(11)

THIS LETTER SATISFIES COMMITMENT NO. ________

THIS LETTER (DOES) (DOES NOT) ESTABLISH A NEW COMMITMENT

WPPSS CORRESPONDENCE NO. G03-81-2756

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CE LOVE-WO/A
DD O'SULLIVAN/270-W/A
PG PECK-WO/A
JA PUZAUSKAS-WO/A
CL QUAMME-WO/A
JP SLUKA-WO/A
CE TRAPP-WO/A
JE WERLE-WO/A

November 17, 1981
G03-81-2756

U. S. Nuclear Regulatory Commission, Region V
Office of Inspection and Enforcement
1450 Maria Lane, Suite 210
Walnut Creek, California 94596-5368

Attention: Mr. B. H. Faulkenberry
Chief, Reactor Construction Projects Branch

Gentlemen:

Subject: PROJECT NOS. 3 AND 5
DOCKET NUMBERS 50-508 AND 50-509
FINAL REPORT OF POTENTIAL 10CFR50.55(e)
STRUCTURAL STEEL CONNECTIONS-UNIT NO. 5 (D/N #019)

References: 1) Letter, G03-81-1027, R. S. Leddick to B. H. Faulkenberry, dated May 7, 1981.
2) Letter, G03-81-2370, R. S. Leddick to B. H. Faulkenberry, dated August 14, 1981.

On January 28, 1981, your office was provided with notification of a condition potentially reportable in accordance with the requirements of 10CFR50.55(e). The problem concerned erection of structural steel and associated documentation for both Units 3 and 5. Interim reports were submitted on May 7, 1981 and August 14, 1981 by references 1 and 2 respectively.

Attached is the final report for Unit 5 only. It summarizes the problem, details corrective/preventive actions taken and provides an evaluation of the nonconforming conditions. Presently, Morrison-Knudsen is preparing a statistical analysis report for Unit 3. The final report for Unit 3 will be provided to your office by January 8, 1982.

Should you have any questions or desire further information, please contact me directly.

Very truly yours,

R. S. Leddick
Program Director, WNP-3/5

cc: J. Adams - NESCO-WO/A
D. Smithpeter - BPA-WO/A
Ebasco - New York-WO/A
WNP-3/5 Files - Richland-WO/A

FILE COPY

AUTHOR: DR COODY:tt | SECTION: JA PUZAUSKAS | FOR APPROVAL OF: AM CUTRONA, DE TRAPP, JE WERLE, DE DOBSON | FOR SIGNATURE OF: RS LEDDICK

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

WPPSS NUCLEAR PROJECTS NO. 3 & 5

ENGINEERING FINAL REPORT

STRUCTURAL STEEL
CONNECTIONS - UNIT NO. 5

OCTOBER 31, 1981

10 CFR 50.55e - D/N #019

TABLE OF CONTENTS

CONCLUSIONS

The nonconforming conditions discussed in this report consisted of both documentation and hardware deviations in the structural steel connections of the Unit 5 Reactor Auxiliary Building.

A reinspection of all visible bolts was performed by the erection contractor and the results of this reinspection were used to prepare a statistical analysis. This statistical analysis along with calculations of the design stresses in the bolts was used to justify acceptance of the "AS-Built" condition of the bolts which were not accessible for reinspection.

The connections with bolts which turned at the "job inspection torque" will be repaired by welding the connection clip angles to the connecting member. The miscellaneous hardware deviations will be reworked to make the bolts and connections conform to drawing, specification and code requirements.

These nonconforming conditions constitute both significant breakdowns in Morrison-Knudsen's quality assurance program and significant deficencies in construction as defined by 10 CFR 50.55e.

INTRODUCTION

On Jan 21, 1981, Morrison-Knudsen Co., Inc, (M-K) the erection contractor of the structural steel for the Reactor Auxiliary Building, issued a Stop Work Order preventing any further bolting, welding, and erection of structrual steel by their employees. On the same date M-K issued Corrective Action Request (CAR)-33 which describes the conditions which must be met prior to lifting the Stop Work Order. (See Exhibit 1). The Stop Work Order and CAR-33 were initiated based on the discovery, by on-site NRC inspector, of numerous documentation and hardware inconsistencies in the bolted connections of structural steel members.

The NRC was notified of the deficiencies in letters G03-81-503, dated Feburary 19,1981 and G03-81-1072 dated May 7, 1981.

A. POTENTIAL PROBLEMS

(M-K) is contractually required to install the size, quantity and type of high strength bolts as specified on the detail drawings prepared by Fought and Co. of Portland, Ore. Fought and Co. was both the detailer and steel fabricator of the structural steel supplied to M-K for erection. Failure to install the required number, size, and type of bolts, nuts, and washers may reduce the load carrying capacity of the connection and result in stresses in the building structure that exceed code allowables at the design loads.

M-K is contractually required to install the bolts, nuts, and washers in accordance with American Institute of Steel Construction's (AISC) "Manual of Steel Construction" and Ebasco Specification 3240-501 WA "High Strength Bolted Field Connections for Structural Steel." Both of these documents permit bolt tensioning by either "calibrated wrench tightening" or "turn-of-nut tightening" method. Proper bolt tensioning is required to produce the required clamping force between faying surfaces to transmit shear across the connection. Failure to obtain the clamping force may reduce the load carrying capacity of the connection, and result in stresses in the building structure that exceed code allowables at the design loads.

B. APPROACH TO THE RESOLUTION OF THE PROBLEM

CAR-33 required that the following three actions be performed prior to lifting the Stop Work Order.

1. All accessible structural steel bolted and welded connections in both units are to be examined by zone to verify conformance to drawings, specifications, etc.

2. All QC structural steel permanent plant documented records shall be verified for acceptability and conformance to actual field conditions.

3. To preclude recurrence, all construction, QC, engineering and supervisory personnel involved with structural steel erection shall receive documented training and indoctrination in structural steel erection and inspection requirements.

Item 1 was specifically defined to require a 100% visual inspection and a 20% actual torque verification of all visible bolts. (See Exhibit 2) In areas of three(3) foot thick floor slabs and in the pipe chase slabs, some or all bolts in a connection were embedded in concrete and could not be inspected.

As a result of the inspections and verifications performed per Items 1 and 2 of CAR-33, M-K generated NCR 5779 for Unit No 3 and NCR's 5500, 5501, 5502, 5503, 5504, and 5505 for Unit No 5. NCR 5779 and the deviatio discovered in Unit No 3 will be addressed in a separate report.

NCR 5500 identified the twenty-five (25) original inspection reports which covered all of the connections in the El 351 pipe chase slab. During re-verification, per Item 2, documentation errors and inconsistencies were discovered. The connections could not be reinspected as they were embedded in concrete. The documentation errors and inconsistencies included incorrect identification of vendor drawings, incorrect member identificatio incorrect quantity of bolts in the connection, and identification of nonexistent connections.

NCR 5501 identified eight (8) reinspection reports addressing connections with bolts which turned at the "Job Inspection Torque". In all, twenty-eight (28) connections had bolts which turned at the "Job Inspection Torque". (See Exhibit 3) Ten (10) of the connections had bolts which were 100% reinspected and eighteen (18) of the connections had bolts which were not accessible.

NCR 5502 identified three (3) reinspection reports addressing connections embedded in concrete for which no previous traceable documentation could be found and which had bolts which could not be visually inspected. Only three(3) connections fell into this category. On connection 94E to 139B six (6) bolts out of eight (8) were tested and found acceptable. On connection 42C to 424B eleven (11) bolts out of twenty (20) were tested and found acceptable. On connection 93AB to 302F none of the four (4) bolts were visible and therefore were not tested.

NCR 5503 identified six reinspection reports addressing connections not embedded in concrete for which no previous traceable documentation could be found and which had bolts which could not be visually inspected. In all ten (10) connections fell into this category.

	Visible	Torque Tested	Total Bolts In Connection
259E to 262E	4	4	10
246E to 415E	19	18	20
48D to 415A	14	16	24
48C to 414A	16	12	28
278G to 421A	16	13	18
303C to 240B	5	5	8
303C to 249C to 303C	5	5	8
303C to 249C to 303D	5	4	8
249A to 413A to 249D	19	16	22
48A to 413A	16	11	28

NCR 5504 identified nine (9) particular connections with miscellaneous nonconformaning conditions. These deviations include 1) excessive bolt projection, 2) missing hardened washers, 3) undersized washers, 4) presence of burrs in bolt holes, 5) bolts exhibiting less than minimum torque, 6) missing hardened washers, 7) missing re-entrant corners, 8) lack of "flush nut" projection, and 9) a documentation error in which the original inspection report identified 7/8" Ø bolts when in fact 1" Ø bolts were installed.

NCR 5505 identified nineteen (19) particular connections for which no previo documentation could be found. These connections were 100% visually re-inspected and more than 50% torque tested. All nineteen (19) connections were found to be acceptable.

After completion of the program required by Car-33 the Stop Work Order for Unit No 5 was lifted on March 13, 1981.

EVALUATION OF THE NONCONFORMING CONDITIONS

On July 16, 1981 M-K issued a report titled "Statistical Study Of Possible Structural Steel Bolt Failures In Unit No. 5." (See exhibit 4) In this report M-K concluded that for bolts:

1. Total number of deficient structural steel bolts in Unit #5, with a 99% confidence level vary between nine (9) and thirty-two (32) each. (3273 bolts untested)

2. Total number of deficient structural steel bolts in Unit #5 with a 95% confidence level, vary between twelve (12) and twenty-nine (29) each. (3273 bolts untested)

3. The highest probability of bolts having less than the minimum torque in Unit #5, is twenty (20) out of 3273 bolts not tested.

and for connections

1. The untested connections (794) in Unit #5 vary from 98.01% to 99.30%, of being within design strength, utilizing a 95% confidence level.

