Vogt Power International

A Babcock Power Inc. Company

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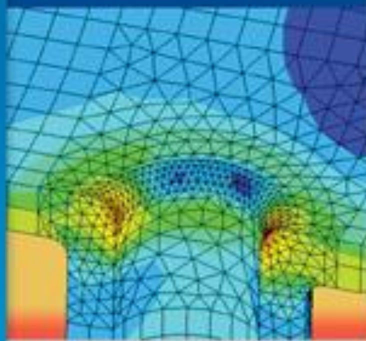

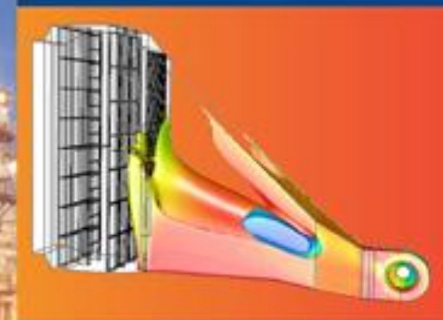

Design Considerations for Advanced Combined Cycle Plant Using Fast Start Drum Type HRSGs

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Fast Starts and Cycling

Fast Start-ups and Cycling are not the Same

Fast Start-ups are desired:

- To limit the total Emissions during a start
- To Reduce start-up cost
- To Achieve Full load revenues faster

Cycling Occurs when:

- Units are started and shutdown according to load demand
- Units are in load following mode
- Cost effectiveness of plant drives the amount of cycling to some extent.

Fast Start Ups are Invariably Connected with Cycling

Vogt Approach to Fast Start HRSG Design

Traditional Approach:

Design for Mechanical Integrity of the Pressure parts to withstand

- specified number of start-up cycles and
- number of hours at elevated temperatures

Usually a Life Cycle analysis is done using ASME / API or EN Code procedures

These analyses are inadequate because:

- They are based on assumed number and types of cycles which may not happen in real life
- Considers only the pressure parts
- No provision for gauging the effect of operation beyond the specified envelop

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Vogt Approach

DESIGN

- Design for Mechanical Integrity of the Pressure parts to withstand
  - specified number of start-up cycles and
  - number of hours at elevated temperatures

- Check the Effect of Cycling on Non Pressure parts
- Consider Operations Impact on Valves and Attemperator Design

OPERATIONS

- Determine the impact of Operations which are beyond those specified
- Determine Water Chemistry Control Requirements for all modes of operations including shutdowns and lay-ups
- Develop the complete Emission control picture

