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MASTER

REPORT RD-0009

PRESSURE DROP EXPERIMENTS OF THE TITLE II FUEL ASSEMBLY FOR THE EXPERIMENTAL GAS COOLED REACTOR

SECTION III OF

THE FUEL ASSEMBLY HEAT TRANSFER AND CHANNEL PRESSURE DROP EXPERIMENTS FOR THE EGCR RESEARCH AND DEVELOPMENT PROGRAM

October 3, 1960

Contract No. AT(10-1)-925
Mod. IX

Prepared By

ALLIS-CHALMERS MANUFACTURING COMPANY
Atomic Energy Division
Nuclear Power Department
Experimental Gas Cooled Reactor Project
Washington, D.C.

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REPORT RD-0009

PRESSURE DROP EXPERIMENTS

Prepared by:

W. H. Crandall — Responsible Engineer

R. M. Higgins — Group Leader

Approved by:

A. W. Dromerick — Section Head

W. F. Banks 11/14/60 — Project Manager

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FOREWORD

The data described in this report (Section III of the final report) were obtained from tests conducted by Allis-Chalmers Manufacturing Company between February and June 1960 pursuant to Modification IX of Contract No. AT(10-1)-925 and were run concurrently with Heat Transfer tests reported under Section IV.

ABSTRACT

Pressure drop data for the Title I EGCR fuel assembly have been presented in Section I. The data presented in this section cover the pressure drop tests of the Title II fuel assembly design modification and refinements as occurred during the Title II test phase. All tests were conducted with the chosen 3.000-in. ID fuel assembly sleeve and with the outer six tubes of the seven tube cluster located on a 2.000-in. dia. bolt circle. The tests included two designs of spider support pieces, and three designs of mid-length spacers. The pressure loss data are presented in the form of velocity head coefficients for the various components of inlet, full element length, exit, and the 14-in. center length over a range of Reynolds Numbers from 20,000 to 90,000.

I. INTRODUCTION

The determination of the coolant pressure drop across the reactor core is dependent upon the geometry of the flow channels of the fuel elements. The effect of revisions in design of fuel assembly spiders and spacers made since the Title I tests are difficult, if not impossible, to predict with satisfactory accuracy without the benefit of test results. It was for this reason that the Title I phase of testing was extended to include production models of the fuel element assemblies of the later Title I design which included Title II design changes.

II. OBJECTIVE

The primary objective of the tests herein described was to obtain experimental data on fuel channel pressure loss coefficients of the Title II fuel assembly designs.

A secondary objective was to determine the effect of relative angular rotation between fuel assemblies on pressure drop losses.

III. SCOPE

The original scope for this phase of the Pressure Drop Program was to obtain experimental fuel pressure loss coefficients of prototype production fuel assemblies. During the course of the program, the scope was enlarged to include loss coefficients of several versions of mid-length spacer designs and two spider support designs. The data assisted in the final choice of the Title II design, which was assembled and tested in the final phase of the extended program.

This report (Section III) presents the resulting pressure loss coefficients of four separate tests. The tests were conducted in the open air rig at Allis-Chalmers Manufacturing Company, Nuclear Power Department, Washington, D. C.

IV. RESULTS

The over-all pressure loss was separated into four major components similar to those reported in the Title I effort. The four components are:

1. C_s, a combined friction and form loss measured over a 14-in. length within the first fuel assembly of the fuel column which includes the Mid-Length spacer;

2. C_s', an over-all pressure loss of one complete fuel assembly measured from a point upstream of the exit end of one fuel assembly to a corresponding point on the next assembly;

3. C_c, an entrance loss measured from the inlet plenum to a point immediately downstream of the first fuel assembly;

4. C_e, an exit loss measured from a point downstream of the exit end of the last assembly to the exit plenum.

All four losses are expressed as coefficients of velocity head within the fuel assembly. Four combinations of a spacer-and spider configuration, chosen from two spider and three spacer designs, were tested in the open-air test rig. Individual plots of the coefficients versus Reynolds Number appear in Appendix A.

The values of C_s, C_s', C_c, and C_e at a Reynolds Number of 50,000 are listed in Table I at the end of this section, along with similar values from two test arrangements of the Title I fuel assembly previously reported in Section I. One of the Title I test arrangements had no Mid-Length spacers, and the second had 45° helical vane spacers at the mid length of each tube. By comparing the listed results, the following generalization can be made:

1. The Mod. IV Mid-Length Spacer (Dwg. SK-D-161) creates less pressure loss than the other three designs tabulated. By comparison, the Mod. I spacer (Dwg. SK-D-162) creates a 10% greater added loss to C_s, the Mod. II spacer (Dwg. SK-D-161) creates a 65% greater added loss and the Title I spacer creates about 145% greater added loss.

2. The combined inlet and exit losses to and from the fuel element assemblies ($C_c + C_e$) include exit and entrance losses from and to plenums plus the losses of the two 3.000-in. ID x 29-in. long dummy elements. The combined losses are least with the Mod. I spiders (Dwg. SK-D-163), although about the same for the Title I (Dwg. D-104 RD) test spiders (2% higher) and about 10% greater for the production specimen of Title I design (Dwg. SK-MS-15).

3. The pressure losses of the mating pairs of adjacent spiders, including the short open space between the fuel assemblies, is least with the Title I test spiders, approximately 36% greater for the Title I production models and about 21% greater for the Mod. I spiders.

4. The effect of rotating the second of three fuel assemblies 30° with respect to the first and third assembly causes the over-all pressure loss, C_s' to increase 2-3% with the Title I specimens and 3-5% with the Mod. I spiders.

A scatter of test points below Reynolds Number 30,000 existed due to an unpredictable flow phenomena, caused by opening the vent valve, which was done at low flow conditions to reduce excessive compressor surging and also to reduce manometer fluctuation.

In this series of tests, opening the vent valve was not objectionable as the coefficients are firmly established for the higher Reynolds Numbers. The next series of tests to be run were for the most part in the low flow range (i.e., below N_{RE} 30,000), the vent valve effect was overcome by inserting a resistance plate upstream of the orifice, but also uncovered a -4.5% to -5.0% error in all flow measurements. This correction has been applied to all of the test data of this report, and should be applied to the data in Section I report (Ref. 6). The quoted values of Section I report in Table I have been so corrected as noted in the footnotes of the Table.

Accuracy of test results is estimated to be approximately 5%. A detailed commentary of accuracy is included on Page 12 in the Discussion section of this report.

TABLE I

TYPICAL TEST RESULTS AT REYNOLDS NO. = 50,000

Test Symbol	ID In. Sleeve	Ligament Ratio	De (4 x Hyd Rad)	Mid-Spacer Identity		Spider Identity	C_s	C'_s Orientation* 0^o	C'_s Orientation* 30^o	C_c	C_e	C_{Spacer} Δ	C_{Spider} Orientation 0^o ΔΔ	C_{Spider} Orientation 30^o ΔΔ
6	3.002	1.983	0.05125 ft.	Mod. II SK-D-161	Straight Vanes 60^o Pad	Prod. Run Title I SK-MS-15	0.850	1.854	1.890	0.501	1.095	0.326	0.491	0.531
7	3.002	1.983	0.05125 ft.	Mod. I SK-D-162	30^o Helical Vanes 30^o Pad	Prod. Run Title I SK-MS-15	0.743	1.704	1.761	0.504	1.076	0.217	0.454	0.513
8	3.002	9.983	0.05125 ft.	Mod. IV SK-D-161	Straight Vanes 30^o Pad	Title II Mod. I SK-D-163	0.724	1.637	1.726	0.556	0.865	0.197	0.402	0.496
9	3.002	1.983	0.05125 ft.	Mod. II SK-D-161	Straight Vanes 60^o Pad	Title II Mod. I SK-D-163	0.849	1.788	1.847	0.552	0.900	0.326	0.436	.491
1-3	3.016	1.88	0.05199 ft.	None	None	Test Mock Up Title I SK-FF-104	0.517**	1.319***	1.446***	0.496□	0.986□	-	0.293	0.420
6-3	3.016	1.88	0.05199 ft.	Drawing SK-FF-136	45^o Helical Vanes (No Pad)	Test Mock Up Title I SK-FF-104	0.998□	1.868□	1.941□	0.496□	0.968□	0.480	.360	0.434

*Orientation refers to the angular position of the three test fuel assemblies to each other. At zero degree, the cross-sections of the three assemblies are in line, and at 30 degrees, the center assembly is rotated 30 degrees with respect to the other two assemblies.

**Calculated from $C_s = f \frac{L}{De}$ with f = 0.023 obtained from Reference 1, Page 5 corrected for -4.5 to -5.0% error of flow measurement and L = 1.1666 ft.

***Calculated from $C'_s = f' \frac{L}{De}$ with f = 0.028 and 0.031 respectively obtained from Reference 1, Page 5 corrected for -4.5 to -5.0% error of flow measurement and L = 2.4166 ft.

Δ Calculated from $C_{Spacer} = C_s - f \frac{L}{De}$ with f = 0.023 and L = 1.1666 ft.

ΔΔ Calculated from $C_{Spider} = C'_s - C_{Spacer} - C_{T.L.}$ where $C_{T.L.} = f \frac{L}{De}$ with f = 0.023 and L = 2.2917 ft. for assemblies 6, 7, 8 and 9 and L = 2.312 ft. for assemblies 1-3 and 6-3.

□ Obtained direct from Reference 1, Page 5, corrected for - 4.5% to -5.0% error of flow measurement.

V. CONCLUSIONS

The Title I Test Spiders actually created less pressure loss (0.15 velocity head) but were not considered fully representative of Title I design which was still being revised during the test program (see page 8 of Ref. 6).

Eliminating the Title I Test Spiders from contention and using a minimum pressure loss as a criterion for choice of Title II design spacers and end spiders, the Mod. I spiders and the Mod. IV Mid-Length Spacers would be the preferred choice. The Mod. I Spacers, however, differing from the Mod. IV Spacers only by the use of a larger pad, creates essentially the same loss as the Mod. IV Spacers contributing less than an 0.02 additional velocity head per assembly over that created by the Mod. IV Spacers.

The Mod. I end spiders stand out as a more distinct choice over the Title I production end spiders. The sum of entrance and exit losses, and the losses of a pair of spiders at each pair of adjacent assemblies of the Title I production specimens are about 10% and 13% higher, respectively, than the losses of the Mod. I spacers.

It should be noted that the inlet and exit loss coefficients each include a 29-in. length tubular dummy element. The final dummy designs, having more intricate air flow passages, are expected to increase these loss coefficients appreciably, and the mock ups of the final design will be tested as soon as the design drawings are available.

VI. TEST RIG

The Pressure Drop Rig is essentially the same as described in Section I of Report RD-0007, with the exception of the graphite sleeves, which were supplied by ORNL from production prototype sleeves. By mutual agreement between Allis-Chalmers and ORNL the sleeves were not drilled to accommodate velocity probes. The remaining description is copied verbatim from Section I [(6)].

The pressure drop experiments were performed with three full-scale fuel assemblies placed in series. Dummy assemblies were placed at the inlet and discharge ends of the column of test assemblies. The dummy assembly was a 29-in. long hollow carbon steel cylinder having the same bore as the fuel assembly sleeves. Plenum chambers were placed at the upstream and downstream ends of the test section. A centrifugal compressor delivered air at about 170 F to the test section. The compressor inlet and the test section exit were open to the atmosphere. An orifice meter was installed between the compressor discharge and test section inlet.

The blower and flow control system was capable of varying the flow over the range described previously. Pressure drop over the three test assemblies was measured by means of U-tube glass manometers. Various density fluids were available to fill the manometers. The choice of fluid was dependent upon the magnitude of the differential pressure to be measured. Two inclined water manometers were available to accurately measure low differential pressures.

Air temperature measurements in the test rig were made at the orifice, the inlet of the test section, and outlet of the test section. Temperature measurements were taken with mercury-in-glass thermometers. Provisions were also available to obtain these temperature measurements with thermocouples. The use of thermocouples proved to be an unnecessary refinement; experience did not dictate their necessity.

Flow measurement through the rig was made by means of a concentric orifice plate mounted between standard orifice flanges. Both the differential pressure and the statis pressure downstream of the orifice were measured by means of manometers. Flow control was achieved by means of two butterfly-type valves; one valve was located in the take-off from main flow to act as a by-pass, and was vented to atmosphere, the other valve used for throttling was located just upstream of pressure drop test section.

Static pressure measurements were made at selected stations along the fuel assembly test section. Each static pressure tap was connected to a manometer leg and the manometer registered the differential pressure between stations. The location of static pressure taps along the test section is shown schematically on Flowsheet SK-D-168. A more detailed description of the test equipment is contained in Appendix C of the Title I report [6].

VII. TEST SPECIMENS

The fuel assembly test specimens convered by this report were supplied by ORNL from a pilot production run of Title I fuel assemblies manufactured in accordance with Drawing SK-MS-15 appearing in A-C Study 100(4). Complete flow geometry except for mid-length spacers, Detail 7, was retained and the only other modifications to internal parts was to thread the end caps, Detail 6, to provide for a bolted assembly of fuel tubes and spiders in lieu of the weld in sub-assembly D of Drawing SK-MS-15. This permitted the mid-length spacers, which were slipped on the tubes and held in place by cement, to be readily interchanged.

A typical fuel assembly was therefore full size and consisted of a 5-in. OD, 3-in. ID, 29-in long graphite cylinder (called a sleeve) in which a cluster of seven empty tubular fuel elements were supported by spiders at each end of the sleeve. Four pressure taps were provided to form a piezometric ring at two axial positions, 5-1/2-in. and 19-1/2 in. from the upstream end of the sleeve. The fuel element tubes were 0.75-in. OD stainless steel tubes void of fuel. For reactor operation, the tubes will be filled with UO_2 pellets. The spider at each end of the sleeves supported the tubes with one tube on the sleeve center line and the remaining six tubes equally spaced around the central tube on a 2.00-in. bolt circle. Reproductions of the general arrangement of the reactor fuel assembly drawing, SK-FF-15, and details of the production run test specimens of Title I spider, Drawing SK-D-163, appears in Appendix B.

The drawing SK-D-163 also contains the alternate ORNL modified test spiders A-103-30, which were substituted in the last two test assemblies (see Fig. 6, Appendix B).

The mid-length spacers, Detail 4, of SK-MS-15, was replaced successively by three modifications of the 45° helical finned designes called Mod. I, Mod. II and Mod. IV designs. All three designs were 1/4-in. long over-all without any hub extensions. The Mod. I spacers shown on Drawing SK-D-162 in Appendix B have 30° helical vanes with the one vane of the spacers on the six outer tubes containing a fabricated 1/4-in. or 30° arc pad. The outer spacers were assembled so that the vane with the pad was adjacent to the graphite sleeve ID. The Mod. II central spacers were a simple 0.757-in. OD x 0.826-in. OD x 1/4-in. long cylinder. Vanes on the outer spacers were straight with one vane enlarged to a 60° arc solid pad. Mod. IV spacers were identical to Mod. II except that the enlarged pad or vane was reduced from a 60° arc to a 30° arc width. Both Mod. II and Mod. IV spacers are shown on Drawing SK-D-161 in Appendix B.

As in the Title I test program, the tests were run with three full scale fuel assemblies in series. The same plenum and dummy assemblies, one at each end of the series of fuel assemblies, were used in this Title II test effort. The dummy elements were twenty-nine in. x 3.000-in. ID graphite cylinders. A schematic drawing of the arrangement with the test stations identified is on Drawing SK-D-168.

The final design of the dummies are expected to be of a more complex shape. The lower dummy will contain either replaceable or adjustable orifices and both dummies will probably include neutron reflectors to prevent straight through neutron streaming. A mock up will be made of the final dummy design and will be tested as a follow up of this phase of the program to obtain accuracy entrance and exit losses and to obtain, if necessary, control orifice data.

VIII. DISCUSSION

The division of the over-all pressure loss into four separate components has been defined in the Results Section, Page 4 and plots of coefficients C_s, C_s', C_c and C_e versus Reynolds Number appear in Appendix A.

Coefficient C_s was obtained by measuring the pressure drop over a 14-in. axial length in the center of the fuel assembly between test stations 1-6 and 1-10. The mid-length spacers are included within this length. The coefficient C_s' represents the over-all pressure loss of one complete fuel assembly, measured between similar points (1-10 and 2-10) on each adjacent pairs of fuel element assembly. The numbering system of the test stations is in accordance with flow sheet SK-D-168. Entrance losses, which include the loss of the 3.00-in. ID x 29-in. long dummy are measured between the plenum test station 3 and the test station 1-6 just downstream of the first assembly spider. The exit loss, C_e, was determined from measurements between test station 3-10, just upstream of the end of the third fuel assembly, and the exit plenum, test station 22.

All coefficients were calculated from the equations determined from the general energy equation using an approximation of adiabatic expansion or compression between test points. Details of the derivations of the equations were present in Section I of this report[6] and will not be repeated here. The equations are:

$$C_c = \text{entrance loss} = \frac{2g\rho_1 P_1}{G_2^2} \left(\frac{P_2}{P_1}\right)^{2/k} \left(\frac{k}{k-1}\right) \left[1 - \left(\frac{P_2}{P_1}\right)^{k-1/k}\right] + \left(\frac{A_2}{A_1}\right)^2 \left(\frac{P_2}{P_1}\right)^{2/k} - 1 \qquad (1)$$

and,

$$C_e = \text{exit loss} = \frac{2g\rho_2 P_2}{G_1^2} \left(\frac{P_1}{P_2}\right)^{2/k} \left(\frac{k}{k-1}\right) \left[\left(\frac{P_1}{P_2}\right)^{k-1/k} - 1\right] + 1 - \left(\frac{A_1}{A_2}\right)^2 \left(\frac{P_1}{P_2}\right)^{2/k} \qquad (2)$$

$$C_s \text{ (14'' section)} = \frac{2g \quad 1 \; P \; 1}{G_2 \qquad 2} \left(\frac{P_2}{P_1}\right)^{2/k} \left(\frac{k}{k-1}\right) \left[1 - \left(\frac{P_2}{P_1}\right)^{k-1/k}\right] + \left(\frac{P_2}{P_1}\right)^{2/k} - 1 \qquad (3)$$

$$C_s' \text{ (full length)} = \text{(same as } C_s) \qquad (4)$$

Subscript 1 refers to upstream stations, and subscript 2 refers to downstream station for each pair of test stations involved.

It was necessary to use the above four formulas to account for the compressibility effects of the air in the low pressure loop. For the actual reactor calculations, in which the system pressure is sufficiently high to cause the pressure ratio between test stations to be essentially unity, the coefficients can be used with little or no error in the conventional simple formula for non-compressible flow:

$$P = C \left(\frac{G^2}{\rho}\right) \left(\frac{1}{2g}\right) \qquad (5)$$

The acceleration effects of temperature change would have to be added in the reactor pressure loss cases and is not included in the scope of this series of tests. Study 115[5] is suggested for this aspect of the pressure loss.

The table of Results, Page 5, lists the four coefficients C_s, C_s', C_c and C_e at a Reynolds Number of 50,000 offer a convenient way of comparing the losses of the two spider and three mid-length spacers designs. The table also includes the results, taken from the Title I report (Section 1)[6], of two assemblies for comparison purposes. The two cases were for the Title I spiders modeled from SK-FF-104 without any mid-length spacers and for the 45° helical mid-length spacers, Drawing SK-FF-136. Both cases used a 3.016-in. ID sleeve bore and a 2.00-in. BC spacing of outer fuel elements. The friction factor, f, determined along the 14-in. axial length in the center portion of the fuel element without mid-length spacers, was multiplied by appropriate L/De values to obtain an equivalent loss coefficient for the friction loss of the tube cluster for each test setup. By subtracting the resulting equivalent loss coefficients from the appropriate C_s and C_s' loss coefficients, the added losses due to spacers and spiders were isolated and shown as coefficients $C_{(spider)}$ and $C_{(spacer)}$ in the last two columns of the table of Results, Page 5.

