DATE: December 21, 1956

SUBJECT: Metallographic Examination of Cambridge Nos. 1 and 2
Metallography Report No. 267

TO: W. D. Manly
FROM: J. E. VanCleve
J. H. DeVan
A. E. Goldman

DISTRIBUTION
2. W. D. Manly
3-6. A. Taboada
7. J. H. Coobs
8. D. A. Douglas
9. E. E. Hoffman
10. W. H. Jordan
11. S. J. Cromer
12. H. W. Savage
13. M. Bender
14. W. F. Boudreau
15. R. D. Schultheiss
16. A. P. Fraas
17. E. R. Dytko
18. R. B. Oliver
19. J. H. DeVan
20. R. L. Heestand
21. A. W. Savolainen
22. H. C. Gray
23. J. Zasler
24-26. R. J. Gray
27. R. S. Crouse
28-31. P. Pairiarca
32. R. E. MacPherson

NOTICE
This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

SECRET COVER SHEET
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
Introductions

The radiators designated Cambridge #1 and #2 were visually examined and modified before operation by H. C. Hopkins. The modifications included the removal of the heavy side plates and slitting of the heavy base plate.

The initial examination revealed poor quality braze joints at the top and bottom plates of Cambridge #1. However, the same plates of Cambridge #2 were adequately brazed. The copper core of the fins was exposed in many of the tube-to-fin joints on both radiators, indicating that the braze material had not covered the fin collars.

The radiators were first operated using intermediate heat exchangers ORNL #1 and #2, type I.H.E. #3, the first of which failed after 648 hours operation. The examination of these heat exchangers has previously been reported. These heat exchangers were replaced by B.S. and B #1 and #2, type I.H.E. #3, which operated 1397 additional hours without apparent failure. The examination of these heat exchangers is now being conducted.

Fig. 1 shows the radiators in the as-received condition after cleaning. The operation of the radiators was halted June 14, 1956 after a total operating time of 2045 hours without failures. The total time, 579 hours were under isothermal conditions between 1200 and 1400°F, and 1466 hours were at a ΔT of 200°F. The radiators endured 12 thermal cycles during this period.

Mass Transfer:

Four samples were removed from each radiator and examined for evidence of mass transfer. Two samples were taken from the air inlet banks and two from the air outlet banks of each radiator, as shown in Figs. 2, 3, 4 and 5. In these figures the sample locations, numbered one through four, appear as cut-away areas. The sample numbers increased in the direction of increasing NaK fluid temperature. The tubes in these samples were split longitudinally slightly off the center line of the tubes, and the samples were then mounted and ground down to the exact center of the tube. In this manner it was hoped that a viewing edge would be provided in which no mass transfer was lost due to the sectioning and grinding operation.

Fig. 7 shows the mass transfer encountered in sample number four taken from Cambridge number one. This sample contained the coolest NaK among the samples examined, and the deposits at this point reached a maximum thickness of .005 inches.

Fig. 8 shows the mass transfer deposit in sample number one from the same radiator. This sample contained the hottest NaK. The deposit as shown measures .001 inches.

Fig. 9 shows the mass transfer deposited in sample number four taken from Cambridge #2. The appearance and extent of the deposit is similar to that observed in the number four sample from Cambridge #1. (Fig. 7).

Fig. 10 shows the mass transfer deposited in sample number one from Cambridge #2. Again the deposits are similar to those in the corresponding sample from Cambridge #1. (Fig. 8).

In both radiators the average thickness of the deposit was .004 inches. There was little or no difference in the appearance of the deposit in the two radiators.
Tube-To-Fin Joints:

Twelve samples were removed from the air inlet and air outlet banks of both radiators and numbered from one to twenty-four as shown in Figs. 2, 3, 4, and 5. Each sample contained a portion of three tubes joined to nineteen or more fins. The samples were cross-sectioned to reveal two opposed joint areas, then mounted, polished, and examined at 80 X.

A total of 2718 joint areas from Cambridge # 1 and 2664 joint areas from Cambridge # 2 were examined. The percentages of tube-to-fin adherence and the degree of oxidation of the fin collars were noted and are tabulated in columns 1 and 2 of Table 1. In Table 1 the results of the examination of tube-to-fin joints in these radiators can be compared with five previously examined radiators. These figures indicate that the Cambridge brazing technique was better than the York technique in two cases out of the three tabulated but still does not meet the specifications.

While examining the samples for fin-to-tube integrity, a total of eight small cracks were found in the brazing alloy fillets of the six samples having sump plates cut from Cambridge # 1. Eight more small cracks were found in the six samples having sump-support plates cut from the same radiator. Twelve samples having sump plates were removed from Cambridge # 2. Six samples had a total of twelve cracks, while the remaining six were free from cracks.

