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Pipe Size Calculation for Steam Supply

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***Abstract:** Pipe designers and engineers often encounter complex mathematical equations to determine the diameter required for adequate steam discharge capacity at specific flow velocities. This article aims to simplify the calculation of steam pipe sizes. The formulas and factors derived herein can be utilized for determining pipe diameters in steam applications. Ultimately, the findings provide engineers and designers with practical tools to enhance the reliability and efficiency of steam system.*
***Keywords:** Handy formula for Steam pipe size calculation, Pipe diameter calculation for steam supply, Pipe design for steam, Volumetric flow rate of steam, Steam Pipe dia calculation, Steam Flow velocity.*

I. INTRODUCTION

The effective design and sizing of steam pipes are critical for optimizing system performance and ensuring operational safety in industrial applications. This article presents a comprehensive methodology for calculating steam pipe sizes, considering factors such as steam pressure, flow rate, temperature, and the physical properties of steam. Our handy formula significantly streamlines the steam pipe sizing process, enabling designers to achieve accurate results in a fraction of the time required by conventional methods. Traditional calculations often involve complex equations and lengthy analyses, requiring frequent reference to steam tables and other resources, which can be cumbersome and time-consuming. By simplifying these calculations, our formula reduces the workload for engineers while maintaining accuracy,

II. STEAM PIPE SIZE CALCULATION

The continuity equation, expressed as Q=AV, is fundamental in fluid dynamics, illustrating the relationship between volumetric flow rate, cross-sectional area, and flow velocity. In this equation, Q represents the volumetric flow rate, A is the cross-sectional area of the pipe or channel, and V is the velocity of the fluid. Understanding this equation is crucial for engineers and designers when sizing pipes and ensuring efficient fluid transport in various applications.

A. *Key Parameters for Steam Pipe Sizing*

- *Steam Flow Rate:* The mass flow rate of steam, typically given in tons per hour (TPH) or kilograms per second (kg/s).
- *Steam Pressure:* Usually provided in bar (either gauge or absolute pressure).
- *Specific Volume:* The volume occupied by one kilogram of steam, which depends on the pressure and temperature of the steam. This is obtained from standard steam tables.
- *Steam Velocity:* The desired velocity of the steam through the pipe, generally recommended to be between 25 to 35 m/s for process steam systems to balance efficiency and safety.

B. *Derivation of formula for Steam Pipe Size Calculation*:

$$Q = AV$$

$$A = \frac{\pi}{4} D^2$$

$$Q = \frac{\pi}{4} D^2 V$$

$$D = \sqrt{\frac{4Q}{\pi V}} \quad \ldots\ldots\ldots\ldots\ldots (i)$$

Where:

D : Pipe diameter
V : Average velocity in the pipe
Q : Volumetric flow rate of Steam

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Generally, in the industry, the flow of steam is referred to and measured in TPH (tons per hour). Therefore, we first need to convert the flow of steam from TPH to m³/hr, transforming it into volumetric flow. For this conversion, we refer to the steam table to find the specific volume of steam at the selected pressure and temperature. In industrial applications, process steam is typically used at saturated temperatures or with a few degrees of superheat.

$$Q = TPH\left(\frac{1000}{3600}\right) v\, 10^9 \quad \text{. . . . . (ii)}$$

Where:

Q : Volumetric flow rate of Steam (mm^3/sec)

TPH : Steam flow rate (tons per hour)

v : Specific volume of steam at particular pressure and temperature (m^3/kg)

Note: When selecting the specific volume of steam from the steam table, it is important to consider that the pressure measured in the industry is "gauge pressure," while the pressure listed in the steam table is "absolute pressure." Ensure to convert gauge pressure to absolute pressure for accurate calculations. A small steam table is provided in this article (Table 2) for the reference.

By substituting the value of Q from equation (ii) into equation (i)

$$D = \sqrt{\frac{4 * TPH * 1000 * v * 10^9}{\pi * V * 3600 * 1000}} \quad \text{. . . . .} \ (iii)$$

Where:

D : Pipe diameter (mm)

V : Average velocity of steam in the pipe (m/sec)

The equation (iii) is the comprehensive formula which can be directly used to calculate the pipe diameter for steam pipeline. The value of following 3 variables.

a) TPH – The process steam flow / steam consumption in the industrial application in ton per hour.
b) v - Specific volume of steam at particular pressure and temperature (m^3/kg) from steam table.
c) V - The average velocity of steam in the pipe (m/sec) is generally considered to be between 25 and 35 m/sec for process steam applications.

