ENGINEERING INFORMATION

Hot water and steam service

WHAT IS STEAM?

Like other substances, water can exist in the form of a solid, when we call it ice; as a liquid when we call it water or as a gas when we call it steam. In this section our attention will largely be concentrated on the liquid and gas phases and on the change from one phase to the other.

If heat energy is added to water, its temperature rises until a value is reached at which the water can no longer exist as a liquid. We call this the "saturation" point and with any further addition of energy, some of the water will boil off as steam. This evaporation requires relatively large amounts of energy, and while it is being added, the water and the steam released are both at the same temperature.

Equally, if we can encourage the steam to release the energy that was added to evaporate it, the steam will condense and water of the same temperature will be formed.

WHY STEAM?

Steam has been used as a conveyor of energy since the Industrial Revolution. After its first use for cooking food, it has continued to be a flexible and versatile tool for the industry wherever heating is needed.

It is produced by the evaporation of water which is a relatively cheap and plentiful commodity in most parts of the world. Its temperature can be adjusted very accurately by the control of its pressure, using valves; it carries relatively large amounts of energy in a small mass and when it is encouraged to condense back to water, high rates of energy flow (into the material being heated) are obtained, so that the heat using system does not have to be unduly large.

THE FORMATION OF STEAM

The best way of explaining the formation of steam is by considering an imaginary, idealised, experiment (see **Fig. 1**).

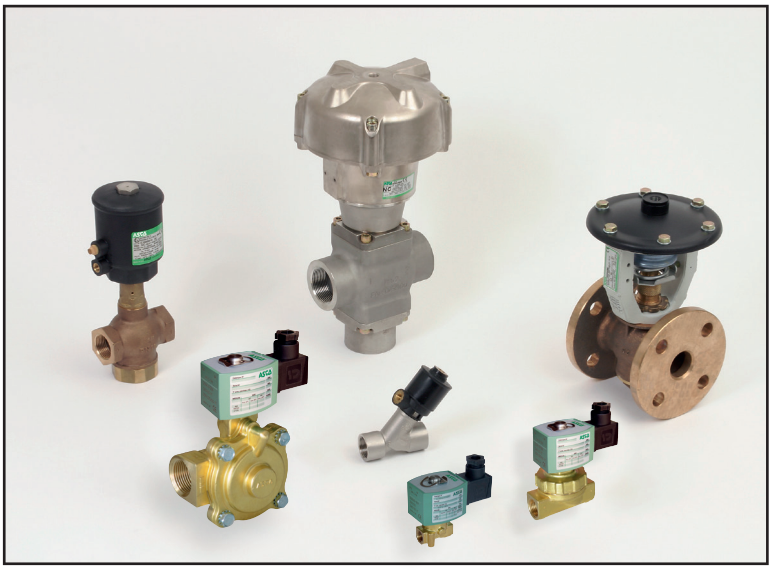
Suppose we took a cylinder with its bottom end closed and surrounded it with insulation which was 100% efficient so that there was no heat loss from it. If we poured into the cylinder 1 kg of water at the temperature of melting ice, 0°C, we could use this as a datum point and say that for our purposes its heat content, or enthalpy, was zero. Any addition of heat to the water would raise its temperature, until it reaches 100°C (the cylinder being open at the top so that only atmospheric pressure is applied to the water).

With any further addition of enthalpy, the water cannot exist as a liquid and some of it will boil off as steam.

The total enthalpy held by each kilogram of liquid water at the boiling temperature is called the "specific enthalpy of saturated water" and is shown by the symbol "hf".

The extra enthalpy which has to be added to each kilogram of water to turn it into steam is called the "specific enthalpy of evaporation" and is show by the symbol "hfg".

The total enthalpy in each kilogram of steam clearly is the sum of these two. It is called the "specific enthalpy of steam" and can be shown by: hf + hfg = hg.



When the total specific enthalpy of evaporation has been added to the kilogram of water in our cylinder, then all the water will exist as steam at atmospheric pressure.

Its volume will be much more than the volume of the liquid water (over 1.600 times). Clearly the molecules of water in the liquid condition are held together more closely than the molecules of steam. The process of evaporation can be considered as one of adding sufficient energy to each molecule that it can break the bonds holding them together, so that it can leave the liquid in the cylinder and move freely in the gas phase.

Now it is to be expected that if the pressure above the liquid were increased, the molecules would find it more difficult to leave. We would have to give them more energy before they could break the bonds and move into the gas phase, which means that the temperature of the water would increase to over 100°C before boiling occurred.

This is, indeed, exactly what is found in practice. If our imaginary cylinder were fitted with a frictionless piston, and a weight placed on top of the piston so as to apply pressure to the water, then the temperature of the water could be increased above the normal 100°C before any evaporation commenced.

However, at any given pressure there is a corresponding temperature above which water cannot exist as a liquid, and any enthalpy above the "specific enthalpy of saturated water" will evaporate some of the liquid.

Equally, if the pressure of the water is lowered below the normal atmospheric pressure, than it is easier for the molecules to break free. They require a lower energy level, so the temperature at which boiling occurs, and the corresponding "enthalpy of saturated water", are reduced.

