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FIS
Clean & Efficient Combustion

Smart Stack Damper

Furnace Improvements

www.heatflux.com

New Damper Design Saves Energy

- Why talk about draft control?
- Draft and Excess O_2 are the two parameters that are being monitored and controlled
- Lot of progress has been made in Oxygen Analyzers in the last 20 years
- Very little attention has been paid to draft control
- Poor design and quality of final control element- stack dampers
- Very few dampers really operate properly in the Industry (most are left fully open)

Fired Heater Operation

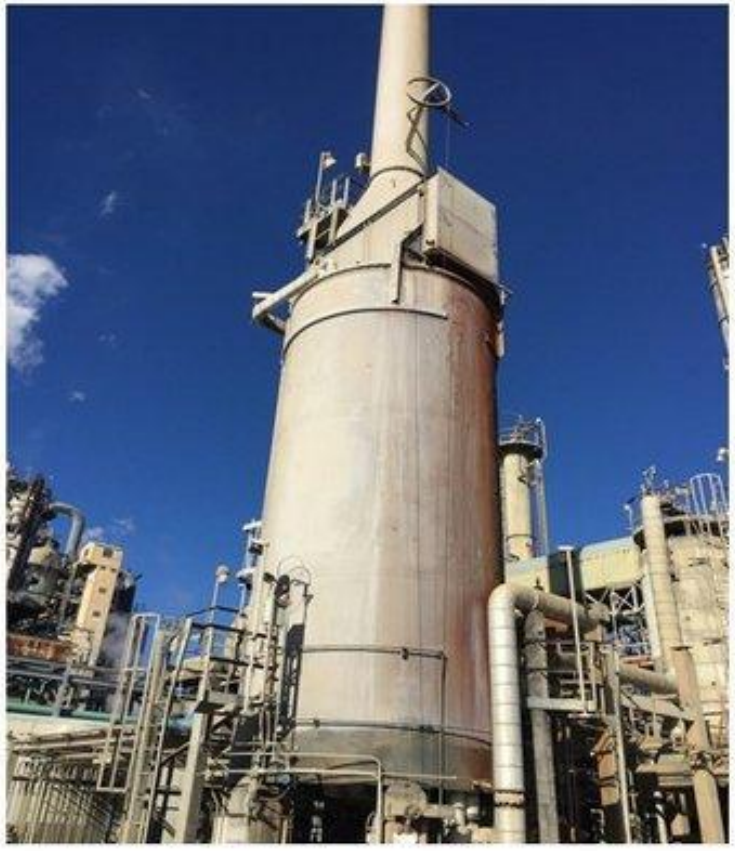
- Operators need to adjust stack damper for draft control in fired heaters
- 90% of fired heaters in US are natural draft heaters
- Tramp air is directly dependent upon the draft inside the heater
- High draft can even affect the flame patterns
- Tramp air leakage can misguide the operating personnel

Tramp Air Leakage

- Air can leak from all the openings
  - Peep Doors, Header Boxes, Tube Penetrations etc.
- This air does not mix with fuel and shows up in O_2 analyzers
- It absorbs the heat that should be transferred to the heater tubes
- All air entering heater should be entering through the burners that are on

Stacks are highly oversized

- Stacks are designed for 115-120% of the loads and maximum ambient temperatures of 95°F to 105°F
- Stack design use 1.5 velocity heads pressure drop across damper, we need only 0.5 in fully open position
- Stack diameters and height are often decided by structural stability and minimum height considerations
- Stacks are over designed and produces very high draft in fired heaters



Stack Damper Operation

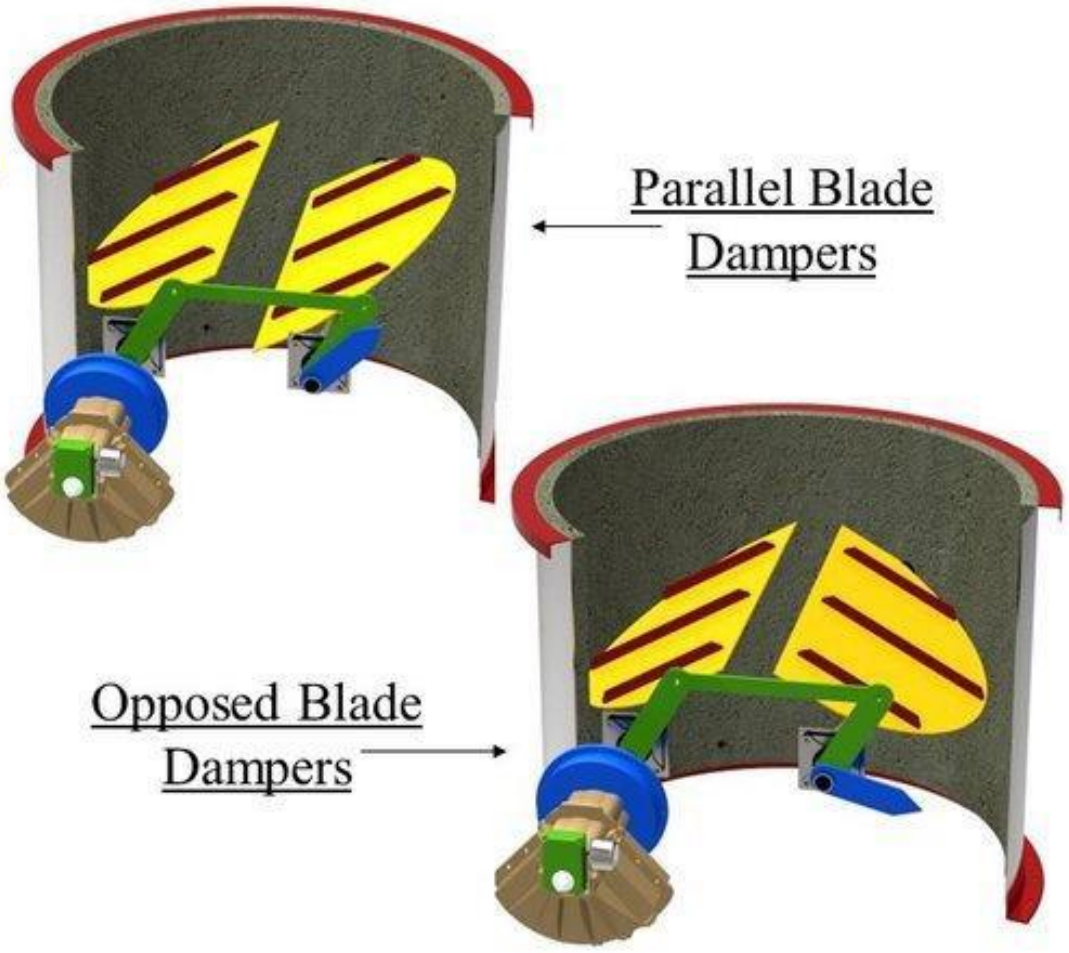
- Draft in natural draft heaters varies with ambient air temperature
- Night time cooler air temperature produces higher drafts, almost 0.1 inch extra draft is available
- Stack damper needs to be adjusted at least twice a day to optimize the heater operation
- Stack damper position for 115% load is around 55°-60° open
- Stack damper needs to be open at 45°-50° for full load operation

