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STRESS CORROSION CRACKING IN HIGH STRENGTH FERROUS ALLOYS

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GENERAL DYNAMICS | FORT WORTH

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STRESS CORROSION CRACKING IN HIGH STRENGTH FERROUS ALLOYS

by

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STRESS CORROSION CRACKING IN HIGH STRENGTH FERROUS ALLOYS

ABSTRACT

This paper describes tests performed to investigate the stress corrosion cracking of AISI Type 4340 steel in the 260,000- to 292,000 psi strength range. Various protective coatings were evaluated comparatively on the basis of a sustained axial tensile load equivalent to 70% of the ultimate strength. Round,tensile-type specimens tested the coatings as applied to a machined or shot-peened surface by alternate immersion in 5% salt water.

The results indicated that the peened surface had more resistance to cracking than the machined surface. Electro-deposited silver and copper increased the susceptibility as did electroless nickel, vapor-deposited aluminum, and dry film lubricant. A patented Electrolized plate, a silicone paint, and a flame sprayed aluminum coating provided good corrosion protection for the machined surface. Nickel-cadmium diffusion coating provided satisfactory protection at a lower strength level. Erratic results were obtained when some of the coatings were applied to specimens cut from a forging.

Bent beam specimen tests determined the effects of anodic and cathodic metals in contact with AISI 4340. Results revealed that contact with anodic metals increased slightly the resistance to stress corrosion cracking.

INTRODUCTION

Much has been said about the use of high strength steels in the components of supersonic aircraft and missiles. Designers strive to achieve the optimum combination of physical and mechanical properties. Strength and strength-to-weight ratio receive careful consideration, as do fatigue strength and elevated temperature properties. But the stress corrosion and stress corrosion cracking characteristics of materials, as defined by Williams,[1] often leave the designer in a quandary.

Tables of data for the relative corrosion resistance of metals and alloys are readily available from the producers of metal products and from corrosion and metal handbooks.[2,3] These data spotlight the areas of potential corrosion problems, but usually considerable service experience is required to disclose unexpected hazards. To test the multitude of environments to which metals may be subjected during a service life would be prohibitive; and then too, the temper selected for the test specimens might be other than that of the proposed component.

Such was the case for the AISI 4340 steel forging which precipitated this investigation. Stress corrosion cracking at strengths below 200,000 psi is not normally considered problematical,[4] but in the 260,000 to 292,000 psi range there was precious little knowledge about this alloy. Catastrophic failures appeared from apparently inextricable circumstances.

Recently the problem of stress corrosion cracking required expeditious remedial action. The laboratory tests presented by this paper were designed to find a suitable method for protecting the 4340 steel forging from stress corrosion cracking. The results of these accelerated tests provided some temporary solutions to the problem. Simultaneously, a program was planned, and is now in progress, for a more complete evaluation of several ultra high-strength materials and their susceptibility to stress corrosion cracking.

SPECIMENS

Initially, stress corrosion data was gathered on round, tensile-type specimens cut from the forged part. Later the same type specimens were made from mill rolled rod stock of AISI 4340* and 17-4PH** type steels. All the specimens were longitudinal, including those from the forgings. Analytically, the forgings conformed to the specifications for an air melted AISI 4340 steel, MIL-S-5000A(2).

With respect to the forged billet, the specimens were taken at about mid-radius. The thin wall of the finished part limited the specimen diameter to 5/16 inch. To preserve the manufacturer's heat treatment, the Type A configuration, Figure 1, was machined from the fully hardened forging. The Type B configuration replaced the first design because a uniform diameter in the reduced section was difficult to maintain. The continuous surface

* MIL-S-5000
** AMS 5643

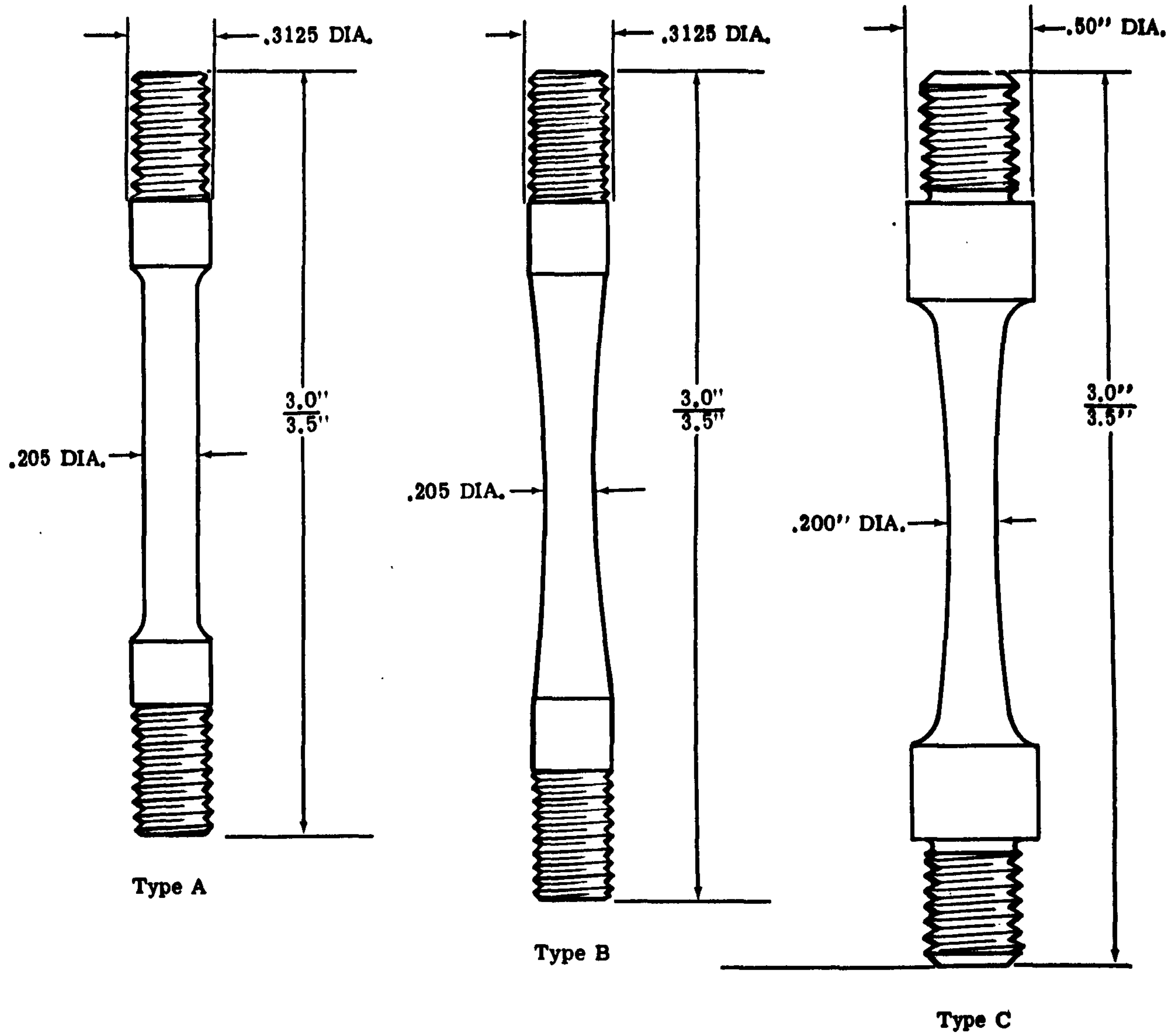

Figure 1 STRESS CORROSION SPECIMEN DESIGNS

of the Type B test section made it easier to remove tool marks during the polishing operation. Unfortunately, the Type B specimen was more rigid and the slightest bending stresses were concentrated in the threads. Thread failures were more frequent in the Type B specimen, even though an adequate thread relief cut was made in the shoulder.

Specimens prepared for the subsequent materials evaluation program have the Type C configuration. Thread failures have been eliminated.

HEAT TREATMENT

As mentioned, the specimens from the forging were not reheat treated, but were stress relieved by baking at 375°F for from 2 to 4 hours before the stress corrosion tests.

All the rod and sheet specimens were heat treated according to MIL-H-6875B and were tempered at 400°F. The excess material left on the test section diameter for heat treatment was removed between the first and second draws. Polishing, after the second draw, was followed by a stress relief at 375°F. Four groups of rod stock specimens were heat treated as batches and the average tensile strength for each is recorded in Table 1.