2. The untested connections (794) in Unit #5, vary from 97.8% to 99.51%, of being within design strength utilizing a 99% confidence level.

3. The probability of having less than 98% design strength in 794 untested connections in Unit #5, is 0.023%

4. The probability of having less than 97.5% design strength in 794 untested connections in Unit #5, is less than 0.0002.

The probabilities for the connections were generated assuming that an identified "loose bolt" has zero shear strength. In fact, most of the "loose bolts" were properly torqued but turned under the "job inspection torque" of the reinspection. Because of this, the probabilities calculated for connections are conservative.

NCR 55C[illegible]

The El 351 pipe chase framing typically consists of W12 x 40 vertical hangers bolted above to the main floor beams and bolted at the pipe chase slab level to W8 x 24 beams. The other end of the W8 x 24 beams are welded to embedded plates. The pipe chase hangers and beams are braced laterally by C12 x 20.7 channels which are bolted to the W8 x 24 beams. (See Exhibit 5)

The typical hanger to beam, and beam to channel connections in the pipe chase slabs were analyzed as if one bolt in each connection was carrying no load. The resulting stress in the remaining bolts was determined to be less than the allowable stress of the AISC Manual of Steel Construction. (See Exhibit 6)

The results of the reinspection were used to calculate the probabilities of having one or more and two or more loose bolts in the 794 uninspected connections, most of which are located in the El 351 pipe chase slab. (See Exhibit 7)

The results of the statistical analysis indicate that

1) The highest probability of one or more loose bolts per connection is approximately 9.64% with twenty-one (21) connections out of 794 affected.

2) The highest probability of two or more loose bolts per connection is approximately 11.06% with thirteen (13) connections out of 794 affected.

Based on the fact that the structural integrity of the bolted connection is achieved within code allowable stresses with an assumed one bolt per connection and the possibility of experiencing two loose bolts in any single connection is relatively small, it is the opinion of the engineer that the pipe chase connections identified in the NCR will not adversely affect the safety, operability or maintainability of the plant.

Connection	Quantity, Size and type of bolts	Design Load	Stress in Bolts (ksi) Calculated	Allowable	Stress in remaining bolts if one bolt is assumed to carry zero load (Ksi)	% over allowab
65C-44A	20-7/8" Ø A325	166K	13.80	15.0	14.53	-0-
4A-298C	16-7/8" Ø A325	102K	10.60	15.0	11.31	-0-
96G-44A	16-7/8" Ø A325	106K	11.02	15.0	11.75	-0-
4A-298E	16-7/8" Ø A325	102K	10.60	15.0	11.31	-0-
97B-41A	16-7/8" Ø A325	106K	11.02	15.0	11.75	-0-
1A-271G	16-7/8" Ø A325	120K	12.47	15.0	13.30	-0-
97C-41A	16-7/8" Ø A325	106K	11.02	15.0	11.75	-0-
1A-299A	16-7/8" Ø A325	102K	10.60	15.0	11.31	-0-
97D-41A	16-7/8" Ø A325	100K	10.39	15.0	11.09	-0-
1A-299B	16-7/8" Ø A325	102K	10.60	15.0	11.31	-0-
64C-424B	16-7/8" Ø A325	137K	14.24	15.0	15.19	1.3
66B-425B	14-7/8" Ø A325	120K	14.25	15.0	15.35	2.3
48A-407A	24-1" Ø A490	348K	18.46	20.0	19.26	-0-
07A-252A	14-1" Ø A490	225K	20.46	20.0	22.04	10.2
52A-423B	22-1" Ø A490	245K	14.18	20.0	14.85	-0-
23B-245E	14-1" Ø A490	140K	12.73	20.0	13.71	-0-
58F-248A	8-1" Ø A490	27.3K	4.34	20.0	4.97	-0-
48A-264G	16-1" Ø A490	143K	11.38	20.0	12.14	-0-
7A-245C	8-7/8" Ø A325	78.9	16.40	15.0	N/A*	N/A*
5C-262F	8-7/8" Ø A325	27.3K	5.68	15.0	N/A*	N/A*
A-428B	14-1 1/8" Ø A490	388K	27.88	32.0	30.03	-0-
8B-40A	14-1 1/8" Ø A490	445K	31.98	32.0	34.44	7.6
5G-40A	8-7/8" Ø A325	70K	14.55	15.0	16.63	10.8
A-297G	8-7/8" Ø A325	70K	14.55	15.0	16.63	10.8

*Connection will be 100% retorqued

onnection	Quantity, Size and type of bolts	Design Load	Stress in Bolts (ksi) Calculated	Allowable	Stress in remaining bolts if one bolt is assumed to carry zero load (Ksi)	% over allowab
5D-40A	16-7/8" Ø A325	106K	11.02	15.0	11.75	-0-
A-272E	16-7/8" Ø A325	120K	12.47	15.0	13.30	-0-
4C-429B	14-7/8" Ø A325	120K	14.25	15.0	15.35	2.3
1E-402A	20-7/8" Ø A325	175K	14.55	15.0	N/A*	N/A*
3B-402A	26-1" Ø A325	292K	14.30	15.0	N/A*	N/A*
2A-243A	20-1" Ø A325	200K	12.73	15.0	N/A*	N/A*
8A-243B	8-7/8" Ø A325	70K	14.55	15.0	N/A*	N/A*
3B-275C	8-7/8" Ø A325	79K	16.42	15.0	N/A*	N/A*
5C-423A	26-1" Ø A490	315K	15.43	20.0	16.04	-0-
3A-244A	26-1" Ø A490	370K	18.12	20.0	18.84	-0-
A-425B	22-1 1/8" Ø A490	640K	29.27	32.0	30.66	-0-
5B-41A	22-1 1/8" Ø A490	640K	29.27	32.0	30.66	-0-
2B-430B	24-1" Ø A325	275K	14.59	15.0	15.22	1.5
0B-252C	24-1" Ø A325	278K	14.75	15.0	15.39	2.6
0E-45A	16-7/8" Ø A325	106K	11.02	15.0	11.75	-0-
A-294A	16-7/8" Ø A325	140K	14.55	15.0	15.52	3.5
1E-426B	14-7/8" Ø A325	120K	14.25	15.0	15.35	2.3

nnections 93K-280F, 93D-264G, 93D-264F, 93AD-266B, 93AC-41A are standard ritical pipe chase hanger to floor member connections. See Exhibit 6 r design loads and bolt stresses.

e four connections marked with an asterisk on Exhibit 3 will be reworked retorquing all bolts in the connections. The remaining 24 connections on hibit 3 will be repaired by welding the connection clip angles to the nnecting members in accordance with approved procedures.

onnection will be 100% retorqued

CR 5502

onnection	Quantity, Size and type of bolts	Design Load (Kips)	Stress in Bolts (ksi) Calculated	Allowable	Stress in remaining bolts if one bolt is assumed to carry zero load (Ksi)	% over allow
C-424B	20-1 1/8" Ø A325	295K	14.83	15.0	15.6	4.
E-139B	8-7/8" Ø A325	54K	11.22	15.0	12.83	-0
AB-302F	4-7/8" Ø A325	20K	8.31	15.0	11.09	-0

ased on the above calculated stresses and the relatively small possibility of periencing two or more loose bolts in these particular connections (See hibit 7), it is the Engineer's opinion that these connections will not versely affect the safety, operability or maintainability of the plant.

CR 5503

onnection	Quantity, Size and type of bolts	Design Load (Kips)	Stress in Bolts (ksi) Calculated	Allowable	Stress in remaining bolts if one bolt is assumed to carry zero load (Ksi)	% over allow
59E-262E	10-7/8" Ø A325	15.5K	2.58	15.0	2.86	-0-
46E-415A	20-7/8" Ø A325	165K	13.72	15.0	14.44	-0-
8D-415A	24-1 1/8" Ø A490	490K	20.54	20.0	21.43	7.2
8C-414A	28-1 1/8" Ø A490	490K	17.61	20.0	18.26	-0-
78G-421A	18-7/8" Ø A325	155K	14.32	15.0	15.16	1.1
49A-413A	14-7/8" Ø A490	111K	13.19	20.0	14.20	-0-
3A-249D	22-7/8" Ø A490	266K	20.10	20.0	21.07	5.3
3A-413A	28-1 1/8" Ø A490	481K	17.28	20.0	17.92	-0-

onnections 303C-240B, 303C-249C-303C and 303C-249B-303D are not permanent tructural steel connections

Based on the above calculated stresses and the relatively small possibility of experiencing two or more loose bolts in these particular connections (See Exhibit 7), it is the Engineer's opinion that these connections will not adversely affect the safety, operability, or maintainability of the plant.

NCR 5504

The first eight nonconforming conditions identified on this NCR will be reworked in such a manner as to make the bolts and connections conform to the drawing, specification, and code requirements. The ninth item is a documentation deficiency and the reinspection has verified that the correct bolt size has been installed in the connection.

NCR 5505

The nineteen connections were 100% visually reinspected and more than 50% torqued tested. All nineteen connections were found to be acceptable.

EXHIBIT 1

CORRECTIVE ACTION REQUEST 33

MORRISON KNUDSEN

FORM QC-15-CA1
REV. 0

CORRECTIVE ACTION REQUEST

PROJECT Satsop
REQUEST NO. 33

NO. 3240-263 UNIT NO. 3 & 5 REPLY DUE DATE 1-23-81

AREA Structural Steel
PAGE 1 OF

CONDITION DESCRIPTION

10 CFR 50, Criteria X, states in part, "A program for inspection of activities affecting quality shall be established and executed...to verify conformance with the the documented instructions, procedures and drawings for accomplishing the activity."

Contrary to the above requirements, the NRC has noted numerous instances where Structural Steel has been erected improperly and subsequently accepted by Q.C. inspection. Reference NRC Docket #80-06-04 and NRC Weekly Inspection Report for the week of January 23, 1981.

