EXPERIMRNT 12: TO FIND THE HEAT TRANSFER COEFFICIENT FOR DROP WISE CONDENSATION AND FILM WISE CONDENSATION PROCESS.

Introduction

In all applications, the steam must be condensed as it transfer heat to a cooling medium, e.g. cold water in the condenser of a generating station, hot water in a heating calorimeter, sugar refinery, etc. During condensation very high heat fluxes are possible & provided the heat can be quickly transferred from the condensing surface to the cooling medium, heat exchangers using steam can be compact & effective.

Theory

Steam may condense on to a surface in two distinct models, known as “Film wise” & “Drop wise”. For the same temperature difference between the steam & the surface, drop wise condensation is much more effective than film wise & for this reason the former is desirable although in practical plants it rarely occurs for prolonged periods.

Instrument image

Film Wise Condensation

Unless specially treated, most materials are wet table & as condensation occurs a film condensate spreads over the surface. The thickness of the film depends upon a numbers of factors, e.g. the rate of condensation. The viscosity of the condensate and whether the surface is vertical or horizontal, etc.

Fresh vapor condenses on to the outside of the film & heat is transferred by condition through the film to the metal surface beneath. As the film thickness if flows downward & drips from the points leaving the film intact & at an equilibrium thickness. The film of liquid is a barrier to the transfer of heat and its resistance accounts for most of the difference between the effectiveness of film wise and drops wise condensation.

Drop wise condensation

By specially treating the condensing surface the contact angle can be changed and the surface becomes ‘non-wet table’. As the steam condenses, a large number of generally spherical beads cover the surface. As condensation proceeds, the beads become larger. Coalesce, and then strike downwards over the surface. The moving bead gathers all the static beads along its downward in its trail. The ‘bare’ surface offers very little resistance to the transfer of heat and very high fluxes are therefore possible.

Unfortunately, due to the nature of the material used in the construction of condensing heat exchangers, film wise condensation is normal. (Although many bare metal surface are ‘non-wettable’ this is not true of the oxide film which quickly covers the bare material)

Description

The equipment consists of a metallic container in which steam generation takes place. The lower portion houses suitable electric heater for steam generation. A special arrangement is provided for the container for filling the water. The glass cylinder houses two water cooled copper condensers, one of which is chromium plated to promote drop wise condensation and the other is in its natural state to give film wise condensation. A connection for pressure gauge is provided. Separate connections of two condensers for passing water are provided. One Rota meter with appropriate can be used for measuring water flow rate in one of the condensers under test.

A digital temperature indicator provided has multipoint connections. Which measures temperatures of steam, two condensers, water inlet & outlet temperature of condenser water flow?

Experimental procedure

1. Fill water in steam generator by opening the valve.
2. Start water flow through one of the condensers, which is to be tested and note down water flow rate in Rota meter. Ensure that during measurement, water is flowing only through the condenser under test and second valve is closed.
3. Connect supply socket to mains and switch ON the heater switch.
4. Slowly steam generation will start in the steam generator of the unit and steam rises to test section, gets condensed on the tubes and falls down in the cylinder.
5. Depending upon type of condenser under test Drop wise or Film wise can be visualized.
6. If the water flow rate is low then steam pressure in the chamber will rise and pressure gauge will read the pressure. If the water flow rate is matched then condensation will occur at more or less atmospheric pressure or up to 1 Kg pressure.
7. Observations like temperatures, water flow rates. Pressures are noted down in the observations table at the end of each set.

Specification

Condenser: One chromium plated for drop wise condensation & one natural finish for Film wise condensation otherwise identical construction.

Dimensions: 45 mm outer dia. 170 mm length. Fabricated from copper with reverse flow in concentric tubes. Fitted with temperature sensor for surface temp Measurement.

Main Unit: M.S. Fabricated construction comprising test section & steam generation section. Test section provided with glass cylinder for visualization of the process.

Heating Elements: Suitable water heater (3 kW)

Instrumentation:

1) Temperature Indicator: Digital 0-199.9 ° C with multi-channel switch.
2) Temperature Sensors : RTD PT – 100,K type
3) Rota meter for measuring water flow rate.
4) Pressure Gauge: Dial type 0-2 Kg/cm^2

Observations & Calculations

D_i = 35 mm D_o=45 mm

Sr.no.			
Steam Pressure Kg/ cm^2			
Condenser Under Test			
Water Flow Rate LPM			

Temperature

Plated Condenser Outer Surface	**T_1**			
Plain Condenser Outer Surface	**T_2**			
Steam	**T_3**			
Water Inlet to Condenser	**T_4**			
Water Outlet from Condenser	**T_5**			

Calculation

Film wise condensation

Water flow m_w = kg/sec

Water inlet temperature T_4 = °C

Water outlet temperature T_5 = °C

Heat transfer rate at the condenser wall,

$Q = m_w \times C_p \times (T_5 - T_4)$

Where,
C_P = Specific heat of water = 4.186 k J / Kg K

A =π x d x L m^3 Surface area of the condenser

Where,
d=dia of condenser=0.045 m
L=length of condenser=0.170 m

Experimental heat transfer coefficient

$$h = \frac{Q}{Ax(Ts - Tw)}$$

Where,

T_S= Temperature of steam (T_1)

T_W = Condenser wall temperature (T_2 or T_3)

Theoretically, for film wise condensation heat transfer coefficient

$$h=0.943 \quad \left(\frac{h_{fg} \times \rho^2 \times g \times k^3}{(T_S - T_W) \times \mu \times L}\right)$$

Where

h_{fg} = Latent heat of steam at T_S J/kg (take from temperature tables in steam tables)

ρ = Density of water, Kg/m

g = Gravitational acceleration, m/sec^2

k = Thermal conductivity of water w/m°C

μ = Viscosity of water, N.s/m^2

L = Length of condenser = 0.170 m

Above values at mean temperature, $T_m = \frac{T_S+T_W}{2}$ °C (from data book)

Conclusion

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Marks Obtained **Sign of Faculty**