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Performance Evaluation of Radiant Oil Heat Exchanger

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Abstract: Double pipe heat exchangers are used to recover heat between two process fluids and electric heaters are used to heat fluids by using electrical energy in various processes in various industries. The Pipe in Pipe Heat Exchanger is a combination of double pipe heat exchanger and electric heater. The fluid flowing through the conduit is heated with the help of electric heater. In this paper, fabrication of pipe in pipe heat exchanger and standardization in industrial scale by studied theoretical and experimental values for parameters like friction factor, Reynold number, convective heat transfer co-efficient within the mass flow rate range between 0.17 Kg/sec – 1.41 Kg/sec

Keywords* — *Heat Exchanger, Concentric pipe, Heat Transfer Co-efficient, Reynolds Number, Electric Heater, Radiation

I. INTRODUCTION

Electric heating is a process in which electrical energy is converted to heat energy. Common applications include space heating, cooking, water heating and industrial processes. An electric heater is an electrical device that converts an electric current into heat. The heating element inside every electric heater is an electrical resistor and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use Nichrome wire as the active element; the heating element, depicted on the right, uses Nichrome wire supported by ceramic insulators.

Advantages of electric heating methods over other forms include precision control of temperature and distribution of heat energy, combustion not used to develop heat, and the ability to attain temperatures not readily achievable with chemical combustion. Electric heat can be accurately applied at the precise point needed in a process, at high concentration of power per unit area or volume.

Pipe in Pipe Heat Exchanger utilizes counter flow to maximize the temperature difference between the shell side and tube side fluids which results in less surface area required for a given duty. These exchangers are suitable for high pressure, high temperature, extreme temperature crossing and low to moderate surface area requirements.

Pipe in pipe heat exchanger is used to heat the dowtherm oil. This oil is in turn used to heat the kerosene oil which is further used for oil impingement in the transformers. The design, analysis and implementation of heat exchangers are an important part of heat transfer. Fabrication of any double pipe heat exchanger requires inner pipe, outer pipe, fitting material, temperature measuring device (PT100), pressure gauge and stop watch etc. Once fabricated, the heat exchanger should be standardized by calibrating different heat exchanger parameter such as Reynold number, friction factor, pressure drop, heat transfer coefficient with standard equation and graph. Standardization of the new fabricated setup is the most important step.

The project is combination of Pipe in Pipe heat exchanger and electrical radiant heating. It has advantages of flow pattern of double pipe heat exchanger and precision control of temperature of electric heating. For this type of arrangement, it is important to study the flow parameters of liquid in exchanger along with the heat pickup and temperature rise.

II. SPECIFICATION OF THE SETUP

The experimental study is done in a double pipe heat exchanger having the specification as listed in Table 1. The procedure of the experiment is as follows:

1. Switch on the heater.
2. Allow the oil to flow for about 10-11 min so that the heater elements attain its desired temperature.
3. The oil flow is adjusted with the help of bypass valve to fix the Reynolds number. We also

measure the flow rate of oil through heat exchanger with the help of flow meter.

4. For the given Reynolds number, we take the readings of oil temperature across the heat exchanger in the interval of one min duration.
5. The temperature readings are then used to calculate the actual heat transfer co efficient and actual power utilized.

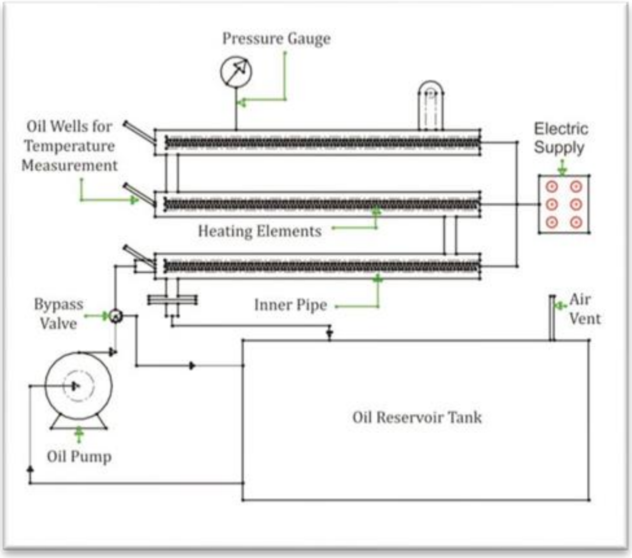

Fig.1: Layout of heat exchanger

Power Input	20kW, 415V, 3 Phase
Pipe Material	AISI 1010
No of exchanger units	6
Pipe length (mm)	1160
Active length (mm)	1120
OD of outer pipe (mm)	108
ID of outer pipe (mm)	100
OD of inner pipe (mm)	48
ID of inner pipe (mm)	40
Material of formers	Ceramic
No of formers in each pipe	22
Material of wire	Ni-chrome
No of heating elements	12
No of turns in each element	2457
Wire gauge	22
Wire diameter (mm)	0.64
Tank capacity (liters)	100
Flowmeter	Rotary type
Temperature measuring instrument	Platinum Resistance Thermometer
Centrifugal pump	$11m^3$/hr. 2900 rpm
Number of valves	2 (Drain-off, Bypass)
Heat Exchanger Fluid	Dowtherm Oil
Insulation Material	Glass Wool

Table 1: Heater Specifications

III. Standardization Of The Setup

Standardization of the experimental setup is done by obtaining the friction factor & heat transfer results for the smooth tube & comparing them with the standard equations available.