As a result of the above, a Stop Work Order (ref. IOC-81-73) has been issued for all Structural Steel welding, bolting and erection. (continued Page 2)

REPLY REQUESTED FROM Project Manager INITIATED BY [signature] 1-21-81
Q.A. ENGINEER DATE

REVIEWED BY
PROJECT QUALITY ENGINEER DATE

CAUSE AND CORRECTIVE ACTION

PREPARED BY AUTHORIZED BY
NAME DATE

CORRECTIVE ACTION VERIFIED BY
Q.A. ENGINEER DATE FOLLOW-UP
Q.A. ENGINEER DATE

REVIEWED BY
PROJECT QUALITY ENGINEER DATE

DISTRIBUTION J. Davis J. Sowers (Boise)
R. A. Davis
G. Hill

EXHIBIT 1

The following conditions must be met prior to resumption of work:

1. All accessible Structural Steel physical bolted and welded connections in both units are to be examined by zone to verify conformance to drawings, specifications, etc.

2. All QC Stuctural Steel permanent plant documented records shall be verified for acceptability and conformance to actual field conditions.

3. To preclude recurrence, all construction, QC, engineering and supervisory personell involved with Structural Steel Erection shall receive documented training and indoctrination in Structural Steel Erection and Inspection Requirements.

As evidence of compliance to the above conditions are submitted and found acceptable to the Project Quality Manager, the Stop Work Order may be lifted by zones.

EXHIBIT 1 (co

EXHIBIT 2

JOB INSPECTION TORQUE VALUES FOR REINSPECTION

MORRISON-KNUDSEN COMPANY, INC.

INTER-OFFICE CORRESPONDENCE

IOC-81-163

DATE: February 13, 1981

TO: Richard Davis

FROM: Jack Davis

LOCATION: Satsop Power Plant

LOCATION: Contract 2879
Elma, Washington

SUBJECT: Verification of Structural Bolting Per CAR #33

Engineering having reviewed the varying job torque as noted per IOC-81-154, is now assigning the values for minimum torque required by AISC.

During the verification of structural bolts per CAR #33 the inspection teams shall perform 100% visual and 20% actual torque verification using the ft-lb values noted on attached sheet.

If there are any questions please contact this office.

Attachment

MCL/kh

cc: D. Reed
R. Wisdom
M. Lentz
M-K File

EXHIBIT 2

A325

DIAMETER	MINIMUM TENSION REQUIRED PER TABLE 3 AISC	TORQUE IN.-LB	TORQUE FT.-LB
7/8"	39,000#	6,825	569
1"	51,000#	10,200	850
1 1/8"	56,000#	12,600	1,050

A490

DIAMETER	MINIMUM TENSION REQUIRED PER TABLE 3 AISC	TORQUE IN.-LB	TORQUE FT.-LB
7/8"	49,000#	8,575	715
1"	64,000#	12,800	1,067
1 1/8"	80,000#	18,000	1,500

EXHIBIT 3

CONNECTIONS WITH BOLTS WHICH TURNED AT THE "JOB INSPECTION TORQUE"

EXHIBIT 3

CONNECTIONS WITH BOLTS WHICH TURNED AT THE "JOB INSPECTION TORQUE"

NCR 5501

REPORT NO.	CONNECTION	LOOSE BOLTS	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECTIONS
5SB-152	265C-44A-298C	2	3	8	20
	296G-44A-298E	2	2	4	16
	297B-41A-271G	1	1	4	16
	297C-41A-299A	1	4	4	16
	297D-41A-[illegible]9B	2	2	4	16
	264C-424B	1	10	13	16
	266B-425B	1	4	8	14
153	93K-280F	4	2	4	4
	93D-264G	4	2	4	4
	93D-264F	2	2	4	4
159	248A-407A-252A	4	9	20	24
	252A-423B-245E	2	6	19	22
	268F-248A-264G	1	1	16	16
	267A-245C-262F	3	8	8	8 *
162	47A-428B-40A	4	7	7	14
	295G-40A-297G	1	1	8	8
	295D-40A-272E	2	3	4	16
	294C-429B	1	7	8	14
165	251E-402A	1	20	20	20 *
	243B-402A-243A	7	26	26	26 *
	278A-243B-275C	4	8	8	8 *
166	93AD-266B	1	2	4	4
	93AC-41A	2	4	4	4
175	245C-423A-244A	1	17	17	26
	44A-425B-41A	2	6	16	22

EXHIBIT 3 (cont'd)

NCR 5501

EPORT NO.	CONNECTION	LOOSE BOLTS	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECITONS
5SB-158	252B-430B-252C	2	11	20	24
	290E-45A-294A	1	4	4	16
	271E-426B	2	3	8	14

EXHIBIT 4

STATISTICAL STUDY OF POSSIBLE STRUCTURAL STEEL BOLT FAILURES IN UNIT #3

SUBJECT: Statistical Study of Possible Structural Steel Bolt Failures in Unit #5.

PREPARED BY: Henry Burgell and Chung Ho Chen

DATED: July 16, 1981

REFERENCE: Ronald Walpole and Raymond Harris, Probability and Statistics for Engineers and Scientists, MacMillan Company, New York.

REPORT LISTING

E 4-2

CONCLUSIONS

A. BOLTS

1. Total number of deficient structural steel bolts in Unit #5, with a 99% confidence level varing between nine (9) and thirty-two (32) among 3,273 bolts not tested.

2. Total number of deficient structural steel bolts in Unit #5, with a 95% confidence level, varing between twelve (12) and twenty-nine (29) among 3,273 bolts not tested.

3. The highest probability of bolt failures in Unit #5, is twenty (20) failures out of 3,273 bolts not tested.

B. CONNECTIONS

1. The untested connections in Unit #5 lie between 98.01% to 99.30%, of design strength, utilizing a 95% confidence level.

2. The untested connections (794) in unit #5 lie between 97.8% to 99.51% of design strength utilizing a 99% confidence level.

3. The probability of having less than 98% design strength in 794 untested connections in Unit #5, is 0.023.

4. The probability of having less than 97.5% design strength in 794 untested connections in Unit #5, is less than 0.0002.

STATEMENT OF PROBLEM

Nonconformance Reports 5500, 5502, and 5503 deal with the fact that documentation deficiencies existed for a portion of Units #5 that preceded the acceptance of structural steel bolts. The bolts in question were either loaded with concrete, otherwise inaccessible, such that conventional bolt testing methods became impossible. This report has been generated to support the Morrison-Knudsen Company,Inc., recommended disposition of "Accept As Is" based upon the lack of such documentation should not seriously impact the true structural intent of the connections.

Data to present a statiscal analysis was based upon Non-Conformance Reports 5501 and 5505.

STATISTICAL METHOD SYNOPSIS

All data was based upon that furnished by H. W. Holcombe, Contract 263, Quality Assurance Auditor to Jack Davis, Contract 263 Engineering Manager on Interoffice Memorandum, IOC-81-560, dated May 18, 1981. This IOC has been included in this report as an attachment.

A portion of structural steel bolts in Unit #5 were retested. The statistics involved in finding the probability and confidence level involving individual bolts, was the binomial distribution curve. This type of distribution is appropriate since all the testing was done on a "pass - reject" basis. Thus all probabilities and confidence levels on bolts were estimated in the binomial distribution basis.

The structural design strength of the connections in question was statistically estimated using the normal distribution. The assumption was made that percentage of design strength can be estimated on a simple ratio of bad versus good bolts in any one connection. This assumption was necessary to generate data in order to statistically estimate design strength. Thus all probabilities and confidence levels on connection integrity were estimated using the normal distribution.

SUBJECT: Statistical Study of Bolt Failure Test.

PREPARED BY: Henry E-rgell - Chung Ho Chen

DATE: June 30, 1981

REFERENCE: Ronald E. Walpole and Raymond H. Myers, probability and statistics for Engineers and Scientists, MacMillan Company, N.Y., 1972, Pages 81 - 84.

A) Given conditions: (see attached IOC-81-560)
Bolts tested: 9940 pieces
Bolts failed to pass the test: 61 pieces
Bolts not tested: 3273 pieces

B) Assumption: Probability of failure is $\frac{61}{9940}$ or 0.00613682.

C) Numerical Study: From reference, the Binomial Distributions can be presented as:

$$b(x;n,p) = \binom{n}{x} p^x q^{n-x}, \quad x=0,1,2,..n$$

* Please refer to sample calculation (page 8 of 21)

D) Results: See attached Table 1 and Figure 1.

E) Conclusion: From Fig. 1, the highest probablity of failure is approximately 8.87%, with twenty bolts failure among 3273 bolts. It also shows that the probability of failures of 30 (or above) bolts is almost zero.

