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LOCAL BUCKLING OF TUBULAR STEEL COLUMNS

TWO HIGH-STRENGTH STEEL TUBULAR COLUMN TEST

by

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This work has been carried out as part of an
investigation sponsored by the American Iron and
Steel Institute.

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1. INTRODUCTION

1.1 Background

In a variety of structures subjected to three-dimensional loading, such as offshore oil drilling platforms, tubular members are used since this shape provides equal resistance to buckling in all directions. The design of such members with respect to local buckling is handicapped by the discrepancies between the currently available design recommendations. The sparsity and wide scatter of experimental data appear to be the cause of these discrepancies.

The design curves presently used for local buckling are shown in Figure 1. Of particular interest are the AISI (1) (American Iron and Steel Institute) and Marshall (2) curves which are recommended by AISI and API (3) (American Petroleum Institute) for practical use in the design of fabricated tubular members in this country. The disagreement between these curves is substantial, expecially in the range of $F_c/F_y =$ .5 to .8.

The results of an AISI-supported project dealing with the local buckling of tubular columns fabricated from 50 ksi (345 MPa) steel, labeled P1 - P7 are shown in Figure 2 (4). The test points were very consistent among themselves, forming a continuous curve with very little scatter, showing that the principal American design rules (AISI and API) are unduly conservative. However, this conclusion cannot be extended to other grades of steel without further research.

In this research project, two high-strength steel tubular columns,

P8 and P9, were tested and failed by local buckling above the proportional limit. Specimen P8 was tested to determine the effect of a transverse weld on the local buckling stress and specimen P9 was tested to determine the effect of a higher yield stress on the local buckling stress.

The experimental results will serve as a basis to formulate a design recommendation for practical consideration of local buckling stresses in the design of tubular columns.

2. DESCRIPTION OF TEST SPECIMENS

2.1 Geometric and Material Parameters

Test specimens P8 and P9 and the pertinent notation are shown in Figure 3. The dimensions and other parameters for each of the specimens are listed in Table 1.

Specimen P8 was made from ASTM A572 steel and P9 from A514 Type B steel. The nominal yield stress values were 50 ksi and 100 ksi, respectively.

Specimen P8 was made by modifying a previously tested specimen P6 (4). After removing the buckled portion and rewelding the end ring, the specimen was cut at a midheight into two halves. The longitudinal welds were staggered and the specimen rewelded. In the process, the length was reduced while all other dimensions remained unchanged.

Specimen P9 was fabricated by cold-rolling a flat plate in a pyramid three-roll plate bending machine and then welding the longitudinal seam. The submerged arc process was used to place a multi-pass vee weld.

2.2 Preparation of the Specimen Ends

The ends of each specimen were prepared so that the load could be applied uniformly to the specimen wall. This was accomplished by welding a 6 in. (127mm) wide X 1 in. (25.4mm) thick ring to each end of the specimen.

2.3 Material Properties

Static yield stress values obtained from flat plate coupons at a
zero strain rate were used in evaluating the test results. The coupons
were made in accordance with ASTM Standards (5). The yield stress
values, taken as an average of 3 or 4 coupon tests, are listed for each
specimen in Column 3 of Table 1.

3. TEST SETUP AND INSTRUMENTATION

3.1 <u>Test Arrangement & Instrumentation</u>

A schematic representation of the test setup is shown in Figure 4. The test specimen is shown standing between the loading head and the test floor. The surface of the specimen was whitewashed to give a visual indication of surface yielding during the test.

The instrumentation consisted of mechanical and electrical-resistance gages. Four mechanical gages located at the corners of the machine head were used to measure longitudinal shortening of the test specimens. Three electric-resistance gages located at midheight were equally spaced around the circumference of the specimen. These gages served in the alignment of the specimens and as an alternate means for determining longitudinal strains during the test.

The lateral deflection of the specimen wall relative to the ends of the specimen was measured by means of a special movable dial gage rig. The rig consisted of eight mechanical dial gages permanently attached to a trussed frame. The bottom end of the rig sat on the base plate and touched the specimen wall, while the top end was held against the specimen by means of an electromagnet. Readings were taken at thirteen locations around the circumference by successively repositioning the dial gage rig.

4. TEST PROCEDURE

4.1 Alignment

The tests were conducted on a 5-million pound hydraulic Baldwin testing machine. The first phase of each test consisted of alignment of the specimen in the testing machine. The loading head of the machine has a mechanism for controlling tilting, and, by careful adjustment, a practically concentric load could be applied.

