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SUBJECT: Examination of Corrosion Specimens from  
Slurry Blanket Mockup Run SM-4.

TO: E.G. Bohlmann

FROM: S.A. Reed and E.L. Compere

SUMMARY

Generally low attack rates were displayed by specimens of type 347 stainless steel, titanium-75A and Zircaloy-2 which were exposed for 2396 hr in slurry blanket mock-up Run SM-4. The leading coupon of the array, of type 347 stainless steel, suffered more severe attack due to erosive action by the slurry. Coupons of SA-212-B carbon steel were consumed during the run. No stress corrosion cracking was noted on samples, placed in the pressurizer, of types 347 and AM 350 stainless steels, titanium-6Al4V alloy or Zircaloy-2.

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In cooperation with the program in the Systems Development Section on the slurry blanket mock-up, the Reactor Materials Research Section prepared two sets of corrosion specimens for field exposure in the experimental mock-up equipment during Run SM-4.

The results of the examination of a previous set of specimens which were exposed in Run SM-3 have been reported.<sup>1</sup>

One set of sixteen in-line coupon-type corrosion specimens and a set of eight stress specimens were exposed for a total period of 2396 hr (2236 hr in slurry) in Run SM-4 of the slurry blanket mock-up, which was terminated January 20, 1957.

The flow velocity across the in-line specimens varied from an estimated 20 fps to 13 fps as a result of varying flow rates in the system while the pump was operated from a variable frequency generator. The in-line coupon specimens consisted of two samples each of type 347 stainless steel, SA-212-B carbon steel, titanium RC-55, and Zircaloy-2.

The coupons, contained in a type 347 stainless steel holder, were not insulated. Each specimen was machined to the dimensions 2.35 in x 1.0 in x 0.20 in from special 1/4-in plate stock from the controlled materials stores of the Reactor Materials Research Section. The holder and specimens are described in drawing No. TS-4910.

The assembly is shown in Figures 1 and 2. The stress specimens, placed in the system pressurizer consisted of two samples each of type 347 stainless steel, type AM 350 stainless steel, titanium-6Al4V alloy and Zircaloy-2. One specimen of each alloy was suspended in the gas-vapor space of the vertical pressurizer, while the comparison specimens were placed on the lower section of the specimen holder which was normally below the level of the liquid in the pressurizer. Flow over these specimens was negligible.

A brief operating summary of Run SM-4 is given in Table I. A detailed description of the run is in preparation<sup>2</sup> by the Systems Development Section.

As shown in Table I, the specimens were exposed for a period of 160 hr before slurry charging was begun. They were exposed to slurry a total of 2236 hr. Operating temperatures during the run varied from 150 to 200°C.

The slurry charges consisted of a composite of batches of IO-series, 800°C-calcined thoria to which was added approximately 3500 ppm SO<sub>2</sub>, based on thorium, as sulfuric acid. Most of the thoria had been circulated previously in Run SM-3.

As shown in Table II, corrosion rates, except for SA-212-B carbon steel were low. The upstream coupon of the array, of type 347 stainless steel, displayed a higher rate (about ten-fold) than specimens of the same alloy contained in the down stream positions of the specimen array. The higher rate of that specimen was attributed to increased erosive attack by impinging slurry particles

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<sup>1</sup>Summary of Specimen Corrosion Data from Slurry Blanket Mock-up Run SM-3, ORNL CF-57-10-5.

<sup>2</sup>To be issued by L.F. Parsley, et al of the Systems Development Section.

and by other entrance effects. The pattern of attack may be seen in Figures 1 through 6.

Attack of type 304 stainless steel ranged from 0.45 to 0.85 mpy on three specimens, the fourth, the coupon at the entrance of the specimen array, showed 4.3 mpy. Three specimens of titanium RC-55 displayed weight gains; the corrosion rate of the fourth specimen was 0.03 mpy. Zircaloy-2 attack rates ranged from 0.09 to 0.25 mpy. The four coupons of SA-212-B carbon steel dissolved during the test, indicating a corrosion rate greater than 350 mpy. It is probable that the presence of sulfuric acid in the slurry contributed to the aggressive attack of the carbon steel. Also possible galvanic action between the uninsulated carbon steel specimens and the stainless steel holder could have occurred.

