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Joseph Kozol

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Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

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In response to fleet and depot needs to reduce hazardous waste in aircraft paint stripping and to conform to regulations eliminating the use of toxic chemical paint strippers, the Naval Air systems Team (Materials Division, Depots and Headquarters) teamed with the Air Force at Warner Robins Air Logistics Center in proof of concept development, characterization and documentation of a mature, advanced paint removal system, the Boeing xenon/flashlamp CO_2 (Flashjet®) process. Extensive metallic and composite materials testing was conducted. This paper describes the development and characterization program leading to authorization of the process for use on fixed-wing Navy aircraft.

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Qualification of an Environmentally Safe and Effective Paint Removal Process for Aircraft

Joseph Kozol

Naval Air Systems Command
Materials Division
Patuxent River, MD 20670

ABSTRACT

In response to fleet and depot needs to reduce hazardous waste in aircraft paint stripping and to conform to regulations eliminating the use of toxic chemical paint strippers, the Naval Air Systems Team (Materials Division, Depots and Headquarters) teamed with the Air Force at Warner Robins Air Logistics Center in proof of concept development, characterization and demonstration of a mature, advanced paint removal system, the Boeing xenon/flashlamp CO_2 (Flashjet^R) process. Extensive metallic and composite materials testing was conducted. This paper describes the development and characterization program leading to authorization of the process for use on fixed-wing Navy aircraft.