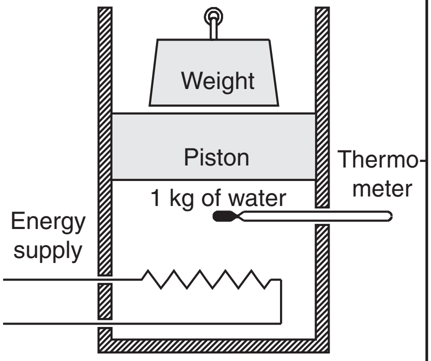


Fig. 1

DEFINITIONS

Enthalpy

This is the term given for the total energy, due to both the pressure and temperature, of a fluid or vapour (such as water or steam) at any given time and condition.

The basic unit of measurement for all types of energy is the joule (symbol J). Since one joule represents a very small amount of energy, it is usual to multiply it by 1.000 and use kilojoules (kJ).

Specific Enthalpy

Is the enthalpy (total energy) of a unit mass (1 kg). The units generally used are kJ/kg.

Specific Heat Capacity

A measure of the ability of a substance to absorb heat. It is the amount of energy (joules) required to raise 1 kg by 1 K. Thus specific heat capacity is expressed in kJ/kgK.

The specific heat capacity of water is 4,186 kJ/kgK. This simply means that an increase in enthalpy of 4,186 kJ will raise the temperature of 1 kg of water by 1 K.

Absolute Pressure & Gauge Pressure

The theoretical pressureless state of a perfect vacuum is "absolute zero". Absolute pressure is, therefore, the pressure above absolute zero.

For instance, the pressure exerted by the atmosphere is 1,013 bar abs at sea level. Gauge pressure is the pressure shown on a standard gauge fitted to a steam system. Since gauge pressure is the pressure above atmospheric pressure, the zero on the dial of such a gauge is equivalent to approx. 1,013 bar abs. So a pressure of 3 bar abs would be made up of 1,987 bar gauge pressure (barg) plus 1,013 bar absolute atmospheric pressure.

Heat and Heat Transfer

Heat is a form of energy and as such is part of the enthalpy of a liquid or gas. Heat transfer is the flow of enthalpy from matter at a high temperature to matter at a lower temperature, when they are brought together.

Enthalpy of Saturated Water

Let us assume that water is available for feeding to a boiler at atmospheric pressure, at a temperature of 10°C, and that the water will begin to boil at 100°C. 4,186 kJ will be required to raise each kg of water through 1°C. Therefore, for each kg of water in the boiler, the increase in enthalpy is (90 x 4,186) = 376,74 kJ in raising the temperature from 10°C to 100°C. If the boiler holds 10.000 kg mass (10.000 litres) the increase in enthalpy to bring it up to boiling point is 376,74 kJ/kg x 10.000 kg = 3.767.400 kJ.

It must be remembered that this figure is not the enthalpy of saturated water, but merely the increase in enthalpy required to raise the temperature from 10°C to 100°C. The datum point of the steam tables is water at 0°C, which is assumed to have a heat content of zero for our purposes. (The absolute heat content clearly would be considerable, if measured from absolute zero at minus 273°C.)
The enthalpy of saturated water at 100°C is then 100 x 4,186 = 418,6 kJ.

Enthalpy of Evaporation

Suppose for the moment that any steam which is formed in the boiler can be discharged freely into the atmosphere. When the water has reached 100°C heat transfer between the furnace and water continues but there is no further increase in temperature. The additional heat is used in evaporating the water and converting it into steam.

The enthalpy which produces a change of state from liquid to gas without change of temperature is called the "enthalpy of evaporation". The enthalpy of evaporation is the difference between the enthalpy of saturated water and that of dry saturated steam.

Enthalpy of Saturated Steam

We have established that the steam generated in our boiler contains enthalpy which is accounted for in two ways. The sum of these two enthalpies is known as the "enthalpy of saturated steam".

In every kg mass of steam at 100°C and at atmospheric pressure, the enthalpy of saturated water is 419 kJ, the enthalpy of evaporation is 2.257 kJ, and the enthalpy of saturated steam is 2.676 kJ. These figures are taken from the steam tables.

STEAM PRESSURE

We have already mentioned the term "atmospheric pressure". This is simply the pressure exerted on all things, in all directions, by the earth's atmosphere. The unit of pressure is the bar (1 bar = 100 kPa). The pressure exerted by the atmosphere, when water is boiling at 100°C, happens to be 1,01325 bar. This is so close to 1 bar that we usually take atmospheric pressure as being 1 bar, the approximation being sufficiently close for almost all practical purposes.

Now look again at the imaginary cylinder with the frictionless piston (**fig. 1**) which we mentioned earlier. If water is heated up in the cylinder until steam is generated, the steam will build up below the piston until the pressure of the steam and water is sufficient to balance the weighted piston. Any more steam being released from the water will then push the piston up the cylinder, the pressure remaining constant. If we were able to pump some more water into the cylinder we could maintain the water level, whilst at the same time releasing steam which would move the piston even further along the cylinder.

We have already said that if the cylinder or boiler, is operated at a pressure above atmospheric pressure, then the temperature of the saturated water and of the steam is greater than 100°C. If the pressure were 10 bar absolute, the saturated water temperature would be 180°C. In order to reach this higher temperature, the water must be given a greater quantity of "enthalpy of saturated water". On the other hand, we find that enthalpy of evaporation needed to convert the saturated water into steam, is lowered as the pressure increases.

At high pressure, the molecules of steam are more tightly packed, and the extra energy needed for them to break free from the liquid water (where they already have a high energy level) is lowered in quantity.

