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I. HRT

1. Cooling Water System

Concern for possible stress corrosion of the stainless steel parts of the cooling water system due to chlorides in the untreated service water led to reappraisal of the system.

Methods that can be taken to prevent stainless steel stress corrosion include: elimination of tensile stress at the exposed surface, removal of surface discontinuities, cathodic protection, and treatment of the corroding fluid to reduce its corrosiveness. The last-named measure appears the most practical for the HRT system. Building 7500 service water contains approximately 10 ppm chloride whereas the desirable maximum is about 1 ppm.

The existing design includes two separate sources of cooling water:

a) Potable building service water. This water is used to cool the cell space coolers, reactor thermal shield, refrigeration condensers, the fuel and blanket sample station coolers and the waste evaporator condensers. The effluent water is discharged to the cooling tower for make-up. Of this equipment, only the sample station coolers are of stainless, and since these items are located outside the cell, they are not considered as critical from a stress corrosion standpoint.

b) Cooling tower effluent. This water is divided into two streams, that to the turbine condenser, turbine oil cooler, and deaerating heater vent condenser, which are non-stainless items, and from which the water is returned to the cooling tower; and that to the cell equipment such as circulating pumps, dump coolers, etc., all of which are important from a stress corrosion standpoint and from which the water is discharged through the charcoal adsorber beds to

waste. The water requirement for these last-named items is about 20% of the total HRT cooling load.

A detailed study is under way of both the steady-state and dump cooling loads for the cell equipment with a view toward designing a separate demineralized water closed circulating loop, discharging heat through a heat exchanger to the cooling tower. Available surplus heat transfer equipment is being considered. A circulating pump of about 350 gpm capacity at 100-ft head is required. Preliminary examinations indicate that the piping modifications necessary to make this change are not prohibitive. It is estimated that the bulk temperature of the cooling tower water would be raised 12.3°F by this arrangement, to a total of about 102.3 °F, a value which may be unacceptably high. Other sources of demineralized water are also under consideration.

2. Refrigeration System

Design was completed for addition of eight pairs of new refrigerant lines to the system, involving four new penetrations through the shield, cans for the insulated lines inside the shield, and modification of the valve manifold stations. These new lines serve additional freeze jackets and provide two pairs of spares for the fuel side and three pairs of spares for the blanket side.

Design of a clamp-on type freezer and operating mechanism (for 1/2" pipe size), based on use of a C-clamp, was completed. A prototype was built and tested by Bldg. 7500 personnel with satisfactory results, so that design of similar freezers and operators for the five other requisite pipe sizes are now in progress.

Testing of the installed refrigeration system disclosed that some of the refrigerant lines to the cold traps had been inadvertently interchanged. The

test results were studied and recommendations were made for changes which led to proper operation.

Tests of the installed system indicated that back flow was taking place through solenoid valves when de-energized. A ball check valve was devised in the union fitting on the valves and tested with satisfactory results. In modifying the 16 solenoid valves, however, heat applied for silver-soldering the ball retaining pin in place was sufficient to oxidize the lapped-in seat (and in some cases the steel ball) rather heavily. On further complaint of back-flow through the valves, each of the valves was tested and found to be leaking badly due to the above-mentioned oxidation. Swing check valves are now being installed rather than the improvised ball checks.

A design report on the entire HRT refrigeration system, including the freeze jackets, is now in progress.

3. Off-Gas Vent for Fuel Storage Tanks

The present HRT design shows the off-gas from the outer dump tank reflux condenser discharged through the hold-up tank directly into the stack. This design was based on the premise that the solution would be stripped of fission product gases while in the inner dump tank so that little activity would be present in the off-gas from the outer storage tanks. Cognizance has now been taken of the presence of bromine-83 and iodine 133 and 135 in the inner dump tank solution, which, if allowed to decay in the outer dump tanks to krypton-83 and xenon 133 and 135, causes considerable concern for the activity in the vent line from these tanks. The radiation level at a distance of one foot from line 165 in the east valve pit has been estimated to be about 100 r/hr one hour after shutdown after long-time operation at 5-Mw reactor power level with about 54 curies/sec released to the stack; 24 hours after shutdown the radiation at

Line 165 would be about 16 r/hr and about 5 curies/sec released to the stack.

