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STRESS CORROSION RESISTANT FASTENERS

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This paper describes a family of high performance aerospace fasteners made from corrosion resistant alloys for use in applications where corrosion and stress-corrosion cracking are of major concern. The materials discussed are mainly A-286, Inconel 718, MP35N* AND MP159. Most of the fasteners utilize cold worked and aged materials to achieve the desired properties. The fasteners are unique in that they provide a combination of high strength and immunity to stress corrosion cracking not previously attainable. A discussion of fastener stress corrosion failures is presented including a review of the history and a description of the mechanism. Case histories are presented to illustrate the problems which can arise when material selection is made without proper regard for the environmental conditions. Mechanical properties and chemical compositions are included for the fasteners discussed. Several aspects of the application of high performance corrosion resistant fasteners are discussed including galvanic compatibility and torque-tension relationships.

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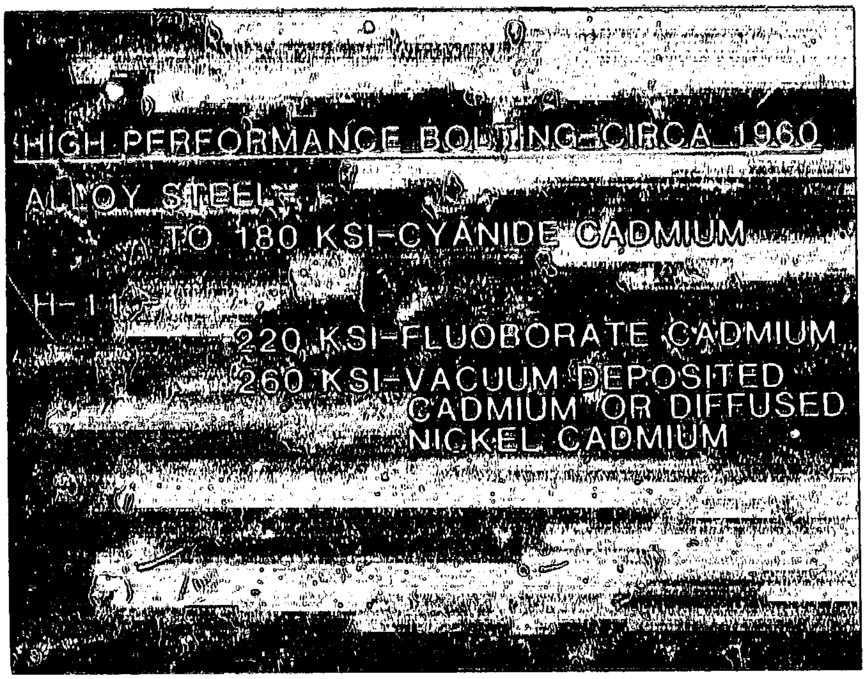
*MP35N is a registered trademark of SPS Technologies.



