TIGHTENING PROCEDURE

HSFG BOLTS

Bharat Heavy Electricals Limited

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INTRODUCTION

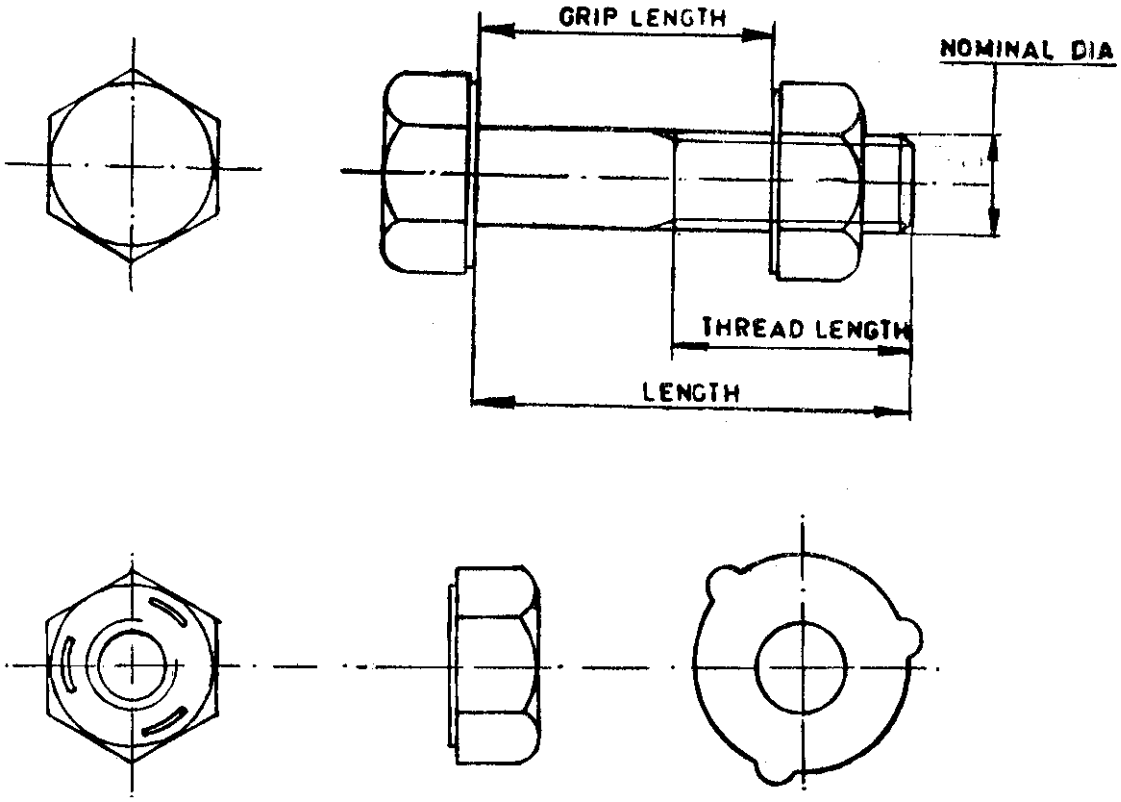
The use of High Strength Friction Grip bolts in Structural connections has several important advantages over conventional bolted and riveted joints. The HSFG bolted structural joints can have rigidity comparable to welded joints with less number of bolts as against ordinary bolted or riveted connections.

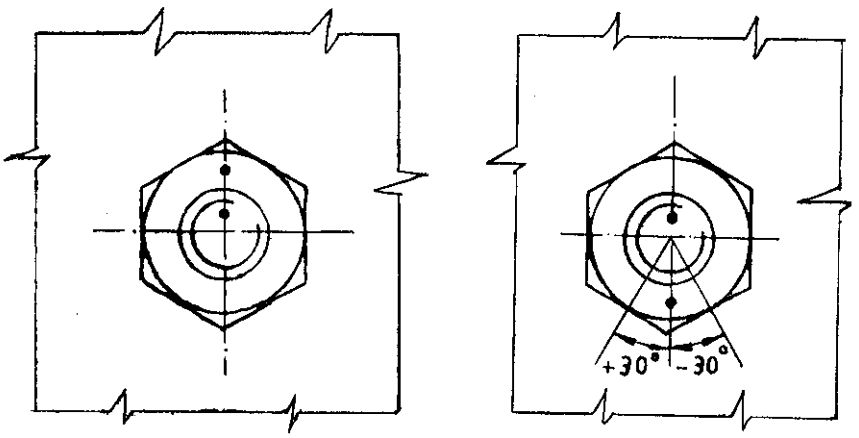
Unless the HSFG bolts are tightened to the required minimum shank tension or the clamping force, the designed strength of the connection will not be achieved.

This manual describes the method of tightening of High Strength Friction Grip bolts to the required minimum Shank Tension by PART TURN METHOD. An illustrative example is given in the annexures to explain the salient features of the tightening and inspection of a HSFG bolted joint

Any suggestion towards the improvement of this manual would be most welcome.

H. S. F. G. BOLT, NUT AND WASHER





1-A

AFTER SNUG TIGHTENING

1-B

AFTER FINAL TIGHTENING

Fig. 1 HSFG BOLT, NUT AND WASHER

TIGHTENING PROCEDURE FOR HSFG BOLTS

1. INTRODUCTION

In a friction grip joint, force is transferred by virtue of the friction between interfaces. To develop this friction, a normal load is applied to the joint by using high strength bolts **Tightened to Proof Load.**

1.1 The Friction Grip Principle, therefore, depends on tightening each high strength friction grip bolt (HSFG Bolt) to a **Minimum Shank Tension,** so that the specified clamping force on the components being joined shall be induced and thus enabling the applied load being transferred by friction between the joint faces rather than relying on the shear strength of the bolts. A high strength bolted joint is about $3\frac{1}{2}$ times safer than the comparable ordinary bolted joint.

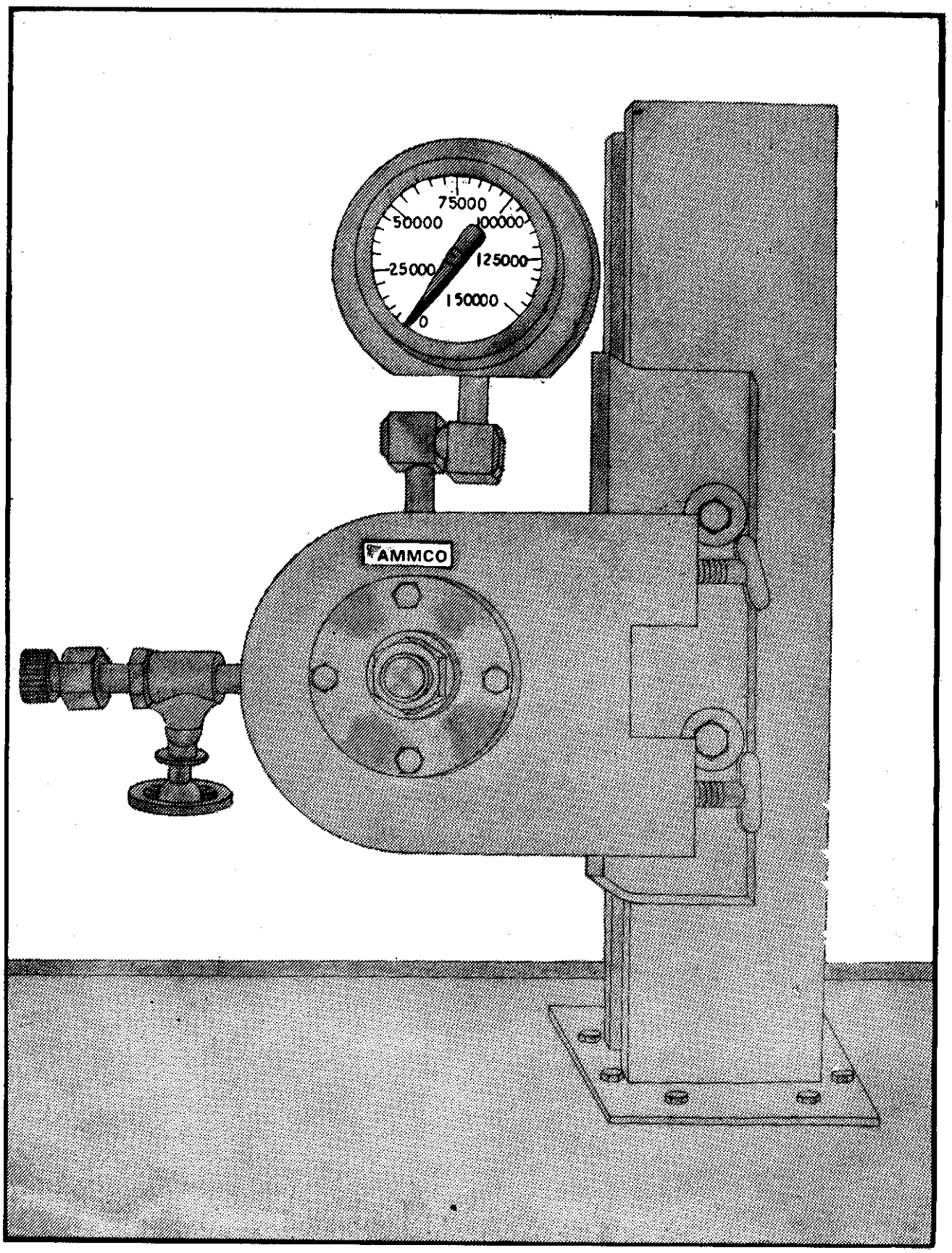


FIG. 2 BOLT TENSION CALIBRATOR

This is a hydraulic instrument which measures the actual bolt tension developed by tightening the bolt or nut. Pressure is transmitted through the hydraulic fluid to the specially calibrated gauge which indicates bolt tension directly in Kgs./Pounds.

Figure shows the calibrator clamped to the beam, column or a special fixture which should be rigid enough to withstand the torque developed.

2. THE TOOLS AND EQUIPMENTS

Although it is feasible to tighten High Strength Friction Grip Bolts by the use of manual wrenches alone, it will be most difficult to obtain sufficient torque. Erection is slow and costly, and results are generally unsatisfactory.

2.1 **Impact Wrenches :** Use of Standard Impact Wrench is suggested for all High Strength Friction Grip Bolting. Adequate wrenches are now available for M 24 bolts which are the ones normally used. In selecting an Impact Wrench, it is wise to choose one which has a torque output in excess of the theoretical figure required for tightening, thus making some allowance for loss of performance due to wear, air leakage, etc. and to help overcome the energy absorbed by higher than usual thread friction or " springy " joints.

