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POOL BOILING HEAT TRANSFER WITH MERCURY AND MERCURY CONTAINING DISSOLVED SODIUM

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Abstract—Mercury was boiled from type 304 stainless-steel horizontal cylindrical heaters of ¾-in/dia. with the system pressure varied from 24 to 1170 mm Hg, pool detph from 7 to 34 cm and sodium concentration from 0 to 0·232 wt %.

Increasing system pressure increased the heat-transfer rate at a given condition in pure mercury and mercury containing more than 0·041 % sodium; the inverse effect was observed at a sodium concentration of 0·0036 %. The effect of pool depth was insignificant especially at high system pressure; local liquid temperatures exceeding the surface saturation value were detected only at great pool depths at low system pressure. Immersion up to 8 weeks had little effect on the type 304 S.S. mirror-finish heating element. Increasing sodium concentration has an adverse effect on the heat-transfer coefficient up to a certain level and then the trend changed. Up to 0·232 wt % of sodium addition in mercury did not raise the heat-transfer rate above the comparable value for pure mercury. Boiling results were found reproducible on many spot checks after an initial period of operation of the apparatus.

INTRODUCTION

INTEREST in a boiling-condensing intermediate heat exchanger for the ING thermal neutron facility [1] led to a study at Chalk River Nuclear Laboratories on the improvement of heat transfer in mercury by the addition of sodium under saturated pool-boiling conditions.

Earlier work associated with mercury binary-power cycles and high-temperature coolants for nuclear reactors was reviewed. Conflicting trends appear in the available data and no satisfactory correlation is possible. Surveys on liquid–metal boiling in general [2, 3] were found useful in the literature search.

Lyon *et al.* [4] studied heat transfer in liquid metals in saturated pool boiling. The heater was a ¾-in dia. horizontal tube made of type 316 stainless steel. Their vessel, 3·25 in dia. × 5 in long, was charged with mercury with and without additives at atmospheric pressure. Chromel–alumel thermocouples imbedded in the wall of the heater (at top and side) measured temperatures that were used to determine the boiling surface temperatures. They concluded that pure mercury (and pure cadmium) experienced only film boiling upon reaching the saturation temperature and attributed this effect to the inability of these liquid metals to wet stainless steel. Additives in mercury increased the heat-transfer coefficient, as much as ten times for 0·1 % sodium addition.

Bonilla *et al.* [5] boiled mercury with and without additives on a horizontal low-carbon steel plate, fitted in a 3 in O.D. stainless-steel tube, at pressures from 4 mm Hg to 45 lb/in^2, with pool depths between 2 and 10 cm. Contrary to Lyon's results, Bonilla *et al.* stated that after the test surface had been in frequent use for a few weeks over a range of boiling temperature and heat fluxes, film boiling was never obtained with pure mercury; presumably boiling removed the last traces of oxygen or oxide from the surface. They found that mercury containing small amounts of magnesium and titanium yielded immediate wetting of the test surface,

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further increasing heat flux at a given temperature driving force by some 25 per cent.

Avery [6] studied the effect of the surface geometry on boiling mercury and mercury with 0·1 % sodium. He used two boiling plates in an apparatus that was similar to Bonilla's. Despite efforts to reproduce identical surface conditions on each plate, the two different plates gave considerably different results, and Avery concluded that there was significant difference in the microscopic geometry of the two surfaces.

More recently, Shimazaki [7] reported results for pool-boiling heat transfer in mercury from a vertical heater sheathed in Haynes 25 alloy. He studied the effect of system contamination and various clean-up procedures. Because of the difference in geometry, his results are not comparable to those in the present work.

Because of conflict and sparsity in the information on pool-boiling mercury, the present work was initiated to provide design information for such systems. Extensive and systematic experimental studies were carried out, including the effect of sodium concentration in mercury on heat transfer rate from type 304 S.S. horizontal cyclindrical heaters placed in a large pool of the liquid metal.

EXPERIMENTAL APPARATUS

The experimental apparatus consisted primarily of a vertical boiling vessel containing an electrically heated horizontal test tube. Other major appurtenances, as shown schematically in Fig. 1, were a vertical water-jacketed condenser, guard heaters, an outer pressure vessel, inert gas supplies, vacuum systems, sample stations, charge and dump tanks and instrumentation. All equipment and lines coming in contact with liquid metal or its vapor were made of type 304 stainless steel. Components were assembled by Heli-arc welding with type 347 S.S. welding rods. Where welding was impractical, Swagelok type 316 S.S. compression fittings were used.

Boiling took place from the surface of an 8 in long × $\frac{3}{4}$ in O.D. electrically heated test section extending completely across the long dimension in the lower part of a 4 × 8 × 24 in high boiling vessel.

The test tube was a specially developed electrical heater, as shown in Fig. 2, consisting of an X-750 Inconel tube placed inside boron nitride electrical-insulation sleeves and swaged into a type 304 S.S. tube. Five iron–constantan thermocouples insulated with alumina and sheathed in type 316 S.S. tubing of 0·020 in O.D. were embedded in grooves machined on the inner wall of the test tube. Six voltage tappings were provided along the heating element for the accurate measurement of power dissipation.

A water-cooled condenser removed the heat from the boiling vessel. Fifteen parallel cooling coils of $\frac{1}{2}$ in O.D. were welded around the condenser sleeve to make up three separate cooling systems.

The outer vessel was fabricated from $\frac{1}{4}$-in thick mild steel plate rolled into a 20 in I.D. × 40 in long cylinder, flanged at the top and capped at the bottom. This vessel was necessary to (a) control the atmosphere around the boiling vessel thus reducing oxidation of the heating element, (b) balance the inert gas pressure with the system pressure, to avoid distorting the shape of the boiling vessel and (c) contain toxic liquid metal within the vessel should there be any leak. A $\frac{1}{4}$ in O.D. × 1 in long quartz tube was placed at the center of the bottom cap through a welded Swagelok fitting for the visual detection of any liquid metal leak in the system.

