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THERMAL FATIGUE AND OXIDATION DATA OF SUPERALLOYS INCLUDING DIRECTIONALLY SOLIDIFIED EUTECTICS

by

V. L. Hill and V. E. Humphreys
Metals Research Division

IIT RESEARCH INSTITUTE
10 West 35 Street
Chicago, Illinois 60616

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Peter T. Bizon, Project Manager

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Project Manager, Peter T. Bizon, Materials and Structures Division
NASA-Lewis Research Center, Cleveland, Ohio 44135

16. Abstract Thermal fatigue and oxidation data were obtained on 61 specimens, representing 15 discrete alloy compositions or fabricating techniques and three coating systems. Conventionally fabricated alloys included V57, MM 200, René 77, René 125, MM 246, MM 509, IN-738, IN-792 + Hf, and MM 200 + Hf. The directionally solidified alloys were MM 200, MM 200 single crystal, MM 200 bicrystal, cellular $\gamma/\gamma'-\delta$, lamellar $\gamma/\gamma'-\delta$ and lamellar $\gamma/\gamma'-\delta$ (0.06C). The coatings systems included pack aluminide (JoCoat) on IN-738 and IN-792 + Hf. Overlay coatings evaluated included NiCrAlY on IN-738, IN-792 + Hf, MM 200 DS, MM 200 DS single crystal, and cellular $\gamma/\gamma'-\delta$ and NiCrAlY/Pt on lamellar $\gamma/\gamma'-\delta$ and lamellar $\gamma/\gamma'-\delta$ (0.06C). Specimens of uncoated MM 200 DS bicrystal, MM 200 DS single crystal, and MM 200 DS survived 15,000 cycles without transverse cracking on the small radius of the double-edge wedge specimen. The lamellar $\gamma/\gamma'-\delta$ eutectic specimen, both NiCrAlY/Pt-coated and uncoated, survived 4500-7500 cycles prior to first crack initiation. Cellular $\gamma/\gamma'-\delta$ eutectic exhibited variable thermal fatigue resistance of 75-7500 cycles to first crack initiation. However, all eutectic specimens developed longitudinal cracks prior to 200 cycles. Aluminide coatings on IN-738 and IN-792 exhibited cracks in 150-250 cycles compared to 250-600 cycles for the uncoated alloys. The NiCrAlY overlay coatings on IN-738, IN-792 + Hf, and MM 200 + Hf DS exhibited initial thermal cracks at 2250-4250 cycles. Uncoated alloys V57, MM 002, and René 77 cracked in 75-150 cycles, whereas first crack initiation in René 125, MM 246, MM 509, and MM 200 + Hf occurred in 150-400 cycles. All the uncoated alloys, except MM 509, exhibited significant oxidation weight loss in 7,500-15,000 cycles. MM 509 specimens had weight losses only slightly higher than coated specimens through 7,500 cycles. All coated specimens had low weight loss.

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FOREWORD

This report describes the results of thermal fatigue and oxidation testing of test Series 7 specimens on NASA contract NAS3-17787. The report covers part of the work conducted on this contract during the period 15 January 1975 to 15 January 1977. Other IITRI work on fluidized bed thermal fatigue testing has been reported in NASA CR-72738, CR-121211, CR-121212, and CR-134775.

The NASA personnel who contributed to the program included:

Peter T. Bizon	-	Project Manager
John R. Danicic	-	Contract Specialist
Horace C. Moore	-	Contract Specialist
Edward J. Kolman	-	Contract Specialist
Allen L. Jones	-	Contract Specialist
John E. Dilley	-	Contract Specialist

IITRI personnel assigned to this program included: M.A.H. Howes, Director, Metals Division; V. L. Hill (Project Manager); V. E. Humphreys (Project Engineer); W. C. Keeney and J. Andersen (Contract Specialists); Harry Nichols, B. A. Humphreys, M. Scroll, and V. Johnson.

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SUMMARY

Thermal fatigue and oxidation testing described in this report is part of a general study of thermal fatigue being conducted by the NASA-Lewis Research Center. Earlier work in the study has been reported in NASA CR-72738, CR-121211, CR-121212, and CR-134775. All testing on this contract has been conducted employing fluidized bed heating and cooling. Testing in this program was over the temperature range 1088°/316°C employing double-edge wedge specimen.

Thermal fatigue and oxidation data were obtained on 61 specimens, representing 15 discrete alloy compositions or fabricating techniques and three coating systems. Conventionally fabricated alloys included V57, MM 002, René 77, René 125, MM 246, MM 509, IN-738, IN-792 + Hf, and MM 200 + Hf. The directionally solidified alloys were MM 200, MM 200 single crystal, MM 200 bicrystal, cellular $\gamma/\gamma'-\delta$, lamellar $\gamma/\gamma'-\delta$ and lamellar $\gamma/\gamma'-\delta$ (0.06C). The coatings systems included pack aluminide (JoCoat) on IN-738 and IN-792 + Hf. Overlay coatings evaluated included NiCrAlY on IN-738, IN-792 + Hf, MM 200 DS, MM 200 DS single crystal, and cellular $\gamma/\gamma'-\delta$ and NiCrAlY/Pt on lamellar $\gamma/\gamma'-\delta$ and lamellar $\gamma/\gamma'-\delta$ (0.06C).

Specimens of uncoated MM 200 DS bicrystal, MM 200 DS single crystal, and MM 200 DS survived 15,000 cycles without transverse cracking on the small radius of the double-edge wedge specimen. The lamellar $\gamma/\gamma'-\delta$ eutectic specimen, both NiCrAlY/Pt-coated and uncoated, survived 4500-7500 cycles prior to first crack initiation. Cellular $\gamma/\gamma'-\delta$ eutectic exhibited variable thermal fatigue resistance of 75-7500 cycles to first crack initiation. However, all eutectic specimens developed longitudinal cracks prior to 200 cycles. Aluminide coatings on IN-738 and IN-792 exhibited cracks in 150-250 cycles compared to 250-600 cycles for the uncoated alloys. The NiCrAlY overlay coatings on IN-738, IN-792 + Hf, and MM 200 + Hf DS exhibited initial thermal cracks at 2250-4250 cycles. Uncoated alloys V57, MM 002, and René 77 cracked in 75-150 cycles, whereas first crack initiation in René 125, MM 246, MM 509, and MM 200 + Hf occurred in 150-400 cycles.

All the uncoated alloys, except MM 509, exhibited significant oxidation weight loss in 7,500-15,000 cycles. MM 509 specimens had weight losses only slightly higher than coated specimens through 7500 cycles. All coated specimens had low weight loss.

1. INTRODUCTION

This report, NASA CR-135272, on Contract NAS3-17787 summarizes thermal fatigue and oxidation data for 61 specimens of conventionally fabricated nickel- and cobalt-base superalloys, directionally solidified nickel-base superalloys, and directionally solidified eutectics. Coatings on selected alloys were evaluated in the program. Double-edge wedge test specimens were cycled in a fluidized bed facility over the temperature range 1088°/316°C (1990°/600°F) for periods up to 15,000 cycles. Heating and cooling times were 180 sec each for a total thermal cycle of 360 sec. Weight change, as well as crack initiation and propagation, were obtained in the program.

Thermal fatigue data obtained previously on this contract have been reported in NSAS CR-134775.(1) Additional thermal fatigue data obtained in the IITRI fluidized bed on Contract NAS3-14311 are reported in NASA CR-72738,(2) CR-121211,(3) and CR-121212.(4) This effort comprises part of the general study of thermal fatigue being conducted by the NASA-Lewis Research Center. Further details of the study have been reported by Spera et al.,(5,6) Bizon et al.,(7-9) and Howes.(10)

Any material exposed to repeated rapid thermal transients is subject to tensile failure by thermal fatigue, also sometimes defined as thermal shock. The thermal fatigue degradation mechanism involves accumulation of damage during multiple thermal cycles. Thermal shock, on the other hand, generally involves failure in relatively few cycles. The difference generally lies in the tensile ductility of the material within the temperature range of the imposed thermal cycle. Ductile materials tend to fail by thermal fatigue, whereas brittle materials fracture by thermal shock.

Material properties, other than ductility, important in thermal fatigue are hot tensile strength, elastic modulus, thermal conductivity, and thermal expansion. Oxidation resistance apparently also plays a role in thermal fatigue. The interrelationship of material properties, the imposed thermal cycle, and component geometry defines the ability of a structure to resist thermal fatigue. However, the synergistic effects of these variables are quite complex and prediction of thermal fatigue behavior from basic properties is difficult. A major objective of the current NASA program is to develop and verify a usable model for thermal fatigue by comparing experimental data with computer-derived predictions of thermal fatigue life.

Thermal fatigue data in this report were generated using a multiple retort fluidized bed test facility consisting of one heating bed and two cooling beds. Glenny and co-workers reported the first use of fluidized beds to study thermal fatigue.(11) Fluidized bed heating and cooling provides very rapid heat transfer for both portions of the thermal cycle. An additional advantage of fluidized bed testing is that it provides a ready means of exposing a number of samples under identical test conditions. In this program, up to 36 test specimens were exposed simultaneously.

The objective of the thermal fatigue test program was threefold:

1. Determine the number of imposed thermal cycles to initiation of the first transverse crack.

2. Obtain data on the rate of propagation of the three largest cracks.

3. Generate qualitative oxidation data for the various materials.

Cycling of test specimens was generally continued until the three largest cracks reached a length of about 10 mm (0.4 in.). This corresponds to the approximate width of the tapered section of the test specimen. In some cases, exposure of specimens was continued in order to obtain oxidation data for specific alloys.

During the test program, some alloys exhibited longitudinal cracks originating in the end notches used for specimen support. Longitudinal cracks were sometimes observed prior to initiation of transverse cracks in the radiused test section. Whenever longitudinal cracking was significant, the crack lengths were also measured at each inspection period. Longitudinal cracks are significant because they alter the stress distribution in the test specimen and thereby modify transverse cracking behavior.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

Thermal fatigue testing in this program involved 61 specimens of bare and coated high temperature alloys consisting of 15 distinct alloy compositions and/or fabrication procedures. In addition, 10 coating-substrate combinations were evaluated. At least two specimens of each alloy condition or coating-substrate combination were evaluated in the program. All test specimens were supplied by the NASA-Lewis Research Center

Table 1 is a summary of the compositions of the 15 basic test alloys and/or alloy conditions. Compositional data were supplied by the alloy producers. All IN-792 specimens were hafnium modified, but only part of the MM 200 specimens contained the hafnium addition. The MM 200 directionally solidified single crystal and bicrystal specimens were of the unmodified composition.

Tensile properties at 760°C (1400°F) and creep-rupture properties at 982°C (1800°F) of the test alloys are summarized in Tables 2 and 3, respectively. These data were generated at the NASA-Lewis Research Center on the same heats of the alloys used to fabricate the thermal fatigue specimens. Significant deviation for the time-to-rupture at proof stress is observable for IN-738, MM002, René 77, and MM 200 + Hf in Table 3.

Determination of the effects of three coating systems on thermal fatigue resistance was included in the test program. A pack aluminide coating (JoCoat), applied by specification PWA 273, was evaluated on both IN-738 and IN-792 + Hf. A NiCrAlY overlay coating, applied by specification PWA 267, was evaluated on IN-738, IN-792 + Hf, MM 200 + Hf, and cellular $\gamma/\gamma'-\delta$ eutectic substrates. Finally, a NiCrAlY/Pt coating, applied by specification PWA 267 + Pt, was employed for directionally solidified specimens of the lamellar $\gamma/\gamma'-\delta$ and $\gamma/\gamma'-\delta$ (0.06C) eutectic alloys. In this report, the NiCrAlY coating is defined as "overlay," whereas the platinum-containing overlay coating is identified as the NiCrAlY/Pt coating.

2.2 Test Conditions

The fluidized bed thermal fatigue test facility is shown in Figure 1. This equipment includes one hot bed and two cold, or intermediate, temperature beds. The lower bed temperature is maintained by a water-cooled heat exchanger for testing at ambient cold bed temperatures. For testing at a 316°C (600°F) intermediate bed temperature in this program, the heat exchanger was removed and the desired intermediate bed temperature was maintained by the heating elements. Heat transfer media in both hot and cold beds was 28-48 mesh tabular alumina.

During testing in this program, up to 36 test specimens were cycled simultaneously in two coupled holding fixtures. At any time during testing, one holding fixture was in the hot bed and the other in either of the two intermediate beds. The transfer carriage, operated by air cylinder, can be programmed for any combination of heating and cooling time. Transfer time between beds was about 5 sec, and the heating and cooling time 180 sec each in the current test program.

Thermal fatigue data in this program were obtained using the 101 mm long double wedge simulated blade shape and the holding fixture shown in Figure 2. Test specimens were supported by 6.3 mm wide notches machined 6.8 mm deep in the ends of the specimen. The notched specimens provide ease of fabrication and specimen removal from the fixture for examination. In addition, the potential for superimposition of mechanical stresses due to the fixture is minimized.

The holding fixture shown in Figure 2, capable of retaining 18 test specimens, was fabricated from austenitic stainless steels. End plates were 12.7 mm thick 310 stainless steel with a radius 0.25 mm less than the specimen notches. The side supports were fabricated from 304 stainless steel channel. During testing, the test fixture also generated thermal fatigue cracks and required frequent replacement.

Thermal fatigue testing of the 61 specimens was conducted in two basic groupings of 36, cycled nominally for 7500 cycles at 1088°/316°C (1990°/600°F). The Group 1 samples consisted of 36 double wedge samples without prior cycling. Group 2 specimens consisted of 25 specimens without prior cycling and 12 specimens from Group 1 that did not crack in 7500 cycles. Group 1 specimens were also added to the second test sequence as Group 2 samples were removed from testing due to excessive cracking. Accordingly, eleven of the Group 1 samples were exposed for 15,000 and one for 13,000 cycles. These 61 test specimens comprised test Series 7 of Contract NAS3-17787.

During testing at 1088°/316°C, specimens were removed at selected intervals for gravimetric analysis and crack length measurements. The nominal removal times were 25, 50, 100, 200, 300, 500, 700, and 1000 cycles, followed by examination every 500 cycles for exposures greater than 1000 cycles. Lengths of the three longest cracks were determined by visual measurements under a microscope at 30X. The number of cycles to crack initiation was taken as the average of the number of cycles at the last inspection without cracks and the number of cycles at the first inspection with a crack. However, specimens were generally retained in the test program after crack initiation to obtain oxidation data.

Table 4 summarizes the dimensions and identification of the 61 test specimens evaluated in the program. Both the as-received and final dimensions are shown. Data on total thermal cycles imposed on each specimen are included for reference.

3. RESULTS

3.1 Oxidation Behavior

Weight change data for the 61 test specimens are contained in Tables 5 through 7. Table 5 comprises weight change data for Group 1 specimens through 7500 cycles; Table 6 provides similar data for Group 2 samples. Oxidation data in Table 7 are for Group 1 specimens for the 7,500 to 15,000 cycle exposure. These data are separated from the Group 1 initial information in Table 5, since they were generated along with oxidation data for the Group 2 specimens.

Figures 3 to 6 are plots of the oxidation data for four selected groupings of the 25 discrete alloys and/or alloy-coating combinations. Plotted data are for the average of the duplicate and/or triplicate specimens of each alloy condition, except for the cellular $\gamma/\gamma'-\delta$ eutectic samples (N1,O1) in Figure 6. The plot in Figure 6 is for a single sample of cellular $\gamma/\gamma'-\delta$ eutectic (N1) and overlay coated cellular $\gamma/\gamma'-\delta$ eutectic (O1).

Oxidation data in Tables 5 to 7 and Figures 3 to 6 are expressed in percent of the original weight since oxidation is not uniform over the test specimen. In general, the majority of the oxidation occurs on the wedge areas of the specimen. This is because these areas are exposed to the maximum temperature of the thermal cycle for longer periods than the thicker center section of the specimen. Thermocouple calibration tests reported in NASA CR-121211[3] indicated that for double wedge specimens the center section of the specimen is nominally 17-30°C (31-54°F) less than the maximum temperature of the wedge section at the end of a 180 sec heating cycle. Thermocouple calibration data also indicate that the wedge sections of the specimen were within 25°C of the 1088°C maximum temperature for the average time of about 75 sec at the end of the 180 sec. Qualitatively, therefore, the cumulative exposure was equivalent to about 20 hr at 1088° ± 25°C (1990° ± 45°F) for each 1000 cycles of testing. This corresponds to 150 and 300 hr for 7,500 and 15,000 cycle exposures, respectively. Rapid thermal cycling, however, accelerates oxidation significantly in comparison to isothermal exposure at 1088°C (1990°F).

Figure 3 indicates that uncoated hafnium-modified MM 200 and MM 200 DS exhibited better oxidation resistance than MM 200 DS single crystal and bicrystal material. At 7500 cycles, weight losses were 2.8% and 3.8% for MM 200 + Hf and MM 200 + Hf DS, respectively. At this exposure, the weight losses were 5.8% and 6.5% for MM 200 DS single crystal and MM 200 bicrystal, respectively. At 15,000 cycles, weight losses were 7.6% for MM 200 + Hf DS compared to 10.3% for single crystal MM 200 DS and 11.3% for bicrystal MM 200 DS.

The NiCrAlY coating on single crystal MM 200 indicated slightly smaller weight loss (0.07%) at 7500 cycles compared to the overlay NiCrAlY coating (0.14-0.15%) on MM 200 + Hf and MM 200 + Hf DS. Weight loss of the overlay coating on MM 200 + Hf at 15,000 cycles was 0.5%. Visually, none of the coatings on the MM 200 materials indicated significant deterioration through the 7,500 or 15,000 cycle exposures.

Figure 4 compares oxidation of uncoated IN-738, IN-792 + Hf, and MM 509 with that of coatings on these alloys. Weight loss at 7500 cycles was 5.6-5.8% for IN-738 and IN-792 + Hf, i.e., slightly less than single and bicrystalline directionally solidified MM 200.

but about twice that of MM 200 + Hf. MM 509 exhibited a weight loss at 7500 cycles (0.32%) similar to that of aluminide coated IN-792 + Hf (0.24%) and IN-738 (0.18%, 6000 cycles), as well as that of the overlay (NiCrAlY) coatings (0.27-0.33%) on these alloys.

Oxidation data plotted in Figure 5 are for the uncoated superalloys V57, MM 002, MM 246, René 77, and René 125. For these alloys the highest weight loss rate was for V57 specimens --6.6% after 2000 cycles. At this exposure, V57 samples were removed from the test. René 77 exhibited the second highest weight loss of 7.1% at 7500 cycles, compared to 4.0 and 5.0% for MM 246 and René 125, respectively. Lowest weight loss (1.4%) after 7500 cycles was recorded for MM 002.

Figure 6 is a plot of the percent weight change for the $\gamma/\gamma'-\delta$ eutectic specimens. For the uncoated alloys, the single cellular eutectic specimen, N1, indicated a higher weight loss (5.3%) than the average of the duplicate lamellar (3.2%) and lamellar 0.06C (2.5%) eutectic specimens at 7500 cycles. The NiCrAlY/Pt coating exhibited low weight loss, 0.07 to 0.14%, on both lamellar $\gamma/\gamma'-\delta$ and $\gamma/\gamma'-\delta$ (0.06C) DS specimens.

Weight change data for the uncoated alloys at 7500 cycles reflected the following ranking in order of increasing oxidation resistance: V57, René 77, MM 200 DS bicrystal, IN-792 + Hf. IN-738, MM 200 DS single crystal, cellular $\gamma/\gamma'-\delta$ eutectic, lamellar $\gamma/\gamma'-\delta$ (0.06C) eutectic, MM 002 and MM 509. For comparison, MM 509 exhibited weight loss (0.32%) about one-twentieth that of René 77 (6.1%) and one seventeenth that of IN-738 (5.6%) after 7500 cycles.

Weight change indicated little difference in oxidation behavior of the three coating systems through 7500 cycles. Weight losses for all coated specimens were low, 0.07-0.8%. Generally, the NiCrAlY/Pt coating indicated the lowest weight loss (0.07-0.14%), with pack aluminide intermediate (0.27%), and the NiCrAlY overlay having highest losses at 0.27-0.79%. At these relatively low losses of 0.08-0.9 g (0.07-0.8%) a significant contribution to the weight loss may have been due to spalling of metal from the fatigue cracked areas. The high weight loss of DS MM 200 and the eutectics indicates that protective coatings are required for these alloy systems.

3.2 Thermal Fatigue Resistance

Accumulated thermal cycles to first crack initiation for Group 1 and Group 2 specimens are summarized in Tables 8 and 9, respectively. In these tables, the alloys are ranked in increasing cycles to first crack initiation on the 0.635 mm small radius. Thermal cycles to crack initiation on the 1.016 mm large radius are included for comparison. Generally, cracking of the large radius is of lesser importance, particularly if preceded by cracking of the small radius. The emergence of thermal cracks on the small radius influences the stress distribution in the specimen. This can increase the cycle time to initiation of cracks on the large radius.

Cycles to first crack in Tables 8 and 9 are based on the mean between the last inspection period without a crack and the inspection period when a crack was first visible. For example, if no cracks were observed at 100 cycles but became visible at 200 cycles, origination of the first crack is considered to be 150 cycles. Accordingly, thermal fatigue data in Tables 8 and 9 have an inherent potential error varying from $\pm$ 12 cycles to $\pm$ 150 cycles for exposures less than 1000 cycles. The error is $\mp$ 250 cycles for exposures above 1000 cycles, based on the inspection periods described previously.

Fatigue data in Table 8 indicate that the lowest fatigue life was that of the $\gamma/\gamma'-\delta$ eutectic specimens. One specimen, of cellular $\gamma/\gamma'-\delta$ + overlay (O1), did survive 7500 cycles without transverse cracks. The wide scatter for this material might have resulted from inherent structural defects in the specimen. Eutectic specimens, however, did develop severe longitudinal cracks, as will be discussed subsequently. The highest thermal fatigue resistance, >15,000 cycles, for Group 1 specimens was obtained for MM 200 DS single crystal, MM 200 DS bicrystal, MM 200 + Hf + overlay, and MM 200 + Hf DS. One of the three specimens of MM 200 + Hf DS (C5), however, did develop a crack at 11,750 cycles.

Data in Table 8 indicate that uncoated IN-738 had higher fatigue resistance (600 cycles) than IN-792 + Hf (250-600 cycles) and MM 509 (250-400 cycles). Aluminide coatings decreased the fatigue resistance of IN-738 (150 cycles) and IN-792 + Hf (150-250 cycles). Conversely, the NiCrAlY overlay coating increased the cycles to first crack initiation for both coated IN-738 (2,250-3,750 cycles) and IN-792 + Hf (2,750-4,750 cycles). However, MM 200 + Hf DS + overlay (2,250-4,250 cycles) exhibited lower fatigue resistance than that of uncoated MM 200 + Hf DS (11,750->15,000 cycles). No reason for the higher thermal fatigue resistance of one specimen (A1) compared to the other samples (A2,A3) of MM 200 + Hf was apparent.

Thermal cycles for first crack initiation for Group 2 specimens, summarized in Table 9, indicate limited fatigue resistance of uncoated V57, MM 002, René 77, René 125, and MM 246. All specimens of these alloys exhibited small radius cracks in 75-250 cycles. Data for the lamellar eutectic alloys indicate greater resistance to transverse cracking than that of the Group 1 cellular alloys. Some specimens of both coated and uncoated $\gamma/\gamma'-\delta$ and $\gamma/\gamma'-\delta$ (0.06C) survived 7500 cycles without small radius cracks. The 0.06C eutectic specimen appeared to be slightly more resistant than the unmodified lamellar eutectic.

One specimen of MM 200 DS single crystal + overlay (T1) exhibited a small radius crack at 6,250 cycles whereas the other sample survived 7500 cycles without cracking. Group 1 specimens of MM 200 DS single crystal were exposed 15,000 cycles without small-radius cracks. Thus, the behavior of this material correlated with data for Group 1 alloys MM 200 + Hf DS and MM 200 + Hf DS + overlay. In both cases, overlay specimens exhibited cracking in fewer cycles than the uncoated material.

Ranking the uncoated alloys in terms of small-radius first crack initiation resulted in the following order of increasing fatigue resistance: René 77, V57, MM 002, René 125, MM 246, MM 509, IN-792 + Hf, MM 200 + Hf, and IN-738, with no cracking of MM 200 DS, MM 200 + Hf DS, and MM 200 DS single crystal. A similar ranking for coated alloys was: IN-738, (aluminide), IN-792 + Hf (aluminide), IN-738 (overlay), MM 200 DS + Hf (overlay), IN-792 + Hf (overlay), MM 200 DS single crystal (overlay), and MM 200 + Hf (overlay). Eutectic alloys cannot be included in rankings because of data scatter and longitudinal cracking.

Table 10 contains optically measured crack lengths for the three longest cracks on each Group 1 specimen as a function of accumulated cycles. Similar data for Group 2 specimens are contained in Table 11. Crack lengths shown are measured on both top and bottom surfaces and averaged to obtain the mean crack length. Each of the cracks is located from the bottom (numbered end) of the test specimen. Also identified in these tables is the total number of observable cracks on both the small (0.635 mm) and large (1.016 mm) radius.

Table 12 summarizes the longitudinal crack propagation from the end notches for Group 2 eutectic specimens through 7500 cycles. Longitudinal cracks became measurable on all Group 2 eutectic specimens at 200 cycles. Table 12 includes data for both top and bottom (numbered end) surfaces of the specimen. Each data point consists of the average of measurements on both sides of the specimen. At 7500 cycles, longitudinal crack lengths varied from about 13 to 28 mm.

Figures 7 and 8 show the as-received appearance of typical conventionally fabricated superalloy and eutectic alloys, respectively. As shown in Figure 8, the edges of Group 2 eutectic specimens were radiused at the ends to reduce longitudinal cracking. None of the Group 1 eutectic specimens or any other alloy, had similar end preparation.

Figures 9 to 20 show the appearance of all 61 test specimens after thermal cycling. In all photographs, the small radius is at the right. Longitudinal cracking of the Group 1 eutectic samples is illustrated in Figure 15, and that of Group 2 eutectic specimens in Figures 17 and 18.

4. DISCUSSION

Longitudinal cracking of eutectic specimens was apparently due to the inherent properties of the directionally solidified structure. These cracks initiated at relatively few thermal cycles and, in most cases, prior to transverse cracks on the small radius. Contouring the ends of the test specimen had little influence on transverse cracking. The existence of longitudinal cracks unquestionably altered the stress distribution in the specimen resulting in a lower stress in wedge areas during cycling. Thus, the initiation of transverse cracks in the small radius for eutectic specimens cannot be compared directly with the other alloys tested. In any case, the observed longitudinal cracking behavior of the eutectics in this program indicates a significant potential problem in application of these alloys.

Comparison of crack initiation of aluminide and NiCrAlY coatings on IN-738 and IN-792 + Hf indicates a possible infusion of coating ductility. The brittle aluminide coating developed transverse cracks significantly earlier than the parent metal and the more ductile NiCrAlY overlay coating. Thus, it appears that the aluminide coating, although providing similar oxidation protection, did reduce thermal fatigue resistance during cycling over the range 1088°/316°C. This, again, may be an important criterion in selection of coating systems for high-temperature cyclic operation. The relatively high weight losses for uncoated directionally solidified alloys indicate a well-defined need for protective coatings.

5. SUMMARY OF RESULTS

Thermal fatigue and oxidation data on the 61 test specimens of test Series 7 at 1088°/316°C indicate the following conclusions:

1. The best oxidation resistance for the 15 uncoated alloys was obtained for MM 509, 0.32% weight loss in 7500 cycles. This weight loss was comparable to several of the coated specimens. Poorest oxidation resistance was obtained for V57, 6.6% weight loss in 2000 cycles. The remaining 13 discrete uncoated alloys, or fabrication techniques, had weight losses varying from 1.0 to 7.0% in 7500 cycles.

2. Directionally solidified $\gamma/\gamma'-\delta$ eutectic alloys exhibited weight losses of 2.4 to 5.3% in 7500 cycles.

3. Uncoated MM 200 + Hf and MM 200 + Hf DS had weight losses of 2.7-3.3% in 7500 cycles, compared to 5.5-6.3% for MM 200 DS single crystal and bicrystal.

4. All pack aluminide, NiCrAlY and NiCrAlY/Pt coatings survived 7500 cycles with low weight losses of 0.07 to 0.34% and no apparent coating failures. An exception was the single specimen of NiCrAlY overlay coated cellular $\gamma/\gamma'-\delta$, whose loss was 0.8% in 7500 cycles. Metal loss due to longitudinal cracking may have contributed to the higher weight loss for this, and other specimens.

5. Highest resistance to thermal fatigue, 11,750 to >15,000 cycles to first crack initiation, was obtained for directionally solidified alloys MM 200 DS bicrystal, MM 200 + Hf + overlay, MM 200 + Hf DS, and MM 200 DS single crystal. Directional solidification of MM 200 + Hf increased the exposure to first visible crack from 400-1750 cycles to 11,750->15,000 cycles.

6. First crack initiation on the small radius occurred for uncoated V57, MM 002, and René 77 in 75-150 cycles; in 150-400 cycles for René 125, MM 246, and MM 509; and 250-600 cycles for IN-738, IN-792 + Hf, and MM 200 + Hf. One specimen of MM 200 + Hf survived 1750 cycles prior to first crack initiation.

7. All DS eutectic specimens initiated longitudinal cracks originating in the mounting notches in 100-200 cycles that propagated during continued cyclic exposure. These cracks reduced stresses affecting the initiation of transverse cracks.

8. Because initiation of transverse cracking was affected by early longitudinal cracking, cellular $\gamma/\gamma'-\delta$ DS eutectic specimens indicated widely variable cycles to first transverse crack for uncoated (75-400) and for NiCrAlY overlay coated (75->7500) specimens. This may also have resulted from inherent defects in the material. Transverse small-radius cracks occurred in lamellar $\gamma/\gamma'-\delta$ and $\gamma/\gamma'-\delta$ (0.06C) at 4750-6250 cycles, for both uncoated and NiCrAlY/Pt coated specimens. One specimen each of coated and uncoated $\gamma/\gamma'-\delta$ (both 0.06C modified and unmodified) survived 7500 cycles without small-radius cracks.

