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SOUND DIVISION - VIBRATION SECTION

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SUPERSONIC MEASUREMENT OF WALL THICKNESS IN DIESEL LINERS

By F. W. Struthers

FR-2932

Report S-2932

Approved by:

Dr. H. M. Trent - Head, Vibration Section

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Numbered Pages 10
Plates 5
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ABSTRACT

This report covers the results of Diesel liner wall thickness inspections with the Sonigage made subsequent to the initial inspections described in NRL Report S-2850. Twelve model 248 Diesel liners were inspected at New York Naval Shipyard and nineteen at Norfolk Naval Shipyard.

Improved filler design and inspection techniques expedited these tests and enabled more comprehensive data to be taken. Besides such factors as minimum thickness, and the presence of core shifting, an estimate of the general homogeneity of the core, and the existance of suspected porous areas are noted.

TABLE OF CONTENTS

PLATES

Supersonic Measurement of Wall Thickness in Diesel Liners

Refs: (a) NRL Report (S-2850) of June 1946.
(b) BuShips ltr. to NRL 369-2(334) of 13 May 1946.

I. INTRODUCTION

1. Reference (a) describes the Sonigage developed by the Research Laboratories Division, General Motors Inc., and certain features originating at NRL to adapt it for measuring the wall thickness of Diesel liners. The results of inspection of nineteen liners at the Norfolk Naval Shipyards were shown, with a brief discussion.

2. The experience obtained in the inspection of these nineteen liners suggested several desirable improvements, particularly in maintaining contact between the crystal probe and the liner surface and in the preparation of inspection areas. The inspection of thirty-one additional liners at the New York and Norfolk Naval Shipyards demonstrated that real progress had been made in effecting these improvements.

3. The inspection surfaces of all liners were uniform, and continuous contact could be maintained between the probe and the liner surface for a series of longitudinal points of inspection. Under these conditions it was possible to estimate the relative homogeneity existing between the cores of the liners inspected. The difference between the indications, due to reflections from rough backing surface and to porosity or other inhomogeneity in the core, becomes more apparent to an operator as experience is gained in the use of the Sonigage.

II. IMPROVED MEASURING TECHNIQUES

4. Following the initial inspections at the Norfolk Naval Shipyard, an exhausive study was made of the fillers which adapt the flat crystal probe to the curved liner surface. The first inspections showed definitely that a duralumin or aluminum filler was more efficient than one made of steel. The specific acoustic impedance (density x velocity) of steel is 4.54×10^6, that of aluminum is 1.68×10^6, and that of quartz is 1.52×10^6. It is thus seen that a truer impedance match exists between quartz and aluminum, providing a better transmission medium for the latter and less refraction of the supersonic beam.

5. For overall clarity of oscilloscope indications, a filler whose maximum thickness was .050" was chosen. Although somewhat less attenuation was realized with thinner fillers, the clarity of the indications was impaired.

6. Duralumin was considered superior to aluminum for its wearing property and showed less frictional drag on the liner surface in operation.

7. During the first inspection tests, contact was lost if the probe was not maintained in a nearly vertical position, a position which was difficult to maintain in practice. Reducing the height of the retaining rim overcame this trouble, permitting the probe to be held at slight angles with the normal to the surface, and thus increasing ease of inspection without losing contact. This retention of contact over a series of inspection areas was vital to a ready comparison of their relative homogeneity.

8. If a comparison of the relative homogeneity of cores between a group of liners is to be attempted, it is desirable to have a uniform inspecting surface. Emphasis was made on this factor in the preparation of the surface of the liners dealt with in this report. Buffing was confined to strips approximately five inches in width spaced every 90°, each strip covering the five longitudinal inspection points.

9. As an aid and check on oscilloscope thickness indications, four steel standards .062", 0.250", 0.375", and 0.500" thick were occasionally referred to during the inspection.

10. The New York Naval Shipyard provided NRL with two Diesel liners, one similar to those covered in NRL Report S-2850 and a Model-248, the type tested in New York. These were discarded liners, the Model-248 having a visibly porous region in the high pressure end. Practice on this liner proved of much value later in the Norfolk tests, especially in judging the homogeneity of the liners inspected there.

III. INSPECTION OF LINERS

11. In accordance with Ref. (b), on 3 June 1946 the Sonigage was carried to the New York Naval Shipyard and set up in a room in the Metallurgy Laboratory. Twelve Model-248 Diesel liners were on hand awaiting inspection prior to metal spraying by the Schori process. Since this model was somewhat different from that first tested at Norfolk, having no longitudinal reinforcing ribs, some time was devoted to a preliminary survey to choose the most suitable thickness of filler to be used.

12. In the meantime the inspection surfaces of the other liners was being smoothed with emery cloth. The liner while being inspected was mounted on an improved form of balancing stand facilitating access with the probe to all inspection areas.

13. The .050" duralumin and aluminum fillers were used exclusively throughout the inspection. In general these liners showed a narrower range of thickness variations and decidedly clearer thickness indications on the oscilloscope, thus facilitating inspection.

14. On 17 June 1946, in accordance with Ref. (b), the Sonigage was taken to the Norfolk Naval Shipyard for inspection of nineteen model 278 liners. The location and conditions of test, with the exception of temperature, were the same as existed for the first inspections covered in NRL Report S-2850. The Model-278 liner was similar to that inspected at the New York Naval Shipyard. Fortunately the buffing of the inspecting areas was in the case of those familiar with the earlier inspections, and the inspection surfaces of all liners were uniform. The filler, a .050" duralumin, had been improved so that contact could be readily maintained throughout each five longitudinal inspecting points. One filler was used exclusively on all nineteen liners.

15. Eleven liners were inspected June 18th while the temperature in the shop was above 90° and the humidity near saturation. This demonstrated the reliability of the Sonigage operating under abnormal conditions.

IV. DISCUSSION OF RESULTS

16. The liners inspected and covered in this report showed in general more uniformity of thickness, less evidence of core shift and thin areas than did those examined during the previous inspection.

17. Improved inspection technique discloses certain areas appearing to be porous, confined largely to the low pressure end opposite or near the water outlet opening. These were noted in the Model-278 liners #476V, 136A, X-1, 226A, and 638V. Slight core shifting was suggested in eleven liners of this model, but was not significant in the remaining eight.

18. Five of the Model-248 liners showed no evidence of core shifting; seven suggested varying degrees of shift.

19. The experience gained in the inspection of 50 liners leads to the conclusion that, with training, an inspector can differentiate between significant variations in the oscilloscope indications due to uneven backing surface, and those caused by inhomogeneities in the core. As in the interpretation of radiographs in X-ray inspection, much depends on the judgment and training of the observer in supersonic inspection.

20. The Sonigage offers a variety of methods of analysis, foremost of which is the possibility of progressively narrowing the searching beam by going to higher frequencies. This feature enables the observer to determine the nature and extent of an inhomogeneity. A crack will register on the oscilloscope as a definite shift in phase of the indication, not to be confused with indication amplitude variations caused by general porosity.

21. An inspection of the graphs and observations made during the tests suggests the following classifications for the liners inspected.

Model-248 Diesel Liners Inspected at the New York Naval Shipyard

Alignment of bore	Homogeneity of core	Liner Serial Number	Remarks
Good	Very good	513R	
"	" "	17	
"	" "	181	
"	Good	200	
"	Good	156	
Appreciable core shift	Very good	184	
"	Good	174	
"	"	208	
"	"	16	
"	"	178	
"	"	157	
"	Fair	206	Indications not clear 4 positions

Model-278 Diesel Liners Inspected at the
Norfolk Naval Shipyard

Alignment of core	Homogeneity of core	Liner Serial number	Remarks
Good	Very good	12	
"	" "	632V	
"	" "	467V	
"	Good	476V	D-000°x
"	"	322A	
"	"	510R	
"	Fair	186A	D-000°x
"	"	317V	Less clear indications
Appreciable core shift	Very good	513V	
" "	Good	483R	
" "	"	958N	
" "	"	465A	
" "	"	1125	
" "	"	638V	D-000°x
" "	"	478R	
" "	Fair	1139	
" "	"	X-1	D-000°x
" "	"	655P	less clear indications
" "	"	226A	D-000°x

x area appears to be inhomogeneous

V. CONCLUSIONS

22. As a result of the recent tests at the New York and Norfolk Naval Shipyards the following conclusions may be made:

(a) The conclusions set forth in NRL Report S-2850 are borne out by these more recent tests. (Briefly these were that the Sonigage, by use of a filler, could measure the thickness, concentricity, and degree of core shift in a Diesel liner wall; that the Sonigage is electrically and mechanically reliable; and that the back surface of a liner

wall is sufficiently smooth to give reliable reflections at the frequencies used.)

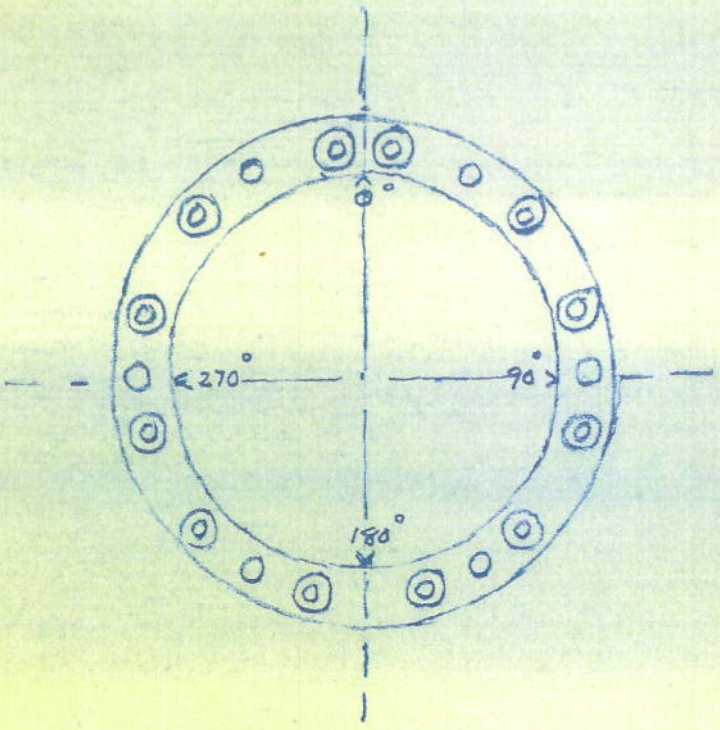
(b) The Sonigage developed by General Motors Research Division with additional features worked out by NRL can be used satisfactorily to measure the wall thickness of Diesel liners and to determine if core shift is present. With experience the trained operator can evaluate as to the general homogeneity of the liner core.

