SMUD

SACRAMENTO MUNICIPAL UTILITY DISTRICT

Received 9-18-69

RANCHO SECO NUCLEAR GENERATING STATION
UNIT NO. 1

ATTACHMENT B

SUPPLEMENTAL INFORMATION ON VSL TENDON SYSTEM

DOCKET 50-312

SEPTEMBER 1969

ATTACHMENT B

SUPPLEMENTAL INFORMATION ON VSL TENDON SYSTEM

Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, 8600 Dübendorf

Swiss Federal Laboratory for Testing Materials and Research

— 8600 Dübendorf —

C O P Y

Untersuchungsbericht

TEST-REPORT EMPA No. 66'565

Customer: L o s i n g e r & Co SA, B E R N E / Switzerland
on behalf of VSL Corporation,
236 North Santa Cruz Avenue, Los Gatos, California 95030

Object: 2 cables, each consisting of 55 x 1/2" dia. Supa-7 strands (270 k) and 2 VSL Anchor heads type E 5-55 each with 55 wedges.

Order: of January 22, 1969
Ultimate load capability tests

Date of receipt: January 22, 1969

Tests carried out on January 29 and 30, 1969

Results of ultimate load tests

Test carried out in the Laboratories of the EMPA

1. Test equipment
2. Test procedure
3. Description of tests with results

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Remark: The use of this report for the purpose of publicity of any kind, including mere reference to it, requires the approval of the directors of the EMPA

F 94147

1. Test equipment

- One Amsler 2'000 t (metric) press, type 2'000 D 160 (see photograph EMPA N° 52'879).
- The press was provided with a spring-pressure gauge 2000 tons. Maximum clear height 26'-3".
- One special steel device allowing to use the Amsler press for tensile tests (see sketch EMPA N° 4-46'452).
- One x-y writer Honeywell Model 580 M.
- Two inductive displacement pick-ups.
- Two carrier wave amplifiers 5kHz of Hottinger Baldwin Messtechnik GmbH, type KWS/ -5.
- One dial gauge extensometer.

2. Test procedure

The tendon is positioned in the special steel device. The latter is then moved on rails into the Amsler press. The wedges in the anchor heads are locked in by means of a hammer. The initial length of the tendon is recorded. The load-extension diagram is recorded on the x-y writer by means of the 2 carrier wave amplifiers. A dial gauge extensometer was used to check the extension recorded by the writer.

The load was first brought to a level of 33 t (short tons), in order to control the writer, then brought back to zero.

3. Description of tests with results

All data given in short tons

3.1 Test A

Test date: January 29, 1969.

Test personnel: Mr. Ginzery, Mr. Vollenweider, Mr. Blaser } EMPA.

Objective: The purpose of the tests was to determine

- The ultimate load capability of a VSL Tendon type EE 5-55 consisting of 55 strands and two VSL Anchorages.
- The maximum elongation of the tendon at ultimate load.

3.1.1 Specimen (Data supplied by customer)

- One cable consisting of 55 strands, 7 wires, Supa-7 grade (270 k) low relaxation.

  Manufacturer: British Ropes Ltd., Doncaster, England.

  Nominal diameter of one strand: 1/2" (12.7 mm).

  Nominal area of one strand: 0.153 in2 (98.7 mm2).

  Physical properties

  ultimate strength of a strand: 41'300 lb (18'733 kg),

  yield strength (at 1 % extension): 35'105 lb (15'923 kg),

  approximate modulus of elasticity: 30.1×10^6 lb/in2 (21'163 kg/mm2),

  minimum elongation at rupture: 4 % on 24 inches.

  Strand reference number: 3243 B.

  Test reference of manufacturer: D 4H/583.

- 2 VSL Anchor heads type E 5-55.
  Manufacturer: Losinger & Co SA, Berne, Licensor of VSL System.

- 110 VSL Wedges 1/2" Supa.
  Manufacturer: Losinger & Co SA, Berne, Licensor of VSL System.

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3.1.2 Minimum required

Guaranteed ultimate load of tendon = 41'300 x 55 = 2'271'500 lb = 1'135.75 t (1'030.33 metric tons).

0179 Minimum required extension of tendon at ultimate load = 3 %.

3 % of test length = 120.5 x 0.03 = 3.615 in (91.8 mm).

3.1.3 Results of test A

Load			Number of broken wires		* Extension		
short tons	metric tons	% of f's	total	% of total wires	in	mm	%
1'127	1'022	99.2	1	0.26	3.70	94.0	3.07
1'139	1'033	100.3	2	0.52	4.25	108.0	3.53
1'142	1'036	100.6	3	0.78	4.53	115.0	3.76
1'142	1'036	100.6	4	1.04	4.64	118.0	3.86
1'141	1'035	100.5	7	1.82	4.80	122.0	3.99

* Extensions taken from diagram EMPA N° 3-48'453.
The values include an allowance of 0.354 in (9 mm) for drawn-in of wedges during test.

No visible distortion was observed in VSL Anchor head after rupture of tendon.

3.2 Test B

Test date: January 30, 1969

Test personnel: Mr. Ginzery, Mr. Vollenweider, Mr. Blaser } EMPA.

Objective: As per 3.1.

3.2.1 Specimen: As per 3.1.1.

3.2.2 Results of test B

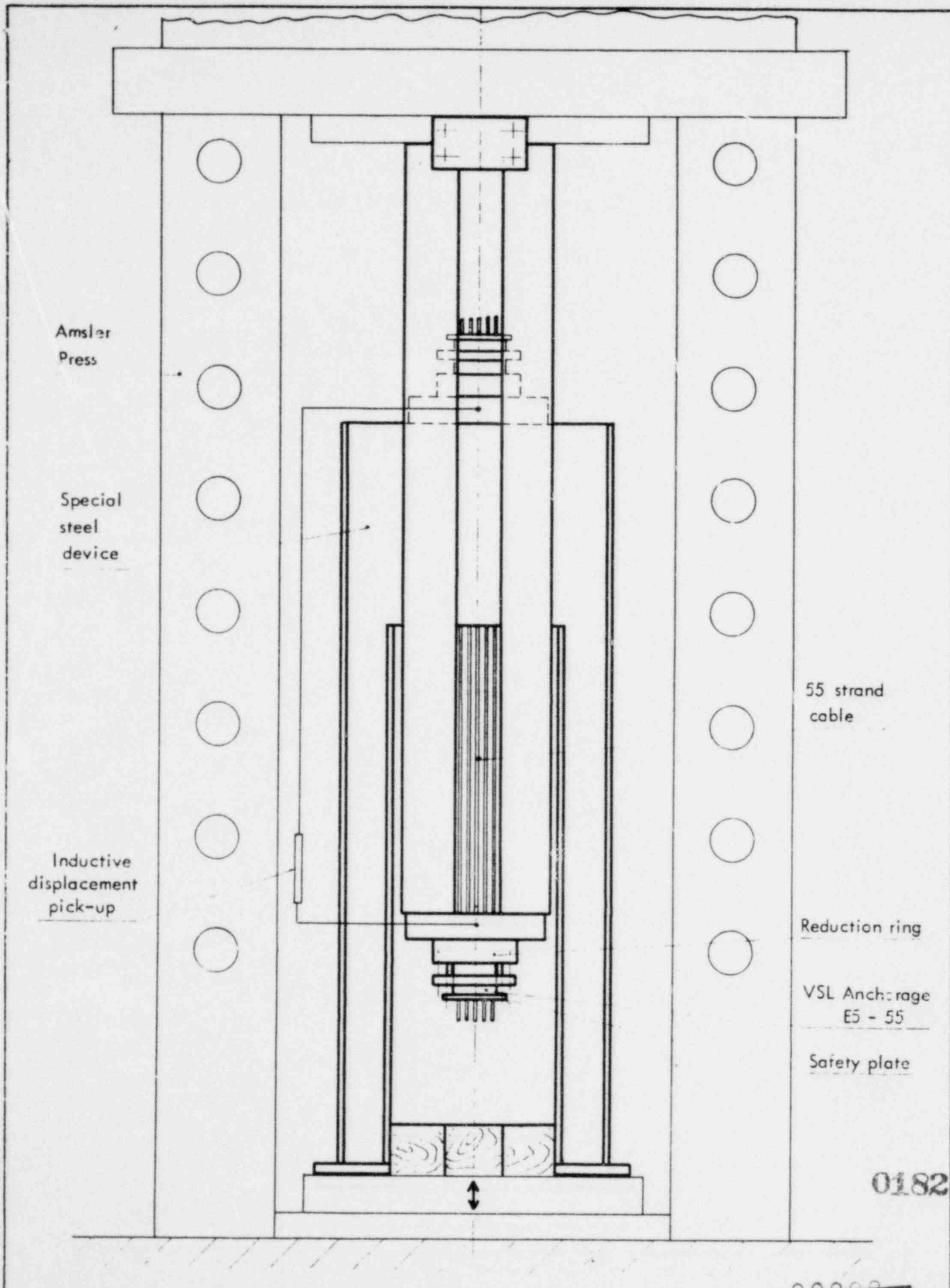
Load			Number of broken wires		* Extension		
short tons	metric tons	% of f's	total	% of total wires	in	mm	%
1'131	1'026	99.6	1	0.26	3.84	97.5	3.19
1'124	1'020	99.0	3	0.78	3.86	98.0	3.20
1'130	1'025	99.5	4	1.04	4.11	104.5	3.42
1'135	1'030	99.9	5	1.30	4.45	113.0	3.69
1'135	1'030	99.9	6	1.56	4.57	116.0	3.79
1'136	1'031	100.0	7	1.82	4.82	122.5	4.00
1'142	1'036	100.6	8	2.08	5.16	131	4.28

* Extensions taken from diagram EMPA N° 3-48'454.
The values include an allowance of 0.354 in (9 mm) for draw-in of wedges during test.

No visible distortion was observed in VSL Anchor head after rupture of tendon.

Dübendorf, January 30, 1969

Swiss Federal Laboratory for Testing Materials and Research



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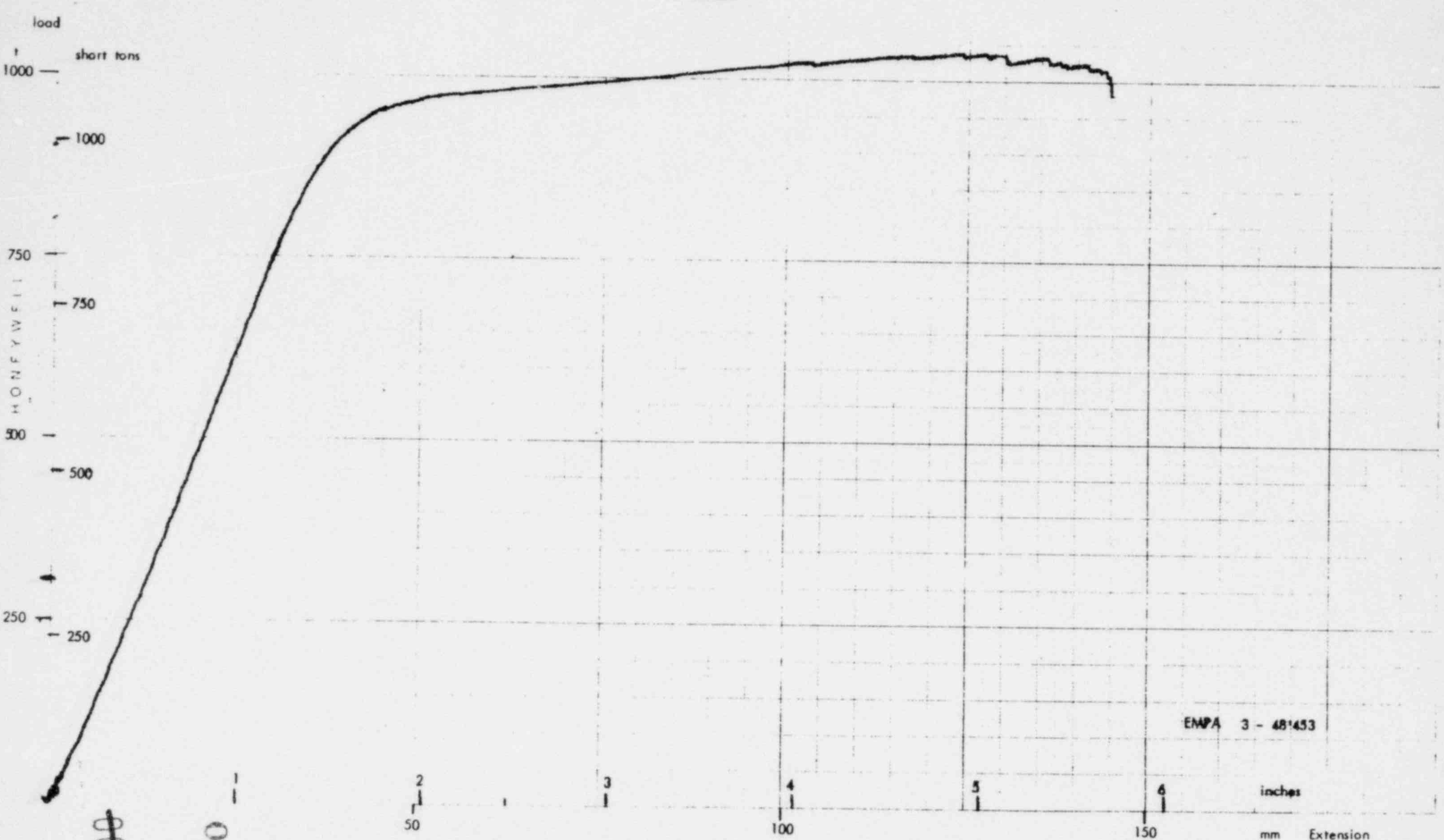
TEST INSTALLATION

EMPA	Auftrags-Nr. 66'565	Auftraggeber: Losinger + Co SA Berne	Gezeichnet: 30. 1 69	Zeichnungsnummer: 4 — 48'452

LOAD - EXTENSION DIAGRAM OF VSL TENDON

Test A



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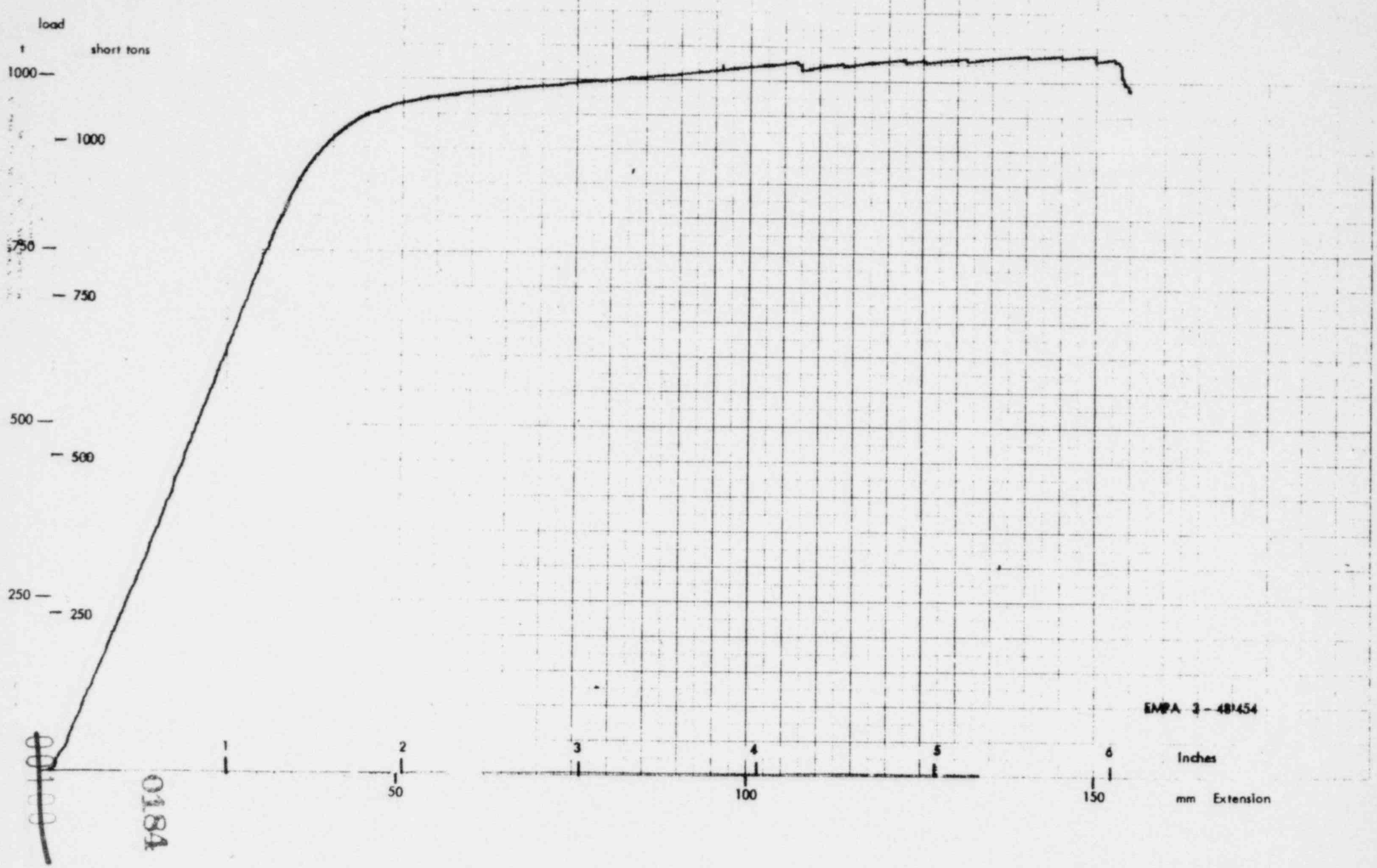
LOAD - EXTENSION DIAGRAM OF VSL TENDON

Test B



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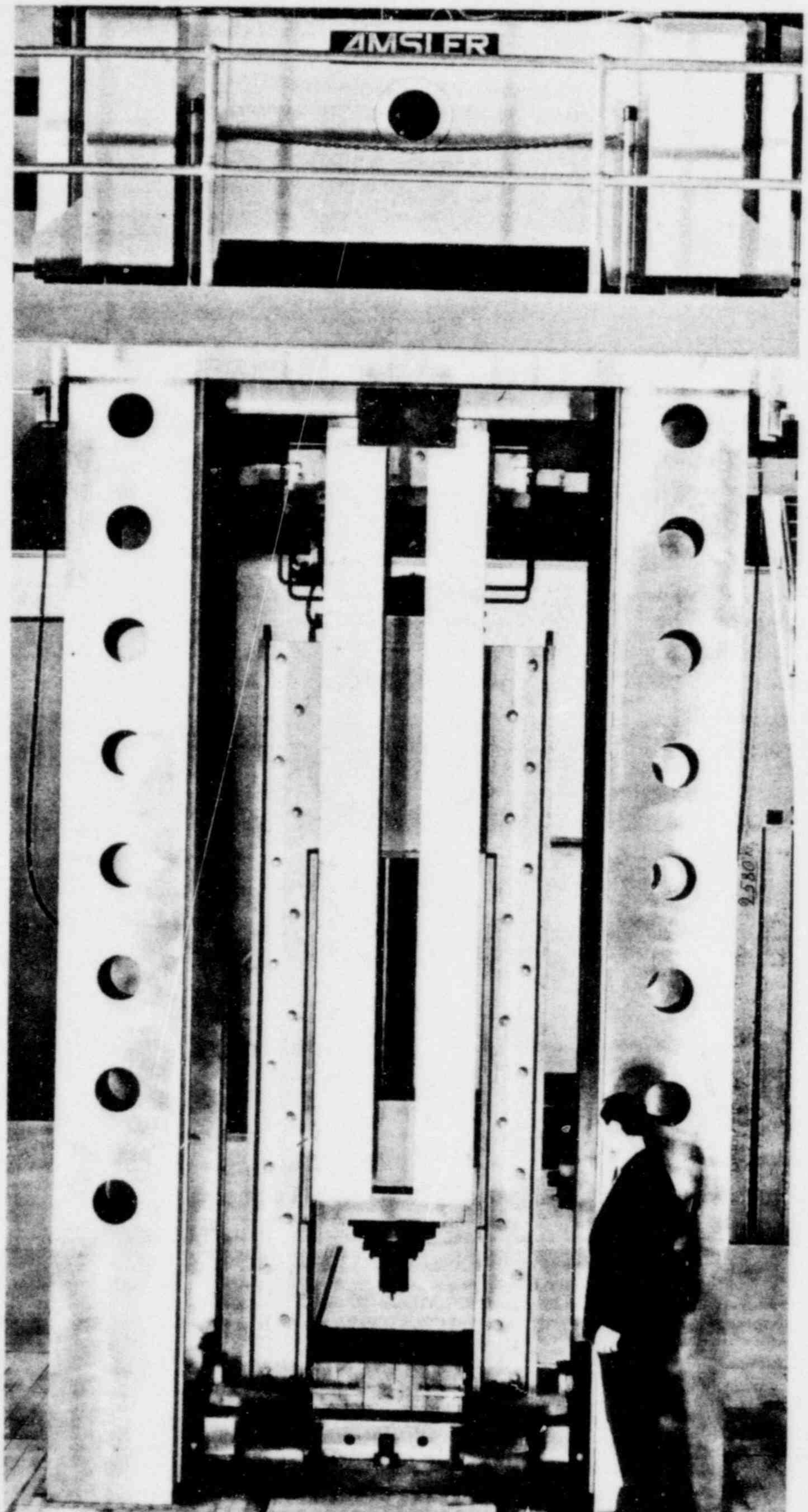
T e s t   I n s t a l l a t i o n

Photograph EMPA Nº 52'879



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BRITISH ROPES LIMITED

INSPECTION DEPARTMENT

DONCASTER MILL

TEST REPORT

STRAND FOR PRESTRESSED CONCRETE

HB/D

TEST REFERENCE: D4H/ 583

DATE: 2nd August, 1968.

DISTRIBUTION:

Customer	(3)
K.W.Longbottom Esq.	(1)
File	(1)

B.R. SERIAL: 32/6792

CUSTOMER ORDER NO:

STRAND SENT TO:

Herr Dietrich,
E.M.P.A.

INSPECTION ON BEHALF OF:

Herr Dietrich,

E.M.P.A.

MATERIAL: 1/2" 'Supa' 7 P.S.C. Strand. (L-R)

SPECIFICATION NO.: BR Data Sheet 3/63

% TESTED: 100

REPRESENTING: 1 coil

WEIGHT: 1036 lbs.

APPROX. I.D. OF COIL OR REEL: 3 ft.

NOMINAL STEEL AREA: 0.153 in^2

NOMINAL WEIGHT: 0.525 lb / ft.

	STRAND REFERENCE NUMBER	REEL IDENTITY NUMBER	NOMINAL STRAND DIA. IN.	BREAKING LOAD ~~KILOS~~ POUNDS	LOAD AT 0.2% ~~0.1%~~ OFFSET ~~KILOS~~ POUNDS	LIMIT OF PROP 0.01 % OFFSET ~~KILOS~~ POUNDS	ELONGATION ON 24 in. TO FRACTURE %	WEIGHT OF STRAND IN COIL OR ON REEL ~~KILOS~~ POUNDS	APPROXIMATE LENGTH IN COIL OR ON REEL ~~METRES~~ FEET
SPEC. MIN.			1/2	41300	35105	24780	4.0		
	3243 B.		1/2	43700	38900	33000	7.3	1036	1973

TECHNICAL INFORMATION: For current information and any technical queries regarding this strand, please refer to

TECHNICAL SERVICES—WIRE DIVISION

DONCASTER

QUOTING CERTIFICATE AND STRAND REFERENCE NUMBERS

TESTED BY: ~~00102~~

APPROVED AND RELEASED BY: 0186

Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, 8600 Dübendorf
Swiss Federal Laboratory for Testing Materials and Research
— 8600 Dübendorf —

Untersuchungsbericht

TEST-REPORT   EMPA No. 71'620/1

Customer: L o s i n g e r & Co. A.-G.   B e r n e

Object: one anchor head type "VSL E 5-55, 1:29.1.69"
made of Ck 45, standardized, Ø 12,5" x 5,9"

Concern: order 291/Die/bf dated 27.8.1969

- Data supplied by the client -

Date of receipt: 27.8.1969   Execution of investigation:

Investigation order : 1) Tension test with strain controls and impact test with Charpy-V-notch.

2) A photograph of the cut anchor head with representation of the samplings.

T E S T R E S U L T S

1. Tension test with strain control
2. Impact tests
3. Photograph EMPA-Nr. 56 988

R e m a r k

The results of further tests at the anchor head follow in a separate test-report.

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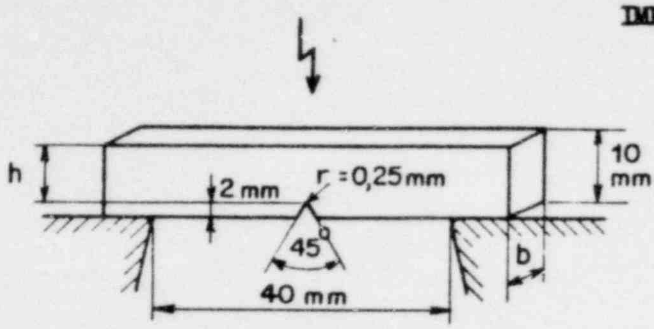
Kerbschlagversuche
Essais de résilience — Prove di resilienza
IMPACT TESTS



Schlagarbeit des Pendelhammers
Travail du mouton
Impact energy of the pendulum hammer: 217 ft.lb

Probenform:
Forme de l'éprouvette: Charpy-V-Kerbe
Form of the specimen: Charpy-V-notch

Bezeichnung Désignation **Designation**	Versuchs-Temperatur Température d'essai **Temperature** °C	Abmessungen Dimensions **Dimensions** cm b	 h	Querschnittsfläche Section **Cross section** b x h cm²	Kerbschlagzähigkeit Résilience **Notch toughness** K ft.lb	Biegungswinkel Angle de flexion **Bending angle** φ°	Beschaffenheit der Bruchfläche Etat de la section de rupture **Condition of fracture aerea**
L B	**sampling axial in the center of the anchor head**						
1	-24	1.00	0.80	0.80	3.6	2	gritty
2	-24	1.00	0.80	0.80	4.3	2	gritty
3	-24	1.00	0.80	0.80	4.3	2	gritty
	sampling in axial direction on the half radius of the anchor head						
4	-24	1.00	0.80	0.80	5.1	2	gritty
5	-24	1.00	0.80	0.80	3.6	2	gritty
6	-24	1.00	0.80	0.80	5.1	2	gritty

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RT – Raumtemperatur
TA – Température ambiante
TA – Temperatura d'ambiente

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TENSION TEST WITH STRAIN CONTROL

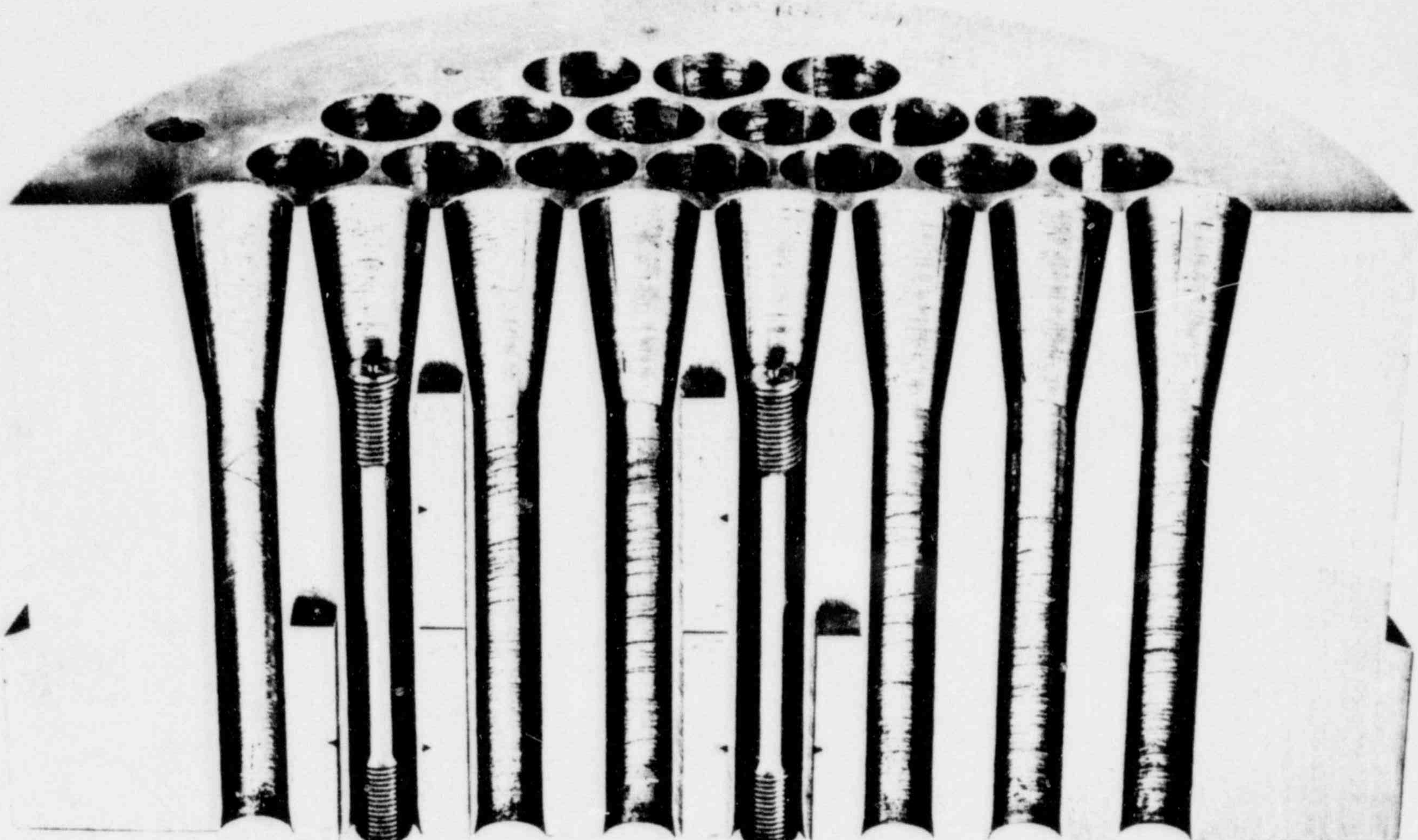
Indications about test material: Tensil test specimens with circular cross-section and threaded heads, taken from the anchor head; polished surface.

Methode of test: σ_s of 2 ‰ permanent set, recorded with inductive strain-measuring instrument, L_o = 50 mm

Designation of the bars	Dimension size Ø mm	Cross section A_o mm2	Elastic limit σ_s mm2	Tensile strength σ_B kg/mm2	$\frac{\sigma_s}{\sigma_B}$	Contraction ψ %	Elongation after breakage δ_{10} %	δ_5 %	δ_{Gl} %	Remarks
LB	samplings axial in the center of the anchor head									
1	9.98	78.2	27.9	62.5	0.45	37	-	22.6	14.0	toothed, languid fraction
	samplings in axial direction on the half radius of the anchor head									
2	9.98	78.2	26.5	62.0	0.43	45	-	24.4	15.2	toothed, languid fraction

Dübendorf, September 4, 1969

PHOTO EMPA-NR. 56 988



samplings: in axial direction on the half radius ↑ in the center ↑

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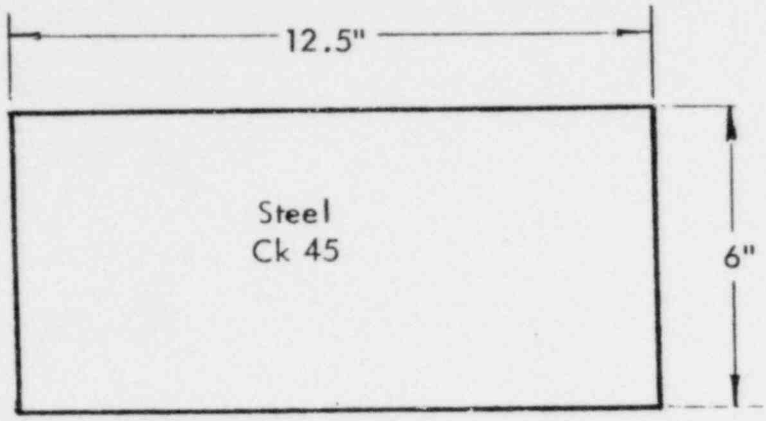
ANCHORAGE MATERIALS USED IN EMPA TEST NO. 71' 620/1

VSL E5-55
ANCHOR HEAD:



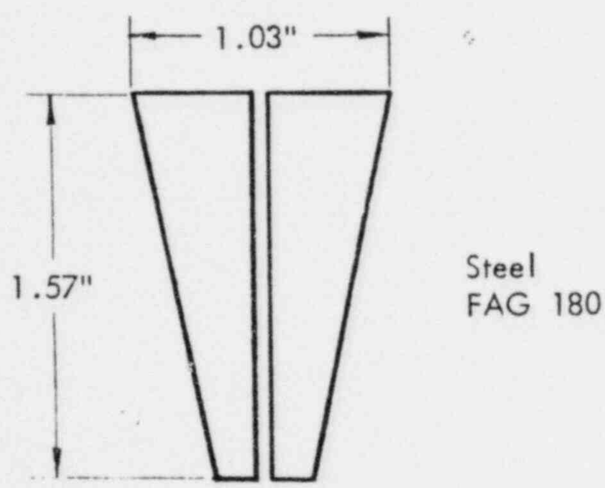
CHEMISTRY:

C	Mn	Si	S	P
.0470	0715	0300	0032	.0012

MECHANICAL PROPERTIES:

Heat Treatment	Y.P.	U.T.S.	% Elongation
Normalized	48.25 ksi	85-106 ksi	18%

VSL WEDGES:



CHEMISTRY:

C	Mn	Si	P	S	Ni	Cr	Mo
.16	.77	.33	.018	.006	1.30	.87	.17

MECHANICAL PROPERTIES:

Heat Treatment

Case hardened to .016" depth

RELATIVE DEFLECTIONS, STRAINS AND STRESSES
IN A VSL E5-55 STRAND BEARING PLATE

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<u>Date and Location of Tests:</u> March 11, 1969 and June 3, 1969 at
University of California
Structural Research Laboratory
Richmond, California

<u>Purpose:</u> To test the acceptability of the VSL E5-55 strand bearing plate whose dimensions and composition are as follows (typical for both Tests No. 1 and No. 2):

Carbon	=	.20
Manganese	=	1.25
Phosphorus	=	.02
Sulphur	=	.25
Tensile Strength	=	67,000 psi
Yield Point	=	45,000 psi
Elongation in 2"	=	30%
Reduction of Area	=	60%
Brinell Hardness	=	149
E_s	=	30×10^6 (max.)
Dimensions of Plate	=	24" x 24" x 3-1/2" with a 9" diameter center hole

These tests were performed to demonstrate the acceptability of the VSL E5-55 Strand Bearing Plate. The investigation was conducted in two parts. In Test No. 1, relative deflections of the surface of the bearing plate were measured as various percentages of the ultimate load for a 55-strand tendon were applied. In Test No. 2, a second identical plate was loaded in the same fashion except in this instance, strain gage measurements were made on the top surface and edges. Loads were applied to the anchor heads on both tests with a ram. In both tests the plates had no transition trumpets, and the concrete blocks on which they were tested had exactly the same cross-section as the plates themselves. Neither of these conditions is presumed to have offered structural advantages to the sample plate not present in an actual field condition. Of equal importance to these deflection and stress spot checks was a general inspection of the plates from both tests after the load had been released to ascertain the location and magnitude of any permanent deformations or cracks which would indicate yield, relaxation or brittle failure.

Test No. 1 - Deflection Test

Measurements were made by placing a straight edge along numbered lines on the plate surface and measuring with a feeler gage the gap between the straight edge and the plate surface. The corners of the plate were used as datum. Edge of plate elevations for straight edge position parallel to edges of the plate were calculated assuming a parabolic curve from the corners to the measured low point on the center of each edge. To these calculated deflections were added the feeler gage measurements.

At 100% f's (2,272 K) the corners of the plate were observed to have lifted clear of the concrete 0.014 inches. This gap reduced to zero about 2 inches down each edge from the corner. Upon release of load, the plate evidenced no permanent deformation other than permissible initial set. The concrete block on which the bearing plate was tested was 24' x 24' x 24'. Interfaces between the block and bearing plate and the block and floor were grouted level with hydrostone.

Block failed after about 10 minutes of sustained load at 2,272,000 pounds. Failure was non-explosive in nature, there being no sound of fragmentation. Cause was apparently insufficient curing time, as the second test block being reinforced in the same fashion did not fail at 109% of f's. The most important conclusions from Test No. 1 were that the top surface of the plate, from a plot of contours, appeared to be concave toward the concrete. This assessment was later borne out to be correct on Test No. 2 which indicated radial tension and circumferential compression over the entire top surface of the plate.

After removal of 2,272 K load, there was no visible deformation of the bearing plate other than permissible initial set, indicating an essentially elastic action.

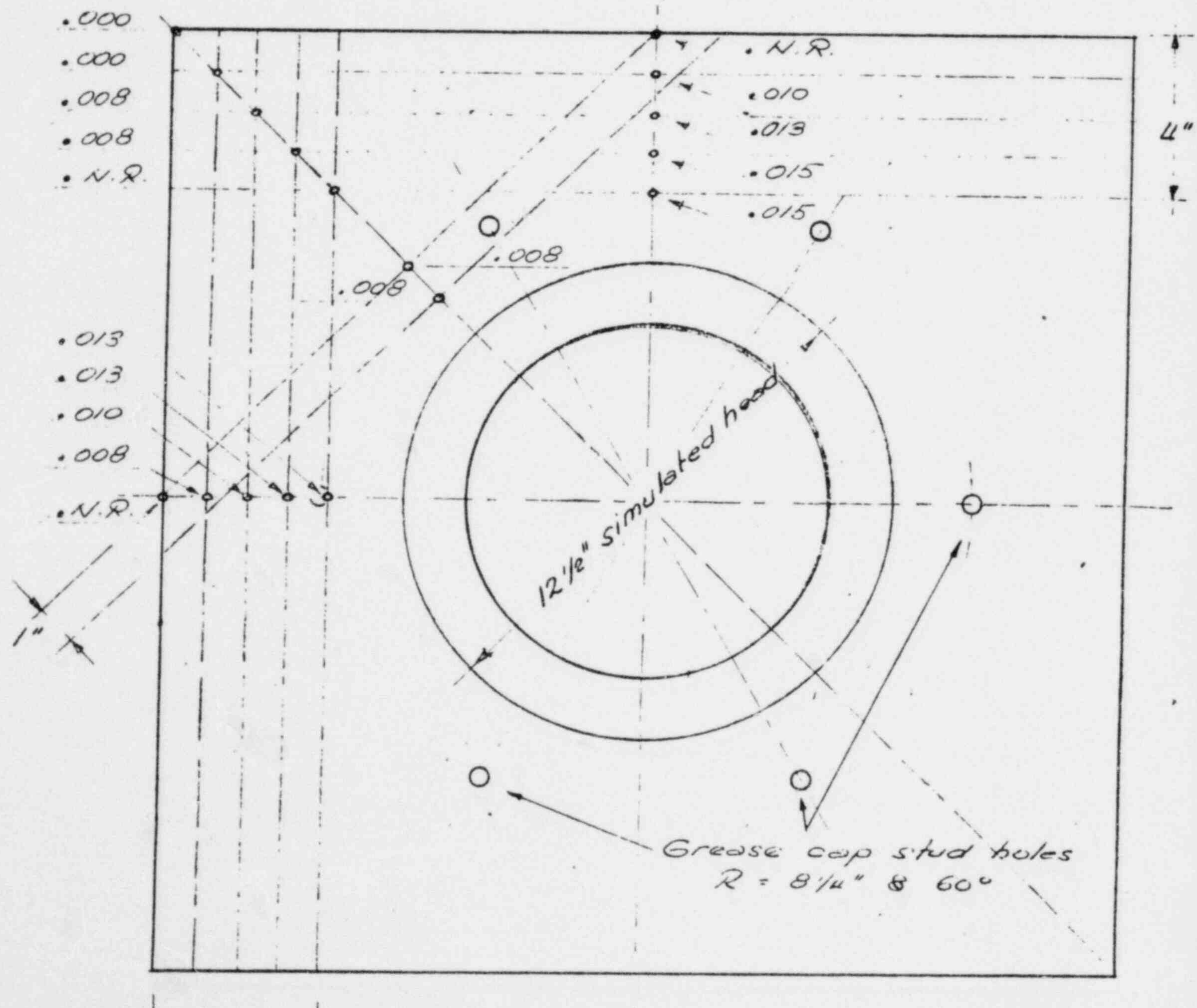
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" x 24" x 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CALI.



Load = 50 %

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0195

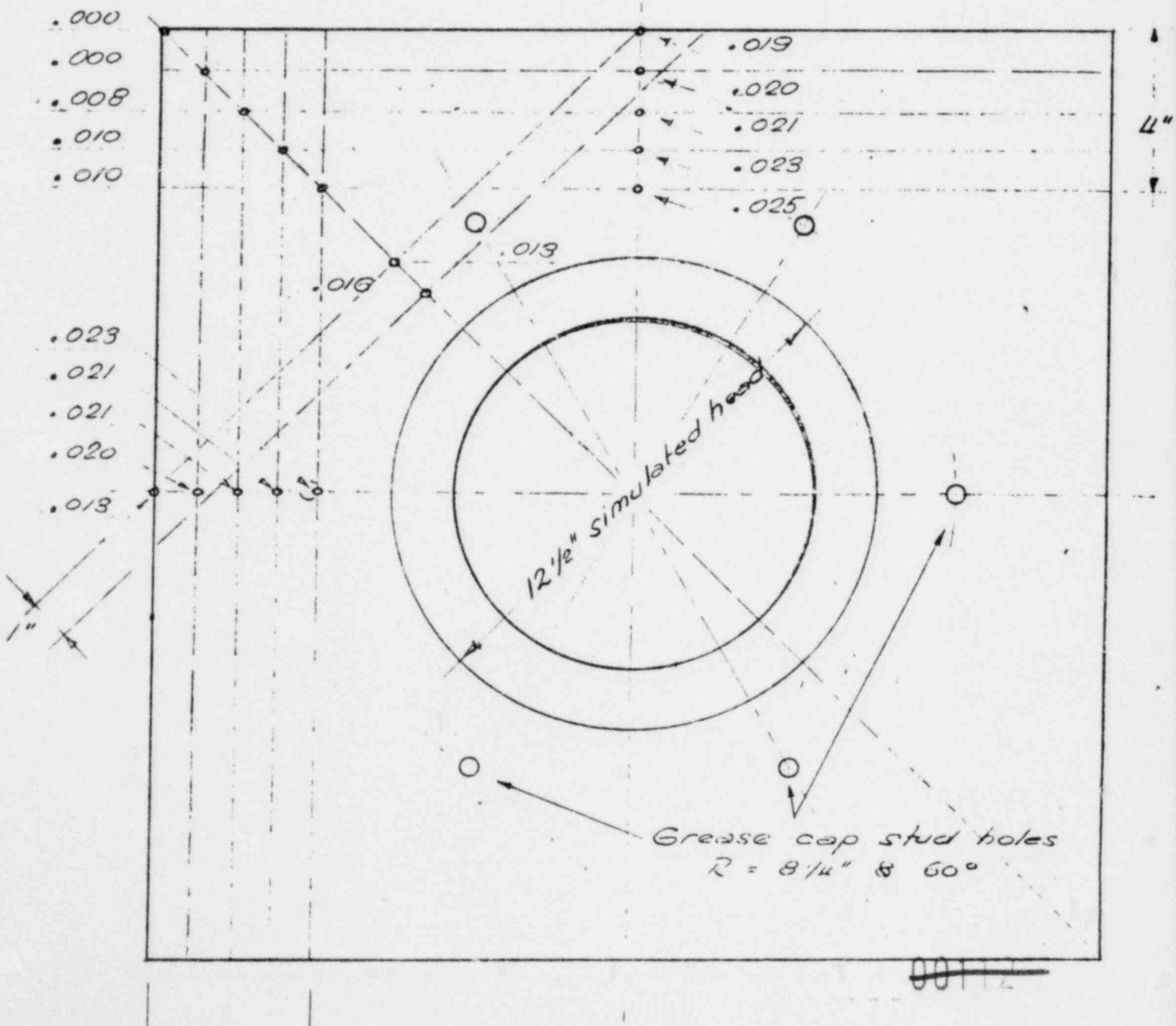
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" × 24" × 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CAL[illegible]



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0196

Load = 75 %

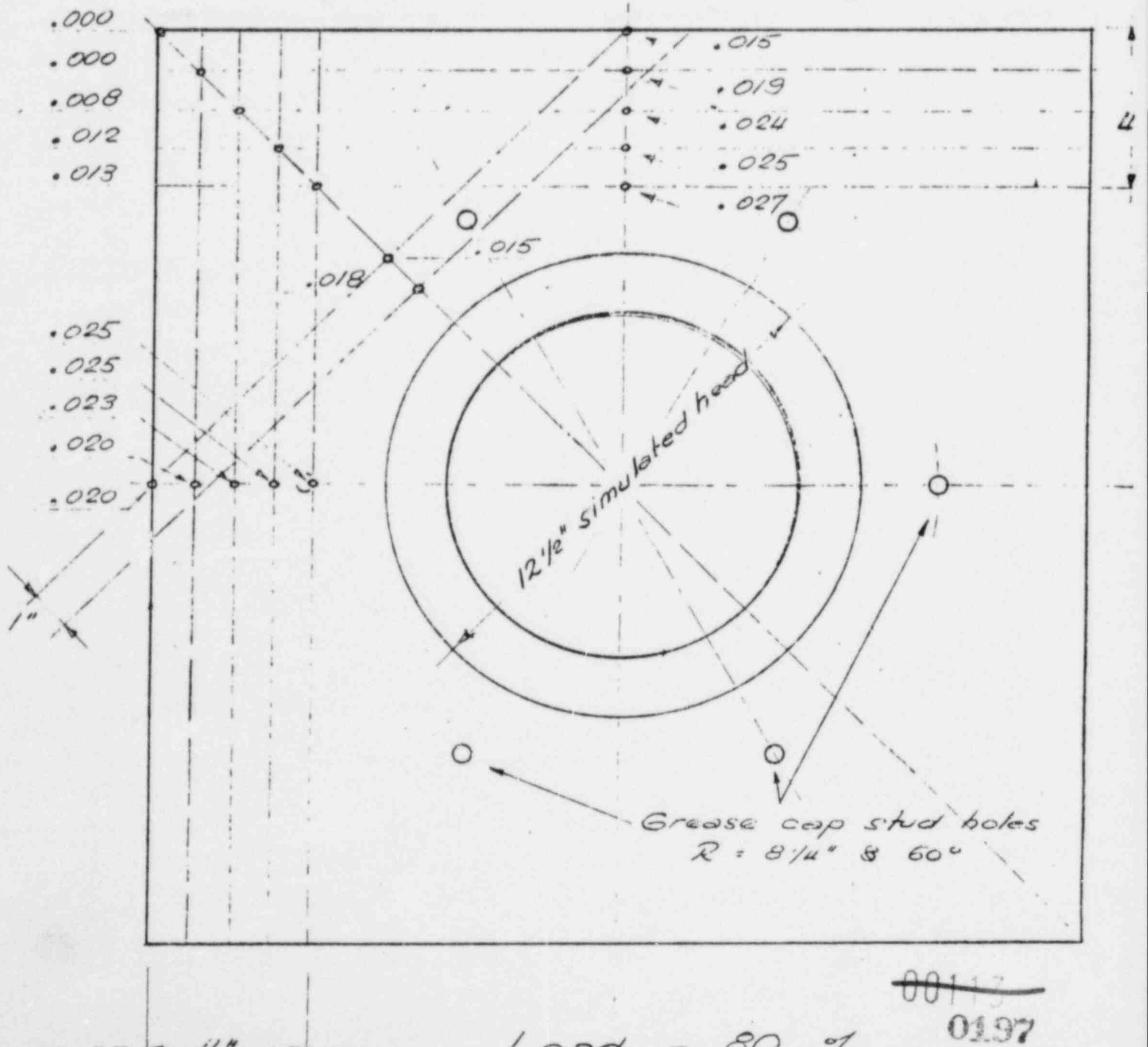
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" x 24" x 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CAL



Load = 80 %

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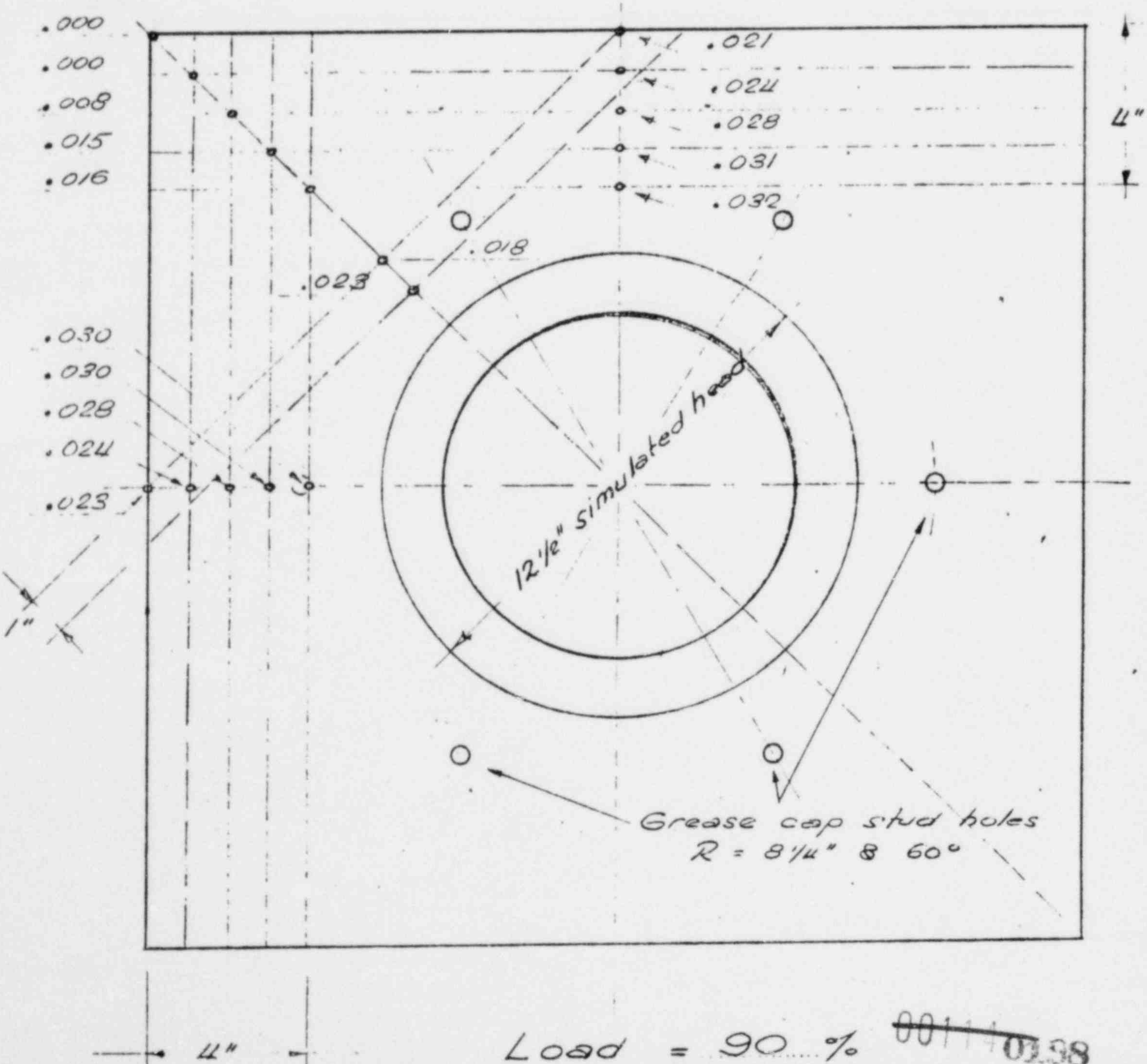
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" × 24" × 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CALI.



Load = 90 %

N.R. = No reading

100 % = 2,270 Kips

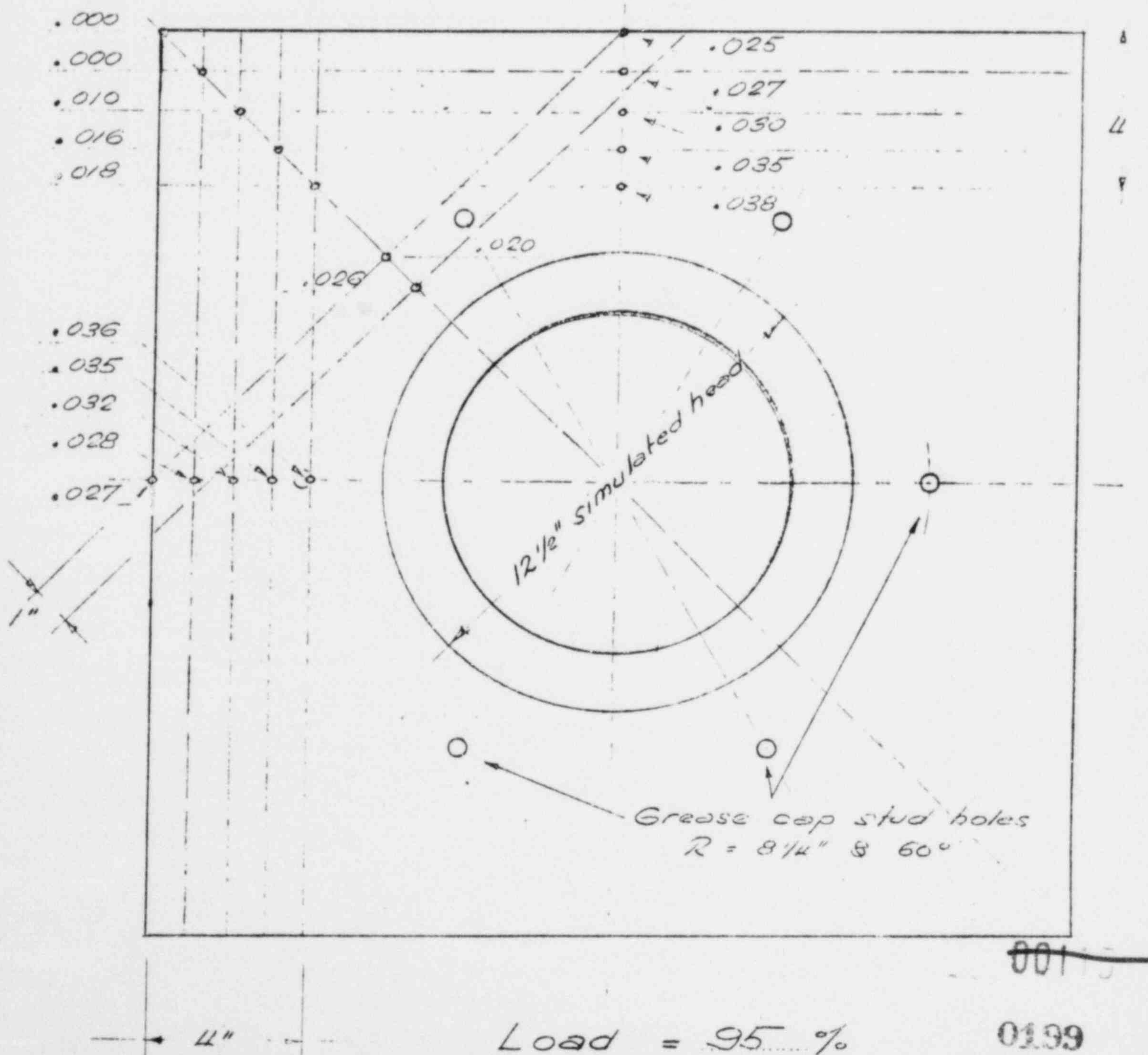
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" × 24" × 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CAL



Load = 95 %

N.R. = No reading   100 % = 2,270 Kips

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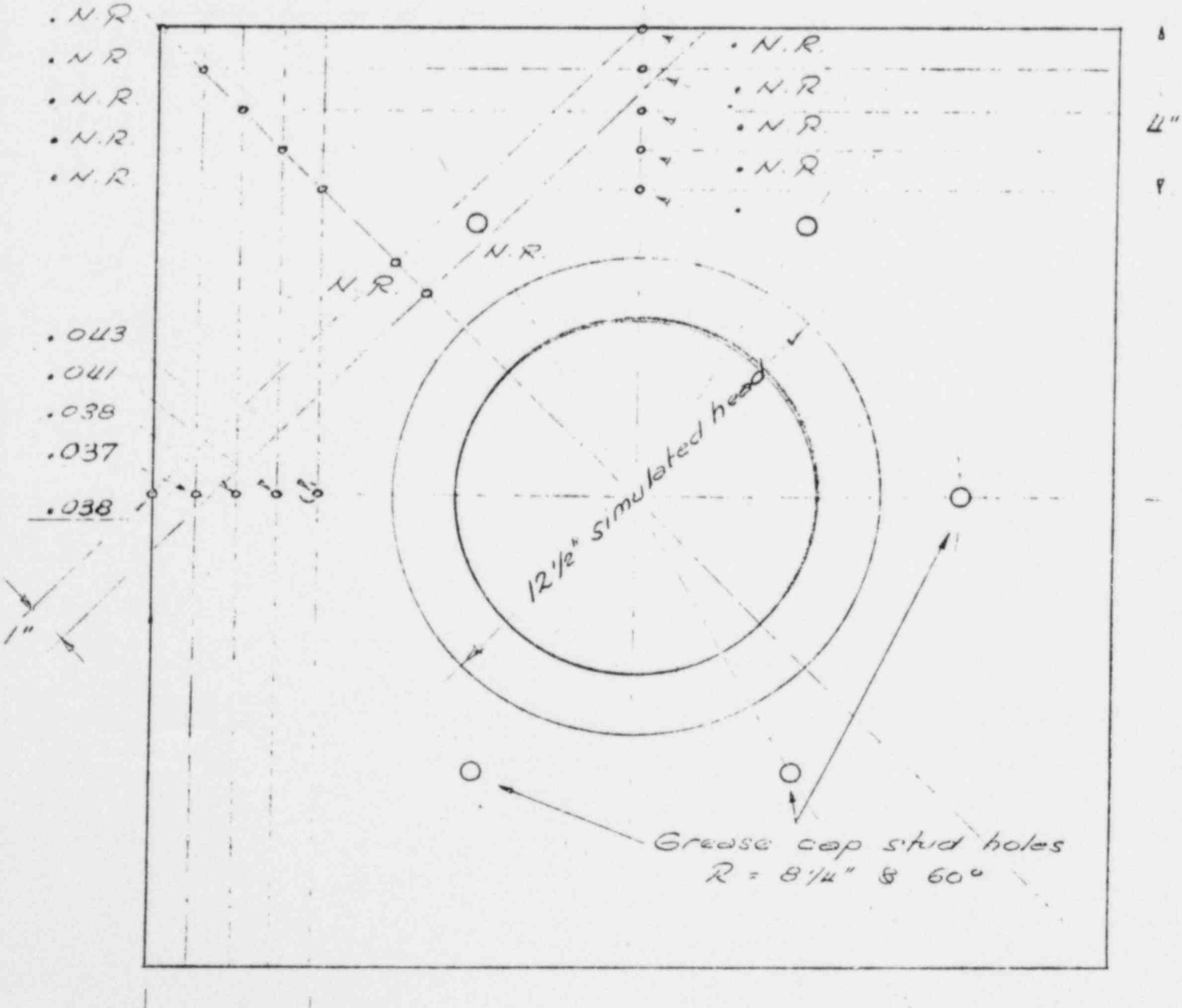
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" x 24" x 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CALI



Load = 100 %

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0200

N.R. = No reading

100 % = 2,270 Kips

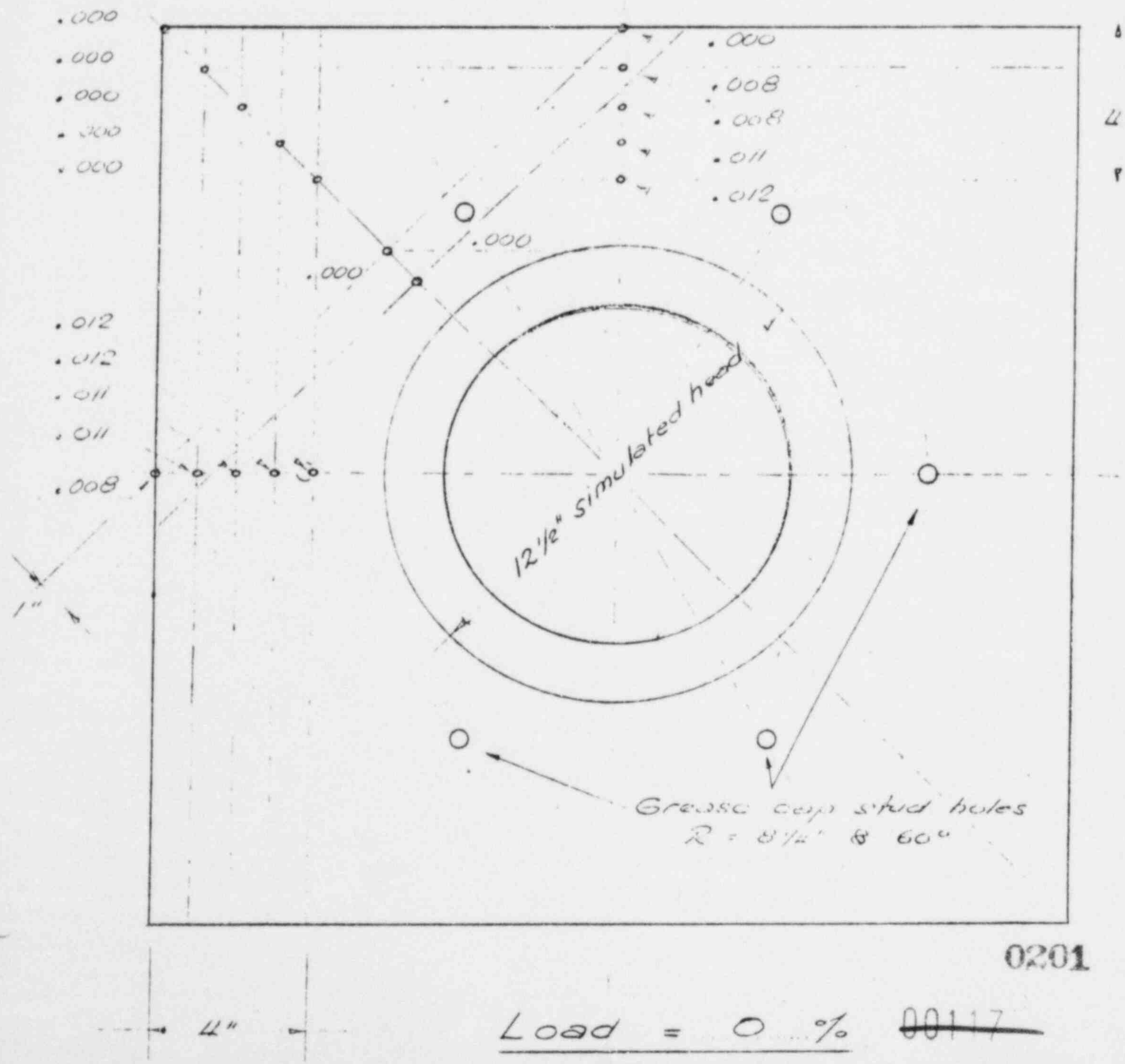
VSL Corporation
Los Gatos

DEFLECTION TEST ON VSL E5-55 BEARING PLATE

24" x 24" x 3½

RELATIVE DEFLECTION READINGS

MADE ON 11th MARCH 69 AT UNIVERSITY OF CALIFORNIA STRUCTURAL RESEARCH LABOR., RICHMOND, CALIF



0201

Load = 0 % ~~00117~~

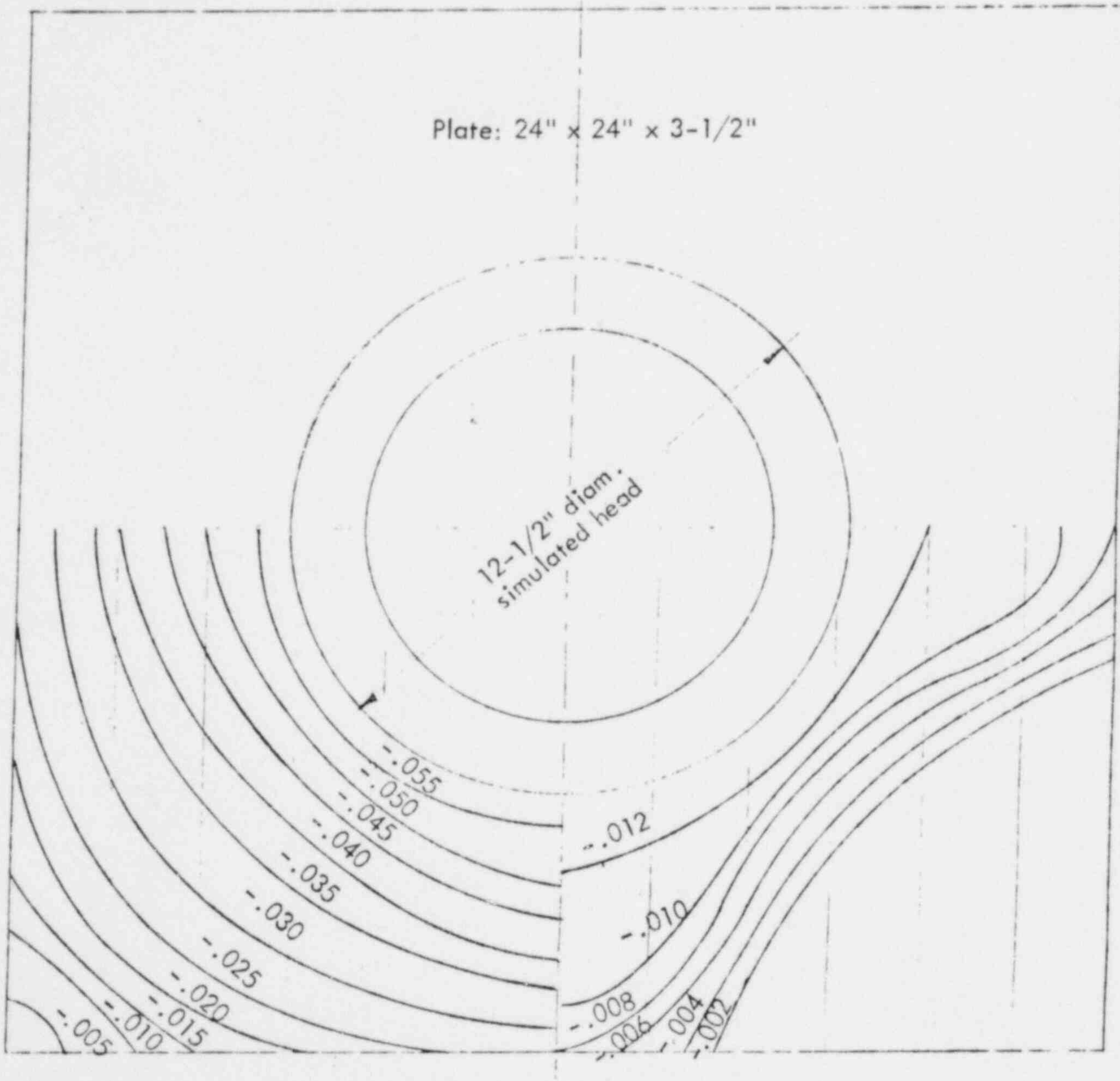
N.R. = No reading

100 % = 2,270 Kips

VSL Corporation
Los Gatos, California

REDUCED DEFLECTION DATA

For conditions of maximum loading of 2,272 K and 0.00 K after removal of loading.



