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TECHNICAL MEMORANDUM

U.S. NAVAL APPLIED SCIENCE LABORATORY
NAVAL BASE
BROOKLYN I, NEW YORK

-USNASL-9110-P-1J

REPORT OF INSPECTION AND PROGRESS
IN
APPLICATION OF STELLITE 6B OVERLAYS OF
HIGH POINT (PC(H)-1)

SF013-13-01, Task 0906

Bureau Identification No. 14-906-1

Lab. Project 9300-17, Technical Memorandum #4

5 FEB 1964

MATERIAL SCIENCES DIVISION

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Lab.Project 9300-17
Technical Memorandum #4

Ref: (a) BUSHIPS ltr Ser 526-1578 of 4 Oct 1963
(b) BUSHIPS ltr Ser 440-144 of 19 Sep 1963
(c) SUPSHIPS USN Seattle ltr PC(H)(NObs 4359), Ser 252-4447 (Undated, Recd. 13 Sep 1963)
(d) BUSHIPS ltr PC(H)-1, Ser 526-1579 of 4 Oct 1963
(e) NAVAPLSCIENLAB ltr 9370:JZL:rgp, Lab.Project 9300-17 of 10 Oct 1963
(f) NAVSHIPYD BREM dwg (PC(H)-1-518-1134226 of 16 Oct 1963, Mod to Aft Foils and Struts in way of Stellite Cladding
(g) NAVSHIPYD BREM msg R240316Z of 10 Oct 1963 to NAVAPLSCIENLAB
(h) USNEES Report 910160A of 30 Dec 1960
(i) FONCON between CAPT P.A. Gisvold (BUSHIPS Code 634) and J.Z. Lichtman (NAVAPLSCIENLAB Code 9370) of 6 Dec 1963
(j) FONCON between J.Z. Lichtman (NAVAPLSCIENLAB Code 9370) and N.B. Wright (NAVSHIPYD PUGET, Code 255) of 6 Dec 1963
(k) NAVAPLSCIENLAB spdltr 9370:JZL:cn,Lab.Project 9300-17 of 22 Nov 1963
(l) NAVAPLSCIENLAB ltr 9370:AR:nr, 9190 of 12 Nov 1963

Encl:
(1) Table 1 - Puget Sound Naval Shipyard Conferees
(2) Photo L-19527-60 - Condition of starboard strut, nacelle and foil areas (aft sections)
(3) Photo L-19527-61 - Condition of starboard strut, nacelle and foil areas (forward sections)
(4) Photo L-19527-62 - Condition of port strut, nacelle and foil areas (forward section)
(5) Photo L-19527-63 - Condition of port strut, nacelle and foil areas (forward and aft sections)
(6) Photo L-19527-64 - Conditions of port strut, nacelle and foil areas (aft section)
(7) Photo L-19527-65 - Conditions of aft foil, amidships, forward areas, and port nacelle and foil (outboard, forward, underside)
(8) Table 2 - Shear Adhesion Test Data

1. Introduction. This report covers the inspection of the foil and strut assemblies of PC(H)-1 made by a representative of the U.S. Naval Applied Science Laboratory during the period of 31 October to 4 November 1963. This work is continuing under the Hydrofoils Materials Research Program recently established in the NAVAPLSCIENLAB. The NAVAPLSCIENLAB representative advised on the making of appropriate repairs to the eroded areas by means of Stellite 6B overlays, and other means of preventing erosion damage to these assemblies.

2. Background. A conference was held at BUSHIPS on 30 September 1963, as reported in reference (a), to develop courses of action to correct deficiencies in propellers and deteriorating effects in the foils and struts of HIGH POINT (PC(H)-1.) Previous report, reference (b), described inspection of PC(H)-1 made by BUSHIPS personnel; erosion damage of the coatings of the aft foils and struts, galvanic corrosion damage of these bared areas, and cavitation erosion, cracking and bending of the propeller blades, were reported. Report, reference (c), covering inspections made by Boeing representatives, described erosion damage of the aft

struts and foils. The discussions at the conference indicated the following conclusions and action to be taken in respect to the damage of the foils and struts:

a. Conclusions:

(1) No erosion-resistant elastomeric coatings are currently available having adequate adhesive strength to resist the shear stresses active during flight.

