ESTIMATING THE COST OF STEAM LOSS THROUGH THE ORIFICE OF A STEAM TRAP

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Investigation of steam loss in a steam system, or routine or preventive maintenance procedures, may reveal that one or more steam traps are leaking. How does the cost of repairing or replacing the defective steam traps compare to the value of the lost steam?

When a steam trap malfunctions, steam in form of vapor escapes through the outlet valve or orifice. The steam that escapes is wasted energy that cannot be recovered. By determining the amount of steam that escapes, it is possible to determine the financial loss and whether or not a trap maintenance and repair program would be beneficial. Steam loss through an orifice can be estimated using a variant of the Napier formula:

$$\textbf{Steam Flow (lb/hr)} = 24.24 \times P_a \times D^2$$

where:

$P_a = P_{gage} + P_{atmospheric}$
P_a = Absolute Pressure, psia
P_{gage} = Gage Pressure, psig
$P_{atmospheric}$ = Atmospheric Pressure, psi = 14.696 psi
D = Diameter of Orifice, in.

Example

P_{gage} =	5	psig
P_a =	19.696	psia
D =	0.1875	in

W = 24.24 x 19.696 psia x (.1875 x .1875) = 16.78 lbs/hr

ESTIMATING ANNUAL FUEL COST PER STEAM TRAP

For a trap that is leaking continuously throughout the entire heating season, the cost for the loss of steam in the trap can be determined using the following formulas:

Formula for Annual Fuel Cost per Trap - Using Cost per MMBtu in Natural Gas in Commercial Heating Systems:

$$Q = \frac{L \times H \times E \times 10^{-6} \times C}{BE}$$

where:

Q = Energy Lost ($)
L = Lb/Hr of steam lost = 16.78 lbs/hr (0.187” orifice, 5 psig)
H = Hours in heating season = 5,808
E = Latent heat of steam at 5 psig = 960.8 Btu/lb
10^{-6} = MMBtu/Btu
C = Cost of gas per million Btu = $6.23
BE = Boiler Efficiency = 80%

Q = (16.78) (5,808) (960.8) (10^{-6}) (6.23)/0.80 = **$729.20**

Equipment Cost

If a steam trap maintenance program were to be implemented and the cost to repair or replace each defective trap were known, the Equipment Cost for the project can be determined as follows:

Equipment Cost = Cost per Trap x Number of Traps

The Cost per Trap is:	3/4" Float and Thermostatic Trap	=	$ 65
	1 hour labor	=	35
	Cost per Trap	=	$100

Calculating the Equipment Cost for one trap:

Equipment Cost = $100 x 1 = $100

Simple Payback (years)

The Simple Payback in terms of years is beneficial in determining the financial return of the proposed trap maintenance program. The quicker the payback, the more a project can be justified.

$$\text{Simple Payback} = \frac{\text{Equipment Cost}}{\text{Savings}}$$

Using the Annual Fuel Cost per Trap ($/M-Lb) and the Equipment Cost from above, the Simple Payback can be determined:

$$\text{Simple Payback} = \frac{\$100}{\$729.20} = \textbf{0.1371 years or (1.645 months)}$$

Figuring a total annual energy savings of **$729.20** and an equipment cost of $100 for a new trap, the savings acquired from the replacement of just one trap would be enough to pay for 7 new traps. Greater savings and quicker paybacks would occur by using less expensive repair kits rather than a new unit in specific instances.

This is an example of the cost effectiveness of implementing a steam trap preventive maintenance program where traps are inspected, maintained, repaired and replaced on a regular basis.

References

Techniques for Testing Steam Trap Operation, by Milton Hilmer, Chief Engineer, Sarco Co., Inc.
Technical Publishing Company – 1977