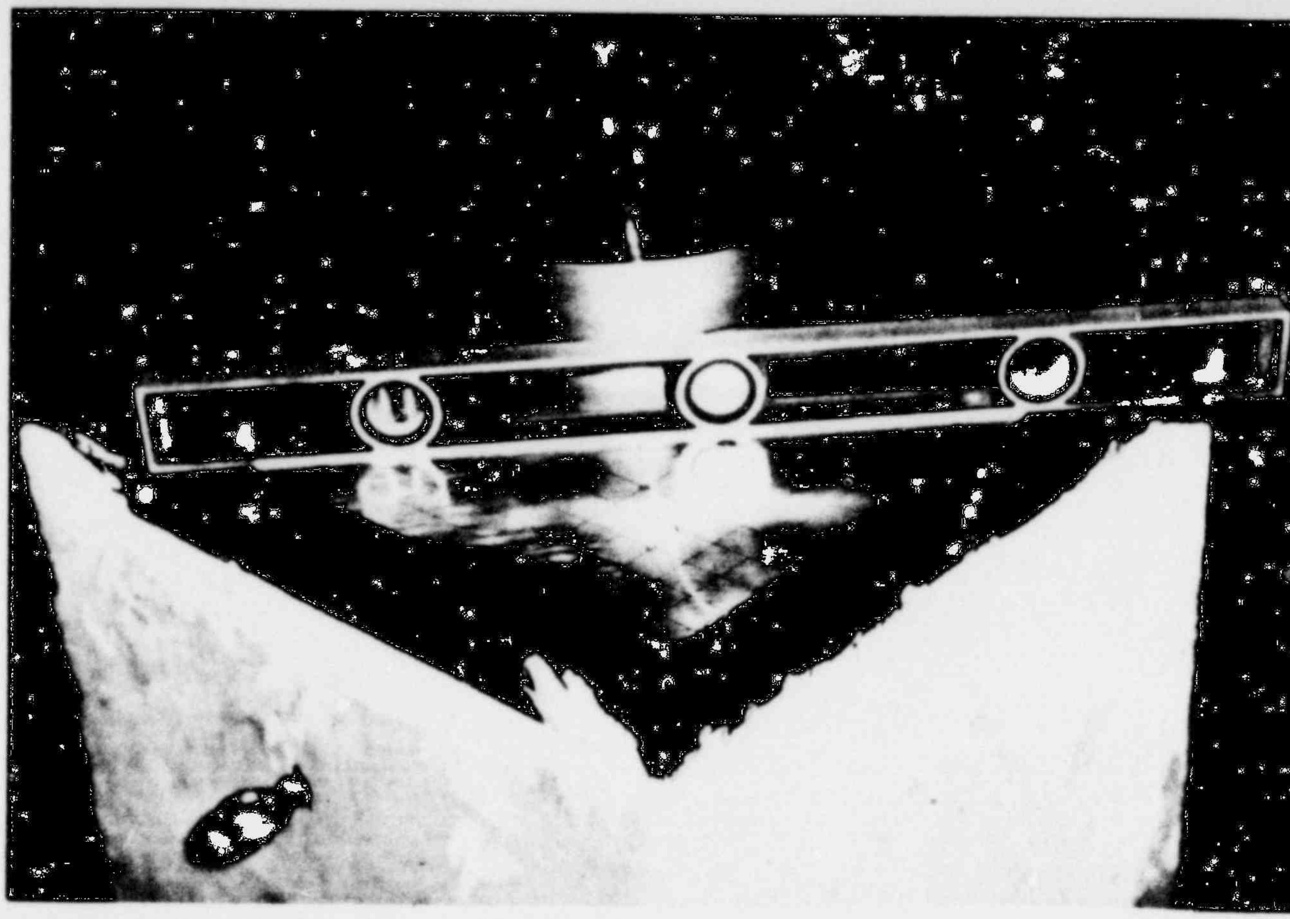
Load = 2,272 K

Load = 0.00 K

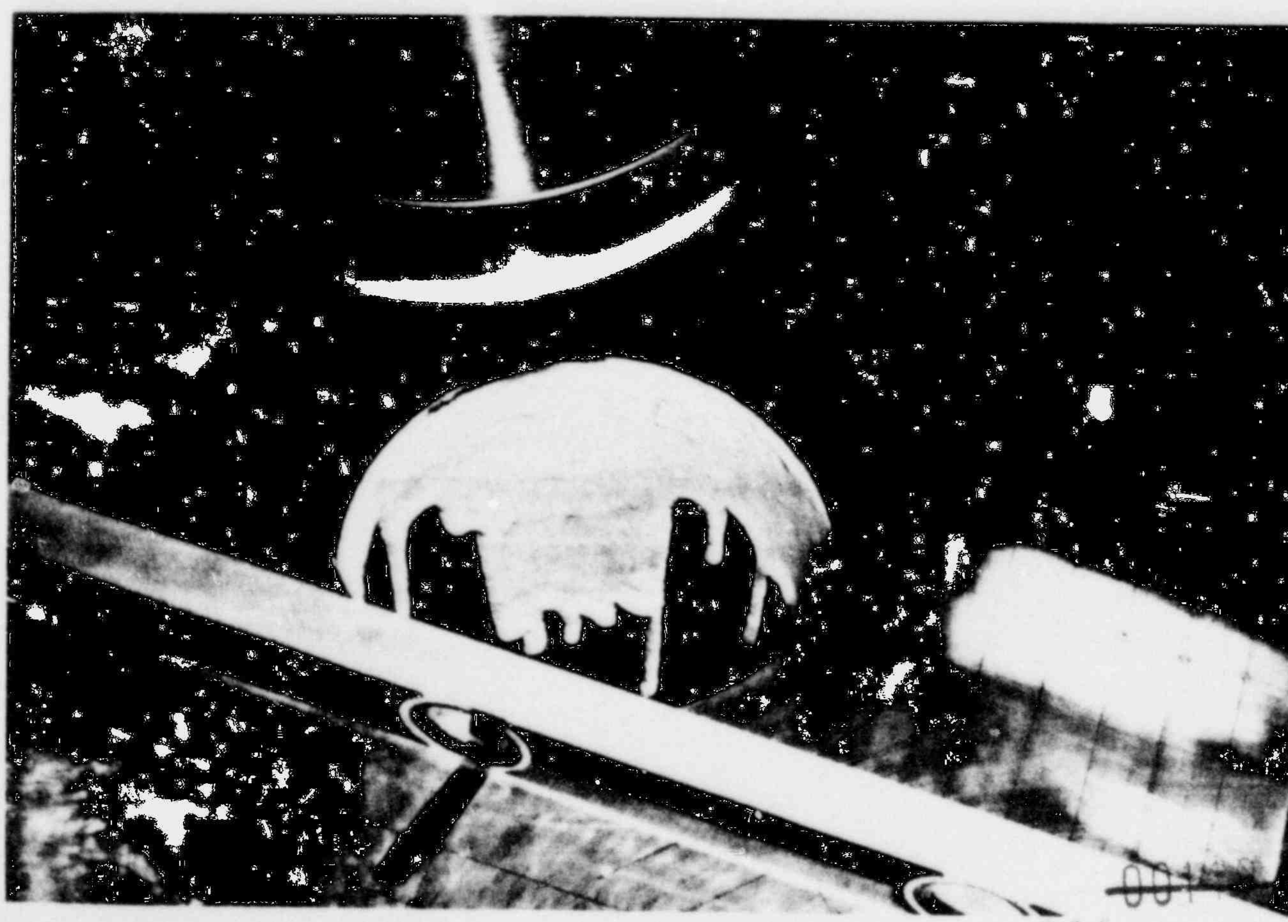
Absolute deflections were obtained by assuming a parabolic curve between datum corners along an edge, calculating the deflection of points of bearing of straight edge and adding to them the feeler gage measurements.

~~00113~~
0202

11 March 1969



Test No. 1
Test set-up demonstrating method of measuring deflection.



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Test No. 1
Bearing plate showing initial set deformation after removal of 2,272,000 lb. load.

Test No. 2 - Stresses Associated with Strain Gage Readings

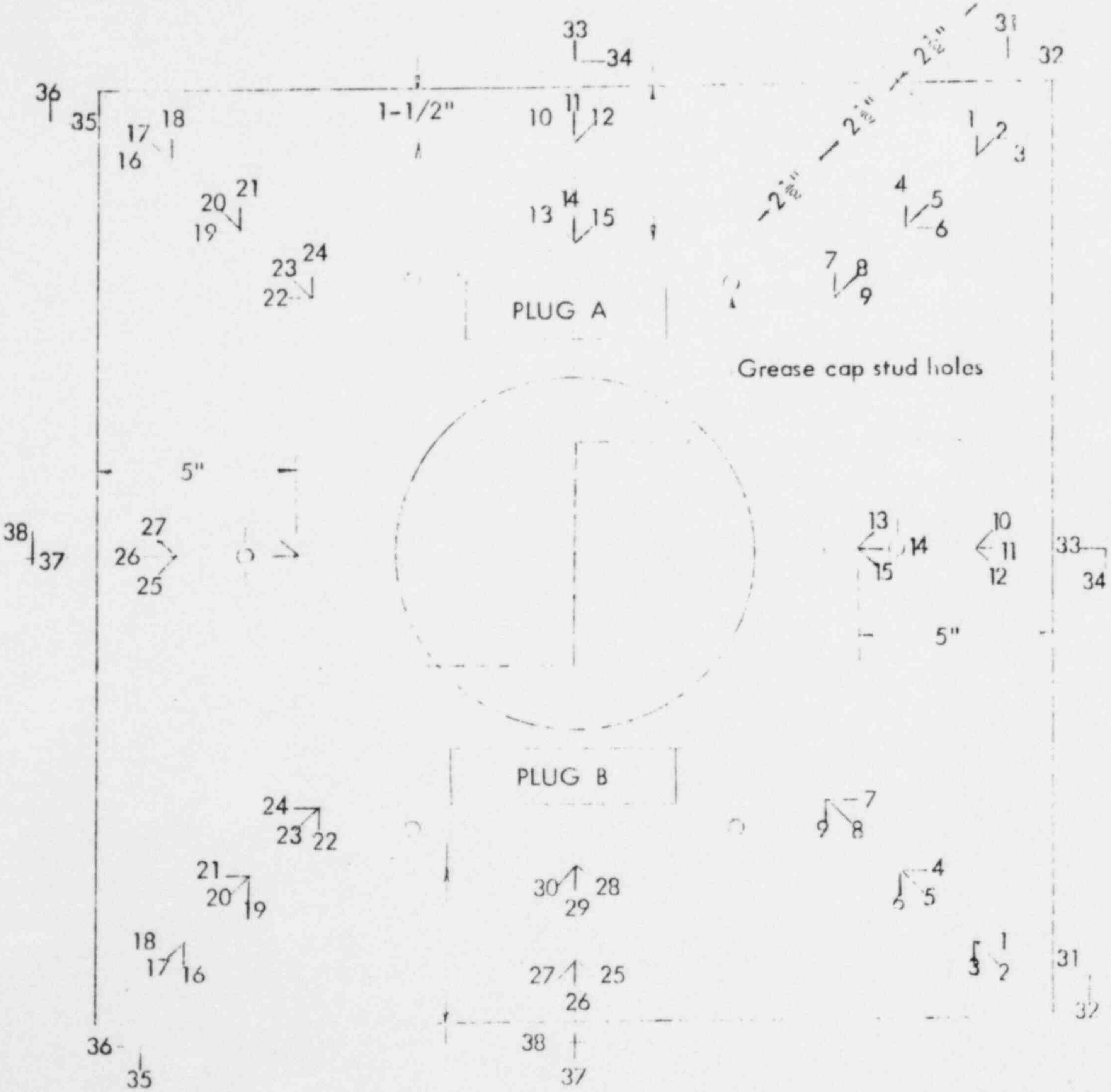
This test was conducted in the same fashion as Test No. 1. A plate identical to that used in Test No. 1 was centered on the test block, the anchor head centered on the plate and then the ram force applied in incremental percentages of the 2,272,000 pound ultimate load. On this test, however, strains in the planes of the top surface and the edges were measured rather than vertical deflections of points on the top surface. Initial set deflections on this plate were measured with a straight edge after the final load of 2,470,000 pounds (109% f's) had been removed. These final deformations were marginally less than those in Test No. 1. The concrete block in this test, having attained its 28-day strength, showed only hairline cracks under maximum load. The maximum stress resolved from observed strain gage readings was 47,900 psi compression at 109% of f's. After removal of the 2,470,000 pound load, there was no visible deformation of the bearing plate other than permissible initial set, indicating an essentially elastic action.

~~00120~~

VSL Corporation
Los Gatos, California

VSL E5-55 BEARING PLATE
LOCATION OF STRAIN GAGES

Tested on June 3, 1969 at University of California Structural Research Laboratory, Richmond, California.



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Strain Gage Readings in Micro Inches Per Inch

Plug A

% r's Load (kips)	Zero	680	910	40% 1,135	1,360	60% 1,590	1,710	80% 1,820	1,930	90% 2,020	2,160	100% 2,270	2,370	2,470
1	1745	1720	1710	1700	1695	1690	1685	1690	1680	1675	1670	1655	1650	1640
2	3005	3005	3020	3030	3035	3040	3040	3045	3050	3060	3070	3085	3090	3110
3	2190	2170	2160	2155	2150	2145	2145	2145	2145	2140	2135	2125	2120	2115
4	2760	2720	2720	2720	2710	2690	2675	2660	2650	2640	2620	2600	2585	2555
5	1740	1760	1765	1775	1790	1810	1820	1845	1850	1870	1885	1910	1925	1960
6	2775	2755	2760	2760	2760	2745	2735	2725	2725	2715	2700	2690	2680	2660
7	2300	2245	2235	2220	2210	2190	2180	2170	2160	2140	2115	2080	2060	2025
8	3420	3465	3500	3530	3555	3580	3590	3610	3625	3645	3670	3705	3725	3770
9	1480	1465	1460	1450	1445	1440	1435	1435	1425	1415	1395	1375	1360	1335
10	2100	2035	2030	2020	2010	1975	1960	1940	1925	1910	1890	1855	1835	1780
11	2910	2940	2955	2970	2985	3015	3030	3050	3060	3075	3095	3110	3130	3165
12	3210	3175	3170	3160	3145	3115	3100	3090	3080	3060	3045	3015	3000	2970
13	2140	2055	2035	2015	2000	1965	1945	1920	1900	1870	1845	1795	1770	1705
14	2745	2820	2855	2885	2915	2950	2965	2980	2995	3010	3035	3070	3095	3150
15	3060	3025	3000	2975	2950	2915	2900	2890	2875	2850	2820	2790	2765	2740
16	1940	1915	1920	1920	1915	1905	1895	1890	1885	1880	1870	1860	1855	1845
17	1570	1570	1570	1575	1575	1590	1595	1610	1615	1620	1630	1645	1655	1675
18	2550	2530	2535	2535	2535	2520	2515	2510	2505	2500	2495	2490	2480	2475
19	1530	1500	1490	1480	1475	1470	1465	1465	1460	1450	1440	1425	1415	1400
20	1965	1995	2020	2035	2050	2060	2065	2080	2090	2100	2115	2140	2155	2185
21	1110	1080	1070	1060	1050	1040	1035	1030	1020	1005	990	965	950	930
22	2205	2150	2150	2140	2130	2110	2100	2085	2075	2060	2045	2025	2010	1980
23	1770	1815	1835	1850	1870	1905	1920	1940	1955	1970	2000	2030	2050	2085
24	2435	2410	2415	2410	2400	2380	2365	2350	2340	2320	2300	2275	2255	2230
25	2220	2165	2145	2130	2115	2095	2085	2075	2065	2050	2030	2005	1985	1945
26	2770	2815	2840	2860	2880	2895	2900	2915	2925	2940	2960	2985	3000	3030
27	1180	1120	1110	1095	1080	1065	1060	1055	1050	1035	1020	1000	985	955
28	2845	2760	2745	2720	2690	2620	2585	2535	2500	2445	2360	2325	2325	2320
29	1290	1350	1370	1380	1385	1380	1375	1360	1350	1335	1295	1310	1345	1430
30	2040	1940	1920	1900	1870	1815	1780	1740	1715	1680	1625	1625	1600	1635
31	1640	1620	1615	1615	1610	1615	1615	1620	1620	1620	1620	1620	1620	1620
32	3170	3150	3160	3165	3165	3160	3150	3150	3150	3150	3150	3145	3145	3145
33	1630	1610	1605	1600	1595	1590	1585	1585	1585	1580	1575	1560	1555	1540
34	2080	2090	2110	2130	2145	2160	2165	2175	2185	2195	2210	2230	2245	2270
35	1025	1010	1005	1005	1000	1005	1005	1010	1015	1010	1010	1010	1010	1010
36	1680	1665	1675	1675	1680	1670	1665	1660	1665	1660	1660	1655	1660	1655
37	1695	1680	1675	1670	1670	1660	1650	1650	1645	1635	1620	1605	1590	1560
38	2290	2290	2305	2315	2330	2355	2365	2380	2395	2410	2435	2470	2500	2550

Strain Gage Readings in Micro Inches Per Inch

Plug B

% F's Load				40%		60%		80%		90%		100%		
(kips)	Zero	680	910	1,135	1,360	1,590	1,710	1,820	1,930	2,020	2,160	2,270	2,370	2,470
1	1945	1925	1915	1910	1905	1900	1900	1900	1900	1900	1890	1890	1880	1880
2	3355	3360	3370	3380	3385	3390	3390	3395	3400	3405	3420	3425	3440	3450
3	1860	1835	1825	1820	1815	1810	1805	1800	1800	1800	1785	1780	1770	1765
4	2720	2695	2700	2695	2685	2670	2660	2655	2645	2640	2625	2620	2605	2600
5	1395	1415	1420	1430	1440	1460	1475	1490	1505	1515	1535	1550	1580	1595
6	2825	2800	2810	2805	2800	2780	2765	2760	2745	2740	2720	2710	2685	2675
7	1945	1920	1900	1895	1880	1870	1865	1870	1855	1850	1825	1820	1800	1790
8	2655	2700	2735	2760	2785	2805	2820	2835	2855	2870	2900	2920	2965	2990
9	2480	2455	2445	2435	2420	2410	2395	2390	2370	2365	2335	2320	2290	2270
10	3085	3035	3030	3015	3000	2970	2950	2940	2920	2910	2880	2865	2835	2820
11	2295	2320	2335	2350	2370	2390	2410	2430	2445	2455	2485	2500	2535	2555
12	3120	3090	3085	3080	3070	3045	3025	3015	3000	2990	2960	2945	2910	2890
13	1975	1900	1860	1830	1790	1750	1720	1700	1650	1615	1525	1450	1270	1190
14	2905	2970.	3000	3030	3050	3060	3055	3050	3040	3035	3010	2990	3000	3040
15	2220	2175	2150	2130	2090	2055	2020	2000	1955	1925	1830	1780	1645	1545
16	2360	2350	2355	2355	2350	2345	2330	2330	2325	2320	2310	2310	2300	2295
17	2620	2625	2625	2630	2630	2645	2650	2665	2670	2680	2690	2700	2720	2730
18	2540	2525	2530	2525	2520	2510	2500	2500	2490	2490	2480	2475	2460	2455
19	1870	1850	1840	1835	1820	1810	1805	1805	1795	1785	1760	1745	1720	1700
20	2855	2885	2910	2930	2940	2955	2965	2975	2990	3000	3020	3040	3065	3085
21	1905	1870	1860	1850	1840	1835	1830	1830	1820	1815	1800	1795	1780	1770
22	2280	2280	2285	2280	2270	2255	2235	2220	2205	2190	2160	2140	2095	2065
23	2010	2060	2080	2100	2120	2150	2170	2195	2215	2225	2260	2280	2310	2335
24	2100	2050	2045	2040	2030	2015	2000	1990	1980	1970	1950	1945	1920	1910
25	1920	1890	1875	1860	1840	1825	1815	1810	1800	1790	1760	1740	1710	1690
26	2450	2485	2510	2535	2550	2570	2580	2590	2610	2620	2645	2665	2690	2710
27	2380	2330	2310	2295	2280	2260	2255	2250	2240	2230	2210	2195	2170	2150
28	3810	3790	3785	3775	3750	3720	3695	3680	3660	3645	3600	3570	3540	3530
29	3210	3270	3290	3310	3340	3370	3395	3415	3440	3455	3490	3510	3630	3700
30	2955	2885	2870	2855	2830	2800	2770	2750	2730	2715	2670	2635	2610	2610
31	3275	3265	3260	3255	3255	3255	3260	3265	3265	3260	3260	3260	3260	3265
32	2785	2775	2780	2785	2785	2780	2770	2770	2770	2770	2765	2770	2770	2765
33	2195	2190	2180	2180	2170	2170	2170	2170	2170	2165	2155	2150	2140	2130
34	2355	2350	2365	2380	2390	2405	2415	2425	2435	2445	2465	2480	2505	2530
35	1830	1820	1815	1810	1810	1810	1815	1820	1820	1820	1820	1820	1820	1820
36	2495	2485	2490	2495	2495	2490	2480	2480	2480	2480	2480	2480	2480	2475
37	1920	1910	1900	1895	1890	1885	1880	1880	1870	1865	1840	1825	1800	1780
38	2600	2610	2630	2645	2660	2670	2680	2695	2715	2725	2760	2780	2815	2845

Stresses in psi = Difference in Strain Gage Readings in Micro Inches Per Inch

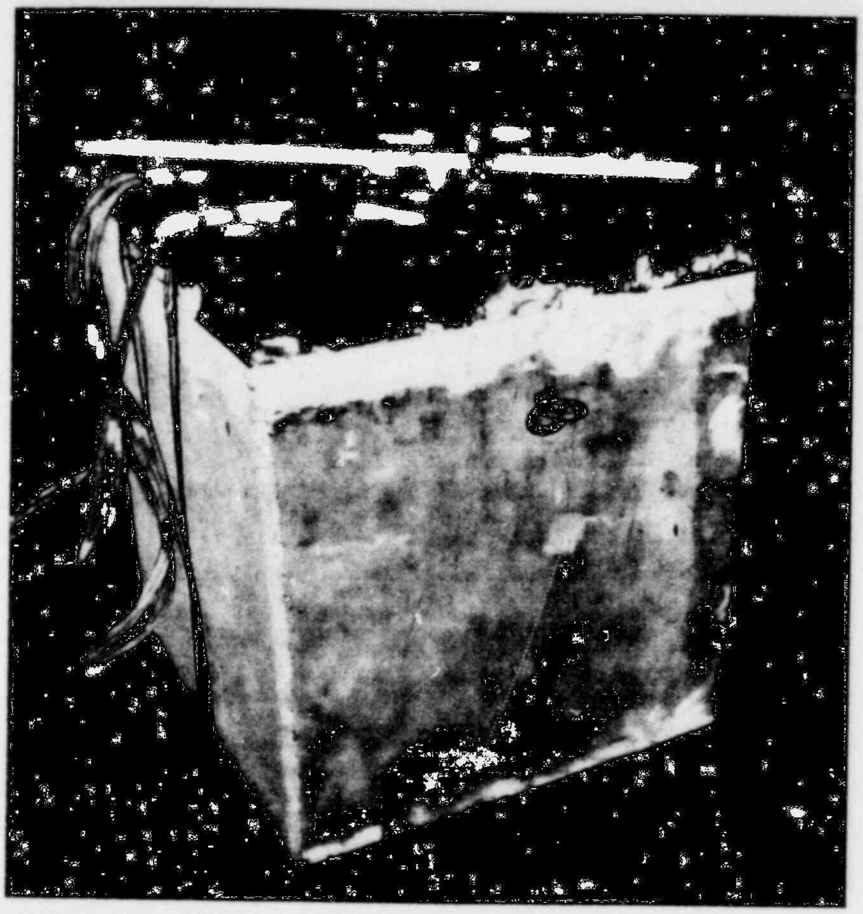
Plug A

%f's			40%		60%		80%		90%		100%		
Load (kips)	680	910	1,135	1,360	1,590	1,710	1,820	1,930	2,020	2,160	2,270	2,370	2,470
1	-750	-1050	-1350	-1500	-1650	-1800	-1650	-1950	-2100	-2250	-2700	-2850	-3150
2	0	+450	+750	+900	+1050	+1050	+1200	+1350	+1650	+1950	+2400	+2550	+3150
3	-600	-900	-1050	-1200	-1350	-1350	-1350	-1350	-1500	-1650	-1950	-2100	-2250
4	-1200	-1200	-1200	-1500	-2100	-2550	-3000	-3300	-3600	-4200	-4800	-5250	-6150
5	+600	+750	+1050	+1500	+2100	+2400	+3150	+3300	+3900	+4350	+5100	+5550	+6600
6	-600	-450	-450	-450	-900	-1200	-1500	-1500	-1800	-2250	-2550	-2850	-3450
7	-1650	-1500	-2400	-2700	-3300	-3600	-3900	-4200	-4800	-5550	-6600	-7200	-8250
8	+1350	+2400	+3300	+4050	+4800	+5100	+5700	+6150	+6750	+7500	+8550	+9150	+10500
9	-450	-600	-900	-1050	-1200	-1350	-1350	-1650	-1950	-2550	-3150	-3600	-4350
10	-1950	-2100	-2400	-2700	-3750	-4200	-4800	-5250	-5700	-6300	-7350	-7950	-9600
11	+900	+1350	+1800	+2250	+3150	+3600	+4200	+4500	+4950	+5550	+6000	+6600	+7650
12	-1950	-1200	-1500	-1950	-2850	-3300	-3600	-3900	-4500	-4950	-5850	-6300	-7200
13	-2550	-3150	-3750	-4200	-5250	-5850	-6600	-7200	-7100	-7950	-10350	-11110	-13050
14	+2250	+3300	+4200	+7100	+6150	+6600	+7050	+7500	+7950	+8700	+9750	+10500	+12150
15	-1050	-1800	-2550	-3300	-4350	-4800	-5100	-5550	-6300	-7200	-8100	-8850	-9600
16	-750	-600	-600	-750	-1050	-1350	-1500	-1650	-1800	-2100	-2400	-2550	-2850
17	0	0	+150	+150	+600	+750	+1200	+1350	+1500	+1800	+2250	+2550	+3150
18	-600	-450	-450	-450	-900	-1050	-1200	-1350	-1500	-1650	-1800	-2100	-2250
19	-900	-1200	-1500	-1650	-1800	-1950	-1650	-2100	-2400	-2700	-3150	-3450	-3900
20	+900	+750	+1200	+1650	+1950	+2100	+3450	+3750	+4050	+450	+5250	+5700	+6600
21	-900	-1200	-1500	-1800	-2100	-2250	-2400	-2700	-3150	-3600	-4350	-4800	-5400
22	-1650	-1650	-1950	-2250	-2850	-3150	-3600	-3900	-4350	-4800	-5400	-4850	-6750
23	+1350	+1950	+2400	+3000	+4050	+4500	+5100	+5550	+6000	+6900	+7800	+8400	+9450
24	-750	-600	-750	-1050	-1650	-2100	-2550	-2850	-3450	-4050	-4800	-5400	-6150
25	-1650	-2250	-2700	-3150	-3750	-4050	-4350	-4650	-5100	-5700	-6450	-6750	-8250
26	+1350	+2100	+2700	+3300	+3750	+3900	+4350	+4650	+5100	+5700	+6450	+6900	+7800
27	-1800	-2100	-2550	-3000	-3450	-3600	-3750	-3900	-4350	-4800	-5400	-5850	-6750
28	-2550	-3000	-3750	-4470	-6750	-7800	-9300	-10350	-12000	-14550	-15600	-15600	-15750
29	+1800	+2400	+2700	+2850	+2700	+2550	+2100	+1800	+1350	+150	+ 600	+1650	+4200
30	-3000	-3600	-4200	-5100	-6750	-7800	-9000	-9750	-10800	-12450	-12450	-17600	-12150
31	-600	-750	-750	-900	-750	-750	-600	-600	-600	-600	-600	-600	-600
32	-600	-300	-150	-150	-300	-600	-600	-600	-600	-600	-750	-750	-750
33	-600	-750	-900	-1050	-1600	-1350	-1350	-1350	-1500	-1650	-2100	-2250	-2700
34	+300	+900	+1500	+1950	+2400	+2550	+2850	+3150	+2550	+3900	+4500	+4950	+5700
35	-450	-600	-600	-750	-600	-600	-450	-300	-450	-450	-450	-450	-450
36	-450	-150	-150	0	-300	-450	-600	-450	-600	-600	-750	-600	-750
37	-450	-600	-450	-750	-1050	-1350	-1350	-1500	-1800	-2250	-2700	-3150	-1050
38	0	+450	+750	+1600	+1950	+2250	+2700	+3150	+3600	+4350	+5400	+6300	+7800

Stresses in psi – Difference in Strain Gage Readings in Micro Inches Per Inch

Plug B

% f's			40%		60%		80%		90%		100%		
Load (kips)	680	910	1,135	1,360	1,590	1,710	1,820	1,930	2,020	2,160	2,270	2,370	2,470
1	-600	-900	-1050	-1200	-1350	-1350	-1350	-1350	-1350	-1650	-1650	-1950	-1950
2	+150	+450	+750	+900	+1050	+1050	+1200	-1350	+1500	+1950	+2100	+2550	+2850
3	-750	-1050	-1200	-1350	-1500	-1650	-1800	-1800	-1800	-2250	-2400	-2700	-2850
4	-750	-600	-750	-1050	-1500	-1800	-1950	-2250	-2400	-2850	-3000	-3450	-3600
5	+600	+750	+1050	+1350	+1950	+2400	+2850	+3300	+6600	+4200	+4650	+5550	+6000
6	-750	-450	-600	-750	-1350	-1800	-1950	-2400	-2550	-3150	-3450	-4200	-4500
7	-750	-1350	-1500	-1950	-2250	-2400	-2250	-2700	-2850	-3600	-3750	-4350	-4650
8	+1350	+2400	+3150	+3900	+4500	+4950	+5400	+6000	+6450	+7350	+7950	+9300	+10050
9	-750	-1050	-1350	-1800	-2100	-2550	-2700	-3300	-3450	-4350	-4800	-5700	-6300
10	-1500	-1650	-2100	-2550	-3450	-4050	-4350	-4950	-5250	-6150	-6600	-7500	-7950
11	+750	+1200	+1650	+2250	+2850	+3450	+4050	+4500	+4800	+5700	+6150	+7200	+7800
12	-900	-1050	-1200	-1500	-2250	-2850	-3150	-3600	-3900	-4800	-5250	-6300	-6900
13	-2250	-3450	-4350	-5550	-6750	-7650	-7250	-9750	-10800	-13500	-15750	-21150	-23550
14	+1950	+2850	+4050	+4350	+4950	+4500	+4350	+4050	+3900	+3150	+2550	+2850	+4050
15	-1350	-2100	-2700	-3900	-4950	-6000	-6600	-7950	-8850	-11500	-13200	-17250	-20250
16	-300	-150	-150	-300	-450	-900	-900	-1050	-1200	-1500	-1500	-1800	-1950
17	+150	+150	+300	+300	+750	+900	+1350	+1500	+1800	+2100	+2400	+3000	+3300
18	-450	-300	-450	-300	-900	-1200	-1200	-1500	-1500	-1800	-1950	-2400	-2550
19	-600	-900	-1050	-1500	-1800	-1950	-1950	-2250	-2550	-3300	-3750	-4500	-5100
20	+900	+1650	+2250	+2250	+3000	+3300	+3600	+4050	+4350	+4950	+5550	+6300	+6900
21	-1050	-1350	-1650	-1950	-2100	-2250	-2250	-2550	-2700	-3150	-3300	-3750	-4050
22	0	+150	0	-300	-750	-1350	-1800	-2250	-2700	-3600	-4200	-5550	-6450
23	+1500	+2100	+2700	+3300	+4200	+4800	+5550	+6150	+6450	+7500	+8100	+9000	+9750
24	-1500	-1650	-1800	-2100	-2550	-3000	-3600	-3600	-3900	-4500	-4650	-5400	-5700
25	-900	-1350	-1800	-2400	-2850	-3150	-3300	-3600	-3900	-4800	-5400	-6300	-6900
26	+1050	+1800	+2550	+3000	+3600	+3900	+4200	+1600	+5100	+5850	+6450	+7200	+7800
27	-1500	-2100	-2550	-3000	-3600	-3750	-3900	-4200	-4500	-5100	-5550	-6300	-6900
28	-600	-750	-1050	-1800	-2700	-3450	-3900	-4500	-4950	-6300	-7200	-7100	-8400
29	+1800	+2400	+3000	+3900	+4800	+5550	+6150	+6900	+7350	+8400	+9000	+12600	+14700
30	-2100	-2550	-3000	-3750	-4650	-5550	-6150	-6750	-7200	-7550	-9600	-10350	-10350
31	-300	-450	-600	-600	-600	-450	-300	-300	-450	-450	-450	-450	-300
32	-300	-450	0	0	-150	-450	-450	-450	-450	-600	-450	-450	-600
33	-150	-450	-450	-750	-750	-750	-750	-750	-900	-1200	-1350	-1500	-1950
34	-150	+300	+750	+1050	+1500	+1800	+2100	+2400	+2700	+3300	+3750	+4500	+5250
35	-300	-450	-600	-600	-600	-450	-300	-300	-300	-300	-300	-300	-300
36	-300	-150	0	0	-150	-450	-450	-450	-450	-450	-450	-450	-600
37	-300	-600	-750	-900	-1050	-1200	-1200	-1500	-1950	-2400	-2850	-3600	-4200
38	+300	+900	+1350	+1800	+2100	+2400	+2850	+3450	+3750	+4800	+5400	+6450	+7350



Test No. 2
Test set-up bearing plate, strain gages and concrete block.

Test No. 2
Strain gage layout.

Test No. 2
Bearing plate showing initial set deformation after removal of 2,470,000 lb. load.

00127

Test No. 2
View of bottom face of anchor head after removal of 2,470,000 lb. load.

0211

COMMENTARY FROM UNIVERSITY OF CALIFORNIA

ON TESTS NO. 1 AND NO. 2

~~00128~~

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

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DEPARTMENT OF CIVIL ENGINEERING
DIVISION OF STRUCTURAL ENGINEERING
AND STRUCTURAL MECHANICS
STRUCTURAL RESEARCH LABORATORY

1301 SOUTH 46TH STREET
RICHMOND, CALIFORNIA 94804

July 7, 1969

VSL Corporation
Post Office Box 459
Los Gatos, California 95030

Attn: Mr. Ed. Davis

Re: E.S. 7053

Gentlemen:

This letter is written to certify that two VSL E5-55 post-tensioning anchorage bearing plates were loaded as shown in Tables I and II at the Structural Research Laboratory of the University of California, Berkeley.

The 24" x 24" x 3½" bearing plates were loaded using the test setup shown in Figure I which was assembled in the four million pound capacity Universal Testing Machine located at this laboratory. Each bearing plate was placed atop a 24" x 24" x 24" concrete block whose cross-section was the same as the bearing plates in the plane perpendicular to the line of action of the applied load. The bearing plate and block each have 9" diameter center holes. The hole through the block was of constant cross-section, and was not tapered to accept a transition trumpet. To assure an even bearing surface for the bearing plate, a hydrostone grout was used between the bearing plate and the concrete block. The concrete block itself was seated in hydrostone between its bottom and the base plate of the testing machine. In each test the load was applied by the testing machine acting on a VSL Type E5-55 Anchorage bearing directly upon the bearing plate.

The first bearing plate loading was conducted on April 11, 1969. During this loading, personnel from the VSL Corporation using a straight edge and feeler gauges, measured and recorded the deflection of several points on the top surface of the bearing plate at the values of load as shown in Table I. After sustaining this maximum load for approximately five minutes, the concrete block supporting the bearing plate failed.

TABLE II

Load Used for VSL E5-55
Bearing Plate Strain

June 9, 1969

Pounds
680,000
910,000
1,135,000
1,360,000
1,590,000
1,710,000
1,820,000
1,930,000
2,020,000
2,160,000
2,270,000
2,370,000
2,470,000
0

Upon conclusion of this second bearing plate loading, the plate was inspected and showed no apparent sign of any permanent bending, or any sign of cracking. As on the first plate tested, there was a slight indentation into the bearing plate at the location where the anchorage had pressed upon it.

Loading of the two bearing plates was conducted under the supervision of Eugene R. Serex, Associate Development Engineer at the Structural Research Laboratory.

Very truly yours,

J. G. Bouwkamp Rmt

J. G. BOUWKAMP
Professor of Civil Engineering

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Block failure was by cracking vertically down the exposed faces parallel to the line of action of the applied load. As the load-deflection measurements were not actually taken by laboratory personnel, we cannot certify any conclusions made as a result of those measurements made by VSL personnel. Inspection by our personnel after the test revealed no apparent visible permanent deformation of the bearing plate other than a very slight indentation of the anchorage into the bearing plate. No cracks in the bearing plate were apparent during this visual inspection.

TABLE I

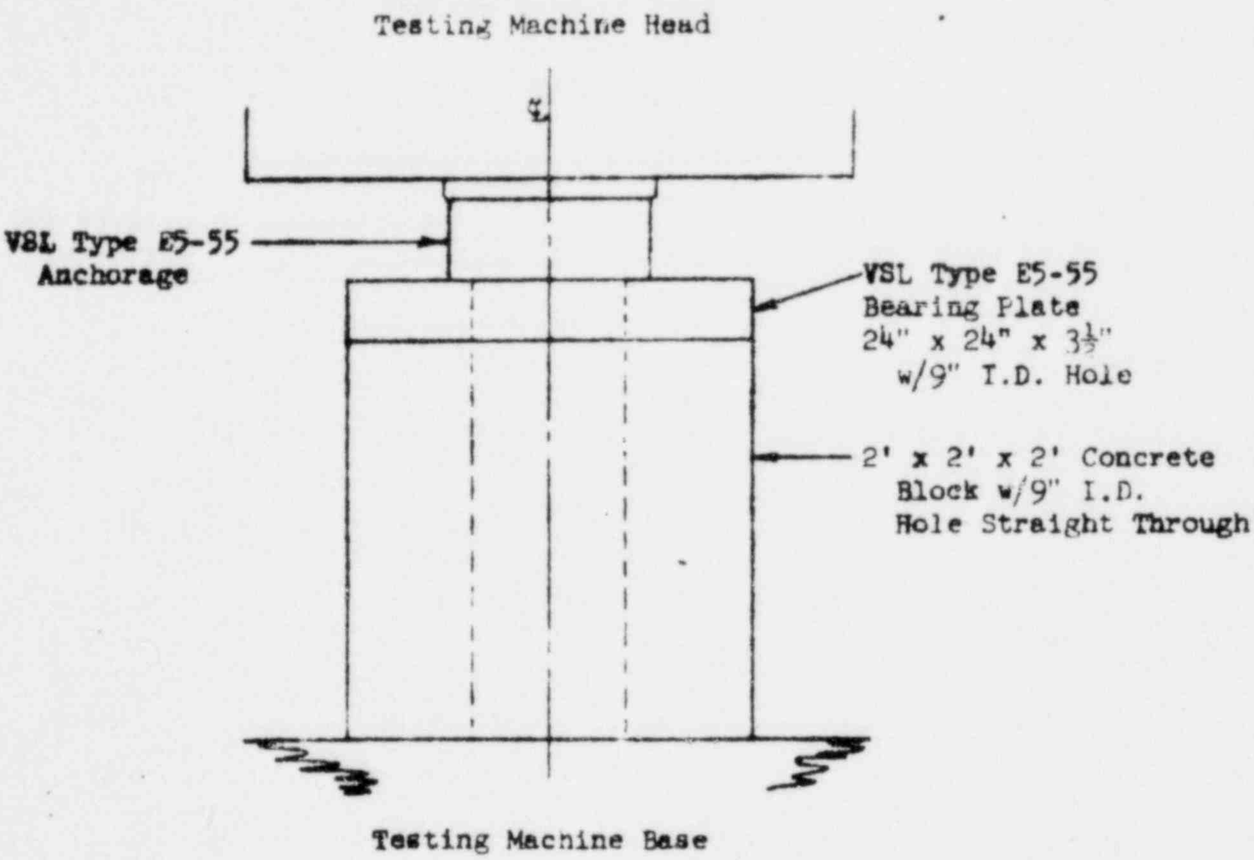
Loads Used for Deflection Measurements of VSL E5-55 Bearing Plate

April 11, 1969

Pounds
568,000
1,135,000
1,705,000
1,820,000
2,045,000
2,160,000
2,270,000*

* Concrete block failed after sustaining load for approximately five minutes.

The second bearing plate was tested on June 9, 1969. This bearing plate had been instrumented on its top surface with 60 strain gages and on each of its four edges with 4 strain gages for a total of seventy-six gages. Measurements of the strain at each gage were made at the loadings shown in Table II. These strain measurements were recorded by VSL Corporation employees and witnessed by Structural Research Laboratory personnel. The values of strain recorded are not included in this report as this data is already in the possession of VSL Corporation. This data is in the files of the Structural Research Laboratory should there be an occasion that VSL or its representatives need access to it.



VSL CORPORATION

Bearing Plate Test Setup

FIGURE I

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Test No. 3 - Computer Analysis

As a supplement to Tests No. 1 and No. 2, a three-dimensional stress analysis of the VSL E5-55 strand bearing plate was made at the University of Stuttgart in Germany. The Finite Element Method was applied to the analysis of deformations.

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INSTITUT FÜR STATIK UND DYNAMIK DER
LUFT-UND RAUMFAHRTKONSTRUKTIONEN

UNIVERSITY OF STUTTGART

Director : Professor Dr. J.H. Argyris

Research Report

to

Losinger u.Co. A.G.
Bern,
Switzerland

Three-Dimensional Analysis of a Bearing Plate Using the Finite Element Method

by

I. Grieger

0218

~~0013~~

June 1969

Table of Contents

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Summary

The finite element method[1,2,6] is applied to the analysis of deformations and stresses in a bearing plate (type E 5-55) which is a part of a prestressed concrete construction.

A very short summary of the Displacement Method is given at the beginning of the report. This method is the basis of the ASKA Language[3]. ASKA (Automatic System for Kinematic Analysis) is a problem-oriented language to solve one-, two- and three-dimensional structural problems. The analysis of the problem was done on our UNIVAC 1107 computer. Finally, some typical results are plotted for the various sections and the behaviour of the structure is shown.

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Notation

Matrices

$\mathbf{a}$	kinematic connection
$\mathbf{k}$	element stiffness
$\mathbf{K}$	structure stiffness
$\mathbf{P}$	element forces
$\mathbf{r}$	displacements
$\boldsymbol{\rho}$	element displacements
$\boldsymbol{\omega}$	displacement function
$\boldsymbol{\sigma}$	stresses

Scalars

ℓ	length
r, R	radius
p	pressure
P	force
ϕ	angle

A Short Resumé of the Displacement Method.

The ASKA-Language is build on the Matrix Theory of Structures, Displacement Method (DM). It is therefore perhaps appropriate to give a short description of the DM. For those seeking a deeper understanding of the basic theory, refs. 1,2,6 should be suitable.

When working with the DM it is as a rule convenient to introduce all nodal displacements as unknowns. The deformations of the finite elements are then calculated in terms of the displacements at the nodal points. From the deformations of the elements the internal forces can be found using the stress-strain relationship. Then applying the equilibrium criterion at each nodal point a set of linear simultaneous equations is obtained, giving the unknown forces necessary to cause the imposed displacements.

Although the displacements are chosen as single nodal displacements, more complex generalized displacement functions may be also used.

The idealised structure is divided into a set of standard finite elements, as in Fig.1. For each standard element the variation of the displacements within the element and between adjacent nodal points has already been decided upon, from which the element stiffness matrix $\mathbf{k}_i$ can be found. All the element stiffness matrices are referred to the same basic co-ordinate system (OXYZ). They are, however, best calculated by using the natural stiffness approach in the local co-ordinate system (O'x' y' z') and then by successive congruent transformations the basic stiffness matrices are computed. And finally the "summation" of the element stiffnesses at the proper nodal points produces the stiffness matrix $\mathbf{K}$ for the assembled structure [2].

The element stress vector $\mathbf{P}$ represents the generalized stresses in all elements, where the stresses in one element are expressed as those forces acting at the points on the boundary of the element in the direction of the global axis (OXYZ). Corresponding to this matrix the element strains $\boldsymbol{\rho}$ represent the displacement vector of the element boundary points. Arranging the element stiffnesses in the super diagonal stiffness matrix

$$\mathbf{k} = \lceil \mathbf{k}_1 \ \mathbf{k}_2 \ldots \mathbf{k}_i \ldots \mathbf{k}_s \rfloor \qquad (1)$$

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where s is the number of elements in the assembled structure, the following matrix relation holds

$$P = k\varrho \qquad (2)$$

Now let the unknown displacement vector of the structure r have entries for each nodal point, giving the displacements as components along and around the basic axis (OXYZ). Therefore, since the boundary points of the various elements and their displacements are identical with those of the corresponding nodal points of the structure to which they are connected, the kinematic connection matrix a contains only 'ones' and 'zeros'[2], or in matrix notation

$$\varrho = a r \qquad (3)$$

If, for the applied loading, only concentrated generalized forces at the nodal points along or about the major axis are allowed, then expressed with the load matrix R and applying the principle of virtual work [1], it follows that

$$r^t R = \varrho^t P \qquad (4)$$

or

$$r^t R = r^t a^t P \qquad (5)$$

and finally

$$R = a^t P = a^t k \varrho = (a^t k a) r = K r \qquad (6)$$

so that

$$K = a^t k a \qquad (7)$$

In order to avoid singularities in the assembled stiffness matrix of the structure (eqn.(7)), it is necessary that all modes of deformations be linearly independent from one another. This is assured in ASKA by eliminating all superfluous degrees of freedoms already in the transformation matrix a. Once the assembled stiffness matrix of the structure is known to be non-singular, a direct solution gives the unknown displacements

$$r = K^{-1} R \qquad (8)$$

This elementary and short description of the DM does not intend to give an up-to-date survey of the latest achievements and refinements of the method, but is meant as an explanation of the theory behind ASKA.

As is evident from above reflections, the greatest problem is to idealise and describe the structure and to provide the necessary input data (co-ordinates, thicknesses, loading, etc.) in a short and concise manner suitable for the computer. We might also mention that after the computations are completed the understanding of the printed results may not be without its difficulties.

The main purpose of ASKA is concentrated on trying to minimize these difficulties by offering an engineer-oriented computer language which can be used with hardly any previous computer experiences. By no means is it thought to be the best and final solution, but rather a hopeful and practical step in the right direction.

Description of the Problem.

The bearing plate is part of a construction of prestressed concrete (type E 5-55, patent Losinger, see also [7]). The bearing plate (a thick square plate with a hole in the middle) is fixed on the concrete (Figs. 2 and 3). The prestressing cables which are going through the plate are clamped in the anchor head. The main part of the structure is the bearing plate which is elastically supported by the concrete. The anchor head presses the plate, whereby the surface of contact is an important region.

A good idealisation should contain all three features.

Idealisation of the Structure.

The structure is given and the idealisation is then the first step. To simulate the elastic support the plate is analysed with a 10" concrete socle. (Fig.4) The socle is rigidly fixed. The stress concentrations are expected on the surface of contact between anchor head and bearing plate.

To study these interactions and to apply the loads a part from the head is also idealised. For a detailed investigation of the stresses in this region, a finer mesh is used. The corners of the plate are not important for the stress distribution. To simplify the idealisation, a circular plate is analysed. In this case the problem is an axisymmetric problem and could be solved with the TRIAX 6 element[4] (Fig.5). The elastic properties are shown in Fig. 4.

External Loads.

The breaking load of the prestressing cables is applied as a constant pressure on the top of the anchor head. The nodal loads are kinematically consistent with the applied presssure which means that the virtual work of the nodal forces and the nodal displacements is equal to that of the distributed loads and the corresponding displacement functions (modes) of the element. Consider now, for example, a constant pressure p to one surface of a TRIAX 6 element. The displacement functions ω, corresponding to the nodal displacements $\xi = 1$ are shown in Fig. 6. The forces acting at the nodal points are found using the principle of virtual work in the form

$$P = \int_A \omega \, p \, dA \qquad (9)$$

For TRIAX 6 :

$$\begin{aligned} dA &= r \, d\phi \, dr \\ dr &= R \, d\xi \end{aligned} \qquad (10)$$

Load at point 1 of the element

$$P_1 = \int_0^{\phi=1} \int_{r_1}^{r_3} \omega \, p \, r \, dr \, d\phi = R^2 p \int_{\xi_1}^{\xi_3} \omega_1(\xi) \, \xi \, d\xi \qquad (11)$$

The results for $p =$ const. and $\phi = 1$

$$\begin{aligned} P_1 &= \tfrac{1}{6} r_1 \ell p \\ P_2 &= \tfrac{2}{3} r_2 \ell p \\ P_3 &= \tfrac{1}{6} r_3 \ell p \end{aligned} \qquad (12)$$

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where ℓ is the length of the loaded side of the element.

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Results.

For 6 cross-sections the calculated stresses are plotted in the Appendix. Normal stresses in the radial (σ_{rr}), the vertical (σ_{zz}) and the circumferential (σ_{tt}) directions are shown for the different cross-sections. Shear stresses σ_{rz} are also plotted. Figs. 7 – 12 display the distribution of the von Mises equivalent stress $\overline{\sigma}$ (eqn.(13)), which indicates the stress concentration on the surface of contact between anchor head and bearing plate.

$$\overline{\sigma} = \sqrt{\frac{1}{2}\left[(\sigma_{rr}-\sigma_{zz})^2+(\sigma_{zz}-\sigma_{tt})^2+(\sigma_{tt}-\sigma_{rr})^2+6\sigma_{rz}^2\right]} \qquad (13)$$

References.

1. ARGYRIS, J.H., Energy Theorems and Structural Analysis, a. Part I General Theory, Aircraft Engineering, Vol.26, 1954: Oct. pp. 347-356, Nov. pp.383-387, 394, Vol.27, 1955: Feb. pp.42-58, March pp.80-94, April pp.125-134, May pp.145-158, ARGYRIS, J.H. and KELSEY, S., b. Part II Applications to Thermal Stress Analysis and to Upper and Lower Limits of St.Venant Torsion Constant. Aircraft Engineering, Vol.26, 1954: Dec. pp.410-422, also published London, Butterworths 1960

2. ARGYRIS, J.H., Recent Advances in Matrix Methods of Structural Analysis "Progress in Aeronautical Sciences," Vol.4, Pergamon Press, 1964.

3. ARGYRIS, J.H., KAMEL, H., SØRENSEN, M., SCHMID, G., PRETSCH, H. ASKA - Automatic System for Kinematic Analysis, User's Manual, ISD Report No.8 Issued by the Institut für Statik und Dynamik der Luft-und Raumfahrtkonstruktionen, 1st edition, October 1965

4. ARGYRIS, J.H., The TRIAX 6 Element for Axisymmetric Analysis by the Matrix Displacement Method, Part I: Foundations, Part II: Elastic Stiffness and Influence of Initial Strains, The Journal of the Royal Aeronautical Society, Vol.70, No.672, pp.1102-1106, December 1966

5. BUCK, K.E., SELMA, Programmers Manual, ISD Report No.26, December 1965 Revision 1, October 1968

6. TURNER, M.J., GLOUGH, R.W., MARTIN, H.C., TOPP, L.J., Stiffness and Deflection Analysis of Complex Structures, Journal of the Aeronautical Sciences, Vol.23, No.9, September 1956, pp.805-823, 854.

7. Losinger u.Co., A.G., Spannbetonbau VSL Litzen-Spannverfahren, Bern 1968.

Appendix

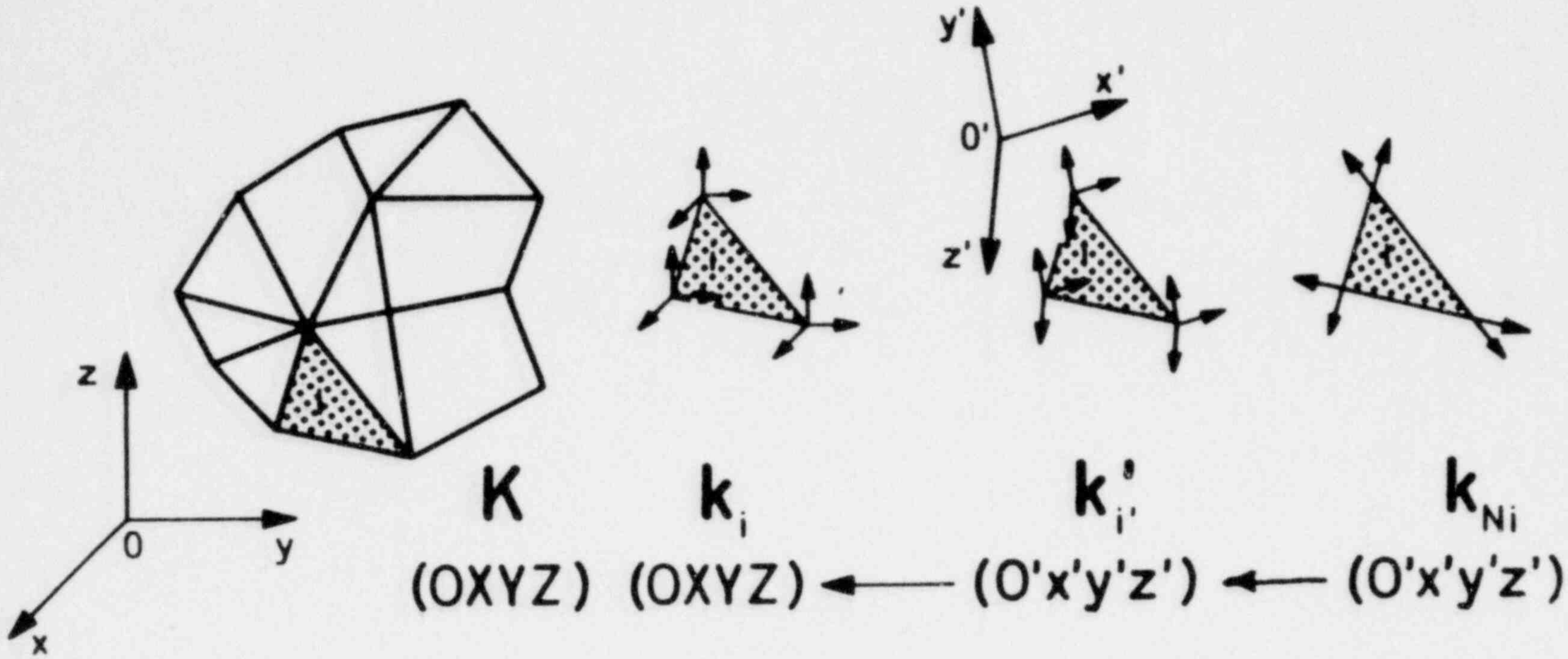


Fig. 1

Description of a Structure with Finite Standard Elements

Fig. 2 Bearing Plate

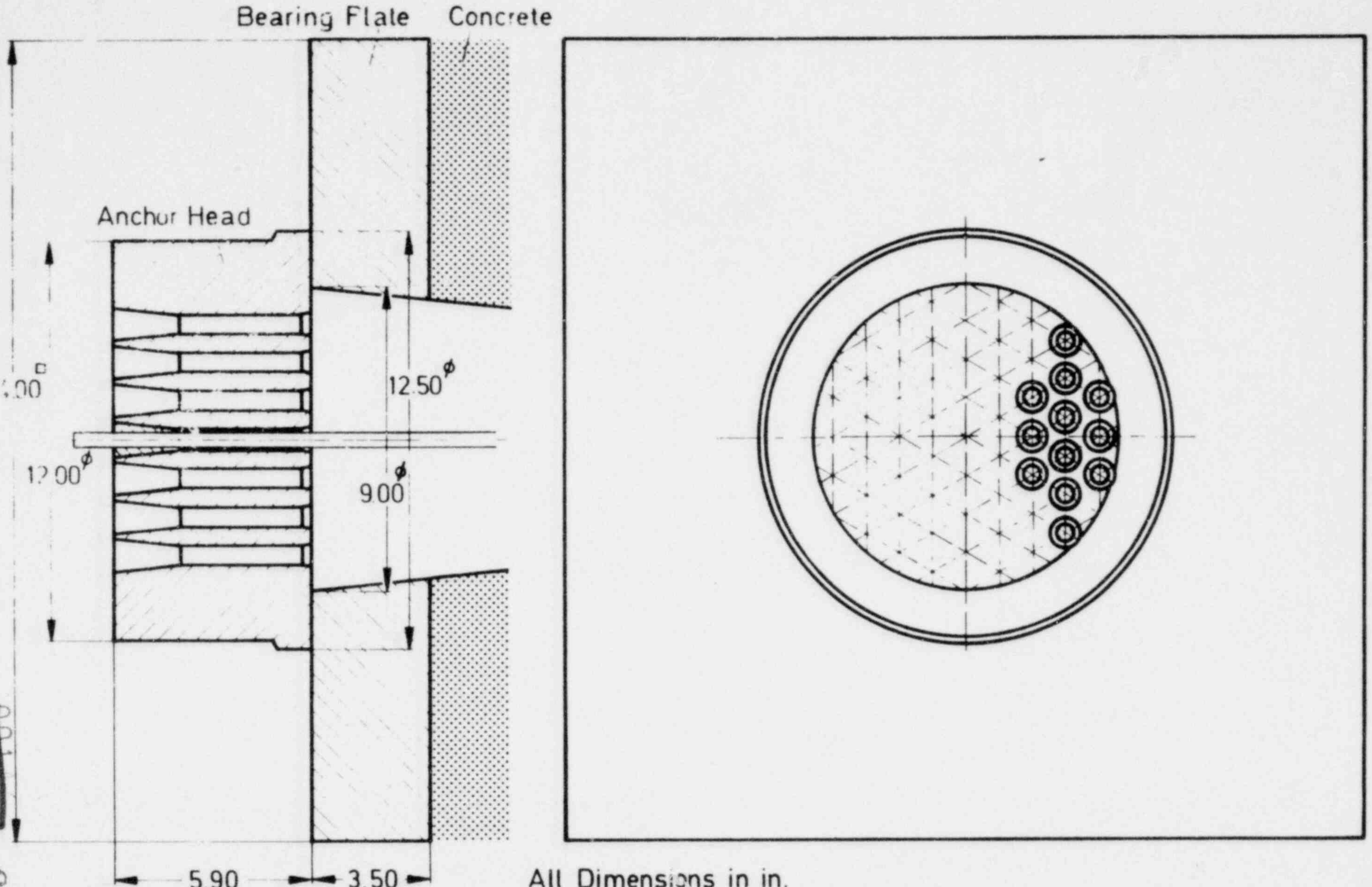


Fig. 3 Bearing Plate under Axial Thrust
Geometry

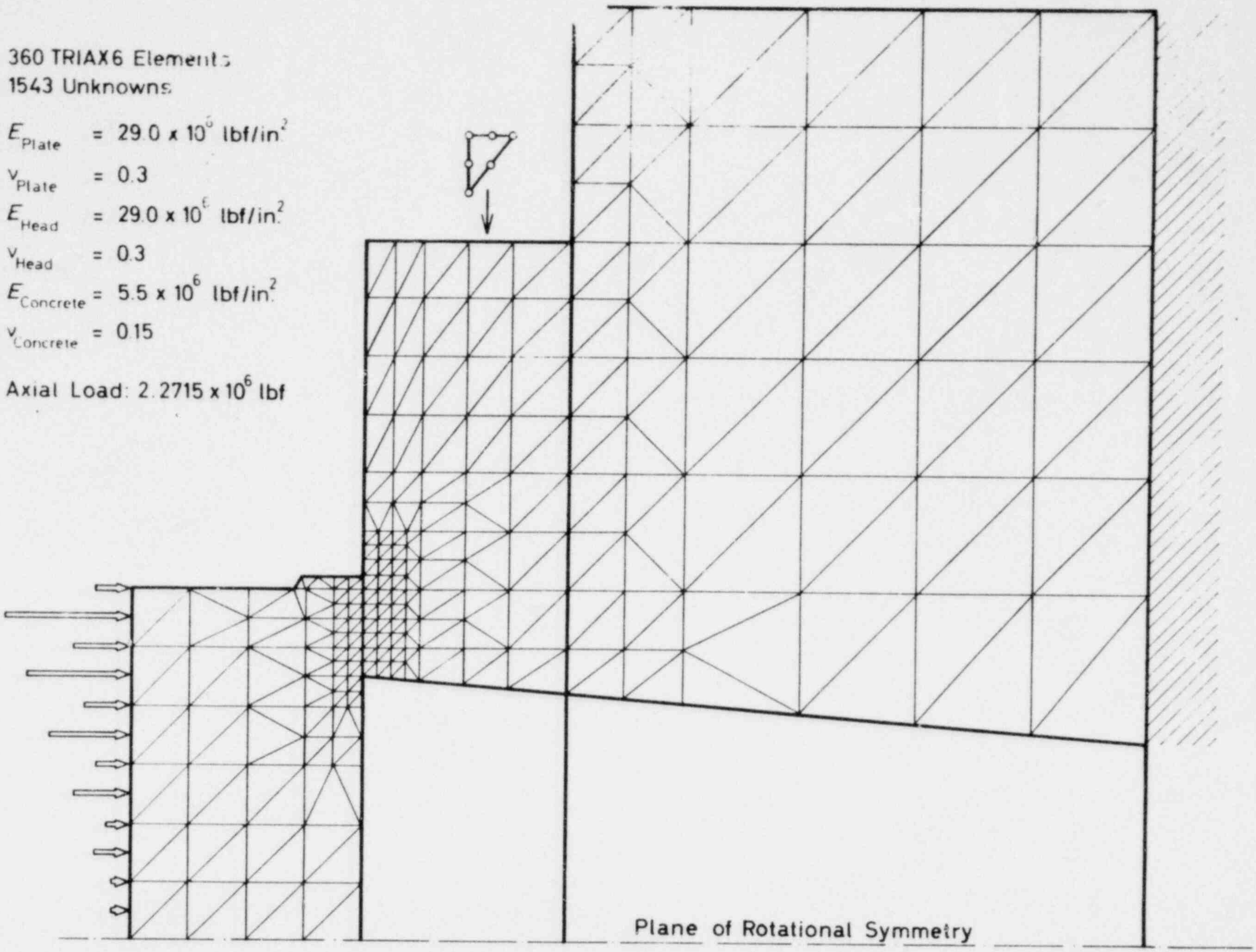
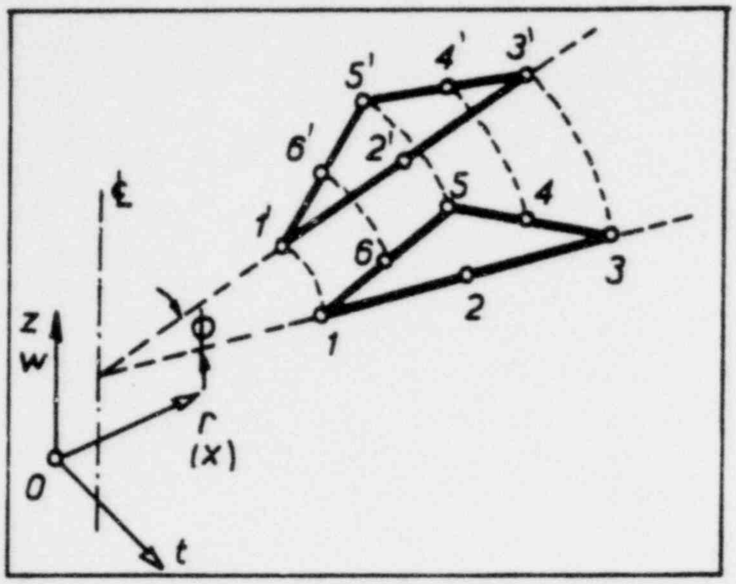


Fig. 4 Bearing Plate under Axial Thrust

Idealisation



Element description:

Segment with the angle $\phi = 1$ from an axisymmetric body, the cross-section being a triangle with six nodal points.