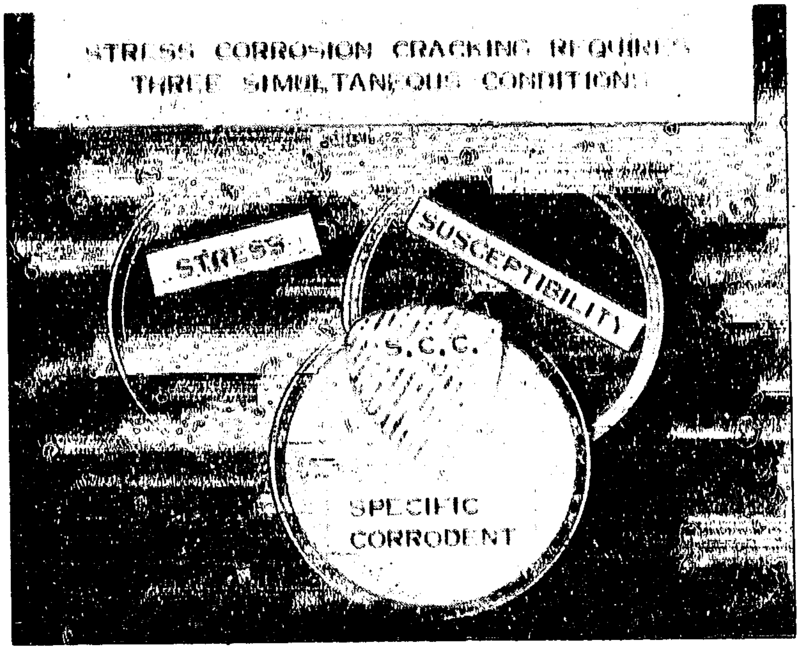
HIGH PERFORMANCE BOLTING-CIRCA 1960

ALLOY STEEL
TO 180 KSI-CYANIDE CADMIUM

H-11
220 KSI-FLUOBORATE CADMIUM
260 KSI-VACUUM DEPOSITED
CADMIUM OR DIFFUSED
NICKEL CADMIUM

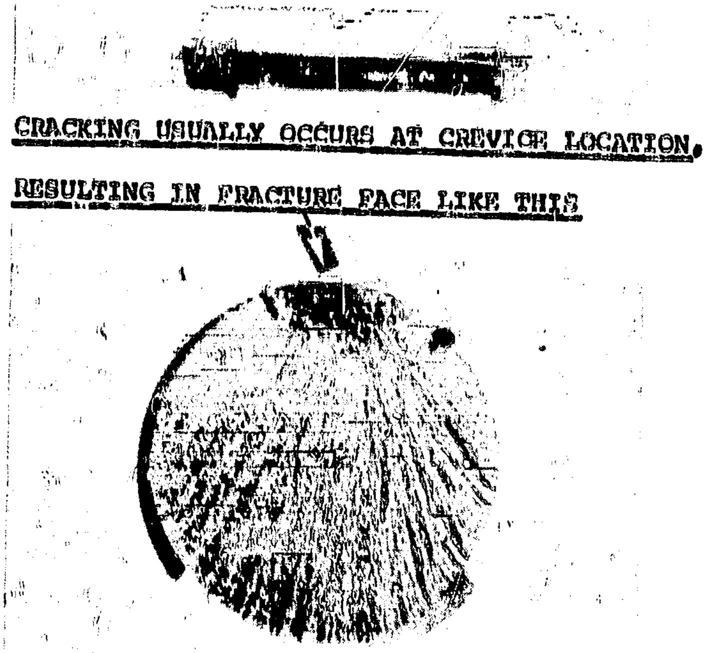
INTRODUCTION

Fasteners made from alloy steel and modified tool steels have been used in critical aerospace applications for decades with a great deal of success. Tensile strengths as high as 260 KSI and even 300 KSI have been achieved and used in applications which required a high degree of integrity and on which the integrity of the structure depended. Field failures occurred as a result of stress corrosion cracking although the failures were uncommon and not well understood until recently. As the need for lightweight structures increased, fastener sizes decreased, preloads increased, and design redundancies were reduced to provide the maximum mission capability at the lowest cost. One result was an increase in the incidence of stress corrosion cracking failures. The susceptibility of the noncorrosion resistant materials, the general higher stresses, and the presence of corrosive environments were the main contributors to the increase. Coatings were found to extend the fastener life somewhat, but were not capable of totally preventing stress corrosion cracking. Attempts were made to protect the area of the fasteners from corrosion with various sealants, but these were only partially successful. In recent years, the most critical applications for high performance fasteners have been filled by those fasteners made from corrosion resistant materials.



HISTORY OF STRESS CORROSION FAILURES IN SERVICE

A review of the history of stress corrosion failure of fasteners reveals that the majority of failures have occurred in bolts with 220 KSI and 260 KSI psi minimum tensile strengths. These parts are almost universally made of AMS 6487, an alloy developed from the basic H-11 steel composition. For airframe applications, these bolts are usually coated with fluoborate cadmium per NAS 672 (220 KSI fasteners) or vacuum-deposited cadmium per MIL-C-8837 (260 KSI fasteners).



