



Safer By Design



*Building Intrinsic Safety into High
Pressure Steam Boiler Plants*

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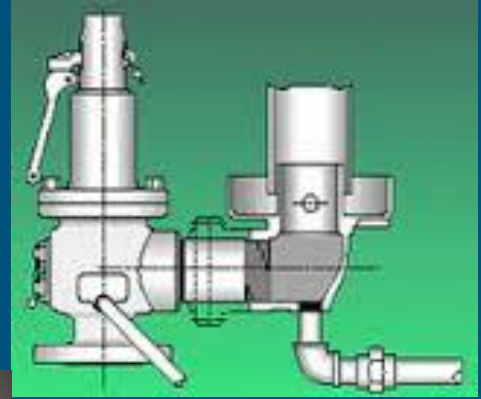


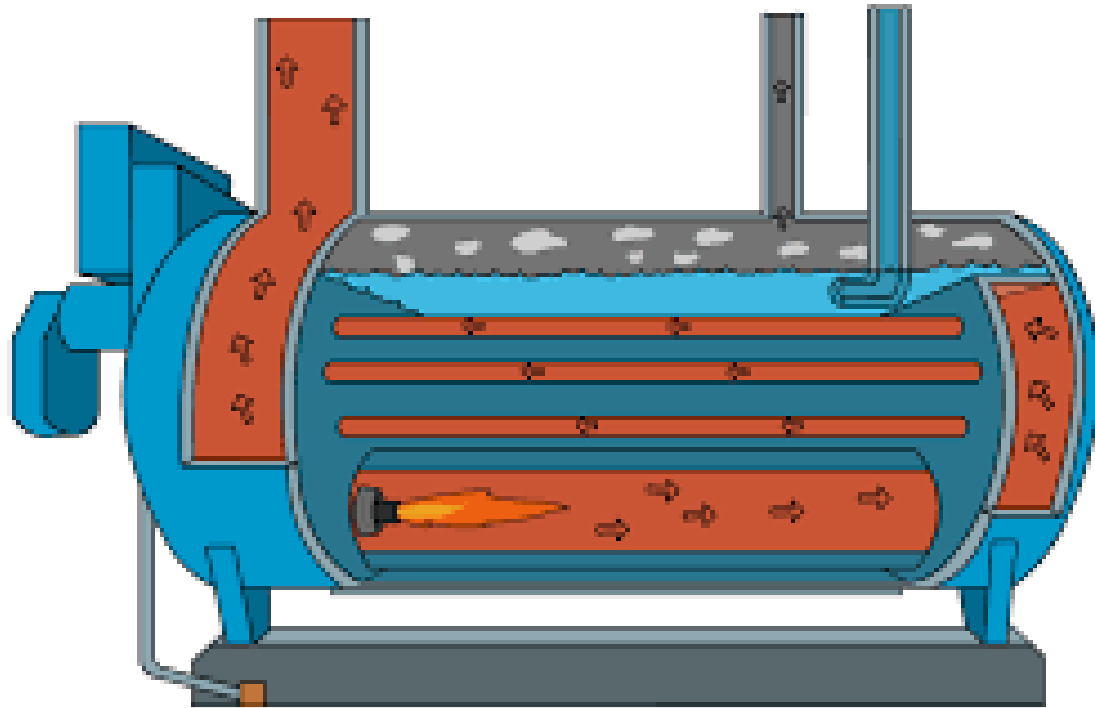


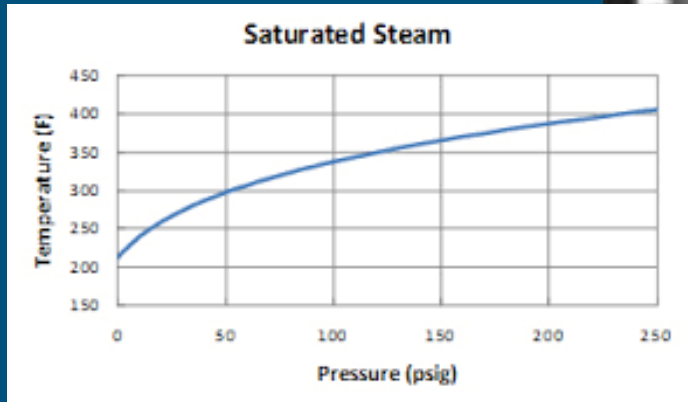
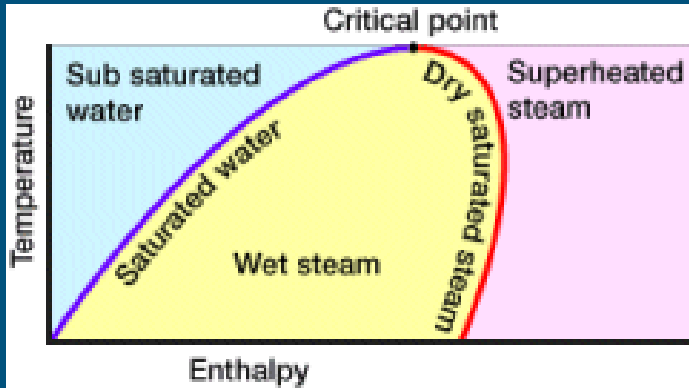


