Insight into process steam issues

Gary Sowerby Eur.Ing. C.Eng. M.E.I., who runs JGS Associates and is the author of the *Process Steam Guide*, provides an in-depth analysis of steam distribution system problems and solutions.

Providing assistance to engineers faced with steam process problems was the simple philosophy that started a small company, JGS Associates, some five years ago, giving on-site lectures covering process steam applications and associated equipment.

During the last five years, various steam training sessions have been carried out at the request of senior engineering managers responsible for hospitals and staff operating essential and important process steam plant installations.

Created from particulars of many hospital managers' needs, various technical steam topics and on-site lectures, and from my own experiences over some 38 years, has been the published *Process Steam Guide*.

To attempt to adequately outline, or indeed comment, on all the technical subjects covered in the index of this 80-page guide is not possible in this article.

However, if I was asked to choose a typical technical example from one of the prepared steam training lectures, it would be "The Design of a Steam Distribution Layout with Associated Equipment". This was actually carried out at the request of Nigel Phillips, General Manager (Estate Maintenance) at the United Bristol Healthcare NHS Trust, to a group of his senior managers and engineers.

This lecture basically goes through a worked example for sizing a steam distribution main from a boiler rated at 5,444 kg/h operating at 10 bar g steam pressure. From four given plant room steam loads, the respective branch line sizes are then calculated.

Going through this "step by step" exercise, attention is made to the importance of the following:

1 Particular consideration given to selecting steam working pressure required at point of use and checking effect of pressure drop over length of pipe due to resistance of flow.
2 Checking through the sizing of steam supply lines using methods of velocity and pressure drop.
3 General layout of steam main and respective branch supply lines to plant rooms. Condensate drainage. Avoiding the risks of waterhammer. General safety awareness.
4 Calculation of pipe expansion and its support for the distribution steam system.
5 Importance of steam quality. Achieving adequate air venting of steam plant. Minimising the risks of corrosion.
6 Reducing heat losses and importance of good quality lagging.
7 Reasons for pressure reduction. From an insurance point of view, could there be a need for considering selective reducing valves and the utilisation of separators to improve steam quality?

> Considerable sums of money can be spent on generating and using steam efficiently – but there is a danger capital can be wasted

1 Selecting steam working pressure

Considerable sums of money can be spent on generating and using steam efficiently, but, by the same token, all this capital can be wasted unless the steam distribution system is up to its job of conveying the correct amount of steam so that it also reaches the associated plant rooms at the right pressure, reasonably dry and free from air.

The duty of the engineer then, is not so much to generate steam at a certain pressure in the boiler, but to deliver steam to the steam user at the right pressure.

The right pressure at which the steam is to be distributed is determined by the point of use on the process or heating plant needing the highest pressure. From these comments, it is essential to calculate and size the right pipe for the amount of steam it has to carry. If the pipe is too small, then high pressure drop and steam starvation at the user end will happen. There is also greater risk of erosion, waterhammer and noise due to increase in steam velocity.

On the other hand, if the pipe is too large for the steam load, while this may not be detrimental to the operation of the plant, the capital cost of the steam distribution system will be unnecessarily high.

2 Sizing of steam supply lines

When selecting the correct pipe size, the following must be known:

i) Amount of steam to be handled.
ii) Steam working pressure.
iii) Acceptable pressure drop along distribution pipe length.
iv) Steam pressure required at point of usage.

Knowing this information, we can then set about sizing the steam distribution pipework, using the two methods, both of which have an unknown factor which must be assumed:

i) Velocity.
ii) Pressure drop.

If pipework is sized on the basis of velocity, then calculations are based on the volume of steam being carried in relation to the cross sectional area of the pipe.

