

TESTING OF 11 BOLTS

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Enclosure

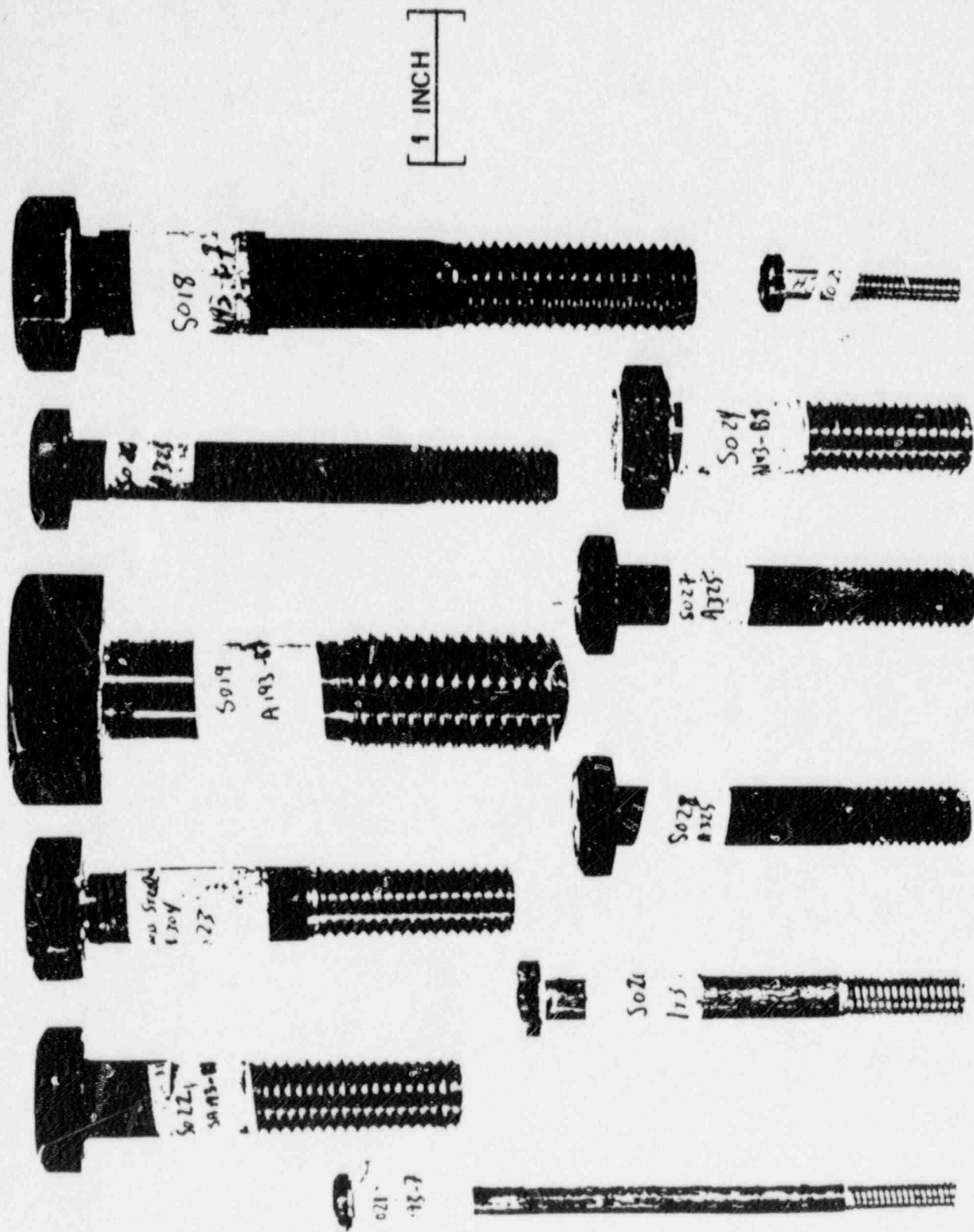


FIGURE 1 . PHOTOGRAPH OF
" AS RECEIVED " BOLTS.

