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AN EXPERIMENTAL STUDY OF THE INTERFACE OF A CONDENSING VAPOUR REGION

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Abstract—An experimental study of the nature and characteristics of the interface between a condensing vapour region and the fluid outside is carried out. The interface is generated as a result of condensation at one end of an enclosed region, open to the atmosphere at this end, and is accentuated by the density difference between the fluids on either side. The study considers the steady-state and transient behaviour of the interface. The dependence of its location and thickness on the amount of vapour condensed is determined. The variation of the mean temperature and velocity and of the temperature disturbance level across the interface are studied in order to determine the basic characteristics of such an interface. The magnitude of mixing across the interface is also considered in terms of disturbance to the interface and the amount of vapour generated by the heat input. The study provides information for the design of such systems, in terms of the dependence of the important features of the interface on the parameters of the condensation system.

NOMENCLATURE

- d, thickness of the interface;
- D, diameter of the condensation zone;
- L, latent heat of vaporization of the condensing fluid;
- $\dot{m}$, mass rate of introduction of the interfacing fluid into the condensation zone;
- Q, heat input into the system;
- Q_c, characteristic heat input, defined as the heat input for unit rate of generation of the condensing vapour;
- Re, Reynolds number based on condensing vapour properties and on the diameter D;
- t, mean temperature;
- t_r, room temperature;
- t_c, saturation vapour temperature of the primary condensing vapour;
- t_i, temperature in the interfacing region;
- t_{ib}, saturation vapour temperature of the interfacing condensing vapour;
- t'_{max}, maximum local temperature disturbance;
- U_0, uniform axial velocity of the vapour in the condensation zone away from the condensing coils, defined in equation (1);
- V, horizontal, or radial, mean velocity;
- x, vertical distance from the bottom of the coils, Fig. 1;
- y, horizontal distance from the wall of the condensation zone, Fig. 1.

Greek symbols

- τ, time;
- τ_c, characteristic time, taken as time taken by liquid to attain its boiling point starting at the room temperature.

INTRODUCTION

THIS paper considers the nature of the interface that arises between a condensing vapour region and the fluid outside. If the vapour is enclosed in a given space, which is open to the atmosphere at one end and where condensation occurs circumferentially, an interface is generated with the ambient fluid as a result of the condensation process of the vapour. The study of such an interface is of considerable importance in considerations of vapour containment in the region and of mixing of fluids on either side of the interface. These considerations relate to fluid loss from the system and to the shielding effects of the interface. This configuration arises in several practical circumstances. Among the most important of these is the condensation thermal processing system, such as that employed for metal bonding, degreasing, curing, etc. [1–3]. In several other cases of condensation heat transfer and also in many experimental arrangements, condensation occurs at the cooled condensing surfaces and gives rise to an interface which is similar to that generated in an enclosed region of the condensing vapour, discussed above. In all such cases, the interface arises predominantly due to the condensation of the vapour and the consequent flow field generated adjacent to the condensing surfaces. It would obviously be accentuated by a stable stratification due to the density difference between the fluids on either side.

Condensation over surfaces has been studied in considerable detail [4–6]. However, the nature of the interface that results from the condensing action, in a vapour zone open to the ambient, has not been studied in detail, although some minor experimental information does exist [1–2].

Similarly, the nature of the interface between two fluids of different density has been the object of study of several investigators, as discussed by Turner [7]. One may anticipate the basic features of a condensation interface in terms of many of these known results. The present work is directed at an experimental study of this interface and the determination of its nature, in terms of temperature and velocity variation across it, and its dependence on the various parameters of the system.

The basic configuration considered is that of an enclosed region, in which vapour is continuously generated by a supply of heat to the contained liquid and one end of which contains the condensing surfaces, in the form of condensing coils, where the interface is generated. Fluids whose vapour density is larger than that of air are considered. Of particular interest were the transient nature of the interface, the temperature and velocity variation across it, effect of disturbance on the stability of the interface and on mixing across it, and the dependence of the location and spread of the interface on the amount of vapour generated.

Several very interesting results are obtained. It is found that the interface is very sensitive to disturbances, which cause a significant enhancement in fluid mixing across it. The temperature and velocity gradients are found to be very sharp, with most of the variation occurring in the region of the lower end of the condensing coils, which is also found to be the most disturbed region in the condensation zone. A variation in the amount of vapour generated and, hence, in that to be condensed, is found to shift the interface slightly but to essentially leave the thickness of the interface unaffected over a fairly wide variation of the heat input. A change in the fluid which forms the interfacing region, with the primary condensing vapour, is found to significantly affect the interface and its basic characteristics. The paper determines the basic features of the interface and provides extensive information for the design of such thermal processing systems.

