Steam Sparging & Filtration

Design Guide & Part Selection

mott corporation

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Steam Sparging - Steam and Porous Metal

Rigid construction and high-temperature capability of Mott porous metal materials are properties ideally suited to handle steam sparging and filtration at all temperature and pressure conditions.

Mott's porous metal can control the pressure drop along an element reducing the chance of steam hammer and distributing the steam along the entire length of the element ensuring maximum surface area contact. Typically steam is introduced into a process from an open ended pipe or a drilled pipe. This results in large steam bubbles which collapse and cause steam hammer.

Materials and Media

Mott's standard porous metal alloy is 316LSS. Other alloys typically utilized in steam sparging and filtration include:

- Hastelloy® C276
- Inconel® 600
- Titanium

Media Grade 10 is recommended for steam sparging.

The Process

Steam filtration removes rust, pipe scale, and other build-up deposited in a steam distribution system. These materials can damage process equipment and the final product of a process downstream. Benefits of steam filtering include:

- Protect flow control valves
- Prevent fouling of heat exchangers
- Protect pressure regulators
- Keep steam sanitary when injected into food, pharmaceutical, or beverage processes

Steam sparging is the direct injection of steam into a process, so it is also important to filter the steam. If the steam is not filtered prior to the element, the element will act as a filter and will cause plugging. Examples of sparging applications that requires steam filtration include:

- Bottling, packaging and canning processes
- Hot water preparation for consumption
- Sanitary food/beverage and pharmaceutical processes
- Heating liquids (such as soups, sauces, etc.)

What is Steam Hammer?

Rapidly collapsing bubbles create frequent pressure changes that sound like a hammer rapping against a pipe wall; the larger the bubble collapse, the greater the pressure shock.

HOW DOES IT OCCUR?
It occurs when the steam injection rate exceeds the heat transfer capacity of the system to condense the steam instantaneously. This is controlled by the surface area of the bubble relative to the heat content of the steam.

WHAT DAMAGE CAN IT CAUSE?
It is significant cause of piping and process system failure. Pressure gages are quickly destroyed and system instruments are rendered useless.

HOW IS IT PREVENTED?
When sized properly Mott's porous metal media eliminates steam hammer. The steam bubbles exiting the porous metal are smaller, creating a larger surface area of liquid/steam contacting. This allows for more area per volume of steam causing a more rapid rate of condensation, therefore permitting higher steam injection rates. This capacity is a function of several system parameters including agitation and water temperature rise.

Mott's Products

This guide will describe how to select Mott porous metal media for both sparging and filtration applications.

- Static Steam Spargers
- Dynamic Steam Spargers
- Steam Filtration

It is essential for one to understand steam tables to work with the principles and calculations involved in these applications. See attached *Table 1* for further details.

Static Steam Spargers

Static steam spargers are fixed in a tank that can either be agitated or non-agitated. The difference regarding agitation is important when considering steam hammering. Agitation increases the heat transfer rate, which condenses the bubbles faster therefore eliminating hammer. As a result an agitated system can be designed for faster sparger rates than with a non-agitated system.

Table 2 below demonstrates how the steam volume flow below the hammer point is greater for agitated runs.

Table 2: Recommended Maximum Steam Exit Velocities for Media Grade 10

	Steam Pressure, psig	Mass Rate, lb/min ft^2	Steam Velocity (V_s), CFM/ft^2	Ave Water Temp, °F
Non-Agitated	5.5	13.5	135	130
Agitated	7.5	20.0	185	130

Sparger elements are all-welded, rigid metallic structures that can be placed into a tank in a variety of ways. The spargers can be welded directly to the tank or have various fittings welded to the porous material for easy removal. Typical fittings include hex nipples, flange mountings, or NPT reducers. Various sizes and arrangements are available. See Mott's literature, reference ***PMSPARG,*** for static sparger arrangements and elements.

How to Size

Static sparger sizing is based on the steam exit velocity from the porous sparger surface, expressed in feet per minutes (FPM), calculated from cubic feet per minute (CFM) per square foot of sparger surface area (CFM/ft^2). Steam volume is calculated at head or liquid pressure at the sparger element. It is *not* based on steam pressure available to the sparger.

Steps

1. Determine the volumetric flow rate of steam at process system pressure, which is the pressure on the sparger surface.
2. Determine the amount of steam based on heating requirement.
3. Select the appropriate volumetric flux depending on agitation.
4. Determine the surface area of the sparger.
5. Determine appropriate sparger configuration to accommodate the required area.

Design Example for Static Sparger Application

Process: 500 gallons of H_2O in a non-agitated tank, 48 inch diameter and 5 foot head at the sparger. Heat from 60-100°F in 10 minutes. 2 psi across element.

Determine: Sparger area and appropriate equipment.

Glossary:

w – mass of steam
m - lbs
C_p - BTU / lb°F
ΔT - °F
ΔH_v - BTU / lb
ΔT_s - Saturation Temperature °F
V_s - Specific Volume Ft^3

Solution:

Step 1 – Calculate steam pressure at sparger

P_{steam}= (Head Pressure + Pressure Across Element)

Head Pressure = (5 ft)(0.433 psi/ft)(1. Sp.G.)= 2.16 psi

P_{steam}= 2.16 + 2 = 4.16 psi

Step 2 – Calculate the mass of steam (w) by combining the heat lost and heat gained equation.

$$w = \frac{mC_p\Delta T}{(\Delta H_v + C_p\Delta T_s)}$$

Variables:

m = (500 gal)(8.43 lbs/gal) = 4215 lbs
Steam at 4.16 psi gage
Temperature = 227.8°F
ΔH_v = 961.2 BTU/lb
Specific Volume = 20.82 ft^3/lb

(**From Steam Table**)

$$w = \frac{(4215.0\ lb)(1BTU / lb°F)(100\text{-}60°F)}{(961.2\ BTU / lb + (1BTU / lb°F)(227.7\text{-}100°F))}$$

w=154.8 lbs
w=154.8 lbs in 10 minutes = 15.5 lbs/min

Step 3 – Calculate Steam Volume Flow, CFM.

Specific Volume x Mass of Steam = Volume Flow
(20.82 ft^3/lb) x (15.5 lbs/min) = 322.7 CFM

Step 4 – Select a Steam Velocity, V_s, from Table 2 within the given range. In this case, V_s = 135 CFM/ft^2.

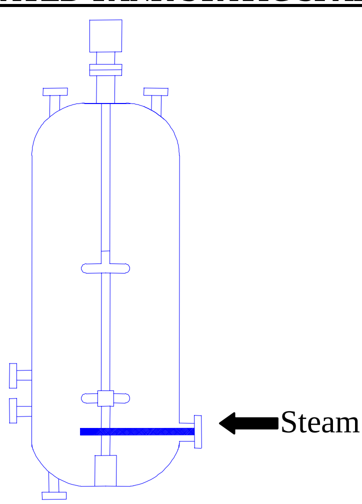
Step 5 – Calculate the Area by dividing the Volume Flow by the Steam Velocity:

$$\text{Area} = \frac{322.7\ \text{CFM}}{135\ \text{CFM} / ft^2} = 2.39\ ft^2$$

Step 6 – Determine the appropriate equipment for this size sparger by consulting Mott Technical Sales.

Note: If the tank was agitated, rates up to 185 CFM/ft^2 could have been reached, therefore allowing for a smaller sparger area, 1.77 ft^2 (Ref: Table 2).