Discussion:

Both Cambridge # 1 and # 2 radiators showed poor adherence of sump and sump-support plates to the tubes which tended to limit the number and extent of cracks. All the cracks found were in the braze alloy fillets as shown in Fig. 6. Note that the sump-support plate does not contact the tube wall on the right, a very common occurrence in the radiators.

The maximum thickness of mass transfer deposits in these radiators is approximately one third the maximum thickness observed in ORNL # 1 intermediate heat exchanger, which operated in conjunction with the radiators. This heat exchanger exhibited .015 inches of mass transfer after 993 hours of Δ T operation in the temperature range of 1500-1600°F. This compares with a maximum value of .005 inches (Figs. 7 and 9) for each radiator following 1466 hours of Δ T operation in the temperature range of 1300-1400°F. The maximum Δ T utilized through the heat exchanger was 300°F, while that across the radiators was 200°F.

Although a direct comparison with other dynamic tests is difficult because of differences in system surface areas and volumes, it is nevertheless interesting that the deposit thickness in these heat exchanger test components show good agreement with sodium pump loops operated strictly as corrosion tests. These latter systems yield a maximum deposit of .015 inches at 1500°F and .003 inches at 1300°F in tests operating for 1000 hours at a Δ T of 300°F.
Experimental Report No. 7405-2-4, "Cambridge Radiators # 1 and # 2 Performance Test and Operating History" H. C. Hopkins, August 8, 1956.

2 CF 56-7-123, "Examination of ORNL # 1 and # 2 Intermediate Heat Exchangers, Type I.H.E. # 3 J. H. DeVan and R. S. Crouse, July 20, 1956

Memo to W. D. Manly from G. M. Slaughter, "Metallographic Examination of I.H.E. # 3 Failure" April 11, 1956

CF 56-7-82 "Metallographic Examination of I.H.E. # 3," J. E. VanCleve, Jr. July 12, 1956
Fig. 1
Cambridge Radiators As Received After Operation
Fig. 4
Cambridge #2 Showing Location of Sample

Fig. 5
Cambridge #2 Showing Location of Sample
Fig. 6
Line Drawing in Sump and Sump-Support Plate

Fig. 7
Sample No. 4 From Cambridge #1. Note Mass Transfer to .005 inches.
Fig. 8
Sample No. 1 From Cambridge #1. Note Mass Transfer to .001 inches.

Fig. 9
Sample No. 4 From Cambridge #2. Note Mass Transfer to .005 inches.
Y-19673

Fig. 10

Sample No. 1 from Cambridge #2. Note Mass Transfer to .001 inches.
<table>
<thead>
<tr>
<th></th>
<th>Cambridge #1</th>
<th>Cambridge #2</th>
<th>York #9</th>
<th>York #4</th>
<th>York #3</th>
<th>PWA #2</th>
<th>ORNL #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of joint areas examined</td>
<td>2718</td>
<td>2664</td>
<td>2608</td>
<td>2757</td>
<td>2684</td>
<td>3210</td>
<td>2282</td>
</tr>
<tr>
<td>Percent of joint areas having 75-100% adherence</td>
<td>91.6</td>
<td>92.9</td>
<td>44.6</td>
<td>60.7</td>
<td>90.4</td>
<td>100</td>
<td>87.7</td>
</tr>
<tr>
<td>Percent of joint areas having 50-74% adherence</td>
<td>2.9</td>
<td>4.6</td>
<td>21.2</td>
<td>18.8</td>
<td>5.9</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Percent of joint areas having 25-49% adherence</td>
<td>0.5</td>
<td>0.5</td>
<td>9.4</td>
<td>5.5</td>
<td>1.1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Percent of joint areas having 0-24% adherence</td>
<td>5.0</td>
<td>2.0</td>
<td>24.8</td>
<td>15.0</td>
<td>2.6</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Percent of joint areas having non-oxidized copper fins</td>
<td>81.3</td>
<td>37.0</td>
<td>23.5</td>
<td>61.9</td>
<td>84.5</td>
<td>100</td>
<td>12.1</td>
</tr>
<tr>
<td>Percent of joint areas having slightly oxidized copper fins</td>
<td>4.0</td>
<td>5.3</td>
<td>8.5</td>
<td>19.5</td>
<td>7.5</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Percent of joint areas having heavily oxidized copper fins</td>
<td>14.7</td>
<td>57.7</td>
<td>68.0</td>
<td>18.6</td>
<td>8.0</td>
<td></td>
<td>85.4</td>
</tr>
<tr>
<td>Number of hours of 1000-1600°F service</td>
<td>2045</td>
<td>2045</td>
<td>1283</td>
<td>1356</td>
<td>361</td>
<td>1199</td>
<td>716</td>
</tr>
</tbody>
</table>