Air Preheat System Upgrade on Coker Heaters

Ashutosh Garg

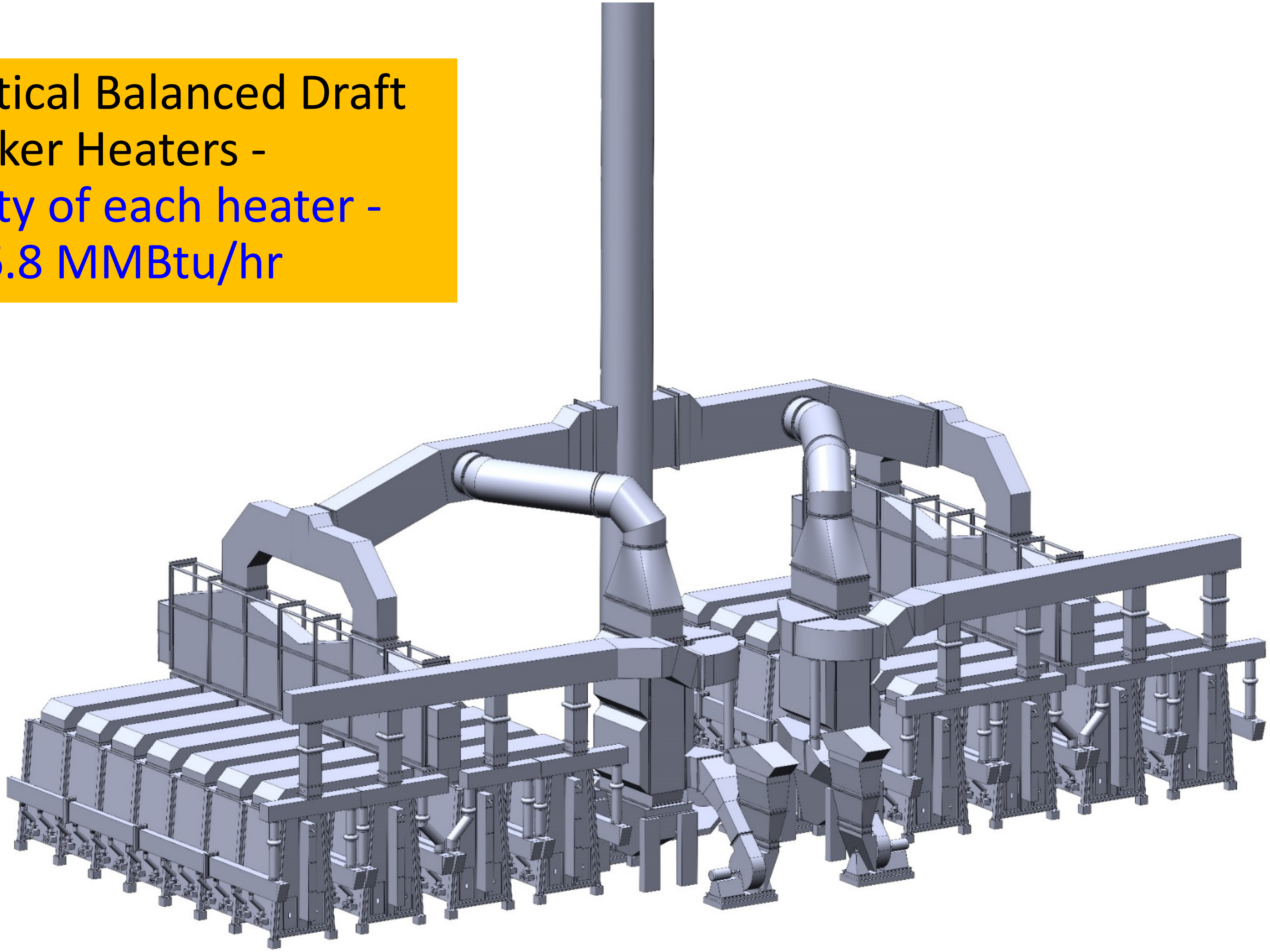
Furnace Improvements

Air Preheat System

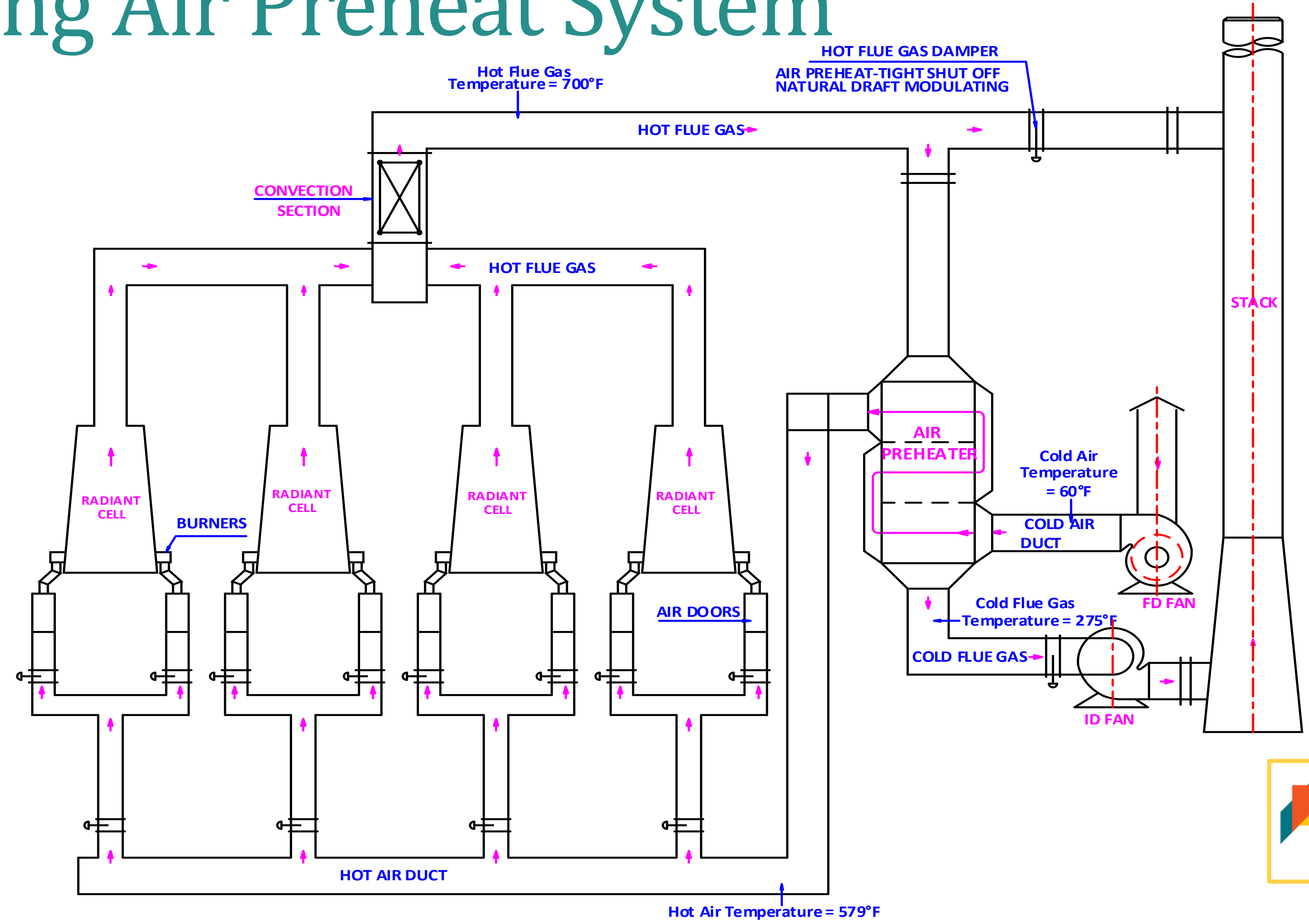
- Not popular
- Misconception about NOx emissions
- Number of APH installations not in use
- Heaters operating in Natural draft mode losing energy
- Energy prices are very low ??
- Our fired heaters are not very efficient
- But???

Two identical Balanced Draft Coker Heaters -

Heat duty of each heater - 126.8 MMBtu/hr



Existing Air Preheat System



INCLINED FIRING SYSTEM SPLIT FLOW TECHNOLOGY
FIS
SMART STACK DAMPERS

AIChE® 11th SOUTHWEST
PROCESS TECHNOLOGY CONFERENCE

Operating Issues with Air Preheating Systems

- Air Preheater
  - Corrosion
  - Air leakage
  - High flue gas side pressure drop
- Bypass duct limitation
- Burners
  - Non uniform air flow to burners
- Flue gas bypass to stack, ID fan limiting
- Client was throughput limited

Air Preheater Problems

- Low tube metal temperature and excessive corrosion problems:
  - Non- uniform air flow distribution
  - Cold zones in static air preheater
  - APH Design was deficient with respect to acid dew point corrosion

Existing Air Preheater

- Type-Recuperative Cast Iron
- Heat Duty- 15.05 MMBtu/hr
- Flue Gas Side Details
  - Flowrate- 130,150 lb/hr
  - Inlet/Outlet Temperature - 700°F/ 275°F
  - Pressure Drop- 2.0 inches WC
- Air Side Details
  - Flowrate- 117,700 lb/hr
  - Inlet /Outlet Temperature- 60°F/ 579°F
  - Pressure Drop- 4.3 inches WC
- Minimum Tube Metal Temperature- 230°F