(c) The Sonigage will function satisfactory at higher than average conditions of temperature and humidity. Eleven liners were inspected June 18th with temperatures above 90° and the relative humidity near saturation.

(d) Inspectors should be given preliminary training to acquire a facility in the interpretation of oscilloscope thickness indications. Samples illustrative of various types of inhomogeneities should be studied.

VI. RECOMMENDATIONS

23. It is recommended that Navy Yards purchase Sonigage units and arrange for a representative to receive instruction in its uses at NRL.



END VIEW OF LINER

LOCATION OF POINTS CHECKED WITH SONIGAGE

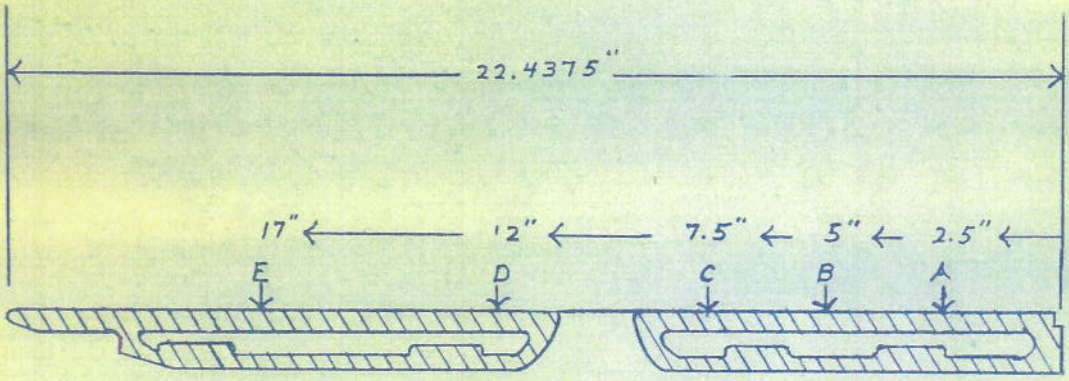


PLATE 1

S-2932

LINER SERIAL NUMBER	GRAPH PLATE NO	DEGREES ON CIRCUM-FERENCE	LONGITUDINAL INSPECTION POINTS THICKNESS IN INCHES				
			A	B	C	D	E
156	III A	0	.460	.435	.385	.360	.310
		90	.460	.435	.385	.360	.310
		180	.480	.460	.410	.310	.360
		270	.460	.440	.435	.370	.290
206	III A	0	.460	.460	.410	.360	.310
		90	.460	.480	.430	.360	.320
		180	.385	.390	.410	.420	.390
		270	.460	.460	.450	.385	.390
200	III B	0	.410	.390	.385	.360	.350
		90	.460	.440	.385	.360	.290
		180	.450	.460	.400	.380	.335
		270	.480	.435	.420	.360	.335
513R	III B	0	.420	.410	.350	.340	.290
		90	.440	.425	.400	.380	.350
		180	.385	.350	.360	.340	.320
		270	.450	.435	.410	.360	.320
16	III C	0	.385	.385	.350	.350	.320
		90	.460	.440	.430	.350	.350
		180	.380	.350	.360	.360	.370
		270	.450	.440	.435	.370	.370
181	III C	0	.460	.410	.390	.360	.350
		90	.435	.435	.410	.360	.340
		180	.385	.375	.360	.350	.340
		270	.460	.470	.435	.360	.360
184	III D	0	.450	.440	.440	.385	.360
		90	.485	.435	.420	360	.335
		180	.435	.410	.385	.340	.310
		270	.385	.385	.360	.330	.300
17-	III D	0	.460	.460	.435	.385	.340
		90	.460	.435	.435	.370	.320
		180	.450	.420	.420	.335	.340
		270	.485	.450	.420	.350	.320

LINER SERIAL NUMBER	GRAPH PLATE No	DEGREES ON CIRCUM-FERENCE	LONGITUDINAL INSPECTION POINTS THICKNESS IN INCHES				
			A	B	C	D	E
174	III E	0	.350	.285	.285	.290	.280
		90	.435	.385	.350	.335	.330
		180	.360	.360	.350	.330	.310
		270	.400	.345	.360	.310	.300
208	III E	0	.380	.350	.350	.310	.310
		90	.485	.420	.410	.340	.320
		180	.410	.360	.360	.335	.340
		270	.460	.485	.435	.350	.350
157	III F	0	.460	.440	.410	.385	.335
		90	.520	.485	.485	.420	.410
		180	.430	.385	.350	.300	.300
		270	.470	.460	.410	.350	.310
178	III F	0	.485	.460	.430	.385	.360
		90	.485	.435	.410	.350	.300
		180	.410	.430	.400	.350	.340
		270	.480	.435	.420	.285	.310

