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Lehigh column program - further tests, Proposal to Lehigh Project Subcommittee, 1951

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TO: MEMBERS, LEHIGH PROJECT SUBCOMMITTEE

LEHIGH COLUMN PROGRAM
FURTHER TESTS

Gentlemen:

The attached proposal is our recommendation to you for further work on the Lehigh Column Program sponsored by American Institute of Steel Construction, American Iron and Steel Institute, Bureau of Ships, Bureau of Yards and Docks, Column Research Council (Advisory), and Office of Naval Research.

The question raised here is not a matter of funds but of the desirability of the particular tests proposed.

Could we please have your vote on the attached postcard. We would also appreciate receiving any suggestions you care to make.

Robert L. Ketter
Research Assistant

Lynn S. Beedle
Assistant to the Director

LSB:RLK:fs

CC: CRC Committee D

Enclosures (2)

COLUMN TEST PROPOSAL

INTRODUCTION

Progress Report "K"(1) summarized the experimental results of the first eleven tests conducted in the general column program and recommended a test program based on these findings. Since the time of approval of this proposal, 9 tests have been carried out. The results of these as well as the first eleven are the basis of Progress Report No. 6(2)

Even though several tests from the previous proposal remain to be performed, it is considered that a further program should now be outlined for approval in order that there be no delays.

VARIABLES

The principal variable being studied in the present investigation is that of the condition of loading.

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(1) Ketter, Robert L., and Beedle, Lynn S., "Some Results of Column Tests and Proposed Program", Progress Report K, November 1950.

(2) Ketter, Robert L., Beedle, Lynn S., and Johnston, Bruce G., "Column Strength Under Combined Bending and Thrust", Progress Report No. 6 (to appear in the Welding Journal Research Supplement).

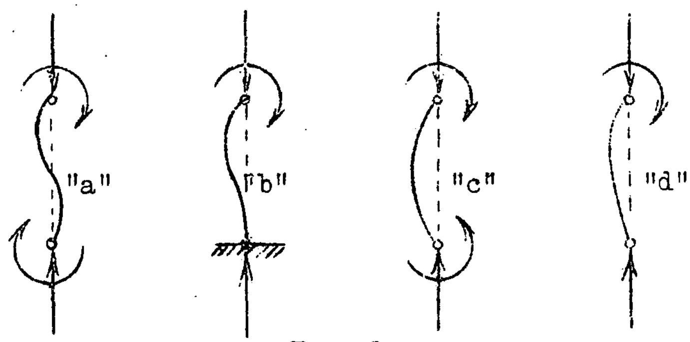

Fig. 1

Other variables receiving attention are:

2. slenderness ratio
3. size of member
4. ratio of P/P_y

In addition of these variables, it is now proposed to investigate the influence of the following factors

5. flexural axis
6. sequence of loading
7. residual stresses, and
8. rotation capacity.

Influence of sequence of loading will be investigated by testing a column with a condition of loading the same as one previously tested but using a different path for reaching the collapse load. On all but one of the previous tests the full magnitude of axial load has been applied prior to the application of any ~~axial~~ loading ~~load~~ moment; it has been considered as a more severe loading condition than one in which bending moment was applied prior to axial load.

The influence of residual stress has been discussed in Progress Reports 5 and M[3]. It is proposed to test a column in the range in which residual stress causes the maximum deviation from that predicted on the basis of small coupon tests. It is also proposed to test a column which will bend about the weak axis since this constitutes (theoretically) the most unfavorable condition when considering cooling residual stresses.

In the analysis of frames using plastic theory, it is assumed that the columns in conjunction with the beams can rotate sufficiently to allow plastic hinges to develop elsewhere in the structure. Further attention will be given to "rotation capacity" - the ability of a column to maintain its maximum moment while deforming plastically.

PROPOSAL

The proposed tests are shown in Table I and Figs. 2 and 3.

Table I tabulates for each test model the variables that would be studies. These are indicated with x's. The principal

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(3) "Summary Report", 205 Project Staff, Progress Report M, September 17, 1951.

variable being studied in each case is noted by the symbol ⓧ.

