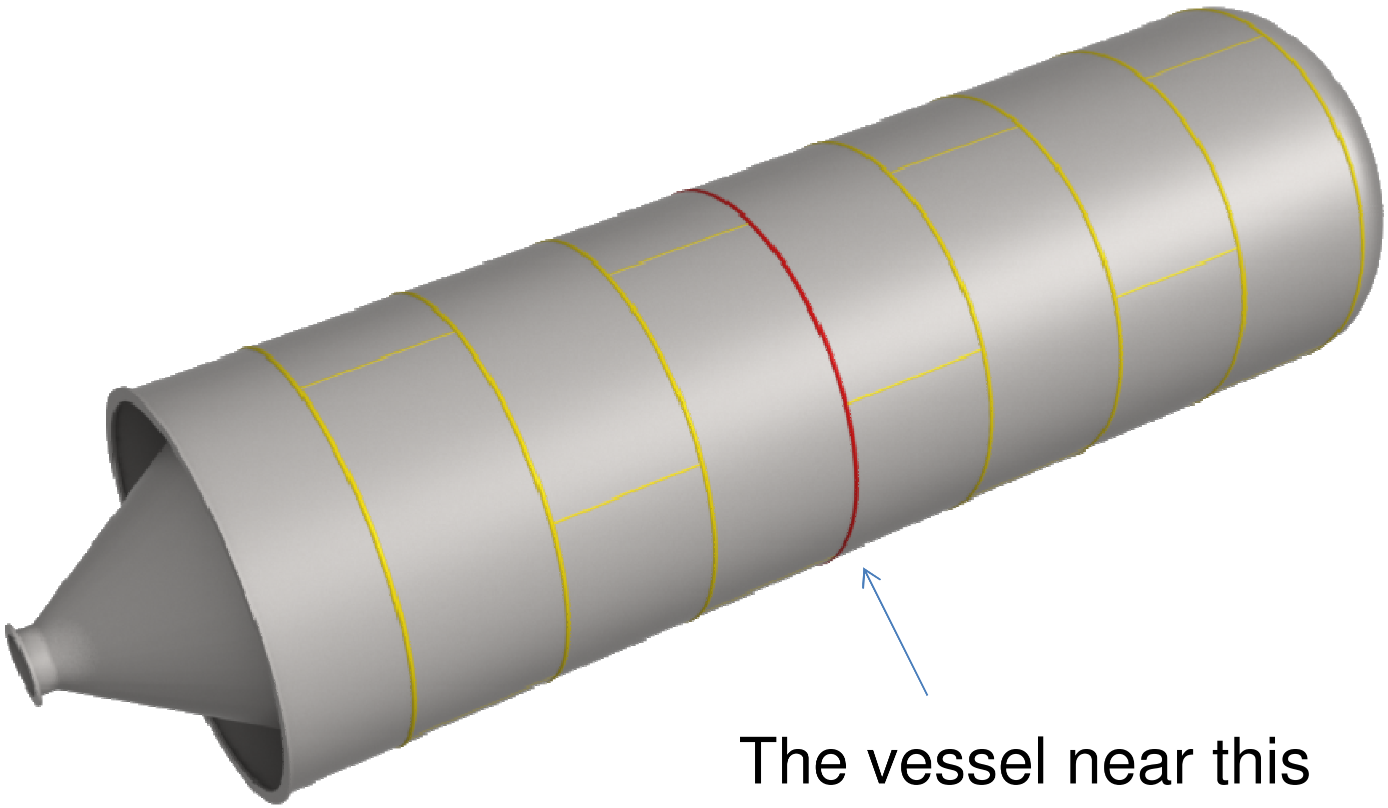
9. Closure seam is LPWHT



The vessel near this seam has material that sees 2 PWHT cycles

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Common Issues for PWHT and LPHWT

- Cans should be round and concentric when joined to reduce internal moments and forces.
- Supports required to maintain roundness.
- Supports must allow thermal expansions to prevent buckling during heating and cooling.
- Vessel must be supported to reduce bending and sagging.
- Maximum temperatures and duration must be controlled.