APH System

Existing Air Preheater was corroded and leaking air into flue gas

INCLINED FIRING SYSTEM SPLIT FLOW TECHNOLOGY SMART STACK DAMPERS

AIChE 11th SOUTHWEST PROCESS TECHNOLOGY CONFERENCE

Existing FD Fan

- Fan rated for 34,652 acfm at 120°F with 10.5inch W.C pressure rise (TB)
- Drive Arrangement- #7 SWSI
- Fan Speed- 1,200 rpm
- Motor - 100 H.P
- Steam APH is provided at the inlet
- Inlet guide vanes to control the flow
- Provided with 20 ft tall suction stack consisting of rain hood with screen, silencer and steam APH coils

Suction Stack

Forced Draft Fan

Existing FD fan was limiting due to APH leakage
Suction filter was getting clogged with coke particles

Existing Steam Air Preheater

- Provided at FD Fan inlet duct to preheat air in winter to avoid Acid Dew Point Corrosion in main APH
- Heat Duty- 1.61 MMBtu/hr
- Air inlet / outlet temperature : 10 °F / 60 °F

Steam APH Coils

Existing steam air preheater was undersized and getting clogged with coke particles

Existing ID Fan

- Rated for 58,530 acfm at 350°F with 5.1 inch WC static rise (TB)
- Arrangement- #7 SWSI Grade Mounted
- Inlet pneumatically operated damper to control the flow
- Fan Speed- 900 rpm
- Motor- 75 HP

Induced Draft Fan

ID fan was undersized and was limiting

Limitation of the Heaters and APH System

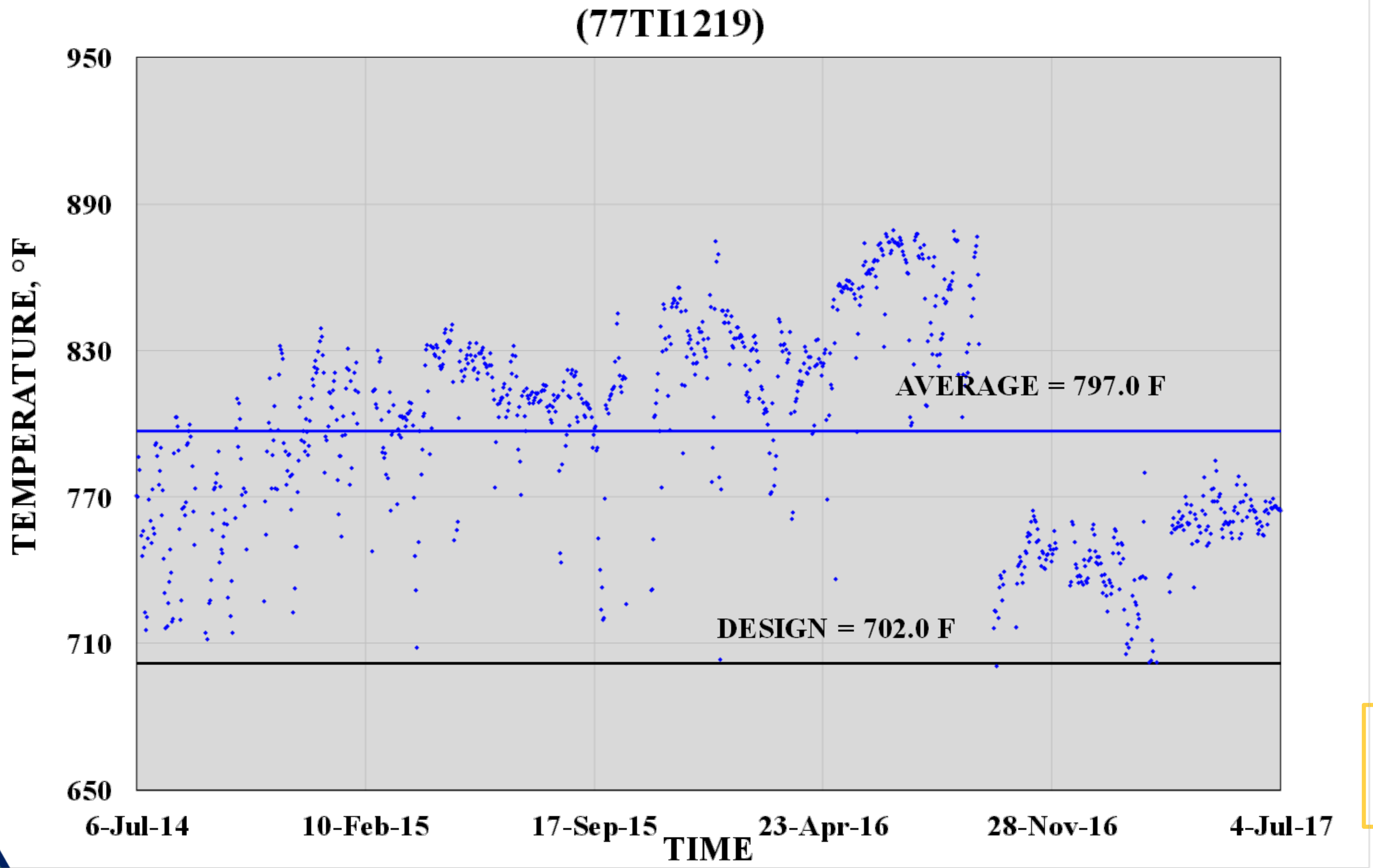
- Heater
  - High flue gas convection section exit temperature, almost 30-40% flue gas bypassing the air preheater (calculated thermal efficiency -85%)
- Air Preheater
  - Acid Dew Point or Cold Block Corrosion
- ID & FD Fans
  - ID and FD fans were limited in capacity thereby limiting the heater production
- Combustion / Cold Air By-pass Duct was undersized