Wrench sockets should be marked on the outer periphery each 90 degrees – by alternate single and double lines – to enable the operator to easily measure nut rotation.

2.2 **Torque control pneumatic impact wrenches :** Many erectors still use torque-control pneumatic Impact Wrenches. These wrenches can be used to tighten by the Turn-of-Nut method by simply eliminating the torque cut-off device. If the user prefers to use the torque cut-off, it is essential that continual testing be done on a Bolt-Tension Calibrator to check and recheck the proper torque requirement for each lot and diameter of bolts.

Suitable Impact Wrenches should perform the required tightening of each bolt in approximately 10 seconds. If they do not, then check for —

- Damaged or dry bolt and nut threads
- Poor fit of joint plies
- Bad alignment of holes causing bolt to trap
- Insufficient quantity and/or pressure of air supply
- Any restrictions or leaks on air line
- Excessive length of air line
- Blockage of gauge filter at tool air inlet.

If the tool is sluggish, it must be blown through with paraffin to clear it and then relubricated with light oil SAE 510.

A good source of Impact Wrenches is

M/s. Ingersoll-Rand Company, Tool & Hoist Division
28, Kennedy Boulevard, East Brunswick, N. J. 08816, USA

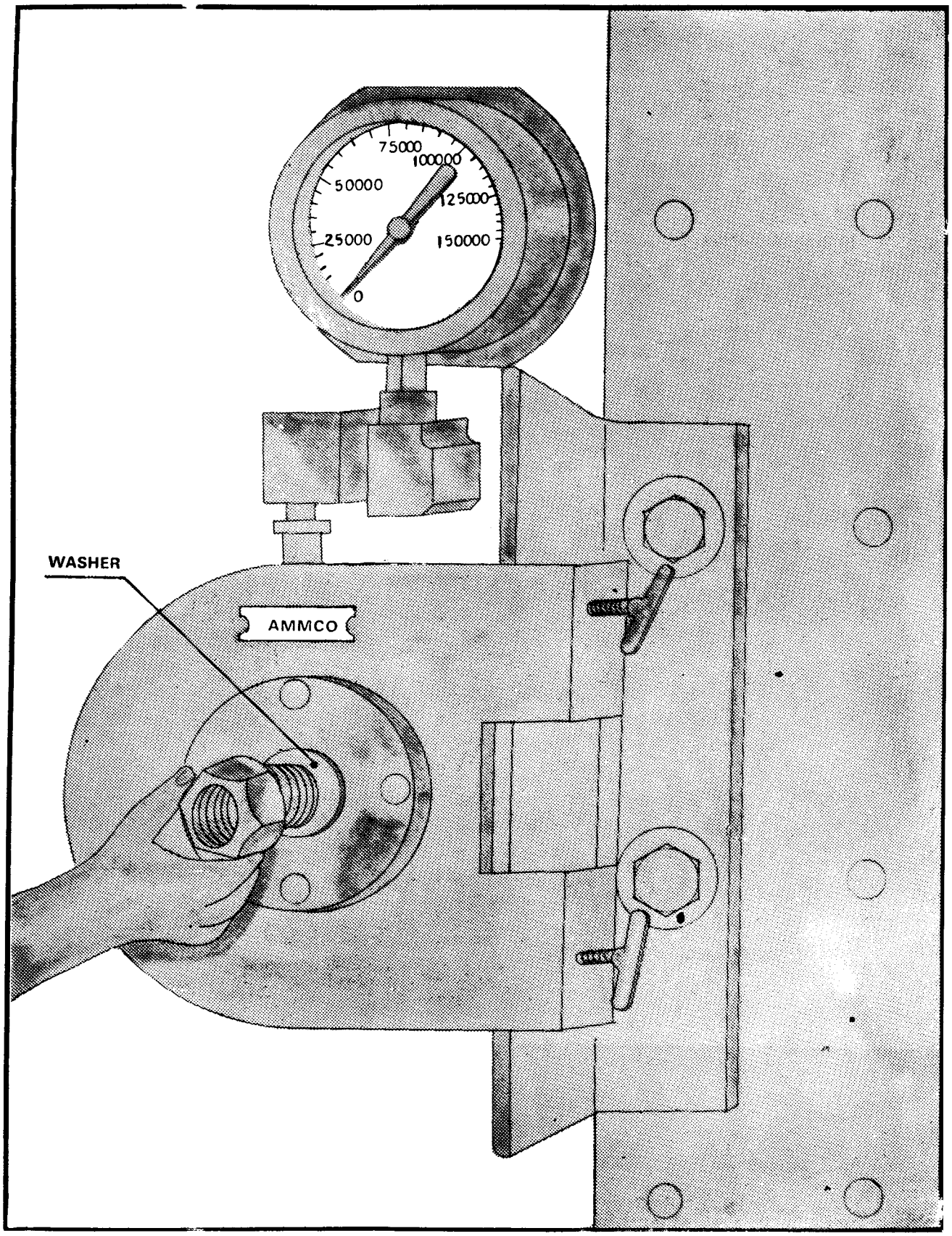


FIG. 3

If the nut is to be torqued the bolt is inserted from the rear. A hardened washer should then be placed under the nut. When the nut has been 'run' on to the bolt as far as possible by hand, calibration may proceed. The procedure is illustrated for a M 24 bolt to specification BS 4395 Part-1

It is recommended to use the following Impact Wrench for tightening High Strength Friction Grip Bolts :

Impact Wrench Model No. 2934 B2

Equipment	Weight Less Socket Kg.	Length mm	Rated Capacity Bolt Size	
			Bolt Grade B. S. 4395	Dia mm
Inside Trigger	8.4	286	Part 1	27
1" Sq. drive			Part 2	24

3 **Energy :** The ideal source of energy is compressed air. Most of the erectors have access to compressed air for use with the equipment. Most pneumatic wrenches require 1 cu. metre/min. (35 cu. ft./min.) at a pressure of 690 KN/sq. m. (100 lbs/sq. in) for optimum performance. To maintain this a $\frac{3}{4}$" hose dia is usually required from the compressor reducing valve to the wrench keeping the line as short as possible and normally not more than 3 metres. When a large number of wrenches are used, an auxiliary air receiver should be operated to maintain adequate pressure.

2.4 **Manual Torque Wrenches :** If manual torque wrenches are proposed to be used, there are many makes of adjustable presetting and break-back types available in the market but none is available for output torques of more than 1000 lb.ft. Therefore, for tightening High Strength Friction Grip Bolts of size M24, if normal torque wrenches are to be used, these are to be used along with 5:1 Torque Multipliers. The following Torque Wrenches and Torque Multipliers are recommended :

A. Torque Wrench :

Torque Wrench Model No.5R

Torque Range lb-ft.	Length mm	Weight Kg.	Square Drive Size
300-750	1470	7.3	$\frac{3}{4}$"

B. Torque Multiplier :

Highwayman Torque Multiplier Model No.3 having the following specifications :

Velocity Ratio	...	5.33 : 1
Multiplication Factor	...	5 : 1
Efficiency	...	94% app.
Max. out	...	1250 lb-ft.
Input drive	...	1.5/16" A/F male hexagon female $\frac{1}{2}$" sq drive
Output drive	...	$\frac{3}{4}$" sq.

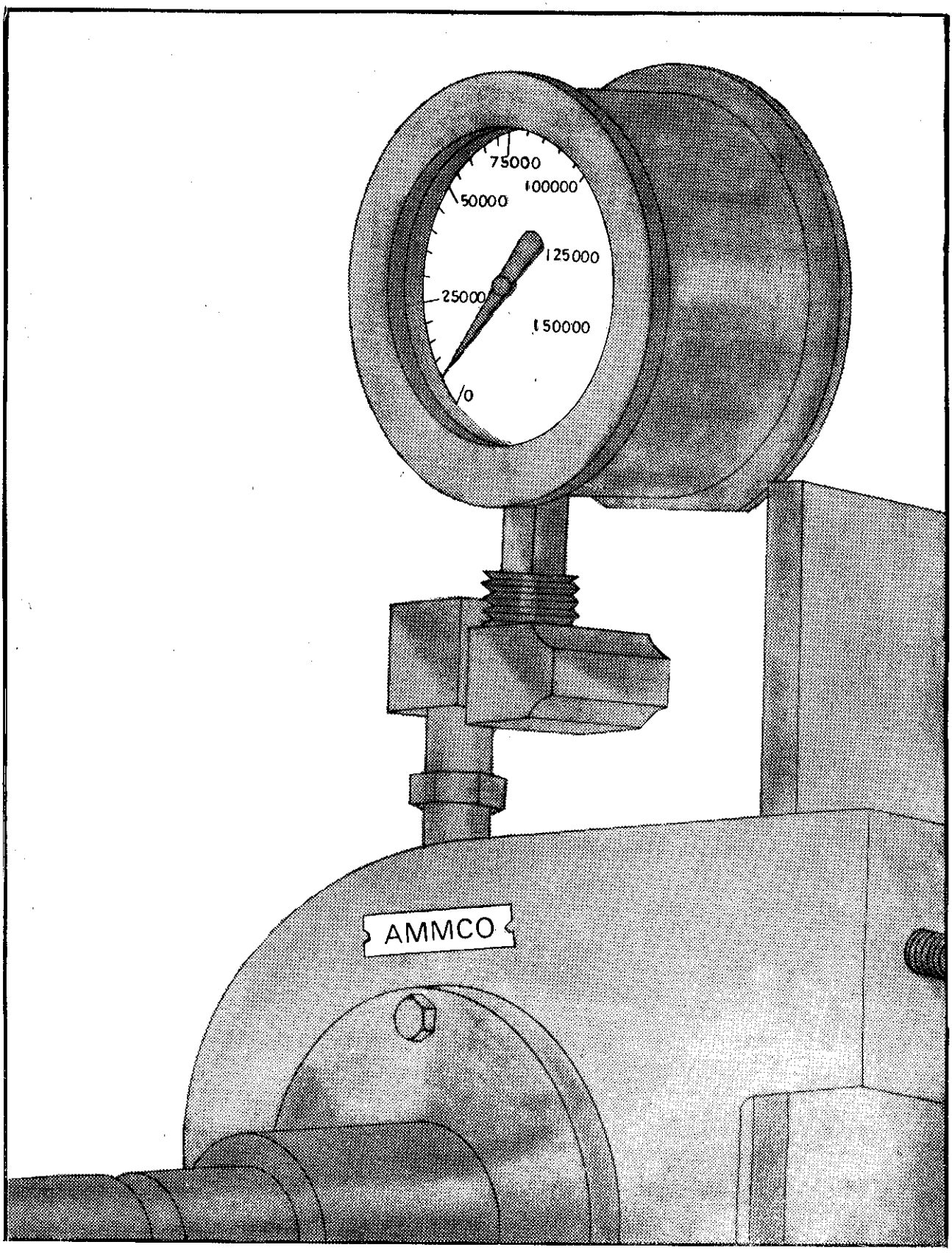


FIG. 4

SNUG TIGHTENED CONDITION

First the operation of the wrench shouldbe checked by tightening the nut to sung condition. The dial indicates 'Snug' as being approximately 5000 lb. But normal 'Snug' may be as high as 10,000 lb.