(2) Previous coatings have shown erosion damage in limited areas, permitting damage of the exposed metal as described below. Bonded overlays of cavitation erosion resistant Stellite 6B on the HY-80 in these areas offer the most promising solution to prevent damage of the HY-80 at the present time.

b. Action:

(1) Puget Sound Naval Shipyard, under reference (d), was requested to investigate the feasibility of applying Stellite 6B overlays or inlays on specific areas of the struts, foils and nacelles which are experiencing severe erosion damage. Coordination with NAVAPLSCIENLAB was encouraged, to arrive at appropriate fabrication and application procedures.

3. NAVAPLSCIENLAB in response to reference (d), submitted a report, reference (e), covering the properties, fabricability, and procurement data on Stellite 6B for use in fabricating and applying overlays to PC(H)-1. Adhesion tests were also initiated to develop adhesive bonding procedures and confirm data obtained from other sources, as reported in reference (e). Puget Sound Naval Shipyard issued drawing, reference (f), for the fabrication and mounting of Stellite cladding, including therein information covered in reference (e). Subsequently, Puget Sound Naval Shipyard under reference (g), informed NAVAPLSCIENLAB that Stellite forming was scheduled to start 28 October 1963, with installation of overlay tentatively scheduled for 4 November; NAVAPLSCIENLAB representative was requested to arrive at Puget Sound Naval Shipyard on 31 October. Mr. J.Z. Lichtman of NAVAPLSCIENLAB was at Puget Sound Naval Shipyard from 31 October to 4 November to inspect the eroded and other areas of PC(H)-1 and confer with personnel of Puget Sound Naval Shipyard, enclosure (1), on the fabrication and installation procedures for Stellite overlays, and erosion damage of PC(H)-1. This report covers:

a. Inspection of eroded and other areas of PC(H)-1.
b. Fabrication and installation procedures for Stellite overlays to eroded areas.
c. Adhesive [illegible] conducted to develop adhesion bonding procedures.
d. Future action based on the inspection and changes in propeller specifications.

4. Inspection of eroded and other areas of PC(H)-1.

a. Operation prior to present docking. PC(H)-1 had been docked previously from 4 to 13 September, during which time the inspection, reference (b), was conducted. After undocking on 13 September it was flown for 20 minutes at 1430 rpm on 26 September. Because of blade cracks and erosion damage to the aft strut and foil coatings, the boat was docked for the present inspection and repair program on 21 October. It was therefore waterborn for 13 days before flight and 25 days after flight prior to the present docking.

b. Coating and structural damage. The coating and metal damage on the aft struts, foils and nacelles observed on 25 October (coating damage) and 1 November (metal damage) are shown on enclosures (2) through (7) as follows:

Area(2)	Coating, Enclosure	Metal, Enclosure
Stbd. strut, nacelle, foil inbd. aft	2A	2B,2C
Stbd. strut, nacelle, foil inbd. fwd	3A	3C
Stbd. strut, nacelle, foil outbd. fwd	3B	--
Port foil, nacelle, outbd. fwd	4A(1)	4B
Port strut, nacelle, foil, flap inbd. aft	5A	5B,5C
Port strut, nacelle, foil, inbd. fwd	5D,6B	--
Port strut, nacelle, foil, flap, outbd. aft	6A,6C	6C
Foil, amidships, fwd	7A	--
Port nacelle, foil, underside inbd.	7B	--

Notes: (1) Previous photo of coating damage taken 5 September 1963.
(2) Upper surfaces, except as noted.

c. The following observations are made from the above photographs and inspection:

(1) The damage to the coating consists of erosion and adhesion separation.

(2) The damage to the strut, nacelle, and foil metal (HY-80) consists of corrosion to a depth of approximately 1/16 inch, enclosures (2)B, (2)C, (4)B, (5)B, (5)C and (6)D. This damage developed in areas where erosion damage and adhesion failure of the coating occurred. Isolated pits of approximately 1/8 inch depth and 1/2 inch diameter are also shown, enclosures (3)C, (4)B and (5)B. No cavitation erosion damage of the HY-80 steel was observed. The levels of intensity of cavitation erosion stress was apparently sufficient to cause cavitation erosion of the vinyl and epoxy coating materials but not of the HY-80 substrate.

(3) Severe erosion at the sea water inlet, enclosures (3)B and (5)D, had occurred with peeling away of the polyurethane coating. Repair of these areas with Devcon A epoxy smoother was underway when inspected on 1 November; no photomacrographs of the erosion damage of these areas were taken previously.

