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INDENTED NOSE SHAPE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of tests was performed in the Longshot Facility of the Von Karman Institute for Fluid Dynamics (VKI) in Rhode-St. Genese, Belgium, in support of USAF Grant AFOSR 78-3474. This post test report is a summary of 16 tests conducted in the Longshot Facility during the periods of 5-16 June 1978 (Phase I) and 18-29 September 1978 (Phase II). The complete test results are included in the VKI post test report. The purpose of these test was to measure local pressure and heat transfer distributions on a concave body configuration over a range of Mach number and Reynolds number conditions. Both small and large over

DD FORM 1 JAN 73 1473 404 788 UNCLASSIFIED LB surface roughness body data were obtained at zero and three degrees angle of attack. High speed cine Schlieren Photographs of the model bow shock structure and dynamics were obtained.

Hypersonic Heat Transfer Test Program in the VKI Longshot Facility

Test Summary Report

V. DiCristina

19 January 1979

AVSD-0028-79-CR

Contract No. F49620-78-C-0029

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Department of the Air Force
Air Force Office of Scientific Research (AFSC)
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CONTENTS

1.0 INTRODUCTION AND SUMMARY

A series of tests were performed in the Longshot Facility of the Von Karman Institute for Fluid Dynamics (VKI) in Rhode-St. Genese, Belgium in support of USAF Great AFOSR 78-3474 This post test report is a summary of sixteen tests conducted in the Longshot Facility during the periods of 5-16 June 1978 (Phase I) and 18-29 September 1978 (Phase II). The complete test results are included in the VKI post test report.

The purpose of these tests was to measure local pressure and heat transfer distributions on a concave body configuration over a range of Mach number and Reynold number conditions. Both small and large surface roughness body data were obtained at zero and three degrees angle of attack.

The calorimeter instrumentation was calibrated at VKI during the period 24-28 April 1978. The instrumented test model was delivered to the VKI facility for the first series of tests on 5 June 1978. All data measurements were made as planned including high speed cine schlieren photographs of the model bow shock structure and dynamics.

The results of the first eight tests are included here, the complete data set including the large roughness body data will be issued as part of the final VKI test report.

2.0 DISCUSSION

2.1 TEST FACILITY

The VKI Longshot facility was used for this program. Longshot differs from a conventional gun tunnel in that a heavy piston is used to compress the nitrogen test gas to very high pressure and temperatures. The test gas is then trapped in a reservoir at peak conditions by the closing of a system of check values. The flow conditions decay monotonically during 20 milliseconds running time as the nitrogen trapped in the reservoir flows through the 6^{o} half angle conical nozzle into the pre-evacuated open jet test chamber. The maximum supply conditions used in these tests are approximately 60,000 lb/in^2 at $1900^{o}K$ to $2350^{o}K$. These conditions provide unit Reynolds numbers of 8.5×10^6 per foot at a Mach number of 16 and 3.5×10^6 at $M = 20$.

2.2 MODEL DESIGN

The test model design was a concave body configuration shown in Figure 1. This model configuration was designated as model M. The model was fabricated from 303 stainless steel having a wall thickness of approximately 0.2 inches. The first series of tests (runs 1-8) were performed with a small 5 mil roughness over the model surface. The rough surface was achieved by sand blasting. The second series of tests (runs 9-16) were performed with large 65 mil roughness elements over the model surface. The large roughness was created by bonding aluminum spheroid particles onto a sprayed adhesive and coated with a sprayed acrylic. The local calorimeter and pressure port areas did not contain roughness elements.

2.3 INSTRUMENTATION

The test model was instrumental with both pressure and heat flux gages. The gage locations are shown in Figure 1. The test model contains eleven heat flux gages and nine pressure taps. Only eight pressure measurement channels were available at the test facility. The last pressure tape on the concave surface was not connected. PCB model 112A21 high resolution pressure tranduces were connected through short flexible tubes to the surface taps.

The heat transfer gages are smooth calorimeter discs fabricated from .004 inch high conductivity copper stock. A 1 mil wire chromel alumel thermocouple is welded to the copper disc which is bonded to an insulating holder. Twenty calorimeters were fabricated and calibrated at the VKI facility. Table I lists the measured calibration constant (C_T) for each gage. The values shown are the coverage of two measurements. The actual measured disc thickness (X_A) is also shown compared with the calculated effective disc thickness (XE). The data was derived from the following relationships:

$$C_T = \frac{\dot{Q}_C}{\Delta E/\Delta t}$$

$$X_E = \frac{C_T}{\rho\, C_P} = .00523\ C_T$$

where: $\dot{Q}_C$ = calibration heat flux
$\Delta E/\Delta t$ = thermocouple EMF output
X_E = Effective gage thickness
C_T = Calibration constant
ρ = Density, copper
C_P = Specific heat, copper

The variations in X_E are due to the thermocouple weld joints.

2.4 TEST MATRIX

The matrix for the sixteen runs made in the Phase I and II test series is shown in Table II. The small surface roughness model is designated as MR1 and the large roughness model as MR2. The pressure and heat transfer gages were intermixed on the model surface as shown in Figure 1. In order to obtain a complete distribution of pressure and heat transfer measurements for the angle of attack cases both a positive and negative incidence angle was run for the same test conditions as shown in Table II.

2.5 TEST RESULTS

The data measurements for each run included surface pressure, heat transfer and schlieren photos of the model flow field.

The model flow field and bow shock structure was recorded using a 6000 spark per second cine schlieren system. Figures 2 and 3 show the recorded bow shock time sequence. As expected the model contour generates an unstable flow field which results in an oscillating bow shock. The observed oscillations indicate a frequency of 1500-2000 cps. The Strouhal number which depends on the flow frequency (f), model diameter (d), and freestream velocity (V_∞) is:

$$St = Df/V_\infty$$

From the observed oscillations the average Strouhal number appears to be St = 0.13 which is about 30% lower than previously observed from tests at $M_\infty = 10$ and $Re_\infty = 8 \times 10^6$ ft^{-1}.

The measured pressure distributions are shown in Figures 4 to 11. The pressure data has been normalized with respect to the measured pitot pressure measurement. The heat transfer distributions are shown in Figures 12 to 19. The heat transfer data are the measured values for each run condition.

TABLE I

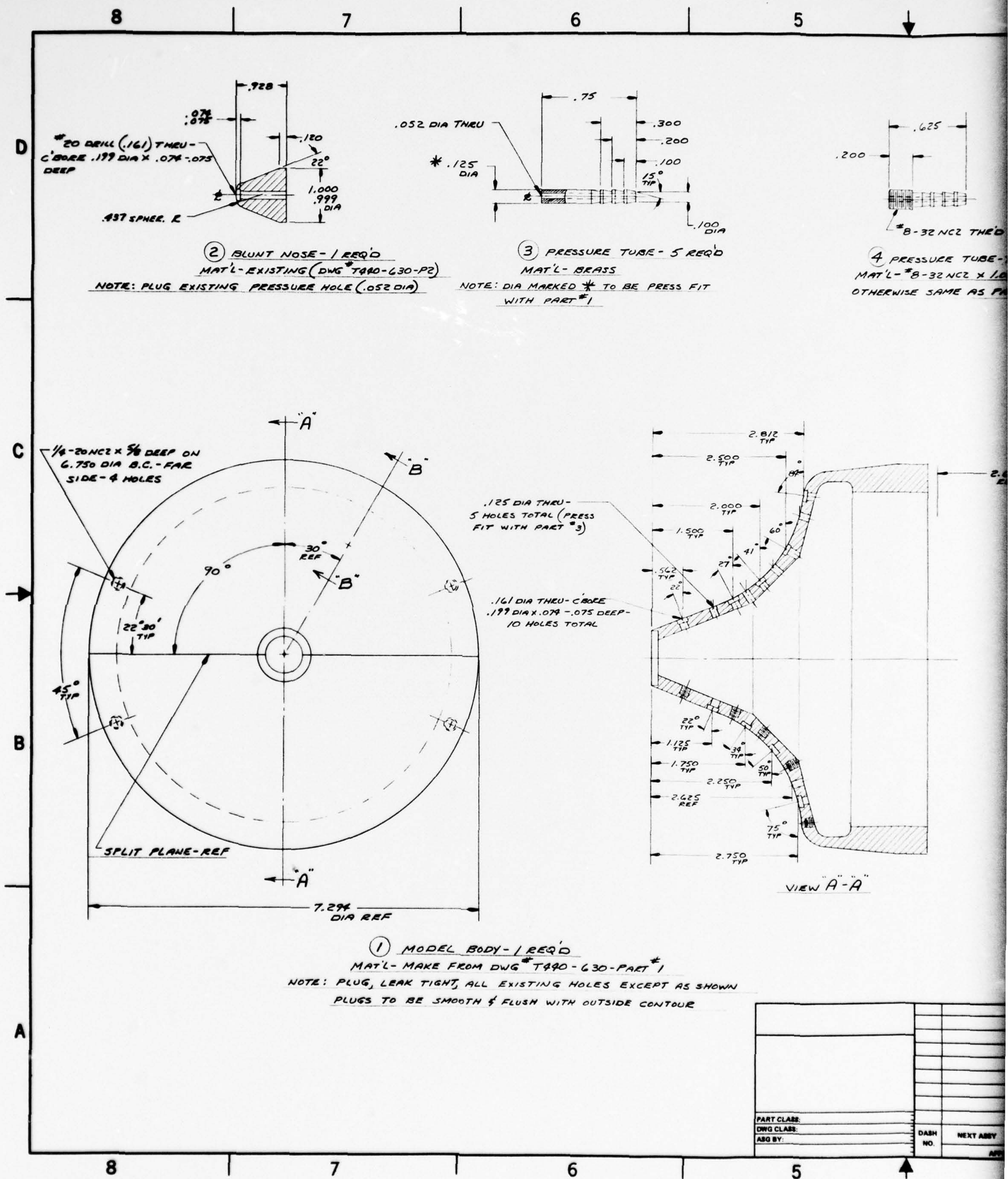
Heat Transfer Gage Calibration Data

Gage No.	Avg. Calib. Coeff., C_T	Effect. Gage Thickness, X_E (in.)	Actual Gage Thickness (in.)
1	.733	.0038	.0031
2	.671	.0035	.0036
3	.530	.0028	.0035
4	.555	.0029	.0038
5	.654	.0034	.0038
6	.548	.0029	.0032
7	.480	.0025	.0034
8	.456	.0024	.0036
9	.495	.0026	.0034
10	.667	.0035	.0038
11	.783	.0041	.0037
12	.951	.0050	.0035
13	.580	.0030	.0031
14	.606	.0032	.0034
15	.612	.0032	.0034
16	.626	.0033	.0037
17	.595	.0031	.0036
18	.585	.0031	.0035
19	.505	.0026	.0036
20	.676	.0035	.0033

TABLE II

VKI Longshot Test Matrix

Run No.	Model	(degree)	M_{∞}	Re_{∞} (ft^{-1})
		Phase I		
1	MR1	0	20	2.0×10^6
2	MR1	0	20	3.3×10^6
3	MR1	0	16	4.5×10^6
4	MR1	0	16	8.6×10^6
5	MR1	+3	20	3.3×10^6
6	MR1	-3	20	3.3×10^6
7	MR1	+3	16	6.6×10^6
8	MR1	-3	16	8.6×10^6
		Phase II		
9	MR2	0	20	2.0×10^6
10	MR2	0	20	3.3×10^6
11	MR2	0	16	4.5×10^6
12	MR2	0	16	8.6×10^6
13	MR2	+3	20	3.3×10^6
14	MR2	-3	20	3.3×10^6
15	MR2	+3	16	8.6×10^6
16	MR2	-3	16	8.6×10^6



#20 DRILL (.161) THRU - C'BORE .199 DIA × .074-.075 DEEP
.437 SPHER. R
(2) BLUNT NOSE - 1 REQ'D
MAT'L - EXISTING (DWG #T440-630-P2)
NOTE: PLUG EXISTING PRESSURE HOLE (.052 DIA)
.052 DIA THRU
(3) PRESSURE TUBE - 5 REQ'D
MAT'L - BRASS
NOTE: DIA MARKED * TO BE PRESS FIT WITH PART #1
#8-32 NC2 THR'D
4 PRESSURE TUBE-
1/4-20NC2 × 5/8 DEEP ON 6.750 DIA B.C. - FAR SIDE - 4 HOLES
.125 DIA THRU - 5 HOLES TOTAL (PRESS FIT WITH PART #3)
.161 DIA THRU - C'BORE .199 DIA × .074 - .075 DEEP - 10 HOLES TOTAL
SPLIT PLANE - REF
7.294 DIA REF
VIEW "A"-"A"
(1) MODEL BODY - 1 REQ'D
MAT'L - MAKE FROM DWG #T440-630-PART #1
NOTE: PLUG, LEAK TIGHT, ALL EXISTING HOLES EXCEPT AS SHOWN
PLUGS TO BE SMOOTH & FLUSH WITH OUTSIDE CONTOUR
PART CLASS:
DWG CLASS:
ASG BY:
DASH NO.
NEXT ASSY