The Torque wrench and Multiplier can be obtained from :

M/s. Norbar Torque Tools Ltd
Swan Close, Banbury, Oxon, Great Britain.

2.5 **Bolt-Tension Calibrators**: (See Fig. 2) Bolt-Tension Calibrator is a portable tool which is used at the erection site to calibrate all types of wrenches to ensure that correct bolt tension is achieved on tightening. This is a hydraulic instrument which measures the actual bolt tension created by tightening the nut. There are several models in the market but the most popular one is

Bolt-Tension Calibrator Model No. ML-104 marketed by

M/s. Skidmore-Wilhelm Manufacturing Co
442 South Green Road, Cleveland, Ohio 44121 USA

This model can measure bolt tensions between 6.8 tonnes and 49.90 tonnes and thus, is suitable for all sizes of High Strength Friction Grip Bolts upto and including M30.

NOTE : It is very important to be noted that no erector should proceed with the High Strength Friction Grip Bolting for steel structure unless this Bolt Tension Calibrator is available at erection site and put to proper use.

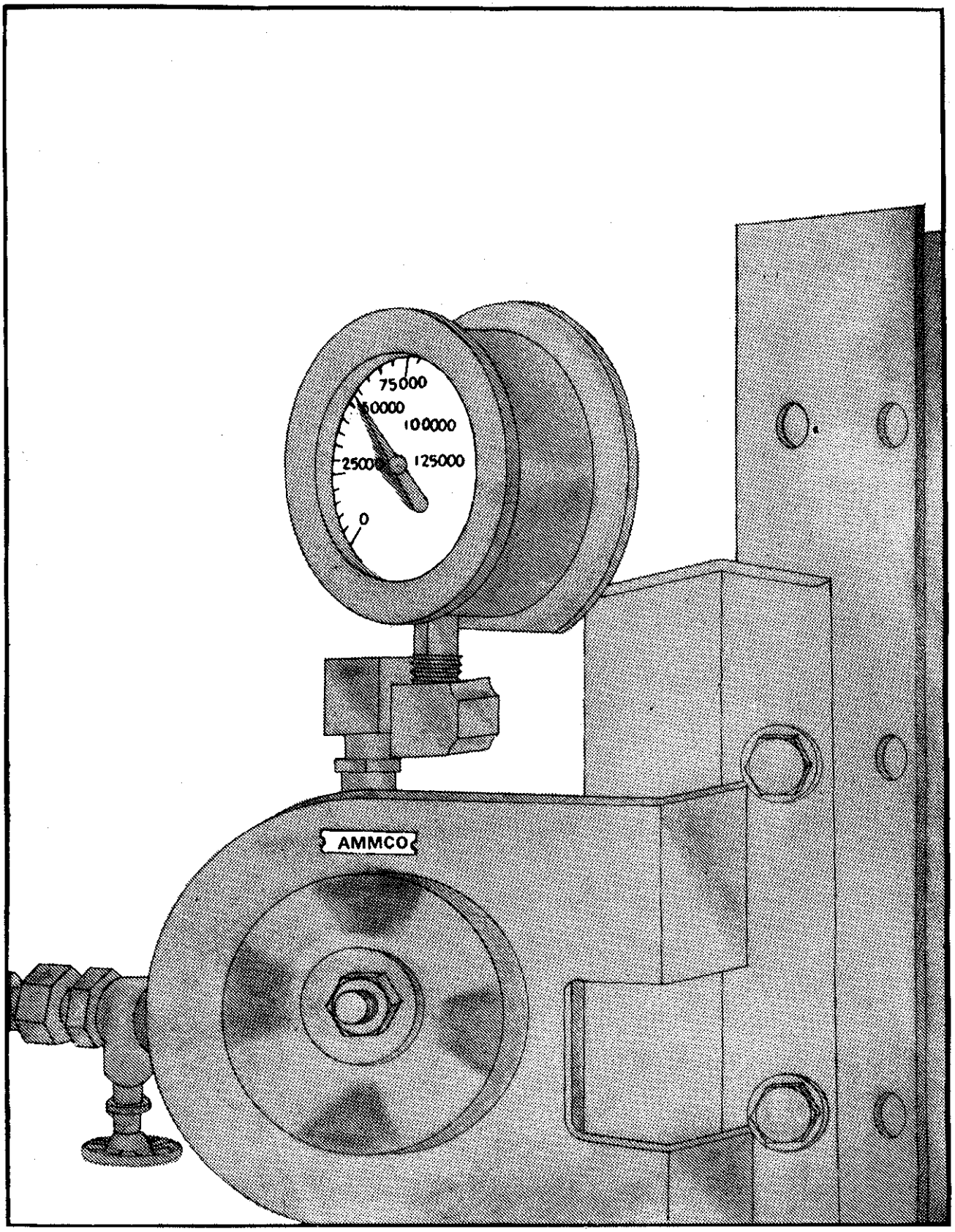


Fig. 5

TIGHTENED TO MIN. SHANK TENSION

Figure shows the dial after the operator has torqued from 'Snug' to the required minimum tension marked on the dial as 51,000 lb. (21 tonnes).

3. TIGHTENING PROCEDURE FOR HIGH STRENGTH FRICTION GRIP BOLTS

High Strength Friction Grip Bolts must be tightened to a minimum proof load specified in specifications. These are minimum loads and the bolts are deliberately tightened into the plastic range.

3.1 Recommended bolt tensions for M24 Bolts to B.S.4395 : Part 1 :

Minimum bolt tension	...	212 KN (21.6 Tonnes)
Bolt tension for setting inspection wrenches	...	218 KN (22.2 Tonnes) (105%)
Approximate equivalent Torque for the required Min. bolt tension	...	Average 680 ft.lbs.

3.2 Methods of tightening High Strength Friction Grip Bolts :

i. Part Turn Method-Procedure

Stage 1 : The members to be joined are brought together and the holes aligned with enough **drift pins** distributed over the joint, to maintain dimensions and plumbness of the structure.

Stage 2 : HSFG Bolts with washers, under the turned element are then placed in all the holes of the joint not used for drift pins and hand tightened. The bolts are then snug tightened to a tension of approximately 10000 lbs for M24 Bolts progressively away from the fixed or rigid points to the free edges to draw the members into close contact. This sequence may proceed either from top to bottom or bottom to top or it may be more convenient to go staggered pattern from the centre of the joint to the top or bottom.

It is a good practice to take a second run over the bolts with the wrench in the same sequence as above to check the snug tight position as the load-transmitting plies will be drawn in gradually tending to loosen those bolts already snug tightened.

The following are to be looked into :

a. At the time of assembly, the surfaces in contact should be free from paint, or any other foreign material like, oil, dust, loose rust, burns and other defects which would interfere with the development of friction between them.

b. Ensure that the alignment of members is such that the bolts fit the holes freely – forcing the bolts into the holes by means of hammering which will damage the threads should be avoided at all costs.

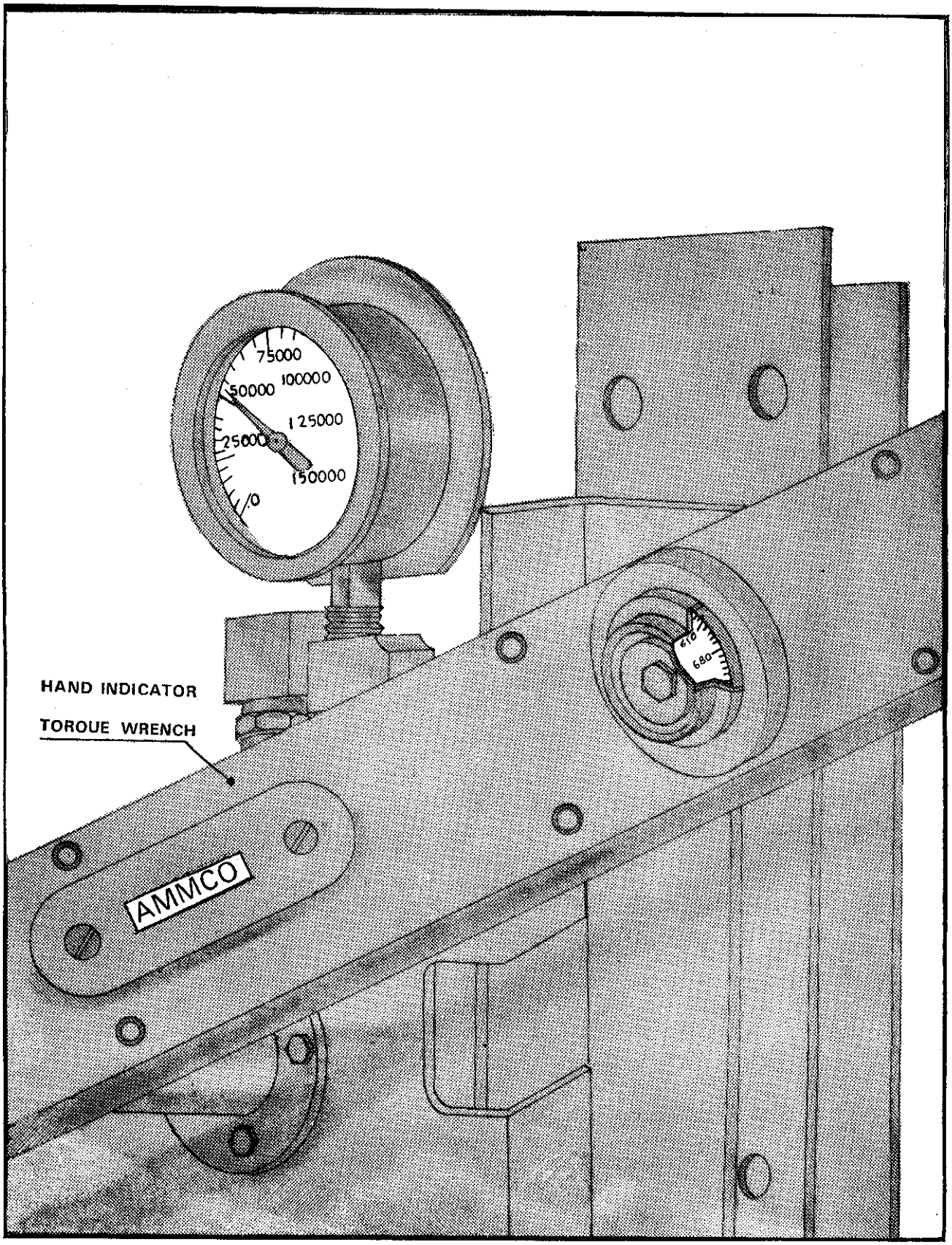


FIG. 6 DIAL READING FOR MINIMUM SHANK TENSION

The operator is using a hand indicator torque wrench to check the torque corresponding to a bolt tension of 51,000 lbs (21 Tonnes). The dial on the wrench is set at 'zero' and sufficient torque applied to slightly move the nut in the tightening direction. The dial indicates the corresponding torque value. This test should be made on at least three bolts of each lot and the torque figures averaged. This average is to be used for inspection of installed bolts of the same lot.

c. If required, because of bolt entering and wrench operation clearances, tightening may be done by turning the bolt, while the nut is prevented from rotating.

d. During tightening, the bolt head or nut should be held by a hand spanner or spud wrench to prevent it from turning.

e. The nut shall be so placed in the joint that its identification mark is clearly visible after tightening.

f. The bolted parts are to be in contact over the entire surface. However, as long as the specified tension is achieved in the bolts, the equivalent clamping force will exist between the parts even though 100 per cent contact is not realised.

