REINHOLD ENVIRONMENTAL ®

2022 Reinhold/PCUG Round Table Presentation

Hosted by Duke Energy in the Charlotte Sheraton/Le Meridien Hotel, Charlotte, NC on June 27-28, 2022

Duke Energy Dual Fuel

Cliffside, Belews Creek and Marshall Natural Gas Firing Update





Richard Roy, PE
Dual Fuel Cliffside Project Engineer
Cliffside Station System Owner

AGENDA

- ❑Goals of the Dual Fuel Programs
- ❑Projects timelines
- ❑Unit Designs
- ❑Installations
- ❑All unit's lessons learned
- ❑ Emissions challenges
- ❑All units testing results

2016 Program Goals

Reduce environmental footprint

- Reduced CO2
- Reduction in Fuel Oil usage and handling
- Reduction in coal usage

Increase fleet flexibility to adapt to renewables

- Lowered Unit Minimum Load
- Increased Unit Ramp Rates

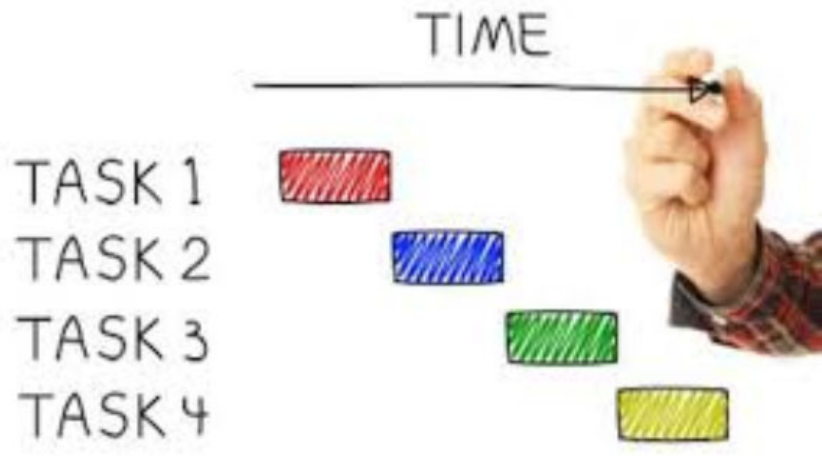
Deliver savings to our customers

- Option to utilize lowest cost fuel on a daily basis
- Drive competition
- Respond to fuel procurement bottlenecks

Projects Status

Cliffside

- Approved July 2016
- Feb 2018 - Engineering Complete
- Mar 2018 - Construction Start
- Unit 5 - Nov 2018 In Service
- Unit 6 - Dec 2018 In Service
- Unit 5 & 6 - Spring 2019 Performance Testing Complete
- **Firing Natural Gas or Coal based on Economics**



Belews Creek

- Approved Aug 2017
- Oct 2017 – Engineering kick-off
- Nov 2018 – Engineering Complete
- Unit 1 – Fall 2019 In Service
- Unit 2 – Fall 2020 In Service
- Performance testing complete Unit 1 June 2020
- **Firing Natural Gas or Coal based on Economics**

Marshall

- Approved Dec 2017
- Feb 2017 – Engineering kick-off
- Fall 2019 – Engineering Complete
- Units 3 & 4 – Fall 2020 In Service Date
- Units 1 & 2 – Fall 2021 In Service Date
- **Firing Natural Gas or Coal based on Economics**

Cliffside Unit 5

Unit Design

- Commercial in 1972
- 600 MWg
- Combustion Engineering Boiler
- 4 Corner T-Fired
- 24 coal burners
- 2400 psig (Sub-Critical)
- 1005 F SH / RH
- 100% MCR Heat Release 5910 mmBTU/hr

- SOFA
- CCOFA
- LOFIR

Environmental Controls include

- Selective Catalytic Reduction (SCR)
- Electrostatic Precipitator
- Wet Flue Gas Desulfurization (WFGD)

Gas System Design

- Riley Design
- 40% Gas Firing Capacity
- 2 Levels of Wafer Style Gas Burners
  - Located in Auxiliary Air Ports
- Each Burner Heat Release = 271 mm BTU/hr
- 1 Level of Wafer Style Ignitor for LOFIR level
  - Located in Auxiliary Air Port
- Each Ignitor Heat Release = 40 mmBTU/hr

- Goal is to operate with 2 Gas Levels and 4 Coal levels in service at Full load if doing 40%
- When U6 operating at full load – only 10% available by gas supply contract.
- Actual gas firing capacity 220 MW

Gas Emissions Targets @ MCR (60/40 co-fire)

- NOx < Baseline
- CO < 0.08 lb/mmBTU
- 2170 mmBTU/hr Heat Input from Gas (40%)
- Baseline Excess Air (3% O3 wet)

Cliffside Unit 6

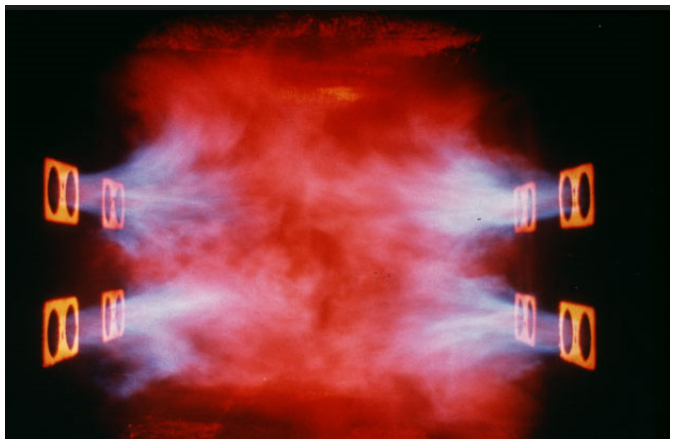
Unit Design

- Commerical in 2012
- 905 MWg
- Hitachi Boiler
- Opposed Wall Fired Spiral Furnace
- 30 coal burners / 3 Elevations per Wall
  - Full load on 25 burners
- 6 Pulverizers
- 3700 psig (Super-Critical)
- 1055 F SH / 1075 F RH
- Each Burner Heat Release = 320 mmBTU/hr

- OFA
- Side Air Ports

Environmental Controls include

- Selective Catalytic Reduction (SCR)
- Spray Dryer Absorber (SDA)
- Fabric Filter
- Wet Flue Gas Desulfurization (WFGD)



Gas System Design

- Riley Design
- 100% Gas Capacity
- 30 Gas Burners / 3 Elevations per Wall
  - 28 burners needed for full load
- Each Burner Heat Release = 263 mmBTU/hr
- Cane style gas burner located in Secondary Air Plenum of existing coal burners
- 1 Gas Flow Control Skid per burner level (Qty 6)
- Actual gas firing capacity 905 MW

- Gas Targets:
  - NOx < 0.25 #/mmBTU,
  - CO < 0.037 #/mmBTU
  - VOC < 0.0023 #/mmBTU
  - Excess Air < 17%
  - MCR, 100% Natural Gas

Belews Creek Units 1 & 2

Unit Design

- Babcock and Wilcox
- 1170 MWg
- Opposed Wall Fired
- 80 coal burners / 4 Elevations per Wall
  - Full load on 72 burners
- 3500 psig (Super-Critical)
- 1005 F SH / RH
- 100% MCR Heat Release = 10,590 mmBTU/hr
- OFA

Gas System Design

- Riley Design
- 50% Gas Capacity (~70% with ignitors)
- 32 Gas Burners / 2 Elevations per Wall
- Each Burner Heat Release = 171 mmBTU/hr
- Cane style gas burner located in Secondary Air Plenum
- 1 Gas Pressure Control Skid per burner level (Qty 4)
- Goal is to operate with 4 gas levels and 4 pulverizer burner sets in service at full load
- Replacing fuel oil ignitors with natural gas ignitors on remaining 48 burners = 50 mmBTU/hr
- Actual gas firing capacity 850 MW (72%)

Marshall Units 3 & 4

Unit Design

- Combustion Engineering
- 700 MWg
- 8 Corner T-Fired
- 48 coal burners
- 3500 psig (Super-Critical)
- 1007 F SH / 1000 F RH
- 100% MCR Heat Release = 6930 mmBTU/hr

- SOFA
- CCOFA
- LOFIR

Gas System Design

- Riley Design
- 50% Gas Capacity
- 2 Levels of Wafer Style Gas Burners
  - Located in Auxiliary Air Ports
- Each Burner Heat Release = 212 mmBTU/hr
- 1 Gas Pressure Control Skid per burner level (2)

- 1 Level of Wafer Style Ignitor for LOFIR level
  - 42 mmBTU/hr
  - Located in Auxiliary Air Port

- Goal is to operate with 2 Gas Levels and 4 Coal levels in service at Full load
- Actual gas firing capacity 420 MW (60%)