9. Aluminide coatings on IN-738 and IN-792 + Hf decreased the exposure to first crack initiation to 150-250 cycles compared to 250-600 cycles for the uncoated alloys and 2250-4750 cycles for NiCrAlY overlay coated specimens. Overlay coating on MM 200 + Hf increased cycles to first crack initiation from 400-1750 to >13,500 cycles.

10. Crack initiation for NiCrAlY/Pt overlay coated specimens indicated little influence on thermal fatigue resistance of DS eutectics, but the NiCrAlY coating did modify cracking behavior of MM 200 + Hf and MM 200 single crystal. Uncoated MM 200 + Hf DS survived 15,000 cycles without cracking as compared to 2250-4250 cycles for NiCrAlY overlay coated material. One NiCrAlY overlay coated specimen of MM 200 DS single crystal initiated a crack in 6250 cycles, whereas all three uncoated specimens survived 15,000 cycles without cracking. Thus, the NiCrAlY overlay coating increased the fatigue resistance of conventionally cast IN-738, IN-792 + Hf, and MM 200 + Hf but decreased the thermal fatigue resistance of MM 200 + Hf DS and MM 200 DS single crystal.

11. High weight losses for directionally solidified MM 200, MM 200 + Hf, and the eutectic alloys demonstrated a need for protective coating during cyclic operation at 1088°C. All coated specimens had low weight loss.

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Table 1

SUMMARY OF ALLOY COMPOSITIONS

Alloy	Alloy Composition, w/o																		
	C	Si	Mn	P	S	Ni	Cr	Co	Fe	Al	Ti	Mo	W	Cb	Ta	B	Zr	Hf	Other
V 57	0.04	0.10	0.12	0.01	0.004	26.4	14.7	--	Bal	0.2	2.8	1.5	--	--	--	0.006	--	--	V 0.41
MM 509	0.62	<0.1	<0.1	--	0.003	10.0	23.4	Bal	<0.1	--	0.2	--	7.0		3.5	<0.01	0.5	--	
IN-792 + Hf	0.10	<0.05	0.01	<0.01	0.003	Bal	12.0	9.1	<0.1	3.3	4.1	1.9	3.8		3.8	0.013	0.08	0.5	Cu <0.05, Pb 1.0 ppm, Bi 0.2 ppm
IN-738	0.12	0.03	0.01	<0.01	0.001	Bal	16.2	8.3	0.10	3.5	3.5	1.7	2.6	0.8	1.6	0.013	0.06	--	Pb <0.001, Bi <0.5 ppm
MM 246	0.15	<0.1	<0.1	<0.1	0.002	Bal	8.9	10.9	0.18	5.3	1.6	2.4	9.6		1.6	0.016	0.06	--	0.08Cu, Pb <2 ppm, Bi <0.3 ppm, Ag <5 ppm
MM 002	0.15	0.06	0.04	--	0.001	Bal	9.2	10.7	0.10	5.8	1.4	<0.1	9.8	--	2.6	0.02	0.05	1.4	Cu <0.01
René 77	0.06	<0.1	<0.01	--	0.004	Bal	14.2	15.5	0.10	4.2	3.3	4.4	--	--	--	0.016	<0.01	--	Pb <1 ppm, Bi 0.25 ppm Cu <0.01
René 125	0.16	0.08	0.04	<0.01	0.002	Bal	8.8	10.4	0.07	4.7	2.6	1.7	6.9	0.08	3.8	0.02	0.05	1.6	Cu 0.01, V 0.01, Mg 0.008, Bi <0.3 ppm
MM 200 + Hf	0.16	<0.20	<0.20	--	--	Bal	8.33	10.63	<0.35	5.04	2.04	--	11.86	1.00		0.016	0.10	2.08	Cu <0.01, Pb <1 ppm
MM 200 + Hf DS	0.16	<0.20	<0.20	--	--	Bal	8.33	10.63	<0.35	5.04	2.04	--	11.86	1.00		0.016	0.10	2.08	Cu <0.01, Pb <1 ppm, Bi <0.3 ppm
MM 200 DS single crystal	0.15	<0.10	<0.10	--	--	Bal	8.08	9.31	<0.10	4.85	1.88	---	12.76	1.05		0.018	0.03	--	Cu <0.10, Pb <1 ppm, Bi <0.3 ppm
MM 200 DS bicrystal	0.15	<0.10	<0.10	--	--	Bal	8.08	9.31	<0.10	4.85	1.88	--	12.76	1.05		0.018	0.03		Cu <0.10, Pb <1 ppm, Bi <0.3 ppm
Lamellar γ/γ'-δ[a]	--					Bal	6.0			2.5				20.1					
Cellular γ/γ'-δ[a]	--					Bal	6.0			2.5				20.1					
Lamellar γ/γ'-δ[a] (0.06C)	0.06					Bal	6.0			2.5				20.1					

[a] Nominal

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Table 2

TENSILE PROPERTIES OF TEST MATERIALS AT 760°C (1400°F)

Alloy	Tensile Properties[a]						
	Proportional Limit			Ultimate Tensile Strength			Reduction of Area, %
	psi	N/cm^2	% of Nominal	psi	N/cm^2	% of Nominal	
V 57	71,500	49,500	102	79,500	55,000	88	15.0
MM 509	43,000	29,500	80	90,000	62,000	105	14.0
IN-792 + Hf	112,000	77,000	78	152,000	105,000	93	8.7
IN-738	102,000	70,500	89	136,000	94,000	97	13.1
MM 246	117,000	80,500	94	149,000	102,500	99	7.9
MM 002	117,500	81,000	98	150,000	103,500	98	12.1
René 77	114,000	78,500	114	147,500	101,500	108	13.0
René 125	129,500	89,500	95	157,000	108,000	103	7.5
MM 200 + Hf	121,500	84,000	100	137,000	94,500	101	11.9
MM 200 + Hf DS	124,000	85,500	93	162,500	112,000	107	12.3
MM 200 DS single crystal	116,000	80,000	97	135,500	93,500	89	13.6
Lamellar γ/γ'-δ[b]	143,000	98,500	-	150,000	103,500	-	16.0
Cellular γ/γ'-δ[b]	143,000	98,500	-	150,000	103,500	-	16.0
Lamellar γ/γ'-δ + 0.06C[b]	143,000	98,500	-	150,000	103,500	-	16.0

[a]Average of two tests.

[b]Nominal.

Table 3

SUMMARY OF 982°C (1800°F) CREEP-RUPTURE PROPERTIES

Alloy	Stress-Rupture Properties[a] psi	N/cm^2	Time to Rupture, hr	% of Nominal Life[b]	Reduction of Area, %
V 57					
MM 509	15,000	10,500	132.2,150.6	141.4	22.2
IN-792 + Hf	22,100	15,000	107.5,111.5	109.5	14.1
IN-738	20,000	14,000	47.3, 58.7	53.0	31.5
MM 246	28,000	19,500	68.2, 76.4	72.3	14.9
MM 002	27,000	18,500	23.1, 48.2	35.7	6.8
René 77	18,000	12 500	39.3, 55.9	47.6	9.7
René 125	26,000	18 000	61.3, 82.3	71.8	19.7
MM 200 + Hf	27,000	18,500	35.5, 50.3	42.9	7.2
MM 200 + Hf DS	29,000	20,000	101.9,156.5	129.2	51.5
MM 200 DS single crystal	30,000	20,500	41.5, 61.9	51.7	60.0
Lamellar $\gamma/\gamma'-\delta$[c]	40,000	27,500	--	--	14.0
Cellular $\gamma/\gamma'-\delta$[c]	39,000	27,000	--	--	14.0
Lamellar $\gamma/\gamma'-\delta$ + 0.06C[c]	40,000	27,500	--	--	14.0

[a]Average of two tests.

[b]Nominal 100 hr.

[c]Nominal.

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Table 4

DIMENSIONS AND IDENTIFICATION OF TEST SPECIMENS

Alloy	Specimen Identification	Measured Radius, mm		Initial Dimension, mm			Total Test Cycles	Final Dimension, mm		
		Small	Large	Length	Width	Thickness		Length	Width	Thickness
				Group 1						
MM 200 + Hf	A1	0.71	1.04	102.08	31.19	6.30	7,500	101.98	30.98	6.29
	A2	0.71	1.04	101.68	31.12	6.28	7,500	101.66	30.84	6.28
	A3	0.71	1.07	101.42	31.12	6.40	7,500	101.44	30.85	6.37
MM 200 + Hf + overlay[a]	B1	0.89	1.20	102.46	31.39	6.63	13,500	102.29	31.45	6.63
	B2	0.89	1.32	102.90	31.29	6.86	15,000	102.67	31.34	5.81
	B3	0.86	1.32	102.51	31.39	6.79	15,000	102.41	31.39	6.79
MM 200 + Hf DS	C1	0.86	1.25	102.46	31.22	6.51	15,000	102.24	30.58	6.35
	C2	0.79	1.22	102.29	31.67	6.49	15,000	101.91	30.59	6.23
	C5	0.78	1.12	103.00	31.34	6.40	15,000	102.74	30.58	6.27
MM 200 + Hf DS + overlay[a]	D2	0.74	1.09	101.68	31.04	6.50	7,500	101.70	31.09	6.53
	D3	0.61	0.86	101.93	31.04	6.79	7,500	101.87	31.12	6.92
	D5	0.64	0.99	101.65	30.84	6.52	7,500	101.34	31.03	6.54
MM 200 DS single crystal	E1	0.64	0.79	101.92	30.38	6.03	15,000	100.86	29.67	5.73
	E2	0.51	0.89	101.68	29.16	5.61	15,000	101.17	28.42	5.33
	E3	0.61	0.74	101.35	29.77	5.90	15,000	100.99	29.06	5.62
MM 200 DS bicrystal	F1	0.69	0.79	96.27	30.20	6.30	15,000	95.71	29.36	5.91
	F2	0.61	1.12	97.49	30.23	6.19	15,000	97.49	29.52	5.87
	F5	0.71	1.27	97.84	30.30	6.32	15,000	97.36	29.52	6.01
IN-792 + Hf	G2	0.66	1.07	101.40	31.14	6.21	7,500	101.24	31.14	6.45
	G3	0.66	1.04	101.35	31.19	6.22	7,500	101.38	30.91	6.06
IN-792 + Hf + Al coated[b]	H2	0.71	1.09	101.50	31.14	6.23	7,500	101.87	31.22	6.22
	H3	0.74	1.07	101.73	31.29	6.27	7,500	101.82	31.34	6.28
IN-792 + Hf + overlay[a]	I1	0.71	0.84	101.60	30.96	6.50	7,500	101.55	30.96	6.51
	I3	0.74	0.99	101.88	30.96	6.49	7,500	101.91	31.14	6.45
IN-738	J2	0.61	1.12	101.96	31.14	6.06	7,500	101.85	30.86	5.91
	J4	0.61	1.04	102.34	31.32	6.18	7,500	101.93	30.92	6.04
IN-738 + Al coated[b]	K2	0.71	1.09	101.78	31.39	6.22	6,000	101.[illegible]8	31.22	6.32
	K5	0.71	1.09	101.50	31.19	6.42	5,500	101.47	31.22	6.41
IN-738 + overlay[a]	L1	0.71	0.94	101.78	30.94	6.45	7,500	101.44	31.05	6.45
	L3	0.66	0.94	101.93	31.14	6.26	7,500	101.60	31.23	6.25
MM 509	M1	0.64	1.07	102.03	31.70	6.32	7,500	102.01	31.90	6.33
	M2	0.61	1.07	101.78	31.70	6.34	7,500	101.91	31.80	6.31
γ/γ'-δ eutectic DS (cellular)	N1	0.69	1.24	101.73	31.78	6.42	7,500	101.70	31.36	6.43
	N2	0.69	1.12	101.75	31.68	6.42	100	101.75	31.68	6.42
γ/γ'-δ eutectic DS (cellular) + overlay[a]	O1	0.76	1.12	101.63	32.13	6.67	7,500	101.71	32.37	6.68
	O2	0.71	1.09	101.68	32.15	6.66	100	101.68	32.15	6.66
				Group 2						
γ/γ'-δ eutectic DS (lamellar)	P1	0.46	0.76	101.60	30.81	6.26	7,500	101.50	31.55	6.32
	P2	0.43	0.97	101.65	31.00	6.40	7,500	101.53	31.70	6.49
γ/γ'-δ eutectic DS (lamellar) + NiCrAlY/Pt overlay[c]	Q1	0.56	0.97	100.94	30.81	6.46	7,500	100.94	31.99	6.48
	Q2	0.38	0.74	101.52	30.71	6.46	7,500	101.50	31.67	6.49
γ/γ'-δ eutectic (0.06C) DS (lamellar)	R1	0.51	0.86	101.70	31.65	6.39	7,500	101.65	31.34	6.51
	R2	0.43	0.74	101.90	32.11	6.43	7,500	101.04	31.85	6.54
γ/γ'-δ eutectic (0.06C) DS (lamellar) + NiCrAlY/Pt overlay[c]	S1	0.46	1.02	101.42	31.65	6.47	7,500	101.46	31.60	6.49
	S2	0.53	0.94	101.61	31.37	6.46	7,500	101.70	31.55	6.47
MM 200 DS single crystal + overlay[a]	T1	0.41	0.94	101.75	29.16	6.51	7,500	101.65	31.65	6.51
	T2	0.61	1.19	101.49	29.64	6.95	7,500	101.50	32.16	5.96
V 57	V1	0.71	0.86	98.53	30.81	6.18	2,000	96.77	31.24	6.26
	V2	0.71	0.86	98.53	30.81	6.14	2,000	96.98	31.04	6.12
	V5	0.69	0.86	98.50	30.73	6.18	2,000	97.26	31.04	6.05
MM 002	W1	0.76	0.86	98.37	30.71	6.09	7,500	98.37	30.53	6.14
	W2	0.76	0.86	98.43	30.73	6.18	7,500	98.43	30.71	6.21
	W3	0.61	0.91	98.40	30.68	6.14	7,500	98.43	30.48	6.[illegible]
MM 246	X1	0.71	0.86	98.30	38.81	6.15	7,500	98.22	30.48	6.10
	X2	0.71	0.84	98.37	30.71	6.05	7,500	98.20	30.43	6.04
	X5	0.64	0.84	98.07	30.71	6.09	7,500	97.94	30.46	5.94
René 77	Y1	0.66	0.84	98.37	30.76	5.69	7,500	98.15	30.38	6.12
	Y2	0.66	0.91	98.45	30.76	5.61	7,500	98.12	30.49	6.03
	Y4	0.74	0.89	98.40	30.71	5.64	7,500	98.15	30.46	6.11
René 125	Z2	0.69	0.84	98.35	30.86	6.16	7,500	98.17	30.56	6.05
	Z3	0.69	0.84	98.42	30.78	6.13	7,500	98.25	30.46	6.00
	Z6	0.61	0.91	98.35	30.91	6.14	7,500	98.25	30.58	6.01

[a]NiCrAlY overlay coatings applied by specification PWA 267.

[b]Pack aluminide coatings (JoCoat) applied by specification PWA 273.

[c]NiCrAlY/Pt overlay coatings applied by specification PWA 267 + Pt.

Table 5

WEIGHT CHANGE DATA FOR GROUP 1 SPECIMENS

Material	Sample Identification	Starting Weight, g	Weight Change at Given Cycles,[a] %: 100	200	300	500	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
MM 200 + Hf	A1	126.1791	.018	.032	.038	.043	.045	.042	.026	-0.08	-0.24	-0.31	-0.59	-0.76	-0.97	-1.30	-1.52	-2.30	-2.30	-2.62	-2.79
	A2	125.6270	.010	.019	.024	.029	.029	.028	.022	-0.05	-0.22	-0.30	-0.43	-0.53	-0.57	-0.89	-1.14	-1.79	-1.93	-2.09	-2.28
	A3	126.6466	.017	.029	.034	.032	.026	.019	.001	-0.05	-0.33	-0.41	-0.90	-1.02	-1.06	-1.65	-1.86	-2.04	-2.30	-2.88	-3.15
MM 200 + Hf + overlay	B1	134.7711	.006	.003	.004	.008	.007	.004	.002	-0.01	-0.02	-0.04	-0.05	-0.07	-0.08	-0.09	-0.11	-0.13	-0.14	-0.16	-0.17
	B2	137.6995	.003	.004	.006	.011	.009	.007	.004	0	-0.01	-0.01	-0.03	-0.04	-0.06	-0.07	-0.08	-0.11	-0.12	-0.14	-0.15
	B5	137.0364	.001	.004	.006	.007	.005	.003	.001	-0.01	-0.02	-0.03	-0.06	-0.06	-0.07	-0.08	-0.09	-0.11	-0.12	-0.15	-0.17
MM 200 + Hf DS	C1	130.9854	.005	.015	.022	.032	.034	.030	.002	-0.24	-0.41	-0.60	-1.01	-1.29	-1.35	-1.76	-2.20	-2.70	-2.80	-3.22	-3.38
	C2	130.5329	.010	.019	.024	.031	.036	.033	.019	-0.23	-0.41	-0.64	-0.97	-1.21	-1.69	-2.02	-2.35	-2.64	-2.77	-3.10	-3.30
	C5	129.7829	.009	.029	.033	.048	.049	.050	.01	-0.14	-0.61	-0.74	-1.43	-1.63	-1.67	-2.00	-2.38	-2.56	-3.41	-3.63	-3.87
MM 200 + Hf DS + overlay	D2	128.6899	.002	.005	.008	.012	.011	.009	.005	0	0	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.09	-0.10	-0.12	[illegible]
	D3	130.5038	.001	.006	.006	.011	.007	.004	.001	0	-0.02	-0.03	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.11	-0.13	-0.15
	D5	128.1565	.001	.006	.009	.010	.010	.007	.003	0	-0.02	-0.02	-0.05	-0.06	-0.07	-0.09	-0.09	-0.11	-0.13	-0.16	-0.19
MM 200 DS single crystal	E1	114.6683	.024	.032	.042	.049	[illegible]	[illegible]	-.011	-0.87	-1.24	-1.66	-2.21	-2.70	-3.03	-3.23	-3.89	-4.40	-4.70	-5.20	-5.32
	E2	103.5326	.023	.028	.044	.059	[illegible]	.045	-.050	-0.36	-1.45	-1.57	-2.41	-2.98	-3.07	-3.49	-3.76	-4.31	-5.00	-5.31	-5.49
	E3	110.1965	.012	.031	.040	.050	.056	.061	-.006	-0.40	-1.32	-1.47	-2.41	-2.93	-3.02	-3.58	-3.82	-4.29	-4.87	-5.32	-5.56
MM 200 DS bicrystal	F1	114.9243	.011	.022	.035	.023	[illegible]	.029	-.052	-1.20	-1.73	-2.24	-2.82	-3.56	-3.68	-4.29	-5.27	-5.90	-6.20	-6.84	-7.00
	F2	116.2061	.019	.028	.039	.049	.059	.069	-.035	-0.64	-1.50	-1.84	-2.84	-3.28	-3.34	-4.24	-4.66	-5.03	-5.20	-5.76	-5.83
	F5	116.9272	.013	.025	.037	.051	.051	.057	-.043	-0.36	-1.33	-1.51	-2.29	-2.89	-2.96	-3.66	-4.16	-4.56	-4.70	-5.42	-5.97
IN-792 + Hf	G2	120.2165	.035	.045	.063	.073	.037	.033	-.014	-0.62	-2.07	-2.44	-2.84	-3.24	-3.93	-4.12	-4.51	-5.25	-5.59	-5.93	-6.14
	G3	120.1295	.021	.044	.052	.069	.067	.065	-.027	-0.29	-0.99	-1.37	-2.21	-2.60	-3.33	-3.55	-3.95	-4.44	-4.71	-5.29	-5.44
IN-792 + Hf + Al coat	H2	119.7792	.009	.015	.018	.021	.011	.004	-.009	-0.03	-0.06	-0.08	-0.12	-0.14	-0.16	-0.18	-0.20	-0.22	-0.24	-0.26	-0.28
	H3	120.5508	.010	.015	.018	.023	.021	.018	.007	0	-0.03	-0.04	-0.06	-0.08	-0.09	-0.11	-0.13	-0.14	-0.17	-0.18	-0.20
IN-792 + Hf + overlay	I1	124.2494	.002	.005	.007	.012	.013	.010	.004	-0.01	-0.04	-0.06	-0.08	-0.10	-0.12	-0.14	-0.16	-0.18	-0.21	-0.24	-0.25
	I3	123.3035	.004	.006	.014	.015	.010	.005	-.002	-0.02	-0.05	-0.07	-0.10	-0.11	-0.13	-0.16	-0.17	-0.21	-0.23	-0.26	-0.28
IN-738	J2	116.3581	.022	.046	.053	.069	.073	.070	.024	-0.38	-1.39	-1.55	-2.12	-2.78	-3.32	-3.66	-4.03	-4.77	-5.01	-5.30	-5.61
	J4	116.4591	.021	.043	.050	.059	.065	.060	.033	-0.26	-1.04	-1.27	-2.08	-2.92	-3.32	-3.48	-3.94	-4.55	-4.86	-5.24	-5.52
IN-738 + Al coat	K2[b]	117.4508	.013	.015	.017	.025	.025	.020	.010	-0.02	-0.05	-0.07	-0.08	-0.09	-0.12	-0.14	-0.17	-0.18	-	-	-
	K5[c]	118.6811	.013	.018	.026	.034	.028	.023	.004	-0.03	-0.08	-0.11	-0.13	-0.17	-0.19	-0.22	-0.24	-	-	-	-
IN-738 + overlay	L1	120.5007	.003	.009	.008	.011	.007	.003	-.008	-0.02	-0.07	-0.08	-0.10	-0.13	-0.15	-0.18	-0.21	-0.25	-0.27	-0.29	-0.31
	L3	119.0636	.002	.008	.009	.009	.006	.001	-.010	-0.02	-0.06	-0.08	-0.11	-0.14	-0.16	-0.19	-0.21	-0.25	-0.29	-0.32	-0.34
MM 509	M1	130.3803	.014	.023	.034	.038	.042	.035	.024	0	-0.01	-0.04	-0.06	-0.08	-0.11	-0.15	-0.15	-0.21	-0.23	-0.28	-0.29
	M2	129.2594	.013	.013	.013	.013	.004	-.006	-.019	-0.04	-0.06	-0.09	-0.12	-0.16	-0.19	-0.21	-0.23	-0.24	-0.29	-0.34	-0.34
[illegible]- eutectic (cellular)	N1	128.7447	.038	.088	.108	.096	-.005	-.070	-.184	-0.44	-1.31	-1.46	-2.49	-2.72	-2.87	-3.43	-3.61	-3.97	-4.34	-4.08	-5.26
	N2[d]	128.2936	.046	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]- eutectic (cellular) + overlay	O1	132.5654	.013	.026	.057	.045	.018	.001	-.027	-0.07	-0.16	-0.20	-0.27	-0.34	-0.39	-0.46	-0.49	-0.56	-0.64	-0.70	-0.79
	O2[d]	132.0808	.011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a] All weight changes are positive except where noted.

[b] Removed from test after 2500 cycles; replaced at 4500 cycles.

[c] Removed from test after 3000 cycles; replaced at 4500 cycles.

[d] Removed from test after 100 cycles.

Table 6

WEIGHT CHANGE DATA FOR GROUP 2 SPECIMENS

Material	Sample Identification	Starting Weight, g	Weight Change at Given Cycles,[a] 100	200	300	500	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500
Lamellar γ/γ'-α eutectic	P1	125.5251	.044	.067	.086	.096	.085	.071	-.049	-.24	-.75	-.89	-1.40	-1.41	-1.93	-1.99	-2.19	-2.29	-2.93	-3.12	-3.25
	P2	127.9152	.041	.062	.081	.089	.082	.055	-.108	-.26	-.64	-.80	-1.31	-1.37	-1.90	-1.96	-2.26	-2.36	-2.54	-2.73	-3.06
Lamellar γ/γ'-α eutectic + NiCrAlY/Pt coat	Q1	129.1304	.003	.009	.010	.011	.013	.010	.016	.011	-.009	-.013	-.013	-.022	-.038	-.043	-.046	-.059	-.086	-.114	-.128
	Q2	128.2215	.006	.012	.014	.014	.015	.013	.014	.011	-.001	-.012	-.020	-.028	-.061	-.063	-.067	-.086	-.093	-.100	-.140
Lamellar γ/γ'-α eutectic (0.06C)	R1	125.4724	.034	.049	.069	.078	.079	.074	-.028	-.19	-.71	-.80	-1.01	-1.06	-1.78	-1.80	-2.05	-2.13	-2.47	-2.53	-2.60
	R2	130.3767	.033	.046	.072	.078	.075	.066	-.096	-.22	-.52	-.65	-.97	-1.05	-1.74	-1.78	-2.00	-2.06	-2.17	-2.22	-2.35
Lamellar γ/γ'-α eutectic (0.06C)+NiCrAlY/Ti coat	S1	129.2028	.005	.010	.011	.014	.014	.013	.018	.015	.009	-.012	-.016	-.024	-.045	-.067	-.069	-.077	-.094	-.126	-.133
	S2	129.1955	.002	.007	.008	.010	.011	.008	.010	.005	.001	-.023	-.026	-.029	-.066	-.080	-.081	-.095	-.110	-.124	-.142
MM 200 DS + single crystal + overlay	T1	116.6730	.005	.011	.009	.011	.014	.012	.016	.019	.019	.011	.007	-.001	-.029	-.032	-.034	-.039	-.049	-.062	-.069
	T2	112.1022	.003	.009	.009	.011	.013	.012	.015	.013	.014	.002	.001	-.007	-.022	-.029	-.034	-.037	-.043	-.053	-.064
V 57	V1	109.0892	-.16	-.43	-.69	-1.27	-1.90	-2.35	-4.18	-6.75	b										
	V3	108.6878	-.14	-.45	-.77	-1.35	-1.92	-2.45	-4.28	-6.59	b										
	V5	108.1022	-.21	-.42	-.63	-1.09	-1.73	-2.13	-3.88	-6.46	b										
MM 002	W1	115.1252	.018	.026	.028	.030	.033	.030	.034	.044	-.031	-.087	-.14	-.27	-.65	-.70	-.91	-.96	-1.71	-1.82	-1.89
	W2	116.5213	.017	.026	.027	.031	.031	.027	.036	.036	-.023	-.081	-.12	-.19	-.50	-.53	-.73	-.83	-.87	-.90	-1.01
	W3	115.8355	.015	.023	.027	.029	.030	.029	.031	.019	-.095	-.157	-.21	-.36	-.82	-.85	-.94	-1.06	-1.10	-1.15	-1.21
MM 246	X1	115.7291	.042	.036	.017	-.054	-.154	-.208	-.526	-.71	-1.27	-1.57	-1.85	-1.99	-2.94	-3.00	-3.67	-3.81	-4.39	-4.47	-4.50
	X2	113.8608	.013	.020	.022	.022	.018	.016	-.019	-.11	-.33	-.59	-.74	-.97	-1.73	-1.78	-2.19	-2.20	-2.46	-2.51	-3.46
	X5	113.2826	.015	.024	.030	.030	.027	.018	-.025	-.19	-.54	-.90	-1.13	-1.37	-2.28	-2.31	-3.10	-3.13	-3.94	-4.01	-4.10
Rene [illegible]	Y1	110.9572	.045	.068	.071	.077	.097	.084	-.739	-1.59	-2.49	-3.07	-3.38	-3.98	-5.03	-5.04	-5.55	-5.55	-6.40	-6.47	-6.70
	Y2	109.4653	.045	.062	.070	.082	.089	.067	-.635	-1.52	-2.61	-3.47	-3.67	-[illegible].87	5.21	-5.21	-6.03	-6.12	-6.26	-7.09	-7.43
	Y4	110.7196	.045	.064	.072	.087	.089	.058	-.825	-1.93	-2.88	-3.67	-3.94	-4.57	-5.57	-5.58	-6.24	-6.24	-6.36	-6.53	-6.93
Rene 125	Z2	116.8762	.032	.045	.053	.063	.062	.057	-.182	-.51	-1.34	-1.89	-2.56	-2.46	-3.94	-3.55	-4.03	-4.06	-4.77	-4.87	-4.99
	Z3	116.8639	.033	.049	.057	.070	.069	.056	-.227	-.80	-1.79	-2.19	-2.28	-2.76	-3.97	-3.94	-4.28	-4.52	-4.97	-5.04	-5.19
	Z6	116.3775	.033	.048	.056	.063	.063	.063	-.106	-.60	-1.61	-1.99	-2.26	-2.43	-3.68	-3.65	-3.99	-4.05	-4.53	-4.59	-4.68

[a] All weight changes are positive except where noted

[b] Removed from test after 2000 cycles

Table 7

WEIGHT CHANGE DATA FOR GROUP 1 SPECIMENS CONTINUED EXPOSURE

Material	Sample Identification	Starting Weight, g	Weight Change at Given Cycles,[a] %							
			8000	8500	9000	9500	10,000	10,500	11,000	11,500
MM 200 + Hf + overlay	B1	134.7711	-0.21	-0.21	-0.22	-0.23	-0.29	-0.30	-0.30	-0.31
	B2	137.6995	-0.19	-0.20	-0.21	-0.25	-0.27	-0.30	-0.31	-0.32
	B5	137.0364	-0.20	-0.21	-0.24	-0.26	-0.29	-0.31	-0.33	-0.35
MM 200 + Hf DS	C1	130.9854	-4.16	-4.28	-4.59	-4.85	-5.39	-5.47	-5.75	-5.76
	C2	130.5329	-3.95	-4.04	-4.49	-4.72	-5.54	-5.62	-5.80	-5.92
	C5	129.7829	-4.57	-4.71	-5.25	-5.62	-6.00	-6.15	-6.25	-6.31
MM 200 DS single crystal	E1	114.6683	-6.14	-6.33	-7.04	-7.35	-7.94	-8.00	-8.12	-8.23
	E2	103.5326	-6.38	-6.53	-7.10	-7.57	-8.20	-8.24	-8.35	-8.34
	E3	110.1965	-6.35	-6.62	-7.22	-7.40	-8.25	-8.30	-8.45	-8.57
MM 200 DS bicrystal	F1	114.9243	-7.85	-8.02	-8.76	-8.91	-9.75	-9.78	-9.97	-10.03
	F2	116.2061	-6.71	-6.86	-7.60	-7.72	-8.59	-8.62	-8.66	-8.70
	F5	116.9271	-6.39	-6.53	-7.36	-7.[illegible]9	-8.40	-8.42	-8.47	-8.57

Material	Sample Identification	Starting Weight, g	Weight Change at Given Cycles,[a] %						
			12,000	12,500	13,000	13,500	14,000	14,500	15,000
MM 200 + Hf + overlay	B1	134.7711	-0.35	-0.38	-0.40	-	-	-	-
	B2	137.6995	-0.35	-0.36	-0.37	-0.38	-0.40	-0.43	-0.45
	B5	137.0364	-0.42	-0.42	-0.42	-0.43	-0.46	-0.49	-0.52
MM 200 + Hf DS	C1	130.9854	-6.21	-6.31	-6.61	-6.67	-6.67	-6.96	-7.02
	C2	130.5329	-7.01	-7.01	-6.98	-7.00	-7.33	-7.45	-7.84
	C5	129.7829	-6.93	-7.03	-7.27	-7.40	-7.55	-7.76	-7.80
MM 200 DS single crystal	E1	114.6683	-8.87	-9.11	-9.57	-9.60	-9.86	-9.88	-9.91
	E2	103.5326	-9.02	-9.24	-9.67	-9.67	-9.85	-10.06	-10.09
	E3	110.1965	-9.38	-9.61	-9.72	-9.72	-9.99	-10.35	-10.38
MM 200 DS bicrystal	F1	114.9243	-11.02	-11.13	-11.70	-11.73	-11.94	-11.96	-12.12
	F2	116.2061	-9.55	-9.65	-10.12	-10.31	-10.61	-10.70	-10.74
	F5	116.9271	-9.37	-10.01	-10.26	-10.32	-10.37	-10.87	-11.03

[a]All weight changes are positive except where noted.