In this regard, it is noteworthy that pits up to 3/16 in. in depth were observed in the carbon steel sphere in localized areas opposite the inlet jets where the spray coat of metallized stainless steel had failed. Therefore attack of the coupon specimens appeared comparable to those areas in the blanket sphere.

By microscopic and metallurgical examination, no cracks were observed in the stressed specimens contained in the system pressurizer. Data for these specimens are shown in Table III.

TABLE I

Operating Summary, Slurry Blanket Mockup Run SM-4<sup>(1)</sup>

| Circulation<br>Hours | Loop<br>Temperature,<br>°C | Frequency | Slurry<br>Concentration<br>gTh/KgH <sub>2</sub> O | pH                 |                 | SO <sub>4</sub> <sup>=</sup> /Th<br>ppm | Gas Analysis- (3)<br>cc/150 cc bomb |                 |                |
|----------------------|----------------------------|-----------|---|--------------------|-----------------|---|-------------------------------------|-----------------|----------------|
|                      |                            |           |   | Slurry             | Supernate       |   | O <sub>2</sub>                      | CO <sub>2</sub> | H <sub>2</sub> |
|                      |                            |           |   | 0-160              | Rm.Temp. to 170 |   | 60                                  | 9.5             | 6.5            |
| 160-400              | 170                        | 60        | Loading to 350                                    | 5.4-6.9            | 6.0-6.7         | 5800-3390                               | 0.3                                 | 2.7             | -              |
| 574                  | 200                        | 60        | 398   | 6.8                | 6.8             | 3100                                    | -                                   | 0.4             | 0.8            |
| 642                  | 200                        | 60        | 376   | 6.6                | -               | 3270                                    | -                                   | 1.4             | 1.5            |
| 804                  | 200                        | 60        | 365   | 6.3                | -               | 3400                                    | 0.2                                 | 0.5             | 1.2            |
| 972                  | 200                        | 50        | 322   | 6.6                | 7.2             | 3170                                    | 0.4                                 | 0.3             | 0.7            |
| 1000-1220            | 170-190                    | 60        | Loading to 595                                    | 6.6-6.8            | 7.2-6.3         | 2650-3610                               | 0.2-21.5                            | 0.4-0.0         | 1.0-0.9        |
| 1303                 | 190                        | 60        | 595   | 6.7                | 6.3             | 3610                                    | 21.5                                | 0.0             | 0.9            |
| 1468                 | 190                        | 46.5      | 478   | 6.6                | 6.1             | 3500                                    | 0.5                                 | 3.3             | 7.0            |
| 1635                 | 175                        | 60        | 566   | 6.6                | -               | 3240                                    | 0.6                                 | 0.3             | 2.4            |
| 1807                 | 150                        | 60        | 591   | 6.4                | -               | 3700                                    | 1.0                                 | 0.2             | 0.6            |
| 1969                 | 150                        | 46        | 581   | 6.5                | 5.9             | 3540                                    | 0.3                                 | 0.2             | 2.2            |
| 2133                 | 190                        | 42        | 426   | 6.5                | 5.8             | 3620                                    | 0.4                                 | 0.8             | 3.9            |
| 2307                 | 190                        | 50        | 459   | 6.5                | -               | 3260                                    | 1.8                                 | 0.8             | 6.0            |
| 2396                 | 190                        | 50        | 461   | 4.8                | 6.1             | 2750                                    | 0.8                                 | 1.2             | 5.7            |
| 2396                 |                            |           |   | 6.3 <sup>(2)</sup> |                 |   |                                     |                 |                |