Vogt Approach - Continued

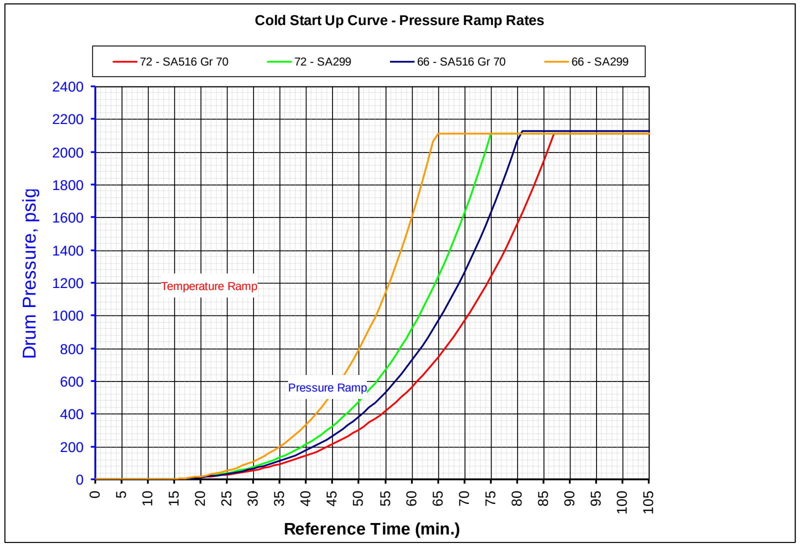
MONITORING for MAINTENANCE

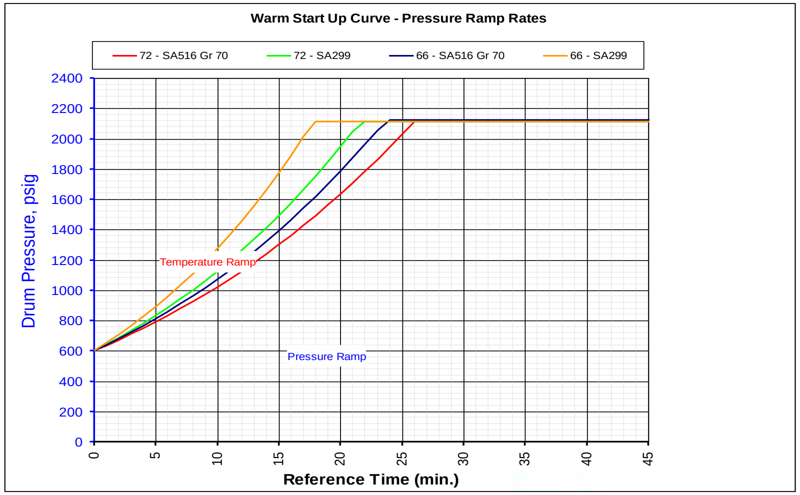
- Monitor the Life Consumption as the operations progress to gauge the effect of all operations
- Since all components do not age uniformly, it is necessary to determine the Critical Components and monitor life consumption individually
- Develop Focused Inspection Schedule based on actual operations for more Cost Effective Maintenance
- Consider the complete Operating Envelop not just start-ups and Regular Operations
  - Start-ups
  - Ramping to Load
  - Load Changes
  - Shutdowns
  - Lay-ups
  - Regular Operations

Pressure Part Design Consideration : DRUM

Drum Design

- Design
  - Utilizes Steam Drum for storage volume and steam / water separation.
  - Storage volume is normally sized for swell and hold up time.
  - Reduction in drum size will lead to faster start up times
- **Control System**
  - Conventional controls known by all operators.
  - Will utilize IBD or Start Up Drain for swell control.
- **Materials of Construction**
  - All Carbon Steel Construction
  - Utilize SA299 Gr B for Drum





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Other Design Considerations

- **Full Penetration Welds**
- **Larger Headers**
- **Purge Credit Features**
- **Automated Vents and Drains**
  - Remove condensate and gasses. Avoid Thermal Shock
  - Requires condensate drain pots for positive verification of condensate clearing in HP superheaters and Reheaters
- **Wet Reheaters**
  - High Pressure Superheater bypass to Cold Reheat
  - Flow of steam through Reheater when there is no ST.
  - Avoid high metal temperature and Thermal Shock due to quenching with initial steam flows
- **Motorized Blowdowns**
  - Water circulation through Economizers, Evaporator Circulation,
  - Drum Chemistry Control

Cycling Design Considerations

- **Leak Proof Valves**
  - In attemperators for avoiding impingement and Water dump into Superheaters
  - Keep system under pressure to conserve energy during shutdown.
- **Stack Dampers**
  - Improve the operating cycles
    - Cold to Warm
    - Warm to Hot
  - Cold start causes 7 times more life usage than a warm start
  - Warm start causes 4 times more life usage than a Hot start
  - Stops heat migration and thereby reduce thermal shock on Economizer sections
- **Metal Temperature TCs**
- **Minimization of Bends**
- **Flexible Connections**
- **Smaller diameter, tubes, headers and drums**