(At very high pressure indeed, above about 221 bar, the energy level of the molecules of steam is just the same as that of the molecules of water, and the enthalpy of evaporation becomes zero!)

Steam Volume

If 1 kg (mass) of water (which is 1 litre by volume) is all converted into steam, the result will be exactly 1 kg (mass) of steam. However, the volume occupied by a given mass depends on its pressure. At atmospheric pressure 1 kg of steam occupies nearly 1.673 cubic metres (m^3) At a pressure of 10 bar abs, that same 1 kg of steam will only occupy 0,1943 m^3. The volume of 1 kg of steam at any given pressure is termed its "Specific Volume" (symbol Vg).

The volume occupied by a unit mass of steam decreases as its pressure rises. This is shown in graph form in **fig. 2**.

TYPES OF STEAM

Dry Steam and Wet Steam

The steam tables show the properties of what is usually known as "dry saturated steam". This is steam which has been completely evaporated, so that it contains no droplets of liquid water.

In practice, steam often carries tiny droplets of water with it and cannot be described as dry saturated steam. Nevertheless, it is often important that the steam used for process or heating is as dry as possible.

Steam quality is described by its "dryness fraction" - the proportion of completely dry steam present in the steam being considered.

The steam becomes "wet" if water droplets in suspension are present in the steam space, carrying no specific enthalpy of evaporation. The small droplets of water in wet steam have weight but occupy negligible space. The volume of wet steam is, therefore, less than that of dry saturated steam (it is the water droplets in suspension which make wet steam visible).

Steam as such is a transparent gas but the droplets of water give it a white cloudy appearance due to the fact that they reflect light.

Superheated Steam

As long as water is present, the temperature of saturated steam will correspond to the figure indicated for that pressure in the steam tables. However, if heat transfer continues after all the water has been evaporated, the steam temperature will again rise. The steam is then called "superheated", and this "superheated steam" can be at any temperature above that of saturated steam at the corresponding pressure.

Saturated steam will condense very readily on any surface which is at a lower temperature, so that it gives up the enthalpy of evaporation which, as we have seen, is the greater proportion of its energy content. On the other hand, when superheated steam gives up some of its enthalpy, it does so by virtue of a fall in temperature. No condensation will occur until the saturation temperature has been reached, and it is found that the rate at which we can get energy to flow from superheated steam is often less than we can achieve with saturated steam, even though the superheated steam is at a higher temperature.

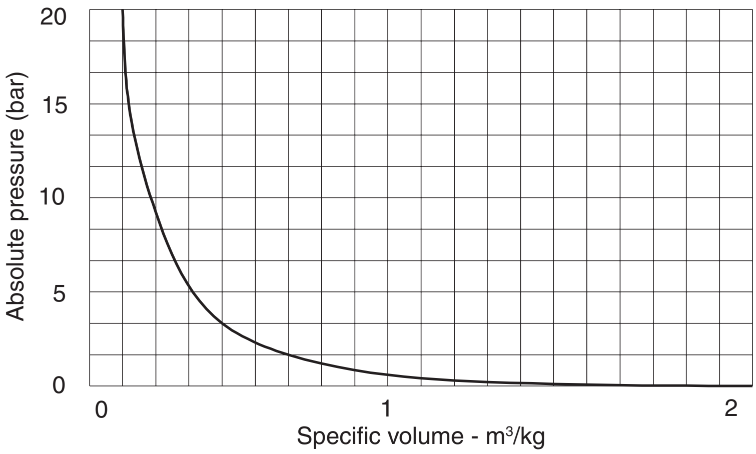


fig. 2

STEAM GENERATION

The chemical energy which is contained in coal, gas or other boiler fuel is converted into heat energy when the fuel is burned. This heat energy is transmitted through the wall of the boiler furnace to the water. The temperature of the water is raised by this addition of heat energy until saturation point is reached, it boils.

The heat energy which has been added and which has had the effect of raising the temperature of the water is know as the "Enthalpy of Saturated Water" (symbol hf). At the point of boiling, the water is termed "Saturated Water".

Heat transfer is still taking place between the furnace wall and the water. The additional enthalpy produced by this heat transfer does not increase the temperature of the water. It evaporates the water which changes its state into steam. The enthalpy which produces this change of state without change of temperature is known as the "Enthalpy of Evaporation" (symbol hfg).

Thus the steam generated in our boiler has two lots of enthalpy. These are the enthalpy of saturated water and the enthalpy of evaporation.

Adding these together, we arrive at the "Enthalpy of Saturated Steam" (symbol hg).

Thus hf + hfg = hg

Fig. 3 shows the enthalpy of saturated steam at atmospheric pressure. Compare it with **Fig. 4** which shows the changed enthalpy of saturated steam at the higher pressure of 10 bar abs.

The enthalpy of each kg of saturated steam in **Fig. 4** has increased, but only slightly (by 102,1 kJ). The enthalpy of saturated water has **increased** a great deal (by 343,8 kJ) whereas the enthalpy of evaporation has **decreased** (by 247,7 kJ).

The basic rules that arise from this are:

I) When steam pressure increases:
  - Enthalpy of saturated steam increases slightly
  - Enthalpy of saturated water increases
  - Enthalpy of evaporation decreases

II) When steam pressure decreases:
  - Enthalpy of saturated steam decreases slightly
  - Enthalpy of saturated waterdecreases
  - Enthalpy of evaporation increases

Thus, the lower the steam pressure the higher the Enthalpy of Evaporation.