(4) The corrosion damage, enclosures (5)A and (5)C, occurred in the area described in reference (c), enclosure (1), paragraph 1 a. Two holes less than 1/8 inch in diameter had penetrated through the strut. The areas were ground to solid metal and weld-repaired with 9018 weld rod. Enclosure (5)C shows no damage of the weld. Corrosion of the HY-80 occurred in adjacent areas where epoxy smoother had been used to fill ground-out areas, and erosion of the smoother had occurred, enclosure (5)C. The 9018 weld was apparently cathodic to the adjacent HY-80 and showed no corrosion.

(5) Considerable blistering of the vinyl anti-corrosive and anti-fouling coating on the aft foils (Navy formula 117, 119, 121) was shown, enclosure (6)B.

(6) The adhesive strength of the polyurethane coating was low, resulting in peeling at the sea water inlets, enclosures (3)B, and (4)D, and at the foil leading edge, enclosure (7)A.

d. Condition of coating on upper areas of aft struts, and forward foil, strut, flaps and rudders. The neoprene coating on the forward and aft upper strut areas showed no damage. The vinyl anti-corrosive and anti-fouling coatings (Navy Formula 117, 119 and 121) on the forward foil assembly showed no blistering or other defects, except for peeling separation of the leading flap areas in the way of the flap recesses, and rudder areas in similar recess areas. The latter coatings on the aft struts from the neoprene coating 4-1/2 feet above the nacelle-strut intersection, down to approximately 15 inches above the nacelle-strut intersection also showed no damage.

5. Fabrication and installation procedures for Stellite overlays.

a. Forming of Stellite. Tests were conducted on 31 October in Shop 11 to define optimum forming temperatures within the range indicated in paragraph 4e of reference (e). Sheets 0.156 inches thick x 8 inches x 6 inches were bent to a 180° bend at 1-1/2 inch diameter on the 8 inch axis after preheat to 1100F and 2000F. The former cracked. The latter specimen formed without cracks. As a result of these tests, the Stellite sheet will be preheated to 2000F before forming. Patterns of the areas to be overlayed as defined in reference (f) will be taken after grinding eroded areas, sand-blasting to insure optimum bond, and rebuilding with epoxy smoother (Devcon A). Forming of the Stellite will be made to these patterns.

b. Bonding of overlays. On the basis of the shear adhesion tests carried out in the NAVAPLSCIENLAB as described in paragraphs 6 and 7 below, it is recommended that changes be made in procedures described in reference (e), paragraph 4c(2) and reference (f), note 3. These changes will simplify the application procedures, provide longer working time of adhesives, and insure non-metallic contact between the HY-80 and Stellite. The recommended changes are as follows:

(1) Sandblast Stellite surfaces to be bonded, in lieu of chromic acid etch, to simplify substrate pretreatment.

(2) Use Raybond 86009 epoxy adhesive (3/2 by weight of resin/hardener) in lieu of 3M Primer EC 1459 and Scotchweld EC1838 A and B, to obtain longer working time and brushability (lower viscosity of adhesives).

(3) Use one ply (0.003 inches thick) of glass cloth, style 112, 1100 finish in the epoxy adhesive film to insure against metallic contact between the Stellite overlay and the metallic (HY-80 or other) substrate.

(4) The normal cure time of the Raybond adhesive is 7 days at 74F. To accelerate the adhesive cure and completion of the overlay application (fairing in of Stellite margins and application of Navy Formulas 117, 119 and 121) a heat cure for four hours at 140F is recommended. This may be accomplished after assembly of the overlay using banks of heat lamps such as used in the curing of glass-reinforced epoxy shaft coverings by the Puget Sound Naval Shipyard, Code 307A.

6. Shear adhesion tests of epoxy adhesives. These adhesion tests were carried out to evaluate the processes described in reference (e), paragraph 4C(2), and develop improvements. The following factors were studies:

a. Stellite surface pretreatment:

(1) Sandblast, using Joplin No. 7 grit
(2) Electroetch 10 seconds, reference (e), paragraph 4c(2)

b. Epoxy Adhesives:

(1) Raybestos-Manhatten adhesive Raybond 86009 (3/2 by wt. resin/hardener).

(2) 3M Scotchweld adhesive EC 1838 A and B (1/1 by wt. resin/hardener). The 3M-EC 1459 primer was not received and was not used in these tests.

(3) Use of glass cloth ply (0.003 in. thick) in epoxy film to insure against metallic contact and possibility of galvanic corrosion.