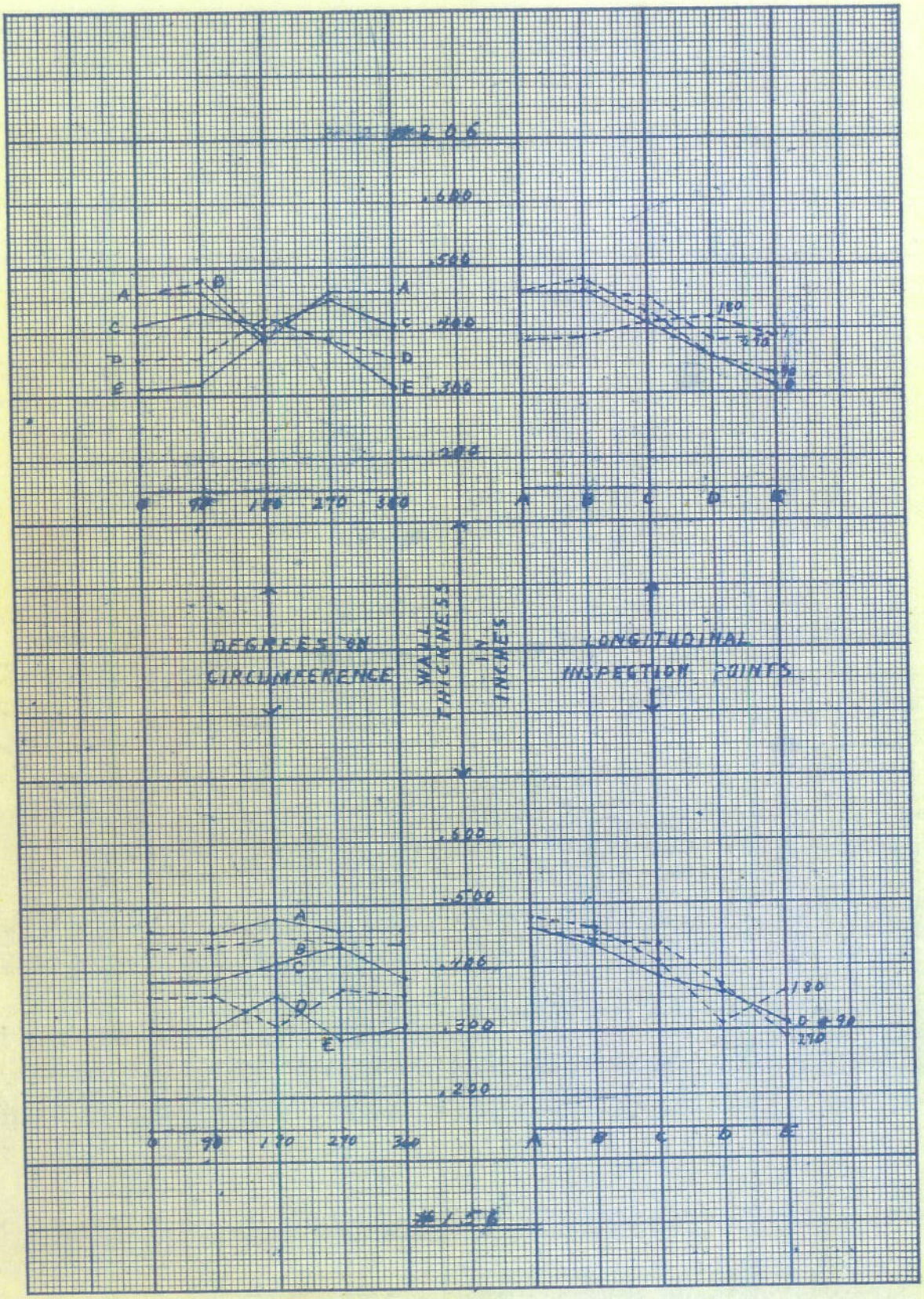


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PLATE 3A

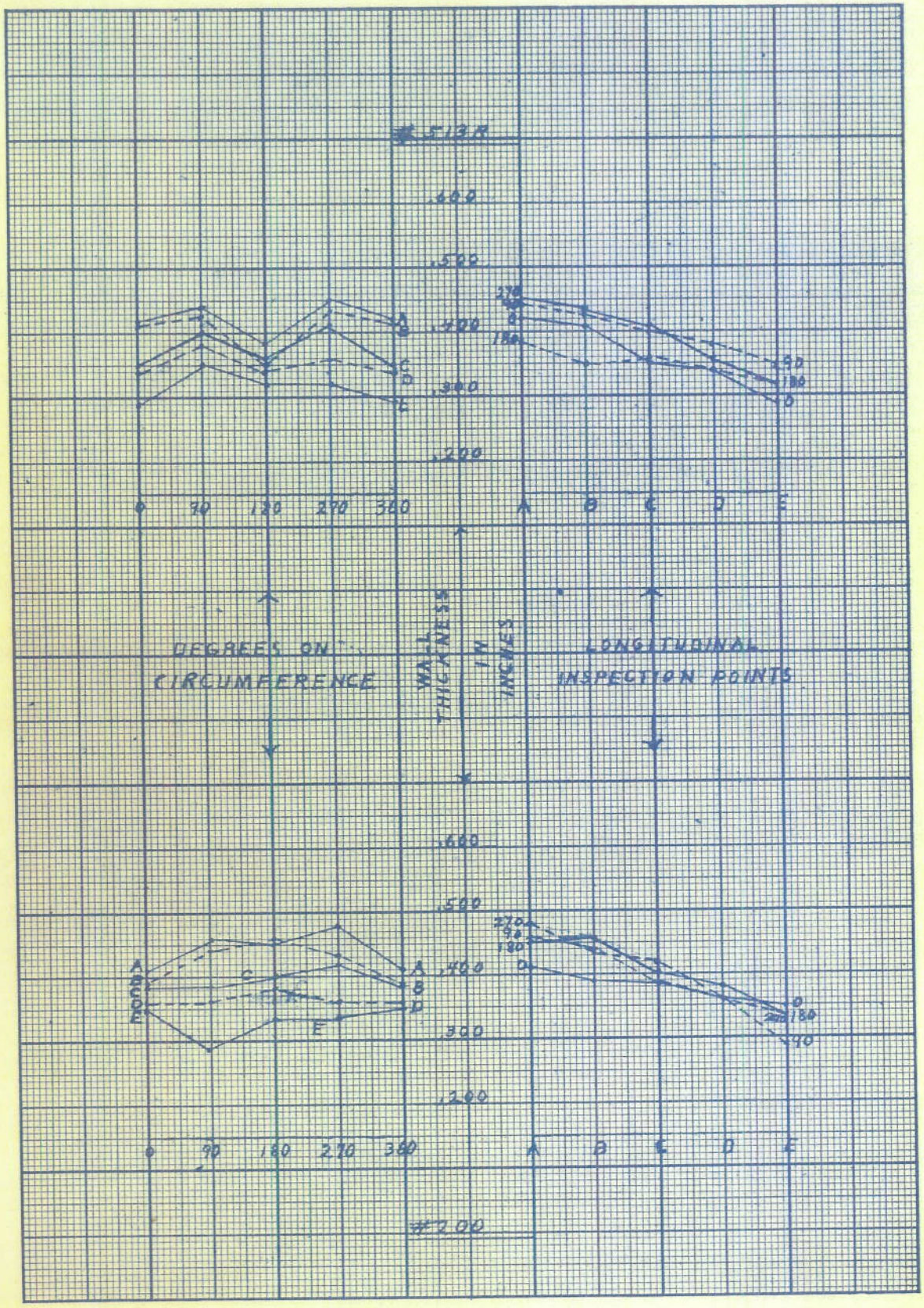

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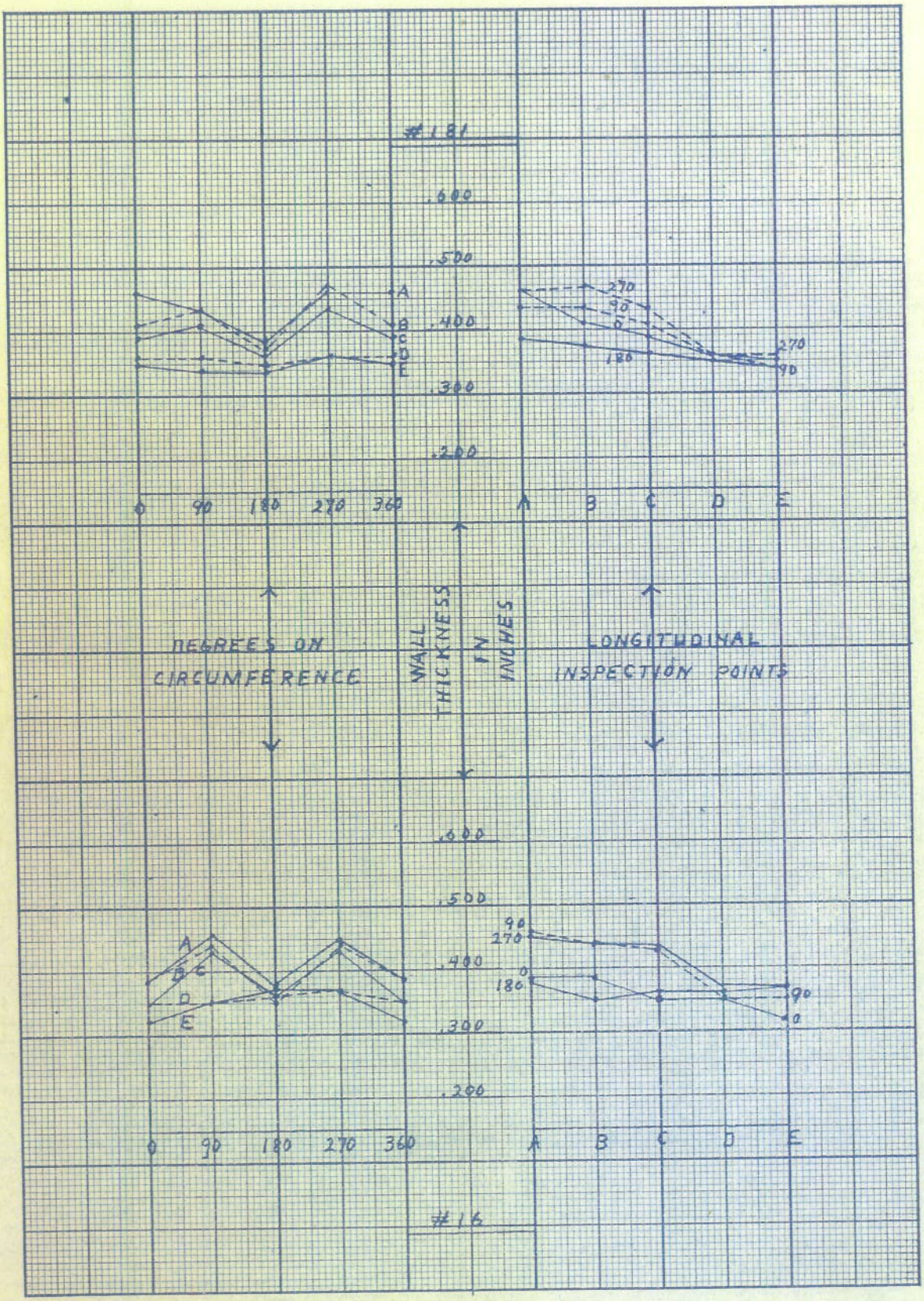
PLATE 3B



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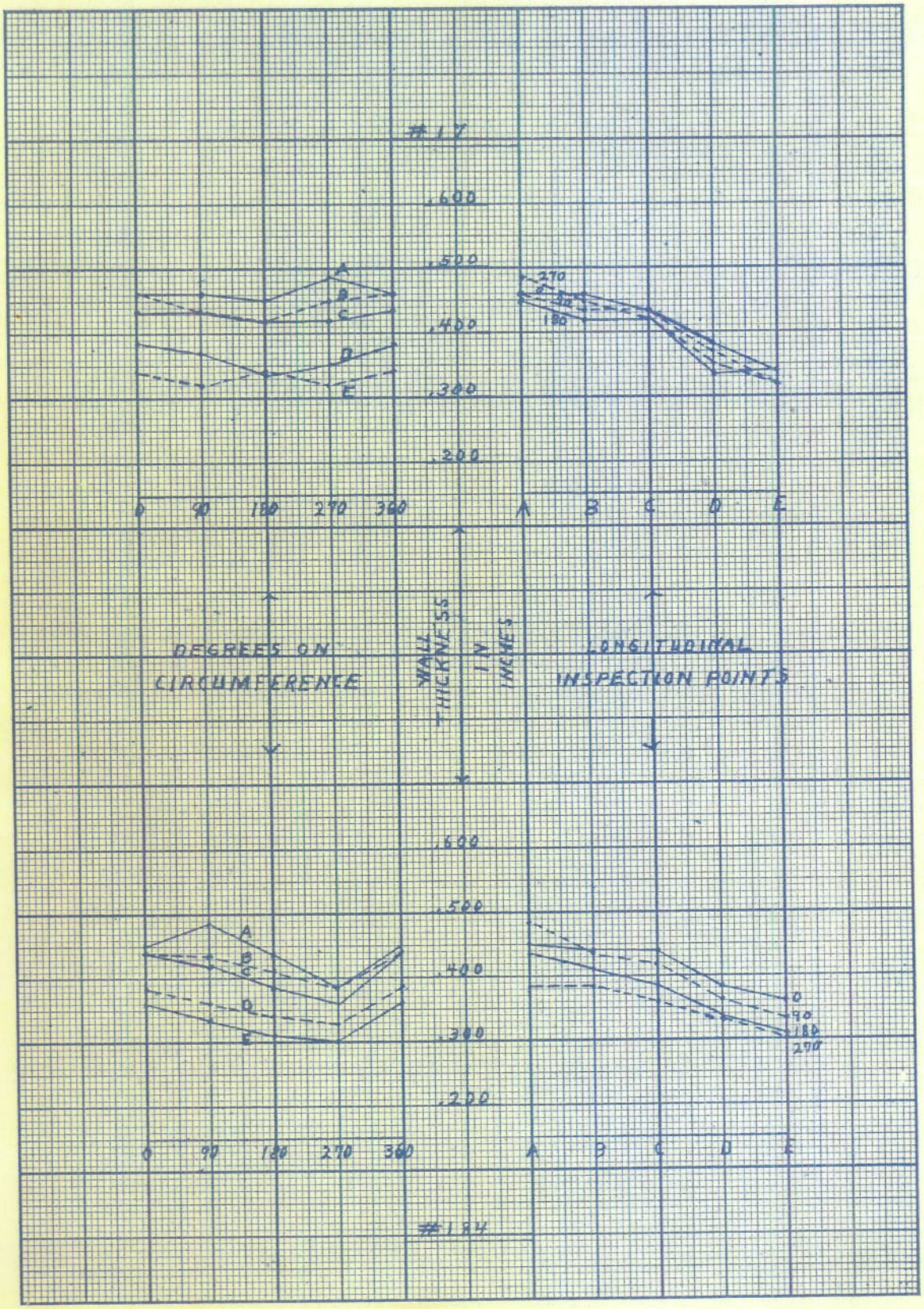