Thank You

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mangiarotti SPA

Pressure Equipment for Oil, Gas and Chemical Industry

Post Weld Heat Treatments for Coke Drums

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Since 1930

mangiarotti – current PWHT capabilities (1)

- Sedegliano (Headquarters) Inland Workshop :
  - single piece – one shot HT up to 22ft x 22ft x 86 ft
  - local HT (either by electric resistance, computer-controlled, 110 kW power – or with gas burners) with no size limits when the particular construction sequence requires so (e.g. : tubular reactors with duplex tubes)
- San Giorgio di Nogaro Port Facility :
  - single piece – one shot HT up to 34ft x 34ft x 200 ft(*)
  - local HT as for Sedegliano Workshop
- Milano Workshop :
  - single piece – one shot HT up to 26ft x 26ft x 72 ft
  - local HT by electric induction, 400 kW power

(*) length virtually unlimited upon availability of panels to be fabricated on a case-by-case basis

mangiarotti – current PWHT capabilities(2) Sedegliano(Inland Facility) Fixed Furnace

Fixed furnace
22ft x 22ft x 86ft

mangiarotti – current PWHT capabilities(3) San Giorgio (Port Facility) Modular Furnace

Single span (Small)

17ft x 17ft x 400ft

Double span (Large)

34ft x 34ft x 200ft

mangiarotti – current PWHT capabilities(4)
Milan Inland Facility

Fixed furnace
26ft x 26ft x 72ft

mangiarotti – future PWHT capabilities

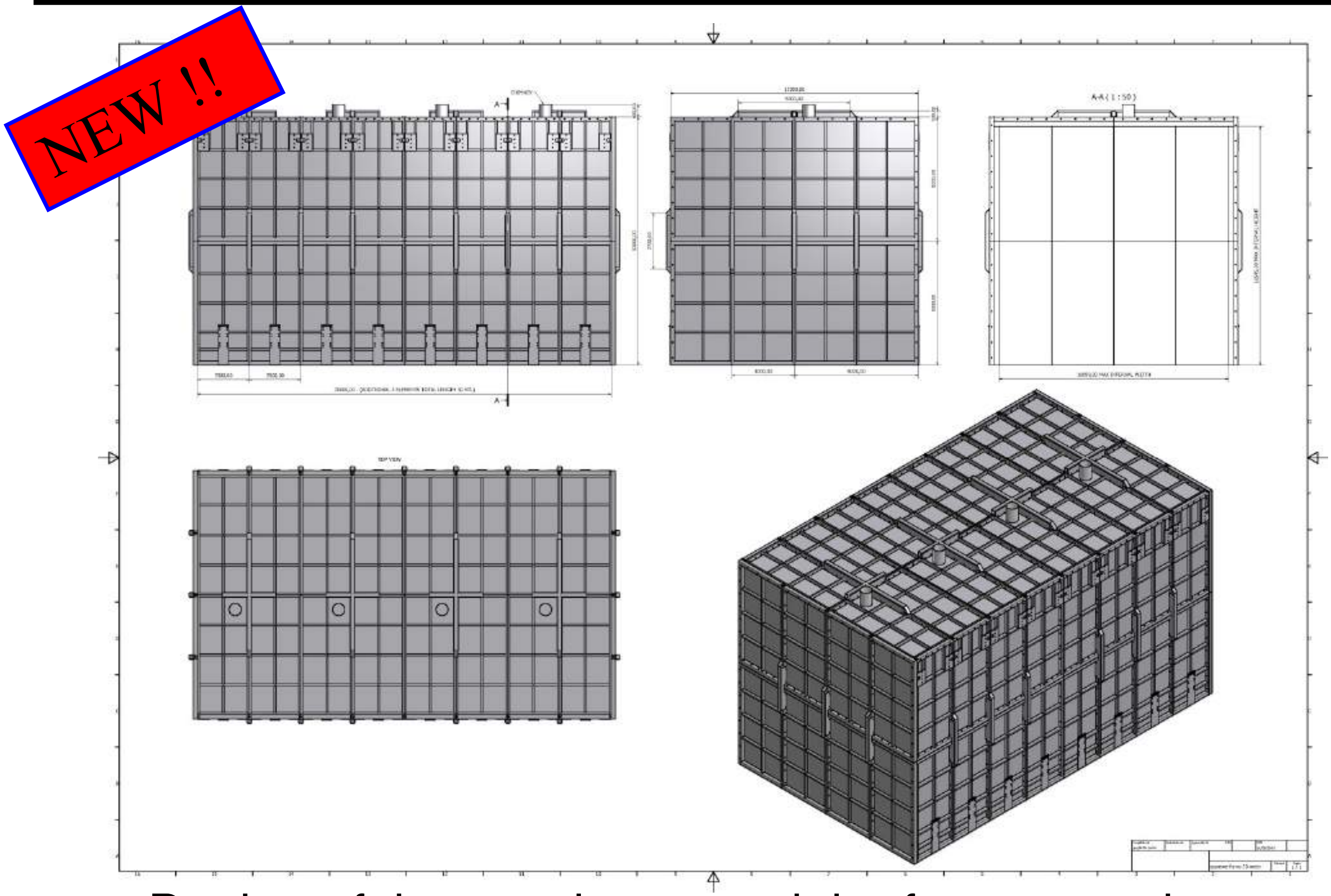
NEW !!