Stack Damper Operation

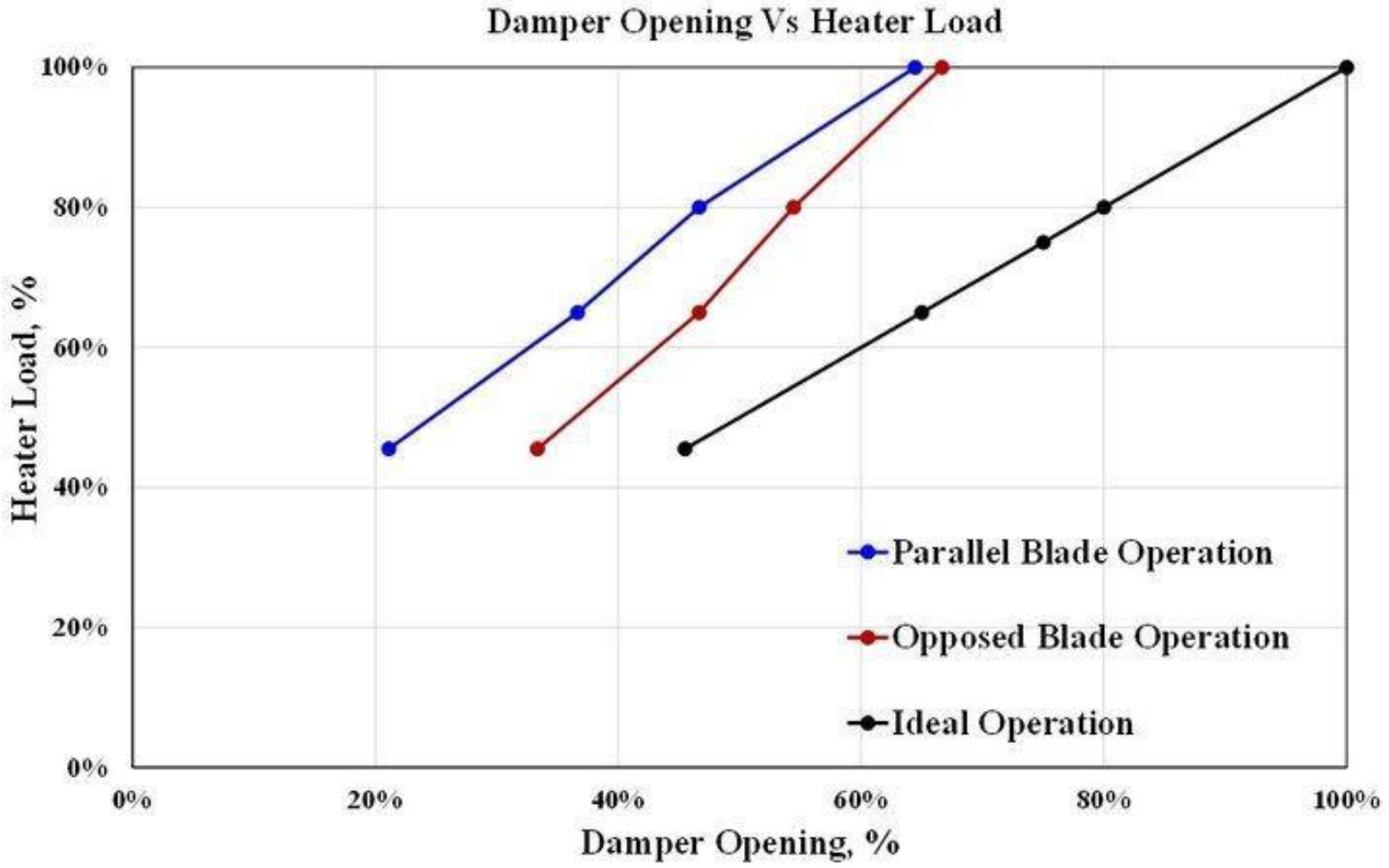
- For a manually operated damper, the stack damper operation becomes very cumbersome
- For a pneumatically operated dampers, the operators are concerned about closing the damper and tripping the heater
- In practice, most of the time damper blades are left fully open

Conventional Damper Blade System

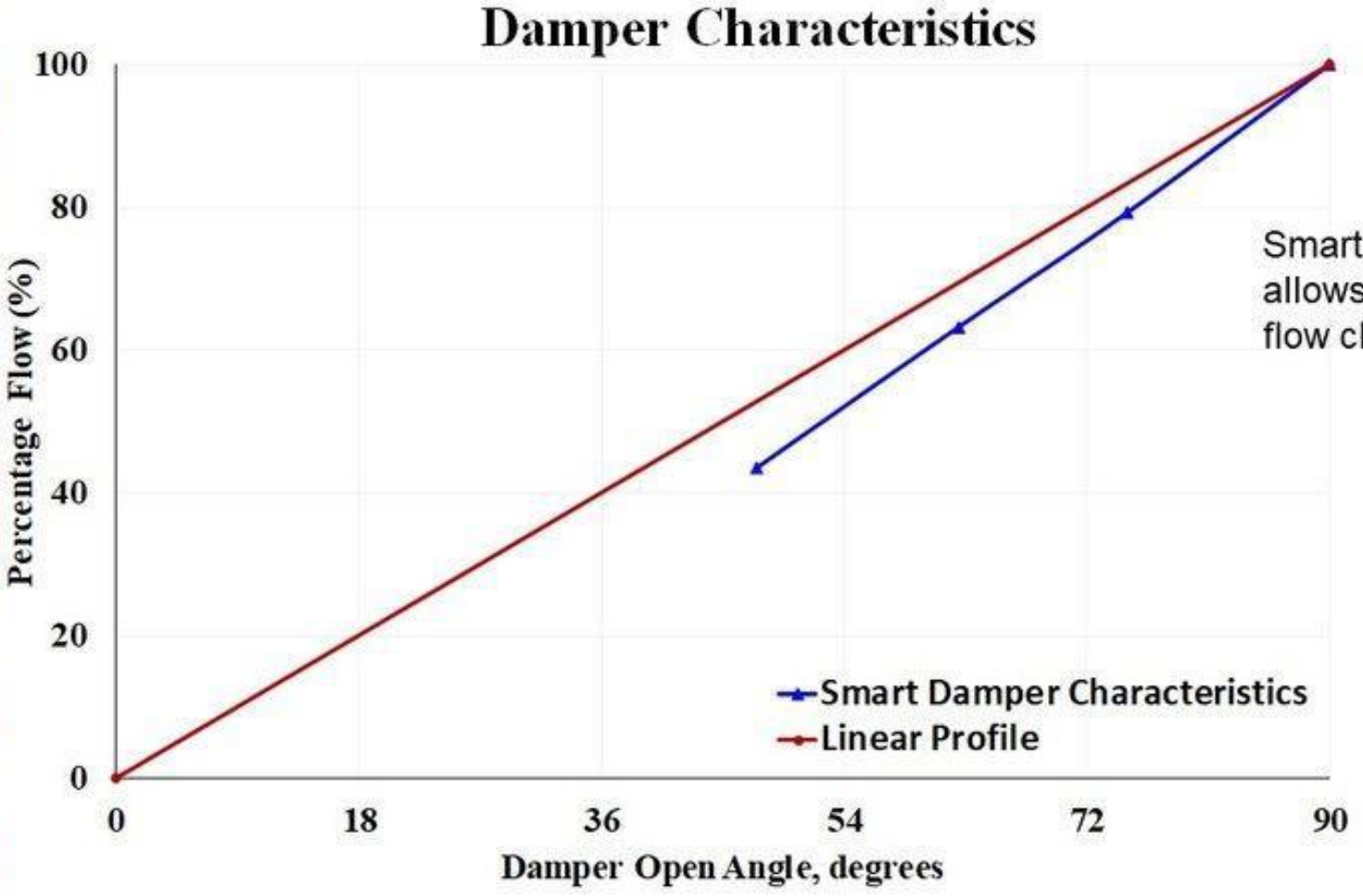
- Parallel or Opposed Blade Operation
- All the blades are operated with a single actuator
- All the damper blades move at the same angle
- Non-Linear damper flow characteristics makes the system less efficient for draft control