Marshall Units 1 & 2

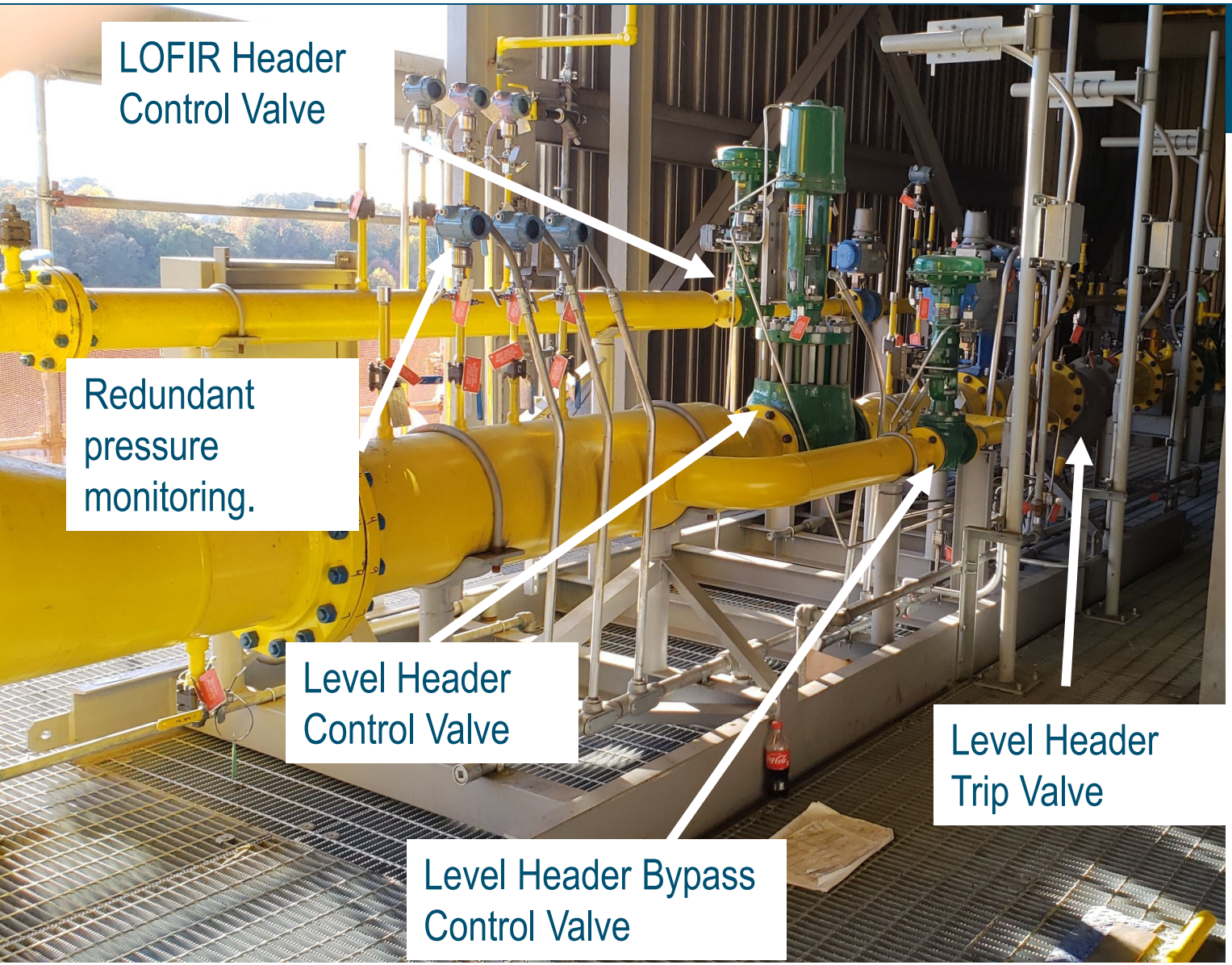
Unit Design

- Combustion Engineering
- 400 MWg
- 8 Corner T-Fired
- 40 coal burners
- 2400 psig (Sub-Critical)
- 1050 F SH / 1000 F RH
- 100% MCR Heat Release = 3885 mmBTU/hr

- SOFA
- CCOFA

Gas System Design

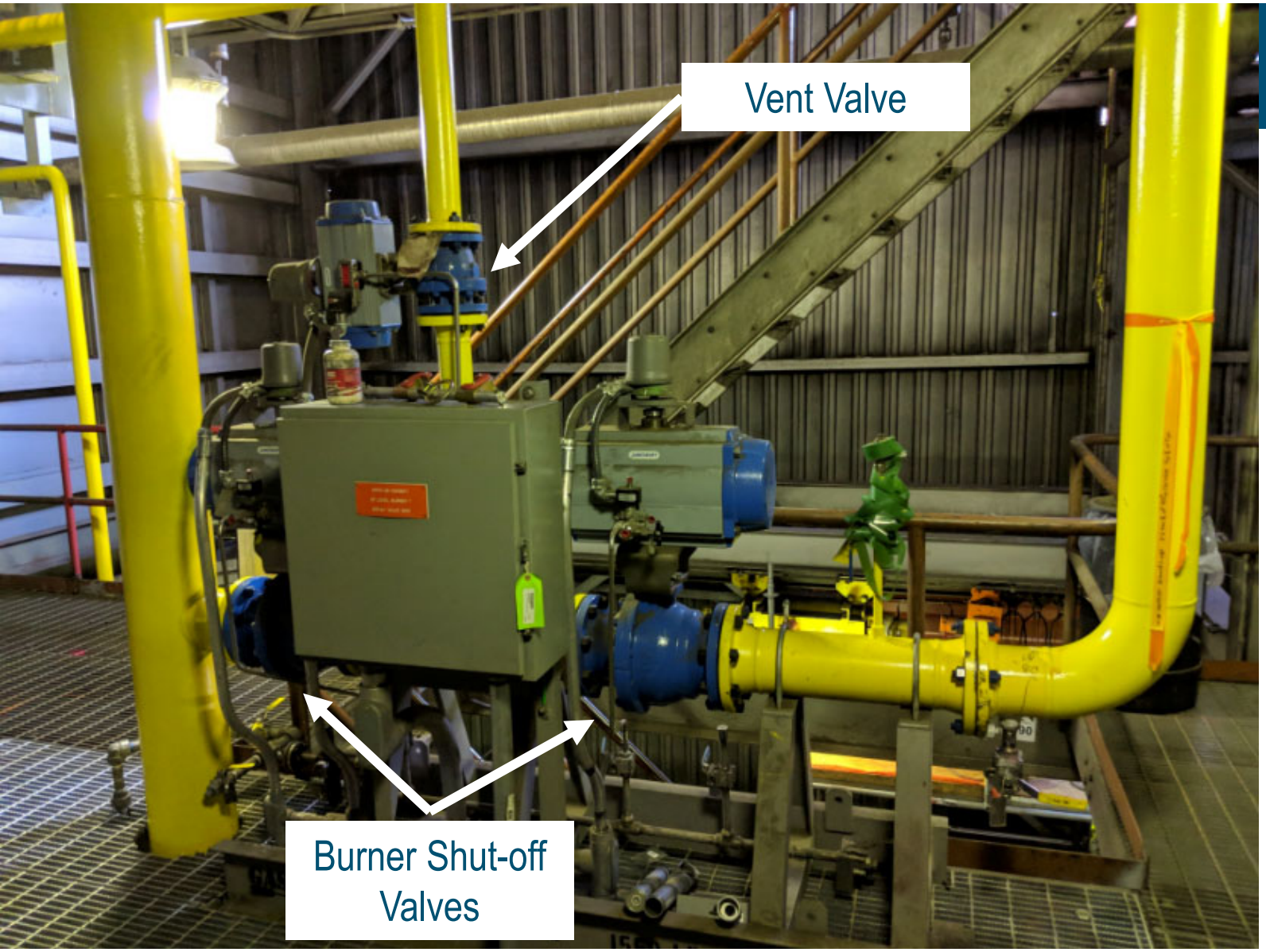
- Riley design
- 40% Gas Capacity
- 2 Levels of Wafer Style Gas Burners
  - Located in Auxiliary Air Ports
- Each Burner Heat Release = 90 mmBTU/hr
- 1 Gas Pressure Control Skid per unit
- 1 Level of Wafer Style Ignitor for LOFIR level
  - 18 mmBTU, Located in Auxiliary Air Port
- When Units 3 & 4 are utilizing maximum gas only 10% available for use on 1 & 2, 40% capacity provides flexibility for times when 3 & 4 are at reduced load or possibly offline
- Actual gas firing capacity 185 MW (46%)



Cliffside Unit 5

Fuel Control Skid

Very similar to other skids

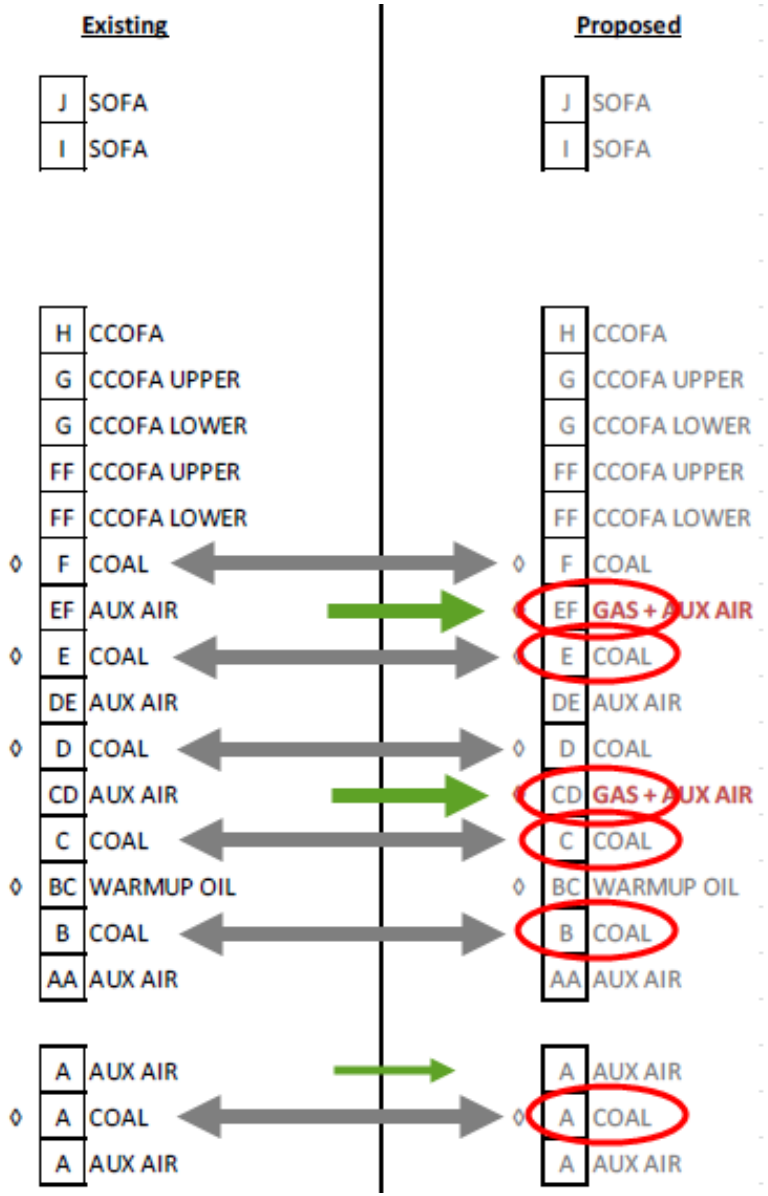


Cliffside Unit 5

Burner Shut-off Skid

Very similar to other units.

