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Column test manual, 1951

R. L. Ketter

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COLUMN TEST MANUAL

FEBRUARY 1951

Edited by

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and

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Department of Civil Engineering

and Mechanics

Fritz Lab. № 205 A.03

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PREFACE

This manual is prepared to provide a supplemental source of information to those currently engaged in the Fritz Engineering Laboratory 205 project, with major emphasis being directed toward the column part of the investigation. For material not related solely to columns see Project 205 Manual, report No. 205.04.

Material given herein is of the type that will be most helpful to those just starting on the project; however, also included is information with regard to "Loading Equipment", etc. that will be useful to all.

References to more complete sources of information are included where necessary.

GENERAL INFORMATION

The column investigation at Lehigh University is part of a larger investigation* sponsored jointly by the Welding Research Council and the Navy Department with funds furnished by the following:

American Institute of Steel Construction
American Iron and Steel Institute
Column Research Council (Advisory)
Institute of Research, Lehigh University

Office of Naval Research (Contract No. 39303)
Bureau of Ships
Bureau of Yards and Docks

The current investigation is for a period of 5 years. The project director is Lynn S. Beedle, Ass't to the Director, Fritz Engineering Laboratory.

OBJECTIVES

The eventual objective of the program is to develop practical design methods, based on elastic and plastic action. In order to accomplish this we must first determine the influence of the loading condition on the interaction curve, relating this to existing specifications thereby determining the true load factors implied in present design practice.

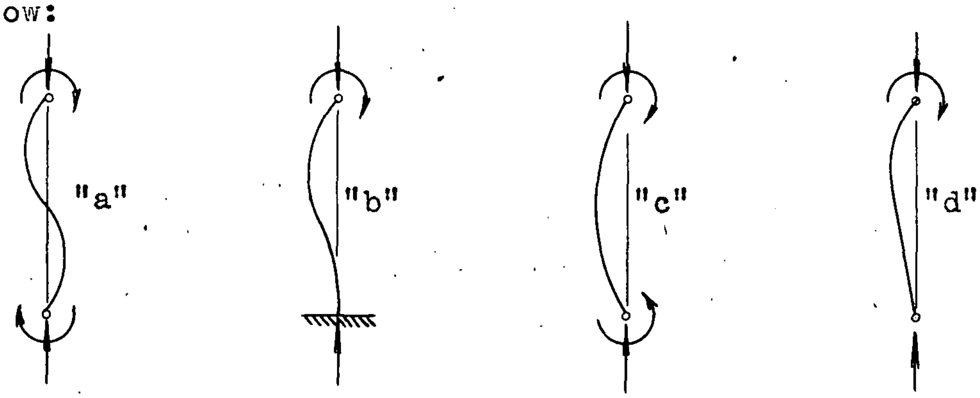
The phase of the program being studied now is that of determining the plastic behavior of the column as influenced by a number of variables, such as condition of loading,

* "Strength of Welded Continuous Frames and Their Components"

slenderness ratio, the ratio P/P_y , and shape of cross-section.

LOADING CONDITIONS

In this manual, as-well-as in the column program in general, the term "Loading Condition" will refer to a particular combination of axial load and end bending moment. The possible loading conditions which are being investigated are shown below:

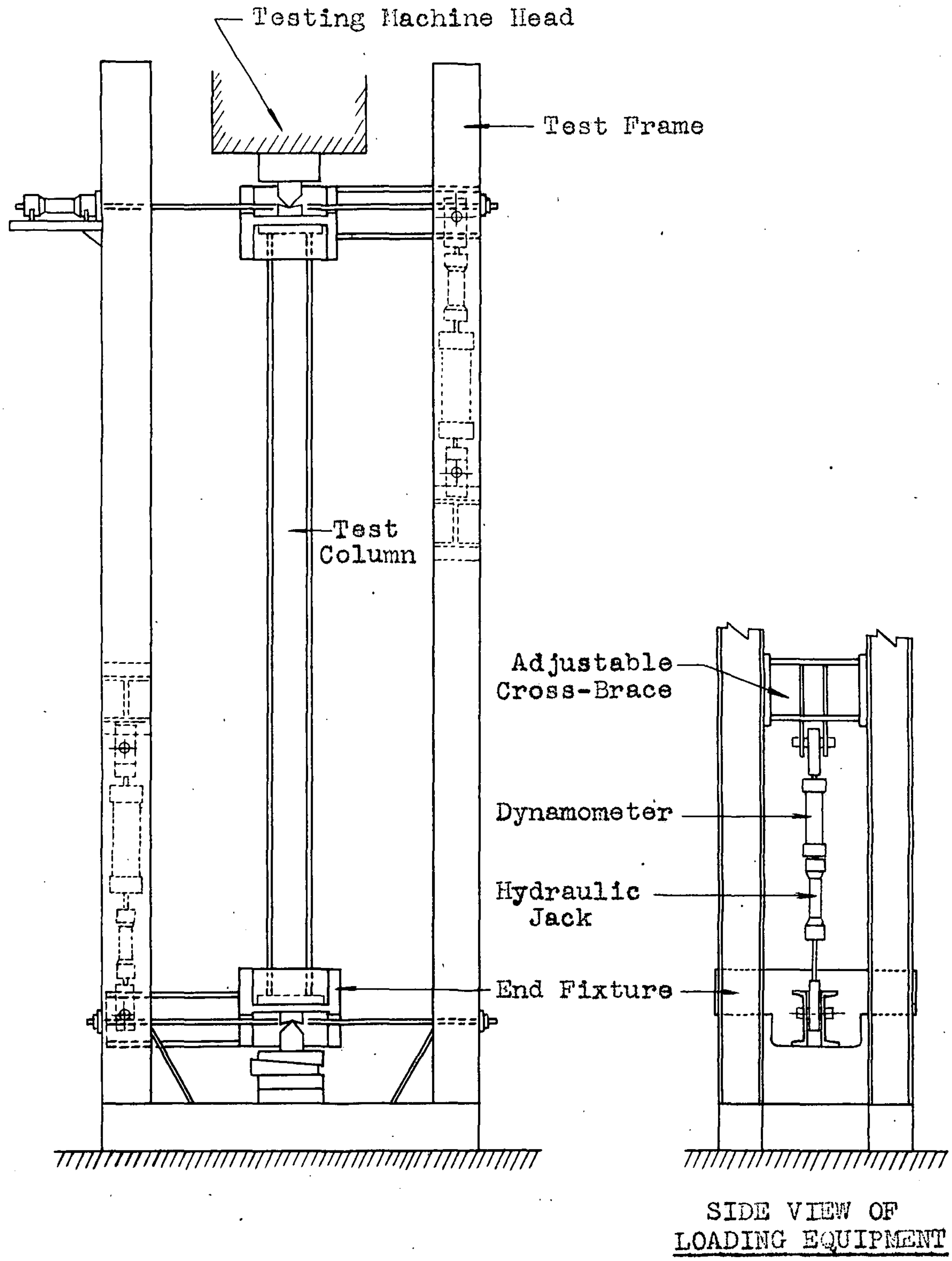


Pure axial loading would be a special case of condition "c" when the end bending moment is equal to zero.

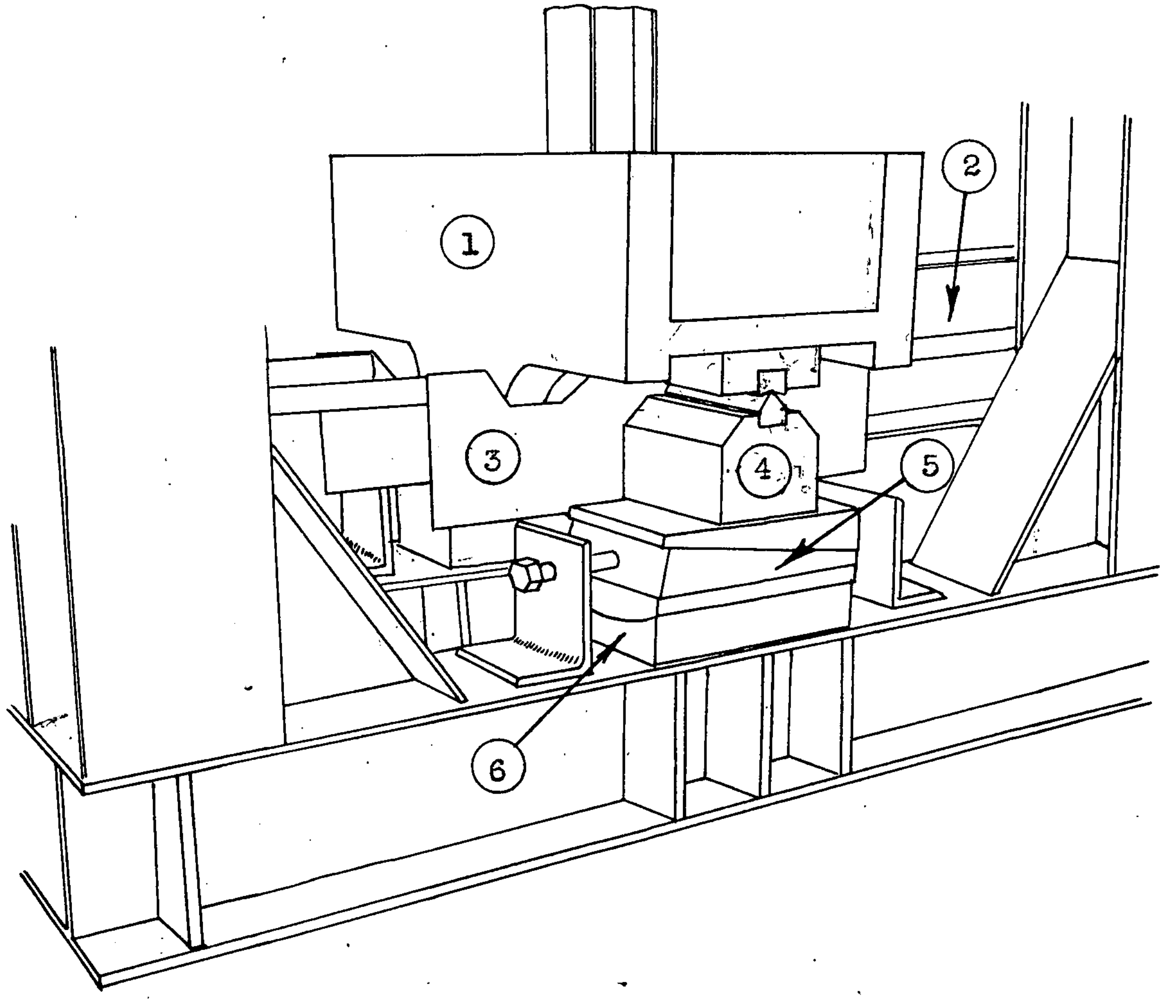
DESCRIPTION OF THE LOADING FRAME:

