UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

May 26, 1988

MEMORANDUM FOR: Tom Rehm, Assistant for Operations, OEDO

FROM: John C. Bradburne, Director
Congressional Affairs, GPA

SUBJECT: CONGRESSIONAL REQUESTS RE: SUBSTANDARD FASTENERS

On Tuesday, May 24, representatives of CA, OI, and Vendor Branch met with the staff of Congressman Dingell's Subcommittee on Oversight and Investigations to answer questions about the data base accumulated as a result of the fastener testing required in NRC Bulletin No. 87-02. During that meeting, Mr. Dingell's staff requested the following items:

- For the 15 safety-related fasteners that were seriously out of specification, provide information on: (1) what the plants have done with the inventories that the fasteners were taken from (e.g., quarantined, disposed, etc.); (2) locations within the plants where fasteners from those inventories had actually been used; and (3) for cases where fasteners from those inventories were determined to have been installed in the plants, whether those fasteners have been removed or left in place.

- Provide the test results showing the degree of non-conformance for bolts suspected of being mismarked as to Grade 8.0 vs. 8.2 and Grade 5.0 vs. 5.2.

- As soon as it is completed, provide a copy of the "Temporary Instruction" to NRC inspectors regarding follow-up actions for plants with inventories containing non-conforming fasteners.

- Indicate whether nuts were tested for anything other than hardness, and if so, what.

- List the eight vendors that are being considered for NRC inspection action as a result of the information contained in the data base.

- Provide a computer run of licensee 50.73 reports involving fastener failures over the past five years. If this is not possible, any substitute information on licensee reports involving fastener failures would be appreciated.

- Provide the names of nuclear power plants that are actively under construction at this time (as opposed to completed plants that are awaiting licensing).

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- Provide a debugged run of the INEL data base on the results of the fastener testing by close-of-business on June 10, 1988 at the latest. (The Dingell staff believes that it is absolutely essential that they have this document in time to review it in detail before the June 16 hearing.)

Please provide these items to Congressional Affairs as your receive them. Due to the upcoming hearing, there is insufficient time to hold the individual items until a complete package can be prepared. Please provide guidance as necessary on whether the information provided in response to each item may be used publicly.

Contact: J.DelMedico, x2-1693

FRANKLIN RESEARCH CENTER

DIVISION OF ARVIN/CALSPAN

Analyses of High Strength Bolts

FRC Report F-6177-1

TECHNICAL REPORT

20TH & RACE STREETS PHILADELPHIA, PA 19103 TWX 710-670-1889 TEL (215) 448-1000

8704210222 (16pp)

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Analyses of High Strength Bolts

FRC Report F-6177-1

USNRC Contract No. NRC-05-86-168
Task Order No. M-301

Prepared for

Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555

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1. INTRODUCTION

The Franklin Research Center (FRC) has conducted an independent evaluation of the chemical and mechanical characteristics of a group of high strength steel bolts. This study was initiated because of a recent Industrial Fasteners Institute research report [1] and media reports that "counterfeit" bolts were being used in structural applications in the nuclear industry. Of primary concern were claims that bolts that were marked as being hardened alloy steel were actually carbon steel. Hardened alloy steel bolts resist tempering, retain strength, and do not relax at elevated temperatures, whereas carbon steel bolts have less temperature softening resistance.

Twenty-six bolts were submitted to FRC for comparative analyses. Twenty-one of these were marked with 6 radial lines 60° apart indicating they conformed to the requirements for Grade 8 bolts as specified in SAE 429k [2]. Two bolts had 6 radial marks 30° apart indicating that they were Grade 8.2 of SAE 429k. The remaining three bolts were marked "A 490" per Type 1 classification in ASTM specification A 490 [3].

As described in the following sections of this report, the bolts were subjected to the various tests required by the specifications. Based upon the results of all these tests, several conclusions and recommendations are presented.

2. ANALYSES AND DISCUSSION

The bolts submitted for evaluation are listed in Table 1 with the identification numbers assigned by the U.S. Nuclear Regulatory Commission (NRC). Markings present on the heads are also noted. The mechanical and chemical requirements in the relevant specifications are listed in Tables 2 and 3 along with the results of the various tests, which are discussed below.

2.1 MECHANICAL REQUIREMENTS AND TESTS

The mechanical requirements, test methods, and test procedures for Grades 8 and 8.2 bolts are given in SAE 429k [2], whereas the mechanical requirements for A 490 bolts are given in ASTM A 490 [3] and the test methods and procedures are given in ASTM F 606 [4]. Since the SAE and ASTM property and methodology specifications are the same, requirements and test data for all the bolts are presented jointly in Table 2.

The standards cite the proof load, i.e., the load at or below which no permanent elongation should be incurred, and the minimum load at which tensile failure should occur for a bolt of given diameter, thread type, and dimensions. However, for a bolt with a length less than 2 1/4 times its diameter, proof and tensile tests are not required. Rather, hardness tests are specified to determine conformance to the mechanical requirements of the standards. For the bolts covered by this report, all except five--6177-1, 6177-2, 6177-17, 6177-23, and 6177-24--had a length greater than 2 1/4 times the diameter.

Furthermore, for any bolt of length less than 8 times the diameter and a diameter such that the specified tensile load is less than 100,000 pounds, proof load and wedge tensile strength determinations are required to be conducted on the full-size sample. All of the bolts fell into this category. Finally, for all of the bolts, the specifications required that core hardness be determined at the mid-radius of a transverse cross section through the threaded portion one diameter from the end of the bolt and that surface hardness be measured on an end, hexagon flat, or unthreaded shank. ASTM A 490 also required near surface and core hardness tests on a longitudinal section.

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

Table 1. Bolt Identification

Bolt	ID	Grade Marking(1)	Manufacturer's Mark	Size	Thread Type
6177-1	860962792A	8	LE	3/4-16	Fine
6177-2	" B	8	LE	3/4-16	Fine
6177-3	860830527A	8	RT	3/4-16	Fine
6177-4	" B	8	RT	3/4-16	Fine
6177-5	860912841A	8	--	3/8-24	Fine
6177-6	" B	8	--	3/8-24	Fine
6177-7	" C	8	--	3/8-24	Fine
6177-8	" D	8	--	3/8-24	Fine
6177-9	" E	8	--	3/8-24	Fine
6177-10	850431409A	8	--	5/16-18	Coarse
6177-11	" B	8	--	5/16-18	Coarse
6177-12	" C	8	--	5/16-18	Coarse
6177-13	860859665A	8.2	KS	3/4-10	Coarse
6177-14	" B	8.2	KS	3/4-10	Coarse
6177-15	870085789	8	CEM	9/16-12	Coarse
6177-16	870085790	8	CEM	5/8-11	Coarse
6177-17	870085791	8	CEM	7/8-9	Coarse
6177-18	870085792	A 490 (2)	TB	3/4-10	Coarse
6177-19	870085793	A 490 (2)	TB	3/4-10	Coarse
6177-20	870085794	A 490 (2)	TB	3/4-10	Coarse
6177-21	870085795	8	LE	5/8-11	Coarse
6177-22	870085796	8	LE	5/8-11	Coarse
6177-23	870085797	8	N/LE	3/4-10	Coarse
6177-24	870085798	8	N/LE	3/4-10	Coarse
6177-25	870085799	8	N/LE	1/2-13	Coarse
6177-26	870085800	8	LE	1/2-13	Coarse

1. According to SAE J429k for Grades 8 and 8.2 or ASTM A 490.
2. Type 1, based on the absence of Type 2 or 3 markings.

From the data in Table 2, it can be concluded that, with the exception of bolt 6177-15, all the bolts met or exceeded the specified mechanical test parameters. Since the hardness of bolt 6177-15 did meet the specification, the low tensile strength in a single test may reflect experimental data scatter, rather than an inherent low strength.

2.2 CHEMICAL REQUIREMENTS AND TESTS

The chemical requirements for Grades 8 and 8.2 and A 490 Type 1 bolts are listed in Table 3, along with the results of the chemical analyses. These data show that there was a wide range of composition among the bolts. Except for three groups of the Grade 8 bolts, all bolts met the relatively broad specifications called for in SAE J429k and ASTM A 490. Bolts 6177-3, 6177-4, and 6177-10 to 6177-12 had carbon contents lower than the minimum specified for Grade 8, whereas bolts 6177-5 through 6177-9 had been fabricated from carbon steel rather than alloy steel (see footnote in Table 3 for definition of alloy steel).

None of these bolts are necessarily out of specification, since, as is noted in the footnote in Table 3, for bolts of this size the substitution of carbon steel or SAE 1541 (or 1541H) steel for alloy steel in Grade 8 bolts is permissible by agreement between producer and consumer. In the present case, the chemical composition of bolts 6177-5 through 6177-9 does fall within the range specified for 1541 steel; thus, these bolts could have been supplied to a distributor, correctly marked as Grade 8, under a substitution agreement between the distributor and producer.

The composition of the Grade 8 marked bolts with low carbon (6177-3, 6177-4, and 6177-10 to 6177-12) was very similar to that of bolts 6177-13 and 6177-14, which are marked as Grade 8.2. However, all of the former bolts are included in the size range for which carbon steel may, under proper agreement, be substituted for alloy steel. Furthermore, since the material in all these bolts is actually a higher alloy than a plain carbon steel, it would more than qualify as a substitute for a Grade 8 steel with slightly more carbon but less alloying. Indeed, they met the mechanical requirements because of the strengthening effect of manganese and chromium alloying additions.

Table 2. Bolt Strength Requirements and Test Data

NRC Bolt	FRC Bolt	Requirements: Proof Load (Stress) (psi)	Requirements: Proof Load[1] (lb)	Requirements: Tensile Strength (Stress) (min/psi)	Requirements: Tensile Load[1] (min/lb)	Requirements: Core Hardness (min/R_c)	Requirements: Surface Hardness (max) 30N	Test Results: Elongation at Proof Load[2]	Test Results: Tensile Load (lb)	Test Results: Core Hardness R_c	Test Results: Surface Hardness 30N
860962792A	6177-1	120,000	(3)	150,000	(3)	33	58.6	(3)	(3)	36	48
860962792B	6177-2	"	(3)	"	(3)	"	"	(3)	(3)	37	47
860830527A	6177-3	"	44,800	"	56,000	"	"	0	64,000	35	45
860830527B	6177-4	"	44,800	"	56,000	"	"	0	62,100	36	43
860912841A	6177-5	"	10,500	"	13,200	"	"	0.00020	15,300	38	48
860912841B	6177-6	"	10,500	"	13,200	"	"	0.00020	15,440	37	51
860912841C	6177-7	"	10,500	"	13,200	"	"	0.00020	15,400	38	44
860912841D	6177-8	"	10,500	"	13,200	"	"	0.00042	14,760	36	51
860912841E	6177-9	"	10,500	"	13,200	"	"	0.00036	14,840	37	52
850431409A	6177-10	"	6,300	"	7,850	"	"	0	8,440	36	51
850431409B	6177-11	"	6,300	"	7,850	"	"	0.00011	8,400	36	50
850431409C	6177-12	"	6,300	"	7,850	"	"	0	8,260	35	54
860859665A	6177-13	"	40,100	"	50,100	"	"	0	56,200*	37	55
860895665B	6177-14	"	40,100	"	50,100	"	61	0	57,200	38	48
870085789	6177-15	"	21,800	"	27,300	"	61	0	24,100	36	46
870085790	6177-16	"	27,100	"	33,900	"	58.6	0	35,600	35	46
870085791	6177-17	"	(3)	"	(3)	"	"	(3)	(3)	35	47
870085792	6177-18	"	40,100	" (4)	50,100 (5)	" (6)	(7)	0.0002	53,050	33	53 (33 R_c)
870085793	6177-19	"	40,100	" (4)	50,100 (5)	" (6)	(7)	0.0002	52,250	30	53 (33 R_c)
870085794	6177-20	"	40,100	" (4)	50,100 (5)	" (6)	(7)	0.0002	52,500	30	52 (33 R_c)
870085795	6177-21	"	27,100	"	33,900	"	58.6	0	38,800	35	54
870085796	6177-22	"	27,100	"	33,900	"	"	0	38,650	37	55
870085797	6177-23	"	(3)	"	(3)	"	"	(3)	(3)	34	59
870085798	6177-24	"	(3)	"	(3)	"	"	(3)	(3)	34	60
870085799	6177-25	"	17,000	"	21,300	"	"	0	24,450	32	59
870085800	6177-26	"	17,000	"	21,300	"	"	0	24,750	34	60

1. From Table 5 in SAE 429k (for all bolts except 18-20). and from Table 5 in ASTM A 490 (for bolts 18-20) based on bolt size and thread type.
2. Length should be the same before and after loading within a tolerance of ± 0.0005 in.
3. Bolt length less than 2 1/4 times the diameter. Therefore only hardness test required.
4. 170,000 psi max.
5. 56,800 lb max.
6. 38 R_c max.
7. No more than the equivalent of 3 points R_c higher than hardness 1/8 in from surface.

* Unusually rapid drop during yield.