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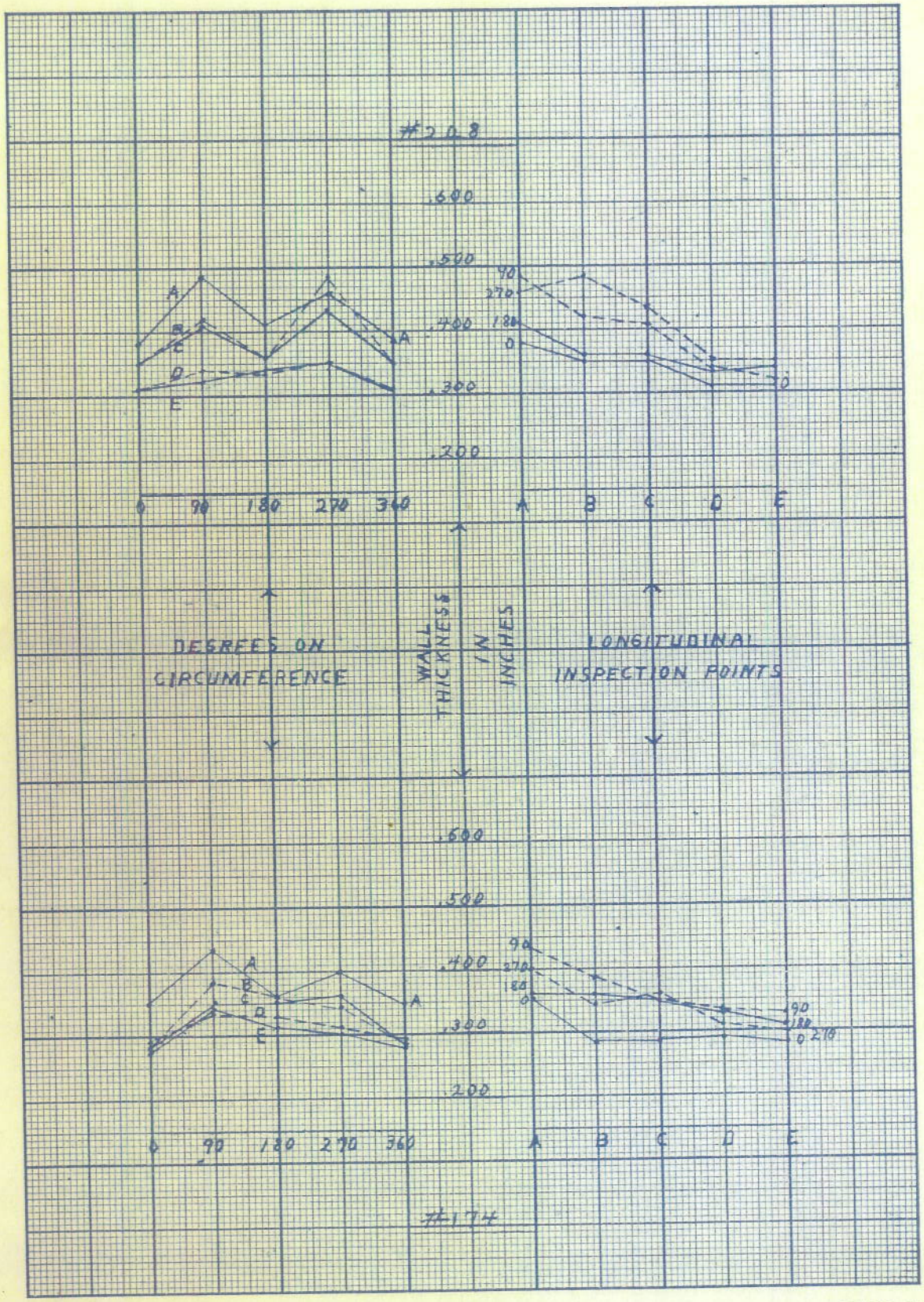

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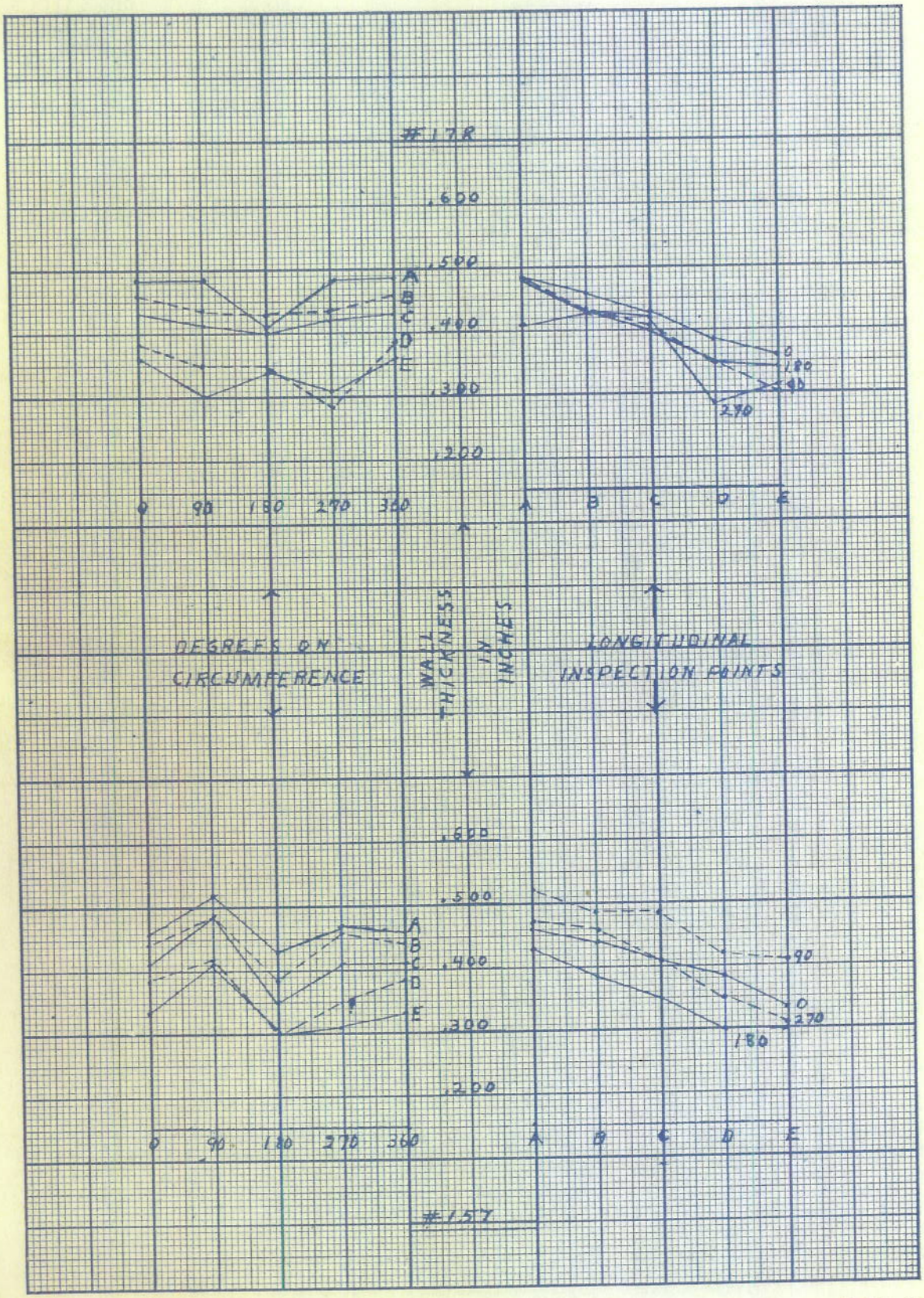

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PLATE 3F

LINER SERIAL NUMBER	GRAPH PLATE NUMBER	DEGREES ON CIRCUM-FERENCE	LONGITUDINAL INSPECTION POINTS THICKNESS IN INCHES				
			A	B	C	D	E
476 V	V A	0	.450	.430	.370	.360	.320
		90	.460	.420	.410	.320	.310
		180	.385	.385	.385	.360	.320
		270	.440	.440	.430	.350	.340
483 R	V A	0	.390	.330	.310	.320	.320
		90	.430	.420	.380	.320	.300
		180	.390	.360	.350	.320	.310
		270	.390	.360	.360	.320	.320
12	V B	0	.390	.360	.350	.310	.310
		90	.390	.385	.350	.320	.320
		180	.390	.370	.360	.330	.335
		270	410	.410	.380	.330	.320
1139	V B	0	.410	.350	.340	.300	.310
		90	.430	.390	.375	.335	.335
		180	.430	.430	.410	.350	.330
		270	.420	.380	.350	.285	.300
1125	V C	0	.385	.360	.350	.335	.330
		90	.460	.420	.430	.320	.320
		180	.410	.400	.380	.320	.300
		270	.385	.370	.350	.320	.320
322 A	V C	0	.435	.385	.350	.335	.320
		90	.435	.430	.385	.335	.335
		180	.390	.410	.370	.350	.340
		270	.435	.390	.350	.310	.320
186 A	V D	0	.435	.360	.335	.350	.335
		90	.430	.420	.360	.320	.310
		180	.440	.410	.380	.335	.310
		270	.460	.420	.420	.350	.335
X-1	V D	0	.450	.390	.320	.260	.320
		90	.440	.410	.360	.310	.330
		180	.385	.350	.320	.290	.290
		270	.450	.420	.420	.320	.320
465 A	V E	0	.460	.410	.385	.310	.350
		90	.435	.390	.320	.330	.330
		180	.430	.370	.380	.320	.320
		270	.490	.435	.440	.330	.330
317 V	V E	0	.450	.440	.350	.340	.330
		90	.460	.435	.385	.320	.320
		180	.435	.420	.380	.320	.300
		270	.430	.420	.420	.330	.310