It is not considered practical to store the fuel in the inner tanks for the requisite decay time (estimated at about 11 days) for safe venting of the outer tank directly into the stack. Further, the pressure build-up in the outer tanks has been estimated to become excessive in only a few hours unless the tanks are vented. A separate charcoal adsorber bed may be used for retention of the radiolytic gases, but preliminary estimates indicate that the volume of bed required is large (approaching the size of the main HRT adsorber beds) and also an explosive situation exists with the presence of the D_2 and O_2 in contact with the cesium catalyst formed by the xenon decay. Tests are now being made of a natural circulation type recombiner. The completion of the design for the off-gas system for the outer dump tanks has been postponed pending results of these tests.

4. Corrosion Specimen Holders

a) Conceptual designs of corrosion specimens and corrosion specimen holders for the core and blanket systems have been prepared.

b) Heat generation in sample holders. A rough estimate was made of the heat generation in the components of a design for a sample holder to be inserted into the core of the HRT. A titanium rod 0.367" dia. was planned as the main structural member of the holder. The highest temperature reached in the sample holder will probably be reached in this rod, since it has the least surface to volume ratio as well as having the highest thermal neutron cross section (the other components being zircaloy, stainless steel or titanium).

The thermal flux at the center of the reactor was taken as 1.7×10^{14} n/cm²-sec. The following assumptions were made:

- a) Each neutron absorbed resulted in one 8.8 mev gamma.
- b) All gammas produced in the titanium rod were absorbed by the rod.
- c) All other heat sources were taken as 50% of the gamma heating.

The heat absorption rate was then found to be 3.48×10^{14} mev/cc-sec, or about 12.4 watts/gm. At steady state the rate of heat removal must be 61,800 Btu/hr-ft². Assuming natural convection, the heat transfer coefficient, h_c is: ⁽¹⁾

$$h_c = 130 (\Delta t)_f^{1/3}$$

where Δt is the temperature drop, °F, between surface of rod and the fuel solution. If the heat removal rate is designated q/A , then,

$$q/A = h_c (\Delta t)_f = 130 (\Delta t)_f^{4/3} = 61,800 \text{ Btu/hr-ft}^2$$

and

$$(\Delta t)_f = 102^\circ\text{F}$$

With an operating fuel temperature of 536°F, the surface temperature would thus be about 638°F, or about the boiling point of the fuel solution when at 2,000 psia.

While 638°F may be somewhat high because of the assumptions made, this rough estimate indicates that the central rod should be designed with greater surface area to reduce the danger of boiling and phase separation of the fuel solution at the sample holder.

5. Flange Test Program

a) Flange test facility. A natural convection loop is in the process of being designed and built. The facility provides 2000 psia saturated steam to eight sets of flanges ranging in pipe size from 1/2 to 3-1/2 inch. It is hoped to simulate HRT cyclic conditions with the facility and thus evaluate

⁽¹⁾ Aven, R. E., "Some Heat Removal Considerations of the HRT Pressure Vessel During Operation, CE 55-7-64.

the many factors which influence the reliability of flanged joints. Various combinations of bolting will be tested with both oval and octagonal ring gaskets in order to find the best type of joint for the HRT. It is hoped that a reliable combination can be found in time to permit making any necessary modifications to the reactor flanged joints before the reactor operates at a high power level.

b) Flange bolt extensometers. Some extensometers have been built which will measure the bolt extension by the use of dial indicators while tightening. These devices are being checked on some flanges to see if they provide a satisfactory means of determining bolt load.

c) Flange deflection measuring device. A device has been fabricated and partly tested for measuring flange rotation about the gasket due to tightening, pressure, and temperature cycling. Further development will be carried out in the future.

d) Flange and gasket inspection equipment. Requisitions have been issued for the purchase of gaging equipment with which to accurately measure the dimensions of rings and grooves of flanged joints.

6. Replacement Pressure Vessel

a) Specifications for a replacement core, pressure vessel and blast shield (HRT-1114, 1115 and 1116) were issued for comments and will be re-issued soon for final approval. Two drawings have been prepared as part of these specifications (E-25601 and E-25602).

b) Supports and blast shield. Pressure vessel supports were designed from the standpoint of accessibility and installation with respect to the presently installed HRT pressure vessel and its supporting structure. The blast shield design is based on structural containment of the impact forces incident to a pressure vessel failure due to embrittlement.