Damper Flow Characteristics



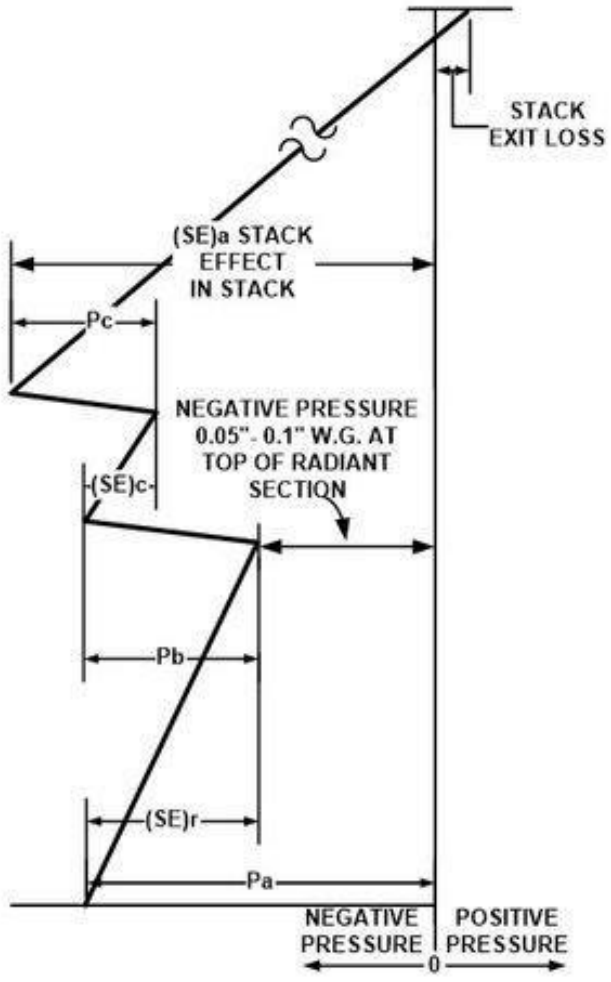
Smart Stack Damper Characteristics



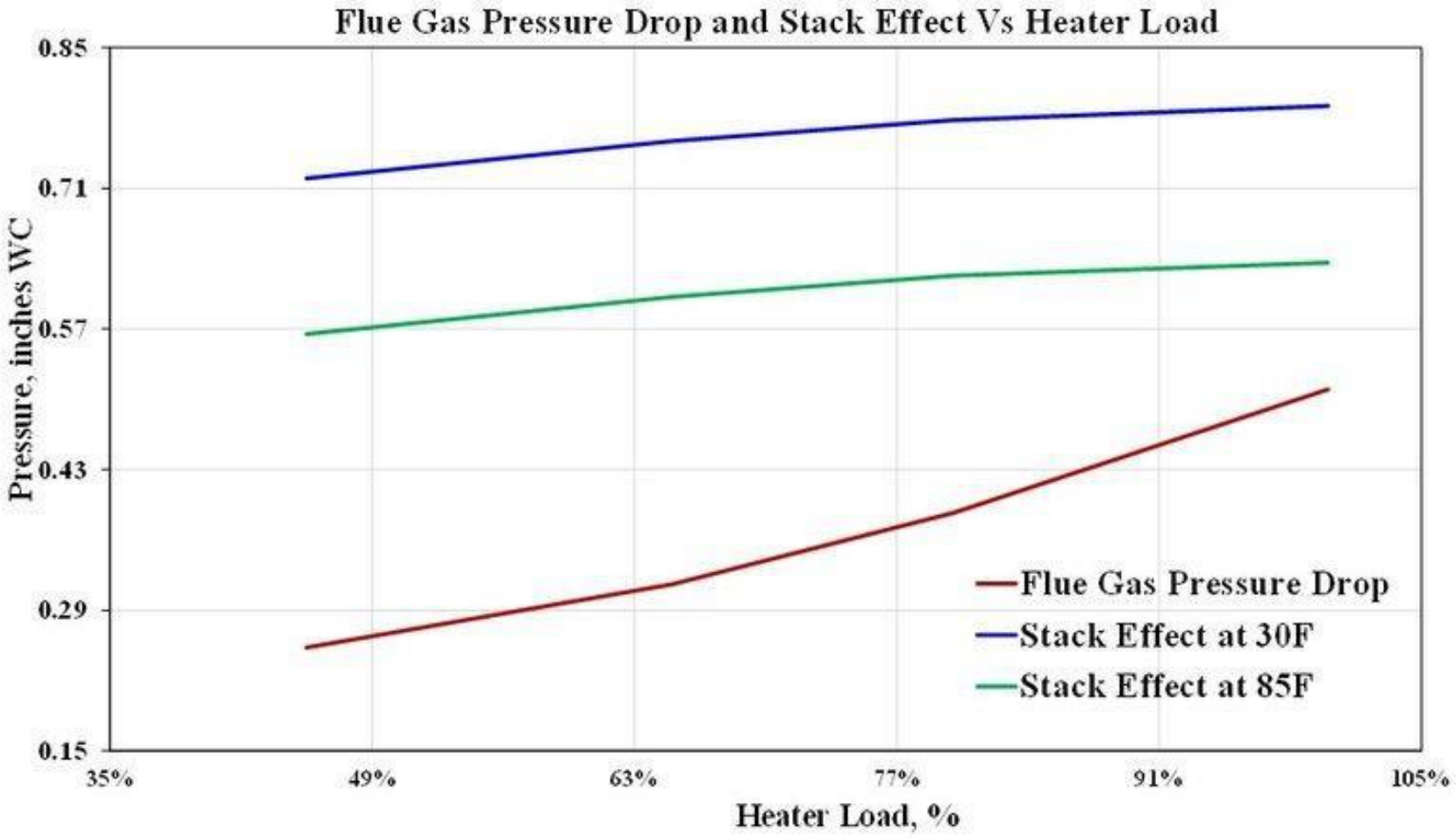
Smart Stack Damper design allows close to linear damper flow characteristics

Fired Heater Draft Profile

- Damper is modulated to maintain 0.1”WC draft at arch
- **Flue Gas Pressure Drop** consists of pressure losses along:
  - Convection Section & Stack Entry
  - Stack friction
  - Stack exit loss
- **Stack effect**:
  - Movement of ambient air into the heater resulting from buoyancy due to density difference in hot flue gas and ambient air resulting from temperature differences

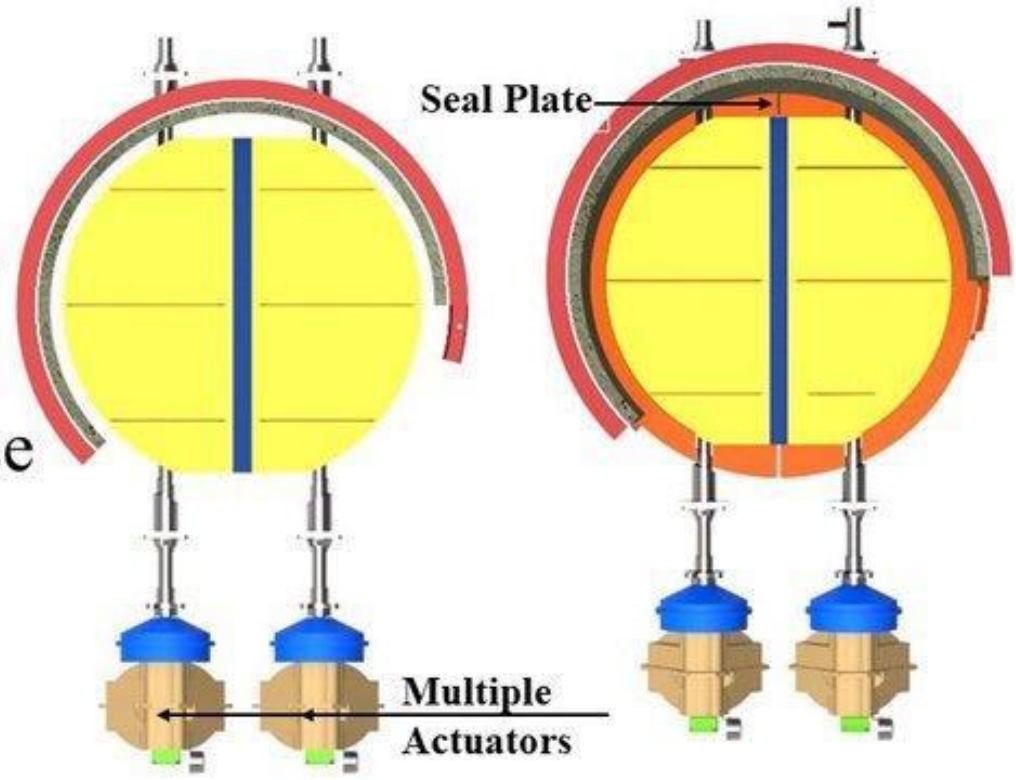


Stack damper needs to consume higher pressure drop as the heater load goes down



Smart Stack Damper (SSD)

