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TESTS OF SODIUM BOILING IN A SINGLE TUBE-IN-SHELL HEAT EXCHANGER OVER THE RANGE 1720° TO 1980° F (1211 TO 1355 K)

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ABSTRACT

Sodium was boiled in a vertical, 1/2-inch (1.27-cm) inside diameter by 4-foot (1.22-m) long tube. The columbium alloy boiler operated at flow rates of 75 to 380 lbm/hr (9.4 to 48 g/sec) and up to 0.93 quality. Boiling performance depended on whether the inlet flow was two-phase or liquid. Two-phase momentum pressure drops were $1\frac{1}{2}$ times frictional drops. Qualities over 0.9 were obtained at some critical (burnout) boiling conditions. Liquid superheats up to 250° F (139 K) existed before initiation of boiling.

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TESTS OF SODIUM BOILING IN A SINGLE TUBE-IN-SHELL HEAT EXCHANGER OVER THE RANGE 1720° TO 1980° F (1211 TO 1355 K)

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SUMMARY

A single tube-in-shell, vertically oriented, boiling heat exchanger with no tube inserts was tested in a sodium boiling heat-transfer facility as part of a research program applied to advanced Rankine cycle space-power-system components. This bimetallic multiloop facility was constructed of type 316 stainless steel and columbium-1-percent-zirconium alloy and included a large high-vacuum vessel. The counterflow boiler had a nominal length of 4 feet (1.22 m) and a center tube inside diameter of 1/2 inch (1.27 cm).

The boiler was operated at test fluid flow rates of 75 to 380 pounds per hour (9.4 to 48 g/sec), boiling temperatures of 1720° to 1980° F (1211 to 1355 K), and exit vapor qualities up to 0.93. The total test time covered over 1100 hours at temperatures in excess of 800° F (700 K).

Average overall heat-transfer coefficients, two-phase pressure drops, and critical (burnout) conditions were obtained. Both steady and unsteady boiling performance was evaluated. The boiler heat-transfer performance depended greatly on the tube inlet flow condition, whether two-phase or liquid phase. The boiling pressure drop as a function of exit quality was normalized by the liquid velocity head, and the momentum pressure drop accounted for approximately 60 percent of the total two-phase pressure drop. Critical qualities in excess of 90 percent were obtained under steady conditions. Liquid bulk superheat values in excess of 250° F (139 K) were obtained before initiation of boiling.

INTRODUCTION

Future space vehicles may require the capacity to generate relatively large amounts of electrical power. For these large power levels the use of turboalternators driven by the vapor from a Rankine cycle system appears attractive. In order to achieve low specific weight and high efficiency in space, boiling temperatures of 1800° to 2200° F

(1255 to 1478 K) are required. The alkali metals (sodium, potassium, etc.) have been proposed as working and heat-transfer fluids in order to meet the high temperature requirements. In turn, the need for suitable containment materials for the alkali metals has led to consideration of refractory-metal alloys (columbium, tantalum, etc.) for system components. In addition to the temperature requirements, the power system must operate unattended for periods in excess of 10 000 hours in a stable and reliable manner.

One design being considered to achieve these requirements is the once-through boiler concept, in which a subcooled liquid is converted into a superheated vapor in one continuous pass through heated tubes. This concept is attractive because it eliminates the boiler recirculation loop, thus improving reliability and reducing weight. In addition, the recirculation loop would introduce phase separation problems in a zero gravity environment.

The development of heat-exchanger boilers for space-power systems has been handicapped by a lack of reliable and applicable data and analytical design procedures. Traditional water boiler data are primarily related to gas-fired, recirculating boilers using high-pressure fluids. For the space-power-system boiler, which employs an equivalent low-pressure fluid, information is required for two-phase heat transfer and pressure drop, the definition of the various boiling regimes, the prediction of critical heat-transfer conditions such as "burnout" and critical flow rates, and the requirements for thermal and hydraulic stability. The analytical predictions of two-phase heat-transfer and hydraulic performance have limited or uncertain applicability and in most cases require accurate experimental data for their use. The best and most recent data for alkali metal boilers is that contained in references 1 to 3. These works are limited either with respect to temperature or the use of electrically heated (constant flux) boilers.

A program for the study of alkali-metal heat-exchanger boilers was established at the Lewis Research Center to obtain experimental data in the areas of interest. Specific objectives of the investigation reported herein were to obtain data on the heat transfer, vaporization, and hydraulic performance of a single tube-in-shell heat-exchanger boiler with sodium at saturation temperatures up to 2000° F (1366 K). Information relating to boiler stability was also desired. In addition to the boiling data, it was desired to determine and define any related critical problem areas.

The experimental boiler used in this investigation was a single tube-in-shell counterflow heat exchanger oriented so that the vaporizing fluid flowed vertically upwards. The boiler tube was straight, hollow, and circular, with no inserts. Sodium was used for both the vaporizing and heating fluids. All components operating above 1500° F (1089 K) were constructed of a columbium-1-percent-zirconium (Cb - 1-Zr) alloy, while the remainder of the system was fabricated from 316 stainless steel. Data were obtained over a range of boiling fluid flow rates of 75 to 380 pounds per hour (9.4 to 48 g/sec), boiling temperatures of 1720° to 1980° F (1211 to 1355 K), and vapor qualities up to 93 percent.

This report presents a description of the boiling facility, the experimental boiler, the test instrumentation and controls, as well as the experimental data. The data reported include liquid-phase pressure drop and heat transfer, heat transfer and pressure drop during steady-state boiling, data obtained during boiling with ramp and step changes of certain test variables, and liquid bulk superheat values obtained before initiation of boiling. All values, dimensional equations, tabulated material and data, and figures are presented in both the U.S. Customary and SI units. All symbols and nomenclature are defined in appendix A.

FACILITY

The complete alkali-metal boiling heat-transfer facility is shown schematically in figure 1. A simplified diagram (fig. 2) shows the two main flow loops, which are joined together thermally at a single tube-in-shell heat-exchanger boiler. Both main loops contain sodium and both have pumped bypass coolant loops. All components designed to operate in excess of 1500° F (1089 K) were fabricated of Cb - 1-Zr alloy and are contained in a high-vacuum vessel. The rest of the system was constructed of 316 stainless steel. Heat is generated by electric resistance heaters and heat rejection is by sodium-to-air heat exchangers.

Two-Phase Loop

The ac conduction pump 1 (figs. 1 and 2) pumps the test fluid (liquid sodium) through a throttle valve and electromagnetic flowmeter to the preheater. After entering the vacuum vessel, a transition in the piping is made from the 316 stainless steel to the Cb - 1-Zr alloy tubing. All Cb - 1-Zr components are wrapped with a minimum of two layers of tantalum foil to act as an oxygen getter. The preheater consists of approximately 100 feet (~30 m) of 1-inch (2.54-cm) inside diameter, 0.05-inch (0.127-cm) wall Cb - 1-Zr tubing arranged in an elongated coil. The coil turns are separated vertically by alumina blocks. Electric power is supplied to the preheater from a 125-kilowatt, 30-volt saturable reactor and transformer and is rectified to a maximum ripple of 10 percent. Heat is generated in both the preheater tubing wall and the flowing sodium. The preheater can be controlled manually or by an automatic control sensing the preheater exit temperature.

In preliminary tests a direct connection was made from the preheater to the inlet of the test boiler. (Details of the boiler are given in the section TEST BOILER.) Extreme

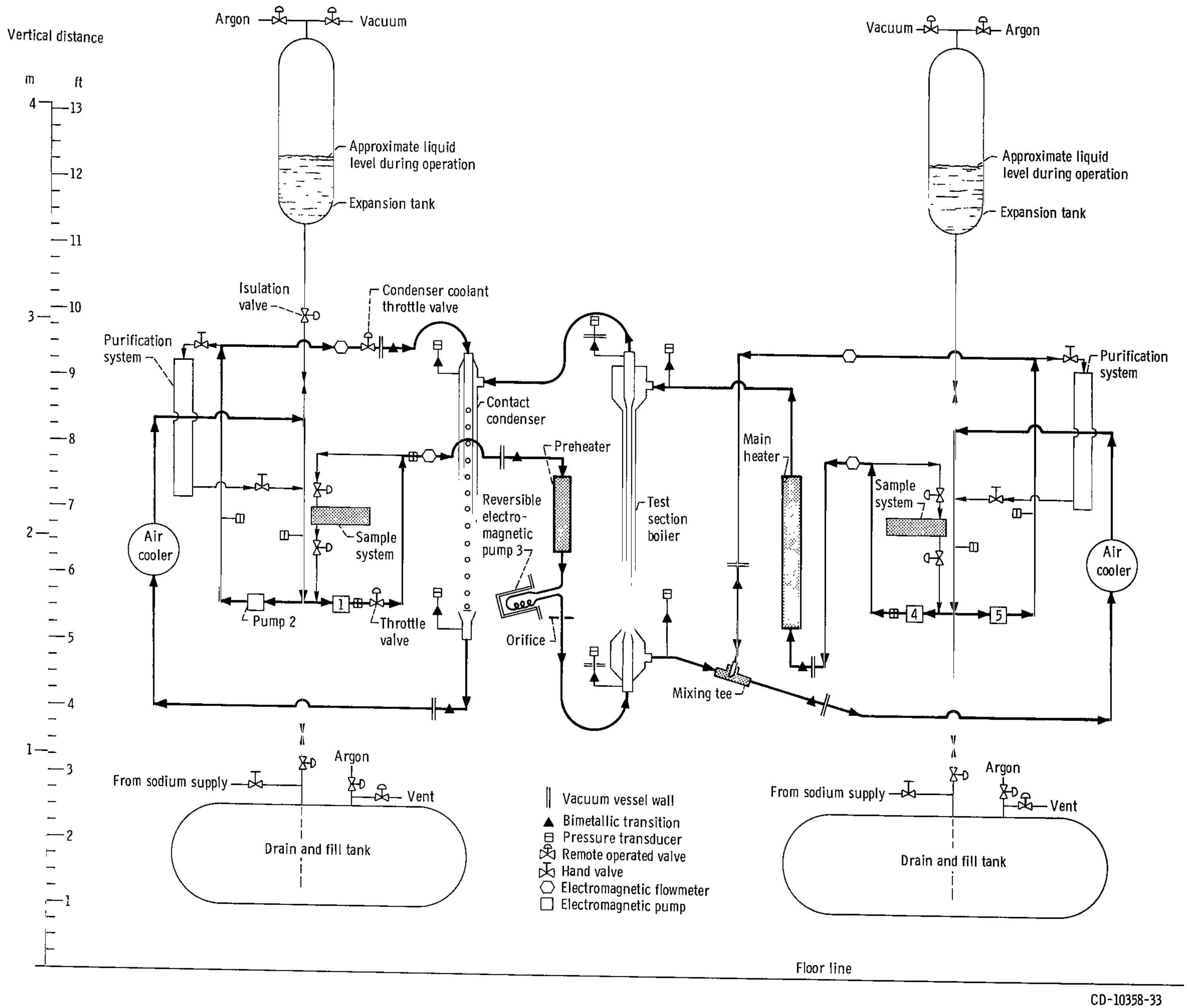


Figure 1. - Alkali metal boiling heat-transfer facility.

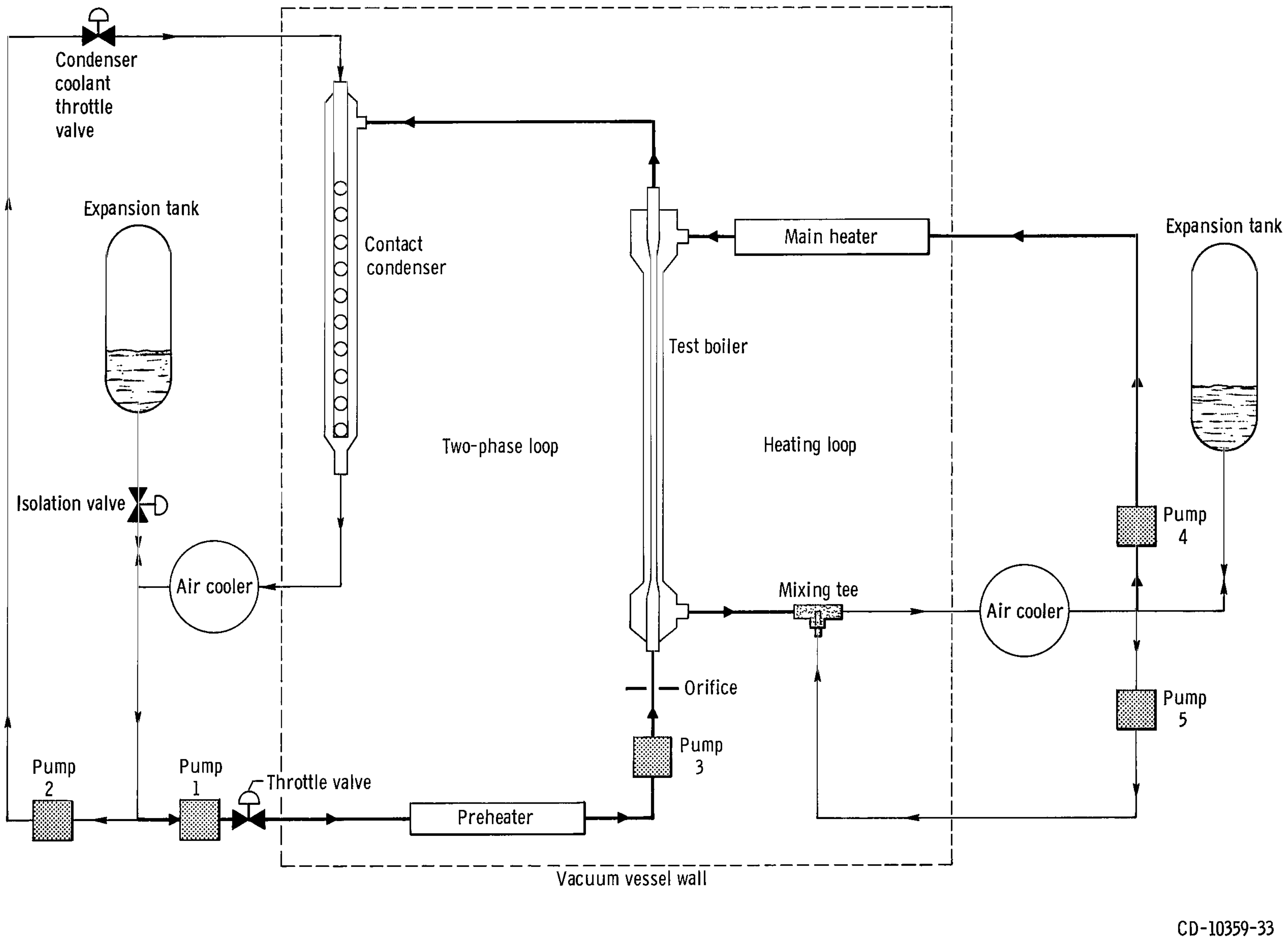


Figure 2. - Boiling and heating loops.

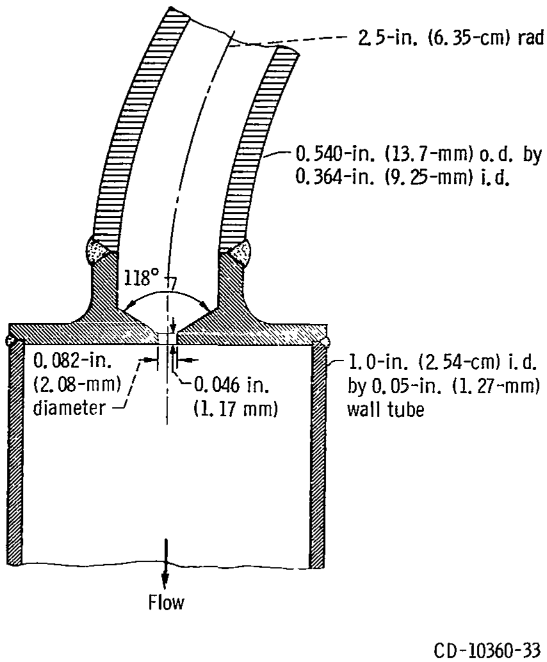


Figure 3. - Orifice upstream of test boiler.

flow and pressure instabilities including reverse flow were encountered and the preheater quite often filled with vapor. Prior to the final test program, pressure drop devices were installed between the preheater and boiler to protect the preheater from vapor and possibly contribute to loop stability. The pressure drop devices consisted of an 0.082-inch (2.08-mm) diameter orifice (fig. 3) and a reversible helical-induction electromagnetic pump (pump 3 in figs. 1 and 2). The construction of this pump is such that the fluid pumping cell is within the vacuum vessel and has no direct connection to the primary electrical coils external to the vessel. When operated in the reverse mode, this pump opposes pump 1 and provides a pressure drop analogous to the dynamic braking of an induction motor.

On leaving the boiler the test fluid enters the shell side of the contact condenser. This condenser consists of a 2.5-inch (6.35-cm) inside diameter by 46.25-inch (21.2-m) long vertical shell containing a 45-inch (1.14-m) long by 1.5-inch (3.8-cm) inside-diameter coolant-distributor tube. Liquid sodium is pumped through a throttle valve in the bypass loop into the distributor tube at a temperature less than 1400° F (1033 K). The coolant flows out of the distributor tube through 228, 3/32-inch (2.38-mm) diameter holes, condensing the vapor and cooling the mixture to less than the stainless-steel temperature limit of 1500° F (1089 K). The mixture leaves the vacuum vessel in stainless-steel pipe and flows through the sodium-to-air cooler, which is a finned tube heat exchanger with a rating of 400 kilowatts. The flow then splits (figs. 1 and 2), returning to the pumps of the main and bypass loops.

Pressure level in the loop is set by adjusting the pressure of the argon cover gas in the expansion tank, which is connected to the suction side of pumps 1 and 2. Pressure control may be achieved manually or automatically. An isolation valve in the line to the expansion tank allows the loop to operate as a constant inventory system when desired. Flow control is achieved manually by regulating the two throttle valves and the three pumps, as well as by the thermal performance of the boiler and condenser.

Heating Loop

The heating loop is similar to the two-phase loop and has both a main loop and a coolant bypass loop. Argon cover-gas pressure in the expansion tank is set manually to a level high enough to ensure that the sodium heating fluid is in a liquid state at all times. The mixing tee (figs. 1 and 2) is used to lower the temperature of the liquid discharging from the boiler to 1400° F (1033 K). The air-to-sodium heat-exchanger cooler, used in this loop, is identical to that of the two-phase loop. The main heater is also similar to the two-phase loop preheater and consists of a coil of approximately 250 feet (76 m) of 1-inch (2.54-cm) inside diameter by 0.05-inch (0.127-cm) wall Cb - 1-Zr tubing. Electric power is supplied to the heater from a 600 kilowatt, 110 volt saturable reactor and transformer, and is rectified to a maximum ripple of 10 percent. Both manual and automatic control of the heating rate can be used. Flow control is achieved by the voltage setting of the two ac conduction type of electromagnetic pumps.

Auxiliary Equipment

In addition to the heating and two-phase loops, the facility requires considerable auxiliary and support equipment. Included in this category are (1) the vacuum vessel and vacuum pumping system, (2) auxiliary heaters including piping trace heaters, (3) liquid-metal purification and sampling systems, (4) argon cover-gas system, (5) loop vacuum system, (6) fill and dump systems, (7) coolant systems, (8) safety systems, and (9) necessary operational controls and instrumentation.

Vessel vacuum systems. - A vacuum environment was used to minimize oxidation of the columbium alloy components for the facility design life of 5000 hours and maximum temperatures of 2300° F (1533 K). For these conditions the data of Barrett and Rosenblum (ref. 4) indicate a maximum allowable oxygen partial pressure of 10^{-7} torr (1.33×10^{-5} N/m^2). The vacuum vessel, fabricated of 304 stainless steel, is a horizontal cylinder $17\frac{1}{2}$ feet (5.33 m) long and 7 feet (2.13 m) in diameter. Satisfactory oxygen partial pressures were achieved in the vessel while operating at the test temperatures. Complete details of the vessel and its pumping and monitoring systems, as well as its pump-down and bake-out history are given in a report by Groesbeck in reference 5.

Auxiliary heating systems. - All stainless-steel components and piping have electrical resistance heaters strapped to them in order to maintain the sodium temperature above the melting point and to aid in outgassing the loops. Chromel-Alumel thermocouples are attached to both the heaters and loop components. Stainless-steel reflective foil is wrapped around the heaters and loop components and the whole assembly is covered by commercial fibrous type thermal insulation.

Purification and sampling systems. - The heating and cooling loops have separate sodium purification systems. These systems are of conventional design, consisting of a hot trap, a cold trap, a plugging valve, an electromagnetic flowmeter, an air-to-sodium cooler, and the appropriate isolation valves.

The sampling systems consist of a bypass loop around each of the main flow pumps. A sample tube is connected into the system by flared fittings. Isolation valves provide for the removal of the sample tube as well as connecting it to the sodium loop or to a vacuum purge.

Argon gas system. - High-purity argon is used as cover gas, to purge all loop plumbing, and for back-filling the vacuum vessel. A liquid-argon supply is boiled off and the gas piped to the test cell where it passes through a hot-trap purifier before entering the system.

Loop vacuum systems. - Both liquid-metal loops are evacuated by a common mechanical vacuum pump equipped with a Freon-refrigerated cold trap. The loops can be evacuated to approximately 10^{-3} torr (0.133 N/m^2) after a bake-out at approximately 400° F (478 K).

Coolant systems. - All cooling air is obtained from the laboratory central air supply. Air is used in the sodium-air heat exchangers, to cool the electromagnetic pumps, in the cold trap and cooler of the purification systems, and to freeze out sections of the loops in lieu of or as a back up to valves. Laboratory cooling tower water flowing through copper tubes cools the wall of the vacuum vessel. Demineralized water is used as the coolant for the seals of the penetrations of the 125- and 600-kilowatt heater power leads into the vacuum vessel.

Safety systems. - Safety equipment includes appropriate overtemperature and pressure alarms, flow and heating interlocks, sodium oxide smoke detectors, and appropriate containment structures. All cooling air and any possible sodium oxidation products are ducted from the test cell to a large scrubber system before venting to atmosphere.

TEST BOILER

Description

The test boiler used in this investigation is a single tube-in-shell counterflow heat exchanger. The entire boiler is fabricated of Cb - 1-Zr alloy. Figure 4 is a photograph

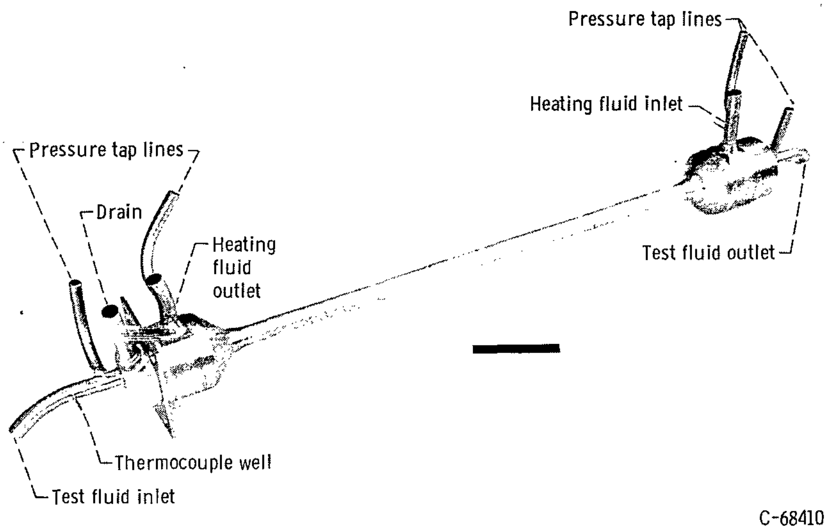
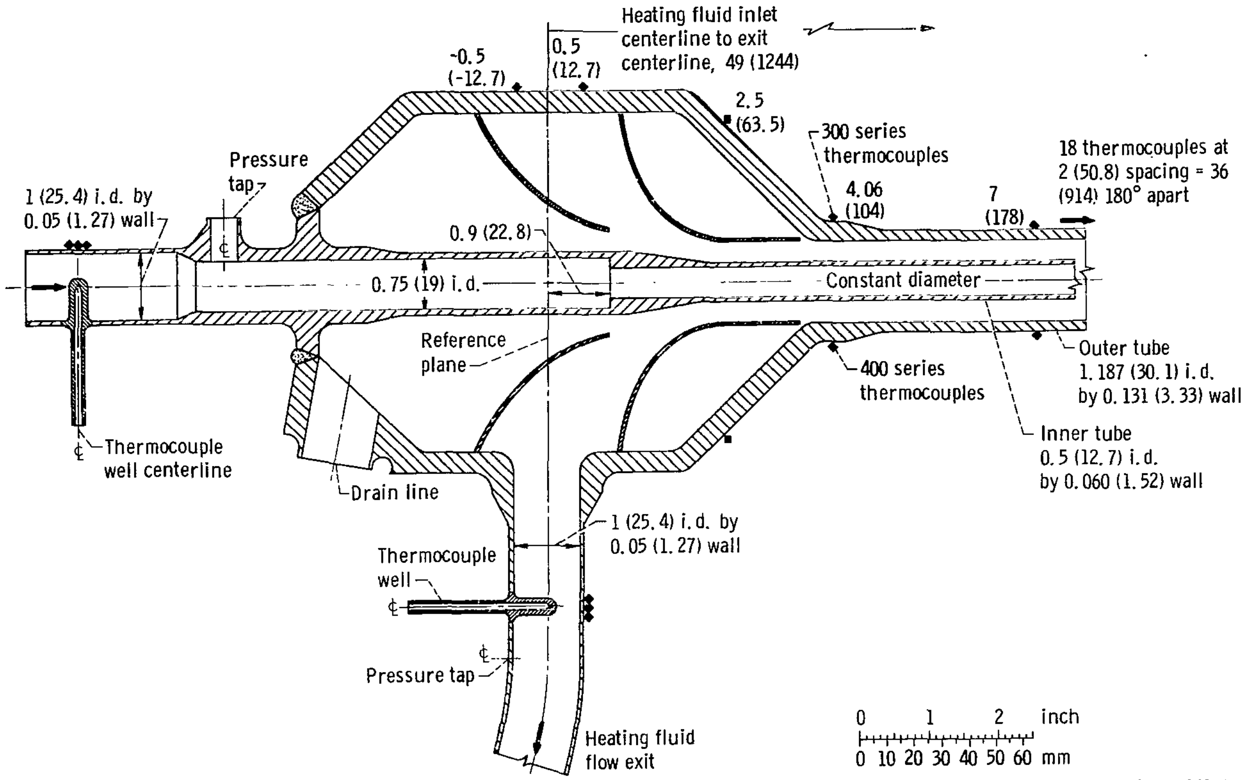


Figure 4. - Test boiler assembly.

of the assembled boiler with the connecting pipe stubs. Details of the boiler and instrumentation locations are shown (to scale) in figure 5. The boiler is mounted so the boiling sodium in the inner tube flows vertically upwards. The heating fluid enters and leaves the shell through 6-inch (15-cm) diameter end plenums with the fluid being guided between two sheet-metal funnel baffles. Spacer pins 120° apart are located every 10 inches (25.4 cm) along the test tube to preserve concentricity of the tube in the shell. After completion of instrumentation, the entire assembly was wrapped in 10 layers of dimpled 0.001-inch (0.025-mm) thick tantalum foil to provide reflective thermal insulation. The centerline of the shell exit connection is taken as the reference plane for all axial dimensions.

Design and Fabrication

The boiler was designed on the basis of the following arbitrary limitations and assumptions:



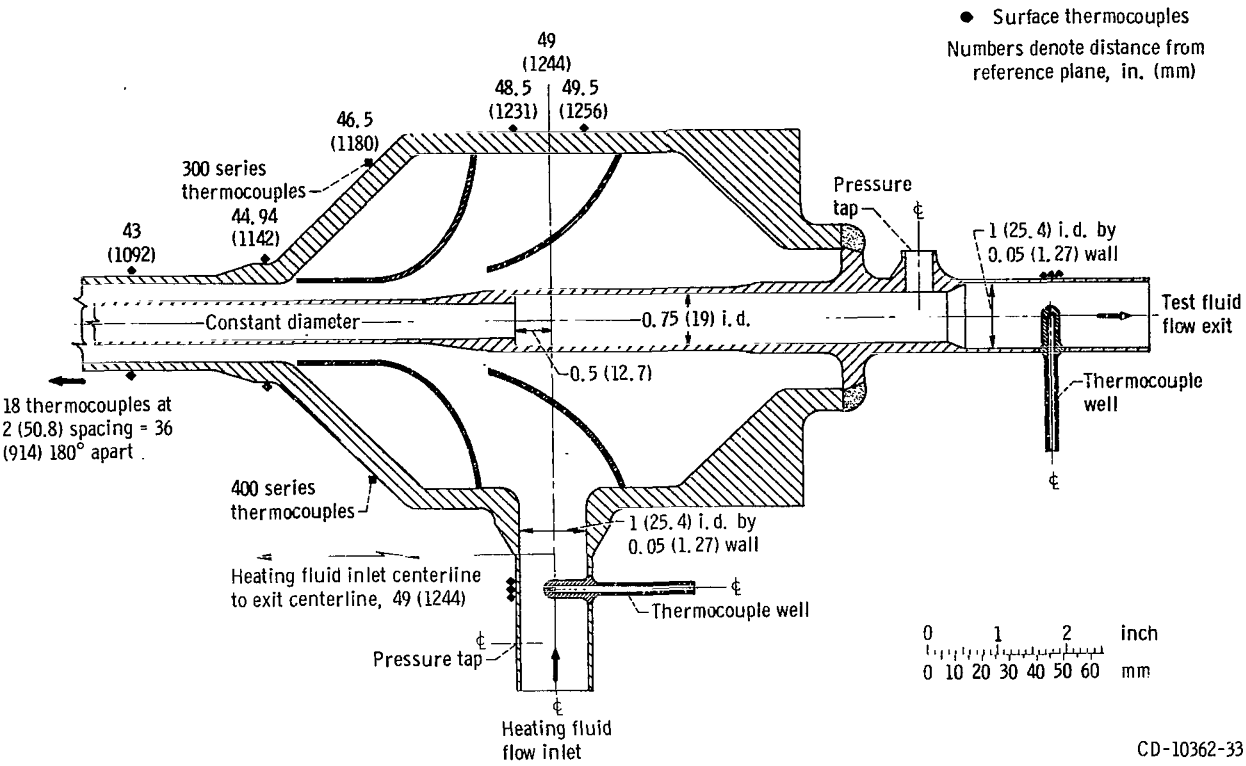
(a) Bottom end.

Figure 5. - Detail of test section.

Maximum fluid temperature, ^{o}F; K	2240; 1500
Maximum heat input, kW	500
Vapor exit Mach number	0.5
Overall heat-transfer coefficient, $Btu/(hr)(ft^2)(^oF)$; $W/(m^2)(K)$	4000; 22 000

It was desired to vaporize sodium over the entire range from zero exit quality to superheated vapor. Based on these assumptions and estimates of the expected two-phase pressure drop, a tube having an inside diameter of 1/2 inch (1.27 cm) with a length to diameter ratio of approximately 100 was selected. The dimensions of the shell annular gap were then determined from the predictions of Seban and Bailey (ref. 6) for liquid-metal convective heat transfer in annuli.

The boiler mechanical design was chosen as a rigid structure with no bellows. The boiler is restrained at only one point (the bottom end plenum) and allowed to grow vertically as it thermally expands, thus putting the inner tube in tension. Differential expansions corresponding to mean temperature differences between shell and tube of up to 500^{o} F (278 K) could be tolerated. Allowable design pressure and mechanical stresses were based on the 5000-hour stress-rupture values with a safety factor of 2. Thermal



(b) Top end.

(All dimensions are in inches (mm).)

stresses were based on the high-temperature yield-stress values. End loads were minimized by providing sufficient flexibility in all connecting lines.

The entire boiler was fabricated under clean-room conditions from Cb - 1-Zr alloy seamless tubes, forgings, and plate. The boiler is an all-welded structure. All welding was done in a suitable dry box using the tungsten - inert-gas (argon) technique. The atmosphere in the dry box was continuously monitored for moisture and oxygen levels and frequent test welds and bend tests were made throughout the fabrication process.

INSTRUMENTATION

Instrumentation of the system is discussed under separate headings for research instrumentation, auxiliary instrumentation, and recording equipment.

Research Instrumentation

Flow rate. - The liquid-metal flow rates for both main and bypass loops were measured by electromagnetic flowmeters installed in the stainless-steel piping exterior to the vacuum vessel. No calibration of these flowmeters was made; the flow rate was computed from vendors' calibrations and the relations of reference 6. The magnet-field strength was checked before and after testing and was found to be essentially unchanged and acceptably close to the vendor's values. Without an actual in-place calibration it is difficult to assess the flowmeter accuracy, but the boiler heat balances discussed subsequently and calibration of similar flowmeters indicate flow measurement error of less than ±5 percent. The minimum signal utilized from any of the flowmeters was no less than 0.3 millivolt.

Pressure. - Pressures of research interest were measured at the inlet and exit of the boiler on both heating and two-phase loops, at the condenser vapor inlet and condensate outlet, and between the two-phase loop throttle valve and the preheater inlet. All pressure measurement locations are indicated in figures 1 and 5. Pressures at all these locations were measured by Bourdon pressure gages. These gages utilize a slack diaphragm that isolates the sodium test fluid from a NaK capillary tube connected to the Bourdon tube. The diaphragms of these gages stood off from the flow loops a distance sufficient to cool the fluid to the vendor's operating limits. The connecting lines and diaphragms were electrically trace-heated to prevent freezing of the sodium and to maintain an approximately constant temperature at the diaphragms. The Bourdon tube movement was transmitted to the recording equipment by a pneumatic system.

Strain-gage pressure transducers were also used to measure pressure at the four terminal points (figs. 1 and 5) of the boiler. The transducers were of the unbonded strain-gage type and were rated for use with corrosive fluids at temperatures up to 600° F (588 K). These transducers were connected to the pressure tap line adjacent to the Bourdon tube slack diaphragms. A strain-gage transducer was also used to measure the argon gas pressure in the expansion tank and to provide an electrical signal to the automatic cover-gas-pressure control.

Several in-loop calibrations were made for all pressure gages and transducers and are discussed in appendix B. The calibrations, which included the read-out equipment, indicated an error of approximately ±1 percent. Readout limits for the slack diaphragm gages were no better than 0.3 psia (2 kN/m^2 abs). During test operation the strain-gage transducers on the two-phase loop at the boiler were subjected to overtemperature. As a result either the transducer signal was lost or it experienced an excessive zero shift. These transducers, therefore, were not used for absolute pressure measurements but to obtain an indication of the boiler transient pressure behavior.

Temperature. - The temperatures of all Cb - 1-Zr alloy components were measured by platinum-platinum-13-percent-rhodium, ISA type R, thermocouples. The 0.02-inch (~0.5-mm) diameter wire was insulated by two-hole high purity alumina tubes and beads. The silicon and iron content of the alumina was within the limits specified in reference 7 for long time stability. No metal sheaths were employed. With the exception of four well inserts at the boiler terminals, all thermocouples were spot welded to the metal surface. The insulated thermocouple leads were secured by tantalum straps. The installation of thermocouples on the boiler shell is shown in figure 6. After installation, the thermocouples were insulated by wrapping the surface with several layers of dimpled tantalum foil. The location of all thermocouples on the boiler shell are indicated in figure 5. Two rows of thermocouples, 180° apart circumferentially, and designated as the 300 series and 400 series, were positioned 2 inches (5.08 cm) apart axially along the constant diameter section of the shell. In the case of the well inserts the insulated thermocouples were mechanically pushed into the wells and the alumina tubes were then wired into place. The well insert thermocouples were not used in the data reduction. At the beginning of the test they agreed closely with corresponding surface thermocouples, but after a period of time they started to read low and their transient response decreased. Examination after shutdown showed that the thermocouples had moved part way out of the wells and were no longer in good thermal contact.

In addition to the boiler, thermocouples were located at the exit of the main and preheater, on the line connecting the preheater to the boiler, at the condenser vapor inlet,

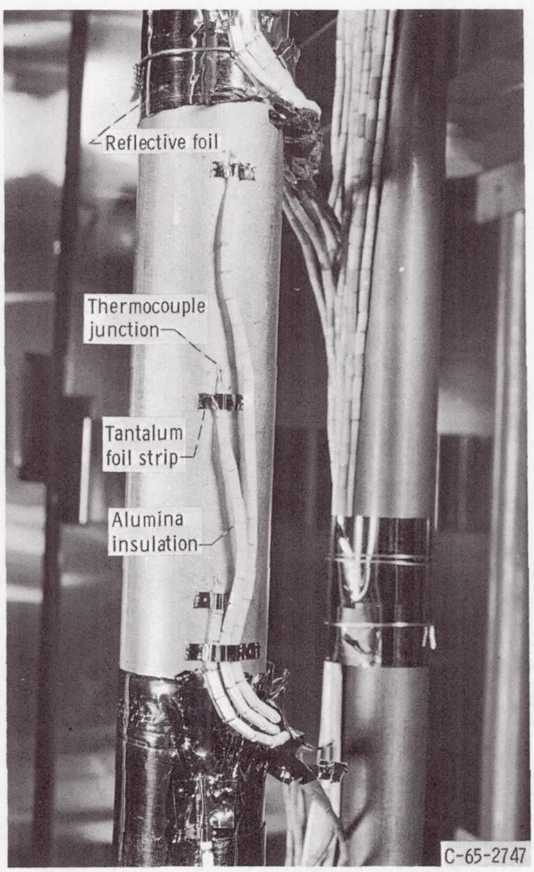


Figure 6. - Typical thermocouple installation on boiler shell.

at the condenser coolant inlet and outlet, at the mixing tee coolant inlet and outlet, and at four axial locations on the condenser shell (positioned 6 in. (15.34 cm) with first thermocouple 6 in. (15.34 cm) from vapor inlet location).

The platinum alloy thermocouple leads ran from the hot junction to vacuum-sealed, electrically insulated, multipin connectors installed in a flange on the vacuum vessel wall. At this point a junction to copper was made and copper extension leads then led to the readout and recording instruments. The temperature of this junction was monitored by Chromel-Alumel thermocouples attached to the connectors and flange. All thermocouples used for final data reduction were recorded on a central digital system. This system contained a controlled 100° F (311 K) reference junction.

The platinum-platinum-13-percent-rhodium thermocouple wire was calibrated by the vendor and was within the ISA ±1/4 percent specification. Direct, in-place calibration of the thermocouples was not made because of the inaccessibility of the test components and the difficulty of introducing an accurate reference inside the vacuum tank. Corrections, which are discussed in appendix B, were applied to the temperatures measured by the surface thermocouples at the inlet and exit of the boiler tube. All the temperatures presented herein are considered to be within the ±1/4 percent error limit.

No pickup or other effects of the large electrical heaters on the thermocouples were obtained, except in cases of lead shorting or breaking, wherein a ground loop could be set up. All readings in which there was a definite indication of thermocouple failure or malfunction were deleted from the data presentation of this report.

Auxiliary Instrumentation

In addition to the research data, many other measurements were made throughout the facility. These measurements were for general control and monitoring of the system, operation and control of subsystems, and for safety assurance.

All liquid-metal flow rates were measured with electromagnetic flowmeters. Liquid-metal pressures were obtained from slack diaphragm, Bourdon tube gages. Temperatures of liquid metal, argon gas, cooling air, and miscellaneous components were measured by surface and immersion Chromel-Alumel ISA type K, stainless-steel sheathed thermocouples. The liquid-level in the fill and drain tanks were measured by spark-plug type of probes, while the liquid level in the expansion tanks was measured by J-type resistance probes.

Vacuum measurements in the loop piping were made with thermocouple gages. Nude ionization gages were used in the vacuum vessel. A mass-spectrometer residual gas analyzer was installed at the pumping connection to the vacuum vessel to monitor the composition of the environment (especially the oxygen partial pressure) for the refractory-metal components.

Sodium oxide smoke detectors were installed at all exhaust air connections to the system.

Electric power to the main and preheaters was measured by panel indicating voltmeters and ammeters as well as by recording wattmeters.

Recording Equipment

All measurements desired for permanent record and data reduction were recorded on magnetic tape by a central automatic digital data system. Each recording cycle consisted of 181 words scanned at the rate of 20 words per second. A 10-millivolt range was used for the platinum thermocouples, the flowmeter signal, and the pressure transducer voltages. A 50-millivolt range was used for the Chromel-Alumel thermocouples. The system had a resolution of ± 1 microvolt.

All of the critical data recorded on the digital system as well as the output of the slack diaphragm pressure gages were also indicated and recorded on continuous single and multipoint null-balance strip chart recorders. The boiler tube inlet and exit pressures, the liquid metal flow rates in both main loops, and four selected boiler temperatures were also fed into a multichannel oscillograph. Additional data were visually monitored on panel indicators and manually recorded as desired.

EXPERIMENTAL PROCEDURE

The experimental procedure and test plan were designed to obtain primarily steady-state heat-transfer and pressure-drop performance of the boiler while separately varying the independent operating variables over significant ranges. The independent operating variables were the heating fluid flow rate and boiler shell inlet temperature, test fluid exit pressure and flow rate, and preheater exit temperature. The majority of tests were made with the two-phase loop vented to a controlled gas pressure in the expansion tank, but a few check tests were made with a constant inventory by closing the expansion tank isolation valve (figs. 1 and 2). Tests were made during two different operating periods. In the first preliminary sequence the preheater and boiler were directly connected. This test series was terminated by a sodium leak caused by a valve bellows failure. No boiling data from this preliminary test series are reported herein because the boiling was extremely unstable, the exit vapor quality was low, and better data were obtained in the second series reported herein. The facility has been operated for over 1100 hours at temperatures in excess of 800° F (700 K).

Filling and Starting

The filling and start-up sequences were the same for both the heating and two-phase loops. After completion of the cold gas pressure calibration, the loops and vacuum vessel were valved off from the argon gas supply and the loop and vessel vacuum pumps were started. On completion of the cold pump-down, the loop trace heaters, vacuum vessel wall heaters, and a radiant space heater inside the vessel were turned on, and the system temperatures gradually increased to approximately 400° F (478 K). During this period all systems were leak checked with a helium mass spectrometer leak detector. The loops were then backfilled with argon and the hot-gas pressure calibrations performed. The loops were then re-evacuated and the bake-out was considered complete when the pressures stabilized. Loop and vacuum vessel pressures of less than 10^{-3} and 10^{-7} torr, respectively, were attained.

The fill and drain tanks were then valved off from the loops. Reactor grade sodium was then forced by argon gas from the supply drums through a micrometallic filter into the fill tanks. After closing the charging valves and opening the loop fill valves (fig. 1), argon pressure was applied to the sodium forcing it up into the evacuated loops. When the sodium reached the desired level in the expansion tanks, the fill valves were closed and the circulation pumps were started. As soon as continuous flow was ensured, the main and preheaters were started and trace heaters on flow lines and the radiant space heater were turned off. The peak temperatures in the systems were raised to over 1000° F (811 K) as soon as possible in order to keep oxides and other impurities in solution until they were removed by the purification system. The cold-trap temperature was maintained at 300° F (422 K). Progress of the purification process was monitored by the plugging valve and by analysis of liquid metal samples. The main and preheater temperatures were raised in steps as fast as the outgassing rate would allow. An upper limit of 5×10^{-6} torr was maintained for the vacuum vessel and the atmosphere was continuously checked with the residual gas analyzer. When loop temperatures reached 1500° F (1089 K) hot trapping was initiated. After completion of the sodium purification and outgassing of the components inside the vacuum vessel, the pumps were temporarily stopped and a no-flow pressure calibration was made. The pumps were then restarted and the system was considered ready for research testing.

All-Liquid Tests

Prior to the boiling experiments several series of all-liquid runs were made. The purpose of these tests was to measure the pressure-drop characteristics of important components, to check the performance of the pumps, to obtain liquid-metal convective heat-transfer data for the heat exchanger boiler, to check the boiler heat balance, and to determine the general performance of the system. Data were obtained for flow rates in both loops up to 4500 pounds per hour (570 g/sec), temperatures up to 2160° F (1455 K), and with pumps 1 and 3 in various combinations of operating modes. After completion of the two-phase tests, liquid-phase convective heat-transfer checks were again made. The results of these calibration tests are presented in appendix B.

Two-Phase Tests

Initiation of boiling was generally very difficult, particularly in the preliminary test sequence. The boiling initiation problem was caused primarily by the ability of the sodium to support large amounts of liquid superheat. Operating techniques were eventually established by which boiling could be achieved when desired with a minimum disturbance to the system. These techniques and the problem of liquid superheat are discussed in the section RESULTS AND DISCUSSION.

After obtaining a steady boiling condition, the system was ready for recording the data. A steady condition is defined as one in which the independent variables were held constant and the mean value of the dependent variables remained constant even though oscillations existed. Steady-state data were taken over the following ranges:

Boiler exit temperature, $^{\circ}$F; K	1719 to 1983; 1210 to 1357
Test fluid flow rate, lb/hr; g/sec	75 to 380; 9.4 to 48
Boiler inlet subcooling, $^{\circ}$F; K	up to 454; 252
Heating fluid flow rate, lb/hr; g/sec	4830 to 5960; 600 to 750
Heating fluid inlet temperature, $^{\circ}$F; K	1874 to 2191; 1296 to 1473
Boiler exit quality	0.08 to 0.93

The general procedure was to set the two flow rates, the preheater exit temperature, and test-fluid exit pressure, and then to vary the heating fluid inlet temperature until the desired range was covered or operating limits were reached. Test was ended when (1) no further increase in exit quality could be obtained, (2) the system became excessively unstable, or (3) design thermal stress limits were reached. Limited tests were made in which some of the other independent variables were held constant. After setting a condition and determining that all drift had ceased, the data were recorded on the central digital data system, strip charts and oscillographs were marked, and data from nonrecording instruments were read. Boiling runs also were made in which ramp variations of some of the test variables were made. These included a decrease and increase of the preheater temperature and a decrease of the test fluid flow rate. Tests covering step changes of the test fluid flow rate and pressure were also made. Data were also taken for the conditions of boiling initiation (liquid superheat) by raising the heating fluid inlet temperature and also by decreasing the two-phase loop pressure.

RESULTS AND DISCUSSION

Several types of boiler operation were encountered during the investigation reported herein. These may be categorized with respect to the following: (a) steady or unsteady performance, (b) existence of a critical heat-transfer condition (burnout), and (c) the phase state of the test fluid at the boiler inlet. It was possible to flash the test fluid at the orifice upstream of the boiler to vapor qualities up to 0.03. For all tests in which the test fluid entered the boiler in the liquid phase (subcooled or superheated), superheated liquid existed for considerable distances inside the boiler before vaporization commenced. Heat-transfer regimes experienced included liquid convection, high rates of boiling (nucleate), critical boiling heat transfer (burnout), transition boiling (post-burnout), and vapor convection. Superheated vapor at the boiler exit was not obtained (exit quality > 1.0) nor was there any indication of two-phase critical (acoustic limited) flow rates. The aforementioned types of boiler operation and thermal regimes are subsequently discussed in terms of heat-transfer coefficients, pressure drop, critical or exit quality, as well as the independent test variables.

Data Tables

The tabulated data reported herein are given in tables I and II. Table I presents the basic measurements and some computed parameters including quality, pressure drop, rate of heat transfer, and overall heat-transfer coefficients. The data of table I are generally ordered with respect to increasing values of the following variables:

(1) Test fluid exit saturation temperature

(2) Test fluid flow rate

(3) Heating fluid inlet temperature

The remarks column in table I identifies the conditions of the tests. The remarks column is divided into five subcolumns.

Table II lists the local temperatures along the boiler shell.

The run numbers given in tables I and II indicate the chronological sequence of testing.

Boiler Oscillations

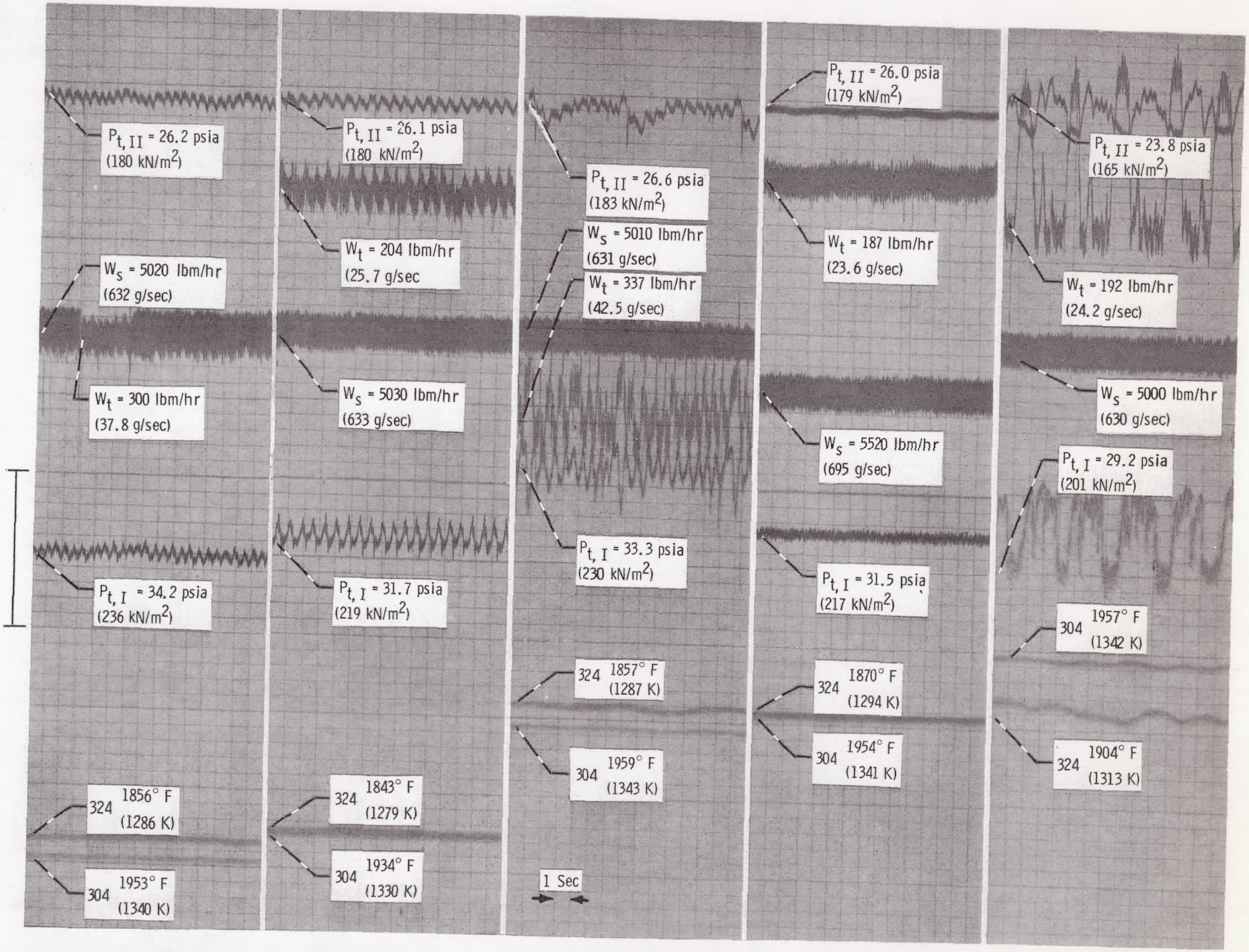
Oscillations of the test fluid flow rate, pressure, and temperature were frequently encountered during the investigation. The objectives and system capabilities of this investigation precluded a basic study of boiler stability. The variations in time of certain variables were recorded as a possible aid in characterizing and understanding the range of boiler performance obtained. For this purpose the output of the flowmeters, the test fluid strain-gage pressure transducers, and two shell thermocouples were recorded on a multichannel oscillograph. Typical traces are shown in figure 7. Considerable noise is apparent in some of the signals (particularly flow rate) which is attributed to read-out system deficiencies as well as to the large electric heaters. Considering first the two-phase inlet condition, the test fluid flow rate and pressures exhibit a regular oscillation with a dominant frequency of 1 to 2 hertz. For the two-phase inlet tests without burnout occurring, the amplitude of the flow and pressure oscillations varied from that barely detectable to approximately ±10 percent and the shell thermocouples were steady. With burnout somewhat larger amplitudes were obtained and the shell temperatures began to show some variation. In terms of the remarks code of table I all the two-phase inlet tests are rated as S to OF as a function of increasing amplitude but with a regular oscillation of essentially constant frequency.

When the test fluid inlet condition was at the two-phase to liquid transition (alternately two-phase and liquid), the oscillations became more complex and irregular, the amplitude of the flow and pressure variations increased markedly, and the shell temperatures varied continuously. These oscillations are rated as OF and F.

For the case of the test-fluid inlet condition being in the liquid phase, the flow, pressure, and temperature traces were either very steady or extremely unsteady. In fact, the liquid inlet condition gave the most steady and the most unsteady results of the entire investigation. In addition to a larger amplitude, the oscillations became increasingly complex and irregular, and a lower frequency (1/4 to 1/3 Hz) appeared which was not obtained with the two-phase inlet results. In some cases the oscillations became so severe that back flow occurred and sometimes stopped boiling by activating safety interlocks. The oscillations are rated as either S or F.

In all cases the inlet pressure and flow oscillations were out of phase by approximately 180°. For the liquid inlet case the inlet and exit pressures were always in phase while for the two-phase case they were both in and out of phase. Generally the pressures were in phase for the two-phase case only at conditions of low quality, high heat-transfer coefficients, and small oscillations. Any attempts to analyze the oscillations and boiler stability must take account of the particular conditions of these tests including the large liquid inventory outside the boiler, the expansion tank, the condenser coolant bypass loop, as well as a compressible fluid feed for the two-phase inlet tests.

Scale factors per 10 divisions:
$P_{t,\,I}$ and $P_{t,\,II}$, 15 psi (103 kN/m^2)
W_t, 100 lbm/hr (1.26 g/sec)
Temperature, 92° F (52 K)
(Increase ↓)



Run 12; two-phase (small oscillation) | Run 19; two-phase (large oscillation) | Run 22; transition from two-phase to liquid phase | Run 9; liquid phase (steady) | Run 24; liquid phase (unsteady)

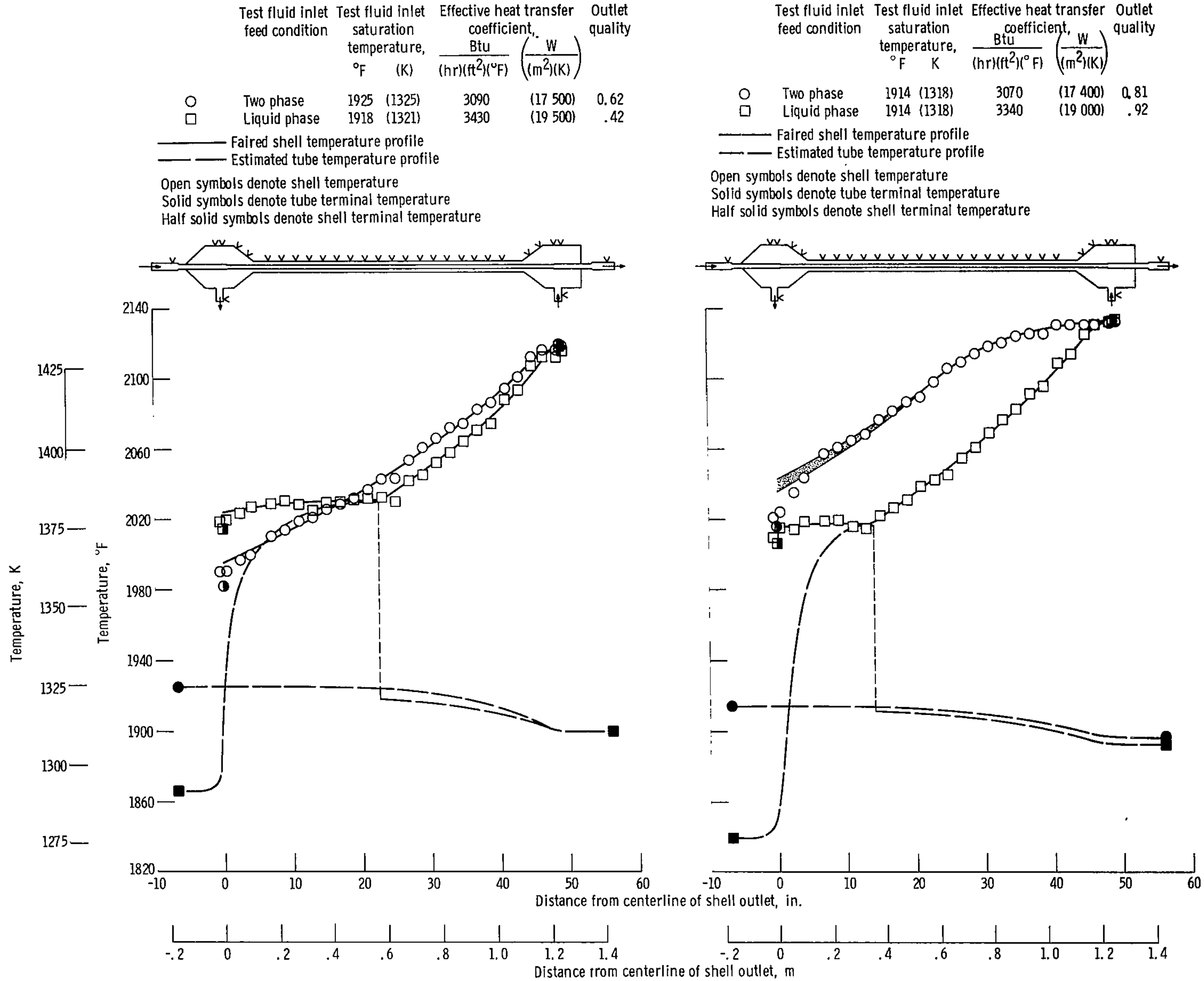
Figure 7. - Typical oscillations of flow rates, pressures, and shell temperatures obtained for various test fluid inlet conditions. Note: (1) Only mean values are listed, and (2) Relative position of some traces has been changed. (304 and 324 denote 300 series shell temperatures at 44.9 inch (114 cm) and 4.1 inch (10 cm), respectively.)

Boiling Heat Transfer

The boiling heat-transfer results are presented and discussed in terms of shell axial temperature profiles, overall heat-transfer coefficients, and the conditions of critical heat transfer (burnout).

Boiler shell temperature profiles. - Considerable insight as to the boiling behavior may be obtained from a study of the axial variation of the shell temperature. Typical boiler shell profiles are shown in figure 8. The thermocouples on the end plenums should be given little weight (especially at the reference plane end) because of the increased radial and axial conduction. Shown are two of the major types of shell profiles obtained. All conditions in figure 8(a) are essentially the same except that, in one case, the sodium entering the tube is in a two-phase condition (flashing existing at the upstream orifice) and, in the other case, the inlet feed is a subcooled liquid. For the case of the two-phase inlet, the shell temperature increases along the boiler following a generally smooth curve indicating a continuous increase in vapor quality and the same general type of heat transfer and boiling. The overall heat-transfer coefficient is relatively large (3090 Btu/(hr)(ft^2)($^\circ$F); 17 500 W/(m^2)(K)) and appears to have only minor variations along the length of the boiler. The test fluid temperature is estimated from considerations of two-phase pressure drop as no local measurements were made.

In contrast, the shell temperatures for the case of the liquid-phase inlet in figure 8(a) increase slightly initially and then are almost uniform to approximately halfway along the boiler. At this point there is a sudden transition and the shell temperatures rapidly increase and follow a curve very similar to that for the two-phase inlet condition. The isothermal zone represents a region of superheated liquid sodium in the tube which eventually breaks down to a saturation condition that is then followed by high performance boiling heat transfer. The existence of liquid superheat within a boiler under steady, continuous flowing conditions has been reported by Bond (ref. 2) for potassium in a constant heat flux boiler. Shell profiles similar to the superheated liquid curve of figure 8(a) have been reported by Collins et al. (ref. 8) for a multitube heat exchanger potassium boiler although no explanation was given. The liquid inlet profile of figure 8(a) indicates a maximum liquid superheat of approximately 110° F (61 K). Sudden vaporization of this amount of superheat would produce a quality of approximately 0.02 assuming no other heat sources. Considering this value of quality (corresponding to vapor filling approximately 3/4 of the tube cross section) and the sudden sharp increase in the shell profile, vaporization may be assumed to occur at a high rate from a single, well defined interface with no nucleation. Downstream of this vapor interface the fluid is probably in a steady annular flow pattern with a thin liquid film on the wall. The overall heat-transfer coefficient in this downstream region is even higher (3430 Btu/(hr)(ft^2)($^\circ$F); 19 500 W/(m^2)(K)) than for the two-phase inlet case and also appears independent of



(a) Nominal test fluid flow rate, 215 pounds mass per hour (27.1 g/sec).

(b) Nominal test fluid flow rate, 130 pounds mass per hour (16.3 g/sec).