INCLINED FIRING SYSTEM SPLIT FLOW TECHNOLOGY F I S SMART STACK DAMPERS

AIChE 11th SOUTHWEST PROCESS TECHNOLOGY CONFERENCE

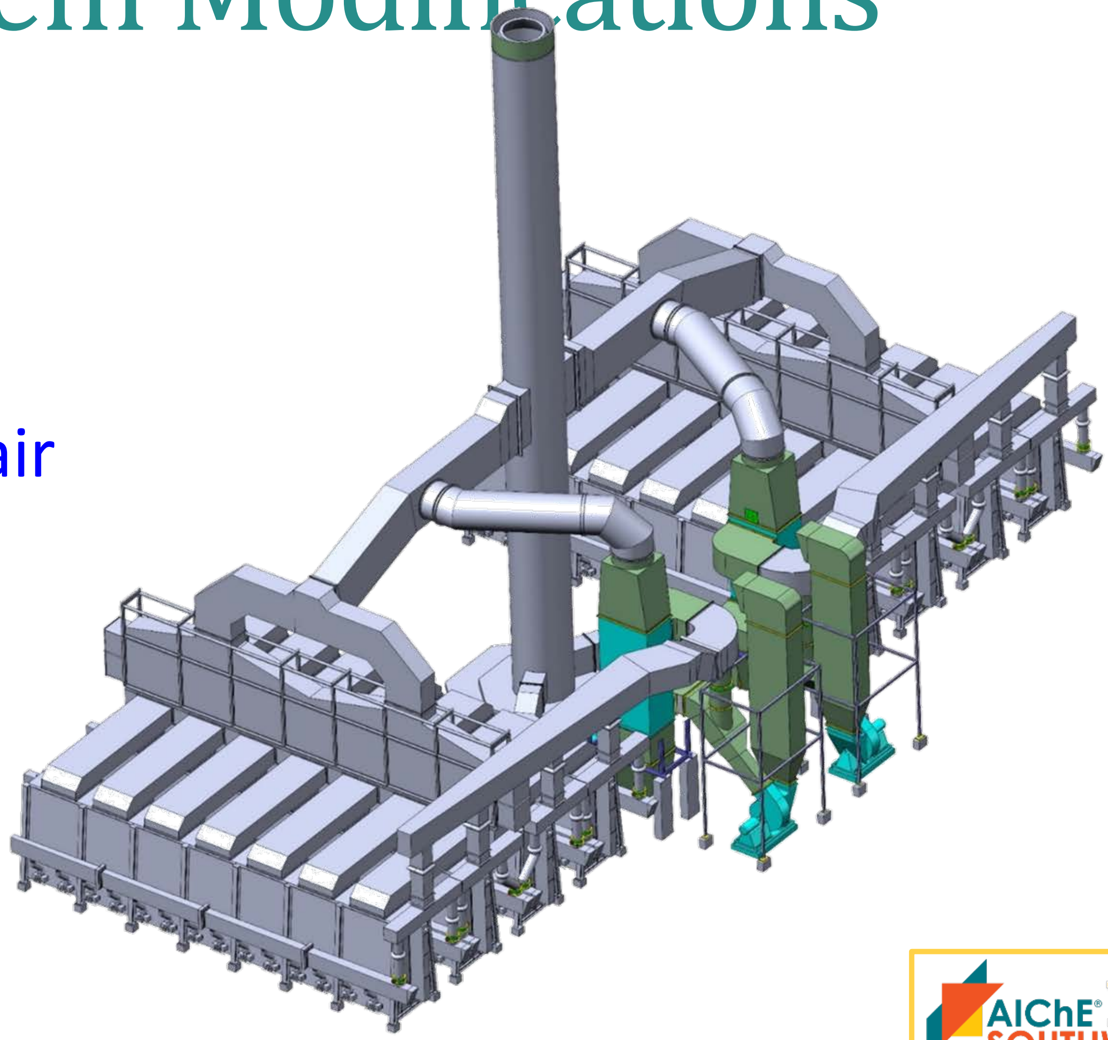
Flue Gas Temperature Leaving Convection

Flue gas temperature to Air Preheater is higher by almost 100-180F



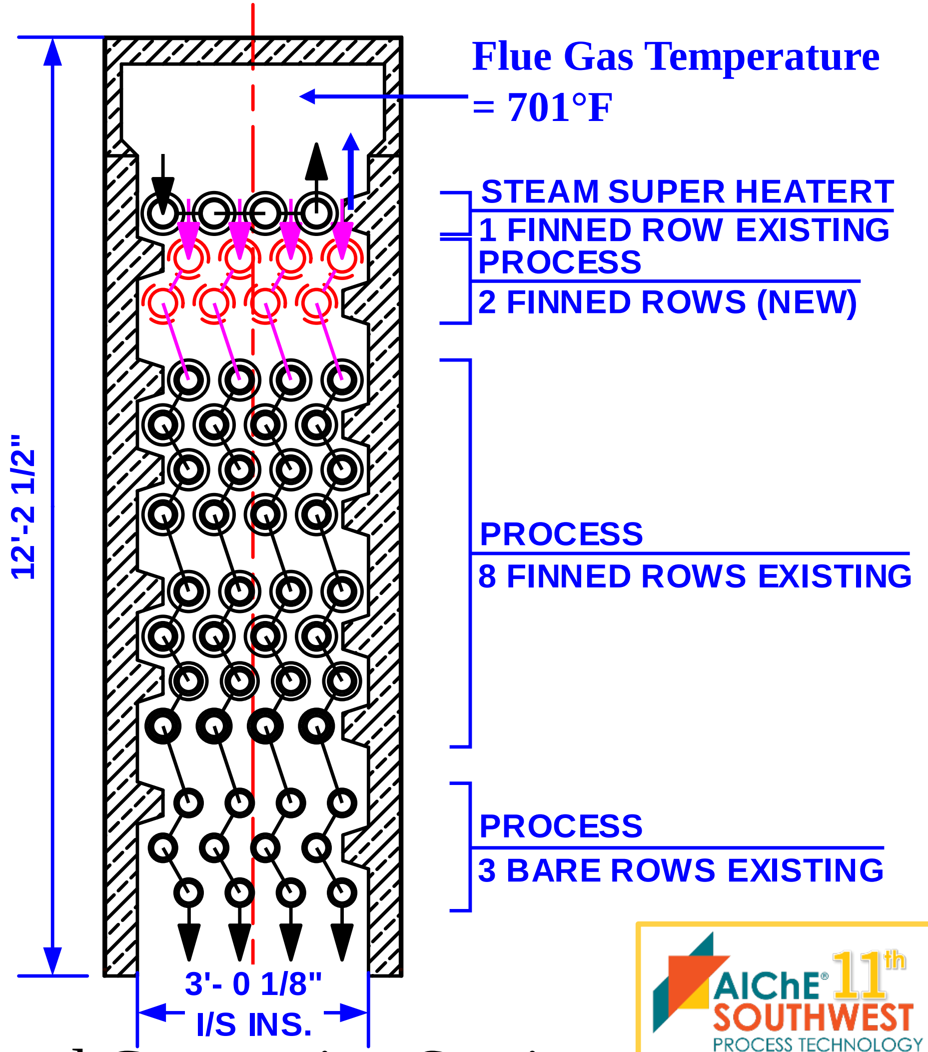
Air Preheating System Modifications

- Systems approach:
- Installation of new APH, FD fans, ID fans, Steam APH
- Modification of combustion air and flue gas ducts
- Installation of additional convection tubes



Addition of Process Coils in Convection

- Two future rows provision to be used.
- Fin configuration of process coils in future rows: 1” ht. x 0.06” thk. X 5 FPI
- 8,858 ft^2 additional heat transfer area in process convection
- Flue gas temperature leaving the convection section is reduced from 834°F to 701°F



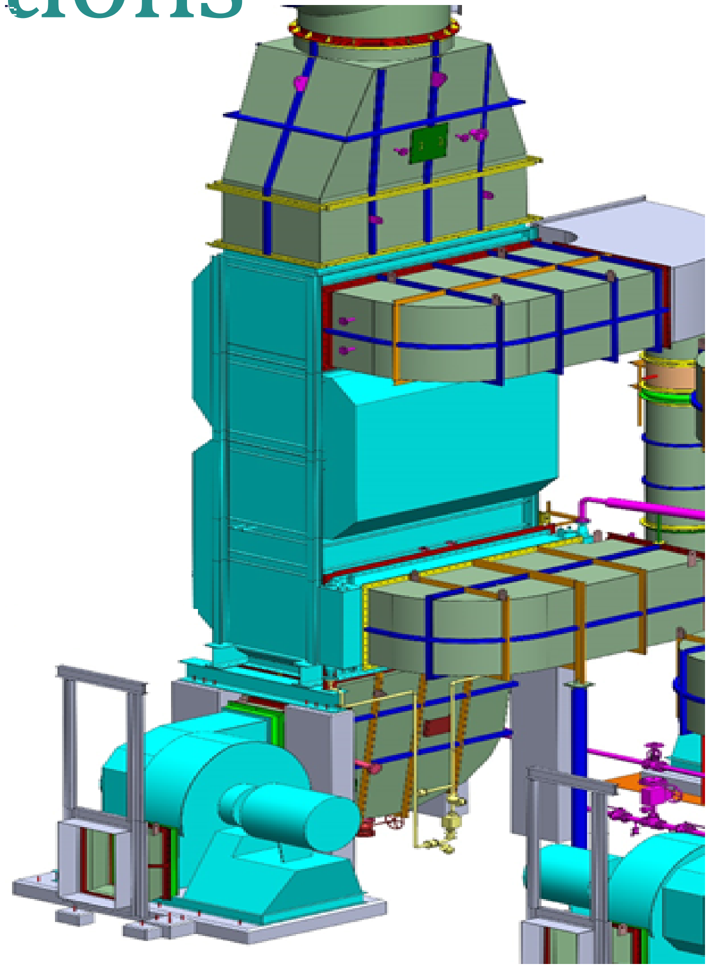
Proposed Convection Section

Air Preheater Recommendations

- New Plate Type APH
- Preheater design revised to 300°F flue gas temperature
- 20% higher flue gas flow rate
- Steam air preheater upstream to ensure constant air temperature of 120°F
- Glass /Ceramic Coating on metal plates to avoid dew point corrosion in cold end.

❖ Design Heat Duty of 17.7 MMBtu/hr..

❖ Minimum tube metal temperature (TMT) of 279°F



Existing and Proposed APH Comparison

Parameter	Unit	Existing	Proposed
Absorbed Duty	MMBtu/hr	15.05	17.7
Air Flow Rate	lb/hr	117,700	155,038
Air Inlet / Outlet Temperature	°F	60 / 579	120 / 585
Flue Gas Flow Rate	lb/hr	130,150	162,714
Flue Gas Inlet / Outlet Temperature	°F	700 / 275	701 / 300
ΔP on Air Side (allowable/calculated)	in WC	- / 4.3	4.3 / 2.6
ΔP on Flue Gas Side (calculated)	in WC	2.0	2.9
Minimum Metal Temperature	°F	230	278.6

Existing vs. Proposed FD fan

Parameter	Unit	Existing	Proposed
Combustion Air Flow Rate	lb/hr	141,240	168,832
Air Temperature	°F	120	125
Static Pressure Rise	inch WC	10.5	14.07
Maximum Fan Speed	rpm	1,200	1,200
Motor Rating	HP	100	150

Existing vs. Proposed ID fan

Parameter	Unit	Existing	Proposed
Flue Gas Flow Rate	lb/hr	156,180	207,249
Flue Gas Temperature	°F	350	400
Static Pressure Rise	inch WC	5.0	10.62
Maximum Fan Speed	rpm	900	1,200
Motor Rating	HP	75	200

New ID fan motor is three times larger than the existing ID fan motor

Ducting Modifications

1. Combustion Air Duct Modification
   - FD fan suction stack:
     - Additional 20 ft FD fan suction stack
   - Cold Air bypass duct:
     - Size increased from 1’-8” (current size) to 3’-4”
     - Sized for Full Air Flow during forced draft operation
   - FD fan discharge duct:
     - Smoother transition to APH
     - Angled baffle plates and turning vanes

Ducting Modifications

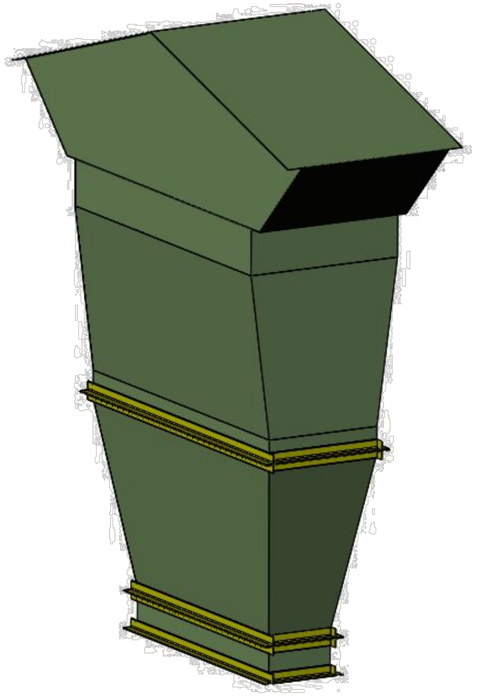
- Hot Air Duct Modification:
  - Smooth outlet transition from APH with turning vanes
  - Guide vanes and baffles
  - Pressure drop plate to increase the air side pressure drop to 0.68 inch WC in burners