AGITATED TANK STATIC SPARGER



- Sparging element(s) located in vessel or tank.
- Circulation will occur in the vessel due to the change in density of the gas/liquid phase relative to the liquid

Dynamic Versus Static

The difference between Dynamic and Static spargers is the ability to control liquid velocity, which in turn controls the steam through the tube wall. Liquid velocity in a static tank is caused only by agitation. Therefore, there is normally no direct way to control or measure it. In a dynamic system, the liquid velocity is the flow of liquid through the pipes, over the surface of the sparger. This liquid velocity can be controlled, therefore allowing much higher steam rates maintained under the hammer point.

Some practical liquid velocities are 5-20 ft/sec and possibly higher. *Table 3* shows how the rates of Dynamic and Static spargers compare.

Table 3: Comparison Between Static and Dynamic Spargers

STATIC	**CFM/FT²**
Agitated & Non-Agitated	185
DYNAMIC	**CFM/FT²**
Intrusive & Non-Intrusive	750 (Up to 40 FPS)

In most cases Dynamic spargers allow for much higher exit velocities because of forced convection and higher heat transfer rates. As the difference in temperature between the water and steam decreases, the rate of heat transfer will decrease.

Dynamic Steam Spargers

There are two types of Dynamic spargers, Intrusive and Non-Intrusive. Intrusive spargers are inserted into a pipeline, while non-intrusive spargers become a section of the pipeline.

Non-Intrusive

Mott's GasSavers® are a shell and tube design, fitted into a pipe section. Steam flows from the annulus of the shell and tube through the porous tube wall. The liquid flows straight through the center of the sparger without intrusion (non-intrusive).

Non-intrusive spargers can handle larger scale applications by allowing unrestricted flow in a pipe system without mechanical problems. Mott has produced GasSavers up to 12 inches in diameter. For large pipe sizes, a side stream GasSaver is recommended. This method provides a system that can be installed and serviced outside of the main pipe. The side stream can be pumped from the main pipe or it can come from an external source.

Intrusive

One end of the sparger is fixed with a fitting into the pipe, while the other end is freely suspended within the pipe. Liquid therefore flows through the annulus of the pipe wall and sparger element. Adjusting the dimensions of the pipe and sparger diameter will control the liquid velocity.

The setup can cause sparger flexing with long elements due to turbulence present in the system. This problem can limit the length of an intrusive sparger element for applications with restrictions on the pipe diameter. If the element is made shorter with a larger diameter, it will be more rigid and less likely to vibrate.

Intrusive spargers are simple to install and inexpensive. However, they are not conducive to conditions where the liquid has a high solids content, or where the element needs to be longer to provide surface area. Non-intrusive spargers are more suitable for these situations.

How to Size

Dynamic pipeline sparger sizing is based on the water inlet velocity to the sparger, the steam exit velocity, and the pressure in the pipeline. Water inlet velocities can be from 1-20 FPS and sometimes as high as 40 FPS. The steam exit velocity should then be selected from design Table 2.

Steps

1 – Determine heat required.
2 – Obtain the steam requirement using the heat required and the steam pressure.
3 – Select an appropriate steam velocity depending on the given water velocity.
4 – Determine the surface area of the sparger.
5 – Determine the appropriate configuration of spargers to accommodate the calculated area.

Design Example for <u>Non-Intrusive</u> Sparging

Process: 150 gal/min H_2O heated from 50-150°F; Steam Pressure, P_{steam}, 50 psig; Line Pressure=30 psig; and Water Velocity, V, 20 ft/sec.

Determine: Sparger area and appropriate equipment.

Solution:

<u>Step 1</u> – Calculate the heat required, Q, using

$$Q = mC_p\Delta T$$

Variables:
m = (150 gal/min)(8.43 lbs/gal)=1,264.5 lb/min
C_p = 1 BTU/lb °F
ΔT = 150-50°F=50°F

In this example, Q = 126,450 BTU/min = 7,587,000 BTU/hr

<u>Step 2</u> – Obtain the Steam Requirement, *S*, by using **Figure 1** (attached) with the calculated *Q* and the given Steam Pressure, P_{steam}, 50 psig. S= 700 CFM.

<u>Step 3</u> – Obtain the Steam Velocity, Vs, by using **Figure 2** (attached) with the given water velocity, 20 ft/sec. Vs = 800 CFM/ft^2.

Step 4 – Calculate the area by dividing the Volume Flow by the Steam Velocity.

$$Area = \frac{700\ CFM}{800\ CFM/ft^2} = 0.875\ ft^2$$

Step 5 – Determine the appropriate equipment for this size sparger by consulting Mott Technical Service.

NON-INTRUSIVE SANITARY GASSAVER®

Design Example for Intrusive Sparging

An intrusive sparger is often placed into an existing system. Therefore, the dimensions of that system dictate the positioning of the sparger. For example, if existing pipes are 1.5 inches, the sparger element has to be <1.5 inches. Using the same requirements as the previous example, it may not be feasible to use an intrusive sparger. This can be verified through **Table 4**. The calculated area 0.875 ft^2 is unachievable even choosing the longest length of a 1.0 inch diameter element. Lengths of 24 and 36 inches are even too long. The maximum length of a suspended sparger element should be limited to 18 inches.

Table 4: Section from Sparging Design Guide

Diameter Inches	Length Inches	Area Ft^2
1.0	6.0	0.13
	12.0	0.26
	18.0	0.39
	24.0	0.52
	36.0	0.78
0.75	6.0	0.10
	12.0	0.20
	18.0	0.29
	24.0	0.39
	36.0	0.59

The dimensions of the pipe would have to be altered, or a non-intrusive sparger could be used.

INTRUSIVE SPARGERS

STEAM FILTRATION

Steam filtration is usually required to remove rust, pipe scale and other particles picked up in the steam distribution system. Steam can contain particles ranging from 10-150 µm in size, which will effect an application depending on the destination of the steam.

Steam containing particles of that size can damage the equipment and/or contaminate the actual product being developed. Another problem exists if the process contains a Mott sparger without a separate steam filter. The sparger will take on the role of the filter and begin to plug, causing a decline in sparger performance.

How to Size

Basic criteria for steam filtration is the required particle removal size and allowable pressure drop, clean and/or dirty. The objective in sizing is to meet those criteria with an economical filter.

The typical steam data given is a mass flow rate in pounds per hour, the steam pressure, the particle removal requirement expressed as a micron size to be removed, and the allowable pressure drop.

If dirty pressure drop is given, a clean pressure drop should be selected which is 20-25% of the dirty pressure. This should allow for a reasonable duty cycle.

Steps:

1 – Select the filter media to meet the removal requirement.
2 – Determine the mass flux for that media which meets the pressure drop requirement.
3 – Calculate the required area from the mass flow rate and the mass flux.
4 – Determine the appropriate filter configuration.

Sizing Notes:

Select the Filter Media
Steam is considered a gas for filtration purposes. The media ratings in gas service can be used as a guide to select the grade that will satisfy the particle retention requirement. If critical performance is required, the media selected should be tested and evaluated by trial because filtration efficiency is dependent on operating velocity and other process conditions.

Determine the Mass Flux
Mass flux-pressure drop tables are provided at the end of this guide (**Figures 1-6**). These steam pressure curves are based on volumetric velocity through the filter media converted to mass flow at the steam pressure.

