ASSOCIATION OF AMERICAN RAILROADS

RESEARCH AND TEST DEPARTMENT

REPORT NO. LT-431
(Project No. T-302)

LABORATORY INVESTIGATION OF PRESTRESSED CONCRETE CROSSTIES AND FASTENERS MANUFACTURED IN THE U.S.S.R.

JULY, 1977

AAR TECHNICAL CENTER

Chicago, Illinois

TECHNICAL REPORT DATA

1. Report No. LT-431	2. Report Date July, 1977	3. Period Covered January-April, 1977

4. Title and Subtitle
Laboratory Investigation of Prestressed Concrete Crossties and Fasteners Manufactured in the U.S.S.R.

5. Author(s)
O. W. Knoblock

6. Performing Organization Name and Address
Association of American Railroads
Research and Test Department
3140 S. Federal Street
Chicago, Illinois 60616

7. Type of Report
Test

8. Contract or Grant No.

9. Sponsoring Agency Name and Address
Department of Transportation
Federal Railroad Administration
Washington, D. C. 20590

10. No. of Pages
30

11. No. of References

12. Supplementary Notes
AAR Test Division Project No. T-302

13. Abstract

Soviet manufactured prestressed concrete crossties and fasteners were tested using AREA Bulletin 655 as a guide. The ties were subjected to the following tests:

Rail Seat (Positive and Negative moment)
Rail Seat Repeated Load
Tie Center (Positive and Negative moment)
Rail Seat Ultimate and Tendon Anchorage
Fastener Uplift
Fastener Repeated Load
Fastener Longitudinal Restraint
Electrical Impedance

14. Subject Terms
Concrete Crosstie
Tie Fastener

15. Availability Statement
Director of Operations
AAR Technical Center
3140 South Federal
Chicago, Illinois 60616

TABLE OF CONTENTS

	Page
Summary	iii
Introduction	1
Acknowledgments	1
Description of Ties and Fasteners	1
Description of Tests	4
Test Results	9
Conclusions	23
ANSI-Conversion Table and Abbreviation Descriptions	25

SUMMARY

Soviet manufactured prestressed concrete monoblock crossties and their fastening system were tested using AREA (American Railway Engineering Association) Bulletin 655 as a guide. Following are results of those tests:

Rail Seat Vertical Load (Negative) was terminated at 25,000 lb. (111.2 kN) when cracking occurred. This is the flexural capacity of the tie and is expressed as 145,880 inch-lb. (16482 Nm).

Rail Seat Vertical Load (Positive) without tie plate was terminated at 44,000 lb. (195.7 kN) when cracking occurred. This is the flexural capacity of the tie and is expressed as 273,240 inch-lb. (30871 Nm).

Rail Seat Ultimate was terminated with destruction of the tie at 55,000 lb. (246.9 kN). No tendon slippage was detected until failure.

Negative Bending Moment (Tie Center) was terminated at 10,000 lb. (44.4 kN) when cracking occurred. This is the flexural capacity of the tie and is expressed as 143,750 inch-lb. (16241 Nm).

Positive Bending Moment (Tie Center) was terminated at 4,000 lb. (17.8 kN) when cracking occurred. This is the flexural capacity of the tie and is expressed as 57,500 inch-lb. (6496 Nm).

Fastener Uplift Test was performed on the tie-tie plate hold down bolt, which was attached to the tie, to 10,000 lb. (44.5 kN) without failure.

Fastening Repeated Load Test was performed but tie-tie plate hold down bolt broke before 3 million cycles in two tests; one test using U. S. load (30 kips (133.4 kN)) and a second test using Soviet load (21.9 kips (97.4 kN)).

Rail Seat Repeated Load was run to 3 million cycles with steel tie plate in place and using the U. S. load. From the initial precracking of the tie to the bottom reinforcement, the cracking progressed another 3 inches (76.2 mm) before test completion, but tie continued to take load. The plate was found to be cracked in half after test.

Fastener Longitudinal Restraint Test using 3,700 lb. (16.5 kN) load, which is the value used for 30 inch (762 mm) tie spacing, resulted in slippage during a 3 minute hold period at that load, of .002 inch (.051 mm) and at a 15 minute hold of .001 inch (.025 mm).

Electrical Impedance Test resulted in 131,000 ohms of resistance after tie-fastener immersion and drainage.

ASSOCIATION OF AMERICAN RAILROADS

RESEARCH AND TEST DEPARTMENT

REPORT NO. LT-431
(Project No. T-302)

LABORATORY INVESTIGATION OF PRESTRESSED CONCRETE CROSSTIES AND FASTENERS MANUFACTURED IN THE U.S.S.R.

INTRODUCTION

In April, 1976 twelve Soviet concrete monoblock ties, steel tie plates and fasteners were received at the AAR Technical Center from the FRA through the U.S.-U.S.S.R. agreement on cooperation in the field of transportation. Physical tests, both static and dynamic were to be performed using AREA (American Railway Engineering Association) Bulletin 655 as a guide.

ACKNOWLEDGMENTS

This investigation was under the direct supervision of Mr. G. H. Way, Assistant Vice President, Research and Test Department. Project engineer was Mr. O. W. Knoblock, Manager-Test Division, who also prepared this report.

Costs associated with this investigation were borne by the AAR.

DESCRIPTION OF CROSSTIES

Figure 1 of this report shows a typical tie which is set up for Positive Bending Moment (tie center). Average tie weight is 580 lb. (263 kg); average length 107 inch (272 mm). Longitudinal reinforcement consists of two 0.121 inch diameter (3.07 mm) wires together in four rows across and six rows high. Bottom of ties are waffled but rough finished.

Referring to the components in Figure 2 of this report, the .840 inch (21.3 mm) diameter Tee headed tie plate bolt fastens to the tie by passing the bolt head down through a molded slot in

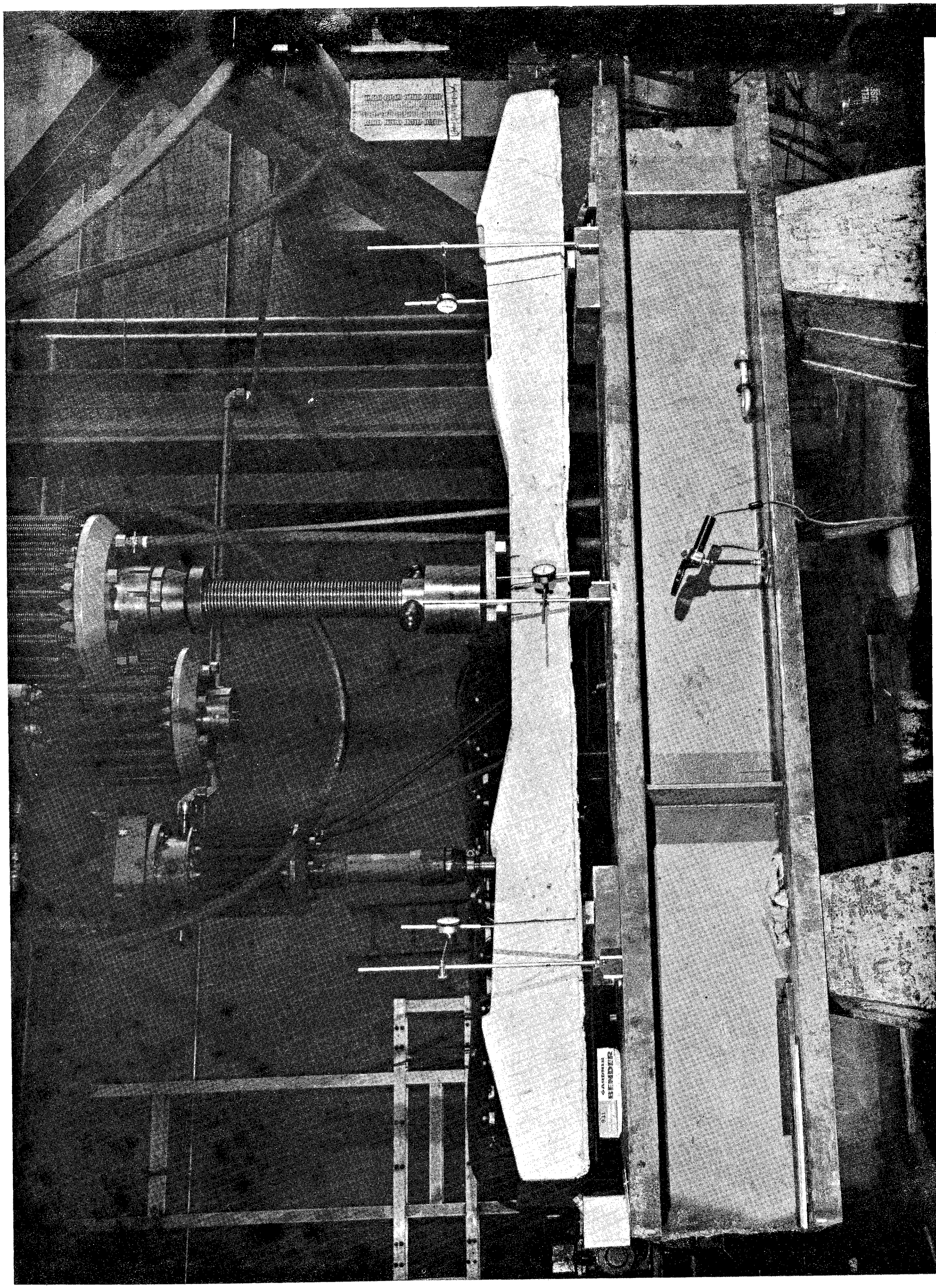


Figure 1-Set-up for Positive Bending Moment (Tie Center).