Figure 8. - Comparison of boiler temperature profiles for two-phase and liquid-phase test-fluid inlet feed conditions. Nominal shell flow rate, 5000 pounds mass per hour (630 g/sec).

length. The reduced exit quality for the liquid inlet test reflects the sizable length of the boiler over which little or no heat transfer occurs.

Results for a lower test fluid flow rate are shown in figure 8(b). Again, all variables are the same except for the inlet feed state. For the liquid inlet test, the effect of reducing the test fluid flow rate is to reduce the amount of liquid superheat and to move the point of superheat breakdown further upstream. Following the initiation of vaporization, a region of large overall heat-transfer coefficients again results, and an exit quality of 0.92 is obtained without reaching a critical heat-transfer condition.

Lowering the test fluid flow rate has considerable effect on the boiler performance for the two-phase inlet case. A critical heat-transfer condition is obtained at approximately halfway along the boiler (indicated by the inflection of the shell temperature profile) which is followed by a transition region of reduced heat transfer. The entire shell profile lies above, and the exit quality is less than that obtained for the corresponding liquid inlet case. The overall heat-transfer coefficient upstream of the critical point was about the same as that obtained at the larger test fluid flow rate (fig. 8(a)). This test, however, was quite unsteady with oscillations of the shell temperatures (indicated by shading in fig. 8(b)).

The shell temperatures of the liquid inlet tests of figure 8 were constant with respect to time, and this was quite generally the case. However, in some tests large-amplitude oscillations of flow and pressure existed and fluctuations of the shell temperatures were noted (run 24, fig. 7). These oscillations are not considered to be directly related to the existence of the superheat condition but probably arise from interactions with other parts of the system and specific operating techniques. In general the steady tests with a liquid-phase inlet condition and liquid superheat in the boiler resulted in the largest local heat fluxes and exit qualities.

Average overall heat-transfer coefficients. - Overall heat-transfer coefficients averaged over the full boiler length were computed for all the boiling runs reported herein. (Details of the calculation are given in appendix C.) Typical average coefficients are presented in figure 9 as a function of the boiler exit quality for a test-fluid exit temperature of 1740° F (1222 K). Similar results were obtained at the other exit temperatures. The data show considerable scatter with respect to both the flow rate and exit quality as well as with the type of boiling. Some major trends, however, exist. The heat-transfer coefficients for the liquid-phase inlet tests were usually considerably less than those for the two-phase inlet conditions, reflecting the low heat transfer in the liquid superheat region. For tests with a critical (burnout) condition, the largest average coefficients occurred when the critical condition was obtained first at the boiler exit. Subsequent increase in the heating rate would force the critical point upstream into the boiler, and the average coefficient would decrease sharply with only a small increase in exit quality. For the two-phase inlet tests, the average coefficient tends to decrease with increasing exit quality and appears to vary inversely with the test fluid flow rate.

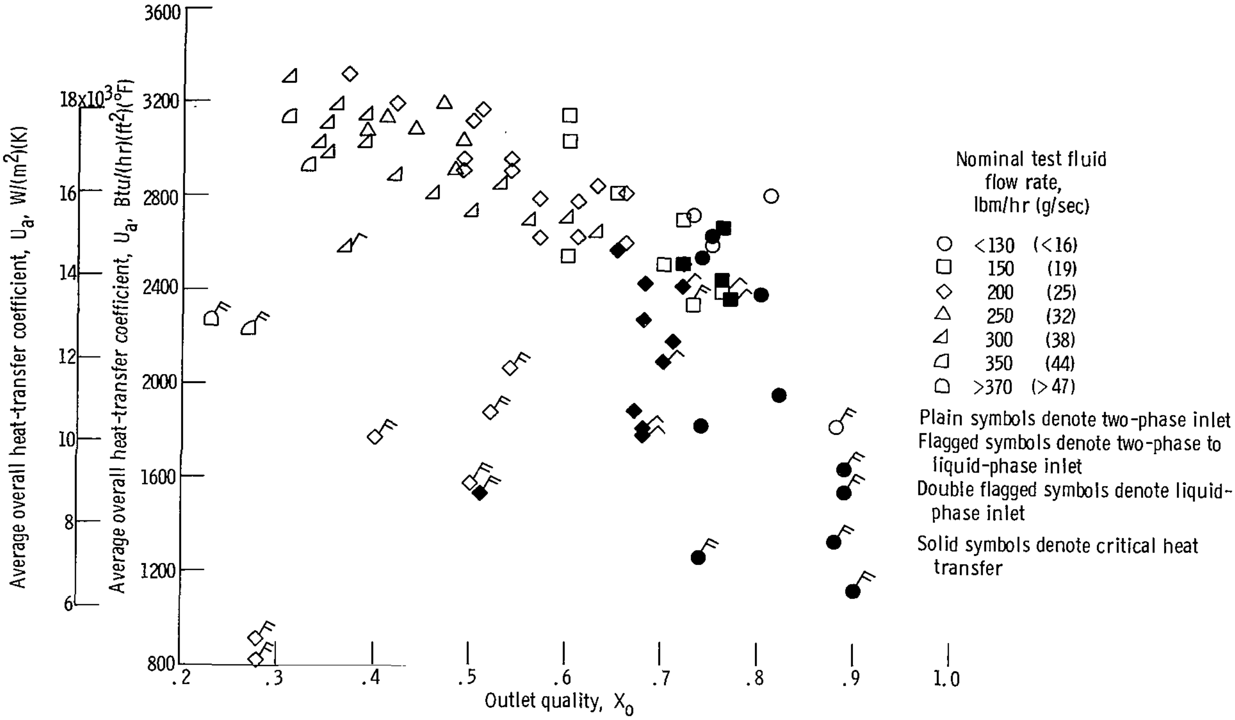


Figure 9. - Variation of average overall heat-transfer coefficient with outlet quality. Test fluid exit temperature, 1740° F (1222 K); heating fluid flow rate, 5000 pounds mass per hour (630 g/sec).

Much of the scatter and confusion of figure 9 results from plotting together the data of several different heat-transfer regimes in terms of an average coefficient based on a logarithmic temperature difference taken over the entire boiler length. Under these conditions such a definition is no longer valid. For these reasons the heat-transfer coefficients subsequently are discussed separately for the various boiling regimes.

Effective overall heat-transfer coefficients. - An effective overall heat-transfer coefficient may be computed for the region of relatively high rates of boiling heat transfer. This region is taken as extending from the axial location where a two-phase condition is first obtained to the location of critical heat transfer or the boiler exit whichever is reached first (see appendix C). Effective coefficients are presented in figure 10 for the liquid-inlet tests as a function of the boiler outlet or critical quality. With the exception of the unsteady results, the data fall within a scatter band of less than ±10 percent. No significant trends with test fluid flow rate or exit temperature were found. The data might be interpreted as showing a slight increase in heat-transfer coefficient with increasing quality. The actual boiling coefficient at the inner surface of the tube, however, is considered to be large relative to the shell convective and tube wall conductances, and hence could vary considerably with only a minor effect on the overall coefficient. As

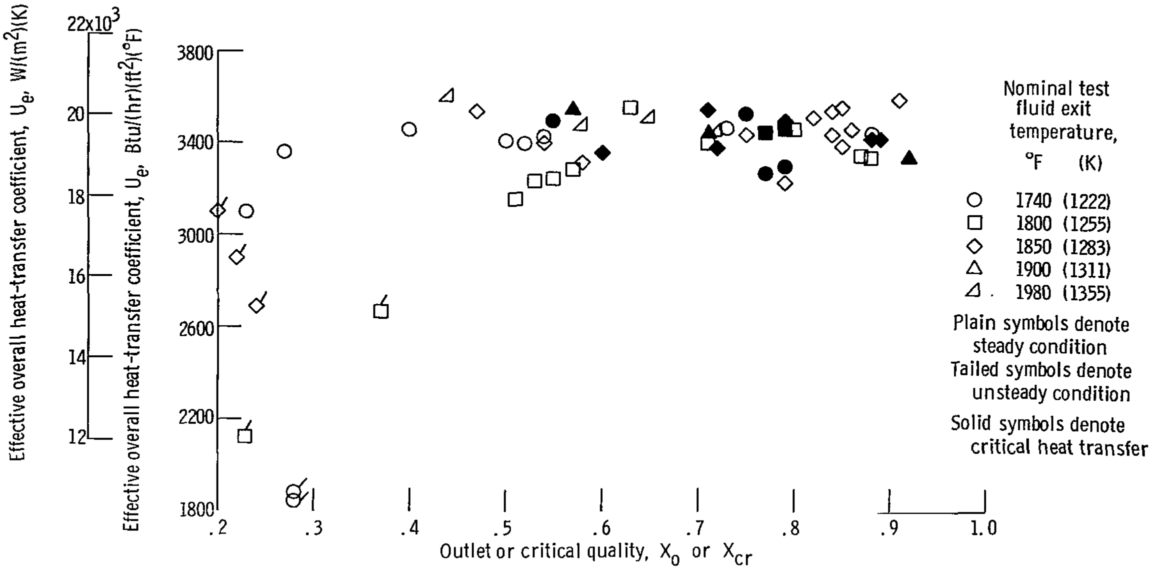


Figure 10. - Variation of effective overall heat-transfer coefficient with outlet or critical quality for liquid-phase boiler inlet tests and for various test fluid exit temperatures. Test fluid flow rate, 75 to 380 pounds mass per hour (9.4 to 48 g/sec); heating fluid flow rate, 4880 to 5860 pounds mass per hour (613 to 750 g/sec).

stated in the discussion of the shell temperature profiles (fig. 8), it is felt that vaporization at the point of liquid superheat breakdown occurs from a single, well defined interface. The vapor quality corresponding to the liquid superheat at breakdown varied from about 0.01 to 0.04 over the whole range of conditions of this investigation. For sodium at the conditions of this investigation, a flow pattern map based on generalized relations such as Baker's (ref. 9) or recent boiling data (ref. 10) indicates that the bubble-slug-annular two-phase flow pattern transitions occur at qualities of less than 0.005 to 0.02. Thus, for the liquid inlet tests, a sudden transition from a liquid phase to a fully developed, stable annular-flow pattern with a minimum of liquid entrainment in the vapor core could be expected. Such a flow pattern would be favorable for steady boiling with large boiling heat-transfer coefficients and high qualities without the occurrence of a critical heat-transfer condition.

Effective overall heat-transfer coefficients for tests with a two-phase inlet condition are shown in figure 11. The quality in this sequence was increased by increasing the heating-fluid inlet temperature with all other conditions including the preheater exit temperature and pump voltage held constant. The data show a definite decrease in the effective coefficient as the quality is increased until a critical condition is reached. As the heating-fluid temperature is increased further, the critical condition moves upstream into the tube at successively lower qualities and with perhaps a slight increase in the effective coefficient. In addition, as the quality increased, all the tests become increasingly unsteady. The results of figure 11 do not necessarily indicate a direct effect of

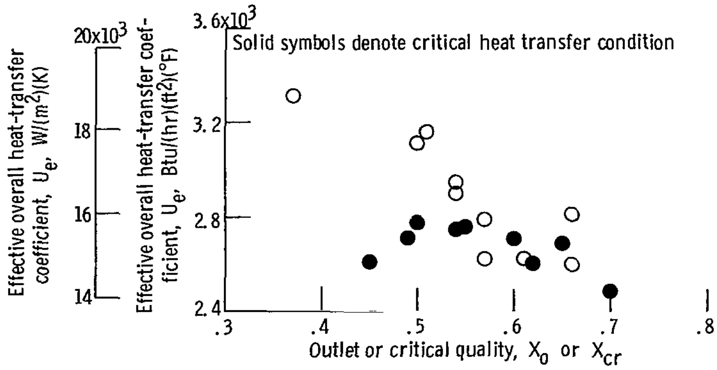


Figure 11. - Typical variation of effective heat-transfer coefficient with outlet or critical quality for two-phase inlet tests with increasing heating fluid inlet temperature. Test fluid flow rate, 200 pounds mass per hour (25.2 g/sec); heating fluid flow rate, 5000 pounds mass per hour (630 g/sec); exit saturation temperature, 1740° F (1222 K); preheater exit temperature, 1945° F 1336 K).

exit or critical quality on the effective heat-transfer coefficient. Instead, the decline in the heat-transfer coefficient is probably a function of the inlet phase condition and the rate of heating. Krakoviak (ref. 11) has reported the effectiveness of flashing at the inlet to a boiler to obtain stable, high performance boiling. He indicated that, in addition to eliminating liquid superheat, flashing at the inlet could produce an inlet quality sufficient to avoid the flow pattern transition from bubble to slug to annular. Such a mechanism was suggested for the liquid-inlet tests (see discussion of fig. 8) where the quality corresponding to the liquid superheat was always large enough to ensure an optimum flow pattern. Referring to the data of figure 11, the test at an exit quality of 0.37 had an inlet quality of almost 0.01 and a heat-transfer coefficient of 3310 Btu per hour per square foot per $^{\circ}$F (18 800 W/(m^2)(K)) was obtained. This value of the coefficient corresponds closely to that obtained for the liquid inlet case of figure 10 at similar values of quality at superheat breakdown. As the exit quality for the tests of figure 11 was increased (increasing heating fluid temperature with all other conditions constant) the pressure drop (and hence, inlet pressure) across the boiler increased. Thus there was less temperature drop across the orifice upstream of the boiler and the boiler inlet quality decreased. At the same time the driving temperature difference ($\Delta t_o = t_{si} - t_{to}$) was increasing and hence increased the local heat fluxes and the axial heat flux and quality gradients. It is believed that these two factors (inlet quality and Δt_o) are the source of the decrease in the effective overall heat-transfer coefficient. It should be noted that while the heat-transfer coefficients for the liquid inlet case showed no effect of Δt_o, the equivalent quality of superheat breakdown was always greater than the inlet quality of the two-phase inlet tests.

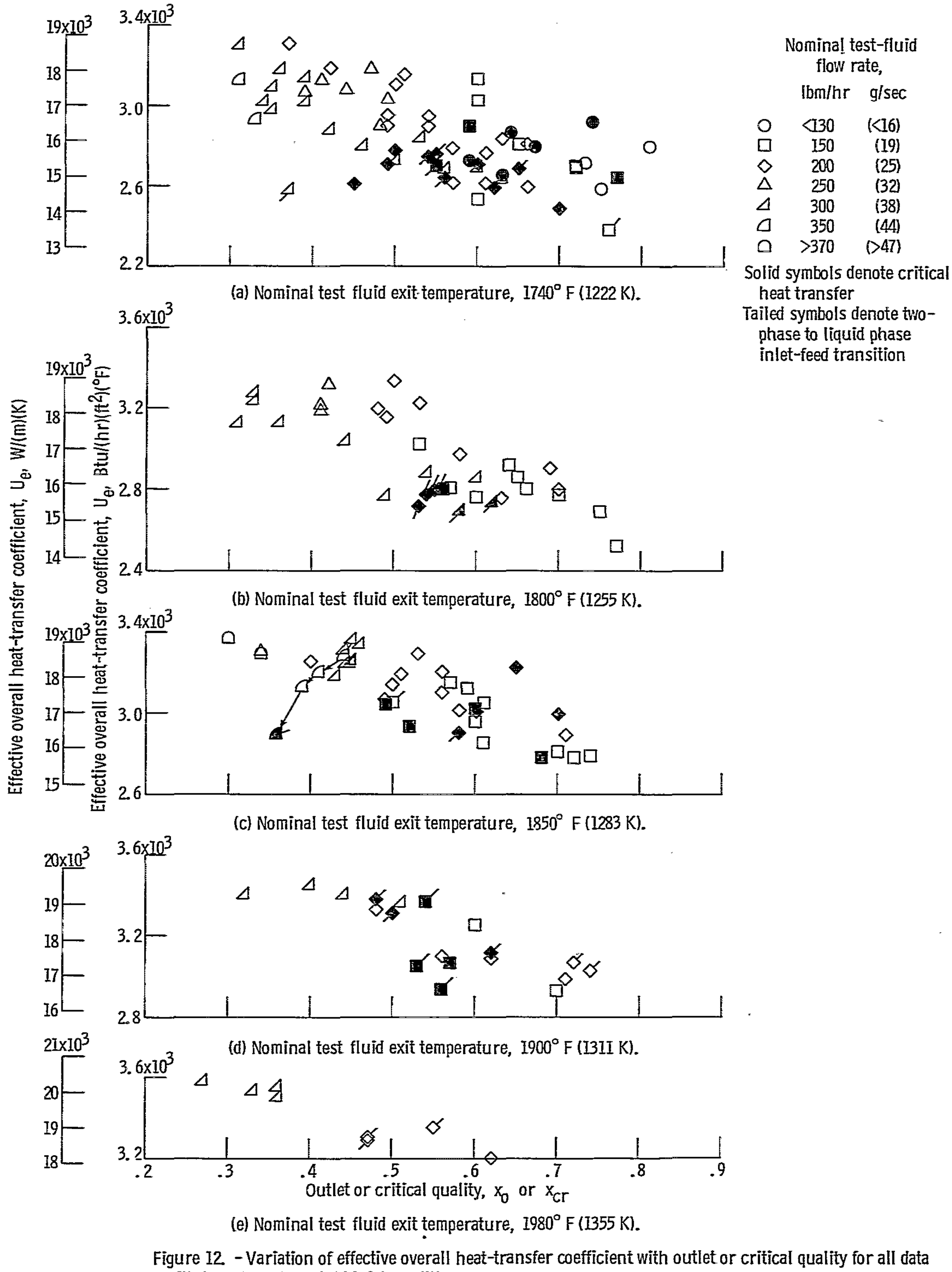


Figure 12. - Variation of effective overall heat-transfer coefficient with outlet or critical quality for all data with two-phase test fluid inlet condition.

The effective overall heat-transfer coefficients for all the two-phase inlet tests are shown in figure 12. These results are generally similar to those of figure 11 except for an increase in scatter which resulted from the tests being made over a range of preheater exit temperatures. There appears to be a trend for the heat-transfer performance to improve with increasing test fluid boiler exit temperature. This result might be expected because the fluid property parameters, particularly the liquid to vapor density ratio, become more favorable as saturation temperature increases.

The sequence of results connected by arrows in figure 12(c) (runs 224 to 228) shows the decrease in heat-transfer coefficient caused by a decrease in the test fluid inlet quality. In this test series the preheater exit temperature was continuously decreased with the shell side conditions, the two-phase loop-system pressure, and the pump voltages held constant. All other variables were allowed to seek their own levels. The history of this transition from a two-phase boiler inlet to a liquid phase inlet condition is shown in figure 13. The curve for the temperature upstream of the orifice and the ori-

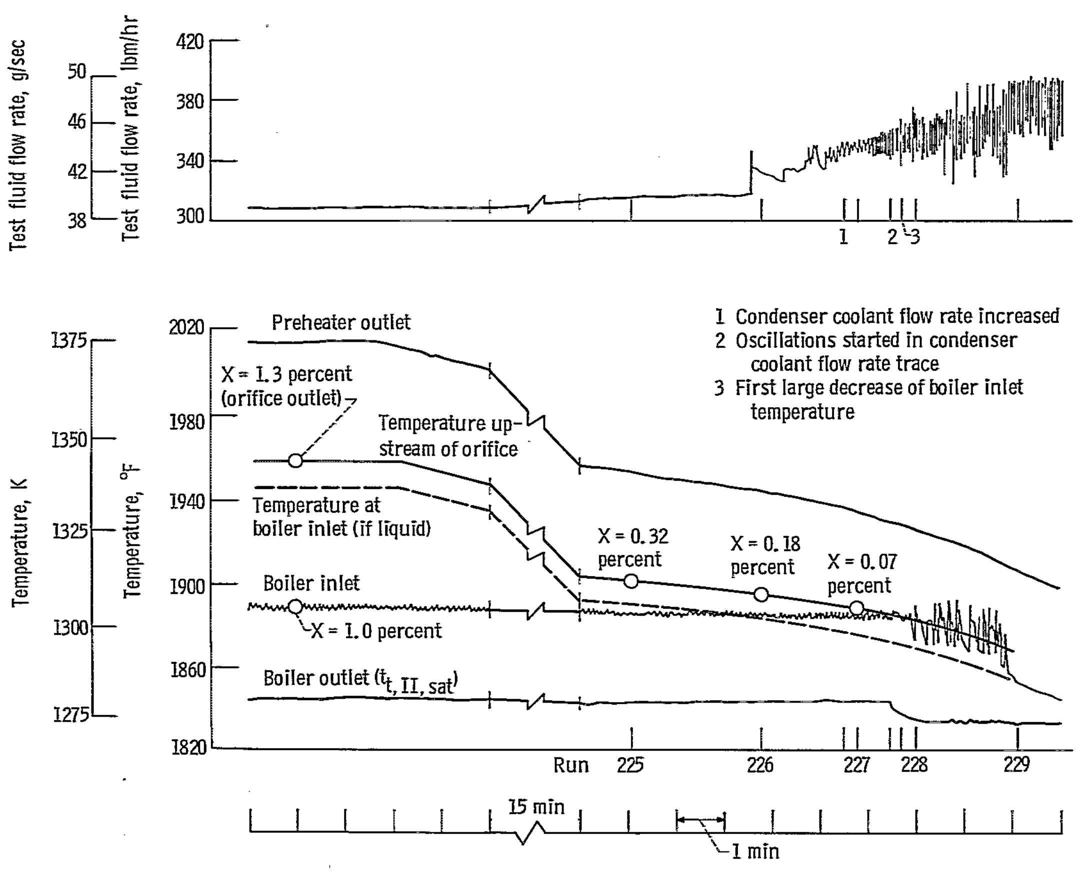


Figure 13. - Transition from two-phase boiler inlet conditions to liquid-phase inlet conditions. All temperatures are for test fluid.

fice and boiler inlet qualities are calculated and should be taken as only approximate because no direct measurements of temperature and pressure were made between the preheater exit and the boiler inlet. The dashed curve (temperature at the boiler inlet if liquid phase) represents the liquid temperature drop equivalent to the heat loss from the orifice to the boiler inlet.

For the first test in the sequence (run 224, taken 33 min before run 225) the boiler was operating very steadily with an inlet quality of approximately 0.01 and an exit quality of 0.45. The flow trace on the oscillograph (not shown in fig. 13) indicated that little other than electrical noise and a relatively high heat-transfer coefficient was obtained. The performance continued steady for $25\frac{1}{2}$ minutes at which time a decrease in the preheater exit temperature was initiated. Approximately 5 minutes after the start of the preheater temperature ramp the flow trace on the oscillograph showed the first indication of a small oscillation with a frequency of approximately 2 hertz. At this time the quality at the boiler inlet was at least 0.075. As the preheater exit temperature (and test fluid inlet quality) was further reduced, the flow rate increased slightly, and the test fluid inlet and exit temperatures and pressures remained essentially constant but with small increases in the oscillations. At the time of run 226 the computed inlet phase condition was very close to zero quality, the heat-transfer coefficient had decreased, and the exit quality had decreased to 0.41. At approximately the same time the flow rate increased suddenly, fluctuated randomly, and finally resumed a more regular oscillation, but at a greater amplitude. This increase in flow rate might be considered as resulting from the orifice changing from a condition of discharging vapor to that of superheated liquid which then reverts to a saturation condition before the boiler inlet. If the fluid is considered to be in the liquid phase, the heat loss between the orifice and the boiler inlet would be sufficient to lower the computed inlet temperature to, or slightly, below saturation at the time when the first flow rate increase occurred.

Shortly before run 227 the condenser coolant flow rate experienced a sudden, unknown increase and the amplitude of the test fluid flow rate oscillations increased. The boiler inlet, however, was still at a saturation condition. Approximately 40 seconds after run 227, an oscillation of the condenser coolant flow rate developed, and the boiler exit temperature decreased. This decrease probably resulted from the decrease in vapor load and increase in coolant flow rate to the condenser, causing a decrease in condenser inlet pressure (the condenser was probably flooded with liquid) and hence a decrease of the boiler exit pressure and temperature. At about 20 seconds before run 228, large, irregular fluctuations appeared in the test fluid boiler inlet temperature, pressure, and flow rate. It was at this point that the computed temperature upstream of the orifice had reached a value corresponding to saturation at the boiler inlet mean pressure. Simultaneously with the appearance of these irregular fluctuations, the boiler shell temperatures showed a sudden sharp increase. This condition continued for about 2 minutes during which alternate slugs of liquid and vapor were entering the boiler.

Further reductions in the preheater exit temperature resulted in subcooled liquid at the boiler inlet and superheated liquid in the boiler. The presence of liquid within the boiler caused a sharp decrease in exit quality and pressure drop which, in turn, caused a flow rate increase. Subsequent reductions in the preheater exit temperature resulted only in further reductions in the boiler inlet temperature. Later the preheater exit temperature was increased. The test fluid temperature at the boiler inlet increased correspondingly and finally reached a condition of liquid superheat of 97° F (54 K) without upstream vaporization. During this liquid feed condition, major oscillations of all the variables were obtained corresponding to the oscillograph traces of figure 7 (run 24). It was found that this unsteady condition could usually be eliminated by a sudden decrease of the test fluid flow rate from a previously high value. Either a steady, liquid-inlet condition or a two-phase inlet condition would result depending on the level of the preheater exit temperature.

Local parameters. - Local parameters (heat-transfer coefficients, quality, etc.) generally were not computed because no measurements were made of the local tube wall or local bulk temperatures for either the test or heating fluids. Some insight into the nature of the local overall coefficients, however, may be obtained by use of the measured shell outside wall temperatures and by approximating the local test fluid bulk temperature from the overall pressure drop data. One way of utilizing the measured shell temperatures is the method suggested by Stein (ref. 12) in which the natural logarithm of a dimensionless shell temperature $(t_s - t_{t,i}/t_{s,i} - t_{t,i})$ is plotted against the dimensionless axial distance $(4l/Pe\, d_h)$. A linear plot indicates a constant heat-transfer coefficient and the value of the coefficient is proportional to the slope of the plot. A few plots of this type were made, which indicated the following:

(1) For the liquid inlet tests, the local overall heat-transfer coefficient was constant in the boiling region except for a short transition length following the liquid superheat breakdown. The value of the coefficients agreed well with those of figure 10 (~3500 Btu/(hr)(ft^2)($^{\circ}$F); 19 900 W/(m^2)(K)). The local coefficient upstream of the location of liquid superheat breakdown also was constant and agreed well with predictions based on liquid-phase convection in both tube and shell and the tube wall thermal conductivity.

(2) For the two-phase inlet tests a constant local coefficient was obtained only in the downstream section of the boiler. Near the boiler inlet a lower value of the coefficient was obtained which gradually increased with length until reaching an asymptote whose maximum value corresponded to that of the boiling region of the liquid inlet tests (fig. 10). As the inlet quality was reduced and/or the Δt_o increased, the value of this asymptote of constant local heat-transfer coefficient decreased corresponding to the decrease in effective overall coefficient shown in figures 11 and 12. The magnitude of this constant coefficient varied from a maximum of approximately 3500 Btu per hour per square foot per $^{\circ}$F (19 900 W/(m^2)(K)) to a minimum of approximately 2500 Btu per hour per square foot per $^{\circ}$F (14 200 W/(m^2)(K)).

The local heat-transfer coefficient may also be determined by assuming the heating fluid (shell side) coefficient and differentiating the shell temperature distribution to obtain an approximate heat flux. The actual local heating fluid bulk temperature and heat flux can then be obtained by a trial process. Using a local test fluid temperature approximated from the overall pressure-drop data, the local overall heat-transfer coefficient, quality, and tube wall temperatures can be computed. Results of such an approach are shown in figure 14 for run 66. Details of the computation are given in appendix C. This run had a two-phase inlet condition, was relatively steady, and had a relatively large effective coefficient (3310 Btu/(hr)(ft^2)(^{o}F); 18 800 W/(m^2)(K)). The local heat flux and quality varied almost exponentially with length, while the local overall heat-transfer co-

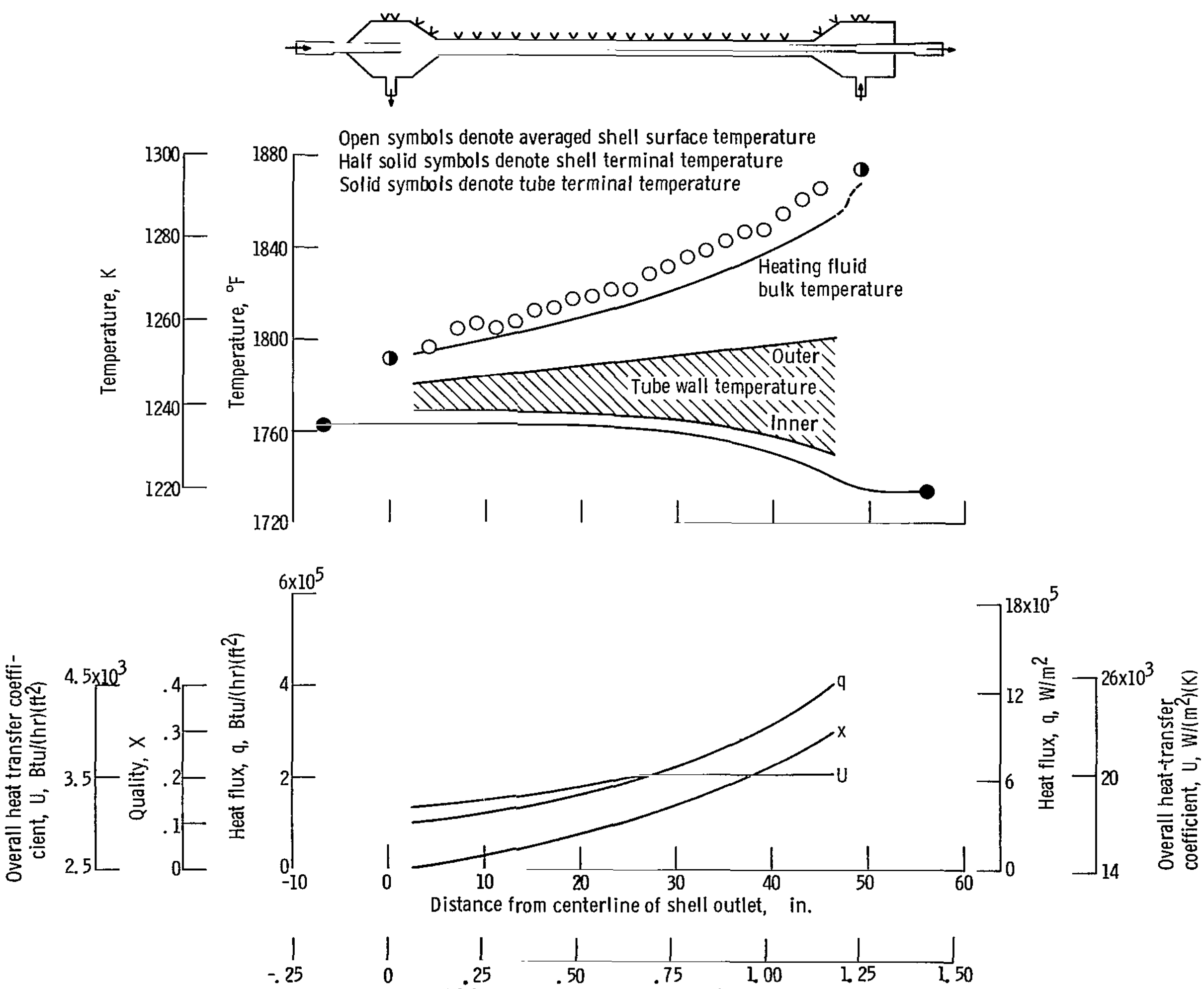


Figure 14. - Typical variations of local heat transfer and vapor quality along test boiler. Heating fluid flow rate, 5040 pounds mass per hour (635 g/sec); test fluid flow rate, 197 pounds mass per hour (24.8 g/sec).

efficient increased in the upstream section of the boiler and was essentially constant thereafter. The local pressure dropped imperceptably in the first half of the boiler. This result would be expected because (as will be discussed in the section Two-Phase Pressure Drop) the friction term is a minor part of the total pressure drop and, in the first part of the boiler, the liquid on the tube wall is moving relatively slowly, minimizing the frictional pressure drop while the low quality gives a small momentum pressure drop. The computed results of figure 14 indicate that the heating fluid convection and tube wall conduction constitute the major part of the thermal resistance. Hence large variations in the local boiling coefficient would have only minor effects on either the local or effective average overall coefficients.

Boiling heat-transfer coefficients. - Tube-side boiling heat-transfer coefficients were not computed for all the tests because of the limited precision of the data and uncertainty as to the correct value of the shell-side convective coefficient. The problem of accuracy is well illustrated by the values shown in figure 14. The estimated tube inner wall to test fluid bulk temperature difference for this run was less than 10° F (5.6 K) which is close to the ±1/4 percent thermocouple limit of error.

The problem arising from the uncertainty as to the shell convective coefficient is seen by considering Dwyer's (ref. 13) prediction for the convective coefficient at a constant heat-flux boundary condition. For the conditions of this investigation, Dwyer's prediction plus the tube wall conductance gives a combined conductance of 3470 Btu per hour per square foot per $^{\circ}$F (19 700 W/(m^2)(K)) (see appendix C), which is about the same or even less than the experimental overall coefficients (figs. 10 and 12). Other predictions for the shell coefficient (refs. 6 and 14), however, give values at least 25 percent greater than Dwyer. A value of the shell coefficient 25 percent greater than Dwyer's prediction was used in the computations for figure 14. The resulting boiling heat-transfer coefficient varied from about 15 000 to 40 000 Btu per hour per square foot per $^{\circ}$F (85 000 to 230 000 W/(m^2)(K)).

Despite the uncertainty as to the absolute value of the boiling coefficients, the variation along the boiler is fairly well defined. Near the boiler inlet the lowest value of the boiling coefficient is obtained which then increases rapidly as the mass quality increases along the tube, finally attaining a relatively high value with little change thereafter. This type of axial variation and the approximate magnitudes obtained may be taken as indicating that the boiling heat transfer process may follow the models proposed by Dengler and Addoms (ref. 15), Chen (ref. 16), and Sachs and Long (ref. 17). These models suggest that initially the boiling heat transfer is primarily by nucleation (values in agreement with pot boiling nucleate heat transfer) with a small additional contribution of the stream convection. As the fluid travels along the tube and quality increases, the convective term increases and the nucleate term decreases. Finally the nucleation process is suppressed entirely and the heat transfer is by a two-phase convective process. In this last region heat is being transferred convectively through a thin liquid film on the tube wall with evaporation occurring at a liquid-vapor interface. The convection is assumed to be controlled by an effective velocity which is taken as a function of the local liquid fraction. If the convectively controlled heat-transfer mechanism is correct, the sodium boiling heat-transfer coefficients would increase less with increase in quality than would a fluid of Prandtl number of 1 because of the relatively minor effect of velocity on liquid metal convective coefficients.

Downstream of the location of a critical heat-transfer condition, the change in the local boiling coefficient is so rapid, and the accuracy of computation so limited that meaningful values of the coefficient cannot be computed. The variations of the shell temperature profiles in this region indicate that the coefficient drops quickly from a high boiling value to one several orders of magnitude less and probably approaches the condition of vapor convective heat transfer.

Critical heat-transfer condition. - One of the most important parameters used to evaluate boiling performance is the condition of critical heat transfer (variously referred to as critical heat flux, DNB, boiling crises, etc.). Critical conditions were obtained in this investigation over a wide range of qualities and locations in the boiler and for both steady and unsteady conditions. The critical condition was taken as that at which an inflection in the shell temperature profiles (and hence, decrease in heat-transfer rate) was observed. The critical heat flux was computed by averaging the values obtained by differentiating the shell temperature profile and that obtained by the product of the effective overall coefficient and the local estimated shell to test fluid temperature difference.

For a constant heat flux boiler it is common to present the critical quality in terms of the critical heat flux. The value of this approach for heat exchanger data is not clear. However, the experimental values for the sodium boiler are presented in these terms in figure 15. Included in the figure are results for boiling potassium (refs. 1, 3, and 18). All the data show considerable scatter, reflecting the general difficulty in determining critical conditions as well as unsteadiness of individual runs. The two-phase inlet sodium data show a general trend of decreasing quality with increasing heat flux, as do the potassium data. The liquid inlet sodium data show high critical qualities at the high heat fluxes. These data appear to vary from the trend of the two-phase inlet data. The liquid-inlet data at the lowest quality ($X_{cr} \sim 0.6$) are the most unsteady of the results shown.

Critical qualities may also be presented as a function of a velocity-length parameter. Figure 16 presents the sodium and reference potassium data in these terms. The length used is that from the shell exit station or the point of liquid superheat breakdown to the point of the critical condition. The data follow a decreasing trend of quality with an increase of the velocity-length parameter. This same trend was found by Stone (ref. 19) for low-pressure water boiling in a heat exchanger of similar dimensions to

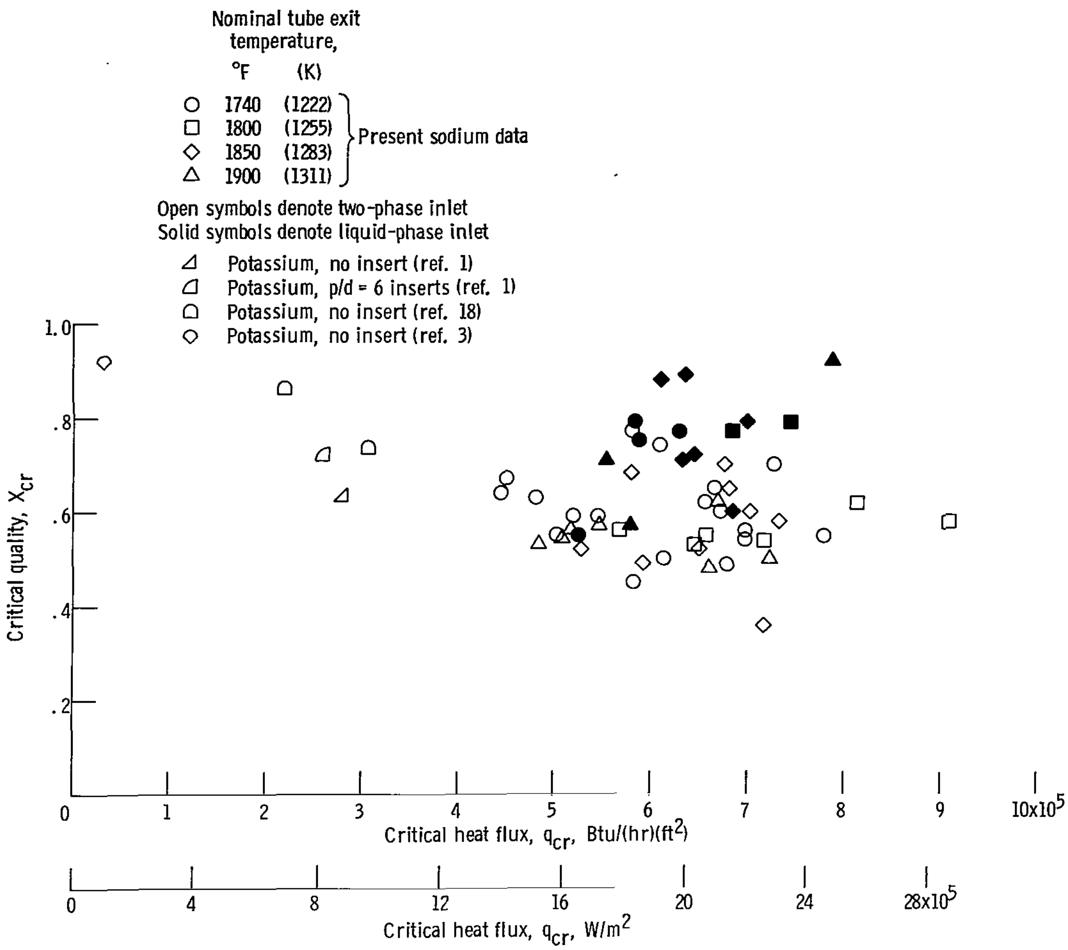


Figure 15. - Variation of critical quality with critical heat flux.

that used in this investigation. The sodium data show no particular trend with temperature level and generally fall below the potassium data. The liquid inlet data again show generally larger values of the critical quality than do the two-phase inlet data. This trend is consistent with a similar trend obtained for the heat-transfer coefficients and with the postulate that the liquid inlet condition produces a more favorable two-phase flow pattern than does the two-phase conditions of low inlet quality. It may be that different mechanisms operate to produce the critical condition for the two inlet feed cases. For the case of the two-phase inlet data, the critical condition may result primarily from a nucleate boiling process similar to that obtained in pot boiling. In the case of the liquid-inlet tests the critical condition may result from the breakup of thin liquid films.

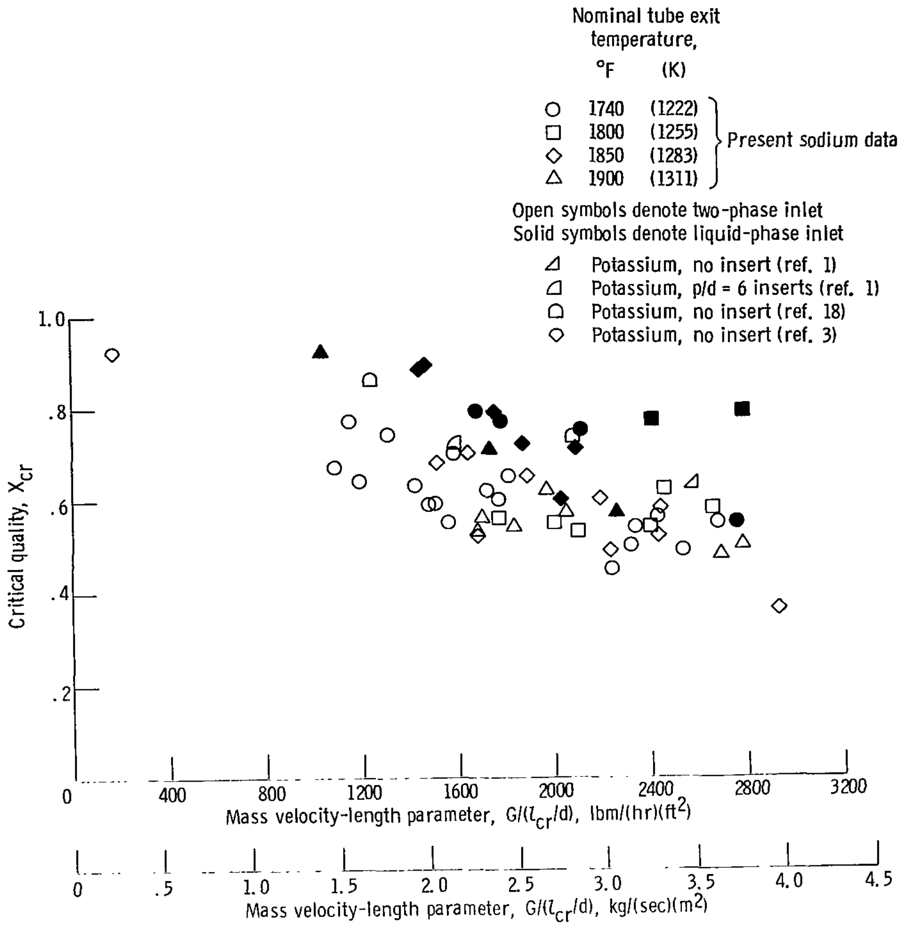


Figure 16. - Variation of critical quality with mass velocity-length parameter.

Miscellaneous Results

In addition to the tests in which data were taken in a steady condition, transients tests were made also. The effect of varying the preheater exit temperature on the boiling performance has already been discussed in the section Effective overall heat-transfer coefficients. Tests were also made in which the test fluid flow rate was gradually decreased with all other conditions held constant. The results generally agreed with the steady run tests showing a decrease in the heat-transfer coefficient and in the steadiness of all variables. As the lower flow rates were approached the pressure drop across the upstream orifice decreased so that it was unable to provide a boiler inlet quality of the required magnitude for optimum performance. At very low flow rates the heat loss between the preheater and the boiler was great enough to cause a temperature drop in the test fluid of a magnitude that suppressed vaporization at the orifice and produced a subcooled liquid inlet condition at the boiler.

The results of step changes in the test fluid flow rate were consistent with the ramp and steady condition tests. Step changes of ±5 psi (34.4 kN/m^2) were made in the system pressure level with all other conditions constant. Following a very short transition period the system and boiler readjusted to the new pressure level with no significant changes in performance or steadiness of operation. This result might be expected because of the general insensitivity of all the results to pressure level and to the relatively small magnitude of the pressure steps.

Most of the results reported herein were obtained with the isolating value between the boiling loop and the expansion tank open. A few check runs were made with the isolating value closed giving a nominally constant inventory system. Generally no discernable difference in results was obtained with the value open or closed except for a slight trade off between the amplitude of flow and pressure oscillations. The insensitivity of the results to the value position probably results from the presence of the condenser coolant bypass loop.

The experimental facility was operated for over 1100 hours at temperatures from approximately 800° to 2200° F (700 to 1477 K). Only a single shutdown was experienced that resulted from the failure of a stainless-steel valve bellows. All the columbium alloy components were fabricated and operated successfully without major problems. Although no detailed post-test metallurgical analysis was made, visual observations showed no serious effects of corrosion or oxidation. After the aforementioned valve failure, a section of the columbium alloy tubing between the preheater and boiler was removed. Examination of this sample showed the presence of a hard, thin layer, approximately 0.002 inch (0.051 mm) thick, on the inside surface of the tube. X-ray diffraction tests indicated this layer to consist of a sodium-oxygen-columbium compound. In addition, photomicrographs and chemical analysis indicated that some mass transfer had occurred. There was no indication, however, that these factors affected the nature or repeatability of the heat-transfer results. Chemical analysis and visual examination of the tantalum foil wrap showed no evidence of oxidation of the exterior of the columbium from the vacuum environment. Once the system in the vacuum tank was outgassed at the maximum temperature there was no difficulty in maintaining the desired vacuum environment with respect to both total and oxygen partial pressure. Sodium was charged into the system, purified, tested, and drained without major problems. Chemical analysis of sodium samples taken during and after the test period showed purity levels (especially oxides) to be well within acceptable limits.

Two-Phase Pressure Drop

Typical variations of the experimental two-phase pressure drop are presented in

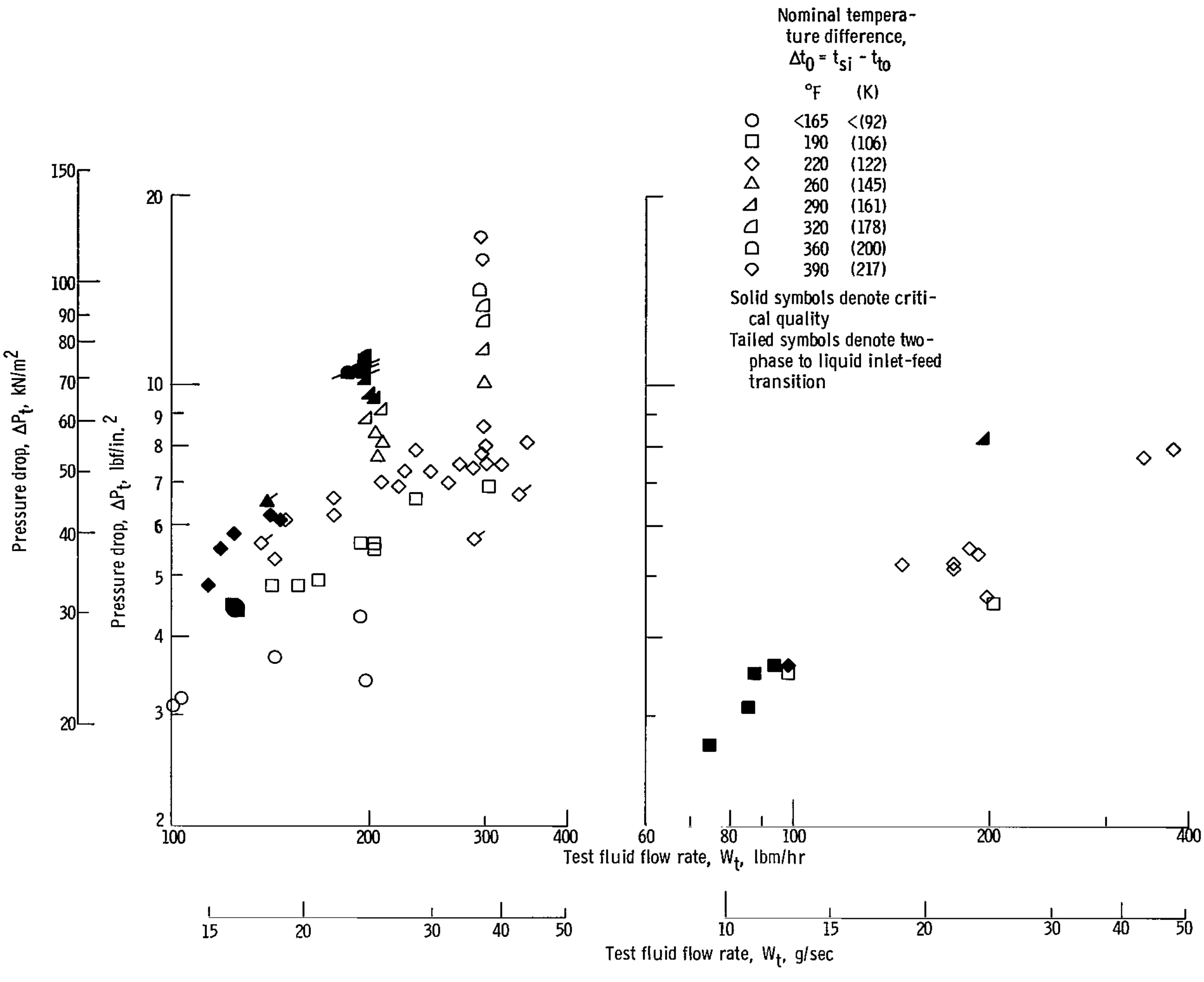


Figure 17. - Variation of two-phase pressure drop with test fluid flow rate. Test fluid exit saturation temperature, 1740° F (1222 K); heating fluid flow rate, ~5000 pounds mass per hour (630 g/sec).

figure 17 as a function of the test fluid flow rate for various heating fluid inlet temperatures at constant heating fluid flow rate and for a nominal tube exit temperature of 1740° F (1222 K). Data are given for both two-phase and liquid-phase inlet conditions. For both cases the data generally show a positive slope with increasing test fluid flow rate as well as can be determined within the experimental scatter. The total two-phase pressure drop increases with increasing heating-fluid inlet temperature (increasing quality) at constant test-fluid flow rate. Similar results were obtained at the other (higher) tube-exit temperature levels, but with a decrease in the magnitude of the pressure drop. This reduction would be expected from the decrease in liquid-vapor density ratio with the increase in temperature-pressure.

All the experimental pressure drop data are presented in figure 18 as a function of the outlet quality. The pressure-drop parameter for the upper curve in each data set is

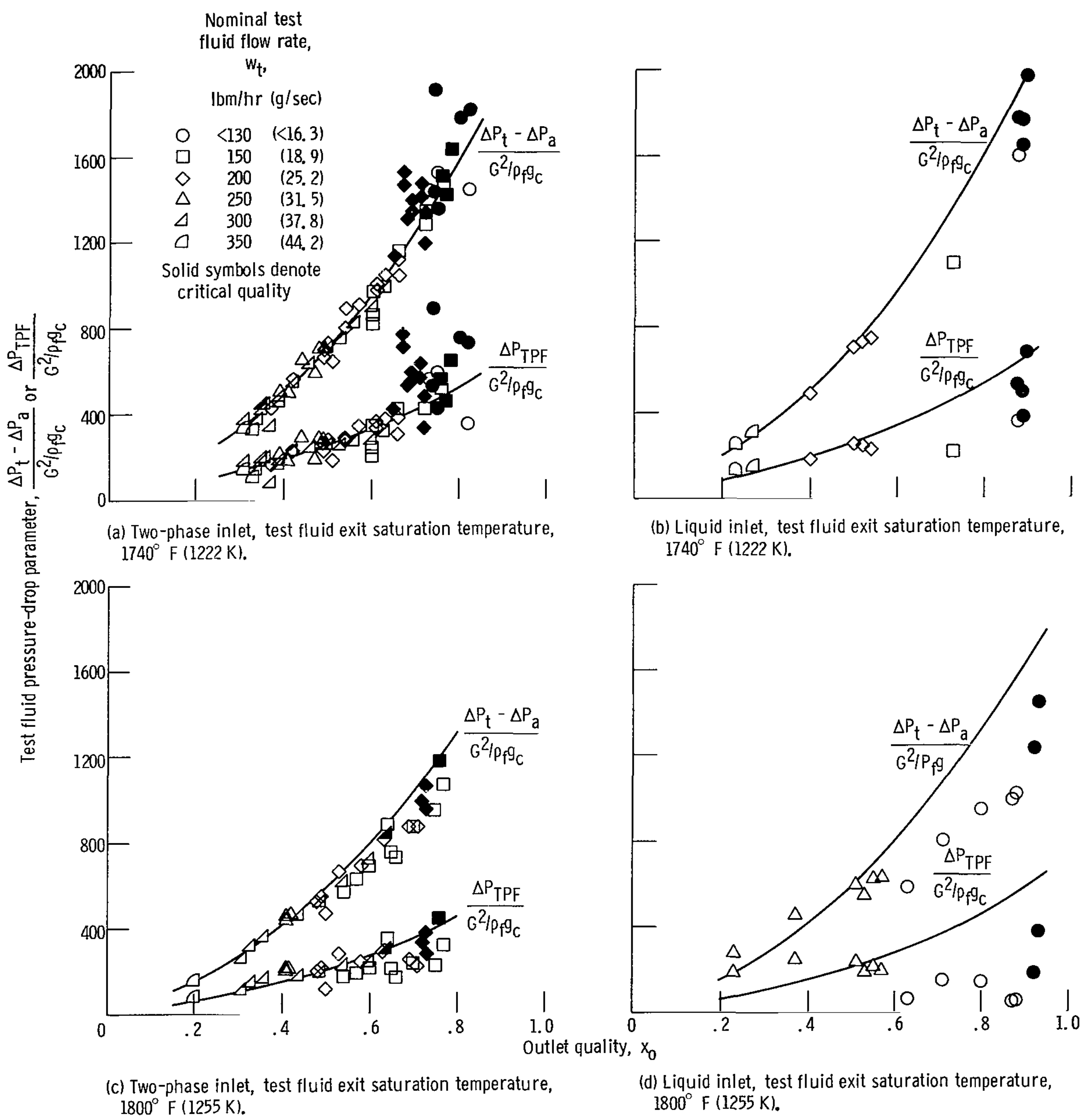
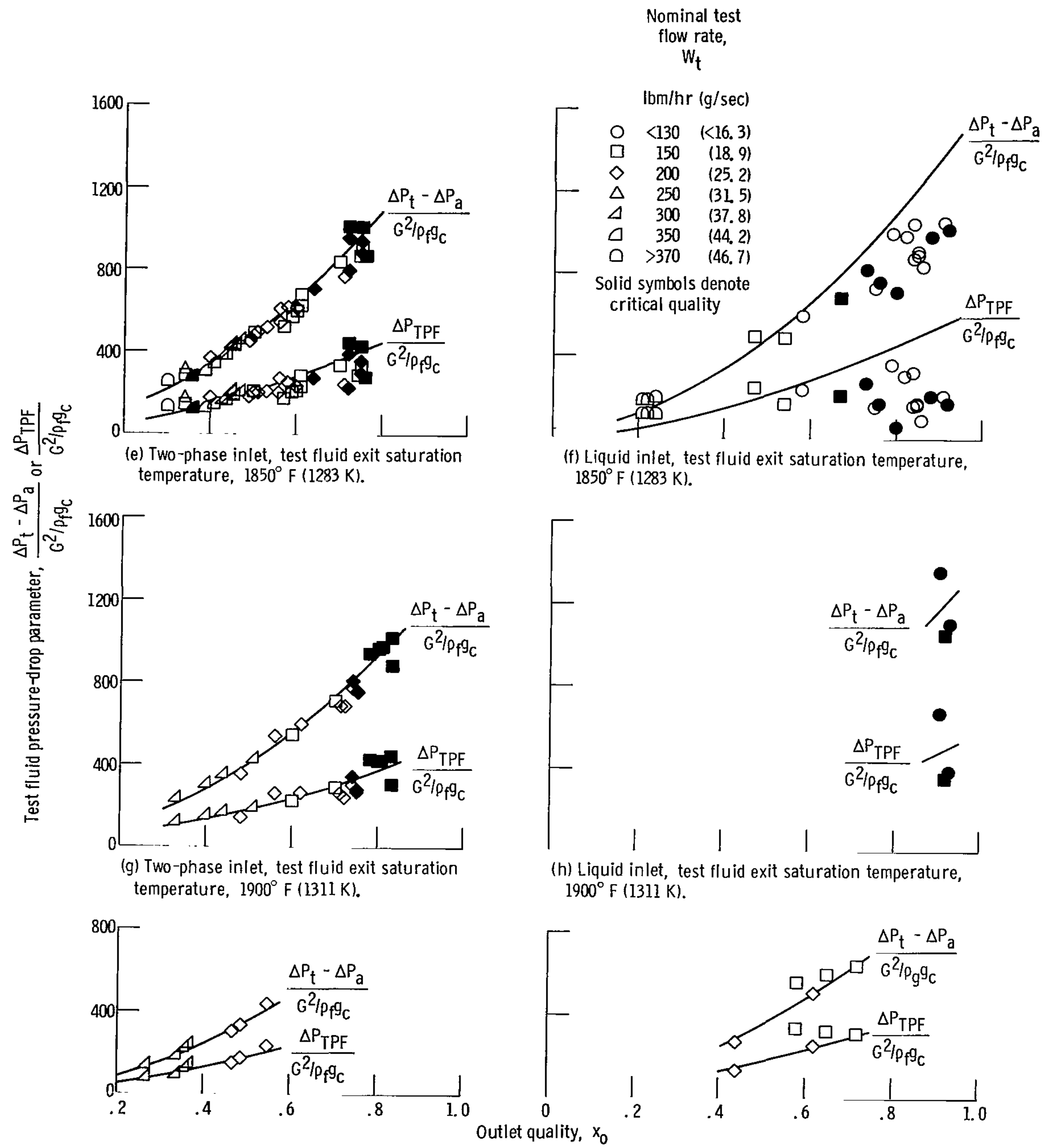


Figure 18. - Variation of test fluid pressure-drop parameter with exit quality.



(e) Two-phase inlet, test fluid exit saturation temperature, 1850° F (1283 K).

(f) Liquid inlet, test fluid exit saturation temperature, 1850° F (1283 K).

(g) Two-phase inlet, test fluid exit saturation temperature, 1900° F (1311 K).

(h) Liquid inlet, test fluid exit saturation temperature, 1900° F (1311 K).

(i) Two-phase inlet, test fluid exit saturation temperature, 1980° F (1355 K).

(j) Liquid inlet, test fluid exit saturation temperature, 1980° F (1355 K).

Figure 18. - Concluded.

the total measured pressure drop minus the liquid static head normalized with respect to the liquid-phase velocity head. The static-head correction was computed by a modification of the method of reference 19 and was practically negligible in most cases. The lower curve represents the two-phase frictional pressure drop. The use of the liquid velocity head is purely arbitrary and is used for normalization purposes. Results are given for both the two-phase and liquid inlet conditions. The faired curves in figure 18 are arbitrarily faired through the data for identification purposes only and are identical for the two-phase and liquid inlet cases. The frictional pressure drop was obtained by subtracting out the momentum pressure drop, which was calculated using the liquid fraction correlation of Baroczy (ref. 20). The liquid velocity head appears to normalize the two-phase pressure drops fairly well for all conditions except where critical heat-transfer conditions were exceeded. A spread in the pressure drop at postcritical conditions would be expected. Both the frictional and the sum of the momentum and frictional pressure drops decrease with increase in the tube exit pressure. The momentum pressure drop was approximately $1\frac{1}{2}$ times the two-phase frictional pressure drop over the range of investigation. The results for the liquid-phase inlet condition appear to be almost the same as for the two-phase inlet condition, although in the liquid-phase inlet case the length of two-phase friction is reduced and variable. This result was expected because the pressure drops in the first part of the boiler are always small. Thus, whether the frictional drop is liquid or two-phase in this region would make little change in the total pressure drop. No attempts were made to correlate the data or compute two-phase friction factors because of the doubtful applicability of existing correlations and uncertainty as to the correct definition of two-phase properties, Reynolds numbers, and friction factors.