BOLT IDENTIFICATION: 50-18

BOLT SPECIFICATION: A 193-B7

BOLT SIZE: 3/4 - 10 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
142.22 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
59.16 R _A	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.34	0.37 - 0.49
Manganese	0.96	0.65 - 1.10
Phosphorus	0.12	0.035 max
Sulfur	0.006	0.040 max
Silicon	0.28	0.15 - 0.35
Chromium	1.55 (Note 1)	0.75 - 1.20
Nickel	0.06	-
Molybdenum	0.19	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

BOLT IDENTIFICATION: 50-19

BOLT SPECIFICATION: A 193-B7

BOLT SIZE: 1" - 8 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
143.03 ksi	125 ksi (min.)

Failure Location - Shoulder

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
27.6 R _C	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.40	0.37 - 0.49
Manganese	0.98	0.65 - 1.10
Phosphorus	0.005	0.035 max
Sulfur	0.016	0.040 max
Silicon	0.21	0.15 - 0.35
Chromium	1.80 (Note 1)	0.75 - 1.20
Nickel	0.34	-
Molybdenum	0.19	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

BOLT IDENTIFICATION: S0-20

BOLT SPECIFICATION: A 193-B7

BOLT SIZE: 3/8" - 16 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
151.74 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
23.83 R _C	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.41	0.37 - 0.49
Manganese	0.97	0.65 - 1.10
Phosphorus	<0.005	0.035 max
Sulfur	0.008	0.040 max
Silicon	0.27	0.15 - 0.35
Chromium	1.51 (Note 1)	0.75 - 1.20
Nickel	0.05	-
Molybdenum	0.22	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

BOLT IDENTIFICATION: SO-21

BOLT SPECIFICATION: A 193-B7

BOLT SIZE: 1/4" - 20 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
158.80 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
62.6 R _A	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.41	0.37 - 0.49
Manganese	0.94	0.65 - 1.10
Phosphorus	0.020	0.035 max
Sulfur	0.024	0.040 max
Silicon	0.27	0.15 - 0.35
Chromium	1.46 (Note 1)	0.75 - 1.20
Nickel	0.47	-
Molybdenum	0.23	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

BOLT IDENTIFICATION: S0-22

BOLT SPECIFICATION: A 193-B8

BOLT SIZE: 5/8" - 11 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
98.14 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
47 R _A	223 HB (max.)
(equates to 138 HB)	

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.06	0.08 max
Manganese	1.24	2.00 max
Phosphorus	0.030	0.045 max
Sulfur	0.033 (Note 1)	0.030 max
Silicon	0.40	1.00 max
Chromium	19.1	18.00 - 20.00
Nickel	8.8	8.00 - 10.50
Molybdenum	0.36	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Permissible variation for sulfur (0.005% over) by specification
allows acceptance of this value.

BOLT IDENTIFICATION: 50-23

BOLT SPECIFICATION: A 193-B8

BOLT SIZE: 5/8" - 11 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
89.65 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
63.6 R _A (Note 1)	223 HB (max.)
(equates to 262 HB)	

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.06	0.08 max
Manganese	1.75	2.00 max
Phosphorus	0.050 (Note 1)	0.045 max
Sulfur	0.021	0.030 max
Silicon	0.72	1.00 max
Chromium	19.0	18.00 - 20.00
Nickel	9.0	8.00 - 10.50
Molybdenum	0.40	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Although specification allows a maximum hardness of 241 HB (A193), this bolt exceeds hardness maximum. 2) Permissible variation for phosphorus (0.010% over) by specification allows acceptance of this value.

BOLT IDENTIFICATION: S0-24

BOLT SPECIFICATION: A 193-B8

BOLT SIZE: 5/8" - 11 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
89.91 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
61.3 R _A (Note 1)	223 HB (max.)
(equates to 234 HB)	

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.05	0.08 max
Manganese	1.70	2.00 max
Phosphorus	0.020	0.045 max
Sulfur	0.025	0.030 max
Silicon	0.70	1.00 max
Chromium	19.3	18.00 - 20.00
Nickel	9.0	8.00 - 10.50
Molybdenum	0.42	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) For bolt sizes 3/4 in. diameter and under, a maximum hardness of 241 HB is permitted (A193).

BOLT IDENTIFICATION: S0-25

BOLT SPECIFICATION: A 193-B8

BOLT SIZE: 1/4" - 20 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
114.46 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
57.7 R _A (equates to 167 HB)	223 HB (max.)