At 50℃, the oil properties are:

Flow rate = 30lpm = 5×10^{-4} m^3/s

Cross sectional area = 6.044×10^{-3} m^2

Density = 940 kg/m^3

C_p = 1.748 kJ/kgK

k = 0.1183 W/mK

Calculation of heat exchanger is carried out by calculating heat transfer coefficient. For the same radiation from inner surface to outer surface of inner pipe needs to be calculated to determine surface contact temperature. By radiation the contact temperature is calculated as 285 ℃.

Theoretical value of h

Q = A×V

Thus velocity = 0.0827 m/s

And mass flow rate = 0.47 kg/s

$$Re = \frac{\rho VD}{\mu} = 2126$$

Pr = 28.1

Using Sieder-Tate equation,

$Nu = 0.027\times Re^{4/5}\times Pr^{1/3}$

Nu = 85 W/m^2K

Actual value of h

ΔT = 12℃ within one minute

Thus, rise in temperature per second = 0.2℃

Time for one pass = 0.0827×1.12×6 = 81 sec

Thus, temperature rise in one pass = ΔT = 16℃

$Q = mC_p\Delta T = 0.47\times1.478\times16 = 13.14$ kW

$Q = UA\Delta T$

Surface of the pipe = 0.1749 m^2

Temperature of the surface = 285℃

13.14 = h×0.1749×6× (285-50)

h = 53.3 W/m^2K

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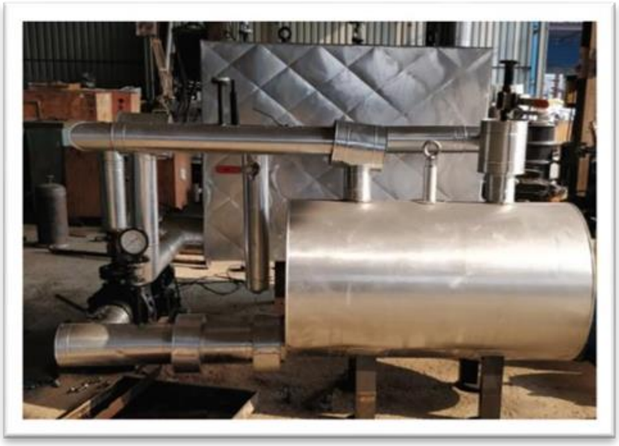

Fig.2: Experimental Setup Of Heat Exchanger

IV. RESULT AND DISCUSSION

Reynolds Number	Theo. value of h (W/m^{2}K)	Actual value of h (W/m^{2}K)	Power output (kW)	Effectiveness (%)
771	38	21.7	5.35	26.75
2126	85	53.5	13.14	65.7
3550	129	14	3.41	17.05
6431	207	11	2.46	12.3

Table 2: Observations

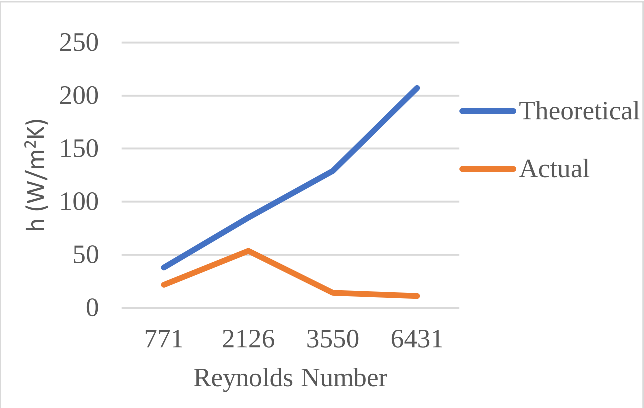

Fig.3: Plot of h v/s Reynolds Number

Thus, we can see from the above observations that the heat transfer co-efficient increases with increase in the Reynolds number within laminar region of the flow. As the flow enters in the turbulent region the heat transfer co-efficient goes on reducing with the Reynolds number.

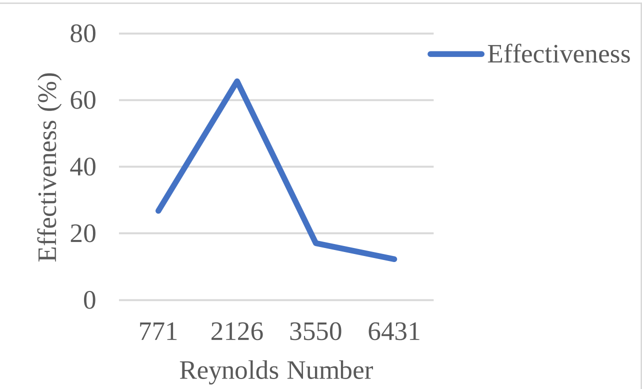

Fig.4: Plot of Effectiveness for various flow

Similarly, the power output also shows the same behavior as of the heat transfer coefficient, it increases with Reynolds number in laminar region and reduces with Reynolds number in turbulent region.

V. CONCLUSION

Now we can see that maximum effectiveness is obtained at the end of the laminar region and near the transition stage. So, we can calculate the Reynolds number for the corresponding maximum effectiveness and pass the oil at that flow rate to achieve maximum temperature rise.

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