Stage 3: Knock out drift pins, replace with bolts. Bring these bolts to snug tight position as in Stage 2.

Stage 4: Make permanent location marks on each nut and the protruding end of the bolt as shown in fig. 1-A to record their relative positions. This mark may be made with paint or by using a cold chisel.

Stage 5: Complete tightening of installed bolts by turning each nut by $\frac{1}{2}$ turn with tolerance $\pm$ 30° (1/12th of a turn). Tightening should proceed systematically from the most rigid part of the joint to its free edges.

Stage 6: Mark the joint to indicate that tightening has been completed. After final tightening, a nut or bolt is slackened for any reason, the bolt and nut are to be discarded and not to be used again.

Figure 2 to 6 gives an illustrative example of the calibration procedure.

Figure 7 & 8 give the check for required minimum tension by snug $\pm \frac{1}{2}$ turn.

Figure 9 to 16 illustrate how the tightening of structural steel connection should proceed (Turn of unit method.)

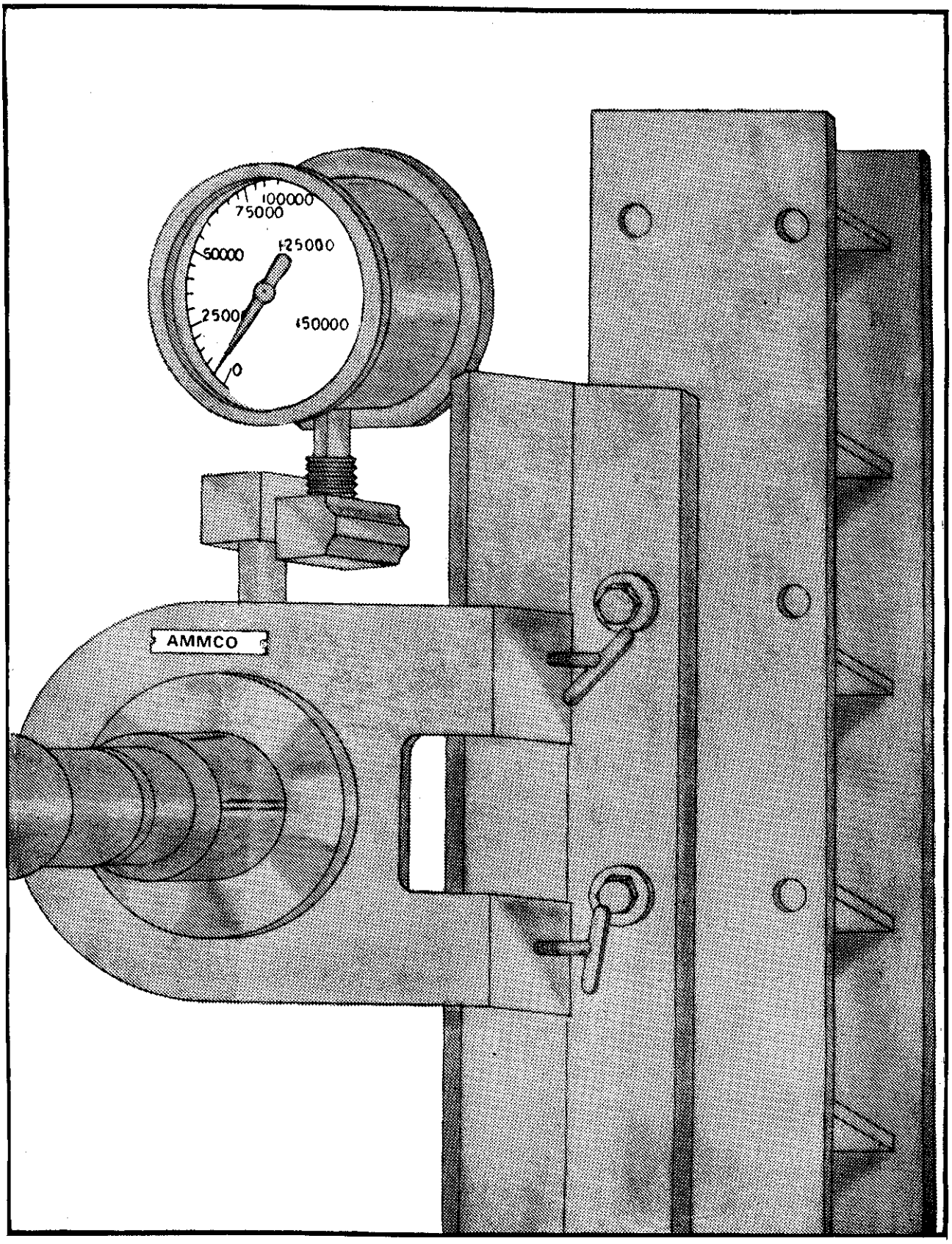


FIG. 7 SNUG TIGHTENING USING IMPACT WRENCH

Check for required minimum tension by snug + ½ turn

A few bolts are to be checked to determine whether 'Snug' plus the required half turn produce at least the required minimum tension. In the Figure dial reading shows the nut is Snug tightened.

4. INSPECTION OF HIGH STRENGTH FRICTION GRIP BOLTED JOINT

i. Check markings on bolt heads and nuts.

ii. Check that hardened washers have been used under bolt head or nut whichever is torqued.

iii. Observe installation to determine that specified tightening procedure, **Part turn method**, is being carried out.

iv. Check that all joints are marked to indicate that tightening has been completed.

Sides of bolt heads and nuts tightened with a pneumatic impact wrench should show slight peening, indicating that the wrench has been applied.

v. Check tightening on proportion of bolts using an inspecting wrench. This will normally be a hand torque wrench.

vi. Adjust or check inspecting torque wrench by tightening in a calibrating unit at least three sample bolts from lot used so that tension is developed.

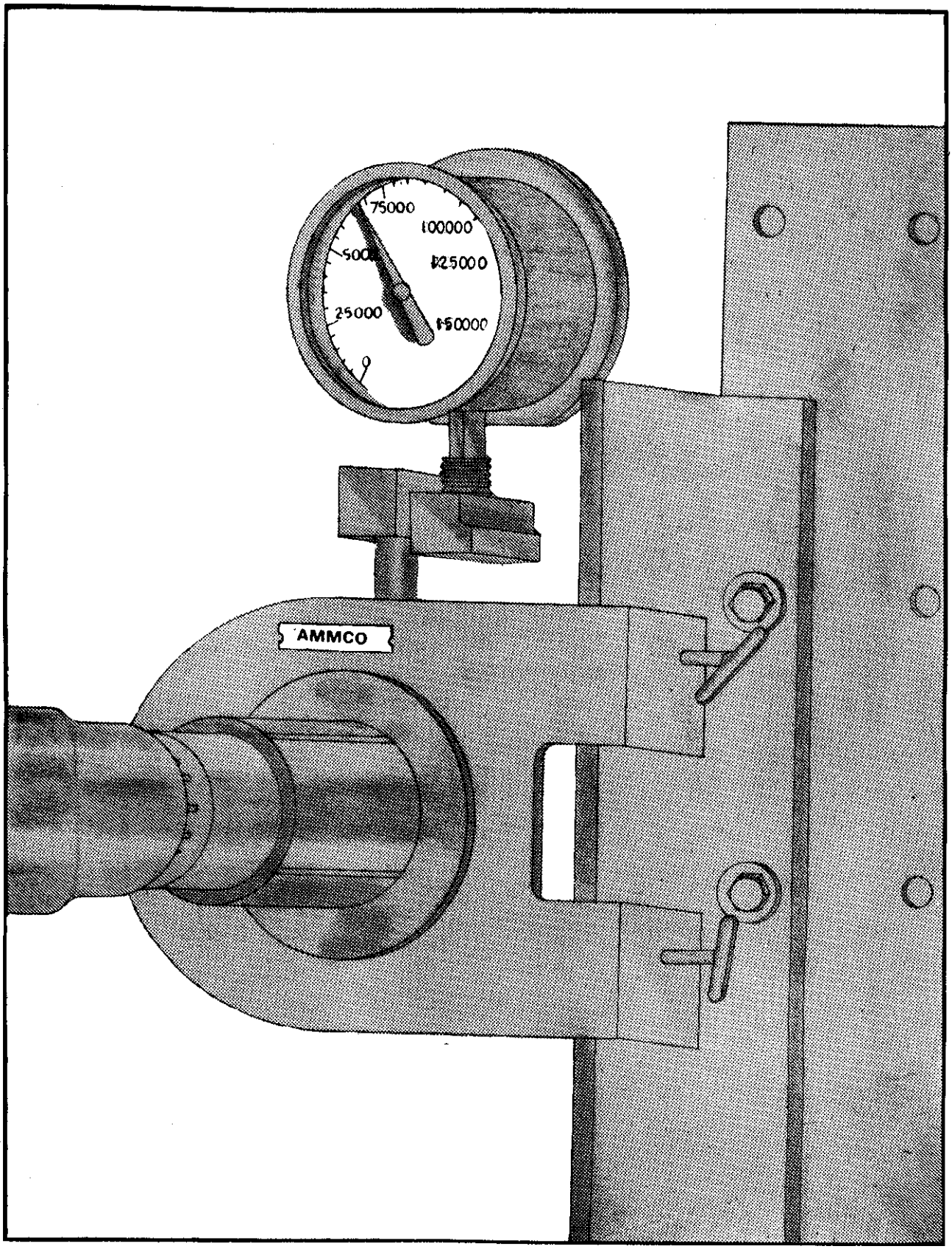


FIG. 8 SNUG + HALF TURN USING IMPACT WRENCH
(DIAL READING - 67000 PSI)

The nut has been rotated by the required half turn from the 'Snug' tight condition by impact wrench. The calibrator dial indicates that the tension in the bolt is beyond the required minimum tension. The dial reading is 67,000 lbs which is well beyond the required minimum tension of 51,000 lbs.