Liquid Superheat

The initiation of boiling was one of the major problems encountered. This problem arises from the ability of sodium to maintain itself in a liquid state at temperatures considerably above saturation. This condition of liquid superheat was experienced by Bond and Hoffman (refs. 2 and 3) for potasssium and sodium in natural circulation and forced-flow loops with a constant flux heating condition. A series of tests were made in this investigation to determine the maximum bulk superheat at boiling initiation. Runs were made in which boiling initiation at the tube exit was achieved by raising the heating fluid inlet temperature and also by lowering the test fluid exit pressure with all other conditions held constant. The results of these tests are shown in figure 19. The bulk superheat is defined as the test fluid bulk temperature minus the local test fluid saturation temperature at the point just before boiling was initiated. Included in the figure are the

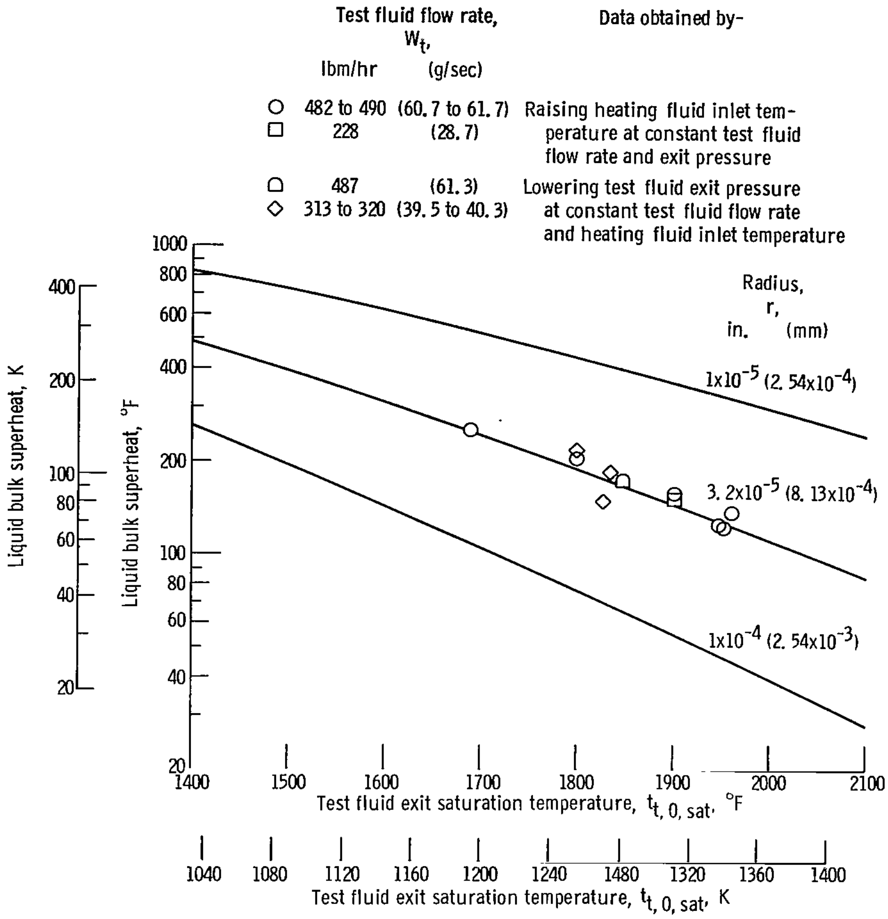


Figure 19. - Liquid bulk superheat required to initiate boiling at test fluid exit. Nominal heating fluid flow rate, 5000 pounds mass per hour (630 g/sec).

predicted bulk superheats obtained from the static force balance on a spherical bubble as given by the relation

$$\Delta P = \frac{2\sigma}{r}$$

and the vapor pressure curve of reference 21. This computed bubble radius is a measure of the effective cavity size required for the initiation of nucleation.

The experimental results appear to follow a line of constant radius ($\sim 3.2\times 10^{-5}$ in.; $\sim 8.13\times 10^{-4}$ mm). No significant differences in bulk superheat are apparent with either the method of boiling initiation or the test fluid flow rate. It should be noted that, because of the large heating fluid flow rate relative to the test fluid flow rate, the exit region of the boiler during liquid phase flow was at an essentially isothermal condition and zero heat flux. The indicated effective radius is extremely small. However, the photomicrographs of the Cb - 1-Zr tube wall given by Bond (ref. 2) indicate that the radius of available effective cavities was in the range of 5×10^{-6} to 1×10^{-4} inch (1.3×10^{-4} to 2.5×10^{-3} mm). Edwards and Hoffman (ref. 22) also indicated effective cavity sizes of the same order of magnitude for the initiation of boiling of potassium in a 316 stainless-steel as-received tube.

Holtz and Chen (refs. 23 and 24) have suggested that the incipient boiling condition is determined by the effective cavity size corresponding to the maximum cavity deactivation condition (maximum pressure and minimum temperature) encountered before nucleation. To apply Chen's predictions, however, requires knowledge of the cavity geometry, contact angle, and residual inert gas pressure in the cavity as well as the prior pressure-temperature history. If a cylindrical cavity with a residual inert-gas partial pressure of 1 psia (6.9 kN/m^2) is assumed, Chen's analysis predicts that a cavity of 3.5×10^{-5} inch (8.9×10^{-4} mm) would give the experimental values of bulk liquid superheat for boiling incipience.

The values for incipient bulk liquid superheat shown in figure 19 should not be confused with the values that exist in the liquid-phase inlet boiling tests (discussed in the section Boiling Heat Transfer), which are not a measure of boiling incipience but represent an equilibrium vaporization condition after boiling has been started. These liquid superheats obtained during boiling were always less than the values given in figure 19.

SUMMARY OF RESULTS

The experimental investigation of sodium boiling in a single tube-in-shell heat exchanger reported herein is summarized as follows:

1. The refractory metal experimental boiler was operated in a vacuum environment for over 1100 hours at temperatures from approximately 800° to 2200° F (700 to 1477 K). Boiling was obtained over a range of flow rates from 75 to 380 pounds per hour (9.4 to 48 g/sec), boiling temperatures from 1720° to 1980° F (1211 to 1355 K), and exit vapor qualities up to 93 percent.

2. No major operational problems were encountered in the use of columbium - 1-percent-zirconium components, the handling of the sodium, and the attainment of the proper vacuum environment.

3. Sodium pressure drop and heat-transfer data were obtained in the liquid phase, and extensive boiling test data were obtained, including overall heat-transfer coefficients, two-phase pressure drop, boiler outlet quality, and critical heat-transfer conditions.

4. The sizable amount of liquid superheat required for boiling initiation was determined both by increasing the heating fluid temperature and decreasing the boiling fluid pressure.

5. Boiling was obtained with two different tube inlet feed conditions: (a) a two-phase inlet condition obtained from flashing at an orifice upstream of the boiler, and (b) liquid-phase inlet conditions, including subcooled and superheated liquid feeds and liquid superheat within the boiler. For the two-phase inlet, unsteadiness and lowered heat-transfer performance were obtained as the amount of inlet flashing was reduced. Steady, high performance boiling was generally obtained with the liquid-phase inlet condition.

6. Critical heat-transfer conditions at qualities in excess of 0.9 were obtained under steady conditions. The value of the critical quality and its variation with boiler operating conditions appeared to be a function of both the inlet feed condition and the steadiness of the test.

7. Over the range of the investigation, the two-phase pressure drops as a function of tube exit quality could be normalized adequately by the liquid-phase velocity head. The two-phase momentum loss was approximately $1\frac{1}{2}$ times the two-phase frictional pressure drop of the boiler tube.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, March 3, 1969,
120-27-02-03-22.

APPENDIX A

SYMBOLS

All symbols are defined for both the U.S. Customary units and the International System (SI) units. U.S. Customary units are defined in terms of the foot-hour-pound mass convention, although inches and seconds are sometimes used in the text. All equations, of course, require units which are dimensionally consistent.

A	area, ft^2; m^2
c	liquid specific heat capacity at constant pressure, Btu/(lbm)(^{o}F); J/(kg)(K)
d	diameter, ft; m
e	effective height of irregularities in tube wall, ft; m
f	friction factor defined as $f = 2g_c \Delta P/(l/d)\rho V^2$, dimensionless
G	mass velocity, lbm/(hr)(ft^2); kg/(sec)(m^2)
g	acceleration due to gravity, 4.17×10^8 ft/hr^2; 9.81 m/sec^2
g_c	conversion factor, 4.17×10^8 ft-lbm/(lbf)(hr^2); 1.0 (m)(kg)/(N)(sec^2)
H	fluid enthalpy, Btu/lbm; J/kg
h	heat-transfer coefficient, Btu/(hr)(ft^2)(^{o}F); W/(m^2)(K)
I	enthalpy rate ratio = $(Wc)_s/(Wc)_t$, dimensionless
K	two-phase velocity ratio, V_g/V_f, dimensionless
k	thermal conductivity, Btu/(hr)(ft)(^{o}F); W/mK
l	axial length along boiler measured from reference plane, see fig. 5, ft; m
Nu	Nusselt number, dimensionless
P	absolute pressure, lbf/ft^2; kN/m^2
Pe	Peclet number, dimensionless
Q	rate of heat transfer, Btu/hr; W
q	heat flux based on tube inside diameter, Btu/(hr)(ft^2); W/m^2
R	fraction of tube cross-sectional area occupied by liquid, dimensionless
Re	Reynolds number, dimensionless
r	radius, ft; m

s	thickness of conducting layer, ft; m
t	temperature, $^{\circ}F$; K
U	overall heat-transfer coefficient for heat exchanger, Btu/(hr)(ft^2)($^{\circ}$F); W/(m^2)(K)
V	velocity, ft/sec; m/sec
W	mass flow rate, lbm/hr; kg/sec
X	thermodynamic quality, dimensionless
ϵ	eddy diffusivity for momentum, ft^2/hr; m^2/sec
θ	logarithmic mean temperature difference, $^{\circ}F$; K
ν	kinematic viscosity, ft^2/hr; m^2/sec
ρ	density, lbm/ft^3; kg/m^3
σ	vapor-liquid surface tension, lbf/ft; kg/m

Subscripts:

a	average
c	contact condenser
cr	critical heat-transfer condition
e	effective
F	friction
f	liquid phase
fg	vaporization
G	gravitational
g	vapor phase
h	hydraulic
i	inlet or inside
l	indicates axial location along boiler of variable of interest
m	momentum
max	maximum
min	minimum
o	outlet or outside
s	shell

sat	saturation
sc	subcooled
TP	two-phase condition
t	tube
w	wall
I	measuring station at inlet of a component
II	measuring station at outlet of a component

APPENDIX B

CALIBRATIONS

Various calibrating tests were made in order to determine instrument calibrations and corrections, component pressure-drop characteristics, heat balances, and liquid-phase convective heat transfer.

Pressure Instrumentation

In-loop calibrations were made for all pressure transducers. All these calibrations were made against the cover-gas pressure in the respective expansion tanks with precision (±0.1 percent) Bourdon pressure gages used as a reference. These calibrations were made before and after the boiling test period. Measurements were made with the loops filled with argon both at room temperature and with all transducers and isolating diaphragms at operating temperatures. Calibrations were also performed with the system filled with hot liquid sodium and all flow stopped. After correcting for liquid static heads, the liquid and gas calibrations agreed well. Both the scatter of the data points for each individual calibration and the reproducibility from one calibration to another was within ±1 percent of full scale. This is equivalent to ±0.75 psi (5.2 kN/m^2) for the transducer used.

Thermocouple Corrections

The platinum - platinum-13-percent-rhodium thermocouple wire was calibrated by the vendor and was within the ISA ±1/4 percent specification. A direct in-place calibration of the thermocouples was not possible because of the inaccessibility of the equipment inside the vacuum tank and the difficulty of introducing an accurate and reliable reference. Calibrations were developed for the surface inlet and exit thermocouples on the tube side of the boiler and at the condenser vapor inlet by plotting the measured temperatures against the respective pressures for tests in which saturation conditions existed assuming thermal equilibrium. Such data are plotted in figure 20 for thermocouples spotwelded to the metal surface together with the saturation curve for sodium given in reference 21. A scatter band based on the reference saturation curve and the nominal error of pressure and temperature measurements is also indicated. Although much of the data fall within the scatter band, particularly for the condenser inlet, the boiler tube measurements appear to bias toward low temperatures and show an increasing deviation with increasing temperature. The saturation curve of reference 21 was determined with

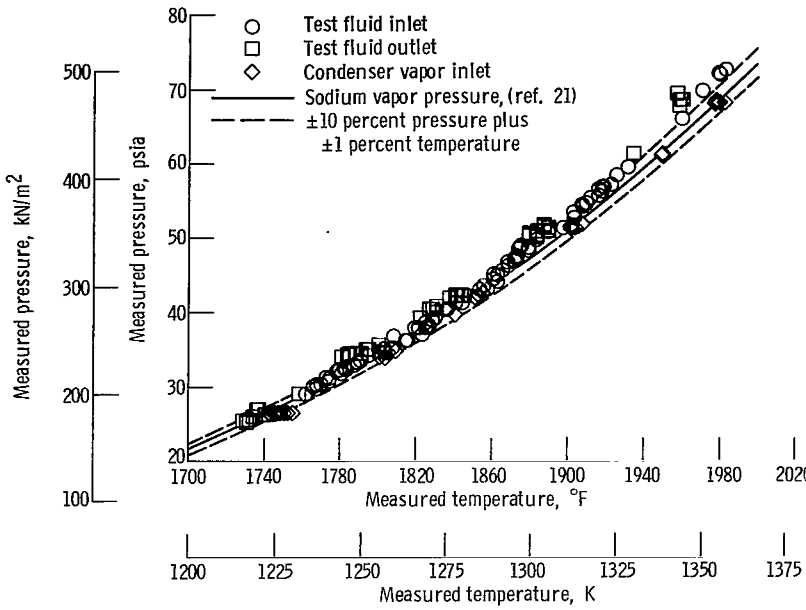


Figure 20. - Comparison of measured pressures and temperatures with reference saturation curve for sodium.

a high degree of precision and is accepted as essentially correct. In view of these considerations, it was decided that the boiler-tube temperatures were reading low, and correction curves were developed based on measured temperatures and temperatures given by the reference saturation curve at measured pressures.

The shell and heating fluid thermocouple readings are considered to be accurate without corrections. Heat balances plus the large amount of thermal insulation around the boiler indicated very little heat loss (and hence no conduction corrections) except at the end plenums where conduction effects could become important. Isothermal tests showed negligible difference between the thermocouples distributed along the shell or between the shell temperatures and the heating fluid inlet and exit surface thermocouples. In addition, liquid-liquid heat-transfer tests were made in which the heating fluid flow rate was many times that of the test fluid flow rate. For these conditions a heat exchanger effectiveness of almost 100 percent should exist with the region of the shell near the heating fluid inlet near isothermal. Such was the case, and the corrected tube side exit temperatures agreed well with the uncorrected shell temperatures in this region as well as with the uncorrected heating fluid inlet temperature.

Liquid-Phase Tests

System pressure calibration. - The data obtained during the system pressure-drop calibration are presented in table III. These data were obtained during the final test series in which pump 3 was installed and operated in both the forward and reverse modes. All pressures listed in table III are the absolute pressures at the pressure tap elevations shown in figure 1 (p. 4). The throttle valve downstream of pump 1 was in the open position for all the data of table III. The pressure drop from the throttle valve to the test section inlet is corrected for static head to the test section inlet elevation. The characteristics of the two pumps were close to that expected, the pumps being essentially constant head machines in the flow-rate range of interest. The measured head developed by pump 1 was generally less than that given in the vendor's performance curves, and pump 3 developed a greater head than predicted. The reasons for these discrepancies are not known but may be related to the amount of cooling air applied to the pumps. In addition, the predicted performance of pump 3 is calculated and is not based on any experimental data. The measured performance of both pumps was generally consistent and repeatable.

The pressure drop from the pump 1 outlet to the boiler inlet is shown in figure 21 as a function of the test fluid flow rate for the case of the pump 1 operating alone. The data

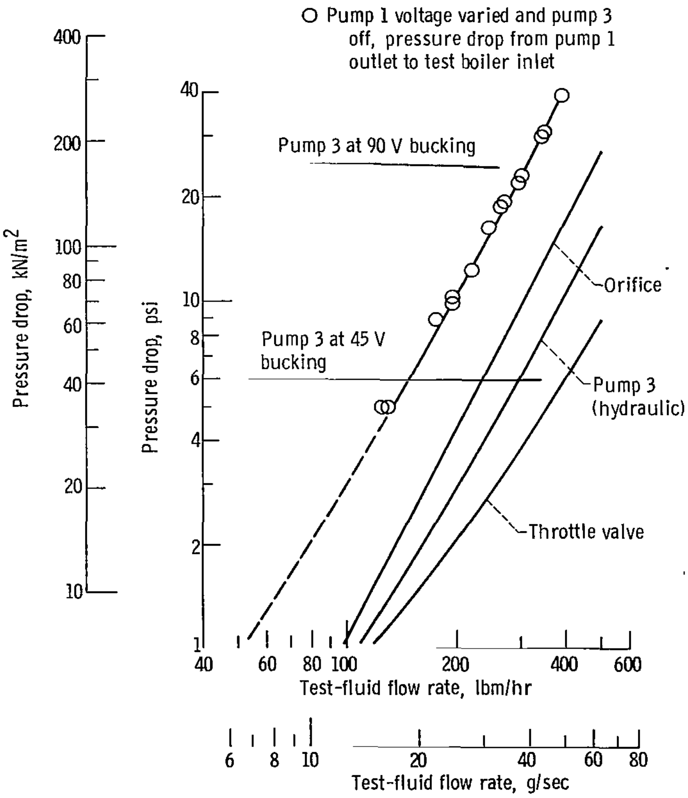


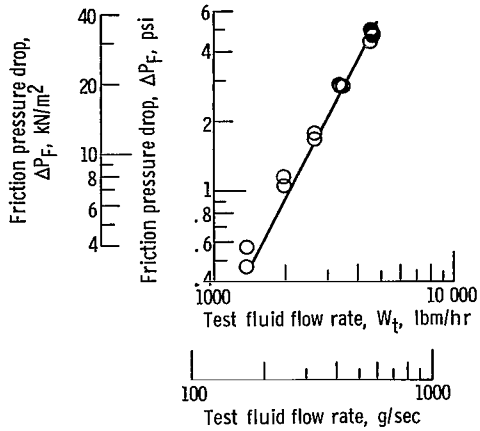
Figure 21. - Liquid pressure drops upstream of test boiler. Orifice and pump 3 (hydraulic) curves from water calibrations. Throttle valve curve from data of table III.

appear to follow a square function of the flow rate through most of the range of interest. This pressure drop consists of the drop through the throttle valve, the preheater, pump 3, the orifice, and connecting lines. The pressure drops through the preheater and connecting lines are very small, approximately 5 percent of the total drop ahead of the boiler. The pressure drops through the rest of the system are also small. Also included in figure 21 are the pressure-drop characteristics of the other components upstream of the boiler. The pressure drop across the orifice was obtained from a water calibration and shows a characteristic more like a short nozzle than that of a standard square-edge orifice. The pressure drop across the throttle valve was obtained from the data of table III. The hydraulic pressure drop across pump 3 was obtained from a water calibration of the pump cell. The electrical braking or electric pressure drop of pump 3 when operated in the reverse mode may be obtained by taking the difference in pressure drops with and without bucking at the same flow rate. This electrical pressure drop is shown in figure 21 for two pump voltages. The pressure drop is almost independent of flow reflecting the constant head characteristic of the pump.

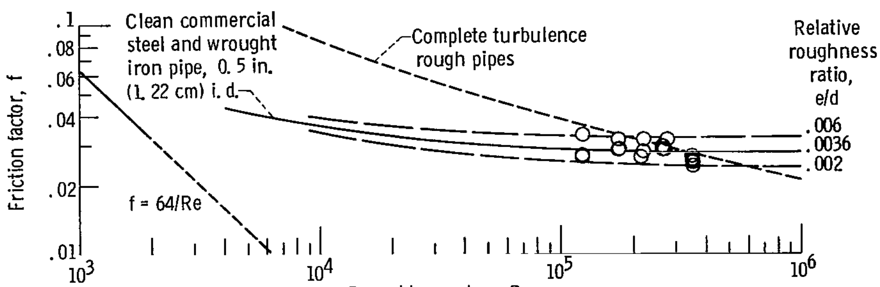
Boiler calibrations. - The data obtained during the calibration tests of the boiler for pressure drop, heat balance checks, and liquid-phase convective heat-transfer rates are given in tables IV and V (pp. 120 to 125). Table V presents the shell temperature distributions obtained during these tests. The data in these tables include that taken during both the preliminary and final test periods.

The experimental pressure drop across the boiler tube is shown in figure 22(a) as a function of the test-fluid flow rate. The data shown are the measured values corrected for the inlet contraction and exit expansion effects and for the liquid static head to the pressure tap. In addition, no runs of table IV were plotted for which the pressure differences approached the limits of accuracy of measurements. The solid line drawn in figure 22(a) is a square function of the flow rate and represents the data fairly well except at the smaller flow rates where a possible transition region may exist. The same data are shown in figure 22(b) in the form of a friction factor f against the Reynolds number. The reference curves for commercial pipe and for various values of the relative roughness e/d are taken from the Moody chart as given in reference 25. The data follow the reference curve for commercial steel pipe very well and appear to be entering the transition region at Reynolds numbers less than 3×10^5. The band of relative roughness values in which the data lie is approximately equal to the procurement specification tolerance for the tube inside diameter.

The heat balance across the boiler is shown by the data of figure 23, where the heat absorbed by the tube flow is plotted against the heat given up by the shell. Again, no data of table IV for which the temperature differences approach the limits of temperature measurement accuracy are shown in figure 23. Practically all the data fall within a ±10 percent variation from a line of perfect agreement. The data may be interpreted as showing a slightly smaller heating rate for the tube as compared with the shell, but



(a) Pressure drop as function of flow rate.



(b) Friction factor as function of Reynold's number.

Figure 22. - Experimental boiler tube liquid-phase frictional pressure drop.

the magnitude of this heat loss is very small, indicating a very high effectiveness for the foil wrap insulation on the shell. Heat losses from the main body of the boiler shell are considered negligible; the main heat losses probably occur at the end plenums where the larger shell-wall thickness increases conduction and where radiation is increased by virtue of the larger diameter of the end plenums.

Liquid convective heat transfer. - The data of tables IV and V provide information from which overall liquid metal heat-transfer coefficients may be calculated. It was not intended in this report to make a detailed analysis of liquid metal convective heat transfer. However, a few check calculations were made primarily to determine values of the annulus convective coefficient for use in comparing with the boiling overall heat-transfer coefficients. The heat-transfer coefficients were computed using the customary logarithmic mean temperature difference based on the heat exchanger terminal temperatures, as well as the method suggested by Stein (ref. 12), which uses a dimensionless local shell temperature and a dimensionless axial distance. The analyses using the local shell temperatures indicated that the overall heat-transfer coefficient was fully developed and constant over nearly the entire length of the heat exchanger. End effects would

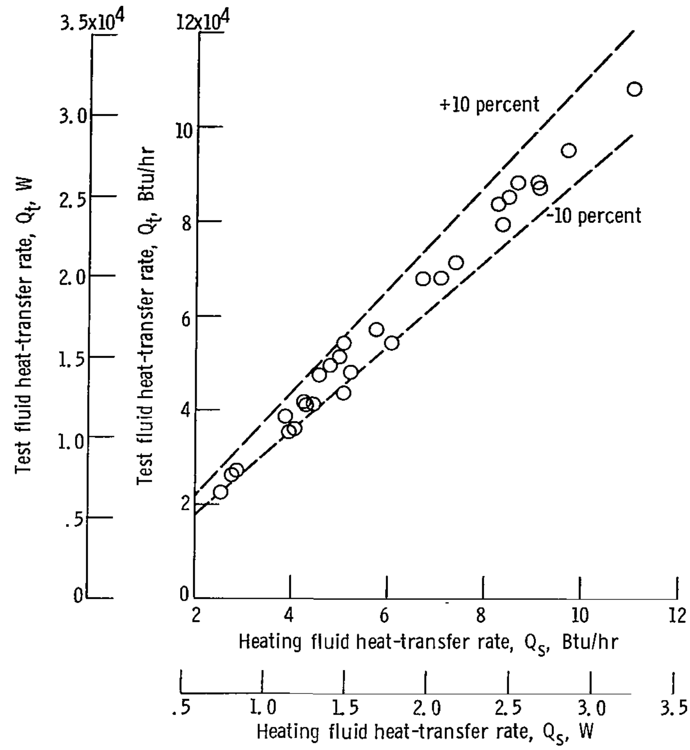


Figure 23. - Comparison of heating fluid heat-transfer rate with test fluid heat-transfer rate for liquid-phase convective heat-transfer tests.

be expected, resulting from end heat loss and conduction, the reduction in diameter at the tube inlet, the large change in the annulus cross-sectional area, and the normal temperature and velocity profile development lengths.

The experimental overall coefficients for the case of the enthalpy rate ratio (I) equal to unity appeared to agree with values based on the predictions of Dwyer (ref. 13) for tubes and annuli. The tube wall conductivity was taken from reference 26. For the case of enthalpy rate ratios other than unity, Stein (ref. 14) predicts that the constant temperature solution represents a lower limit for the Nusselt number at very large values of I and that the Nusselt number can exceed the constant heat flux solution for values of I less than unity. This last case is of interest as it is the condition for the shell heat transfer during boiling. A few experimental liquid-phase overall heat-transfer coefficients were computed for a constant shell flow rate and varying values of I. Although the data are limited with respect to extent and accuracy, they do appear to follow the trend predicted by Stein. For all the cases calculated there was no explicit evidence of a significant contact resistance that might arise from sodium oxide films or argon gas layers.

APPENDIX C

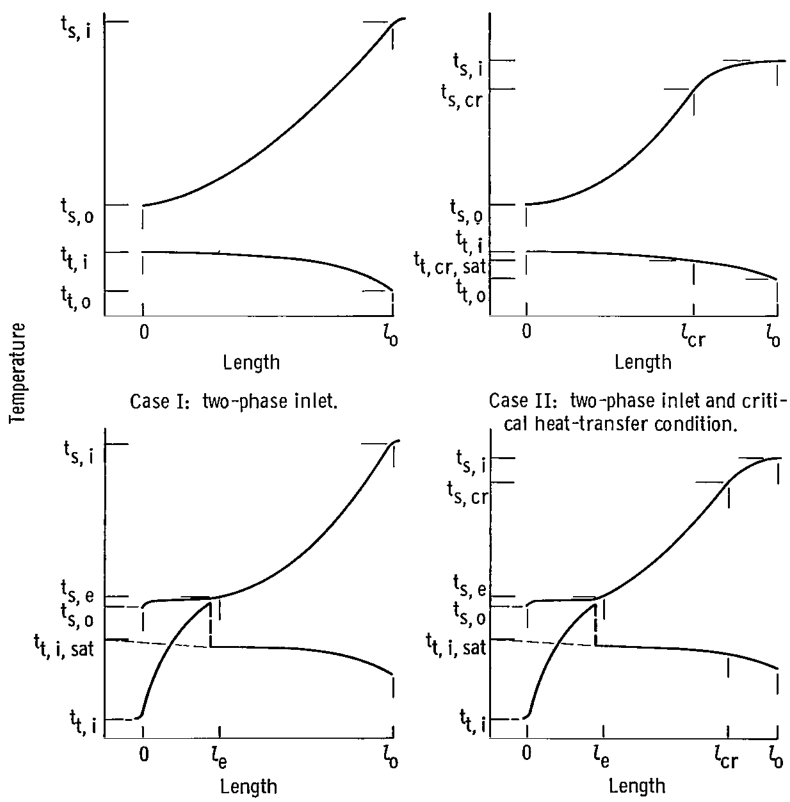
CALCULATIONS

Heat-Transfer Coefficients and Quality

The rate of heat transfer to the test fluid is based primarily on the shell side measurements from the relation

$$Q_s = W_s c_s (\Delta t)_s$$

where $(\Delta t)_s$ is the difference in measured shell temperatures at axial locations appropriate to the case of interest. All the boiling runs can be classified as one of four cases as indicated in figure 24.



Case I: two-phase inlet.

Case II: two-phase inlet and critical heat-transfer condition.

Case III: liquid inlet.

Case IV: liquid inlet and critical heat-transfer condition.

Figure 24. - Boiling run classifications.

The overall heat-transfer coefficient U is based on an area A associated with the inside diameter of the tube and is defined as

$$U = \frac{Q_s}{A\theta}$$

where θ is a logarithmic mean temperature difference between the heating and test fluids defined as

$$\theta = \frac{(\Delta t_{max} - \Delta t_{min})}{\ln\left(\frac{\Delta t_{max}}{\Delta t_{min}}\right)}$$

where Δt_{max} and Δt_{min} are the maximum and minimum temperature differences between fluids taken at axial location appropriate to the case of interest. The area A is taken between the same axial locations.

The rate of heat transfer required to raise the test fluid to a liquid saturation condition Q_{sc} when it enters the boiler in a subcooled condition is given by

$$Q_{sc} = W_t c_t (t_{sat} - t_{t,i})$$

where t_{sat} is the saturation temperature corresponding to the test fluid pressure at the axial location where the thermodynamic quality is zero.

The thermodynamic quality is defined as

$$X = \frac{H_{f,i} + \frac{Q_s}{W_t} - \frac{Q_{sc}}{W_t} - H_{f,l}}{H_{fg,l}} + X_i$$

where the subscript l refers to the axial location of interest and X_i is the quality (positive values only) of the test fluid entering the boiler for the two-phase inlet tests. This relation assumes no pressure drop from the tube inlet to the point of zero quality for subcooled inlet cases.

Specific relations and definitions for the four boiling cases are as follows:

Case I: Two-phase inlet and no critical heat-transfer condition. -

$$Q_s = W_s c_s (t_{s,i} - t_{s,o})$$

where $t_{s,i}$ and $t_{s,o}$ are shell temperatures taken from a faired curve at the 46.5-inch (118-cm) and 0 stations, respectively.

$$\Delta t_{max} = (t_{s,i} - t_{t,o})$$

$$\Delta t_{min} = (t_{s,o} - t_{t,i})$$

$$A = \pi d(l_o - l_i)$$

where $(l_o - l_i)$ is the length from 0 to 46.5-inch (118-cm) station. For this case the overall coefficient averaged over the entire boiler U_a and the effective coefficient U_e are identical.

For the quality calculation, the location l is taken at the 46.5-inch (118-cm) station and the test fluid condition is assumed to be equal to the measured tube exit values.

Case II: Two-phase inlet and critical heat-transfer condition. - The average overall heat-transfer coefficient U_a and exit quality are computed as for case I. For the effective overall heat-transfer coefficient $Q_s = W_s C_s (t_{s,cr} - t_{s,o})$, where $t_{s,cr}$ is the shell temperature at the critical heat-transfer condition (taken at point of inflection of shell profile), $\Delta t_{max} = (t_{s,cr} - t_{t,cr})$, where $t_{t,cr}$ was determined as follows. An approximation of the quality at the critical location was made using an estimated value of the test fluid temperature. A two-phase frictional pressure drop for this quality was obtained from the faired curves of figure 18. This pressure drop is that which would occur over the entire tube length so it was reduced by the ratio of the critical boiling length l_{cr} (taken from the tube inlet to the critical location) to the total tube length. To this adjusted frictional pressure drop was added the appropriate momentum and gravitational pressure drops. Subtracting this total-pressure drop from the measured inlet pressure gave the pressure at the critical location. Finally, a smooth curve was faired through this pressure and the measured inlet and exit pressures. The faired value of pressure at the critical location (and, hence, saturation temperature) was that used in calculations.

$$\Delta t_{min} = (t_{s,o} - t_{t,i})$$

$$A = \pi d(l_{cr} - l_i)$$

where l_{cr} is the length from 0 to critical location. For the effective critical quality calculation $H_{f,l}$ and $H_{fg,l}$ are evaluated at temperature $t_{t,cr}$.

Case III: Liquid-phase inlet and no critical heat-transfer condition. - Again the average overall heat-transfer coefficient and exit quality are computed as for case I. For the effective coefficient the boiling length is taken as extending from a location slightly beyond the point of liquid superheat breakdown to the end of the tube. This location l_e was arbitrarily selected to eliminate a short transition section following the liquid superheat breakdown.

$$Q_s = W_s c_s (t_{s,i} - t_{s,e})$$

where $t_{s,e}$ is the shell temperature at l_e.

$$\Delta t_{max} = (t_{s,i} - t_{t,o})$$

$$\Delta t_{min} = (t_{s,e} - t_{t,e})$$

where $t_{t,e}$ is the saturation temperature at the pressure equal to the inlet pressure minus all gravitational and momentum heads from the tube inlet to l_e,

$$A_e = \pi d(l_o - l_e)$$

For the effective quality calculation $H_{f,l}$ and $H_{fg,l}$ are evaluated at $t_{t,e}$.

Case IV: Liquid-phase inlet and critical heat-transfer condition. - The average heat-transfer coefficients and exit quality are computed as for the other cases.

For the effective coefficient the boiling length is taken as the same as for case III except it extends only to the critical location instead of to the tube exit.

$$Q_s = W_s c_s (t_{s,cr} - t_{s,e})$$

$$\Delta t_{max} = (t_{s,cr} - t_{t,cr})$$

$$\Delta t_{min} = (t_{s,e} - t_{t,e})$$

$$A = \pi d(l_{cr} - l_e)$$

The temperatures $t_{t,cr}$ and $t_{t,e}$ are obtained in the same manner as for the corresponding values of cases II and III, respectively. For the effective critical quality $H_{f,l}$ and $H_{fg,l}$ are evaluated at $t_{t,cr}$.

Pressure Drop

The experimental pressure drop across the boiler tube was obtained by taking the difference of the measured inlet and exit pressures. The two-phase frictional pressure drop was obtained by subtracting calculated values of the gravitational and momentum loss terms from the measured values of total pressure drop as follows:

$$\Delta P_{TPF} = \Delta P_t - \Delta P_m - \Delta P_G$$

where ΔP_t is the measured pressure drop across the boiler tube. The gravitational loss, ΔP_G, consists of two terms, the static head corresponding to the region of all liquid and that for the two-phase region,

$$\Delta P_G = \Delta P_{G,f} + \Delta P_{G,TP}$$

$$\Delta P_{G,f} = \rho_f l_f$$

where l_f is the distance from the boiler inlet to the location of the first appearance of vaporization. The two-phase gravitational term is given by the relation of reference 19,

$$\Delta P_{G,TP} = \rho_f l_{TP}\left(\frac{g}{g_c}\right)\left\{\frac{\left(\frac{1}{K} - 1\right)}{\left(\frac{1}{K}\frac{\rho_f}{\rho_g} - 1\right)} + \frac{\left(\frac{1}{K}\frac{\rho_f}{\rho_g} - \frac{1}{K}\right)}{\left(\frac{1}{K}\frac{\rho_f}{\rho_g} - 1\right)^2} \ln\left[\frac{1 + X_o\left(\frac{1}{K}\frac{\rho_f}{\rho_g} - 1\right)}{X_o}\right]\right\}$$

where K is the ratio of the mean vapor velocity to the mean liquid velocity and was taken as equal to the cube root of the liquid to vapor density ratio,

$$K = \left(\frac{\rho_f}{\rho_g}\right)^{1/3}$$

The momentum loss term ΔP_m was obtained from

$$\Delta P_m = \frac{G^2}{g_c}\left(\frac{1}{\rho_o} - \frac{1}{\rho_f}\right)$$

where ρ_o is the mean two-phase density at the boiler exit and ρ_f is the liquid density at the boiler inlet. For the case of separated phases and slip, the momentum term may be written in terms of the cross-sectional area liquid fraction (liquid holdup) as

$$\Delta P_m = \frac{G^2}{\rho_f g_c}\left\{\left[\frac{\rho_f X_o^2}{\rho_g(1 - R_o)}\right] + \frac{(1 - X_o)^2}{R_o} - 1\right\}$$

where the liquid fraction at the boiler exit R_o is taken from the correlation of Baroczy (ref. 20).

Shell and Tube Wall Thermal Conductance

In order to compute the boiling heat-transfer coefficient from the measured overall heat-transfer coefficient the thermal conductance of the shell convection and of the tube wall must be known. The conductance of the tube wall referenced to the tube inside diameter is

$$h_w = \left(\frac{k}{s}\right)_w = \frac{k_w}{\frac{d_i}{2} \ln\left(\frac{d_o}{d_i}\right)}$$

The thermal conductivity of the Cb - 1-Zr alloy was taken from reference 26.

Dwyer (ref. 13) gives relations for the shell convection for the case of a constant heat-flux condition. For the geometry of this investigation, the relation is,

$$Nu_s = \frac{h_s d_h}{k_f} = 5.94 + 0.0215\left[Pe - \frac{1.82\ Re}{\left(\frac{\epsilon_{max}}{\nu}\right)^{1.4}}\right]^{0.781}$$

Reference 13 also gives the term (ϵ_{max}/ν) as a function of the Reynolds number Re. Assuming a heating fluid flow rate of 5000 pounds per hour (630 g/sec) and an average temperature of 2000° F (1366 K), Dwyer's prediction gives a shell convective coefficient referenced to the tube inside diameter of 6090 Btu per hour per square foot per $^{\circ}$F (34 600 W/(m^2)(K)).

Assuming a mean tube wall temperature of 1900° F (1310 K) yields a value of 8060 Btu per hour per square foot per $^{\circ}$F (46 000 W/(m^2)(K)) for the tube wall conductance. The combined conductance then is 3470 Btu per hour per square foot per $^{\circ}F$ (19 700 $W/(m^2)(K)$).

The prediction of Lyons (ref. 6) for the shell convective coefficient is approximately 25 to 30 percent greater than Dwyer's. The analysis of Stein (ref. 14) suggests that the shell convective coefficient for a boiling liquid-metal heat exchanger could be appreciably greater than the predictions for the constant heat flux condition. If a coefficient is assumed 25 percent greater than Dwyer's, the combined convective and wall conductance becomes 3920 Btu per hour per square foot per $^{\circ}F$ (22 200 $W/(m^2)(K)$).

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TABLE I. - DATA

(a) U.S.

Run	Boiler measurements								Condenser measurements					
	Flow rate, lbm/hr		Pressure psia		Temperature, °F				Coolant		Shell temperature, °F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, °F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, °F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
85	4950	75	28.4±0	25.7±0.4	1639±1	1736+3	1921	1843	1440	1164	1593±31	1434±3	1415±1	27.4
82	4990	86±4	28.8±0	25.7±0.5	1669±1	1736±4	1933	1847	1430	1142+1	1703±23	1456±2	1432	27.2
115	4960	88±10	29.2±0.3	25.7±1.1	1706±5	1736+10	1926	1844	3470	1352	1564±0	1487±1	1449	27.1
83	4980	94±2	29.4±0.1	25.8±0.4	1691±1	1737±3	1937	1844	1420	1152	1668±50	1494±2	1470±1	27.6
84	4960	99±1	29.4±0.1	25.8±0.4	1701±0	1737±3	1945	1847	1400	1163+1	1725±9	1526+3	1495±3	27.5
74	4980	99±2	29.1±0	25.6±0.3	1698±2	1735±3	1926	1827+1	2320	987+1	1336±3	1231±1	1197±1	27.3
113	4980	101±11	28.8±0.4	25.7±1.0	1762±3	1736±9	1895	1805±4	3770	1303	1519±18	1443±11	1403±6	27.0
112	4980	104±9	29.0±0.3	25.8±1.0	1764±2	1737±9	1894	1801	3790	1303	1535	1449±4	1409±2	27.3
114	5040	104±8	29.2±0.2	26.0±1.1	1766±2	1738±10	1905	1809±1	3450	1342	1643±40	1506±1	1460±3	27.7
50	4950	114±6	30.3±0.4	25.5±1.0	1774±3	1734±9	1967	1858±1	5930	1376	1692±25	1517±2	1456	26.9
49	4940	119±4	30.6±0.7	25.1±0.8	1776±5	1732±6	1966	1856	5970	1343	1684±34	1482±2	1425	26.9
73	4990	124+11	29.6±0.3	25.1±0.8	1768±3	1731±7	1930	1819	3330	1260	1700	1466±2	1412±6	26.8
46	4980	125±10	31.4±0.2	25.6±1.1	1782±1	1735+10	1965	1854	6080	1347	1677±42	1491	1429	26.9
72	4970	126±14	29.6±0.3	25.2±0.9	1768±3	1731±8	1929	1820	3360	1275	1707±15	1477+3	1429±2	26.8
44	4980	137±13	31.2±0.4	25.6±1.1	1780±3	1735±10	1965	1845±3	5820	1364	1725	1533±3	1455	27.2
111	4920	140+13	32.6±0.5	26.1+1.1	1790±3	1740±10	1985	1858	4420	1347+1	1730±4	1552±12	1476±1	27.4
108	4920	142+11	32.4±0.6	26.2+1.0	1789±4	1741±8	1978	1854	7620	1368	1662±28	1508±12	1440±4	27.7
71	4950	142±10	30.2±0.3	25.4+1.0	1773±2	1734±9	1925	1816	2880	1289±1	1726+2	1528	1471±1	26.8
107	4910	143±12	31.8±0.6	26.5±1.0	1785±4	1744±8	1965	1844	7750	1369	1635±70	1508±10	1439±2	27.9
106	4970	144±2	29.9±0.3	26.2±0.8	1771±2	1741±6	1907	1808	7680	1368	1545±8	1463	1421±1	27.6
110	4980	146±10	32.5±0.5	26.4±1.1	1789±3	1742±10	1976	1851	4230	1345	1735±1	1553±12	1477	27.6
109	4890	147	31.5±0.1	26.3±0.4	1782±1	1742±3	1987	1865	6550	1362±2	1720±9	1549±27	1447	27.8
33	4990	149±13	32.1±0	26.0±0.7	1786±0	1740±5	1964	1842	5750	1367	1733±2	1548±5	1461±1	27.3
21	4990	156^{+34}_{-16}	30.5±0.6	25.7±2.2	1775±4	1736±19	1934	1828	3590	1330	1732±1	1529±4	1466+2	26.4
70	5010	167±3	30.3±0.3	25.4±0.9	1773±2	1734+7	1927	1814	2880	1303	1727±1	1549±3	1490±3	27.0
6	4950	176^{+4}_{-8}	31.7±0	26.5±0	1757±1	1743+0	1968	1861	6370	1401+1	1711±3	1553±3	1468	28.2
5	4970	176±11	31.5±0	26.4±0	1753±1	1742±2	1963	1860	6390	1382	1642±16	1526±24	1451	28.0
41	5000	176±8	32.4±0.3	25.8±0.9	1788+2	1738±7	1964	1843	6230	1368	1731	1542	1456	27.3
32	4970	177±11	32.2±0	26.0±0.7	1787±0	1739±6	1962	1840+1	5800	1364+1	1731±2	1545	1459	27.7
62	4930	185±15	36.5±0.7	26.0±0.7	1816±5	1739±6	2085	1936+2	5950	1364	1732	1556+5	1480±2	27.3
9	5520	187+2	31.5±0	26.0±0	1685±2	1739+0	1962	1858	3200±400	1282+2	1739	1534±1	1474±1	27.6
60	4930	189+12	36.7±0.5	26.1±0.6	1817±4	1740±5	2066±16	1911±1	6010	1363±1	1735±1	1573±17	1481±2	27.6
61	4930	189+19	36.5±0.8	26.0±0.7	1816±5	1738±7	2073	1925±4	6130	1362	1730±2	1568±4	1478±6	27.6
24	5000	192^{+43}_{-60}	29.2±0.7	23.8±3.5	1705±1	1719±32	1962	1895±4	5800	1209	1408±18	1308±4	1269±3	26.0
69	4990	194±3	31.0±0.3	25.4±0.6	1779+2	1734±5	1924	1814	2930	1319	1724±2	1563	1505±2	26.9
68	5910	194±3	29.7±0.2	25.4±0.7	1769±2	1733±6	1882	1801	2940	1325±1	1724±2	1537	1480±1	27.0

[a]Indeterminate.

[b]F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c]S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d]Position of valve in line connecting expansion tank to two-phase loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Boiler computed values									Remarks				
Test fluid		Heating fluid heat-transfer rate, Q_s, Btu/hr	Length, in.		Heat transfer coefficient, Btu/(hr)(ft^2)(^oF)		Quality		Test fluid inlet phase condition (b)	Steadiness of flow rate, pressure, and temperature (c)	Position of valve (d)	Type of run (e)	Type of change (f)
Pressure drop, ΔP_t, psi	Inlet subcooling, ΔT_{sc}, ^oF		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, x_o	Critical, x_{cr}					
2.7	120	114×10^3	22.5	32.5	1120	3500	0.90	0.55	L	S	O	U	O
3.1	93	128	23.5	38 - 39	1330	3530±10	.88	.75±0.04		S			
3.5	59	108	(a)	21 - 26	1260	(a)	.74	(a)		OF			
3.6	75	140	22.5	43	1540	3300	.89	.79		S			
3.6	65	147	22.5	43	1640	3270	.89	.77		S			
3.5	66	146	24.5	--------	1820	3440	.88	---------		S			
3.1	0	(125±8)×10^3	--------	--------	2590±260	--------	.75±0.06	---------	F	O			
3.2		125±3	--------	--------	2720±120	--------	.73±0.02	---------		OF			
3.2		139±4	--------	--------	2800±140	--------	.81±0.03	---------		O			
4.8		154	--------	29.5	1950	2660	.82	.63		S			
5.5		146	--------	29.5	1820	2730	.74	.59		OF			
4.5		151±12	--------	42	2540±320	2800±450	.74±0.06	.67±0.07		O			
5.8		164	--------	35	2380	2920	.80	.74		OF			
4.4		155±9	--------	39	2630±240	2870±270	.75±0.04	.64±0.05		OF			
5.6		172	--------	--------	2390	--------	.76	---------	TF	OF			
6.5		178±4	--------	33	2360±80	2710±110	.77±0.02	.55±0.02	TF	F			
6.2		176±12	--------	32.5 - 37	2440±260	2900±470	.76±0.05	.59±0.04	F	F			
4.8		152±6	--------	--------	2810±180	--------	.65±0.03	---------		OF			
5.3		169±4	--------	--------	2510±90	--------	.72±0.02	---------		OF			
3.7		141	--------	--------	3030	--------	.60	---------		SO			
6.1		184±8	--------	46.5	2670±200	2650±150	.76±0.04	.77±0.04		OF			
5.2		176	22.5	--------	2340±50	3470	.73	---------	L	S			
6.1		176±6	--------	--------	2700±140	--------	.72±0.02	---------	F	OF			
4.8		152±8	--------	--------	2540±180	--------	.60±0.04	---------	F	F			
4.9		164	--------	--------	3140	--------	.60	---------	F	OF			
5.2	27	158	23.5	--------	2060	3430	.54	---------	L	S			
5.1	29	152	26	--------	1870	3400	.52	---------	L	S			
6.6	0	184±2	--------	--------	2840±50	--------	.63±0.01	---------	F	O			
6.2	0	177±3	--------	--------	2770±40	--------	.61±0.01	---------	F	OF			
10.5	0	206±5	--------	28	1780±70	2640±180	.68±0.02	.56±0.04	TF	OF			
5.5	97	159	22.5	--------	1570	3410	.50	---------	L	S			
10.6	0	219	--------	29 - 31	2180	2780±100	.71	.50	F	O			
10.5	0	205±12	--------	26 - 29	1880±160	2710±30	.67±0.04	.49±0.02	F	OF			
5.4	60	92±7	25 - 27.5	--------	820±65	1880±110	.28±0.02	---------	L	F			
5.6	0	160	--------	--------	3110	--------	.50	---------	F	SO			
4.3	0	133	--------	--------	3190	--------	.42	---------	F	S			

[e]U indicates all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

Run	Boiler measurements								Condenser measurements					
	Flow rate, lbm/hr		Pressure, psia		Temperature, ^{o}F				Coolant		Shell temperature, ^{o}F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, ^{o}F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, ^{o}F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
59	4950	195±13	36.4±0.7	26.1±1.0	1816±4	1740±8	2059	1901	5970	1362	1740	1568±5	1485±3	27.4
58	4930	196±14	36.1±0.4	25.9±1.2	1813±3	1738±10	2041	1906±15	5990	1361	1735±2	1563±8	1480±1	27.4
104	5080	196±11	37.7±1.9	26.6±0.9	1824±6	1744±8	2082	1934	9260	1380	1744±1	1544	1456±2	28.2
8	5450	196±84	34.1±1.1	25.9±3.6	1798±1	1738±30	2039	1940	2930±180	1280	1734±11	1534	1486±5	28.1
63	4950	197±5	35.0±0.3	26.2±1.4	1806±2	1740±12	2024	1875±1	5960	1359±1	1739	1558	1477±3	27.5
66	5040	197±3	28.9±0.2	25.5±0.7	1763±1	1734±7	1874	1792	4370	1323	1537±8	1462±3	1413	26.8
103	5050	197±10	37.0±0.4	26.5±1.1	1819±3	1743±9	2061	1910	8840	1380	1734±6	1542±7	1462±5	28.2
105	5050	197±18	37.7±0.9	26.8±1.0	1824±6	1745±9	2106	1957	9200	1380±1	1738±2	1548±1	1457±1	28.0
25	5000	198^{+36}_{-44}	29.4±0.7	24.8±3.6	1713±1	1728±32	1960	1889±5	5680	1278	1436±2	1374±6	1335±5	26.0
102	4880	200±10	36.2±0.5	26.6±1.1	1815±3	1744±9	2048	1894	8960	1379	1740±2	1548±4	1461±1	27.9
78	4960	203±5	30.0±0.3	25.5±0.4	1715±1	1734±4	1927	1830	3140	1223±1	1511±4	1432±2	1379	26.9
65	5040	203±3	31.3±0.3	25.8±0.9	1781±2	1737±8	1938	1826	6100	1363	1731±3	1532	1446	27.4
56	4960	204±10	34.3±0.4	25.9±0.8	1802±2	1738±7	2001	1867	5970	1364	1734	1554±5	1473±1	27.3
57	4970	204±6	35.4±0.3	25.9±0.8	1808±3	1739±6	2031	1883±1	5990	1365±1	1736	1562±2	1480±2	27.3
19	5030	204±4	31.7±0	26.1±0.7	1784±0	1740±6	1940	1827	4990	1357	1736	1537±1	1465±4	28.0
52	5000	205±5	33.8±0.5	26.1±1.0	1798±3	1740±8	1983	1853	5980	1364	1740±7	1556	1461±1	27.6
51	5010	208±6	33.0±0.5	26.0±0.7	1793±3	1738±7	1967	1842	6220	1362±1	1734±1	1540	1458±1	27.3
101	4870	209±3	36.1±0.3	27.0±1.2	1813±3	1747±11	2034	1885	8980	1381±1	1738	1546±1	1457±1	28.2
39	4960	209±9	32.8±0.2	25.8±0.9	1791±2	1738±7	1966	1838	5990	1366	1734	1553	1463	27.5
55	4960	210±9	34.0±0.4	25.9±1.2	1799±3	1738±10	1995	1862	5970	1363	1735	1554±4	1466±1	27.5
31	4990	221±5	33.0±0	26.1±0.8	1793±0	1740±6	1964	1841	5860	1366	1733±1	1553±3	1462±1	27.7
38	4950	226±9	33.1±0.4	25.8±0.9	1793±3	1738±7	1961	1841	5980	1366	1734	1557±2	1464	27.3
354	4990	235	36.9±0.3	29.0±0.8	1816±5	1764±6	1994	1862	5610	1370±1	1761±2	1553	1481	31.1
17	5020	235±3	32.7±0	26.1±0.7	1790±0	1740±6	1946	1833	4940	1363±1	1734±4	1553	1471	27.8
30	4980	247±5	33.4±0	26.1±0.8	1796±0	1741±6	1965	1839	5850	1364	1736	1558±2	1465	27.8
15	4960	263	33.1±0	26.1±0.7	1793±0	1740±6	1949	1834	4770	1361±1	1733	1564	1475	27.7
37	4980	273±3	34.1±0.2	26.6±0.9	1800±1	1743±8	1965	1844	5970	1368	1735±2	1555	1465	27.9
28	4980	286±2	33.8±0	26.4±0.9	1798±0	1742±8	1962	1839	5750	1362	1735±1	1552	1468	28.0
23	5000	288^{+30}_{-45}	32.4±0.6	26.7±3.4	1788±4	1743±29	1966	1850	6000	1370	1731±1	1540±9	1461±4	27.5
96	4890	294±4	41.1±0.4	26.9±1.3	1846±2	1747±11	2102	1922	7860	1372±1	1742±1	1598±10	1484±3	28.2
100	4830	295±8	44.0±0.4	26.8±1.3	1863±2	1746±10	2151	1958	8950	1378	1744	1586±4	1486±1	28.0
98	4880	296±4	42.9±0.3	27.1±1.1	1856±2	1748±10	2132	1943	8790	1373	1744	1580±8	1480±3	28.2
90	4930	296	34.5±0.2	26.7±0.8	1803±1	1745±7	1964	1843	5930	1370	1738	1556±6	1469	27.8
94	4860	298±2	39.3±0.3	26.7±1.1	1834±2	1744±10	2071	1905	7460	1377	1742±1	1601±4	1486±3	28.0
95	4880	298±2	40.4±0.3	27.1±1.1	1841±2	1748±10	2083	1909	7680	1378±2	1745±2	1595±3	1489±1	28.2
93	4910	298±2	38.2±0.4	26.9±0.9	1827±2	1746±8	2040	1883	7230	1374±2	1742±1	1580±5	1479	28.0

[a] Indeterminate.

[b] F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c] S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d] Position of valve in line connecting expansion tank to two-phase loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Boiler computed values									Remarks				
Test fluid		Heating fluid heat-transfer rate, Q_s, Btu/hr	Length, in.		Heat transfer coefficient Btu/(hr)(ft^2)(^{o}F)		Quality		Test fluid inlet phase condition (b)	Steadiness of flow rate, pressure, and temperature (c)	Position of valve (d)	Type of run (e)	Type of change (f)
Pressure drop, ΔP_t, psi	Inlet subcooling, ΔT_{sc}, ^{o}F		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet X_o	Critical, X_{cr}					
10.3	0	(218±6)×10^3	---------	32	2270±90	2610±60	0.68±0.02	0.45±0.01	F	OF	O	U	O
10.2		217×10^3	---------	42	2430	2600	.68	.62	F	O			
11.1		225±4	---------	30 - 31.5	2090±60	2750±50	.70±0.02	.54±0.01	TF	OF			
8.2	2	164±21	(a)	(a)	1520±200	(a)	.51±0.07	(a)	L	F			
8.8	0	200±9	---------	--------	2600	--------	.66±0.03	---------	F	OF			
3.4		121	---------	--------	3310	--------	.37	---------	F	S			
10.5		230±3	---------	40	2410±60	2690±70	.72±0.01	.65±0.01	TF	OF			
10.9		220±9	---------	26 - 28	1810±100	2760±220	.68±0.03	.55±0.01	TF	OF			
4.6	53	96±14	23.5 - 25	--------	910±140	1840±330	.28±0.05	---------	L	F			
9.6	0	223	---------	46.5	2510	2490	.72	.70	F	OF			
4.5	56	137	25	--------	1770	3460	.40	---------	L	S			
5.5	0	172	---------	--------	3160	--------	.51	---------	F	SO			
8.4		202	---------	--------	2620	--------	.61	---------	F	O			
9.5		218	---------	41 -44	2570	2710±130	.65	.60±0.03		O			
5.6		165	---------	--------	2950	--------	.49	---------		OF			
7.7		190±3	---------	--------	2790±40	--------	.57±0.01	---------		OF			
7.0		183	---------	--------	2900	--------	.54	---------		OF			
9.1		225±5	---------	--------	2810±110	--------	.66±0.01	---------		O			
7.0		185±5	---------	--------	2950±130	--------	.54±0.01	---------					
8.1		195±4	---------	--------	2620±90	--------	.57±0.01	---------					
6.9		177	---------	--------	2900	--------	.49	---------					
7.3		179	---------	--------	2900	--------	.48	---------		OF		U	O
7.9		187±2	---------	--------	3030±50	--------	.49	---------		S		AS	P
6.6		170	---------	--------	3080	--------	.44	---------		OF		U	O
7.3		187±3	---------	--------	3190±80	--------	.47	---------		OF			
7.0		170	---------	--------	3070	--------	.39	---------		OF			
7.5		182	---------	--------	3130	--------	.41	---------		S			
7.4		182	---------	--------	3140	--------	.39	---------		O			
5.7	5	175±13	---------	--------	2580±260	--------	.37±0.03	---------	TF	F			
14.2	0	265	---------	--------	2690	--------	.56	---------	F	O			
17.2	0	299	---------	--------	2640	--------	.63	---------	F	OF			
15.8		286	---------	--------	2700	--------	.60	---------		O			
7.8		171	---------	--------	2980	--------	.35	---------		S			
12.6		241	---------	--------	2730	--------	.50	---------		O			
13.3		254	---------	--------	2840	--------	.53	---------		O			
11.3		223	---------	--------	2800	--------	.46	---------		SO			

[e]U indicates all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

TABLE I. - Continued. DATA

(a) Continued. U. S.

Run	Boiler measurements								Condenser measurements					
	Flow rate, lbm/hr		Pressure, psia		Temperature, ^{o}F				Coolant		Shell temperature, ^{o}F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, ^{o}F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, ^{o}F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
91	4990	298	35.4±0.2	26.8±0.8	1809±1	1745±7	1983	1853	5880	1370±1	1744±1	1558	1480	27.9
92	4920	299±3	36.8±0.3	26.7±1.1	1818±2	1744±10	2015	1867	5870	1368±1	1742±1	1592±8	1489±2	27.7
13	4990	300	33.9±0	26.4±0.9	1799±0	1743±7	1953	1836	4870	1362±1	1735±1	1574±6	1481	27.8
12	5020	300	34.2±0	26.2±0.8	1801±0	1740±7	1960	1839	4890	1364±1	1734±1	1581±15	1485	27.7
75	4900	304±1	33.0±0.2	26.1±0.7	1792±2	1740±6	1928	1823	2360	1076	1544±18	1402	1342	27.3
27	5010	318±3	34.1±0	26.6±0.8	1800±0	1744±7	1963	1842	5700	1469±104	1737±1	1561	1469	28.0
22	5010	337^{+24}_{-37}	33.3±0.3	26.6±2.2	1791±3	1744±19	1964	1844	6000	1370±1	1714±15	1556±10	1466	27.7
35	5020	342	34.0±0	26.3±0.3	1799±0	1741±2	1964	1862	5740	1365	1727±2	1529±10	1452±2	27.6
26	4990	347±3	34.7±0	26.6±0.8	1804±2	1744±7	1965	1842	5870	1367	1738±2	1553±2	1469	28.0
34	4990	380	34.8±0	26.9±0.5	1805±0	1747±4	1963	1862	5890	1365±1	1695±20	1518±2	1455±1	27.8
146	5040	105	36.7±0	34.0±0.3	1727±1	1799±2	1998	1895	4970	1327	1560	1482	1434	36.2
147	5060	105	36.6±0	34.0±0.3	1723±1	1799±2	1978±1	1885	4270	1345	1566	1481	1440±1	35.8
143	5060	105	37.7±0	34.0±0.3	1726±1	1799±2	2029	1921±1	4270	1351	1647±6	1494±11	1460±5	36.2
149	5110	105	36.1±0	34.2±0.3	1718±1	1801±2	1938	1862±1	4270	1349±1	1533±1	1454	1422	35.7
148	5050	106	35.7±0	33.4±0.3	1720±1	1795±2	1959	1872±2	4270	1354	1558±3	1478	1441	35.7
145	5040	108	36.9±0	34.0±0.3	1724±1	1799±2	2008	1903	4330	1350	1652±21	1516	1460±1	35.7
144	5050	110	37.4±0	33.9±0.6	1732±0	1800±3	2038	1929	4310	1356	1724±39	1523±1	1469±1	35.7
348	4990	148±2	39.4±0.2	35.4±1.2	1835±1	1809±8	1991±1	1882	5520	1357	1597±13	1492±4	1443	36.9
142	5010	159±8	40.1±0.5	34.0±1.3	1839±3	1800±8	2066	1935±7	4930	1355	1792±3	1562±10	1478±5	36.0
141	4990	161±11	39.7±0.5	34.0±1.2	1837±3	1799±9	2053	1916±1	4970	1354±1	1792±2	1574±3	1483±1	35.9
140	5000	164±8	39.4±0.3	34.2±1.4	1834±3	1800±10	2039	1906	4880	1354	1788±5	1567±4	1481±1	35.8
136	5060	164±3	38.0±0	34.2±1.4	1826±3	1801±9	1989±1	1879±1	4930	1344	1645±41	1508	1448	35.9
137	5070	164±3	38.4±0	34.2±1.3	1829±2	1801±9	2002	1887±1	5010	1356	1719±6	1533±1	1463±1	35.9
134	4990	165±2	37.6±0	34.4±1.0	1823±2	1803±6	1964	1866	4980	1335±1	1559±7	1474	1427±1	36.0
139	5040	166±4	39.1±0	34.2±1.3	1833±3	1800±10	2026	1905±9	4880	1353±1	1791±2	1556±1	1474±1	35.7
135	5080	167±2	37.6±0	34.0±1.1	1823±3	1799±8	1979	1873±1	4940	1344	1610±10	1499±3	1445±1	35.4
138	5010	169±3	38.8±0	34.5±1.2	1831±4	1802±9	2013	1890±2	4940	1373	1788±6	1567±4	1491±2	36.1
132	4960	196±9	42.5±1.1	34.2±1.3	1853±7	1801±9	2123	1966±3	8240	1372±1	1785±2	1556±4	1457±4	36.1
350	5010	196±1	39.3±0.2	34.1±1.1	1834±2	1800±8	1993	1879±1	5530	1366	1629	1531	1463	36.1
128	5000	198±3	41.4±0.1	34.5±1.2	1847±1	1803±8	2064	1918	8160	1369	1735±3	1538±9	1455±1	36.1
127	5030	198±3	41.2±0.3	34.7±1.1	1846±2	1804±8	2049	1906±1	8240	1370	1677±33	1525±1	1452±1	36.1
131	4970	200±8	42.1±0.5	34.3±1.1	1851±3	1802±7	2102	1944±2	8180	1370	1790±2	1557±3	1460±5	36.1
130	4960	201±6	41.9±0.3	34.7±1.1	1850±2	1805±7	2092	1937±3	8210	1370	1794±1	1552±2	1457±4	36.1
133	5050	202±2	38.0±0	34.1±1.0	1826±0	1800±7	1976	1869	8260	1361	1545±7	1467±7	1418±3	36.1
129	4970	203±2	41.9±0.3	34.6±1.2	1850±2	1804±8	2079	1928	8290	1370±1	1783±11	1550	1456±1	36.1
126	5010	203±4	40.3±0.2	34.5±1.3	1841±1	1803±9	2024	1897	8190	1370	1661±30	1520±2	1445	36.1

[a]Indeterminate.

