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Department of Nuclear Energy

Building 130

March 2, 1988

Mr. James Conway
U.S. Nuclear Regulatory Commission
Vendor Programs Branch
Mail Stop 9D4
Washington, DC 20555

Ref: Testing of Farley Bolting Materials, Fin A-3866, Task Assignment 9

Dear Jim:

Enclosed is four copies of a report on the metallurgical evaluation of five bolts that had been obtained from the Farley plant and tested by C.J. Czajkowski of BNL. These five bolts (SO-18 through SO-21 and SO-23) had originally been out of specification after the original tensile and chemical testing. The results of the testing are:

SO-18 — Exceeded chromium level and had below maximum carbon level. (Note: insufficient carbon level was inadvertently not identified in the previous report.) This bolt is considered "suitable for service" after reevaluation and examination.

SO-19 Through SO-21 — Exceeded chromium levels. These bolts are considered "suitable for service" after reevaluation and examination.

SO-23 — Exceeded maximum hardness. This bolt is considered acceptable after retesting in accordance with ASTM A370-77.

If there are any questions, please feel free to call.

Very truly yours,

John H. Taylor, Group Leader
Plant Systems & Equipment Analysis

WS:af
Encl.

cc:
S. Baker, NRC
C. Czajkowski
B. Grenier, NRC
R. Hall
W. Kato
W. Shier
J. Stone, NRC
File

A/17

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: March 1, 1988

TO: John Taylor

FROM: C. J. Czajkowski (FTS 666-4420) C Jzykowski

SUBJECT: Retesting of Bolts SO-18 through SO-21 and SO-23 for USNRC FARLEY

Pursuant with Task Order No. 9 under FIN A-3866, please find attached copies of metallurgical evaluations for bolts identified as SO-18 through SO-21 and SO-23. These bolts had previously been found (my memo to you 10/20/87) to be out of specification after the original tensile and chemical testing.

The results of the retesting are:

SO-18: Exceeded chromium level and had below maximum carbon level. (Note: insufficient carbon level was inadvertently not identified in 10/30/87 report.) This bolt is considered "suitable for service" after reevaluation and examination.

SO-19 thrugh SO-21: Exceeded chromium levels. These bolts are considered "suitable for service" after reevaluation and examination.

SO-23: Exceeded maximum hardness. This bolt is considered acceptable after retesting in accordance with ASTM A370-77.

This completes Task 9 under FIN A-3866. Four additional copies of the report are attached for transmittal to the NRC. If there are any questions, please contact me at the above number.

CJC/ts
Attachments

cc: (w/attachments)
M. Schuster
W. Shier
P. Soo

BOLT IDENTIFICATION: SO-13 **BOLT SPECIFICATION:** A193-B7

BOLT SIZE: 3/4 - 10 UNC

TENSILE STRENGTH:

Actual	Required by Specification
142.22 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual	Required by Specification
59.16 R_A	Not Required

CHEMICAL ANALYSIS:

	Actual w/o	Required by Specification w/o
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.

METALLURGICAL EVALUATION

BOLT IDENTIFICATION: SO-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 election 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: SO-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."

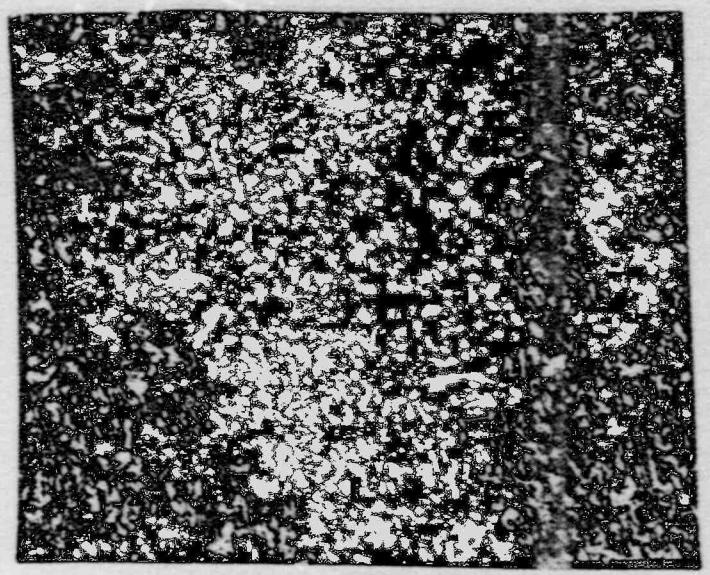

Figure 1 Optical photomicrograph of tempered martensite structure of SO-18 (400X).