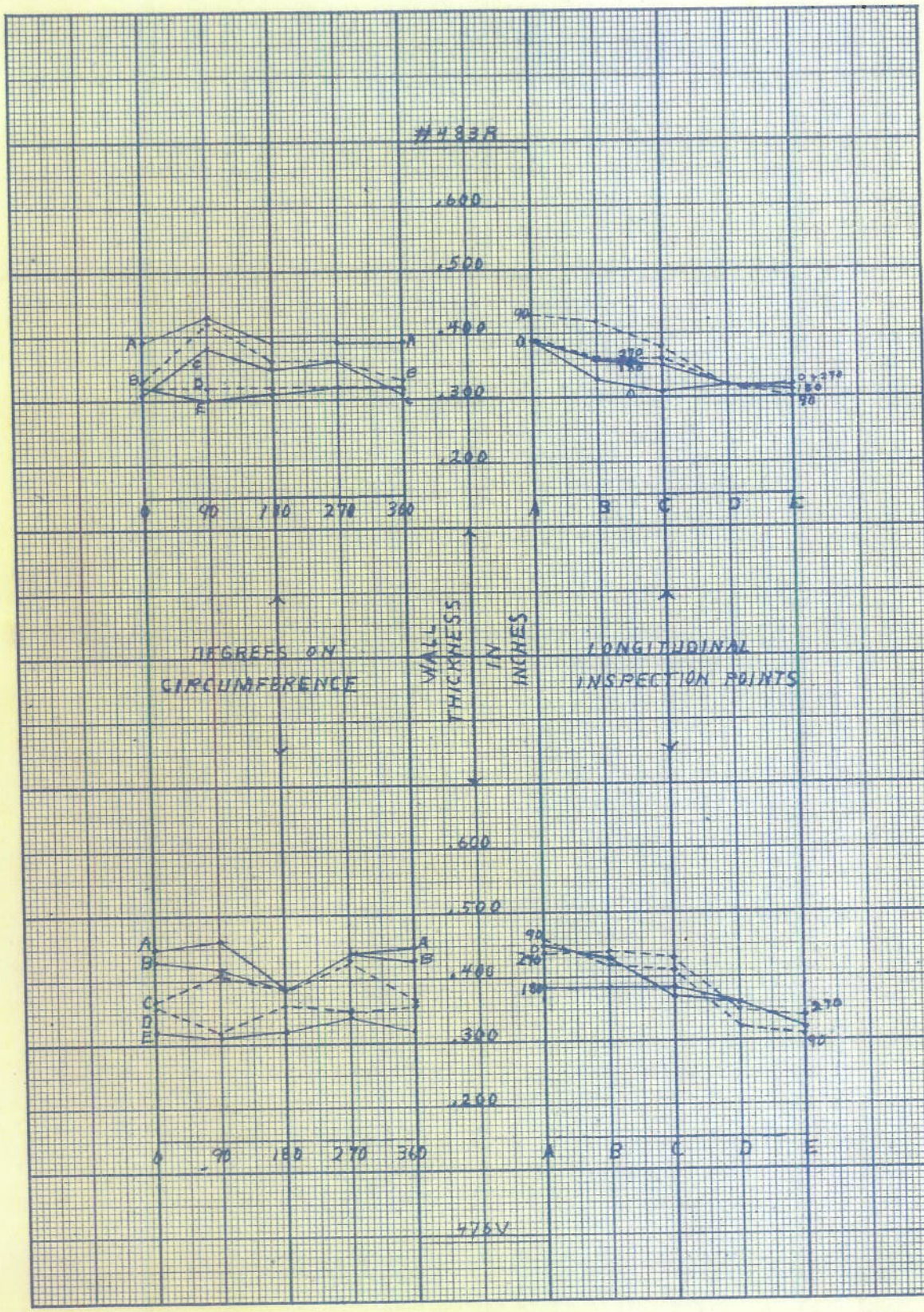

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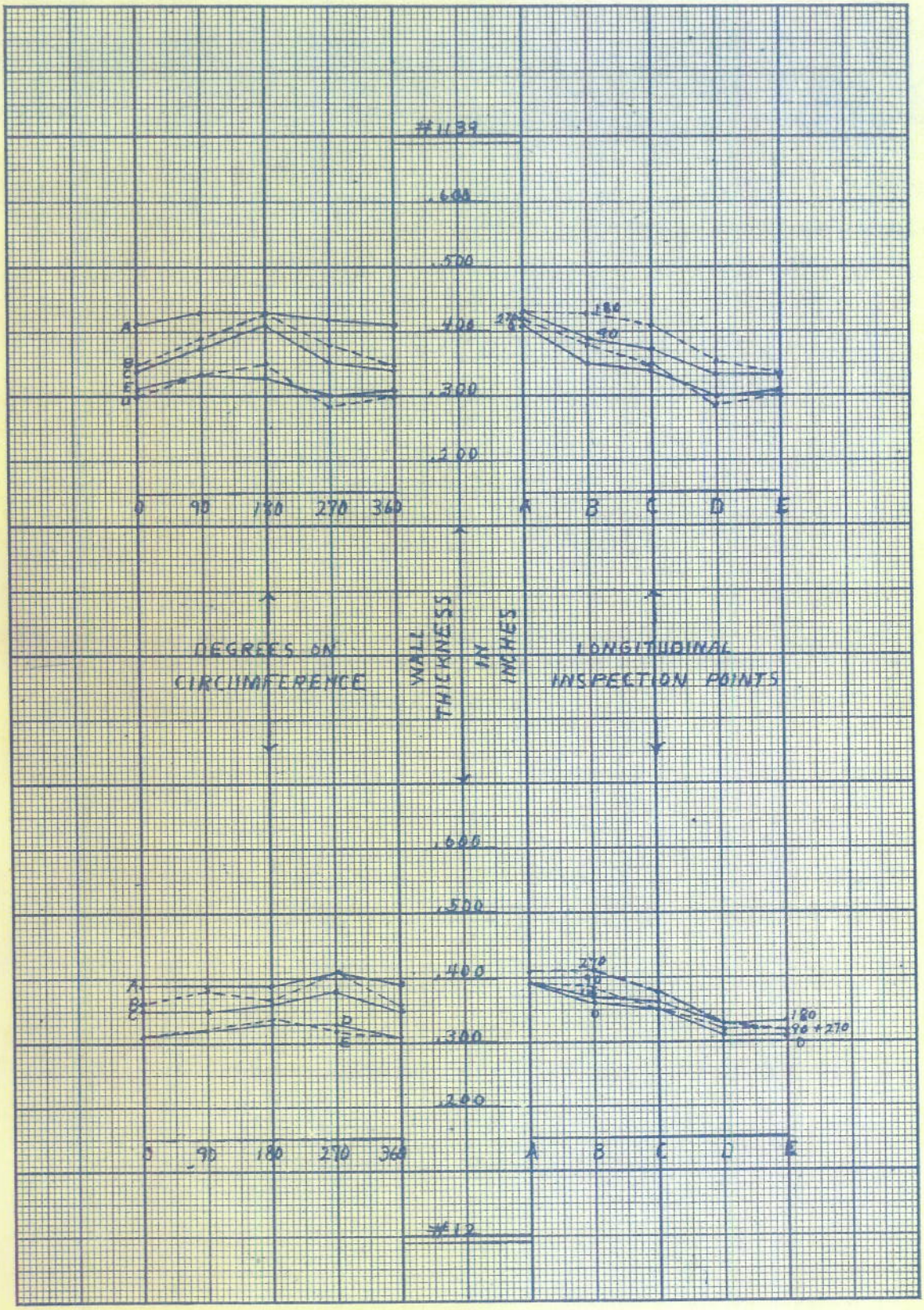
PLATE 5A

LINER SERIAL NUMBER	GRAPH PLATE NUMBER	DEGREES ON CIRCUM-FERENCE	LONGITUDINAL INSPECTION POINTS THICKNESS IN INCHES				
			A	B	C	D	E
958N	V F	0	.385	.380	.350	.300	.270
		90	.385	.360	.360	.350	.320
		180	.420	.385	.345	.350	.350
		270	.370	.330	.310	.320	.310
632V	V F	0	.460	.435	.385	.335	.330
		90	.450	.435	.410	.360	.345
		180	.430	.400	.350	.340	.340
		270	.440	.425	.410	.340	.320
513V	V G	0	.385	.385	.350	.335	.310
		90	.450	.420	.380	.335	.310
		180	.435	.400	.340	.350	.330
		270	.460	.440	.390	.345	.325
510R	V G	0	.460	.435	.380	.320	.310
		90	.435	.420	.410	.350	.350
		180	.420	.385	.350	.335	.330
		270	.440	.425	.375	.350	.350
467V	V H	0	.435	.420	.350	.310	.300
		90	.460	.435	.360	.310	.285
		180	.450	.435	.380	.320	.320
		270	.435	.420	.390	.335	.335
655P	V H	0	.430	.430	.350	.340	.335
		90	.390	.380	.335	.300	.290
		180	.460	.440	.385	.340	.350
		270	.435	.435	.410	.345	.310
226A	V I	0	.430	.370	.350	.335	.330
		90	.450	.430	.390	.360	.335
		180	.435	.420	.380	.320	.270
		270	.450	.440	.385	.345	.330
638V	V I	0	.460	.410	.335	.345	.335
		90	.460	.435	.390	.345	.320
		180	.435	.400	.340	.335	.335
		270	.460	.450	.410	.345	.320
478R	V J	0	.420	.400	.350	.300	.285
		90	.435	.435	.410	.350	.330
		180	.410	.370	.360	.330	.320
		270	.440	.440	.390	.340	.310



