DEGASSING SPARGER PLATE
SCREENING TESTS
SEPTEMBER 1958

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DEGASSING SPARGER PLATE

SCREENING TESTS

SEPTEMBER 1958

By
D. C. Starkweather

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I. INTRODUCTION

Two volatile fission gases, xenon and krypton, are formed during the operation of a nuclear reactor. As the concentration of these gases increases, the reactor becomes poisoned and its operation is adversely affected. Removal of these gases as they are formed is necessary for continuous reactor operation.

As a part of the Liquid Metal Fuel Reactor Experiment (LMFRE) project at the Research Center, a test program was undertaken to screen gas sparging methods in which helium would be used to remove the volatile fission products from a flowing mixture of liquid bismuth and uranium. The selection of the sparging method was to be based on the ability of the device, when submerged in stagnant and flowing baths of both water and mercury at room temperature and pressure, to produce small, uniformly distributed bubbles. Final acceptance of the method, however, would be governed by its action under actual operating conditions when bubbling helium gas through a U-Bi mixture.
II. SUMMARY

This report describes the work performed while testing methods of introducing the flow of liquids onto the sparger plate surface and while testing porous metal sparger plates and plates containing various size drilled holes. These plates were tested when submerged in both water and mercury while using compressed air as the sparging gas.

As a result of this work, a sparger plate assembly design was made that, it is believed, will operate satisfactorily in the double-pump sump of Radiation Loop No. 2 for the Engineering Test Reactor (ETR) at Arco, Idaho. Included in this report are arrangement and detail drawings of this assembly (see Fig. 4, 5, and 6) which has the following features:

1. A divided flow path, each containing a sparger plate, so that the liquid velocity is reduced to approximately 0.5 ft/sec as it passes over each plate.

2. Each sparger plate contains fifteen No. 80 drilled holes to provide uniformly distributed bubbling action at gas flows as low as 0.04 cfm per plate at 0.62 psi static pressure.

3. At constant liquid flow conditions, a drainable dam located downstream from each sparger plate maintains a constant liquid depth over the plate regardless of level variations in the sump tank itself.

4. All of the U-Bi mixture must pass over the sparger plates.

5. Baffling has been located at the discharges of the sparger plates to insure complete release of any entrained gases from the liquid before it returns to the circulating pump.

6. All portions of the sparger assembly are designed to permit complete drainage of liquid metal.

7. The sparger assembly is totally enclosed to prevent any liquid metal spray, caused by bursting gas bubbles, from impinging on the sump tank surfaces.
8. The sparger gas plenum chambers are designed to prevent any possible liquid metal seepage through the sparger holes from accumulating and eventually filling the chambers. This is accomplished by having the plenum chambers as open-end tubes that extend below the sump liquid level. Any seepage merely returns to the sump. As the sparger gas is admitted to the plenum chambers, it displaces only that head of liquid equal to the gas static pressure.

Bubbles created by a 10-micron porous plate appeared to be smaller than those produced by a plate containing No. 80 drilled holes. However, the porous plate was not incorporated in the design for two reasons: (1) unavailability of necessary sizes of porous materials chemically compatible with U-Bi matrices, and (2) non-uniformity of bubbling action produced by the porous stainless steel plates used during this series of tests.

No statement can be made at this time about the efficiency of the sparger plate assembly shown in Figures 4, 5, and 6. This can be done only after it has been installed and tested in a system containing bismuth and uranium.
III. CONCLUSIONS

Bubble size, as judged by eye, is controlled by the size of the gas opening. This is based on the observation that the porous plate containing 10-micron average size pores produced smaller bubbles than the plate containing No. 80 drilled holes; the No. 80 drilled holes formed smaller bubbles than the No. 70 drilled holes.