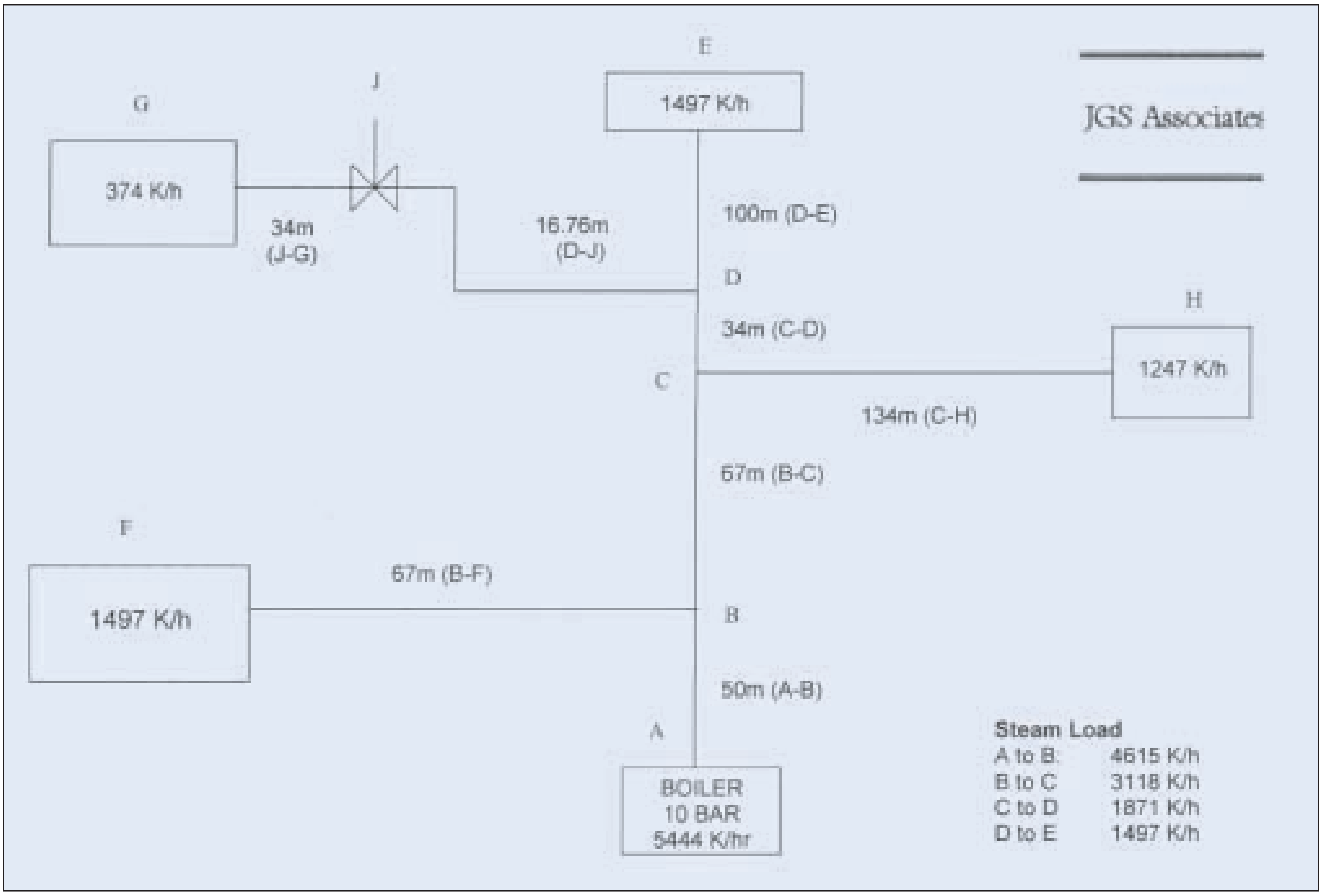


Figure 1: Basic layout drawing showing capacities (kg) and distances (m).

From my own experience, handed down over the years, reasonable velocities for saturated steam are between 15 and 40 metres/second. As an average figure, I have always worked on 25 m/s.

However, it must be stressed that even these figures can be high in terms of their effect on pressure drop. In longer steam distribution lines, with distances over 50 metres, it may be wise to restrict velocities to 15 m/s if high pressure drops are to be avoided. This can be so when distributing the steam at much lower operating pressures.

By using recognised saturated steam pipeline capacity charts, it is possible to select pipe sizes from the steam pressure and flow rate using the velocity and pressure drop methods.

Before focusing on these two methods of sizing the steam distribution lines, considered can be Figure 1. This is a Basic layout drawing with capacities (kg) and distances (m). Shown is a steam boiler rated 5,444 kg/h operating at 10 bar g steam pressure – reference A. From A, the layout shows four plant rooms – F, H, G and E and the distribution pipework.

To simplify the distance (metres) and steam loads (kg/h) in all the figures, I have already calculated a conservative allowance of 10% for fittings in all quoted linear distances and 10% for emission losses for each of the stated steam loads. I say conservative, since in other cases you could argue to use a much higher percentage allowance. Also in all cases steam pressure is in bar g.

From the layout, the longest straight length of main is A to E.

In most cases, any steam plant is designed for use at a given pressure which therefore determines the designed pressure at the plant, at E.

Assuming pressure at E is not known, let us say for this steam main exercise that the pressure must be no less than 9.25 bar g – an allowable pressure drop of 0.75 bar.

Therefore, adding the total distances of A to B (50 m), B to C (67 m), C to D (34 m) and D to E (100 m), the steam main A to E equals 251 m with a total load of 4,615 kg/h.

The author would like to stress, at the start of this exercise of calculating pressure drop and velocity with regard to the distance and amount of steam to be passed down each section of pipe, that the modern method employed worldwide is now in the use of dedicated computer software.

By utilising the electronic method, not only can the engineer simply type in the relevant technical data, but within seconds the screen will show all the recommended pipe sizing, very accurate readings for the pressure drop and velocity figures. Plus there can be a full print out.

Therefore, in this instance, I will only list out the computerised figures for each section of the distribution main and branch lines.

Before going through this information, however, I will, for the interest of the reader, just quickly run through just one manual exercise using Figure 2 (steam pipeline sizing chart – pressure drop) and Figure 3 (steam pipeline sizing chart – velocity).

I would like to emphasise that although one can achieve a good read out from these two charts, these figures cannot compare with the accuracy and automatic print out from the relevant computer software programs.

With reference to Figure 2 (steam pipeline sizing chart – pressure drop), taking steam load 4,615 kg/h at 10 bar g saturated steam, running a horizontal line from the saturation temperature curve where it intersects on sloping line 4,615 kg/h, draw a vertical line to 125 mm pipe size which at its intersection would show a horizontal line to the left – a pressure drop of 0.18 bar per 100 metres.

Taking the steam main A to B, 50 metres would calculate to give a total pressure drop of 0.18 x .50 m which equals 0.09 bar.

Since 125 mm, in engineering circles,

It is essential to calculate and size the right pipe for the amount of steam it has to carry

is known as a “bastard” size, we would, in all probability, go for a 150 mm pipe. However, for the purpose of this exercise, let us stay with 125 mm.

With reference to Figure 3 (steam pipeline sizing chart – velocity), running a horizontal line from the right hand saturation temperature curve to intersection of sloping line at 4,615 kg/h, draw a vertical line until it intersects with horizontal line which shows 125 mm and a velocity of approximately 19 m/s, which is erring on the right side of my ideal of 25 m/s.

If we did choose to go for the 150 mm pipe, then as well as reducing the pressure drop below 0.18 bar per 100 metres, we would also further reduce the velocity.

Having reached reference B, the steam main continues with a steam load (minus 1,497 kg/h) of 3,118 kg/h.

Having gone through the first section of pipe sizing for A to B, I can now proceed with the more accurate readings of pressure drop and velocity taken from a universally used computer software steam sizing programme for the complete distribution system and branch lines – Figure 4 (final layout drawing showing recommended pipeline sizes, pressure drops and velocities).