(1)Furnished by L. F. Parsly, et al., of the Systems Development Section

(2) Recheck of above pH

(3) No oxygen was added

TABLE II

In-Line Coupon Corrosion Rates In Slurry Blanket Mockup Run SM-4

| Material Type                              | Position<br>in<br>Holder | Weight Change, mg |          | Weight Loss<br>mg/cm <sup>2</sup> (b) | Corrosion Rate,<br>mpy, Defilmed |
|--|--------------------------|-------------------|----------|---------------------------------------|----------------------------------|
|  |                          | Scrubbed          | Defilmed |                                       |                                  |
| 347 Stainless Steel                        | 1 <sup>(a)</sup>         | -774.4            | -791.9   | 21.9                                  | 4.20                             |
| Zircaloy-2                                 | 2                        | - 36.9            | - 37.1   | 1.02                                  | 0.25                             |
| Titanium RC-55                             | 3                        | + 19.0            | - 3.7    | 0.10                                  | 0.03                             |
| SA-212 Grade B Boiler Plate <sup>(d)</sup> | 4                        | -64,763.0         |          | 1,788                                 | >350 <sup>c</sup>                |
| 347 Stainless Steel                        | 5                        | -117.8            | -158.2   | 4.37                                  | 0.85                             |
| Zircaloy-2                                 | 6                        | -21.5             | -21.9    | 0.60                                  | 0.15                             |
| Titanium RC-55                             | 7                        | +36.9             | +12.0    | Weight Gain                           | Weight Gain                      |
| SA-212 Grade B Boiler Plate <sup>(d)</sup> | 8                        | -65,171.7         |          | 1,799                                 | >350 <sup>c</sup>                |
| 347 Stainless Steel                        | 9                        | -36.0             | -85.1    | 2.35                                  | 0.45                             |
| Zircaloy-2                                 | 10                       | -14.1             | -14.5    | 0.40                                  | 0.10                             |
| SA-212 Grade B Boiler Plate <sup>(d)</sup> | 11                       | -64,197.8         |          | 1,772                                 | >350 <sup>c</sup>                |
| Titanium RC-55                             | 12                       | +57.1             | +7.0     | Weight Gain                           | Weight Gain                      |
| SA-212 Grade B Boiler Plate <sup>(d)</sup> | 13                       | -65,349.3         |          | 1,804                                 | >350 <sup>c</sup>                |
| Titanium RC-55                             | 14                       | +48.0             | +7.8     | Weight Gain                           | Weight Gain                      |
| Zircaloy-2                                 | 15                       | -12.7             | -12.7    | 0.35                                  | 0.09                             |
| 347 Stainless Steel                        | 16                       | -37.0             | -88.0    | 2.43                                  | 0.47                             |

a) Leading coupon, upstream position

b) Exposed area, 36.22 cm<sup>2</sup>

c) Specimen dissolved during test

d) Carbon Steel



TABLE III

Inspection of Pressurizer Stress Specimens  
Exposed in Slurry Blanket Mock-Up Run SM-4

| Alloy          | Position        | Specimen Size (in.) | Stress (psi) | Strain ( $\mu$ in) | Comments  |
|----------------|-----------------|---------------------|--------------|--------------------|---|
| 347SS          | gas-vapor space | 1/16 x 3/8 x 3      | 30,400       | 1,200              | The specimen were scarred during removal from the holder. Therefore no reliable weight losses could be determined for corrosion calculations. |
| 347SS          | in liquid       | "                   | 30,400       | 1,200              |   |
| AM350SS        | gas-vapor space | "                   | 28,000       | 1,100              | Rates computed from weight losses did not exceed 0.2 mpy.   |
| AM350SS        | in liquid       | "                   | 28,000       | 1,100              |   |
| Titanium-6Al4V | gas-vapor space | "                   | 87,000       | 6,500              |   |
| Titanium-6Al4V | in liquid       | "                   | 87,000       | 6,500              |   |
| Zircaloy-2     | gas-vapor space | 1/8 x 3/8 x 3       | 9,500        | 1,300              | No cracking or pitting was observed during microscopic and metallurgical examinations.  |
| Zircaloy-2     | in liquid       | "                   | 9,500        | 1,300              |   |

