

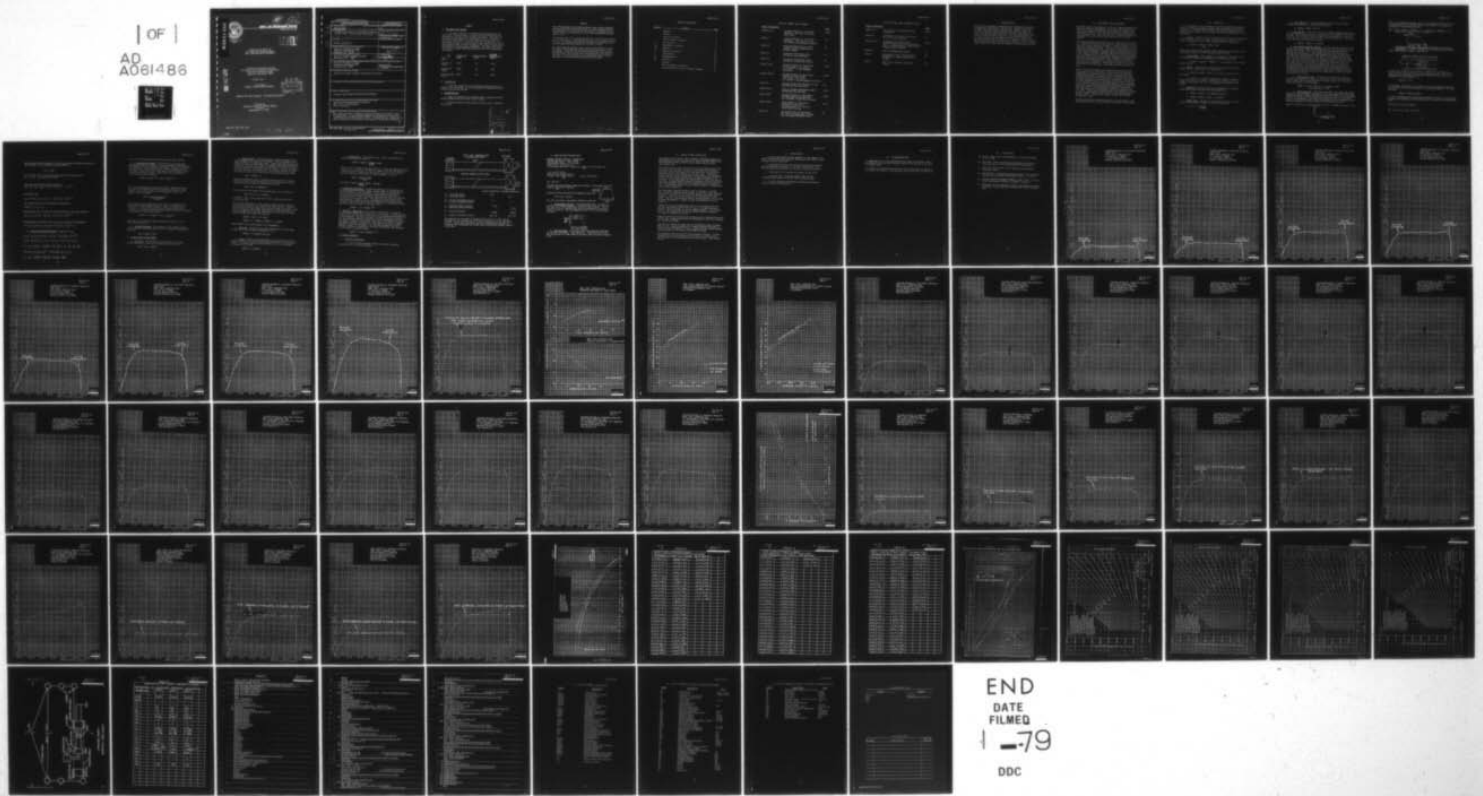
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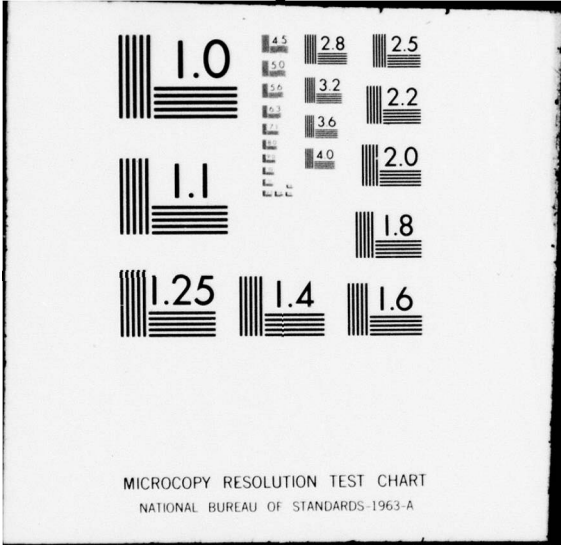
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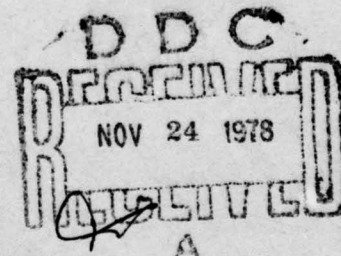
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A STUDY OF THE EFFECT OF  
DIFFERENT CAM DESIGNS ON MARK 7  
MOD 1 ARRESTING GEAR PERFORMANCE

Launching and Recovery Division  
Ship Installations Engineering Department  
Naval Air Engineering Center  
Lakehurst, New Jersey 08733

2 AUGUST 1978

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## SUMMARY

A. PROCEDURES AND RESULTS

1. In order to predict the theoretical performance of the Mark 7 Mod 1 Arresting Gear, a computer program was written that attempted to simulate actual recovery operations. The output of this program was compared to experimental results in order to verify its reliability. Once this check was accomplished, new cam designs as well as the existing K-5 cam, rotated on its dwell, were used as inputs in order to compare the effects of each set of coordinates on recovery gear performance. The table below lists the results for peak operating conditions with the corresponding ram strokes.

<u>CAM</u>	<u>WEIGHT (LBS)</u>	<u>VELOCITY (KNOTS)</u>	<u>CYLINDER PRESSURE (PSI)</u>
K-5 (118")	50000	111	10000
Rotated K-5 (122")	50000	111	9600
Rotated K-5 (126")	50000	111	9200
New Cam Design (122")	50000	111	9600

B. CONCLUSIONS

1. Since the rotated K-5 cam provides the same reduction in load as a new cam design, it is not necessary to replace the existing K-5 cam with any new cam.

C. RECOMMENDATIONS

1. Adopt the procedure for rotating cams as outlined in Mark 7 Service Bulletin 300 to all Mark 7 Mod 1 ships.

2. Study the effect of cam rotation on Mark 7 Mod 2 and Mark 7 Mod 3 ships.

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## PREFACE

The arresting gear systems aboard present ships contain hydraulic engines that develop retarding forces to arrest landing aircraft. The cams, which are driven by the ram stroke of the engine, act as control devices in regulating the fluid flow through the constant runout valve.

The present Mark 7 Mod 1 Arresting Gear has a 118.1-inch ram stroke, at 18:1 reeve ratio, a deck span of 95 feet, and is equipped with a K-5 cam. The maximum allowable MEC pressure is 10,000 psi, and it has an energy absorbing capacity of  $31 \times 10^6$  ft-lbs.

The upper balanced constant runout valve insures positive closure and allows for extended ram travel through a rotated cam or new cam design. After the 122-inch radial coordinate, cable stretch provides payout which can be used by rotating the cam to the 126-inch mark. This study shows how the additional service stroke increases the energy absorbing capability of the gear.

## TABLE OF CONTENTS

<u>Section</u>	<u>Subject</u>	<u>Page</u>
	Summary. . . . .	1
	Preface. . . . .	2
	Table of Contents. . . . .	3
	List of Tables & Figures . . . . .	4
I	Introduction . . . . .	6
II	Equipment & Procedures . . . . .	7
III	Analysis . . . . .	8
IV	Results & Discussion . . . . .	17
V	Conclusions. . . . .	18
VI	Recommendations. . . . .	19
VII	References . . . . .	20
	Figures. . . . .	21
	List of Symbols in Analysis. . . . .	72
	List of Symbols as Used in Computer Program. . . . .	73

## LIST OF TABLES AND FIGURES

<u>Table or Figure No.</u>		<u>Page</u>
Figures 1-8	Cylinder Pressure vs. Ram Stroke Simulation: MK 7 Mod 1, K-5 Cam, 118" Stroke	21-28
Figure 9	Cylinder Pressure vs. Ram Stroke Simulation: MK 7 Mod 1, K-5 Cam, 118" Stroke, Peak Engaging Condition	29
Figure 10	Mechanical Efficiency vs. Total Energy; Velocity Coefficient vs. Aircraft Weight	30
Figure 11	Comparative Performance Plots: K-5 Cam vs. New Cam Design	31
Figure 12	Comparative Performance Plots: K-5 Cam vs. Rotated Cam on Dwell	32
Figures 13-18	Cylinder Pressure vs. Ram Stroke: New Cam Design - 122" Stroke, A-3 Aircraft - Varied Engaging Velocities	33-38
Figures 19-24a	Cylinder Pressure vs. Ram Stroke: Rotated K-5 Cam on Dwell 122" Stroke + 126" Stroke A-3 Aircraft - Varied Engaging Velocities	39-45
Figure 25	Aircraft Weight Dial Settings K-5 Cam, Rotated Cam, New Cam Design	46
Figure 26-29	Plots of Pressure Simulations Used in Determining Dial Settings	47-50
Figure 30-32	Cylinder Pressure vs. Ram Stroke: New Cam Design and Rotated Cam F-4J Aircraft, Varied Thrust Ratings	51-53
Figure 33-36	Cable Tension vs. Ram Stroke Hookload vs. Ram Stroke New Cam Design, F-4J - Aircraft, Varied Thrust Ratings	54-57
Figure 37	Valve Stem Lifts vs. Ram Stroke: MK 7 Mod 1 Arresting Gear, K-5 Cam, New Cam Design, Rotated K-5 Cam	58



## LIST OF TABLE AND FIGURES (cont.)

<u>Table or Figure No.</u>		<u>Page</u>
Tables 1-3	K-5, New Cam, and Rotated K-5 Cam Coordinates	59-61
Figure 38	Geometrical vs. Effective Flow Area, MK 7 Mod 1 Arresting Gear	62
Figures 39-42	Performance Charts From Actual Aircraft Tests on MK 7 Mod 1 Arresting Gear: Cylinder Pressure, Cable Tension, Hookload, Anchor Tension	63-66
Figure 43	Mark 7 Arresting Gear Layouts	67
Table 4	Correlation of MK 7 Recovery System Parameters to Computer Simulation Program	68
Table 5	Mark 7 Mod 1 Hydraulic Simulation Program	69

## I. INTRODUCTION

This study is intended to investigate the feasibility of new cam configurations aboard Mark 7 Mod 1 ships. Present cam contours on these ships have service strokes of 118. inches. There is, however, within the engine framework additional available ram travel that had been previously used for cross-head battery position and two-block safety distance. Since the installation of the upper balanced control valve insures positive closure and limited ram overtravel, allowances for crosshead battery positioning and two-block safety distance can be reduced. Thus, in effect, usable engine ram travel can be increased for operational purposes.

## II. EQUIPMENT AND PROCEDURES

The first step in this study was to write a computer program that simulated aircraft arrestments. To do this, the layout of the Mark 7 Mod 1 gear was drawn and the interaction of the various components analyzed. Once these descriptions and interactions were understood, they were formulated into engineering equations, assembled into logical order, and detailed into a computer program.

The computer program was subject to test. Certain relationships, (i.e. mechanical efficiency and velocity coefficients) were unknown and to best approach the values of these variables, a trial and error procedure was used. That is, with the core of the program described mathematically, the unknown variables were used as inputs into the program. Repeated inputs of these variables over a wide range of aircraft velocities and weights finally evolved a set of numbers that, over a select range of aircraft arrestment histories, gave the best hypothetical simulation in comparison to the known experimental results. These "numbers" were then put into a curve-fit program and one equation for each of the relationships was formulated. Mechanical efficiency and velocity coefficients are discussed in the analysis section of this report.

Results from the program proved compatible with existing test data from the RALS. Both sets of data, the theoretical and experimental, considered the K-5 cam as part of the arresting-system configuration. The next step was to develop new cam coordinates over extended strokes and to investigate the effect of these coordinates on recovery gear performance. Various layouts were designed and the coordinates used as inputs. Because of the physical structure of the arresting gear, the tolerances needed for cross-head positioning and safety stops, and the fact that cable stretch occurs during an arrestment, the maximum "new cam design" set of coordinates could be increased to 122 vs. 118". (Cable stretch over the next four inches and rotation of the "new cam design" would provide for the maximum service stroke of 126".) The K-5 cam could be rotated on its dwell 8" from 118 to 126".

The actual layouts of these cam designs, and the pressure cards developed from their use, are shown in the results of this study.

## III. ANALYSIS

A. It is intended in this analysis to show the mathematical equations used in the computer program, a theoretical discussion of the unknown variables (i.e. mechanical efficiency, and velocity coefficient) developed in the program, and the design conditions established to improve performance.

1. RUNOUT. Aircraft runout is defined from the point of intersection of the aircraft hook to the final position where the aircraft stops. Given an engaging velocity, ACVEL, aircraft runout is defined as

$$a. \text{ RUNOUT} = \text{RUNOUT} + \text{ACVEL} \times \text{TIME} \\ \text{(PT)}$$

where (PT) references any variable from a previous time and TIME is the incremental period over which the calculation is made.

2. CABLE LENGTH. Cable length is the measure of distance of any one cable from the point of engagement to the sheaves on deck.

$$a. \text{ CBLNTH} = (\text{RUNOUT}^2 + \text{HSPAN}^2)^{.5} \text{ where HSPAN} = 1/2 \text{ the deck} \\ \text{pendant length.}$$

3. PAYOUT. Cable payout is the amount of cable fed from the engine that is transferred to the carrier deck.

a.  $\text{CBLPOU} = \text{CBLNTH} - \text{HSPAN}$  or in terms of cable fed from the engine.

b.  $\text{CBLPOU} = 2 \times \text{NSHVES} \times \text{STROKE}$  where NSHVES = number of movable sheaves any one cable is attached to, stroke is the ram-stroke of the engine, and (2) is the mechanical advantage of the system.

4. RAMSTROKE. Can be defined as the distance the crosshead moves along its guided tracks and from equation 3b.

$$a. \text{ STROKE} = \text{CBLPOU} / 2 \times \text{NSHVES} \text{ and from 3a.}$$

$$b. \text{ STROKE} = \text{CBLNTH} - \text{HSPAN} / 2 \times \text{NSHVES}$$

5. RUNOUT ANGLE. Knowing the runout and the length of cable on deck, from a right triangle it is easily seen that

$$a. \text{ COS } (\theta) = \frac{\text{RUNOUT}}{\text{CBLNTH}}$$

6. CABLE VELOCITY. Given an engaging velocity of the airplane as ACVEL, the velocity of the cable it hooks is

$$a. \text{ CBLVEL} = \text{ACVEL} / \text{COS } (\theta)$$

7. RAM VELOCITY. The cable, through a system of sheaves whose effect is neglected in this analysis, is connected to the crosshead which drives the ram. The crosshead contains 9 upper and 9 lower sheaves. One cable from the deck is reeved through one set of these sheaves in one bank, and since there are two banks per crosshead

$$a. \text{ RAMVEL} = \text{CBLVEL} / 2 \times \text{NSHVES}$$

8. MAIN ENGINE CYLINDER PRESSURE. With the ram set in motion by the arresting wire rope, there is a subsequent build up of retarding "forces" within the cylinder. This force is actually the cylinder pressure applied over a unit area. The constant runout valve, the cam, and the chain drive system regulate the pressure drop from the main engine cylinder into the accumulator. The "key" to the control valve is the cam. The cam rotates on to a valve stem which fits into the valve seat and at the end of an arrestment is completely closed. The cam is driven by a chain drive which is hooked to the moving crosshead, which, as mentioned before, is driven by the engaged wire rope. Thus, there is an enclosed system. An airplane engages a wire rope which drives a crosshead which forces fluid through a control valve whose stem lift is regulated by a cam which is driven by a chain drive. Complete rotation of the cam will shut the control valve, stop the fluid flow, and bring the aircraft to a stop.

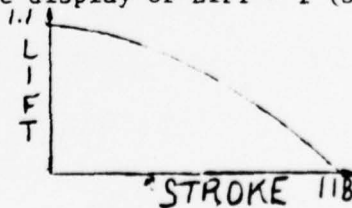
a. Control Valve Area. The cam and its rotational position determines the amount of opening in the control valve. From a geometric layout, taken over an extended series of lifts, the control valve area varies according to the following:

$$\text{AREORF} = 1.1107 \times (\text{LIFT}) \times (2 \times \text{VALDIA} - \text{LIFT})$$

(See NAEC MISC. 07352)

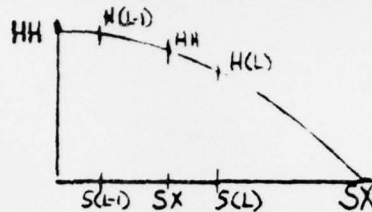
b. Valve Stem Lift. The "valve stem lift" is actually the transposition of the cam radial coordinates to the valve stem which effectively regulates cylinder pressure and closes the control valve. It is a function of the ram stroke, and is in essence the primary motive for this report. That is, to determine a set of cam coordinates that over an extended (from previous designs) ram stroke produces the optimum pressure card.

Figure 1 below gives a simple display of  $\text{LIFT} = f(\text{STROKE})$  for the K-5 Cam.



