



July 31, 1987

Mr. Ellis W. Merschoff, Acting Chief
Vendor Inspection Branch
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
4340 East West Highway
Bethesda, MD 20014

TRANSMITTAL OF FINAL MATERIALS TECHNOLOGY LAB REPORT TESTS OF SAFETY-RELATED BOLTS, AND NUTS FROM SAN ONOFRE AND RANCHO SECO NUCLEAR POWER PLANS (FIN A6181) - BLB-55-87

- Ref: (a) G. E. Marx ltr to S. B. Milam, Marx-16-85, "Transmittal of NRC Form 189 for Technical Assistance for Vendor Program Inspection" (FIN A6181) January 14, 1985
- (b) Task Order 87D, Rev. 1, Project 1, "Test Safety-Related Bolts and Nuts from San Onofre and Rancho Seco," June 24, 1987

Dear Mr. Merschoff:

In accordance with FIN A6181, Reference (a), EG&G Idaho, Inc. is providing technical assistance to the Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation (NRR). This assistance involves the evaluation of vendor-related problems with valves, pumps, relays and fuel casks. Task Order 87D, Rev. 1, Reference (b), required EG&G Idaho, Inc. to verify mechanical and chemical tests and perform additional tests on 14 bolts and studs and 3 nuts used in safety-related applications at the San Onofre and Rancho Seco Nuclear Plants.

The enclosed materials technology Lab Report completes the work scope requirements of Task Order 87D, Rev. 1.

Very truly yours,

B. L. Barnes, Manager
Reactor Inspections Unit

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PDR FOIA
MCGRATHB9-334 PDR
jm

Enclosure:
As Stated

- cc: C. M. Abbate, NRC-NRR
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TESTS OF SAFETY-RELATED BOLTS, STUDS AND NUTS
FROM SAN ONOFRE AND RANCHO SECO
NUCLEAR POWER PLANTS

1. Introduction. The U.S. Nuclear Regulatory Commission, Office of Nuclear Regulation, Vendor Inspection Branch submitted ~~12 bolts, 2 studs, and 3 nuts~~ used in safety-related applications to EG&G Idaho, Inc. for testing. Fasteners serial numbers S0-1 through S0-6 were obtained from Rancho Seco Nuclear Power Plant and fasteners serial numbers S0-7 through S0-17 were obtained from San Onofre Nuclear Power Plant. This assignment was authorized and funded by Task Order 87D, Rev. 1, FIN A6181, Project 1.

2. Testing. In order to determine the acceptance standards for each stud, nut, and bolt, the identification grade marks on each fastener were correlated with the grade marks and related specifications identified in the Industrial Fastener Institute's Fastener Standard. The results of this correlation are presented in Table 1. Not all of the requirements defined in the ASTM Standards were evaluated. For example, process requirements for the fasteners and dimensional requirements for the threads are defined but were not evaluated. The tests defined in the NRC Task Order were the tests that were accomplished.

2.1 Mechanical Testing. Tensile and hardness tests were conducted in accordance with ASTM A-370, Mechanical Testing of Steel Products, which is the standard for mechanical testing of steel fasteners. The specific tests required for each fastener were determined by reviewing the standard applicable to each grade of fastener.

2.1.1 Hardness Tests. Hardness tests were performed using a standard Rockwell hardness tester. Acceptable hardness machine performance was verified by performing hardness tests on certified test blocks prior to testing each fastener. A total of four

hardness tests were performed on each fastener and an average hardness value was then calculated based on the four measurements and reported in either Rockwell C or Rockwell B scale units.

2.1.2 Tensile Tests. Tensile tests were accomplished using a 100,000 pound load capacity, Instron Model 1128, tensile test machine having a load weighing accuracy of $\pm 0.5\%$ of indicated load. Load versus deflection values were automatically recorded and retained for each tensile test.

Full-size specimens were tested to determine the ultimate loads for all bolts and studs except bolts S0-9, S0-16 and S0-17. Crosshead travel and loads were automatically recorded for all full-size specimens.

The ultimate loads that were determined for full size bolts S0-3 and S0-5 were questionable since considerable yielding and shearing in the bolt threads occurred during the test. After testing, inspection of the bolt bodies revealed the diameters were unchanged after testing, which indicates the ultimate loads in the threaded section occurred prior to yielding of the material in the bolt bodies. Because the initial test results were questionable standard 0.25 inch round tensile specimens were machined from each bolt body (S0-3 and S0-5) which were then tensile tested using a 1.0-inch extensometer to determine the 0.2% offset yield strength. The 0.2% offset yield strength values that were obtained during these tests have compared with the breaking loads obtained during the full-size specimens which confirmed that the original loads were less than 0.2% offset yield strength in the bolt bodies and the results for the machined specimens were valid. The results for the machined specimens from the body of bolts S0-3 and S0-5 are reported in the individual test reports. The initial results, for the full size tensile test, which were questionable, are not reported.