1

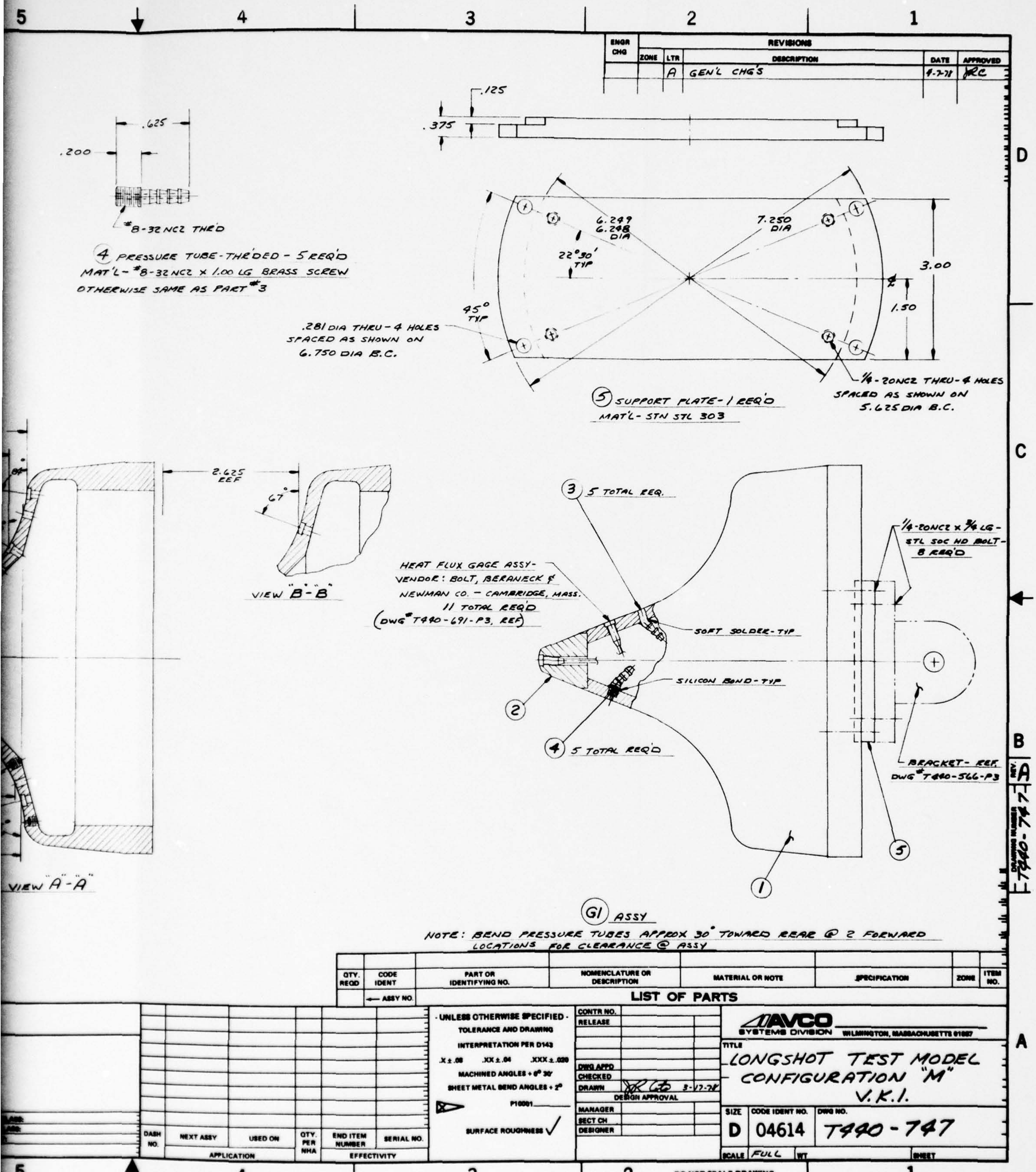
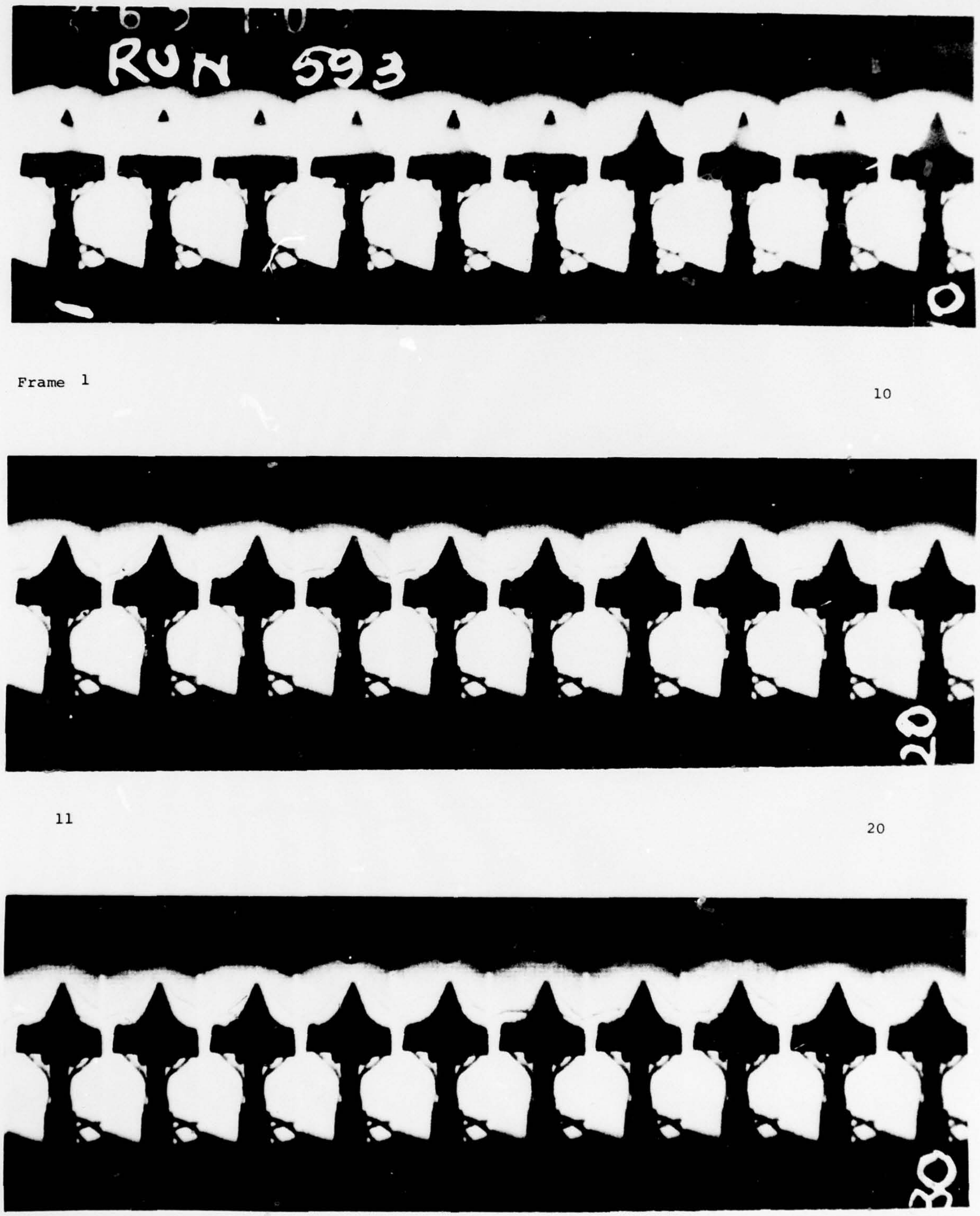

REVISIONS
A GEN'L CHG'S 9-7-78 JRC
.125
.375
.625
.200
#8-32 NCZ THR'D
4 PRESSURE TUBE-THR'DED - 5 REQ'D
MAT'L - #8-32 NCZ x 1.00 LG BRASS SCREW
OTHERWISE SAME AS PART #3
6.249
6.248
DIA
7.250
DIA
22°30' TYP
3.00
1.50
45° TYP
.281 DIA THRU - 4 HOLES
SPACED AS SHOWN ON
6.750 DIA B.C.
1/4-20NCZ THRU - 4 HOLES
SPACED AS SHOWN ON
5.625 DIA B.C.
5 SUPPORT PLATE - 1 REQ'D
MAT'L - STN STL 303
2.625 REF
67°
VIEW "B"-"B"
3 5 TOTAL REQ.
1/4-20NCZ x 3/4 LG - STL SOC HD BOLT - 8 REQ'D
HEAT FLUX GAGE ASSY -
VENDOR: BOLT, BERANECK & NEWMAN CO. - CAMBRIDGE, MASS.
11 TOTAL REQ'D
(DWG# T440-691-P3, REF)
SOFT SOLDER - TYP
SILICON BOND - TYP
2
4 5 TOTAL REQ'D
BRACKET - REF
DWG# T440-566-P3
1
5
VIEW "A"-"A"
G1 ASSY
NOTE: BEND PRESSURE TUBES APPROX 30° TOWARD REAR @ 2 FORWARD LOCATIONS FOR CLEARANCE @ ASSY
LIST OF PARTS
UNLESS OTHERWISE SPECIFIED - TOLERANCE AND DRAWING INTERPRETATION PER D143
AVCO SYSTEMS DIVISION WILMINGTON, MASSACHUSETTS 01887
LONGSHOT TEST MODEL CONFIGURATION "M" V.K.I.
SIZE D
CODE IDENT NO. 04614
DWG NO. T440-747
SCALE FULL
DO NOT SCALE DRAWING

FIGURE 1

FIGURE 2a
Cinė Schlieren Flow Field
Run No. 593 Model MR1
$M_\infty = 16$, $R_{e_\infty} = 8.6 \times 10^6/\text{ft}$, $\alpha = -3^\circ$