7. The results of the shear adhesion tests are given in Table 2, enclosure (8). The following additional results were indicated:

a. The viscosity of the Raybond adhesive was lower than the 3M 1838 adhesive. Brush applications to large areas of the HY-80 and Stellite 6B would be more readily accomplished with the former.

b. The pot life of the Raybond adhesive was approximately 1-1/2 to 2 hours; that of the 3M adhesive was approximately 30 to 60 minutes. The longer pot life would facilitate the application of adhesive and assembly of the overlay to the substrate.

Recommendations based on these results are given in paragraph 5b.

8. Future action and recommendations:

a. Prevention of corrosion damage to struts, foils and nacelles. The HY-80 is highly susceptible to corrosion damage when the anti-corrosive coatings are eroded because of tip vortex cavitation from the forward propeller, or because of inadequate adhesive strength of the coating. The bronze propellers may contribute significantly to galvanic corrosion damage of the HY-80. Potential measurements between the propellers and foil and strut assembly would contribute to this understanding. On the indication that galvanic corrosion may contribute to the strut and foil damage, and on the basis of discussions, references (i) and (j), it is planned to install anodes on the hull, outboard of the aft struts. These anodes will be in addition to currently installed anodes inboard of the aft struts. Anodes will not be installed on the outboard ends of the aft foils, as recommended in reference (k). Electrical conductivity between the hull and strut-foil assembly should be checked to insure galvanic protection of HY-80 during hull-borne periods.

b. Resistance of Stellite 6B to high velocity sea water flow. No information was available and none was given in reference (e) on the corrosion resistance of Stellite 6B to high velocity sea water flow. Naval Marine Engineering Laboratory (MEL) in reference (h) described high velocity nozzle tests in which HY-80 showed a high corrosion rate, while nickel and stainless alloys showed a low corrosion rate. NAVAPLSCIENLAB will forward to Marine Engineering Laboratory samples of Stellite 6B to determine its high velocity corrosion resistance. This information will be related to the performance of the Stellite B overlays on PC(H)-1.

c. Resistance of propeller alloys to cavitation erosion. Reference (d) requested the procurement of Superston alloy propellers in accordance with alloy 2 of MIL-B-21230A (SHIPS), from Columbian Bronze Corporation. It is expected that these propellers would have higher cavitation erosion resistance and mechanical strength than the previous PC(H)-1 propellers of nickel manganese bronze manufactured by Coolidge Propeller Company. To permit experimental verification of the relative erosion resistance, NAVAPLSCIENLAB requests that (1) Puget Sound Naval Shipyard be requested to ship to NAVAPLSCIENLAB a Coolidge propeller which has been damaged beyond repair, and (2) Columbian Bronze Corporation be requested to supply NAVAPLSCIENLAB a Superston casting approximately 1-1/2 inches in diameter x 12 inches long, cast at the same time as the PC(H)-1 propellers. Puget Sound Naval Shipyard is agreeable to forwarding a non-repairable propeller to NAVAPLSCIENLAB on the basis of the Bureau's request.

d. NAVAPLSCIENLAB activity. Effort of NAVAPLSCIENLAB in areas above is continuing under the Hydrofoil Materials Research Program currently underway. This program as outlined in reference (1) covers aspects of hydrofoil materials development in the following areas:

(1) Surface protection
(2) Structural materials design criteria, and
(3) Hydrofoil assembly systems

9. In summary:

(a) An inspection of the struts, nacelles and foil assemblies of PC(H)-1 was made by a NAVAPLSCIENLAB representative during the period of 31 October to 4 November 1963, as described in paragraph 4b,c and d. This inspection showed:

(1) Damage to coatings of struts, nacelles and foil downstream of forward propellers includes erosion and adhesion separation.

(2) Damage to strut, nacelle and foils areas downstream of forward propellers and in other areas is caused by static and high velocity corrosion of exposed HY-80. No evidence of cavitation erosion of the HY-80 was observed in these areas.

(3) Severe erosion damage of sea water inlets in struts had occurred. Personal inspection by NAVAPLSCIENLAB representative was not possible during above period because epoxy smoother had already been applied to these areas prior to Stellite overlay.

(4) Blistering of the anti-corrosive and anti-fouling coatings (Navy formulas 117, 119 and 121) occurred on the aft foils.

(5) The adhesive strength of the polyurethane coating applied to the sea water inlets and areas of the leading edge of the aft foil was low, permitting peeling of the coating.