In order that the above loading conditions can be realized by use of only one loading device, a loading frame capable of applying an end moment independent of axial load was designed. Its essential features are described in Progress Report No. 2* - "Tests of Columns under Combined Thrust and Moment".

* Progress Report No. 2 - "Ultimate Strength of Welded Continuous Frames and Their Components."



COLUMN TEST APPARATUS



① Bottom End Fixture

② Moment Arm

③ Lateral Support Plates

④ Knife Edge

⑤ Wedge Blocks

⑥ Cyl. Bearing Block

LOWER END FIXTURE DETAIL

PREPARATION FOR COLUMN TEST

1. Prepare Note Book for Test.

A. Column Preparation:

1. Obtain Length measurement, x-section measurements, weigh (this should be done by the Research Ass't. or under his direct supervision). (See page 14)
2. Weld End Plates. (See sketch page 13).
3. Install SR-4 Gages.
   a. Check resistance of all gages including that for temperature compensation.
4. Install level bar brackets.
5. Photographs (if anything unusual is to be shown).
6. White wash
7. Bolt column into upper fixture.

B. Lower Assembly:

1. Install cylindrical bearings, (check to see that these are greased), wedge blocks, knife-edge supports.
2. Grease knife-edges.
3. Place lower fixture on knife-edge blocks in approximate positions (block up moment arm).
4. Install lateral support equipment on lower fixture.
5. Install holding pieces on lower section.

C. Column Installation:

1. Install in place the knife-edge seat blocks on upper column end fixture.
2. Lift column assembly with crane. Lower down through the the frame and bolt column to lower assembly.

3. Attach upper lateral support equipment.

4. Install upper holding pieces. Release crane.

D. Pumping System:

1. Install pumps and tubing.

2. Check pumps.

3. Install upper pinned connectors.

E. Installation in Machine:

1. With the special lift gear, place moment frame with column installed on testing machine table.

2. Shift crane hook over limiting bar. Lift load with crane.

3. Lay rollers on machine base.

4. Place load back on rollers. Attach angle brackets to machine base. Rig lines for hauling into position.

5. Keeping slack just out of grommet and sling lines, pull frame assembly into approximate position with block and fall.

6. Pick load with resting machine head, remove crane hook, remove rolls, place load on machine base in proper alignment on base.

7. Clamp frame to testing machine.

F. Alignment of Column and Frame:

1. Lift column only with the testing machine head and adjust cylindrical wedge, and knife-edge blocks as accurately as possible.

2. Lower column to knife-edges or raise knife-edges with wedge blocks until column axis is in line.

3. Check to see that moment arm is midway between frame columns. Adjust with lateral support.

4. Check to see that spacing of knife-edge blocks is correct.

5. Check alignment of column vertical axis with respect to <u>shown</u> horizontal axis of base (offset around the bottom end fixture with a plumb bob.)

6. Check overall alignment with research assistant.

G. <u>Pumping System:</u>

1. Install all remaining equipment for applying end moments.

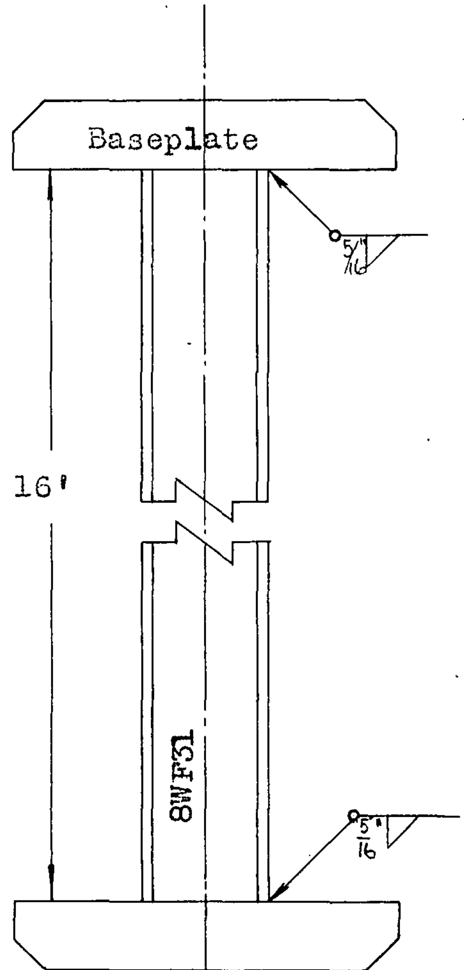
2. Adjust to hold column in line with machine axis.

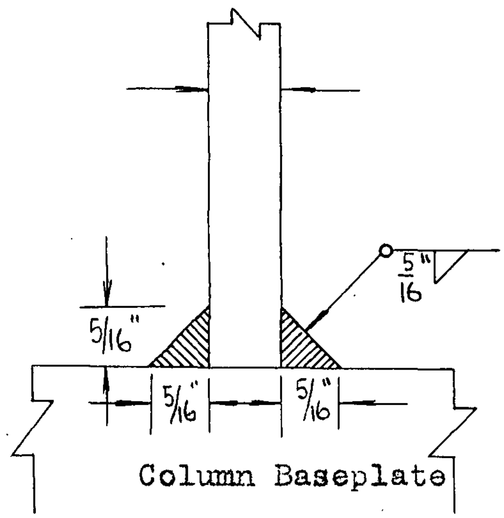
H. <u>Upper Loading System:</u>

1. Install upper loading assembly.

2. Apply small increment of axial load and <u>install wedge blocks</u> under head of machine.

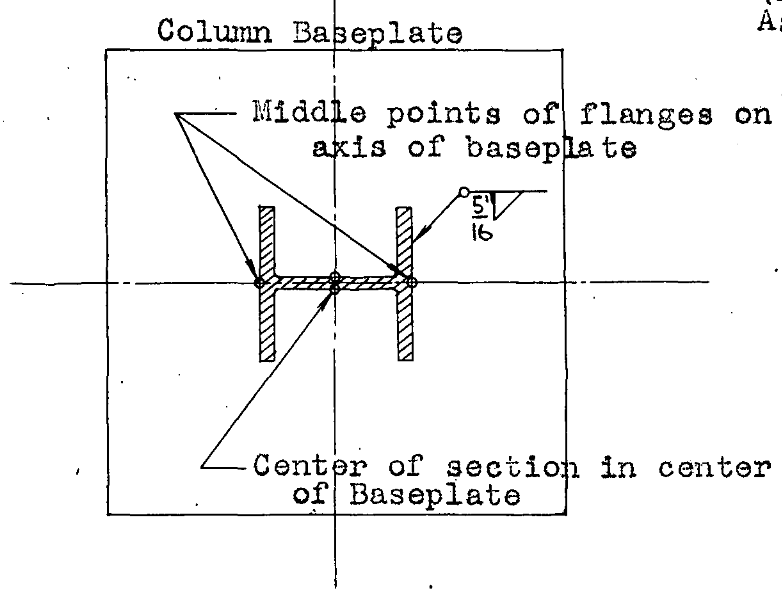
# # #





IMPORTANT: Deep penetration in the Root of the Fillet Weld.

Note: Be sure to locate flanges (E. & W.) on Baseplates as Assigned on Column Specimen.



WELDING OF THE COLUMN TO THE BASEPLATE

MEASUREMENTS OF THE SPECIMEN

Because rolled structural sections of the same nominal size are not exactly what the handbook records, it is necessary to list information as to the weight, length of the column to be tested, and average cross-section measurements. The first two items are straight forward and should give no trouble whatsoever; however, obtaining average cross-sectional dimensions may prove to be troublesome. Such questions as how many readings should be taken and where they are to be taken are of major importance. Because of this, the following is recommended.

1. Record to the nearest 0.0001 inch the thickness of the web at 10 uniformly spaced points over each end of the specimen.
2. Record to the nearest 0.0001 inch the thickness of the flanges by taking at least 10 readings uniformly spaced along each side of each flange of the column. (40 readings total).
3. Depth and Width of the Section is recorded to the nearest 0.001 inch at 10 uniformly spaced points along the column.
4. At least 2 sections other than the ends should be measured for variation in flange thickness across the section. (For tapered flange sections, this would be due to slope of flanges). A form for recording this information is shown on page .