The 17-4PH specimens were aged to the H900* condition and polished. Some AISI 4340 was also tested after tempering at 800°F.

* Mill solution treated plus 1 hr - 900 F.

TABLE 1

ULTIMATE TENSILE STRENGTH

Item	Average Tensile Strength - psi
AISI 4340 (800°F draw)	216,000
PH 17-4 (Condition H 900)	210,000
AISI 4340 Forged Part Specimens	
S/N 5A 33 (1)	272,000
S/N 5A 27 (1)	268,000
S/N 76 EHA (1)	283,000
S/N 189 EGA (1)	269,000
AISI 4340 Bar Stock Specimens	
Batch Number	
1	286,000
2	286,000
3	283,000
4	283,000

(1) Forging Serial Number

AXIAL STRESS TESTS

A battery of 23 sustained load test machines was available for the typical stress corrosion setup shown by Figure 2. An axial load on the specimen was obtained by dead weights acting through a 20:1 lever arm. The arm was balanced over a knife edge fulcrum and the specimen was suspended between upper and lower extension rods. Alignment of the specimens was maintained by a gimbal between the lever arm and rod. The lower rod was held by a spherically seated nut. Integral with the machine was an automatic timer which marked tenths of hours until failure occurred.

Hastelloy grips were pin connected to the extension rods and the lower grip was enclosed by the polyethylene container. Figure 3 shows the details of the grip and container. A polyethylene cover minimized evaporation of the solution and restricted the splash when a specimen broke. To exclude the saline solution from the specimen threads, they were originally coated with a vacuum bag compound and later by liquid neoprene. (On the tests now in process, the solution is restricted to the test section by sealing the container between the grip and shoulder of the Type C specimen.) Because this was a comparative investigation, no other attempt was made to determine or restrict any galvanic currents which may have developed between the grips and the specimen.

Salt water, a 5% NaCl-distilled water solution, was conveyed to the container from a polyethylene reservoir by Tygon tubing.

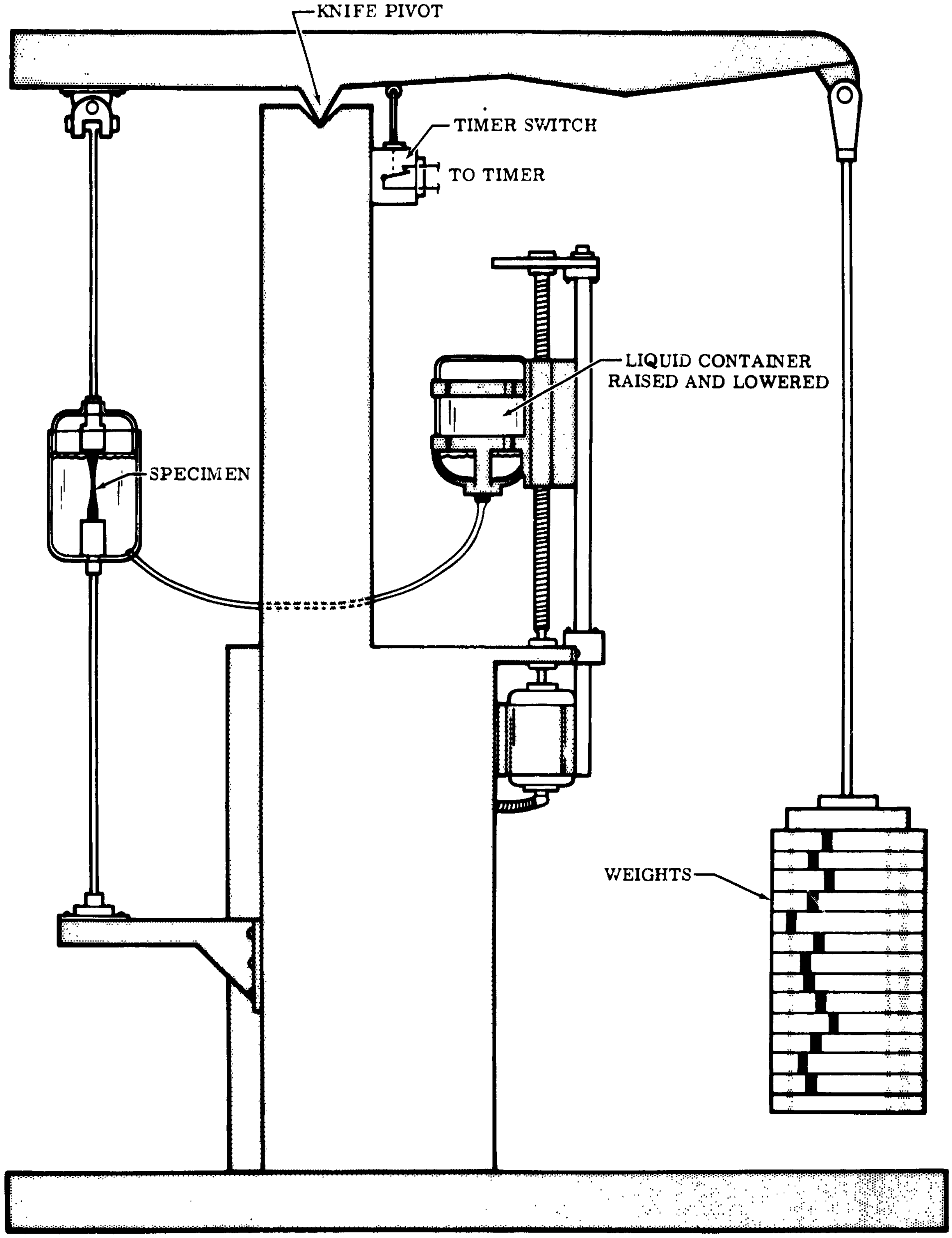

Figure 2 STRESS CORROSION TEST FIXTURE SCHEMATIC

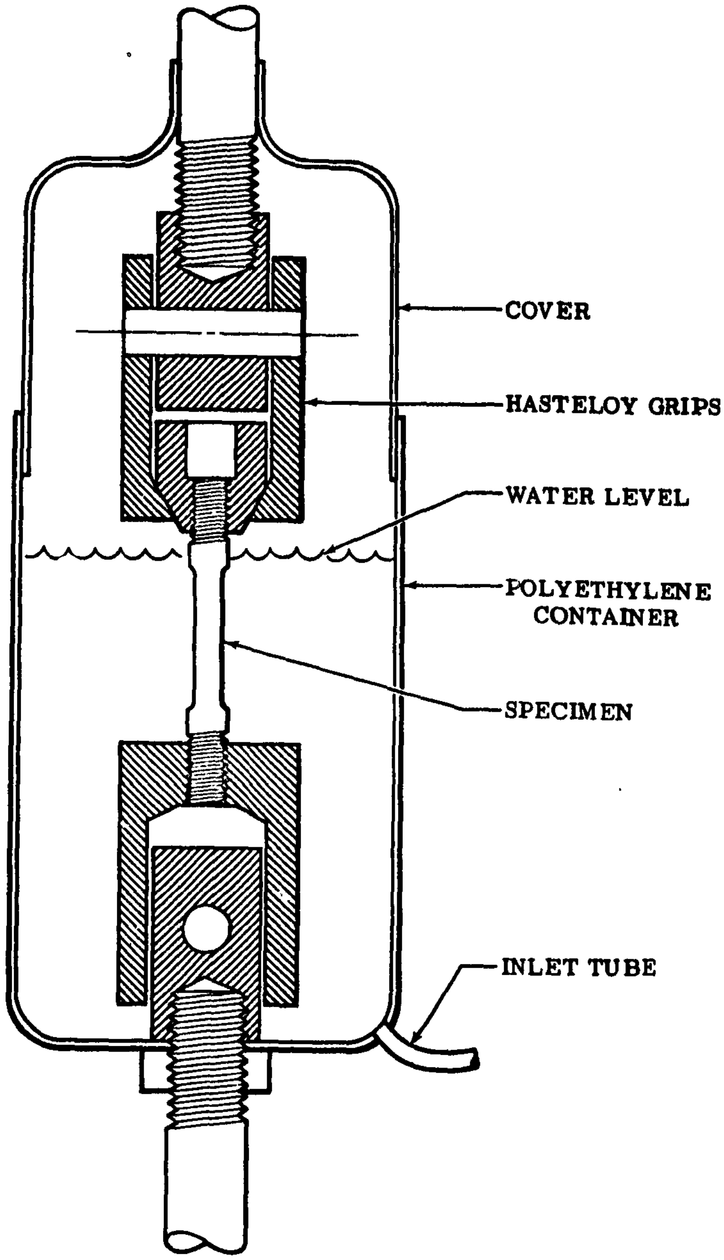

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Figure 3 GRIP FIXTURES AND CONTAINER FOR STRESS CORROSION TEST

Each specimen had its own reservoir which was automatically raised and lowered. The elevator was timed to immerse the specimens 5 minutes and expose them to the latent container atmosphere for 15 minutes. The tests were conducted at the ambient temperature of an air conditioned laboratory, about 78°F. Approximately every 48 hours the solution was changed and the system was flushed, but the specimen was not disturbed.