Cliffside 5 Burner Elevations



- Gas Levels interspersed between Coal Levels
  - Based on modeling results to control temperatures and heat flux
  - Provides Gas ignition source for coal burners
  - Wafer Style gas ignitor for A Coal Burner
- Optimum Firing Arrangement
  - 2 Gas Levels In Service - CD and EF
  - 4 Coal Pulverizers In Service
    - A and B
    - Select 1 C or D
    - Select 1 E or F based on Temperature Control

Marshall 1, 2 burner elevations

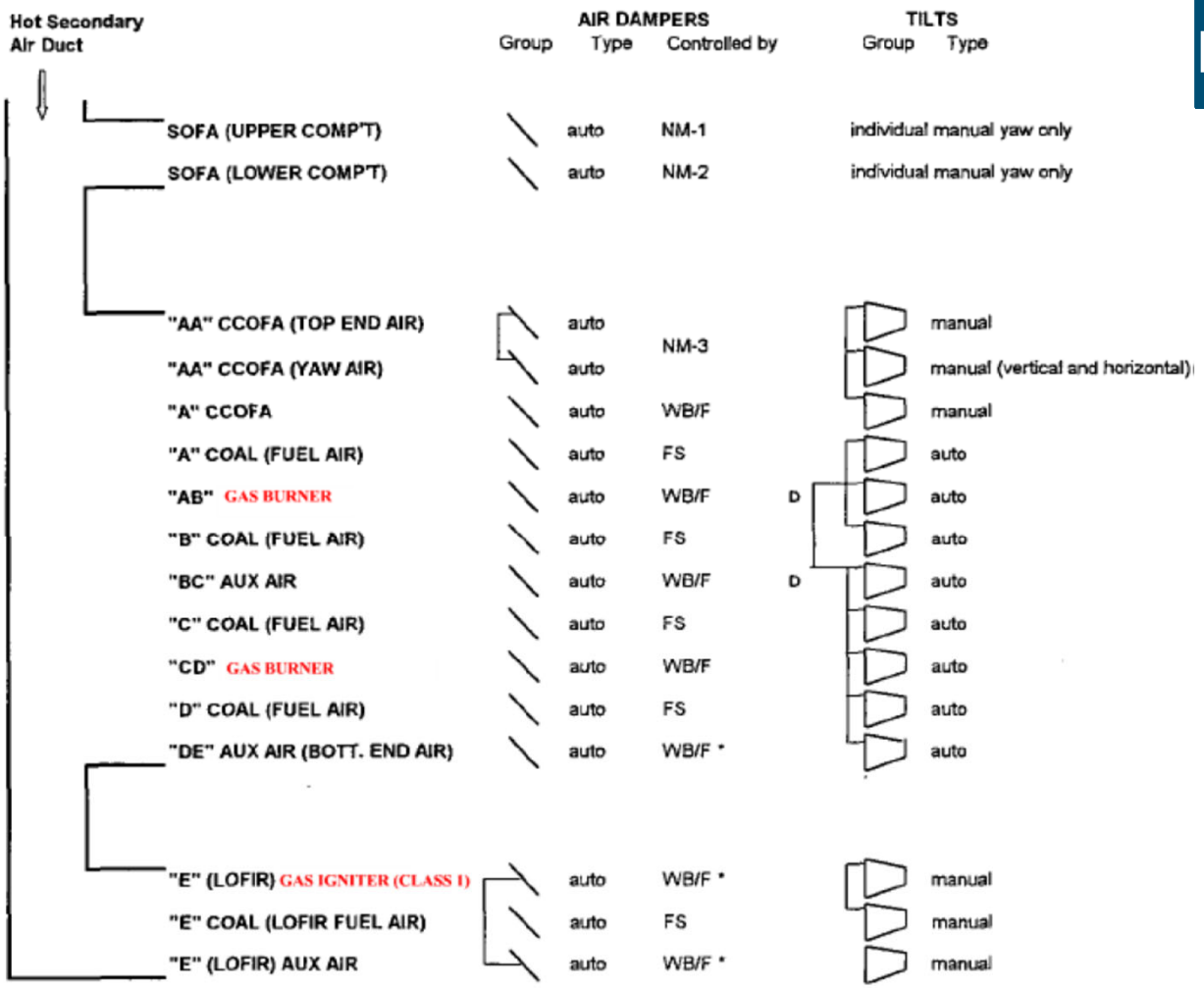
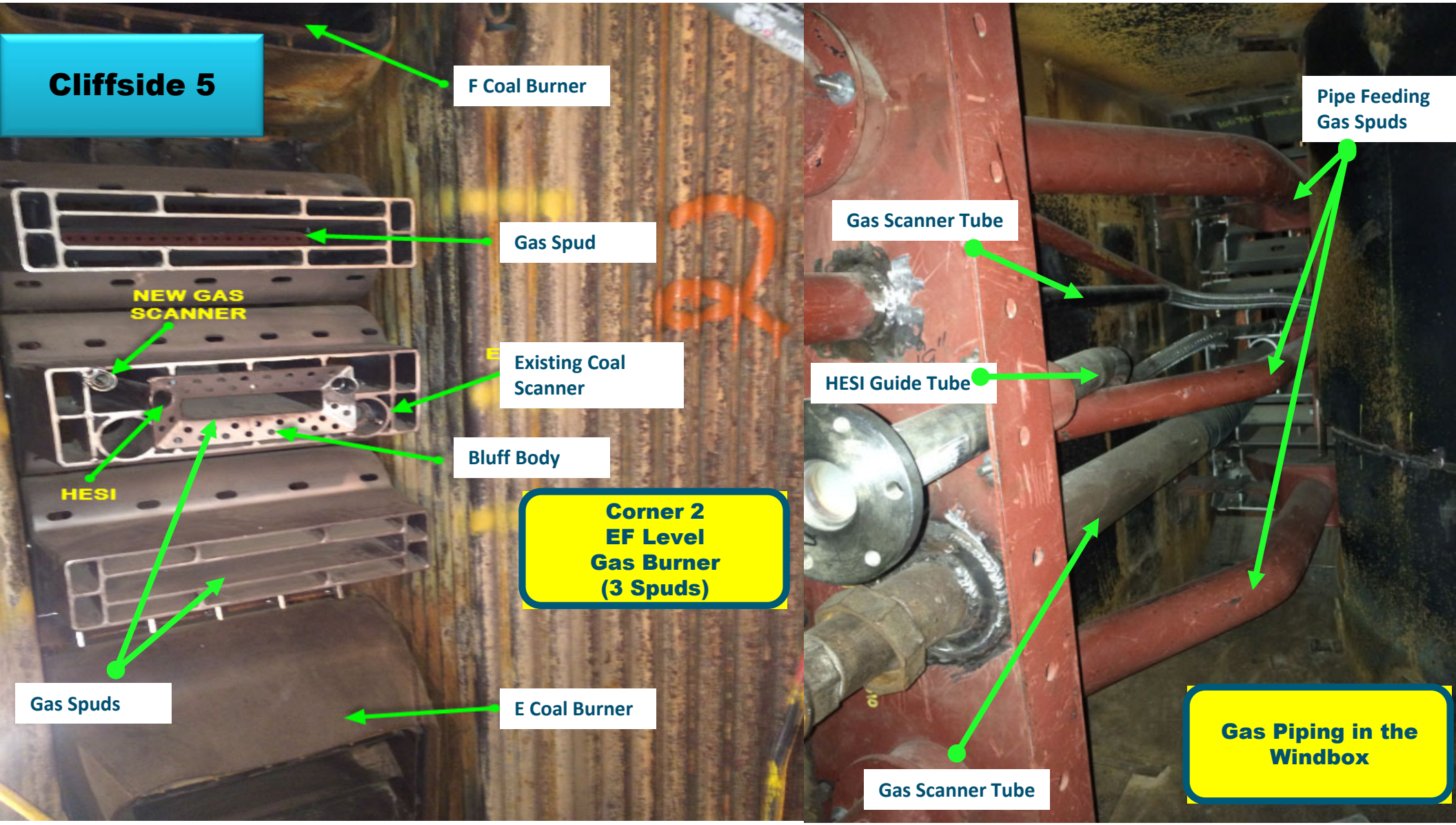
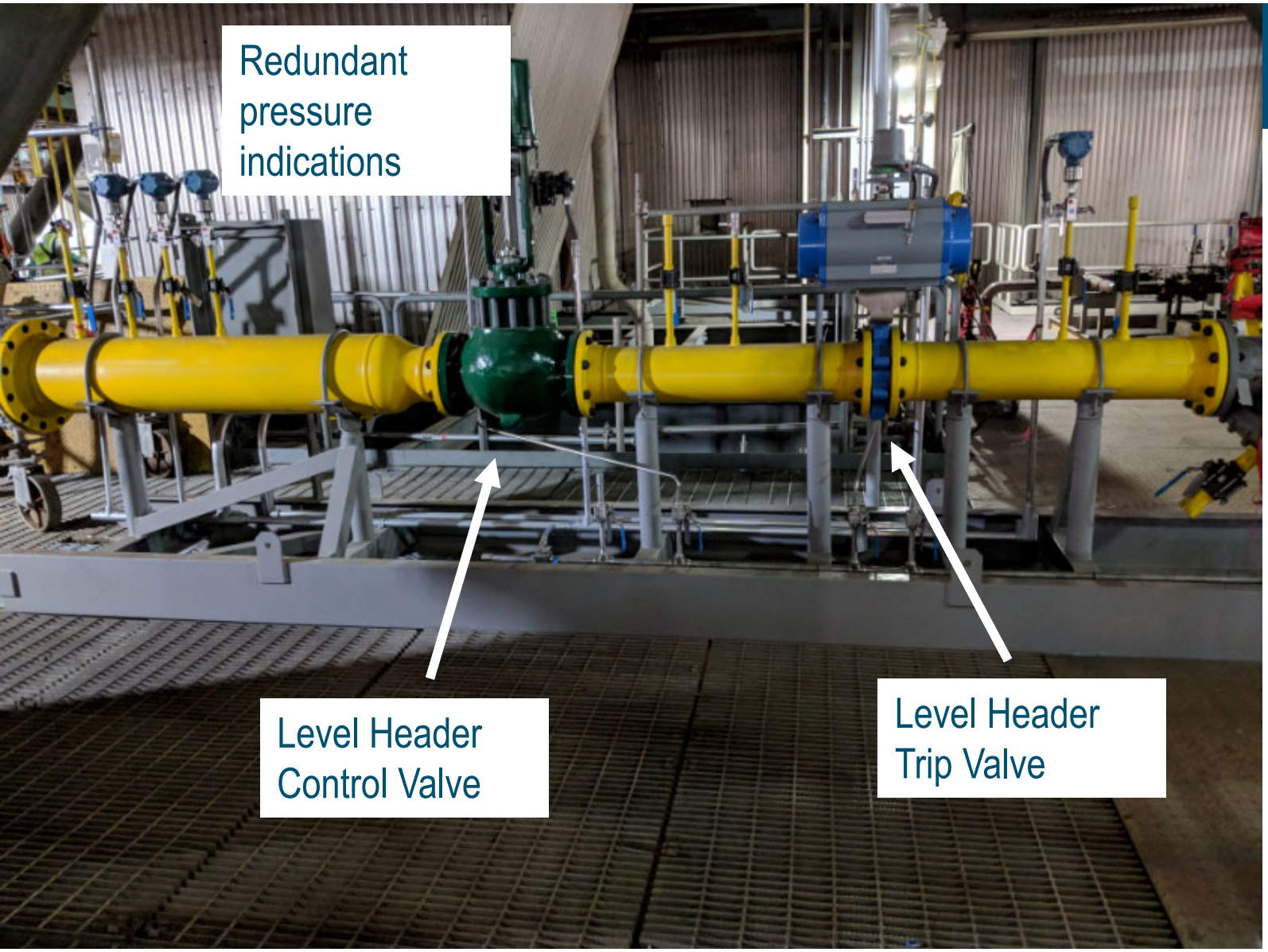