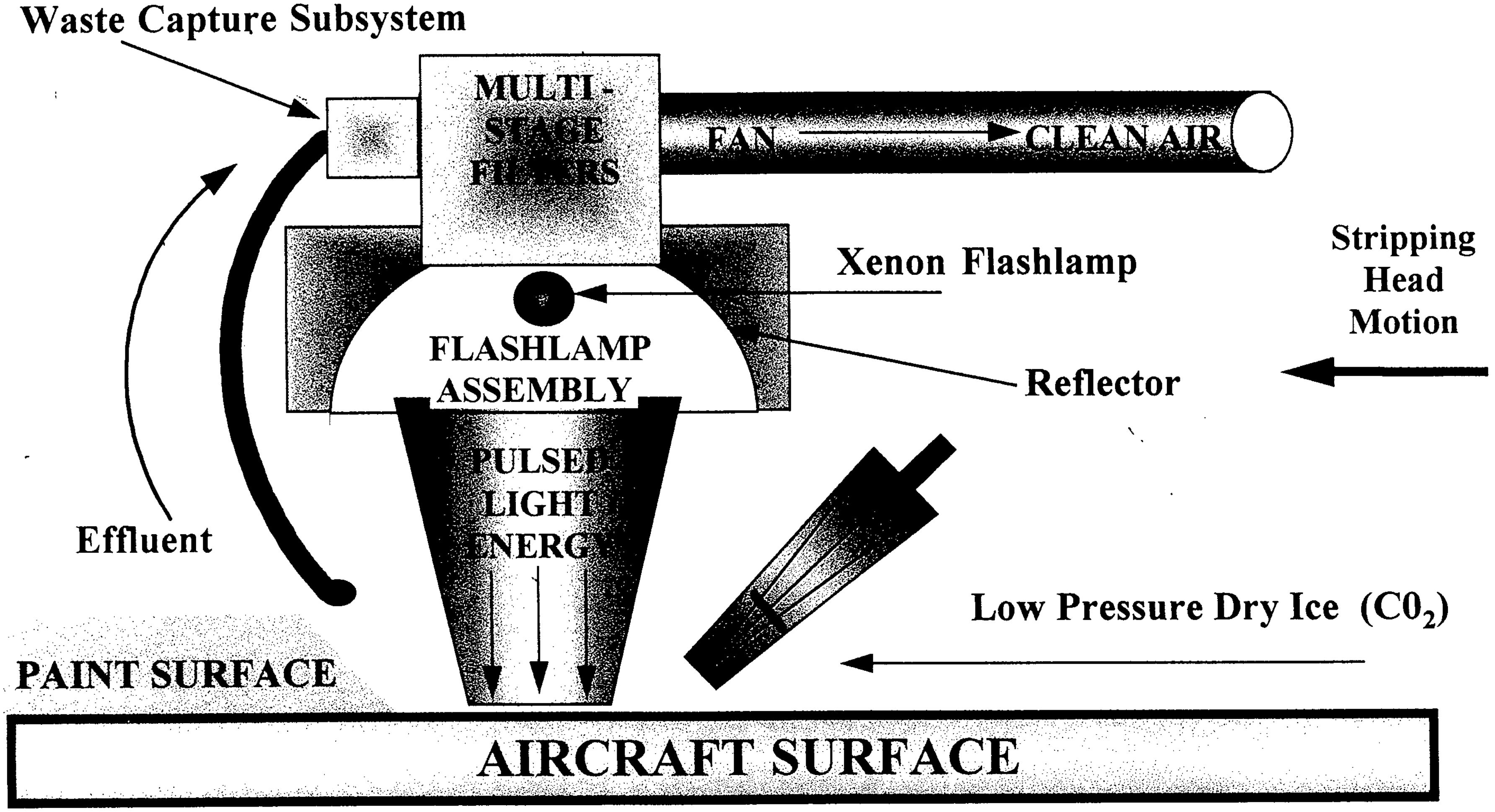
INTRODUCTION

During the life cycle of military aircraft, paint stripping and recoating are required periodically for inspection, maintenance and repair as well as for changes in paint schemes and special-purpose coatings. The paint systems used on military aircraft have included epoxy primers and polyurethane topcoats, which are more difficult to remove than the enamels or acrylics used earlier. Chemical paint strippers historically used for aircraft have contained toxic and hazardous components and aircraft depainting operations are a major source of hazardous waste generation in the Department of Defense. Federal and state agencies have begun to restrict the use of these hazardous materials and Government directives require significant reductions in hazardous waste generation.

A primary concern in choosing a paint stripping method for aircraft is whether the method will cause any damage or degrade the properties of the underlying metallic or composite substrate. The Naval Air Systems Team (Laboratories, Depots and Headquarters) partnered with the Air Force at Warner Robins Air Logistics Center in investigating mature, advanced paint removal technologies and conducted a joint Navy-Air Force- Industry program for development, evaluation and qualification of the Boeing synergistic xenon flashlamp/carbon dioxide pellet (Flashjet^R) coatings removal process for aircraft depainting, shown schematically in Figure 1. The Boeing Flashjet stripping head assembly is illustrated in Figure 2. In addition to the stripping head, the system is comprised of a control console, power module, dry ice particle delivery system, liquid CO_2 storage facility, compressor and an effluent capture system. Paint stripping with the