[b]F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c]S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d]Position of valve in line connecting expansion tank to two-phase loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Boiler computed values									Remarks				
Test fluid		Heating fluid heat-transfer rate, Q_s, Btu/hr	Length, in.		Heat transfer coefficient, Btu/(hr)(ft^2)(^{o}F)		Quality		Test fluid inlet phase condition (b)	Steadiness of flow rate, pressure, and temperature (c)	Position of valve (d)	Type of run (e)	Type of change (f)
Pressure drop, ΔP_t, psi	Inlet subcooling, ΔT_{sc}, ^{o}F		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}					
8.6	0	188×10^3	----	----	3020	--------	0.39	---------	F	S	O	U	O
10.1		203	----	----	2880	--------	.42	---------					
7.5		170	----	----	3100	--------	.35	---------					
8.0		178	----	----	3180	--------	.36	---------					
6.9		(150±3)×10^3	----	----	3300±240	--------	.31±0.01	---------					
7.5	0	178	----	----	3020	--------	.34	---------		OF			
6.7	3	182±11	----	----	2930±230	--------	.33±0.02	---------	TF	F			
7.7	0	150	21	----	2230	3360	.27	---------	L	S			
8.1	0	177±4	----	----	3130±100	--------	.31±0.01	---------	F	S			
7.9	0	145	23.5	----	2270	3100	.23	---------	L	S			
2.7	91	153	22.5	----	1615	3350	.87	---------		O			
2.6	93	140	20	----	1600	3460	.80	---------					
3.7	98	163	24	40	1500	3430	.93	0.77					
1.9	95	112	18	----	1560	3560	.63	---------					
2.3	91	126	21	----	1540	3400	.71	---------					
2.9	95	158	21.5	----	1595	3340	.88	---------					
3.5	90	168	26	40.5	1520	3460	.92	.79					
4.0	0	155	----	----	2930	--------	.64	---------	F			BS	W
6.1		195±14	----	31	2220±230	2810±350	.76±0.05	.56±0.06	TF	F		U	O
5.7		202	----	----	2530	--------	.77	---------	F	F			
5.2		199	----	----	2700	--------	.75	---------		F			
3.8		161	----	----	2770	--------	.60	---------		OF			
4.2		174	----	----	2870	--------	.65	---------		OF			
3.2		144±4	----	----	3030±150	--------	.53±0.02	---------		SO			
4.9		190	----	----	2780	--------	.70	---------		O			
3.6		155	----	----	2820	--------	.57	---------		O			
4.3		182	----	----	2810	--------	.66	---------		O			
8.3		231±5	----	30	2150±70	2780±100	.72±0.02	.54±0.02	TF	F			
5.2		169	----	----	3230	--------	.53	---------	F	SO		AS	W
6.9		223	----	----	2910	--------	.69	---------	F	O		U	O
6.5		204	----	----	2770	--------	.63	---------	F	O			
7.8		234±5	----	35	2470±80	2720±100	.72±0.02	.53±0.02	TF	F			
7.2		235±8	----	37	2620±150	2800±180	.72±0.03	.55±0.03	TF	F			
3.9		164	----	----	3340	--------	.50	---------	F	SO			
7.3		233±5	----	----	2810±100	--------	.70±0.02	---------	F	O			
5.8		191	----	----	2980	--------	.58	---------	F	O			

[e] U indicated all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f] O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

TABLE I. - Continued. DATA

(a) Continued. U.S.

Run	Boiler measurements									Condenser measurements				
	Flow rate, lbm/hr		Pressure, psia		Temperature, ^{o}F				Coolant		Shell temperature, ^{o}F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, ^{o}F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, ^{o}F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
347	5050	204	40.3±0.1	35.7±0.9	1840±1	1811±6	2012±19	1882	5650	1363±1	1646±2	1523	1455±1	37.1
346	5110	212±1	40.3±0.1	35.5±1.1	1840±2	1809±8	1993	1880	5670	1365	1655±6	1524±2	1459	37
364	4960	245	42.9±0.1	34.7±0.3	1819±1	1804±2	2100	1949	6200	1371	1798	1580±4	1487	36.3
355	4940	246	39.9±0.1	34.3±0.8	1838±1	1801±5	1993±2	1877	5590	1366±1	1708±26	1542	1466±1	36.1
359	4950	247	42.0±0.2	34.1±0.5	1802±1	1800±3	2079±1	1935±1	5440	1365	1796±2	1582±1	1489±1	36.1
363	4970	247	42.4±0.1	34.9±0.2	1781±0	1805±2	2086	1941±1	6230	1369	1800	1665±7	1476	36.7
353	4990	248	40.1±0.1	34.3±0.8	1840±0	1801±5	1993	1878	5640	1367	1713±22	1545±6	1467	36.0
365	4980	250	43.1±0.1	34.7±0.4	1852±1	1804±3	2097±1	1951	6220	1371±1	1798	1585	1483±1	36.4
351	4990	250	39.9±0.2	34.3±0.9	1838±1	1802±6	1994	1879±1	5550	1366±1	1709±20	1543±1	1467±1	36.1
360	4980	259±36	40.9±0.9	34.2±4.0	1805±2	1799±28	2080	1970±2	5770	1359±1	1638±58	1512±3	1451±3	34.8
362	4950	273±23	38.9±0.6	34.0±3.4	1754±1	1798±22	2032	1947	2920	1326	1646±4	1507±5	1464±1	34.8
124	5030	295±2	49.6±0.4	34.9±1.4	1894±4	1805±10	2189	1995	8290	1369	1796	1609±10	1492±1	36.1
349	5010	297	41.3±0.2	35.7±0.9	1847±1	1811±6	1992	1884	5730	1368±1	1675	1535±3	1466	36.9
119	5040	298	42.8±0.2	34.6±1.3	1856±1	1804±9	2056	1915±1	7250	1368	1794	1569	1466	36.0
118	5010	300	40.5±0.3	34.0±1.1	1841±2	1800±7	2004	1883	5570	1356±1	1764±2	1553±1	1467±2	35.1
345	5090	300	41.4±0.1	35.6±0.9	1847±1	1810±6	2011±20	1884	5640	1367	1674±7	1540±1	1465±1	36.9
117	5010	302	39.0±0.3	34.2±0.9	1832±2	1801±6	1976±1	1870	5600	1357±1	1622±16	1523±2	1453±1	35.1
122	5000	304±4	48.4±0.4	35.0±1.5	1887±2	1806±10	2164±1	1972	8250	1365	1798±1	1598±9	1484±2	36.1
121	5040	306±5	46.9±0.3	35.2±1.4	1879±2	1807±10	2135	1963±3	7780	1367	1799±1	1596±3	1482±1	36.1
120	5000	307±9	44.4±0.1	34.6±1.3	1865±1	1804±9	2104±1	1939	6930	1363±1	1799	1590±2	1480	36.1
123	5010	318±12	49.5±0.2	34.9±1.4	1893±1	1805±10	2187	1993±1	8250	1357	1796	1591±2	1477	36.1
116	4970	350	38.0±0.3	34.0±0.7	1826±2	1799±5	1929	1849	5560	1345	1544	1472	1417	35.5
193	5100	86	43.8±0	41.8±0.5	1713±1	1850±3	1994±1	1916±1	2490	1338	1575±4	1505±1	1474±1	43.5
184	5940	98	43.8±0	41.3±0.6	1735±2	1846±4	2028	1943	4050	1364	1608±9	1517±1	1470±1	43.1
181	5880	99	44.3±0	41.7±0.5	1737±1	1849±3	2029	1942	4060	1334	1567±2	1490	1445	43.1
185	5550	100	43.5±0	41.0±0.5	1738±1	1845±3	2029	1937	4060	1359±1	1601±1	1511±2	1465±1	43.1
178	5310	102	44.3±0	41.6±0.3	1745±1	1848±2	2028±1	1940	4090	1361	1606±8	1508±1	1464	43.3
179	5610	103	44.5±0	42.2±0.4	1753±1	1852±2	2029	1942	4080	1362	1597±8	1515±2	1468	44.1
176	5060	105	44.3±0	41.6±0.3	1752±2	1848±2	2032	1936	4110	1344±1	1579±2	1494±1	1451	43.3
175	5090	105	44.8±0	42.3±0.4	1748±1	1853±2	2040	1942	4090	1344	1588±1	1496±1	1453±1	44.1
186	5580	105	43.7±0	41.5±0.2	1741±1	1848±2	2040	1955±1	4050	1357	1579	1500	1456	43.1
182	5960	105	43.5±0	41.2±0.4	1765±1	1846±2	2030	1950	4060	1340	1576±12	1479	1440±1	43.1
172	5020	106	44.7±0	42.1±0.2	1790±1	1852±1	2061	1960±1	4100	1338±1	1588±5	1492±1	1451	43.6
171	5080	107	45.1±0	42.4±0.3	1761±1	1853±2	2071	1968	4010	1338	1586±6	1500±2	1454±1	43.9
183	5900	107	43.6±0	41.2±0.4	1755±1	1846±2	2030±1	1952	4080	1347	1569±1	1488	1443±2	43.1
173	5080	110	44.7±0	42.3±0.3	1759±1	1852±2	2051	1957	4100	1341	1558	1484±1	1445±1	43.8

[a]Indeterminate.

[b]F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c]S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d]Position of valve in line connecting expansion tank to two-place loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Test fluid: Pressure drop, ΔP_t, psi	Test fluid: Inlet subcooling, ΔT_{sc}, ^oF	Heating fluid heat-transfer rate, Q_s, Btu/hr	Boiler computed values: Length, in.: Effective, l_e	Length, in.: Critical, l_{cr}	Heat transfer coefficient, $Btu/(hr)(ft^2)(^oF)$: Average overall, U_a	Heat transfer coefficient: Effective, U_e	Quality: Outlet, X_o	Quality: Critical, X_{cr}	Remarks: Test fluid inlet phase condition (b)	Steadiness of flow rate, pressure, and temperature (c)	Position of valve (d)	Type of run (e)	Type of change (f)
4.6	0	162×10^3	----	------	3160	-------	0.49	---------	F	S	O	BS	W
4.8	0	164	----	------	3200	-------	.48	---------	F	↓	↓	AS	W
8.2	37	228	15	------	2190	3290	.57	---------	L			U	O
5.6	0	165	----	------	3190	-------	.41	---------	F			AS	P
7.9	49	208	14.5	------	2020	3160	.51	---------	L			U	O
7.5	72	218	15.5	------	1945	3240	.53	---------	L			U	O
5.8	0	169	----	------	3320	-------	.42	---------	F			AS	P
8.4	5	224	15.5	------	2400	3250	.55	---------	L			U	O
5.6	0	167	----	------	3220	-------	.41	---------	F			BS	P
6.7	40	163	23	------	1440	2670	.37	---------	L	F		U	O
4.9	78	111	24.5	------	1010	2120	.23	---------	L	F		U	O
14.7	0	302	----	43 - 45	2665	2740±60	.64	0.62±0.01	TF	O		U	O
5.6	↓	160	----	------	3280	-------	.33	---------	F	S		AS	W
8.2		213	----	------	3040	-------	.44	---------	↓	O		U	O
6.5		177	----	------	3130	-------	.36	---------		S		U	O
5.8		159	----	------	3230	-------	.33	---------		S		BS	W
4.8		153	----	------	3130	-------	.31	---------		S		U	O
13.4		294	----	------	2860	-------	.60	---------		O		↓	↓
11.7		268	----	------	2890	-------	.54	---------		↓			
9.8		243	----	------	2770	-------	.49	---------	TF				
14.6		$(302\pm4)\times10^3$	----	44	2690±60	2700±60	.59±0.01	.58±0.01	TF				
4.0		111	----	------	3260	-------	.20	---------	F	S			
2.0	148	114	17	------	1300	3230	.79	---------	L	↓			
2.5	126	150	20	45	1505	3420	.92	.88	↓				
2.6	129	152	23.5	------	1535	3590	.91	---------					
2.5	122	147	21.5	46.5	1490	3420	.88	.89					
2.7	122	143	22.5	------	1480	3440	.84	---------					
2.3	113	147	21	------	1550	3460	.86	---------					
2.7	112	143	20.5	------	1500	3510	.82	---------		SO			
2.5	119	149	21.5	------	1520	3560	.85	---------		S			
2.2	123	140	24	46	1350	3500	.80	.79		S			
2.3	95	133	26.5	45	1390	3550	.76	.71		S			
2.6	77	148	25	------	1500	3540	.84	---------		SO			
2.7	108	152	24.5	------	1385	3390	.85	---------		S			
2.4	105	131	24	45	1340	3380	.73	.72		↓			
2.4	108	139	26	------	1360	3440	.75	---------	↓		↓	↓	↓

[e]U indicated all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

TABLE I. - *Continued.* DATA

(a) Continued. U. S.

Run	Boiler measurements: Flow rate, lbm/hr: Heating fluid, W_s	Boiler measurements: Flow rate, lbm/hr: Test fluid, W_t	Boiler measurements: Pressure, psia: Test fluid: Inlet, $P_{t,I}$	Boiler measurements: Pressure, psia: Test fluid: Outlet, $P_{t,II}$	Boiler measurements: Temperature, ^oF: Test fluid: Inlet, $T_{t,I}$	Boiler measurements: Temperature, ^oF: Test fluid: Outlet, $T_{t,II}$	Boiler measurements: Temperature, ^oF: Heating fluid: Inlet, $T_{s,I}$	Boiler measurements: Temperature, ^oF: Heating fluid: Outlet, $T_{s,II}$	Condenser measurements: Coolant: Flow rate, W_c, lbm/hr	Condenser measurements: Coolant: Inlet temperature, $T_{c,f,I}$, ^oF	Condenser measurements: Shell temperature, ^oF: At 6-in. station, $T_{c,s}$	Condenser measurements: Shell temperature, ^oF: At 12-in. station, $T_{c,s}$	Condenser measurements: Outlet: Temperature, $T_{c,II}$, ^oF	Condenser measurements: Outlet: Pressure, $P_{c,II}$, psia
192	5090	115	44.1±0.3	42.0±0.3	1778±1	1851±2	1994	1917±1	2480	1334±2	1582±1	1505±2	1475±2	43.5
287	4970	143	45.6±0.2	42.9±0.6	1418±1	1856±4	2059	1954±1	5420	1368±1	1577±12	1484±2	1439±2	45.2
191	5100	145	44.2±0	41.6±0.4	1814±1	1848±3	1991±3	1916±1	2490	1320±1	1582±4	1499±2	1466±2	43.5
290	5110	150±3	46.8±0.2	42.6±1.6	1879±1	1855±9	2058	1935	7270	1375	1611±10	1510±2	1451±1	43.9
288	5040	152	46.3±0.2	42.6±0.4	1843±2	1854±3	2058	1950±3	5330	1384±2	1651±1	1536±2	1481	45.1
286	4940	155±7	46.7±0.2	42.5±1.3	1879±1	1854±7	2058	1935±2	5390	1361	1662±23	1530±5	1465±1	43.7
163	5150	159±2	45.2±0.2	42.4±1.1	1870±1	1853±7	2009±1	1912±1	3580	1336±1	1622±8	1523±2	1456±14	44.0
190	5060	161	44.6±0	41.9±0.9	1866±2	1850±5	1993	1905±1	2520	1313±1	1635±7	1525±1	1484±2	43.5
343	5120	164±5	46.3±0.3	42.8±1.2	1876±2	1855±7	2031	1921±2	5500	1359±3	1624±4	1505±1	1451	----
170	5070	165±5	48.2±0.6	42.5±1.3	1886±3	1854±7	2132±2	1998±3	5290	1358	1830±12	1566±11	1482±2	43.8
167	5050	166±4	47.7±0.4	42.8±1.5	1883±2	1855±9	2085±1	1951±2	5370	1361±1	1786±6	1554±5	1479±1	43.5
168	5070	166±4	47.8±0.4	42.8±1.5	1884±2	1855±9	2097	1959±3	5070	1358	1846±2	1574±2	1483±2	44.1
165	5080	166±2	46.4±0.2	42.5±1.2	1876±1	1854±7	2039±1	1926±3	4850	1364±2	1665±13	1532±1	1467±2	44.2
188	5090	166±4	45.5±0	42.1±1.0	1871±2	1851±6	2029	1922±1	4800	1328±2	1595±5	1491±3	1437±1	43.5
169	5110	167±5	48.3±0.6	42.5±1.3	1887±3	1854±7	2114	1977±3	5170	1360	1841±2	1583±12	1484±5	44.0
164	5090	168	45.7±0.2	42.3±1.2	1873±2	1853±7	2024±1	1920±2	4410	1349±3	1630±1	1525±1	1464±3	43.9
166	5040	171±4	47.0±0.3	42.7±1.3	1879±2	1855±8	2062±1	1938±2	5290	1358±1	1686±4	1540±7	1471±1	44.2
158	5110	193±6	48.4±0.3	42.5±1.5	1887±3	1854±9	2103	1960	6450	1372±2	1779±46	1576±5	1481±1	43.8
159	5120	196±6	49.1±0.4	42.8±1.5	1891±2	1855±9	2114	1966±1	6440	1367±3	1819±25	1579±3	1484±2	44.2
342	5050	197±2	46.6±0.2	42.4±1.1	1878±1	1853±7	2032±1	1919	6140	1367	1609±17	1511	1453	----
161	5090	198±11	50.1±0.5	42.6±1.4	1896±3	1855±8	2149	1992±2	6980	1367	1823±13	1570±6	1479±1	44.2
160	5110	198±8	50.6±0.3	43.5±1.5	1899±2	1860±9	2130	1972±2	6480	1388±21	1849±1	1587	1484±1	44.7
162	5080	199±16	50.1±1.2	42.3±1.5	1896±6	1853±8	2168±1	2016	6940	1371	1728±18	1581±13	1480	43.8
344	5070	200±2	46.5±0.2	42.4±1.1	1877±1	1853±7	2029	1919	5390	1365	1643±15	1524	1463±1	----
156	5080	200±4	46.8±0	42.3±1.2	1879±1	1853±7	2051	1930±1	4670	1358±2	1828	1566	1486±2	43.7
157	5080	200±5	47.4±0.6	42.3±1.5	1882±3	1853±8	2069	1940	5890	1365	1716±78	1547±7	1476±1	43.8
155	5110	200±2	46.5±0	42.5±1.1	1877±1	1853±6	2027	1921	4690	1352	1659±13	1532±4	1468	43.8
189	5090	204	45.3±0	42.1±0.9	1870±2	1852±5	1994±1	1904±1	3070	1292±1	1622±11	1492±1	1443±1	43.5
187	5080	206±2	46.1±0	42.1±0.9	1874±2	1851±6	2031	1920±1	4800	1340	1612	1510	1455	43.8
253	4990	212±1	46.5±0.1	40.8±1.0	1877±0	1844±6	2056	1925	4910	1319	1801	1544	1452	42.2
341	5080	215±5	48.4±0.1	42.5±1.3	1888±1	1854±7	2084	1947±2	7370	1373±1	1688±24	1546±2	1464	44.3
352	4970	262	43.6±0.1	39.3±1.0	1861±1	1834±6	1994	1894	5610	1357	1582±1	1504±1	1445	40.8
220	4990	301	49.3±0.2	40.9±1.2	1892±1	1844±7	2094	1943±2	4300	1310±1	1836±1	1596±2	1500±1	42.5
221	4960	305	49.3±0.1	41.2±1.0	1893±1	1845±7	2092	1942±1	4340	1312±1	1840±3	1591	1501±1	42.7
219	4970	305	49.4±0.3	41.4±1.3	1892±2	1847±8	2093	1940	4140	1311	1836±1	1596±5	1505±2	42.7
224	4950	310	49.0±0.2	40.6±1.3	1891±2	1843±8	2093±1	1937±1	4775	1315±1	1827±3	1585±8	1495±1	42.1

[a] Indeterminate.

[b] F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c] S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d] Position of valve in line connecting expansion tank to two-place loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Boiler computed values									Remarks				
Test fluid		Heating fluid heat-transfer rate, Q_s, Btu/hr	Length, in.		Heat transfer coefficient, Btu/(hr)(ft^2)(^{o}F)		Quality		Test fluid inlet phase condition	Steadiness of flow rate, pressure, and temperature	Position of valve	Type of run	Type of change
Pressure drop, ΔP_t, psi	Inlet subcooling, ΔT_{sc}, ^{o}F		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}	(b)	(c)	(d)	(e)	(f)
2.1	85	111×10^3	18.5	--------	1530	3320	0.58	---------	L	S	O	U	O
2.7	454	144	26	--------	860	3400	.54	---------	L	S		DR	T
2.6	50	113	21	--------	1890	3540	.47	---------	L	S		U	O
4.2	0	176	----	--------	2780	--------	.72	---------	F	O		U	O
3.7	33	166	17	44 - 45	2160	3360	.67	0.60	L	S		U	O
4.2	0	174	----	--------	2810	--------	.70	---------	F	O		BR	T
2.8		148	----	--------	3150	--------	.57	---------	F	O		U	O
2.7		131	----	--------	3050	--------	.50	---------	TF	OF			
3.5		161	----	--------	3050	--------	.61	---------	F	O			
5.7		$(191\pm9)\times10^3$	----	26.5 - 29	1910±120	3010±200	.71±0.04	.60±0.03		F			
4.9		198	----	--------	2790	--------	.74	---------		F			
5.0		203	----	40.5	2590	2780	.76	.68		F			
3.9		164	----	--------	2850	--------	.61	---------		O			
3.4		162	----	--------	2960	--------	.60	---------		S			
5.8		201±9	----	25 - 30	2300±150	3040±500	.75±0.03	.49±0.04		F			
3.4		160	----	--------	3120	--------	.59	---------		O			
4.3		175±3	----	37.5	2650±70	2930±60	.64±0.01	.52±0.01		OF			
5.9		222	----	--------	2890	--------	.71	---------		F			
6.3		226	----	43 - 45	2850	2990±10	.72	.70±0.04		F			
4.2		167	----	--------	3290	--------	.53	---------		O			
7.5		240	----	30	2510	3060	.75	.52	TF	F			
7.1		239	----	37 - 40	2900	3220±110	.75	.65±0.01	F	F			
7.8		232	----	30	2150	2900	.72	.58	TF	F			
4.1		164	----	--------	3190	--------	.51	---------	F	O			
4.5		181	----	--------	3100	--------	.56	---------		SO			
5.1		194	----	--------	3000	--------	.60	---------		F			
4.0		161	----	--------	3140	--------	.50	---------		S			
3.2		132	----	--------	3250	--------	.40	---------					
4.0		163	----	--------	3060	--------	.49	---------					
5.7		192	----	--------	3200	--------	.56	---------					
5.9		203	----	--------	3010	--------	.58	---------		O			
4.3		143	----	--------	3300	--------	.34	---------		S		AS	P
8.4		225	----	--------	3340	--------	.46	---------		SO		U	O
8.1		221	----	--------	3240	--------	.45	---------		S		U	O
8.0		221	----	--------	3250	--------	.45	---------		SO		U	O
8.4		227	----	--------	3360	--------	.45	---------		S		BR	T

[e]U indicated all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

TABLE I. - Continued. DATA

(a) Continued. U. S.

Run	Boiler measurements								Condenser measurements					
	Flow rate, lbm/hr		Pressure, psia		Temperature, °F				Coolant		Shell temperature, °F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, °F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, °F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
222	4930	311	49.3±0.1	41.1±1.3	1892±1	1845±8	2095±1	1941±1	4270	1312	1834±3	1587±1	1498	42.6
250	4940	313	49.6±0.1	40.8±1.1	1894±1	1844±7	2094	1943	5150	1320±1	1834	1570±5	1475±1	42.2
223	4980	317	48.9±0.1	41.1±1.3	1890±2	1845±8	2092±2	1944±2	4270	1315±2	1834±3	1589±4	1496±4	42.7
225	4980	326	48.6±0.1	40.8±1.1	1889±2	1844±7	2094	1942±1	4600	1313	1833±2	1582±3	1485	42.2
226	4980	334	48.6±0.2	40.8±1.1	1888±1	1844±7	2092	1946	4570	1318	1834±4	1589±2	1481	42.4
227	4980	349±8	48.6±0.2	40.9±1.1	1889±2	1844±7	2093	1945	4770	1318	1827±1	1578	1478	42.4
228	4940	359±13	48.3±0.2	40.8±1.1	1887±2	1844±7	2092±2	1948±3	4810	1318±2	1819±12	1578±11	1479±5	42.7
229	4960	373±20	45.9±0.8	39.7±3.0	1848±1	1836±19	2091	1987±2	4770	1312±3	1626±22	1503±4	1433±4	40.5
231	4980	373±20	45.9±0.8	40.1±3.4	1778±0	1838±22	2094±1	1993±2	4710	1317±1	1600±17	1488±4	1430±2	40.9
340	5100	373	51.0±0.2	42.8±1.5	1901±1	1855±9	2084	1948	7470	1371	1754±24	1564	1471	44.3
289	4960	375	50.0±0.2	42.7±1.1	1896±1	1855±6	2055	1931	7220	1367±1	1714±3	1545	1462±1	43.8
230	4960	377±17	45.9±0.8	39.8±2.5	1803±1	1837±16	2093	1992	4720	1314	1609±29	1490±4	1431±1	40.5
218	5030	89±4	51.9±0	49.3±1.3	1659±1	1892±7	2080	1988±1	2550	1313	1606±12	1507±1	1472±2	50.7
217	5060	101±5	52.3±0	49.6±1.5	1715±1	1895±6	2081±1	1978±1	2560	1295±2	1635±12	1511±4	1477±3	50.9
215	5000	131	53.7±0	49.6±0.7	1839±2	1893±4	2133±1	2007±2	4070	1349±1	1742±46	1563±6	1496±2	51.1
214	5020	134±7	53.7±0.5	50.0±1.8	1914±3	1897±8	2133±2	2016	5930	1358±1	1585±3	1497±2	1449	51.5
212	4990	139±12	54.4±0.5	50.8±2.0	1917±3	1900±10	2123±1	1997	6000	1360±1	1609	1512	1461	51.7
213	5100	140±9	54.6±0.7	50.4±2.3	1918±4	1899±10	2123	2000±1	5940	1362	1602±4	1512±1	1460±1	51.5
210	5050	144±9	54.4±0.2	50.2±2.1	1917±1	1898±9	2110	1988±2	5990	1361	1621±1	1507±5	1455±1	51.7
211	5020	146±5	54.6±0.7	50.4±2.3	1918±4	1899±10	2109	1987±2	6020	1360	1612±9	1516±3	1457±1	51.5
209	5050	151±5	53.4±0.3	50.0±1.6	1913±1	1896±8	2083	1967	5900	1361	1596	1505	1450±1	51.5
216	5000	161±3	52.9±0.3	49.6±1.5	1910±2	1895±6	2056±1	1955	3400	1327±1	1630±20	1518	1471±2	51.4
204	5040	200±10	57.1±0.3	50.4±1.6	1930±2	1898±8	2191	2038±3	6070	1367	1870±7	1588±4	1489±3	52.0
208	5080	200±3	56.7±0.6	50.3±1.8	1928±3	1897±9	2153	2001	5930	1366±1	1854±17	1591±2	1492	51.1
200	5020	201±3	55.2±0	50.6±1.2	1922±2	1899±6	2095	1975	4160	1353±1	1739±13	1568±3	1495±2	52.0
203	4980	203±9	57.0±0.4	50.5±1.7	1930±2	1898±9	2171	2014	6120	1366±1	1853±20	1595±4	1493	52.0
205	5040	203±9	57.1±1.1	50.7±1.5	1930±5	1900±7	2179	2024	6000	1367	1873	1598±2	1492±1	51.5
201	4980	204±4	56.0±0	50.8±1.4	1925±1	1900±7	2127±6	1983	4540	1356	1862±6	1589±2	1507±3	52.0
202	5010	204^{+11}_{-5}	56.5±0.5	50.6±1.7	1928±2	1898±9	2152	1999	6040	1372±4	1829±9	1590±5	1488	52.0
207	5080	204±7	56.9±0.2	51.0±1.7	1929±1	1901±8	2151	2002	5950	1368	1854	1596	1493	52.0
199	5040	206	54.1±0	50.9±0.9	1916±1	1900±5	2061±1	1956	4190	1341	1638±19	1524±1	1465	----
195	5060	294	55.5±0	51.2±1.0	1923±1	1902±5	2061	1958±1	4690	1368±1	1652±4	1553±4	1486	----
196	5040	300	57.2±0	51.5±1.1	1931±1	1903±6	2101	1974±1	4930	1372	1753±28	1585±2	1507	----
198	5010	304±2	59.5±0	51.3±1.3	1941±1	1902±7	2159±2	2001±2	6500	1369	1879±4	1610±3	1497±1	----
197	5010	305	58.5±0	51.7±1.3	1937±2	1904±7	2131	1987	5650	1371	1867±17	1603±2	1506±1	----
338	4990	150	71.4±0.1	68.1±0.6	1890±0	1979±2	2161	2052	5320	1374±1	1608±3	1515±1	1468±1	68.9

[a]Indeterminate.

[b]F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c]S indicates very steady with essentially no oscillations; So, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d]Position of valve in line connecting expansion tank to two-phase loop, O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Boiler computed values: Test fluid: Pressure drop, ΔP_t, psi	Boiler computed values: Test fluid: Inlet subcooling, ΔT_{sc}, ^oF	Boiler computed values: Heating fluid heat-transfer rate, Q_s, Btu/hr	Boiler computed values: Length, in.: Effective, l_e	Boiler computed values: Length, in.: Critical, l_{cr}	Boiler computed values: Heat transfer coefficient, Btu/(hr)(ft^2)(^{o}F): Average overall, U_a	Boiler computed values: Heat transfer coefficient, Btu/(hr)(ft^2)(^{o}F): Effective, U_e	Boiler computed values: Quality -: Outlet, X_o	Boiler computed values: Quality -: Critical, X_{cr}	Remarks: Test fluid inlet phase condition (b)	Remarks: Steadiness of flow rate, pressure, and temperature (c)	Remarks: Position of valve (d)	Remarks: Type of run (e)	Remarks: Type of change (f)
8.2	0	221×10^3	--------	--------	3240	--------	0.44	---------	F	SO	O	U	O
8.8		222	--------	--------	3310	--------	.44	---------		S		U	O
7.8		221	--------	--------	3180	--------	.43	---------				U	O
7.8		225	--------	--------	3280	--------	.44	---------				DR	T
7.8		221	--------	--------	3200	--------	.41	---------				DR	T
7.7		218	--------	--------	3130	--------	.39	---------		O			
7.5		$(205\pm15)\times10^3$	--------	43.5 - 45	2840±300	2900±280	.35±0.03	0.36±0.02	TF	F			
6.2	26	155±5	25.5 - 28	--------	1570±70	2690±170	.24±0.01	---------	L	F			
5.8	96	139±9	16.5 - 36	--------	1150±80	3100±400	.20±0.02	---------	L	F		U	O
8.2	0	204	--------	--------	3290	--------	.34	---------	F	S		U	O
7.3	0	180	--------	--------	3370	--------	.30	---------	F	O		U	O
6.1	71	144±8	27	--------	1260±90	2900	.22±0.01	---------	L	F		AR	T
2.6	246	139	17	30.5-32.5	1070	3550±30	.91	.57±0.04		O		U	O
2.7	192	155	18.5	40	1365	3440	.93	.71		O			
4.1	75	197	22.5	46.5	1890	3340	.92	.92		S			
3.7	0	174	--------	24	2030	3070±70	.81	.57±0.02	F	OF	C		
3.6		186	--------	30	2470	2940	.83	.56	TF	F	O		
4.2		187	--------	(a)	2460	(a)	.83	(a)		F	C		
4.2		187	--------	29	2720	3370	.80	.54		OF	O		
4.2		183	--------	32	2700	3060	.78	.53		OF	C		
3.4		171	--------	--------	2930	--------	.70	---------	F	O	O		
3.3		155	--------	--------	3250	--------	.60	---------	F	O	O		
6.7		237	--------	26 - 27	2410	3310±190	.74	.50±0.03	TF	F	O		
6.4		237	--------	--------	3030	--------	.74	---------	TF	OF	C		
4.6		182	--------	--------	3100	--------	.56	---------	F	O	O		
6.5		243±5	--------	38	2830±100	3110±120	.74±0.02	.62±0.01	TF	OF	O		
6.4		245	--------	27.5 - 28	2720	3380±100	.75	.48±0.01	TF	F	C		
5.2		203	--------	--------	3090	--------	.62	---------	F	SO	O		
5.9		232	--------	--------	2980	--------	.71	---------	F	SO			
5.9		235	--------	--------	3070	--------	.72	---------	TF	OF			
3.2		158	--------	--------	3330	--------	.48	---------	F	SO			
4.3		152	--------	--------	3400	--------	.32	---------		S			
5.7		191	--------	--------	3450	--------	.40	---------		S			
8.2		246	--------	--------	3360	--------	.51	---------		SO			
6.8		217	--------	--------	3400	--------	.44	---------		SO			
3.3	102	161	17.5	--------	1800	3510	.65	---------	L	S			

[e]U indicated all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exit pressure changed; T, preheater exit temperature changed.

TABLE I. - Continued. DATA

(a) Concluded. U. S.

Run	Boiler measurements								Condenser measurements					
	Flow rate, lbm/hr		Pressure, psia		Temperature, °F				Coolant		Shell temperature, °F		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, lbm/hr	Inlet temperature, $T_{c,f,I}$, °F	At 6-in. station, $T_{c,s}$	At 12-in. station, $T_{c,s}$	Temperature, $T_{c,II}$, °F	Pressure, $P_{c,II}$, psia
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
337	5150	150	71.9±0.2	68.4±0.6	1889±1	1980±2	2175±1	2063±1	5270	1358	1624±2	1511	1456±1	69.0
339	5020	152	71.2±0.1	68.0±0.7	1893±1	1978±3	2143±1	2044	5260	1366	1587±3	1500±1	1455	68.4
336	5080	195±3	72.5±0.2	68.4±1.8	1996±2	1980±7	2176	2048±1	6240	1371±1	1641±8	1533	1473	----
334	5090	195±7	72.1±0.1	68.5±1.7	1995±1	1980±7	2151	2042±1	5590	1363	1627±2	1516±2	1461	----
335	5100	198	71.4±0.1	68.6±0.4	1943±1	1980±2	2151	2053±1	4240	1345	1654±24	1513	1462	----
332	5100	200±2	72.1±0.1	69.2±1.0	1994±0	1983±4	2135±1	2032	5970	1359	1580±4	1496	1448	----
333	5090	202±4	71.7±0.1	69.0±0.9	1993±1	1982±4	2136	2033	5000	1360	1646±7	1514±1	1462	----
331	5010	293±2	72.1±0.1	69.4±1.2	1995±2	1983±5	2109	2017	5860	1373	1599±7	1509	1455±1	----
329	5010	295	72.7±0.1	68.5±1.4	1997±1	1980±6	2146	2029±1	5940	1364±1	1665	1537	1468±3	----
330	5090	296±3	69.9±0.1	67.5±2.7	1985±1	1976±11	2008	1979	2980	1290±1	1469±1	1409±1	1375±2	----
328	5040	297	72.3±0.1	68.7±0.7	1995±1	1981±3	2134	2026±1	5700	1364	1661±10	1528±1	1468	----
327	5050	297	66.0±0.2	61.3±1.4	1969±1	1951±6	2121	2005±1	5630	1366	1671±11	1550±2	1473±1	----

[a]Indeterminate.

[b]F indicates two phase; TF, transition from two phase to liquid phase; L, liquid phase.

[c]S indicates very steady with essentially no oscillations; SO, between S and O; O, relatively small-amplitude regular oscillations; OF, between O and F; F, large amplitude oscillations which are not necessarily regular.

[d]Position of valve in line connecting expansion tank to two-phase loop. O indicates open; C, closed.

FOR TWO-PHASE RUNS

customary units

Test fluid		Boiler computed values							Remarks				
		Heating fluid heat-transfer rate, Q_s, Btu/hr	Length, in.		Heat transfer coefficient, Btu/(hr)(ft^2)(^oF)		Quality -		Test fluid inlet phase condition	Steadiness of flow rate, pressure, and temperature	Position of valve	Type of run	Type of change
Pressure drop, ΔP_t, psi	Inlet subcooling, ΔT_{sc}, ^oF		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}	(b)	(c)	(d)	(e)	(f)
3.5	105	177×10^3	17	----	1870	3450	0.72	----	L	S	O	U	O
3.2	98	146	13	----	1760	3480	.58	----	L	S			
4.1	0	192	--	----	3200	----	.62	----	F	O			
3.6	0	170	--	----	3350	----	.55	----	TF	OF			
2.8	49	141	20	----	1925	3600	.44	----	L	S			
2.9	0	151	--	----	3290	----	.47	----	TF	OF			
2.7		152	--	----	3300	----	.47	----	TF	OF			
2.7		126	--	----	3580	----	.27	----	F	S			
4.2		168	--	----	3550	----	.36	----					
2.4		36	--	----	(a)	----	.08	----					
3.6		154	--	----	3530	----	.33	----					
4.7		171	--	----	3500	----	.36	----					

[e]U indicated all variables being held constant; BR, one variable continuously changed before run; DR, one variable continuously changed during run; AR, one variable continuously changed after run; BS, stepchange of one variable made before run; AS, stepchange of one variable made after run.

[f]O indicates no variables being changed; W, test-fluid flow rate changed; P, test-fluid exist pressure changed; T, preheater exit temperature changed.

(b) SI

Run	Boiler measurements								Condenser measurements					
	Flow rate, g/sec		Pressure, kN/m^2 abs		Temperature, K				Coolant		Shell temperature, K		Outlet	
			Test fluid		Test fluid		Heating fluid							
	Heating fluid, W_s	Test fluid, W_t	Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$	Flow rate, W_c, g/sec	Inlet temperature, $T_{c,f,I}$, K	At 15.2-cm station, $T_{c,s}$	At 30.5-cm station, $T_{c,s}$	Temperature, $T_{c,II}$, K	Pressure, $P_{c,II}$, kN/m^2 abs
85	624	9.5	196±0	177±3	1166±1	1220±2	1322	1279	182	902	1140	1052±2	1042	189
82	629	10.8±0.5	199±0	177±3	1182±1	1220±2	1329	1281	180	890	1204±13	1064±1	1051	187
115	625	11.1±1.3	202±2	177±8	1203±3	1220±6	1325	1280	437	1006	1124±4	1081	1060	187
83	627	11.8±0.3	203±1	178±3	1195±1	1220±2	1331	1280	179	895	1182±28	1085±1	1072	190
84	625	12.5±0.1	203±1	178±3	1200±0	1220±2	1336	1281	176	902	1214±5	1103±2	1086±2	190
74	627	12.5±0.3	201±0	177±2	1199±1	1219±2	1325	1270	292	803	998±2	939	921	188
113	627	12.7±1.4	199±3	177±7	1234±2	1220±5	1308	1258±3	475	979	1105±10	1057±6	1035±3	186
112	627	13.1±1.1	200±2	178±7	1235±1	1220±5	1307	1256	477	979	1108	1060±2	1038±1	188
114	635	13.1±1.0	202±1	179±8	1236±1	1221±6	1313	1260	435	1001	1168±22	1192	1067	191
50	624	14.4±0.8	209±3	176±7	1241±2	1219±5	1348	1287	747	1020	1195±14	1098±1	1064	186
49	622	15.0±0.5	211±5	173±6	1242±3	1218±3	1347	1286	752	1001	1191±19	1079±1	1047	186
73	629	15.6±1.4	204±2	173±6	1238±2	1217±4	1327	1266	420	955	1200	1070±1	1040±3	185
46	627	15.7±1.3	217±1	177±8	1245±1	1219±6	1347	1285	766	1004	1187±23	1084	1049	186
72	626	15.9±1.8	204±2	174±6	1238±2	1217±4	1327	1266	423	964	1204±8	1076±2	1049±1	185
44	627	17.3±1.6	215±3	177±8	1244±2	1219±6	1347	1280±2	733	1013	1214	1107±2	1064	188
111	620	17.6±1.6	225±3	180±8	1250±2	1222±6	1358	1287	566	1004	1216±2	1117±7	1075	189
108	620	17.9±1.4	224±4	181±7	1249±2	1222±4	1354	1285	960	1015	1179±16	1093±7	1055±2	191
71	624	17.9±1.3	208±2	175±7	1240±1	1219±5	1325	1264	363	971	1214±1	1104	1073	185
107	619	18.0±1.5	219±4	183±7	1247±2	1224±4	1347	1280	976	1116	1163±39	1093±5	1055±1	193
106	626	18.2±0.3	206±2	181±6	1239±1	1222±3	1315	1260	968	1015	1113±4	1068	1045	190
110	627	18.4±1.3	224±3	182±8	1249±2	1223±6	1353	1283	533	1003	1219	1118±7	1076	190
109	616	18.5±1	217±3	181±1	1245±2	1223±2	1359	1291	825	1012±1	1211±5	1116±17	1059	192
33	629	18.8±1.6	222±0	179±5	1247±0	1222±3	1346	1278	725	1015	1218±1	1115±3	1067	188
21	629	$19.7^{+4.4}_{-1.6}$	210±4	177±16	1241±2	1220±10	1330	1271	452	994	1218	1105±2	1070±1	182
70	631	21.1±0.4	209±2	175±6	1240±1	1219±4	1326	1263	363	979	1215	1116±2	1083±2	186
6	624	$22.2^{+0.5}_{-1.0}$	219±0	183±0	1231±1	1224±0	1349	1289	802	1034	1206±2	1118±2	1071	195
5	626	22.2±1.4	217±0	182±0	1224±1	1223±1	1346	1288	805	1023	1167±9	1103±13	1061	193
41	630	22.2±1.0	224±2	178±6	1249±1	1221±4	1346	1279	785	1015	1217	1112	1064	188
32	626	22.3±1.4	222±0	179±5	1248±0	1222±3	1345	1277	731	1013	1217±1	1114	1066	191
62	621	23.3±1.9	252±5	179±5	1265±3	1222±3	1414	1331±1	750	1013	1218	1120±3	1078±1	188
9	696	23.5±0.3	217±0	179±0	1191±1	1222±0	1345	1287	403±50	968±1	1221	1107	1074	190
60	621	23.8±1.5	253±3	180±4	1265±2	1222±3	1403±9	1317	757	1013	1219	1129±9	1078±1	190
61	621	23.8±2.4	252±6	179±5	1264±3	1221±4	1407	1325±3	773	1012	1216±1	1126±2	1077±3	190
24	630	$24.2^{+5.4}_{-7.6}$	202±5	164±24	1203±1	1210±18	1345	1308±2	731	927	1038±10	982±2	961±2	179
69	629	24.4±0.4	214±2	175±4	1244±1	1219±3	1324	1263	369	988	1213±1	1123	1091±1	186
68	745	24.4±0.4	205±1	175±5	1238±1	1218±3	1301	1256	371	992	1213±1	1109	1078	186

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K	heat-transfer rate, Q_s, kW	Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
19	67	33.4	0.571	0.825	6.4	19.8	0.90	0.55
21	52	37.5	.597	0.965 - 0.990	7.5	20.0±0.1	.88	.75±0.04
24	33	31.7	(a)	.534 - 0.660	7.1	(a)	.74	(a)
25	42	41.0	.571	1.09	8.7	18.7	.89	.79
25	36	43.1	.571	1.09	9.3	18.5	.89	.77
24	37	42.8	.622	-----------	10.3	19.5	.88	---------
22	0	36.5±2.3	-----	-----------	14.7±1.5	--------	.75±0.06	---------
22		36.5±0.9	-----	-----------	15.4±0.7	--------	.73±0.02	---------
22		40.7±1.2	-----	-----------	15.9±0.8	--------	.81±0.03	---------
33		45.1	-----	.750	11.1	15.1	.82	.63
38		42.8	-----	.750	10.3	15.5	.74	.59
31		44.3±3.5	-----	1.07	14.4±1.8	15.9±2.5	.74±0.06	.67±0.07
40		48.1	-----	.889	13.5	16.6	.80	.74
30		45.5±2.6	-----	.990	14.9±1.4	16.3±1.5	.75±0.04	.64±0.05
39		50.4	-----	-----------	13.5	--------	.76	---------
45		52.1±1.2	-----	.838	13.4±0.4	15.4±0.6	.77±0.02	.55±0.02
43		51.6±3.5	-----	.826 - 0.940	13.8±1.5	16.4±2.7	.76±0.05	.59±0.04
33		44.5±1.8	-----	-----------	15.9±1.0	--------	.65±0.03	---------
37		49.5±1.2	-----	-----------	14.1±0.5	--------	.72±0.02	---------
25		41.3	-----	-----------	17.2	--------	.60	---------
42		54.0±2.3	-----	1.18	15.1±1.1	15.0±0.9	.76±0.04	.77±0.04
36		51.6	.571	-----------	13.3±0.3	19.7	.73	---------
42		51.6±1.8	-----	-----------	15.3±0.8	--------	.72±0.02	---------
33		44.5±2.3	-----	-----------	14.4±1.0	--------	.60±0.04	---------
34		48.1	-----	-----------	17.8	--------	.60	---------
36	15	46.3	.597	-----------	11.7	19.5	.54	---------
35	16	44.5	.660	-----------	10.6	19.3	.52	---------
46	0	54.0±0.6	-----	-----------	16.1±0.3	--------	.63±0.01	---------
43	0	51.9±0.9	-----	-----------	15.7±0.2	--------	.61±0.01	---------
72	0	60.4±1.5	-----	.711	10.1±0.4	15.0±1.0	.68±0.02	.56±0.04
38	54	46.6	.571	-----------	8.9	19.3	.50	---------
73	0	64.2	-----	.736 - 0.787	12.4	15.8±0.6	.71	.50
72	0	60.1±3.5	-----	.660 - 0.736	10.6±0.9	15.4±0.2	.67±0.04	.49±0.02
37	33	26.9±2.1	0.635 - 0.699	-----------	4.7±0.4	10.6±0.6	.28±0.02	---------
39	0	46.9	------------	-----------	17.6	--------	.50	---------
30	0	39.0	------------	-----------	18.1	--------	.42	---------

TABLE I. - Continued. DATA

(b) Continued. S. I.

Run	Boiler measurements: Flow rate, g/sec: Heating fluid, W_s	Flow rate: Test fluid, W_t	Pressure, kN/m^2 abs: Test fluid: Inlet, $P_{t,I}$	Pressure: Test fluid: Outlet, $P_{t,II}$	Temperature, K: Test fluid: Inlet, $T_{t,I}$	Temperature: Test fluid: Outlet, $T_{t,II}$	Temperature: Heating fluid: Inlet, $T_{s,I}$	Temperature: Heating fluid: Outlet, $T_{s,II}$	Condenser measurements: Coolant: Flow rate, W_c, g/sec	Coolant: Inlet temperature, $T_{c,f,I}$, K	Shell temperature, K: At 15.2-cm station, $T_{c,s}$	Shell temperature: At 30.5-cm station, $T_{c,s}$	Outlet: Temperature, $T_{c,II}$, K	Outlet: Pressure, $P_{c,II}$, $\frac{kN}{m^2 abs}$
59	624	24.6±1.6	251±5	180±7	1264±2	1222±4	1399	1311	752	1012	1222	1126±3	1080±2	189
58	621	24.7±1.8	249±3	179±8	1262±2	1221±6	1389	1314±8	755	1011	1219±1	1123±4	1078	189
104	640	24.7±1.4	260±6	184±6	1268±3	1224±4	1412	1330	1165	1022	1224	1113	1064±1	195
8	687	24.7±10.6	235±8	179±25	1254±1	1221±16	1388	1333	369±23	967	1219±6	1107	1181±3	194
63	624	24.8±0.6	241±2	181±10	1258±1	1222±7	1380	1297	751	1010	1222	1121	1076±2	190
66	635	24.8±0.4	199±1	176±5	1235±1	1219±4	1296	1251	550	991	1109±4	1068±2	1040	185
103	636	24.8±1.3	255±3	183±8	1266±2	1224±5	1400	1316	1112	1022	1219±3	1112±4	1068±3	195
105	636	24.8±2.3	260±6	185±7	1268±3	1225±5	1425	1342	1159	1022	1221±1	1115	1065	193
25	630	$25.0^{+4.5}_{-5.5}$	203±5	171±25	1207±1	1215±18	1344	1304±3	716	965	1053±1	1019±3	997±3	179
102	615	25.2±1.3	250±3	184±8	1263±2	1224±5	1393	1307	1130	1021	1222±1	1115±2	1067	193
78	625	25.6±0.6	207±2	176±3	1208±1	1219±2	1326	1272	396	935	1095±2	1051	1021	186
65	635	25.6±0.4	216±2	178±6	1245±1	1220±4	1332	1270	768	1013	1217±2	1106	1059	189
56	625	25.7±1.3	236±3	179±6	1256±1	1221±4	1367	1292	752	1013	1219	1118±3	1074	188
57	626	25.7±0.8	244±2	179±6	1260±2	1222±3	1384	1301	755	1014	1220	1123±1	1077±1	188
19	634	25.7±0.5	219±0	180±5	1246±0	1222±3	1333	1270	629	1009	1220	1109	1069±2	193
52	630	25.8±0.6	233±3	180±7	1254±2	1222±4	1357	1285	753	1013	1222±4	1119	1067	190
51	631	26.2±0.8	228±3	179±5	1251±2	1221±4	1348	1278	784	1012	1219	1111	1065	188
101	614	26.3±0.4	249±2	186±8	1263±2	1226±6	1385	1302	1131	1023	1221	1114	1065	195
39	625	26.3±1.1	226±1	178±6	1250±1	1221±4	1347	1276	755	1014	1219	1118	1068	190
55	625	26.5±1.1	235±3	179±8	1255±2	1221±6	1363	1289	752	1013	1219	1118±2	1076	190
31	629	27.8±0.6	228±6	180±6	1251±0	1222±3	1346	1278	738	1014	1218	1118±2	1068	191
38	624	28.5±1.1	228±3	178±6	1251±2	1221±4	1345	1278	753	1014	1219	1120±1	1069	188
354	629	29.6	254±2	200±6	1264±3	1235±3	1363	1289	707	1017	1234±1	1118	1078	215
17	633	29.6±0.4	226±0	180±5	1250±0	1222±3	1336	1273	622	1013	1219±2	1118	1073	192
30	627	31.1±0.6	230±0	180±6	1253±0	1222±3	1347	1277	737	1013	1220	1121±1	1069	192
15	625	33.2	228±0	180±5	1251±0	1222±3	1338	1274	600	1011	1218	1124	1075	191
37	627	34.4±0.4	235±1	184±6	1255±1	1224±4	1347	1280	752	1015	1219±1	1119	1069	193
28	627	36.0±0.3	233±0	182±6	1254±0	1223±4	1345	1277	725	1012	1219	1117	1071	193
23	630	$36.3^{+3.8}_{-5.7}$	223±4	184±23	1249±2	1224±16	1347	1283	756	1017	1217	1111±5	1067±2	190
96	616	37.0±0.5	284±3	186±9	1281±1	1226±6	1423	1323	990	1018	1223	1143±5	1080±2	195
100	609	37.2±1.0	303±3	185±9	1290±1	1225±6	1450	1343	1128	1021	1224	1136±2	1081	193
98	615	37.3±0.5	296±2	187±8	1286±1	1226±6	1440	1335	1107	1018	1224	1133±4	1077±2	195
90	621	37.3	238±1	184±6	1257±1	1224±4	1346	1279	747	1017	1221	1120±3	1071	192
94	612	37.5±0.3	271±2	184±8	1274±1	1224±6	1406	1313	940	1020	1223	1145±2	1081±2	193
95	615	37.5±0.3	278±2	187±8	1278±1	1226±6	1413	1316	968	1021±1	1225±1	1141±2	1083	195
93	619	37.5±0.3	264±3	186±6	1270±1	1224±4	1389	1301	911	1019±1	1223	1133±3	1077	193

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid heat-transfer rate, Q_s, kW	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality -	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
71	0	64.0±1.8	------------	0.813	12.9±0.5	14.8±0.3	0.68±0.02	0.45±0.01
70	0	63.6	------------	1.07	13.8	14.7	.68	.62
76	0	66.0±1.2	------------	0.762 - 0.800	11.8±0.3	15.6±0.3	.70±0.02	.54±0.01
57	1	48.1±6.2	(a)	(a)	8.6±1.1	(a)	.51±0.07	(a)
61	0	62.7	------------	------------	14.7	--------	.66	---------
23		35.5	------------	------------	18.8	--------	.37	---------
72		67.5±0.9	------------	1.02	13.7±0.3	15.2±0.4	.72±0.01	.65±0.01
75		64.5±2.6	------------	.660 - 0.712	10.2±0.6	15.6±1.2	.68±0.03	.55±0.01
32	29	28.1±4.1	0.597 - 0.635	------------	5.1±0.8	10.4±1.9	.28±0.05	---------
66	0	65.4	------------	1.18	14.2	14.1	.72	.70
31	31	40.2	0.635	------------	10.0	19.6	.40	---------
38	0	50.4	------------	------------	17.9	--------	.51	---------
58		59.2	------------	------------	14.9	--------	.61	---------
66		64.0	------------	1.04 - 1.12	14.6	15.4±0.7	.65	.60±0.03
39		48.4	------------	------------	16.7	--------	.49	---------
53		55.7±0.9	------------	------------	15.8±0.2	--------	.57±0.01	---------
48		53.7	------------	------------	16.4	--------	.54	---------
63		66.0±1.5	------------	------------	15.9±0.6	--------	.66±0.01	---------
48		54.2±1.5	------------	------------	16.7±0.7	--------	.54±0.01	---------
56		57.1±1.2	------------	------------	14.9±0.5	--------	.57±0.01	---------
48		51.9	------------	------------	16.4	--------	.49	---------
50		52.5	------------	------------	16.4	--------	.48	---------
54		54.8±0.6	------------	------------	17.2±0.3	--------	.49	---------
46		49.8	------------	------------	17.5	--------	.44	---------
50		54.8±0.9	------------	------------	18.1±0.5	--------	.47	---------
48		49.8	------------	------------	17.4	--------	.39	---------
52		53.4	------------	------------	17.7	--------	.41	---------
51		53.4	------------	------------	17.8	--------	.39	---------
39	3	51.3±3.8	------------	------------	14.6±1.5	--------	.37±0.03	---------
98	0	80.6	------------	------------	15.2	--------	.56	---------
117	0	87.6	------------	------------	15.0	--------	.63	---------
109		83.8	------------	------------	15.3	--------	.60	---------
54		50.1	------------	------------	16.9	--------	.35	---------
87		70.6	------------	------------	15.5	--------	.50	---------
92		74.5	------------	------------	16.1	--------	.53	---------
78		65.4	------------	------------	15.9	--------	.46	---------

TABLE I. - Continued. DATA

(b) Continued. S.I.