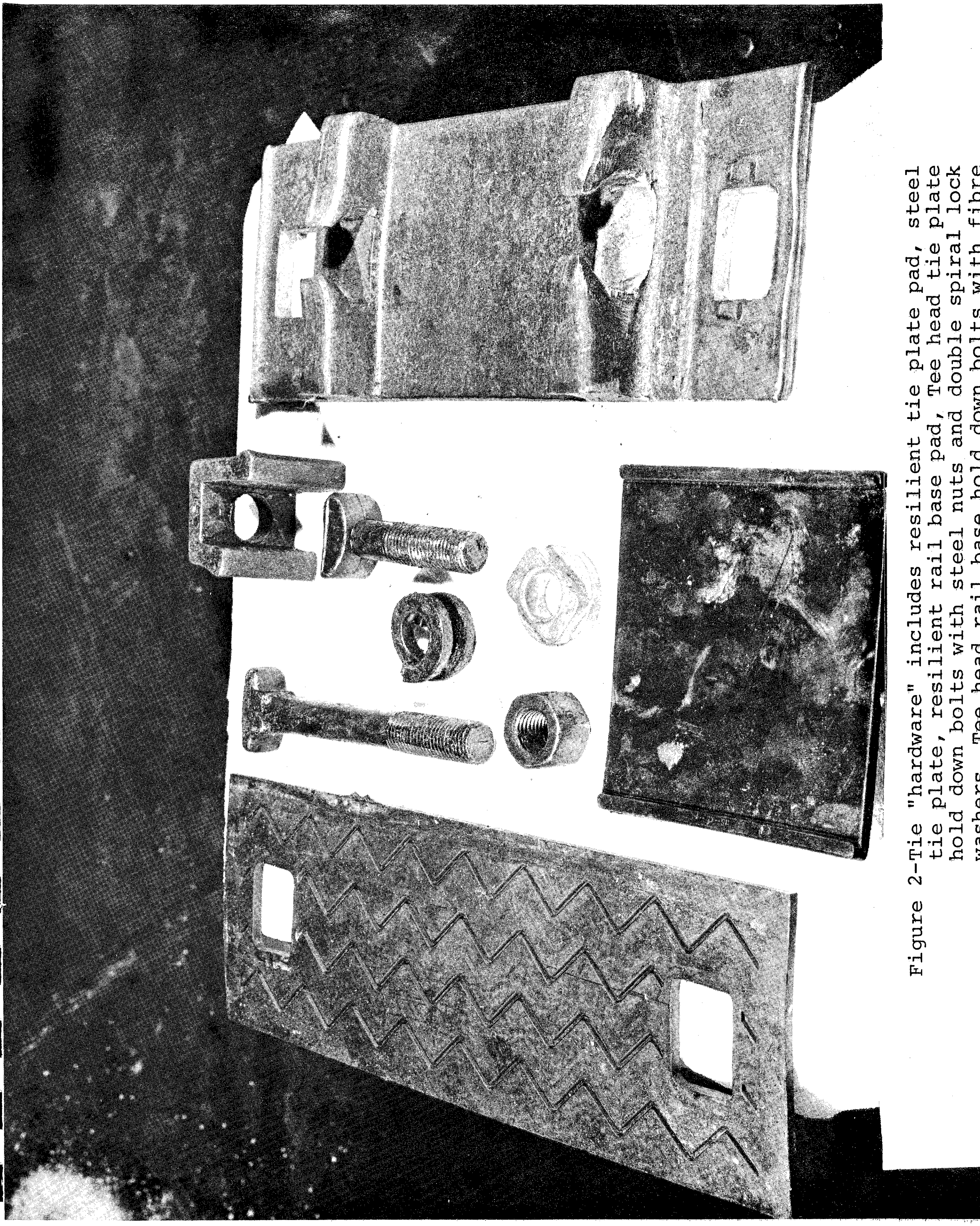


Figure 2-Tie "hardware" includes resilient tie plate pad, steel tie plate, resilient rail base pad, Tee head tie plate hold down bolts with steel nuts and double spiral lock washers, Tee head rail base hold down bolts with fibre washers and steel nuts and steel clips.

the top surface of the tie, then ¼ turn locks the bolt head in the tie. A resilient tie plate pad is then put in place and the steel tie plate is placed on top of the pad. Fibre washers are dropped over the bolt and they nest in a slot in the tie plate. A steel flat washer is next applied over the fibre washer and a steel nut is torqued to 150 ft.lb. (21 kg-m) (203.5 Nm).

A resilient rail base pad is applied to the tie plate and the rail placed on top of the pad. A short Tee headed bolt is inserted in a slot in the tie plate shoulder. A rail clip is dropped over the bolt and a double spiral steel washer and a flat steel washer and nut follow and the nut torqued to the same value as the tie-tie plate nut.

U.S. 132 lb. RE rail was used for all tests as it is almost identical to Soviet rail size.

DESCRIPTION OF TESTS

Following is an explanation of tests performed on the subject tie and fasteners, as taken, in part, from AREA Bulletin 655. Maximum wheel loads for both U.S. and Soviet were used; 41,000 lb. (183.4 kN) and 29,700 lb. (132.1 kN) respectively. Rail seat load is higher than the above two figures because of the influence of adjacent wheels and tie spacing. These figures would be U.S. 48,150 lb. (214.2 kN) and Soviet 34,879 lb. (155.1 kN).

10.9.1.4 Rail Seat Vertical Load (Negative)

With the tie supported and loaded as shown in Figure 3 of this report, a load increasing at a rate of not greater than 5 kips per minute shall be applied until cracking occurs. Load and deflection will be recorded at each increment of load and bending moment will be calculated. This final load "P" will be used to calculate the bending moment which will be considered the flexural capacity of the tie at rail seat (negative).

Rail Seat Vertical Load (Positive)

a) With the tie supported and loaded as shown in Figure 3, a load increasing at the rate of not greater than 5 kips per minute shall be applied until cracking occurs. Load and deflection will be recorded at each increment of load and bending moment will be calculated. This final load "P" will be used to calculate the bending moment which will be considered the flexural capacity of the tie at rail seat (positive).

b) Because this tie is normally used with a steel tie plate the above will be performed again using a tie plate in position at rail seat location.

10.9.1.5 Rail Seat Repeated Load (With Tie Plate)

After Rail Seat Vertical Load (Positive), Item b, has been completed the load shall be increased until cracking extends to the bottom reinforcing rods or wire. Then 3 million cycles will

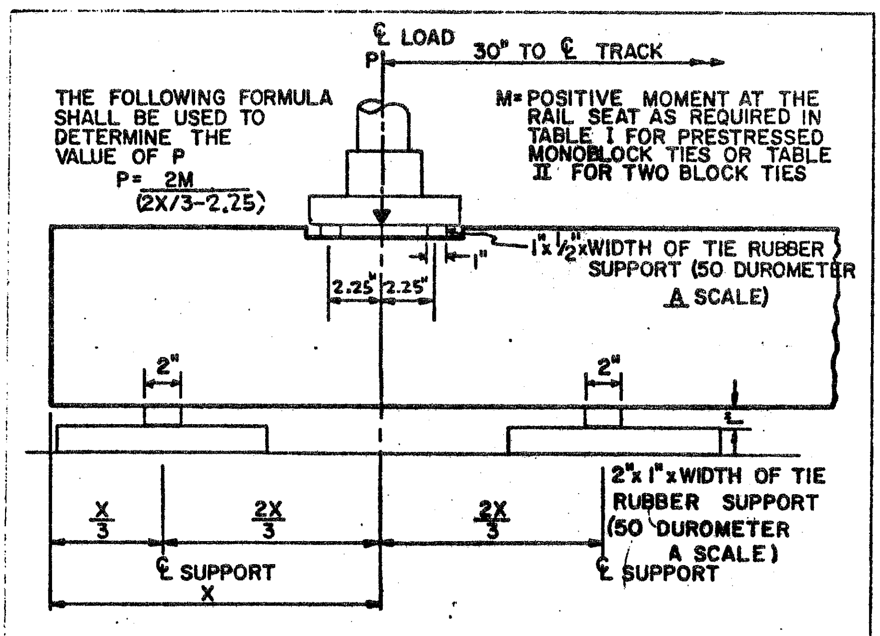


FIGURE I POSITIVE RAIL SEAT MOMENT TEST

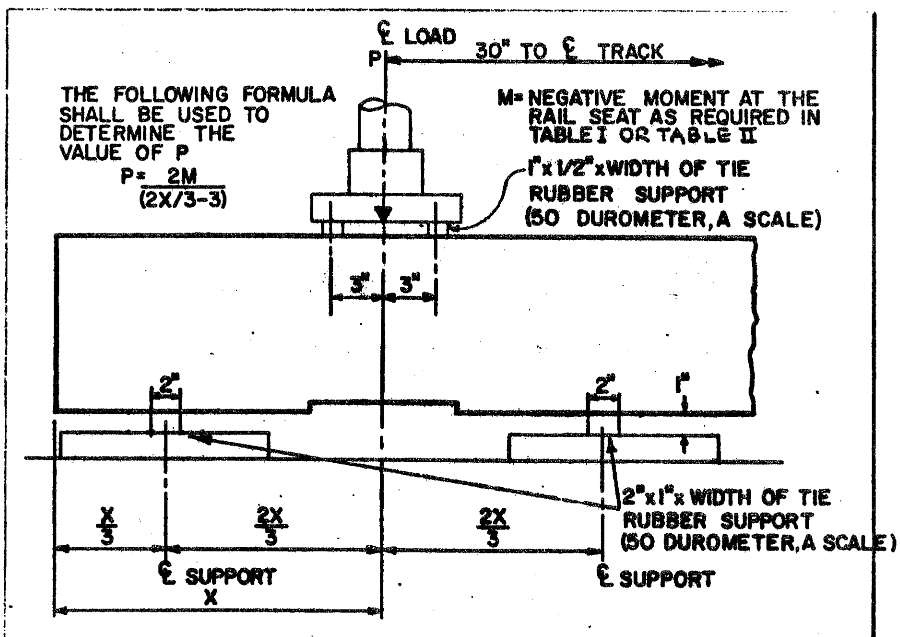


FIGURE VII RAIL SEAT NEGATIVE MOMENT TEST

Figure 3-Showing typical set-ups for rail seat positive and negative moment tests as taken from AREA Bulletin 655.

be applied at 1.1 P* load, using a minimum residual load of 4 kips.