Figure 1: Marshall Unit 1 Air Dampers and Control Mode

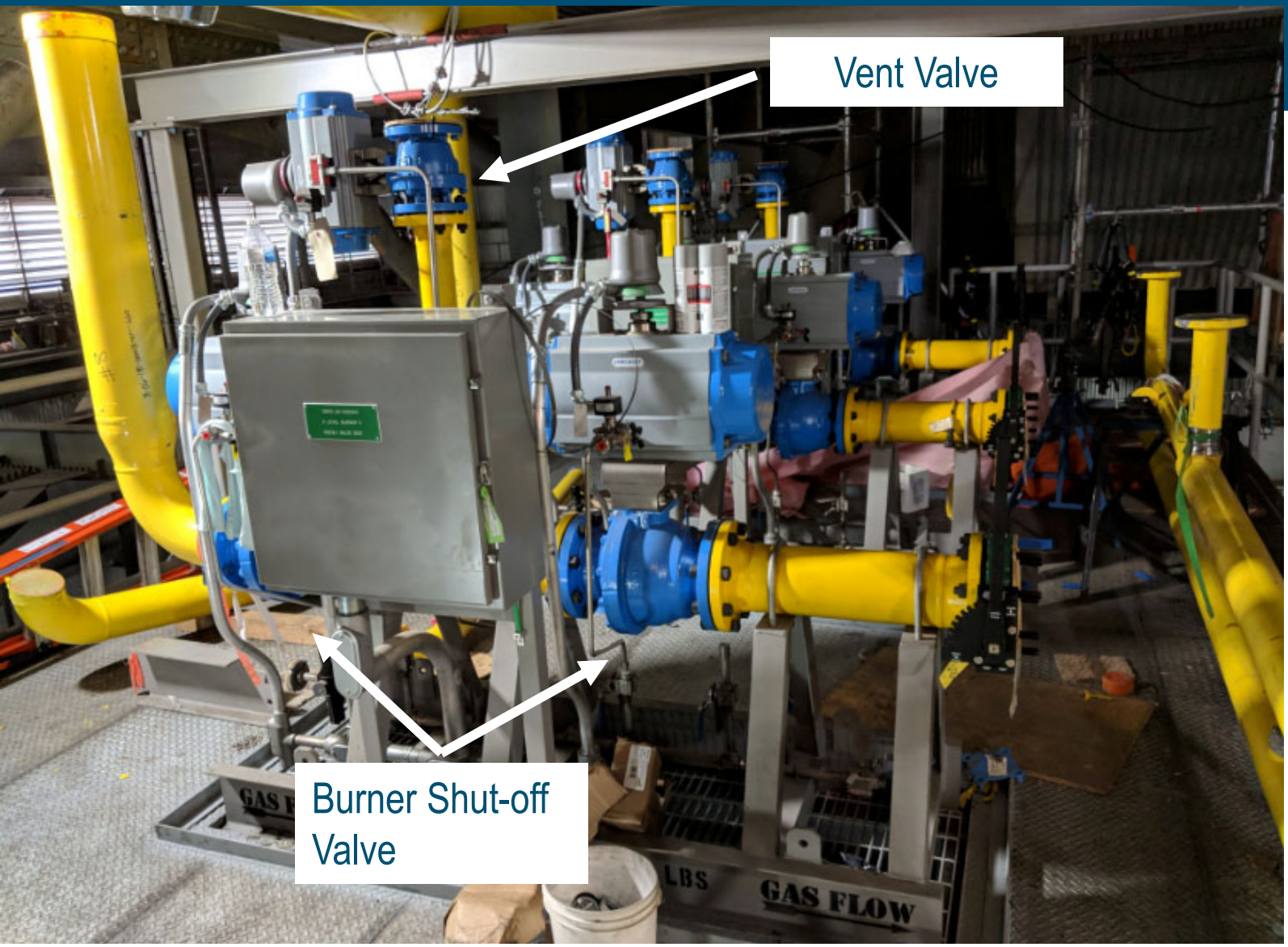
- Gas Levels interspersed between Coal Levels
  - Based on modeling results to control temperatures and heat flux
  - Provides Gas ignition source for coal burners
  - Wafer Style gas ignitor for A Coal Burner


Cliffside 5
F Coal Burner
Gas Spud
NEW GAS SCANNER
Existing Coal Scanner
HESI
Bluff Body
Corner 2
EF Level
Gas Burner
(3 Spuds)
Gas Spuds
E Coal Burner
Pipe Feeding Gas Spuds
Gas Scanner Tube
HESI Guide Tube
Gas Scanner Tube
Gas Piping in the Windbox