EXPERIMENTAL ARRANGEMENT

An experimental arrangement for the study of the interface, generated due to condensation, between the condensing vapour and the ambient fluid, must consist of a mechanism, for the generation of the vapour, and of a condensation region, in contact with fluid outside, where condensation occurs and gives rise to the interface. The system considered for the present study is shown in Figs. 1 and 2, the former being in terms of the inviscid flow field and the latter as the actual physical system. Vapour is generated by the supply of heat to a boiling liquid sump at the bottom of a container, at the top end of which condensing coils are located circumferentially. Condensation at this end gives rise to an interface with the fluid outside.

The experiment was carried out in two cylindrical glass containers, each of diameter 0.3 m, the heights being 0.45 and 0.65 m. Stainless steel condensing coils, of diameter 0.01 m and of six turns, were located near the top of the condensing vapour region and were maintained at a temperature lower than the boiling point of the fluid by circulating water through them. The glass tank was insulated with glass wool so as to minimize the heat loss at the sides and to have most of the condensation at the coils. The heat input was through resistive heaters, capable of supplying up to 5 kW, positioned in the liquid whose depth was kept around 0.08 m. The fluid outside the condensation region was usually air at atmospheric pressure. Interfacing with another lighter condensing fluid of lower boiling point, as compared to the primary fluid, was also considered. In this case, a separate set of coils was needed for the condensation of the interfacing fluid. The bigger tank

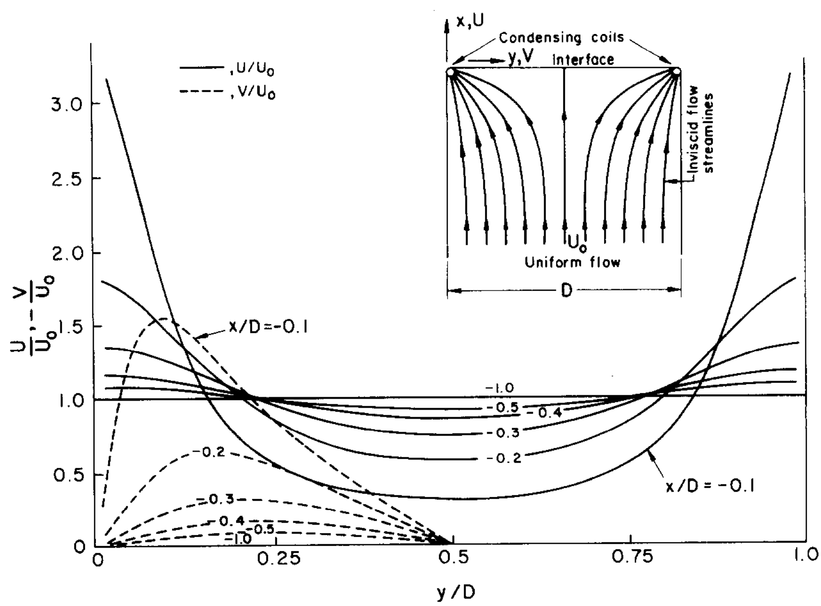

FIG. 1. Inviscid flow field in the condensation region.

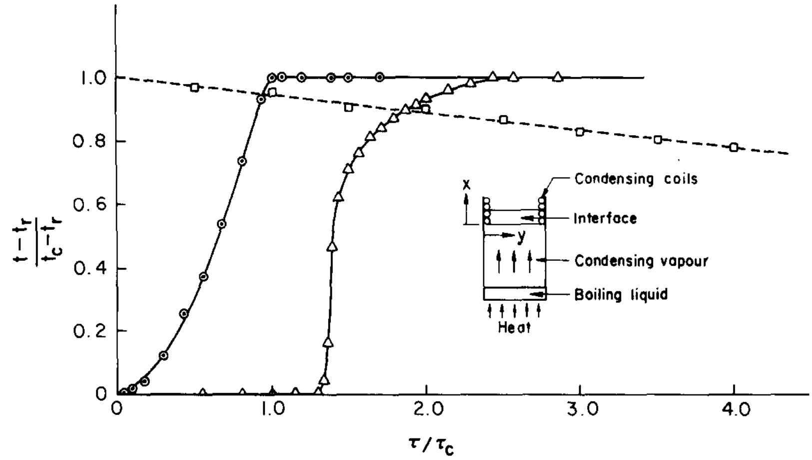

FIG. 2. The transient temperature response of the liquid during heating and cooling and of the condensing vapour zone during heating. Data: ⊙, Liquid temperature following start up; □, Liquid temperature following shut down; △, Vapour temperature just below the condensing coils.

was employed and the primary condensation region was kept the same as that with air as the interfacing fluid. The temperature of water through the lower coils was kept higher than the boiling point of the interfacing fluid and lower than that of the primary, or higher boiling, fluid. This ensures condensation on the lower, or primary, coils of only the primary fluid. This arrangement is of practical interest in systems where the condensing interfacing vapour provides a blanket to the primary fluid and, thus, reduces the loss of the more expensive primary fluid. This relates both to conservation of fluid and to environmental considerations. In arrangements, where the fluid for thermal processing is not very expensive and does not cause environmental problems, as is the case in degreasing systems, air would be the natural interfacing fluid. The condensation region being open to the atmosphere, the pressure is atmospheric and the liquid boils at its standard boiling point.