- Multiple pneumatic actuators provided to operate damper blades individually
- Independent control of damper blades changes the damper characteristics providing precise control at any load
- Seal plate is **optional** to avoid any leakage of flue gas, and provide additional pressure drop



Salient Features

- Multiple pneumatic operators with hand actuators at the panel
- Three pressure transmitters at arch
- Better controlling characteristics
- Operator friendly
- Avoid tramp air leakage
- Can be controlled from the control room

Stack Damper with 2 Blades

Conventional Design with Single Control Driver

Parallel

Opposed

Smart Stack Damper with Two Control Drivers

Stack Damper with 4 Blades

Conventional Design with Single Control Driver

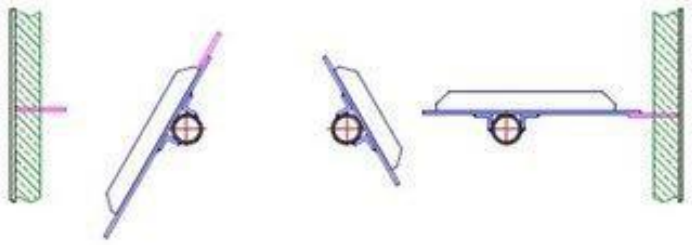
Parallel

Opposed

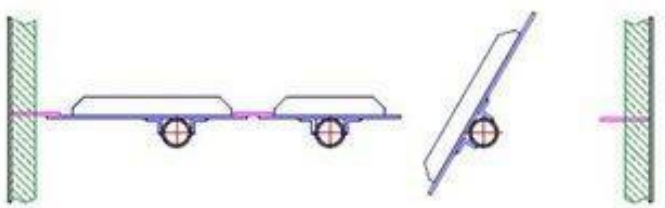
Smart Stack Damper with Three Control Drivers

General Operating Philosophy for SSD

- Operating philosophy for a smaller diameter stack with 3 damper blades
- One actuator will be operated as per the heater load, another actuator will be adjusted to maintain the required draft at the arch
- This allows us to make major adjustment with one actuator quickly as the load is adjusted and then smaller adjustments can be done with the other actuator



Option-1



Option-2

Case Study 1

Heater operates for 3 days in a year at 100% capacity

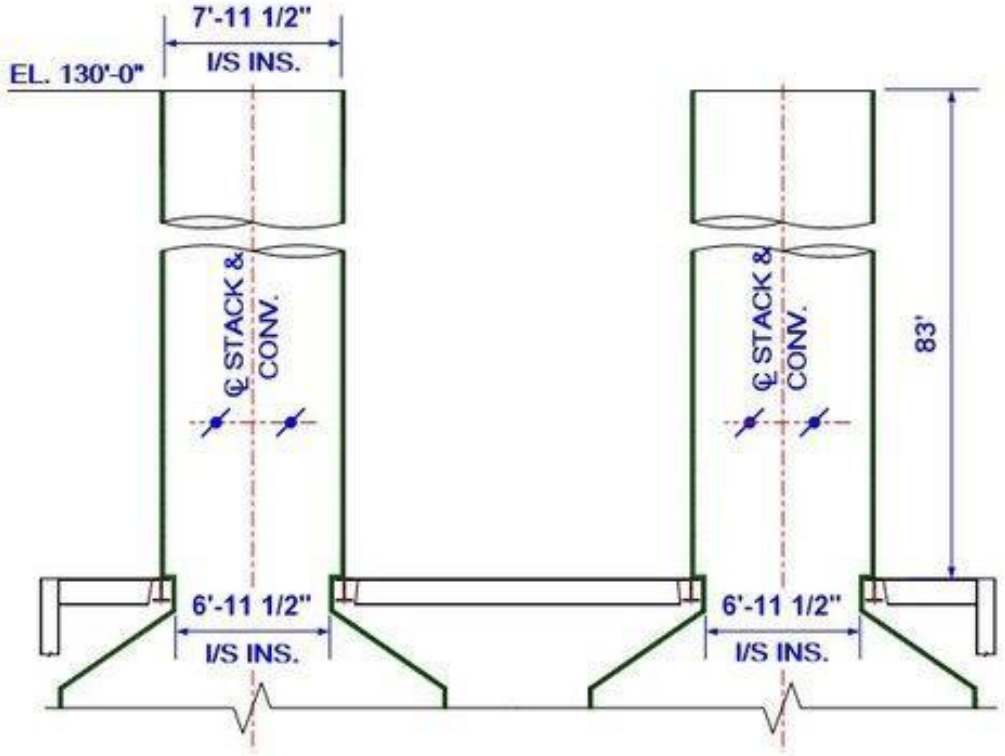
Rest of the year runs at lower capacity

Process Conditions

Parameter	Unit	100% Load	80% Load	65% Load	45.5% Load
Heater Load	MMBtu/hr	327.7	260.9	213.4	149
Flue gas flow rate per stack	lb/hr	183,587	145,493	116,115	79,881
Flue gas temperature	°F	529.3	478.3	435.6	383.2
Flue gas density	lb/ft^3	0.037	0.039	0.041	0.045
Ambient temperature	°F	85	85	85	85

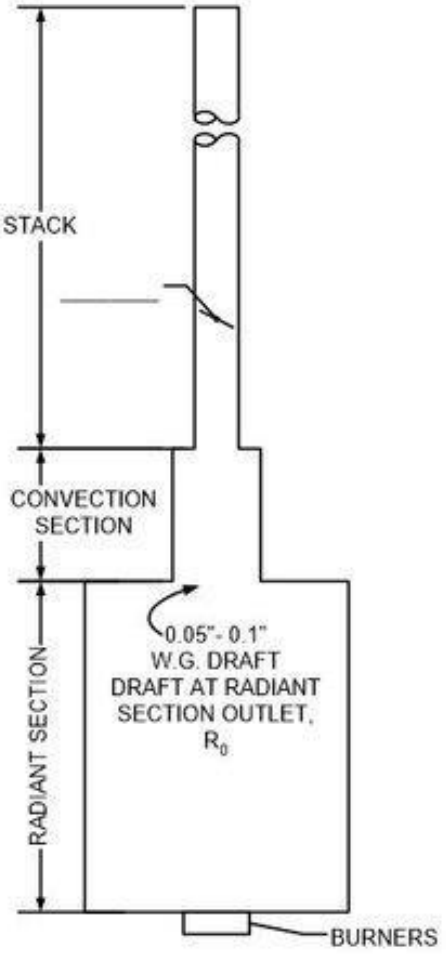
Existing Stack Details

- 2 Identical Stacks per Heater
  - Location– Top of Convection
  - Type– Self supporting
  - Stack Diameter– 7’-11 ½” (I/S Insulation)
  - Stack Length– 83 ft
  - Stack Elevation– 130 ft
- Damper
  - Two blades- Parallel Operation

