Cycling operation for HRSGs
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- Features to be considered in the design of HRSGs specified for cycling operation
- Example of one unit designed for base load and retrofitted to cycling operations
WHY CYCLING?

Combined cycles can operate in two possible scenarios

BASE LOAD: the HRSG operates constantly at full load (100% MCR)

CYCLING MODE: the HRSG operates with frequent load variation, start-up, shut-down to cope with the market energy demand
IMPORTANT FACTORS AFFECTING HRSG CYCLING

• Fatigue in critical components (HPSH, IPRH, HP Drum)
• Number of cold&warm start-ups, quick load variation, trips, load rejection
• Start-up time and allowable gradients
• Thermal shocking
FATIGUE DUE TO ...

Alternating stress (+ / -)

Direct loading (internal pressure and mechanical loading)

Thermal stress: thermal gradients, temperature expansion, thickness of components

All these are amplified by stress concentration caused by sharp corners or geometrical singularities
Lessening the effects of fatigue

1) Minimize heat losses

2) Minimize extension of pressure and temperature cycles (holding the pressure, sparging steam, stack damper, insulation of the stack, etc...)

3) Control start-up rates

4) Minimize stress concentrations
N/E BEST PRACTISE FOR CYCLING

- Tubes to headers connections
- Minimization of HP drum thickness
- Superheater and reheater proper expansion
- Superheater and reheater drainage system design
- Desuperheating system
- Fatigue analysis through finite element approach
- Experience in field stress monitoring (BSE)
TUBE TO HEADER CONNECTIONS

“SET-ON” FOR HIGH ALLOY STEEL (HP SH, IP RH);

“FORGED STUBS” ON CRITICAL CONNECTIONS FOR FATIGUE (HPSH and IPRH outlet);

“STICK-THROUGH” FOR ALL CARBON STEEL CONNECTIONS
TUBE TO HEADER
“SET-ON” CONSTRUCTION

**NOTE:**
1. ALL TUBE HOLES MUST BE DRILLED.
2. THIS STANDARD APPLIES TO RADIAL AND HILLSIDE CONNECTIONS.
3. THIS STANDARD APPLIES TO ALL TUBES AND TUBE STUBS WITH “SET-ON” CONSTRUCTION.

**HOLE IN HEADER TOLERANCE**
+ 0" (0mm)
-1/32" (1mm)

**MINIMUM TUBE THICKNESS FROM THERMAL DATA SHEETS**

**FIT-UP TOLERANCE**
+1/16" (2mm)

**ALTERNATE ATTACHMENT BEVEL TUBE**

**NO BEVEL ON TUBE**

\[ H = A - (2.28 \times t) \]

**MINIMUM TUBE THICKNESS**

**HEADER I.D.**

**TUBE O.D.**

**Uncontrolled**
FORGED STUBS

DETAIL "E"

SEE DWG N1008-00-M-262
TUBE TO HEADER
STICK THROUGH” CONSTRUCTION

NOTE:
1. EITHER SINGLE 60° BEVEL OR SINGLE “J” BEVEL IS ACCEPTABLE.
2. IF $t_H$ IS EQUAL TO OR LESS THAN $t_W$, $t_W$ SHALL BE EQUAL TO $t_H$.
3. THIS CONSTRUCTION IS ACCEPTABLE FOR ANY MATERIAL COMBINATIONS.
4. THE WELD PROCEDURE MUST HAVE PROVISIONS FOR ENSURING
   THAT THE FULL DEPTH OF WELD REQUIRED BY $t_W$ IS ACHIEVED.
5. TUBE HOLE FINISH SHALL BE 250 NOMINAL MICROINCHES (AA)
   ROUGHNESS IN ACCORDANCE WITH ANSI STANDARD B46.1.
6. PREPRODUCTION SAMPLES INDICATING AN ACCEPTABLE PROCEDURE
   IS REQUIRED TO OBTAIN WELD PROCEDURE APPROVAL.

