

T H E S I S

"THE SUPERHEATING OF STEAM BY INTERNAL COMBUSTION"

FOR

DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

Under

Prof. R. L. Wales

by

W. C. Burnley

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THE SUPERHEATING OF STEAM BY INTERNAL COMBUSTION.

It often occurs that a mechanical subject attracts more or less wide attention and then falls into disuse for a short period, to be taken up when the conditions, governing its use, appear to be more favorable. This seems especially true with the subject of superheated steam.

Considerable attention was given to this subject as far back as the year 1850 when we find reports of tests made on engines using superheated steam, which show a remarkable increase in efficiency over those of the same engine tested with saturated steam.

Attempts were made to superheat steam by placing a coil of pipes in the fire box of the furnace. Then by passing through the coils, the steam was superheated. This was not satisfactory because the joints would not stand the expansion without leakage and secondly because the temperature of the furnace was so high that the coils were easily burned out.

The Babcock and Wilcox Co. have made superheaters to go with their water tube boilers. These superheaters are placed in the middle pass of the hot gases where the temperature is not so high. Hence these superheaters are of longer duration than those discussed in the preceeding paragraph.

It is plainly seen that the reasons for failure of the old types of superheaters is due, first, to the extensive expense required to keep the superheaters repaired. The pipes or coils are always in contact with hot gases, and since steam is not a good conductor of

of heat, the pipes contain the extra heat that should be conducted into the steam; second, to the difficulty of maintenance. The pipes are so placed to gather the most heat and are generally in the furnace setting. These superheaters require some attention, and since it is not possible to enter the furnace while in operation, no attention can be given them until the plant is closed.

With the Internal Superheater, it will be shown that an entirely different line has been followed. The method is more of a direct way and is intended to give better results than the superheaters of the present day. The plan is as follows: To inject a gaseous fuel compressed with the necessary air for its combustion, directly into the steam main and to ignite it, and allow the hot gases and flames to mix with the steam.

The great advantage in superheating steam in this manner is the efficiency. All the heat is available and with the proper apparatus an efficiency of 100% could be obtained.

By superheating steam we also increase the thermal efficiency. We may raise the temperature at which the steam receives its heat and so increase its efficiency without producing a dangerous pressure. According to the law of efficiency in heat-engines, the heat transformed into mechanical energy bears the ratio to the whole heat received by the fluid as the range of temperatures is to the absolute temperature at which the heat is received. Peabody gives the following formula for efficiency: $E = \frac{T_1 - T_2}{T}$. It is seen from this formula, that the higher initial temperature, the greater the efficien-

cy which can be obtained. This temperature is to be obtained by superheating the steam.

The prevention of initial condensation during admission without the use of steam-jackets is one of the most important advantages that can be attached to the use of superheated steam. If the superheating were sufficient to carry the steam through the engine to the cut-off without becoming saturated steam, the necessity of a steam jacket would be obviated. Hence more work could be obtained per pound of engine without the steam-jackets.

To show the theoretic value of such a superheater, let us assume a case. Suppose we had a 50 H.P. engine working at an absolute pressure of 100# per square inch; also assume the quality of the steam to be 98%; that it be desired to give the steam 100° F superheat using Producer Gas that has a calorific value of 130 B.T.U.s per cubic feet and that the engine requires 25# superheated steam per H.P. per hour. Suppose the run be made for an hour.

The total water used by engine = 1250 lbs. The temperature of steam at 100# absolute is 327.5. There would be 25# water in steam. Heat of vaporization at this pressure is 884. $884 \times 25 = 22100$ B.T.U. required to evaporate 25# water at 100# absolute pressure.

Heat required to superheat 1250# steam 100° F is $1250 \times 100 \times .48 = 60000$ B.T.U.

Then total heat given to the steam would be $60000 + 22100 = 82100$ B.T.U.

Let us estimate that the efficiency was 96%. It would require 85500

B.T.U. to give this result. And if the gas evolved 130 B.T.U. per cubic foot, this would require 660 cubic feet of gas per hour. To produce this gas would cost 5 cts. per 1000 cubic foot or 3.3 cts. per hour. The cost of producer gas was found from the Engineering Record. This shows that the cost to superheat steam 100° F for such an engine per H.P. hour would be 3.3 cts. To accomplish this would mean much more to the user of steam and he would gain by the superheat many times the price paid for superheating.