Table 3. Chemical Requirements and Test Data

Bolt		C Min	C Max	Mn Min	P Max	S Max	Si	B Min	Cr	Ni	Mo
		Elements (%)									
Grade 8, 429k[1]		0.28	0.55	—	0.04	0.045	—		—	—	—
Grade 8.2, 429k		0.15	0.25	0.74	0.048	0.058	—	0.0005	—	—	—
ASTM A 490, Type 1[2]		0.26	0.50	—	—	—	—	—	—	—	—
NRC Bolt	FRC Bolt										
860962792A	6177-1	0.43		0.67	0.011	0.012	0.24	<0.001	0.33	<0.01	0.26
860962792B	6177-2	0.43		0.64	0.012	0.012	0.26	0.001	0.32	<0.01	0.24
860830527A	6177-3	0.21		0.95	0.011	0.014	<0.01	<0.001	0.21	<0.01	<0.01
860830527B	6177-4	0.21		0.95	0.015	0.012	<0.01	<0.001	0.20	<0.01	0.12
860912841A	6177-5	0.37		1.54	0.015	0.023	0.22	<0.001	0.07	<0.01	0.01
860912841B	6177-6	0.39		1.56	0.013	0.018	0.23	<0.001	0.02	<0.01	0.02
860912841C	6177-7	0.36		1.52	0.012	0.023	0.20	<0.001	0.12	<0.01	0.01
860912841D	6177-8	0.39		1.58	0.014	0.019	0.21	<0.001	0.06	<0.01	0.01
860912841E	6177-9	0.39		1.55	0.014	0.019	0.23	<0.001	0.07	<0.01	<0.01
850431409A	6177-10	0.20		1.02	0.013	0.018	0.04	0.002	0.19	<0.01	<0.01
850431409B	6177-11	0.20		0.99	0.014	0.017	0.03	0.002	0.23	<0.01	0.01
850431409C	6177-12	0.20		0.94	0.014	0.011	0.01	<0.001	0.19	<0.01	0.01
860859665A	6177-13	0.21		1.01	0.014	0.021	0.02	<0.001	0.17	<0.01	0.01
860895665B	6177-14	0.22		1.03	0.014	0.021	0.03	<0.001	0.19	<0.01	0.01
870085789	6177-15	0.44		0.92	0.014	0.035	0.31	<0.001	0.99	<0.01	0.20
870085790	6177-16	0.43		0.93	0.014	0.035	0.32	<0.001	1.00	<0.01	0.20
870085791	6177-17	0.39		0.90	0.013	0.033	0.26	<0.001	1.01	<0.01	0.22
870085792	6177-18	0.39		0.87	0.011	0.022	0.27	<0.0005	0.95	<0.01	0.17
870085793	6177-19	0.39		0.86	0.014	0.025	0.28	<0.0005	0.94	<0.01	0.16
870085794	6177-20	0.38		0.87	0.011	0.025	0.28	<0.0005	0.97	<0.01	0.16
870085795	6177-21	0.38		0.61	0.011	0.015	0.22	0.0007	0.30	<0.01	0.17
870085796	6177-22	0.39		0.63	0.011	0.016	0.22	0.0006	0.27	<0.01	0.18
870085797	6177-23	0.40		0.58	0.014	0.010	0.26	0.0007	0.32	<0.01	0.14
870085798	6177-24	0.40		0.60	0.011	0.011	0.27	0.0005	0.33	<0.01	0.15
870085799	6177-25	0.36		0.95	0.011	0.012	0.23	0.0005	0.54	<0.01	0.02
870085800	6177-26	0.37		0.92	0.011	0.013	0.21	0.0005	0.54	<0.01	0.03

1. Medium carbon alloy steel with no specified alloy content. "Carbon Steel may be used by agreement between producer and consumer, for sizes 1/4 - 3/4 in diameter products. SAE 1541 (or 1541H) steel, oil quenched and tempered may be used at the option of the producer for products 7/16 in nominal diameter and smaller." SAE J429k

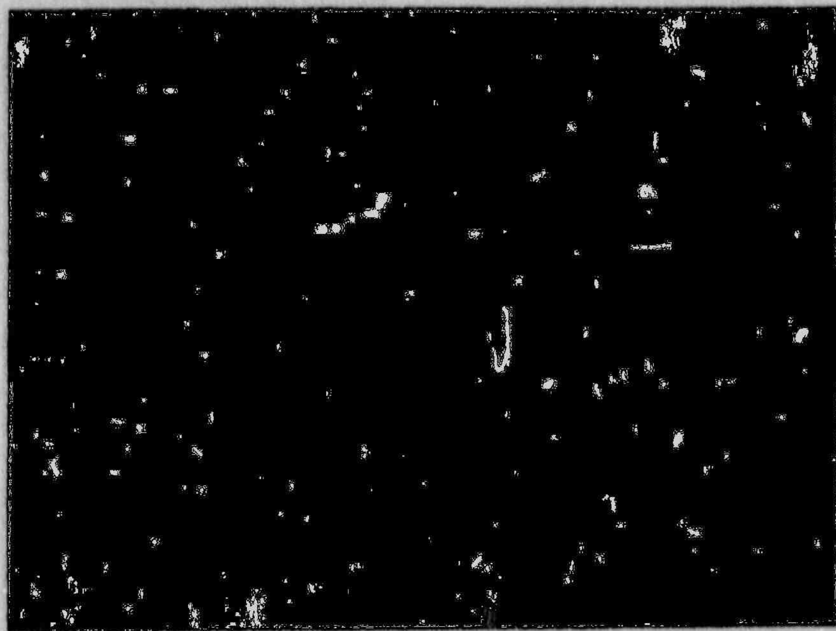
2. Alloy steel with no specified alloy content. "Note 4 - Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65%; silicon, 0.60%; copper, 0.60%; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zironium, or any other alloying elements added to obtain a desired alloying effect." ASTM A 490.

Accordingly, the determination of whether or not these bolts are out of specification, i.e., mismarked, depends on whether or not the steel substitution was in accordance with an agreement between a purchaser (a distributor or an end user) and the producer.

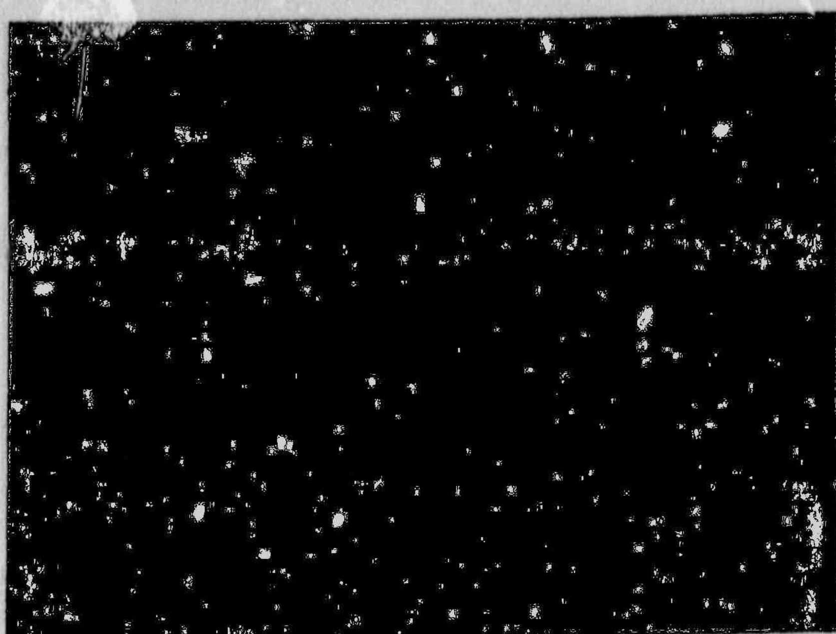
From the above findings, it is clear that if the end user does not purchase directly from the producer, but from a distributor, he may not be aware that he has purchased carbon steel rather than alloy steel Grade 8 bolts. In many cases, this will present no problem, since both materials would behave similarly except at high and low temperatures. At low temperatures, the carbon steel would be expected to exhibit a higher ductile to brittle transition temperature and a lower shelf impact energy than an alloy steel. Furthermore, at elevated temperatures, the carbon steel would soften at a lower temperature or in shorter times than the alloy steel.

There is also the possibility that bolts with carbon content lower than specified in Grade 8 could have high temperature characteristics superior to those of a Grade 8 bolt with specified carbon because of different alloying additions. Thus, when specific temperature/property characteristics are required, testing of sample bolts is necessary to assure adequate service performance.

As further evaluation of the quality of the low carbon and the 1541 steel bolts, the microstructures of bolts 6177-3, 6177-4, and 6177-10 to 6177-12 were analyzed in longitudinal cross sections. A uniform, fine-grained martensitic microstructure was present in all the bolts studied, as shown in the micrographs in Figures 1 through 4. Thus, consistent with the mechanical properties, none of these bolts can be considered poor quality, and whether or not any of them can be classified as having been mismarked would depend on whether or not compositional substitutions had been agreed upon during the original purchase from the fabricator.

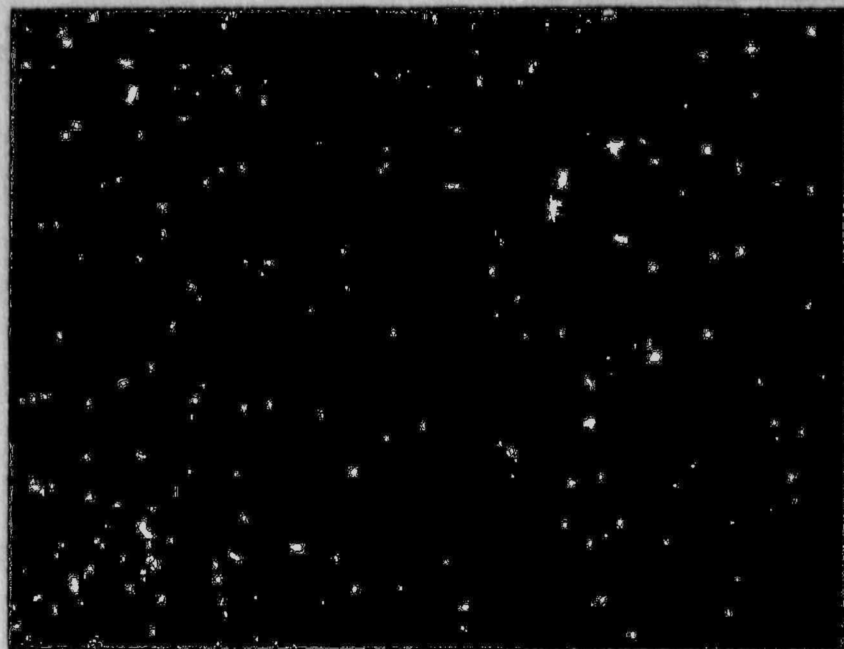


A. Bolt 6177-3 100 X

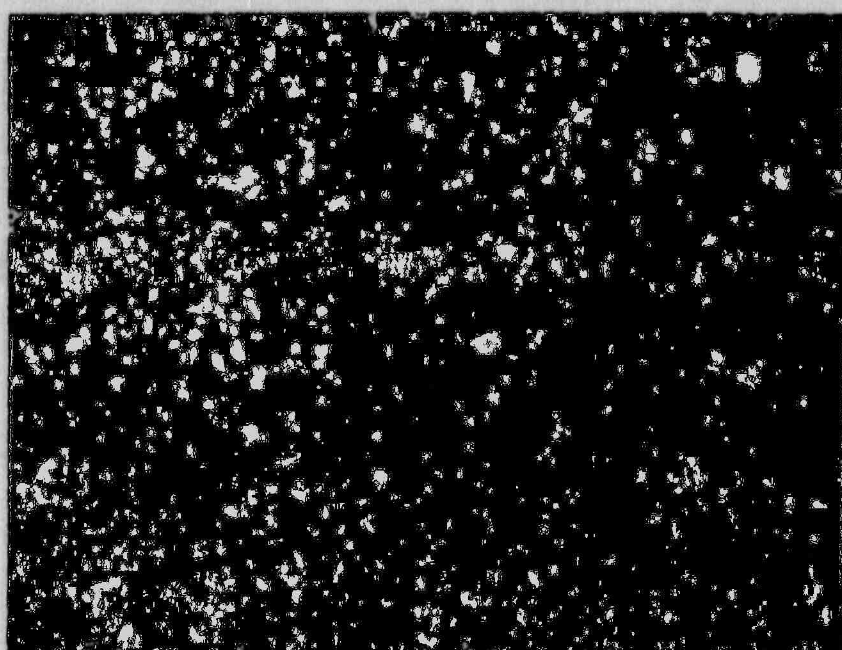


B. Bolt 6177-4 100 X

Figure 1. Micrographs showing a uniform, fine-grained, tempered martensitic microstructure in bolts with carbon content lower than specified (without agreed upon substitution) for Grade 8.

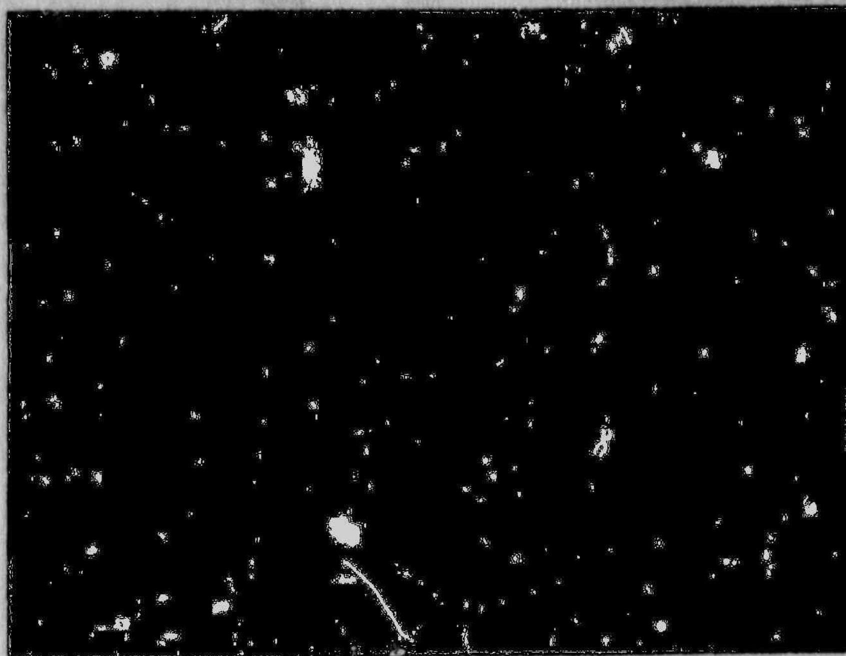


A. Bolt 6177-5 100 X

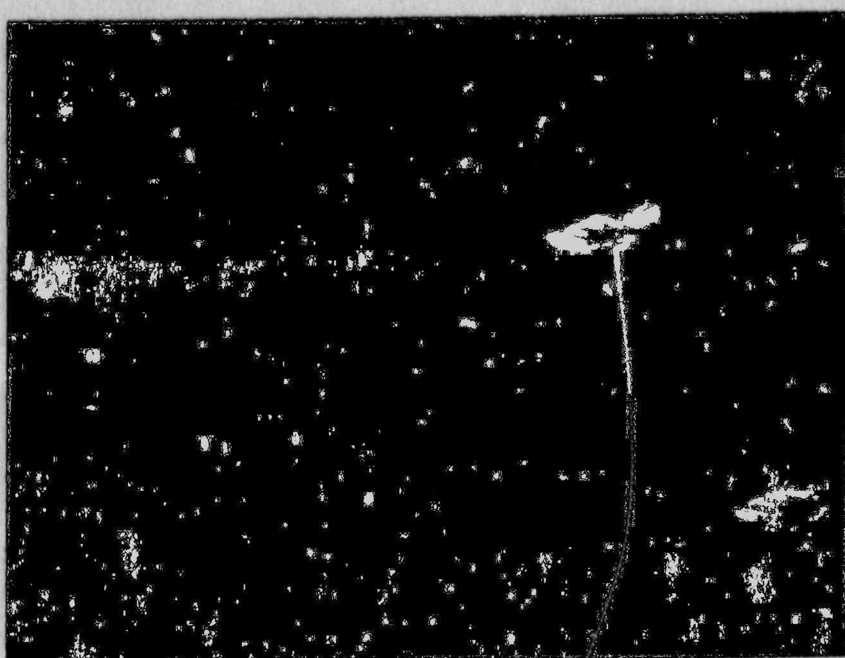


B. Bolt 6177-6 100 X

Figure 2. Micrographs showing a fine-grained, tempered martensitic microstructure in two bolts marked as Grade 8, which were carbon rather than alloy steel. The microstructure is uniform except for some slight carbon banding.