7. HRT Specifications

a) The following specifications have been issued for comments:

HRP-6 - Heat Exchanger Tube Joint Welding

HRP-8 - Ultrasonic Testing

HRP-DS-1a - Weld Joint Preparation

The following specifications have been issued for approval:

HRP-A213-347 - Heat Exchanger Tubing

HRT-306 - Pressure Balancing Control Valve

HRT-1031 - Replacement Steam Generator

HRT-1113 - Thermal Cycle Tests

8. Miscellaneous HRT Work

a) Differential temperature flow measuring assemblies are being designed to indicate the flow from the two feed and four purge pumps. Present plans are to use the feed coolers for the feed pumps and to install hot water jackets on the discharge lines of the purge pumps.

b) A drawing has been completed showing the extension of the existing T section supports on the HRT steam generator. This revision will make the bolts accessible from the top of the cell. (Dwg. D-25605)

c) A ball float for an experimental level indicator, which may be installed in the HRT hold-up tank, was designed and a sketch made for inclusion in a purchase requisition (Req. 16D-69911).

d) The steam drum pit piping drawings are being brought up-to-date and four process monitors will be located and mounted in the cell. Two of the monitors will be shielded with 4" of lead.

e) A memo was written and sketch provided, regarding the addition of a counter weight assembly to the blanket dump tank weigh system in order to reduce the load on the pneumatic weigh cell and thereby increase its range.

f) Several drawings are being made to add removal clips to the mountings of the feed and purge pumps. The clips are used in connection with the tools designed by Vitro for removal of the pumps.

g) Tools are being designed for use with the pressurizer rupture disc assembly. They will provide for unbolting and replacement of the internal disc housing.

h) Drawings of the periscope mounts at the north wall and the lighting facility to be used with the periscope are in the final drafting stage.

i) A new approved drawing list (Issue No. 11) will be issued soon.

j) Revisions to the piping at the pressurizer rupture disc assembly are being made in accordance with field sketches. Two pairs of flanges will be eliminated and part of the piping will be re-routed and shortened.

k) A list of HRP 347 stainless steel material requirements is being compiled for use in purchasing a stock supply for needs over the next two years.

II. DEVELOPMENTAL WORK

1. Thermal Cycling Loop

Preliminary calculations have been made for a thermal cycling loop to be used by the Engineering Development Section for testing of high-pressure equipment experiencing rapid temperature fluctuations. A tentative flowsheet has been prepared. The system presently planned consists of an intermediate heat exchanger of about 120 sq. ft. effective surface area supplied with saturated steam from a 5000 lb/hr, 2000 psig, package steam generator of the Basler type, to heat a solution that will be circulated through the test equipment at the requisite high pressure. Cooling will be accomplished by boiling off water from the intermediate heat exchanger. The test loop is being designed with

the requirements of the HRT main heat exchanger thermal cycling tests in mind. Specifications prepared by the Engineering Development Section for the package steam generator and the intermediate heat exchanger have been reviewed. Preliminary work incident to preparation of detailed design of the thermal cycling loop is now underway.

2. The final drawings of the experimental diaphragm pump loop have been checked and will be issued as soon as they are completed. (TD-D-2963, 2964, 2965, 2966 and 2967). A report has also been written (R. C. Moren - May 25, 1956).

3. HRT Bellows Test

The loop for testing a duplicate of the bellows in the HRT reactor vessel has been built and is being given a pre-operational check out. Some flange studies will be carried out on the 10 inch - 1500 lb. flange at a later date.

4. Miscellaneous Loop Work in Progress

- a) 200A loop layouts.
- b) In-pile loop layouts.
- c) Slurry pump casing liner with insert.
- d) 200 AT pressurizer design.
- e) Toroid rotator drawings.

III. HOMOGENEOUS RESEARCH REACTOR

The first rough draft of a preliminary feasibility report on a circulating fuel aqueous homogeneous research reactor has been prepared. The objective of this reactor is to supply as many research facilities as practical in a region of 10^{15} - 10^{16} neutrons/cm²-sec, of as large a size as practical. The purpose of the report is to delineate the nature, scope and relative importance of the problems pertaining to this type of reactor, rather than finding their optimum solution. In order to achieve this objective, designs and layouts of the major components of the proposed system were made. Beyond this objective, the designs were

carried only to a stage of completion required to make a preliminary cost estimate. This estimate indicates that the total fixed plant investment will be in the order of \$48,000,000, which, if 125,000 Kw of electrical power is produced will amount to \$384/Kw. The key design parameters on which the plant is based are listed in Table 1.

Table 1

Key Design Parameters

The present status of homogeneous reactor technology is deemed to be adequate to permit the design, construction and operation of a feasible reactor complex based on the following design parameters, provided successful solutions of the problems which are uniquely associated with the experimental facilities of the reactor can be resolved.