Run	Boiler measurements: Flow rate, g/sec: Heating fluid, W_s	Flow rate, g/sec: Test fluid, W_t	Pressure, kN/m^2 abs: Test fluid: Inlet, $P_{t,I}$	Pressure: Test fluid: Outlet, $P_{t,II}$	Temperature, K: Test fluid: Inlet, $T_{t,I}$	Temperature, K: Test fluid: Outlet, $T_{t,II}$	Temperature, K: Heating fluid: Inlet, $T_{s,I}$	Temperature, K: Heating fluid: Outlet, $T_{s,II}$	Condenser measurements: Coolant: Flow rate, W_c, g/sec	Coolant: Inlet temperature, $T_{c,f,I}$, K	Shell temperature, K: At 15.2-cm station, $T_{c,s}$	Shell temperature, K: At 30.5-cm station, $T_{c,s}$	Outlet: Temperature, $T_{c,II}$, K	Outlet: Pressure, $P_{c,II}$, $\frac{kN}{m^2 abs}$
91	629	37.5	244±1	185±6	1260±1	1224±4	1357	1285	741	1017	1224	1121	1077	193
92	620	37.6±0.4	254±2	184±8	1266±1	1224±6	1375	1292	740	1015	1223	1140±4	1083±1	191
13	629	37.8	234±0	182±6	1255±0	1224±4	1340	1275	614	1012	1219	1129±3	1078	192
12	633	37.8	236±0	181±6	1256±0	1222±4	1344	1277	616	1013	1219	1133±8	1080	191
75	617	38.3±0.1	228±1	180±5	1251±1	1222±3	1326	1268	298	853	1113±10	1034	1001	188
27	631	40.1±0.4	235±0	184±6	1255±0	1224±4	1346	1278	718	1071±57	1220	1122	1071	193
22	631	$42.5^{+3.0}_{-4.7}$	230±2	184±15	1250±2	1224±10	1346	1279	756	1017	1208±8	1119±5	1070	191
35	633	43.1	234±0	181±2	1255±0	1222±1	1346	1290	723	1014	1215±1	1104±5	1062±1	190
26	629	43.7±0.4	239±0	184±6	1257±1	1224±4	1347	1278	740	1015	1221±1	1118±1	1071	193
34	629	47.9	240±0	186±3	1258±0	1226±2	1346	1290	742	1014	1197±11	1099±1	1064	192
146	635	13.2	253±0	234±2	1215±1	1255±1	1365	1308	626	993	1122	1079	1052	250
147	638	13.2	252±0	234±2	1213±1	1255±1	1354	1302	537	1003	1125	1078	1055	247
143	638	13.2	260±0	234±2	1214±1	1255±1	1383	1322	↓	1006	1170±3	1085	1067±3	250
149	644	13.2	249±0	236±2	1210±1	1256±1	1332	1289	↓	1005	1107	1063	1045	246
148	636	13.3	246±0	230±2	1211±1	1252±1	1343	1295±1	↓	1008	1120±2	1077	1056	↓
145	635	13.6	254±0	234±2	1213±1	1255±1	1371	1312	545	1005	1173±11	1097	1067	↓
144	636	13.9	258±0	234±4	1218±0	1255±2	1387	1327	543	1009	1213±21	1101	1071	↓
348	629	18.6±0.3	272±1	244±8	1275±1	1260±4	1361	1301	696	1009	1142±7	1084±2	1057	254
142	631	20.0±1.0	276±3	234±9	1277±2	1255±4	1403	1330±4	621	1008	1251±2	1123±5	1076±3	248
141	629	20.3±1.4	294±3	234±8	1275±2	1255±5	1396	1319	626	1008	1251	1129±2	1079	248
140	630	20.7±1.0	272±2	236±10	1274±2	1255±6	1388	1314	615	1008	1249±3	1125±2	1078	247
136	638	20.7±0.4	262±0	236±10	1270±2	1256±5	1360	1299	621	1002	1169±23	1093	1060	248
137	639	20.7±0.4	265±0	236±9	1271±1	1256±5	1368	1303	631	1009	1210±3	1107	1068	248
134	629	20.8±0.3	259±0	237±7	1268±1	1257±3	1346	1292	627	997	1121±4	1074	1048	248
139	635	20.9±0.5	270±0	236±9	1273±2	1255±6	1381	1313±5	615	1007	1250±1	1119	1074	246
135	640	21.0±0.3	259±0	234±8	1268±2	1255±4	1355	1295	622	1002	1149±5	1088±2	1058	244
138	631	21.3±0.4	268±0	238±8	1272±2	1256±5	1374	1305±1	622	1018	1249±3	1125±2	1084±1	249
132	625	24.7±1.1	293±8	236±9	1284±4	1256±5	1435	1347±2	1038	1018	1247±1	1119±2	1065±2	↓
350	631	24.7±0.1	271±1	235±8	1274±1	1255±4	1362	1299	697	1014	1160	1106	1068	↓
128	630	25.0±0.4	286±1	238±8	1281±1	1257±4	1402	1321	1026	1016	1219±2	1110±5	1064	↓
127	634	25.0±0.4	284±2	239±8	1281±1	1257±4	1394	1314	1035	1017	1187±18	1103	1062	↓
131	626	25.2±1.0	290±3	236±8	1283±2	1256±4	1423	1335±1	1030	1017	1250±1	1120±2	1067±3	↓
130	625	25.3±0.8	289±2	239±8	1283±1	1258±4	1418	1331±2	1032	1017	1252	1117±1	1065±2	↓
133	636	25.4±0.3	262±0	235±7	1270±0	1255±4	1353	1293	1040	1011	1113±4	1070±4	1043±2	↓
129	626	25.6±0.3	289±2	239±8	1283±1	1257±4	1410	1326	1043	1017	1246±6	1116	1064	↓
126	631	25.6±0.5	278±1	238±9	1278±1	1257±5	1380	1309	1030	1017	1178±16	1100±1	1058	↓

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid heat-transfer rate, Q_s, kW	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality -	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
59	0	55.1	-----	-----	17.1	--------	0.39	---------
70		59.5	-----	-----	16.3	--------	.42	---------
52		49.8	-----	-----	17.6	--------	.35	---------
55		52.2	-----	-----	18.0	--------	.36	---------
48		44.0±0.9	-----	-----	18.7±1.4	--------	.31±0.01	---------
52		52.2	-----	-----	17.1	--------	.34	---------
46	2	53.3±3.2	-----	-----	16.6±1.3	--------	.33±0.02	---------
53	0	44.0	0.534	-----	12.6	19.1	.27	---------
56	0	51.9±1.2	-----	-----	17.7±0.6	--------	.31±0.01	---------
54	0	42.5	.597	-----	12.9	17.6	.23	---------
19	51	44.8	.571	-----	9.2	19.0	.87	---------
18	52	41.0	.508	-----	9.1	19.6	.80	---------
26	54	47.8	.610	1.02	8.5	19.5	.93	0.77
13	53	32.8	.457	-----	8.8	20.2	.63	---------
16	51	36.9	.534	-----	8.7	19.3	.71	---------
20	53	46.3	.547	-----	9.0	18.9	.88	---------
24	50	49.2	.660	1.03	8.6	19.6	.92	.79
28	0	45.5	-----	-----	16.6	--------	.64	---------
42		57.1±4.1	-----	.787	12.6±1.3	15.9±2	.76±0.05	.56±0.06
39		59.2	-----	-----	14.3	--------	.77	---------
36		58.3	-----	-----	15.3	--------	.75	---------
26		47.2	-----	-----	15.7	--------	.60	---------
29		51.0	-----	-----	16.3	--------	.65	---------
22		42.2±1.2	-----	-----	17.2±0.8	--------	.53±0.02	---------
34		55.7	-----	-----	15.8	--------	.70	---------
25		45.5	-----	-----	16.0	--------	.57	---------
30		53.3	-----	-----	15.9	--------	.66	---------
57		67.8±1.5	-----	.762	12.2±0.4	15.8±0.6	.72±0.02	.54±0.02
36		49.5	-----	-----	18.3	--------	.53	---------
48		65.3	-----	-----	16.5	--------	.69	---------
45		59.8	-----	-----	15.7	--------	.63	---------
54		68.6±1.5	-----	.890	14.0±0.5	15.4±0.6	.72±0.02	.53±0.02
50		68.9±2.3	-----	.940	14.8±0.9	15.9±1.0	.72±0.03	.55±0.03
27		48.1	-----	-----	18.9	--------	.50	---------
50		68.3±1.5	-----	-----	15.9±0.6	--------	.70±0.02	---------
40		56.0	-----	-----	16.9	--------	.58	---------

TABLE I. - Continued. DATA

(b) Continued. SI

Run	Boiler measurements								Condenser measurements					
	Flow rate, g/sec		Pressure, kN/m^2 abs		Temperature, K				Coolant		Shell temperature, K			
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, g/sec	Inlet temperature, $T_{c,f,I}$, K	At 15.2-cm station, $T_{c,s}$	At 30.5-cm station, $T_{c,s}$	Temperature, $T_{c,II}$, K	Pressure, $P_{c,II}$, $\frac{kN}{m^2}$ abs
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
347	636	25.7	278±1	245±6	1277±1	1261±3	1373±10	1301	712	1013	1170±1	1101	1064	256
346	644	26.7±0.1	278±1	245±8	1277±1	1260±4	1362	1299	714	1014	1175±3	1102±1	1066	255
364	625	30.9	296±1	239±2	1265±1	1257±1	1422	1338	780	1017	1254	1133±2	1081	250
355	622	31.0	275±1	236±6	1276±1	1256±3	1362±1	1298	704	1014	1204±14	1112	1070	249
359	624	31.1	290±1	235±3	1256±1	1255±2	1410	1330	685	1014	1253±1	1134	1083	249
363	626	31.1	293±1	241±1	1245±0	1258±1	1414	1334	784	1016	1255	1180±4	1075	253
353	629	31.2	276±1	236±6	1277±0	1256±3	1362	1298	711	1015	1207±12	1113±3	1070	248
365	627	31.5	297±1	239±3	1284±1	1257±2	1420	1339	783	1017	1254	1135	1079	251
351	629	31.5	275±1	236±6	1276±1	1256±3	1363	1299	699	1014	1205±11	1112	1070	249
360	627	32.6±4.5	282±6	236±28	1258±1	1255±15	1411	1350±1	727	1010	1165±32	1095±2	1061±2	240
362	624	34.4±2.9	268±4	234±23	1230±1	1254±12	1384	1337	368	992	1170±2	1093±3	1069	240
124	634	37.2±0.3	342±3	241±10	1307±2	1258±6	1471	1363	1043	1016	1253	1149±5	1084	249
349	631	37.4	285±1	246±6	1281±1	1261±3	1362	1302	722	1015	1186	1108±2	1070	255
119	635	37.5	295±1	239±9	1286±1	1257±5	1398	1319	913	1015	1252	1127	1070	248
118	631	37.8	279±2	234±8	1278±1	1255±4	1369	1301	702	1009	1235±1	1118	1070±1	242
345	641	37.8	286±1	246±6	1281±1	1261±3	1373±11	1302	711	1015	1185±4	1111	1069	255
117	631	38.0	269±2	236±6	1273±1	1256±3	1353	1294	706	1009	1156±9	1101±1	1063	242
122	630	38.3±0.5	334±3	241±10	1303±1	1259±6	1457	1351	1039	1014	1254	1143±5	1080±1	249
121	635	38.6±0.6	324±2	243±10	1299±1	1259±6	1441	1346±2	980	1015	1255	1142±2	1079	
120	630	38.7±1.1	306±1	239±9	1291±1	1257±5	1424	1332	873	1013	1255	1138±1	1077	
123	631	40.1±1.5	341±1	241±10	1307±1	1258±6	1470	1362	1039	1009	1253	1139±1	1076	
116	626	44.1	262±2	234±5	1270±1	1255±3	1327	1282	701	1003	1113	1073	1043	245
193	643	10.8	302±0	288±3	1207±1	1283±2	1363	1320	314	999	1130±2	1091	1074	300
184	748	12.3	302±0	285±4	1219±1	1281±2	1382	1335	510	1013	1148±5	1097	1072	298
181	741	12.5	306±0	288±3	1220±1	1282±2	1383	1334	511	997	1125±1	1083	1058	298
185	699	12.6	300±0	283±3	1221±1	1280±2	1383	1331	511	1010	1145	1095±1	1069	298
178	669	12.8	306±0	287±2	1225±1	1282±1	1382	1333	515	1012	1147±4	1093	1069	299
179	707	13.0	307±0	291±3	1229±1	1284±1	1383	1334	514	1012	1142±4	1097±1	1071	304
176	638	13.2	306±0	287±2	1229±1	1282±1	1384	1331	517	1002	1132±1	1085	1061	299
175	641	13.2	309±0	292±3	1226±1	1284±1	1389	1334	515	1002	1137	1087	1063	304
186	703	13.2	302±0	286±1	1223±1	1282±1	1389	1341	510	1009	1132	1089	1064	298
182	751	13.2	300±0	284±3	1236±1	1281±1	1383	1339	511	1000	1131±7	1077	1055	298
172	633	13.3	308±0	290±1	1250±1	1284±1	1400	1344	516	999	1137±3	1084	1061	301
171	640	13.5	311±0	292±2	1234±1	1284±1	1406	1348	505	999	1136±3	1089±1	1063	303
183	743	13.5	301±0	284±3	1230±1	1281±1	1383	1340	514	1004	1127	1082	1057±1	298
173	640	13.8	308±0	292±2	1233±1	1284±1	1395	1342	516	1000	1121	1080	1058	302

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Test fluid		Boiler computed values						
		Heating fluid heat-transfer rate, Q_s, kW	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality -	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
32	0	47.5	-----	---------	17.9	--------	0.49	---------
33	0	48.1	-----	---------	18.1	--------	.48	---------
57	21	66.8	0.381	---------	12.4	18.7	.57	---------
39	0	48.4	-----	---------	18.1	--------	.41	---------
54	27	61.0	.368	---------	11.4	17.9	.51	---------
52	40	64.0	.394	---------	11.0	18.4	.53	---------
40	0	49.5	-----	---------	18.8	--------	.42	---------
58	3	65.7	.394	---------	13.6	18.4	.55	---------
39	0	49.0	-----	---------	18.3	--------	.41	---------
46	22	47.8	.585	---------	8.2	15.1	.37	---------
34	43	32.5	.622	---------	5.7	12.0	.23	---------
101	0	88.5	-----	1.09 - 1.14	15.1	15.5±0.4	.64	0.62±0.01
39		46.9	-----	---------	18.6	--------	.33	---------
57		62.5	-----	---------	17.2	--------	.44	---------
45		51.9	-----	---------	17.7	--------	.36	---------
40		46.6	-----	---------	18.3	--------	.33	---------
33		44.8	-----	---------	17.7	--------	.31	---------
92		86.1	-----	---------	16.2	--------	.60	---------
81		78.5	-----	---------	16.4	--------	.54	---------
68		71.2	-----	---------	15.7	--------	.49	---------
101		88.5±1.2	-----	1.12	15.3±0.4	15.3±0.4	.59±0.01	.58±0.01
28		32.5	-----	---------	18.5	--------	.20	---------
14	82	33.4	.432	---------	7.4	18.3	0.79	---------
17	70	44.0	.508	1.14	8.5	19.4	.92	.88
18	72	44.6	.597	---------	8.7	20.3	.91	---------
17	68	43.1	.546	1.18	8.4	19.4	.88	.89
19	68	41.9	.571	---------	8.4	19.5	.84	---------
16	63	43.1	.534	---------	8.8	19.6	.86	---------
19	62	41.9	.521	---------	8.5	19.9	.82	---------
17	66	43.7	.546	---------	8.6	20.2	.85	---------
15	68	41.0	.610	1.17	7.7	19.8	.80	.79
16	53	39.0	.673	1.14	7.9	20.1	.76	.71
18	43	43.4	.635	---------	8.5	20.1	.84	---------
19	60	44.5	.622	---------	7.8	19.2	.85	---------
17	58	38.4	.610	1.14	7.6	19.2	.73	.72
17	60	40.7	.660	---------	7.7	19.5	.75	---------

TABLE I. - Continued. DATA

(b) Continued. SI

Run	Boiler measurements								Condenser measurements					
	Flow rate, g/sec		Pressure, kN/m^2 abs		Temperature, K				Coolant		Shell temperature, K		Outlet	
	Heating fluid, W_s	Test fluid, W_t	Test fluid		Test fluid		Heating fluid		Flow rate, W_c, g/sec	Inlet temperature, $T_{c,f,I}$, K	At 15.2-cm station, $T_{c,s}$	At 30.5-cm station, $T_{c,s}$	Temperature, $T_{c,II}$, K	Pressure, $P_{c,II}$, kN/m^2 abs
			Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
192	641	14.5	304±2	290±2	1243±1	1283±1	1363	1320	312	997±1	1134	1091±1	1075±1	300
287	626	18.0	314±1	296±4	1043±1	1286±2	1399	1341	683	1015	1131±7	1080±1	1055±1	312
191	643	18.3	305±0	287±3	1263±1	1282±2	1361±2	1320	314	989	1134±2	1088±1	1070±1	300
290	644	18.9±0.4	323±1	294±11	1299±1	1286±5	1399	1330	915	1019	1150±5	1094±1	1061	303
288	635	19.1	319±1	294±3	1279±1	1285±2	1399	1338±2	672	1024±1	1172	1108±1	1078	311
286	622	19.5±0.9	322±1	293±9	1299±1	1285±4	1399	1330±1	679	1011	1179±13	1105±3	1069	302
163	649	20.0±0.3	312±1	292±8	1294±1	1284±4	1372	1317	451	998	1156±4	1101±1	1064±8	304
190	638	20.3	308±0	289±6	1292±1	1283±3	1362	1313	318	985	1163±4	1103	1080±1	300
343	645	20.6±0.6	319±2	295±8	1297±1	1286±4	1384	1322±1	693	1010±2	1157±2	1091	1061	---
170	639	20.8±0.6	332±4	293±9	1303±2	1285±4	1440±1	1365±2	667	1010	1272±7	1125±6	1079±1	302
167	636	20.9±0.5	329±3	295±10	1301±1	1286±5	1414	1339±1	677	1012	1247±3	1118±3	1077	300
168	639	20.9±0.5	330±3	295±10	1302±1	1286±5	1420	1343±2	639	1010	1281±1	1129±1	1079±1	304
165	640	20.9±0.3	320±1	293±8	1297±1	1285±4	1388	1325±2	611	1013±1	1180±7	1106	1070±1	305
188	641	20.9±0.5	314±0	290±7	1295±1	1283±3	1383	1323	605	993±1	1141±3	1084±2	1054	300
169	644	21.0±0.6	333±4	293±9	1303±2	1285±4	1430	1354±2	651	1011	1278±1	1134±7	1080±3	304
164	641	21.2	315±1	292±8	1296±1	1284±4	1380	1322±1	555	1005±2	1161	1103	1069±2	303
166	635	21.5±0.5	324±2	294±9	1299±1	1286±4	1401	1332±1	667	1010	1192±2	1111±4	1073±1	305
158	644	24.3±0.8	334±2	293±10	1303±2	1285±5	1424	1344	812	1018±1	1244±25	1130±3	1078	302
159	645	24.7±0.8	339±3	295±10	1305±1	1286±5	1430	1347	811	1015±2	1266±14	1132±2	1080±1	305
342	636	24.8±0.3	322±1	292±8	1298±1	1284±4	1384	1321	774	1015	1149±9	1095	1063	---
161	641	25.0±1.4	346±3	294±10	1308±2	1286±4	1449	1362±1	879	1015	1268±7	1127±3	1077	305
160	644	25.0±1.0	349±2	300±10	1310±1	1288±5	1439	1351±1	816	1027±12	1282	1137	1080	308
162	640	25.1±2.0	346±8	292±10	1308±3	1284±4	1460	1375	875	1017	1215±10	1133±7	1078	302
344	639	25.2±0.3	321±1	292±8	1298±1	1284±4	1383	1321	679	1014	1168±8	1102	1068	---
156	640	25.2±0.5	323±0	292±8	1299±1	1284±4	1395	1327	588	1010±1	1271	1125	1081±1	302
157	640	25.2±0.6	327±4	292±10	1301±2	1284±4	1405	1333	742	1014	1209±43	1115±4	1075	302
155	644	25.2±0.3	321±0	293±8	1298±1	1284±3	1381	1322	590	1007	1177±7	1106±2	1071	302
189	641	25.7	312±0	290±6	1294±1	1284±3	1363	1313	387	973	1156±6	1084	1057	300
187	640	26.0±0.3	318±0	290±6	1295±1	1283±3	1384	1322	605	1000	1151	1094	1064	302
253	629	26.7±0.1	321±1	282±7	1298±0	1280±3	1398	1325	619	988	1256	1113	1062	291
341	640	27.1±0.6	334±1	293±9	1304±1	1285±4	1413	1337±1	929	1018	1193±13	1114±1	1069	306
352	626	31.8	301±1	271±7	1289±1	1274±3	1363	1307	707	1009	1134	1091	1058	282
220	629	38.0	340±1	282±8	1306±1	1280±4	1419	1335±1	541	983	1275	1142±1	1089	293
221	625	38.4	340±1	284±7	1307±1	1280±4	1418	1334	546	984	1277±2	1139	1089	294
219	626	38.4	340±2	286±9	1306±1	1281±4	1418	1333	521	984	1275	1142±3	1091±1	294
224	624	39.0	338±1	280±9	1305±1	1279±4	1418	1331	602	986	1270±2	1135±4	1086	290

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid heat-transfer rate, Q_s, kW	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality -	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
14	47	32.6	0.470	------------	8.7	18.8	0.58	---------
19	252	42.2	.660	------------	4.9	19.3	.54	---------
18	28	33.1	.538	------------	10.7	20.1	.47	---------
29	0	51.6	-----	------------	15.8	--------	.72	---------
26	18	48.7	.432	1.12 - 1.14	12.2	19.0	.67	0.60
29	0	51.0	-----	------------	15.9	--------	.70	---------
20		43.4	-----	------------	17.9	--------	.57	---------
19		38.4	-----	------------	17.3	--------	.50	---------
24		47.2	-----	------------	17.3	--------	.61	---------
39		56.0±2.5	-----	.673 - 0.736	10.8±0.7	17.1±1.1	.71±0.04	.60±0.03
34		58.0	-----	------------	15.8	--------	.74	---------
34		59.5	-----	1.03	14.7	15.7	.76	.68
27		48.1	-----	------------	16.1	--------	.61	---------
23		47.5	-----	------------	17.8	--------	.60	---------
40		59.0±2.5	-----	.635 - 0.762	13.0±0.8	17.2±2.8	.75±0.03	.49±0.04
23		46.9	-----	------------	17.7	--------	.59	---------
30		51.3±0.9	-----	.952	15.0±0.4	16.6±0.3	.64±0.01	.52±0.01
41		65.0	-----	------------	16.4	--------	.71	---------
43		66.2	-----	1.09 - 1.14	16.1	16.9±0.1	.72	.70±0.04
29		49.0	-----	------------	18.7	--------	.53	---------
52		70.3	-----	.762	14.2	17.4	.75	.52
49		70.0	-----	.940 - 1.02	16.4	18.3±0.6	.75	.65±0.01
54		68.0	-----	.762	12.2	16.4	.72	.58
28		48.1	-----	------------	18.1	--------	.51	---------
31		53.0	-----	------------	17.6	--------	.56	---------
35		56.9	-----	------------	17.0	--------	.60	---------
28		47.2	-----	------------	17.8	--------	.50	---------
22		38.7	-----	------------	18.4	--------	.40	---------
28		47.8	-----	------------	17.3	--------	.49	---------
39		56.3	-----	------------	18.1	--------	.56	---------
41		59.5	-----	------------	17.1	--------	.58	---------
30		41.9	-----	------------	18.7	--------	.34	---------
58		66.0	-----	------------	18.9	--------	.46	---------
56		64.8	-----	------------	18.4	--------	.45	---------
55		64.8	-----	------------	18.4	--------	.45	---------
58		66.6	-----	------------	19.0	--------	.45	---------

TABLE I. - Continued. DATA

(b) Continued. SI

Run	Boiler measurements								Condenser measurements					
	Flow rate, g/sec		Pressure, kN/m^2 abs		Temperature, K				Coolant		Shell temperature, K		Outlet	
			Test fluid		Test fluid		Heating fluid							
	Heating fluid, W_s	Test fluid, W_t	Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Flow rate, W_c, g/sec	Inlet temperature, $T_{c,f,I}$, K	At 15.2-cm station, $T_{c,s}$	At 30.5-cm station, $T_{c,s}$	Temperature, $T_{c,II}$, K	Pressure, $P_{c,II}$, $\frac{kN}{m^2 \text{ abs}}$
222	621	39.2	340±1	284±9	1306±1	1280±4	1419	1334	537	984	1274±2	1137	1087	294
250	622	39.4	342±1	282±8	1307±1	1280±4	1419	1335	649	989	1274	1127±3	1075	291
223	627	40.0	337±1	284±9	1305±1	1280±4	1418±1	1335±1	537	986±1	1274±2	1138±2	1086±2	294
225	627	40.0	336±1	282±8	1304±1	1280±4	1419	1334	580	985	1273±1	1134±2	1080	291
226	627	42.1	336±1	282±8	1304±1	1280±4	1418	1336	575	988	1274±2	1138±1	1078	292
227	627	44.0±1.0	336±1	282±8	1304±1	1280±4	1418	1336	601	988	1270	1132	1076	292
228	622	45.2±1.6	333±1	282±8	1303±1	1280±4	1418±1	1337±2	606	988±1	1266±7	1132±6	1077±3	294
229	625	47.0±2.5	316±6	274±21	1282±1	1275±10	1417	1359±1	601	984±2	1158±12	1090±2	1051±2	279
231	627	47.0±2.5	316±6	277±23	1243±0	1276±12	1419	1362±1	593	987	1144±9	1082±2	1050±1	282
340	643	47.0	352±1	295±10	1311±1	1286±5	1413	1337	941	1017	1230±13	1124	1073	306
289	625	47.2	345±1	294±8	1308±1	1286±3	1397	1328	909	1015	1208±2	1113	1068	302
230	625	47.5±2.1	316±6	274±17	1257±1	1275±9	1418	1362	594	985	1149±16	1083±2	1050	279
218	634	11.2±0.5	358±0	340±9	1177±1	1306±4	1411	1360	321	985	1147±7	1093	1073±1	350
217	638	12.7±0.6	360±0	342±10	1208±1	1308±3	1411	1354	322	975±1	1163±12	1095±2	1076±2	351
215	630	16.5	370±0	342±5	1277±1	1307±2	1440	1370±1	512	1005	1223±25	1123±3	1086±1	353
214	633	16.9±0.9	370±3	345±12	1318±2	1309±4	1440±1	1375	747	1010	1135±2	1087±1	1060	355
212	629	17.5±1.5	375±3	350±14	1320±2	1311±6	1435	1365	756	1011	1149	1095	1067	357
213	643	17.6±1.1	377±5	347±16	1321±2	1310±6	1435	1366	748	1012	1145±2	1095	1066	355
210	636	18.1±1.1	375±1	346±14	1320±1	1310±5	1427	1360±1	755	1012	1156	1092±3	1064	357
211	633	18.4±0.6	377±5	347±16	1321±2	1310±6	1427	1359±1	759	1011	1151±5	1097±2	1065	355
209	636	19.0±0.6	368±2	345±11	1318±1	1308±4	1413	1348	743	1012	1142	1091	1061	355
216	630	20.3±0.4	365±2	342±10	1316±1	1308±3	1398	1341	428	993	1161±11	1099	1073±1	347
204	635	25.2±1.3	394±2	347±11	1327±1	1310±4	1473	1387±2	765	1015	1294±4	1137±2	1082±2	359
208	640	25.2±0.4	391±4	347±12	1326±2	1309±5	1451	1367	747	1014	1285±9	1139±1	1084	353
200	633	25.3±0.4	381±0	349±8	1323±1	1310±3	1419	1352	524	1007	1221±7	1126±2	1086±1	359
203	627	25.6±1.1	393±3	348±12	1327±1	1310±5	1461	1374	771	1014	1284±11	1141±2	1085	359
205	635	25.6±1.1	394±8	350±10	1327±3	1311±4	1466	1380	756	1015	1295	1143±1	1084	355
201	627	25.7±0.5	386±0	350±10	1325±1	1311±4	1437±3	1357	571	1009	1290±3	1138±1	1093±2	359
202	631	$25.7^{+1.4}_{-0.6}$	390±3	349±12	1326±1	1310±5	1451	1366	761	1017	1271±5	1138±3	1082	359
207	640	25.7±0.9	392±1	352±12	1327±1	1311±4	1450	1368	750	1017	1285	1142	1085	359
199	635	26.0	373±0	351±6	1320±1	1311±3	1400	1342	528	1000	1165±10	1102	1069	---
195	638	37.0	383±0	353±7	1324±1	1312±3	1400	1343	590	1017	1173±2	1118±2	1081	---
196	635	37.8	395±0	355±8	1328±1	1312±3	1423	1352	621	1017	1229±15	1135±1	1092	---
198	631	38.3±0.3	410±0	354±9	1333±1	1312±4	1455±1	1367±1	819	1016	1299±2	1150±2	1087	---
197	631	38.4	403±0	357±9	1331±1	1313±4	1439	1359	712	1017	1292±9	1146±1	1092	---
338	629	18.9	492±1	470±4	1305±0	1355±1	1456	1395	670	1019	1148±2	1097	1071	475

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid heat-transfer rate, Q_s, K	Length, m		Heat-transfer coefficient, $kW/(m^2)(K)$		Quality	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
56	0	64.8	----------	----------	18.4	--------	0.44	--------
61		65.0	----------	----------	18.8	--------	.44	--------
54		64.8	----------	----------	18.0	--------	.43	--------
54		66.0	----------	----------	18.6	--------	.44	--------
54		64.8	----------	----------	18.1	--------	.41	--------
53		64.0	----------	----------	17.7	--------	.39	--------
52		60.1±4.4	----------	1.10 - 1.14	16.1±1.7	16.4±1.6	.35±0.03	0.36±0.02
43	14	45.5±1.5	0.648 - 0.711	----------	8.9±0.4	15.2±1.0	.24±0.01	--------
40	53	40.7±2.6	.673 - 0.914	----------	6.5±0.5	17.6±2.3	.20±0.02	--------
57	0	59.8	----------	----------	18.7	--------	.34	--------
50	0	52.8	----------	----------	19.1	--------	.30	--------
42	39	42.2±2.3	0.686	----------	7.1±0.5	16.4	.22±0.01	--------
18	137	40.7	.431	0.775 - 0.825	6.1	20.1±0.2	.91	.57±0.04
19	108	45.5	.470	1.02	7.7	19.5	.93	.71
28	42	57.7	.571	1.08	10.7	19.0	.92	.92
26	0	51.0	----------	.610	11.5	17.4±0.4	.81	.57±0.02
25		54.5	----------	.761	14.0	16.7	.83	.56
29		54.8	----------	(a)	13.9	(a)	.83	(a)
29		54.8	----------	.736	15.4	19.1	.80	.54
29		53.6	----------	.813	15.3	17.4	.78	.53
23		50.1	----------	----------	16.6	--------	.70	--------
23		45.5	----------	----------	18.4	--------	.60	--------
46		69.5	----------	.660 - 0.686	13.7	18.8±1.1	.74	.50±0.03
44		69.5	----------	----------	17.2	--------	.74	--------
32		53.3	----------	----------	17.6	--------	.56	--------
45		71.3±1.5	----------	.965	16.0±0.6	17.6±0.7	.74±0.02	.62±0.01
44		71.8	----------	.698 - 0.711	15.4	19.2±0.6	.75	.48±0.01
36		59.5	----------	----------	17.5	--------	.62	--------
41		65.0	----------	----------	16.9	--------	.71	--------
41		68.9	----------	----------	17.4	--------	.72	--------
22		46.3	----------	----------	18.9	--------	.48	--------
30		44.5	----------	----------	19.3	--------	.32	--------
39		56.0	----------	----------	19.5	--------	.40	--------
57		72.1	----------	----------	19.1	--------	.51	--------
47		63.6	----------	----------	19.3	--------	.44	--------
23	57	47.2	.445	----------	10.2	19.9	.65	--------

TABLE I. - Concluded. DATA

(b) Concluded. S. I.

Run	Boiler measurements								Condenser measurements					
	Flow rate, g/sec		Pressure, kN/m^2 abs		Temperature, K				Coolant		Shell temperature, K		Outlet	
			Test fluid		Test fluid		Heating fluid							
	Heating fluid, W_s	Test fluid, W_t	Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$	Flow rate, W_c, g/sec	Inlet temperature, $T_{c,f,I}$, K	At 15.2-cm station, $T_{c,s}$	At 30.5-cm station, $T_{c,s}$	Temperature, $T_{c,II}$, K	Pressure, $P_{c,II}$, $\frac{kN}{m^2 abs}$
337	649	18.9	495±1	471±4	1304±1	1355±1	1464	1401	664	1010	1157±1	1095	1064	476
339	633	19.2	491±1	469±5	1307±1	1354±2	1446	1391	663	1014	1137±2	1089	1064	471
336	640	24.6±0.4	500±1	471±12	1364±1	1355±4	1464	1393	786	1017	1167±4	1107	1074	---
334	641	24.6±0.9	497±1	472±12	1363±1	1355±4	1450	1390	704	1013	1159±1	1097±1	1067	---
335	643	25.0	492±1	473±3	1335±1	1355±1	1450	1396	534	1003	1174±13	1096	1068	---
332	643	25.2±0.3	497±1	477±7	1363±0	1357±2	1441	1384	752	1010	1133±2	1086	1060	---
333	641	25.4±0.5	495±1	476±6	1362±1	1356±2	1442	1385	630	1011	1170±4	1097	1068	---
331	631	36.9±0.3	497±1	478±8	1363±1	1357±3	1427	1376	738	1018	1143±4	1094	1064	---
329	631	37.2	501±1	472±10	1365±1	1355±3	1447	1383	748	1013	1180	1109	1071±2	---
330	641	37.3±0.4	482±1	465±19	1358±1	1353±6	1371	1355	376	972	1071	1038	1019±1	---
328	635	37.4	498±1	474±5	1363±1	1356±2	1441	1381	718	1013	1178±5	1104	1071	---
327	636	37.4	455±1	422±10	1349±1	1339±3	1434	1369	709	1014	1183±6	1116±1	1074	---

[a]Indeterminate.

FOR TWO-PHASE RUNS

units

Boiler computed values								
Test fluid		Heating fluid heat-transfer rate, Q_s, kW	Length, m		Heat-transfer coefficient, kW/(m^2)(K)		Quality	
Pressure drop, ΔP_t, kN/m^2	Inlet subcooling, ΔT_{sc}, K		Effective, l_e	Critical, l_{cr}	Average overall, U_a	Effective, U_e	Outlet, X_o	Critical, X_{cr}
24	58	51.9	0.432	---	10.6	19.5	0.72	---
22	54	42.7	.331	---	10.0	19.7	.58	---
28	0	56.3	-----	---	18.1	----	.62	---
25	0	49.8	-----	---	19.0	----	.55	---
19	27	41.3	.508	---	10.9	20.4	.44	---
20	0	44.2	-----	---	18.6	----	.47	---
19		44.5	-----	---	18.7	----	.47	---
19		36.9	-----	---	20.3	----	.27	---
29		49.2	-----	---	20.1	----	.36	---
17		1.1	-----	---	(a)	----	.08	---
25		45.2	-----	---	20.0	----	.33	---
32		50.1	-----	---	19.8	----	.36	---

TABLE II. - BOILER SHELL SURFACE TEMPERATURES

(a) U.S. customary units

		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES																										
		49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
RUN	SERIES	TEMPERATURES, DEGREES FAHRENHEIT																										
85	400	1920	1918	1918		1919	1918	1910		1907	1898	-0	1880	1876	1869	1865		-0	1852	1849	1843	1843	1850	1850	1841	1845	1846	1843
	300				1921	1922	1919	1913	1910	1906	1901	1893	1883	1883	1870	1873	1863	1860	1855	1857	1855	1854	1854	1854	1851	1848	1849	1844
82	400	1935	1933	1931		1930	1924	1913		1904	1900	-0	1887	1879	1874	1867		1855	-0	1854	1859	1846	1852	1851	1843	1848	1849	1846
	300				1933	1931	1927	1915	1910	1906	1903	1895	1886	1885	1873	1873	1863	1864	1862	1860	1853	1857	1857	1858	1854	1848	1849	1849
115	400	1925	1924	1924		1922	1924	1919		1921	1923	1923	-0	1921	1903	1909		-0	1899	1894	1884	1881	1878	1874	1856	1854	1844	1842
	300				1926	1925	1926	1925	1923	1924	1925	1924	1918	1921	1907	1913	1907	1908	1901	1897	1891	1889	1884	1880	1868	1856	1845	1843
83	400	1937	1937	1937		1925	1919	1910		1897	1893	1890	1872	1872	1867	1864		1851	1854	1853	1845	1846	1850	1851	1841	1845	1847	1844
	300				1932	1927	1922	1909	1903	1901	1897	1890	1881	1880	1868	1869	1860	1861	1856	1856	1852	1853	1854	1854	1851	1849	1847	1842
84	400	1948	1946	1944		1934	1926	1913		1903	1898	1893	1886	1886	1872	-0		1855	-0	1855	1846	1850	1853	1850	1847	1850	1848	1846
	300				1942	1931	1928	1914	1911	1906	1902	1894	1888	1884	1872	1873	1868	1864	1862	1860	1857	1858	1858	1859	1855	1851	1851	1849
74	400	1926	1925	1927		1910	1900	1889		1880	1874	1871	1865	1858	1850	1846		1838	1846	1835	1825	1829	1836	1833	1824	1828	1826	1830
	300				1919	1905	1902	1891	1889	1882	1876	1872	1866	1865	1851	1854	1846	1844	1842	1842	1839	1838	1839	1839	1835	1835	1833	1831
113	400	1897	1896	1894		1884	1877	1871		1866	1862	1860	1858	1851	1846	1843		1838	1835	1832	1821	1824	1822	1819	-0	1810	1802	1805
	300				1891	1884	1884	1876	1875	1871	1866	1864	1861	1856	1844	1849	1844	1842	1839	1837	-0	1829	1831	1826	1818	1813	1808	1805
112	400	1892	1891	1891		1882	1880	1874		1869	1866	1862	1861	-0	1846	1842		1837	-0	1834	1822	1822	1823	1822	1808	1806	1806	1803
	300				1891	1889	1887	1882	1881	1876	1871	1871	1864	1857	1851	1853	1846	1844	1840	1837	1833	1832	1831	1827	1820	1813	1809	1806
114	400	1905	1903	1904		1895	1893	1887		1879	1879	1877	1870	-0	1858	1855		1843	1845	1842	1835	1833	1831	1830	1818	1817	1815	1811
	300				1901	1896	1892	1884	1885	1879	1877	1875	1871	1863	1856	1860	1852	1851	1848	1846	1840	1839	1841	1834	1828	1821	1814	1812
50	400	1970	1967	1968	1961	1964	1959	1956		1953	1947	1942	1938	1932	1924	1919		1904	1904	1903	1889	1888	1885	1881	1869	1872	1859	1857
	300				1967	1968	1966	1964	1963	1959	1957	1953	1939	1940	1927	1929	1925	1921	1913	1909	1903	1901	1898	1893	1878	1870	1866	1863
49	400	1968	1967	1966	1960	1965	1963	1961		1959	1957	-0	1950	1942	1930	1926		-0	1913	1909	1896	1896	1895	1890	1877	1868	1862	1860
	300				1969	1968	1966	1963	1962	1960	1957	1953	1945	1940	1930	1932	1925	1921	1914	1910	1904	1903	1898	1894	1884	1870	1869	1864
73	400	1930	1929	1927	1915	1916	1910	1902		1892	1889	1887	1881	1875	1865	1864		1854	1855	1853	1843	1842	1839	1835	1825	1831	1825	1821
	300				1924	1915	1916	1909	1904	1901	1896	1891	1883	1881	1870	1873	1866	1862	1856	1855	1850	1848	1847	1845	1835	1831	1822	1822
46	400	1969	1965	1966	1959	1962	1959	1953		1948	1946	1940	1936	1928	1900	1912		-0	1902	1898	1883	1884	1882	1878	1864	1861	1854	1852
	300				1967	1964	1965	1960	1960	1955	1952	1947	1939	1937	1921	1923	1914	1914	1905	1904	1894	1893	1888	1886	1873	1862	1859	1856
72	400	1930	1929	1927	1919	1916	1914	1908		1902	1899	1896	1890	1881	1875	1874		1864	1862	1857	1848	1850	1848	1844	1828	1827	1823	1822
	300				1927	1920	1918	1912	1907	1906	1904	1900	1891	1886	1873	1877	1873	1871	1863	1859	1856	1850	-0	1851	1838	1831	1825	1822
44	400	1966	1966	1964	1955	1962	1956	1949		1940	1934	-0	1926	1920	1911	1908		1897	1895	1891	1881	1880	1879	1872	1861	1859	1851	1847
	300				1966	1959	1957	1947	1941	-0	1936	1932	1924	1921	1908	1910	1905	1900	1895	1893	1887	1885	1881	1879	1868	1861	1854	1849
111	400	1985	1986	1982		1978	1973	1964		1957	1952	1947	1946	1932	1922	1921		1909	1909	1903	1894	1890	1890	1886	1869	1871	1862	1858
	300				1983	1979	1975	1968	1964	1959	1955	1950	1942	1936	1924	1927	1916	1916	1910	1906	1899	1896	1897	1888	1879	1873	1863	1859
108	400	1980	1980	1977		1971	1965	1958		1949	1943	1943	1931	1924	1904	1910		1897	1898	1895	1883	1880	1879	1874	1862	1862	1851	1851
	300				1976	1975	1973	1968	1966	1963	1959	1953	1946	1944	1926	1926	1919	1916	1909	1906	1859	1896	1891	1889	1874	1865	1860	1857

71	400	1925	1926	1924	1913	1912	1905	1897		1893	1887	1884	1881	1873	1864	1864		1857	1854	1850	1839	1840	1839	1834	1826	1824	1819	1818
	300				1921	1915	1914	1905	1901	1899	1893	1889	1885	1880	1867	1871	1865	1860	1857	1854	1847	1846	1845	1841	-0	1828	1822	1821
107	400	1965	1965	1963		1950	1944	1937		1931	1925	1923	1900	1907	1898	1895		1885	1883	1879	1870	1868	1867	1864	1854	1856	1848	1846
	300				1959	1950	1947	1938	1933	1932	1928	1922	1915	1911	1900	1902	1896	1893	1887	1887	1882	1877	1875	1873	1862	1856	1847	1846
106	400	1907	1905	1904		1893	1888	1879		1872	1870	1868	1863	1855	1850	1855		-0	1838	1835	1827	1823	1825	1828	1811	1814	1810	1808
	300				1900	1892	1888	1881	1879	1876	1873	1868	1861	1860	1850	1850	1844	1844	1839	1838	1834	1831	1831	1829	1823	1816	1814	1810
110	400	1978	1976	1975		1961	1954	1943		1936	1929	1926	1923	1914	1907	1904		1893	-0	1888	1874	1877	1875	1869	1860	1861	1849	1853
	300				1970	1960	1959	1948	1946	1943	1936	1932	1930	1925	1910	1914	1906	1903	1899	1896	1889	1885	1884	1878	1868	1862	1855	1856
109	400	1987	1986	1985		1963	1953	1941		1926	1919	1919	1908	1898	1888	1884		-0	1874	1874	1864	1868	1872	1871	1861	1868	1868	1865
	300				1974	1959	1954	1940	1935	1929	1925	1919	1911	1906	1892	1894	1887	1883	1878	1876	1871	1877	1876	1878	1873	1873	1872	1868
33	400	1966	1964	1963	1954	1951	1946	1938		1928	1925	1921	1917	1909	1904	1895		1887	1887	1884	1872	1874	1872	1868	1863	1853	1848	1844
	300				1961	1950	1947	1935	1932	1926	1925	1919	1911	1908	1896	-0	1895	1892	1887	1884	1880	1877	1873	1872	1857	1853	1848	1845
21	400	1938	1934	1934	1930	1925	1922	1917		1911	1908	1906	-0	1896	1888	1881		1873	1873	1871	1858	1859	1858	1854	1841	1838	1834	1831
	300				1935	1924	1923	1916	1914	1908	1907	1904	1897	1896	1884	1883	1881	1880	1874	1870	1866	1863	1861	1860	1848	1841	1837	1835
70	400	1929	1926	1925	1915	1908	1902	1895		1885	1881	1876	1871	1866	1861	-0		1847	1844	1843	1834	1829	1833	1831	1820	1822	1816	1814
	300				1921	1908	1897	1899	1893	1888	1887	1881	1874	1873	1859	1861	1857	1854	1849	1849	1841	1839	1840	1836	1827	1823	1820	1817
6	400	1970	1969	1969	1954	1950	1936	1928		1916	1909	1904	1900	1894	1884	1882		1872	1876	1873	1862	1865	1869	1870	1864	1863	1863	1862
	300				1961	1944	1942	1930	1923	1919	1923	1906	1903	1898	1884	1887	1878	1881	1876	1874	1874	1870	1875	1875	1869	1868	1864	1865
5	400	1966	1965	1964	1950	1945	1934	1922		1914	1905	1901	1883	1889	1883	1880		1882	1871	1871	1860	1865	1869	1865	1864	1862	1861	1860
	300				1955	1938	1937	1923	1919	1915	1908	1903	1899	1894	1879	1883	1878	1875	1874	1873	1869	1871	1872	1872	1867	1864	1863	1862
41	400	1966	1964	1965	1955	1952	1943	1937		1925	1922	1918	1913	1901	1902	1894		1883	1885	1881	1867	1868	1869	-0	1850	1851	1843	1841
	300				1961	1948	1944	1936	1934	1928	1925	1922	1915	1911	1899	1901	1893	1891	1890	1887	1878	1876	1876	1871	1860	-0	1849	1846
32	400	1966	1963	1963	1953	1948	1940	1932		1925	1919	1915	1910	1905	-0	1893		1882	1882	1879	1866	1866	1867	1863	1853	1851	1847	1843
	300				1959	1946	1941	1933	1931	1926	1921	1917	1911	1908	1895	1895	1891	1888	1884	1880	1874	1872	1870	1868	1858	1849	1847	1845
62	400	2086	2084	2082	2074	2078	2078	2072		2070	2066	2062	2054	2044	2031	2028		2012	2007	1999	1987	1986	1977	1971	1956	1954	1938	1934
	300				2082	2081	2081	2075	2072	2072	2071	2063	2055	2051	2034	2035	2026	2022	2011	2005	2001	1992	1988	1983	1964	1954	1943	1940
9	400	1963	1960	1960	1947	1943	1934	1922		1910	1908	1903	1892	1891	1884	1879		1872	1870	1871	1859	1864	1869	1865	1861	1860	1863	1858
	300				1954	1938	1936	1924	1921	1913	1911	1905	1900	1895	1882	1886	1880	1880	1873	1872	1872	1872	1872	1873	1870	1863	1866	1861
60	400	2065	2063	2063	2053	2055	2052	2033		2036	2027	2021	2016	2004	1995	1991		1975	1972	1966	1952	1954	1948	1942	1928	1925	1912	1910
	300				2060	2053	2054	2044	2040	2031	2029	2020	2012	2008	1990	1992	1985	1979	1971	1968	1962	1955	1955	1950	1934	1926	1917	1916
61	400	2076	2072	2072	2066	2065	2064	2058		2052	2046	2040	2032	2021	2009	2005		1986	1985	1980	1964	1964	1959	1953	1938	1939	1923	1921
	300				2070	2066	2068	2061	2058	2053	2047	2041	2034	2027	2010	2011	2004	1997	1987	1985	1977	1972	1969	1965	1946	1939	1930	1927
24	400	1964	1962	1962	1945	1953	1944	1939		1932	1926	1923	1923	1918	1909	1910		-0	1906	1905	1898	1903	1908	1904	1896	1895	1891	1889
	300				1957	1947	1945	1937	1935	1928	1927	1921	1918	1914	1906	1911	1910	1910	1912	1915	1907	1913	1911	1913	1904	1896	1897	1894
69	400	1925	1925	1925	1913	1908	1902	1892		1885	1878	1875	1871	1865	1857	1854		1848	1845	1842	1831	1831	1831	1827	1819	1819	1816	1816
	300				1919	1908	1903	1893	1891	1887	1880	1875	1872	1869	1855	1858	1853	1850	1848	1845	1838	1838	1839	1834	1827	1820	1818	1818
68	400	1884	1882	1882	1873	1867	1867	1856		1852	1848	1848	1841	1838	1829	1829		1818	1826	1822	1814	1815	1815	1813	1806	1805	1799	1804
	300				1879	1868	1867	1862	1857	1854	1851	1848	1846	1841	1832	1835	1830	1832	1826	1826	1822	1820	1822	1817	1813	1809	1804	1806
59	400	2056	2052	2053	2043	2044	2039	2025		2016	2007	2004	1996	1988	1977	1973		1952	1957	1954	1939	1939	1935	1937	1915	1917	1906	1901
	300				2051	2044	2044	2036	2031	2027	2021	2016	2003	2001	1984	1983	1978	1972	1964	1960	1954	1950	1946	1943	1924	1916	1911	1905
58	400	2045	2041	2041	2030	2024	2017	2008		1997	1996	1983	1978	-0	1961	1953		1938	1940	1937	1922	1922	1917	1916	1904	1905	1894	1891
	300				2037	2026	2026	2013	2007	2002	1997	1987	1981	1979	1960	1965	1957	1952	1947	1944	1936	1932	1930	1925	1911	1908	1896	1897
104	400	2083	2080	2080		2072	2067	2061		2053	2048	2040	2034	2025	2015	2007		-0	1992	1987	1969	1971	1967	1961	1946	1945	1933	1930
	300				2079	2075	2074	2066	2063	2058	2053	2047	2038	2032	2017	2016	2008	2005	1998	1992	1984	1982	1977	1973	1956	1947	1940	1935
8	400	2043	2039	2040	2025	2022	2012	2007		1993	-0	1982	1976	1968	1957	1957		1950	-0	1949	1942	1944	1948	1947	1939	1936	1937	1934
	300				2032	2024	2016	2010	2005	2001	1996	1991	1983	1977	1963	1968	1961	1964	1958	1960	1954	1956	1957	1955	1950	1937	1942	1939

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(a) Continued. U. S. customary units

RUN	SERIES	49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES																										
		TEMPERATURES, DEGREES FAHRENHEIT																										
63	400	2026	2023	2022	2012	2011	2002	1996		1985	1982	1973	1966	1957	1950	1942		1933	1931	1927	1915	1915	1912	1908	1889	1886	1885	1878
	300				2019	2005	2001	1990	1984	1978	1975	1970	1961	1957	1945	-0	1942	1936	1929	1928	1924	1919	1916	1914	1902	1889	1890	1883
66	400	1874	1873	1873	1862	1862	1852	1844		1838	1837	1835	1830	1827	1821	-0		1820	1814	1810	1803	1802	1803	1802	1794	1794	1792	1792
	300				1870	1860	1857	1852	1845	1844	1839	1836	1835	1831	1822	1823	1818	1820	1816	1815	1812	1808	1810	1808	1802	1797	1796	1794
103	400	2060	2059	2058		2049	2044	2035		2025	2019	2014	2007	1997	1988	1985		-0	1968	1962	1951	1951	1945	1941	1923	1923	1912	1908
	300				2055	2051	2048	2036	2032	2027	2023	2015	-0	2000	1984	1988	1980	1975	1969	1965	1960	1955	1952	1949	1934	1925	1917	1914
105	400	2108	2106	2106		2099	2098	2094		2094	-0	2089	2084	2074	2061	2055		2040	2035	2030	2011	2011	2007	1999	1984	1983	1960	1960
	300				2105	2102	2102	2100	2100	2098	2097	2092	2086	2077	2062	2062	2052	2047	2038	2028	2023	2018	2013	2007	1990	1979	1968	1965
25	400	1964	1961	1964	1948	1949	1943	1936		1931	1921	1921	1917	1916	1904	1905		1896	1899	1901	1892	1897	1904	1900	1894	1894	1890	1889
	300				1955	1941	1940	1929	1926	1920	1917	1912	1907	1903	1895	1895	1898	1892	1898	1894	1894	1894	-0	1898	1899	1896	1894	1893
102	400	2050	2046	2046		2030	2021	2010		1997	-0	1987	1982	1974	1964	1958		1946	1944	1941	1926	1928	1924	1919	1909	1905	1899	1896
	300				2040	2027	2022	2011	2007	2001	1996	1990	1983	1977	1963	1963	1953	1952	1945	1939	1935	1931	1929	1924	1905	1909	1902	1900
78	400	1928	1927	1924		1909	1901	1889		1882	1872	1870	1867	1862	-0	1846		1842	1841	1840	1831	1836	1839	1836	1831	1832	1828	1830
	300				1919	1902	1902	1892	1888	1880	1878	1875	1867	1863	1853	1855	1849	1847	1846	1845	1840	1840	1844	1845	1838	1834	1834	1833
65	400	1939	1938	1936	1928	1923	1919	1907		1900	1893	1889	1884	1879	1872	1864		1850	1857	-0	1842	1841	1841	1840	1829	1830	1825	1825
	300				1932	1922	1916	1908	1904	1899	1895	1888	1886	1882	1871	1869	1862	1864	1859	1859	1850	1852	1850	1847	1840	1830	1831	1827
56	400	2009	2006	2006	1994	1993	1981	1970		1963	1960	1952	1947	1939	1933	1927		1911	1913	1911	1899	1896	1896	1892	1879	1874	1866	1866
	300				2001	1986	1982	1971	1967	1962	1958	1952	1946	1941	1927	1928	1923	1919	1912	1909	1903	1901	1898	1894	1886	1878	1875	1869
57	400	2032	2030	2031	2019	2019	2010	2003		1992	1988	1980	1976	1967	1957	1949		1935	1935	1932	1919	1919	1914	1908	1893	1895	1883	1880
	300				2025	2017	2013	2001	1997	1993	1987	1980	1970	1967	1954	1952	1946	1945	1938	1932	1925	1923	1921	1917	1903	1893	1889	1887
19	400	1942	1939	1939	1930	1926	1916	1909		1900	1900	1896	1889	-0	1874	1874		1863	1866	1861	1850	1849	1849	1844	1838	1837	1830	1830
	300				1934	1926	1921	1910	1908	1904	1901	1898	1888	1888	1876	1877	1871	1870	1864	1865	1859	1855	1856	1852	1843	1838	1831	1831
52	400	1935	1983	1981	1969	1965	-0	1946		1935	1931	1928	1922	1917	1908	1900		1892	-0	1889	1875	1876	1877	1873	1862	1856	1852	1851
	300				1977	1961	1956	1947	1944	1941	1934	1930	1923	1921	1909	1910	1901	1899	-0	1893	1886	1884	1882	1880	1870	1860	1858	1854
51	400	1967	1966	1967	1956	1951	1943	1933		1926	1921	1917	1911	1904	1896	1892		1883	1881	1878	1866	1868	1867	1863	1853	1850	1840	1844
	300				1961	1950	1948	1938	1935	1930	1926	1923	1916	1910	1896	1899	1895	1891	1887	1884	1875	1873	1873	1871	1860	1852	1849	1847
101	400	2031	2030	2030		2016	2008	1997		1988	1981	1974	1970	1961	1953	1947		1927	-0	1928	1916	1916	1913	1907	1893	1893	1885	1884
	300				2026	2012	2009	1997	1993	1986	1983	1976	1969	1966	1950	1951	1946	1942	1937	1932	1927	1923	1931	1918	-0	1894	1889	1889
39	400	1966	1966	1966	1952	1948	1940	1934		1923	1920	1917	1910	-0	1893	1891		1884	1880	1877	1864	1864	1864	1873	1848	1845	1843	1841
	300				1959	1949	1945	1934	1929	1926	1922	1917	1909	1905	1894	1895	1887	1885	1880	1877	1871	1871	1868	1865	1856	1848	1848	1843
55	400	1997	1995	1995	1984	1980	1967	1957		1951	1946	1937	1934	1926	1921	1916		1901	1913	1901	1890	1888	1886	1881	1871	1869	1860	1859
	300				1990	1975	1970	1959	1956	1954	1948	1941	1933	1932	1919	1918	1910	1908	1904	1903	1895	1891	1890	1888	1881	1869	1863	1863
31	400	1966	1963	1962	1952	1949	1940	1929		1920	1916	1911	1896	1898	1892	1889		1878	1887	1877	1867	1865	1863	1859	1849	1848	1841	1841
	300				1957	1946	1942	1933	1930	1926	1922	1917	1909	1906	1893	1893	1888	1885	1879	1877	1874	1871	1869	1867	1859	1852	1850	1845

38	400	1966	1964	1968	1950	1946	1939	1931		1923	1915	1899	1907	1899	1884	1888		1880	1879	1875	1862	1861	1862	1859	1847	1850	1843	1841
	300				1958	1945	1938	1931	1928	1923	1918	1913	1905	1900	1889	1892	1887	1884	1880	1877	1870	1869	1867	1865	1857	1851	1850	1846
354	400	1992	1989	1969		1971	1963	1950		1941	1937	1935	1917	1918	1911	1907		1897	-0	1895	1883	1824	1883	1878	1868	1871	1865	1864
	300				1982	1970	1965	1953	1947	1944	1943	1935	1925	1924	1910	-0	1909	1903	1901	1899	1892	1893	1888	1887	1880	1872	1867	1866
17	400	1947	1945	1945	1935	1931	1915	1910		1904	1901	1897	1892	1881	1880	1875		-0	1867	1864	1853	1851	1851	1847	1838	1838	1834	1832
	300				1940	1928	1923	1912	1910	1907	1903	1899	1890	1889	1875	1878	1872	1872	1869	1867	1860	1858	1857	-0	1845	1841	1837	1835
30	400	1968	1965	1966	1954	1950	1942	1930		1919	1912	1911	1905	1898	1892	1888		1877	1882	1872	1862	1861	1863	1860	1849	1849	1842	1842
	300				1957	1945	1943	1933	1930	1924	1921	1916	1908	1903	1889	1893	1886	1886	1881	1881	1874	1871	1869	1866	1856	1851	1847	1847
15	400	1953	1950	1950	1937	1934	1926	1910		1907	1901	1899	1879	1886	1879	1876		1861	1866	1862	1852	1853	1854	1851	1842	1840	1836	1835
	300				1944	1930	1928	1918	1915	1911	1907	1901	1895	1891	1877	1882	1876	1874	1869	-0	1862	1863	1861	1856	1848	1842	1840	1840
37	400	1966	1964	1962	1949	1947	1939	1928		1918	1915	1916	1904	1896	1888	1885		1789	1876	1871	1864	1861	1863	1860	1850	1851	1846	1843
	300				1959	1945	1939	1927	1925	1920	1916	1910	1903	1899	1890	1892	1884	1885	1881	1878	1872	1869	1868	1865	1856	1850	1846	1843
28	400	1965	1963	1963	1950	1946	1936	1927		1917	1912	-0	1904	1898	1890	1884		1875	1876	1868	1863	1863	1861	1856	1847	1848	1845	1844
	300				1956	1944	1938	1930	1927	1921	1917	1912	1905	1901	1889	1893	1887	1885	1878	1877	1870	1869	1868	1866	1858	1847	1848	1845
23	400	1967	1966	1964	1954	1958	1955	1949		1944	1939	1938	1930	1924	1911	1913		-0	1901	1898	1886	1887	1883	1879	1861	1860	1854	1849
	300				1962	1959	1956	1951	1948	1946	1942	1938	1929	1925	1910	1915	1908	1905	1899	1895	1890	1884	1884	1880	1871	1861	1858	1852
96	400	2105	2103	2102		2079	2068	2056		2040	-0	2028	2020	2011	2003	1996		-0	1975	1971	1959	1957	1955	1949	1936	1937	1916	1925
	300				2093	2075	2068	2055	2049	2044	2039	2034	2021	2016	2001	2002	1993	1989	1980	1976	1971	1966	1964	1960	1945	1938	1931	1928
100	400	2154	2150	2150		2131	2117	2106		2090	2081	2077	2065	2056	2044	2035		2020	2020	2015	1998	2000	1995	1989	1974	1973	1961	1957
	300				2143	2126	2119	2105	2099	2091	2084	2075	2065	2057	2041	2042	2034	2028	2022	2014	2009	2004	2002	1996	1982	1973	1967	1963
98	400	2134	2132	2132		2109	2099	2081		-0	2060	2051	2045	2036	2026	2020		-0	2001	1999	1984	1985	1978	1971	1956	1958	1945	1943
	300				2123	2103	2100	2086	2079	2072	2055	2058	2048	2043	2025	2023	2019	2013	2005	1999	1995	1990	1986	1982	1965	1956	1951	1948
90	400	1964	1963	1962		1944	1936	1924		1912	1908	1903	1899	1893	1884	1879		1864	-0	1866	1859	1862	1869	1859	1847	1848	1845	1845
	300				1956	1939	1937	1926	1923	1917	1910	1905	1900	1899	1886	1887	1882	1879	1877	1875	1870	1869	1867	1864	1856	1851	1849	1848
94	400	2070	2070	2068		2048	2037	2026		2013	2007	2001	1994	1984	1975	1969		-0	1956	1953	1939	1935	1934	1928	1913	1915	1906	1904
	300				2061	2045	2038	2025	2019	2014	2009	2002	1994	1988	1974	1974	1966	1960	1956	1953	1949	1944	1940	1936	1923	1915	1908	1906
95	400	2083	2081	2080		2058	2047	2035		2021	2011	2008	2000	1990	1978	1974		1963	-0	1958	1945	1946	1941	1936	1924	1923	1915	1913
	300				2071	2054	2049	2033	2028	2019	2017	2008	1997	1993	1977	1981	1974	1971	-0	1959	1955	1948	1947	1942	1928	1925	1917	1916
93	400	2041	2038	2037		2016	2006	1994		1980	-0	1970	1962	1956	1941	1938		-0	1925	1919	1905	1909	1908	1904	1892	1892	1887	1884
	300				2028	2012	2006	1991	1988	1982	1977	1968	1959	1957	1942	1945	1936	1934	1927	1926	1922	1914	1915	1912	1902	1896	1889	1886
91	400	1984	1981	1979		1962	1954	1942		1929	1924	1921	1915	1906	-0	1895		1887	1886	1882	1873	1873	1873	1870	1859	1860	1857	1856
	300				1974	1959	1953	1941	1938	1934	1928	1922	1916	1912	1898	1901	1894	1893	1888	1889	1883	1878	1879	1876	1870	1864	1857	1855
92	400	2012	2009	2008		1988	1978	1968		1954	1949	1942	-0	1929	1922	1917		-0	1901	1901	1889	1891	1890	1887	1874	1871	1869	1868
	300				2000	1986	1981	1968	1963	1954	1955	1946	1938	1934	1921	1922	1916	1912	1907	1905	1899	1899	1896	1894	1884	1874	1874	1873
13	400	1959	1959	1954	1942	1939	1929	1921		1908	1903	1900	1896	1887	1881	1879		1869	1884	1864	1854	1856	1856	1851	1843	1843	1844	1841
	300				1948	1935	1931	1921	1916	1910	1907	1903	1896	1891	1879	1883	1877	1876	1871	1869	1865	1865	1863	1859	1850	1845	1854	1842
12	400	1961	1958	1959	1944	1944	1933	1921		1909	1908	1903	1897	1891	1881	1880		-0	1872	1869	1856	1859	1858	1855	1847	1844	1843	1841
	300				1953	1938	1936	1924	1921	1914	1909	1907	1900	1893	1885	1885	1882	1878	1872	1873	1863	1865	1865	1861	1856	1849	1846	1845
75	400	1930	1926	1925		1909	1902	1894		1881	1878	1877	1871	-0	1857	1854		1847	1850	1844	1836	1841	1837	1835	1825	1827	1823	1822
	300				1923	1909	1902	1892	1891	1888	1884	1877	1869	1869	1859	1862	1854	1854	1850	1850	1846	1843	1842	1840	1833	1830	1828	1824
27	400	1966	1963	1962	1951	1946	1937	1928		1916	1912	1910	1902	1897	1887	1883		1875	1875	1874	1861	1863	1864	1858	1849	1849	1841	1844
	300				1956	1942	1939	1928	1925	1918	1917	1910	1904	1901	1886	1890	1885	1882	1879	1878	1869	1872	1869	1866	1857	1851	1849	1848
22	400	1967	1966	1964	1954	1946	1940	1928		1919	1914	1909	1906	1899	1891	1887		1878	1872	1874	1862	1864	1861	1860	1850	1853	1843	1846
	300				1959	1944	1943	1930	1928	1920	1918	1910	1906	1901	1889	1890	1887	1884	1880	1877	1871	1869	1868	1866	1857	1852	1848	-0
35	400	1966	1962	1963	1950	1945	1932	1922		1913	1909	1904	1899	1895	1889	1885		1874	1872	1874	1864	1864	1871	1869	1861	1861	1863	1862
	300				1957	1941	1935	1925	1922	1918	1911	1908	1903	1900	1888	1890	1884	1883	1880	1878	1873	1875	1875	1875	1871	1866	1864	1864

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(a) Continued. U.S. customary units

DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES

TEMPERATURES, DEGREES FAHRENHEIT

RUN	SERIES	49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
26	400	1966	1963	1962	1951	1945	1937	1928		1917	1912	1907	-0	1895	-0	1885		1876	1874	1865	1862	1864	1862	1861	1848	1849	1848	1843
	300				1955	1941	1941	1928	1923	1919	1912	1912	1902	1901	1887	1888	1887	1882	1877	1877	1870	1870	1868	1866	1860	1852	1849	1847
34	400	1967	1963	1963	1951	1944	1932	1923		1913	1908	1903	1900	1894	1880	1881		1873	1875	1875	1865	1867	1872	1870	1863	1864	1865	1864
	300				1957	1941	1938	1927	1923	1917	1912	1907	1903	1899	1886	-0	1884	1883	1879	1878	1872	1876	1876	1876	1872	1866	1867	1865
146	400	1999	1999	1997		1981	1973	1960		1950	1938	1939	1945	1927	1921	1917		-0	1908	1907	1897	1899	1903	1903	1896	1899	1899	1897
	300				1991	1977	1974	1963	1959	1952	1949	1944	1937	1933	1919	1922	1918	1914	1912	1910	1907	1908	1908	1909	1906	1900	1899	1899
147	400	1977	1977	1977		1960	1953	1943		1934	1929	1926	1920	1915	1906	1903		1892	1893	1891	1887	1890	1890	1896	1880	1888	1889	1887
	300				1968	1959	1956	1945	1942	1936	1932	1927	1921	1920	1905	1908	1902	1901	1899	1898	1894	1893	1896	1896	1894	1891	1888	1884
143	400	2026	2026	2026		2018	2011	2000		1987	1978	1975	1968	1960	1949	1943		-0	1933	1931	1921	1927	1929	1929	1917	1924	1927	1921
	300				2024	2019	2017	2001	1994	1989	1985	1979	1968	-0	1950	1952	1946	1940	1937	1934	1934	1935	1934	1935	1930	1928	1925	1922
149	400	1937	1937	1934		1921	1917	1910		1900	1895	1898	1892	1886	1877	1877		1870	1871	1871	1863	1867	1869	1867	1857	1866	1865	1862
	300				1931	1925	1920	1911	1907	1905	1903	1899	1892	1890	1880	1885	1879	1876	1876	1876	1872	1872	1874	1875	1871	1869	1864	1863
148	400	1956	1956	1956		1943	1935	1926		1917	1915	1918	1907	1899	1891	1889		1884	1882	1882	1874	1876	1879	1880	1879	1873	1877	1873
	300				1952	1942	1939	1928	1925	1920	1918	1915	1909	1903	1891	1896	1893	1891	1888	1887	1881	1885	1885	1886	1884	1876	1880	1876
145	400	2008	2006	2006		1989	1978	1969		1957	1951	1947	1940	1936	1926	1914		1908	1912	1911	1898	1903	1908	1907	1899	1901	1903	1901
	300				2000	1987	1982	1972	1966	1960	1956	1952	1944	1939	1926	1929	1923	1920	1916	1916	1912	1914	1914	1913	1911	1906	1907	1903
144	400	2037	2037	2034		2030	2023	2010		1997	1991	1984	1976	1966	1960	1954		1942	1940	1938	1930	1928	1935	1935	1923	1932	1931	1926
	300				2035	2032	2026	2011	2006	2001	1996	1986	1976	1974	1958	1960	1950	1950	1945	1942	1940	1940	1942	1940	1938	1935	1933	1928
348	400	1986	1986	1985		1974	1968	1958		1954	1951	1951	1937	1940	1931	1928		1918	1919	1916	1908	-0	1907	1903	1885	1890	1885	1882
	300				1983	1974	1972	1961	1958	1956	1955	1952	1946	1944	1932	-0	1929	1926	1922	1920	1915	1916	1912	1911	1901	1893	1886	1885
142	400	2066	2065	2065		2056	2051	2044		2035	2027	2024	2018	2009	1998	1994		1979	1985	1975	1963	1962	1957	1952	1942	1942	1927	1926
	300				2064	2062	2060	2050	2049	2046	2042	2033	2024	2022	2007	2006	1999	1995	1989	1983	1976	1974	1972	1967	1951	1940	1934	1933
141	400	2055	2051	2053		2030	2032	2024		2014	2008	2005	2002	1993	1983	1978		1964	1963	1961	1948	1950	1944	1940	1931	1928	1912	1917
	300				2049	2037	2035	2026	2023	2016	2012	2006	2001	1994	1980	1983	1978	1970	1967	1962	1958	1954	1951	1948	1939	1930	1925	1922
140	400	2039	2037	2035		2024	2018	2007		1994	1992	1989	1983	1975	1966	1963		1953	1952	1946	1937	1938	1934	1930	1915	1908	1911	1906
	300				2031	2022	2018	2007	2002	2000	1995	1988	1982	1980	1964	1967	1961	1959	1952	1949	1946	1943	1938	1936	1927	1921	1912	1908
136	400	1991	1988	1989		1975	1967	1961		1948	1949	1942	1944	1936	1931	1923		-0	1915	1912	1901	1901	1902	1898	1885	1886	1880	1880
	300				1984	1976	1971	1964	1961	1958	1956	1953	1946	1943	1931	1933	1928	1925	1921	1919	1912	1912	1904	1906	1897	1888	1885	1883
137	400	2001	2000	1999		1986	1978	1972		1964	1960	1957	1939	1946	1937	1936		-0	1923	1922	1912	1910	1909	1907	1895	1893	1886	1887
	300				1995	1986	1984	1975	1970	1968	1965	1959	1951	1950	1939	1938	1933	1930	1928	1924	1918	1917	1918	1911	1903	1895	1892	1887
134	400	1964	1964	1962		1950	1945	1938		1931	1928	1927	1924	1916	1907	1903		1897	1899	1898	1885	1888	1888	1885	1869	1870	1868	1868
	300				1958	1949	1950	1943	1941	1938	1935	1930	1925	1919	1910	1911	1907	1904	1901	1899	1896	1896	1896	1891	1881	1873	1870	1867

139	400	2025	2023	2024		2008	2000	1992		1986	1980	1988	1972	1966	1957	1951		1943	1942	1939	1925	1928	1927	1924	1908	1907	1900	1898
	300				2019	2008	2003	1995	1993	1990	1984	1980	1972	1970	1958	1957	1949	1948	1945	1941	1932	1932	1931	1928	1918	1910	1903	1904
135	400	1980	1978	1978		1966	1958	1951		1944	1939	1938	1933	1927	1919	1919		1905	-0	1907	1896	1891	1894	1892	1878	1880	1876	1873
	300				1974	1967	1966	1953	1951	1950	1945	1939	1935	1932	1920	1923	1919	1916	1911	1910	1907	1904	1902	1900	1891	1882	1876	1875
138	400	2015	2013	2012		1998	1991	1984		1973	1969	1966	1963	1955	1948	1941		1932	1934	1932	1918	1919	1918	1914	1901	1900	1895	1891
	300				2007	1998	1995	1985	1980	1976	1972	1970	1963	1956	1947	1942	1944	1942	1934	1931	1925	1926	1926	1921	1909	1901	1898	1897
132	400	2124	2120	2124		2115	2111	2108		2101	2093	2087	2081	2071	2059	2051		2038	2036	2030	2011	2013	2008	2001	1988	1986	1971	1966
	300				2121	2119	2115	2110	2108	2103	2097	2089	2080	2075	2060	2058	2050	2045	2040	2031	2024	2020	2019	2011	1996	1987	-0	1974
350	400	1991	1988	1988		1975	1969	1959		1949	1946	1943	1927	1931	1924	1919		1907	1910	1907	1897	1893	1894	1892	1882	1886	1882	1876
	300				1984	1982	1971	1959	1956	1952	1950	1945	1937	1936	1924	-0	1918	1911	1913	1912	1906	1903	1901	1899	1892	1889	1885	1881
128	400	2064	2063	2061		2046	2039	2028		2019	2012	2009	2001	1990	1982	1979		1966	1965	1962	1947	1948	1945	1939	1926	1928	1920	1917
	300				2055	2044	2041	2028	2024	2020	2017	2011	2003	1998	1984	1986	1979	1975	1968	1968	1961	1957	1955	1951	1937	1931	1923	1923
127	400	2046	2045	2045		2029	2021	2011		2000	1994	1992	1977	1975	1969	1964		1951	1951	1948	1935	1938	1936	1931	1914	1915	1910	1908
	300				2038	2027	2025	2012	2006	2001	1998	1992	1986	1982	1969	1970	1965	1961	1955	1951	1948	1946	1943	1940	1923	1919	1914	1912
131	400	2101	2099	2100		2087	2080	2070		2059	2054	2048	2041	2033	2022	2019		2004	-0	1998	1985	1981	1979	1973	1951	1963	1947	1945
	300				2097	2088	2080	2070	2068	2062	2056	2047	2038	2034	2021	2020	2013	2010	2003	1999	1993	1989	1988	1981	1968	1962	1954	1946
130	400	2093	2091	2091		2081	2075	2067		2057	2052	2039	2040	2031	2021	2014		1996	1997	1993	1981	1978	1975	1968	1951	1949	1937	1936
	300				2088	2084	2082	2071	2067	2062	2057	2050	2039	2034	2021	2021	2013	2008	2001	1996	1992	1987	1985	-0	1964	1950	1947	1940
133	400	1975	1975	1974		1961	1954	1946		1939	1936	1933	1928	1924	1913	1914		1904	1903	1899	1892	1892	1890	1887	1873	1875	1874	1871
	300				1967	1966	1957	1949	1946	1941	1938	1934	1929	1928	1913	1915	1908	1908	1904	1905	1899	1894	1895	1893	1886	1879	1872	1870
129	400	2081	2078	2079		2062	2053	2044		2034	2027	2022	2018	2009	1999	1992		1981	1978	1977	1963	1964	1957	1953	1939	1939	1930	1927
	300				2074	2063	2057	2048	2044	2037	2032	2025	2017	2012	1999	1999	1994	1988	1984	1977	1972	1968	1966	1962	1949	1940	1937	1934
126	400	2026	2022	2023		2009	2002	1992		1981	1976	1973	1969	1963	1956	1950		1937	1938	1935	1921	1923	1922	1919	1905	1902	1896	1894
	300				2018	2006	2002	1993	1989	1983	1979	1975	1970	1968	1953	1954	1947	1945	1943	1940	1933	1929	1928	1925	1916	1907	1905	1901
347	400	1991	1988	1989		1973	1965	1959		1952	1946	1942	1928	1932	1927	1921		1912	1910	1910	1899	1901	1901	1897	1885	1886	1882	1881
	300				1985	1974	1968	1959	1958	1954	1951	1948	1941	1938	1926	-0	1929	1922	1919	1917	1908	1908	1907	1906	1898	1889	1888	1885
346	400	1990	1989	1990		1974	1964	1956		1951	1946	1941	1927	1928	1927	1920		1910	1910	1910	1897	1898	1899	1896	1884	1885	1883	1882
	300				1984	1974	1971	1962	1959	1954	1949	1946	1940	1939	1927	-0	1921	1919	1918	1917	1908	1908	1905	1904	1897	1890	1888	1885
364	400	2099	2096	2095		2071	2059	2043		2026	2022	1998	-0	2000	1991	1981		1970	1970	1967	1955	1957	1960	1961	1949	1952	1953	1949
	300				2087	2066	2059	2044	2038	2030	2025	2018	2008	2005	1990	1990	1983	1979	1974	1971	1965	1967	1966	1967	1962	1958	1959	1953
355	400	1990	1990	1989		1974	1966	1954		1946	1940	1941	1923	1925	1919	1917		1909	-0	1903	1894	1894	1895	1891	1877	1869	1882	1876
	300				1984	1971	1970	1959	1954	1951	1947	1941	1936	1932	1918	-0	1919	1913	1913	1910	1905	1905	1901	1900	1891	1887	1882	1883
359	400	2078	2078	2078		2053	2040	2025		2023	2006	2000	1983	1983	1977	1974		1960	1958	1953	1944	1944	1948	1945	1940	1945	1943	1940
	300				2066	2049	2044	2027	2022	2016	2012	2004	1997	1990	1976	1978	1972	1966	1963	1960	1953	1957	1956	1953	1952	1946	1944	1942
363	400	2092	2083	2086		2061	2047	2031		2019	2011	2006	-0	1991	1984	1977		1964	1963	1959	1951	1950	1952	1954	1944	1949	1946	1942
	300				2075	2056	2049	2035	2029	2022	2017	2008	2001	1997	1981	1981	1978	1971	1969	1963	1957	1962	1960	1960	1958	1949	1948	1947
353	400	1993	1990	1988		1974	1960	1956		1944	1943	1942	1923	1927	1922	1915		1906	-0	1901	1893	1891	1893	1892	1880	1877	1880	1878
	300				1985	1972	1966	1956	1955	1949	1944	1943	1934	1932	1922	-0	1913	1916	1912	1908	1901	1903	1900	1900	1893	1884	1895	1882
365	400	2097	2095	2094		2071	2054	2041		2025	2023	2012	1994	1999	1990	1980		1970	1970	1967	1951	1958	1959	1958	1951	1955	1953	1953
	300				2084	2065	2058	2042	2037	2029	2024	2017	2007	2004	1989	1988	1983	1978	1974	1972	1963	1967	1966	1964	1963	1957	1955	1958
351	400	1992	1990	1989		1974	1966	1954		1947	1943	1940	1928	1927	1917	1918		1908	1908	1906	1897	1895	1896	1891	1883	1884	1880	1880
	300				1984	1973	1971	1957	1953	1953	1949	1943	1933	1933	1922	-0	1917	1918	1912	1911	1906	1905	1901	1900	1895	1888	1880	1880
360	400	2081	2078	-0		2064	2051	2043		2030	2012	2018	2002	2006	1996	1992		1982	1987	1983	1976	1978	1979	1982	1975	1978	1976	1972
	300				2072	2058	2052	2041	2039	2033	2027	2020	2012	2004	1992	1992	1989	1987	1988	1986	1981	1985	1983	1983	1983	1978	1976	1974
362	400	2031	2027	2027		2014	2006	1998		1990	1986	1980	1968	1971	1969	1967		-0	1964	1964	1957	1957	1963	1963	1949	1955	1949	1947
	300				2021	2013	2009	2000	1997	1995	1991	1986	1972	1977	1965	1967	1965	1965	1967	1970	1962	1966	1964	1964	1963	1956	1952	1950
124	400	2190	2189	2187		2171	2164	2149		2135	2129	2120	2111	2098	2090	2081		2063	2057	2057	2039	2039	2035	2029	2012	2008	2000	1995
	300				2181	2171	2169	2155	2148	2142	2136	2126	2114	2108	2091	2091	2079	2075	2069	2061	2054	2050	2046	2040	2021	2012	2005	2000

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(a) Continued. U.S. customary units

RUN	SERIES	49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES																										
		TEMPERATURES, DEGREES FAHRENHEIT																										
349	400	1988	1989	1989		1973	0	1954		1947	1944	1942	1931	1929	1923	1919		1910	1911	1907	1899	1896	1898	1894	1884	1889	1885	1884
	300				1983	1972	1966	1956	1953	1952	1950	1944	1937	1932	1922	-0	1919	1917	1916	1915	1908	1904	1905	1903	1898	1893	1890	1887
119	400	2058	2048	2053		2035	2027	2014		2003	1999	1993	1988	1982	1974	1966		-0	1954	1954	1938	1940	1938	1935	1921	1919	1915	1914
	300				2046	2032	2026	2016	2012	2007	2004	1998	1990	1987	1974	1974	1966	1964	1962	1958	1950	1948	1946	1943	1931	1924	1921	1919
118	400	2004	2004	2004		1986	1979	1970		1959	1953	1952	1952	1941	1931	1925		1921	1922	1916	1904	1908	1906	1901	1887	1892	1890	1886
	300				1998	1986	1984	1972	1966	1960	1960	1956	1946	1941	1932	1935	1929	1926	1921	1918	1915	1913	1911	1909	1900	1894	1891	1889
345	400	1992	1989	1988		1972	1964	1960		1946	1943	1940	1926	1931	1924	1917		1910	1913	1911	1896	1897	1902	1898	1888	1887	1891	1883
	300				1985	1973	1965	1957	1954	1952	1948	1945	1937	1934	1924	-0	1922	1919	1915	1914	-0	1910	1907	1904	1897	1892	1891	1890
117	400	1977	1975	1974		1958	1952	1943		1933	1930	1927	1922	1913	1907	1905		1899	1896	1894	1888	1888	1886	1885	1875	1875	1874	1872
	300				1968	1960	1954	1944	1944	1938	1934	1931	1923	1919	1909	1912	1907	1906	1900	1900	1897	1897	1893	1892	1885	1878	1874	1875
122	400	2166	2164	2163		2141	2129	2106		2100	2094	2085	2079	2058	2059	2049		-0	2037	2030	2013	2017	2012	2006	1988	1987	1980	1975
	300				2153	2136	2130	2115	2109	2102	2098	2089	2078	2072	2056	2056	2050	2045	2036	2032	2025	2023	2019	2012	2000	1991	1985	1980
121	400	2136	2136	2133		2111	2100	2086		2073	2067	2060	2053	2045	2035	2027		2016	2012	2008	1995	1994	1990	1985	1972	1972	1961	1958
	300				2125	2108	2102	2088	2082	2076	2072	2064	2051	2048	2034	2034	2025	2022	2016	2011	2005	2001	2001	1993	1980	1973	1967	1960
120	400	2107	2104	2104		2083	2073	2061		2047	2043	2036	0	2020	2013	2004		1994	1995	1991	1974	1978	1973	1969	1955	1951	1946	1943
	300				2095	2079	2075	2064	2060	2053	2046	2042	2033	2029	2015	2012	2008	2004	1999	1995	1987	1986	1985	1980	1964	1955	1950	1949
123	400	2189	2187	2185		-0	2161	2147		-0	2127	2119	2112	2058	2089	2083		2066	2066	2054	2042	2039	2037	2031	2013	2012	1998	1993
	300				2179	2168	2164	2151	2143	2138	2134	2122	2110	2105	2087	2086	2077	2072	2065	2060	2054	2047	2044	2039	2022	2012	2003	2000
116	400	1926	1928	1926		1916	1911	1900		1896	1894	1891	1888	1884	1879	1874		1868	1870	1869	1862	1858	1859	1861	1850	1852	1851	1850
	300				1923	1916	1913	1903	1903	1900	1896	1893	1890	1888	1876	1881	1876	1874	1873	1874	1869	1867	1870	1867	1860	1855	1855	1849
193	400	1994	1993	1990		1979	1974	1965		1959	1955	1953	1945	1942	1936	1934		1933	1923	1924	1922	1916	1921	1922	1914	1918	1917	1914
	300				1987	1978	1972	1965	1964	1960	1958	1953	1947	1945	1934	1936	1933	1932	1929	1930	1927	1926	1930	1929	1926	1921	1922	1918
184	400	2027	2027	2027		2015	2007	1999		1990	1989	1994	1979	1972	1964	1962		1951	-0	1949	1940	1946	1948	1947	1940	1949	1944	1941
	300				2024	2014	2010	2002	2000	1995	1992	1988	1980	1977	1967	1968	1961	1960	1959	1958	1950	1957	1956	1956	1953	1948	1946	1944
181	400	2030	2028	2028		2013	2009	1999		1990	1987	1981	1979	1971	1965	1961		1952	1952	1951	1940	1944	1947	1948	1940	1945	1940	1942
	300				2022	2012	2012	2002	1999	1993	1989	1985	1981	1977	1964	1966	1962	1960	1958	1957	1952	1954	1954	1956	1951	1947	1944	1944
185	400	2030	2026	2028		2014	2007	1999		1989	1983	1981	1973	1970	1963	1957		1951	1954	1948	1940	1941	1945	1946	1938	1942	1937	1941
	300				2105	2010	2009	2000	1997	1991	1987	1983	1977	1973	1961	1963	1955	1958	1955	1952	1949	1951	1952	1952	1948	1944	1942	1944
178	400	2030	2026	2027		2013	2003	1995		1987	1981	1970	1972	1967	1959	1957		1946	1949	1949	1938	1940	1946	1935	1935	1940	1941	1936
	300				2024	2012	2007	1997	1995	1991	1986	1982	1975	1972	1960	1962	1956	1954	1955	1945	1947	1931	1951	1951	1948	1940	1943	1940
179	400	2030	2028	2030		2015	2006	1999		1991	1986	1982	1978	1971	1964	1960		1951	1954	1954	1942	1946	1949	1949	1940	1944	1953	1942
	300				2024	2011	2011	2000	1999	1993	1989	1985	1981	1977	1963	1966	1963	1960	1957	1955	1951	1954	1954	1956	1951	1947	1945	1947

176	40C	2031	2032	2031		2015	2007	1996		1988	1982	1978	1974	1968	1959	1954		1947	1949	1944	-0	1939	1990	1941	-0	1939	1937	1934
	30C				2025	2014	2009	2000	1996	1990	1987	1982	1976	1971	1958	1961	1955	1954	1944	1950	1946	1949	1949	1948	1946	1940	1942	1940
175	40C	2039	2038	2038		2022	2015	2003		1995	1989	1987	1979	1971	1964	1961		1952	1946	1952	1943	1946	1947	1949	1941	1946	1945	1939
	30C				2032	2023	2016	2004	2003	1997	1996	1988	1979	1978	1964	1969	1961	1961	1956	1956	1955	1954	1957	1956	1951	1948	1946	1944
186	40C	2040	2036	2039		2023	2013	2003		1996	1991	1976	1983	1976	1973	1964		1957	1961	1963	1956	1958	1959	1960	1952	1958	1958	1951
	30C				2033	2022	2018	2005	2005	2000	1996	1990	1983	1979	1969	1970	1967	1968	1966	1968	1965	1968	1970	1966	1964	1960	1961	1957
182	40C	2030	2028	2027		2014	2008	1998		1990	1986	1983	1977	1972	1962	1960		1956	1960	1957	1952	1961	1957	1957	1944	1955	1956	1950
	30C				2023	2014	2011	2000	1996	1994	1988	1986	1980	1975	1962	1967	1964	1966	1962	1962	1963	1964	1966	1963	1956	1958	1956	1952
172	40C	2061	2059	2059		2041	2032	2020		2008	2004	-0	1994	1986	1975	1973		-0	1971	1971	1962	1967	1969	1969	1966	1964	1967	1962
	30C				2051	2037	2035	2021	2018	2011	2003	2003	1994	1990	1978	1981	1976	1976	1976	1975	1975	1976	1979	1977	1969	1969	1969	1966
171	40C	2071	2069	2069		2050	2041	2029		2016	2011	2007	2001	1996	1984	1979		-0	1981	1979	1969	1976	1977	1978	1968	1971	1975	1968
	30C				2061	2046	2045	2030	2028	2021	2015	2012	2003	1997	1986	1987	1984	1983	1983	1981	1982	1983	1985	1984	1978	1978	1976	1973
183	40C	2030	2029	2027		2013	2006	1997		1989	1986	1981	1977	1973	1965	1959		1954	1957	1960	1951	1956	1957	1956	1951	1951	1951	1949
	30C				2024	2013	2008	2001	1998	1993	1990	1986	1979	1976	1965	1967	1962	1964	1964	1962	1960	1961	1967	1964	1961	1955	1955	1955
173	40C	2050	-0	2045		2031	2023	2013		2002	1996	1982	1988	1978	1972	1966		1965	1966	1968	1956	1967	1964	1964	1954	1960	1962	1956
	30C				2043	2028	2028	2014	2010	2005	2000	1997	1989	1983	1973	1974	1972	1972	1970	1972	1968	1972	1973	1970	1965	1963	1964	1959
192	40C	1993	1993	1992		1978	1975	1964		1958	1954	1952	1947	1941	1934	1934		1926	1928	1928	1921	1921	1924	1924	1914	1920	1919	1916
	30C				1987	1979	1976	1967	1963	1962	1960	1956	1947	1946	1934	1938	1930	1932	1930	1931	1928	1929	1933	1931	1927	1924	1919	1919
287	40C	2056	2054	2055		2036	2027	2017		2006	2000	2003	1987	1985	1975	1974		1970	-0	1976	1966	1971	1974	1976	1962	1967	1962	1954
	30C				2049	2036	2032	2021	2015	2009	2007	2001	1994	1989	1975	1980	1980	1979	1979	1979	1978	1979	1979	1979	1972	1972	1965	1957
191	40C	1992	1991	1990		1978	1972	1964		1957	1953	1951	1949	1940	1933	1932		1926	1925	1926	1917	1921	1925	1924	1912	1919	1921	1919
	30C				1987	1979	1977	1969	1967	1962	1958	1956	1951	1946	1937	1939	1936	1934	1930	1930	1928	1931	1931	1931	1927	1924	1924	1920
290	40C	2057	2054	2055		2042	2035	2025		2020	2016	2012	2000	2001	1994	1989		1977	1977	1976	1963	1965	1962	1963	1945	1945	1939	1938
	30C				2050	2040	2038	2030	2027	2021	2018	2015	2005	2006	1992	1992	1991	1986	1982	1977	1971	1972	1968	1964	1954	1947	1944	1941
288	40C	2056	2055	2046		2038	2023	2016		2006	2002	1999	1985	1984	1975	-0		1958	1960	1959	1949	1948	1952	1953	1944	1951	1952	1948
	30C				2047	2035	2031	2019	2015	2011	2007	2000	1992	1988	1977	1979	1972	1969	1965	1963	1960	1961	1961	1961	1956	1953	1950	1949
286	40C	2056	2054	2055		2046	2043	2036		2028	2027	2022	2010	2011	2001	1994		0	1983	1981	1967	1968	1967	1962	1942	1943	1940	1935
	30C				2052	2046	2046	2038	2035	2031	2030	2025	2017	2013	2004	2001	1998	1996	1989	1987	1981	1978	1975	1974	1958	1947	1944	1942
163	40C	2010	2011	2009		1995	1991	1984		1975	-0	1972	1964	1961	1955	1951		1941	1943	1940	1930	1925	1929	1927	1917	1918	1913	1909
	30C				2005	1999	1995	1985	1983	1981	1978	1974	1967	1965	1955	1957	1951	1949	1946	1944	1939	1939	1940	1933	1927	1919	1915	1918
190	40C	1991	1990	1990		1980	1973	1967		1961	1959	1956	1963	1952	1941	1938		1930	1932	1929	1920	1917	1920	1919	1908	1911	1908	1905
	30C				1988	1981	1979	1972	1970	1968	1965	1962	1956	1955	1944	1946	1941	1938	1936	1937	1930	1928	1930	1927	1921	1913	1911	1907
343	40C	2029	2028	2028		2017	2009	2002		1999	1994	1992	-0	1982	1976	1970		1960	1962	1958	1946	1944	1947	1944	1932	1934	1923	1924
	30C				2025	2016	2011	2004	2002	1999	1997	1992	1988	1986	1973	1979	1969	1968	1965	1964	1957	1956	1953	1952	1941	1934	1931	1929
170	40C	2135	2131	2129		2129	2127	2122		2125	2124	2124	2121	2118	2104	2101		2067	2082	2076	2059	2053	2053	2048	2021	2011	2003	1996
	30C				2131	2131	2130	2127	2126	2129	2127	2123	2117	2114	2100	2099	2090	2087	2078	2071	2067	2059	2055	2051	2032	2015	2007	2001
167	40C	2084	2081	2081		2068	2060	2051		2045	2041	2036	2030	2021	2013	2009		1994	2007	1994	1982	1979	1979	1976	1964	1967	1953	1940
	30C				2077	2069	2065	2055	2053	2047	2043	2036	2029	2026	2013	2015	2008	2007	2002	1998	1990	1988	1986	1980	1972	1964	1960	1957
168	40C	2101	2095	2089		2089	-0	2073		2063	2060	2054	2047	2047	2031	2027		2014	2015	2011	1998	1995	1995	1989	1974	1974	1962	1964
	30C				2094	2087	2084	2074	2070	2064	2061	2054	2049	2045	2031	2031	2025	2022	2016	2014	2006	2003	2002	1995	1986	1974	1971	1967
165	40C	2035	2036	2032		2027	2014	2014		2006	2000	1994	1992	1988	1979	1975		1964	1969	1966	1955	1949	1949	1948	1940	1932	1929	1929
	30C				2036	2027	2023	2018	2015	2010	2007	2002	1996	1993	1980	1984	1978	1976	1971	1970	1965	1959	1959	1956	1948	1940	1932	1931
188	40C	2026	2025	2029		2015	2011	2002		1997	1984	1988	0	1980	1974	1967		1960	1960	1958	1944	1949	1944	1941	1927	1931	1925	1922
	30C				2023	2014	2012	2002	2002	1997	1995	1989	1986	1985	1971	1974	1971	1967	1965	1961	1955	1954	1954	1950	1941	1932	1927	1928
169	40C	2115	2110	2112		2108	2108	2101		2103	2099	2094	2090	2082	2070	2059		2049	2046	2041	2023	2024	2001	2016	1993	1987	1979	1980
	30C				2113	2111	2110	2106	2105	2103	2098	2094	2085	2080	2066	2065	2055	2053	2047	2041	2033	2031	2026	2022	2005	1990	1987	1983
164	40C	2023	2025	2025		2010	2004	2000		1991	1989	1983	1982	1979	1968	1964		1955	1956	1953	1946	1947	1940	1939	1928	1928	1921	1920
	30C				2023	2012	2008	2000	1999	1996	1991	1988	1983	1980	1967	1967	1963	1962	1958	1956	1950	1950	1949	1944	1939	1932	1925	1924

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(a) Continued. U.S. customary units

		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES																										
		49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
RUN	SERIES	TEMPERATURES, DEGREES FAHRENHEIT																										
166	400	2063	2061	2061		2052	2045	2038		2031	2025	2022	2018	2011	2001	1999		1990	1988	1982	1972	1974	1971	1971	1951	1950	1941	1942
	300				2059	2052	-0	2042	2038	2033	2030	2024	2018	2013	2000	2003	1997	1995	1990	1988	1980	1979	1977	1974	1964	1952	1950	1947
158	400	2103	2102	2101		2088	2079	2071		2063	2055	2050	2045	2038	2029	2024		2012	2010	2007	1993	1995	1990	1985	1970	1971	1962	1960
	300				2097	2085	2083	2072	2068	2062	2058	2051	2045	2041	2025	2025	2021	2018	2014	2009	2002	2010	1998	1994	1981	1973	1965	1964
159	400	2112	2112	2110		2098	2091	2073		2068	2069	2059	2053	2043	2033	2029		2017	2017	2014	1999	2002	1998	1994	1978	1980	1972	1968
	300				2105	2093	2089	2077	2073	2066	2065	2059	2050	2044	2032	2033	2028	2024	2016	2013	2009	2005	2004	1999	1985	1981	1973	1971
342	400	2029	2029	2029		2016	2009	2000		1992	-0	1982	1971	1974	1967	1961		1954	1955	1952	1939	1943	1942	1936	1921	1924	1924	1922
	300				2024	2014	2012	2002	2000	1996	1994	1989	1983	1979	1967	1967	1965	1963	1959	1956	1951	1952	1946	1948	1933	1931	1927	1925
161	400	2148	2149	2148		2139	2134	2124		2119	2111	2106	2101	2089	2076	2070		-0	2049	2046	2042	2031	2027	2021	2009	2010	1999	1995
	300				2146	2144	2143	2140	2137	2135	2131	2126	2118	2111	2093	2093	2085	2078	2068	2064	2054	2052	2047	2043	2020	2011	2004	2002
160	400	2129	2127	2127		2117	2113	2103		2092	2086	2083	2077	2068	2057	2049		-0	2032	2029	2012	2015	2010	2004	1988	1986	1987	1975
	300				2125	2120	2118	2108	2103	2097	2093	2086	2077	2070	2057	2057	2052	2048	2039	2035	2030	2027	2024	2019	2000	1991	1986	1981
162	400	2170	2168	2167		2162	2158	2161		2148	2143	2136	2129	2118	2099	2102		2091	2081	2077	2059	2060	2053	2046	2029	2030	2015	2012
	300				2166	2164	2164	2160	2159	2158	2155	2148	2139	2136	2118	2114	2105	2111	2095	2087	2079	2073	2069	2064	2042	2031	2021	2019
344	400	2028	-0	2026		2013	2006	1998		1990	1986	1971	1967	1972	1965	1961		1948	1952	1949	1939	1938	1940	1937	1923	1927	1925	1921
	300				2022	2014	2011	2000	1997	1995	1992	1987	1979	1976	1966	1969	1962	1957	1955	1956	1948	1946	1944	1944	1936	1930	1923	1921
156	400	2052	2049	2047		2036	2028	2018		2011	2006	1999	1996	1991	1982	1977		1968	1968	1965	1954	1954	1952	1944	1935	1939	1934	1929
	300				2044	2034	2030	2018	2017	2013	2009	2003	1997	1996	1981	1982	1977	1975	1969	1967	1961	1960	1960	1955	1946	1939	1937	1931
157	400	2068	2067	2067		2055	2047	2037		-0	2022	2021	2014	2008	2000	1986		1985	1984	1979	1969	1967	1966	1965	1952	1954	1946	1943
	300				2062	2053	2047	2039	2037	2032	2029	2022	2013	2009	1999	2001	1994	1992	1986	1983	1978	1973	1974	1970	1960	1953	1948	1947
155	400	2029	2026	2027		2014	2005	1998		1991	1986	1982	1979	1974	1964	1959		1950	1952	1944	1939	1941	1939	1935	1923	1926	1921	1921
	300				2021	2010	2010	2002	1999	1994	1990	1985	1981	1978	1965	1967	1963	1960	1958	1954	1948	1947	1946	1944	1935	1928	1925	1924
189	400	1989	1992	1991		1980	1975	1969		1962	1956	1955	1945	1948	1942	1937		-0	1932	1929	1921	1921	1921	1918	1904	1909	1904	1906
	300				1989	1979	1979	1971	1969	1965	1962	1959	1955	1953	1941	1940	1941	1938	1935	1933	1926	1928	1927	1925	1916	1908	1907	1907
187	400	2029	2028	2028		2014	2007	1999		1991	1988	1985	1981	1973	1966	1962		1954	1955	1952	1938	1942	1940	1940	1925	1928	1925	1921
	300				2023	2014	2011	2001	1997	1994	1991	1988	1982	1978	1967	1969	1965	1964	1959	1955	1952	1950	1951	1947	1934	1931	1928	1925
253	400	2054	2052	2052		2040	2032	2024		-0	2010	2008	1992	1997	1983	1985		-0	1968	1967	1954	1958	1951	1946	1933	1933	1926	1925
	300				2049	2037	2033	2023	2021	2006	2013	2006	2001	1995	1985	1986	1981	1976	1971	1969	1962	1962	1960	1956	1944	1933	1934	1933
341	400	2081	2080	2079		2065	2057	2047		2036	2034	2028	2012	2014	2012	1999		1992	1990	1986	1972	1978	1976	1970	1957	1957	1952	1948
	300				2073	2061	2060	2048	2043	2040	2036	2032	2025	2020	2008	2006	2003	1999	1994	1991	1984	1985	1980	1978	1968	1962	1956	1953
352	400	1994	1990	1990		1978	1970	1961		1955	1949	1948	1949	1937	1931	1929		1916	1921	1919	1905	1909	1913	1906	1897	1899	1893	1893
	300				1987	1976	1975	1966	1962	-0	1955	1951	1944	1944	1932	-0	1929	1928	1927	1921	1917	1919	1916	1915	1908	1901	1896	1899
220	400	2087	2088	2086		2071	2059	2046		2035	2028	2022	2017	2005	2000	1995		1985	1983	1982	1970	1969	1965	1963	1953	1954	1951	1943
	300				2082	2065	2062	2046	2042	2037	2032	2026	2015	2014	1999	2000	1994	1991	1987	1983	1978	1975	1975	1970	1961	1952	1946	1949

221	40C	2092	2088	2089		2068	-0	2047		2032	2028	2018	2016	2006	1999	1994		1979	1981	1977	1968	1966	1965	1963	1947	1948	1946	1943
	30C				2080	2067	2062	2048	2044	2037	2032	2028	2017	2013	2000	1999	1996	1992	1986	1984	1975	1977	1975	1970	1961	1951	1951	1950
219	40C	2090	2090	2089		2068	2060	2045		2032	2030	2023	2015	2009	2003	1995		1982	1982	1978	1963	1968	1964	1963	1948	1947	1947	1941
	30C				2080	2066	2062	2049	2044	2036	2031	2027	2017	2012	2001	1998	1997	1989	1987	1983	1975	1977	1972	1970	1961	1952	1952	1946
224	40C	2087	2090	2087		2069	2056	2046		2034	2028	2021	2013	2003	1998	1992		1985	1979	1978	1967	1968	1968	1960	1947	1948	1947	1943
	30C				2081	2062	2062	2047	2043	2036	2030	2025	2015	2010	1999	1998	1995	1989	1985	1979	1975	1975	1971	1970	1956	1950	1950	1945
222	40C	2089	2089	2089		2069	2055	2048		2034	2030	2025	2019	2008	2002	1995		1985	1982	1979	1970	1968	1967	1964	1940	1950	1945	1944
	30C				2081	2067	2063	2050	2047	2038	2034	2027	2021	2013	2000	2001	1998	1992	1989	1985	1978	1978	1976	1970	1962	1950	1950	1949
250	40C	2093	2090	2091		2069	2057	2047		2034	2027	2022	2014	2009	1999	1994		-0	1984	1979	1967	1964	1967	-0	1951	1951	1948	1944
	30C				2081	2066	2060	2050	2042	2037	2033	2027	2017	2013	2001	2002	1995	1991	1987	1984	1979	1976	1976	1971	1959	1953	1952	1948
223	40C	2090	2090	2090		2067	2060	2050		2036	2033	2027	2022	2013	2007	1999		1990	1990	1982	1974	1972	1971	1967	1955	1955	1947	1945
	30C				2082	-0	2061	2053	2047	2041	2038	2031	2024	2020	2006	2007	2000	1998	1992	1990	1982	1980	1979	1975	1963	1957	1952	1952
225	40C	2090	2091	2090		2069	2059	2049		2041	2034	2027	2021	2015	2003	2002		1991	1989	1985	1972	1973	1968	1966	1952	1956	1945	1946
	30C				2081	2068	2062	2053	2046	2041	2037	2032	2022	2019	2003	2006	1999	1997	1991	1989	1980	1979	1978	1975	1963	1956	1952	1950
226	40C	2086	2087	2087		2068	2061	2046		2046	2033	2027	2021	2015	2007	2001		1989	1989	1987	1974	1970	1972	1966	1956	1955	1948	1945
	30C				2081	2068	2063	2053	2049	2042	2038	2032	2026	2020	2008	2007	2002	1998	1995	1990	1984	1983	1980	1978	1964	1958	1954	1953
227	40C	2091	2089	2089		2070	2062	2049		2050	2033	2029	2014	2016	2006	2004		1991	1991	1987	1976	1971	1971	1968	1956	1956	1949	1948
	30C				2082	2070	2064	2053	2048	2045	2041	2034	2025	2021	2010	2008	2002	1999	1993	1992	1983	1982	1978	1976	1966	1958	1956	1950
228	40C	2091	2087	2084		2070	2062	2054		2044	2041	2034	2029	2022	2014	2013		2001	2000	1993	1983	1982	1979	1975	1962	1958	1952	1951
	30C				2087	2067	2066	-0	2051	2045	2040	2035	2028	2022	2010	2009	2005	2000	1996	1994	1984	1984	1982	1978	1970	1962	1957	1955
229	400	2090	2089	2089		2069	2060	2049		2037	2032	2027	2022	2017	2010	2008		2005	2013	2007	2004	-0	2006	2008	1992	1987	1988	1983
	30C				2083	2067	2063	2052	2046	2040	2035	2029	2024	2021	2011	2013	2012	2013	2012	2013	2006	2009	2010	2009	2002	1988	1990	1986
231	40C	2091	2089	2088		2070	2061	2051		2038	2033	2027	-0	2018	2013	2013		-0	2012	2011	2004	2007	2009	2008	1993	1999	1990	1990
	30C				2083	2069	2063	2052	2045	2041	2038	2033	2025	2026	2013	2017	2015	2018	2016	2019	2016	2015	2017	2017	2006	2001	1994	1988
340	40C	2081	2080	2078		2062	2053	2041		2029	2026	2021	2005	2007	1999	1996		-0	1985	1979	1970	1967	1968	1965	1951	1956	1952	1948
	30C				2072	2059	2052	2041	2036	2033	2029	2022	2013	2010	2000	2000	1994	1994	1988	1988	1981	1980	1976	1975	1965	1960	1955	1953
289	40C	2055	2053	2053		2034	2024	2016		2006	2009	1995	1986	1985	1976	1976		1965	-0	1960	1952	1952	1952	1948	1935	1938	1937	1936
	30C				-0	2034	2030	2020	2013	2008	2005	2000	1996	1990	1977	1979	1976	1973	1969	1968	1960	1961	1959	1958	1948	1938	1940	1940
230	40C	2093	2088	2089		2069	2060	2049		2037	2031	-0	2021	2012	2011	2008		2002	2008	2017	2002	2002	2006	2005	1995	2001	1994	1991
	30C				2082	2069	2063	2052	2047	2043	2040	2032	2027	2025	2013	2018	2013	2017	2016	2019	2015	2015	2017	2016	2007	2001	1995	1991
218	40C	2079	2077	2078		2074	2068	2061		2055	2055	2045	2039	2030	2022	2018		2003	2014	2002	1992	1995	1995	2006	1987	1993	1992	1988
	30C				2078	2077	2077	2067	2064	2061	2055	2048	2040	2038	2024	2023	2016	2013	2009	2008	2002	2004	2004	2003	2001	1994	1996	1990
217	40C	2080	2079	2077		2063	2053	2044		2036	2031	2026	2017	2012	2006	2004		1996	1991	1986	1978	1978	1982	1984	1978	1984	1981	1978
	30C				2072	2063	2057	2047	2045	2041	2038	2031	2024	2021	2008	2009	2004	1999	1996	1996	1991	1994	1995	1992	1990	1986	1983	1978
215	40C	2135	2132	2131		2116	2107	2095		2082	2076	2069	2059	2052	2048	2040		2028	2025	2021	2009	2011	2014	2015	2008	2011	2008	2008
	30C				2126	2113	2112	2098	2092	2083	2078	2070	2063	2058	2043	2045	2039	2034	2029	2024	2020	2022	2024	2023	2019	2017	2022	2011
214	40C	2133	2131	2131		2129	2129	2124		2124	2119	2119	2115	2110	2115	2099		-0	2083	2077	2065	2063	2059	2056	2034	2035	2023	2019
	30C				2131	2133	2133	2129	2126	2125	2123	2119	2114	2110	2097	2098	2090	2087	2081	2077	2072	2067	2064	2059	2044	2036	2026	2023
212	40C	2122	2122	2120		2115	2111	2104		2094	2090	2050	2078	2075	2063	2058		2048	-0	2039	2024	2029	2024	2024	2007	2011	2004	1998
	30C				2118	2119	2119	2114	2109	2108	2103	2098	2089	2084	2071	2071	2065	2062	2056	2050	2046	2044	2037	2035	2019	2014	2008	2003
213	40C	2121	2122	2120		2112	2109	2100		2092	2089	2085	2080	2073	2062	2061		2049	2049	2043	2034	2033	2029	-0	2011	2014	2005	1997
	30C				2119	2118	2116	2110	2108	2106	2104	2098	2090	2083	2067	2070	2062	2060	2053	2051	2046	2040	2038	2033	2022	2016	2007	2004
210	40C	2109	2108	2105		2102	2099	2091		2085	2082	2079	2072	2062	2056	2053		2038	2041	2036	2023	2020	2021	-0	2001	2000	1993	1988
	30C				2107	2106	2104	2096	2095	2092	2089	2083	2074	2071	2059	2059	2053	2050	2046	2043	2037	2034	2030	2027	2012	2002	1997	1993
211	40C	2111	2107	2106		2095	2088	2082		2077	2071	2066	2063	2056	2049	2045		2033	2034	-0	2016	2016	2014	2010	1996	1998	1990	1987
	30C				2104	2097	2098	2091	2089	2084	2080	2074	2069	2065	2051	2051	2047	2043	2039	2033	2027	2025	2024	2020	2006	1998	1989	1994

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(a) Concluded. U.S. customary units

DISTANCE FROM CENTER-LINE OF SHELL OUTLET, INCHES

TEMPERATURES, DEGREES FAHRENHEIT

RUN	SERIES	49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
209	400	2034	2081	2032		2067	2061	2053		-0	2041	2039	2035	2029	2020	2018		2009	2008	2004	1992	1992	1992	1990	1976	1979	1970	1971
	300				2077	2066	2065	2057	2054	2050	2047	2043	2039	2034	2021	2024	2017	2017	2011	2008	2003	2001	2000	1996	1988	1980	1976	1974
216	400	2056	2054	2055		2042	2038	2030		2024	2022	2017	2012	2009	2002	1937		1990	1991	1986	1975	1976	1974	1969	-0	1958	1958	1956
	300				2051	2044	2040	2031	2029	2026	2023	2021	2016	2012	2001	2004	2000	1998	1993	1994	1986	1987	1984	1981	1973	1964	1963	1960
204	400	2189	2188	2138		2162	2185	2172		2164	2159	2168	2145	2134	2124	2118		-0	2098	2096	2078	2080	2073	2063	2058	2054	2044	2038
	300				2188	2185	2182	2178	2174	2171	2166	2161	2152	2147	2128	2127	2117	2112	2106	2101	2092	2089	2086	2079	2064	2057	2048	2044
208	400	2154	2152	2152		2137	2130	2120		2109	2100	2098	2093	2084	2074	2069		2057	2055	2049	2037	2035	2034	2029	2014	2016	2004	2004
	300				2146	2136	2133	2124	2119	2114	2110	2103	2096	2090	2075	2076	2067	2064	2058	2054	2048	2045	2041	2036	2023	2016	2010	2008
200	400	2096	2093	2092		2079	2072	2063		2056	2052	2048	2043	2036	2028	2022		2011	2013	2010	1997	1998	1996	1993	1980	1978	1975	1972
	300				2088	2077	2073	2064	2062	2057	2053	2049	2037	2040	2026	2027	2022	2020	2016	2014	2007	2006	2006	2001	1992	1986	1981	1979
203	400	2171	2169	2169		2157	2147	2141		2130	2124	2118	2112	2104	2092	2086		2091	2069	2067	2052	2054	2049	2044	2028	2028	2017	2015
	300				2166	2155	2156	2144	2140	2133	2129	2123	2115	2109	2093	2091	2087	2081	2077	2070	2063	2061	2059	2054	2039	2031	2022	2022
205	400	2180	2179	2179		2169	2164	2155		2145	2138	2133	2124	2115	2105	2101		2083	2069	2080	2062	2062	2062	2054	2039	2038	2027	2022
	300				2175	2170	2168	2162	2157	2154	2147	2140	2131	2124	2108	2105	2098	2093	2087	2081	2074	2072	2067	2061	2049	2039	2031	2029
201	400	2120	2119	2118		2101	2094	2086		2074	2066	2065	2060	2053	2044	2041		2022	2027	2023	2012	2009	2009	2006	1994	1996	1986	1986
	300				2112	2101	2096	2087	2082	2078	2074	2068	2062	2057	2044	2046	2039	2036	2031	2029	2022	2021	2018	2015	2004	1996	1992	1991
202	400	2154	2151	2151		2134	2125	2117		2113	2098	2095	2091	2082	2072	2067		-0	2054	2050	2036	2034	2032	2028	2012	2013	2002	2001
	300				2144	2131	2129	2118	2113	2108	2103	2096	2090	2084	2069	2071	2063	2060	2055	2050	2044	2041	2039	2035	2021	2014	2008	2007
207	400	2152	2150	2149		2134	2125	2114		2110	2099	2091	2085	2078	2069	2064		-0	2052	2048	2034	2035	2030	2027	2013	2013	2005	2002
	300				2145	2134	2129	2118	2115	2109	2105	2099	2091	2087	2072	2071	2064	2061	2056	2052	2044	2042	2040	2035	2023	2014	2007	2007
199	400	2063	2061	2060		2047	2040	2033		2027	2016	2021	2016	2010	2002	1998		1992	1994	1984	1976	1974	1976	1974	1961	1963	1958	1958
	300				2055	2045	2042	2034	2032	2027	2024	2020	2016	2013	2000	2003	1996	1996	1993	1990	1985	1983	1982	1980	1971	1965	1963	1962
195	400	2060	2060	2057		2044	2039	2029		-0	2017	2015	1998	2003	1997	1994		1985	-0	1983	1974	1973	1974	1973	1961	1965	1961	1959
	300				2055	2046	-0	2032	2030	2026	2024	2020	2011	2010	1998	2001	1996	1992	1991	1990	1985	1982	1982	1980	1972	1966	1964	1963
196	400	2101	2099	2098		2083	2075	2065		2054	2046	2045	2041	2033	2025	2019		2013	2013	2007	1995	1999	1998	1994	1979	1982	1980	1978
	300				2091	2079	2076	2066	2061	2056	2051	2047	2041	2035	2024	2024	2020	2017	2013	2011	2006	2004	2003	2000	1991	1985	1983	1967
198	400	2163	2160	2160		2140	2127	2119		2106	2096	2090	2086	2072	2067	2060		2050	2059	2043	2029	2032	2028	2024	2009	2012	2002	2002
	300				2151	2136	2132	2119	2113	2107	2102	2095	2087	2082	2066	2066	2061	2058	2053	2048	2042	2040	2039	2034	2021	2015	2009	2010
197	400	2130	2129	2128		2111	2102	2092		2079	2074	2069	2064	2055	2044	2039		2030	2030	2026	2011	2015	2011	2008	1994	1995	1993	1989
	300				2123	2104	2105	2093	2088	2083	2078	2073	2065	2058	2047	2046	2042	2037	2033	2030	2023	2022	2021	2017	2007	1999	1997	1993
338	400	2158	2155	2156		2141	2132	2122		2111	2110	2105	2089	2091	2082	2079		2072	2073	2068	2056	2061	2063	2063	2054	2054	2058	2054
	300				2152	2140	2136	2124	2121	2116	2113	2108	2101	2095	2084	2086	2083	2082	2074	2074	2067	2072	2069	-0	2066	2060	2061	2056

337	400	2174	2172	2172		2156	2147	2136		2124	2122	2116	2101	2104	2000	2090		2079	2082	2079	2067	2068	2070	2072	2064	2068	2068	2063
	300				2167	2155	-0	2138	2134	2129	2126	2120	2113	2111	2096	2096	2090	2092	2086	2084	2078	2080	2079	2078	2075	2070	2070	2067
339	400	2142	2142	2145		2126	2119	2109		2102	2098	2092	2080	2082	2074	2071		2061	2065	2060	2052	2053	2055	2052	2044	2050	2051	2048
	300				2136	2126	2121	2114	2109	2105	2102	2095	2091	2087	2074	2077	2072	2070	2066	2066	2060	2063	2062	2061	2058	2051	2055	2050
336	400	2174	2174	2173		2158	2151	2144		2132	2131	2125	2114	2116	2108	2102		2101	2093	2089	2077	2078	2075	2071	2059	2058	2055	2050
	300				2168	2160	2155	2144	2140	2137	2134	2131	2125	2121	2106	2106	2105	2104	2097	2095	2085	2087	2083	2081	2071	2062	2059	2055
334	400	2150	2150	2148		2137	2130	2121		2114	2111	2110	2095	2097	2088	2087		-0	2078	2074	2064	2064	2063	2059	2047	2050	2046	2042
	300				2144	2136	2133	2123	-0	2119	2117	2112	2106	2105	2090	2092	2087	2085	2082	2080	2073	2072	2069	2067	2057	2051	2045	2042
335	400	2152	2148	2148		2132	2125	2117		2107	2104	2100	2087	2088	2080	2077		2073	2070	2068	2057	2062	2068	2063	2053	2056	2052	2055
	300				2142	2131	2128	2118	2114	2109	2105	2102	2096	2091	2080	2080	2078	2076	2073	2073	2069	2072	2070	2072	2068	2064	2062	2058
332	400	2132	2131	2131		2122	2115	2105		-0	2096	2094	2083	2084	2076	2074		2067	2068	2065	2054	2055	2054	2050	2036	2041	2037	2034
	300				2128	2121	2119	2109	2106	2104	2103	2098	2092	2087	2077	2082	2078	2075	2071	2070	2064	2064	2061	2059	2046	2044	2040	2038
333	400	2134	2132	2131		2123	2117	2108		2101	2095	2102	2083	2089	2076	2075		2066	2064	2063	2054	2053	2051	2050	2038	2044	2037	2033
	300				2128	2122	2119	2111	2108	2106	2105	2099	2093	2090	2077	2081	2076	2072	2069	2068	2063	2061	2060	2057	2049	2043	2038	2036
331	400	2105	2105	2105		2095	2087	2081		2074	2072	2069	2058	2061	2055	2053		2045	2046	2044	2035	2035	2036	2033	2021	2025	2023	2020
	300				2101	2095	2089	2083	2081	2078	2077	2071	2068	2066	2054	2057	2053	2051	2050	2050	2043	2044	2041	2041	2034	2027	2027	2025
329	400	2147	2142	2143		2130	2131	2113		2104	2099	2102	2084	2084	2078	2077		2064	-0	2063	2051	2056	2052	2048	2039	2044	2040	2035
	300				2137	2128	2127	2115	2112	2109	2106	2099	2095	2093	2078	2081	2079	2074	2071	2070	2063	2063	2060	2059	2048	2043	2043	2039
330	400	2010	2001	2006		2005	2000	1996		1996	1960	1996	1987	1996	1991	1989		1983	-0	1989	1979	1983	1986	1985	1977	1981	1983	1980
	300				2006	2005	2003	2002	2003	2001	2001	2000	1997	1998	1989	1993	1994	1992	1995	1994	1990	1991	1991	1990	1986	1982	-0	1984
328	400	2133	2129	2130		2116	2110	2104		2093	2092	2088	2075	2076	2070	2066		2056	2056	2055	2042	2046	2046	2042	2030	2032	2033	2029
	300				2126	2116	2114	2104	2102	2097	2094	2092	2087	2082	2069	2072	2070	2065	2062	2063	2056	2055	2053	2052	2043	2038	2036	2033
327	400	2121	2120	2119		2103	2097	2086		2080	2074	2068	2058	2060	2050	2048		-0	2040	2037	2025	2024	2027	2024	2012	2015	2013	2009
	300				2114	2105	2100	2092	2089	2085	2080	2073	2071	2066	2052	2057	2050	2047	2054	2046	2037	2037	2035	2032	2022	2017	2016	2012

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(b) SI units

DISTANCE FROM CENTER-LINE OF SHELL OUTLET, CENTIMETERS

TEMPERATURES, DEGREES KELVIN

RUN	SERIES	126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
85	400	1322	1321	1321		1321	1321	1316		1315	1310	0	1300	1298	1294	1292		-0	1264	1283	1279	1279	1283	1283	1278	1281	1281	1279
	300				1323	1323	1321	1318	1316	1314	1312	1307	1302	1301	1294	1296	1290	1289	1286	1287	1286	1286	1285	1285	1284	1282	1282	1280
82	400	1330	1329	1328		1328	1324	1318		1313	1311	0	1304	1299	1296	1293		1286	-0	1285	1288	1281	1284	1284	1279	1282	1282	1281
	300				1329	1328	1326	1319	1317	1314	1312	1308	1303	1302	1296	1296	1290	1291	1290	1288	1285	1287	1287	1288	1285	1282	1283	1283
115	400	1325	1324	1324		1323	1324	1322		1323	1324	1324	-0	1322	1313	1316		-0	1310	1307	1302	1300	1299	1297	1287	1286	1280	1279
	300				1325	1325	1325	1325	1324	1324	1325	1324	1321	1322	1315	1318	1315	1316	1311	1309	1306	1305	1302	1300	1293	1286	1281	1279
83	400	1332	1331	1332		1325	1321	1317		1309	1307	1305	1296	1296	1293	1291		1284	1285	1285	1280	1281	1283	1284	1278	1280	1281	1280
	300				1329	1326	1323	1316	1313	1312	1309	1305	1300	1300	1293	1293	1289	1289	1286	1286	1284	1285	1285	1285	1284	1283	1281	1279
84	400	1338	1337	1336		1330	1326	1318		1312	1310	1307	1303	1303	1295	0		1286	0	1286	1281	1283	1285	1283	1281	1283	1282	1281
	300				1334	1328	1327	1319	1317	1314	1312	1308	1304	1302	1295	1296	1293	1291	1290	1289	1287	1288	1288	1288	1286	1284	1284	1283
74	400	1325	1325	1326		1317	1311	1305		1300	1296	1295	1291	1288	1283	1281		1277	1281	1275	1269	1272	1275	1274	1269	1271	1270	1272
	300				1322	1313	1312	1306	1305	1301	1298	1295	1292	1291	1284	1285	1281	1280	1279	1278	1277	1276	1277	1277	1275	1275	1274	1273
113	400	1309	1306	1307		1302	1298	1295		1292	1290	1289	1288	1284	1281	1279		1276	1275	1273	1267	1269	1268	1266	0	1261	1256	1258
	300				1306	1302	1302	1297	1297	1295	1292	1291	1289	1287	1280	1283	1280	1278	1277	1276	0	1272	1272	1270	1265	1263	1260	1258
112	400	1306	1306	1306		1301	1300	1296		1294	1292	1290	1289	0	1281	1279		1276	-0	1274	1268	1268	1268	1268	1260	1259	1259	1257
	300				1306	1305	1304	1301	1300	1298	1295	1295	1291	1287	1284	1285	1281	1280	1278	1276	1274	1273	1273	1270	1266	1263	1260	1259
114	400	1314	1312	1313		1308	1307	1303		1299	1299	1298	1294	0	1287	1286		1279	1280	1279	1275	1274	1273	1272	1265	1265	1263	1262
	300				1312	1309	1307	1302	1303	1300	1298	1297	1295	1291	1286	1289	1284	1284	1282	1281	1277	1277	1278	1274	1271	1267	1263	1262
50	400	1350	1348	1349	1345	1347	1344	1342		1340	1337	1334	1332	1329	1325	1321		1313	1313	1312	1305	1304	1303	1301	1294	1296	1288	1287
	300				1348	1348	1348	1347	1346	1344	1342	1340	1333	1333	1326	1327	1325	1323	1318	1316	1312	1312	1310	1307	1298	1294	1292	1290
49	400	1349	1348	1347	1344	1347	1346	1345		1344	1343	0	1339	1334	1328	1325		-0	1318	1316	1309	1309	1308	1305	1298	1293	1290	1288
	300				1349	1348	1348	1346	1346	1344	1343	1340	1336	1333	1328	1329	1325	1323	1319	1317	1313	1313	1310	1308	1302	1294	1293	1291
73	400	1327	1327	1326	1319	1320	1317	1312		1307	1305	1304	1300	1297	1292	1291		1285	1286	1285	1279	1279	1277	1275	1269	1272	1269	1267
	300				1324	1319	1320	1316	1313	1311	1309	1306	1301	1300	1294	1296	1292	1290	1287	1286	1283	1282	1281	1280	1275	1272	1268	1268
46	400	1349	1347	1347	1344	1346	1344	1340		1338	1336	1333	1331	1327	1323	1318		-0	1312	1310	1302	1302	1301	1299	1291	1289	1285	1284
	300				1348	1347	1347	1344	1344	1342	1340	1337	1333	1331	1323	1324	1319	1319	1314	1313	1308	1307	1304	1303	1296	1290	1288	1286
72	400	1328	1327	1326	1321	1320	1319	1315		1312	1310	1309	1305	1301	1297	1296		1291	1290	1287	1282	1283	1282	1280	1271	1270	1268	1268
	300				1326	1322	1321	1318	1315	1315	1313	1311	1306	1303	1296	1298	1296	1295	1290	1288	1286	1283	0	1284	1276	1273	1269	1268
44	400	1348	1347	1346	1342	1345	1342	1338		1333	1330	0	1325	1322	1317	1315		1309	1308	1306	1301	1300	1299	1295	1289	1288	1284	1281
	300				1347	1344	1343	1337	1334	0	1331	1329	1324	1323	1315	1316	1314	1311	1308	1307	1304	1303	1300	1300	1293	1289	1285	1282
111	400	1358	1359	1357		1354	1352	1346		1343	1340	1337	1337	1329	1323	1322		1316	1316	1313	1307	1306	1305	1303	1294	1295	1290	1287
	300				1357	1355	1352	1348	1347	1344	1342	1339	1334	1331	1324	1326	1320	1320	1316	1314	1310	1309	1309	1304	1299	1296	1291	1288
108	400	1355	1355	1354		1351	1347	1343		1338	1335	1335	1328	1324	1313	1317		1309	1310	1308	1302	1300	1299	1296	1290	1290	1284	1284
	300				1353	1352	1351	1349	1348	1346	1344	1340	1336	1335	1326	1326	1322	1320	1316	1314	1310	1309	1306	1305	1296	1291	1289	1287