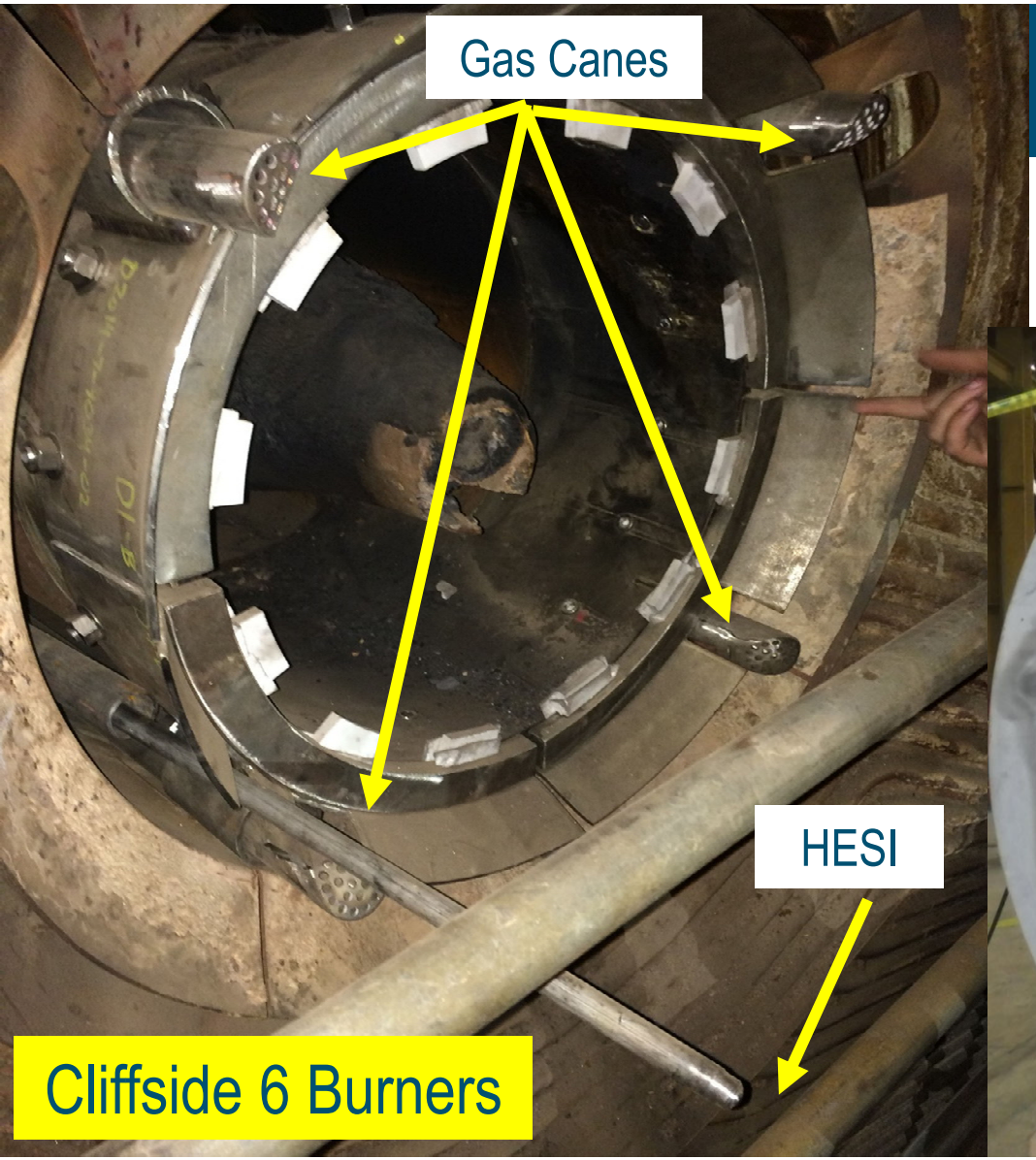
Cliffside Unit 6

Fuel Control Skid

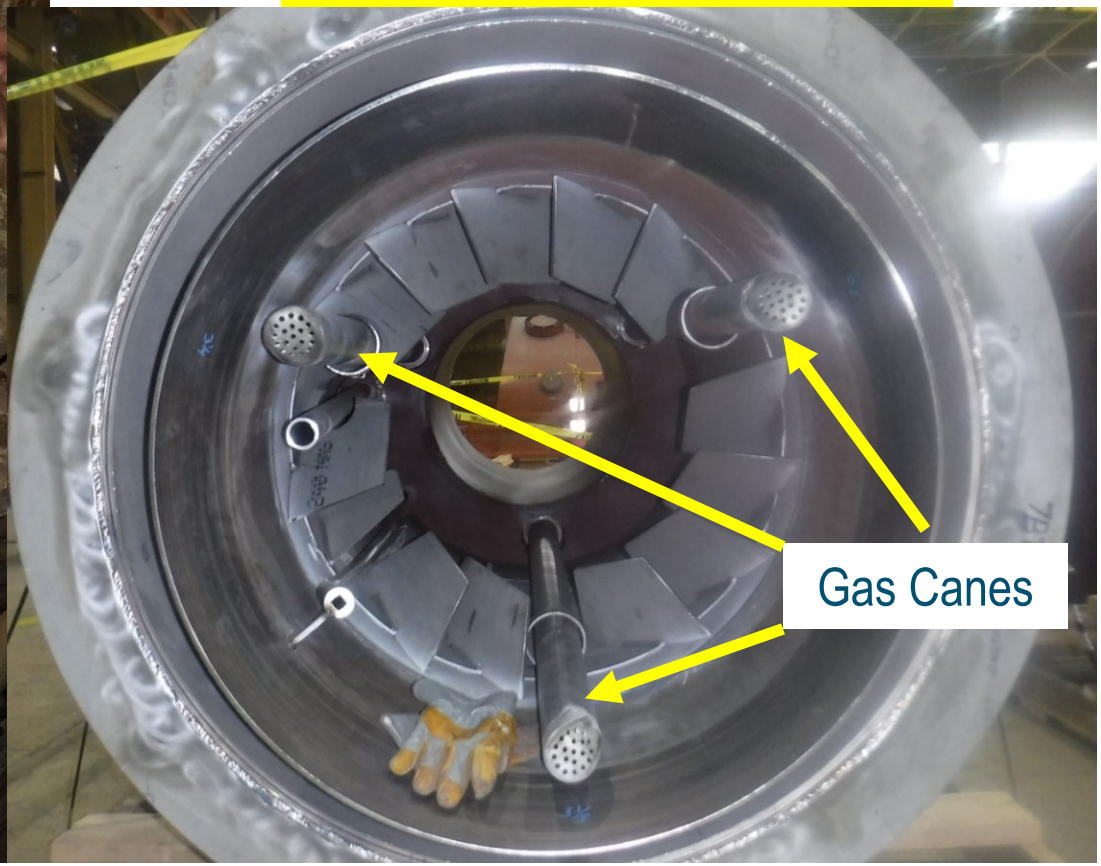


Cliffside Unit 6

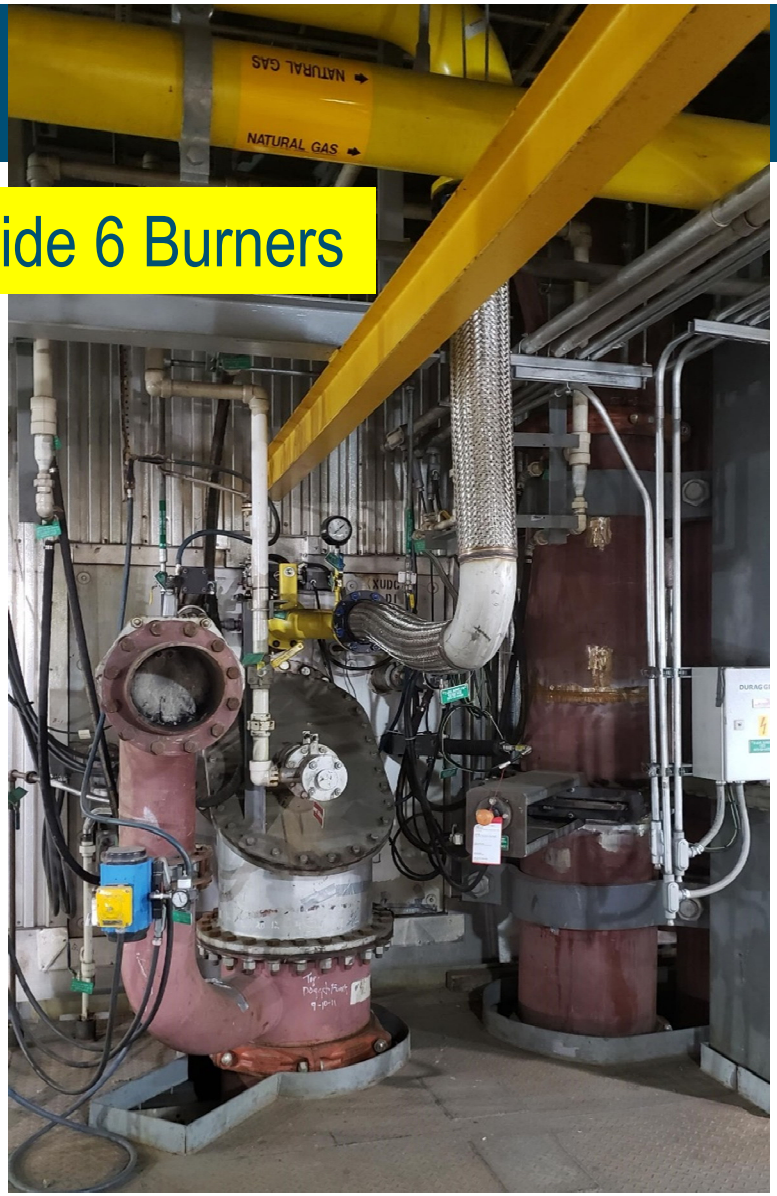
Burner Shut-off Skid



Belews Creek Burners



Cliffside 6 Burners

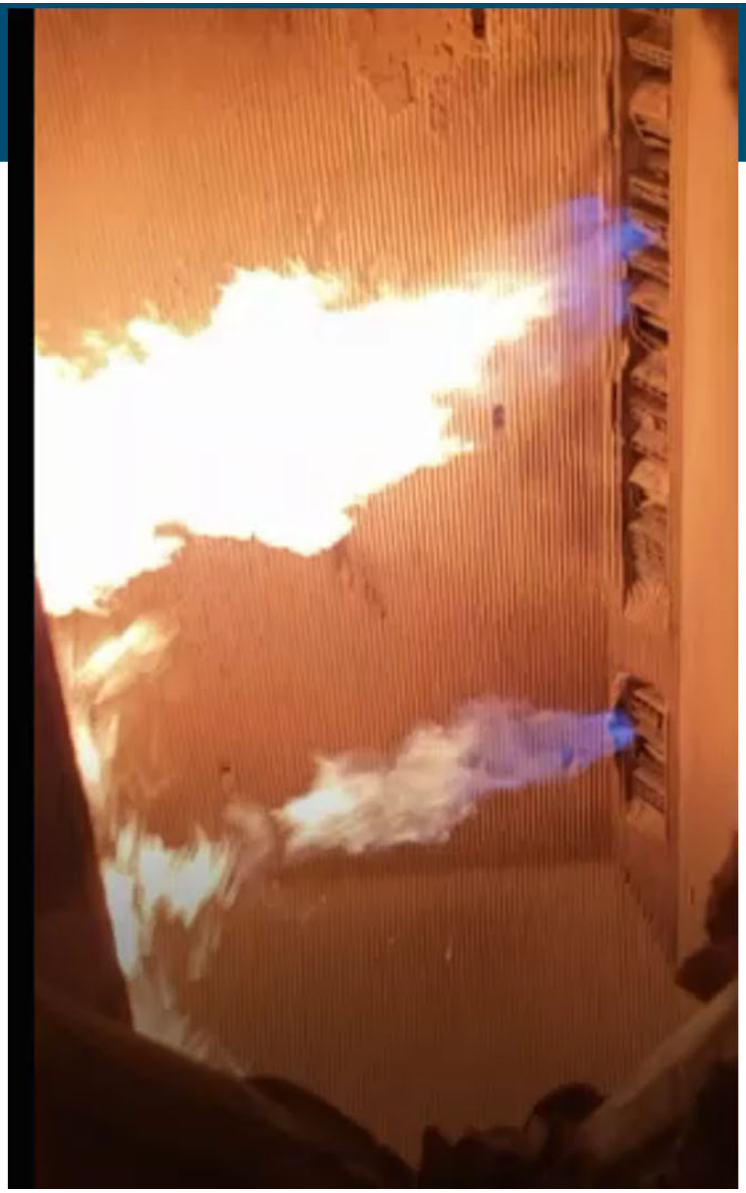


Belews Creek Burners

Cliffside 5
Early Ignition Testing with HESI LOFIR Gas Ignitor

Required low burner air flow.

