

Examination of Fasteners
from the
Salem Nuclear Generating Station

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1. Introduction

Examination and testing of two stud bolts and four nuts were conducted at Brookhaven National Laboratory (BNL) for the U. S. Nuclear Regulatory Commission (NRC). These were carried out to confirm portions of a root cause analysis conducted by the NRC licensee at the Salem Nuclear Generating Station.

2. Tests and Results

Two stud bolts and four nuts were received at BNL accompanied by documentation (shown in Appendix A) which identified the stud bolts nuts as 7/8 x 5 1/2. The bolts and nuts appeared to be unused and fabricated from a non-magnetic steel. (See Figure 1.) Markings on the ends of the stud bolts and the nuts (shown in Figures 2a and 2b) are standard, identifying the material and manufacturer. B8 on the stud bolt shows that the material conforms to ASTM A193/A193M; the nuts' marking, 8B, connotes ASTM A194/A194M (Ref. 1). The "V" mark is the manufacturer's code marking.

Dimensional Characteristics

The dimensional characteristics of the stud bolts were determined according to System 21 and System 22, of ANSI/ASME B1.3M (Ref 2). For external threads, System 21 requires testing for GO maximum material, NOT GO functional diameter, and major diameter. System 22 is more restrictive, in that more parameters must be checked: GO maximum material, minimum material, major diameter, minor diameter, and root profile.

Various gages may be used and measuring instruments may be used for determining thread characteristics under ASME B1.3M. Under System 21, GO and NOT GO threaded ring gages, respectively, are generally used for the first two parameters, while an optical comparator can be used for the major diameter. Other types of snap gages, pitch micrometers, thread measuring wires, etc., are acceptable as described in the ASME standard.

GO and NOT GO gages are functional tests in which a bolt or threaded stud is threaded into the gage, which resembles a threaded nut. The GO gage, which determines that maximum material is not exceeded, is passed when the bolt of interest can be threaded through the gage and beyond. The NOT GO gage is passed when the bolt of interest can not be threaded into the gage for three turns. The NOT GO gage measures functional diameter.

The optical comparator magnifies and projects an image of the thread profile on a screen. Profile dimensions are checked using appropriate linear and angular scales on the instrument, and by use of overlay charts of thread profile, radius, or other parameters. Flank angles, thread crest, root radius, axial plane pitch, and other parameters of interest. Most commonly, major, minor, and pitch diameters are identified, then measured using table transverse readouts.

BNL Central Shops Division, as part of its support function, has an Inspection Group

which maintains the capability for System 21 and 22 characterization methods. Using these methods, the Inspection Group evaluated the stud bolts according to dimensional limits specified in ANSI/ ASME B1.1-1989 (Ref. 3) for 7/8-9 UNC-2A threads, and "accepted" them. (The inspection report is Appendix B.) The inspection report notes that the minor diameter was measured at 0.727 inches, and that the specified maximum minor diameter should be 0.7368 inches, according to the Machinery's Handbook (Ref. 4). The Handbook contains specifications from ANSI /ASME B1.1 dated 1966. The more recent specifications dated 1989 (Ref. 3), call for a maximum minor diameter of 0.7408. In either case, no minimum value is specified, so the threads meet specification as determined by System 21 and System 22.

Hardness Tests

For the hardness tests, a one inch section was removed from each stud bolt. Four measurements using the Rockwell A scale were obtained on the face of each bolt. Average values (see table below) corresponded to a Rockwell hardness of 90.5 on the B scale. The specification for ASTM A193 material in a Class B8 Class bolt is a maximum 96 on the Rockwell B hardness scale.

Stud Bolt	Rockwell A ^a	Rockwell B ^b
#1	55.75 ±	90.5
#2	55.75 ±	90.5

- a. Average of four measurements.
b. Conversion value.

Hardness test were also conducted on the four nuts. Three measurements on each bolt were averaged to obtain the Rockwell A values, which were then converted to the Rockwell B scale value shown. ASTM A193/194M specifies a hardness range for Grade 8 nuts of 60 to 105 on the Rockwell B hardness scale. These nuts meet this specification.

Nut	Rockwell A ^a	Rockwell B ^b
#1	62.5 ± 0.0	101.1
#2	61.0 ± 0.9	98.5
#3	60.7 ± 1.8	98.1
#4	61.5 ± 1.8	99.5

- a. Average of four measurements.
b. Conversion value.