C. Simplification of Calculation and Generation of Handy Formula

$$D = \sqrt{\frac{4 * TPH * 1000 * v * 10^9}{\pi * V * 3600 * 1000}} \quad \text{. . . . .} \ (iii)$$

$$D = \sqrt{TPH} \times \sqrt{\frac{4 * v * 10^9}{\pi * V * 3600}} \quad \text{. . . . .} \ (iv)$$

In the equation (iv), If the velocity is fixed then the value of $\left(\sqrt{\frac{4 * v * 10^9}{\pi * V * 3600}}\right)$ will be a constant "C2".

$$\boxed{\boldsymbol{D = \sqrt{TPH} \times C2}}$$

Where, C2 is the constant value at a fixed velocity of steam in pipeline. Let's call it DC factor for "Steam pipe size calculation".
The above formula provides a straightforward method for calculating pipe sizes based on a given flow rate of steam and its velocity of flow.

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D. DC factor for Steam Pipe Size Calculation

The values of DC factor at different velocity are given in Table 1 for Steam pipe size calculation.

TABLE 1
DC FACTOR AT DIFFERENT VELOCITY OF STEAM IN PIPE

PRESSURE barG	DC factor for Steam pipe size calculation 'C2'		
	at 25 m/sec velocity	at 30 m/sec velocity	at 35 m/sec velocity
3.0	80.23	73.77	68.31
3.5	76.51	69.85	64.67
4.0	72.82	66.48	61.55
4.5	69.54	63.48	58.78
5.0	66.74	60.93	56.41
5.5	64.26	58.66	54.31
6.0	62.13	56.72	52.51
6.5	60.05	54.82	50.75
7.0	58.26	53.18	49.24
7.5	56.66	51.72	47.88
8.0	55.14	50.34	46.60
8.5	53.71	49.03	45.39
9.0	52.38	47.81	44.27
10.0	50.03	45.67	42.28

E. How to use "Handy Formula":

1) To calculate the pipe diameter in millimeters, multiply the square root of the flow QQQ value in TPH (tons per hour) by the DC factor at the selected velocity from Table 1.
2) Please note that the calculated pipe size refers to the inner diameter of the pipe.

EXAMPLES - 1

Calculate the required pipe size for a steam flow rate of 50 TPH (tons per hour) at saturated temperature and 8 bar pressure, with a velocity of 25 m/s, using the formula Q = AV.

SOLUTION

Flow (TPH) - 50 TPH
Velocity V - 25 mps
Pressure - 8.0 bar (G)

Let's find the specific volume of steam at 8 bar gauge pressure, which is approximately 9 bar absolute pressure, from the steam table (Table 2).

Specific volume (v) - 0.215 m^3/kg

Put the above values in the equation (iii)

$$D = \sqrt{\frac{4 * TPH * 1000 * v * 10^9}{\pi * V * 3600 * 1000}}$$

$$D = \sqrt{\frac{4 * 50 * \cancel{1000} * 0.215 * 10^9}{\pi * 25 * 3600 * \cancel{1000}}}$$

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$$D = \sqrt{\frac{7 * 4 * 50 * 0.215 * 10^6}{22 * 25 * 3.6}}$$

$$D = 10^3 * \sqrt{\frac{301}{1980}}$$

$$D = 10^3 * 0.3898977$$

$$D = 389.89\, mm\ (inner\ diameter\ of\ pipe)$$

The next available pipe size in the market is 400 NB, Hence selected pipe size shall be 400 NB for the given parameter in the question.

EXAMPLES - 2

Calculate the required pipe size for the steam having parameter same as mentioned in the example – 1 by using "DC Factor" method / Handy formula.

SOLUTION

Flow (TPH) - 50 TPH
Velocity V - 25 mps
Pressure - 8.0 bar (G)
DC Factor for steam at 8 barG pressure and 25 m/sec velocity (C2) – 55.14

$D = \sqrt{TPH} \times C2$ . . . .(ii)

$D = \sqrt{50} \times 55.14$

$D = 389.89\, mm\ (inner\ diameter\ of\ pipe)$

Here, we can see that the calculation of Steam pipe size is very simple by using the DC factor.

EXAMPLES - 3

What will be the pipe size for the steam flow rate of 17 TPH at 6 barG pressure and at a velocity of 30 mps?

SOLUTION

Flow (TPH) - 170 TPH
Velocity V - 30 mps
Pressure - 6.0 bar (G)
DC Factor for steam at 6 barG pressure and 25 m/sec velocity (C2) – 56.72

$D = \sqrt{TPH} \times C2$ . . . .(ii)

$D = \sqrt{17} \times 56.72$

$D = 233.86\, mm\ (inner\ diameter\ of\ pipe)$

The next available pipe size in the market is 250 NB, Hence selected pipe size shall be 250 NB for the given parameter in the question.