Determine the Filter Configuration
The process conditions, space constraints, standard sizes, and economics determine the filter configuration. Normally, the filter elements are selected by diameter and length, which provides a certain filter surface area. A number of elements are determined to provide the total area needed. This number of elements is then provided by selecting the appropriate housing size.

Design Example for Steam Filtration

Process: Steam Pressure @ 60 psig;
Mass Flow Rate 6,000 lbs/hr;
Allowable Dirty Pressure Drop 5 psid;
Removal Rating of ≥ 10µm

Determine: Required filter area and elements.

Solution:

Step 1 – Using Figures 1-6 for the determined micron rating and given pressure drop, obtain the Mass Flux Rate, lbs/hr-ft^2.

Mass Flux Rate = 3,700 lbs/hr-ft^2

Step 2 – Calculate the required filter area by dividing the Mass Flux Rate by the Mass Flow.

$$\frac{6{,}000 \text{ lbs/hr}}{3{,}700 \text{ lbs/hr-ft}^2} = 1.62 \text{ ft}^2$$

Step 3 – Determine the number of elements needed to satisfy the calculated filter area.

Using 10 inch long elements with a diameter of 2 inches, each element would have an area of 0.87 ft^2. To accommodate the 1.62 ft^2 filter area, you would need two elements.

DESIGN REFERENCES

TABLE 1

PROPERTIES OF SATURATED STEAM
(Abstracted from Keenan and Keyes, THERMODYNAMIC PROPERTIES OF STEAM)

Pressure psig	Saturation Temperature °F	Heat of Evaporation Btu/lb	Specific Volume $ft^{3/}lb$
0.0	212.00	970.3	26.80
1.3	216.32	967.6	24.75
2.3	219.44	965.5	23.39
5.3	227.96	960.1	20.09
10.3	240.07	952.1	16.30
15.3	250.33	945.3	13.75
20.3	259.28	939.2	11.90
25.3	267.25	933.7	10.50
30.3	274.44	928.6	9.40
40.3	287.07	919.6	7.79
50.3	297.97	911.6	6.66
60.3	307.60	904.5	5.82
70.3	316.25	897.8	5.17
80.3	324.12	891.7	4.65
90.3	331.36	886.0	4.23
100.0	337.90	880.0	3.88
110.3	344.33	875.4	3.59
120.3	350.21	870.6	3.33
125.3	353.02	868.2	3.22
130.3	355.76	865.8	3.11
140.3	360.50	861.3	2.92
150.3	365.99	857.1	2.75
160.3	370.75	852.8	2.60
180.3	379.67	844.9	2.34
200.3	387.89	837.4	2.13
225.3	397.37	828.5	1.92
250.3	406.11	820.1	1.74

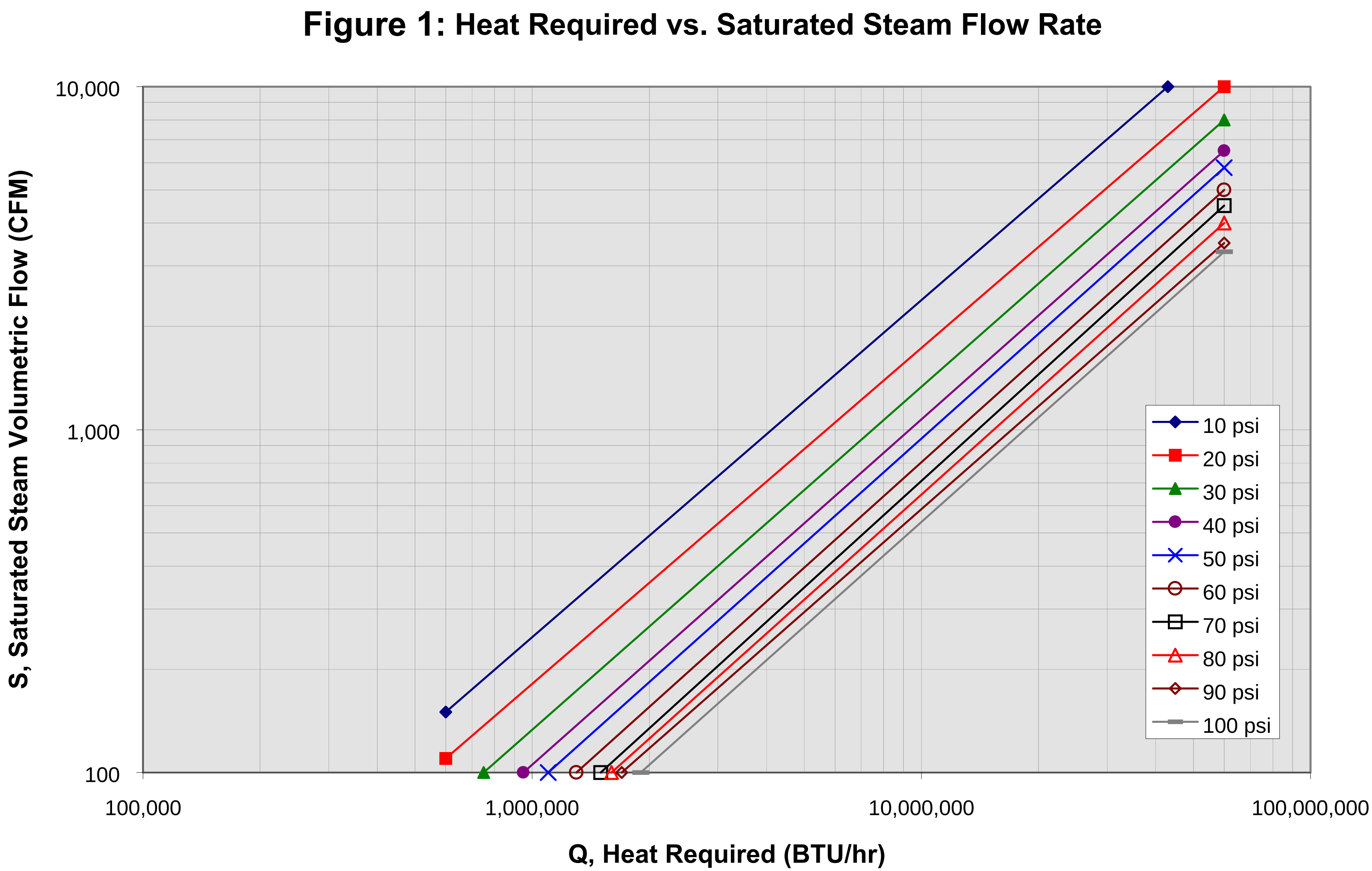


Figure 1: Heat Required vs. Saturated Steam Flow Rate
10,000
1,000
100
S, Saturated Steam Volumetric Flow (CFM)
100,000
1,000,000
10,000,000
100,000,000
Q, Heat Required (BTU/hr)
10 psi
20 psi
30 psi
40 psi
50 psi
60 psi
70 psi
80 psi
90 psi
100 psi