(6) The coating on the forward foil and strut assembly, and on areas

approximately 15 inches above the aft natelle-strut joint, were in good condition.

b. The fabrication and application of Stellite 6B overlays to areas of the aft struts and foils of PC(H)-1 were initiated on 31 October as described in paragraph 5, and are summarized below.

(1) Forming tests showed that preheating sheet Stellite 6B at 2000F would permit forming to a 180° bend at 1-1/2 inch diameter without cracking.

(2) Adhesion tests have shown that:

(a) Sandblasting of Stellite 6B is feasible, replacing electro-etching, as a surface pretreatment for adhesive bonding.

(b) Epoxy adhesives (with a glass cloth ply to insure against metallic contact) will give high shear adhesive strength of Stellite 6B to low - alloy steel.

(c) Accelerated cure of the adhesive may be achieved by moderate heat cure (4 hours at 140°F).

c. To prevent or diminish corrosion damage to the aft struts, nacelles and foils, it was planned to mount zinc anodes on the hull, outboard of the aft struts, as described in paragraph 8a.

d. High velocity corrosion resistance tests of Stellite 6B were proposed, as described in paragraph 8b.

e. The determination of the relative cavitation erosion resistance of the proposed Superston alloy, MIL-B-21230A, alloy 2 and the Coolidge nickel-manganese bronze, was proposed, as described in paragraph 8c.

f. Phases of work above being carried out by NAVAPLSCIENLAB are continuing under the Hydrofoils Materials Research Program recently established in NAVAPLSCIENLAB, reference (1).

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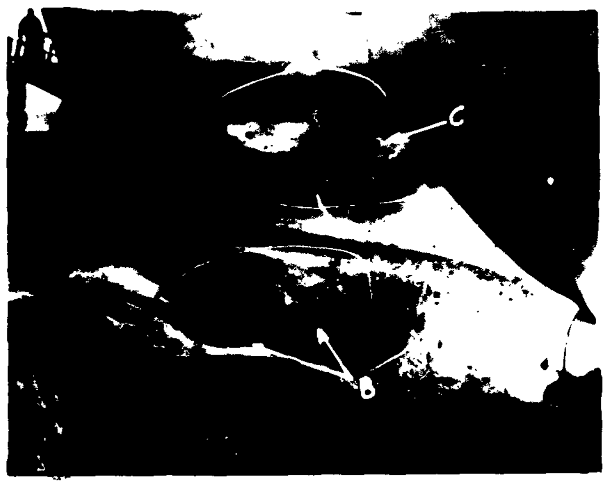
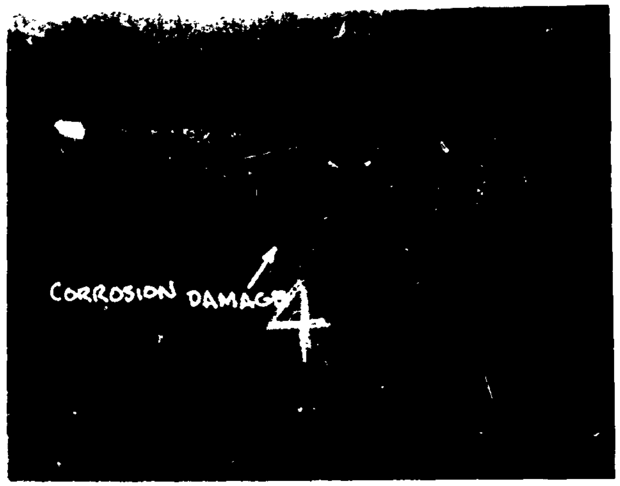
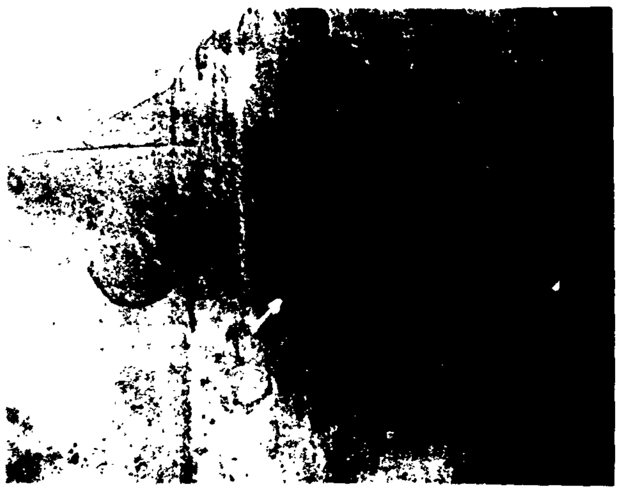
Enclosure (1)