Table 8

ACCUMULATED THERMAL CYCLES TO FIRST CRACK INITIATION FOR GROUP 1 SPECIMENS

Alloy	Condition	Specimen Identification	Cycles to First Crack: Small Radius 0.635 mm (0.025 in.)	Cycles to First Crack: Large Radius 1.016 mm (0.040 in.)
γ/γ'-δ eutectic	DS (cellular)	N2	75	12[a]
		N1	400	150
γ/γ'-δ eutectic	DS (cellular) + overlay[b]	O2	75	-[a]
		O1	>7,500	>7,500
IN-738	Al coated[c]	K2	150	>7,500
		K5	150	>7,500
IN-792 + Hf	Al coated[c]	H3	150	400
		H2	250	>7,500
MM 509		M1	250	400
		M2	400	400
IN-792 + Hf		G2	250	850
		G3	600	1,750
MM 200 + Hf		A2	400	4,750
		A3	400	1,750
		A1	1,750	2,250
IN-738		J2	600	1,750
		J4	600	2,250
IN-738	Overlay coated[b]	L3	2,250	7,250
		L1	3,750	>7,500
MM 200 + Hf	DS + overlay[b]	D2	2,250	>7,500
		D5	2,250	7,250
		D3	4,250	4,250
IN-792 + Hf	Overlay coated[b]	I3	4,750	1,750
		I1	2,[illegible]	2,250
MM 200	DS bicrystal	F2	>15,000	11,750
		F1	>14,750	14,750
		F5	>15,000	>15,000
MM 200 + Hf	Overlay coated[b]	B1	>13,500	>13,500
		B2	>15,000	>15,000
		B5	>15,000	>15,000
MM 200 + Hf	DS	C5	11,750	14,750
		C1	>15,000	>15,000
		C2	>15,000	>15,000
MM 200	DS single crystal	E1	>15,000	>15,000
		E2	>15,000	>15,000
		E2	>15,000	>15,000

[a]Removed at 100 cycles for NASA examination.

[b]NiCrAlY overlay coating.

[c]Pack aluminide coating (JoCoat).

Table 9

ACCUMULATED THERMAL CYCLES TO FIRST CRACK INITIATION
FOR GROUP 2 SPECIMENS

Alloy	Condition	Specimen Identification	Cycles to First Crack: Small Radius 0.635 mm (0.025 in.)	Cycles to First Crack: Large Radius 1.016 mm (0.040 in.)
René 77		Y1	75	150
		Y2	75	75
		Y4	75	150
V57		V1	75	250
		V3	150	250
		V5	75	150
MM 002		W1	75	400
		W2	75	150
		W3	150	150
René 125		Z2	150	2,250
		Z3	150	1,250
		Z6	150	1,750
MM 246		X1	250	2,750
		X2	150	400
		X3	150	400
$\gamma/\gamma'-\delta$	DS eutectic (lamellar) + NiCrAlY/Pt coating[a]	Q1	4,750	>7,500
		Q2	>7,500	>7,500
$\gamma/\gamma'-\delta$	DS eutectic (lamellar)	P2	6,250	>7,500
		P1	>7,500	7,250
$\gamma/\gamma'-\delta$	DS eutectic (0.06C) (lamellar)	R2	6,250	>7,500
		R1	>7,500	>7,500
$\gamma/\gamma'-\delta$	DS eutectic (0.06C) (lamellar) + NiCrAlY/Pt coating[a]	S1	6,250	>7,500
		S2	>7,500	>7,500
MM 200	DS single crystal + overlay[b]	T1	6,250	>7,500
		T2	>7,500	>7,500

[a] NiCrAlY/Pt overlay coating.

[b] NiCrAlY overlay coating.

Table 10

SUMMARY OF CRACK PROPAGATION FOR GROUP 1 SPECIMENS

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	1st Crack Back	1st Crack Avg.	2nd Crack Front	2nd Crack Back	2nd Crack Avg.	3rd Crack Front	3rd Crack Back	3rd Crack Avg.	Total Cracks Observed
Specimen N2: γ/γ'-δ Eutectic[a]											
Distance from bottom, in.:				.97 (24.6 mm)			2.09 (53.1 mm)				
0.044	25	0.46	0.47	0.47							1
(1.12 mm)	100	0.46	0.47	0.47	0.43	0.42	0.43				2
Distance from bottom, in.:				2.71 (68.8 mm)			1.40 (35.6 mm)				
0.027	50	No cracks									
(0.69 mm)	100	0.32	0.35	0.34	0.36	0.32	0.34				2
Specimen O2: γ/γ'-δ Eutectic + Overlay[a]											
Distance from bottom, in.:				1.75 (44.5 mm)							
0.028	50	No cracks									
(0.71 mm)	100	0.36	0.41	0.38							1
Specimen N1: γ/γ'-δ Eutectic[a]											
Distance from bottom, in.:				2.75 (69.9 mm)			2.06 (52.3 mm)			1.94 (49.3 mm)	
	100	No cracks									
0.049	200	0.06	0.04	0.05	0.03	0.03	0.03				2
(1.24 mm)	300	0.06	0.07	0.07	0.04	0.03	0.04	0.04	0.02	0.03	3
	500	0.07	0.07	0.07	0.04	0.03	0.04				2
	700	0.07	0.08	0.08	0.08	0.05	0.07	0.04	0.02	0.03	3
	1000	0.08	0.08	0.08	0.10	0.06	0.08	0.04	0.03	0.03	3
	1500	0.08	0.08	0.08	0.10	0.05	0.08	0.04	0.03	0.04	4
	2000	0.10	0.10	0.10	0.10	0.07	0.09	0.04	0.03	0.04	4
	2500	0.12	0.10	0.11	0.10	0.08	0.09	0.04	0.03	0.04	4
	3000	0.12	0.11	0.12	0.10	0.08	0.09	0.04	0.03	0.04	4
	3500	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.03	0.04	4
	4000	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.03	0.04	4
	4500	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	5000	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	5500	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	6000	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	6500	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	7000	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
	7500	0.12	0.12	0.12	0.11	0.09	0.10	0.04	0.04	0.04	4
Distance from bottom, in.:				2.94 (74.7 mm)			2.75 (69.9 mm)			3.06 (77.7 mm)	
	300	No cracks									
0.027	500	0.02	0.02	0.02	0.01	0.01	0.01				2
(0.69 mm)	700	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	3
	1000	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	3
	1500	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	4
	2000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	2500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	3000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	3500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	4000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	4500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	5000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	5500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	6000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	6500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	7000	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
	7500	0.05	0.05	0.05	0.04	0.03	0.04	0.03	0.03	0.03	4
Specimen K2: IN-738 + Al Coat											
Distance from bottom, in.:				1.5 (38.1 mm)			2.94 (74.4 mm)			2.5 (63.5 mm)	
	100	No cracks									
0.028	200	0.22	0.20	0.21	0.12	0.20	[illegible]	0.13	[illegible]	[illegible]	20
(0.71 mm)	300	0.25	0.27	0.26	[illegible]	0.21	0.20	0.17	0.14	[illegible]	26
	500	0.28	0.30	0.29	0.19	0.22	0.21	0.19	0.23	[illegible]	25
	700	0.32	0.30	0.31	0.23	0.25	0.24	0.20	[illegible]	[illegible]	29
	1000	0.34	0.31	0.33	0.32	0.31	[illegible]	0.23	0.25	[illegible]	[illegible]
	1500	0.34	0.32	0.33	0.34	0.31	0.33	[illegible]	[illegible]	0.30	[illegible]
	2000	0.37	0.39	0.38	0.35	0.35	0.34	[illegible]	[illegible]	[illegible]	[illegible]
	2500	0.37	0.39	0.38	0.36	0.35	[illegible]	0.37	[illegible]	[illegible]	3
	3000	0.37	0.39	0.39	0.40	0.39	0.40	[illegible]	0.32	[illegible]	[illegible]
	3500	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	0.40	[illegible]	[illegible]
	4000	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	>0.40	>0.40	[illegible]
	4500	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	>0.40	>0.40	3
	5000	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	>0.40	[illegible]	[illegible]
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	>0.40	[illegible]	3
	6000	>0.40	>0.40	>0.40	>0.40	>0.40	[illegible]	[illegible]	[illegible]	>0.40	[illegible]

(Removed after 3000 cycles; replaced after 4500 cycles)

Table 10 (cont.)

Edge Radius, in.	Cycles	1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
Specimen K5: IN-738 + Al Coat											
Distance from bottom, in.:		2.5 (63.5 mm)			1.56 (39.6 mm)			1.13 (28.7 mm)			
	100	No cracks									
0.028	200	0.19	0.21	0.20	0.16	0.16	0.16	0.09	0.01	0.05	14
(0.71 mm)	300	0.22	0.26	0.24	0.25	0.27	0.26	0.10	0.05	0.08	14
	500	0.27	0.30	0.29	0.31	0.30	0.31	0.10	0.07	0.09	14
	700	0.29	0.33	0.31	0.31	0.31	0.31	0.10	0.11	0.11	14
	1000	0.33	0.34	0.34	0.32	0.31	0.32	0.13	0.12	0.13	15
	1500	0.35	0.35	0.35	0.37	0.35	0.36	0.26	0.22	0.24	15
	2000	0.38	0.37	0.38	0.38	0.37	0.38	0.27	0.26	0.27	15
	2500	0.39	0.40	0.40	0.40	0.40	0.40	0.30	0.27	0.29	15
	3000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
	3500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
	4000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
	4500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
	5000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	15
(Removed after 2500 cycles; replaced after 4500 cycles)											
Specimen H3: IN-792 + Al Coat											
Distance from bottom, in.:		1.69 (42.9 mm)			2.62 (66.5 mm)			3.00 (76.2 mm)			
0.029 (0.74 mm)	100	No cracks									
	200	0.17	0.16	0.17	0.17	0.17	0.17	0.07	0.07	0.07	7
	300	0.18	0.18	0.18	0.20	0.19	0.20	0.08	0.08	0.08	7
	500	0.21	0.20	0.21	0.25	0.25	0.25	0.08	0.09	0.09	11
	700	0.21	0.22	0.22	0.25	0.27	0.26	0.09	0.11	0.10	11
	1000	0.21	0.25	0.23	0.27	0.30	0.29	0.12	0.12	0.12	11
	1500	0.26	0.27	0.27	0.27	0.30	0.29	0.18	0.14	0.16	14
	2000	0.27	0.28	0.28	0.31	0.33	0.32	0.18	0.19	0.19	14
	2500	0.31	0.29	0.30	0.37	0.36	0.37	0.20	0.19	0.20	14
	3000	0.31	0.29	0.30	0.37	0.37	0.37	0.21	0.22	0.22	14
	3500	0.31	0.29	0.30	0.37	0.38	0.38	0.22	0.22	0.22	14
	4000	0.31	0.29	0.30	0.38	0.38	0.38	0.22	0.22	0.22	14
	4500	0.31	0.29	0.30	0.38	0.38	0.38	0.24	0.24	0.24	14
	5000	0.31	0.30	0.31	0.38	0.38	0.38	0.25	0.24	0.25	14
	5500	0.31	0.30	0.31	0.38	0.38	0.38	0.25	0.24	0.25	14
	6000	0.31	0.30	0.31	0.38	0.38	0.38	0.26	0.24	0.25	14
	6500	0.31	0.30	0.31	0.38	0.38	0.38	0.26	0.24	0.25	14
	7000	0.35	0.33	0.34	0.38	0.38	0.38	0.26	0.24	0.25	14
	7500	0.35	0.35	0.35	0.38	0.38	0.38	0.26	0.24	0.25	14
Distance from bottom, in.:		1.75 (44.5 mm)			3.06 (77.7 mm)			2.06 (52.3 mm)			
	300	No cracks									
0.042	500	0.18	0.13	0.16	0.06	0.04	0.05	0.02	0.07	0.04	5
(1.07 mm)	700	0.21	0.17	0.19	0.07	0.05	0.06	0.03	0.07	0.05	5
	1000	0.21	0.18	0.20	0.08	0.05	0.07	0.03	0.05	0.05	6
	1500	0.27	0.25	0.26	0.09	0.06	0.08	0.06	0.08	0.07	6
	2000	0.30	0.26	0.28	0.10	0.06	0.08	0.12	0.14	0.13	6
	2500	0.30	0.27	0.29	0.12	0.08	0.10	0.15	0.15	0.15	6
	3000	0.30	0.28	0.29	0.12	0.11	0.12	0.18	0.16	0.17	6
	3500	0.30	0.28	0.29	0.15	0.14	0.15	0.18	0.16	0.17	6
	4000	0.30	0.28	0.29	0.17	0.14	0.16	0.18	0.16	0.17	6
	4500	0.30	0.29	0.30	0.19	0.20	0.20	0.18	0.16	0.17	6
	5000	0.32	0.31	0.32	0.23	0.21	0.22	0.18	0.17	0.18	6
	5500	0.32	0.31	0.32	0.23	0.22	0.23	0.18	0.17	0.18	6
	6000	0.32	0.31	0.32	0.23	0.22	0.23	0.19	0.17	0.18	6
	6500	0.33	0.31	0.32	0.23	0.22	0.23	0.19	0.18	0.19	6
	7000	0.33	0.32	0.33	0.24	0.22	0.23	0.21	0.22	0.22	6
	7500	0.33	0.33	0.33	0.24	0.22	0.23	0.21	0.22	0.22	6
Specimen H2: IN-792 + Al Coat											
Distance from bottom, in.:		2.50 (63.5 mm)			1.25 (31.8 mm)			1.88 (47.8 mm)			
	200	No cracks									
0.028	300	0.18	0.18	0.18	0.22	0.18	0.20	0.15	0.13	0.14	3
(0.71 mm)	500	0.25	0.23	0.24	0.22	0.26	0.24	0.16	0.18	0.17	[illegible]
	700	0.27	0.24	0.26	0.24	0.31	[illegible]	[illegible]	0.19	[illegible]	[illegible]
	1000	0.29	0.32	0.31	0.28	0.35	[illegible]	[illegible]	0.19	[illegible]	4
	1500	0.32	0.34	0.33	0.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
	2000	0.33	0.36	0.35	0.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2500	0.34	0.38	0.36	0.3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3000	0.35	0.39	0.37	0.3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3500	0.36	0.39	0.37	0.3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
	4000	0.36	0.39	0.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
	4500	0.39	0.39	0.39	0.39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6

Table 10(cont.)

Edge Radius, in.	Cycles	1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
	5000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	6000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	6500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
Specimen M1: MM 509											
Distance from bottom, in.:		1.44 (36.6 mm)			2.57 (65.3 mm)			3.06 (77.7 mm)			
0.025 (0.64 mm)	200	No cracks									
	300	0.08	0.07	0.08							1
	500	0.08	0.09	0.09	0.15	0.12	0.13	0.05	0.07	0.06	14
	700	0.11	0.12	0.12	0.21	0.21	0.21	0.13	0.11	0.12	18
	1000	0.13	0.12	0.13	0.23	0.22	0.23	0.14	0.12	0.13	18
	1500	0.14	0.12	0.13	0.25	0.22	0.24	0.16	0.13	0.15	18
	2000	0.24	0.21	0.22	0.33	0.25	0.29	0.23	0.27	0.25	18
	2500	0.28	0.30	0.29	0.35	0.37	0.36	0.30	0.32	0.31	20
	3000	0.30	0.30	0.30	0.35	0.37	0.36	0.32	0.32	0.32	22
	3500	0.31	0.30	0.31	0.35	0.37	0.36	0.33	0.32	0.33	22
	4000	0.31	0.30	0.31	0.35	0.37	0.36	0.33	0.32	0.33	22
	4500	0.31	0.30	0.31	0.35	0.37	0.36	0.36	0.33	0.35	22
	5000	0.32	0.30	0.31	0.35	0.37	0.36	0.36	0.35	0.36	24
	5500	0.32	0.30	0.31	0.35	0.37	0.36	0.36	0.35	0.36	>24
	6000	0.33	0.32	0.33	0.37	0.38	0.38	0.36	0.35	0.36	>24
	6500	0.33	0.32	0.33	0.37	0.38	0.38	0.36	0.35	0.36	>24
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>24
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>24
Distance from bottom, in.:		1.38 (35.1 mm)			2.44 (62 mm)			3.0 (76.2 mm)			
0.042 (1.07 mm)	300	No cracks									
	500	0.05	0.01	0.03	0.02	0.01	0.02				2
	700	0.05	0.02	0.04	0.02	0.02	0.02	0.03	0.02	0.03	7
	1000	0.12	0.10	0.11	0.04	0.03	0.04	0.04	0.03	0.04	9
	1500	0.15	0.14	0.15	0.07	0.05	0.06	0.06	0.05	0.06	16
	2000	0.26	0.27	0.27	0.07	0.14	0.11	0.10	0.12	0.11	16
	2500	0.32	0.29	0.31	0.15	0.15	0.15	0.19	0.22	0.21	24
	3000	0.34	0.30	0.32	0.19	0.18	0.19	0.24	0.22	0.23	24
	3500	0.34	0.30	0.32	0.20	0.20	0.20	0.24	0.22	0.23	24
	4000	0.34	0.30	0.32	0.24	0.22	0.23	0.25	0.22	0.24	24
	4500	0.34	0.30	0.32	0.24	0.23	0.24	0.27	0.23	0.25	24
	5000	0.34	0.30	0.32	0.24	0.23	0.24	0.27	0.23	0.25	24
	5500	0.35	0.30	0.33	0.24	0.23	0.24	0.27	0.23	0.25	>24
	6000	0.35	0.30	0.33	0.24	0.23	0.24	0.27	0.23	0.25	>24
	6500	0.37	0.36	0.37	0.25	0.23	0.24	0.27	0.24	0.26	>24
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>24
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>24
Specimen M2: MM 509											
Distance from bottom, in.:		1.25 (31.8)			2.00 (50.8 mm)			2.50 (63.5 mm)			
0.024 (0.61 mm)	300	No cracks									
	500	0.12	0.10	0.11	0.10	0.10	0.10	0.07	0.08	0.08	18
	700	0.13	0.12	0.13	0.11	0.16	0.13	0.09	0.08	0.09	28
	1000	0.13	0.15	0.14	0.12	0.16	0.14	0.10	0.09	0.10	33
	1500	0.21	0.19	0.20	0.15	0.19	0.17	0.19	0.18	0.19	41
	2000	0.27	0.28	0.28	0.15	0.22	0.19	0.27	0.26	0.27	41
	2500	0.31	0.29	0.30	0.18	0.24	0.21	0.30	0.27	0.29	41
	3000	0.34	0.29	0.32	0.22	0.24	0.23	0.31	0.31	0.31	41
	3500	0.34	0.30	0.32	0.32	0.24	0.28	0.32	0.31	0.32	41
	4000	0.36	0.33	0.35	0.34	0.32	0.33	0.36	0.34	0.35	41
	4500	0.37	0.35	0.36	0.34	0.36	0.35	0.37	0.37	0.37	41
	5000	0.37	0.35	0.36	0.34	0.36	0.35	0.37	0.37	0.37	41
	5500	0.37	0.36	0.37	0.36	0.36	0.36	0.37	0.37	0.37	41
	6000	0.38	0.36	0.37	0.36	0.36	0.36	0.38	0.37	0.38	41
	6500	0.40	0.38	0.39	0.38	0.37	0.38	0.38	0.37	0.38	41
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	41
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	41
Distance from bottom, in.:		1.25 (31.8 mm)			2.88 (73.2 mm)			2.25 (57.2 mm)			
0.042 (1.07 mm)	300	No cracks									
	500	0.03	0.02	0.03	0.02	0.02	0.02	0.07	0.06	0.07	8
	700	0.03	0.02	0.03	0.03	0.03	0.03	0.07	0.07	0.07	12
	1000	0.04	0.06	0.05	0.03	0.05	0.04	0.20	0.16	0.18	[illegible]
	1500	0.11	0.10	0.11	0.05	0.06	0.06	0.21	0.19	0.20	[illegible]
	2000	0.21	0.14	0.18	0.15	0.08	0.12	0.30	0.26	0.28	[illegible]

Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	1st Crack Back	1st Crack Avg.	2nd Crack Front	2nd Crack Back	2nd Crack Avg.	3rd Crack Front	3rd Crack Back	3rd Crack Avg.	Total Cracks Observed
	2500	0.24	0.16	0.20	0.19	0.13	0.16	0.31	0.27	0.29	27
	3000	0.24	0.22	0.23	0.20	0.18	0.19	0.31	0.27	0.29	27
	3500	0.24	0.25	0.25	0.23	0.24	0.24	0.31	0.28	0.30	28
	4000	0.25	0.25	0.25	0.25	0.24	0.25	0.33	0.29	0.31	28
	4500	0.27	0.28	0.28	0.29	0.26	0.28	0.33	0.31	0.32	28
	5000	0.29	0.28	0.29	0.29	0.27	0.28	0.35	0.34	0.35	28
	5500	0.30	0.28	0.29	0.29	0.27	0.28	0.36	0.34	0.35	28
	6000	0.31	0.28	0.30	0.30	0.28	0.29	0.36	0.34	0.35	28
	6500	0.33	0.30	0.32	0.32	0.30	0.31	0.36	0.35	0.36	28
	7000	0.33	0.30	0.32	0.32	0.30	0.31	0.36	0.35	0.36	28
	7500	0.37	0.33	0.35	0.32	0.31	0.32	0.36	0.35	0.36	28
Specimen G2: IN-792											
Distance from bottom, in.:		3.00 (76.2 mm)			1.06 (26.9 mm)			2.13 (54.1 mm)			
	200	No Cracks									
0.026 (0.66 mm)	300	0.18	0.20	0.19	0.10	0.14	0.12	0.10	0.12	0.11	5
	500	0.25	0.26	0.26	0.15	0.14	0.15	0.15	0.19	0.17	5
	700	0.25	0.27	0.26	0.18	0.15	0.17	0.19	0.20	0.20	5
	1000	0.27	0.29	0.28	0.20	0.18	0.19	0.21	0.20	0.21	7
	1500	0.29	0.29	0.29	0.22	0.20	0.21	0.21	0.20	0.21	7
	2000	0.33	0.30	0.32	0.31	0.30	0.31	0.30	0.29	0.30	7
	2500	0.35	0.36	0.36	0.35	0.35	0.35	0.32	0.34	0.33	7
	3000	0.36	0.38	0.37	0.38	0.36	0.37	0.32	0.34	0.33	7
	3500	0.36	0.39	0.38	0.38	0.36	0.37	0.33	0.34	0.34	7
	4000	0.36	0.39	0.38	0.38	0.36	0.37	0.34	0.34	0.34	10
	4500	0.36	0.39	0.38	0.38	0.38	0.38	0.34	0.34	0.34	10
	5000	0.39	0.39	0.39	0.39	0.39	0.39	0.34	0.35	0.35	10
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	10
	6000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	10
	6500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	10
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	10
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.30	>0.40	10
Distance from bottom, in.:		2.13 (54.1 mm)			2.5 (63.5 mm)			1.44 (36.6 mm)			
	700	No Cracks									
0.042 (1.07 mm)	1000	0.10	0.10	0.10							1
	1500	0.15	0.14	0.15	0.04	0.05	0.05				2
	2000	0.20	0.22	0.21	0.04	0.05	0.05	0.05	0.02	0.04	3
	2500	0.23	0.25	0.24	0.07	0.05	0.06	0.14	0.12	0.13	5
	3000	0.23	0.26	0.24	0.10	0.08	0.09	0.14	0.15	0.15	5
	3500	0.24	0.26	0.25	0.11	0.08	0.10	0.15	0.17	0.16	5
	4000	0.25	0.26	0.26	0.11	0.10	0.11	0.26	0.23	0.25	7
	4500	0.28	0.27	0.28	0.15	0.14	0.15	0.26	0.23	0.25	7
	5000	0.28	0.27	0.28	0.20	0.17	0.19	0.26	0.24	0.25	7
	5500	0.30	0.28	0.29	0.20	0.19	0.20	0.26	0.24	0.25	7
	6000	0.30	0.29	0.30	0.22	0.19	0.21	0.26	0.24	0.25	7
	6500	0.30	0.29	0.30	0.22	0.19	0.21	0.27	0.24	0.26	7
	7000	0.30	0.29	0.30	0.22	0.20	0.21	0.28	0.24	0.26	17
	7500	0.30	0.30	0.30	0.22	0.21	0.22	0.28	0.26	0.27	17
Specimen G3: IN-792											
Distance from bottom, in.:		1.0 (25.4 mm)			2.25 (57.2 mm)			1.81 (46 mm)			
	500	No Cracks									
0.026 (0.66 mm)	700	0.07	0.06	0.07	0.05	0.04	0.05				2
	1000	0.16	0.11	0.14	0.15	0.17	0.16				2
	1500	0.16	0.13	0.15	0.16	0.17	0.17				2
	2000	0.18	0.14	0.16	0.20	0.19	0.20	0.18	0.21	0.20	8
	2500	0.22	0.24	0.23	0.30	0.27	0.29	0.25	0.25	0.25	8
	3000	0.23	0.24	0.24	0.30	0.30	0.30	0.25	0.26	0.26	8
	3500	0.25	0.28	0.27	0.30	0.30	0.30	0.25	0.27	0.26	9
	4000	0.25	0.30	0.28	0.30	0.30	0.30	0.26	0.27	0.27	9
	4500	0.27	0.30	0.29	0.30	0.30	0.30	0.27	0.27	0.27	9
	5000	0.31	0.34	0.33	0.30	0.35	0.33	0.28	0.29	0.29	11
	5500	0.34	0.35	0.35	0.31	0.35	0.33	0.30	0.30	0.30	11
	6000	0.36	0.36	0.36	0.31	0.35	0.33	0.30	0.30	0.30	11
	6500	0.36	0.36	0.36	0.31	0.35	0.33	0.30	0.30	0.30	11
	7000	0.36	0.36	0.36	0.32	0.35	0.34	0.30	0.30	0.30	11
	7500	0.38	0.36	0.37	0.32	0.35	0.34	0.31	0.32	0.32	11
Distance from bottom, in.:		3.06 (77.7 mm)			2.44 (62 mm)			1.81 (46 mm)			
	1500	No Cracks									
0.041 (1.04 mm)	2000	0.18	0.17	0.18	0.0[illegible]	0.07	0.07	0.03	0.0[illegible]	0.03	4
	2500	0.22	0.20	0.21	0.11	0.10	0.11	0.11	0.1[illegible]	0.12	9
	3000	0.23	0.22	0.23	0.11	0.12	0.12	0.18	0.16	0.17	9
	3500	0.24	0.24	0.2[illegible]	0.14	0.1[illegible]	0.13	0.18	0.22	0.20	9
	4000	0.24	0.24	0.2[illegible]	0.1[illegible]	0.17	0.16	0.19	0.22	0.21	9

Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in.									Total Cracks Observed
		1st Crack			2nd Crack			3rd Crack			
		Front	Back	Avg	Front	Back	Avg	Front	Back	Avg	
	4500	0.26	0.25	0.26	0.19	0.19	0.19	0.19	0.22	0.21	9
	5000	0.26	0.25	0.26	0.19	0.19	0.19	0.20	0.25	0.23	9
	5500	0.26	0.27	0.27	0.19	0.19	0.19	0.20	0.25	0.23	11
	6000	0.27	0.27	0.27	0.19	0.19	0.19	0.20	0.25	0.23	11
	6500	0.27	0.27	0.27	0.25	0.20	0.23	0.20	0.25	0.23	11
	7000	0.27	0.27	0.27	0.25	0.21	0.23	0.23	0.25	0.24	11
	7500	0.27	0.27	0.27	0.25	0.25	0.25	0.23	0.25	0.24	11
Specimen A2: MM 200 + Hf											
Distance from bottom, in.:		1.63 (41.4 mm)			2.63 (66.8 mm)			1.0 (25.4 mm)			
	300	No Cracks									
0.028	500	0.20	0.23	0.22	0.05	0.05	0.05				2
	700	0.21	0.24	0.23	0.05	0.06	0.06				2
(0.71 mm)	1000	0.30	0.27	0.29	0.08	0.13	0.11				2
	1500	0.30	0.28	0.29	0.08	0.14	0.12				2
	2000	0.30	0.30	0.30	0.21	0.23	0.22	0.07	0.06	0.07	7
	2500	0.30	0.30	0.30	0.21	0.24	0.23	0.13	0.10	0.12	7
	3000	0.30	0.30	0.30	0.21	0.24	0.23	0.16	0.11	0.14	7
	3500	0.33	0.32	0.33	0.21	0.24	0.23	0.17	0.12	0.15	7
	4000	0.33	0.33	0.33	0.21	0.24	0.23	0.17	0.14	0.16	7
	4500	0.33	0.33	0.33	0.23	0.24	0.24	0.21	0.19	0.20	7
	5000	0.35	0.38	0.37	0.32	0.34	0.33	0.22	0.26	0.24	7
	5500	0.36	0.38	0.37	0.33	0.35	0.34	0.25	0.26	0.26	8
	6000	0.36	0.38	0.37	0.33	0.34	0.34	0.26	0.26	0.26	8
	6500	0.36	0.38	0.37	0.35	0.34	0.35	0.26	0.26	0.26	8
	7000	0.37	0.38	0.38	0.36	0.35	0.36	0.26	0.26	0.26	9
	7500	0.37	0.38	0.38	0.36	0.35	0.36	0.27	0.26	0.27	9
Distance from bottom, in.:		1.88 (47.8 mm)			2.25 (57.2 mm)			2.50 (63.5 mm)			
	4500	No Cracks									
0.041	5000	0.05	0.04	0.05	0.04	0.04	0.04	0.07	0.05	0.06	3
(1.04 mm)	5500	0.06	0.06	0.06	0.05	0.04	0.05	0.08	0.06	0.07	3
	6000	0.07	0.06	0.07	0.05	0.05	0.05	0.08	0.06	0.07	6
	6500	0.07	0.06	0.07	0.05	0.05	0.05	0.08	0.06	0.07	6
	7000	0.11	0.08	0.10	0.05	0.05	0.05	0.12	0.09	0.11	6
	7500	0.11	0.08	0.10	0.07	0.05	0.06	0.12	0.09	0.11	6
Specimen A3: MM 200 + Hf											
Distance from bottom, in.:		1.00 (2.54 mm)			2.00 (50.8 mm)			2.69 (68.3 mm)			
	300	No Cracks									
0.028	500	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.02	10
(0.71 mm)	700	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	10
	1000	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.04	10
	1500	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.03	0.04	11
	2000	0.08	0.06	0.07	0.17	0.12	0.15	0.14	0.08	0.11	13
	2500	0.15	0.11	0.13	0.19	0.15	0.17	0.20	0.17	0.19	14
	3000	0.17	0.15	0.16	0.20	0.17	0.19	0.21	0.22	0.22	15
	3500	0.19	0.16	0.18	0.22	0.26	0.24	0.28	0.27	0.28	17
	4000	0.19	0.19	0.19	0.24	0.28	0.26	0.28	0.27	0.28	18
	4500	0.24	0.21	0.23	0.25	0.29	0.27	0.28	0.28	0.28	21
	5000	0.24	0.21	0.23	0.26	0.29	0.28	0.29	0.30	0.30	21
	5500	0.25	0.21	0.23	0.26	0.29	0.28	0.29	0.30	0.30	21
	6000	0.25	0.21	0.23	0.26	0.29	0.28	0.29	0.30	0.30	21
	6500	0.25	0.21	0.23	0.26	0.29	0.28	0.29	0.30	0.30	21
	7000	0.30	0.28	0.29	0.26	0.29	0.28	0.29	0.30	0.30	21
	7500	0.31	0.29	0.30	0.26	0.29	0.28	0.29	0.32	0.31	21
Distance from bottom, in.:		1.31 (33.3 mm)			1.75 (44.5 mm)			2.69 (68.3 mm)			
	1500	No Cracks									
0.042	2000	0.03	0.03	0.03							1
(1.07 mm)	2500	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	7
	3000	0.08	0.06	0.07	0.04	0.04	0.04	0.07	0.07	0.07	8
	3500	0.08	0.07	0.08	0.07	0.06	0.07	0.08	0.07	0.08	8
	4000	0.11	0.08	0.10	0.07	0.07	0.07	0.10	0.09	0.10	12
	4500	0.11	0.09	0.10	0.10	0.07	0.09	0.11	0.10	0.11	12
	5000	0.13	0.10	0.12	0.10	0.09	0.10	0.12	0.10	0.11	12
	5500	0.13	0.10	0.12	0.10	0.10	0.10	0.12	0.10	0.11	12
	6000	0.13	0.10	0.12	0.13	0.10	0.12	0.12	0.10	0.11	12
	6500	0.13	0.10	0.12	0.15	0.12	0.13	0.12	0.10	0.11	12
	7000	0.16	0.13	0.15	0.16	0.13	0.15	0.15	0.15	[illegible]	[illegible]
	7500	0.16	0.15	0.16	0.18	0.17	[illegible]	0.15	[illegible]	[illegible]	[illegible]

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Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. — 1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
Specimen A1: MM 200 + HC											
Distance from bottom, in.:		1.43 (36.3 mm)			2.38 (60.5 mm)			2.80 (71.1 mm)			
	1500	No Cracks									
0.028 (0.71 mm)	2000	0.04	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.02	6
	2500	0.15	0.08	0.12	0.12	0.10	0.11	0.11	0.10	0.11	8
	3000	0.15	0.12	0.14	0.16	0.14	0.15	0.12	0.14	0.13	8
	3500	0.17	0.15	0.16	0.17	0.20	0.19	0.16	0.15	0.16	9
	4000	0.20	0.18	0.19	0.17	0.21	0.19	0.26	0.19	0.22	9
	4500	0.20	0.20	0.20	0.24	0.24	0.24	0.25	0.20	0.23	10
	5000	0.20	0.20	0.20	0.24	0.24	0.24	0.25	0.20	0.23	12
	5500	0.20	0.20	0.20	0.24	0.24	0.24	0.25	0.20	0.23	12
	6000	0.20	0.21	0.21	0.25	0.24	0.25	0.25	0.20	0.23	12
	6500	0.22	0.22	0.22	0.25	0.24	0.25	0.25	0.20	0.23	12
	7000	0.22	0.22	0.22	0.25	0.24	0.25	0.25	0.20	0.23	12
	7500	0.22	0.22	0.22	0.25	0.24	0.25	0.25	0.26	0.26	12
Distance from bottom, in.:		2.5 (63.5 mm)			1.31 (33.3 mm)			2.94 (74.7 mm)			
	2000	No Cracks									
0.041 (1.04 mm)	2500	0.04	0.02	0.03	0.04	0.02	0.03	0.02	0.02	0.02	9
	3000	0.04	0.03	0.04	0.04	0.03	0.04	0.02	0.02	0.02	9
	3500	0.07	0.07	0.07	0.06	0.11	0.09	0.08	0.06	0.07	9
	4000	0.07	0.07	0.07	0.10	0.11	0.11	0.09	0.06	0.08	9
	4500	0.09	0.08	0.09	0.13	0.11	0.12	0.09	0.07	0.08	9
	5000	0.10	0.09	0.10	0.17	0.14	0.16	0.15	0.10	0.13	9
	5500	0.10	0.09	0.10	0.17	0.15	0.16	0.15	0.11	0.13	9
	6000	0.12	0.10	0.11	0.17	0.15	0.16	0.16	0.11	0.14	9
	6500	0.13	0.10	0.12	0.19	0.17	0.18	0.16	0.11	0.14	9
	7000	0.13	0.10	0.12	0.19	0.17	0.18	0.16	0.11	0.14	9
	7500	0.13	0.10	0.12	0.20	0.18	0.19	0.16	0.11	0.14	11
Specimen J2: IN-738											
Distance from bottom, in.:		2.00 (50.8 mm)			2.75 (69.9 mm)			1.13 (28.7 mm)			
	500	No Cracks									
0.024 (0.61 mm)	700	0.05	0.01	0.03							1
	1000	0.11	0.10	0.11	0.13	0.09	0.11	0.11	0.10	0.11	8
	1500	0.12	0.13	0.13	0.16	0.14	0.15	0.15	0.14	0.15	8
	2000	0.25	0.19	0.22	0.30	0.21	0.26	0.19	0.22	0.21	6
	2500	0.25	0.24	0.25	0.33	0.33	0.33	0.26	0.27	0.27	8
	3000	0.26	0.28	0.27	0.36	0.34	0.35	0.26	0.28	0.27	9
	3500	0.28	0.31	0.30	0.38	0.35	0.37	0.28	0.31	0.30	9
	4000	0.28	0.31	0.30	0.38	0.35	0.37	0.32	0.32	0.32	11
	4500	0.35	0.33	0.34	0.38	0.35	0.37	0.35	0.35	0.35	12
	5000	0.35	0.35	0.35	0.39	0.36	0.38	0.38	0.38	0.38	12
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	~0.40	>0.40	>0.40	>0.40	12
	6000	>0.40	~0.40	>0.40	>0.40	~0.40	>0.40	~0.40	~0.40	>0.40	12
	6500	>0.40	~0.40	>0.40	>0.40	~0.40	>0.40	>0.40	>0.40	~0.40	12
	7000	>0.40	>0.40	>0.40	>0.40	~0.40	~0.40	~0.40	~0.40	~0.40	12
	7500	>0.40	>0.40	>0.40	>0.40	~0.40	>0.40	>0.40	>0.40	~0.40	12
Distance from bottom, in.:		2.75 (69.9 mm)			1.75 (44.5 mm)			2.50 (63.5 mm)			
	1500	No Cracks									
0.044 (1.12 mm)	2000	0.07	0.06	0.07	0.05	0.05	0.05				2
	2500	0.17	0.17	0.17	0.12	0.12	0.12	0.08	0.07	0.08	4
	3000	0.18	0.17	0.18	0.17	0.15	0.16	0.11	0.08	0.10	4
	3500	0.19	0.17	0.18	0.23	0.21	0.22	0.11	0.12	0.12	5
	4000	0.23	0.19	0.21	0.23	0.22	0.23	0.11	0.15	0.13	5
	4500	0.26	0.22	0.24	0.25	0.22	0.25	0.14	0.15	0.15	5
	5000	0.26	0.24	0.25	0.26	0.25	0.25	0.15	0.15	0.15	9
	5500	0.26	0.25	0.26	0.26	0.24	[illegible]	0.16	0.15	[illegible]	[illegible]
	6000	0.26	0.25	0.26	0.28	0.25	0.26	0.16	[illegible]	[illegible]	13
	6500	0.26	0.25	0.26	0.31	[illegible]	[illegible]	0.19	[illegible]	0.19	13
	7000	0.26	0.25	0.26	0.31	0.26	0.29	0.19	[illegible]	0.19	13
	7500	0.26	0.26	0.26	0.32	0.27	0.30	0.21	[illegible]	0.20	13
Specimen J4: IN-738											
Distance from bottom, in.:		2.75 (69.9 mm)			1.63 (41.4 mm)			2.19 (55.6 mm)			
	500	No Cracks									
0.024 (0.61 mm)	700	0.21	0.20	0.21	0.14	0.15	0.15	0.10	0.11	0.11	3
	1000	0.22	0.20	0.21	0.18	0.15	0.17	0.12	0.11	0.12	4
	1500	0.25	0.22	0.24	0.20	0.21	0.21	0.21	0.23	0.22	4
	2000	0.30	0.23	0.27	0.24	0.25	0.25	0.22	0.25	0.24	6
	2500	0.32	0.32	0.32	0.35	0.36	0.36	0.32	0.35	0.33	6

Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. — 1st Crack: Front	1st Crack: Back	1st Crack: Avg	2nd Crack: Front	2nd Crack: Back	2nd Crack: Avg	3rd Crack: Front	3rd Crack: Back	3rd Crack: Avg	Total Cracks Observed
	3000	0.33	0.35	0.34	0.35	0.36	0.36	0.32	0.36	0.34	6
	3500	0.35	0.37	0.36	0.35	0.36	0.36	0.36	0.36	0.36	6
	4000	0.37	0.39	0.38	0.35	0.36	0.36	0.36	0.36	0.36	6
	4500	0.40	0.40	0.40	0.35	0.37	0.36	0.36	0.38	0.37	6
	5000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	5500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	6000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	6500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	7000	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
	7500	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	>0.40	6
Distance from bottom, in.:				1.31 (33.3 mm)			2.56 (65 mm)			1.94 (49.3 mm)	
	2000	No Cracks									
0.041 (1.04 mm)	2500	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	7
	3000	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.02	7
	3500	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.03	7
	4000	0.03	0.02	0.03	0.05	0.02	0.04	0.03	0.02	0.03	7
	4500	0.03	0.03	0.03	0.06	0.02	0.04	0.03	0.02	0.03	7
	5000	0.03	0.03	0.03	0.06	0.02	0.04	0.03	0.02	0.03	7
	5500	0.03	0.03	0.03	0.06	0.04	0.05	0.03	0.03	0.03	7
	6000	0.03	0.03	0.03	0.08	0.06	0.07	0.03	0.03	0.03	12
	6500	0.03	0.03	0.03	0.09	0.10	0.10	0.11	0.09	0.10	12
	7000	0.03	0.03	0.03	0.13	0.12	0.13	0.18	0.16	0.17	12
	7500	0.15	0.12	0.14	0.20	0.19	0.20	0.21	0.20	0.21	12
Specimen L3: IN-738 + Overlay											
Distance from bottom, in.:				1.81 (46 mm)			2.88 (73.2 mm)			1.06 (26.9 mm)	
	2000	No Cracks									
0.026 (0.66 mm)	2500	0.27	0.27	0.27							1
	3000	0.27	0.31	0.29							1
	3500	0.30	0.33	0.32							1
	4000	0.35	0.35	0.35							1
	4500	0.35	0.35	0.35							1
	5000	0.36	0.36	0.36							1
	5500	0.38	0.36	0.37							1
	6000	0.38	0.37	0.38	0.07	0.07	0.07				2
	6500	0.38	0.37	0.38	0.07	0.08	0.08				2
	7000	0.38	0.40	0.39	0.09	0.09	0.09	0.16	0.14	0.15	3
	7500	0.38	0.40	0.39	0.16	0.12	0.14	0.16	0.19	0.18	3
Distance from bottom, in.:				2.06 (52.3 mm)							
	7000	No Cracks									
0.037 (0.94 mm)	7500	0.12	0.09	0.11							1
Specimen L1: IN-738 + Overlay											
Distance from bottom, in.:				2.56 (65 mm)			1.94 (49.3 mm)			1.63 (41.4 mm)	
	3500	No Cracks									
0.028 (0.71 mm)	4000	0.21	0.22	0.22							1
	4500	0.25	0.27	0.26							1
	5000	0.28	0.30	0.29							1
	5500	0.32	0.31	0.32							1
	6000	0.33	0.31	0.32							1
	6500	0.33	0.31	0.32							1
	7000	0.38	0.36	0.37	0.08	0.10	0.09	0.04	0.02	0.03	3
	7500	0.38	0.40	0.39	0.13	0.13	0.13	0.05	0.04	0.05	5
Specimen I3: IN-792 + Overlay											
Distance from bottom, in.:				1.44 (36.6 mm)							
	1500	No Cracks									
0.039 (0.99 mm)	2000	0.11	0.11	0.11							1
	2500	0.27	0.26	0.27							1
	3000	0.29	0.31	0.30							1
	3500	0.32	0.32	0.32							1
	4000	0.33	0.33	0.33							1
	4500	0.34	0.35	0.35							1
	5000	0.36	0.36	0.36							1
	5500	0.40	0.40	0.40							1
	6000	0.40	0.40	0.40							1
	6500	0.40	0.40	0.40							1
	7000	>0.40	>0.40	>0.40							1
	7500	>0.40	>0.40	>0.40							1

Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
Distance from bottom, in.:				2.56 (65 mm)			0.88 (22.4 mm)				
	4500	No Cracks									
0.029	5000	0.18	0.20	0.19	0.22	0.22	0.22				2
(0.74 mm)	5500	0.26	0.28	0.27	0.23	0.23	0.23				2
	6000	0.31	0.32	0.32	0.25	0.28	0.27				2
	6500	0.32	0.32	0.32	0.27	0.28	0.28				2
	7000	0.32	0.32	0.32	0.27	0.28	0.28				2
	7500	0.32	0.36	0.34	0.27	0.31	0.29				2
Specimen I1: IN-792 + Overlay											
Distance from bottom, in.:				1.5 (38.1 mm)							
	2000	No Cracks									
0.033	2500	0.26	0.26	0.26							1
(0.84 mm)	3000	0.28	0.27	0.28							1
	3500	0.28	0.30	0.29							1
	4000	0.28	0.30	0.29							1
	4500	0.30	0.30	0.30							1
	5000	0.30	0.30	0.30							1
	5500	0.32	0.31	0.32							1
	6000	0.34	0.32	0.33							1
	6500	0.34	0.32	0.33							1
	7000	0.34	0.32	0.33							1
	7500	0.34	0.32	0.33							1
Distance from bottom, in.:				2.88 (73.2 mm)							
	2500	No Cracks									
0.028	3000	0.14	0.15	0.15							1
(0.71 mm)	3500	0.14	0.15	0.15							1
	4000	0.20	0.21	0.21							1
	4500	0.20	0.24	0.22							1
	5000	0.23	0.28	0.26							1
	5500	0.23	0.28	0.26							1
	6000	0.30	0.29	0.30							1
	6500	0.30	0.29	0.30							1
	7000	0.30	0.29	0.30							1
	7500	0.30	0.29	0.30							1
Specimen D2: MM 200 + Hf DS + Overlay											
Distance from bottom, In.:				2.69 (68.3 mm)			1.56 (39.6 mm)			0.81 (70.6 mm)	
	2000	No Cracks									
0.029	2500	0.29	0.31	0.30							1
(0.74 mm)	3000	0.30	0.32	0.31							1
	3500	0.31	0.34	0.33							1
	4000	0.32	0.35	0.34	0.21	0.26	0.24	0.16	0.19	0.18	3
	4500	0.37	0.37	0.37	0.25	0.27	0.26	0.22	0.22	0.22	3
	5000	0.37	0.39	0.38	0.29	0.31	0.30	0.25	0.27	0.26	3
	5500	0.37	0.39	0.38	0.30	0.31	0.31	0.25	0.27	0.26	3
	6000	0.38	0.39	0.39	0.32	0.31	0.32	0.27	0.27	0.27	4
	6500	0.38	0.39	0.39	0.32	0.31	0.32	0.30	0.28	0.29	4
	7000	0.38	0.39	0.39	0.32	0.31	0.32	0.30	0.28	0.29	4
	7500	0.38	0.39	0.39	0.32	0.31	0.32	0.30	0.29	0.30	5
Specimen D5: MM 200 + Hf DS + Overlay											
Distance from bottom, in.:				2.13 (54.1 mm)			1.31 (33.3 mm)			2.56 (65 mm)	
	2000	No Cracks									
0.025	2500	0.14	0.16	0.15							1
(0.64 mm)	3000	0.16	0.18	0.17							1
	3500	0.23	0.25	0.24							1
	4000	0.24	0.27	0.26	0.12	0.15	0.14				2
	4500	0.26	0.28	0.27	0.13	0.19	0.16				2
	5000	0.26	0.30	0.28	0.21	0.19	0.20				2
	5500	0.30	0.32	0.31	0.23	0.24	0.24				2
	6000	0.33	0.32	0.33	0.30	0.30	0.30				2
	6500	0.33	0.32	0.33	0.30	0.30	0.30				2
	7000	0.33	0.32	0.33	0.31	0.30	0.31				2
	7500	0.34	0.35	0.35	0.32	0.32	0.32	0.11	0.09	0.10	3
Distance from bottom, in.:				1.31 (33.3 mm)			2.81 (71.4 mm)				
	7000	No Cracks									
0.036 (0.99 mm)	7500	0.06	0.06	0.06	0.05	0.05	0.05				2

Table 10 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
Specimen D3: MM 200 + Hf DS + Overlay											
Distance from bottom, in.:				2.25 (57.2 mm)			2.56 (65 mm)			1.25 (31.8 mm)	
	4000	No Cracks									
0.024	4500	0.12	0.14	0.13							1
(0.61 mm)	5000	0.17	0.17	0.17							1
	5500	0.17	0.20	0.19							1
	6000	0.25	0.23	0.24							1
	6500	0.26	0.23	0.25							1
	7000	0.27	0.25	0.26	0.04	0.03	0.04	0.03	0.07	0.05	4
	7500	0.27	0.29	0.28	0.04	0.03	0.04	0.04	0.09	0.07	5
Distance from bottom, in.:				1.5 (38.1 mm)			2.88 (73.2 mm)				
	4000	No Cracks									
0.034	4500	0.15	0.15	0.15							1
(0.86 mm)	5000	0.15	0.15	0.15							1
	5500	0.20	0.20	0.20							1
	6000	0.21	0.23	0.22							1
	6500	0.23	0.24	0.24							1
	7000	0.26	0.26	0.26	0.12	0.11	0.12				2
	7500	0.27	0.26	0.27	0.12	0.11	0.12				2
Specimen F2: MM 200 DS Bicrystal											
Distance from bottom, in.:				2.25 (57.2 mm)							
	11,500	No Cracks									
.044	12,000	0.05	0.05	0.05							1
(1.12 mm)	12,500	0.05	0.06	0.06							1
	13,000	0.08	0.06	0.07							1
	13,500	0.08	0.06	0.07							1
	14,000	0.09	0.08	0.09							1
	14,500	0.09	0.08	0.09							1
	15,000	0.10	0.08	0.09							1
Specimen C5: MM 200 + Hf DS											
Distance from bottom, in.:				1.25 (31.8 mm)							
	11,500	No Cracks									
.031	12,000	0.01	0.01	0.01							1
(0.79 mm)	12,500	0.01	0.01	0.01							1
	13,000	0.01	0.01	0.01							1
	13,500	0.03	0.03	0.03							1
	14,000	0.03	0.03	0.03							1
	14,500	0.06	0.05	0.06							1
	15,000	0.06	0.06	0.06							1
Specimen F1: MM 200 DS Bicrystal											
Distance from bottom, in.:				0.94 (23.9 mm)							
	14,500	No Cracks									
.055 (1.40 mm)	15,000	0.03	0.02	0.03							1

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Table 11

SUMMARY OF CRACK PROPAGATION FOR GROUP 2 SPECIMENS

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
				Specimen V1: V57							
Distance from bottom, in.:		2.94 (74.7mm)			2.5 (63.5mm)			1.88 (47.8mm)			
	50	No cracks									
.023	100	0.11	0.16	0.14							1
(0.71mm)	200	0.11	0.16	0.14	0.06	0.07	0.07				2
	300	0.12	0.16	0.14	0.10	0.09	0.10	0.10	0.14	0.12	7
	500	0.16	0.21	0.19	0.14	0.15	0.15	0.15	0.14	0.15	11
	700	0.20	0.26	0.23	0.17	0.16	0.17	0.20	0.20	0.20	13
	1000	0.26	0.28	0.27	0.18	0.24	0.21	0.25	0.22	0.24	16
	1500	0.29	0.33	0.31	0.22	0.25	0.24	0.27	0.26	0.27	16
	2000	0.31	0.32	0.32	0.22	0.25	0.24	0.36	0.27	0.32	18
Distance from bottom, in.:		1.25 (31.8mm)			1.13 (28.7mm)			1.0 (25.4mm)			
	200	No cracks									
.034	300	0.03	0.03	0.03	0.02	0.03	0.03	0.04	0.03	0.04	5
(0.86mm)	500	0.10	0.07	0.09	0.08	0.06	0.07	0.07	0.06	0.07	6
	700	0.14	0.11	0.13	0.08	0.11	0.10	0.10	0.10	0.10	8
	1000	0.14	0.11	0.13	0.08	0.11	0.10	0.10	0.10	0.10	11
	1500	0.15	0.11	0.13	0.14	0.12	0.13	0.11	0.14	0.13	11
	2000	0.17	0.13	0.15	0.18	0.13	0.16	0.16	0.15	0.16	11
				Specimen V3: V57							
Distance from bottom, in.:		2.0 (50.8mm)			1.0 (25.4mm)			1.38 (35.1mm)			
	100	No cracks									
.023	200	0.13	0.06	0.10							1
(0.71 mm)	300	0.16	0.10	0.13	0.11	0.14	0.13	0.04	0.04	0.04	3
	500	0.16	0.10	0.13	0.16	0.14	0.15	0.11	0.10	0.11	12
	700	0.19	0.14	0.17	0.20	0.22	0.21	0.12	0.14	0.13	12
	1000	0.21	0.14	0.18	0.22	0.22	0.22	0.14	0.14	0.14	12
	1500	0.22	0.21	0.22	[illegible]	0.27	0.29	0.17	0.21	0.19	12
	2000	0.22	0.25	0.24	0.32	0.32	0.32	0.17	0.24	0.21	12
Distance from bottom, in.:		1.31 (33.3mm)			1.06 (26.9mm)			2.25 (57.2mm)			
	200	No Cracks									
.034	300	0.11	0.05	0.08	0.04	0.03	0.04				2
(0.86mm)	500	0.12	0.08	0.10	0.07	0.05	0.06	0.04	0.04	0.04	3
	700	0.12	0.15	0.14	0.08	0.06	0.07	0.09	0.04	[illegible]	7
	1000	0.12	0.15	0.14	0.08	[illegible]	0.07	0.09	0.05	0.07	8
	1500	0.22	0.17	0.20	0.08	0.10	0.09	0.09	0.09	0.09	10
	2000	0.25	0.20	0.23	0.12	0.10	0.11	0.14	0.10	0.12	10
				Specimen V5: V57							
Distance from bottom, in.:		1.13 (28.7mm)			2.19 (55.6mm)			2.5 (63.5mm)			
	50	No Cracks									
.027	100	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	4
(0.69 mm)	200	0.07	0.04	0.06	0.06	0.02	0.04	0.04	0.12	0.08	4
	300	0.18	0.17	0.18	0.13	0.13	0.13	0.12	0.25	0.19	15
	500	0.21	0.24	0.23	0.13	0.13	0.13	0.12	0.25	0.19	18
	700	0.29	0.26	0.28	0.15	0.12	0.14	0.16	0.25	0.21	18
	1000	0.30	0.26	0.28	0.17	0.13	0.15	0.16	0.27	0.22	18
	1500	0.30	0.26	0.28	0.23	0.18	0.21	0.33	0.32	0.33	18
	2000	0.33	0.27	0.30	0.25	0.22	0.24	0.33	0.32	0.33	15
Distance from bottom, in.:		1.25 (31.8mm)			1.94 (49.3mm)			1.06 (26.9mm)			
	100	No Cracks									
.034	200	0.15	-	0.08	0.12	-	0.06				2
(0.86mm)	300	0.15	0.13	0.14	0.15	0.13	0.14	0.13	0.06	0.09	6
	500	0.17	0.13	0.15	0.23	0.16	0.20	0.13	0.13	0.13	8
	700	0.17	0.13	0.15	0.24	0.17	0.21	0.13	0.13	0.13	10
	1000	0.20	0.14	0.17	0.24	0.17	0.21	0.13	0.13	0.13	10
	1500	0.21	0.15	0.18	0.26	0.22	0.24	0.14	0.15	0.15	12
	2000	0.18	0.21	0.20	0.35	0.37	0.36	0.30	0.26	0.28	12
				Specimen W1: MM 002							
Distance from bottom, in.:		1.0 (25.4mm)			1.88 (47.8mm)			2.81 (71.4mm)			
	50	No Cracks									
.030	100	0.12	0.08	0.10							1
(0.76 mm)	200	0.15	0.17	0.16	0.14	0.08	0.11	0.16	0.11	0.14	4
	300	0.21	0.17	0.19	0.16	0.08	0.12	0.19	0.11	0.15	6
	500	0.21	0.17	0.19	0.19	0.08	0.14	0.19	0.15	0.17	6
	700	0.22	0.20	0.21	0.23	0.20	0.22	0.20	0.16	0.18	6

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Table 11 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	Back	Avg	2nd Crack Front	Back	Avg	3rd Crack Front	Back	Avg	Total Cracks Observed
	1000	0.22	0.20	0.21	0.23	0.20	0.22	0.21	0.17	0.19	6
	1500	0.24	0.24	0.24	0.23	0.21	0.22	0.23	0.22	0.23	6
	2000	0.25	0.25	0.25	0.25	0.24	0.25	0.26	0.23	0.25	6
	2500	0.29	0.29	0.29	0.25	0.24	0.25	0.26	0.23	0.25	6
	3000	0.29	0.29	0.29	0.25	0.24	0.25	0.27	0.23	0.25	6
	3500	0.34	0.35	0.35	0.28	0.24	0.26	0.27	0.23	0.25	6
	4000	0.34	0.35	0.35	0.28	0.24	0.26	0.27	0.24	0.26	6
	4500	0.35	0.37	0.36	0.34	0.30	0.32	0.28	0.31	0.30	7
	5000	0.36	0.37	0.37	0.34	0.32	0.33	0.28	0.31	0.30	8
	5500	0.35	0.37	0.37	0.34	0.32	0.33	0.28	0.31	0.30	8
	6000	0.36	0.37	0.37	0.34	0.32	0.33	0.30	0.31	0.31	8
	6500	0.36	0.37	0.37	0.34	0.32	0.33	0.32	0.31	0.32	8
	7000	0.36	0.37	0.37	0.34	0.32	0.33	0.33	0.34	0.34	8
	7500	0.36	0.38	0.37	0.34	0.34	0.34	0.34	0.35	0.35	8
Distance from bottom, in.:				1.38 (35.1mm)			2.75 (69.9mm)			2.06 (52.3mm)	
	300	No Cracks									
.034 (0.86mm)	500	0.05	0.03	0.04							1
	700	0.06	0.03	0.04	0.03	0.03	0.03				2
	1000	0.07	0.05	0.06	0.03	0.03	0.03				2
	1500	0.11	0.10	0.11	0.03	0.03	0.03	0.05	0.04	0.05	4
	2000	0.11	0.10	0.11	0.03	0.03	0.03	0.05	0.04	0.05	4
	2500	0.11	0.10	0.11	0.03	0.03	0.03	0.05	0.04	0.05	4
	3000	0.11	0.10	0.11	0.03	0.03	0.03	0.05	0.04	0.05	5
	3500	0.12	0.10	0.11	0.06	0.05	0.06	0.05	0.05	0.05	6
	4000	0.12	0.16	0.14	0.06	0.05	0.06	0.09	0.08	0.09	6
	4500	0.15	0.18	0.17	0.06	0.05	0.06	0.11	0.11	0.11	7
	5000	0.15	0.20	0.18	0.06	0.05	0.06	0.11	0.12	0.12	8
	5500	0.26	0.20	0.23	0.25	0.24	0.25	0.11	0.12	0.12	8
	6000	0.26	0.20	0.23	0.25	0.24	0.25	0.14	0.13	0.14	8
	6500	0.26	0.20	0.23	0.25	0.24	0.25	0.14	0.13	0.14	8
	7000	0.26	0.20	0.23	0.25	0.24	0.25	0.15	0.13	0.14	9
	7500	0.26	0.20	0.23	0.25	0.24	0.25	0.15	0.13	0.14	9

Specimen W2: MM 002

Edge Radius, in.	Cycles	1st Crack Front	Back	Avg	2nd Crack Front	Back	Avg	3rd Crack Front	Back	Avg	Total Cracks Observed
Distance from bottom, in.:				1.06 (26.9mm)			1.38 (35.1mm)			2.44 (62 mm)	
	50	No Cracks									
.030 (0.76 mm)	100	0.07	0.07	0.07	0.15	0.11	0.13	0.0[illegible]	0.04	0.05	4
	200	0.12	0.12	0.12	0.24	0.22	0.23	0.19	0.13	0.16	5
	300	0.12	0.13	0.13	0.25	0.23	0.24	0.19	0.15	0.17	5
	500	0.12	0.13	0.13	0.27	0.24	0.26	0.21	0.17	0.19	5
	700	0.14	0.14	0.14	0.27	0.25	0.26	0.22	0.17	0.20	5
	1000	0.14	0.15	0.15	0.27	0.26	0.27	0.23	0.17	0.20	6
	1500	0.15	0.15	0.15	0.28	0.26	0.27	0.26	0.22	0.24	6
	2000	0.18	0.20	0.19	0.29	0.30	0.30	0.26	0.24	0.25	6
	2500	0.18	0.20	0.19	0.29	0.30	0.30	0.26	0.24	0.25	6
	3000	0.20	0.23	0.22	0.30	0.32	0.31	0.26	0.24	0.25	7
	3500	0.20	0.24	0.22	0.31	0.33	0.32	0.26	0.24	0.25	7
	4000	0.20	0.24	0.22	0.31	0.33	0.32	0.26	0.25	0.26	7
	4500	0.20	0.26	0.23	0.31	0.33	0.32	0.26	0.26	0.26	8
	5000	0.22	0.26	0.24	0.31	0.33	0.32	0.26	0.27	0.27	8
	5500	0.22	0.26	0.24	0.31	0.33	0.32	0.33	0.31	0.32	8
	6000	0.24	0.26	0.25	0.31	0.33	0.32	0.33	0.31	0.32	8
	6500	0.27	0.26	0.27	0.32	0.33	0.33	0.33	0.31	0.32	10
	7000	0.27	0.27	0.27	0.32	0.33	0.33	0.34	0.31	0.33	10
	7500	0.27	0.28	0.28	0.32	0.34	0.33	0.34	0.32	0.33	10
Distance from bottom, in				1.5 (38.1mm)			2.88 (73.2mm)			0.88 (22.4mm)	
	100	No Cracks									
.034 (0.86mm)	200	0.05	0.03	0.04							1
	300	0.05	0.03	0.04							1
	500	0.06	0.03	0.05							1
	700	0.06	0.03	0.05							1
	1000	0.06	0.03	0.05							1
	1500	0.06	0.03	0.05							1
	2000	0.06	0.06	0.06							1
	2500	0.06	0.06	0.06	0.04	0.03	0.04				2
	3000	0.06	0.06	0.06	0.07	0.05	0.06				2
	3500	0.12	0.11	0.12	0.07	0.05	0.06	0.17	0.10	0.14	3
	4000	0.17	0.14	0.16	0.11	0.13	0.12	0.19	0.16	0.18	5
	4500	0.17	0.15	0.16	0.11	0.15	0.13	0.19	0.16	0.18	7
	5000	0.17	0.15	0.16	0.11	0.15	0.13	0.19	0.16	0.18	9
	5500	0.17	0.17	0.17	0.11	0.15	0.13	0.20	0.21	0.21	10
	6000	0.18	0.17	0.19	0.15	0.15	0.15	0.20	0.21	0.21	10
	6500	0.19	0.17	0.18	0.15	0.15	0.15	0.20	0.21	0.21	10
	7000	0.19	0.17	0.18	0.16	0.15	0.16	0.20	0.21	0.21	10
	7500	0.21	0.18	0.20	0.18	0.17	0.18	0.20	0.21	0.21	13

Table 11 (cont.)