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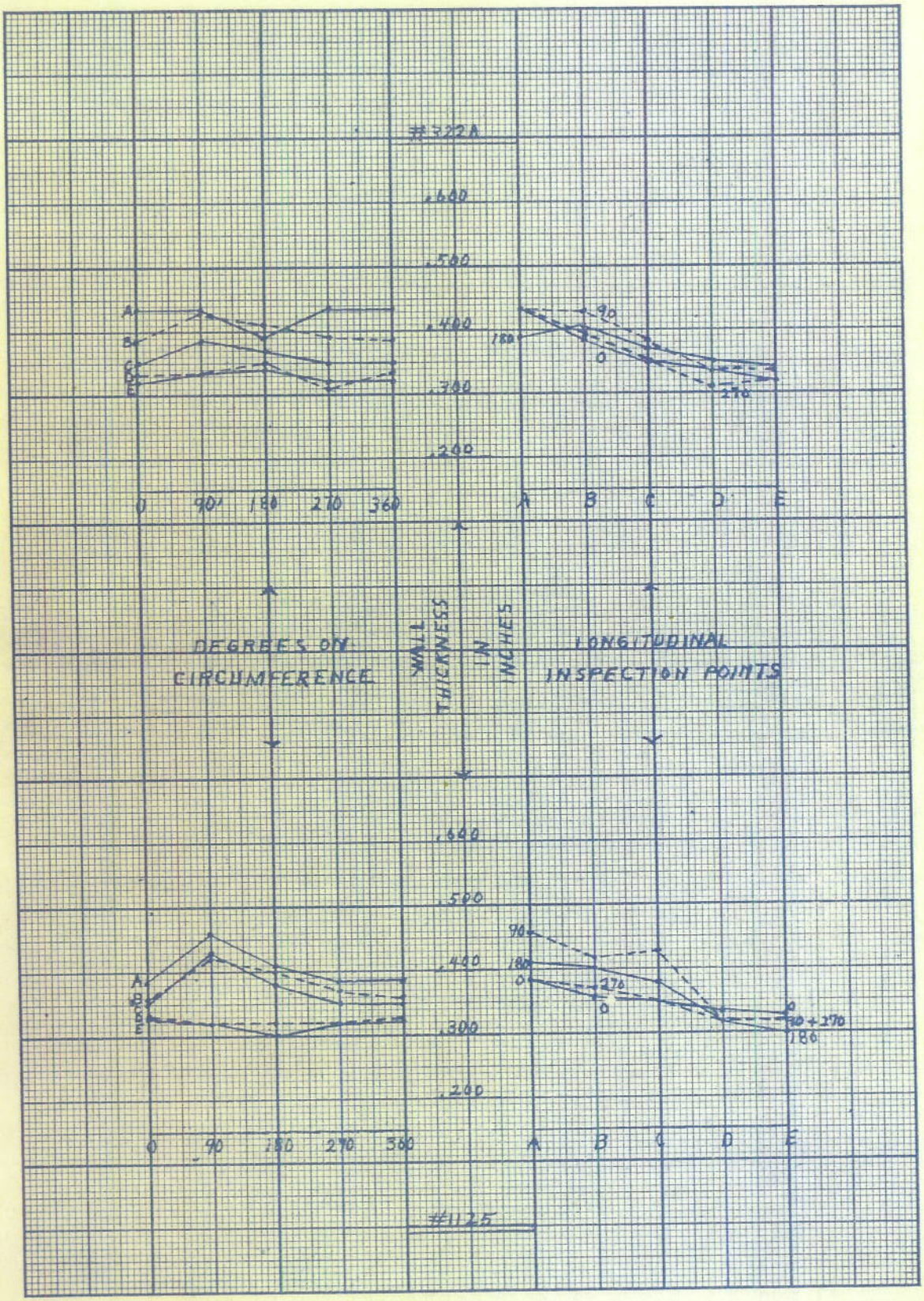

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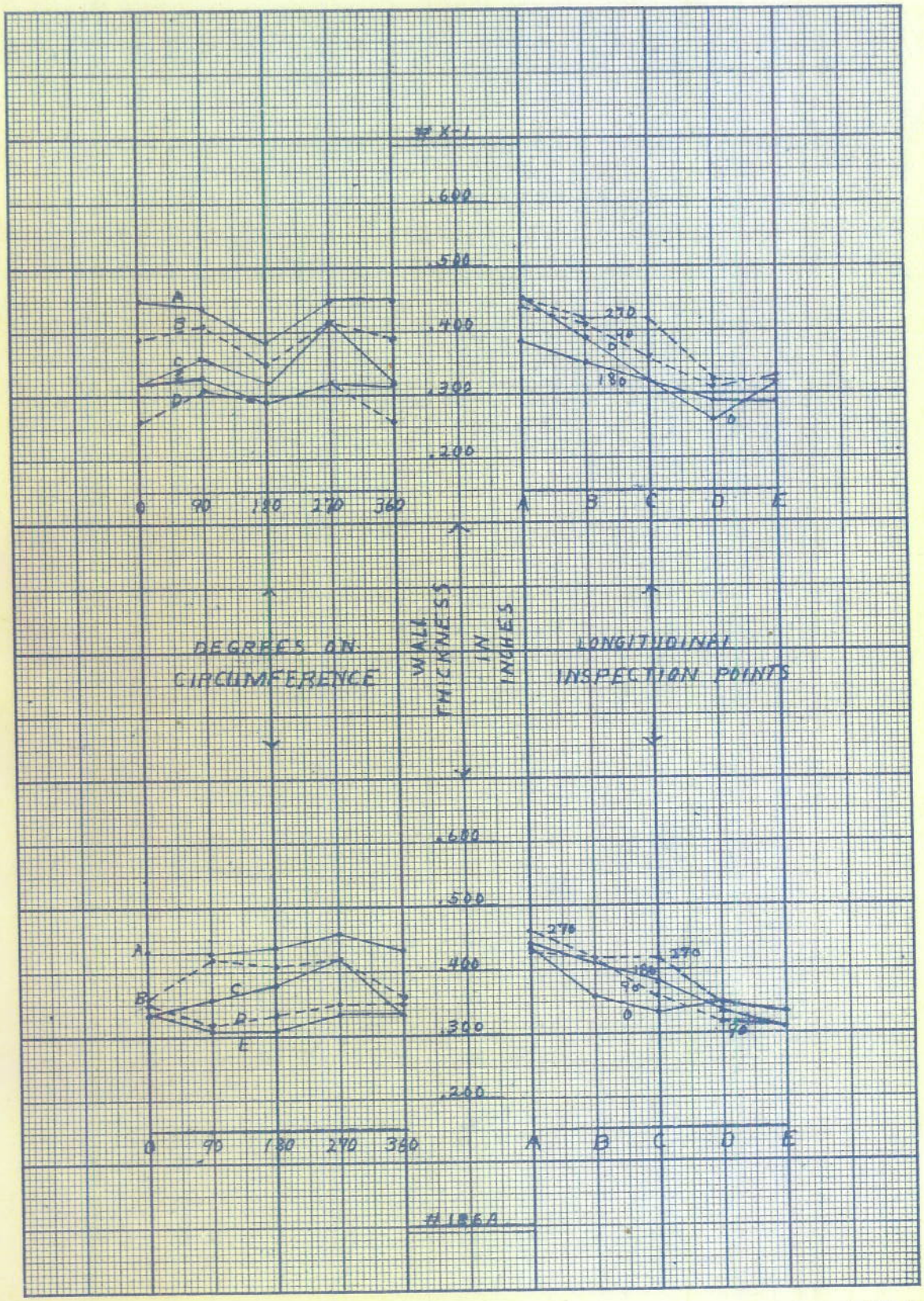

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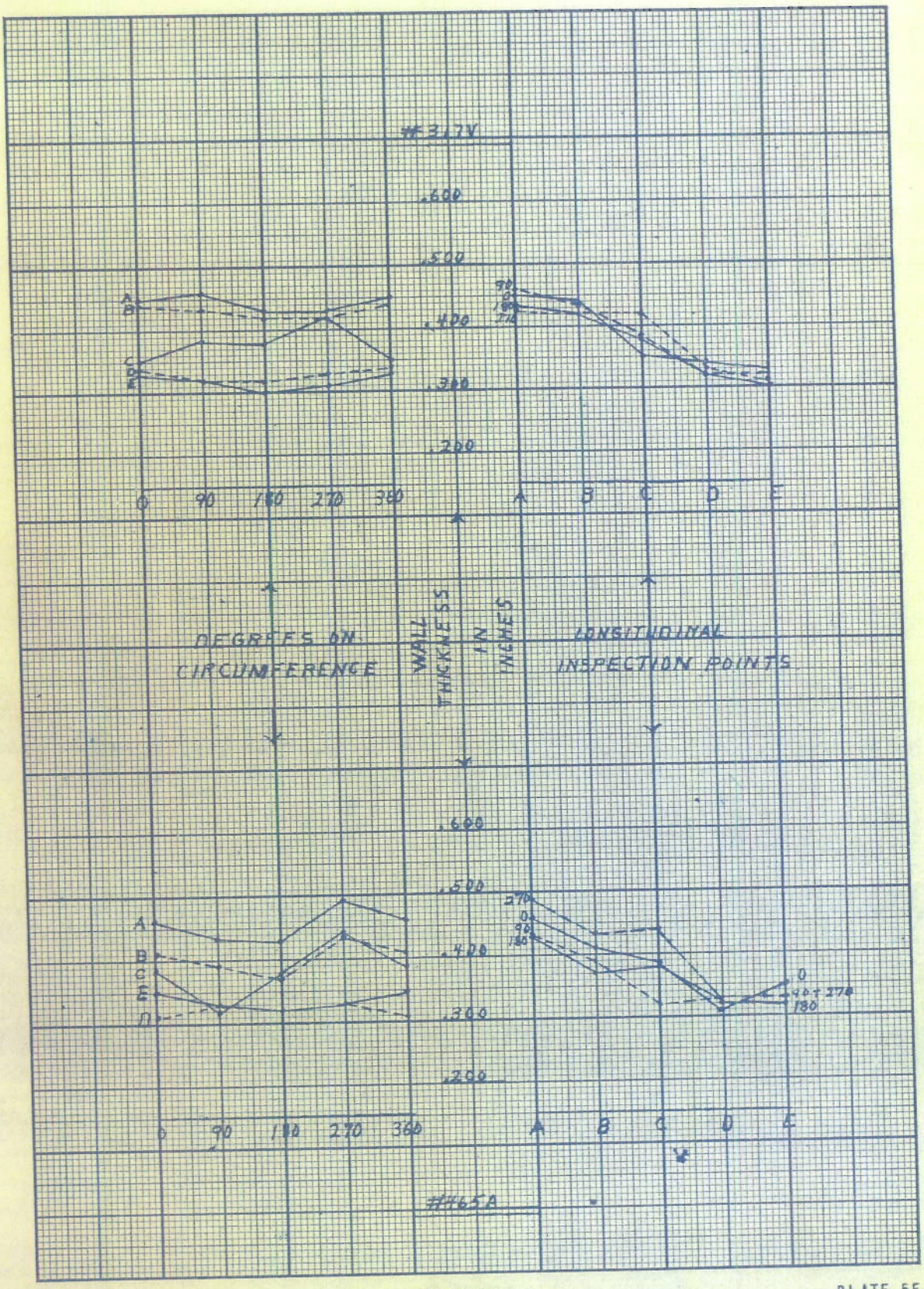