Cycling Design Considerations

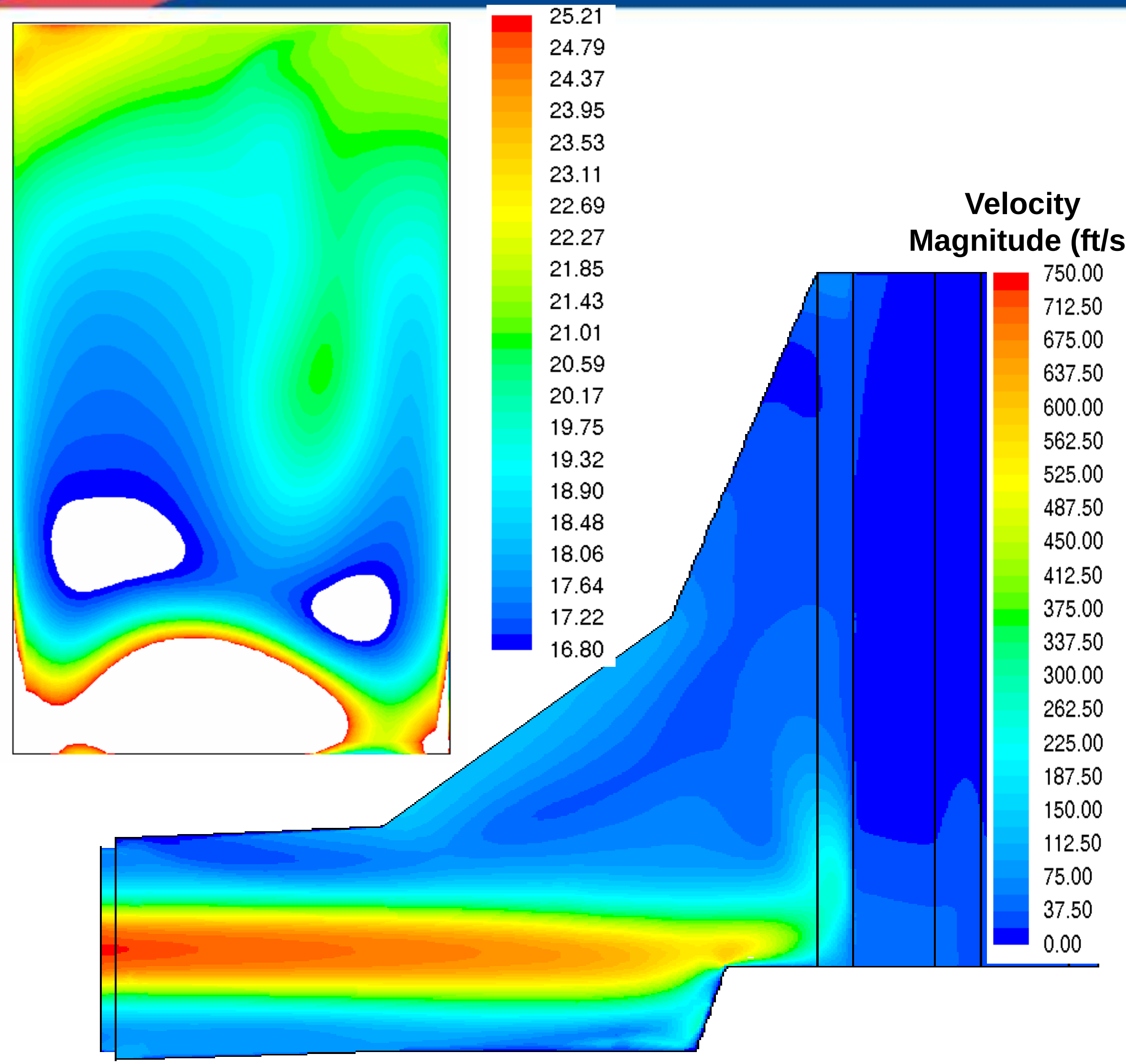
Less Effective Design Features for Cycling

- **Bypass System**
  - Do not allow for emissions to be met during simple cycle operation
  - Gas side dampers to control start-up, but difficult to control
  - Increased maintenance problems due to moving parts in hot gas path
- **External Steam Sparging**
  - Keep boiler warm with external steam
  - May be used for Freeze Protection
  - Requires external steam source usually from a aux boiler
  - Steam cost may increase operating cost

Impact on Non Pressure Part

CFD analysis to determine the :