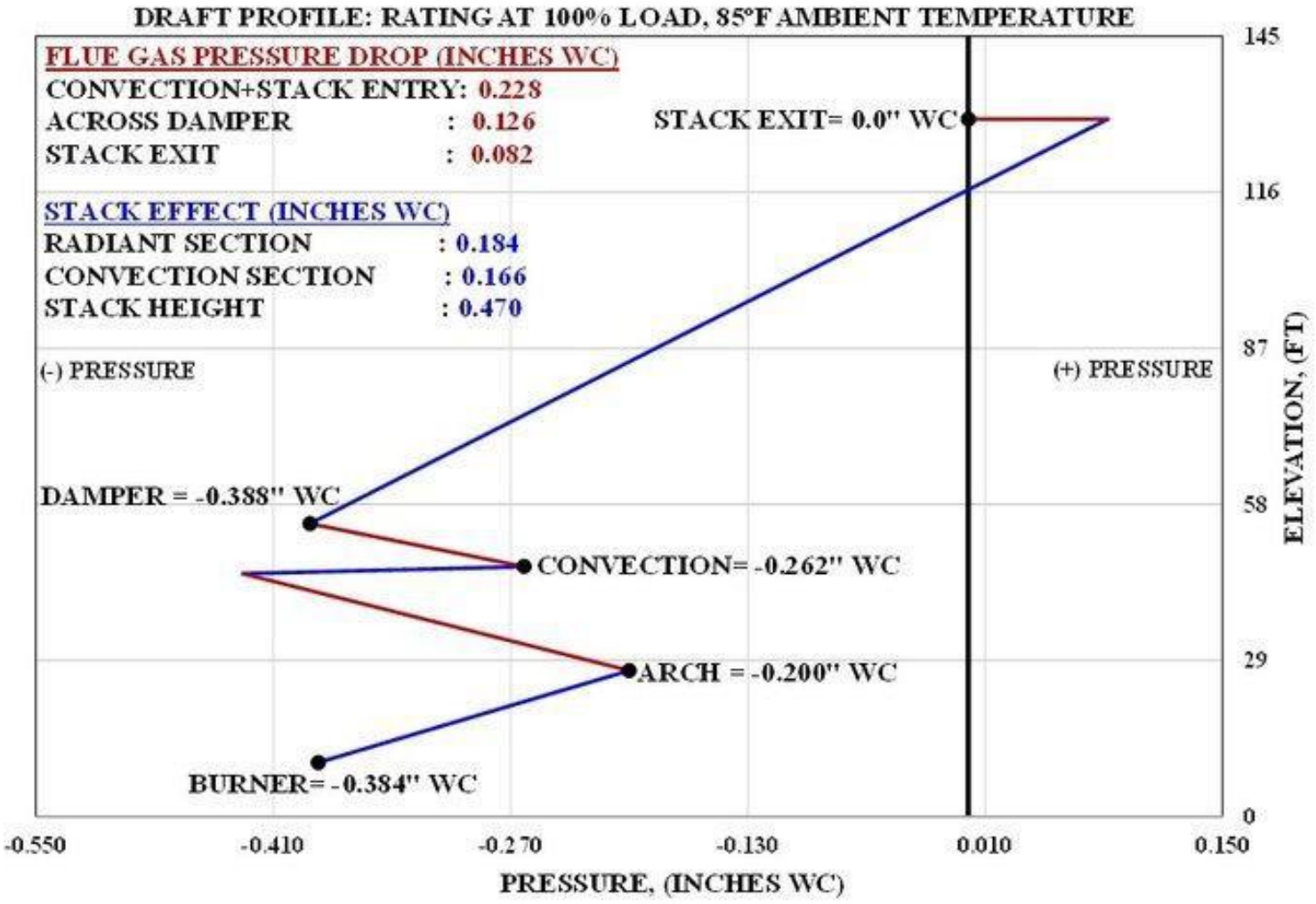


Stack Rating Calculation

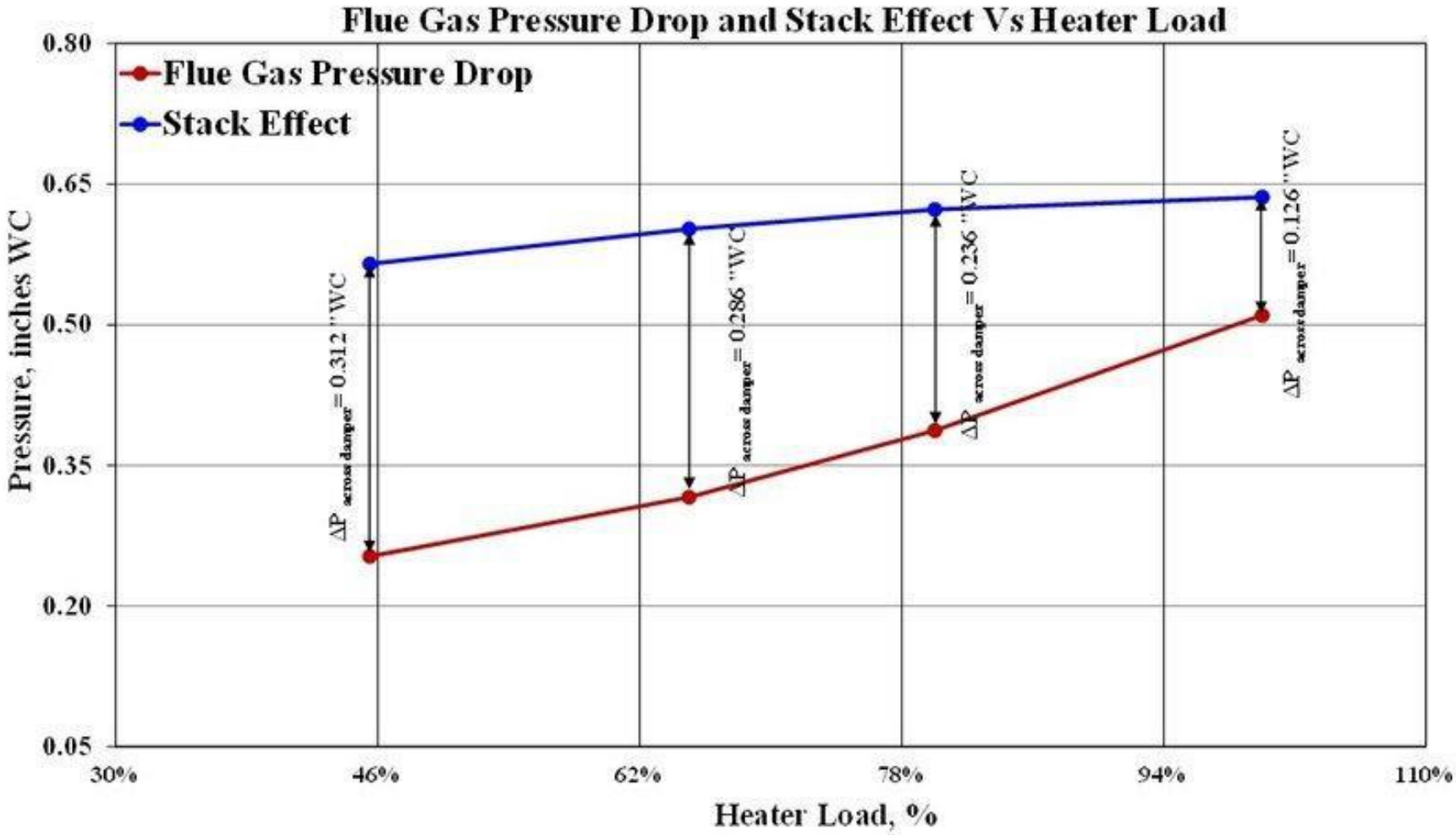
- Stack rating calculation is performed at 100% heater load
- Draft at arch: 0.200" WC
- Stack effect is considered at a maximum ambient temperature of 85°F and average flue gas temperature along radiant, convection and stack section
- Flue gas side pressure drop:
  - Along convection section tubes
  - Stack entry loss= 0.5 velocity head
  - Pressure drop across damper= 1.5 velocity head (60° Open)
  - Stack exit loss= 1 velocity head