Static Load Tests

Static load tests were initiated to monitor the load relaxation behavior of the stud bolts. A block of tool steel was machined to permit access for strain gage leads while maintaining flat surfaces for uniform contact with the nut faces, and nominal clearance for the stud bolts. (See Figure 3 for a schematic representation of the static load block..)

The nuts were installed without lubricant and tightened to a torque calculated to induce 50% yield stress in the stud bolt, as directed by the NRC Project monitor. The calculated torque, 121 ft-lbs, was applied using a calibrated torque wrench. The nuts were re-torqued after approximately 30 minutes, as described in an EPRI report on bolting practices (Ref. 5).

Prior to installation, two precision strain gages were bonded to each stud bolt, which had been machined at its midpoint to provide a flat surface for the strain gage. The machining was just sufficient to remove the threads, and the strain gages were aligned with the bolt axis. The gages (Micro-Measurements, Romulus, MI) were calibrated on installation to yield direct readout of microstrain (microinches/inch) on a digital strain indicator (Model V/E-20A, Vishay Measurements Group, Raleigh, NC). One of the pieces from the hardness tests was fitted with a gage to monitor and compensate for ambient temperature changes. Readings were taken daily for about two months, at which time, since there were no changes in the readings, the static load test was terminated. The raw strain data are tabulated in Appendix C, and the temperature compensated data are displayed in Figure 4.

Figure 4 indicates that the stud bolts, after an initial elongation, maintained a constant strain for the duration of the test.

3. Conclusions

Two 7/8-9 UNC x 5 1/2 stud bolts were tested for dimensional characteristics, hardness, and performance under static load. The bolts were found to be acceptable under both System 21 and System 22 gaging requirements. The bolts and the nuts met hardness criteria specified in ASTM 193/193M and ASTM 194/194M, respectively. The bolts maintained a constant elongation under a static load test for two months.

4. References

1. Industrial Fasteners Institute, Fastener Standards, Sixth Edition, Industrial Fasteners Institute (1988).
2. ANSI/ASME B1.3M-1992, "Screw Thread Gaging Systems for Dimensional Acceptability - Inch and Metric Screw Threads," American Society for Mechanical Engineers, New York, 1993.
3. ANSI/ASME B1.1-1989, "Unified Inch Screw Threads," American Society for Mechanical Engineers, New York, 1989.

4. E. Oberg, F. D. Jones, and H. L. Horton, Machinery's Handbook: A Reference for the Mechanical Engineer, Draftsman, Toolmaker, and Machinist, Industrial Press, Inc., New York (1979)/
5. J. Bickford and M. Loomis, "Good Bolting Practices, Vol. 1: Large Bolt Manual" EPRI-NP 5067, Electric Power Research Institute (1987).