L. S. THAYER, PHOTOGRAPHER.

BOILER EXPLOSION AT BEAVER MILLS, KEENE, N. H., MAY 22, 1893.







STEAM TABLE

PROPERTIES OF SATURATED STEAM

Gage Pressure PSIG	Temperature °F	Heat in Btu/lb.			Specific Volume Cu. ft/lb.	
		Sensible	Latent	Total		
In. (Ng) Vac.	25	134	102	1017	1119	142.0
	20	162	129	1001	1130	73.9
	15	179	147	990	1137	51.3
	10	192	160	982	1142	39.4
	5	203	171	976	1147	31.8
	0	212	180	970	1150	26.8
	1	215	183	970	1151	25.2
	2	219	187	966	1153	22.5
	3	222	190	964	1154	22.3
	4	224	192	962	1154	21.4
	5	227	195	960	1155	20.1
	10	239	207	953	1160	16.5
	20	259	227	939	1166	11.9
	30	274	243	929	1172	9.46
	40	286	258	920	1176	7.82
	50	298	267	912	1179	6.68
	60	307	277	906	1183	5.84
	70	316	277	898	1184	5.18
	80	324	294	891	1185	4.67
	90	331	302	886	1188	4.24
	100	338	309	880	1189	3.89
	110	344	316	875	1191	3.59
	120	350	322	871	1193	3.34
	130	356	328	866	1194	3.12
	140	361	333	861	1194	2.92
	150	366	339	857	1196	2.74
	175	377	351	847	1198	2.41
	200	388	362	837	1199	2.14
	225	397	371	828	1200	1.92
	250	406	382	820	1202	1.75
	275	414	391	812	1203	1.60
	300	421	398	805	1203	1.47
	325	429	407	797	1204	1.36
	350	435	414	790	1204	1.28
	375	442	421	784	1205	1.19
	400	448	428	777	1205	1.12
	450	460	439	766	1205	1.00
	500	470	453	751	1204	.89
	550	479	464	740	1204	.82
	600	489	475	728	1203	.74

Pascal's Law



Flash Steam Calculation

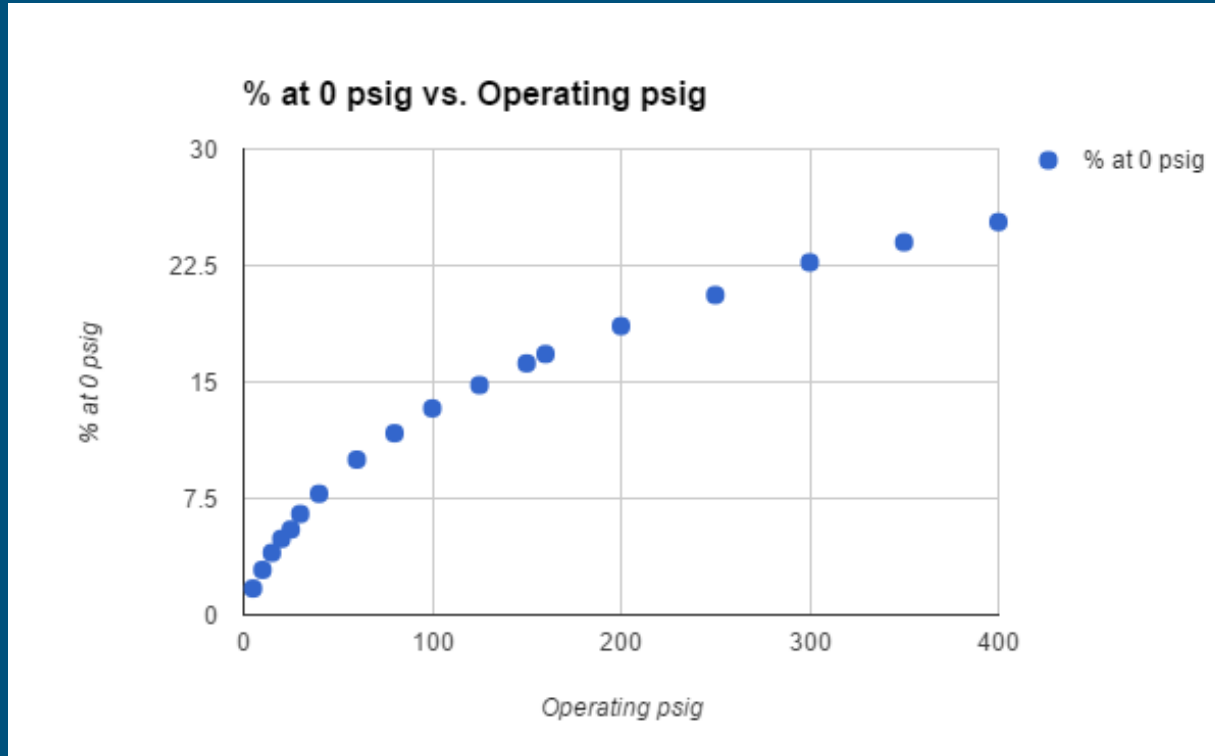
$$W = \frac{(h_{il} - h_{fl})}{h_{fe}}$$