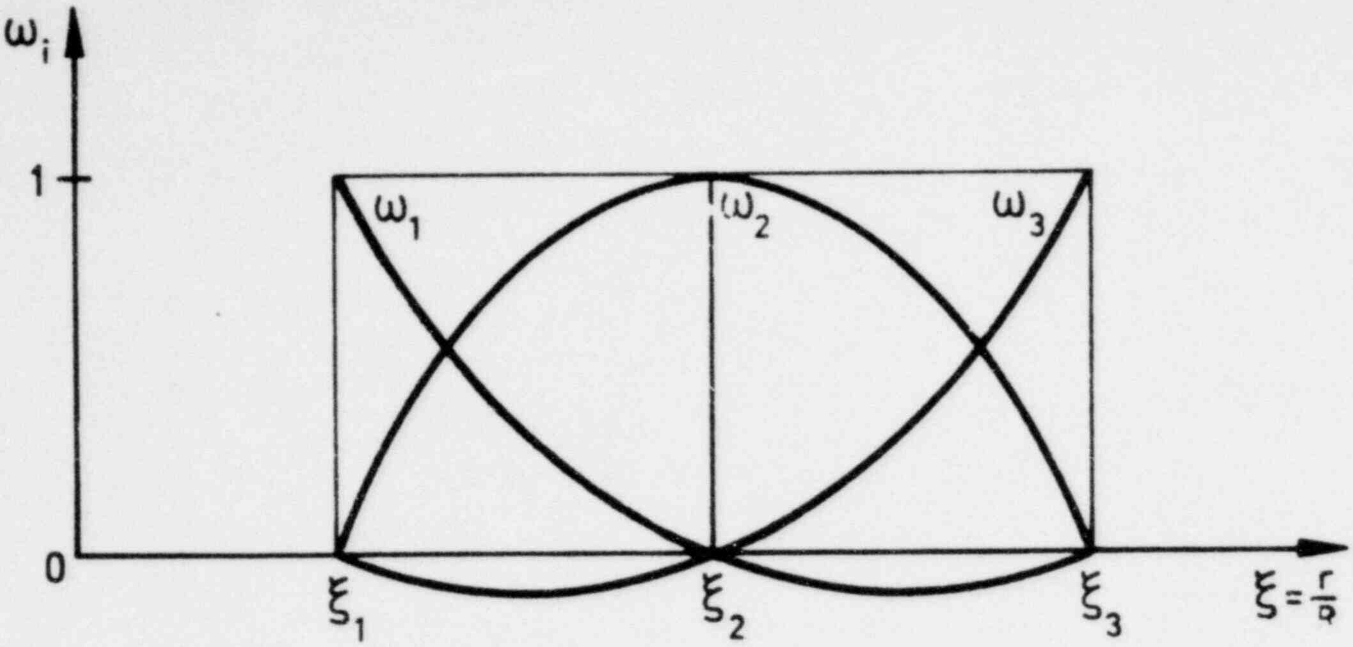
Computed stresses:

At each point the stress system

$$\left\{ \sigma_{rr} \quad \sigma_{zz} \quad \sqrt{2}\sigma_{rz} \quad \sigma_{tt} \right\}$$

In all, 24 stresses per element and loading case.

Fig. 5 TRIAX6 Element for the Analysis of Problems with Axisymmetric Geometry and Loading



$$\omega_1 = \frac{(\xi - \xi_2)(\xi - \xi_3)}{(\xi_1 - \xi_2)(\xi_1 - \xi_3)}$$

$$\omega_2 = \frac{(\xi - \xi_1)(\xi - \xi_3)}{(\xi_2 - \xi_1)(\xi_2 - \xi_3)}$$

$$\omega_3 = \frac{(\xi - \xi_1)(\xi - \xi_2)}{(\xi_3 - \xi_1)(\xi_3 - \xi_2)}$$

Fig. 6 TRIAX6 Element
Displacement Functions

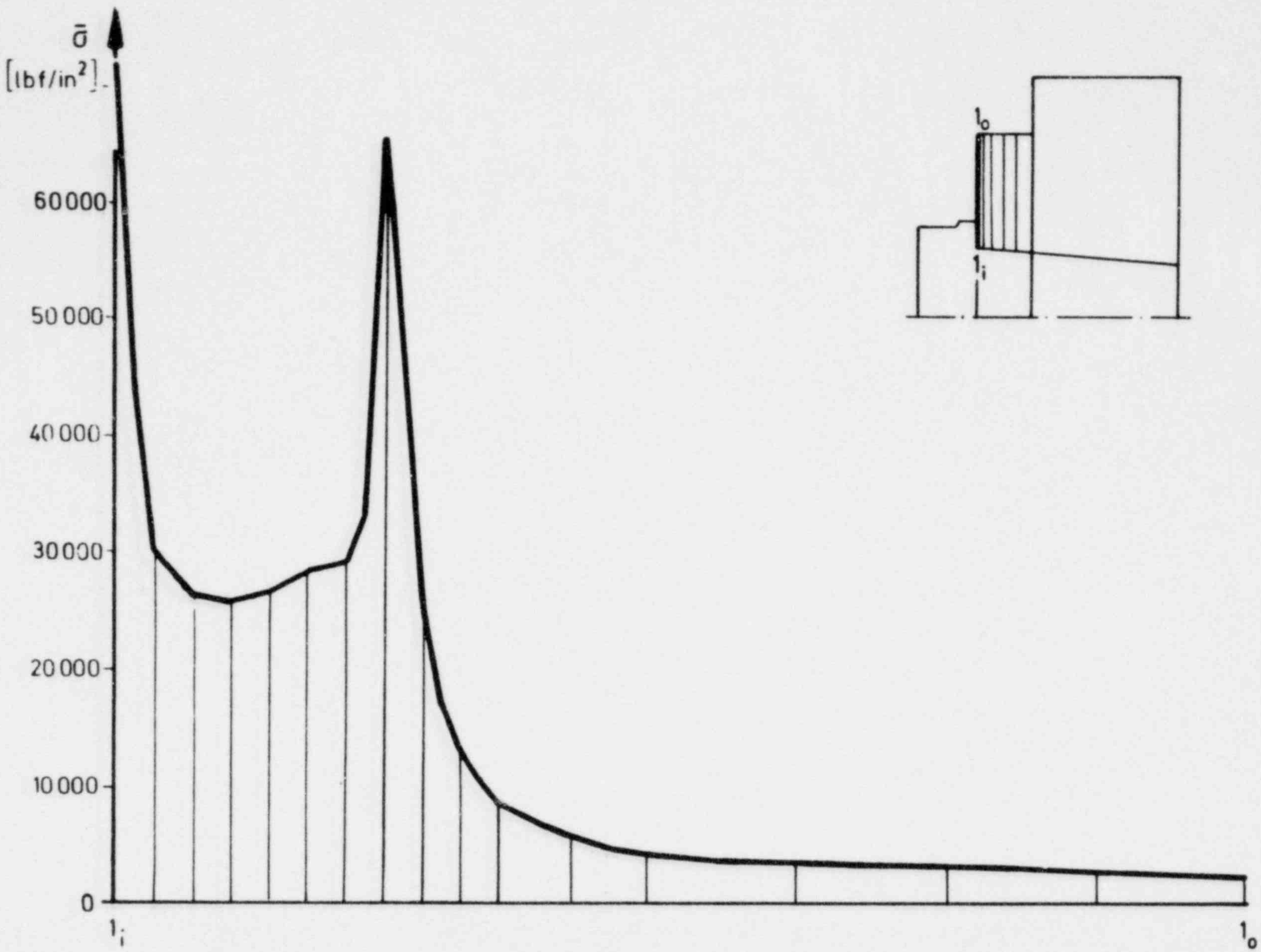


Fig. 7

Bearing Plate

Equivalent Stress $\bar{\sigma}$ in Cross Section 1

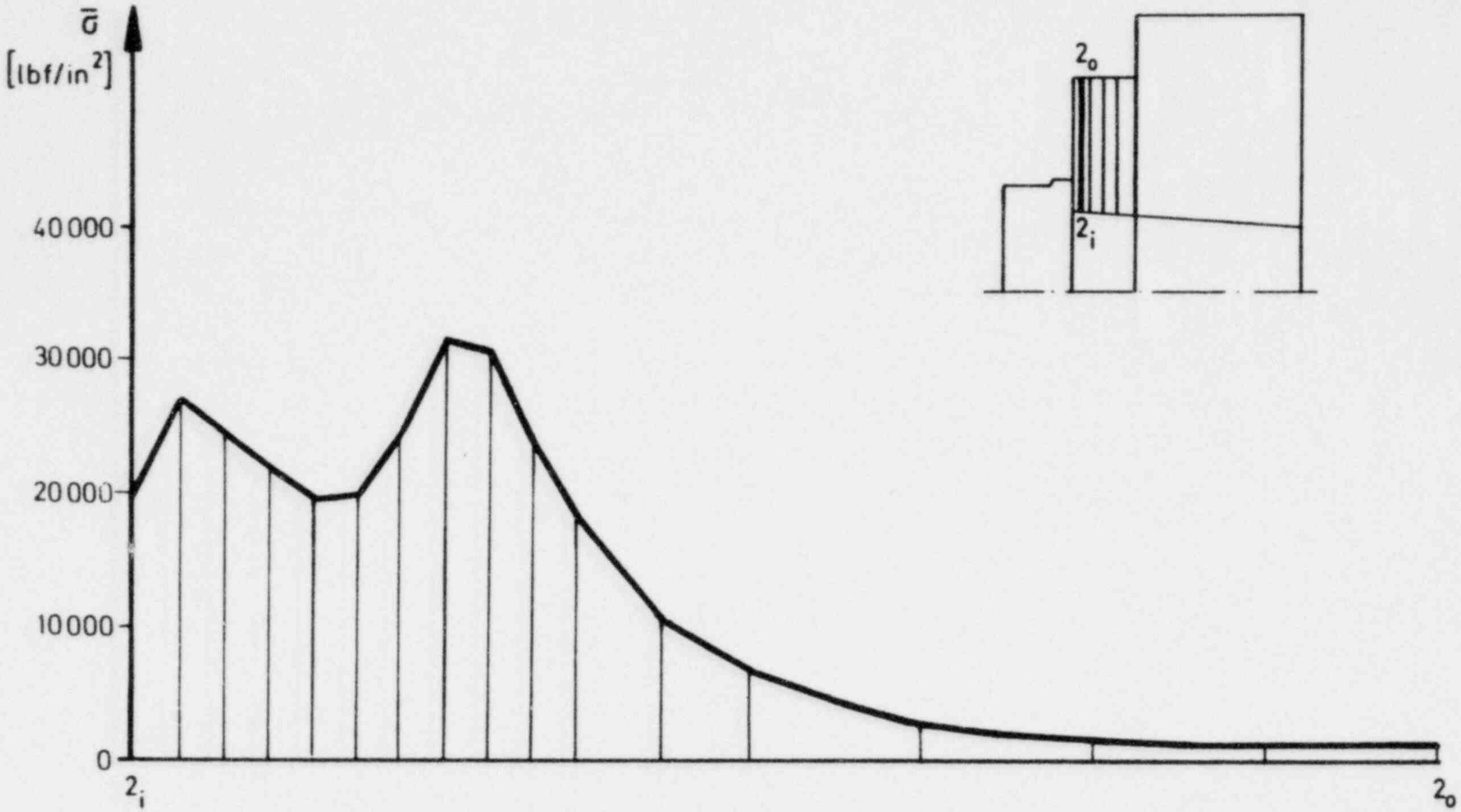


Fig. 8

Bearing Plate

Equivalent Stress $\bar{\sigma}$ in Cross Section 2

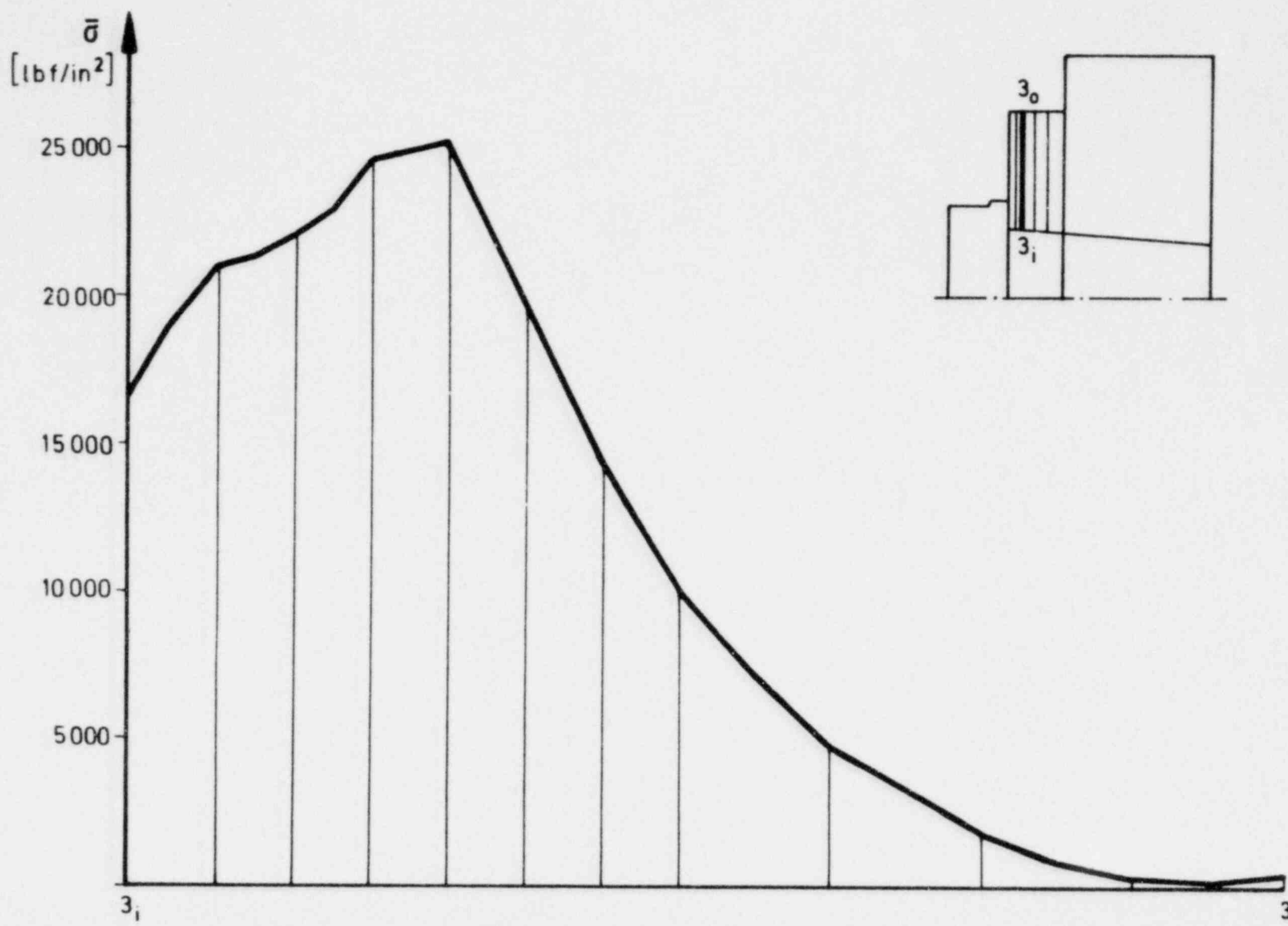


Fig.9

Bearing Plate

Equivalent Stress $\bar{\sigma}$ in Cross Section 3

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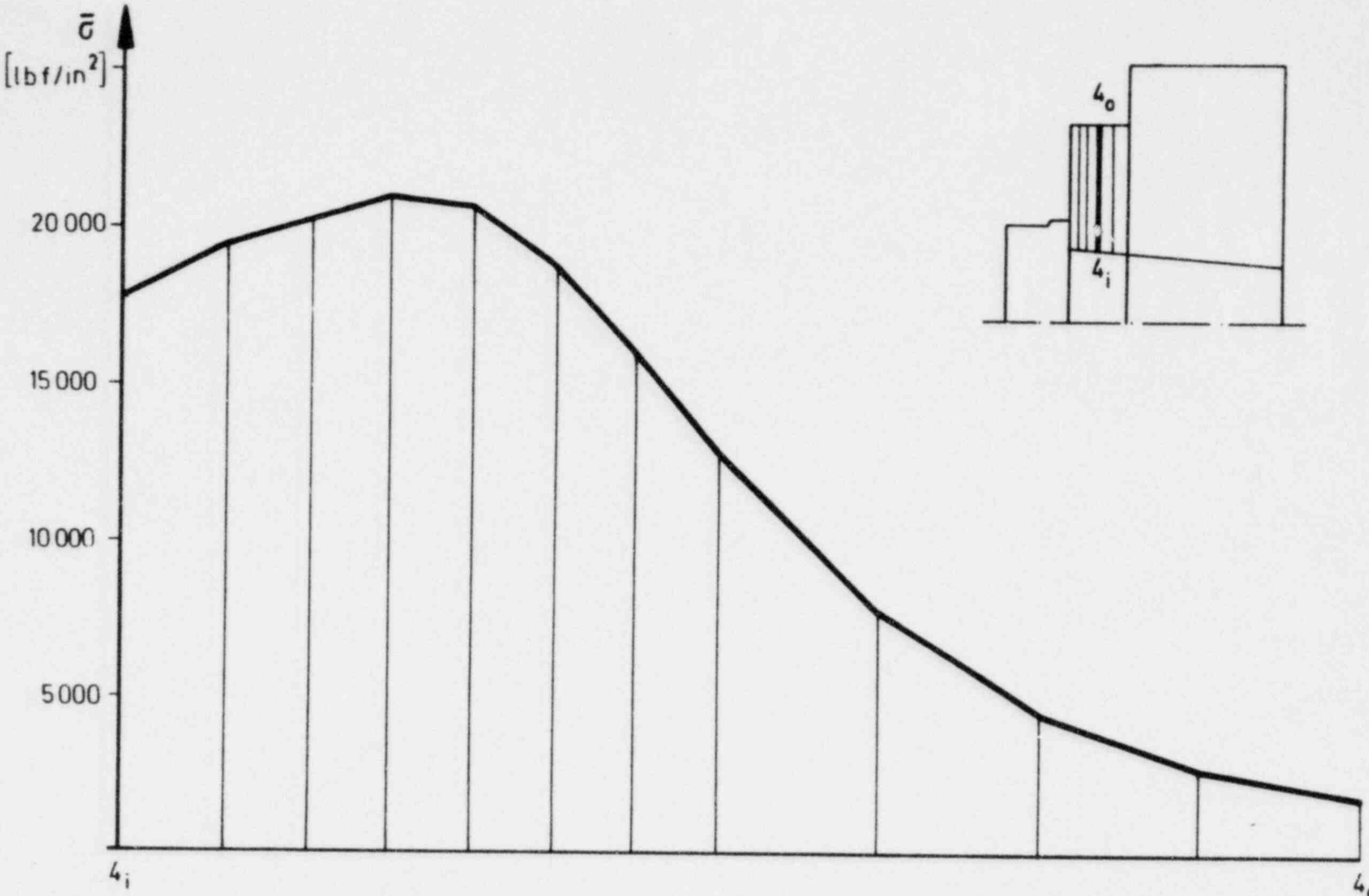

Fig. 10

Bearing Plate

Equivalent Stress $\bar{\sigma}$ in Cross Section 4

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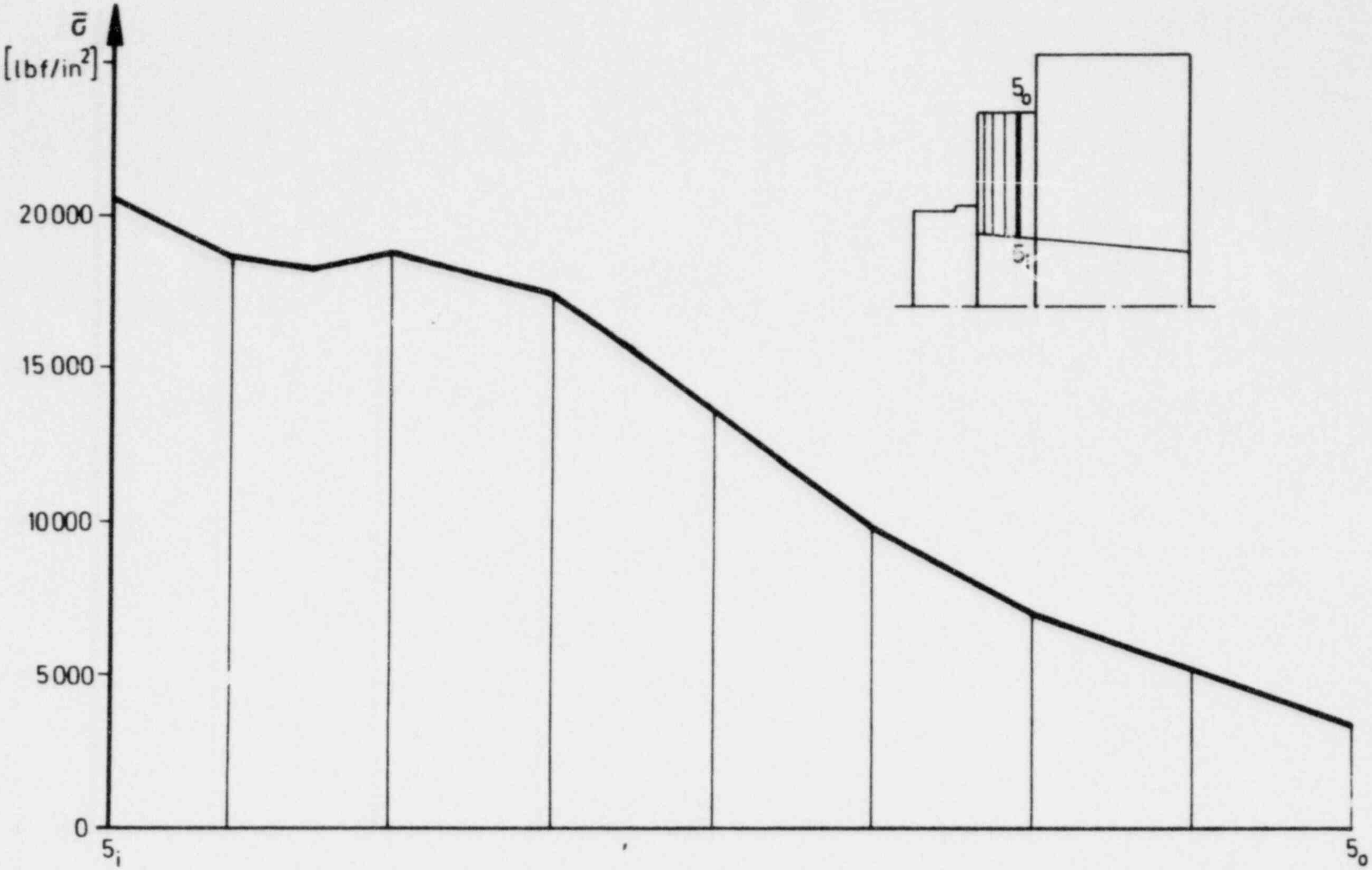

Fig. 11

Bearing Plate

Equivalent Stress σ̄ in Cross Section 5

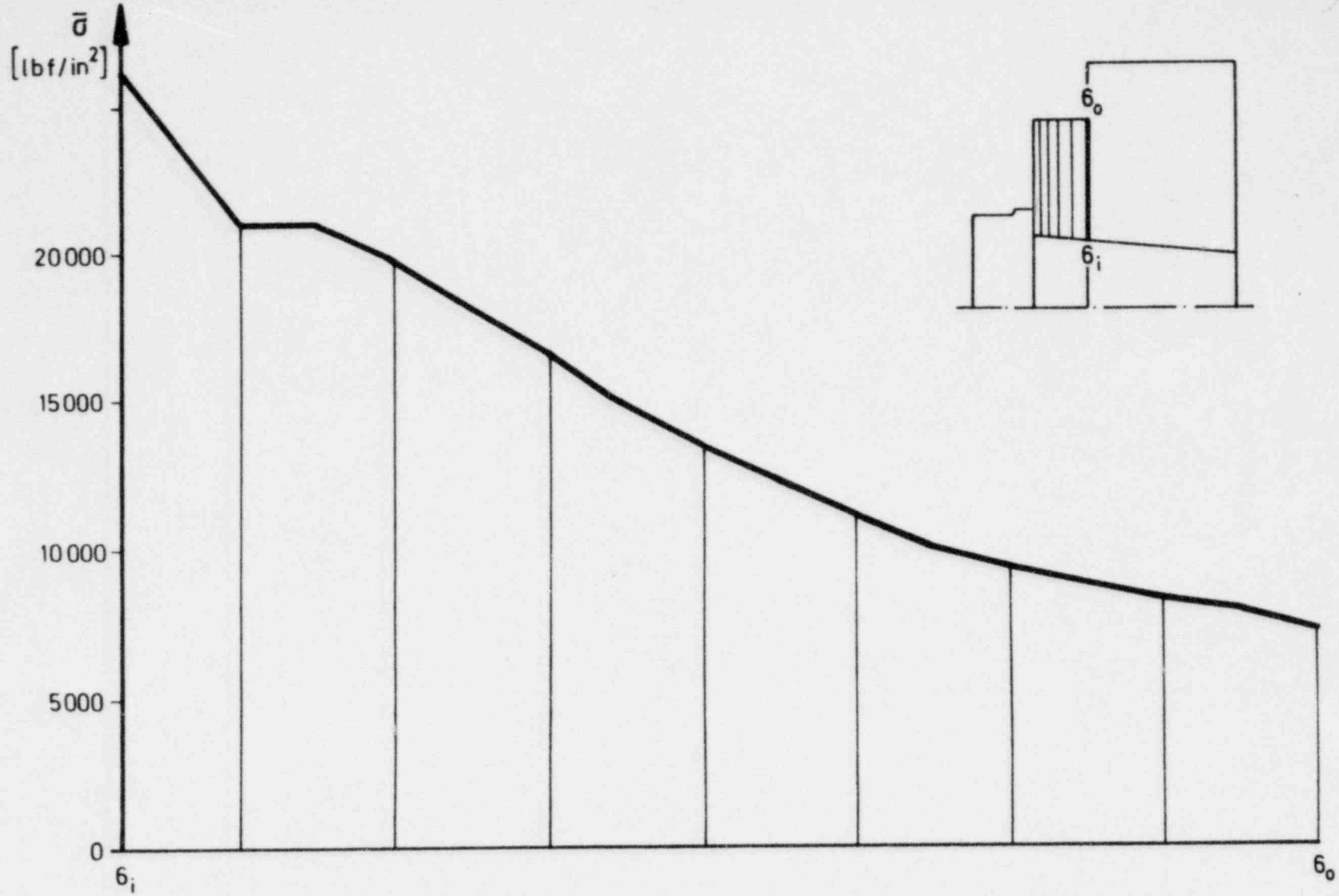

Fig. 12

Bearing Plate

Equivalent Stress $\bar{\sigma}$ in Cross Section 6

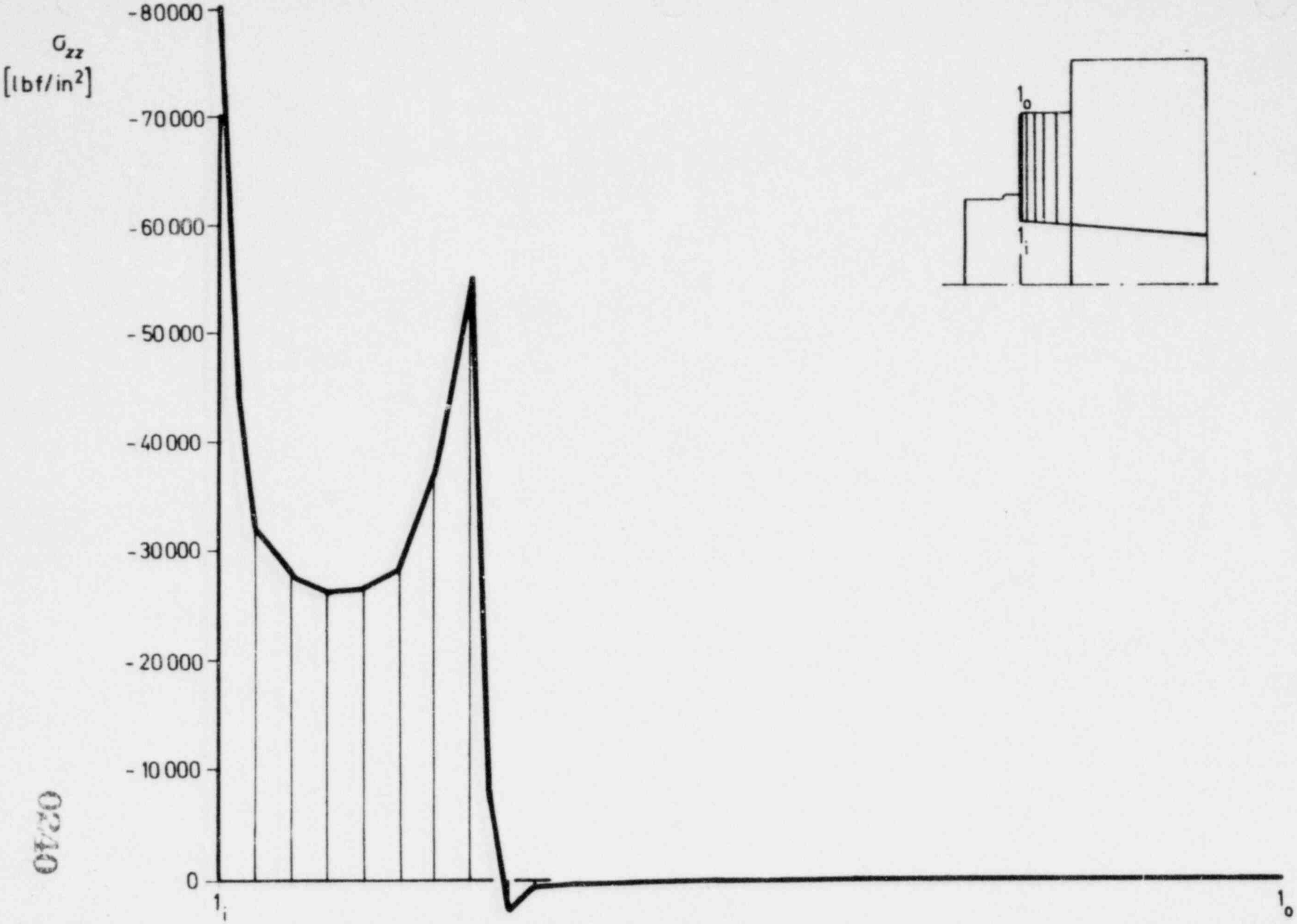

Fig. 13 **Bearing Plate**

Vertical Normal Stress σ_{zz} in Cross Section 1

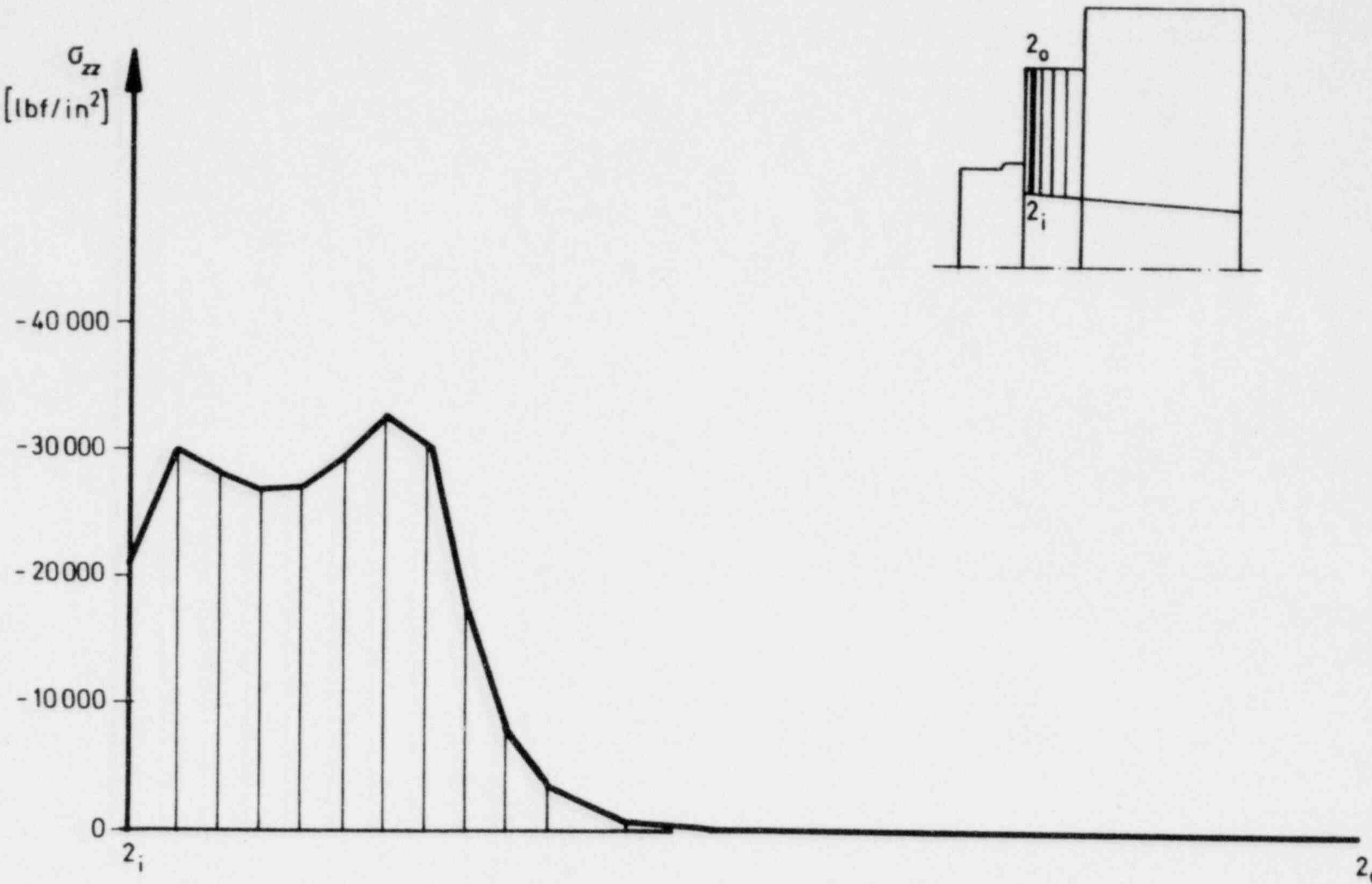

Fig. 14

Bearing Plate

Vertical Normal Stress σ_{zz} in Cross Section 2

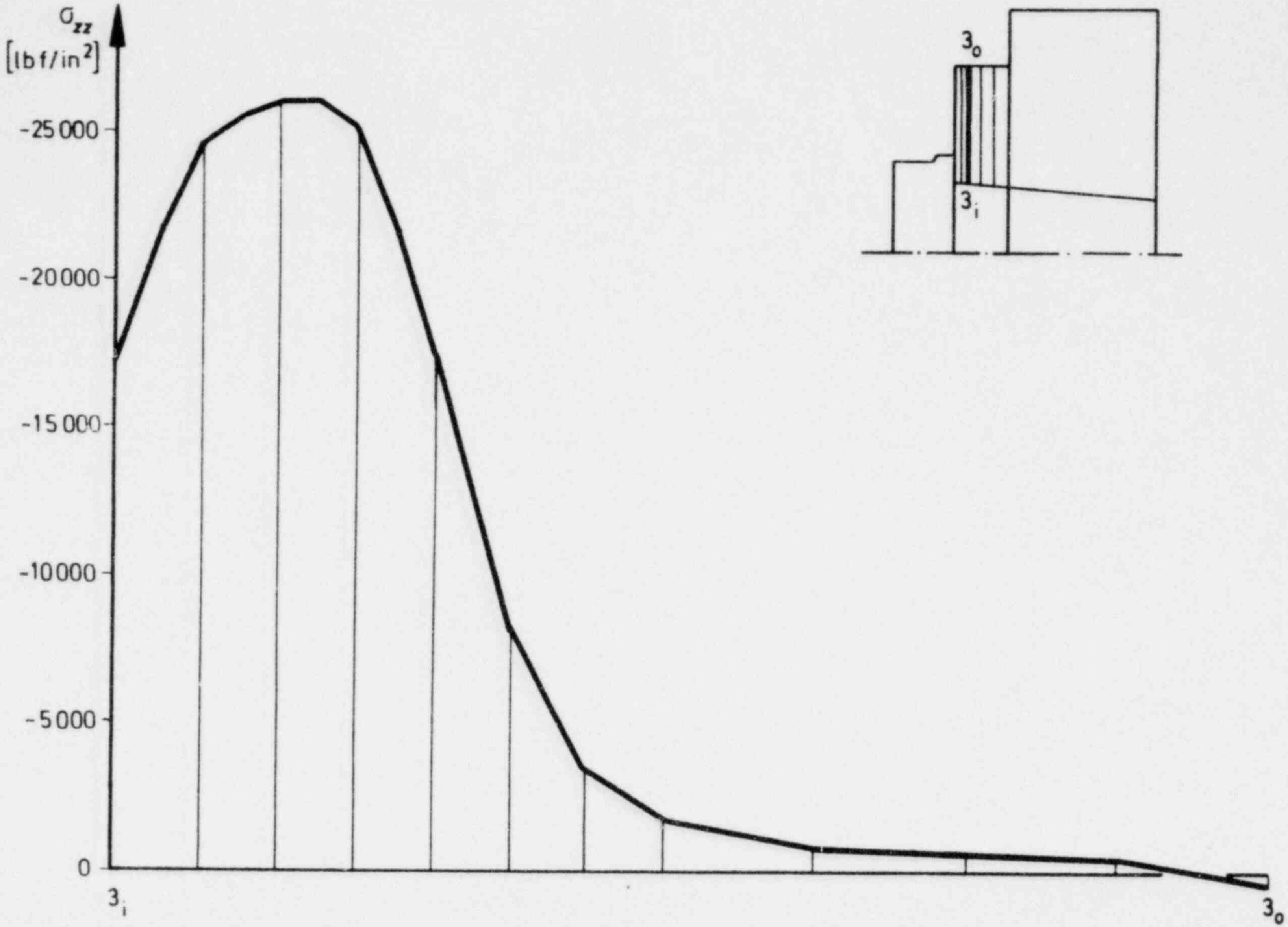

Fig. 15

Bearing Plate

Vertical Normal Stress σ_{zz} in Cross Section 3

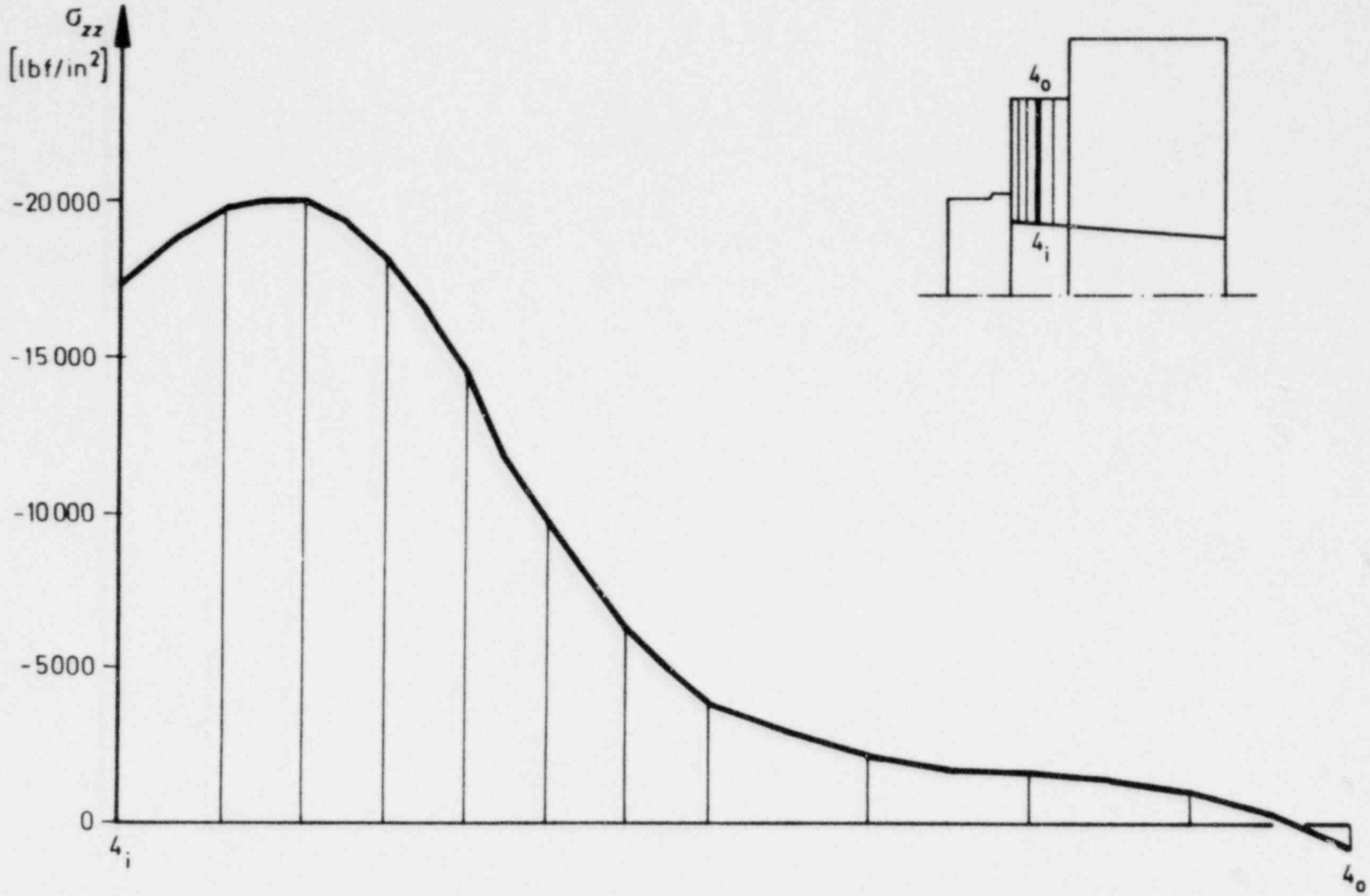

Fig. 16 **Bearing Plate**

Vertical Normal Stress σ_{zz} in Cross Section 4

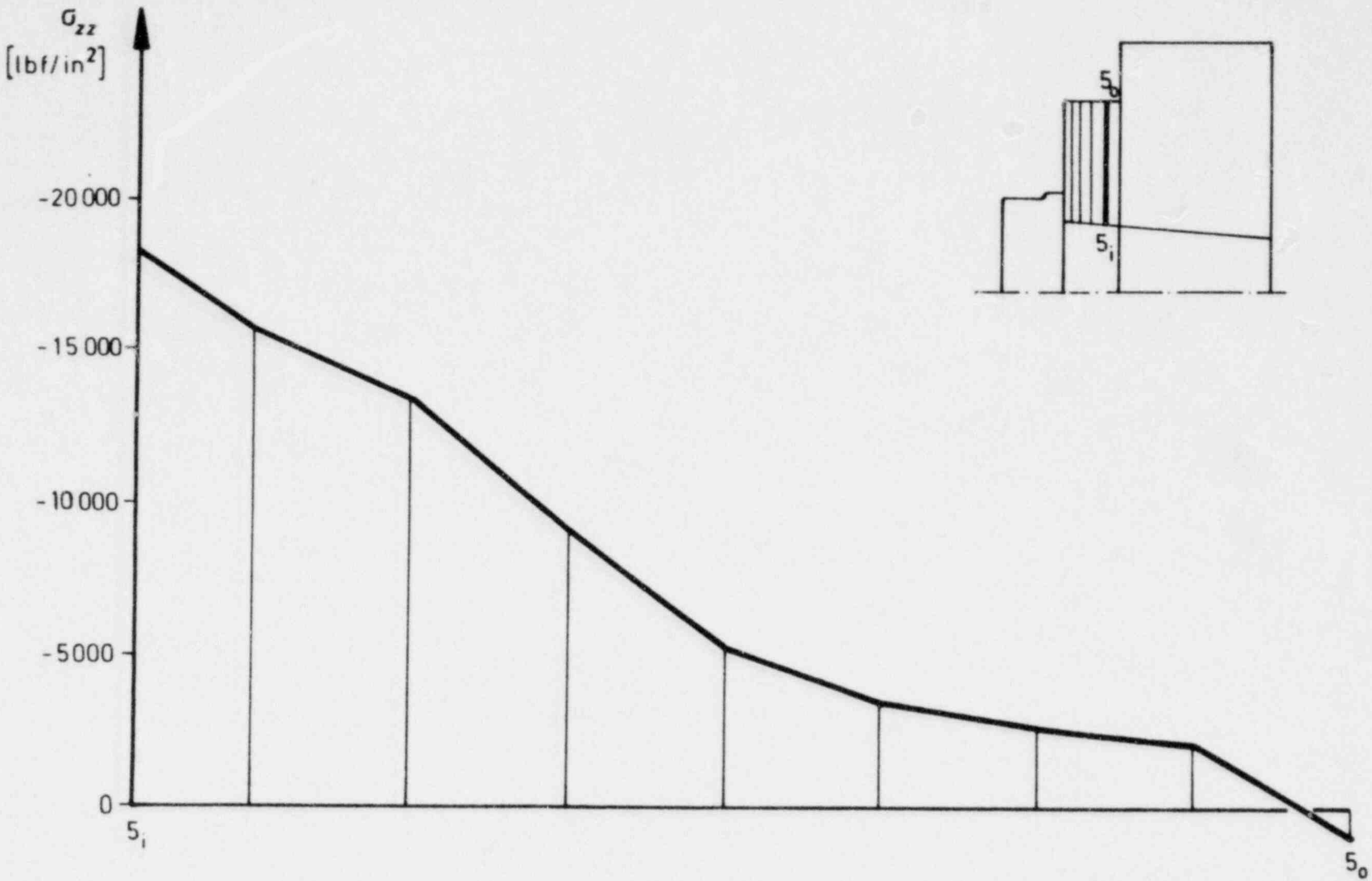

Fig. 17 Bearing Plate

Vertical Normal Stress σ_{zz} in Cross Section 5

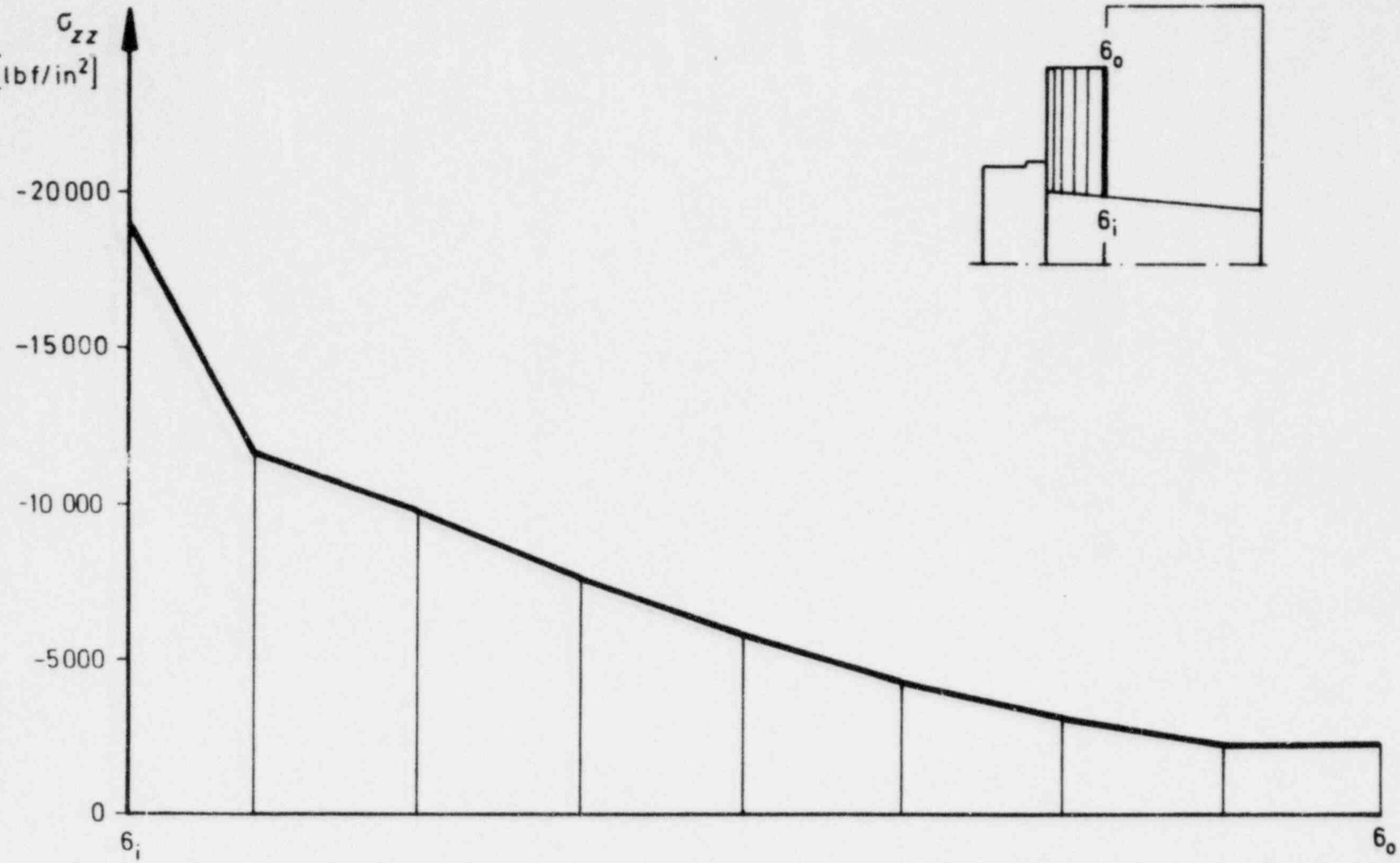

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Fig. 18

Bearing Plate

Vertical Normal Stress σ_{zz} in Cross Section 6

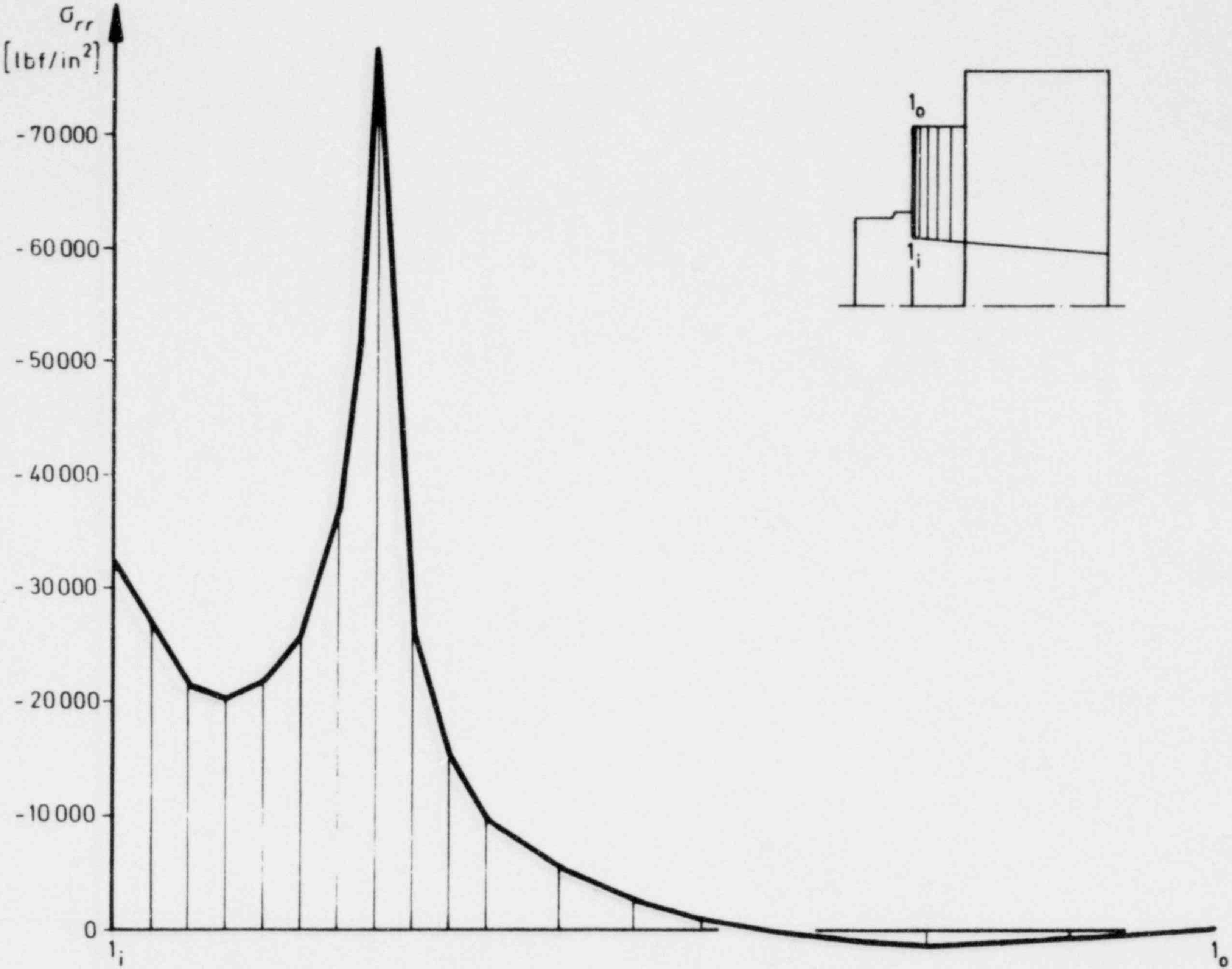

Fig. 19 Bearing Plate

Radial Normal Stress σ_{rr} in Cross Section 1

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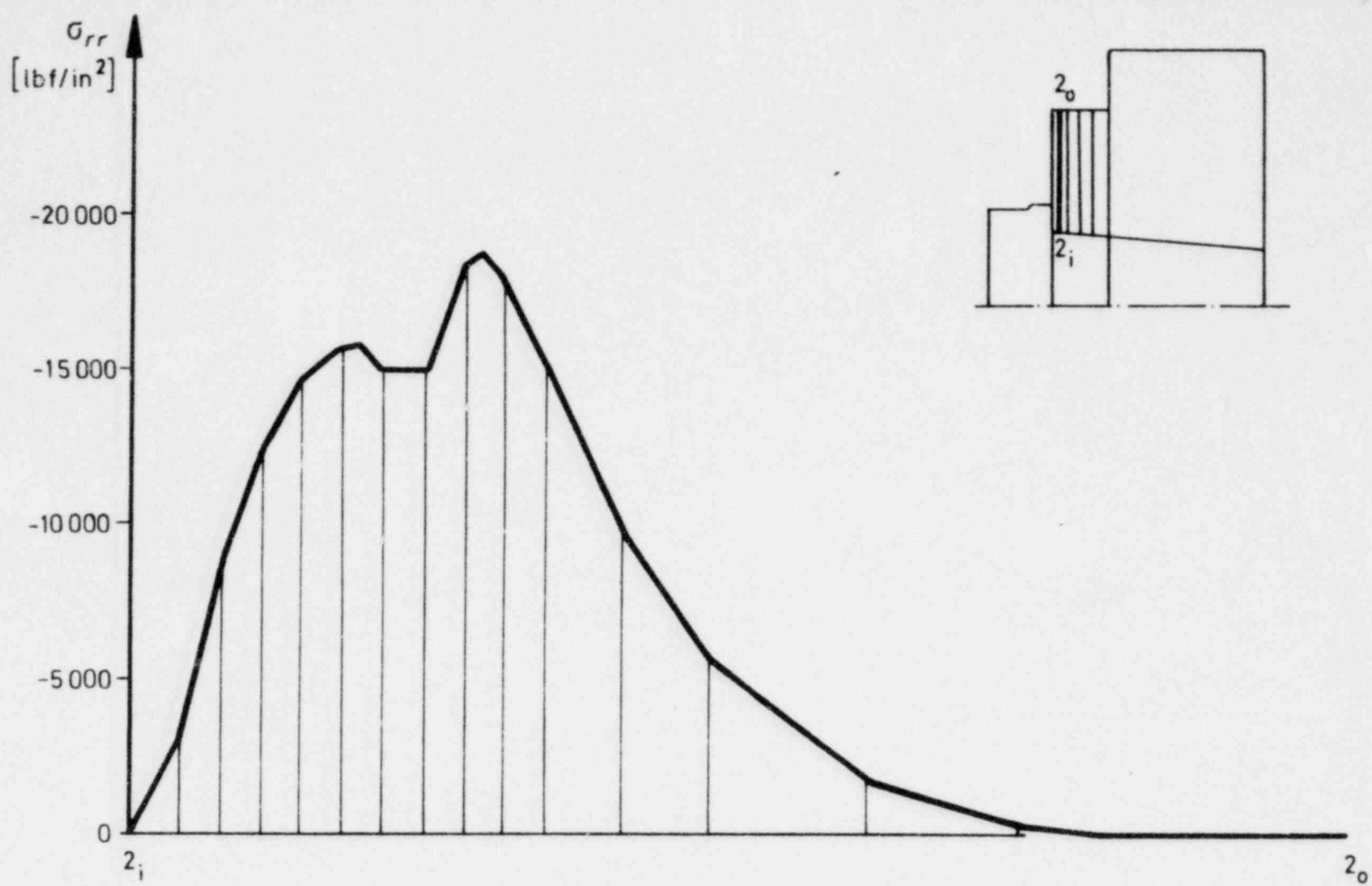

Fig. 20 Bearing Plate

Radial Normal Stress σ_{rr} in Cross Section 2

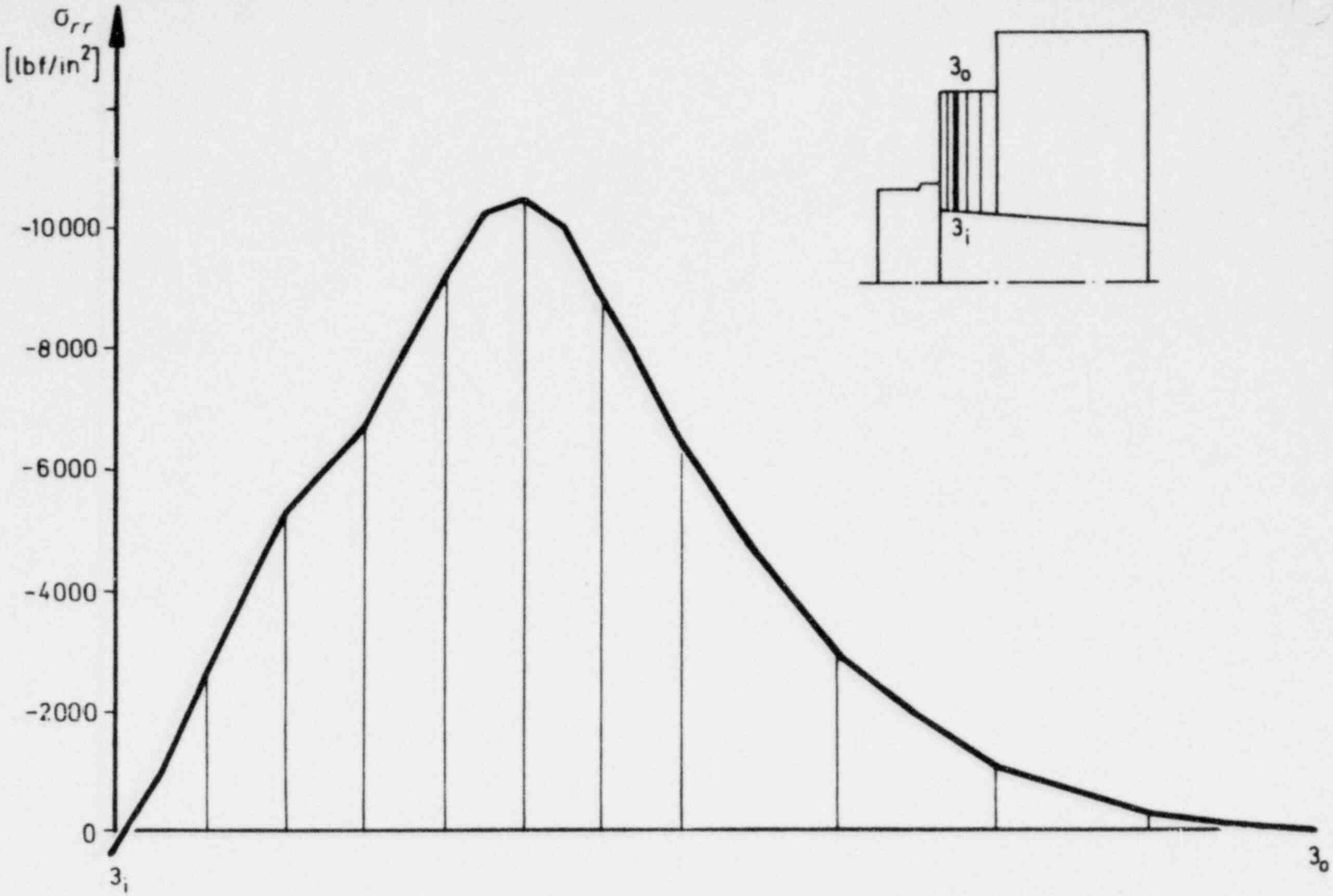

Fig. 21 **Bearing Plate**

Radial Normal Stress σ_{rr} in Cross Section 3

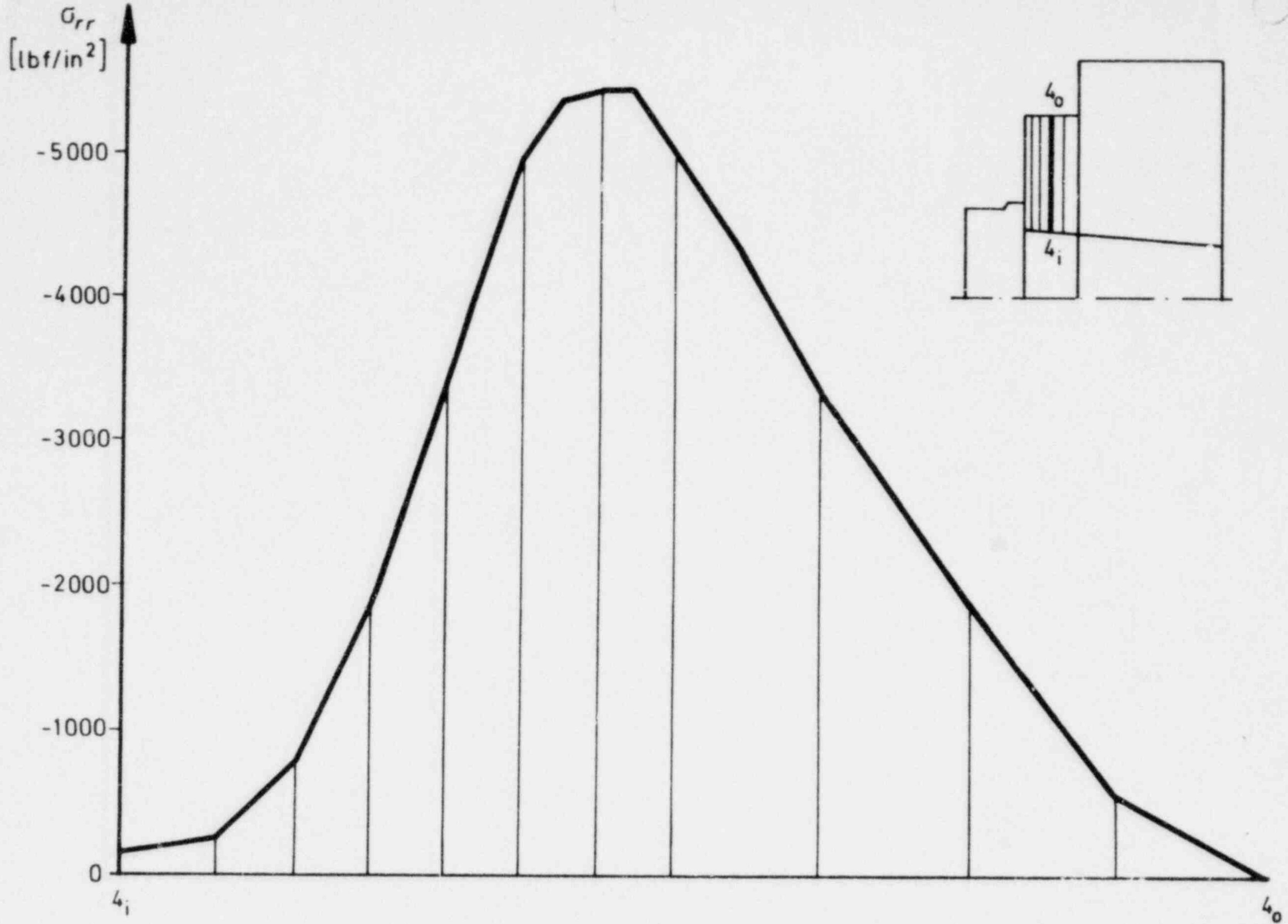

Fig. 22

Bearing Plate

Radial Normal Stress σ_{rr} in Cross Section 4

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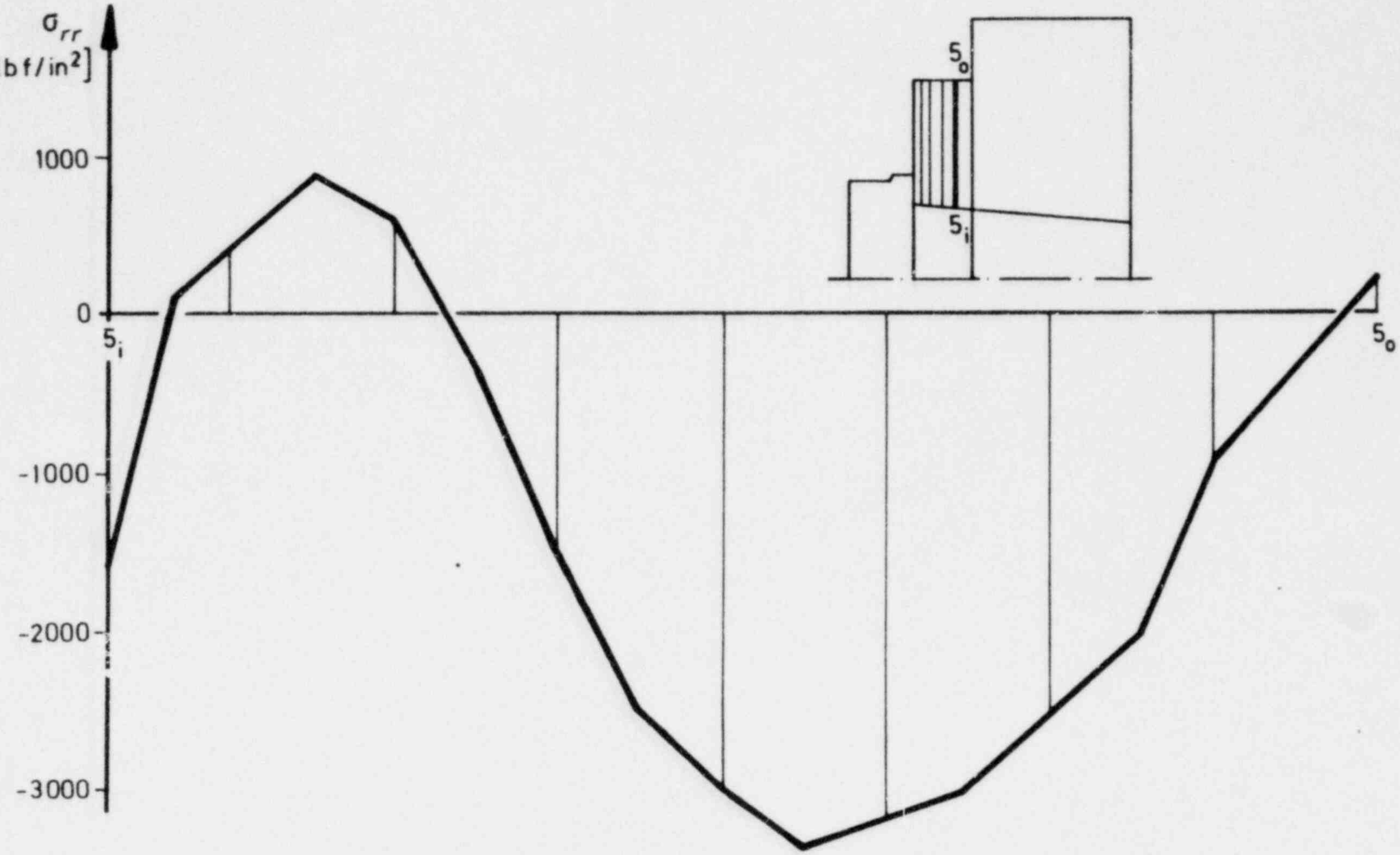