Figure 2: Design Line for No Steam Hammer

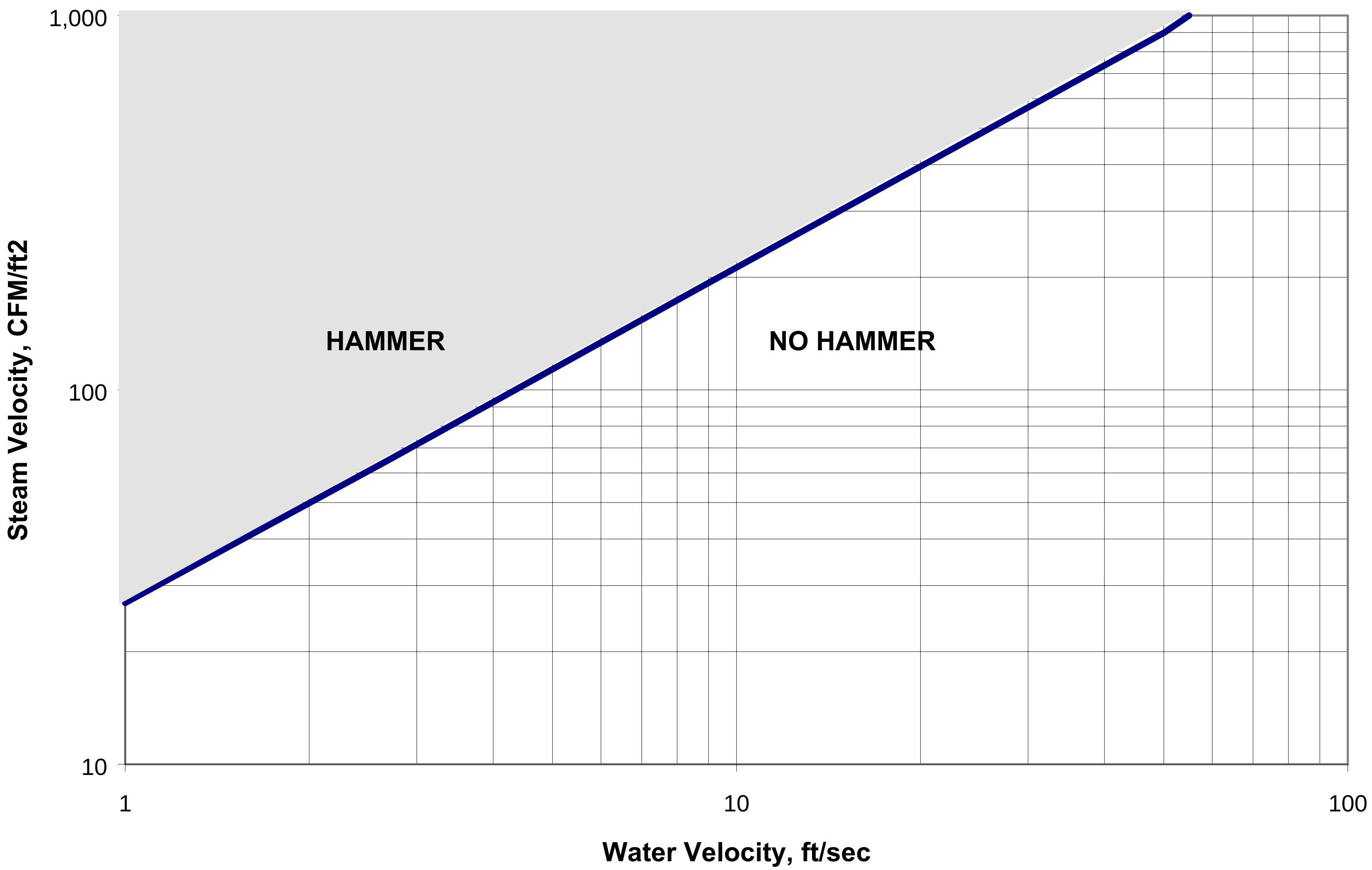


Figure 3: Conversion of Steam Volume Flow to Mass Flow

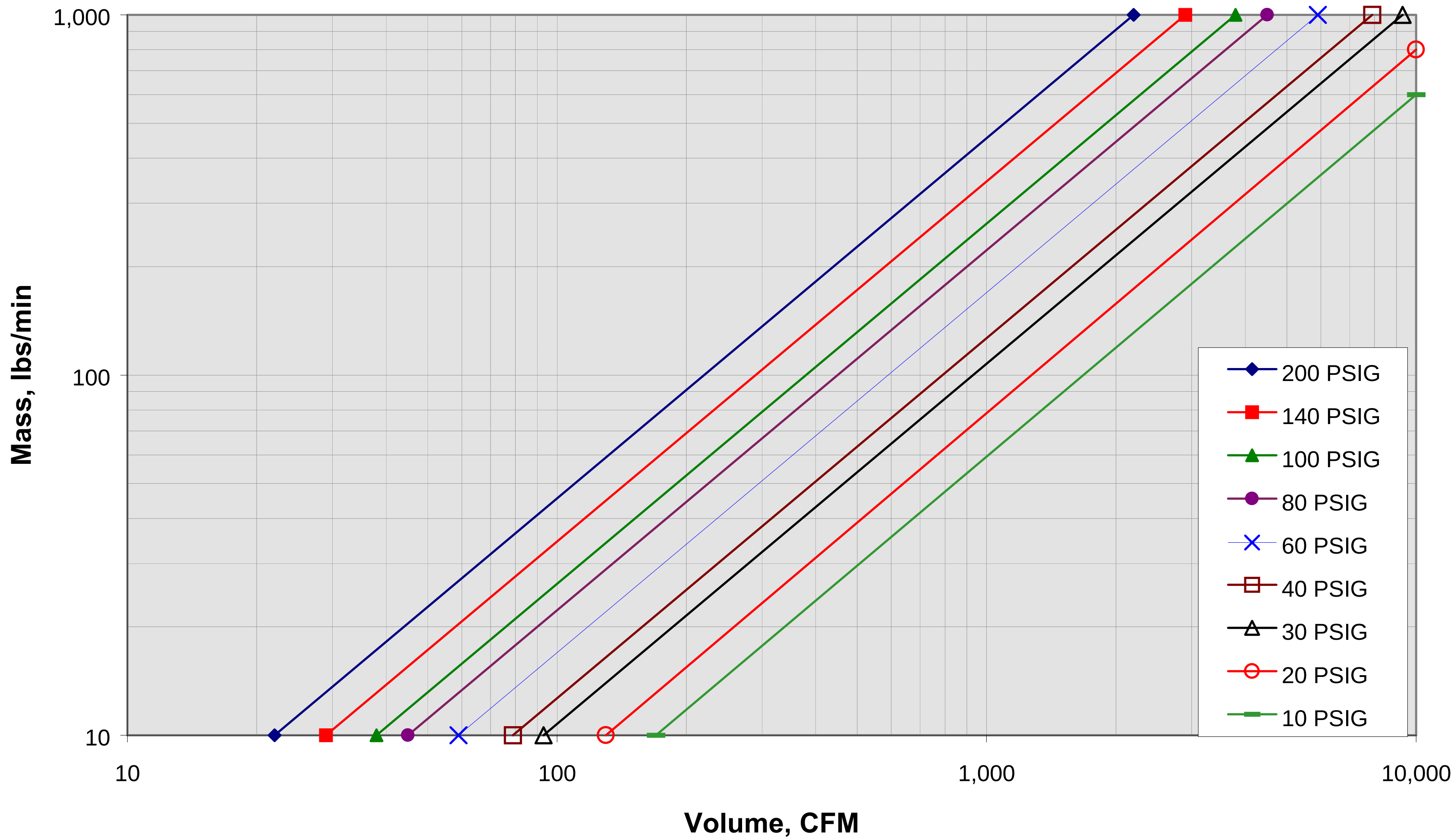


Figure 4: Porous Media Pressure Drop

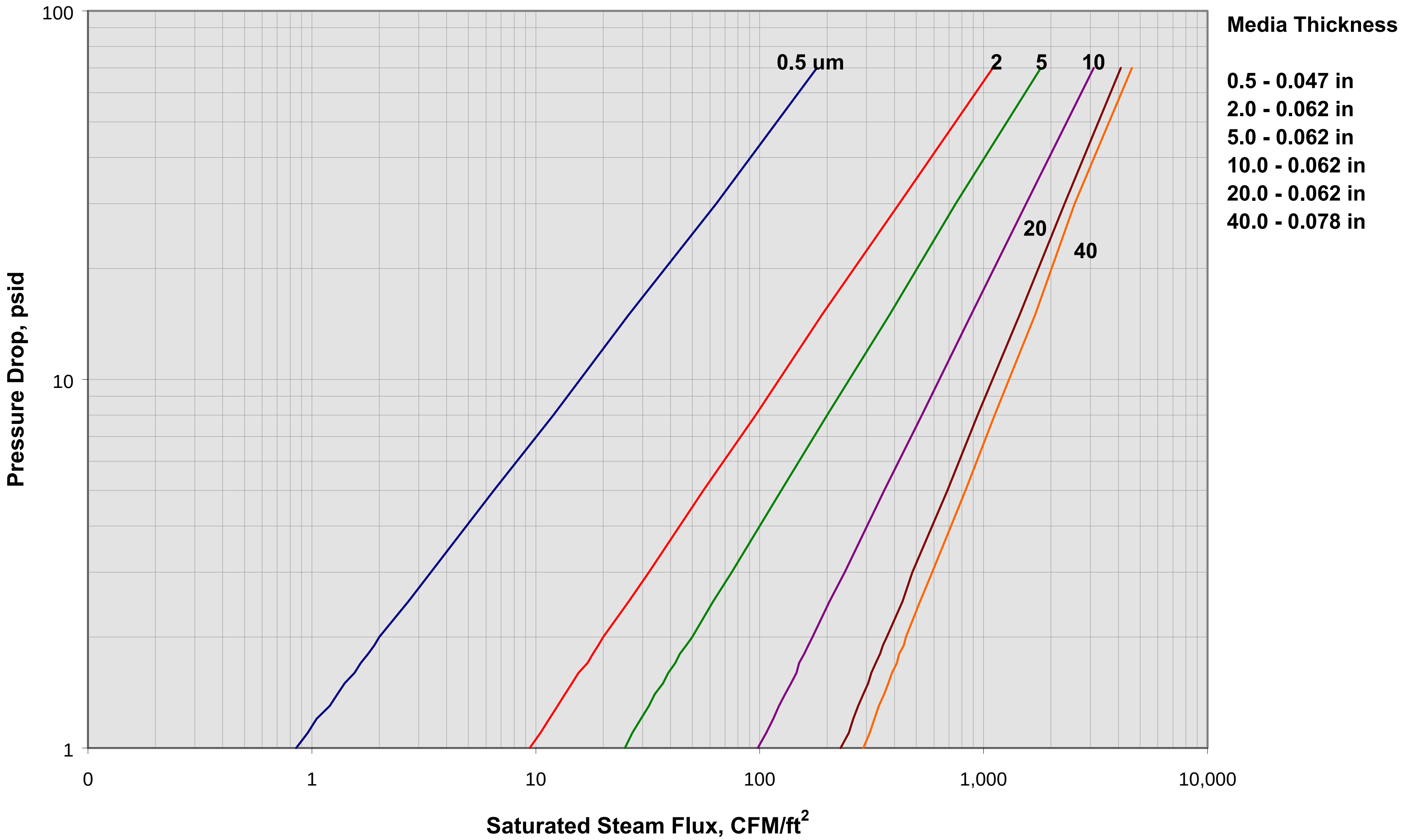


Figure 5: Media Pressure Drop by Steam Pressure

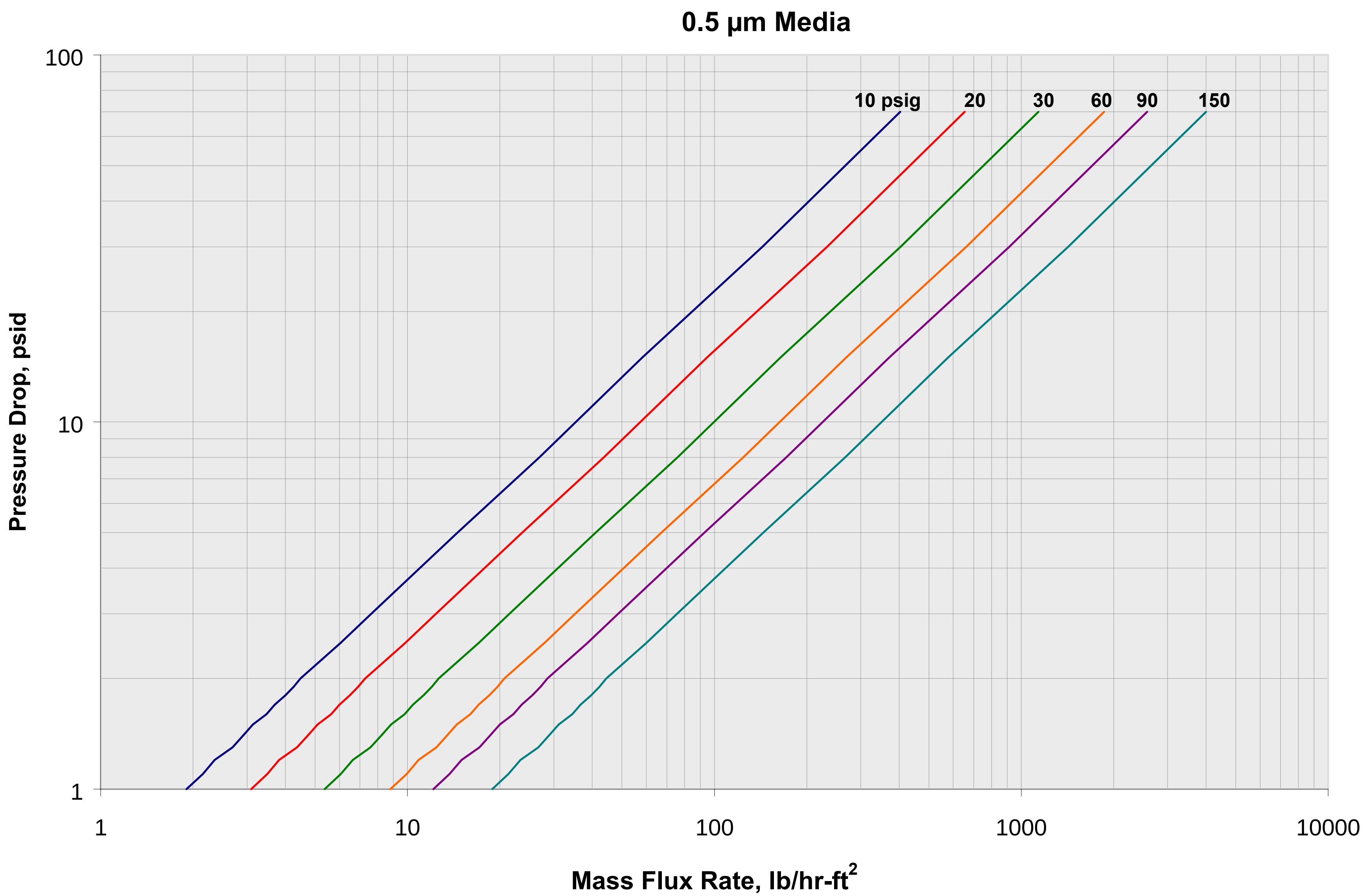