Edge Radius, in.	Cycles	1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
					Specimen W3: MM 002						
Distance from bottom, in.:			1.19 (30.2mm)			1.69 (42.9mm)			2.19 (55.6mm)		
	100	No Cracks									
.024 (0.61 mm)	200	0.22	0.21	0.22	0.05	0.03	0.04	0.13	0.17	0.15	5
	300	0.23	0.22	0.23	0.06	0.03	0.05	0.22	0.19	0.21	5
	500	0.24	0.22	0.23	0.07	0.03	0.05	0.25	0.19	0.22	5
	700	0.25	0.22	0.24	0.07	0.04	0.06	0.25	0.23	0.24	7
	1000	0.25	0.24	0.25	0.07	0.04	0.06	0.26	0.23	0.25	7
	1500	0.28	0.26	0.27	0.09	0.06	0.08	0.28	0.25	0.27	7
	2000	0.28	0.28	0.28	0.11	0.09	0.10	0.28	0.25	0.27	7
	2500	0.28	0.28	0.28	0.11	0.10	0.11	0.28	0.25	0.27	7
	3000	0.28	0.28	0.28	0.14	0.14	0.14	0.28	0.25	0.27	9
	3500	0.29	0.28	0.29	0.16	0.15	0.16	0.33	0.30	0.32	9
	4000	0.30	0.29	0.30	0.16	0.16	0.16	0.33	0.30	0.32	10
	4500	0.30	0.30	0.30	0.16	0.16	0.16	0.35	0.30	0.33	11
	5000	0.30	0.30	0.30	0.19	0.16	0.18	0.35	0.30	0.33	11
	5500	0.30	0.30	0.30	0.19	0.16	0.18	0.35	0.33	0.34	11
	6000	0.30	0.30	0.30	0.21	0.16	0.19	0.35	0.33	0.34	11
	6500	0.31	0.30	0.31	0.21	0.19	0.20	0.35	0.35	0.35	11
	7000	0.31	0.30	0.31	0.22	0.19	0.21	0.35	0.35	0.35	11
	7500	0.31	0.31	0.31	0.22	0.20	0.21	0.35	0.35	0.35	11
Distance from bottom, in.:			0.88 (22.4mm)			2.25 (57.2mm)			1.19 (30.2mm)		
	100	No Cracks									
.036 (0.91mm)	200	0.04	0.07	0.06	0.08	0.03	0.06	0.02	0.03	0.03	3
	300	0.04	0.07	0.06	0.09	0.07	0.08	0.04	0.07	0.06	4
	500	0.07	0.12	0.10	0.09	0.08	0.09	0.10	0.12	0.11	7
	700	0.08	0.13	0.11	0.09	0.08	0.09	0.10	0.13	0.12	7
	1000	0.10	0.13	0.12	0.09	0.08	0.09	0.12	0.13	0.13	8
	1500	0.11	0.13	0.12	0.09	0.08	0.09	0.12	0.13	0.13	10
	2000	0.17	0.20	0.19	0.09	0.08	0.09	0.19	0.13	0.16	10
	2500	0.17	0.20	0.19	0.09	0.08	0.09	0.19	0.13	0.16	10
	3000	0.17	0.20	0.19	0.09	0.08	0.09	0.20	0.13	0.17	10
	3500	0.17	0.20	0.19	0.09	0.08	0.09	0.22	0.16	0.19	10
	4000	0.17	0.20	0.19	0.09	0.08	0.09	0.22	0.16	0.19	10
	4500	0.19	0.21	0.20	0.11	0.12	0.12	0.22	0.21	0.22	10
	5000	0.19	0.21	0.20	0.14	0.13	0.14	0.23	0.21	0.22	10
	5500	0.20	0.21	0.21	0.14	0.13	0.14	0.23	0.22	0.23	10
	6000	0.20	0.21	0.21	0.14	0.13	0.14	0.24	0.22	0.23	10
	6500	0.20	0.21	0.21	0.14	0.13	0.14	0.24	0.22	0.23	11
	7000	0.21	0.21	0.21	0.14	0.13	0.14	0.24	0.22	0.23	11
	7500	0.21	0.21	0.21	0.14	0.15	0.15	0.24	0.25	0.25	11
					Specimen X1: MM 246						
Distance from bottom, in.:			0.88 (22.4mm)			1.88 (47.8mm)			2.56 (65 mm)		
	200	No Cracks									
.028 (0.71 mm)	300	0.02	-	0.01	0.07	0.11	0.09	0.08	0.12	0.10	3
	500	0.04	0.04	0.04	0.23	0.16	0.20	0.22	0.16	0.19	3
	700	0.04	0.04	0.04	0.25	0.22	0.24	0.23	0.17	0.20	5
	1000	0.05	0.04	0.05	0.26	0.23	0.25	0.23	0.20	0.22	5
	1500	0.05	0.04	0.05	0.28	0.23	0.26	0.27	0.22	0.25	11
	2000	0.15	0.23	0.19	0.32	0.25	0.29	0.31	0.26	0.29	11
	2500	0.28	0.23	0.26	0.32	0.25	0.29	0.31	0.26	0.29	11
	3000	0.31	0.35	0.33	0.32	0.31	0.32	0.33	0.27	0.30	11
	3500	0.32	0.35	0.34	0.32	0.31	0.32	0.33	0.27	0.30	11
	4000	0.34	0.35	0.35	0.33	0.31	0.32	0.35	0.31	0.33	11
	4500	0.34	0.35	0.35	0.38	0.36	0.37	0.35	0.33	0.34	11
	5000	0.34	0.36	0.35	0.38	0.36	0.37	0.35	0.35	0.35	11
	5500	0.34	0.36	0.35	0.38	0.36	0.37	0.36	0.35	0.36	11
	6000	0.35	0.36	0.36	0.38	0.36	0.37	0.36	0.35	0.36	11
	6500	0.35	0.36	0.36	0.38	0.36	0.37	0.36	0.35	0.36	11
	7000	0.36	0.37	0.37	0.38	0.37	0.38	0.37	0.35	0.36	11
	7500	0.36	0.37	0.37	0.38	0.37	0.38	0.37	0.38	0.38	11
					Specimen X1: MM 246						
Distance from bottom, in.:			1.0 (25.4mm)			1.31 (23.3mm)			2.50 (63.5mm)		
	[illegible]	No Cracks									
.034 (0.86mm)	3000	0.02	0.02	0.02	0.10	0.11	0.11	0.05	-	0.03	7
	3500	0.02	0.02	0.02	0.12	0.11	0.12	0.05	0.02	0.04	7
	4000	0.02	0.04	0.03	0.12	0.14	0.13	0.07	0.06	0.07	8
	4500	0.07	0.09	0.08	0.15	0.20	0.18	0.08	0.08	0.08	8
	5000	0.10	0.10	0.10	0.20	0.20	0.20	0.08	0.08	0.08	10

Table 11 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	Back	Avg	2nd Crack Front	Back	Avg	3rd Crack Front	Back	Avg	Total Cracks Observed
	5500	0.10	0.10	0.10	0.20	0.20	0.20	0.10	0.08	0.09	11
	6000	0.10	0.11	0.11	0.21	0.20	0.21	0.10	0.08	0.09	11
	6500	0.10	0.11	0.11	0.21	0.20	0.21	0.10	0.08	0.09	13
	7000	0.10	0.11	0.11	0.21	0.20	0.21	0.11	0.09	0.10	16
	7500	0.15	0.14	0.15	0.21	0.20	0.21	0.13	0.14	0.14	16
Specimen X2: MM 246											
Distance from bottom, in.:		1.5 (38.1 mm)			1.06 (26.9 mm)			2.81 (71.4 mm)			
.028 (0.71 mm)	100	No Cracks									
	200	0.15	0.18	0.17							1
	300	0.16	0.18	0.17	0.17	0.14	0.16	0.17	0.22	0.20	4
	500	0.17	0.18	0.18	0.17	0.18	0.18	0.17	0.22	0.20	7
	700	0.18	0.20	0.19	0.18	0.16	0.18	0.20	0.23	0.22	7
	1000	0.19	0.20	0.20	0.19	0.18	0.19	0.20	0.23	0.22	8
	1500	0.21	0.20	0.21	0.21	0.18	0.20	0.22	0.23	0.23	8
	2000	0.26	0.25	0.26	0.23	0.21	0.22	0.23	0.23	0.23	8
	2500	0.26	0.26	0.26	0.25	0.23	0.24	0.26	0.23	0.25	8
	3000	0.26	0.27	0.27	0.25	0.25	0.25	0.27	0.23	0.25	9
	3500	0.26	0.27	0.27	0.27	0.26	0.27	0.27	0.24	0.26	10
	4000	0.26	0.27	0.27	0.29	0.28	0.29	0.28	0.25	0.27	10
	4500	0.32	0.32	0.32	0.29	0.29	0.29	0.32	0.28	0.30	12
	5000	0.32	0.32	0.32	0.29	0.29	0.29	0.33	0.32	0.33	13
	5500	0.32	0.32	0.32	0.29	0.30	0.30	0.33	0.32	0.33	13
	6000	0.32	0.32	0.32	0.29	0.30	0.30	0.33	0.32	0.33	13
	6500	0.32	0.36	0.34	0.29	0.32	0.31	0.35	0.32	0.34	13
	7000	0.32	0.36	0.34	0.29	0.32	0.31	0.35	0.32	0.34	16
	7500	0.32	0.36	0.34	0.29	0.33	0.31	0.35	0.36	0.36	16
Distance from bottom, in.:		2.06 (52.3 mm)			0.88 (22.4 mm)			2.88 (73.2 mm)			
.033 (0.84 mm)	300	No Cracks									
	500	0.08	0.11	0.10							1
	700	0.09	0.11	0.10							[illegible]
	1000	0.09	0.11	0.10							[illegible]
	1500	0.14	0.15	0.15							1
	2000	0.19	0.18	0.19							1
	2500	0.19	0.18	0.19	0.05	0.06	0.06				2
	3000	0.20	0.18	0.19	0.05	0.06	0.06				2
	3500	0.20	0.18	0.19	0.05	0.06	0.06	0.01	0.01	0.01	3
	4000	0.21	0.25	0.23	0.08	0.08	0.08	0.04	0.02	0.03	7
	4500	0.27	0.25	0.26	0.10	0.14	0.12	0.04	0.02	0.03	7
	5000	0.27	0.25	0.26	0.10	0.14	0.12	0.04	0.02	0.03	8
	5500	0.27	0.25	0.26	0.11	0.14	0.13	0.04	0.02	0.03	8
	6000	0.28	0.27	0.28	0.11	0.14	0.13	0.04	0.02	0.03	9
	6500	0.28	0.27	0.28	0.14	0.14	0.14	0.04	0.02	0.03	11
	7000	0.28	0.27	0.28	0.15	0.14	0.15	0.04	0.02	0.03	14
	7500	0.28	0.27	0.28	0.15	0.18	0.17	0.06	0.11	0.09	15
Distance from bottom, in.:		1.94 (49.3 mm)			1.31 (33.3 mm)			2.81 (71.4 mm)			
.025 (0.64 mm)	100	No Cracks									
	200	0.05	0.02	0.04							1
	300	0.07	0.07	0.07	0.06	0.07	0.07	0.12	0.09	0.11	6
	500	0.13	0.07	0.10	0.13	0.08	0.11	0.14	0.14	0.14	6
	700	0.16	0.14	0.15	0.16	0.21	0.19	0.18	0.17	0.18	6
	1000	0.17	0.14	0.16	0.17	0.21	0.19	0.19	0.18	0.19	6
	1500	0.22	0.20	0.21	0.25	0.23	0.24	0.23	0.20	0.22	6
	2000	0.22	0.25	0.24	0.27	0.30	0.29	0.28	0.31	0.30	8
	2500	0.29	0.25	0.27	0.28	0.30	0.29	0.28	0.31	0.30	8
	3000	0.29	0.25	0.27	0.29	0.31	0.30	0.28	0.32	0.30	8
	3500	0.29	0.25	0.27	0.29	0.31	0.30	0.32	0.32	0.32	8
	4000	0.29	0.27	0.28	0.31	0.32	0.[illegible]2	0.34	0.32	0.33	8
	4500	0.29	0.30	0.30	0.32	0.32	0.32	0.34	0.32	0.33	8
	5000	0.29	0.30	0.30	0.33	0.35	0.34	0.34	0.34	0.34	8
	5500	0.31	0.30	0.31	0.34	0.35	0.35	0.34	0.34	0.34	8
	6000	0.31	0.30	0.31	0.34	0.35	0.35	0.34	0.34	0.34	8
	6500	0.31	0.33	0.32	0.34	0.35	0.35	0.36	0.36	0.36	8
	7000	0.31	0.33	0.32	0.34	0.35	0.35	0.37	0.37	0.37	9
	7500	0.31	0.35	0.33	0.34	0.36	0.35	0.37	0.37	0.37	10
Distance from bottom, in.:		1.88 (47.8 mm)			2.38 (60.5 mm)			1.25 (31.8 mm)			
.033 (0.84 mm)	300	No Cracks									
	500	0.03	0.03	0.03	0.06	0.11	0.09	0.04	0.05	0.05	4
	700	0.03	0.03	0.03	0.07	0.11	0.09	0.05	0.05	0.05	4
	1000	0.03	0.03	0.03	0.07	0.11	0.09	0.05	0.05	0.05	5
	1500	0.03	0.03	0.03	0.09	0.11	0.10	0.05	0.05	0.05	5
	2000	0.04	0.03	0.04	0.12	0.11	0.12	0.05	0.05	0.05	5

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Table 11(cont.)

Edge Radius, in.	Cycles	1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
	2500	0.08	0.07	0.08	0.12	0.11	0.12	0.05	0.05	0.05	5
	3000	0.09	0.07	0.08	0.12	0.11	0.12	0.11	0.10	0.11	5
	3500	0.11	0.08	0.10	0.17	0.17	0.17	0.11	0.10	0.11	5
	4000	0.11	0.08	0.10	0.17	0.17	0.17	0.11	0.10	0.11	5
	4500	0.11	0.09	0.10	0.17	0.18	0.18	0.11	0.10	0.11	7
	5000	0.11	0.09	0.10	0.17	0.18	0.18	0.11	0.10	0.11	7
	5500	0.11	0.09	0.10	0.17	0.18	0.18	0.11	0.10	0.11	7
	6000	0.11	0.09	0.10	0.17	0.18	0.18	0.11	0.10	0.11	7
	6500	0.13	0.12	0.13	0.19	0.18	0.19	0.11	0.10	0.11	7
	7000	0.13	0.12	0.13	0.19	0.18	0.19	0.11	0.10	0.11	7
	7500	0.13	0.12	0.13	0.19	0.18	0.19	0.11	0.10	0.11	8
Specimen Y1: René 77											
Distance from bottom, in.:				1.0 (25.4 mm)			1.63 (41.4 mm)			2.75 (69.9 mm)	
	50	No Cracks									
.026 (0.66 mm)	100	0.14	0.11	0.13	0.19	0.15	0.17	0.12	0.08	0.10	9
	200	0.18	0.16	0.17	0.20	0.21	0.21	0.19	0.11	0.15	9
	300	0.16	0.17	0.18	0.21	0.21	0.21	0.19	0.14	0.17	10
	500	0.18	0.17	0.18	0.21	0.21	0.21	0.20	0.16	0.18	10
	700	0.18	0.18	0.18	0.22	0.21	0.22	0.21	0.16	0.19	10
	1000	0.18	0.18	0.18	0.22	0.21	0.22	0.21	0.16	0.19	10
	1500	0.18	0.18	0.18	0.22	0.21	0.22	0.21	0.20	0.21	10
	2000	0.18	0.18	0.18	0.22	0.21	0.22	0.21	0.20	0.21	10
	2500	0.29	0.24	0.27	0.22	0.21	0.22	0.21	0.20	0.21	10
	3000	0.31	0.29	0.30	0.27	0.30	0.29	0.25	0.25	0.25	10
	3500	0.31	0.29	0.30	0.27	0.30	0.29	0.25	0.25	0.25	10
	4000	0.32	0.29	0.31	0.28	0.30	0.29	0.25	0.25	0.25	10
	4500	0.32	0.29	0.31	0.29	0.30	0.30	0.27	0.28	0.28	10
	5000	0.32	0.32	0.32	0.29	0.31	0.30	0.27	0.28	0.28	10
	5500	0.33	0.32	0.33	0.29	0.31	0.30	0.32	0.33	0.33	10
	6000	0.33	0.32	0.33	0.30	0.31	0.31	0.33	0.33	0.33	10
	6500	0.33	0.32	0.33	0.31	0.31	0.31	0.35	0.34	0.35	10
	7000	0.33	0.32	0.33	0.31	0.31	0.31	0.35	0.34	0.35	10
	7500	0.36	0.34	0.35	0.31	0.31	0.31	0.36	0.35	0.36	10
Distance from bottom, in.:				1.0 (25.4 mm)			2.44 (62 mm)			2.81 (71.4 mm)	
	100	No Cracks									
.033 (0.84 mm)	200	0.07	0.05	0.06	0.05	0.04	0.05	0.07	0.08	0.08	5
	300	0.09	0.07	0.08	0.05	0.09	0.07	0.09	0.08	0.09	6
	500	0.11	0.08	0.10	0.07	0.09	0.08	0.09	0.08	0.09	6
	700	0.11	0.08	0.10	0.08	0.09	0.09	0.09	0.14	0.12	6
	1000	0.12	0.09	0.11	0.08	0.09	0.09	0.09	0.14	0.12	6
	1500	0.19	0.16	0.18	0.09	0.10	0.10	0.13	0.14	0.14	7
	2000	0.19	0.16	0.18	0.15	0.12	0.14	0.14	0.18	0.16	12
	2500	0.19	0.16	0.18	0.15	0.12	0.14	0.15	0.20	0.18	12
	3000	0.22	0.20	0.21	0.17	0.19	0.18	0.20	0.20	0.20	14
	3500	0.24	0.21	0.23	0.17	0.19	0.18	0.21	0.20	0.21	15
	4000	0.25	0.21	0.23	0.17	0.19	0.18	0.21	0.20	0.21	15
	4500	0.25	0.22	0.24	0.23	0.20	0.22	0.22	0.21	0.22	15
	5000	0.25	0.23	0.24	0.23	0.20	0.22	0.22	0.21	0.22	7
	5500	[illegible]	0.23	0.24	0.23	0.21	0.22	0.22	0.21	0.22	8
	6000	0.26	0.23	0.25	0.23	0.21	0.22	0.22	0.21	0.22	11
	6500	0.26	0.23	0.25	0.24	0.22	0.23	0.24	0.23	0.24	11
	7000	0.26	0.26	0.26	0.24	0.22	0.23	0.24	0.23	0.24	11
	7500	0.27	0.26	0.27	0.24	0.22	0.23	0.24	0.25	0.25	11
Specimen Y2: René 77											
Distance from bottom, in.:				1.88 (47.8mm)			.94 (23.9 mm)			3.06 (77.7 mm)	
	50	No Cracks									
.026 (0.66 mm)	100	0.15	0.12	0.14	0.17	0.14	0.16	0.09	0.12	0.11	5
	200	0.16	0.17	0.17	0.21	0.19	0.20	0.14	0.16	0.15	9
	300	0.17	0.17	0.17	0.23	0.20	0.22	0.17	0.21	0.19	9
	500	0.25	0.24	0.25	0.23	0.20	0.22	0.20	0.21	0.21	9
	700	0.25	0.24	0.25	0.23	0.20	0.22	0.20	0.21	0.21	9
	1000	0.25	0.24	0.25	0.23	0.20	0.22	0.20	0.21	0.21	9
	1500	0.25	0.24	0.25	0.23	0.21	0.22	0.20	0.22	0.21	9
	2000	0.26	0.27	0.27	0.23	0.25	0.24	0.26	0.26	0.26	11
	2500	0.28	0.28	0.28	0.25	0.26	0.26	0.28	0.28	0.28	11
	3000	0.30	0.31	0.31	0.28	0.29	0.29	0.31	0.31	0.31	12
	3500	0.31	0.31	0.31	0.28	0.29	0.29	0.31	0.31	0.31	12
	4000	0.31	0.31	0.31	0.28	0.29	0.29	0.31	0.31	0.31	12
	4500	0.31	0.34	0.33	0.32	0.31	0.32	0.32	0.32	0.32	12
	5000	0.31	0.34	0.33	0.32	0.31	0.32	0.32	0.32	0.32	12
	5500	0.32	0.34	0.33	0.32	0.31	0.32	0.33	0.32	0.33	12

Table 11 (cont.)

Edge Radius, in.	Cycles	1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
		Crack Length, in.									
	6000	0.32	0.34	0.33	0.33	0.35	0.35	0.33	0.32	0.33	12
	6500	0.32	0.35	0.34	0.36	0.35	0.36	0.33	0.32	0.33	12
	7000	0.32	0.35	0.34	0.36	0.35	0.36	0.33	0.32	0.33	12
	7500	0.32	0.35	0.34	0.36	0.35	0.36	0.35	0.35	0.35	12
Distance from bottom, in.:				2.0 (50.8 mm)			1.38 (35.1 mm)			2.75 (69.9 mm)	
	50	No Cracks									
.036 (0.91 mm)	100	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	4
	200	0.12	0.15	0.14	0.08	0.04	0.06	0.07	0.08	0.08	5
	300	0.18	0.17	0.18	0.14	0.16	0.15	0.07	0.09	0.08	5
	500	0.18	0.17	0.18	0.14	0.16	0.15	0.16	0.16	0.16	7
	700	0.18	0.17	0.18	0.14	0.16	0.15	0.17	0.16	0.17	7
	1000	0.18	0.17	0.18	0.15	0.16	0.16	0.17	0.16	0.17	8
	1500	0.21	0.17	0.19	0.15	0.16	0.16	0.17	0.17	0.17	8
	2000	0.21	0.20	0.21	0.15	0.16	0.16	0.20	0.20	0.20	9
	2500	0.24	0.22	0.23	0.18	0.19	0.19	0.21	0.21	0.21	9
	3000	0.24	0.22	0.23	0.21	0.20	0.21	0.22	0.25	0.24	10
	3500	0.26	0.22	0.24	0.22	0.20	0.21	0.24	0.26	0.25	10
	4000	0.27	0.22	0.25	0.22	0.20	0.21	0.24	0.26	0.25	10
	4500	0.27	0.23	0.25	0.24	0.25	0.25	0.24	0.26	0.25	11
	5000	0.27	0.25	0.26	0.24	0.26	0.25	0.26	0.26	0.26	11
	5500	0.27	0.25	0.26	0.25	0.26	0.26	0.26	0.27	0.27	12
	6000	0.27	0.25	0.26	0.25	0.26	0.26	0.27	0.27	0.27	12
	6500	0.27	0.25	0.26	0.26	0.27	0.27	0.29	0.27	0.28	12
	7000	0.27	0.25	0.26	0.26	0.27	0.27	0.29	0.27	0.28	12
	7500	0.28	0.26	0.27	0.26	0.27	0.27	0.29	0.27	0.28	12
Specimen Y4: René 77											
Distance from bottom, in.:				1.13 (28.7 mm)			1.81 (46 mm)			2.94 (74.7 mm)	
	50	No Cracks									
.029 (0.74 mm)	100	0.17	0.12	0.15	0.12	0.17	0.15	0.15	0.10	0.13	6
	200	0.22	0.19	0.21	0.16	0.23	0.20	0.20	0.19	0.20	6
	300	0.23	0.22	0.23	0.16	0.23	0.20	0.20	0.19	0.20	6
	500	0.23	0.22	0.23	0.18	0.23	0.21	0.20	0.19	0.20	6
	700	0.26	0.22	0.24	0.19	0.23	0.21	0.20	0.20	0.20	6
	1000	0.26	0.22	0.24	0.19	0.23	0.21	0.20	0.20	0.20	6
	1500	0.30	0.29	0.30	0.21	0.23	0.22	0.22	0.20	0.21	8
	2000	0.32	0.32	0.32	0.29	0.29	0.29	0.23	0.24	0.24	10
	2500	0.32	0.33	0.33	0.29	0.30	0.30	0.26	0.28	0.27	10
	3000	0.32	0.33	0.33	0.32	0.33	0.33	0.32	0.31	0.32	10
	3500	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.31	0.32	10
	4000	0.33	0.35	0.34	0.33	0.34	0.34	0.33	0.35	0.34	10
	4500	0.37	0.36	0.37	0.35	0.34	0.35	0.34	0.35	0.35	11
	5000	0.37	0.36	0.37	0.35	0.34	0.35	0.34	0.35	0.35	11
	5500	0.37	0.36	0.37	0.35	0.34	0.35	0.34	0.35	0.35	11
	6000	0.37	0.36	0.37	0.35	0.34	0.35	0.34	0.35	0.35	11
	6500	0.37	0.36	0.37	0.35	0.35	0.35	0.34	0.35	0.35	11
	7000	0.37	0.36	0.37	0.35	0.35	0.35	0.34	0.35	0.35	11
	7500	0.38	0.36	0.37	0.35	0.35	0.35	0.35	0.35	0.35	11
Distance from bottom, in.:				0.88 (22.4 mm)			2.38 (60.5 mm)			2.94 (74.7 mm)	
	100	No Cracks									
.035 (0.89 mm)	200	0.07	0.06	0.07	0.06	0.15	0.11	0.11	0.10	0.11	5
	300	0.12	0.07	0.10	0.06	0.15	0.11	0.12	0.10	0.11	5
	500	0.12	0.07	0.10	0.07	0.15	0.11	0.12	0.10	0.11	8
	700	0.12	0.07	0.10	0.08	0.16	0.12	0.13	0.11	0.12	8
	1000	0.12	0.08	0.10	0.09	0.16	0.13	0.13	0.11	0.12	8
	1500	0.14	0.14	0.14	0.10	0.18	0.14	0.17	0.15	0.16	8
	2000	0.18	0.19	0.19	0.11	0.18	0.15	0.20	0.25	0.23	9
	2500	0.20	0.20	0.20	0.19	0.21	0.20	0.21	0.25	0.23	9
	3000	0.22	0.26	0.24	0.21	0.21	0.21	0.27	0.26	0.27	11
	3500	0.23	0.26	0.25	0.21	0.22	0.22	0.28	0.26	0.27	11
	4000	0.23	0.26	0.25	0.21	0.22	0.22	0.28	0.26	0.27	11
	4500	0.27	0.26	0.27	0.26	0.22	0.24	0.30	0.27	0.29	11
	5000	0.28	0.26	0.27	0.26	0.26	0.26	0.30	0.27	0.29	12
	5500	0.28	0.26	0.27	0.28	0.26	0.27	0.32	0.27	0.30	13
	6000	0.28	0.26	0.27	0.28	0.26	0.27	0.32	0.27	0.30	13
	6500	0.29	0.26	0.28	0.29	0.26	0.28	0.32	0.27	0.30	13
	7000	0.29	0.26	0.28	0.29	0.26	0.28	0.32	0.27	0.30	13
	7500	0.29	0.26	0.28	0.29	0.26	0.28	0.32	0.27	0.30	14
Specimen Z2: René 125											
Distance from bottom, in.:				1.13 (28.7 mm)			1.69 (42.9 mm)			2.56 (65 mm)	
	100	No Cracks									
.027 (0.69 mm)	200	0.07	0.11	0.09							1
	300	0.08	0.14	0.11							1
	500	0.18	0.14	0.16							1
	700	0.19	0.19	0.19	0.03	0.03	0.03				2
	1000	0.19	0.19	0.19	0.05	0.04	0.05				2