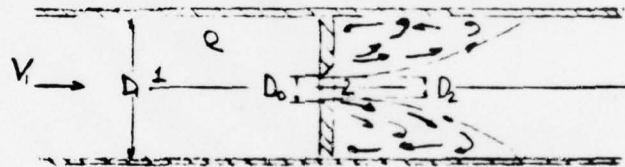
NOTE: In the computer program, since all calculated strokes didn't have a corresponding lift from input data, it was necessary to interpolate according to the following equation:

$$(HH) = \text{LIFT} = (\text{STROKE} - \text{STROKE (L - 1)} / \text{STROKE (L)} - \text{STROKE (L - 1)}) \times (\text{LIFT (L)} - \text{LIFT (L - 1)}) + \text{LIFT (L - 1)}$$



c. Discharge Coefficient, Contraction Coefficient, and Velocity Coefficient. It can be assumed that the constant runout control valve acts similar to a sharp edge orifice.

SHARP EDGED ORIFICE IN A PIPE



For this type of device the contraction coefficient is defined as  $\text{CONCOF} = A_2/A_0$ , where  $A_2$  and  $A_0$  are the respective areas. The velocity coefficient is a measure of loss during contraction, that is, it is a function of the Reynold Number, R.

$$\text{VELCOF} = f (R)$$

The discharge coefficient is a function of both the Reynolds number and the ratio of the contraction diameter to the conduit diameter. It can be defined by

$$\text{DSHCOF} = \text{CONCOF} \times \text{VELCOF}$$

In order to determine the pressure drop through the orifice it is necessary to apply these equations as well as Bernoulli's equation for incompressible flow.

Referring to the above diagram

$$v_{1t}^2 / 2g + P_1 / \rho = v_{2t}^2 / 2g + P_2 / \rho$$

The continuity equation relates  $V_{1t}$  and  $V_{2t}$  with the contraction coefficient  
That is  $V_1 A_1 = V_2 A_o$  (CONCOF); setting CONCOF =  $C_c$

$$V_1 A_1 = V_2 A_o C_c$$

For the Mark 7 Mod 1 it has been experimentally determined that  
 $C_c = 1.1 A_o - .217$  (NAEC MISC. 07262)

From continuity and Bernoulli's equation  
 $(P_1 - P_2) / \rho = (V_{2t}^2 / 2g) \times (1 - C_c^2 (A_o / A_1)^2)$

solving for  $V_{2t}$

$$V_{2t} = ((2g (P_1 - P_2) / \rho) / (1 - C_c^2 (A_o / A_1)^2))^{.5}$$

The actual velocity to the theoretical velocity is

$$VELCOF = C_v = V_A / V_T$$

multiplying by  $C_v$  to obtain the actual velocity at the vena contracta

$$V_{2A} = C_v \times ((2 (P_1 - P_2) / \rho) / (1 - C_c^2 (A_o / A_1)^2))^{.5}$$

Multiplying by the area of the jet  $C_c \times A_o$  produces the discharge Q.

$$Q = C_c C_v A_o ((2 (P_1 - P_2) / \rho) / (1 - C_c^2 (A_o / A_1)^2))^{.5}$$

d. Pressure Drop Across Orifice. Since  $Q_1 = V_1 A_1$

$$V_1 A_1 = C_c C_v A_o \times ((2 (P_1 - P_2) / \rho) / (1 - C_c^2 (A_o / A_1)^2))^{.5}$$

$$V_1^2 A_1^2 = C_c^2 C_v^2 A_o^2 \times ((2 (P_1 - P_2) / \rho) / (1 - C_c^2 (A_o / A_1)^2))$$

$$P_1 - P_2 = (\rho V_1^2 / 2) \times ((A_1^2 / A_o^2) / (C_c^2 C_v^2)) \times (1 - C_c^2 (A_o^2 / A_1^2))$$

Since  $A_1 \gg A_o$ ,  $(A_o / A_1)^2 \rightarrow 0$  and since  $C_d = C_c \times C_v$

$$P_1 - P_2 = (\rho V_1^2 / 2) \times (A_1^2 / A_o^2) \times (1 / C_d^2) = DPMEC$$

which is the pressure drop across the control valve orifice.

e. Accumulator Pressure. It is known for most aircraft arrestments, that the pressure in the accumulator varies between 400 and 650 psi over a complete ram stroke. Since it is not known how accumulator pressure varies with cylinder pressure, it was necessary to use these fixed conditions as valid estimates of the accumulator pressure change. Given these initial conditions, the following equation applies:

$$PACCO \times VOLACO^{1.4} = PACCT \times VOLACT^{1.4}$$

The original pressure and volumes are known, (PACCO and VOLACO), the new volume (VOLACT) can be calculated as a function of ram stroke\*, and so the pressure in the accumulator at any time PACCT can be calculated.

$$PACCT = \frac{PACCO \times VOLACO^{1.4}}{VOLACT^{1.4}}$$

\*The volume in the accumulator varies with the displacement of fluid from the main engine cylinder. Since it is not an exact function, i.e. varies with piston area and ram stroke, it was necessary to interpolate from the known initial and final conditions to determine how this volume varies.

$$VOLACT^{1.4} = (VOLACO - (SK \times STROKE))^{1.4}$$

where SK is the calculated dummy variable that best fits the prescribed conditions.

f. Cylinder Pressure. The pressure in the cylinder is the sum of the drop across the orifice and the increase in accumulator pressure.

$$PMEC = DPMEC + PACCT$$

#### 9. FORCES ACTING ON THE SYSTEM.

a. Ram Force. The ram force is the build-up of cylinder pressure acting as a unit vector against the piston area

$$FRAM = PMEC \times AREPTN$$



b. Cable Tension. The arresting gear cables are wrapped around two crossheads, one fixed and one movable. Each crosshead has two banks of sheaves, an upper and lower. Coming down from the top side connection with the deck pendant and wrapped around some intermediate directional sheaves, each cable is wrapped around either both upper banks of sheaves or both lower banks of sheaves. Thus on the movable crosshead the ram force developed by the pressure buildup is equal and opposite to the tension developed by the wrapped around wires.

$$\text{FRAM} - \text{CBLTEN} = 0$$

Since one individual cable is wrapped around nine rows of sheaves, applying a force to the top and bottom of the sheaves, the total cable tension in reaction to the ram force is now

$$\text{FRAM} - (9 \times 2 \times \text{CBLTEN}) = 0$$

Since there are two cables, one for each bank, the net result is

$$\text{FRAM} - (9 \times 2 \times 2 \times \text{CBLTEN}) = 0$$

or  $\text{CBLTEN} = \text{FRAM} / 36$  for the Mark 7 Mod 1 arresting gear with a conventional wrap.

In the above discussion, it was noted that the net force acting in the opposite direction to the ram was the cable tension. There is another force, friction drag, which also acts within the system. This force is due to cable drag, cable bounce, slipper friction, etc. It is the summation of all the additional force outside of the main engine cylinder that arrest the aircraft.

$$\text{CBLTEN} = \text{FRAM} / 36 + \text{FDRAG}$$

$$\text{FDRAG} = (1 - \text{MCHEFF}) \times \text{TOTENG} / 2 \times \text{CBLPOU}$$

where TOTENG is the total energy of the engagement.

c. Hookload. Hookload is the force transmitted from the cable to the hook. For on center arrestments it is

$$\text{HKLOAD} = 2 \times \text{CBLTEN} \times \text{COS} (\theta)$$

d. Thrust. Engine thrust developed by the aircraft acts in the opposite direction to the retarding forces developed by the arresting engine. A standard method of approximating it is .4 to .65 times the weight of the plane.

$$\text{THRUST} = K \times \text{ACWGHT}$$

e. Deceleration. From Newton's Law,  $F=Ma$ , the combination of hookload and thrust results in

$$\text{THRUST} - \text{HKLOAD} = \frac{\text{ACWGHT}}{\text{ACGTY}} \times \text{DECEL}$$

DECEL = rate of change of aircraft velocity. Since the engaging velocity is known, it is possible, through the computer program, and assuming a constant aircraft acceleration during each time step, to calculate the new velocity at the end of the time increment. That is

$$\text{DECEL} = \frac{\text{VELIN} - \text{VELOF}}{\text{TIME}}$$

$$\text{and VELOF} = \text{VELIN} + \frac{\text{ACGTY}}{\text{ACWGHT}} (\text{THRUST} - \text{HKLOAD})$$

10. MECHANICAL EFFICIENCY. Mechanical efficiency is defined as the energy absorbed by the main engine cylinder taken as a percentage of the total energy of the arrestment. Since previous experimental calculations of mechanical efficiency neglected aircraft thrust, it was necessary to make theoretical approximations using the computer program as to its actual value. The equation developed from these approximations is similar to the experimental result obtained from the Mark 7 Mod 3 gear, and in fact, was effective in producing suitable hydraulic pressure cards for the Mark 7 Mod 1.

$$\text{MCHEFF} = .201 (\text{TOTENG})^{.084}$$

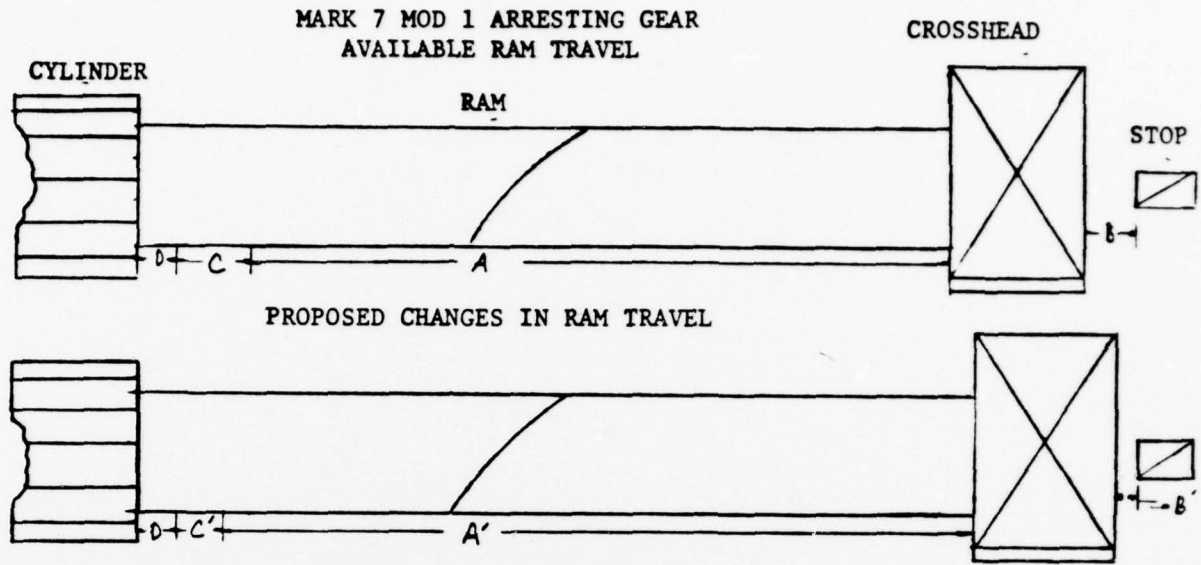
11. VELOCITY COEFFICIENT. The velocity coefficient is a measure of the viscous losses during contraction of the fluid. Actual velocity coefficients for any type orifice can be only determined experimentally. It was necessary, therefore, to apply the same theoretical procedure for approximating velocity coefficients as with mechanical efficiency. The range of velocity coefficients was known. For different weights and speeds, different coefficients were substituted until suitable hydraulic cards were developed. For the sake of simplicity in the computer program, an equation for velocity coefficients was developed as a function of aircraft weight.

$$\text{VELCOF} = 3.126 \times (\text{ACWGHT})^{-.111}$$

## 12. DESIGN CONDITIONS.

### a. Hydraulic Ram Stroke.

(1) The following diagrams compare the present operating conditions with the proposed changes.



Present Conditions    Proposed Conditions

A - Total Ram Travel	118"	
A' - Total Ram Travel		122"
B - Initial Crosshead Location	9"	
B' - Initial Crosshead Location		7"
C - Two-Block Safety Distance	4 5/8"	
C' - Two-Block Safety Distance		2 5/8"
D - Two-Block Stopper	<u>2 1/4"</u>	<u>2 1/4"</u>
E - Length of Two-Block Stroke	133 7/8"	133 7/8"

The reduction of the two-block distance from 4 5/8" to 2 5/8" and the placement of the crosshead at the 7" mark, allows for a total ram travel of 122". As the cable stretches, and the crosshead moves towards the crosshead stop, additional ram travel can be utilized by further rotation of the cam.

b. Mean Cylinder Pressure Drop

Maximum Cylinder Pressure - 10,000 psi  
 Present Ram Travel - 118.1 inches  
 Proposed Ram Travel - 122.0 inches  
 Piston Area - 314.16 sq. in.  
 Total Energy Absorbed =  $10,000 \text{ psi} \times \frac{118.1 \text{ in.} \times 314.16 \text{ sq. in.}}{12}$

=  $30.9 \times 10^6$  ft-lbs.

Mean Cylinder Pressure Drop =  
 $(10,000 - dp) \times \frac{122 \times 314.16}{12} = 30.9 \times 10^6$  ft-lbs.

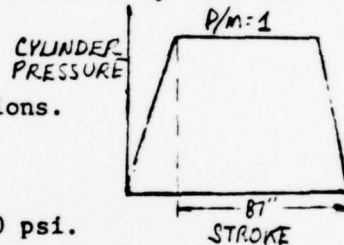
dp = 320 psi

The Mean Cylinder Pressure range is 87 inches. So the drop over this range is  $\frac{122 \times 320}{87} = 450$  psi.

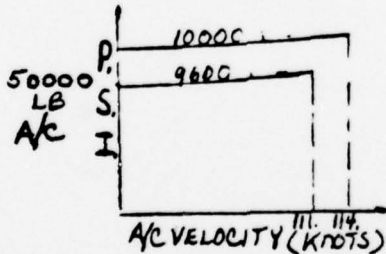
Assuming an 85% efficiency after maximum conditions.

$.85 \times 450 = 380$  psi

For 122" ram travel, the design condition is 400 psi.



c. New Engaging Velocity. From NAEC MISC 09344, a 50,000 lb. aircraft @ 111 knots, develops a 10,000 psi MEC pressure. The 400 psi drop due to the extended ram travel corresponds to a velocity change of 3 knots. The new engaging velocity is now theoretically 114 knots.



d. New Dial Curve. An aircraft dial curve has been developed for the 122" ram stroke. (See Figure 25). The effect of the new cam coordinates on a wide range of pressure cards is shown in Figures 26-29.

## IV. RESULTS AND DISCUSSION

The reliability of the MK 7 Mod 1 hydraulic simulation program was established by pressure simulations of actual aircraft test events. The experimental and theoretical plots showed similar trends. (See Figures 1-8).

The aircraft weight dial settings used in the simulation were from the actual test settings. Velocity coefficients and mechanical efficiency values (See Figure 10) were taken from the theoretical equations derived specifically for the Mod 1 gear. The thrust ratings used in the A-3 performance simulations and the development of the aircraft weight settings were .4 times the weight of the aircraft. In the development of simulations for 118.1 inch stroke, the thrust ratings varied according to projected aircraft capability. (This was necessary because over an extended runout a variance of .1 to .2 percentage points for the K factor results in a significant total energy difference).

The main engine cylinder pressure limit of the Mod 1 is 10,000 psi. Aircraft calibration test reports for the Mod 1 gear show that a 50,000 lb. aircraft at 111 knots will develop this peak cylinder pressure. (The A-3 was used because it is the heaviest in the fleet. The F-4J also develops critical loads because of its specific aircraft requirements). Figure 9 shows the simulation of this condition.

Figures 11 and 12 are comparison plots of the pressure trends for the 122" cam designs and the 118" K-5 cam. The simulations were made for the A-3 aircraft at various engaging speeds. (See Figures 13-24). The trends meet the 400 psi design criteria throughout the range of engaging velocities.

Figure 25 shows the aircraft dial settings for the extended stroke and the K-5 cam. Figures 26-29 show the development of the dial settings for the new cam design.

The F-4J is a 38,000 lb. plane with an afterburner thrust to weight ratio of .63. Figure 30 shows the cylinder pressures developed in the F-4 using the standard .4 ratio. Figures 31 and 32 show pressure simulations for an F-4J under its landing conditions.

The hydraulic cards for the F-4J show underset conditons. The MEC pressure limit is not exceeded, but the limits for cable tension and hookload are with the afterburner thrust ratings. (See Figures 33-36).

V. CONCLUSIONS

1. The new cam design and the standard K-5 cam rotated on its dwell develop significant pressure reductions in MK 7 Mod 1 arresting gear recovery operations.
2. Peak cable tensions and hookloads should also be reduced with the extended ram stroke, but in order to determine this a more detailed dynamic analysis of the Mod 1 system is necessary.
3. NATF Report R-172 verifies the trends of this study.
4. A rotated cam or a new cam design shows the same theoretical performance of the MK 7 Mod 1 Arresting Gear.
5. The MK 7 program can adequately simulate the hydraulic loads in an aircraft operation.

VI. RECOMMENDATIONS

1. Establish 122" as the operating service stroke for the Mark 7 Mod 1 Arresting Gear with an upper balanced control valve and with a new reeve of purchase cable.
2. Achieve the increased service stroke (from the present 118 inches to 122 inches) by rotation of the existing control valve cam, P/N 502715-1P.