- Monfalcone Workshop currently under construction :
  - big new facility conceived and designed to ultra-modern fabrication standards with specific emphasis to optimizing nuclear as well as conventional large/thick/heavy equipment fabrication
  - will replace Milano facility (which has a logistic limit being located close to the city center)
  - scheduled and expected to be 100% up and running as of January, 2011

PWHT capability :

- single piece – one shot HT up to 38ft x 36ft x 98 ft
  - local HT facilities : see other facilities

mangiarotti – future PWHT capabilities(4) at NEW Monfalcone Port Facility



Modular furnace
38ft x 36ft x 98ft

Design of the new large modular furnace under construction

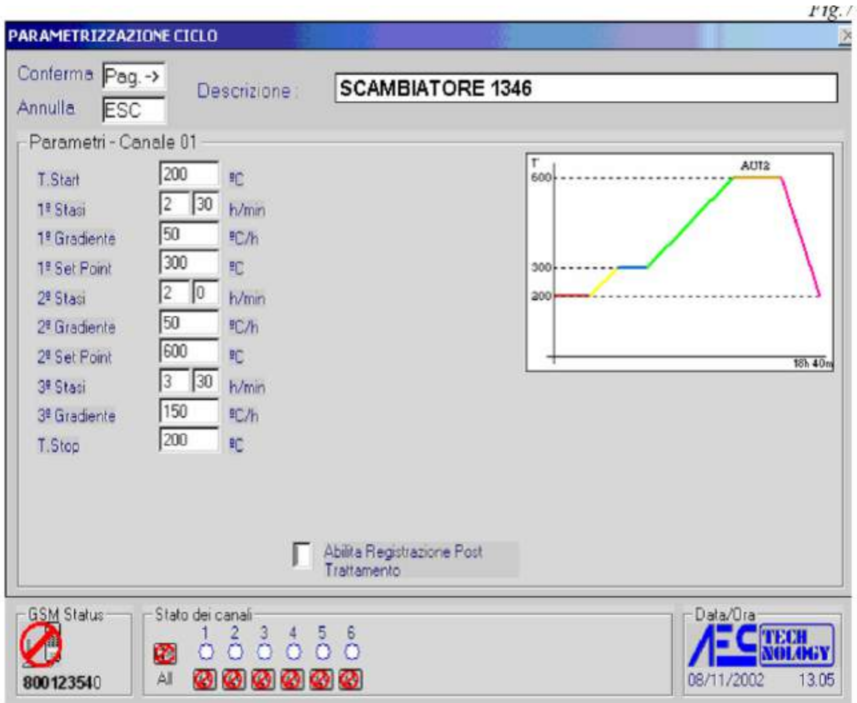
Confused on mangiarotti facilities locations ? A quick re-cap…

Sometimes, a LPWHT is unavoidable(1)…

- When a specific fabrication sequence requires it, to avoid treating a part of the equipment (e.g. due to specific metallurgy not allowing heat treatment)
- In such cases, proper systems have to be set up for accurate heating, temperature holding, and cooling down, without affecting areas of metal not to be HT

Sometimes, a LPWHT is unavoidable (2)…

…but a perfectly controlled temperature cycle must be applied (example of our AEC Technology 380V 120kW computerized electric resistance LPWHT machine)