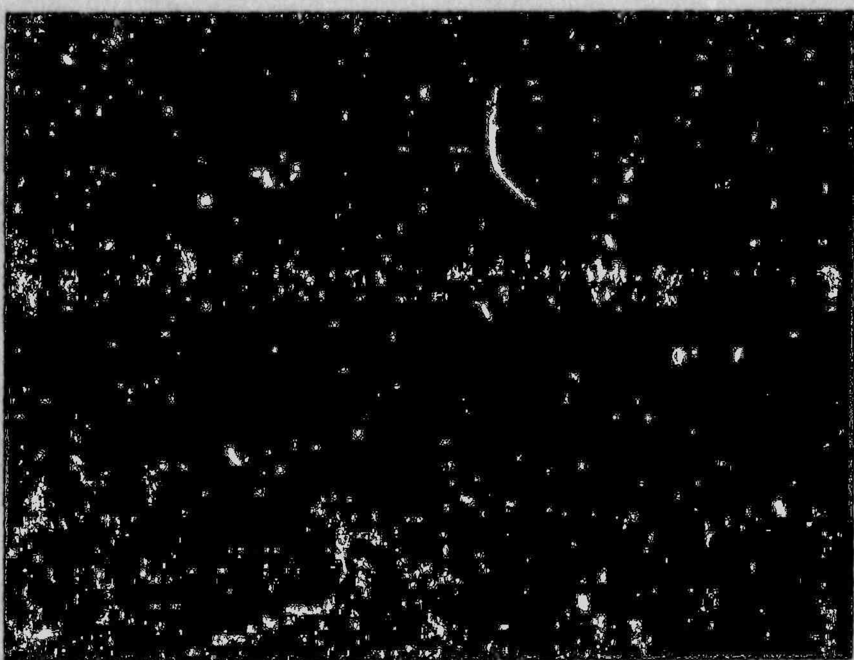


A. Bolt 6177-10 100 X



B. Bolt 6177-12 100 X

Figure 3. Micrographs showing a uniform, fine-grained, tempered martensitic microstructure in two bolts with carbon content lower than specified (without agreed upon substitution) for Grade 8. A higher magnification micrograph of bolt 6177-12 is given in Figure 4.



B. Bolt 6177-12 500 X

Figure 4. Micrograph showing, at a higher magnification than in Figure 3, the uniform, fine microstructure in a carbon steel bolt with a Grade 8 marking.

3. CONCLUSIONS AND RECOMMENDATIONS

Based on the above analyses and discussions, the following conclusions and recommendations are presented:

1. All bolts except one met or exceeded the mechanical property requirements in the relevant specifications. The one bolt (6177-15) that had a slightly low tensile strength did meet the hardness specification and, thus, the single test may reflect inherent experimental scatter.

2. Some of the bolts marked as Grade 8 per SAE J492k were out of specification with regard to chemical composition. However, if these bolts had been supplied by a producer under agreed-upon composition substitutions, they would not be in violation of the broad composition range permissible in J429k. Thus, the bolts cannot be considered mismarked or "counterfeit" unless it can be shown that an agreement for substitution had not been made in conjunction with their original fabrication and purchase.

3. All bolts which would have been outside of Grade 8 composition requirements, in the absence of agreed-upon substitutions, exhibited uniform, fine microstructures, consistent with the mechanical properties. Thus, the overall quality of these bolts is not in question.

4. If the end user of high strength bolts purchases them from a distributor, who in turn purchased them from a producer with agreed upon composition substitutions, he may not be aware that he has carbon rather than alloy steel bolts. Thus, the end user must qualify his order of Grade 8 bolts, if they are between 1/4 and 3/4 in diameter, as to the type of steel, if an alloy steel is deemed necessary for the intended application.

5. When specific service conditions require retention of strength at high temperature or require low temperature toughness, testing of bolt samples should be performed to assure that bolts will have necessary characteristics. Grade specifications in and of themselves are so broad that they assure room temperature properties only.

4. REFERENCES

1. False Grade 8 Engineering Performance Marks on Bolting and Improper Marking of Grade 8 Nuts, Industrial Fastener Institute Research Report, Cleveland, OH, April 4, 1986

2. SAE J429k: Standard Mechanical and Material Requirements for Externally Threaded Fasteners, Society of Automotive Engineers, Warrendale, PA, 1980

3. ASTM A 490: Heat Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength, American Society for Testing and Materials, Philadelphia, PA, 1985

4. ASTM F 606: Conducting Tests to Determine the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets, American Society for Testing and Materials, Philadelphia, PA, 1986

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W. JAMES LIPPOLD
MANAGER
NUCLEAR ENGINEERING SERVICES DEPARTMENT

September 30, 1987

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Commercial Quality Mechanical Fastener Evaluation

REFERENCE: (a) Letter from Mr. J. A. Tiernan (BG&E) to NRC Document Control Desk, dated May 11, 1987, Use of Mechanical Parts Purchased Commercial Quality in ASME Section XI Class 1, 2 and 3 Systems

(b) Teleconference between Mr. A. R. Thornton (BG&E) and Mr. L. E. Tripp (NRC), on September 15, 1987, same subject

Gentlemen:

In Reference (a) we stated our intentions to remove, test and evaluate specific mechanical fasteners in ASME Section XI Code Class Systems. Since that time, we have worked steadily and committed considerable resources to complete the testing and evaluation in a timely manner. This letter provides the results of our evaluation and the actions we have taken and plan to take as discussed in Reference (b).

Evaluation Results

We have tested individually 1539 fastener components or pieces, where a piece is a stud, nut or bolt. Each has received a surface examination, a hardness test and a chemical analysis. Approximately 150 pieces we removed from the plant which we do not plan to test. Of these, 50 pieces were misplaced or mislabeled when they were removed from the plant. Approximately 100 pieces cannot be decontaminated without the expenditure of significant additional resources and radiation exposure. We do not believe the information we would receive from testing those 100 pieces would justify the resources and exposures that would be required. We also feel the remaining 1539 fasteners are representative of those not tested.

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A1/4

All 1539 pieces have been compared to the applicable chemistry and hardness material specifications to determine whether they were adequate to have performed their design function. Initially, 399 pieces yielded test results that were out of specification. The chemical composition for 174 of the 399 pieces differed slightly from the material requirements, but the hardness was within specification. For these it was clear that the pieces were of the correct material and that the critical property - strength as determined from hardness measurements - was adequate. We therefore determined that these were adequate to have performed their design function.

A number of other pieces had the chemical compositions within the specification range or only slightly out of range, but the hardness was just beyond the specified range. Based upon engineering judgment, we determined that fasteners with hardness within 10% of the specified strength were adequate. This meant reducing the minimum hardness for B7 studs from 26 HRC to 23 HRC and, 2H nuts from 24 HRC to 22 HRC. We found 40 pieces were acceptable with this criteria. This engineering judgment was substantiated by the evaluation performed on the remaining 185 pieces.

The remaining 185 pieces come from 26 different locations within the plant. An evaluation specific to each location was performed to determine if the pieces had adequate strength. We analyzed each of these 185 pieces in a manner consistent with the class of each item and found that in all cases the actual material properties were adequate to ensure the structural integrity of the system. Data relating to these results are listed in Attachment 1.

Conclusion

From the above, we conclude that although a significant number of pieces did not meet their originally specified requirements, all would have functioned to ensure the structural integrity of their system. Because our testing and evaluations of the 1539 fasteners yielded adequate results, we are confident that the use of commercial quality fasteners in our Class 1, 2 and 3 systems never posed an unreviewed safety question.

Immediate Preventive Actions

In early June 1987, BG&E initiated a comprehensive investigation to identify the root cause of the mechanical fastener traceability situation that had arisen at Calvert Cliffs. Several issues were identified for which corrective action was felt to be prudent, but the primary causes were found to be (1) inadequate awareness of the material quality and traceability requirements for mechanical fasteners used in the maintenance of ASME Class 1, 2 and 3 systems, and (2) the absence of formal easy-to-use documentation to assist our personnel in the identification of code boundaries during maintenance planning activities.

To correct these problems, maintenance personnel and quality control inspectors were given special training and instruction on the code requirements that apply to fasteners in Class 1, 2 and 3 systems. In addition, formal guidance documents were provided to maintenance personnel to facilitate the identification of code boundaries during routine maintenance planning activities. These actions ensure that present-day maintenance activities affecting Class 1, 2 or 3 systems are identified as such when the maintenance order is written and that appropriate replacement fastener materials are specified accordingly on the maintenance order form. To monitor the performance of individual maintenance work activities in the field, quality control inspections are conducted in accordance with existing QA program requirements.

Supplemental Actions

The immediate actions described above provide reasonable assurance that all applicable material quality and traceability standards will be maintained in current and future maintenance activities at Calvert Cliffs. Nonetheless, a number of supplemental actions are presently under consideration which would simplify and further improve procedures for controlling the procurement, storage, and use of mechanical fasteners. The objective of these supplemental initiatives is to make the overall maintenance process more effective and thereby less prone to error. Examples of these initiatives include:

- o Replacement of the commercial quality (72/78 series) fastener stock inventory with Nuclear Class 1 fasteners;
- o Implementation of a fastener standardization program for all fastener applications in the plant;
- o Development of a comprehensive computer database for use by engineers, maintenance planners, and purchasing personnel in identifying specific code requirements and allowable procurement methods for each piece of mechanical equipment ; and
- o Upgrade of the material descriptions in the material management system (MMS) computer database to improve consistency in stock item descriptions and to provide more flexibility in the types of computer sorts that can be performed.

Should you have further questions regarding this matter, we will be pleased to discuss them with you.

Very truly yours,

[signature]

WJL/SRC/dlm

Attachment

cc: D. A. Brune, Esquire
J. E. Silberg, Esquire
R. A. Capra, NRC
S. A. McNeil, NRC
W. T. Russell, NRC
T. Foley/D. C. Trimble, NRC

bcc: J. A. Tiernan
R. F. Ash/R. C. L. Olson
C. H. Cruse/P. E. Katz
R. E. Denton/J. A. Mihalcik
R. M. Douglass/S. E. Jones, Jr.
T. N. Pritchett/M. Gavrilas/E. I. Bauereis
J. R. Lemons/R. P. Heibel
W. J. Lippold/A. R. Thornton
F. J. Munno
R. B. Pond/R. E. Cantrell
L. B. Russell/J. T. Carroll
R. E. Lapp
C. M. Rice
R. G. Staker
W. R. Horlacher, III
D. L. Shaw, Jr.
L. S. Larragoite
S. R. Cowne
P. E. McGrane
M. E. Bowman/L. E. Salyards

ATTACHMENT 1

MCQ FASTENER STRENGTH EVALUATION

MO #	Piece #	Desc.	Marking	Spec.	Hardness	Strength (KSi)	Comment
590A	1	S	HB	B7	22 HRC	112	Chemistry OK [1]
494A	6	N	S	2H	---	--	Forging Lap [2]
651A	6	N	815 *	2H	10.3 HRC	90	Chemistry OK
564A	1-7	S		B7	90 HRB	89	Stainless Steel [3]
564A	14,15,16	N		2H	90 HRB	89	Stainless Steel
781A	1-12	B		SAE Grade 5	2.5 HRC	80	Low Carbon Steel [4]
781A	15-20	B	MD	SAE Grade 5	5.0 HRC	86	Low Carbon Steel
781A	21-40	N (Nly #16)		2H	5.4 HRC	86	Low Carbon Steel
667A	21-52	N		2H	88 HRB	85	Low Carbon Steel
598B	6	N		2H	---	--	Forging lap
585A	9-24	N		2H	10 HRC	90	Low Carbon Steel
607A	3	B		B7	88 HRB	85	Low Carbon Steel
607A	4	B		B7	80 HRB	72	Low Carbon Steel
607A	5	N		2H	72.7 HRB	65	Low Carbon Steel
646B	3-5	N	*	2H	20 HRC	108	Chemistry OK
302A	21	N	S	2H	20 HRC	108	Chemistry OK
850A (#22)	9-24	N		2H	88 HRB	89	Low Carbon Steel
797A	2,4	S	HB	B7	22 HRC	112	Chemistry OK
646A	3	S		B7	75 HRB	68	Low Carbon Steel
850A (#21)	9,10,12 14-23	N	* #21	2H	10.3 HRB	90	Low Carbon Steel
670A	2	N		2H	15 HRC	94	Low Carbon Steel

ATTACHMENT 1

MCQ FASTENER STRENGTH EVALUATION

MO #	Piece #	Desc.	W/	Spec.	Hardness	Strength (KSi)	Comment
761A	1,2,4,5	S		B7	90 HRB	89	Low Carbon Steel
761A	6	S		B7	22 HRC	112	Chemistry OK
761A	10-16,19-21	N		2H	92 HRB	93	Low Carbon Steel
718A	1	B	*	B7	16.5 HRC	95	Chemistry OK
588A	4	B	C	B7	71.4 HRB	62	Low Carbon Steel
588A	8	N		2H	86 HRB	81	Low Carbon Steel
771A	17	S		B7	21 HRC	110	Chemistry OK
601A	5	S		B7	21 HRC	110	Carbon Slightly Low
850A (#23)	4	S		B7	21 HRC	110	Chemistry OK
850A	9-24	N		2H	90 HRB	89	Low Carbon Steel
837A	4	B		SAE Grade 5	19.5 HRC	106	Chemistry OK
837A	10	N		2H	90 HRB	89	Low Carbon Steel
768A	1	B		A325	---	--	Forging Lap
696A	4,5,10-13	N		2H	70 HRB	62	Stainless Steel
757A	21	N	JS	2H	---	--	Forging Lap

N = Nut
S = Stud
B = Bolt

---

[1] Chemical composition was in specification.

[2] Indications that were found by NDE.

[3] Piece was composed of stainless steel.

[4] Piece was composed of Low Carbon Steel.

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CHARLES CENTER · P. O. BOX 1475 · BALTIMORE, MARYLAND 21203

JOSEPH A. TIERNAN
VICE PRESIDENT
NUCLEAR ENERGY

May 12, 1988

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Fastener Testing

Gentlemen:

On November 5, 1987, our Project Manager, Scott McNeil, selected ten bolts and two nuts from our warehouse with the intention of testing them to determine their physical properties. We selected an equal number of fasteners from the same bins and tested them at our material testing facility.

At Mr. McNeil's request, we have attached a table summarizing the results of our testing. Please send us the results of your testing in a format similar to the attached table.

We found three minor discrepancies with the specification requirements.

Item	Discrepancy
72-175(1)	Hardness was 0.3 HRC (or 1.2%) below the minimum hardness of 25 HRC.
72-175(2)	Hardness was 0.4 HRC (or 1.4%) below the minimum hardness of 25 HRC.
72-229(2)	Hardness was 1.5 HRC (or 4.4%) above the maximum hardness of 34 HRC.

These hardness variations are minor and, based on past experience, would not adversely affect the strength or ductility of the material.

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Mr. McNeil also requested a list of vendors that BG&E purchases fasteners from, or have purchased fasteners from in the past. We have attached such a list. It is not intended to be all-inclusive, but it does represent our principal vendors.

Should you have any additional questions regarding fasteners used at Calvert Cliffs, please do not hesitate to contact us.