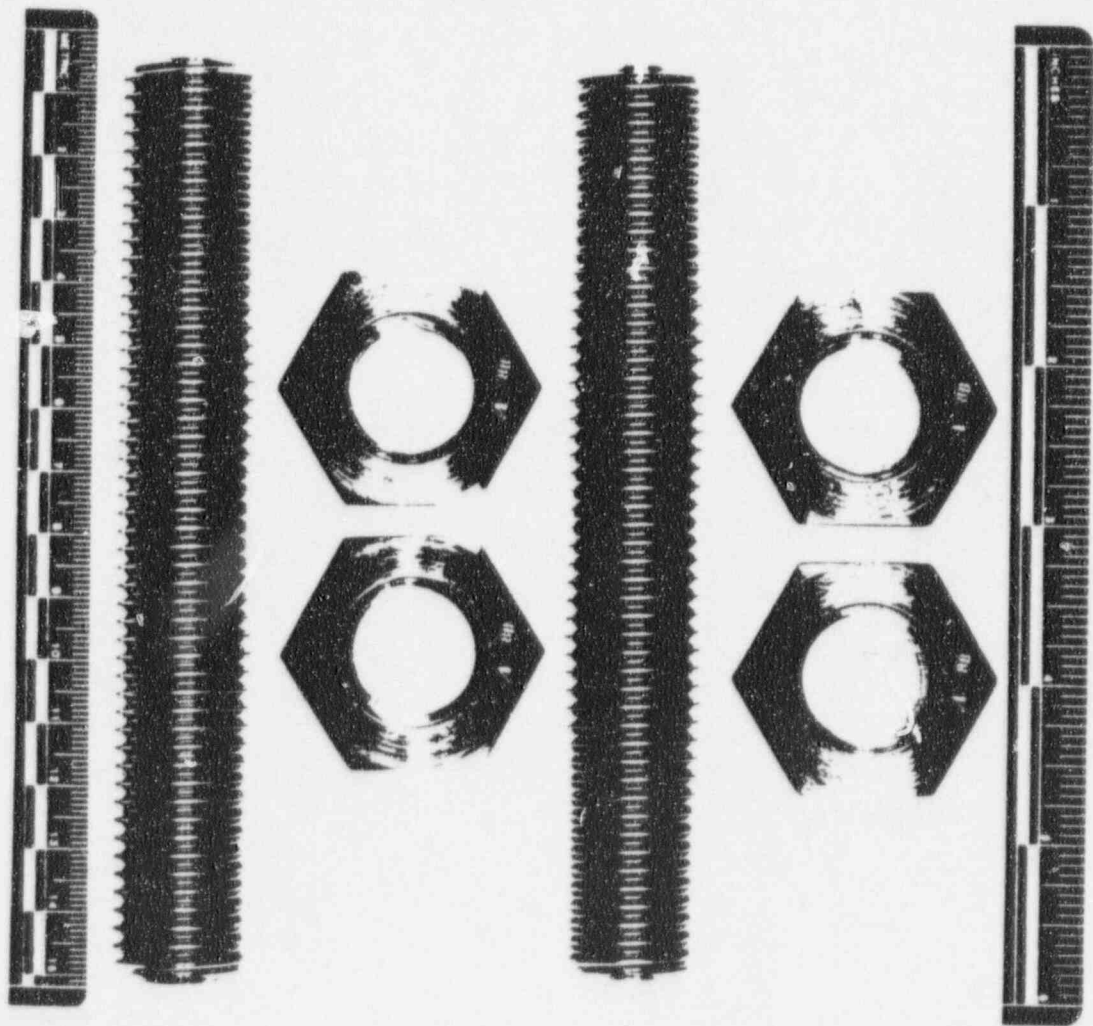


Figure 1. Stud Bolts and nuts as received from Salem.



Figure 2a. Marking on end of stud bolt.

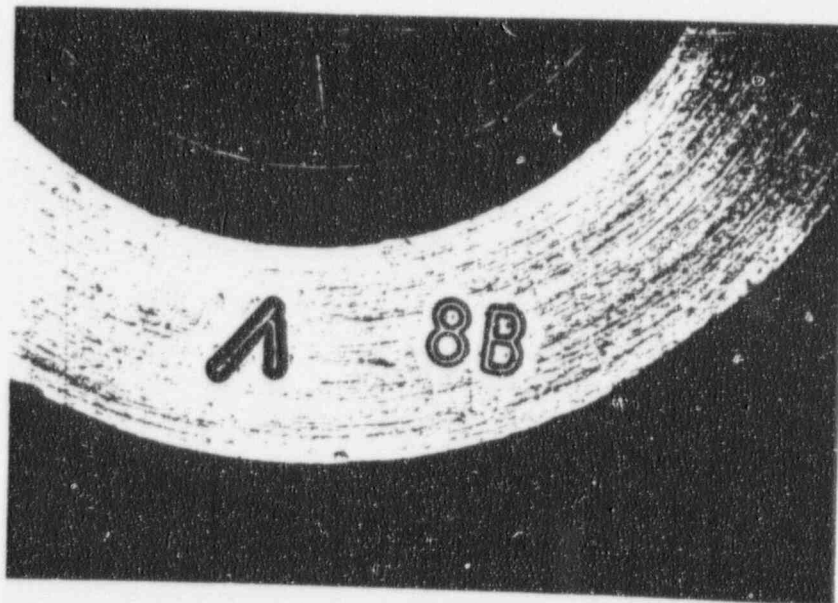


Figure 2b. Marking on nut contact surface.