*Theoretical or calculated load P from page 14.

10.9.1.6 Negative Bending Moment (Tie Center)

With the tie supported and loaded as shown in Figure 4, a load increasing at a rate not greater than 5 kips per minute shall be applied until cracking occurs. Load and deflection will be recorded at each increment of load and bending moment will be calculated. This final load "P" will be used to calculate the bending moment which will be considered the flexural capacity of the tie (negative).

10.9.1.7 Positive Bending Moment (Tie Center)

With the tie supported and loaded as shown in Figure 4, a load increasing at a rate not greater than 5 kips per minute shall be applied until cracking occurs. Load and deflection will be recorded at each increment of load and bending moment will be calculated. This final load "P" will be used to calculate the bending moment which will be considered the flexural capacity of the tie (positive).

10.9.1.8 Ultimate and Tendon Anchorage

Typical Rail Seat test set-up (positive). Load to 1.1 P and if cracking occurs at or above this figure then load shall be increased to 1.5 P.

If cracking occurs above P but below 1.1 P load shall be increased to 1.75 P.

Strand slippage shall be measured in 500 lb. increments.

Upon completion of above measurements load shall be increased until ultimate load is reached and then recorded.

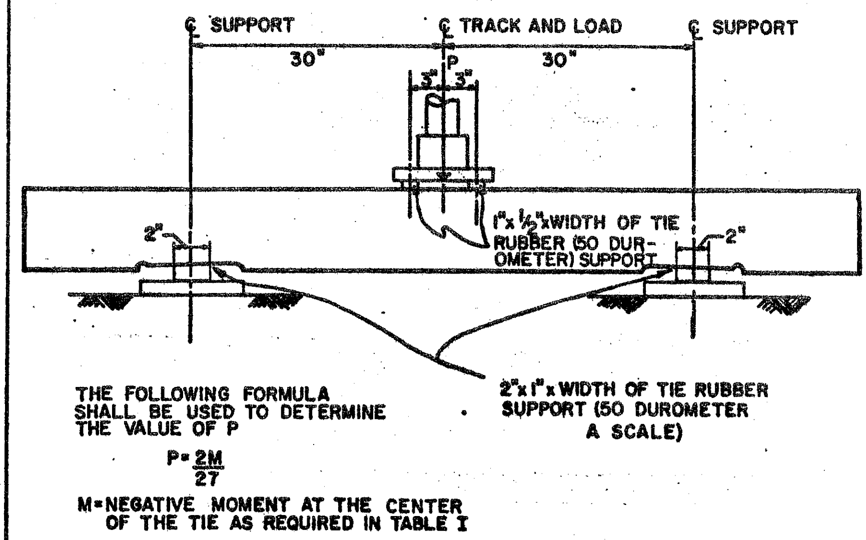
10.9.1.10 Fastening Uplift Test

Because of the positive method of anchoring there will be no separation between tie, plate and/or rail and therefore no load "P".* In lieu, a total uplift force, of 10,000 lb. will be applied to determine the integrety of the fastening system.

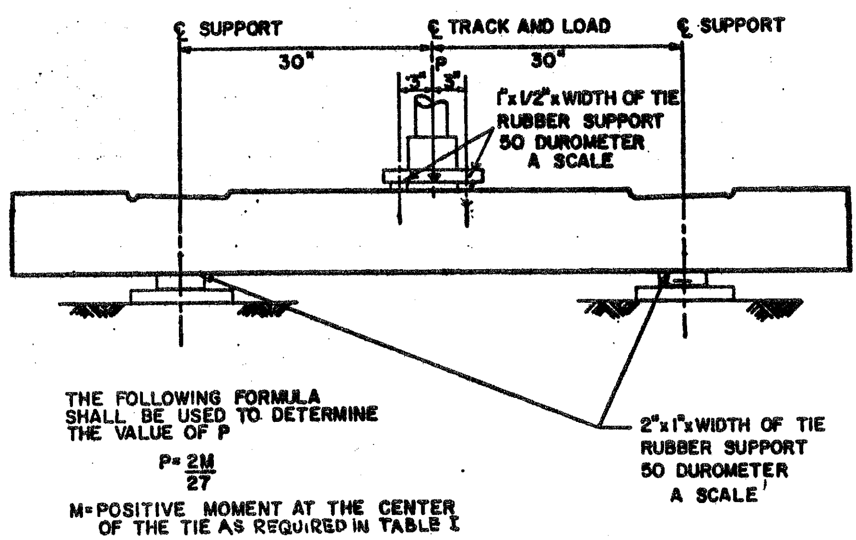
*Load "P" is that load needed to separate rail from tie plate or tie plate from tie. 2P is used as a "proof" load, which shall produce no failure of the fastening system.

10.9.1.11 Fastening Repeated Load

As shown in Figure 5 downward and upward forces will be applied at an angle of 20^{o} to the vertical axis of the rail at a rate not to exceed 300 cpm for 3 million cycles. The magnitude of the upward load shall be 0.6 P where "P" is 10,000 lb. Springs will be used to generate the upward load, so therefore the downward load shall be 30 kips plus 0.6 P.



TIE CENTER NEGATIVE MOMENT TEST FIGURE II



TIE CENTER POSITIVE MOMENT TEST FIGURE III

Figure 4-Showing typical set-ups for tie center positive and negative moment tests as taken from AREA Bulletin 655.

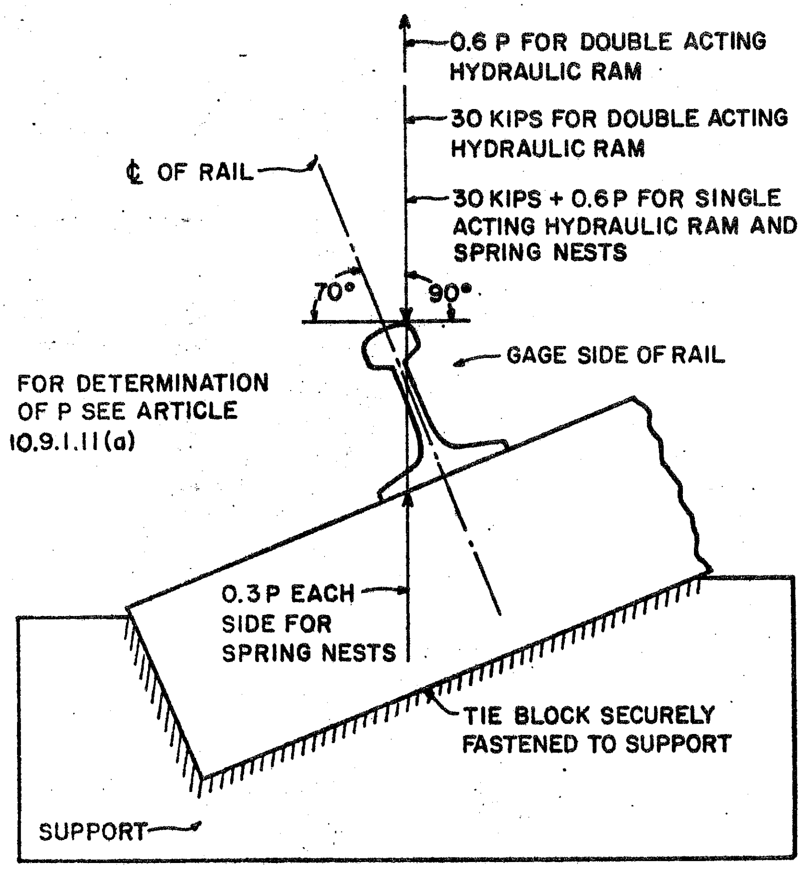


FIGURE VI FASTENING REPEATED LOAD TEST

Figure 5-Showing typical set-up for fastener repeated load test as taken from AREA Bulletin 655.

10.9.1.12 Fastener Longitudinal Restraint

Using same tie and fasteners from repeated load test a load in 500 lb. increments will be applied to the rail at the base until 3700 lb.* is reached. This is a maximum value for a maximum tie spacing (30 inch). This load shall be held for 15 min. with slippage measured after the first 3 min. and after 15 min. The test will be repeated pushing in the opposite direction.

*Load figure is derived from temperature expansion of rail (force) versus number of rail fasteners per given distance (tie spacing).