*Ultimate loads for fasteners S0-7, S0-8, S0-10, S0-12, and S0-14 were determined using full size specimens. The maximum loads that

were obtained during testing of these bolts were converted and reported as ultimate tensile values in pounds per square inch. The 0.2% offset yield strengths were determined from the load-strain diagrams that used crosshead travel for the strain measurements. Since the ultimate tensile strengths and 0.2% yield strengths that were determined for these fasteners met the minimum defined requirements, machined specimens were not made or tested for these fasteners.

Standard 0.50 inch round tensile specimens were machined and tested for bolts S0-9, S0-16, and S0-17 and standard 2.0-inch extensometers were used to determine the 0.2% offset yield strength for the specimens.

3. Metallographic Examination. Metallographic specimens were prepared for bolts S0-3 and S0-5. Longitudinal and transverse sections were taken from each bolt body. These sections were mounted, polished, etched with a nital solution (5% HNO₃ and 95% methyl alcohol), and examined at 100 and 400 magnifications (Figures 1 and 2) for bolt S0-3. A ferritic structure was observed, and an ASTM grain size of 8 to 8.5 was determined. This grain size is normal for a bolt of this size made from AISI 1008 or 1010 mild steel.
4. Chemical Analysis. Samples for chemical analysis were obtained from each stud, nut and bolt. Weighted portions of the samples (approximately 0.5 g) were submitted for chemical analysis. The samples were analyzed for carbon, chromium, copper, manganese, molybdenum, nickel, silicon, sulfur, phosphorus and vanadium. Samples were analyzed by EG&G Idaho, Inc. and the Ford Chemical Co., Salt Lake City. For samples having inconsistent or inconclusive results, repeat analyses were conducted by independent laboratories for verification. The verification analyses were done by WINCO (Westinghouse Idaho Nuclear Co., Inc.) and National Spectrographics Laboratories, Cleveland, Ohio. During the verification analysis, boron amounts were also determined for Bolts S0-1, S0-2, S0-4, and S0-6. The standards for these bolts (ASTM

A-325 and A-449) allow two types of bolts; Type 1 without a minimum allowable boron content, and a Type 2 that requires a specified minimum of 0.0005% boron.

The specific elements required for product analysis are defined in the ASTM standard that is specified for each fastener, and only the results obtained for the required elements are reported in the individual fastener reports.

5. Certification of Accuracy of Chemical Test Results. Appropriate quality assurance and quality control (QA/QC) measures were to be taken and reported by all contracted laboratories. The reproducibility for EG&G, Ford and National Spectrographic were reported to be within $\pm 5\%$. For the WINCO analysis, duplicate samples of NBS standard 72E were submitted along with the bolt samples which provided comparative results. The Ford results that were suspected to be in error were recorded and noted in the individual test reports as being acceptable for engineering information only.

5. Discussion of Results. A review of the test results revealed the following significant findings:

- o Bolts S0-1 and S0-2 meet the chemical and mechanical requirements of ASTM A-325 Type 1, the required standard. However, these bolts contained 0.0041% boron, which also qualifies them as Type 2 bolts. The minimum boron content for Type 2 bolts is 0.0005%. ASTM A-325 does not define a maximum amount of boron for either the Type 1 or Type 2 bolts, and the standard does not specifically prohibit the intentional addition of boron to a Type 1 bolt. The identification marks on the bolts indicate they were produced by Unyrite Fastener Manufacturing Company, Ltd, a Japanese manufacturer. Since bolts S0-1 and S0-2 are marked as Type 1 bolts, are apparently manufactured in a foreign country, and contain appreciable amounts of boron they may be considered in the same class as the controversial SAE J429 fasteners that have been discussed in the national news media.

- o Bolts SO-3 and SO-5 do not meet the chemical or mechanical requirements specified in ASTM A-193 Grade B-7, the required standard for these bolts. The identification marks (Figure 3) on these bolts indicate they were produced by Clark Brothers Bolt Company, a U.S. manufacturer. The bolts should have been made from an alloy steel containing chromium and molybdenum, such as AISI 4140, or 4145 steel. The bolts were probably made from AISI 1008 or 1010 steel. These bolts are not suitable for either high temperature or high strength, which is the intended applications defined in the ASTM Standard.