Draft Profile: Stack Rating Condition



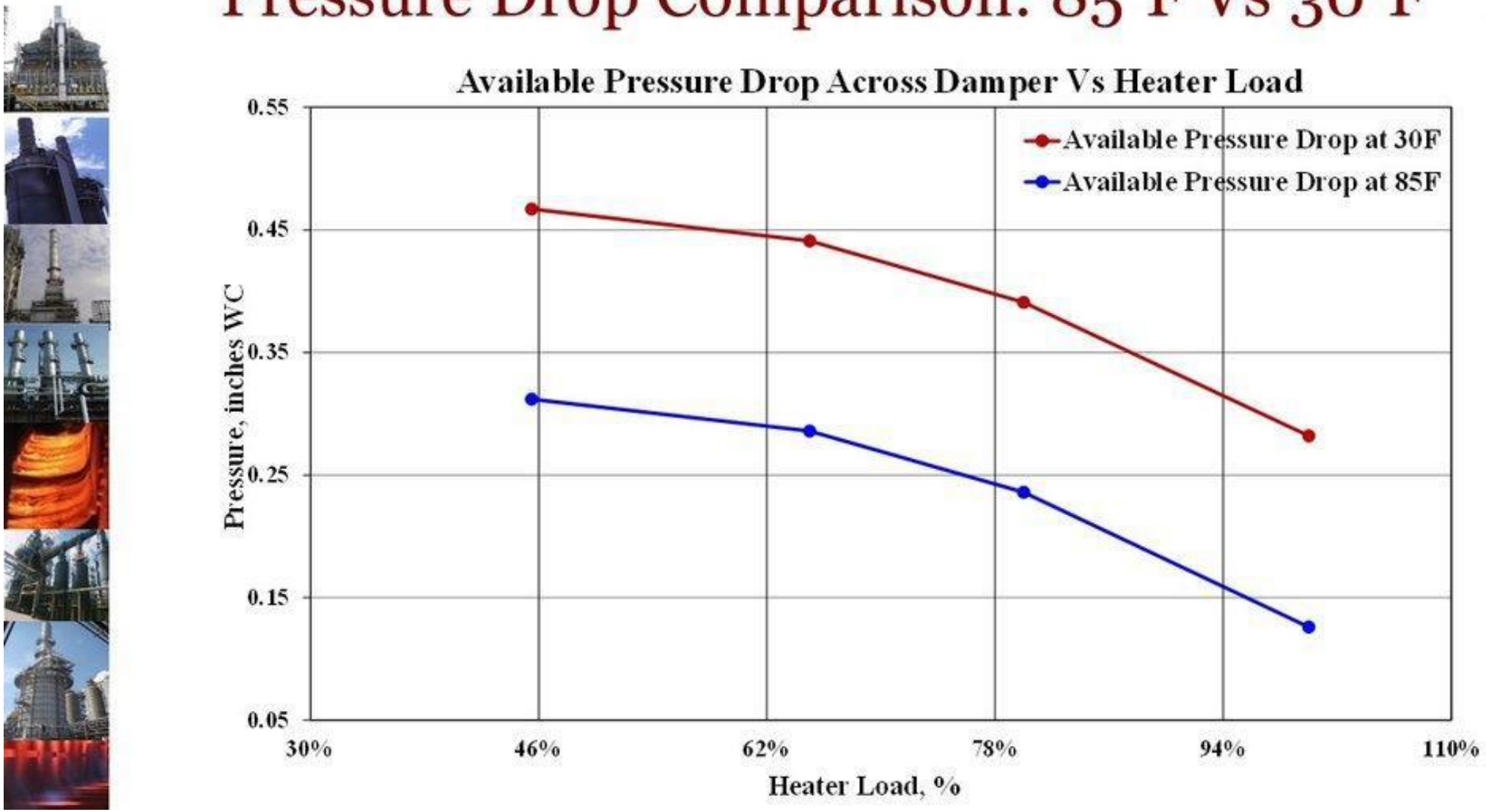
Available Pressure Drop Across Damper



Available Pressure Drop Across Damper

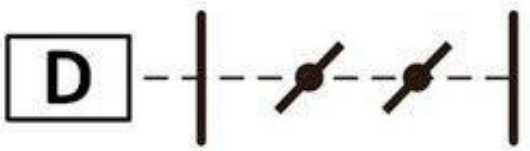
Pressure Drop Across Damper, inches WC		
Heater Load	Ambient Temperature, 85°F	Ambient Temperature, 30°F
100%	0.126	0.282
80%	0.236	0.391
65%	0.286	0.441
45.5%	0.312	0.467

Pressure Drop Comparison: 85°F Vs 30°F

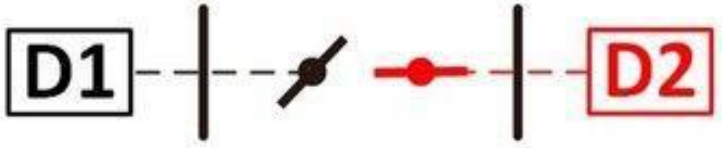


Damper Operation

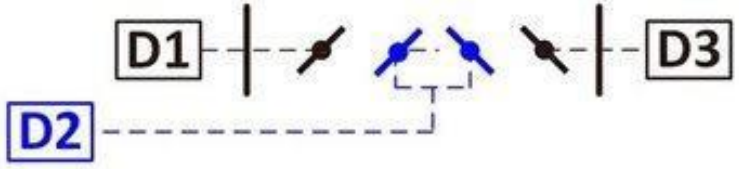
- **Parallel and opposed blade operation**
  - All the blades move at same angle (Θ)
- For SSD operation two options are evaluated:
  - **2 damper blade system**
    - Each damper blade can be operated individually at angles Θ_1 and Θ_2
  - **4 damper blade system**
    - Centre two damper blades are operated together with a single actuator at angle Θ_2
    - Extreme two damper blade are operated at angle Θ_1 and Θ_3



Parallel Blade Dampers



SSD: Option 1



SSD: Option 2

Option 1

2 Blade Damper Operation

Damper Operation

- Parallel and opposed blade operation, all the blades move at same angle (Θ)
- SSD operation, the dual damper blades are operated independently at Θ_1 and Θ_2

Conventional System

SSD

Damper Openings at Different Loads

Comparison of Damper Openings					
Heater Load	ΔP Across Damper	Parallel	Opposed	SSD	
%	inches WC	Θ	Θ	Θ_1	Θ_2
100	0.126	58°	60°	67.5°	67.5°
80	0.236	42°	49°	54°	54°
60	0.286	33°	42°	0°	75°
45.5	0.312	19°	30°	0°	52°

Impact of Ambient Temperature

- Two ambient conditions were considered to study the change in two blade damper angles for 100% heater load

Comparison of Damper Angles					
Ambient Temperature	ΔP Across Damper	Parallel	Opposed	SSD	
°F	inches WC	Θ	Θ	Θ_1	Θ_2
85	0.126	58°	60°	67.5°	67.5°
30	0.282	46.5°	52.5°	57.5°	57.5°

Option 2

4 Blade Damper Operation

Damper Angles

Comparison of Damper Angles						
Heater Load	ΔP Across Damper	Parallel	Opposed	SSD		
%	inches WC	Θ_1	Θ_1	Θ_1	Θ_2	Θ_3
100	0.126	58°	60°	0°	87.5°	90°
80	0.236	42°	49°	0°	65°	90°
60	0.286	33°	42°	0°	73°	0°
45.5	0.312	19°	30°	0°	60°	0°

Impact of Ambient Temperature

- Two ambient conditions were considered to study the change in damper angles

Comparison of Damper Angles						
Ambient Temperature	ΔP Across Damper	Parallel	Opposed	SSD		
ºF	inches WC	Θ_1	Θ_1	Θ_1	Θ_2	Θ_3
85	0.126	58º	60º	0º	87.5º	90º
30	0.282	46.5º	52.5º	0º	68.5º	90º

Summary

- SSD provides flexibility of altering damper configuration for various heater loads

- With multiple actuators, one actuator could be used for major adjustments and other actuators for minor adjustments

