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Potassium Vapor Topping Cycle
Technical Progress Report for Period
October 1, 1976-December 31, 1976

Robert S. Holcomb

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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Engineering Technology Division

POTASSIUM VAPOR TOPPING CYCLE

TECHNICAL PROGRESS REPORT FOR PERIOD
OCTOBER 1, 1976 - DECEMBER 31, 1976

Robert S. Holcomb

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Prepared by the
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POTASSIUM VAPOR TOPPING CYCLE
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ABSTRACT

The potassium vapor topping cycle is a concept for increasing the efficiency of the Rankine vapor cycle by raising the peak temperature by employing a potassium vapor cycle with a turbine inlet temperature of 1500 to 1600°F (815 to 870°C) in which the waste heat rejected from the condensing potassium vapor is transferred to boiling water and steam in a conventional steam cycle. An efficiency of about 50% is calculated for this cycle with a natural circulation potassium boiler fired by gas or oil.

An ERDA program is underway at ORNL to build a full-scale potassium boiler tube bundle and burner module and test it with water and then potassium. This is the first in a series of quarterly progress reports.

The water test which was begun in July 1976 was completed except for the vapor separator test. The results of the argon distribution test indicate that the argon flow rate in all of the boiler tubes will be adequate to provide nucleation promotion for stable boiling of potassium. The heat load of individual boiler tubes was measured and it was found that the outer bank of tubes has an average heat load that is about 67% of the average for each bank. A peak temperature difference of 45°F (25°C) between the tube temperature of the inner and outer banks was measured during startup indicating that there should be no problems from thermal stresses.

Nearly all of the mechanical design work for the potassium system components has been completed. The electrical and instrument and controls design is just getting well underway. Welding and piping fabrication on the condenser has been nearly completed. Fabrication of parts for the condenser enclosure is more than halfway done. Fabrication of the cylindrical portion of the drain tank has been completed.

I. SCOPE

A. Introduction

An important step that can be taken to reduce our national fuel consumption is to increase the efficiency of our thermodynamic cycles. Few realize that a major factor in keeping our consumption from increasing more rapidly than it has during the past century has been an increase in the thermal efficiency of steam plants by about a factor of 8. Unfortunately, there has been no further increase since about 1950 because at that time we reached the upper practicable temperature limit for the steam cycle; namely, about 1000°F (538°C). To reach higher thermal efficiencies, it will be necessary to go to higher temperatures and this in turn implies the use of other working fluids. A leading candidate for an advanced thermodynamic cycle is a potassium or cesium vapor cycle.

The approach proposed by ORNL entails raising the peak temperature of the thermodynamic cycle by employing a potassium vapor Rankine topping cycle that operates with a turbine inlet temperature of 1500 to 1600°F (815 to 870°C) and superimposed on a conventional steam cycle with a turbine inlet temperature of about 1000°F (538°C) by transferring the waste heat rejected from the condensing potassium vapor to the boiling water of the steam cycle.¹ Design studies have indicated that with a natural circulation boiler fired by gas or oil in a potassium topping cycle, a cycle efficiency of about 50% can be achieved.²

The basic layout of the power plant envisioned is shown in Fig. 1. Three basic systems are coupled to form the power plant, i.e., a gas turbine that supercharges the combustion chamber for the potassium boiler, the potassium vapor topping cycle, and an essentially standard steam cycle. The most important components involving new technology are the furnace-potassium boiler unit and the potassium condenser-steam generator unit, both of which employ tube bundle modules as their basic unit of construction.

The ORNL gas- or oil-fired potassium boiler concept employs a basic tube bundle module that consists of two annular rows of 1-in. diameter stainless steel tubes arranged around a 22-in. diameter, long, vertical, cylindrical chamber. A full-scale test unit is shown in Fig. 2. The flame from the burner directs hot gas upward through this combustion chamber.

Fig. 1. Flow sheet for the proposed potassium vapor topping cycle system showing the relationships of the major components.

Fig. 2. Photo of the ORNL potassium boiler under construction.

The tubes are bent at the top to provide flow passages between them so that the hot gas from the top of the combustion chamber can flow radially outward and then downward through an outer annulus over the outer row of tubes. To reduce the amount of heat transfer surface area required, the furnace and combustion chambers would be operated at a pressure of 6 to 10 atm, i.e., substantially above the 2 atm which would be the design operating pressure of the potassium vapor system. Potassium would circulate under natural thermal convection from a header tank at the top of the tube bundle through two downcomers, one on either side, to two ring-shaped manifolds at the bottom, and then vertically upward through the tubes back to a header drum and vapor separator at the top of the header tank.