E4-6

CHANCES OF FAILURES FOR UNTESTED BOLTS

NUMBER OF FAILURES	PROBABILITY
1	2.62×10^{-6} %
5	3.8×10^{-3} %
10	4.6×10^{-1} %
15	4.63 %
20	8.87 %
25	4.9 %
30	~0 %

TABLE I. THE PROBABILITY OF FAILURE

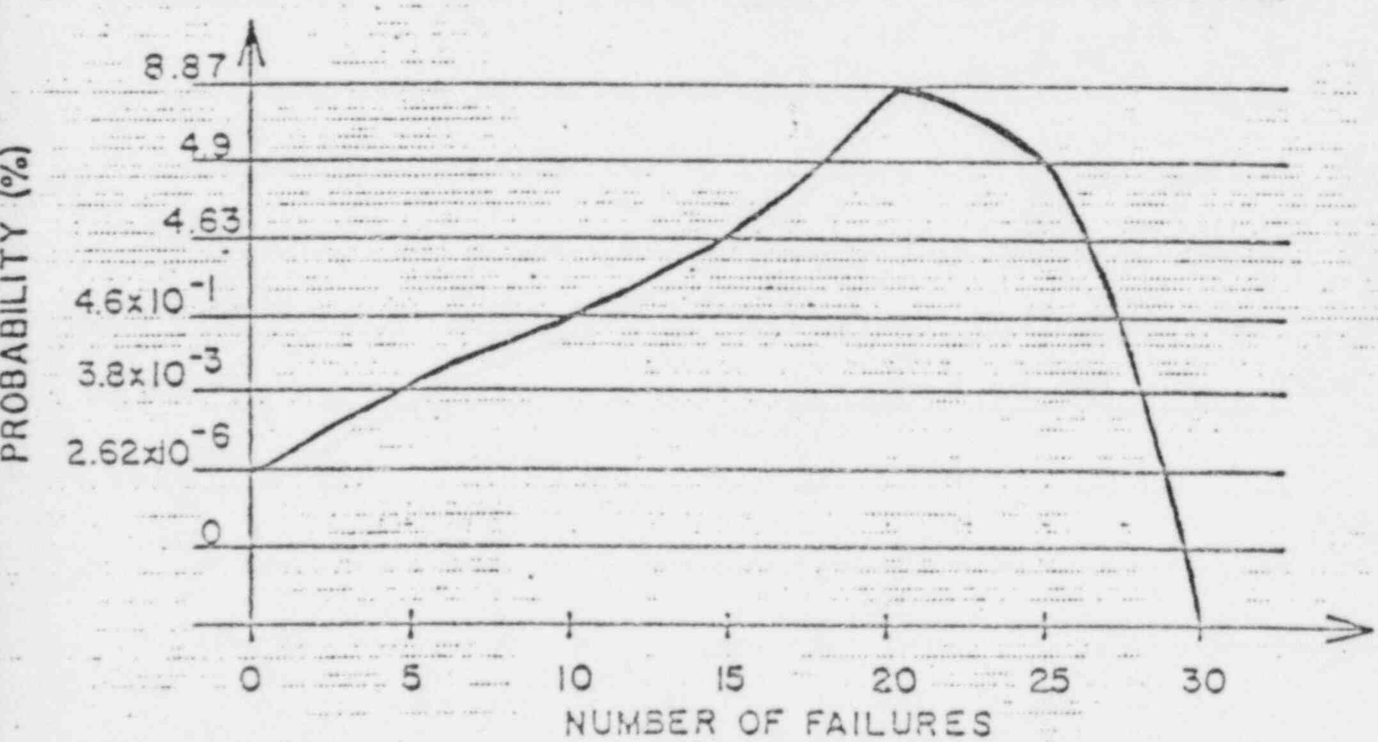


FIG. 4 BINOMIAL DISTRIBUTION OF FAILURES OF BOLTS.

E4-7

Sample calculation*: (*page-6 of 21)

Note: Formula:

$$b(x;n,p) = \binom{n}{x} p^x q^{n-x},\ x=0,1,2...n$$

where $b(x;n,p)$: binomial distribution

x : no. of failures (or successes)

n : total no. of trials

p : success or failure probability

$q = 1-p$: failure or success probability

Ex: In this study the failure probability was assumed as $\frac{61}{9940}$ or 0.00613682. Find the probability that exactly 20 of the next 3273 bolts tested failed.

$$p = \frac{61}{9940} = 0.00613682$$

$$q = 1 - p = 0.99386318$$

$$x = 20$$

$$n = 3273$$

$$b(x;n,p) = \binom{3273}{20} (0.00613682)^{20} (0.99386318)^{3273 - 20}$$

$$= 0.0887278225 = 8.87\%$$

A) Given conditions:

Bolts tested - 9940 pieces

Bolts failed to pass the test - 61 pieces

Bolts not tested - n = 3,273 pieces

B) Assumption: Probability of failure, p is $\frac{61}{9940}$ = 0.00613682.

C) Numerical study:

Confidence interval can be approximated as"

$$p - z\sqrt{\frac{p\,q}{n}} < \hat{p} < p + z\sqrt{\frac{p\,q}{n}}$$

Where $\hat{p}$ is the probability of failures in a untested sample of size n, p is the probability of failure in the sample tested and q = 1-p, z is the value of the standard normal curve leaving an area of d/2 to the right where d = 1 - % confidence interval. (see ref.)

In our case, the untested sample number n = 3,273 and probability of failure is p = 0.00613682. Using the value of z = 1.96 from reference for 95% confidence interval. The 95% confidence interval of failures ($\hat{p}$) can be calculated as:

$$0.00613682 - 1.96\sqrt{\frac{(0.00613682)(0.99386318)}{3273}} < \hat{p} < 0.00613682 + 1.96\sqrt{\frac{(0.00613682)(0.99386318)}{3273}}$$

OR $0.0035401383 < \hat{p} < 0.0089347107$

OR 12 < No. of failures < 29 for 95% confidence level

The same formula can be followed to calculate the 99% of confidence interval as: 9 < No. of failures < 32

Reference: Ronald E. Walpole and Raymond H. Myers, Probability and statistics for Engineers and Scientists, MacMillan Company, N.Y. , 1972 , pp.203

RAW DATA LISTING

CONNECTION	LOOSE BOLTS	NO. OF TESTED BOLTS IN CONNECTION	PERCENT OF DESIGN STRENGTH
265C-44A-298C	2	3	33
296G-44A-298E	2	2	0
297B-41A-271G	1	1	0
297C-41A-299A	1	4	75
297D-41A-299B	2	2	0
264C-424B	1	10	90
266B-425B	1	4	75
93K-280F	4	4	0
93D-264G	4	4	0
93D-264F	2	4	50
248A-407A-252A	4	9	55
252A-423B-245E	2	6	67
268F-248A-264G	1	1	0
267A-245C-262F	3	8	62.5
47A-428B-40A	4	7	43
295G-40A-297G	1	1	0
295D-40A-272E	2	3	33
294C-429B	1	7	87
251E-402A	1	20	95
243B-402A243A	7	26	73
278A-243B-275C	4	8	50
93AD-266B	1	2	50
93AC-41A	2	4	50
245C-423A-244A	1	17	94
44A-425B-41A	2	6	67
252B-430B-252C	2	11	82
290E-45A-294A	1	4	75
271E-426B	2	3	33
29-1020	all of the rest of the connections		100.0

Total number of connections.................................... 1814
Total number of connections inspected.......................... 1020
Total number of connections with deficiency.................... 28
Total number of connections uninspected........................ 794
Percentage of connection strength (compared to design strength).98.66%
Deviation.. 9.33%
Probability of 794 uninspected connections in Unit #5, have
average strength less than 98% of design strength is....... 0.023%
Probability of 794 uninspected connections in Unit #5, have
average strength less than 97.5% of design strength is..... 0.0002%

NOTE: Since all bolts which failed to pass the test were hand tightened to connections , the bolts still can resist some shear stress. The percentage shown in this list should be treated as a maximum value (or worst condition).

The uninspected connections in Unit #5, lie between 98.01% to 99.30% of design strength utilizing a 95% confidence interval.

The uninspected connections lie between 97/8% to 99.51% of design strength, utilizing a 99% confidence interval.

REF: Probability and Statistics for Engineer's and Scientist's; page 162 thru 189.

E 4-11

TABLE ONE

Inspection results of Unit #5 bolts.

STATISTICAL ANALYSIS:

1. Mean percentage of design strength.

$$X = \frac{\sum_{i=1}^{n} X_i}{n} \quad \text{where } n = 1020, \quad X_1 = 33, \quad X_2 = 0.0 \text{ etc.}$$

$$X_{29} = 100, \; X_{30} = 100$$

$$X_{1020} = 100$$

$$= 98.66\%$$

2. Deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2 / n}{n - 1}}$$

$$= 9.33\%$$

3. Probability of 794 connections with average strength less than 98% of design strength (normal dist.)

$$\sigma_x = \sigma / \sqrt{n} = 9.33 / \sqrt{794} = 0.331$$

$$z = \frac{\bar{x} - X}{\sigma_x} = \frac{98 - 98.66}{0.331} = -1.99$$

$$Pr(\bar{x} < 98\%) = Pr(z < -1.99) = 0.023$$

Where = coordinate of normal curve, σ_x = sampling deviation, $\bar{x}$ = sampling mean, Pr = probability.

4. Probability of 794 connections with average strength, less than 97.5% of Design strength.

$$z = \frac{97.5 - 98.66}{0.331} = -3.5$$

$$Pr(\bar{x} < 97.5\%) = Pr(z < -3.5) \ll 0.0002$$

cont.

5. 95% confidence interval.

$$\bar{x} - Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \quad \text{OR}$$

$$98.66 - \frac{1.96 \times 9.33}{\sqrt{794}} < \mu < 98.66 + \frac{1.96 \times 9.33}{\sqrt{794}}$$

OR $98.01\% < \mu < 99.30\%$

6. 99% confidence interval

$$98.66 - \frac{2.575 \times 9.33}{\sqrt{794}} < \mu < 98.66 + \frac{2.575 \times 9.33}{\sqrt{794}} \quad \text{OR}$$

$97.8\% < \mu < 99.51\%$

Where $\bar{x}$ = sampling mean

$Z_{\alpha/2}$ = value of the standard normal distribution leaving an area of $\alpha/2$ to the right. (Ref: Page 459 of Reference)

σ = deviation

n = sample size

E 4.13

MORRISON-KNUDSEN COMPANY, INC.

INTER-OFFICE CORRESPONDENCE IOC-81-560

DATE: May 18, 1981

TO: J. Davis

FROM: H. W. Holcombe

LOCATION: Satsop Power Plant

LOCATION: Contract 2879
Elm.., Washington

SUBJECT: Statistical Analysis of Results of CAR #33

As per your request, attached is the Statistical Report for Structural Steel Bolting Reinspection as per Corrective Action Request No. 33 for Unit No. 5.

This report consists of the following attachments:

Attachment A - Overall statistical results of Unit 5, including the baseline numbers used as reference throughout report.