## VII. REFERENCES

- (a) DD 979 - Mark 7 Mod 1 Arresting Gear - K-5 Cam Coordinates by R. R. Hood
- (b) NAEF MISC. 07262 - Geometrical and Effective Flow Area vs. Stem Lift: Mark 7 Mod 2-3 Arresting Gear Control Valve
- (c) NAEC MISC. 09335 - Mark 7 Mod 1 Arresting Gear Hydraulic Performance Charts
- (d) NAEC-ENG-7511 - Performance Analysis of Mark 7 Mod 3 Recovery System Based on Aircraft Calibration Tests by J. Zurzolo
- (e) Aircraft Recovery Equipment Handbook - Mark 7 Mod 1, 2, and 3, NAVAIR Publications 51-5BAA-1, 51-5BBA-1, 51-5BCA-1
- (f) NATF Report R-172; Evaluation of Mark 7 Arresting Gear Service Changes No. 307 and 320 with the RALS Mark 7 Mod 1 Arresting Gear



CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
EVENT 36579  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-4 A/C WEIGHT-13900 LBS.  
ENGAGING VELOCITY-100.0 KNOTS

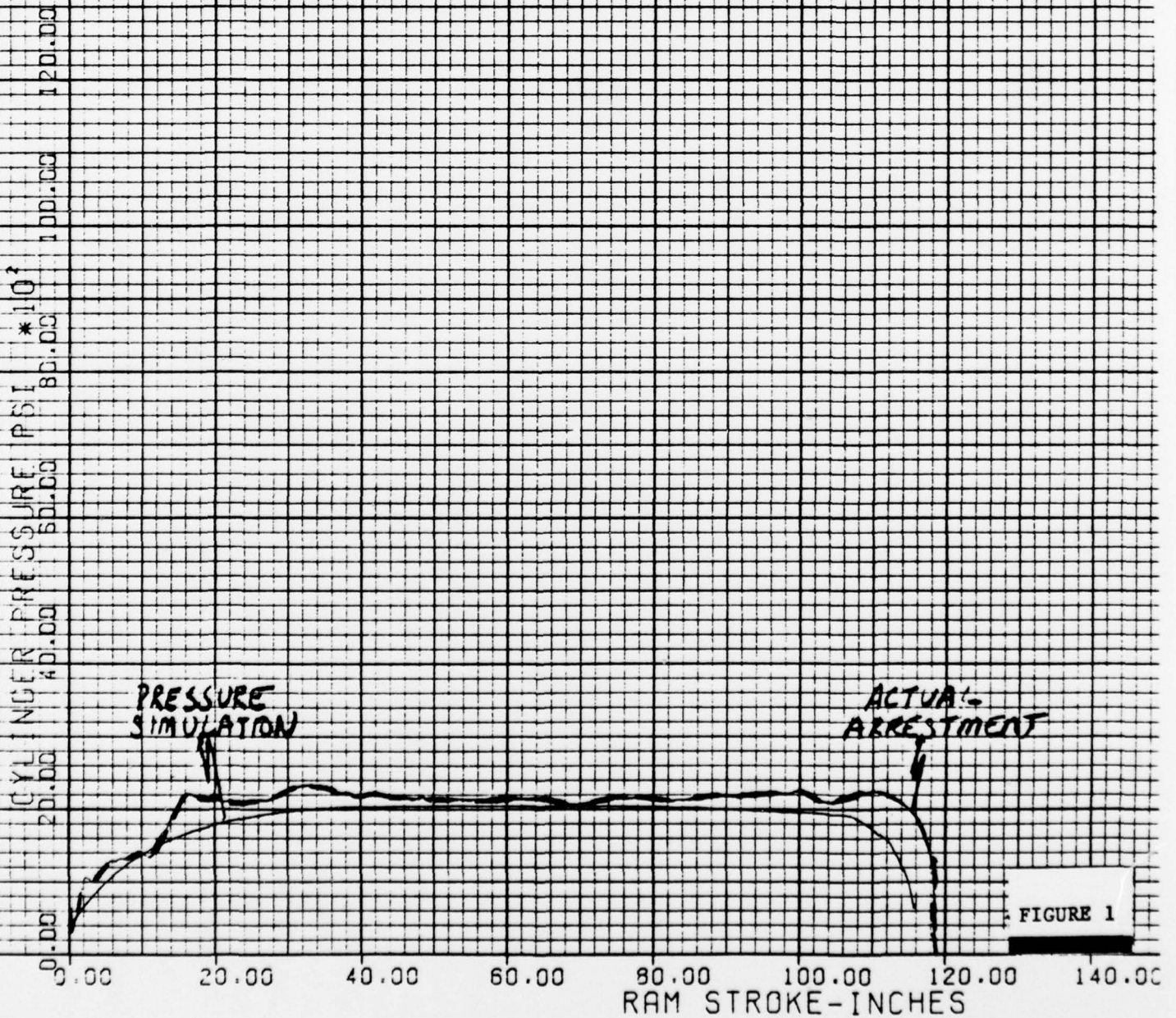


FIGURE 1

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
EVENT 36589  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-4 A/C WEIGHT 14000 LBS.  
ENGAGING VELOCITY-113.4 KNOTS

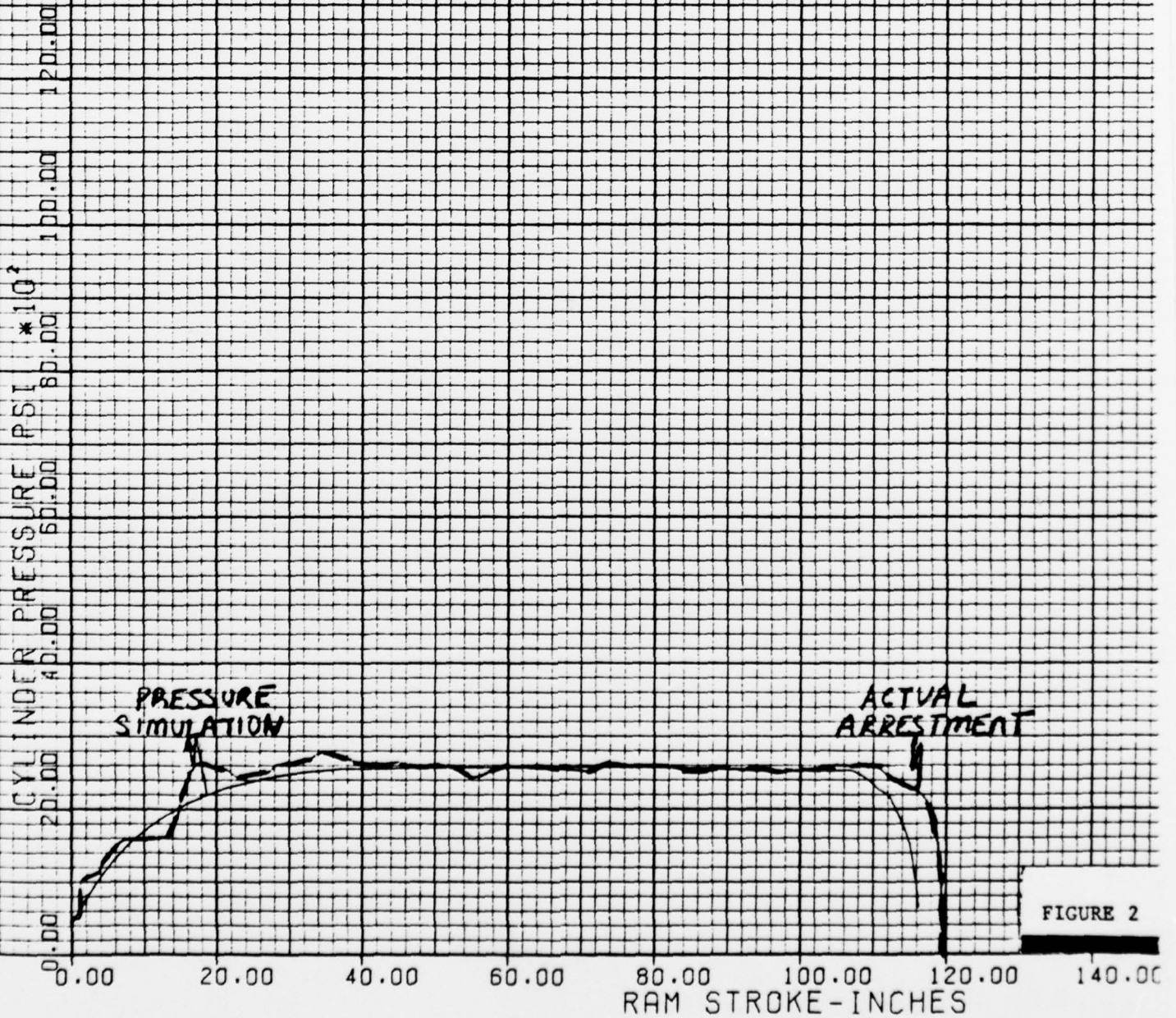


FIGURE 2

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
EVENT 36574  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-7 A/C WEIGHT 25200 LBS.  
ENGAGING VELOCITY-110.4 KNOTS

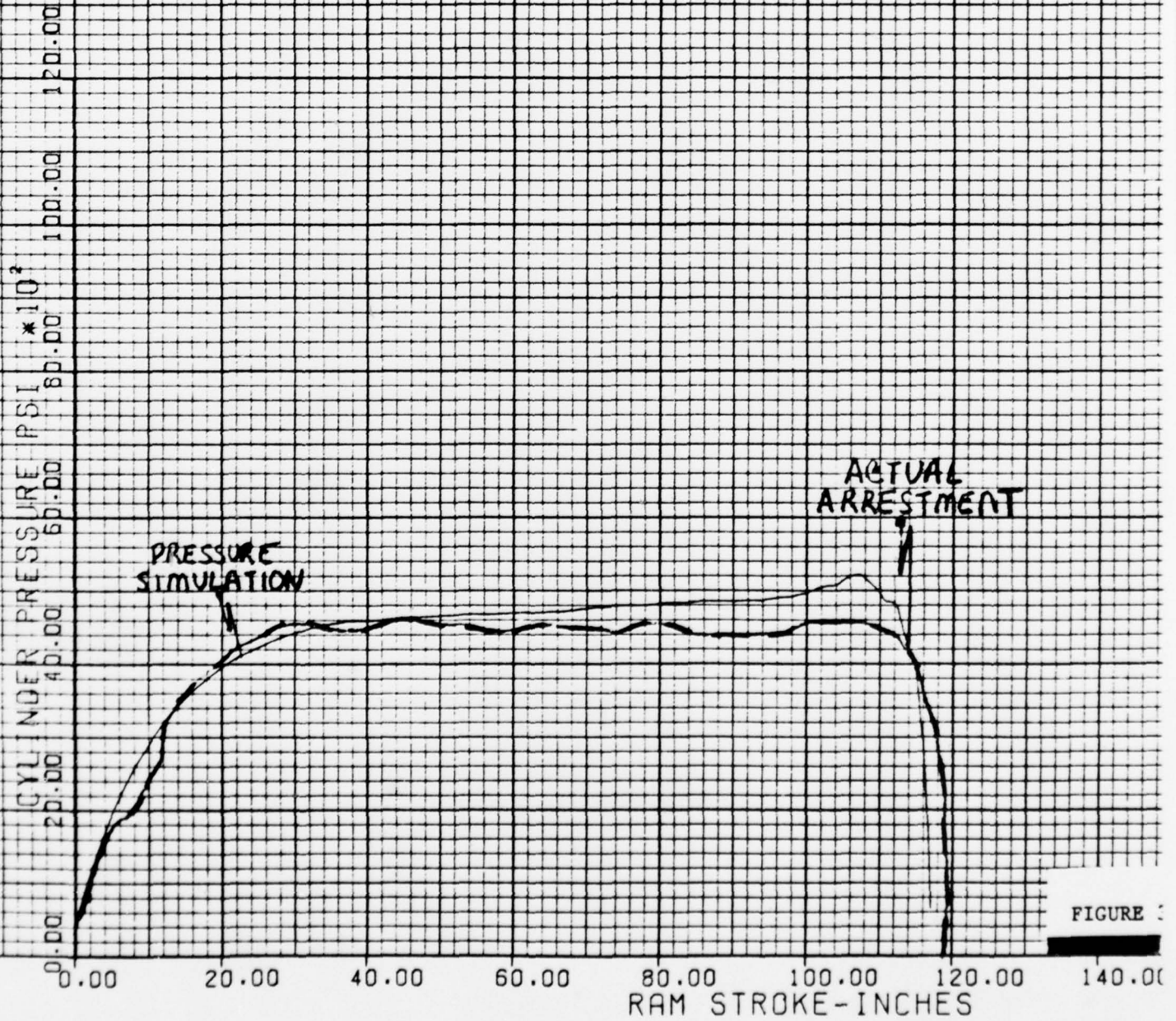


FIGURE 2

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
EVENT 36575  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-7 A/C WEIGHT 25100 LBS.  
ENGAGING VELOCITY-105. KNOTS

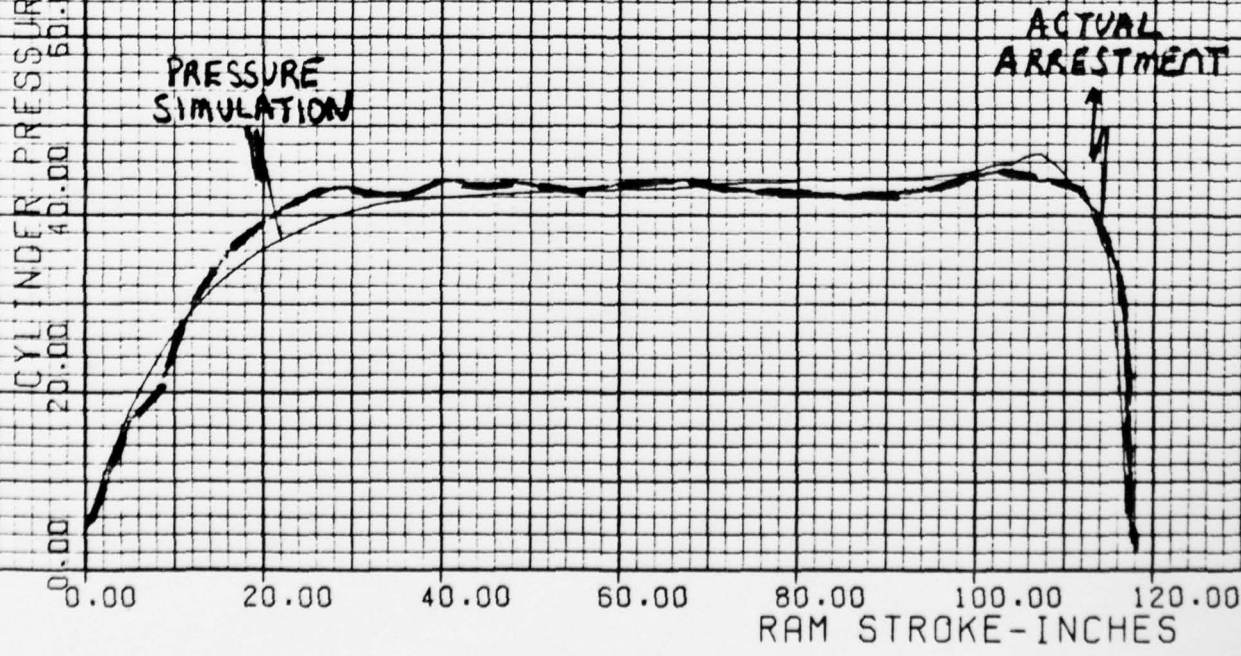
CYLINDER PRESSURE PSI \* 10<sup>3</sup>  
120.00  
100.00  
80.00  
60.00  
40.00  
20.00  
0.00

0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00  
RAM STROKE-INCHES

PRESSURE  
SIMULATION

ACTUAL  
ARRESTMENT

FIGURE 4



CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
EVENT 36667  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
F-4J A/C WEIGHT 37200 LBS.  
ENGAGING VELOCITY-93.0 KNOTS