Finally, we come to the last branch supply line serving plant room G via a yet to be sized steam reducing valve which we will come to shortly.

Dealing with the upstream supply line, the steam load is 374 kg/h with steam pressure 9.83 bar g at point D.

From the computer software and short distance of 16.76 metres, the pressure drop would be quite small (.05 bar). However, checking on velocity, a 40 mm pipe would handle this amount giving a velocity of 14.2 m/s.

Having reached the position of the reducing valve, let us assume, for the purpose of this exercise, the steam supply is then having to be reduced to 2 bar g steam pressure serving a typical plate heat exchanger in plant room G.

Therefore, from the software, with the 374 kg/h steam load at 2.0 bar g, steam pressure over a distance of 34 metres, a 65 mm pipe would give a pressure drop of 0.04 bar and a velocity of 20.3 m/s.

However, the advantage of using a reducing valve would simply mean adjusting up slightly the setting of the valve to compensate for this small

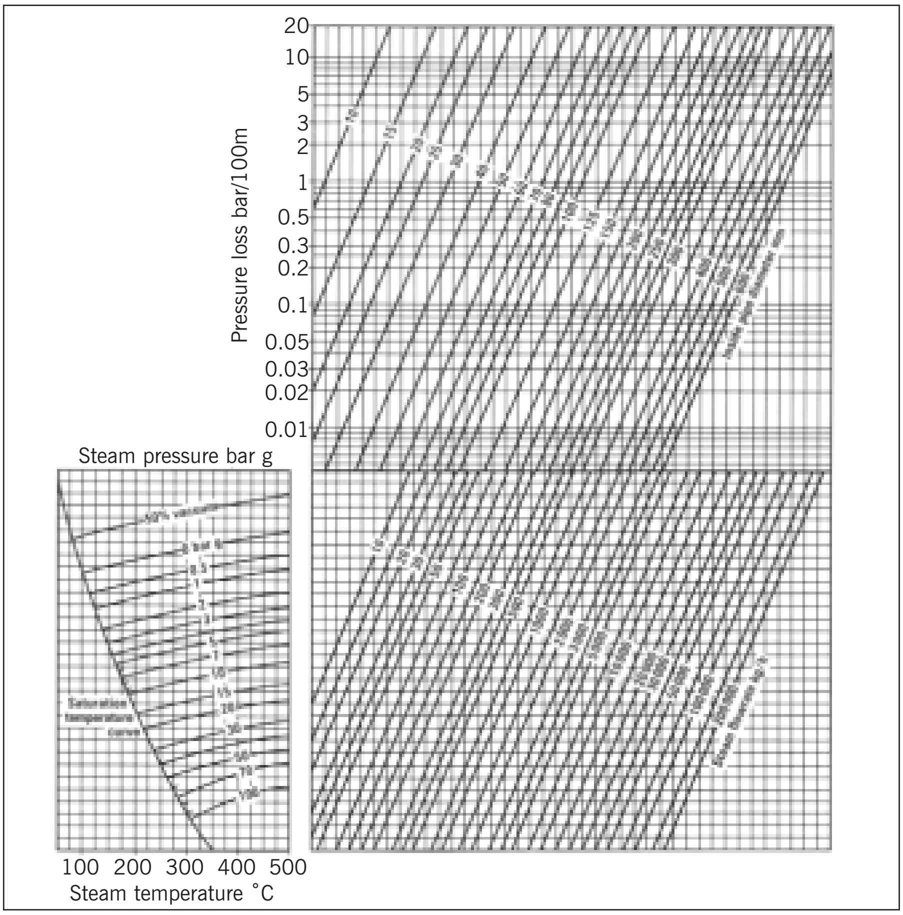


Figure 2: Steam Pipeline Sizing Chart – pressure drop.

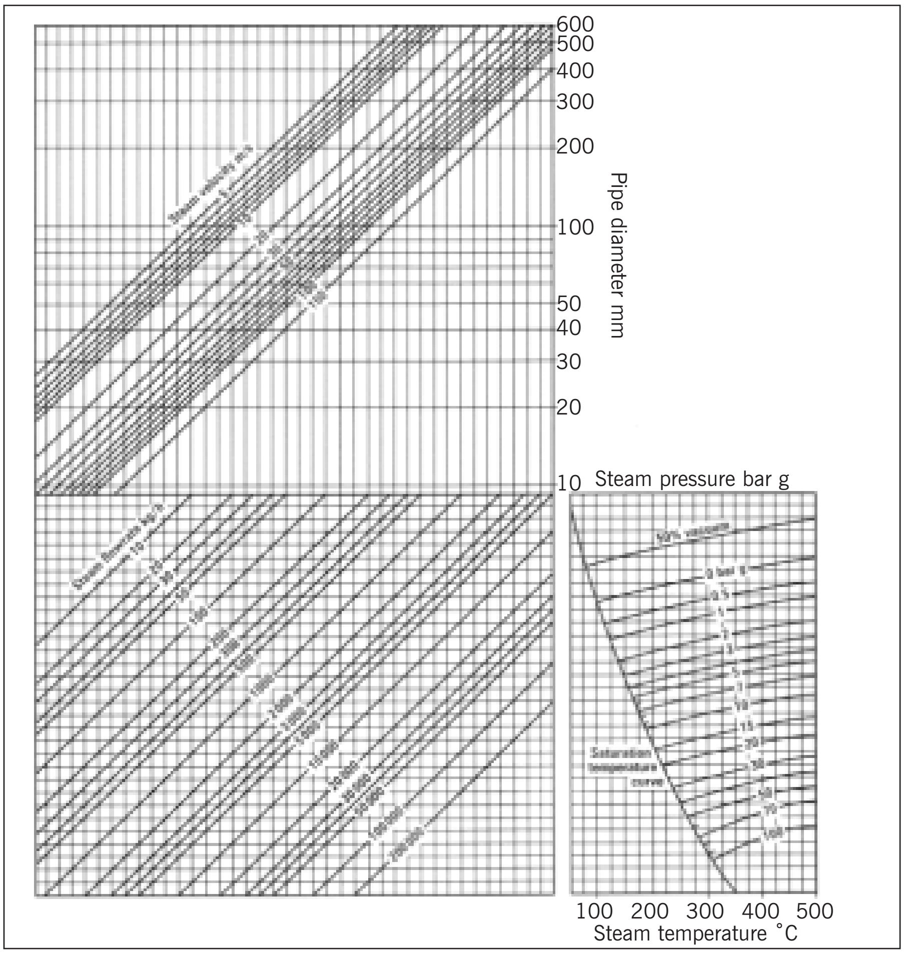


Figure 3: Steam Pipeline Sizing Chart – velocity.