All necessary provisions such as thermocouples, voltage tappings, power leads to both guard heaters and the main test section, charging and discharging lines, etc., into the boiling and outer vessels were made through the blank flange using Conax glands. To maintain the liquid metal as free of oxides as possible, filtered argon gas was used as a cover gas. Liquid–nitrogen cold traps were provided in the vacuum system to remove condensibles. A cold trap was also provided just above the boiling vessel to

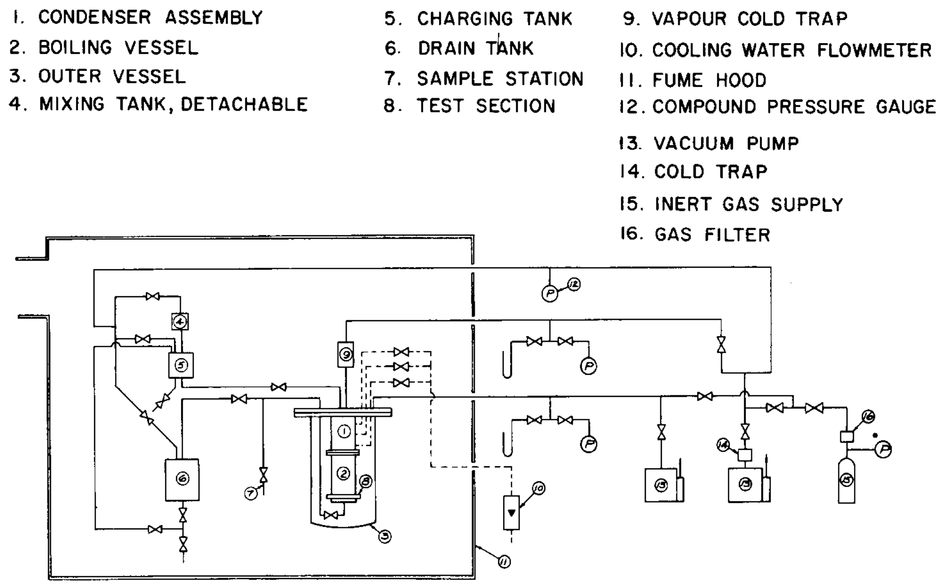

FIG. 1. Schematic diagram of experimental apparatus.

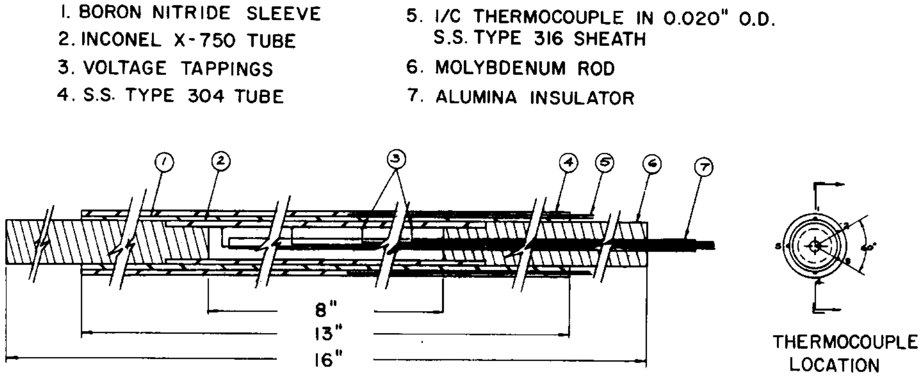

FIG. 2. Heating element assembly.

condense and trap any liquid–metal vapor which might penetrate beyond the condenser.

Power to the test section was supplied from a 30 KVA, 15 V, 2000 A a.c. power source controlled by a motor-driven variac on the primary side. Power to the test section was measured by means of a 1000/5 current transformer, calibrated ammeter and voltmeter. Guard heaters consisted of four sections of Nichrome wire wound over insulation around the boiling vessels. This made it possible to operate only a part or all of the guard heaters depending on the pool depth in the boiling vessel. A 3 kW 110 V a.c. variac with I/C Pyr-O-Vane control powered the guard heaters which maintained the temperature of the pool.

Thermocouples used in the apparatus, except those in the test tubes, were either 0·040 in O.D. or 0·250 in O.D. stainless steel sheathed, alumina insulated, ungrounded iron–constantan couples.

All of them were calibrated up to 1300°F. The temperatures of the liquid and vapor space were measured by six thermocouples, two of which were vertically adjustable to measure temperatures at any desired location throughout the boiling vessel.

The boiling apparatus was located inside a fume hood, as shown in Fig. 3, which had a mercury vapor detector and an exhaust. Power supply control and recording equipment were console mounted, outside the fume hood. Temperatures of primary importance were recorded on either a single-pen strip chart, a 16 point recorder, or by a potentiometer. Thermocouple selection switches allowed for the continuous monitoring of any one temperature of interest. Thermocouples in the test heater were also used as the temperature-sensing elements of a power-shutoff circuit to avoid burn-out of the test-heater. Pressure in the vessels were measured either by open-end mercury manometers or by calibrated Bourdon gauges, depending on the operating pressure range. The level of the liquid was measured by an insulated probe which could be lowered until electrical contact was made with the liquid surface.

The test liquids were analysed by spectrophotometry before and after the test.

EXPERIMENTAL PROCEDURE

Upon completion, the apparatus was thoroughly cleaned by repeated washings with dilute nitric acid followed by distilled water, and then flushed with acetone. It was then vacuum dried, tested for pressure and vacuum, and any leaks were corrected. In all subsequent cleaning, concentrated nitric acid was used to remove traces of the test liquid in the boiling vessel and this was followed by distilled water and acetone rinses.

A preliminary test was performed with distilled water as the test fluid and the results compared with those obtained by other works [4, 8] who used similar test geometry. This gave an indirect calibration check of the present apparatus. After the water test, the water was drained from the system, and then it was evacuated while heated to over 250°F for over 40 h to remove traces of water.

Two procedures for charging the boiling vessel with test liquids were adopted. For the pure mercury experiment, a known amount of triply distilled mercury was poured into the charging tank (see Fig. 1) which was then evacuated and refilled with purified cover gas several times to ensure a dry and inert atmosphere in the system. For mercury–sodium tests, a measured amount of pure metallic sodium was charged into a glass capsule within a dry-box having an inert atmosphere. The sealed capsule containing sodium was then placed with pure mercury in the mixing tank (see Fig. 1) which has filters made of fine mesh stainless steel. Mechanical shaking of the tank broke the capsule and mixed the sodium with mercury. The test liquid was then transferred into the boiling vessel by pressurising the charge tank from the cover gas supply.

With the test liquid at the correct depth in the vessel, the power to the guard heater(s) was turned on to bring the test liquid to the desired saturation temperature. When thermal equilibrium was reached, temperature and pressure readings were recorded. Power to the test heater was increased in steps up to a certain maximum heat flux. At each power level, the power to the guard heater was automatically adjusted to maintain the desired liquid pool temperature, and when a steady state was reached (within 20–60 min), temperature, pressure and power readings were recorded. In some cases, tests were made with decreasing power to see if there was a hysteresis. Usually only one test run was made in a day and the same test condition was repeated (once or more) on some later day to check the reproducibility of data.

RESULTS AND DISCUSSIONS

The range of the variables investigated in the present study is shown in Table 1.