Desired LPWHT cycle easily and precisely acquired by the control software

Control system for electric resistance LPWHT

Sometimes, a LPWHT is unavoidable (3)…

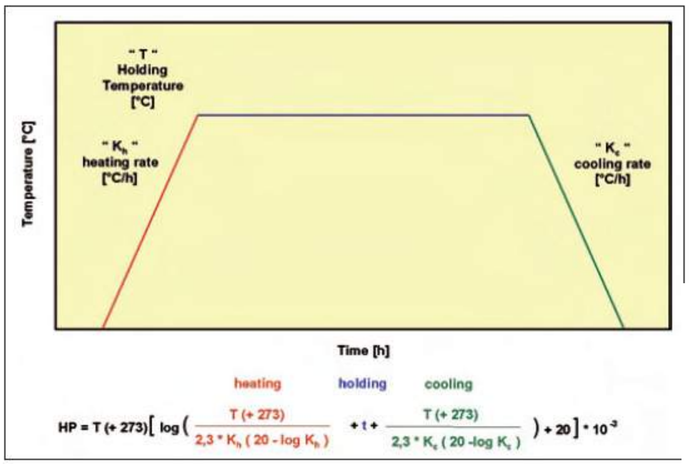
Examples of LPWHT and ISR in Tubular Reactors / HP Heat Exchangers / HC Reactors :

Automized electric LPWHT

Tangential Gas Burners thermocouple controlled LPWHT

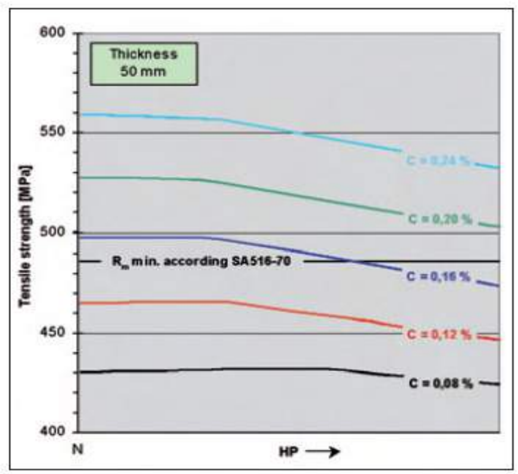
Local ISR with fixed toroidal chamber furnace and rotating equipment for optimal and steady heat distribution along circumference and vertical axis

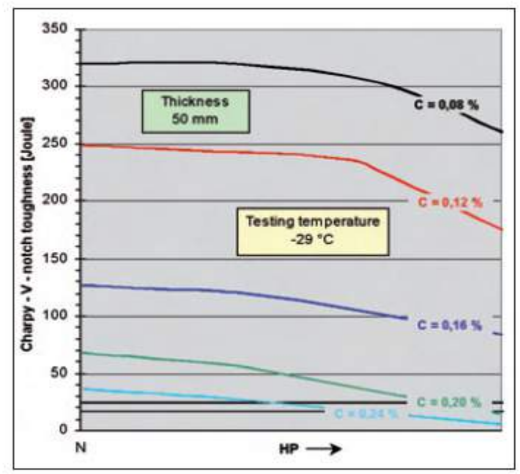
Besides the stress issue, there is a metallurgical problem with the LPWHT



Hollomon Parameter (HP) as an index of HT "damage" (accounting for both temperature and time)

Typical properties drop as a result of higher HP (longer HT and/or higher T)





Graphs are courtesy of Dillinger-Hütte GTS

But, on Coke Drums LPWHT can be avoided…

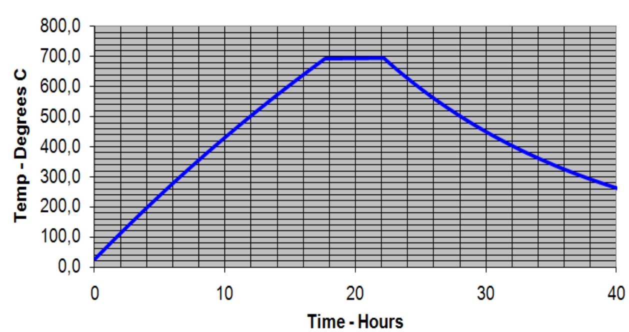
…as long as :

- Suitable facilities are available (adequate furnace size and modern automized control system)
- The heat treatment is properly designed to achieve accurate and reliable control of metal temperatures (rather than internal air temperature) => well thought-out thermocouples distribution on piece
- Supporting and / or reinforcement members are designed to control CD deformation and prevent permanent distortions => temporary removable internal & external steel structures