Averages calculated from the above readings will be assumed to be the average cross-sectional dimensions of the section.

A check should be made against the Area obtained by use of these dimensions and that obtained by using the weight of the column and taking into account the density of steel.

An impression should be made of the cross-section to determine the size of the radius of fillets and as a permanent record. This is usually accomplished by using carbon paper directed toward a sheet of graph paper which is held by a piece of cardboard. If these are held against the end of the column (without sliping) and a rubber mallet is used to lightly tap around the section, the carbon paper will be deposited on the graph paper thus giving the sought impression.

An overall list of properties and dimensions to be determined is shown on page 22 of the Project 205 Manual.

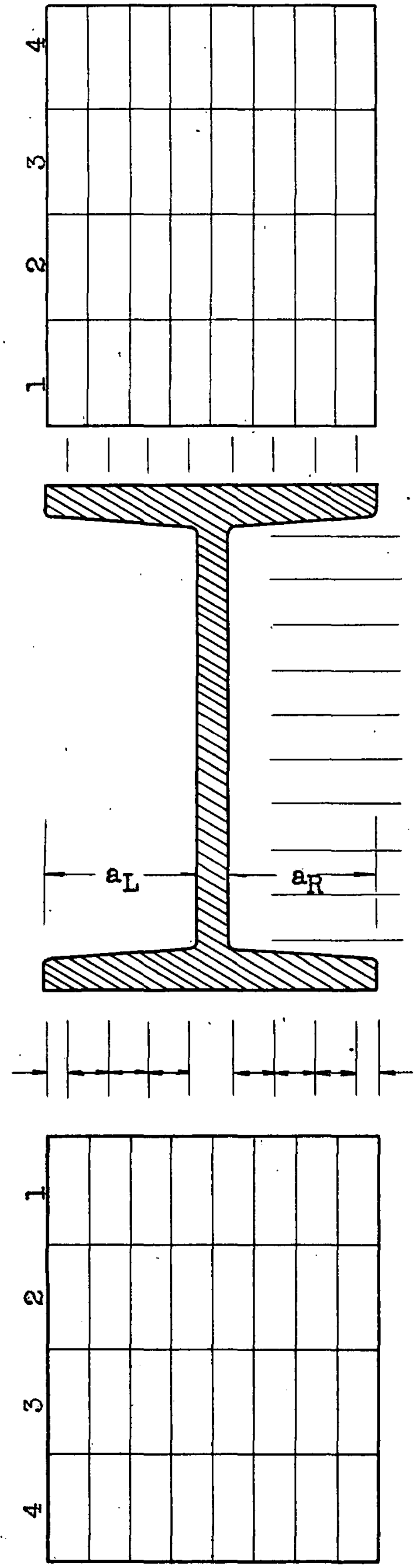
Tables for recording measurements are shown on page 16 and page 17 .

Test No. ____________

Section ____________

Date ____________

In Charge ____________



1	2	3	4

a_R					
a_L					
Width					
Depth					

DIMENSIONS FOR PARALLEL FLANGE SECTIONS

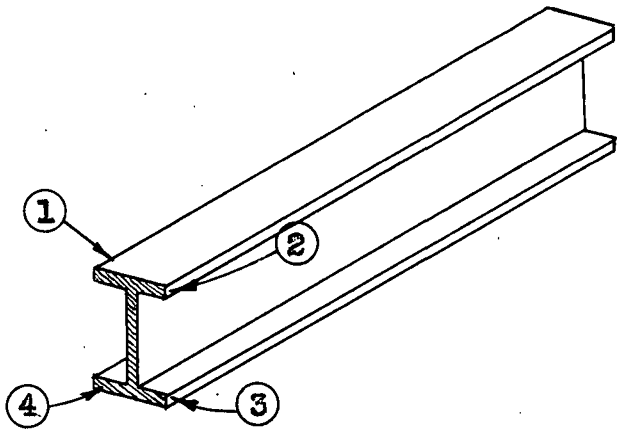
TEST NUMBER ______________

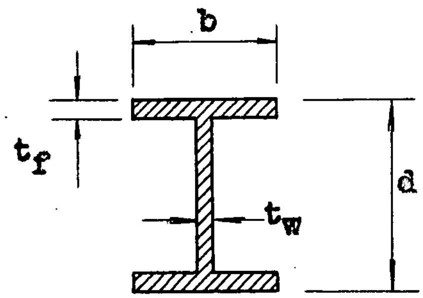
SECTION ______________

HEAT NUMBER ______________

IN CHARGE ______________

DATE ______________





LENGTH ______________

WEIGHT ______________

t_f Along Flanges				t_w Across Ends		b	d
1	2	3	4	top	bottom		

t_f Across Ends							
top				bottom			
1	2	3	4	1	2	3	4

P R O G R A M

Steps and Items to check at each load.

1. Select loads, write date and time. Compute new load in machine.
2. Dynamometer sheet - Get reading of strain indicator.
3. Set axial load on machine.
4. Apply MOMENT at top and bottom and adjust axial load if needed.
5. Adjust lateral tie rods so there is no lateral displacement. (Tolerance: 0.002")
6. Repeat 4 and 5, as needed.
7. Take readings of all gages.
8. Take final reading of load and dynamometer as a check.
9. Check whitewash for yielding. (Make sketches).
10. Write notes describing happenings since last load.
11. Plot all important curves. (Criterion gage at least).
12. Take photograph if something can be shown.
13. Check over complete set-up for clearances.
14. Go on to new load.

IN PLASTIC RANGE

a. Hold the load constant.

b. Keep a "Criterion" sheet. Check a t end of set of readings. (15 units in 15 minutes maximum allowable)

FRICTION TEST

This is a preliminary to the main test. Its purpose is to see that all instruments used are working properly and that the friction encountered is not sufficient to endanger accuracy.

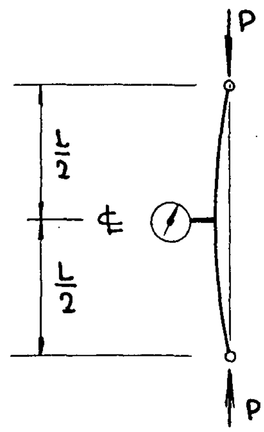
Readings should be taken on all gages until certain that they are working correctly. Readings recorded while unloading should check those while loading. If they do not check something is wrong. Be sure that none of the gages are stuck, deflection rig frame is not binding, etc. (Note: The first few readings are seldom correct. Therefore load and unload the column 3 or 4 times to eliminate sluggishness in the gages. Then proceed with loading.)

During this test, a Southwell Plot* should be made to predict the true buckling load for the set up. Procedure is outlined on page 20.

(Note: Do not, under any condition, apply a load to the column more than 40% of the predicted initial yield value.)

* A Southwell Plot is made for axial load alone (no moment).

Method of Obtaining:



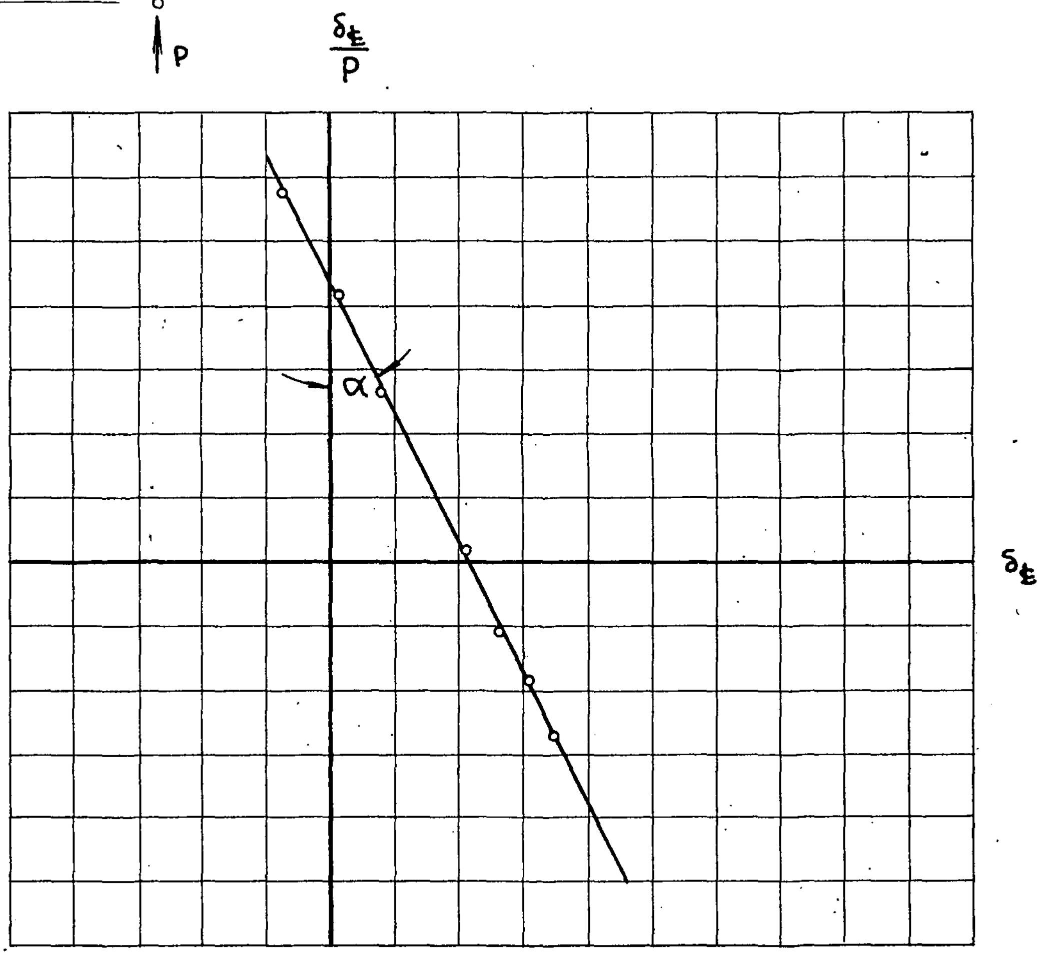
During Alignment test (friction) record centerline deflection in both strong and weak direction. (no moment)

With this information:

1. Divide deflection by axial load.
2. Plot results of 1. above against deflection.

Then:

$$P_{cr} = \tan \alpha$$



For further information see Timoshenko's "Theory of Elastic Stability", page 177.