The distilled water test results are plotted in

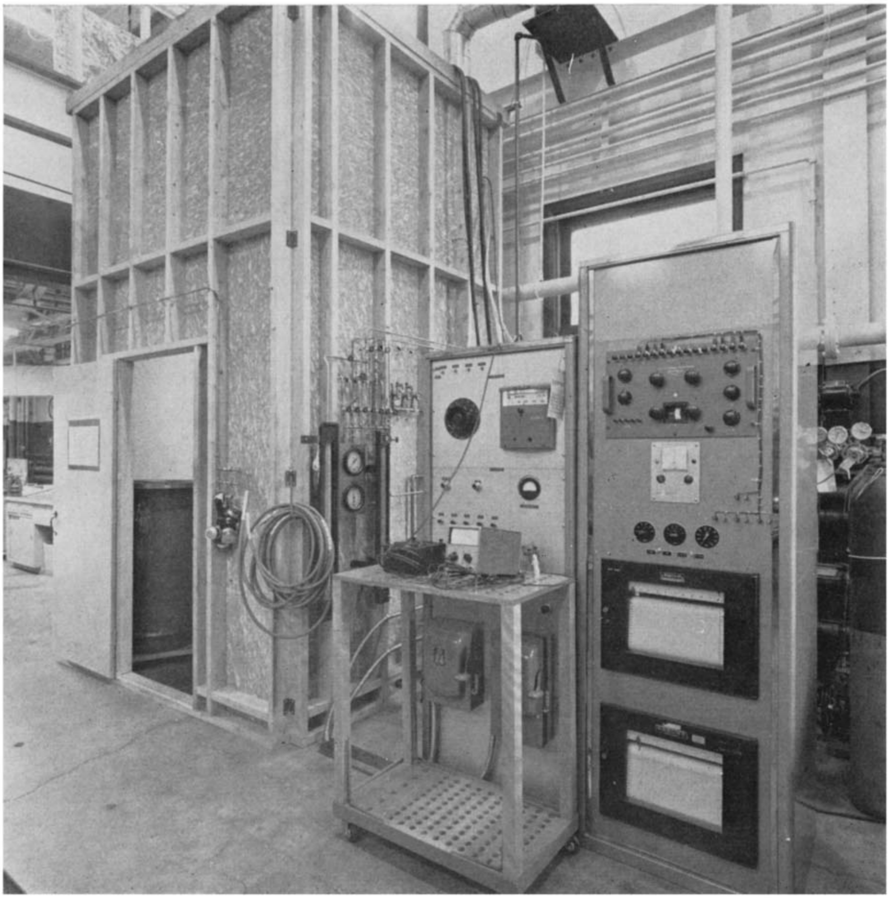

FIG. 3. Liquid metal pool boiling facilities.

*Table 1. Ranges of variables investigated**

Fluid	Pressure (mm Hg)	Pool depth (cm)	Heat flux (Btu(h ft^2)	Na concentration (wt %)
Water	760	15	up to 92000	
Pure mercury	24 → 1170	7 → 34	up to 125000	
Mercury plus sodium	36 → 760	10·4	up to 65000	0 ~ 0·232

* Surface condition: mirror finish S.S. type 304 tube.

Fig. 4 and show good agreement with the data of Lyon [4] and Colver [8], who also boiled water from the outside of electrically heated tubes. The temperature difference ΔT in the present paper is that between the average bulk liquid measured by three thermocouples in the liquid pool (two at 1·25 in above and one at 1 in below the heater surface) and the average of five temperature readings obtained circumferentially around the test heater (corrected to the values at the heating surface). No significant circumferential difference in the wall temperature distribution was observed with water.

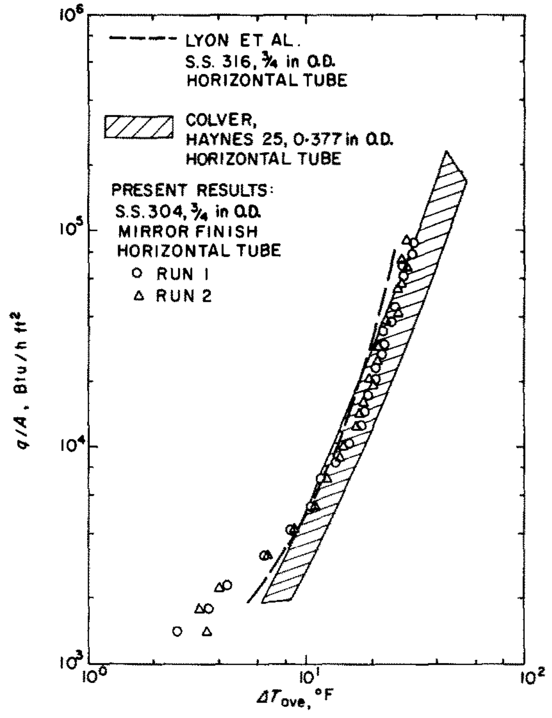

FIG. 4. Comparison of pool boiling water data with previous results at 1 atm.

The power dissipated in the test tube was determined by measuring the voltage and current individually. Voltage drops were measured at five intervals along the length of the heater using six voltage tapping provided as illustrated in Fig. 2. This eliminated the uncertainty in the estimation of electrical lead losses and therefore little error was introduced in calculating the radial heat flux near the centre of the heating tube where five thermocouples were embedded to measure the wall temperature. Including uncertainties in the input transformer, current transformer, voltmeter, ammeter and the dimension of the test tube, the probable maximum error in the wall heat flux, (q/A), was about 3·5 per cent. The local mean wall temperature was determined by averaging the measured temperatures, and was then corrected to give an equivalent surface value. Since the temperature pattern was not always the same, there may be some error in estimating the mean value. The most significant error in the temperature of the boiling surface is introduced in correcting the mean of the measured wall temperatures for depth of embedding. Accounting for this and for the instrument error, the uncertainty in the surface temperature was estimated to be about 3 degF at 10000 Btu/h ft^2 and about 6 degF at 100000 Btu/h ft^2.

Pure mercury system

During the first few days of boiling operation after a new heating tube was installed in the apparatus, the wall superheat for a given test condition was not constant. However, after the heating surface had been used for some time over a range of heat flux and system pressure, a stable boiling condition was obtained. All the results reported in the present paper were obtained after about 30 h of initial boiling.

Figures 5(a) and (b) show the effect of system pressure on the boiling of pure mercury at pool depths of 18 and 10·4 cm, respectively, and are representative of tests at six different pool depths. In all cases, decreasing the system pressure increases the temperature difference ΔT for a given heat flux just as for ordinary liquids, and the effect of pressure is reduced as the pool depth increases which is in accord with the findings of Bonilla *et al.* [5]. As the heat flux decreases, the effect becomes less.