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.09 (Note 1)	0.08 max
Manganese	0.57	
Phosphorus	0.050 (Note 1)	0.045 max
Sulfur	0.021	0.030 max
Silicon	0.43	1.00 max
Chromium	19.3	18.00 - 20.00
Nickel	9.5	8.00 - 10.50
Molybdenum	0.36	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Permissible variations for both carbon (0.01% over) and
phosphorus (0.010% over) by specification allows acceptance of these values.

BOLT IDENTIFICATION: 50-26

BOLT SPECIFICATION: A 325

BOLT SIZE: 1/2" - 13 UNC

TENSILE STRENGTH:

Actual
144.3 ksi

Required by Specification
120 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual
24.75 R_C
(equates to 167 HB)

Required by Specification
24 R_C min - 35 R_C max

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.33	0.27 min (Product)
Manganese	0.86	0.47 min (Product)
Phosphorus	0.008	0.048 max (Product)
Sulfur	0.013	0.058 max (Product)
Silicon	0.29	-
Chromium	0.08	-
Nickel	0.06	-
Molybdenum	<0.01	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Meets chemical requirements for Type 1 bolts.

BOLT IDENTIFICATION: SO-27

BOLT SPECIFICATION: A 325

BOLT SIZE: 1/2" - 13 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
133.17 ksi	120 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
21.25 R _C (Note 1)	24 R _C min - 35 R _C max

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.42 (Note 2)	0.27 min (Product)
Manganese	0.88	0.47 min (Product)
Phosphorus	0.005	0.048 max (Product)
Sulfur	0.025	0.058 max (Product)
Silicon	0.17	-
Chromium	<0.01	-
Nickel	0.08	-
Molybdenum	<0.01	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) For bolts where both tensile and hardness tests are performed, acceptance shall be based on tensile results (in event of low hardness readings) - A 325. 2) Meets chemical requirements for Type 1 bolts.

BOLT IDENTIFICATION: S0-28

BOLT SPECIFICATION: A 325

BOLT SIZE: 1/2" - 13 UNC

TENSILE STRENGTH:

Actual
141.48 ksi

Required by Specification
120 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual
22 R_C (Note 1)

Required by Specification
24 R_C min - 35 R_C max

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.40 (Note 2)	0.27 min (Product)
Manganese	0.35	0.47 min (Product)
Phosphorus	<0.005	0.048 max (Product)
Sulfur	0.020	0.058 max (Product)
Silicon	0.21	-
Chromium	<0.01	-
Nickel	0.10	-
Molybdenum	<0.01	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) For bolts where both tensile and hardness tests are performed,
acceptance shall be based on tensile results (in event of low hardness
readings) - A 325. 2) Meets chemical requirements for Type 1 bolts.

BOLT IDENTIFICATION: S0-18

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 3/4 - 10 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
142.22 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
59.16 R _A	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.34 (Note 2)	0.37 - 0.49
Manganese	0.96	0.65 - 1.10
Phosphorus	0.12	0.035 max
Sulfur	0.006	0.040 max
Silicon	0.28	0.15 - 0.35
Chromium	1.55 (Note 1)	0.75 - 1.20
Nickel	0.06	-
Molybdenum	0.19	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring in permissible variations (0.05% over). 2) Carbon content below minimum level after factoring permissible variation. Note: inadvertently not identified on original 10/30/87 report.

Enclosure

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: S0-18

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 3/4 - 10 UNC

Methodology:

1. A section was cut from the bolt, mounted in epoxy, then metallurgically ground, polished and etched (2% Nital). The section showed (Figure 1) a tempered martensite microstructure consistent with this type of material.
2. Half of the fracture face (after tensile testing) was examined under the scanning electron microscope (SEM) (Figure 2). The resulting fractograph showed a dimpled rupture appearance which indicated good ductility in the fracture.

Conclusions:

The bolt is considered to be suitable for service for the following reasons:

1. The polished section showed a microstructure consistent for this grade of bolt. The SEM examination revealed that the fracture (after tensile testing) was ductile in nature. This coupled with the fact that the bolt met the tensile requirements of A193-B7 material and was only 0.01% below the minimum carbon level and 0.35% above the maximum chromium level (all other chemical requirements were met) leads one to believe that the tensile requirements will not be a problem for this bolt. The only other major consideration would be if the bolt could fail in a brittle (as opposed to ductile) manner in service (Notch Toughness) due to these chemical composition variances.

