PROCESS STEAM PRODUCTION USE AND CONTROL

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Introduction

In the short time available, it is not possible to go into a lot of detail about Process Steam, or for that matter, to cover the whole field of the Production Use and Control of Process Steam, so I shall confine myself to a few significant and interesting points. Now, it is inevitable that at some stage most of us wonder: "Why do we use steam for Process heating, are there not other substances better suited to carry out this job?" Well, there might be better substances but if there are, they will have very little chance of ousting steam by now, when one considers the time, thought, study and money that has, for many years, gone into perfecting the use of steam for process heating. It would have to be a very far-seeing person who would be prepared to spend millions of rand and years of time developing some other substance to the point where it can be shown to be better than steam. Thus, we can concentrate all our energies making the best use of steam, safe in the knowledge that our energies will not be wasted by the sudden appearance of something better.

Steam has a number of advantages—firstly, it is the vapour stage of water which is common in all industrial areas and, as found, is harmless and therefore easy to handle. In changing from the liquid to the vapour stage and back again it absorbs and gives out large amounts of heat reasonably easily. In its liquid stage it occupies a comparatively small volume and, with a reasonable amount of care, can be heated to very high temperatures without danger of dissociation. This latter attribute should not concern the average mill or factory engineer because these very high temperatures are only used in the case of the generation of large amounts of electricity and a few other specialist applications.

Production of Process Steam

Steam for industrial processes can be obtained in three main ways, namely:

(1) Directly from boilers at the temperature and pressure required.

(2) From pass-out turbines.

(3) From reducing stations.

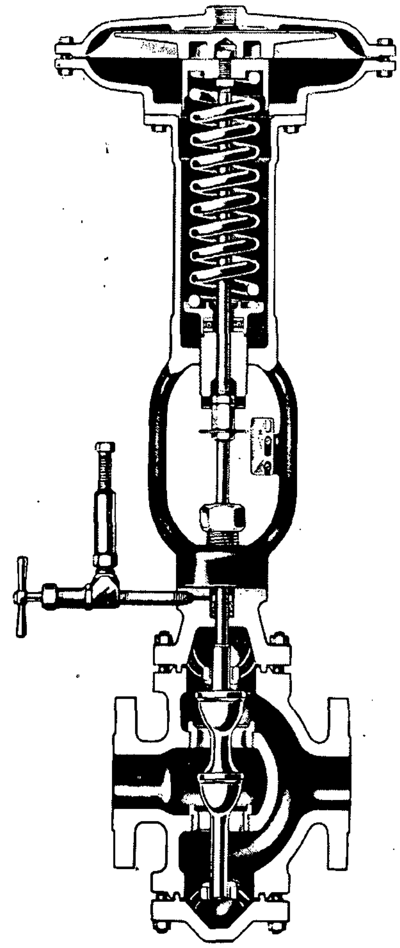
Basically, of course, all process steam originates from boilers of one kind or another—the types of boilers are many and varied, the actual design being influenced by individual firms, application, type of fuel, etc. There are a few unusual sources of steam such as the natural hot springs in New Zealand and Italy where the steam has been harnessed for the generation of electricity, or the patented steam generators burning oxygen and hydrogen which, although they are only about 40 cubic feet in total volume, can produce their full output of up to 100,000 lbs/hr at 500 p.s.i. or more within a few seconds of being started up.

However, as in the first case the steam is very wet and contains large quantities of corrosive substances and, in the latter case, the fuel costs are about 100 times the fuel costs of a normal boiler, neither are likely to concern the average production engineer who is interested in efficient and economic production methods. Although boilers would appear to be the most obvious of all sources of process steam, the choice of a boiler of suitable pressure and temperature is not always straightforward. I shall deal with this aspect at a later stage.

Pass-out turbo-generators are used in many industries which require both electricity and steam in their manufacturing processes, even in places where a public electricity supply is readily available. The reason for this is mainly economic.