The normal expected problem of isolating close coupled losses aggravated by attempts to break out the friction component is apparent to a mild extent as evidenced by a close look at the table. For example, the $C_{(spider)}$ coefficient which includes the same end spiders as those used in Tests 6 and 7, would be expected to offer the same loss coefficient. The second type of spiders used for both Tests 8 and 9 should also offer duplicate spider pressure loss coefficients. However, it can be seen that when the exit loss coefficients stations are preceded by the Mod. II spacers at the center of the fuel element, the resulting coefficients are about 0.04 velocity heads (8%) greater than compared to when either the Mod. I or Mod. IV spacer preceded the exit loss stations. This can be attributed to the location of test station 3-10, located 5 inches behind the mid-length spacers, which is in a region still affected by the turbulence of the mid-length spacers. The error of such a reading, if it actually exists, would be essentially compensated provided all of the loss coefficients used in any future analysis are taken from the same run. It was with this thought in mind that the final assembly arrangement Number 9 was made which tested the chosen Mod. I spiders in an assembly with the chosen Mod. II spacers.

The mechanical accuracy of test results has been estimated to be ±4% as outlined in Section I[1] based on the following tolerances:

a.	Ds	±0.001"
b.	dt	±0.001"
c.	T gas temperature	±5° F
d.	P gas pressure	±0.1" Hg
e.	L	±1/32"
f.	Orifice diameter	±0.0002
g.	Orifice flange, ID	±0.004"
h.	Coefficient of discharge	±1.00%
i.	Orifice expansion factor (depends on ratio of orifice to flange ID)	±0.0045%
j.	Velocity of approach (depends on ratio of orifice to flange ID)	±0.09%
k.	Manometer reading	±0.6% at high flow ±0.3% at low flow

By applying the extremes of the above tolerance factors directly into the equations for flow and pressure drop readings, a prediction of basic data accuracy is 5.25% at high flow and 5.9% at low flow. This would assume that all tolerances occur at their peak value and in a direction so as to enhance the resulting error to its greatest magnitude. By application of the more subtle square root of the sum of the squares law, the range of prediction of accuracy would reduce to approximately 2.0% at the high flow and 2.1% at the lower flows.

The latter approach might be considered optimistic whereas the strict multiplication of factors would be considered very pessimistic. Therefore, a realistic value of 4%, which is a value between the two methods, is predicted for basic data error.

Consideration must also be given to the reliability of the application of the derived formula for compressible flow coefficients which offers values at Reynolds Number of 50,000 approximaterly 5% below that of the application of the basic data in incompressible formula. Exactness of the formulas will probably continue to leave some area of doubt, however, the incompressible formula treatment would be recognized as an unquestionable upper limit for the coefficients. Since application of other processes offered answers within 1% of those of the adiabatic treatment used in this report, an accuracy of the expansion effect on coefficients of 80% is suggested or a net effect of ±1% on the actual coefficient value. Adding the full 1% to the basic 4% value, results in the prediction of an over-all test point accuracy of ±5%.

IX. REFERENCES

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5. Devlin. L.H., and Kintner, L.L., Allis-Chalmers EGCR Study No. 115 of Thermal Performance of Experimental Gas Cooled Reactor, Washington, D.C., 1959.

6. Allis-Chalmers Report RD-0007, Pressure Drop Experiments on a Proposed Fuel Assembly for the Experimental Gas Cooled Reactor, Section I of Fuel Assembly, Heat Transfer and Channel Pressure Drop Experiment for the EGCR Research and Development Program, by R. M. Higgins and C. L. Beaudoin, Washington, D.C., January 20, 1960.

X. NOMENCLATURE

A	=	Coolant flow area, ft^2
C_V	=	Specific heat of coolant at constant volume, Btu/lb-^oF
C_c	=	Entrance contraction coefficient, dimensionless
C_e	=	Exit expansion coefficient, dimensionless
C_{spacer}	=	Apparent added pressure loss coefficient due to mid-length spacers, dimensionless
C_{spider}	=	Apparent pressure loss coefficient caused by one pair of spiders and space between adjacent fuel element, dimensionless
C_s	=	Pressure loss coefficient of 14" axial length of center of fuel assembly, dimensionless
C_s'	=	Pressure loss coefficient of fuel length of one fuel element assembly, dimensionless
D_e	=	Equivalent diameter for flow, ft
f	=	Moody friction factor, dimensionless
g_c	=	Conversion factor, ft-lb/lb-sec^2
H_L	=	Total energy loss, ft
k	=	Ratio of specific heat, cp/cv, dimensionless
L	=	Friction length, ft
N_M	=	Mach number, dimensionless
P	=	Static pressure
R	=	Gas constant, ft/^oF
T	=	Coolant temperature, ^oF
U	=	Internal energy of coolant, ft

V	=	Coolant velocity, ft/hr
ρ	=	Coolant density, lb/ft^3
ν	=	Specific volume of coolant, ft^3/lb
Z	=	Ligament ratio

<u>Subscripts</u>

1	=	The <u>upstream</u> station of 2 stations between which pressure drop is being considered.
2	=	The <u>downstream</u> station of 2 stations between which pressure drop is being considered.

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APPENDIX A

Pressure Drop Data Curves

INDEX FOR PRESSURE DROP CURVES

Figure No.	Title	Fuel Assembly Components			
		Mid-Length Spacers	Spiders	Sleeve	Test Symbol
1	Inlet & Exit Coefficient, C_c&C_e-vs-N_{RE}	Mod II	Title I	Title I	6
2	Same as (1) Except 2nd Ass'm Rotated 30°	(SK-D-161)	Production	Production	(Runs)
3	Fuel Assembly Coefficient, C_s& C_s'-vs-N_{RE}	Straight Vanes	Run of	Run of	269 to 314
4	Same as (3) Except 2nd Ass'm Rotated 30°	60° Pad	SK-MS-3&4	SK-MS-15	
5	Inlet & Exit Coefficients, C_c& C_e-vs-N_{RE}	Mod I	Title I	Title I	7
6	Same as (5) Except 2nd Ass'm Rotated 30°	(SK-D-162)	Production	Production	(Runs)
7	Fuel Assembly Coefficients, C_s& C_s'-vs-N_{RE}	30° Helical	Run of	Run of	315 to 344
8	Same as (7) Except 2nd Ass'm Rotated 30°	Vanes - 30° Pad	SK-MS-3&4	SK-MS-15	
9	Inlet & Exit Coefficients, C_c& C_e-vs-N_{RE}	Mod IV	Mod I	Title I	8
10	Same as (9) Except 2nd Ass'm Rotated 30°	(SK-D-161)	(SK-D-163)	Production	(Runs)
11	Fuel Assembly Coefficients, C_s& C_s'-vs-N_{RE}	Straight Vanes		Run of	345 to 389
12	Same as (11) Except 2nd Ass'm Rotated 30°	30° Pad		SK-MS-15	
13	Inlet & Exit Coefficients, C_c& C_e-vs-N_{RE}	Mod II	Mod I	Title I	9
14	Same as (13) Except 2nd Ass'm Rotated 30°	(SK-D-161)	(SK-D-163)	Production	(Runs)
15	Fuel Assembly Coefficients, C_s& C_s'-vs-N_{RE}	Straight Vanes		Run of	385 to 414
16	Same as (15) Except 2nd Ass'm Rotated 30°	60° Pad		SK-MS-15	

NOTE: Sleeve ID = 3.0002 in., Tube OD = 0.750 in. and Tube Spacing BC = 2.000 in. on all assemblies.

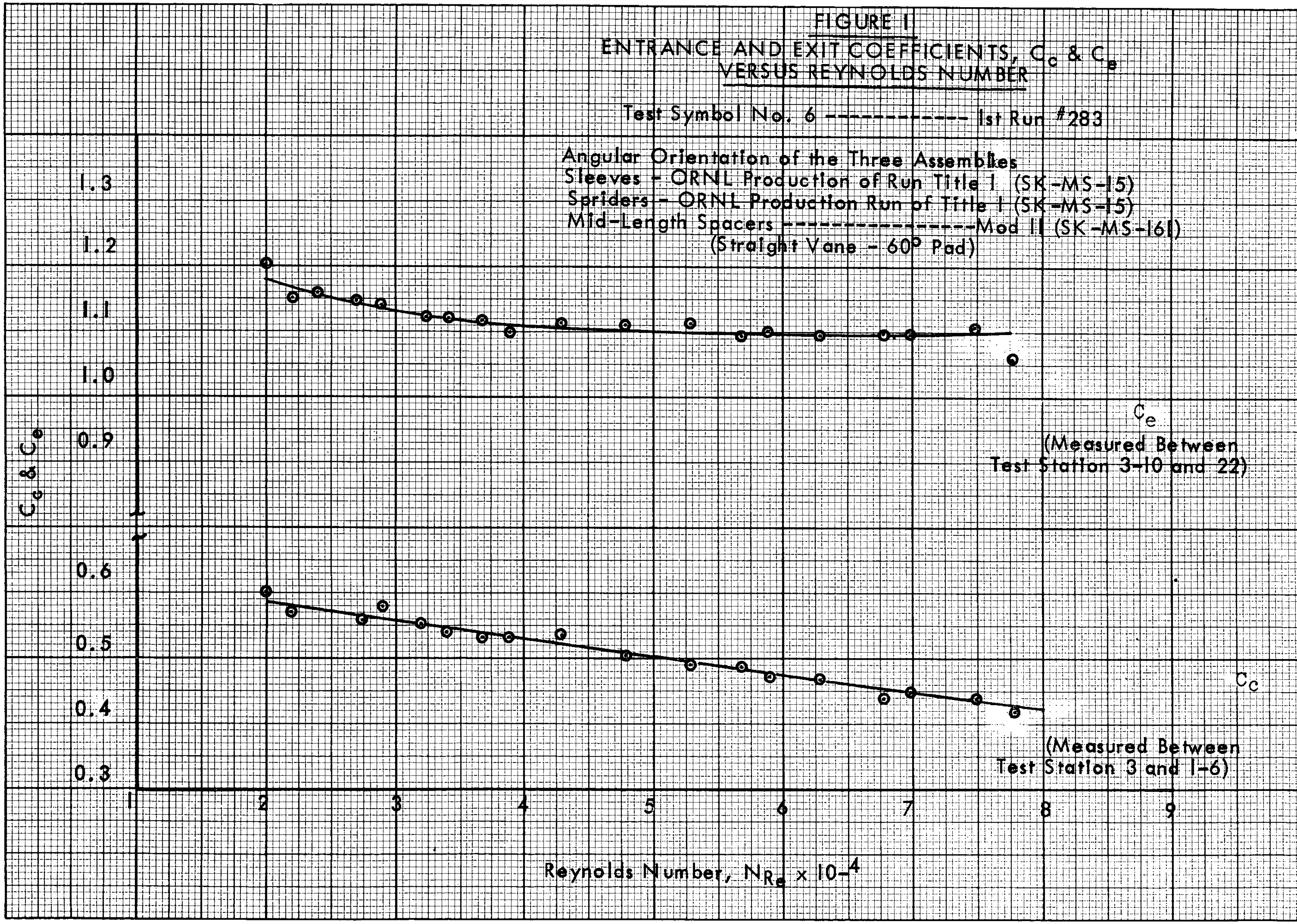


FIGURE I
ENTRANCE AND EXIT COEFFICIENTS, Cc & Ce
VERSUS REYNOLDS NUMBER
Test Symbol No. 6 ------------ 1st Run #283
Angular Orientation of the Three Assemblies
Sleeves - ORNL Production of Run Title I (SK-MS-15)
Spriders - ORNL Production Run of Title I (SK-MS-15)
Mid-Length Spacers ---------------Mod II (SK-MS-161)
(Straight Vane - 60° Pad)
Ce
(Measured Between
Test Station 3-10 and 22)
Cc
(Measured Between
Test Station 3 and 1-6)
Cc & Ce
1.3
1.2
1.1
1.0
0.9
0.6
0.5
0.4
0.3
1
2
3
4
5
6
7
8
9
Reynolds Number, NRe x 10-4

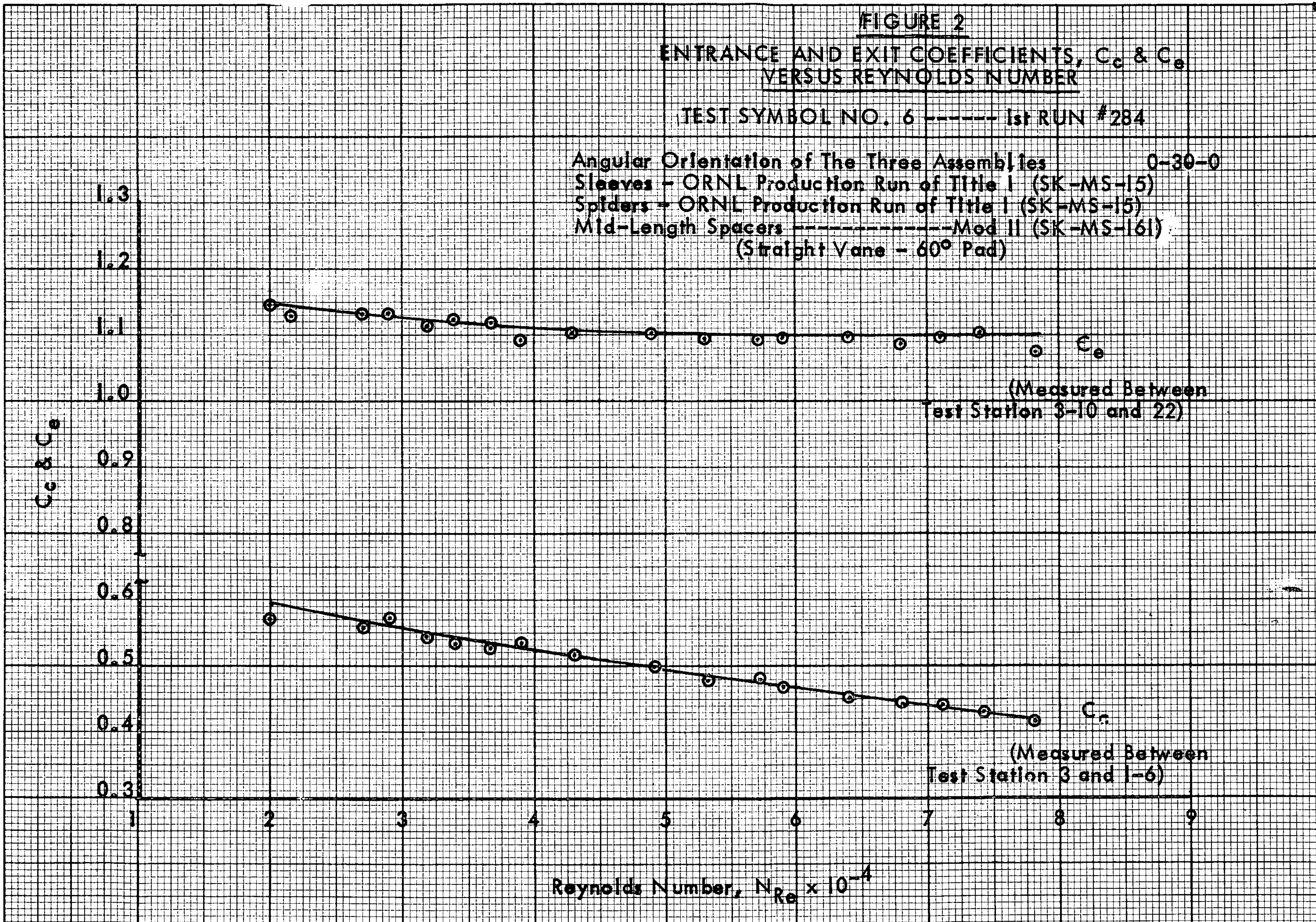


FIGURE 2

ENTRANCE AND EXIT COEFFICIENTS, C_c & C_e VERSUS REYNOLDS NUMBER

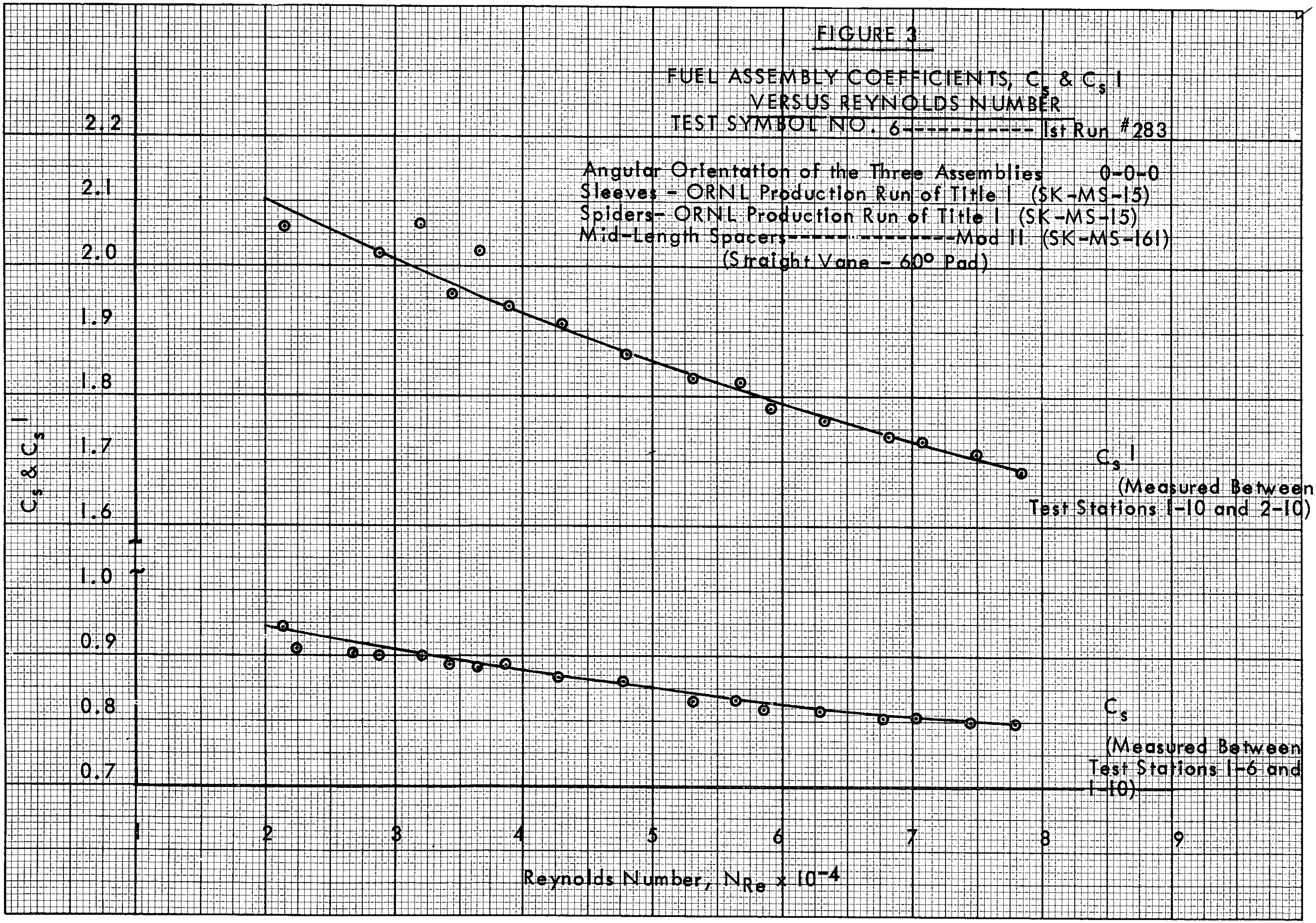


FIGURE 3
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s I
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 6----------- 1st Run #283
Angular Orientation of the Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I (SK-MS-15)
Spiders- ORNL Production Run of Title I (SK-MS-15)
Mid-Length Spacers----- ---------Mod II (SK-MS-161)
(Straight Vane - 60° Pad)
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.0
0.9
0.8
0.7
C_s & C_s I
C_s I
(Measured Between Test Stations 1-10 and 2-10)
C_s
(Measured Between Test Stations 1-6 and 1-10)
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