5. INSPECTION PROCEDURE

The erection supervisor should work closely with inspectors in tne calibration of the torque wrenches and establishment of average torque tension equivalents as indicated in Figs 2–8.

One of the inspection procedurs is the examination of nut surfaces to determine whether each unit has been impacted.

1. **Inspection of HSFG Bolted joint tightened by Part-Turn Method using Hardened Washer.**

   If bolts have been tightened without using a hardened washer under the turned element, any torque wrench inspection is not valid.

   Atleast 2 bolts in each connection or 10% of the belts in large connection shall be checked.

   Torque wrenches used for inspection must be the same one which has been calibrated as described earlier in Figs 2-8.

   To check the torque in tightened bolts, first the dial is set at zero and torque applied until **the nut moves slightly** (5°) in the tightening direction. The dial on the wrench will then show whether or not the expected torque is present.

   The torque readings higher than those measured for bolts tightened to the required minimum tension are not cause for rejection.

2. **Inspection of HSFG Bolted joint tightened by Part-Turn Method without Hardened Washer.**

   The procedure is of two stages.

   Stage 1 : Inspection after snug tightening but before final tightening.

   Inspector must ensure punch marks on the bolt and the nut as shown in figure 1-A.

   Stage 2 : Inspection after final tightening of the joint.

   The punch marks must be 180° apart so that snug + $\frac{1}{2}$ turn is assured as shown in fig. 1-B. A tolerance of $\pm$ 30° is permitted.

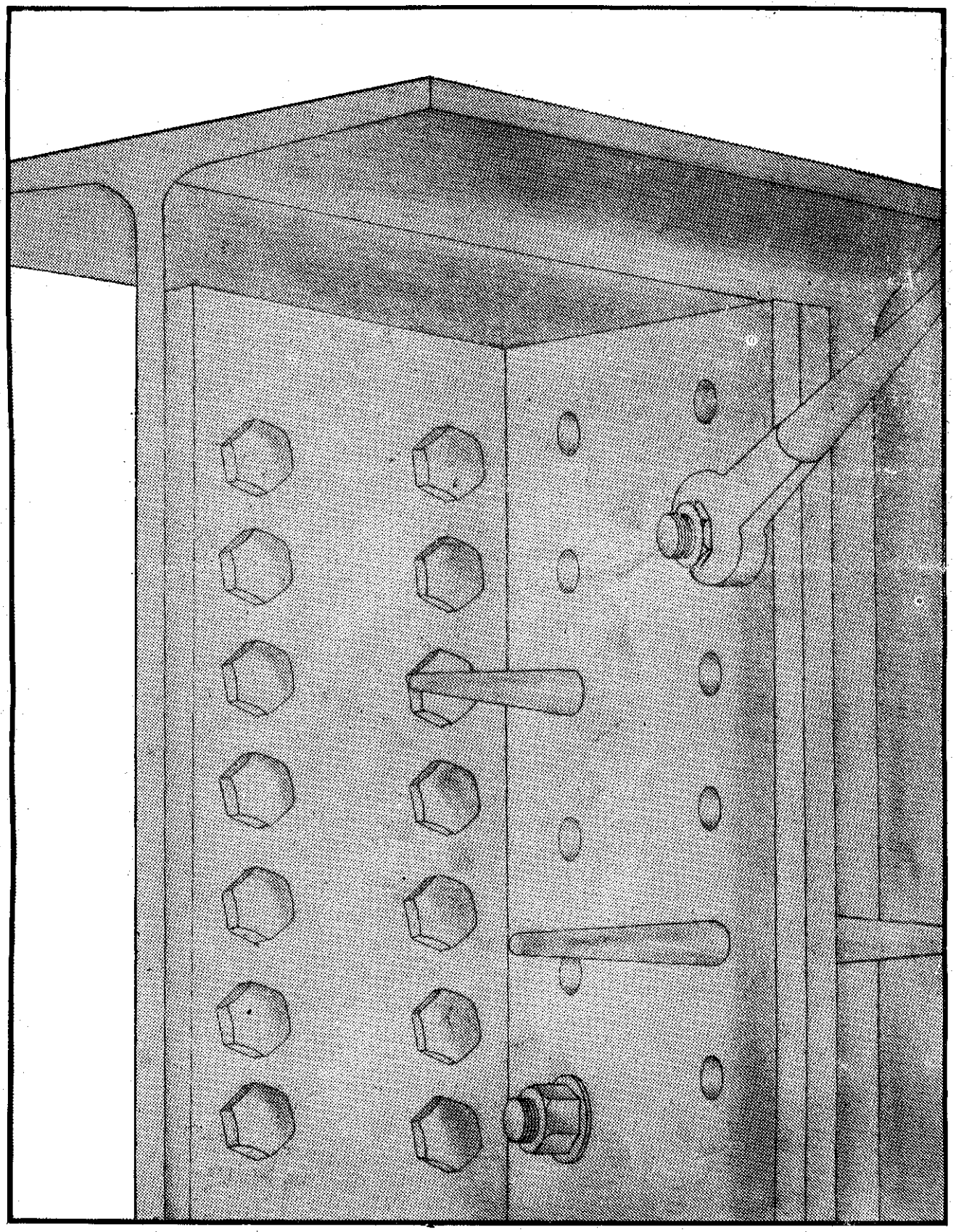


FIG. 9 FLAIRING - UP OF HOLES USING DRIFT PINS

Tightening Procedure – Turn-of-nut method (Figs. 9-16)
First the holes are ' Flaired-up ' with enough drift pins to maintain dimensions and plumbness of the structure. Sufficient bolts are then installed to hold the connection in place. Washers are provided under the rotating head. Only hand tightening is sufficient at this point.

APPENDIX–A

STANDARD HIGH STRENGTH FRICTION GRIP BOLTS, NUTS & WASHERS METRIC SERIES TO BS 4395 (PART 1 & 2)

Nom. Dia D	Thread Pitch	Width A/F of Bolts & Nuts		Thickness of Head		Nut Thickness		Hardened & Tempered Flat Round Washers	
		Max	Min	Max	Min	Max	Min	Outside Max/Min	Inside Max/Min
M16	2.0	27	26.16	10.45	9.55	15.55	14.45	37/36	17.8/17.4
M20	2.5	32	31.00	13.90	12.10	18.55	17.45	44/43	21.5/21.1
M22	2.5	36	35.00	14.90	13.10	19.65	18.35	50/48.5	23.4/23.0
M24	3.0	41	40.00	15.90	14.10	22.65	21.35	56/54.5	26.4/26.0
M27	3.0	46	45.00	17.90	16.10	24.65	23.35	60/58.5	29.4/29.0
M30	3.5	50	49.00	20.05	17.95	26.65	25.35	60/64.5	32.8/32.4
M33	3.5	55	53.80	22.05	19.95	29.65	28.35	75/73 5	35.8/35.4
M36	4.0	60	58.80	24.05	21.95	31.80	30.20	85/83.5	38.8/38 4

Threads : Coarse pitch series ISO Metric Screw Threads, Medium Class of fit 6g and 6H for bolts & nuts respectively

Thread Lengths : 2D + 6 mm for lengths upto and including 125 mm for Part 1
2D + 12 mm for lengths upto and including 125 mm for Part 2
2D + 12 mm for lengths over 125 mm upto and including 200 mm for Part 1
2D + 18 mm for lengths over 125 mm upto and including 200 mm for Part 2
2D + 25 mm for lengths over 200 mm for Part 1
2D + 30 mm for lengths over 200 mm for Part 2

ALL DEMENSIONS ARE IN MILLI METRE.

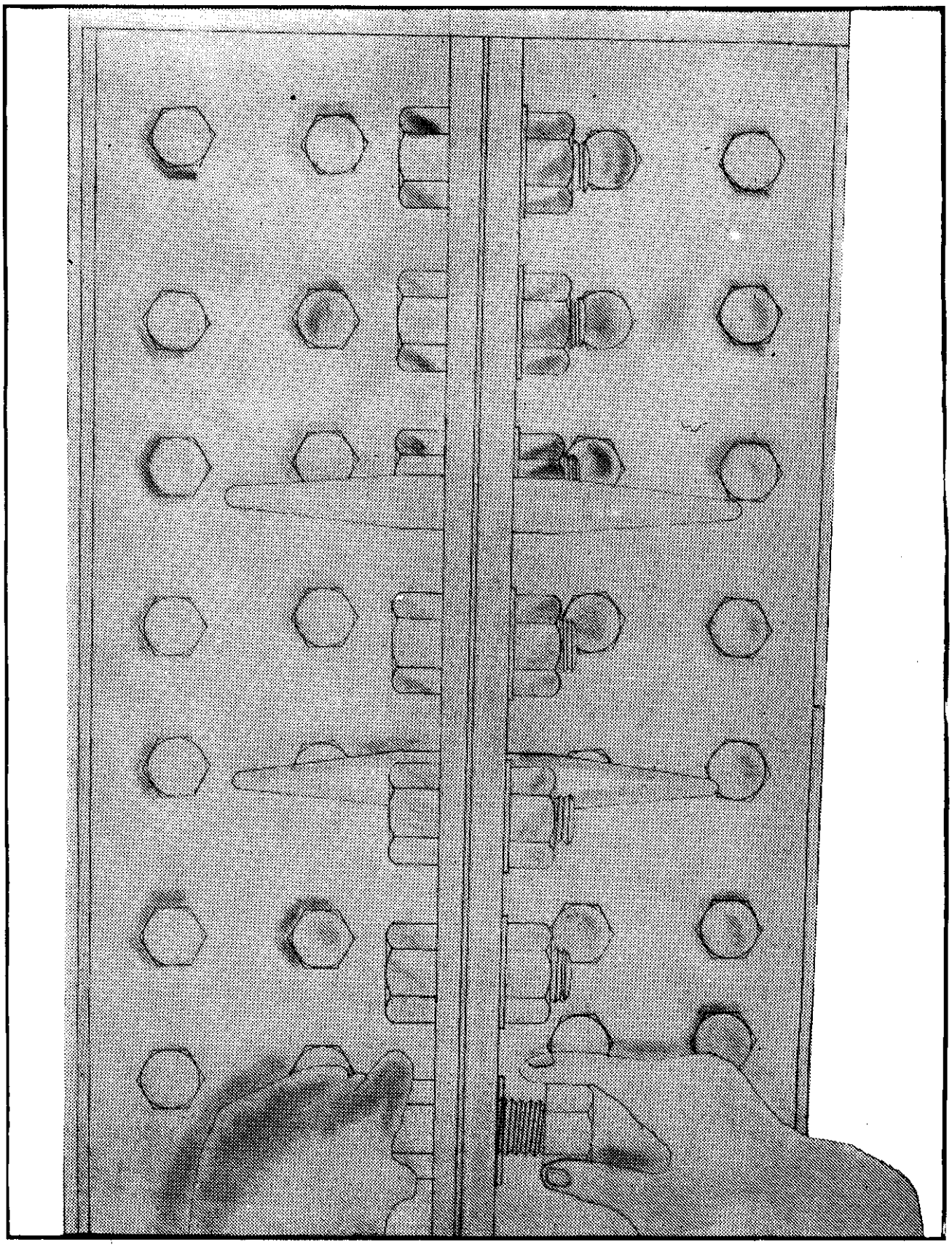


FIG. 10 BOLTS ASSEMBLED WITH NUTS & WASHERS

Fig. shows the connection after all the holes except the ones with drift pins have been filled with bolts and assembled with nuts and washers. It may be noted that the beam connection has been left out of the picture to show the gap between the angles which will be drawn together during the 'Snugging' operation.