In Figs. 2 and 3 are shown interaction curves for all the possible condition of loading for those lengths of 8WF31 and 4WF13 specimens available. The solid lines indicate those tests completed to date. Dashed lines denote the proposed models.

The following is a discussion of the proposed tests.

A. MODELS I.G. I.I. AND I.J* (Table I and Fig. 2)

These tests complete a series to determine the effect of slenderness ratio on loading conditions "a", "c" and "d". These would also partially complete two other series to determine the effect of loading condition for particular values of L/r. However the principal reason for the tests is the importance of rotation capacity. Since the previous tests developed adequate strengths, the proposed experiments would be unnecessary if a conclusive trend had been indicated with respect to rotation

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* The test numbering scheme is as follows:

a. The roman numerals indicate series numbers, identifying the size of the cross-section and the flexural axis.

b. In the proposal stages within each series, the model is assigned a letter.

c. Finally, when a test is completed it is assigned a number in sequence of test.

capacity. This is lacking and the tests are therefore needed.

B. <u>MODELS I.L, I.M, II.L, AND II.M (Fig. 2. Table I)</u>

One of the areas of uncertainty in the experimental program is the effect of sequence of loading with respect to axial load and bending moment. These tests comprise a series to investigate this variable.

Model I.L will be carried out by first applying a moment to the member and then adding axial load to collapse. The relative values of these will be such as to reach collapse approximately where failure was observed in test T-5. A similar proceedure will be followed in II.L and II.M. In I.M, the combination of end moment and axial load used for test T-8 will be attained by first applying an axial load of approximately 0.6 P_y then increasing moment to failure.

C. <u>MODELS II.A AND II.B (Fig. 2, Table I)</u>

These tests, carried over from the previous proposal(1), together with T-17 are for a study of size effect, a comparison being made with T-3, T-4 and T-12 (Series I).

D. MODELS II.D, II.E, II.F, II.G, II.I, II.J, AND II.K

These tests would comprise three dependent series. The first (of which II.A is a part) composed of II.A, II.D, and II.E, would investigate the effect of slenderness ratio for loading condition "c". Tests II.J, II.G, II.D and II.K would comprise the second series of this group. They would investigate for an L/r value of 84, the effect of loading condition. The third series, like the second would investigate the effect of loading condition at an L/r value of 112. This series would consist of II.F, II.E and II.I in addition to T-9.

E. MODELS II.H AND V.A (Table I, Figs. 2, 3 and 4)

Since residual stress is theoretically most effective in reducing column load carrying capacity when bending is allowed in the weak direction, the effect of flexural axis and residual stress will be studied by these tests. The two columns of 4WF13 section have the same slenderness ratio but one will be allowed to deform about the x-x axis and the other about the y-y axis. Others in this series are T-11, T-15, T-18, IV.A and IV.B (see below). Fig. 4 indicates the tests at various L/r values.

SEQUENCE OF TESTS

Table II outlines the suggested sequence of tests. This is based on the number of variables studied, relative importance of primary variable studied by each test (these are circled in Table I), and number of columns of one length in a group (this would facilitate the setting up of each test).

ANALYTICAL WORK

As is the customary procedure at Fritz Laboratory, analytical work will proceed concurrently with the experimental program. Progress Reports will be issued from time to time summarizing findings.

Robert L. Ketter

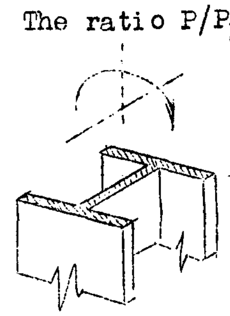
Lynn S. Beedle

F. MODELS I.A AND IV.B (Table I. Fig. 3 and 4)

These are the two tests mentioned in the Residual Stress Pilot proposal of a separate program[4]. IV.B is for comparison with T-11 except that flexure about the y-y axis will be allowed. IV.A, at L/r = 84, is in an L/r range where the influence of residual stress is theoretically the greatest. In addition, since IV.A would have the same L/r as V.A, the effect of size of member would be indicated.