Preliminary studies have also indicated that a particularly attractive system could be obtained by coupling a potassium or cesium vapor cycle to a fluidized bed coal combustion system. One very promising concept is a fluidized bed that would operate at a temperature of about 1700°F (927°C) and a pressure of about 5 atm. This pressure yields an acceptable pressure drop with a bed of sufficient depth to employ a vertical tube natural circulation boiler. To minimize the problems of turbine bucket erosion, corrosion, and deposits the hot gases leaving the bed would be cooled to about 1000°F (538°C) before being admitted to a gas turbine to give a power output just sufficient to drive the compressor. The studies indicate that a cycle efficiency of about 48% can be achieved with this type of system.

The key factor in achieving the lower capital cost and higher thermal efficiency projected by the ORNL design lies in employing a vertical tube, natural circulation boiler rather than a horizontal tube, forced circulation boiler. Therefore, being a new design, it is very important that it be shown that the natural circulation boiler can be operated successfully. A program for testing a full-scale tube bundle and burner module first on water and then potassium was initiated to investigate the uncertainties that have become evident in the course of the design. These uncertainties fall into four major problem areas: burner performance; combustion gas heat transfer; flow distribution of the two-phase potassium liquid-vapor mixture and the tube bundle temperature distribution; and the vapor separator effectiveness. In many cases the cumulative uncertainties in the analysis are

substantial and can be resolved only by obtaining test data. A section through the test module is shown in Fig. 3.

The water test is designed to get as detailed an insight into these problems as possible. The water tests are being run with boiling at atmospheric pressure. In the first phase of the tests the top of the boiler drum is open so that visual observation of the flow from the boiler tubes is possible. The boiler drum being open will also make it much easier to install instrumentation that will yield a detailed picture of the flow distribution than will be the case in later tests with potassium.

The potassium test will provide a test of the boiler bundle and furnace at the design conditions of full pressure and temperature for potassium operation. While visual observation and measurement of flows from each boiler tube cannot be done while operating with potassium, the tube bundle temperature distribution will provide an indication of the potassium two-phase flow distribution.

The results obtained from the test program will provide boiler design data that will be beneficial to both gas-fired and fluidized bed coal-fired systems.

B. Objective

The overall objectives of the program are to complete the water test; design, fabricate and install the potassium system; and run the potassium test.

1. Water Test

- a. Check out the boiler and furnace.
- b. Check out combustion air seals.
- c. Measure tube bundle and flue gas temperature distribution.
- d. Observe argon distribution.
- e. Operate at a power level of 2×10^6 Btu/hr.
- f. Observe boiling stability.
- g. Establish minimum power level for stable boiling in outer tube bank.
- h. Measure heat load on individual boiler tubes.
- i. Observe vapor separator performance.

Fig. 3. Section through the gas-fired potassium boiler tube bundle module, burner and furnace assembly.

2. Potassium System

- a. Complete the design of components and modifications for the potassium system.
- b. Perform system modifications and fabrication of components, including tower extension, condenser, drain tank, piping, sample box, electrical system, instruments and controls.
- c. Install the potassium system components.

3. Potassium Test

- a. Check out system.
- b. Measure tube bundle and flue gas temperature distribution.
- c. Monitor boiling nucleation problem.
- d. Operate at power levels up to 4×10^6 Btu/hr.
- e. Observe liquid level control.
- f. Observe vapor separator performance.
- g. Run 2000 hr endurance test.
- h. Determine minimum argon flow required for nucleation.

