

Fundamentals of Making Energy-Saving and Cost-Efficient Boiler Exhaust Systems – Design Solutions and Applications

ASHRAE Qatar Oryx Chapter – 10th November 2012
Presenter: Steen Hagensen



A photograph of three people in an office setting. A man in a dark suit and glasses is leaning over a desk, pointing at a laptop. Another man in a dark suit is standing behind him, also looking at the laptop. A woman in a light-colored shirt is standing to the right, looking on. On the desk is a white architectural model of a building with multiple windows. The background shows office shelves and a clock on the wall.

***Make the unimaginable and impossible POSSIBLE!
A guide for using the ASHRAE's chimney design
equation to design boiler exhaust systems that
save space, reduce installation cost and energy -
and allow the designer to design systems that
normally would be deemed impossible***



Z223.1-NFPA54 / International Fuel Gas Code (Venting of equipment)

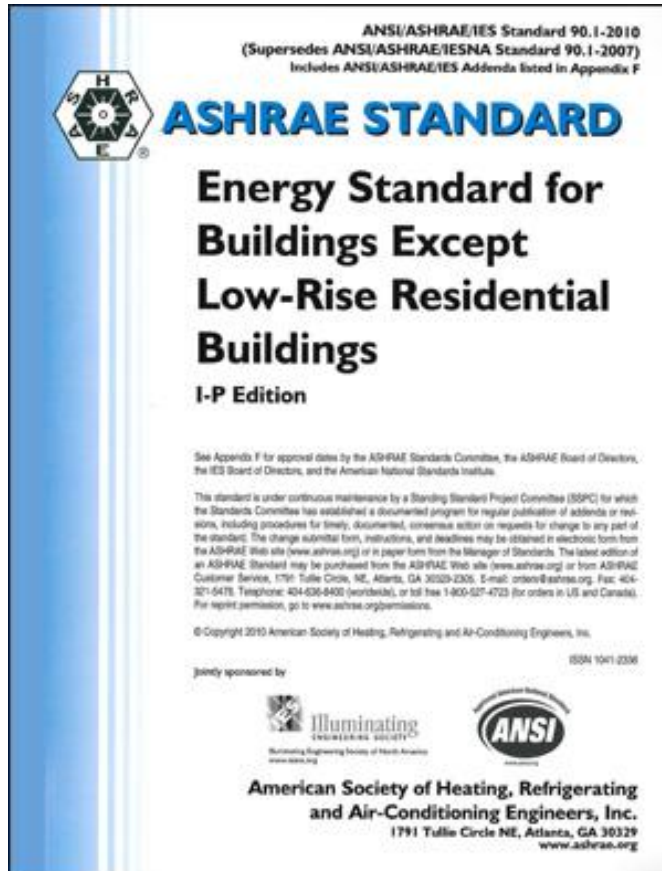
Minimum Safe Performance

A venting system shall be designed and constructed so as to develop a positive flow adequate to remove flue or vent gases to the outside atmosphere.

Equipment Draft Requirement

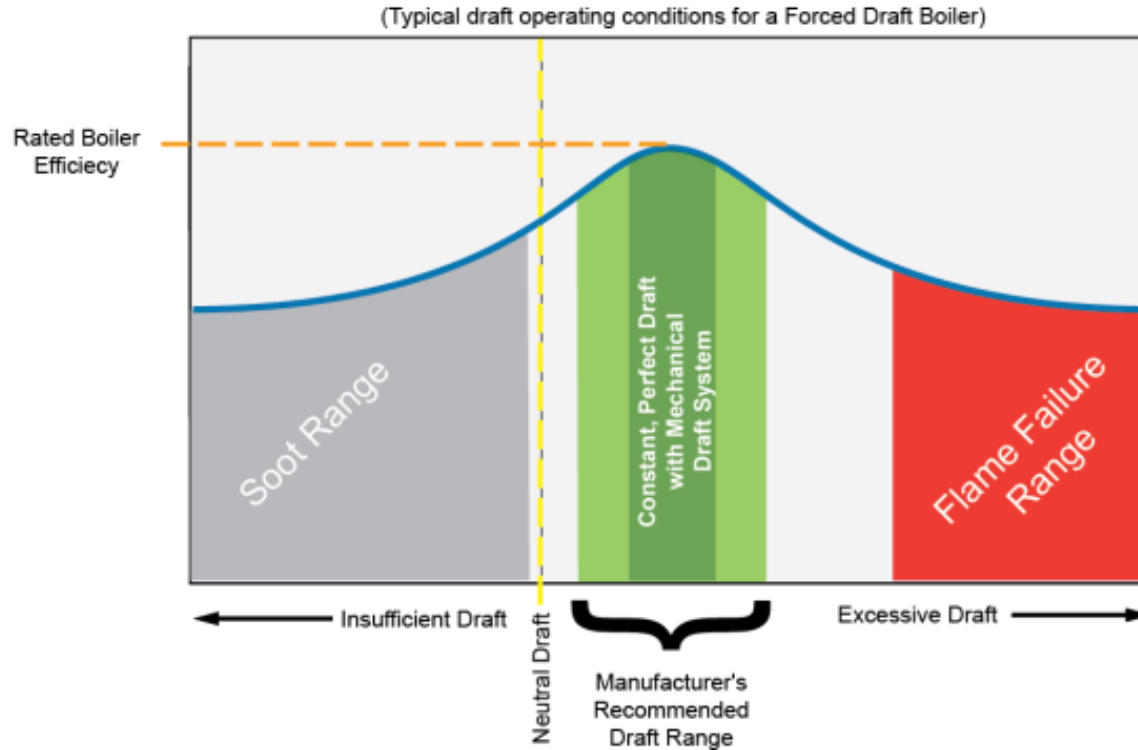
A venting system shall satisfy the draft requirement of the equipment in accordance with the manufacturer's instructions.

ASHRAE 90.1 – Boiler Efficiency



- Current average boiler use: 6570 hours per year
- Current average operating efficiency: 77%
- Efficiency threshold: 85%

Boiler Draft vs Efficiency



ASHRAE Chimney Design Equation

INPUTS:

$$l = 4.13 \times 10^5 \frac{d_i^2}{M} \left(\frac{\Delta p B}{k T_m} \right)^{1/2}$$



- Appliance Type
- Fuel Type
- kW Input
- CO₂% in Flue Gases
- Flue Gas Temperature
- Ambient Temperature
- Altitude
- Flue Layout

RESULTS:

- Flue Gas Volume
- Flue Gas Velocity
- Theoretical Draft
- Total Pressure Losses
- Appliance Outlet Pressure

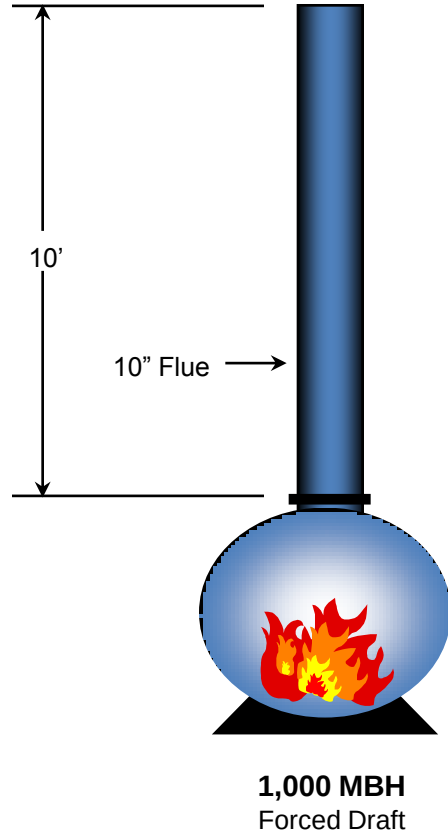
+

Theoretical Draft (-)

Pressure Losses (+)

Outlet Pressure

Chimney Design



Theoretical Draft:

- Chimney Height
- Flue Gas Temperature
- Surrounding Temperature
- Barometric Pressure

- 15 Pa

Pressure Loss:

- Flue Gas Volume
- Total Resistance

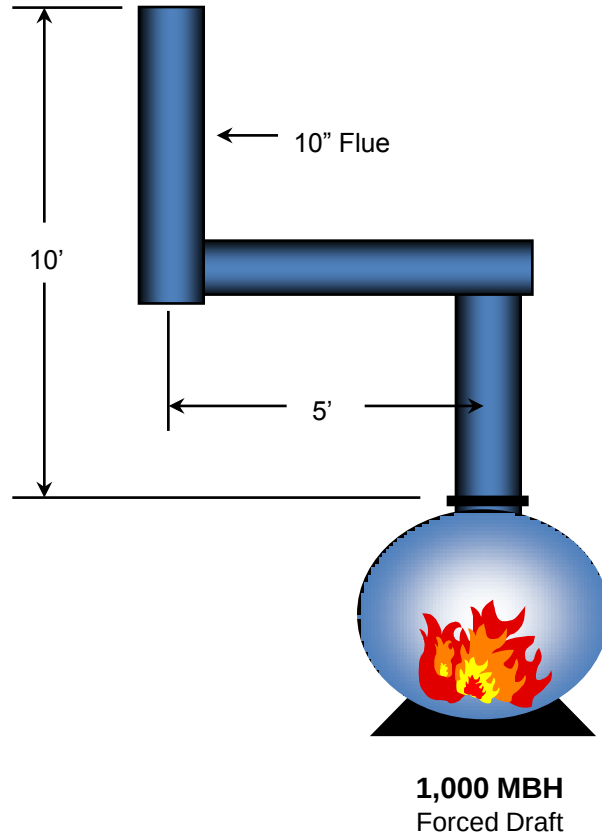
+ 8 Pa

Difference at Outlet:

- Specified by Equipment
- Efficiencies
- Safety

- 7 Pa

Chimney Design



Theoretical Draft:

- Chimney Height
- Flue Gas Temperature
- Surrounding Temperature
- Barometric Pressure

- 15 Pa

Pressure Loss:

- Flue Gas Volume
- Total Resistance

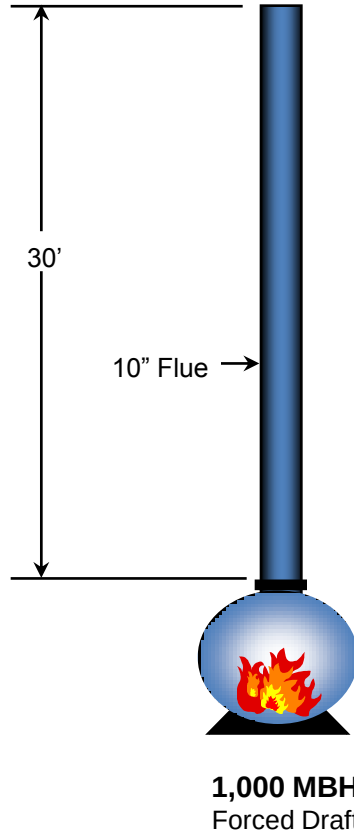
+ 22 Pa

Difference at Outlet:

- Specified by Equipment
- Efficiencies
- Safety

+ 7 Pa

Chimney Design



Theoretical Draft:

- Chimney Height
- Flue Gas Temperature
- Surrounding Temperature
- Barometric Pressure

- 45 Pa

Pressure Loss:

- Flue Gas Volume
- Total Resistance

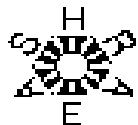
11 Pa

Difference at Outlet:

- Specified by Equipment
- Efficiencies
- Safety

- 34 Pa

Chimney Design



1996 Edition

Chimney Equation Default Values:

8.5% CO₂, 60° F Ambient, 360° F Flue Gas, & Sea Level

Appliance Values:

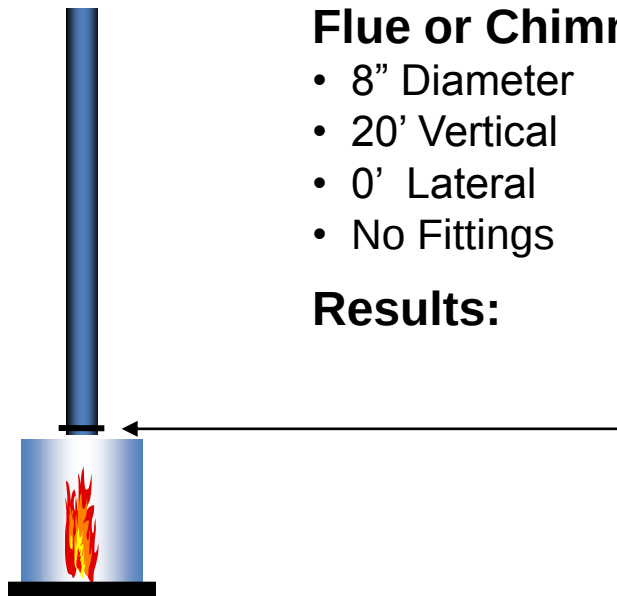
1,000 MBH Input with 8" Diameter Flue Outlet

Flue or Chimney Layout:

- 8" Diameter
- 20' Vertical
- 0' Lateral
- No Fittings

Results:

- **27 Pa** Natural Draft
- + 26 Pa Pressure Loss
- **1 Pa** at Flue Outlet



Chimney Design



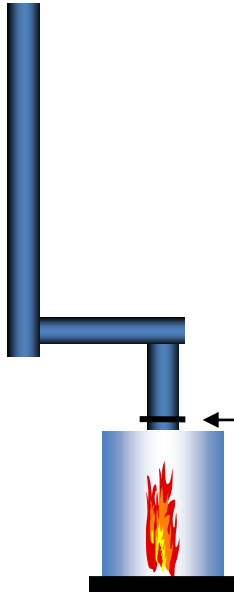
1996 Edition

Chimney Equation Default Values:

8.5% CO₂, 60° F Ambient, 360° F Flue Gas, & Sea Level

Appliance Values:

1,000 MBH Input with 8" Diameter Flue Outlet



Flue or Chimney Layout:

- 8" Diameter
- 20' Vertical
- 5' Lateral
- (2) Fittings

Results:

- **27 Pa** Natural Draft
+ 48 Pa Pressure Loss
+ **21 Pa** at Flue Outlet

Chimney Design



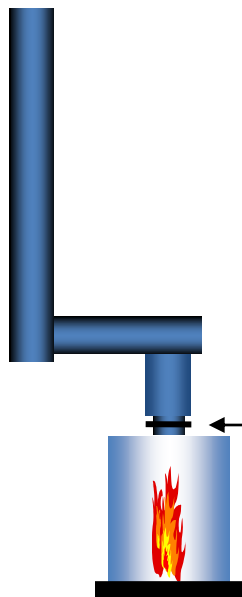
1996 Edition

Chimney Equation Default Values:

8.5% CO₂, 60° F Ambient, 360° F Flue Gas, & Sea Level

Appliance Values:

1,000 MBH Input with 8" Diameter Flue Outlet



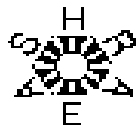
Flue or Chimney Layout:

- 10" Diameter
- 20' Vertical
- 5' Lateral
- (2) Fittings

Results:

- **27 Pa** Natural Draft
- + 19 Pa** Pressure Loss
- **8 Pa** at Flue Outlet

Chimney Design



1996 Edition

Chimney Equation Default Values:

8.5% CO₂, 60° F Ambient, 360° F Flue Gas, & Sea Level

Appliance Values:

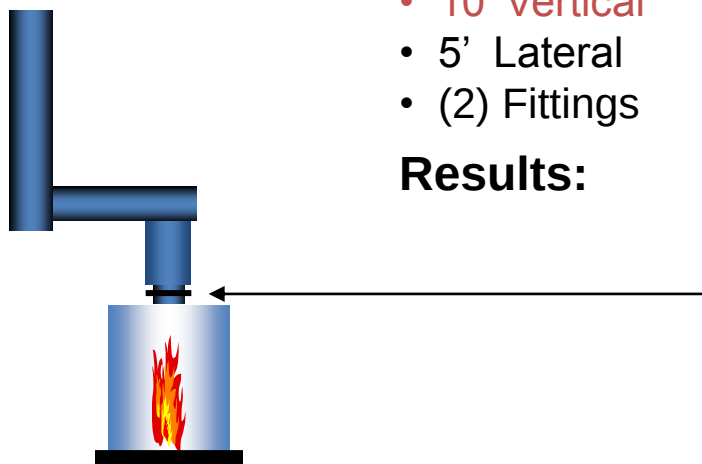
1,000 MBH Input with 8" Diameter Flue Outlet

Flue or Chimney Layout:

- 10" Diameter
- 10' Vertical
- 5' Lateral
- (2) Fittings

Results:

- **13 Pa** Natural Draft
+ 18 Pa Pressure Loss
+ **5 Pa** at Flue Outlet



Chimney Design



1996 Edition

Chimney Equation Default Values:

8.5% CO₂, 60° F Ambient, 360° F Flue Gas, & Sea Level

Appliance Values:

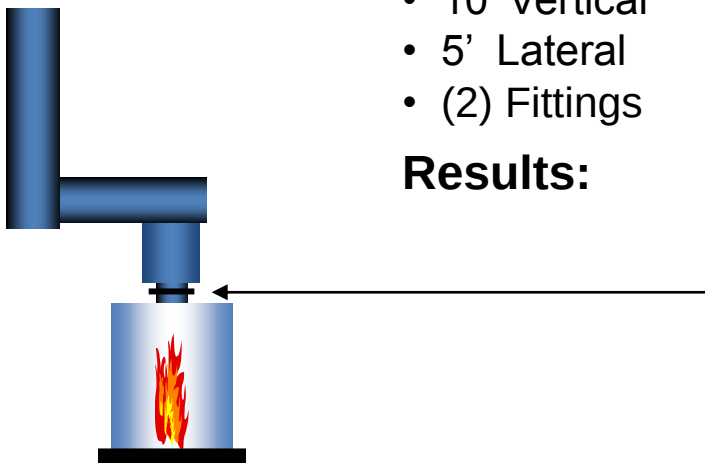
1,000 MBH Input with 8" Diameter Flue Outlet

Flue or Chimney Layout:

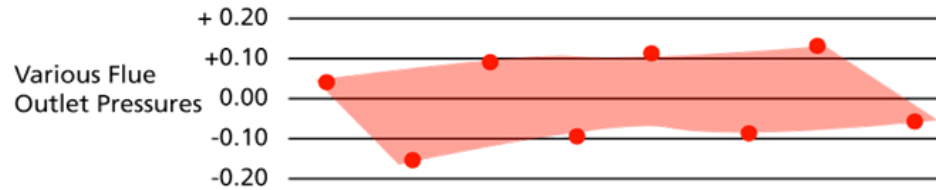
- 12" Diameter
- 10' Vertical
- 5' Lateral
- (2) Fittings

Results:

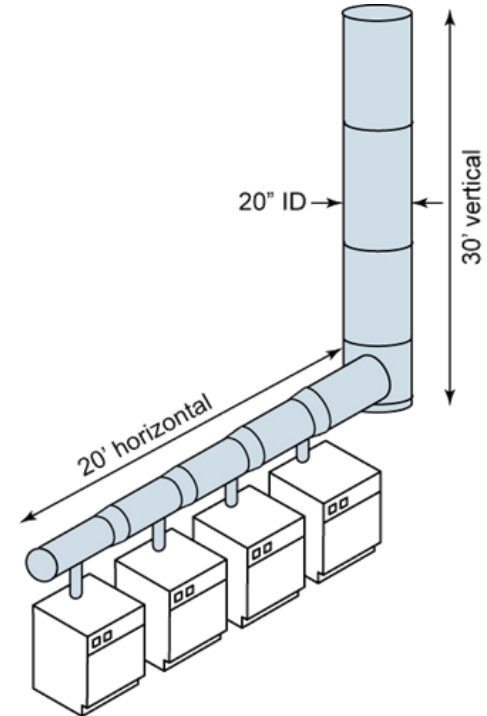
- **13 Pa** Natural Draft
- + **8 Pa** Pressure Loss
- **5 Pa** at Flue Outlet



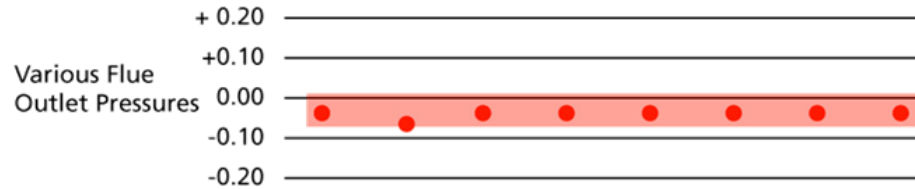
Natural Draft Boiler Exhaust System



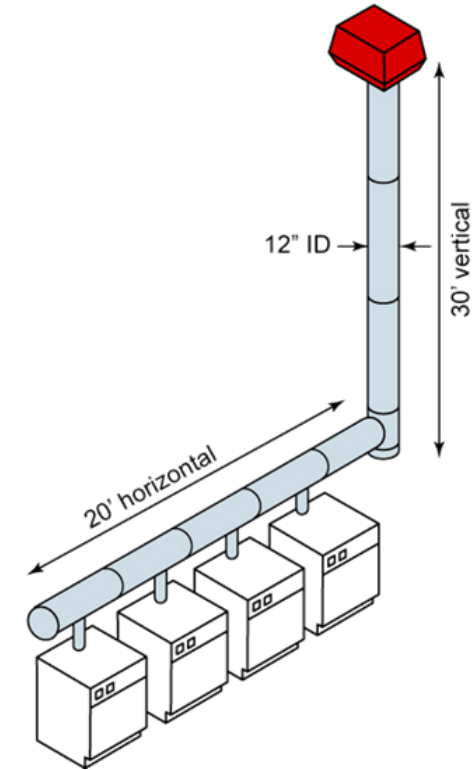
Boilers Firing	1 Boiler		2 Boilers		3 Boilers		4 Boilers	
Stack Condition	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Theoretical Draft	.000	-.189	.000	-.189	.000	-.189	.000	-.189
Total Pressure Loss	.025	.025	.092	.092	.107	.107	.133	.133
Difference, at Outlet	.025	-.164	.092	-.097	.107	-.082	.133	-.056



Modulating Boiler Exhaust System



Boilers Firing	1 Boiler		2 Boilers		3 Boilers		4 Boilers	
Stack Condition	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Theoretical Draft	.000	-.189	.000	-.189	.000	-.189	.000	-.189
Mechanical Draft	-.145	.000	-.222	-.033	-.354	-.165	-.542	-.353
Total Pressure Loss	.105	.105	.182	.182	.314	.314	.502	.502
Difference, at Outlet	-.04	-.084	-.04	-.04	-.04	-.04	-.04	-.04



Appliance Categories

NFPA 54 / International Fuel Gas Code

- **Category I**
- **Category II**
- **Category III**
- **Category IV**

NFPA 54

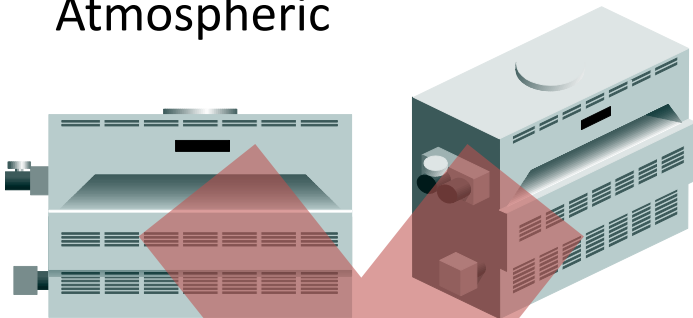
IAS (A.G.A.)

**ANSI Z
223.1**



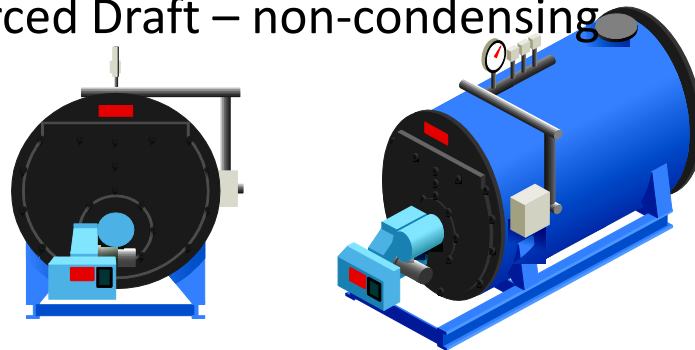
Appliance Categories

Atmospheric



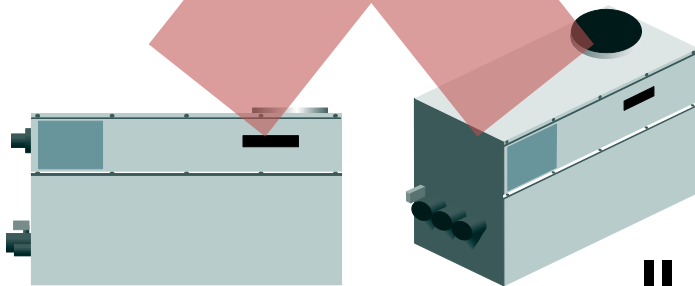
I

Forced Draft – non-condensing



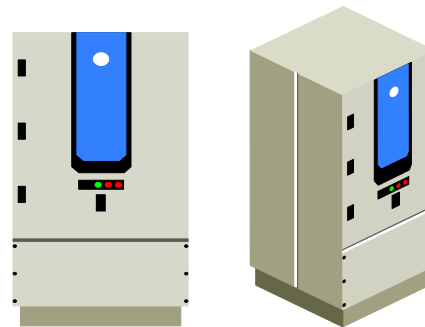
III

Fan-Assisted



II

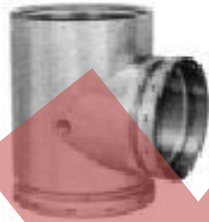
Forced Draft – condensing



IV

Chimney Flue/ Vent Material

Aluminium Liner



-

I

III

+

Stainless Steel 316 inner, 304 outer



Stainless Steel 316 inner, 304 outer



II

IV

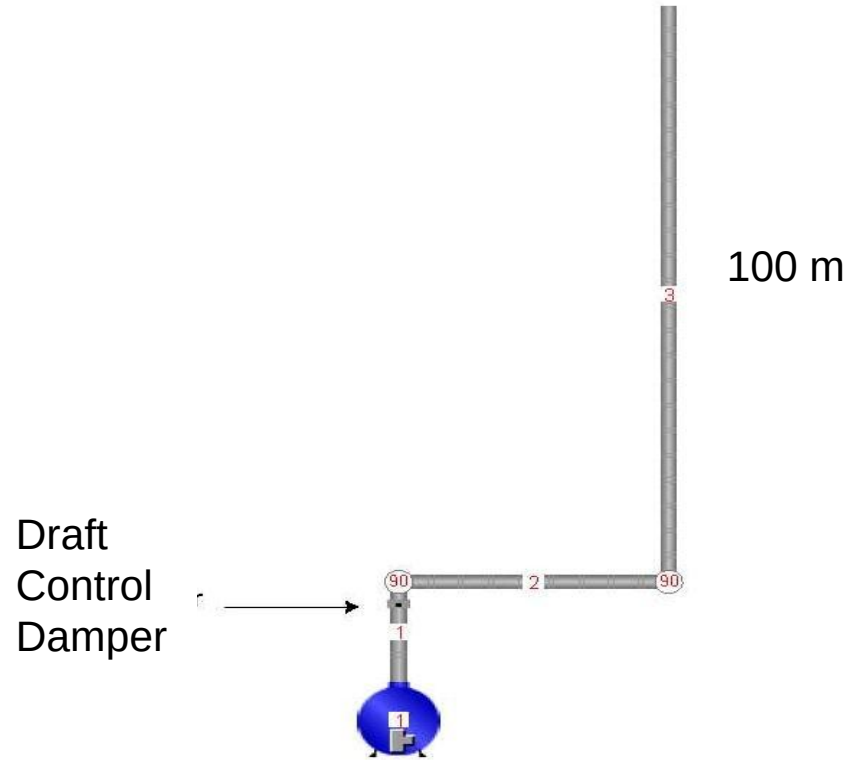
Modern System Design

- Design Software
- Vent type application
- Operating temperature
- Resistance factors
- Ambient temperature variations
- Code violations



Demand-Controlled Boiler Exhaust Systems

Example – Over-draft Application



Example – Over-draft Application

System Data:

System Type : VENT Description : ICB 70HP Steam

Location Data:

Local Altitude : 0 ft A.S.L. Ambient Temperature : 90 °F
Barometric Pressure : 29.92 in. Hg

Equipment Data:

Appl. No.	Manufacturer	Model	Category	Fuel	Input MBH	CO2%	Temp. Rise, °F	Baro. Damper	Draft Req'd
1	Cleaver-Brooks	CB-70	III	Natural Gas	2930	9.00	360	NO	-0.5 to 0.5

