KAPL-1826

AEC Research and Development Report
UC-25. Metals and Ceramics
(TID-4500, 13th Edition)

Knolls
Atomic Power
Laboratory

Two-tube Griscom Russell Evaporator

C. F. Barrett, Jr.
June 28, 1957

Operated for the
United States Atomic
Energy Commission by
GENERAL ELECTRIC

OTS- 754

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UC-25, Metallurgy and Ceramics
(TID-4500, 13th ed)

General Electric Company
KNOLLS ATOMIC POWER LABORATORY
Schenectady, New York

GRISCOM-RUSSELL TWO-TUBE EVAPORATOR

C. F. Barrett, Jr.

June 28, 1957

Authorized Classifier

Date

Operated for the
United States Atomic Energy Commission
by the
General Electric Company
Contract No. W-31-109 Eng-52

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ABSTRACT

This report presents the results of the metallographic examination of the Griscom-Russell two-tube evaporator after testing for a total steaming time of 3856 hr. The complete absence of any adverse effect on the material leads to the conclusion that 2-1/4% Cr -1% Mo alloy steel can be used advantageously in liquid metal heat exchangers when the oxygen content of the boiler water is controlled.

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GRISCOM-RUSSELL TWO-TUBE EVAPORATOR

C. F. Barrett, Jr.

INTRODUCTION

This report presents the results of the metallographic examination of the Griscom-Russell two-tube evaporator after testing for a total steaming time of 3856 hr at the Mine Safety Appliances Company, Callery, Pennsylvania.

The evaporator had several unique features with respect to other types of liquid metal heat exchangers.

1. The material used for tubes and tube sheet was 2-1/4% Cr - 1% Mo steel rather than the customary austenitic stainless steel.
2. The tubes were expanded after assembly to provide an intimate contact between the outer surface of the inner tube and the inner surface of the outer tube for most effective heat transfer.
3. The inner tube was grooved on the outer face to provide space for the gas used as the "third fluid" for leak detection.

The design was designated by Griscom-Russell as the "Bentube" design. Both inner and outer tubes were attached at the tube sheet by a seal weld on the outer face and by rolling the tube into the tube sheet in accordance with standard commercial practice. The 2-1/4% chromium - 1% molybdenum steel tubes were both in the annealed condition in this evaporator. The oxygen content of the water was controlled by the use of sulfite ranging from 17 to 60 ppm. The boiler water specification, shown in Table 1, did not specify sulfite content, but this was added by MSA to ensure an excess of sulfite and maintain free oxygen within specification.

TABLE 1. Boiler Water Specification

pH	10.6 to 11.2
PO ₄ , ppm	50 to 300
Hardness, ppm CaCO ₃	< 10
Oxygen, ppm	< 0.005
Chlorine, ppm	< 0.1
Total solids, ppm	< 1000

Steam was generated at 500 psig with NaK at an inlet temperature of 850°F as the primary fluid. Nitrogen and helium were used at different times as the third fluid gas.

RESULTS OF DETAILED EXAMINATION

The evaporator was cut open longitudinally in such a manner as to leave one tube in each half. Examination of the tubes, tube sheets, and shell showed all to be in excellent condition with no evidence of pitting or other corrosion attack. Some loose scale was observed at the inlet end. Scattered rust spots were also noted.

One half was cut longitudinally through the tube sheet at the tube, and the tube was cross sectioned at six locations along the length. None of the sections examined showed any evidence of corrosive attack either of a general nature or by pitting. This includes both the surfaces exposed to the NaK and to the boiler water.

Figures 1, 2, and 3 are photomicrographs of the entire cross section at 50X magnification and of the inner and outer tube at 100X magnification from a typical tube cross section. Figure 4 shows the microstructure of the seal welds and the crevices between the tube and tube sheet.

Measurements of the annulus between the inner and outer tubes on the land between the grooves are shown in Table 2. Two readings 180 deg apart are shown for each cross section.

TABLE 2. Annulus Measurements

<u>Sample No.</u>	<u>Width of Annulus, in.</u>	
1	0.00016	0.00029
2	0.00010	0.00026
3	0.00020	0.00036
4	0.00029	0.00020
5	0.00013	0.00033
6	0.00029	0.00029

FIGURE 1 TYPICAL CROSS SECTION THROUGH TUBE SHOWING
BOTH INNER AND OUTER TUBES

50X

KS-17886
Unclassified

FIGURE 2 ENLARGED VIEW OF OUTER TUBE SHOWING SLIGHT
DECARBURIZATION AT OUTER FACE

100X

Note lack of pitting on outer face exposed to boiler water

KS-17887
Unclassified

FIGURE 3 ENLARGED VIEW OF INNER TUBE SHOWING SLIGHT
DECARBURIZATION AT OUTER FACE

100X

Note absence of attack on inner face exposed to the NaK

KS-17888
Unclassified

FIGURE 4 MICROSTRUCTURE OF WELDS AND CREVICES

Typical structure
of seal weld at
tube joint

Typical structure
of tube - tubesheet
crevice area at tube
sheet surface exposed
to boiler water or
NaK

Typical structure
of repair weld using
Inco Rod "A" when
inner tubes were
re-tubed

KS-17889
Unclassified

The sample designated No. 1 in Table 2 was located nearest the inlet end, No. 6 was nearest the outlet end, and the others were approximately equidistant between. No distinct trend can be determined from these data except, possibly, that the outlet end tends to have a somewhat wider annulus than the inlet end.

CONCLUSIONS

The complete absence of any adverse effect on this material during these tests leads to the conclusion that the 2-1/4% Cr - 1% Mo steel can be used advantageously in liquid metal heat exchangers when the oxygen content of the boiler water is controlled.

Design advantages include the higher heat conductivity of the ferritic material and a lower thermal coefficient of expansion with resulting lower stresses, in addition to a lower material cost and freedom from susceptibility to chloride stress corrosion.

REFERENCE

MSA Technical Report 51, "Two-Tube Steam Evaporator No. 3," W. Milich, E. A. Schultz, and E. C. King, November 26, 1956.