The fluid to be chosen for study had to have several important characteristics. Its boiling point must be high enough, so that it remains liquid at room temperature and also provides the temperature level necessary for the thermal process of interest, and its vapour density must be high, compared to air, for a stable stratification which would aid the containment of the vapour. Several liquids are suitable and the two fluids chosen were a high boiling fully fluorinated Fluorocarbon (boiling point 215°C and vapour density $21.0\,\mathrm{kg\,m^{-3}}$) and R113, trichlorotrifluoroethane (boiling point 47.6°C and density $7.4\,\mathrm{kg\,m^{-3}}$), chosen mainly for their availability, inertness and applicability in many cleaning and heating processes, see, for instance, [1–3]. Most of the other properties are in the range generally known for Freons, [2].

Extensive temperature measurements were taken to study the general nature of the temperature field in the two regions and in the interface. These were obtained from several fixed and movable chromel–alumel thermocouples of $1.25 \times 10^{-4}\,\mathrm{m}$ wire diameter. The output was measured and recorded on a strip chart recorder. Velocities were measured by means of a Disa high temperature hot-wire probe, 55A75, capable of measuring in media at temperatures up to 750°C, employing a sensor overheat ratio of 1.4 for the medium temperatures encountered in this study. No condensation occurs on the sensor due to its high temperature and care was taken to avoid condensate flow from the supports on to the hot wire. Calibration of the hot wire was done in corresponding condensing vapour by employing cylindrical flow channels, of varying diameter, located over the region of vapour generation, the velocity being determined from the condensate collected and the fluid loss. It was also checked with the value obtained from the amount of vapour generated, as determined from the heat input. However, repeatability of only about 10% was observed and a more accurate calibrating device is needed for greater accuracy in the measurements. In this study, only a few traverses of the two regions were taken to determine the general nature of the flow in the interface. The location and extent of the interface was inferred from the temperature measurements. The heat input to the system was obtained from the measurement of current and voltage input to the heaters. Measurements of the mean and disturbance temperature and of mean velocity were taken. Weight measurements were used in the determination of quantity of interfacing fluid added to the system.

RESULTS AND DISCUSSION

The flow under study is generated as a result of heat input into the liquid at the bottom of the condensation zone and the removal of the vapour thus generated as condensate at the condensing coils. This condensate could be removed from the system and allowed to flow back to the boiling liquid sump. The flow can, therefore, be looked upon as a uniform flow in the region far from the coils, with the coils themselves as sinks where the flow eventually converges. This can be further visualized, for the diameter D of the container large compared to the interface thickness d, as a two-dimensional flow resulting from a uniform flow approaching two line sinks, located as shown in Fig. 1, with the interface at the level of the coils. This flow can be analyzed quite easily for the inviscid flow circumstance and the general nature of flow, thus generated, is shown. The velocity components are normalized by the uniform flow velocity U_0, generated due to the heat input, and the distances x and y by D. The velocity field is, then, one that arises from a series of equal and equidistant sinks along the y-axis and is obtained from Streeter [8] as:

$$U = -\frac{2\pi C/D}{\cos h\left(\frac{2\pi x}{D}\right) - \cos\left(\frac{2\pi y}{D}\right)} \sin h\left(\frac{2\pi x}{D}\right) \quad (1)$$

$$V = -\frac{2\pi C/D}{\cos h\left(\frac{2\pi x}{D}\right) - \cos\left(\frac{2\pi y}{D}\right)} \sin\left(\frac{2\pi y}{D}\right), \quad (2)$$

where $2\pi C$ is the strength of the sinks and is related to the flow rate. The uniform axial velocity U_0 that arises at large negative x is $2\pi C/D$ and is employed in the nondimensionalization.

The velocity profiles across the flow region at various values of x/D are shown. At large distances from the coils, the flow is essentially uniform, with U approaching U_0 and V approaching zero. The axial velocity is essentially uniform in the central region due to symmetry and the radial velocity is zero. In the figure, only half of the V-component profile is shown, the profile being symmetric about the central axis. It is interesting to note that the uniform flow condition is attained in a distance of only about one diameter D away from the interface and that even at $x/D = -0.1$, the axial velocity is quite uniform in the central region. The vertical velocity component approaches high values near the coils due to flow concentration. The coils being finite in an actual circumstance, the interface will have a finite thickness and three dimensional and viscous effects will also alter the flow field. However, the general features of the flow will be expected to be similar to those shown. Mixing would occur across the interface due to disturbances and due to the flow in the two regions, resulting in fluid loss from the condensing region. These aspects are of particular interest in this study.