- The length of the duct required for taming the Velocity
- Configuration required for proper distribution
- 75-80 % of the area within 20% of the average velocity
- The forces on various walls of the duct



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Impact of Exhaust Profile on Pressure part design

- Tube Wrappers Design
- Tube supports (tube Bumper) Design
- Design, height and thickness of the tube sheets
- Fin type and fin configuration.
- Side wall baffles.
- Shop installed center baffles
- Field installed center (nose) baffles

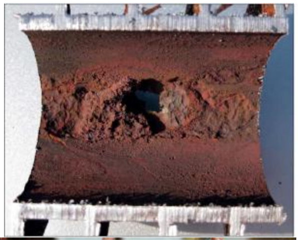
Operational

On-Line Monitoring of Water Chemistry & Dosing

- Water Chemistry is upset all the time –
  - during start-ups,
  - shutdowns,
  - lay-ups and storage

- Monitoring is required at all times
  - pH, 9.0-9.6. LP – 8.8
  - DO 2-7 ppb Operation, 20ppb Max upset
  - Conductivity- Specific 0.1 Max
  - Cation and Degassed CC are becoming more prevalent
  - Na
  - Corrosion Product Transport (Fe & Cu)
  - Silica
- No Cascading Blowdown
  - Avoid water chemistry Imbalance
  - Hot water impingement on cold IP, LP drums

- Use AVT with Phosphate as reserve
- Condensate polisher may be needed
- Dosage to be calibrated for expected water quantity
- FAC Considerations
- Nitrogen Blanketing during Lay-ups
- Condensate Leakage Monitoring and Control



Through the wall tube failure and pitting due to bad chemistry

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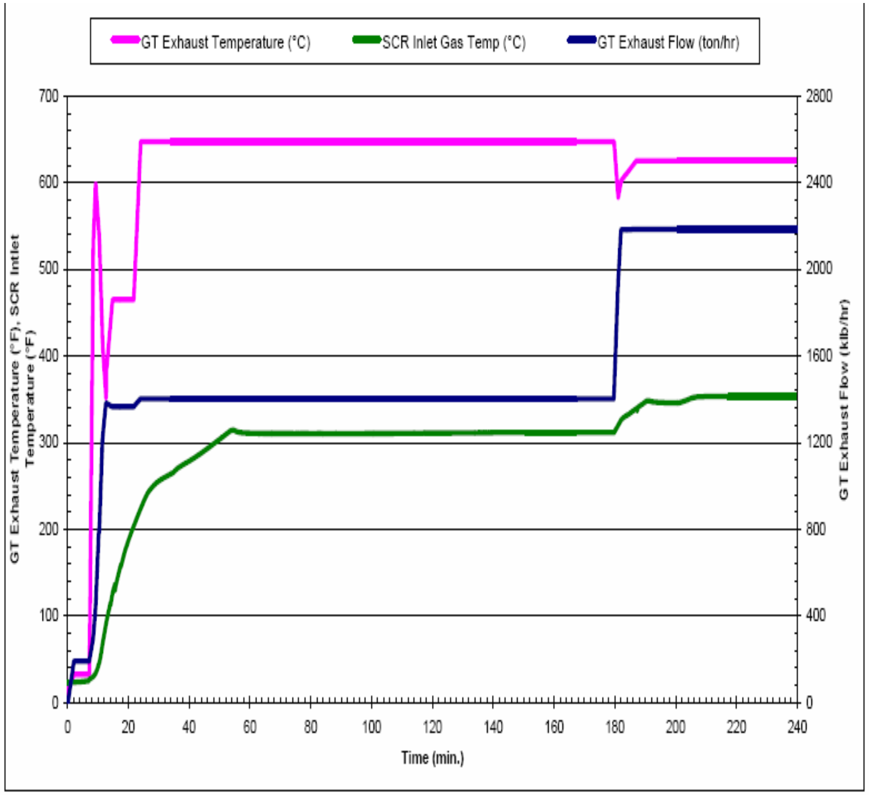
Operational