10.9.1.14 Electrical Impedance

Immerse tie (with fasteners and rails) in water for six hours, drain for one and then measure impedance across the two rail using an a-c 10 volt, 60 Hertz potential for a period of 15 min.

TEST RESULTS

10.9.1.4 Rail Seat Vertical Load (Negative)

Following table shows these test results as force applied to the tie, the bending moment and deflection to ultimate:

Force applied		Bending moment		Deflection	
kips	Newtons	In. kips	Nm	Inches	mm
5	22240	29.18	3297	-	-
10	44480	58.35	6592	.0105	.2667
15	66720	87.53	9889	.029	.7366
20	88960	116.70	13185	.042	1.0668
25 (1st crack)	111200	145.88	16482	.065	1.651
37 (2nd crack)	164576	215.89	24391	-	-
39.4 (ultimate)	175251	229.90	25974	-	-

10.9.1.4 Rail Seat Vertical Load (Positive)

10.9.1.8 Ultimate and Tendon Anchorage

Following tables show these test results as force applied to the tie, the bending moment, deflection to ultimate and tendon slippage:

WITHOUT TIE PLATE

Force applied		Bending moment		Deflection		Tendon slippage	
kips	Newtons	In. kips	Nm	Inches	mm	Inches	mm
5	22240	31.05	3508	.0395	.991	0	0
10	44480	62.10	7016	.0395	.991	0	0
15	66720	93.15	10524	.096	2.438	.0005	.0127
20	88960	124.20	14032	.0975	2.477		
25	111200	155.25	17540	.0995	2.527		
30	133440	186.30	21048	.1065	2.705		
35	155680	217.35	24556	-	-		
40	177920	248.40	28068	-	-		
44 crack on both sides - 3½ in. long	195712	273.24	30871	-	-	.0005	.0127
						No Ultimate	

WITH TIE PLATE

Force applied		Bending moment		Deflection		Tendon slippage	
kips	Newtons	In. kips	Nm	Inches	mm	Inches	mm
5	22240	31.05	3508	0	0	0	0
10	44480	62.10	7016	0	0		
15	66720	93.15	10524	0	0		
20	88960	124.20	14032	.0025	.0635		
25	111200	155.25	17540	.0075	.1905		
30	133440	186.30	21048	.013	.3302		
35	155680	217.35	24556	.018	.4572		
40	177920	248.40	28068	.0275	.6985		
45	200160	279.45	31572	.0375	.9525		
50 two cracks on both sides - 4 in. long	222400	310.50	35080	.057	1.4478	0	0
55.5	246864	344.66	38939	-	-	Ultimate	

Following Figures 6, 7 and 8 are photographs of actual set-ups used in performing the Rail Seat Positive and Negative moment, Ultimate and Tendon Slippage tests:

10.9.1.5 Rail Seat Repeated Load (with Tie Plate)

Using the set-up as shown in Figure 3 of this report, load was applied until bottom of tie cracked up to the bottom reinforcement at 38 kips (169 kN). Load was then increased to the value of 1.1 P or 42,000 lb. (187 kN) and dynamically cycled for 3 million times. Tie continued to take this load, which is the calculated U. S. load, for the duration of test.

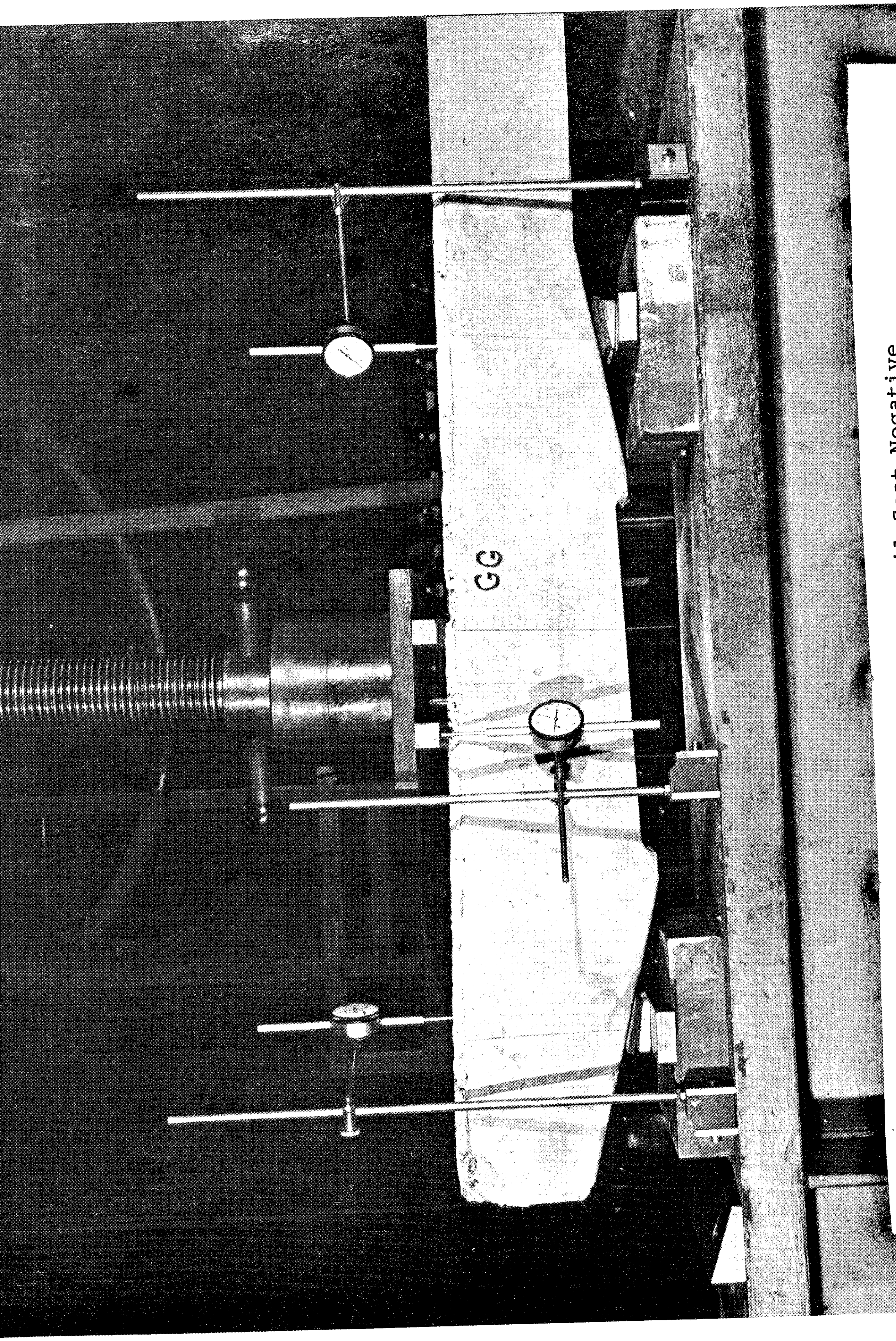


Figure 6-Set-up for performing Rail Seat Negative Moment test.

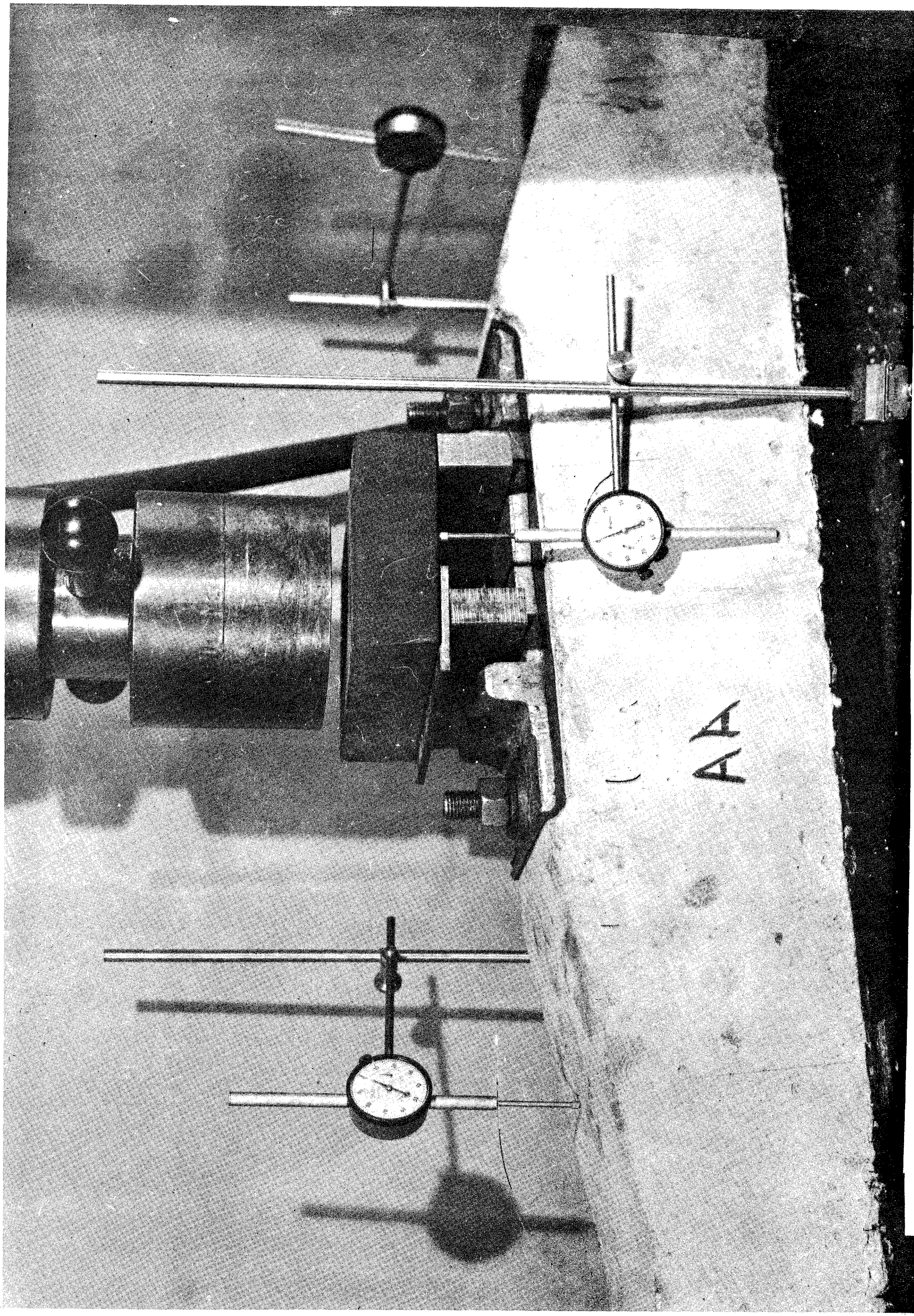


Figure 7-Set-up for performing Rail Seat Positive Moment test and ultimate.