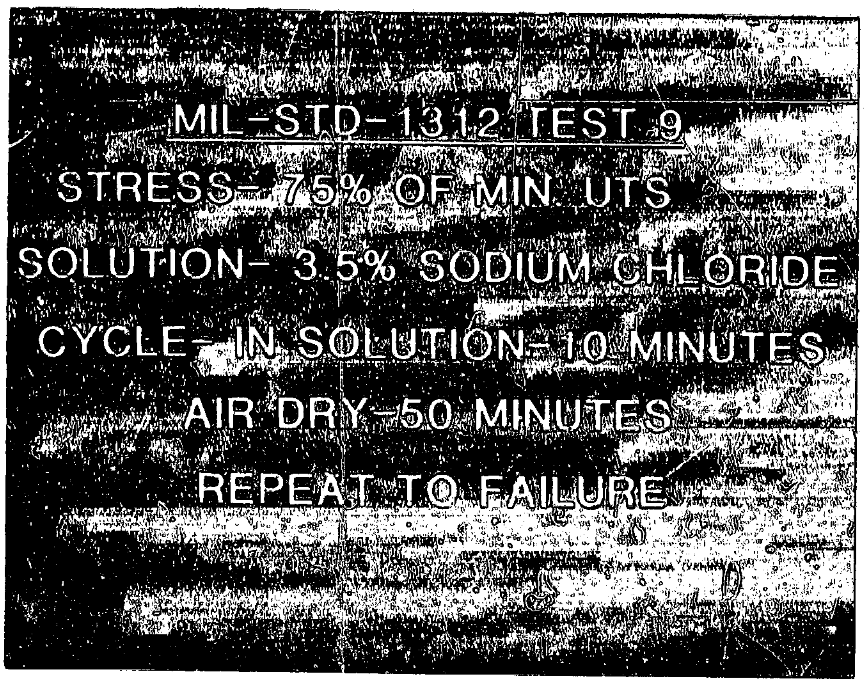
CRACKING USUALLY OCCURS AT CREVICE LOCATION,

RESULTING IN FRACTURE FACE LIKE THIS

Stress corrosion failures exhibit a classic fracture with the crack initiation occurring at a surface corrosion pit generally associated with a crevice condition in the joint. The corrosion aided crack propagates to an extent dependent on the stress on the part and the fracture toughness of the material. When the crack grows to the extent that the uncracked section can no longer sustain the stress in the presence of the sharp crack, the part fails. A typical stress corrosion failure is shown in this photograph.

SEM FRACTOGRAPH AMS 6[illegible] x70[illegible]
INTERGRANULAR FRACTURE WITH CORROSION
PRODUCTS.

A typical stress corrosion failure fractograph exhibits a "rock candy" like fracture face. Secondary cracking is extensive and corrosion product covers the exposed facets of the individual grains.



MIL-STD-1312 TEST 9

STRESS- 75% OF MIN. UTS

SOLUTION- 3.5% SODIUM CHLORIDE

CYCLE- IN SOLUTION-10 MINUTES

AIR DRY-50 MINUTES

REPEAT TO FAILURE

LABORATORY STRESS CORROSION TESTS

Concern over stress corrosion cracking failure led to the development of a standard test which was ultimately adopted as a military standard (MIL-STD-1312 test no. 9). This test requires preloading the nut and bolt to be tested into a cylinder of similar material by a reproducible method such as measured bolt extension. The preloaded assembly is placed in an apparatus which immerses it in 3.5% NaCl solution for 10 minutes and then places it into moving air for 50 minutes. This cycle is repeated until failure occurs. The time to failure is recorded.