COATINGS TESTED

Table 2 shows the various coatings tested for the protection of the AISI 4340 steel. These coatings were applied to specimens which were either shot peened or as machined and polished. Shot, .019- to .028-inch diameter peened the test section of the specimen to an Alman intensity of .011. Samples from each batch of specimens were tested as controls for both the shot peened and as machined conditions. The effectiveness of the coating was judged on the basis on the comparative time to failure, allowing about 700 hours test time. All specimens electrolytically plated were baked after plating for 16 hours at 375°F.

FORGED PART SPECIMENS

One of the most startling revelations of the tests was the disparity between the test life of the specimens taken from the four forged parts. Figure 4 shows that two of the forgings had lives exceeding 250 hours, while two others survived less than

TABLE 2

COATINGS TESTED

Coating	Description	Nominal Thickness, inch
Copper	Commercially electroplated	.001
Silver	Commercially electroplated	.001
Chromium	Crack-free chromium (1)	.004
Electroless Ni	Chemically reduced nickel	.0005
Electrolized*	Patented process	.0005
Ni-Cd	0.0005 electrodeposited Ni followed by 0.0003 electrodeposited Cd diffused at 630°F for 6 hours	.001
Aluminum	Vapor Deposited	.001
Aluminum**	Flame Sprayed	.003
ZnTi Paint	Zinc-dust dibutyltitanate	-
Silicone	Primer XP 214 (2)	-
Dry Film Lubricant	GD/FW developed, Type X38 (3)	-

* A patented process of the Electrolizing Company, A Division of Advance Industries, Incorporated, Chicago, Illinois

** Flame sprayed by the North American Aviation, Inc., Columbus Division, Columbus, Ohio

(1) CF-500 - Metal Thermit Corp., Rahway, N. J.

(2) Commercial Designation, Andrew Brown Co., Irving, Texas

(3) Molybdenum Disu' ide Compound.

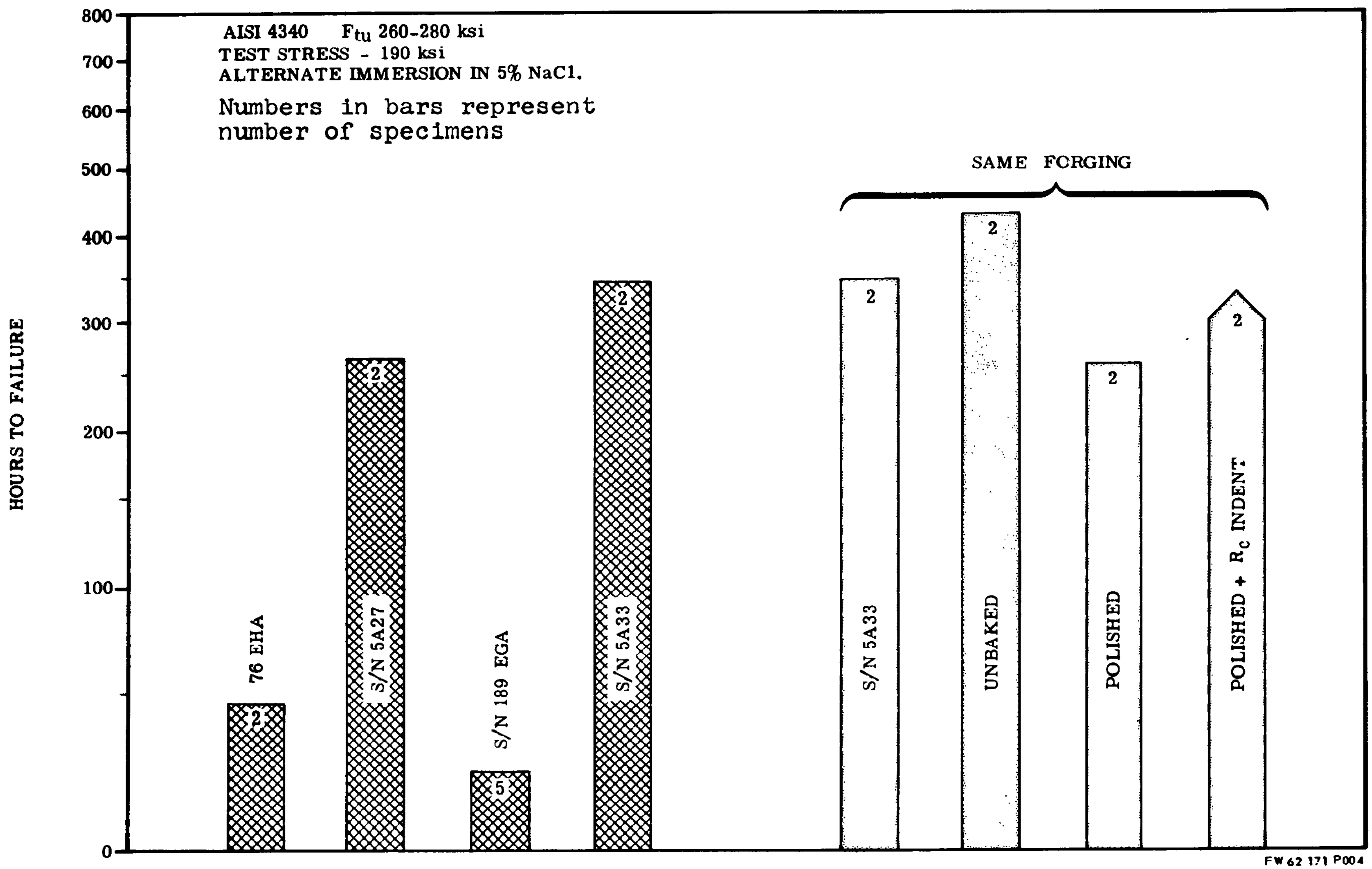

Figure 4. AVERAGE STRESS CORROSION LIFE OF FORGE PART SPECIMENS.

POINTED BAR INDICATES STOPPED TEST.

50 hours. Although the specimens were cut from the forgings in a longitudinal direction, a few specimens were machined from the parting plane of the forging which resulted in a grain flow that was almost transverse. Certain areas exhibited segregation which is believed to have contributed to stress corrosion cracking, particularly as the grain direction approached the transverse. An example of the segregation observed may be seen in Figure 5.

In actual service, the susceptibility of the part was undoubtedly increased by a semi-dendritic grain structure. Although the part was forged within a radial inch of size, the intricate final machining operations often removed the adequately forged surface material, thereby exposing the marginal substructure to the environs and stress corrosion.

Specimens from the forged parts were also used to determine the effects of polishing, surface nicks, and no pretest baking. Referring again to Figure 4, it may be seen that polishing the test section with levigated alumina to produce a metallographic finish, did not improve the resistance to stress corrosion cracking. Putting a Rockwell C indentation in two of these highly polished specimens failed to shorten their lives. Neglecting to bake the specimens appeared to improve the resistance. However, because these specimens were all from the same part and its susceptibility to stress corrosion cracking was above average, the finishes apparently reflect normal scatter.

Figure 5 - ALLOY SEGREGATION EXPOSED BY STRESS CORROSION CRACKING IN A 4340 FORGED PART SPECIMEN. 20X

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Shot peening forged part specimens effectively doubled their life. Figure 6 shows the average life of the unpeened specimens compared with eight which were peened. Seven of these had not failed after 200 hours and one was still running after 546 hours.