$$13.3\% = \frac{(309 - 180)}{970}$$

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	100	338	309	880	1189	3.89
	110	344	316	875	1191	3.59
	120	350	322	871	1193	3.34
	130	356	328	866	1194	3.12
	140	361	333	861	1194	2.92
	150	366	339	857	1196	2.74

Flash Steam (% of saturated volume at psig)

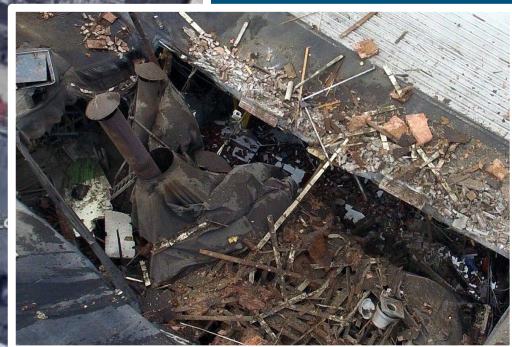
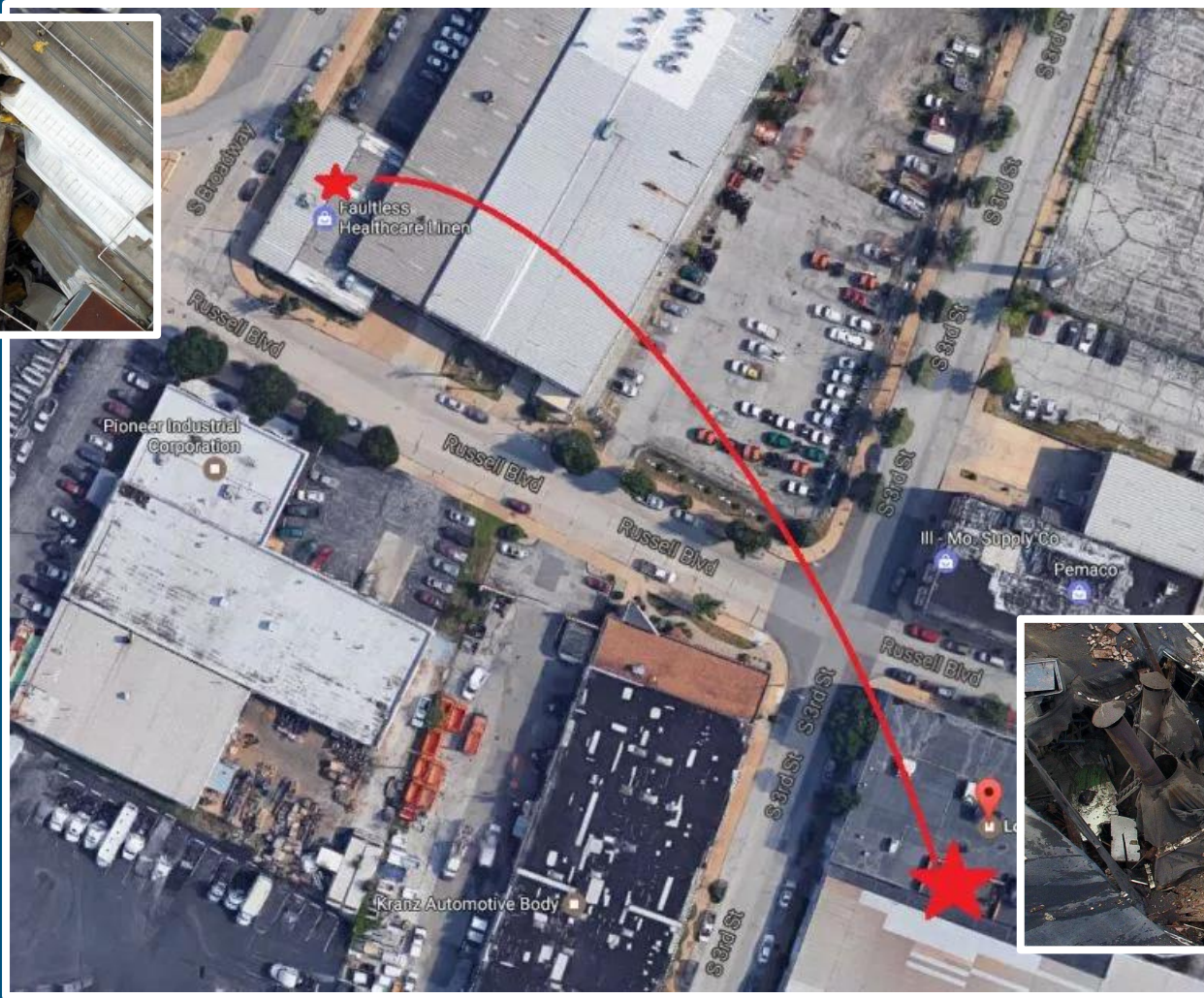
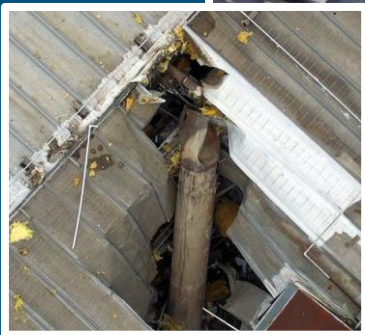