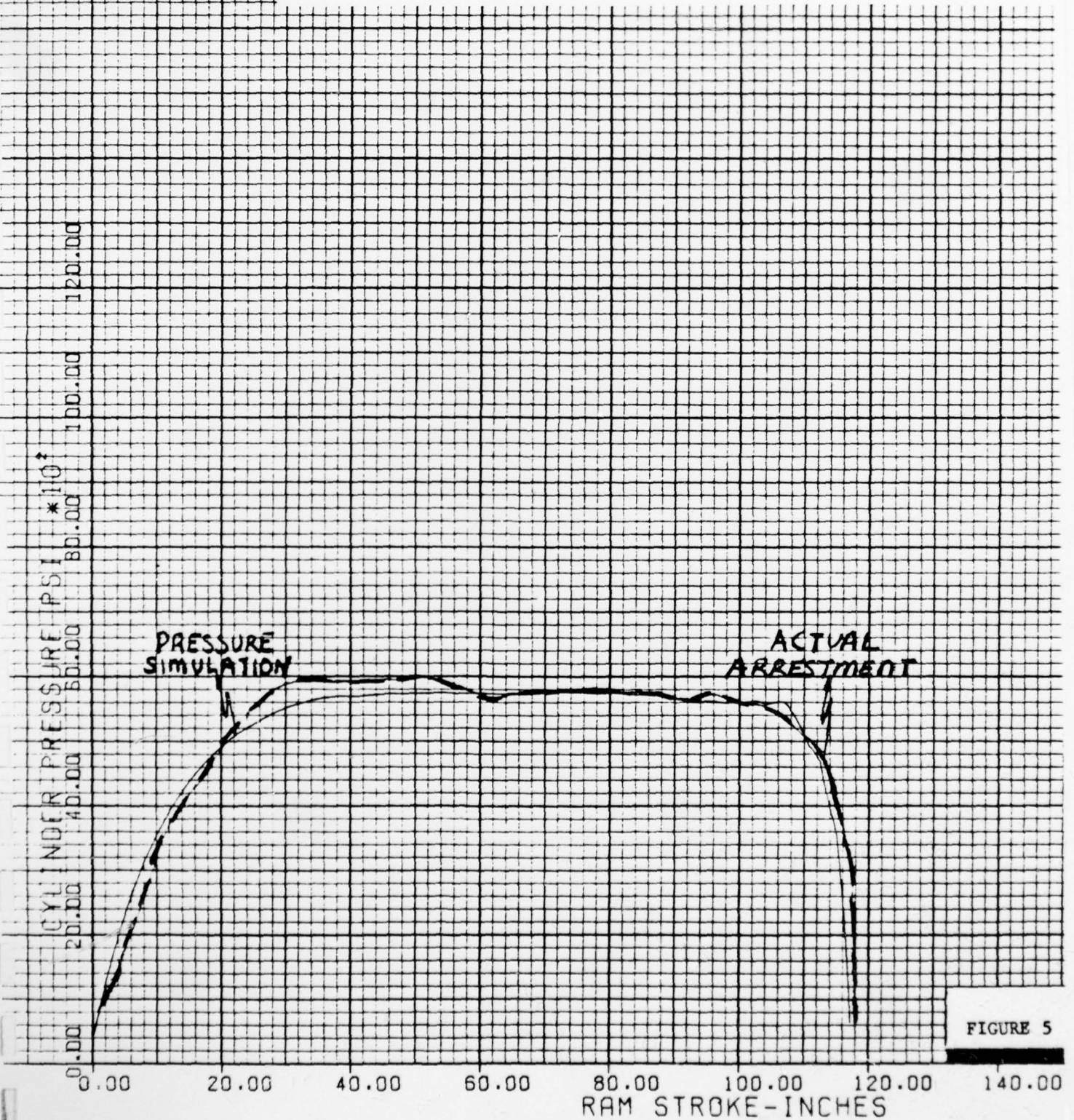


FIGURE 5

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
EVENT 36668  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM 118.1" STROKE  
F-4J A/C WEIGHT 36800 LBS.  
ENGAGING VELOCITY-108.9 KNOTS

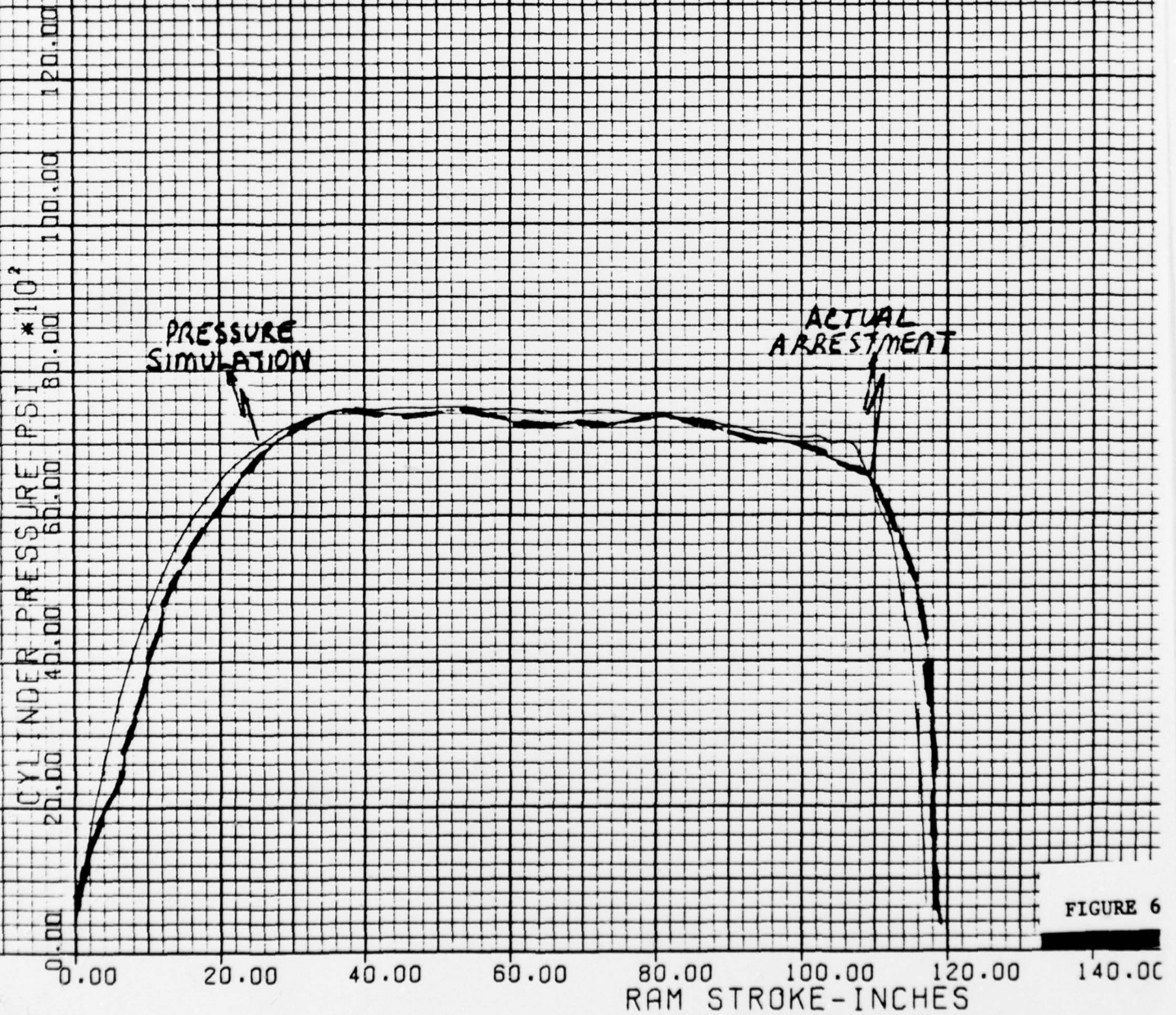


FIGURE 6

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
EVENT 36644  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-3 A/C WEIGHT 49200 LBS.  
ENGAGING VELOCITY-90 KNOTS

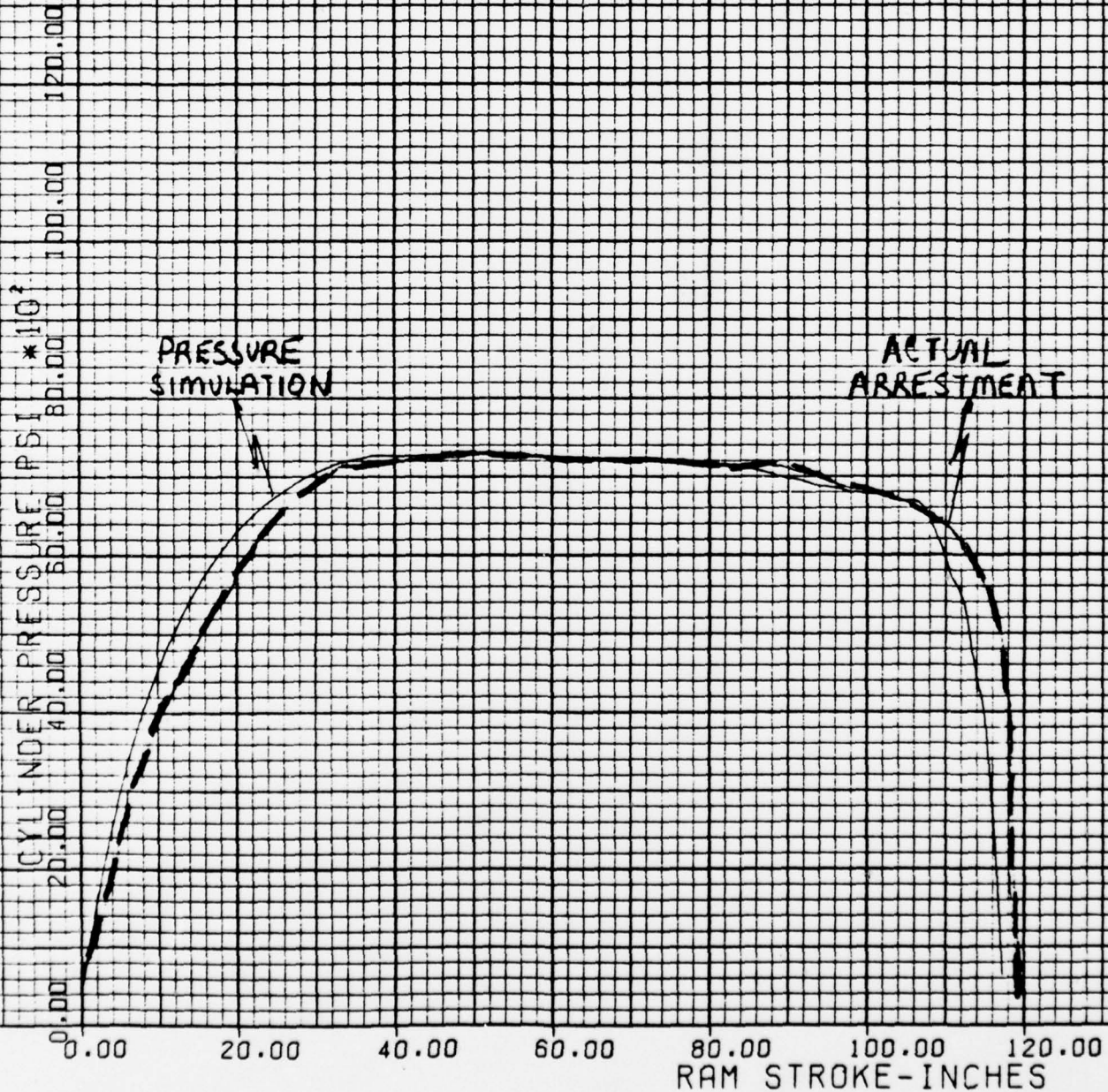


FIGURE 7

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
EVENT 36649  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" STROKE  
A-3 A/C WEIGHT 49500 LBS.  
ENGAGING VELOCITY-105.4 KNOTS

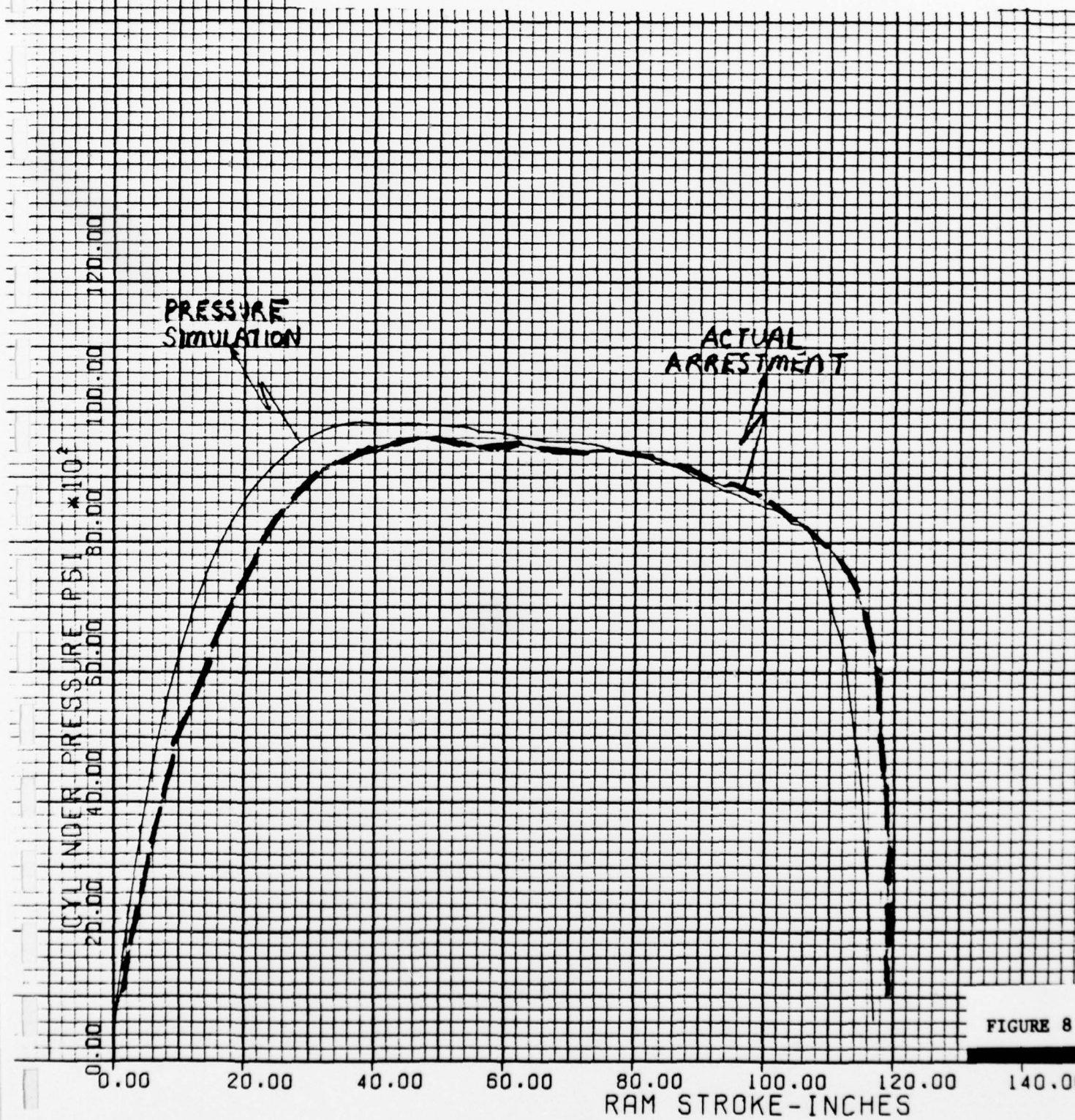


FIGURE 8



CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD I ARRESTING GEAR  
K-5 CAM-118.1" RAMSTROKE  
A-3 A/C WEIGHT 50000 LBS.  
ENGAGING VELOCITY-111.0 KNOTS  
DIAL SETTING-3.16

MAXIMUM MAIN ENGINE CYLINDER PRESSURE  
FOR MOD I ARRESTING GEAR  
50000 LB A/C @ 111 KNOTS

CYLINDER PRESSURE (PSI) \*10<sup>2</sup>  
120.00  
100.00  
80.00  
60.00  
40.00  
20.00  
0.00