Boiling apparently commenced at heat fluxes of about 7000–9000 Btu/h ft^2, as indicated by thermocouples located in the vapor space, the exact value depending on the system pressure and pool depth. The liquid superheats required for initiation of boiling seemed to be between 10 and 20 degF.

The high liquid density of mercury produces relatively large hydrostatic pressure. At a system pressure (i.e. above the liquid) of 24 mm Hg there is an increase of about 90 degF in local saturation temperature in the first 7 cm in pool depth.

As the system pressure increases, the difference decreases as shown in Table 3. The liquid temperature as a function of pool depth was measured at different pool depths and system pressures in the present study. In tests with system pressure greater than 380 mm Hg, the liquid temperature at any depth did not exceed the saturation value at the surface. However, at a system pressure of 24 mm Hg, the temperature of the bulk liquid in the pool was slightly greater (about 3–15 degF) than the free surface saturation temperature at liquid depths from 7 to 34 cm. These small or zero superheats appear to be caused by strong natural convection currents associated with the geometry of the present test system. The temperature difference ΔT is, therefore, defined as that between the average bulk temperature measured and the average of

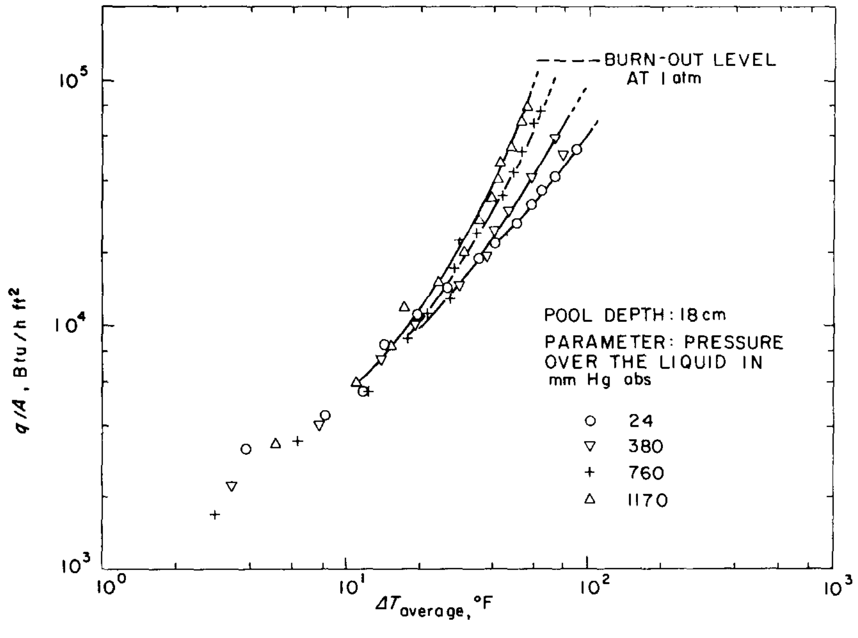

FIG. 5(a). Effect of pressure on pool boiling of pure mercury.

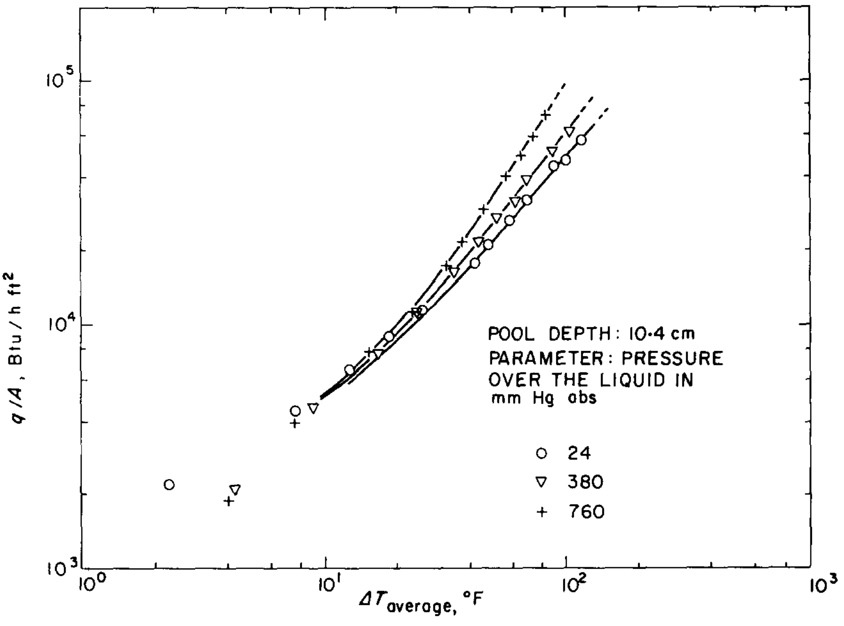

FIG. 5(b). Effect of pressure on pool boiling of pure mercury.

the five temperature readings around the test heat surface.

The effects of pool depth and aging at 760 and 24 mmHg are shown in Figs. 6(a) and (b) and the present data are compared to the previous boiling experiments by others [4, 5]. Strictly speaking, only the data of Lyon [4] should be compared with the present results, since different results have been reported for horizontal plates and horizontal cylindrical surfaces [3]. There appears to be serious disagreement between the present experiment and Lyon's results. The difference in magnitude and slope is apparent. Although the microscopic structure of the boiling surface, surface material and impurity content of the mercury differed in the two experiments, it is not thought that the difference in results should be so great. Small systematic errors in the averaging and extrapolation of the measured wall temperatures to the true surface temperature would hardly account for all this discrepancy.

Contrary to the findings of Bonilla *et al.* [4] who concluded that greater depths seem to require, in general, larger ΔT values, the present results at atmospheric pressure do not indicate any clear effect of pool depth. As system pressure decreases, on the other hand, the results of the present experiment, shown in Fig. 6(b), indicated that greater depths require smaller ΔT values. This is expected because the effect of hydrostatic pressure must be comparable to that of increased system pressure and should be more pronounced at lower system pressure. Nevertheless, it may be concluded that the effect of pool depth is a minor factor.

Over a period of 3 months of frequent use, no erratic boiling such as shifting back and forth from nucleate to film boiling as reported by Bonilla [10] was ever observed in any test run. Neither did the present experiments show a phenomenon reported by Marto and Rohsenhow [9] for sodium pool boiling in which initially the wall temperature rises to a high value and then drops significantly when nucleate boiling is established.