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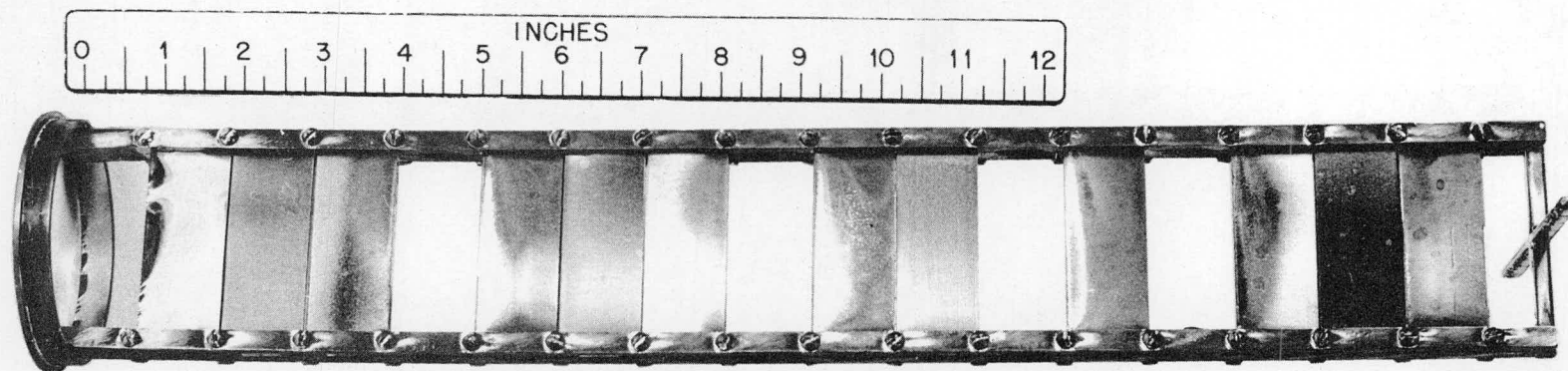


Fig. 1 In-line corrosion specimens removed from slurry blanket mock-up run SM-4 (top view); slurry flow left to right

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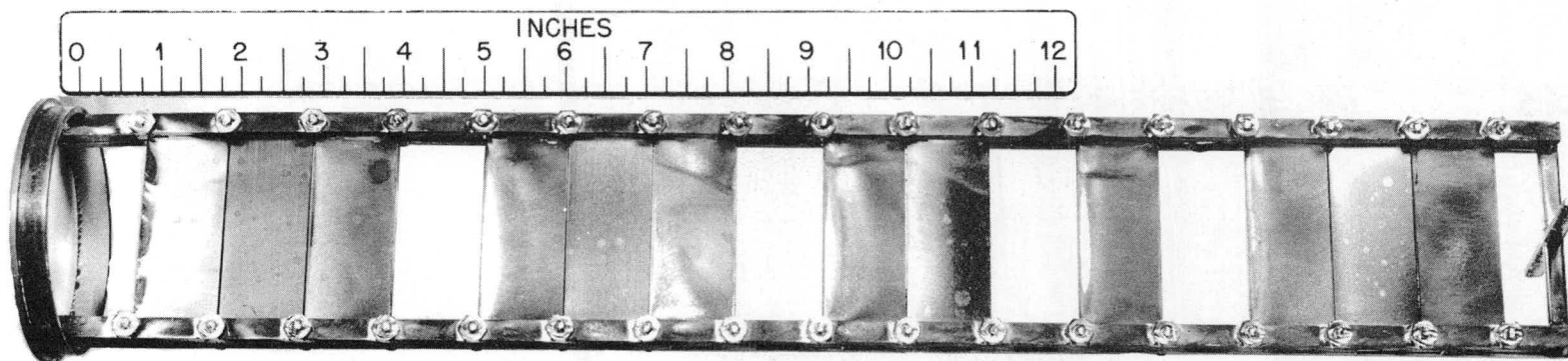