- o Stainless steel bolts SO-12 and SO-14 met the mechanical requirements but did not meet the chemical requirements specified in ASTM A-193 Grade B-8M, and nuts SO-13 and SO-15 did not meet the chemical requirements specified in ASTM A-194 Grade 8, the required standards. Mechanical requirements are not specified for nuts. The identification marks on these bolts and nuts (Figure 4) indicate they were produced by Highland Nut and Bolt Company, a U.S. manufacturer. Since the analyses for bolts SO-12 and SO-14, and nuts SO-13 and SO-15 indicated a molybdenum content greater than 2.0%, the material was probably intended for AISI Type 316 stainless steel nuts made to the requirements of ASTM A-194. Apparently both the stainless steel bolts and the stainless steel nuts were made from the same heat of material. The nickel and chromium requirements for ASTM A-193 and A-194 are:

Type	AISI Number	ASTM Standard	Chromium (%)	Nickel (%)
Bolt	Type 304	ASTM A-193 Grade B8	18.00-20.00	8.00-10.50
	Type 316	ASTM A-193 Grade B8M	16.00-18.00	10.00-14.00
Nut	Type 304	ASTM A-194 Grade 8	18.00-20.00	8.00-10.50
	Type 316	ASTM A-194 Grade 8M	17.00-19.00	9.00-13.00

Since the nickel content is less than 10% the material does not meet the requirements, for a Type 316 bolt. Since the chromium content is less than 18%, the material does not meet the requirements for either a Type 304 nut or bolt. Only the chemical

requirements for a Type 316 nut would be met, and Type 316 nuts were not one of the types of stainless steel fasteners that were submitted for evaluation.

The results of the limited evaluations of safety related fasteners provided, indicate that the basic specification requirements of fasteners S0-3, S0-5, S0-12, S0-13, S0-14, and S0-15 were not met.

TABLE 1. GRADE MARKS AND REQUIRED ASTM STANDARDS FOR FASTENERS SUBMITTED FOR EVALUATION

	<u>Sample Identification</u>	<u>Grade Mark</u>	<u>ASTM Standard</u>
<i>Rancho Seco</i>	S0-1	A-325	✓ A-325 Type 1
	S0-2	A-325	✓ A-325 Type 1
	S0-3	B7	✓ A-193 Grade B-7 ✓
	S0-4		✓ A-449 Type 1 ✓
	S0-5	B7	✓ A-193 Grade B-7 ✓
	S0-6		✓ A-449 Type 1 ✓
<i>San Onofre</i>	S0-7	B7	✓ A-193 Grade B-7
	S0-8	B7	✓ A-193 Grade B-7
	S0-9	B7	✓ A-193 Grade B-7
	S0-10	BBM	✓ A-193 Grade B-8M
	S0-11	8	A-194 Grade 8
	S0-12	BBM	✓ A-193 Grade B-8M
	S0-13	8	✓ A-194 Grade 8
	S0-14	BBM	✓ A-193 Grade B-8M
	S0-15	8	✓ A-194 Grade 8
	S0-16	B7	✓ A-193 Grade B-7
	S0-17	B7	A-193 Grade B-7

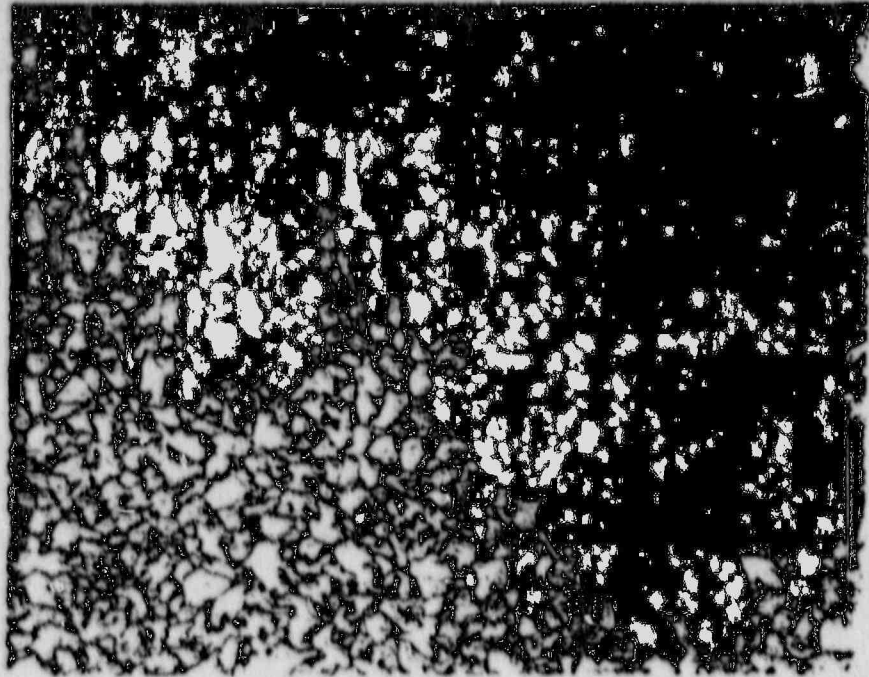


Figure 1. Photomicrograph at 100 magnifications of bolt S0-3 showing an ASTM grain size of 8 to 8.5.