@CJZERO

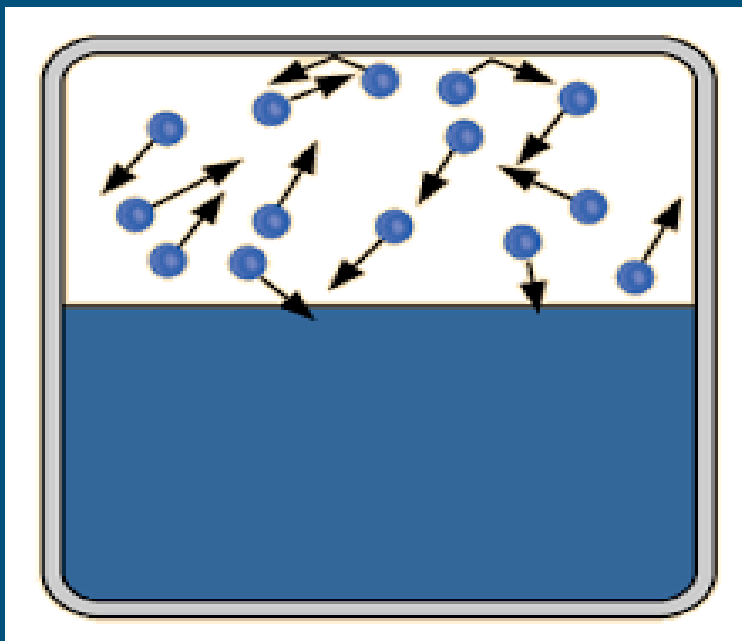
THE UNEXPLAINED FILES
TOMORROW 19/16c



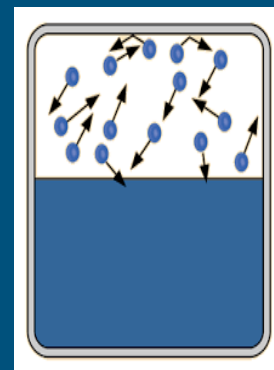


Unique Risk Factors of High Pressure Steam Boilers

1. Operational volume of pressurized, saturated water present
2. Operating pressure above ambient (atmospheric) pressure



600 psig



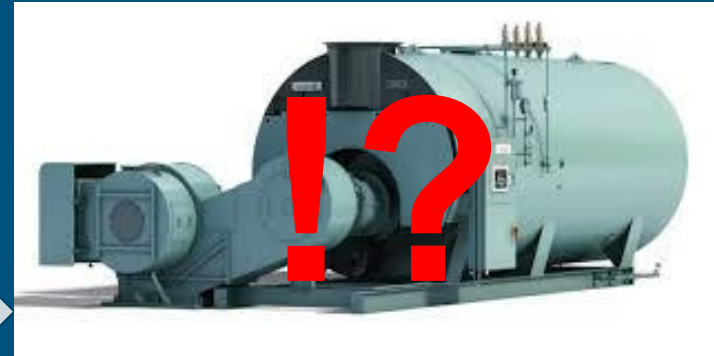
100 psig

T
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**75,000 lbs/hr:
7,500+ gallons
@
250+ psig !**



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Safety Risk Reduction



Site-wide Catastrophe



Isolated Equipment Failure

Comparison of 100 Hp Rated Power Boilers

Scotch- Marine Firetube

A: 728 gal
B: 482 gal
C: 628 gal

613 gal average

Flexible Watertube

A: 157 gal
B: 125 gal

141 gal average (less than ¼ FT)