A few of the forged part specimens were protectively coated. Electrolizing shortened the life of both the peened and as machined specimens, although the peened lasted four times longer than the unpeened. The dry film lubricant gave erratic results, that is, four machined surface specimens failed in an extremely short time, while one finally failed in the threads after 400 hours. As might be expected, the peened specimens with dry film lubricant ran considerably longer. Four as machined specimens were coated with Zn-Ti Paint[4] and, compared with their uncoated counterpart, there was a notable improvement in the resistance to cracking.

The possibility of hydrogen embrittlement as a factor in the forged part was evaluated by sustained load tests. After 150 hours at 75% of the notched ultimate strength, none of the notched tensile-type specimens had failed and the test was stopped.

Considered as a group, the forged part specimen results revealed the irregular susceptibility of the material to stress corrosion cracking. Shot peening provided a more significant protection than any of the other three coatings, as shown by the individual test results in Table 3.

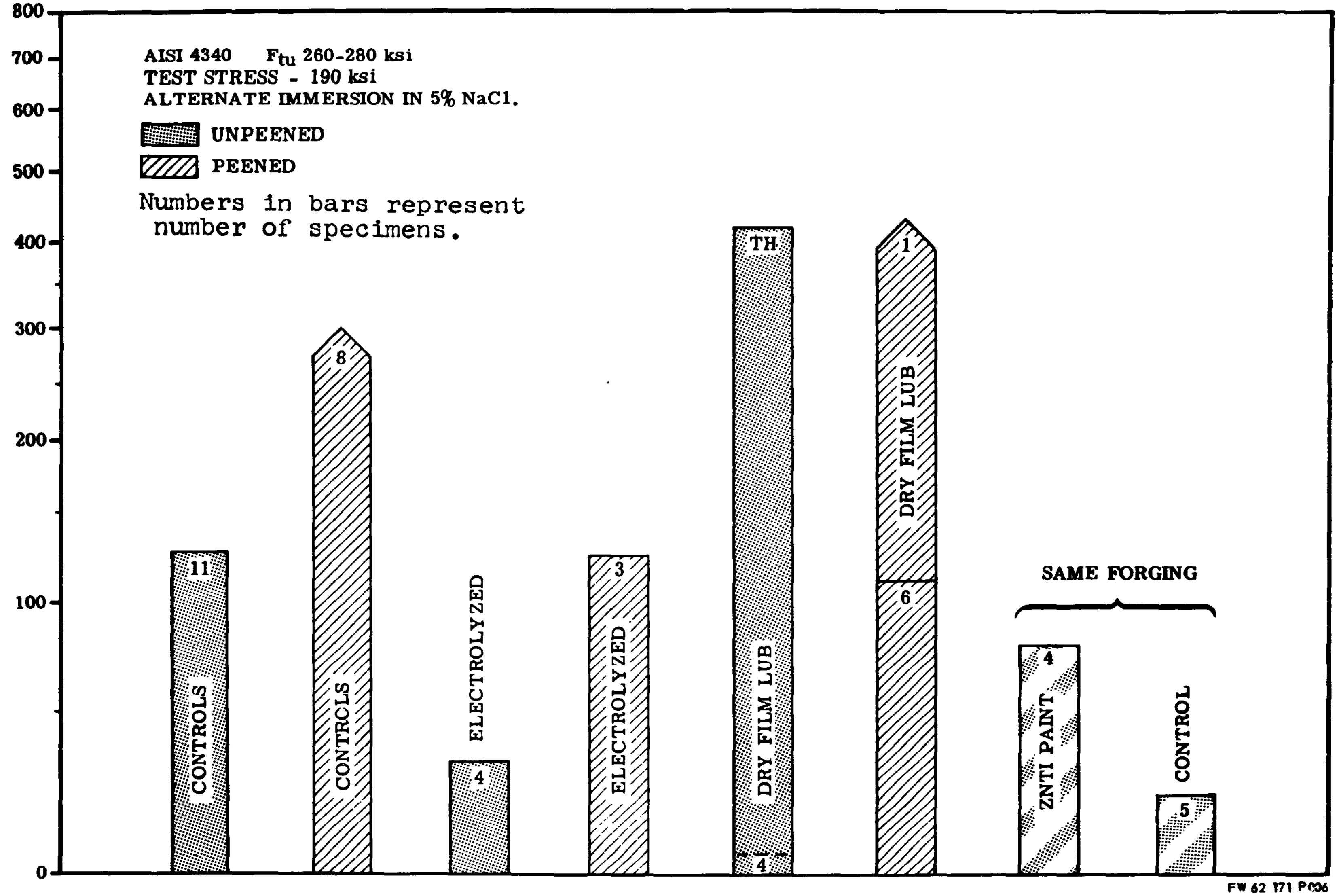

Figure 6. AVERAGE STRESS CORROSION LIFE OF FORGED PART SPECIMENS.

POINTED BARS INDICATE STOPPED TEST.

TABLE 3

RESULTS OF ALTERNATE IMMERSION STRESS CORROSION TESTS, AISI 4340 FORGED PART SPECIMENS

Forging S/N	& Spec. Type	Pretreatment	Time-Hours
Controls, Bare			
76EHA	A		9.7
	B		82.7
5A27	A		263.4
	B		251.2
189EGA	A		0.6, 27.4, 37.8, 18.1, 21.7
5A33	A		189.1
	B		503.2*
5A33	A	without baking	524.0, 348.0
Special Surface Preparation, Bare			
5A33	A	polished	292.6
	B	"	219.0
	A	" +R_C indent.	252.0**
	B	" " "	417.0**
Shot Peened Bare			
76EHA	A		340.3, 22.1*
	B		546.8**, 359.8**
5A27	A		0.2*
	B		335.1**
189EGA	A		208.5**, 208.6**, 208.7**, 208.8**
Coated, Electrolized			
76EHA	A		89(est.), 4.4, 2.8
189EGA	A		31.1, 1.1*, 32.8
76EHA	A	peened	1.2
189EGA	A	"	63.5, 311.0
Coated, Dry Film Lubricant			
189EGA	A		0.3, 4.4, 4.0, 11(est.)
5A33	A		4.9*, 424.0*
189EGA	A	peened	42.5, 78.6, 145.4
5A27	A	"	51.0*
	B	"	430.3**
76EHA	A	"	43.9, 149.4
	B	"	203.8
Coated, Zinc-Tatanate Paint			
189EGA	A		155.8, 73.4, 33.1, 47.3

* Thread failure
**Test stopped

COATINGS ON ROD STOCK

It is immediately apparent, from Figure 7, that the bare rod stock specimens have almost three times the life of the forged part specimens. This might be expected from the more homogenous fine grained structure with a known longitudinal grain direction. A typical stress corrosion fracture, shown by Figure 8, consists of an initial intergranular attack followed by the cup-cone rupture of a ductile tensile failure.

Striking too, is the short survival of the copper, silver, and electroless nickel plated specimens. These metals are cathodic to the steel and accelerated the corrosive attack. For example, small fissures in the electroless nickel coating led to the pitting attack illustrated by Figure 9. As stresses build up at these concentrating points, intergranular cracking develops until failure occurs. The crack-free chromium plate offered good protection, although it eventually succumbed to the corrosive media and began to spall.

Looking again at Figure 7, the Electrolized coating afforded the best protection and was the only one of the group to have life longer than the control specimens. Electrolizing seemed to shorten the life of the shot peened specimens slightly. Two sources of vapor deposited aluminum were also tested. This laboratory's