The transient behaviour of the condensation region, with the high boiling fluorocarbon interfaced with air, is shown in Fig. 2. The measured temperature t is nondimensionalized as $(t-t_r)/(t_c - t_r)$, where t_r is room temperature and t_c the saturation vapour temperature of the condensing vapour. A thermocouple was located in the liquid and another in the vapour zone slightly below the condensing coils. Temperature differences of order 0.5°C could be measured to an estimated inaccuracy of about 5%. As the heat is turned on, the lower thermocouple records a temperature rise after a certain time interval, which is a function of the heat input, liquid properties and the location of the thermocouple. Time is measured from the instant this thermocouple records a temperature change and is nondimensionalized by a characteristic time τ_c, which is simply the time taken by the liquid temperature, as measured by the thermocouple, to rise from the room temperature to the boiling point of the liquid. This characteristic time is obviously a function of the fluid properties, heat input and loss to the environment. It is, therefore, a characteristic of the system. The thermocouple in the liquid shows a steady rise and the other thermocouple shows a temperature change following the onset of boiling in the liquid. It shows a very steep initial rise, followed by a more gradual approach to the saturation vapour temperature at atmospheric pressure. This indicates the vertical rise of a sharp interface, between the vapour and air, which diffuses out as the open end of the container is reached. Visually too, an almost horizontal and distinct interface was seen to rise gradually upwards. The sharp temperature rise is registered as this interface crosses the thermocouple. Due to mixing with air as a result of disturbance at the open end, the interface initially diffuses out and is eventually established as a distinct and sharp demarcation between the two regions. The time taken for the interface to be established, following the onset of boiling in the liquid, is also found to be close to τ_c for the system under study.

Also shown in Fig. 2 is the liquid temperature decay following the turning off of the heat input. Since the cooling is largely by natural convection, a slow rate of cooling is observed. Up to a time interval four times τ_c, only 20% of the total temperature drop has occurred. Due to this slow cooling, the liquid remains at fairly large temperatures for a large period of time, resulting in significant fluid loss due to the high saturation vapour pressure at these temperatures. A need to accelerate the cooling process to reduce fluid loss is, therefore, indicated.

The variation of the mean temperature with height x is shown in Fig. 3. The measured temperature t is

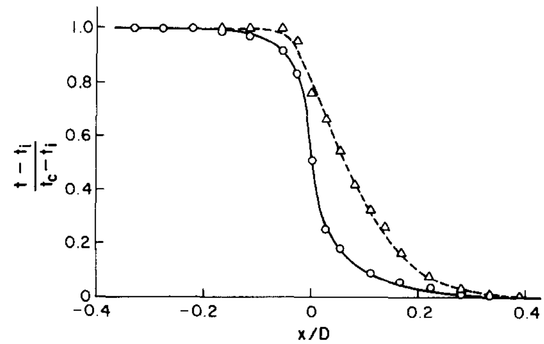

FIG. 3. Mean temperature variation across the interface. Data: ○, High boiling fluorocarbon interfaced with Refrigerant 113 vapour; △, R113 Vapour interfaced with air.

nondimensionalized with the uniform temperatures t_c and t_i in the condensing and interfacing regions respectively as $(t-t_i)/(t_c-t_i)$. The temperature variation is shown for two cases, one when the high boiling fluid is interfaced with Refrigerant 113 and the other when the latter interfaces with air. Horizontal traverses of the thermocouple revealed that the temperature variation was small, as expected from buoyancy effects generated due to temperature differences. Figure 3 shows several interesting and important features. The temperature gradient is found to be very steep, being much steeper for the higher boiling fluid. The maximum value of the temperature gradient is about $60°C\,cm^{-1}$ and about $10°C\,cm^{-1}$ in the other. This is expected from the larger temperature and density difference between the two zones in the first case. The heat input was adjusted so that the amounts of vapour generated in the two cases were essentially equal. The condensing coils stretch from $x = 0$ to $x = 0.2D$. It is observed that condensation causes a temperature variation, due to mixing and thermal diffusion, well before $x = 0$ and right up to the end of the coils, though most of the condensation occurs in a region close to $x = 0$. The temperatures in the two regions were found to be essentially uniform. For an interface with another condensing vapour, as in the first case, the temperature in the interfacing region was found to be larger than the boiling point of the interfacing fluid, R113, due to mixing across the interface. For air open to the atmosphere as the interfacing fluid, the temperature in the interfacing region was, obviously, close to the room temperature, being larger for a partially enclosed region, again due to leakage across the interface. This aspect is considered in detail later.

The mean velocity variation with x along the centreline of the condensation zone, is shown in Fig. 4. The velocity is presented as Reynolds number Re, based on the properties of the high boiling vapour, which interfaces with air in this case. The diameter D is used as the characteristic dimension. The velocity of the vapour is found to be uniform in the region away from the coils, as expected from the inviscid solution, and this uniform velocity is attained in a very short distance away from the bottom of the coils. The velocity in air is essentially zero, since the ambient medium is stationary. The velocity distribution shows a sharp decline to zero from the high uniform value measured in the condensation zone. The distance over which this variation occurs is even smaller than that for the temperature variation. This indicates that the flow in the interface occurs over a very short distance and thermal diffusion, without large scale mixing, leads to the interfacing fluid being heated over a larger distance. Due to the stable stratification that exists, not much flow would occur vertically, though the temperature distribution does spread out. In the case of an unstable stratification, as would be the situation for a vapour lighter than the interfacing fluid, large scale mixing and flow would arise and the narrow interface observed here would not be expected.