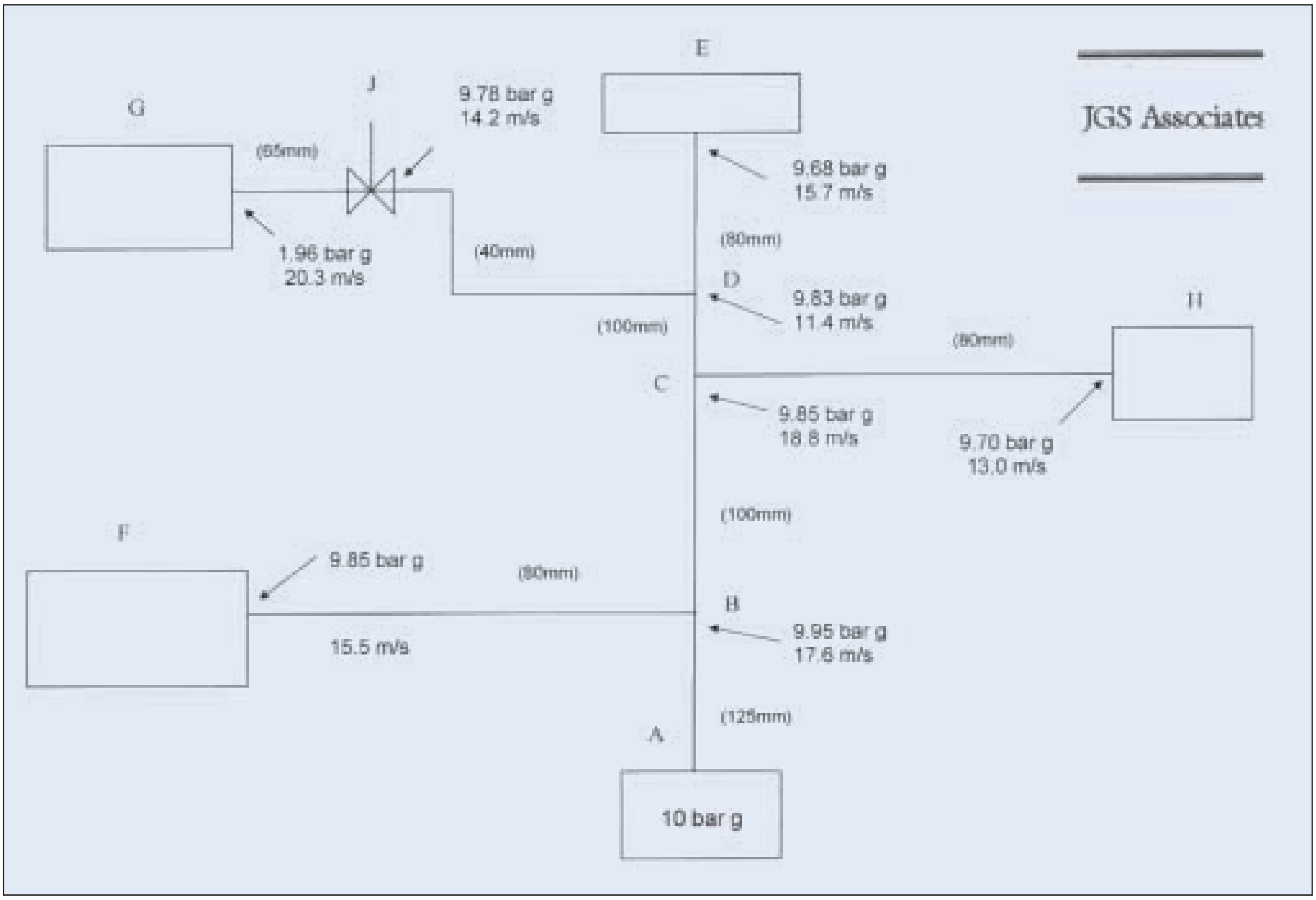


Figure 4: Final layout drawing showing pipeline sizes, pressure drops and velocities.

pressure drop. From the manufacturer of pilot operated steam reducing valves, in practice, one would be installing at least a 32 mm or indeed a 25 mm size unit for this duty.

In summing up this important Section 2 (sizing of steam supply lines) I hope I have adequately shown the importance of adding into the capacity and linear distance figures the emission losses factor and fittings factor, also the significance of checking the effect of pressure drop and velocity.

All of Section 2 concentrated on the four given steam plant room loads from a boiler rated at 5,444 kg/h operating at 10 bar g steam pressure.

For reasons of future steam demand, one could argue into the logic of increasing up the size of the steam main, based on the boiler's output or further upgrading of the plant in general.

From my own experience it has always advisable, within reasonable levels, to consider sizing up the steam main for future steam demand.

3 General layout of steam main and branch supply lines

In any steam main, some of the steam will be condensed by radiation loss.

For example, a 100 mm line, well lagged and 30 metres long carrying steam at 7.0 bar g and with surrounding air at 10°C will condense approximately 16 kg/h of steam.