Ultra-low Volume Watertube

A: 45 gal
B: 49 gal
C: 53 gal

49 gal average (less than 1/10th FT; ~1/3 FWT)

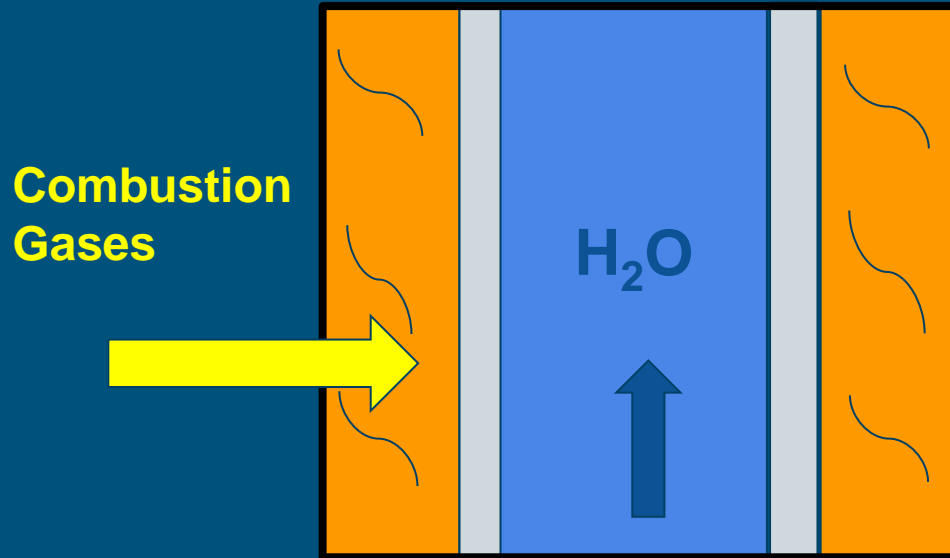
Isolated Equipment Failure



Destructive test of a **500 Hp** once through, forced flow steam generator performed for the TSSA (Technical Standards & Safety Administration, Ontario, CANADA).

- ~314 gal. operational water volume (~.77 gal/HP)
- Feedwater flow reduced, simulating low water conditions
- All low water protective safety devices REMOVED
- Burner allowed to continue, melting down pressure vessel, until flame safeguard caused fuel interruption.

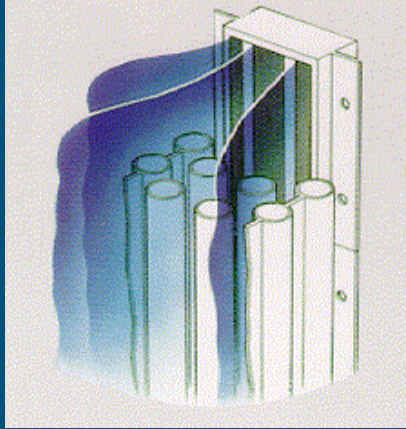
Design Challenges



“Don't tell people how to do things, tell them what to do, and let them surprise you with their results.” -George S. Patton