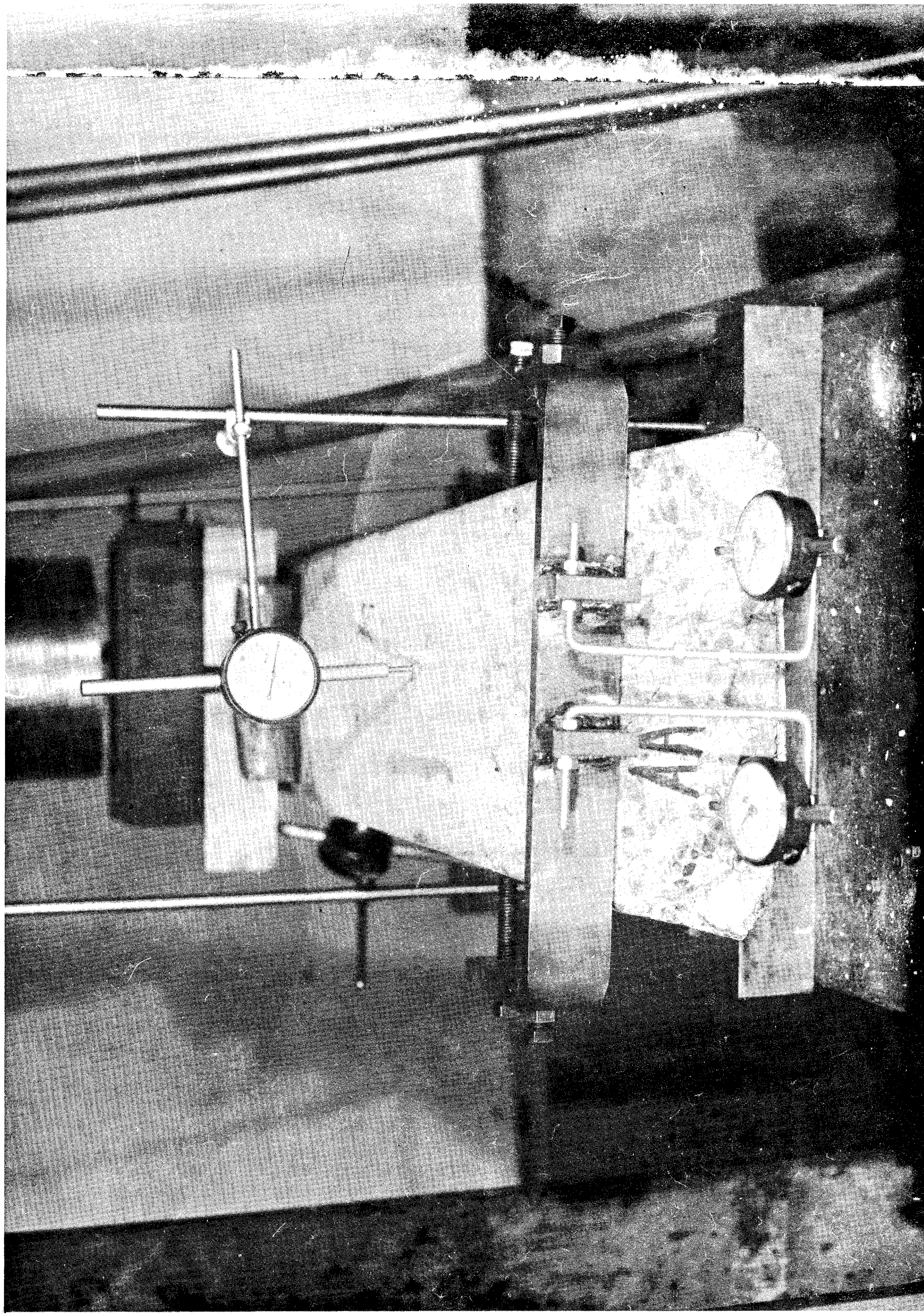


Figure 8-Set-up for measuring tendon anchorage during Rail Seat Positive Moment test.

Because Soviet "P" load 27,686 lb. (123 kN) differs from U. S. "P" load, 38,220 lb. (170 kN), the repeated load was first run using the U. S. load and because the tie did not fail, further testing using Soviet load was not necessary. The 38,220 lb. (170 kN) figure was derived as following:

From AREA Bulletin 655 the U. S. rail seat load for 21 inch (Russian) tie spacing is 48,150 lb. (214 kN) times two rails is 96,300 lb. (428 kN) per tie. Tie length of 9 ft. (108 inch) (2743 mm) divided into 96,300 equals 891.67 lb. (3966 N) load per inch of tie.

$$M = \frac{W\ L^2}{2}$$

Where M = Moment at rail seat

W = Vertical load per inch of tie

L = Distance from rail center line to tie end

$$M = \frac{891.67 \times 22'' \times 22''}{2} = 215{,}784 \text{ in.lb. } (24.4 \text{ kN-m})$$

To the 215,784 in.lb. is added ten percent of this figure as a factor of safety. This was done in calculating values in Table 1 of the Bulletin. Final figure is 237,362 in.lb. (26.8 kN-m).

Finally the "P" value is found as follows:

$$P = \frac{2M}{(2x/3-2.25)}$$

Where M = Bending moment in inch pounds

x = Distance from rail seat center line to end of tie

2.25" is half the distance between support blocks on rail seat

$$P = \frac{2 \cdot 237{,}362 \text{ in.lb.}}{2 \cdot 22 \text{ in.}/3-2.25 \text{ in.}} = 38{,}220 \text{ lbs. } (170 \text{ kN})$$

$$1.1\ P = 42{,}000 \text{ lb. } (187 \text{ kN})$$

Upon disassembling the test set-up it was discovered that the steel tie plate had broken in half in the rail base seat area as shown in the following photograph labeled Figure 9.