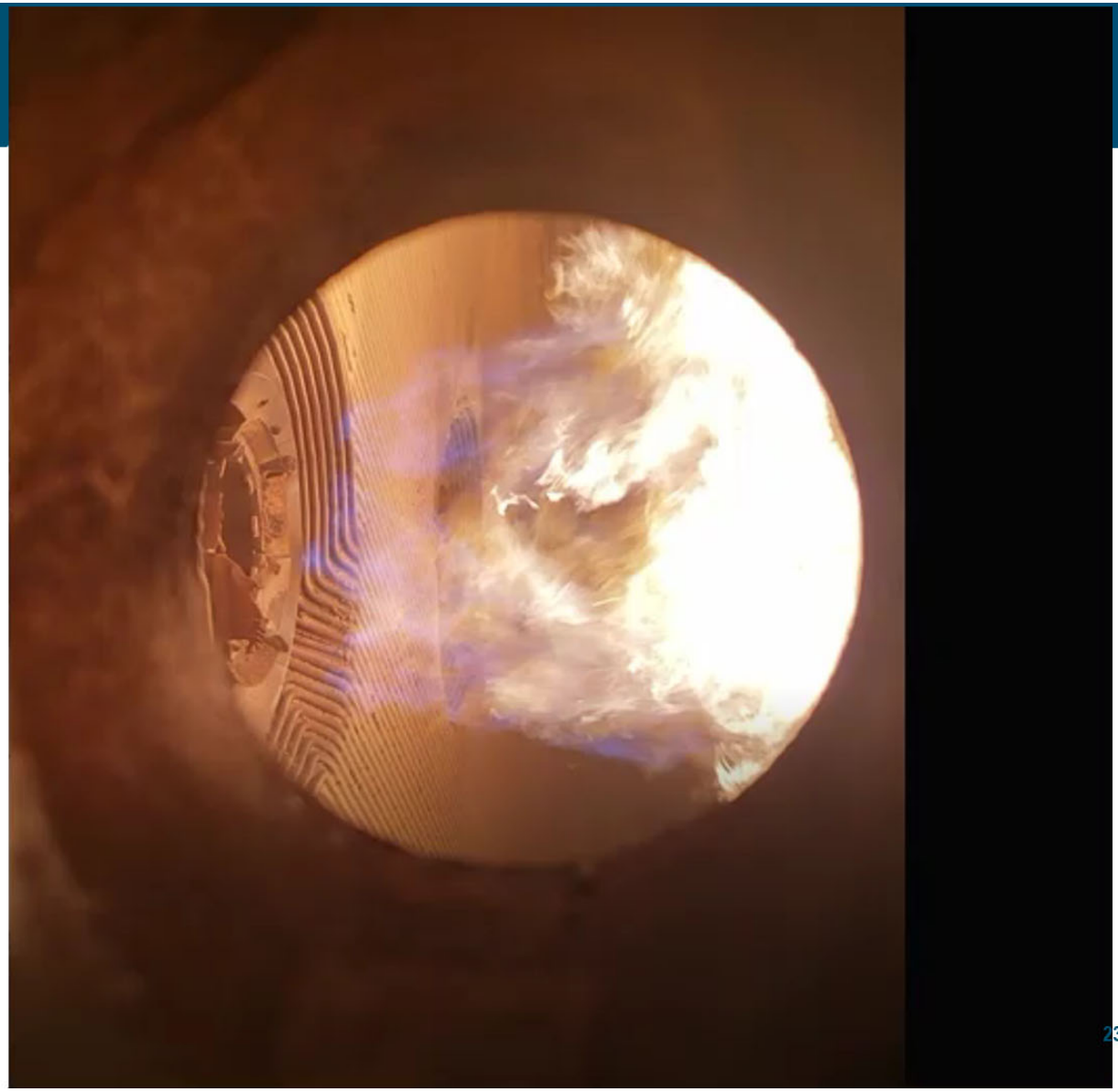
Cliffside 5



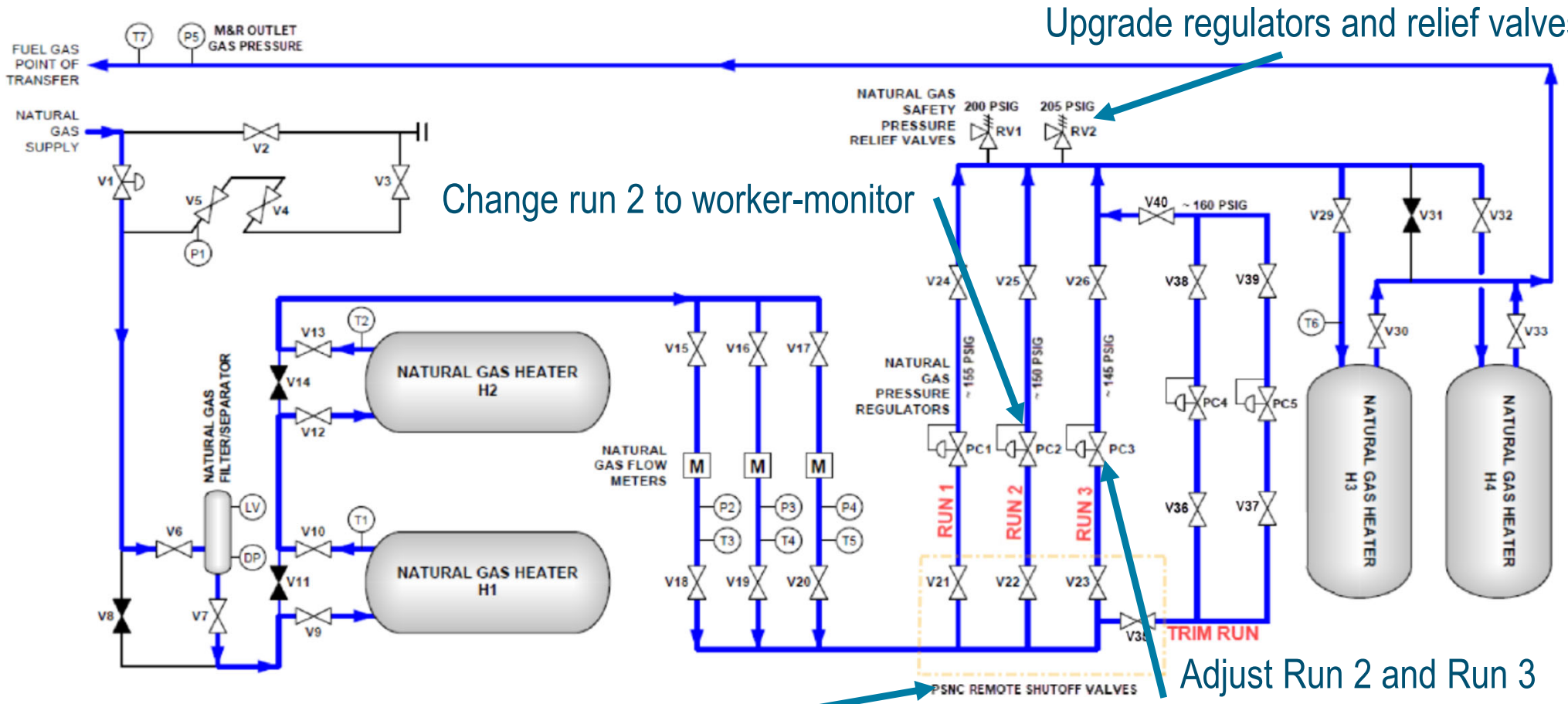
Main Gas Burner

LOFIR Gas Ignitor

Cliffside 6
Main Gas Burner
Low Output



Cliffside Lessons Learned – M&R station Design Vibration



Cliffside Lessons Learned – Hot Burners leads to missing parts

Burner thermocouples in alarm management,
Poor welds on gas coupling.
BC had poor welds on ignitor nozzle tip

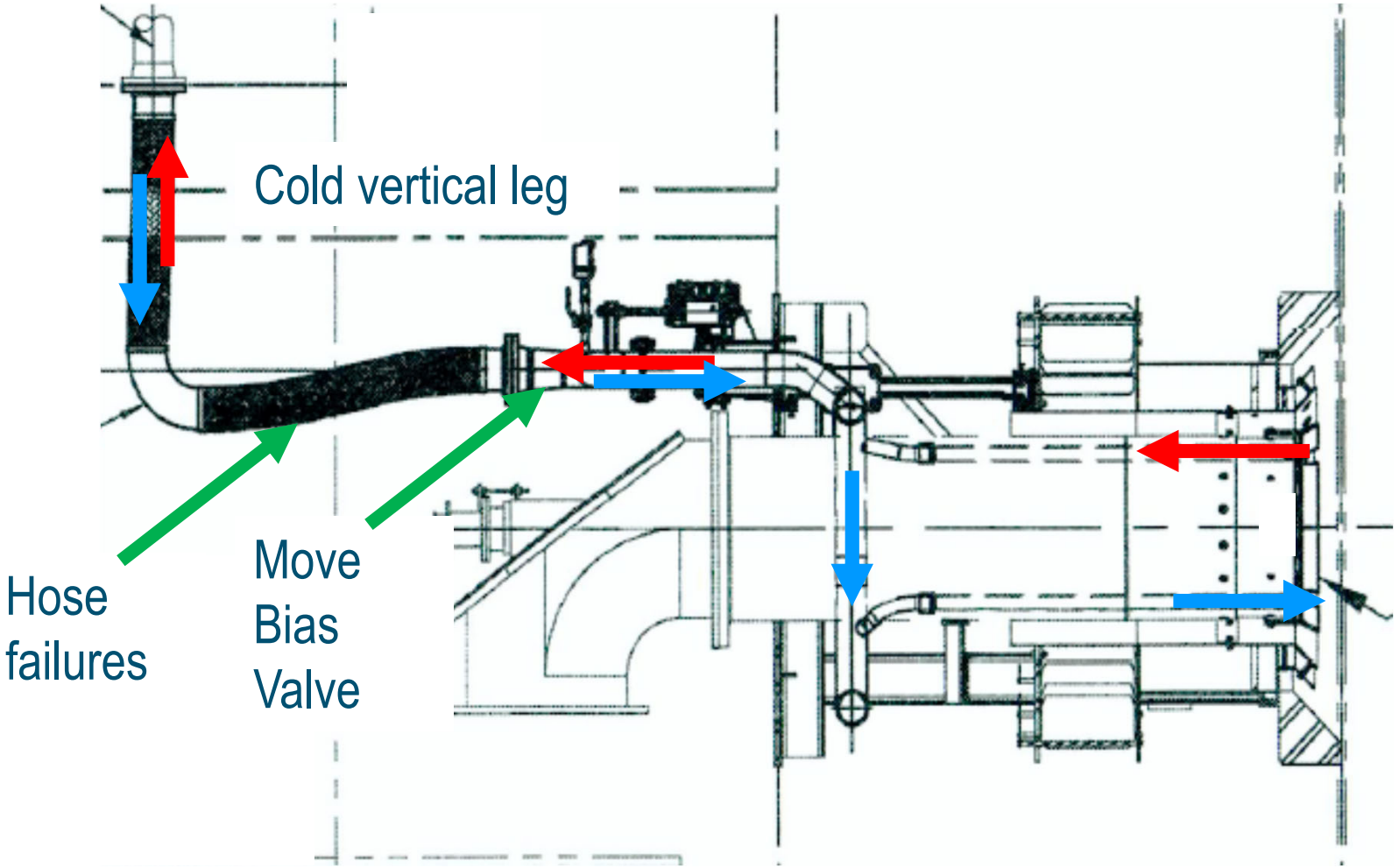
Cliffside Lessons Learned – Flame scanner line-of-vision

Cliffside - Moved closer, reduce piping Articulating head, file management
- Still not able to light coal from gas on Unit 6 due to line of sight.

Belews Creek – Upper 32 have 4 files to distinguish different flame types
- **Lower 48 continues to have issues with gas ignitor scanner**

Marshall – Overheated scanners due to insufficient cooling air flow.
- Changed cover on scanner lens to provide angled line of sight