Tilting of the loading head was not sufficient for achieving a uniform load because the end rings of the specimen were not truly flat. A layer of gypsum grout, Hydrostone, was poured between the end rings and the testing machine. After hardening, the grout could transmit loads uniformly to the specimen without any further alignment.

4.2 Test Sequence

Following alignment, the test began with the application of 20 kips (90 KN) of load and the attachment of the four longitudinal dial gages. Readings taken at this load were used as the initial reference condition for all subsequent readings.

Each specimen was loaded in increments of 100 kips (445 KN). At each load increment, readings were taken of the longitudinal dial gages and of the electric-resistance gages. The lateral displacement readings of the dial gage rig were taken at the initial load of 90 KN and at several intermediate loads prior to buckling.

5. TEST RESULTS

5.1 Behavior of the Specimens

The test behavior of both specimens is shown in Figure 5. The load is given as the average axial stress nondimensionalized with respect to the static yield stress of the material (ordinate), and the deformation is given as the average longitudinal strain (abscissa).

After some initial nonlinearity due to self-adjustments in the grouted ends of the specimens, the test curves followed a linear elastic path. The proportional limits were .8 Fy and .9 Fy for P8 and P9, respectively. In each case, the maximum stress was limited by local buckling.

After initial buckling, there was an immediate reduction in stress which stabilized at approximately .25 Fy for each specimen. The rate of reduction varied as a function of the elastic response of the testing machine and the stiffness of the test specimens.

Following the initial reduction in stress, the stress gradually decreased until a constant stress level was achieved. This occurred in the range of strain of .005 to .006 for each specimen. Beyond this range of strain, the stress increased marginally and the tests were terminated.

5.2 Discussion of Test Results

The buckling stresses of P8 and P9 are plotted in Figure 2. The results of the test indicate that for specimen P8 the transverse weld

had no effect on the buckling stress. This is illustrated by the proximity of the test points P6 and P8 on the graph. The actual buckling stresses were .88 Fy for P6 and .87 Fy for specimen P8. Test point P8 lies on a continuous curve formed from test points obtained in tests on 50 ksi steel columns, indicating that for 50 ksi steel the principle American design rules (AISI and API) are conservative.

Test specimen P9, made of 100 ksi steel, gave a test point which is significantly above the other Lehigh test on 50 ksi specimens. This indicates that for higher strength steels, the design curves may also be conservative. However, before this conclusion can be made for 100 ksi steel, more research is needed.

6. SUMMARY AND CONCLUSIONS

Local buckling tests were conducted on two tubular test specimens. The specimens were fabricated from high-strength steel plate by cold-rolling and welding.

The maximum stresses achieved in the test were limited by local buckling. The buckling stresses of each specimen were greater than its proportional limit and thus the buckling was inelastic.

The following conclusions can be drawn from the results of these tests:

1. The design rules for local buckling currently recommended by AISI and API are adequately conservative for tubular members fabricated from 50 ksi steel falling within the range of parameters tested.

2. These design rules appear to be conservative for tubular members fabricated from 100 ksi steel.

3. A transverse weld in a tubular member does not appear to affect the local buckling stress.

7. ACKNOWLEDGEMENTS

8. NOMENCLATURE

MPa	Megapascal
kN	Kilonewton
mm	Millimeter
m	Meter
Fy	Average Yield Stress
Fc	Critical Local Buckling Stress
OD	Outside Diameter
L	Length
t	Thickness
E	Modulus of Elasticity

TABLE 1: ACTUAL SPECIMEN DATA

No.	Steel	Coupon Static F_y (MPa)	Measured OD (m)	t (mm)	L (m)	D/t	α	F_c/F_y
1	2	3	4	5	6	7	8	9
P1	A572 Gr50	319.17	0.717	8.349	2.05	84.85	7.51	0.998
P2	A633 GrD	346.68	0.741	8.037	2.05	92.26	6.42	1.008
P3	A572 Gr50	319.17	1.190	8.349	3.05	141.53	4.50	0.989
P3A	A572 Gr50	319.17	1.190	8.349	2.03	141.53	4.50	1.009
P4	A633 GrD	346.68	1.217	8.037	3.05	151.39	3.88	0.951
P5	A572 Gr50	377.16	1.787	7.165	3.03	248.38	2.17	0.814
P6	A572 Gr50	372.05	1.533	7.262	3.03	210.05	2.60	0.889
P7	A572 Gr50	372.05	1.203	7.262	3.03	164.62	3.32	0.941
P8	A572 Gr50	372.05	1.533	7.262	2.44	210.05	2.60	0.872
P9	A514 Type B	622.76	1.532	6.553	2.44	232.84	1.40	0.912