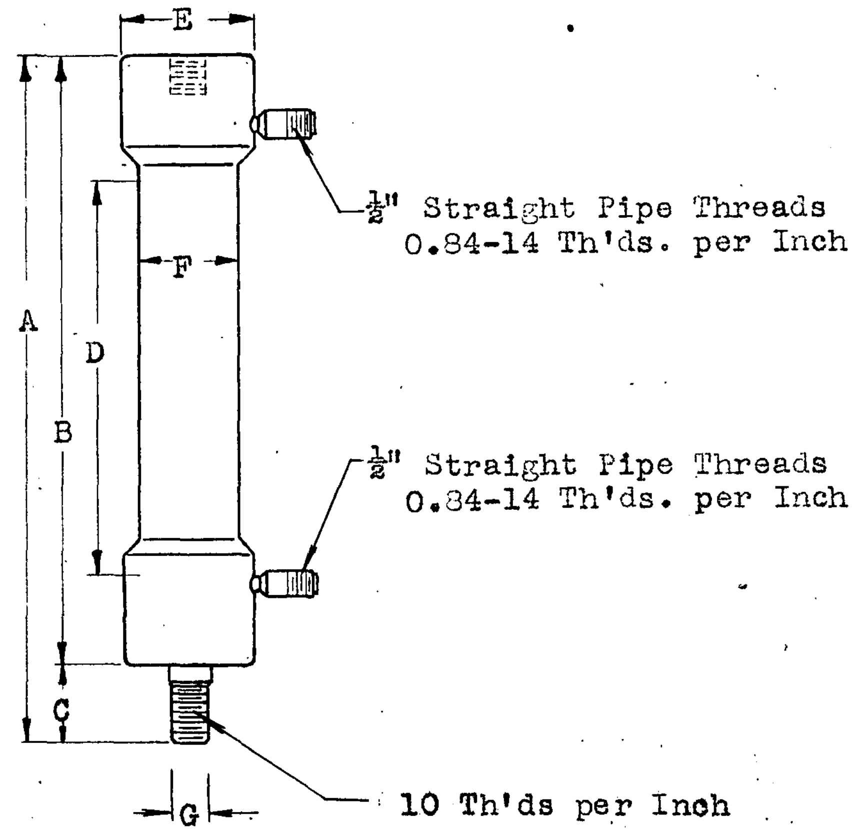
SOUTHWELL PLOT

for

Experimentally Determining Buckling Load

P U M P S & J A C K S

DESCRIPTION	NUMBER AVAILABLE
1. JACK CAPACITY (TENSION)	
Small: 10,000 psi --------- 30 kips; 30,000 psi --------- ~~90 kips~~; DWG.#12749-1 (203 L 12/21/46)	2
Large: 10,000 Psi --------- 50 kips; 30,000 psi -------- ~~150 kips~~; DWG.#12750-2	4
2. JACK CAPACITY (COMPRESSION) Same as in TENSION ONLY if restrained against buckling laterally at all critical points.	
3. PUMP CAPACITY Proof-Tested to 25,000 psi (203 L 1/24/47); Maximum working load ---------- 20,000 psi; DWG # 12695-1	7



G		A	B	C	Stroke D	E	F	Piston Diameter
1 1/8"	Small Jack	21.0"	18.75"	2.25"	12.0"	4.00"	3.00"	2.313"
1 1/4"	Large Jack	21.13"	19.63"	2.50"	12.0"	4.50"	3.69"	2.812"

Note: Jacks Manufactured by MESSINGER BEARING, Inc., Philadelphia, Pennsylvania. Same as type manuf. for "THE GLENN L. MARTIN COMPANY", Baltimore, Md.

HYDRAULIC JACKS

NOTES ON OPERATION OF HIGH PRESSURE PUMP *

FILLING PUMP:

To fill pump remove filter plug from top of oil filter and pour in oil with small funnel or pump oil can. The reservoir will hold 3.18 quarts of oil. Fill until oil runs out of small drilled hole in side of oil filter.

BLEEDING PUMP:

Before operating pump it is necessary to bleed all the air trapped in the pump. With the pump handle at the end of its stroke in the downward position, remove either of the two small allen screws at the extreme rear of the pump block and holding a finger securely over the hole, raise the pump handle to extreme stroke, now remove finger and push pump handle down slowly, oil will flow out. Continue this process until a steady stream of oil is noted with no air bubbles visible. Do not at any time lift handle without having finger over bleeder opening. Replace small allen set screw. Now connect line to pump with jack end free, pump until a steady stream of oil is flowing from the line with no air bubbles and connect line to jack. To connect pressure gage, pump until there is an air free flow of oil from the upper connection (gage connection) then connect pressure gage. The system is now ready for operation.

Gage - It is not necessary to have the gage filled with oil. Merely connect up gage as described above.

Jacks- Do not pull plunger out or push it in by hand. It must be pumped to the desired position. It is not necessary to get all the air out of the jacks.

* taken from paper by J. A. Ready and L. S. Beedle

DISASSEMBLY OF PUMP:

Drain the oil from the reservoir, by removing magnetic plug from the bottom of the reservoir. Remove 5-7/8" allen bolts from side of pump, this allows removing the pump block from the reservoir. Unscrew end cap, turn pinion gear until the piston is all the way back (handle in upward position) remove handle stud in pinion gear and slide out pinion gear. Slide out rack and plunger. It is now possible to unscrew the retaining bushing (special wrench is needed) and oil feed bushing (special allen wrench is needed). To remove the relief valve simply unscrew the relief valve bushing. The check valve may be cleaned by removing end disk taking out spring and ball and blowing out ball seat. Then placing ball in seat and tapping lightly, this will seat the ball and give a good seal.

TROUBLE SHOOTING:

1. If the pump will not bleed or air continues to enter pump, the pump is not properly aligned to reservoir, loosen allen bolts and retighten, check relief valve bushing.

2.* If after pressure has been built up in the system, the handle will not stay down after a pressure stroke, the check valve needs cleaning, (improper seating of the pressure valve). If in such case you will crack open the relief valve, reducing the built-up pressure only a little, and then close the relief valve immediately, the grit particle may become dislodged and the pump will resume normal operation. The relief valve may be cracked open and closed promptly 2 or 3 times in quick

* letter to L. S. Beedle from "Messinger Bearing Co."

succession. This will agitate the ball check and seat it more firmly. The pump handle should be given short violent strokes. This usually invariably corrects failure to hold pressure.

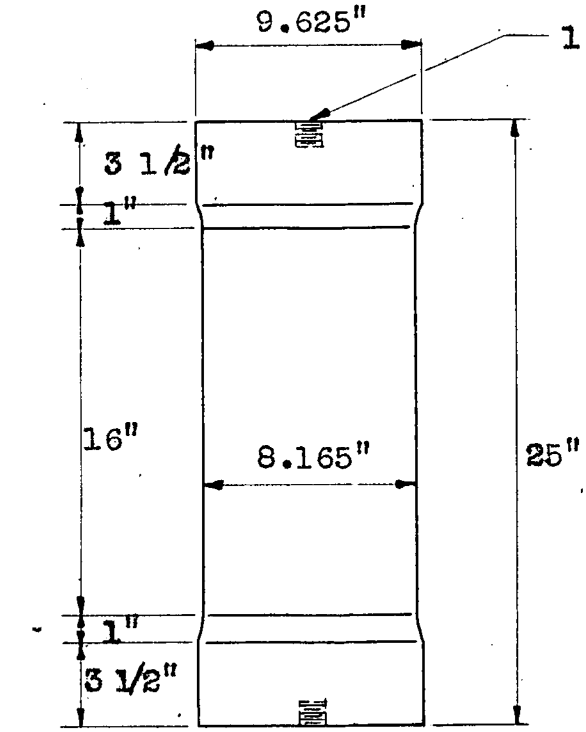
NOTE:

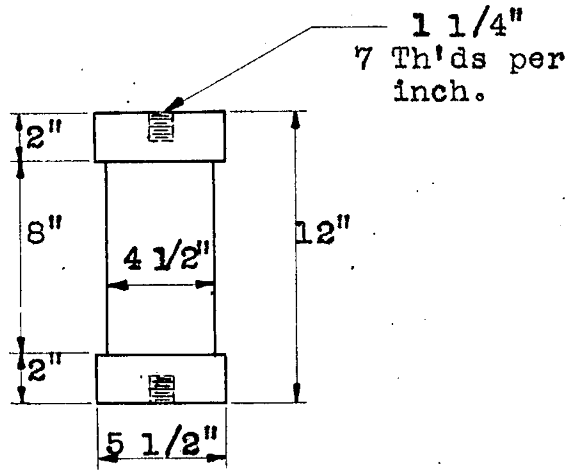
Do not scratch lapped surface on pump block or on reservoir block between the 4 - 7/8" allen bolts. Handle carefully.