Cliffside Lessons Learned – Natural circulation leads to hose failures

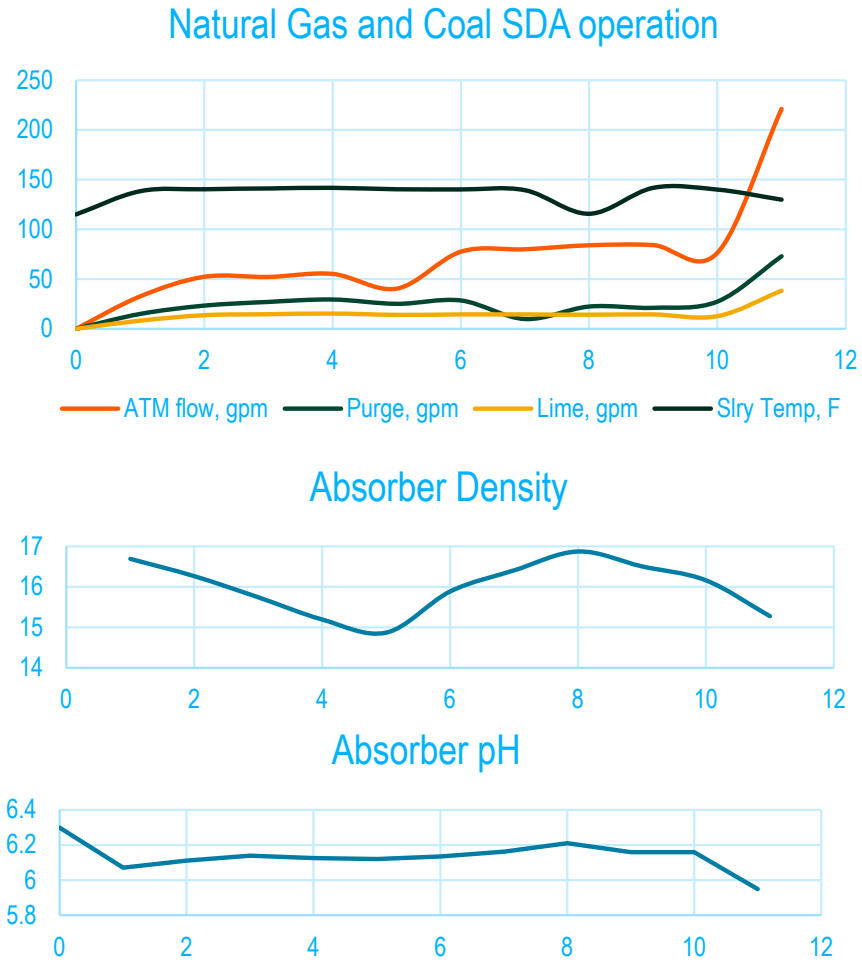


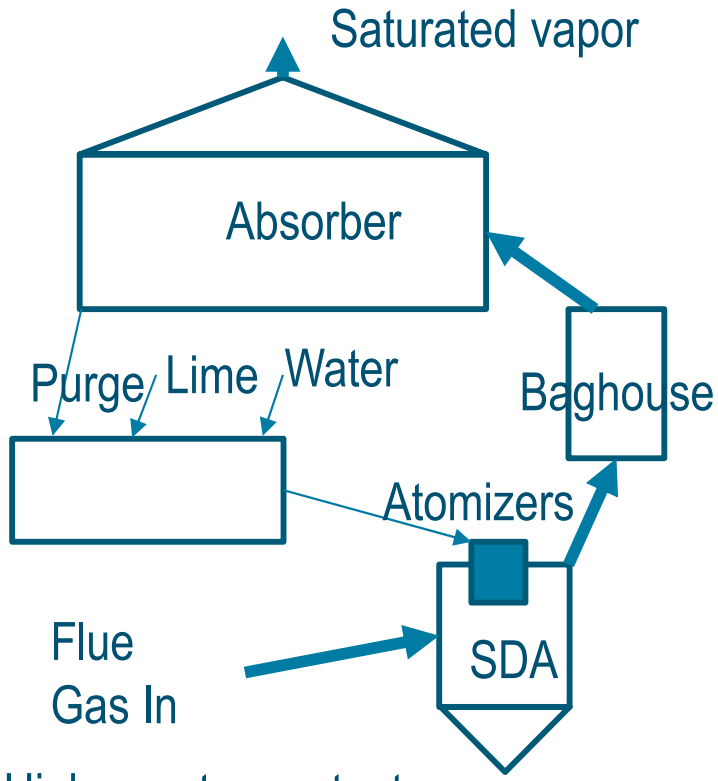
Cliffside Lessons Learned – Natural circulation leads to hose failures

Upgrade hose material to 310 SS on all units

Moved Bias Valve

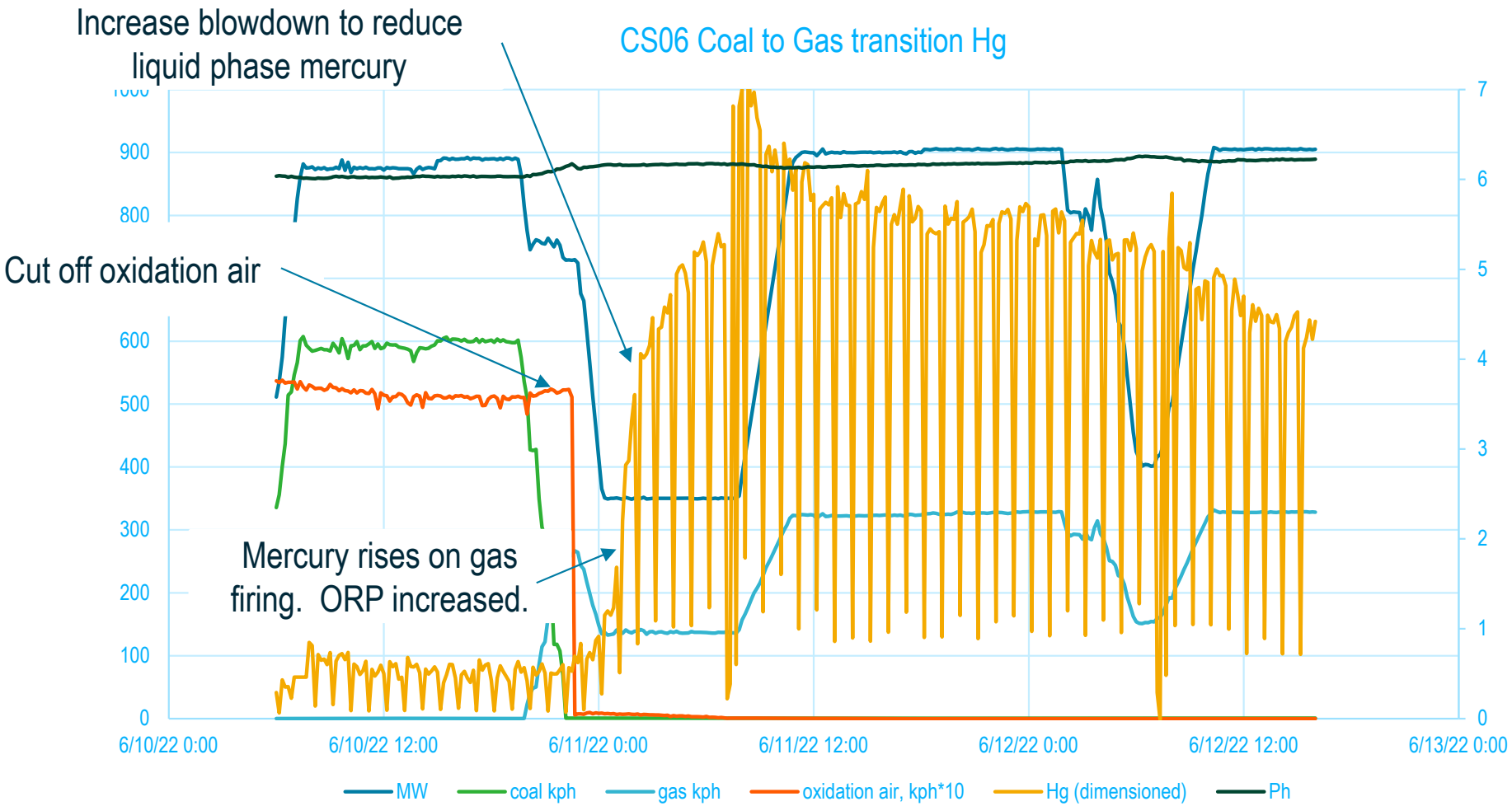
Cliffside Lessons Learned – FGD Temp, purge and Ph