Since pure mercury did not display the usual nucleate boiling heat transfer characteristic, the

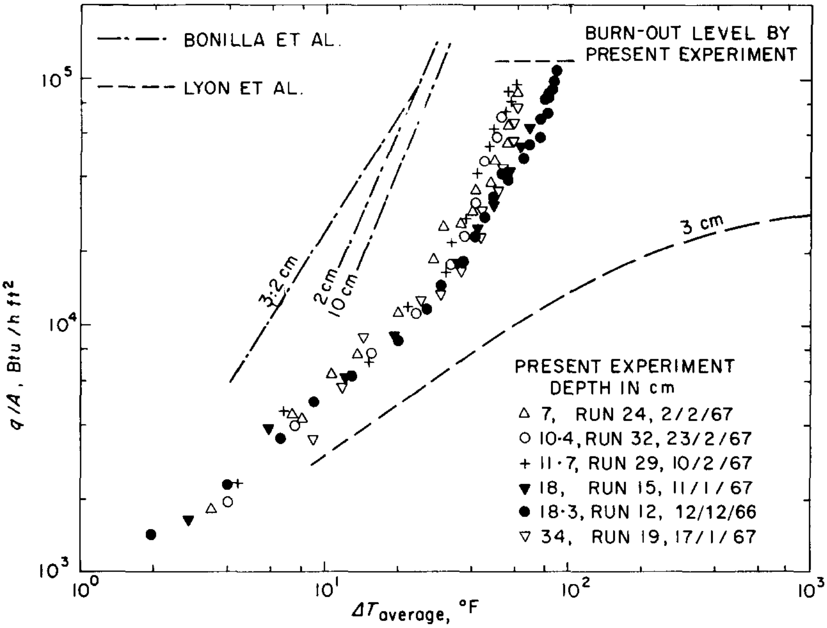

FIG. 6(a). Effects of aging and pool depth, pool boiling of pure mercury, system pressure over the liquid: 760 mm Hg.

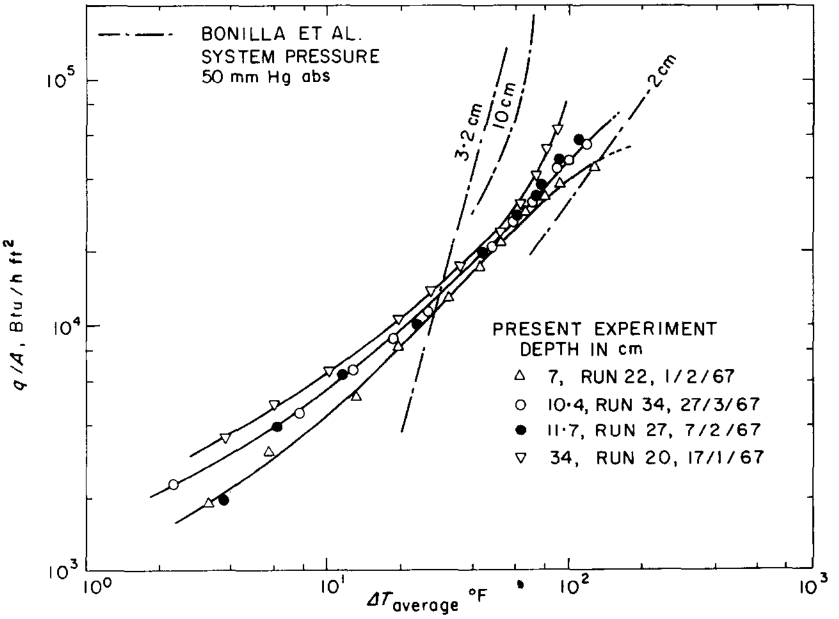

FIG. 6(b). Effects of aging and pool depth on pool boiling of pure mercury, system pressure over the liquid: 24 mm Hg.

several predictions available for liquid metal nucleate boiling were not tested.

Burn-out heat fluxes at pressures between 760 and 260 mm Hg for pure mercury obtained from two almost identically manufactured test heaters were between 10^5 and $1{\cdot}20 \times 10^5$ Btu/h ft^2.

The results of Run 12 almost coincide with those of Run 15 in Fig. 6(a) despite the interim operation for about 30 days, indicating that prolonged immersion of the type 304 stainless steel heating element in pure mercury has little effect on the boiling process. This excellent reproducibility in the present results is also demonstrated by Runs 27 and 34 in Fig. 6(b).

Mercury–sodium system

The effect of sodium concentration in mercury is shown in Figs. 7(a) and (b). It appears that at any system pressure less than about 200 mm Hg, the addition of sodium does not alter the characteristics of pool boiling heat transfer for mercury.

Lyon obtained improved pool boiling heat transfer at sodium concentration of 0·1% at atmospheric pressure. The present results indicate that increased concentration has an adverse effect on the heat transfer coefficient up to a certain level of additive concentration and then the trend changes, as illustrated in Fig. 7(c).

Although the reason is not clear, this unusual behaviour may be related to a particular surface condition and material. Temperature and the concentration level of sodium in mercury definitely affect the interfacial relationships between the liquid and solid surfaces, and consequently may alter the contact angle. Nearly all data at a given sodium concentration formed a consistent pattern and the excellent reproducibility is demonstrated in Fig. 7(a) by Runs 48 and 51.

The effect of pressure on the pool boiling of mercury with sodium summarized in Fig. 8 seems to be a function of sodium concentration and to differ from the ordinary liquid. Up to a sodium concentration of about 0·01 wt%, system pressure appears to have little or no

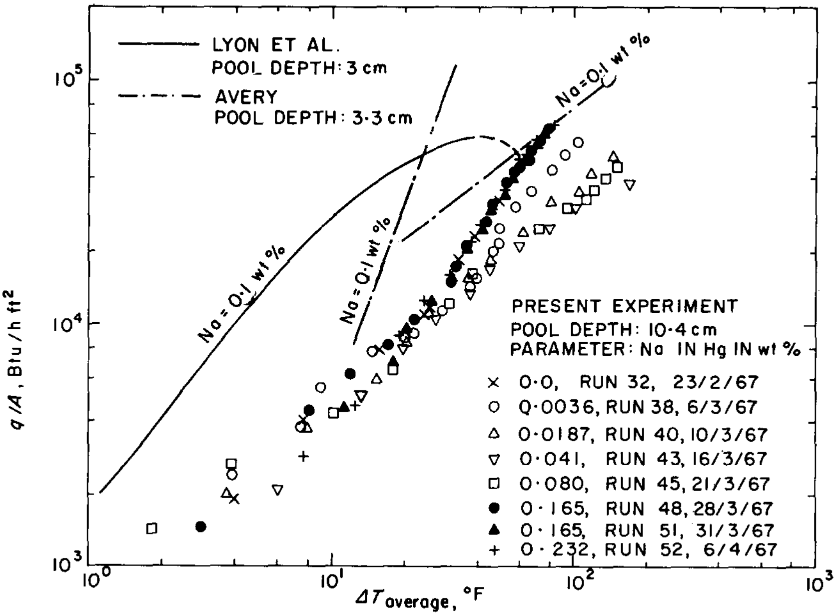

FIG. 7(a). Pool boiling of mercury–sodium amalgam at 1 atm (effect of Na concentration in Hg).