Very truly yours,

JAT/WPM/dlm

Attachment

cc: D. A. Brune, Esquire
J. E. Silberg, Esquire
R. A. Capra, NRC
S. A. McNeil, NRC
W. T. Russell, NRC
D. C. Trimble, NRC

PART ID	MARKINGS	SIZE	C	Mn	P	S	Si	Cr	Mo	HARDNESS (HRC)
			ELEMENTAL WEIGHT PERCENT							
72-155(1)	KS Grade 5	5/8" x 1"	0.375	0.973	0.025	0.025	0.222	0.089	0.02	30.1
72-155(2)	FM Grade 5	5/8" x 1"	0.324	0.911	0.012	0.017	0.230	0.072	0.02	30.2
72-165	FM Grade 5	9/16" x 3"	0.303	0.876	0.013	0.017	0.252	0.106	0.01	26.1
72-175(1)	Grade 5	3/8" x 3"	0.384	0.824	0.015	0.018	0.242	0.066	0.01	24.7
72-175(2)	Grade 5	3/8" x 3"	0.451	0.830	0.015	0.020	0.259	0.063	0.01	24.6
72-218(1)	KS Grade 5	5/16" x 1	0.464	0.801	0.023	0.024	0.237	0.084	0.02	27.3
72-218(2)	KS Grade 5	5/16" x 1	0.401	0.832	0.023	0.022	0.236	0.084	0.02	26.2
72-226	J Grade 5	3/8" x 1"	0.399	0.882	0.016	0.015	0.035	0.269	0.00	25.7
72-229(1)	KS Grade 5	1/2" x 3"	0.357	0.906	0.014	0.016	0.240	0.079	0.01	33.7
72-229(2)	KS Grade 5	1/2" x 3"	0.358	0.868	0.014	0.017	0.249	0.080	0.01	35.5
445767(1)	(-)2H AME	Nut 1 1/8"	0.448	0.839	0.026	0.017	0.237	0.130	0.01	25.4
445767(2)	(-)2H AME	Nut 1 1/8"	0.399	0.925	0.026	0.023	0.239	0.153	0.02	26.0

Table No. 1: Chemistry and Hardness Results

Principal Vendors
of
BG&E Fasteners

1. A&G Engineering Company
   4640 East LaPalma Avenue
   Anaheim, CA 92806
   Tel: (800) 242- 6587

2. Leonard Jed, Company
   1301 Covington Street
   Baltimore, MD 21230
   Tel: (301) 685-1482

3. Kenneth G. Lilly Fasteners
   P. O. Box 6005
   Newark, DE 19711
   Tel: (302) 366-7640

4. Standard Nut & Bolt
   Abbott & Hatch Streets
   Cumberland, RI 02864
   Tel: (401) 722-6700

5. Sta-Put Fastener Manufacturing Company
   3900 Vero Road
   Baltimore, MD 21227
   Tel: (301) 247-5500

6. Vincent Brass and Aluminum
   Charlotte, NC 28230
   Tel: (800) 438-6914

7. Mil-Spec Fasteners
   Route 30 Box 59A
   Hampstead, MD 21074
   Tel: (301) 239-7761

8. A & A Bolt & Screw
   1110 Batavia Farm Road
   Baltimore, MD 21237
   Tel: (301) 687-8831

9. C-S Metal Services, Inc.
   7325 Washington Boulevard
   Baltimore, MD 21227
   Tel: (301) 796-5661

Jim Stone

NRC Form 366 (9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES 8/31/88

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1): Calvert Cliffs, Unit 1

DOCKET NUMBER (2): 0 5 0 0 0 3 1 7

PAGE (3): 1 OF 0 8

TITLE (4): Use of Fasteners (Bolts, Studs, Threaded Rod & Nuts) in ASME Class 1, 2, & 3 Systems without Proper Certification, Special NDE, or Special Marking.

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 4	2 3	8 7	8 7	— 0 0 9 —	0 2	0 2	0 3	8 8	Calvert Cliffs, Unit 2	0 5 0 0 0 3 1 8
										0 5 0 0 0

OPERATING MODE (9): 5

POWER LEVEL (10): 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

[ ] 20.402(b)	[ ] 20.405(c)	[ ] 50.73(a)(2)(iv)	[ ] 73.71(b)
[ ] 20.405(a)(1)(i)	[ ] 50.36(c)(1)	[ ] 50.73(a)(2)(v)	[ ] 73.71(c)
[ ] 20.405(a)(1)(ii)	[ ] 50.36(c)(2)	[ ] 50.73(a)(2)(vii)	[ ] OTHER (Specify in Abstract below and in Text, NRC Form 366A)
[ ] 20.405(a)(1)(iii)	[ ] 50.73(a)(2)(i)	[ ] 50.73(a)(2)(viii)(A)	
[ ] 20.405(a)(1)(iv)	[X] 50.73(a)(2)(ii)	[ ] 50.73(a)(2)(viii)(B)	
[ ] 20.405(a)(1)(v)	[ ] 50.73(a)(2)(iii)	[ ] 50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME: Bruce Montgomery, Senior Engineer

TELEPHONE NUMBER: AREA CODE 3 0 1 — 2 6 0 - 3 9 4 6

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

[ ] YES (If yes, complete EXPECTED SUBMISSION DATE) [X] NO

EXPECTED SUBMISSION DATE (15): MONTH | DAY | YEAR

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On April 23, 1987, with the unit in cold shutdown, we determined there were instances where commercial-quality fasteners without the requisite material traceability and certification had been installed in ASME Section XI Class 1, 2, and 3 systems. There are no similar events previously reported in an LER. We reviewed all maintenance work performed on ASME Section XI systems since initial plant operation (approximately 40,000 maintenance requests, or MRs, were involved) and found that commercial quality fasteners had been inappropriately used in 61 cases. These fasteners, totalling over 1600 studs, bolts, and nuts, were removed and replaced with properly certified fasteners. The removed fasteners were tested for strength and chemistry. The testing revealed only 16 fasteners were judged to fail ASTM specifications. However, the results showed that 115 of the fasteners were made of a material different from the material grade that was specified for the locations they were installed. Engineering analyses showed that in all cases the fasteners would have performed their intended functions under accident conditions. The causes of this event have been identified and corrective action has been taken to prevent recurrence.

On April 23, 1987, with the unit in cold shutdown, we determined there were instances where commercial-quality fasteners without the requisite material traceability and certification had been installed in ASME Section XI Class 1, 2, and 3 systems. There are no similar events previously reported in an LER. We reviewed all maintenance work performed on ASME Section XI systems since initial plant operation (approximately 40,000 maintenance requests, or MRs, were involved) and found that commercial quality fasteners had been inappropriately used in 61 cases. These fasteners, totalling over 1600 studs, bolts, and nuts, were removed and replaced with properly certified fasteners. The removed fasteners were set aside for subsequent testing. The test results are summarized in this report.

In our earlier reports, LERS 87-009-000 and 87-009-001, we concluded that this event was caused by: inadequate precautions placed on repair and replacement planning activities regarding the use of safety-related fasteners purchased by the commercial quality method, an overall lack of awareness of the material quality and traceability requirements for mechanical fasteners used within ASME Section XI boundaries, and the absence of formal, easy-to-use documentation to assist our personnel in the identification of code boundaries during maintenance planning activities.

While these were the primary causes of the event, we now conclude that two additional conditions existed which contributed substantially to the event's severity. The first condition was a lack of specific written instruction to mechanics regarding the proper material grade of fasteners to use on a job. The second condition was the presence of a "free-stock" supply of fasteners inside the plant which had a composition that was highly conducive to error in the selection of fasteners.

The purpose of this supplemental report is to identify the causes and implications of this event and to describe the actions taken to prevent recurrence.

A total of 1689 uncertified fasteners (studs, bolts and nuts) were removed from ASME Section XI Class 1, 2, and 3 systems and were bagged and tagged for testing. Of these, 50 pieces were misplaced or mislabeled and 100 pieces could not be decontaminated. Consequently, these 150 fasteners could not be tested. The remaining 1539 fasteners were tested to determine their physical and chemical properties relative to the strength and material composition requirements specified for the systems in which they were installed. The results of this testing program are summarized in Table 1.

TABLE 1

Summary of Material Testing

on Uncertified Fasteners(1)

	EVALUATION CATEGORY	NUMBER OF PIECES
a.	Within specified strength and chemistry	1194
b.	Within specified strength, slight deviations in chemistry	174
c.	Within 10% of strength, within or very close to specified chemistry	40
d.	Significant deviations in strength and/or chemistry	131(2)

(1) Each piece received a surface examination, a hardness test and a chemical analysis. Bolt heads and studs also received a magnetic particle test. Test results were compared against the ASTM standard applicable to the system or component the piece was removed from. In the majority of cases the applicable standard was ASTM-193, Grade B7 for studs and bolts, and ASTM-194, Grade 2H for nuts.

(2) Most of these bore no markings.

The 131 pieces which did not meet specification had been installed in 25 different locations within the plant. Using the measured strength of each piece, an engineering evaluation specific to each location was performed to determine whether system structural integrity had been compromised. In all cases the actual material strength properties were more than adequate to assure system integrity. Because the unit had operated across its full range (0-100% power), including transients, these fasteners were subjected to the full range of operating conditions. Additionally, the analyses that were performed indicate that the fasteners would have performed their intended function under accident conditions. Therefore, there is no safety significance associated with this event.

A detailed investigation was conducted to determine the specific circumstances which led to 131 pieces being out-of-specification (O.O.S.). Each piece was visually re-examined for markings or any other physical attributes that are characteristic of material grade. The chemistry and hardness test results were also closely re-examined. Based on this re-evaluation it was determined that the majority of the 131 fasteners in question were out-of-specification because they were made from a different material. Whereas ASTM-193-B7/ASTM-194-2H (for bolts/nuts, respectively) was normally the material specified for use, these pieces were predominantly ASTM-307-B/ASTM-563-A material. The results of this evaluation are presented in Table 2.

TABLE 2

RE-EVALUATION OF 131 O.O.S. FASTENERS

	DEVIATION CATEGORY	ITEM	NUMBER OF PIECES
a.	Other Material		
*	Stainless Steel	Studs	8
		Nuts	9
*	ASTM-307-B	Studs/ Bolts	2
*	ASTM-563-A	Nuts	96
		TOTAL	115

TABLE 2 (continued)

	DEVIATION CATEGORY	ITEM	NUMBER OF PIECES
b.	Manufacturing Deficiencies		
*	Forging Laps	Bolts	1
		Nuts	3
*	Other (possible manufacturing process deficiencies)	Bolts/ Studs	12
		TOTAL	16
		GRAND TOTAL	131

During this review a very strong correlation was found between the presence of ASTM grade markings and passing test results. The only exceptions to this were the four forging laps and 12 failures attributed to possible manufacturing process deficiencies. An even stronger correlation was found to exist between pieces that bore no markings and those that were determined to be ASTM-307-B/ASTM-563-A material (mostly A-563 nuts). This should not be unexpected as the ASTM standard does not specify any unique marking for this class of low carbon steel, and it is normal and customary industry practice to supply this material without markings.

A-307/A-563 material is a low carbon steel with a lower tensile strength relative to A-193/A-194 (which is a medium alloy steel), and is normally specified for use at Calvert Cliffs in lower stress bolting applications. These applications include flanged connections in certain low pressure fluid systems, some piping supports, miscellaneous structural applications, etc. These applications encompass many of those which are classified safety-related but which fall outside ASME Section XI boundaries.

Another investigation was then conducted to determine how A-307/A-563 material became installed in systems where A-193/A-194 material was specified. We reviewed the original maintenance orders under which these particular fasteners were installed, and found in virtually all of them that instructions regarding fasteners were either insufficient or absent. In many cases the maintenance planner focused on providing guidance for other aspects of the job and may have assumed that the mechanic would know which fasteners to use. In other cases, such as with the simple replacement of gaskets, the planner apparently did not foresee the possibility that new fasteners could be needed. In each of these cases, the mechanic was left without specific written guidance, and apparently the mechanic did not request that this guidance be provided before starting the job.

To determine the source of A-307/A-563 fasteners, the warehouse inventory was checked and we found that safety-related A-563 nuts were commonly stocked in significant quantities and in 19 different sizes. A-307 studs and bolts, on the other hand, were found to be stocked in rather limited quantities. An inspection of the commercial quality, safety-related "free-stock" staging area in the plant machine shop revealed that A-563 nuts were readily available to mechanics in all 19 sizes. These nuts were stored in bins adjacent to bins containing A-194-2H nuts. The bins, while marked with size and material stock number, were not marked with the ASTM grade. For cases where mechanics were not given specific instructions on either the applicable ISI Class or material grade, the above situation was highly conducive to the chance use of A-563 fasteners.

It should be noted that none of the fasteners (neither the A-194 nor the A-563 nuts) obtained from the free-stock storage area were appropriate for use in ASME Section XI systems. This is because they were procured by the commercial-quality safety related method and therefore did not have the individual material traceability required for use within Section XI boundaries. The main reason they were mistakenly used was a perception on the part of some of our personnel that these fasteners, because they were safety related, were qualified for use in any safety-related application. Once this error was made and fasteners were drawn from the free stock area, there was a good chance that A-563 nuts would be mistakenly selected when A-194 nuts were called for.

Based on the investigation findings summarized above, the following statements can be made regarding the implications of this event:

1. Procurement control or receipt inspection practices did not contribute to this event;

2. No underlying trends were found in the test results to indicate that any manufacturers were supplying substandard, mismarked or fraudulent fasteners. In fact, the test results suggest a consistently high level of material quality;

3. All causes identified were internal to BG&E and pertain to the administrative controls governing the selection and use of fasteners in maintenance work; and

4. No evidence exists that the structural integrity of any safety systems has been compromised by this event.

The following actions have been taken to prevent recurrence of this event and to ensure that mechanical fasteners used in maintenance activities conform to applicable ASME and ASTM requirements:

1. Maintenance planners have been instructed to clearly identify the applicable code class on each maintenance order and to specifically identify any spare parts that may be needed to complete the job. Fasteners are specified by grade and mechanics have been instructed to check fasteners for proper grade markings prior to use.

2. A color-coded set of P&ID's were developed showing ASME Section XI Class 1, 2, and 3 system boundaries. These P&ID's are used by the maintenance planners to confirm the applicability of code requirements on each job. This will ensure that ASME repair and replacement program requirements are properly applied to maintenance work.

3. An approved repair and replacement program complying with ASME Section XI, Addenda through Summer 1983, has been implemented. Appropriate engineering, maintenance and quality assurance personnel have been trained on the program.

4. All A-563 nuts were removed from the "free-stock" supply area in the plant and returned to the Calvert Cliffs warehouse. This will eliminate the possibility of further errors in the use of A-563 material.

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	PAGE (3)
Calvert Cliffs, Unit 1	0 5 0 0 0 3 1 7	8 7	— 0 0 9	— 0 2	0 8 OF 0 8

TEXT (If more space is required, use additional NRC Form 366A's) (17)

The actions described above provide reasonable assurance that material quality and traceability standards applicable to fasteners will be maintained in current and future maintenance activities at Calvert Cliffs. Additional actions will be implemented during 1988 that will greatly simplify and improve control over fastener procurement, storage, and use. These measures will further reduce the potential for error, and will reduce overall costs. They include the development of a standardized fastener program which substantially consolidates the Calvert Cliffs fastener inventory both in terms of quality level and material grade; performing a review of all mechanical procurement specifications to identify original construction code requirements with the objective of extending the benefits of lessons learned from this event to other mechanical components besides fasteners; consolidating all mechanical maintenance and spare parts related information within a comprehensive computer database for use by maintenance planners and engineering personnel; and improving our spare parts inventory database to clearly identify the code class for which parts are qualified.