G. MODELS IV.C, IV.D, IV.E, IV.F AND IV.G (Table I, Fig. 3)

These are a series (at a practical L/r range) in which bending moment will be applied about the weak (y-y axis). Loading conditions "b" and "c" are included. The ratio P/P_y for models IV.D and IV.F is the same, and IV.G is at a P/P_y value intermediate between 1.0 and that of IV.F.



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(4) Beedle, Lynn S., "The Influence of Residual Stress on Column Strength" (A Proposed Pilot Investigation), October 2, 1951. Fritz Laboratory Report No. 220A3.

TABLE I SUMMARY OF VARIABLES STUDIED IN THE PROPOSED PROGRAM

VARIABLES STUDIED	SERIES I 8WF31 x-x					SERIES II 4WF13 x-x												SERIES IV 8WF31 y-y							SERIES V 4WF13 y-y	
TEST MODELS	I.G*	I.I*	I.J*	I.L	I.M	II.A*	II.B*	II.D	II.E	II.F	II.G	II.H	II.I	II.J	II.K	II.L	II.M	IV.A	IV.B	IV.C	IV.D	IV.E	IV.F	IV.G	V.A	VII.A** 220A TA
Loading Condition	x	x	x			x	x	x	x	x	x		x	x	x											
Slenderness Ratio	x	x	x			x	x	x	(x)	(x)	(x)	x	(x)	(x)	(x)			x	x							
Size of Member						(x)	(x)											x							x	
Flexural Axis								x				x						x	x	(x)	(x)	(x)	(x)	(x)	x	
Residual Stress								(x)				(x)						(x)	(x)						(x)	(x)
Sequence of Loading				(x)	(x)											(x)	(x)									
Rotation Capacity	(x)	(x)	(x)																							
Shape																										
Sidesway																										
Restrained Column																										

* Carried over from previous proposal, Progress Report "K"[1].

** It is planned to conduct this test of an annealed column in a separate investigation of the influence of residual stress on column strength[4].

TABLE II

SUGGESTED SEQUENCE OF TESTS

TEST MODEL NUMBER	PRINCIPAL VARIABLE STUDIED	LENGTH OF COLUMN
II.A	Size of Member	8 ft.
II.B	Size of Member	8 ft.
II.M	Sequence of Loading	8 ft.
I.J	Rotation Capacity	8 ft.
IV.A	Residual Stress	15 ft.
IV.B	Residual Stress	9.36 ft.
V.A	Residual Stress	8 ft.
II.H	Residual Stress	12 ft.
II.D	Residual Stress	12 ft.
II.L	Sequence of Loading	16 ft.
I.L	Sequence of Loading	16 ft.
I.M	Sequence of Loading	16 ft.
II.E	Slenderness Ratio	16 ft.
II.F	Slenderness Ratio	16 ft.
II.I	Slenderness Ratio	16 ft.
II.G	Slenderness Ratio	12 ft.
II.K	Slenderness Ratio	12 ft.
II.J	Slenderness Ratio	12 ft.
I.I	Rotation Capacity	12 ft.
I.G	Rotation Capacity	12 ft.
IV.C	Flexural Axis	12 ft.
IV.G	Slenderness Ratio	12 ft.
IV.F	Flexural Axis	12 ft.
IV.E	Flexural Axis	12 ft.