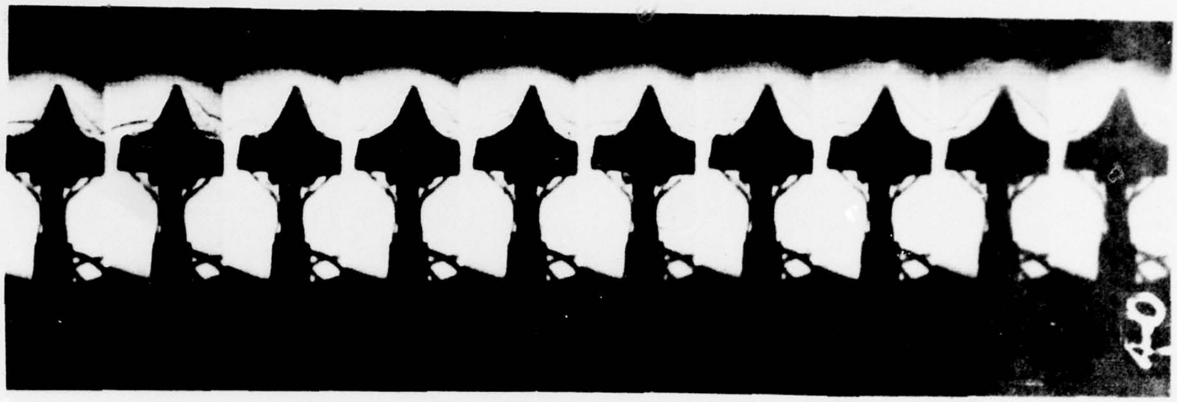


Frame 1 ... 10

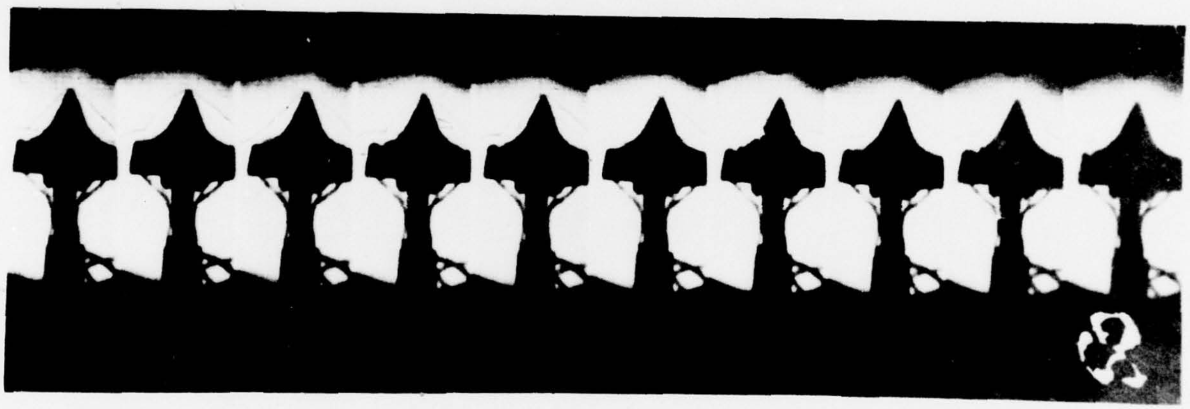
11 ... 20

21 ... 30

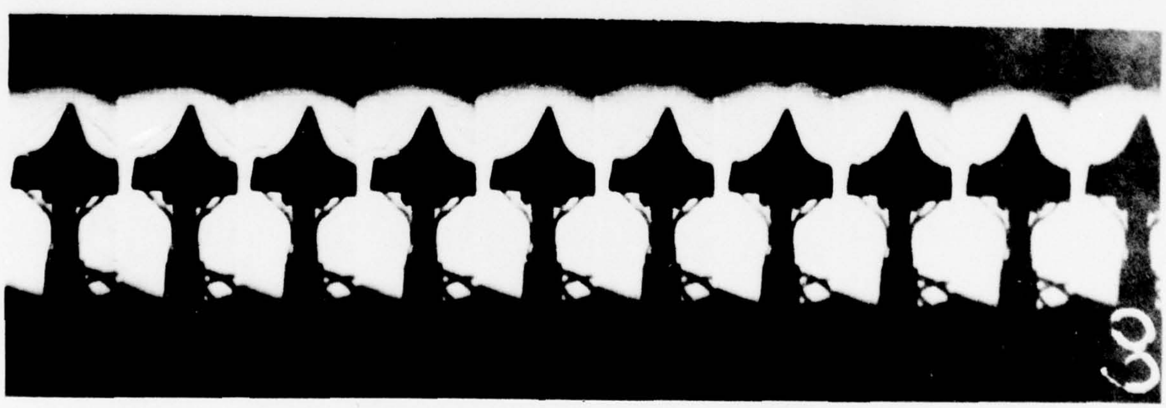
Figure 2b
Ciné Schlieren Flow Field
Run No. 593 Model MR1
$M_{\infty} = 16$, $R_{e_{\infty}} = 8.6 \times 10^{6}/\text{ft}$, $\alpha = -3^{\circ}$



Frame 31 40

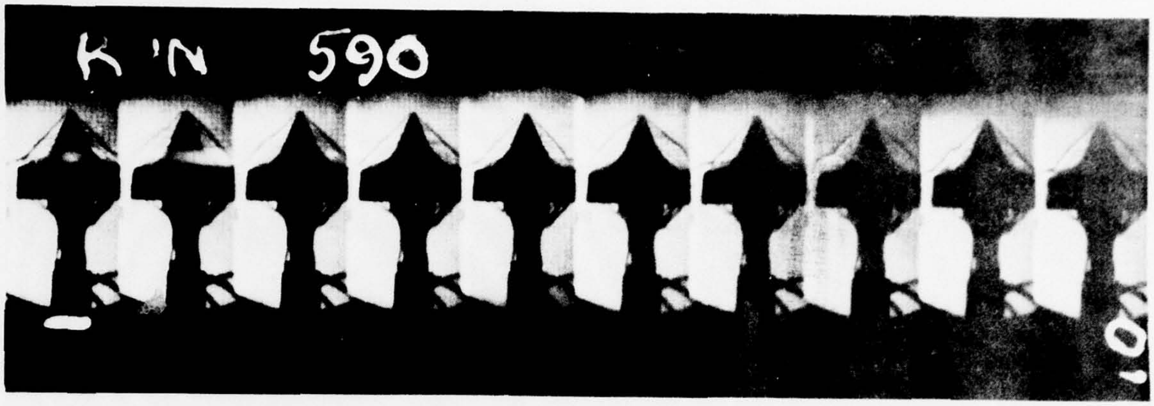


41 50

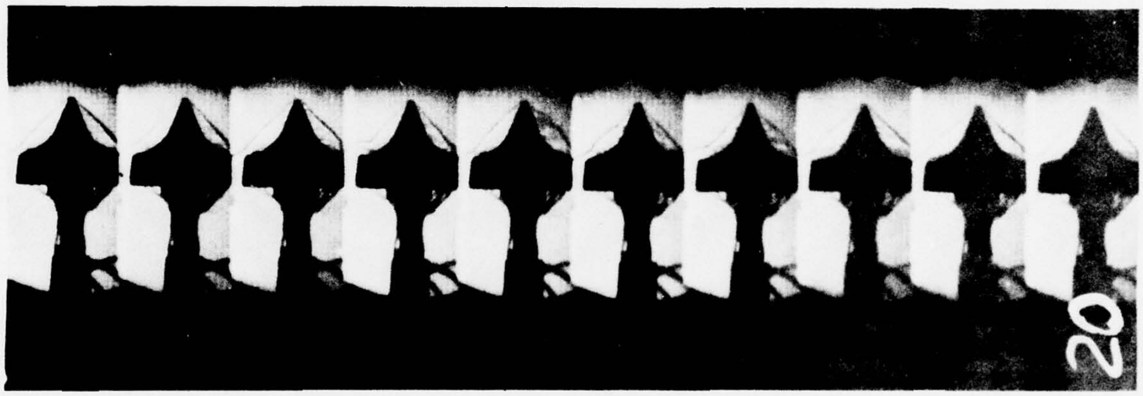


51 60

Figure 3a
Cine Schlieren Flow Field
Run No. 590 Model MR1
$M_\infty = 20$, $R_{e_\infty} = 2.0 \times 10^6$/ft, $\alpha = 0^\circ$



Frame 1 10



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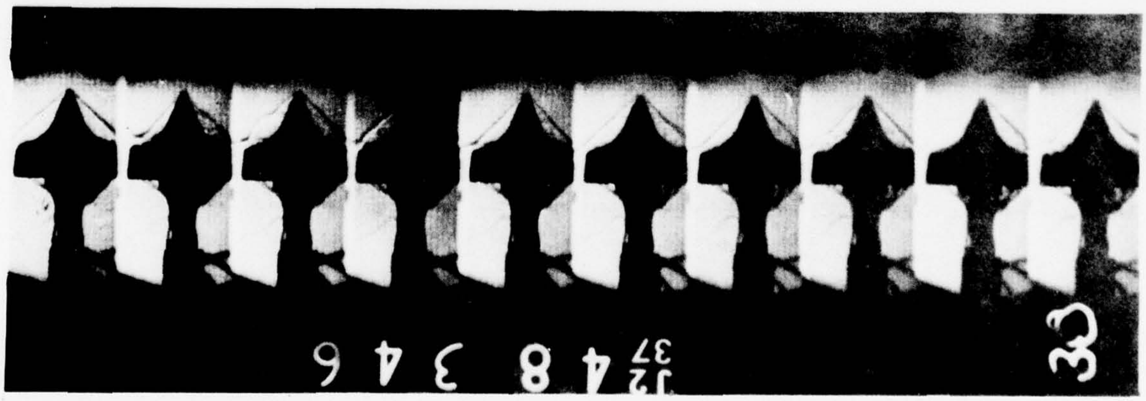
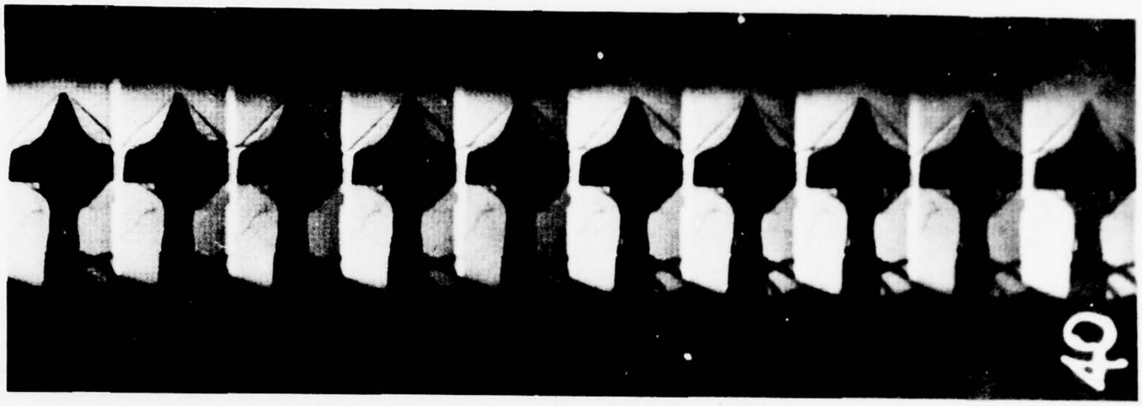
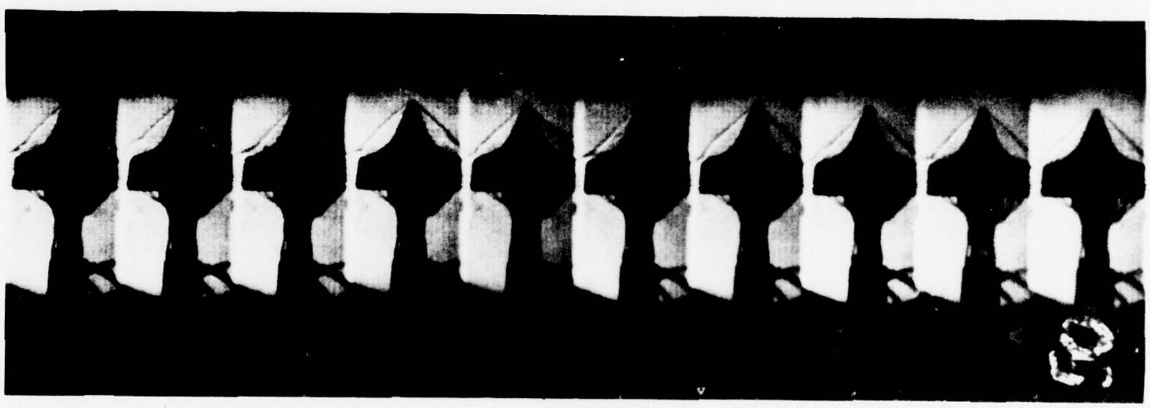


21 30

Figure 3b
Cine Schlieren Flow Field
Run No. 590 Model MR1
$M_{\infty} = 20$, $R_{e_{\infty}} = 2.0 \times 10^{6}/\mathrm{ft}$, $\alpha = 0^{\circ}$



Frame 31 40



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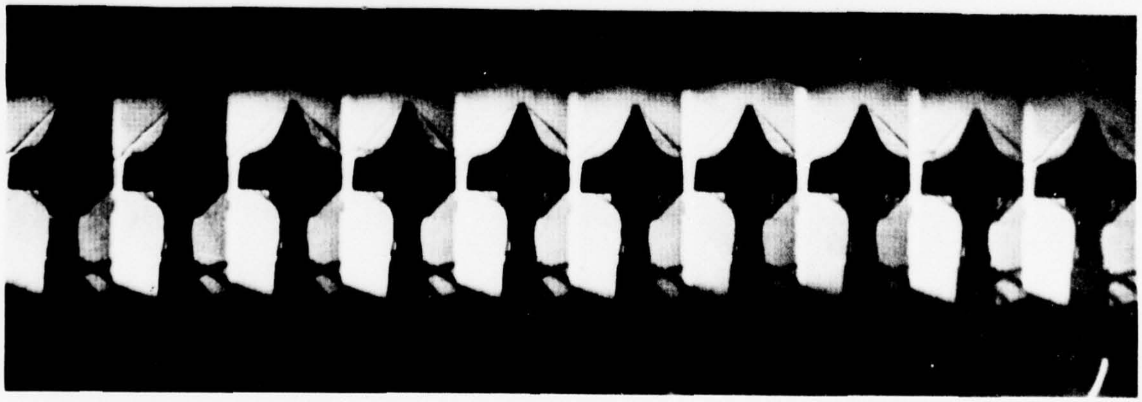