Case Study 2

Coker Heater-

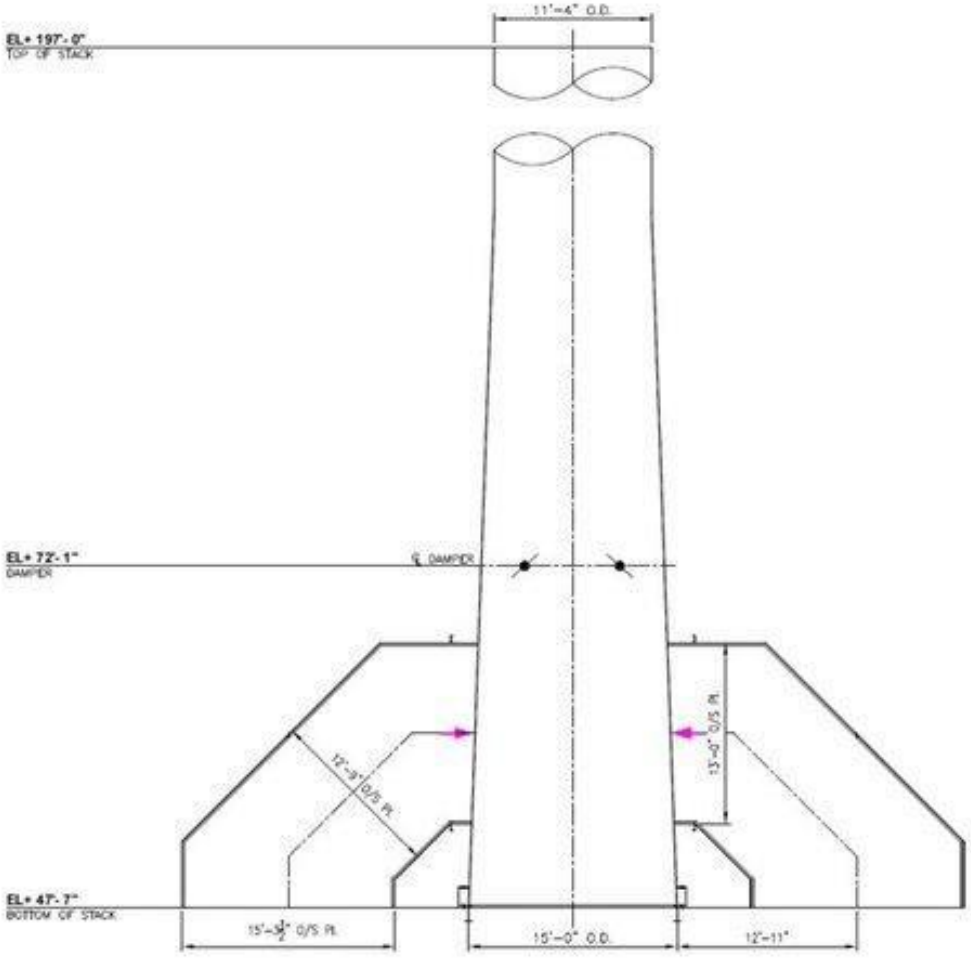
Stack designed for very low pressure drop along the off-take ducts and damper

Process Conditions

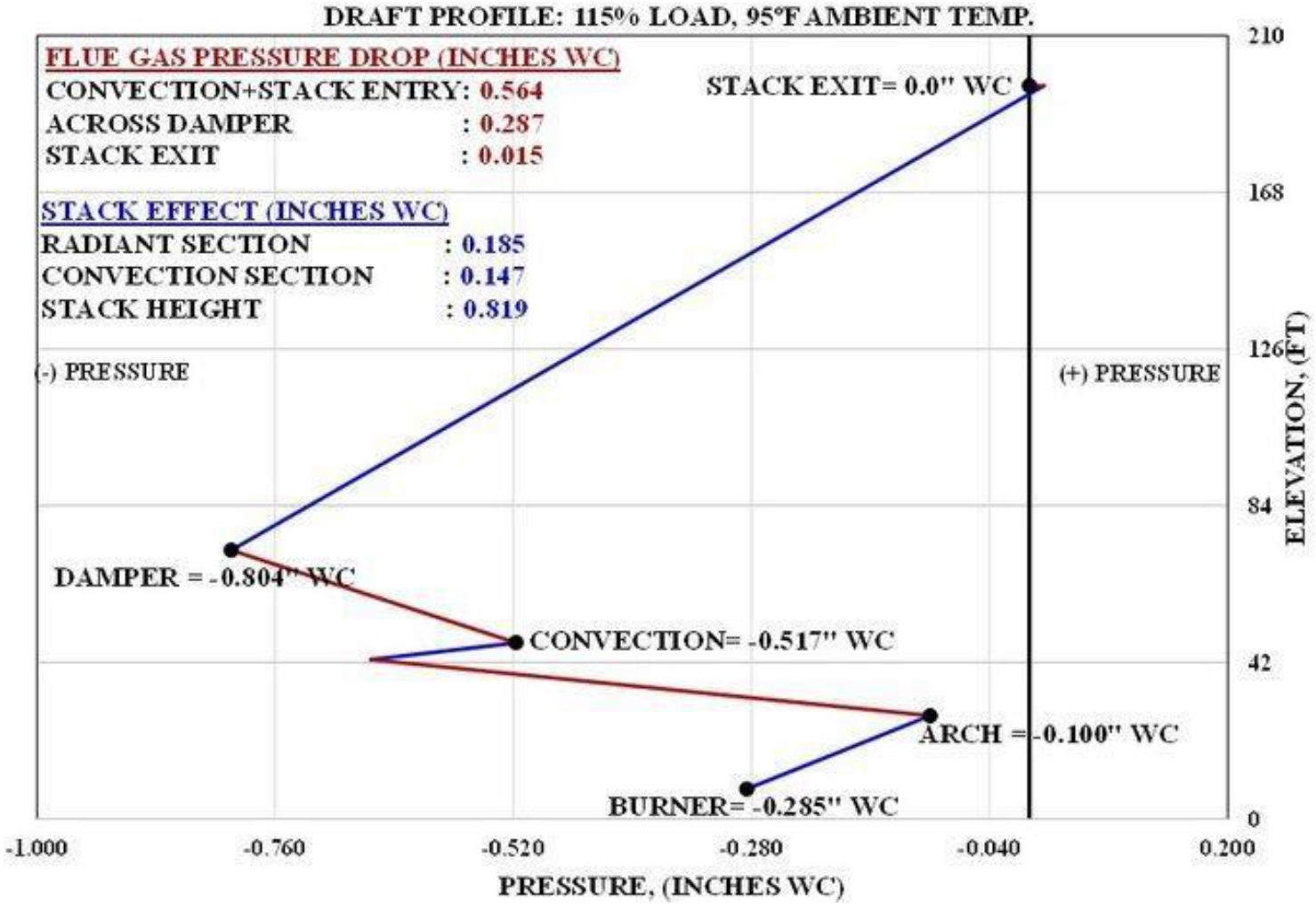
Parameter	Unit	100% Load	75% Load	60% Load	50% Load
Heater Load	MMBtu/hr	22.5	16.9	13.5	11.3
Flue gas flow rate	lb/hr	26,661	19,552	15,502	12,842
Flue gas temperature	°F	773.0	712.6	680.9	661.5
Flue gas density	lb/ft^3	0.030	0.032	0.032	0.033
Ambient temperature	°F	95	95	95	95