Table 11 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. 1st Crack Front	Back	Avg	2nd Crack Front	Back	Avg	3rd Crack Front	Back	Avg	Total Cracks Observed
	1500	0.19	0.19	0.19	0.11	0.14	0.13	0.16	0.20	0.18	3
	2000	0.26	0.28	0.27	0.15	0.20	0.18	0.24	0.23	0.24	3
	2500	0.26	0.28	0.27	0.28	0.32	0.30	0.24	0.26	0.25	3
	3000	0.28	0.28	0.28	0.28	0.32	0.30	0.28	0.30	0.29	4
	3500	0.29	0.28	0.29	0.28	0.32	0.30	0.29	0.30	0.30	4
	4000	0.29	0.30	0.30	0.28	0.32	0.30	0.30	0.31	0.31	5
	4500	0.31	0.30	0.31	0.28	0.32	0.30	0.32	0.31	0.32	6
	5000	0.32	0.31	0.32	0.28	0.32	0.30	0.32	0.31	0.32	6
	5500	0.35	0.33	0.34	0.32	0.32	0.32	0.32	0.33	0.33	6
	6000	0.35	0.33	0.34	0.32	0.32	0.32	0.32	0.33	0.33	6
	6500	0.36	0.36	0.36	0.32	0.32	0.32	0.32	0.33	0.33	6
	7000	0.37	0.38	0.38	0.32	0.35	0.34	0.35	0.34	0.35	6
	7500	0.37	0.38	0.38	0.32	0.35	0.34	0.37	0.38	0.38	6
Distance from bottom, in.:				2.69	(68.3 mm)						
	2000	No Cracks									
.033 (0.84 mm)	2500	0.10	0.10	0.10							1
	3000	0.11	0.12	0.12							1
	3500	0.13	0.13	0.13							1
	4000	0.16	0.17	0.17							1
	4500	0.16	0.17	0.17							1
	5000	0.18	0.18	0.18							1
	5500	0.19	0.18	0.19							1
	6000	0.19	0.18	0.19							1
	6500	0.19	0.20	0.20							1
	7000	0.20	0.21	0.21							1
	7500	0.20	0.21	0.21							1
Specimen 23: René 125											
Distance from bottom, in.:				1.06	(26.9 mm)		1.88 (47.8 mm)			2.81 (71.4 mm)	
	100	No Cracks									
.027 (0.69 mm)	200	0.14	0.12	0.13							1
	300	0.18	0.13	0.16							1
	500	0.19	0.16	0.18							1
	700	0.25	0.16	0.21							1
	1000	0.25	0.16	0.21							1
	1500	0.25	0.23	0.24	0.05	0.07	0.06	0.14	0.12	0.13	8
	2000	0.25	0.23	0.24	0.09	0.09	0.09	0.23	0.23	0.23	9
	2500	0.30	0.30	0.30	0.20	0.24	0.22	0.24	0.23	0.24	9
	3000	0.33	0.33	0.33	0.20	0.24	0.22	0.25	0.23	0.24	9
	3500	0.33	0.34	0.34	0.24	0.25	0.25	0.25	0.24	0.25	9
	4000	0.35	0.36	0.36	0.24	0.25	0.25	0.25	0.25	0.25	9
	4500	0.36	0.38	0.37	0.30	0.29	0.30	0.29	0.29	0.29	9
	5000	0.36	0.38	0.37	0.30	0.29	0.30	0.29	0.29	0.29	10
	5500	0.36	0.38	0.37	0.30	0.29	0.30	0.30	0.29	0.30	10
	6000	0.37	0.38	0.38	0.31	0.30	0.31	0.33	0.29	0.31	10
	6500	0.38	0.38	0.38	0.31	0.31	0.31	0.33	0.32	0.33	10
	7000	0.38	0.38	0.38	0.32	0.31	0.32	0.33	0.32	0.33	11
	7500	0.38	0.38	0.38	0.32	0.31	0.32	0.33	0.33	0.33	11
Distance from bottom, in.:				1.88	(47.8 mm)		0.94 (23.9 mm)			2.63 (66.8 mm)	
	1000	No Cracks									
.033 (0.84 mm)	1500	0.03	0.03	0.03							1
	2000	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	8
	2500	0.07	0.05	0.06	0.05	0.04	0.05	0.13	0.08	0.11	8
	3000	0.07	0.05	0.06	0.05	0.04	0.05	0.13	0.08	0.11	8
	3500	0.11	0.11	0.11	0.07	0.09	0.08	0.13	0.09	0.11	8
	4000	0.11	0.11	0.11	0.07	0.09	0.08	0.13	0.10	0.12	8
	4500	0.17	0.15	0.16	0.07	0.09	0.08	0.17	0.18	0.18	10
	5000	0.17	0.15	0.16	0.07	0.09	0.08	0.17	0.18	0.18	10
	5500	0.17	0.15	0.16	0.08	0.09	0.09	0.17	0.21	0.19	10
	6000	0.17	0.15	0.16	0.08	0.09	0.09	0.17	0.21	0.19	10
	6500	0.17	0.15	0.16	0.08	0.09	0.09	0.20	0.21	0.21	10
	7000	0.17	0.15	0.16	0.11	0.10	0.11	0.20	0.21	0.21	10
	7500	0.19	0.17	0.18	0.13	0.10	0.12	0.22	0.21	0.22	10
Specimen 26: René 125											
Distance from bottom, in.:				2.88	(73.2 mm)		1.44 (36.6 mm)			2.25 (57.2 mm)	
	100	No Cracks									
.024 (0.61 mm)	200	0.19	0.19	0.19							1
	300	0.22	0.25	0.24	0.12	0.10	0.11				2
	500	0.27	0.26	0.27	0.21	0.19	0.20	0.11	0.09	0.10	3
	700	0.27	0.27	0.27	.22	0.22	0.22	0.12	0.13	0.13	3
	1000	0.28	0.27	0.28	0.23	0.22	0.23	0.12	0.13	0.13	3

Table 11 (cont.)

Edge Radius, in.	Cycles	Crack Length, in. — 1st Crack Front	1st Crack Back	1st Crack Avg	2nd Crack Front	2nd Crack Back	2nd Crack Avg	3rd Crack Front	3rd Crack Back	3rd Crack Avg	Total Cracks Observed
	1500	0.28	0.27	0.28	0.23	0.22	0.23	0.16	0.15	0.16	5
	2000	0.32	0.34	0.33	0.29	0.26	0.28	0.17	0.17	0.17	5
	2500	0.32	0.34	0.33	0.29	0.26	0.28	0.17	0.17	0.17	5
	3000	0.34	0.34	0.34	0.29	0.27	0.28	0.18	0.17	0.18	5
	3500	0.35	0.35	0.35	0.30	0.27	0.29	0.23	0.21	0.22	5
	4000	0.36	0.35	0.36	0.30	0.27	0.29	0.23	0.21	0.22	5
	4500	0.36	0.35	0.36	0.33	0.32	0.33	0.23	0.25	0.24	5
	5000	0.36	0.36	0.36	0.33	0.32	0.33	0.23	0.25	0.24	5
	5500	0.36	0.36	0.36	0.33	0.32	0.33	0.27	0.28	0.28	5
	6000	0.36	0.36	0.36	0.33	0.32	0.33	0.29	0.30	0.30	5
	6500	0.36	0.36	0.36	0.33	0.32	0.33	0.29	0.30	0.30	5
	7000	0.41	0.40	0.41	0.33	0.32	0.33	0.30	0.30	0.30	5
	7500	0.41	0.40	0.41	0.33	0.32	0.33	0.31	0.32	0.32	5
Distance from bottom, in.:				1.44 (36.6 mm)			1.06 (26.9 mm)			0.94 (23.9 mm)	
	1500	No Cracks									
.036 (0.91 mm)	2000	0.09	0.11	0.10							1
	2500	0.12	0.11	0.12							1
	3000	0.12	0.11	0.12							1
	3500	0.13	0.12	0.13	0.02	0.02	0.02				2
	4000	0.13	0.12	0.13	0.02	0.02	0.02				2
	4500	0.13	0.15	0.14	0.02	0.02	0.02				2
	5000	0.16	0.15	0.16	0.02	0.02	0.02				2
	5500	0.17	0.16	0.17	0.02	0.02	0.02				2
	6000	0.20	0.19	0.20	0.02	0.02	0.02				2
	6500	0.20	0.19	0.20	0.02	0.02	0.02				2
	7000	0.20	0.19	0.20	0.02	0.02	0.02	0.02	0.02	0.02	3
	7500	0.20	0.19	0.20	0.03	0.02	0.03	0.02	0.04	0.03	7
Specimen Q1: γ/γ'-δ Eutectic + NiCrAlY/Pt Coat											
Distance from bottom, in.:				2.19 (55.6 mm)			2.0 (50.8 mm)			1.63 (41.4 mm)	
	4500	No Cracks									
.022 (0.56 mm)	5000	0.08	0.08	0.08	0.05	0.05	0.05	0.07	0.07	0.07	4
	5500	0.12	0.12	0.12	0.08	0.08	0.08	0.12	0.12	0.12	4
	6000	0.13	0.12	0.13	0.08	0.08	0.08	0.12	0.12	0.12	4
	6500	0.15	0.15	0.15	0.09	0.09	0.09	0.14	0.15	0.15	4
	7000	0.15	0.17	0.16	0.10	0.11	0.11	0.17	0.17	0.17	4
	7500	0.17	0.17	0.17	0.10	0.11	0.11	0.17	0.17	0.17	4
Specimen P2: γ/γ'-δ Eutectic											
Distance from bottom, in.:				2.44 (62 mm)							
	6000	No Cracks									
.017 (0.43 mm)	6500	0.01	0.01	0.01							1
	7000	0.01	0.01	0.01							1
	7500	0.01	0.01	0.01							1
Specimen R2: 0.06C γ/γ'-δ Eutectic											
Distance from bottom, in.:				2.06 (52.3 mm)			1.81 (46 mm)			1.75 (44.5 mm)	
	6000	No Cracks									
.017 (0.43 mm)	6500	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	6
	7000	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	5
	7500	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	7
Specimen S1: 0.06C γ/γ'-δ Eutectic + NiCrAlY/Pt Coat											
Distance from bottom, in.:				2.06 (52.3 mm)							
	6000	No Cracks									
.018 (0.46 mm)	6500	0.11	0.11	0.11							1
	7000	0.14	0.14	0.14							1
	7500	0.14	0.14	0.14							1
Specimen T1: MM 200 DS Single Crystal + NiCrAlY/Pt Coat											
Distance from bottom, in.:				2.44 (62 mm)			2.31 (58.7 mm)				
	6000	No Cracks									
.024 (0.61 mm)	6500	0.06	0.05	0.06							1
	7000	0.06	0.05	0.06							1
	7500	0.07	0.05	0.06	0.06	0.01	0.04				2
Specimen P1: γ/γ'-δ Eutectic											
Distance from bottom, in.:				2.0 (50.8 mm)			2.31 (58.7 mm)				
.030 (0.76 mm)	7000	No Cracks									
	7500	0.01	0.01	0.01	0.01	0.01	0.01				2

Table 12

SUMMARY OF LONGITUDINAL CRACK PROPAGATION FOR GROUP 2 EUTECTIC SPECIMENS

Number of Cycles	Average Longitudinal Crack Length, mm[a]							
	γ/γ'-δ		γ/γ'-δ + NiCrAlY/Pt Coated		γ/γ'-δ (0.06C)		γ/γ'-δ (0.06C) + NiCrAlY/Pt Coated	
	P1 Top/Bot.	P2 Top/Bot.	Q1 Top/Bot.	Q2 Top/Bot.	R1 Top/Bot.	R2 Top/Bot.	S1 Top/Bot.	S2 Top/Bot.
200[b]	12.7/ 9.9	2.5/11.4	2.8/ 3.8	9.4/ 4.8	5.6/ 2.0	5.6/ 1.5	10.9/ 4.8	4.8/ 1.8
1000	15.0/ 6.4	5.6/14.7	7.8/ 8.1	17.3/ 8.1	8.6/ 6.4	9.5/ 7.9	15.0/ 7.8	7.9/ 7.8
1500	21.6/16.5	7.1/16.6	10.7/ 8.9	18.5/10.8	10.9/ 6.4	10.9/10.9	16.5/ 8.4	9.1/ 9.1
2000	21.8/16.6	9.9/19.8	13.5/11.4	20.2/13.5	12.3/10.3	11.9/13.1	17.4/11.1	10.3/11.5
2500	22.2/18.6	10.7/19.8	16.3/11.9	21.8/14.7	12.7/11.5	12.3/11.9	19.1/13.5	11.5/12.3
3000	23.0/19.4	11.9/20.6	16.3/13.1	22.2/15.5	12.7/12.7	12.3/11.9	19.1/13.5	11.5/12.7
3500	24.2/19.8	11.9/22.2	16.6/13.5	22.6/15.9	13.1/12.7	13.9/12.3	19.8/13.5	11.5/13.1
4000	25.8/20.2	12.7/22.2	18.2/13.9	23.4/16.3	13.5/14.3	13.9/14.7	20.6/13.5	11.9/14.3
4500	25.8/20.6	13.1/22.6	19.1/15.5	24.2/16.6	13.9/15.1	16.3/14.7	20.6/15.5	12.3/15.5
5000	25.8/21.4	13.1/23.8	19.8/15.5	24.2/16.6	14.7/15.1	17.0/15.1	20.6/15.5	12.3/15.5
5500	25.8/21.4	13.5/24.6	20.6/15.9	25.0/17.4	15.9/16.3	17.0/16.3	21.4/15.5	12.7/17.0
6000	25.8/21.4	13.9/24.6	20.6/15.9	25.0/17.4	16.3/16.3	18.6/16.3	21.8/16.3	12.7/17.0
6500	26.2/21.4	13.9/25.4	20.6/15.9	25.0/17.9	16.3/16.6	19.1/16.3	21.8/16.3	13.1/17.0
7000	26.2/22.2	14.3/25.8	21.0/16.3	25.4/17.9	16.3/16.6	19.1/17.4	21.8/16.3	13.1/17.4
7500	26.6/22.2	14.3/26.2	21.4/16.3	25.8/17.9	17.0/17.0	19.1/17.4	21.8/16.3	13.1/17.4

[a]Average crack length calculated from two scale measurements.

[b]Cyclic exposure with first observable longitudinal cracks.

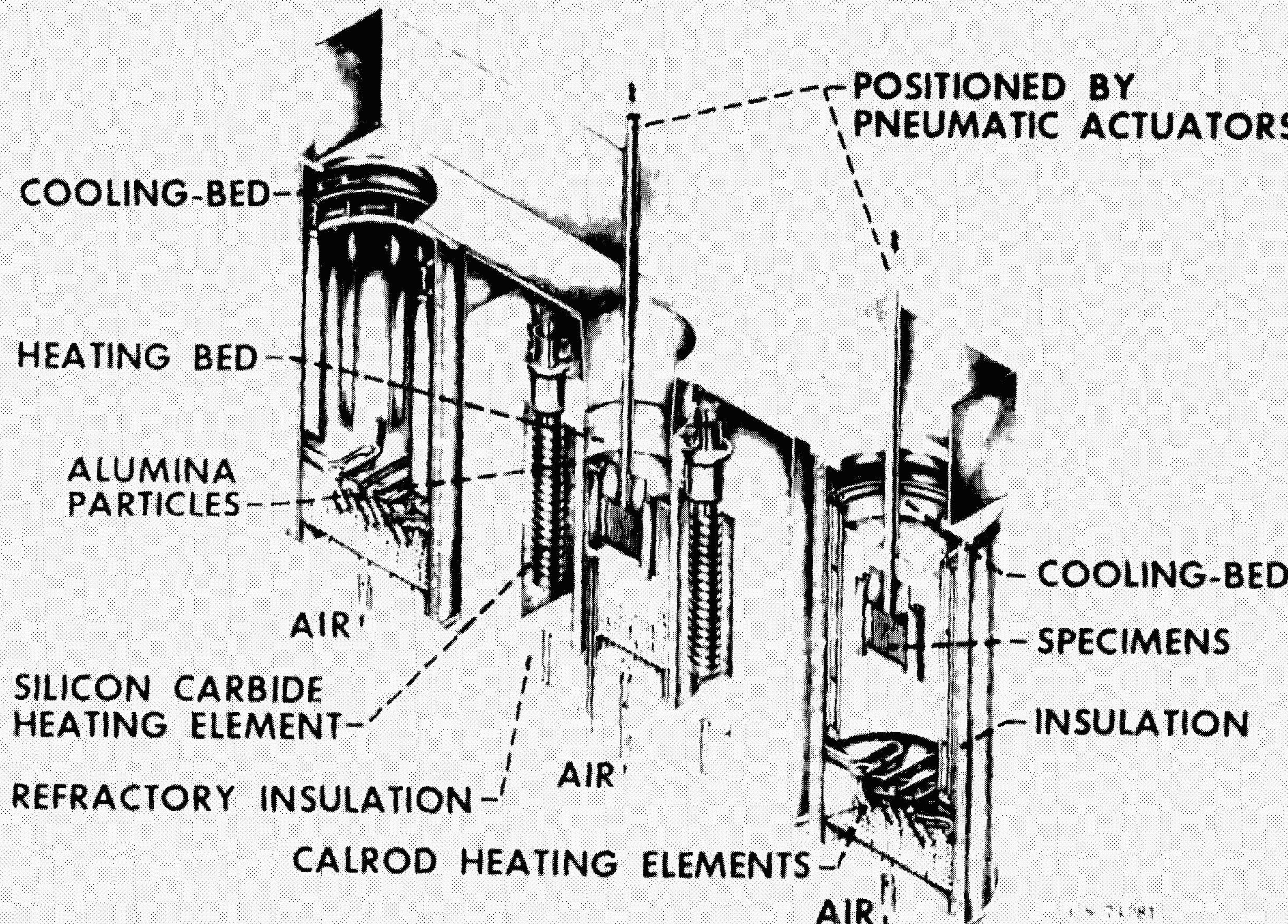
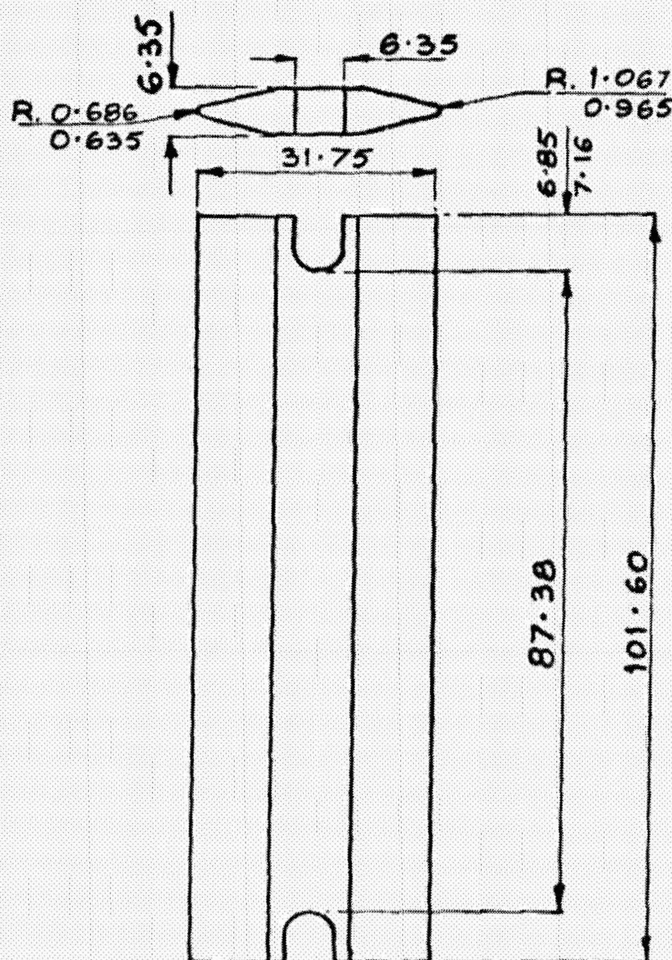
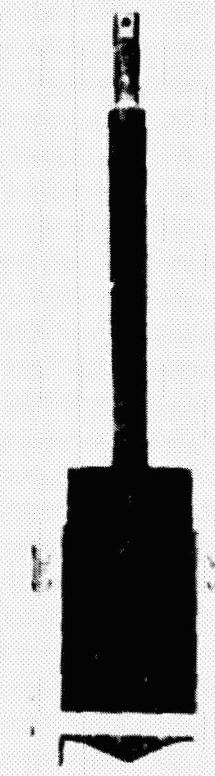


Figure 1
Fluidized Bed Thermal Fatigue Facility



Double-Edge Wedge Specimen
(dimensions in mm)



Neg. No. 45935 X 1/12

Holding Fixture

Figure 2

Double-Edge Wedge Test Specimen and **Holding Fixture**

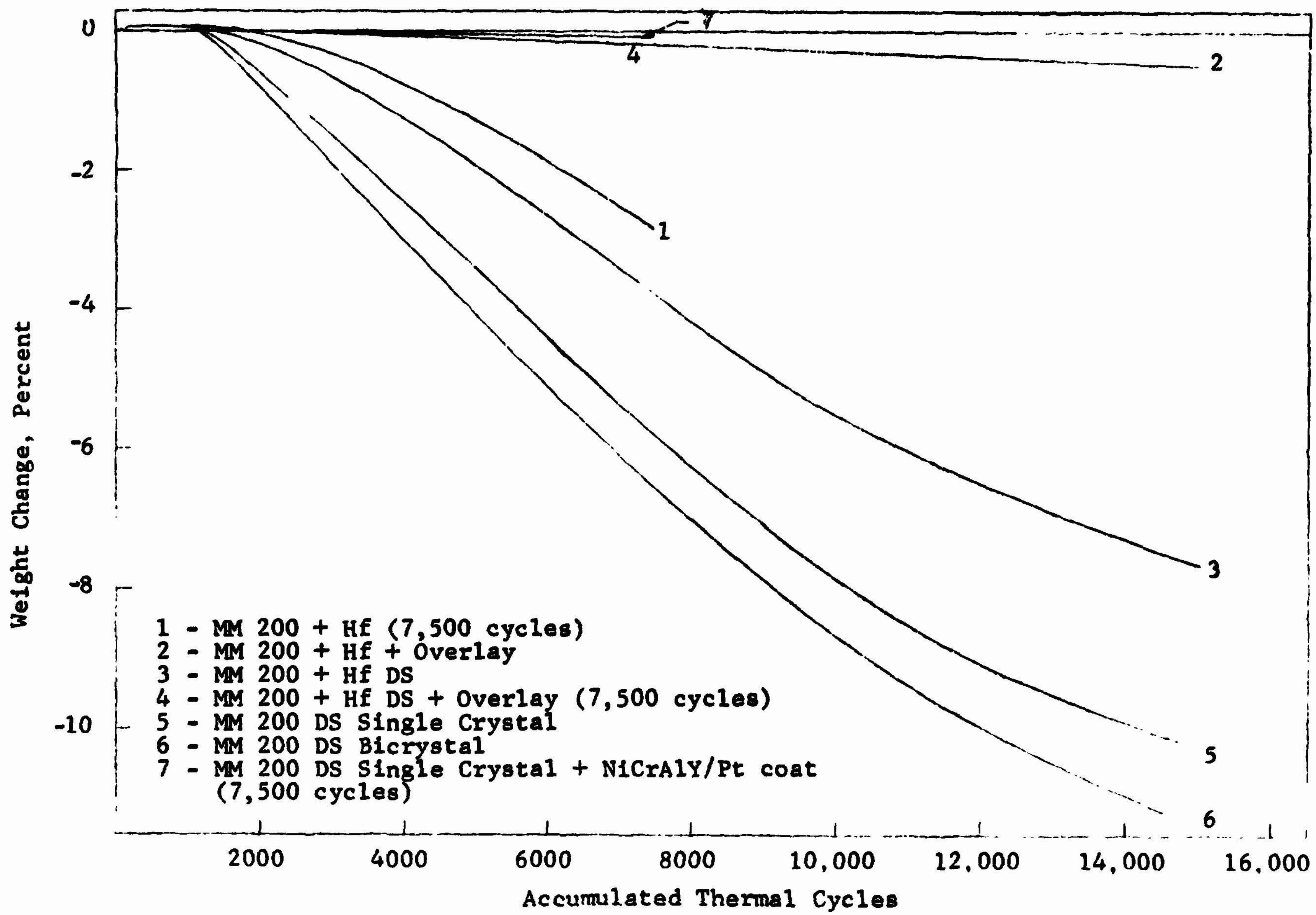


Figure 3

Percent Weight Change versus Accumulated Cycles for Coated and Uncoated MM 200

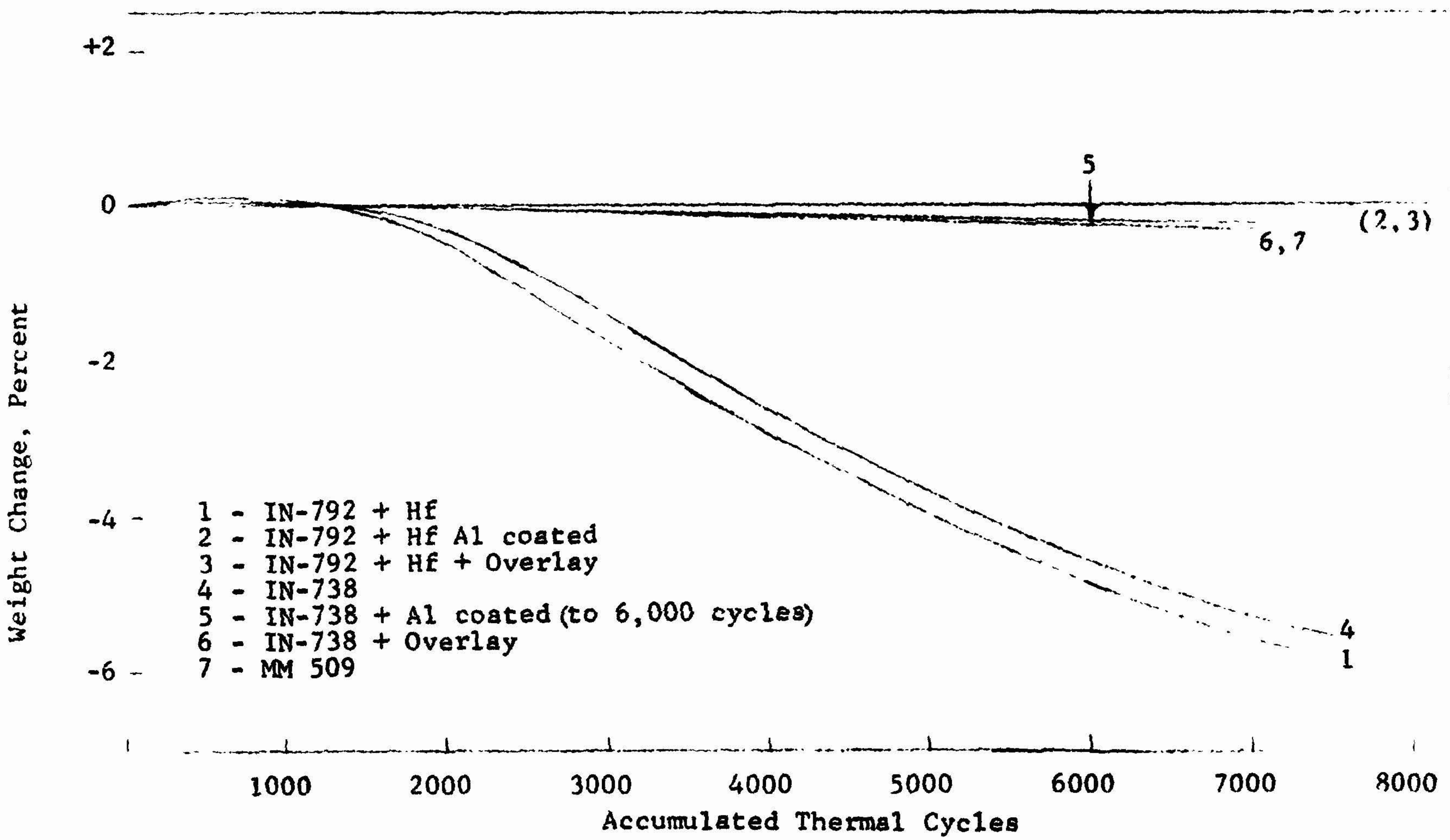


Figure 4

Percent Weight Change versus Accumulated Cycles for Coated and Uncoated IN-738, IN-792 + Hf, and MM 509