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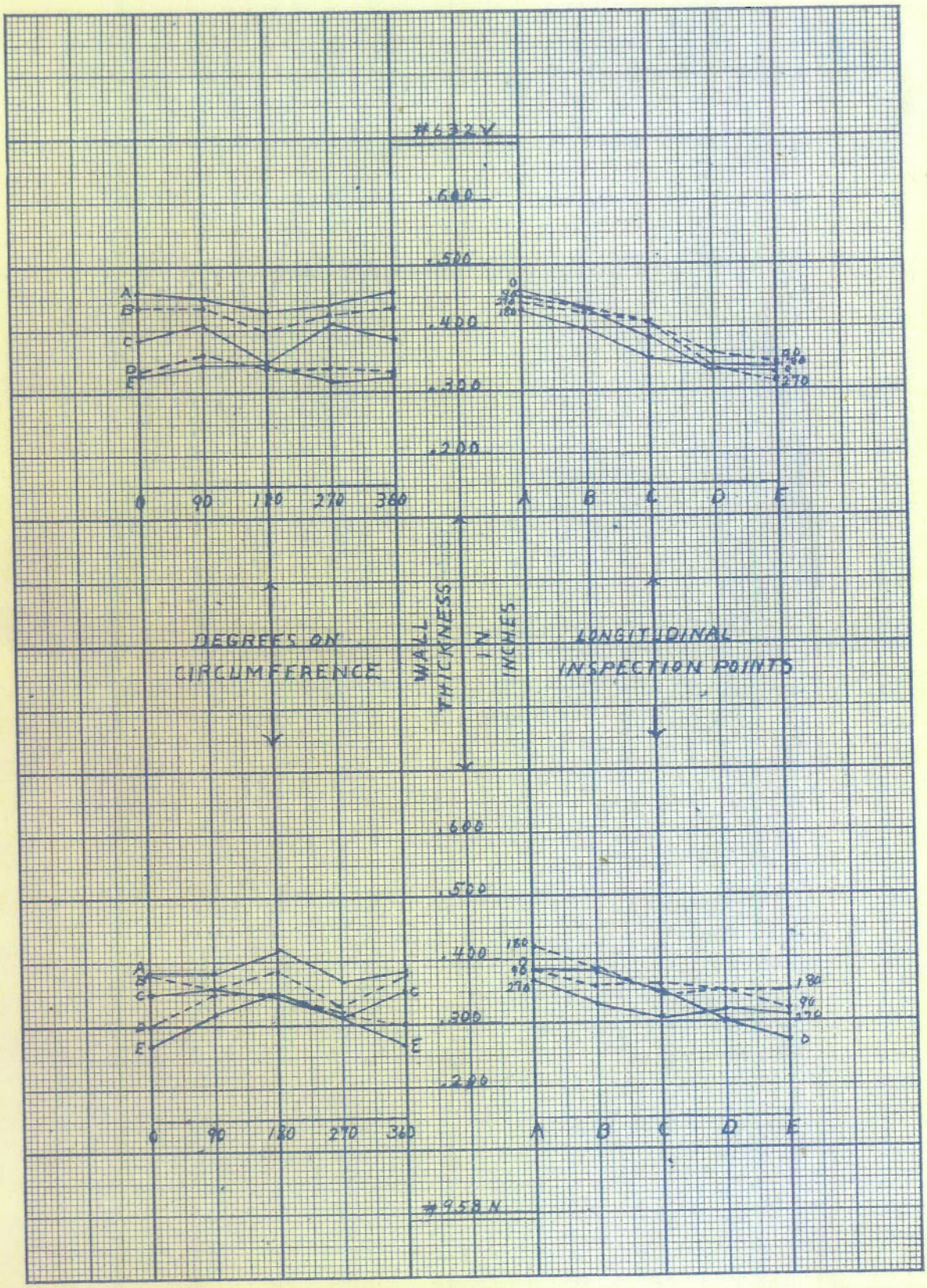