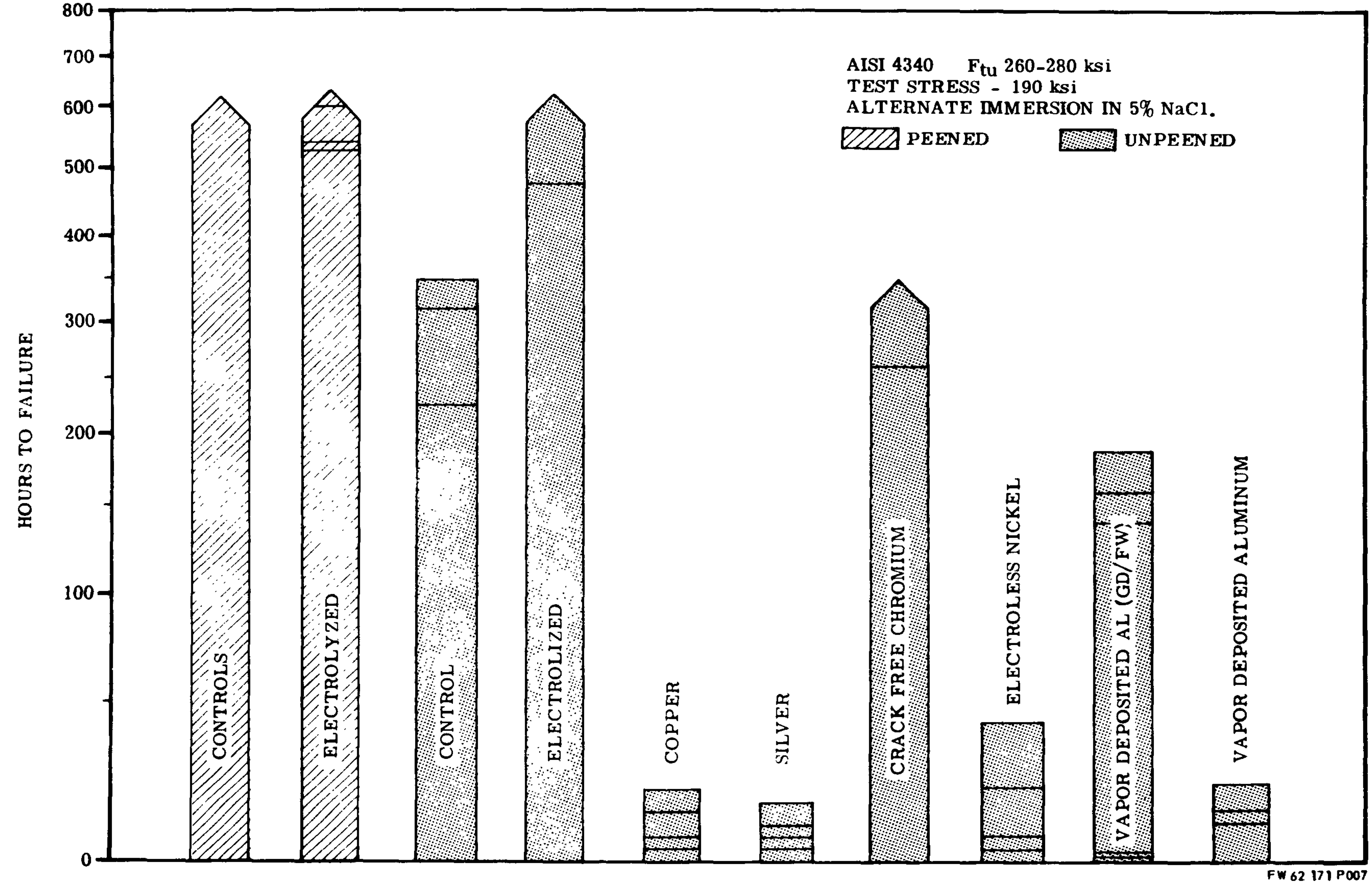

Figure 7. THE EFFECT OF VARIOUS PLATES ON THE STRESS CORROSION LIFE OF ROD STOCK SPECIMENS.
HORIZONTAL LINES INDICATE FAILURES
POINTED BARS INDICATE STOPPED TEST.

Figure 8 - STRESS CORROSION CRACKING ORIGINATED AT THE RIGHT SIDE OF THIS TYPICAL BAR STOCK SPECIMEN. 20X

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Figure 9 - A PITTING ATTACK DEVELOPED IN THE STEEL UNDER FISSURES IN THE ELECTROLESS NICKEL PLATE. 1000X

FW 62 171 P009

deposit was somewhat thinner than the vendor's. The longer life of the laboratory specimens was probably due to the rapid galvanic consumption of the anodic aluminum and hence the evolution of less monatomic hydrogen. The peculiarity of the aluminum coating to form round blister marks, which exposed the bare steel, was believed to be further evidence of hydrogen evolution (Figure 10).

DRY FILM LUBRICANT

The application of a dry film lubricant reduced the resistance to stress corrosion cracking of both the unpeened and peened specimens (Figure 11). The suspected cause of this loss of resistance was the phosphate pretreatment which severely pitted the steel. The extent of the pitting is shown by Figure 12. However, when the pretreatment was not applied the stress corrosion cracking was more rapid, and if the dry film lubricant was removed by vapor honing the resistance to cracking was nearly restored to the level of the control specimen. Both the peened and unpeened specimens responded in a similar manner.

A few specimens with dry film lubricant were tested at 140 ksi stress (50% Ftu), but even at this low stress level the survival time was below the control specimens tested at 190 ksi stress.