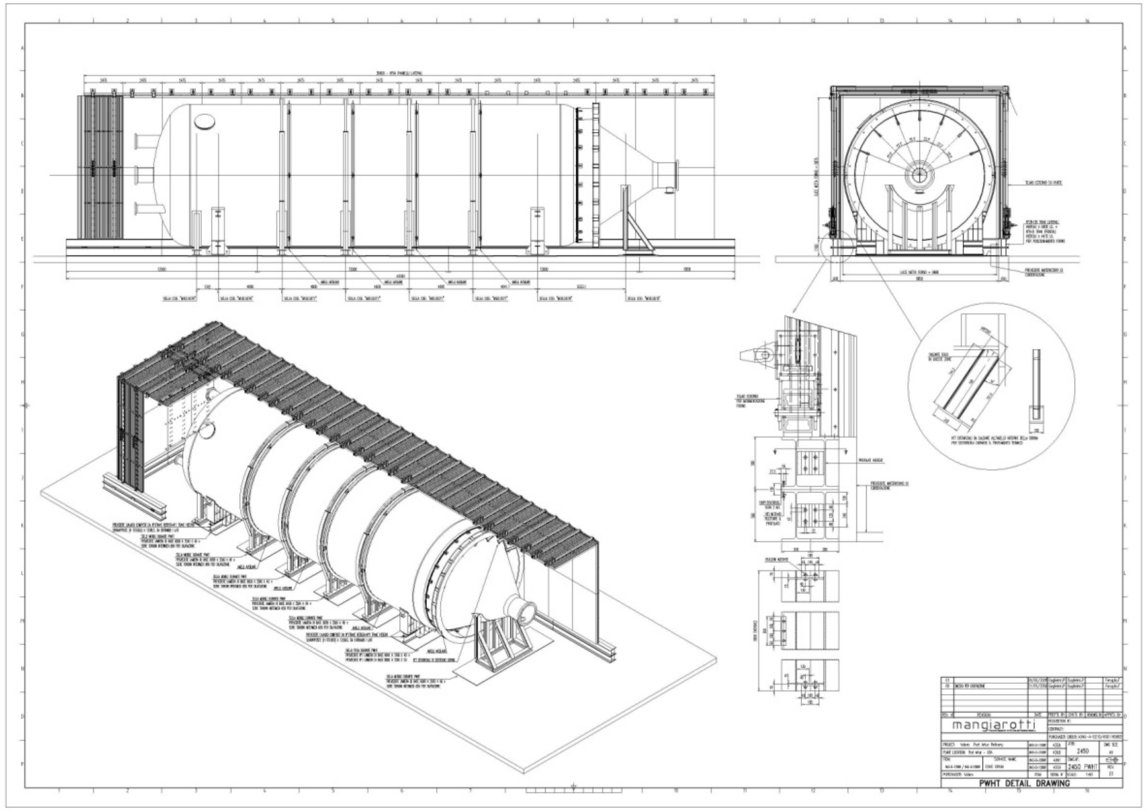
Single piece PWHT on Coke Drums(1)

Numerical Integration Results of the Thermal Transient Differential Equation :

Job = K2450 / Item = Coke Drum	Heating Profile: Time		Heat Power Output		Heated Mass = 404000 Kg - Oven Size = 9,6x9,6x40 m				
Interval	from	to			Temp at the beginning of the interval	Temp at the end of the interval	Resulting temp rate in the interval	Thermal Energy Output	Fuel (LPG) Consumption Heater Efficiency = 0,7
	h	h	% of max	kCal/h	°C	°C	°C/h	kCal	Kg
First	0	17,5	67,0	2.412.000	25	689	37,9	42.612.000	5540
Second	17,5	22	20,0	720.000	689	696	0,0	3.240.000	430
Third	22	150	0,0	0	696	25	-20,0	0	0
TOTAL	0	150	-	-	25	25	0,0	45.852.000	5970