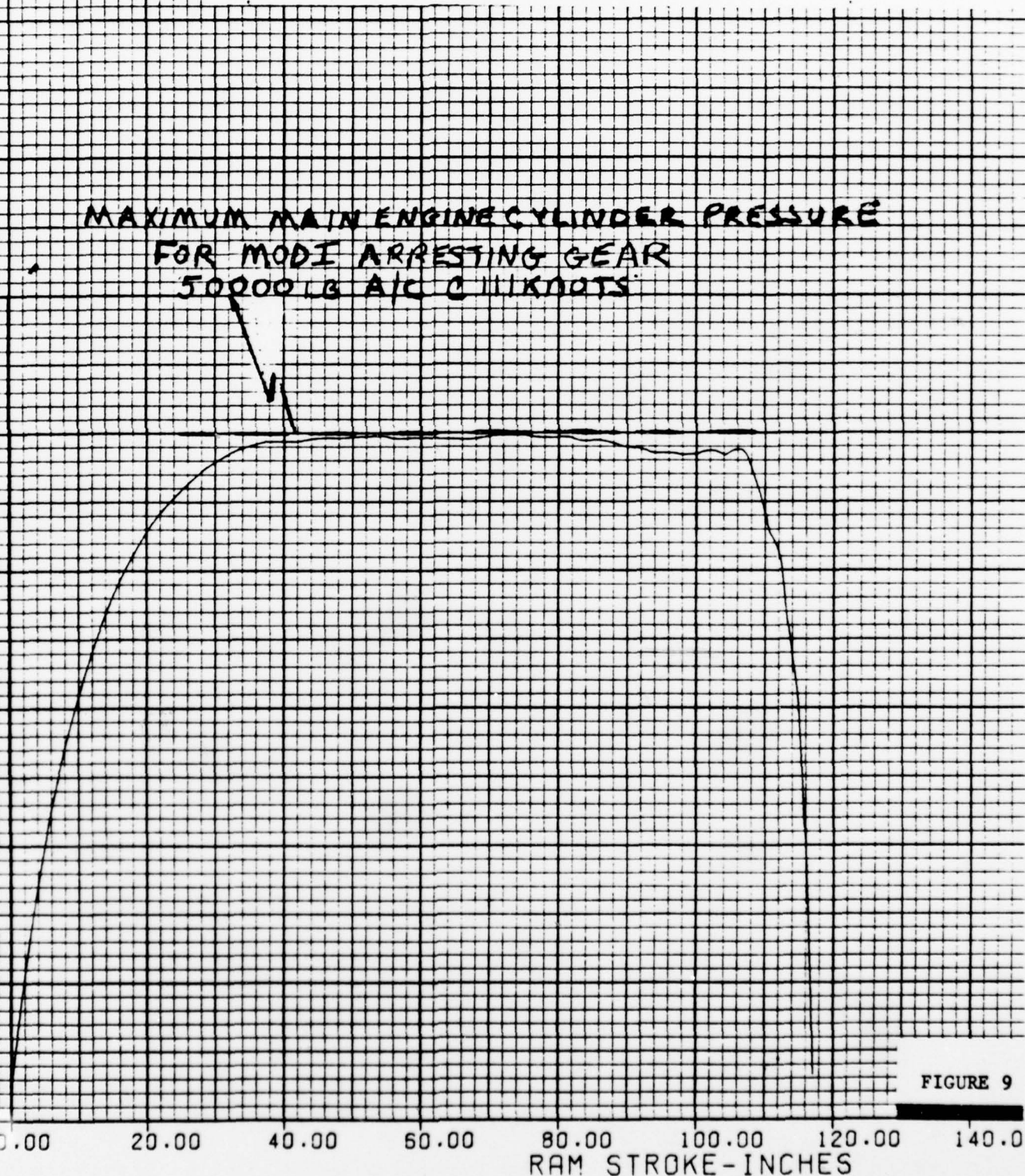
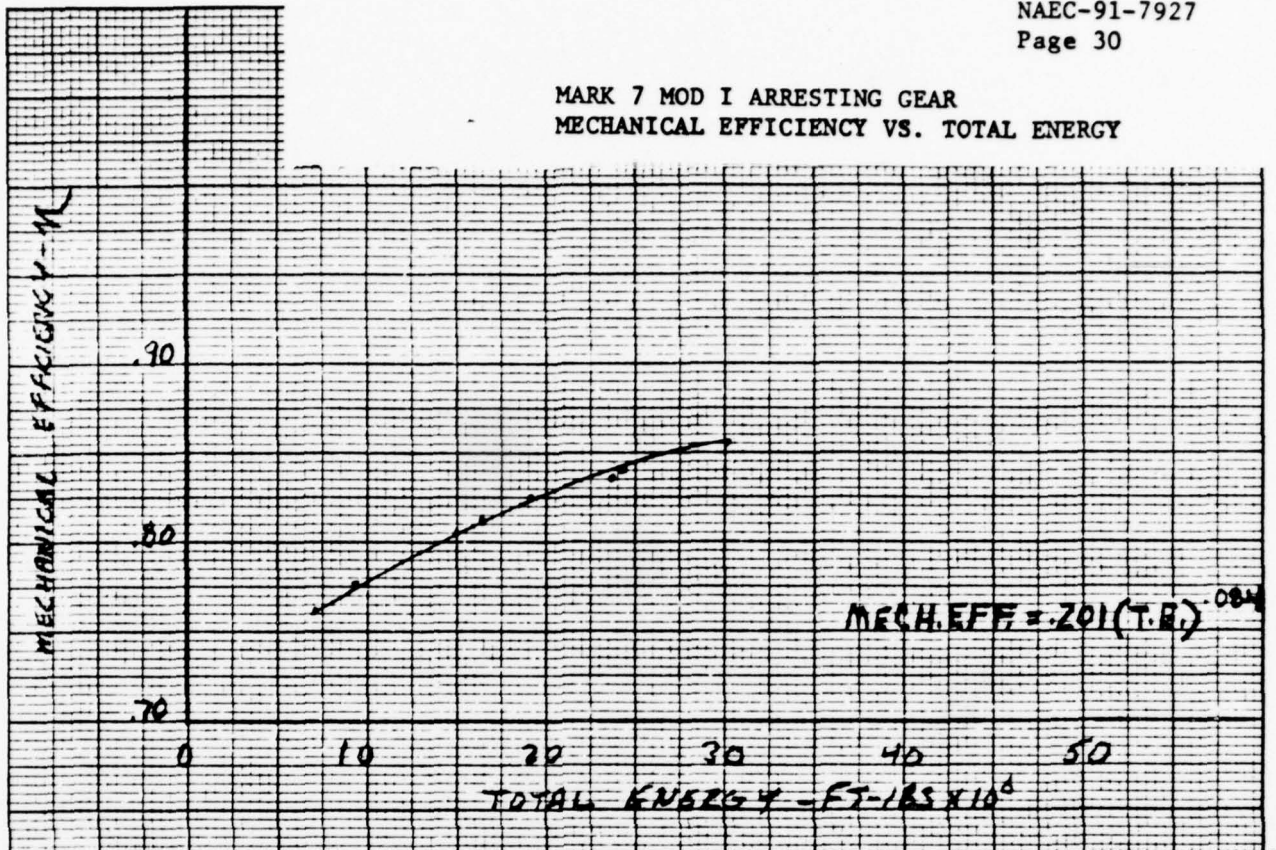


FIGURE 9

MARK 7 MOD I ARRESTING GEAR  
MECHANICAL EFFICIENCY VS. TOTAL ENERGY



MARK 7 MOD I ARRESTING GEAR  
VELOCITY COEFFICIENT VS. AIRCRAFT WEIGHT

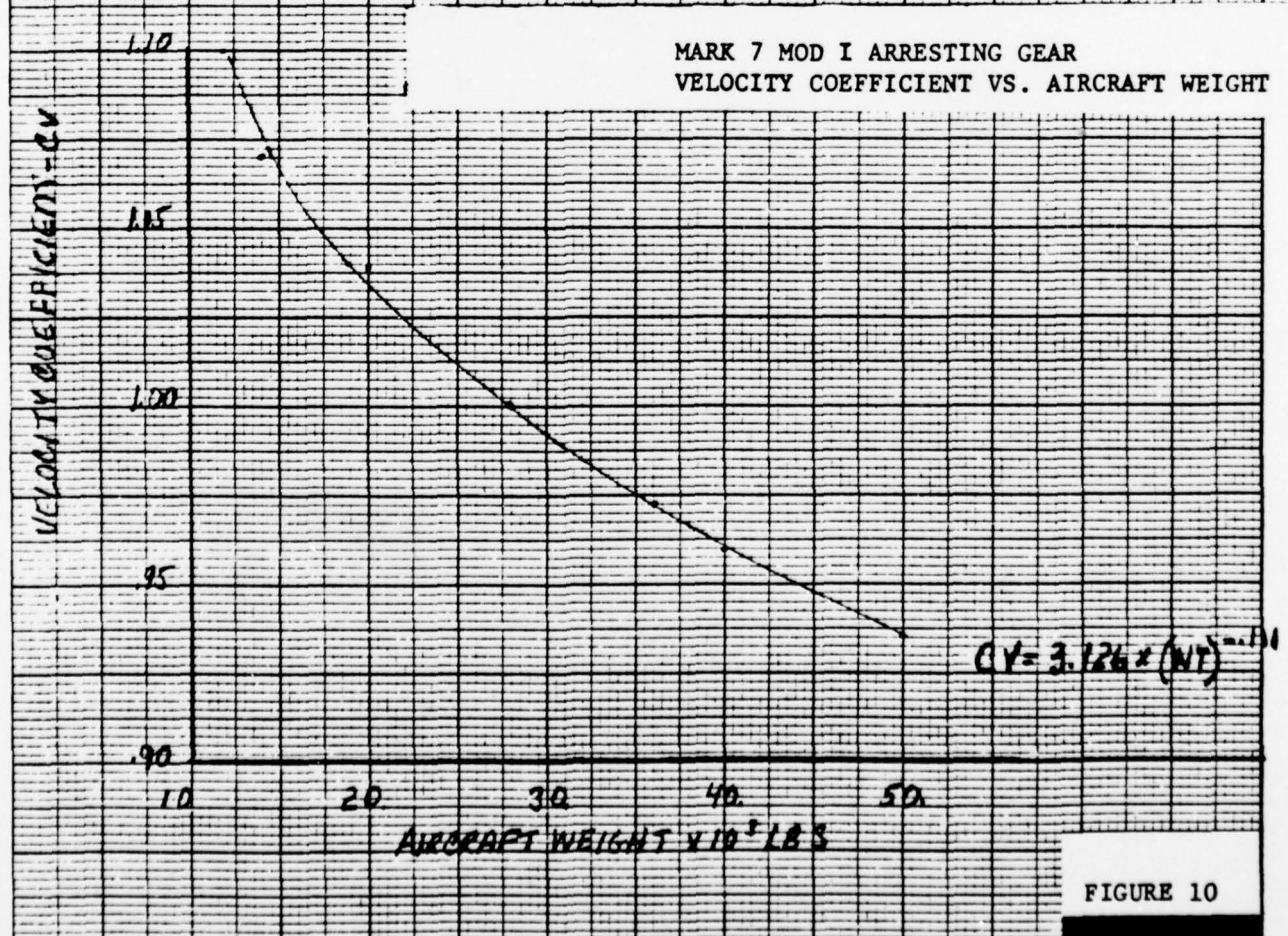


FIGURE 10

MARK 7 MOD 1 ARRESTING GEAR  
PEAK CYLINDER PRESSURE VS. ENGAGING VELOCITY  
COMPARATIVE PERFORMANCE PLOTS  
A-3 AIRCRAFT

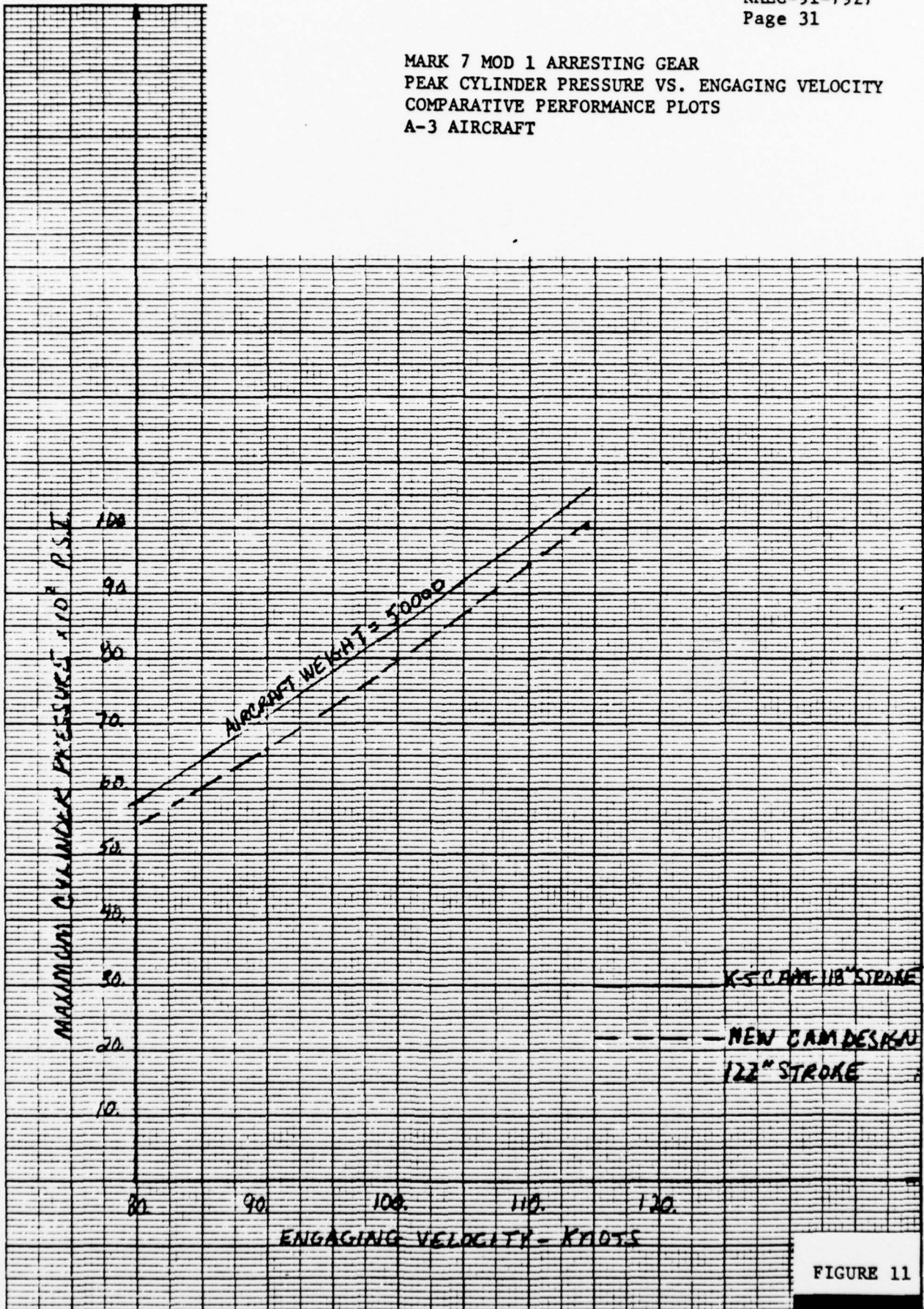


FIGURE 11

MARK 7 MOD 1 ARRESTING GEAR  
PEAK CYLINDER PRESSURE VS. ENGAGING VELOCITY  
COMPARATIVE PERFORMANCE PLOTS  
A-3 AIRCRAFT

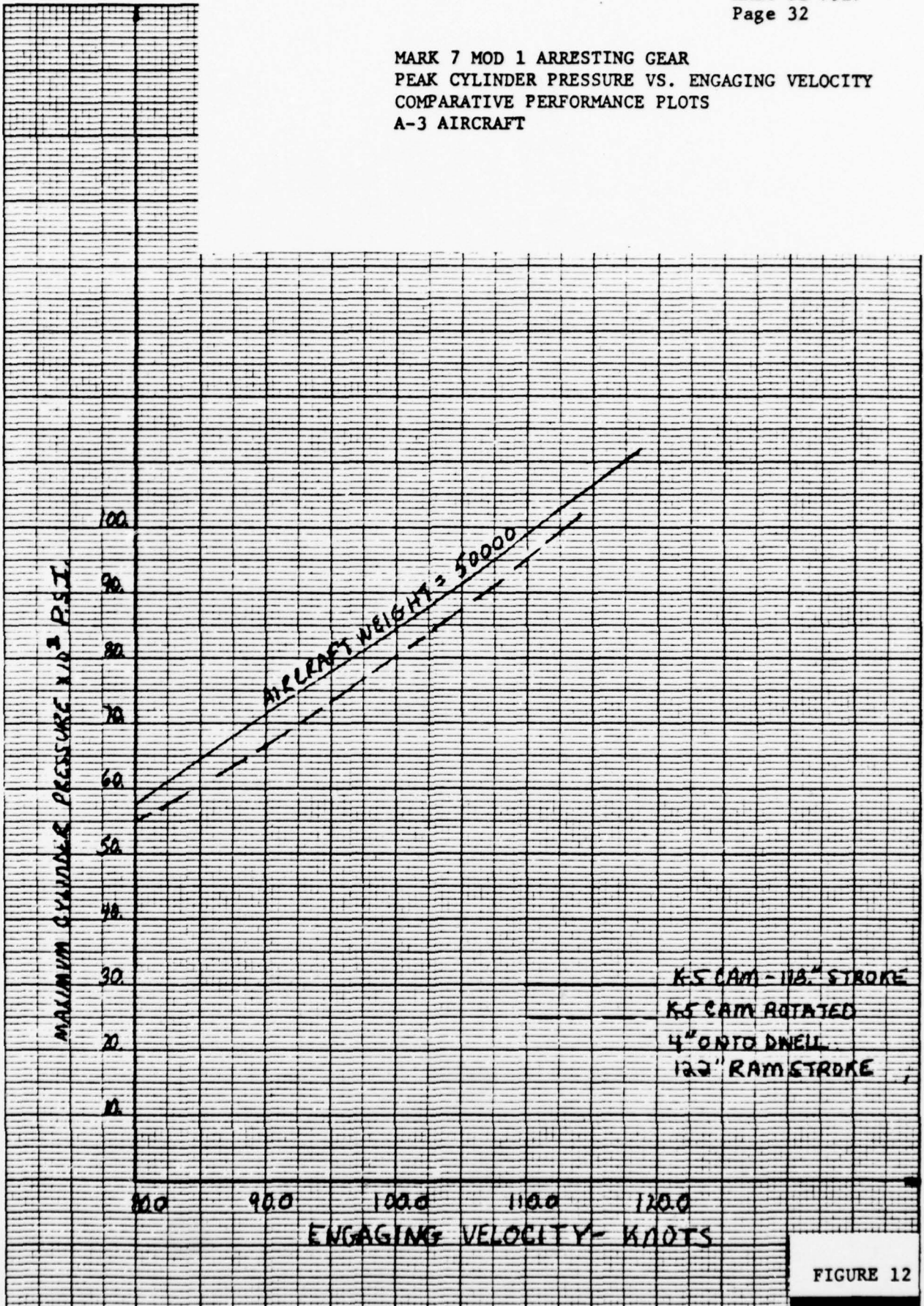


FIGURE 12

CYLINDER PRESSURE VS. RAM STROKES SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT 50000 LBS.  
ENGAGING VELOCITY-80 KNOTS  
DIAL SETTINGS-3.3