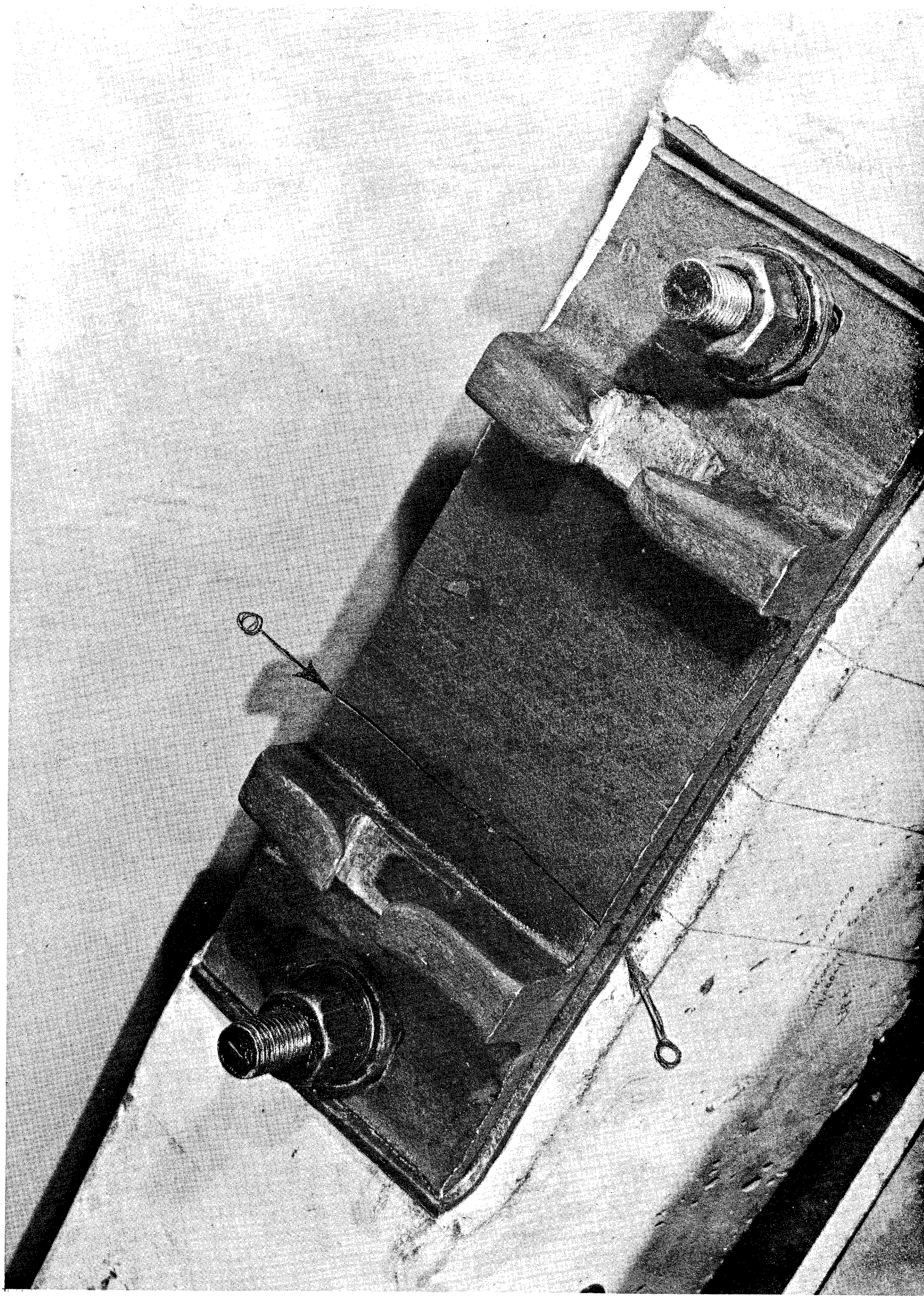


Figure 9-Arrows indicate location of break in the tie plate discovered after the dynamic rail seat test.

10.9.1.6 Negative Bending Moment (Tie Center)

A tie was set-up as in Figures 4 and 10 and subjected to a vertical load to determine the "P" value and then continued to ultimate. Following table shows load and deflection:

Force applied		Bending moment		Deflection	
kips	Newtons	In. kips	Nm	Inches	mm
5	22240	71.88	8121	.161	4.09
10	44480	143.75	16241	.315	8.00
light cracking					
11	48928	158.15	17868	.356	9.04
12	53376	172.50	19489	.417	10.59
13	57824	186.90	21116	.473	12.01
15	66720	215.65	24364	Ultimate	

The value of "P" is 10,000 lb. (44.5 kN) or 143,750 inch-lbs. (16241 Nm).

10.9.1.7 Positive Bending Moment (Tie Center)

A tie was set-up as in Figure 4, bottom, and subjected to a vertical load to determine the "P" value and then continued to ultimate. Following table shows load and deflection:

Force applied		Bending moment		Deflection	
kips	Newtons	In. kips	Nm	Inches	mm
4	17792	57.50	6496	.165	4.19
light cracking					
5	22240	71.88	8121	.188	4.78
6	26688	86.25	9745	.212	5.38
7	31136	100.65	11371	.237	6.02
11.6	51597	166.75	18839	Ultimate	

The value of "P" is 4,000 lb. (17.8 kN) or 57,500 inch-lbs. (6496 Nm)

10.9.1.10 Fastener Uplift Test

Figure 11 shows the method of testing the integrety of the tie plate "hold down" bolt. This bolt is dropped into a molded slot in the crosstie and then quarter turned to lock it in place. A maximum of 10 kips (44.5 kN) upward was applied without failure.

10.9.1.11 Fastening Repeated Load

A tie section and rail fastening system were installed under a pulsating jack as shown in Figure 12. The preload springs shown in that figure are compressed to .6P (P is 10,000 lb. taken from Fastener Uplift Test). Downward force on the rail head is

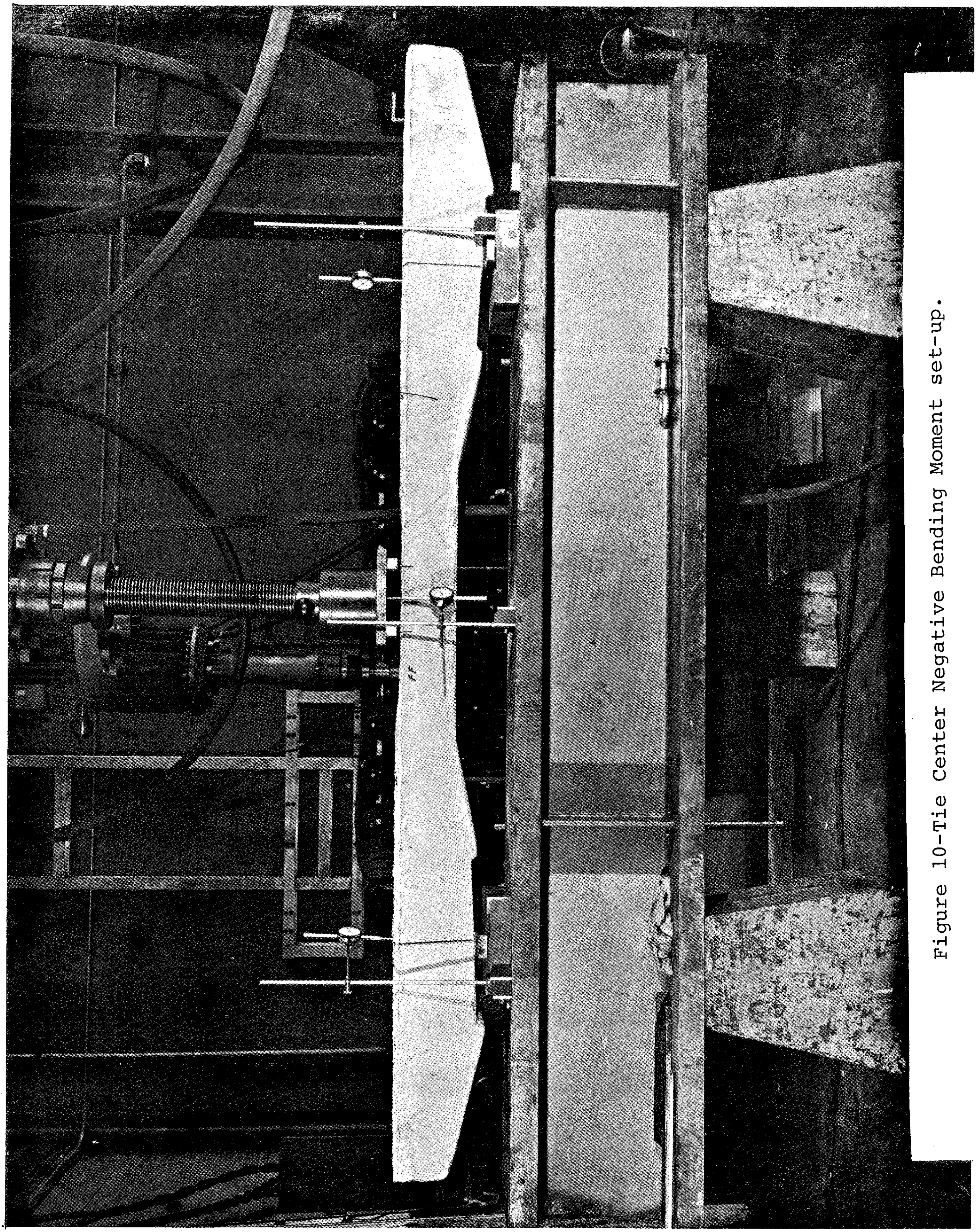


Figure 10-Tie Center Negative Bending Moment set-up.