Fig. 2 In-line corrosion specimens removed from slurry blanket mock-up run SM-4 (bottom view); slurry flow left to right

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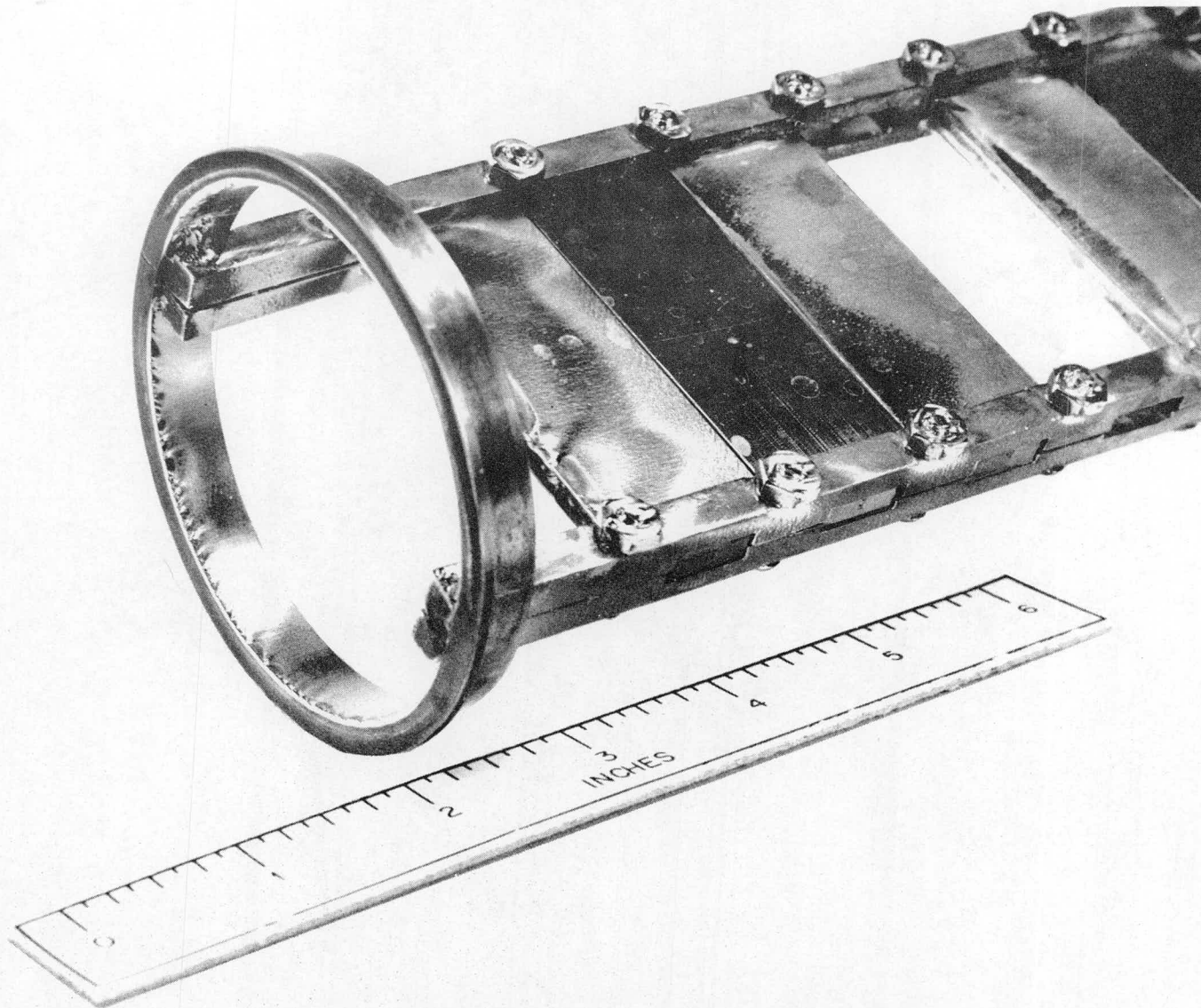