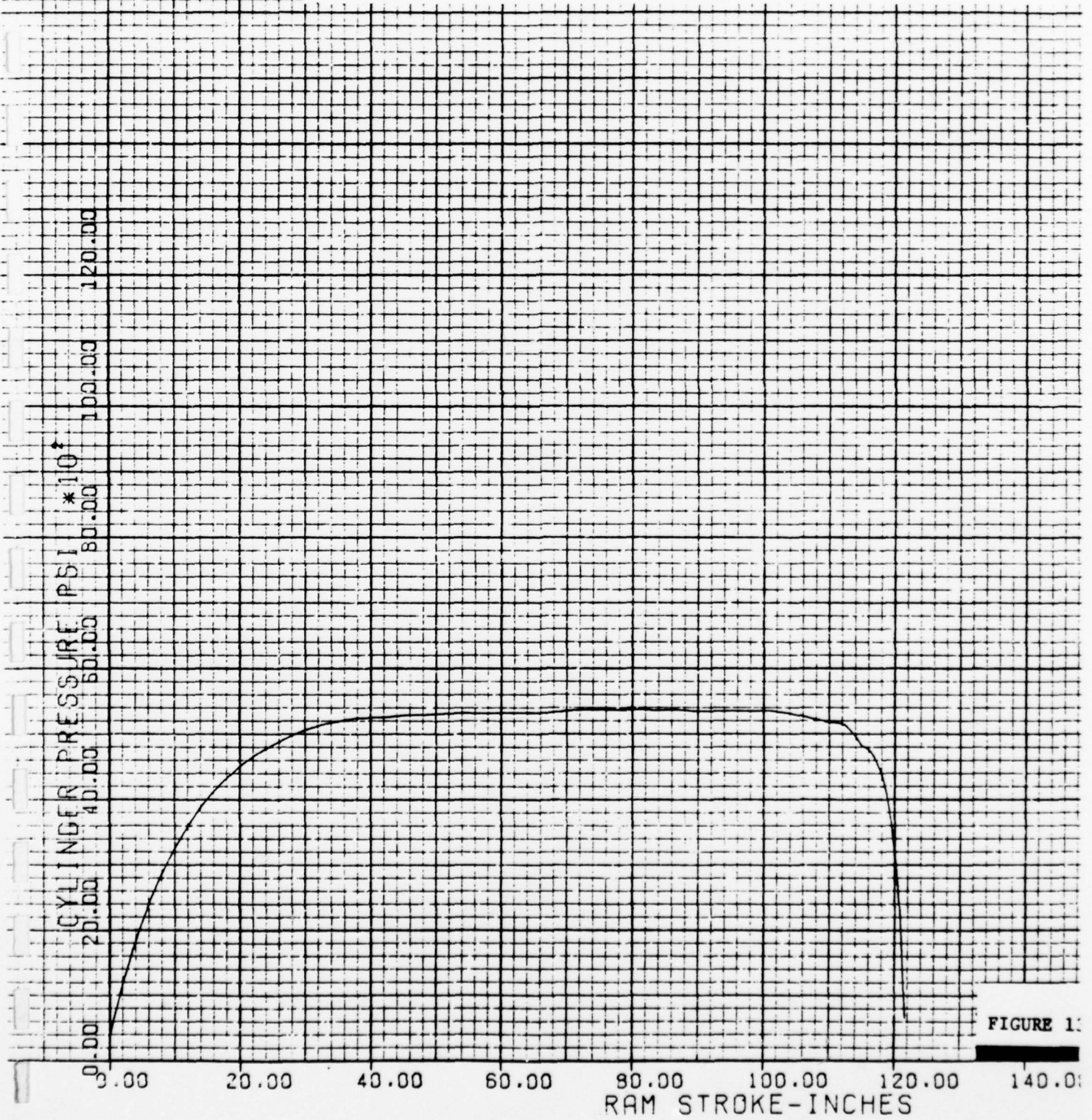


FIGURE 13

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-90.0 KNOTS  
DIAL SETTING-3.3

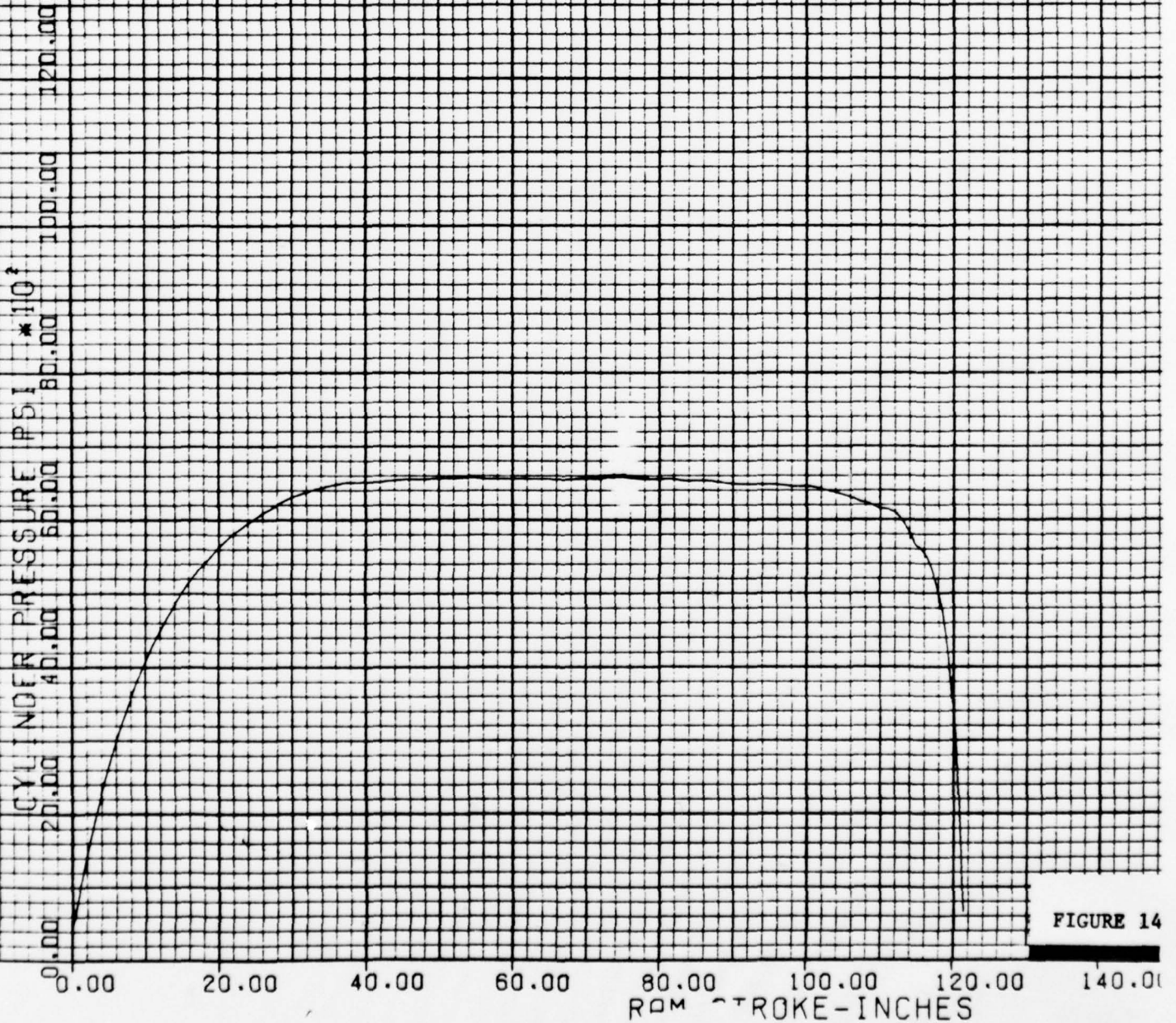


FIGURE 14

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-100 KNOTS  
DIAL SETTING-3.3

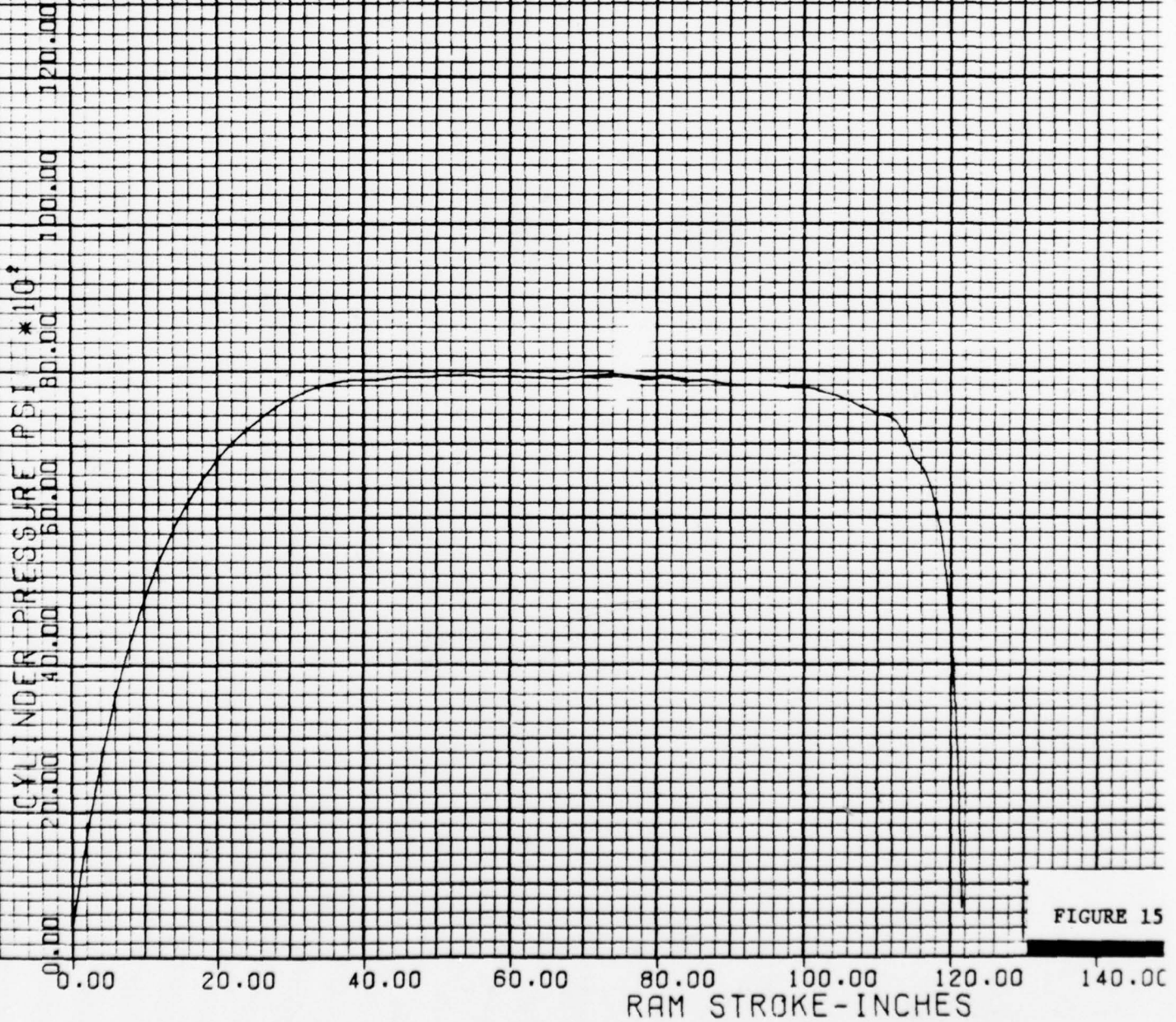


FIGURE 15

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-3.3

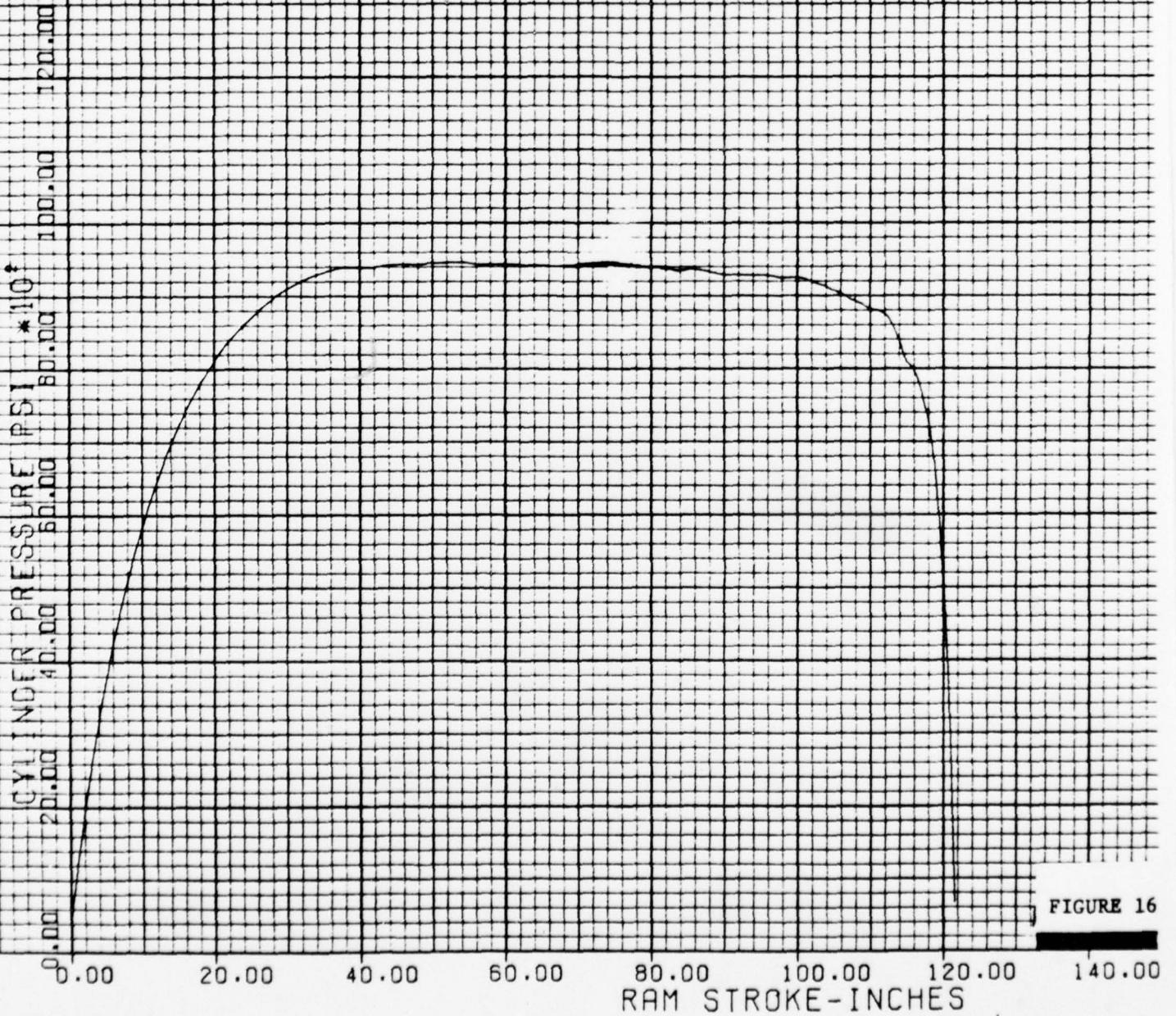


FIGURE 16



CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-111.0 KNOTS  
DIAL SETTING-3.3

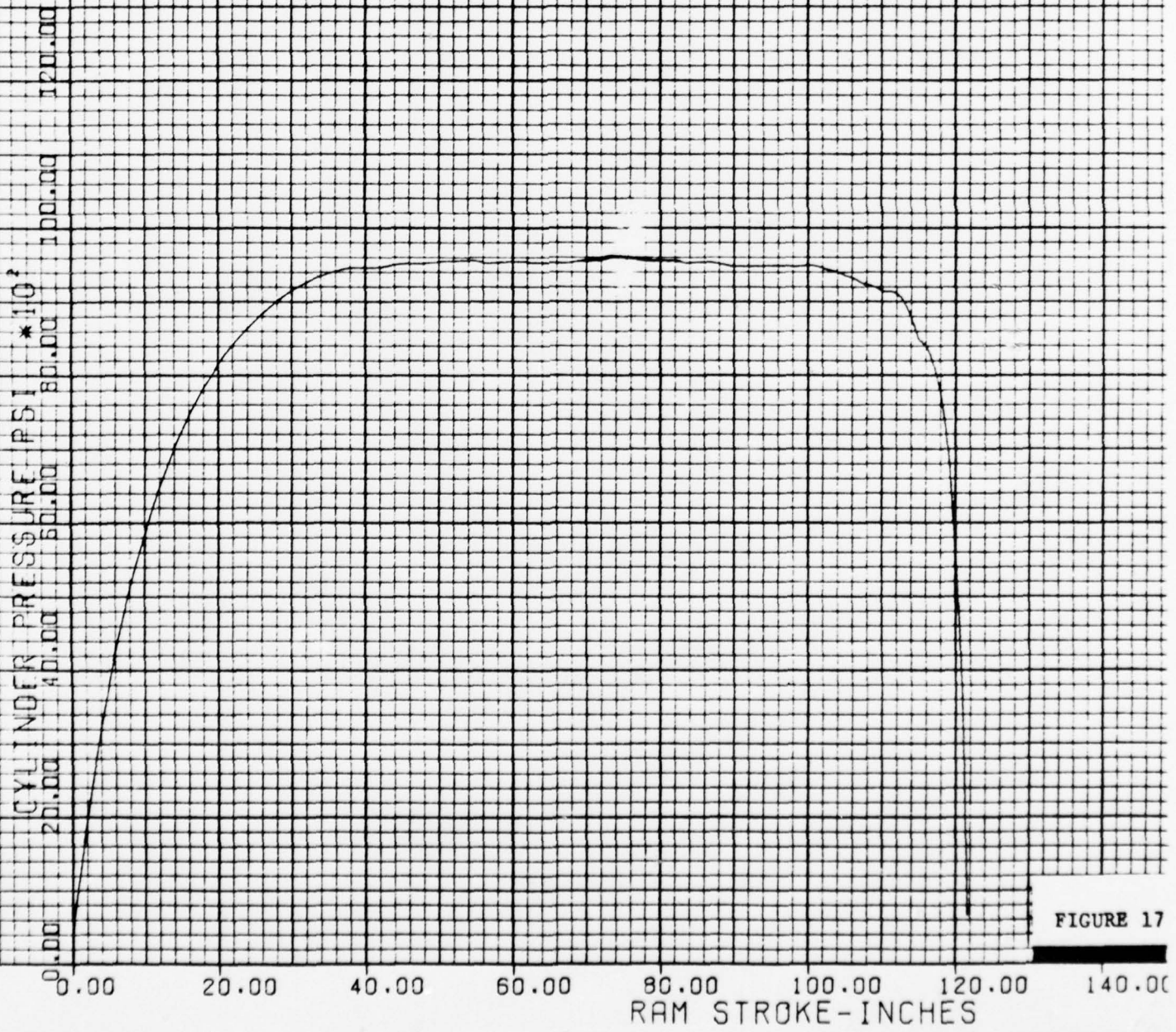


FIGURE 17

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-114.0 KNOTS  
DIAL SETTING-3.3