2. Flue Gas Duct Modification

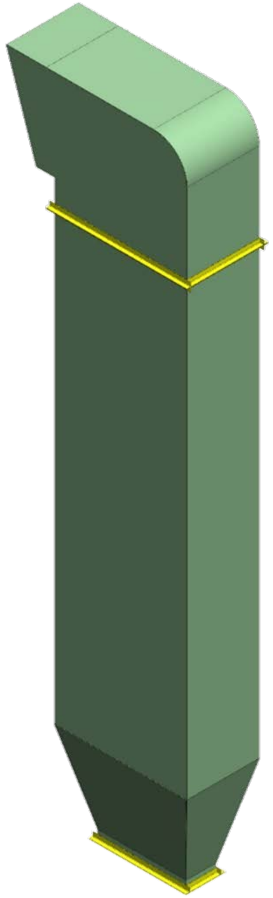
- Hot Flue Gas Duct Modifications
  - Inlet transition to APH has gradual expansion with angled baffles
- Cold Flue Gas Duct Modifications
  - New duct with turning vanes

New FD fan Suction Stack

- 40 ft height from FD fan flange inlet (20 ft more than existing suction stack)
- 90 degree elbow
- Provided with fine wire mesh screen to block bird feathers entering APH



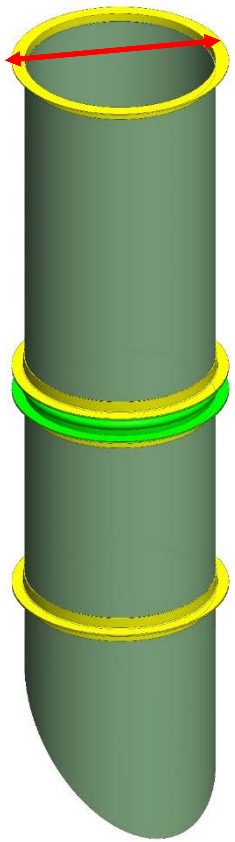
Existing
(20 ft)



Proposed
(40 ft)

New Cold Air Bypass Duct

- Increased size to 3’-4” from 1’-8” (outside plate)
- Controlled by pneumatically operated, tight shut off damper



3.25 ft
o/s Plate
diameter

Proposed Bypass Duct

Steam Preheat Coil

Parameter	Unit	Existing Steam Preheater	New Steam Preheater Coils
Heat Duty	MMBtu/ hr	1.61	6.11
Air Inlet Temperature	°F	10	10
Air Outlet Temperature	°F	60	180