This is probably less than 1% of the carrying capacity of the steam main. Nevertheless, it means that at the end of one hour, the steam main would contain not only steam but 16 litres of water, and at the end of, let us say, two hours, 32 litres of water.

So it is essential that some provision must be made to remove this build up of water.

Whenever possible, the steam main should be run with a fall of not less than 12 mm in 3 metres in the direction of steam flow. Always avoid the desire to run steam mains uphill.

By allowing the steam main to fall in the direction of flow, both steam and condensate are running in the same direction and drain points can be formed in the line to collect and remove condensate. Such drain points, or dirt pockets, should be formed on average at intervals of 30 – 50 metres along the length of the steam main, and any low point on the steam main, for example a riser or dropper, should of course be similarly drained. It must be stressed that the correct formation of a drain point is very important.

Taking the exercise of sizing the long steam main for boiler A to E, in general terms over this distance one would be considering a minimum of six drain traps at regular intervals along this 251 m length.

A common fault for drainage is to weld a 15 mm or 20 mm stub into a large bore steam main. This is absolutely useless, as only a very small proportion of the condensate can find its way to the small orifice of the outlet.

Adequate drainage can only be given if large bore drain pockets are provided. The ideal is to have a pocket of equal diameter to the steam main, but whereas it is practical to use an equal tee on a steam main up to say 100 mm bore, it is permissible on the grounds of economy to use the following suggested sizes:-

Steam mains diameter	Drain/dirt pocket
Up to 100 mm	Bore same as steam main. Depth at least 100 mm.
125, 150 and 200 mm	Bore 100 mm. Depth at least 150 mm.
250 mm and above	Bore half that of steam main. Depth at least diameter of steam main.

From a practical point of view, the drain line off-take should be at least 25/30 mm

Nominal pipe size (mm) Steel/Copper		Interval of horizontal run metres		Interval of vertical run metres	
Bore	Outside dia.	Mild steel	Copper	Mild steel	Copper
12	15		1.0		1.2
15	18	2.0	1.2	2.4	1.4
20	22	2.4	1.4	3.0	1.7
25	28	2.7	1.7	3.0	2.0
32	35	2.7	1.7	3.0	2.4
40	42	3.0	2.0	3.6	2.4
50	54	3.4	2.0	4.1	2.4
65	67	3.7	2.0	4.4	2.9
80	76	3.7	2.4	4.4	3.2
100	108	4.1	2.7	4.9	3.6
125	133	4.4	3.0	5.3	4.1
150	159	4.8	3.4	5.7	
200	214	5.1		6.0	
250	267	5.8		5.9	

Figure 5: Recommended support for pipework

from the bottom of the pocket for steam mains up to 100 mm, and roughly a third to the centre of the pocket for larger steam mains, allowing a space below for any dirt and pipe scale to settle. From my own experience, I also like to see fitted a removable flange, plug or blow-down valve for cleaning purposes.

Waterhammer and its effects

Waterhammer may occur when condensate is pushed along a pipe by the steam instead of being drained away at the low points, and is suddenly stopped by impacting on an obstacle in the system.

When obstructed, perhaps by a bend or tee in the pipe, the kinetic energy of the water is converted into pressure energy and a pressure shock is applied to the obstruction.

Commonly there is a banging noise and possible movement of the pipe. In severe cases, the fittings may fracture with almost explosive effect and consequent loss of live steam at the fracture providing a hazardous situation.

Fortunately, waterhammer may be avoided if steps are taken to ensure that the condensate in the pipework is not allowed to collect along the pipework.

Avoiding waterhammer is a better alternative than attempting to contain it by choice of materials and pressure ratings of equipment.

Common sources of waterhammer trouble occur at the low points in the pipework. For example:

1 Sags in the line.
2 Incorrect use of concentric reducers and strainers. For this reason it is better to fit strainers on their sides in steam lines.
3 Inadequate drainage of steam lines.

In conclusion, to minimise the possibility of waterhammer:

1 Steam lines should be arranged *with a gradual fall* in the direction of flow, with drain points installed at regular intervals and at low points.
2 Check valves are *always fitted after* steam traps, which would otherwise allow condensate to run back into the steam line or plant during shut-down.
3 Isolation valves should be *opened slowly* to allow any condensate which may be lying in the system to flow gently towards, and through, the steam traps before it is picked up by the high velocity steam. This is especially important at start-up, particularly when steam plant has been shut down for routine repair/maintenance work.

Branch lines

It is important to remember that steam branch lines are generally much shorter in length than the steam mains.

Sizing branches on the basis of a given pressure drop is accordingly less important on shorter lengths of pipe. With a steam main several hundred metres long, a pressure drop limitation

> Steam lines should be arranged with a gradual fall in the direction of flow

of say 0.5 bar may be perfectly valid, even though one could have lower velocities than otherwise expected. In a typical branch line of 5 or 10 metres, the same velocity could lead to values of only 0.01 or 0.02 bar.

Clearly these pressure drops are insignificant and for branch lines of 5 or 10 metres, from my own experience, it is acceptable to work on a velocity figure of 25 m/s. However, as I mentioned earlier, in Section 2, with over 50 metres, then it is always prudent to firstly check the value of pressure drop followed by the velocity.

Having said that, it should be stressed that a large accumulative pressure drop can be created if the branch pipeline contains several fittings like high limit controls, strainers, connections and elbows.

In cases like this, it would be wise to restrict velocities below 15 m/s unless the pressure drop is also calculated.

The "golden rule" with branch lines, is always ensure they are taken off the top of the steam main. On branch line drop legs serving plant at a lower level after the steam main, also install a drain point with a proper steam trap set.

Mains drainage method

The use of steam traps is the most efficient method of draining condensate from a steam distribution system.