The Metals Handbook, 8th Edition, Vol. 1, Properties and Selection of Metals, defined Notch Toughness as:

"...the ability of a metal to yield plastically under high localized stress, such as might occur at the root of a notch..."

This measure of a material's property would be very applicable to fasteners.

Carbon Content

This same reference mentions that as carbon content is raised in the range from 0.15 to 0.80% in normalized plain carbon steels, the notch toughness decreases (at room temperature). This lowering of energy absorption is accompanied by a subsequent raising of the transition temperature (6°F per 0.01% increase in carbon content above 0.30% carbon). The net effect of this lower amount of carbon on this particular bolt would then be to increase the amount of energy absorbed and decrease the transition temperature as much as 6°F. Both of which should be beneficial to the bolt's "suitability for service."

BOLT IDENTIFICATION: S0-18

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 3/4 - 10 UNC

Chromium Content

The Metals Handbook, 8th Edition, Vol. 1, Properties and Selection of Metals, states:

"Chromium has slight effect on transition temperature..."

Since the impact properties should not be significantly impaired due to the higher chromium content, the bolt is considered "suitable for service."

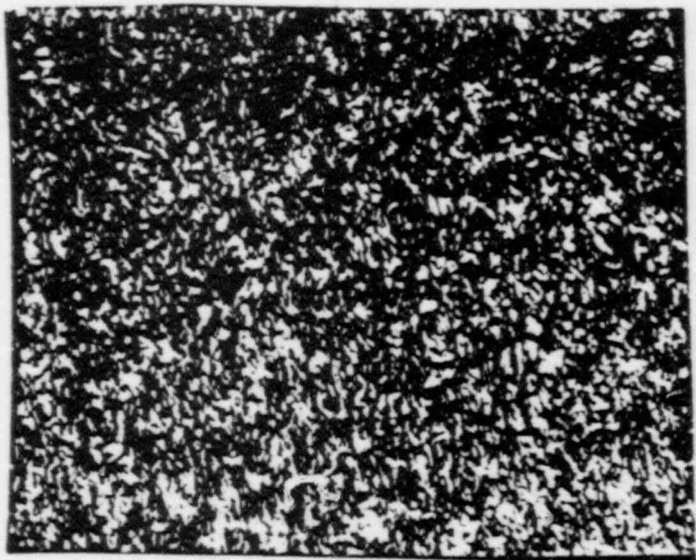


Figure 1 Optical photomicrograph of tempered martensite structure of S0-18 (400X).

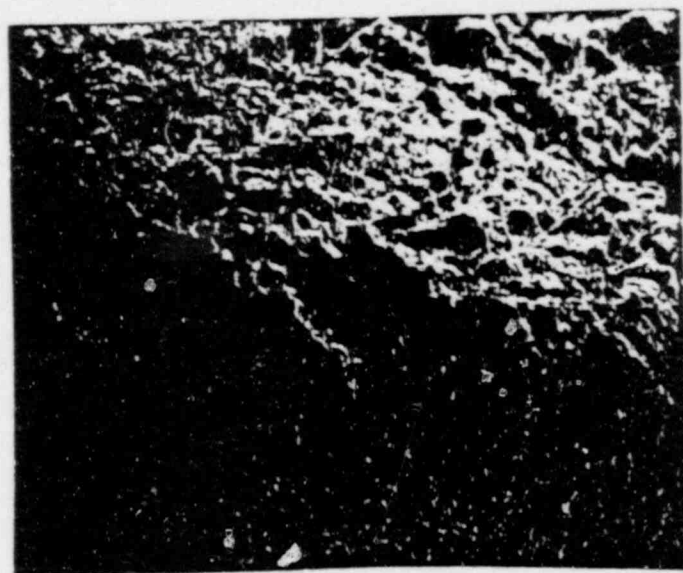


Figure 2 SEM fractograph of S0-18 showing ductile failure (1000X).