Fig. 3 In-line corrosion specimens removed from slurry blanket mock-up run SM-4 (bottom view); enlarged section of leading coupons and specimen holder. Flow left to right

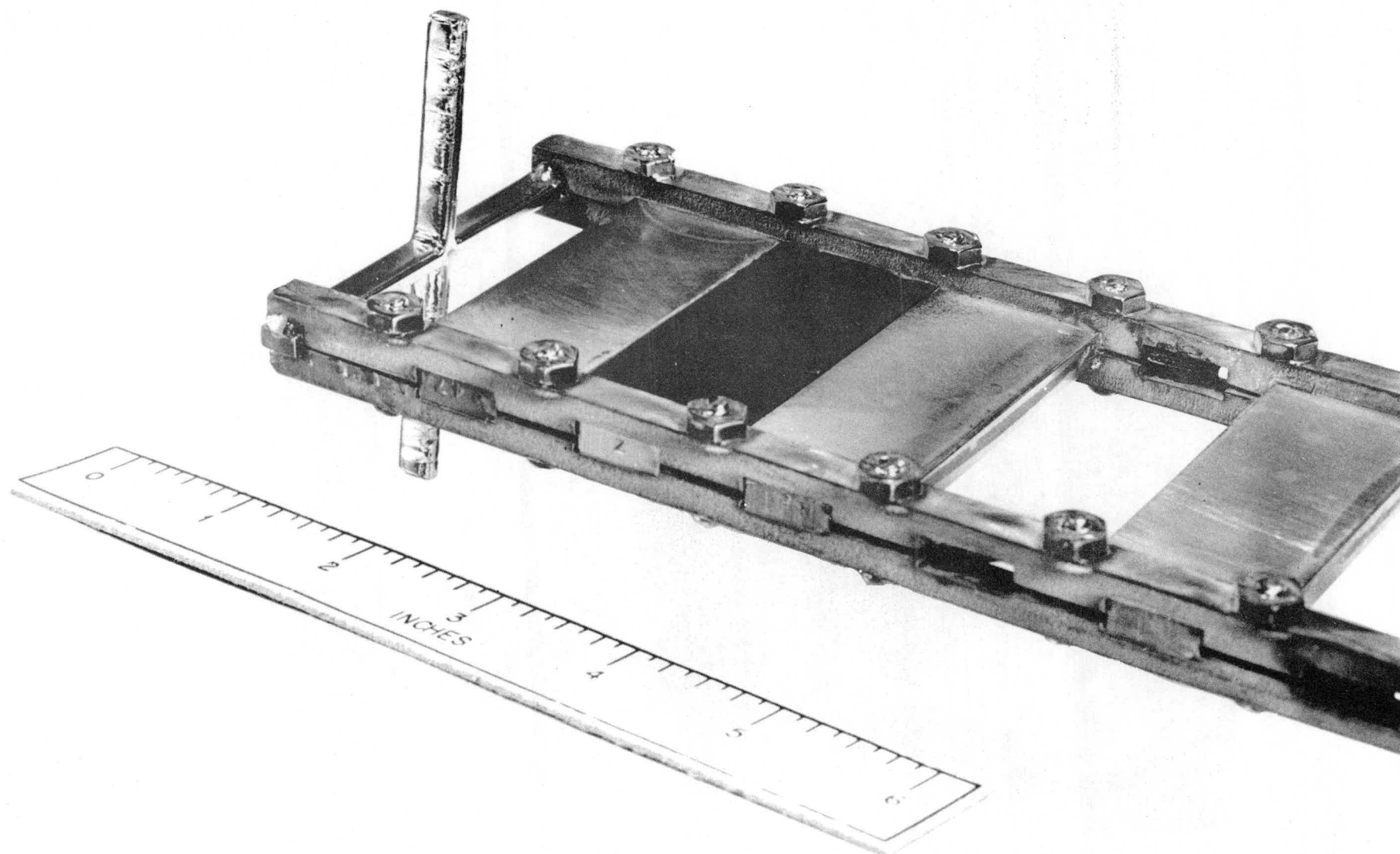


Fig. 4 In-line corrosion specimens removed from slurry blanket mock-up Run SM-4 (bottom view); enlarged section of trailing coupons and specimen holder. Flow left to right