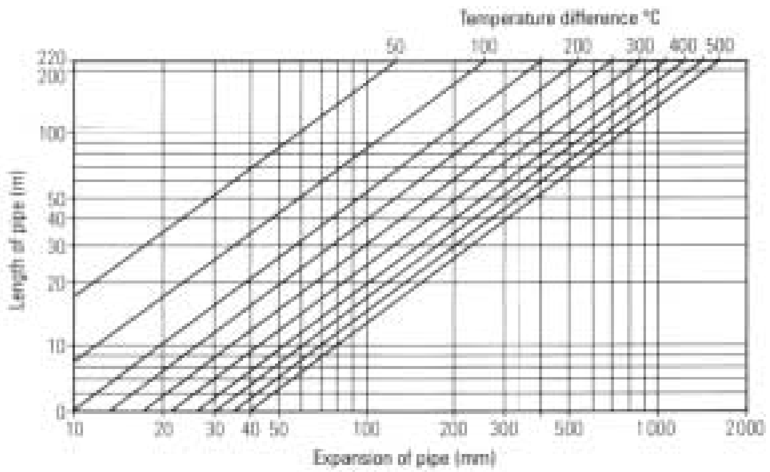
Steam traps cover several types and variable process and heating applications. Because of this they merit a separate subject and presentation in their own right. However, in the interests of this article covering steam distribution, I would simply add the following important considerations:

1 The steam trap should discharge at, or very close to, saturation temperature, unless long cooling legs are used between the drain point and steam trap. This normally means choosing between mechanical steam traps, like float and inverted bucket, or thermodynamic.
2 With outside steam mains and the possibility of frost damage, the thermodynamic steam trap is the best choice. These traps can be thawed out without suffering any damage.
3 Historically, on poorly laid out installations, where there could be the risk of waterhammer, float traps may not be the ideal due to their susceptibility to float damage.

Table 1 Expansion Co-efficients

Material	Temperature range (°C) <0	0 – 100	0 – 200	0 – 300	0 – 400	0 – 500	0 – 600	0 – 700
Carbon steel 0.1% – 0.2% C	12.8	13.9	14.9	15.8	16.6	17.3	17.9	–
Alloy steel 1% Cr 0.5% Mo	13.7	14.5	15.2	15.8	16.4	17.0	17.6	–
Stainless steel 18% Cr 8% Ni	9.4	20.0	20.9	21.2	21.8	22.3	22.7	23.0

Expansion in various steel pipe lengths at various temperature differences



A chart showing the expansion in various steel pipe lenghts at various temperature differences

Temperature of saturated steam

bar g	1	2	3	4	5	7.5	10	15	20	25	30
°C	120	134	144	152	159	173	184	201	215	226	236

However, for general process heating applications, where a steam trap is needed to handle high condensate capacities, discharge air on start-up and handle instantaneous loads, the mechanical float trap is the first choice followed by the second choice bucket steam trap.

4 Thermodynamic steam traps are suitable for draining steam mains whether long runs of large diameter pipe down to general drain legs or dirt pockets on steam branches.

To summarise, general layout and steam mains drainage means observing a few simple rules:

1 Steam lines should be installed to fall in the direction of flow at not less than 12 mm per 3 metres of pipe.
2 Steam mains should be drained at regular intervals of 30 – 50 metres and at any low points in the system including droppers and risers.
3 Where drainage has to be provided in straight lengths of pipe, then a large bore pocket (dirt pocket) should be used to properly collect condensate.
4 When strainers are installed, make sure they are fitted on their side and not downwards.
5 Branch connections must always be taken from the top of the main so that the driest steam is taken off.
6 Steam traps should always be selected for the correct application. In cases where there can be the risk of waterhammer, always select a robust steam trap for the job.
7 Terminal end arrangements should have a steam trap together with an automatic air vent with a by-pass. Typical position is at ‘E’ on Figure 1 (basic layout drawing).

4 Pipe expansion and its support

All pipes will be installed at ambient temperature. Pipes carrying hot water or steam operate at higher temperatures. It therefore follows that they will expand especially in length, with an increase from ambient to working temperature. This may cause stresses on certain areas within the distribution system, such as a pipe joint, which could be fractured. The amount of expansion can be readily calculated using the following equation or read from various published charts:

Expansion = L x <Σ x } (mm)

L = Length of pipe between anchors (m)
<Σ = Temperature difference between ambient temperature and operating temperature °C
} = Expansion coefficient (mm/m°C) x 10^{-3}

Expansion coefficients (})(mm/m°C) x 10^{-3}) See Table 1.

Example: Calculate the expansion of 30 metres of carbon steel pipe from ambient (10°C) to 152°C (steam at 4.0 bar):

L = 30 metres
<Σ = 152°C – 10°C = 142°C
} = 14.9 x 10^{-3}mm in the range of 0-200°C for carbon steel pipe

Expansion = 30 x 142 x 14.9 x 10^{-3}mm
Expansion = 63.5 mm

Alternatively, the amount of pipe expansion can be determined by using the wide range of technical charts readily available from several well-known engineering associations. One very useful type of chart I use for finding the approximate expansion of a variety of steel pipe lengths is shown on this page.

Example: Find the approximate expansion from 15°C of 100 metres of carbon steel pipework used to distribute steam at 265°C.
Temperature difference is 265 – 15°C = 250°C.

Where the diagonal temperature difference line of 250°C cuts the horizontal pipe length line at 100 m, drop a vertical line down.

For this example an approximate expansion of 330 mm is indicated.

The pipework must be sufficiently flexible to accommodate the movements of the components it has to heat up.

In most layouts of small bore steam mains of short length and plenty of bends, there are sufficient movements in the fittings to allow for expansion. In much larger mains, and whenever there are long runs of steam pipe, some provision must be made for expansion.

Sometimes this is done by stressing the main when cooled – “cold draw” as it is known.