51 60

FIGURE NO. 4

WALL PRESSURE ON CONCAVE BICONIC

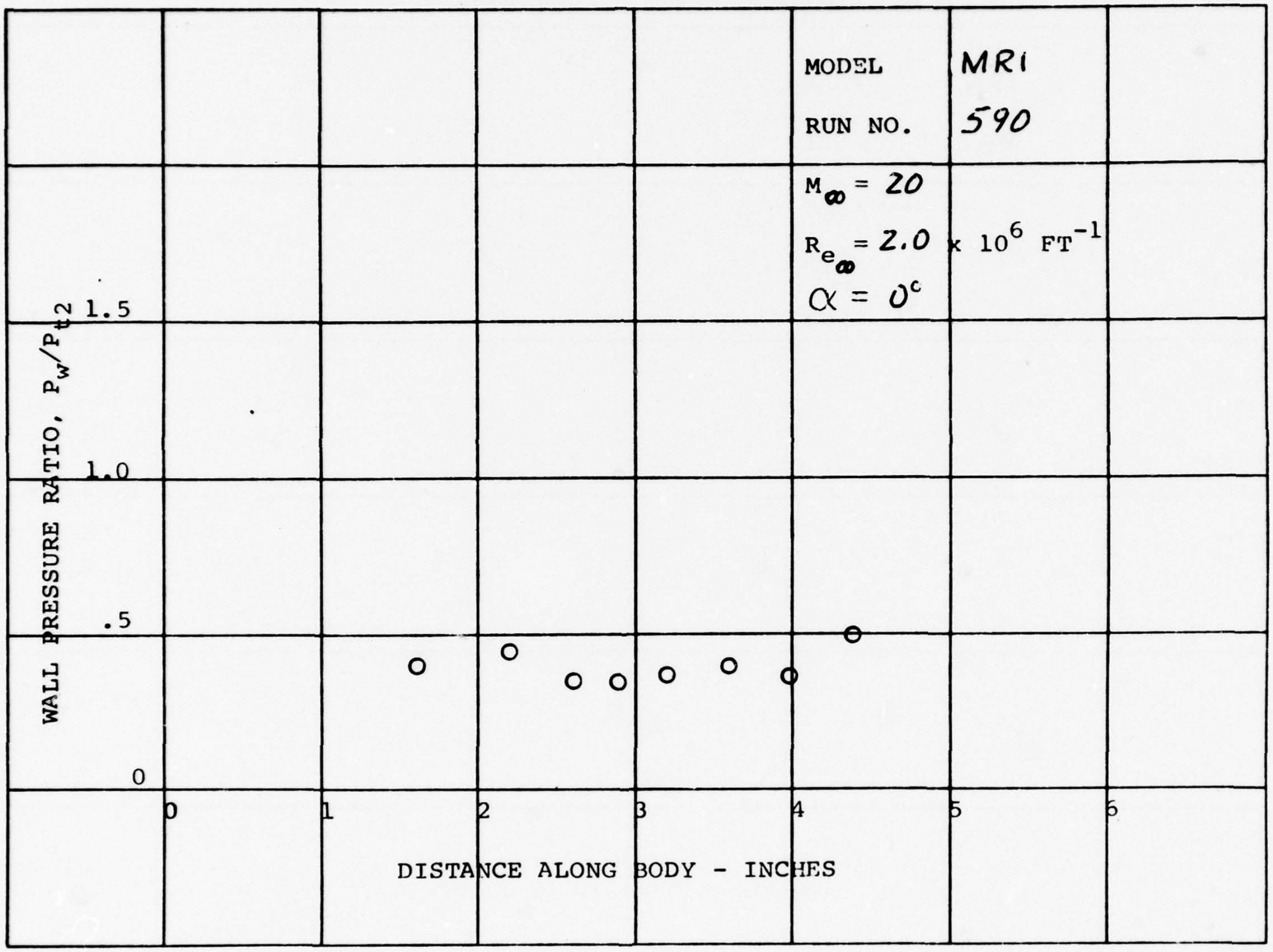

FIGURE NO. 5

WALL PRESSURE ON CONCAVE BICONIC

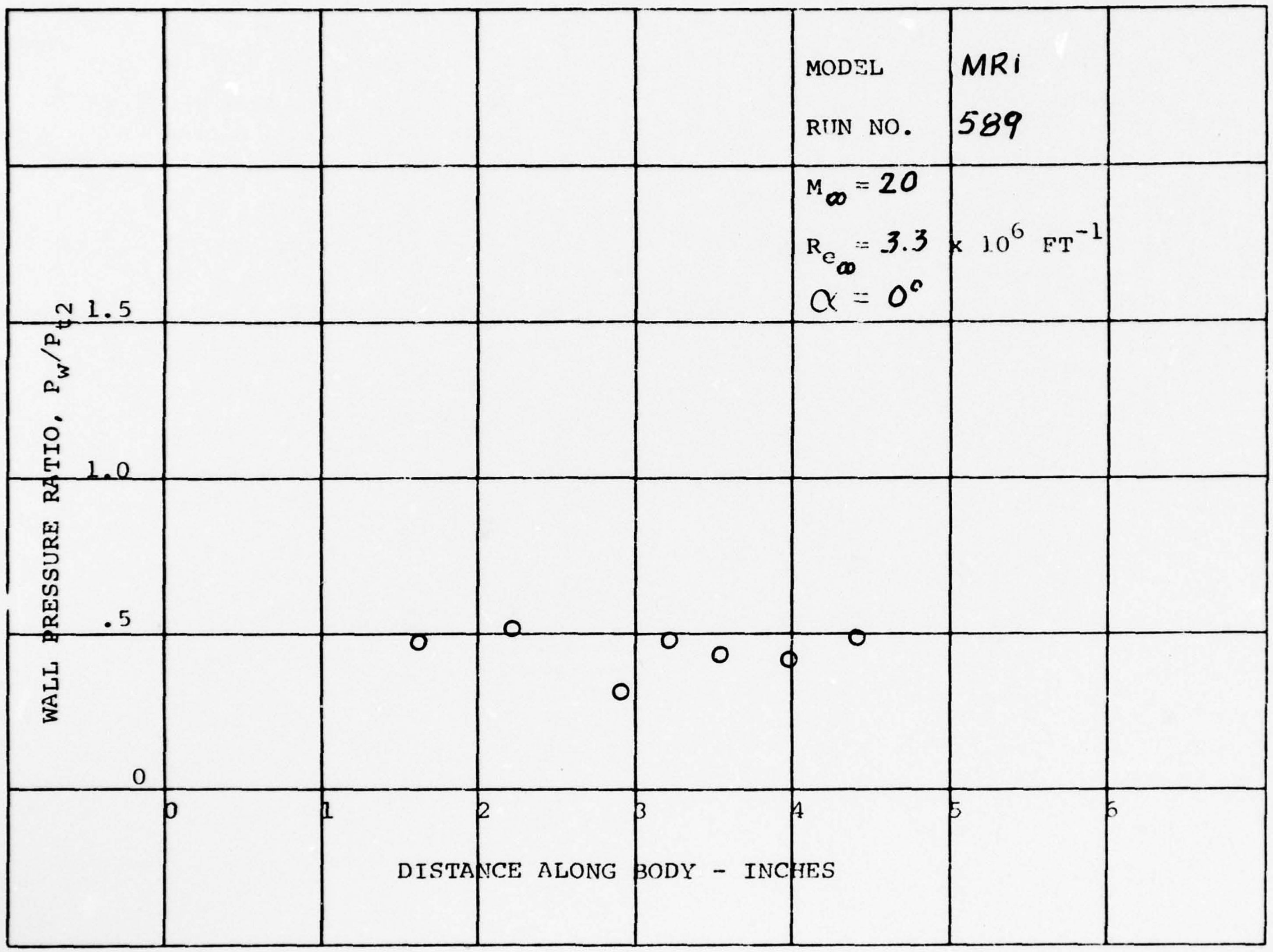

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FIGURE NO. 6

WALL PRESSURE ON CONCAVE BICONIC

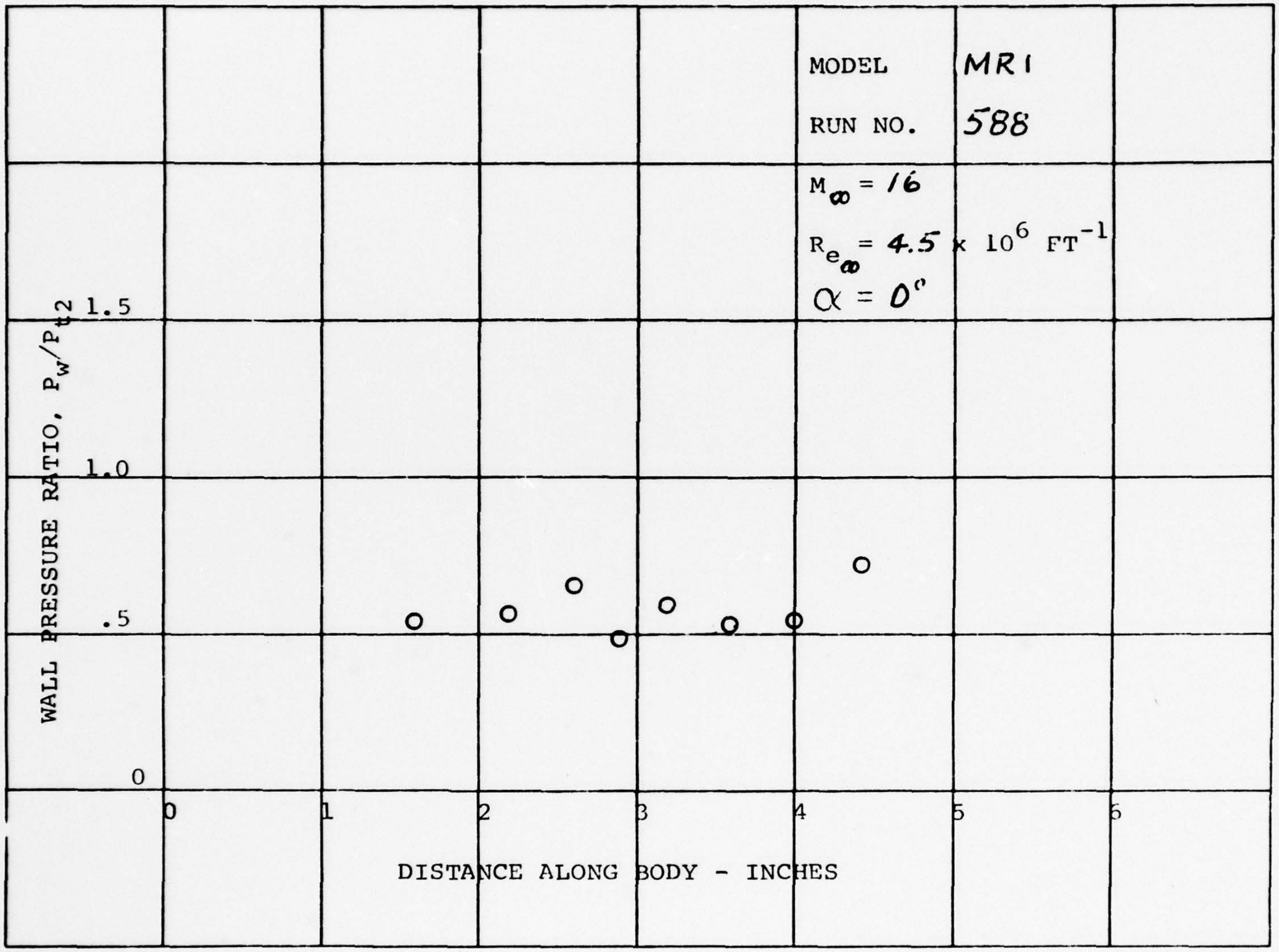

FIGURE NO. 7

WALL PRESSURE ON CONCAVE BICONIC

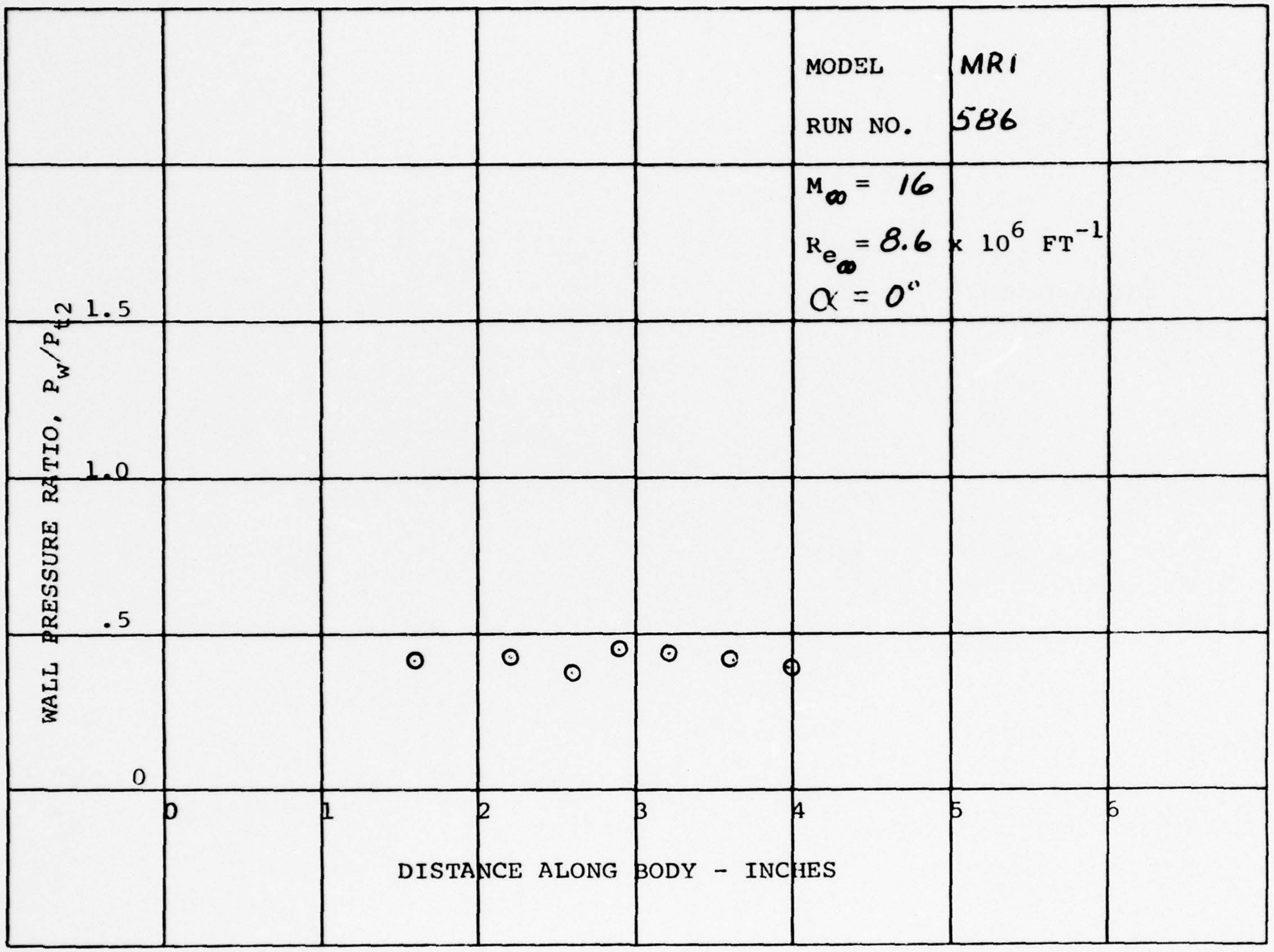