Vent System - Mechanical:

Section No.	Model	Size in.	Vert. ft	Hori. ft	Flow lb/h	Velocity FPM	Temp. °F	Dt in.W.C.	Delta P in.W.C.	K-Value	Fitting(s)
1	Pressure Stack	12ø	4	-	2789	1355	448	0.022	0.027	0.400	90°L
2	Pressure Stack	12ø	-	14	2789	1344	440	0.000	0.043	0.650	90°L
3	Pressure Stack	12ø	305	-	2789	1175	327	1.276	0.440	7.625	None

Results - Mechanical (System OFF):

Appliance ON (Input)	MBH Input	Massflow (Lbs/hr)	Draft (60°F)	Draft (90°F)	Draft (120°F)	Temp. (°F)	Min. Vel. FPM	Max. Vel. FPM
HIGH FIRE	2930	2789	-1.310	-0.788	-0.785	245	1175	1355
LOW FIRE	732	697	-1.296	-0.774	-0.771	123	251	338

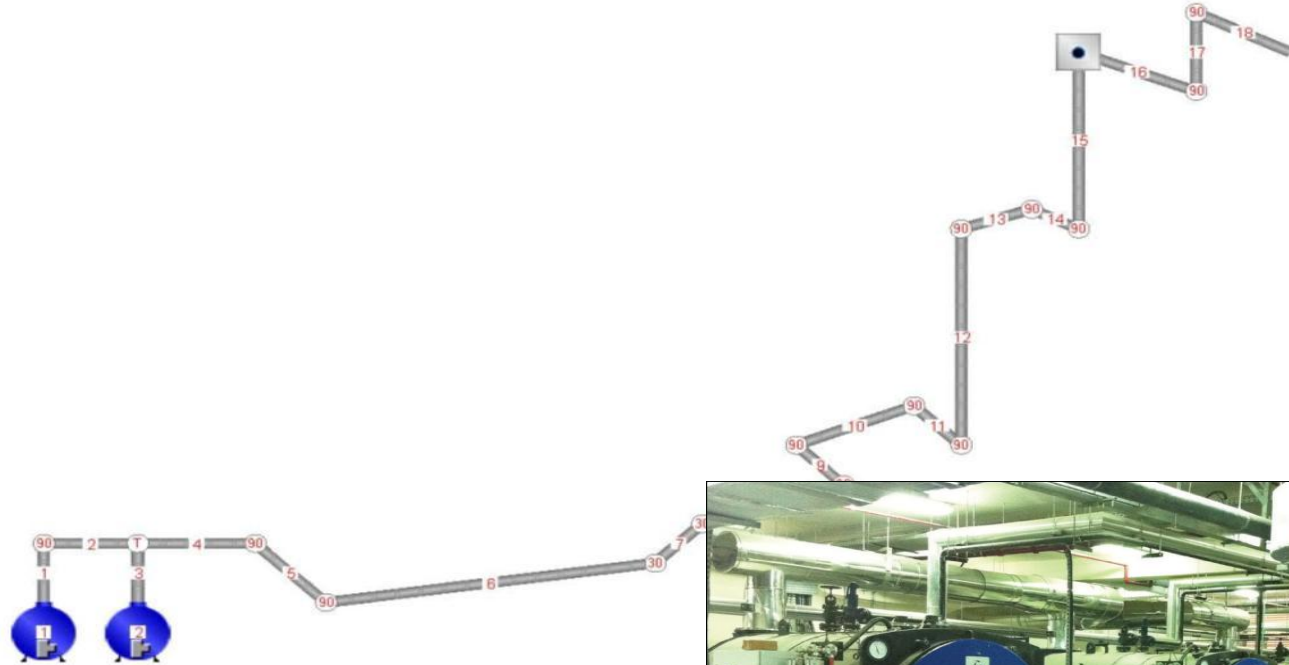
Volumetric Flow : 923 CFM

Max. Inlet Pressure : 0.691 in. W.C.

Venting Solution:

MODS

Example – Downsize



Example – Downsize

System Data:

System Type : VENT Description : 2 HW Boilers - 800kW - 18in

Location Data:

Local Altitude : 0 ft A.S.L. Ambient Temperature : 90 °F
Barometric Pressure : 29.92 in. Hg

Equipment Data:

Appl. No.	Manufacturer	Model	Category	Fuel	Input MBH	CO2%	Temp. Rise, °F	Baro. Damper	Draft Reqd.
1	Cleaver-Brooks	CBH-80	III	Natural Gas	3350	9.00	360	NO	Verify w/mfr.
2	Cleaver-Brooks	CBH-80	III	Natural Gas	3350	9.00	360	NO	Verify w/mfr.

Vent System - Mechanical:

Section No.	Model	Size in.	Vert. ft.	Hori. ft.	Flow lb/h	Velocity FPM	Temp. °F	Dt in.W.C.	Delta P in.W.C.	K-Value	Fitting(s)
1	Pressure Stack	12ø	0	-	3189	1548	447	0.043	0.043	0.500	90°L
2	Pressure Stack	14ø	-	15	3189	1124	436	0.000	0.015	0.321	90°T
3	Pressure Stack	12ø	8	-	3189	1548	447	0.043	0.126	1.450	90°T
4	Pressure Stack	18ø	-	8	6378	1358	435	0.000	0.029	0.433	90°L
5	Pressure Stack	18ø	-	46	6378	1334	419	0.000	0.071	1.067	90°L
6	Pressure Stack	18ø	-	107	6378	1275	380	0.000	0.121	1.903	30°L
7	Pressure Stack	18ø	-	8	6378	1234	353	0.000	0.016	0.253	30°L
8	Pressure Stack	18ø	-	39	6378	1218	343	0.000	0.058	0.950	90°L
9	Pressure Stack	18ø	-	28	6378	1197	329	0.000	0.046	0.767	90°L
10	Pressure Stack	18ø	-	36	6378	1179	317	0.000	0.053	0.900	90°L
11	Pressure Stack	18ø	-	8	6378	1167	309	0.000	0.025	0.433	90°L
12	Pressure Stack	18ø	24	-	6378	1158	303	0.090	0.040	0.700	90°L
13	Pressure Stack	18ø	-	9	6378	1147	296	0.000	0.026	0.450	90°L
14	Pressure Stack	18ø	-	3	6378	1144	294	0.000	0.020	0.350	90°L
15	Pressure Stack	18ø	30	-	6378	1136	289	0.107	0.028	0.500	None
16	Pressure Stack	18ø	-	24	6378	1123	280	0.000	0.039	0.700	90°L
17	Pressure Stack	18ø	3	-	6378	1117	276	0.010	0.020	0.350	90°L
18	Pressure Stack	18ø	1	-	6378	1115	275	0.003	0.001	0.017	None

Example – Downsize

24 inch (610 mm) boiler exhaust

Results - Mechanical (System OFF):

Appliance ON (Input)	MBH Input	Massflow (Lbs/hr)	Draft (70°F)	Draft (95°F)	Draft (130°F)	Temp. (°F)	Min. Vel. FPM	Max. Vel. FPM
ALL (FULL)	6700	6378	-0.070	+0.042	+0.041	257	382	1548
1 (100%), 2 (33%)	4466	4251	-0.236	-0.125	-0.125	217	382	1548
1 (100%)	3350	3295	-0.253	-0.142	-0.142	193	288	1548
1 (33%)	1116	1168	-0.209	-0.098	-0.099	127	92	513
Volumetric Flow : 1923 CFM			Max. Inlet Pressure : 0.095 in. W.C.					

Venting Solution:

IPVB350

18 inch (450 mm) boiler exhaust

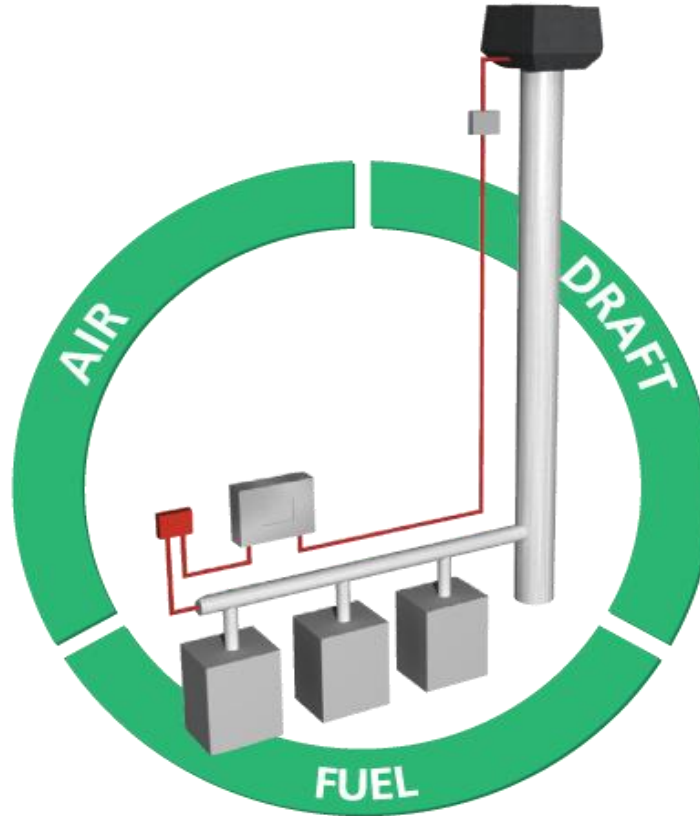
Results - Mechanical (System OFF):

Appliance ON (Input)	MBH Input	Massflow (Lbs/hr)	Draft (70°F)	Draft (95°F)	Draft (130°F)	Temp. (°F)	Min. Vel. FPM	Max. Vel. FPM
ALL (FULL)	6700	6378	+0.355	+0.466	+0.465	275	1115	1548
1 (100%), 2 (33%)	4466	4251	-0.063	+0.048	+0.047	234	513	1548
1 (100%)	3350	3295	-0.157	-0.046	-0.046	207	523	1548
1 (33%)	1116	1168	-0.196	-0.084	-0.085	126	163	513
Volumetric Flow : 1971 CFM			Max. Inlet Pressure : 0.752 in. W.C.					