BOLT IDENTIFICATION: SO-19

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 1" - 8 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
143.03 ksi	125 ksi (min.)

Failure Location - Shoulder

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
27.6 R _C	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.40	0.37 - 0.49
Manganese	0.98	0.65 - 1.10
Phosphorus	0.005	0.035 max
Sulfur	0.016	0.040 max
Silicon	0.21	0.15 - 0.35
Chromium	1.80 (Note 1)	0.75 - 1.20
Nickel	0.34	-
Molybdenum	0.19	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENT: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: SO-19

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 1"- 8 UNC

Methodology:

1. A section was cut from the bolt, mounted in epoxy, then metallurgically ground, polished and etched (2% Nital). The section showed (Figure 3) a tempered martensite microstructure consistent with this type of material.
2. Half of the fracture face (after tensile testing) was examined under the scanning electron microscope (SEM) (Figure 4). The resulting fractograph showed a dimpled rupture appearance which indicated good ductility in the fracture.

Conclusions:

The bolt is considered to be suitable for service for the following reasons:

1. The polished section showed a microstructure consistent for this grade of bolt. The SEM examination revealed that the fracture (after tensile testing) was ductile in nature. These observations plus the fact that the bolt met the tensile requirements and all of the chemical requirements (except chromium) of the specification leads one to examine the ability of the bolt to resist rapid failure (notch toughness).

Chromium Content

The Metals Handbook, 8th Edition, Vol. 1, Properties and Selection of Metals, states:

"Chromium has slight effect on transition temperature..."

Since the impact properties should not be significantly impaired due to the higher chromium content, the bolt is considered "suitable for service."



Figure 3 Optical photomicrograph of tempered martensite structure of S0-19 (400X).

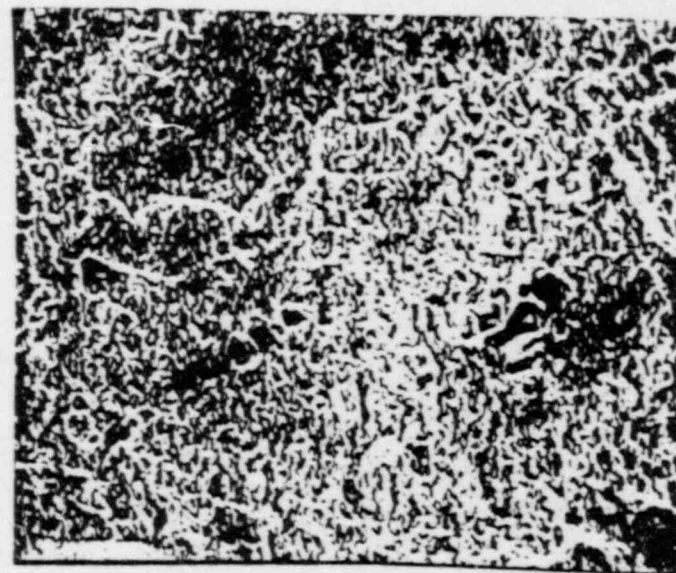


Figure 4 SEM fractograph of S0-19 showing ductile failure (1000X).

BOLT IDENTIFICATION: S0-20

BOLT SPECIFICATION: A 193-87

BOLT SIZE: 3/8" - 16 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
151.74 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
23.83 R _C	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.41	0.37 - 0.49
Manganese	0.97	0.65 - 1.10
Phosphorus	<0.005	0.035 max
Sulfur	0.008	0.040 max
Silicon	0.27	0.15 - 0.35
Chromium	1.51 (Note 1)	0.75 - 1.20
Nickel	0.05	-
Molybdenum	0.22	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: S0-20

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 3/8" - 16 UNC

Methodology:

1. A section was cut from the bolt, mounted in epoxy, then metallurgically ground, polished and etched (2% Nital). The section showed (Figure 5) a tempered martensite microstructure consistent with this type of material.
2. Half of the fracture face (after tensile testing) was examined under the scanning electron microscope (SEM) (Figure 6). The resulting fractograph showed a dimpled rupture appearance which indicated good ductility in the fracture.