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PLATE 5F

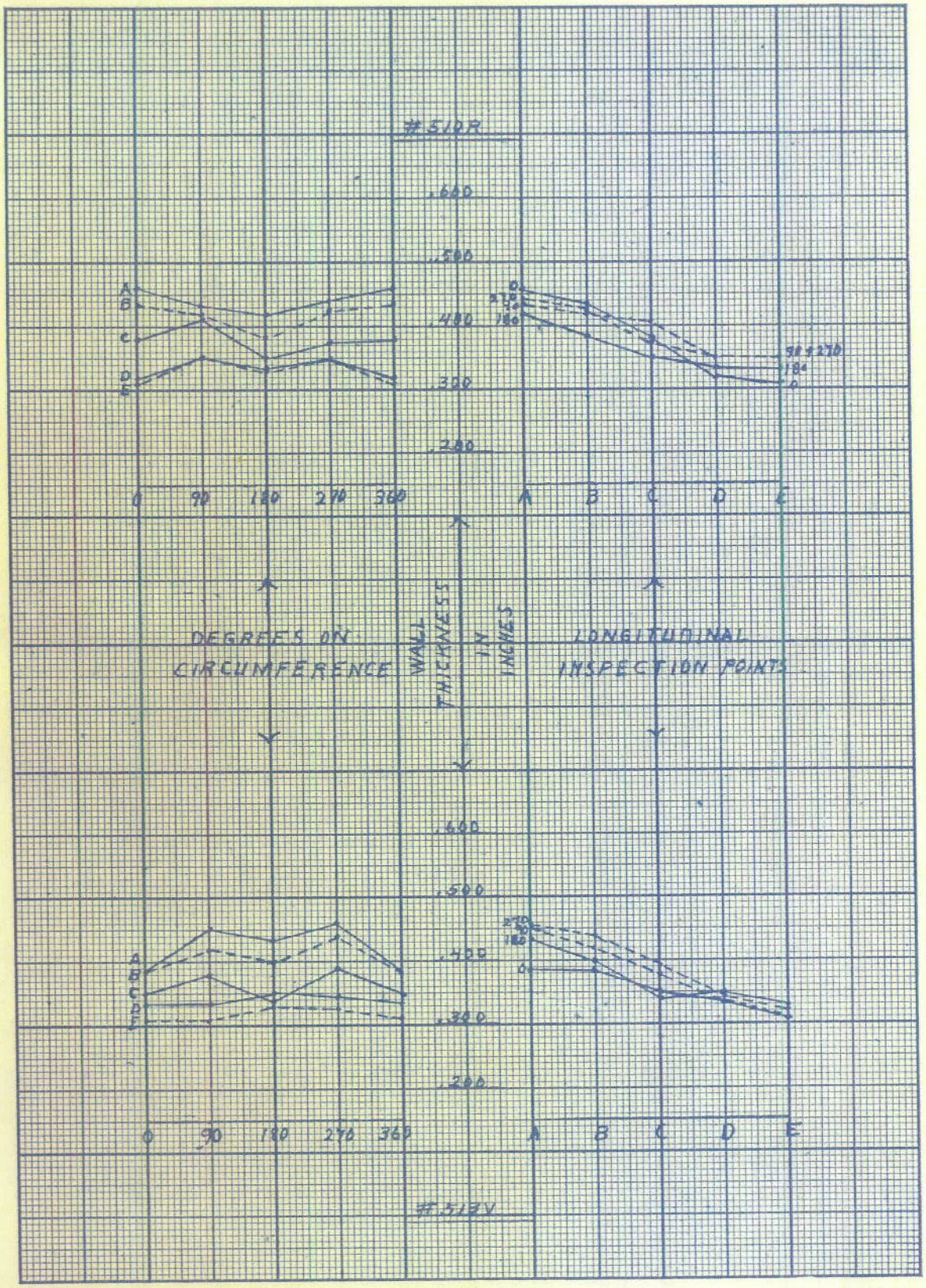

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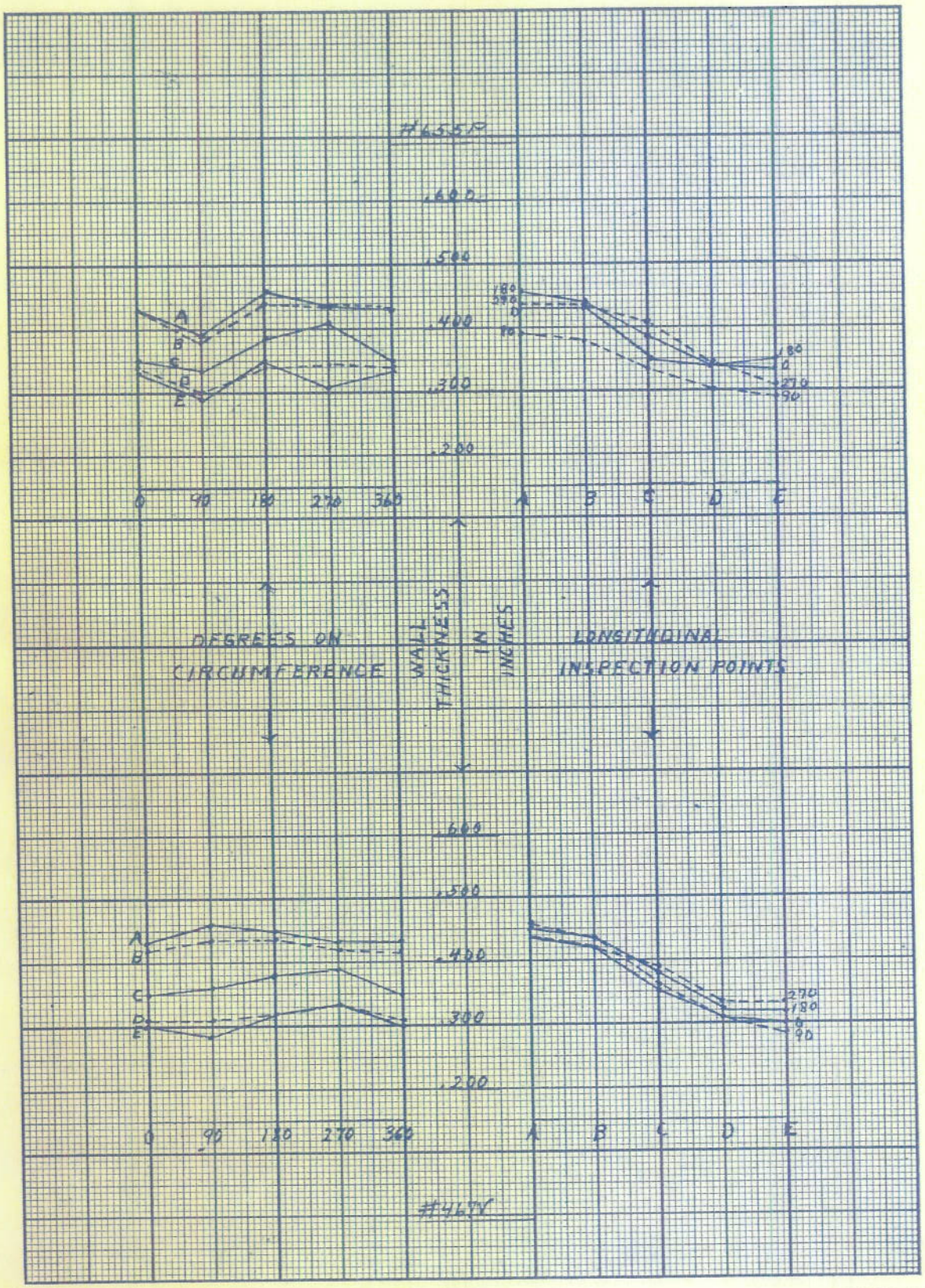
PLATE 5G



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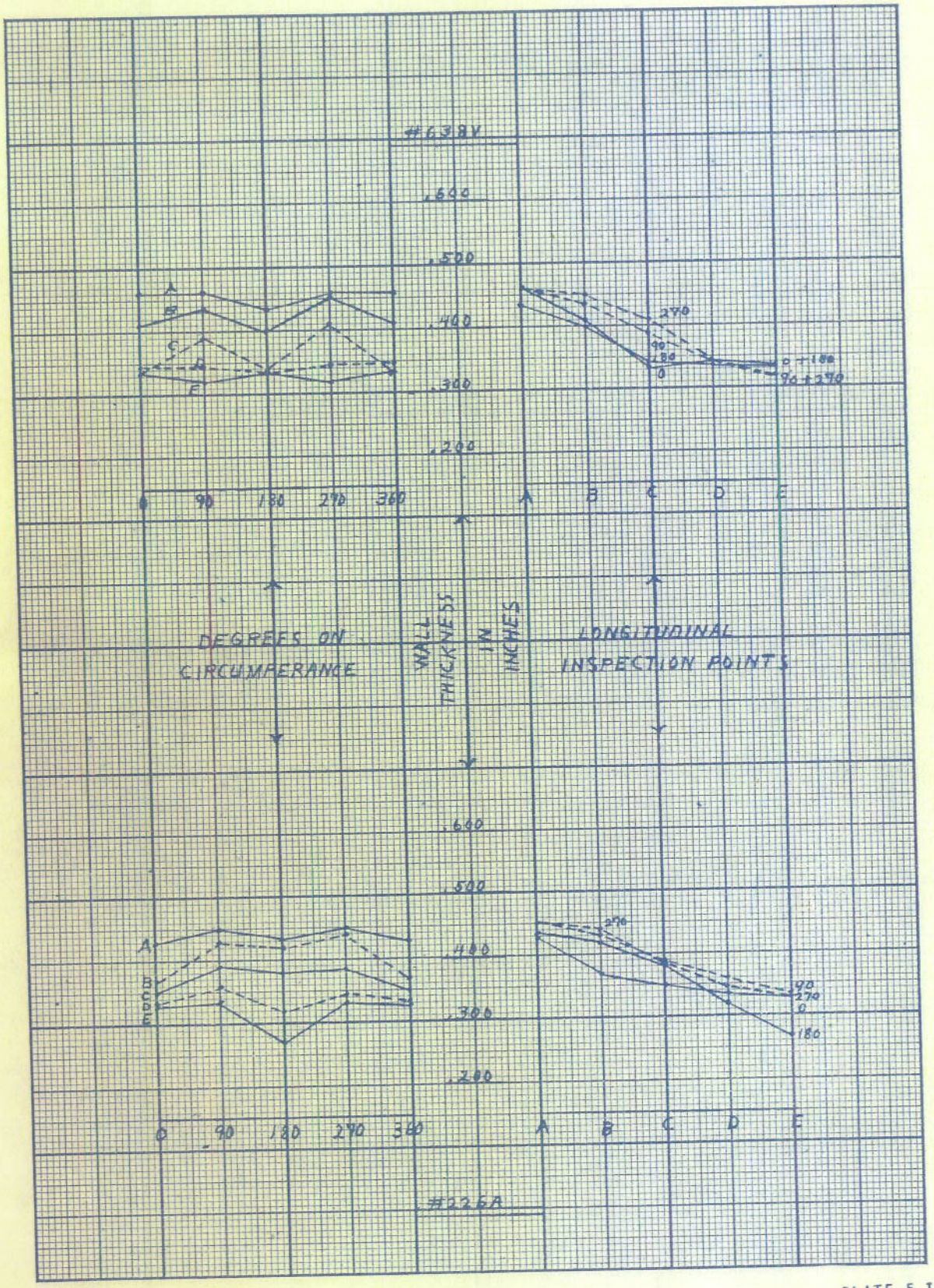

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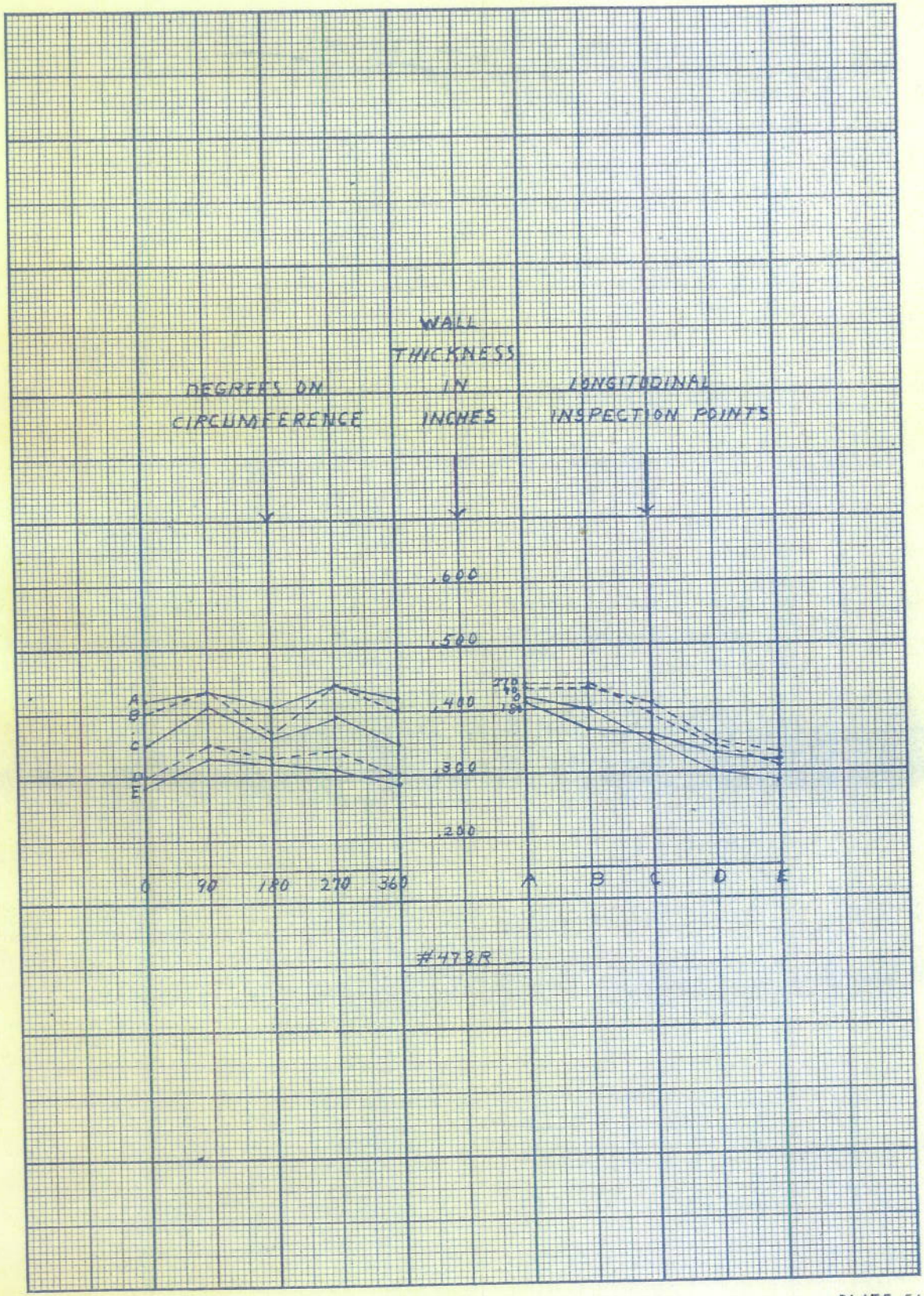
PLATE 5 I



S- 2932

PLATE 5J