Figure 2. Photomicrograph at 400 magnifications of bolt S0-3 showing a normal ferritic structure.

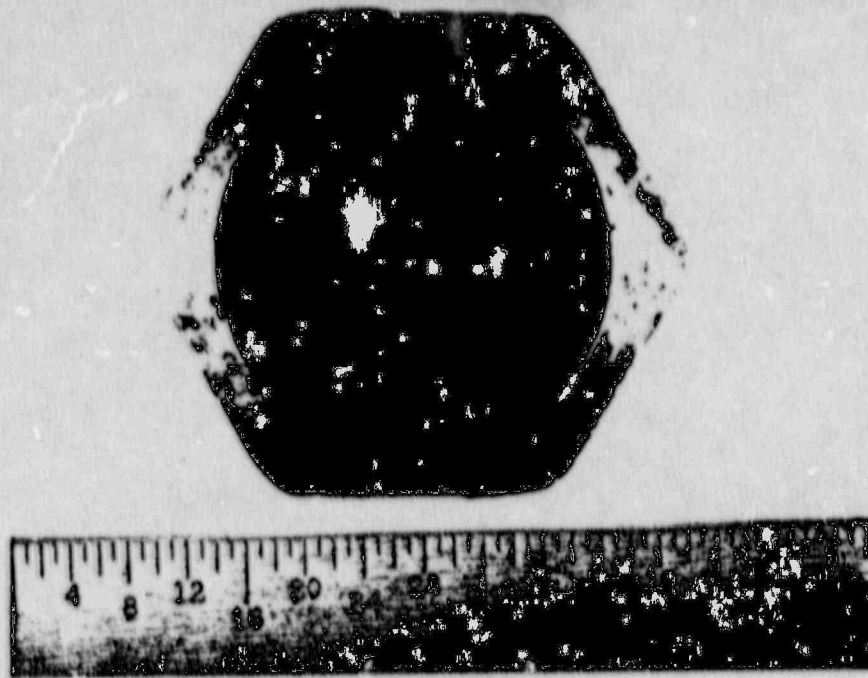


Figure 3. Photomicrograph of identification mark on bolt SO-3 indicating the producer was Clark Brothers Bolt Company.

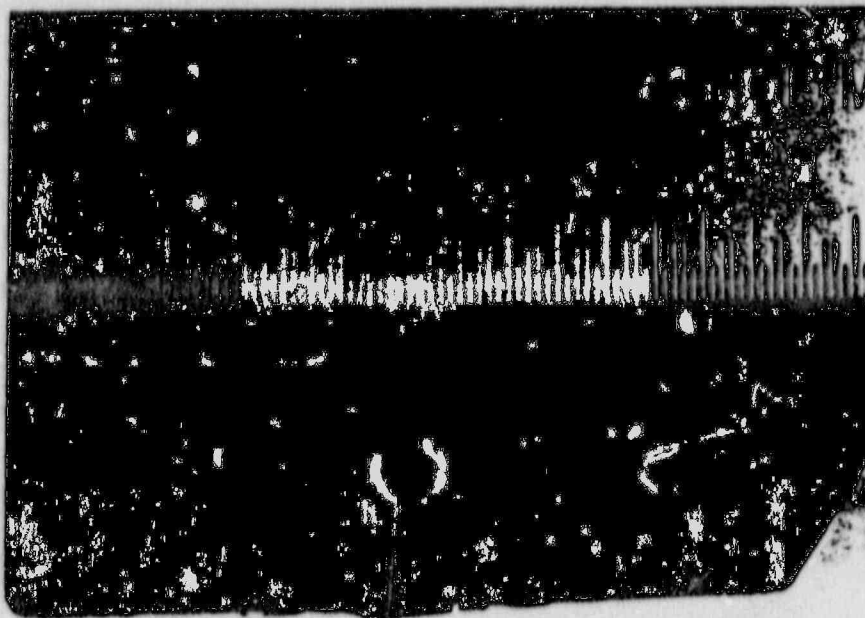


Figure 4. Photomicrograph of identification mark on nut SO-13 indicating the nut was produced by Highland Nut and Bolt Company.