The simplified Mollier diagram (**fig. 5**) shows the change of state from water to steam and the effect of adding enthalpy to either phase. The vertical axis shows temperature. The horizontal axis is actually enthalpy divided by the temperature at which the enthalpy is added. The use of this rather artificial factor means that the area below the lines on the graph represents enthalpy. This makes it easy to show on the diagram the information which otherwise has to be given in steam tables.

At point A on the graph, water at 0°C is taken to have an enthalpy content of 0. As enthalpy is added, the temperature rises along the line AB. Point B is the saturation (boiling) point T1, corresponding to the pressure in the system. From point B to point C, enthalpy of evaporation is added at constant temperature T1. Any further addition of enthalpy beyond point C will then increase the temperature of the steam, for example to T2 at point D. The part of the graph to the right of the line on which C and D lie, represents superheated steam. T2 is the temperature of the superheated steam and T2 - T1 is the amount of superheat added. Increasing the pressure on the water and steam results in a curve like AEFG.

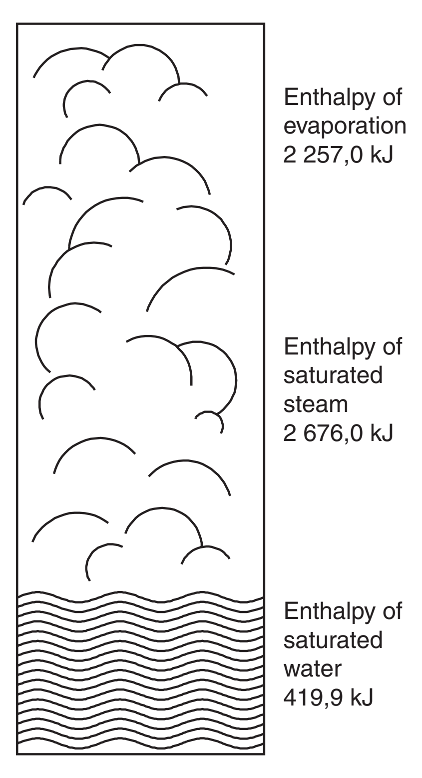


Fig. 3

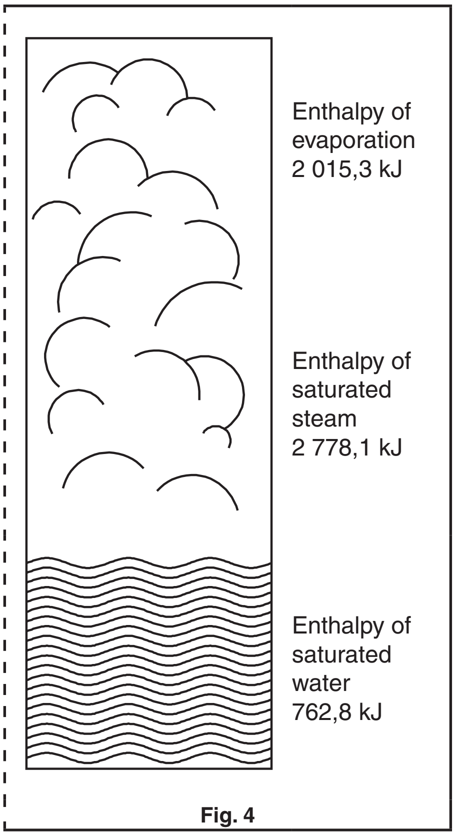
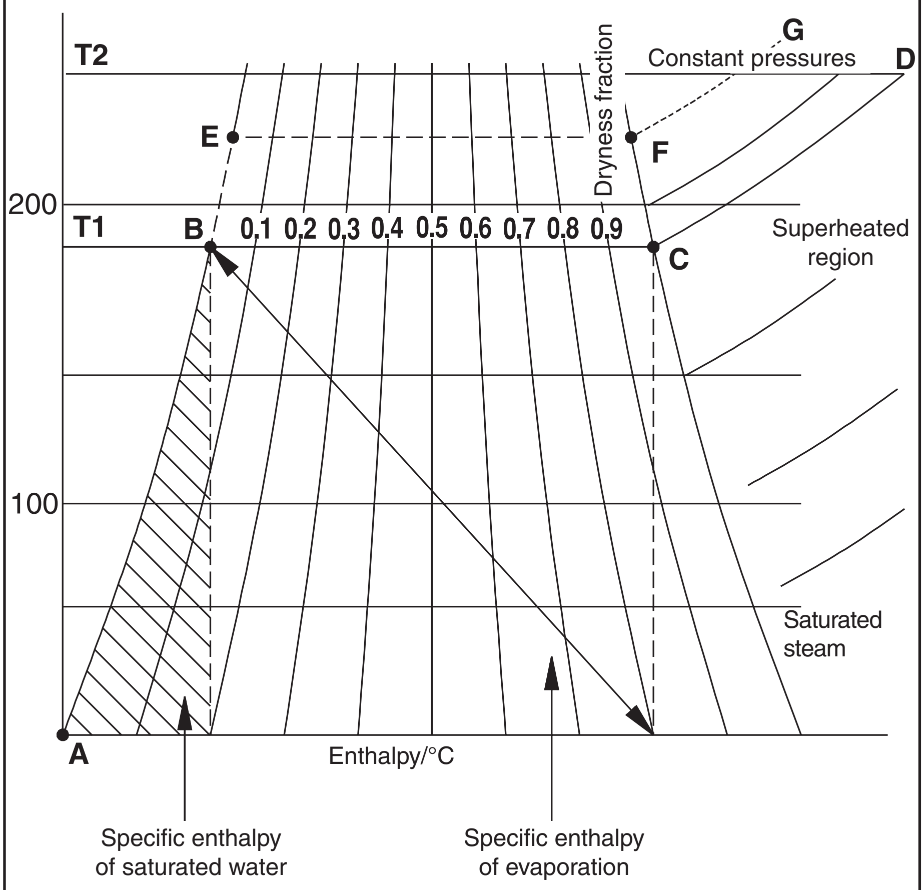