Notes:

$$D = OD - t$$

$$\alpha = Et/F_y D$$
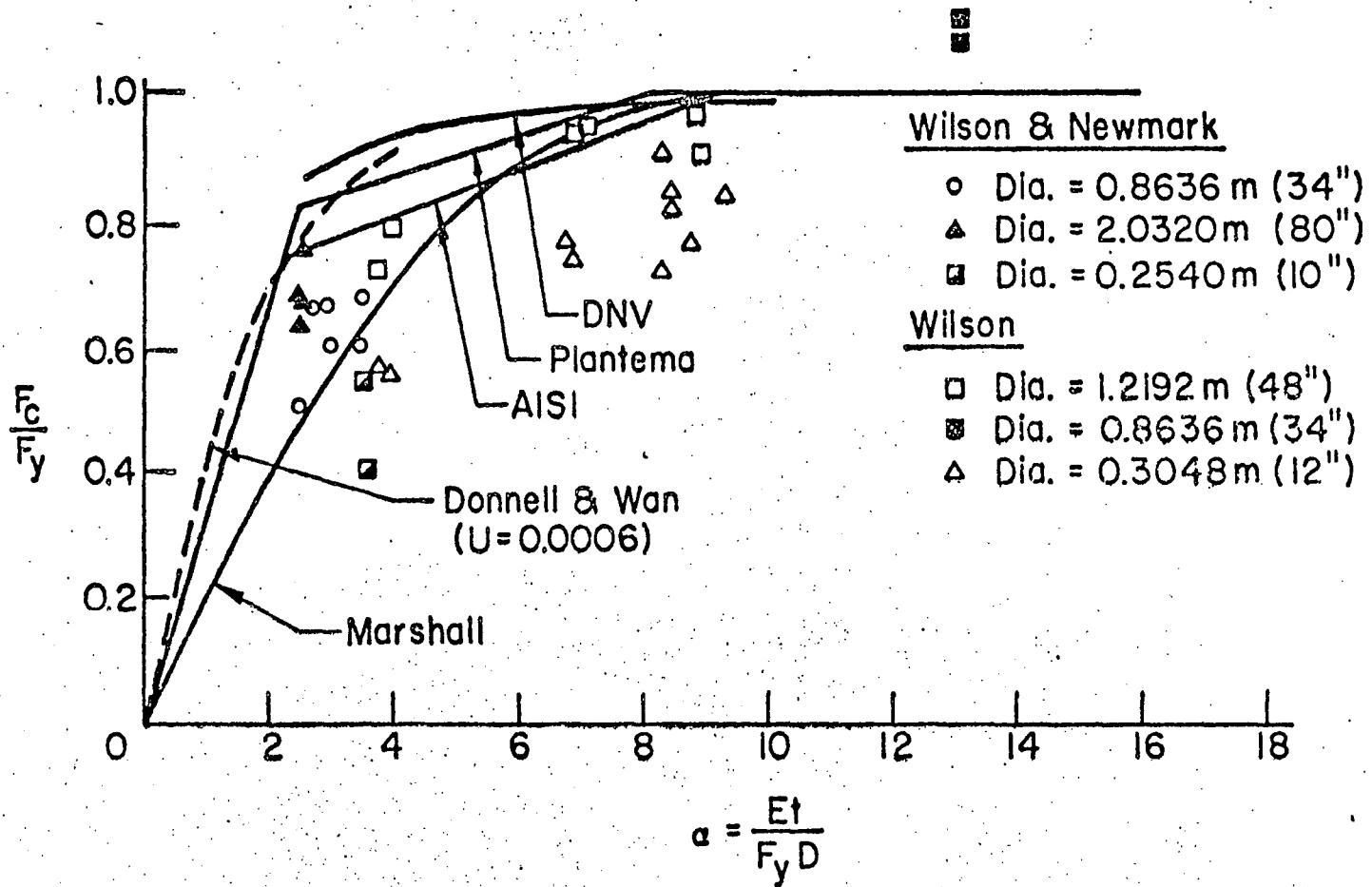