Sample Identification: S0-1
Source: Rancho Seco
Sample Type: Bolt
Size: 2 7/8 x 3/4
Identification Grade Mark: A-325
ASTM Standard: A-325 Type 1

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - more than 0.25	-	0.22*	0.35	-
Manganese - 0.57 or above	0.79	0.80	-	-
Phosphorus - less than 0.048	-	0.01	-	-
Sulphur - less than 0.058	-	0.025	-	-
Boron - not specified	-	-	0.0041**	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Load - 40,100 pounds

Rockwell Hardness - Rc 24-35

Actual Mechanical Measurements (EG&G Idaho)

44,250 pounds

Rc 28.6

Remarks:

Bolt S0-1 meets the minimum requirements evaluated by EG&G and defined in ASTM A-325-86a Type 1.

* The test data suspected to be in error - reported for engineering information only.

** Boron amount exceeds the 0.0005% minimum specified for a Type 2 bolt therefore, bolt S0-1 meets both Types 1 and 2 requirements.

Sample Identification: S0-2
Source: Rancho Seco
Sample Type: Bolt
Size: 2 7/8 x 3/4
Identification Grade Mark: A-325
ASTM Standard: A-325 Type 1

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - not less than 0.25	-	0.23*	0.35	-
Manganese - not less than 0.57	0.80	0.81	-	-
Phosphorus - not more than 0.048	-	0.01	-	-
Sulphur - not more than 0.058	-	0.024	-	-
Boron - not controlled	-	-	0.0041**	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Load - 40,100 pounds

Rockwell Hardness - Rc 24-35

Actual Mechanical Measurements (EG&G Idaho)

46,200 pounds

Rc 28.1

Remarks:

Bolt S0-2 meets the minimum requirements evaluated by EG&G and defined in ASTM A-325-86a Type 1.

* The test data suspected to be in error - reported for engineering information only.

** Boron amount exceeds the 0.0005% minimum specified for Type 2 bolt therefore, bolt S0-2 meets both Types 1 and 2 requirements.

Sample Identification: S0-3
 Source: Rancho Seco
 Sample Type: Bolt
 Size: 2 3/4 x 5/8
 Identification Grade Mark: B7
 ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
+ Carbon - 0.37 - 0.49	-	0.22*	0.071	0.070
+ Chromium - 0.75 - 1.20	0.06	0.09	-	-
+ Manganese - 0.65 - 1.10	0.38	0.81*	0.40	-
+ Molybdenum - 0.15 - 0.25	0.01	0.03	-	-
Silicon - 0.15 - 0.35	0.04	0.22*	-	-
Phosphorus - less than 0.035	-	0.009	-	-
Sulfur - less than 0.040	-	0.022	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

+ Ultimate Tensile Strength - 125 Ksi
 + 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

53.8 Ksi
 40.3 Ksi
 30.3%
 78.6%
 Rb 61.6

Remarks:

Bolt S0-3 does not meet the chemical or mechanical requirements defined in ASTM A-193/A-193 M-86 Grade B-7.

* The test data suspected to be in error - reported for engineering information only.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Clark Brothers Bolt Co., Midland, Connecticut. (Industrial Fastner Institute registration.)

Sample Identification: S0-4
Source: Rancho Seco
Sample Type: Bolt
Size: 2 3/4 x 5/8
Identification Grade Mark:
ASTM Standard: A-449 Type 1

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.25 - 0.58	-	0.25*	0.37	-
Manganese - not less than 0.57	0.80	0.81	-	-
Phosphorus - not more than 0.042	-	0.010	-	-
Sulfur - not more than 0.058	-	0.021	-	-
Boron - not controlled	-	-	Less than 0.0005	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Load - 27,100 pounds

Proof Load - 19,200 pounds

Maximum Rockwell Hardness - Rc 34

Actual Mechanical Measurements (EG&G Idaho)

29,500 pounds

26,000 pounds**

Rc 22.9

Remarks:

Bolt S0-4 meets the minimum evaluated requirements of ASTM A-449-86 Type 1.

* Test data suspect - reported for engineering information only.

** Proof load based on proportional limit measured from tensile test.

Sample Identification: S0-5
Source: Rancho Seco
Sample Type: Bolt
Size: 2 3/4 x 5/8
Identification Grade Mark: B7
ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
+ Carbon - 0.37 - 0.49	-	0.23*	0.061	0.077
+ Chromium - 0.75 - 1.20	0.06	0.09	-	-
+ Manganese - 0.65 - 1.10	0.39	0.80*	0.040	-
+ Molybdenum - 0.15 - 0.25	0.01	0.03	-	-
Silicon - 0.15 - 0.35	0.04	0.20*	Less than 0.10	-
Sulfur - less than 0.040	-	0.020	-	-
Phosphorus - less than 0.035	-	0.008	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

+ Ultimate Tensile Strength - 125 Ksi
 + 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

55.5
 48.4
 28.4
 75.7
 Rb 57.4

Remarks:

Bolt S0-5 does not meet the chemical or mechanical requirements defined in ASTM A-193/A-193 M-86 Grade B-7.