Fig. 23 **Bearing Plate**

Radial Normal Stress σ_{rr} in Cross Section 5

0250

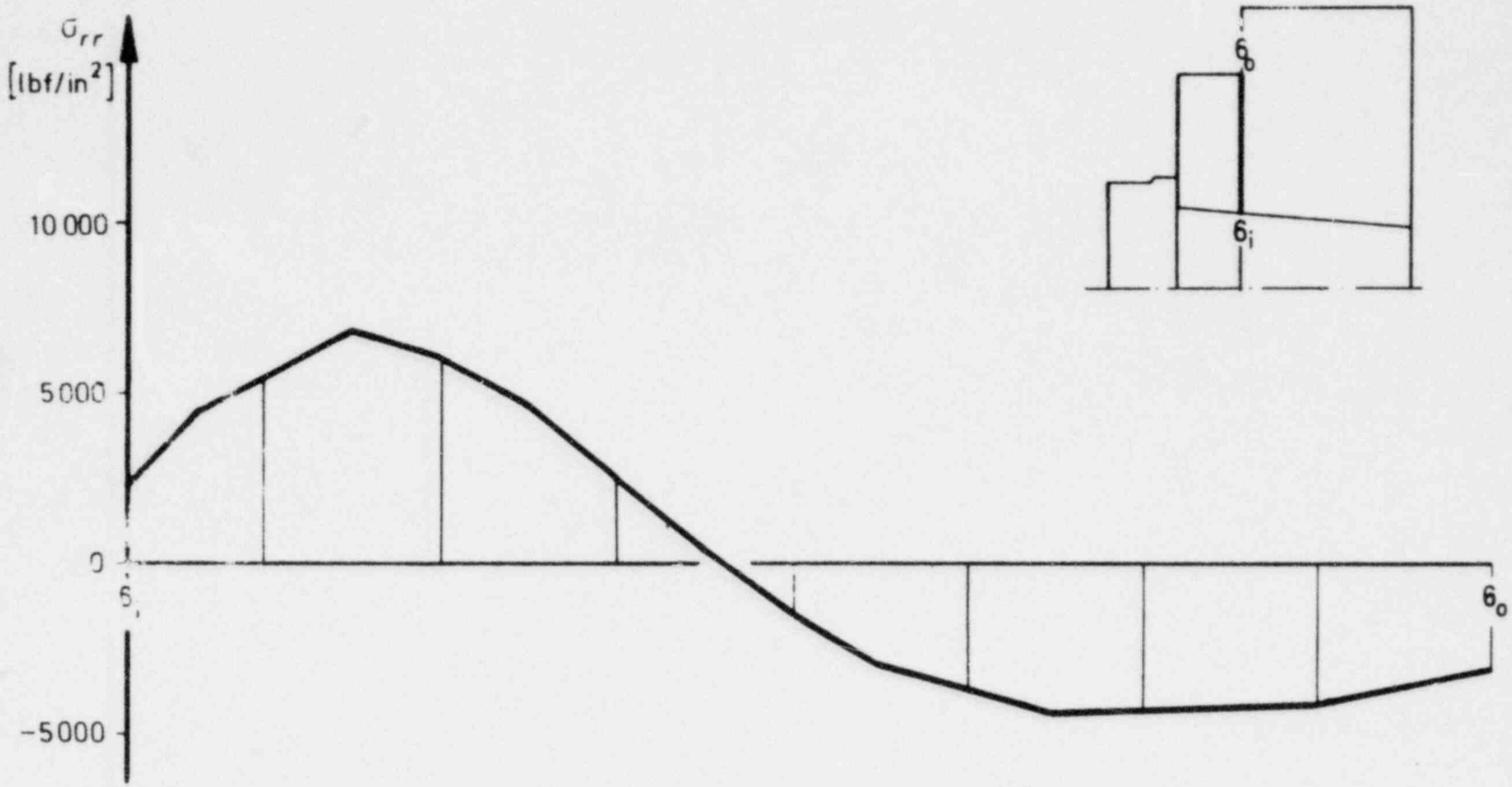

Fig. 24

Bearing Plate

Radial Normal Stress σ_{rr} in Cross Section 6

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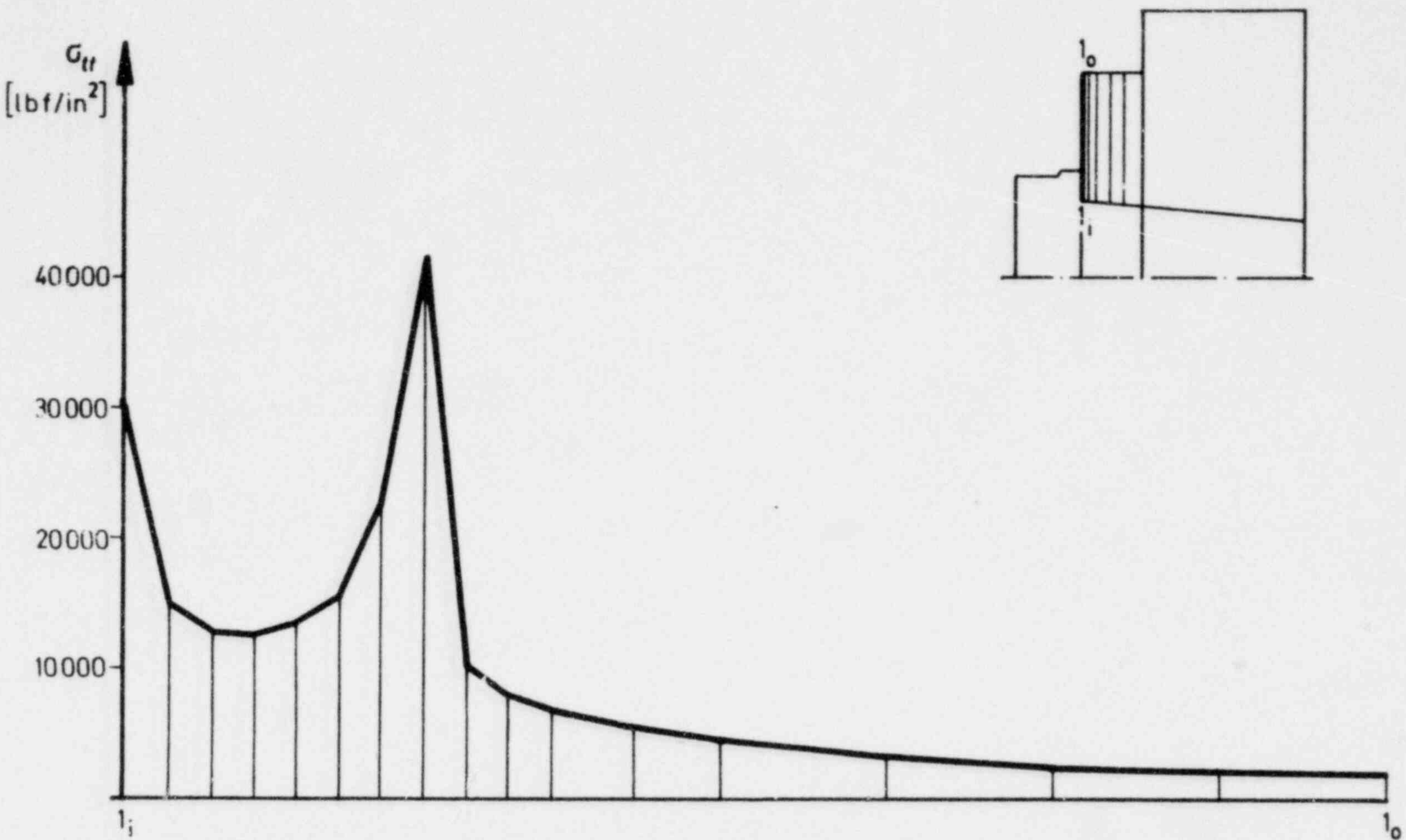

Fig. 25 **Bearing Plate**

Circumferential Normal Stress σ_{tt} in Cross Section 1

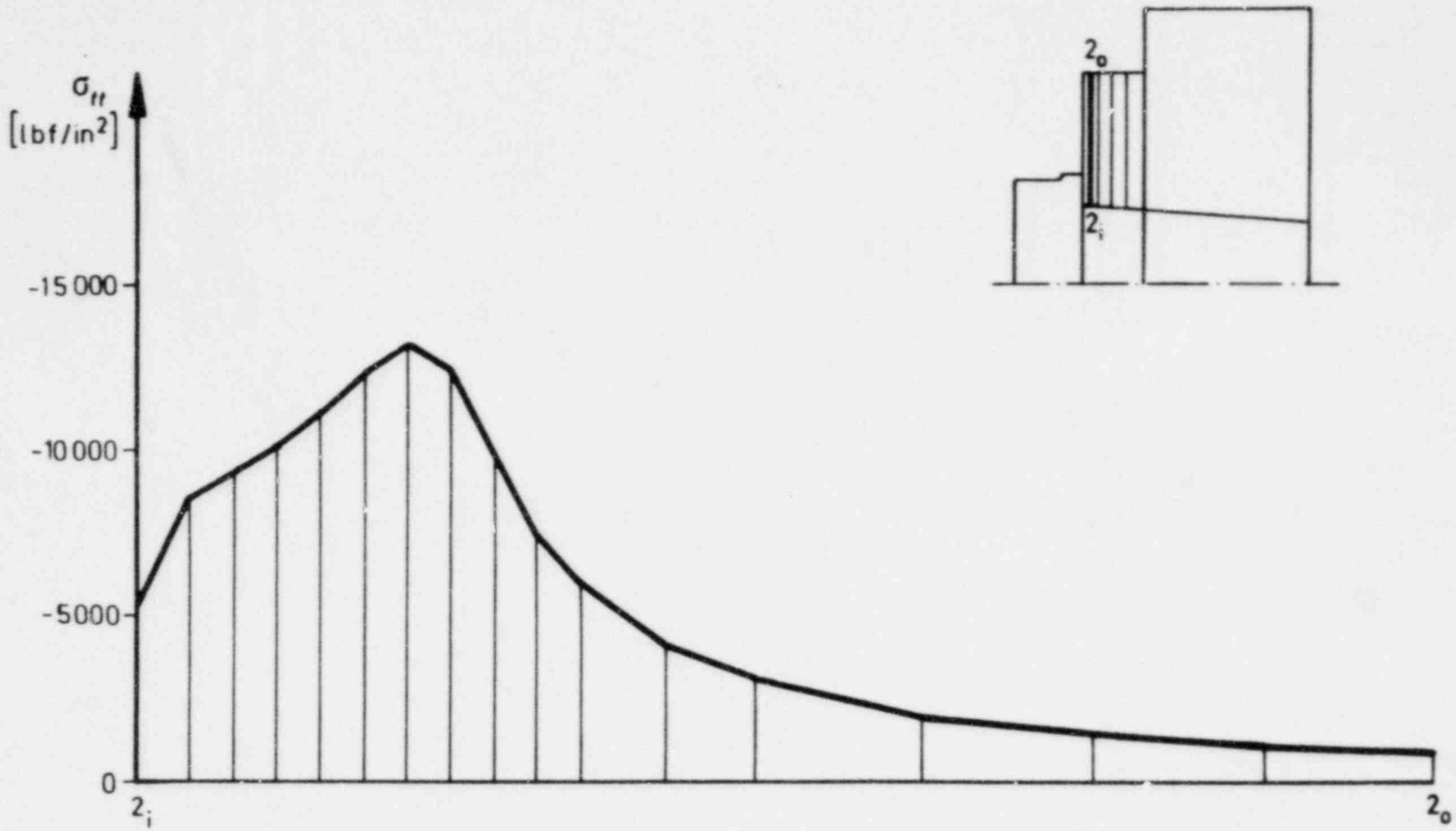

Fig. 26

Bearing Plate

Circumferential Normal Stress σ_{tt} in Cross Section 2

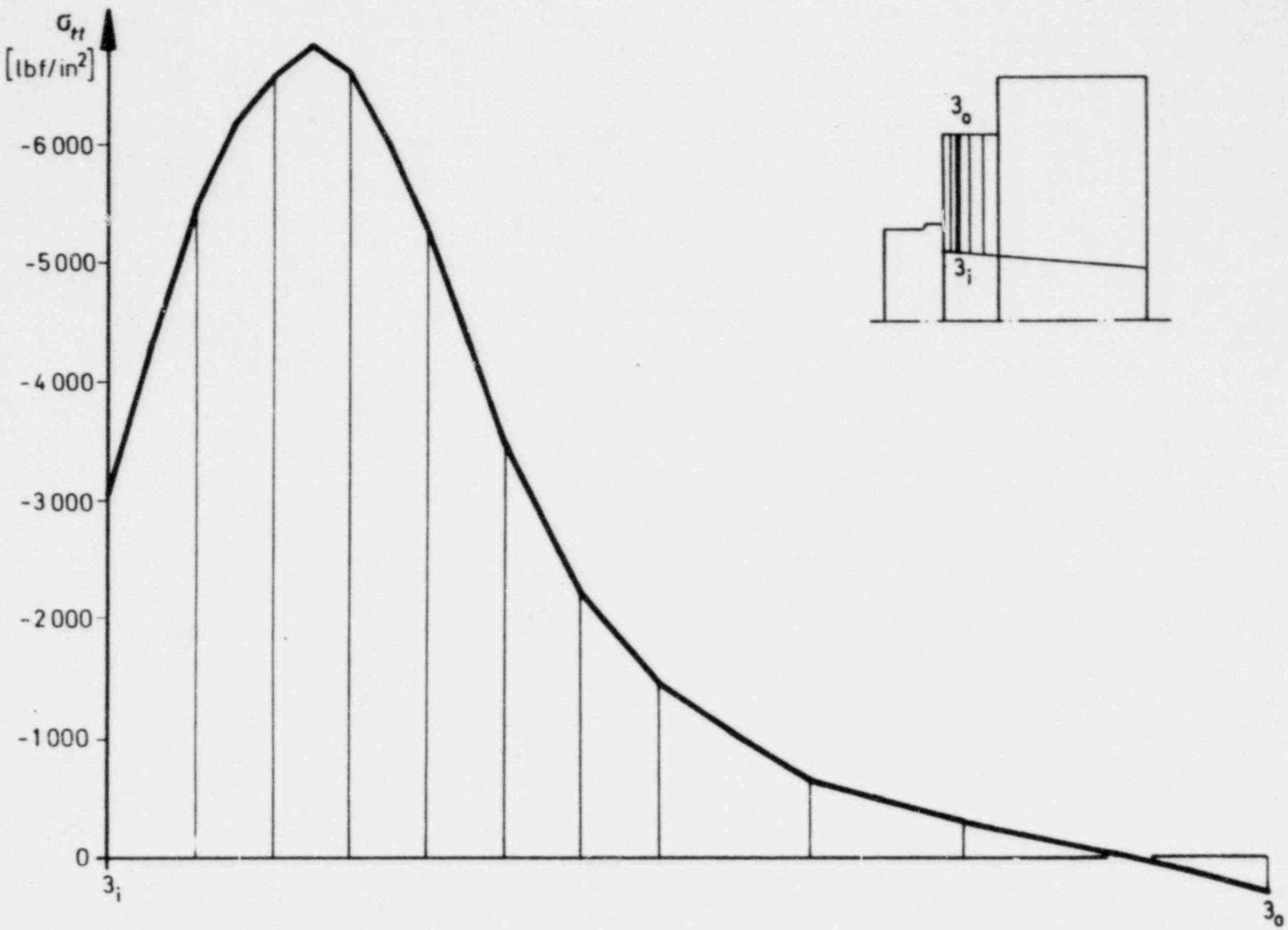

Fig. 27 Bearing Plate

Circumferential Normal Stress σ_{tt} in Cross Section 3

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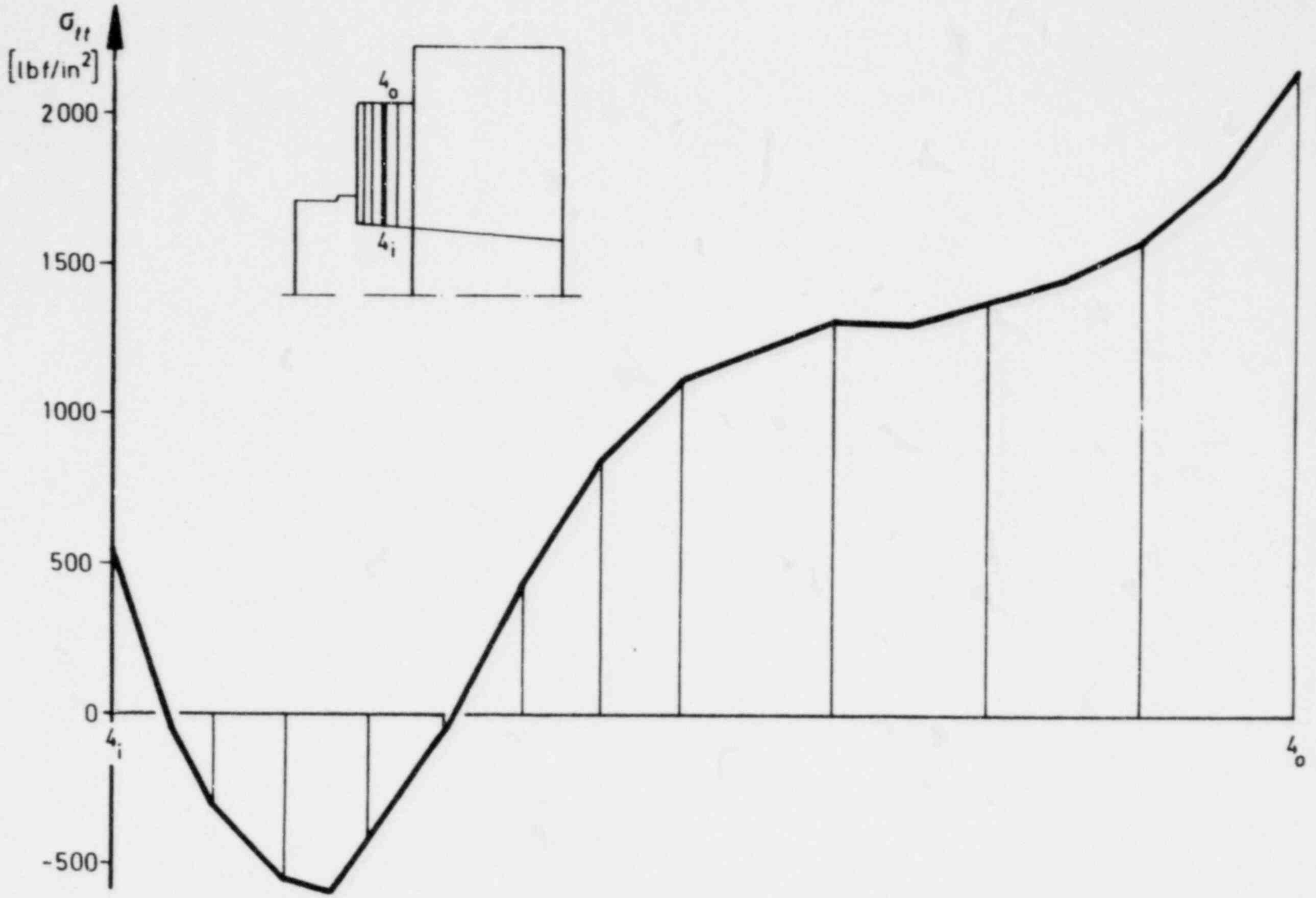

Fig. 28

Bearing Plate

Circumferential Normal Stress σ_{tt} in Cross Section 4

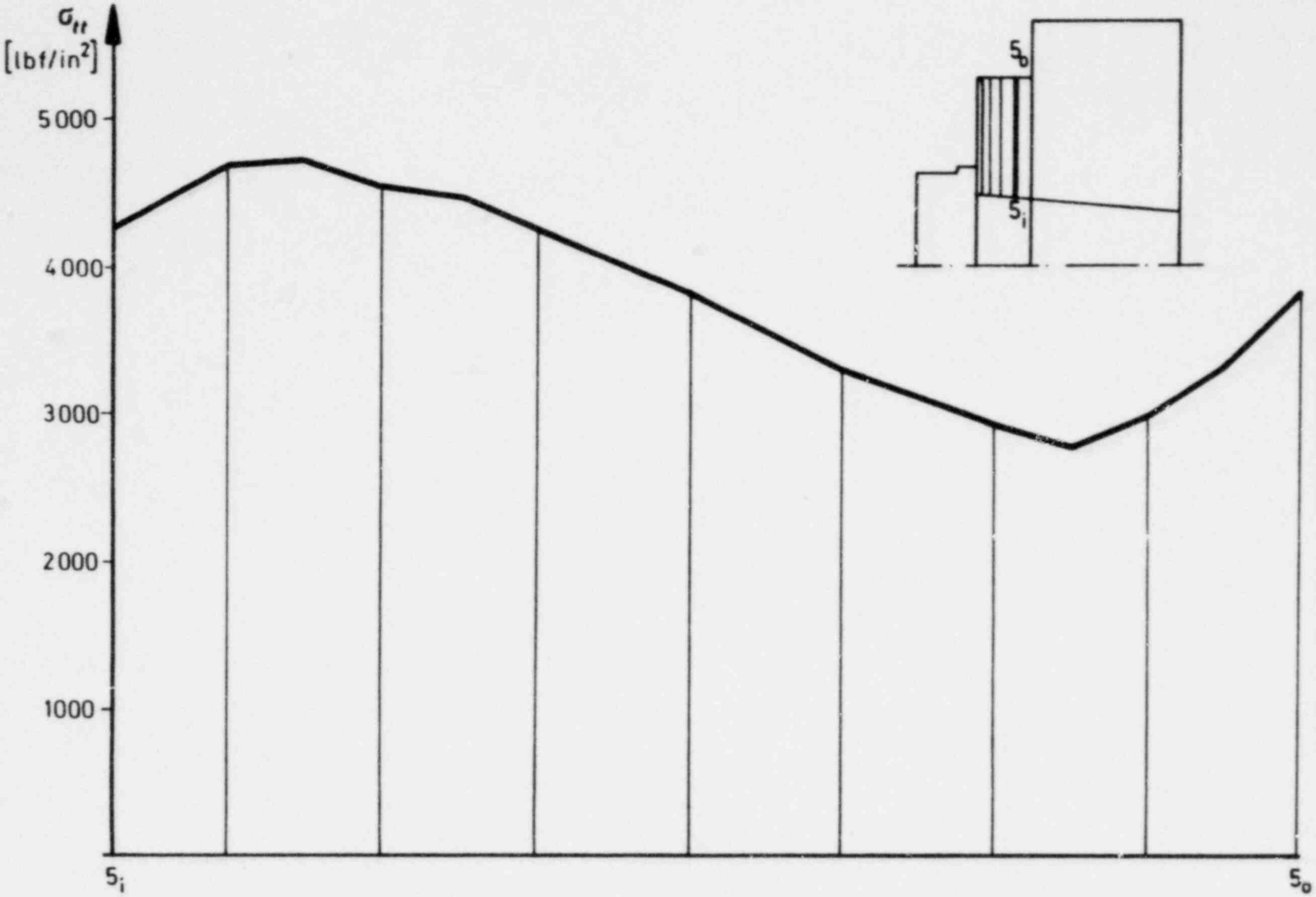

Fig. 29 **Bearing Plate**

Circumferential Normal Stress σ_{tt} in Cross Section 5

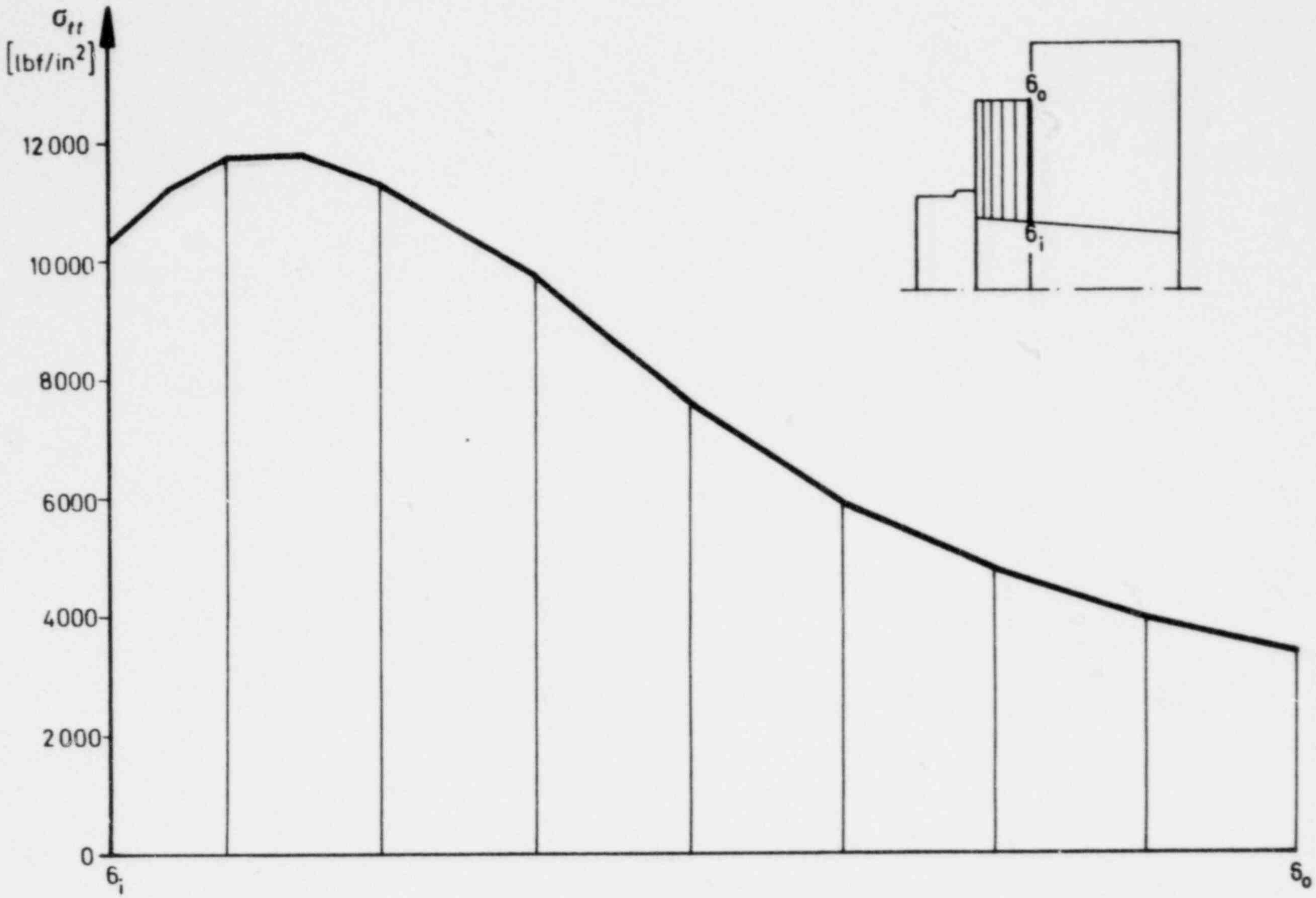

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Fig. 30 **Bearing Plate**

Circumferential Normal Stress σ_{tt} in Cross Section 6

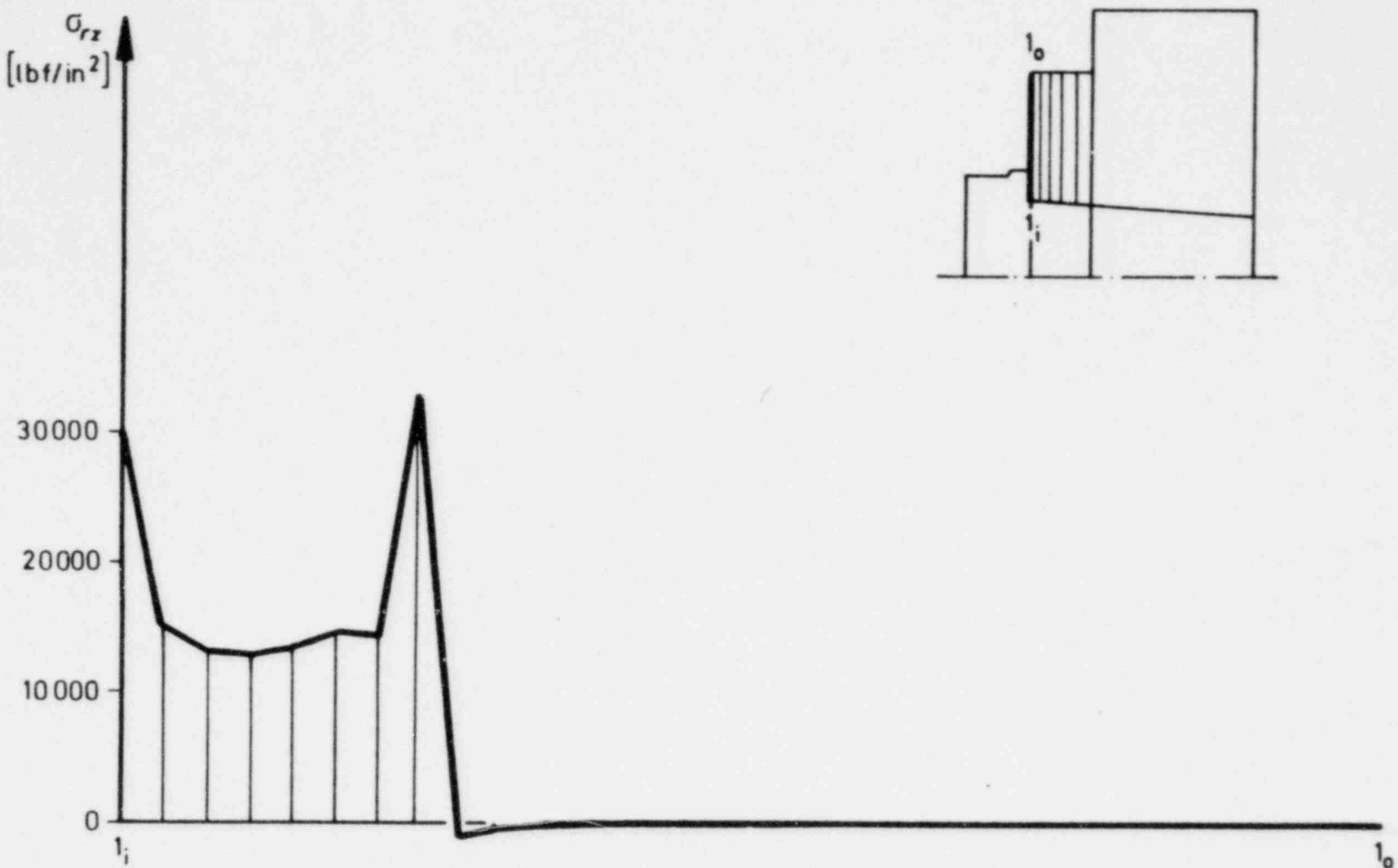

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Fig. 31

Bearing Plate

Shear Stress σ_{rz} in Cross Section 1

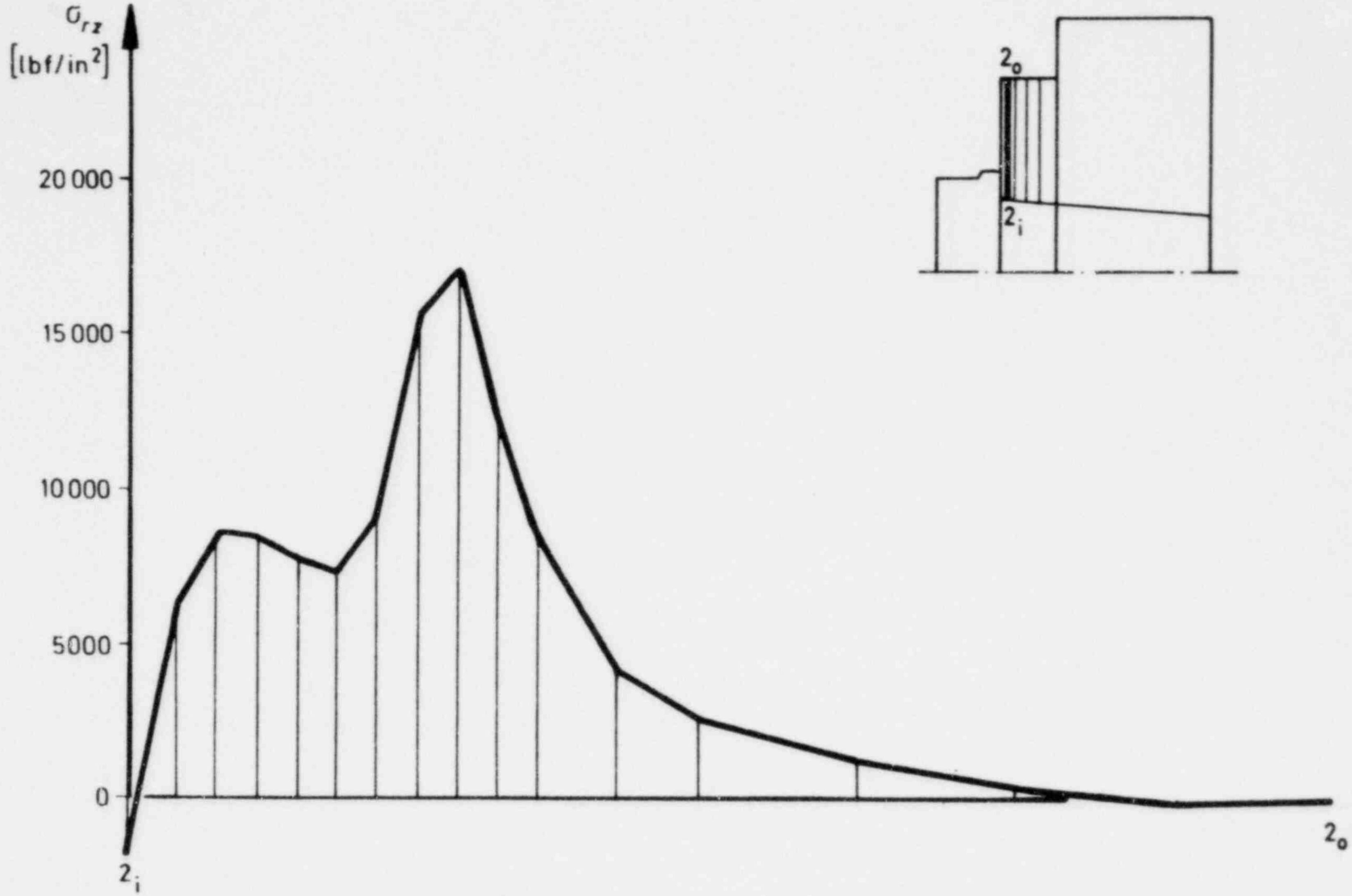

Fig. 32 **Bearing Plate**

Shear Stress σ_{rz} in Cross Section 2

0259 0175

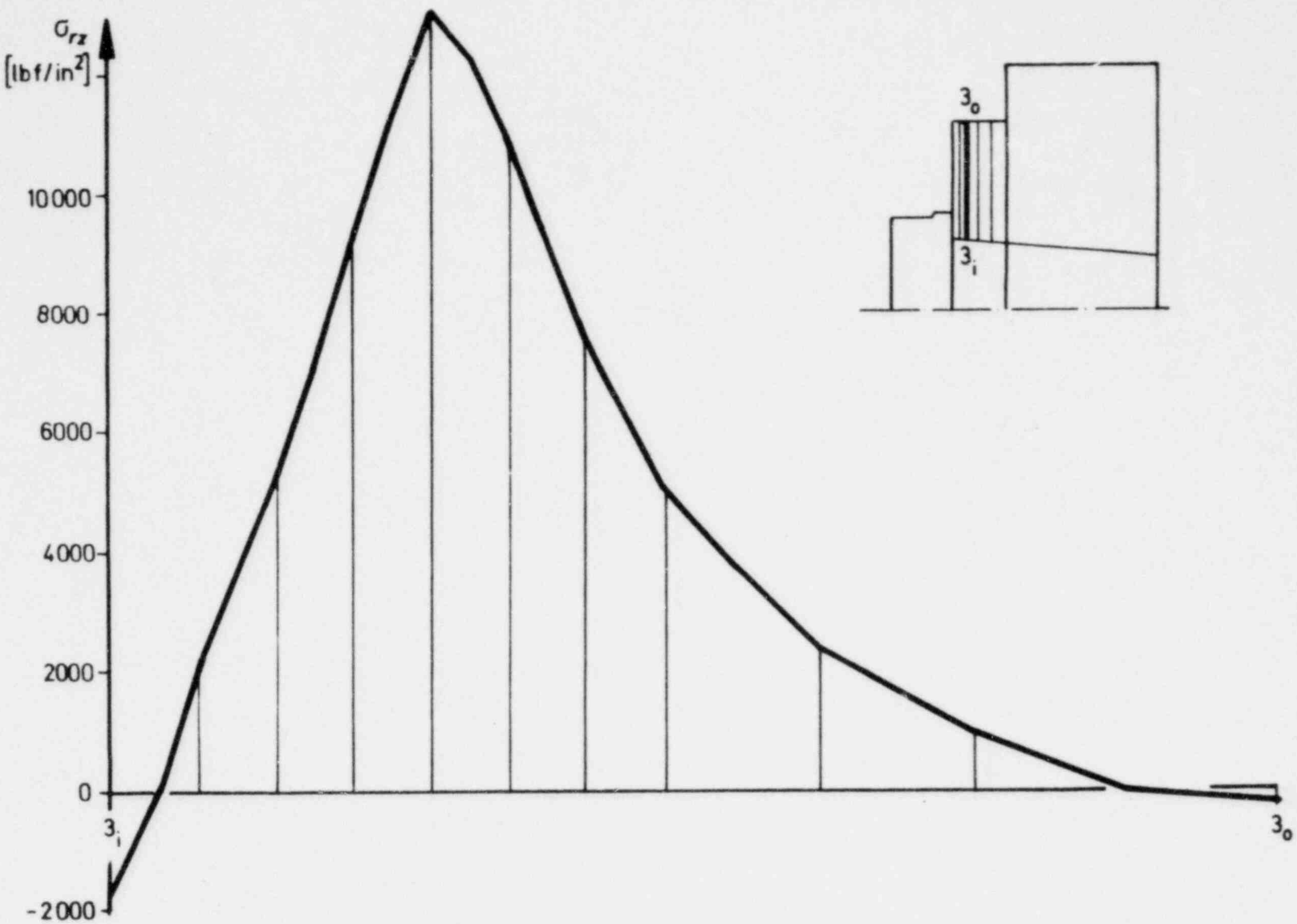

Fig. 33 Bearing Plate

Shear Stress σ_{rz} in Cross Section 3

0260

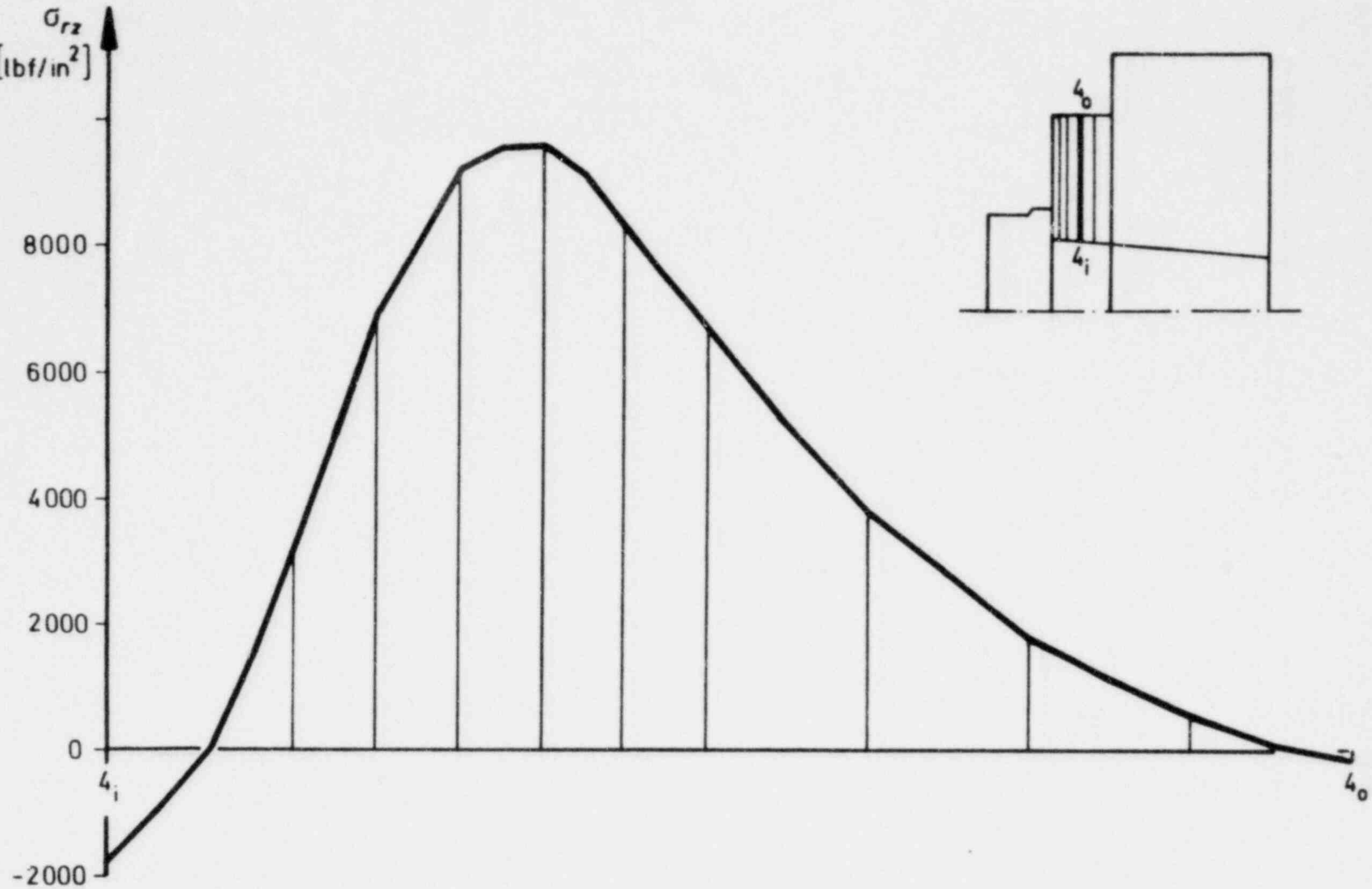

Fig. 34 **Bearing Plate**

Shear Stress σ_{rz} in Cross Section 4

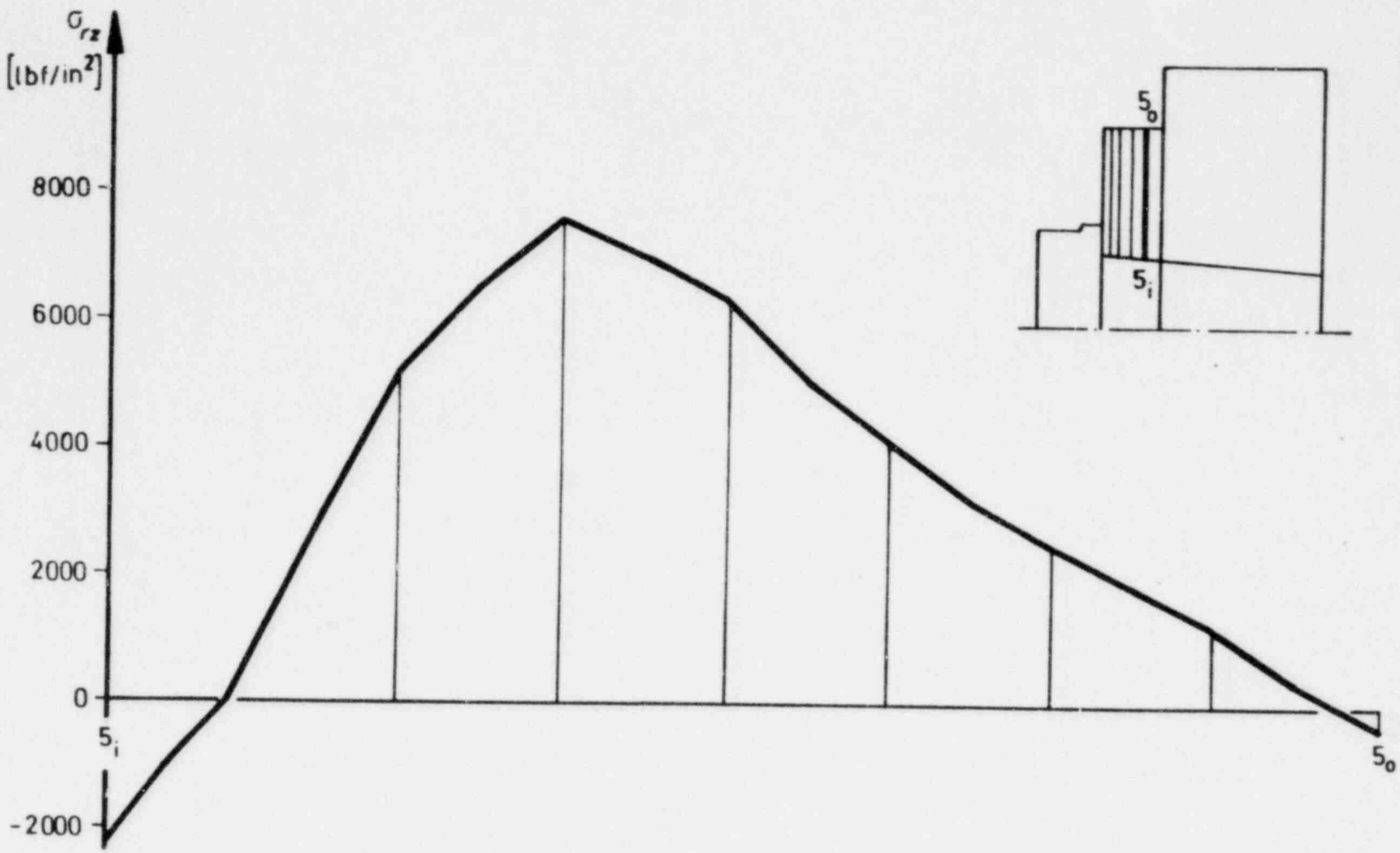

Fig. 35

Bearing Plate

Shear Stress σ_{rz} in Cross Section 5

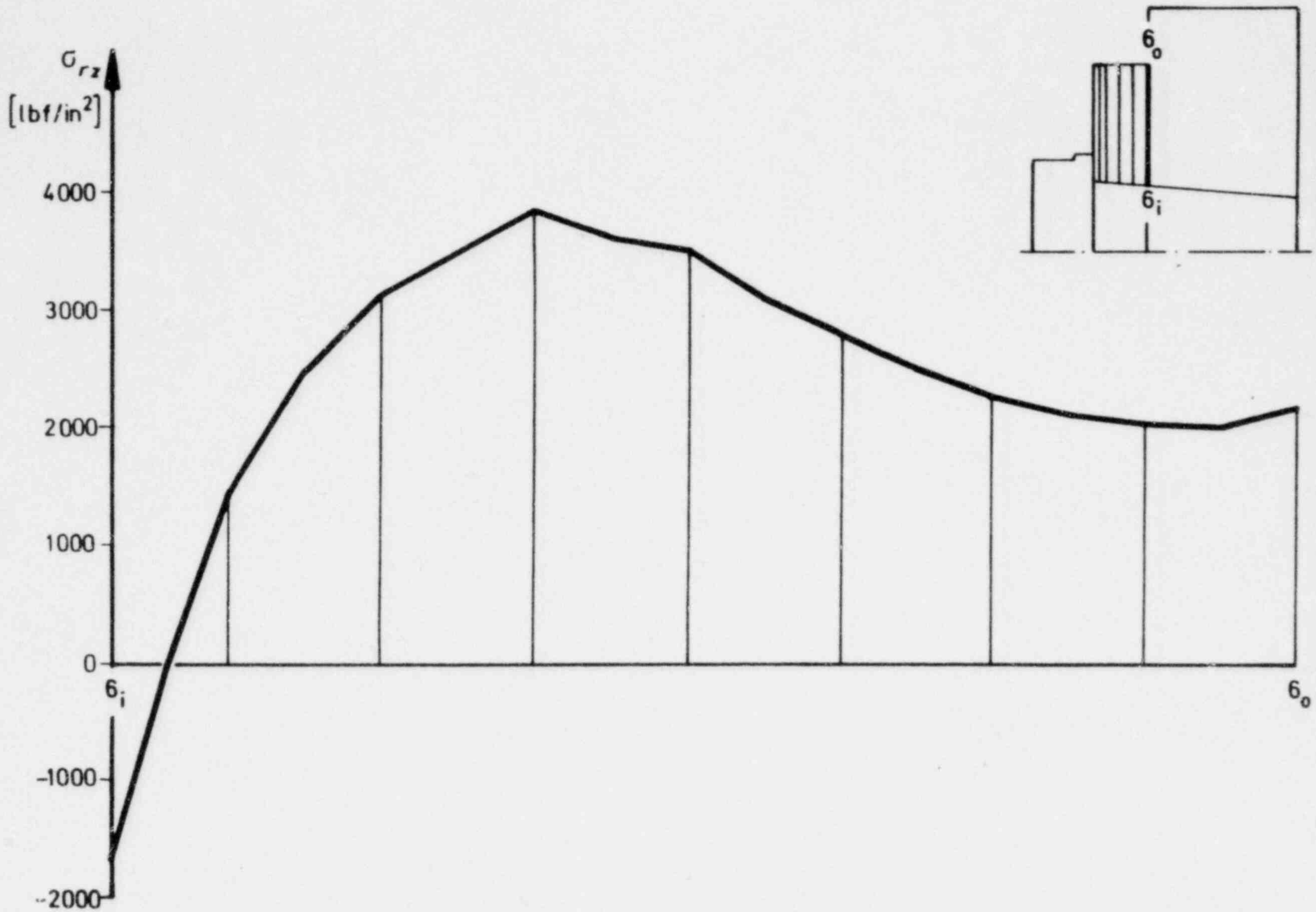

Fig. 36 **Bearing Plate**

Shear Stress σ_{rz} in Cross Section 6

Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, 8600 Dübendorf

Swiss Federal Experiment Station of Testing Materials for Industry, Construction Engineering and Trade, 8600 Dübendorf

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Untersuchungsbericht

TEST-REPORT EMPA No. 66'829/2

Customer: L o s i n g e r & Co SA, B E R N E / Switzerland
Licensor for the VSL Prestressing System

Object: One VSL Tendon consisting of 12 x 1/2" 270 k strands and one VSL Anchorage, type E 5-12

Order of February 3, 1969

Low temperature test

Date of receipt: February 5, 1969 **Execution of investigation:** out on February 6, 1969

Results of ultimate load test

Test carried out in the Laboratories of the EMPA

1. Testing installation
2. Test procedure
3. Test results

Appendix 1: Testing installation

Appendix 2: Photographs

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1. Testing installation

- one test frame
- one VSL Post-tensioning jack 400 tons
- one gauge calibrated to ± 1/2 %
- one electric power pump

2. Test procedure

2.1 Objective: The purpose of the test was at ultimate load to demonstrate the ductility of the steel used in the VSL anchorage under low temperature conditions.

2.2 Test date: February 6, 1969.

2.3 Test personnel: Mr. Dr. A. Roesli, Mr. H. Wernli, Mr. W. Stuerzinger } EMPA.

2.4 Test specimen (data supplied by customer)

One VSL tendon consisting of

a) 12 strands 270 k, stabilized.
Manufacturer: CF & I, Denver / Colorado.

b) One standard VSL anchor head E 5-12 and
12 standard VSL wedges 1/2".
Manufacturer: Losinger & Co SA, Berne.

c) One special bearing plate embedded in concrete.
Material: High Strength Low Alloy Structural Steel (fully killed) normalized.

Chemical composition

C	=	0.14 - 0.20	S	=	0.040 max.
Si	=	0.40 - 0.55	Cr	=	0.030 max.
Mn	=	1.20 - 1.50	Ni	=	0.030 max.
P	=	0.040 max.	Cu	=	0.030 max.

d) One concrete block 13 3/4" x 13 3/4" x 22" reinforced.

Cylinder strength: approx. 4.800 psi.

2.5 Procedure

The anchorage on the concrete block (see appendix 1) is placed in a container filled with alcohol and dry ice to provide a temperature of approx. -31°F (-35°C). The anchorage was cooled down during 1 hour.

The tendon was then stressed to failure by means of a hydraulic VSL Post-tensioning jack.

3. Test results

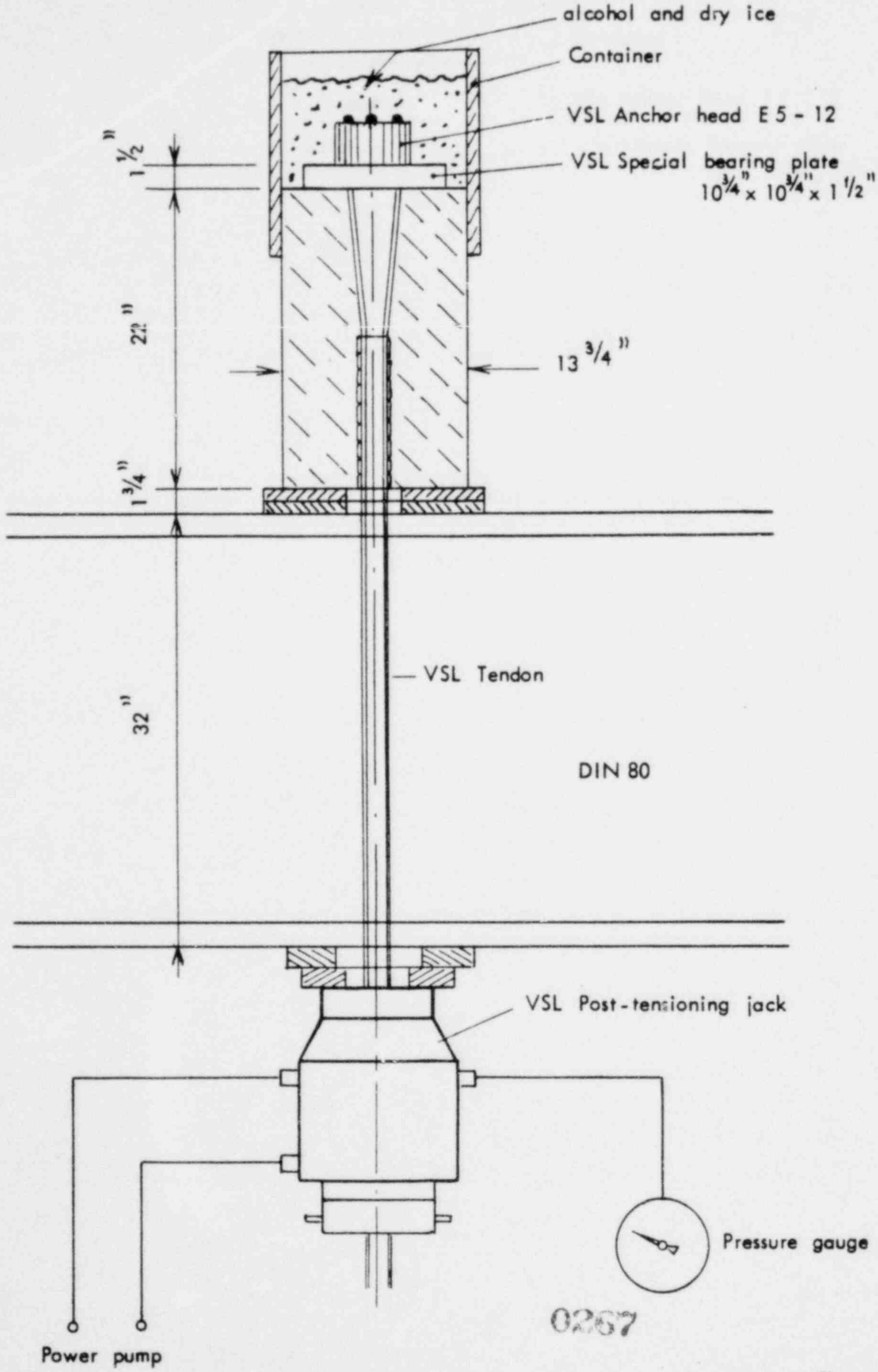
At the load of 251.3 short tons (corresponding to 101.5 % of f's) the first wire rupture occured.

No visual distortion and no damage was observed at any of the anchorage parts.

No failure of the concrete block took place at ultimate load of the tendon and no visible cracks were observed.

Appendix 1

TESTING INSTALLATION



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EMPA	Auftrags-Nr. 66829/2	Auftraggeber: Losinger & Co., Bern	Gezeichnet: Febr. 69	Zeichnungsnummer: 4 — 48 563

Appendix 2 : Photographs

Photo 1

The anchor head is cooled down to -31°F (-35°C) by means of alcohol and dry ice.

Appendix 2 : Photographs

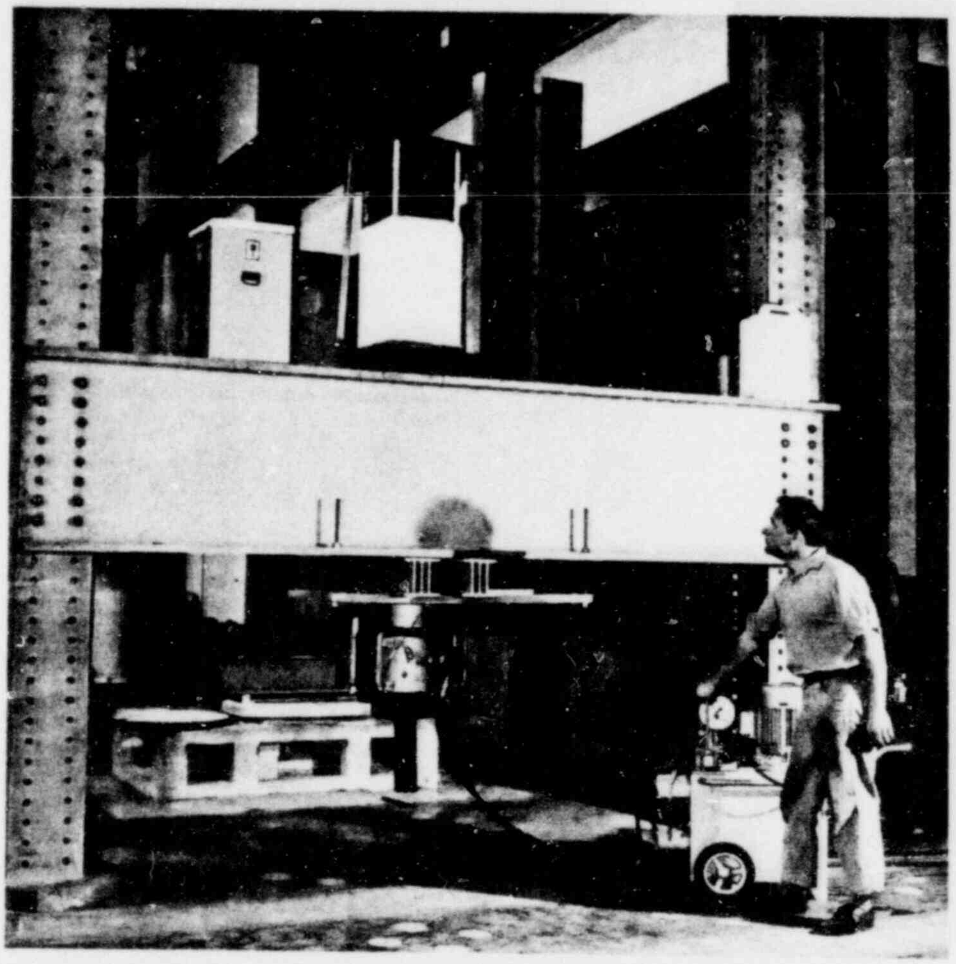


Photo 2

Ultimate load test of a tendon.

At the load of 251.3 short tons applied with a hydraulic VSL Post-tensioning jack the first wire rupture occured.

The anchor head was cooled down to -31°F.

Dübendorf, February 7, 1969

Engineer of test

0269

Swiss Federal Laboratory for
Testing Materials and Research

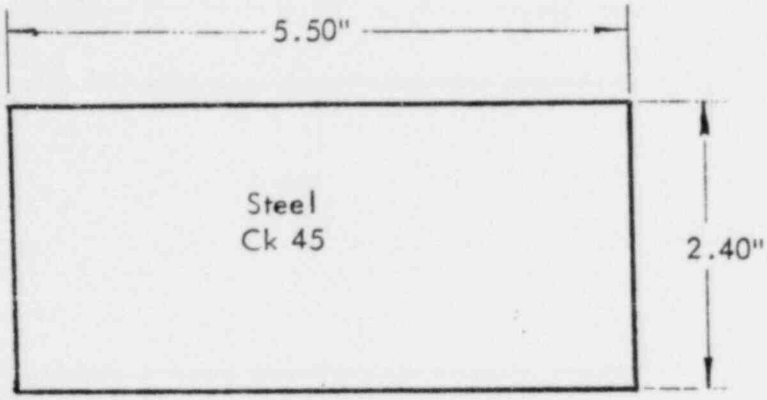
~~00185~~

A. 7511

ANCHORAGE MATERIALS USED IN EMPA TEST NO. 66' 829/2

VSL E5-12

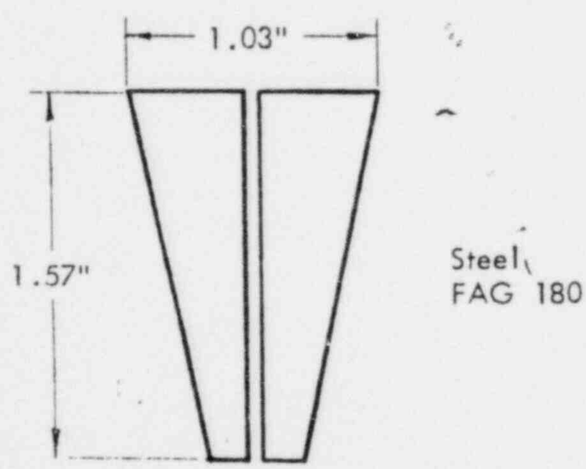
ANCHOR HEAD:



CHEMISTRY:	C	Mn	Si	S	P
	.0470	0715	0300	0032	.0012

MECHANICAL PROPERTIES:	Heat Treatment	Y.P.	U.T.S.	% Elongation
	Normalized	48.25 ksi	85-106 ksi	18%

VSL WEDGES:



CHEMISTRY:	C	Mn	Si	P	S	Ni	Cr	Mo
	.16	.77	.33	.018	.006	1.30	.87	.17

MECHANICAL PROPERTIES:

Heat Treatment

Case hardened to .016" depth

0270

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Swiss Federal Laboratory for Testing Materials and Research

— 8600 Dübendorf —

Untersuchungsbericht

TEST-REPORT

EMPA No. 57'749-E

Customer: Losinger & Co SA, BERNE

Contractors and Civil Engineers / VSL International

Object: a) Cable with 12 x 1/2" dia. Supa-7 (270 k) strands and 2 clamping rings.

b) 2 anchor heads E.5-12, are injected with NO-OX-ID Grease.