Venting Solution:

IPVB400

Why Packaged Boiler Exhaust Systems?



Benefits of Packaged Boiler Exhaust Systems

Where

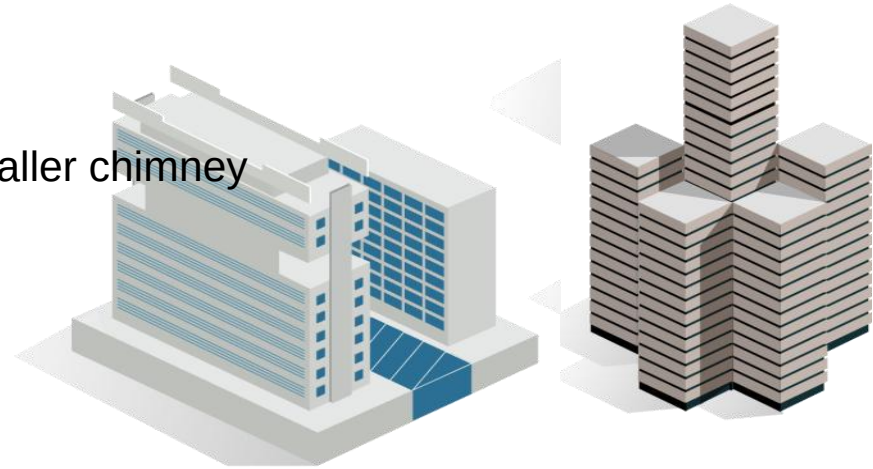
- Hotels / Resorts / Apartment Buildings
- Hospitals

What

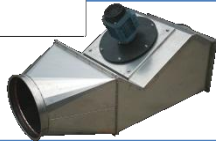
- Steam boilers
- Calorifiers / Water Heaters

Why

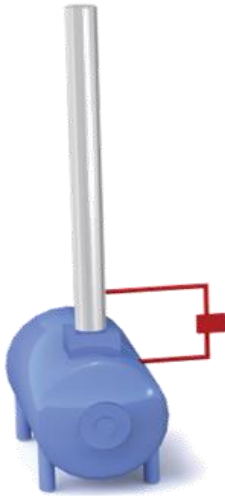
- Save space, Save material – use smaller chimney
- Reduce number of chimneys
- Avoid “over-crowded” boiler-rooms
- Aesthetics
- Safety and redundancy
- Single supplier responsibility



Packaged Boiler Exhaust Systems

	Boiler Exhaust System	And Over-draft Control	Or Fan-Powered Chimney
Stainless steel boiler exhaust (316/304), 25 mm insulation			
Modulating fan control with boiler interlock			
Boiler exhaust fan (variable speed)			
Modulating Over-Draft Damper			

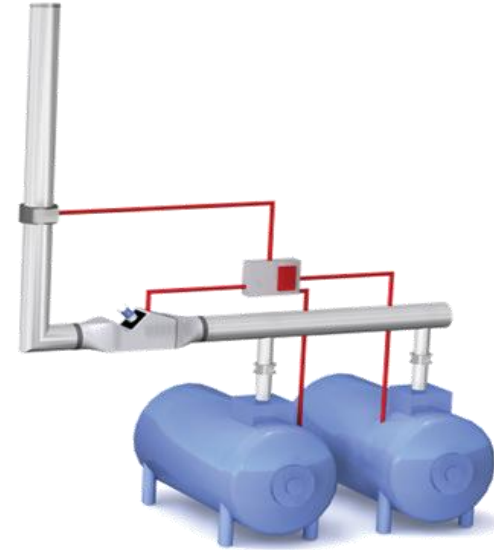
Packaged Boiler Exhaust Systems



Boiler exhaust
with safety
controls



Boiler exhaust
with over-draft
control



Boiler exhaust with
over-draft control and
modulating draft
control

IPVB 300 - 685 – Inline Power Venter

- SS316L construction
- Direct drive, TEFC variable speed motor
- Maintenance free
- 575°F Continuous
- All gas-fired or oil-fired boilers
- Simple design with few components reduces the risk of failure and simplifies service
- UL 378 – Draft Equipment



IPVB 300 - 685 – Inline Power Venter



Motor and impeller drive unit can be removed without removing the fan from the stack system



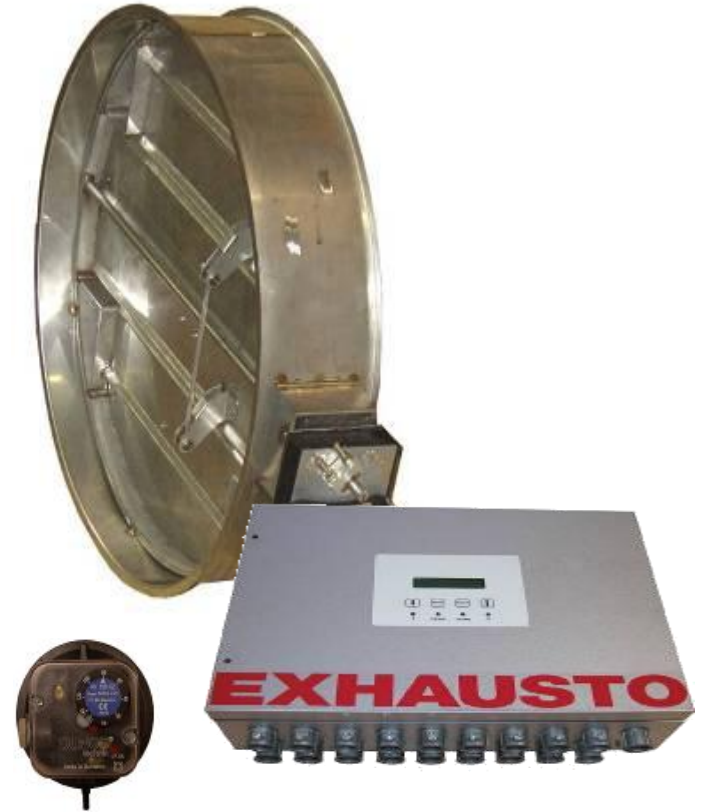
Modulating Over-Draft Damper System

MDF Damper

- Sizes – 12 in. to 48 in. diameters
- Multiple opposed blades made of 16 gauge type 316 stainless
- Pressure stack flange connections
- Rated to 700°F

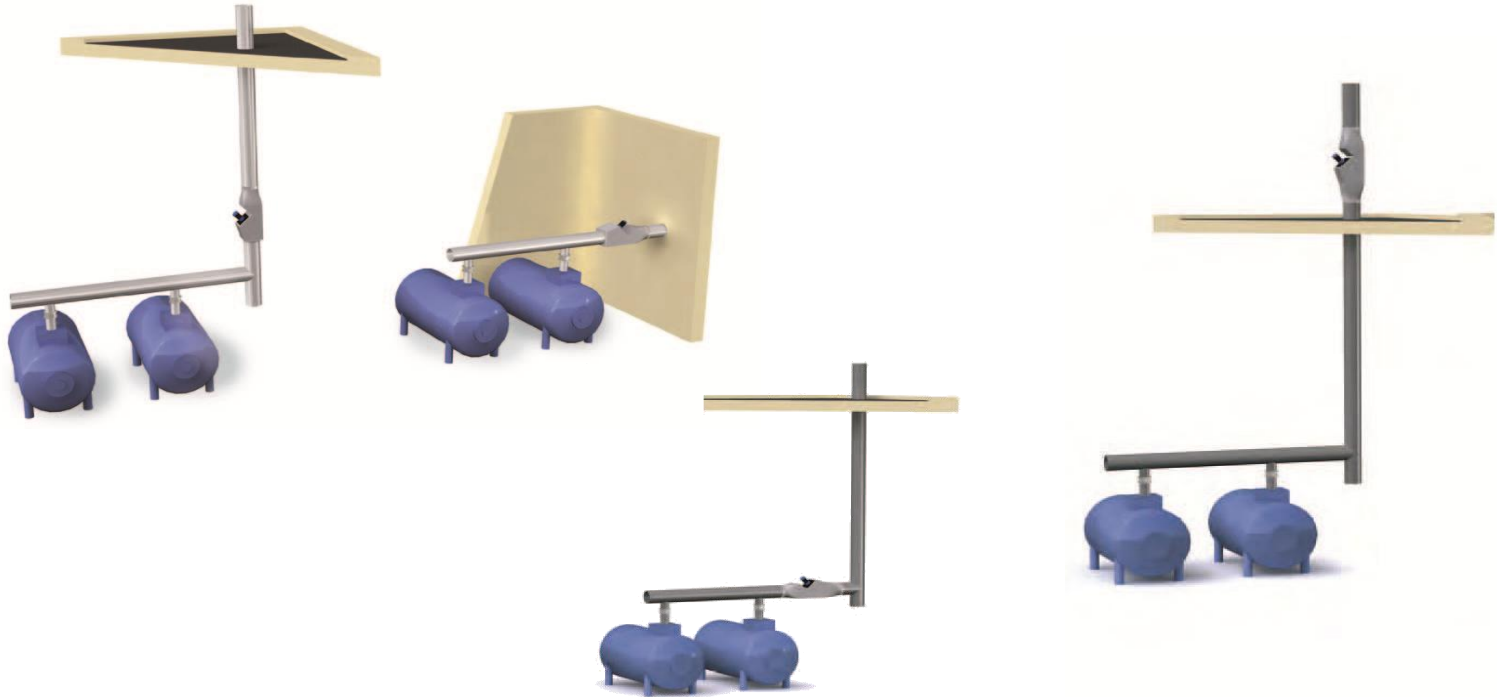
EBC30

- Prime function
- Additional over-pressure protection for Forced-draft boilers



IPVB 300 - 500 – Power Venter

Anywhere You Want It



ENERVEX Chimney Flue

EPS

High Pressure Twin-Wall
Stainless Steel Multi-Purpose
Exhaust Duct and Chimney
System