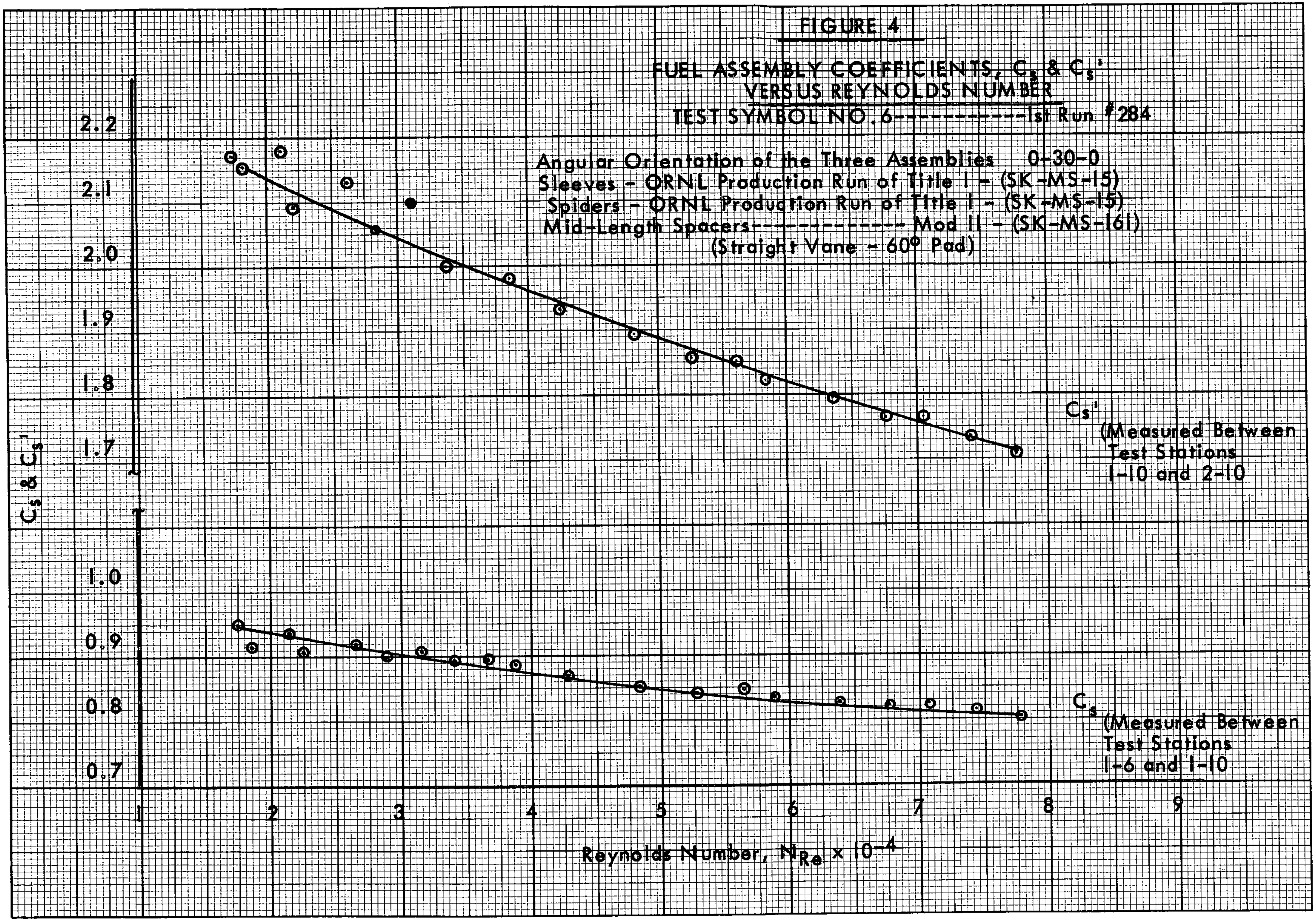


FIGURE 4
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s'
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 6------------1st Run #284
Angular Orientation of the Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I - (SK-MS-15)
Spiders - ORNL Production Run of Title I - (SK-MS-15)
Mid-Length Spacers------------Mod II - (SK-MS-161)
(Straight Vane - 60° Pad)
C_s'
(Measured Between Test Stations 1-10 and 2-10
C_s
(Measured Between Test Stations 1-6 and 1-10
C_s & C_s'
2.2
2.1
2.0
1.9
1.8
1.7
1.0
0.9
0.8
0.7
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

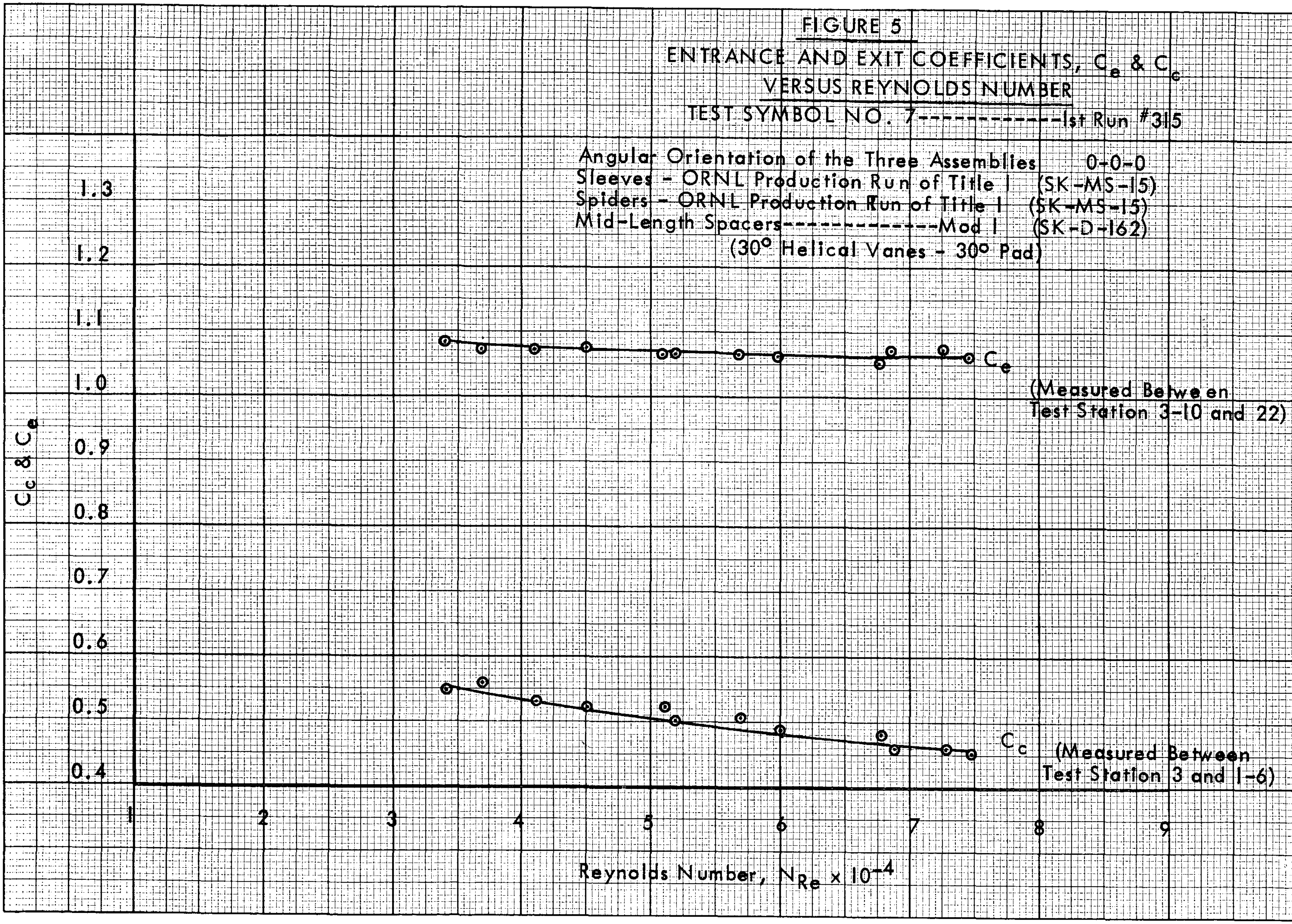


FIGURE 5
ENTRANCE AND EXIT COEFFICIENTS, C_e & C_c
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 7------------1st Run #315
Angular Orientation of the Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I (SK-MS-15)
Spiders - ORNL Production Run of Title I (SK-MS-15)
Mid-Length Spacers------------Mod I (SK-D-162)
(30° Helical Vanes - 30° Pad)
C_e
(Measured Between Test Station 3-10 and 22)
C_c
(Measured Between Test Station 3 and 1-6)
C_c & C_e
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

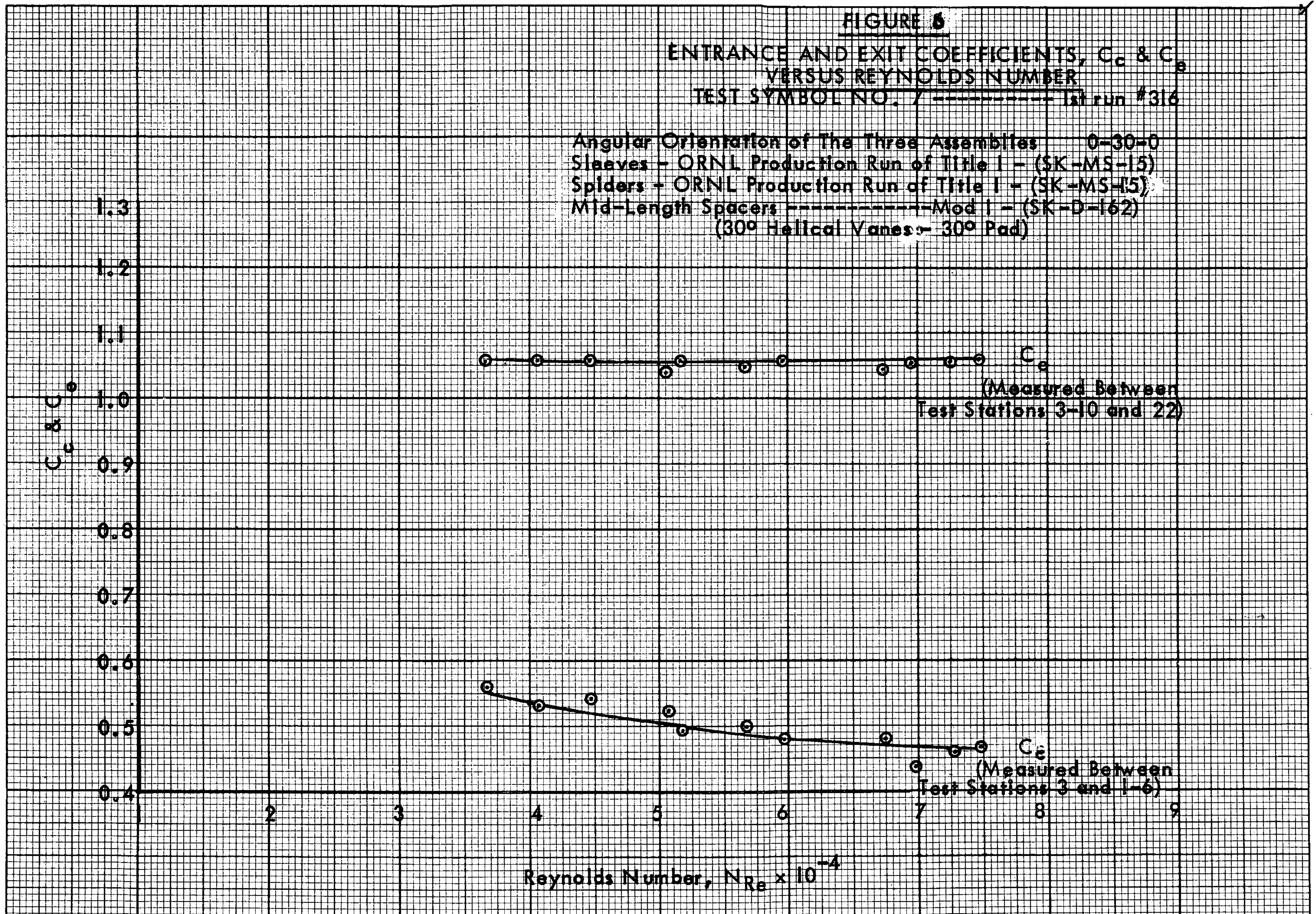


FIGURE 6
ENTRANCE AND EXIT COEFFICIENTS, C_c & C_e
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 7 ------------ 1st run #316
Angular Orientation of The Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I - (SK-MS-15)
Spiders - ORNL Production Run of Title I - (SK-MS-15)
Mid-Length Spacers ------------Mod I - (SK-D-162)
(30° Helical Vanes - 30° Pad)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
C_c & C_e
C_e
(Measured Between
Test Stations 3-10 and 22)
C_e
(Measured Between
Test Stations 3 and 1-6)
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

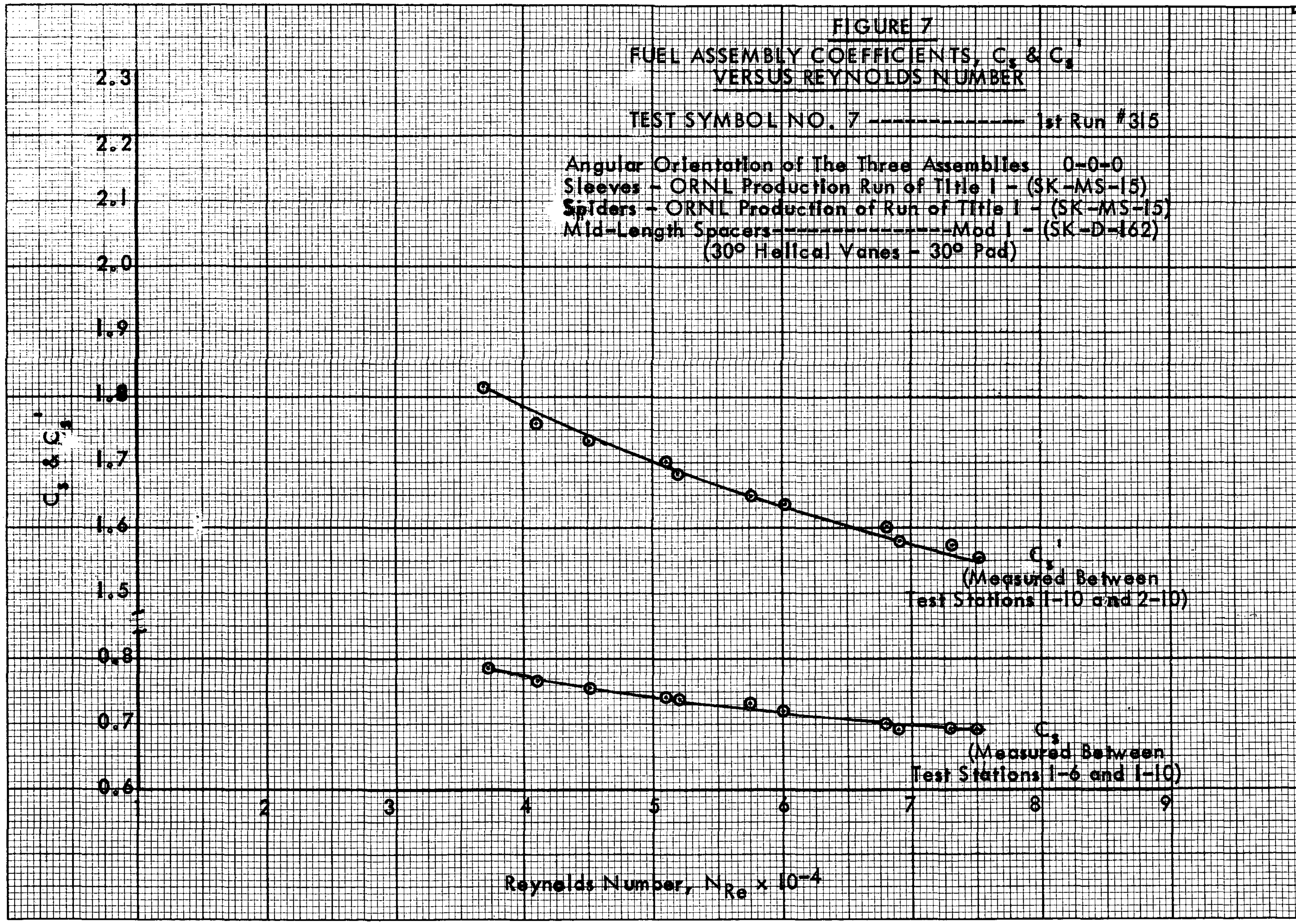


FIGURE 7
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s'
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 7 ------------- 1st Run #315
Angular Orientation of The Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I - (SK-MS-15)
Spiders - ORNL Production of Run of Title I - (SK-MS-15)
Mid-Length Spacers---------------Mod I - (SK-D-162)
(30° Helical Vanes - 30° Pad)
C_s'
(Measured Between
Test Stations 1-10 and 2-10)
C_s
(Measured Between
Test Stations 1-6 and 1-10)
C_s & C_s'
Reynolds Number, $N_{Re} \times 10^{-4}$
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
0.8
0.7
0.6
1
2
3
4
5
6
7
8
9