* The test data suspected to be in error - reported for engineering information only.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Clark Brothers Bolt Co., Midland Connecticut. (Industrial Fasteners Institute registration.)

Sample Identification: S0-6
Source: Rancho Seco
Sample Type: Bolt
Size: 2 3/4 x 5/8
Identification Grade Mark:
ASTM Standard: A-449 Type 1

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.25 - 0.58	-	0.24*	0.37	-
Manganese - 0.57 or above	0.81	0.81	-	-
Phosphorus - less than 0.048	-	0.009	-	-
Sulfur - less than 0.058	-	0.024	-	-
Boron - not controlled	-	-	Less than 0.0005	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Load - 27,100 pounds

Proof Load 19,200 pounds

Maximum Rockwell Hardness - Rc 34

Actual Mechanical Measurements (EG&G Idaho)

31,200 pounds

27,000 pounds**

Rc 24.7

Remarks:

Bolt S0-6 meets the minimum evaluated requirements of ASTM A-449-86 Type 1.

* Test data suspect - reported for engineering information only.

** Proof load based on proportional limit measured from tensile test.

Sample Identification: S0-7
Source: San Onofre
Sample Type: Stud
Size: 6 3/4 x 1
Identification Grade Mark: B7
ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.37 - 0.49	-	0.38	-	-
Chromium - 0.75 - 1.20	1.12	0.88	-	-
Manganese - 0.65 - 1.10	0.87	0.83	-	-
Molybdenum - 0.15 - 0.25	0.15	0.17	-	-
Silicon - 0.15 - 0.35	0.24	0.30	-	-
Phosphorus - less than 0.035	-	0.035	-	-
Sulfur - less than 0.040	-	0.025	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 125 Ksi
 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

146.9 Ksi*
 132.0 Ksi**
 -
 -
 Rc 33

Remarks:

Stud S0-7 meets the minimum evaluated requirements of ASTM A-193/A-193 M-86 Grade B-7.

* Tensile test conducted on full size stud as defined in ASTM A-370-86a Supplement S11.1.4

** Yield strength determined using cross head travel.

Sample Identification: S0-8
 Source: San Onofre
 Sample Type: Stud
 Size: 6 3/4 x 1
 Identification Grade Mark: B7
 ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.37 - 0.49	-	0.39	-	-
Chromium - 0.75 - 1.20	1.13	0.88	-	-
Manganese - 0.65 - 1.10	0.88	0.81	-	-
Molybdenum - 0.15 - 0.25	0.14	0.17	0.16	-
Phosphorus - less than 0.035	-	0.036	-	-
Silicon - 0.15 - 0.35	0.23	0.29	-	-
Sulfur - less than 0.040	-	0.026	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 125 Ksi
 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

146.9 Ksi*
 132.9 Ksi**
 -
 Rc 34.2

Remarks:

Stud S0-8 meets the minimum evaluated requirements of ASTM A-193/A-193 M-86 Grade B-7.

* Tensile test conducted on full size stud as defined in ASTM A-370-86a Supplement S11.1.4.

** Yield strength determine using cross head travel.

Sample Identification: S0-9
Source: San Onofre
Sample Type: Bolt
Size: 5 1/2 x 1 1/2
Identification Grade Mark: B7
ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.37 - 0.49	-	0.40	-	-
Chromium - 0.75 - 1.20	1.17	0.94	-	-
Manganese - 0.65 - 1.10	0.82	0.81	-	-
Molybdenum - 0.15 - 0.25	0.20	0.19	-	-
Silicon - 0.15 - 0.35	0.17	0.28	-	-
Phosphorus - less than 0.035	-	0.030	-	-
Sulfur - less than 0.040	-	0.024	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 125 Ksi
 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

141.0 Ksi
 124.0 Ksi
 19%
 60%
 Rc 27.5

Remarks:

Bolt S0-9 meets the minimum evaluated requirements of ASTM A-193/A-193 H-86 Grade B-7.