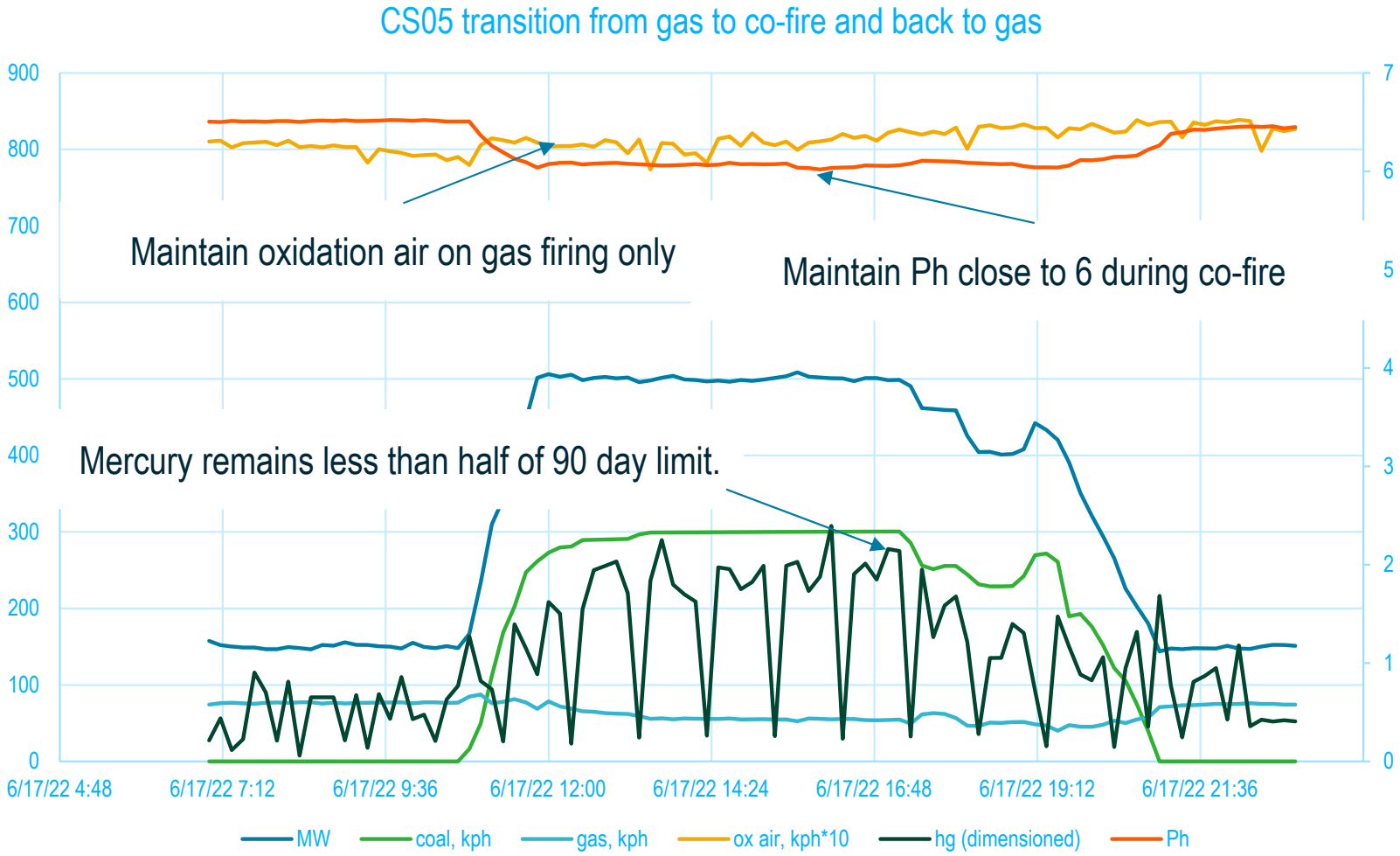


Higher water content means less cooling

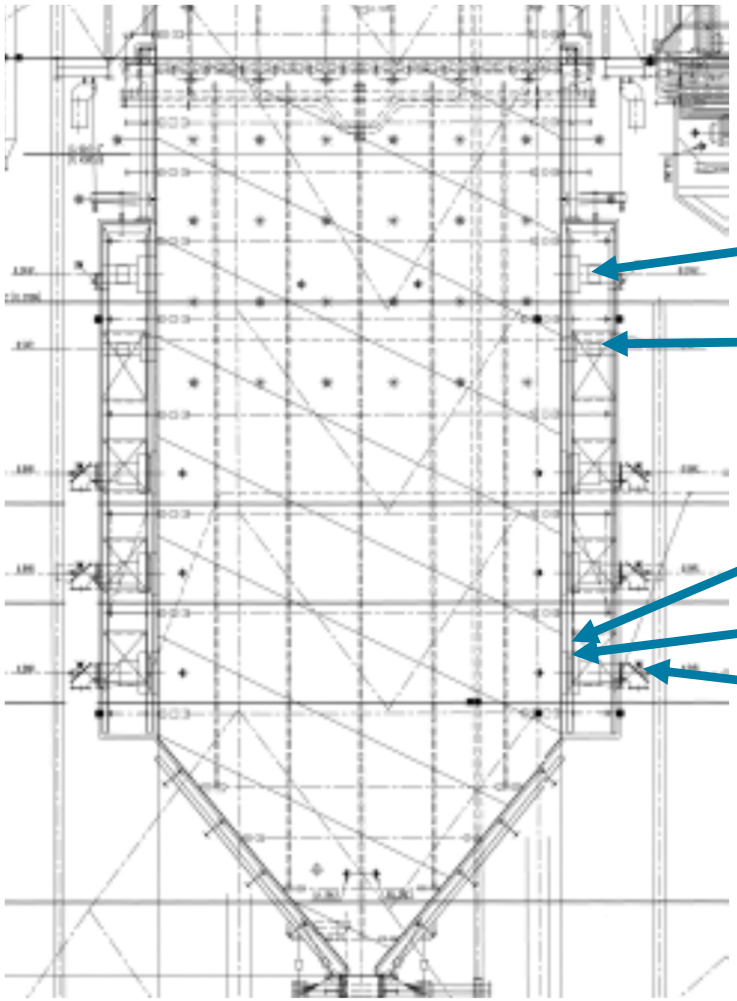
Cliffside Lessons Learned – FGD Hg



Cliffside Lessons Learned – FGD Hg



Cliffside 6 (wall-fired) Lessons Learned – CO tuning



Total stoichiometry 1.2 to 1.24

- Overfire Air (30 registers)
- Side Air (8 registers)

Upper Zone
0.49 to 0.4 stoich.

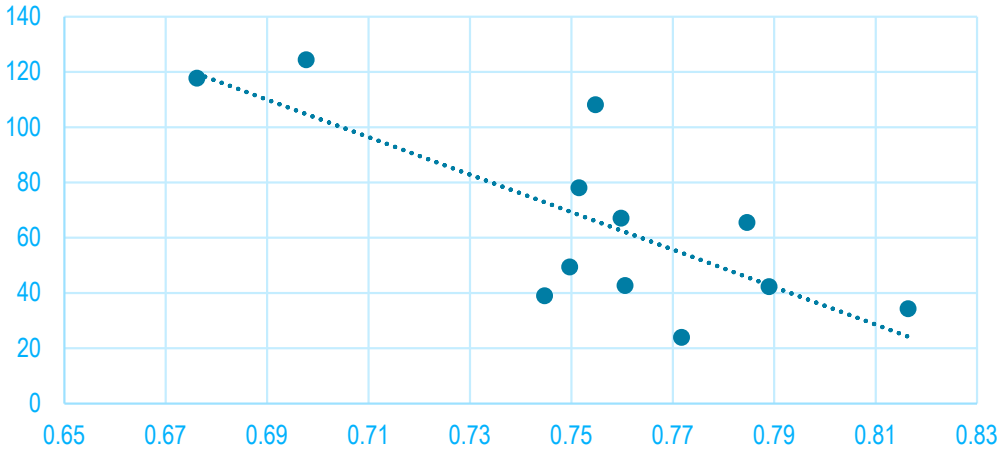
Air control per burner (30)

- Tertiary Air (burner register)
- Secondary (uncontrolled)
- Primary Air (0.3 stoich.)

Lower Zone
0.75 to 0.8 stoich.

Cliffside 6 (wall-fired) Lessons Learned – CO tuning

CO versus lower furnace stoichiometry
Coal only

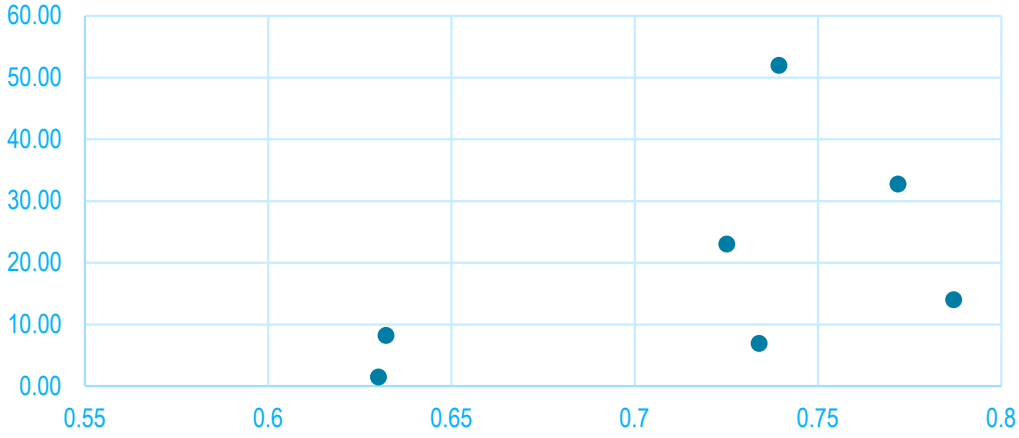


- Coal is much more predictable on lower furnace stoich.

- Need to push air down to replace pulverizer primary air

- Create swirl with OFA (arrangement/mixing dependent)

CO versus lower furnace stoichiometry
Natural gas



Cliffside Lessons Learned

Purge Design and Validation NFPA 56

Procedure developed so that natural gas and air are not mixed in piping system.

- Natural Gas must be purged with Inert Gas (nitrogen) from piping systems for maintenance, then compressed air.
- Nitrogen and compressed air delivery piping must be designed
- Procedure must be validated

HESI Failures

- Upgrade HESI material

Transient Study

Cliffside 5 – Results

Burner design output achieved

Steam temperatures maintained

FGD operations impacted as expected

- Slurry temp increased with higher gas ratio

Improved unit startup for operations

- Emissions met targets (60% coal, 40% natural gas)
  - CO – 0.015 lb/mmbtu (target 0.08)
  - SCR Inlet NOx – 0.164 lb/mmbtu (target 0.25)

Min Load – 50 MWg reduction from Coal to Gas operation, Based on steam side issues – Turbine L0

Cliffside 6 – Results

Burner design output achieved

Met steaming requirements (Full Load)

Maintained design steam temperatures

Improved unit startup for operations

Less impact to some AQCS systems than expected

- SDA
- SCR

Maintain Heat-rate; lower boiler efficiency is offset with lower parasitic load. (PA fan, Pulverizers, 3 ARP)

Increase net generation as reduction in parasitic load

Emissions met targets @17% Excess Air

- CO – 0.03 lb/mmbtu (target 0.037)
- SCR inlet NOx – 0.109 lb/mmbtu (target 0.25)
- VOC @ air heater exit – 0.0019 lb/mmbtu (target 0.0023)
- Needed to achieve 78% lower furnace stoichiometry with no primary air.

Min Load – (350 to 250) 100 MWg reduction from Coal to Gas operation

- Unit Dry to Wet (steam side) transfer is the limiting factor

Ramp Rate

- Increase only limited by steam side, No hold points from min to max load for pulverizer light off.

Belews Creek – Results

Burners design output achieved

Steam temperatures targets met.

FGD operations impacted as expected

- Slurry temp increased with higher gas ratio

- BC1 Emissions
  - MCR 50/50 Co-fire CO 0.002; met project targets
  - 50% MCR (Max) Gas CO 0.001; met project targets
  - Met VOC, NOx targets

- BC2 Emissions
  - MCR Co-fire CO 0.0069; met project targets
  - 50% Gas (Max) CO 0.002; met project targets
  - Met VOC, NOx targets

Marshall – Results

Burners design output achieved

Steam temperatures targets met.

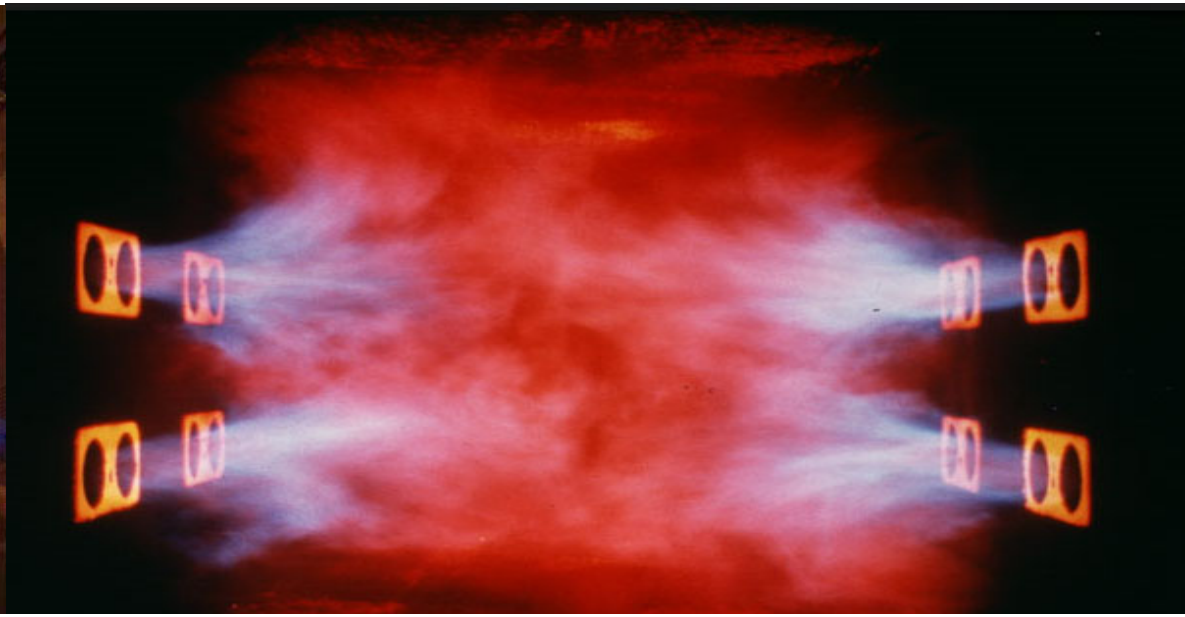
FGD operations impacted as expected

- Slurry temp increased with higher gas ratio

- MSS1, MSS 2 Emissions
  - MCR Coal CO 0.035, 0.057 lb/mmbtu; met project targets
  - MCR Co-fire CO 0.0037, 0.044 lb/mmbtu; met project targets
  - Max Gas CO 0.0027, 0.002 lb/mmbtu; met project targets
  - Met VOC, NOx targets

- MSS3, MSS 4 Emissions
  - MCR Coal CO 0.0316, 0.053 lb/mmbtu; met project targets
  - MCR Co-fire CO 0.0096, 0.087 lb/mmbtu; met project targets
  - Max Gas CO 0.0073, 0.0042 lb/mmbtu; met project targets
  - Met VOC, NOx targets

Questions ??

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