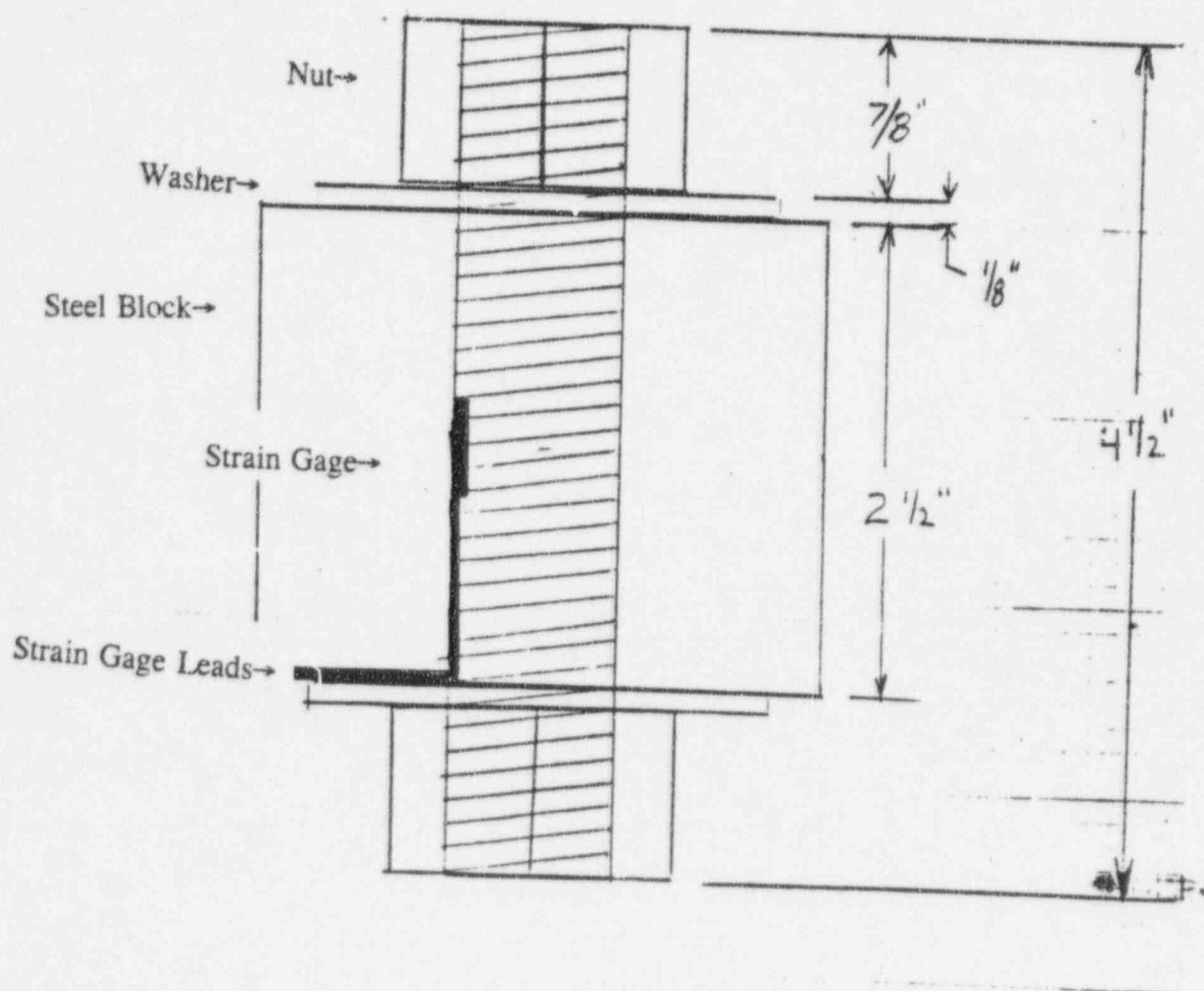


Figure 3. Schematic diagram of static load set-up.