The amount of movement to be taken up by the piping and any device incorporated in it can be reduced by “cold draw”. The total amount of expansion is first calculated for each section between fixed anchor points. The pipes are left short by half of this amount, and stretched cold by pulling up bolts at a flanged joint, so that at ambient temperature, the system is stressed in one direction. When warmed through half

Temperature Difference Steam to Air °C	PIPE SIZES									
	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	100mm	150mm
	W/m									
56	54	65	79	103	108	132	155	188	233	324
67	68	82	100	122	136	168	198	236	296	410
78	83	100	122	149	166	203	241	298	360	500
89	99	120	146	179	205	246	289	346	434	601
100	116	140	169	208	234	285	337	400	501	696
111	134	164	198	241	271	334	392	469	598	816
125	159	191	233	285	321	394	464	555	698	962
139	184	224	272	333	373	458	540	622	815	1133
153	210	255	312	382	429	528	623	747	939	1305
167	241	292	357	437	489	602	713	838	1093	1492
180	274	329	408	494	556	676	808	959	1190	1660
194	309	372	461	566	634	758	909	1080	1303	1852

Note: Heat emission from bare horizontal pipes with ambient temperatures between 10°C and 21°C and still air conditions.

Figure 6: Typical Heat Emission Chart

of the total temperature rise, the piping is unstressed. At working temperature and having fully expanded, the piping is stressed in the opposite direction.

Some of the popular types of expansion components are listed as follows:

Full loop

This is simply one complete turn of pipe and should preferably be fitted in a horizontal rather than vertical position to prevent condensate build-up.

Great care must be taken not to fit these loops the wrong way round, as indeed when ordering, otherwise wrong handed loops may be supplied.

This design is rarely used today due to space taken up by pipework. However, large steam users such as power stations still tend to use them.

Horse shoe or lyre loop

When space is available, this type is sometimes used, best fitted horizontally so that the loop and main are on the same plane. If, for some reason, the loop is installed vertically above the main, then a drain point must be provided on the upstream side.

Expansion loops

This is really a development of the horse shoe loop. Expansion loops are fabricated from lengths of straight pipes and elbows welded at the joints.

Sliding joints

These are sometimes used because they take up little room, but it is essential that the pipeline is rigidly anchored and guided to the manufacturer's instructions, otherwise steam pressure tends to blow the joint apart in opposition to the expanding pipework forces.

Misalignment will cause the sliding sleeve to bend while regular maintenance of the gland packing is also needed.

Bellows

This design has the advantage that it is an in-line fitting and requires no packing as does the sliding joint type. However, it does have the same disadvantages in that pressure inside tends to extend the fitting so that anchors and guides must be able to withstand this force.

The bellows can be incorporated into a properly designed expansion fitting which is capable of absorbing not only axial movement of the pipeline but some lateral and angular displacement as well.

Bellows can incorporate limit rods which limit over-compression and over-entension of the element.

Where larger forces are expected, some form of additional mechanical reinforcement should be built into the devise, such as hinged stay bars.

Pipe supports/spacing

Roller supports are an ideal method for supporting pipes while allowing them to move in two directions.

For steel pipework, the rollers should be manufactured from ferrous material. For copper pipework, they should be manufactured from non-ferrous material. It is good practice for pipework supported on rollers to be fitted with a pipe saddle bolted to a support bracket at not more than 6 metre centres to keep the pipework in alignment while expansion and contraction occurs.

> Where there can be the risk of waterhammer, always select a robust steam trap for the job

Generally, pipe supports should be provided which comply with: BS3974 Part 1. 1974. Pipe hangers, slider and roller type supports.

Some of the important points are as follows:

1. Pipe supports should be *provided at joints* in the pipe bends, tees, valves, flanges and at intervals not greater than shown in Figure 5 (Recommended support for pipework). The reason for supporting at joints is to eliminate the stresses in screwed or flanged joints.
2. Where two or more pipes are supported on a common bracket, the spacing between the supports should be that for the *smallest* pipe.
3. When an appreciative movement will occur – where straight pipes are greater than 15 metres in length, the supports should be of the *roller* type.
4. Vertical pipes should be adequately supported at the base, to withstand the total weight of the vertical pipe. Branches from vertical pipes should *not* be used as a means of support for the pipe, because this will place undue strain on the tee joint.
5. All pipe supports should be specifically designed to suit the outside diameter of the pipe concerned. The use of oversized pipe brackets is not good engineering practice.

I trust I have given a reasonable overview of steam expansion in the time available to the reader but I cannot stress enough that the safest way to deal with the whole solution is to have a specialist engineer visit the site and give on-the-spot advice. Having witnessed the results of not giving proper attention to steam expansion, I cannot stress how essential it is to seek the expert advice from recommended bellows' manufacturers regarding the issue of expansion on these distribution installations.

5 Steam quality

As soon as steam has left the boiler, some of it must condense to replace the heat being lost through the pipe wall. Insulation will naturally reduce the heat loss. The heat flow and the condensation rate are small, but finite amounts will

Figure 7a. Steam Process Guide index (also see next page).

accumulate if appropriate action is not taken.

The condensate will form droplets on the inside of the pipe wall, and these can merge into a film as they are swept along by the steam flow.

Condensate will also accumulate towards the bottom of the pipe, and consequently the thickness of the film will be greatest there.

If this build-up continues, droplets of condensate will be thrown into the steam flow. This will result in very wet steam which reduces heat transfer efficiently and the working life of steam control equipment.

Anything that will reduce the propensity for wet steam in mains or branches has to be of benefit. A steam separator will remove both droplets of water from pipe walls and entrained mist.

The presence and effect of water-hammer can in many cases be eradicated by fitting a separator in a steam main.

Another important point about steam quality, often overlooked, is the need for adequate air venting. When steam is first turned on to a steam main after a period of shut-down, the main can be full of air, and further amounts of air and other non-condensable gases will enter with the steam. All these gases will accumulate within the steam pipe, and in the steam spaces of heat exchangers, when the steam condenses, unless steps are taken to discharge them. Always remember, these discharged gases, primarily oxygen and carbon dioxide, can give rise to corrosion of steam plant surfaces, piping and fittings. The most harmful is oxygen.