The advantages obtained from this type of a superheater would be: No radiation losses, simplicity, durability and low cost of repairs. The additional heat would be supplied immediately before entering the steam chest, hence the superheated steam would not have to travel through a long line of pipe, thus a large part of the radiation is prevented. A superheater thus placed could be closely watched so that when in need of repairs it could be given attention. Such a superheater would also show marked durability since the steam is not heated by conduction, but by direct contact with the flame. Deterioration need not be great since all parts are surrounded by steam; hence will not readily burn out. These reasons would give such a superheater precedence over the present ones.

The apparatus for testing is shown by plate No. 1. It is very simple in construction. It consists of a combustion tube, A, see plate 1, surrounded by the steam main. The lighting device B, which with the aid of a spark coil and spark plug set fire to the gases; and a pipe line C, to carry the compressed gases into the combustion tube.

The operation was thus: the gas and air, in the proper proportions to burn, were compressed in a compressor, passed through a water-seal to prevent striking back. Just before entering the combustion tube, small pieces of quartz were placed in the gas pipe to secure the prevention of back-firing. A calorimeter was placed in the steam main to determine the quality of steam. A gage and thermometer well determined the pressure and temperature respectively. A condenser was used to determine the amount of steam per hour.

Several tests were made to determine the efficiency of the apparatus with different results.

The difficulty seemed largely to be in the fact that the gas was not measured correctly. The gas was drawn through the pipes by a compressor and at each stroke of the pump, the gas would momentarily rush through the meter. This would give the moving parts of the meter inertia and would allow them to move and indicate that gas was being used when perhaps there would be a vacuum in the pipe and possibly a short distance beyond the meter. As to showing that this is possibly true; the gas-meter always moved in jerks at the same instant the pump would make a stroke. Better apparent efficiency was obtained when a small supply of gas was used.

This difficulty could be easily overcome by placing a tank in the pipe line just before the gas was drawn in the compressor. This would take up the pulsations of the pump and would allow a continuous stream of gas to flow through the meter and would cause it to register correctly.

The results of three tests will be given to verify the above

statement:

Length of run	45 min.
Barometer	14.2# per sq.in.
Steam pressure abs.	44.2#
Temperature of steam	376.5° F.
Quality of steam	99.4%
Per cent of moisture in steam	.6%
Amount of steam used per hour	113.6#
Amount of gas used per hour	75.2 cu.ft.
Amount of water in steam	.68#
Amount of superheat	103.5° F.
Heat required to superheat 113.6# water 103.5°F	5600. B.T.U.
Heat " " vaporize .68# water	629 B.T.U.
Total heat added	6229 B.T.U.
Heat used from gas	41450 B.T.U.
Efficiency of apparatus	15%
Length of run	15 min.
Barometer	14.3# per sq.in.
Steam pressure abs.	44.9# "
Temperature of steam	292.8° F.
Quality of steam	98.8%
Per cent moisture in steam	1.2%
Amount of steam used per hour	216 #
" " gas " " "	40 cu.ft.

Amount of water in steam	2.6#
Amount of superheat	18.6°F.
Heat required to superheat 216# steam 18.60°F.	1940 B.T.U.
" " " vaporize 2.6# water	2498 "
Total heat given steam	4438 "
Heat given up by gas	22000
Efficiency of apparatus	20 %
Length of run	10 min.
Barometer	14.3#
steam pressure abs.	35.1#
Temperature of steam	298.3° F.
Quality of steam	97.1%
Per cent moisture in steam	2.9%
Amount of steam used per hour	197.8#
" " gas " " "	36 cu.ft.
" " water in steam	5.7#
Amount of superheat	38.3° F.
Heat required to superheat 197.8# steam 38.3°F.	3640. B.T.U.
" " " vaporize 5.7# water	5320 "
Total heat given steam	8960 "
" " " up by gas	19220 "
Efficiency of apparatus	46.5%

By inspecting these tests it is seen that the more gas used the less the efficiency of the apparatus. This shows that the meter reading was too high because of the inertia given the revolving

parts by the pulsations of the pump.

This superheater could be put into practical use better than the présent superheaters. For instance take a practical case. To furnish the gas use a Suction Gas Producer, pass the feed water before entering feed water heater around the hot gases. This would cool the gases and also give some heat to the feed water. A compression cylinder could be attached to the cylinder of the engine and worked from the same piston rod. The combustion tube could then be placed in the steam line just above the lubricator, thus making a very efficient plant.

In conclusion it might be said that the reason the experiment did not give satisfaction was due to the fact that the gas meter did not read correctly but otherwise the test was successful in every detail.