Sample Identification: SO-10
Source: San Onofre
Sample Type: Bolt
Size: 6 1/2 x 7/8
Identification Grade Mark: B8M
ASTM Standard: A-193 Grade B-8M

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.03	-	-
Chromium - 16.00 - 18.00	17.60	17.00	-	-
Nickel - 10.00 - 14.00	10.24	-	-	-
Molybdenum - 2.00 - 3.00	2.17	2.14	-	-
Manganese - less than 2.00	1.41	1.42	-	-
Phosphorus - less than 0.045	-	0.036	-	-
Silicon - less than 1.00	0.40	0.92	-	-
Sulfur - less than 0.030	-	0.020	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 75 Ksi
 0.2% Offset Yield Strength - 30 Ksi
 Elongation - 30%
 Reduction in area - 50%
 Maximum Rockwell Hardness - Rb 96

Actual Mechanical Measurements (EG&G Idaho)

79.4 Ksi*
 44.9 Ksi**
 -
 -
 Rb 76.9

Remarks:

Bolt SO-10 meets the minimum requirements evaluated by EG&G and defined in ASTM A-193/A-193 M-86 Grade B-8M.

* Tensile test conducted on full size bolt as defined in ASTM A-370-86a, Supplement S11.1.4.

** Yield strength determined using cross head travel.

Sample Identification: SO-11
Source: San Onofre
Sample Type: Nut
Size: 7/8
Identification Grade Mark: 8
ASTM Standard: A-194 Grade 8

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.05 , 0.03	-	-
+ Chromium - 18.00 - 20.0	17.24, 16.91	17.24 , 17.21	17.35	-
Nickel - 8.0 - 10.5	10.17, 9.87	-	9.60	-
Manganese - less than 2.00	1.31, 1.32	1.42 , 1.41	-	-
Phosphorus - less than 0.045	-	0.035, 0.035	-	-
Silicon - less than 1.00	0.40, 0.40	0.92 , 0.95	-	-
Sulphur - less than 0.030	-	0.020, 0.020	-	-
Molybdenum - not specified	2.29, 2.26	2.27 , 2.24	2.34	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Actual Mechanical Measurements (EG&G Idaho)

Rockwell Hardness - Rb 60-105

Rb 76.6

Remarks:

Nut SO-11 ~~does not~~ meet the chemical requirements defined in ASTM A-194/A-194 M-85a Grade 8.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Highland Bolt and Nut Co., Utica, Michigan. (Fastener Technology International registration.)

Sample Identification: S0-12
Source: San Onofre
Sample Type: Bolt
Size: 6 1/2 x 7/8
Identification Grade Mark: B8M
ASTM Standard: A-193 Grade B-8M

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.04	-	-
Chromium - 16.00 - 18.00	16.81	17.22	17.42	-
+ Nickel - 10.00 - 14.00	9.53	-	9.36	9.26
Molybdenum - 2.00 - 3.00	2.17	2.10	2.24	-
Manganese - less than 2.00	1.41	1.37	-	-
Phosphorus - less than 0.045	-	0.032	-	-
Silicon - less than 1.00	0.40	0.95	-	-
Sulfur - less than 0.030	-	0.022	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 75 Ksi
 0.2% Offset Yield Strength - 30 Ksi
 Elongation - 30%
 Reduction in area - 50%
 Maximum Hardness - Rb 96

Actual Mechanical Measurements (EG&G Idaho)

77 Ksi*
 41.3 Ksi**

 Rb 76.9

Remarks:

Bolt S0-12 does not meet the chemical requirement of ASTM A-193/A-193 M-86 Grade B-8M.

* Tensile test conducted on full size bolt as defined in ASTM A-320-86a, Supplement S11.1.4.

** Yield strength determined using cross head travel.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Highland Bolt and Nut Co., Utica, Michigan. (Fastener Technology International registration.)

Sample Identification: S0-13
Source: San Onofre
Sample Type: Nut
Size: 7/8
Identification Grade Mark: 8
ASTM Standard: A-194 Grade 8

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.03	-	-
+ Chromium - 18 - 20	16.69	16.99	17.41	-
Nickel - 8.0 - 10.5	9.91	-	9.57	-
Manganese - less than 2.00	1.43	1.48	-	-
Phosphorus - less than 0.045	-	0.033	-	-
Silicon - less than 1.00	0.44	0.93	-	-
Sulfur - less than 0.030	-	0.023	-	-
Molybdenum - not specified	2.13	2.11	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Rockwell Hardness - Rb 60 - 105

Actual Mechanical Measurements (EG&G Idaho)

Rb 77.5

Remarks:

Nut S0-13 does not meet the chemical requirements defined in ASTM A-194/A-194 M-85a Grade 8.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Highland Bolt and Nut Co., Utica, Michigan. (Fastener Technology International registration.)