FIGURE 1

FLASHJET® COATINGS REMOVAL PROCESS



~~Synergism of Pulsed Light and Dry Ice~~

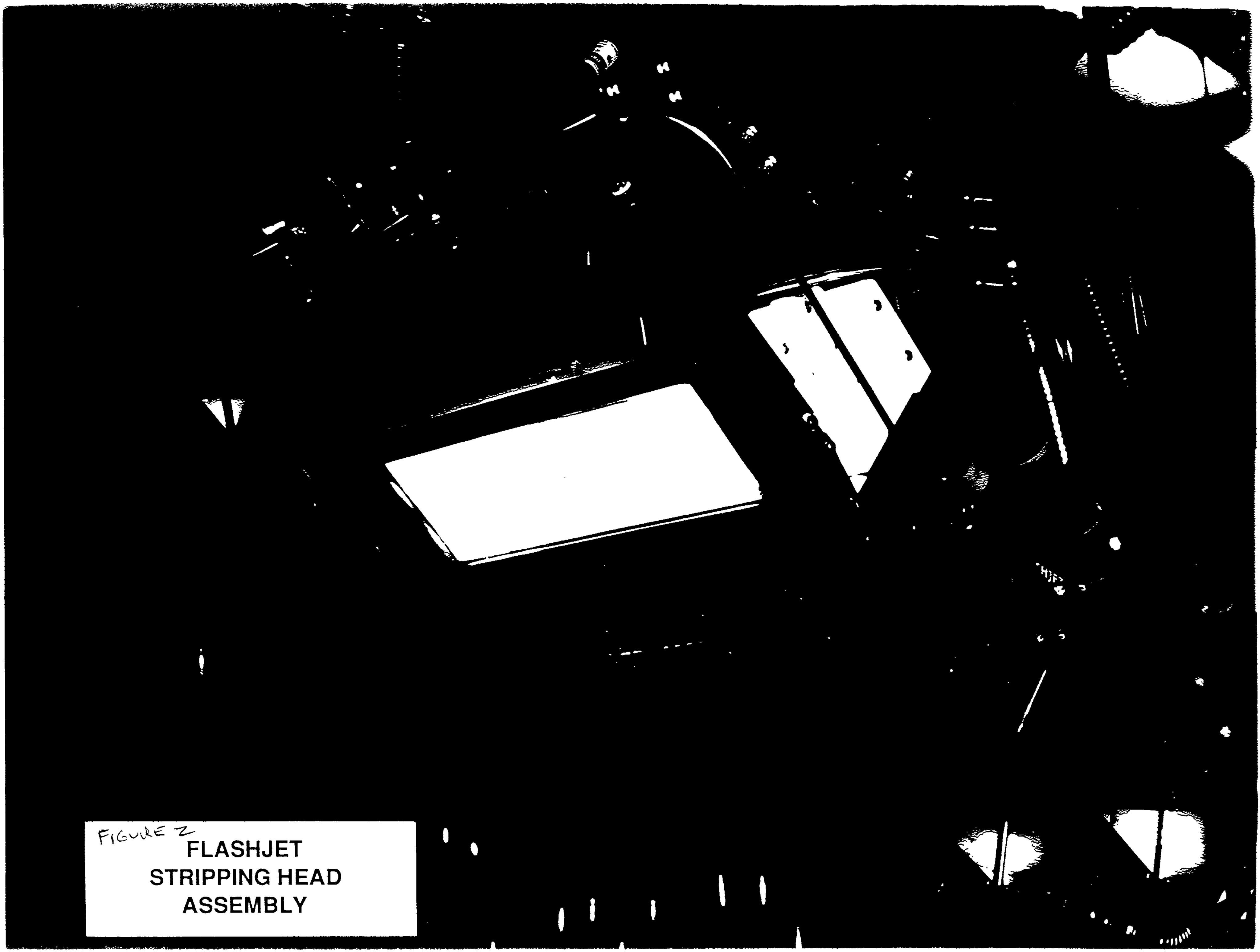


FIGURE 2

FLASHJET
STRIPPING HEAD
ASSEMBLY

Flashjet process was shown to reduce the hazardous waste stream significantly. The qualification process involved establishing acceptable, reproducible process parameters and testing to demonstrate that the Flashjet process can be used to remove Navy aircraft paint systems selectively to primer or substrate without damage to mechanical properties of the thin, structural aluminum alloys or graphite/epoxy substrates used in Navy aircraft.

PROCESS OPTIMIZATION

Under a program initiated by the U.S. Air Force at Warner Robins Air Logistics Center, Georgia, in 1991, McDonnell Douglas Aerospace (now the Boeing Co.) was contracted to develop and demonstrate the Flashjet process to provide efficient strip rates without damage to sensitive substrates (Ref. 1). With the sponsorship of the Strategic Environmental Research and Development Program (SERDP), the Navy teamed with WR-ALC in 1992 in order to leverage funds and optimize operating parameters for maximum coatings removal rates and good process control without overheating and damaging the substrate (Ref. 2). The operating parameters under consideration were input voltage, flash repetition rate, stripping head rate of travel, standoff distance and CO_2 delivery pressure, feed rate and impingement angle.

ENVIRONMENTAL SAFETY AND EFFECTIVENESS

Environmental issues were addressed by Boeing during operation of the Flashjet process. The system was demonstrated to capture airborne contaminants and to meet NESHAP and OSHA requirements for hazardous air pollution emissions. Operational safety requirements for ultraviolet radiation protection and hearing protection were established.

MATERIALS CHARACTERIZATION

With Air Force and Navy supervision, extensive testing was performed to evaluate the effects of flashlamp/CO_2 paint stripping assemblies on the mechanical properties of aircraft aluminum alloys and polymer composite substrates (Ref. 2). For these test programs, aluminum alloy and graphite/epoxy laminate panels were painted with epoxy primer and polyurethane topcoat, typical of military paint schemes. Panels were air dried for 7 days followed by an artificial age/cure for 7 days at 150^0F. Paint was removed by the Flashjet process to the primer, to the substrate and to an abusive saturation condition defined by an increased number of passes (increased dwell time) after stripping to the substrate. Substrate temperatures were recorded using adhesive backed temperature indicators to indicate peak temperatures reached in stripping. Panels instrumented with thermocouples embedded from the (unpainted) underside were used to confirm that temperature peaks lasted only on the order of milliseconds, indicating that exposure times and temperatures would not be expected to cause degradation of properties. This was to be confirmed by subsequent mechanical properties tests.

Metal fatigue life tests with a load spectrum representative of an F/A-18 aircraft were conducted on 2024-T3 and 7075-T6 aluminum bare and clad material, using open hole and unnotched crack initiation and crack growth specimens, according to a test matrix shown in Table I. A test matrix for determination of the effects of the stripping process on the properties of AS4/3501-6 graphite epoxy laminates is shown in Table II. The laminates used in these tests included those typical of a bonded-on patch repair and external structure as well as a surface sensitive layup for longitudinal flexure tests.