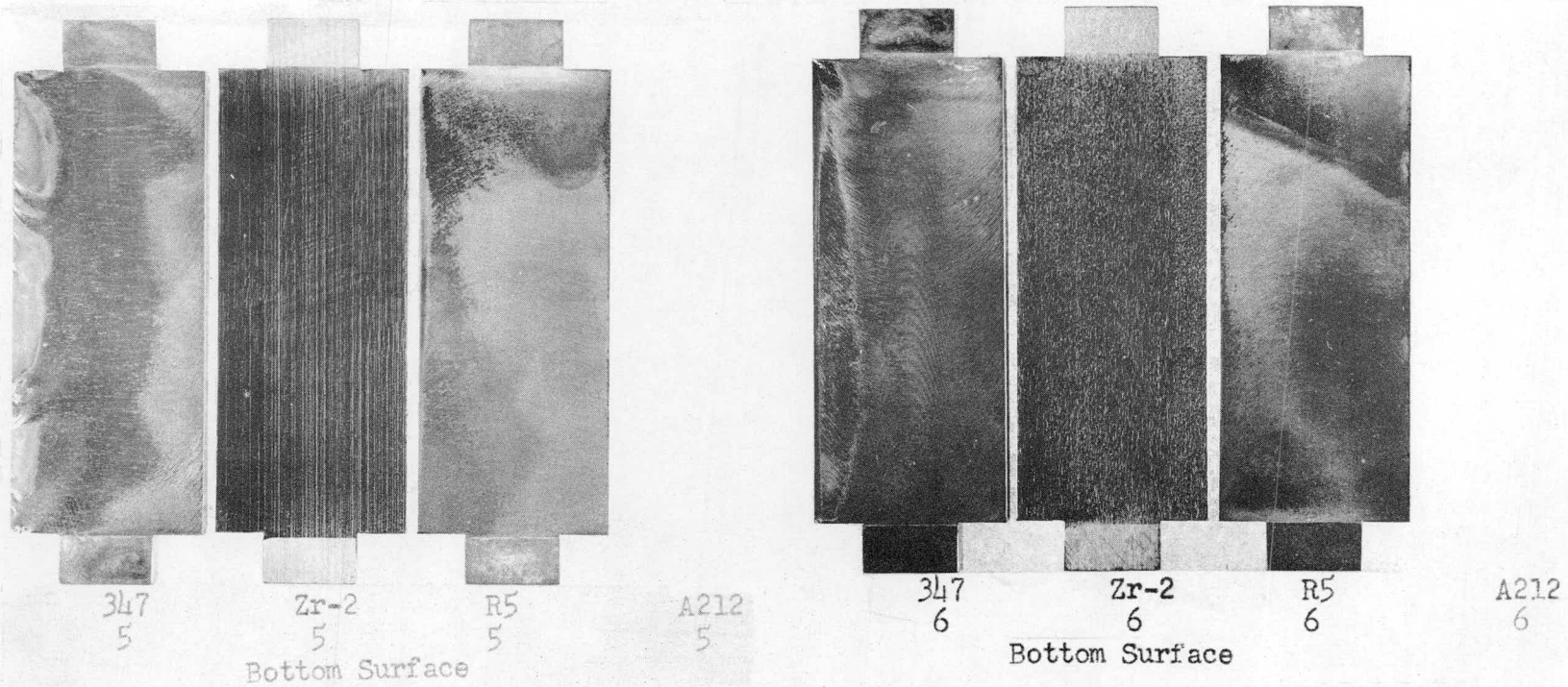


Fig. 5 Relative positions of in-line specimens from run SM-4, flow left to right. Note erosive attack on lead specimen, 347(5), and on 347(6) specimen downstream of SA-212-B coupon which dissolved (Specimen Nos. 1 through 8)