Public electricity utilities can only use part of the heat put into the steam for the generation of electricity, the larger proportion being thrown away in the condensers. For example, in a generating station using steam at 1,500 p.s.i.g. absolute and 1,000° F., the total heat of each pound of steam entering the turbine is 1,488.5 B.T.Us. while the total heat of this steam when it enters the condenser at 28 ins mercury vacuum is 1,105.7 BTUs. Thus only 383 B.T.Us. of heat are used for generating electricity from each pound of steam supplied, the rest being dissipated to atmosphere or the local river through the condenser cooling water. Now if we assume that the temperature of the condensate extracted from the condenser is 101° F. and this is the starting temperature of the cycle, then as this water contains 69 B.T.U.s/lb the total quantity of heat supplied to the steam by the boilers is 1,419.5 B.T.Us. Therefore the 383 B.T.Us. used for the generation of electricity amounts only to 27% of the heat supplied by the boiler. By means of bleeding steam from the turbines for feed water heating and also the use of re-heat cycles, this figure can be increased to 33 or 34%. Naturally when one purchases electricity from a public utility company one has to pay for all the heat used up, not only for that small portion used for the generation of electricity.

Now, on the other hand, if a pass-out non-condensing (back pressure) turbo-generator is installed in a factory, the steam, after giving up some of its heat for generating the electrical power needs of the factory, is available for other purposes such as heating and drying, thus the cost of electricity is directly proportional to the heat absorbed and is therefore about 34% of the cost of electricity generated by a public utility company. I am referring here, of course, only to marginal costs. Such things as the interest and redemption of the capital required for the installation of the equipment would have to be taken into consideration together with the fixed charges and demand

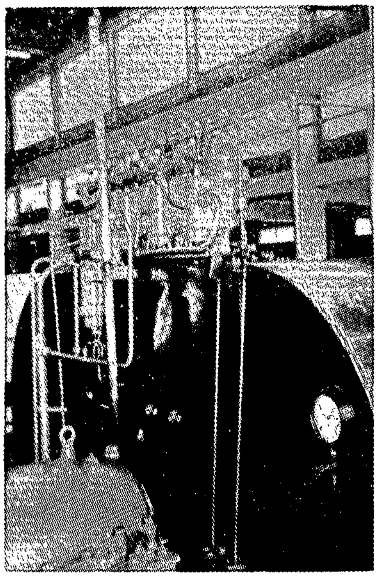


Air Operated Double Seat Reducing Valve

charges made by the supplier of electricity before one could determine whether it was an economical proposition or not. The large number of pass-out turbines installed in mills and factories throughout the world would indicate that it very often is an economic proposition.

Naturally the steam and electrical demands of a mill would have to be balanced at all times for such a unit to be workable and as this is a virtual imposibility, pass-out turbines are fitted with either an atmospheric relief valve or, which is more economical, an L.P. stage and a small condenser, to dispose of excess steam. To compensate for shortage of steam in the pass-out main, reducing stations are generally fitted between the H.P. steam main and the pass-out main. A reducing station normally consists of a double seat valve as illustrated in the sectional view above, or in the case of a small difference in pressure between the two steam mains, a butter-fly valve operated by a pneumatic or hydraulic motor.

The pass-out steam from the turbo-generator is controlled from a sensing element in the pass-out main, the control being a series of valves or a disc valve mounted on the steam chest to which the pass-out main is connected. These valves control the steam flowing to the lower pressure stages of the turbine or to the atmosphere, and not, as is often believed, the steam to the pass-out. Thus if the pass-out pressure rises, due to a fall in steam demand, the valves would open allowing steam to escape down the turbine to the condenser or directly to atmosphere. It will be realised that in the case of a condensing turbine, as more steam enters the L.P. cylinder, and provided the electrical load is constant at the time, the speed of the turbine will tend to rise. This speed change is countered by the speed governor which will reduce the steam supply to the turbine sufficiently to control the speed. As a result of this reduced amount of steam entering the turbine there will be less steam available for pass-out and therefore the pass-out pressure falls, which in turn causes the valves controlling the steam to the L.P. cylinder to close partly thus increasing the pass-out pressure and reducing the steam to the L.P. cylinders which causes the turbine to slow down. This is again compensated for by the governor and the reverse process takes place. If this is not properly controlled, severe hunting of the turbine speed and pass-out pressure can take place. Various means are adopted to prevent this hunting, all of which basically consist of means of damping the pass-out control valves to such an extent that they are sufficiently slow acting to prevent hunting. In this manner equilibrium conditions are reached fairly quickly although slight fluctuations of the pass-out pressure have to be tolerated.