The nature and magnitude of disturbances in the interface were also studied to determine the level of mixing there and the resulting stability of the interface. On one hand, it is a stably stratified circumstance and, on the other, a temperature difference exists, between the two zones, which is expected to give rise to motion. A comparison of $\Delta\rho/\rho$, where ρ is the density of saturated primary vapour and $\Delta\rho$ the density difference across the interface, for the two considerations, indicates a comparable effect. The Rayleigh number Ra is found to be very large, around 10^8, and, hence, turbulent

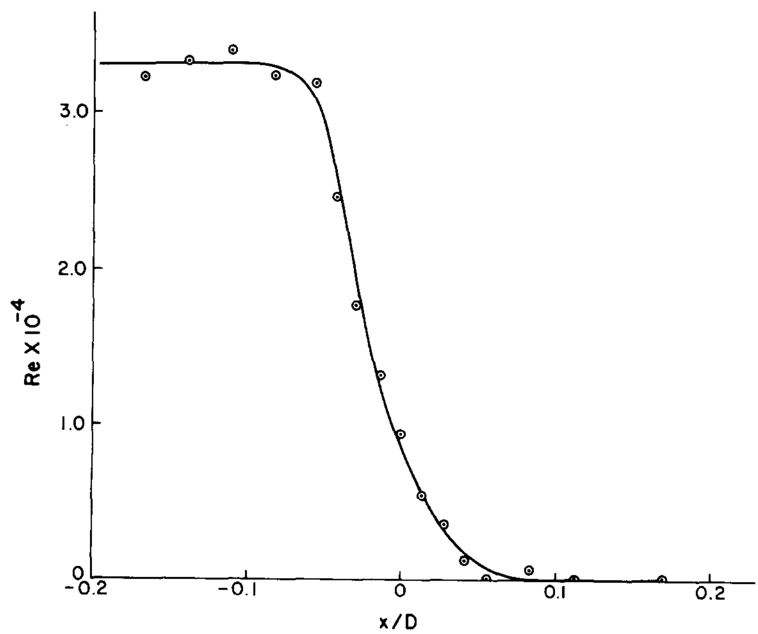

FIG. 4. Mean velocity variation across the interface, along the centreline of the system, in terms of the Reynolds number Re of the vapour.

flow is expected if a stable stratification were not present, the problem then being simply of heating from below [9]. Here $Ra = g\beta\Delta T x^3/v^2 \cdot Pr$, where g is acceleration due to gravity, β the coefficient of thermal expansion of vapour, x the thickness of the interface, ΔT the temperature difference across it, v the vapour kinematic viscosity and Pr its Prandtl number. However, due to the density gradient that exists, the instability is considerably curbed (Jaluria and Gebhart [10]) and the disturbance magnitudes are much smaller than what is anticipated in a turbulent natural convection flow, as measured by Jaluria and Gebhart [11]. The distribution of the measured local maximum of the temperature disturbance t'_{max}, normalized by the mean temperature difference across the interface $(t_c - t_i)$, is shown in Fig. 5, for the primary high boiling fluid interfaced with R113 and also for the latter interfaced with air. mixing and consequent fluid loss across the interface.

The dependence of the location, in x, and the depth of the interface on the heat input Q was also studied. This is a very important consideration in the design of such systems, since it relates to the extent of condensation surface to be provided. The results obtained are shown in Fig. 6. The heat input Q is nondimensionalized by a characteristic value Q_c which is taken as the heat input needed for a unit rate (1 kg s^{-1}) of vapour generation. Therefore, Q_c is proportional to the latent heat of vaporization of the fluid employed for the primary zone and Q/Q_c is related to the amount of vapour generated for the given heat input. The heat input is partially lost to the environment and the remaining goes into the generation of the vapour. Figure 6 shows the dependence of the location of the two edges of the interface on the heat input. The edges are taken as vertical positions where 1% change has occurred from that across the interface. For the results shown, the interface is between the high boiling fluid and air. Therefore, it is much sharper and narrower than the curves shown earlier in Fig. 3, for a given Q. The value of Q/Q_c employed here ranges from 0 to 0.07.