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FIGURE NO. 8

WALL PRESSURE ON CONCAVE BICONIC

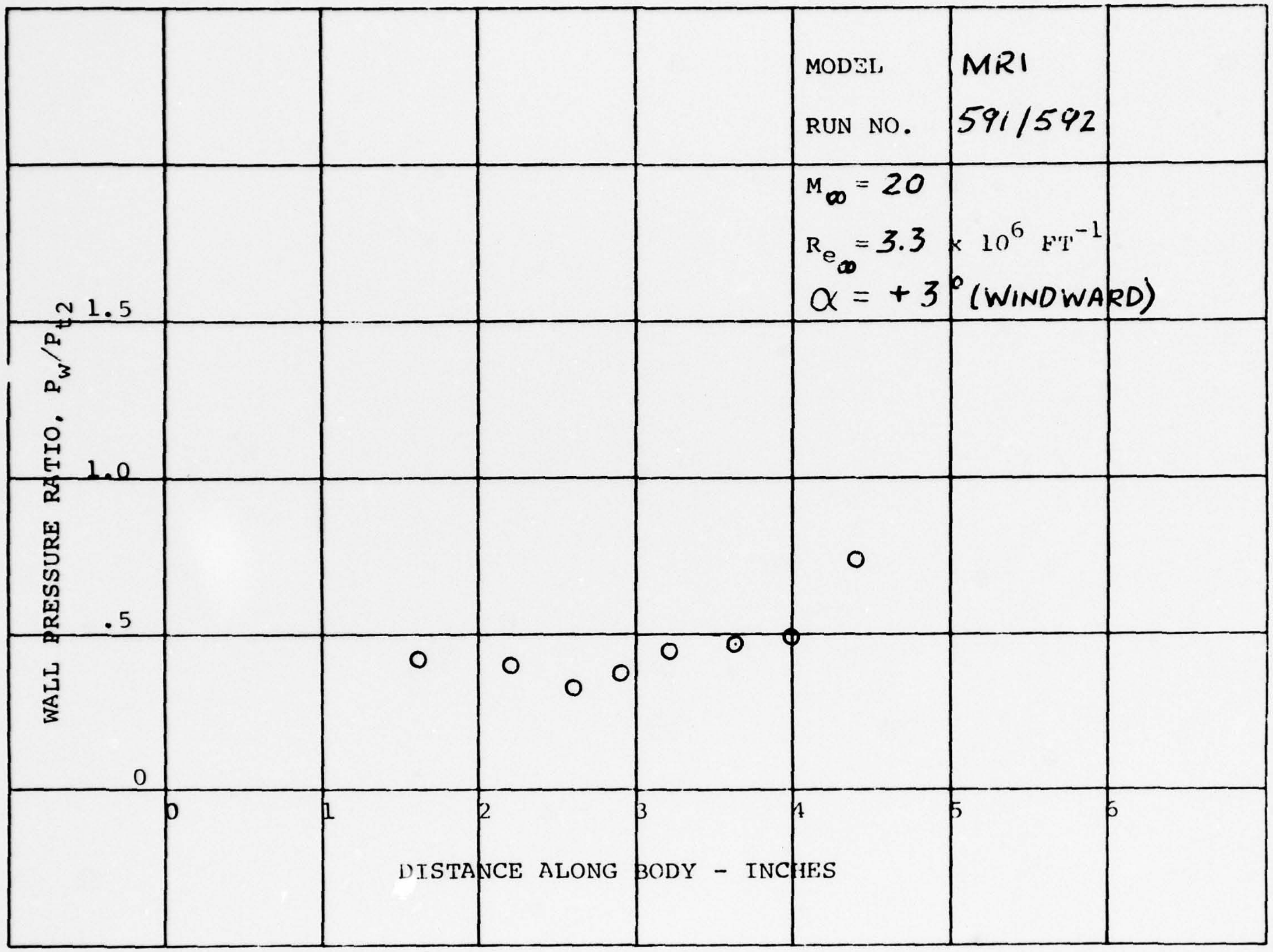

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FIGURE NO. 9

WALL PRESSURE ON CONCAVE BICONIC

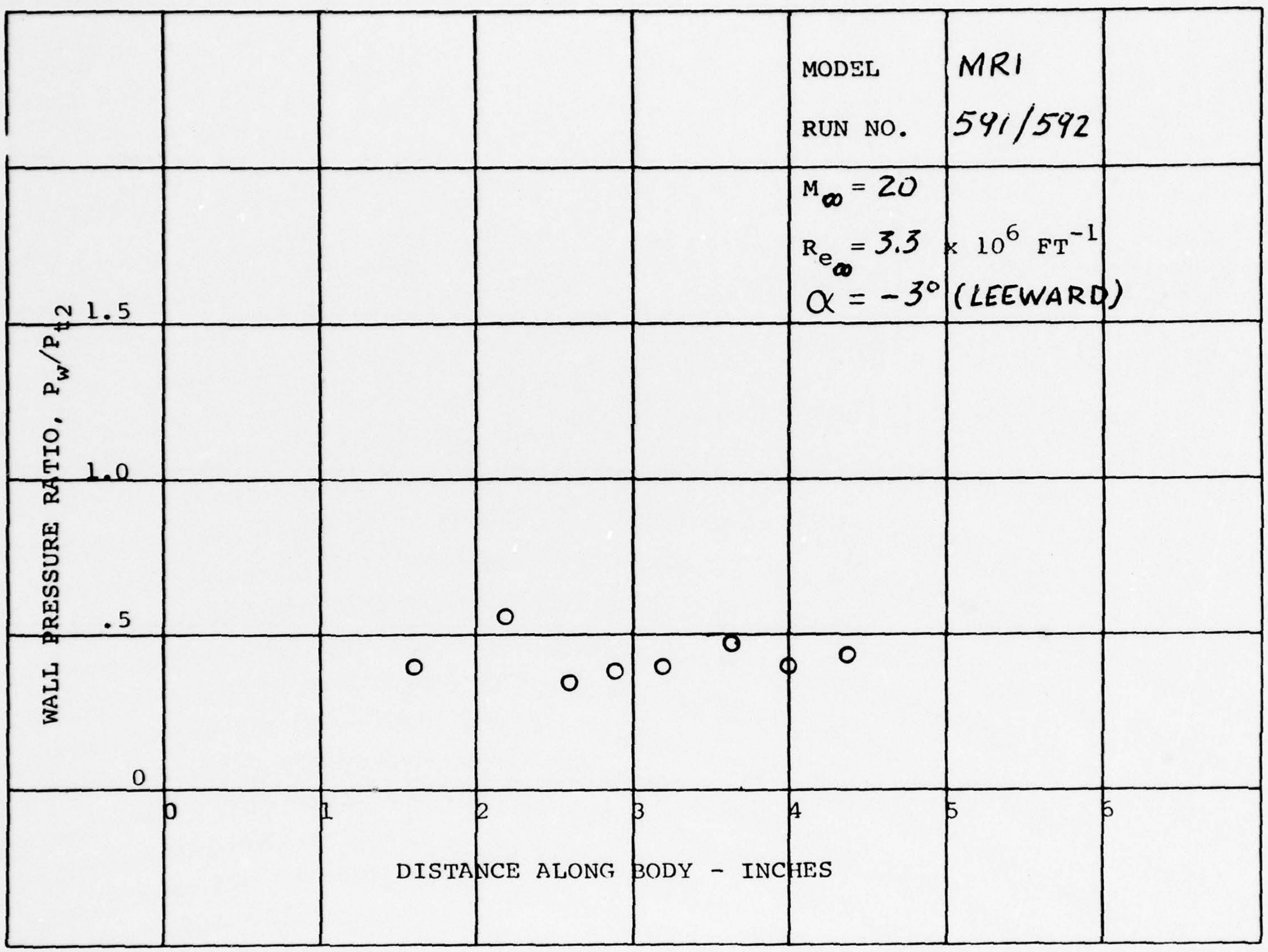

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FIGURE NO. 10

WALL PRESSURE ON CONCAVE BICONIC

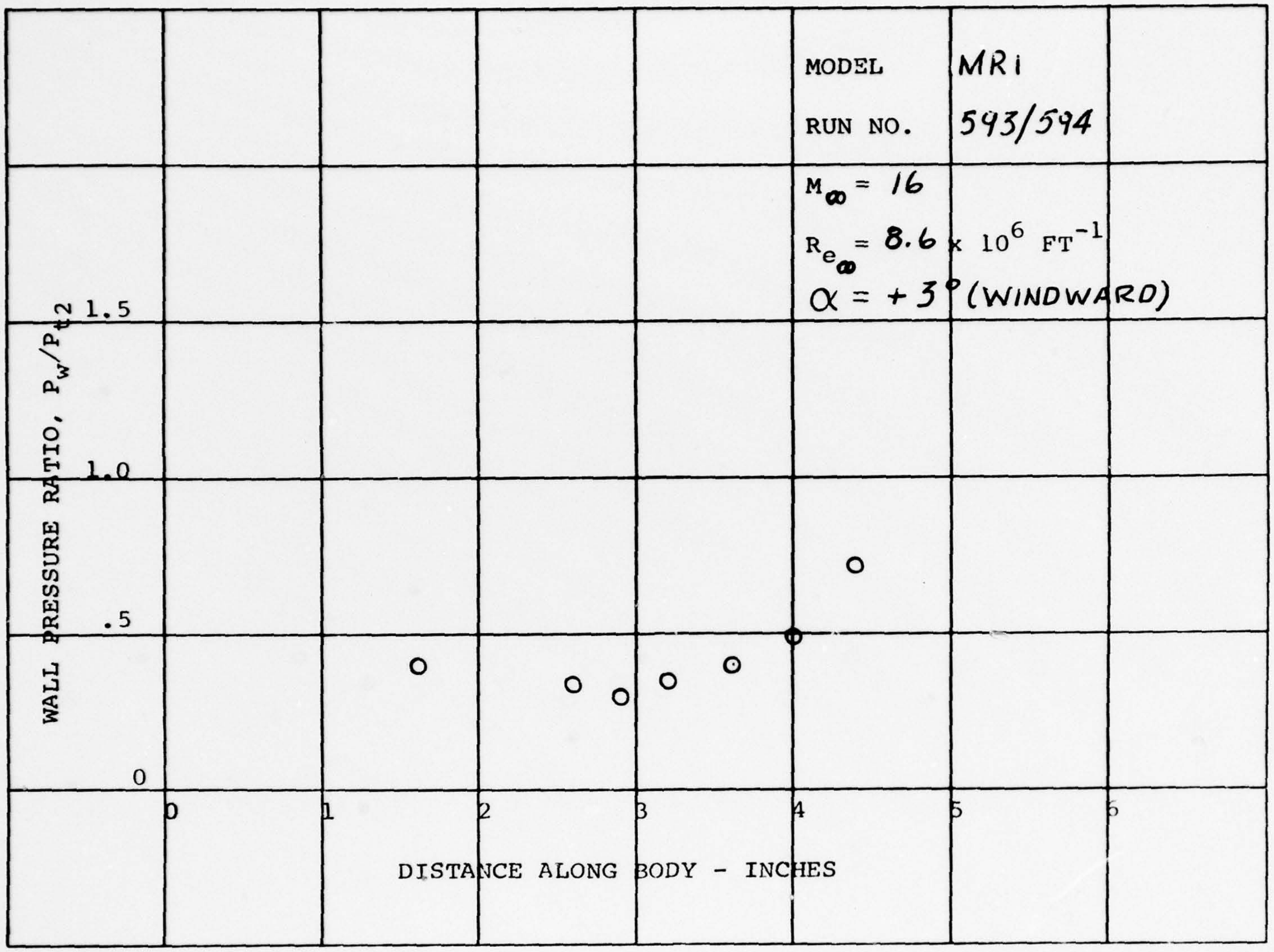