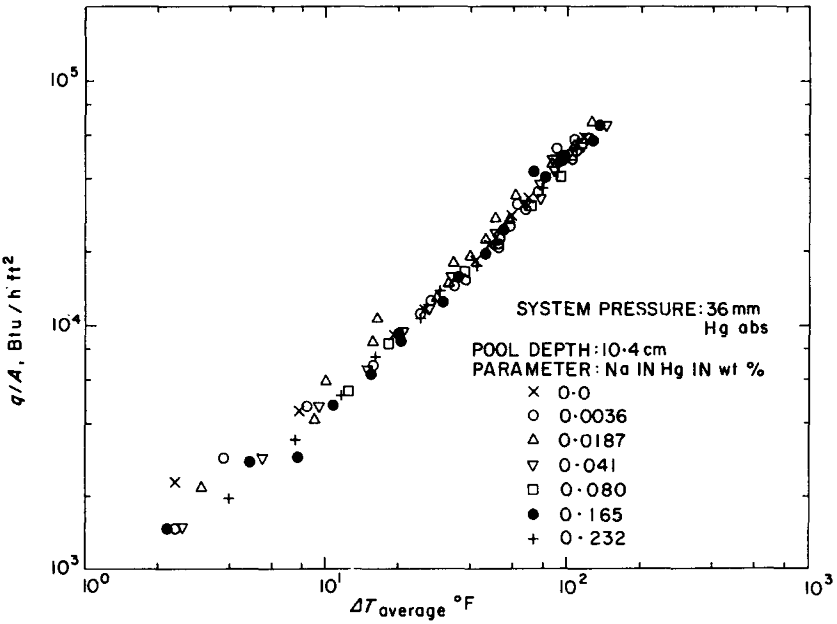

FIG. 7(b). Pool boiling of mercury–sodium amalgam (effect of Na concentration in Hg).

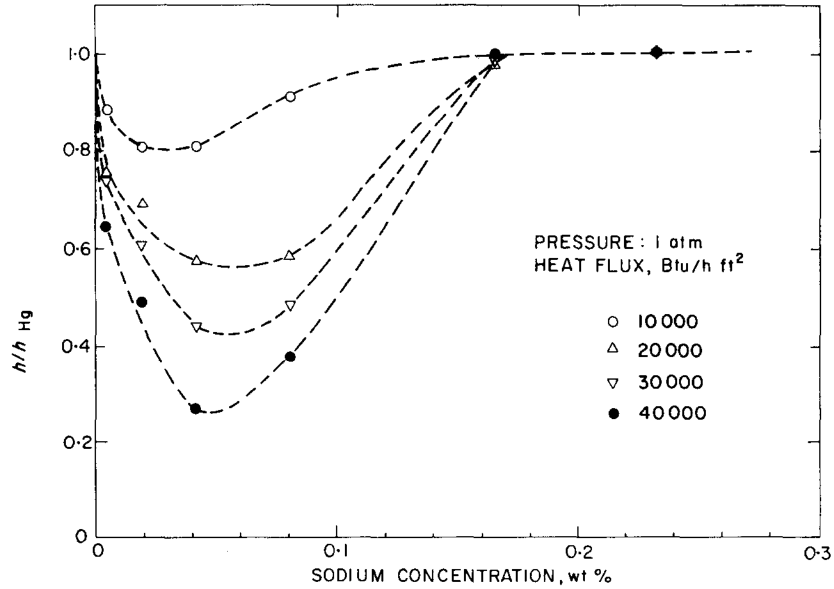

Fig. 7(c). Effect of sodium concentration on heat-transfer coefficients mercury–sodium amalgam pool boiling on a horizontal tube.

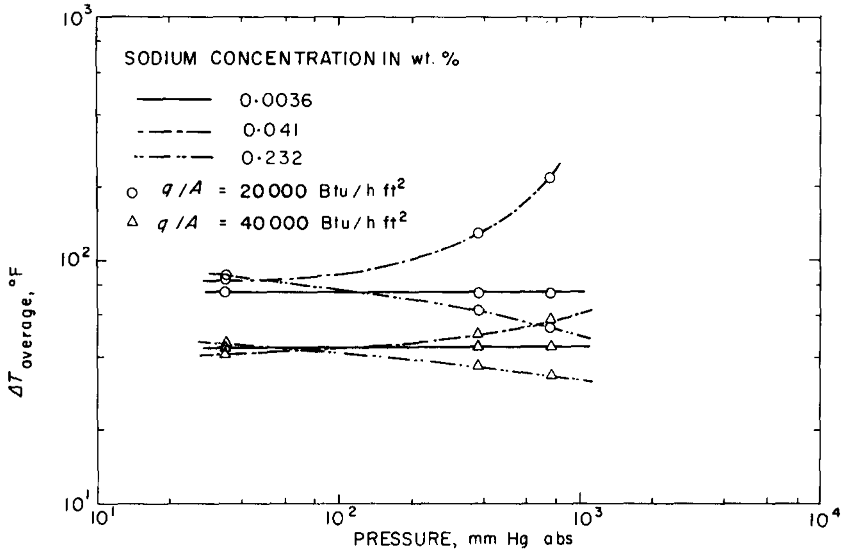

FIG. 8. Effects of pressure and sodium concentration on pool boiling of mercury–sodium amalgam.

effect on the heat-transfer characteristic. For concentration between about 0·01 and 0·08 wt %, increasing pressure resulted in decreasing heat-transfer rate. This is quite contrary to the trend for pure mercury and other liquids. Upon reaching a sodium concentration of about 0·1 wt %, the effect of system pressure is inverted; that is the increase in the system pressure increases the heat-transfer rate (i.e. increasing ΔT).

Heat-transfer coefficients varied markedly around the circumference of the heating tube as shown in Fig. 9—from half to twice the average at most. The pattern of the distribution was different to the rest in those tests with sodium showing a decreasing heat-transfer coefficient with increasing sodium concentration and with increasing system pressure. All other tests showed generally similar patterns with maximum coefficients at the lowest thermocouple (see Fig. 2), and a minimum at thermocouple 2, at 60°.