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CHARLES CENTER • P.O. BOX 1475 • BALTIMORE, MARYLAND 21203

NUCLEAR OPERATIONS DEPARTMENT
CALVERT CLIFFS NUCLEAR POWER PLANT
LUSBY MARYLAND 20657

February 3, 1988

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Docket No. 50-318
License No. DPR 69

Dear Sirs:

The attached revision to LER 87-09 is being forwarded to you for your information.

Should you have any questions regarding this report, we would be pleased to discuss them with you.

Very truly yours,

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FRANKLIN RESEARCH CENTER

DIVISION OF ARVIN/CALSPAN

ANALYSES OF SA-193 AND SA-325 FASTENERS

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1. INTRODUCTION

The Franklin Research Center (FRC) conducted a series of analyses in order to characterize a group of high strength studs and bolts that were representative of stock in supply bins in nuclear power plants. In particular, it was of interest to determine if the bolts met the specifications required by their markings. This investigation was undertaken as a direct result of a recent Industrial Fasteners Institute research report [1] which cited extensive evidence of false markings on Grade 8 bolts.

Three different grades or classes of bolts and stud fasteners were submitted to FRC by NRC Region I personnel. Table 1 lists these fasteners in groups in accordance with imprinted markings and by numbers assigned by the NRC. The markings on eight fasteners indicated they complied with ASME SA-193,B7 [2] requirements, four to ASME SA-325 [3], Type 1, and one to ASME SA-193,B8 [2].

As discussed below, samples from each of these fasteners were subjected to chemical, hardness, macroscopic, and microscopic analyses to check for compliance with the relevant specification as well as to characterize the uniformity and general quality of each fastener.

Table 1. Bolt Identification

Sample	Size	Spec	Grade
1A Stud	5/8x4	SA193	B7
5A Bolt	1/2x4	"	"
6A Stud	1/2x4 1/2	"	"
7A Bolt	5/8x3 3/4	"	"
9A Bolt	3/8x3	"	"
10A Stud	3/8x4 1/2	"	"
12A Bolt	5/8x4	"	"
13A Bolt	1/2x2 3/4	"	"
2A Bolt	5/8x4	SA325	1
4A Bolt	1/2x3/8	"	"
8A Bolt	7/8x2 1/2	"	"
11A Bolt	7/8x2 1/2	"	"
3A Bolt	5/8x3 1/2	SA193	B8

2. ANALYSES AND DISCUSSION

2.1 CHEMICAL ANALYSES

The results of the chemical analyses, along with the specified chemistries, are presented in Table 2. For the SA-193,B7 fasteners, it is evident that, with the exception of a slightly low carbon content for bolt 5A and a high molybdenum content for bolt 7A, all the chemistries were within the limits of the specifications. The deviations for 5A and 7A would not be expected to compromise their service performance.

Although bolts 2A, 4A, 8A, and 11A contained boron, they nevertheless were correctly marked as Type 1, based on their carbon contents. While boron is required in Type 2 fasteners, it is neither required nor forbidden in Type 1.

Finally, bolt 3A's chemistry complied with the SA-193,B8 specification.

The mismarking of Grade 8 bolts reported in Reference 1 primarily involved the substitution of plain carbon, boron steels, which should have been marked as Grade 8.2 under SAE J429k [4], for medium carbon alloy steels. For the fasteners tested by FRC, a comparable situation would be an SA-193,B7 marking on an SA-325 material bolt or stud. From the data in Table 1, it is clear that there was no such mismarking on the samples studied.

2.2 HARDNESS TESTING

Hardness testing was carried out on the as-received outside diameter (OD) surface of the shank of each bolt, on a finely ground transverse cross section of each fastener, and on a metallographically prepared longitudinal cross section of each fastener. In the latter case, micro- as well as macrohardness testing was conducted to obtain data nearer to the OD surface, i.e., near the threads. The averaged results of these tests are given in Table 3, along with specified hardnesses. In addition, the approximate tensile strength of each bolt, based on the average hardness data, is tabulated along with the specified tensile strength requirements.

With the exception of some low readings on the as-received OD surfaces (likely reflecting the inherent errors in testing on a curved, rough surface), all hardnesses (and hence, the approximate tensile strengths) for the

Table 2. Chemical Data for Bolt Evaluation

			Chemistry								
Sample	Spec	Grade	C	Mn	P	S	Si	Cr	Mo	Ni	B
	SA193	B7	0.37/ 0.49	0.65/ 1.10	0.035 Max.	0.040 Max.	0.15/ 0.35	0.75/ 1.20	0.15/ 0.25	-	
1A Stud			0.40	0.92	0.014	0.017	0.25	1.04	0.16		
5A Stud			0.35	0.91	0.018	0.013	0.33	0.98	0.16		
6A Stud			0.42	0.97	0.010	0.015	0.27	1.00	0.17		
7A Bolt			0.42	0.62	0.019	0.013	0.26	0.93	0.54		
9A Bolt			0.39	0.91	0.021	0.018	0.25	1.00	0.15		
10A Stud			0.43	0.97	0.022	0.014	0.30	0.91	0.17		
12A Bolt			0.43	0.83	0.018	0.018	0.28	1.05	0.18		
13A Bolt			0.40	0.90	0.024	0.013	0.27	0.91	0.16		
	SA325	1	0.27 Min.	0.47 Min.	0.048 Max.	0.058 Max.	-	-	-	-	
	SA325(1)	2	0.13/ 0.37	0.67 Min.	0.048 Max.	0.058 Max.	-	-	-	-	0.0005 Min.
2A Bolt			0.42	0.71	0.010	0.021					0.002
4A Bolt			0.37	0.71	0.017	0.012					0.002
8A Bolt			0.34	1.00	0.17	0.026					0.001
11A Bolt			0.40	0.78	0.018	0.020					0.001
	SA193	B8	0.08 Max.	2.00 Max.	0.045 Max.	0.030 Max.	1.00 Max.	18.0/ 20.0	-	8.0/ 10.50	-
3A Bolt			0.06	0.99	0.03	0.013	0.64	18.48		10.0	

1. Although the bolts in this group were marked as Type 1, the chemical requirements for Type 2 are included because boron, which is not defined in Type 1 requirements, was present in the bolts.

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Table 3. Hardness Data for Bolt Evaluation

Sample	Spec	Grade	Macrohardness: Surface(1)	Macrohardness: Edge(2)	Macrohardness: Mid(2) Radius	Macrohardness: Center(2)	Macrohardness: Center(3)	Microhardness(4): Center(3)	Microhardness(4): Near(3) Threads	Tensile Strength(5) (ksi)
	SA193	B7	$26R_C$ Min. (based on 125 ksi Tensile Min.)							125 Min.
1A Stud			-	$29R_C$	$30R_C$	$29R_C$	$26R_C$	$23R_C$	28	132
5A Bolt			$27R_C$	33	32	31	31		31	142
6A Stud			-	32	28	31	28		30	136
7A Bolt			26	31	29	30	28		30	136
9A Bolt			28	30	30	30	27		29	136
10A Stud			-	29	29	30	27		26	132
12A Bolt			26				32		31	142
13A Bolt			24				30		32	136
	SA325	1	$24\text{-}35R_C$							120 Min.
	SA325	2(7)	$24\text{-}35R_C$							120 Min.
2A Bolt			27	32	33	32	32	30	29	142
4A Bolt			18	27	23	22	21	19	29	118
8A Bolt			28	32	33	31	30		30	142
11A Bolt			20	31	30	29	26		35	136
	SA193	B8	Class 1: $96R_B$ Max.(6) ($82R_B$ Min. based on 75 ksi Tensile Min.) Class 2(8): $35R_C$ Max. ($27R_C$ Min. based on 125 ksi Min.)							75 Min. 125 Min.
3A Bolt			$85R_B$	$18R_C$	$19R_C$	$19R_C$	$100R_B$	37	35	106

1. Hardness measurements on the as-received outside surface of the shank.
2. Hardness measurements on transverse cross sections.
3. Hardness measurements on longitudinal cross sections.
4. R_C or R_B converted from Knoop readings.
5. Approximate tensile strength based on average hardness.
6. For size 3/4 inch diameter and smaller, a maximum of 100 R_B is permitted.
7. Type 2 specification requirement included per Note 1 in Table 2.
8. Specifications for Class 2 are included for comparison, since test hardness values were at the upper limit of Class 1 requirements.

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SA-193,B7 fasteners met or exceeded those required in the specifications. The low carbon in bolt 5A and the high molybdenum content in bolt 7A did not adversely affect the hardnesses of these bolts.

One of the SA-325 bolts, 4A, had slightly lower hardness (and hence, slightly lower approximate tensile strength) than required. Tensile testing would be required as a critical check on compliance, since actual tensile data takes precedence over hardness data in determining compliance, or lack thereof, with the specification.

The macrohardness of bolt 3A was at the maximum specified in SA-193,B8 Class 1, but was less than the requirement for Class 2. The microhardness readings were significantly higher than the macrohardness, likely because of the greater influence of the rapid work hardening characteristics of 18-8 type stainless steels on microhardness indentations than on macrohardness indentations.

2.3 MACROSCOPIC CHARACTERIZATION

The transverse cross sections of all fasteners except 12A and 13A, and longitudinal cross sections of heads and shanks of all of the bolts were macroetched to evaluate whether any gross inhomogeneities existed. Macrographs of the samples are presented in Figures 1 and 2, and a summary of the observations is included in Table 4.

The transverse cross sections exhibited macroscopically uniform etching characteristics. There was some pitting on a microscopic level, indicating carbon segregation and/or inclusion stringers. Macroetching of longitudinal bolt sections revealed desirable material flow lines in the heads of all bolts except 7A. This latter bolt head had clearly been machined, which leads to a bolt with lower resistance to bolt head failures than a bolt with an upset formed head. Nevertheless, since specifications SA-193 and SA-325 state material requirements, but not bolt or stud manufacturing processes, the machined bolt is not in conflict with the specification.

Also, as indicated in Table 4, the threads on all fasteners except 7A had been rolled. Again, although such machined threads are not in violation of SA-193, rolled threads are generally considered to be preferable for service performance, particularly in fastener sizes below 3/4 in diameter [4].

Table 4. Bolt Evaluation Data

Sample	Spec	Grade	Macroetching Longitudinal	Macroetching Transverse	Threads	Microstructure
	SA193	B7				
1A Stud			-	Uniform	Rolled	Gross carbon banding segregation
5A Bolt			Forged Head	Uniform	Rolled, Irregular	Uniform
6A Stud			-	Uniform	Rolled	Moderate carbon banding segregation
7A Bolt			Machined Head	Uniform	Machined, Rough	Pronounced carbon banding segregation
9A Bolt			Forged Head	Uniform	Rolled	Moderate carbon banding segregation
10A Stud			-	Uniform	Rolled	Uniform
12A Bolt			Forged Head	Uniform	Rolled	Minor carbon banding segregation
13A Bolt			Forged Head	Uniform	Rolled	Minor carbon banding segregation
	SA325	1				
2A Bolt			Forged Head	Uniform	Rolled	Uniform
4A Bolt			Forged Head	Uniform	Rolled	Mostly uniform, some grain boundary ferrite
8A Bolt			Forged Head	Uniform	Rolled	Uniform
11A Bolt			Forged Head	Uniform	Rolled	Uniform, minor amount of free ferrite
	SA193	B8				
3A Bolt			Forged Head	Uniform	Rolled	Annealed in center Cold drawn at OD, 1/4 to 3/8 in deep

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2.4 MICROSTRUCTURE

The expected microstructures for SA-193,B7 and SA-325 fasteners would be quenched and tempered martensite, whereas that for SA-193,B8 would be either carbide solution treated, i.e., annealed, for Class 1 or cold worked for Class 2. As can be seen from the data in Table 4 and the micrographs in Figures 3 through 16, the microstructure in all the samples except 3A (austenitic steel) was, indeed, quenched and tempered martensite. However, in some SA-193,B7 samples, the degree of carbon banding segregation was significant, with the worst case being bolt 1A (Figure 3), in which bands of free ferrite were present. Such a nonuniform microstructure is undesirable since low strength ferrite can be a crack intiation site, particularly under fatigue loading conditions. Accordingly, although the SA-193 specification does not define any limits on segregation or microstructural uniformity, it is reasonable to recommend that bolts with marked carbon segregation should be considered as questionable for use in critical applications, unless tensile and impact tests can demonstrate adequate anticipated service performance.

None of the fasteners exhibited excessive inclusions or decarburization of the threads which would compromise their service behavior.

The microstructure of bolt 3A, shown in Figures 15 and 16, was nonuniform from the OD to the center, in that the center was annealed and the outer periphery had been worked, most likely from thread rolling. This is consistent with SA-193 which states that "where practical, all threads shall be formed after heat treatment." Since the specification covers the material prior to thread rolling, the deformation can help explain why the hardness (see Section 2.2) was at the upper limit specified in SA-193,B8 for Class 1 material. Accordingly, the bolt is clearly within the Class 1 specification, assuming all the deformation had, indeed, been incurred during thread rolling. (Deformation of the stock material to strengthen it would have required that the B8 marking be underlined to identify the strain hardened material as Class 2, grade B8.)

3. CONCLUSIONS

Based upon the analyses conducted, the following conclusions can be stated:

1. None of the fasteners had been improperly marked with regard to classification.

2. The carbon content of bolt 5A was slightly lower and the molybdenum content of bolt 7A was higher than required by SA-193. These deviations should not adversely affect service behavior.

3. The hardness of bolt 4A was slightly below that specified by SA-325. Tensile testing would be required to determine whether such a bolt should have been rejected as being out of specification.

4. One bolt, 7A, had machined threads and head. Although this fabrication method does not violate the requirements imposed by the B7 marking, the bolt could be inferior in service performance (depending on the service conditions) to a bolt with upset head and rolled threads.

5. The microstructure on several B7 bolts exhibited undesirable carbon segregation, which can negatively affect service performance. Since such a characteristic is not specifically addressed in SA-193, compliance with the specification does not necessarily assure a high quality fastener.

4. REFERENCES

1. False Grade 8 Engineering Performance Marks on Bolting and Improper Marking of Grade 8 Units, Industrial Fastener Institute Research Report, April 4, 1986

2. SA-193: Specification for Alloy Steel and Stainless Steel Bolting Material for High-Temperature Service, American Society of Mechanical Engineers, 1986

3. SA-325: Specification for High Strength Bolts for Structural Steel Joints, American Society of Mechanical Engineers, 1986

4. SAE J429k: Standard Mechanical and Material Requirements for Externally Threaded Fasteners, Society of Automotive Engineers, 1980

Figure 1. Macrographs showing macroetched transverse cross sections of the fasteners. There were no pronounced inhomogeneities or defects. (Hardness indentations are evident on some samples.)