Existing Stack Details

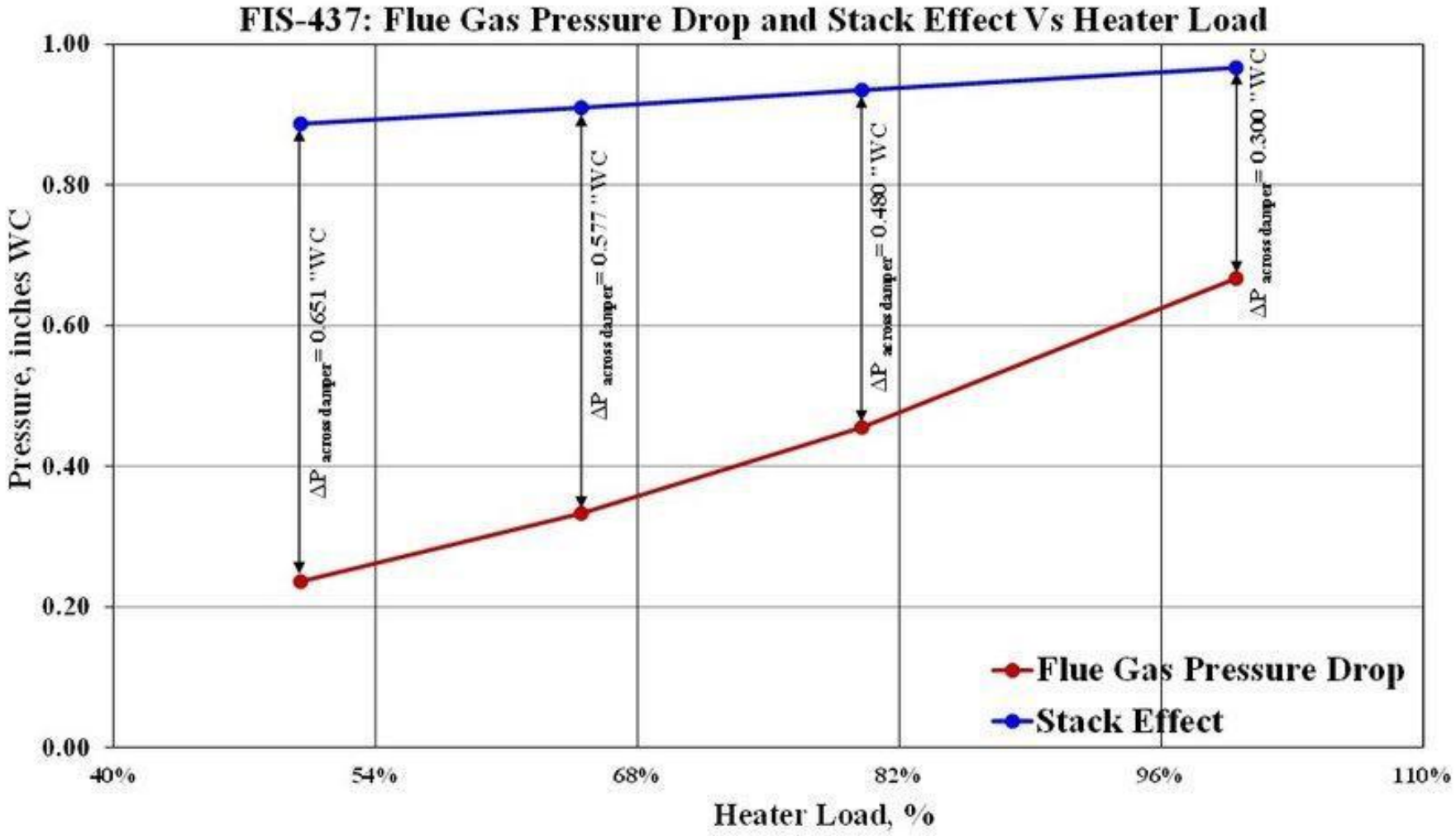
- Location– Top of Convection
- Type– Self supporting
- Stack Diameter (Uninsulated)
  - Base- 15’-0”
  - Damper Location- 13’2”
  - Tip- 11’3”
- Stack Length – 149’5”
- Stack Elevation – 197 ft
- Damper
  - Two blades- Parallel Operation



Draft Profile: Stack Rating Condition



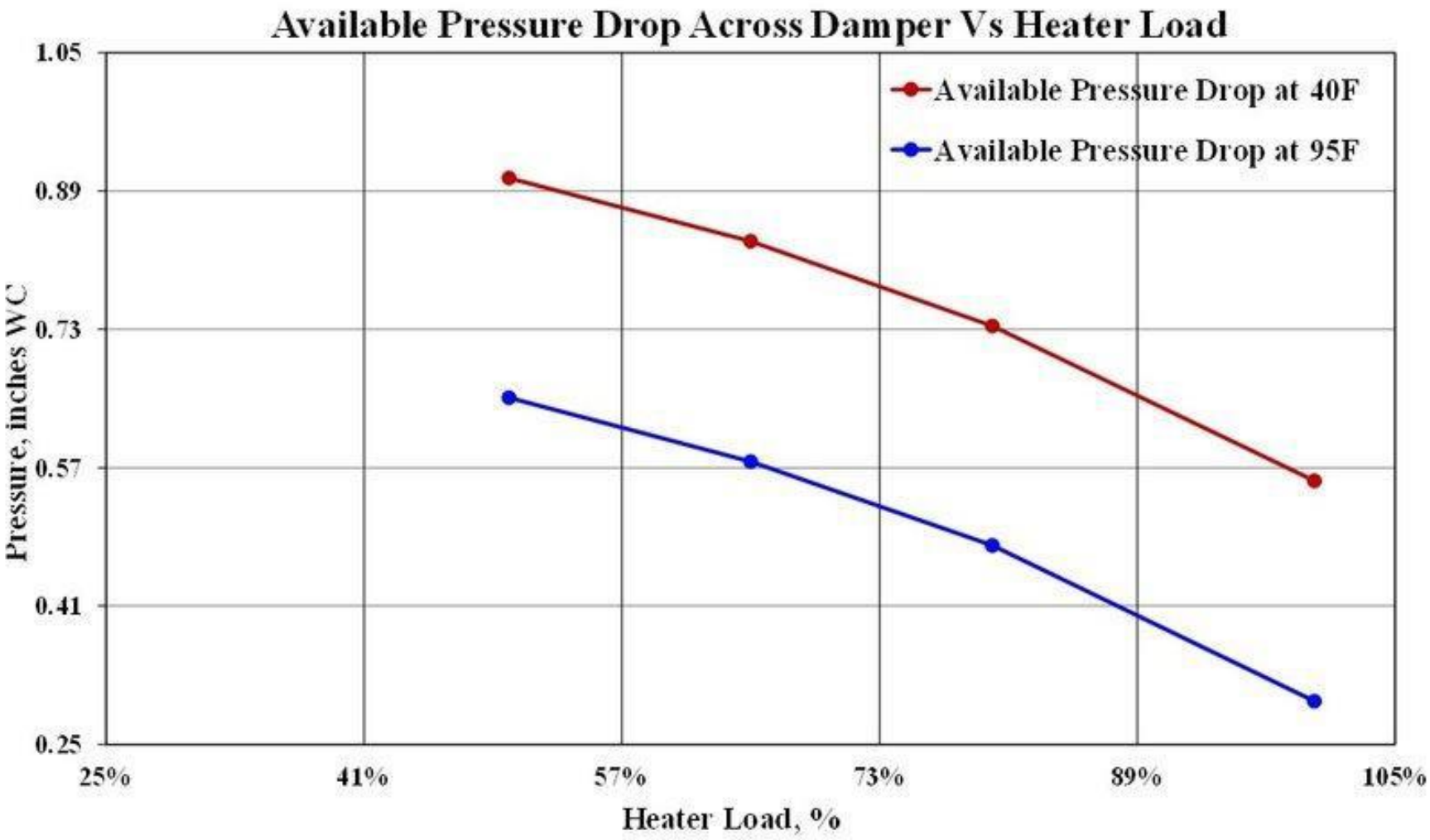
Available Pressure Drop Across Damper



Available Pressure Drop Across Damper

Pressure Drop Across Damper, inches WC		
Heater Load	Ambient Temperature, 95°F	Ambient Temperature, 40°F
100%	0.300	0.555
80%	0.480	0.734
65%	0.577	0.832
50%	0.651	0.905

Pressure Drop Comparison: 95°F Vs 40°F



Damper Operation

- In parallel and opposed blade operation all the blades move at same angle (Θ)
- For SSD-
  - 4 damper blade system with 3 actuators is considered
  - Extreme 2 blades can be operated individually at angles Θ_1 and Θ_3
  - Middle two blades can be operated together at angle Θ_2

Conventional **SSD**

* In this design seal plate was considered

Damper Angles

Comparison of Damper Angles						
Heater Load	Pressure Drop Across Damper	Parallel	Opposed	SSD		
%	inches WC	Θ	Θ	Θ_1	Θ_2	Θ_3
100	0.300	13	25	0	0	90
80	0.480	3.5	12	0	0	56
65	0.577	-	-	0	0	42
50	0.651	-	-	0	0	29

Impact of Ambient Temperature

- Two ambient conditions were considered to study the change in damper angles for 100% heater load

Comparison of Damper Angles						
Ambient Temperature	Pressure Drop Across Damper	Parallel	Opposed	SSD		
°F	inches WC	Θ	Θ	Θ_1	Θ_2	Θ_3
95	0.300	13	25	0	0	90
40	0.555	6.5	18	0	0	65

Summary

- With conventional damper blade system, for heater loads below 80%, draft at arch cannot be maintained at 0.1 inch WC
  - Even with stack damper blades fully closed draft at arch will be more than 0.1 inch WC

- Smart Stack Damper system with 4 blades and 3 actuators provides draft control for 0.1" WC over the wide range of operating conditions

- Flexibility to operate the blades individually provides, efficient and reliable control over draft