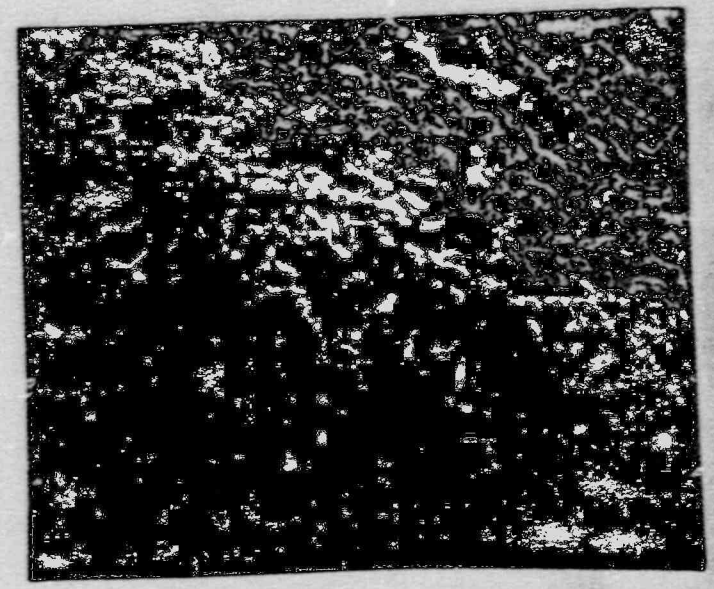

Figure 2 SEM fractograph of SO-18 showing ductile failure (1000X).

BOLT IDENTIFICATION: SO-19 **BOLT SPECIFICATION:** A193-B7

BOLT SIZE: 1" - 8 UNC

TENSILE STRENGTH:

Actual	Required by Specification
143.03 ksi	125 ksi (min.)

Failure Location - Shoulder

HARDNESS:

Actual	Required by Specification
27.6 R_c	Not Required

CHEMICAL ANALYSIS:

	Actual w/o	Required by Specification w/o
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)

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 election 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."

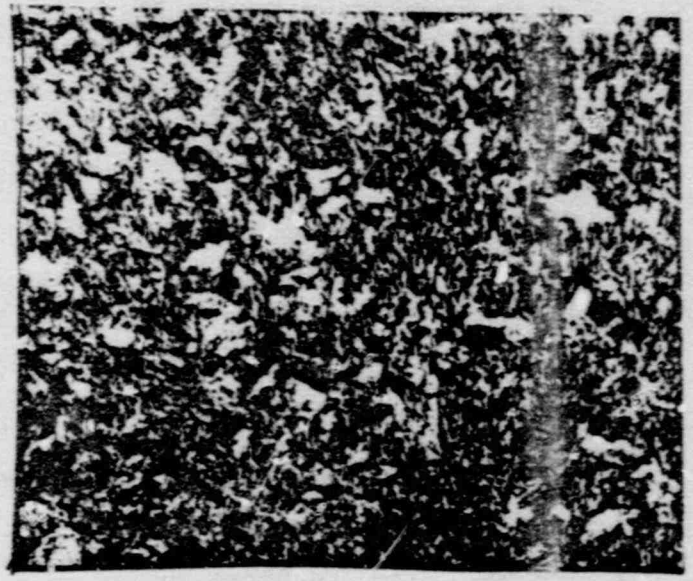

Figure 3 Optical photomicrograph of tempered martensite structure of S0-19 (400X).

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

BOLT IDENTIFICATION: SO-20 **BOLT SPECIFICATION:** A 193-B7

BOLT SIZE: 3/8" - 16 UNC

TENSILE STRENGTH:

Actual	Required by Specification
151.74 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual	Required by Specification
23.83 R_C	Not Required

CHEMICAL ANALYSIS:

	Actual w/o	Required by Specification w/o
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: SO-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 election 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."