DYNAMOMETERS

Serial No.	Description	Design Load (in kips)	Max. Load (in kips)
205-1	Aluminum Tube 12" Long - 4½" Dia.	14	12
205-2	Aluminum Tube 12" Long - 4½" Dia	14	12
205-A	Aluminum Tube 24" Long - 8" Dia.	100	85
205-B	Aluminum Tube 24" Long - 8" Dia.	100	85
205-C	Aluminum Tube 24" Long - 8" Dia.	100	85
205-D	Aluminum Tube 24" Long - 8" Dia.	100	85
R-1	Steel Ring (Undergrad. Lab.)	?	30*
R-2	Steel Ring (Undergrad. Lab.)	?	30*
R-3	Steel Ring (Undergrad. Lab.)	?	20*
R-4	Steel Ring (Undergrad. Lab.)	?	20*

* The reason for allowable load being different than that shown on original drawing is that steel specified on drawing was not used for actual ring. (Note: these loads are for tension and will yield if over loaded).



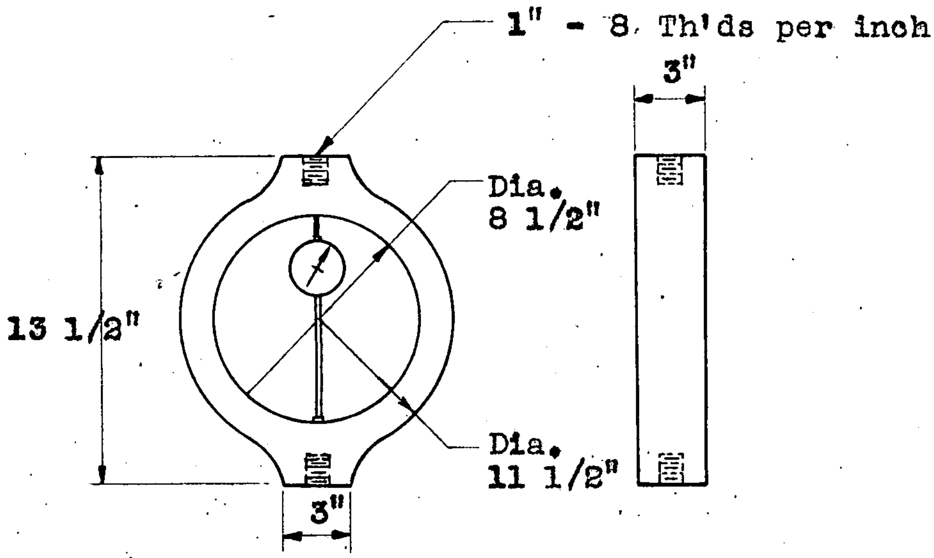


SMALL ALUMINUM TUBE
DYNAMOMETER

AD-1 SR-4 gages
Gage Factor 2.01

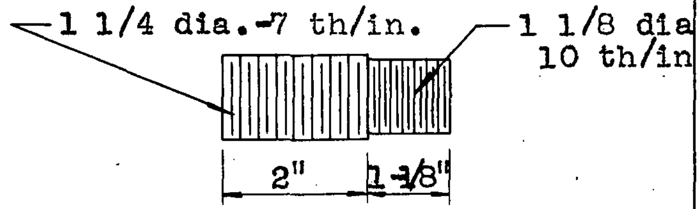
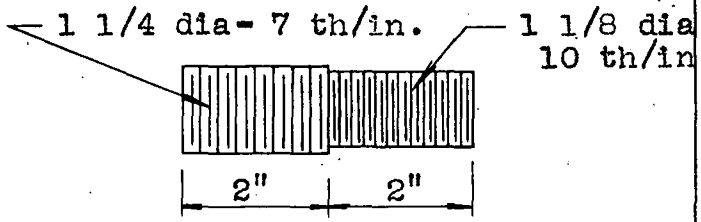
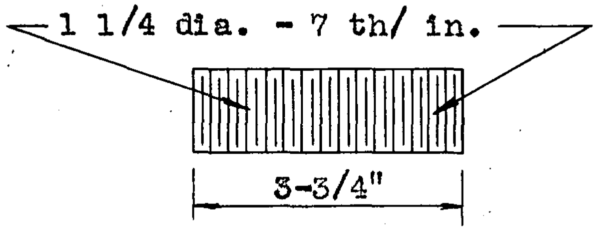
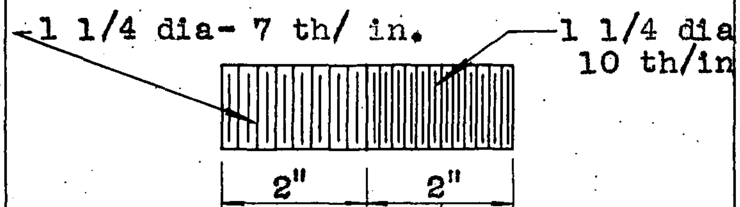
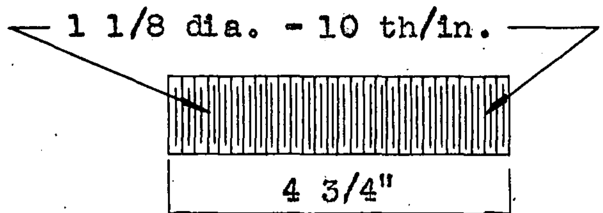
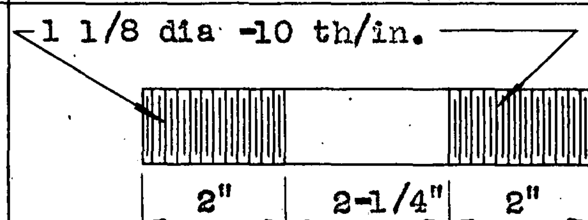
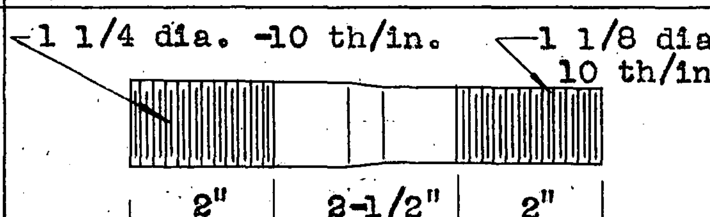
LARGE ALUMINUM TUBE
DYNAMOMETER