Fig. 4



Temperature - Enthalpy/°C Graph

Fig. 5

CONDENSATION OF STEAM

As soon as steam leaves the boiler, it begins to give up some of its enthalpy to any surface at a lower temperature. In doing so, some of the steam condenses into water at the same temperature. The process is the exact reverse of the change from water to steam which takes place in the boiler when heat is added. It is the enthalpy of evaporation which is given up by the steam when it condenses.

Fig. 6 shows a coil heated vessel which might be found in any plant using steam. The vessel is filled with the product to be heated and steam is admitted to the coil. The steam then gives up its enthalpy of evaporation to the metal wall of the coil, which transfers it to the product. Hot water is formed as the steam condenses and runs down to the bottom of the coil. This "condensate", as it is properly known, must be drained away.

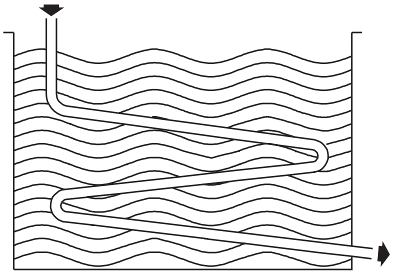


Fig. 6

If the steam in the coil condenses at a faster rate than the condensate is able to drain away, the bottom of the coil will begin to fill with water as shown in **Fig. 7**. We call this "waterlogging".

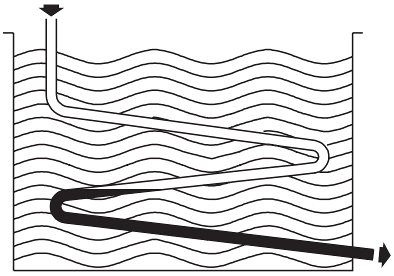


Fig. 7

THE STEAM CIRCUIT

The steam generated in the boiler must be conveyed through pipework to the places where its heat energy is required. In the first place, there will be one or more main pipes or "steam mains" from the boiler in the general direction of the steam using plant. Smaller branch pipes then carry steam to the individual pieces of equipment.

When the boiler valve is opened (slowly of course) steam immediately rushes from the boiler into and along the main. The pipework is cold initially and so heat transfer takes place from the steam. The air surrounding the pipes is also cooler than the steam, so the system as it warms up will begin to radiate heat to the air. This heat loss to the atmosphere causes more steam to condense. However large or small the quantity of enthalpy lost from the steam main, it can only be supplied by the condensation of some of the steam.

The water falls towards the bottom of the pipe and is also carried along by the steam flow to low points in the main. When an ASCO valve on a piece of steam using equipment is opened, steam from the distribution system enters the equipment and again comes into contact with surfaces cooler than itself. The steam then gives up its enthalpy of evaporation and it condenses.

There is now a continuous flow of steam coming out of the boiler. To keep up the supply, more and more steam must be generated.

In order to do this, fuel is fed to the furnace and more water is pumped into the boiler to make up for water which has been evaporated to provide steam.

The basic steam circuit should be completed, as shown in **Fig. 8**, by returning all condensate to the boiler feed tank.

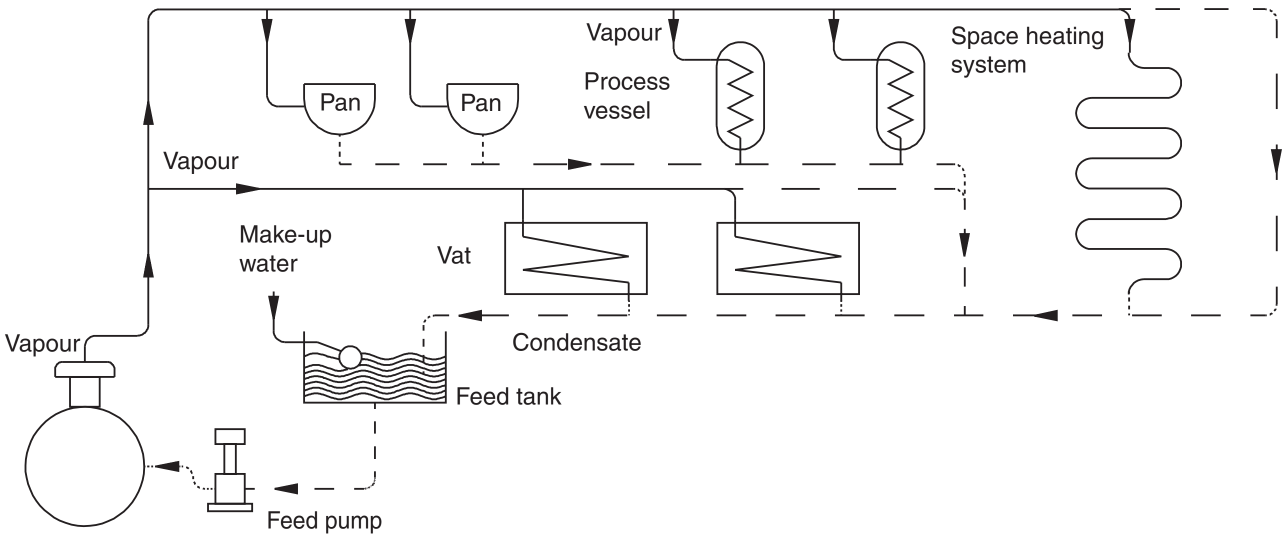


Fig. 8

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TABLE OF PHYSICAL CHARACTERISTICS OF SATURATED STEAM (page 6)