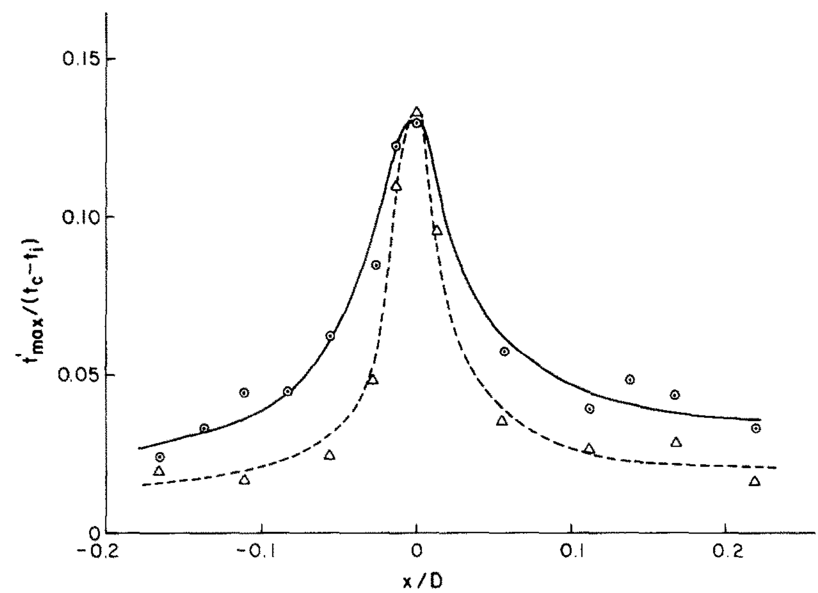

FIG. 5. The variation of the maximum local temperature disturbance t'_{max} across the interface. Data: ⊙, High boiling fluorocarbon interfaced with Refrigerant 113 vapour; △, R113 vapour interfaced with air.

The curves are very similar in form and show that the maximum temperature disturbance is about 15% of the temperature difference $(t_c - t_i)$ across the interface. The disturbance level is, therefore, not as large as may be expected in similar natural convection flows, mainly because of the stable stratification that exists. Another interesting feature is that the disturbance peaks sharply at $x = 0$ for both cases. Therefore, the most disturbed region is the level at which condensation commences. The curves are almost symmetrical in form and the disturbance dies out very rapidly away from $x = 0$. The high boiling fluid gives a broader profile, perhaps due to larger Δt involved in the flow. The bottom of the condensation coils is, therefore, an important location with respect to instability and disturbance in the interface. This indicates the need to keep external disturbance to this layer small and to keep a strong stable stratification, in order to minimize the

The two curves in Fig. 6, for the edges of the interface, are similar in form, in that they both rise sharply with increasing Q, at low values of Q, and then more gradually beyond Q/Q_c of around 0.03. This is a very interesting result since it points out that for a high enough Q, the location of the interface is largely independent of the heat input. As Q is increased the lower edge of the interface rises very sharply indicating that the increased velocity, which results at larger Q, pushes up the interface. However, the interface then stabilizes and does not move up significantly with increasing Q. Interestingly, the lower edge stabilizes just above the bottom of the

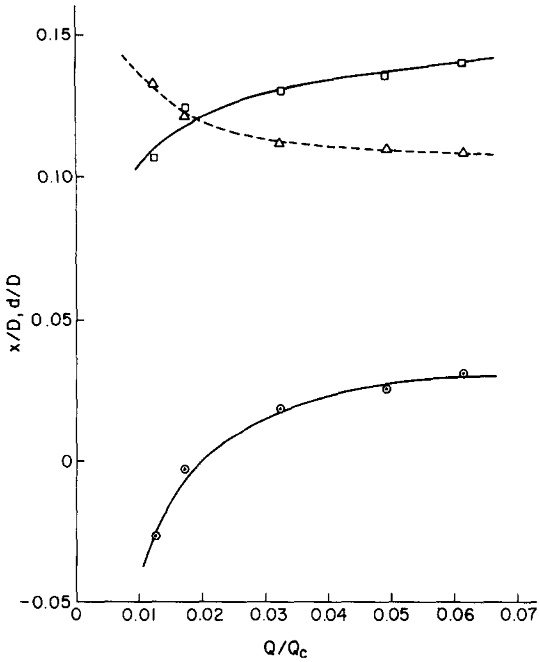

FIG. 6. The dependence of the position and thickness of the interface on the heat input Q. Data: ⊙, Lower edge of the interface; □, Upper edge of the interface; △, Interface thickness.

coils, at $x/D \approx 0.03$. The upper edge rises less sharply and continues to move gradually with increasing Q. The depth of the interface shows a steep decline as Q is increased, indicating the initial establishment of the interface, and then becomes essentially independent of Q beyond $Q/Q_c \simeq 0.04$. Therefore, this figure shows that as Q is increased from fairly low values, the interface undergoes significant variation till Q is high enough for a proper establishment of the interface, beyond which there is only a slight shift in the interface and its thickness becomes essentially independent of the heat input. At low values of Q, the amount of vapour generated is small and the condensation mechanism is not strong enough to give rise to a sharp well defined interface, which is then achieved as Q increases. The increasing amount of condensate must give rise to an increasing velocity level in the interface. Most of the condensation is again found to occur in the immediate vicinity of the lower most condensation coils. The results, nondimensionalized with D, may be expected to hold as long as a narrow well defined interface exists. For large diameters, a weak interface would result and these results may be modified if the interface thickness is comparable to the chamber diameter D.