71	400	1325	1326	1325	1318	1317	1314	1309		1307	1304	1302	1300	1296	1291	1291		1287	1286	1283	1277	1278	1277	1274	1269	1269	1266	1266
	300				1323	1319	1318	1314	1311	1310	1307	1305	1303	1300	1293	1295	1291	1289	1287	1285	1281	1281	1280	1278	0	1271	1268	1267
107	400	1347	1347	1346		1339	1336	1331		1328	1325	1324	1311	1315	1310	1308		1303	1301	1299	1294	1293	1292	1291	1285	1287	1282	1281
	300				1344	1339	1337	1332	1329	1329	1326	1323	1319	1317	1311	1312	1309	1307	1304	1304	1301	1298	1297	1296	1290	1287	1281	1281
106	400	1315	1314	1313		1307	1304	1299		1295	1294	1293	1291	1286	1283	1286		-0	1276	1275	1270	1268	1269	1271	1261	1263	1261	1260
	300				1311	1306	1304	1300	1299	1297	1296	1293	1289	1288	1283	1283	1280	1280	1277	1277	1274	1272	1272	1271	1268	1264	1263	1261
110	400	1354	1353	1353		1345	1341	1335		1331	1327	1325	1323	1319	1315	1313		1307	-0	1304	1297	1298	1297	1294	1289	1289	1283	1285
	300				1350	1344	1344	1338	1337	1335	1331	1329	1327	1325	1316	1318	1315	1313	1311	1309	1305	1303	1302	1299	1293	1290	1286	1286
109	400	1359	1359	1358		1346	1340	1334		1325	1321	1321	1315	1310	1304	1302		-0	1297	1297	1291	1293	1296	1295	1289	1293	1293	1292
	300				1352	1344	1341	1333	1330	1327	1325	1321	1317	1315	1307	1308	1304	1302	1299	1298	1295	1298	1298	1299	1296	1296	1295	1293
33	400	1348	1347	1346	1341	1340	1337	1332		1327	1325	1322	1320	1316	1313	1308		1304	1304	1302	1295	1297	1296	1293	1291	1285	1282	1280
	300				1345	1339	1337	1331	1329	1325	1325	1321	1317	1316	1309	-0	1308	1307	1304	1302	1300	1298	1296	1295	1287	1285	1282	1280
21	400	1332	1330	1330	1328	1325	1323	1320		1317	1316	1314	0	1309	1304	1300		1296	1296	1295	1287	1288	1287	1285	1278	1277	1274	1273
	300				1330	1324	1324	1320	1319	1315	1315	1313	1309	1309	1302	1301	1301	1300	1296	1294	1292	1290	1289	1289	1282	1278	1276	1275
70	400	1327	1326	1325	1319	1315	1312	1308		1303	1300	1298	1295	1292	1290	-0		1282	1280	1279	1274	1272	1274	1272	1266	1267	1264	1263
	300				1323	1316	1309	1310	1307	1304	1304	1301	1297	1296	1288	1289	1287	1286	1283	1283	1278	1277	1278	1276	1271	1268	1267	1265
6	400	1350	1349	1349	1341	1338	1331	1326		1320	1316	1313	1311	1308	1302	1301		1295	1298	1296	1290	1292	1294	1294	1291	1290	1291	1290
	300				1345	1335	1334	1328	1324	1322	1323	1315	1313	1310	1302	1304	1299	1300	1298	1297	1296	1294	1297	1297	1294	1293	1291	1291
5	400	1347	1347	1346	1338	1336	1330	1323		1318	1314	1311	1302	1305	1302	1300		1301	1295	1295	1289	1291	1294	1291	1291	1290	1289	1289
	300				1341	1332	1332	1323	1322	1319	1315	1313	1310	1308	1299	1301	1299	1297	1296	1296	1294	1295	1295	1295	1292	1291	1290	1290
41	400	1348	1347	1347	1341	1340	1335	1331		1325	1323	1321	1318	1311	1312	1308		1301	1303	1300	1293	1293	1294	-0	1283	1284	1279	1278
	300				1345	1338	1336	1331	1330	1326	1325	1323	1320	1317	1310	1311	1307	1306	1305	1304	1299	1298	1298	1295	1288	-0	1282	1281
32	400	1347	1346	1346	1340	1338	1333	1328		1325	1321	1319	1317	1314	-0	1307		1301	1301	1299	1292	1292	1292	1291	1285	1284	1282	1279
	300				1344	1337	1334	1329	1328	1325	1323	1321	1317	1316	1308	1308	1306	1304	1302	1300	1296	1295	1294	1293	1287	1283	1282	1280
62	400	1414	1413	1412	1407	1410	1410	1406		1405	1403	1401	1396	1391	1384	1382		1373	1370	1366	1360	1358	1354	1350	1342	1341	1332	1330
	300				1412	1411	1411	1408	1406	1407	1406	1402	1397	1395	1385	1386	1381	1379	1373	1369	1367	1362	1360	1357	1347	1341	1335	1333
9	400	1346	1344	1344	1337	1335	1330	1323		1317	1315	1313	1306	1306	1302	1300		1295	1294	1295	1288	1291	1294	1292	1289	1289	1291	1288
	300				1341	1332	1331	1324	1322	1318	1317	1313	1311	1308	1301	1303	1300	1300	1296	1295	1295	1296	1296	1296	1294	1290	1292	1289
60	400	1403	1401	1402	1396	1397	1395	1385		1387	1381	1378	1375	1369	1364	1362		1352	1351	1348	1340	1341	1337	1334	1327	1325	1318	1317
	300				1400	1396	1396	1391	1388	1384	1383	1378	1373	1371	1361	1362	1358	1355	1351	1349	1345	1341	1342	1339	1330	1326	1320	1320
61	400	1409	1406	1407	1403	1403	1402	1399		1395	1392	1389	1384	1378	1372	1369		1359	1358	1355	1347	1347	1344	1341	1332	1333	1324	1322
	300				1406	1403	1404	1400	1399	1396	1393	1389	1385	1382	1372	1372	1369	1365	1360	1358	1354	1351	1349	1347	1336	1332	1328	1326
24	400	1347	1345	1345	1336	1340	1336	1333		1329	1326	1324	1324	1321	1316	1317		-0	1314	1313	1310	1313	1315	1313	1308	1308	1306	1305
	300				1343	1337	1336	1331	1330	1326	1326	1323	1321	1319	1314	1317	1316	1316	1317	1319	1315	1318	1317	1318	1313	1309	1309	1308
69	400	1325	1325	1325	1318	1315	1312	1307		1303	1298	1297	1295	1292	1287	1285		1282	1280	1278	1273	1273	1273	1270	1266	1266	1264	1264
	300				1322	1315	1313	1307	1306	1304	1300	1297	1296	1294	1286	1288	1285	1283	1282	1280	1276	1276	1277	1274	1270	1267	1265	1266
68	400	1302	1301	1301	1296	1292	1293	1287		1284	1282	1282	1278	1277	1271	1271		1265	1270	1268	1263	1264	1264	1262	1259	1258	1255	1257
	300				1299	1293	1293	1290	1287	1285	1284	1282	1281	1278	1273	1275	1272	1273	1270	1270	1267	1266	1268	1265	1262	1260	1258	1259
59	400	1398	1396	1396	1390	1391	1388	1380		1376	1370	1369	1364	1360	1354	1352		1340	1343	1341	1332	1332	1331	1331	1319	1320	1314	1311
	300				1395	1391	1391	1387	1384	1381	1378	1375	1368	1367	1358	1357	1354	1351	1346	1344	1341	1339	1336	1335	1324	1320	1317	1314
58	400	1391	1389	1389	1383	1380	1376	1371		1365	1364	1357	1354	0	1345	1341		1332	1333	1331	1323	1323	1320	1320	1313	1314	1307	1306
	300				1387	1381	1381	1374	1371	1367	1365	1360	1356	1355	1344	1347	1342	1340	1337	1336	1331	1329	1328	1325	1317	1315	1309	1309
104	400	1413	1411	1411		1406	1403	1401		1396	1393	1389	1385	1380	1375	1370		-0	1362	1359	1349	1351	1348	1345	1337	1336	1329	1328
	300				1410	1408	1402	1403	1402	1399	1396	1393	1387	1384	1376	1376	1371	1369	1365	1362	1358	1356	1354	1351	1342	1337	1333	1330
8	400	1390	1388	1387	1380	1379	1373	1370		1363	0	1356	1353	1349	1343	1343		1339	-0	1338	1334	1336	1338	1337	1333	1331	1332	1330
	300				1384	1380	1376	1372	1369	1367	1364	1362	1357	1354	1346	1349	1345	1347	1343	1344	1341	1342	1343	1342	1339	1332	1335	1333

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(b) Continued. SI units

RUN	SERIES	126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, CENTIMETERS																										
		TEMPERATURES, DEGREES KELVIN																										
63	400	1381	1379	1379	1373	1373	1368	1364		1358	1356	1352	1348	1343	1339	1334		1329	1328	1326	1319	1319	1318	1315	1305	1303	1302	1299
	300				1377	1369	1367	1361	1358	1354	1353	1350	1345	1343	1336	0	1334	1331	1327	1326	1324	1321	1320	1319	1312	1305	1305	1302
66	400	1297	1296	1296	1290	1290	1284	1280		1277	1276	1275	1272	1270	1267	0		1266	1263	1261	1257	1257	1257	1256	1252	1252	1251	1251
	300				1294	1288	1287	1284	1281	1280	1277	1276	1275	1272	1267	1268	1266	1266	1264	1264	1262	1260	1261	1260	1257	1254	1253	1252
103	400	1400	1399	1399		1394	1391	1386		1381	1377	1374	1370	1365	1360	1358		-0	1349	1345	1339	1339	1336	1334	1324	1324	1318	1315
	300				1397	1395	1393	1386	1384	1381	1379	1375	0	1367	1358	1360	1355	1353	1349	1347	1344	1341	1340	1338	1330	1325	1320	1319
105	400	1426	1425	1425		1421	1421	1419		1419	-0	1416	1413	1408	1400	1397		1389	1386	1383	1373	1373	1370	1366	1358	1357	1344	1344
	300				1425	1423	1423	1422	1422	1421	1420	1417	1414	1410	1401	1401	1396	1392	1387	1382	1379	1376	1374	1370	1361	1355	1349	1347
25	400	1346	1345	1346	1338	1338	1335	1331		1328	1323	1323	1320	1320	1313	1314		1309	1311	1312	1307	1310	1313	1311	1307	1308	1306	1305
	300				1341	1334	1333	1327	1326	1322	1321	1318	1315	1313	1309	1308	1310	1307	1310	1308	1307	1308	0	1310	1311	1309	1307	1307
102	400	1394	1392	1392		1383	1378	1372		1365	0	1359	1357	1352	1347	1343		1336	1335	1334	1325	1327	1324	1321	1316	1314	1310	1309
	300				1389	1382	1379	1373	1370	1367	1364	1361	1357	1354	1346	1346	1340	1340	1336	1333	1330	1328	1327	1324	1313	1316	1312	1311
78	400	1327	1326	1325		1316	1312	1305		1301	1296	1294	1293	1290	-0	1281		1279	1278	1278	1273	1275	1277	1275	1272	1273	1271	1272
	300				1322	1312	1312	1307	1304	1300	1299	1297	1293	1290	1285	1286	1283	1282	1281	1281	1277	1278	1280	1280	1276	1274	1274	1274
65	400	1333	1332	1331	1326	1324	1322	1315		1311	1307	1305	1302	1299	1295	1291		1283	1287	-0	1279	1278	1278	1277	1271	1272	1270	1269
	300				1329	1323	1320	1315	1313	1310	1308	1304	1303	1301	1295	1294	1290	1291	1288	1288	1283	1284	1283	1282	1278	1272	1272	1270
56	400	1371	1370	1370	1363	1363	1356	1350		1346	1344	1340	1337	1333	1329	1326		1317	1318	1317	1310	1309	1309	1307	1299	1297	1292	1292
	300				1367	1359	1356	1351	1348	1346	1343	1340	1336	1334	1326	1326	1324	1322	1318	1316	1313	1312	1310	1308	1303	1299	1297	1293
57	400	1384	1383	1384	1377	1377	1372	1368		1362	1360	1355	1353	1348	1343	1338		1330	1330	1329	1322	1322	1319	1316	1307	1308	1301	1300
	300				1381	1376	1374	1367	1365	1363	1359	1355	1350	1348	1341	1340	1336	1336	1332	1329	1325	1324	1323	1321	1312	1307	1305	1304
19	400	1334	1333	1333	1327	1325	1320	1316		1311	1311	1309	1305	0	1297	1296		1290	1292	1289	1283	1283	1283	1280	1276	1276	1272	1272
	300				1330	1325	1322	1316	1316	1313	1312	1310	1304	1304	1298	1298	1295	1295	1291	1292	1288	1286	1286	1284	1279	1277	1272	1272
52	400	1358	1357	1356	1349	1347	0	1336		1330	1328	1327	1323	1321	1316	1311		1307	-0	1305	1297	1298	1298	1296	1290	1286	1284	1284
	300				1354	1345	1342	1337	1336	1334	1330	1327	1324	1322	1316	1316	1311	1310	0	1307	1303	1302	1301	1300	1294	1289	1288	1286
51	400	1349	1348	1348	1342	1339	1335	1329		1325	1323	1320	1317	1313	1309	1306		1301	1301	1299	1292	1293	1293	1290	1285	1283	1278	1280
	300				1345	1339	1338	1332	1330	1328	1326	1324	1320	1317	1309	1310	1308	1306	1304	1302	1297	1296	1296	1295	1289	1284	1283	1281
101	400	1384	1383	1383		1375	1371	1365		1360	1356	1352	1350	1345	1340	1337		1326	-0	1327	1320	1320	1318	1315	1307	1307	1303	1302
	300				1381	1373	1371	1365	1363	1359	1357	1353	1349	1347	1339	1340	1336	1334	1331	1328	1326	1324	1328	1321	0	1308	1305	1305
39	400	1347	1347	1348	1340	1338	1333	1330		1324	1322	1320	1317	0	1307	1306		1302	1300	1298	1291	1291	1291	1296	1282	1280	1279	1278
	300				1344	1338	1336	1330	1327	1325	1323	1320	1316	1314	1307	1308	1304	1303	1300	1298	1295	1295	1293	1291	1287	1282	1282	1279
55	400	1365	1364	1364	1358	1356	1348	1343		1340	1337	1332	1330	1325	1322	1320		1311	1318	1312	1305	1304	1303	1301	1295	1294	1289	1288
	300				1361	1353	1350	1344	1342	1341	1338	1334	1329	1329	1322	1321	1316	1316	1313	1312	1308	1306	1305	1304	1301	1294	1290	1290
31	400	1348	1346	1346	1340	1338	1333	1327		1322	1320	1317	1309	1310	1307	1305		1299	1304	1298	1292	1292	1290	1288	1283	1282	1278	1278
	300				1342	1337	1334	1329	1328	1325	1323	1321	1316	1314	1307	1307	1304	1303	1299	1298	1296	1295	1294	1292	1288	1284	1283	1280

38	400	1347	1347	1349	1339	1336	1333	1328		1324	1319	1311	1315	1310	1302	1304		1300	1299	1297	1290	1290	1290	1288	1281	1283	1279	1278
	300				1343	1336	1332	1328	1326	1324	1321	1318	1314	1311	1305	1307	1304	1302	1300	1298	1294	1294	1293	1291	1287	1283	1283	1281
354	400	1362	1361	1360		1350	1346	1338		1334	1331	1330	1320	1321	1317	1315		1310	-0	1308	1302	1269	1301	1299	1293	1295	1292	1291
	300				1357	1350	1347	1341	1337	1335	1335	1330	1325	1324	1316	0	1316	1313	1312	1310	1307	1307	1304	1304	1300	1295	1292	1292
17	400	1337	1336	1336	1330	1328	1321	1316		1313	1311	1310	1307	1301	1300	1297		-0	1293	1291	1285	1284	1284	1281	1276	1277	1274	1273
	300				1333	1326	1324	1317	1317	1315	1313	1310	1306	1305	1297	1299	1295	1235	1294	1292	1289	1288	1287	0	1281	1278	1276	1275
30	400	1348	1347	1347	1341	1339	1334	1328		1322	1317	1317	1314	1310	1306	1304		1298	1301	1296	1290	1289	1290	1288	1283	1283	1279	1278
	300				1343	1336	1335	1329	1327	1325	1322	1320	1315	1313	1305	1307	1303	1303	1301	1300	1296	1295	1294	1292	1287	1284	1281	1281
15	400	1340	1339	1339	1332	1330	1326	1317		1315	1312	1310	1299	1303	1299	1298		1289	1292	1290	1284	1285	1285	1284	1279	1278	1276	1275
	300				1335	1328	1326	1321	1319	1317	1315	1311	1308	1306	1298	1301	1297	1296	1293	0	1290	1290	1289	1287	1282	1279	1277	1277
37	400	1348	1347	1345	1338	1337	1333	1326		1321	1319	1320	1313	1309	1304	1303		1250	1297	1295	1291	1289	1290	1289	1283	1284	1281	1279
	300				1344	1336	1333	1326	1325	1322	1320	1316	1313	1311	1305	1306	1302	1303	1300	1299	1296	1294	1293	1292	1287	1283	1281	1279
28	400	1347	1346	1346	1339	1337	1331	1326		1320	1317	0	1313	1310	1305	1302		1297	1298	1293	1291	1290	1289	1287	1281	1282	1280	1280
	300				1342	1335	1332	1328	1326	1323	1320	1317	1314	1311	1305	1307	1303	1303	1299	1298	1294	1294	1293	1292	1288	1282	1282	1280
23	400	1348	1347	1347	1341	1343	1341	1338		1335	1333	1332	1328	1324	1317	1318		0	1311	1310	1303	1304	1301	1299	1289	1288	1285	1283
	300				1345	1344	1342	1339	1338	1337	1334	1332	1327	1325	1316	1319	1315	1314	1310	1308	1306	1302	1302	1300	1295	1289	1287	1284
96	400	1425	1424	1423		1411	1405	1397		1389	0	1382	1378	1373	1368	1364		-0	1353	1350	1344	1342	1341	1338	1331	1332	1320	1325
	300				1418	1408	1404	1397	1394	1391	1388	1385	1378	1375	1367	1367	1363	1360	1355	1353	1350	1348	1347	1344	1336	1332	1328	1327
100	400	1452	1450	1450		1439	1432	1426		1417	1412	1410	1403	1398	1391	1386		1377	1378	1375	1365	1366	1364	1360	1352	1351	1345	1343
	300				1446	1436	1432	1425	1421	1417	1413	1408	1402	1398	1389	1390	1386	1382	1379	1374	1371	1369	1367	1364	1357	1351	1348	1346
98	400	1441	1440	1440		1427	1422	1411		0	1400	1395	1392	1387	1381	1378		0	1367	1366	1358	1358	1354	1350	1342	1343	1336	1335
	300				1435	1424	1422	1415	1411	1407	1397	1399	1393	1390	1381	1379	1377	1374	1369	1366	1364	1361	1359	1356	1347	1342	1339	1338
90	400	1347	1346	1345		1335	1331	1324		1318	1315	1313	1311	1307	1302	1299		1291	0	1292	1288	1290	1293	1288	1281	1282	1280	1280
	300				1342	1332	1331	1325	1324	1320	1316	1314	1311	1310	1303	1304	1301	1299	1298	1297	1295	1294	1293	1291	1286	1284	1283	1282
94	400	1406	1405	1404		1393	1387	1381		1374	1371	1367	1363	1358	1353	1349		0	1342	1340	1333	1330	1330	1327	1318	1319	1314	1313
	300				1400	1391	1387	1380	1377	1374	1372	1367	1363	1360	1352	1352	1348	1345	1342	1340	1338	1335	1333	1331	1324	1319	1315	1314
95	400	1412	1412	1411		1399	1393	1386		1378	1373	1371	1367	1361	1355	1352		1346	-0	1343	1336	1337	1333	1331	1324	1324	1320	1318
	300				1406	1396	1393	1385	1382	1377	1376	1371	1365	1363	1354	1356	1352	1351	-0	1344	1342	1338	1337	1334	1327	1325	1320	1320
93	400	1389	1388	1387		1375	1370	1363		1355	0	1350	1345	1342	1334	1332		-0	1325	1322	1314	1316	1316	1313	1306	1307	1304	1302
	300				1382	1373	1370	1362	1360	1356	1354	1349	1344	1343	1334	1336	1331	1330	1326	1326	1323	1319	1319	1318	1312	1309	1305	1303
91	400	1357	1356	1355		1346	1341	1334		1327	1324	1323	1319	1314	0	1308		1304	1303	1301	1296	1296	1296	1294	1288	1289	1287	1286
	300				1352	1344	1340	1334	1332	1330	1326	1323	1320	1318	1310	1312	1307	1307	1304	1305	1302	1299	1299	1298	1294	1291	1287	1286
92	400	1373	1372	1371		1360	1354	1349		1341	1338	1334	0	1327	1323	1320		-0	1312	1311	1305	1306	1306	1304	1297	1295	1294	1293
	300				1367	1359	1356	1349	1346	1341	1341	1336	1332	1330	1322	1323	1320	1318	1315	1314	1311	1310	1309	1308	1302	1297	1297	1296
13	400	1344	1344	1341	1334	1333	1327	1322		1316	1313	1311	1309	1304	1300	1299		1294	1191	1291	1286	1287	1286	1283	1280	1280	1280	1278
	300				1338	1330	1328	1323	1320	1316	1315	1313	1309	1306	1299	1302	1298	1298	1295	1294	1291	1292	1291	1288	1283	1281	1285	1275
12	400	1345	1343	1344	1336	1335	1329	1323		1316	1315	1312	1310	1306	1300	1300		-0	1295	1294	1287	1288	1287	1286	1281	1280	1279	1278
	300				1340	1332	1331	1324	1322	1319	1316	1315	1311	1307	1303	1303	1301	1299	1295	1296	1290	1292	1291	1289	1286	1283	1281	1280
75	400	1327	1326	1325		1316	1312	1308		1300	1298	1298	1295	0	1287	1285		1281	1283	1280	1275	1278	1276	1275	1269	1270	1268	1268
	300				1323	1316	1312	1307	1306	1304	1302	1298	1294	1293	1288	1290	1286	1285	1283	1283	1281	1279	1279	1278	1274	1272	1271	1269
27	400	1348	1346	1345	1339	1336	1331	1326		1320	1318	1317	1312	1309	1304	1301		1297	1297	1296	1289	1291	1291	1288	1283	1282	1278	1280
	300				1342	1334	1333	1327	1325	1321	1320	1316	1313	1312	1303	1305	1303	1301	1299	1298	1294	1295	1294	1292	1287	1284	1282	1282
22	400	1348	1347	1347	1341	1336	1333	1327		1322	1318	1316	1314	1310	1306	1304		1299	1295	1297	1290	1291	1289	1289	1283	1285	1279	1281
	300				1344	1335	1335	1327	1327	1322	1321	1317	1314	1312	1305	1306	1304	1302	1300	1298	1295	1294	1293	1292	1287	1284	1282	0
35	400	1347	1345	1346	1339	1336	1329	1323		1318	1316	1313	1311	1308	1305	1303		1297	1295	1297	1291	1291	1295	1294	1290	1289	1290	1290
	300				1342	1334	1330	1325	1323	1321	1317	1316	1312	1311	1304	1305	1302	1301	1300	1299	1296	1297	1297	1297	1295	1292	1291	1291

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(b) Continued. SI units

		DISTANCE FROM CENTER-LINE OF SHELL OUTLET, CENTIMETERS																										
		126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
RUN	SERIES	TEMPERATURES, DEGREES KELVIN																										
26	400	1348	1346	1345	1339	1336	1332	1327		1320	1318	1315	0	1308	-0	1303		1297	1297	1292	1290	1291	1290	1289	1282	1282	1282	1275
	300				1342	1334	1333	1326	1324	1321	1318	1318	1312	1312	1304	1304	1304	1301	1298	1298	1294	1295	1293	1292	1289	1284	1283	1281
34	400	1348	1346	1346	1339	1335	1329	1324		1318	1315	1313	1311	1308	1300	1300		1296	1297	1297	1291	1292	1295	1294	1290	1291	1291	1291
	300				1342	1333	1332	1326	1323	1320	1318	1315	1312	1311	1303	-0	1302	1301	1299	1299	1296	1298	1298	1298	1295	1292	1293	1292
146	400	1366	1366	1365		1356	1351	1344		1339	1332	1333	1336	1326	1322	1320		0	1315	1315	1309	1311	1313	1313	1308	1310	1311	1310
	300				1362	1354	1352	1346	1344	1340	1338	1336	1331	1329	1322	1323	1321	1318	1318	1316	1315	1316	1315	1316	1314	1311	1310	1310
147	400	1354	1354	1354		1344	1340	1335		1330	1327	1325	1322	1319	1314	1313		1306	1307	1306	1304	1305	1305	1308	1300	1304	1305	1304
	300				1349	1344	1342	1336	1334	1331	1329	1326	1323	1322	1314	1315	1312	1312	1310	1310	1308	1307	1309	1309	1308	1306	1304	1302
143	400	1381	1381	1381		1377	1373	1367		1359	1354	1352	1349	1344	1338	1335		0	1329	1328	1322	1326	1327	1327	1320	1325	1326	1322
	300				1380	1377	1376	1367	1363	1360	1358	1355	1349	0	1339	1340	1337	1333	1331	1330	1330	1330	1330	1331	1327	1327	1325	1323
149	400	1331	1331	1330		1323	1320	1316		1311	1308	1310	1306	1303	1298	1298		1294	1295	1295	1290	1293	1294	1292	1287	1292	1291	1290
	300				1328	1325	1322	1317	1315	1314	1313	1310	1306	1305	1300	1302	1299	1298	1297	1298	1296	1295	1296	1297	1295	1293	1291	1290
148	400	1342	1342	1342		1335	1330	1325		1320	1319	1321	1315	1310	1306	1305		1302	1301	1301	1296	1298	1300	1300	1300	1296	1298	1296
	300				1340	1334	1333	1327	1325	1322	1321	1319	1316	1313	1306	1309	1307	1306	1304	1304	1301	1303	1303	1303	1302	1298	1300	1297
145	400	1371	1370	1370		1360	1354	1349		1343	1339	1337	1333	1331	1325	1319		1315	1318	1317	1310	1313	1315	1315	1310	1312	1313	1311
	300				1367	1359	1357	1351	1348	1345	1342	1340	1335	1333	1326	1327	1324	1322	1320	1320	1318	1319	1318	1318	1317	1314	1315	1312
144	400	1387	1387	1386		1383	1379	1372		1365	1361	1358	1353	1347	1344	1341		1334	1333	1332	1327	1327	1330	1330	1323	1329	1328	1325
	300				1386	1384	1381	1373	1370	1367	1364	1358	1353	1352	1343	1345	1338	1339	1336	1334	1333	1333	1334	1333	1332	1330	1329	1326
348	400	1359	1359	1356		1352	1349	1343		1341	1339	1339	1332	1333	1328	1327		1321	1322	1320	1315	0	1315	1312	1303	1305	1303	1301
	300				1357	1352	1351	1345	1343	1342	1341	1340	1336	1335	1329	0	1327	1325	1323	1322	1319	1320	1318	1317	1311	1307	1303	1302
142	400	1403	1402	1403		1398	1395	1391		1386	1381	1380	1377	1371	1365	1363		1355	1358	1353	1346	1346	1343	1340	1334	1334	1326	1325
	300				1402	1401	1400	1394	1393	1392	1390	1385	1380	1379	1370	1370	1366	1363	1361	1357	1353	1352	1351	1348	1339	1333	1330	1329
141	400	1397	1395	1396		1383	1384	1380		1374	1371	1370	1367	1363	1357	1354		1347	1346	1345	1337	1338	1335	1333	1328	1327	1318	1321
	300				1394	1387	1386	1381	1379	1375	1373	1370	1367	1363	1355	1357	1354	1350	1348	1346	1343	1341	1339	1337	1332	1328	1325	1323
140	400	1388	1387	1386		1380	1377	1370		1363	1362	1360	1357	1353	1347	1346		1340	1340	1337	1331	1332	1330	1328	1319	1315	1317	1314
	300				1384	1379	1376	1370	1368	1366	1363	1360	1356	1355	1346	1348	1345	1344	1340	1338	1336	1335	1332	1331	1326	1323	1318	1315
136	400	1361	1360	1361		1352	1348	1345		1338	1338	1334	1335	1331	1328	1324		-0	1319	1318	1311	1311	1312	1310	1302	1303	1300	1300
	300				1357	1353	1351	1347	1345	1343	1342	1341	1336	1335	1328	1329	1326	1325	1323	1321	1318	1317	1313	1314	1310	1304	1303	1301
137	400	1367	1367	1366		1359	1354	1351		1347	1344	1343	1332	1336	1332	1331		-0	1324	1323	1318	1316	1316	1315	1308	1307	1303	1304
	300				1364	1359	1358	1353	1350	1349	1347	1344	1339	1339	1333	1332	1329	1327	1327	1324	1321	1320	1321	1317	1313	1308	1307	1304
134	400	1347	1347	1345		1339	1336	1332		1328	1327	1326	1324	1320	1315	1313		1309	1311	1310	1303	1304	1304	1303	1294	1295	1293	1292
	300				1343	1338	1339	1335	1334	1332	1330	1328	1325	1321	1316	1317	1315	1313	1312	1310	1309	1309	1309	1306	1300	1296	1294	1292

139	400	1381	1379	1380		1371	1366	1362		1359	1355	1360	1351	1348	1343	1339		1335	1334	1333	1325	1326	1326	1324	1315	1315	1311	1310
	300				1377	1371	1368	1364	1363	1361	1358	1355	1351	1350	1343	1343	1338	1337	1336	1334	1329	1329	1328	1326	1321	1316	1313	1312
135	400	1355	1354	1354		1347	1343	1339		1335	1333	1332	1329	1326	1322	1321		1314	-0	1315	1309	1306	1308	1307	1299	1300	1298	1296
	300				1352	1348	1348	1340	1339	1338	1336	1333	1330	1329	1322	1324	1321	1320	1317	1316	1315	1313	1312	1311	1306	1301	1298	1297
138	400	1375	1374	1373		1365	1362	1358		1352	1349	1348	1346	1342	1337	1334		1328	1330	1329	1321	1322	1321	1318	1311	1311	1308	1306
	300				1371	1365	1364	1358	1356	1353	1351	1350	1346	1342	1337	1334	1336	1334	1330	1328	1325	1325	1325	1323	1316	1312	1310	1309
132	400	1435	1435	1435		1431	1428	1427		1422	1418	1415	1411	1406	1399	1395		1387	1386	1383	1373	1374	1371	1367	1360	1358	1350	1348
	300				1434	1433	1431	1428	1426	1424	1420	1416	1411	1408	1400	1399	1394	1391	1388	1384	1380	1377	1377	1372	1364	1359	-0	1352
350	400	1362	1360	1360		1352	1349	1344		1338	1336	1335	1326	1328	1324	1321		1315	1317	1315	1310	1307	1308	1306	1301	1303	1301	1298
	300				1358	1356	1350	1344	1342	1340	1339	1336	1331	1331	1325	0	1321	1317	1318	1318	1314	1312	1311	1310	1306	1305	1303	1301
128	400	1402	1401	1400		1392	1388	1382		1377	1373	1371	1367	1361	1356	1355		1348	1347	1345	1337	1338	1336	1333	1326	1326	1322	1320
	300				1397	1391	1389	1382	1380	1378	1376	1372	1368	1365	1358	1358	1355	1353	1349	1349	1345	1342	1342	1339	1332	1328	1324	1324
127	400	1392	1391	1391		1383	1378	1373		1366	1363	1362	1354	1353	1349	1347		1339	1339	1337	1330	1332	1331	1328	1319	1320	1317	1315
	300				1388	1382	1380	1373	1370	1367	1365	1362	1359	1357	1349	1350	1347	1345	1342	1339	1338	1337	1335	1333	1324	1322	1319	1318
131	400	1422	1422	1422		1415	1411	1406		1399	1396	1393	1389	1385	1379	1377		1369	-0	1365	1358	1356	1355	1352	1339	1346	1337	1336
	300				1420	1415	1411	1406	1404	1401	1398	1393	1388	1385	1378	1378	1374	1372	1368	1366	1363	1360	1360	1356	1349	1345	1341	1337
130	400	1418	1417	1417		1411	1408	1404		1398	1395	1388	1389	1383	1378	1374		1365	1365	1363	1356	1354	1353	1349	1339	1338	1332	1331
	300				1415	1413	1412	1406	1404	1401	1398	1394	1388	1385	1378	1378	1374	1371	1367	1364	1362	1359	1358	0	1346	1339	1337	1333
133	400	1352	1352	1352		1345	1341	1336		1333	1331	1329	1327	1324	1318	1319		1313	1313	1310	1307	1307	1306	1303	1296	1287	1296	1295
	300				1348	1347	1342	1338	1337	1334	1332	1330	1327	1326	1318	1320	1315	1315	1313	1314	1310	1308	1308	1307	1303	1299	1295	1294
129	400	1411	1410	1410		1401	1396	1391		1386	1381	1379	1377	1372	1366	1362		1356	1354	1354	1346	1347	1343	1340	1333	1333	1328	1326
	300				1408	1401	1398	1393	1391	1387	1384	1381	1376	1373	1366	1366	1363	1360	1357	1354	1351	1349	1348	1345	1338	1233	1331	1330
126	400	1381	1379	1379		1372	1367	1362		1356	1353	1351	1349	1346	1342	1339		1331	1332	1330	1323	1323	1323	1322	1314	1312	1309	1308
	300				1376	1370	1368	1362	1360	1357	1355	1352	1350	1348	1341	1341	1337	1336	1335	1333	1329	1327	1327	1325	1320	1315	1313	1311
347	400	1362	1360	1360		1352	1347	1344		1340	1337	1334	1327	1329	1326	1323		1318	1317	1317	1310	1312	1312	1309	1303	1303	1301	1301
	300				1358	1352	1349	1344	1343	1341	1339	1338	1333	1332	1325	0	1327	1323	1322	1320	1315	1316	1315	1314	1310	1305	1304	1303
346	400	1361	1360	1361		1352	1347	1342		1339	1337	1334	1326	1327	1326	1322		1316	1317	1316	1309	1310	1310	1309	1302	1302	1302	1301
	300				1357	1352	1351	1345	1344	1341	1338	1336	1333	1332	1326	0	1322	1322	1321	1320	1315	1315	1314	1313	1309	1305	1304	1303
364	400	1422	1420	1419		1406	1399	1391		1381	1379	1365	0	1366	1362	1356		1350	1350	1348	1342	1342	1344	1345	1338	1340	1340	1338
	300				1415	1403	1400	1391	1388	1383	1380	1376	1371	1369	1361	1361	1357	1355	1352	1350	1347	1348	1348	1348	1345	1343	1344	1341
355	400	1361	1361	1360		1352	1348	1341		1337	1333	1334	1324	1325	1321	1320		1316	-0	1312	1308	1308	1308	1306	1298	1294	1301	1298
	300				1358	1351	1350	1344	1341	1339	1337	1334	1331	1329	1321	0	1322	1318	1318	1317	1313	1314	1312	1311	1306	1304	1301	1301
359	400	1410	1410	1410		1396	1389	1381		1379	1370	1366	1357	1357	1354	1352		1344	1343	1340	1335	1336	1338	1336	1333	1336	1335	1338
	300				1403	1394	1391	1382	1379	1375	1373	1369	1365	1361	1353	1354	1351	1348	1346	1345	1340	1343	1342	1341	1340	1337	1336	1334
363	400	1417	1412	1414		1401	1393	1384		1377	1372	1370	0	1361	1358	1354		1347	1346	1344	1339	1339	1340	1341	1335	1238	1337	1334
	300				1408	1398	1394	1386	1382	1379	1376	1371	1367	1365	1356	1356	1354	1351	1349	1346	1343	1345	1344	1344	1343	1338	1328	1337
353	400	1363	1361	1360		1352	1344	1342		1336	1335	1334	1324	1326	1323	1319		1314	-0	1312	1307	1306	1307	1306	1300	1298	1300	1299
	300				1358	1351	1347	1342	1342	1338	1335	1335	1330	1329	1323	0	1318	1320	1318	1315	1312	1313	1311	1311	1307	1302	1308	1302
365	400	1420	1419	1419		1406	1396	1390		1380	1379	1373	1363	1366	1361	1355		1350	1350	1348	1340	1343	1344	1343	1339	1341	1340	1340
	300				1413	1403	1399	1390	1387	1383	1380	1376	1370	1369	1360	1360	1357	1354	1352	1351	1346	1348	1347	1347	1346	1243	1341	1343
351	400	1362	1361	1361		1352	1347	1341		1337	1335	1333	1326	1326	1320	1321		1315	1315	1314	1309	1308	1308	1306	1302	1202	1300	1306
	300				1358	1352	1350	1343	1341	1340	1338	1335	1329	1329	1323	0	1320	1321	1318	1317	1314	1314	1312	1311	1308	1304	1300	1300
360	400	1411	1410	-0		1402	1395	1390		1383	1373	1376	1368	1370	1364	1362		1356	1359	1357	1353	1354	1355	1356	1353	1354	1353	1353
	300				1406	1399	1395	1389	1388	1385	1381	1378	1373	1369	1362	1362	1360	1359	1360	1359	1356	1358	1357	1357	1357	1354	1353	1352
362	400	1384	1381	1381		1374	1370	1366		1361	1359	1355	1348	1350	1349	1348		-0	1347	1347	1343	1343	1346	1346	1338	1342	1338	1337
	300				1378	1374	1372	1366	1365	1363	1362	1359	1351	1354	1347	1348	1347	1347	1348	1350	1346	1347	1347	1347	1346	1342	1340	1339
124	400	1472	1471	1470		1461	1457	1449		1441	1438	1433	1428	1421	1416	1412		1401	1398	1398	1388	1388	1386	1383	1373	1371	1367	1362
	300				1467	1462	1460	1453	1449	1445	1442	1437	1430	1427	1417	1417	1410	1408	1405	1400	1396	1394	1392	1389	1378	1373	1369	1366

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(b) Continued. SI units

RUN	SERIES	DISTANCE FROM CENTER-LINE OF SHELL OUTLET, CENTIMETERS																										
		126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
		TEMPERATURES, DEGREES KELVIN																										
349	400	1360	1360	1360		1352	0	1341		1337	1335	1334	1328	1327	1324	1321		1316	1317	1315	1310	1309	1310	1308	1302	1305	1303	1302
	300				1357	1351	1348	1342	1341	1340	1338	1336	1331	1329	1323	0	1321	1320	1320	1319	1315	1313	1313	1313	1310	1307	1305	1304
119	400	1339	1393	1396		1386	1382	1374		1368	1366	1363	1360	1356	1352	1348		-0	1341	1341	1332	1333	1332	1330	1323	1321	1319	1315
	300				1392	1384	1381	1375	1373	1371	1369	1365	1361	1359	1352	1352	1347	1347	1345	1343	1339	1338	1337	1335	1328	1324	1322	1322
118	400	1369	1369	1368		1359	1355	1350		1344	1340	1340	1340	1333	1328	1325		1322	1323	1320	1313	1315	1315	1312	1304	1306	1305	1303
	300				1365	1359	1357	1351	1348	1344	1344	1342	1337	1334	1328	1330	1327	1325	1322	1321	1319	1318	1317	1316	1311	1307	1306	1305
345	400	1362	1360	1360		1351	1347	1344		1337	1335	1333	1325	1328	1324	1320		1317	1318	1317	1309	1309	1312	1310	1304	1304	1306	1302
	300				1358	1351	1347	1343	1341	1340	1338	1336	1331	1330	1324	0	1323	1322	1320	1319	0	1317	1315	1313	1309	1307	1306	1305
117	400	1354	1352	1352		1343	1340	1335		1329	1328	1326	1323	1318	1315	1314		1310	1309	1308	1304	1304	1303	1303	1297	1297	1296	1295
	300				1349	1344	1341	1336	1335	1332	1330	1328	1323	1322	1316	1318	1315	1314	1311	1311	1309	1309	1307	1307	1303	1299	1297	1297
122	400	1459	1457	1457		1445	1438	1426		1422	1419	1414	1411	1399	1399	1394		-0	1387	1383	1374	1376	1373	1370	1360	1359	1355	1353
	300				1451	1442	1439	1430	1427	1423	1421	1416	1410	1407	1398	1397	1394	1392	1387	1384	1380	1379	1377	1373	1367	1362	1358	1355
121	400	1442	1442	1441		1428	1422	1414		1407	1404	1400	1396	1391	1386	1382		1376	1373	1371	1364	1363	1361	1358	1351	1351	1345	1343
	300				1436	1426	1423	1415	1412	1409	1407	1402	1395	1393	1385	1385	1380	1379	1375	1373	1369	1367	1367	1363	1355	1351	1348	1344
120	400	1426	1424	1424		1413	1407	1400		1392	1390	1386	0	1377	1374	1369		1363	1364	1362	1352	1354	1352	1349	1342	1339	1336	1335
	300				1420	1411	1408	1402	1400	1396	1392	1390	1385	1383	1375	1373	1371	1369	1366	1364	1360	1359	1358	1355	1347	1341	1339	1338
123	400	1472	1471	1469		0	1456	1448		-0	1437	1433	1428	1421	1416	1413		1403	1403	1397	1390	1388	1387	1384	1374	1373	1365	1363
	300				1466	1460	1457	1450	1446	1443	1441	1434	1428	1425	1415	1416	1409	1407	1403	1400	1396	1393	1391	1388	1379	1373	1368	1367
116	400	1326	1326	1325		1320	1317	1311		1309	1308	1306	1304	1302	1299	1296		1293	1294	1294	1290	1288	1288	1289	1283	1284	1284	1283
	300				1324	1320	1318	1313	1313	1311	1309	1307	1305	1304	1298	1300	1298	1297	1296	1297	1293	1293	1294	1293	1289	1286	1286	1282
193	400	1363	1363	1361		1355	1352	1347		1344	1342	1340	1336	1334	1331	1330		1329	1324	1324	1323	1320	1323	1323	1319	1321	1321	1319
	300				1359	1354	1351	1347	1347	1344	1343	1340	1337	1336	1330	1331	1329	1329	1327	1328	1326	1325	1327	1327	1325	1323	1323	1321
184	400	1382	1382	1382		1375	1370	1366		1361	1360	1363	1355	1351	1347	1345		1340	-0	1338	1333	1336	1338	1337	1333	1338	1335	1334
	300				1380	1374	1372	1368	1366	1364	1362	1360	1355	1354	1348	1349	1345	1344	1344	1343	1339	1342	1342	1342	1341	1337	1337	1336
181	400	1383	1382	1382		1374	1371	1366		1361	1359	1356	1355	1350	1347	1345		1340	1340	1339	1333	1335	1337	1338	1333	1336	1333	1334
	300				1379	1373	1373	1368	1366	1363	1361	1358	1356	1354	1346	1348	1345	1344	1343	1343	1340	1341	1341	1342	1340	1337	1335	1336
185	400	1383	1381	1382		1374	1370	1366		1361	1357	1356	1352	1350	1346	1343		1340	1341	1338	1333	1334	1336	1337	1332	1334	1332	1334
	300				1425	1372	1372	1367	1365	1361	1359	1357	1354	1352	1345	1346	1342	1343	1341	1340	1338	1339	1340	1340	1338	1336	1334	1335
178	400	1383	1381	1381		1374	1368	1363		1359	1356	1350	1351	1348	1344	1343		1336	1338	1338	1332	1333	1336	1330	1331	1333	1334	1331
	300				1380	1373	1370	1365	1364	1362	1359	1356	1353	1351	1344	1345	1342	1341	1341	1336	1337	1328	1339	1339	1337	1333	1335	1333
179	400	1383	1382	1383		1375	1370	1366		1362	1359	1356	1354	1351	1346	1344		1339	1341	1341	1334	1336	1338	1338	1333	1335	1341	1334
	300				1380	1373	1373	1367	1366	1363	1360	1358	1356	1354	1346	1347	1346	1344	1342	1342	1339	1341	1341	1342	1339	1337	1336	1337

176	400	1384	1384	1383		1375	1371	1364		1360	1357	1355	1352	1349	1344	1341		1337	1338	1336	-0	1332	1333	1334	-0	1333	1332	1330
	300				1381	1374	1372	1366	1364	1361	1359	1357	1353	1350	1343	1345	1341	1341	1335	1338	1336	1338	1338	1338	1337	1333	1334	1333
175	400	1388	1387	1387		1379	1375	1368		1364	1360	1359	1355	1351	1346	1345		1340	1337	1340	1335	1337	1337	1338	1334	1337	1336	1333
	300				1384	1379	1376	1369	1368	1365	1364	1360	1355	1354	1347	1349	1345	1345	1342	1342	1342	1341	1343	1342	1340	1338	1336	1335
186	400	1389	1386	1388		1379	1374	1366		1364	1361	1353	1357	1353	1351	1346		1342	1345	1346	1342	1343	1344	1345	1340	1343	1343	1339
	300				1385	1379	1375	1369	1369	1366	1364	1361	1357	1355	1349	1350	1348	1349	1348	1349	1347	1349	1350	1348	1346	1344	1345	1342
182	400	1383	1382	1381		1374	1371	1365		1361	1359	1357	1354	1351	1345	1344		1342	1344	1343	1340	1345	1343	1343	1336	1342	1342	1339
	300				1379	1374	1373	1367	1364	1363	1360	1359	1355	1353	1346	1348	1347	1347	1345	1345	1346	1346	1347	1346	1342	1343	1342	1340
172	400	1401	1399	1399		1389	1384	1378		1371	1369	0	1363	1358	1353	1352		-0	1351	1350	1345	1348	1349	1349	1347	1347	1348	1345
	300				1395	1387	1386	1378	1376	1373	1368	1368	1363	1361	1355	1356	1353	1353	1353	1353	1352	1353	1355	1354	1349	1349	1349	1347
171	400	1406	1405	1405		1394	1389	1383		1376	1373	1371	1367	1364	1358	1355		-0	1356	1355	1349	1353	1354	1354	1348	1350	1353	1349
	300				1401	1392	1391	1383	1382	1378	1375	1373	1368	1365	1358	1360	1358	1357	1357	1356	1357	1357	1358	1358	1354	1354	1353	1351
183	400	1383	1382	1382		1374	1370	1365		1360	1359	1356	1354	1352	1347	1344		1341	1343	1344	1339	1342	1343	1342	1339	1339	1339	1338
	300				1380	1374	1371	1367	1366	1363	1361	1359	1355	1353	1347	1348	1345	1346	1347	1345	1344	1345	1348	1347	1345	1342	1342	1341
173	400	1394	1364	1391		1384	1379	1374		1368	1364	1356	1360	1354	1351	1347		1347	1348	1348	1342	1348	1346	1347	1341	1344	1346	1342
	300				1390	1382	1382	1374	1372	1369	1367	1365	1361	1357	1352	1352	1351	1351	1350	1351	1348	1351	1351	1350	1347	1346	1347	1344
192	400	1363	1363	1362		1354	1353	1347		1343	1341	1340	1337	1334	1330	1330		1325	1327	1326	1323	1323	1325	1324	1319	1322	1322	1320
	300				1359	1355	1353	1348	1346	1345	1345	1342	1337	1337	1330	1332	1328	1329	1327	1328	1326	1327	1329	1328	1326	1325	1322	1322
287	400	1398	1397	1397		1367	1382	1376		1370	1367	1368	1359	1358	1353	1352		1350	-0	1353	1348	1350	1352	1353	1345	1348	1346	1341
	300				1393	1387	1384	1378	1375	1372	1370	1367	1363	1361	1353	1356	1355	1355	1355	1355	1354	1355	1355	1355	1351	1351	1347	1343
191	400	1362	1362	1361		1354	1351	1347		1343	1340	1340	1338	1333	1329	1329		1326	1325	1326	1320	1323	1325	1324	1318	1321	1323	1322
	300				1360	1355	1354	1349	1348	1345	1343	1342	1339	1337	1331	1332	1331	1330	1328	1327	1327	1328	1328	1328	1326	1324	1324	1322
290	400	1398	1397	1397		1390	1386	1381		1378	1375	1373	1367	1367	1363	1360		1354	1354	1353	1346	1347	1345	1346	1336	1336	1333	1332
	300				1394	1389	1388	1383	1382	1378	1376	1375	1370	1370	1362	1362	1362	1359	1356	1354	1350	1351	1349	1347	1341	1337	1336	1334
288	400	1398	1397	1392		1388	1379	1376		1370	1368	1366	1358	1358	1353	-0		1343	1344	1344	1338	1338	1340	1341	1336	1339	1340	1338
	300				1393	1386	1384	1377	1375	1373	1371	1366	1362	1360	1354	1355	1351	1349	1347	1346	1344	1345	1345	1345	1342	1340	1338	1338
286	400	1398	1396	1397		1392	1390	1387		1382	1381	1379	1372	1373	1367	1363		0	1357	1356	1348	1348	1348	1345	1334	1335	1333	1330
	300				1396	1392	1392	1388	1386	1384	1383	1380	1376	1374	1369	1367	1365	1364	1360	1359	1356	1354	1353	1352	1343	1337	1335	1334
163	400	1372	1372	1372		1364	1362	1358		1353	-0	1351	1347	1345	1342	1339		1334	1335	1333	1327	1325	1327	1326	1320	1321	1318	1316
	300				1369	1366	1363	1358	1357	1356	1354	1352	1348	1347	1341	1343	1339	1338	1337	1336	1332	1333	1333	1329	1326	1321	1319	1321
190	400	1362	1361	1361		1355	1351	1348		1345	1344	1342	1346	1340	1334	1332		1327	1329	1327	1322	1320	1322	1321	1315	1317	1315	1314
	300				1360	1356	1355	1351	1350	1349	1347	1345	1342	1342	1335	1337	1334	1332	1331	1331	1328	1327	1328	1326	1322	1318	1317	1315
343	400	1382	1382	1382		1376	1372	1368		1366	1363	1362	0	1357	1353	1350		1345	1345	1343	1336	1336	1337	1335	1329	1330	1324	1324
	300				1380	1376	1373	1369	1368	1366	1365	1362	1360	1359	1352	1355	1349	1349	1347	1347	1343	1342	1340	1340	1334	1330	1328	1327
170	400	1441	1439	1438		1438	1437	1434		1436	1435	1436	1434	1432	1424	1423		1404	1412	1409	1400	1396	1396	1393	1378	1372	1368	1365
	300				1439	1439	1438	1437	1437	1438	1437	1435	1432	1430	1422	1422	1417	1415	1410	1406	1404	1399	1397	1395	1384	1375	1370	1367
167	400	1413	1412	1411		1404	1400	1395		1391	1389	1387	1383	1378	1374	1372		1363	1370	1363	1357	1355	1355	1353	1346	1348	1341	1333
	300				1409	1405	1403	1397	1396	1392	1391	1386	1382	1381	1373	1375	1371	1371	1367	1365	1361	1360	1359	1355	1351	1346	1345	1342
168	400	1423	1419	1416		1416	-0	1407		1401	1400	1396	1393	1393	1384	1381		1374	1375	1372	1365	1364	1364	1360	1352	1352	1345	1346
	300				1419	1415	1413	1408	1406	1402	1400	1396	1394	1392	1384	1384	1380	1379	1375	1374	1370	1368	1367	1363	1359	1352	1350	1348
165	400	1386	1387	1384		1381	1374	1374		1370	1367	1363	1362	1360	1355	1353		1346	1349	1348	1341	1338	1338	1337	1333	1329	1327	1327
	300				1386	1381	1379	1376	1375	1372	1370	1368	1364	1363	1356	1357	1355	1353	1350	1350	1347	1344	1344	1342	1338	1333	1329	1328
188	400	1381	1380	1382		1375	1372	1368		1365	1358	1360	0	1355	1352	1348		1344	1344	1343	1335	1338	1335	1334	1326	1328	1325	1323
	300				1379	1374	1373	1368	1368	1365	1364	1361	1359	1358	1351	1352	1350	1348	1347	1345	1342	1341	1341	1339	1334	1329	1326	1326
169	400	1430	1428	1429		1426	1427	1423		1424	1422	1419	1416	1412	1405	1399		1394	1392	1389	1379	1380	1367	1376	1363	1359	1355	1355
	300				1429	1428	1427	1426	1425	1424	1421	1418	1414	1411	1403	1403	1397	1396	1393	1389	1385	1384	1381	1378	1369	1361	1359	1357
164	400	1379	1380	1380		1372	1369	1367		1361	1361	1357	1357	1355	1349	1347		1342	1342	1340	1337	1337	1333	1333	1326	1326	1323	1322
	300				1379	1373	1371	1366	1366	1364	1361	1360	1357	1355	1348	1348	1346	1345	1343	1342	1339	1339	1338	1335	1333	1329	1325	1324

TABLE II. - Continued. BOILER SHELL SURFACE TEMPERATURES

(b) Continued. SI units

DISTANCE FROM CENTER-LINE OF SHELL OUTLET, CENTIMETERS

TEMPERATURES, DEGREES KELVIN

RUN	SERIES	126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
166	400	1401	1401	1401		1395	1391	1388		1384	1381	1379	1376	1373	1367	1366		1361	1360	1356	1351	1352	1351	1350	1340	1339	1334	1334
	300				1399	1395	-0	1390	1388	1385	1383	1380	1377	1374	1367	1368	1365	1364	1361	1360	1356	1355	1354	1352	1346	1340	1338	1337
158	400	1424	1423	1423		1415	1410	1406		1401	1397	1395	1392	1388	1383	1380		1373	1372	1370	1363	1364	1361	1358	1350	1351	1345	1345
	300				1420	1414	1412	1406	1404	1401	1399	1395	1392	1389	1381	1380	1378	1376	1374	1372	1368	1372	1366	1363	1356	1351	1347	1347
159	400	1429	1429	1428		1421	1417	1407		1404	1405	1399	1396	1390	1385	1383		1376	1376	1374	1366	1367	1365	1363	1354	1355	1351	1349
	300				1425	1418	1416	1409	1407	1403	1402	1399	1394	1391	1384	1385	1382	1380	1375	1374	1371	1369	1369	1366	1358	1356	1352	1350
342	400	1383	1382	1382		1375	1372	1366		1362	-0	1357	1350	1352	1348	1345		1341	1342	1340	1333	1335	1334	1331	1322	1324	1324	1323
	300				1380	1374	1373	1368	1366	1364	1363	1360	1357	1355	1348	1348	1347	1346	1344	1342	1339	1340	1337	1338	1329	1328	1326	1325
161	400	1449	1449	1449		1444	1441	1435		1432	1428	1425	1422	1416	1409	1405		-0	1394	1392	1390	1384	1381	1378	1372	1372	1366	1364
	300				1447	1447	1446	1444	1443	1441	1439	1437	1432	1428	1418	1418	1414	1410	1404	1402	1397	1395	1393	1390	1378	1373	1369	1367
160	400	1438	1437	1437		1432	1429	1424		1418	1414	1412	1409	1404	1398	1394		-0	1384	1383	1373	1375	1372	1369	1360	1359	1359	1353
	300				1436	1433	1432	1426	1423	1420	1418	1414	1409	1406	1398	1398	1395	1393	1388	1386	1383	1382	1380	1377	1367	1361	1359	1358
162	400	1461	1460	1459		1457	1454	1456		1449	1446	1442	1438	1432	1421	1423		1417	1412	1409	1399	1400	1396	1392	1383	1383	1375	1373
	300				1459	1457	1457	1455	1455	1454	1452	1449	1444	1442	1432	1430	1425	1428	1419	1415	1410	1407	1405	1402	1390	1384	1378	1377
344	400	1382	-0	1381		1374	1370	1365		1361	1359	1350	1348	1351	1347	1345		1338	1340	1338	1332	1332	1333	1331	1323	1326	1325	1323
	300				1379	1374	1372	1367	1365	1363	1362	1359	1355	1353	1348	1349	1346	1343	1342	1342	1338	1336	1336	1336	1331	1327	1324	1323
156	400	1335	1394	1393		1387	1382	1376		1372	1370	1366	1364	1362	1356	1354		1349	1349	1347	1341	1341	1340	1335	1330	1333	1330	1327
	300				1391	1385	1383	1377	1376	1374	1372	1368	1365	1364	1356	1357	1354	1353	1349	1348	1345	1345	1344	1341	1336	1333	1331	1328
157	400	1404	1404	1404		1397	1393	1387		0	1378	1378	1374	1371	1366	1359		1358	1358	1355	1349	1348	1348	1347	1340	1341	1337	1335
	300				1401	1396	1393	1388	1387	1384	1382	1379	1374	1372	1366	1367	1363	1362	1359	1357	1355	1351	1352	1350	1344	1341	1338	1337
155	400	1382	1381	1391		1374	1369	1365		1362	1359	1357	1355	1352	1347	1344		1339	1340	1335	1333	1333	1332	1331	1324	1326	1323	1323
	300				1378	1372	1372	1367	1366	1363	1361	1358	1356	1354	1347	1348	1346	1344	1343	1341	1338	1337	1336	1335	1330	1326	1325	1325
189	400	1369	1362	1362		1355	1353	1349		1345	1342	1342	1336	1338	1334	1332		-0	1329	1327	1322	1323	1323	1321	1313	1316	1313	1314
	300				1361	1355	1355	1350	1349	1347	1345	1344	1341	1340	1333	1333	1333	1332	1330	1329	1325	1326	1326	1325	1320	1316	1315	1315
187	400	1383	1382	1382		1374	1371	1366		1362	1360	1358	1356	1351	1347	1345		1341	1341	1340	1332	1334	1333	1333	1325	1327	1325	1323
	300				1379	1374	1373	1367	1365	1363	1362	1360	1356	1354	1348	1349	1347	1346	1344	1341	1340	1339	1339	1337	1330	1328	1327	1325
253	400	1397	1396	1395		1389	1384	1380		0	1372	1371	1362	1365	1357	1358		-0	1349	1348	1341	1343	1339	1337	1329	1329	1325	1325
	300				1394	1387	1385	1379	1378	1370	1374	1370	1367	1364	1358	1358	1356	1353	1351	1349	1345	1345	1344	1342	1335	1329	1330	1329
341	400	1412	1411	1411		1403	1398	1393		1387	1385	1382	1373	1374	1373	1366		1362	1361	1359	1351	1354	1353	1350	1343	1343	1340	1338
	300				1407	1400	1400	1393	1391	1389	1387	1384	1381	1377	1371	1370	1368	1366	1363	1361	1358	1358	1355	1355	1348	1345	1342	1341
352	400	1363	1361	1361		1354	1350	1345		1342	1338	1338	1338	1331	1326	1327		1320	1323	1322	1314	1316	1318	1314	1309	1310	1307	1307
	300				1359	1353	1353	1346	1345	0	1342	1339	1336	1335	1329	0	1327	1327	1326	1323	1320	1321	1320	1319	1315	1311	1309	1310
220	400	1415	1415	1414		1406	1399	1392		1386	1382	1379	1376	1370	1367	1364		1358	1357	1356	1350	1349	1347	1346	1340	1341	1339	1335
	300				1412	1403	1401	1392	1390	1387	1384	1381	1375	1374	1366	1367	1363	1362	1359	1357	1354	1353	1353	1350	1345	1340	1337	1338