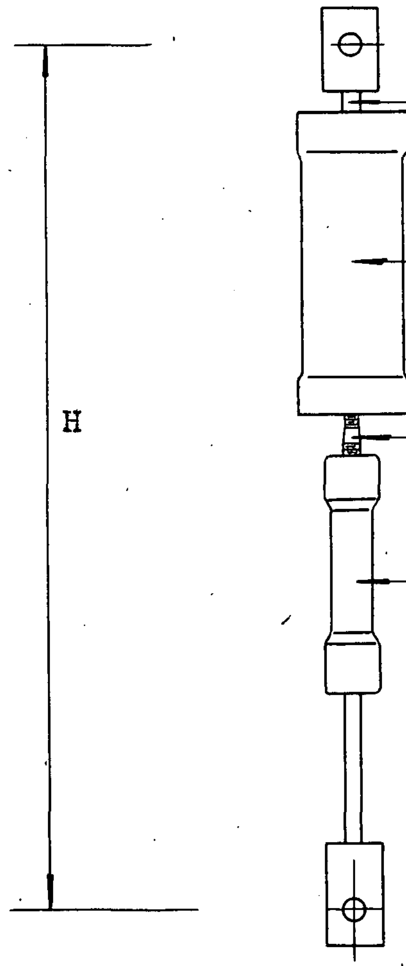
AD-1 SR-4 gages
Gage Factor - 2.04



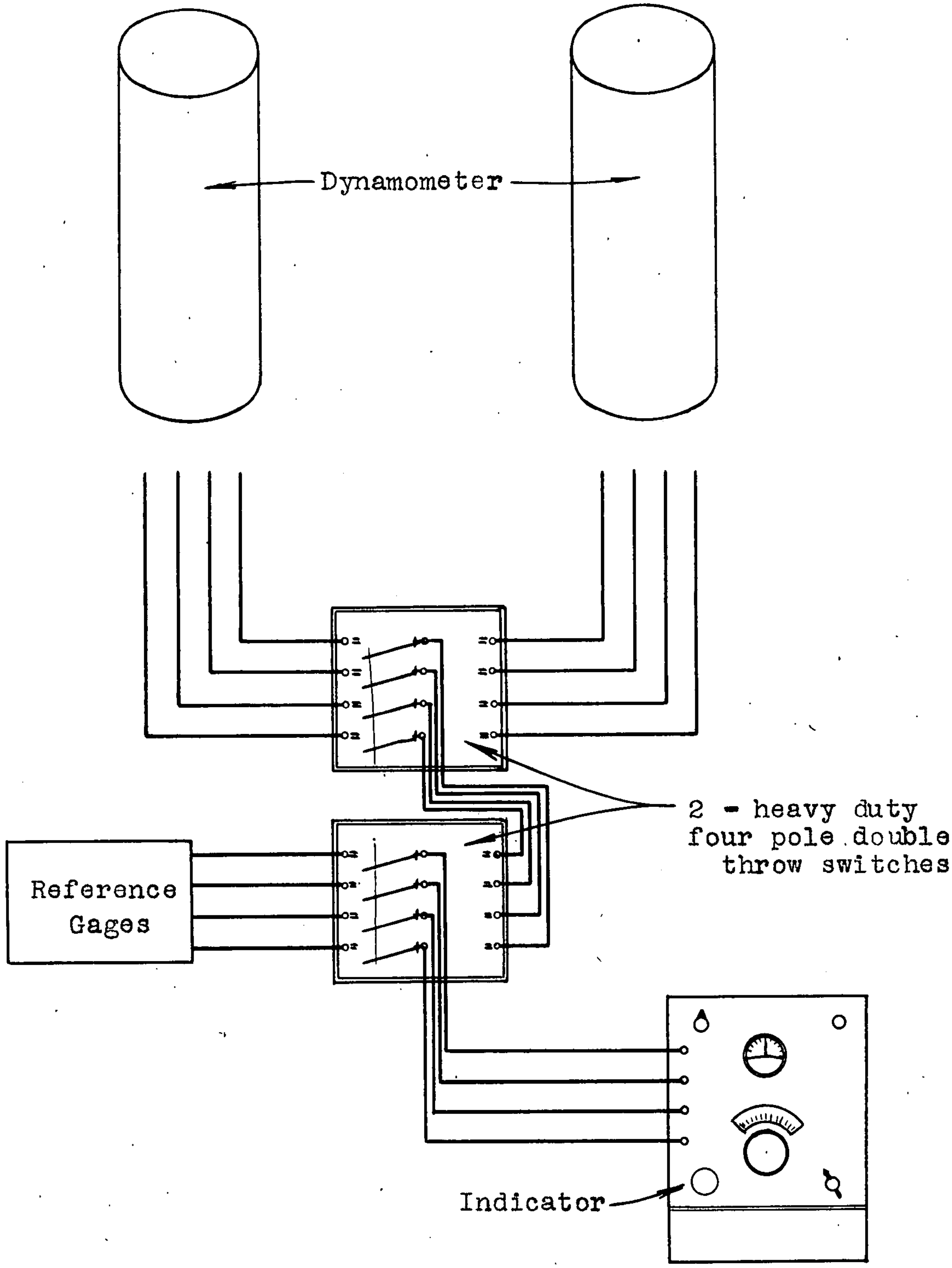
STEEL RING
DYNAMOMETER

CONNECTING SCREWS

No.	Sketch	Number Available	
A		2	
B		1	
C		1	
D		1	
E		1	
F		4	
G		4	

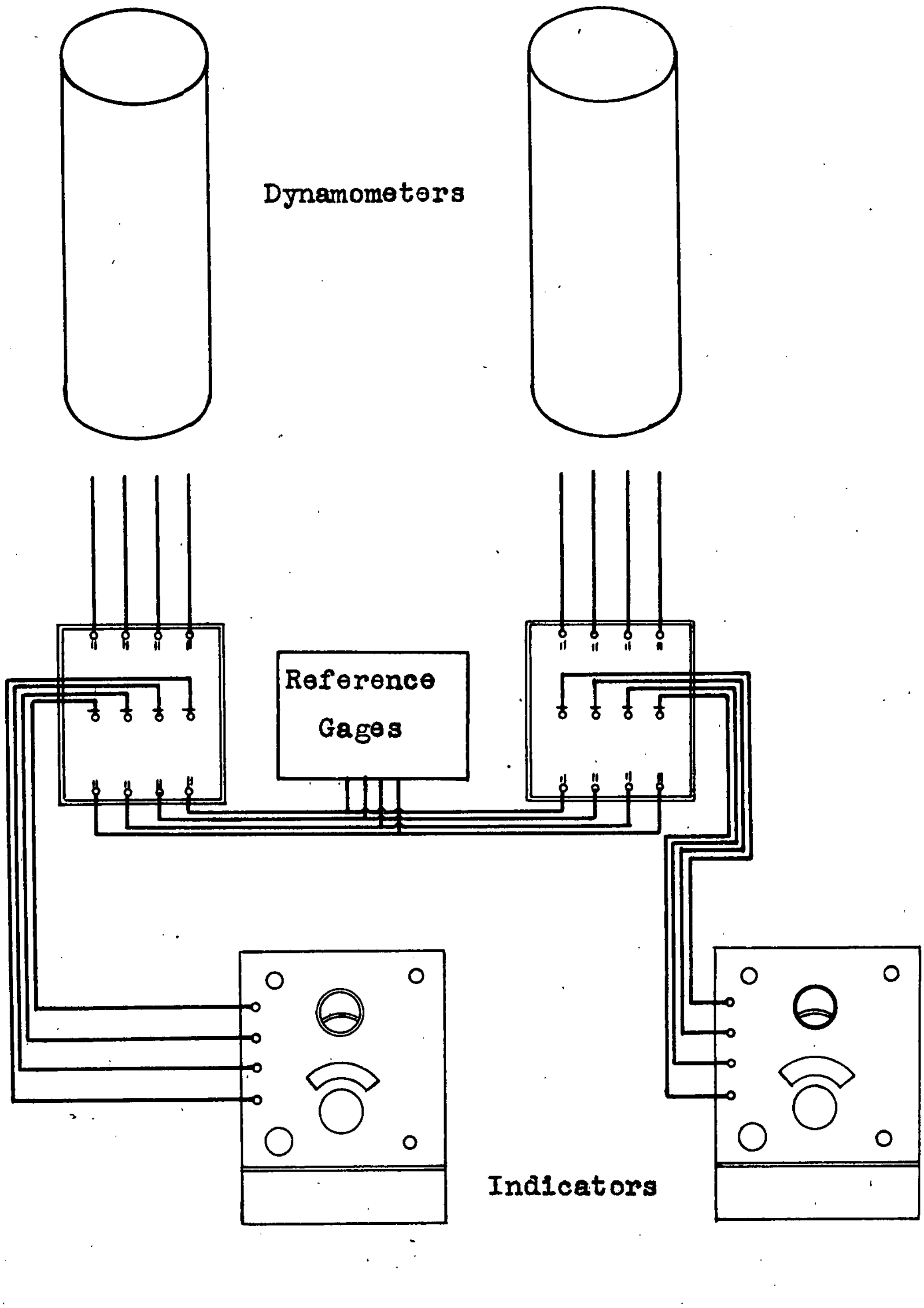


DYNAMOMETER	JACK	CONNECTION SCREW "A"	CONNECTION SCREW "B"	H
LARGE	LARGE			
LARGE	SMALL			67"
SMALL	LARGE			
SMALL	SMALL			46 3/4"
RING	SMALL			



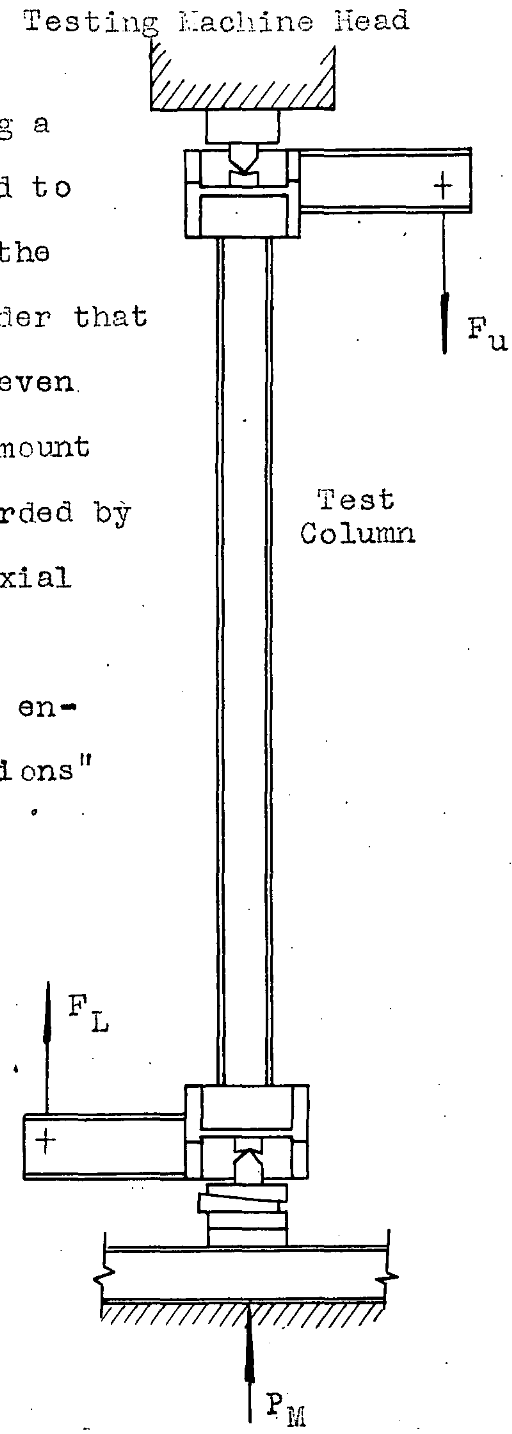
WIRING DIAGRAM FOR USING REFERENCE GAGES

WITH DYNAMOMETERS



WIRING DIAGRAM FOR USING REFERENCE GAGES

WITH DYNAMOMETERS



P_M is the load indicated by the Testing Machine

AXIAL LOAD APPLICATION:

Since moment is obtained by applying a force at the end of arms rigidly attached to the column, an axial load is imposed on the column due to moment application. In order that a constant axial load can be maintained even though this condition exists a certain amount must be subtracted or added to that recorded by the testing machine to obtain the true axial load on the column.