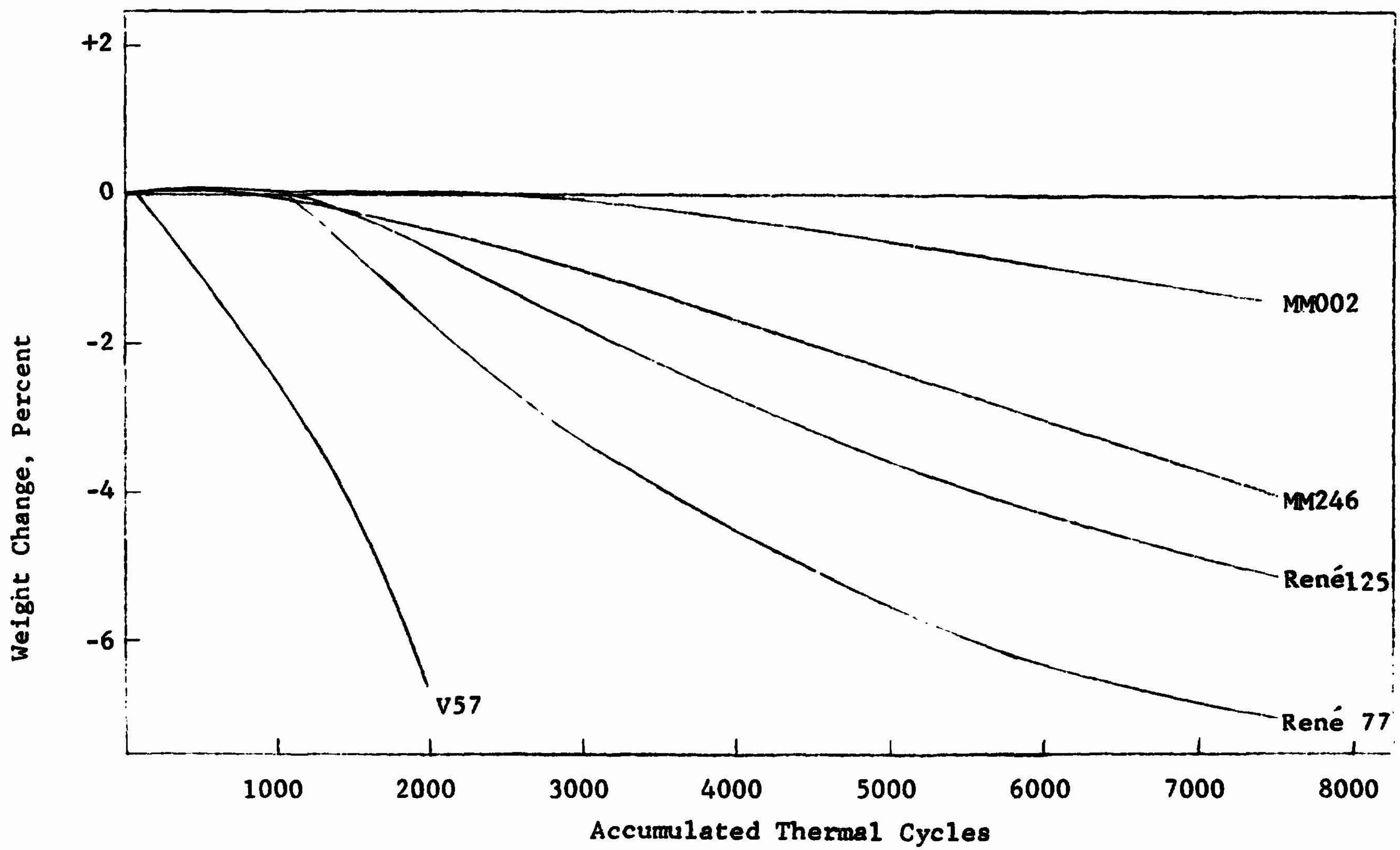


Figure 5

Percent Weight Change versus Accumulated Cycles for Uncoated Superalloys

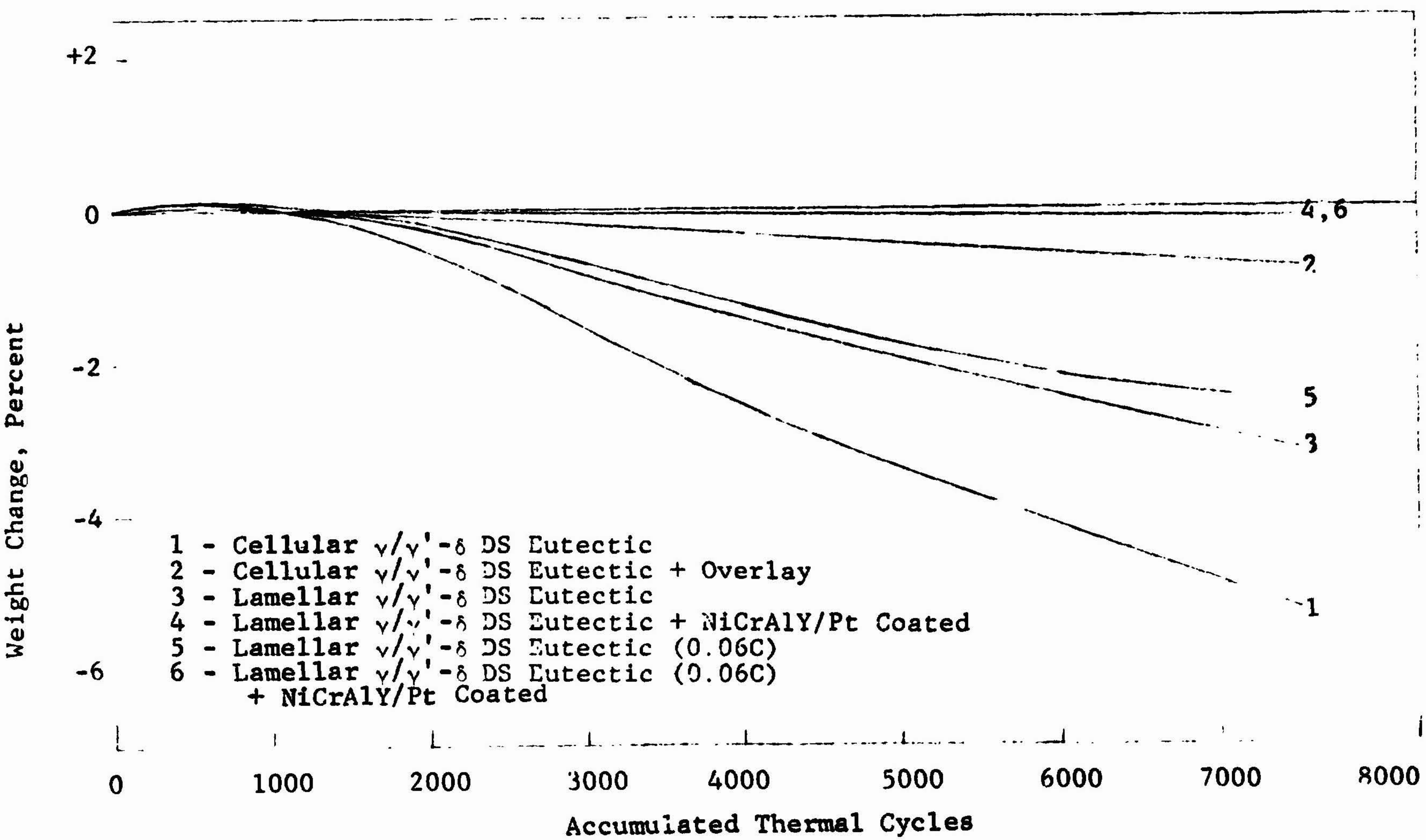
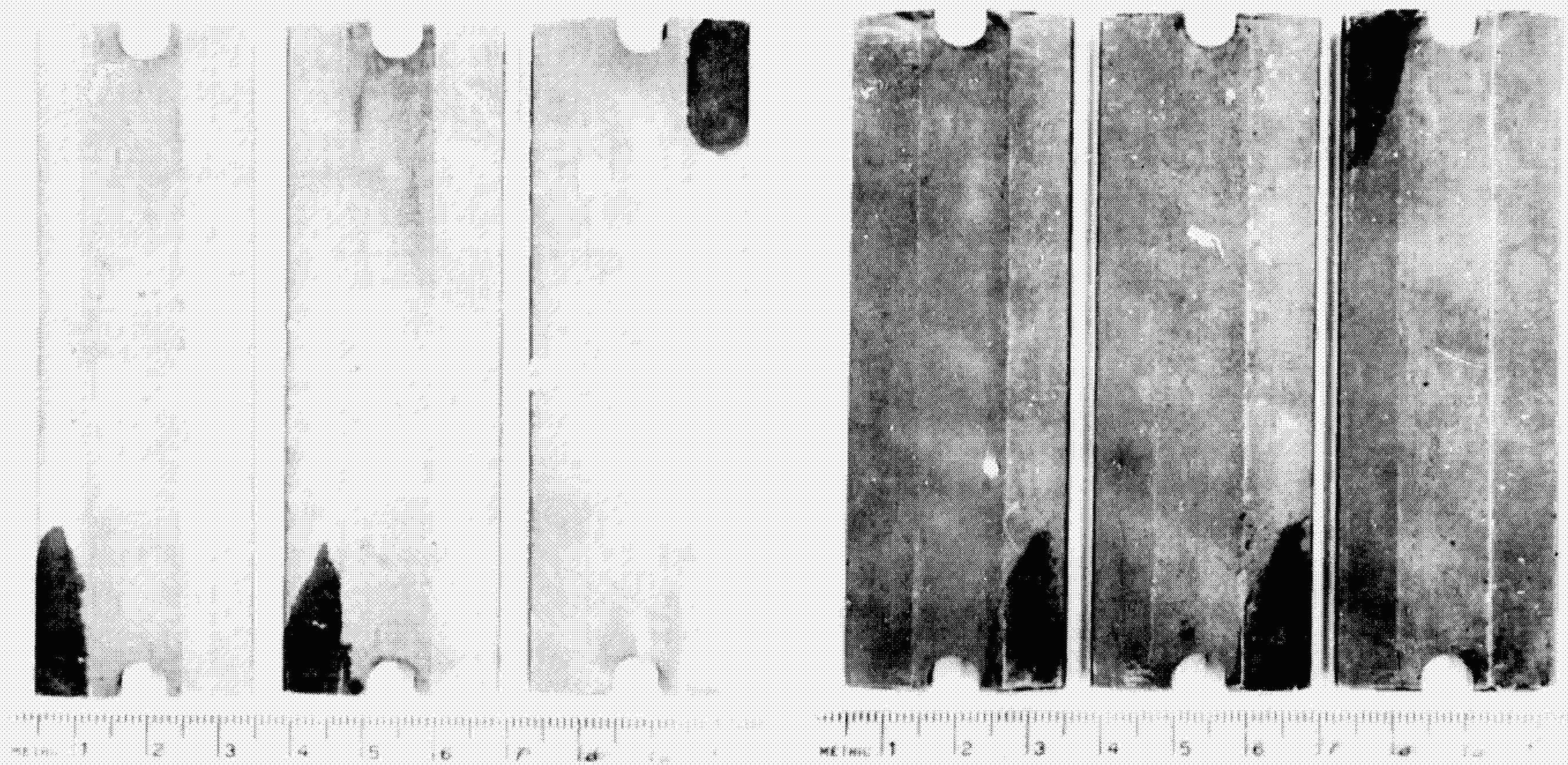


Figure 6

Percent Weight Change versus Accumulated Thermal Cycles for Coated and Uncoated $\gamma/\gamma'-\delta$ DS Eutectic Alloys



Neg. No. 44526 1X

V1 V2 V5

(a) V 57

Neg. No. 44520 1X

Y1 Y2 Y4

(b) René 77

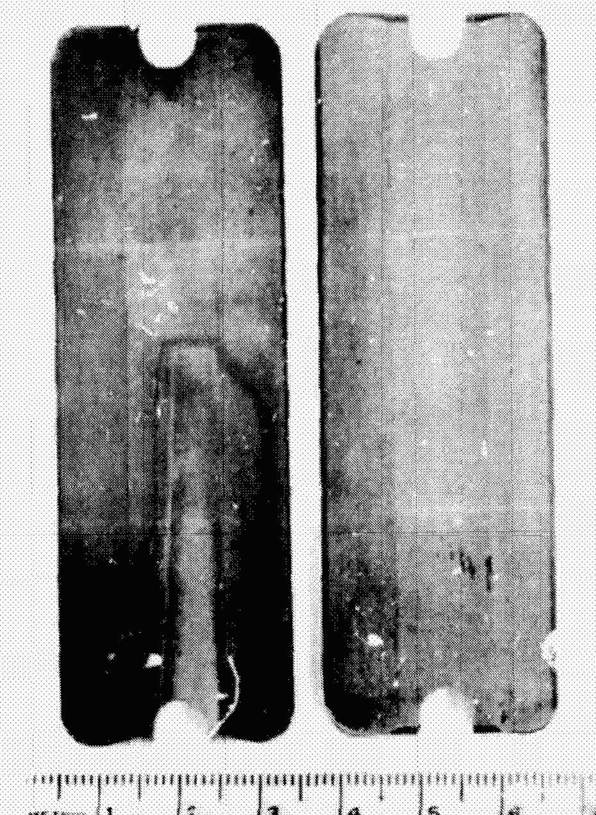
Figure 7

Typical Appearance of Conventionally Fabricated Superalloy Double-Edge Wedge Specimens As-Received

Neg. No. 44534 1X

P1 P2

(a) DS $\gamma/\gamma'-\delta$ eutectic (lamellar)



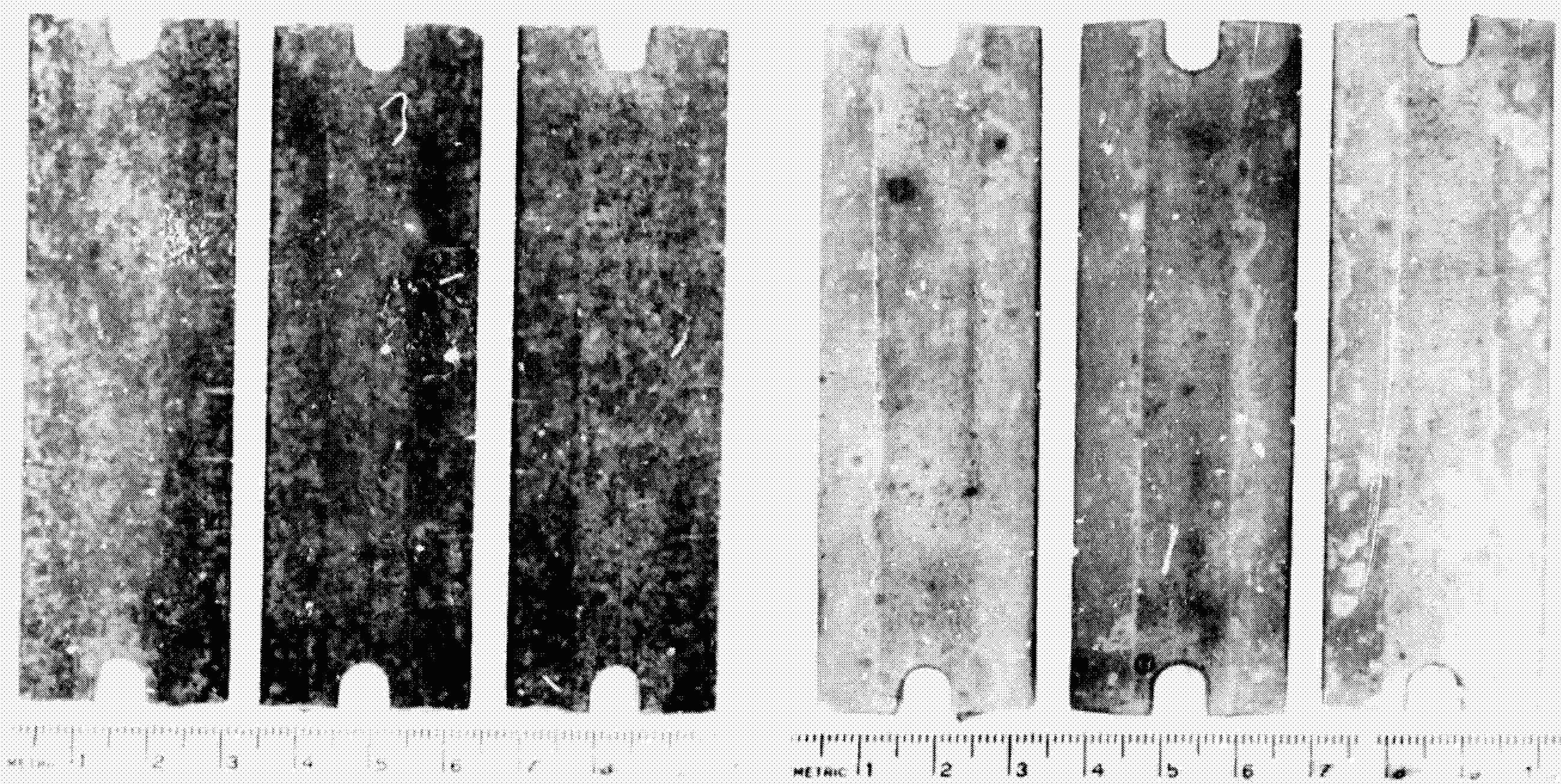
Neg: No. 44532 1X

S1 S2

(b) DS $\gamma/\gamma'-\delta$ eutectic (0.06C) (lamellar) + NiCrAlY/Pt coating

Figure 8

Typical Appearance of DS $\gamma/\gamma'-\delta$ Eutectic Double-Edge Wedge Specimens As-Received



Neg. No. 43712 1X

A1 A2 A3

(a) MM 200 + Hf, 7,500 cycles

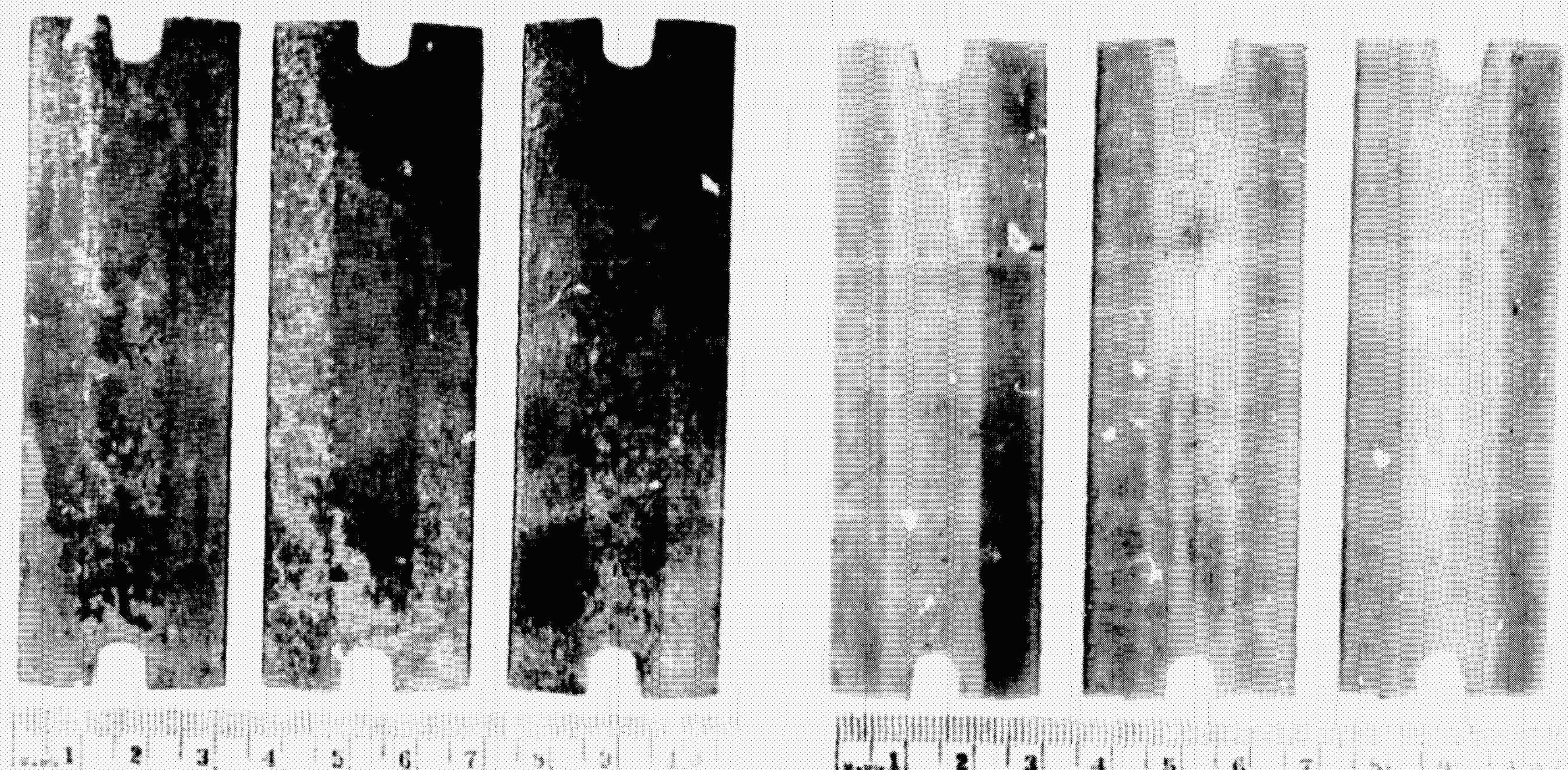
Neg. No. 45139 1X

B5 B2 B1

(b) MM 200 + Hf + overlay, 15,000 cycles

Figure 9

Appearance of MM 200 + Hf after Indicated Thermal Cycles



Neg. No. 45138 1X

C5 C2 C1

(a) MM 200 + Hf DS, 15,000 cycles

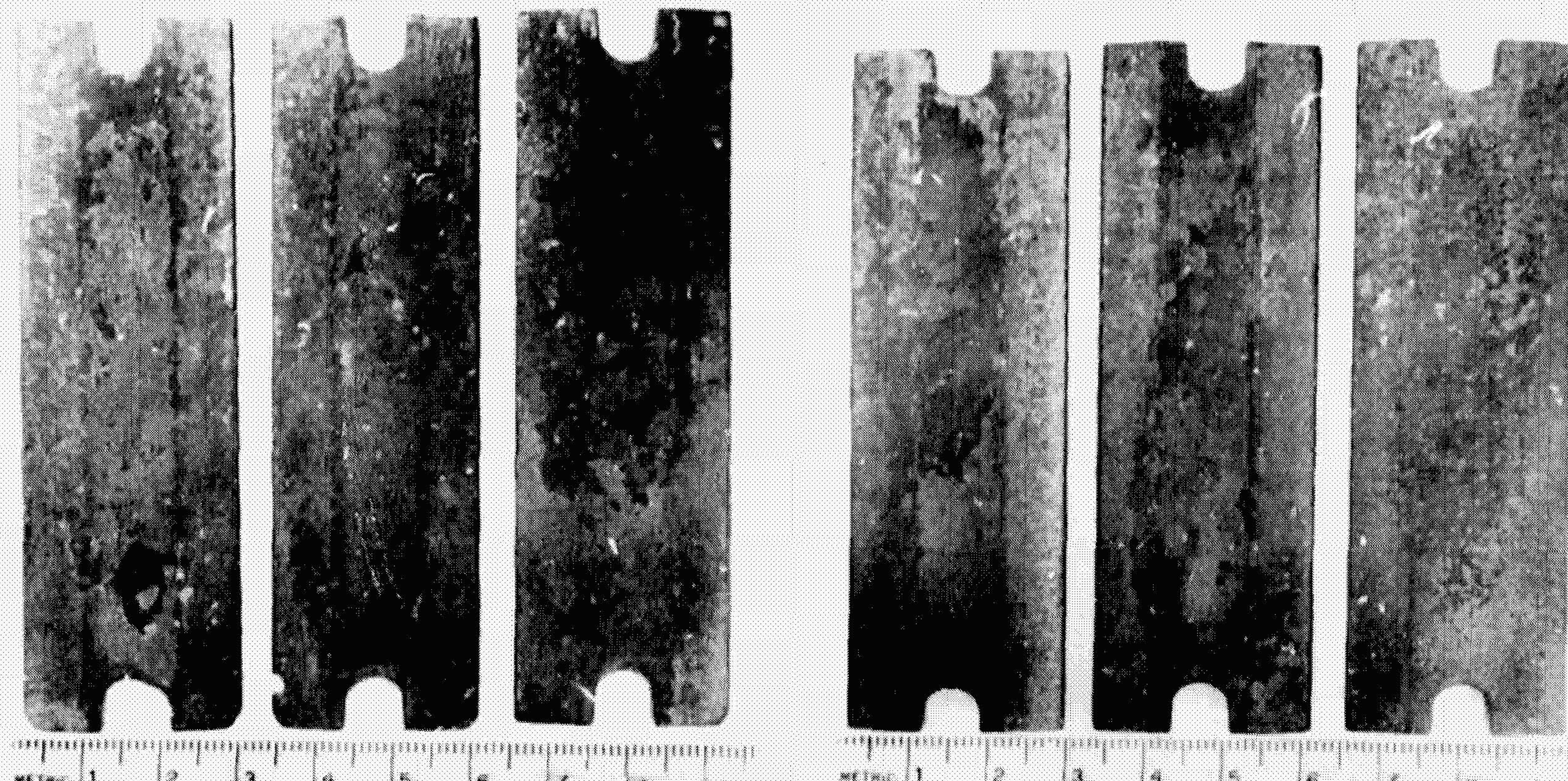
Neg. No. 43709 1X

D2 D3 D5

(b) MM 200 + Hf DS + overlay. 7,500 cycles

Figure 10

Appearance of MM 200 + Hf DS after Indicated Thermal Cycles



Neg. No. 45137 1X

E3 E2 E1

(a) MM 200 DS single crystal

Neg. No. 45140 1X

F5 F2 F1

(b) MM 200 DS bicrystal

Figure 11

Appearance of Directionally Solidified MM 200 after 15,000 Thermal Cycles

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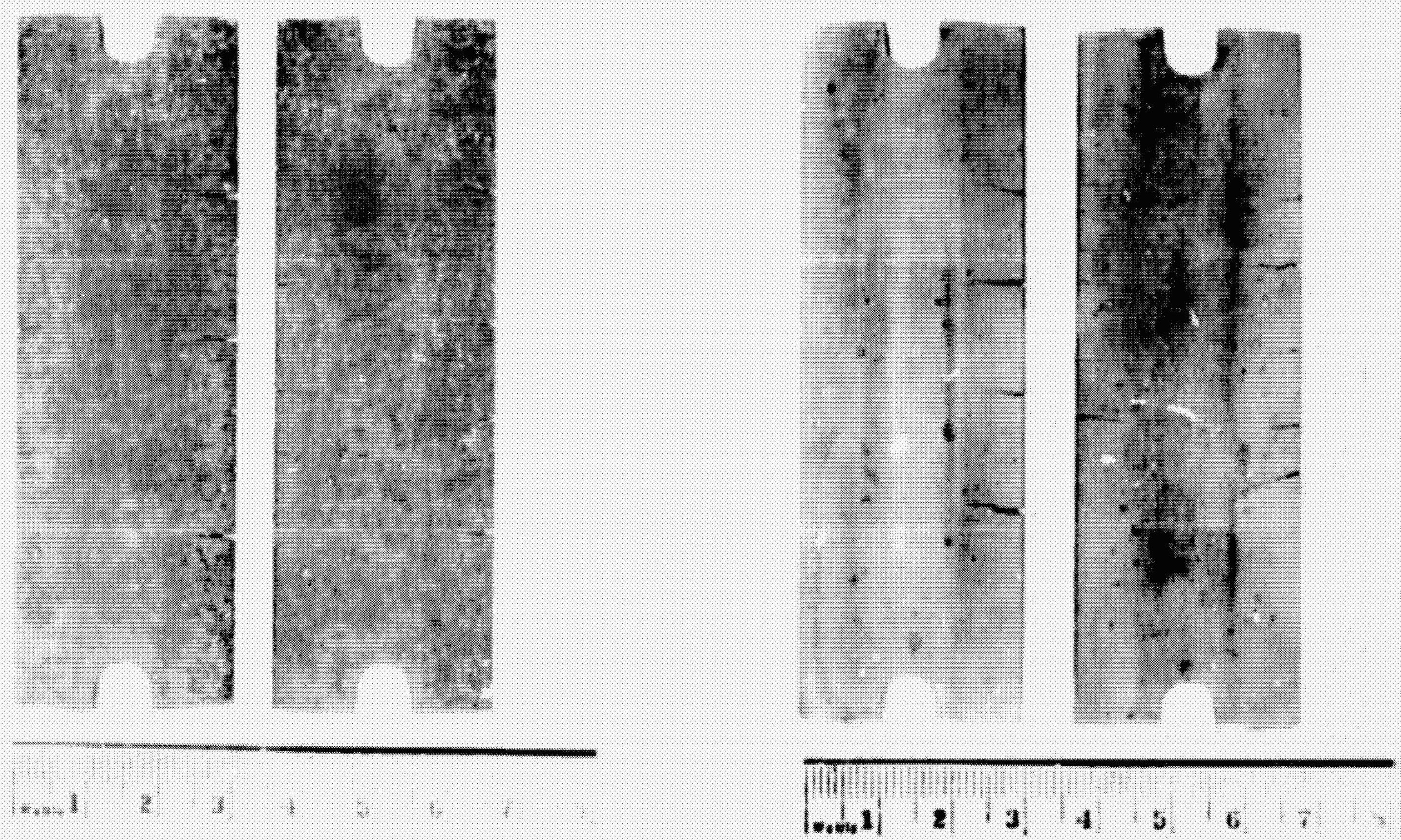