TABLE 1 - PUGET SOUND NAVAL SHIPYARD CONFEREES

NAME	CODE
CAPT. T.A. Efird, USN	240
CDR. D.R. Hamlin, USN	241
C. L. Newstrom	247
N. B. Wright	255
J. Wonderly	255
J. N. Wessel	303
R.B. Callison	307
W. B. Lew	307A
W. H. Miles	307B
W. H. Travis	Shop 11
LT. H. Billerbeck,USN	OIC, HIGH POINT (PC(H)-1)







APPLIED SCIENCE LABORATORY LAB. PROJECT 9300-17

Condition of Starboard Strut, Nacelle and Foil Areas (aft sections) inboard

A - Starboard strut, nacelle, foil, aft, inboard
B - Nacelle and Foil, Aft (B of A)
C - Starboard strut aft. Inboard (C of A)

Enclosure (2)

PHOTO No. L-19527-60

A

B

C

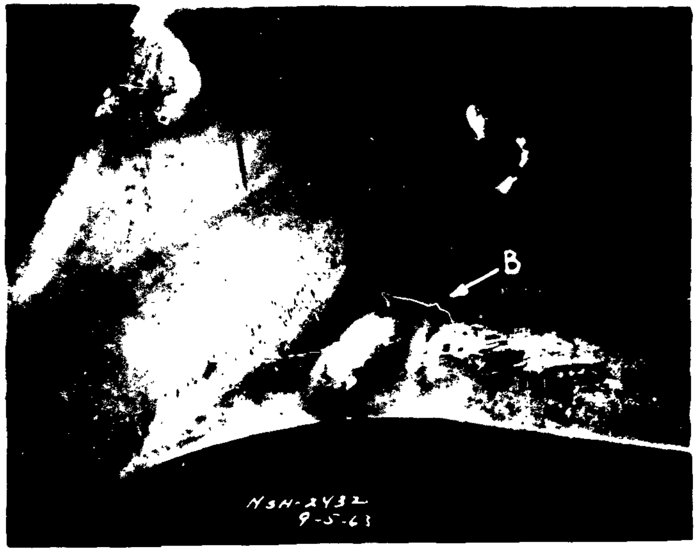
APPLIED SCIENCE LABORATORY LAB PROJECT 9300-17

Condition of Starboard Strut, Nacelle and Foil Areas (Forward sections)

A - Starboard nacelle, foil, strut, inboard, forward
B - Starboard nacelle. foil, strut, outboard, forward
C - Foil inboard of starboard nacelle, forward (C of A)

Enclosure (3)

PHOTO No. [illegible]