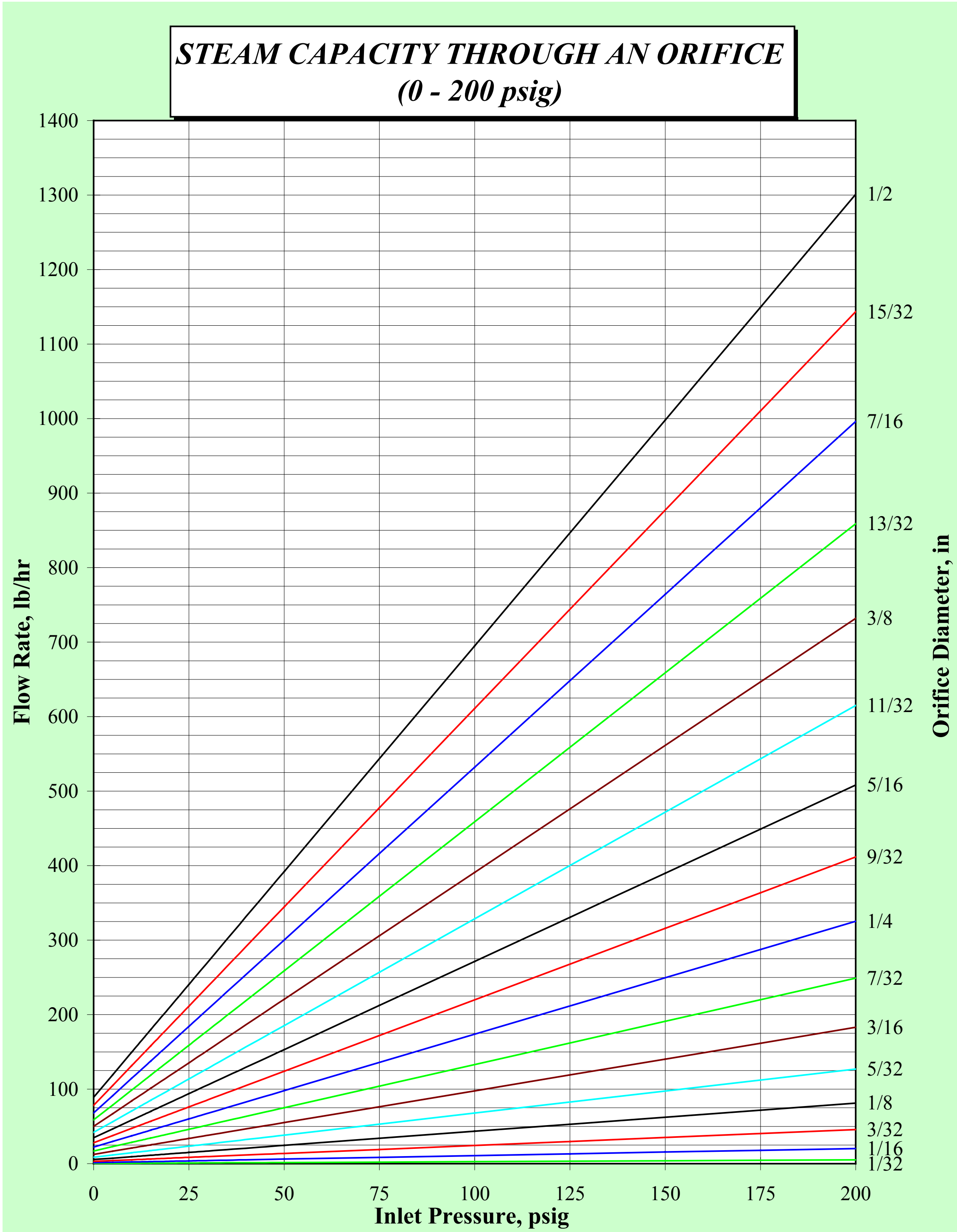
Testing Traps to Keep Your System Operating Effectively and Efficiently, by Joe Radle October 10, 2000
Employed by Spirax Sarco, Inc. for 28 years.