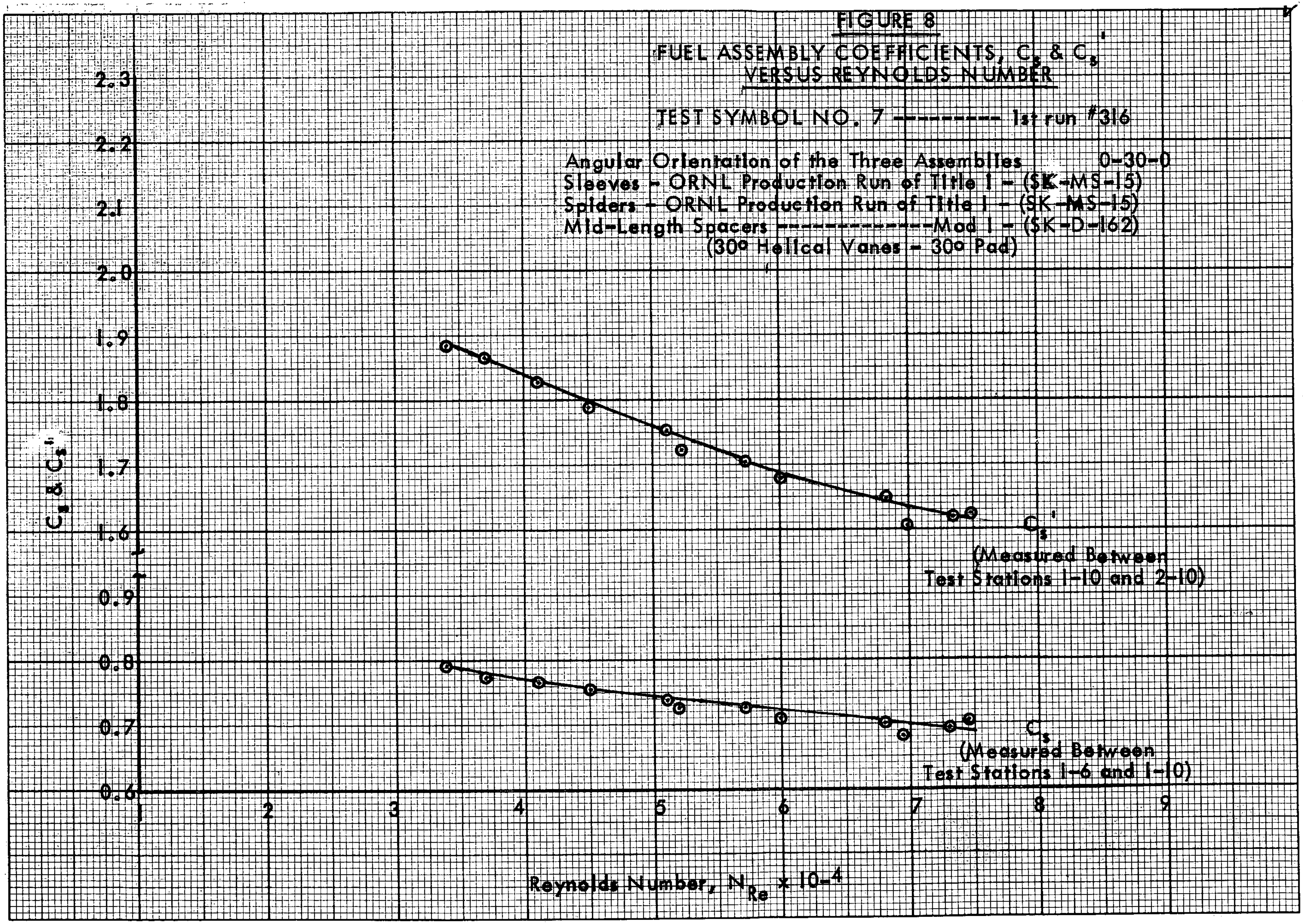


FIGURE 8
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s'
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 7 ---------- 1st run #316
Angular Orientation of the Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I - (SK-MS-15)
Spiders - ORNL Production Run of Title I - (SK-MS-15)
Mid-Length Spacers --------------Mod I - (SK-D-162)
(30° Helical Vanes - 30° Pad)
C_s'
(Measured Between Test Stations 1-10 and 2-10)
C_s
(Measured Between Test Stations 1-6 and 1-10)
C_s & C_s'
Reynolds Number, $N_{Re} \times 10^{-4}$
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
0.9
0.8
0.7
0.6
1
2
3
4
5
6
7
8
9

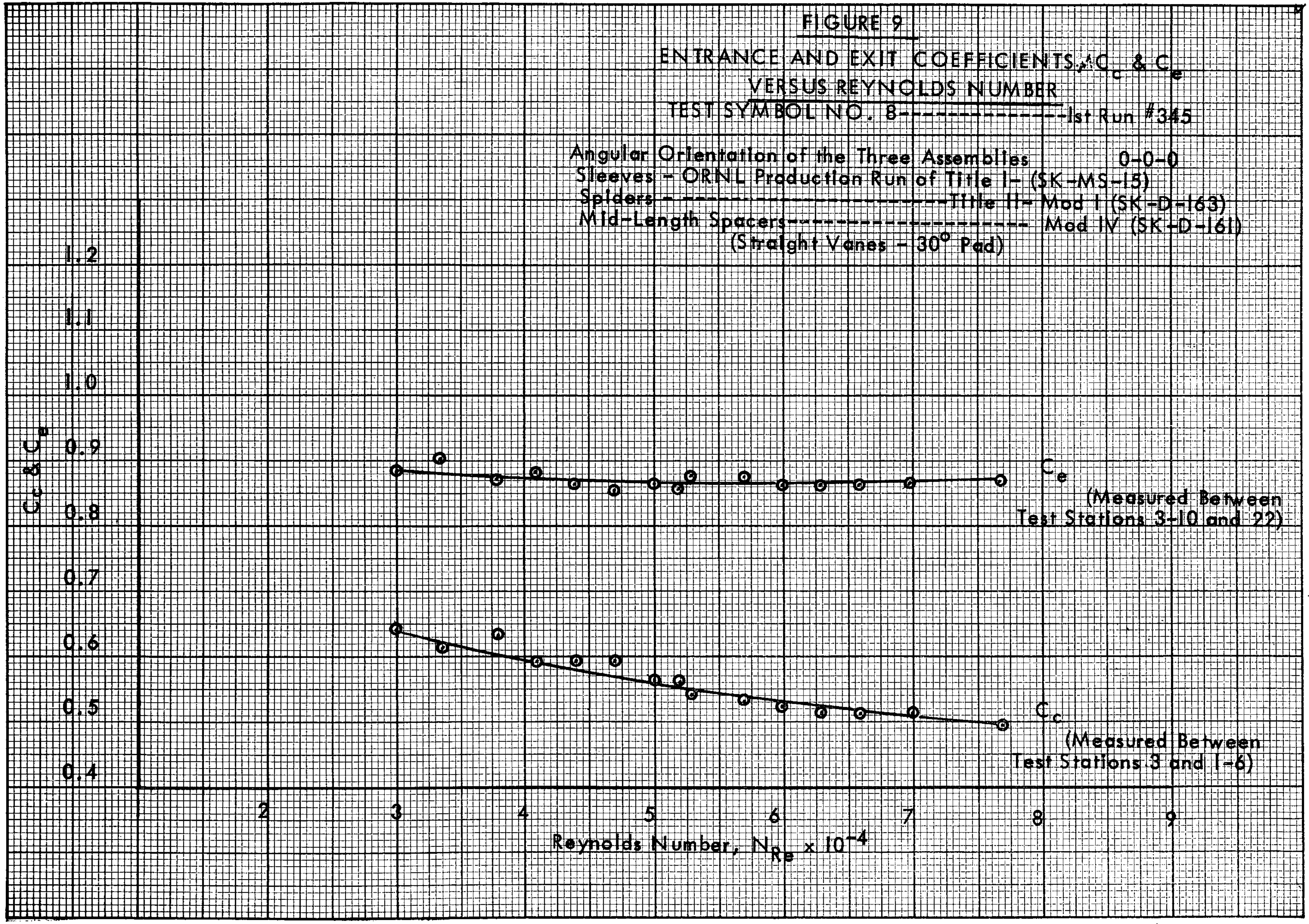


FIGURE 9

ENTRANCE AND EXIT COEFFICIENTS, C_c & C_e
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 8---------------1st Run #345

Angular Orientation of the Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I- (SK-MS-15)
Spiders - --------------------------Title II- Mod I (SK-D-163)
Mid-Length Spacers-------------------- Mod IV (SK-D-161)
(Straight Vanes - 30° Pad)

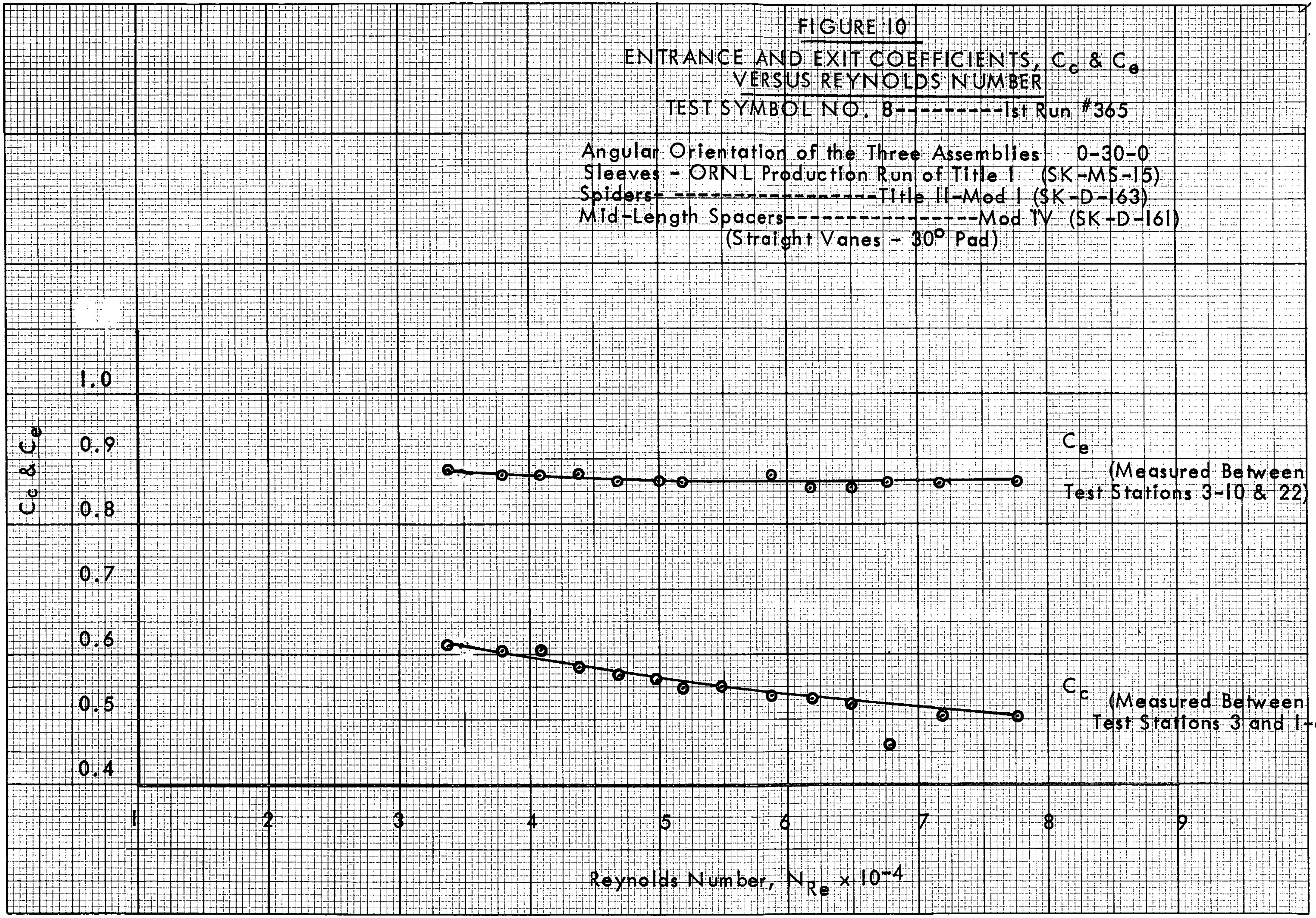


FIGURE 10
ENTRANCE AND EXIT COEFFICIENTS, C_c & C_e
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 8----------1st Run #365
Angular Orientation of the Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I (SK-MS-15)
Spiders- ------------------Title II-Mod I (SK-D-163)
Mid-Length Spacers----------------Mod IV (SK-D-161)
(Straight Vanes - 30° Pad)
C_c & C_e
1.0
0.9
0.8
0.7
0.6
0.5
0.4
C_e
(Measured Between Test Stations 3-10 & 22)
C_c
(Measured Between Test Stations 3 and 1-6)
1
2
3
4
5
6
7
8
9
Reynolds Number, N_{Re} × 10^{-4}

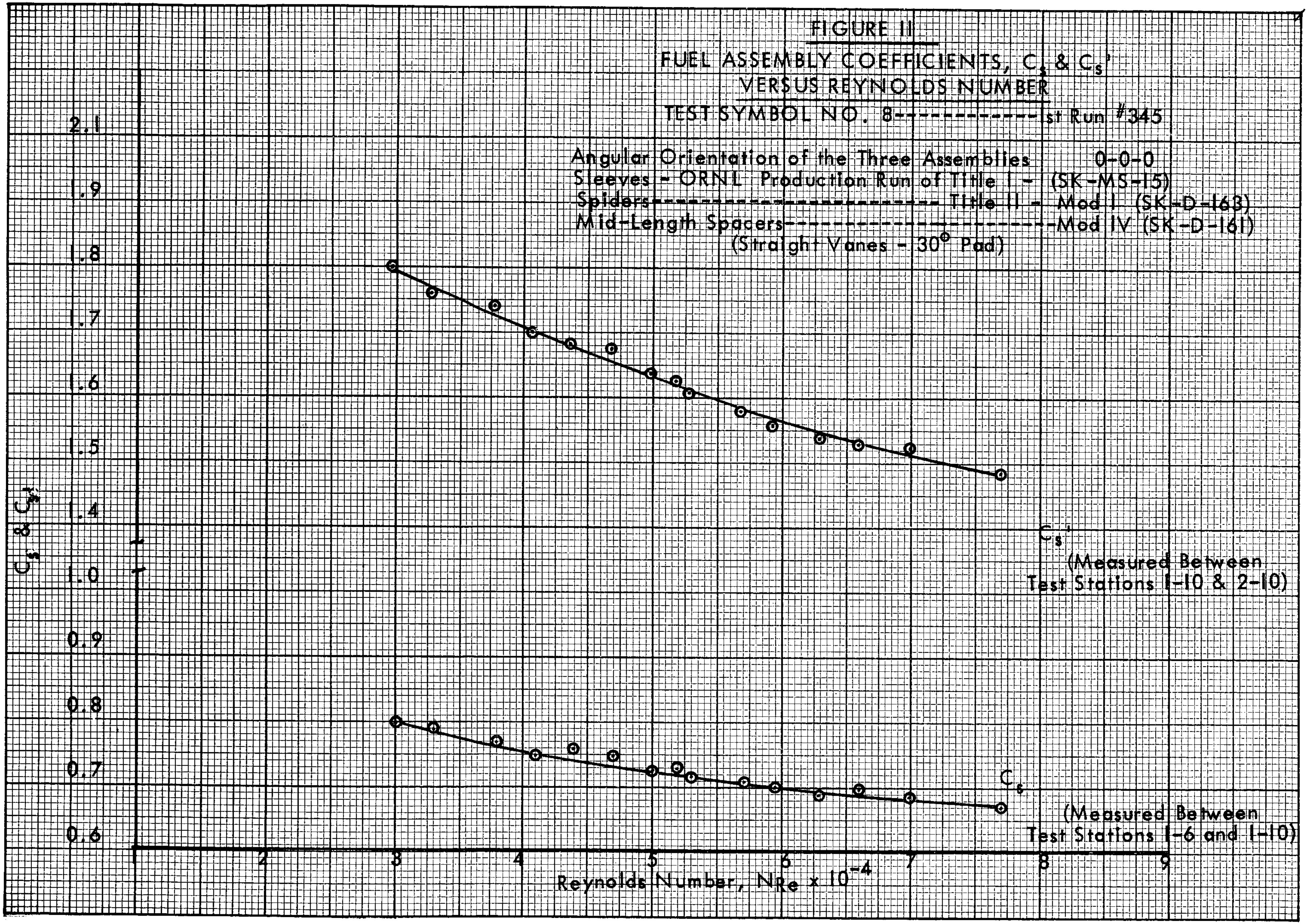


FIGURE 11
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s'
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 8-----------st Run #345
Angular Orientation of the Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I - (SK-MS-15)
Spiders------------------------- Title II - Mod I (SK-D-163)
Mid-Length Spacers----------------------Mod IV (SK-D-161)
(Straight Vanes - 30° Pad)
C_s'
(Measured Between
Test Stations 1-10 & 2-10)
C_s
(Measured Between
Test Stations 1-6 and 1-10)
C_s & C_s'
2.1
1.9
1.8
1.7
1.6
1.5
1.4
1.0
0.9
0.8
0.7
0.6
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