CB12VK
HP Drum temperature gradients

- Drum shell is heated from inside by the boiling water and the heat is transmitted from inside to outside generating a thermal gradient and stress.
MINIMIZE HP DRUM THICKNESS

• The HP drum is the highest thickness component, so most sensitive to fatigue
• Start-up allowable gradient is strictly related to the HP drum thickness
• Use of 15NiCuMoNb (WB36) reduced HP drum tck of 35-40% lower than ASME A516 Gr70 material, reduces fatigue and improves start-up gradient
FATIGUE ANALYSIS

• It is carried out through finite element analysis, using Ansys SW and based on EN 12952-3

• It is extended to the highly stresses components for fatigue and load change (HPSH, RH, HP drum)

• The more “robust” is the design, the worse is for fatigue
BOILER STRESS EVALUATOR

- Monitoring of inner wall / mid wall temperature for critical components (HP drum, HPSH, RH);
- Evaluates on-line the life consumption for fatigue and compares with design data;
- Allows an intelligent “modulation” of the cycling operation in order to minimize the life consumption of the HRSG and optimize its operating life;
- N/E has applications of this system in several plants.
SH/RH DESIGN AND DRAIN SYSTEM

• Condensate can fill HPSH and RH
• Every hot or warm start-up large amount of condensate is generated inside SH/RH coils
• Condensate MUST be removed prior to produce steam
• Drain properly sized and routed
SHTR/RHTR Tube Damage
Spray with Inadequate Steam Flow

- Inadequate quantity of steam to vaporize water (<25% MCR)
- Water drops out
RH BY-PASS

• OPTIMIZATION OF THERMAL PERFORMANCE FOR OFF-DESIGN CASES;
• IMPROVEMENT OF STEAM QUALITY TO THE STEAM TURBINE;
• REDUCED THERMAL STRESS ON RH PIPING;
• OPTIMIZATION OF PIPING LAY-OUT
Reheat Bypass
Common Crossover Line

Desuperheater Location

Sloped Line
SH/RH drains and desuperheater drain pot

Level Switches

Automatic valve is a quick acting ball valve
SH/RH Drains
Consider quick acting metal seated ball valves
SPARGING STEAM

- Ensures that the start-up after W/E is from warm conditions
- Maintains 2bar@120°C inside drums
- Compensates the heat dispersions and losses through boiler casing and stack damper
- Steam demand: 3 T/h, 8bar@170 °C
STACK DAMPER

Expected HP Pressure reduction
after GT shutdown from BASE load

Turbigo HRSG

Stack damper closed

HP Drum pressure (barm)

Hours after shutdown
Tube to Tube Temperature Differences

• SH/RH tubes in each row operate at a different temperature

• Different ways to absorb expansion
  – Internal coil flexibilities
  – Allow parts to move freely

High pressure drop results in good steam flow distribution minimizing temperature differences
Spring Support of Header

Fixed Header

Floating Header of Same Coil
Example of Brindisi flexibilization

• Scope: modification of Module 1 bundle supports method in order to make the units suitable for cycling + RH repairs.

• Turn-key Contract (Engineering + material supply + erection activities).

• Tight time schedule: 35 solar days allowed to complete the works
Example of Brindisi flexibilization – baseline configuration
Example of Brindisi flexibilization – final configuration
Brindisi Flex - Supports modifications SH1
Brindisi Flex - Supports modifications RH
Brindisi Flex - Supports modifications SH2

CONDIZIONE D'ANALISI: - SUPPORTI ORIGINALI

CONDIZIONE D'ANALISI: - SUPPORTI MODIFICATI

NOOTER/ERIksen
Brindisi Flex. - 3D Model
Brindisi Flex. - 3D Model
Brindisi Flex. - 3D Model
Brindisi Flex. - Implementation
Brindisi Flex. - Implementation
Brindisi Flex. - Implementation
Brindisi Flex. - Implementation
Conclusions

• Many of the HRSGs originally specified and designed for base-load conditions now are required to run as cycling units.

• Retrofitting of these units is possible to include features necessary to meet severities of cycling duty.

• To accomplish the above it is highly advisable to ask the services of an engineering firm (preferably an HRSG manufacturer).