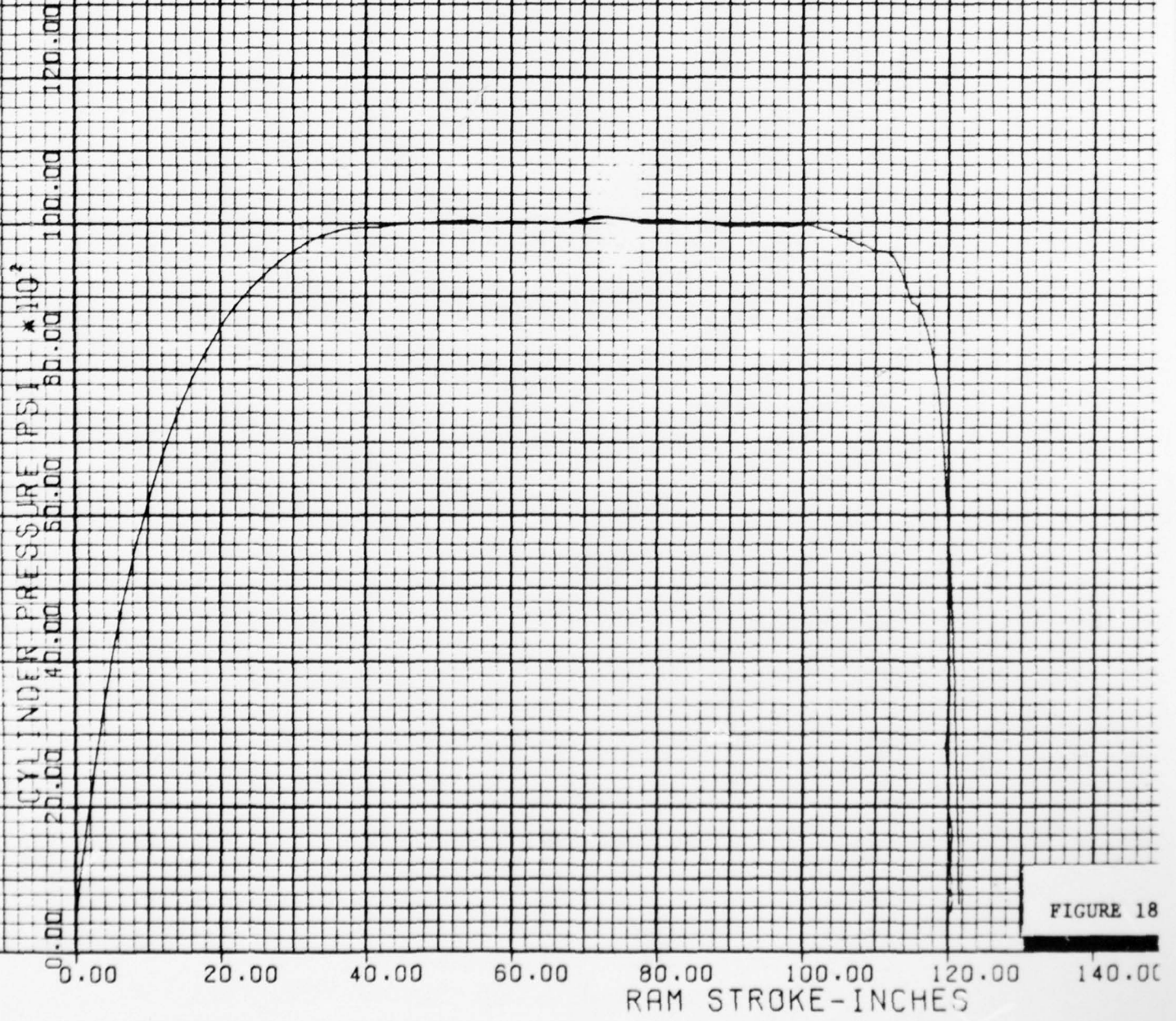


FIGURE 18

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-80.0 KNOTS  
DIAL SETTING-3.16

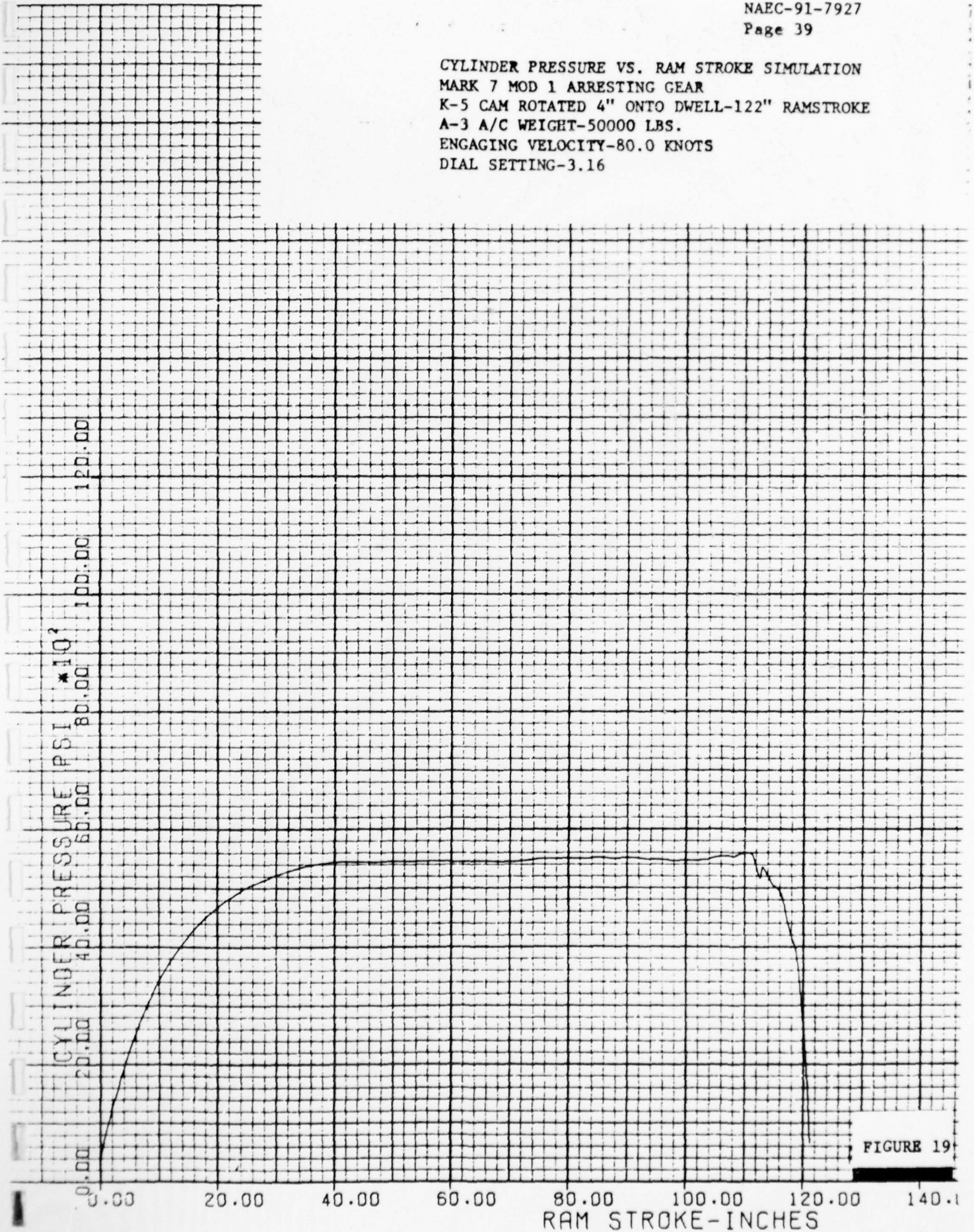


FIGURE 19

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-90.0 KNOTS  
DIAL SETTING-3.16

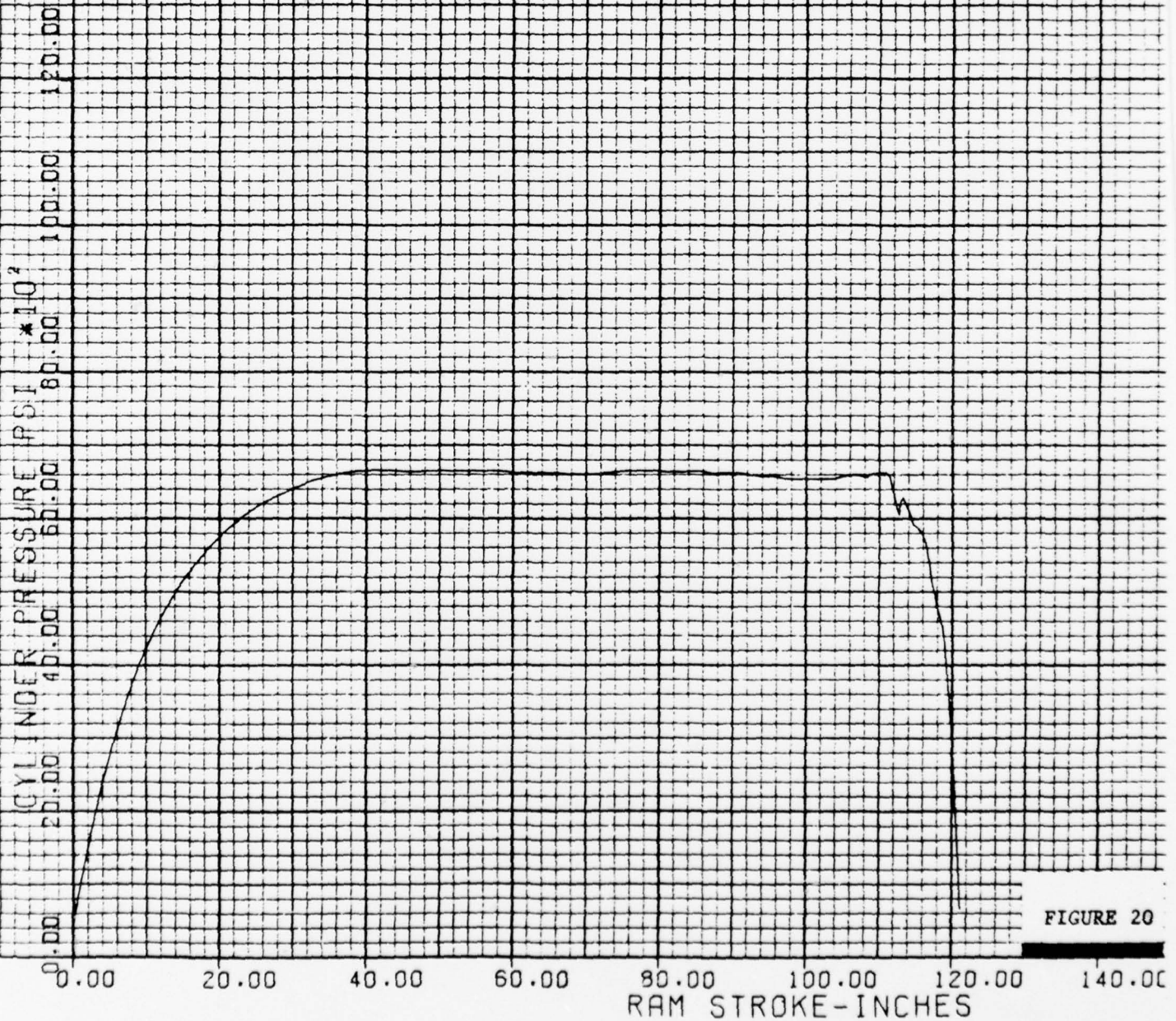


FIGURE 20

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-100.0 KNOTS  
DIAL SETTING-3.16

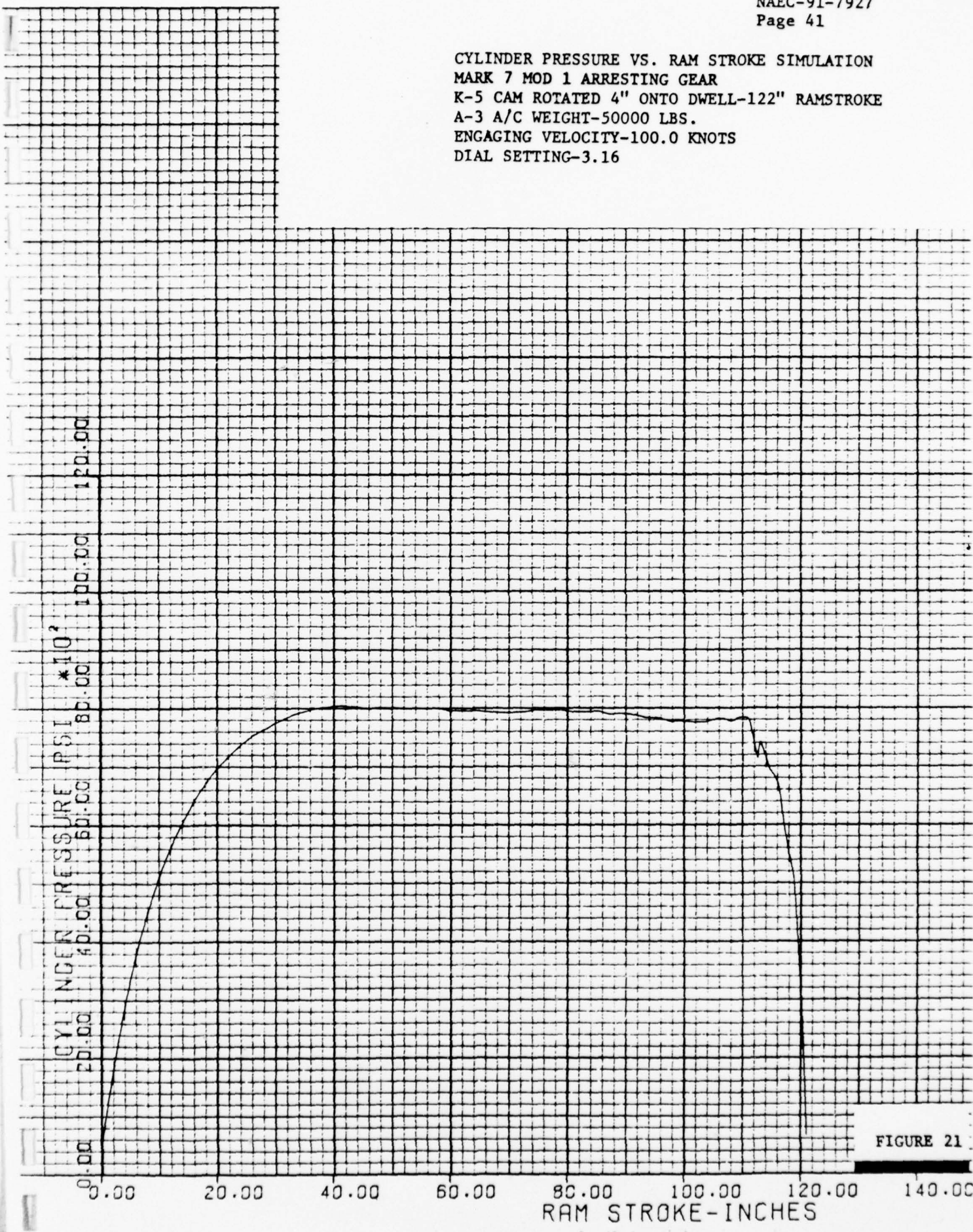


FIGURE 21

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-3.16

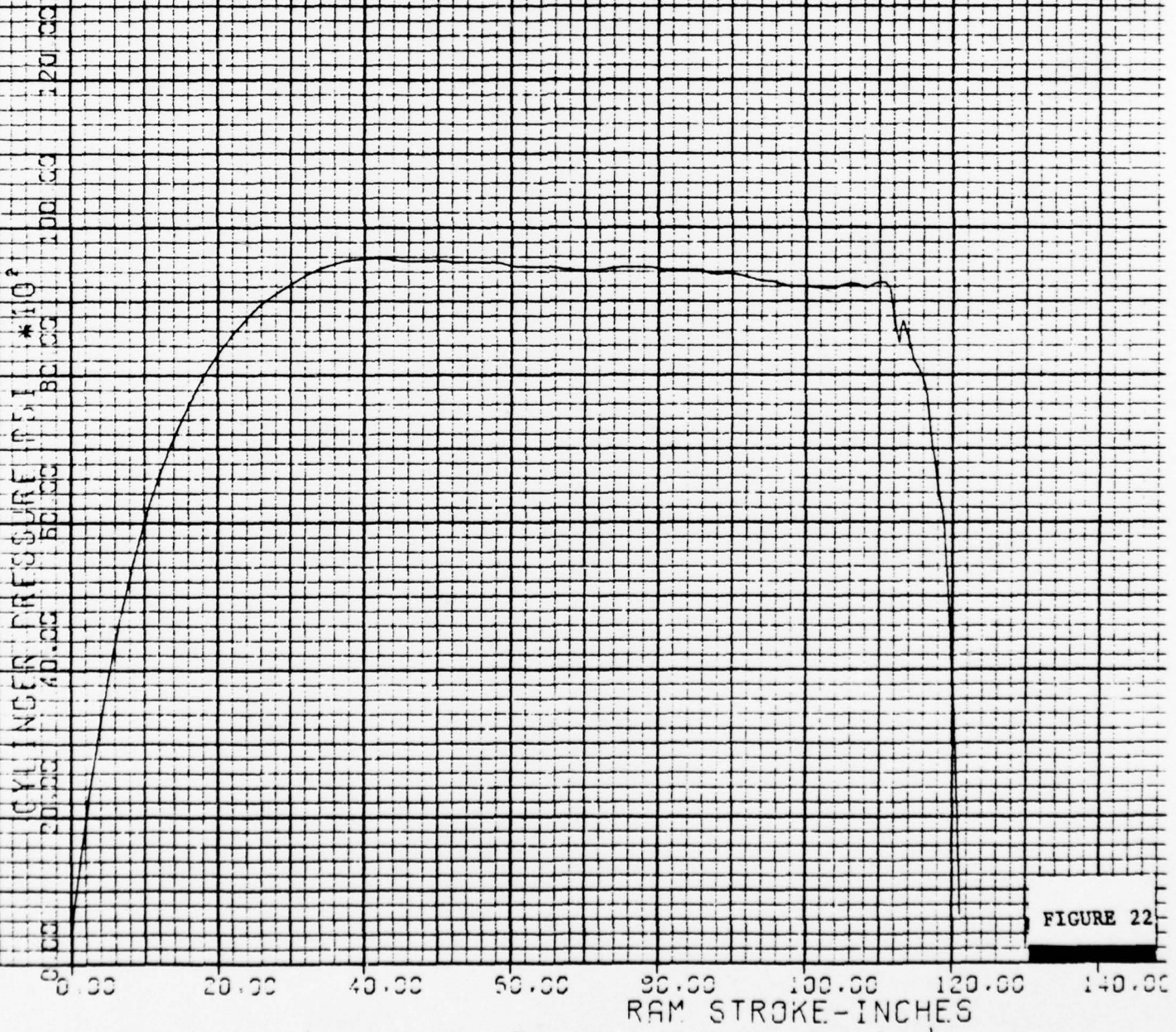


FIGURE 22

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD 2 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-500000 LBS.  
ENGAGING VELOCITY-111.0 KNOTS.  
DIAL SETTING-3.16