We have already seen that a relationship exists between steam pressure and saturation temperature: that enthalpies of saturated water, evaporation and saturated steam vary and interact with pressure and that the volume changes with changes in pressure.

Since the enthalpy figures relate to 1 kg (mass) they are known as “**Specific Enthalpy of Liquid Water**” (saturated, sensible heat), “**Specific Enthalpy of Steam**” (saturated, total heat) and “**Specific Enthalpy of Evaporation**” (latent heat).

The values are stated in the table of physical characteristics of saturated steam on the following page.

To calculate the saturated steam temperature at a given absolute pressure use the following proximation:

$$T = (Pa^{0,26}) \times 100 \quad (°C)$$

Pa = pression abs

STEAM FLOW

Because of the nature of steam there are some rules to be taken into account for the proper estimation of piping systems for the transport of steam.

During the steam mass flow through the piping a certain loss in pressure is developed due to the friction on the pipe walls.

To keep the losses and deterioration within acceptable limits the steam velocity has to be held on the following practical values:

Main transport steam pipes	: 20 - 40 m/s
Secondary steam pipes	: 15 - 20 m/s
Utility steam pipes	: 10 - 15 m/s
Condensate pipes	: 15 m/s

Steam velocity calculations are carried out using the following equation:

$$V = \frac{Q}{A \cdot 3600} \quad (m/s)$$

$$Q = Qm \times Vg \quad (m^3/h)$$

V = Steam velocity (m/s)
Q = Volume flow (m^3/h)
Qm = Mass flow of steam (kg/h)
Vg = Specific volume steam (m^3/kg)
A = Area section of the pipe (m^2)

A piping system with an area of 1 cm^2 (d = 12,7 mm) connected to a pressure of 1 barg will carry 10 kg/h steam with a speed of approx. 25 m/s.

To ensure the good operation of pilot operated solenoid valves it is important to know the minimum mass flow on which the valve function is based.

The mass flow is expressed in kg/h and can be calculated with the following equation:

$$Qm = Kv \times Fg_m \quad (kg/h)$$

Kv = flow coefficient (m^3/h)
Fg_m = graph factor (kg/m^3)

A pilot operated solenoid valve with a Kv = 4,3 (m^3/h) and a minimum operating pressure differential of at least 0,35 bar is connected to a 6 barg steam system.

The minimum mass flow Qm, for the above mentioned application, can be found as follows:

Select in **fig. 9** the 6 barg inlet pressure, cross horizontally the 0,35 bar pressure drop curve and find vertically on the Fgm scale the value 35.

Qm = 4,3 x 35 = 150,5 kg/h

The piping system has to convey this minimum mass flow at least. If this flow is critical or not reached it is recommended to select a valve with a lower Kv value.