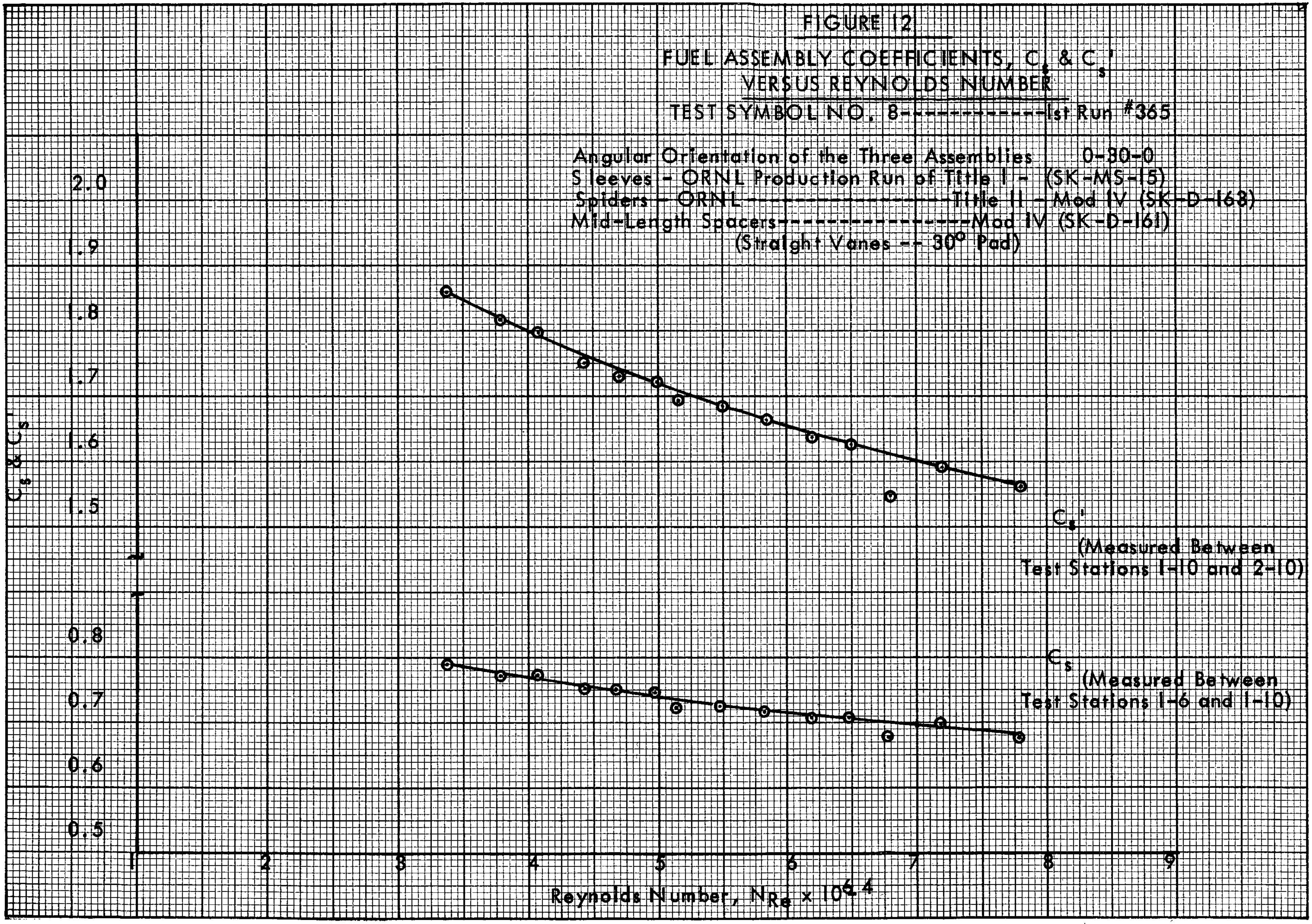


FIGURE 12

FUEL ASSEMBLY COEFFICIENTS, C_s & C_s' VERSUS REYNOLDS NUMBER

TEST SYMBOL NO. 8 ------------ 1st Run #365

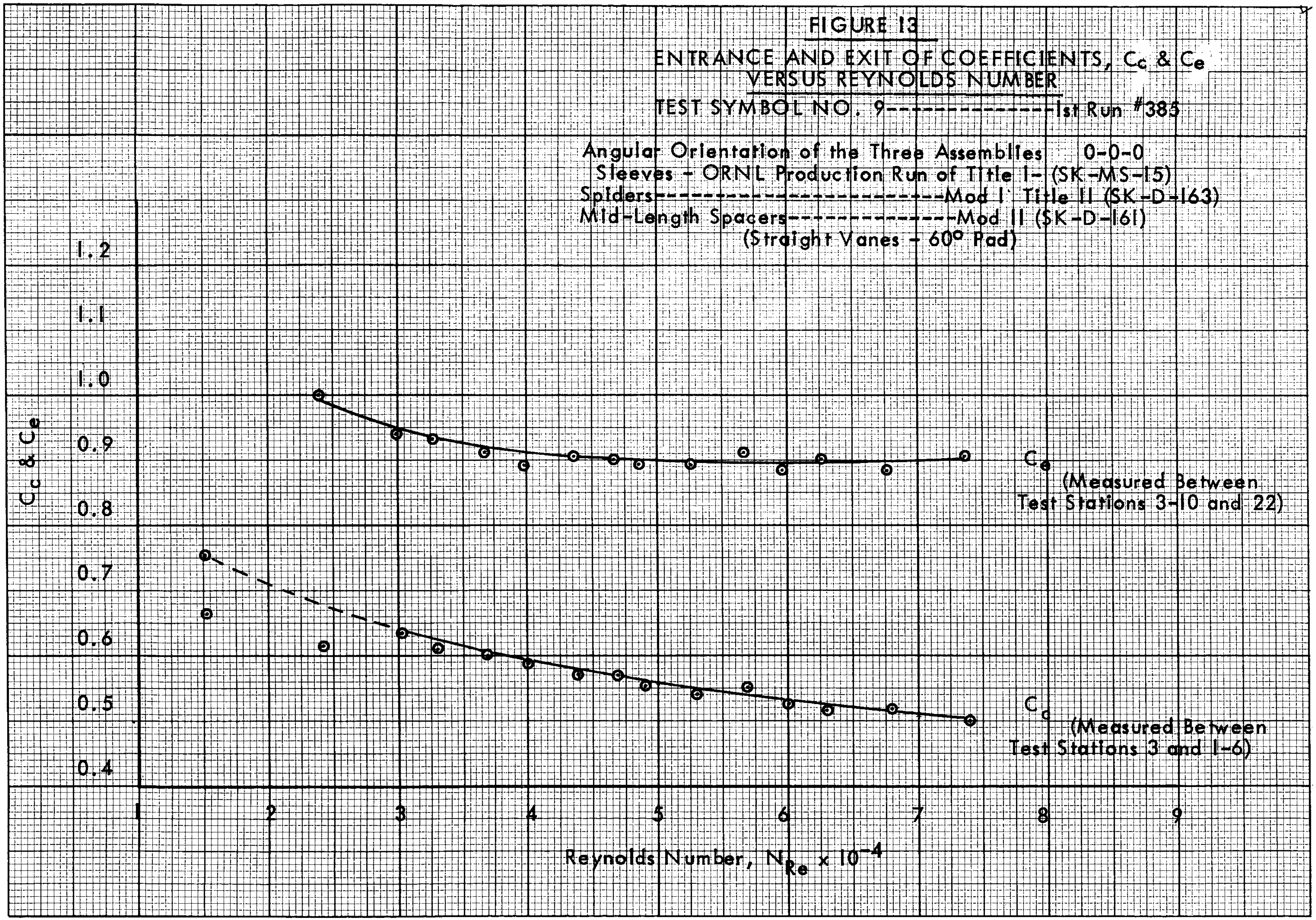


FIGURE 13
ENTRANCE AND EXIT OF COEFFICIENTS, Cc & Ce
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 9--------------1st Run #385
Angular Orientation of the Three Assemblies 0-0-0
Sleeves - ORNL Production Run of Title I- (SK-MS-15)
Spiders-------------------------Mod I Title II (SK-D-163)
Mid-Length Spacers--------------Mod II (SK-D-161)
(Straight Vanes - 60° Pad)
Cc & Ce
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
Ce
(Measured Between
Test Stations 3-10 and 22)
Cc
(Measured Between
Test Stations 3 and 1-6)
1
2
3
4
5
6
7
8
9
Reynolds Number, NRe x 10-4

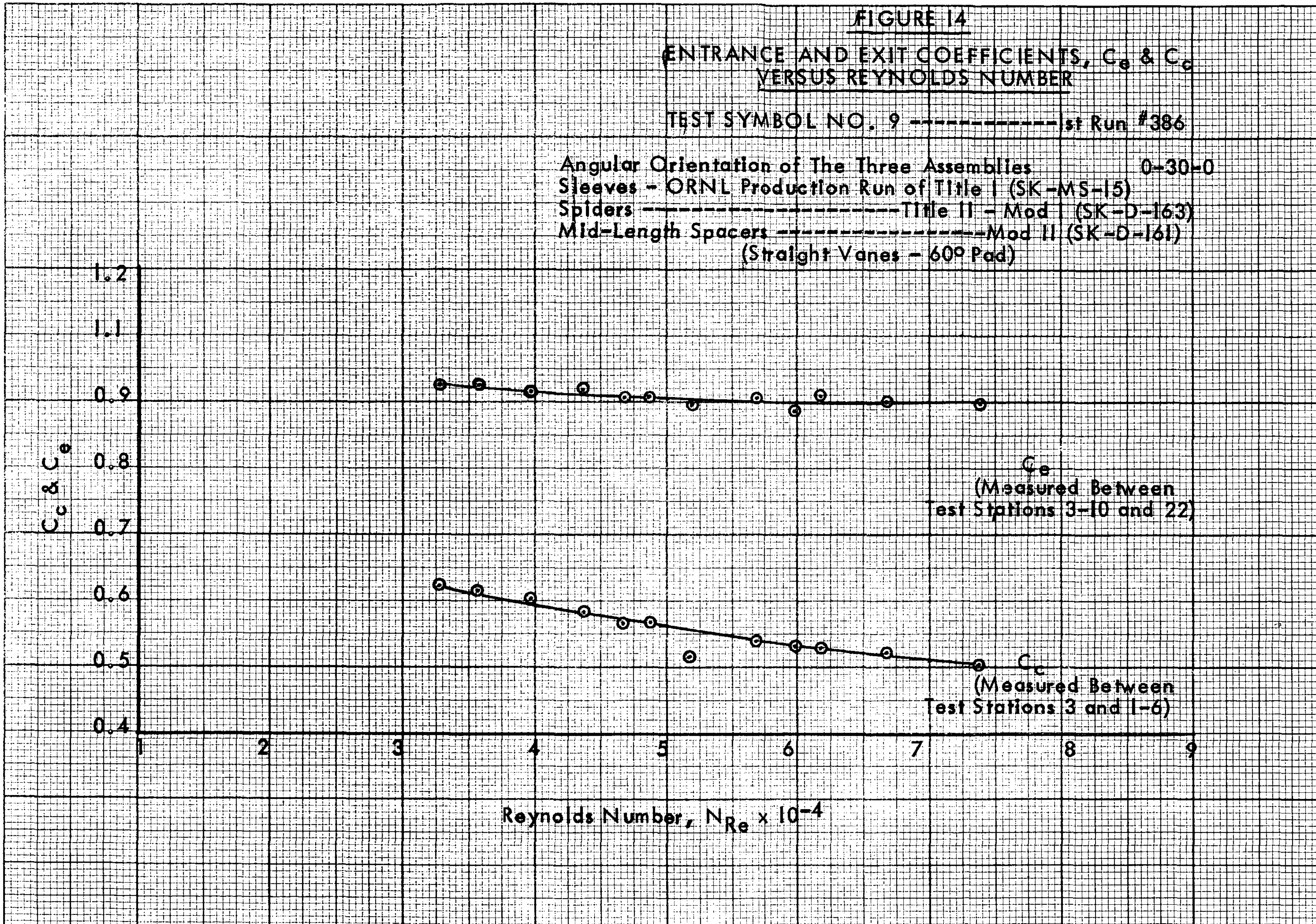


FIGURE 14
ENTRANCE AND EXIT COEFFICIENTS, Ce & Cc
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 9 ------------ st Run #386
Angular Orientation of The Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I (SK-MS-15)
Spiders -------------------- Title II - Mod I (SK-D-163)
Mid-Length Spacers ---------------- Mod II (SK-D-161)
(Straight Vanes - 60° Pad)
Ce
(Measured Between
Test Stations 3-10 and 22)
Cc
(Measured Between
Test Stations 3 and 1-6)
Cc & Ce
1.2
1.1
0.9
0.8
0.7
0.6
0.5
0.4
1
2
3
4
5
6
7
8
9
Reynolds Number, NRe x 10-4

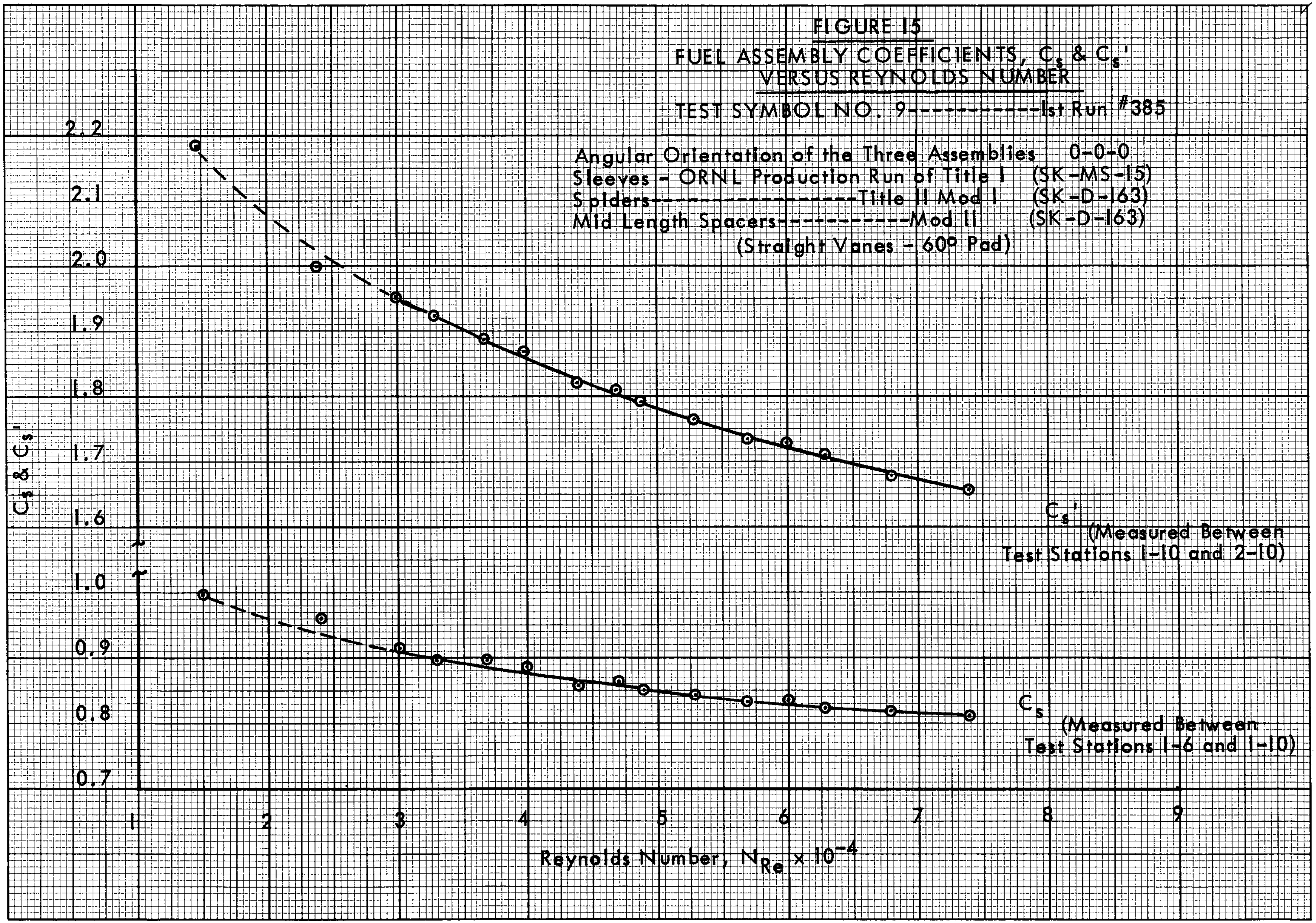


FIGURE 15
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s' VERSUS REYNOLDS NUMBER

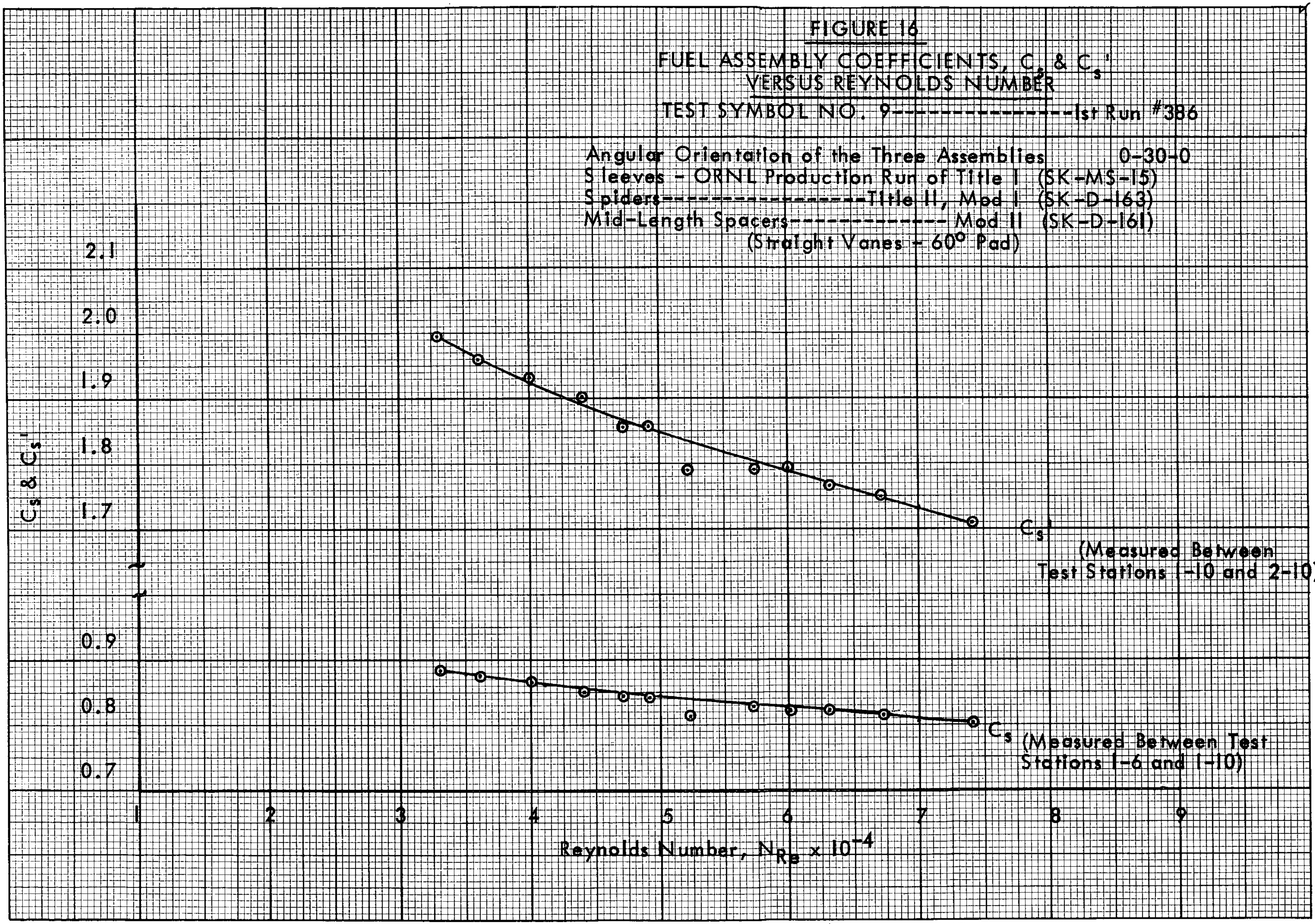


FIGURE 16
FUEL ASSEMBLY COEFFICIENTS, C_s & C_s'
VERSUS REYNOLDS NUMBER
TEST SYMBOL NO. 9 -------------- 1st Run #386
Angular Orientation of the Three Assemblies 0-30-0
Sleeves - ORNL Production Run of Title I (SK-MS-15)
Spiders ---------------- Title II, Mod I (SK-D-163)
Mid-Length Spacers ------------ Mod II (SK-D-161)
(Straight Vanes - 60° Pad)
C_s & C_s'
2.1
2.0
1.9
1.8
1.7
0.9
0.8
0.7
C_s' (Measured Between Test Stations 1-10 and 2-10)
C_s (Measured Between Test Stations 1-6 and 1-10)
1
2
3
4
5
6
7
8
9
Reynolds Number, $N_{Re} \times 10^{-4}$

Report RD-0009

APPENDIX B

I Photographs

II Drawings

<u>TABLE OF CONTENTS</u>

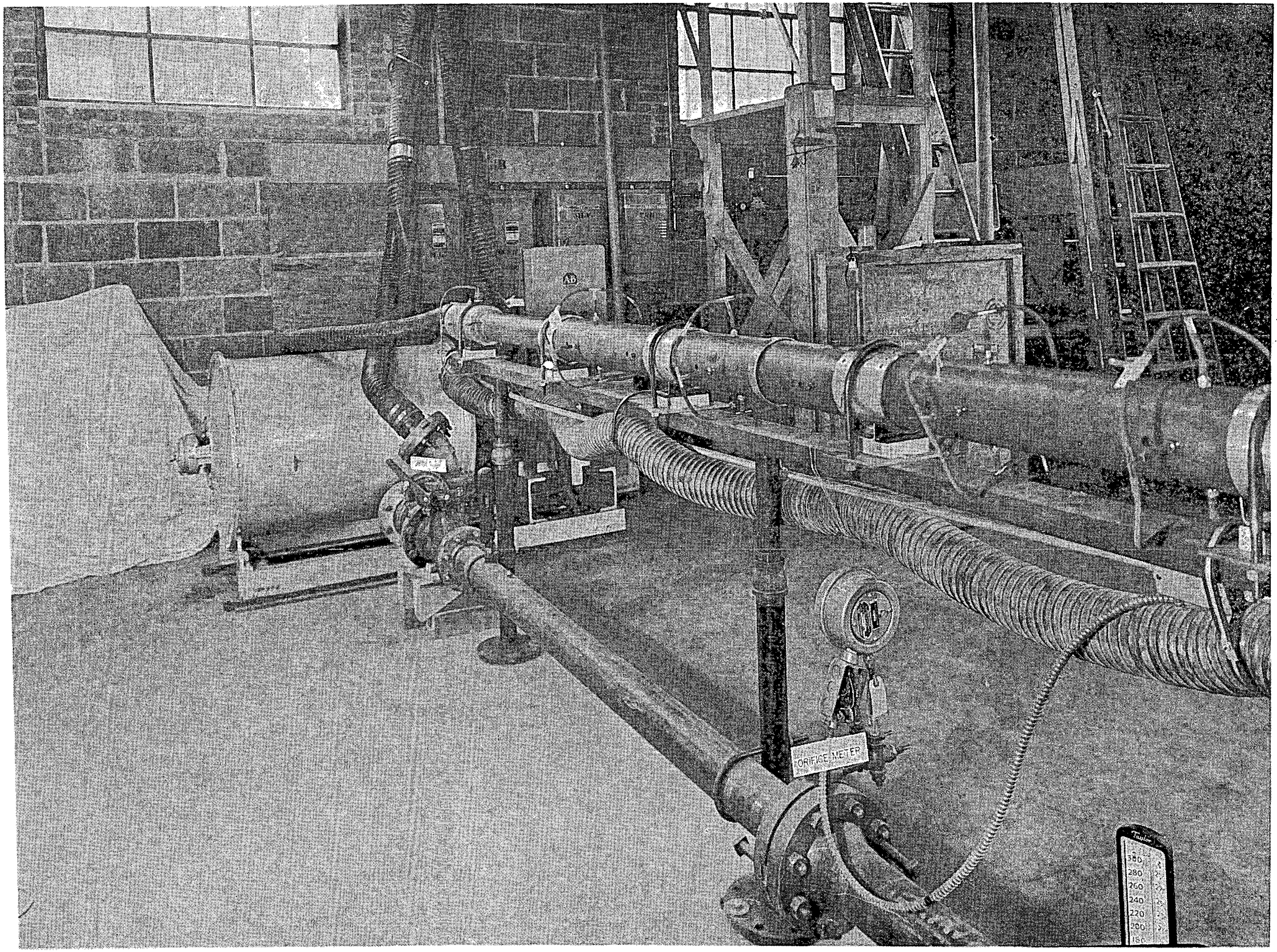


FIGURE I: View Toward Compressor of Orifice Section, Inlet and Outlet Hose, and Pressure Drop Specimens.