STANDARD HIGH STRENGTH FRICTION GRIP BOLTS, NUTS AND WASHERS
METRIC SERIES TO IS 3757 (1985) / IS 6623 (1985) AND IS 6649

Nominal Dia D	Thread Pitch	Width A F of Bolts & Nuts		Thickness of Head		Nut Thickness		Washer	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Outer Dia	Inner Dia
M 16	2.0	27.00	26.16	10.70	9.25	17.10	16.40	30	17
M 20	2.5	34.00	33.00	13.40	11.60	20.70	19.40	37	21
M 22	2.5	36.00	35.00	14.90	13.10	23.60	22.30	39	23
M 24	3.0	41.00	40.00	15.90	14.10	24.20	22.90	44	25
M 27	3.0	46.00	45.00	17.90	16.10	27.60	26.30	50	28
M 30	3.5	50.00	49.00	19.75	17.65	30.70	29.10	56	31
M 36	4.0	60.00	58.80	23.55	21.45	36.60	35.00	66	37

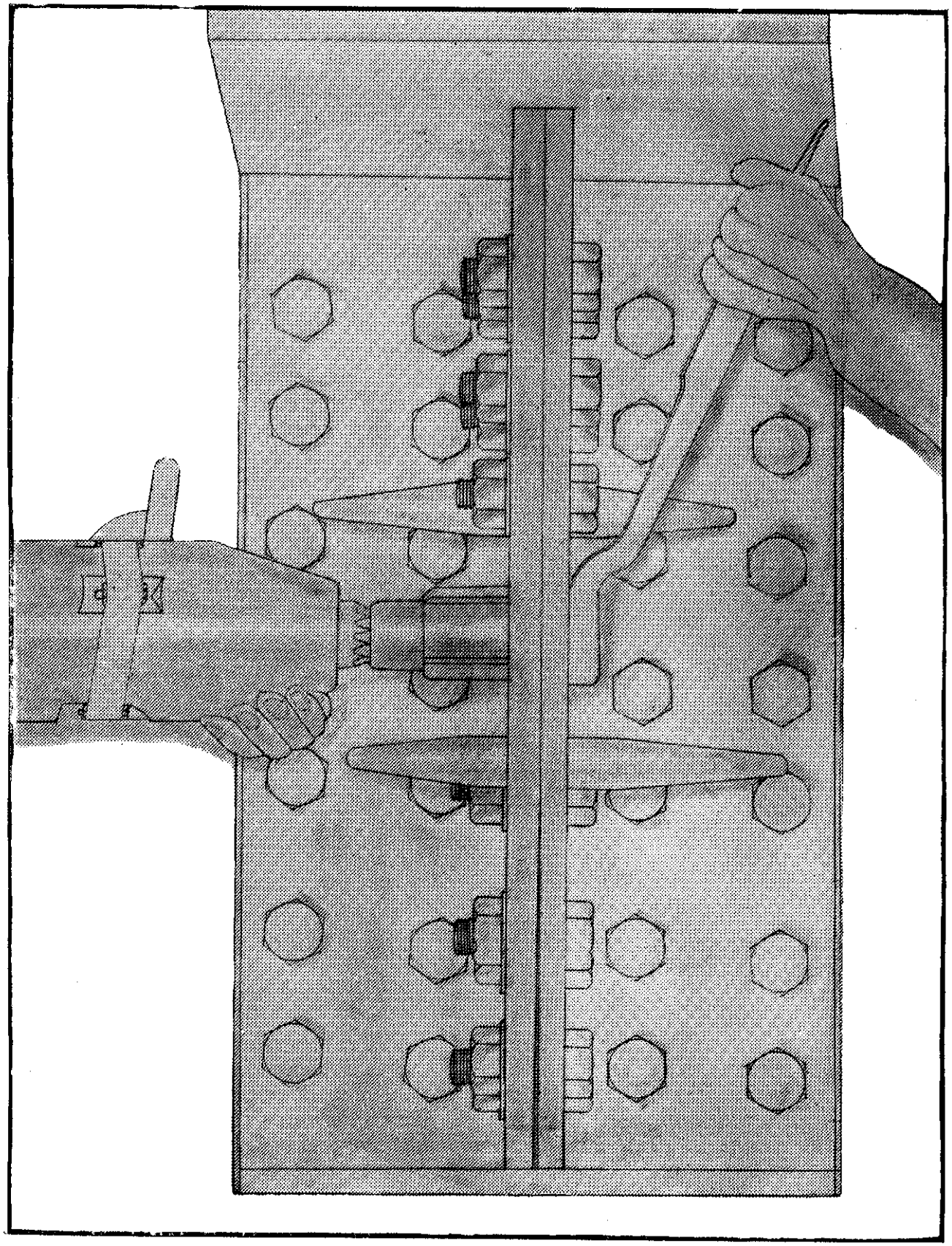


FIG. 11

CONNECTION BEING SNUG TIGHTENED

The bolts and nuts are being Snug tightened. The 'Snug' condition creates sufficient tension to draw the top half of the angles tightly together while the bottom half still remains open.

APPENDIX—B

MECHANICAL PROPERTIES (BOLTS)

METRIC SERIES TO B. S. 4395 (PART 1 & 2)

Nominal Dia	Tensile Strength Min.	Proof Load/Min Shank Tension	Hardness No.	
			Brinell HB Max./Min	Rockwell HCR Max./Min.
(mm)	(1000 kgf)	(1000 kgf)		
		BS 4395 PART 1		
M16	13.25	9.39	321/255	34/25
M20	20.71	14.64	321/255	34/25
M22	25.57	18.10	321/255	34/25
M24	29.79	21.10	321/255	34/25
M27	33.89	23.88	295/223	30/19
M30	41.42	29.19	295/223	30/19
M33	—	—	—	—
M36	60.32	42.51	295/223	30/19
		BS 4395 PART 2		
M16	15.7	12.45	365/280	38/27
M20	24.5	19.41	365/280	38/27
M22	30.3	24.0	365/280	38/27
M24	35.3	28.0	365/280	38/27
M27	45.9	36.3	265/280	38/27
M30	56.1	44.4	365/280	38/27
M33	69.4	55.0	365/280	38/27
M36	—	—	—	—

NOTES: 1. Tensile Strength and proof loads are based on the following gross values:-

Tensile Strength	*B. S. 4395 : Part 1*	*B. S. 4395 : Part 2*
a) For sizes M16 to M24 including	*84.38 kgf/mm²*	*100 kgf/mm²*
b) For sizes M27 to M36 including	*73.83 kgf/mm²*	*100 kgf/mm²*
Proof Loads		
a) For sizes M16 to M24 including	*59.77 kgf/mm²*	*79.2 kgf/mm²*
b) For sizes M27 to M36 including	*52.04 kgf/mm²*	*79.2 kgf/mm²*

2. Hardness values are given for guidance only.

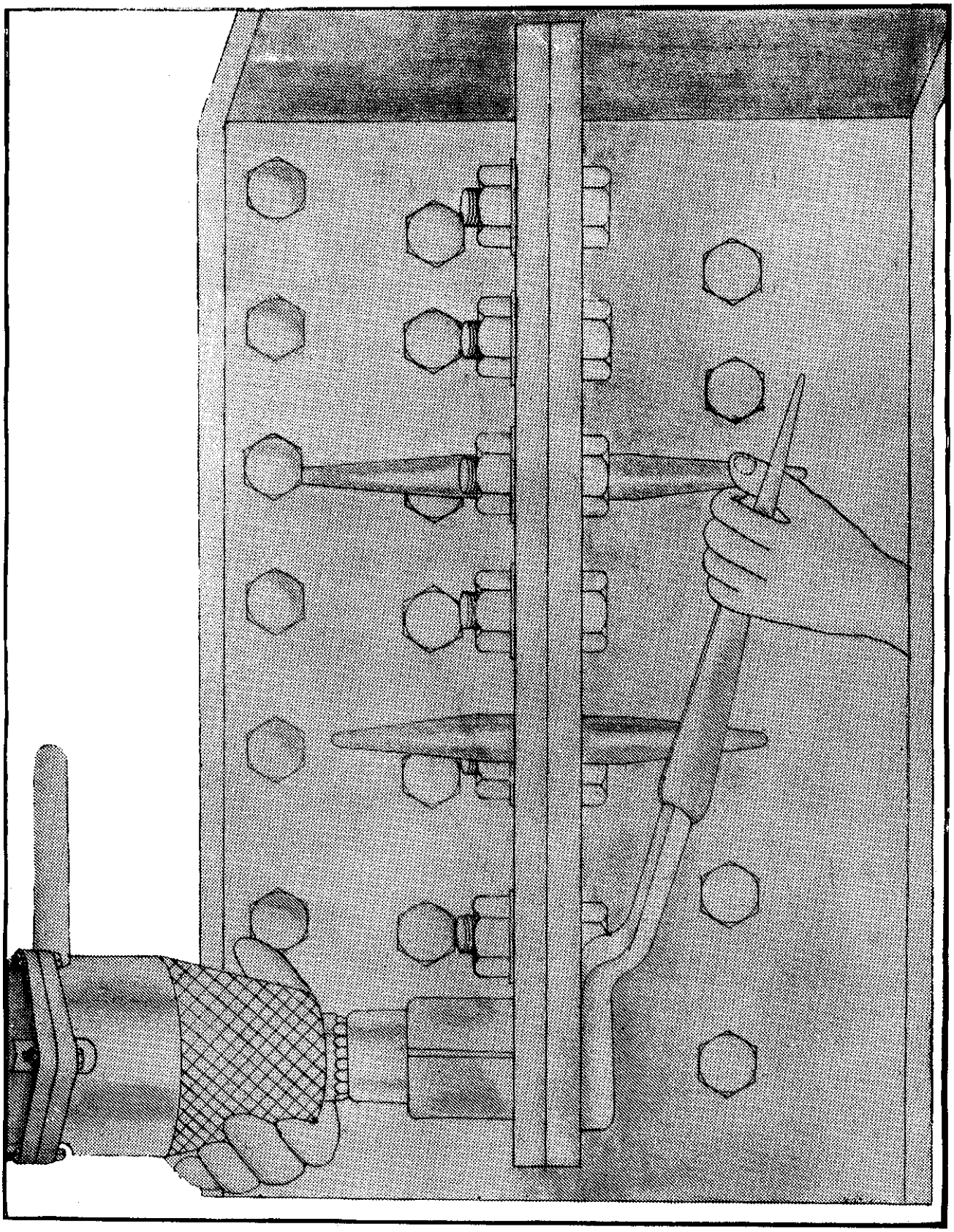


FIG. 12

COMPLETION OF SNUG TIGHTENING

The entire connection is snugged up. As a result, the gap between the angles has entirely disappeared.