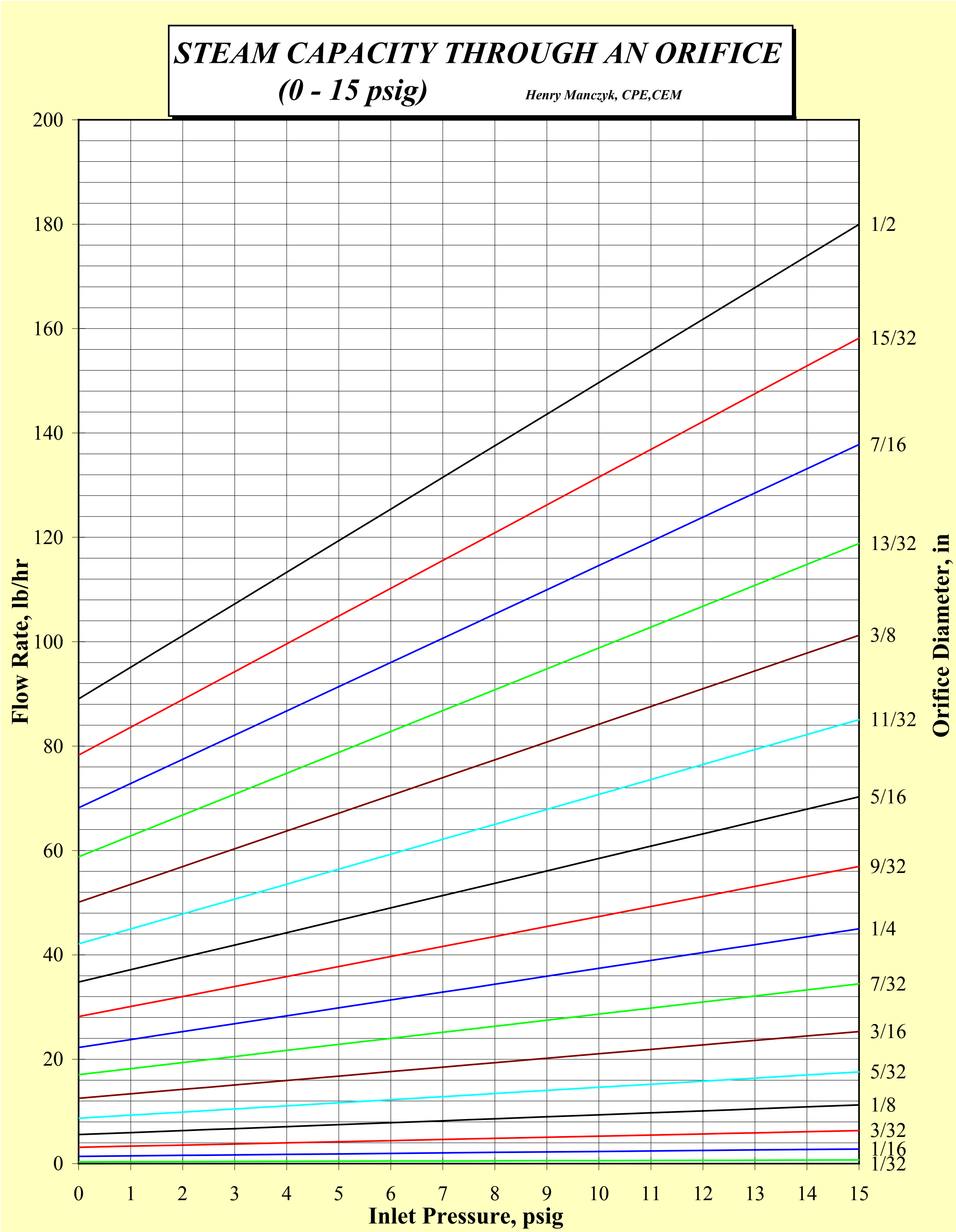
Spirax Sarco Design Of Fluid Systems – Hook-Ups

Note: The attached charts and table illustrate the steam loss at a variety of orifice sizes and steam pressures.

STEAM LOSS THROUGH ORIFICES DISCHARGING TO ATMOSPHERE

Orifice Diameter (inches)		Steam Flow, lb/hr, when steam gage pressure is;												
		2 psi	5 psi	10 psi	15 psi	25 psi	50 psi	75 psi	100 psi	125 psi	150 psi	200 psi	250 psi	300 psi
1/32	0.03125	0.40	0.47	0.58	0.70	0.94	1.53	2.12	2.72	3.31	3.90	5.08	6.27	7.45
1/16	0.0625	1.58	1.86	2.34	2.81	3.76	6.13	8.49	10.86	13.23	15.59	20.33	25.06	29.80
3/32	0.09375	3.56	4.20	5.26	6.33	8.46	13.78	19.11	24.44	29.76	35.09	45.74	56.39	67.04
1/8	0.125	6.32	7.46	9.35	11.25	15.03	24.50	33.97	43.44	52.91	62.38	81.32	100.25	119.19
5/32	0.15625	9.88	11.66	14.62	17.57	23.49	38.29	53.08	67.88	82.67	97.47	127.06	156.65	186.24
3/16	**0.1875**	14.23	**16.78**	21.05	25.31	33.83	55.13	76.44	97.74	119.05	140.35	182.96	225.57	268.18
7/32	0.21875	19.37	22.85	28.65	34.45	46.04	75.04	104.04	133.04	162.04	191.03	249.03	307.03	365.02
1/4	0.25	25.29	29.84	37.41	44.99	60.14	98.01	135.89	173.76	211.64	249.51	325.26	401.01	476.76
9/32	0.28125	32.01	37.77	47.35	56.94	76.11	124.05	171.99	219.92	267.86	315.79	411.66	507.53	603.40
5/16	0.3125	39.52	46.62	58.46	70.30	93.97	153.15	212.33	271.51	330.69	389.87	508.23	626.59	744.94
11/32	0.34375	47.82	56.42	70.74	85.06	113.70	185.31	256.92	328.52	400.13	471.74	614.95	758.17	901.38
3/8	0.375	56.91	67.14	84.18	101.23	135.31	220.53	305.75	390.97	476.19	561.41	731.84	902.28	1072.72
13/32	0.40625	66.79	78.79	98.80	118.80	158.81	258.82	358.83	458.85	558.86	658.87	858.90	1058.9	1258.96
7/16	0.4375	77.46	91.38	114.58	137.78	184.18	300.17	416.16	532.15	648.15	764.14	996.12	1228.1	1460.09
15/32	0.46875	88.93	104.90	131.54	158.17	211.43	344.58	477.74	610.89	744.04	877.20	1143.5	1409.8	1676.12
1/2	0.5	101.18	119.36	149.66	179.96	240.56	392.06	543.56	695.06	846.56	998.06	1301.0	1604.0	1907.06