Order: N° 2911/731 of January 15th 1968

Fatigue tests for Three Mile Island Nuclear Station USA

[The data as supplied by the client]

Date of receipt: January 17th 1968 Execution of investigation: until February 1968

Results of fatigue test

Test carried out in the Laboratories of the EMPA

1. Test procedure
2. Test installation
3. Results of test

0271

~~00167~~

1. Test procedure

Tendon 12 x 1/2" dia. Supa-7 (270 k) strands
with 2 anchor heads E.5-12

(Data as supplied by the client)

12 x 1/2" dia. Supa-7 (270 k) strands: A strand consists of 1 center wire with a diameter of 4,4 mm and 6 outer wires with a diameter of 4,2 mm. The length of the cable is approximately 3400 mm. The strand bundle is reduced to the diameter of the sheath by means of 2 clamping rings. For dimensions see test installation.

Anchor heads

top: Anchor head E.5-12 provided specially for the purpose of this test with a thread. The anchor head rests on a bearing plate which in turn is supported on the framework by sandwich plates (see test installation). A ring nut is threaded into the anchor head. The space immediately below the anchor head is subsequently sealed with a fabric material and injected with NO-OX-ID Grease, supplied by the client (see picture N° 52'394).

bottom: Anchor head E.5-12 connected to the calibrated steel bar (fitted with strain gages) by means of a threaded sleeve and a coupling nut. The space between the calibrated bar and the anchor head is also injected with NO-OX-ID Grease (see pictures N° 52'395 and N° 52'477).

Test equipment

2 coupled Amsler Pulsators of approximately 250 load cycles per min.

1 Amsler slow-cycling Pulsator, approximately 1,7 load cycles per min.

2 Amsler 50 ton jacks.

Framework and a hinged beam which allow one cable to be submitted to a greater load than if the jacks were positioned symmetrically about the cable.

Test procedure

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Determination of load levels with the calibrated bar according to calibration chart of June 26th 1966; test report N° 45'189. ~~00189~~

Time instant recording of loading variations and wire rupturing by means of a sensitive vibration detector, a photoelectronic meter and a digital monochromator.

Picture N° 52'395

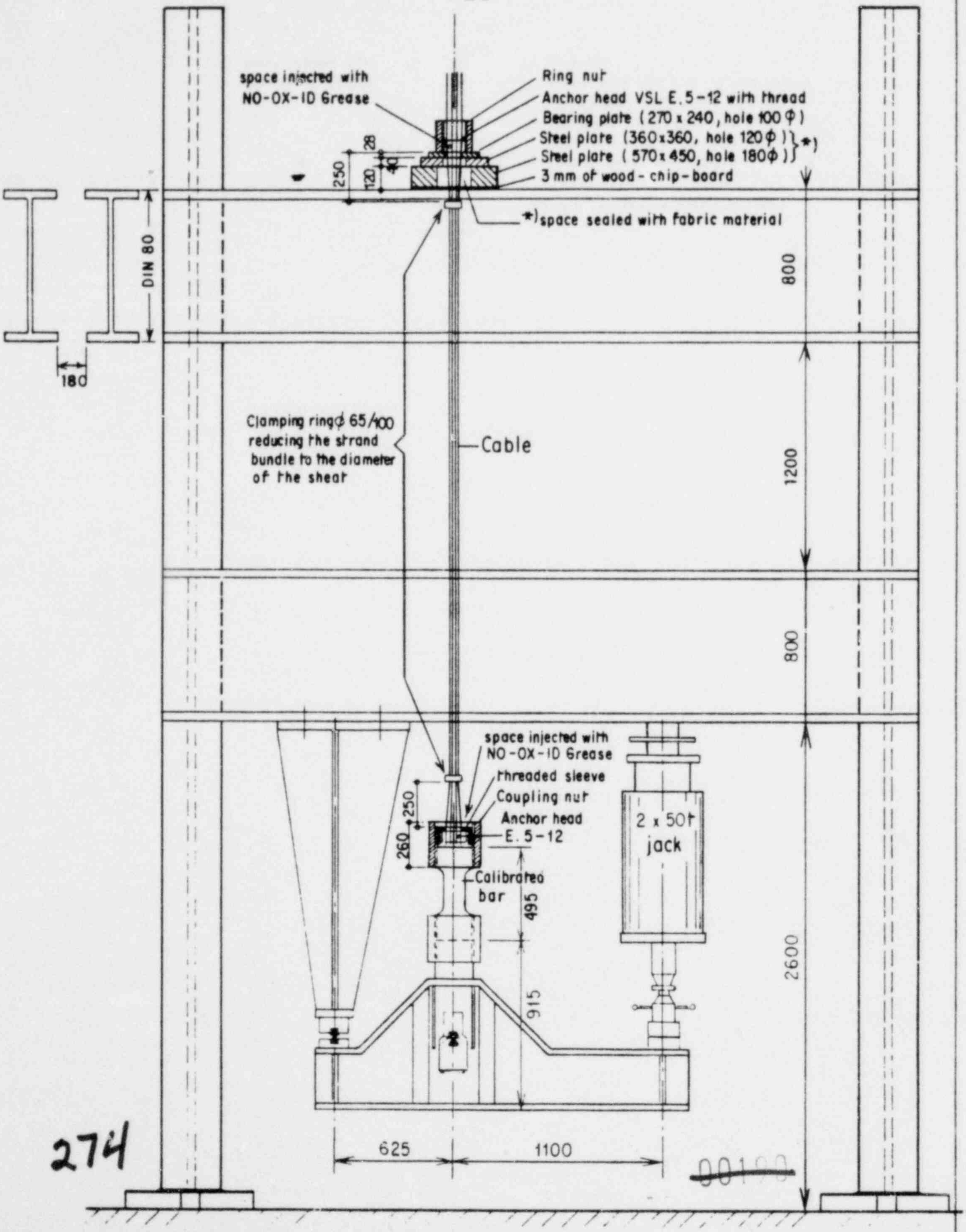
Picture showing the bottom anchorage injected with grease.

Picture N° 52'477

Picture of the bottom anchorage taken of the anchor seat after removal of the cable. The anchor head and the wedges are completely embedded in grease.

2. Test installation for Fatigue test

1 : 25

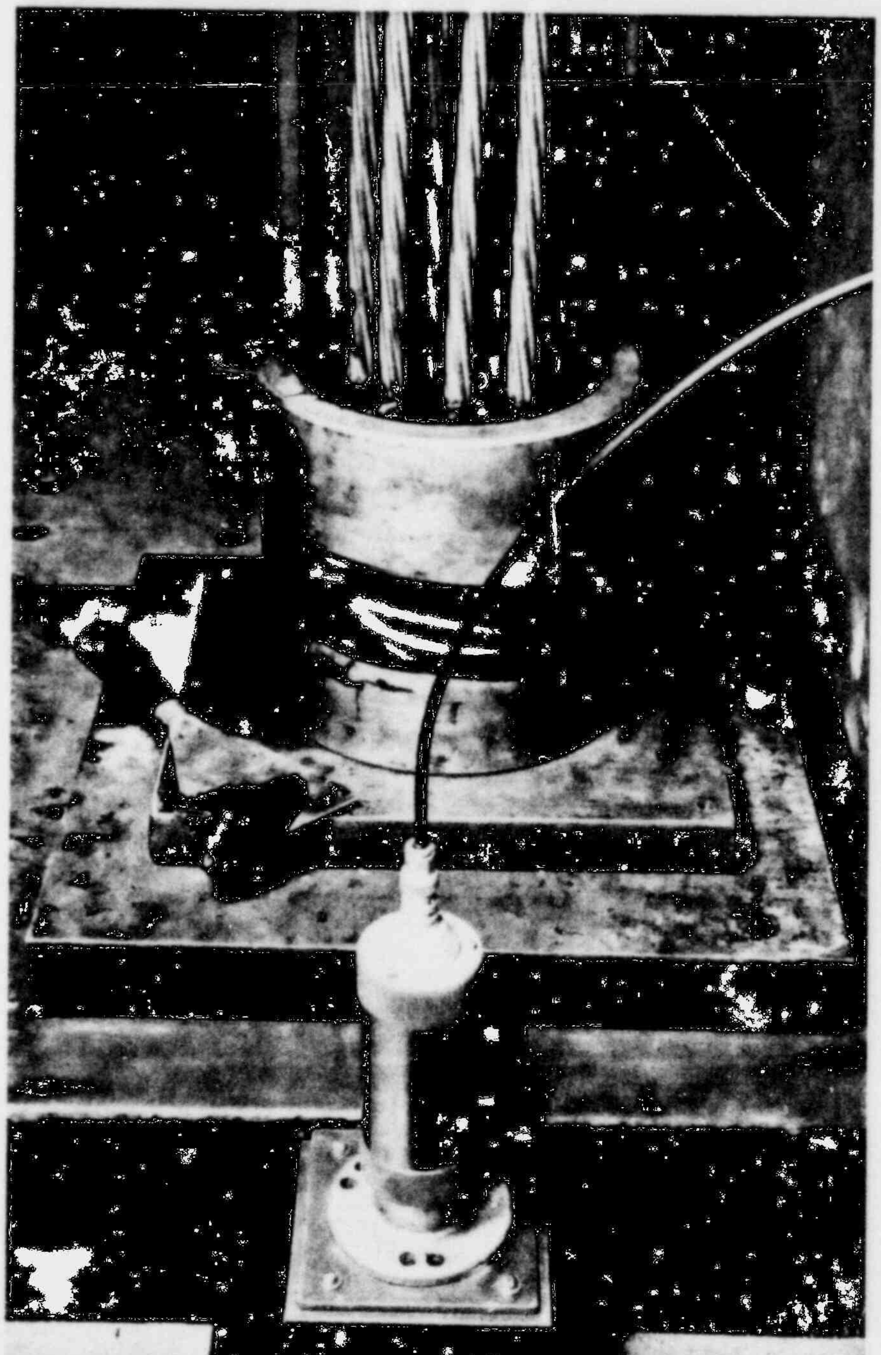


EMPA	Auftrags-Nr	Auftraggeber:	Gezeichnet:	Zeichnungsnummer:
	57'749-E	Losinger & Co AG, Bern	Febr. 68 se	4 — 99385

Date of tests:

Cable A January 18th - 22nd 1968
Cable B January 24th - 31st 1968

Picture N° 52'394



0275

Picture showing the top anchorage injected with grease resting on the framework.

~~00191~~

In the foreground the sensitive vibration detector.

3. Results of Fatigue test

2 cables (A and B) with 12 x 1/2" dia. Supa - 7 (270 K) strands and anchor heads E.5 -12 fully embedded in NO - OX - ID Grease. (above data supplied by the client)

Steel area : $A = 1188\ mm^2$ (1.836 in 2)

$f'_s = 190\ kg/mm^2$ (270.000 psi)

Fatigue test No. 1 : upper level = 0,66 f'_s = 125,4 kg/mm² L_u = 149,0 t

lower level = 0,60 f'_s = 114,0 kg/mm² L_l = 135,4 t

Amplitude Δ = 11,4 kg/mm²

Required 500'000 load cycles with a frequence of 250 load cycles per min.

Fatigue test No 2 : upper level = 0.711 f'_s = 135,1 kg/mm² L_u = 160.5 t

lower lewel = 0.489 f'_s = 92.9 kg/mm² L_l = 110.4 t

Amplitude Δ = 42.8 kg/mm²

Required 50 load cycles with a frequence of 1.7 load cycles per min.

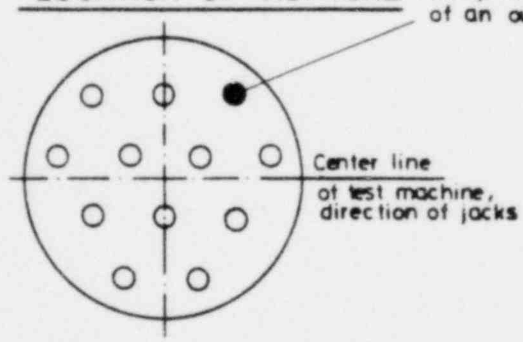
} above data supplied by the client

FATIGUE TEST	LOADS L_u t	LOADS L_l t	STRESSES * upper kg / mm²	STRESSES * lower kg /mm²	STRESSES * Δ kg /mm²	NO. OF LOAD CYCLES	WIRE RUPTURE	REMARKS
1						0		CABLE A
	149.0	135,4	125,4	114,0	11,4	501'800		No rupture of wire
2	0 - 160,5	0 - 110,4	0 - 135,1	0 - 92,9	0 - 42,8	0		CABLE A
						12 (= 0 k)		Adjusting of test machine
	160,5	110,4	135,1	92,9	42,8	62 (= 50k)		No rupture (with full load) of wire
2	0 - 160,5	0 - 110,4	0 - 135,1	0 - 92,9	0 - 42,8	0		CABLE B
						8 (= 0 k)		Adjusting of test machine no rupture of wire
	160,5	110.4	135,1	92,9	42,8	58 (= 50 k)		(with full load)
1	149,0	135,4	125,4	114,0	11,4	0		CABLE B
						501' 800		Test resumed according to client's request } wished by the client
1	149,0	135,4	125,4	114,0	11,4	938' 600	1 top	
	149,0	135,4	126,9	115,3	11,6	1' 259' 100		End of test

* The stresses relate to the remaining steel area after rupture of wire

LOCATION OF RUPTURE

· at top anchor head rupture of an outer wire



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Swiss Federal Laboratory for Testing Materials and Research

A [signature]

~~00192~~

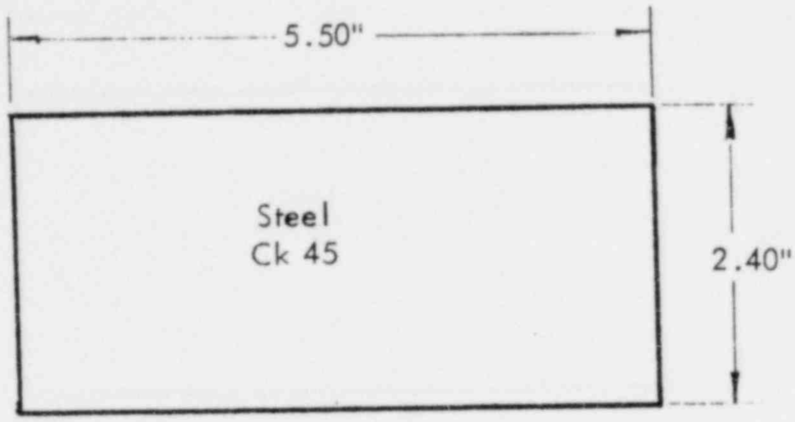
Dubendorf, 28. Feb. 1968

Engineer of Test : *Th. Kertesz*

EMPA	Auftrags-Nr.	Auftraggeber:	Gezeichnet:	Zeichnungsnummer:
	57'749-E	Losinger & Co. Bern	Feb. 68 sc	4-99'386

ANCHORAGE MATERIALS USED IN EMPA TEST NO. 57' 749-E

VSL E5-12 ANCHOR HEAD:



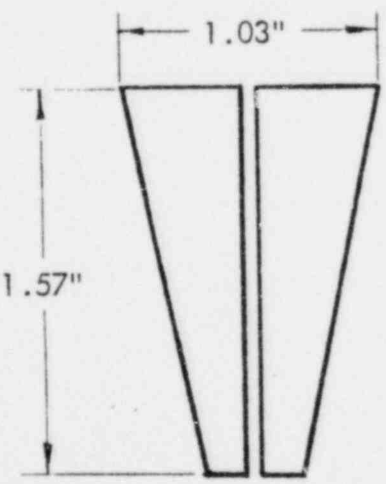
CHEMISTRY:

C	Mn	Si	S	P
.0470	0715	0300	0032	.0012

MECHANICAL PROPERTIES:

Heat Treatment	Y.P.	U.T.S.	% Elongation
Normalized	48.25 ksi	85-106 ksi	18%

VSL WEDGES:



Steel
FAG 180

CHEMISTRY:

C	Mn	Si	P	S	Ni	Cr	Mo
.16	.77	.33	.018	.006	1.30	.87	.17

MECHANICAL PROPERTIES:

Heat Treatment

Case hardened to .016" depth

0277 ~~00193~~

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Swiss Federal Experiment Station of Testing Materials for Industry, Construction Engineering and Trade, 8600 Dübendorf

Untersuchungsbericht

TEST-REPORT EMPA No. 66'829/1

Customer: L o s i n g e r & Co SA, B E R N E / Switzerland
Licensor for the VSL Prestressing System

Object: One VSL Tendon consisting of 12 x 1/2" 270 k strands and two VSL Anchorages, type E 5-12

Order of February 3, 1969

Dynamic test

Date of receipt: February 5, 1969 **Execution of investigation:** out on February 6, 1969

Dynamic test of a VSL Tendon

500 cycles of rapid loading between 0.70 f's and 0.75 f's

Test carried out in the Laboratories of the EMPA

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1. Test specimen

One VSL tendon and one concrete block supplied by customer.

D a t a (supplied by customer)

A) One VSL tendon l = 14' consisting of:

a) 12 - 1/2" 270 k strand, stabilized.

Manufacturer: CF & I, Denver / Colorado.
Strand manufactured in accordance with ASTM A-416.
Strand reference number: 1648 P - C 4 L / III.

b) two VSL anchorages E 5-12

Manufacturer: Losinger & Co SA, Berne.
The bearing plate of the upper end anchorage is embedded in concrete (see appendix 1).
This bearing plate was before used for a low temperature test as described in EMPA test report N° 66'829/2.

B) One concrete block 13 3/4" x 13 3/4" x 22" reinforced.

Age after casting: 2 days.

Concrete compression strength, determined at the EMPA:

5900 psi cube strength
= approx. 4800 psi cylinder strength.

2. Testing installation (see appendix 1)

- Two coupled AMSLER pulsators (max. capacity 500 cycles per minute).
- Two AMSLER 50 ton jacks.
- Framework and a hinged beam to allow a tendon to be subject to a greater load than if the two jacks were positioned symmetrically around the tendon.

3. Test procedure

3.1 Objective

The purpose of the test was to determine the following:

- Loss of strength if tendon is subject to 500 cycles of rapid loading from a stress level of 0.70 f's to a stress level of 0.75 f's and return to 0.70 f's.

  One complete cycle shall take place in 0.1 second.

10

- Deformation of concrete, bearing plate and anchorage assembly.

3.2 Test date: February 6, 1969.

3.3 Test personnel:

Mr. Dr. A. Roesli
Mr. H. Wernli
Mr. W. Stuerzinger
} EMPA.

3.4 Procedure

a) VSL tendon subject to rapid loading as specified under 3.1 above

upper level (0.75 f's) = 186.6 short tons,
lower level (0.70 f's) = 174.2 short tons.

Frequence: 500 load cycles per minute
(one complete cycle takes place in 0.12 second).

In order to obtain the upper stress level approx. 500 load cycles with increasing amplitude had to be applied prior to the 500 cycles with the given amplitude.

b) Concrete block

In order to determine the deformation of the concrete, a number of strain indicators were attached on the four faces of the block in vertical and horizontal direction (see appendix 2).

c) Anchor head and bearing plate

In order to determine the deformation, these parts were measured before and after the rapid loading was applied.

4. Test results

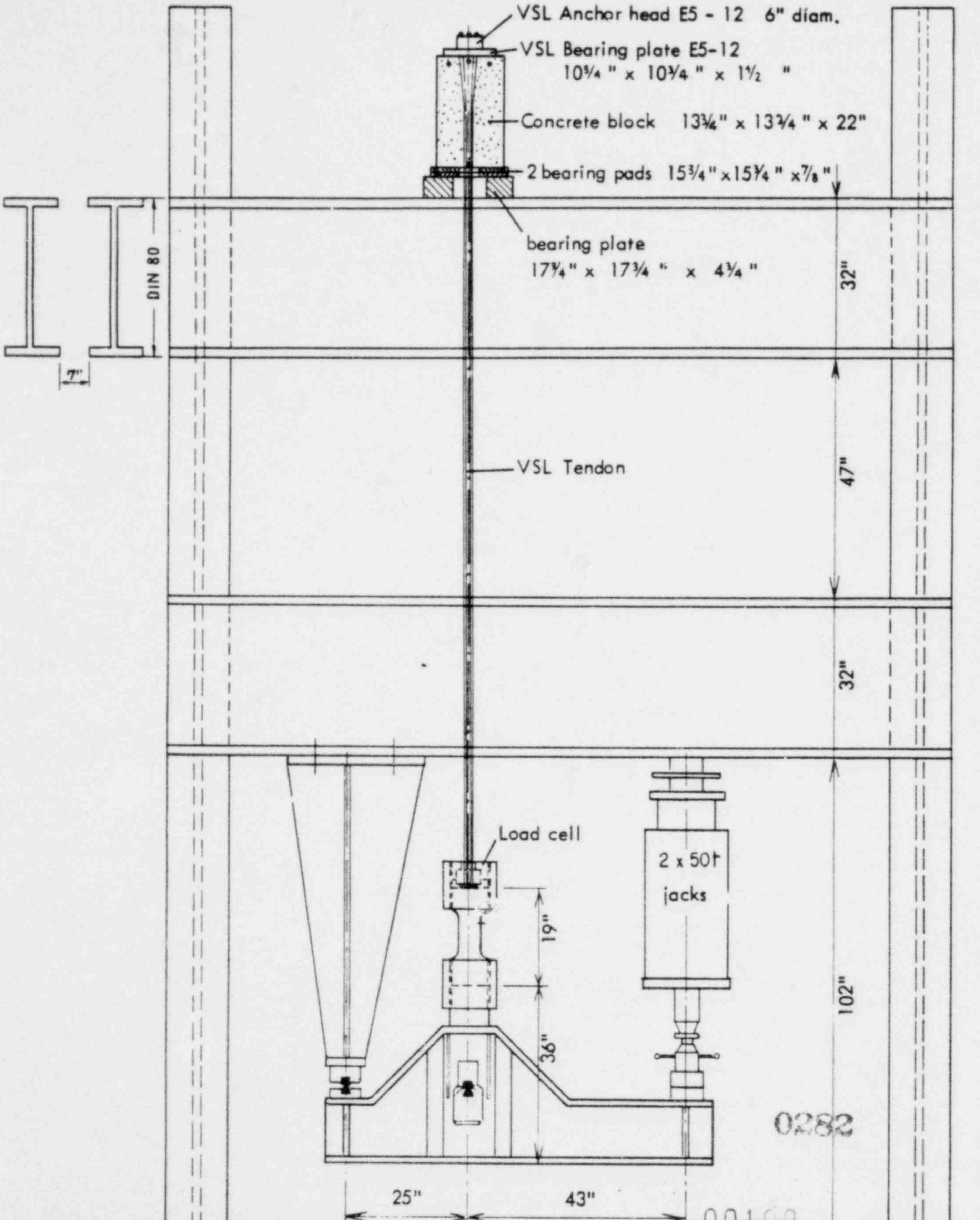
a) No failure of the tendon took place during the time it was subject to the rapid loading. No damage at any parts of the tendon was observed after the test.

b) No failure of the concrete block took place during the time it was subject to the rapid loading. No visible cracks were observed.

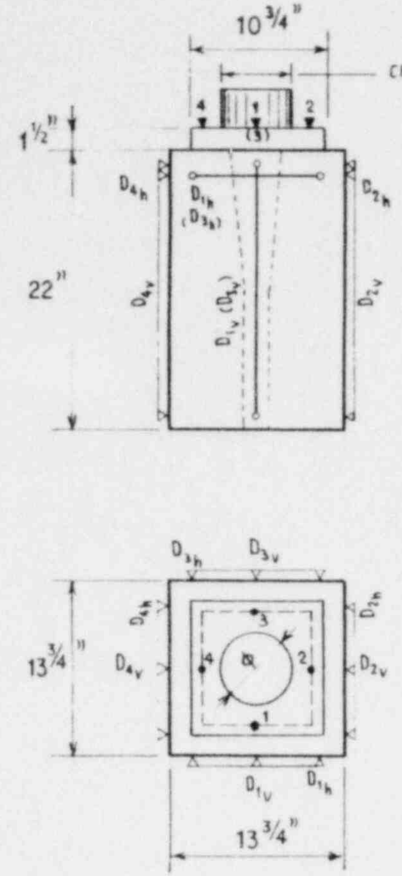
c) Deformation of the concrete see appendix 2.

d) Deformation of bearing plate and anchor head see appendix 2.

TESTING INSTALLATION



F.95224	EMPA	Auftrags-Nr.: 66'829 / 1	Auftraggeber: Losinger & Co., Bern	Gezeichnet: Febr. 69 se	Zeichnungsnummer: 4 — 48'561



Layout of the strain indicators

horizontal: $D_{1h} - D_{4h}$
measured length: 10"

vertical: $D_{1v} - D_{4v}$
measured length: 20"

Deformation of the concrete

Vertical

(after 500 load cycles)

D_{1v}	D_{3v}	$\frac{D_1 + D_3}{2}$	D_{2v}	D_{4v}	$\frac{D_2 + D_4}{2}$	Average total
-45	-25	-35	-40	-25	-33	-34

Horizontal

(after 500 load cycles)

D_{1h}	D_{3h}	$\frac{D_1 + D_3}{2}$	D_{2h}	D_{4h}	$\frac{D_2 + D_4}{2}$	Average total
+90	+90	+90	+80	+90	+85	+87

Dimensions in micro inch / inch
+ = Tension
− = Compression

Deformation of bearing plate and anchor head

Deflection of bearing plate						Change of anchor head diam.	Deflection of anchor head
Face 1	Face 3	$\frac{1+3}{2}$	Face 2	Face 4	$\frac{2+4}{2}$	ϕ	▼
+0,0016	+0,0016	+0,0016	+0,0012	+0,0004	+0,0008	+0,0024	-0,0012

Dimensions in inches: for deflexion +
for uplift −

Dübendorf, February 7, 1969

Engineer of test:

Swiss Federal Laboratory for Testing Materials and Research

0283

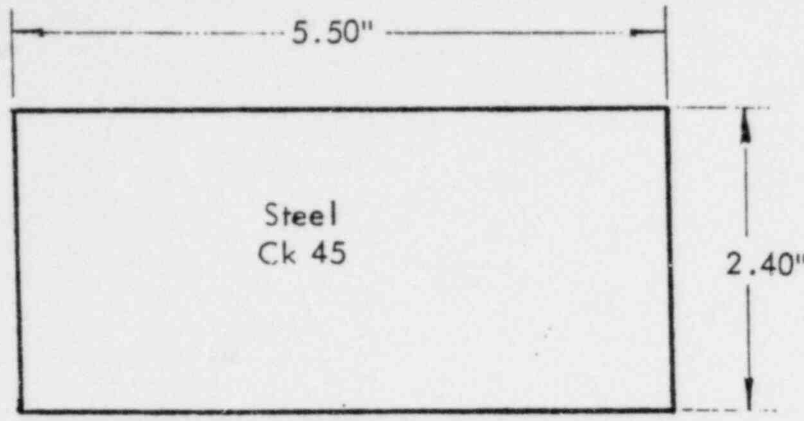
EMPA	Auftrags-Nr 66'829/1	Auftraggeber: Losinger & Co., Bern	Gezeichnet: Febr. 1969	Zeichnungsnummer: 3 - 48'562

Appendix 2

ANCHORAGE MATERIALS USED IN EMPA TEST NO. 66' 829/1

VSL E5-12

ANCHOR HEAD:



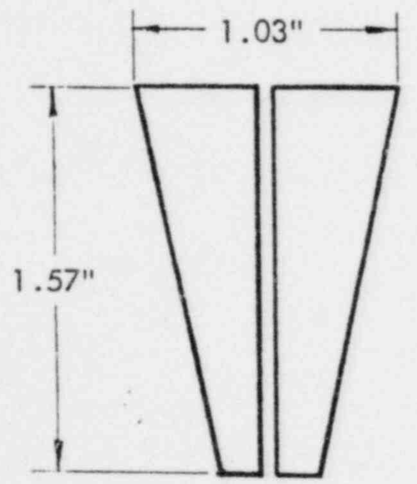
CHEMISTRY:

C	Mn	Si	S	P
.0470	0715	0300	0032	.0012

MECHANICAL PROPERTIES:

Heat Treatment	Y.P.	U.T.S.	% Elongation
Normalized	48.25 ksi	85-106 ksi	18%

VSL WEDGES:



Steel
FAG 180

CHEMISTRY:

C	Mn	Si	P	S	Ni	Cr	Mo
.16	.77	.33	.018	.006	1.30	.87	.17

MECHANICAL PROPERTIES:

Heat Treatment

Case hardened to .016" depth

Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe

Laboratoire fédéral d'essai des matériaux et Institut de recherches Industrie, Génie civil, Arts et Métiers

Laboratorio federale di prova dei materiali ed istituto sperimentale Industria, Genio civile, Arti e Mestieri

VSL Corporation
Post Office Box 459

Los Gatos

California 95o3o/U.S.A.

8600 DÜBENDORF
Ueberlandstrasse 129 Ø 051 / 85 81 31
Postcheckkonto 30 - 520 (Bern)
Telegrammadresse: EMPAPRÜFUNG
Telex Nr. 53 817

Ihre Zeichen V. réf - V. ref.

Ihre Korrespondenz vom V. corresp. du - V. corrisp. del

Unsere Zeichen N. réf. - N. ref. A3/Zei/MG

1oth septembre 1969

Gegenstand Objet - Oggetto

Object: A prestressing cable VSL EE 5-12

Preliminary Report

A dynamic test was carried out on a prestressing cable of 12 strands Ø 1/2". A high range of stress was applied for few loading cycles. Date of test was 9th septembre 1969. The important data and test results are as follows:

1. Tested Elements

   The cable and its anchor heads and wedges were delivered by your firm. The concrete block, which was used to support the upper anchor head, was prepared in Switzerland.

2. Purpose of the test

   To observe the behavior of a VSL prestressing cable under the action of a very high stress range, which was applied for a few loading cycles. These loading conditions are assumed to represent the action of an earthquake.

3. Test Data

   Two loading cycles were fristly applied in one minute. Another 6o loading cycles were applied subsquently with a frequency of 5 repetitions per minute. The lower and upper loading limits were 9o t and 18o t respectively.(i.e. the stress range was between o,4 β_z and o,8 β_z)

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22384/3

VSL Corporation, Los Gatos/California USA

4. Testing Installation

The tested cable was mounted vertically in a testing frame. Its upper anchor head was supported on the concrete block. The movements of one wire and one wedge were measured during the test.

5. Results of Test

Slip of the wire after the first two cycles was	2,2 mm
" " " wedge " " " " " "	2,o mm
Additional slip of the wire after the next 6o cycles was	o,2 mm
" " " " wedge " " " "	o,2 mm

6. Condition of the cable after test

No wire failures occured. Any visible deformations either at the cable or at the anchor heads and wedges could not be observed. The prestressing cable was intact after the test.

Dübendorf, loth septembre 1969

Swiss Federal Laboratory for
Testing Materials and Research

Engineer of Test:

WERK GERLAFINGEN
VERSUCHSANSTALT

VON ROLL AG.

VA BERICHT Nr. 229/69
DATUM: 3.9.1969

TITEL: METALLOGRAPHIC EXAMINATION OF ½" VSL WEDGES (LOSINGER)

VERFASSER: Dr. W. Gerber

VA-240/Ge/Fl/Gl

Gerber

VERTEILER: VSL Corporation, Los Gatos / Calif. 95030 USA (3 copies)
LOSINGER, Bern (2 copies)

~~00283~~

0287

METALLOGRAPHIC EXAMINATION OF ½" VSL WEDGES

A series of VSL Wedges were examined for LOSINGER & Co AG, Bern.

The purpose of the investigation was to determine the condition of and especially the possible crack occurence in wedges having been subject to static and dynamic loading.

Test specimens (according to LOSINGER & Co AG)

condition a) ½" VSL Wedge unused. Specimens no: 1 and 2.
condition b) ½" VSL Wedge having been stressed to 100 % of A.U.T.S. of a VSL Tendon. Specimens no. 3 and 4.
condition c) ½" VSL Wedge having been used in a VSL Tendon which was subject to dynamic loading under the following conditions :

stress levels	: 65 % f's and 70 % f's
frequency	: 3 cycles per sec.
number of cycles obtained	: in excess of 2 million.

Specimens no. 5 and 6.

Metallographic procedures

The threads of the used wedges showed signs of friction at the points of contact with the spirally stranded wire. The areas of contact formed a friction trace that could easy be distinguished from the black untouched rest of the surface. It was of special interest to look for eventual cracks on or at the base of the thread along the friction traces and to compare used (condition b and c) and unused (condition a) wedges.

The used wedges were sectioned along a friction trace. The wedges were then embedded and ground and polished as shown in fig. 1. The arrows indicate the surface ready for microscopic examination.

0288

00204

Results

Fig. 2, 3 and 4 show axial sections of unused wedges. The thread has sharp edges and a smooth surface.
Axial sections of wedges after static loading (condition b) are shown in fig. 5, 6 and 7. The thread edges are slyghtly deformed. There was no sign of damage at the thread base of the specimens examined.
Fig. 8, 9 and 10 finally are pictures of axially sectioned wedges after dynamic loading (condition c). Again the edge of the thread has undergone some minor deformation. In addition, at the lower part of the wedge about 10 % of the thread edges have surface cracks about 0.004" in depth. As it was the case with the wedges having undergone static loading no indication of damage could be found at the thread base of the wedges having experienced dynamic loading.
The micrograph (fig. 11) of an etched unused wedge reveals a normally developped case.

Conclusion

The ½" VSL Wedges examined suffered no damage during static and dynamic loading.

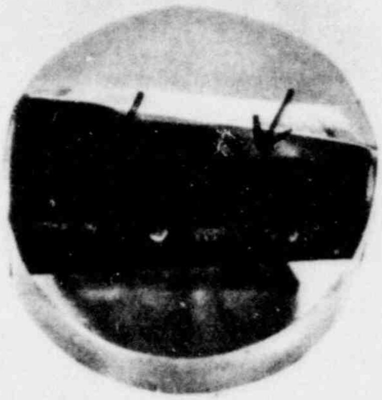

Fig. 1

Embedded wedge.

x 1

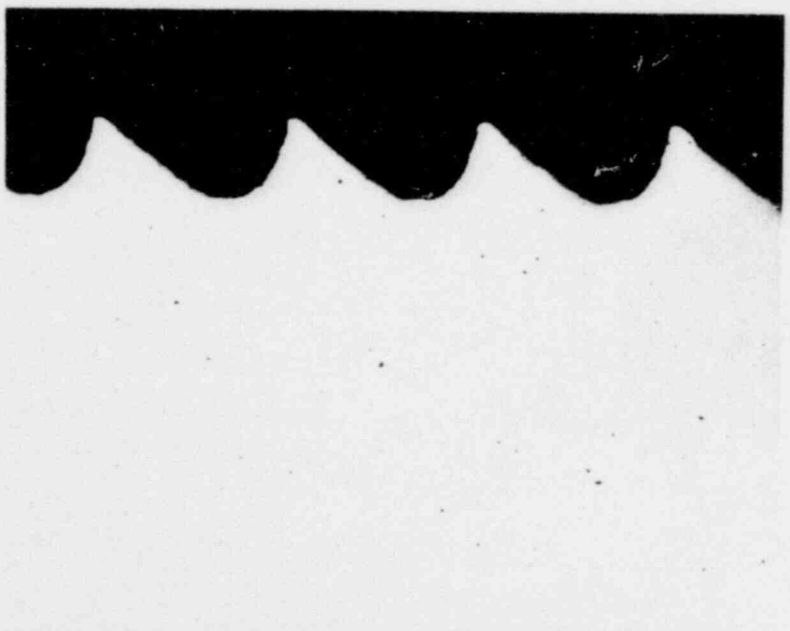

Fig. 2

Wedge no. 1 unused. Axial section, unetched.

x 25

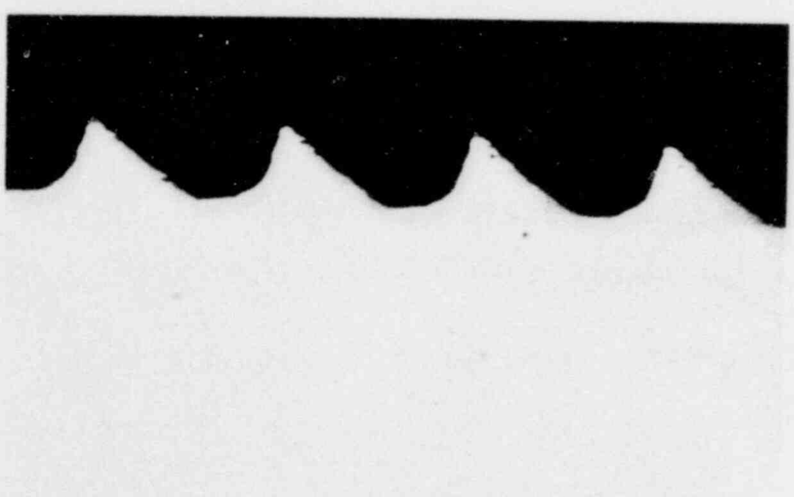

Fig. 3

Wedge no. 2 unused. Axial section, unetched.

x 25

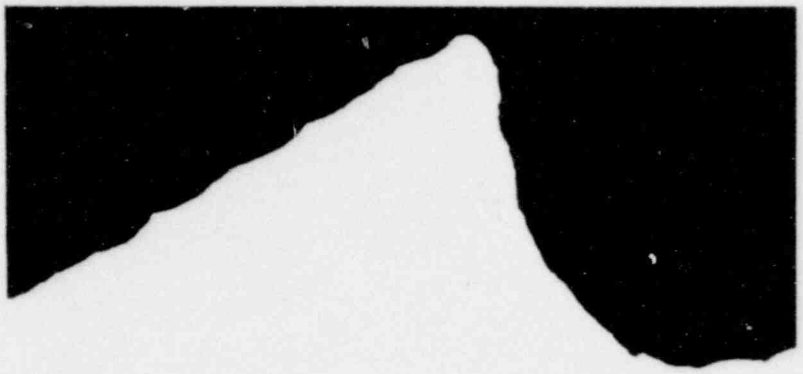

Fig. 4

Detail of wedge no. 1. (This micrograph was made from the counterpart of the section photographed in fig. 2, causing the mirror orientation of the sectioned thread if compared with fig. 2)

x 100

Fig. 5

Wedge having been subject to static loading, no. 3. Axial section along a friction trace, unetched.

x 25

Fig. 6

Wedge having been subject to static loading, no. 4. Axial section along a friction trace, unetched.

x 25

Fig. 7

Detail of wedge no. 3.

x 100

Fig. 8

Wedge having undergone dynamic loading, no. 5. Axial section along a friction trace, unetched.

x 25

Fig. 9

Wedge having undergone dynamic loading, no. 6. Axial section along a friction trace, unetched.

x 25

0292

Fig. 10

Detail from the lower and narrower part of wedge no. 5.
Surface crack near the edge of the thread, depth ~0.004", unetched.

x 100

Fig. 11

Wedge no. 1.
Axial section, etched.

x 25

Testing Division

ABBOT A. HANKS

ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO, CALIFORNIA 94111 • TELEPHONE (415) 397-2464

Materials Engineers
Testing & Inspection
Consulting Investigations

File No. 2615
Lab. No. 80945

December 13, 1965

Tested Dec. 1, 1965

L.R. Yegge Co.
P.O. Box 478
Los Gatos, California

ATTN: Mr. René Friedrich

Re: VSL Type "E" Anchorage Tests

Gentlemen:

We wish to submit the following report of tests made on the VSL Type "E" anchorage assemblies submitted.

A simple hole VSL Type "E" (100 KIP) funnel with two wedge grips was assembled on each end of a 1/2" diameter (270 KIP, PSI) seven-wire strand, placed in our testing machine and a tension load applied.

Test No. 1. . . . Equal spacing of wedge grips.
Test No. 2. . . . Unequal spacing of wedge grips.

Results of Test	Test No. 1	Test No. 2
Load Applied, lbs.	42300	41700
Location of Failure	Strand at Wedge Grips of Anchorage	Strand at Wedge Grips of Anchora

Very truly yours,

Testing Division
ABBOT A. HANKS

Daniel Staab

DS/ja
5-L.R. Yegge Co.
ATTN: Mr. René Friedrich

0234

~~002~~

Testing Division

ABBOT A. HANKS

ESTABLISHED 1866

Materials Engineers
Testing & Inspection
Consulting · Investigations

1300 SANSOME STREET · SAN FRANCISCO, CALIFORNIA 94111 · TELEPHONE (415) 397-2464

File No. 2615
Lab. No. 81055

January 20, 1966

L.R. Yegge Co.
P.O. Box 478
Los Gatos, Calif.
ATTN: Mr. René Friedrich

Re: VSL Type "E" 100 Anchorage Tests

Gentlemen:

We wish to submit the following report of tests made on the previously used, rustyfour funnel, (tapered hole) VSL Type "E" 100 Anchorage assemblies submitted.

One four funnel anchorage was placed on a 1 1/4" thick steel bearing plate on the top of the stationary head and one on the bottom of the moving head of the testing machine.

Four 60" long 1/2" diameter (270KIP, PSI) seven-wire strands were then attached to the four funnel anchorages with three wedge grips on each end of the four strands.

The anchorages were very rusty, as they were exposed to the weather for 17 days before test. Rusty U.S. Steel wire strands were used for the test.

Results

Load applied, lb.	166680
Location of Failure	Four wires of one strand at wedge grip.
Percent of Required Min. Strength	100.9

Note: No deformation of the 1 1/4" bearing plates or anchorages was apparent.

Very truly yours,

Testing Division
ABBOT A. HANKS
Daniel Staab
Daniel Staab

0295

DS/ja
Reports to:
5-L.R. Yegge Co.
ATTN: Mr. René Friedrich

~~00211~~

Testing Division

ABBOT A. HANKS

ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO, CALIFORNIA 94111 • TELEPHONE (415) 397-2464

Materials Engineers
Testing & Inspection
Consulting · Investigations

File No. 2615
Lab. No. 81418

April 14, 1966
Tested April 11, 1966

L. R. Yegge Co.
P.O. Box 478
Los Gatos, Calif.
Attn: Mr. Rene Friedrich

Re: Tests of VSL Type "E" Anchorages

Gentlemen:

Following are the results of tests made on VSL Type E anchorages submitted April 11, 1966.

Test No. 1

One four funnel (4 holes) type "E" anchorage was placed on the top of the stationary head and one four funnel anchorage was placed on the bottom of the moving head of the testing machine. One five foot long ½" diameter (270 KIP, PSI) seven wire strand was attached to each anchorage in one hole of the anchorages with 2 cleaned VSL wedge grips.

Results: Test No. 1

Load Applied, lb	43750
Location of Failure	In Wedge Grips

Test No. 2

Assembled as in test No. 1 except that VSL wedge grips were lightly waxed.

Results:of Test No. 2

Load Applied, lb	43400
Location of Failure	In Wedge Grips

0296

~~00212~~

L. R. Yegge Co.
File No. 2615

Testing Division
Abbot A. Hanks
April 14, 1966

Test No. 3

One four funnel (4 holes) Type "E" anchorage was placed on a 1" thick steel bearing plate on the top of the stationary head and one four funnel Type "E" anchorage was placed on a 1" thick steel bearing plate of the bottom of the moving head of the testing machine. Four five foot long ½" diameter (270 KIP, PSI) seven wire strands were attached at the top and bottom anchorages with two lightly waxed VSL wedge grips in each funnel.

Results: Test No. 3

Load Applied, lb	172300
Location of Failure	One Strand at Wedge Grips

There was no apparent distortion of the 1" steel bearing plate.

Test No. 4

A five foot long ½" diameter (270 KIP, PSI) seven-wire strand was placed in the testing machine with a Supreme 630 XX chuck (with three wedge grips in each chuck) on the top of the stationary head and on the bottom of the moving head of the testing machine.

Results: Test No. 4

Load Applied, lb.	43500
Location of Failure	In Wedge Grips

Testing Division
ABBOT A. HANKS
Daniel Staab
Daniel Staab

Reports to:
5-L. R. Yegge Co.
Attn: Mr. Rene Friedrich

ms

INVESTIGATION OF FORCE DISTRIBUTION

IN A 31-STRAND VSL TENDON

~~002~~

INVESTIGATION OF FORCE DISTRIBUTION IN A 31-STRAND

VSL TENDON

TEST PERIOD: October 1968

TEST LOCATION: South Fork of the Eel River Bridge - located 5 miles South of Garberville on U. S. 101 in California

TEST PERSONNEL: Mr. Rex Elliott - California Division of Highways
Mr. Jim Jurkovich, Jr. - Calif. Division of Highways
Mr. Dave Swanson - VSL Corporation

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0239

STATEMENT OF PURPOSE

This test was initiated by the California Division of Highways to determine the variation in the force distribution between various strands in a VSL #5-31 tendon.

TEST EQUIPMENT

Two VSL 500-ton Center Hole Jacks.
Five single-strand load cells.
One 1000K load cell.

PRESTRESSING TENDON

An E5-31 VSL Tendon which consists of 31, 1/2", 270K strands ducted in galvanized 4-1/2" OD diameter corrugated "Spiro" duct. The four tendons investigated were 692' in length and had an average angle change of .79 radians. The VSL E5-31 tendon has an ultimate strength of 1280 kips. See the enclosed shop plans for tendon location.

STRUCTURE DESCRIPTION

Right Bridge - A three-span haunched box girder bridge with span lengths of 190', 270' and 225'. The structure depth varied between 8' @ midspan to 15' @ the piers. The bridge contained many part length tendons as well as the four continuous tendons that were tested.

TEST METHODS

Single-strand load cells were put on strands behind the VSL pulling head. The 1000K load cell was mounted between the VSL pulling head and jack (see Page #3). When the 1000K load cell recorded a load of 950 kips on the tendon, readings were taken on the individual load cells. A summary of results is shown on Page #3.

DISCUSSION OF TEST RESULTS

The results show that for these 31-strand tendons the force is well distributed among the strands. The normal variation between expected force --

$$\left(\frac{\text{addition of single-strand load cell readings}}{\text{\# of load cells}}\right)$$

-- and measured force was 1%. No particular care was taken in this structure to guarantee that the strands lay parallel. No extra precautions were taken to insure that the jack was installed parallel to the tendon path prior to stressing.

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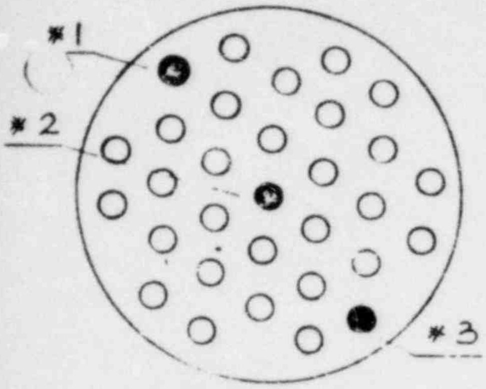
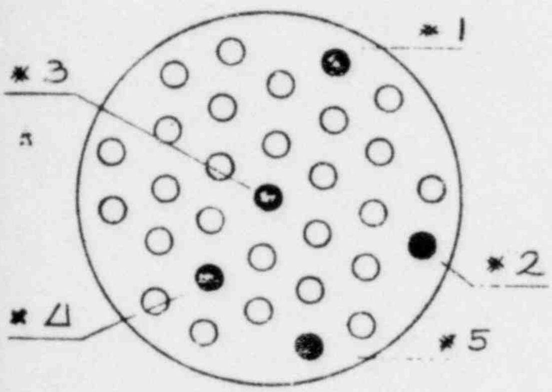
VSL Corporation
Los Gatos California

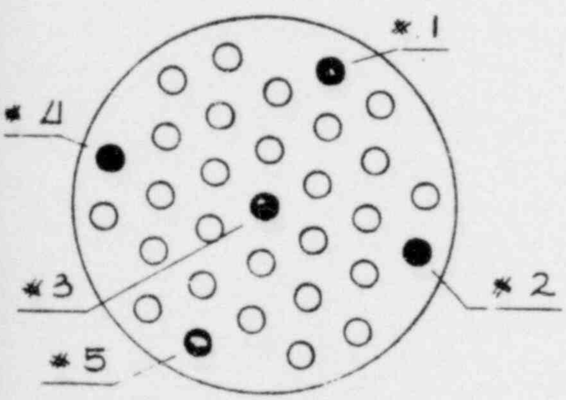
SUMMARY OF TEST RESULTS



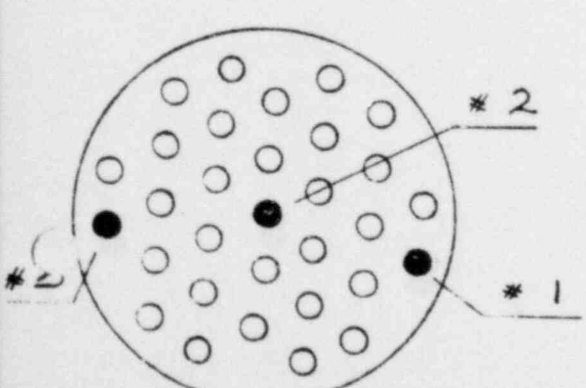
TENDON # 1



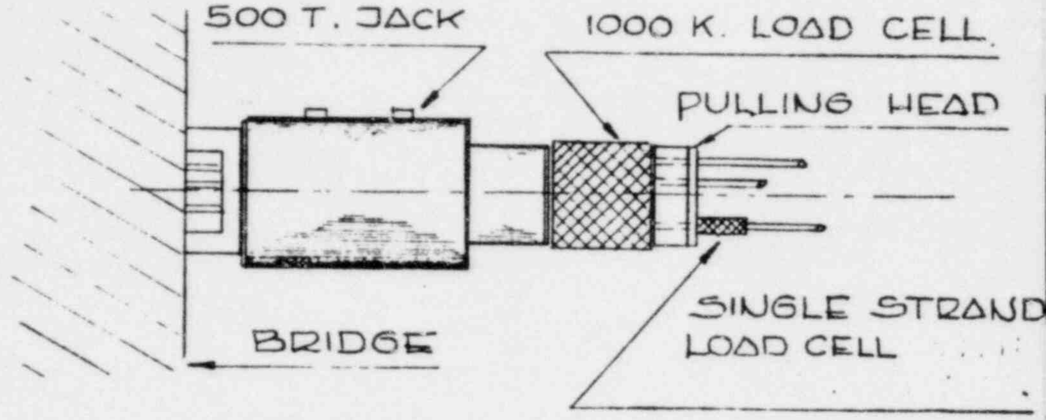
TENDON # 2



TENDON # 17



TENDON # 18



Tendon No.	Tend. Force	Strand No.	Force Strand
	Kips		Kips
# 1	950	1	30.4
		2	30.4
		3	30.2
# 2	950	1	30.3
		2	30.3
		3	30.6
		4	30.2
		5	30.3
# 17	950	1	31.2
		2	29.7
		3	30.5
		4	29.3
		5	29.8
# 18	950	1	31.8
		2	30.3
		3	30.9

0301

~~00217~~

OCTOBER 28th. 1968

Eidgenössische Materialprüfungs- und Versuchsanstalt für Industrie, Bauwesen und Gewerbe, 8600 Dübendorf

Swiss Federal Laboratory for Testing Materials and Research

— 8600 Dübendorf —

COPY - TRANSLATION

Untersuchungsbericht

TEST-REPORT

EMPA No 49'292

Customer: L o s i n g e r + Co SA — B E R N E Switzerland

Contractors and Civil Engineers
VSL International

Object: One tendon " VSL E 5 - 31 "

31 strands 1/2" dia., St 170/190 kg/mm2
(American designation 270 k.)

Subject: Order N° 2911/904890 of March 7th 1968

- Data supplied by the client -

Date of receipt: -

Execution of investigation:

Carried out on December 12th 1967
in the factory IGECO SA in Lyssach

Results of friction test

1) Characteristic of materials
2) Test installation
[Drawing EMPA N° L-99'718]
3) Results of test

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Characteristic of Testmaterial

- Data supplied by the client -

1) Prestressing tendon

Tendon "Soupa", type E 5 - 31, consisting of 31 strands x 1/2" dia. (St 170/190 kg/mm2)
Six outer wires with 4.28 mm dia.
1 core wire with 4.41 mm dia.

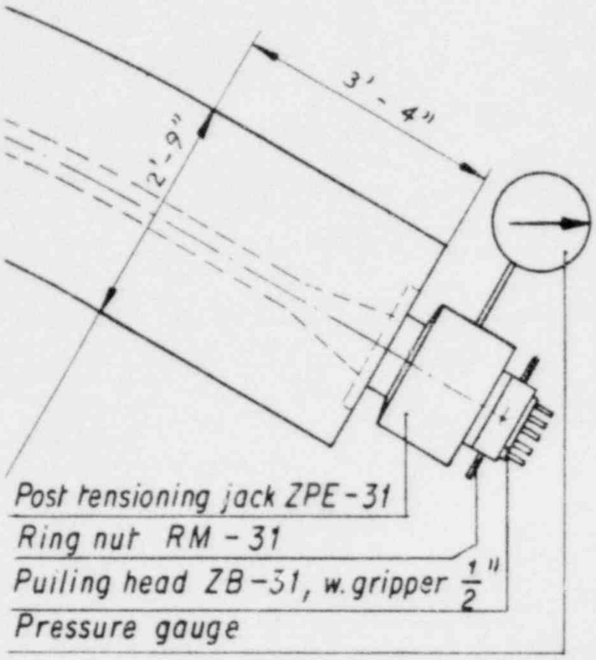
Manufacturer: British Ropes Ltd., England

2) Duct: Steel pipe St.35, bright, Ø 110/100 mm

3) Stressing accessories

	Item	Type	Drawing	Material	Treatment	Manufacturer
Stressing end	Pulling head ZB-31	VSL	G 901.4	St 34 CrNiMo 6	heat treated	Maschinenfabrik, Bern
	Gripper 1/2" XL in 3 parts	CCL	-	-	case hardened	CCL, England
	Ring nut RM-31	VSL	G 889.3	St 34 CrNiMo 6	heat treated	Maschinenfabrik, Bern
Dead end	Pulling head ZB-31	VSL	G 901.4	St 34 CrNiMo 6	heat treated	Maschinenfabrik, Bern
	Gripper 1/2" XL in 3 parts	CCL	-	-	case hardened	CCL, England
	Ring nut RM-31	VSL	G 889.3	St 34 CrNiMo 6	heat treated	Maschinenfabrik, Bern

Stressing end



view of pulling head - stressing end -

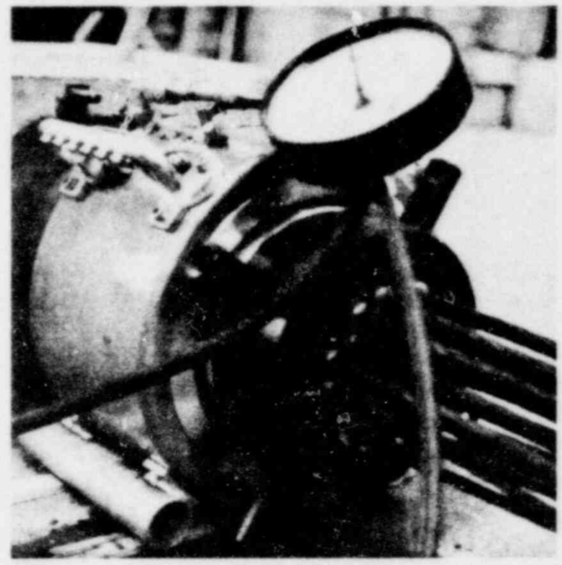


Photo EMPA Nr. 52206

Post tensioning jack with hydraulic pump — stressing end —

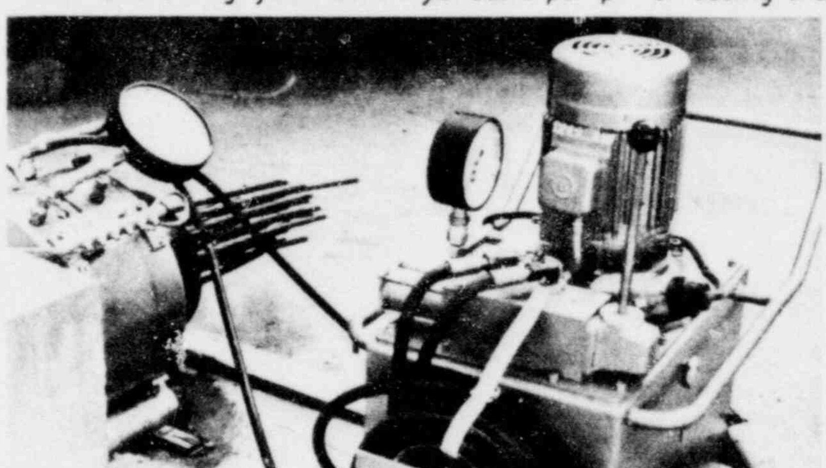


Photo EMPA Nr. 52211

Test installation

Friction test on a tendon VSL E 5-31, cable length approx. 34' - 3".

— Test beam for nuclear reactor —

0304

EMPA	Auftrags-Nr. 49292	Auftraggeber: Losinger & Co. A.G. Bern	Gezeichnet: März 68 Ve.	Zeichnungsnummer L — 99718 a

~~00220~~

R e s u l t s   o f   T e s t

- Temperature + 17°C -

For test installation see drawing EMPA N° L-99'718 a

Post tensioning jacks

Type ZPE-31 Vérin-Jack, piston area 695.1 cm2

Pressure gauge

Stressing end) Type) Division of dial) N° 11523428
Dead end) Mano) 0 + 500 kg/cm2) N° 11618547

Both gauges were supplied by the EMPA.

Stressing end		Dead end			
		Output force at jack			
Input force at jack		Readings of gauge on jack in kg/cm2			Calculated force in tons for average reading
P in tons	Pressure on gauge in kg/cm2	1st reading	2nd reading	Average of 1st & 2nd reading	
0	0	0	0	0	0
50	72	62	63	62,5	43,4
100	144	123	124	123,5	85,8
150	216	186	186	186	129,3
200	288	247	248	247,5	172,0
250	360	310	310	310	215,5
300	432	374	373	373,5	259,6
350	504	428	427	427,5	297,2
0	0	0	0	0	0

Dübendorf, March 13th 1968

Swiss Federal Laboratory for
Testing Materials and Research

[signature]

0305

~~00221~~

FRICTION TEST

TEST PERIOD: October 1968

TEST LOCATION: South Fork of the Eel River Bridge - located 5 miles South of Garberville on U. S. 101 in California

TEST PERSONNEL: Mr. Dave Swanson - VSL Corporation
Mr. Rex Elliott - California Division of Highways
Mr. Jim Jurkovich, Jr. - Calif. Division of Highways

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STATEMENT OF PURPOSE

This test was initiated by the California Division of Highways as a part of their program to determine the friction losses associated with prestressing tendons ducted in rigid conduit.

TEST EQUIPMENT

Two VSL 500-Ton Center Hole Jacks

Two 1000K load cells manufactured by the California Division of Highways

PRESTRESSING TENDON

31, 1/2", 270 K strands ducted in galvanized 4-1/2" diameter corrugated "Spiro" duct.

STRUCTURE DESCRIPTION

Lt. Bridge - A three span bridge with span lengths of 190' - 270' - 243'. The tendon length is 710', and the average angle change is .74 radians.

Rt. Bridge - A three span bridge with span lengths of 190' - 270' - 225'. The tendon length is 692', and the average angle change is .79 radians.

TEST METHODS

Load cells were placed on each end of the tendon between the jack and the pulling head. The load cells were capable of reading applied force within an accuracy of 1%. The tendons were primarily stressed from one end; therefore, the difference in the load cell readings represents the total amount of friction in the system.

SUMMARY OF TEST RESULTS

Tendon Number (Refer to Shop Dwgs)	Force at the Dead End For 960 kips at the Live End		Calculated Dead End Force $\mu = 0.25$ K = 0.0002	
	(Left Bridge)			
1	792	Avg. 790	684	Avg. 698
17	789		709	
	(Right Bridge)			
1	824	Avg. 809	685	Avg. 686
2	783		675	
17	814		690	
18	805		695	

DISCUSSION OF T[illegible]ESULTS

The results of these friction tests show that on this bridge the current friction factors specified by the State of California ($\mu = 0.25$ and K = 0.0002) are very conservative. The measured DEAD END FORCE includes friction loss in the VSL 31-strand anchor block. The friction loss in the anchor block is due to the average strand going through a 3.2 degree angle change. This friction loss amounts to about 2% per anchor block. When the anchor block friction is taken into account, the average DEAD END FORCE measured on the Right Bridge would be 846 kips as compared to an expected force of 686 kips.

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0308

The purpose of these friction tests was to determine appropriate values for coefficients μ and K.

Test No. 1

In this test, a curved reinforced girder was equipped with jacks and gauges on each end. However, no anchor head or wedges were used (except jack pulling heads) so that no anchorage friction had to be taken into consideration. Thus, knowing the input force at the stressing jack and the output at the dead end jack, various values of K were assumed and the basic stress formula then solved for values of μ.

Number of strands	=	31
Diameter of duct	=	3.94" I.D.
L_{girder}	=	34.25'
α	=	1.0472 rad.
K	=	0.0001, 0.0002, 0.0003
P_{jack}, $P_{d\ \ d\ end}$	=	given by the test

$$P_{jack} = P_{dead\ end} \times e^{\mu\alpha + KL} \quad \text{(basic formula)}$$

Solving for μ we get:

$$\mu = \frac{\log_e \frac{P_{jack}}{P_{dead\ end}} - KL}{\alpha}$$

Input Force at Jack No. 1	Force at Dead End	K = .0001	K = .0002	K = .0003
Kips	Kips	μ	μ	μ
110.23	95.68	.1317	.1285	.1252
220.46	189.16	.1430	.1398	.1365
330.69	285.06	.1384	.1352	.1319
440.93	379.20	.1406	.1374	.1341
551.16	475.10	.1384	.1352	.1319
661.39	572.32	.1347	.1314	.1282
771.62	655.22	.1528	.1496	.1463
	Average:	.1399	.1367	.1334

The conclusions that may be drawn from the above results are that on short, highly curved tendons the value of K is not important. The solved values for μ are consistently in a range between .13 and .14. One could not determine from the above results which would be most appropriate of the assumed values for K. A value for K will be determined on Test No. 2 with tendons 710 and 692 feet long (the longest post-tensioned bridge in the United States). Here, the value for K is obviously of major importance and the angular change substantial as well, providing an ideal cross comparison with Test No. 1.

Test No. 2

This test, conducted on a bridge structure, began by stressing the tendons from one end only to a force of 960 kips. The dead end jack was then stressed just enough to lift the dead end anchor head off its bearing plate. In this operation, the anchor head, wedges and strand moved as a unit since the wedges had been seated when jacking previously from the other end. When the dead end anchor just cleared the bearing plate, the dead end reading was taken. Thus, anchorage friction loss (3%) occurred on the live end only.

Number of strands		=	31
Diameter of sheathing		=	4.0" I.D.
Left Bridge:	L	=	710'
	α	=	0.74 rad.
	K	=	0.0001, .0002, .0003
Right Bridge:	L	=	692'
	α	=	0.79
	K	=	.0001, .0002, .0003

Initial force at the live end = 960 kips

Force at the live end minus 3% anchorage friction = 931.20 kips

	Force at Live End	Readings at Dead End	K = .0001	K = .0002	K = .0003
	Kips	Kips	μ	μ	μ
Left Bridge	931.20	792.0	.1227	.0267	< 0
	931.20	789.0	.1279	.0190	< 0
Right Bridge	931.20	824.0	.0673	< 0	< 0
	931.20	783.0	.1320	.0446	< 0
	931.20	814.0	.0827	< 0	< 0
	931.20	805.0	.0968	.0094	< 0

The conclusions which may be drawn from the results of Test No. 2 are that although values of K = .0002 and .0003 might have seemed possible in Test No. 1, they give negative solutions for μ in Test No. 2 and therefore must be excluded. At the same time, it should be noted that the maximum value of μ obtained assuming K = .0001 was .1320 which agrees with the values of μ obtained in Test No. 1

Based on the results of the above, the values of μ = .14 and K = .0003 currently in use in design on nuclear containment structures appear quite conservative.

QUALITY ASSURANCE PROGRAM FOR THE

VSL POST-TENSIONING SYSTEM

INSTALLED IN NUCLEAR CONTAINMENT STRUCTURES

~~00220~~

0312

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

The purpose of this manual is to establish an overall Quality Assurance Program for the VSL Post-tensioning System to be installed in nuclear containment structures. This manual will deal with the entire spectrum of quality assurance from the selection of suppliers of materials and fabrication services to the delivery of the tendons and hardware to the jobsite. (Field erection is outlined in the "Field Erection Manual for the VSL Post-tensioning System Installed in Nuclear Containment Structures".) The object of this effort is to eliminate the manufacture or delivery of discrepant materials or components. "Supplier" as used in this manual shall mean supplier of either materials or services.

It shall be the responsibility of the VSL Quality Assurance Personnel to insure that all materials and manufactured parts adhere to all prescribed specifications, drawings, in-line tests, inspection processes and workmanship standards outlined hereinafter. Where necessary, the VSL Quality Assurance Program shall be prepared to offer assistance to suppliers and fabricators in meeting the quality standards prescribed. This program shall cover the fabrication of tendons by the VSL Corporation and the fabrication of all component parts performed by others.

The VSL Post-tensioning System is the result of extensive development. Prior to its first use in 1964, numerous performance verification tests were conducted to demonstrate the adequacy of the system under a number of parametric variations. Materials, dimensions with related tolerances, surface finishes and other requirements for the various anchorage components were established on the basis of analytic investigations and such tests. These tests included:

Wedge

- Effect of variations of the surface finishes on the wedge-cone interface.
- Effect of variations of the angle of the wedge-cone interface.
- Effect of variations in wedge length.
- Effect of variations in outside and inside diameters.
- Effect of variations in tooth form and overall thread length.
- Effect of variations in case and core hardness and case depth.
- Effect of using materials with different mechanical properties.
- Effect of temperature extremes.