II. PROGRESS TO DATE

A. Work Prior to FY 1976

Work on alkali metal vapor cycles at ORNL began with some design studies under the Aircraft Nuclear Propulsion program in 1954 and was resumed in 1958 with studies of nuclear electric space power plants. This led to an extensive series of component and system tests in the course of which ~200,000 hr of boiling potassium system operation were obtained in the early and middle 1960's. When the pressing need for reductions in both fuel consumption and heat rejection to the environment became evident in 1970 a design study of a potassium vapor cycle plant was carried out under NSF sponsorship.¹⁻³ This plant was designed to operate on clean gaseous fuel derived from coal, the preferred fuel-of-the-future for central stations at that time. The study showed that the greatest uncertainties from both the design and cost standpoints lay in the potassium boiler, and that these could be resolved best by designing, building, and testing a full-scale tube bundle and burner module

first with water and then potassium. Funds to begin this work were made available by NSF in July 1972 and NSF funding was continued in 1973. When ERDA was proposed in June 1973, the responsibility for the potassium vapor cycle work became uncertain, with NSF, the AEC, OCR, and NASA all having claims in this area. As a consequence of these uncertainties, the program remained unfunded through 1974 until ERDA was formed at which time some interim funds were made available from NSF, and funds from ERDA-FE finally became available at ORNL for the program in December 1975.

B. Accomplishments in FY 1976

The shakedown and performance tests of the burner operating outside the boiler in the open air were completed in May 1976. The water system installation was completed and the water test was begun in July 1976. Detailed design of the potassium system was resumed in April 1976 and much of the work was completed by the end of September. Fabrication of components for the potassium system such as the condenser and drain tank was initiated in August.

III. TECHNICAL PROGRESS

A. Summary of Progress this Quarter

1. Water Test

All of the tasks planned for the water test were completed except for the vapor separator test. Those completed include measurement of the argon distribution, heat load of individual boiler tubes, boiler temperature distribution, combustion gas temperature distribution and combustion air pressure drop.

The results of the argon collection tests indicate that the argon flow rate in all of the boiler tubes is in the range of 2 to 11 ml/min, and this is felt to be adequate to provide nucleation promotion for stable boiling of potassium. Measurements of the heat load on individual boiler tubes with a calorimeter show that the outer bank of tubes has an average heat load that is about 67% of the average for the inner bank and the variation for individual tubes is about $\pm 10\%$ from the average for each bank.

Temperature data from thermocouples on the boiler tubes during startup indicate a peak temperature difference of 45°F (25°C) between the tube temperature in the inner and outer banks with the temperature of the liquid downcomer about half-way between. Tube temperatures measured under steady boiling conditions indicate that all of the tubes in the bundle are running at a temperature that is within a few degrees of any other tube. On the basis of these results, no problems from thermal stresses are expected. The combustion gas temperature measurements indicate a fairly uniform flue gas distribution and good heat transfer to the boiler tubes.

The combustion air pressure drop that was observed was higher than would have been predicted for the air flow passing through the burner at a given power level. This is accounted for by the fact that a leak across the sliding seal between the burner and boiler shroud allowed about 40% of the air to bypass the burner and be discharged directly into the exhaust gas stream.

2. Potassium System

Nearly all of the mechanical design work for the potassium system components was completed this quarter. An elevation drawing of the potassium test system is shown in Fig. 4. The tower extension drawings are almost finished and will be released early in January. The condenser modification drawings were all completed. All of the drawings for the condenser enclosure are done. Most of the design work on the potassium vapor and liquid return piping has been completed. The sample box assembly and sample box potassium piping drawings were finished and released.

The design work on the electrical supply and heaters and instruments and controls is just now getting well underway. Thermocouple routing drawings for the condenser and the argon separator were completed. The front layout and wiring details

for three new instrument panels have been determined. The instrument application diagram was completed and is being reviewed.

Fabrication on modifications and new components for the potassium system has proceeded very well during the quarter. Work on piping and welding fabrication on the condenser has been nearly completed. Fabrication of parts for the condenser enclosure is more than halfway completed. Fabrication of the cylindrical portion of the drain tank has been completed and welding of the dished heads to the cylinder has begun. Work was begun on the potassium sampler and enclosure. Modification of several existing instrument panels from another project was begun.

B. Progress by Task

1. Water Test

a. Argon Distribution - Visual observation of the bubbling rate from the outlet of each boiler tube of the argon provided for nucleation indicated that a large part of the gas was coming up the tubes near the injection point and only small amounts were passing through the other tubes. A photograph of the open top of the boiler drum showing the argon bubbles is seen in Fig. 5. A sampling system as shown in Fig. 6 was devised to pump a fraction of the water from one boiler tube at a time and allow the argon to be released and collected in a flask, and the water returned to the lower end of the boiler tube. A plot of the argon collection rate for 15 of the 24 tubes in the "B" inner tube row is shown in Fig. 7. All but three of the tubes fall in the range of 4 to 8 ml/min, with the lowest tube being 2 and the highest 11 ml/min, and this plot is typical for all the tube rows. These data were taken at incipient boiling in the tubes, at which point the peak collection rate that could be obtained with the sampling system was found. Mockup tests with a single boiler tube have shown that, as would be expected, the argon flow rate found at

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Fig. 5. View of the open boiler drum showing argon bubbles in water at ambient temperatures.