FIGURE 1

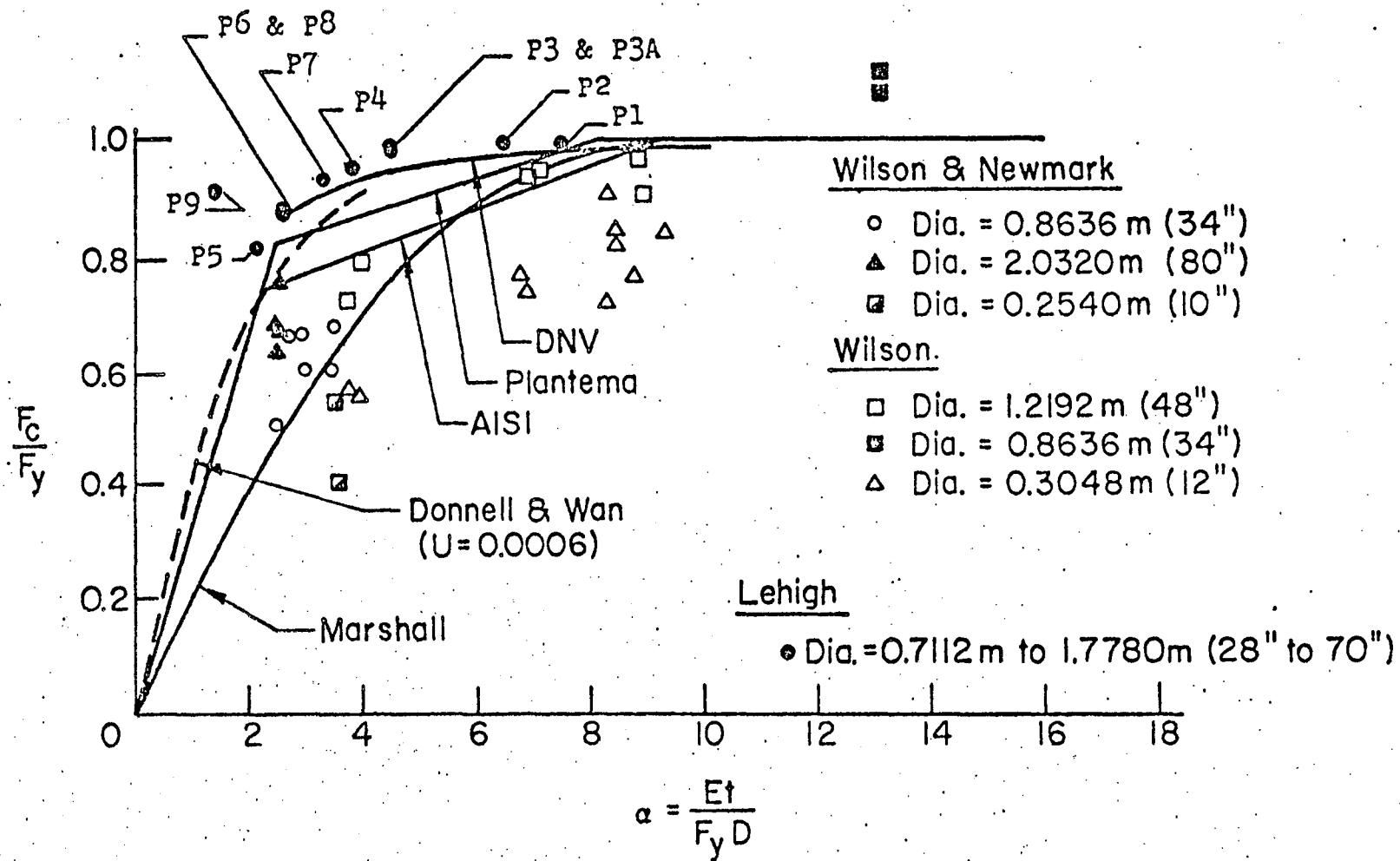DESIGN CURVES AND PREVIOUS TEST RESULTS