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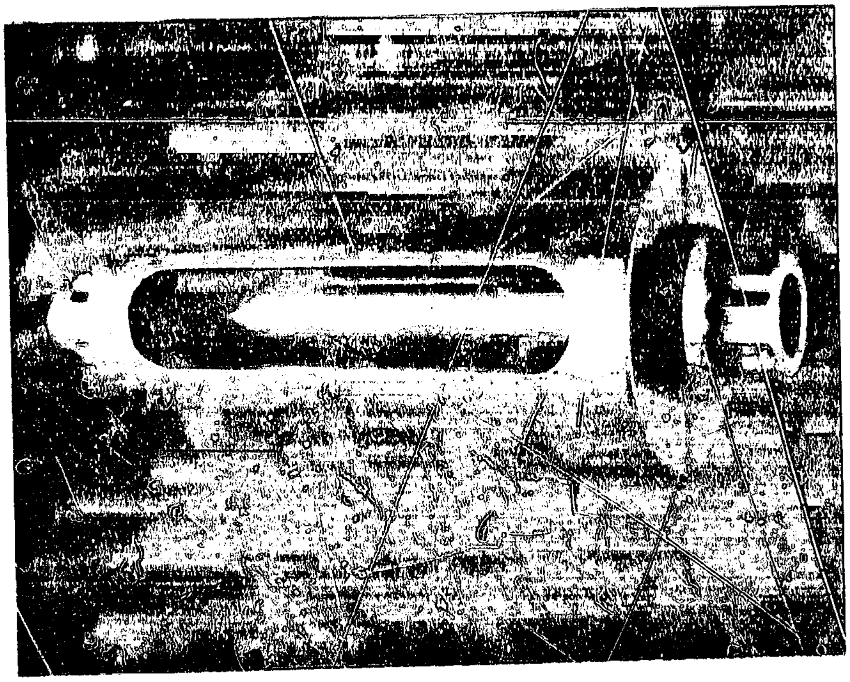
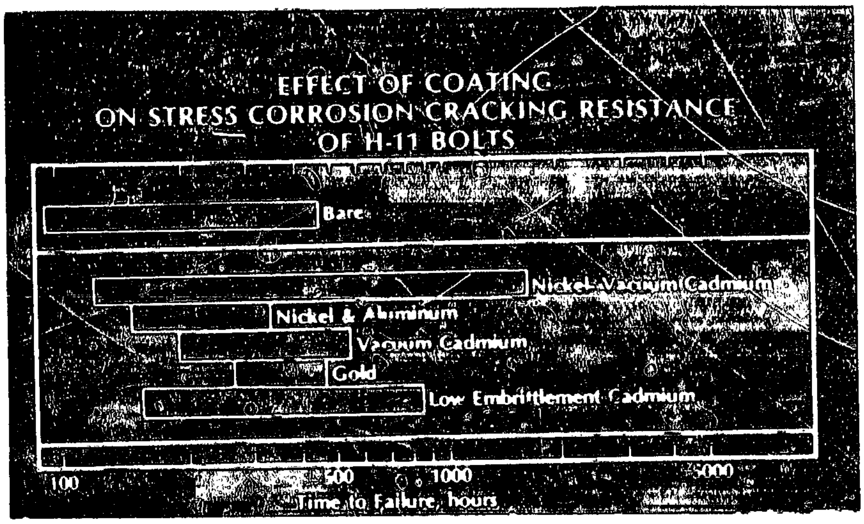


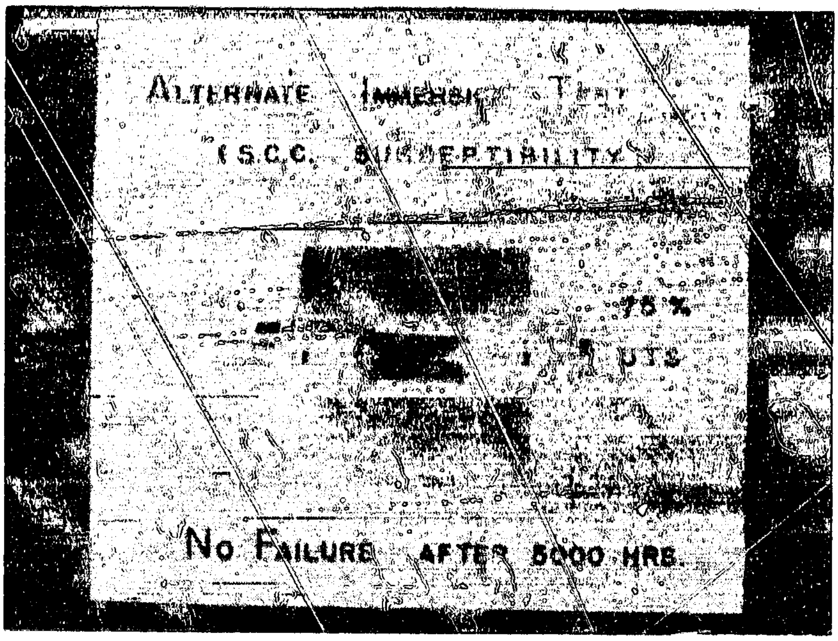
The test assembly consists of a bolt and nut tightened into a cylinder of the appropriate material as shown. Preload is generally developed by developing a predetermined amount of bolt extension while tightening the bolt nut combination. The extension is determined by running a load-extension curve to failure and selecting the elongation at the appropriate preload, usually 75% of ultimate tensile strength.