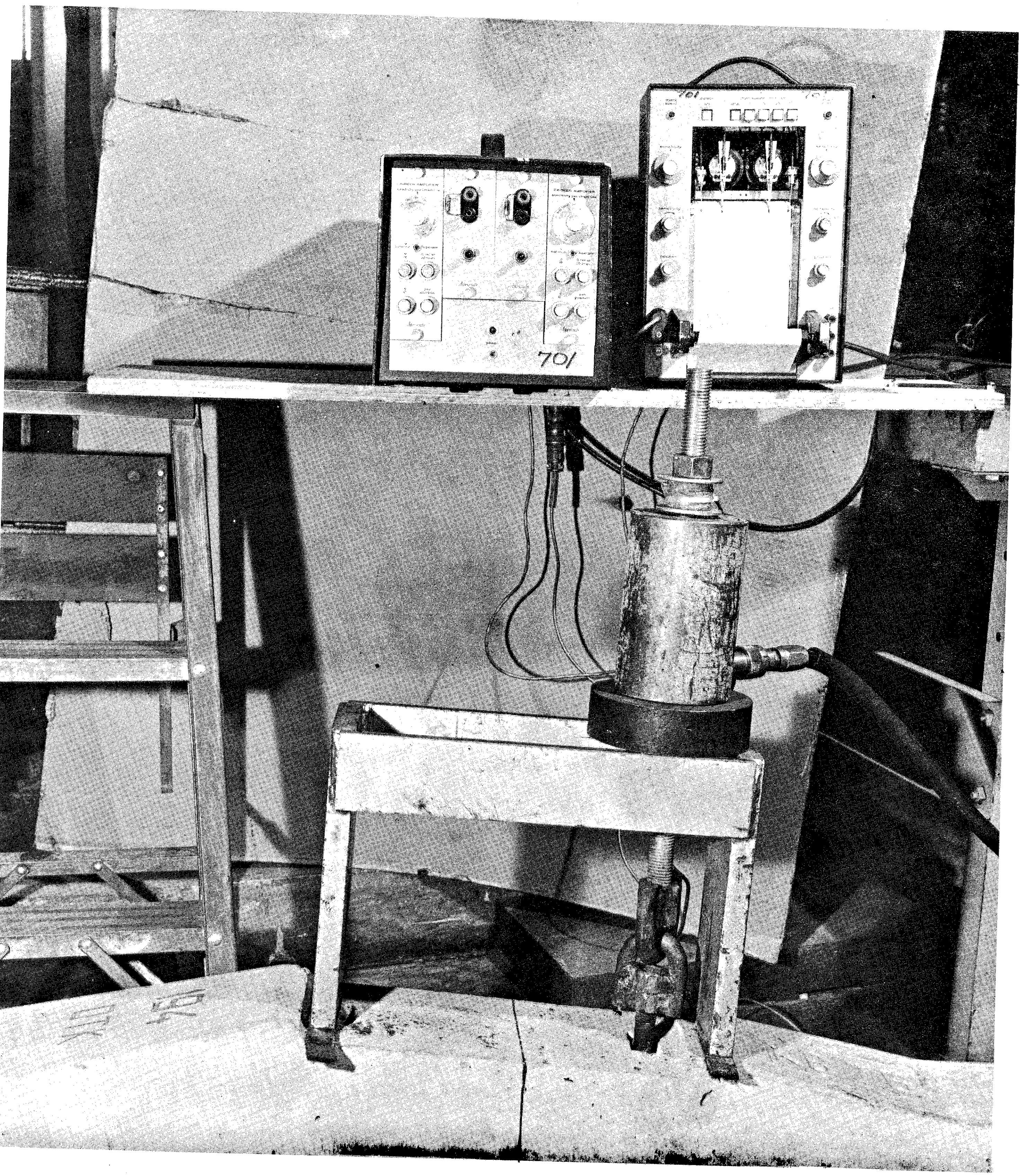


Figure 11-A maximum upward force of 10 kips being applied to the Tee headed tie plate bolt positioned in the tie.

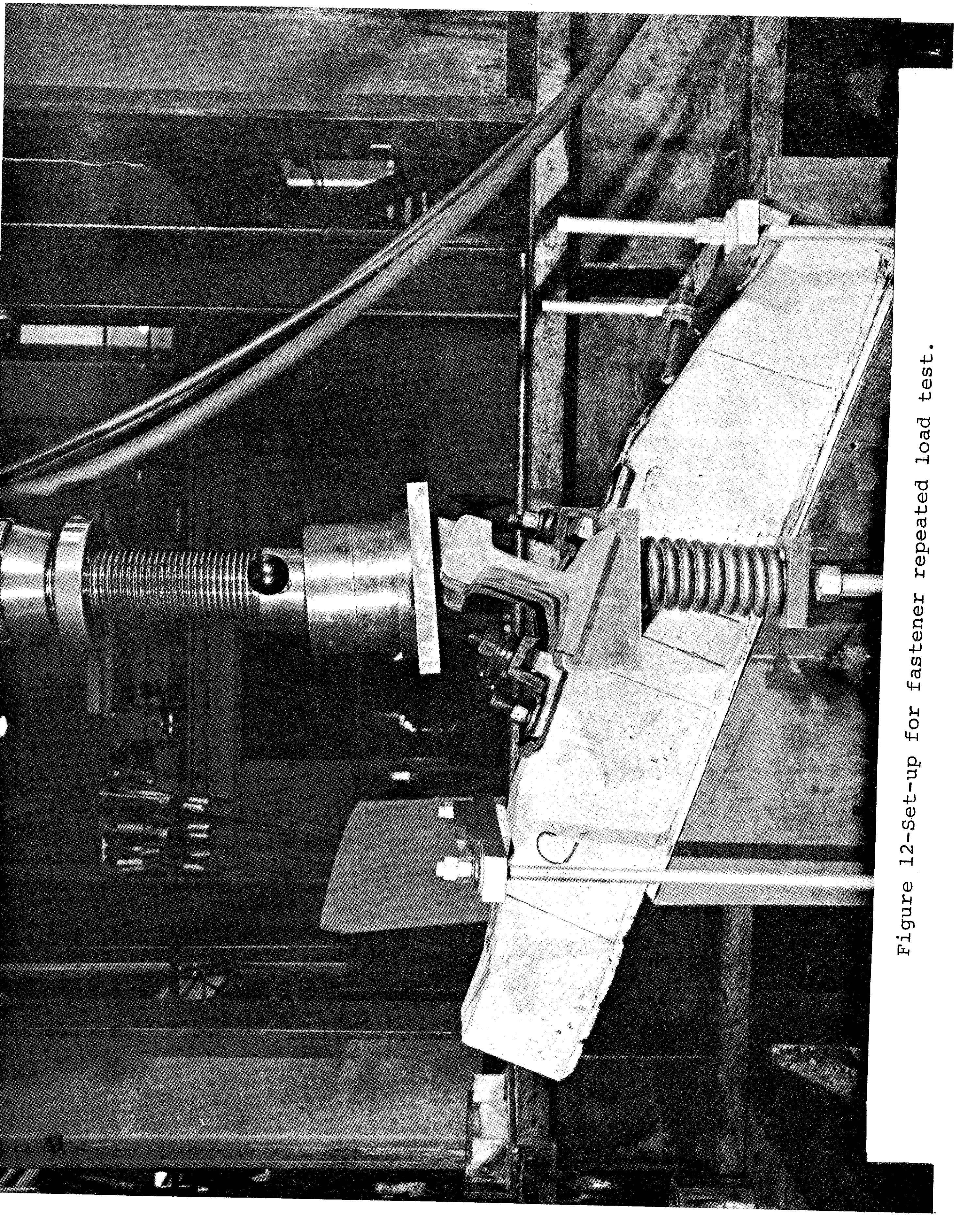


Figure 12-Set-up for fastener repeated load test.

30,000 lb. (133.4 kN) plus .6P for a total of 36,000 lb. (160.1 kN). This 30,000 lb. force was calculated on the basis of U. S. loads. Jack was operated at 250 cpm for 584,700 cycles at which time a broken tie-tie plate hold down bolt was discovered on the low side (see Figure 13). Forces, both springs and jack were then reduced to Soviet values, 4400 lb. (19.6 kN) spring load and 26,300 lb. (116.98 kN) jack load. Jack was operated at 250 cpm for 918,673 cycles at which time a broken tie-tie plate hold down bolt was discovered in the same location as the first test. The fastener test was then discontinued.

Bolts were only tightened at the start of each test and to 150 ft. lb. of torque which is equivalent to the Soviet specified 21 kg-m torque.

10.9.1.12 Fastener Longitudinal Restraint

Figure 14 of this report shows the test set-up for applying load longitudinally to the rail. Upon reaching 3700 lb. (16.5 kN) which is the maximum for 30 inch (762 mm) tie spacing, the rail and tie section were turned end for end and the same load was applied in the opposite direction. Following tables show slippage at each 500 lb. load increment. Maximum force if 21 inch (Soviet) tie spacing were used would be 2600 lb. (11.6 kN).

FASTENER LONGITUDINAL RESTRAINT

Applied Load lbs.	Newtons	Displacement in.	Displacement mm
500	2224	.001	.025
1000	4448	.003	.076
1500	6672	.004	.102
2000	8896	.005	.127
2500	11120	.006	.152
3000	13344	.008	.203
3500	15568	.010	.254
3700 (0 minutes)	16458	.011	.279
3700 (3 minutes)	16458	.013	.330
3700 (15 minutes)	16458	.014	.356
0		.006	.152

REVERSE DIRECTION

Applied Load lbs.	Newtons	Displacement in.	Displacement mm
500	2224	0	0
1000	4448	.001	.025
1500	6672	.0015	.038
2000	8896	.002	.051
2500	11120	.003	.076
3000	13344	.005	.127
3500	15568	.006	.152
3700 (0 minutes)	16458	.007	.178
3700 (3 minutes)	16458	.010	.254
3700 (15 minutes)	16458	.011	.279
0		.007	.178