ENERVEX®
VENTING DESIGN SOLUTIONS

One Chimney Flue – EPS Multi-Purpose

- **Building Heating Chimney** – condensing and non-condensing
- **Engine/Generator Exhaust**
- **Grease Duct / Kitchen Exhaust**



Chimney Flue - EPS

- **Inner Liner:**

316L stainless steel, 1mm thick (1.2mm for diameters of 1000mm and above)

- **Outer wall:**

304 stainless steel, 0.6mm thick (0.8mm for diameters of 700mm and above)

- **Insulation**

25-100mm thick fiber insulation



Chimney Flue - EPS

- Welded continuous construction
- Integral flange at each end
- Male insert for easy centering and assembly
- Graphite seal (no messy silicone sealant)



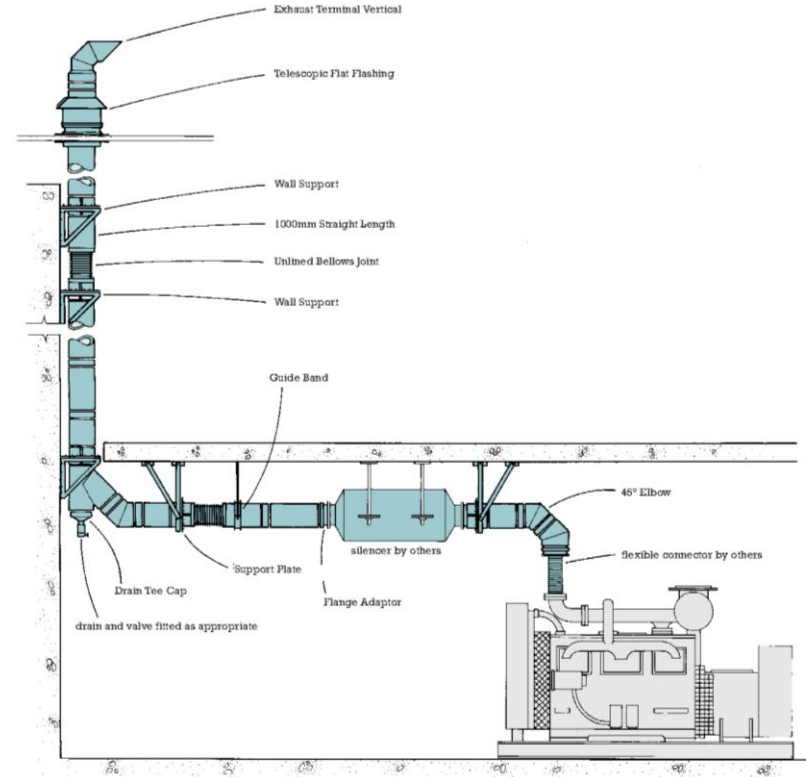
Chimney Flue - EPS

- Easy and accurate assembly
- Hinged v-band



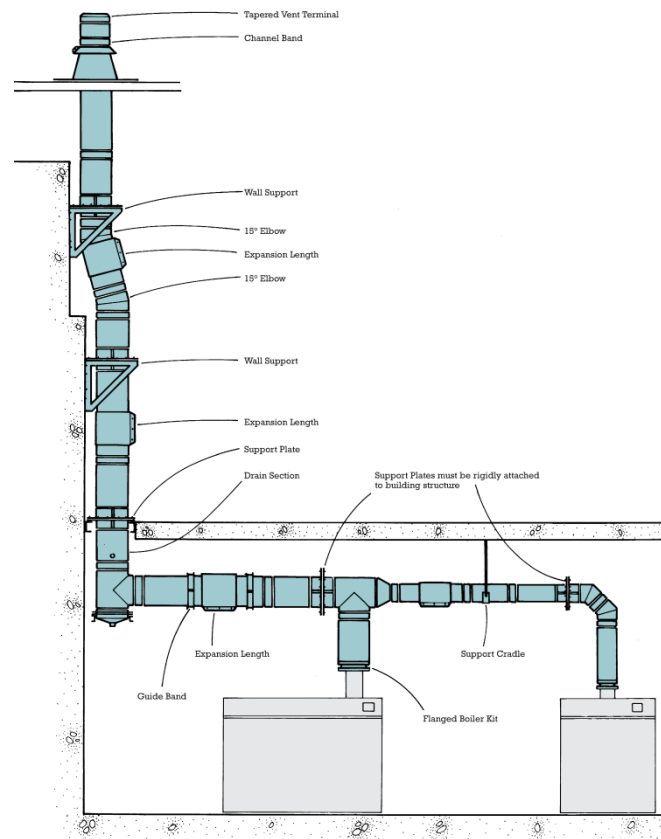
Generator & Engine Exhaust

- NFPA37, Standard for Emergency Generators
- 60" (1500mm) W.C. pressure capability
- 1400°F (760°C)
- 2-4" (25-100mm) insulation



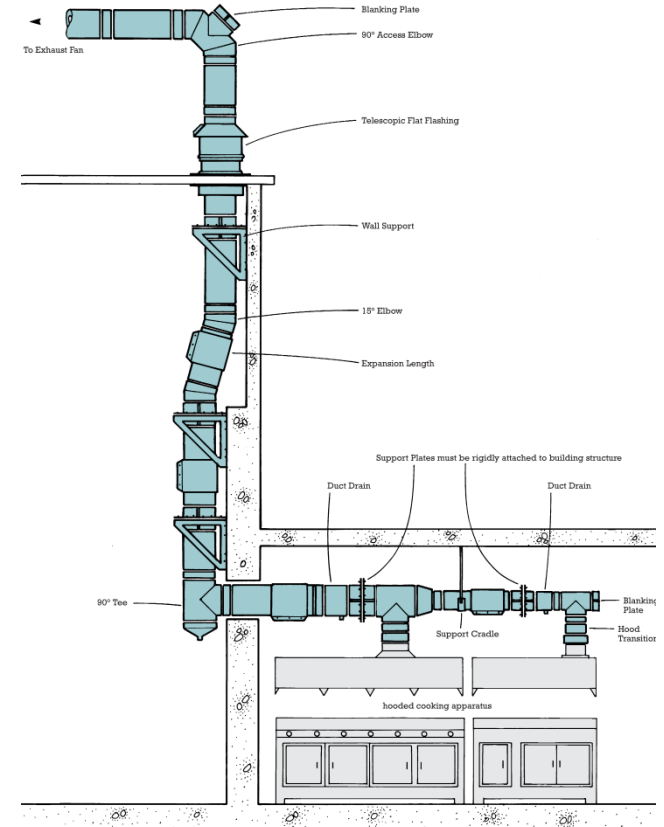
Boiler Exhaust

- UL103 Building Heating Chimney
- UL1738 Chimney for Condensing Heating Appliances
- 60" (1500mm) W.C. pressure capability
- 1400°F (760°C)