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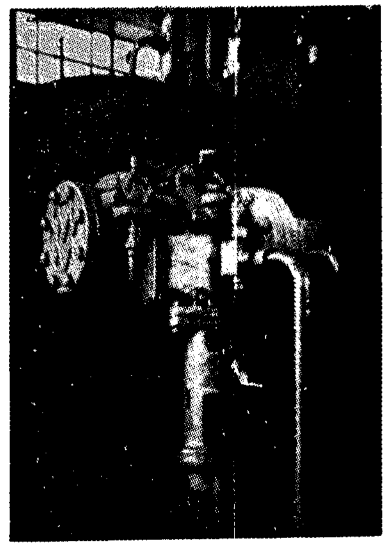

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Actuating Mechanism for Pass-out Control Valves on a 10 M.W. Double Pass-out and Condensing Turbine.

(a) H.P. Valves — 160 p.s.i.
(b) L.P. Valves — 45 p.s.i.

The response rate of reducing stations which boost the pass-out pressure must similarly be carefully adjusted to prevent hunting between the turbine pass-out control valves and the reducing station.

Reducing stations are anathema to many engineers, as no useful work is done when changing the steam pressure from a higher value to a lower value. The attitude of some engineers to reducing stations is summed up very succinctly by Sir Oliver Lyle who says that "A reducing valve is, from the thermodynamic point of view, an invention of the devil. It sets out to degrade good heat, to dissipate the good high potential. It performs its vile task to perfection until it goes wrong. The use of reducing valves might be called an admission of defeat—it is the easy way out".[1] I personally cannot agree completely with his attitude as these valves do perform a useful and in many instances a necessary function.

I would now like to refer back to the question of the choice of pressures for process steam. The mill or factory engineer has little say in this matter normally, as operating pressures are generally specified by the manufacturers of the equipment installed. Within small limits the manufacturer can vary the design pressures to fit in with steam supply equipment in an existing plant, but frequently the design pressure is based upon the temperature required for a particular process, so a steam pressure having a saturated temperature of the desired degree is chosen. Thus it is frequently necessary to generate and supply steam at one pressure to suit a particular process and then reduce and desuperheat the steam to supply another process.

The question of desuperheating is one that frequently arises. It is an axiom that superheated steam is unsatisfactory for heat exchange processes. The reason for this is that the superheated steam has to fall in temperature to give up its heat, and where the temperature difference between the steam and the substance to be heated is small, this fall in temperature of the steam reduces the temperature differential thus slowing down the heat transfer rate. Far more important is the fact that dry steam is a bad conductor of heat and therefore the steam at the heat transfer surface, which has already given up some of its heat and has dropped in temperature acts as an insulating blanket preventing the higher temperature steam from giving up its heat, thus slowing down the heat transfer process even further. On the other hand dry saturated steam gives up a large quantity of heat—latent heat—without change in temperature, i.e. the temperature differential between the steam and the product is maintained throughout the transfer of this heat.