ORNL-DWG 76-19779

Fig. 6. Sampling and collection system for measuring argon flow rate in boiler tubes.

Fig. 7. Peak argon collection rate vs tube location on header.

incipient boiling is also maintained after boiling is well established. It is concluded that this range of argon flow rate will be adequate to provide nucleation promotion for stable boiling of potassium.

b. Boiler Tube Heat Loads - One of the principal objectives of the water test is to determine the stability of boiling and the uniformity of boiling heat load among the individual tubes. A sampler was built and installed in the boiler drum that is designed to collect the two-phase flow from one boiler tube at a time. The steam-water mixture from the tube passes through a calorimeter that is cooled by a measured flow rate of water. By measuring the change in the cooling water temperature it is possible to determine the relative heat load of each boiler tube. The temperatures of the two-phase mixture from the boiler tube and of the condensate leaving the calorimeter were measured to provide an indication that the steam was condensed and the degree of subcooling of the condensate. Figure 8 is a schematic drawing of the calorimeter and a photograph of it is shown in Fig. 9.

A plot of condensate subcooling vs the heat load measured by the calorimeter is shown for two typical tubes in each of the 6 rows in Figs. 10-21. Data points were taken at each of three calorimeter cooling water flow rates. It may be observed from Figs. 10-15, which are for tubes in the inner tube bank, that the value of the heat load at each data point agrees fairly closely for each of the 6 tubes. The slope of the line through the data is inversely proportional to the weight flow rate of condensate; the slope agrees fairly well for the 6 tubes of the inner bank. Note that for the outer tubes, Figs. 16-21, the heat load per tube at each data point is lower than for the inner tubes and the slope of the line is greater, indicating a lower condensate flow rate. The average measured heat load per tube in the outer rows is about 67% of the average for the inner rows. The inner bank of tubes was expected

Fig. 8. Drawing of calorimeter assembly.

Fig. 9. Photograph of calorimeter assembly.

Fig. 10. Condensate subcooling vs heat input into calorimeter.

Fig. 11. Condensate subcooling vs heat input into calorimeter.

Fig. 12. Condensate subcooling vs heat input into calorimeter.

Fig. 13. Condensate subcooling vs heat input into calorimeter.

Fig. 14. Condensate subcooling vs heat input into calorimeter

Fig. 15. Condensate subccoling vs heat input into calorimeter.

Fig. 16. Condensate subcooling vs heat input into calorimeter.

Fig. 17. Condensate subcooling vs heat input into calorimeter.

Fig. 18. Condensate subcooling vs heat input into calorimeter.

Fig. 19. Condensate subcooling vs heat input into calorimeter.

Fig. 20. Condensate subcooling vs heat input into calorimeter.

Fig. 21. Condensate subcooling vs heat input into calorimeter.

to have a greater heat load than the outer bank, since the inner tubes see the high temperature flame and the outer bank is heated only by convection by the flue gases at a lower temperature.

The variation in heat load for the tubes in the inner rows is given in Fig. 22. The highest value is about 16% above the average and the lowest about 10% below. The variation in heat load among the tubes in the outer rows is shown in Fig. 23. A greater variation was found for the outer tube rows, but it was observed that the largest deviation from the average value occurred near the argon injection points. It was hypothesized that the high argon flow rate at these tube positions might be pumping a high flow rate of water through these tubes and this might account for the lower temperatures measured at the discharge of these tubes. A set of data was taken with the argon turned off and these results are shown compared to the data with argon flow in Fig. 24. The values found without argon flow, shown with the solid line, have a variation of only about $\pm 8\%$ from the average. It is concluded that the data without argon flow are representative of the heat load on these tubes and the lower discharge temperature with argon flow yields the wider indicated variation in heat load. All these data were taken at a burner power level of 2.8×10^6 Btu/hr. A set of data was also taken at a burner power level of 2.0×10^6 Btu/hr and the results indicated that stable boiling had not been achieved in the outer bank of tubes at this lower level. A photograph showing boiling at 2×10^6 Btu/hr is presented in Fig. 25 and a high discharge rate of water from two outer tubes is observed indicating unstable boiling in the outer tubes at this power level.

c. Boiler Temperature Distribution - To minimize thermal stress in the boiler tube bundle it is important that the boiler tubes and the liquid downcomers operate with a difference of no more than about 100°F in average temperature.

