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May 26, 2016 Intro to Superheated Steam

Here is a short article lifted from a book written in 1908 about superheated steam. Those new to the steam business will hear this term bandied about and without any explanation, either of what is happening or why it is so very important. The converse of superheated steam is saturated steam. There are many reasons why the former is much more thermodynamically efficient than the latter. For now it is best to accept this fact on faith.

There is a steam engine advertised widely on the internet as being both modern and efficient (it is neither and not even a good idea from a mechanical design perspective) that claims as one of its many virtues that it is designed for the use of saturated steam. People who know what they are doing never advertise that one of their steam engines is designed for saturated steam. That is always the default design in steam engines and not something that one aspires to be making.

Stated very simply, a pot of water will always produce saturated steam and the reason is because the temperature of boiling water (which is where the phase change from liquid to vapor takes place) is determined by the pressure the water in that container is maintained. Superheated steam is hotter than the steam that comes off the top of a container of water.

To make superheated steam one needs a superheater and while this sounds complex it is very simple, a length of metal pipe heated by the fire that the saturated steam that comes out of the boiler passes through. This steam can be heated to whatever temperature one wants irrespective of pressure. In some instances steam has been heated such that the intake steam pipe to an engine and the head and top part of the cylinder glow red hot.

One should acquire a copy of the thin book by Keenan & Keyes, being thrown out of libraries everywhere, for reference. This book has the steam tables in it where one can look up the relationship between temperature of boiling water and pressure; also the volume of steam at various pressures. Information on superheat is included.

Superheated Steam

To meet the above difficulty of the condensation of the water carried over from the boiler, it is now common to subject steam on its way to the engine, or turbine that is to use it, to a process known as superheating. Various forms of superheaters are described later in the book, but the object of all is, the heating of the steam, out of contact with the water from which it was formed, and the formation of all the watery globules, or watery vapour that is carried in suspension, into proper steam at the pressure and temperature of the steam which carries it. The process of superheating confers certain valuable properties upon the steam, that it does not possess in the saturated form. Superheated steam, according to Professor Siebel, transmits heat through an iron pipe, to water on the other side of the pipe, at only $\frac{1}{40}$th the rate that saturated steam does. It need hardly be pointed out what a very valuable property this is, in all apparatus where work is to be obtained from steam by its expansion, and by mechanical work obtained in the process of expansion. Any heat the steam loses by conduction to the cylinder or pipes through which it passes, robs it of a portion of the energy it would expend in driving the piston, or in turning the blade of a turbine wheel. In addition to the above, the specific heat of steam being only about 0·5, the steam produced from a pound of water will have its temperature raised in the proportion of 2 to 1, about, by the application to it of any definite quantity of heat. If the steam to be superheated is in a closed vessel, unable to escape, as when the engines are not taking steam, the application of heat in the process of superheating will raise the pressure of the steam, with the temperature, the pressure and temperature of steam going together in accordance with the figures given in Table 8. Where, as will more usually be the case, the steam is superheated on its way from the boiler to the engines, and is therefore free to expand, its volume will increase with the application of heat, in the same proportion as its pressure would if confined. In considering the question of superheating, it is important to know the quantity of vapour or watery globules present in the steam, and the superheating apparatus, whatever it may be, must provide sufficient heat during the passage of the steam through it, to raise the whole of the water present to the condition of proper steam, at the temperature to which the steam itself is raised. In practice, the maximum quantity of vapour that can be carried over by the steam, under ordinary working conditions, is found by test, and the superheating apparatus is arranged to furnish the necessary heat required for converting this maximum quantity of water into steam during the passage of the steam through the superheater.

Specific Heat of Superheated Steam

The specific heat of superheated steam at atmospheric pressure is taken at 0·48, but according to recent measurements, the specific heat of steam, superheated to 100° F. above the saturated state, is 0·65, and with 200°, 0·75. It is frequently taken as 0·5 for calculations.

It should be noted that the remarks made above, with reference to the additional work to be got out of superheated steam, owing to the lower specific heat, applies to a large extent to steam generated in the boiler, at higher than ordinary atmospheric pressure. Modern practice has tended to gradually increasing steam pressures. In the early days of steam, the old Cornish pumping-engine worked at only a few pounds above atmospheric pressure, the vacuum produced by condensing under the piston being relied on very largely for the work done by the engine. Even as late as thirty years ago, steam pressures of 30 lbs. or thereabouts, were very common all over the United Kingdom. Gradually, however, the pressures used have increased, first to 50 lbs., then to 80 lbs., and now pressures of 250 lbs. per square inch are not uncommon, and the increased pressures all tend to economy in coal, partly for the reason given in connection with the superheating of steam, because the specific heat of steam is so much lower than that of water, and partly because, as mentioned in a previous paragraph, the latent heat of steam steadily decreases, as the pressure increases. And it is the latent heat which forms practically the great source of waste with steam. The more the latent heat can be reduced, the more economical is the use of steam, providing that the energy delivered to the steam is economically applied.

Carnot's Law of the Efficiency of Heat Engines

The law of the efficiency of all heat engines, steam, gas, etc., which was enunciated by the French savant Carnot some eighty years ago, still rules in the heat-engine world. It is as follows:—

The efficiency $= \frac{T_1 - T_2}{T_1}$. The formula is sometimes written

$$\frac{T - T_1}{T}.$$

Where T_1 is the *absolute* temperature at which the heat is received by the engine, and T_2 is the *absolute* temperature at which it is rejected.

In using this formula, another law of heat operation rules, viz. that the final result of successive changes of heat is irrespective of the method of the changes and the steps. In the case of steam, the law may be applied separately to the boiler, to the engine, and to the condenser, or, as is more usual, it may be applied to the combination as a whole. It means that the greater the difference of temperature between the steam generated by the boiler, and that finally ejected from the exhaust of the engine, the higher is the efficiency of the plant as a whole, the greater the proportion of the heat delivered to the water that is recovered from the crank-shaft of the engine, or the shaft of the turbine. The law may be carried further back to the temperature of the furnace, and will be equally applicable, the higher the temperature of the furnace and the lower the temperature of the steam, finally ejected from the exhaust, the higher is the efficiency of the plant, and the lower the consumption of coal in the boiler furnace per B.H.P. at the steam motor-shaft should be.

It will be seen that this law explains a good many things that are at first somewhat puzzling, such as the very large increase of efficiency obtained from the steam turbine by increased vacuum, and the increased efficiency of any steam plant, with higher steam pressures. The above is subject to the steam and the heat being usefully applied. Any leakage of heat, such as radiation from the boiler surface, from the steam-pipes, and from the surface of the engine cylinders, which all go to increase the range of temperature, decrease the efficiency of the heat combination.

STEAM BOILERS, ENGINES AND TURBINES

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