A typical position for using an automatic air vent in conjunction with a drain trap is at the terminal end of a steam main (point E, Figure 1).

Another problem of air in a steam system will be the effect on pressure and temperature. In many instances this can cause the overall temperature to be lower than that suggested by the pressure gauge reading. It is worth noting that a layer of air only 1 micron thick can offer the same resistance to heat as a layer of water 25 microns thick, a layer of iron 2 mm thick or a layer of copper 17 mm thick.

Thus for all of these reasons, it is of utmost importance that air is removed from the system.

Automatic air vents are best suited for the following steam applications:

1 Terminal ends and risers on steam mains.
Normally the discharge for the air vent can be piped to any safe place. In practice, it is often piped back into the condensate line, where it is gravity fed into or towards a vented receiver.
2 In parallel with an inverted bucket trap which is relatively slow to discharge air on plant start-up.
3 In awkward steam spaces such as the opposite side to a steam supply line serving a process jacketed pan/hospital sterilisers/autoclaves.
4 Where there is a large steam space and a steam/air mixture is to be avoided.

6 Reduction of heat losses

Once a steam main has warmed up, condensation will continue to occur as heat is lost by radiation, the rate depending on the steam temperature, ambient temperature and the efficiency of the system's insulation.

The need to insulate all hot parts of the system must be kept in mind, and not only steam mains and branches but also flanges, valves and other fittings.

All this has now been appreciated by the availability of pre-fabricated insulating covers for flanged joints and easily detachable insulating boxes for steam valves and traps.

The calculation of heat losses from steam pipes can be very complex due to variable site conditions. This being so, the commonplace solution can be easily found by the reference to well-published tables quoting heat emission from pipes based on ambient conditions of between 10-21°C from bare horizontal pipes of varying sizes and variable steam pressures. There are several well-known companies and associations that publish these charts. For the purpose of this exercise, I have shown a typical heat emission chart (Figure 6) which is still used to good effect.

7 Pressure reduction

There is no purpose in using steam at any higher pressure than that is necessary for the process, because to do so can put up the cost of plant construction and it can, in certain circumstances, increase radiation losses.

Figure 7b. Steam Process Guide index (continued).

What is important is to select the right reducing valve to give the correct steam reducing pressure to the process plant.

To achieve this, we would employ either a direct acting or pilot operated reducing valve.

The direct acting valve is the simplest design, has relatively low capacity and will allow some fluctuation of the reduced steam pressure.

The pilot operated valve is always recommended where accurate control of reduced steam pressure is important and high capacity.

Concentrating on the pilot operated type, commonly found on hospital steriliser/autoclave installations, the "golden rule" is to properly size this reducing valve from the manufacturer's capacity data and known process steam load figures.

Although reliability and accuracy depend on the correct sizing and selection of reducing valves, great dependence must be made on their correct installation.

The following points emphasise this:

1 All upstream and downstream pipe work and fittings must be adequately sized. From past experience, I size this based on a velocity of 25 m/s.
2 Install a strainer sized as the pipework, upstream of the reducing valve. Fit this strainer on its side and install a fine mesh screen.
3 Ensure that a properly installed dirt leg with steam trap set is also fitted upstream.
4 If site conditions suffer from excessive wet steam, also consider installing a separator.
5 In the interests of safety awareness, also install pressure gauges with "U" syphon and cocks – one upstream and the other downstream.
6 A properly sized safety valve, with locking device and easing lever, must be installed downstream. Ensure that the blow-off pressure conforms to the plant's design criteria. In many cases, the sized safety valve, at its blow-off pressure, must be capable of handling all the steam which could pass through a failed fully open reducing valve.
7 Depending on design specification, in certain cases, a balance pipe is recommended. Ensure this is installed with a slight fall in direction of flow prior to tapping into downstream pipe work. Also ensure that you fit a small isolating valve halfway down the balance pipe length.
8 Finally, in the interests of easy maintenance and servicing of the reducing valve, install good quality isolation valves, sized as the upstream and downstream pipe work.

Reducing valve applications and layouts

No matter how good a reducing valve or its installation is, it is a fact that sometime in its working life the valve will fail and cause the safety valve to blow off steam.

In many instances the engineering department will isolate off and make the necessary arrangements to correct this problem.

All this can take time, and in certain important process plants the delay can cause very costly and unacceptable production losses.

In known cases like this, where process is critical, the solution would be to install two reducing valves in parallel to give a standby facility.

Depending on the actual steam plant and its steam load, turndown would determine the sizing of the standby reducing valve.

Finally, in cases where the pressure reduction is extreme, for example 14.5 bar g reducing down to 1.0 bar g, one would certainly recommend a two stage layout where two reducing valves are installed in series.

Notes

Almost all the content of this article, and details of other steam issues, can be found in the *Process Steam Guide*.

To date, an important part of the author's philosophy is to continue to arrange on-site lectures and training sessions. Not only does this stimulate his own interest in keeping up to date with the modern technology in hospital plant, but it also provides the engineering manager the flexibility to offer training sessions on the premises to his important engineering staff, without undue disruption to their own daily or shift pattern responsibilities.

Having said that, the author is in no way wishing to compete with those well-respected and long-established companies who specialise in offering their own in-house training courses and hands-on experience on an international scale. Long may they continue to flourish in the good work they do for various engineering associations.

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The author would like to acknowledge, with thanks, the kind permission of Spirax Sarco of Cheltenham to reproduce copies of its technical data and steam pipeline capacity charts. These enable the engineer to make a sound indication in the manual exercise of checking the importance of pressure drop and velocity, although the modern tendency towards greater accuracy would favour the use of computer software programmes.

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