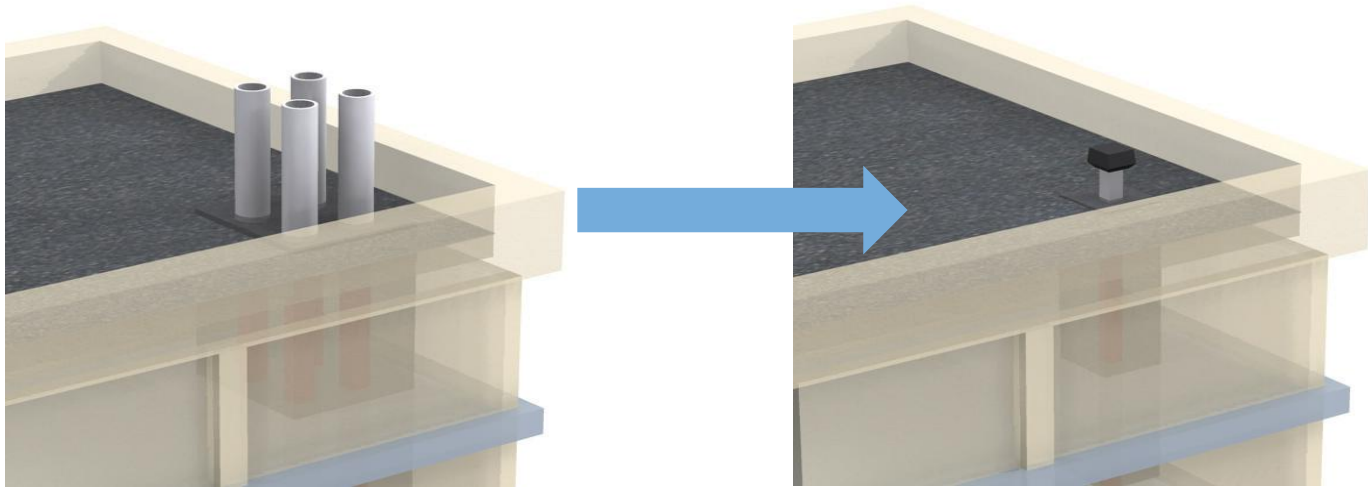


Kitchen Exhaust

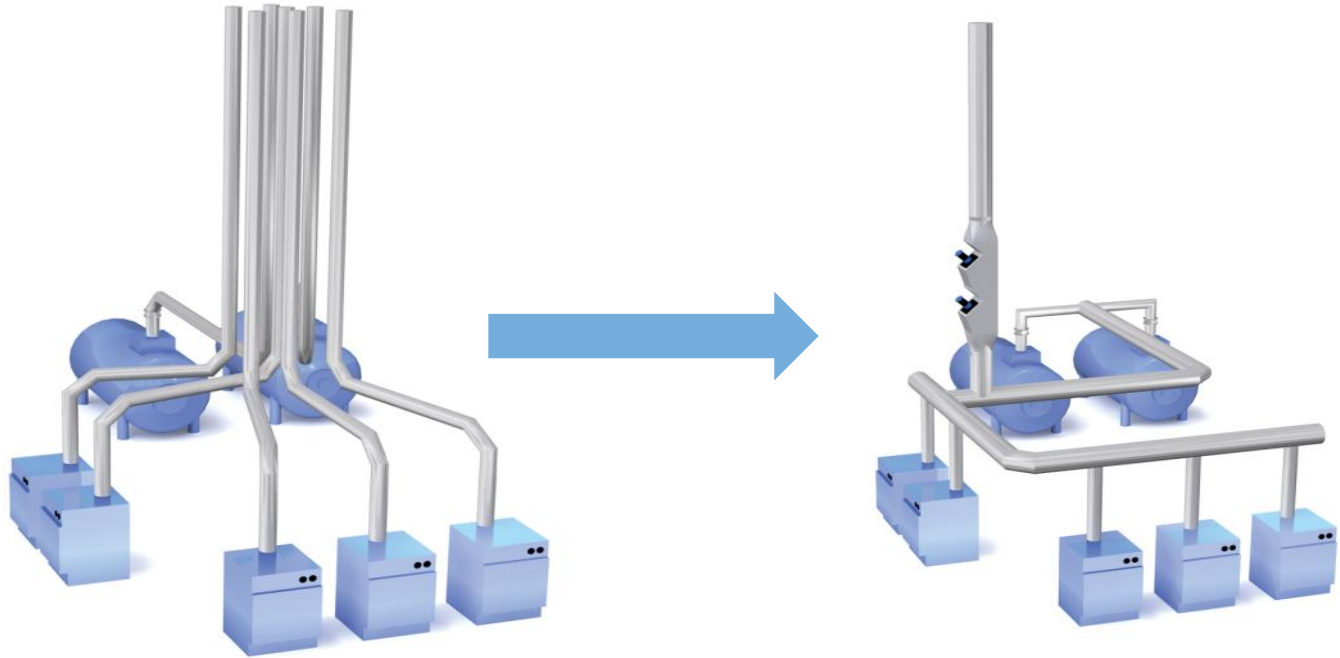
- UL 1978 Grease Duct Exhaust System
- Thermal expansion compensation
- Clean-out access
- No welding
- Easy hood and fan connection