Attachment B - Statistical results of the number of loose bolts which were not correctable during reinspection. Includes NCR 5501 and a portion of NCR 5504.

Attachment C - Statistical results of documentation deficiencies noted and not correctable during reinspection, excluding 351 pipe chase. Includes NCR 5502 and NCR 5503.

Attachment D - Statistical results of NCR 5500 which deals with documentation deficiency in the 351 pipe chase.

When reviewing this report, there are several points that should be noted:

1. NCR 5500 deals with the elevation 351 pipe chase which is a unique condition in which documentation for this area is suspect and all connections are embedded in concrete. It was realized that if this point was not taken into consideration, misleading conclusions could be drawn, i.e. if the number of loose bolts is taken only as a total of Unit 5, it assumes that the 2,751 bolts in the pipe chase is satisfactory. For this reason, percentages in this report are given in three manners: percentage of total Unit 5 connections and bolts, percentage of total Unit 5 excluding 351 pipe chase and percentage of total reinspected.

2. NCR 5504 deals with several miscellaneous hardware problems. A separate breakdown of this NCR was not provided in that each condition should be considered on a case basis and the overall percentage of Unit 5 is negligible. NCR 5504 was considered in the overall hardware problem referenced on Attachment A and the portion dealing with loose bolts on Attachment B.

3. It is recommended that this report be used in conjunction with the referenced Nonconformance Reports and not as the sole basis for accept/reject criteria. There is information in each individual report which may not [illegible] evident in this report, i.e. 1 bolt out of 20 may be loose, but only [illegible] bolt was able to be tested. This report will only indicate 1 out of 20 bolts were loose..

E 4-14

ATTACHMENT A

Statistical Analysis of Results of
Corrective Action Request No. 33

TOTAL Number of Connections in Unit 5..1,814
TOTAL Number of Bolts in Unit 5..12,713
TOTAL Number of Connections in Unit 5 excluding connections in 351 Pipe Chase..1,142
TOTAL Number of Bolts in Unit 5 excluding bolts in 351 Pipe Chase.............9,962

Total Number of Connections in Unit 5 Reinspected.......................1,020

56.2% of total in Unit 5.
89.3% of total excluding 351 pipe chase.

Total Number of Bolts in Unit 5 Reinspected.............................9,440

74.3% of total in Unit 5.
94.7% of total excluding pipe chase.

Total Number of Connections with Hardware Problem (includes NCR 5501 & 5504)....36

2% of total in Unit 5.
3.2% of total excluding 351 pipe chase.
3.5% of connections reinspected.

Total Number of Bolts with Hardware Problem (includes NCR 5501 & 5504).........91

0.7% of total in Unit 5.
0.9% of total excluding 351 pipe chase.
0.96% of bolts reinspected.

Total Number of Connections with Paper Deficiency (includes 351 Pipe Chase).....685

37.8% of total Unit 5.

Total Number of Bolts with Paper Deficiency (includes 351 Pipe Chase)..........2,816

22.2% of total Unit 5.

See Attachment C for Paper Deficiencies excluding 351 Pipe Chase.

See Attachment D for 351 Pipe Chase.

E4-15

ATTACHMENT B

Statistical Analysis of Results of
Corrective Action Request No. 33

Condition: Connection with bolts which did not meet "Job Inspection Torque". Includes connections listed on NCR 5501 and 5504.

Total No. of Connections with loose bolts...........28

1.54% of total in Unit 5.
2.45% of total excluding 351 pipe chase.
2.74% of connections reinspected.

Total No. of loose bolts............................61

0.5% of total in Unit 5.
0.6% of total excluding 351 pipe chase.
0.66% of bolts reinspected.

See Page 2 of Attachment B for specific Connections.

E4-16

ATTACHMENT B

Statistical Analysis of Results of
Corrective Action Request No. 33
Page 2

NCR 5501

REPORT NO.	CONNECTION	LOOSE BOLTS	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECTIONS
5SB-152	265C-44A-298C	2	3	8	20
	296G-44A-298E	2	2	4	16
	297B-41A-271G	1	1	4	16
	297C-41A-299A	1	4	4	16
	297D-41A-299B	2	2	4	16
	264C-424B	1	10	13	16
	266B-425B	1	4	8	14
153	93K-280F	4	2	4	4
	93D-264G	4	2	4	4
	93D-264F	2	2	4	4
159	248A-407A-252A	4	9	20	24
	252A-423B-245E	2	6	19	22
	268F-248A-264G	1	1	16	16
	267A-245C-262F	3	8	8	8
162	47A-428B-40A	4	7	7	14
	295G-40A-297G	1	1	8	8
	295D-40A-272E	2	3	4	16
	294C-429B	1	7	8	14
165	251E-402A	1	20	20	20
	243B-402A-243A	7	26	26	26
	278A-243B-275C	4	8	8	8
166	93AD-266B	1	2	4	4
	93AC-41A	2	4	4	4
175	245C-423A-244A	1	17	17	26
	44A-425B-41A	2	6	16	22

NCR 5504

REPORT NO.	CONNECTION	LOOSE BOLTS	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECTIONS
5SB-158	252B-430B-252C	2	11	20	24
	290E-45A-294A	1	4	4	16
	271E-426B	2	3	8	14

E 4-17

ATTACHMENT C

Statistical Analysis of Results of
Corrective Action Request No. 33

Condition: Connections with fasteners not 100% accessible for reinspection and there is no previous traceable documentation for these connections. Includes reports covered by NCR 5502 and 5503 (excludes reports covered by NCR 5500).

Total No. of Connections with documentation deficiencies............13

0.7% of total Unit 5.
1.1% of total excluding 351 pipe chase.
1.3% of total reinspected.

Total No. of bolts unaccessible and no inspection documentation.....65

0.5% of total Unit 5.
0.6% of total excluding 351 pipe chase.
0.7% of total reinspected.

See Page 2 of Attachment C for specific Connections.

E4-18

ATTACHMENT C

Statistical Analysis of Results of
Corrective Action Request No. 33
Page 2

NCR 5502

REPORT NO.	CONNECTION	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECTIONS
5SB-96	42C-424B	11	14	20
127	94E-139B	6	6	8
148	[illegible]-302F	0	0	4

NCR 5503

REPORT NO.	CONNECTION	BOLTS TESTED	NO. BOLTS VISIBLE	NO. BOLTS IN CONNECTIONS
5SB-77	259E-262E	4	4	10
	246E-415A	18	19	20
84	48D-415A	14	16	24
	48C-414A	12	16	28
88	278G 421A	13	~~16~~	18
95	303C-240B	5	5	8
	303C-249C-303C	5	5	8
	303C-249B-303D	4	5	8
100	249A-413A-249D	16	19	22
114	48A-413A	11	16	28

E 4-19

ATTACHMENT D

Statistical Analysis of Results of
Corrective Action Request No. 33

Condition: The inspection reports for the 351 pipe chase reference connections that do not correspond to configurations as shown on contract drawings. These connections are now embedded in concrete and no reinspection was performed. This condition is addressed on NCR 5500.

Total No. of Connections involved....................672

37% of total Unit 5.

Total No. of bolts involved............... 2751

21.6% of total Unit 5.

See NCR 5500 for specific Connections.

E 4-20

If there are any questions or if clarification is needed as to the basis of this information, please contact the M-K Quality Assurance Department.

H. W. Holcombe
H. W. Holcombe
Q. A. Manager

HWH/tb

Attachments

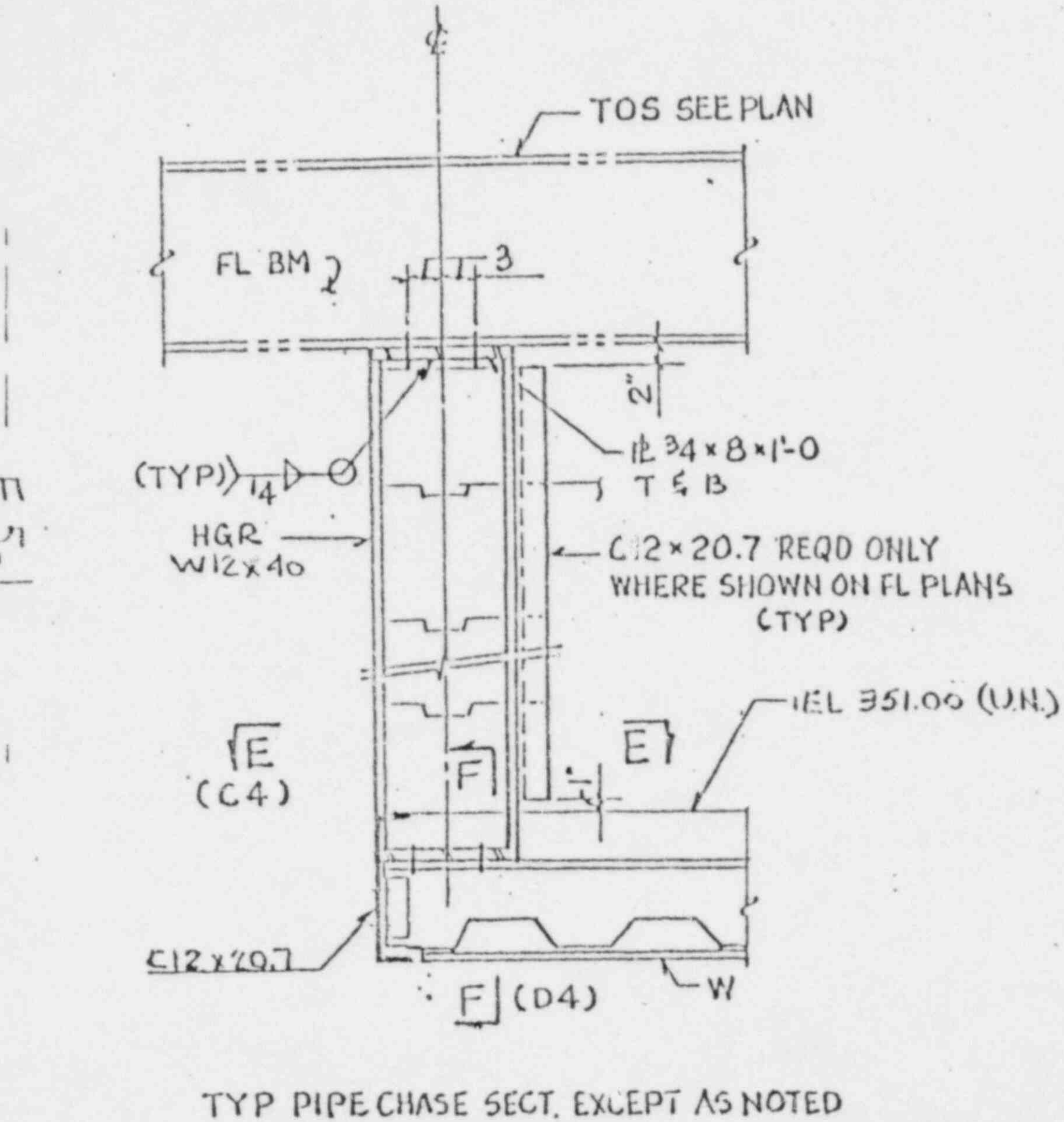
cc: R. A. Davis
D. E. Reed
J. Sowers (Boise)
D. Shapira
CAR 33 File
G. Hill
B. Wisdom
File 10-21
File 17-14
D/C