The difference between the rate of heat transfer of saturated steam and superheated steam can be clearly seen if one looks at two cases of steam at 292° F. In the first case 45 p.s.i.g. dry saturated steam with a saturation temperature of 292° F. is used. When condensing to water of the same temperature this steam gives up 915 B.T.U. for each lb. of steam. In the other case using 40 p.s.i.g. steam superheated to 292° F. (i.e. about 5° F. of superheat) only 1 B.T.U. of heat will be given up by each lb. of steam for every 2° F. drop in temperature until the saturation temperature of 287° F. is reached after which it gives up its latent heat in the normal way without further change of temperature, but by this time the temperature is 5° F. below the temperature required for the process. Therefore when the supply steam is superheated, it is necessary to desuperheat it by injecting water into the steam line until the temperature has been brought to near saturation temperature for the particular pressure being used, before it enters the process unit.

In practice it is often found that a small amount of superheat in the steam being supplied to a unit gives the best results, especially where rate of running has to be considered side by side with efficiency. The explanation for this apparent contradiction lies mainly in the fact that by having a small amount of superheat, all lines and valves, etc. are kept dry and no energy is used up in moving unnecessary condensate around the system and the condensate removal system is handling the minimum amount of condensate. This reasoning applies equally well to long steam supply lines, as there is always a certain amount of heat loss with even the most efficient lagging, so by ensuring sufficient superheat at the supply end to have dry steam at the process end, the trouble of having to drain the steam line at frequent intervals with the consequent loss of good condensate, or expense of recovery, is avoided.

Methods of Control

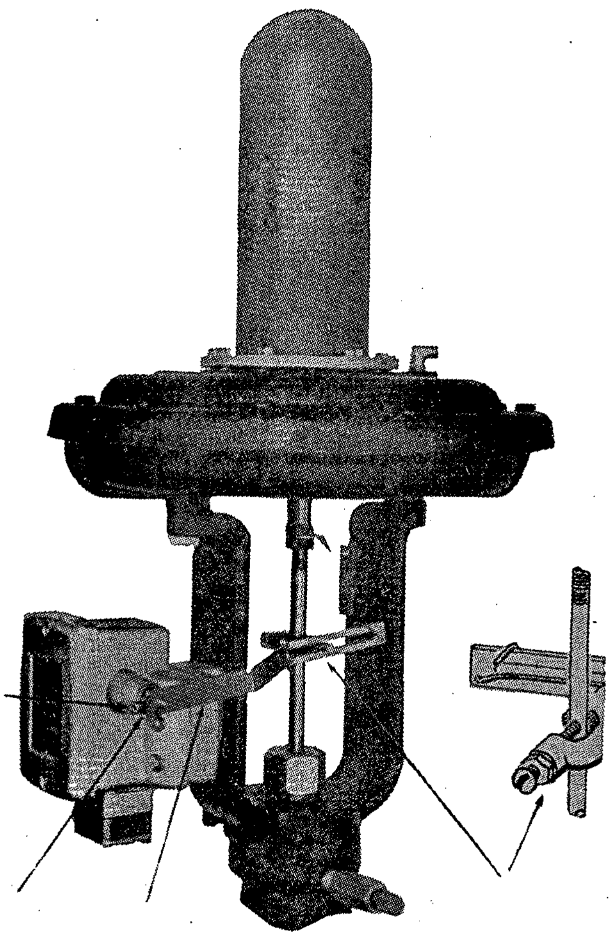
Control of process steam consists basically of measuring some parameter of the finished product, sensing any change from a required standard and as a result causing a steam valve to open or close to increase or decrease the amount of steam flowing to correct the deviation from the set standard.

Measurements such as density, viscosity, temperature, electrical conductivity, pH, etc. can be used depending on the results required. Where this can be done the control can be reasonably simple, but often it is difficult or impossible to take measurements from the product, or there is no suitable apparatus on the market to take the measurements required. In cases like this it is necessary to turn to other—indirect—means of determining what changes in the rate of flow of process steam are required.

As an example, on modern paper machines where a continuous wet sheet of paper has to be dried by passing it around a number of rotating steam heated drying cylinders, it is obvious that a reliable means of measuring the average moisture over the whole width —more than 200 inches on many modern machines— of the fast moving paper sheet, would be a virtual imposibility. As an alternative one thinks of temperature control as a means of ensuring a uniform drying rate. This, however, does present difficulties because if the temperature chosen is one above the saturation temperature of the steam being supplied, then superheated steam would have to be used and no condensation would be permitted, as this would imply a lowering of the temperature, so the steam would have to be blown in and out of the cylinder without making use of the latent heat. If, on the other hand, the actual saturation temperature is chosen, then the control becomes insensitive, as large quantities of heat can be transferred without change of temperature.