Existing Conditions most frequently encountered are: (Using "Table of Corrections" below)

1. If F_u is applied downward:.

   Axial load $- F_u = P_m$

2. If F_L is applied upward:

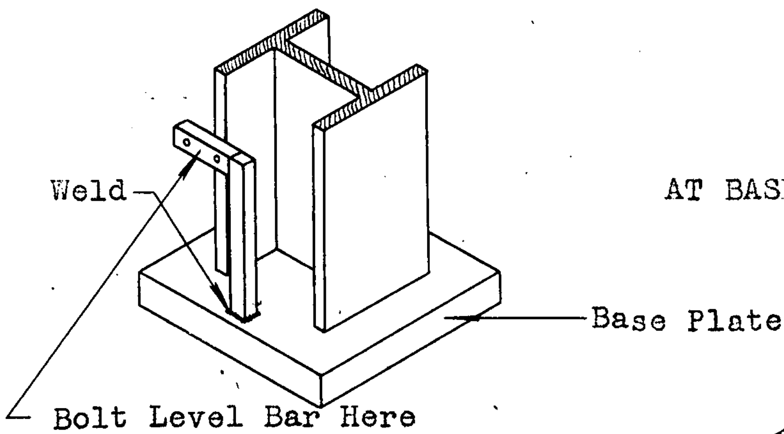
   Axial load $- 0 = P_m$

TABLE OF CORRECTIONS		
THRUST	DIRECTION	CORRECTION TO P_M *
F_u	↓	$- F_u$
F_u	↑	$+ F_u$
F_L	↓ ↑	none

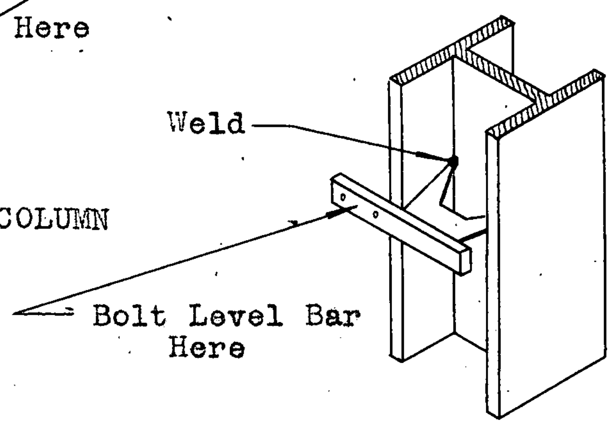
* $P_M = P +$ value shown in table.

ROTATION MEASUREMENTS

Rotation measurements are made by use of a "Level Bar" (see sketch page 34). These are connected to the column base plate or along the column as required by means of special welded attachments.



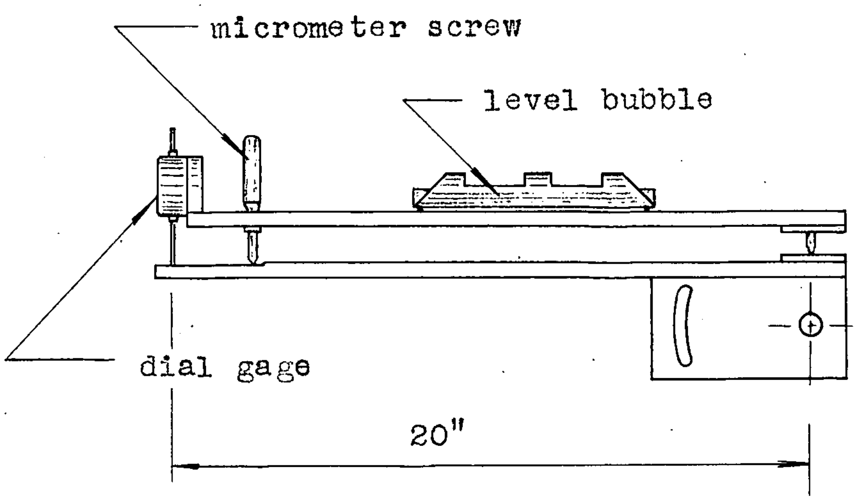
AT BASE PLATE

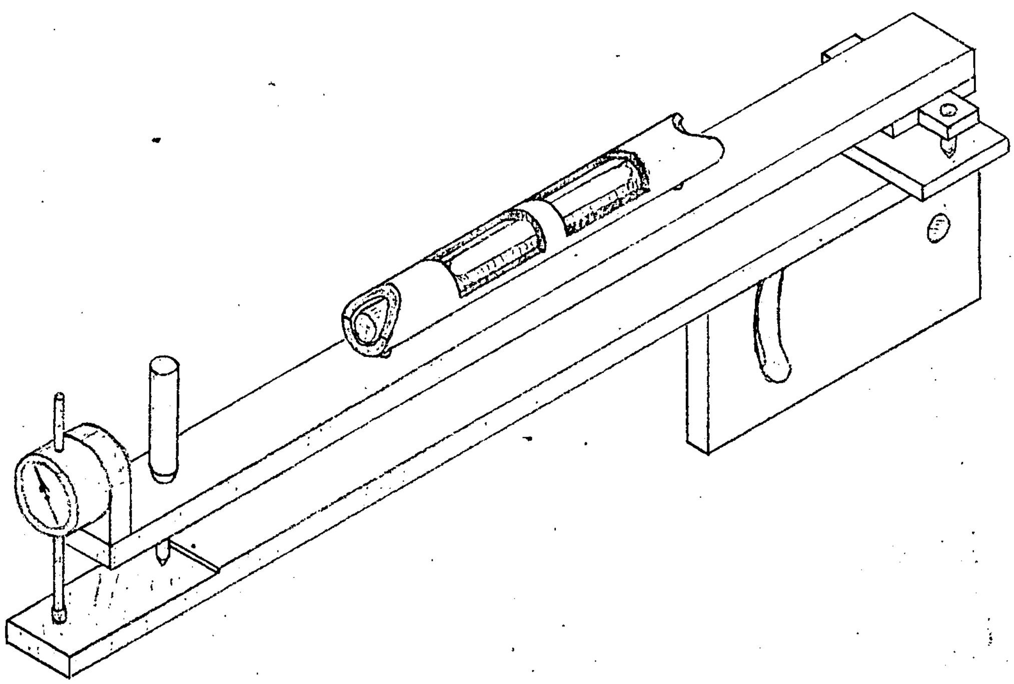


ALONG COLUMN

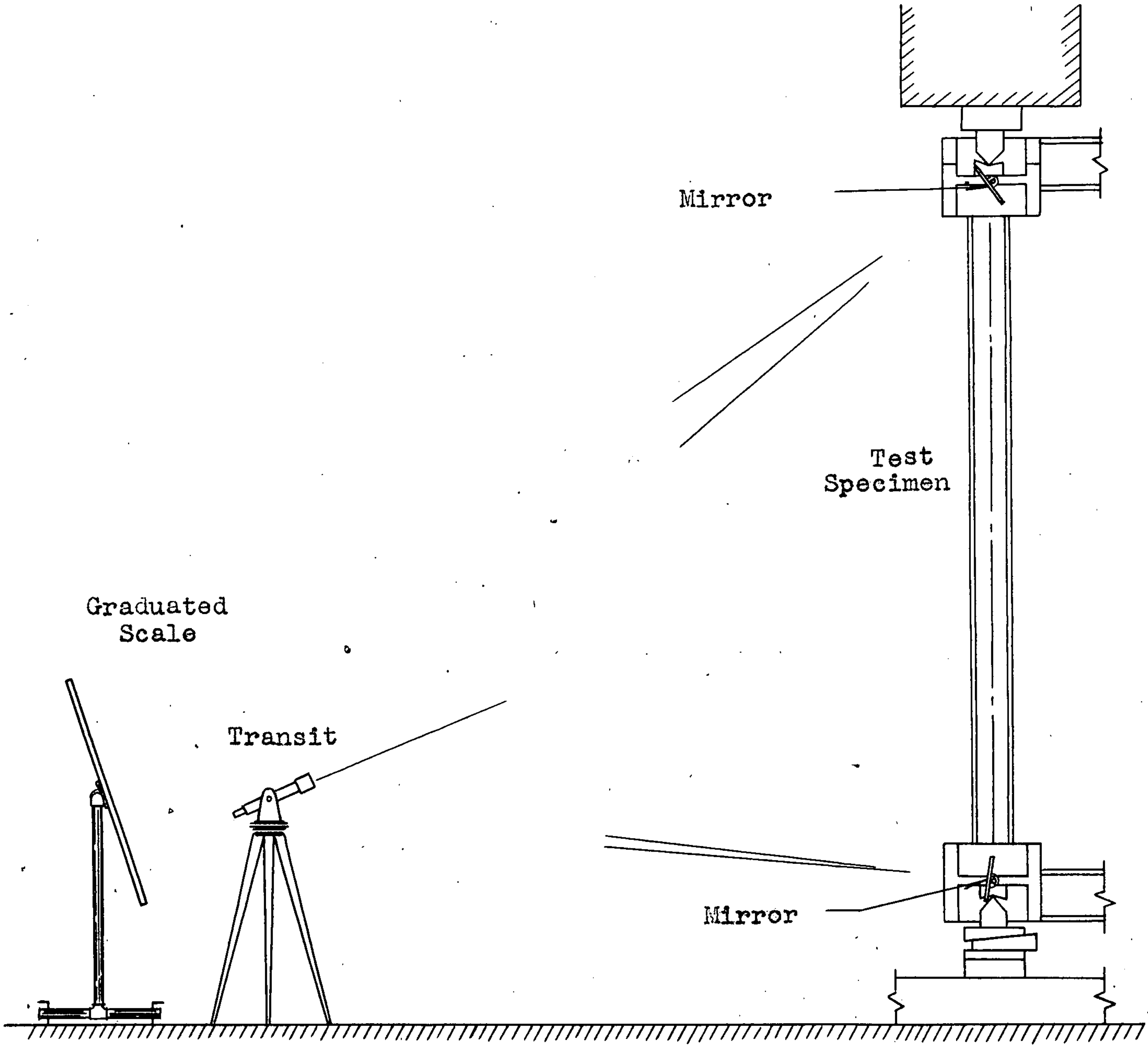
To obtain the true rotation (inches/inch) divide the level bar reading by 20 inches. If a 0.001 dial is used, it is possible to estimate to the nearest 0.0001 inch; therefore, the level bar can obtain rotation measurements to the nearest 0.000005 inches/inch.