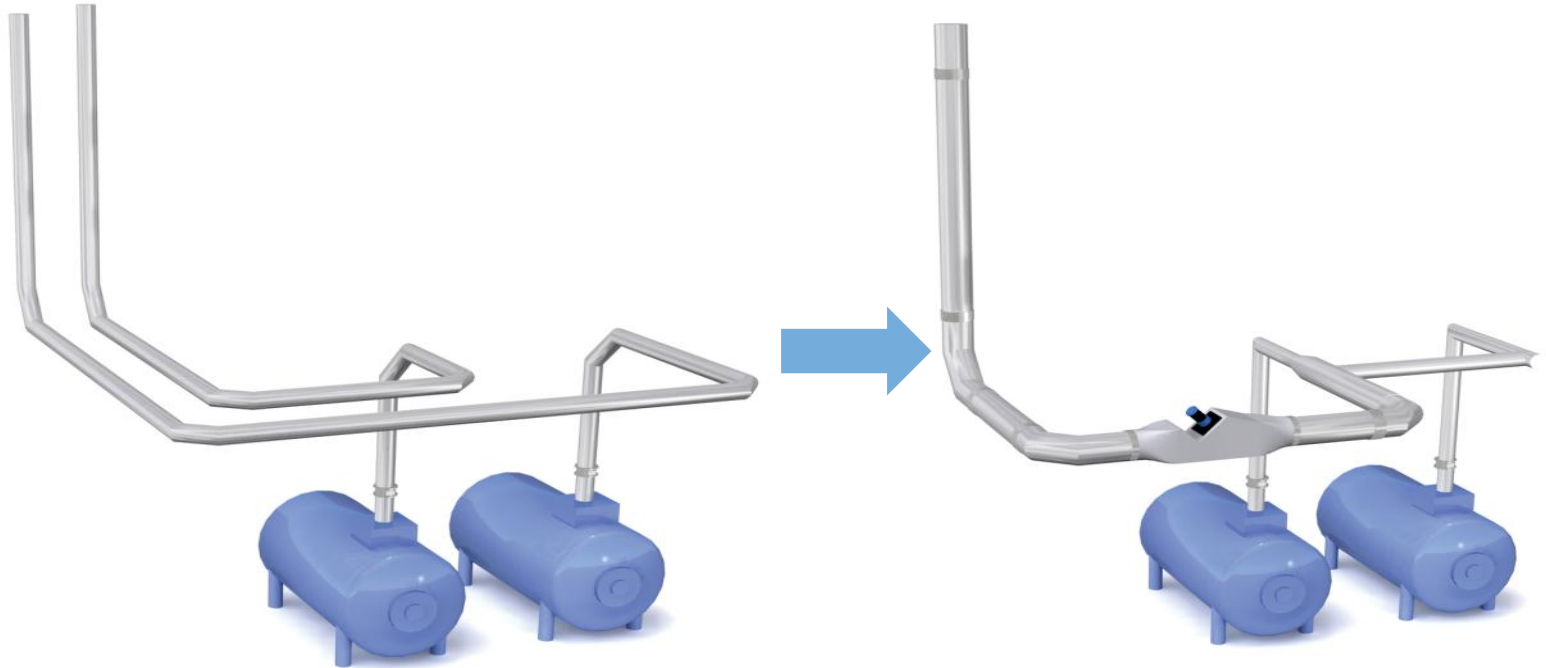
Space Saving & Aesthetics



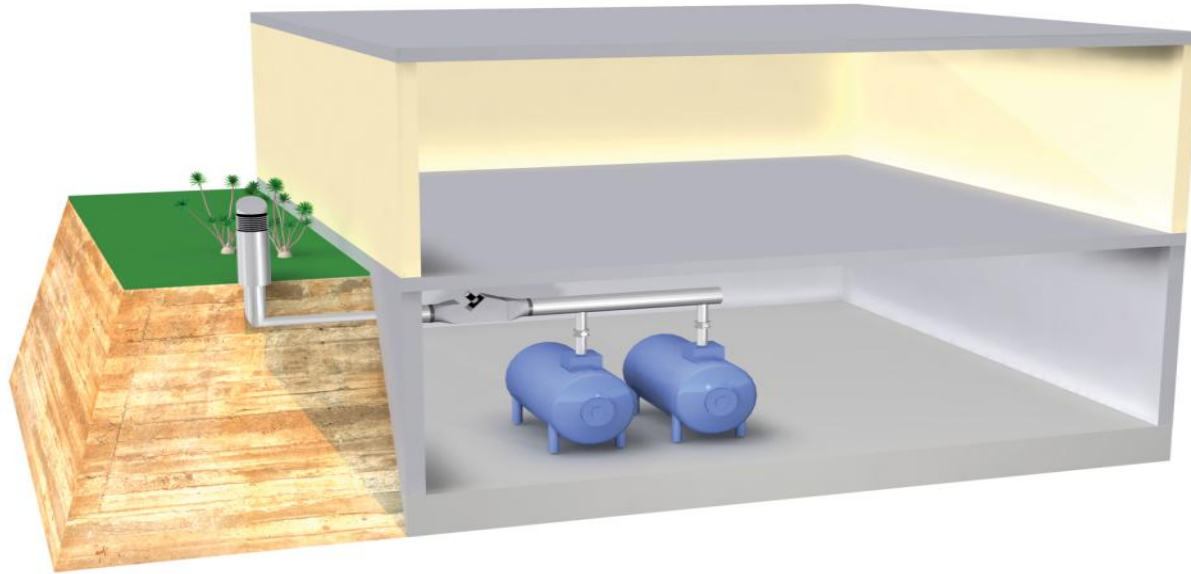
Space Saving



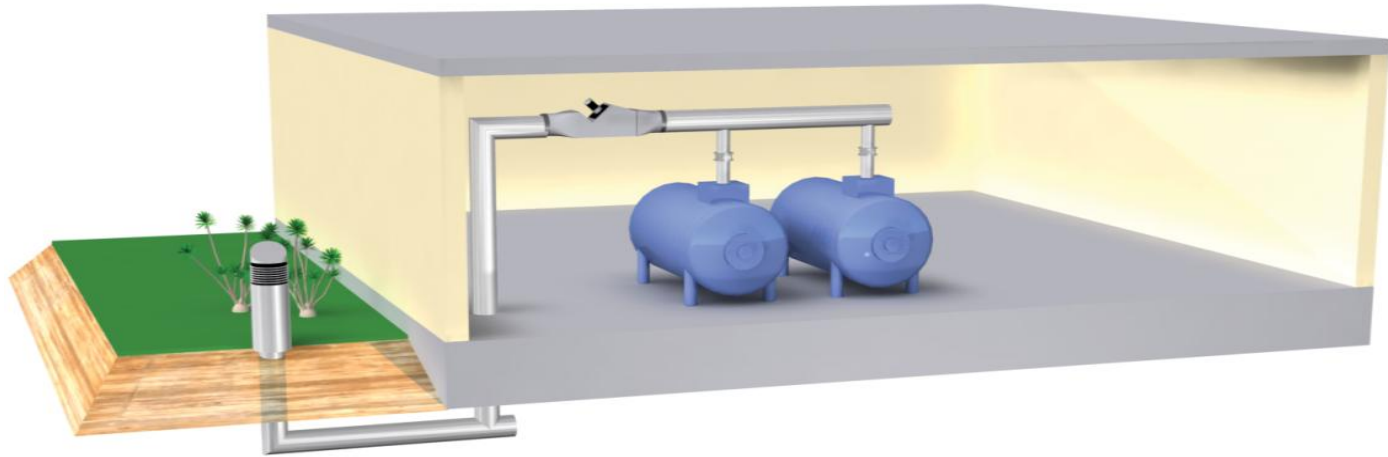
Space Saving



Aesthetics



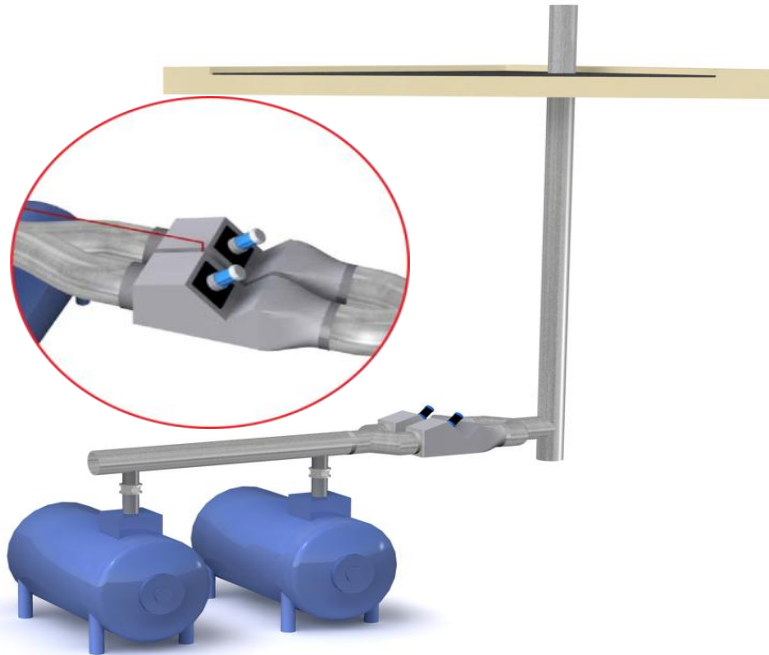
Design Freedom



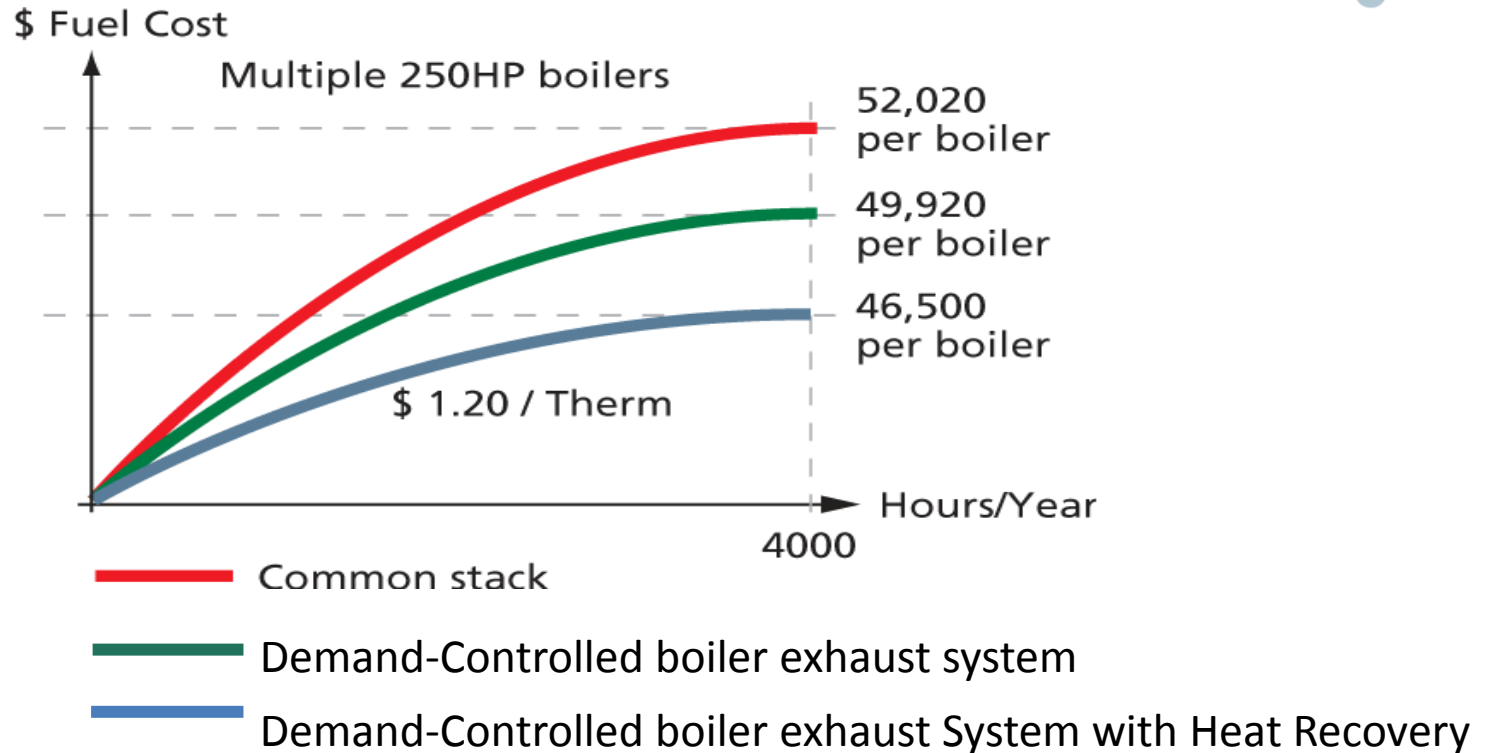
Crowded Boiler Rooms



Redundancy for Critical Installations



Energy Savings



Case Studies/Design Examples

How to get the most out of a creative design



Burj Khalifa Tower / Armani Hotel, Dubai

Six Demand Controlled Boiler Exhaust Systems servicing horizontal venting for side wall termination providing the engineers full flexibility in the design



Khalidiya Palace, Abu Dhabi

Three boilers common vented with a Demand Controlled Boiler Exhaust System using an inline boiler exhaust fan. Savings on material cost over \$ 30,000

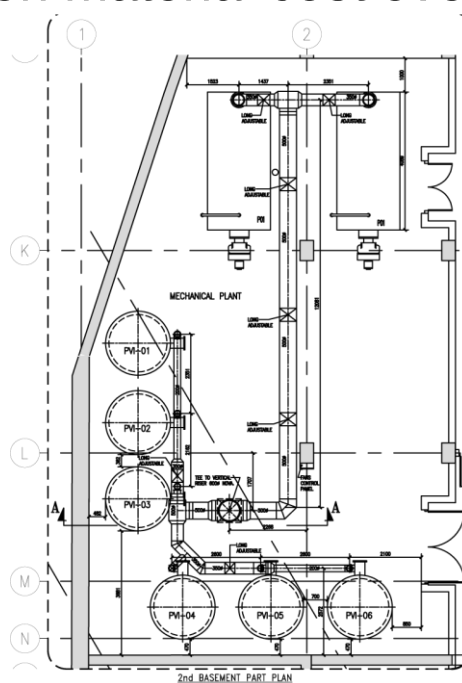


Capital Plaza (Sofitel Hotel), Abu Dhabi

Four boilers common vented with a Demand Controlled Boiler Exhaust System using an inline boiler exhaust fan. Savings on material cost over \$ 60,000



Four boilers common vented with a Demand Controlled Boiler Exhaust System using an inline boiler exhaust fan. Savings on material cost over \$60,000.

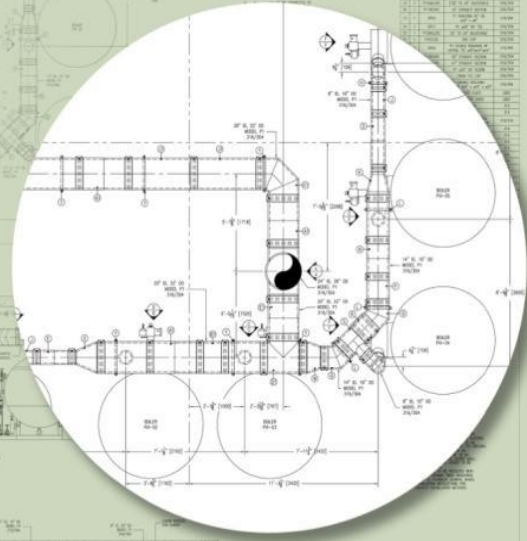


ENERVEX®
VENTING DESIGN SOLUTIONS

Why is This Attractive?

- *Single supplier responsibility.*
- *Space savings = cost savings*
- *Small footprint = less space required*
- *Save energy and reduce emissions*
- *Improve boiler room safety*
- *Enhance aesthetics*

***Make the unimaginable and impossible
POSSIBLE.***



A Final Note

“Chimney system must be designed/approved/supplied by boiler manufacturer”

Let boiler experts deal with the boiler design

Let chimney design experts deal with the chimney design





Questions?

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Thank You!