Conclusions:

The bolt is considered to be suitable for service for the following reasons:

1. The polished section showed a microstructure consistent for this grade of bolt. The SEM examination revealed that the fracture (after tensile testing) was ductile in nature. These observations plus the fact that the bolt met the tensile requirements and all of the chemical requirements (except chromium) of the specification leads one to examine the ability of the bolt to resist rapid failure (notch toughness).

Chromium Content

The Metals Handbook, 8th Edition, Vol. 1, Properties and Selection of Metals, states:

"Chromium has slight effect on transition temperature..."

Since the impact properties should not be significantly impaired due to the higher chromium content, the bolt is considered "suitable for service."

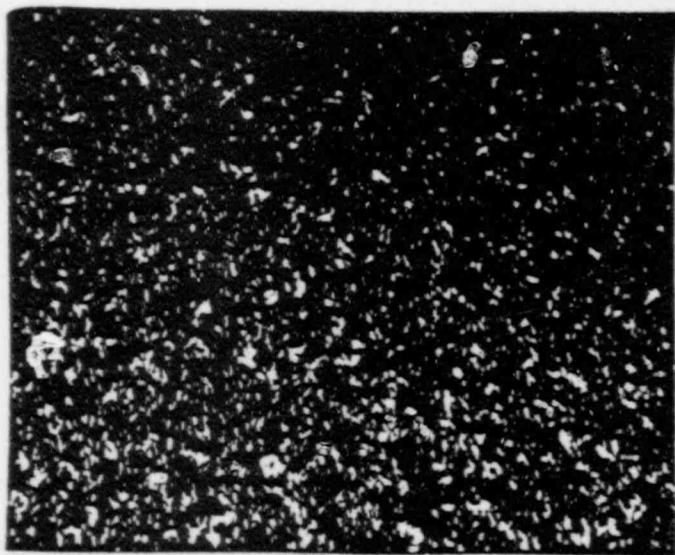


Figure 5 Optical photomicrograph of tempered martensite structure of S0-20 (400X).

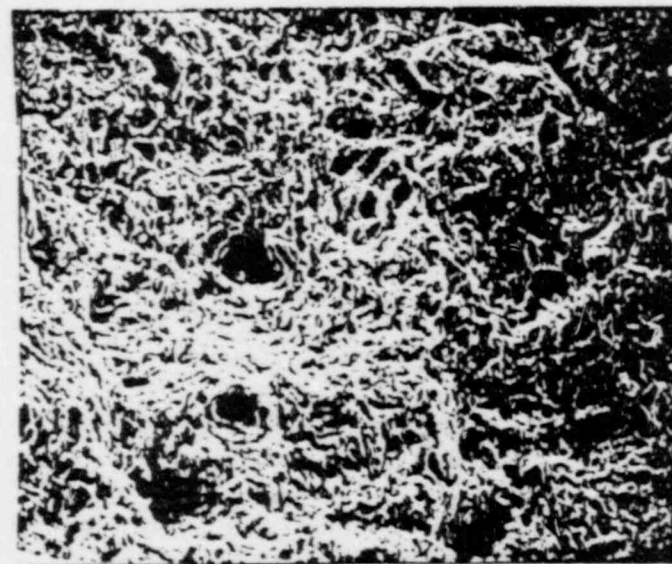


Figure 6 SEM fractograph of S0-20 showing ductile failure (1000X).

BOLT IDENTIFICATION: S0-21

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 1/4" - 20 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
158.80 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
62.6 R _A	Not Required

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.41	0.37 - 0.49
Manganese	0.94	0.65 - 1.10
Phosphorus	0.020	0.035 max
Sulfur	0.024	0.040 max
Silicon	0.27	0.15 - 0.35
Chromium	1.46 (Note 1)	0.75 - 1.20
Nickel	0.47	-
Molybdenum	0.23	0.15 - 0.25
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Chromium value exceeds specification requirements even factoring
in permissible variations (0.05% over)

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: S0-21

BOLT SPECIFICATION: A193-B7

BOLT SIZE: 1/4" - 20 UNC

Methodology:

1. A section was cut from the bolt, mounted in epoxy, then metallurgically ground, polished and etched (2% Nital). The section showed (Figure 7) a tempered martensite microstructure consistent with this type of material.
2. Half of the fracture face (after tensile testing) was examined under the scanning electron microscope (SEM) (Figure 8). The resulting fractograph showed a dimpled rupture appearance which indicated good ductility in the fracture.