The test facility consists of plastic containers of 3½% NaCl solution and a device which immerses the test assemblies in the solution for 10 minutes and removes them for 50 minutes into moving air. The cycle is repated to failure or to a predetermined number of cycles.

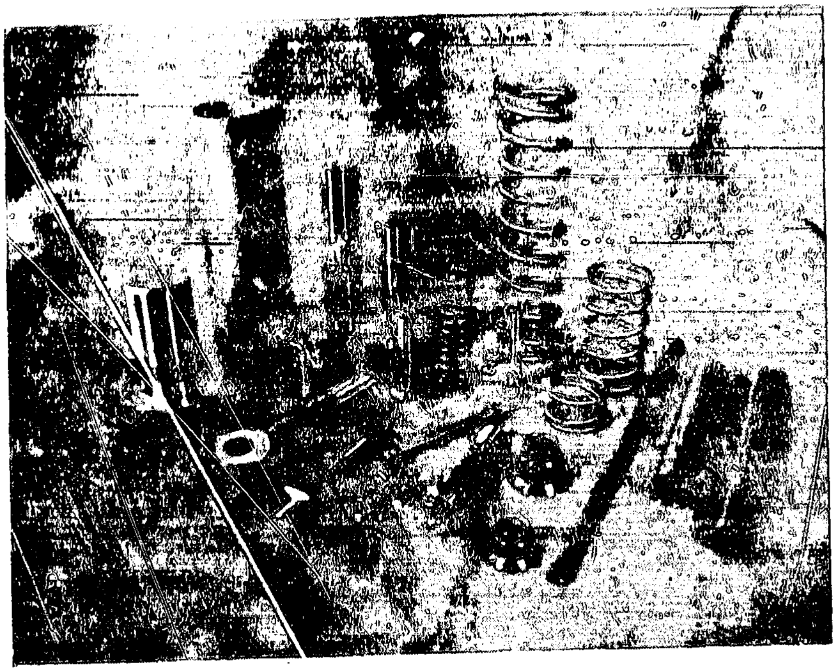


Laboratory testing produces, in a relatively short time, failures with fracture topography identical to that of field failures, providing a laboratory means to assess the relative stress corrosion cracking susceptibility of various materials, strength levels, and coatings at various stress levels. Such tests indicate that coatings can provide some protection to 260 KSI fasteners, but that failures can occur at times not significantly longer than those experienced with bare fasteners.

A new fastener material designated as Multiphase Alloy MP35N offers a combination of characteristics never before equalled in fastener history: high strength, toughness, outstanding corrosion and stress corrosion cracking resistance, and excellent cryogenic properties. Multiphase is a quaternary alloy system with a nominal composition of 35Ni-35Co-20Cr-10Mo. Through a combination of cold working, transformation, and aging, Multiphase can be strengthened to 260,000 psi tensile strength, resulting in the most corrosion resistant high-strength fastener ever manufactured.



MP35N fasteners subjected to the MIL-STD-1312 test experienced no failures in 5000 hours and no stress corrosion failures have occurred in the field despite exposure to high stresses and highly aggressive environments.



MP35N has been applied to a wide variety of products including bolts, nuts, tubing, springs, shear pins and prosthetic devices.