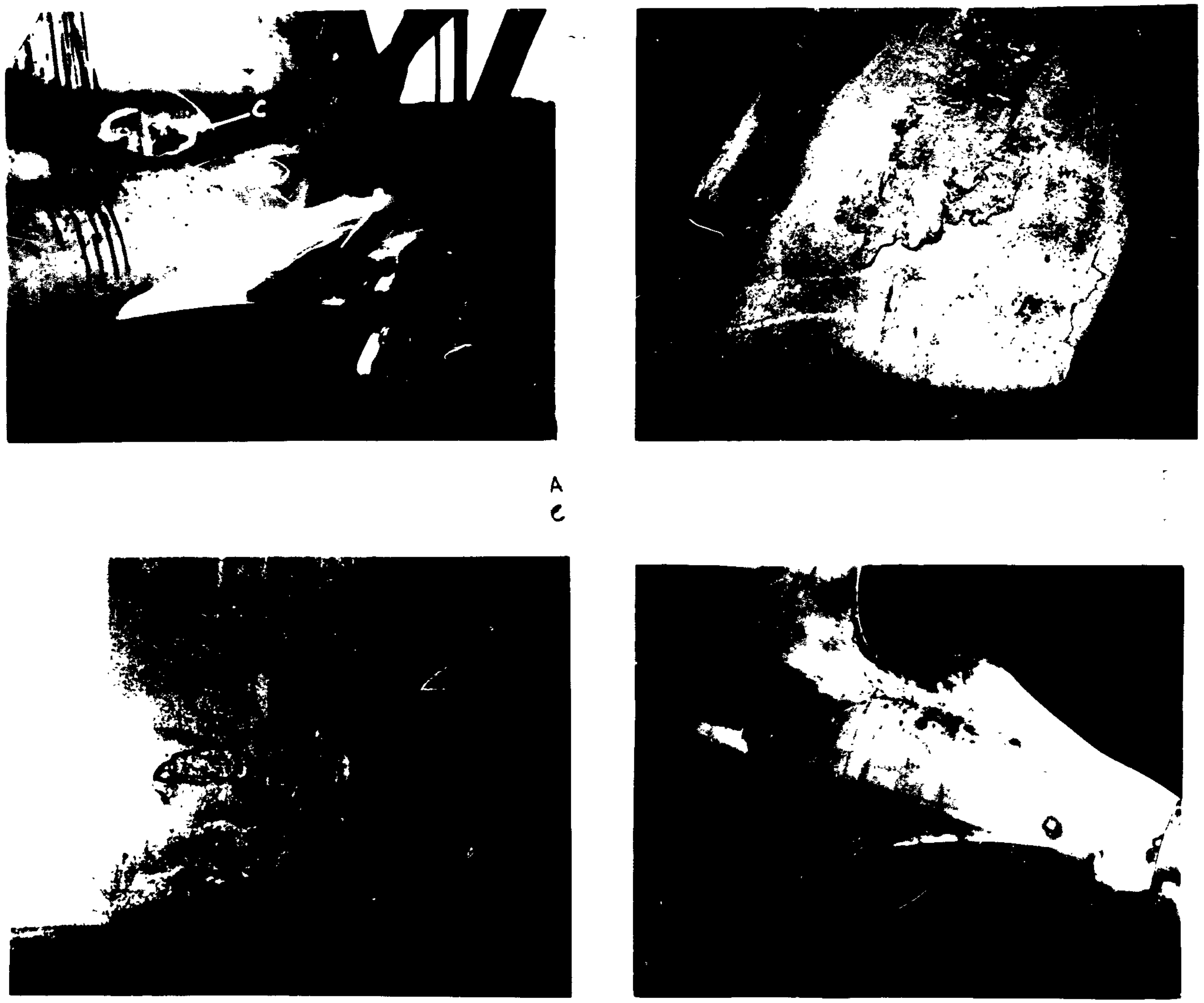


APPLIED SCIENCE LABORATORY LAB. PROJECT 9300-17

Condition of Port Strut, Nacelle and Foil Areas (Forward Sections)

A - Port strut, nacelle, foil, outboard, forward
B - Foil, inboard of port nacelle, forward (B of A)