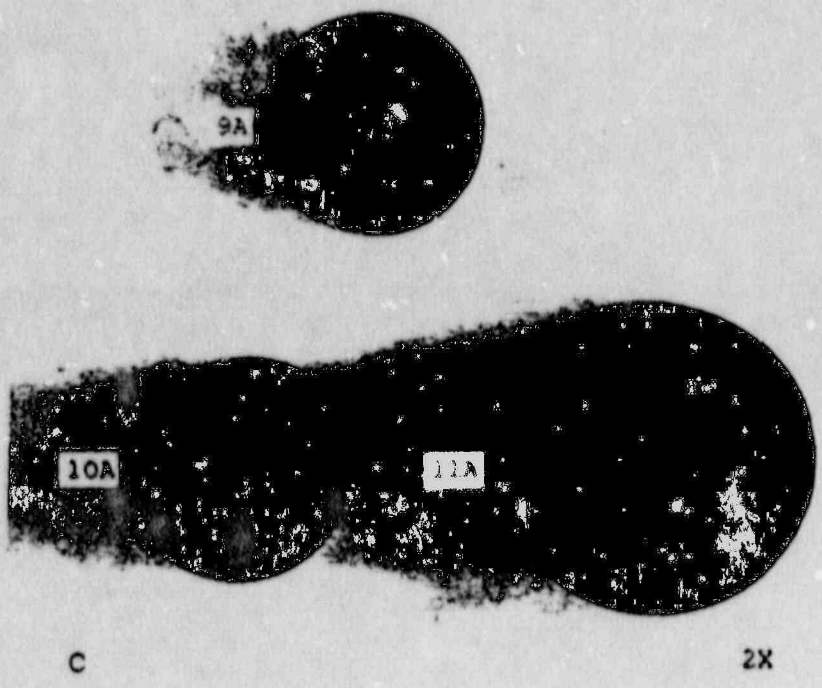


Figure 1. (Cont.)

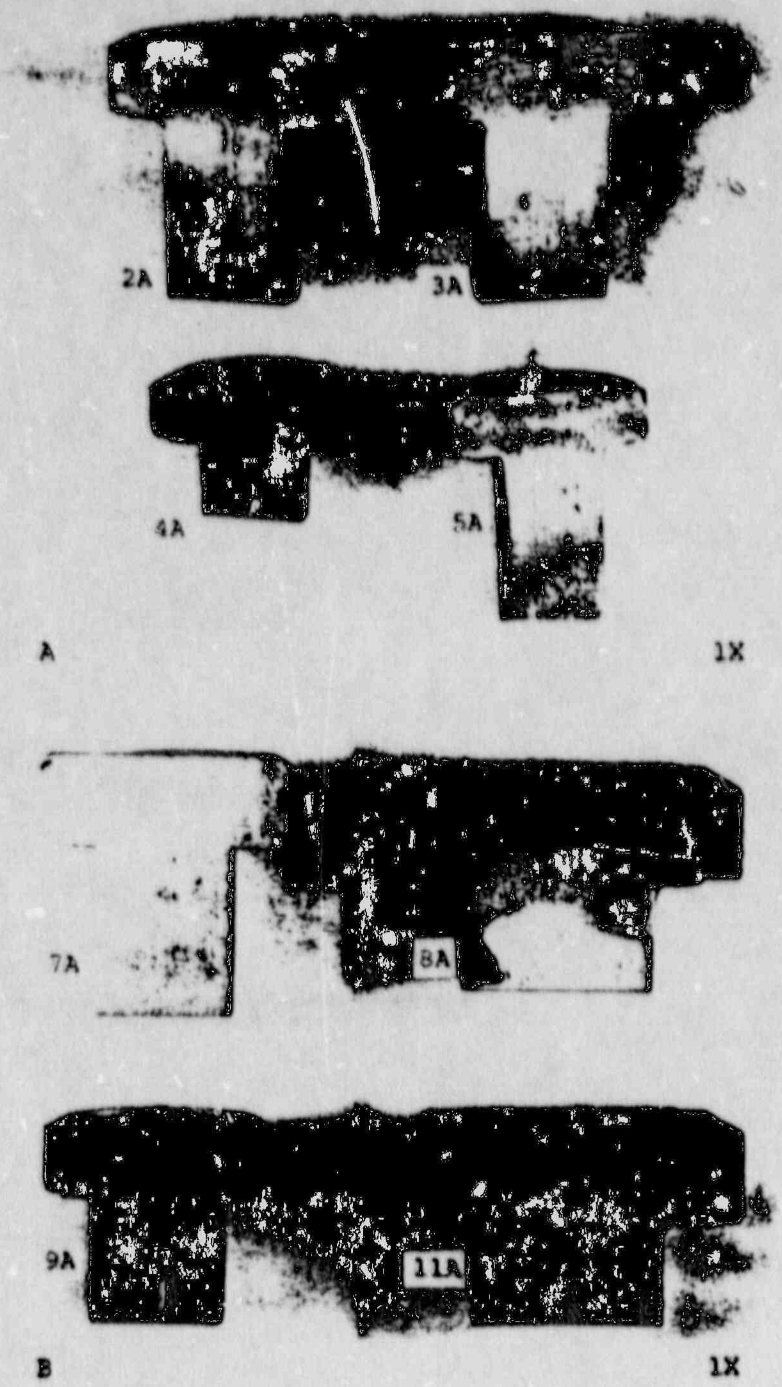
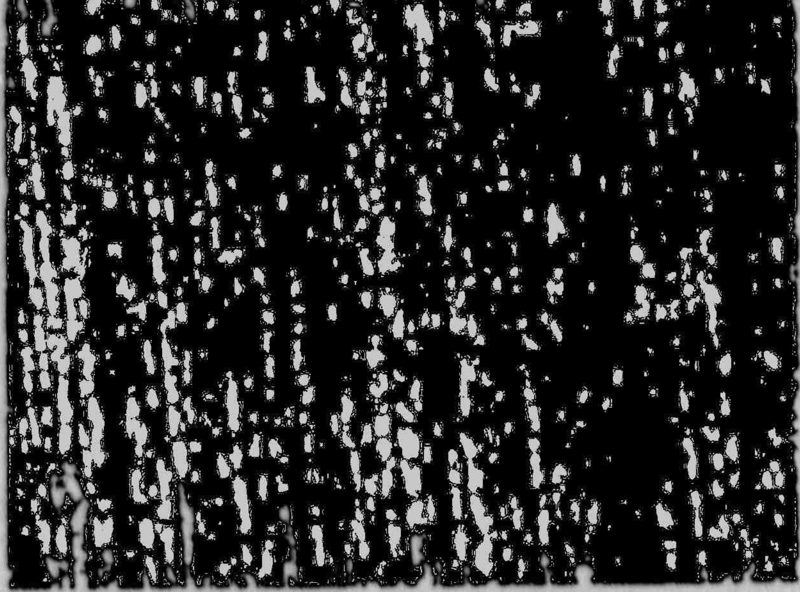


Figure 2. Macrographs showing macroetched longitudinal cross sections of the bolt samples. All bolts except 7A exhibited uniform flow lines from the upsetting process used to form the bolt head. Bolt 7A had been machined rather than forged.

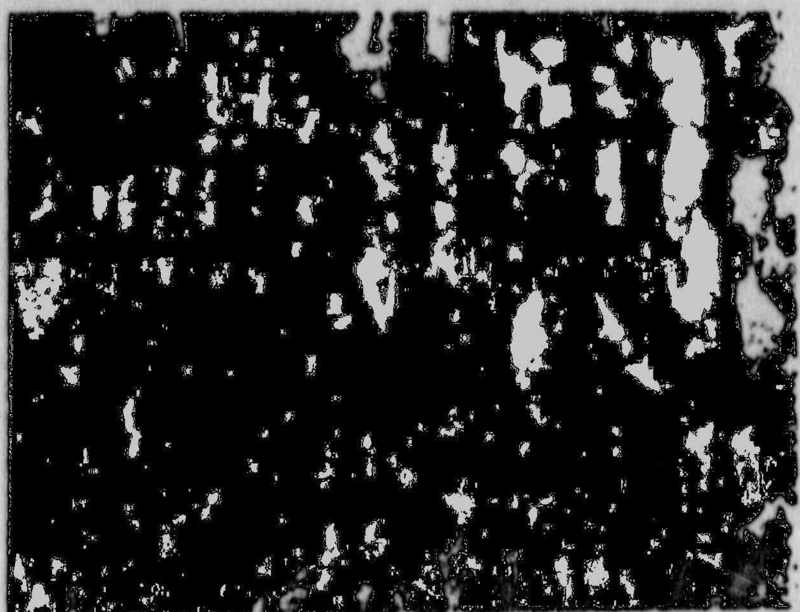
13A 12A

C 1X

Figure 2. (Cont.)

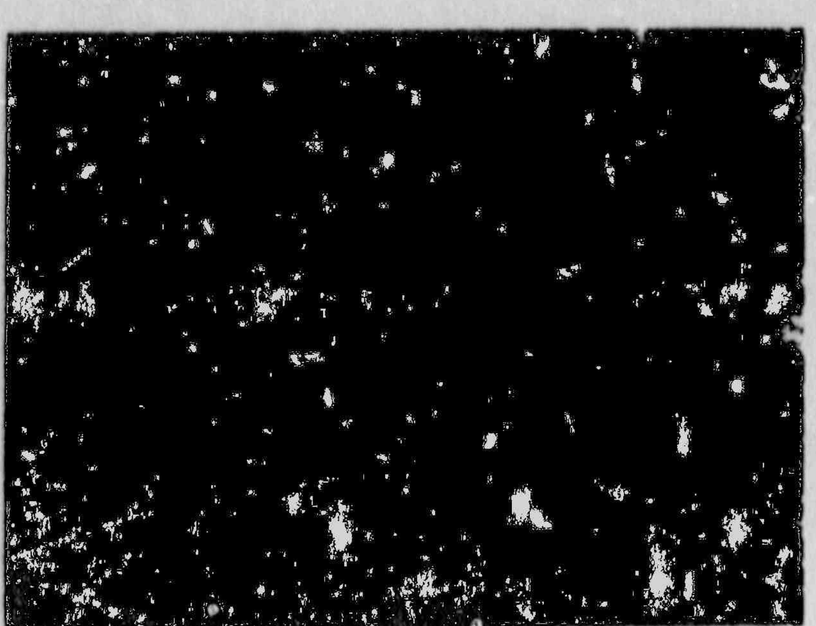


A. Stud ~~11A~~ 1A 12/12/86 100X



B. Stud ~~11A~~ 1A 12/12/86 500X

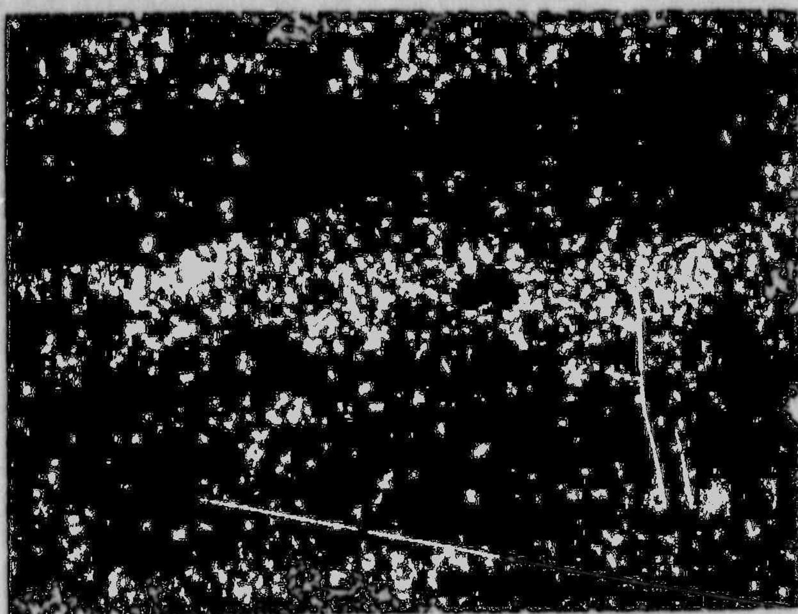
Figure 3. Micrographs showing a quenched and tempered microstructure with bands of high carbon and essentially free ferrite in a longitudinal cross section.



Bolt 5A 500X

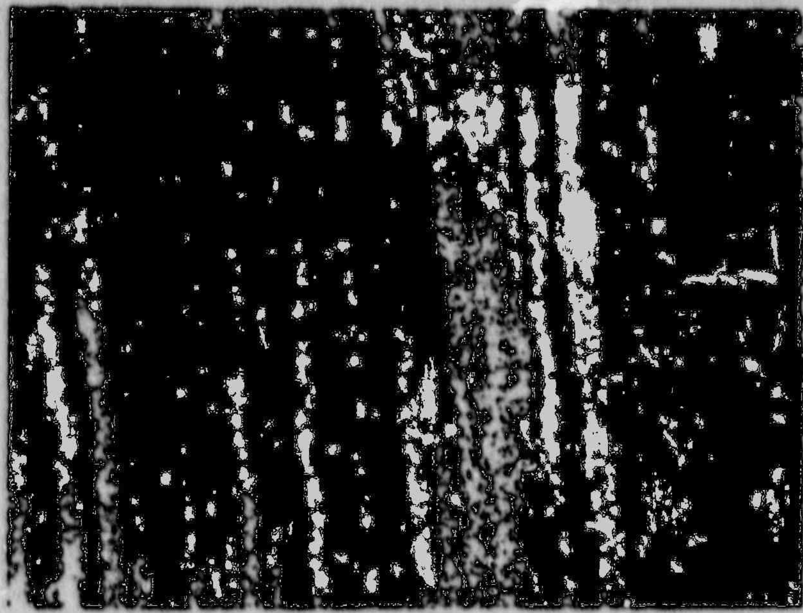
Figure 4. Micrograph showing a quenched and tempered microstructure with some minor carbon banding segregation in a longitudinal cross section.

A. Stud 6A 100X

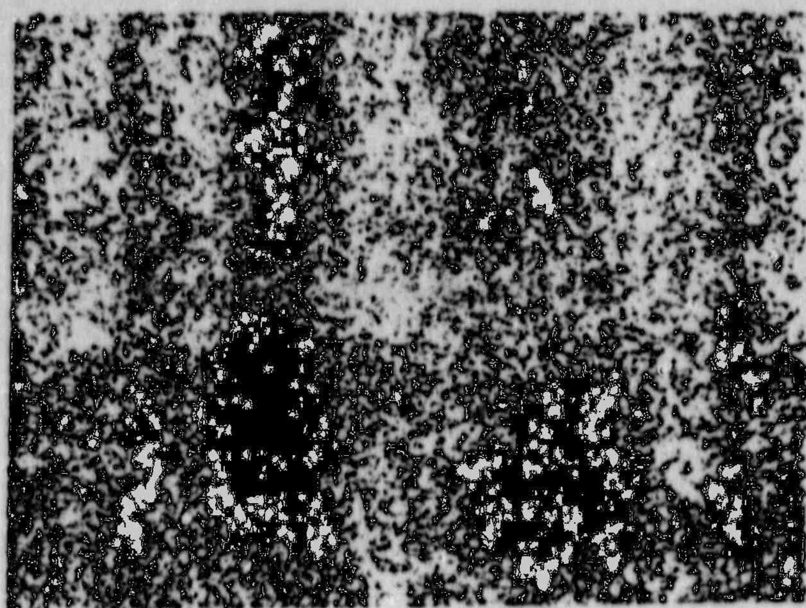


B. Stud 6A 500X

Figure 5. Micrographs showing a quenched and tempered microstructure with some carbon banding in a longitudinal cross section.