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FIGURE NO. 11

WALL PRESSURE ON CONCAVE BICONIC

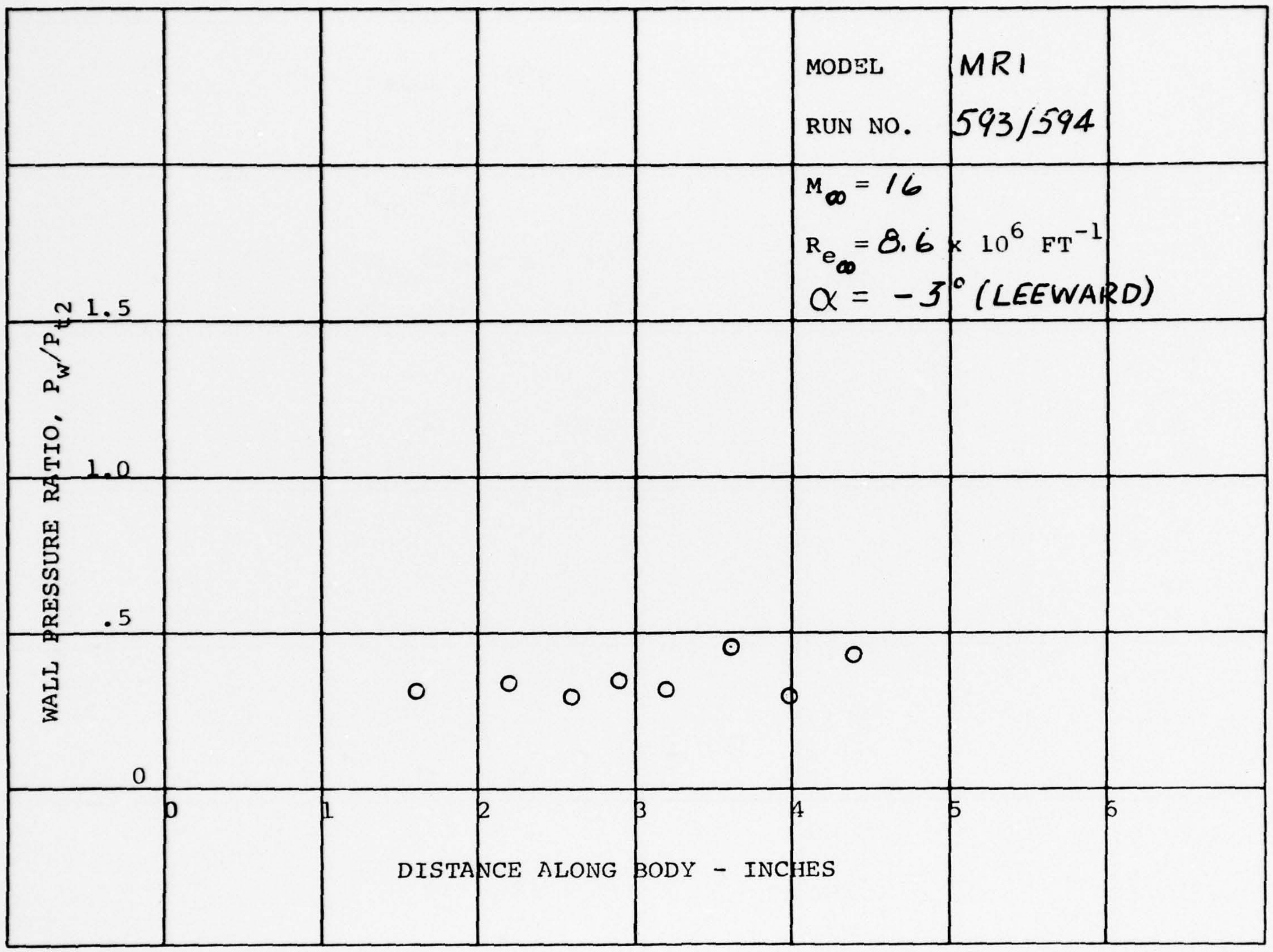

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FIGURE NO. 12

HEAT TRANSFER ON CONCAVE BICONIC

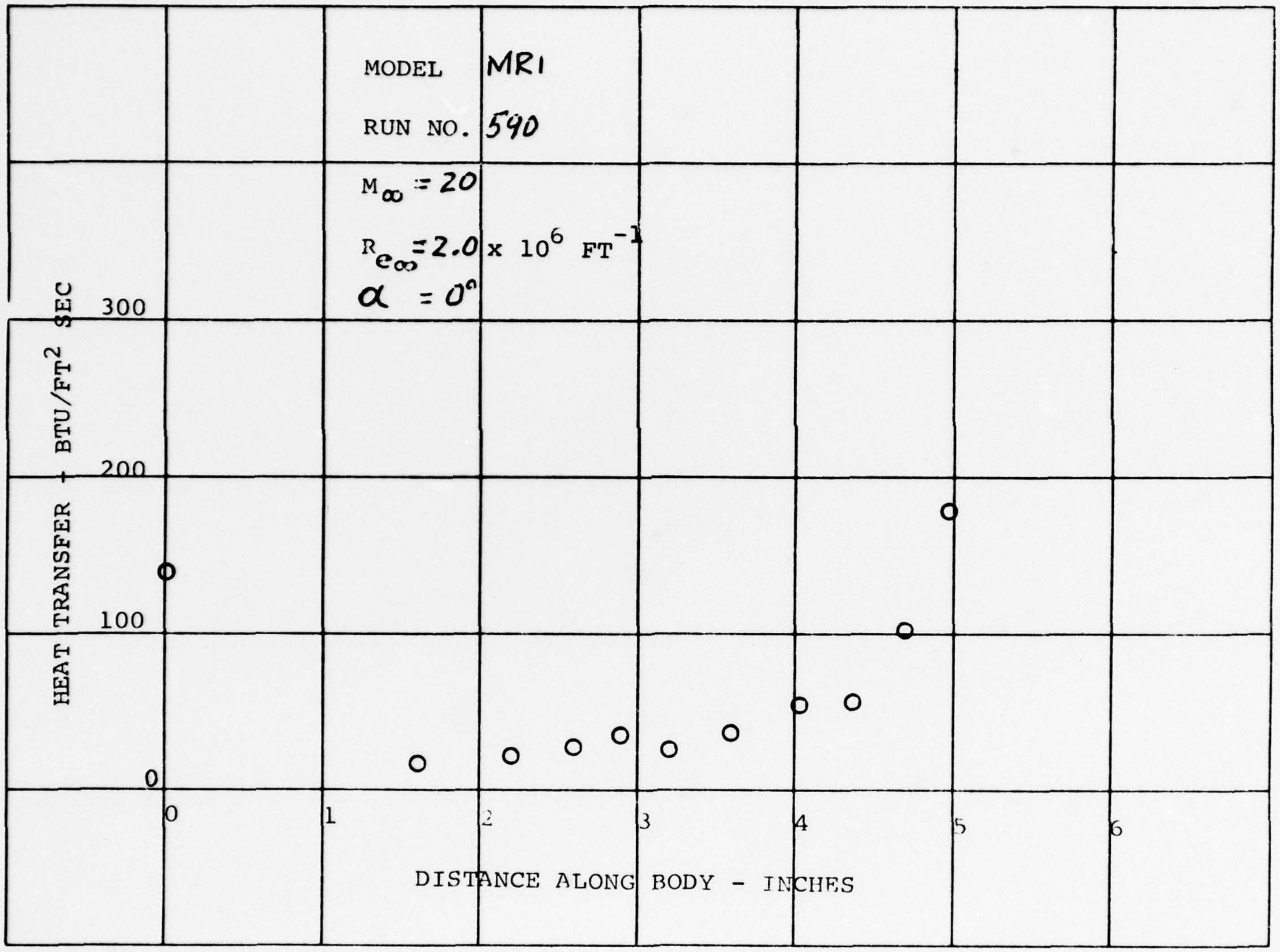

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FIGURE NO. 13

HEAT TRANSFER ON CONCAVE BICONIC