Emission Controls - Discussion

- The fast start Emissions from GT need to be defined for all start-up and Operating conditions
- The SCR Temperature Conditions should be determined based on Dynamic analysis
- SCR efficiency at each of the conditions can then be determined
- The total emissions for each of the starts and operating conditions are calculated

COLD Start - Temperature at SCR



Fast Starts and Cycling Operations

- The key point for Cycling units is Not just Designing for Cycling
- Also need to have the Ability to gauge and **monitor** (as the unit ages) The Impact of Fast Starts and Cycling, on the
  - HRSG Component integrity and
  - Whether the component Replacement is
    - Cost effective and
    - Predictable

This Operational Control Ability can be attained by an On-line Operation Monitoring Software

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Operations Monitoring Through VPI 's LCAMP™ Software

- LCAMP™ (Life Consumption Assessment & Monitoring Program) is such a program
- It is a set of Computer Software for Assessing Consumption and A Process for Controlling the Operations

LCAMP™

- Acquires the actual operating data from Plant DAS
- Analyzes and Conditions the data
- Quantifies the operations using the conditioned data
- Calculates the Life expenditure of Critical and/or Specified HRSG components Dynamically *and*
- Processes the information for various
  - Condition Assessments,
  - Status Reports *and*
  - Control Decisions

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How LCAMP™ Monitors Life Assessment?

- The basic life consumption quantifier is the Damage Factor (d*f*), which takes into account both Fatigue and Creep damage

- LCAMP™ calculates component damage factors using Established Code methodologies and the Actual data as the operations proceed

- Damage Factor (d*f* = *1.0*) indicates Possibility of Crack Initiation in the component.

- d*f* = *1.0* *does not indicate* Component Breakdown

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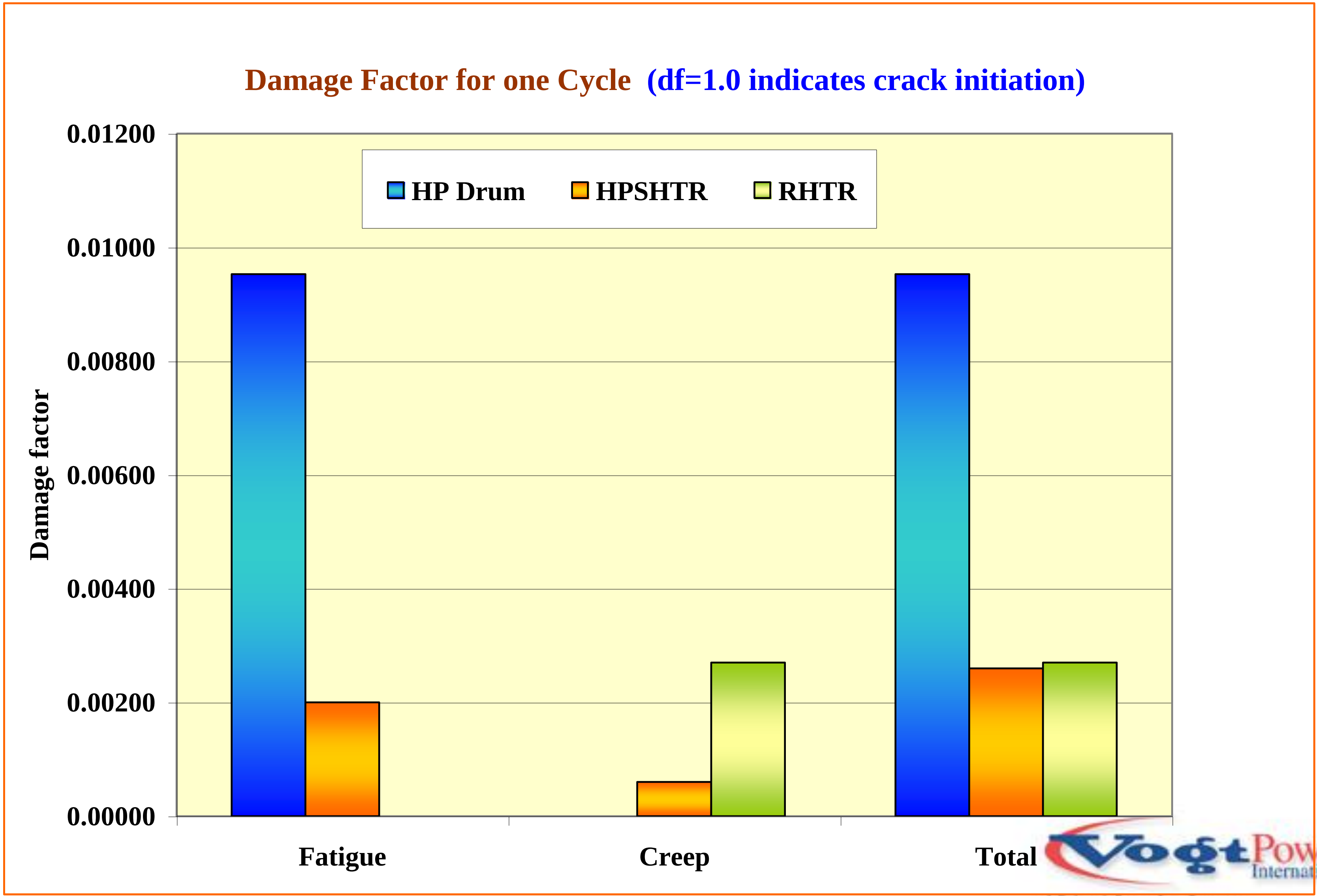
Graphic representation of Total Damage Factor for a given condition