Heat transfer coefficients for distilled water and pure mercury with and without sodium are summarized in Fig. 10 and compared with the results of Lyon *et al.*, [4] and Avery [6]. The present results indicate that pure mercury and mercury with sodium addition apparently do not wet the surface of type 304 stainless steel well for the range of variables covered in the study. System pressure and sodium concentration have some effect on the wettability. The effect of sodium concentration on the wettability is much less than found by Lyon [4].

CONCLUSIONS

The following may be concluded from the present investigation.

1. Pool boiling of pure mercury at a given heat flux (q/A) required a smaller temperature driving force (ΔT) with increase in system pressure at all pool depths. The pressure effect became less at greater pool depth.
2. Pool depth did not affect the (q/A) vs. (ΔT) relationship at high system pressure. At low pressure, greater depth required a smaller ΔT, but this was a minor effect. No significant temperature gradient within the boiling pool was observed.
3. Long immersion (up to 8 weeks) did not

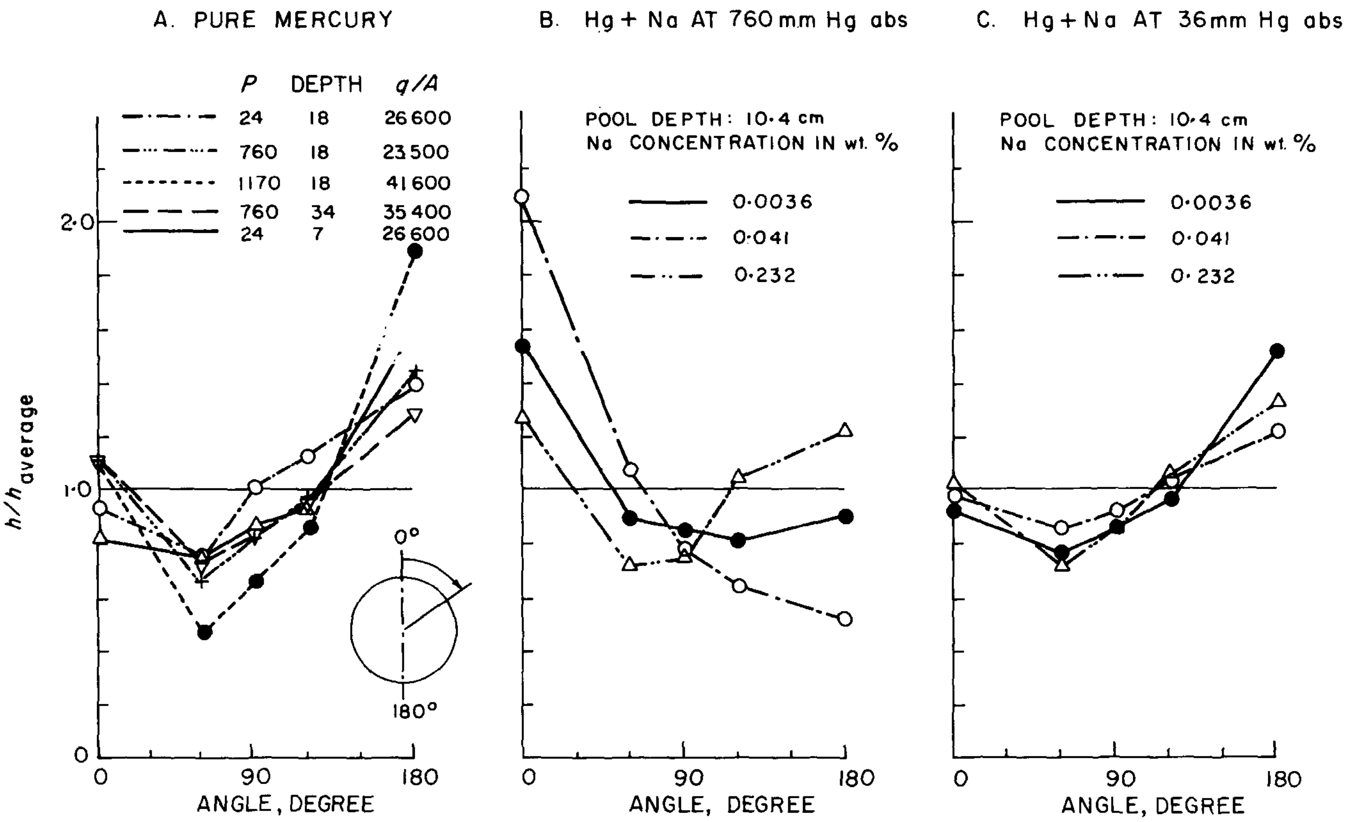

FIG. 9. Variation of local (circumferential) heat-transfer coefficients.

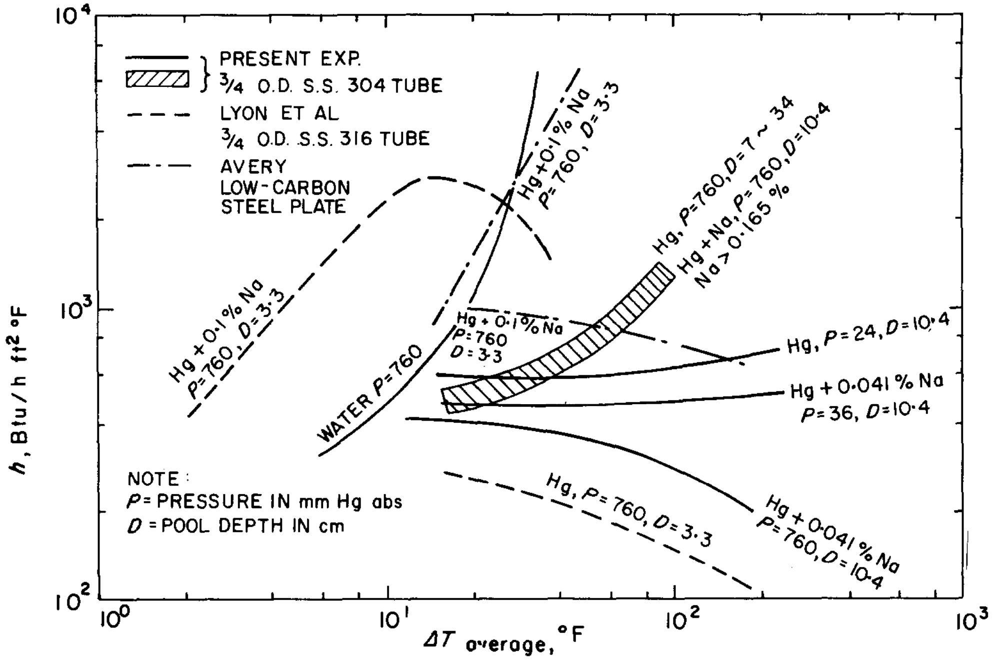

FIG. 10. Comparison of experimental pool boiling heat-transfer coefficients.

influence the heat-transfer characteristic of the heating element made of type 304 stainless steel with a mirror-finish.