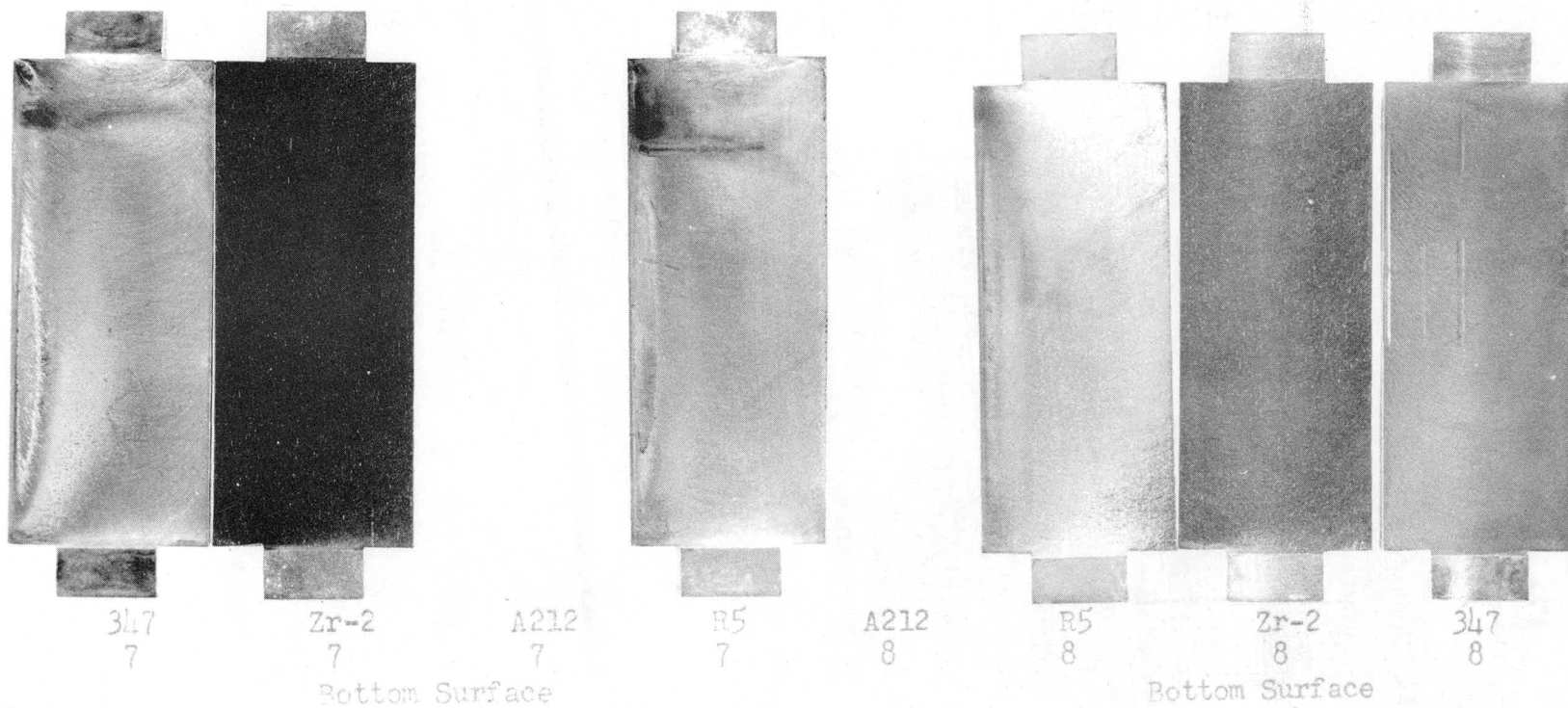


Fig. 6 Relative positions of in-line specimens from run SM-4, flow left to right. (Specimen Nos. 9 through 16)

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