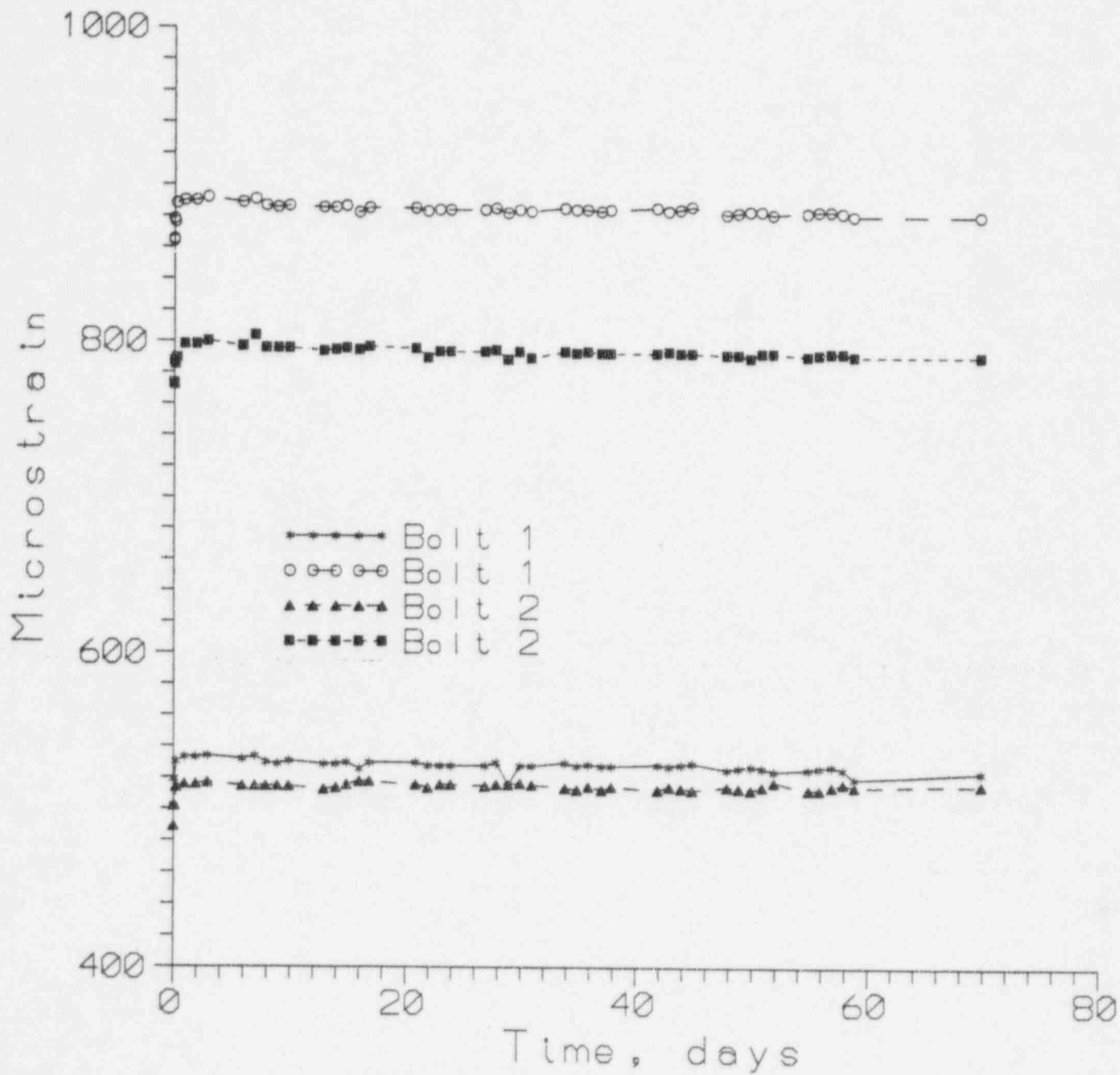


Figure 4. Plot of strain gage readings vs. time.

Appendix A

Documentation Received with Fasteners

[illegible]

Materials

MMIS ISSUE TICKET

TOTAL ISSUED VALUE

MAT FAC #

DATE ISSUED/RETURNED

0160846

MMIS WORK ORDER NO. ACTVY FAC ENV Q CLAIM

00940630110

01

SA

ENV Q

CLAIM

94.76

449

08/11/94

Date Printed:

08/11/94

CHECK ONLY ON

SHIFT FOREMAN

D

RECEIVING FACILITY

ISSUED BY

DATE ISSUED

TIME

AUTH
NUMBERACCOUNT
NUMBERRESP
CENTERWAREHOUSE
LOCATION
CODEPROG
PLAN
NUMBER

RECEIVED BY

DATE RECEIVED

TIME

BURKE

DAVID

E530020

0063

1614

100013



ISSUE



OVERDRAWN



SALVAGE

CHKD BY	DESCRIPTION		UNIT	MATERIAL CODE	QUANTITY ISSUED	QUANTITY RETURNED	TYPE	Work Pkg. Act.	Facility ID	Activity	Sub Act.	Special ID Code	Year Instl.
	Location	Prch						Job Distn		Account	Sub Accnt.		
	BOLT-STUD 7/8X5-1/2 01 AN 03 K1	1	EA	60 0492	2								
	MAT. ID: 00871400004001			MFGR: P/N:						QTY: 000002	MRR PO:		
	TRACE DATA :			TYPE: H NBR: 98312						TYPE: I NBR: 91			
	EXPIRE DATE :			TYPE: M NBR: PO: 363846						TYPE: Q NBR: 57353			
	NUT-HIEX 194-B 7/8-9 01 AN 06 H1	1	EA	60 0918	2								
	MAT. ID: 01647060072001			MFGR: 102A P/N: N/A						QTY: 000002	MRR PO:		
	TRACE DATA :			TYPE: A NBR: 3 NB NO. 582						TYPE: H NBR: DG160 TR# T4E			
	EXPIRE DATE :			TYPE: M NBR: PO: 0393066-0323						TYPE: Q NBR: 67476			

WORK ORDER DESCRIPTION

22CV252 / RETORQUED FLANGE / REPLACE GASKET

COMPONENT ID

52 22CV252

WORK ORDER ACTIVITY

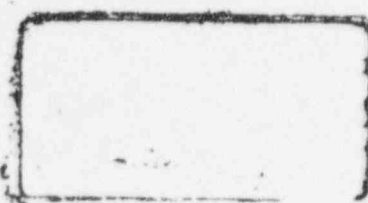
22CV252 / FLANGE RETORQUED / REPLACE GASKET

F. E. G.

0160846

Page # 1

Copy # 01



60 0492 UI: EA
DESC: BOLT-STUD 7/8X5-1/2
EXP : N/A
PART:
M PO: 363846
Q 57353
H 98312
I 91



MFR:

STORAGE LVL: C PM: N
SA



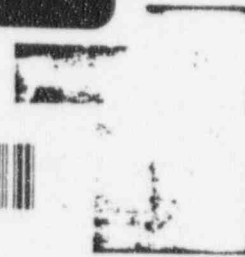
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PO: 0363846 0000 0004

PC: 1 SAFETY RELATED



PSEG



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EXP : N/A
PART: N/A
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Q 57478
A 3,NB,80,S82
H DG160 TR# T46
STORAGE LVL: C PM: N



MFR: 102A



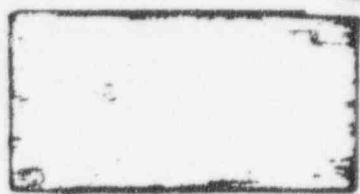
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PO: 0393066 0323 00/2

PC: 1 SAFETY RELATED



PSEG



Appendix B

BNL Central Shops Inspection Report

INSPECTION REPORT

Date	Acct. No.	I.L.R. No.	W.O. No.	P.O. No.	Insp. No.
10/31/92					4-492

DESCRIPTION

Threaded Studs	Drawing No.	No. Pieces
	718-9441C-A	2

VENDOR

EXPLANATION

INSPECTION REQUIRED

☐ Complete ☒ Partial ☐ In-Process as noted

INSPECTION FINDINGS

Note: 2 pcs inspected as per ASME B1.3.4-1992
Sizing systems 21 and 22.

System 21 inspected for 1.1, 1.2, 9 and 14 Thread
gages and measuring equipment Table 3 and Accepted.

System 22 inspected for 1.1, 2.5, 9 and 14
Thread gages and measuring equipment Table 3 and Accepted.
Note: Minor diameter (rounded root) is
.727. As per machinery's hand book minor
dia should be .7368.

NUMBER OF PIECES MEETING SPECIFICATIONS

NO. OF PIECES NOT MEETING SPECIFICATIONS

PAGE 1 OF 1 PAGES

Report Forwarded To

10/31/94
Date

B. B. B. Inspector

ORIGINATOR ACTION

EXPLANATION

- ☐ Accepted Pcs.
☐ Rejected Pcs.
☐ Partial acceptance as noted
☐ To be returned to vendor Pcs.
☐ To be reworked by BNL Pcs.
☐ Scrapped Pcs.