Uniform distribution of bubbles is dependent upon not only the size of the gas opening, but also the uniformity in size of the gas openings. The No. 80 drilled holes produced uniform bubbling action, whereas the No. 70 drilled holes did not. It is believed, however, that the non-uniform bubbling caused by the 10-micron porous plate was a result of nonuniformity of pores in the plate under test.
IV. RECOMMENDATIONS

This program was preliminary in that the method of admitting the liquid to the sparger surface and the bubbling characteristics of various sparger plates were determined by using only compressed air, water, and mercury. Therefore, to ascertain the sparging capability of the assembly shown in Figures 4, 5, and 6, it is recommended that this unit be fabricated and then installed and tested in the double-pump sump of Radiation Loop No. 2 for the ETR.
V. DESCRIPTION OF APPARATUS

As proposed under Atomic Energy Division Specification No. ATC-157-1/463300, the liquid metal was to flow perpendicularly downward onto the surface of a porous metal sparger plate and then spill off into the sump tank. As the liquid flowed across the plate, the sparging gas was to bubble up through and drive off any volatile gases entrained in the liquid.

The test facility shown in Figure 1 was constructed to furnish the desired liquid flow pattern. A modified Gorman-Rupp centrifugal pump with a steel rotor was used to circulate the mercury. Flow was measured by a calibrated orifice fitted with static pressure taps. The flow of the sparging gas, simulated by compressed air, was measured by a calibrated Fischer and Porter Precision Bore Flowrator.

Since the program was to test sparging methods and not materials, the sparger plate consisted of a 6-in. by 6-in. by 1/8-in. porous stainless steel plate containing pores of 10-micron average size. This plate was "Heliarc" welded to the top of a plenum chamber located in a 8 1/4-in by 8 1/4-in. drain box connected to the suction side of the circulating pump.

The downshot method of introducing the liquid metal onto the sparger plate, with its excessive horizontal liquid velocity and tendency for the re-entrainment of gases, was abandoned in favor of directing the liquid as a stream across the face of the sparger plate (see Fig. 2). In an attempt to reduce the liquid velocity to a minimum, a divided flow path was selected, necessitating two sparger plates. Sump tank restrictions limited the stream width to 6 in. By maintaining a liquid depth of 1 in., the liquid velocity at design flow conditions of 2.664 cfm would, therefore, be approximately 0.5 ft/sec over each sparger plate. Because of circulating pump limitations, only one-half of the sparger assembly was fabricated. A 1-in. by 6-in. strip of 10-micron porous stainless steel was used as the sparger plate. Two 1-in. high turning vanes were used
to guide the liquid from the pump discharge pipe to the sparger plate. Considerable channeling occurred, however, at the exits of the turning vanes.

This sparger plate assembly was further modified (see Fig. 3). The porous stainless steel sparger plate was replaced by a 1-in. by 6-in. stainless steel plate containing drilled holes - first, forty-seven No. 70, then, sixteen No. 70, and finally, sixteen No. 80. The turning vanes were replaced by two rows of closely spaced 1/4-in. diameter pins. The row farthest upstream from the sparger plate was placed at approximately 45° to the direction of liquid flow and its pins set on 1/2-in. centers. The row located just downstream of the sharp bend in the liquid stream and adjacent to the sparger plate was made up of pins placed on gradually decreasing centers, 1/2-in. at the inside of the bend to 11/32-in. at the outside of the bend. These two rows of pins eliminated the channeling effect of the turning vanes and produced a smooth, even flow across the sparger plate. An additional row of 1/4-in. diameter pins set on 3/8-in. centers was located downstream of the sparger plate to act as a dam to control the liquid depth. As long as the liquid flow was maintained at the design condition of 1.332 cfm per sparger plate, the depth of liquid over the sparger plate remained constant at 1 in., regardless of liquid level variations in the sump tank itself. The turbulence produced by these pins tended to remove any entrained gas bubbles before the liquid was returned to the circulating pump.
VI. TEST PROCEDURE

The various sparger plate assemblies were tested under similar conditions. First, an air calibration check was made with no liquid over the plate. The plate was then submerged to a depth of 1 in. in a nonflowing water bath, where bubbling action was observed and photographed. Water at a depth of 1 in. was then circulated across the sparger plate at a rate of 2.664 cfm for the single, 6-in. by 6-in. plate, downshot system and 1.332 cfm for the twin, 1-in. by 6-in. plate, horizontal-flowing systems. Again, the bubbling action was observed and photographed. Mercury then replaced the water and the procedure was repeated. The performance of each sparging device was judged by its bubbling action, bubble size, and uniformity of distribution, as seen by the eye. No attempts were made to actually measure the bubble size or to determine the sparging efficiency of each device.
VII. DISCUSSION

The downshot system (Fig. 1), in which the liquid metal was directed perpendicularly downward onto the surface of the porous metal sparger plate, was abandoned because of (1) excessive horizontal velocity of the liquid, (2) the tendency to promote re-entrainment of gases into the liquid, and (3) the unavailability of a porous metal of suitable dimensions that would be chemically compatible with U-Bi mixtures.