Picture of Steam Preheat Coil in Manufacturing Facility

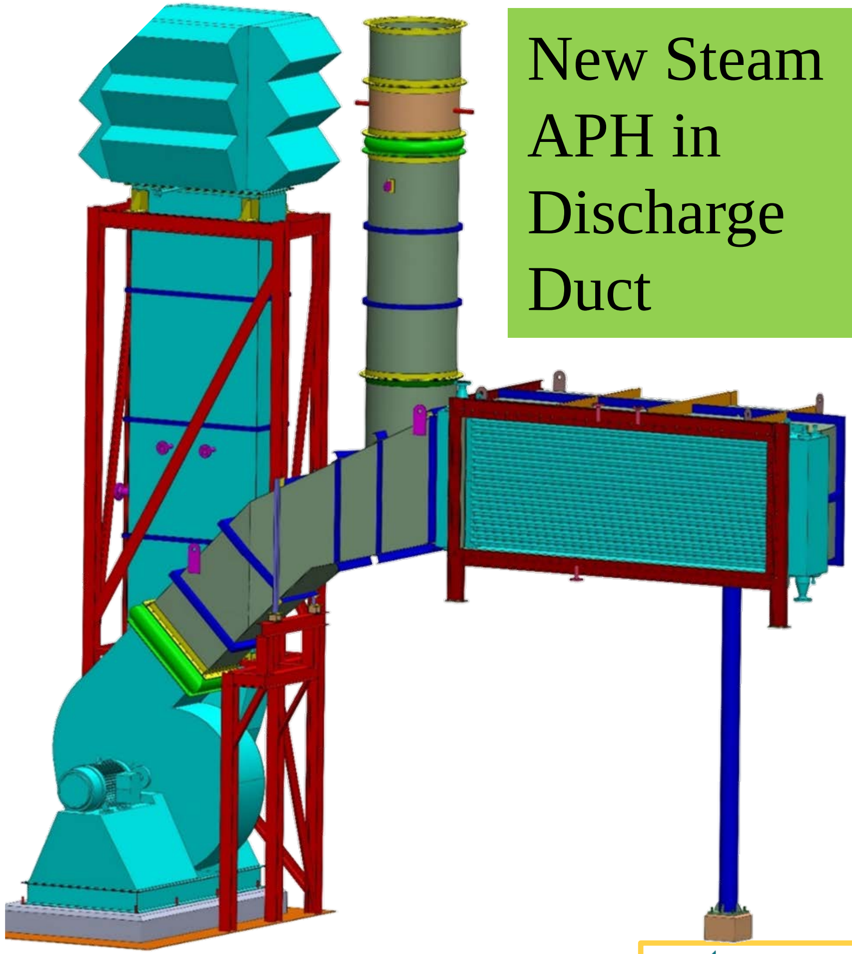
INCLINED FIRING SYSTEM
SPLIT FLOW TECHNOLOGY
SMART STACK DAMPERS

AIChE® 11th SOUTHWEST PROCESS TECHNOLOGY CONFERENCE

Existing v/s New Steam Preheater

Existing Steam APH In Fan Suction

Existing Steam APH Layout

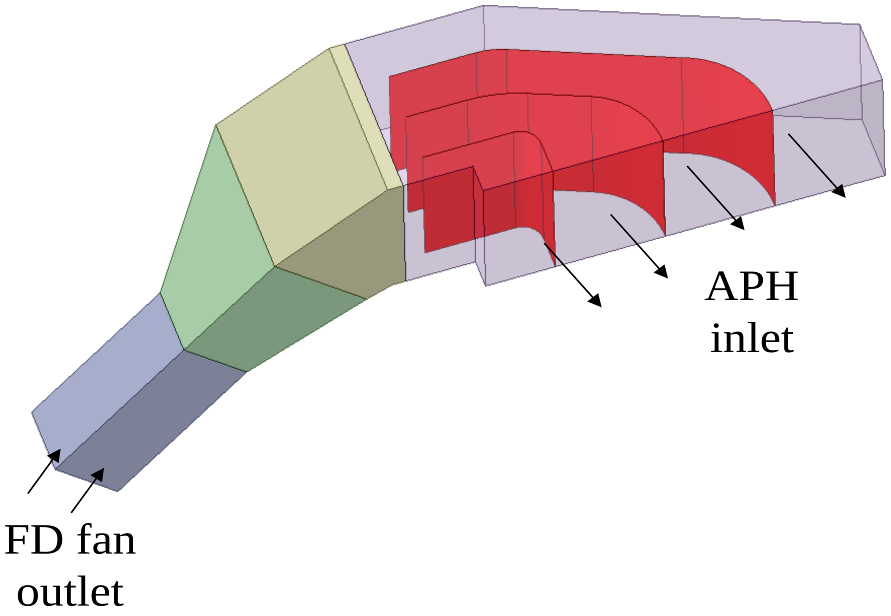


New Steam APH in Discharge Duct

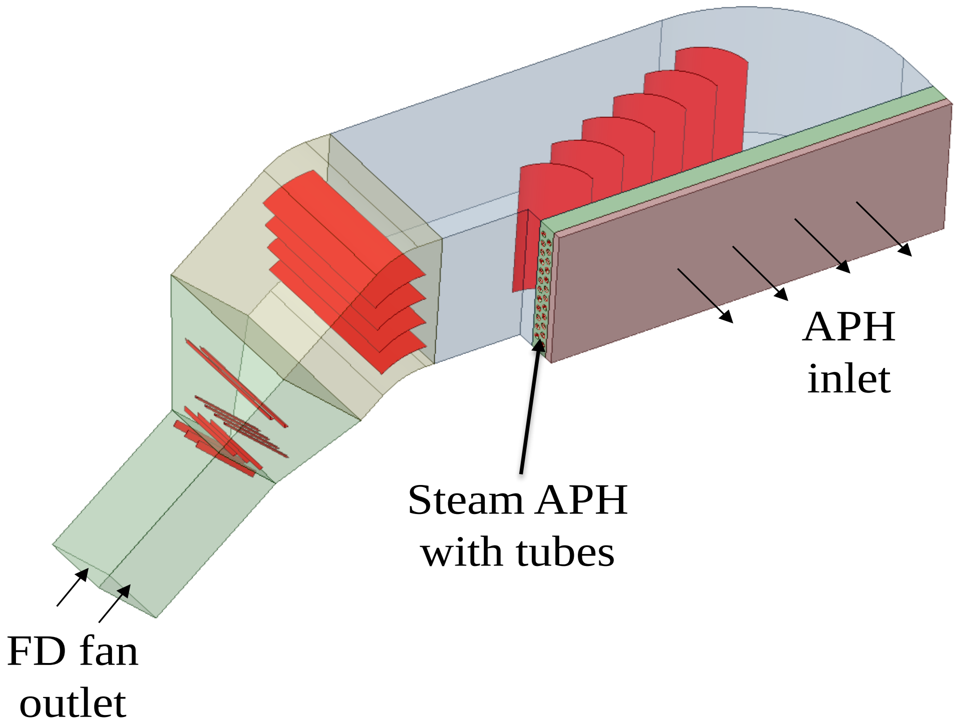
Proposed Steam APH Layout

Existing and Proposed FD fan Discharge Duct

Smoother Transition, Angled baffles and turning vanes provide uniform air flow

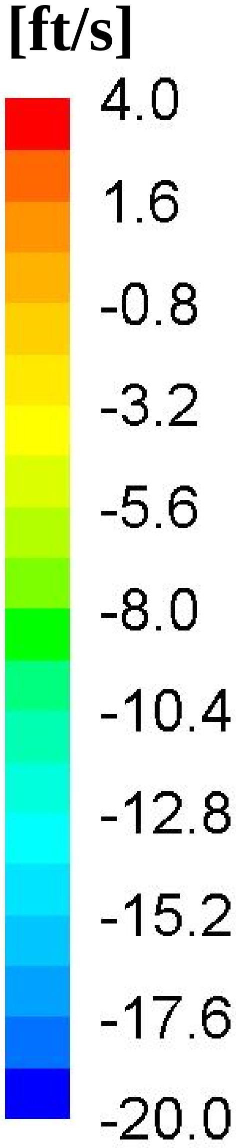


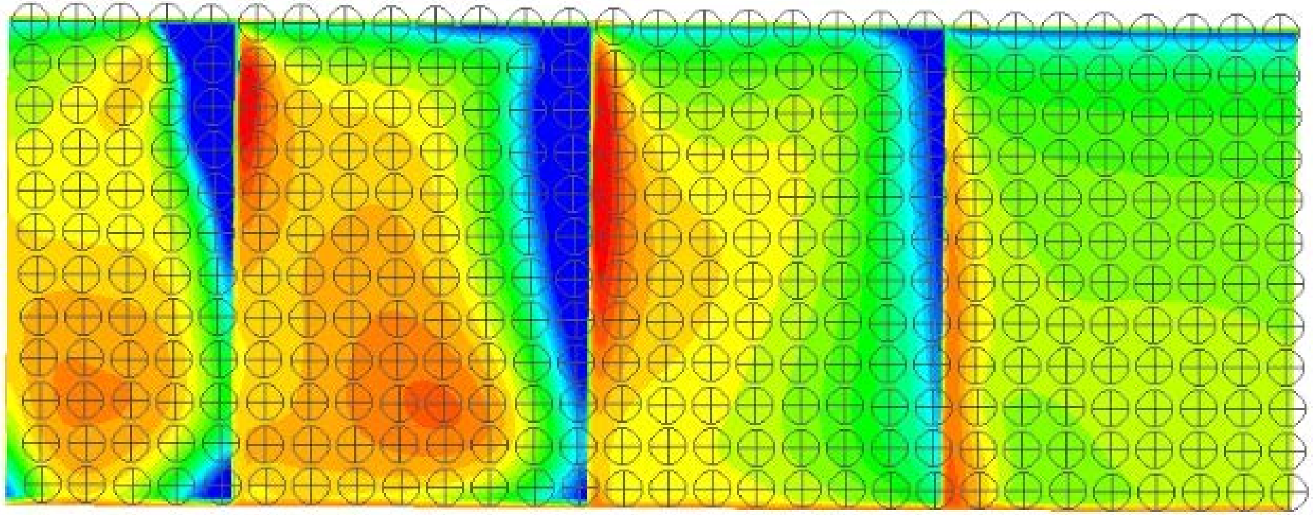
Existing



Proposed

Velocity RMS Deviation at APH Inlet





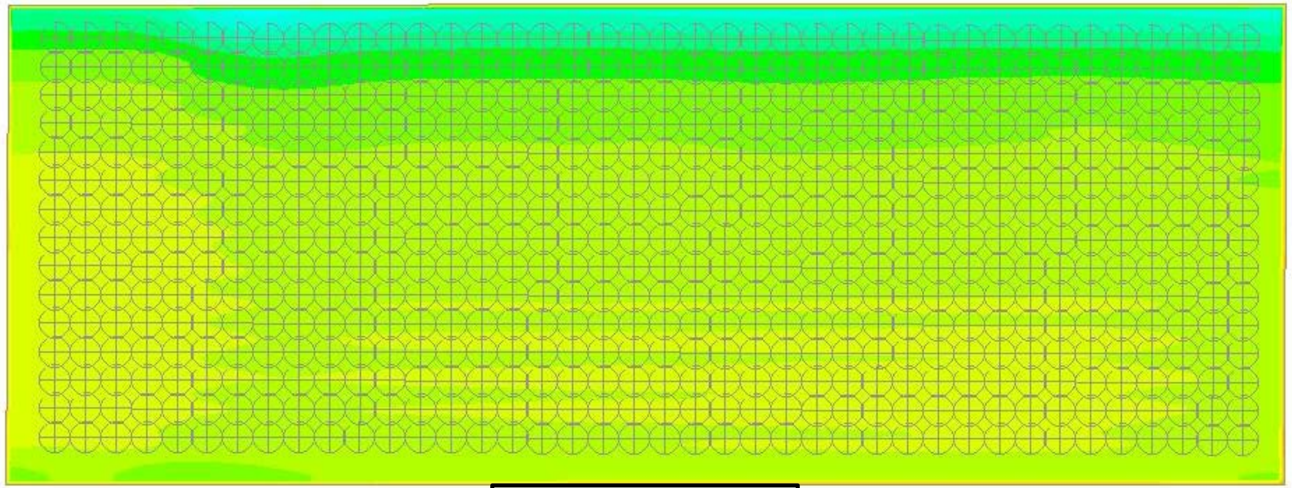
Existing

RMS deviation at APH inlet is: ± **91.0%**

RMS deviation at APH inlet is: ± **13.9%**

Normal velocity profile at APH inlet (after Steam APH)

Due to physical constraints on duct shape it was not feasible to further improve the flow distribution