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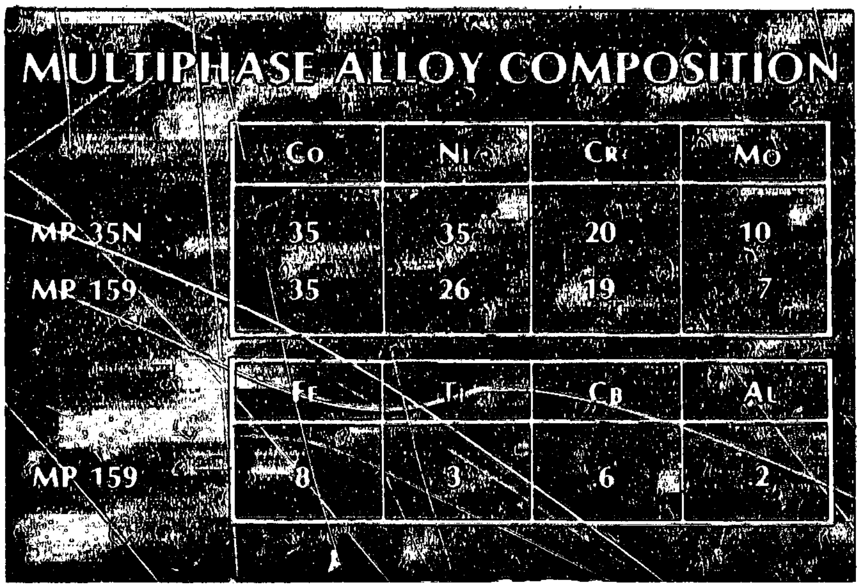
The application of high strength corrosion resistant fasteners to aerospace structure has taken place in both original design and rework as a result of field failures with noncorrosion resistant fasteners. The largest single application involves the use of MP35N alloy and Inconel 718 fasteners in the space shuttle. The original design of the orbiters, solid rocket boosters, and expendable fuel tanks made extensive use of these fasteners to provide reliable fastening in the presence of extremely high loads and aggressive, seacost environments. Inherent corrosion resistance was further mandated because the vacuum conditions of space prohibit the use of cadmium plating or other protective coatings. An MP35N alloy application on Harpoon missile canisters resulted from a series of tests comparing PH13-8Mo to MP35N in resistance to corrosion and stress corrosion cracking. The MP35N alloy was chosen and has been used exclusively for the fasteners which join the individual canisters together and attach the canister assemblies to the launch support structure.



MULTIPHASE ALLOY COMPOSITION

	Co	Ni	Cr	Mo
MP 35N	35	35	20	10
MP 159	35	26	19	7

	Fe	Ti	Cb	Al
MP 159	8	3	6	2

A derivative of the MP35N alloy, MP159 was developed to provide improved high temperature properties and hot forgeability. The MP159 alloy has found many applications in the gas turbine industry, where it provides properties superior to those of Inconel 718.