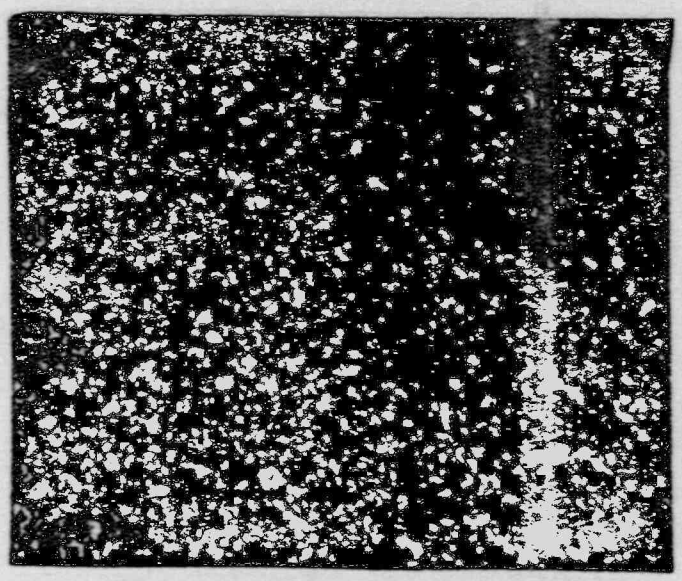

Figure 5 Optical photomicrograph of tempered martensite structure of S0-20 (400X).

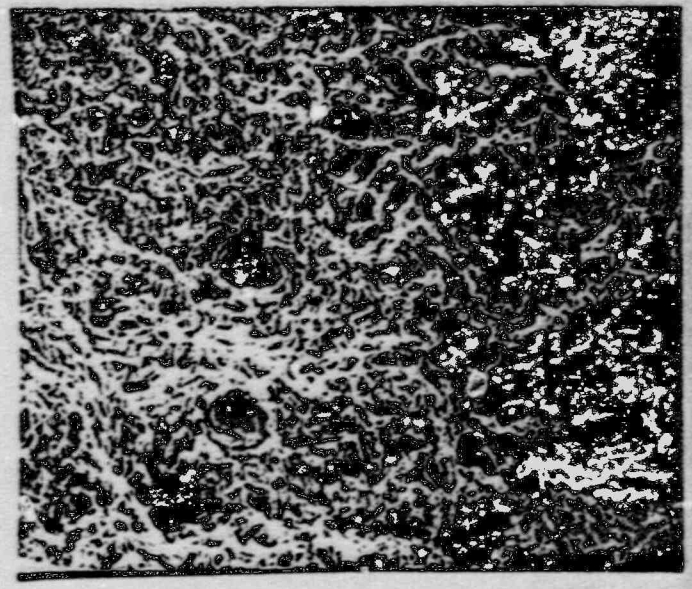

Figure 6 SEM fractograph of S0-20 showing ductile failure (1000X).

BOLT IDENTIFICATION: SO-21 **BOLT SPECIFICATION:** A193-B7

BOLT SIZE: 1/4" - 20 UNC

TENSILE STRENGTH:

Actual	Required by Specification
158.80 ksi	125 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual	Required by Specification
62.6 R_A	Not Required

CHEMICAL ANALYSIS:

	Actual w/o	Required by Specification w/o
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: SO-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 election 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."

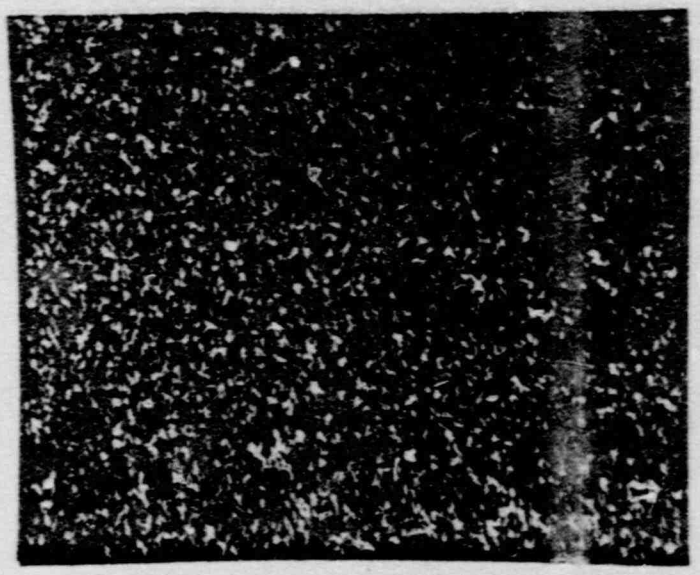

Figure 7 Optical photomicrograph of tempered martensite structure of SO 21 (400X).