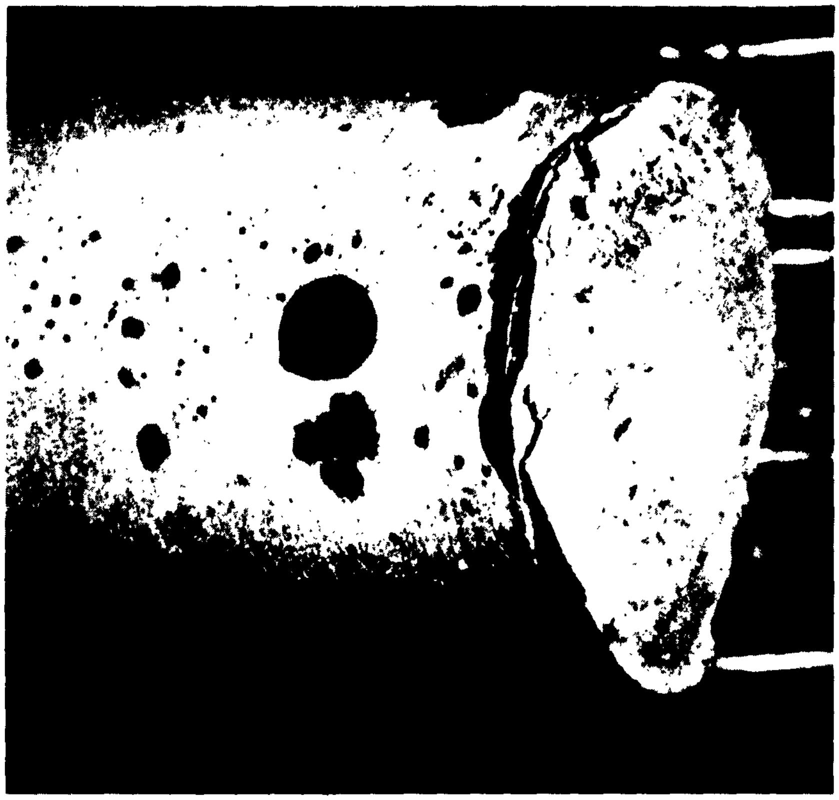

Figure 10 - BLISTER MARKS IN THE VAPOR DEPOSITED ALUMINUM COATING. 15X

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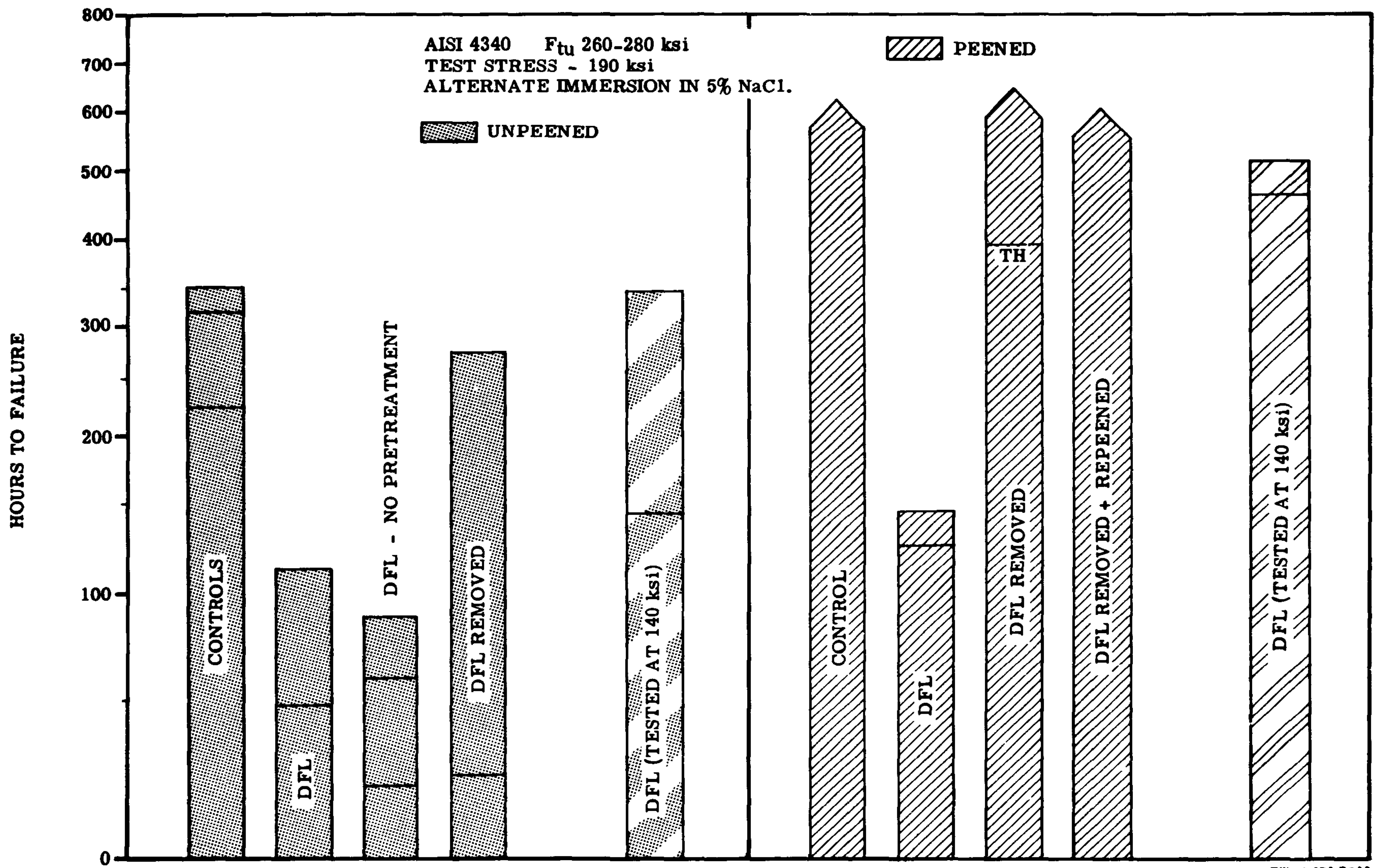

Figure 11. EFFECT OF DRY FILM LUBRICANT ON THE STRESS CORROSION LIFE ROD STOCK SPECIMENS.

HORIZONTAL LINES INDICATE FAILURES.
POINTED BARS INDICATE STOPPED TEST.

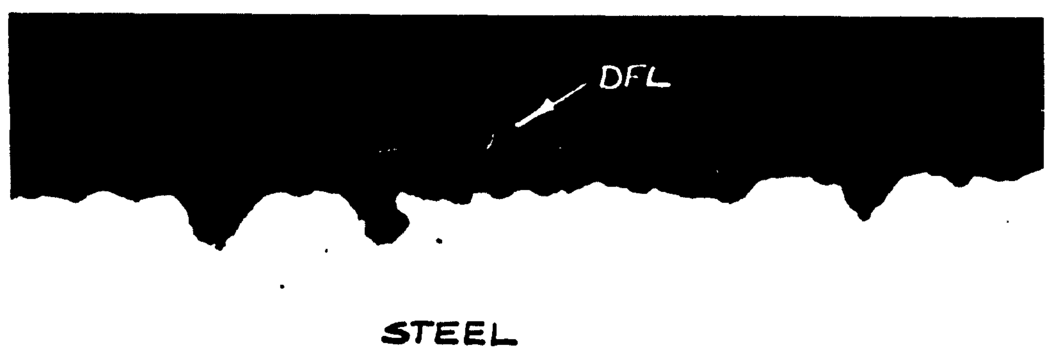

Figure 12 - PITTING OF THE STEEL BY THE PHOSPHATE PRETREATMENT FOR THE DRY FILM LUBRICANT (DFL). 250X

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CONTACT METALS

In close contact with the forged parts were soft aluminum spacers and manganese-bronze bushings. Other areas of the part were protected with a silicone primer paint. Several tests were arranged to determine the effects of these materials in contact with the steel forging. Figure 13 shows that the manganese-bronze bushing and the aluminum foil wrapping failed to shorten significantly the survival time of either the peened or unpeened specimens. Next to the unpeened control specimen results, the silicone primer had the longest life and the least evidence of corrosion. After 600 hours on test the specimen was clean and free of any rust deposits.

The only other specimens showing a complete absence of rust after 600 hours were the flame sprayed aluminum. About midway in the test some of the aluminum coating was filed away to expose an area of bare steel 1/4" x 1/4". At the conclusion of the test, the specimen was sectioned through the bare spot to observe the nature of the attack. In fact, there was no attack or evidence of rust, as may be seen in Figure 14.

EFFECT OF COATINGS ON LOWER STRENGTH STEELS

An electroless nickel and a nickel-cadmium diffusion coating were applied to a few specimens which had been drawn at 700°F. Diffusion of the Ni-Cd at 630°F for six hours produced the coating

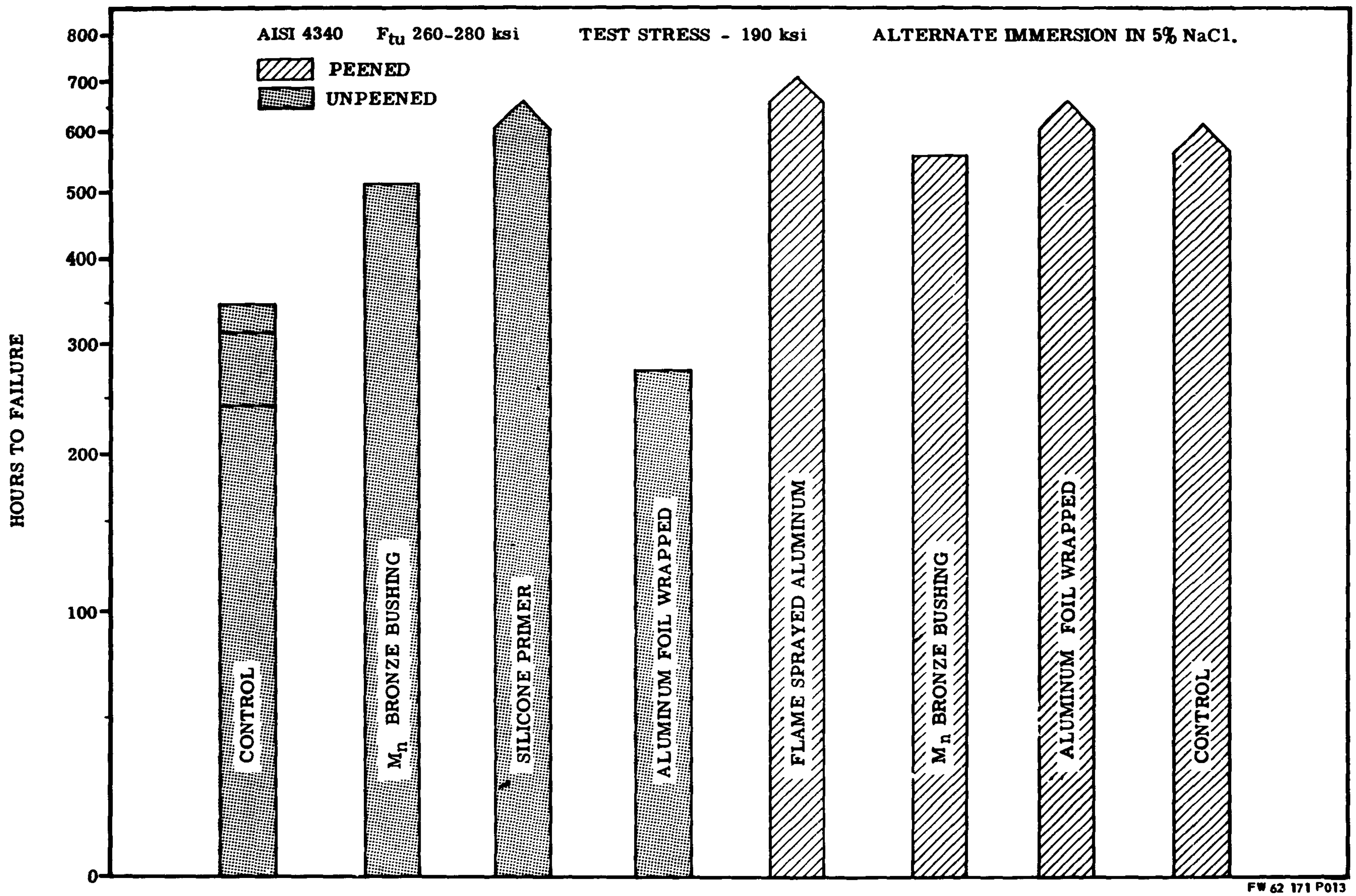

Figure 13. EFFECT OF PAINT AND CONTACT METALS ON THE STRESS CORROSION LIFE ROD STOCK SPECIMENS.
HORIZONTAL LINES INDICATES FAILURES.
POINTED BARS INDICATE STOPPED TEST.