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HRSG Design Features

Vogt LCAMP™ Monitoring Information

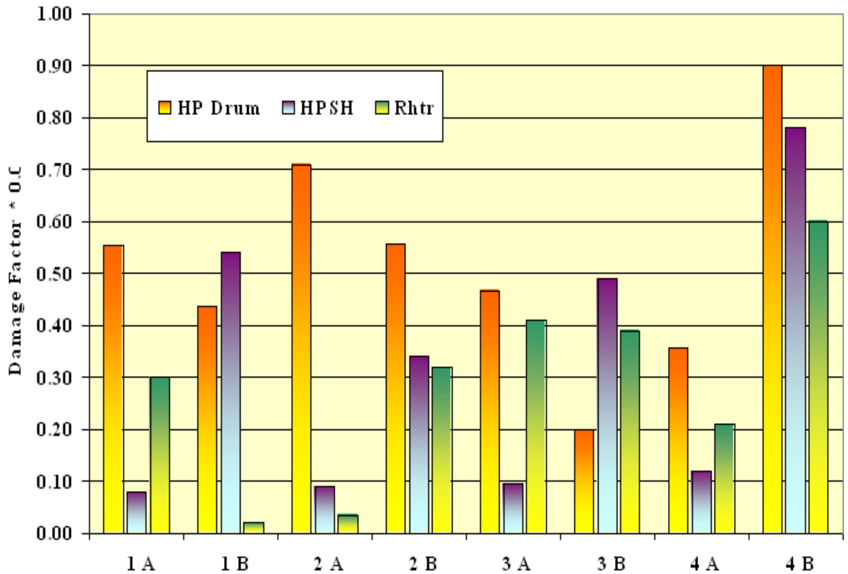

Fig. 16: Comparing consumption of typical start-up procedures from various u

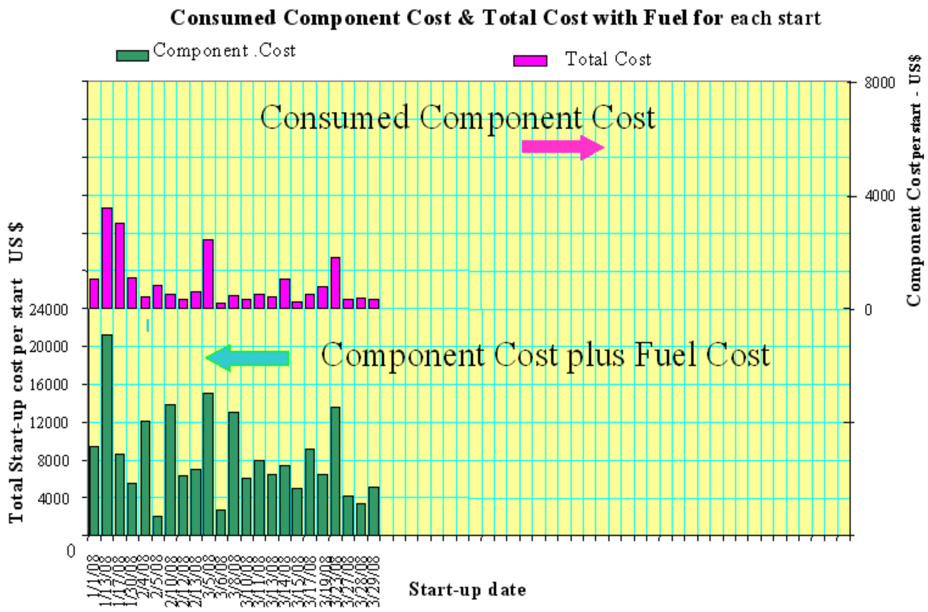

Fig. 17: Cost of Component consumption and the added fuel cost for typical starts

The data from these graphs is used to determine the most economical start-up and operational procedure for various units in the fleet. The decision can be further refined if the revenue making possibility is there for earlier starts.

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HRSG Design Features

Vogt LCAMP™ Software

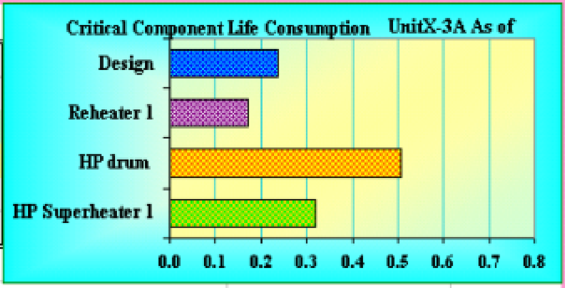
Monitoring Information for Effective Control

Figure shows a typical report indicating all the affecting parameters and status of the unit on certain given date.

This information is based on Actual Operations