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III.STEAM TABLE

TABLE 2

Absolute Pressure	Boiling Point	Specific Volume (steam)	Density (steam)	Specific Enthalpy of Liquid Water (sensible heat)		Specific Enthalpy of Steam (total heat)		Latent heat of Vaporization		Specific Heat
(bar)	*(^oC)*	*(m^3/kg)*	*(kg/m^3)*	*(kJ/kg)*	*(kcal/kg)*	*(kJ/kg)*	*(kcal/kg)*	*(kJ/kg)*	*(kcal/kg)*	*(kJ/kg K)*
0.02	17.51	67.006	0.015	73.45	17.54	2533.64	605.15	2460.19	587.61	1.8644
0.03	24.1	45.667	0.022	101	24.12	2545.64	608.02	2444.65	583.89	1.8694
0.04	28.98	34.802	0.029	121.41	29	2554.51	610.13	2433.1	581.14	1.8736
0.05	32.9	28.194	0.035	137.77	32.91	2561.59	611.83	2423.82	578.92	1.8774
0.06	36.18	23.741	0.042	151.5	36.19	2567.51	613.24	2416.01	577.05	1.8808
0.07	39.02	20.531	0.049	163.38	39.02	2572.62	614.46	2409.24	575.44	1.884
0.08	41.53	18.105	0.055	173.87	41.53	2577.11	615.53	2403.25	574.01	1.8871
0.09	43.79	16.204	0.062	183.28	43.78	2581.14	616.49	2397.85	572.72	1.8899
0.1	45.83	14.675	0.068	191.84	45.82	2584.78	617.36	2392.94	571.54	1.8927
0.2	60.09	7.65	0.131	251.46	60.06	2609.86	623.35	2358.4	563.3	1.9156
0.3	69.13	5.229	0.191	289.31	69.1	2625.43	627.07	2336.13	557.97	1.9343
0.4	75.89	3.993	0.25	317.65	75.87	2636.88	629.81	2319.23	553.94	1.9506
0.5	81.35	3.24	0.309	340.57	81.34	2645.99	631.98	2305.42	550.64	1.9654
0.6	85.95	2.732	0.366	359.93	85.97	2653.57	633.79	2293.64	547.83	1.979
0.7	89.96	2.365	0.423	376.77	89.99	2660.07	635.35	2283.3	545.36	1.9919
0.8	93.51	2.087	0.479	391.73	93.56	2665.77	636.71	2274.05	543.15	2.004
0.9	96.71	1.869	0.535	405.21	96.78	2670.85	637.92	2265.65	541.14	2.0156
1[1)]	99.63	1.694	0.59	417.51	99.72	2675.43	639.02	2257.92	539.3	2.0267
1.1	102.32	1.549	0.645	428.84	102.43	2679.61	640.01	2250.76	537.59	2.0373
1.2	104.81	1.428	0.7	439.36	104.94	2683.44	640.93	2244.08	535.99	2.0476
1.3	107.13	1.325	0.755	449.19	107.29	2686.98	641.77	2237.79	534.49	2.0576
1.4	109.32	1.236	0.809	458.42	109.49	2690.28	642.56	2231.86	533.07	2.0673
1.5	111.37	1.159	0.863	467.13	111.57	2693.36	643.3	2226.23	531.73	2.0768
1.6	113.32	1.091	0.916	475.38	113.54	2696.25	643.99	2220.87	530.45	2.086
1.7	115.17	1.031	0.97	483.22	115.42	2698.97	644.64	2215.75	529.22	2.095
1.8	116.93	0.977	1.023	490.7	117.2	2701.54	645.25	2210.84	528.05	2.1037
1.9	118.62	0.929	1.076	497.85	118.91	2703.98	645.83	2206.13	526.92	2.1124
2.0	120.23	0.885	1.129	504.71	120.55	2706.29	646.39	2201.59	525.84	2.1208
2.2	123.27	0.81	1.235	517.63	123.63	2710.6	647.42	2192.98	523.78	2.1372
2.4	126.09	0.746	1.34	529.64	126.5	2714.55	648.36	2184.91	521.86	2.1531
2.6	128.73	0.693	1.444	540.88	129.19	2718.17	649.22	2177.3	520.04	2.1685
2.8	131.2	0.646	1.548	551.45	131.71	2721.54	650.03	2170.08	518.32	2.1835