Figure 14 - THE FLAME SPRAYED ALUMINUM WAS REMOVED TO EXPOSE THE STEEL. NO CORROSIVE ATTACK WAS EVIDENT. 250X

FW 62 171 P014

shown in Figure 15. Results of the stress corrosion test were good; the minimum specimen life was about 250 hours. One specimen survived over 800 hours before the test was stopped. By comparison, Figure 16, the electroless nickel coating stimulated the susceptibility to stress corrosion cracking.

Table 4 has been included to show the effect of dry film lubricant on precipitation hardening stainless steel type 17-4PH (H900 condition) and of electroless nickel on AISI 4340 tempered at 800°F. Tested at various stress levels, none of the bare specimens showed any susceptibility to the corrosive medium. The coatings did not make the specimens more susceptible. Significantly, the life of these 4340 specimens was not shortened by electroless nickel, but as shown previously, after a 700°F temper the life was decidedly curtailed. Possibly, there is a pronounced susceptibility threshold for the stress corrosion cracking of AISI 4340.

GALVANIC ATTACK

To determine the extent of any galvanic interaction between the steel of the forged part and the aluminum spacer ring and manganese-bronze bushing, pieces of these materials were made electrodes in a 5% NaCl solution.

After allowing five minutes for stabilization of the current flow, the potentials developed by the various pairs of materials were read on a vacuum tube voltmeter, Table 5.

Figure 15 — THE NICKEL CADMIUM DIFFUSION COATING AS APPLIED TO AISI STEEL. 2000X

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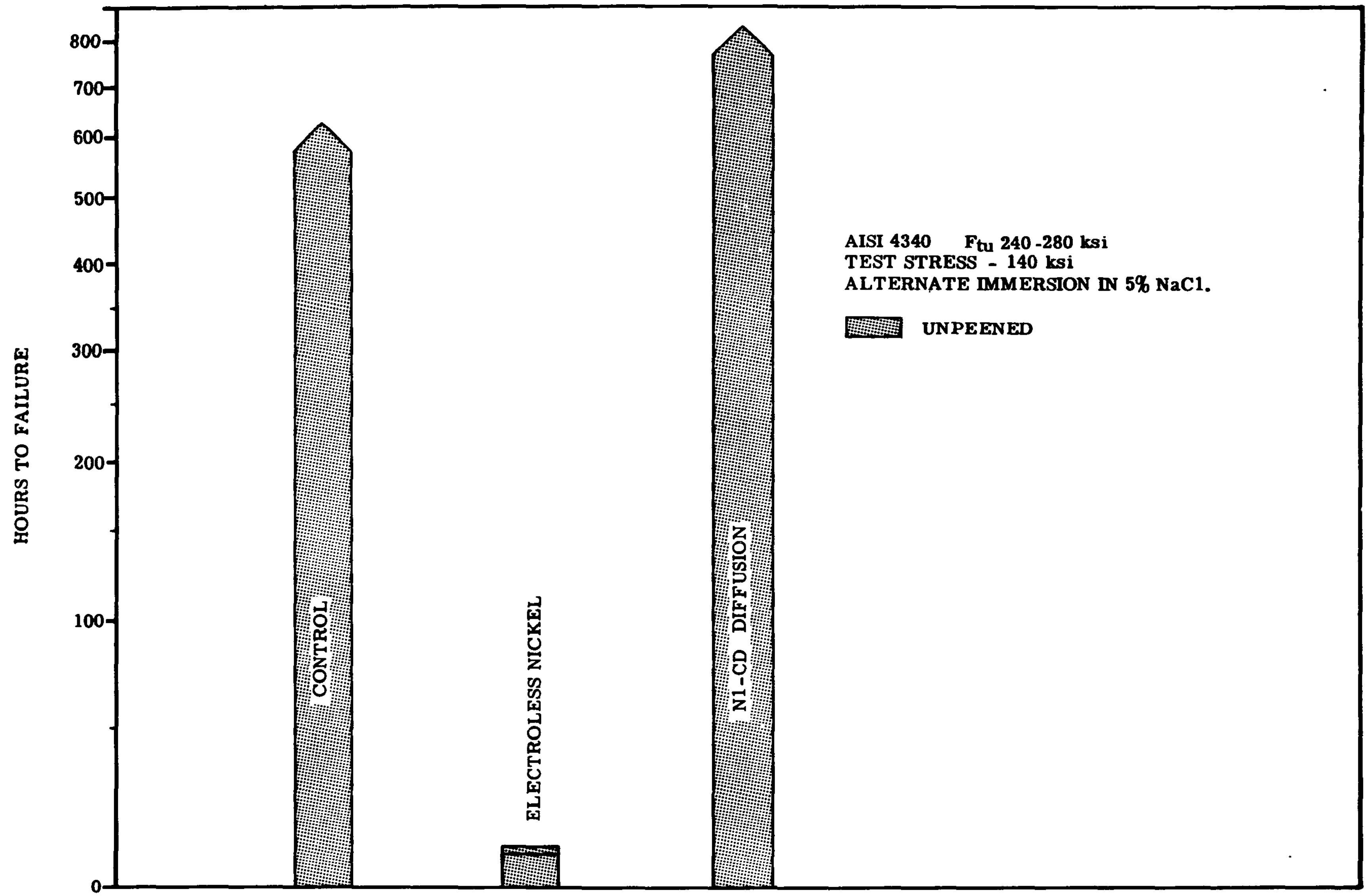

Figure 16. EFFECT OF ELECTROLESS NICKEL AND NICKEL-CADMIUM DIFFUSION COATINGS ON ROD STOCK SPECIMENS.

HORIZONTAL LINES INDICATE FAILURES.

POINTED BARS INDICATE STOPPED TEST.

FW 62 171 PO 16

TABLE 4

RESULTS OF ALTERNATE IMMERSION STRESS CORROSION TESTS, TYPE 17-4PH AND AISI 4340

Surface Preparation	Stress (ksi)	Test Stopped After* (hours)
Type 17-4PH (H900 condition), Type B Specimen		
Bare	150	212, 210
Bare	160	524
Bare + R_c indent.	160	404
Polished	150	212
Polished	160	524
Polished + R_c indent.	160	404
Dry Film Lubricant	150	406
Dry Film Lubricant	160	405
Dry Film Lubricant	170	242, 240
Type AISI 4340 (800°F temper), Type B Specimen		
Bare	150	210, 213
Bare	160	524
Bare	170	240
Polished	150	213, 210
Polished	160	524
Polished	170	240
Electroless Nickel	150	479
Electroless Nickel	160	478
Electroless Nickel	170	241

*None of the specimens failed.

TABLE 5

POTENTIAL MEASUREMENTS OF MATERIALS
IN 5% SODIUM CHLORIDE

Test Materials		
Anode (+)	Cathode (-)	Potential* Volts
4340 steel	Manganese Bronze	0.22
Hard anodized 7075 aluminum (1)	4340 steel	0.18
Bare 7075 aluminum (1)	4340 steel	0.26
Stressed 4340 steel	Unstressed 4340 steel	0.06

*Average for three cells measured to ± 0.02 v.

(1) 7075-T6 Aluminum per QQ-A-283

These materials were then placed in contact with stressed AISI 4340. For this test a bent beam specimen .040 x 1 x 3 inches was ground to thickness, heat treated, and vapor honed to simulate the surface of the finished forging. The test setup is shown by Figure 17. Attachment clamps to hold the dissimilar metals in contact with the steel were made of Teflon and the specimen was insulated from the painted cadmium-plated V block with Mylar polyester tape.