Conclusions:

The bolt is considered to be suitable for service for the following reasons:

1. The polished section showed a microstructure consistent for this grade of bolt. The SEM examination revealed that the fracture (after tensile testing) was ductile in nature. These observations plus the fact that the bolt met the tensile requirements and all of the chemical requirements (except chromium) of the specification leads one to examine the ability of the bolt to resist rapid failure (notch toughness).

Chromium Content

The Metals Handbook, 8th Edition, Vol. 1, Properties and Selection of Metals, states:

"Chromium has slight effect on transition temperature..."

Since the impact properties should not be significantly impaired due to the higher chromium content, the bolt is considered "suitable for service."

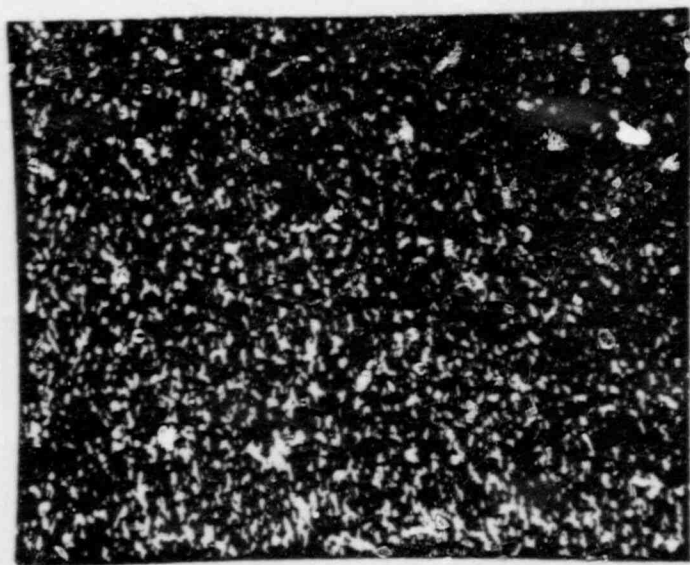


Figure 7 Optical photomicrograph of tempered martensite structure of S0-21 (400X).

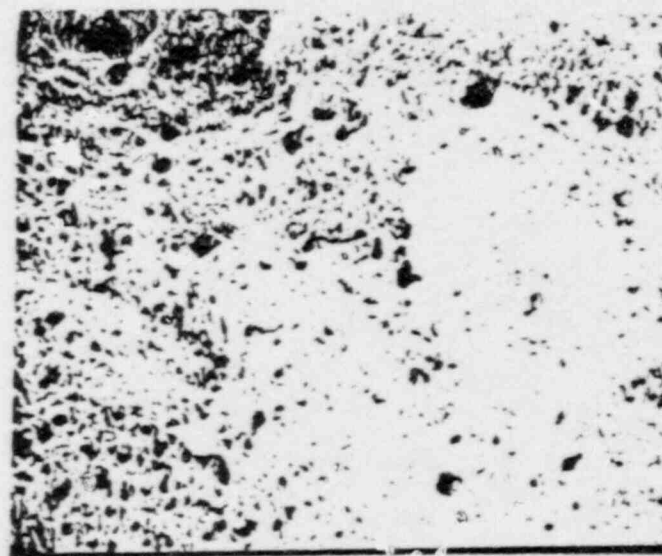


Figure 8 SEM fractograph of S0-21 showing ductile failure (1000X).

BOLT IDENTIFICATION: S0-23

BOLT SPECIFICATION: A 193-B8

BOLT SIZE: 5/8" - 11 UNC

TENSILE STRENGTH:

<u>Actual</u>	<u>Required by Specification</u>
89.65 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

<u>Actual</u>	<u>Required by Specification</u>
53.6 R _A (Note 1)	223 HB (max.)
(equates to 262 HB)	

CHEMICAL ANALYSIS:

	<u>Actual w/o</u>	<u>Required by Specification w/o</u>
Carbon	0.06	0.08 max
Manganese	1.75	2.00 max
Phosphorus	0.050 (Note 2)	0.045 max
Sulfur	0.021	0.030 max
Silicon	0.72	1.00 max
Chromium	19.0	18.00 - 20.00
Nickel	9.0	8.00 - 10.50
Molybdenum	0.40	-
Vanadium	<0.05	-
Columbium + Tantalum	<0.05	-

< = Less than

COMMENTS: 1) Although specification allows a maximum hardness of 241 HB (A193), this bolt exceeds hardness maximum. 2) Permissible variation for phosphorus (0.010% over) by specification allows acceptance of this value.