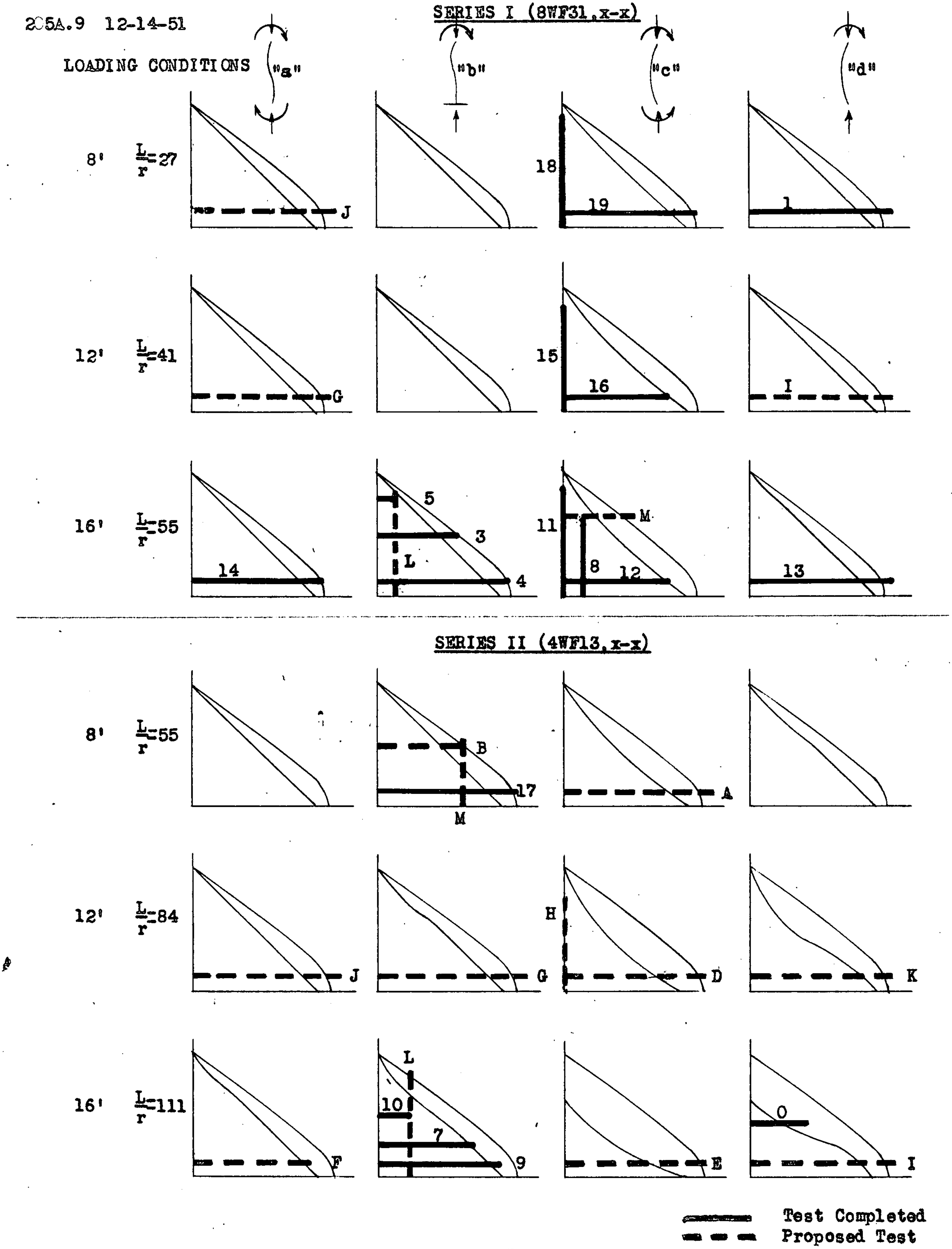