Deflection of the specimen in the jig as measured with a steel scale determined the stress level. Because the thickness was held within ±.001", this was considered a satisfactory method. In fact, the deflection versus stress was verified with several specimens that were fitted with strain gages. The reproducibility, illustrated by Table 6, indicates that the deflection measurement was an adequate index of the tensile fiber stress.

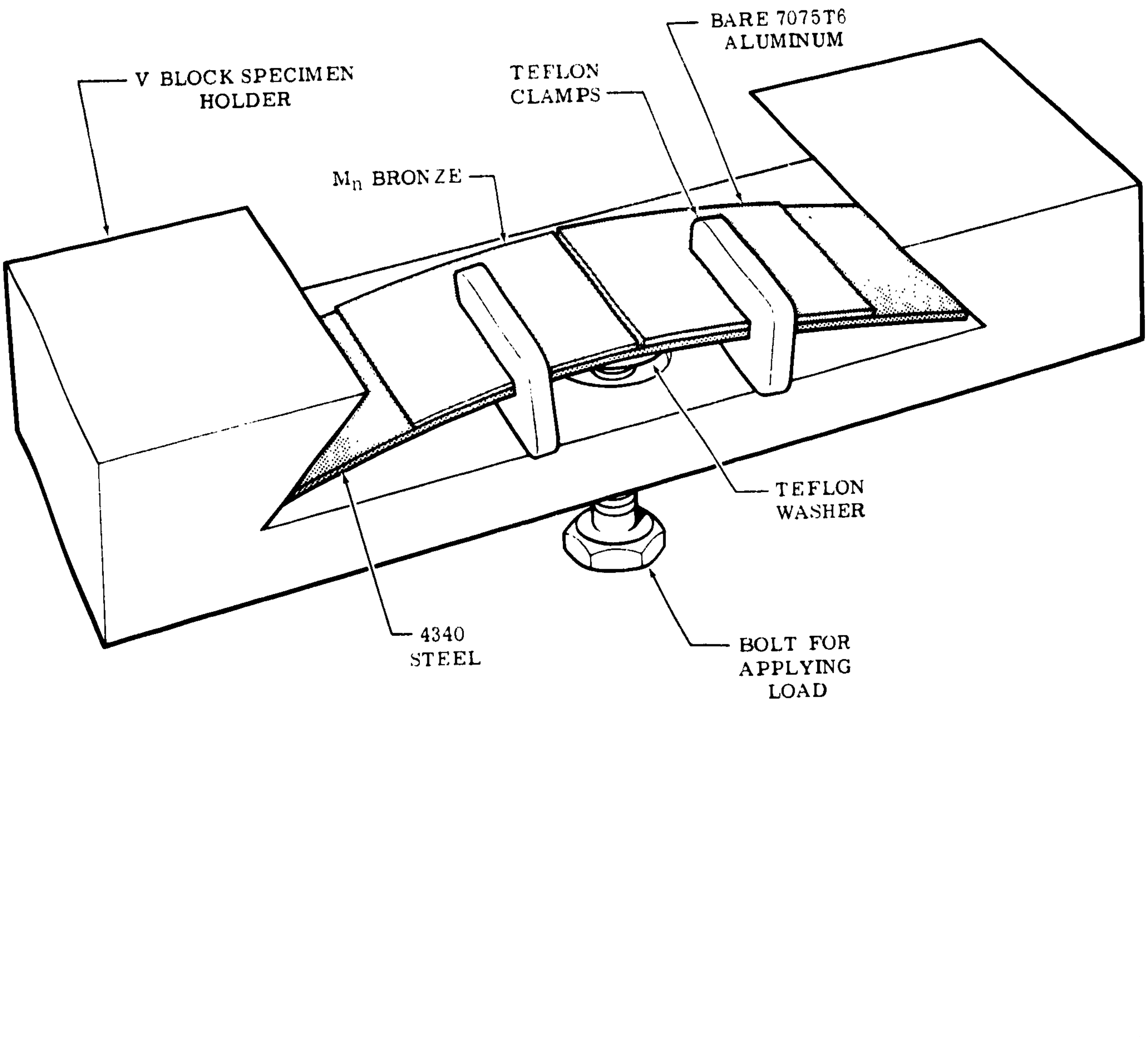

Figure 17 SPECIMEN LOADING DEVICE

TABLE 6

BENT BEAM SPECIMEN LOADS CALCULATED
BY DEFLECTION AND MEASURED BY STRAIN GAGE

	Calculated Stress by Deflection (psi)	Measured Stress by Strain Gage (psi)
	180,000	213,000
	180,000	180,000
	180,000	199,000
	180,000	172,000
Average	180,000	191,000

Bent beam specimens with dissimilar metals attached were exposed to a 20% salt spray environment for a minimum of 250 hours. It is apparent from the data in Table 7 that none of the conditions had a pronounced effect on the susceptibility to stress corrosion. The manganese bronze, both with and without the grease, had the most notable effect, which was partially attributed to its cathodic position relative to the steel.

Grease was applied to some of the specimens when it was found that the moisture content increased after exposure to a humid atmosphere. Moisture can be a problem on the forged part which is coated with grease in the immediate area of concern.

MOISTURE IN GREASES

Several greases were exposed to a cyclic 160°F, 95% relative humidity chamber operated as described in MIL-E-5272B. After 72 hours exposure the moisture content of the greases was determined by a Standard Karl Fisher Aquameter. The results, compared with the unexposed greases, showed that the greases picked up 2 to 3 times their normal water content (Table 8). This water content could have been a contributing factor in the stress corrosion cracking of the AISI 4340 forging. However, tests with the bent beam specimen seem to refute the supposition.

TABLE 7

EFFECT OF CONTACT METALS ON THE STRESS CORROSION OF AISI 4340 IN A 20% SALT SPRAY ATMOSPHERE

(Bent Beam Tensile Stress - 180,000 psi)

Serial	Material Combinations	Specimen Exposure* (Hours)
A	Controls	NF,NF,136
B	Hard Anodized 7075-T6 (1) Aluminum	211,116,211
C	Manganese Bronze	197,244,104.5
D	Hard Anodized 7075-T6 Aluminum + Manganese Bronze (2)	244,NF,NF
E	Bare 7075-T6 Aluminum + Manganese Bronze	NF,197,NF
F	Grease (4L210)	NF,NF,116
G	As Series B + Grease	NF,NF,140
H	As Series C + Grease	NF,116,156
I	As Series D + Grease	167,NF,220
J	As Series E + Grease	NF,NF,NF

*Tests were discontinued after 250 hours if failure had not occurred.

(1) 7075-T6 per QQ-A-283
(2) Manganese Bronze per QQ-B-721

TABLE 8

MOISTURE IN GREASES AFTER EXPOSURE TO HUMIDITY*

Type Grease	Before Exposure** (mg H_2O/gram)	After Exposure** (mg H_2O gram)
MIL-G-21164	2.50	7.95
Royco 60 AMS	3.83	8.60
G 25760 (amber)	3.54	9.69
G 25760 A	4.27	10.53
4L210***	4.06	10.18

*72 hours of RT to 160°F cyclic 95% humidity per MIL-E-5275B.

**Average of 2 specimens using Karl Fisher Aquameter.

***1 part by wt. MIL-M-7866 plus 32 parts by wt. MIL-G-7118.

CONCLUSIONS

From these tests the ground work was laid for a more complete evaluation of alloys proposed for use in structures requiring strength from 260 ksi upwards to 300 ksi.

The results of these tests indicated more clearly what not to use for the protection of AISI 4340. Plating, in general, should be avoided on parts in areas subjected to high tensile stresses. Dry film lubricants of the type tested should not be applied until an environmental, service simulating test program has been completed.

When stress corrosion cracking has even the remote possibility of causing a service failure, shot peening of the part was the best safeguard. Peening in the areas of high stresses seems mandatory; in lower stress regions it may be optional.

The silicone primer and flame sprayed aluminum provide excellent protection for the steel. At the lower strength level a diffused nickel cadmium plate provided good corrosion protection and had little or no effect on the stress corrosion properties.

Dissimilar metals, aluminum and manganese bronze, in contact with AISI 4340 do not appear to increase its susceptibility to stress corrosion cracking.

The remedial action for the forged part mentioned in this program was a complete redesign. Redesign was necessary to circumvent a poorly oriented forged structure which accentuated the stress corrosion cracking problem.

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