Pressure control is another method which can be adopted to maintain a constant drying rate of the paper and in this case provided that the pressure required is below the pressure of the steam supplied, a reasonably precise control can be maintained. Where such a system is used, should the moisture content of the paper in contact with the cylinder suddenly increase, it will absorb more heat from the cylinder thus lowering its surface temperature. As a result the steam in the cylinder will condense at a greater rate and cause a drop in pressure. This drop in pressure is felt by the pressure controller which opens the automatic steam valve, permitting a greater flow of steam which restores the pressure. Where a paper machine has 60 or 70 drying cylinders, it would theoretically be correct to control each cylinder pressure individually, but in practice this presents engineering difficulties in addition to excessive costs, so the machine is divided into four or five groups of cylinders, all the cylinders in one group being supplied from a common, pressure controlled, steam header. A refinement of this type of control is to measure the differential pressure between the common steam header and the common condensate header of a group of cylinders, and by maintaining a constant differential— achieved by bleeding steam to adjacent drying sections— a drying rate proportional to the moisture content of the paper can be maintained.

The instruments of control can be electrical, electronic, hydraulic or pneumatic, with pneumatic generally predominating where an extremely high rate of response is not required. Some of the reasons for this is that where compressed air is used for transmitting a signal, the same compressed air can be used for the actual mechanical operation of the necessary valves, etc. and in addition the compressed air is not toxic or dangerous to those working with it, nor do leaks cause damage to the final product or mess up machinery.

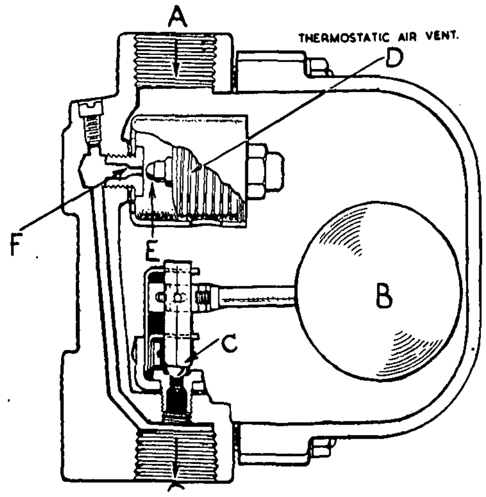


Air Motor as Fitted to Automatic Valves

Steam Trapping, Draining and Venting.

A major aspect of all process steam control is proper draining and steam trapping. It is obvious that if the steam space of a piece of apparatus becomes partly filled with water, the heat transfer area available to the steam is lessened, resulting in a drop in efficiency and a reduced running rate. Conversely if steam is allowed to blow straight through the apparatus, then it is not giving up all its heat, and this is inefficient and wasteful. To prevent a build-up of condensate or loss of steam, automatic steam traps are fitted which will ensure that condensate is allowed to drain freely without permitting the passage of steam.

Steam traps are divided into two main classes—mechanical and thermal—and are probably the most maligned of all the pieces of apparatus used with process steam. Over and over again they are blamed for the poor performance of a process when, in fact, they are being expected to do a job of work for which they are not suitable—because of a wrong choice in the first instance. Yet if properly installed and correctly sized they are reliable and long lasting. They are in fact a simple piece of apparatus which seldom fails. A careful study of the correct application of steam traps in process steam control will be well rewarded by increased efficiency and reduced costs.