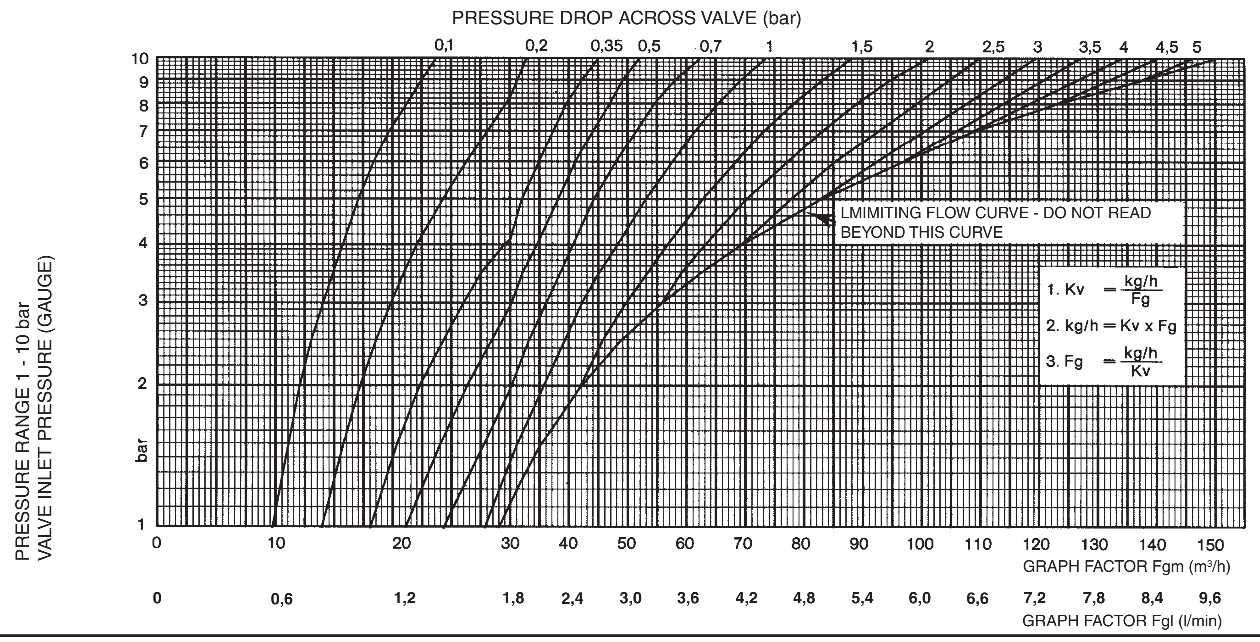

fig. 9

PHYSICAL CHARACTERISTICS OF STEAM

boiling point (fluid)	relative pressure (values in the catalogue pages)	absolute pressure	specific volume (steam)	density (steam)	specific enthalpy of liquid water (sensible heat, hf)		specific enthalpy of evaporation (latent heat, hfg)		specific enthalpy of steam (total heat, hg)		specific heat (steam)	dynamic viscosity (steam)
(°C)	(bar)	(bar)	(m^3/kg)	(kg/m^3)	(kj/kg)	(Kcal/kg)	(kj/kg)	(Kcal/kg)	(kj/kg)	(Kcal/kg)	(kj/kg)	(kg/m.s)
17,51		0,02	67,006	0,015	73,45	17,54	2460,19	587,61	2533,64	605,15	1,8644	0,00001
45,81	-	0,1	14,674	0,0681	191,83	45,82	2392,8	571,61	2584,7	617,46	-	-
60,06	-	0,2	7,649	0,1307	251,4	60,05	2358,3	563,37	2609,7	623,43	-	-
69,1	-	0,3	5,229	0,1912	289,23	69,09	2336,1	558,07	2625,3	627,16	-	-
75,87	-	0,4	3,993	0,2504	317,58	75,86	2319,2	554,03	2636,8	629,9	-	-
81,33	-	0,5	3,24	0,3086	340,49	81,34	2305,4	550,74	2645,9	632,16	-	-
85,94	-	0,6	2,732	0,336	359,86	85,96	2293,6	547,92	2653,5	633,89	-	-
89,95	-	0,7	2,365	0,4228	376,7	89,99	2283,3	545,46	2660	635,45	-	-
93,5	-	0,8	2,087	0,4791	391,66	93,56	2274,1	543,26	2665,8	636,83	-	-
96,71	-	0,9	1,869	0,535	405,15	96,78	2265,7	541,25	2670,9	638,05	-	-
99,63	-	1	1,694	0,59	417,51	99,72	2257,92	539,3	2675,43	639,02	2,0267	0,000012
100	0	1,013	1,673	0,5977	419,04	100,1	2257	539,17	2676	639,27	-	-
102,32	0,087	1,1	1,549	0,645	428,84	102,43	2250,76	537,59	2679,61	640,01	2,0373	0,000012
104,81	0,187	1,2	1,428	0,7	439,36	104,94	2244,08	535,99	2683,44	640,93	2,0476	0,000012
107,13	0,287	1,3	1,325	0,755	449,19	107,29	2237,79	534,49	2686,98	641,77	2,0576	0,000013
109,32	0,387	1,4	1,236	0,809	458,42	109,49	2231,86	533,07	2690,28	642,56	2,0673	0,000013
111,37	0,487	1,5	1,159	0,863	467,13	111,57	2226,23	531,73	2693,36	643,3	2,0768	0,000013
113,32	0,587	1,6	1,091	0,916	475,38	113,54	2220,87	530,45	2696,25	643,99	2,086	0,000013
115,17	0,687	1,7	1,031	0,97	483,22	115,42	2215,75	529,22	2698,97	644,64	2,095	0,000013
116,93	0,787	1,8	0,977	1,023	490,7	117,2	2210,84	528,05	2701,54	645,25	2,1037	0,000013
118,62	0,887	1,9	0,929	1,076	497,85	118,91	2206,13	526,92	2703,98	645,83	2,1124	0,000013
120,42	1	2,013	0,881	1,1350	505,6	120,78	2201,1	525,82	2706,7	646,6	-	-
120,23	0,987	2	0,885	1,129	504,71	120,55	2201,59	525,84	2706,29	646,39	2,1208	0,000013
123,27	1,187	2,2	0,81	1,235	517,63	123,63	2192,98	523,78	2710,6	647,42	2,1372	0,000013
126,09	1,387	2,4	0,746	1,34	529,64	126,5	2184,91	521,86	2714,55	648,36	2,1531	0,000013
128,73	1,587	2,6	0,693	1,444	540,88	129,19	2177,3	520,04	2718,17	649,22	2,1685	0,000013
131,2	1,787	2,8	0,646	1,548	551,45	131,71	2170,08	518,32	2721,54	650,03	2,1835	0,000013
133,54	1,987	3	0,606	1,651	561,44	134,1	2163,22	516,68	2724,66	650,77	2,1981	0,000013
133,69	2	3,013	0,603	1,6583	562,2	134,3	2163,3	516,79	2725,5	651,09	-	-
138,87	2,487	3,5	0,524	1,908	584,28	139,55	2147,35	512,89	2731,63	652,44	2,2331	0,000014
143,63	2,987	4	0,462	2,163	604,68	144,43	2132,95	509,45	2737,63	653,87	2,2664	0,000014
147,92	3,487	4,5	0,414	2,417	623,17	148,84	2119,71	506,29	2742,88	655,13	2,2983	0,000014
151,85	3,987	5	0,375	2,669	640,12	152,89	2107,42	503,35	2747,54	656,24	2,3289	0,000014
151,96	4	5,13	0,374	2,6737	640,7	153,05	2108,1	503,6	2748,8	656,66		
155,47	4,487	5,5	0,342	2,92	655,81	156,64	2095,9	500,6	2751,7	657,23	2,3585	0,000014
158,84	4,987	6	0,315	3,17	670,43	160,13	2085,03	498	2755,46	658,13	2,3873	0,000014