Fig. 22. Relative heat removal rate for inner rows.

Fig. 23. Relative heat removal rate for outer rows.

Fig. 24. Relative heat removal rate for outer row F with and without argon flow.

PHOTO 3230-77

Fig. 25. View of open boiler drum at a boiler power level of 2×10^6 Btu/hr.

Thermocouples are attached on the outside of 12 boiler tubes and the two downcomers at two levels at the positions indicated in the diagrams of Figs. 26 and 27. The boiler is started up with the liquid level in the boiler drum above the outlet of the boiler tubes so that thermal circulation of liquid will maintain as uniform a temperature as possible throughout the tube bundle until boiling begins. A maximum temperature difference of 45°F (25°C) was observed during startup under these conditions. A set of boiler temperature data taken at steady state boiling at a burner power level of 2.4×10^6 Btu/hr is given in Table 1. In general, the temperatures run slightly lower than the water saturation temperature (210°F). This is probably because of contact resistance between the thermocouple and the tube wall. There is a thin layer of insulation over the thermocouple junction to insulate the thermocouple from the flue gas. The higher reading of 225°F (107°C) observed for the lower thermocouple on tube D-11 is probably caused by faulty insulation on that thermocouple.

d. Combustion Gas Temperature Distribution - Combustion gas temperatures are measured in the annulus where the flue gas passes downward over the outer bank of tubes at a point about 7 ft (2.1 m) above the lower ring header and just below the lower ring header where the flue gas discharges from the outer bank of tubes. These locations are indicated in Fig. 27. Two shielded thermocouples, one located near each of the liquid downcomers, are located in the combustion gas stream at each of the two levels. A set of combustion gas temperature data taken at a burner power level of 2.4×10^6 Btu/hr is presented in Table 2. The temperatures observed at the lower elevation are lower than the water saturation temperature, and this is probably accounted for by the fact that the water temperature in the downcomers is below the boiling point just above the top of the burner cup. The low combustion gas temperatures present for operation with water

T.E. ORIENTATION VIEW

Fig. 26. Thermocouple location diagram plan.

Fig. 27. Thermocouple location diagram elevation.

Table 1. Boiler Temperature Distribution

<u>Thermocouple Location</u>		<u>Temperature (°F)</u>
Tube B-1	Upper	190
Tube B-1	Lower	200
Tube A-3	Upper	200
Tube A-3	Lower	195
Tube C-6	Upper	218
Tube C-6	Lower	200
Tube B-13	Upper	195
Tube B-13	Lower	200
Tube A-15	Upper	200
Tube A-15	Lower	200
Tube C-18	Upper	195
Tube C-18	Lower	200
Tube F-6	Upper	205
Tube F-6	Lower	210
Tube E-8	Upper	195
Tube E-8	Lower	200
Tube D-11	Upper	190
Tube D-11	Lower	225
Tube F-16	Upper	195
Tube F-16	Lower	200
Tube E-18	Upper	195
Tube E-18	Lower	205
Tube D-22	Upper	185
Tube D-22	Lower	200
Downcomer		
(North)	Upper	195
(North)	Lower	200
Downcomer		
(South)	Upper	190
(South)	Lower	195

Table 2. Combustion Gas Temperature Distribution

Thermocouple Location	Temperature (°F)
Elevation No. 1 (Near North Downcomer)	245
Elevation No. 1 (Near South Downcomer)	230
Elevation No. 2 (Near North Downcomer)	200
Elevation No. 2 (Near South Downcomer)	205
Exhaust Duct Elbow	175

in the boiler illustrate why the outer bank of tubes have a lower heat load than the inner bank. A thermocouple is also located at the flue gas exhaust duct elbow. The temperature observed here is lower because the combustion gas has given up heat to the incoming air in the preheat tee annulus.