The amount of the high boiling fluid that leaks out from the system across the interface and mixes with the interfacing fluid is a function of the heat input and interface characteristics. For an enclosed interfacing region, as in the case of another condensing vapour region or a partially covered zone containing air, the temperature of the interfacing fluid rises due to high boiling fluid loss across the interface. Therefore, the temperature in the interface region is a measure of the fluid leakage across the interface and, hence, of the effectiveness of the interface in fluid containment. Figure 7 shows the dependence of the temperature in the interfacing air region as a function of the heat input. The measured temperature t_i in the interfacing region is nondimensionalized in terms of the saturation vapour temperature t_c of the condensing vapour and the room temperature t_r. A gradual rise in temperature with Q is observed.

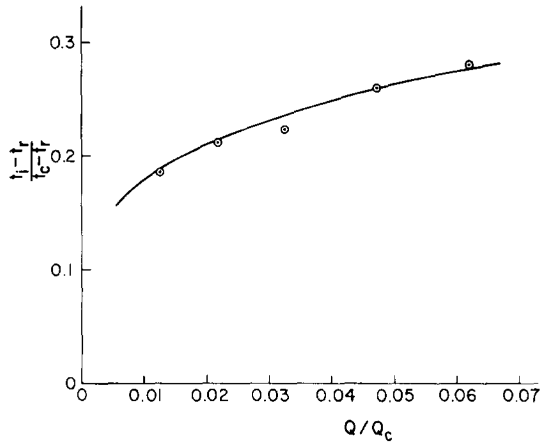

FIG. 7. The dependence of the measured temperature t_i, in the interfacing region, on the heat input, with air as the interfacing fluid and the high boiling fluorocarbon as the primary condensing fluid.

This indicates a continued increase in leakage across the interface with increasing Q. As discussed above, the interface thickness and, hence, its containment effectiveness are essentially unaltered with increasing Q. But the flow velocity increases, leading to an increased fluid loss across the interface into the interfacing region, where the temperature rises in consequence. These measurements are taken along the vertical central axis, the horizontal temperature uniformity in the central region being established due to buoyancy effects, as observed from horizontal traverses and mentioned above.

The stable stratification that exists due to the density difference, between the primary condensing vapour and the interfacing fluid, helps in the containment of the former. However, a disturbance to the interface will lead to a greater mixing and hence to greater fluid loss across the interface. This disturbance may be due to a component, to be thermally treated, being lowered into the condensation zone or due to some other external agency which introduces a significant mixing of the vapour and the interfacing fluid. Figure 8 shows the effect of such a disturbance resulting from the introduction of cold interfacing liquid into the hot primary zone which interfaces with R113. The flow rate of the injected liquid is nondimensionalized by Q/L, where L is the latent heat of the primary fluid and is related to the rate of primary vapour generation. The temperature in the interface region t_i is nondimensionalized in terms of t_c and the saturation

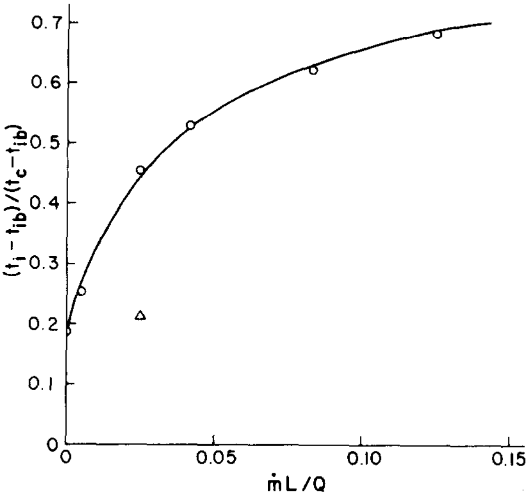

FIG. 8. The variation of the measured temperature t_i, in the interfacing region, employing R113 as the interfacing fluid, with the rate $\dot{m}$ of introduction of R113 into the primary zone. Data: ○, R113 introduced as liquid; △, R113 introduced as vapour.

vapour temperature t_{ib} of R113. It is seen to increase rapidly with the amount of liquid injected, since this liquid boils and vaporizes in the hot zone causing a significant disturbance to the interface as a result of this violent action. This leads to greater mixing and, hence, to greater primary fluid concentration in the interface region, resulting in a higher temperature. The measured temperature for the case when the interfacing fluid is introduced as a vapour, so that the violent boiling action does not occur, is also shown. Clearly, the mixing introduced is much less, as indicated by a much lower temperature. These results are of importance in the design and maintenance of a shielding region and in the minimization of fluid transfer across the interface.