E 4-21

EXHIBIT 5

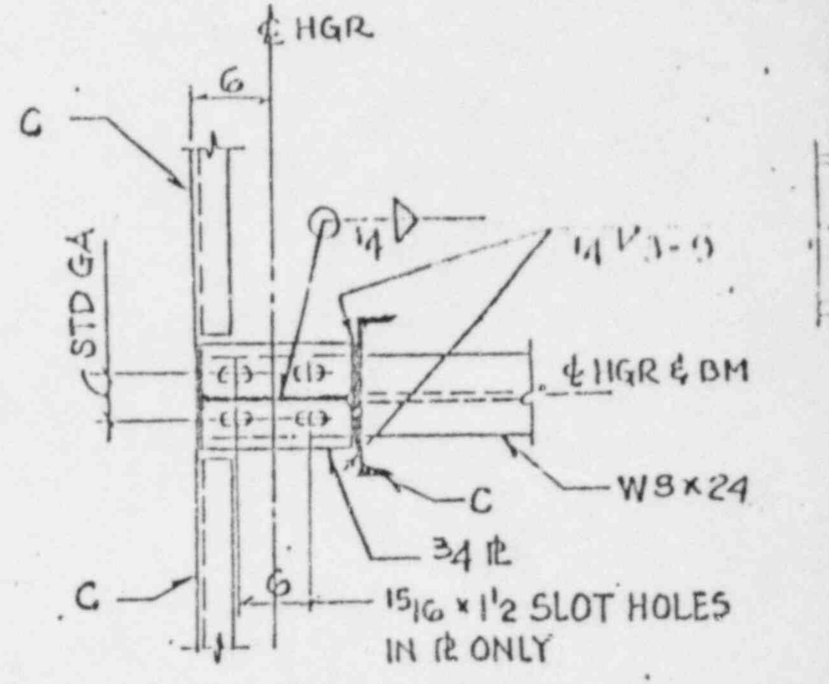
TYPICAL PIPE CHASE FRAMING

2. L4x3½x3/8 CLIP ANGLES ———— EMSCO DESIGN GUIDE A

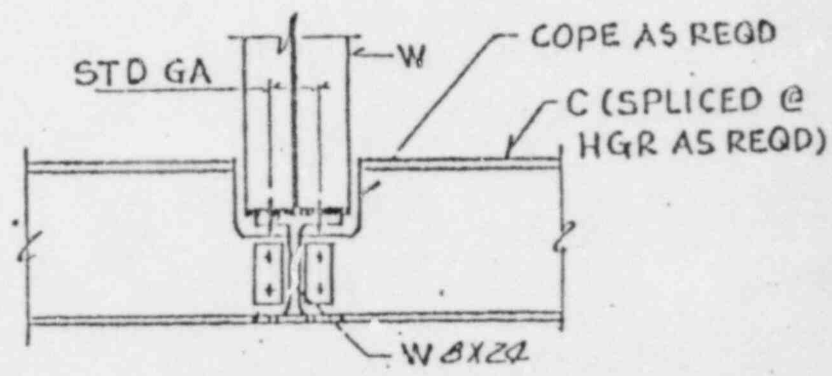


TYP PIPE CHASE SECT. EXCEPT AS NOTED

TYPE H1
NTS



SECT E (C1)
3/4 = 1'-0



SECT F (D2)
3/4 = 1'-0

EXHIBIT 5
TYPICAL PIPE CHASE FRAMING

EXHIBIT 6

DETERMINATION OF BOLT STRESSES IN PIPE CHASE CONNECTIONS

BY [illegible] DATE 1/27/81
CHKD. BY H. Totturgul DATE 1/28/81
SHEET 1 OF 2
OFS NO. 3240-263 DEPT. NO. 653
CLIENT WPPSS
PROJECT WNP 3 + 5
SUBJECT PIPE CHASE EL. 351.00'

PROBLEM: CHECK ADEQUACY OF EACH CONNECTION SHOWN ON ATTACHED SHEET IF ONE BOLT CARRIES NO LOAD.

REFERENCES:
1. WPPSS CALCULATION NO. 3240-RAB-12
2. AISC STEEL CONSTRUCTION MANUAL EIGHTH ED.
3. EBASCO DESIGN GUIDE
4. DWG NO.'S G-3223-3225, G 3402-3405, G-3434, G-3432 SH5.

SOLUTION:

1 LOADINGS

HANGER DESIGN LOAD = 17^k/EACH —— (REF. 1 SHT 3B5 OF 30)
ACTUAL HANGER DESIGN LOAD ≤ 16^k/EACH

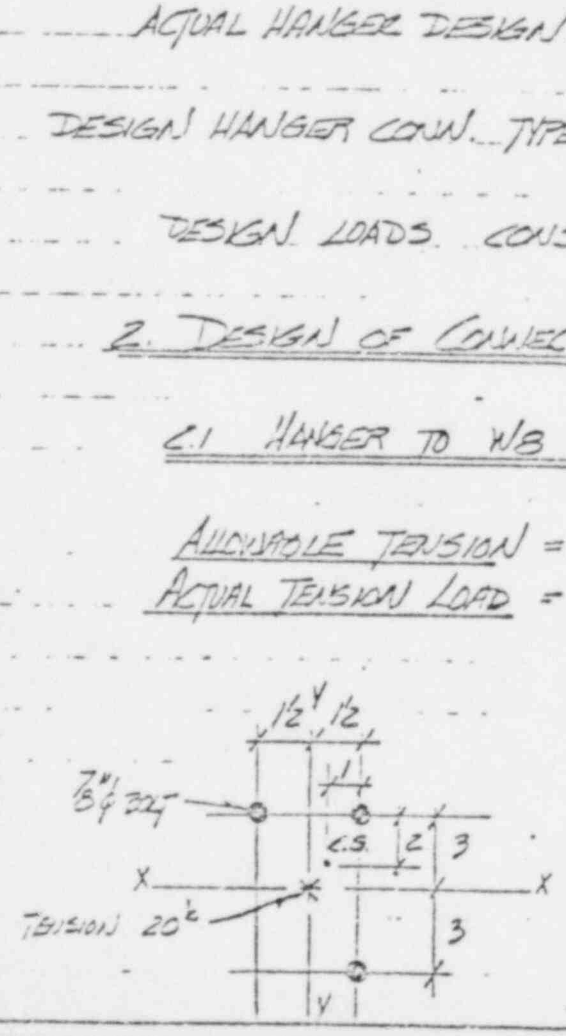
DESIGN HANGER CONN. TYPE H1 LOAD = 20^k —— (REF. 1 SHT 3B11 OF 30)

DESIGN LOADS CONSERVATIVE BY 15% - 20%

2. DESIGN OF CONNECTIONS

2.1 HANGER TO W8 CONNECTION

ALLOWABLE TENSION = 24.05^k/BOLT —— (REF. 1 SHT 3B12 OF 30)
ACTUAL TENSION LOAD = 16^k



ACTUAL TENSION LOAD PER BOLT

$I_{YY} = 2(1)^2 + 1(2)^2 = 6 in^2$; $I_{XX} = 2(2)^2 + 1(4)^2 = 24 in^2$

$T_1 = \frac{16}{3} + \frac{16 \times .5 \times 2}{6} = 8^k < 24^k$

$T_2 = 16/3 + \frac{16 \times 1 \times 4}{24} = 8^k < 24^k$

FORM 331 REV 7-71

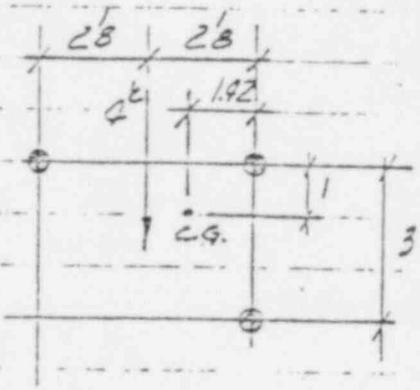
2.2 CHANNEL TO W8 CONNECTION

NOTE: W8 BEAM CARRIES ALMOST TOTAL LOAD OF 16^k.
ASSUME LOAD AT CLIP ANGLES FROM CHANNEL 1/4 THE LOAD OF THE W8.