e. Combustion Air Pressure Drop - An important factor in the operation of the furnace is the pressure drop of the combustion air as it passes through the preheat tee, burner and tube bundle. It has particular significance with respect to the structural integrity of the shroud that confines the combustion gas flow around the outer bank of boiler tubes. The design of the furnace is such that the incoming combustion air pressure is present on the outside of this shroud, and the pressure inside the shroud is just slightly higher than the flue gas discharge pressure. A plot of the pressure difference across the shroud as a function of the burner power level is presented in Fig. 28. The pressure drop increases faster with burner power than would normally be the case. This is brought about by the leaking seal that was discussed

Fig. 28. Differential pressure across boiler shroud vs burner power level.

in earlier reports, which allows about 40% of the incoming combustion air to bypass the burner and leak to the exhaust gas stream. The total air flow, including the excess quantity, is contributing to the pressure drop up to the leaking seal; so that the pressure drop is higher than what it would be for just the air flow that reaches the burner for combustion. The measured pressure drop is about 1.2 psi for a burner power level of 2.88×10^6 Btu/hr. There is no concern about the buckling strength of the shroud at the lower temperatures at which it operates in the water tank, but care must be taken not to exceed the calculated allowable pressure drop at the higher temperature that will be present during the potassium test. The shroud temperature will be monitored as the power level is increased while operating with potassium.

2. Potassium System Design

a. Tower Extension - The structural drawings for the extension have almost been completed. It is expected that these drawings will be released about January 10. The mechanical assembly and component drawings were transmitted to the CPTF contractor who will perform the tower extension and major installation work.

b. Condenser - The design work for modifications of the existing potassium vapor condenser was completed during this quarter. The condenser assembly drawing is shown in Fig. 29.

c. Condenser Enclosure - All of the drawings for the condenser enclosure have been completed.

d. Drain Tank - The design of the drain tank was completed at the end of the previous quarter. The drain tank assembly drawing is presented in Fig. 30.

e. Potassium Piping - The design of the potassium piping is about 80% complete. The vapor piping drawings are all done and the condensate return piping will be completed soon.

1. FOR T/E ATTACHMENTS & MOUNTING PROCEDURES
SEE I & C DWG. # I-10617-QG-006D

2. CLEANLINESS TO BE DETERMINED BY PROJECT ENGINEER PRIOR TO ASSEMBLY IN SYSTEM.

Fig. 29. Potassium vapor condenser assembly drawing.

f. Sample Box - The design work on the potassium sampler box is about 90% complete. Only one or two drawings remain to be finished.

g. Air and Argon Piping - The design of the air and argon piping system is about 50% complete at this time.

h. Electrical - The design of the electric power supply system and the electric heaters for the potassium components is just now getting well underway and is only about 25% complete.

i. Instruments and Controls - The design work on instruments and controls is about 35% complete. The thermocouple location, routing, and attachment drawings for the potassium condenser and the argon separator were completed in December. The terminal box wiring detail for these thermocouples is nearing completion. Work is continuing on the drawing for the resistance-type level element for the boiler drum liquid level indicator.

The front layout and wiring details for three new instrument panels have been determined.

Design of the control interlock circuits, measuring signal circuits and pneumatic circuit schematics is continuing. The instrument application diagram was completed and is being reviewed. All of the instrument components have been identified and a tabulation of these is being made.

3. Potassium System Fabrication

a. Condenser - Work continued on piping and welding fabrication on the potassium vapor condenser and the argon separator during the quarter and this work is nearly complete. A photograph of the condenser is shown in Fig. 31.

b. Condenser Enclosure - Fabrication of the condenser enclosure has progressed well this quarter. Fabrication of parts for the air discharge stack and condenser enclosure assembly is shown in Fig. 32. The enclosure has a diameter

Fig. 31. Potassium vapor condenser with modifications nearly completed.

Fig. 32. Condenser enclosure assembly.

of about 13 ft (4 m) and a height of about 17 ft (5 m). Photographs of the inlet air duct, inlet air plenum, and outlet air plenum are shown in Fig. 33, 34, and 35 respectively.

c. Drain Tank - Fabrication of the cylindrical portion of the drain tank has been completed. The dished heads for the drain tank were received from the vendor and fabrication of the tank has been resumed. The fill and drain tank enclosure has been completed.

d. Sample Box - Work was begun on the potassium sampler and the sampler enclosure.

e. Instruments and Controls - Modification of several existing instrument panels from another project was begun.

Fig. 33. Condenser inlet air duct.

Fig. 34. Condenser inlet air plenum.

Fig. 35. Condenser outlet air plenum.

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