Reactor type	Single-region, circulating fuel Homogeneous
Fuel type	UO ₂ SO ₄ -D ₂ O CuSO ₄
Uranium concentration	
Total uranium	10 g/liter at 250°C
Uranium enrichment	
Uranium-235	0.8 g/liter at 250°C
CuSO ₄ to recombine 100% of gas	0.02 Molar
H ₂ SO ₄ to stabilize U & Cu	0.02 Molar
Maximum nickel concentration	0.01 Molar
Fuel solution temperature	
Minimum (Inlet to reactor vessel)	225°C
Maximum (Outlet of reactor vessel)	275°C
Average (System)	250°C
Temperature increase	50°C

Fuel system pressure	1400 psi
Neutron flux	
Maximum thermal	$\sim 6.5 \times 10^{15} \text{ n/cm}^2\text{-sec}$
Maximum fast	$1-5 \times 10^{15} \text{ n/cm}^2\text{-sec}$
Power density —	
Maximum (at reactor center)	110 Kw/liter
Average	34 Kw/liter
Minimum (at vessel wall)	1.9 Kw/liter
Gross power level	500 Mw
Reactor vessel key specifications:	
Inside diameter	10 ft
Vessel material	Carbon steel Clad with Type 347 HRP stainless steel
Gross volume	14,800 liters
Experimental Facilities	
Horizontal	6 required
Vertical	1 required
Maximum inside diameter	6 in.
Material	Zr-2
Minimum wall thickness	1 in.
External System	
Material	Type 347 stainless steel HRP specifications
Allowable velocities:	
at 225°C	10-15 ft/sec
at 250°C	25-35 ft/sec
at 275°C	30-40 ft/sec
at 300°C	40-50 ft/sec

Reactor control

a) Negative temperature coefficient of reactivity

b) Concentration of fuel

Heat dissipation

Generation of approximately 125 Mw of electrical power

The reference design, as conceived for the purpose of the report, may be described as a heavy-water (D_2O) moderated circulating fuel type of reactor. The nuclear reaction is achieved in a 10 ft. inside diameter essentially spherical shaped pressure vessel having a minimum gross volume of approximately 14,800 liters. The vessel is constructed of carbon steel with a stainless steel corrosion liner and is designed for an internal pressure of 1400 psi in accordance with the rules of the ASME Code for Unfired Pressure Vessels, taking into consideration the thermal stresses resulting from radiation absorption. The pressure shell is pierced at equally spaced intervals on the major diameter for the insertion of 6 six-inch inside diameter experimental thimbles. The thimbles are fabricated of zircaloy-2 for minimum neutron absorption. Other thimbles of smaller size may possibly be located at intermediate position for irradiation of small specimens. A vertical facility also may be provided.

Two main circulating pumps of 17,650 gpm/capacity each are required to circulate the fuel solution through the six main heat exchangers. The pumps will be vertical high-pressure centrifugal pumps of the canned-motor type with special modifications to make them suitable for pumping the corrosive solution.

Each of the main heat exchangers is visualized as a two-drum unit consisting of a vaporizing section and a steam-drum. The two vessels are connected by risers and downcomers to promote circulation. The fuel solution flows through 3280 parallel 3/8 in. 18 BWG stainless steel tubes in the vaporizer section of each of the six exchangers required. The fuel solution gives up 83.3 Mw (2.84×10^8 Btu/hr) to generate 35,600 lbs/hr of saturated steam at 300 psia.

and 417°F. A total of 2.11×10^6 lb/hr of steam is generated and this steam is used to generate electrical power.

In addition to the reactor vessel, piping, pumps and heat exchangers comprising the main high-pressure loop, the reactor complex must have auxiliary equipment for storage of fluid, recombination of decomposition gases, pressurization of the system, etc. These items are placed in shielded cylindrical containment vessels to retain safely the vapors and radioactive gases which would be released in the event of a catastrophic rupture of the high-pressure equipment.

IV. MISCELLANEOUS

R. E. Aven of the Design Section worked jointly with P. R. Kasten in preparation of the paper "Fuel Requirements in Batch and Continuously Processed Homogeneous Reactors" for presentation at the meeting of the ANS, Chicago, June 6-9, 1956.

Abstract: The fuel requirements of a large, heavy water moderated homogeneous reactor have been estimated for a variety of initial loadings, for both batch and continuous methods of fuel removal. The initial loadings consisted of various concentrations of U^{235} and U^{238} . The fuel feed rates were obtained for the batch cases as a function of operating time, and for the continuous cases as a function of feed enrichment and fuel processing cycle time. The associated fuel costs were estimated as a function of operating time for both methods of fuel removal.

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