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: S0-23

BOLT SPECIFICATION: A193-B8

BOLT SIZE: 5/8" - 11 UNC

Methodology:

1. A section was cut from the bolt, mounted in epoxy, then metallurgically ground, polished and etched (electrolytic oxalic acid). The section showed (Figure 9) an austenitic microstructure consistent with this type of material.
2. Half of the fracture face (after tensile testing) was examined under the SEM (Figure 10). The resultant fractograph showed a dimpled rupture appearance which indicates good ductility.
3. Consistent with the requirements of ASTM A370-77, a transverse section through the bolt was cut and six hardness readings taken along the axial length.

Conclusions:

The bolt is considered to meet specification (ASTM A193-81a) requirements after hardness retesting. The specification requirements allow a maximum hardness of 223HB (with a maximum hardness of 241HB allowed for 3/4" diameter and smaller bolts), the six hardness retests showed the following hardnesses:

R_B 82, 83, 82, 85, 79, 88.5

R_B 89.5, equates to 181 HB

All of which are below the specification maximum.

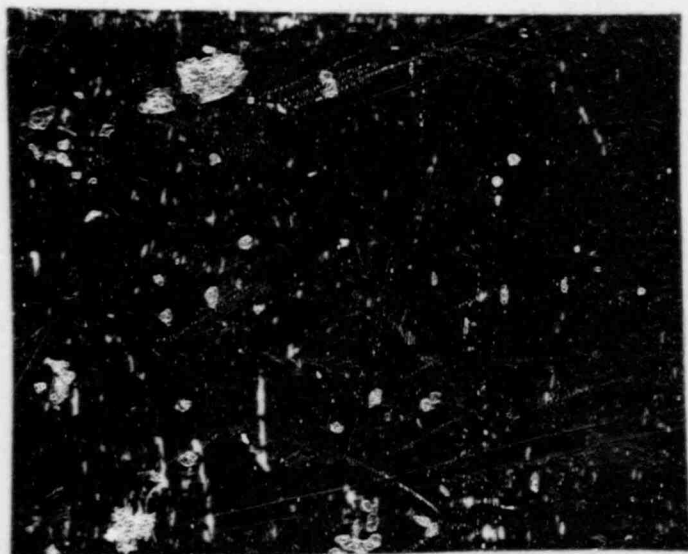


Figure 9 Optical photomicrograph of austenitic structure seen on S0-23 (400X).

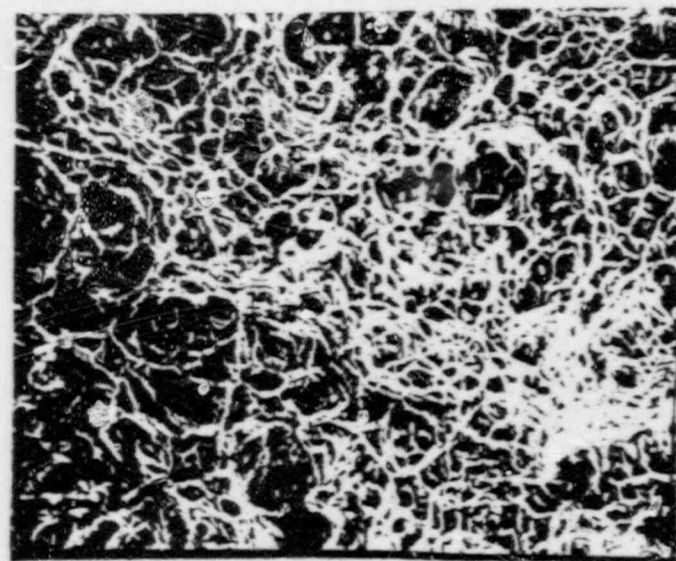


Figure 16 SEM fractograph of S0-23 showing ductile failure (450X).