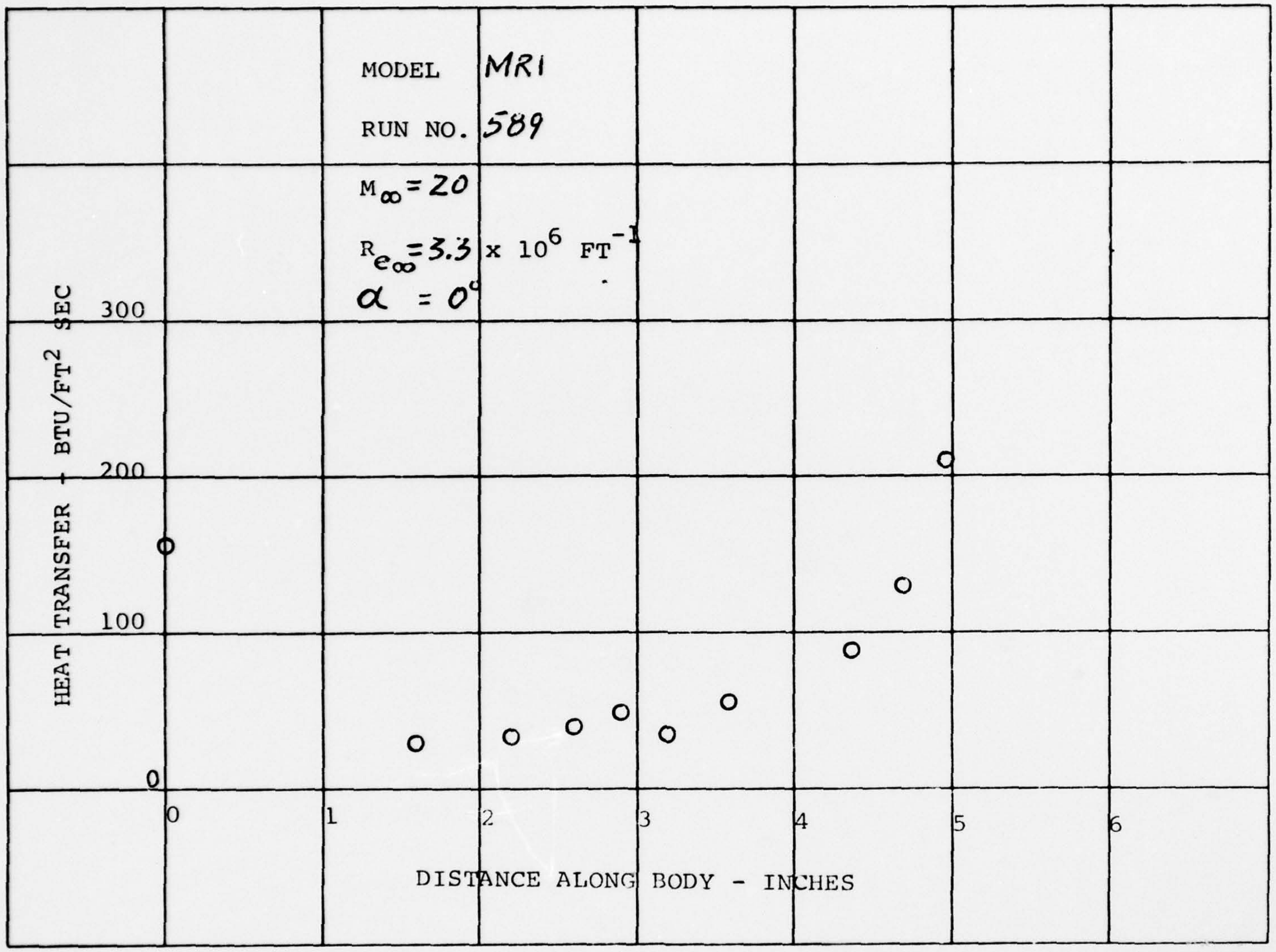

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FIGURE NO. 14

HEAT TRANSFER ON CONCAVE BICONIC

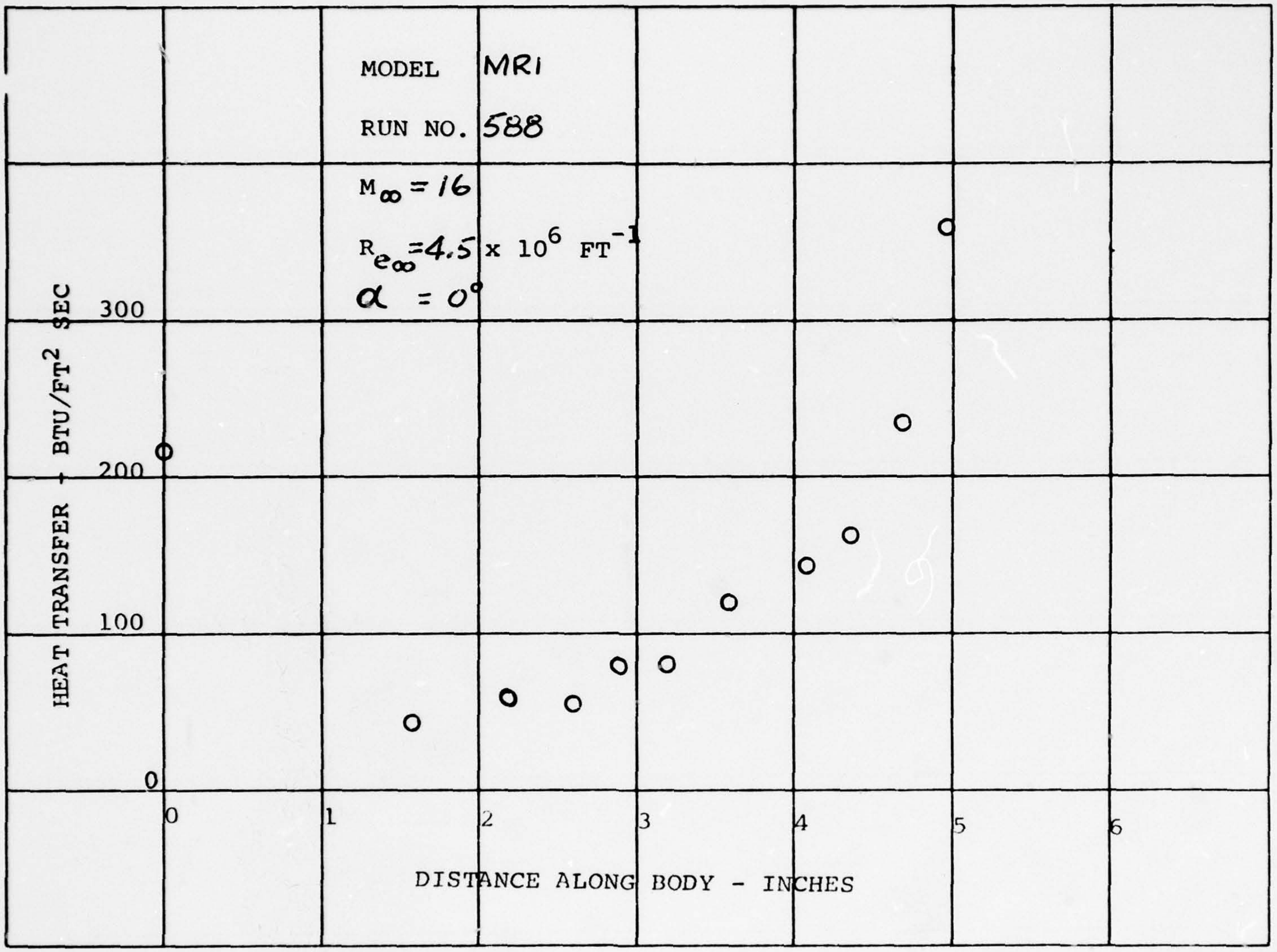

FIGURE NO. 15

HEAT TRANSFER ON CONCAVE BICONIC

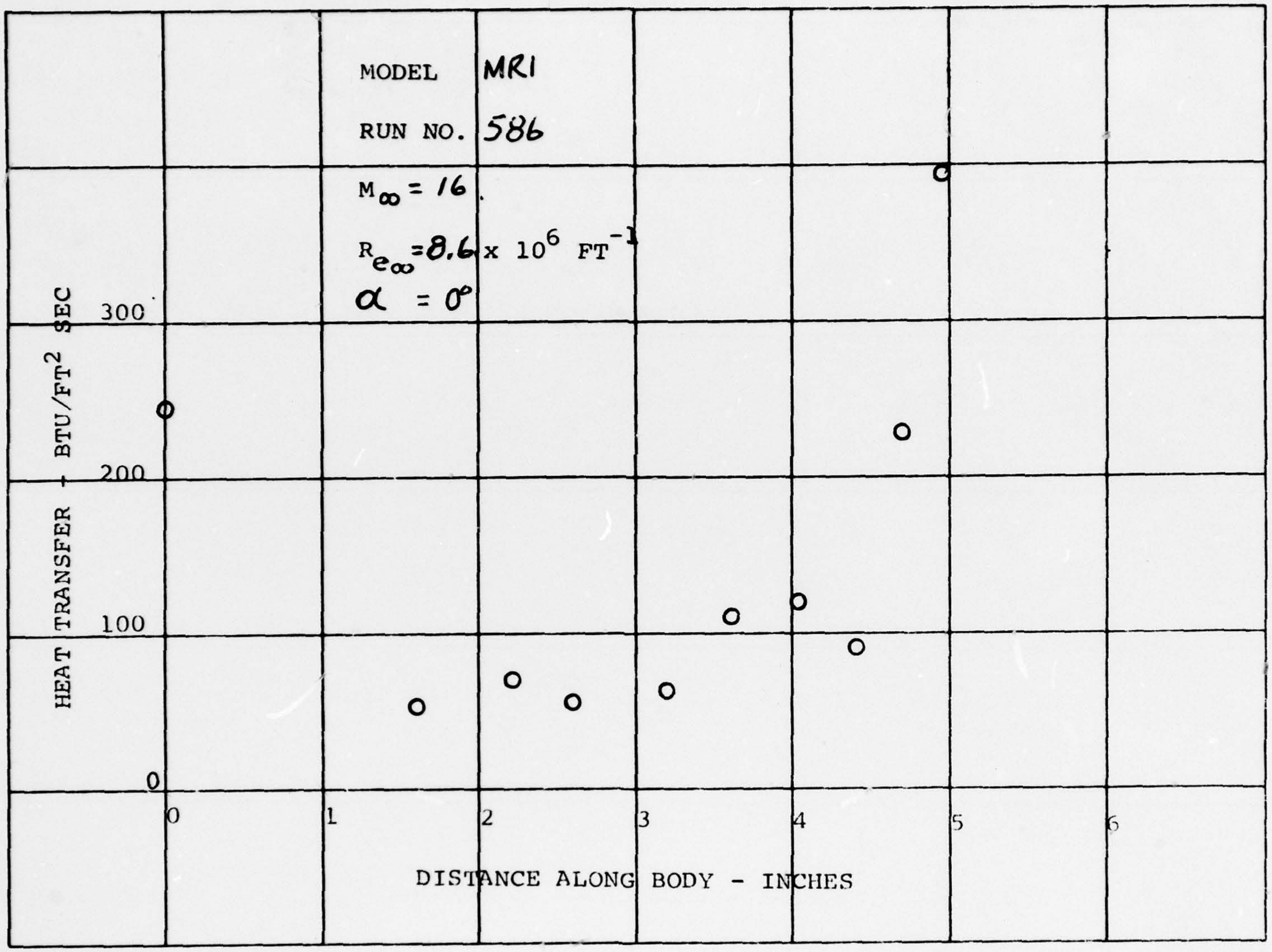

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FIGURE NO. 16

HEAT TRANSFER ON CONCAVE BICONIC

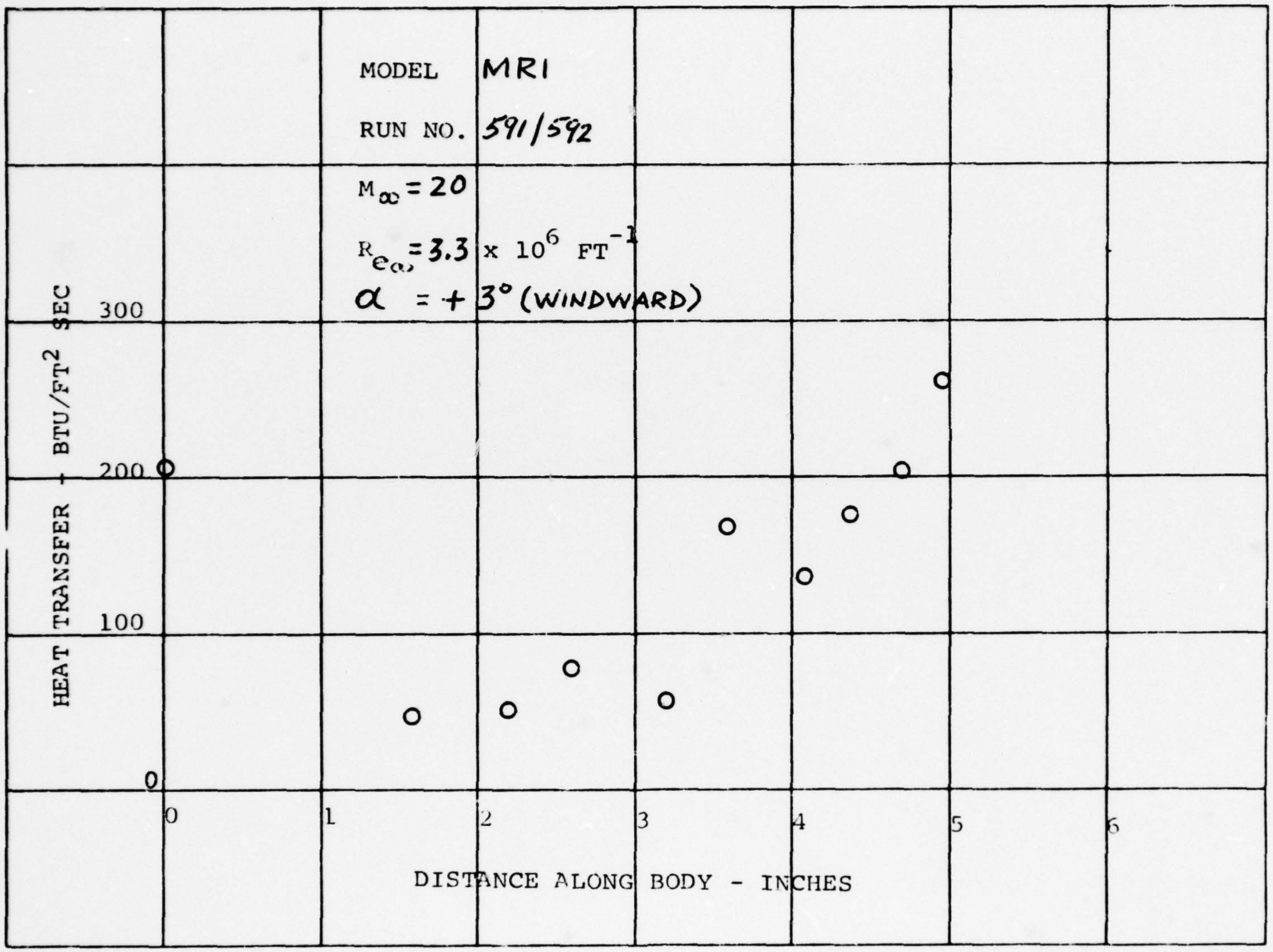