ACTUAL SHEAR LOAD = $16/4 = 4^k$ (VERY, VERY CONSERVATIVE)

ALLOWABLE SHEAR = 10.5^k/BOLT . FRICTION TYPE CONNECTION, SINGLE SHEAR, STD HOLE — AISC PG. 4-5

7/8" φ BOLTS



ACTUAL SHEAR LOAD PER BOLT

$$\Sigma d^2 = \Sigma h^2 + \Sigma v^2 = 2(1.42)^2 + 1(4.25-1.42)^2 + 2(1)^2 + 1(2)^2 = 18\ \text{in.}^2$$

$$V_y = 4/3 + \frac{4 \times (2.125-1.42) \times (4.25-1.42)}{18} = 1.8^k$$

$$V_x = \frac{4(2.125-1.42)(2)}{18} = 0.3^k$$

$$V_{MAX} = \sqrt{(1.8)^2 + (.3)^2} = 1.83^k < 10.5^k$$

3.0 COMPARISON OF ACTUAL TO ALLOWABLE LOADS ON BOLTS

3.1 TENSION

ACTUAL TENSION IN BOLT IS 1/3 THE ALLOWABLE TENSION. ($8/24 = 1/3$)

3.2 SHEAR

ACTUAL SHEAR IN ONE BOLT IS ~ 1/6 THE ALLOWABLE SHEAR. ($1.83/10.5 = 0.17$)

EXHIBIT 7

STATISTICAL STUDY OF POTENTIAL FOR LOOSE BOLTS IN A CONNECTION

A. GIVEN CONDITIONS

CONNECTIONS TESTED : 1020

CONNECTIONS WITH 1 OR MORE LOOSE BOLTS : 28

CONNECTIONS WITH 2 OR MORE LOOSE BOLTS : 17

CONNECTIONS NOT TESTED : 794

TOTAL CONNECTIONS : 1814

B. ASSUMPTIONS :

PROBABILITY OF 1 OR MORE LOOSE BOLTS / CONNECTION : $\frac{28}{1020} = 0.0275$

PROBABILITY OF 2 OR MORE LOOSE BOLTS / CONNECTION $\frac{17}{1020} = 0.01667$

C. NUMERICAL STUDY: FROM REFERENCE, THE BINOMIAL DISTRIBUTIONS CAN BE PRESENTED AS:

$$b(x; n, p) = \binom{n}{x} p^x q^{n-x}, \quad x = 0, 1, 2, 3 \ldots n$$

FROM REFERENCE, THE NORMAL APPROXIMATION TO THE BINOMIAL DISTRIBUTION

$$f(x) = \frac{e^{-\frac{(x-\mu)^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}} \quad (-\infty < x < \infty)$$

WHERE $\mu = np$

$\sigma = \sqrt{npq}$

*SEE SAMPLE CALCULATIONS

D. RESULTS: SEE ATTACHED TABLES

E. CONCLUSIONS: FROM TABLE 1, THE HIGHEST PROBABILITY OF 1 OR MORE LOOSE BOLTS PER CONNECTION IS APPROXIMATELY 8.64%, WITH 21 CONNECTIONS OUT OF 794 AFFECTED.

CONCLUSION (CONT.)

FROM TABLE 2., THE HIGHEST PROBABILITY OF 2 OR MORE LOOSE BOLTS PER CONNECTION IS APPROXIMATELY 11.06%, WITH 13 CONNECTIONS OUT OF 194 AFFECTED.

FROM TABLE 3, THE HIGHEST PROBABILITY OF 1 OR MORE LOOSE BOLTS PER CONNECTION IS APPROXIMATELY 5.73%, WITH 50 CONNECTIONS AFFECTED OUT OF A TOTAL OF 1812.

FROM TABLE 4, THE HIGHEST PROBABILITY OF 2 OR MORE LOOSE BOLTS PER CONNECTION IS APPROXIMATELY 7.31%, WITH 30 CONNECTIONS AFFECTED OUT OF A TOTAL OF 1812.

REFERENCES:

HENRY BURGEL AND CHUNG HO CHEN, STATISTICAL STUDY OF POSSIBLE STRUCTURAL STEEL BOLT FAILURES IN UNIT #5, JULY 16, 1981.

WILLIAM MENDENHALL, INTRODUCTION TO PROBABILITY AND STATISTICS, DUXBURY PRESS, BELMONT.

TABLE 1.

CHANCES OF 1 OR MORE LOOSE BOLTS PER CONNECTION

NO. OF CONNECTIONS	PROBABILITY
0	2.02×10^{-8} %
1	5.44×10^{-7} %
5	1.4×10^{-3} %
10	0.205 %
15	3.01 %
20	8.29 %
21	8.64 %
25	6.45 %
30	1.81 %
40	0.0123 %
50	7.87×10^{-9} %

TABLE 2.

CHANCES OF 2 OR MORE LOOSE BOLTS PER CONNECTION

NO. OF CONNECTIONS	PROBABILITY
0	1.60×10^{-4} %
1	2.16×10^{-3} %
5	0.58 %
10	8.12 %
13	11.06 %
15	9.22 %
20	1.96 %
25	0.12 %
30	2.56×10^{-3} %
40	1.36×10^{-10} %

BY J. Gamerol DATE 9/23/81 SHEET 4 OF 5
CHKD. BY A. Tetirow DATE 10/28/81 OFS NO. 3240-263 DEPT. NO. 653
CLIENT WPPSS
PROJECT WNP 3&5
SUBJECT

TABLE 3

CHANCES OF 1 OR MORE LOOSE BOLTS PER CONNECTION

NO. OF CONNECTIONS	PROBABILITY
1	1.15×10^{-10} %
10	4.30×10^{-7} %
20	5.76×10^{-4} %
30	0.097 %
40	2.09 %
50	5.73 %
60	1.995 %
100	3.28×10^{-11} %
150	~0

TABLE 4

CHANCES OF 2 OR MORE LOOSE BOLTS PER CONNECTION.

NO. OF CONNECTIONS	PROBABILITY
1	4.19×10^{-6} %
10	7.48×10^{-3} %
20	1.26 %
30	7.31 %
40	1.47 %
50	0.01 %
60	2.47×10^{-6} %
100	~0

SAMPLE CALCULATIONS:

EX. IN THIS STUDY THE PROBABILITY OF 1 OR MORE LOOSE BOLTS/CONN. WAS ASSUMED AS $\frac{28}{1020} = 0.0275$. FIND THE PROBABILITY THAT EXACTLY 21 OF THE NEXT 794 CONNECTIONS TESTED WILL HAVE 1 OR MORE LOOSE BOLTS.

$p = \frac{28}{1020} = 0.0275$

$q = 1 - p = 0.9725$

$x = 21$

$n = 794$

$$b(x; n, p) = \binom{n}{x} p^x q^{n-x}, \quad x = 0, 1, 2 \ldots n$$

$$= \binom{794}{21} (.0275)^{21} (.9725)^{794-21} = 0.0864324$$

$$= 8.64\%$$

EX. IN THIS STUDY THE PROBABILITY OF 1 OR MORE LOOSE BOLTS PER CONNECTION WAS ASSUMED AS $\frac{28}{1020} = 0.0275$. FIND THE PROBABILITY THAT EXACTLY 50 OF THE TOTAL 1814 CONNECTIONS WILL HAVE 1 OR MORE LOOSE BOLTS.

$p = \frac{28}{1020} = 0.0275$ $\quad \mu_x = np = 1814(.0275) = 49.885$

$q = 1 - p = 0.9725$ $\quad \sigma^2 = npq = 1814(.0275)(.9725) = 48.5132$

$x = 50$

$n = 1814$

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

$$= (2\pi \times 48.5132)^{-\frac{1}{2}} \exp\left[-(50 - 49.885)^2 / 2 \times 48.5132\right]$$