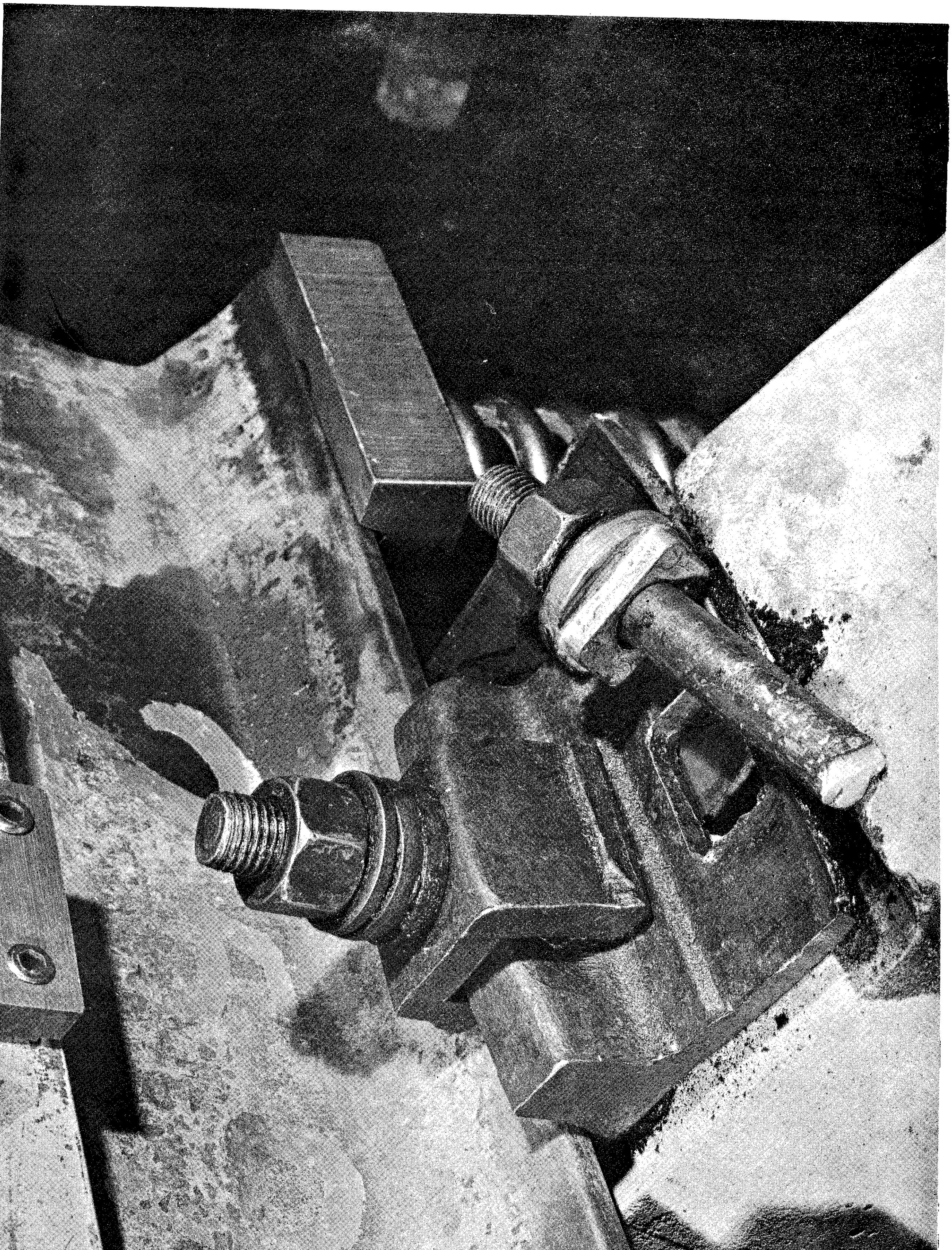


Figure 13-Broken bolt found at 584,700 cycles of the Fastener Repeated Load test.

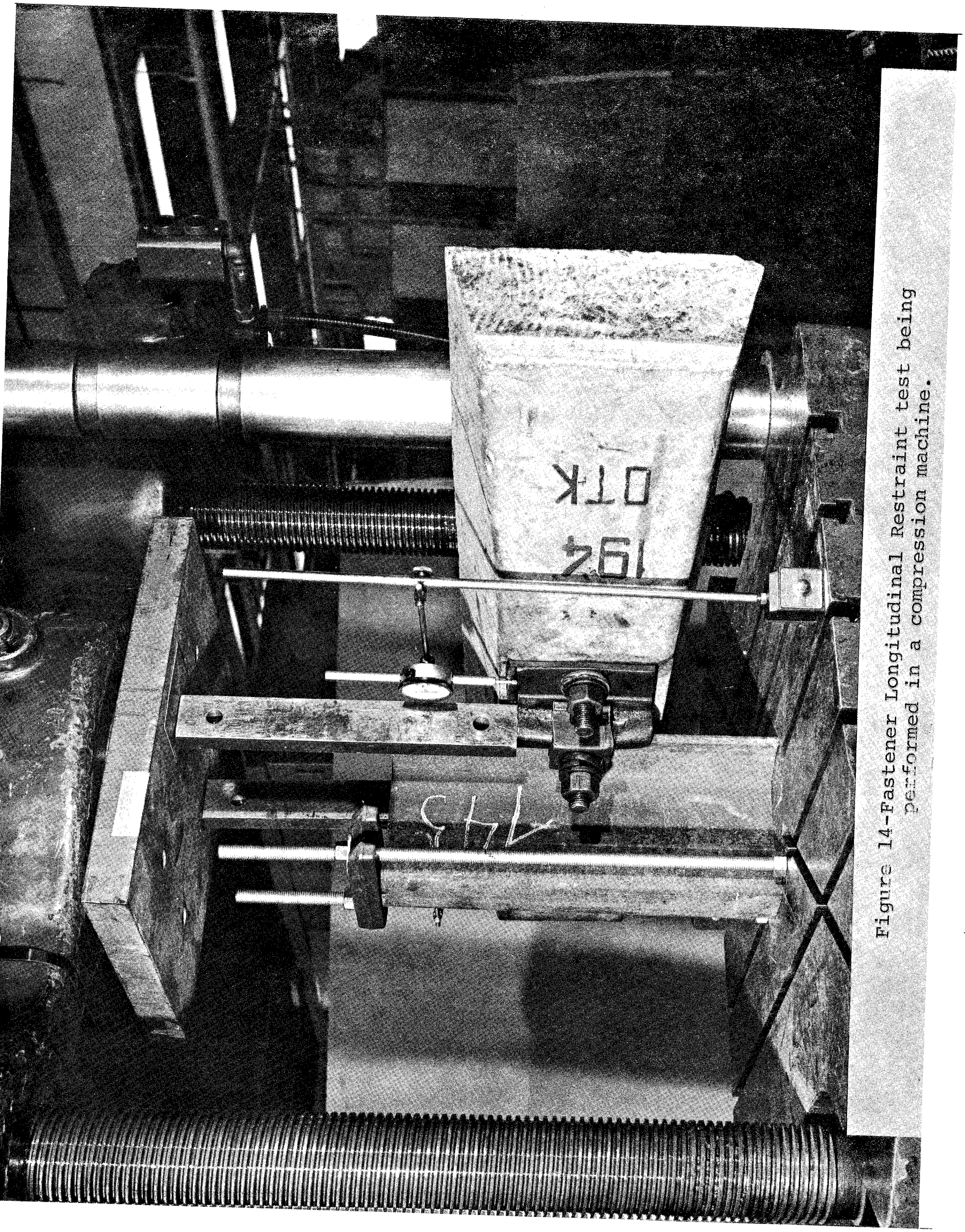


Figure 14-Fastener Longitudinal Restraint test being performed in a compression machine.

10.9.1.14 Electrical Impedance

One full tie with two fastening systems and short rail sections was immersed in water for six hours, allowed to drain for one hour. The electrical resistance was then measured across the rail heads and was found to be 131,000 ohms using an applied voltage of 10 volts A.C. (60 hertz).

CONCLUSIONS

Rail Seat Vertical Load (Negative)

First crack in tie developed at 25,000 lb. (111.2 kN) which is considered load "P". From this the bending moment (flexural capacity of the tie) is calculated to be 145,880 inch-lb. (16482 Nm).

Rail Seat Vertical Load (Positive)

Without the steel tie plate first crack in tie developed at 44,000 lb. (195.7 kN) which is considered load "P". From this the bending moment (flexural capacity of the tie) is calculated to be 273,240 inch-lb. (30871 Nm).

With the steel tie plate first crack in tie developed at 50,000 lb. (222.4 kN) which is considered load "P". From this the bending moment (flexural capacity of the tie) is calculated to be 310,500 inch-lb. (35080 Nm).

Negative Bending Moment (Tie Center)

First crack in tie developed at 10,000 lb. (44.5 kN) which is considered load "P". From this the bending moment (flexural capacity of the tie) is calculated to be 143,750 inch-lb. (16241 Nm).

Positive Bending Moment (Tie Center)

First crack in tie developed at 4,000 lb. (17.8 kN) which is considered load "P". From this the bending moment (flexural capacity of the tie) is calculated to be 57,500 inch-lb. (6496 Nm).

Ultimate and Tendon Anchorage

Rail seat ultimate was performed with steel tie plate in place. Final load was 55,500 lb. (246.9 kN). No tendon slippage was detected during incremental loading to ultimate.

Fastener Uplift Test

A total upward force of 10,000 lb. (44.5 kN) was applied to the tie-tie plate bolt, which was attached to the tie, without failure.

Fastening Repeated Load

This test was performed using U. S. and Soviet "P" loads. In both tests tie-tie plate hold down bolt broke before completion of the tests.

Rail Seat Repeated Load (with Tie Plate)

This test was run to completion (3 million cycles) using U. S. "P" load without tie failure. However steel tie plate was found to be cracked entirely through the rail base seat after completion.

Fastener Longitudinal Restraint

Total permanent slippage at 3700 lb. (16.5 kN) was .006 inch (.152 mm) in either direction. Slippage during the 3 minute hold at 3700 lb. was .002 inch (.051 mm) and at 15 minute hold was an additional .001 inch (.025 mm).

Electrical Impedance

Resistance across rail heads after being immersed in water was 131,000 ohms.

Manager-Test Division

Printed and distributed by the Association of American Railroads, Chicago, Illinois.

ANSI CONVERSION TABLE
(Taken From ASTM E-380)

To Convert From	To	Multiply By
Inch (in)	Metre (m)	2.540 000 E-02
Pound-Mass (lbm Avoirdupois)	Kilogram (Kg)	4.535 924 E-01
Pound-Force (lbsf)	Newton (N)	4.448 222 E+00
Pound-Force-Inch	Newton-Metre (Nm)	1.129 848 E-01

ABBREVIATION DESCRIPTIONS

in.	inch
lb.	pound
ft.-lb.	foot pound-force
kips	1,000 pounds
cpm	cycles per minute
min.	minute
a-c	alternating current
Hertz	cycles per second