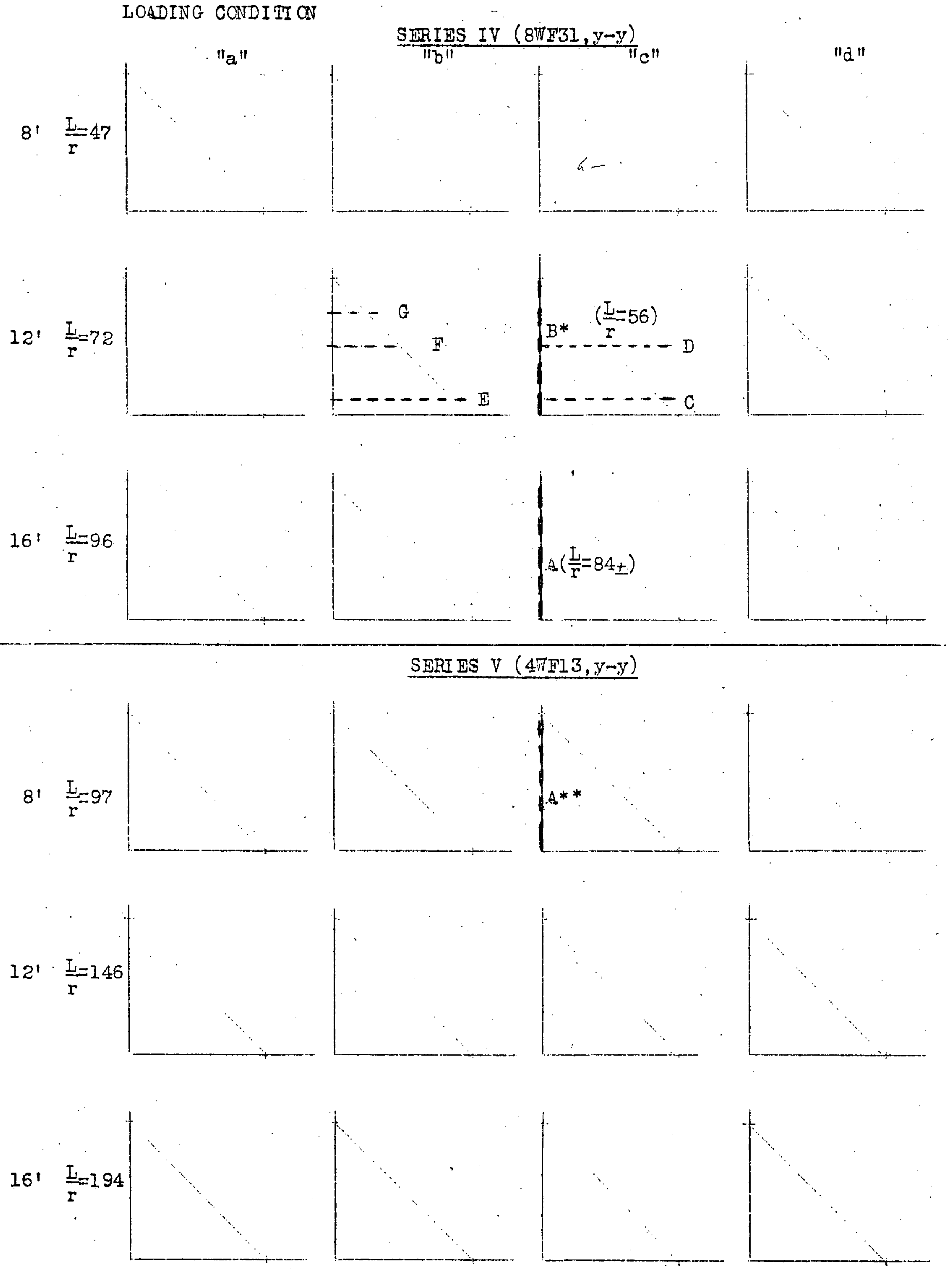