CONCLUSIONS

An extensive experimental study of the interface, between a condensing vapour region and an interfacing fluid, has been carried out. Of particular interest were the transient and steady-state characteristics of the interface. Measurements of mean temperature and velocity variation with height were taken to study the nature of the profiles in the interface and their dependence on the parameters of the condensation system. The location and depth of the interface were inferred from the measured temperature profiles and their dependence on the heat input was studied. The nature of temperature disturbance at the interface was also investigated. The effect of the condensing vapour loss across the interface and, hence, of the heat input and of disturbance to the interface, on the temperature in the interfacing zone was determined.

The interface was found to be very distinct and sharp, the temperature and velocity gradients being high. It was found that the lower edge of the interface is a very disturbed region due to the condensing action of the vapour. The establishment of the interface, following the turning on of the heat input was found to be a fairly uniform process. The characteristic time required for its establishment was determined. An interesting result obtained in this study was the significant dependence of the characteristics of the interface on the heat input at low values of vapour generation. It became essentially independent of the heat input once the interface was properly established. A disturbance to the interface was found to lead to a significant mixing of the fluids on either side of the interface and hence to a greater loss of the primary condensing vapour across the interface. The two regions on either side were found to be fairly uniform in flow and in temperature, a sharp change being observed only at the interface, a disturbance to which leads to a decrease in the effectiveness of primary fluid containment.

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UNE ETUDE EXPERIMENTALE DE LA FRONTIERE D'UNE REGION DE VAPEUR EN CONDENSATION

Résumé—On développe une étude expérimentale sur la nature et les caractéristiques de l'interface entre une vapeur qui se condense et le fluide externe. L'interface résulte de la condensation, sur une frontière tournée vers l'atmosphère, accentuée par la différence de densité entre les fluides de part et d'autre. L'étude concerne le régime permanent et le comportement transitoire de l'interface. La dépendance de sa situation et de son épaisseur sur la quantité de vapeur condensée est déterminée. Les variations de la température moyenne, de la vitesse et du niveau de la perturbation de température à travers l'interface sont étudiées de façon à déterminer les caractéristiques essentielles de cet interface. L'importance du mélange à travers l'interface est considérée en fonction de la perturbation de l'interface et de la quantité de vapeur créée par l'apport de chaleur. L'étude fournit une information sur la description de tels systèmes en considérant la dépendance des caractéristiques de l'interface vis-à-vis des paramètres du système en condensation.

EXPERIMENTELLE UNTERSUCHUNG DER GRENZFLÄCHE EINES KONDENSIERENDEN DAMPFGEBIETES

Zusammenfassung—Eine experimentelle Untersuchung von Art und Eigenschaften der Grenzfläche zwischen einem kondensierenden Dampfgebiet und der außerhalb befindlichen Flüssigkeit wurde durchgeführt. Die Grenzfläche entsteht als Ergebnis der Kondensation an einem Ende eines abgeschlossenen Gebietes, das an diesem Ende offen zur Atmosphäre hin ist, und sie ist gekennzeichnet durch einen Dichteunterschied der Fluide auf beiden Seiten. Die Untersuchung berücksichtigt den stationären Zustand und das Übergangsverhalten der Grenzfläche. Es wird die Abhängigkeit ihrer Lage und Dicke von der Menge des kondensierenden Dampfes ermittelt. Um die grundlegenden Eigenschaften einer solchen Grenzfläche zu bestimmen, wurden einerseits die Veränderung von Mitteltemperatur und Geschwindigkeit, andererseits das Ausmaß der Temperaturstörung senkrecht zur Grenzfläche untersucht. Es wird auch die Größenordnung der Vermischung über die Grenzfläche hinweg, ausgedrückt durch ihre Störung, und die Menge des durch Wärmezufuhr erzeugten Dampfes betrachtet. Die Untersuchung bietet Information für die Auslegung solcher Systeme und zwar, indem die Abhängigkeit der wichtigen Merkmale der Grenzfläche von den Bestimmungsgrößen des Kondensationssystems angegeben wird.

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ МЕЖФАЗОВОЙ ПОВЕРХНОСТИ ПРИ КОНДЕНСАЦИИ ПАРА

Аннотация — Проведено экспериментальное исследование структуры характеристик границы раздела между областью конденсирующегося пара и внешней областью жидкости. Граница образуется в результате конденсации пара в части области, контактирующей с внешней средой. Исследованы стационарный и переходный режимы формирования границы раздела. Определена зависимость положения и толщины границы от количества конденсирующегося пара. Для определения основных характеристик межфазовой границы исследованы изменения её средней температуры и скорости, а также уровня температурных возмущений поперёк границы. Степень смешения в поперечном сечении анализируется исходя из возмущений границы раздела и количества пара, образующегося в результате подвода тепла. Результаты исследования могут использоваться при проектировании соответствующих систем на основании данных о влиянии параметров системы на основные характеристики границы раздела.