Neg. No. 43720 1X

G2 G3

(a) IN-792 + Hf

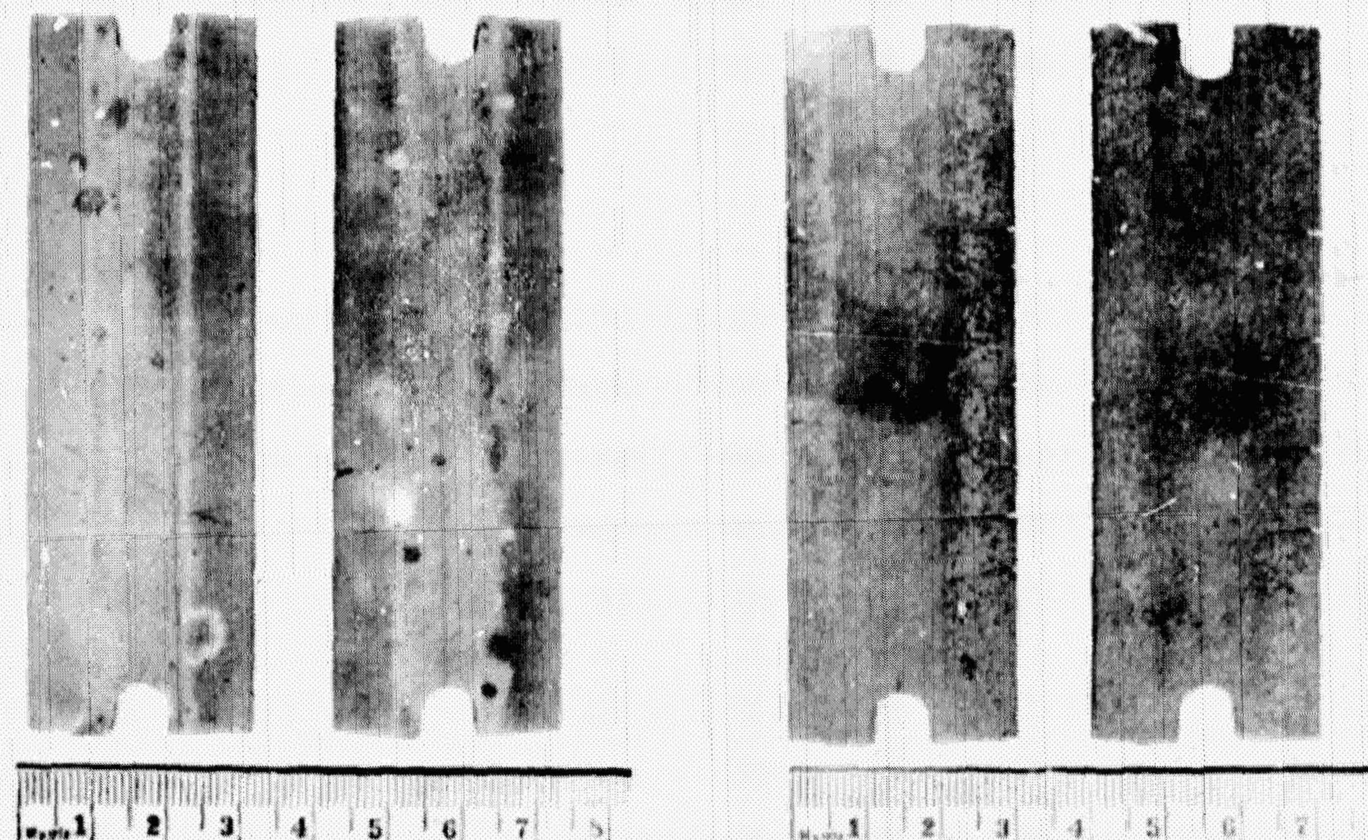
Neg. No. 43719 1X

H2 H3

(b) IN-792 + Hf + Al coating

Figure 12

Appearance of IN-792 + Hf after 7,500 Thermal Cycles



Neg. No. 43718 1X

I1 I3

(a) IN-792 + Hf + overlay

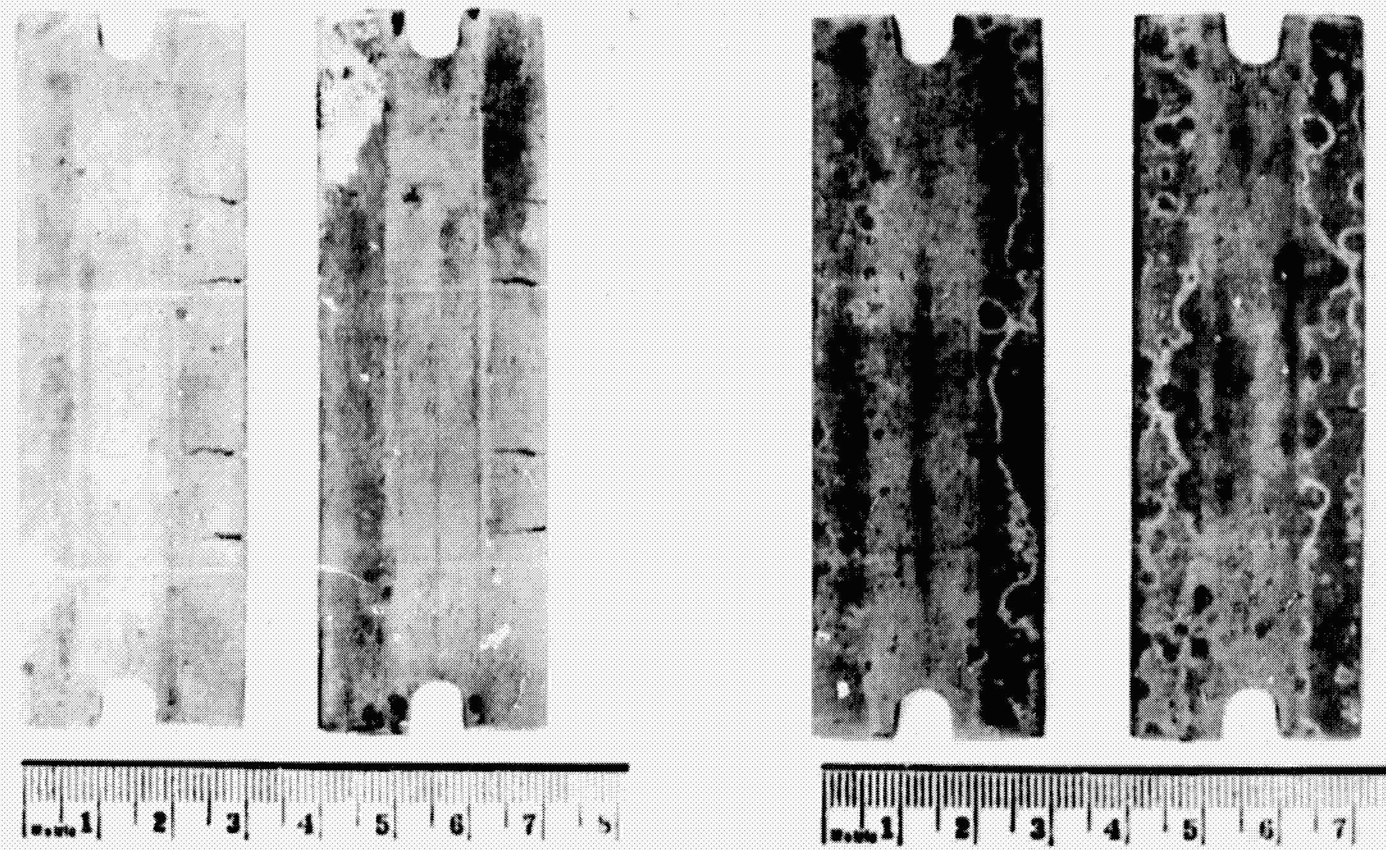
Neg. No. 43717 1X

J2 J5

(b) IN-738

Figure 13

Appearance of IN-792 + Hf and IN-738 after 7,500 Thermal Cycles



Neg. No. 43716 1X

K2 K5

(a) IN-738 + Al coating, 6,000 cycles

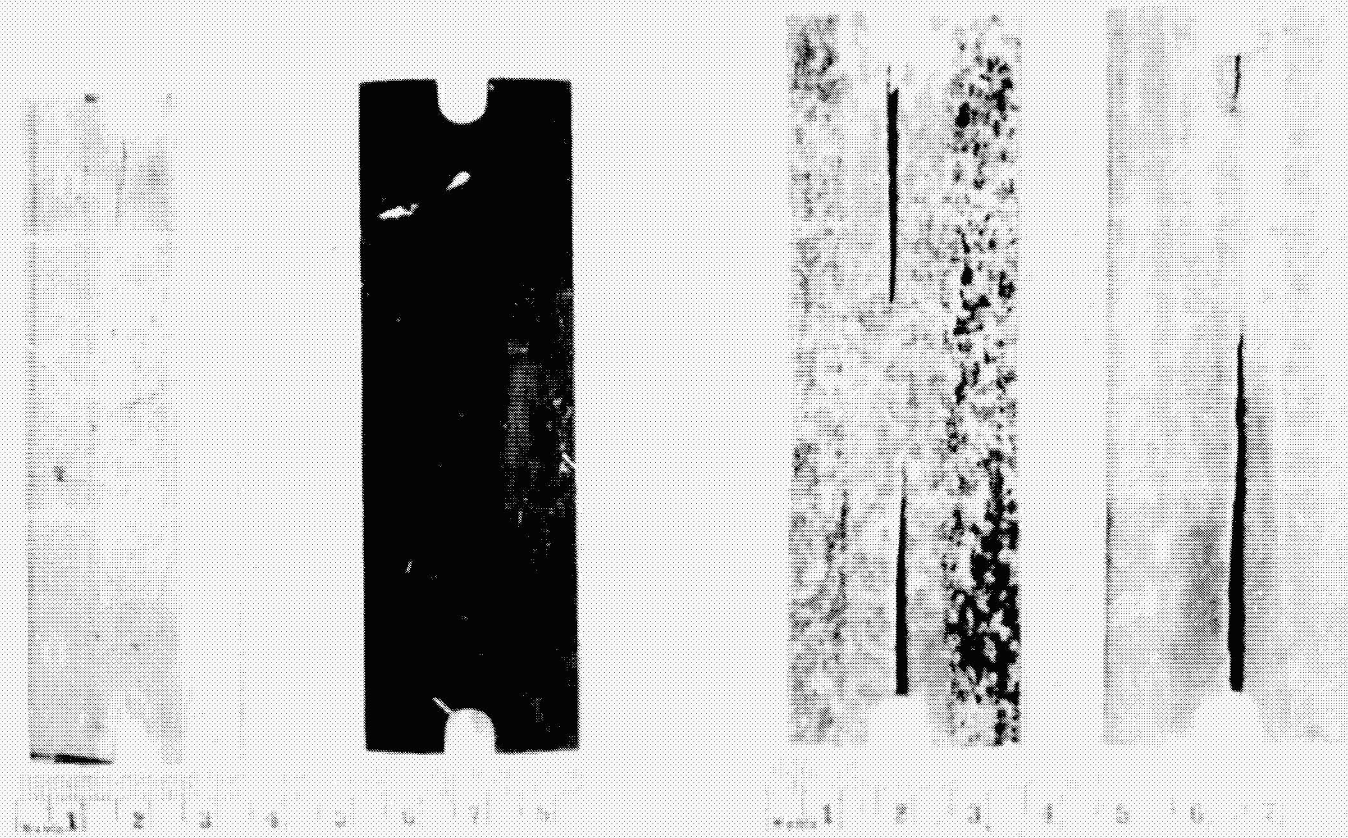
Neg. No. 43715 1X

L1 L3

(b) IN-738 + overlay, 7,500 cycles

Figure 14

Appearance of Coated IN-738 after Indicated Thermal Cycles



Neg. No. 42737 1X

O2 N2

(a) 100 cycles

Neg. No. 43713 1X

N1 O1

(b) 7,500 cycles

Figure 15

Appearance of γ/γ'-δ Eutectic (N1, N2) and γ/γ'-δ Eutectic + Overlay (O1, O2) after Indicated Thermal Cycles

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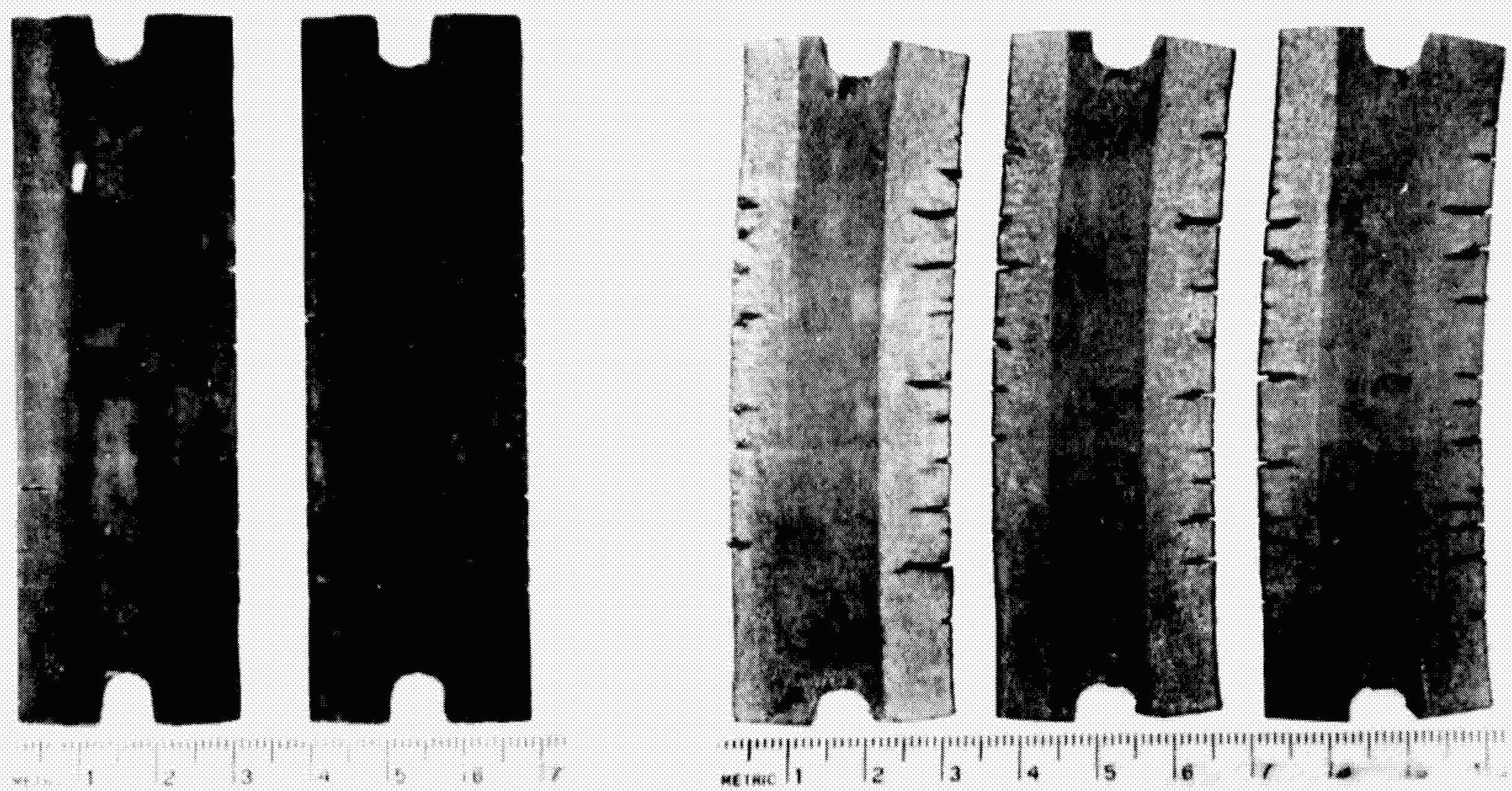


Neg. No. 43714 1X

M1 M2

(a) MM 509, 7,500 cycles

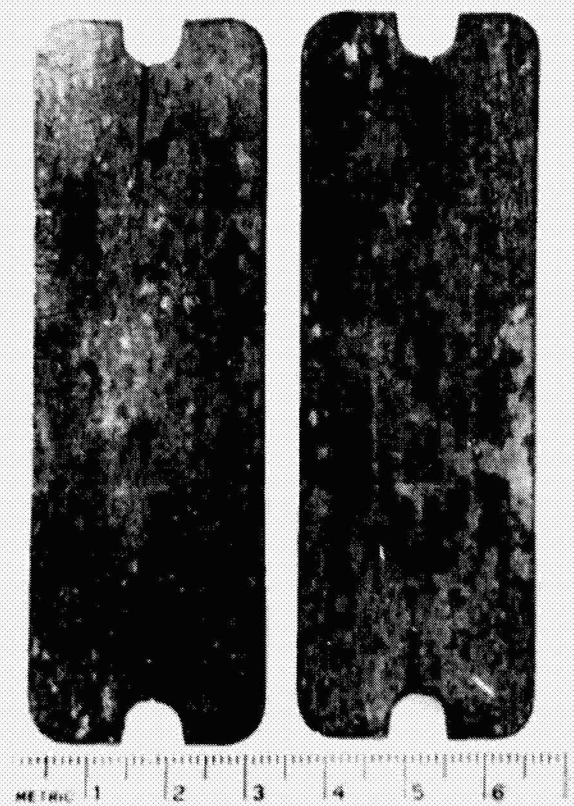
Neg. No. 45133 1X

V5 V3 V1

(b) V57, 2,000 cycles

Figure 16

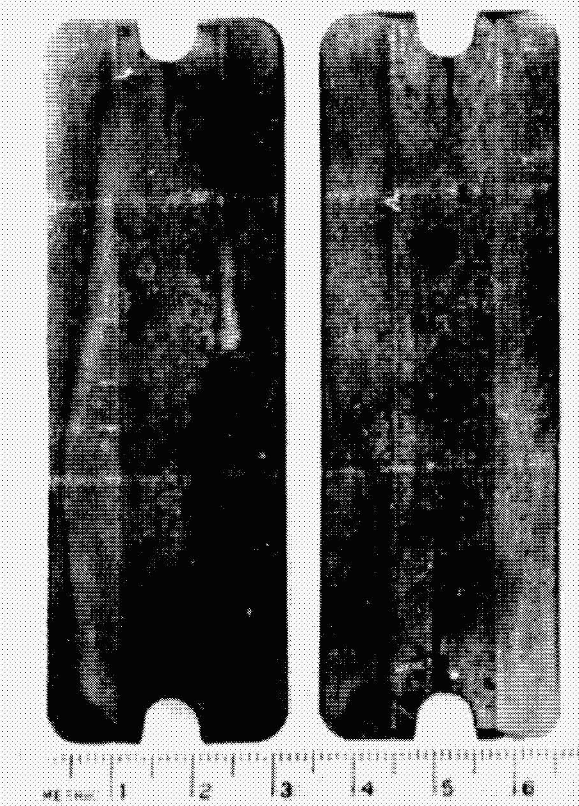
Appearance of MM 509 and V57 after Indicated Thermal Cycles



Neg. No. 45128 1X

P2 P1

(a) γ/γ'-δ eutectic (lamellar)



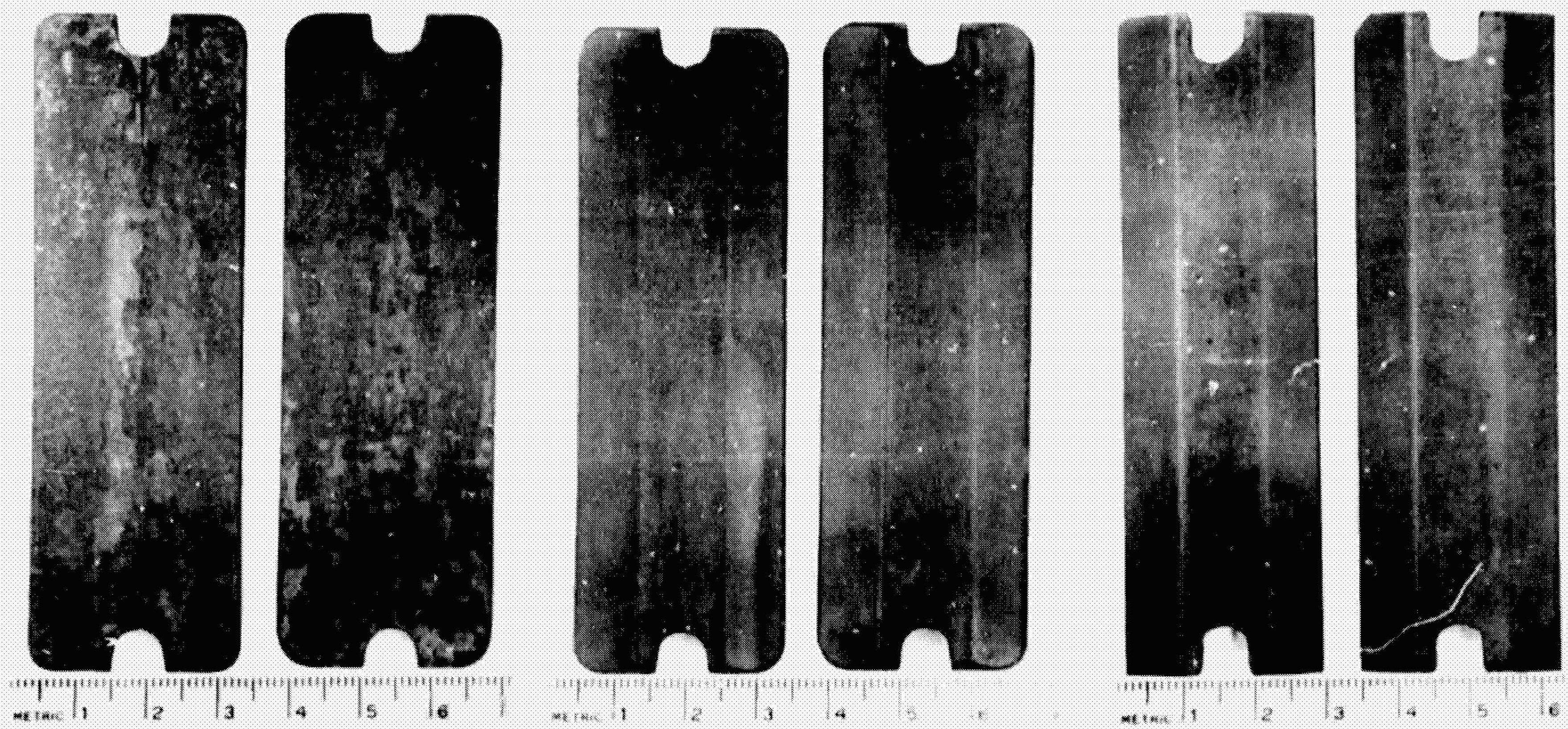
Neg. No. 45131 1X

Q2 Q1

(b) γ/γ'-δ eutectic (lamellar) + NiCrAlY/Pt coating

Figure 17

Appearance of Coated and Uncoated γ/γ'-δ Eutectic after 7,500 Thermal Cycles



Neg. No. 45132 1X

R2 R1

(a) γ/γ'-δ eutectic (0.06C)

Neg. No. 45130 1X

S2 S1

(b) γ/γ'-δ eutectic (0.06C) + NiCrAlY/Pt coating

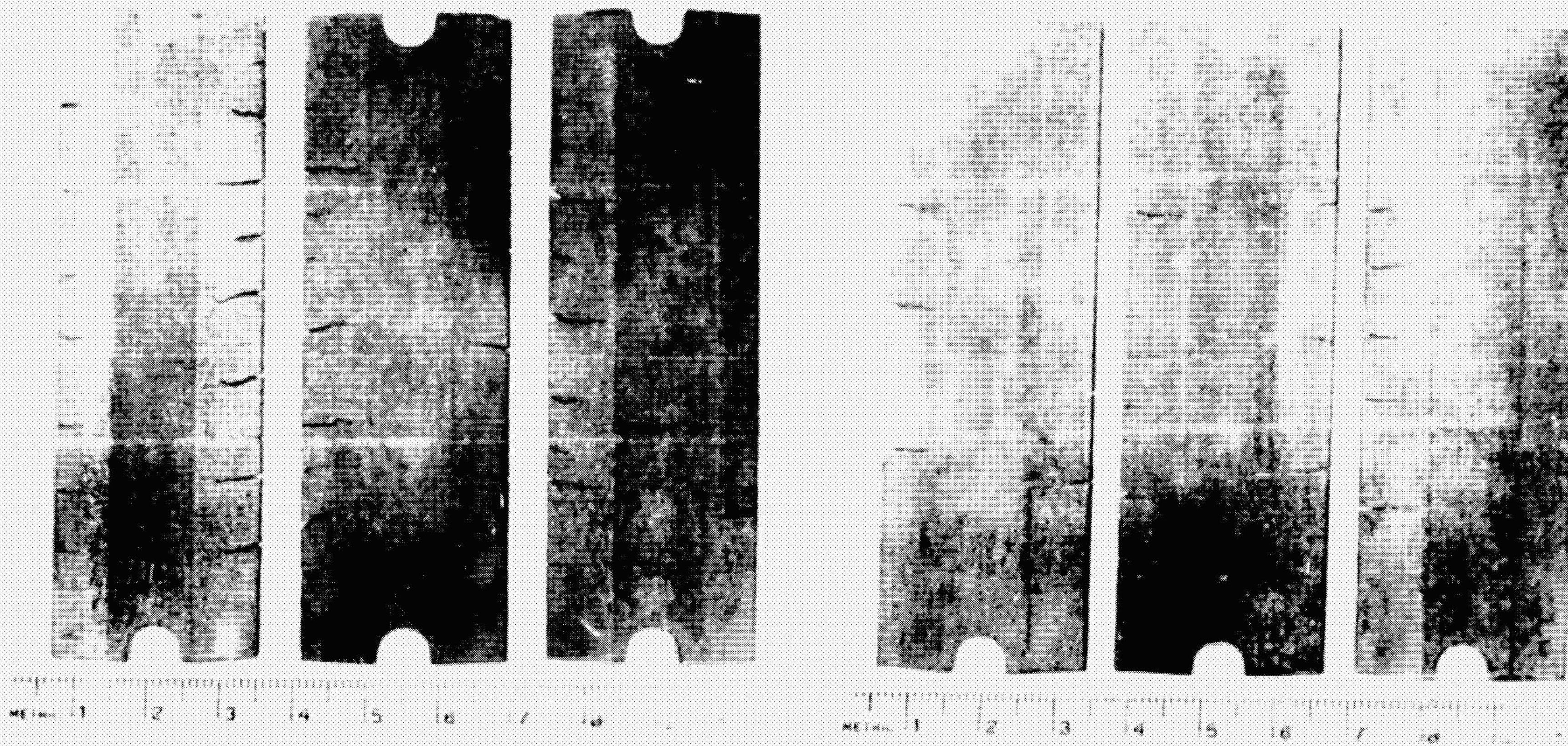
Neg. No. 45129 1X

T2 T1

(c) MM 200 DS + NiCrAlY/Pt coating

Figure 18

Appearance of Coated and Uncoated γ/γ'-δ Eutectic (0.06C) and Coated MM 200 DS after 7,500 Thermal Cycles



Neg. No. 45135 1X

Y4 Y2 Y2

(a) René 77

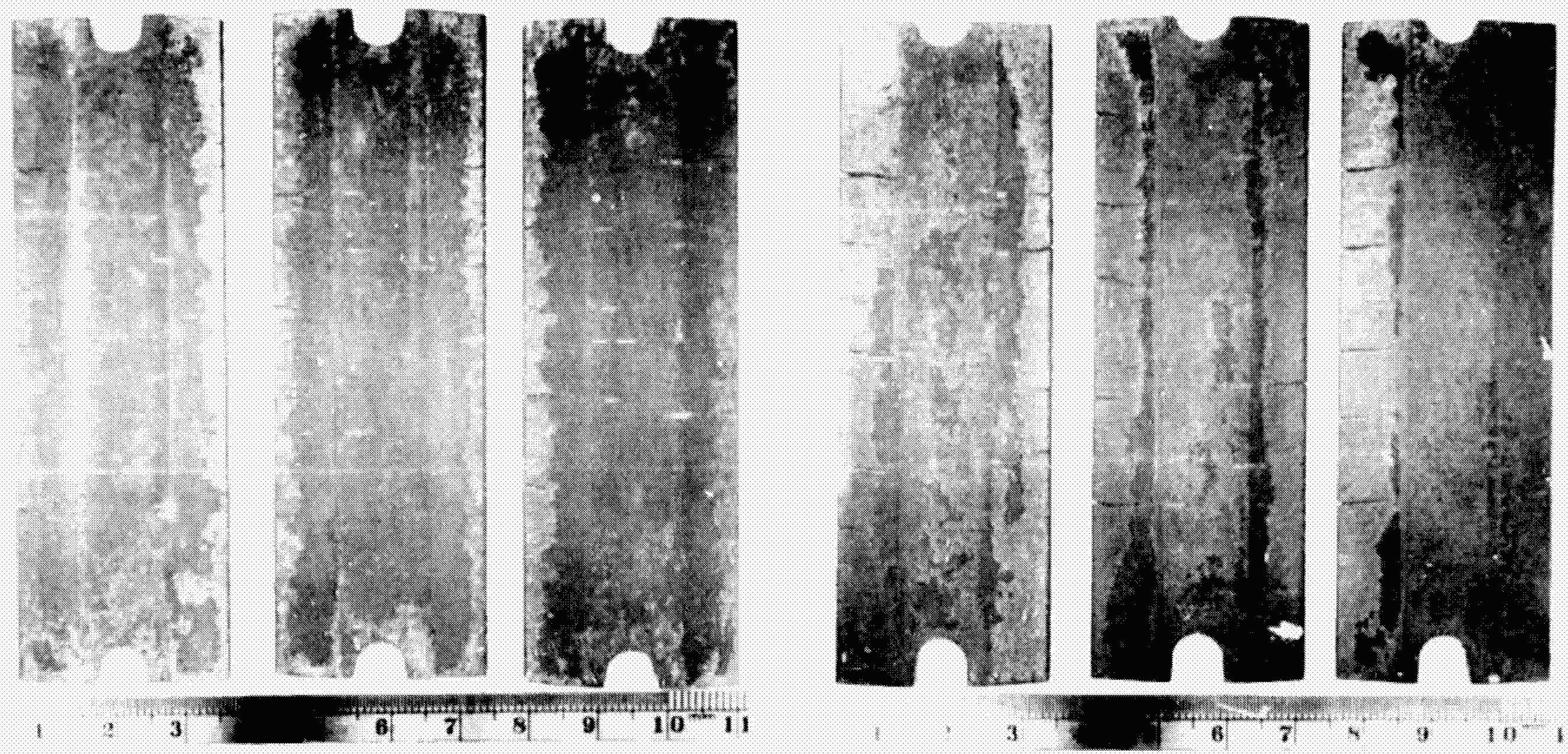
Neg. No. 45141 1X

Z6 Z3 Z2

(b) René 125

Figure 19

Appearance of René 77 and René 125 after 7,500 Thermal Cycles



Neg. No. 45134 1X

W3 W2 W1

(a) MM 002

Neg. No. 45136 1X

X5 X2 X1

(b) MM 246

Figure 20

Appearance of MM 002 and MM 246 after 7,500 Thermal Cycles