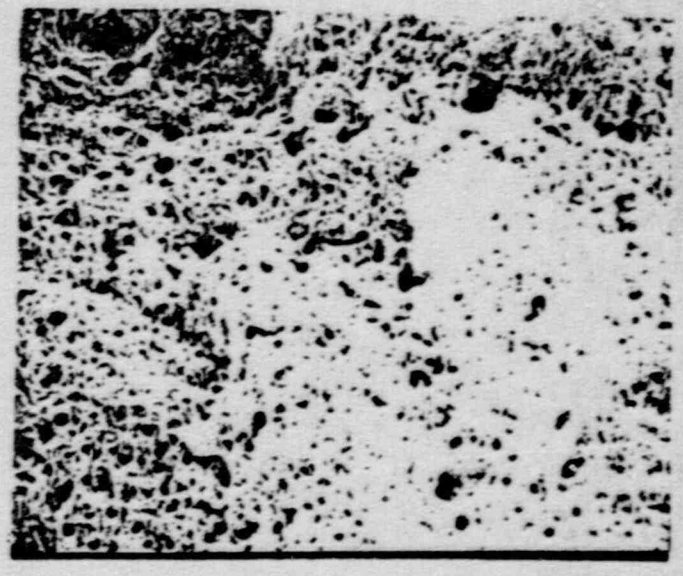

Figure 8 SEM fractograph of SO-21 showing ductile failure (1000X).

BOLT IDENTIFICATION: SO-23 **BOLT SPECIFICATION:** A 193-B8

BOLT SIZE: 5/8" - 11 UNC

TENSILE STRENGTH:

Actual	Required by Specification
89.65 ksi	75 ksi (min.)

Failure Location - Threads

HARDNESS:

Actual	Required by Specification
63.6 R_A (Note 1)	223 HB (max.)
(equates to 262 HB)	

CHEMICAL ANALYSIS:

	Actual w/o	Required by Specification w/o
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: SO-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.

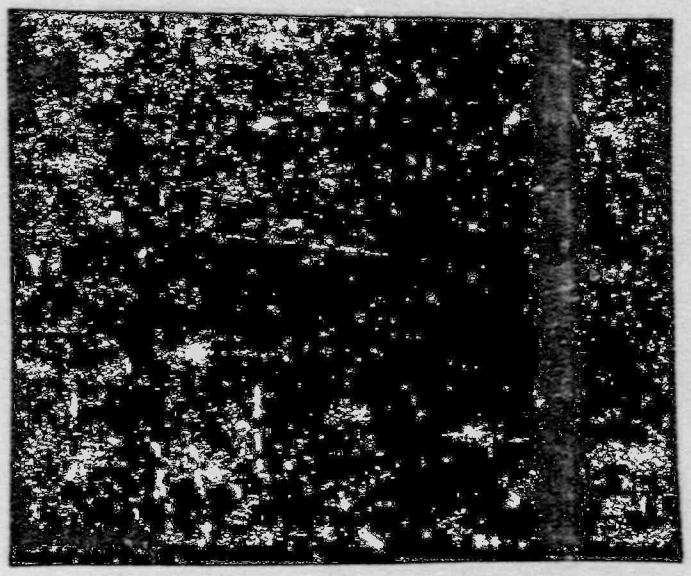

Figure 9 Optical photomicrograph of austenitic structure seen on SO-23 (400X).

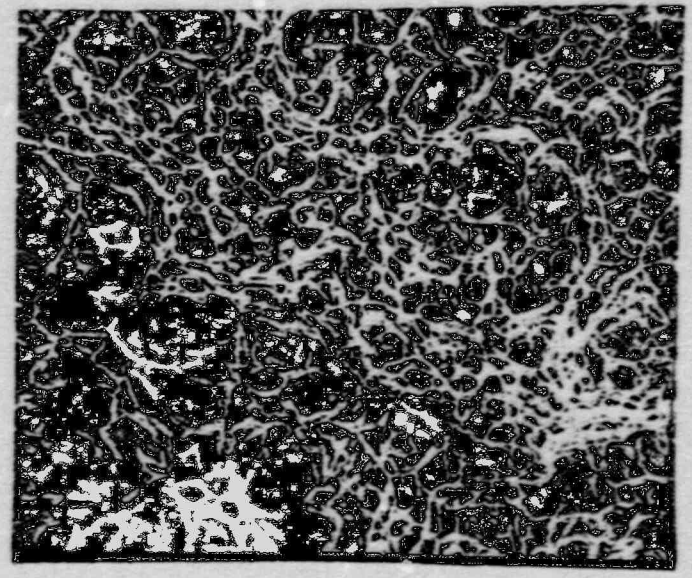

Figure 10 SEM fractograph of SO-23 showing ductile failure (450X).