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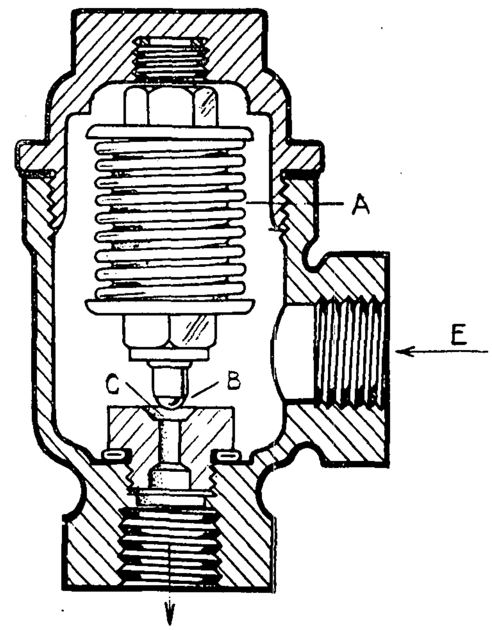

(b)

Two Typical Steam Traps

(a) Mechanical — (Ball Float)

(b) Thermal — (Thermostatic)

In conjunction with steam trapping is the question of air venting. The engineer dealing with process steam should never forget that all steam contains a certain amount of non-condensable gases, and are grouped together under the name "air" in this connection. In many instances it is actual air that has been drawn into steam spaces through glands and traps during shut-down time when the condensing steam creates a vacuum. Now, as is well known, static air is a bad conductor of heat. This feature is used frequently in every-day life, for example, warm clothes are made from material which traps and holds static numerous small pockets of air. Now when air becomes trapped in a steam space, it can reduce heat transfer in two ways. Firstly it can form a thin film all over the heat transfer surface. This thin film is very difficult and sometimes impossible to remove. Steam inlets should be arranged in such a manner that the steam enters at high velocity in a direction which will scour the heat transfer surfaces, and by this means any air that tends to cling to these surfaces is removed. Secondly, pockets of air can form in the steam space. This is as a result of the slow accumulation of air in an area which is not properly vented. Trapped air pockets prevent steam from coming in contact with a portion of the heating surface and although the air does transmit a small amount of heat, the effective heating surface is reduced, which reduces the capacity of the equipment. It is, therefore, essential that all air entering a steam space is properly vented. It is often difficult to determine where these pockets will form—generally, but not always, low down and remote from the steam inlet.

Sir Oliver Lyle states that "The essence of air venting is finding this remote point, or better still, to make the steam follow a certain path to a pre-arranged remote point. Once the remote point has been found, automatic venting can take place which will ensure that the maximum use is made of the heat transfer surfaces."[1]

Steam traps incorporating air venting are available, although in many instances it is necessary to install separate automatic air vents as the condensate path before the steam trap can prevent the removal of air.

Conclusion

No talk in the use of Process Steam would be complete without mention of heat losses. This can be one of the biggest efficiency destroyers on any steam system. All apparatus which carries or controls steam at a temperature above atmospheric will radiate heat to some degree, so if steam is generated at Point "A" and the heat is required at point "B", why waste some of the heat by heating up the space between point "A" and point "B"? Besides wasting heat, the problems of wet steam lines and condensate removal are accentuated. Good lagging is essential throughout, and not, as is so often the case, only in positions where people are likely to come into contact with the hot surfaces. Although no lagging is 100% efficient, if the tables obtainable from most lagging manufacturers are consulted, and the recommended thickness and type of lagging for any specific condition is used, a happy balance between excessive lagging costs and acceptable heat losses is obtained.

Finally, I would like to mention the safety regulations contained in the Factory, Buildings and Works Act and Regulations of 1952, to which all apparatus installed in mills in this country have to conform. Consulting these regulations can be a considerable help to engineers in the design and proper maintenance of equipment. Also as these are formed to ensure the safety of the people who have to work on or around the equipment, breakdowns are less likely to take place on equipment which conforms to these regulations, so owners should not begrudge any money spent in this connection, they should rather look upon this expense as a form of insurance.

References

1. Oliver Lyle, "The Efficient Use of Steam", H.M. Stationery Office, London. 1947.