221	400	1418	1415	1416		1405	-0	1332		1384	1382	1377	1375	1370	1366	1363		1355	1356	1354	1348	1348	1347	1346	1337	1339	1339	1339
	300				1411	1404	1401	1333	1391	1387	1384	1362	1376	1374	1367	1366	1364	1362	1359	1358	1353	1354	1353	1350	1345	1338	1336	1335
219	400	1417	1416	1416		1404	1400	1391		1384	1393	1379	1375	1372	1368	1364		1357	1357	1354	1346	1349	1346	1346	1338	1337	1337	1334
	300				1411	1403	1401	1394	1391	1387	1384	1382	1376	1373	1367	1366	1365	1361	1359	1357	1353	1354	1351	1350	1345	1340	1340	1337
224	400	1415	1417	1415		1405	1398	1392		1385	1382	1378	1374	1368	1365	1362		1358	1355	1354	1348	1348	1349	1345	1337	1338	1337	1335
	300				1411	1401	1401	1393	1390	1386	1383	1381	1375	1372	1366	1365	1364	1360	1358	1355	1353	1353	1351	1350	1342	1338	1339	1336
222	400	1416	1416	1416		1405	1397	1393		1385	1383	1380	1377	1371	1368	1364		1358	1356	1355	1350	1349	1348	1347	1333	1339	1336	1335
	300				1412	1404	1402	1394	1392	1387	1385	1381	1378	1374	1367	1367	1365	1362	1361	1358	1354	1354	1353	1350	1345	1339	1339	1338
250	400	1418	1417	1417		1405	1396	1393		1386	1381	1379	1374	1371	1366	1363		-0	1358	1355	1348	1347	1348	-0	1339	1339	1338	1336
	300				1411	1403	1400	1394	1390	1387	1385	1381	1376	1374	1367	1367	1364	1361	1359	1358	1355	1353	1353	1350	1344	1340	1340	1337
223	400	1416	1417	1416		1404	1400	1394		1387	1385	1381	1379	1374	1370	1366		1361	1361	1356	1352	1351	1350	1348	1341	1342	1337	1336
	300				1412	0	1400	1396	1393	1389	1386	1384	1380	1378	1370	1371	1367	1365	1362	1361	1356	1356	1355	1353	1346	1343	1340	1340
225	400	1417	1417	1416		1405	1399	1394		1389	1385	1382	1378	1375	1366	1367		1361	1360	1358	1351	1351	1349	1348	1340	1342	1336	1336
	300				1412	1404	1401	1396	1392	1389	1387	1384	1379	1377	1368	1370	1366	1365	1361	1360	1356	1355	1354	1353	1346	1342	1340	1339
226	400	1414	1415	1415		1404	1400	1392		1392	1385	1382	1378	1375	1370	1367		1361	1361	1359	1352	1350	1351	1348	1342	1341	1338	1336
	300				1411	1404	1402	1396	1394	1390	1388	1384	1381	1377	1371	1370	1368	1365	1364	1361	1357	1357	1356	1354	1346	1343	1341	1340
227	400	1417	1416	1416		1405	1401	1394		1394	1385	1383	1374	1376	1370	1369		1361	1361	1359	1353	1350	1351	1348	1342	1342	1338	1338
	300				1412	1405	1402	1396	1393	1392	1389	1385	1380	1378	1372	1371	1368	1366	1363	1362	1357	1356	1354	1353	1347	1343	1342	1339
228	400	1417	1415	1413		1405	1401	1397		1391	1389	1385	1382	1379	1374	1374		1367	1366	1363	1357	1356	1355	1353	1345	1343	1340	1340
	300				1412	1404	1403	0	1395	1392	1389	1386	1382	1378	1372	1372	1369	1367	1364	1363	1358	1357	1356	1355	1350	1345	1342	1342
229	400	1416	1416	1416		1405	1400	1393		1387	1384	1381	1378	1376	1372	1371		1369	1374	1370	1369	0	1370	1371	1362	1359	1360	1357
	300				1413	1404	1401	1395	1392	1389	1366	1383	1380	1378	1372	1374	1373	1374	1373	1374	1370	1372	1272	1371	1368	1360	1361	1359
231	400	1417	1416	1416		1405	1401	1395		1388	1385	1382	0	1377	1374	1374		-0	1373	1373	1368	1371	1371	1371	1363	1366	1361	1361
	300				1413	1405	1402	1395	1331	1389	1388	1385	1380	1381	1374	1376	1375	1377	1375	1377	1375	1375	1376	1376	1370	1367	1363	1360
340	400	1411	1411	1410		1401	1396	1389		1383	1381	1378	1369	1370	1366	1364		-0	1358	1355	1350	1348	1349	1347	1339	1342	1340	1337
	300				1407	1399	1396	1389	1387	1385	1383	1378	1374	1372	1366	1367	1363	1363	1360	1360	1356	1355	1353	1353	1347	1344	1341	1340
289	400	1397	1396	1396		1385	1380	1375		1370	1372	1364	1358	1358	1353	1353		1347	-0	1344	1340	1340	1340	1338	1330	1332	1332	1331
	300				-0	1385	1383	1377	1374	1371	1369	1367	1364	1361	1354	1355	1353	1351	1349	1349	1344	1345	1344	1343	1337	1332	1333	1333
230	400	1418	1415	1416		1405	1400	1394		1387	1384	0	1378	1373	1372	1371		1368	1371	1376	1367	1367	1370	1369	1364	1367	1363	1361
	300				1412	1405	1401	1395	1393	1390	1388	1384	1381	1380	1374	1376	1374	1376	1375	1377	1375	1375	1376	1375	1370	1367	1364	1362
218	400	1410	1409	1410		1408	1404	1400		1397	1397	1392	1388	1383	1379	1376		1368	1374	1368	1362	1364	1364	1370	1359	1363	1362	1360
	300				1410	1409	1409	1404	1402	1400	1397	1393	1389	1388	1380	1379	1376	1374	1372	1371	1367	1369	1368	1368	1367	1363	1364	1361
217	400	1411	1410	1410		1401	1396	1391		1386	1384	1381	1376	1373	1370	1369		1364	1362	1359	1354	1354	1357	1357	1354	1357	1356	1354
	300				1407	1401	1398	1393	1391	1389	1388	1384	1380	1378	1371	1371	1369	1366	1364	1364	1362	1363	1363	1362	1361	1359	1357	1354
215	400	1442	1440	1440		1431	1426	1420		1412	1409	1405	1399	1396	1393	1389		1382	1380	1378	1371	1373	1374	1375	1371	1373	1371	1371
	300				1436	1429	1428	1421	1417	1413	1410	1406	1402	1399	1391	1392	1388	1386	1383	1380	1378	1379	1380	1379	1377	1376	1379	1373
214	400	1440	1439	1439		1436	1438	1435		1435	1433	1433	1430	1428	1430	1422		0	1413	1409	1402	1401	1399	1398	1385	1386	1379	1377
	300				1439	1440	1440	1438	1437	1436	1435	1433	1430	1428	1420	1421	1417	1415	1411	1409	1406	1404	1402	1400	1391	1387	1381	1379
212	400	1434	1434	1433		1430	1428	1424		1419	1416	1416	1410	1408	1402	1399		1393	0	1388	1380	1383	1380	1380	1370	1372	1369	1365
	300				1432	1432	1433	1430	1427	1426	1424	1421	1416	1413	1406	1406	1402	1401	1397	1395	1392	1391	1387	1386	1377	1374	1371	1368
213	400	1434	1434	1433		1429	1427	1422		1418	1416	1414	1411	1407	1401	1400		1394	1394	1390	1385	1385	1382	0	1372	1374	1370	1365
	300				1433	1432	1431	1428	1426	1426	1424	1421	1417	1413	1404	1405	1401	1400	1396	1395	1392	1389	1388	1385	1379	1376	1370	1369
210	400	1427	1427	1425		1423	1421	1417		1414	1412	1411	1407	1401	1398	1396		1388	1390	1386	1379	1378	1378	0	1367	1367	1363	1360
	300				1426	1425	1424	1420	1419	1417	1416	1413	1408	1406	1399	1399	1396	1394	1392	1390	1387	1385	1383	1382	1373	1368	1365	1362
211	400	1428	1426	1425		1419	1415	1412		1409	1406	1403	1402	1398	1394	1391		1385	1385	-0	1375	1376	1374	1372	1364	1365	1361	1359
	300				1424	1420	1421	1417	1416	1413	1411	1408	1405	1403	1395	1395	1393	1390	1388	1385	1382	1381	1380	1378	1370	1365	1360	1363

TABLE II. - Concluded. BOILER SHELL SURFACE TEMPERATURES

(b) Concluded. SI units

		DISTANCE FROM CENTER-LINE OF SHELL CUTLET,CENTIMETERS																								
		126	123	118	114	109	104	99	94	89	84	78	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
RUN	SERIES	TEMPERATURES, DEGREES KELVIN																								
209	40C	1413	1412	1412		1404	1400	1396		C	1389	1388	1386	1383	1378	1376		1371	1371	1369	1362	1362	1362	1361	1353	1355	1350	135C
	30C				1409	1403	1402	1398	1397	1394	1393	1390	1388	1386	137P	1380	1376	1376	1373	1371	1368	1367	1366	1364	136C	1355	1353	1352
216	40C	1398	1397	1397		1390	1388	1383		138C	1379	1376	1373	1371	1368	1365		1361	1361	1359	1353	1353	1352	1349	-C	1343	1343	1342
	30C				1395	1391	1389	1384	1383	1381	1379	1378	1375	1373	1367	1368	1367	1366	1363	1363	1358	1359	1358	1356	1351	1346	1346	1344
204	40C	1472	1471	1471		1468	1469	1462		1458	1455	1460	1447	1441	1435	1432		0	1421	1420	1410	1411	1407	14C1	1398	1396	1391	1388
	30C				1471	1470	1468	1465	1463	1462	1459	1456	1451	1448	1438	1437	1431	1429	1426	1422	1417	1416	1414	1410	1402	1398	1393	1391
208	40C	1452	1451	1451		1442	1439	1433		1427	1422	1421	1418	1413	1407	1405		1398	1397	1394	1387	1386	1385	1383	1374	1375	1369	1368
	30C				1447	1442	1441	1435	1433	143C	1428	1424	1420	1416	1408	1409	1404	1402	1399	1396	1393	1391	1390	1387	1379	1376	1372	1371
200	400	1420	1418	1418		1411	1407	14C2		1398	1395	1393	1390	1386	1382	1379		1373	1374	1372	1365	1365	1364	1363	1355	1354	1353	1351
	30C				1415	1409	1407	1402	1401	1398	1396	1394	1387	1388	1381	1382	1378	1377	1376	1374	1370	1370	1370	1367	1362	1358	1356	1355
203	40C	1462	1460	1460		1454	1448	1445		1439	1435	1432	1429	1424	1417	1414		1417	1405	1404	1395	1396	1394	1391	1382	1382	1376	1375
	30C				1459	1453	1453	1446	1445	144C	1438	1435	1430	1427	1418	1417	1415	1412	1409	1405	14C2	1401	1399	1397	1388	1384	1379	1379
205	40C	1466	1466	1466		1460	1457	1452		1447	1443	1440	1435	1431	1425	1423		1413	1405	1411	1401	1401	1401	1397	1388	1387	1381	1379
	300				1464	1461	1460	1456	1454	1452	1448	1445	1439	1436	1427	1425	1421	1418	1415	1412	1407	1406	1404	14C1	1394	1388	1384	1383
201	40C	1433	1432	1432		1423	1418	1414		1408	1403	1402	1400	1396	1391	1389		1379	1382	1379	1373	1372	1372	1370	1363	1364	1359	1359
	300				1429	1423	1420	1415	1412	141C	1408	1404	1401	1398	1391	1392	1388	1387	1384	1383	1379	1378	1377	1375	1369	1364	1362	1362
202	40C	1452	1450	1451		1441	1436	1431		1429	1421	1419	1417	1412	1406	1404		-0	1397	1394	1386	1386	1384	1382	1373	1374	1367	1367
	30C				1446	1439	1438	1432	1429	1426	1424	1420	1416	1413	1405	1406	1401	1400	1397	1394	1391	1389	1388	1386	1378	1374	1371	137C
207	40C	1451	145C	1449		1441	1436	1430		1428	1421	1417	1414	1410	1405	1402		-0	1395	1393	1386	1386	1383	1382	1374	1374	1370	1368
	30C				1447	1441	1438	1432	1430	1427	1425	1422	1417	1415	1406	1406	1402	1400	1398	1395	1391	1390	1388	1386	1379	1374	1371	137C
199	400	14C1	1400	1400		1393	1389	1385		1381	1375	1378	1375	1372	1368	1366		1362	1363	1358	1353	1352	1353	1352	1345	1346	1343	1343
	30C				1397	1392	1390	1386	1384	1382	138C	1378	1375	1374	1367	1368	1365	1364	1362	1361	1358	1357	1357	1356	135C	1347	1346	1345
195	40C	14C0	1400	1398		1391	1388	1382		-C	1376	1375	1365	1368	1365	1363		1358	-0	1357	1352	1351	1352	1351	1345	1347	1345	1344
	30C				1397	1392	C	1384	1383	1381	1380	1377	1373	1372	1366	1367	1364	1362	1362	1361	1358	1357	1357	1355	1351	1348	1346	1346
196	400	1422	1421	1421		1412	1408	1403		1396	1392	1391	1389	1385	1380	1377		1374	1373	1370	1364	1366	1365	1363	1355	1357	1355	1354
	30C				1417	1411	1409	1403	1400	1398	1395	1393	1389	1386	138C	1380	1378	1376	1374	1373	1370	1369	1368	1367	1362	1358	1357	1348
198	40C	1457	1455	1456		1444	1437	1433		1425	1420	1417	1414	14C6	1404	140C		1394	1400	1391	1383	1384	1382	138C	1371	1373	1368	1367
	300				1450	1442	1440	1432	1429	1426	1423	1419	1415	1412	1403	1403	1401	1399	1396	1393	1390	1389	1388	1385	1378	1375	1371	1372
197	4CC	1438	1438	1438		1428	1423	1417		141C	1407	1405	1402	1397	1391	1388		1383	1383	1381	1373	1375	1373	1371	1363	1364	1363	1361
	30C				1435	1424	1425	1418	1415	1412	1410	1407	1402	1399	1393	1392	1390	1387	1385	1383	1379	1379	1378	1376	137C	1366	1365	1363
338	400	1455	1453	1453		1445	144C	1434		1428	1427	1425	1416	1417	1412	141C		1407	1407	1404	1398	1401	1401	14C2	1397	1396	1399	1397
	30C				1451	1444	1442	1436	1434	1431	1429	1426	1422	1419	1413	1414	1413	1412	1408	1407	1403	1406	1405	0	1403	14C0	14C0	1397

337	400	1463	1462	1462		1453	1448	1442		1436	1434	1431	1422	1424	1419	1417		1410	1412	1410	1404	1405	1406	1407	1402	1404	1404	1401
	300				1459	1453	-0	1443	1441	1438	1436	1433	1429	1428	1420	1420	1416	1417	1414	1413	1410	1411	1410	1410	1408	1405	1406	1404
339	400	1446	1445	1447		1437	1432	1427		1423	1421	1417	1411	1412	1408	1406		1400	1403	1400	1395	1396	1397	1395	1391	1394	1395	1393
	300				1442	1437	1433	1430	1427	1425	1423	1420	1417	1415	1408	1409	1407	1405	1403	1403	1400	1402	1401	1400	1399	1395	1397	1394
336	400	1463	1463	1463		1454	1450	1446		1440	1439	1436	1430	1431	1426	1423		1422	1418	1416	1409	1410	1408	1406	1399	1399	1397	1394
	300				1460	1455	1453	1447	1445	1443	1441	1439	1436	1433	1425	1426	1425	1424	1420	1419	1414	1415	1413	1412	1406	1401	1399	1397
334	400	1450	1450	1449		1442	1438	1433		1430	1428	1428	1420	1420	1415	1415		-0	1410	1408	1402	1402	1402	1399	1393	1394	1392	1390
	300				1447	1442	1440	1435	-0	1433	1431	1428	1426	1425	1417	1418	1415	1414	1412	1411	1407	1406	1405	1404	1398	1395	1392	1390
335	400	1451	1449	1449		1440	1436	1432		1426	1424	1422	1415	1416	1411	1410		1407	1405	1404	1398	1401	1404	1402	1396	1398	1395	1397
	300				1446	1439	1439	1432	1430	1427	1425	1423	1420	1417	1411	1411	1410	1409	1407	1407	1405	1407	1405	1406	1404	1402	1401	1399
332	400	1440	1439	1439		1434	1430	1425		C	1420	1419	1412	1413	1409	1407		1404	1404	1402	1396	1397	1397	1394	1387	1389	1387	1385
	300				1437	1433	1433	1427	1425	1424	1424	1421	1418	1415	1409	1412	1410	1408	1406	1405	1402	1402	1400	1399	1392	1391	1389	1388
333	400	1441	1440	1439		1435	1431	1426		1423	1419	1423	1412	1416	1409	1408		1403	1402	1402	1396	1396	1395	1394	1388	1391	1387	1385
	300				1438	1434	1433	1428	1427	1425	1425	1421	1418	1416	1410	1411	1409	1406	1405	1404	1402	1400	1400	1398	1394	1391	1388	1387
331	400	1425	1425	1425		1419	1415	1411		1408	1407	1405	1399	1401	1397	1396		1392	1392	1391	1386	1386	1386	1385	1378	1380	1379	1378
	300				1423	1419	1416	1413	1411	1410	1409	1406	1404	1403	1397	1398	1396	1395	1394	1394	1390	1391	1389	1389	1385	1381	1381	1381
329	400	1448	1446	1446		1439	1439	1429		1424	1421	1423	1413	1413	1410	1409		1402	-0	1401	1395	1398	1395	1393	1388	1391	1389	1386
	300				1443	1438	1437	1430	1429	1427	1426	1421	1419	1418	1410	1411	1410	1407	1406	1406	1401	1401	1400	1399	1393	1390	1390	1388
330	400	1372	1367	1370		1369	1366	1364		1365	1344	1364	1359	1364	1362	1361		1357	-0	1360	1355	1357	1359	1358	1354	1356	1357	1355
	300				1370	1370	1368	1368	1368	1367	1367	1366	1365	1365	1361	1363	1363	1362	1364	1363	1361	1361	1361	1361	1359	1356	C	1358
328	400	1440	1438	1439		1431	1428	1424		1418	1418	1415	1408	1409	1405	1403		1398	1398	1397	1390	1392	1392	1390	1383	1384	1385	1383
	300				1437	1431	1430	1424	1423	1421	1419	1417	1415	1412	1405	1406	1405	1402	1401	1401	1398	1397	1396	1395	1390	1387	1367	1385
327	400	1434	1433	1433		1424	1420	1414		1411	1407	1405	1398	1400	1394	1393		-0	1389	1387	1381	1380	1382	1380	1373	1375	1374	1372
	300				1430	1425	1422	1417	1416	1414	1411	1407	1406	1403	1396	1398	1394	1393	1396	1392	1387	1387	1386	1384	1379	1376	1375	1373

TABLE III. - SYSTEM LIQUID PRESSURE-DROP CALIBRATION

(a) U.S. customary units

Run	Pump voltage, V		Test fluid flow rate, W_t, lbm/hr	Pressure, psia							Temperature, ^{o}F				Pressure drop, psi		
	Pump 1	Pump 3 (a)		Pump 1		Throttle and valve outlet (c)	Test fluid		Condenser		Pump 1		Preheater outlet	Test fluid inlet, $T_{t,I}$	Pump 1	Throttle valve	Throttle valve outlet to test fluid inlet (e)
				Inlet (b)	Outlet		Inlet, $P_{t,I}$ (d)	Outlet, $P_{t,II}$ (d)	Vapor inlet (d)	Outlet, $P_{c,II}$ (d)	Inlet	Outlet					
1	220	+250	760	37.5	49.8	30.5	37.9	36.3	36.2	37.6	1125	1090	1620	1597	12.3	19.3	----
1A	220		700	37.5	49.8	32.8	37.9	36.3	36.2	37.6	1125	1090	1620	1597	12.3	17.0	----
2	120		735	37.6	41.0	21.9	38.0	36.2	36.3	37.7	1105	1075	1590	1599	3.4	19.1	----
3	120		685	37.4	40.6	24.5	37.8	36.0	36.1	37.4	1125	1085	1620	1600	3.2	16.1	----
4	347	+150	585	37.7	71.9	61.1	38.0	36.4	36.3	37.7	1095	1075	1617	1582	34.2	10.8	----
5	297		565	37.8	59.5	50.5	37.9	36.4	36.5	37.7	1030	975	1532	1497	21.7	9.0	----
6	220		525	38.2	48.5	40.8	38.5	37.0	37.0	37.9	935	870	1531	1495	10.3	7.7	----
7	220		515	37.5	49.5	41.0	37.8	36.1	36.3	37.7	1090	1042	1617	1492	12.0	8.5	----
8	120		475	37.4	40.7	33.3	37.6	36.0	36.2	37.5	1075	1020	1619	1575	3.3	7.4	----
9	347	+100	470	37.4	70.0	60.6	37.7	36.0	36.0	37.4	1065	1030	1638	1579	32.6	9.4	----
10	297		445	37.6	59.3	53.2	37.9	36.2	36.4	37.7	1030	955	1532	1489	21.7	6.1	----
11	220		385	38.3	48.1	43.8	38.5	37.0	37.2	37.9	900	810	1533	1477	9.8	4.3	----
12	120		330	37.6	39.7	35.7	37.8	36.2	36.2	37.4	1090	990	1627	1563	2.1	4.0	----
13	120		330	37.6	39.6	34.6	37.8	36.3	36.3	37.7	1035	940	1620	1555	2.0	5.0	----
14	297	+50	340	37.5	59.3	55.1	37.8	36.0	36.3	37.4	1020	925	1534	1472	21.8	4.2	----
15	220	+50	255	38.6	48.1	45.8	38.6	37.1	37.3	38.1	885	750	1536	1451	9.5	2.3	----
16	350	Off	390	37.2	76.3	69.4	37.7	35.9	36.1	37.4	1090	1090	1619	1569	39.1	6.9	32.1
17	350		390	37.0	76.1	69.2	37.4	35.7	35.6	36.9	980	985	1619	1560	39.1	6.9	32.2
18	347		350	37.7	68.2	63.8	38.0	36.4	36.4	37.7	1005	940	1534	1479	30.5	4.4	26.2
19	343		345	37.6	67.3	62.8	37.8	36.1	36.2	37.4	920	855	1534	1468	29.7	4.5	25.4
20	310		300	37.6	60.5	56.8	37.8	36.2	36.3	37.5	1015	825	1534	1461	22.9	3.7	19.4
21	297		295	37.4	59.0	55.4	37.6	36.0	36.1	37.3	1000	895	1536	1463	21.6	3.6	18.2
22	280		270	37.7	56.8	53.8	37.9	36.3	36.4	37.6	990	890	1536	1463	19.1	3.0	16.3
23	250		265	36.8	55.3	51.8	37.0	35.5	35.5	36.9	975	945	1622	1540	18.5	3.5	15.2
24	250		245	37.4	53.8	50.6	37.9	36.2	36.4	37.7	890	835	1619	1530	16.4	3.2	13.1

25	240		220	37.7	49.9	47.6	38.0	36.5	36.3	37.6	915	770	1536	1439	12.2	2.3	10.0
26	220		195	38.5	48.1	46.5	38.6	37.1	37.3	38.0	885	725	1536	1439	9.6	1.6	8.3
27	200		195	36.8	47.2	45.0	37.3	35.7	35.9	37.1	825	785	1622	1510	10.4	2.2	8.1
28	200		175	38.1	46.6	44.6	38.1	36.7	36.7	37.7	970	800	1540	1432	8.5	2.0	6.9
29	160		130	38.1	42.8	41.4	38.2	36.7	36.8	37.8	920	675	1557	1407	4.7	1.4	3.6
30	150		125	37.6	42.5	40.9	37.9	36.4	36.6	37.8	875	750	1622	1470	4.9	1.6	3.4
31	120		80	38.1	40.6	39.3	38.1	36.7	36.9	37.8	945	625	1546	1359	2.5	1.3	1.6
32	Off	+250	740	37.5	37.9	22.0	37.8	36.0	36.1	37.4	1080	1035	1616	1589	.4	15.9	----
33		+220	695	37.4	38.0	20.3	37.8	36.0	36.0	37.3	1105	1075	1439	1430	.6	17.7	----
34		+180	565	37.3	37.7	24.8	37.7	36.1	36.2	37.4	1045	1015	1512	1486	.4	12.9	----
35		+160	490	37.5	37.9	27.8	37.6	36.0	36.0	37.3	1030	985	1609	1556	.6	10.1	----
36		+150	465	37.5	38.0	30.7	37.7	36.0	36.2	37.5	1075	1022	1619	1575	.5	7.3	----
37		+140	430	37.2	37.7	29.8	37.5	35.9	36.0	37.1	1015	965	1619	1559	.5	7.9	----
38		+120	375	37.4	37.9	31.3	37.6	35.9	36.0	37.3	1010	945	1619	1546	.5	6.6	----
39		+100	320	37.6	38.0	33.2	37.8	36.2	36.3	37.7	1015	935	1613	1550	.4	4.8	----
40	(f)	-45	335	37.3	72.5	66.9	37.3	35.8	36.0	37.1	(f)	(f)	1614	1547	35.2	5.6	----
41			280	37.1	63.2	59.2		35.8	35.6	36.9			1618	1537	26.1	4.0	----
42			225	37.1	56.5	53.7		35.7	35.7	37.0			1620	1523	19.4	2.8	----
43			165	37.2	50.5	48.5		35.7	35.8	37.1			1622	1495	13.3	2.0	----
44			100	37.0	46.0	44.8	37.1	35.6	35.8	37.0			1623	1439	9.0	1.2	----
45			45	37.1	44.1	43.0	37.1	35.7	35.8	37.0			1624	1333	7.0	1.1	----
46		-90	265	37.2	79.5	74.5	37.5	35.9	36.0	37.2			1619	1521	42.3	5.0	----
47			230	37.4	75.0	71.2	37.6	36.0	36.2	37.4			1624	1527	37.6	3.8	----
48			190	37.5	71.4	68.6	37.7	36.2	36.2	37.4			1620	1514	33.9	2.8	----
49			155	37.6	68.0	65.6	37.9	36.4	36.4	37.7			1620	1486	30.4	2.4	----
50			105	37.8	65.7	63.9	38.0	36.4	36.4	37.7			1622	1444	27.9	1.8	----
51			60	37.7	64.1	62.8	37.7	36.2	36.3	37.4			1626	1327	26.4	1.3	----

[a]Positive values indicate pumping; negative values, bucking.

[b]Corrected to pump centerline elevation.

[c]Corrected to valve centerline elevation.

[d]Corrected to pressure tap elevation.

[e]Corrected to test fluid inlet elevation.

[f]Not recorded.

TABLE III. - Concluded. SYSTEM LIQUID PRESSURE DROP CALIBRATION

(b) SI units

Run	Pump voltage, V		Test fluid flow rate, W_t, g/sec	Pressure, kN/m^2 abs							Temperature, K				Pressure drop, kN/m^2		
	Pump 1	Pump 3		Pump 1		Throttle valve outlet	Test fluid		Condenser		Pump 1		Pre-heater outlet	Test fluid inlet, $T_{t,I}$	Pump 1	Throttle valve	Throttle valve outlet to test fluid inlet
		(a)		Inlet (b)	Outlet	(c)	Inlet, $P_{t,I}$ (d)	Outlet, $P_{t,II}$ (d)	Vapor inlet (d)	Outlet, $P_{c,II}$ (d)	Inlet	Outlet					(e)
1	220	+250	96	259	344	210	262	250	250	260	880	861	1155	1142	85	134	---
1A	220	+250	88	259	344	226	262	250	250	260	880	861	1155	1142	85	118	---
2	120	+250	93	260	283	151	262	250	250	260	869	852	1138	1143	23	132	---
3	120	+250	86	258	280	169	261	248	249	258	880	858	1155	1144	22	111	---
4	347	+150	74	260	496	422	262	251	250	260	863	852	1153	1134	236	74	---
5	297	+150	71	261	410	348	262	251	252	260	827	797	1106	1087	149	62	---
6	220	+150	66	264	335	282	266	255	255	262	775	739	1106	1086	71	53	---
7	220	+150	65	259	341	283	261	249	250	260	861	834	1153	1084	82	58	---
8	120	+150	60	258	281	230	259	248	250	259	852	822	1155	1130	23	51	---
9	347	+100	59	258	483	418	260	248	248	258	847	827	1165	1132	225	65	---
10	297	+100	56	260	409	360	262	250	251	260	827	786	1106	1082	149	49	---
11	220	+100	49	264	332	302	266	255	257	262	755	705	1107	1076	68	30	---
12	120	+100	42	260	274	246	261	250	250	258	861	805	1159	1123	14	28	---
13	120	+100	42	260	273	239	261	250	250	260	830	778	1155	1119	13	34	---
14	297	+50	43	259	409	380	261	248	250	258	821	769	1107	1073	150	29	---
15	220	+50	32	266	332	316	266	256	257	263	747	672	1109	1061	66	16	---
16	350	Off	49	257	527	478	260	248	249	258	861	861	1155	1127	270	49	222
17	350		49	255	525	477	258	246	246	255	800	803	1155	1121	270	48	222
18	347		44	260	471	440	262	251	251	260	813	778	1107	1077	211	31	182
19	343		44	260	464	433	261	249	250	258	767	730	1107	1071	204	31	175
20	310		38	260	417	392	261	250	250	259	819	714	1107	1067	157	25	134
21	297		37	258	407	382	259	248	249	257	811	753	1109	1068	149	25	126
22	280		34	260	392	371	262	250	251	259	805	750	1109	1068	132	21	112
23	250		33	254	382	358	255	245	245	255	797	780	1156	1111	128	24	105
24	250		31	258	371	349	262	250	251	260	750	719	1155	1105	113	22	90

25	240		28	260	344	328	262	252	250	259	764	683	1109	1055	84	16	69
26	220		25	266	332	321	266	256	257	262	747	658	1109	1055	66	11	57
27	200		25	254	326	310	257	246	248	256	714	692	1156	1094	72	16	56
28	200		22	263	322	308	263	253	253	260	794	700	1111	1051	59	14	48
29	160		16	263	295	285	264	253	254	261	767	631	1120	1037	32	10	25
30	150		16	260	293	282	262	251	252	261	741	672	1156	1072	33	11	24
31	120		10	263	280	271	263	253	255	261	780	603	1114	1010	17	9	11
32	Off	+250	93	259	262	152	261	248	249	258	855	830	1153	1138	---	110	---
33		+220	88	258	262	140	261	248	248	257	869	852	1055	1050	---	122	---
34		+180	71	257	260	171	260	249	250	258	835	819	1095	1081	---	89	---
35		+160	62	257	262	192	260	248	248	257	827	803	1149	1120	---	70	---
36		+150	59	259	262	212	260	248	250	259	852	823	1154	1130	---	50	---
37		+140	54	257	260	206	259	248	248	256	819	791	1154	1121	---	54	---
38		+120	47	258	262	216	260	248	248	257	816	780	1154	1114	---	46	---
39		+100	40	260	262	229	261	250	250	260	819	775	1151	1116	---	33	---
40	(f)	-45	42	257	500	461	257	247	248	256	(f)	(f)	1152	1115	243	39	---
41			35	256	436	408		247	246	254			1154	1109	180	28	---
42			28	256	390	370		246	246	255			1155	1101	134	20	---
43			21	257	348	335			247	256			1156	1086	91	13	---
44			13	255	317	309	256		247	255			1157	1055	62	8	---
45			6	256	304	297	256		247	255			1157	996	48	7	---
46		-90	33	257	548	513	259	248	248	257			1154	1100	291	35	---
47			29	258	517	491	260	248	250	258			1157	1104	259	26	---
48			24	259	492	473	260	250	250	258			1155	1097	233	19	---
49			20	260	469	453	262	251	251	260			1155	1081	209	16	---
50			13	261	453	440	262	251	251	260			1156	1057	192	13	---
51			8	260	442	433	260	250	250	258			1159	993	182	9	---

[a]Positive values indicate pumping; negative values, bucking.
[b]Corrected to pump centerline elevation.
[c]Corrected to valve centerline elevation.
[d]Corrected to pressure tap elevation.
[e]Corrected to test fluid inlet elevation.
[f]Not recorded.

TABLE IV. - TEST BOILER LIQUID PHASE DATA

(a) U.S. customary units

Run	Flow rates, lbm/hr		Terminal temperatures, ^{o}F				Test fluid pressure, psia		Heat-transfer rate, Btu/hr		Heat-transfer rate ratio, Q_t/Q_s	Enthalpy rate ratio, $I = (WC_p)_s/(WC_p)_t$
	Test fluid, W_t	Heating fluid, W_s	Test fluid		Heating fluid		Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Test fluid, Q_t	Heating fluid, Q_s		
(a)			Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{s,II}$						
1	1370	1050	1754	1846	1897	1768	48.7	46.6	41.2×10^3	44.1×10^3	0.932	0.773
2	1360	1530	1755	1864	1899	1794	48.0	45.8	48.3	52.0	.930	1.135
3	1310	1910	1491	1577	1599	1533	24.6	21.9	35.4	39.1	.905	1.468
4	1360	2320	1757	1878	1900	1820	48.5	46.3	54.4	60.4	.901	1.723
5	1310	2870	1491	1580	1594	1549	24.3	21.6	36.0	40.2	.895	2.21
6	1310	3920	1493	1582	1591	1555	24.6	21.9	36.0	43.1	.835	3.01
7	4530	1040	1486	1525	1650	1496	54.4	47.2	54.4	50.5	1.075	.232
8		1540	1486	1534	1646	1507	55.0	47.7	68.0	67.0	1.013	.344
9		2080	1489	1548	1649	1525	54.2	46.7	83.9	82.2	1.020	.463
10		2270	1488	1550	1647	1527	55.1	47.7	88.3	86.2	1.023	.506
11	4510	3070	1488	1555	1644	1544	54.5	47.5	95.1	96.7	.984	.687
12	4510	4000	1488	1565	1645	1558	54.6	47.1	108.3	110.0	.985	.898
13	960	910	1983	2118	2160	1995	----	----	43.7	50.5	.865	.957
14	1750	1040	1498	1548	1595	1507	24.6	21.5	27.1	28.6	.948	.596
15	1990	1040	1678	1755	1834	1692	49.2	46.4	49.7	47.8	1.040	.528
16	2640	1070	1578	1634	1723	1590	50.2	46.6	47.5	45.5	1.045	.410
17	3350	990	1509	1550	1650	1515	50.6	45.6	41.9	42.1	.994	.298
18	600	2900	1503	1600	1602	1577	23.8	21.6	18.0	23.2	.776	4.87
19	650	2930	1600	1693	1695	1667	23.7	21.5	19.5	26.4	.738	4.54
20	1040	2920	1498	1589	1600	1560	24.4	21.9	29.1	36.5	.798	2.83
21	2650	2970	1579	1673	1728	1640	50.6	47.0	79.5	83.2	.955	1.132
22	3300	2970	1496	1582	1656	1559	51.5	46.5	87.5	90.6	.965	.910
23	3470	2970	1497	1579	1652	1555	51.2	46.2	88.5	90.6	.975	.859
24	1980	2350	1675	1783	1827	1734	49.2	46.3	68.3	70.5	.970	1.202
25	2640	2340	1579	1665	1728	1630	49.9	46.2	71.4	73.7	.969	.895
26	3340	3840	1517	1598	1653	1583	50.6	45.6	85.2	84.5	1.008	1.160
27	600	440	1548	1687	1747	1549	36.6	34.7	26.1	27.7	.942	.738
28	600	470	1541	1744	1811	1556	38.7	36.9	38.7	38.5	1.006	.789
29	590	600	1595	1714	1746	1614	37.4	35.5	22.4	25.2	.895	1.021
30		600	1542	1764	1809	1589	38.6	36.7	41.6	42.6	.975	1.026
31		630	1543	1815	1851	1607	52.3	50.5	51.3	49.8	1.031	1.079
32		1090	1557	1853	1872	1710	53.0	51.1	57.2	57.2	1.00	1.885

[a]Runs 1 to 26, preliminary; 27 to 32, final.

TABLE IV. - Concluded. TEST BOILER LIQUID PHASE DATA

(b) SI units

Run	Flow rates, g/sec		Terminal temperatures, K				Test fluid pressure, kN/m^2		Heat-transfer rate, kW		Heat-transfer rate ratio, Q_t/Q_s	Enthalpy rate ratio, $I = (WC_p)_s/(WC_p)_t$
	Test fluid, W_t	Heating fluid, W_s	Test fluid		Heating fluid		Inlet, $P_{t,I}$	Outlet, $P_{t,II}$	Test fluid, Q_t	Heating fluid, Q_s		
(a)			Inlet, $T_{t,I}$	Outlet, $T_{t,II}$	Inlet, $T_{s,I}$	Outlet, $T_{t,II}$						
1	173	132	1230	1281	1309	1237	336	322	12.1	12.9	0.932	0.773
2	171	193	1230	1291	1310	1252	331	316	14.2	15.2	.930	1.135
3	165	241	1084	1131	1143	1107	170	151	10.4	11.4	.905	1.468
4	171	292	1231	1298	1311	1266	334	320	15.9	17.7	.901	1.723
5	165	362	1084	1133	1141	1116	168	149	10.5	11.8	.895	2.21
6	165	494	1085	1134	1139	1119	170	151	10.5	12.6	.835	3.01
7	571	131	1081	1102	1172	1086	375	326	15.9	14.8	1.075	.232
8	↓	194	1081	1107	1170	1093	379	329	19.9	19.6	1.013	.344
9	↓	262	1083	1115	1171	1102	374	322	24.6	24.1	1.020	.463
10	↓	286	1082	1116	1170	1104	380	329	25.9	25.3	1.023	.506
11	569	387	1082	1119	1168	1113	376	328	27.9	28.3	.984	.687
12	569	504	1082	1124	1169	1121	376	325	31.8	32.2	.985	.898
13	121	115	1357	1432	1455	1363	---	---	12.8	14.8	.865	.957
14	220	131	1087	1115	1141	1093	170	148	7.9	8.4	.948	.596
15	251	131	1187	1230	1274	1195	339	320	14.6	14.0	1.040	.528
16	333	135	1132	1163	1213	1138	346	322	13.9	13.3	1.045	.410
17	422	125	1093	1116	1172	1097	349	314	12.3	12.3	.994	.298
18	76	366	1090	1144	1145	1131	164	149	5.3	6.8	.776	4.87
19	82	369	1144	1196	1197	1181	164	148	5.7	7.7	.738	4.54
20	131	368	1087	1138	1144	1122	168	151	8.5	10.7	.798	2.83
21	334	374	1132	1185	1215	1166	349	324	23.3	24.4	.955	1.132
22	416	374	1086	1134	1175	1121	355	321	25.6	26.5	.965	.910
23	437	374	1087	1132	1173	1119	353	319	25.9	26.5	.975	.859
24	250	296	1186	1246	1270	1219	339	320	20.0	20.6	.970	1.202
25	333	295	1132	1180	1215	1161	344	319	20.9	21.6	.969	.895
26	421	484	1098	1143	1173	1134	349	314	25.0	24.8	1.008	1.160
27	76	55	1115	1193	1226	1116	252	239	7.6	8.1	.942	.738
28	76	59	1111	1224	1261	1119	267	254	11.3	11.3	1.006	.789
29	74	76	1141	1207	1225	1152	258	245	6.6	7.4	.895	1.021
30	↓	76	1112	1235	1260	1138	266	253	12.2	12.5	.975	1.026
31	↓	79	1112	1263	1283	1148	361	348	15.1	14.6	1.031	1.079
32	↓	137	1120	1285	1295	1205	366	352	16.8	16.8	1.00	1.885

[a]Runs 1 to 26, preliminary; 27 to 32, final.

TABLE V. - BOILER SHELL SURFACE TEMPERATURES

(a) U. S. customary units

Distance from centerline of shell outlet, in.

TEMPERATURES, DEGREES FAHRENHEIT

RUN	SERIES	49.5	48.5	46.5	44.9	43	41	39	37	35	33	31	29	27	25	23	21	19	17	15	13	11	9	7	4.1	2.5	0.5	-0.5
1	400	1893	1888	1889	1878	1877	1873	1866	1862	1857	1851	1844	1843	1838	1828	1825		1814	1809	1808	1803	1799	1799	1795	1784	1779	1766	1769
	300			1888	1878	1878	1868	1865	1857	1854	1849	1842	1839	1832	1825	1823	1817	1814	1808	1805	1802	1798	1795	1794	1780	1766	1761	
2	400	1899	1895	1896	1885	1889	1889	1883	1883	1880	1872	1870	1870	1862	1657	1855		1845	1845	1839	1835	1831	1831	1827	1814	1806	1795	1791
	300			1893	1888	1889	1885	1883	1879	1876	1872	1868	1866	1861	1853	1853	1846	1845	1841	1836	1832	1831	1827	1823	1809	1797	1784	
3	400	1600	1598	1599	1592	1596	1595	1590	1592	1592	1585	1585	1586	1580	1579	1579		1570	1570	1566	1562	1563	1560	1557	1552	1544	1533	1531
	300			1598	1593	1593	1592	1589	1588	1588	1585	1582	1582	1579	1575	1575	1570	1568	1566	1563	1559	1557	1556	1556	1544	1533	1527	
4	400	1903	1897	1900	1891	1897	1897	1893	1893	1892	1887	1887	1887	1883	1877	1876		1869	1865	1862	1860	1858	1857	1855	1842	1834	1821	1814
	300			1897	1892	1895	1892	1892	1891	1889	1887	1884	1884	1881	1872	1875	1871	1866	1865	1864	1858	1857	1854	1850	1839	1830	1821	
5	400	1597	1592	1594	1588	1591	1591	1588	1591	1590	1587	1587	1590	1584	1581	1582		1577	1577	1575	1572	1572	1572	1571	1564	1562	1551	1549
	300			1588	1585	1587	1587	1585	1584	1584	1582	1582	1581	1580	1577	1578	1574	1572	1572	1571	1568	1567	1567	1565	1555	1549	1545	
6	400	1534	1590	1592	1585	1591	1592	1591	1591	1592	1588	1587	1591	1587	1585	1587		1581	1581	1581	1580	1580	1580	1577	1572	1571	1558	1557
	300			1588	1587	1588	1587	1587	1587	1587	1587	1585	1584	1582	1581	1581	1580	1578	1578	1577	1575	1575	1574	1572	1564	1558	1554	
7	400	1646	1643	1644	1624	1609	1602	1584	1582	1573	1560	1556	1553	1546	1538	1536		1525	1523	1520	1515	1514	1515	1512	1508	1501	1496	1498
	300			1641	1622	1610	1593	1583	1573	1567	1556	1551	1544	1538	1530	1527	1524	1521	1518	1515	1512	1509	1509	1507	1505	1492	1490	
8	400	1644	1640	1641	1626	1623	1617	1606	1602	1592	1583	1580	1577	1569	1561	1557		1550	1546	1543	1537	1533	1534	1530	1524	1515	1509	1508
	300			1641	1630	1620	1609	1604	1594	1589	1582	1574	1569	1561	1554	1553	1546	1543	1538	1534	1531	1530	1527	1525	1521	1507	1502	
9	400	1649	1646	1647	1634	1629	1623	1613	1610	1606	1597	1592	1589	1580	1577	1576		1563	1557	1554	1553	1551	1549	1544	1538	1533	1522	1522
	300			1643	1633	1627	1620	1612	1606	1602	1594	1590	1586	1580	1574	1572	1566	1560	1557	1553	1547	1544	1543	1541	1533	1521	1518	
10	400	1649	1643	1646	1634	1633	1626	1617	1614	1610	1603	1597	1597	1587	1583	1580		1572	1564	1561	1557	1556	1556	1553	1544	1534	1525	1525
	300			1643	1632	1629	1623	1614	1609	1606	1600	1593	1590	1584	1577	1576	1572	1564	1561	1557	1551	1550	1547	1546	1537	1527	1520	
11	400	1649	1644	1647	1636	1637	1632	1627	1624	1620	1614	1612	1610	1603	1600	1594		1589	1582	1582	1579	1576	1574	1569	1561	1556	1547	1546
	300			1644	1634	1629	1629	1620	1617	1616	1610	1607	1604	1600	1592	1592	1586	1580	1580	1577	1573	1573	1569	1567	1556	1546	1541	
12	400	1647	1644	1645	1637	1641	1640	1632	1631	1630	1622	1620	1621	1614	1610	1610		1600	1597	1595	1592	1588	1591	1584	1578	1572	1561	1558
	300			1645	1637	1635	1631	1628	1624	1622	1620	1617	1615	1608	1602	1604	1597	1595	1594	1588	1585	1584	1584	1581	1570	1562	1555	
13	400	2158	2147	2150	2135	2135	2134	2126	2122	2118	2108	2102	2100	2092	2078	2076		2062	2059	2053	2046	2042	2041	2032	2017	2012	1998	2004
	300			2143	2131	2136	2129	2122	2114	2110	2105	2097	2095	2084	2075	2072	2069	2062	2055	2051	2044	2042	2034	2032	2033	1989	1982	
14	400	1592	1590	1592	1580	1580	1579	1569	1570	1566	1557	1556	1557	1550	1546	1544		1533	1533	1530	1527	1526	1527	1524	1517	1514	1507	1508
	300			1585	1578	1578	1569	1565	1560	1557	1552	1550	1546	1543	1537	1536	1531	1529	1526	1524	1523	1521	1518	1517	1511	1501	1499	
15	400	1834	1830	1830	1814	1808	1805	1793	1789	1781	1772	1766	1763	1756	1748	1746		1731	1728	1727	1721	1720	1718	1716	1704	1699	1675	1675
	300			1827	1814	1812	1800	1794	1785	1778	1774	1766	1762	1753	1748	1742	1737	1734	1730	1724	1721	1717	1716	1711	1703	1689	1685	
16	400	1720	1717	1717	1700	1693	1690	1676	1672	1666	1658	1650	1650	1644	1634	1633		1620	1618	1615	1613	1613	1611	1607	1600	1595	1588	1590
	300			1714	1700	1696	1682	1676	1668	1662	1657	1650	1647	1640	1633	1630	1625	1623	1618	1614	1611	1610	1608	1605	1600	1587	1584	
17	400	1646	1643	1644	1626	1614	1610	1596	1592	1583	1574	1569	1566	1559	1553	1550		1538	1537	1534	1531	1530	1530	1528	1521	1520	1515	1517
	300			1643	1626	1620	1604	1596	1586	1580	1573	1567	1560	1556	1549	1547	1543	1537	1536	1533	1530	1528	1527	1525	1521	1511	1508	

18	400	1607	1602	1605	1599	1605	1607	1604	1605	1605	1602	1604	1607	1604	1601	1601		1598	1598	1599	1595	1597	1598	1595	1589	1588	1577	1575
	300			1598	1595	1598	1598	1598	1598	1599	1598	1598	1599	1598	1594	1597	1594	1594	1594	1594	1589	1591	1589	1591	1581	1588	1584	
19	400	1698	1694	1695	1690	1698	1698	1695	1698	1697	1695	1697	1698	1697	1695	1694		1691	1690	1691	1690	1690	1691	1691	1684	1680	1668	1667
	300			1692	1691	1694	1694	1692	1692	1694	1694	1692	1694	1692	1690	1692	1690	1690	1690	1691	1687	1688	1687	1687	1678	1670	1664	
20	400	1603	1600	1601	1594	1600	1600	1599	1599	1599	1594	1593	1599	1596	1589	1590		1584	1586	1586	1581	1580	1583	1581	1574	1574	1561	1560
	300			1599	1596	1599	1597	1596	1596	1596	1594	1593	1593	1591	1587	1590	1587	1584	1584	1583	1580	1580	1579	1579	1570	1561	1556	
21	400	1730	1726	1728	1718	1721	1719	1715	1712	1709	1705	1701	1702	1698	1691	1691		1681	1677	1677	1671	1670	1670	1666	1657	1652	1642	1642
	300			1726	1721	1719	1715	1711	1709	1707	1704	1701	1698	1695	1688	1688	1683	1680	1680	1674	1670	1670	1667	1664	1656	1645	1633	
22	400	1657	1653	1657	1646	1644	1640	1634	1634	1630	1624	1620	1620	1613	1610	1607		1597	1593	1592	1587	1584	1586	1583	1573	1570	1559	1557
	300			1651	1646	1643	1640	1636	1632	1629	1624	1623	1617	1614	1609	1609	1600	1597	1597	1592	1587	1587	1584	1580	1573	1559	1547	
23	400	1654	1650	1652	1641	1645	1640	1635	1634	1631	1625	1610	1620	1615	1611	1607		1600	1594	1593	1588	1584	1584	1583	1573	1568	1557	1555
	300			1651	1647	1641	1640	1634	1630	1628	1625	1620	1617	1613	1607	1607	1600	1595	1594	1590	1585	1585	1583	1580	1571	1558	1552	
24	400	1831	1826	1829	1819	1823	1820	1814	1812	1811	1805	1803	1818	1796	1792	1793		1783	1778	1774	1771	1768	1767	1764	1754	1750	1735	1731
	300			1826	1819	1819	1818	1812	1808	1806	1805	1803	1798	1796	1789	1792	1785	1782	1778	1775	1772	1771	1765	1763	1752	1738	1729	
25	400	1731	1727	1728	1717	1720	1717	1710	1709	1704	1699	1696	1697	1689	1683	1682		1672	1669	1664	1661	1659	1658	1657	1647	1640	1630	1627
	300			1727	1720	1717	1714	1709	1704	1702	1699	1696	1692	1689	1680	1682	1673	1671	1669	1666	1661	1658	1655	1652	1645	1634	1628	
26	400	1655	1652	1653	1646	1649	1648	1643	1643	1640	1633	1632	1633	1629	1623	1625		1616	1613	1612	1609	1608	1609	1603	1595	1598	1585	1583
	300			1652	1648	1648	1645	1642	1638	1639	1635	1633	1632	1626	1623	1622	1619	1615	1613	1611	1608	1608	1605	1603	1593	1583	1579	
27	400	1734	1734	1733	1717	1710	1695	1684		1670	1660	1654	1646	1637	1626	1620		1603	1600	1597	1585	1582	1580	1564	1560	1551	1550	1549
	300				1717	1706	1698	1689	1679	1668	1658	1649	1640	1634	1622	1619	1607	1604	1600	1597	1590	1586	1579	1574	1563	1549	1546	
28	400	1798	1798	1798	1780	1770	1756	1743		1726	1712	1704	1694	1684	1668	1662		1639	1636	1628	1614	1609	1605	1595	1577	1564	1560	1556
	300				1779	1767	1759	1747	1736	1723	1715	1703	1694	1687	1671	1667	1654	1647	1639	1632	1621	1613	1604	1597	1582	1560	1554	
29	400	1738	1737	1738	1729	1727	1719	1718		1712	1707	1708	1702	1696	1688	1684		1670	1673	1667	1656	1655	1655	1646	1632	1619	1615	1612
	300				1732	1731	1725	1721	1718	1714	1710	1705	1700	1698	1687	1688	1679	1679	1673	1670	1663	1659	1655	1649	1635	1616	1611	
30	400	1802	1800	1800	1791	1785	1774	1770		1756	1751	1744	1738	1727	1716	1708		1687	1686	1679	1665	1658	1656	1641	1622	1599	1592	1589
	300				1791	1787	1781	1772	1765	1758	1752	1744	1737	1731	1717	1715	1703	1696	1689	1679	1671	1663	1651	1644	1624	1596	1584	
31	400	1844	1842	1842	1831	1826	1818	1810		1797	1789	1783	1775	1766	1753	1746		1724	1720	1710	1693	1689	1682	1668	1644	1617	1620	1600
	300				1831	1827	1821	1811	1807	1799	1790	1781	1774	1767	1752	1749	1738	1731	1721	1712	1699	1690	1679	1669	1645	1614	1601	
32	400	1871	1869	1869	1861	1865	1860	1857		1856	1853	1852	1848	1846	1835	1831		1820	1820	1815	1801	1798	1794	1782	1760	1725	1714	1696
	300				1861	1863	1860	1857	1856	1853	1852	1849	1845	1842	1831	1831	1826	1824	1819	1815	1807	1798	1793	1782	1760	1719	1696	

TABLE V. - Concluded. BOILER SHELL SURFACE TEMPERATURES

(b) SI units

Distance from centerline of shell outlet, cm

TEMPERATURES, DEGREES KELVIN

RUN	SERIES	126	123	118	114	109	104	99	94	89	84	79	74	69	64	58	53	48	43	38	33	28	23	18	10	6.4	1.3	-1.3
1	400	1307	1304	1305	1299	1298	1296	1292	1290	1287	1284	1280	1279	1276	1271	1269		1263	1260	1260	1257	1255	1255	1253	1248	1244	1236	1238
	300			1304	1299	1299	1293	1291	1287	1285	1283	1279	1277	1273	1269	1268	1265	1263	1260	1258	1256	1254	1253	1252	1244	1236	1234	
2	400	1310	1308	1309	1303	1305	1305	1301	1301	1300	1295	1294	1294	1290	1287	1286		1280	1280	1277	1275	1273	1273	1270	1263	1259	1253	1250
	300			1307	1304	1305	1303	1301	1299	1298	1295	1293	1292	1289	1285	1285	1281	1280	1278	1275	1273	1273	1270	1268	1260	1254	1246	
3	400	1144	1143	1144	1140	1142	1141	1139	1140	1140	1136	1136	1136	1133	1133	1133		1128	1128	1125	1123	1124	1122	1120	1118	1113	1107	1106
	300			1143	1140	1140	1140	1138	1138	1138	1136	1134	1134	1133	1130	1130	1128	1126	1125	1124	1121	1120	1120	1120	1113	1107	1104	
4	400	1313	1309	1311	1306	1309	1309	1307	1307	1306	1304	1304	1304	1301	1298	1298		1294	1291	1290	1289	1288	1287	1286	1279	1274	1267	1263
	300			1309	1306	1308	1306	1306	1306	1305	1304	1302	1302	1300	1295	1297	1295	1292	1291	1291	1288	1287	1285	1283	1277	1272	1267	
5	400	1143	1140	1141	1138	1139	1139	1138	1139	1139	1137	1137	1139	1135	1134	1134		1131	1131	1130	1129	1129	1129	1128	1124	1123	1117	1116
	300			1138	1136	1137	1137	1136	1135	1135	1134	1134	1134	1133	1131	1132	1130	1129	1129	1128	1126	1126	1126	1125	1119	1116	1114	
6	400	1141	1139	1140	1136	1139	1140	1139	1139	1140	1138	1137	1139	1137	1136	1137		1134	1134	1134	1133	1133	1133	1131	1129	1128	1121	1120
	300			1138	1137	1138	1137	1137	1137	1137	1137	1136	1135	1134	1134	1134	1133	1132	1132	1131	1130	1130	1130	1129	1124	1121	1119	
7	400	1170	1168	1169	1158	1149	1145	1135	1134	1129	1122	1120	1118	1114	1110	1109		1103	1101	1100	1097	1096	1097	1095	1093	1089	1086	1088
	300			1167	1156	1150	1140	1135	1129	1126	1120	1117	1113	1110	1105	1104	1102	1100	1099	1097	1095	1094	1094	1093	1091	1084	1083	
8	400	1169	1166	1167	1159	1157	1154	1148	1145	1140	1135	1133	1131	1127	1123	1120		1116	1114	1113	1109	1107	1108	1105	1102	1097	1094	1093
	300			1167	1161	1155	1149	1146	1141	1138	1134	1130	1127	1123	1119	1118	1114	1113	1110	1108	1106	1105	1104	1103	1100	1093	1090	
9	400	1171	1170	1170	1163	1160	1157	1151	1150	1148	1143	1140	1138	1133	1131	1131		1124	1120	1119	1118	1117	1116	1113	1110	1107	1101	1101
	300			1168	1163	1159	1155	1151	1148	1145	1141	1139	1136	1133	1130	1129	1125	1122	1120	1118	1115	1113	1113	1111	1107	1100	1099	
10	400	1171	1168	1170	1163	1163	1159	1154	1152	1150	1146	1143	1143	1137	1135	1133		1129	1124	1123	1120	1120	1120	1118	1113	1108	1103	1103
	300			1168	1162	1160	1157	1152	1149	1148	1144	1140	1139	1135	1131	1131	1129	1124	1123	1120	1117	1116	1115	1114	1109	1104	1100	
11	400	1171	1169	1170	1164	1165	1162	1159	1158	1155	1152	1151	1150	1146	1144	1141		1138	1134	1134	1133	1131	1130	1127	1123	1120	1115	1114
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	300			1169	1165	1164	1161	1160	1158	1156	1155	1154	1153	1149	1145	1146	1143	1141	1141	1138	1136	1135	1135	1134	1128	1123	1119	
13	400	1454	1448	1450	1441	1441	1441	1436	1434	1432	1426	1423	1422	1418	1410	1409		1401	1399	1396	1392	1390	1389	1384	1376	1373	1365	1369
	300			1446	1439	1442	1438	1434	1430	1428	1425	1420	1419	1413	1408	1406	1405	1401	1397	1395	1391	1390	1385	1384	1385	1360	1356	
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	300			1136	1132	1132	1127	1125	1122	1120	1118	1116	1114	1113	1109	1109	1106	1105	1103	1102	1101	1100	1099	1098	1095	1089	1088	
15	400	1274	1272	1272	1263	1260	1258	1251	1249	1245	1240	1236	1235	1231	1226	1225		1217	1215	1215	1211	1211	1210	1209	1202	1199	1186	1186
	300			1270	1263	1262	1255	1252	1247	1243	1241	1236	1234	1229	1226	1223	1220	1219	1216	1213	1211	1209	1209	1206	1201	1194	1191	
16	400	1211	1209	1209	1200	1196	1194	1186	1184	1181	1176	1172	1172	1169	1163	1163		1155	1154	1153	1151	1151	1150	1148	1144	1141	1138	1139
	300			1208	1200	1198	1190	1186	1182	1179	1176	1172	1170	1166	1163	1161	1158	1157	1154	1152	1150	1150	1149	1147	1144	1137	1135	
17	400	1170	1168	1169	1159	1152	1150	1142	1140	1135	1130	1127	1125	1121	1118	1116		1110	1109	1108	1106	1105	1105	1104	1100	1100	1097	1098
	300			1168	1159	1155	1146	1142	1136	1133	1129	1126	1122	1120	1116	1115	1113	1109	1109	1107	1105	1104	1104	1103	1100	1095	1093	

18	400	1148	1145	1147	1144	1147	1148	1146	1147	1147	1145	1146	1148	1146	1145	1145		1143	1143	1144	1141	1143	1143	1141	1138	1138	1131	1130
	300			1143	1141	1143	1143	1143	1143	1144	1143	1143	1144	1143	1141	1143	1141	1141	1141	1141	1138	1139	1138	1139	1134	1138	1135	
19	400	1199	1196	1197	1194	1199	1199	1197	1199	1198	1197	1198	1199	1198	1197	1196		1195	1194	1195	1194	1194	1195	1195	1191	1189	1182	1181
	300			1195	1195	1196	1196	1195	1195	1196	1196	1195	1196	1195	1194	1195	1194	1194	1194	1195	1193	1193	1193	1193	1188	1183	1180	
20	400	1146	1144	1145	1141	1144	1144	1144	1144	1144	1141	1140	1144	1142	1138	1139		1135	1136	1136	1134	1133	1135	1134	1130	1130	1123	1122
	300			1144	1142	1144	1143	1142	1142	1142	1141	1140	1140	1139	1137	1139	1137	1135	1135	1135	1133	1133	1133	1133	1128	1123	1120	
21	400	1216	1214	1215	1210	1211	1210	1208	1206	1205	1203	1200	1201	1199	1195	1195		1189	1187	1187	1184	1183	1183	1181	1176	1173	1168	1168
	300			1214	1211	1210	1208	1206	1205	1204	1202	1200	1199	1197	1193	1193	1190	1189	1189	1185	1183	1183	1181	1180	1175	1169	1163	
22	400	1176	1174	1176	1170	1169	1166	1163	1163	1161	1158	1155	1155	1151	1150	1148		1143	1140	1140	1137	1135	1136	1135	1129	1128	1121	1120
	300			1173	1170	1168	1166	1164	1162	1160	1158	1157	1154	1152	1149	1149	1144	1143	1143	1140	1137	1137	1135	1133	1129	1121	1115	
23	400	1174	1172	1173	1167	1169	1166	1164	1163	1161	1158	1150	1155	1153	1150	1148		1144	1141	1140	1138	1135	1135	1135	1129	1126	1120	1119
	300			1173	1170	1167	1166	1163	1161	1160	1158	1155	1154	1151	1148	1148	1144	1141	1141	1139	1136	1136	1135	1133	1128	1121	1118	
24	400	1273	1270	1271	1266	1268	1266	1263	1262	1261	1258	1257	1265	1253	1251	1251		1246	1243	1241	1239	1238	1237	1235	1230	1228	1219	1217
	300			1270	1266	1266	1265	1262	1260	1260	1258	1257	1254	1253	1249	1251	1247	1245	1243	1241	1240	1239	1236	1235	1229	1221	1216	
25	400	1217	1215	1215	1209	1211	1209	1205	1205	1202	1199	1198	1198	1194	1190	1190		1184	1183	1180	1178	1177	1176	1176	1170	1166	1161	1159
	300			1215	1211	1209	1208	1205	1202	1201	1199	1198	1195	1194	1189	1190	1185	1184	1183	1181	1178	1176	1175	1173	1169	1163	1160	
26	400	1175	1173	1174	1170	1171	1171	1168	1168	1166	1163	1162	1163	1160	1157	1158		1153	1151	1151	1149	1149	1149	1146	1141	1143	1136	1135
	300			1173	1171	1171	1169	1168	1165	1166	1164	1163	1162	1159	1157	1156	1155	1153	1151	1150	1149	1149	1147	1146	1140	1135	1133	
27	400	1219	1219	1218	1209	1205	1197	1191		1183	1178	1174	1170	1165	1159	1155		1146	1144	1143	1136	1134	1133	1124	1122	1117	1116	1116
	300				1209	1203	1199	1194	1188	1182	1176	1171	1166	1163	1156	1155	1148	1146	1144	1143	1139	1136	1133	1130	1124	1116	1114	
28	400	1254	1254	1254	1244	1239	1231	1224		1214	1206	1202	1196	1191	1182	1179		1166	1164	1160	1152	1149	1147	1141	1131	1124	1122	1120
	300				1244	1237	1233	1226	1220	1213	1208	1201	1196	1193	1184	1181	1174	1170	1166	1162	1156	1151	1146	1143	1134	1122	1119	
29	400	1221	1220	1221	1216	1215	1210	1210		1206	1204	1204	1201	1198	1193	1191		1183	1185	1181	1175	1175	1175	1170	1162	1155	1153	1151
	300				1218	1217	1214	1211	1210	1208	1205	1203	1200	1199	1193	1193	1188	1188	1185	1183	1179	1177	1175	1171	1164	1153	1150	
30	400	1256	1255	1255	1250	1247	1241	1239		1231	1228	1224	1221	1215	1209	1204		1193	1192	1188	1180	1176	1175	1167	1156	1144	1140	1138
	300				1250	1248	1245	1240	1236	1232	1229	1224	1220	1217	1209	1208	1201	1198	1194	1188	1184	1179	1173	1169	1158	1142	1135	
31	400	1280	1279	1279	1273	1270	1265	1261		1254	1249	1246	1241	1236	1229	1225		1213	1211	1205	1196	1194	1190	1182	1169	1154	1155	1144
	300				1273	1270	1267	1261	1259	1255	1250	1245	1241	1237	1229	1227	1221	1217	1211	1206	1199	1194	1188	1183	1169	1152	1145	
32	400	1295	1294	1294	1289	1291	1289	1287		1286	1285	1284	1282	1281	1275	1273		1266	1266	1264	1256	1254	1252	1245	1233	1214	1208	1198
	300				1289	1290	1289	1287	1286	1285	1284	1283	1280	1279	1273	1273	1270	1269	1266	1264	1259	1254	1251	1245	1233	1210	1158	

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