A proposed optical rotation system (see page 35) has been considered but as yet has not been used.





LEVEL BAR



PROPOSED OPTICAL ROTATION MEASURING SYSTEM

DEFLECTION MEASUREMENTS

Deflection measurements are made with Dial Gages (1" and 2 " travel) reading to the nearest 0.001 inch, estimating to the nearest 0.0001 inch.

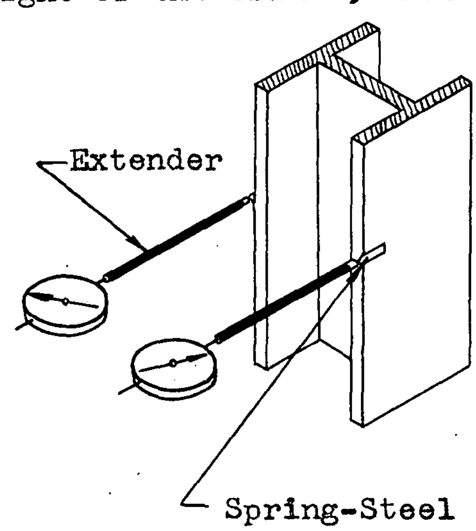
The measurements in the direction of bending are made with gages fastened to small Aluminum Angles which in turn are clamped to a Deflection Rig by means of small "C" clamps.

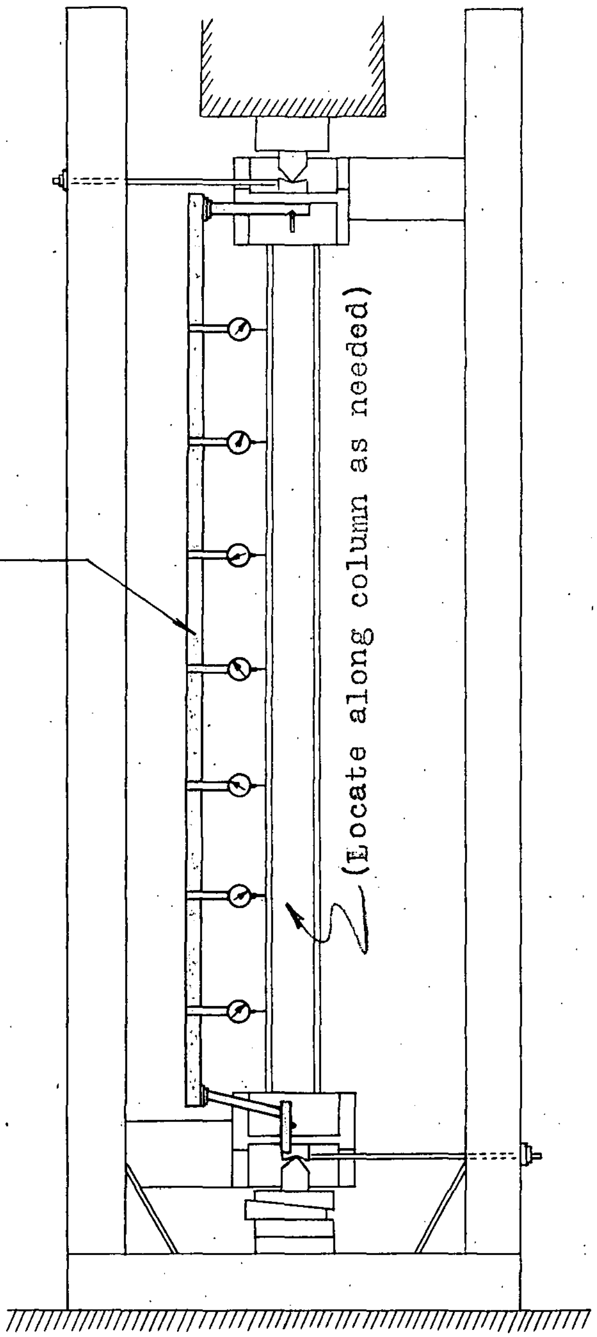
The deflection rig (see page 37) is composed of a steel angle suspended by a bracket which rest at the top on pins directly on the axis of the column in the plane of the junction of the test specimen to the upper base plate. The base bracket of the rig rests against a similar pin on the axis of the column in the plane of the junction of the specimen to the lower base plate.

Because of this arrangement, measurements are always with reference to the original centerline of the column.

LATERAL DEFLECTION GAGES

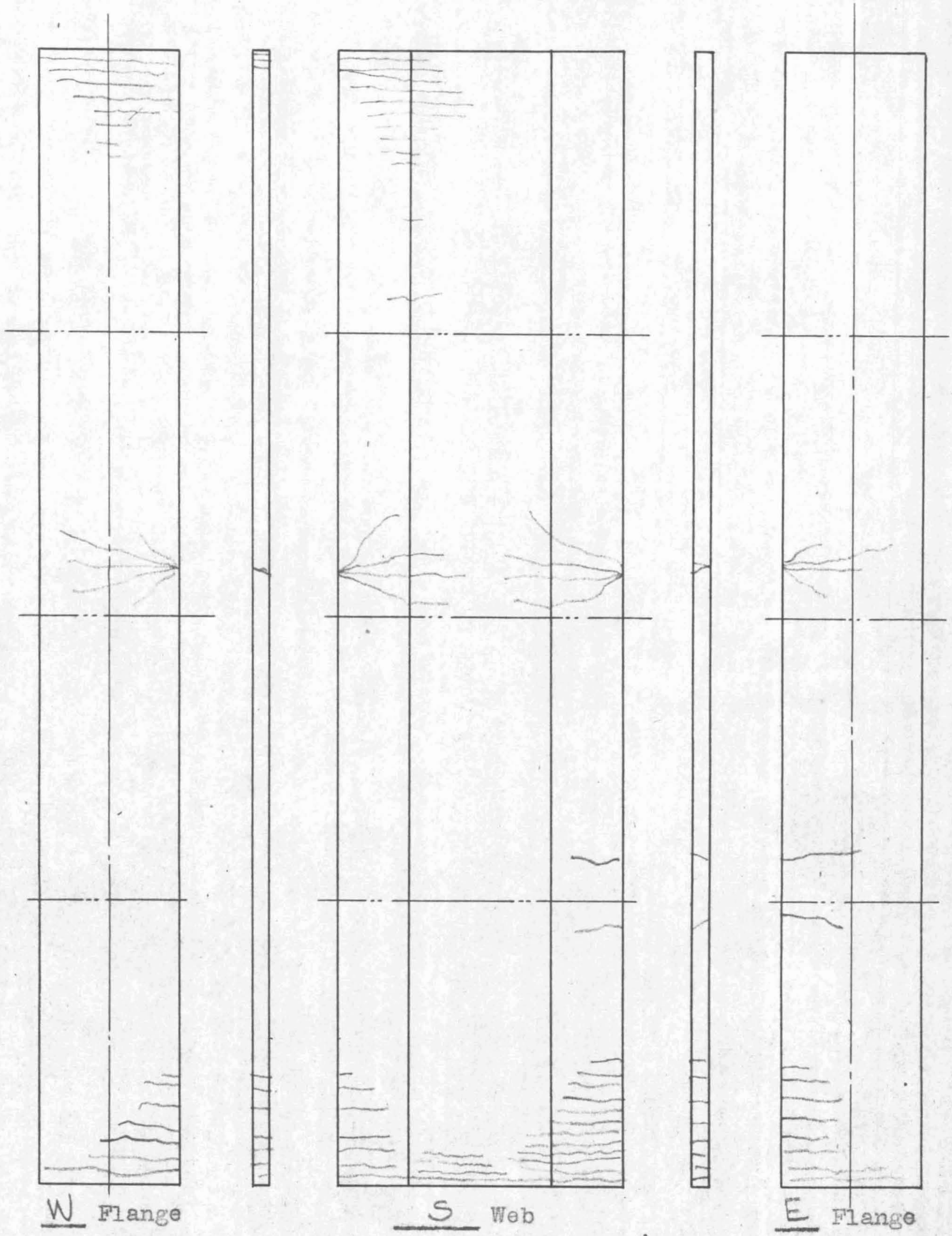
Deflections in the lateral direction are usually measured with Dial Gages located at the mid-height of the column, this point being the most susceptible to this mode of failure. Measurements are made thru the use of extenders clamped to the flanges of the column thru spring steel. By using the spring steel twisted thru 90° we are assured of freedom from restraint in all directions.





Note: To save as many resets as possible, use 2" Travel Dials at points of maximum Deflection.

DEFLECTION GAGE SET-UP



WHITE WASH SKETCH