Anchor Head

- Effect of variations in thickness and diameter.
- Effect of variations in wedge hole diameter and angle.
- Effect of using materials with different mechanical properties.
- Effect of temperature extremes.

Bearing Plate

- Effect of variations in thickness.
- Effect of using materials with different mechanical properties.
- Effect of temperature extremes.

The quality assurance requirements outlined in this manual are the same as those implemented on the VSL System as used in bridge and building construction with the exception that additional requirements are included to satisfy conditions of nuclear containment.

This manual has been revised in June of 1969 and supersedes previous VSL Quality Assurance manuals.

GENERAL REMARKS

Drawings of all anchorage components showing materials and tolerances are appended and made a part of this manual.

- Prestressing Steel, Sheathing, Grease, Miscellaneous Material

  These items will be purchased as a finished product and will be accepted by VSL Corporation if they conform to the applicable specifications.

- Bearing Plate Assembly, Grease Cap

  The items listed on page of this manual will be inspected by the VSL Corporation to assure conformance of the bearing plate assembly to the applicable specifications and corresponding drawing. A 100 percent inspection is considered essential. Every assembly which does not conform to the specifications or corresponding drawing will be rejected. Assemblies which do not conform but, in our opinion, could be installed, shall be set aside and provided with a yellow mark. Such assemblies, along with a detailed report describing non-conformance, shall be made available for inspection by the owner to permit his judgment whether or not this part can be installed.

- Anchor Head

The parameters which will be examined by VSL Corporation to assure conformance of the anchor head to the specifications and corresponding drawings are listed on page 2 of VSL Form NR2. A 100 percent inspection will be performed by VSL Corporation on all these items, although not all items listed are considered critical. Since individual handling of the anchor head is required for tapered hole inspection, these additional parameters can be included at negligible costs. Anchor heads which do not conform to specifications or corresponding drawings will be rejected.

- Wedges

The parameters which will be examined by VSL Corporation to assure conformance of the wedge to specifications and corresponding drawings are listed on page 3 of VSL Form NR3. Again, several of these parameters would not require a 100 percent inspection, but since individual handling is required for thread quality inspection, other parameters can be included at negligible costs. Item (m) refers to carbide precipitation and is not amenable to an exact quantitative analysis. If, in the opinion of the examiner, more than 50 percent of the grain boundary circumferences in the wedge examined are surrounded by carbides, the heat will be rejected and the wedges returned for reprocessing. The carbo-nitriding process is known as the best available and most reliable method of heat treating such parts as the VSL Wedge. Sample testing for hardness and case depth as outlined on page 30 of this manual is therefore considered sufficient. If any of the samples tested demonstrate non-conformance, the entire heat will be rejected and the wedges returned for reprocessing.

The VSL Strand System for post-tensioned concrete requires little precision for the different components compared with other competitive post-tensioning systems. This, along with the ease of its installation, is considered the main reason for its superiority. There are, however, a few parameters, such as the thread quality of the wedge, the taper angle of the wedge, and the anchor head, which require close quality control and, therefore, a 100 percent inspection is considered necessary.

SECTION 2

PERSONNEL

2.1 Program Supervisor

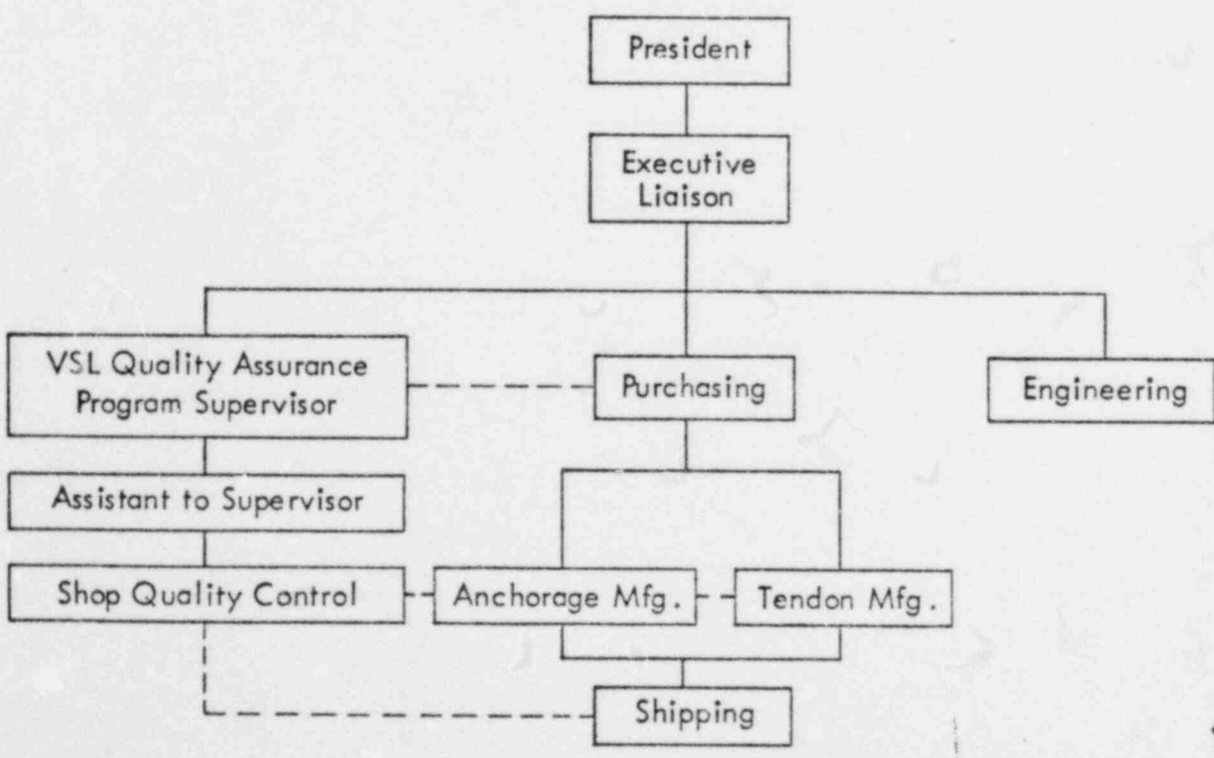
Mr. Donald L. Starn shall be the VSL Quality Assurance Program Supervisor. Mr. Starn shall have full responsibility for the implementation of the VSL Quality Assurance Program. These duties shall include both the performance of Quality Assurance testing and the gathering and dissemination of all Quality Assurance documentation as required.

2.2 Assistant to Program Supervisor

Mr. Robert Latta shall be the Assistant to the VSL Quality Assurance Program Supervisor. Mr. Latta's duties shall include assisting the Program Supervisor and assuming the Supervisor's function in the event of his absence.

2.3 Executive Liaison

Mr. Peter Wick shall be the corporation officer in responsible charge of receiving all documentation on the Quality Assurance Program and will, where necessary, instigate corrective action against a supplier of materials or services. Mr. Wick will hold scheduled weekly meetings with the VSL Quality Assurance Program Supervisor. At these meetings, Mr. Wick will be informed on the progress of the program and will receive notification of situations requiring executive attention.



SECTION 3

PRELIMINARY SPECIFICATIONS

3.1 Prior to selecting acceptable suppliers or fabricators, the Quality Assurance Program Supervisor shall investigate their capabilities, considering such factors as safety, function, interchangeability, workmanship and production capacity.

3.2 Preproduction samples may be requested at this time to evaluate abilities.

3.3 During these investigations, checks shall be made to insure that proposals being proffered are in every respect compatible with the overall specifications of the specific project.

3.4 Substitutions by suppliers to the preliminary specifications which are apparently acceptable shall be evaluated at this time.

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SECTION 4

PRELIMINARY SUPPLIER REVIEW

4.1 The selection of suppliers of materials and manufacturing services shall be preceded by an interview at which the supplier must give assurances on the following points:

4.1.1 It possesses a complete understanding of the items to be produced, their technical requirements and specifications.

4.1.2 It uses adequate quality and material control procedures.

4.1.3 The material it procures or fabricates meets the drawing requirements and meets or exceeds the specification requirements.

4.1.4 Its management controls are capable of correcting all deficiencies early enough to avoid delay in delivery.

4.1.5 Its willingness to provide a specific list of all personnel who will be employed in fabrication, manufacture, quality assurance and reliability functions, with an indication of their tasks, authority and responsibilities.

4.1.6 Its willingness to permit unrestricted inspection by Quality Assurance Inspectors from VSL Corporation, the owner, the engineer and the United States Atomic Energy Commission.

4.2 The VSL Quality Assurance Program Supervisor shall at this time be in a position to submit a list of prospective suppliers to the VSL Purchasing Department. This list shall be constantly monitored and altered as conditions demand.

SECTION 5

SELECTION OF SUPPLIERS

5.1 In the selection of suppliers of material and manufacturing services, such factors as incoming inspection, rework, trouble-shooting and supplier liaison costs shall be taken into account.

5.2 Surveys shall be performed by teams from VSL Quality Assurance, Engineering, and Purchasing and shall investigate the supplier's ability to meet schedule and quality assurance requirements. This survey shall not only determine the supplier's ability to deliver acceptable products on time, but shall also acquaint the supplier with the basis for acceptance by VSL Corporation, and thereby, the owner, his engineer and the U. S. Atomic Energy Commission. The VSL Quality Assurance Program Supervisor shall at this time determine whether the supplier is intending to sub-let any of his work and, if so, shall investigate for approval all sub-suppliers and vendors.

5.3 A review of the organization and facility of all suppliers shall be conducted by the VSL Quality Assurance Program Supervisor.

5.3.1 The supplier must have a well-planned, well-designed, systematized production line. The equipment must permit balanced workloads for economical production within the scheduling required.

5.3.2 The supplier must demonstrate that he can provide positive corrective action in preventing routing errors, materials shortages, labor difficulties, equipment insufficiency, insufficient or inadequate tools, insufficient or inadequate material in process and excessive rejection.

5.3.3 The supplier must demonstrate competency in the area of quality assurance. The VSL Quality Assurance Program Supervisor shall ascertain the supplier's in-house standards, inspection methods, statistical techniques, inspection records, inspection methods, statistical and vendor selection. The supplier's quality assurance department must demonstrate control of raw materials and purchased parts, strategically located in-process test and inspection stations, planned inspection operations, inspection of inspection equipment, tool calibration program, the relationship between the amount of inspection and degree of quality, borderline and rejected materials, and shipping.

5.3.4 On the basis of the above surveys and reviews, suppliers of material and fabrication services shall be selected for the various components of the VSL Post-tensioning System.

SECTION 6

SUPPLIER EVALUATION

6.1 Subsequent to selection of suppliers but prior to production, the VSL Quality Assurance Program Supervisor shall determine specific information and detailed description on how, when and where required tests and inspections will be performed.

6.2 The VSL Quality Assurance Program Supervisor shall explain in detail to each supplier the VSL Inspection Data Sheet to be provided for inspection of all materials and operations within his purview. The VSL Corporation shall thereafter provide these sheets to suppliers for each of the material and part elements of the VSL Post-tensioning System to be provided. Examples of these forms are included in Sections 8 through 12 of this manual.

6.3 VSL Inspection Data Sheets shall provide step-by-step fabrication inspection instructions to the individual supplier. Furthermore, it shall be made clear to the supplier that he cannot be dependent upon VSL Corporation's material receiving inspection but must maintain his own receiving inspection to substantiate the quality of purchased materials and materials shipped to him directly after purchase by VSL Corporation.

6.4 Tests performed on preproduction items submitted by the suppliers of material and fabrication services shall be evaluated by the VSL Quality Assurance Program Supervisor. Items passing these tests shall be considered qualified for production.

. SECTION 7

SURVEILLANCE DURING PRODUCTION

7.1 It shall be the task of the VSL Quality Assurance Program Supervisor to maintain the standards set during the preproduction runs. It must be assured that no changes in drawings, processes or materials are made without approval of the VSL Corporation and that documentation is accurately maintained.

7.2 The VSL Quality Assurance Program Supervisor shall conduct regular audits of supplier performance and make unannounced spot visits to the supplier's plant. These audits shall cover the following:

7.2.1 Incoming inspection (raw materials and components).

7.2.2 In-line and in-process tests.

7.2.3 The proposed plan of tests.

7.2.4 Calibration of test equipment.

7.2.5 Workmanship.

7.2.6 Storage, handling and shipping.

7.3 The VSL Quality Assurance Program Supervisor shall report to the VSL Corporation Executive Liaison and the supplier any discrepancies turned up in the audit. The supplier shall then be required to send the VSL Corporation a written report within three days stating the corrective action it has taken and outlining the plan put into effect to prevent recurrence of the problem.

7.4 Surveillance of tendon fabrication shall include unannounced spot visits to production facilities where audits shall be made on those items listed in 7.2 above. Reports of discrepancies shall be made as outlined in 7.3 above; however, corrective measures may be stated verbally by the VSL Tendon Fabrication Shop foreman to the Executive Liaison.

SECTION 8

ANCHORAGE MANUFACTURE QUALITY CONTROL

8.1 Bearing Plate Assembly.

8.1.1 Material Purchased by VSL Corporation.

8.1.1.1 Bearing Plate.

The material for VSL E5-55 Strand Bearing Plates shall be purchased by the VSL Corporation for shipment to the fabricator. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight, or number of pieces.

(b) Price.

(c) Name of material.

(d) ASTM designation.

(e) Grade and condition.

(f) Requirements for test specimens.

(g) Mechanical properties.

(h) Required tests.

(i) End use of plate.

(j) Shipping information.

See following page for sample of executed purchase order for bearing plates.

8.1.1.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized mill reports and test records will be available.

The above information may be given either by telephone or by letter.

SAMPLE PURCHASE ORDER FOR BEARING PLATE STEEL

PURCHASE ORDER

VSL

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 787

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier)
ADDRESS
CITY

SHIP TO Betra Manufacturing
ADDRESS 50 Bellvue
CITY San Jose, Calif.

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS:	RESALE CERTIFICATE NO.
/28/69)	(8/28/69)	RAIL	San Jose	Net 30 days	[X] A CONFIRMATION [ ] NOT FOR RESALE	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
80,000	lbs.	Carbon Steel Plate, 3-1/2" x 24" x 146" flame cut. Tolerances: Flame cutting ± .125; Thickness - mill standard. No weld repairs are permitted. ASTM A537-67(a) fully killed and modified to 3-1/2" thickness. Grade A Normalized. Test specimens are not to be thermally treated other than normalization.		
		Guaranteed min. yield: 45,000 psi. Transverse Charpy V-Notch of 15 ft.-lbs. minimum at -11° F. Nil-ductility transition temperature lower than -11° F.		
		Notarized test reports are to be submitted to substantiate the following: (a) Heat Number; (b) Chemistry; (c) Mechanical Properties; (d) Impact Properties. (e) NDTT below -11° F.		
End Use: Post-tensioning bearing plate for nuclear reactor containment vessel.				

SPECIAL INSTRUCTIONS

BY

PURCHASE ORDER DISTRIBUTION:
KK 11

WHITE COPY TO VENDOR
GREEN COPY TO "31" SECTION OF GREEN ACCOUNTS PAYABLE FILE
YELLOW COPY TO YELLOW PURCHASE ORDER REGISTER

Any changes bearing on the above data which may occur after original reporting must be made known immediately to the VSL Corporation.

8.1.1.3 A copy of the material purchase order, along with the part drawings, shall be sent to the fabrication shop at the same time the original material purchase order is sent to the material supplier.

Upon receipt by the fabrication shop of material ordered by the VSL Corporation, prompt notice shall be given to the latter stating whether material in the shipment is according to the applicable purchase order and drawing. No work shall be done on bearing plate parts until the VSL Corporation has been thus notified.

It shall be the responsibility of the VSL Quality Assurance Program Supervisor to inform suppliers that they will not be paid for any work which has been done with material which has not been released by the VSL Corporation.

Non-conforming but acceptable material or fabricated components must be approved by the owner prior to use. Pages 2 and 3 of Form NR1 describe the control of these categories.

8.1.1.4 The material shall be checked against drawings and purchase order for sufficient stock to manufacture parts.

8.1.2 Material Purchased by Fabricator.

8.1.2.1 Trumpet.

Trumpet material, grease vent pipe, and welding wire shall be purchased by the fabricator to the specifications shown on the drawings. Notarized mill reports shall be obtained by the fabricator on these materials showing heat numbers.

VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

VSL

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR FABRICATION OF VSL E5-55 STRAND BEARING PLATE ASSEMBLY

1. This form shall accompany each shipment of bearing plates (ASTM A537) when delivered to the jobsite. This form shall be signed or stamped by the fabrication shop quality control inspector and the VSL Quality Assurance Program Supervisor prior to shipment. Two copies shall be retained by the VSL Corporation and one copy by the shop fabricator.

2. Name of fabrication shop: ____________________

3. Material for plate: ASTM A-537, Grade A

   Manufacturer: ____________________

   Heat No.: ____________________

4. Material for trumpet: ASTM A-569-66T

   Manufacturer: ____________________

   Heat No.: ____________________

5. Welding Wire: ASTM E70S-G, GO_2 Shielded

   Manufacturer: ____________________

   Heat No.: ____________________

6. Material for Grease Vent Pipe: 1-1/4" Schedule 40 Pipe

   Manufacturer: ____________________

   Heat No.: ____________________

7. List of checks performed by fabricator:

Item	Type of Sampling	Method	Stamp
(a) Material Specifications	----	Mill certification & VSL Corporation Purchase Order	☐
(b) Outside Dimensions	100%	Rule	☐
(c) Center hole diam. & location	100%	Rule	☐
(d) Grease Cap stud holes and location	100%	Rule	☐
(e) Trumpet & Grease Vent Welds	100%	Visual	☐
(f) Preservative coating	100%	Visual	☐

8. The items listed below have been inspected by VSL Corporation to assure conformance of the bearing plate to applicable specifications:

Item	Type of Sampling	Method	Stamp
(a) Material Specifications	----	Mill certification & VSL Corporation Purchase Order	☐
(b) Outside Dimensions	100%	Rule	☐
(c) Center hole diam. & location	100%	Rule	☐
(d) Grease Cap stud holes and location	100%	Rule	☐
(e) Trumpet & Grease Vent Welds	100%	Visual	☐
(f) Preservative coating	100%	Visual	☐
(g) Stamp marked serial number applied to plate	100%	Visual	☐
(h) All documentation in order preparatory to shipment	----	----	☐

Conforming items shall be marked conspicuously with a green paint mark.

Non-conforming items which may be acceptable with owner's approval shall be marked conspicuously with a yellow paint mark.

Other non-conforming items shall be marked conspicuously with a red paint mark and removed from fabrication area. 0327

9. Documentation appended to this form shall include:

   (a) Unpriced copy of material purchase order for plate, sheet, 1-1/4" pipe and welding wire.

   (b) Notarized mill reports showing heat numbers for plate, sheet, 1-1/4" pipe and welding wire.

   (c) Notarized test reports for bearing plate steel.

10. List of the Bearing Plate Assembly Numbers with associated Heat Numbers (ASTM A537) and Mill Order Numbers from which this shipment of bearing plate assemblies was fabricated:

Bearing Plate No.	Heat No.	Mill Order Number

List of Bearing Plate Assembly Numbers which are non-conforming but acceptable, and which have been approved by owner's inspector:

Bearing Plate No.	Heat No.	Mill Order Number	Defect or Tolerance Exceeded

_______________________ Shop Inspector Date

_______________________ Donald L. Starn Date
VSL Quality Assurance Program Supervisor

0328

0024

8.2 Anchor Heads

8.2.1 The material for VSL E5-55 strand anchor heads shall be purchased by the VSL Corporation for shipment to a fabricator. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight, or number of pieces).

(b) Price.

(c) Name of material.

(d) AISI designation.

(e) Grade and condition.

(f) Requirements for test specimens.

(g) Mechanical properties.

(h) Required tests.

(i) End use of round.

(j) Shipping information.

See following pages for sample of executed purchase order for anchor head and VSL Anchor Head Material Specification.

8.2.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized mill reports and tensile test records will be available.

The above information may be given either by telephone or by letter.

Any changes bearing on the above which may occur after original reporting must be made known immediately to the VSL Corporation.

8.2.3 A copy of the material purchase order, along with the part drawings, shall be sent to the fabrication shop at the same time the original material purchase order is sent to the material supplier.

Upon receipt by the fabrication shop of material ordered by the VSL Corporation, prompt notice shall be given to the latter stating whether material in the shipment is according to the applicable purchase order and drawing.

SAMPLE PURCHASE ORDER FOR ANCHOR HEAD STEEL

PURCHASE ORDER

VSL

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 787

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier)

ADDRESS

CITY

SHIP TO B & C Engrg. & Mfg. Co.

ADDRESS 525 Roberts Ave.

CITY Santa Clara, Calif. 95050

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS	RESALE CERTIFICATE NO.
(7/28/69)	(8/28/69)	RAIL	Santa Clara	Net 30 days	☒ A CONFIRMATION ☐ NOT FOR RESALE	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
40,000	lbs.	Forged carbon steel round, in bar lengths of 126", per VSL Standard Specification AHS-1. Tolerances: Forged to size 12-1/2" Diameter + .25", -0.000.		
		AISI 1026 vacuum degassed; normalized and tempered. Test specimens are to be removed from mid-radius after normalization and tempering.		
		Guaranteed minimum yield of 50,000 psi, Charpy V-Notch of 15 ft.-lbs. at -11° F. Nil-ductility transition temperature lower than -11° F.		
		Notarized test reports are to be submitted to substantiate the following: (a) Heat Number; (b) Chemistry; (c) Mechanical Properties; (d) Impact Properties (e) NDTT no-break.		

SPECIAL INSTRUCTIONS: End Use: Post-tensioning anchor head for use in a nuclear reactor containment structure.

BY

PURCHASE ORDER DISTRIBUTION:

WHITE COPY — TO VENDOR
GREEN COPY — TO "31" SECTION OF GREEN ACCOUNTS PAYABLE FILE
YELLOW COPY — TO YELLOW PURCHASE ORDER REGISTER

KOLOR KEY
MOORE BUSINESS FORMS, INC.

0330

~~002~~

VSL STANDARD SPECIFICATION FOR FORGED CARBON STEEL ROUNDS, HEAT TREATED FOR POST-TENSIONING ANCHOR HEADS

VSL DESIGNATION AHS-1

1. Scope

1.1 This specification covers normalized and tempered forged carbon steel rounds up to and including 13 inches in diameter intended for use as anchor heads in the VSL Post-tensioning System.

1.2 Heat treating procedures and techniques are of fundamental importance and it is pre-supposed that such heat treatment will be in accordance with methods necessary to produce the physical properties required.

2. General Requirements for Delivery

Material shall be produced in such fashion as to allow clean-up turning to 12" diameter without surface imperfections such as seams, cracks or forging laps.

3. Basis of Purchase

The material for VSL E5-55 strand anchor heads shall be purchased by the VSL Corporation for shipment to a fabricator. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight, or number of pieces.

(b) Price.

(c) Name of material: Forged carbon steel round.

(d) AISI designation: AISI 1026.

(e) Grade and condition: Vacuum degassed, normalized and tempered.

(f) Requirements for test specimens: Test specimens to be removed from mid-radius after normalization and tempering.

(g) Mechanical properties: 50,000 psi min. yield; Charpy V-Notch of 15 ft.-lbs. at -11° F. Nil-ductility transition temperature lower than -11° F.

(h) Required tests: Heat number, Chemistry, Mechanical Properties, Impact Properties, NDTT no-break.

(i) End use of round: Post-tensioning anchor head for use in a nuclear reactor containment structure.

(j) Shipping information.

4. Manufacture

The steel shall be made by degassed electric furnace process.

5. Chemical Requirements

AISI Designation	C	Mn	$P_{max.}$	$S_{max.}$
1026	.22/.28	.60/.90	.040	.050

6. Specimen Preparation

Tensile test, NDTT and Charpy V-notch specimens shall be removed from the mid-radius location. Specimens for NDTT and tensile test shall be longitudinal and for V-Notch transverse.

7. Tensile Requirements

Yield Point or Yield Strength at mid-radius, min. psi = 50,000.

Tensile strength, elongation in 2", and reduction of area to be reported for information only.

8. Impact Requirements

Minimum Charpy V-Notch impact values of 15 ft.-lbs. at -11° F. substantiated by impact testing as outlined in ASTM A370 for each heat treat lot.

9. Nil-Ductility Transition Temperature Requirements

An NDT temperature lower than -11° F. shall be substantiated by drop weight testing as outlined in ASTM E208 for each mill heat.

No work shall be done on anchor head parts until the VSL Corporation has been thus notified.

It shall be the responsibility of the VSL Quality Assurance Program Supervisor to inform suppliers that they will not be paid for any work which has been done with material which has not been released by the VSL Corporation.

8.2.4 The material shall be checked against drawings and purchase order for sufficient stock to manufacture parts.

~~002~~

VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR FABRICATION OF VSL E5-55 STRAND ANCHOR HEADS

1. This form shall accompany each shipment of anchor heads when delivered to the jobsite. This form shall be signed or stamped by the fabrication shop quality control inspector and the VSL Quality Assurance Program Supervisor. Two copies shall be retained by the VSL Corporation, and one copy by the shop fabricator.

2. Name of fabrication shop: ____________________

3. Material for anchor head: AISI 1026, VSL Standard Specification AHS-1

   Manufacturer: ____________________

   Heat No.: ____________________

4. List of checks performed by fabricator:

Item	Type of Sampling	Method	Stamp
(a) Material Specifications	----	Mill certification & VSL Corp. Purchase Order	☐
(b) Outside Dimensions	100%	Rule	☐
(c) Hole drilling template	Before drilling each head	VSL Template 001	☐
(d) Hole spacing	100%	VSL Gauge 002	☐
(e) Taper angle	Statistical 5 per head	VSL Gauge 003	☐
(f) Taper roundness	Statistical 5 per head	VSL Gauge 003	☐
(g) Taper max. diameter	Statistical 5 per head	VSL Gauge 003	☐
(h) Taper finish	Statistical 5 per head	Visual	☐
(i) Rear radius	Statistical 5 per head	Visual	☐
(j) Preservative coating	100%	Visual	☐

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5. The items listed below have been inspected by VSL Corporation to assure conformance of the anchor head to applicable specifications:

Item	Type of Sampling	Method	Stamp
(a) Material Specifications	----	Mill certification & VSL Purchase Order	☐
(b) Outside Dimensions	100%	Rule	☐
(c) Hole Spacing	100%	VSL Gauge 002	☐
(d) Taper angle	100%	VSL Gauge 003	☐
(e) Taper roundness	100%	VSL Gauge 003	☐
(f) Taper max. diameter	100%	VSL Gauge 003	☐
(g) Taper finish	100%	Visual	☐
(h) Rear radius	100%	Visual	☐
(i) Preservative coating	100%	Visual	☐
(j) Stamp marked serial number applied to anchor head	100%	Visual	☐
(k) All documentation in order preparatory to shipment	----	----	☐

Conforming items shall be marked conspicuously with a green paint mark.

Non-conforming items shall be marked conspicuously with a red paint mark and removed from fabrication area.

6. Documentation appended to this form shall include the following:

(a) Unpriced copy of material purchase order for forged round.

(b) Notarized test reports for anchor head steel indicating mid-radius tensile strength.

(c) Notarized mill reports showing heat numbers and chemistry.

7. List of Anchor Head Numbers with associated Heat Numbers (AISI 1026) and Mill Order Numbers from which this shipment of anchor heads was fabricated:

Anchor Head Number	Heat Number	Mill Order Number

____
Shop Inspector Date

____
Donald L. Starn, Date
VSL Quality Assurance Program Supervisor

~~00252~~

8.3 Wedges

8.3.1 The material for VSL E5-55 Strand Wedges shall be purchased by the VSL Corporation for shipment to a fabricator. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight or number of pieces).

(b) Price.

(c) Name of material.

(d) AISI designation.

(e) Required tests.

(f) End use of wedge.

(g) Shipping information.

See following pages for sample of executed purchase order for wedges and VSL Wedge Material Specification.

8.3.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized mill reports and hardenability reports will be available.

The above information may be given either by telephone or by letter.

Any changes bearing on the above data which may occur after original reporting must be made known immediately to the VSL Corporation.

8.3.3 A copy of the material purchase order, along with the part drawings, shall be sent to the fabrication shop at the same time the original material purchase order is sent to the material supplier.

Upon receipt by the fabrication shop of material ordered by the VSL Corporation, prompt notice shall be given to the latter stating whether material in the shipment is according to the applicable purchase order and drawing. No work shall be done on wedge parts until the VSL Corporation has been thus notified.

~~00255~~

SAMPLE PURCHASE ORDER FOR WEDGES

PURCHASE ORDER

VSL

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 787

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier)

ADDRESS

CITY

SHIP TO VSL Corporation

ADDRESS 1260 Dell Avenue

CITY Campbell, California

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS:	RESALE CERTIFICATE NO.
(7/28/69)	(8/28/69)	RAIL	Campbell	Net 30 days	☒ A CONFIRMATION ☐ NOT FOR RESALE	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
40,000	lbs.	1-3/16" x 10 to 12' Hot-Rolled Annealed Round Carburizing Grade Alloy Steel; AISI 86L20, per VSL Standard Specification WS-1.		
		Furnish hardenability report and mill report stating chemistry and heat number for each bar.		
		End use of bar: Wedges for post-tensioning anchorage on nuclear containment structure.		

SPECIAL INSTRUCTIONS

BY

PURCHASE ORDER DISTRIBUTION: WHITE COPY TO VENDOR; GREEN COPY TO "31" SECTION OF GREEN ACCOUNTS PAYABLE FILE; YELLOW COPY TO YELLOW PURCHASE ORDER REGISTER

VSL STANDARD SPECIFICATION FOR COLD-DRAWN OR HOT-ROLLED ANNEALED ROUNDS FOR POST-TENSIONING WEDGES

VSL DESIGNATION WS-1

1. Scope

1.1 This specification covers cold-drawn or hot-rolled annealed carburizing grade alloy steel for use as wedges in the VSL Post-tensioning System.

1.2 Later heat treating procedures and techniques will be of fundamental importance. Hardenability reports will accompany each mill heat.

2. General Requirements for Delivery

All bars shall be straight within 1/4 inch in any 5 feet of length. Hot-rolled product annealing shall be performed for optimum machinability.

3. Basis of Purchase

(a) Quantity (dimensions, shipping weight or number of pieces).

(b) Price.

(c) Name of material: Hot-Rolled Round.

(d) AISI designation: AISI 86L20.

(e) Required tests: Furnish hardenability report and mill report stating chemistry and heat number for each bar.

(f) End use of bar: Wedges for post-tensioning anchorage on nuclear reactor containment structures.

(g) Shipping information.

4. Manufacture

The steel shall be made by the open hearth, basic-oxygen or electric furnace processes.

5. Chemical Requirements

AISI Designation	C	Mn	$P_{max.}$	$S_{max.}$	Si	Ni
86L20	.18/.23	.70/.90	.04	.04	.20/.35	.40/.70

Cr.	Mo.	Pb.
.40/.60	.15/.25	.15/.35

6. Tensile Requirements

Yield point, tensile strength, elongation in 2", reduction of area and Brinnell Hardness to be reported for information only.

It shall be the responsibility of the VSL Quality Assurance Program Supervisor to inform suppliers that they will not be paid for any work which has been done with material which has not been released by the VSL Corporation.

8.3.4 The material shall be checked against drawings and purchase order for sufficient stock to manufacture parts.

~~00257~~

VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

VSL

Project: ________________

Owner: ________________

INSPECTION DATA SHEET

FOR FABRICATION OF VSL WEDGES

1. This form shall accompany each shipment of wedges fabricated from a given heat number of steel when delivered to the jobsite. This form shall be signed or stamped by the fabrication shop and heat treatment shop quality control inspectors, and the VSL Quality Assurance Program Supervisor prior to shipment. Two copies shall be retained by the VSL Corporation, one copy by the fabrication shop and one copy by the heat treatment shop.

2. Name of fabrication shop: ________________________________

3. Name of heat treating shop: ________________________________

4. Material for wedge: AISI 86L20, VSL Standard Specification WS-1

   Manufacturer: ________________________________

   Heat No.: ________________

5. List of checks performed by fabricator:

Item	Sample Condition	Type of Sampling	Method	Stamp
(a) Material Specification	---	---	Mill certificates & VSL Corp. Purchase Order	☐
(b) Taper angle, body	Unsplit	First piece from each bar loaded (approx. 120 parts per bar).	Sine bar or comparator	☐

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List of checks performed by fabricator (continued)

	Item	Sample Condition	Type of Sampling	Method	Stamp
(c)	Taper angle, lead-in	Unsplit	First piece from each bar loaded (approx. 120 parts per bar).	Comparator or Gauge	
(d)	Outside diam., length	Unsplit	First piece from each bar loaded (approx. 120 parts per bar).	Dial caliper or comparator	
(e)	Diameter concentricity	Unsplit	First piece from each bar loaded (approx. 120 parts per bar).	Dial caliper or comparator	
(f)	Thread form	Split	First piece from each bar loaded (approx. 120 parts per bar). Statistical 10 per load.	Dial caliper or comparator	
(g)	Thread quality	Split	First piece from each bar loaded (approx. 120 parts per bar). Statistical 10 per load.	Visual	
(h)	Surface finish	Split	First piece from each bar loaded (approx. 120 parts per bar). Statistical 10 per load.	Visual (Fairfield Microfinish Comparator)	
(i)	Split width and symmetry, and Slot	Split	One first piece - off. Statistical 10 per day.	VSL Gauge 004	
(j)	Slot	Split	One first piece - off. Statisrical 10 per day.	Visual	
(k)	Case hardness	Split	One per heat treatment.	Micro hardness	
(l)	Case depth	Split	One per heat treatment.	Microscopic	
(m)	Core hardness	Split	One per heat treatment.	Microhardness	
(n)	Carbide precipitation	Split	One per heat.	Microscopic	
(o)	Burrs and chamfers	Split	One first piece - off. Statistical 10 per day.	Visual	
(p)	Black oxide finish	Split	100%	Visual	

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VSL Form NR3

6. The items listed below have been inspected by VSL Corporation to assure conformance of the wedge to applicable specifications:

	Item	Sample Condition	Type of Sampling	Method	Stamp
(a)	Material Specification	----	---	Mill certificates & VSL Corp. Purchase Order	
(b)	Taper angle, body	Split	100%	Sine bar or comparator	
(c)	Taper angle, lead-in	Split	100%	VSL Gauge 005	
(d)	Outside diam., length	Split	100%	Dial caliper or comparator	
(e)	Diameter concentricity	Split	100%	Dial caliper or comparator	
(f)	Thread form	Split	100%	Visual	
(g)	Thread quality	Split	100%	Visual	
(h)	Surface finish	Split	100%	Visual	
(i)	Split width and symmetry	Split	100%	VSL Gauge 005	
(j)	Case hardness	Split	2% per heat.	Micro hardness	
(k)	Case depth	Split	One per heat.	Microscopic	
(l)	Core hardness	Split	One per heat.	Micro hardness	
(m)	Carbide precipitation	Split	One per heat.	Microscopic	
(n)	Burrs and chamfers	Split	100%	Visual	
(o)	Black oxide finish	Split	100%	Visual	
(p)	Stamp marked heat number on each bag of 110 wedges	----	Each bag.	----	
(q)	All documentation in order preparatory to shipment	----	----	----	

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Conforming lots shall be tagged for release with a green tag stating wedge bag number. Wedges from a given bag shall be used in the like-numbered anchor head.

7. Documentation appended to this form shall include:

   (a) Unpriced copy of material purchase order for steel round.

   (b) Notarized mill reports, including heat numbers, and hardenability reports for steel rounds.

   (c) Notarized heat treatment certificates.

8. List of Wedge Bag Numbers with associated Heat Numbers (AISI 86L20) and Heat Treatment Numbers from which this shipment of wedges was fabricated:

Wedge Bag Number	Anchor Head Number to which Wedge Bag Assigned	Heat Number	Heat Treatment Number

____
Shop Inspector   Date

____
Heat Treatment Inspector   Date

____
Donald L. Starn   Date
VSL Quality Assurance Program Supervisor

8.4 Grease Cap and Seal

Grease cap and gasket material shall be purchased by the fabricator to the specifications shown on the drawings. Notarized mill reports shall be obtained by the fabricator on steel and batch certificates obtained on gasket material.

All grease caps and seals shall be pressure tested by VSL Corporation prior to shipment to jobsite. Caps passing inspection shall be marked conspicuously with a green paint mark and metal stamp marked with the same serialization as the bearing plate, anchor heads and wedges.

SECTION 9

STRAND MANUFACTURE QUALITY CONTROL

9.1 The strand used in VSL E5-55 Strand Tendons shall be purchased by the VSL Corporation for shipment to the VSL Corporation Tendon Fabrication Shop. The purchase order shall contain the following items of information:

(a) Quantity,(dimensions, shipping weight, or number of pieces).

(b) Price.

(c) Name of material.

(d) ASTM designation.

(e) Grade and condition.

(f) Requirements for test specimens.

(g) Mechanical properties.

(h) Required tests.

(i) End use of strand.

(j) Shipping information.

See following page for sample of executed purchase order for strand.

9.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of the required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized mill reports and tensile test records will be available.

The above information may be given either by telephone or by letter.

Any changes bearing on the above which may occur after original reporting must be made known immediately to the VSL Corporation.

SAMPLE PURCHASE ORDER FOR SEVEN-WIRE STRAND

PURCHASE ORDER

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 787

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED.

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier) SHIP TO

ADDRESS ADDRESS

CITY CITY

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS:	RESALE CERTIFICATE NO.
(7/28/69)	(8/28/69)	RAIL		Net 30 days	[X] A CONFIRMATION [ ] NOT FOR RESALE	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
110	12,000' reels	ASTM A416-68 Stabilized 1/2" seven-wire post-tensioning strand; weldless grade; modified to include low-relaxation stabilized strand (4% at 68° at .7 f's in 40 years.		
		Strand shall have a minimum ultimate tensile strength of 270 ksi and elongation of 3-1/2%.		
		A notarized test report shall be required for each reel of strand to substantiate mechanical properties. A notarized mill report for each reel shall include heat numbers for all wire used in the strand on that reel.		
		End Use: Post-tensioning of nuclear reactor containment structure.		

SPECIAL INSTRUCTIONS:

BY

PURCHASE ORDER DISTRIBUTION: A 11

WHITE COPY TO VENDOR
GREEN COPY TO "31" SECTION OF GREEN ACCOUNTS PAYABLE FILE
YELLOW COPY TO YELLOW PURCHASE ORDER REGISTER

~~002~~

VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR MANUFACTURE OF SEVEN-WIRE STRAND

1. Upon delivery of each shipment of strand to the VSL Corporation Tendon Fabrication Shop, this form shall be signed or stamped by the VSL Quality Assurance Program Supervisor. This form shall be retained by the VSL Corporation Tendon Fabrication Shop.

2. Name of manufacturer: ____________________

3. Manufacturing specification: ASTM A416-68 Weldless Grade, modified to include low relaxation stabilized strand.

4. Quality control checks to be verified on the following items by the VSL Quality Assurance Program Supervisor prior to release of strand to VSL Tendon Fabrication Crews.

   (a) Check mill certificates and test to insure material is as required by specifications, purchase order and drawings. ☐

   (b) Strand shall be free from any rusting which is sufficient to cause pitting visible to the naked eye. ☐

   (c) All documentation in order preparatory to tendon fabrication. ☐

5. Documentation appended to this form shall include:

   (a) Unpriced copies of strand purchase order.

   (b) Notarized mill reports showing heat numbers of all wire incorporated into the strand for any one reel.

   (c) Notarized tensile test reports for each reel of strand.

6. List of Reel Numbers, Mill Report Numbers and Heat Numbers for all reels in this shipment:

Mill Report Number	Reel Number	Heat Numbers

Donald L. Stam   Date
VSL Quality Assurance Program Supervisor

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SECTION 10

TENDON SHEATHING QUALITY CONTROL

10.1 The sheathing used in VSL E5-55 Strand Tendons shall be purchased by the VSL Corporation for shipment directly to the jobsite. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight, or number of pieces).

(b) Price.

(c) Name of material.

(d) ASTM designation.

(e) Grade and condition.

(f) Requirements for test specimens.

(g) Mechanical properties.

(h) Required tests.

(i) End use of sheathing.

(j) Shipping information.

See following page for sample of executed purchase order for sheathing.

10.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized mill reports on sheathing will be available.

The above information may be given either by telephone or by letter.

Any changes bearing on the above which may occur after original reporting must be made known immediately to the VSL Corporation.

SAMPLE PURCHASE ORDER FOR TENDON SHEATHING

PURCHASE ORDER

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 787

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED.

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier) SHIP TO (Jobsite Address)

ADDRESS ADDRESS

CITY CITY

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS:	RESALE CERTIFICATE NO.
(7/28/69)	(8/28/69)	RAIL	Jobsite	Net 30 days	☒ A CONFIRMATION ☐ NOT FOR RESALE.	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
12,000	feet	24-gage galvanized spiral wrapped sheathing.		
		40-ft. lengths.		
		Six-inch outside diameter.		
		Sheathing steel shall conform to ASTM A366-66T		
		cold-rolled carbon steel.		
		Notarized mill reports are required on sheathing steel stating heat number and conformance to ASTM Specification.		
		End use of pipe: Sheathing for post-tensioning of		
		nuclear reactor containment structure.		

SPECIAL INSTRUCTIONS

BY

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10.3 The material used in the fabrication of sheathing must conform to the VSL Purchase Order and drawing. It shall be the responsibility of the VSL Quality Assurance Program Supervisor to inform suppliers that they will not be paid for any work which has not been done with materials that are not in accordance with the specifications.

10.4 Material purchased by the fabricator shall be checked against the purchase order for sufficient stock to manufacture sheathing required.

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VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

VSL

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR FABRICATION OF VSL E5-55 STRAND SHEATHING

1. This form shall accompany each shipment of sheathing fabricated from a given heat number of steel when delivered to the jobsite. This form shall be signed or stamped by the VSL Quality Assurance Program Supervisor prior to shipment and two copies shall be retained by the VSL Corporation Fabrication Shop.

2. Name of fabrication shop: ____________________

3. Material for sheathing: ASTM A366-66T

   Manufacturer: ____________________

   Heat Numbers: ____________________

4. Quality control checks to be verified on the following items by the VSL Quality Assurance Program Supervisor prior to release of sheathing for shipment to the jobsite.

   (a) Visual inspection of samples of shipment to insure soundness and freedom from corrosion. ☐

   (b) All documentation in order preparatory to shipment. ☐

5. Documentation appended to this form shall include:

   (a) Unpriced copies of material purchase order for steel strip used in sheathing. This document shall be supplied by the fabricator of the sheathing.

   (b) Notarized mill reports showing heat numbers of sheathing steel included in the shipment.

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____
Donald L. Stam Date
VSL Quality Assurance Program Supervisor

SECTION 11

TENDON SHEATHING FILLER QUALITY CONTROL

11.1 The Tendon Sheathing Filler Material for VSL E5-55 Strand Tendons shall be purchased by the VSL Corporation for shipment by the manufacturer to the jobsite. The purchase order shall contain the following items of information:

(a) Quantity (dimensions, shipping weight, or number of pieces).

(b) Price.

(c) Name of material.

(d) Grade and condition.

(e) Requirements for test specimens.

(f) Required tests.

(g) End use of sheathing filler.

(h) Shipping information.

See following page for sample of executed purchase order for sheathing filler.

11.2 The material supplier shall be required to submit the following data within five days after receipt of the purchase order:

(a) Availability of required materials.

(b) Whether delivery schedule can be met.

(c) Date when notarized test records will be available.

The above information may be given either by telephone or by letter.

Any changes bearing on the above which may occur after original reporting must be made known immediately to the VSL Corporation.

11.3 The material used in the fabrication of sheathing filler must conform to the VSL Purchase Order and drawing. It shall be the responsibility of the VSL Quality Assurance Program Supervisor to inform suppliers that they will not be paid for any work which has been done with materials that are not in accordance with specifications.

11.4 Material purchased by the fabricator shall be checked against the purchase order for sufficient stock to manufacture sheathing filler required.

SAMPLE PURCHASE ORDER FOR TENDON SHEATHING FILLER

PURCHASE ORDER

V S L CORPORATION
P. O. BOX 459
LOS GATOS, CALIFORNIA 95030
TELEPHONE (408) 354-6481

THIS NUMBER MUST APPEAR ON ALL PACKAGES, INVOICES, ETC. № 785

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED.

DO NOT DEVIATE FROM THIS ORDER IN ANY WAY WITHOUT OUR PERMISSION.

TO (Supplier) SHIP TO (Jobsite address)

ADDRESS ADDRESS

CITY CITY

DATE OF ORDER	DATE REQUIRED	SHIP VIA	F. O. B.	TERMS	THIS ORDER IS:	RESALE CERTIFICATE NO.
(7/28/69)	(8/28/69)	RAIL	Jobsite	Net 30 days	☒ A CONFIRMATION ☐ NOT FOR RESALE.	SRGH 26-612993

QUANTITY ORDERED	UNIT	PLEASE SUPPLY THE FOLLOWING ITEMS	UNIT PRICE	AMOUNT
12,000	gallons	Visconorust 2090P Casing Filler. Nuclear Grade.		

Physical Limitations:

(a) Melting Point 120 F Minimum ASTM D-127
(b) Flash Point 385 F Minimum ASTM D-92

Chemical Limitations:

Compounds	Allowable Max.	Test Method
(a) Water Soluble Chlorides (Cl)	5.0 ppm	ASTM Method D512-62 (Limit of Accuracy 0.5 ppm)
(b) Water Soluble Nitrates (NO_3)	4.0 ppm	Hach Chemical Analysis
(c) Water Soluble Sulfides (S)	5.0 ppm	ASTM Method D1255 (Limit of Accuracy 1.0 ppm)

Notarized test results shall be required to substantiate required physical and chemical limitations on each batch of material. Material to be delivered to jobsite in insulated tank trucks and pumped into a storage tank facility provided by VSL Corporation.

SPECIAL INSTRUCTIONS

BY

End Use: Sheathing filler material for post-tensioning of nuclear containment structure.

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VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

VSL

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR MANUFACTURE OF TENDON SHEATHING FILLER

1. This form shall accompany each batch shipment of tendon sheathing filler when delivered to the jobsite. This form shall be signed or stamped by the VSL Quality Assurance Program Supervisor prior to shipment; two copies shall be retained by the VSL Corporation Fabrication Shop.

2. Name of manufacturer: ____________________

3. Manufacturer's product name: ____________________

4. Quality control checks to be verified on the following item by the VSL Quality Assurance Program Supervisor prior to release of tendon sheathing filler for shipment:

   (a) The results of the test on physical and chemical limitations shall be compared to the limitations specified. ☐

5. Documentation appended to this form shall include:

   (a) Unpriced copy of material purchase order for tendon sheathing filler.

   (b) Notarized report substantiating the physical and chemical limitations required.

6. List of the Batch Numbers of material in shipment:

____

____

____

____

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____
Donald L. Starn — Date
VSL Quality Assurance Program Supervisor

SECTION 12

TENDON MANUFACTURE QUALITY CONTROL

12.1 A prefabricated tendon shall consist of the required number of strands lightly coated with grease, bound on one end with a Kellum Grip, and spooled on a weather-proof fabrication reel.

12.2 Tendon shall be fabricated by a VSL Corporation Crew from strand conforming to that described in Section 9 of this manual.

12.3 A copy of the strand purchase order, along with the tendon drawings, shall be sent to the tendon fabrication shop at the same time the original material purchase order is sent to the strand supplier.

Upon receipt of the strand by the tendon fabrication shop, prompt notice shall be given to the person who signed the purchase order and to the VSL Quality Assurance Program Supervisor. No work shall be done on tendon fabrication until both of these parties have been notified.

The VSL Quality Assurance Program Supervisor shall then make the inspection required under Item 4 of the Inspection Data Sheet in Section 9 of this manual prior to commencement of tendon fabrication.

12.4 The material shall be checked by the shop inspector against drawings and purchase order for sufficient stock to manufacture tendons.

00274

VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

Project: ____________________

Owner: ____________________

INSPECTION DATA SHEET

FOR FABRICATION OF VSL E5-55 STRAND TENDONS

1. This form shall accompany each shipment of tendons when delivered to the jobsite. This form shall be signed or stamped by the VSL Quality Assurance Program Supervisor prior to shipment, and two copies shall be retained by the VSL Corporation Tendon Fabrication Shop.

2. List of operations performed by VSL Tendon Fabrication Shop:

	Initial Stamp
(a) Place strand spools on fabrication racks.	☐
(b) Draw strands through corrosion protection applicator.	☐
(c) Band forward end of tendon.	☐
(d) Pull strands to form required length tendon and install Kellum Grip.	☐
(e) Band tendon twice and cut tendon to length between bands.	☐
(f) Attach two tendon identification tags, one on each end.	☐
(g) Spool tendon on shipping spool.	☐
(h) Cover spool with protective wrapper.	☐
(i) Attach tendon identification tag to shipping spool.	☐

3. List of quality control checks performed by VSL Tendon Fabrication Shop Quality Control:

(a) Inspect strand for rust or damage.	☐
(b) Inspect grease coating.	☐
(c) Check to see that tendon identification tags are attached to tendons and shipping spool.	☐

~~00275~~

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4. Quality control checks to be verified on the following items by the VSL Quality Assurance Program Supervisor prior to release of tendons for shipment:

(a) Number of strands. ☐

(b) Length of tendons. ☐

(c) Grease coating. ☐

(d) Two tendon tags securely attached and in order. ☐

(e) All documentation in order preparatory to shipment. ☐

5. Documentation appended to this form shall include the following:

(a) VSL Form NR4, Inspection Data Sheet for Manufacture of Seven-Wire Strand with attachments.

6. List of the tendon numbers included in the shipment:

Tendon Number	Reel Number	Heat Number

Shop Inspector ____________ Date

Donald L. Starn ____________ Date
VSL Quality Assurance Program Supervisor

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SECTION 13

EQUIPMENT

13.1 The following pieces of VSL Corporation Equipment shall be inspected, approved and tagged by the VSL Quality Assurance Program Supervisor prior to shipment to the jobsite.

(a) Jack-pump-gage properly numbered and accompanied by up-to-date calibration charts, in proper working order.

(b) Tendon sheathing filler equipment inspected with preproduction testing to assure it is in proper working order.

(c) Sheathing bending machine in proper working order.

(d) Shipping reels.

(e) Uncoiling frames.

(f) Kellum Grips.

13.2 Recalibration of jacks-pump-gage combinations every six months shall be verified by the VSL Quality Assurance Program Supervisor.

~~00277~~

SECTION 14

HANDLING, SHIPPING AND PRESERVATION

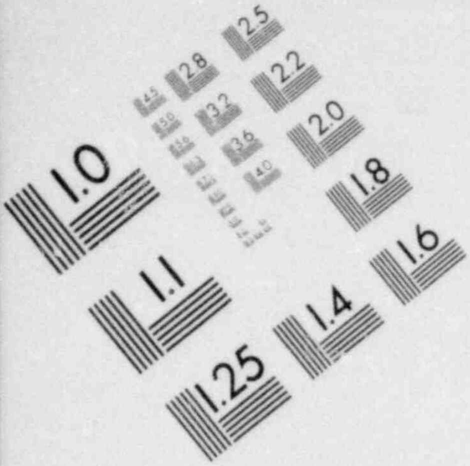
(This section applies specifically to Rancho Seco Unit #1)

14.1 The various materials and equipment provided by the VSL Corporation shall be prepared and loaded for shipment in such a manner as to protect them from damage in transit. Where necessary, heavy parts of equipment shall be mounted on skids or shall be crated, and any articles or materials that might otherwise be lost shall be boxed or wired in bundles and plainly marked for identification. Any part having a shipping weight exceeding four (4) tons shall have its gross weight painted thereon with white paint. All material and equipment shall be loaded so that it will not shift or become damaged during hauling. All parts exceeding two hundred (200) pounds gross weight shall be prepared for shipment so that slings for handling by crane may be readily attached while the parts are on the car or on other methods of conveyance. Boxed parts, where it is unsafe to attach slings to the box, shall be packed with slings attached to the part, the slings to project through the box or crate so that attachment to the hoisting equipment can be readily made. All finished non-ferrous metalwork and devices subject to damage shall be suitably wrapped or otherwise protected from damage during shipment. Proper precautions shall be taken with all electrical equipment and instruments to prevent damage during shipment. The moving elements of all meters and instruments shall be properly blocked or tied to prevent damage during shipment. It shall be a function of the VSL Quality Assurance Program Supervisor to approve shipping methods proposed by suppliers and to verify and ascertain that all sections and parts shipped shall be of such size and dimensions as to provide sufficient clearances through all tunnels, underpasses and all other restrictions that may be encountered in shipment of the contract items to the point of destination listed in the contract.

14.2 Items disassembled for shipment shall be match-marked for ease of reassembly. All pieces, items and units and their containers shall be piecemarked to an approved master numbering system, and shall be tagged with the Sacramento Municipal Utility District's purchase order number.

14.3 Prior to shipment of materials and equipment to the Rancho Seco jobsite, the VSL Corporation shall prepare and submit to the Sacramento Municipal Utility District at least thirty (30) calendar days prior to shipment, a summary of shipping points, shipping weights, classifications, proposed routings and shipping diagrams, if any, and shall review proposed carriers with the District.

The VSL Corporation shall also furnish the following information by telegram as early as possible but not later than the day of shipment:



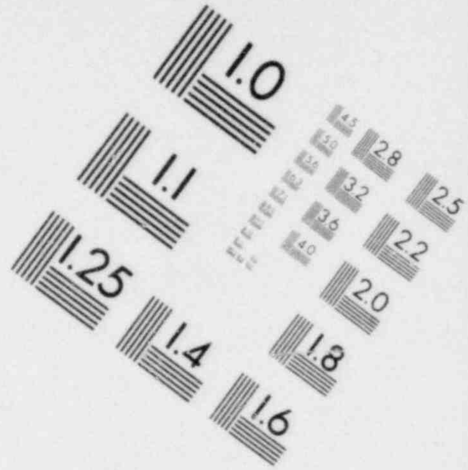
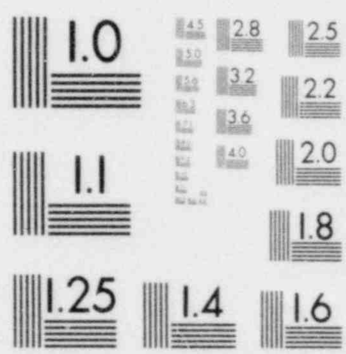
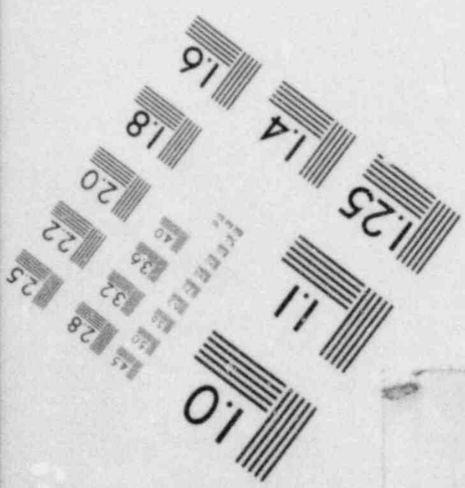


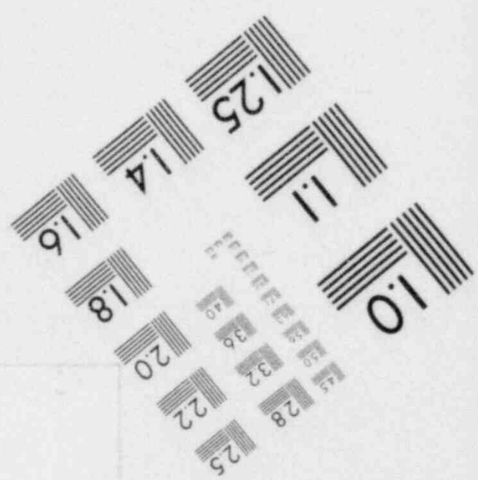
IMAGE EVALUATION TEST TARGET (MT-3)

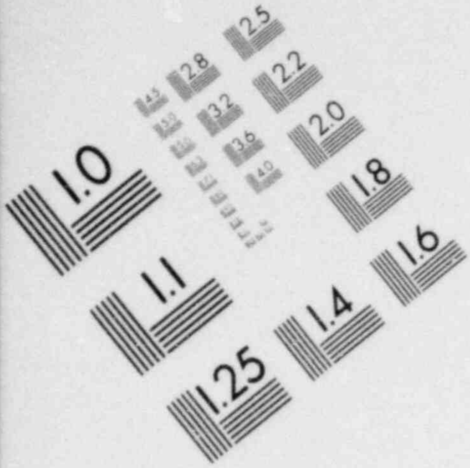


6″

MICROCOPY RESOLUTION TEST CHART







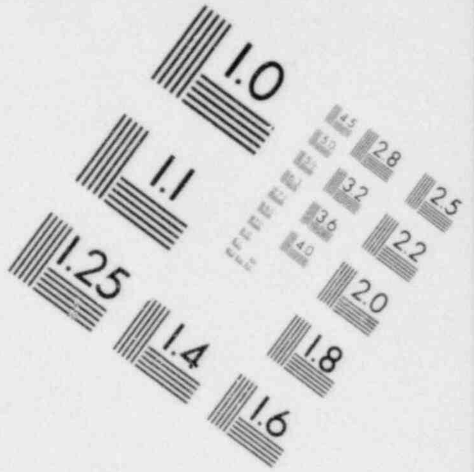
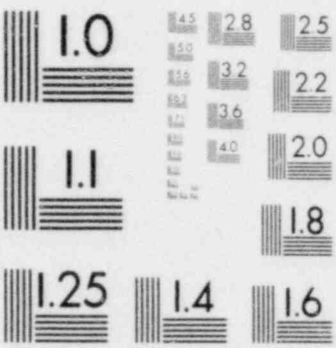
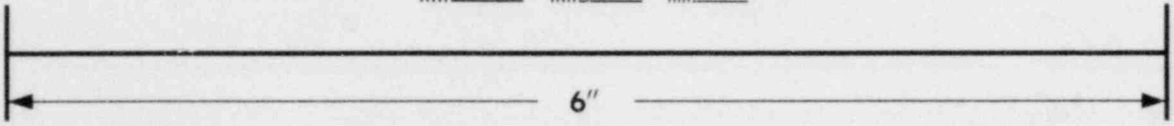
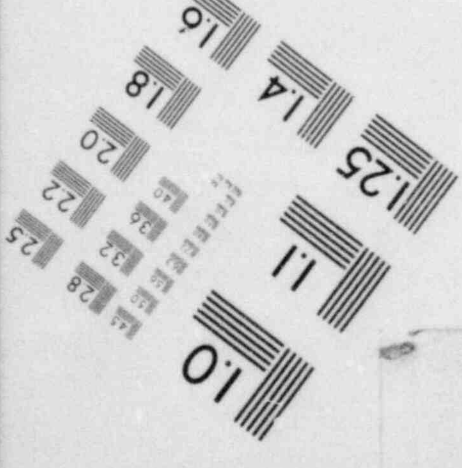


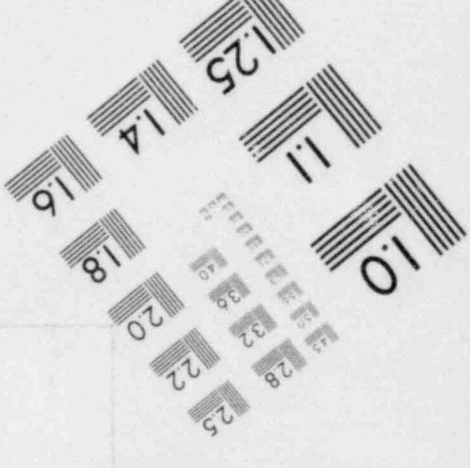
IMAGE EVALUATION TEST TARGET (MT-3)





MICROCOPY RESOLUTION TEST CHART





VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

Project:

Owner:

VSL

SHIPPING DATA

Item:

Shipping Point:

Shipping Weight:

Classification:

Proposed Routing:

Carrier:

Remarks:

~~0027~~

001

(a) Date of shipment.

(b) Routing.

(c) Car number.

(d) Point of origin.

(e) Material being shipped..

14.4 The VSL Corporation shall submit to the District six copies of unpriced sub-orders and all other information necessary for expediting the contract and shall provide free access for representatives of the District to the VSL Corporation shops and to the shops of the VSL Corporation's subcontractors and suppliers.

The Sacramento Municipal Utility District may elect to establish mandatory hold points in the VSL Corporation's production schedule which require witnessing or inspecting by the District's designated representative and beyond which work shall not proceed without the consent of its designated representative. The VSL Quality Assurance Program Supervisor shall assist the Sacramento Municipal Utility District as required in implementing their inspection program and shall incorporate records of these inspections in the appropriate documents.

SECTION 14

HANDLING, SHIPPING AND PRESERVATION

(This section applies specifically to Rancho Seco Unit #1)

14.1 The various materials and equipment provided by the VSL Corporation shall be prepared and loaded for shipment in such a manner as to protect them from damage in transit. Where necessary, heavy parts of equipment shall be mounted on skids or shall be crated, and any articles or materials that might otherwise be lost shall be boxed or wired in bundles and plainly marked for identification. Any part having a shipping weight exceeding four (4) tons shall have its gross weight painted thereon with white paint. All material and equipment shall be loaded so that it will not shift or become damaged during hauling. All parts exceeding two hundred (200) pounds gross weight shall be prepared for shipment so that slings for handling by crane may be readily attached while the parts are on the car or on other methods of conveyance. Boxed parts, where it is unsafe to attach slings to the box, shall be packed with slings attached to the part, the slings to project through the box or crate so that attachment to the hoisting equipment can be readily made. All finished non-ferrous metalwork and devices subject to damage shall be suitably wrapped or otherwise protected from damage during shipment. Proper precautions shall be taken with all electrical equipment and instruments to prevent damage during shipment. The moving elements of all meters and instruments shall be properly blocked or tied to prevent damage during shipment. It shall be a function of the VSL Quality Assurance Program Supervisor to approve shipping methods proposed by suppliers and to verify and ascertain that all sections and parts shipped shall be of such size and dimensions as to provide sufficient clearances through all tunnels, underpasses and all other restrictions that may be encountered in shipment of the contract items to the point of destination listed in the contract.

14.2 Items disassembled for shipment shall be match-marked for ease of reassembly. All pieces, items and units and their containers shall be piecemarked to an approved master numbering system, and shall be tagged with the Sacramento Municipal Utility District's purchase order number.

14.3 Prior to shipment of materials and equipment to the Rancho Seco jobsite, the VSL Corporation shall prepare and submit to the Sacramento Municipal Utility District at least thirty (30) calendar days prior to shipment, a summary of shipping points, shipping weights, classifications, proposed routings and shipping diagrams, if any, and shall review proposed carriers with the District.

The VSL Corporation shall also furnish the following information by telegram as early as possible but not later than the day of shipment:

FIELD INSTRUCTION MANUAL

FOR INSTALLATION OF VSL E5-55 POST-TENSIONING SYSTEM

I. Post-tensioning Materials Identification

A. At the time of arrival at the jobsite, "VSL" Post-tensioning Materials will be identified as follows:

1. Bearing Plates - Identification number stamped in the upper left-hand corner on both sides with a metal stamp.

2. Anchor Heads with Wedges (wedges are held in the anchor head with a removable retainer plate) - The identification number is stamped on the side of the anchor head with a metal stamp.

3. Tendons - Identification numbers are shown on metal tags attached to each end of the tendon.

B. The installation contractor shall install each identified piece of post-tensioning material in the location called out on the Approved "VSL" Shop Drawings. This procedure is necessary so that the location of all post-tensioning material will be a matter of record.

II. Bearing Plates

A. Material

1. VSL E5-55 Bearing Plates weigh approximately 500 lbs. This material must be stored in a clean dry area.

B. Installation

1. Forms at the anchorage must be sturdy enough to provide a secure mounting for the bearing plates.

2. Bearing plates shall not be lifted or moved using the trumpet and/or grout vent to rig to, since neither is designed for this type of loading. VSL E5-55 Bearing Plates are provided with threaded lifting holes into which lifting eyes may be attached.

3. In order to make bearing plate installation and checking possible, bearing plates shall be installed prior to the mild reinforcing around the bearing plate.

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4. Bearing plates shall be installed within a tolerance of 3/4" of the location shown on the Approved VSL Shop Plans.

5. Bearing plates shall be attached to the forms with two 1/2" machine bolts.

6. During sheathing installation, bearing plates shall be adjusted as required to correct any deviation from perpendicularity to the tendon path.

III. Tendon Sheathing

A. Material

1. VSL E5-55 Tendons will be sheathed in 6" O.D., 24-gage, galvanized Spiro sheathing

2. Sheathing lengths will be as follows:

   a. Vertical Tendons - 10 ft.

   b. Horizontal Tendons - 40 ft.

   c. Dome Tendons - 40 ft.

3. Couplers will be made of the same material as the sheathing with a slightly larger diameter and will be 18" long. These couplers thread onto the duct.

4. This sheathing material should be stored in a clean dry area where the ends of the duct are covered, thus eliminating any possible contamination.

B. Installation

1. Sheathing will be installed within a tolerance of 3/4" of the location shown on the "Approved VSL Shop Plans."

2. Sheathing will be wired to mild steel reinforcing or other sheathing with 15-gage tie wire. These ties will be made at close enough intervals to assure that the duct will not be displaced during concrete placing. Experience has shown that 5 to 7 feet tie spacings are adequate. The ties shall be made in such a fashion that they will restrain the duct from floating. The buoyant force on this duct is 29 lbs. per lineal ft.

3. At the buttresses where the reinforcing steel is not adjacent to the horizontal tendons, the installation contractor shall provide chairs to support the sheathing.