FOR LOCAL BUCKLING OF TUBULAR COLUMNS
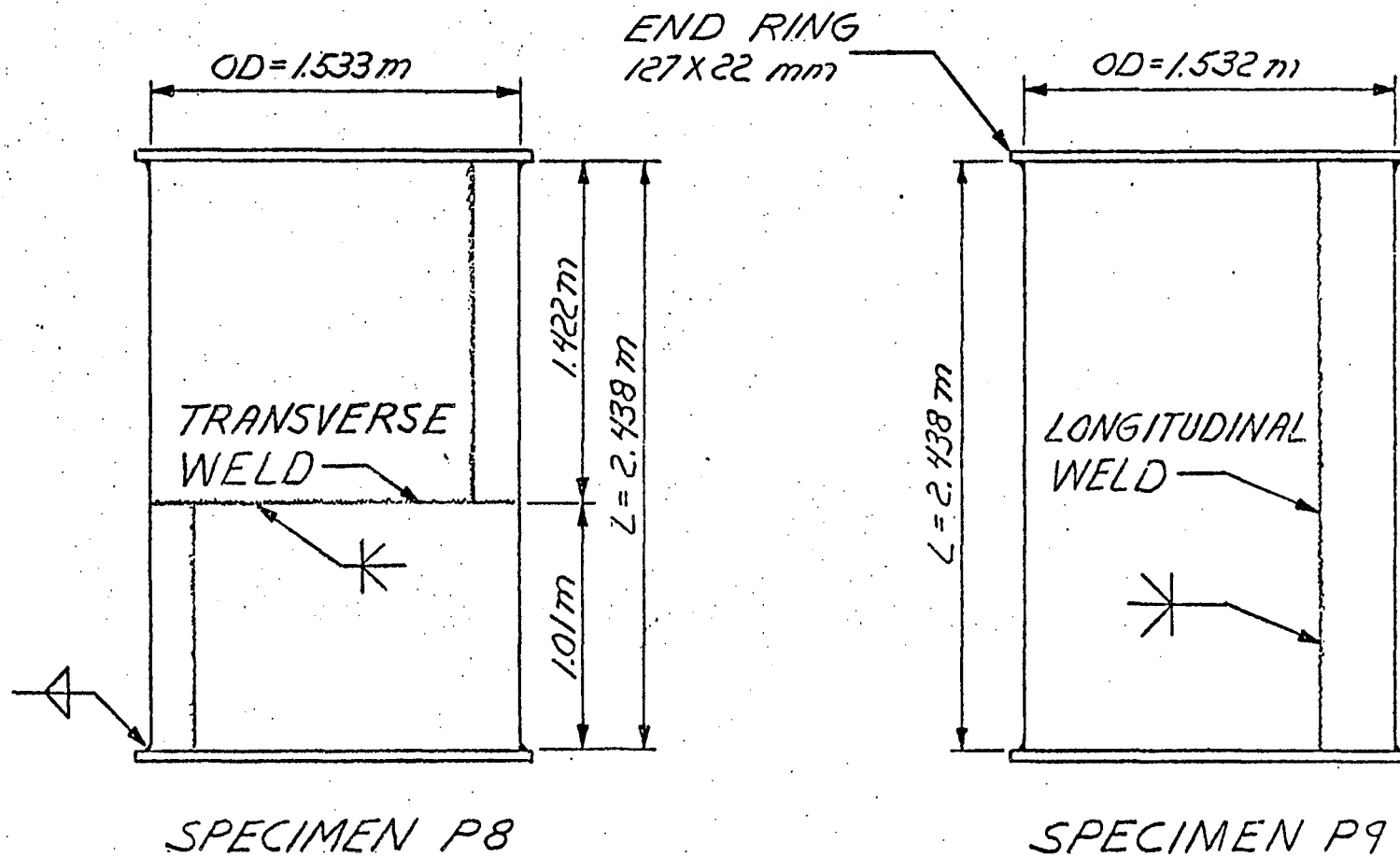
FIGURE 2