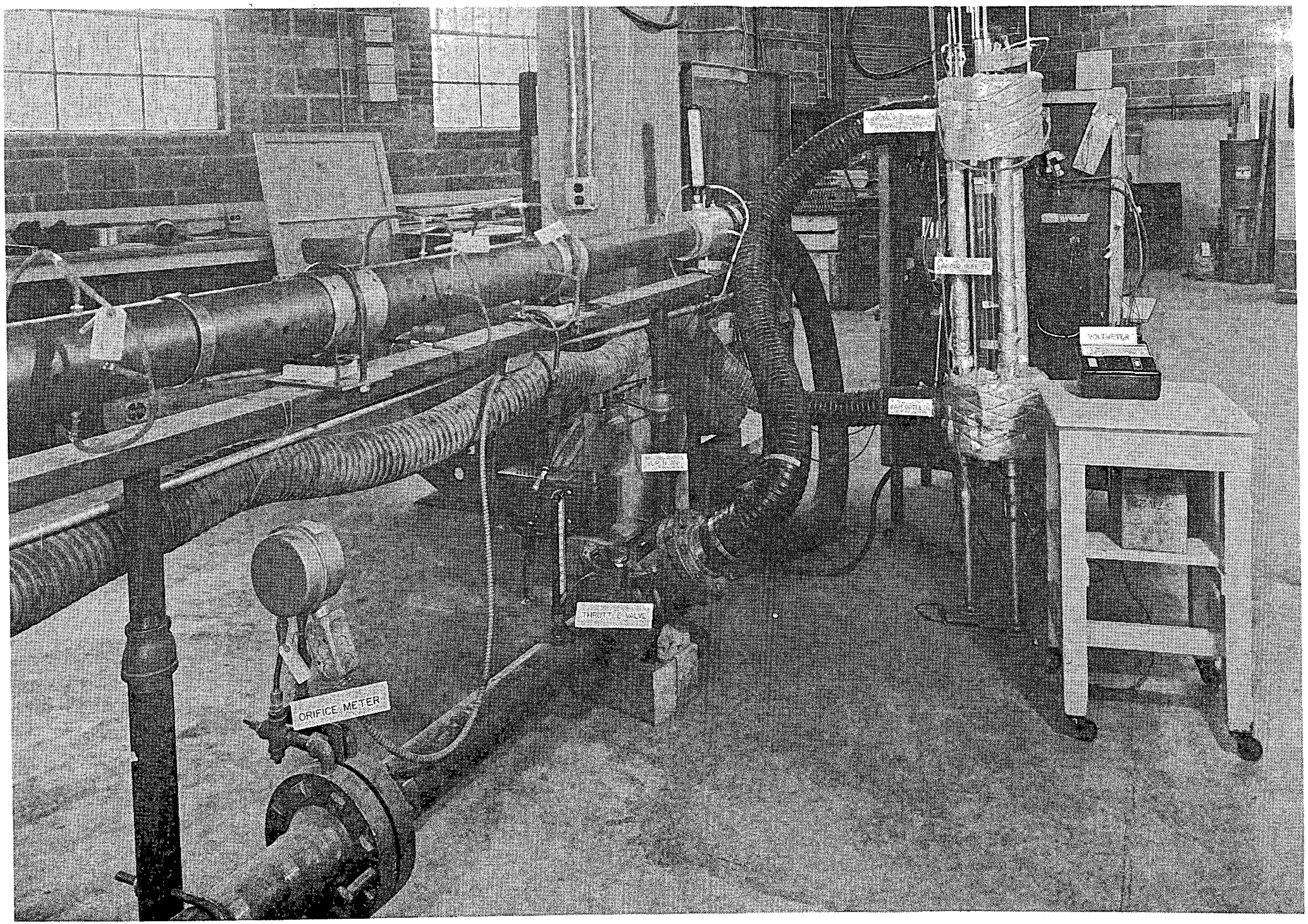


FIGURE 2: View Away from Compressor of Orifice Section, Heat Transfer Rig and Immediate Hose Connections, Throttle Valve, and Pressure Drop Specimens.

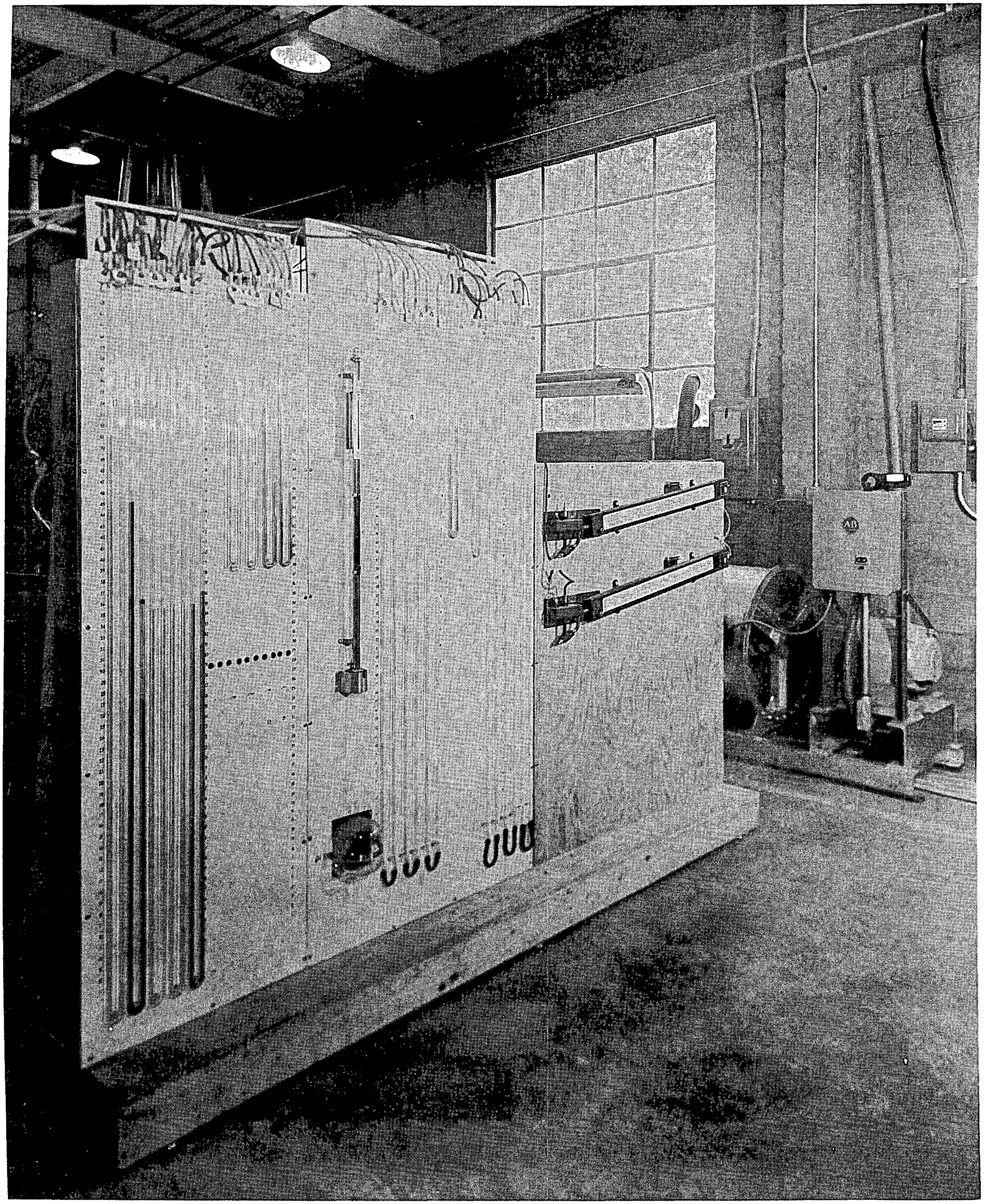


FIGURE 3: MANOMETER BOARD IN OPERATION

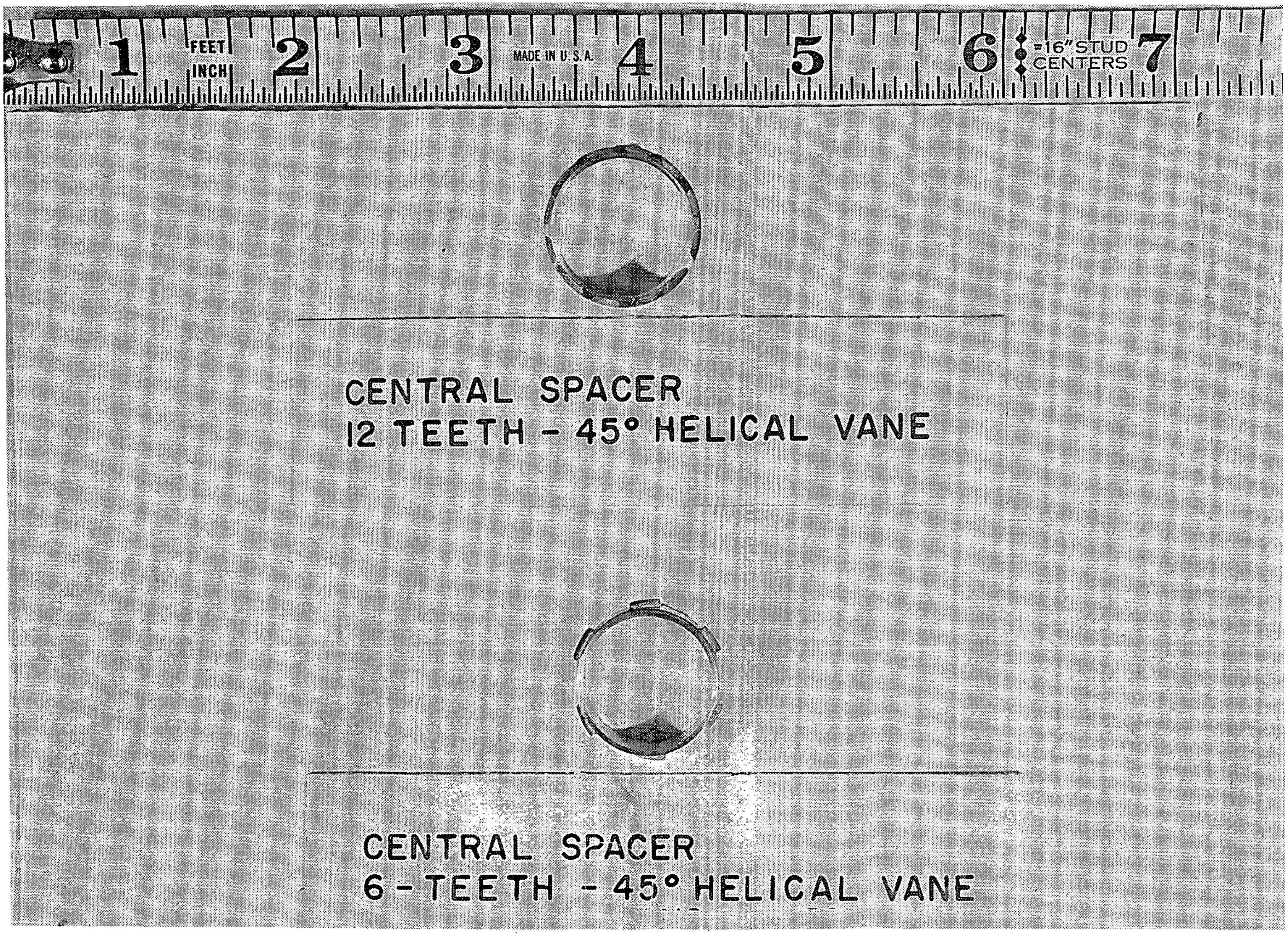


FIGURE 4: Close-up of 12- and 6-Tooth 45-deg Helical-Vaned Spacers.

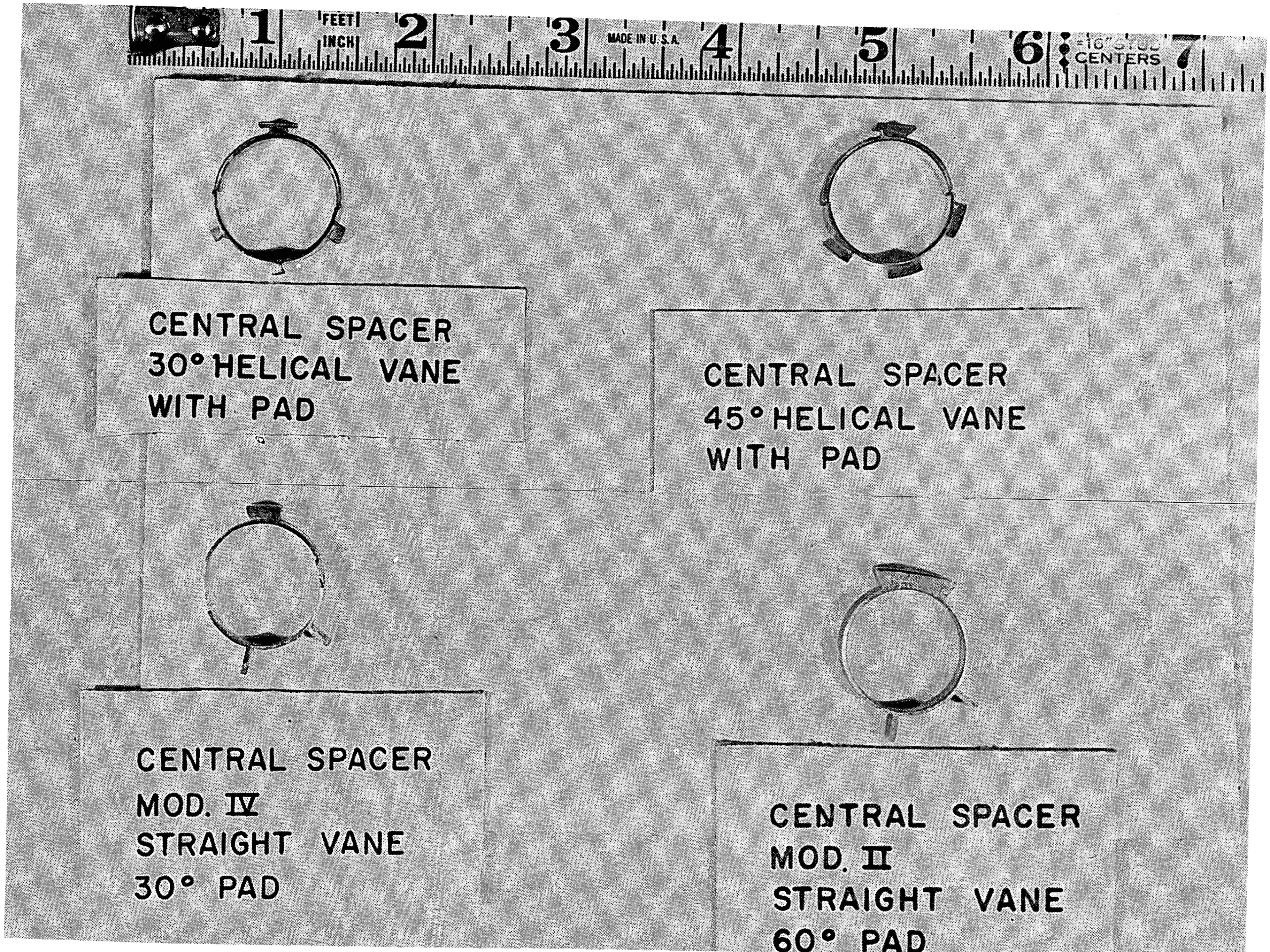


FIGURE 5: CLOSE UP OF CENTRAL SPACERS- 30° HELICAL VANE WITH PAD- MOD. I, 60° PAD, MOD. II, STRAIGHT VANE- 30° PAD, MOD. IV.