4. At couplers, the two pieces being joined shall be within one-half inch of contact and the coupler centered on the joint.

0005 ~~002~~

5. Either or both of the following methods has proved satisfactory in sealing sheathing splices from laitance intrusion.

   a. Tape all joints with a waterproof tape such as "Arno Duct Tape."

   b. Seal all joints with a long potlife, flexible epoxy.

6. All open ends of sheathing shall be capped to prevent intrusion of foreign materials.

7. Sheathing shall be placed through construction joints.

8. After the sheathing has been encased in concrete, a ball 5-5/8" in diameter shall be passed through the sheathing to demonstrate it is free of obstructions. If an obstruction (dent) is encountered, the concrete in this area shall be removed and the sheathing repaired.

IV. Tendons

A. Material

1. Tendons will be delivered to the jobsite on a fabrication reel. The outer end of the tendon will be fitted with a "Kellums Grip."

2. Storage of tendons and anchor heads:

   a. Tendons - The tendons will be delivered to the jobsite protected by a canvas cover. This cover should not be removed until the tendon is to be installed.

   b. Anchor Heads - Anchor heads containing wedges held in by a retainer plate will be delivered to the jobsite in boxes. Each box will contain the two anchor heads for a specific tendon. Anchor head boxes shall remain sealed until the time for anchor head installation.

B. Installation

1. Prior to installation, horizontal tendon ducts shall be drained at low points.

2. Provisions shall be made so that during the pulling operation that portion of the tendon immediately outside of the structure shall be parallel to the axis of the duct.

3. The tendons shall be pulled into the structure in one 55-strand bundle.

4. Horizontal tendons will have a retainer plate directly behind the Kellums Grip. This plate will be caught by the bearing plate and comb out the strands as the tendon is pulled into the structure.

5. A tendon that has evidently become snarled as shown by disparities in the tail end lengths of individual strands shall be removed and repulled.

6. Horizontal and dome tendons will be furnished a minimum of 8' 4" longer than the length from face of bearing plate to face of bearing plate. This length is necessary to install the center hole jack. Each end of a tendon must protrude a minimum of 50" through the bearing plate.

7. For vertical tendons, the 50" minimum protrusion shall apply only to the top bearing plate (jacking end).

8. Clean the strand protruding from the bearing plate before installing anchor head.

After the tendon is pulled into the structure, install an anchor head at each end of the tendon, leaving the loosened wedge retainer plate in place.

V. <u>Stressing</u>

A. Equipment

1. See enclosed drawings of jacking equipment and equipment maintenance instructions.

B. Procedure

1. Unbolt wedge cover plate and slide plate away from the anchor head. Plate will keep the strands combed out inside the jack.

2. Install jack chair over anchor head. The jack chair bolts onto the bearing plate, centering the anchor head along the axis of the tendon.

3. Place jack over strand and attach to the jack chair.

4. Slip pulling head over strand and install jacking wedges. Strands must go through the same relative holes in the anchor head and pulling head.

5. Before stressing, the jack must be lined up with the axis of the tendon to be stressed and all pulling head wedges driven into the pulling head snugly.

6. For tendons that are to be stressed from both ends simultaneously (horizontal and dome), the tendon shall be stressed to 10% of design jacking force. Mark the tendon at both ends for an elongation datum. This shall be accomplished by putting a tape marker on several strands behind the pulling head and measuring to the jack base. For vertical tendons which are to be stressed from one end, the above procedure should be followed at the live end. The end should be marked at 10% P_{jack} and checked at the completion of stressing.

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7. Stress the tendon to design jacking force and record the elongation on both ends. Compare the total elongation with that calculated using the exact modulus of elasticity of the strand. The measured elongation should agree within 5% $\pm$ of the calculated value.

8. Finally, the tendon is released, anchoring with a 1/4" seating loss.

9. On horizontal and vertical tendons, it will be necessary to re-cycle the jacks in order to obtain the required elongation. This re-cycling operation shall take place at one-half of the required jacking force called out on the approved "VSL Shop Plans."

10. The form on page 6 shall be used to record stressing information.

VI. Grease

A. Material

1. The material supplier has not been decided upon yet.

B. Equipment will consist of one 15,000 gallon storage tank (heated), a Moyno pump with a capacity of 50 gpm, accessory hoses and a four-way valve system capable of recirculating grease.

C. Procedure

1. Heat the grease to an optimum temperature of 120° F. The allowable temperature range for pumping is 100° F. minimum to 170° F. maximum.

2. For horizontal and dome tendons, interconnect two tendons so that the grease will be pumped back and wasted at the source.

3. Prior to pumping horizontal tendons, close all intermediate low point vents.

4. Always pump uphill.

5. As pumping proceeds, bleed all air bubbles, foreign matter and diluted grease out of high point and discharge vents before they are closed.

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VSL Corporation
236 N. Santa Cruz Ave.
Los Gatos, Calif. 95030

VSL

Project: ____________________

Owner: ____________________

STRESSING INFORMATION

Tendon Number	Date Stressed	Jack-Pump Combination No.		Calibration Curve No.		End "A" Pressure Gage Reading @ P_j	End "B" Pressure Gage Reading @ P_j	Elongation		
								Measured		Calculated
		End "A"	End "B"	End "A"	End "B"			End "A"	End "B"	Total

Elongation is measured from a datum established at 10% P_{jack}.

Explanation of Symbols:

P_{jack} = Jacking force called for on "Approved VSL Calculations."

Tendon Identification System: 1 (Tendon #) - 1 (Bearing Plate # at End "A"), 128 (Bearing Plate # at End "B") } Represents 1-1, 128

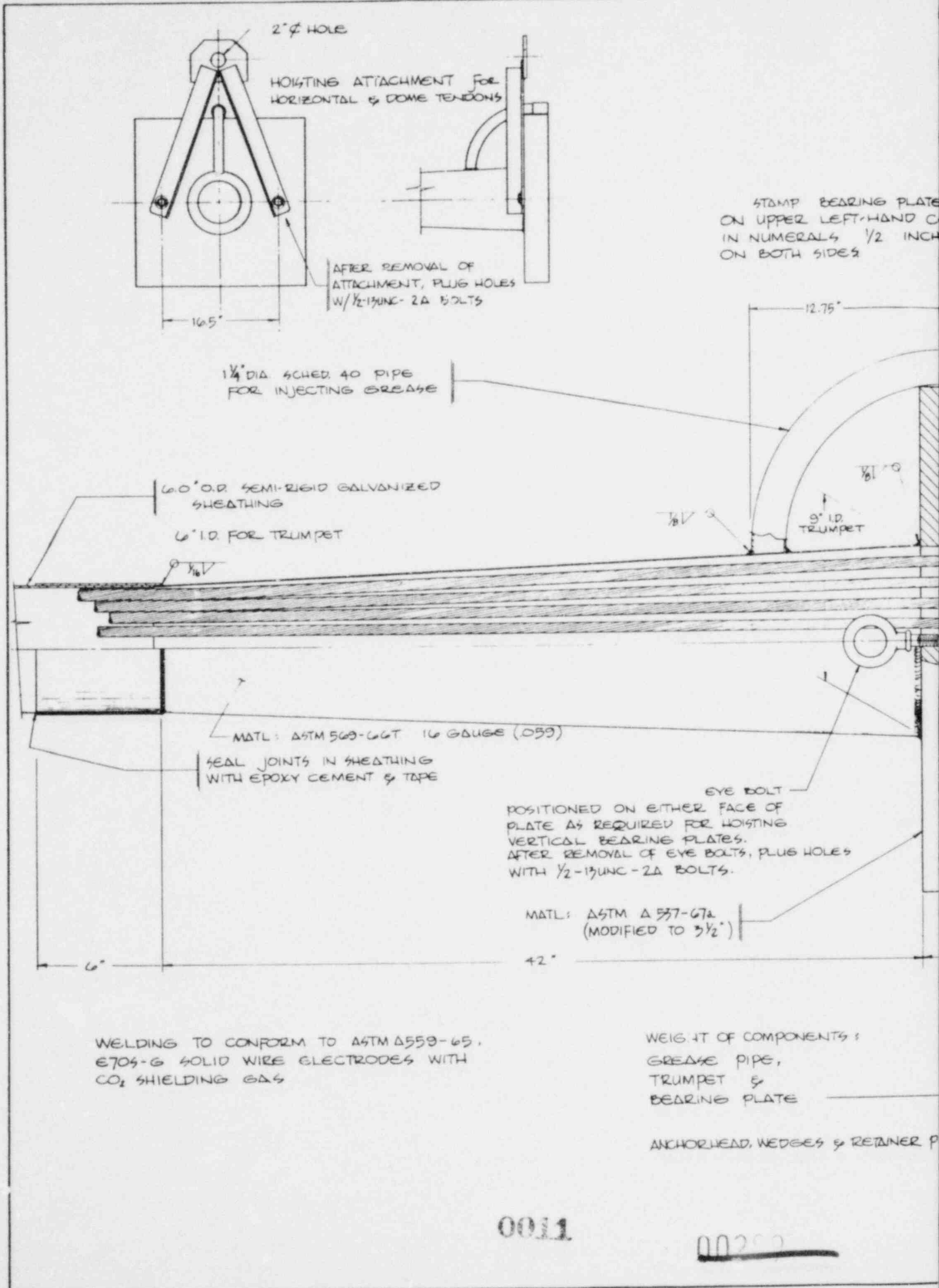
Inspector: ____________________ Installation Superintendent: ____________________

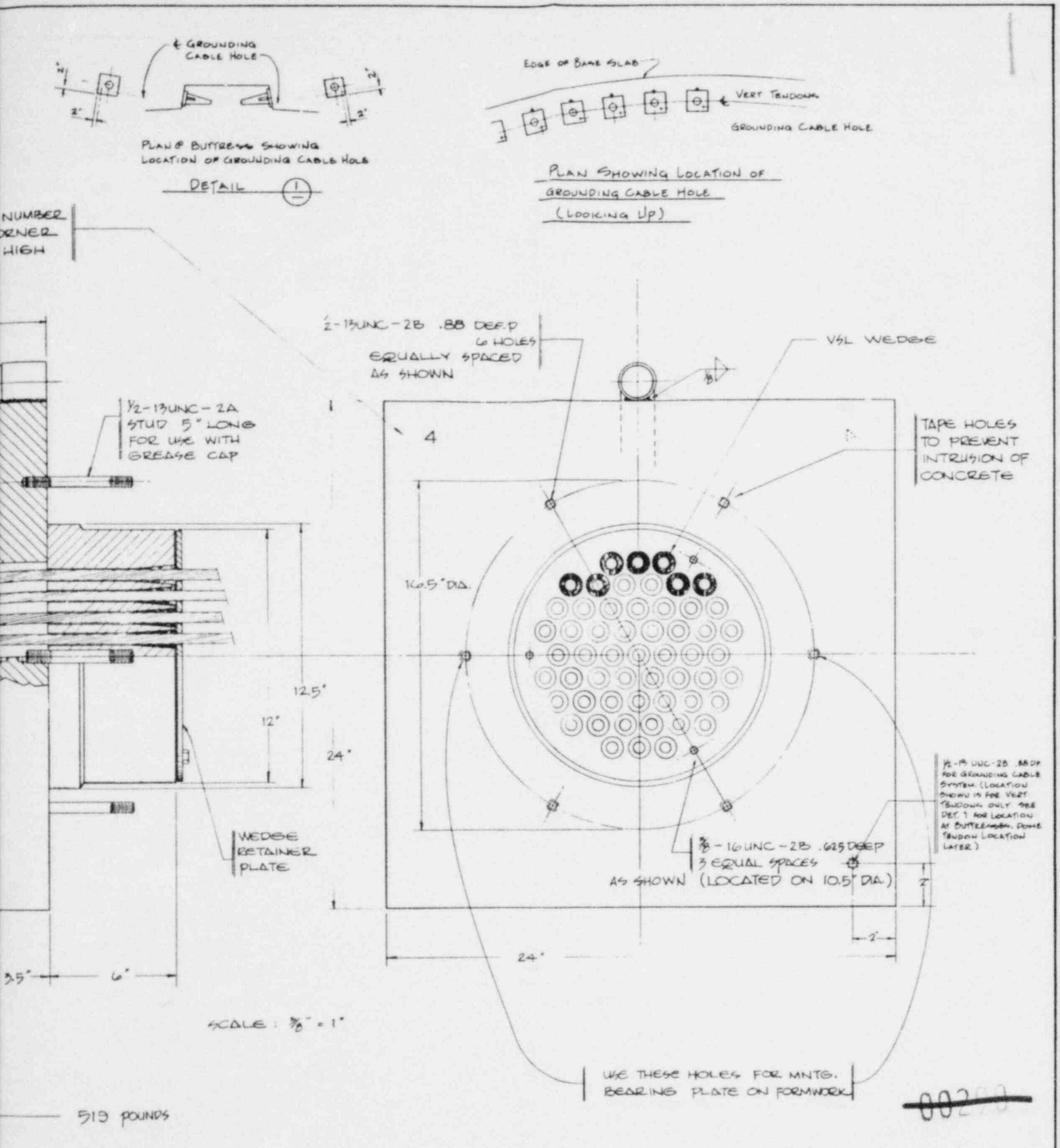
The Drawing No. 3M

has proprietary information deleted.

~~00200~~

0010


2" ⌀ HOLE
HOISTING ATTACHMENT FOR HORIZONTAL & DOME TENDONS
AFTER REMOVAL OF ATTACHMENT, PLUG HOLES W/ 1/2-13UNC-2A BOLTS
16.5"
STAMP BEARING PLATE
ON UPPER LEFT-HAND C
IN NUMERALS 1/2 INCH
ON BOTH SIDES
12.75"
1 1/4" DIA. SCHED. 40 PIPE FOR INJECTING GREASE
6.0" O.D. SEMI-RIGID GALVANIZED SHEATHING
6" I.D. FOR TRUMPET
9" I.D. TRUMPET
MATL: ASTM 569-66T 16 GAUGE (.059)
SEAL JOINTS IN SHEATHING WITH EPOXY CEMENT & TAPE
EYE BOLT
POSITIONED ON EITHER FACE OF PLATE AS REQUIRED FOR HOISTING VERTICAL BEARING PLATES.
AFTER REMOVAL OF EYE BOLTS, PLUG HOLES WITH 1/2-13UNC-2A BOLTS.
MATL: ASTM A 537-67a (MODIFIED TO 3 1/2")
6"
42"
WELDING TO CONFORM TO ASTM A559-65. E70S-G SOLID WIRE ELECTRODES WITH CO2 SHIELDING GAS
WEIGHT OF COMPONENTS:
GREASE PIPE,
TRUMPET &
BEARING PLATE
ANCHORHEAD, WEDGES & RETAINER P
0011



0012

ANCHORAGE ASSEMBLY – E5-55

P.O. NO. C12.05 | BECHTEL DWG. NO. 6292-C12.

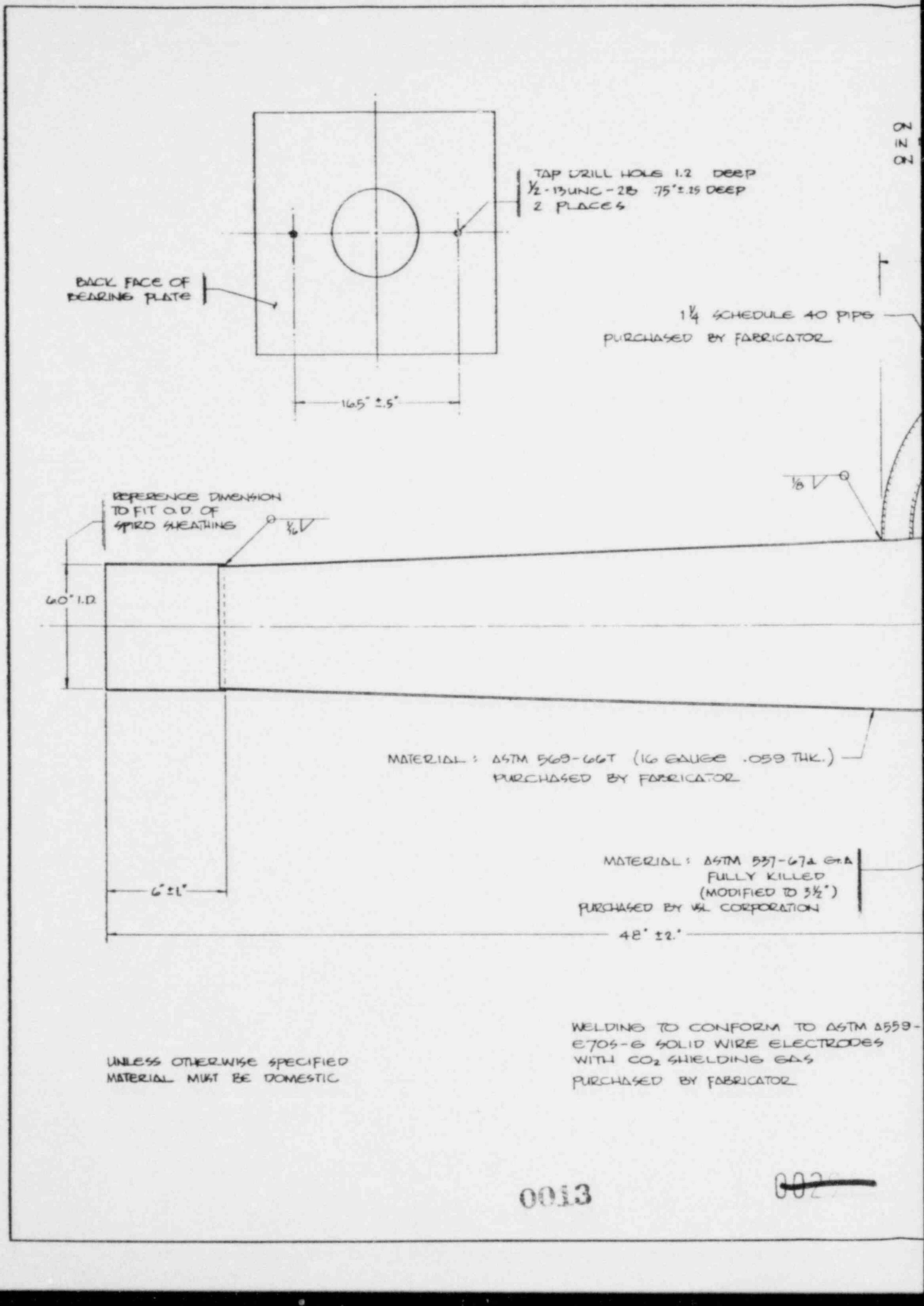
ENG.		
ENG.	WRE	6.18.68
DRN.	EGR	6.19.68
CHK.	DBD	6.19.68

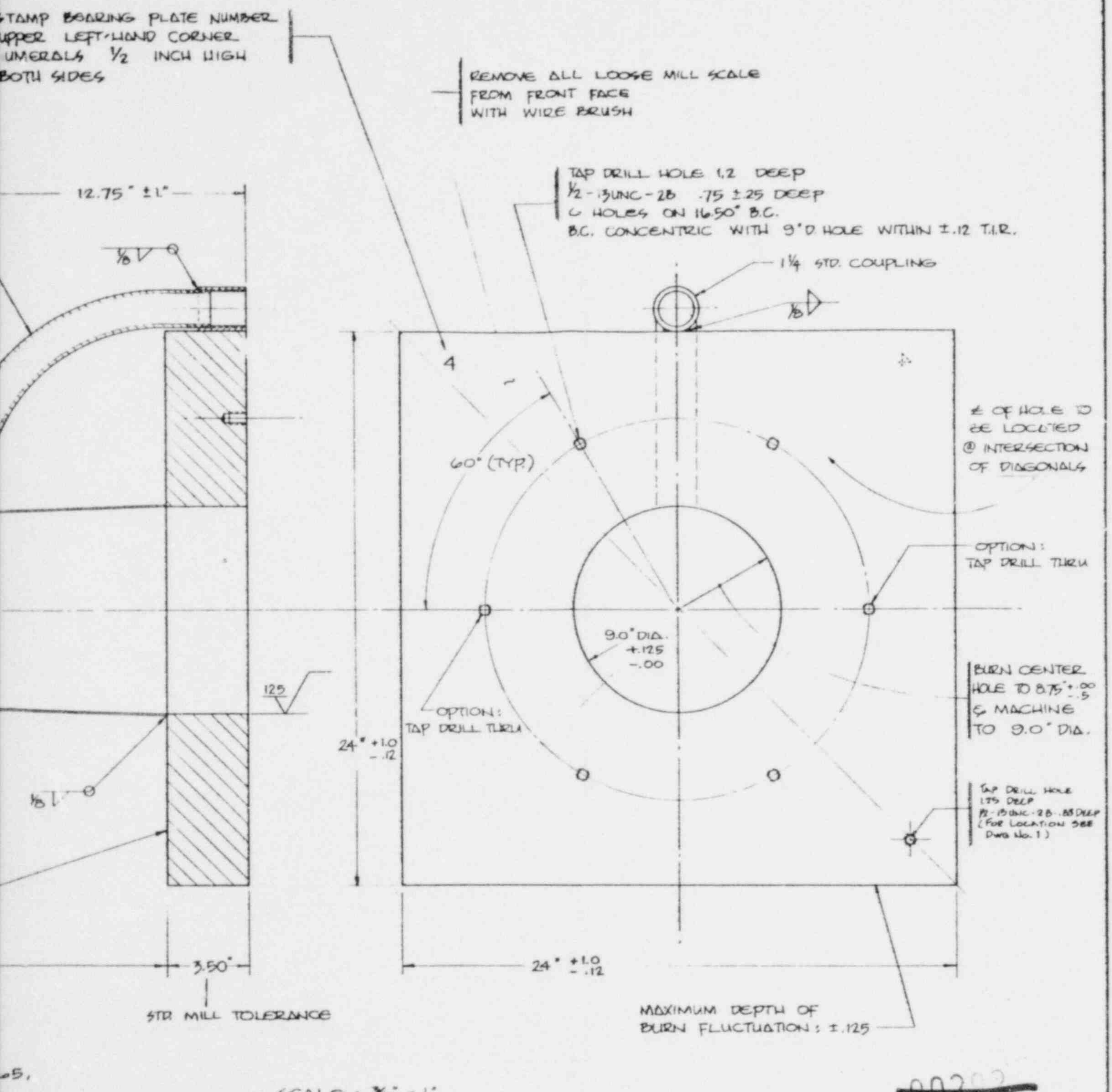
SACRAMENTO MUNICIPAL UTILITY DISTRICT
RANCHO SECO NUCLEAR STATION - UNIT 1

VSL CORPORATION
LOS GATOS, CALIFORNIA

DWG. NO. 1

DATE	REVISIONS	NO.
21 AUG 68	GROUNDING CABLE SYSTEM SHOWN	B
17 JUL 68	TRUMPET LENGTH INCREASED, NOTES ADDED	A


ON
IN
ON
TAP DRILL HOLE 1.2 DEEP
½-13UNC-2B .75"±.25 DEEP
2 PLACES
BACK FACE OF
BEARING PLATE
16.5" ±.5"
1¼ SCHEDULE 40 PIPE
PURCHASED BY FABRICATOR
⅛
REFERENCE DIMENSION
TO FIT O.D. OF
SPIRO SHEATHING
1/16
6.0" I.D.
MATERIAL: ASTM 569-66T (16 GAUGE .059 THK.)
PURCHASED BY FABRICATOR
MATERIAL: ASTM 537-67a Gr.A
FULLY KILLED
(MODIFIED TO 3½")
PURCHASED BY VSL CORPORATION
6"±1"
48" ±2."
WELDING TO CONFORM TO ASTM A559-
E70S-6 SOLID WIRE ELECTRODES
WITH CO2 SHIELDING GAS
PURCHASED BY FABRICATOR
UNLESS OTHERWISE SPECIFIED
MATERIAL MUST BE DOMESTIC
0013



SCALE: 3/8" = 1"

0014

~~002~~

21 AUG 69	GROUNDING CABLE HOLE ADDED	B
25 JUL 68	ALTERATION OF TOLERANCES	A
DATE	REVISIONS	NO

TOLERANCES UNLESS SPECIFIED:
.X .12
.XX .06
.XXX .031
ANGLES 1/2°

BEARING PLATE/TRUMPET WELD ASSY.

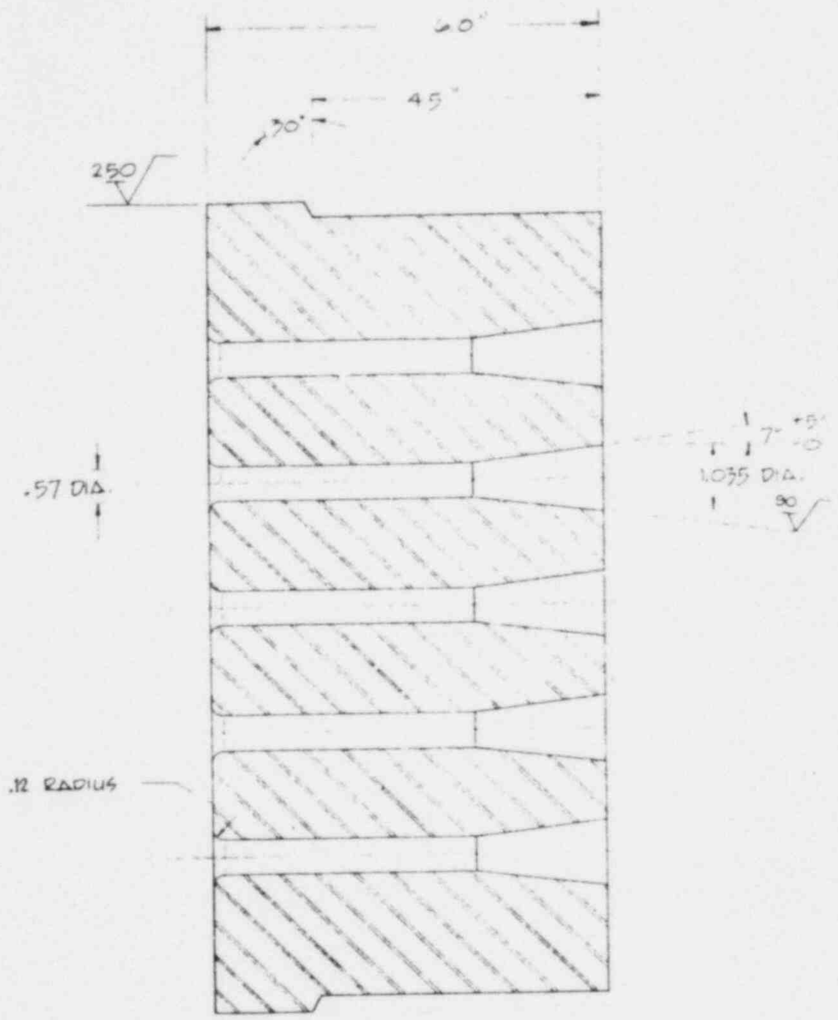
P.O. NO. C12.05 BECHTEL DWG. NO. 6292-C12.05-

ENG walt 7-69
DRN ech 7-69
CHK WBP 7-69

SACRAMENTO MUNICIPAL UTILITY DISTRICT
RANCHO SECO NUCLEAR STATION - UNIT NO. 1

VSL CORPORATION
LOS GATOS, CALIFORNIA

DWG. NO. 1M



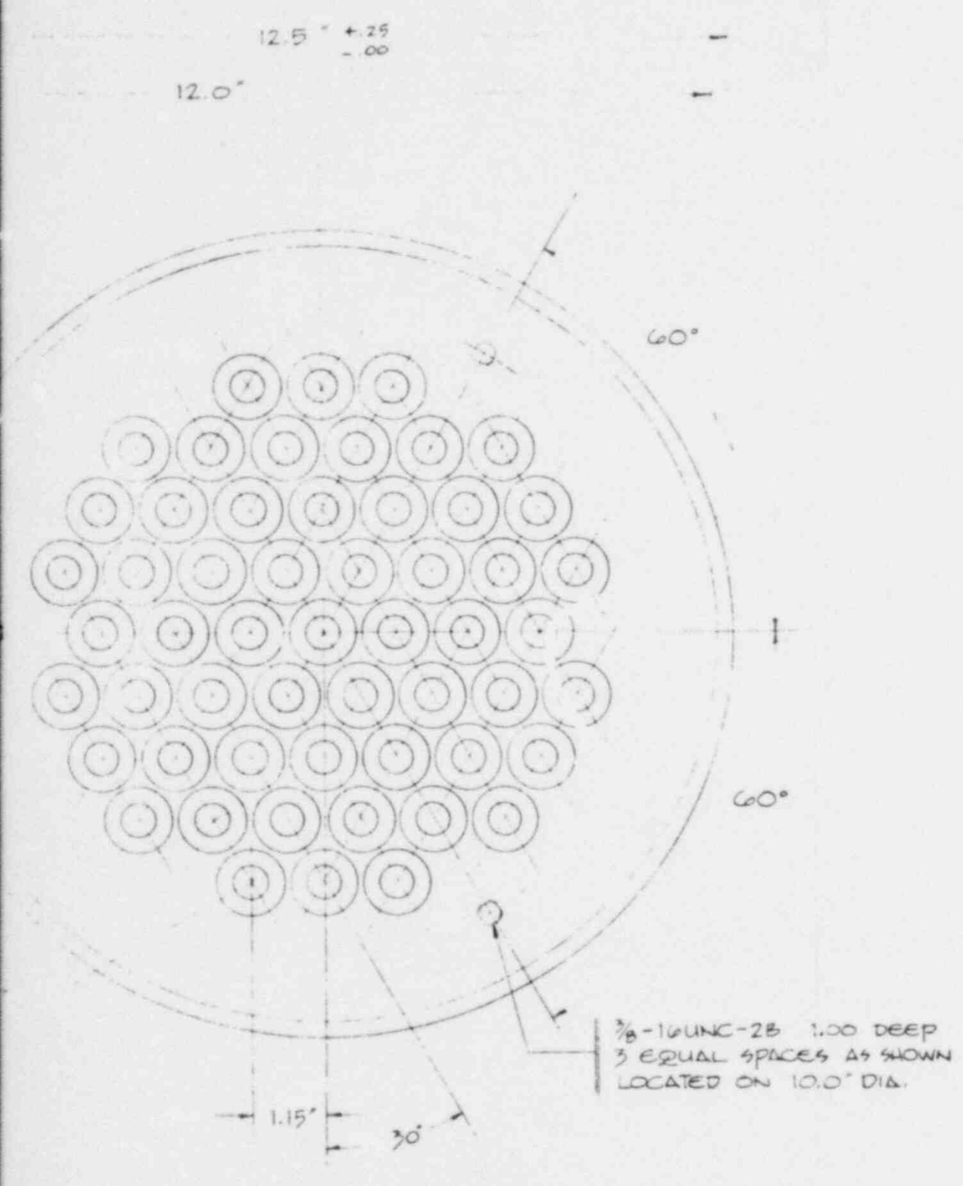
ANCHORHEAD

ALL FINISHED SURFACES TO BE 125 UNLESS OTHERWISE SPECIFIED

BREAK ALL CORNERS

MATERIAL: AISI 1026 OR 10L26 FORGED PER VSL CORPO

UNLESS OTHERWISE SPECIFIED MATERIAL MUST BE DOMESTIC



RATION SPECIFICATION

~~002~~

0016

ANCHORHEAD E5-55

SCALE: 3/4" = 1'

P.O. No C12.05 | BECHTEL DWG. NO. 6292-C12.

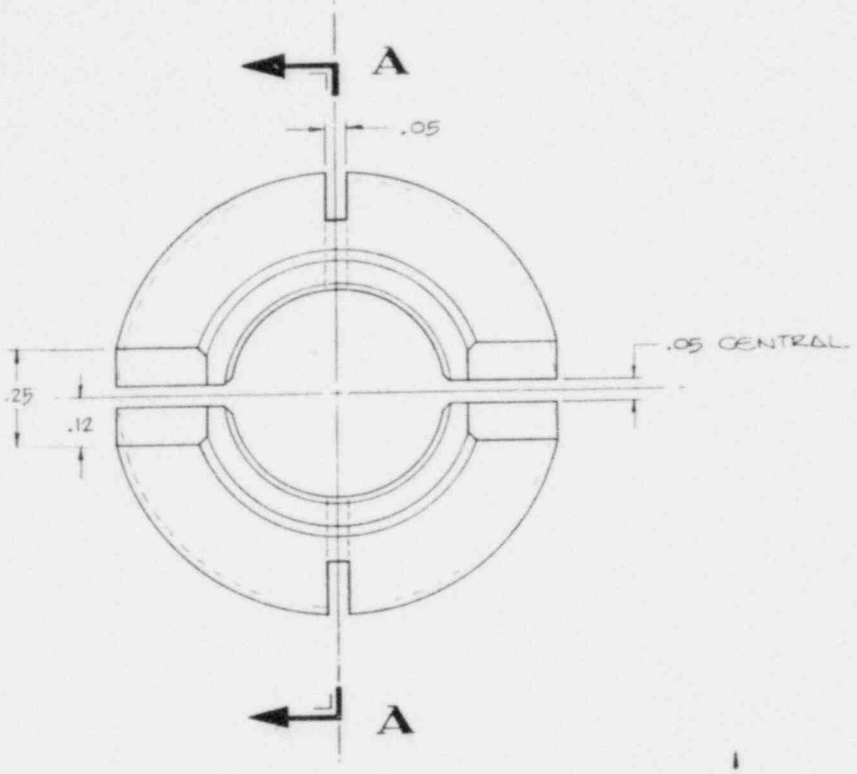
TOLERANCES UNLESS SPECIFIED
.X .030
.XX .010
.XXX .005
ANGLES 1/2°

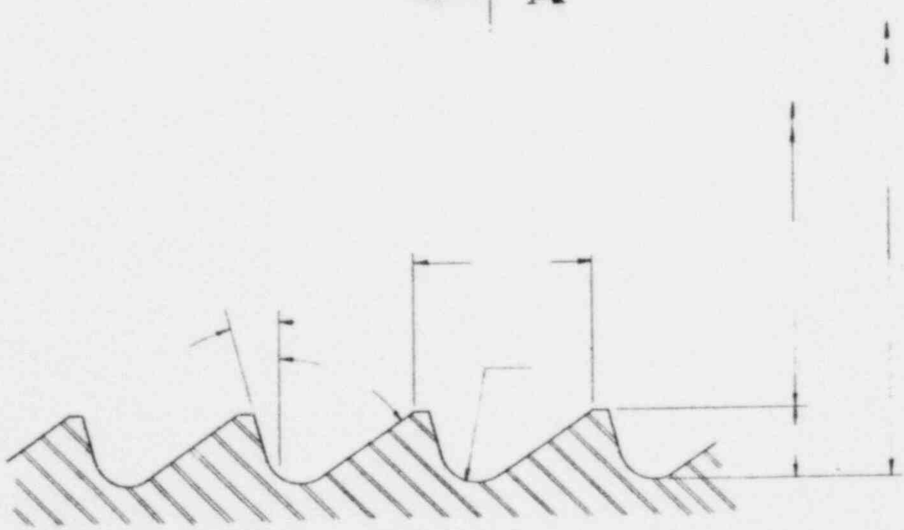
ENG.	RF	7.15.69
DRN.	ECH	7.16.69
CHK.	RENE	7.28.69

SACRAMENTO MUNICIPAL UTILITY DISTRICT
RANCHO SECO NUCLEAR STATION - UNIT No 1

VSL CORPORATION
LOS GATOS, CALIFORNIA

DWG. NO. 2M





THREAD DETAIL

SCALE 50:1

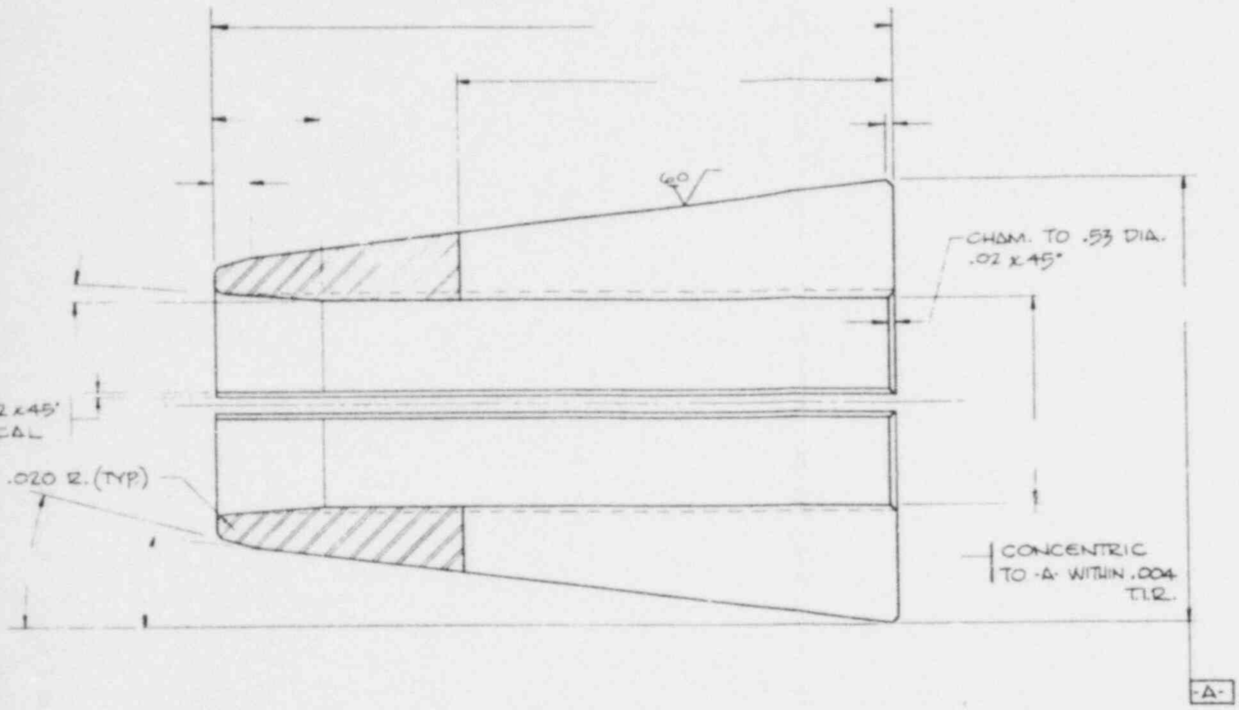
NOTE: TWO IMPERFECT THREADS PERMITTED BEYOND 0.25 FEATHER AREA

ALL
TO B
UNLES

UNLESS OTHERWIS
MATERIAL MUST BE

~~00295~~

0017



SECTION **A-A**

MATERIAL: AISI 86L20 PER VSL CORPORATION SPECIFICATION
HEAT TREATMENT:

BLACK OXIDE FINISH

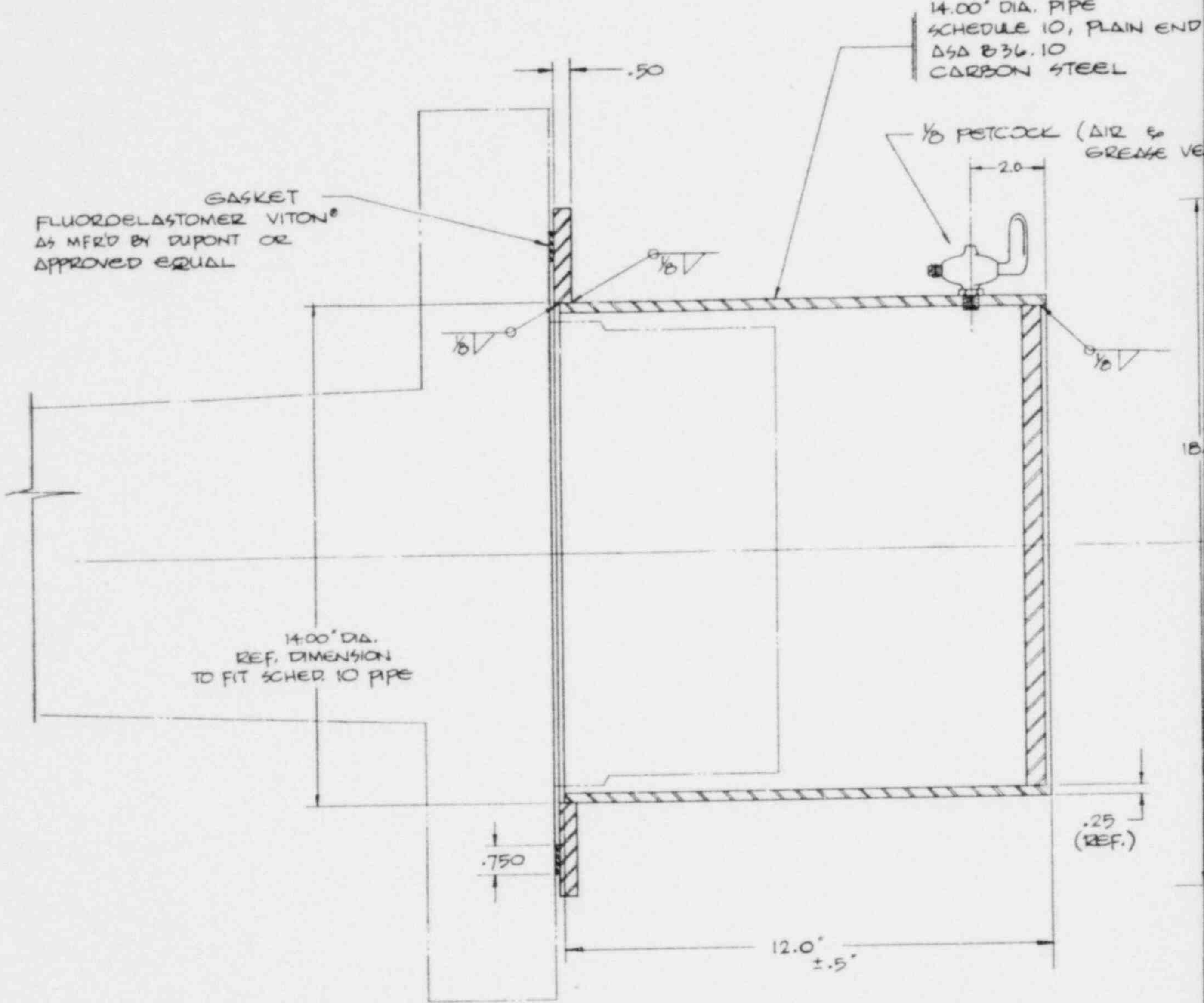
FINISHED SURFACES
125
UNLESS OTHERWISE SPECIFIED

E SPECIFIED
DOMESTIC

0018

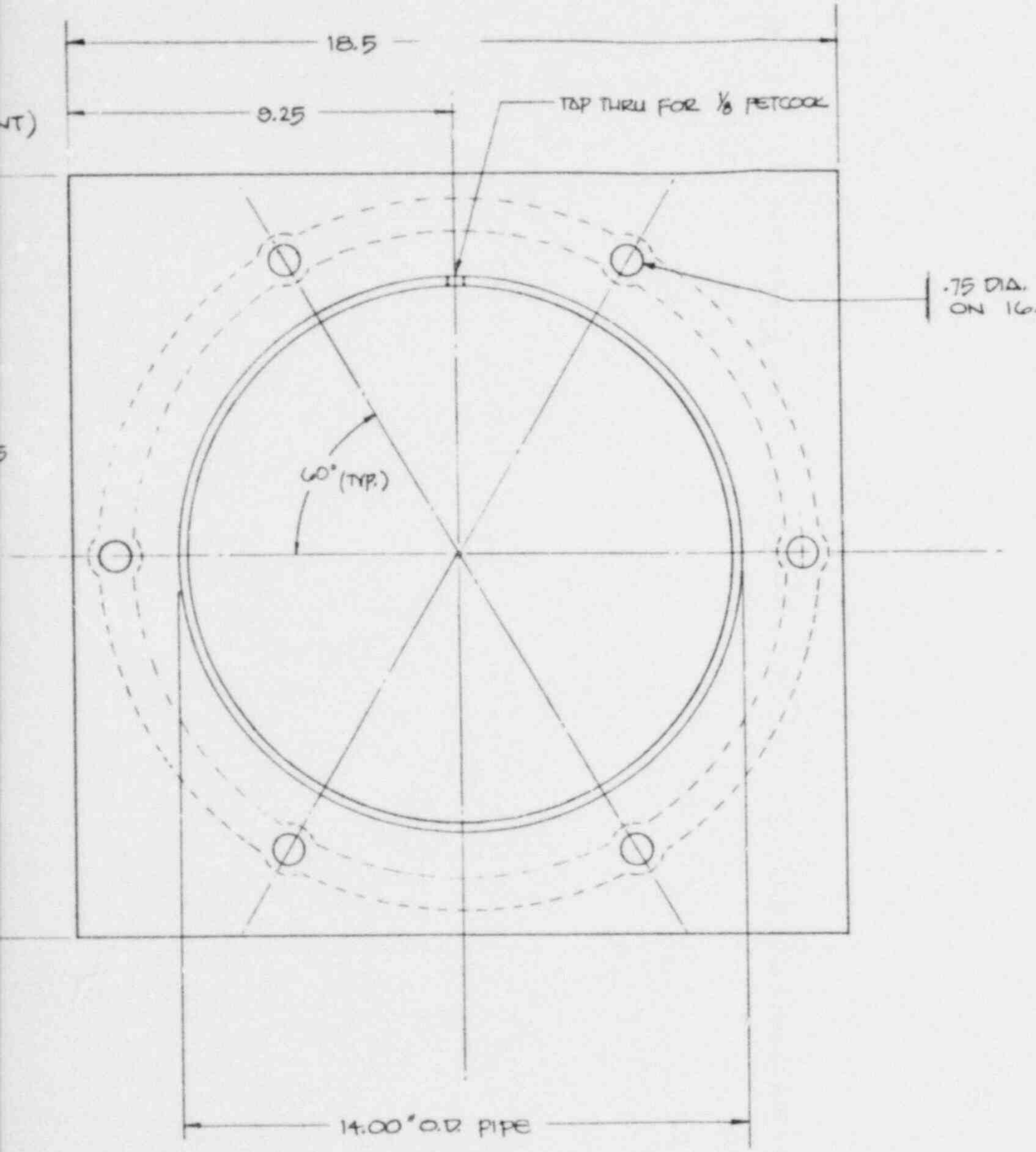
~~002~~

	1/2" VSL WEDGE	
SCALE: 5:1 & NOTED	P.O. Nº C12.05	BECHTEL DWG. NO. 6292-C12.
TOLERANCES UNLESS SPECIFIED .X .030 .XX .010 .XXX .005 ANGLES ½°	ENG. RF 7.17.69 DRN. ECH 7.21.69 CHK. RF 7.22.69	SACRAMENTO MUNICIPAL UTILITY DISTRICT RANCHO SECO NUCLEAR STATION UNIT 1
	VSL CORPORATION LOS GATOS, CALIFORNIA	DWG. NO. 3M



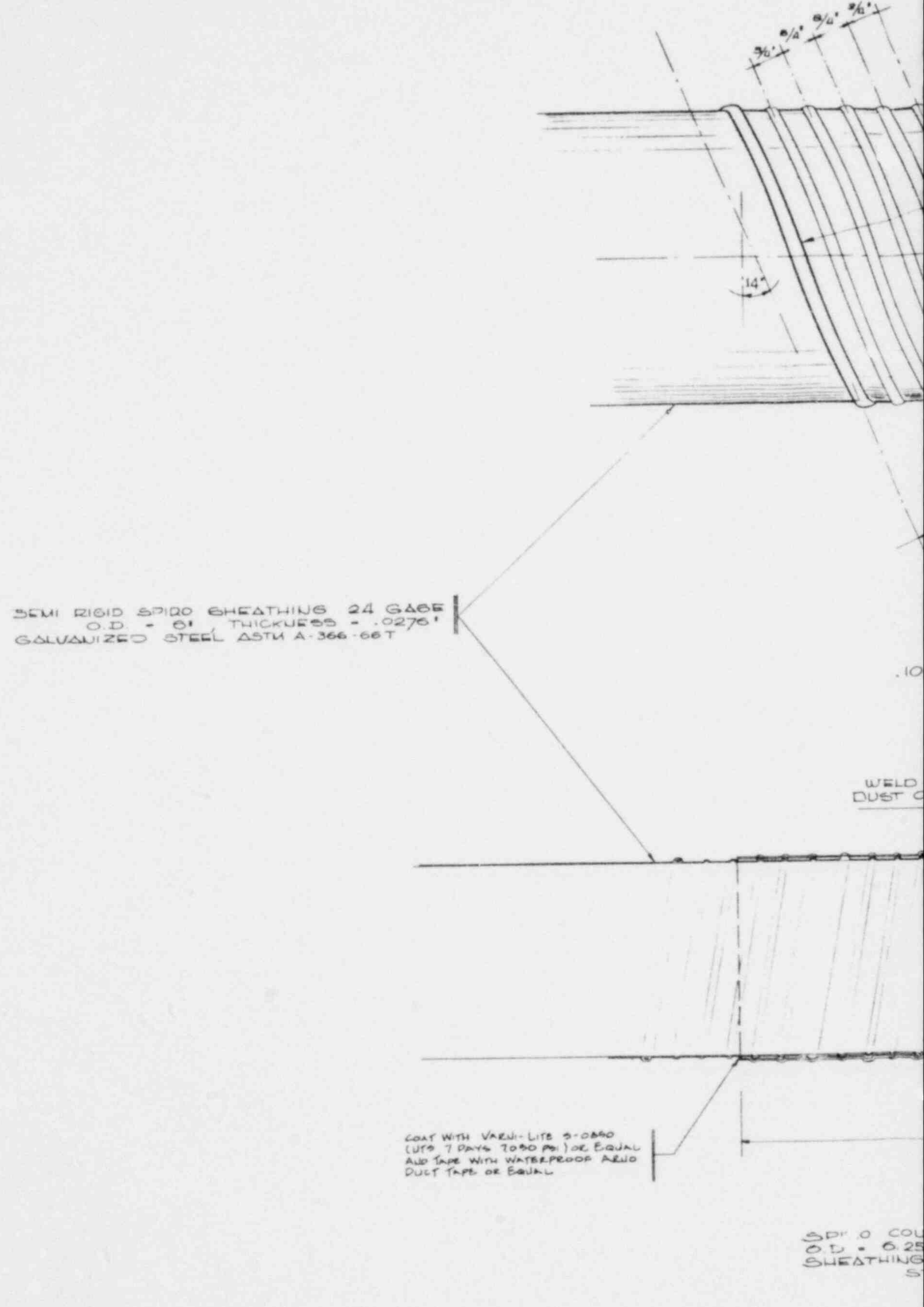
UNLESS OTHERWISE SPECIFIED
MATERIAL MUST BE DOMESTIC

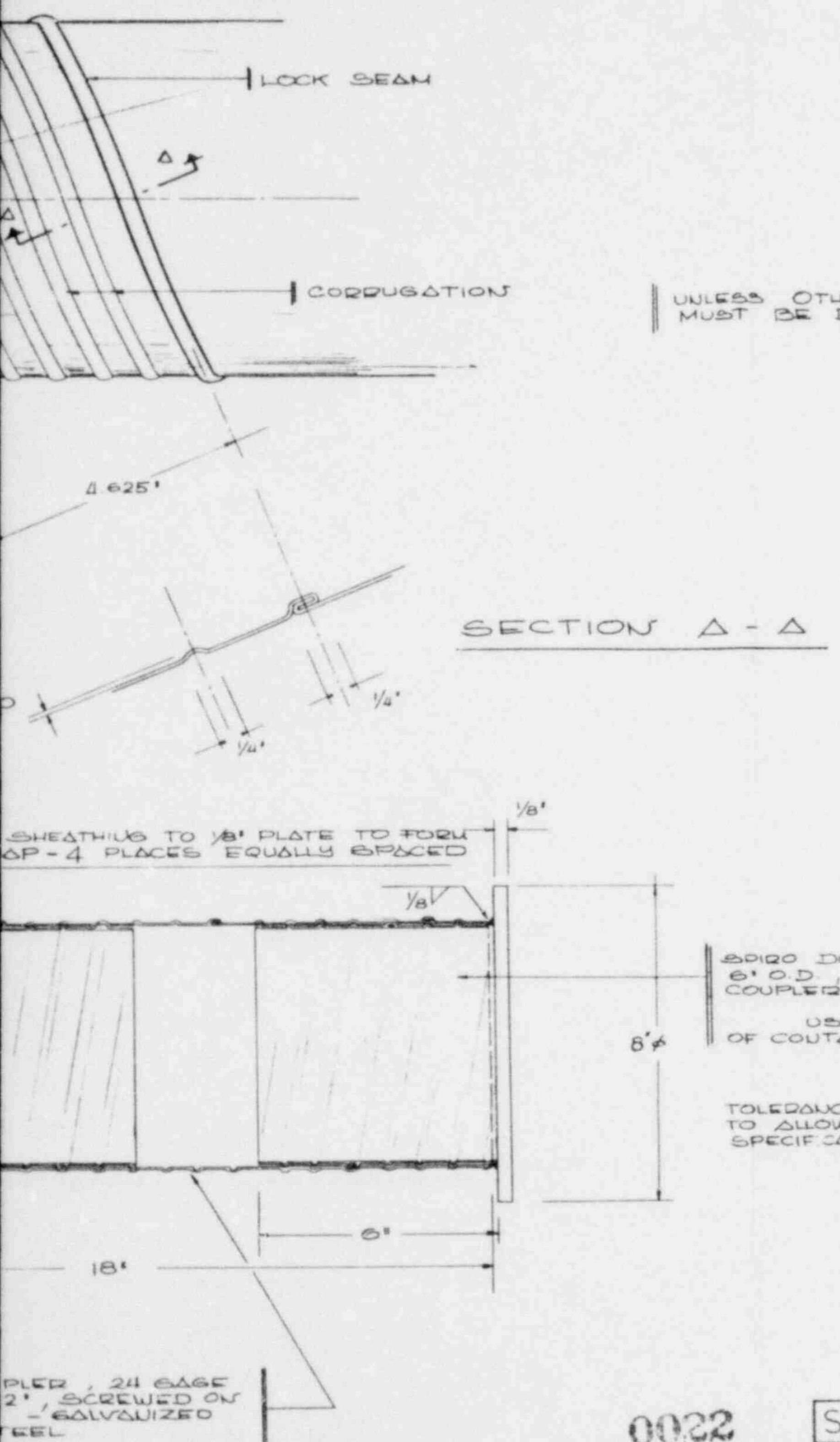
00207



0020

	GREASE CAP			
SCALE: 1/2" = 1"	P.O. Nº C12.05	BECHTEL DWG. NO. 6292-C12.		
TOLERANCES UNLESS SPECIFIED .X .25 .XX .12 .XXX .062 ANGLES 1/2°	ENG. RERE 7.28.69 DRN. ECA 7.28.69 CHK. RF 7.28.69	SACRAMENTO MUNICIPAL UTILITY DISTRICT RANCHO SECO NUCLEAR STATION · UNIT Nº 1		
	VSL CORPORATION LOS GATOS, CALIFORNIA	DWG. NO. 4M		


3/4"
14°
SEMI RIGID SPIRO SHEATHING 24 GAGE
O.D. - 6", THICKNESS - .0276"
GALVANIZED STEEL ASTM A-366-66T
WELD
COAT WITH VARNI-LITE 5-0860
(UTS 7 DAYS 7030 PSI) OR EQUAL
AND TAPE WITH WATERPROOF ARNO
DUCT TAPE OR EQUAL
O.D. - 6.25



SECTION A - A

UNLESS OTHERWISE SPECIFIED MATERIAL MUST BE DOMESTIC

TOLERANCES TO MANUFACTURER'S STANDARDS TO ALLOW CONFORMANCE TO VSL CORPORATION'S SPECIFICATIONS

00300

0022

21 Aug 69	NOTE FOR TAPED JOINTS	A
DATE	REVISIONS	NO

SHEATHING, COUPLER, DUST CAP

ENG	HB	7.22.9	SACRAMENTO MUNICIPAL UTILITY DISTRICT
DRW	HB	7.22.69	RANCHO SECO NUCL. STAT. - UNIT 1
CHK	WBD	7.22.69	

VSL CORPORATION
LOS GATOS CALIFORNIA

DRWG. NO 5M

BEARING PLATE STEELS FOR

RANCHO SECO

~~00301~~

BETHLEHEM STE[illegible] [illegible]ORPORATION

METALLURGICAL [illegible]RTMENT

JUL 14 1969

[illegible]671 (Rev 3 1-65)

DATE SHIPPED	SHIPMENT NO.	CARRIER, INITIAL AND NO.	PLANT
7/11/69	160-7682	Truck	Sparrows Point

V. S. L. Corporation

SHIPPED TO San Jose, California

REPORT OF PHYSICAL AND CHEMICAL TESTS

Gr. A. Pressure Vessel Plates

Customer's Order No.	Section Slab or Mill Order No.	Heat No.	Description	Thickness	Yield Point	Tensile Strength	Elong. % 2"	Red. %	Bends	C	Mn	P	S		Specifications or Remarks
0	Y111875	411Y2161	1-146 x 24	3-½	46000	71500	30.0		OK						ASTM A537
	Y111876	"	3- "	"	46000	71000	29.0		"						GR. A Pressu
	Y111877	"	2- "	"	45000	73000	36.0		OK						Vessel
	Y111878	"	2- "	"	46000	70500	36.0		"						Quality
	Y111879	"	2- "	"	45000	70500	31.0		OK						Mod. Y.P.
	Y111880	401Y9311	1-74 x 24	"	51000	77500	30.0		"						45 Min. Norm

	C	Mn	P	S	Si	Cu	Cr	Ni	Mo
411Y2161	.16	1.22	.012	.019	.26	.15	.15	.20	.050
401Y9311	.19	1.29	.009	.031	.25	.12	.15	.19	.057

Long. & Tran Charpy V Notch Impact of 15ft./lbs at minus 20° & NDT No Break at minus 12°F.

McQuaid Ehn Grain Size

411Y2161	7-8
401Y9311	7-8

Plates and test pieces normalized at 1650°F.

00302

0024

30-2450

08/2450

SUBSCRIBED AND SWORN TO BEFORE ME THIS 18 DAY OF July, 1969

[signature]

NOTARY PUBLIC

Continued on Sheet #2

BETHLEHEM ST[illegible] CORPORATION
METALLURGIC[illegible] DEPARTMENT

JUL 1969

20671 (Rev. 1-65)

DATE SHIPPED	SHIPMENT NO.	CARRIER, INITIAL AND NO.	PLANT
7/11/69	160-7682	Truck	Sparrows Point

SOLD TO: V. S. L. Corporation

SHIPPED TO: San Jose, California.

REPORT OF PHYSICAL AND CHEMICAL TESTS

GR. A Pressure Vessel Plates

Customer's Order No.	Section Slab or Mill Order No.	Heat No.	Description	Thickness	Yield Point	Tensile Strength	Elong. %	Red. %	Bends	C	Mn	P	S		Specifications or Remarks

Sheet #2

Longitudinal & Transverse Charpy V Notch Impact Tests to Meet 15 ft./lb. at minus 20°F.

Heat No.	Description		#1	#2	#3	Avg.	Test Size
411Y2161	Y111875	L	105	118	100	107-2/3	10 x 10 MM.
		T	50	52	56	52-2/3	
	Y111876	L	123	126	100	116-1/3	
		T	58	57	58	57-2/3	
	Y111877	L	129	120	110	119-2/3	
		T	60	57	60	59.0	
	Y111878	L	120	136	122	126.0	
		T	57	61	59	59.0	
	Y111879	L	105	121	122	116.0	
		T	56	45	52	51.0	
401Y9311	Y111880	L	65	63	62	63-1/3	
		T	28	30	27	28-1/3	

Nil Ductility Tests

Heat No.	Description	Thickness	Result
411Y2161	Y111875	3-½	Test Shows No Break at minus 12°F.
"	Y111876	"	" "
"	Y111877	"	" "
	Y111878	"	" "
	Y111879	"	" "
401Y9311	Y111880	"	" "

SUBSCRIBED AND SWORN TO BEFORE ME THIS 18 DAY OF July, 1969

[signature]

NOTARY PUBLIC

ANCHOR HEAD STEELS FOR

RANCHO SECO

~~00304~~

LOS ANGELES
DELIVERY ORDER
TEST REPORT

INVOICE NO
20776 FL

EARLE M. JORGENSEN CO.
STEEL
FORGE DIVISION

LOS ANGELES, CALIFORNIA 90054

(3)

INVOICE NO
S 8-69
MZ

20776 FL

CUSTOMER ORDER-REQ NO | DATE ENTERED 7-15-69 | ENT'D BY B | ORDERED BY

SOLD TO
EARLE M JORGENSEN CO
FORGE DIVISION
LOS ANGELES, CALIFORNIA

SHIP TO

CERTIFIED TEST REPORT

We certify that the material covered by this report has been inspected and tested in accordance with the applicable requirements described herein and test results are on file subject to examination.

By Pamela Lee

SHIP VIA: OUR TRUCK WILL CALL XX | CARRIER | F.O.B. XX

AS

QUANTITY AND DESCRIPTION	WEIGHT	HEAT NO
C-1026 FORGED OVERSIZE TO ALLOW FOR FINISH NORMALIZE SAW CUT ENDS ORANGE WITH BLUE STRIPE 89105		
1 PC - 12-1/2 RND X 6"	225#	A1-216981
MECHANICAL TESTING REQUIRED TEST FOR THE FOLLOWING MECHANICAL PROPERTIES TENSILE TEST FOR 50,000 YIELD WITH 15 FT LB CHARPY V-NOTCH @ MINUS 30 DEGREES F		
WORK ORDER		

2200

SUBSCRIBED AND SWORN TO BEFORE ME THIS 23 day of AUGUST 1969

R. Harold Elston
R. HAROLD ELSTON NOTARY
My Commission Expires ...

OFFICIAL SEAL
R. HAROLD ELSTON
LOS ANGELES COUNTY

HEAT NO | YIELD POINT | TENSILE | ELONG. % IN INCHES | R. OF A.

HARDENABILITY ROCKWELL C

C	MN	P	S	SI	NI	CR	MO	G.S.	MILL	HEAT NO
.25	.83	.010	.010	.21				7/8	SHARON	216981

1	4	5	8	10	16	20	32

FORM 90-F

EARLE M. JORGENSEN CO.

STEEL

FORGE DIVISION

10650 S. ALAMEDA ST. • BOX 2358 TERMINAL ANNEX • PHONE 567-1122 (AREA 213)

LOS ANGELES, CALIFORNIA 90054

CERTIFIED TEST REPORT

Date 8-20-69

Cust. Order No. -

Our Invoice No. 20776 FL

Laboratory No.

Material 1026

Specifications

EARLE M JORGENSEN CO

ITEM: 1 PC 12-1/2" RD X 6"

MECHANICAL PROPERTIES

HEAT NO	LOCATION OF TEST	YIELD 2% OFFSET PSI	ULTIMATE PSI	ELONG %	RED. OF AREA %	HARDNESS	IMPACT *	BEN
A1-216981	L	55500	83700	30	67.7		60 58 56	
REQUIREMENTS -		50000					15	

Remarks: *CHARPY V NOTCH @ MINUS 30 DEG F

MATERIAL WATER QUENCHED AND TEMPERED

WITNESSED BY

SUBSCRIBED AND SWORN TO BEFORE ME

THIS ______ DAY OF ______ 19 __

______ NOTARY PUBLIC

STATE OF CALIFORNIA, LOS ANGELES COUNTY

MY COMMISSION EXPIRES ______

We certify that the material covered by this report has been inspected and tested in accordance with the applicable requirements described herein and test results are on file subject to examination.

EARLE M. JORGENSEN CO.

BY Ron Beattie

~~00306~~

0028

WEDGE STEEL

FOR RANCHO SECO

~~00307~~

0029

BETHLEHEM STEEL

BETHLEHEM STEEL

November 14, 1968

FILE REF.

FROM E. A. Reid, Chief Metallurgist

TO Joseph Field, Metallurgical Engineer

SUBJECT VSL Corporation - Los Getas, California
Request for Low Temperature Impact Properties

Bethlehem Steel Corp.
NOV 15 1968
OFFICE OF
Metallurgical Engineers

Reference: Wire from San Francisco Sales Office dated 9/30/68.

The reference wire stated that VSL Corporation is currently purchasing alloy bars from Columbia Steel & Shafting Co., Western Division, Union City, California who in turn places alloy bar business with Bethlehem. The material purchased is 8620 leaded 1-1/8"Ø x 31/34'. The material is reportedly cold drawn for automatic screw machining, after which the material is case hardened for use as wedges for a post tension anchorage system.

VSL has requested our recommendation for a grade of steel that will meet 15 ft.-lbs. min. Charpy V-Notch impact strength at 0, -25, -30 and -50°F. The wire states that VSL is bidding on nuclear reactor jobs and the AEC has requested that the material must meet 15 ft.-lbs. min. at these test temperatures. The wire further states that the material must be covered by an ASTM specification. VSL is presently using 8620 leaded steel for post tensioning on California bridges and buildings, but they have not been required to guarantee the aforementioned impact test. We assume that the impact test requirement must be met in the core.