STEAM CAPACITY THROUGH AN ORIFICE
(0 - 200 psig)
Flow Rate, lb/hr
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
Inlet Pressure, psig
0
25
50
75
100
125
150
175
200
Orifice Diameter, in
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32



STEAM CAPACITY THROUGH AN ORIFICE
(0 - 15 psig)
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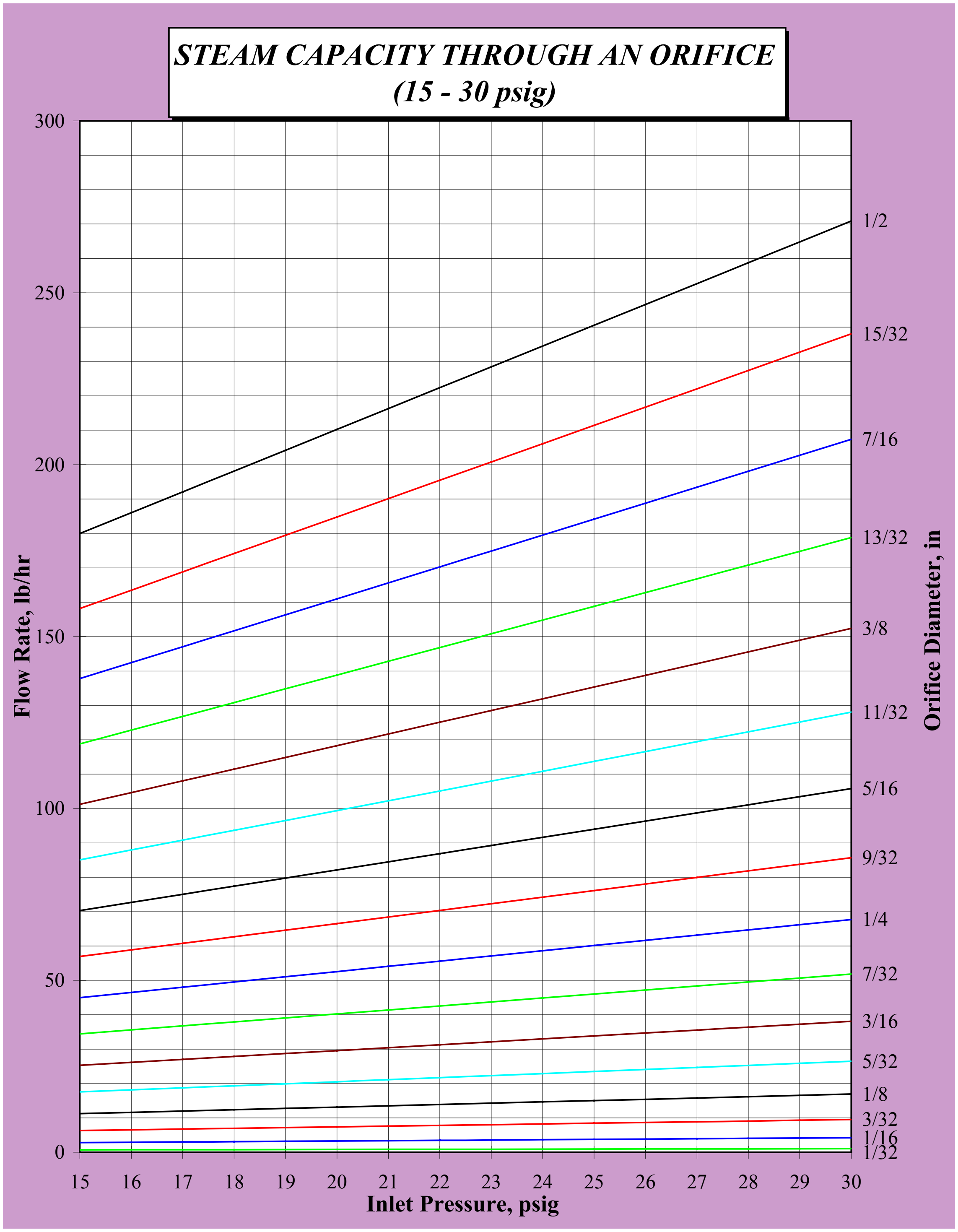
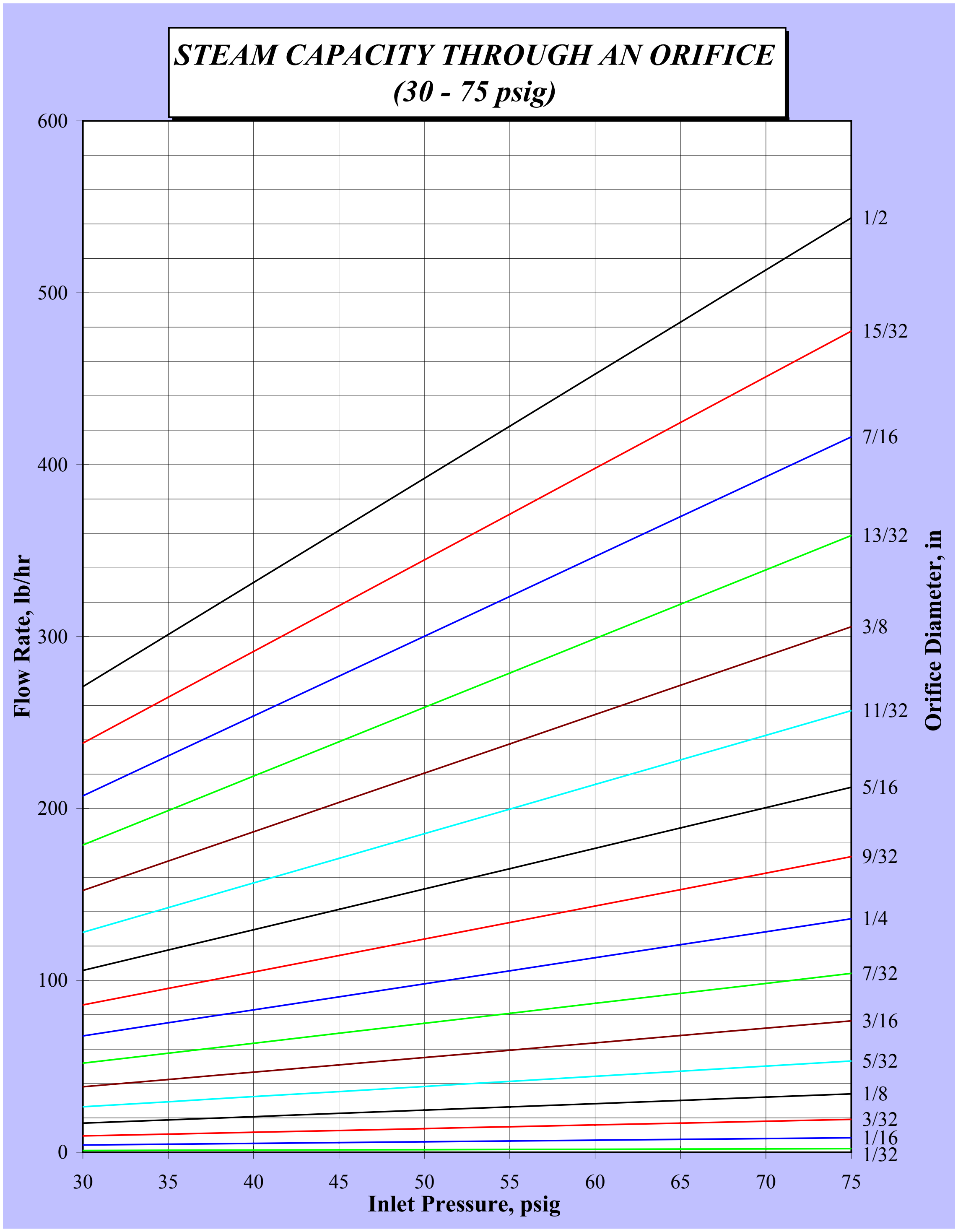
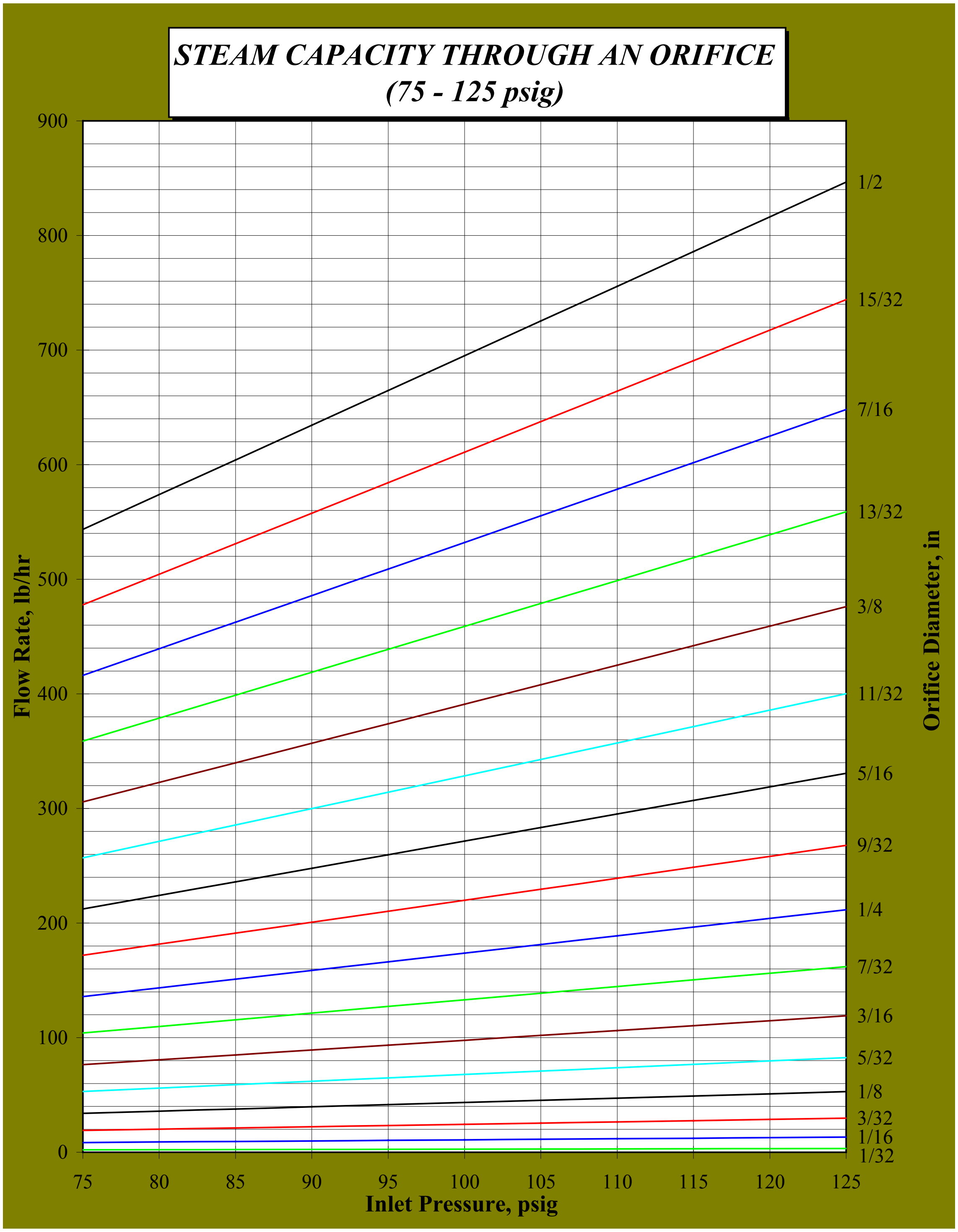
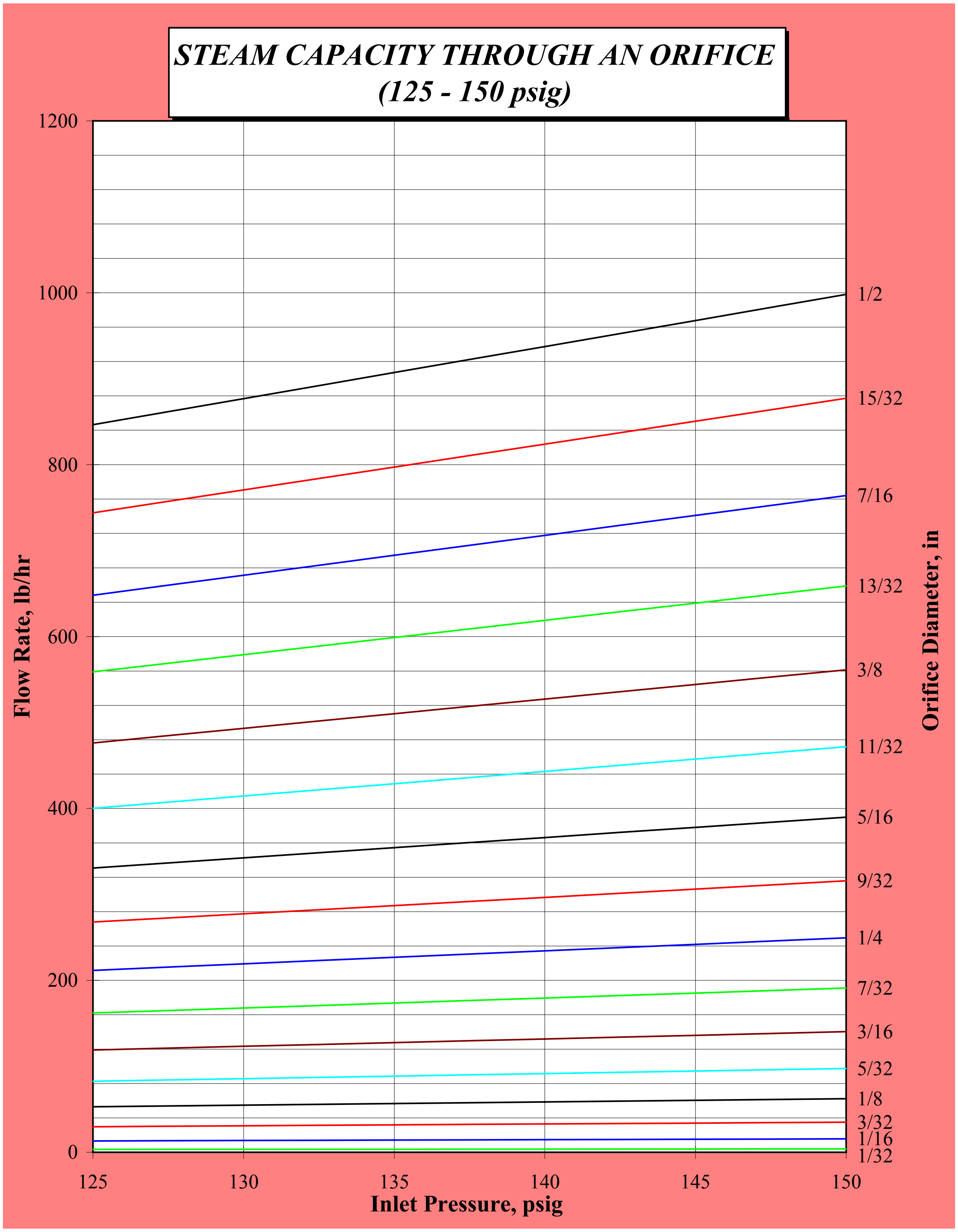
Flow Rate, lb/hr
Inlet Pressure, psig
Orifice Diameter, in
0
20
40
60
80
100
120
140
160
180
200
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32