Down-Fired

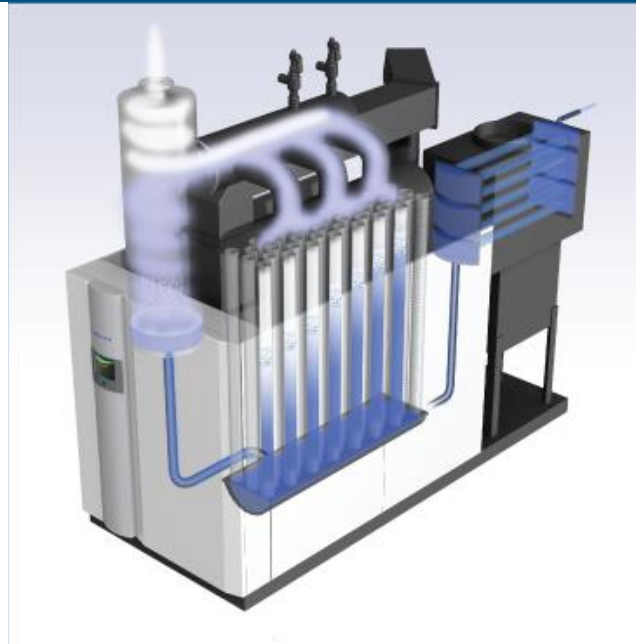


Side-Fired



Up-Fired

Burner Arrangements



Same Minimal Water Concept, Completely Different Designs...

Trade-Offs for Inherent Operational Safety

- start up time
- water treatment (time)
- varying loads/ load change response/ controls
- internal inspection/maintenance access
- operational flexibility (modular redundancy)
- footprint
- standard efficiency (due to tighter heat transfer tolerances)
- fuel selection

Unique Risk Factors of High Pressure Steam Boilers

1. Operational volume of pressurized, saturated water present
2. Operating pressure above ambient (atmospheric) pressure

How do current codes, regulations, and laws reflect this reality..?

The Crux of The Matter...

Most Jurisdictional Codes, Regulations, and Laws...

- Differentiate among requirements based primarily on **STEAMING CAPACITY** (Btus/hr, KW, boiler horsepower, heating surface area, SRV capacity, etc.)
- Little, if any, consideration is given to operating pressure ranges > 15 psig
- Little, if any, consistency exists between jurisdictions regarding requirements, or benchmarks of differentiation between levels of safety
- No explanation, or scientific basis is given, for benchmarks of differentiation for the various safety requirements.

An Extreme Example...

In the Commonwealth of Massachusetts...

8 x 300 HP Ultra Low Water Volume High Pressure Steam Boilers

~135 gal/ea. @ 125 psig (.45 gal/HP);
~1,072 cumulative TOTAL gallons!

Operator Requirements: ≥ 501 HP in aggregate

2nd Class Engineer's license (2nd highest)

Continuous attendance (highest level)

1 x 200 HP Scotch-Marine Firetube High Pressure Steam Boiler

~**1,274 gallons** @ 150 psig (~6.37 gal/HP)

Operator Requirements: ≤ 500 HP in aggregate; ≥ 26 psig; 9HP to ≤ 250 HP

3rd Class Engineer's license

Periodic attendance (lowest level)

Shouldn't Safety Benchmarks Be Based On Science?

Operational Saturated Water Volume:

- Gallons/Boiler Horsepower?
 - ≥ 1 gallon/horsepower?
- Operational Weight/Dry Shipping Weight?
- Pressure Vessel Architecture

Standards should acknowledge science-based safety benchmarks to the industry, incentivizing boiler plant operators to embrace them.

Operating Pressure:

Potential flash steam % production weighed against common pressure range standards

- ≤ 15 psig
- 16 psig to ≤ 150 psig (comm./ind.)
- 151 psig to ≤ 300 psig (co-gen+)
- 301 psig to ≤ 600 psig (30% flash)
- 601+ psig (power generation+)

Operating environments contribute to overall plant safety, and tend to correlate with operating pressure range.

Conclusion: SAFETY - If Not Now, When?

1. Operational saturated water volume & operating pressure are the primary safety risk factors uniquely associated with operating high pressure steam boilers, independent of steaming capacity.
2. Ultra low water volume, inherently safe high pressure steam boilers which mitigate these risk factors, are a diverse, and mature category of boilers, with substantial North American & global presence.
3. ASME & National Board members have tremendous influence over the safety standards of the boiler industry. People's lives and livelihoods depend on its membership bridging the gap between the laws of Nature, and the laws of mankind.

Thank you! Questions?