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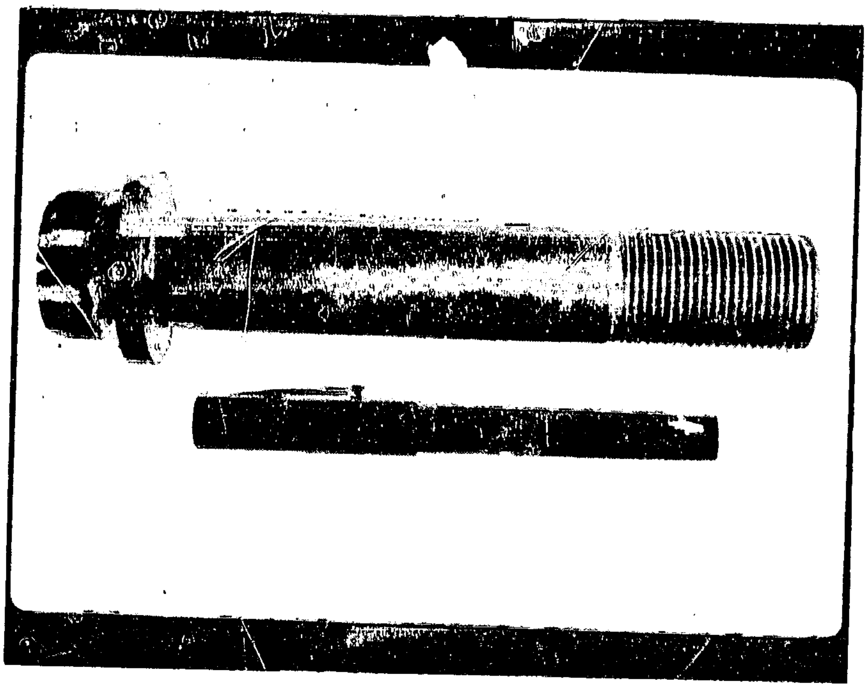
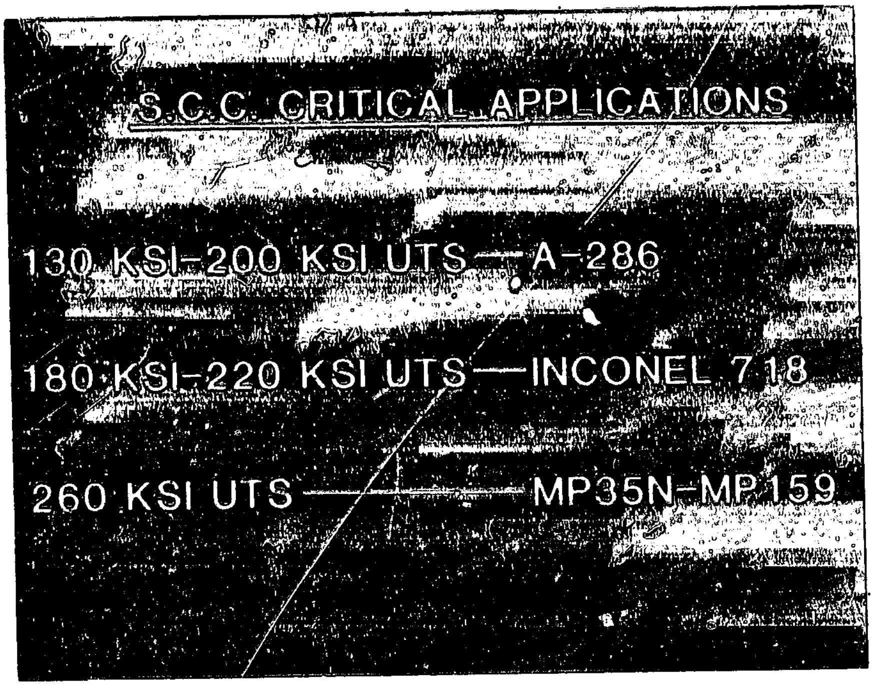


INCONEL 718

Inconel 718 was developed for applications up to 1200°F. In its most commonly used condition, solution treated and aged, it has a minimum tensile strength of 180 KSI. This strength level has permitted its use in applications which would normally use alloy steel fasteners such as MS21250s but in which concern over corrosion and stress corrosion cracking dictates the use of inherently corrosion resistant materials. For applications which require 220 KSI fasteners for which AMS 6487 or alloy steel would have been used, the ideal material for corrosion critical applications is Inconel 718. This is produced by the cold work and age method and the resulting fasteners are mechanically equivalent to their noncorrosion resistant counterparts.



S.C.C. CRITICAL APPLICATIONS

130 KSI–200 KSI UTS—A-286

180 KSI–220 KSI UTS—INCONEL 718

260 KSI UTS——MP35N–MP159

CONCLUSIONS

Recent developments in materials and fasteners have created new design options for the designer of critical structures. Where stress corrosion cracking is of some concern, a family of fasteners has been developed to provide virtual immunity to failures resulting from interaction with aggressive environments. While the purchase price of those fasteners exceeds that of conventional fasteners, the total life cycle cost is attractive when the cost of periodic inspection, replacement, and product liability is considered.

The use of corrosion resistant fasteners will continue to increase as the demand for higher integrity structures grows.