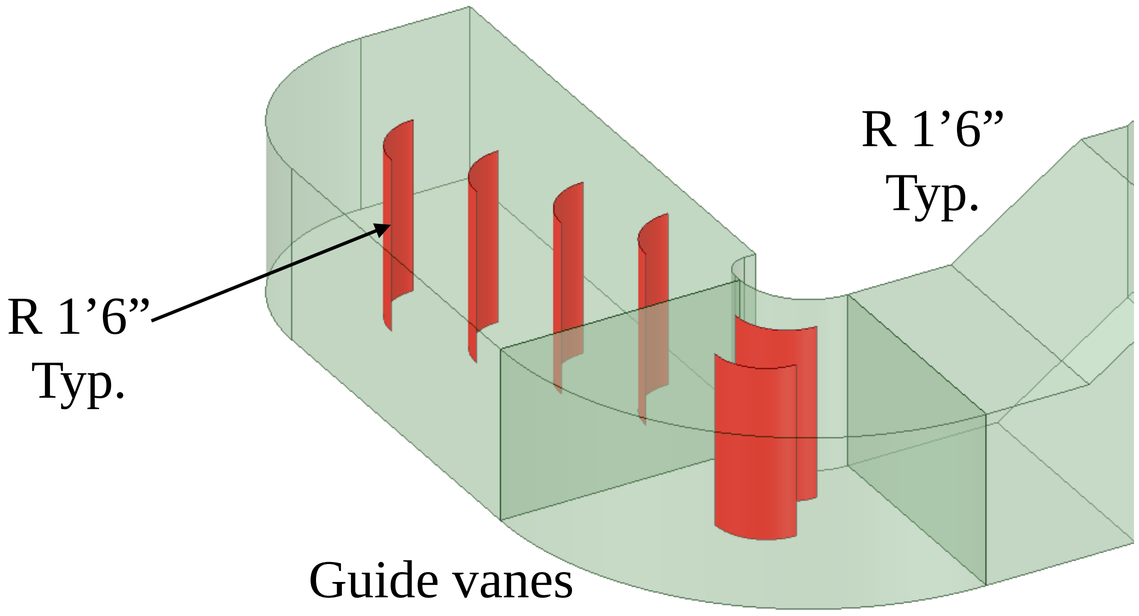
Proposed

Note: Recommended RMS Deviation of velocity is in the range of ± **5%**

PROCESS TECHNOLOGY CONFERENCE

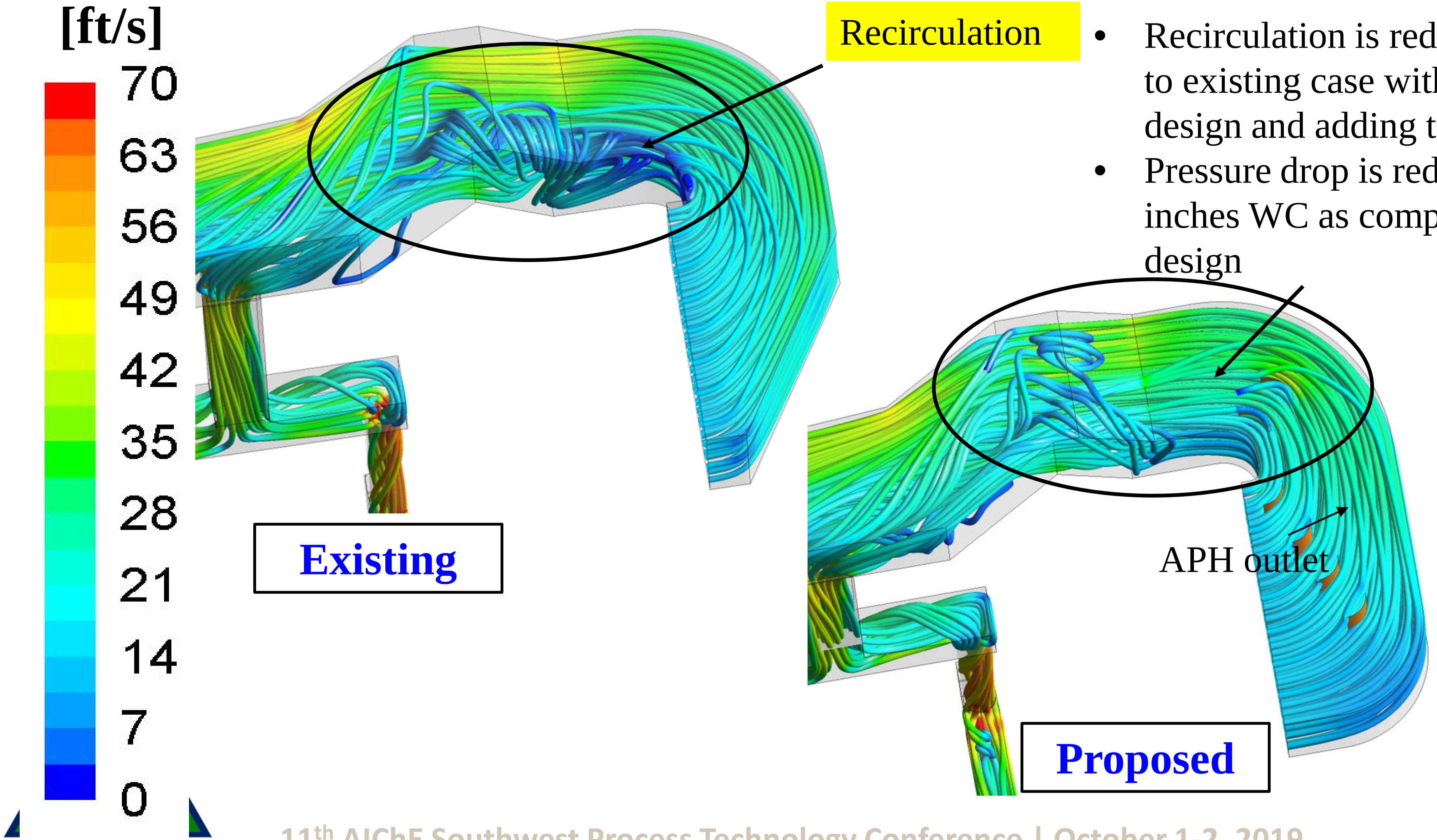
Hot Air Duct Modification for Uniform Air Flow

- Air preheat outlet
- Smooth and turning vanes are added
- Reduced dead zones and recirculation



HA-2N duct modification

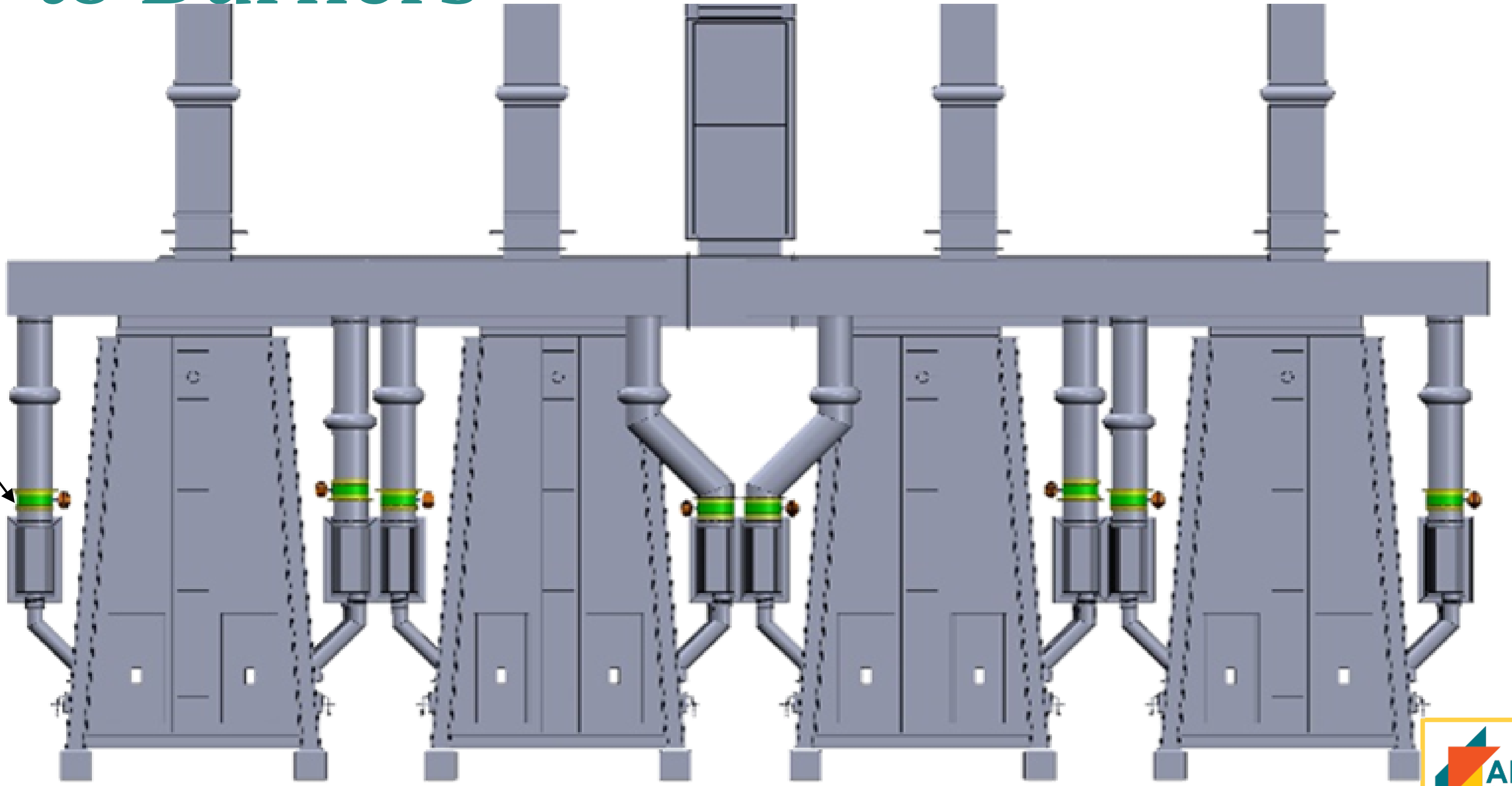
Air Flow Path Lines colored by Velocity



- Recirculation is reduced as compared to existing case with change in duct design and adding turning vanes
- Pressure drop is reduced by 0.05 inches WC as compared to existing design

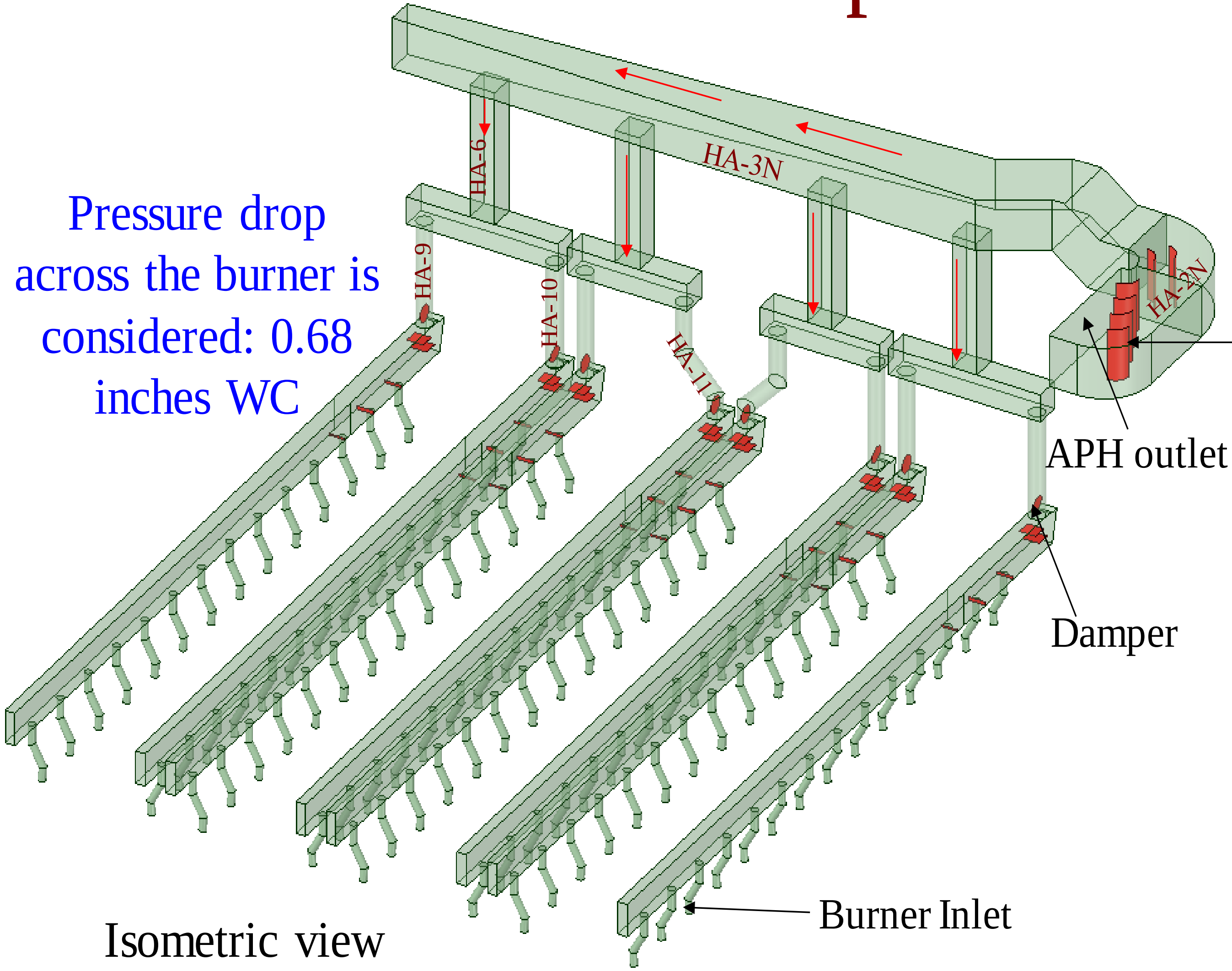
Hot Air Duct Modification for Uniform Air Flow to Burners