APPENDIX—C

MECHANICAL PROPERTIES (NUTS & WASHERS)

Nuts for BS 4395 : Part 1 Bolts				Nuts for BS 4395 : Part 2 Bolts		
Nominal Bolt Dia. (mm)	Proof Load (1000 kgf) (See Note 1)	Hardness Brinell HB Max.	Min.	Proof Load (1000 kgf) (See Note 2)	Hardness Brinell HB Max.	Min.
M16	16.0	302	166	18.8	353	—
M20	25.0	302	166	29.4	353	—
M22	30.9	302	166	36.4	353	—
M24	36.0	302	166	42.3	353	—
M27	46.8	302	166	55.0	353	—
M30	57.2	302	166	67.3	353	—
M33	—	—	—	53.3	353	—
M36	83.3	302	166	—	—	—

Washers for BS 4395 : Part 1 & 2 Bolts

	M16	M20	M22	M24	M27	M30	M33	M36
Max. Hardness Rockwell HRC	38	38	38	38	38	38	38	38
Min. Hardness Rockwell HRC	45	45	45	45	45	45	45	45

NOTES :

1) Based on 102 kgf/mm² on the equivalent stress area of the corresponding bolt.

2) Based on 120 kgf/mm² on the equivalent stress area of the corresponding bolt.

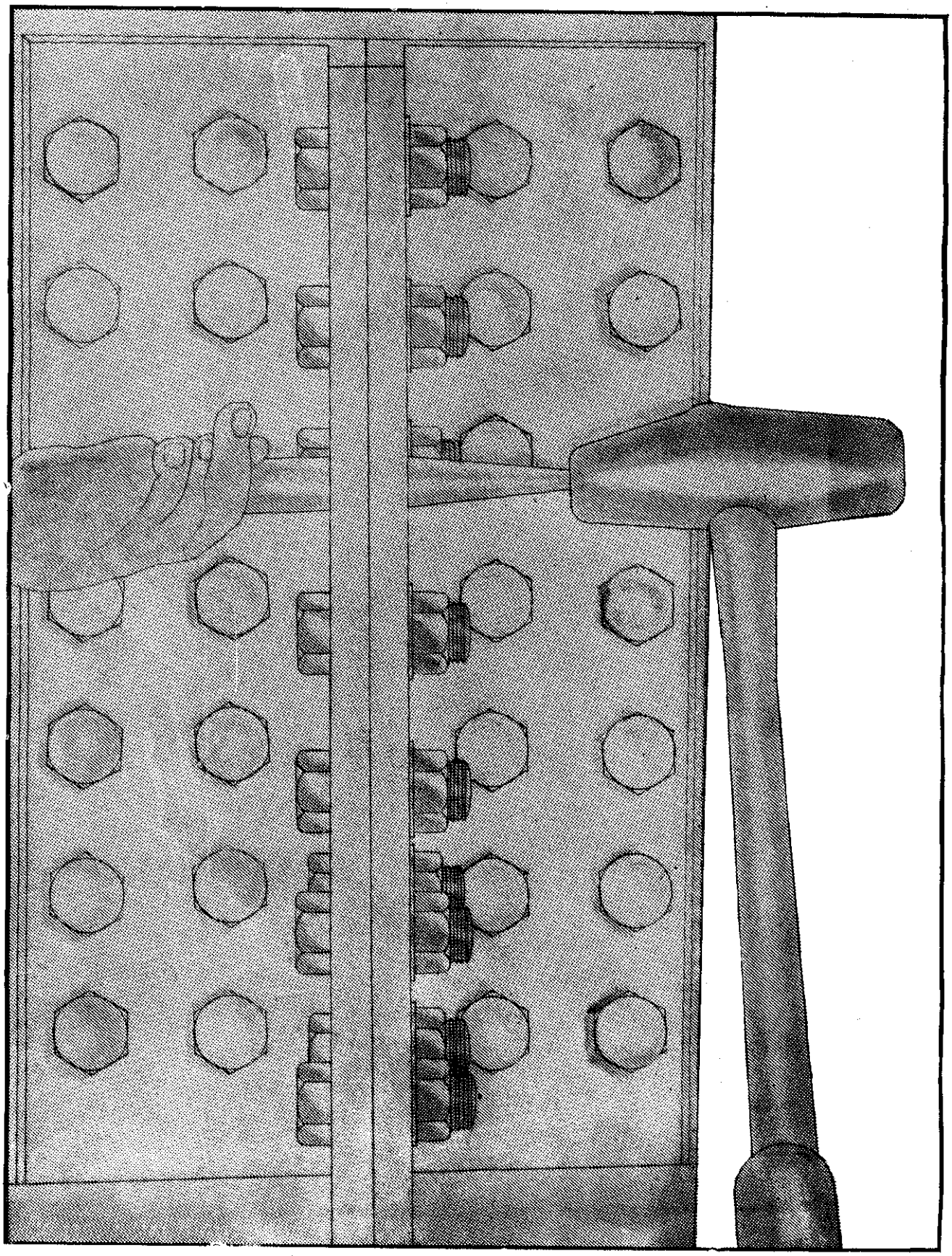


FIG. 13 REMOVAL OF DRIFT PINS & FILLING UP WITH BOLTS & SNUG TIGHTENED

The drift pins are being knocked out and these holes are filled with bolts and torqued up to 'Snug'. The connection is now ready for final tightening.

MECHANICAL PROPERTIES (BOLTS) IS 3757 (1985) / IS 1367 (1979)

Nominal Dia D	Tensile Strength Kg/cm^2		Proof Load/Minimum Shank Tension Property Class N		Hardness of Bolts HRC Min./Max.	HRC Min./Max.
	8.8	10.9	8.8	10.9	8.8	10.9
M 16	80	100	94500	130000	20/30	31/39
M 20	80	100	147000	203000	23/34	31/39
M 22	80	100	182000	252000	23/34	31/39
M 24	80	100	212000	293000	23/34	31/39
M 27	80	100	275000	381000	23/34	31/39
M 33	80	100	416000	570000	23/34	31/39
M 36	80	100	490000	678000	23/34	31/39

MECHANICAL PROPERTIES (NUTS TO IS 6623) - (1985)

Nominal Dia	Proof Load N	Proof Stress N/m^2	Hardness	
			Vickers HV Maximum	Rockwell HR Maximum
M 16	168900	1075		
M 20	263400	1075		
M 22	325700	1075	181	A 89
M 24	379500	1075	To	To
M 27	493400	1075	372	C 38
M 30	603100	1075		
M 36	878300	1075		

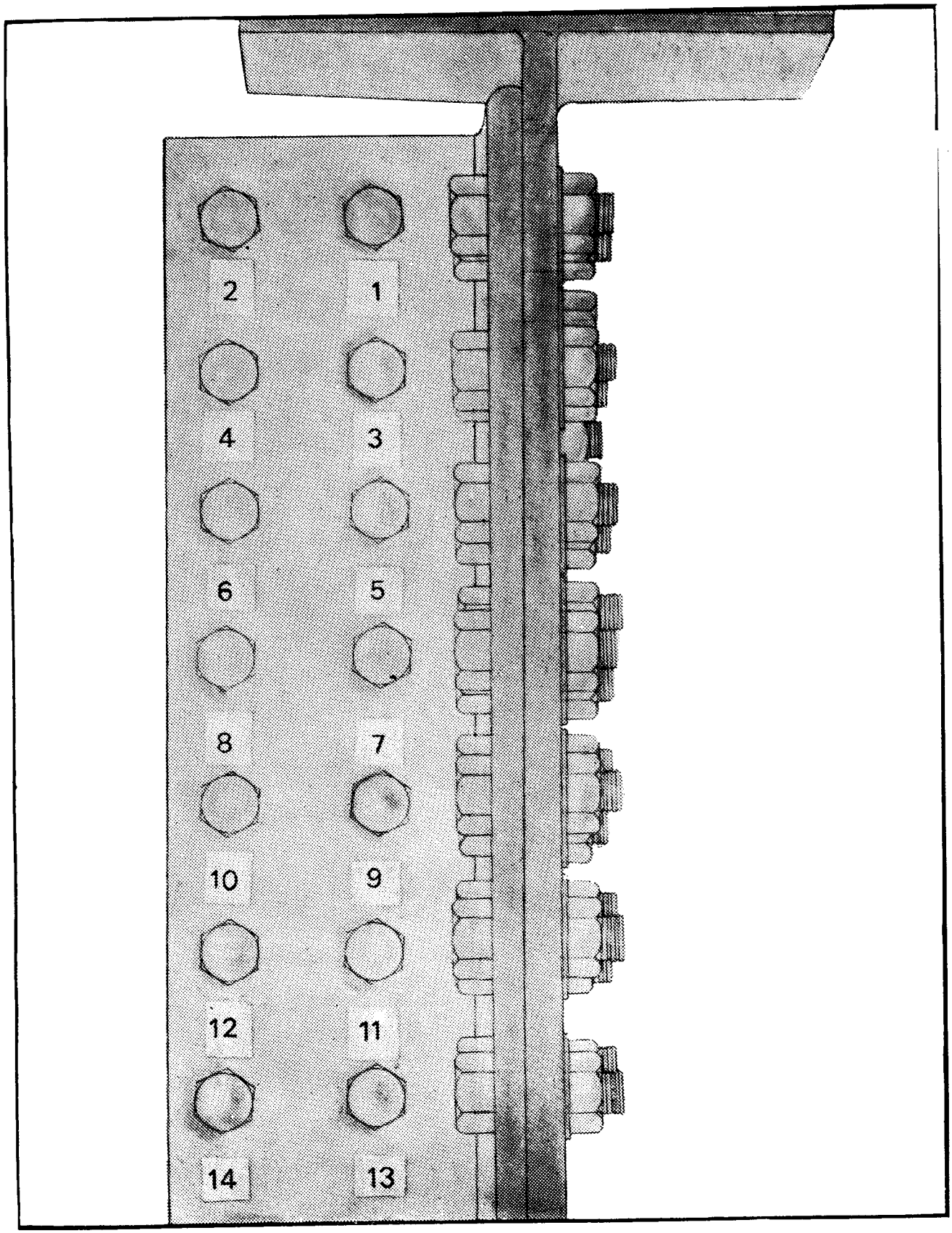


Fig. 14 SUGGESTED TIGHTENING SEQUENCE

In this figure each bolt has been numbered to show a suggested tightening sequence. Bolts and nuts should always be tightened progressively away from the FIXED or RIGID points to the free edges as shown. This sequence may proceed either from top to bottom or from bottom to top, or it may be more convenient to go from the centre to the top or bottom.