SERIES I (8WF31, x-x)
LOADING CONDITIONS
"a"
"b"
"c"
"d"
8'
L/r=27
J
18
19
1
12'
L/r=41
G
15
16
I
16'
L/r=55
14
5
3
L
4
11
M
8
12
13
SERIES II (4WF13, x-x)
8'
L/r=55
B
17
M
A
12'
L/r=84
J
G
H
D
K
16'
L/r=111
F
L
10
7
9
E
0
I
Test Completed
Proposed Test

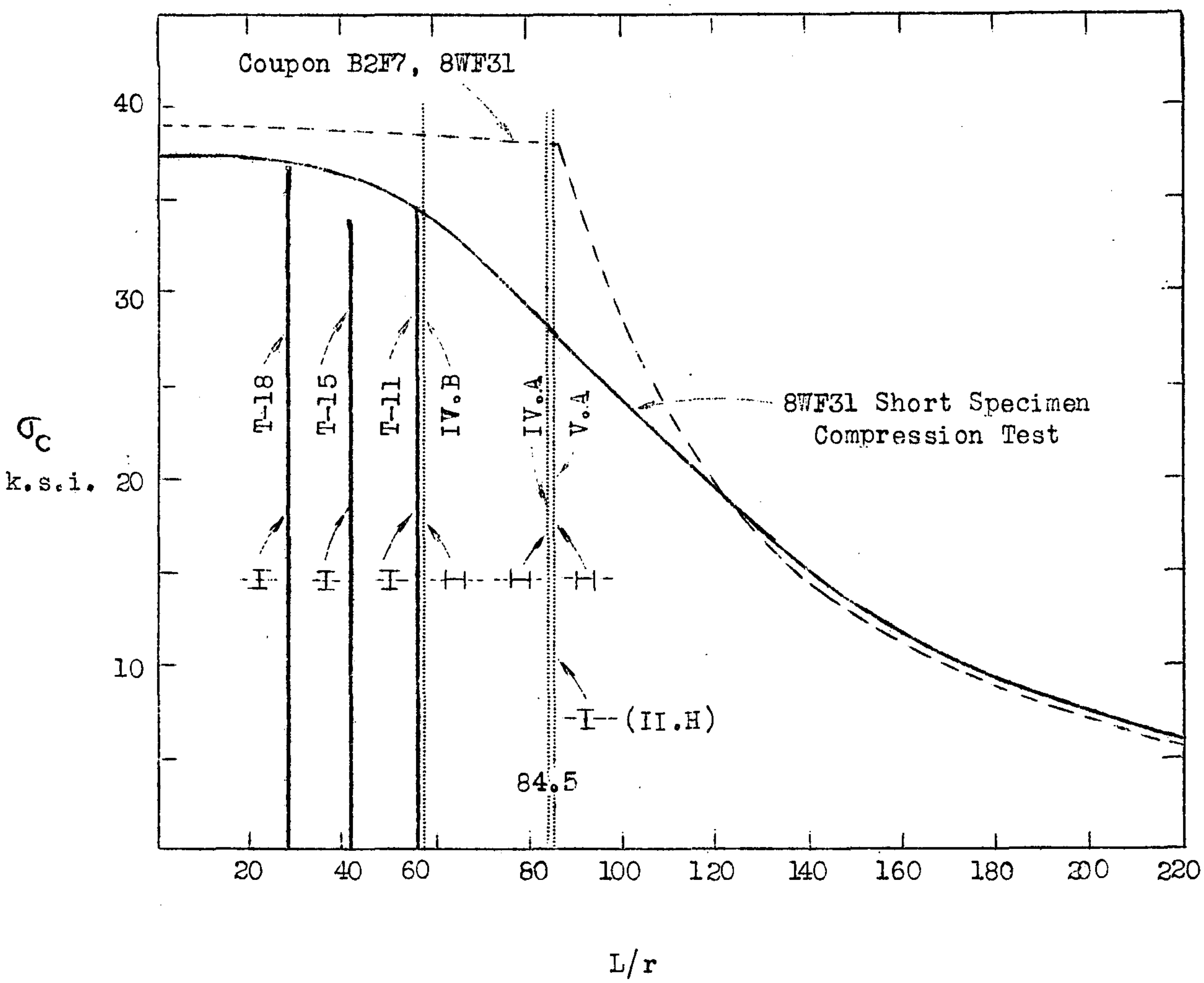
Fig. 2



* (L/r same as T-11)

** (L/r same as T-II.H)

Fig. 3



Coupon B2F7, 8WF31
40
30
σ_c
k.s.i.
20
10
T-18
T-15
T-11
IV.B
IV.A
V.A
8WF31 Short Specimen Compression Test
(II.H)
84.5
20
40
60
80
100
120
140
160
180
200
220
L/r

Fig. 4