By directing the liquid metal as a stream flowing horizontally across the sparger plate surface (Fig. 2), undue splashing was eliminated. It was believed that adequate sparging could be accomplished by passing the liquid metal over a 1-in. by 6-in. strip of stainless steel containing forty-seven No. 70, 0.028-in. diameter, drilled holes. Tests showed that uniformly distributed bubbling was not being created and that liquid metal seepage through the drilled holes was occurring. All holes were checked for possible pluggage and then enlarged with a No. 67, 0.032 in. diameter, drill. Results of this change were that bubbling distribution was not improved, bubble size was increased, and liquid metal seepage rate increased.

Continued communication with vendors of porous plate brought forth no commitments, only the statement that 1-in. diameter disks of either molybdenum or pure iron (both chemically compatible with U-Bi mixtures) were available for use as sparger plates. It was decided to arrange these disks in two staggered rows. For test purposes, however, a 1-in. by 6-in. strip of porous stainless steel was substituted. Tests showed that bubble formation was not uniform again although the bubble size was considerably smaller than that produced by the plate containing No. 67 drilled holes.

Since no deliveries of suitable porous plate material could be guaranteed, and time was important, development of the drilled hole sparger plate was continued. The plate assembly was redesigned to offer a more uniform liquid flow distribution across the sparger plate (see Fig. 3), and to provide a
constant depth of liquid at a given liquid flow rate. A 1-in. by 6-in. stainless steel strip containing only sixteen No. 70 drilled holes was tested. Again, the bubble distribution was not uniform, and liquid metal seepage through the drilled holes tended to fill the plenum chamber.

At this time, it became apparent that bubble size and distribution were functions of the differential gas pressure across the sparger plate holes - the smaller holes would produce smaller size bubbles and more uniform distribution. Therefore, the stainless plate containing sixteen No. 70 drilled holes was replaced by one containing sixteen No. 80 drilled holes, 0.0135-in. diameter. Tests conducted with this plate showed small, evenly distributed bubble formation and complete absence of liquid metal seepage through the drilled holes at no-flow gas conditions. Photographs of the bubbling action produced by this plate with 0.04 cfm air flow at 0.62 psi static pressure when submerged 1-in. in mercury are shown in Figures 7 and 8. Figure 7 illustrates a stagnant bath condition; Figure 8 shows a flowing bath moving from lower left to upper right at a velocity of approximately 0.5 ft/sec.

As a result of this investigation, a sparger assembly, shown in Figures 4, 5, and 6, was designed for the double-pump sump tank for Radiation Loop No. 2 at ETR.
VIII. REMARKS

During the course of the test program, considerable thought was given to other means of introducing helium gas into the liquid metal stream. These were as follows:

A. ANI-118, NI-6542 SPIRAL PLATE DEGASSER

This device was composed of a flat, spiral plate wrapped around a pipe (as a screw), all of which was encased in a cylindrical shell. The liquid metal was to flow downward over the spiral, and the sparging gas was to counter-flow up through the liquid metal.

B. ANI-236, NI-6838 HONEYCOMB TYPE DEGASSER FOR AN LMFR

In this system, the liquid metal drained down the inner walls of a bundle of hexagonal tubes enclosed in a pressure vessel. The sparging gas flow was counter current upwards through the liquid metal.

C. TUBE WALL SPARGER PLATE

In this device, the lower half of the liquid metal return pipe was replaced with a semi-cylindrical section of either porous plate or plate containing drilled holes. The sparging gas was to bubble through the sparger plate and into the liquid metal stream as shown in the sketch attached to the job estimate dated December 30, 1957.