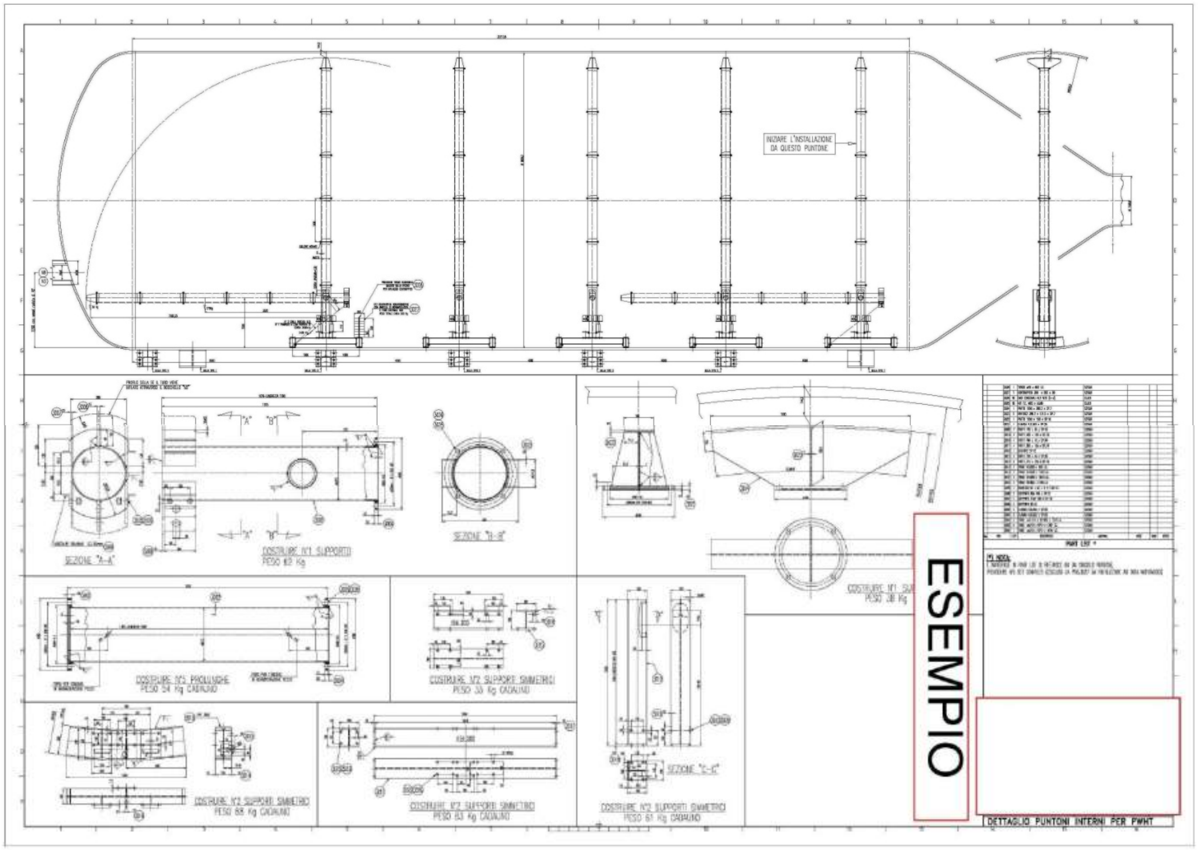


Theoretical thermal transient simulation via our proprietary software



Design of external supporting system for HT

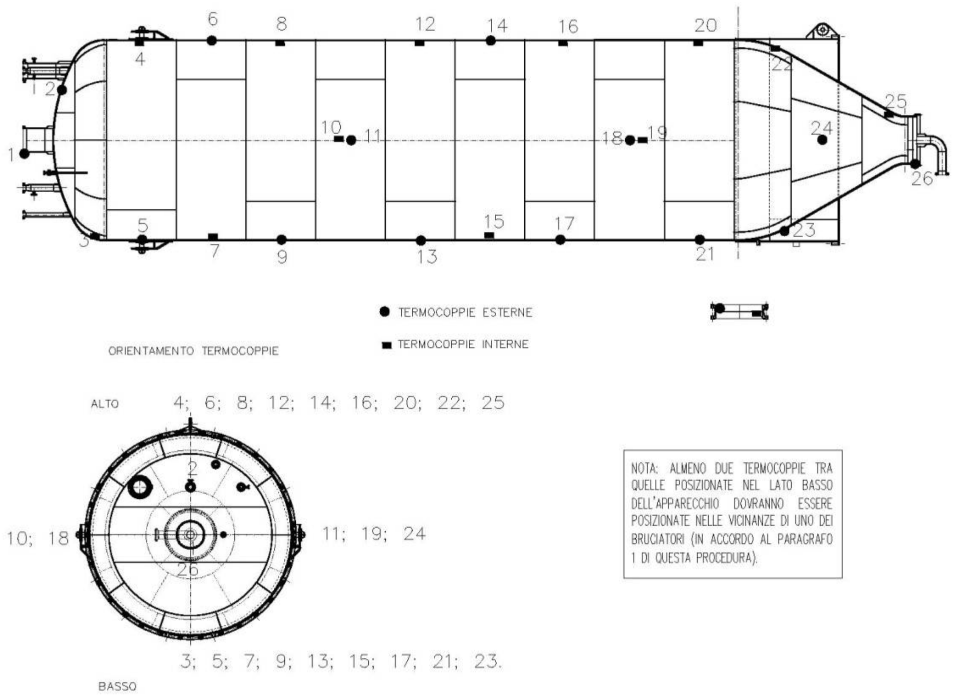
Single piece PWHT on Coke Drums(2)