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FIGURE NO. 17

HEAT TRANSFER ON CONCAVE BICONIC

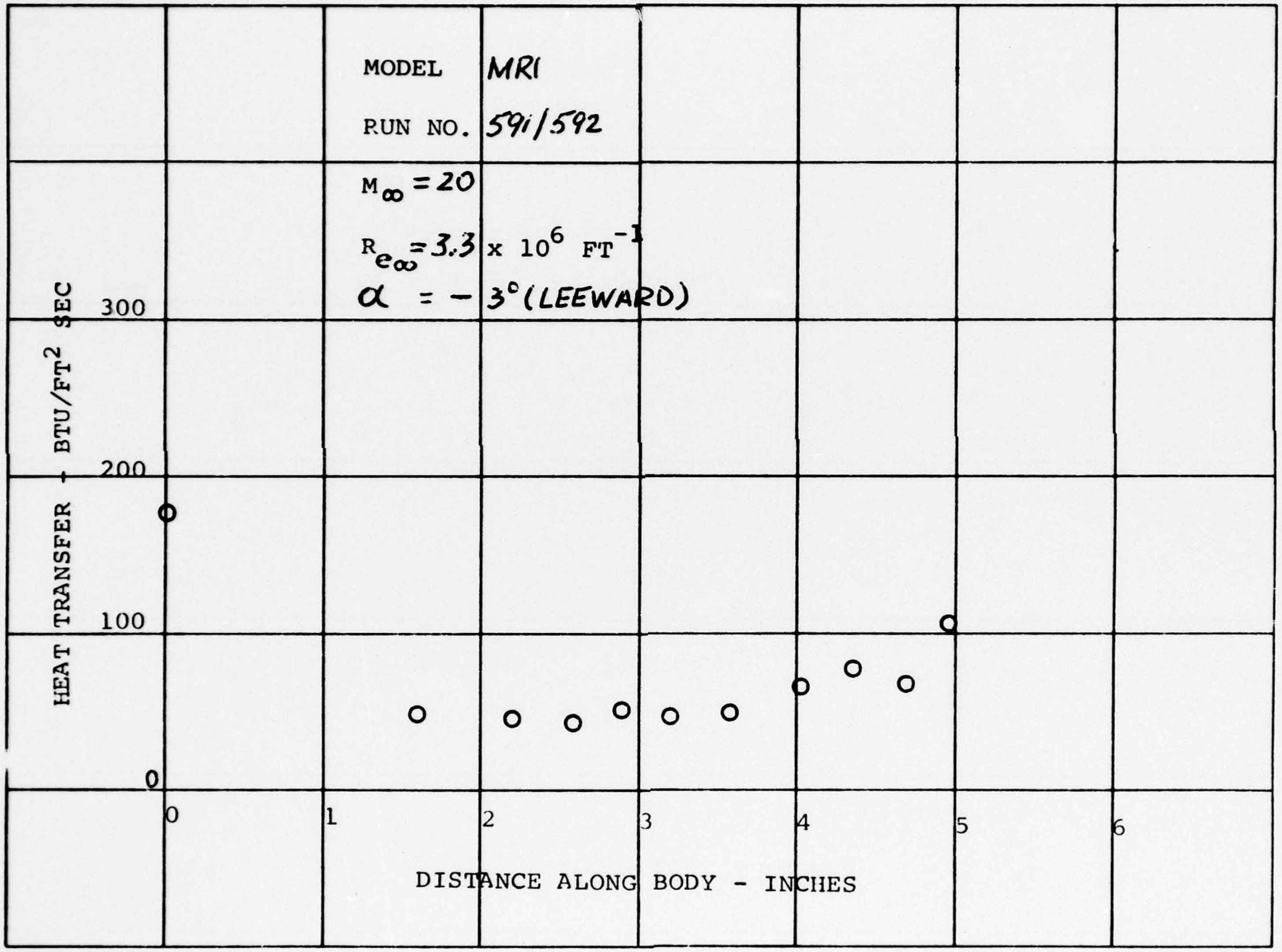

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FIGURE NO. 18

HEAT TRANSFER ON CONCAVE BICONIC

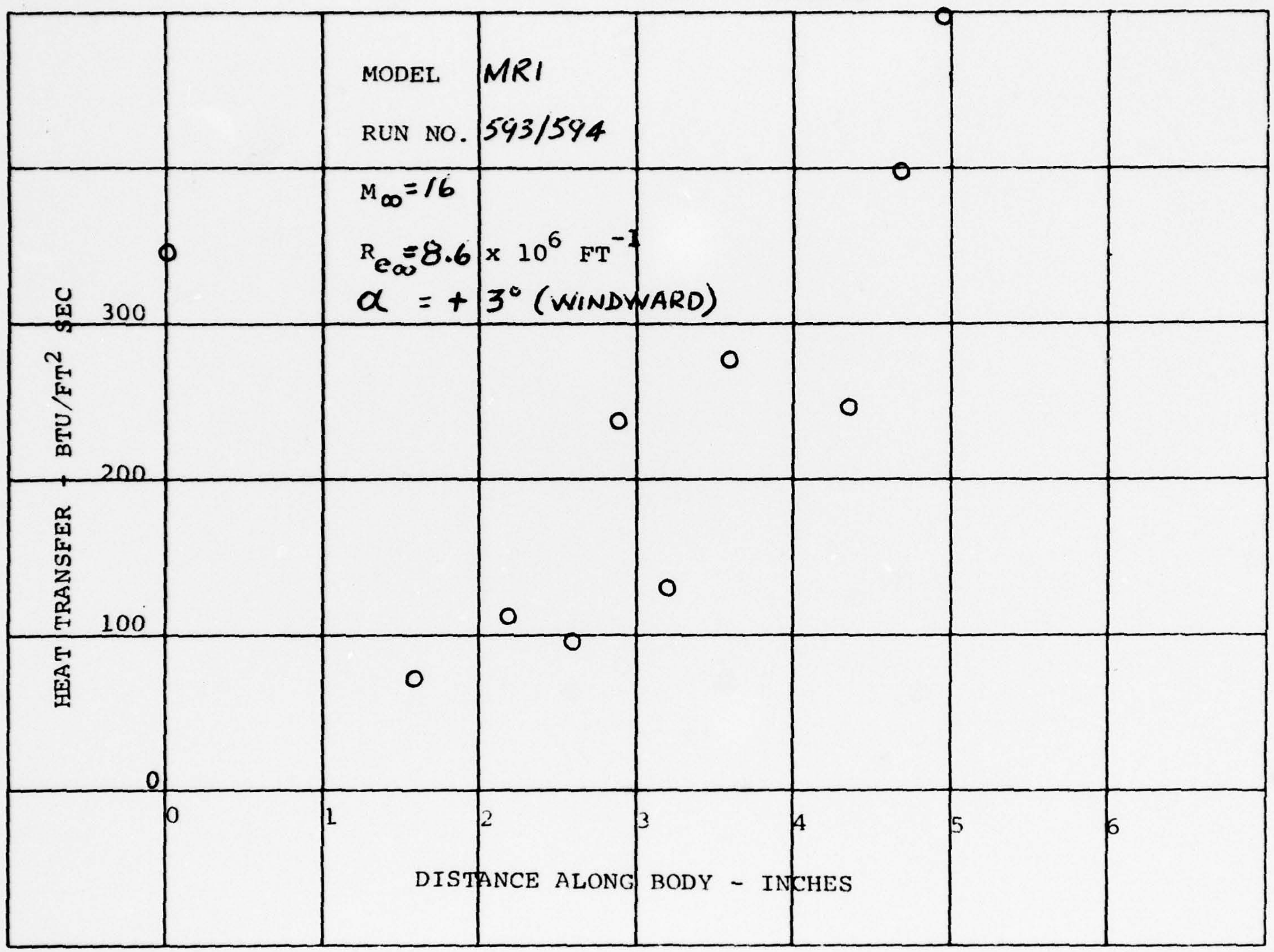
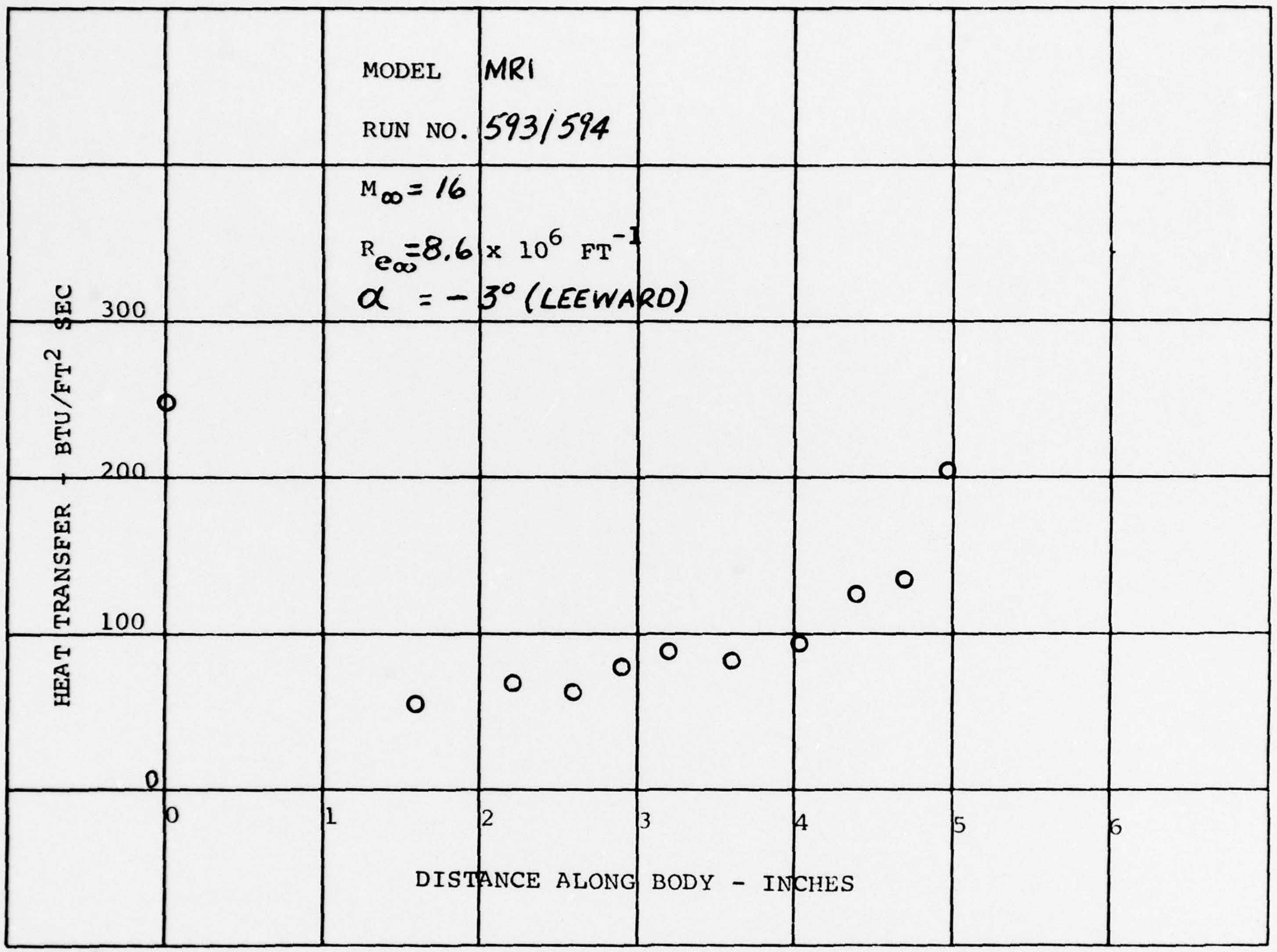


FIGURE NO. 19

HEAT TRANSFER ON CONCAVE BICONIC



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