Pneumatic Operated Dampers



Hot Air Duct – Proposed Geometry

Pressure drop across the burner is considered: 0.68 inches WC



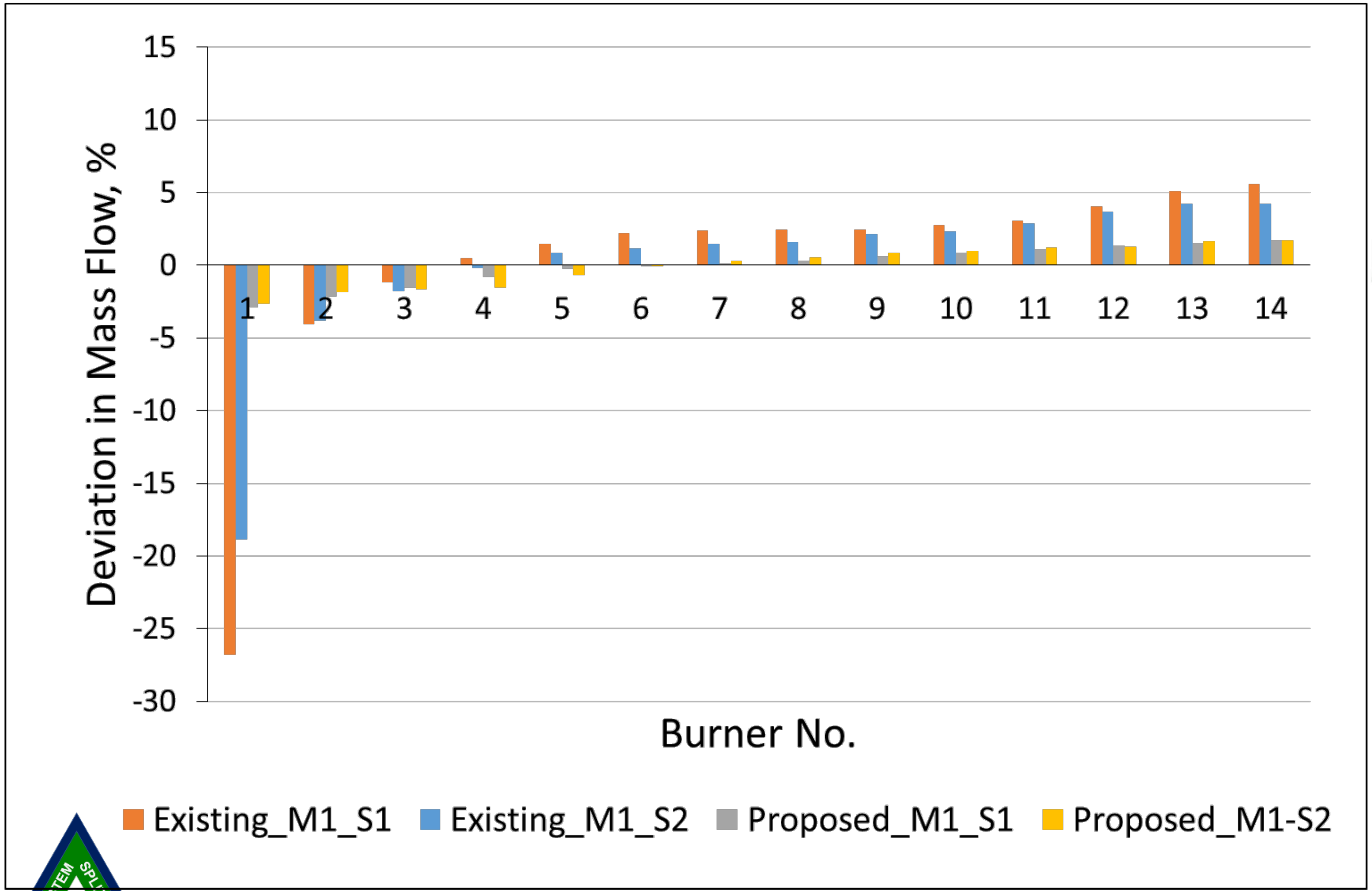
Isometric view

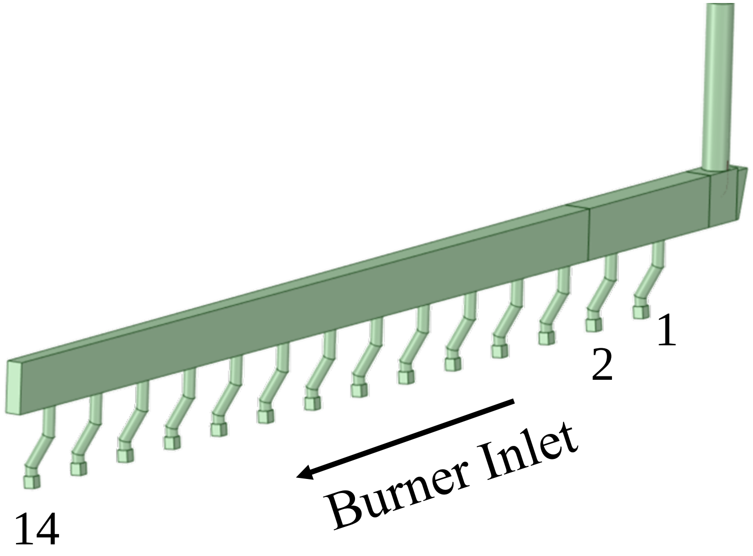
Proposed

SMART STACK DAMPERS
INCLINED FIRING SYSTEM
SPLIT FLOW TECHNOLOGY

AIChE 11th SOUTHWEST PROCESS TECHNOLOGY CONFERENCE

Air Flow Variation to Burners



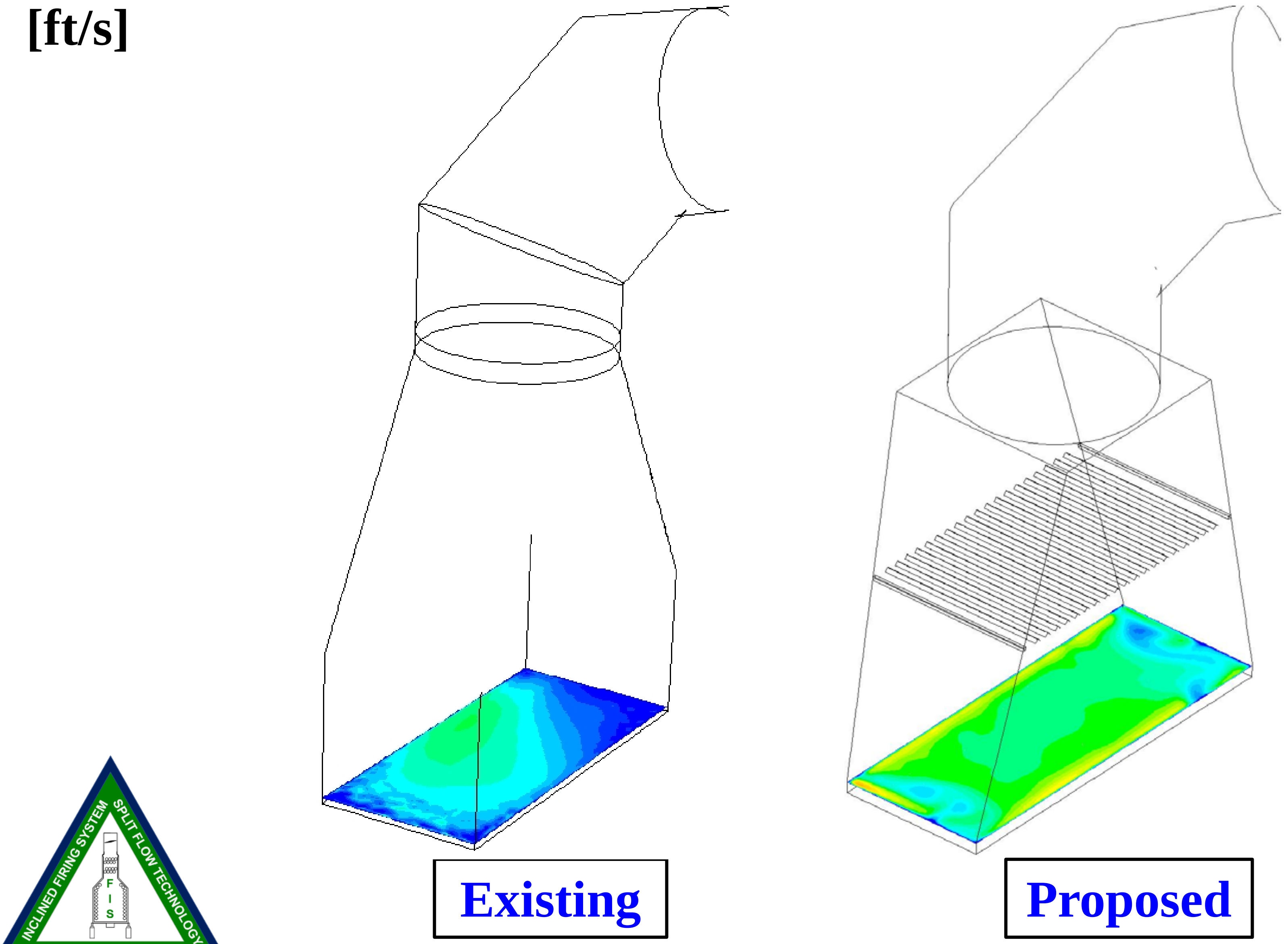


- Mass flow distribution across all the burners is significantly improved for the proposed case
- Improved air flow distribution across burners for other ducts is similar