LCS1 - Life Consumption - to-date LCAMP™

Today's Date	8/13/2008	
Plant	ABC Power	
Unit	UnitX	3A
End Date for Data	3/1/2001	4/25/2008
Start-up Cost	$/hr	



Reference Date (Date information last updated) **Friday, April 25, 2008**

Life Consumption		HP Superheater 1	HP drum	Reheater 1	Design
Life Consumed till ref date	04/25/08	0.3178	0.5084	0.1711	0.2385
Average Usage per hour		5.38E-06	8.04E-06	3.02E-06	

Inspections	df	HP Superheater 1	HP drum	Reheater 1
Component Inspection Date	0.3	October, 2008	May, 2005	February, 2010
Focuseed Inspection	0.5	June, 2012	March, 2008	February, 2016
Detailed Inspection	0.7	January, 2020	January, 2011	February, 2022
Posssible Repair date	0.9	May, 2027	November, 2013	February, 2028

Historical Cycle Data	No. of Cycles till refernce date	
	Total Cycles todate	Avg. Cycles / month
Hot	80	0.8
Warm	931	9.4
Cold	205	2.1
Total	1,217	12.3
Total Hours		

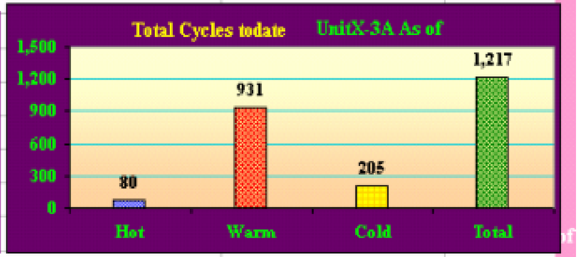


Fig. 18: Typical Life Consumption Report