11/4/94
Date

[Signature]
Departmental Representative

CHECK DISPOSITION, SIGN, RETAIN YELLOW COPY AND RETURN
BALANCE OF REPORT TO INSPECTION AND QUALITY CONTROL,
BUILDING 462, TELEPHONE EXT. 3357

Appendix C

Strain Gage Data from Static Load Test

Date	Time	Temperature (°F)	Gage #1	Stud Gage #4	#1 Gage #5	Stud Gage #6	#2 Gage #7
4/20/95	900	72	-7	519	876	510	786
4/21/95	845	70	-8	512	873	507	783
5/2/95	908	73	-9	515	872	507	782

- a ZERC - set-up
- b 121 ft-lb torque
- c reading
- d 121 ft-lb re-torque

Date	Time	Temperature		Stud	#1	Stud	#2
		(°F)	Gage #1	Gage #4	Gage #5	Gage #6	Gage #7
3/17/95	950	69	-11	517	874	505	783
3/20/95	940	72	-13	515	872	502	781
3/21/95	820	72	-12	518	874	504	783
3/22/95	915	69	-10	506	873	506	779
3/23/95	940	72	-13	515	872	504	781
3/24/95	950	72	-13	515	871	503	777
3/27/95	906	71	-15	515	871	499	779
3/28/95	926	72	-13	515	872	500	780
3/29/95	852	72	-14	515	871	501	780
3/30/95	1247	73	-12	516	872	501	781
3/31/95	845	72	-11	517	874	504	782
4/4/95	849	71	-13	516	873	500	780
4/5/95	850	71	-14	514	870	501	780
4/6/95	900	71	-16	513	869	498	777
4/7/95	847	67	-14	516	873	499	779
4/10/95	900	73	-10	516	872	505	782
4/11/95	841	72	-12	515	871	502	780
4/12/95	858	69	-12	516	872	501	778
4/13/95	841	72	-7	520	877	508	786
4/14/95	842	72	-9	516	873	509	784
4/17/95	902	72	-12	514	871	501	779
4/18/95	836	72	-11	516	873	502	781
4/19/95	858	69	-10	518	874	505	783

Date	Time	Temperature		Stud	#1	Stud	#2
		(°F)	Gage #1	Gage #4	Gage #5	Gage #6	Gage #7
2/21/95 ^a	1040	81	0	0	0	0	0
2/21/95 ^b	1047	81	0	502	865	489	773
2/21/95 ^c	1117	81	-3	498	861	486	769
2/21/95 ^d	1117	81	-3	516	875	499	784
2/21/95	1315	83	-3	516	873	499	782
2/21/95	1610	67	-15	515	873	499	774
2/22/95	900	70	-17	516	873	499	781
2/23/95	900	72	-18	515	872	498	780
2/24/95	845	71	-16	518	876	501	784
2/27/95	852	71	-19	513	870	496	778
2/28/95	1011	68	-17	517	874	498	787
3/1/95	841	73	-13	517	874	502	783
3/2/95	911	72	-15	514	871	500	781
3/3/95	856	71	-17	514	870	498	779
3/6/95	855	73	-13	516	873	500	781
3/7/95	1018	73	-13	516	873	501	782
3/8/95	906	73	-11	519	876	505	785
3/9/95	1139	70	-11	515	872	507	784
3/10/95	846	70	-18	512	868	500	779
3/14/95	830	71	-13	517	873	503	783
3/15/95	1000	70	-11	517	873	503	779
3/16/95	1050	72	-11	517	874	505	783

Date	Time	Temperature		Stud	#1	Stud	#2
		(°F)	Gage #1	Gage #4	Gage #5	Gage #6	Gage #7
2/21/95 ^a	1040	81	0	0	0	0	0
2/21/95 ^b	1047	81	0	502	865	489	773
2/21/95 ^c	1117	81	-3	498	861	486	769
2/21/95 ^d	1117	81	-3	516	875	499	784
2/21/95	1315	83	-3	516	873	499	782
2/21/95	1610	67	-15	515	873	499	774
2/22/95	900	70	-17	516	873	499	781
2/23/95	900	72	-18	515	872	498	780
2/24/95	845	71	-16	518	876	501	784
2/27/95	852	71	-19	513	870	496	773
2/28/95	1011	68	-17	517	874	498	787
3/1/95	841	73	-13	517	874	502	783
3/2/95	911	72	-15	514	871	500	781
3/3/95	856	71	-17	514	870	498	779
3/6/95	855	73	-13	516	873	500	781
3/7/95	1018	73	-13	516	873	501	782
3/8/95	906	73	-11	519	876	505	785
3/9/95	1139	70	-11	515	872	507	784
3/10/95	846	70	-18	512	868	500	779
3/14/95	830	71	-13	517	873	503	783
3/15/95	1000	70	-11	517	873	503	779
3/16/95	1050	72	-11	517	874	505	783