NUT ROTATION* FROM SNUG TIGHT CONDITION

Bolt Length (as measured from underside of head to extreme end of point)	Disposition of Outer Faces of Bolted Parts		
	Both the faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1 : 20 (bevel washer not used)	Both faces sloped not more than 1 : 20 from normal to bolt axis (bevel washer not used)
Upto and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters**	2/3 turn	5/6 turn	1 turn

* Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30°; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45°.

** No research work has been performed by the Council to establish when bolt lengths exceed 12 diameters. Therefore, the required rotation must by determined by actual tests in a suitable tension device simulating the actual conditions.

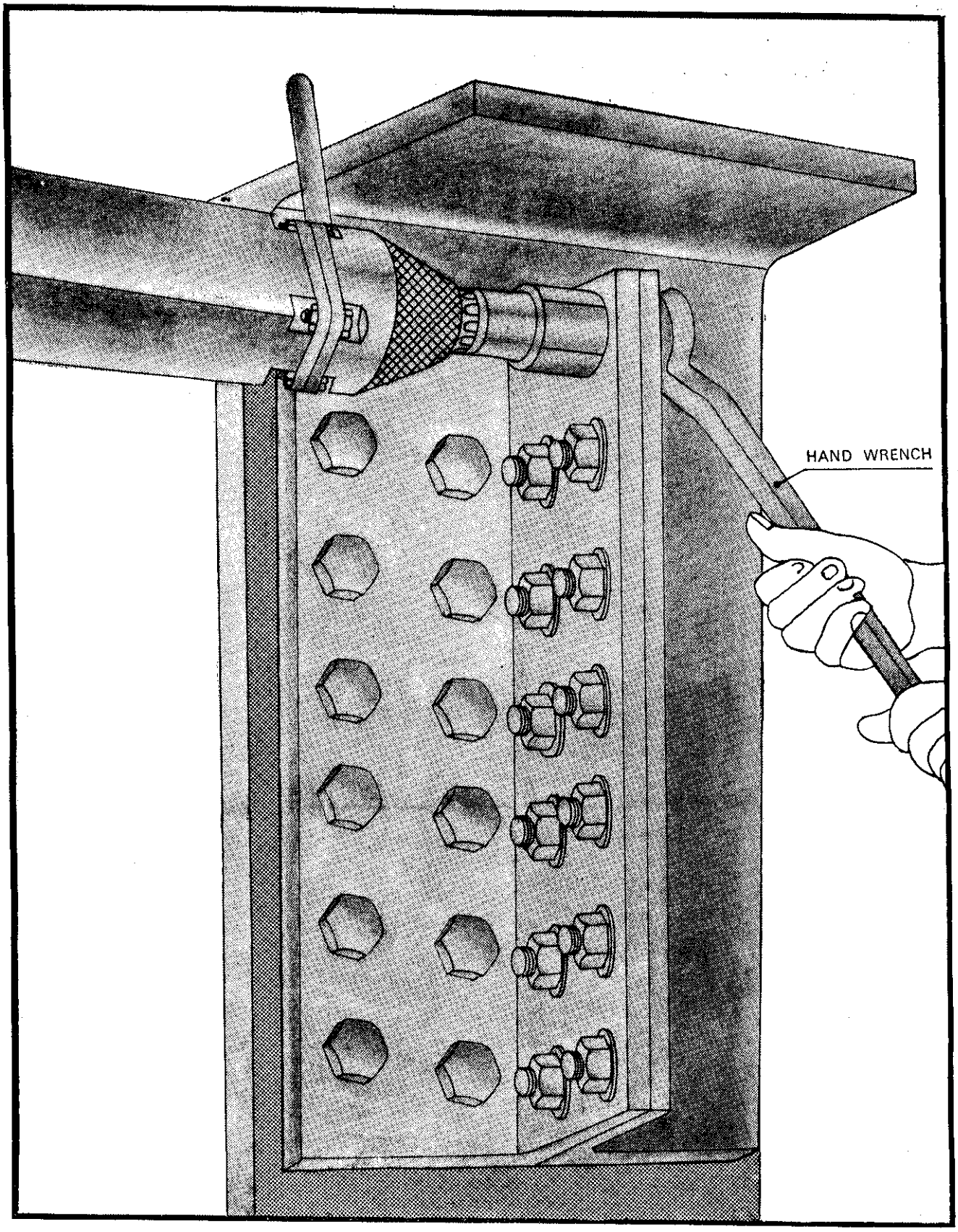


FIG. 15 FINAL TIGHTENING BEYOND SNUG OF BOLT No. 2

Fig. Shows final tightening by means of the required 'Turn' beyond the 'Snug' condition. Here the bolt No. 2 is being tightened. In the final tightening care must be exercised to ensure against rotation of the element not being turned. A hand wrench should be used to hold the end not being torqued. Otherwise the actual required turn measurement may be lost.

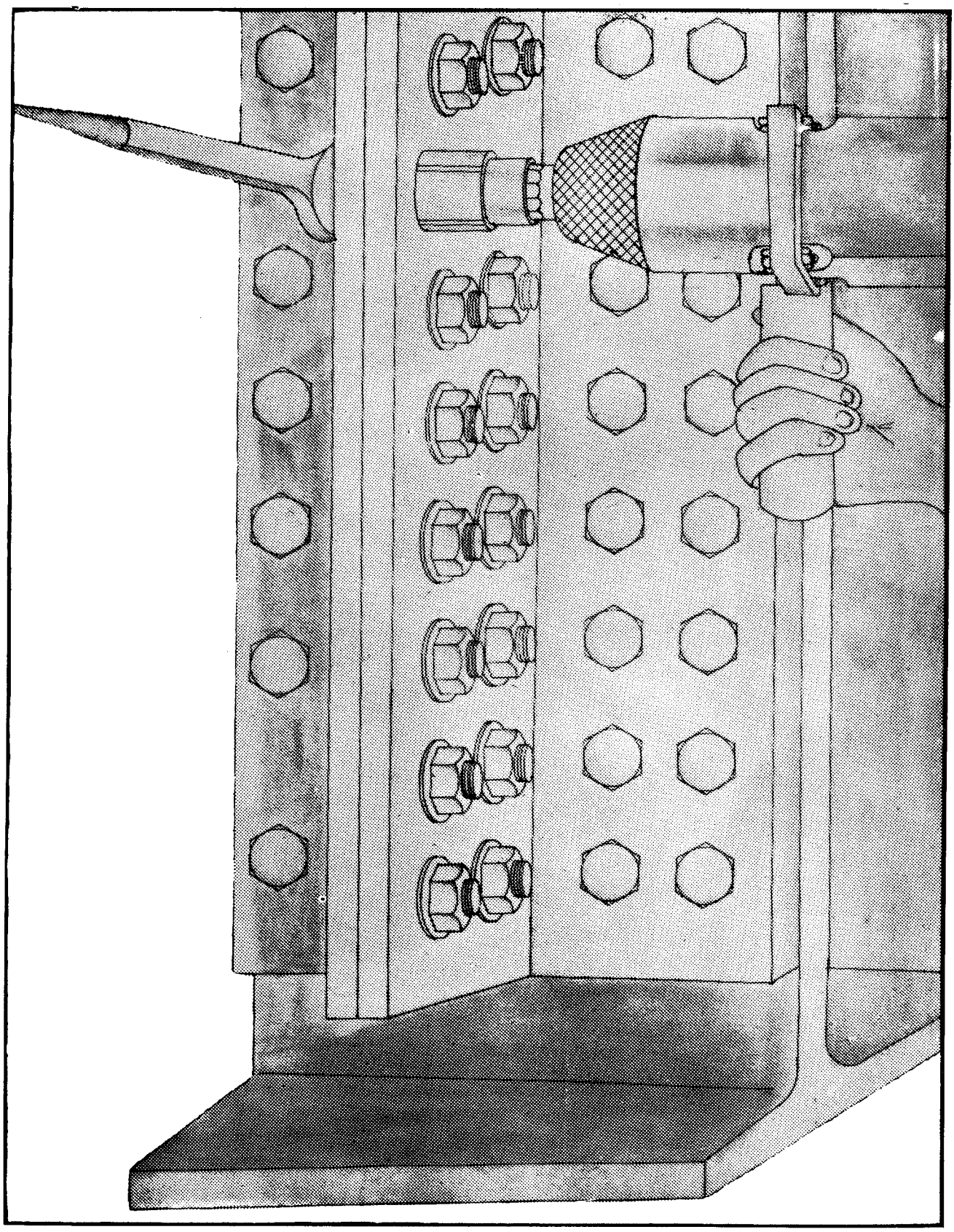


FIG. 16

FINAL TIGHTENING OF BOLT No. 12

The operator has completed
the HALF TURN on bolt No. 12.

REFERENCES

1. *I.S Code of Practice for assembly of structural joints using HSFG fasteners IS–4000—1967.*

2. *"Tightening procedure for High Strength structural bolting" by H C. Trumbore, Bethlehem Steel Corporation USA PA.*

3. *"High Strength Bolting" – GKN bolts & nuts limited, Darlaston, England.*

4. *Article from GKW on HSFG bolts & Tightening procedure.*

5. *AISC manual for structural steel design.*

6. *BS–4395.*

7. *"Turn of Nut" – A 16 mm motion picture film by Bethlehem Steel Corpatation USA PA.*