Sample Identification: S0-14
Source: San Onofre
Sample Type: Bolt
Size: 6 1/2 x 7/8
Identification Grade Mark: B8M
ASTM Standard: A-193 Grade B-8M

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.03	-	-
Chromium - 16.00 - 18.00	16.78	17.04	17.44	-
+ Nickel - 10.00 - 14.00	9.63	-	9.32	9.04
Molybdenum - 2.00 - 3.00	2.14	2.17	2.21	-
Manganese - less than 2.00	1.40	1.50	-	-
Phosphorus - less than 0.045	-	0.030	-	-
Silicon - less than 1.00	0.43	0.93	-	-
Sulfur - less than 0.030	-	0.021	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 75 Ksi
 0.2% Offset Yield Strength - 30 Ksi
 Elongation - 30%
 Reduction in area - 50%
 Maximum Rockwell Hardness - Rb 96

Actual Mechanical Measurements (EG&G Idaho)

76.3 Ksi*
 44.2 Ksi**
 -
 -
 Rb 76.3

Remarks:

Bolt S0-14 does not meet the chemical requirements of ASTM A-193/A-193 M-86 Grade B-8M.

* Tensile tests conducted on full size specimens as defined in ASTM A-370-86a, Supplement S11.1.4.

** Yield strength determined using cross head travel.

+ Indicates test results not within specification requirements.

- **NOTE:** Identification mark indicates the manufacturer was Highland Bolt and Nut Co., Utica, Michigan.
(Fastener Technology International registration.)

Sample Identification: SO-15
Source: San Onofre
Sample Type: Nut
Size: 7/8
Identification Grade Mark: 8
ASTM Standard: A-194 Grade 8

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - less than 0.08	-	0.03	-	-
+ Chromium - 18 - 20	17.11	17.10	17.20	-
Nickel - 8.0 - 10.5	9.53	-	9.50	-
Manganese - less than 2.00	1.39	1.58	-	-
Phosphorus - less than 0.045	-	0.034	-	-
Silicon - less than 1.00	0.43	0.94	-	-
Sulfur - less than 0.030	-	0.020	-	-
Molybdenum - not specified	2.14	2.11	2.18	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Rockwell Hardness - Rb 60 - 105

Actual Mechanical Measurements (EG&G Idaho)

Rb 73.9

Remarks:

Nut SO-15 does not meet the chemical requirements defined in ASTM A-194/A-194 M-85a Grade 8.

+ Indicates test results not within specification requirements.

NOTE: Identification mark indicates the manufacturer was Highland Bolt and Nut Co., Utica, Michigan.
(Fastener Technology International registration.)

Sample Identification: SO-16
Source: San Onofre
Sample Type: Bolt
Size: 5 1/2 x 1 1/2
Identification Grade Mark: B7
ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.37 - 0.49	-	0.36*	0.39	-
Chromium - 0.75 - 1.20	1.08	0.90	-	-
Manganese - 0.65 - 1.10	0.76	0.83	-	-
Molybdenum - 0.15 - 0.25	0.18	0.20	-	-
Silicon - 0.15 - 0.35	0.16	0.27	-	-
Phosphorus - less than 0.035	-	0.034	-	-
Sulfur - less than 0.040	-	0.025	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 125 Ksi
 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

140 Ksi
 120 Ksi
 19%
 60%
 Rc 28.6

Remarks:

Bolt SO-16 meets the minimum evaluated requirements defined in ASTM A-193/A-193 M-86 Grade B-7.

* Test data suspect - reported for engineering information only.

Sample Identification: S0-17
Source: S.n Onofre
Sample Type: Bolt
Size: 5/2 x 1 1/2
Identification Grade Mark: B7
ASTM Standard: A-193 Grade B-7

CHEMICAL COMPOSITION (wt%)

<u>ASTM Chemical Specifications</u>	<u>EG&G Idaho</u>	<u>Ford Chemical Co.</u>	<u>National Spectrographic Laboratories</u>	<u>WINCO</u>
Carbon - 0.37 - 0.49	-	0.38	-	-
Chromium - 0.75 - 1.20	1.26	0.91	-	-
Manganese - 0.65 - 1.10	0.87	0.87	-	-
Molybdenum - 0.15 - 0.25	0.21	0.18	-	-
Silicon - 0.15 - 0.35	0.19	0.29	-	-
Sulfur - less than 0.040	-	0.028	-	-
Phosphorus - less than 0.035	-	0.038*	-	-

MECHANICAL PROPERTIES

Minimum ASTM Mechanical Specifications

Ultimate Tensile Strength - 125 Ksi
 0.2% Offset Yield Strength - 105 Ksi
 Elongation - 16%
 Reduction in area - 50%
 Hardness - not specified

Actual Mechanical Measurements (EG&G Idaho)

143 Ksi
 126 Ksi
 19%
 59%
 Rc 28.6

Remarks:

Bolt S0-17 meets the minimum evaluated requirements defined in ASTM A-449-86 Type 1.

*Test date suspect - reported for engineering information only.