Figure 6: Media Pressure Drop by Steam Pressure

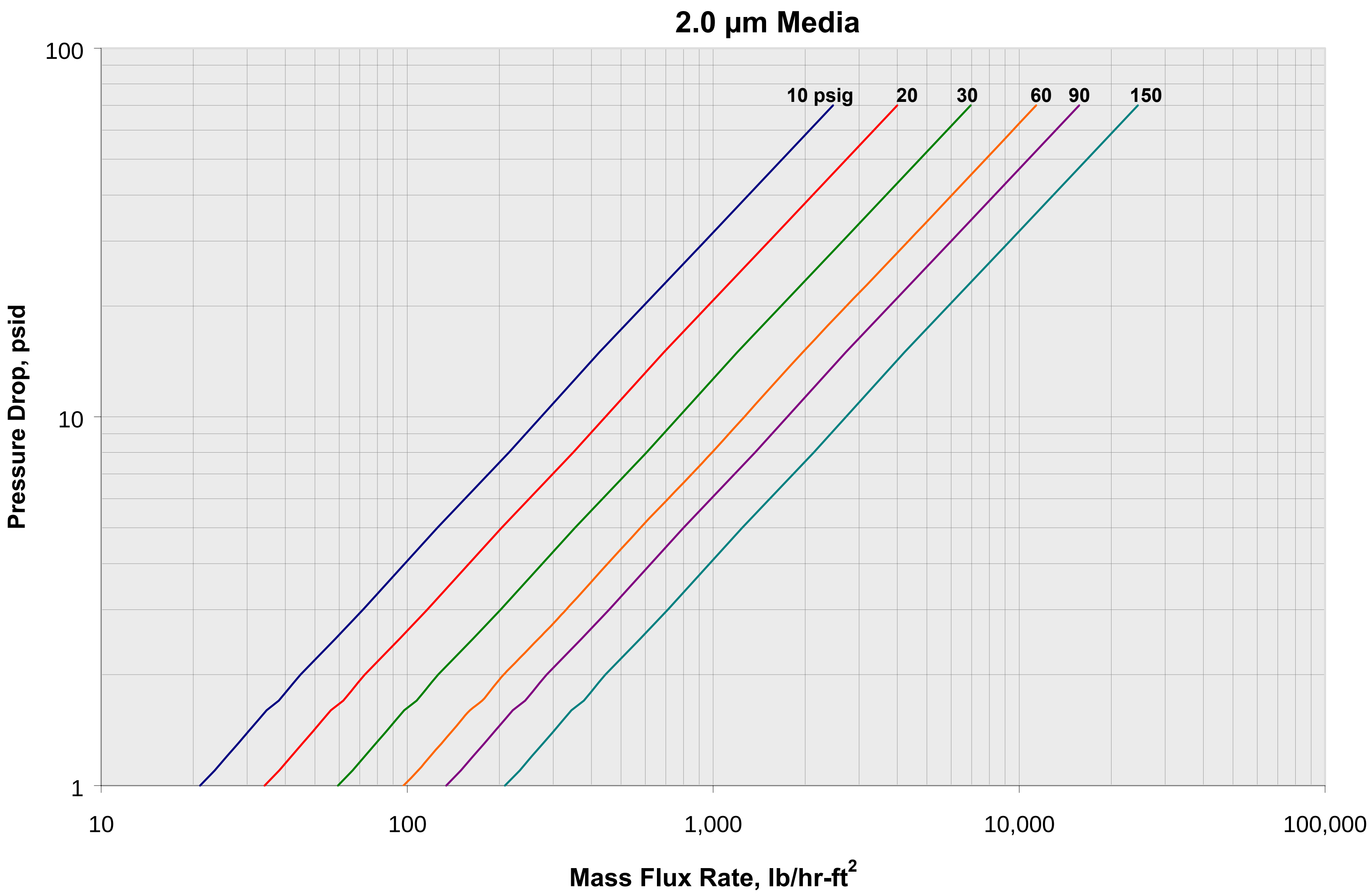


Figure 7: Media Pressure Drop by Steam Pressure

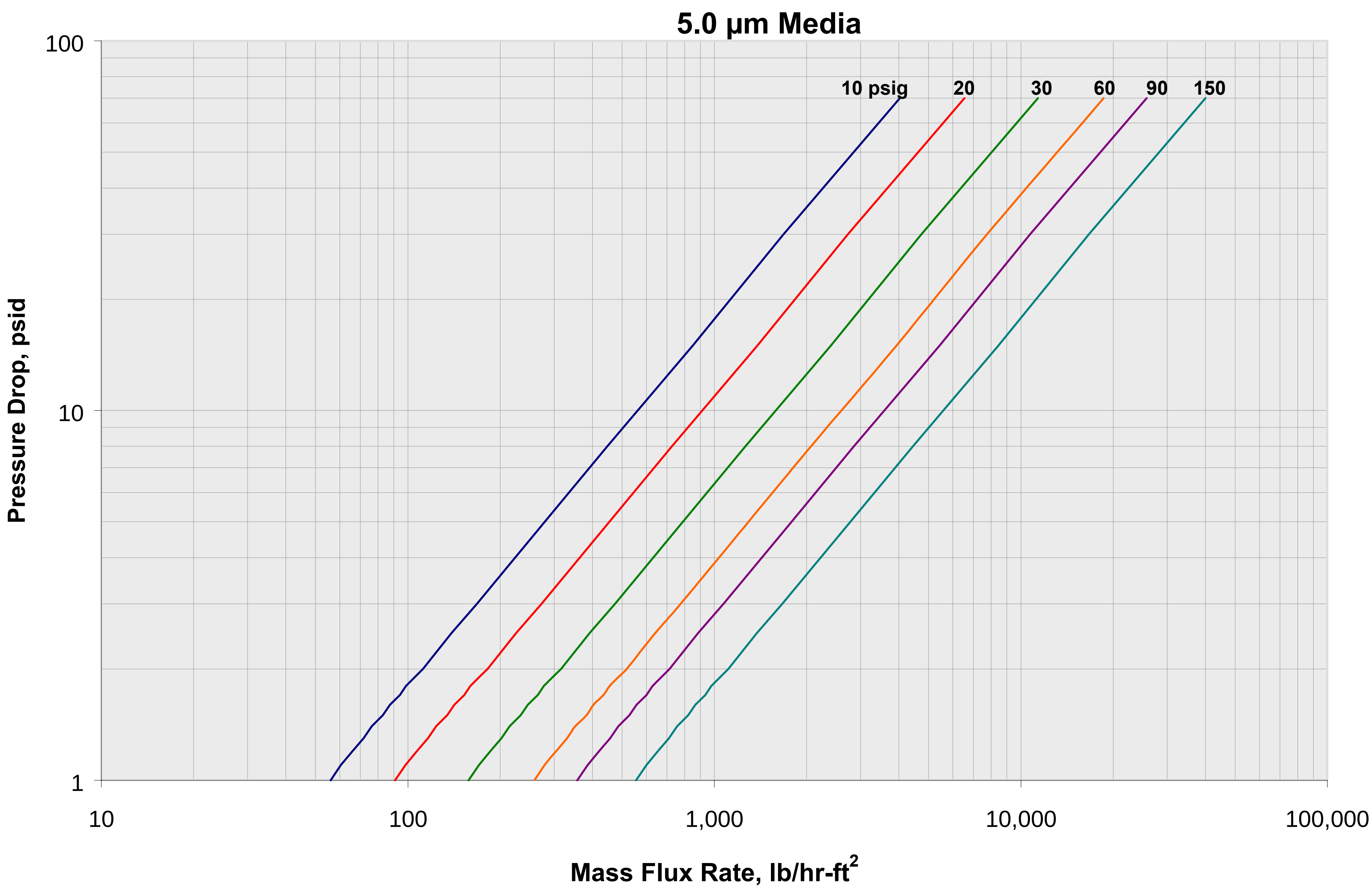


Figure 8: Media Pressure Drop by Steam Pressure

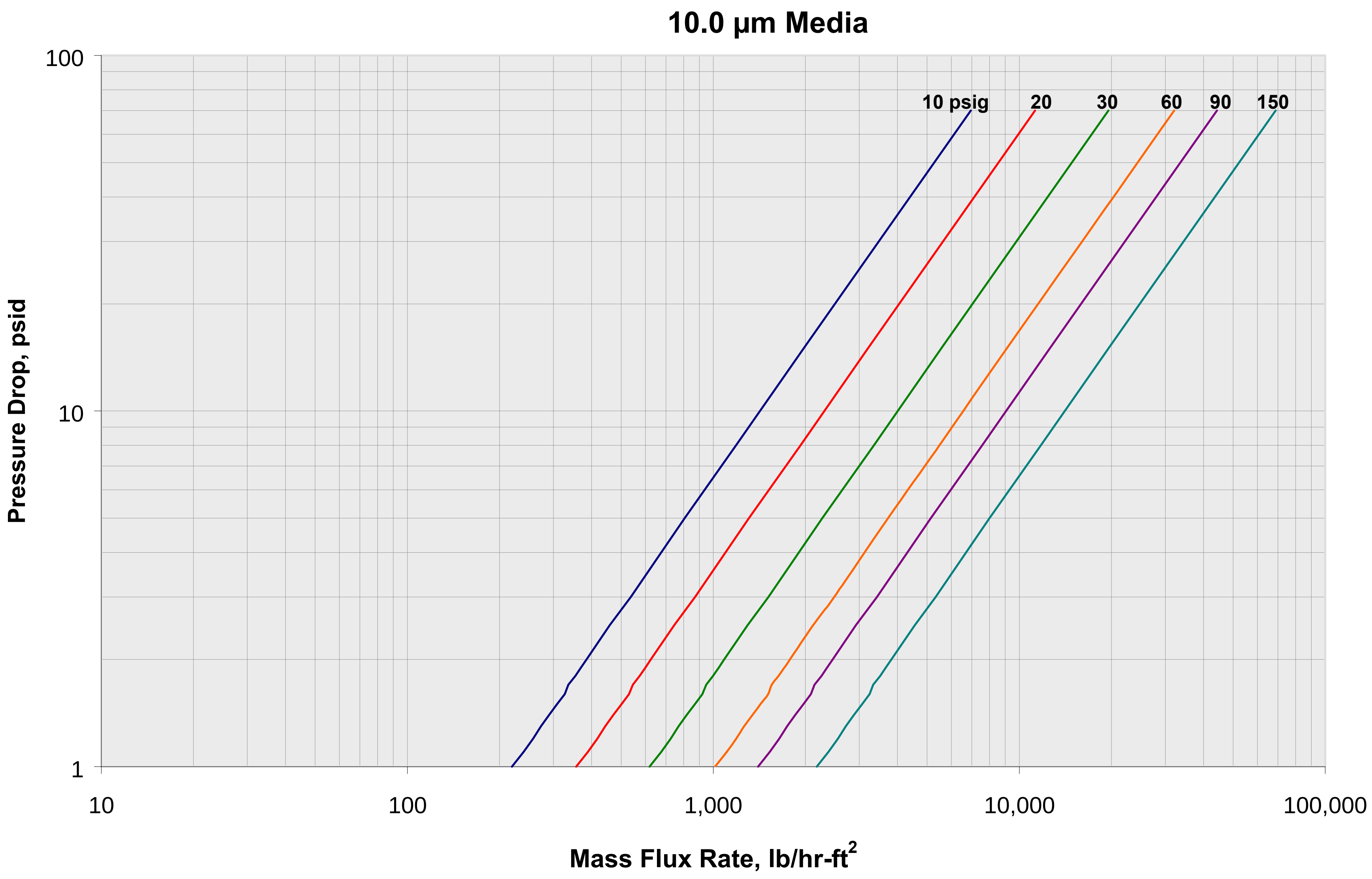


Figure 9: Media Pressure Drop by Steam Pressure

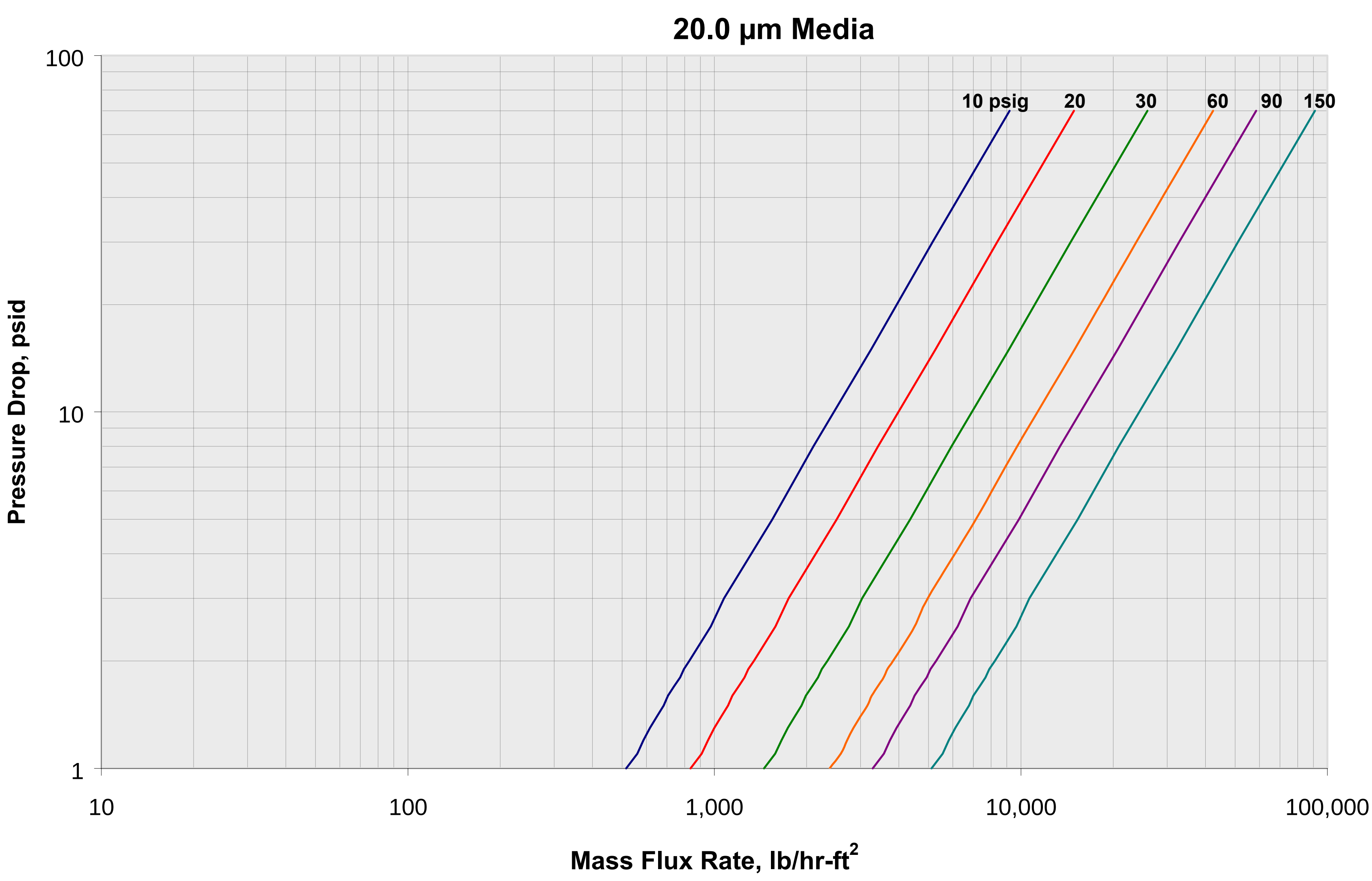