Enclosure (4)
PHOTO No. L-19527-62



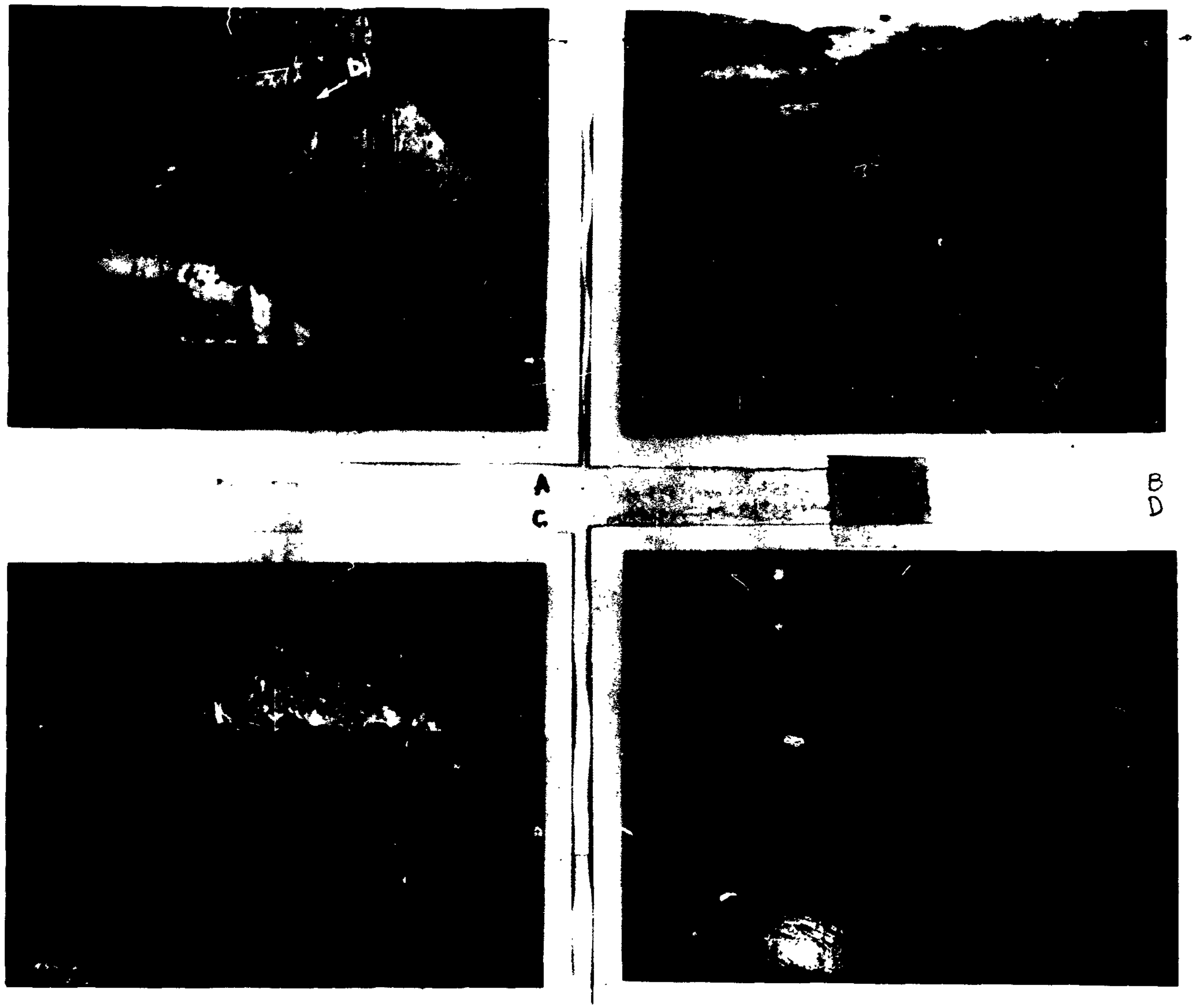
APPLIED SCIENCE LABORATORY LAB. PROJECT 9300-17

Conditions of Port Strut, Nacelle and Foil Areas (forward and aft sections)

A - Port strut. nacelle. foil, inboard. aft
B - Foil inboard of port nacelle, aft (B of A)
C - Port strut, inboard, aft (C of A)
D - Port strut, nacelle. foil, forward inboard

PHOTO No. L-19527-63

Enclosure (5)



APPLIED SCIENCE LABORATORY **LAB. PROJECT** 9300-17

Conditions of Port Strut, Nacelle and Foil Areas (aft sections)

A - Pt strut, nacelle, foil, outboard, aft
B - Foil inboard of port nacelle, aft
C - Port flap, outboard
D - Port strut, outboard (D of A) Enclosure (6)

PHOTO No. L-19527-64

A

APPLIED SCIENCE LABORATORY LAB PROJECT 9300-17

Conditions of Aft Foil, Amidships, Forward Area, and Port Nacelle and Foil (Outboard. Forward, Underside)

A - Aft foil, amidships, leading edge coating damage
B - Aft foil and port nacelle, forward, underside

Enclosure (7)
PHOTO No. L-19527-65

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Enclosure (8)

TABLE 2 - SHEAR ADHESION TEST DATA, STELLITE 6B TO MILD STEEL

SPECIMEN	Stellite Pretreatment	Conditioning	Glass Cloth Ply (4)	Adhesive (2)	Shear Strength psi
1	Sandblast	initial	no	Raybond 86009	2530
2	Sandblast	initial	no	Raybond 86009	2830
3	Sandblast	initial	no	Raybond 86009	2640
				Avg.	2670
4	Electroetch 10 sec	initial	no	Raybond 86009	2690
5	Sandblast	(3)	yes	Raybond 86009	2270
6	Sandblast	(3)	yes	Raybond 86009	2770
				Avg.	2520 (5)
7	Sandblast	(3)	yes	3M 1838	2540
8	Sandblast	(3)	yes	3M 1838	2640
				Avg.	2590

Notes: (1) Separation rate: 0.050 in. / min. ASTM D1002-53T, MIL-A-8623A
(2) Cure 4 hrs at 140F
(3) 89 hrs in sea water at 74F
(4) 1-Style 112 Finish A 1100
(5) Avg. of specimens 5 and 6