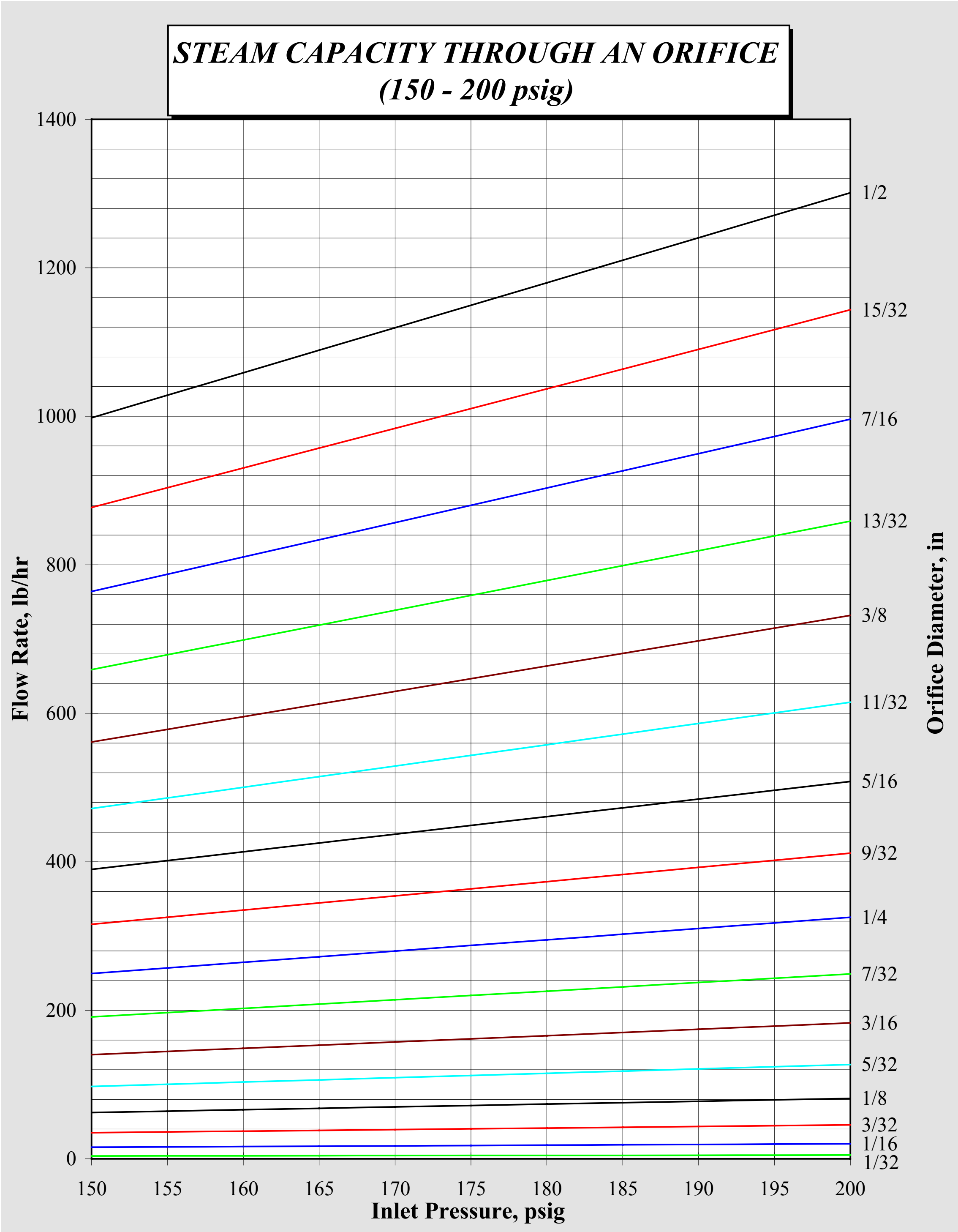

STEAM CAPACITY THROUGH AN ORIFICE
(15 - 30 psig)
Flow Rate, lb/hr
300
250
200
150
100
50
0
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Inlet Pressure, psig
Orifice Diameter, in
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32


STEAM CAPACITY THROUGH AN ORIFICE
(30 - 75 psig)
Flow Rate, lb/hr
Orifice Diameter, in
Inlet Pressure, psig
0
100
200
300
400
500
600
30
35
40
45
50
55
60
65
70
75
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32


STEAM CAPACITY THROUGH AN ORIFICE
(75 - 125 psig)
Flow Rate, lb/hr
Orifice Diameter, in
Inlet Pressure, psig
0
100
200
300
400
500
600
700
800
900
75
80
85
90
95
100
105
110
115
120
125
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32



STEAM CAPACITY THROUGH AN ORIFICE
(125 - 150 psig)
1200
1000
800
600
400
200
0
Flow Rate, lb/hr
125
130
135
140
145
150
Inlet Pressure, psig
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32
Orifice Diameter, in


STEAM CAPACITY THROUGH AN ORIFICE
(150 - 200 psig)
Flow Rate, lb/hr
1400
1200
1000
800
600
400
200
0
150
155
160
165
170
175
180
185
190
195
200
Inlet Pressure, psig
Orifice Diameter, in
1/2
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32