Design of internal temporary reinforcing bars for HT

Single piece PWHT on Coke Drums(3)

Precise temperature control with a suitable number of properly located thermocouples to drive the burners via a PLC system



One-shot PWHT integrated into “smart” fabrication processes (1)

- PWHT is critical, but it’s not the only fabrication issue which may affect residual stresses likely to be detrimental to CD life expectancy
- An array of other fabrication facilities are complimentary to the achievement of the same goal : the minimization of stresses as a result of the entire fabrication process. Examples are : precise bevelling to “state-of-the-art” narrow gap design…

One-shot PWHT integrated into "smart" fabrication processes (2)

- PWHT is critical, but it's not the only fabrication issue which may affect residual stresses likely to be detrimental to CD life expectancy

Special adjustable jigs for CD "petals" assembly to ensure perfect roundness without introducing stress risers

Coke Drum Finished &Ready to Ship !

FOB / Port Loading activities

Large Area for CD Storage

Quick Mangiarotti Overview

heavy plate rolls

Power 6200 Tons Width
3600 mm X 300 mm

machining department

Two large CNC Milling Machines
Y= 5000; X= 18000; Z=1750 +1500

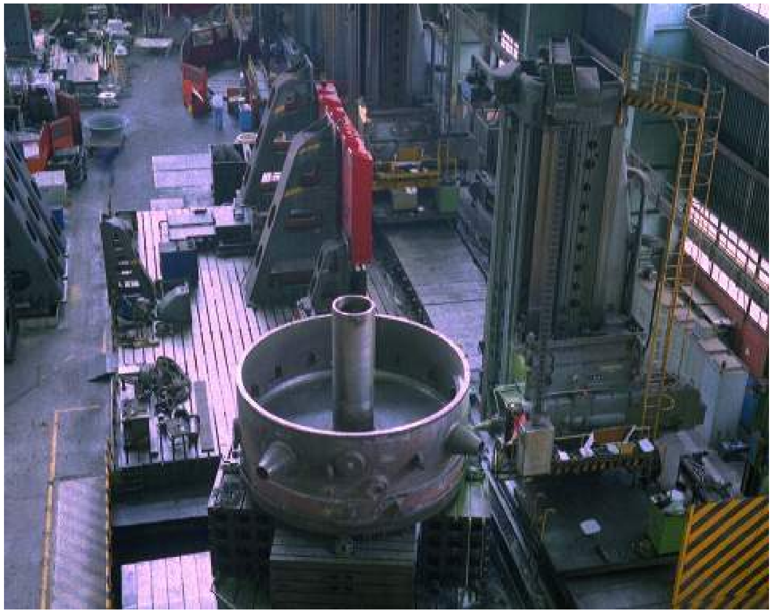
Top picture: Reactors shell belt in position for nozzles cut-outs (4900 mm ID & 263 mm thk).

Side picture: Typical Inner machining on Reactors shell body prior to internal installation (2800 mm ID & 50+8 mm thk of Weld Overlay)

machining department

Vertical Lathe
Capabilities: 7500 mm Dia.; 4000 mm Height;
130 Tons weight.