3.0	133.54	0.606	1.651	561.44	134.1	2724.66	650.77	2163.22	516.68	2.1981
3.5	138.87	0.524	1.908	584.28	139.55	2731.63	652.44	2147.35	512.89	2.2331
4.0	143.63	0.462	2.163	604.68	144.43	2737.63	653.87	2132.95	509.45	2.2664
4.5	147.92	0.414	2.417	623.17	148.84	2742.88	655.13	2119.71	506.29	2.2983
5.0	151.85	0.375	2.669	640.12	152.89	2747.54	656.24	2107.42	503.35	2.3289
5.5	155.47	0.342	2.92	655.81	156.64	2751.7	657.23	2095.9	500.6	2.3585
6.0	158.84	0.315	3.17	670.43	160.13	2755.46	658.13	2085.03	498	2.3873
6.5	161.99	0.292	3.419	684.14	163.4	2758.87	658.94	2074.73	495.54	2.4152
7.0	164.96	0.273	3.667	697.07	166.49	2761.98	659.69	2064.92	493.2	2.4424
7.5	167.76	0.255	3.915	709.3	169.41	2764.84	660.37	2055.53	490.96	2.469
8.0	170.42	0.24	4.162	720.94	172.19	2767.46	661	2046.53	488.8	2.4951
8.5	172.94	0.227	4.409	732.03	174.84	2769.89	661.58	2037.86	486.73	2.5206
9.0	175.36	0.215	4.655	742.64	177.38	2772.13	662.11	2029.49	484.74	2.5456
9.5	177.67	0.204	4.901	752.82	179.81	2774.22	662.61	2021.4	482.8	2.5702
10.0	179.88	0.194	5.147	762.6	182.14	2776.16	663.07	2013.56	480.93	2.5944
11.0	184.06	0.177	5.638	781.11	186.57	2779.66	663.91	1998.55	477.35	2.6418
12.0	187.96	0.163	6.127	798.42	190.7	2782.73	664.64	1984.31	473.94	2.6878
13.0	191.6	0.151	6.617	814.68	194.58	2785.42	665.29	1970.73	470.7	2.7327
14.0	195.04	0.141	7.106	830.05	198.26	2787.79	665.85	1957.73	467.6	2.7767
15.0	198.28	0.132	7.596	844.64	201.74	2789.88	666.35	1945.24	464.61	2.8197
16.0	201.37	0.124	8.085	858.54	205.06	2791.73	666.79	1933.19	461.74	2.862
17.0	204.3	0.117	8.575	871.82	208.23	2793.37	667.18	1921.55	458.95	2.9036
18.0	207.11	0.11	9.065	884.55	211.27	2794.81	667.53	1910.27	456.26	2.9445
19.0	209.79	0.105	9.556	896.78	214.19	2796.09	667.83	1899.31	453.64	2.9849
20.0	212.37	0.1	10.047	908.56	217.01	2797.21	668.1	1888.65	451.1	3.0248

IV. CONSIDERATIONS AND LIMITATIONS

When calculating the pipe size for steam systems, it is important to take into account the following precautions to ensure an optimal design

A. Avoid Excessive Steam Velocities

High steam velocities can cause erosion of the pipe's inner walls, leading to wear and tear over time. It can also result in noise and vibration in the system, leading to mechanical stress. Ensure that the selected velocity (typically 20 to 40 m/s) does not exceed the recommended limits for the system.

B. Account for Pressure Drop

In long pipelines, pressure drop due to friction can become significant. Smaller pipe diameters result in higher pressure drops. Always calculate the expected pressure drop across the length of the pipeline to ensure that the pressure at the end point is adequate for the application.

C. Allow for Pipe Expansion

Steam pipes expand due to heat, especially when dealing with high-pressure steam. Consider using expansion joints or flexible connectors to accommodate the thermal expansion and prevent damage to the system.

D. Standard Pipe Sizes

Ensure that the calculated pipe diameter corresponds to commercially available standard sizes. Piping standards such as ASME B31.1 or API standards should be consulted to select the appropriate pipe size.

E. Safety Margins

It's a good practice to select a slightly larger pipe size than the calculated value to accommodate future expansion of the system or unforeseen variations in steam flow demand. This helps prevent overloading the system in the long run.

F. Consider Steam Traps and Condensate Return

In systems where saturated steam is used, condensation will occur, and steam traps will be required to remove the condensate. The pipe sizing should consider the installation of steam traps and ensure that condensate does not collect in the pipe, which could lead to water hammer.

G. Ensure Proper Insulation

Steam pipes must be properly insulated to prevent heat loss and maintain the efficiency of the system. The insulation also reduces the risk of accidental burns and minimizes thermal stress on the piping system.

V. CONCLUSIONS

The DC factor is a multiplying factor at a particular velocity of Steam to calculate the pipe diameter by multiplying it with the square root of mass flow (TPH). By using the DC factor, the calculation becomes very easy to calculate the Steam pipe size.

VI. GLOSSARY

TPH	:	Tons per hour
mps	:	Meter per sec
C2	:	Dinesh Chauhan's factor (DC factor) for steam pipe size calculation

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