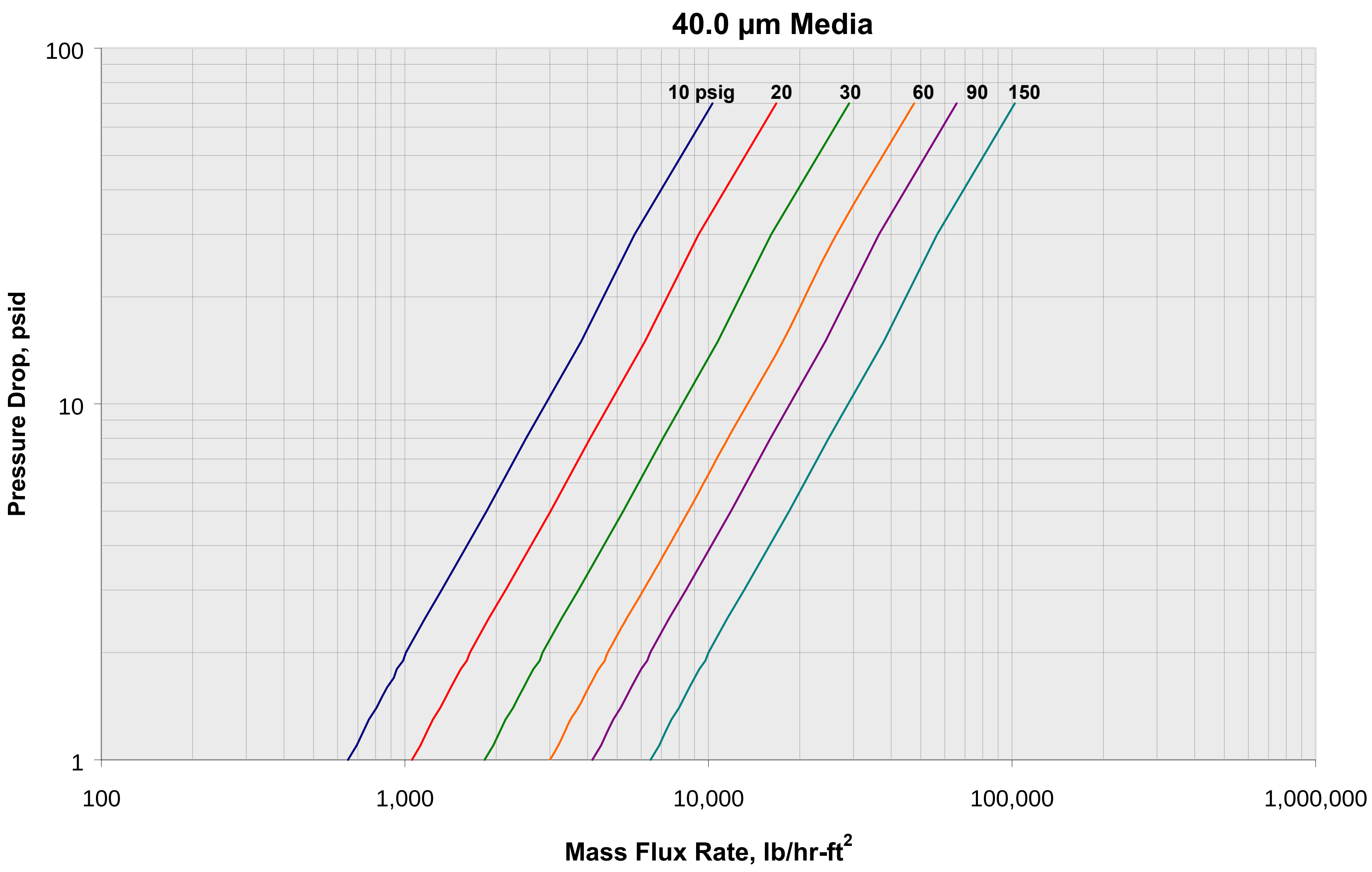


Figure 10: Media Pressure Drop by Steam Pressure



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STEAM SPARGING APPLICATION DATA SHEET

CUSTOMER		**DATE**	
ADDRESS			
CONTACT		**E-MAIL**	
PHONE		**FAX**	

PROCESS DESCRIPTION AND OBJECTIVES: Please complete the following (with details).						