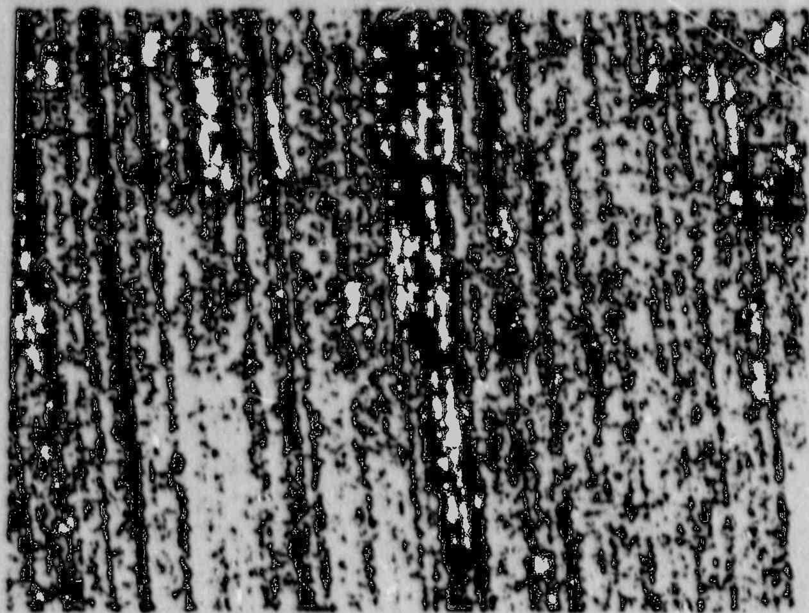


A. Bolt 7 100X

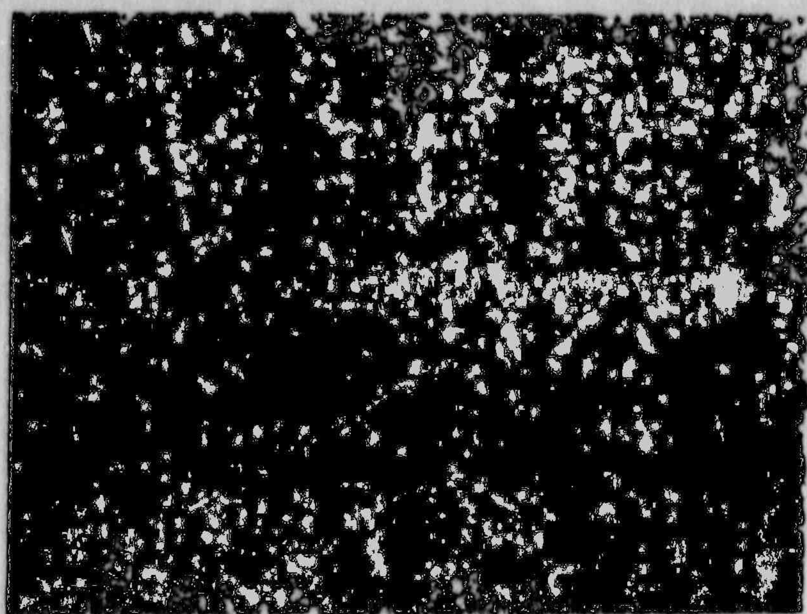


B. Bolt 7 500X

Figure 6. Micrographs showing a quenched and tempered microstructure with pronounced carbon banding segregation in a longitudinal cross section.

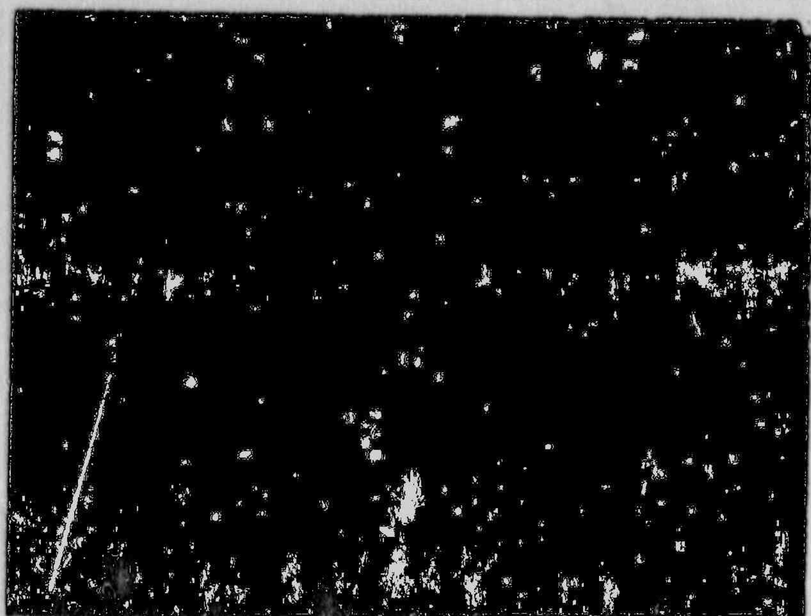


A. Bolt 9 100X



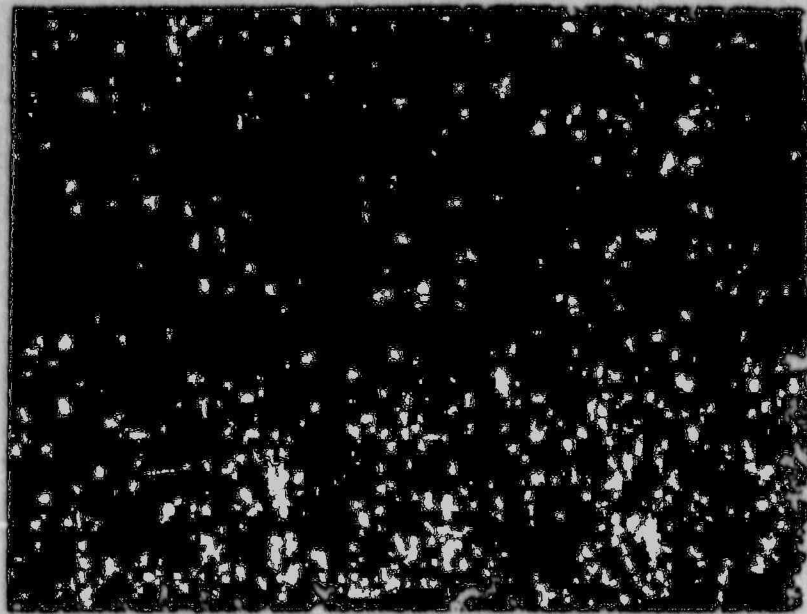
B. Bolt 9 500X

Figure 7. Micrographs showing a quenched and tempered microstructure with some minor carbon banding in a longitudinal cross section.

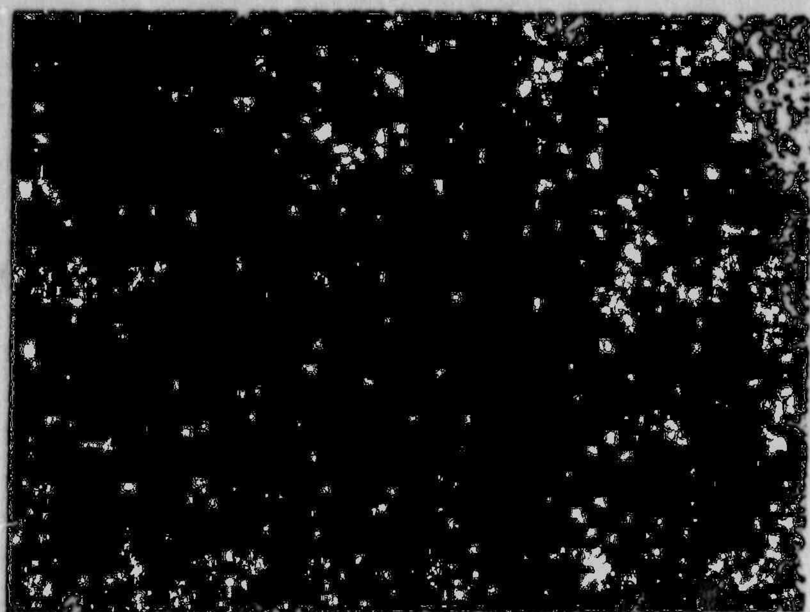


Stud 10A 500X

Figure 8. Micrograph showing a quenched and tempered microstructure with minor carbon banding segregation in a longitudinal cross section.

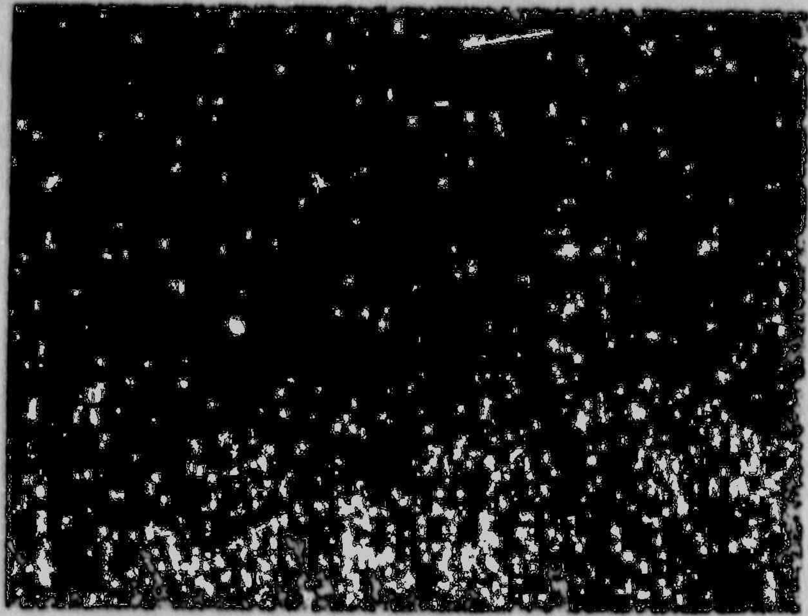


A. Bolt 12A 100X

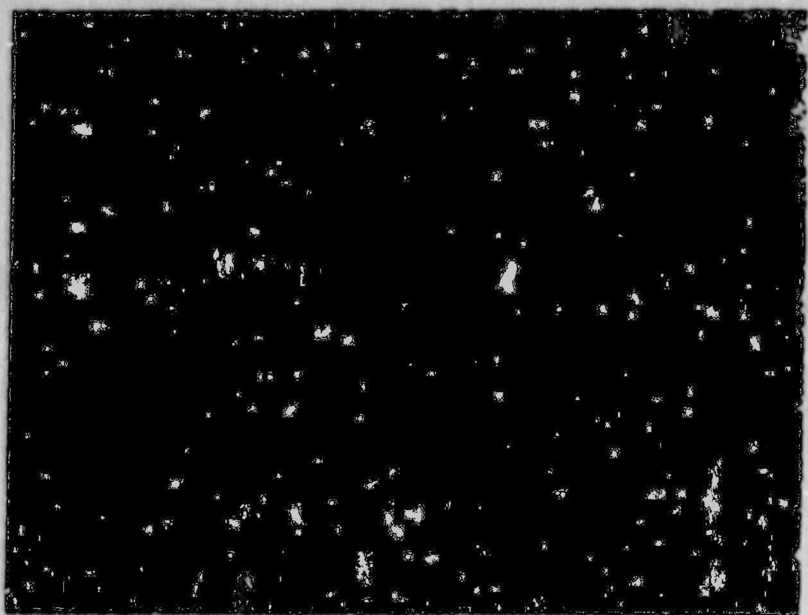


B. Bolt 12 500X

Figure 9. Micrographs showing a quenched and tempered microstructure with very little carbon segregation in a longitudinal cross section.

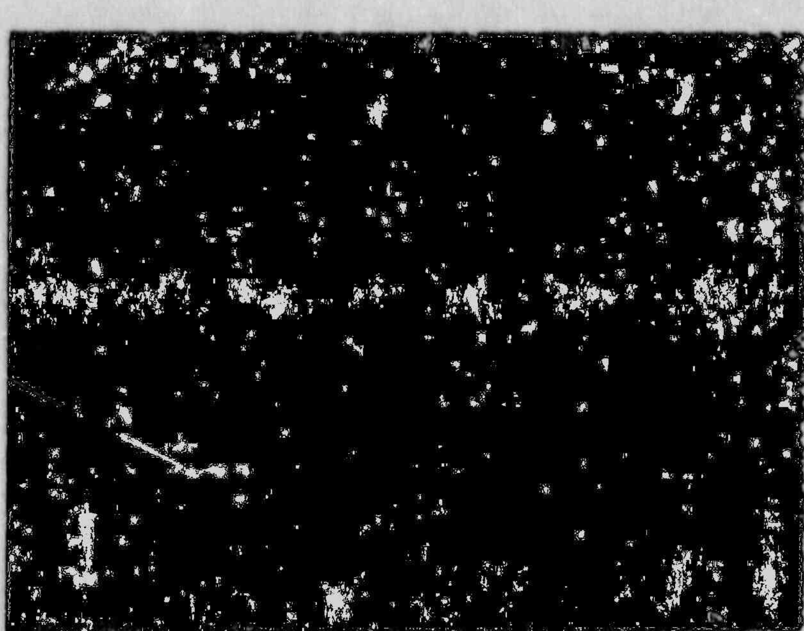


A. Bolt 13A 100X



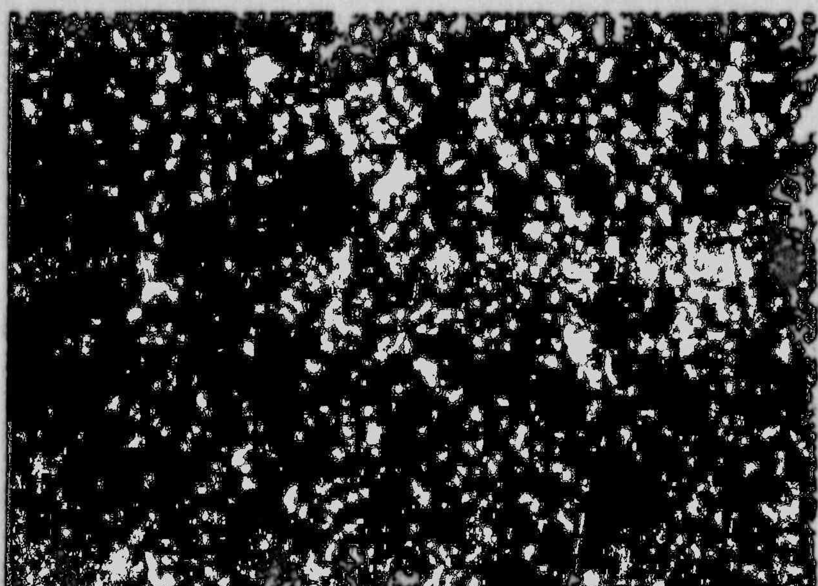
B. Bolt 13A 500X

Figure 10. Micrographs showing a quenched and tempered microstructure with very little carbon segregation in a longitudinal cross section.