The design of all these devices makes their installation in the double-pump sump impractical, and further development was stopped.
FIG. 1: ARRANGEMENT OF EQUIPMENT FOR TESTING SPARGER PLATE

Orifice Static Press. Tubes

Liquid Metal Thermometer

Liquid Metal Orifice Section

6-in. x 6-in. Porous S. S. Plate 10-Micron Pores, Average

Static Press. U-Tube

Modified Gorman - Rupp Pump

Fischer & Porter Precision Bore Flowrator Tube No. 01-N-150-A/13

Thermometer

Regulated Air Supply
FIG. 2: ARRANGEMENT OF EQUIPMENT FOR TESTING SPARGER PLATE

- Turning Vanes
- Orifice Static Press. Tubes
- Liquid Metal Thermometer
- Liquid Metal Orifice Section
- 1-in. x 6-in. Porous S.S. Plate 10-Micron Pores, Average
- Modified Gorman - Rupp Pump
- Fisher & Porter Precision Bore Flowrator Tube No. 01-N-150-A/13
- Air Supply
FIG. 3: ARRANGEMENT OF EQUIPMENT FOR TESTING SPARGER PLATE W/DRILLED HOLES

Level Control Dam

Flow Straightening
Riffle Bars

1-in. x 6-in. S.S.
Plate Containing
Drilled Holes

Orifice Static
Press. Tubes

Liquid Metal
Orifice Section

Liquid Metal
Thermometer

Modified Gorman - Rupp Pump

Fisher & Porter Precision
Bore Flowrator
Tube No. 01-N-150-A/13

Air
Supply
FIG. 4: DEGASSING SPARGER PLATE ASSEMBLY
FOR DUPLEX PUMP SUMP

LOCATION

"A" 4-1/2" LONG RIFFLE SCREEN, 1/4" RND. BARS AT 1/2" CTRS
"B" 6" LONG RIFFLE SCREEN, 3 - 2" LONG SECTIONS
  1 SECTION OF 1/4" RND. BARS AT 1/2" CTRS.
  1 SECTION OF 1/4" RND. BARS AT 7/16" CTRS.
  1 SECTION OF 1/4" RND. BARS AT 11/32" CTRS.
"C" 15 NO. 80 DRILLED HOLES AT 3/8" CTRS.
"D" 6" LONG RIFFLE SCREEN, 1/4" RND. BARS AT 3/8" CTRS.

NOTE: ALL DIMENSIONS TO BE IN INCHES
FIG. 5: ARRANGEMENT OF DEGASSING SPARGER PLATE ASSEMBLY IN DUPLEX PUMP SUMP

LEGEND

LOCATION 

"A" 4-1/2" LONG RIFFLE SCREEN, 1/4" RND. BARS AT 1/2" CTRS. 
"B" 6" LONG RIFFLE SCREEN, 3 - 2" LONG SECTIONS 
- 1 SECTION OF 1/4" RND. BARS AT 1/2" CTRS. 
- 1 SECTION OF 1/4" RND. BARS AT 7/16" CTRS. 
- 1 SECTION OF 1/4" RND. BARS AT 11/32" CTRS. 
"C" 15 NO. 80 DRILLED HOLES AT 3/8" CTRS. 
"D" 6" LONG RIFFLE SCREEN, 1/4" RND. BARS AT 3/8" CTRS

NOTE: ALL DIMENSIONS TO BE IN INCHES.
FIG. 6: DETAILS OF GAS SPARGER ASSEMBLY FOR DUPLEX PUMP SUMP

INLET SECTION
1 - REQD.

SLOPE 1/8 PER FT.

INLET SECTION
SPARER PLATE

SLOPE 2/4 PER FT.

SPARER PLATE
1-REQD.

SLOPE 4/4 PER FT.

GAS PLENUM CHAMBER
2-REQD.

Details of riffle bars and gas ports in sparger plate

Flow

Gas pipe coupling locate on inner face of each plenum chamber

SLOPE 1/8 PER FT.

NOTE: All construction in plate.

RIS Omitted in Elev.
FIG. 8: SPARGER PLATE BUBBLING ACTION IN MERCURY

MERCURY SUPPLY TUBE

DEPTH CONTROL DAM

FLOW STRAIGHTENING RIFFLE BARS

DIRECTION OF FLOW
FIG. 8: SPARGER PLATE BUBBLING ACTION IN MERCURY