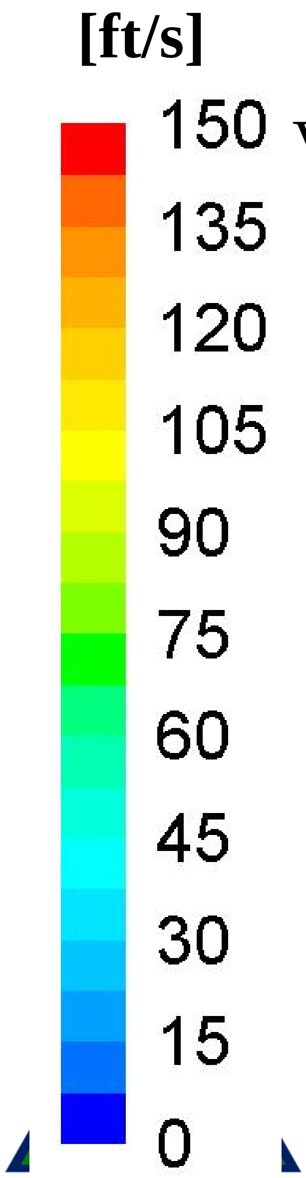
Comparison

- Deviation from average flow rate per burner based on simulation results

Hot Flue Gas Inlet Duct to Air Preheater

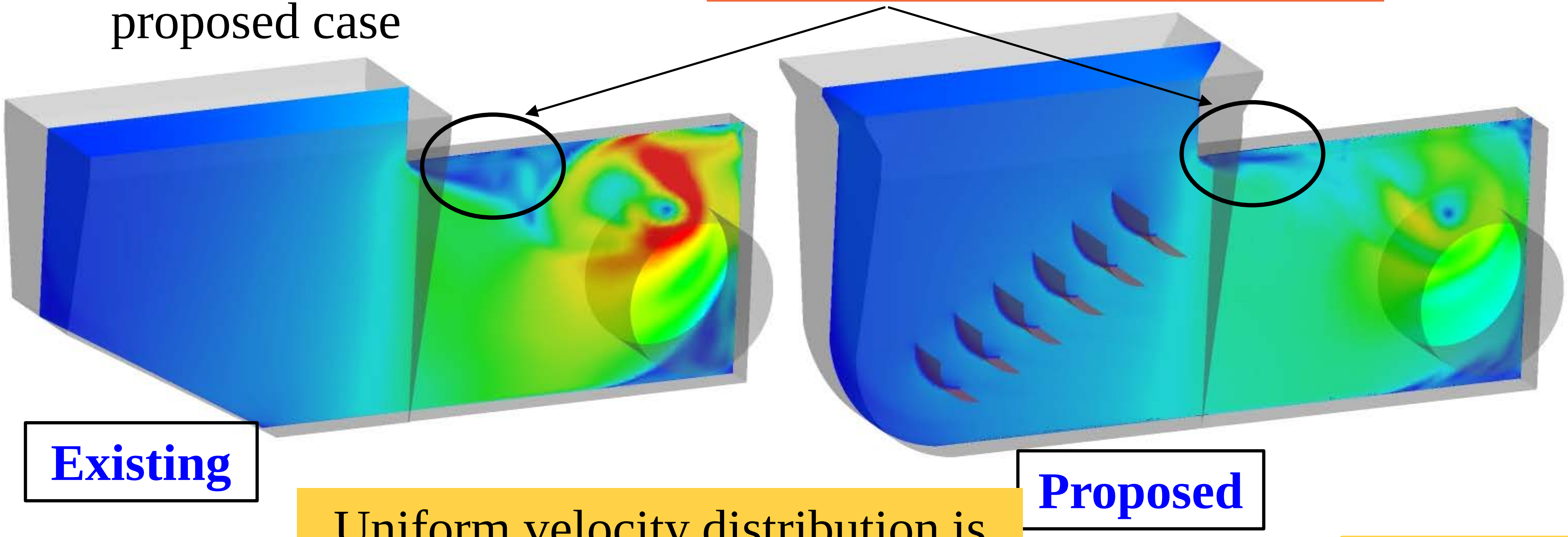


Flue Gas Velocity Profile at ID Suction



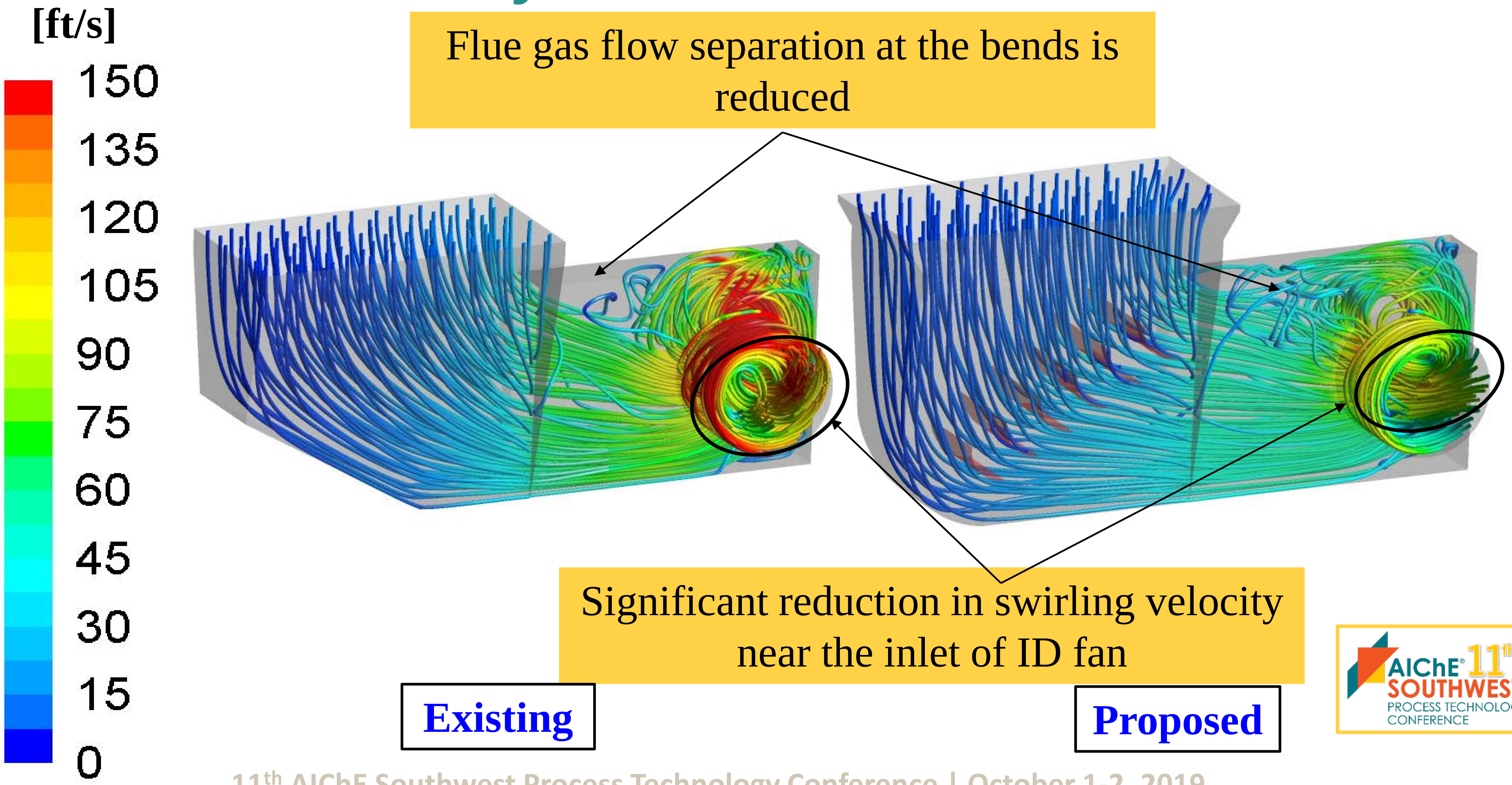
Velocity distribution throughout the duct has improved in the proposed case

Significant reduction in the recirculation zone for the proposed case



Uniform velocity distribution is achieved at the inlet of ID fan for proposed case

Flue Gas Velocity Path Lines at ID Suction



Key Benefits

- Thermal Efficiency of the coker heater increased by 7-8% after the revamp.
- Heater production rate was improved after APH replacement.
- Production rate increased by 4,500 Barrels per day for each heater
- Overall project cost – Total $7.5 Million for two heaters
- At about $8 per Barrel it provided $26 Million additional revenue per year
- Payout -4 months

Thank You!