$$= 0.05726919 = 5.73\%$$

FIGURE 1. PROBABILITY OF 1 OR MORE LOOSE BOLTS PER CONNECTION IN THE 794 UNINSPECTED CONNECTIONS

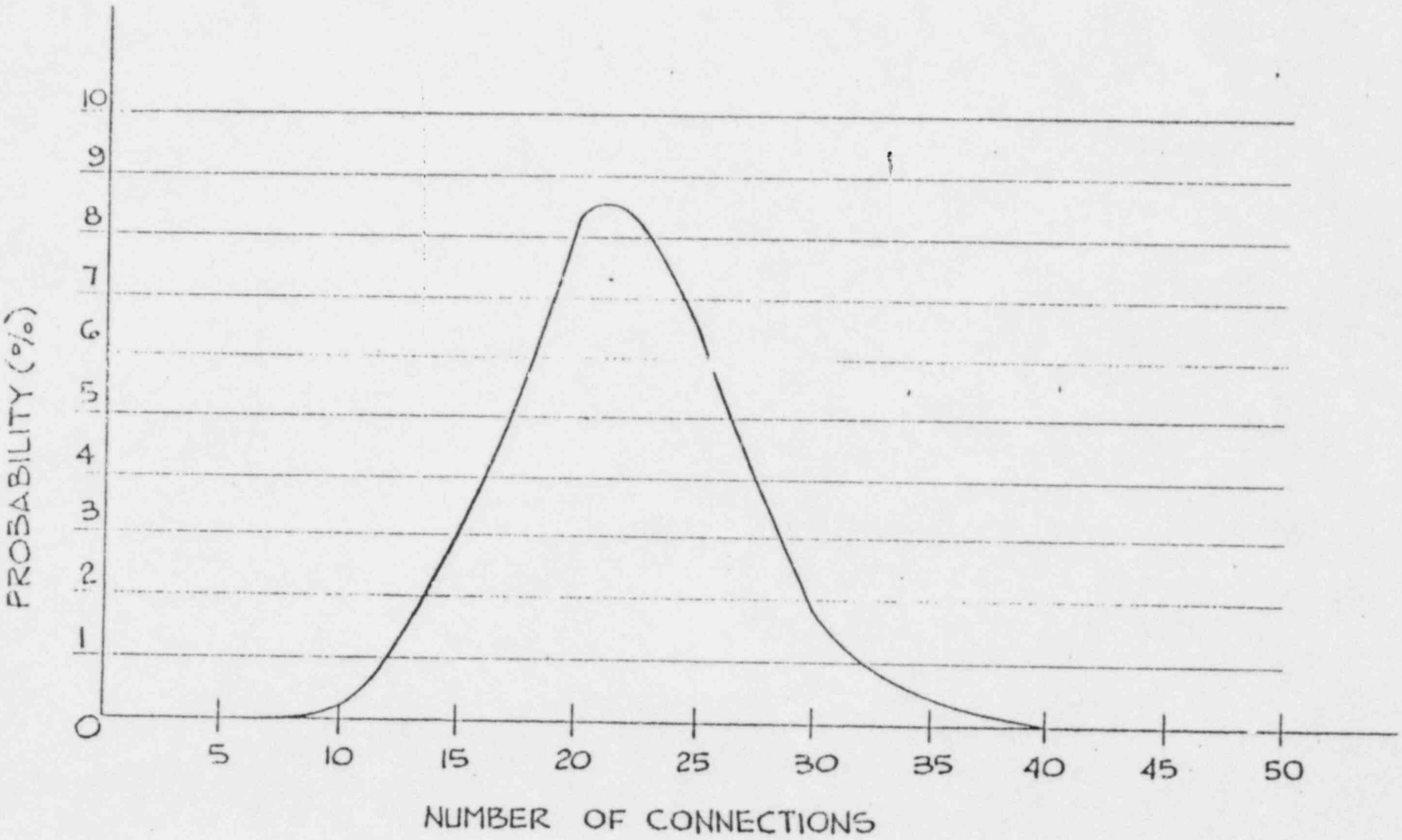


FIGURE 2. PROBABILITY OF 2 OR MORE LOOSE BOLTS PER CONNECTION IN THE 794 UNINSPECTED CONNECTIONS

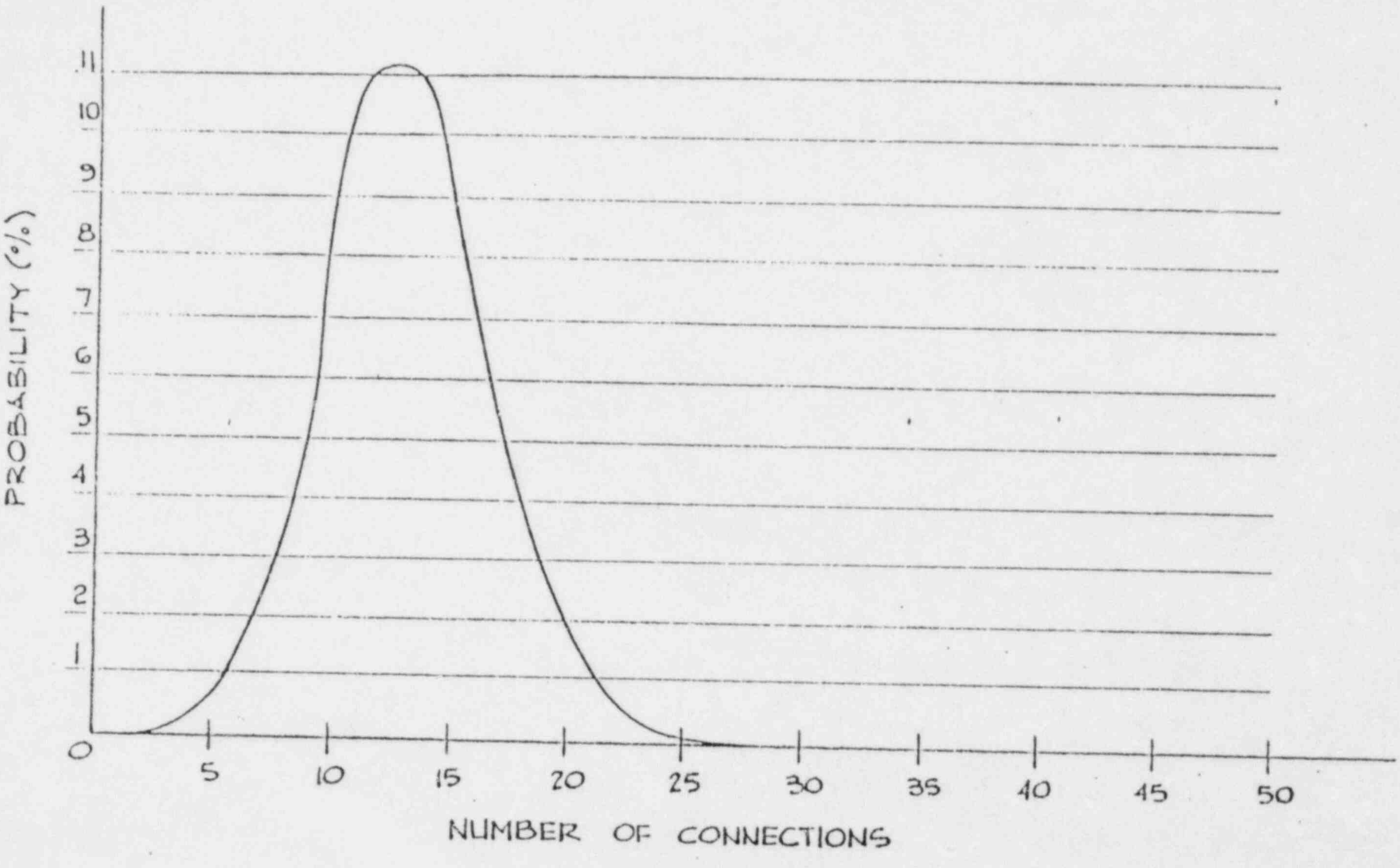


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FIGURE 3. PROBABILITY OF 1 OR MORE LOOSE BOLTS PER CONNECTION IN ALL 1814 CONNECTIONS

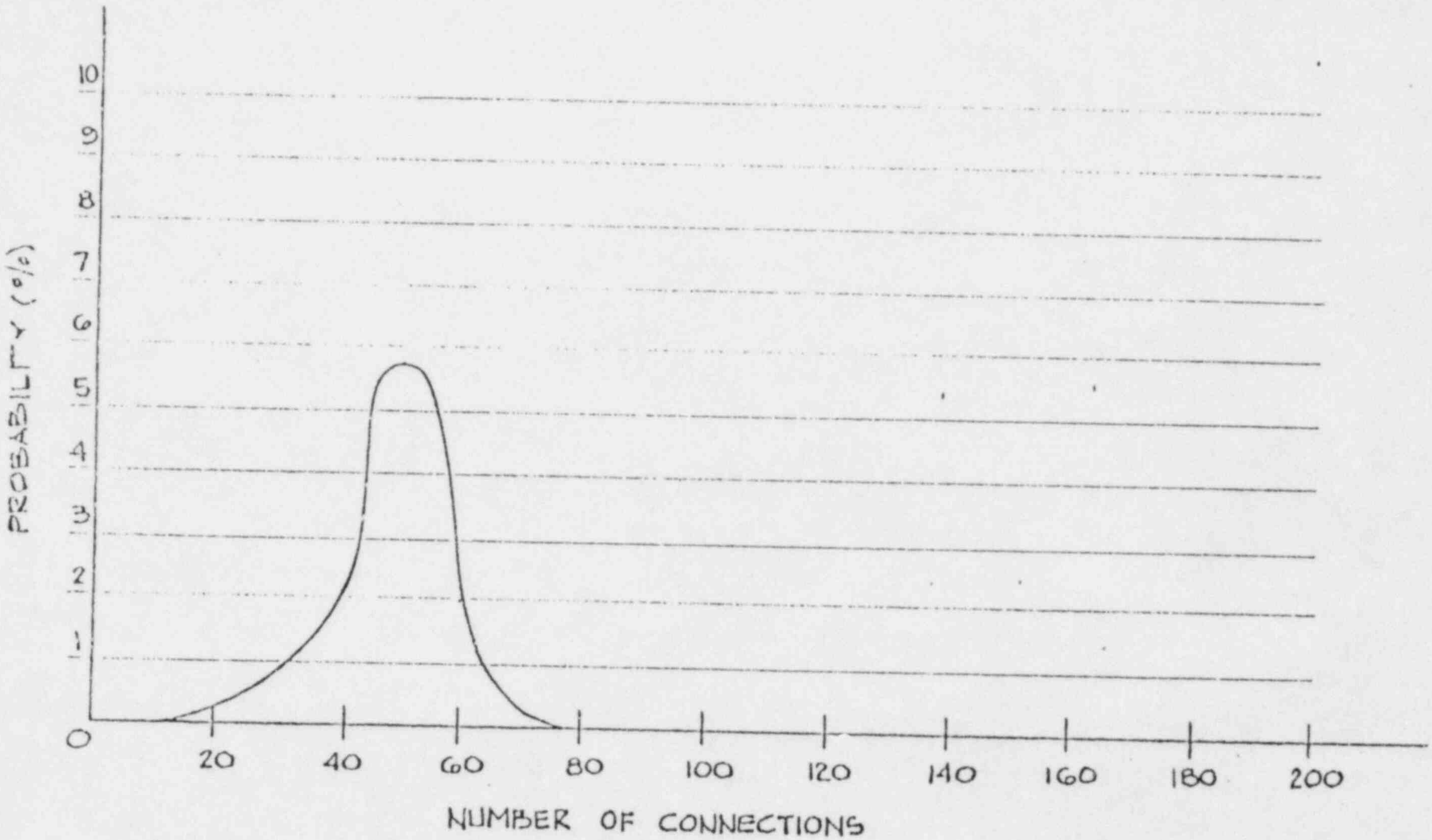

FIGURE 4. PROBABILITY OF 2 OR MORE LOOSE BOLTS PER CONNECTION IN ALL 1814 CONNECTIONS