Since the material will be case hardened, we assume that the wedges will be carburized or carbonitrided, oil quenched and tempered at approximately 450/500°F. The following longitudinal (mid-radius) impact test data were on file on three carburizing grades, 4320, 8620 and 4620:

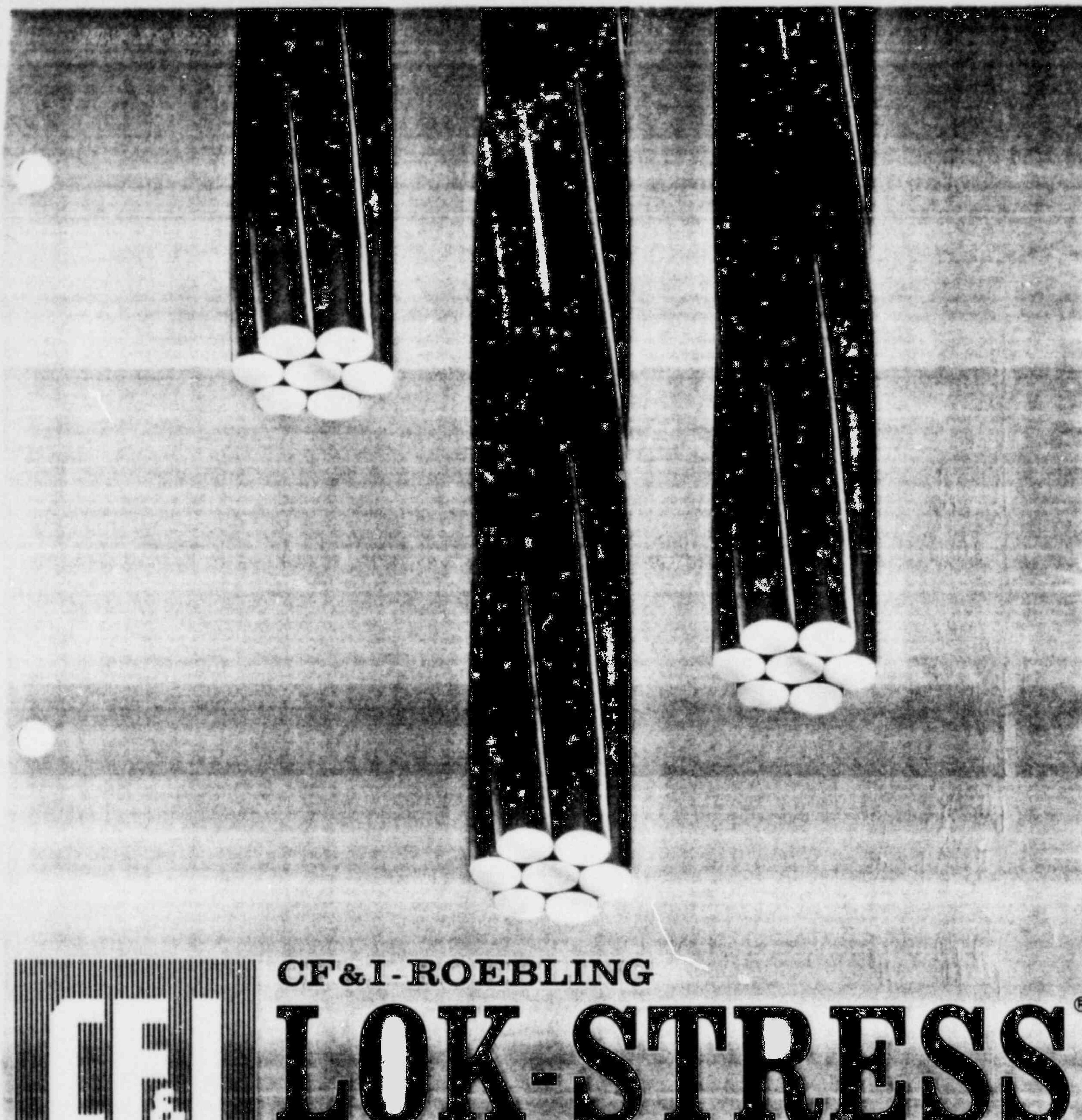
Grade	Size of Barstock Treated	Oil Quench	Temper		Charpy V-Notch Impact @ -65°F	BHN
4320	2-1/2"Ø	1550°F	550°F		18.2 ft.-lbs.	
					29.2 ft.-lbs.	241
					15.6 ft.-lbs.	
				Avg.	21.0 ft.-lbs.	
8620	2-1/4"Ø	1575°F	550°F		12.0 ft.-lbs.	
					14.4 ft.-lbs.	229
					16.9 ft.-lbs.	
				Avg.	14.4 ft.-lbs.	
4620	2-1/4"Ø	1550°F	550°F		35.5 ft.-lbs.	
					32.4 ft.-lbs.	229
					40.5 ft.-lbs.	
				Avg.	36.1 ft.-lbs.	

STRAND FOR

RANCHO SECO

~~00509~~

0031



CF&I STEEL

CF&I-ROEBLING

LOK-STRESS® STRAND

FOR PRESTRESSED CONCRETE TENDONS

~~00310~~

0032

CF&I STEEL

LOK-STRESS STRAND

LOK-STRESS Strand is made by a patented process in which the strand is heated to a stress-relieving temperature and simultaneously subjected to a tensile force sufficient to produce approximately 1% permanent elongation. The molecular structure of strands subjected to this process is locked in position resulting in low stress losses due to relaxation of the strand. Materials and fabrication are identical to those used for stress-relieved strand up to the final operation which combines stress-relieving with the stretching operation that produces the superior qualities.

PHYSICAL PROPERTIES

The physical properties of LOK-STRESS Strand are shown in Table #1. Note that the minimum yield strength is 90% of catalog ultimate as compared to 85% for stress-relieved strand. (See Figure 1)

LOK-STRESS Strand meets all requirements of Standard Specifications for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete ASTM Designation A-416 (Latest Revision).

DESIGN CRITERIA PRETENSIONED BONDED MEMBERS

Its stabilized structure and high yield strength make it possible for LOK-STRESS Strand to sustain high stresses with negligible relaxation loss. These properties permit the use of LOK-STRESS Strand at initial tensions in excess of 70% of catalog ultimate strength.

Since there is not a corresponding increase in efficiency of the strand in temporary gripping devices, care should be exercised to insure adequate safety factor at loads in excess of 70% of catalog ultimate.

A final effective prestressing force in excess of 60% of the guaranteed ultimate strength is also entirely feasible with this material. Since existing codes specify a final stress of 60% of ultimate, the design procedures suggested herein are worked to that value.

Table No. 2 shows stress loss calculations for a typical pretensioned member of normal weight concrete. In preparing this table it was assumed that E_s, modulus of elasticity of the strand, was 28,000,000; that the compressive stress in the concrete at the center of gravity of the strand group was 1,500 psi and that this produced a shortening of the concrete that resulted in a stress loss of 11,000 psi due to elastic shortening and 18,000 psi due to creep and shrinkage of concrete. Working backward from a final force of 60% of ultimate, using the foregoing assumptions for losses due to concrete shortening and a total relaxation of 2% in the LOK-STRESS Strand we find that the initial tension required is 72.25% of ultimate as shown in Table No. 2. For a different intensity of stress in the concrete or other conditions which change the stress loss due to shortening of

CF&I STEEL

concrete, the initial stress required to provide a final of 60% of ultimate can be computed in the same manner using the applicable values. In the stress ranges involved, the difference in relaxation of LOK-STRESS Strand between one stress and another is negligible and its total is always less than 2%. See Figures 2 and 3.

Table No. 3 shows computations for stress in the LOK-STRESS Strand immediately after the prestressing force has been transferred from the casting bed anchors to the prestressed concrete member. This table assumes an initial tension of 72.25% of ultimate and a loss of 11,000 psi due to elastic compression of concrete. Other values can be used where applicable. For each size of strand the net tension after transfer is approximately 67.5% of ultimate. ACI 318-63 and AASHO-1965 permit 70%.

DESIGN CRITERIA POST-TENSIONED MEMBERS

Figure 3 shows losses due to relaxation when LOK-STRESS Strand is anchored at 70% of its ultimate strength and held at constant length. It is conservative to use the values from Figure 3 in computing total losses because, in an actual concrete structure, there would be a decrease in stress due to creep and shrinkage with a corresponding, though small, decrease in relaxation.

ULTIMATE MOMENT CAPACITY

The ultimate moment capacity of most members prestressed with LOK-STRESS Strand is greater than that of identical members prestressed with stress-relieved strands of the same ultimate strength. This increase in ultimate moment capacity is due to the higher yield strength of LOK-STRESS Strand. The following procedure can be used in computing ultimate moment capacity of members using LOK-STRESS Strand:

1. Compute fsu for stress-relieved strand using the formulas given in AASHO or ACI 318-63.
2. Read R from the curve on Figure 4. For values of p less than 0.0010, the increase in ultimate moment using LOK-STRESS Strand is negligible.
3. Multiply the value of f_{su} computed in Step 1 by the value of R determined in Step 2 to get the value of fsu for LOK-STRESS Strand.
4. Use the value of f_{su} determined in Step 3 in the AASHO or ACI 318-63 formulas to compute ultimate moment capacity of the member.

(The curve on Figure 4 was developed from the same equations that were used to develop the ultimate moment equations in AASHO and ACI 318-63. Calculation sheets showing the derivation are available on request.)

CF&I — Roebling Relaxation Tests on 7-Wire Prestressed Concrete Strand

Strand Loaded to 70% of Catalog Ultimate Strength

After 18 hours stress reduced 20,000 p.s.i. below initial stress to allow for elastic compression in the concrete at release plus some allowance for creep and shrinkage during the life of the structure.

Average Temperature = 85° F

Dots represent actual readings from test specimen.

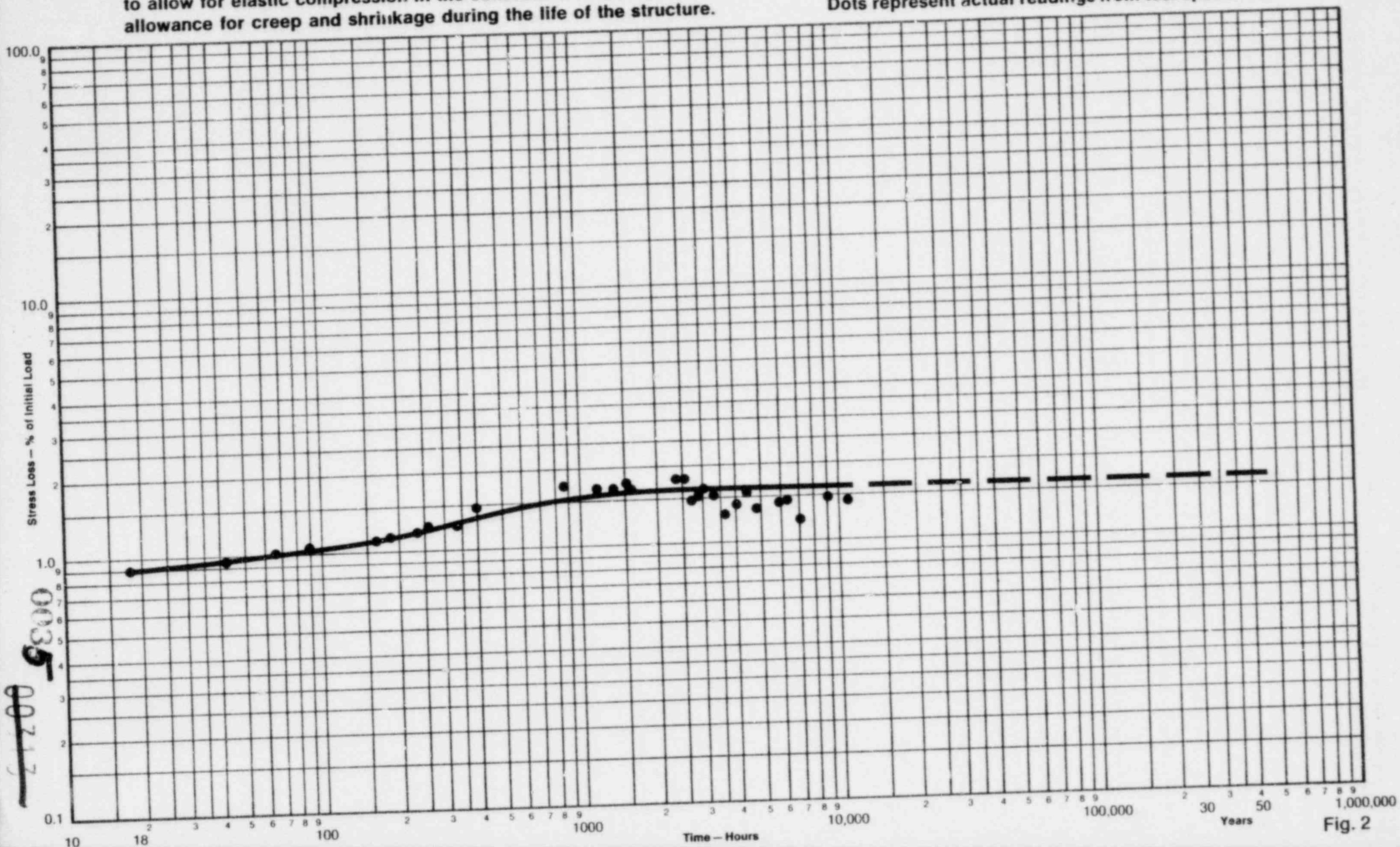


Fig. 2

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Stress Loss Due to Relaxation of Lok-Stress Strand at Various Temperatures

Initial Tension = 70% of Guaranteed Ultimate Strength

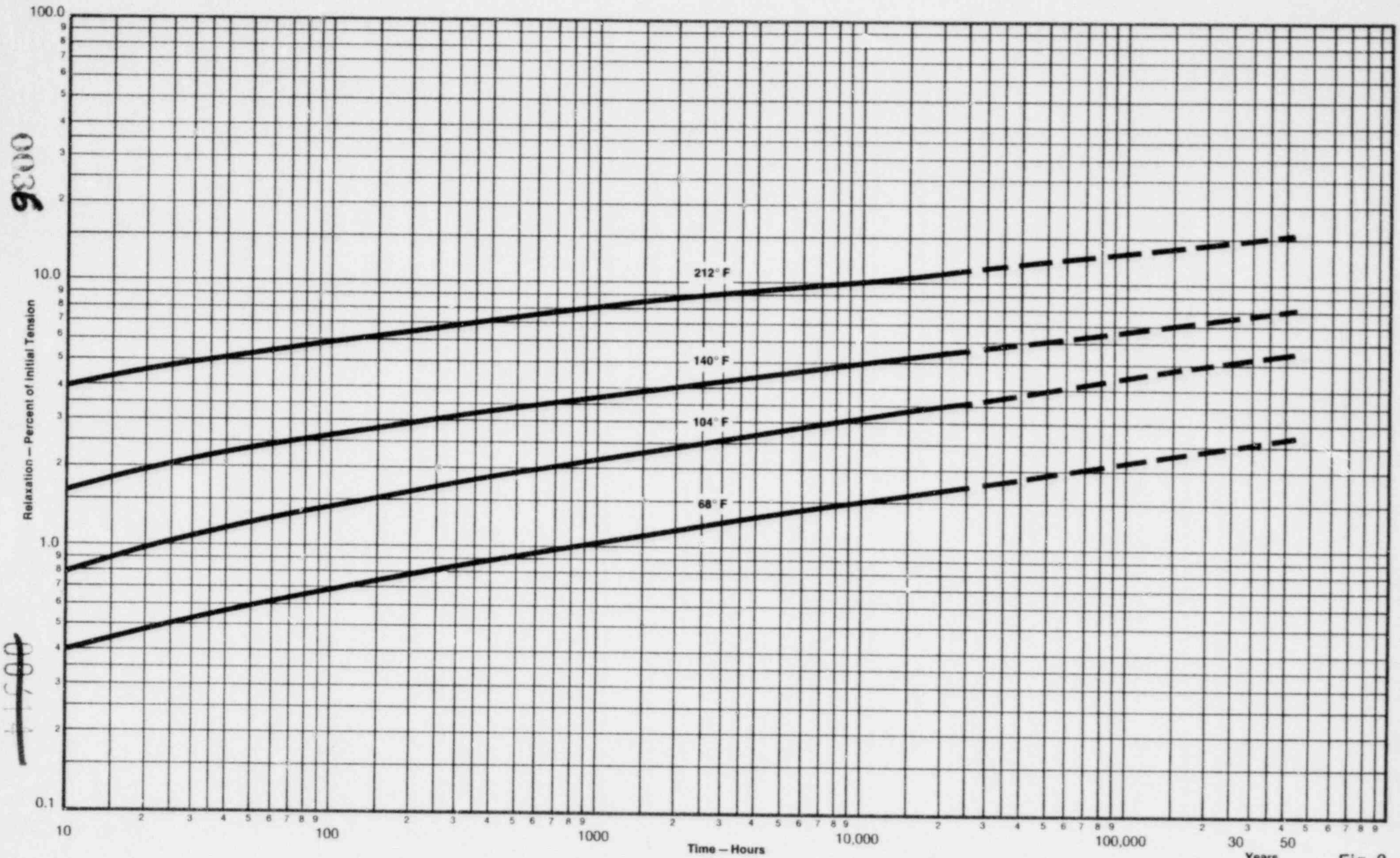
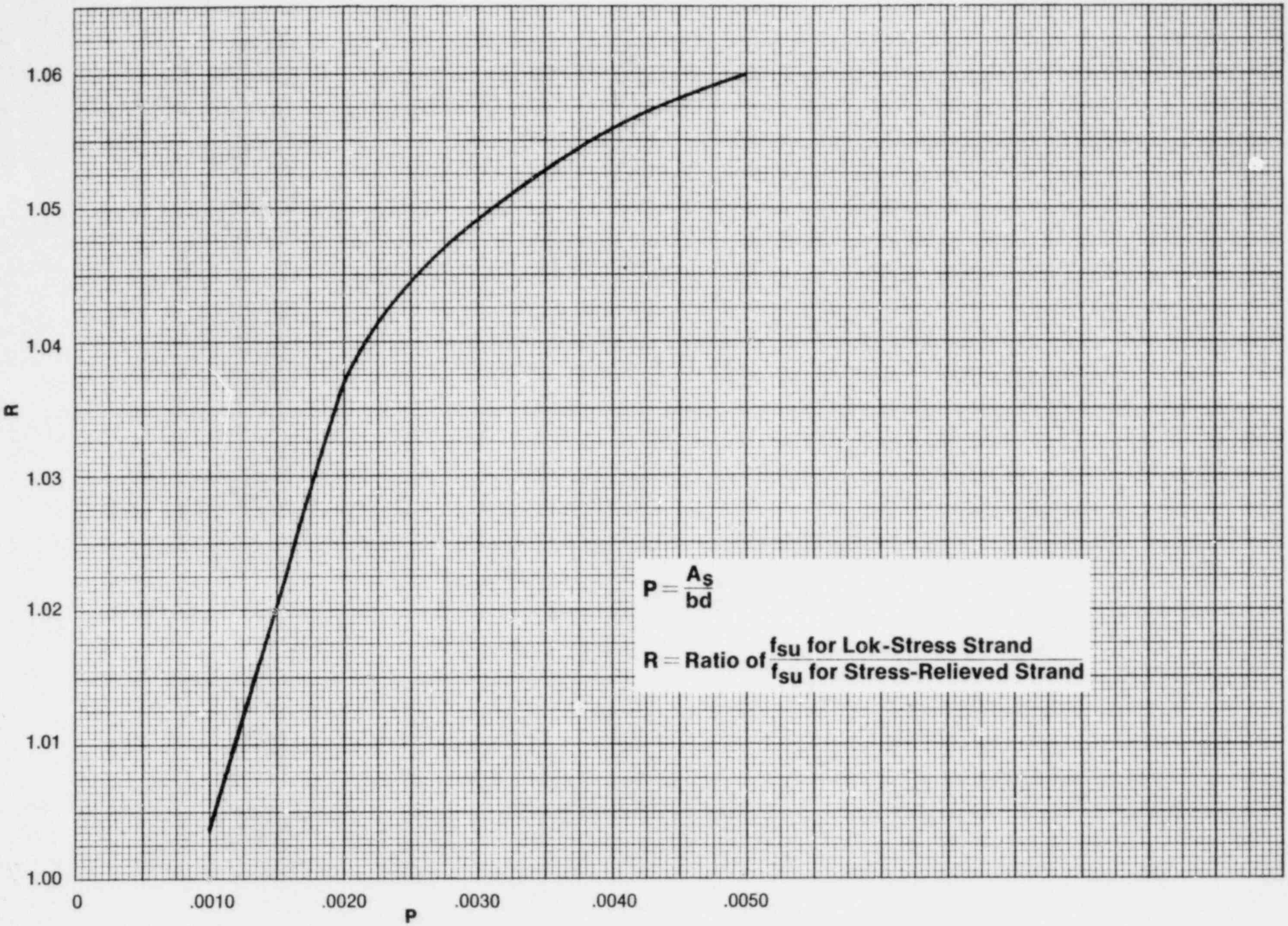


Fig. 3



1.06
1.05
1.04
1.03
1.02
1.01
1.00
R
0
.0010
.0020
.0030
.0040
.0050
P
$P = \frac{A_s}{bd}$
$R = \text{Ratio of } \frac{f_{su} \text{ for Lok-Stress Strand}}{f_{su} \text{ for Stress-Relieved Strand}}$

Fig. 4

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4067 Watts Street
415-658-6713

Los Angeles 91747
13111 Temple Ave., P.O. Box 1211
City of Industry
213-962-6761

COLORADO

Denver 80201 (General Office)
P.O. Box 1920
303-244-0833 (Also Export Sales)

Denver 80216
4950 Colorado Blvd.
303-388-2491

GEORGIA

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404-753-6330

ILLINOIS

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5525 W. Roosevelt Road
312-652-6600
312-242-1100

KANSAS

Wichita 67201
1506 E. Lewis, P.O. Box 1358
316-264-4305

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Needham Heights 02194
617-449-0200

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Detroit 48202
1716 Fisher Building
313-875-1730

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713-644-6261

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801-487-6261

WASHINGTON

Seattle 98134
2200 Sixth Avenue South
206-624-4881

STEEL

~~00316~~

CF&I STEEL CORPORATION

0038

CF&I STEEL CORPORATION
640 SOUTH BROAD STREET
TRENTON, NEW JERSEY 08611

DATA SHEET LS-1

LOK-STRESS STRAND

LOK-STRESS Strand is made by a process in which the strand is heated to a stress-relieving temperature and simultaneously subjected to a tensile force sufficient to produce approximately 1% permanent elongation. The molecular structure of strands subjected to this process is locked in position resulting in low stress relaxation characteristics.

PHYSICAL PROPERTIES

The physical properties of LOK-STRESS Strand are shown in Table #1. Note that the minimum yield strength is 90% of catalog ultimate as compared to 85% for stress-relieved strand.

LOK-STRESS Strand, when used as proposed herein, will have a maximum stress loss due to relaxation in the steel of 2% of initial stress.

LOK-STRESS Strand meets all requirements of Standard Specifications for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete ASTM Designation A-416 (Latest Revision).

DESIGNING WITH LOK-STRESS STRAND

The attached stress loss calculations and proposed uses are in strict agreement with existing design codes and specifications, i.e. ACI Standard Building Code Requirements for Reinforced Concrete, ACI 318-63 and AASHO Standard Specifications for Highway Bridges (Latest Edition).

The design procedure is basically the same as with stress-relieved strand. The compressive stress required is determined and, using Table 4 to find the final load per strand, a strand pattern is established. Because of the reduced difference between initial and final tension and the stability of LOK-STRESS Strand, it is possible to predict and control camber more accurately.

The ultimate moment capacity of most members prestressed with LOK-STRESS Strand is greater than that of identical members prestressed with stress-relieved strands of the same ultimate strength. This increase in ultimate moment capacity is due to the higher yield strength of LOK-STRESS Strand. The following procedure can be used in computing ultimate moment capacity of members using LOK-STRESS Strand:

1. Compute f_{su} for stress-relieved strand using the formulas given in AASHO or ACI 318-63.

2. Read R from the curve on Fig. U4 (attached hereto). For values of p less than 0.0010, the increase in ultimate moment using LOK-STRESS Strand is negligible.

3. Multiply the value of f_{su} computed in Step 1 by the value of R determined in Step 2 to get the value of f_{su} for LOK-STRESS Strand.

4. Use the value of f_{su} determined in Step 3 in the AASHO or ACI 318-63 formulas to compute ultimate moment capacity of the member.

(The curve on Fig. U4 was developed from the same equations that were used to develop the ultimate moment equations in AASHO and ACI 318-63. Calculation sheets showing the derivation are available on request.)

LOK-STRESS Strand with its higher yield strength can be tensioned to higher loads without excessive relaxation. Specifications limit the final effective prestress force to 60% of ultimate after all stress losses. Setting this as the desiredfinal stress and adding the stress losses that will occur in a "typical member", we get an initial tension of 72.25% of ultimate. This is permissible because specifications permit a stress of 70% of ultimate after transfer.

A "typical member" has the following characteristics:

1. Is of the pretensioned type.

2. Is made of regular weight concrete, i.e. 145 to 150 lbs. per cubic foot.

3. Concrete strength at transfer is 3500 to 4000 psi and ultimate strength is 5000 psi.

4. Net compressive stress under final prestress plus dead and any other permanent loads is 1,500 psi at the center of gravity of the strand group at the location in the beam where stresses are computed. In general, stress losses will be higher if the net compressive stress exceeds 1,500 psi or if lightweight concrete is used. Conversely, stress losses will be lower if net compressive stress is less than 1,500 psi or if concrete strengths exceed those listed.

DETERMINATION OF FINAL TENSION AND TENSION IMMEDIATELY AFTER TRANSFER FOR LOK-STRESS STRAND

In Tables 4 and 5 the final tension and the tension immediately after transfer are determined for the conditions describing a "typical member" and an initial tension of 72.25% of ultimate.

Table V gives the final effective prestress force for groups of 3/8", 7/16" and 1/2" diameter LOK-STRESS Strand.

USING LOK-STRESS STRAND

The improvement in the physical properties of LOK-STRESS Strand permits its use at initial tensions in excess of 70% of catalog ultimate strength. However, there is not a corresponding increase in the efficiency of the strand in temporary gripping devices. When using prestressing strand at initial tensions above 70% of catalog ultimate, it is necessary to insure an adequate factor of safety. Particular attention should be given to procedures for maintenance and application of gripping devices and to conditions (such as a drop in temperature) which cause increased tension or otherwise decrease the factor of safety.

Table 1

PHYSICAL PROPERTIES

CF&I-ROEBLING LOK-STRESS PRESTRESSED CONCRETE STRAND

When Used as Tendons

Nominal Diameter Of Strand	Nominal Weight Of Strand Per 1000 ft.	Nominal Area Of Strand	Minimum Ultimate Strength	Yield Strength Requirements	
				Initial Load	Min. Load at 1% Extension
3/8"	292 lbs.	.085 sq.in.	23,000 lbs.	2,300 lbs.	20,700 lbs.
7/16"	400 lbs.	.117 sq.in.	31,000 lbs.	3,100 lbs.	27,900 lbs.
1/2"	532 lbs.	.153 sq.in.	41,300 lbs.	4,130 lbs.	37,170 lbs.
.600"	737 lbs.	.215 sq.in.	54,000 lbs.	5,400 lbs.	48,600 lbs.

0043

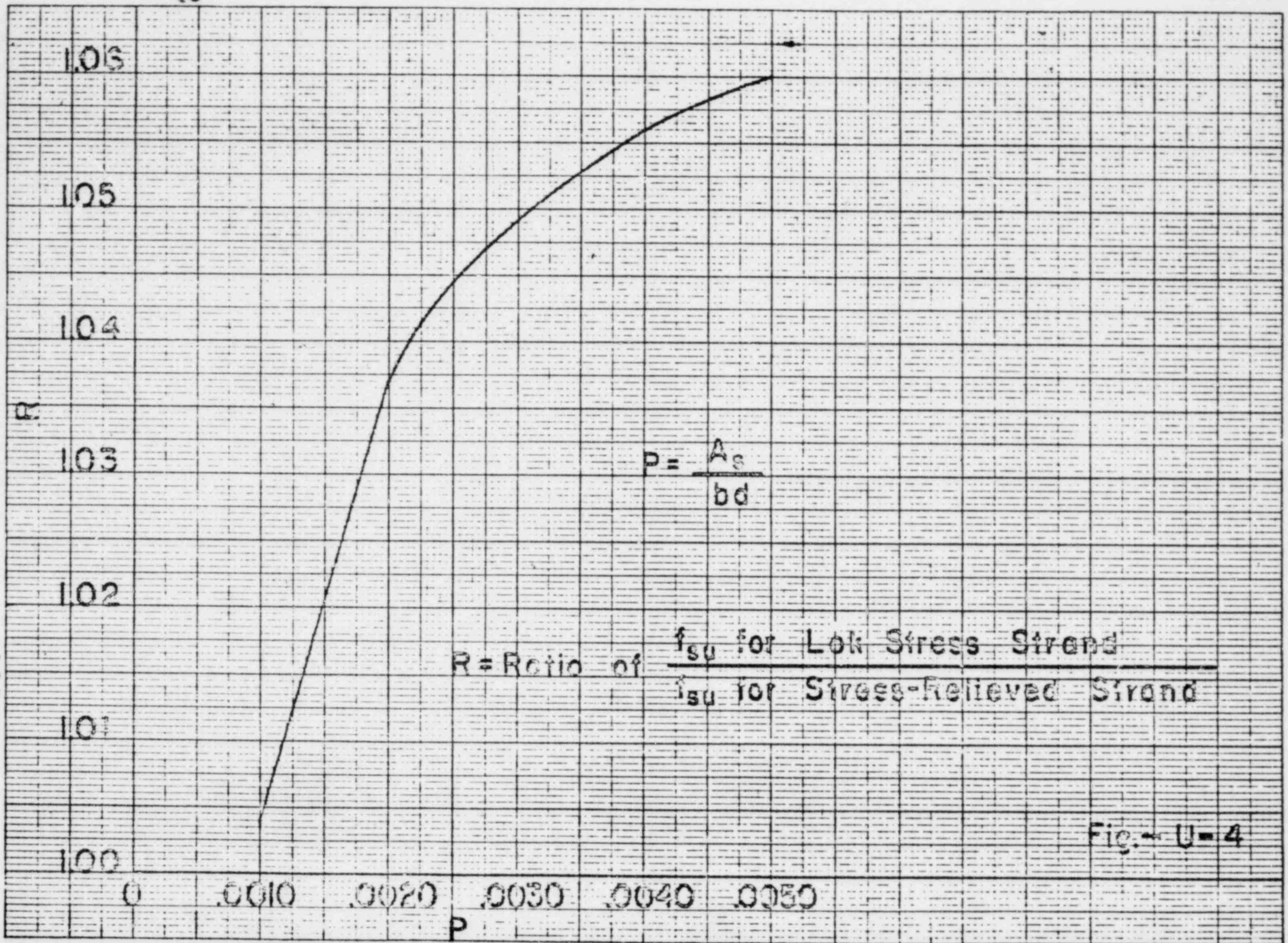
1.06
1.05
1.04
R
1.03
1.02
1.01
1.00
0
.0010
.0020
.0030
.0040
.0050
P
P = As / bd
R = Ratio of fsu for Lok Stress Strand / fsu for Stress-Relieved Strand

Fig. - U-4

CF&I STEEL CORPORATION
640 SOUTH BROAD STREET
TRENTON, NEW JERSEY 08611

COMPARISON OF LOK-STRESS AND STRESS-RELIEVED STRANDS

Because of the reduced stress loss due to relaxation and the increase in yield strength, a more balanced design is obtained with LOK-STRESS strand and camber problems are minimized.

For details of physical properties, see Table 1 of Data Sheet LS-1.

Tables 2, 3, 4 and 5 show strand tensions immediately after transfer of load from anchorages to concrete and also after all stress losses for both stress-relieved and LOK-STRESS strands. The values used for strand relaxation used in these tables are based on long-time tests by CF&I Steel Corporation and verified by numerous tests by others, both in the United States and abroad. The values used for stress loss due to concrete shortening are based on a study of existing test reports and are for a typical member which has the following characterisitics:

1. Is of the pretensioned bonded type.

2. Is made of regular concrete, i.e., 145 to 150 lbs. per cubic foot.

3. Concrete strength at load transfer is 3,500 to 4,000 psi and ultimate strength is 5,000 psi.

4. Net compressive stress under final prestress plus dead and any other permanent loads is 1,500 psi at the center of gravity of the strand group at the location in the beam where stresses are being computed. In general, stress losses will be higher if the net compressive stress exceeds 1,500 psi or if lightweight concrete is used. Conversely, stress losses will be lower if net compressive stress is less than 1,500 psi or if concrete strenghs exceed those listed.

In Tables 2 and 3 the initial tension for stress-relieved strand is given as 70% ultimate and in Tables 4 and 5 the initial tension in LOK-STRESS strand is given as 72.25% ultimate. The 70% value is used for stress-relieved strand because there is a rapid stress loss even at this value and most of any higher load is rapidly lost due to excessive relaxation.

LOK-STRESS strand with its higher yield strength can be tensioned to higher loads without excessive relaxation. ACI 318-63 sets a limit of 60% of ultimate as the maximum allowable stress after all stress losses. Setting this as the desired final stress and adding the stress losses that will occur in what we have defined as a "typical member", we get an initial tension of 72.25% ultimate. This is permissible because ACI 318-63 permits a stress of 70% ultimate after transfer.

For lightweight members with higher losses than regular concrete, initial tensions in excess of 72.25% ultimate can be used in LOK-STRESS strand but only after the casting yard operator has satisfied himself of the safety of the grips, deflecting devices, etc., that he is using.

DESIGN PROCEDURE is basically the same as with stress-relieved strand. The compressive stress required is determined and, using Table 4 to find the final load per strand, a strand pattern is determined. Because of the smaller difference between initial and final tension, camber will be less than with stress-relieved strand.

Because of the higher yield strength of LOK-STRESS strand, the ultimate moment capacity of most members prestressed with LOK-STRESS strand is greater than that of identical members prestressed with stress-relieved strand.

DESIGN COMPARISON of typical prestressed concrete members under various performance criteria are attached. In all examples an economy of strand is achieved. The required ultimate capacity is met comfortably with the reduced steel area accompanied by an appreciable reduction of camber. For details on increase in ultimate capacity, see Figure R-4 of Data Sheet LS-1.

For members not falling into the definition of a "typical member", i.e., a member with more or less than 1,500 psi residual prestress or a member using lightweight concrete, it may be necessary to compute the exact losses. Criteria for determining actual losses are available upon request.

Table 2

Determination of Final Tension ASTM & 270K Stress Relieved Strand	3/8" Dia.		7/16" Dia.		1/2" Dia.	
	ASTM	270K	ASTM	270K	ASTM	270K
1 Minimum Ultimate Strength lbs.	20,000	23,000	27,000	31,000	36,000	41,300
2 Area Sq. inches	0.0799	0.0854	0.1089	0.1167	0.1438	0.1531
3 Initial Tension lbs. (70% Ult.)	14,000	16,100	18,900	21,700	25,200	28,910
4 Initial Stress (f_{F_I})(#3 ÷ #2) psi	175,220	188,525	173,550	185,950	175,240	188,830
5 △ C* psi	29,000	29,000	29,000	29,000	29,000	29,000
6 △ S** psi	19,274	20,737	19,091	20,455	19,276	20,771
7 Total Stress Loss (#5 & #6) psi	48,274	49,737	48,091	49,455	48,276	49,771
8 Final Stress (#4- #7) psi	126,946	138,788	125,459	136,495	126,964	139,059
9 Final Tension lbs. (#8 x #2)	10,140	11,850	13,660	15,930	18,260	21,290

*△C = Stress Loss in strand due to shortening of concrete
Elastic Compression = 11,000 psi; Creep & Shrinkage = 18,000 psi

**△S = Stress Loss in strand due to relaxation of strand
For Stress Relieved Strand = 11% (f_{F_I}) Initial Stress

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Table 3

Determination of tension in ASTM & 270K Stress Relieved Strand immediately after transfer	3/8" Dia.		7/16" Dia.		1/2" Dia.	
	ASTM	270K	ASTM	270K	ASTM	270K
1 Minimum Ultimate Strength lbs.	20,000	23,000	27,000	31,000	36,000	41,300
2 Area Sq. inches	0.0799	0.0854	0.1089	0.1167	0.1438	0.1531
3 Initial Tension lbs (70% Ult.)	14,000	16,100	18,900	21,700	25,200	28,910
4 Initial Tension (f_{F_I}) (#3 ÷ #2) psi	175,220	188,525	173,550	185,950	175,240	188,830
5 △C* psi	11,000	11,000	11,000	11,000	11,000	11,000
6 △S** psi	4,381	4,713	4,339	4,649	4,381	4,721
7 Total Stress Loss (#5 & #6) psi	15,381	15,713	15,339	15,649	15,381	15,721
8 Final Stress (#4- #7) psi	159,839	172,812	158,211	170,301	159,859	173,109
9 Final Tension lbs. (#8 x #2)	12,770	14,760	17,230	19,870	22,990	26,500

*△C = Stress Loss in strand due to shortening of concrete
Elastic Compression = 11,000 psi; Creep & Shrinkage = 0 psi

**△S = Stress Loss in strand due to relaxation of strand
For Stress Relieved Strand = 2.5% (f_{F_I}) Initial Stress

Table 4

	Determination of Final Tension LOK-STRESS Strand	3/8" Dia.	7/16" Dia.	1/2" Dia.
1	Minimum Ultimate Strength lbs.	23,000	31,000	41,300
2	Area Sq. inches	0.0854	0.1167	0.1531
3	Initial Tension lbs. (72.25% Ult.)	16,620	22,400	29,840
4	Initial Stress (f_{F_I}) (#3 ÷ #2) psi	194,614	191,945	194,905
5	△C* psi	29,000	29,000	29,000
6	△S** psi	3,892	3,839	3,898
7	Total Stress Loss (#5 & #6) psi	32,892	32,839	32,898
8	Final Stress (#4- #7) psi	161,722	159,106	162,007
9	Final Tension lbs. (#8 x #2)	13,810	18,600	24,800

*△C = Stress Loss in strand due to shortening of concrete
Elastic Compression = 11,000 psi; Creep & Shrinkage = 18,000 psi

** S = Stress Loss in Strand due to relaxation of strand
For LOK-STRESS Strand = 2.0% (f_{FI}) Initial Stress

NOTE: Initial Tension of 72.25% or Ultimate was chosen to provide an effective prestress force of 60% of Ultimate (Reference section 2606 ACI Building Code 318-63 and Section 1. 13-7 AASHO Specs.)

CF&I STEEL CORPORATION
640 SOUTH BROAD STREET
TRENTON, NEW JERSEY 08611

COMPARISON OF LOK-STRESS AND STRESS-RELIEVED STRANDS

Because of the reduced stress loss due to relaxation and the increase in yield strength, a more balanced design is obtained with LOK-STRESS strand and camber problems are minimized.

For details of physical properties, see Table 1 of Data Sheet LS-1.

Tables 2, 3, 4 and 5 show strand tensions immediately after transfer of load from anchorages to concrete and also after all stress losses for both stress-relieved and LOK-STRESS strands. The values used for strand relaxation used in these tables are based on long-time tests by CF&I Steel Corporation and verified by numercus tests by others, both in the United States and abroad. The values used for stress loss due to concrete shortening are based on a study of existing test reports and are for a typical member which has the following characterisitics:

1. Is of the pretensioned bonded type.

2. Is made of regular concrete, i.e., 145 to 150 lbs. per cubic foot.

3. Concrete strength at load transfer is 3,500 to 4,000 psi and ultimate strength is 5,000 psi.

4. Net compressive stress under final prestress plus dead and any other permanent loads is 1,500 psi at the center of gravity of the strand group at the location in the beam where stresses are being computed. In general, stress losses will be higher if the net compressive stress exceeds 1,500 psi or if lightweight concrete is used. Conversely, stress losses will be lower if net compressive stress is less than 1,500 psi or if concrete strenghs exceed those listed.

Table 5

	Determination of Tension in LOK-STRESS Strands immediately after transfer	3/8" Dia.	7/16" Dia.	1/2" Dia.
1	Minimum Ultimate Strength lbs.	23,000	31,000	41,300
2	Area Sq. inches	0.0854	0.1167	0.1531
3	Initial Tension lbs. (72.25% Ult.)	16,620	22,400	29,840
4	Initial Stress (f_{PI}) (3 ÷ 2) psi	194,614	191,945	194,905
5	$\triangle$C* psi	11,000	11,000	11,000
6	$\triangle$S** psi	1,946	1,920	1,949
7	Total Stress Loss (5 & 6) psi	12,946	12,920	12,949
8	Final Stress (4 - 7) psi	181,668	179,025	181,956
9	Final Tension lbs. (8 x 2)	15,510	20,890	27,860

*$\triangle$C = Stress Loss in strand due to shortening of concrete
Elastic Compression = 11,000 psi; Creep & shrinkage = 0 psi

**$\triangle$S = Stress Loss in strand due to relaxation of strand
For LOK-STRESS Strand = 1% (f_{PI}) Initial Stress

NOTE: Initial tension of 72.25% of Ultimate was chosen to provide an effective prestress force of 60% of Ultimate (Reference section 2606 ACI Bldg. Code 318-63 and section 1.13-7 AASHO Specs.)

CF&I STEEL CORPORATION

TABLE IV

Final Prestressing Force For Groups of 7-wire Uncoated Stress-Relieved & LOK-STRESS Prestressed Concrete Strands

ASTM Stress Relieved Strands 70% Initial 51% Final				270K Stress Relieved Strands 70% Initial 51% Final				LOK-STRESS Strands 72.25% Initial 60% Final			
No. of Strands	3/8" Dia.	7/16" Dia.	1/2" Dia.	No. of Strands	3/8" Dia.	7/16" Dia.	1/2" Dia.	No. of Strands	3/8" Dia.	7/16" Dia.	1/2" Dia.
1	10,140	13,660	18,260	1	11,850	15,930	21,290	1	13,810	18,600	24,80
2	20,280	27,320	36,520	2	23,700	31,860	42,580	2	27,620	37,200	49,60
3	30,420	40,980	54,780	3	35,550	47,790	63,870	3	41,430	55,800	74,40
4	40,560	54,640	73,040	4	47,400	63,720	85,160	4	55,240	74,400	99,20
5	50,700	68,300	91,300	5	59,250	79,650	106,450	5	69,050	93,000	124,00
6	60,840	81,960	109,560	6	71,100	95,580	127,740	6	82,860	111,600	148,80
7	70,980	95,620	127,820	7	82,950	111,510	149,030	7	96,670	130,200	173,60
8	81,120	109,280	146,080	8	94,800	127,440	170,320	8	110,480	148,800	198,40
9	91,260	122,940	164,340	9	106,650	143,370	191,610	9	124,290	167,400	223,20
10	101,400	136,600	182,600	10	118,500	159,300	212,900	10	138,100	186,000	248,00
11	111,540	150,260	200,860	11	130,350	175,230	234,190	11	151,910	204,600	272,80
12	121,680	163,920	219,120	12	142,200	191,160	255,480	12	165,720	223,200	297,60
13	131,820	177,580	237,380	13	154,050	207,090	276,770	13	179,530	241,800	322,40
	141,960	191,240	255,640	14	165,900	223,020	298,060	14	193,340	260,400	347,20
15	152,100	204,900	273,900	15	177,750	238,950	319,350	15	207,150	279,000	372,00
16	162,240	218,560	292,160	16	189,600	254,880	340,640	16	220,960	297,600	396,800
17	172,380	232,220	310,420	17	201,450	270,810	361,930	17	234,770	316,200	421,600
18	182,520	245,880	328,680	18	213,300	286,740	383,220	18	248,580	334,800	446,400
19	192,660	259,540	346,940	19	225,150	302,670	404,510	19	262,390	353,400	471,200
20	202,800	273,200	36[illegible]	20	237,000	318,600	425,800	20	276,200	372,000	496,000
21	212,940	286,860	383,4[illegible]	21	248,850	334,530	447,090	21	290,010	390,600	520,800
22	223,080	300,520	401,720	22	260,700	350,460	468,380	22	303,820	409,200	545,600
23	233,220	314,180	419,980	23	272,550	366,390	489,670	23	317,630	427,800	570,400
24	243,360	327,840	438,240	24	284,400	382,320	510,960	24	331,440	446,400	595,200
25	253,500	341,500	456,500	25	296,250	398,250	532,250	25	345,250	465,000	620,000
26	263,640	355,160	474,760	26	308,100	414,180	553,540	26	359,060	483,600	644,800
27	273,780	368,820	493,020	27	319,950	430,110	574,830	27	372,870	502,200	669,600
28	283,920	382,480	511,280	28	331,800	446,040	596,120	28	386,680	520,800	694,400
29	294,060	396,140	529,540	29	343,650	461,970	617,410	29	400,490	539,400	719,200
30	304,200	409,800	547,800	30	355,500	477,900	638,700	30	414,300	558,000	744,000
31	314,340	423,460	566,060	31	367,350	493,830	659,990	31	428,110	576,600	768,800
32	324,480	437,120	584,320	32	379,200	509,760	681,280	32	441,920	595,200	793,600
33	334,620	450,780	602,580	33	391,050	525,690	702,570	33	455,730	613,800	818,400
34	344,760	464,440	620,840	34	402,900	541,620	723,860	34	469,540	632,400	843,200
35	354,900	478,100	639,100	35	414,750	557,550	745,150	35	483,350	651,000	868,000
36	365,040	491,760	657,360	36	426,600	573,480	766,440	36	497,160	669,600	892,800
37	375,180	505,420	675,620	37	438,450	589,410	787,730	37	510,970	688,200	917,600
	385,320	519,080	693,880	38	450,300	605,340	809,020	38	524,780	706,800	942,400
	395,460	532,740	712,140	39	462,150	621,270	830,310	39	538,590	725,400	967,200
40	405,600	546,400	730,400	40	474,000	637,200	851,600	40	552,400	744,400	992,000

CF&I STEEL CORPORATION

TABLE V

Final Prestressing Force For Groups of 7-wire Uncoated LOK-STRESS Prestressed Concrete Strands

	72.25% Initial 60% Final		
No. of Strands	3/8" Dia.	7/16" Dia.	1/2" Dia.
1	13,810	18,600	24,800
2	27,620	37,200	49,600
3	41,430	55,800	74,400
4	55,240	74,400	99,200
5	69,050	93,000	124,000
6	82,860	111,600	148,800
7	96,670	130,200	173,600
8	110,480	148,800	198,400
9	124,290	167,400	223,200
10	138,100	186,000	248,000
11	151,910	204,600	272,800
12	165,720	223,200	297,600
13	179,530	241,800	322,400
14	193,340	260,400	347,200
15	207,150	279,000	372,000
16	220,960	297,600	396,800
17	234,770	316,200	421,600
18	248,580	334,800	446,400
19	262,390	353,400	471,200
20	276,200	372,000	496,000
21	290,010	390,600	520,800
22	303,820	409,200	545,600
23	317,630	427,800	570,400
24	331,440	446,400	595,200
25	345,250	465,000	620,000
26	359,060	483,600	644,800
27	372,870	502,200	669,600
28	386,680	520,800	694,400
29	400,490	539,400	719,200
30	414,300	558,000	744,000
31	428,110	576,600	768,800
32	441,920	595,200	793,600
33	455,730	613,800	818,400
34	469,540	632,400	843,200
35	483,350	651,000	868,000
36	497,160	669,600	892,800
37	510,970	688,200	917,600
38	524,780	706,800	942,400
39	538,590	725,400	967,200
40	552,400	744,000	992,000

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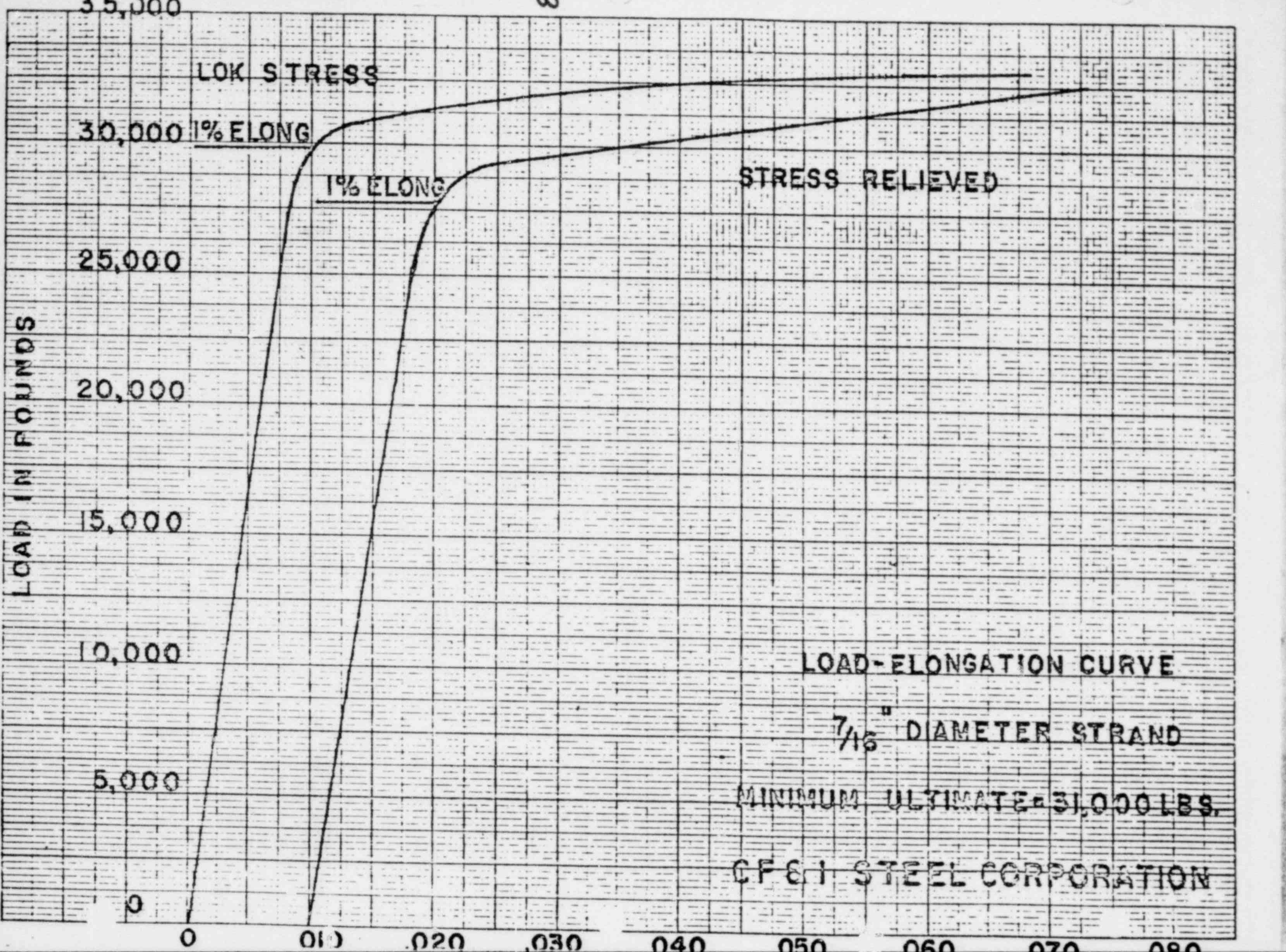

LOAD IN POUNDS
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
LOK STRESS
1% ELONG
1% ELONG
STRESS RELIEVED
LOAD-ELONGATION CURVE
7/16" DIAMETER STRAND
MINIMUM ULTIMATE=31,000 LBS.
CF&I STEEL CORPORATION
0
010
.020
.030
040
050
060
070
080

VSL UNBONDED TENDON INSTALLATIONS

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APPENDIX VI.

Unbonded VSL Tendons

1. Cavern of Veytaux, Switzerland

Owner:	Forces Motrices de l'Hongrin SA, Lausanne
Engineer:	Compagnie d'Etudes de Travaux Publics SA, Lausanne
General Contractor:	Consortium de la Centrale de Veytaux Losinger + Co SA, Lausanne Deneriaz SA, Lausanne Sateg SA, Lausanne Oyex Chessex & Cie SA, Lausanne
Post-tensioning Contractor:	Precontrainte SA, Lausanne

14 rock anchors

2. Stutzmauer Darligen, Switzerland

Owner:	Tiefbauamt des Kantons Bern
Engineer:	Dr. E. Staudacher + R. Siegenthaler, Bern
General Contractor:	Konsortium Stampfli, Maeder und Abplanalp
Post-tensioning Contractor:	Spannbeton AG, Bern

20 alluvial anchors

3. Hangsicherung Tenniken, Switzerland

Owner:	Kanton Basel-Land, Liestal
Engineer:	Blattner, Sissach
General Contractor:	Aschokke AG, Basel
Post-tensioning Contractor:	Spannbeton AG, Bern

8 rock anchors

4. Consolidation of Cavern El Toro, Chile

Owner:	Empresa Nacional de Electricidad SA, Santiago, Chile
Engineer:	Empresa Nacional de Electricidad SA, Santiago, Chile, Elektro-Watt AG, Zurich
General Contractor:	Empresa Nacional de Electricidad SA, Santiago, Chile
Post-tensioning Contractor:	Losinger + Co SA, Berne

20 rock anchors

5. Barrage d'El Kansera, Morocco

Owner:	Ministere des Travaux Publics et des Communications du Royaume de Maroc
Engineer:	Electro-Watt, Zurich
General Contractor:	Fougerolle-Limousin, Paris
Post-tensioning Contractor:	Intrafor-Cofor, Paris

5 rock anchors

6. Tunnels de Glion, Switzerland

Owner: Departement des Travaux Publics du Canton de Vaud, Bureau des Autoroutes
Engineer: Bonnard & Gardel, Ingenieurs-Conseils, Lausanne
General Contractor: Consortium Tunnels de Glion, Veytaux
Post-tensioning Contractor: Precontrainte SA, Lausanne

10 rock anchors

7. Liddell Power Station, Australia

Owner: Electricity Commission of N.S.W.
Engineer: Design by the owner
General Contractor: Transfield Pty, Ltd.
Post-tensioning Contractor: VSL Prestressing (Aust.) Pty. Ltd.

12- and 27-strand rock anchors

8. Marviken Nuclear Containment Structure, Sweden

Engineer: Statens Vattenfallsverk
General Contractor: Statens Vattenfallsverk
Post-tensioning Contractor: AB Spannarmering, Stockholm

4 post-tensioning tendons

9. St. Mary's Cathedral, San Francisco, California

Owner: Archdiocese of San Francisco
Engineer: Leonard F. Robinson
Architect: McSweeney, Ryan & Lee, San Francisco
General Contractor: Cahill Construction Co., San Francisco
Post-tensioning Contractor: VSL Corporation, Los Gatos. California
Design Consultants: Pietro Belluschi, Pier Luigi Nervi

68 post-tensioning tendons

10. Mascot Elevated Roadway, Sydney, Australia

Owner: Department of Civil Aviation
Engineer: Maunsell & Partners
General Contractor: Transbridge Pty Ltd. as subcontractor to Costain (Aust.) Pty. Ltd.
Post-tensioning Contractor: VSL Prestressing (Aust.) Pty. Ltd.

2200 feet of elevated roadway in the vicinity of the new International Airport Complex at Sydney. Spans mainly 120 ft. VSL Cables of 636 and 780 kips. The maximum length of cable is 620 feet.

11. Hunter River Bridge, Newcastle, N.S.W., Australia

Owner: Dept. of Main Roads, N.S.W.
Engineer: Dept. of Main Roads, N.S.W.
General Contractor: Dillingham Construction Co.
Post-tensioning Contractor: VSL Prestressing (Aust.) Pty. Ltd.

Bridge 3,357 feet long consisting of spans 93 to 270 ft. VSL Cables range from 202 to 780 kips. Total steel tonnage 450 t.

12. 540 Alme Street, Apartment Building, San Carlos, California

Owner: Ray Alves
Engineer: Frank Connelly
General Contractor: Alves Construction Co.
Post-tensioning Contractor: L. R. Yegge Company

190 post-tensioning tendons

13. San Francisco International Airport Parking Garage

Owner: Public Utility Commission of San Francisco
Engineer: T. Y. Lin, Kulkay Young & Associates
General Contractor: Martinelli Construction Co., San Francisco

74 post-tensioning tendons

Included in Appendix VII is a list of references for greased tendons for the Atlas System. This list derives its significance from the basic similarity between the Atlas and VSL Systems.

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ATLAS UNBONDED TENDON INSTALLATIONS

Atlas PRESTRESSING CORP.

September 8, 1969

RECEIVED
SEP 0 1 1969
VSL CORPORATION

VSL Corporation
236 North Santa Cruz Ave.
Los Gatos, California 95030

Attn: Mr. Peter Wick

Re: Atlas Projects

Dear Mr. Wick:

Please forgive me for taking so long to comply with your request. It is my desire to cooperate with you by furnishing the information you requested.

In the more than ten years that the Atlas system has been in use, in excess of one and one half million Atlas anchors have been used to post-tension unbonded tendons. Enclosed are several brochures showing a few samples of the projects in which the Atlas system has been used.

Also enclosed are two lists which may be helpful to you. The first is a list of structural engineers throughout the United States for whom Atlas has post-tensioned projects. The second is a list showing a few of the more significant projects on which the Atlas post-tensioning system has been used.

Please call me if I can be of further help to you.

Very truly yours,

ATLAS PRESTRESSING CORP.

Harold D. Long

Harold D. Long
President

HDL:ko
Encl.

~~80357~~

59

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415-781-8535

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1012 J. STREET
SACRAMENTO, CALIFORNIA
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YEHUDA WOLFSON
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1150 S. BEVERLY DRIVE
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1414 FAIR OAKS
SO. PASADENA, CALIFORNIA

NORRIE & DAVIS
SPOKANE, WASHINGTON

RUSSELL H. FULLER
171 SECOND STREET
SAN FRANCISCO, CALIFORNIA

DAVID ALAN WELISCH
693 MISSION STREET
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FRESNO, CALIFORNIA

W. D. CROUCH, JR.
806 RAILROAD AVENUE
SANTA PAULA, CALIFORNIA

KING-BENIOFF & ASSOC.
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LOS ANGELES, CALIFORNIA

JOHN A. BLUME & ASSOC.
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DALTON & DALTON
CONSULTING STRUCTURAL ENGRS.
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OAKLAND, CALIFORNIA

ERKEL & GREENFIELD
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AND ROBERTSON
CONSULTING STRUCTURAL ENGRS.
1840 WASHINGTON BLDG.
SEATTLE, WASHINGTON

ERIC ELSESSER & ASSOC.
737 BEACH
SAN FRANCISCO, CALIFORNIA

RUTHERFORD & CHEKENE
259 GEARY STREET
SAN FRANCISCO, CALIFORNIA

FREDERIC WILHELM
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LOS ANGELES, CALIFORNIA

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SAN FRANCISCO, CALIFORNIA

RICHARD SILBERSTEIN
STRUCTURAL ENGINEER
FRESNO, CALIFORNIA

J. BILMAN & ASSOCIATES
STRUCTURAL ENGINEERS
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CONSULTING STRUCTURAL ENGINEER
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SAN FRANCISCO, CALIFORNIA

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STRUCTURAL ENGINEERS
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485 S. ROBERTSON BLVD.
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SAN FRANCISCO, CALIFORNIA

MOFFETT, NICHOL & BONNEY
PORTLAND, OREGAON

RINNE, HAMMOND & PETERSON
STRUCTURAL ENGINEERS
2450 EL CAMINO REAL
PALO ALTO, CALIFORNIA

ROBERT G. ALBRECHT
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ATLAS PROJECTS

1) T.R.W. Office Building - Los Angeles
Architect: A. C. Martin - Los Angeles
Engineer: A. C. Martin - Los Angeles
Size: 700,000 S.F.
Data: 40' x 64' bay, 3 story rigid frame, 1,000,000# of post-tension.

2) Los Angeles Airport Parking Garages
Architect: T. Y. Lin & Assoc. - Los Angeles
Engineer: T. Y. Lin & Assoc. - Los Angeles
Size: 4,000 cars, 1,300,000 S.F.
Data: 9' x 60' and 20' x 60' bays, 1,300,000# of post-tensioning, 50,000 Atlas anchors.

3) 1000 Unit Dormitory - Arizona State Univ.
Architect: Cartmell & Rossman
Engineer: John K. Parsons
Size: 15 stories
Data: Approximately 250,000# of post-tensioning.

4) F.D.R. Post Office - New York City
Architect: Max O. Urbahn
Engineer: DiStasio & Van Buren
Size: 33 stories, 1,250,000 S.F.
Data: 1,300,000# of post-tensioning, 80,000 Atlas anchors.

5) Makaha Apartments - Hawaii
Architect: Wm. L. Pereira & Assoc. - Honolulu
Engineer: Donald Lo - Hawaii
Size: 14 stories, 1,000,000 S.F.
Data: 600,000# of post-tensioning, 40,000 Atlas anchors.

6) Boston Logan Airport Parking Garage
Architect: Perry, Shaw, Hepburn & Deam
Engineer: Nichols, Norton & Zaldastani, Inc.
Size: 1,100,000 S.F. 3,200 cars
Data: 40,000 Atlas anchors

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7) BOR-SON TOWERS - MINNEAPOLIS
ARCHITECT: THE CERNY ASSOCIATES - MINNEAPOLIS
ENGINEER: CROSIER, GREENBERG & PARTNERS - WINNIPEG
SIZE: 22 STORIES
DATA: 300,000# OF POST-TENSIONING.

8) BEL ARBOR APARTMENTS - SAN FRANCISCO
HUD PROJECT NO:
ARCHITECT: MOGENS MOGENSON
ENGINEER: L. F. ROBINSON
SIZE: 500,000 S.F.
DATA: 500,000# OF POST-TENSIONING.

9) ARCHITECTURE BLDG. - UNIV. OF WASHINGTON
HUD PROJECT NO: 4-9-00246-0
ARCHITECT: DANIEL STREISSGUTH & GENE ZEMA - SEATTLE
ENGINEER: ROBERT ALBRECHT & EINAR SVENSSON - SEATTLE
SIZE: 5 STORIES - 150,000 S.F.

10) WATERGATE APARTMENTS - WASHINGTON, D.C.
ARCHITECT: LUIGI MORETTI, CORNING, MOORE, ELMORE & FISCHER - ROME
ENGINEER: T. Y. LIN & ASSOC. - NEW YORK
SIZE: 13 STORIES, 600,000 S.F.

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SWISS PRESTRESS SPECIFICATIONS

1. Society of Swiss Civil Engineers and Architects

2. Swiss Federal Railway

APPENDIX II

SIA SPECIFICATIONS

Article 5.04 - Prestressing Steels

1. For prestressing, only steels with a high ultimate strength should be used, with a carbon content not exceeding 0.85% and its corrosion resistance having been tested thoroughly by the manufacturer. (See Recommendation #19.)

2. Prestressing wires/strands/bars should be used only if the below listed properties are known and are in accordance with the specifications.

   (a) Values determined from tensile tests (see Recommendation #9).

   - Ultimate tensile strength f'_s.
   - Based on a statistical plot of ultimate strength tests carried out over a given period of time, not more than 5% of the tests shall be below the specified value. Such tests, however, shall not be below 97% of the specified ultimate strength f'_s. After the manufacture of prestressing strand, a test to determine the tensile strength of each heat shall be performed.
   - Steels having an ultimate tensile strength of less than 97% or more than 10% of the guaranteed ultimate strength shall be rejected.
   - Yield point f'_y (at .2% permanent deformation).
   - Ratio: $\frac{f'_y}{f'_s}$
   - Elongation of rupture: λ (based on the gage length of 10 times the diameter of prestressing steel).
   - Elongation obtained on a length equal to 10 times the diameter of the prestressing steel excluding the elongation obtained in the "neck-down" length.
   - Reduction of area ψ.

		Required Minimum Values			
Bar Diameters in mm		≤ 8.0	8.1 to 14.9	15.0 to 30	
f'_s	min.	140	130	100	kg/mm^2
$\sigma_{2.0}/f'_s$		0.85-0.95	0.80-0.90	0.75-0.85	-
λ_{10}	min.	5	6	7	%
λ_{gl}	min.	2	3	5	%
ψ	min.	30	25	20	%

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(b) Fatigue Strength

A dynamic test shall be performed on an individual strand, wire or bar to withstand without failure 2,000,000 cycles from 55 to 70% of its guaranteed minimum ultimate strength.

(c) Reverse Bending Test

Reverse bending for wire or bars up to 12 mm in diameter and for a center wire of a strand around mandrel having a diameter of 10 times the diameter of the wire or bar.

Bar Diameters in mm	< 8.0	8.1 to 12
Steels with smooth surface:		
without artificial notch	10	6
with artificial notch	~3	~3
Steels with profiled surface:		
without artificial deformation	6	-
with deformation	~3	-

(d) Bending for bars having diameters of 12.1 to 30 mm.

A bending over 180° shall be performed on a mandrel having 5 times the diameter of the bar; thereby no cracks in the prestressing steel shall occur.

(e) Relaxation (for all diameters of prestressing steel):

The relaxation of a prestressing steel with an initial tension of 55, 65, 70 and 75% f'_s shall be tested over a period of 1,000 hours (see Recommendation #20). Under an initial stress of 65% f'_s and a normal temperature, the relaxation after 1,000 hours shall not exceed 5%. Based on stresses measured after 100 hours and 1,000 hours, the final stresses can be approximated using the below listed formula.

$$\sigma_{(n)} = \sigma_{(1000)} - 3(\sigma_{(100)} - \sigma_{(1000)}) \qquad \Delta\sigma_{(n)} = \sigma_{(0)} - \sigma_{(n)}$$

In the absence of test results, such final values for relaxation losses shall be assumed as follows:

Initial Stress	$0.55\,f'_s$	$0.65\,f'_s$	$0.70\,f'_s$	$0.75\,f'_s$
$\Delta\sigma_{(n)}/\sigma_{(0)}$	4%	8%	11%	15%

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The following tolerances for the average wire diameter shall be observed:

Bar Diameters in mm	$\leq$ 8	8.1 to 14.9	15.0 to 30
Tolerances of diameter in mm	-0.05 +0.10	-0.10 +0.20	-0.20 +0.40

If prestressing steel is delivered in coils, its diameter shall be such that the stress occurring in the prestressing steel due to coiling shall not exceed 80% of the yield point. Each shipment must be accompanied by the proper heat and identification numbers. The prestressing steel shall be free of grease and oil, as well as pit marks caused by rust. No welding is permitted.

SWISS FEDERAL RAILWAY REQUIREMENTS

Fatigue Testing of a Tendon:

A dynamic test shall be performed on a representative tendon to withstand without failure 2,000,000 cycles from 65 to 70% f'_s at a frequency of 3 cycles per second.

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