4. The heat-transfer coefficient shows a minimum at a sodium concentration of 0·03–0·06 wt%. At concentrations of 0·16 wt% or more (up to 0·232 wt% was tested), the heat-transfer coefficient is the same as for pure Hg.

5. The heat-transfer coefficient varied markedly around the circumference of the heating tube—up to 400 per cent variation at most. The pattern of the distribution was different in those tests with sodium addition which showed a decreasing coefficient with increasing concentration at atmospheric pressure. All other tests had the similar pattern.

6. Burn-out heat fluxes at 760 and 260 mm Hg for pure mercury were about 1·25 × 10⁵ and 1·20 × 10⁵ Btu/h ft², respectively, but this may have been influenced by the particular geometry of the experimental system.

Table 2. Spectrochemical analysis of pure mercury—measured in ppm

Element	Sample*							
	1	2	3	4	5	6	7	8
Al	40	60		40	40			
Cu	30	30	50	20			20	

The following elements were looked for but not detected above limiting 10 ppm.

Ag, As, B, Ba, Bi, Ca, Cd, Co, Cr, Fe, Gn, Hf, K, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Sb, Si, Sm, Sn, Ti, V, W, Y, Zn and Zr.

* Samples 1 and 2 before test runs 1–12
3 and 4 after test runs 1–12
5 and 6 before test runs 13–34
7 and 8 after test runs 13–34

Table 3. Changes in saturation temperature due to hydrostatic head of pool depth for pure mercury, calculated
$\Delta T = T_{sat}$ at wall $- T_{sat}$ at free surface (degF)

Pool depth (cm)	Pressure (mm Hg)			
	24	380	760	1170
7	90	17·2	10·7	5·4
10·4	112	25·5	15·2	9·4
18	147	37	24·2	15·4
33·7	196	61·3	39·5	27·4

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Résumé—Du mercure a été mis en ébullition à partir de réchauffeurs cylindriques horizontaux en acier inoxydable du type 304 de 19 mm de diamètre avec une pression absolue dans le système variant de 24 à 1170 mmHg, une profondeur de réservoir de 7 à 34 cm et une concentration en sodium allant de 0 à 0,232 pour cent en poids.

Le flux de chaleur augmentait avec la pression du système pour des conditions données dans le mercure pur et le mercure contenant plus de 0,041 pour cent de sodium; l'effet inverse de la profondeur du réservoir était négligeable spécialement à des pressions élevées du système; des températures locales du liquide dépassant la valeur de saturation à la surface ont été détectées seulement à de grandes profondeurs de réservoir pour une pression du système faible. Une immersion allant jusqu'à 8 semaines avait peu d'effet sur l'élément de chauffage du type 304 S.S. poli optiquement. L'augmentation de la concentration en sodium avait un effet opposé sur le coefficient de transport de chaleur jusqu'à un certain niveau et alors la tendance se modifiait. Une addition de sodium au mercure jusqu'à 0,232 pour cent en poids n'augmentait pas le flux de chaleur au-dessus de la valeur comparable pour le mercure pur. Les résultats pour l'ébullition étaient reproductibles en effectuant de nombreux essais de vérification après une période initiale d'opération de l'appareil.

Zusammenfassung—Quecksilber wurde an zylindrischen Heizelementen aus Edelstahl der Qualität 304 mit einem Durchmesser von 19 mm zum Sieden gebracht. Der Systemdruck wurde von 24 bis 1170 mm Hg variiert. Die Eintauchtiefe der Heizelemente wurde zwischen 7 und 34 cm geändert und die Natrium Konzentration im Quecksilber schwankte zwischen 0 und 0,232 Gew. %.

Steigender Systemdruck erhöhte die Wärmeübergangszahl für vorgegebene Bedingungen bei reinem Quecksilber und bei Quecksilber mit einem Zusatz von mehr als 0,041 % Natrium; die umgekehrte Wirkung wurde beobachtet bei einer Natrium-Konzentration von 0,0036 %. Die Wirkung der Eintauchtiefe war unwesentlich, besonders bei hohen Systemdrücken; örtliche Flüssigkeitstemperaturen die grösser waren als die Sättigungstemperaturen an der Oberfläche wurden nur bei grossen Eintauchtiefen und niedrigen Systemdrücken beobachtet. Die Eintauchzeit, bis zu 8 Wochen, zeigte geringe Wirkung an der polierten Oberfläche des aus dem Werkstoff 304 SS gefertigten Heizelements. Zunehmende Natriumkonzentration wirkte sich ungünstig auf die Wärmeübergangszahl aus bis zu einem bestimmten Gehalt. Von diesem Gehalt an änderte sich die Einflussrichtung. Bis zu einer Natriumkonzentration von 0,232 Gew. % im Quecksilber erhöht sich die Wärmeübergangszahl nicht über vergleichbare Werte mit reinem Quecksilber. Die Reproduzierbarkeit der Siedeergebnisse wurde nach einer anfänglichen Betriebszeit der Anlage durch viele, punktweise durchgeführte Kontrollversuche bestätigt.

Аннотация—Ртуть нагревалась до кипения с помощью горизонтальных цилиндрических нагревателей диаметром 1,9 см из нержавеющей стали типа 304 при давлении в системе от 24 до 1170 мм рт.ст., глубине объема от 7 до 34 см и концентрации натрия от 0 до 0,232 % на единицу веса. Повышение давления в системе увеличивало интенсивность теплообмена при заданном условии в чистой ртути и ртути, содержащей более 0,041 % натрия. Обратный эффект наблюдался при концентрации натрия 0,0036 %. Влияние глубины объема незначительно, особенно при большом давлении в системе. Местные температуры жидкости, превышающие температуру насыщения на поверхности, обнаруживались только на больших глубинах объема при низком давлении в системе. Погружение на время до 8 недель мало влияло на нагревательный элемент с зеркальной обработкой поверхности из нержавеющей стали типа 304. Увеличение концентрации натрия оказывает обратное влияние на коэффициент теплообмена до определенного предела. Добавка натрия в ртуть до 0,232 % на единицу веса не повышает интенсивности теплообмена выше соответствующей величины для чистой ртути. Результаты опытов отличались воспроизводимостью при многочисленных проверках.