Additional investigation of paint stripping effects on graphite/epoxy composites was conducted in 1995 under a U.S. Navy Follow-On Program (Ref. 3). The effects of the stripping process were determined by tension, compression, four point longitudinal flexure and open hole fatigue tests, according to a test matrix shown in Table III. Two specific 14 ply layups were used for these panels; a surface sensitive layup for longitudinal four point flexure tests and a Navy AV-8B aircraft layup for the remaining tests. Results of the above test programs showed that the xenon flashlamp/CO_2 process can remove paint to the primer or to the substrate of thin, structural aluminum alloys or graphite/epoxy laminates without statistically significant effects on their mechanical properties.

As shown in the test matrix in Table II, interlaminar shear shear tests were conducted on moisturized graphite/epoxy composite after Flashjet stripping. No interlaminar shear strength degradation was observed, as compared to baseline control specimens. Boeing subsequently observed some planar microcracking in the laminates under magnifications over 100X which was thought to have occurred during moisturization of the panels. For the situation of high acoustic loads in fighter aircraft, Boeing conducted additional tests to determine whether moisturized graphite epoxy composite structures exposed to abusive Flashjet stripping would be susceptible to sonic fatigue failure resulting in additional crack propagation (Ref. 4). Sonic fatigue testing consisted of exposing moisturized baseline control, stripped and abusively stripped panels to two service lifetimes of acoustic noise exposure simulating engine ground run-ups and flight operations of a Navy fighter aircraft. Acoustic response surveys involved measurements of microstrain as sound pressure levels were increased. Panels were ultrasonically inspected prior to stripping and after sonic fatigue testing and photomicrographic inspection was performed. It was concluded that exposure to an acoustic environment after Flashjet stripping did not lead to any delamination or propagation of existing cracks.

PROCESS QUALIFICATION

The Flashjet process was found to be non-damaging to metallic and polymer composite structures on fixed-wing aircraft and to be cost effective and environmentally safe and efficient. As a result of the extensive materials testing described above, the Naval Air Systems Command authorized use of the Flashjet paint removal process for removing organic coatings from metallic and monolithic polymer composite fixed-wing aircraft structures.

SUMMARY

An environmentally safe and effective paint removal process suitable for aircraft paint stripping was developed by the Boeing Co. Reproducible operating parameters were established and the process was characterized and demonstrated for use on Navy aircraft, leading to authorization for its use on fixed-wing Navy aircraft.

References

1. D. Breihan, Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Prototype Development and Evaluation Program, MDC 92B0479, 1992
2. D. Breihan, J. Reilly, Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Development and Evaluation Program, U.S. Navy Add-On Program, MDC 93B0341, July, 1993
3. T. Berkel, Xenon Flashlamp and Carbon Dioxide Advanced Coatings Removal Development and Evaluation Program, U.S. Navy Follow-On Program, MDA 95X0019, June 1996.
4. T. Berkel, Acoustic Fatigue Testing of the Flashjet Process, Boeing-STL 99X0017, August, 1999

FATIGUE LIFE/CRACK GROWTH			
	SMOOTH	OPEN HOLE	CENTER CRACK
CLAD AL 7075-T6 (0.032")	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED
CLAD AL 2024-T3 (0.032")	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED	12 BASELINE 12 PRIMER 12 SUBSTRATE 12 SATURATED	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED
AL 7075-T6 (0.016")	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED	6 BASELINE 6 PRIMER 6 SUBSTRATE 4 SATURATED

Table I Aluminum Alloy Test Matrix

TEST	AS4/3501-6 LAMINATE	BASELINE	PRIMER	SUBSTRATE	SATURATED
TENSION	6 PLY	8	10	4	4
	12 PLY	8	10	4	4
COMPRESSION	6 PLY	8	10	4	4
	12 PLY	8	10	4	4
OPEN HOLE TENSION	6 PLY	8	10	4	4
	12 PLY	8	10	4	4
OPEN HOLE COMPRESSION	6 PLY	8	10	4	4
	12 PLY	8	10	4	4
FATIGUE	48 PLY	12	12		12
OPEN HOLE FATIGUE	48 PLY	12	12		12
LONGITUDINAL FLEXURE	14 PLY	8	10	4	4
INTERLAMINAR SHEAR	6 PLY	8	10	4	4
	12 PLY	8	10	4	4
INTERLAMINAR SHEAR (1% MOISTURE)	12 PLY	6	6		

Table II.AS4/3501-6 Test Matrix

TEST	BASELINE	PRIMER	SUBBSTRATE	SATURATION
4-POINT 1ST Set (1)	12	12	12	12
LONGITUDINAL 2ND SET (2)	12	12	12	12
FLEXURE 3RD Set (3)	24	24	24	24
TENSION	12	12	12	12
COMPRESSION	12	12	12	11
OPEN HOLE FATIGUE	12	12	12	12

TABLE III AS-4/3501-6 ADDITIONAL TEST MATRIX