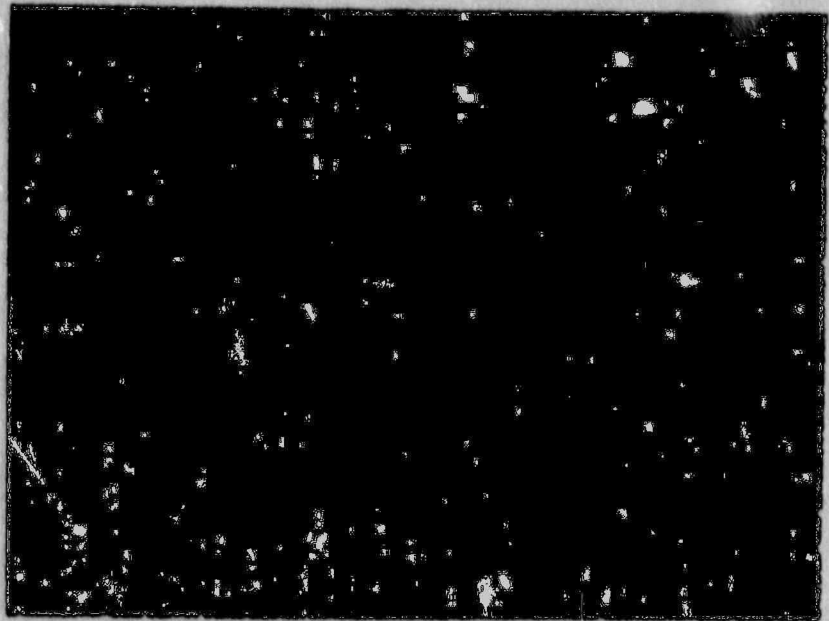
Bolt 2A 500X

Figure 11. Micrograph showing a uniform quenched and tempered microstructure in a longitudinal cross section.

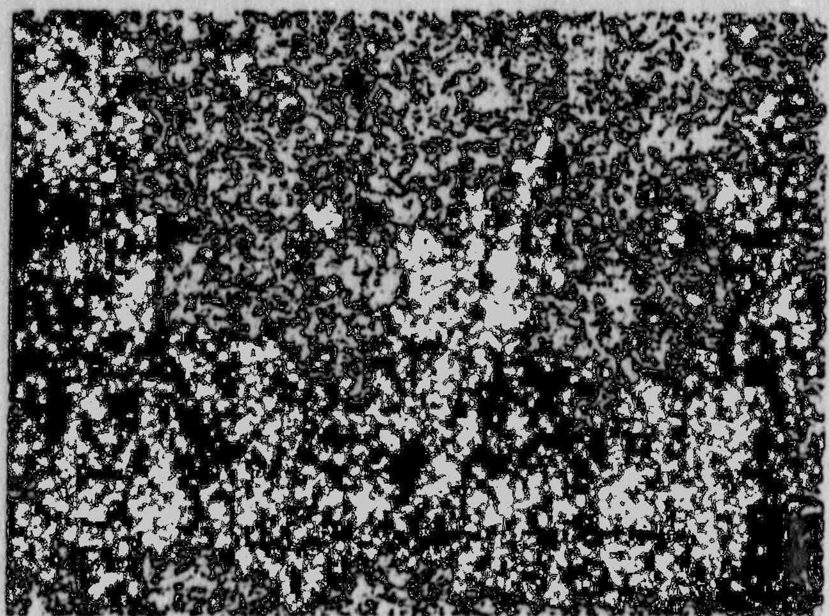


Bolt 4A 500X

Figure 12. Micrograph showing a quenched and tempered (or normalized and tempered) microstructure with a little grain boundary ferrite in a longitudinal cross section.

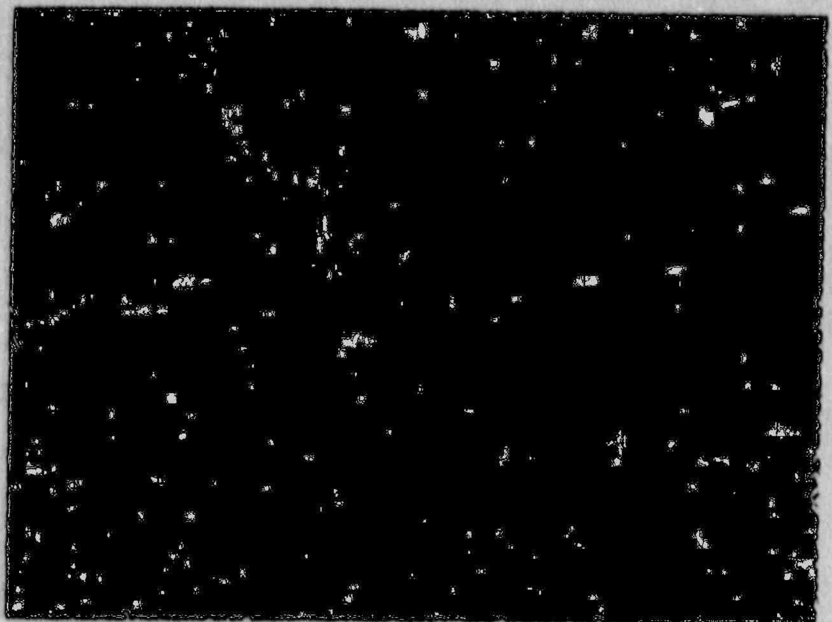


A. Bolt 8A 100X

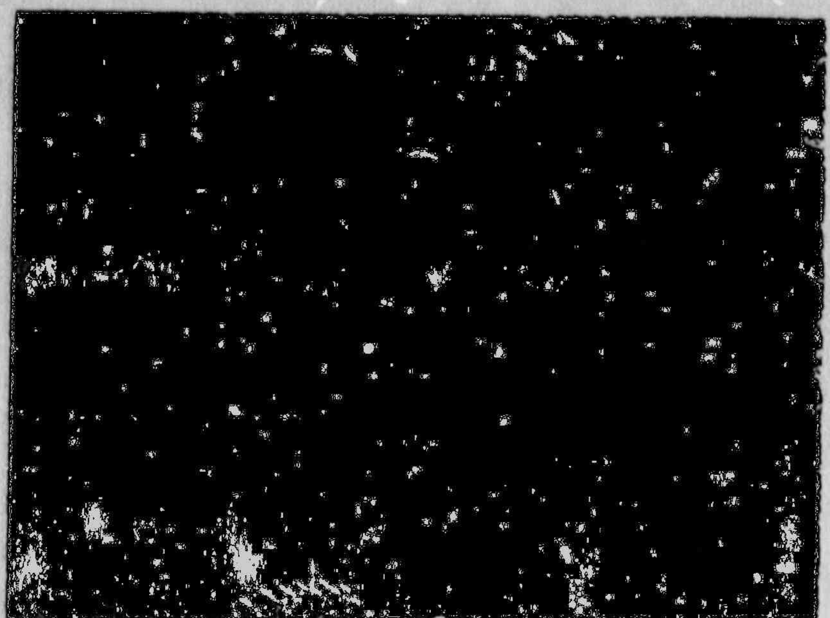


B. Bolt 8A 500X

Figure 13. Micrographs showing a quenched and tempered (or normalized and tempered) microstructure with a little grain boundary ferrite in a longitudinal cross section.

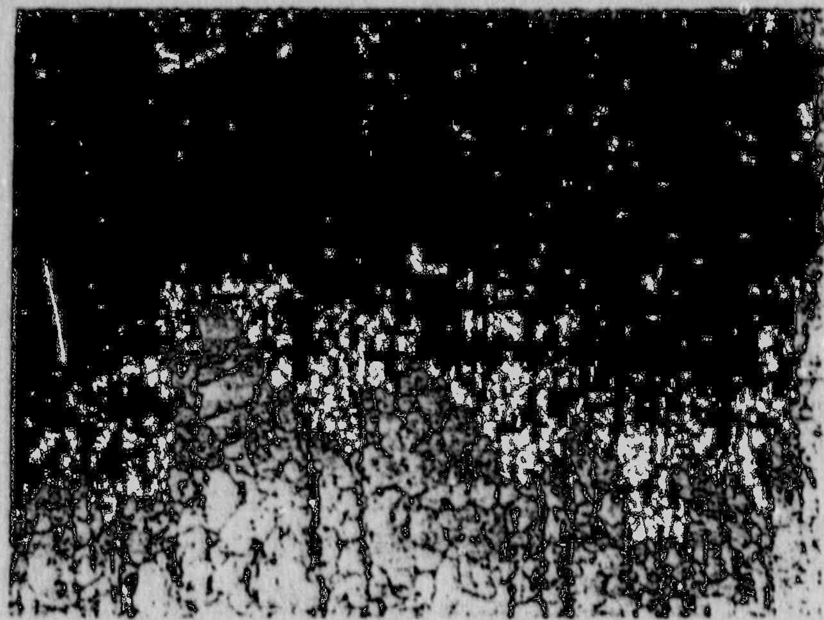


A. Bolt 11A 100X

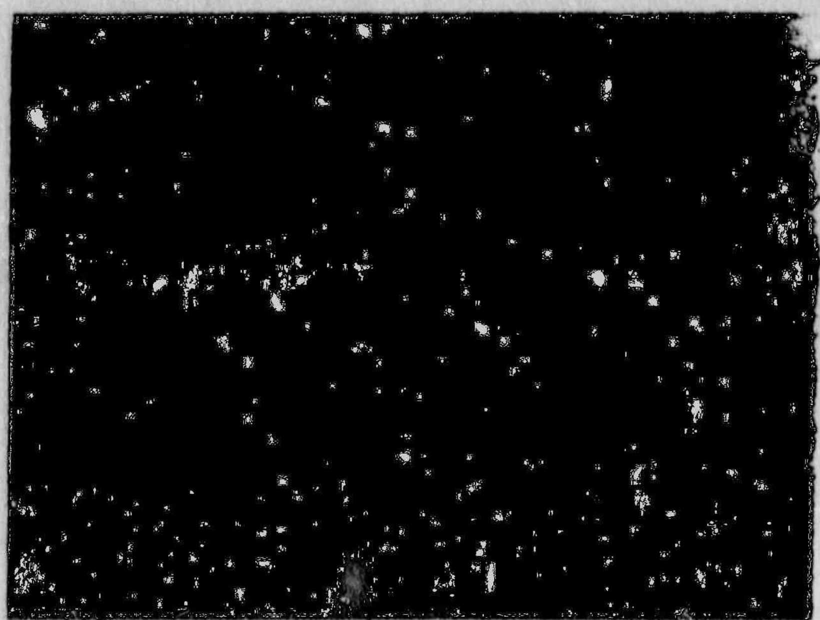


B. Bolt 11A 500X

Figure 14. Micrographs showing a quenched and tempered (or normalized and tempered) microstructure with some grain boundary ferrite in a longitudinal cross section.

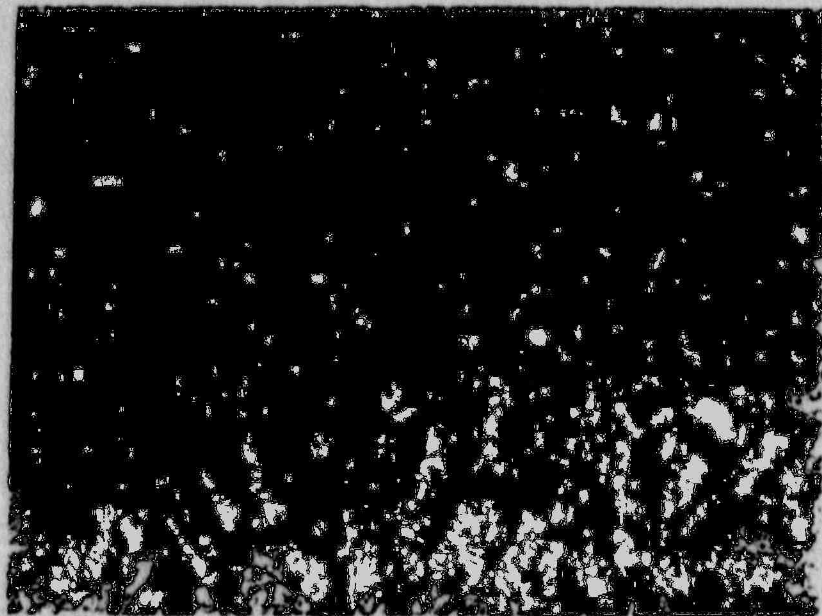


A. Bolt 3A, center 100X

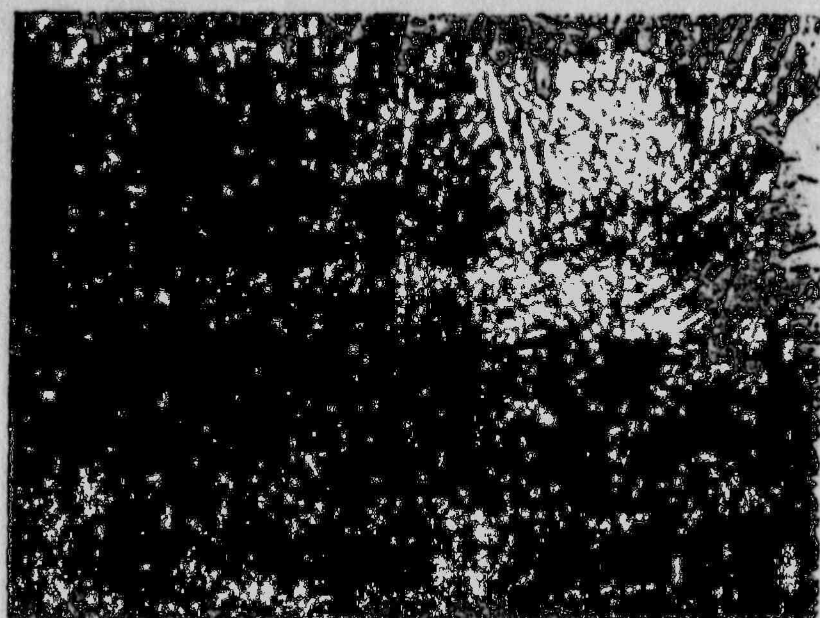


B. Bolt 3A, center 500X

Figure 15. Micrographs showing an annealed austenite microstructure in the center of a longitudinal cross section.



A. Bolt 3A, near OD 100X



B. Bolt 3A, near OD 500X

Figure 16. Micrographs showing a cold worked austenite microstructure near the OD of a longitudinal cross section.