DESIGN CURVES WITH LEHIGH TEST POINTS

OD=1.533 m

END RING 127 X 22 mm

OD=1.532 m

TRANSVERSE WELD

LONGITUDINAL WELD

1.422 m

L=2.438 m

1.01 m

L=2.438 m

SPECIMEN P8

SPECIMEN P9

FIGURE 3

TEST SPECIMENS P8 AND P9

P

GROUTING

LOADING HEAD
OF MACHINE

MAGNET

ELECTRICAL
STRAIN
GAGES

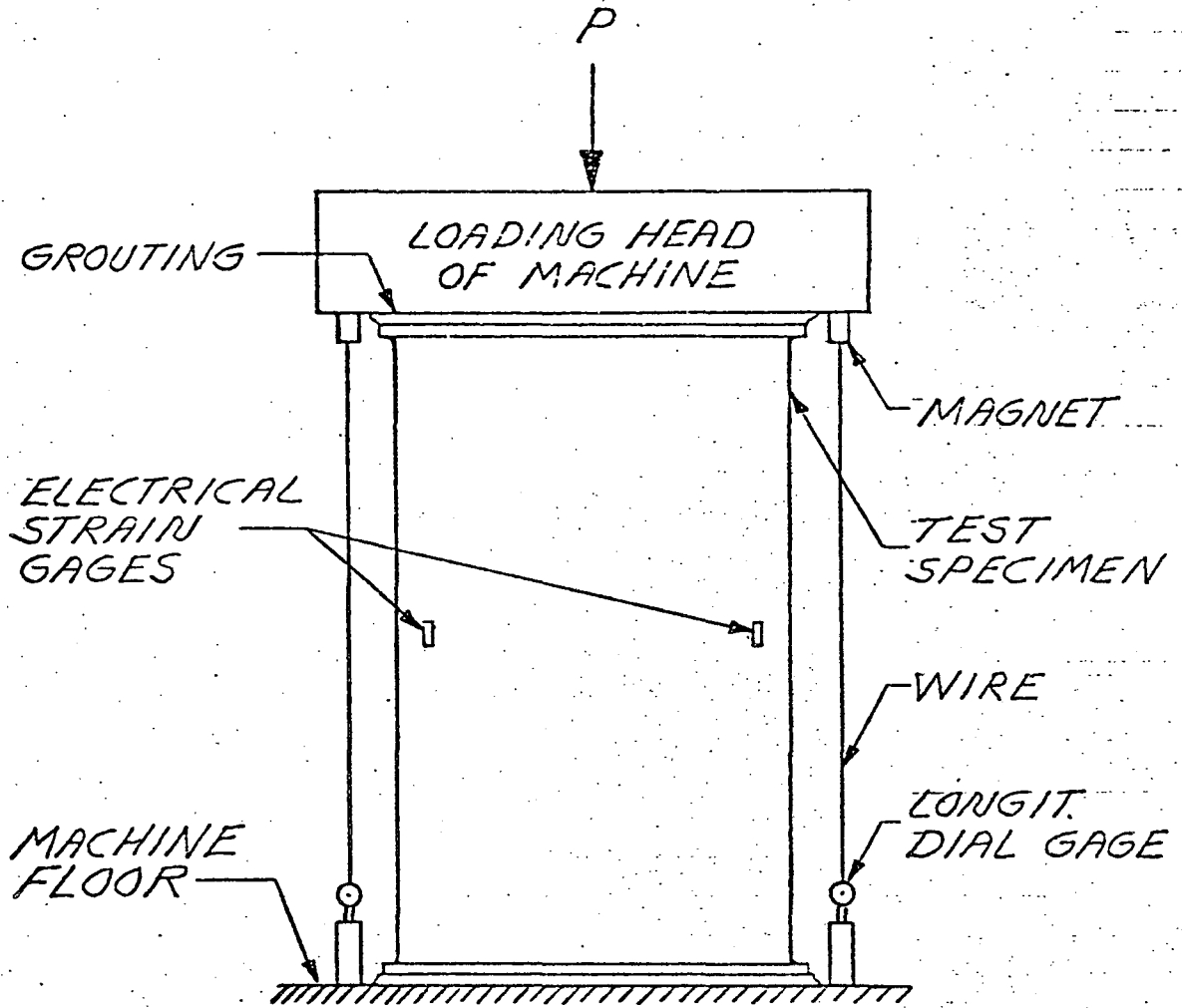TEST
SPECIMEN

WIRE

MACHINE
FLOOR

LONGIT.
DIAL GAGE

FIGURE 4
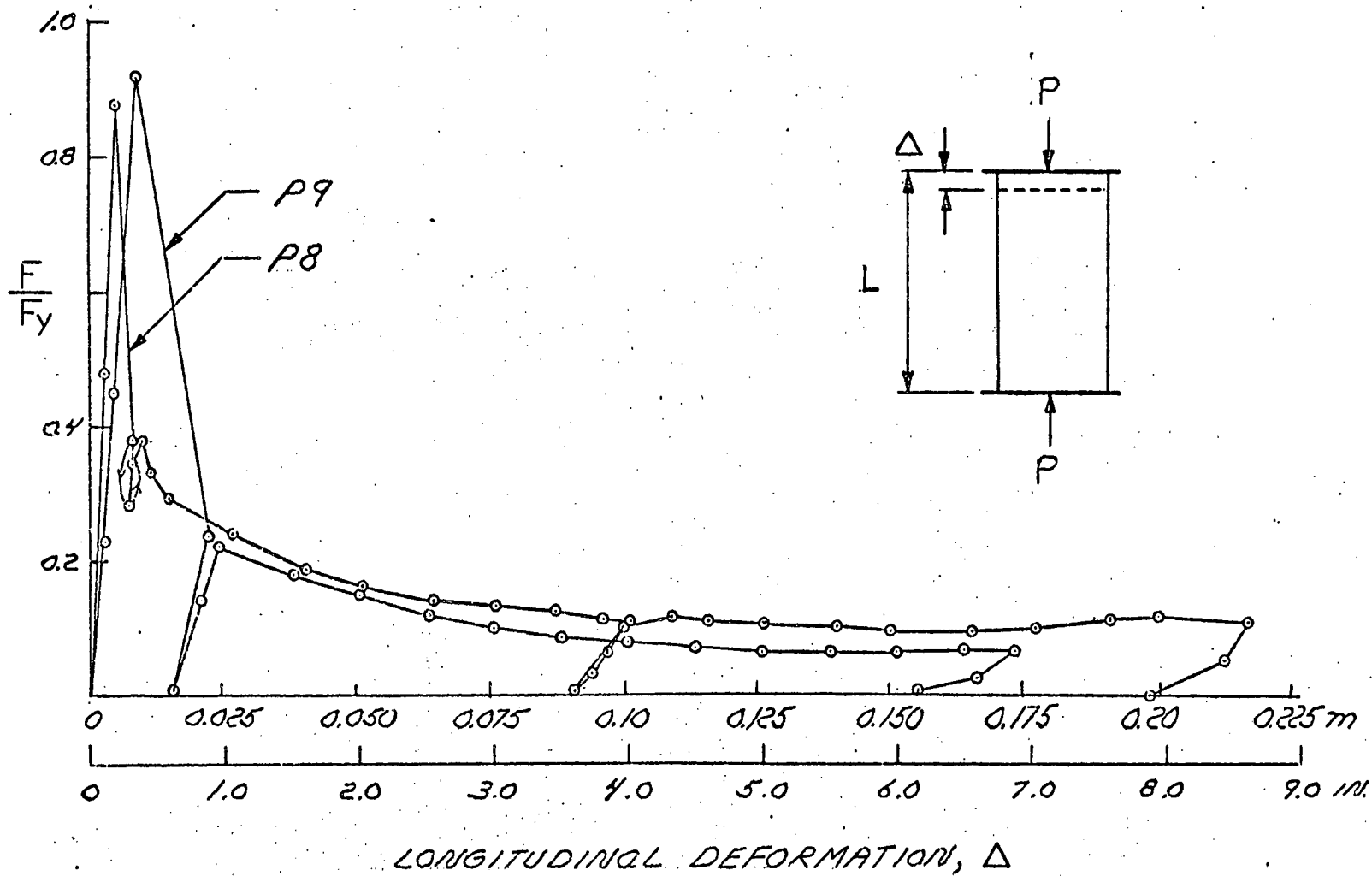
TEST SETUP AND INSTRUMENTATION
FOR SPECIMENS P8 AND P9

FIGURE 5

AVERAGE STRESS-DEFORMATION BEHAVIOR OF SPECIMENS P8 AND P9

REFERENCES

1. American Iron and Steel Institute, "Specification for the Design of Cold-Formed Structural Members", Washington, D. C., 1968, p. 25.

2. Johnston, B. G., ed., Guide to Stability Design Criteria for Metal Structures, Structural Stability Research Council, 3rd edition, John Wiley and Sons, Inc., New York, N.Y., 1976, pp. 261-281.

3. American Petroleum Institute, Division of Production, "API Specification 2B", 2nd edition, API Specification for Fabricated Structural Steel Pipe, October, 1972.

4. Gunzelman, S. X., and Ostapenko, A., "Experimental Local Buckling of Fabricated High-Strength Steel Tubular Columns", Fritz Engineering Laboratory Report No. 406.8, Lehigh University.

5. American Society for Testing and Materials, "ASTM Specification E8-69", Annual Book of ASTM Standards, Part 31, 1971, pp. 194-213.