160	5	6,013	0,31	3,1746	670,09	160,27	2086	498,32	2756,9	658,6	-	-
161,99	5,487	6,5	0,292	3,419	684,14	163,4	2074,73	495,54	2758,87	658,94	2,4152	0,000014
164,96	5,987	7	0,273	3,667	697,07	166,49	2064,92	493,2	2761,98	659,69	2,4424	0,000015
165	6	7,013	0,272	3,6764	697,5	166,62	2066	493,54	2763,5	660,17	-	-
167,76	6,487	7,5	0,255	3,915	709,3	169,41	2055,53	490,96	2764,84	660,37	2,469	0,000015
170,42	6,987	8	0,24	4,162	720,94	172,19	2046,53	488,8	2767,46	661	2,4951	0,000015
172,94	7,487	8,5	0,227	4,409	732,03	174,84	2037,86	486,73	2769,89	661,58	2,5206	0,000015
175,36	7,987	9	0,215	4,655	742,64	177,38	2029,49	484,74	2772,13	662,11	2,5456	0,000015
177,67	8,487	9,5	0,204	4,901	752,82	179,81	2021,4	482,8	2774,22	662,61	2,5702	0,000015
179,88	8,987	10	0,194	5,147	762,6	182,14	2013,56	480,93	2776,16	663,07	2,5944	0,000015
179,97	9	10,013	0,19	5,1546	763	182,27	2015,1	481,39	2778,1	663,66	-	-
184,06	9,987	11	0,177	5,638	781,11	186,57	1998,55	477,35	2779,66	663,91	2,6418	0,000015
184,13	**10**	11,013	0,177	5,6497	781,6	186,71	2000,1	477,8	2781,7	664,52	-	-
187,96	10,987	12	0,163	6,127	798,42	190,7	1984,31	473,94	2782,73	664,64	2,6878	0,000015
191,6	11,987	13	0,151	6,617	814,68	194,58	1970,73	470,7	2785,42	665,29	2,7327	0,000015
194,04	12,987	14	0,141	7,106	830,05	198,26	1957,73	467,6	2787,79	665,85	2,7767	0,000016
198,28	13,987	15	0,132	7,596	844,64	201,74	1945,24	464,61	2789,88	666,35	2,8197	0,000016
212,37	18,987	20	0,1	10,047	908,56	217,01	1888,65	451,1	2797,21	668,1	3,0248	0,000016
217,24	**21**	22,013	0,091	11,032	930,92	222,35	1868,11	446,19	2799,03	668,54	3,1034	0,000016
219,55	21,987	23	0,087	11,525	941,57	224,89	1858,2	443,82	2799,77	668,71	3,1421	0,000016
221,78	22,987	24	0,083	12,02	951,9	227,36	1848,49	441,5	2800,39	668,86	3,1805	0,000017
223,94	23,987	25	0,080	12,515	961,93	229,75	1838,98	439,23	2800,91	668,99	3,2187	0,000017
224,02	**24**	25,013	0,0797	12,547	952,2	229,86	1840,9	439,77	2803,1	669,63	-	-
233,84	28,987	30	0,067	15,009	1008,33	240,84	1793,94	428,48	2802,27	669,31	3,4069	0,000017
242,54	33,987	35	0,057	17,536	1049,74	250,73	1752,2	418,51	2801,95	669,23	3,5932	0,000017
250,33	38,987	40	0,050	20,101	1087,4	259,72	1712,94	409,13	2800,34	668,85	3,7806	0,000018
251,8	**40**	41,013	0,048	20,619	1094,56	261,43	1705,33	407,31	2799,89	668,74	3,8185	0,000018

Boiling point: Temperature of saturated vapour or also of boiling water under the same pressure.

Relative pressure: Pressure above atmospheric pressure measured by commonly used pressure gauges.

Absolute pressure: Relative pressure + 1,013 bar (normal atmospheric pressure at sea level at 0°C).

Specific volume of steam: Number of cubic meters occupied by 1 kg of steam.

Density (or mass density) of steam: Specific mass of steam contained in a volume of 1 m^3.

Specific enthalpy of liquid water: Sensible heat; the quantity of heat contained in 1 kg of boiling water.

Specific enthalpy of steam: Total heat contained in 1 kg of steam. It is the sum of the enthalpy of the various states, liquid (water) and gas (vapour).

Specific enthalpy (or latent heat) of evaporation: Heat required to transform 1 kg of boiling water into vapour without change of temperature (thermal energy required during the change of state from liquid to vapour).

Specific heat of steam: Amount of heat required to raise the temperature of 1 kg of steam by 1°C.

Dynamic viscosity: The viscosity of a fluid characterises the resistance to the movement of the fluid.