Boring Mill
Capabilities: 23000 mm Width; 7200 mm Height;
300 Tons weight max.



deep drilling (INNSE)with 3 spindles

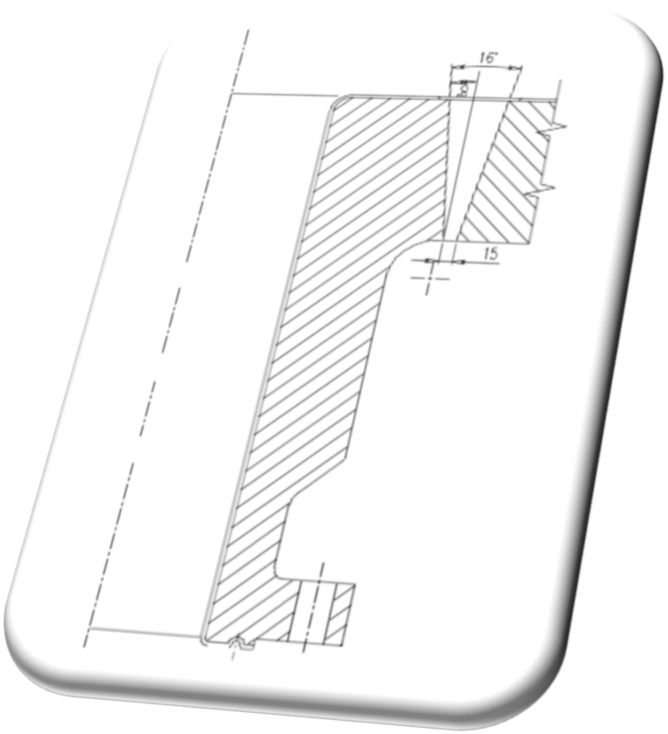
Hole Dia.: 32 mm max. (52 mm with single spindle)
Max. Weight 150 tons; Thk.: up to 1000 mm.

automatic tube weld /roll

Automatic welding and rolling of tubes at tubesheet

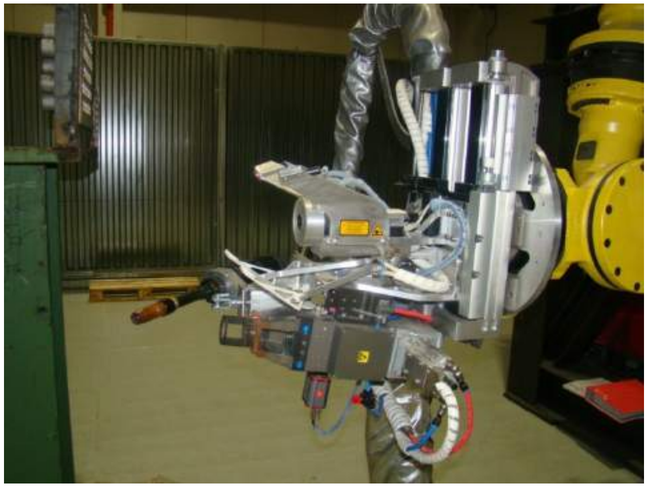
automatic orbital welding of nozzles

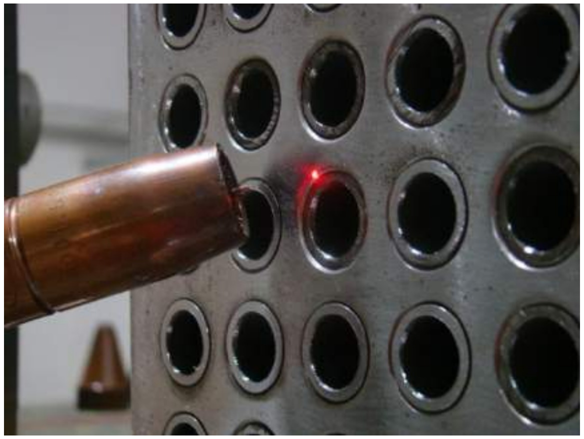
Catalyst Discharge Nozzle Design



SAW welding activity on Catalyst Discharge Nozzle to shell weld. Welder protected from preheating effect by means of coil with cold water circulated system

proprietary LBW robotized system





typical fas/fob/ro-ro load out at porto nogaro

hydrocracking reactors

Hydrocracking Reactors:
-1200 and 600 tons weights
- A336-F22 material
- 11 inches thk

mangiarotti spa

HDS reactors

CCR / FCC reactors

Platforming Reactor with Johnson internals
Installed (Scallops fitted at workshop, Centerpipes
Sent separately to site for assembling)

FCC Reactor

large columns/vessels

large / HP / chained exchangers

Thank You – Hope to see You soon !

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