LIQUID TYPE						
SPECIFIC GRAVITY		DENSITY	(LB /IN3)	SPECIFIC HEAT	BTU/LB DEG F	
INITIAL TEMP (T_1)	DEG F	FINAL TEMP (T_2)	DEG F			
STEAM PRESSURE	PSIG	STEAM TEMPERATURE	DEG F			

( ) IN-TANK SPARGING:			
TANK DIMENSIONS	FT		
LIQUID VOLUME	GAL		
HEATING TIME	HR		
LIQUID HEAD (HEIGHT)	FT		
HEAD SPACE:	FT		
VENTED			
PRESSURIZED AT	PSIG		
AGITATED		NOT AGITATED	
AGITATOR DIAMETER	FT		
AGITATOR SPEED	RPM		
MOUNTING REQUIREMENTS: SPECIFY			
ANSI FLANGE		SIZE	
SANITARY		SIZE	
NPT		SIZE	

( ) CONTINUOUS STEAM SPARGING:			
PIPE SIZE (IPS)	IN		
LIQ FLOW RATE	GPM		
STEAM FLOW RATE	CFM		
LIQ PRESSURE	PSIG		
MOUNTING REQUIREMENTS: SPECIFY			
ANSI FLANGE		SIZE	
SANITARY		SIZE	
NPT		SIZE	
REMARKS:			