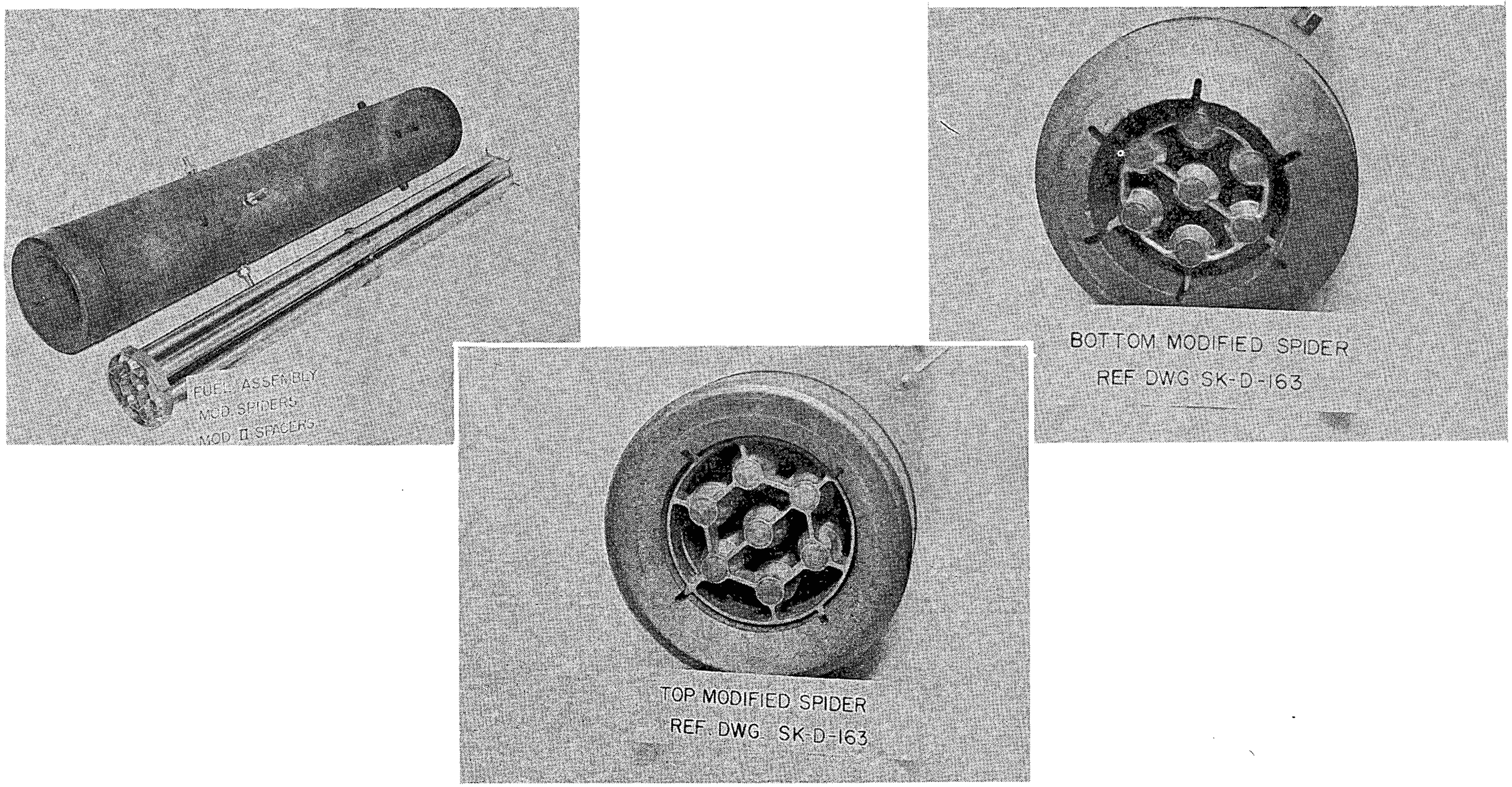
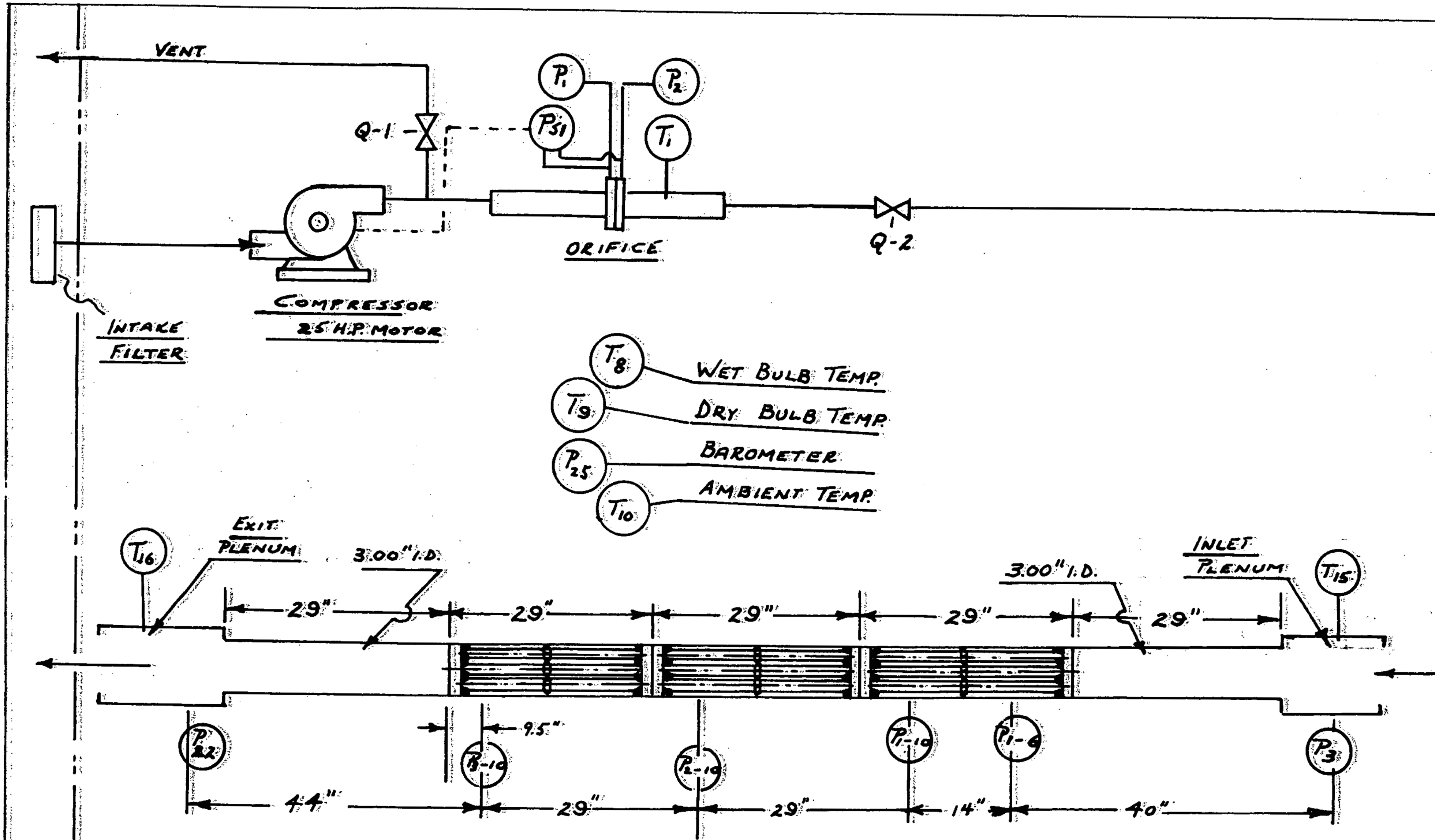


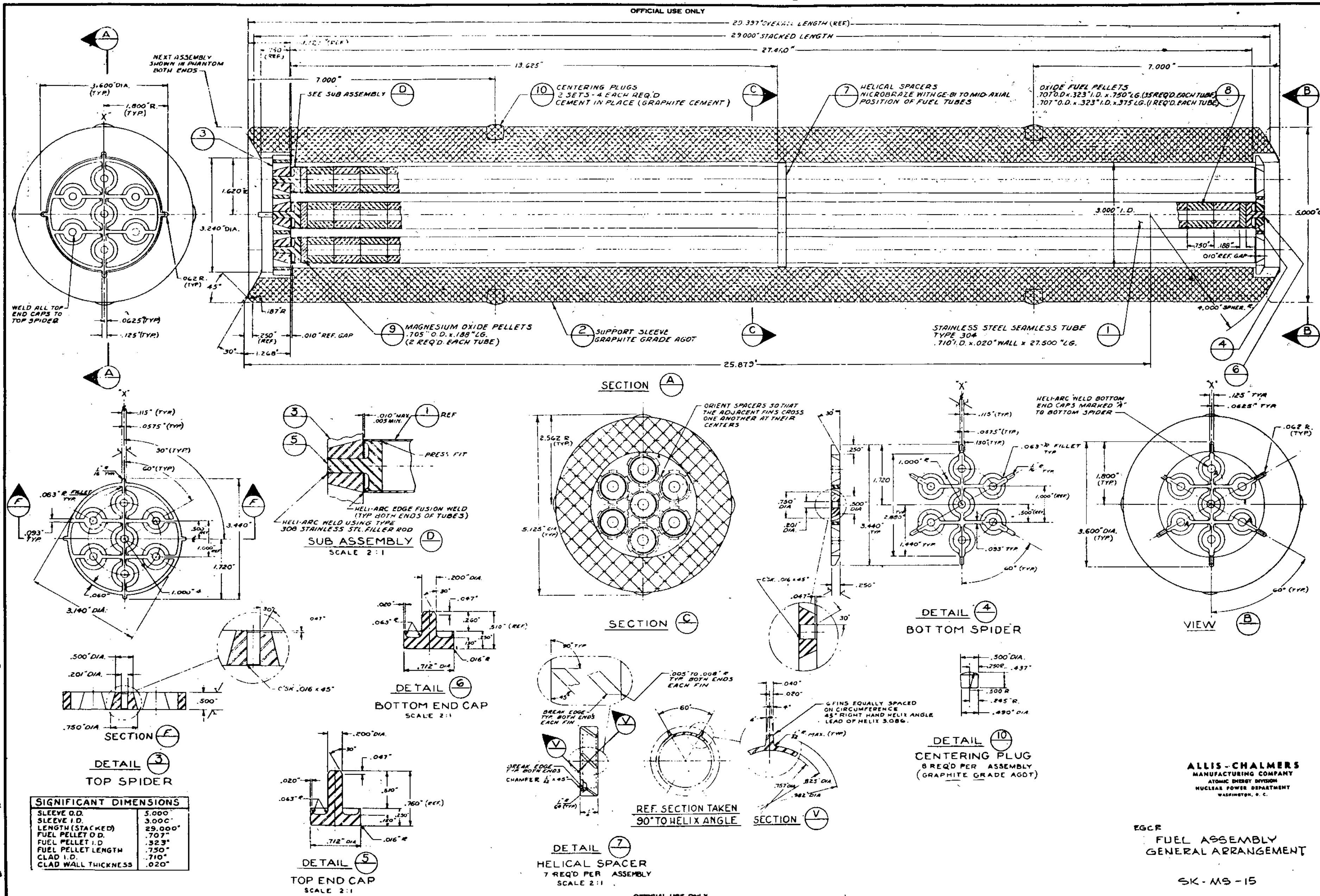
FIGURE 6: PILOT PRODUCTION RUN-TITLE I GRAPHITE SLEEVE AND 7 ROD CLUSTER SUB-ASSEMBLY WITH MOD. I SPIDERS AND MOD. II SPACERS



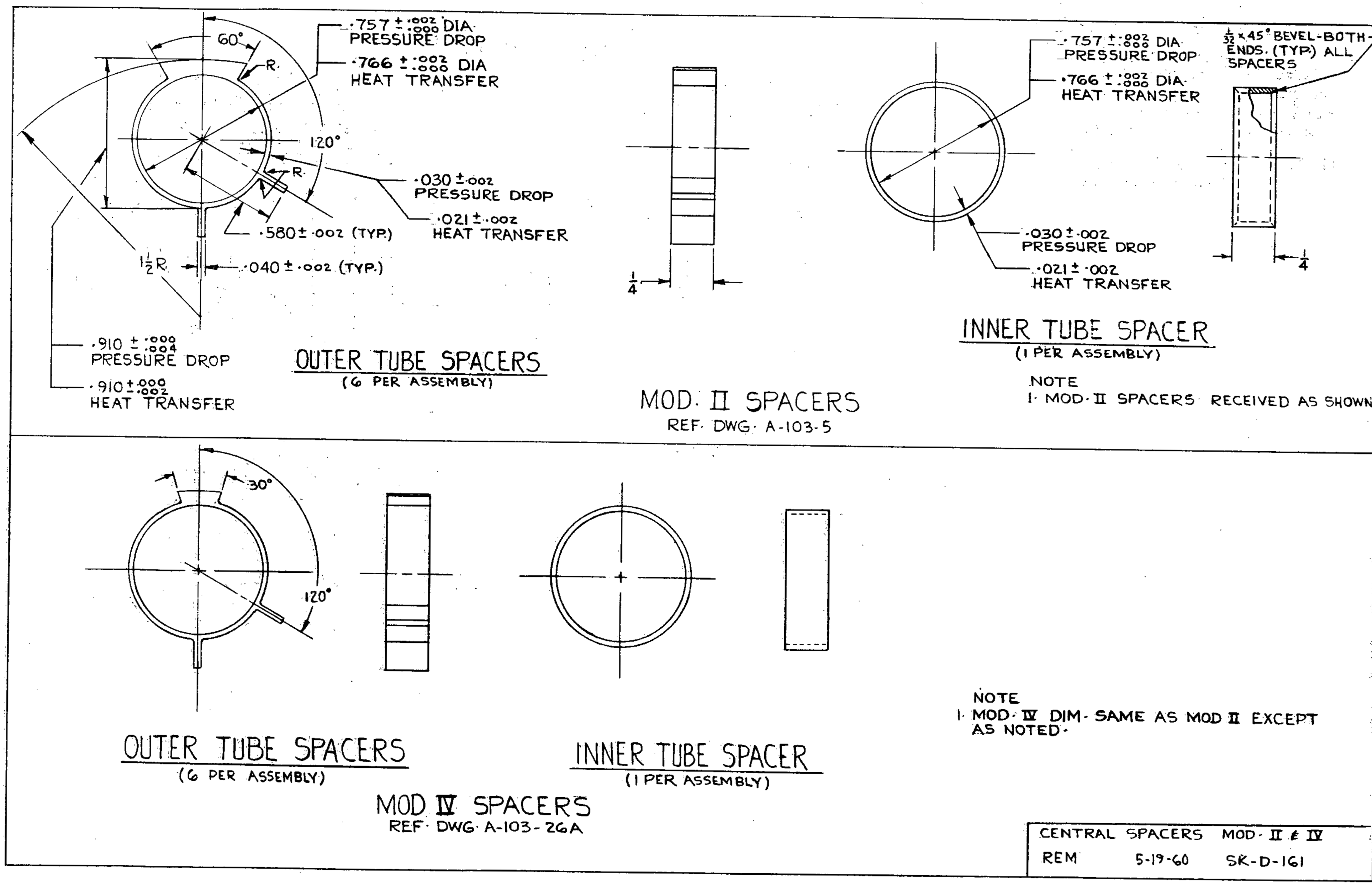
SCHEMATIC
PRESSURE DROP
FLOW SHEET

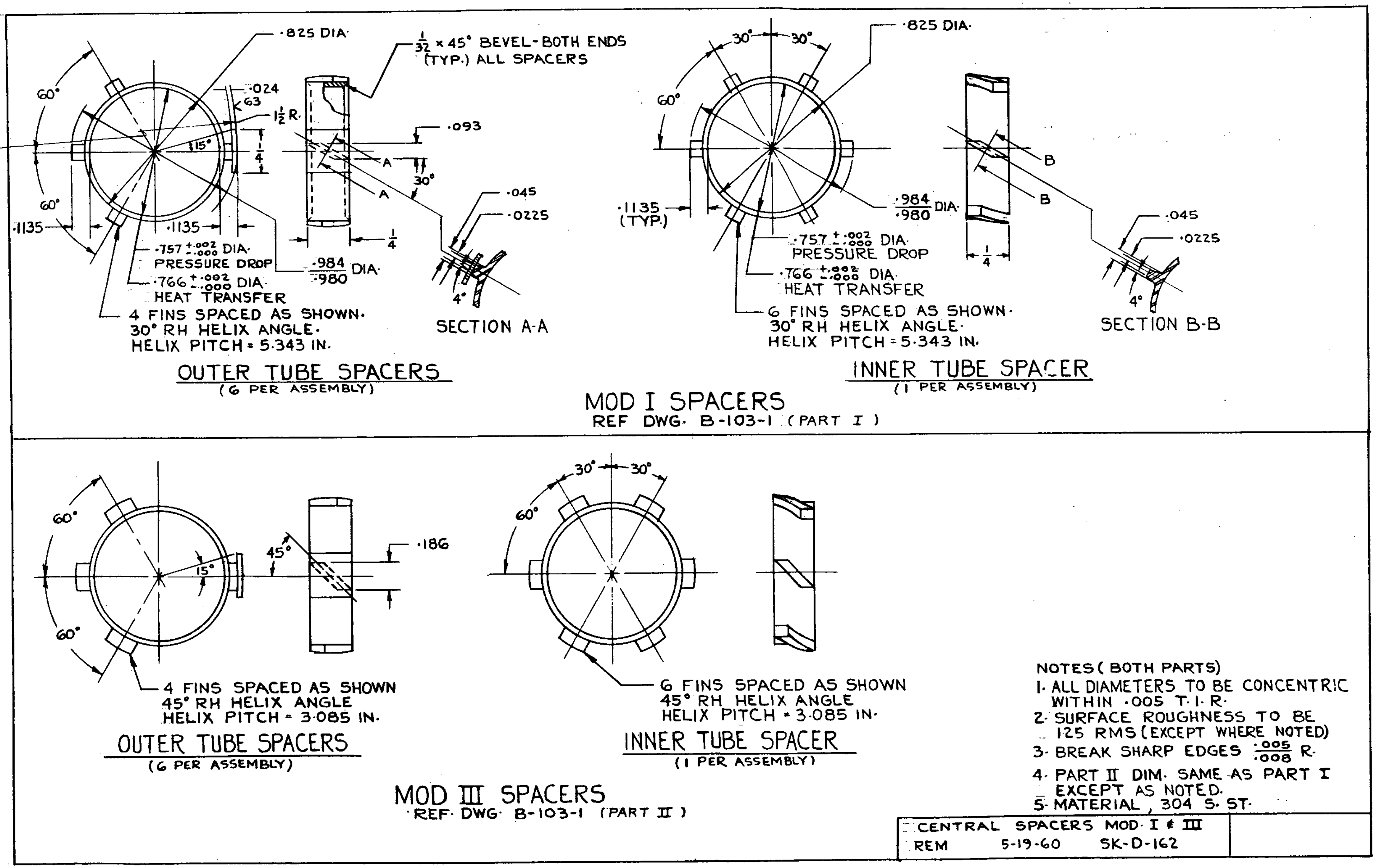
8-5-60 AM

SK-D-168

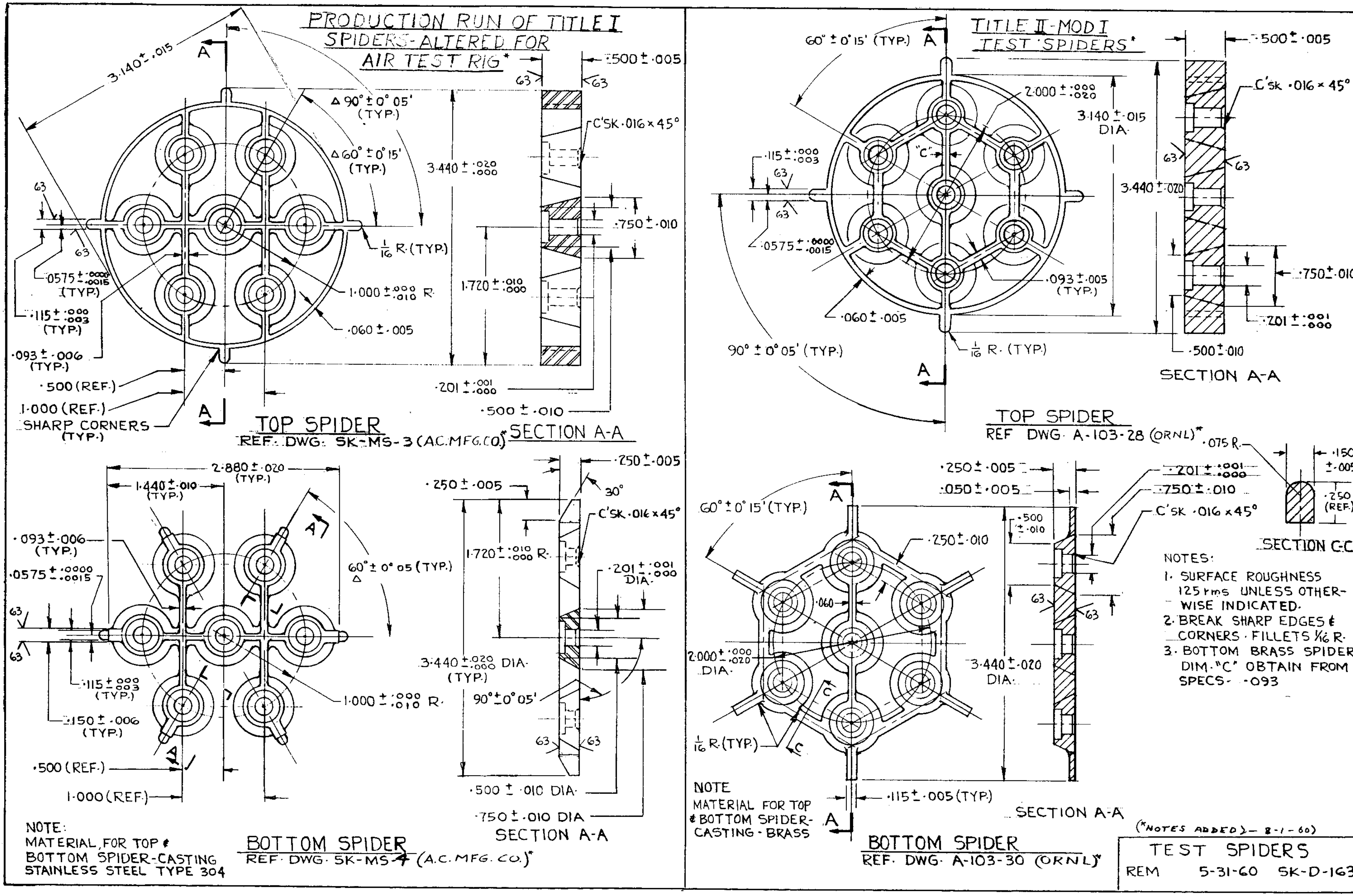


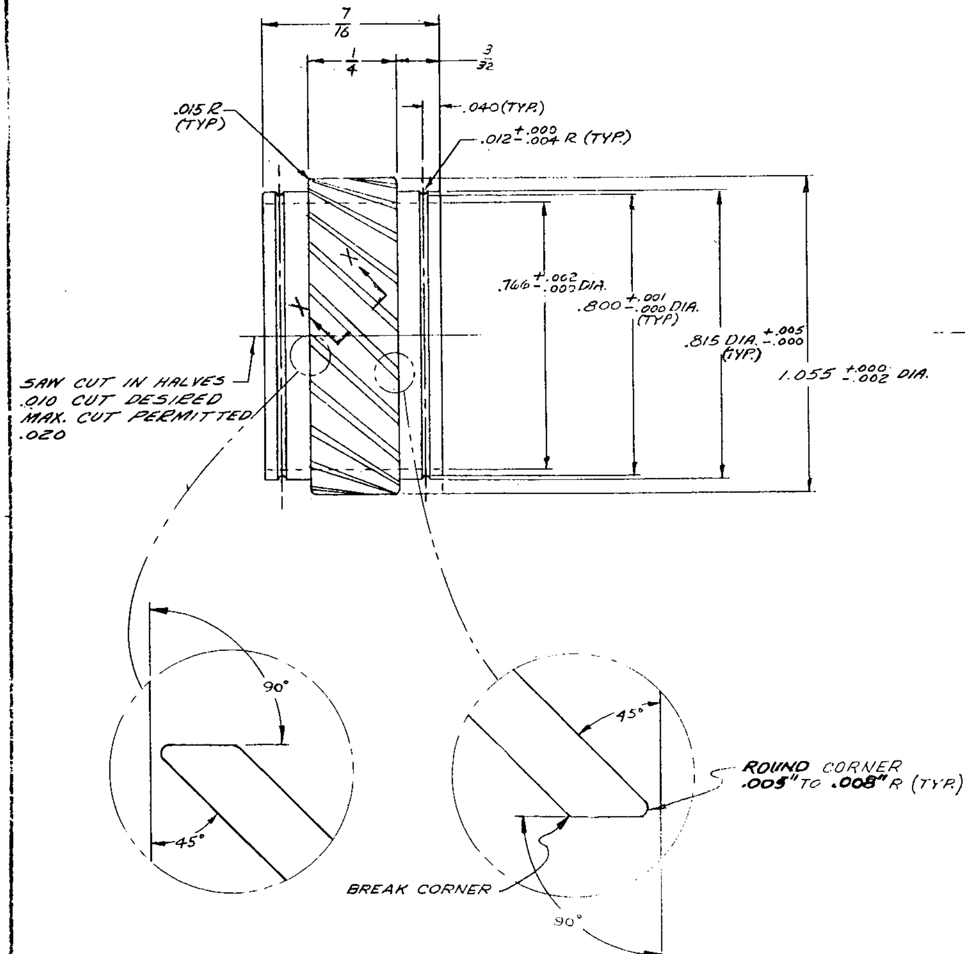
SIGNIFICANT DIMENSIONS	
SLEEVE O.D.	5.000"
SLEEVE I.D.	3.000"
LENGTH (STACKED)	29.000"
FUEL PELLET O.D.	.707"
FUEL PELLET I.D.	.323"
FUEL PELLET LENGTH	.750"
CLAD I.D.	.710"
CLAD WALL THICKNESS	.020"

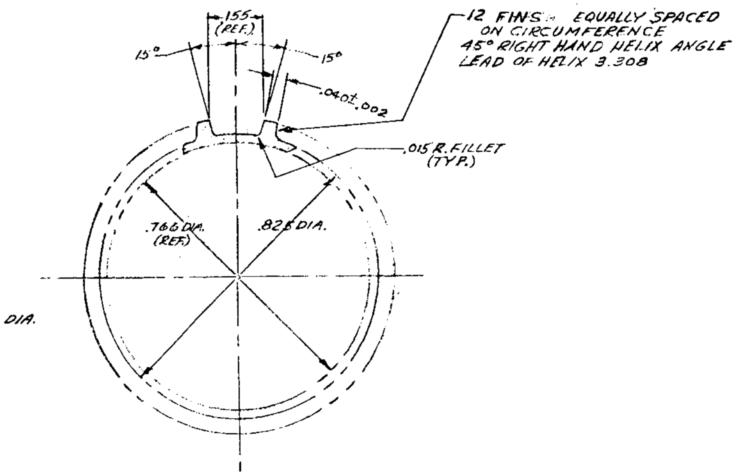

.757 ± .002/.000 DIA. PRESSURE DROP
.766 ± .002/.000 DIA HEAT TRANSFER
60°
R
120°
.030 ± .002 PRESSURE DROP
.021 ± .002 HEAT TRANSFER
.580 ± .002 (TYP.)
1½R
.040 ± .002 (TYP.)
.910 ± .000/.004 PRESSURE DROP
.910 ± .000/.002 HEAT TRANSFER
OUTER TUBE SPACERS
(6 PER ASSEMBLY)
¼
MOD. II SPACERS
REF. DWG. A-103-5
.757 ± .002/.000 DIA. PRESSURE DROP
.766 ± .002/.000 DIA. HEAT TRANSFER
1/32 x 45° BEVEL-BOTH ENDS. (TYP.) ALL SPACERS
.030 ± .002 PRESSURE DROP
.021 ± .002 HEAT TRANSFER
¼
INNER TUBE SPACER
(1 PER ASSEMBLY)
NOTE
1. MOD. II SPACERS RECEIVED AS SHOWN
30°
120°
OUTER TUBE SPACERS
(6 PER ASSEMBLY)
INNER TUBE SPACER
(1 PER ASSEMBLY)
MOD IV SPACERS
REF. DWG. A-103-26A
NOTE
1. MOD. IV DIM. SAME AS MOD II EXCEPT AS NOTED.
CENTRAL SPACERS MOD. II & IV
REM 5-19-60 SK-D-161



.825 DIA.
1/32 × 45° BEVEL-BOTH ENDS (TYP.) ALL SPACERS
.024
63
1 1/2 R.
15°
1/4
.093
A
30°
A
.045
.0225
4°
60°
60°
.1135
.1135
.757 +.002 -.000 DIA. PRESSURE DROP
.766 +.002 -.000 DIA. HEAT TRANSFER
.984 / .980 DIA.
1/4
4 FINS SPACED AS SHOWN. 30° RH HELIX ANGLE. HELIX PITCH = 5.343 IN.
SECTION A-A
OUTER TUBE SPACERS
(6 PER ASSEMBLY)
30°
30°
.825 DIA.
60°
B
B
.984 / .980 DIA.
.1135 (TYP.)
.757 +.002 -.000 DIA. PRESSURE DROP
.766 +.002 -.000 DIA. HEAT TRANSFER
1/4
.045
.0225
4°
6 FINS SPACED AS SHOWN. 30° RH HELIX ANGLE. HELIX PITCH = 5.343 IN.
SECTION B-B
INNER TUBE SPACER
(1 PER ASSEMBLY)
MOD I SPACERS
REF DWG. B-103-1 (PART I)
60°
60°
15°
45°
.186
4 FINS SPACED AS SHOWN 45° RH HELIX ANGLE HELIX PITCH = 3.085 IN.
OUTER TUBE SPACERS
(6 PER ASSEMBLY)
30°
30°
60°
6 FINS SPACED AS SHOWN 45° RH HELIX ANGLE HELIX PITCH = 3.085 IN.
INNER TUBE SPACER
(1 PER ASSEMBLY)
MOD III SPACERS
REF. DWG. B-103-1 (PART II)
NOTES (BOTH PARTS)
1. ALL DIAMETERS TO BE CONCENTRIC WITHIN .005 T.I.R.
2. SURFACE ROUGHNESS TO BE 125 RMS (EXCEPT WHERE NOTED)
3. BREAK SHARP EDGES .005/.008 R.
4. PART II DIM. SAME AS PART I EXCEPT AS NOTED.
5. MATERIAL, 304 S. ST.
CENTRAL SPACERS MOD. I & III
REM 5-19-60 SK-D-162


PRODUCTION RUN OF TITLE I SPIDERS-ALTERED FOR AIR TEST RIG*
3·140 ± ·015
Δ 90° ± 0° 05' (TYP.)
Δ 60° ± 0° 15' (TYP.)
3·440 +·020 -·000
C'SK ·016 × 45°
·500 ± ·005
·750 ± ·010
1/16 R. (TYP.)
1·000 +·000 -·010 R.
1·720 +·010 -·000
·060 ± ·005
·0575 +·0000 -·0015 (TYP.)
·115 +·000 -·003 (TYP.)
·093 ± ·006 (TYP.)
·500 (REF.)
1·000 (REF.)
SHARP CORNERS (TYP.)
·201 +·001 -·000
·500 ± ·010
TOP SPIDER
REF. DWG. SK-MS-3 (A.C. MFG. CO.)*
SECTION A-A
2·880 ± ·020 (TYP.)
1·440 ± ·010 (TYP.)
·250 ± ·005
30°
60° ± 0° 05 (TYP.)
1·720 +·010 -·000 R.
·201 +·001 -·000 DIA.
·150 ± ·006 (TYP.)
3·440 +·020 -·000 DIA. (TYP.)
90° ± 0° 05'
·500 ± ·010 DIA.
·750 ± ·010 DIA.
NOTE: MATERIAL FOR TOP & BOTTOM SPIDER-CASTING STAINLESS STEEL TYPE 304
BOTTOM SPIDER
REF. DWG. SK-MS-4 (A.C. MFG. CO.)*
TITLE II-MOD I TEST SPIDERS*
60° ± 0° 15' (TYP.)
2·000 +·000 -·020
3·140 ± ·015 DIA.
C'SK ·016 × 45°
·115 +·000 -·003
3·440 ± ·020
·0575 +·0000 -·0015
·093 ± ·005 (TYP.)
·060 ± ·005
90° ± 0° 05' (TYP.)
1/16 R. (TYP.)
·750 ± ·010
·201 +·001 -·000
·500 ± ·010
SECTION A-A
TOP SPIDER
REF DWG A-103-28 (ORNL)*
·075 R.
·150 ± ·005
·250 (REF.)
SECTION C-C
·250 ± ·005
·050 ± ·005
·500 ± ·010
·250 ± ·010
·060
2·000 +·000 -·020 DIA.
3·440 ± ·020 DIA.
1/16 R. (TYP.)
·115 ± ·005 (TYP.)
SECTION A-A
NOTES:
1. SURFACE ROUGHNESS 125 rms UNLESS OTHERWISE INDICATED.
2. BREAK SHARP EDGES & CORNERS. FILLETS 1/16 R.
3. BOTTOM BRASS SPIDER DIM. "C" OBTAIN FROM SPECS. ·093
NOTE: MATERIAL FOR TOP & BOTTOM SPIDER-CASTING-BRASS
BOTTOM SPIDER
REF. DWG. A-103-30 (ORNL)*
(*NOTES ADDED) – 8-1-60)
TEST SPIDERS
REM 5-31-60 SK-D-163





NOTES

1. ALL DIAMETERS TO BE CONCENTRIC WITHIN .001 T.I.R. EXCEPT .825 DIAMETERS WHICH CAN BE WITHIN .005 T.I.R.
2. ITEM 1 AS SHOWN
   ITEM 2
   (1) REMOVE EVERY OTHER FIN 6 FINS REQUIRED.
   (2) CHAMFER FIN EDGES AS SHOWN IN DETAIL A.

2

SYM.	DESCRIPTION	DATE	BY	CK
A	ADDED DETAIL A ADDED NOTE 2	8-27-59	J.B.	

REVISIONS

MATERIAL: STAINLESS STL #304

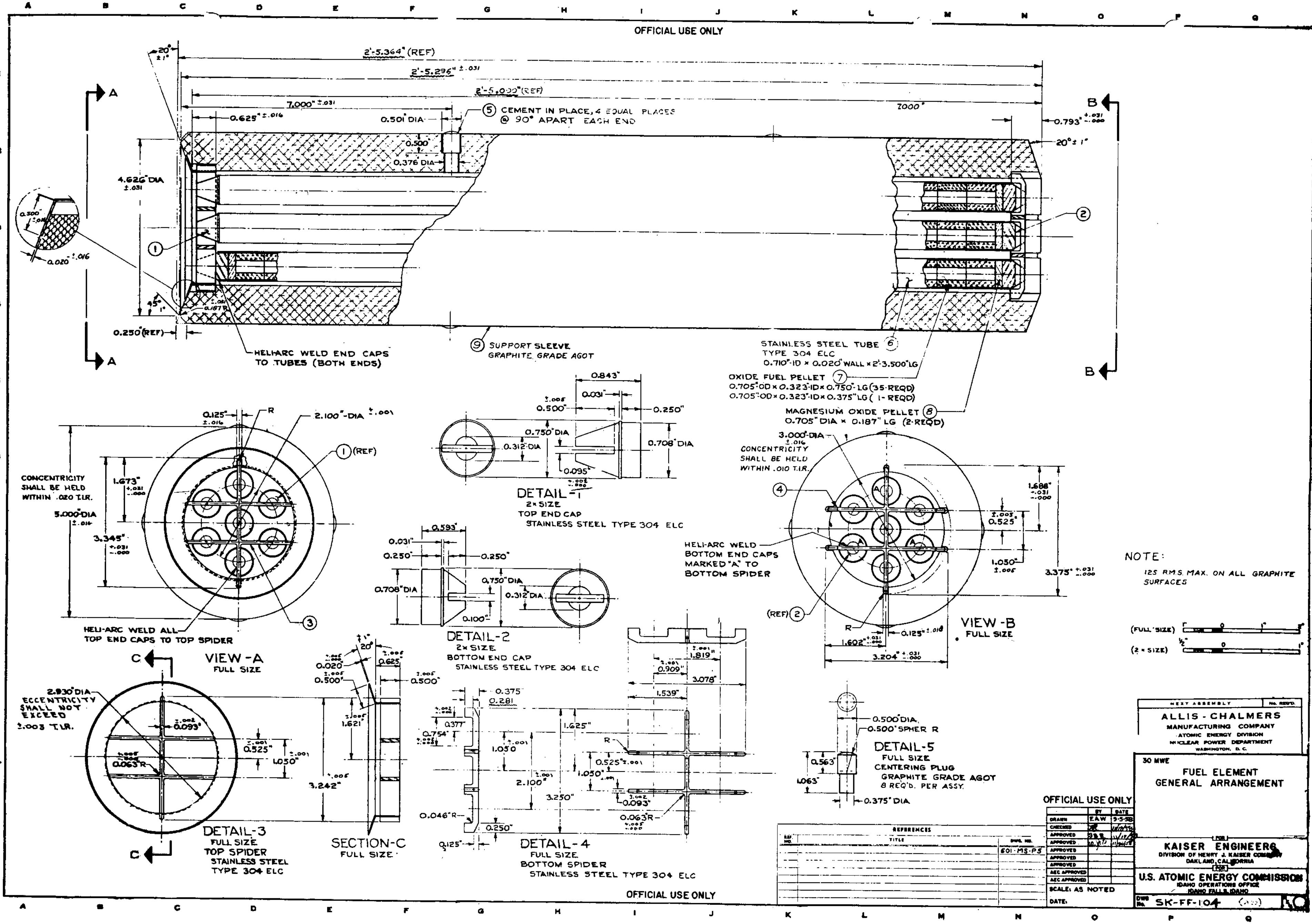
NEXT ASSEMBLY | No. REQ'D.

ALLIS - CHALMERS
MANUFACTURING COMPANY
ATOMIC ENERGY DIVISION
NUCLEAR POWER DEPARTMENT
WASHINGTON, D. C.

TITLE: CENTRAL HELICAL SPACER - DESIGN IV 2.1" B.C.; 2.2/1 RATIO; 3.125" BORE FOR HEAT TRANSFER TEST ONLY

		DATE		
BY	W.T.W.	6-17-59	APP. QWO	
	EAW	6-18-59	APP.	
	HCL	6-18-59		

SK-FF-136 | REV A



OFFICIAL USE ONLY
CEMENT IN PLACE, 4 EQUAL PLACES @ 90° APART EACH END
HELI-ARC WELD END CAPS TO TUBES (BOTH ENDS)
SUPPORT SLEEVE GRAPHITE GRADE AGOT
STAINLESS STEEL TUBE TYPE 304 ELC 0.710" ID × 0.020" WALL × 2'-3.500" LG
OXIDE FUEL PELLET 0.705" OD × 0.323" ID × 0.750" LG (35 REQD) 0.705" OD × 0.323" ID × 0.375" LG (1 REQD)
MAGNESIUM OXIDE PELLET 0.705" DIA × 0.187" LG (2 REQD)
CONCENTRICITY SHALL BE HELD WITHIN .020 T.I.R.
HELI-ARC WELD ALL TOP END CAPS TO TOP SPIDER
VIEW-A FULL SIZE
DETAIL-1 2× SIZE TOP END CAP STAINLESS STEEL TYPE 304 ELC
DETAIL-2 2× SIZE BOTTOM END CAP STAINLESS STEEL TYPE 304 ELC
CONCENTRICITY SHALL BE HELD WITHIN .010 T.I.R.
HELI-ARC WELD BOTTOM END CAPS MARKED "A" TO BOTTOM SPIDER
VIEW-B FULL SIZE
NOTE: 125 RMS MAX. ON ALL GRAPHITE SURFACES
ECCENTRICITY SHALL NOT EXCEED ±.003 T.I.R.
DETAIL-3 FULL SIZE TOP SPIDER STAINLESS STEEL TYPE 304 ELC
SECTION-C FULL SIZE
DETAIL-4 FULL SIZE BOTTOM SPIDER STAINLESS STEEL TYPE 304 ELC
DETAIL-5 FULL SIZE CENTERING PLUG GRAPHITE GRADE AGOT 8 REQ'D. PER ASSY.
OFFICIAL USE ONLY
REFERENCES
501-MS-PS
DRAWN EAW 9-5-58
SCALE: AS NOTED
ALLIS-CHALMERS MANUFACTURING COMPANY ATOMIC ENERGY DIVISION NUCLEAR POWER DEPARTMENT WASHINGTON, D. C.
30 MWE
FUEL ELEMENT GENERAL ARRANGEMENT
FOR KAISER ENGINEERS DIVISION OF HENRY J. KAISER COMPANY OAKLAND, CALIFORNIA
FOR U.S. ATOMIC ENERGY COMMISSION IDAHO OPERATIONS OFFICE IDAHO FALLS, IDAHO
DWG No. SK-FF-104