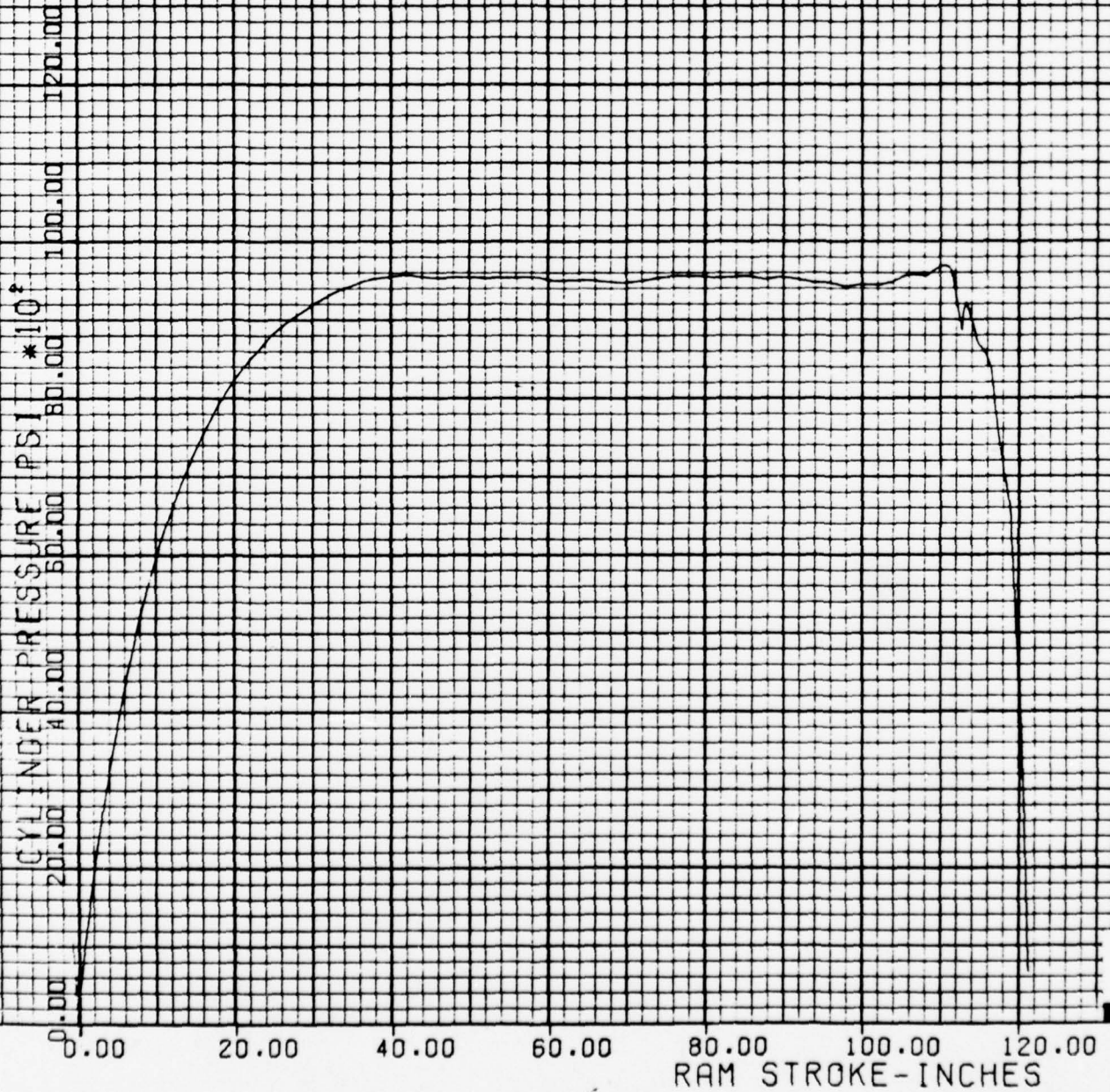


FIGURE 23

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-114 KNOTS  
DIAL SETTING-3.16

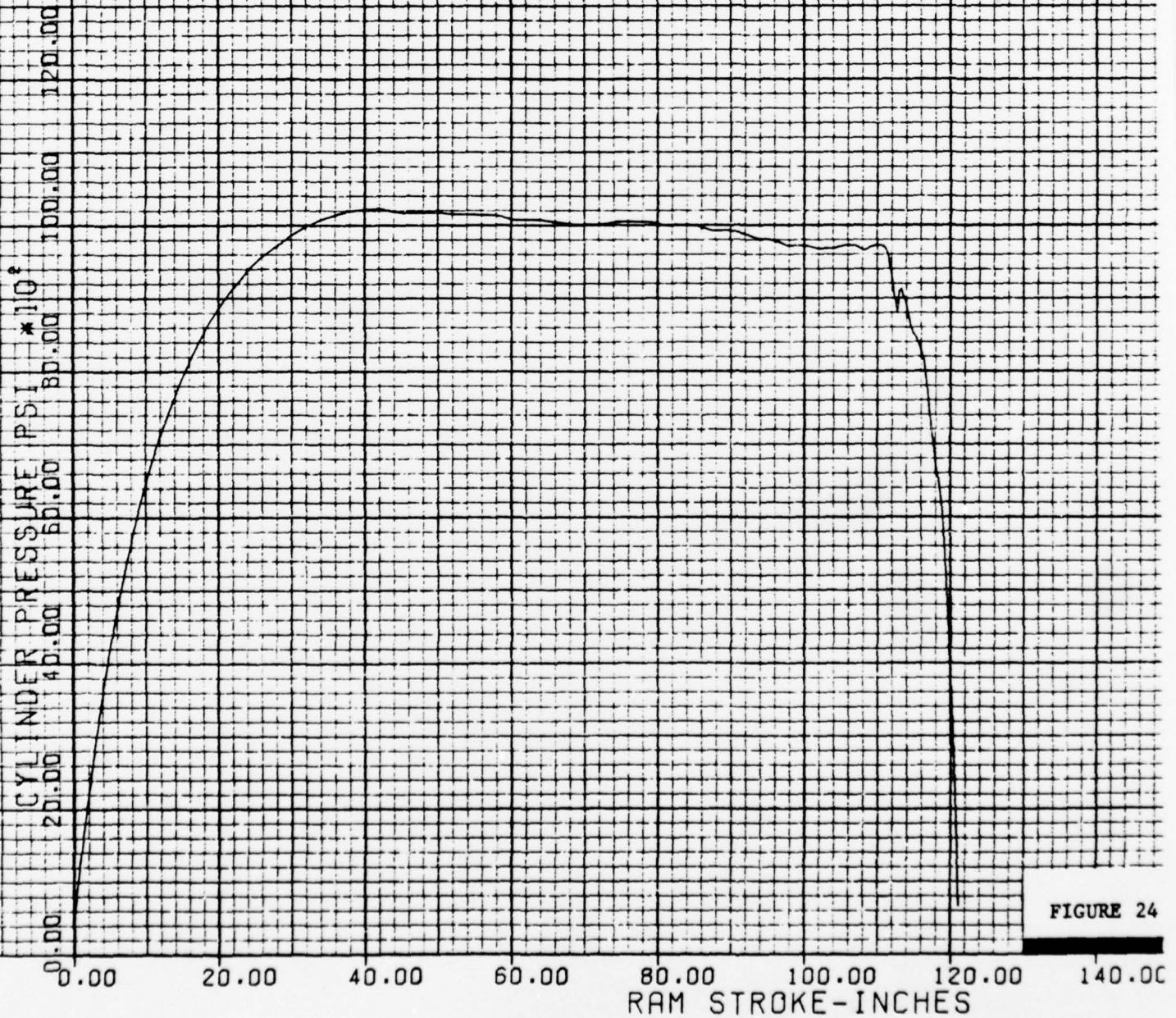


FIGURE 24



CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 8" ONTO DWELL-126" RAMSTROKE  
A-3 A/C WEIGHT-50000 LBS.  
ENGAGING VELOCITY-111 KNOTS  
DIAL SETTING-3.16

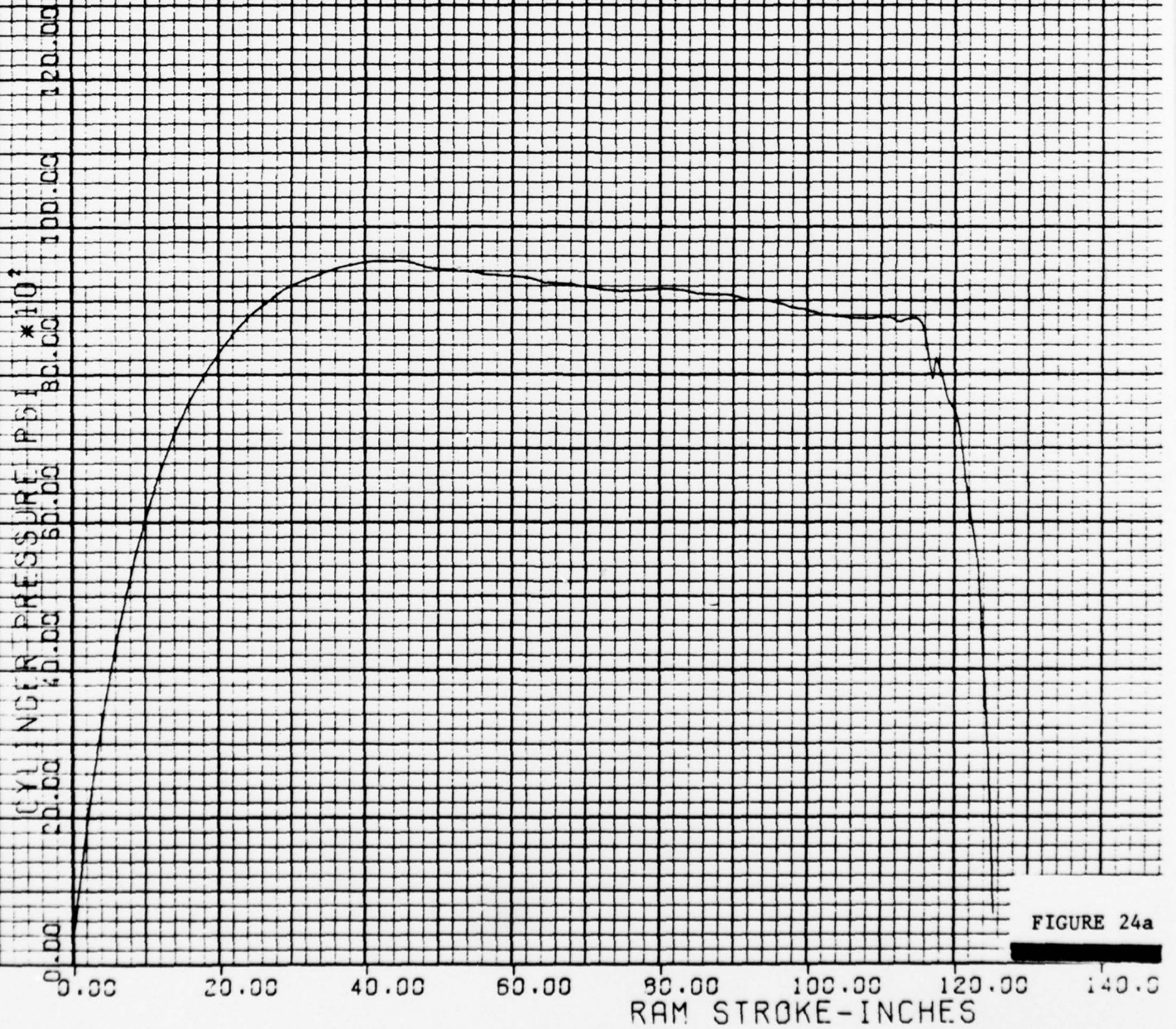


FIGURE 24a

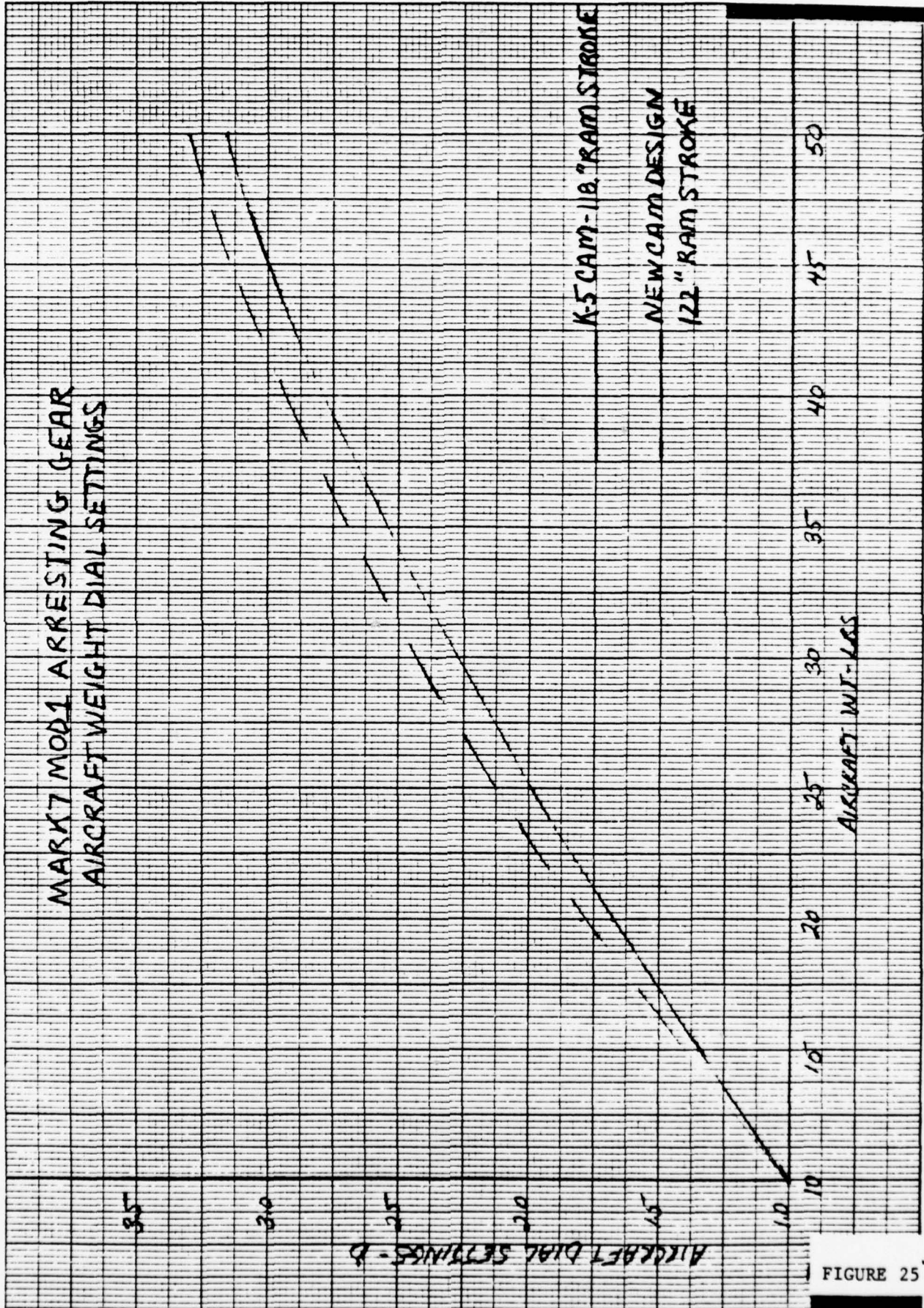


FIGURE 25

CYLINDER PRESSURE VS. RAMSTROKE  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAM STROKE  
A/C WEIGHT-13000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-1.25

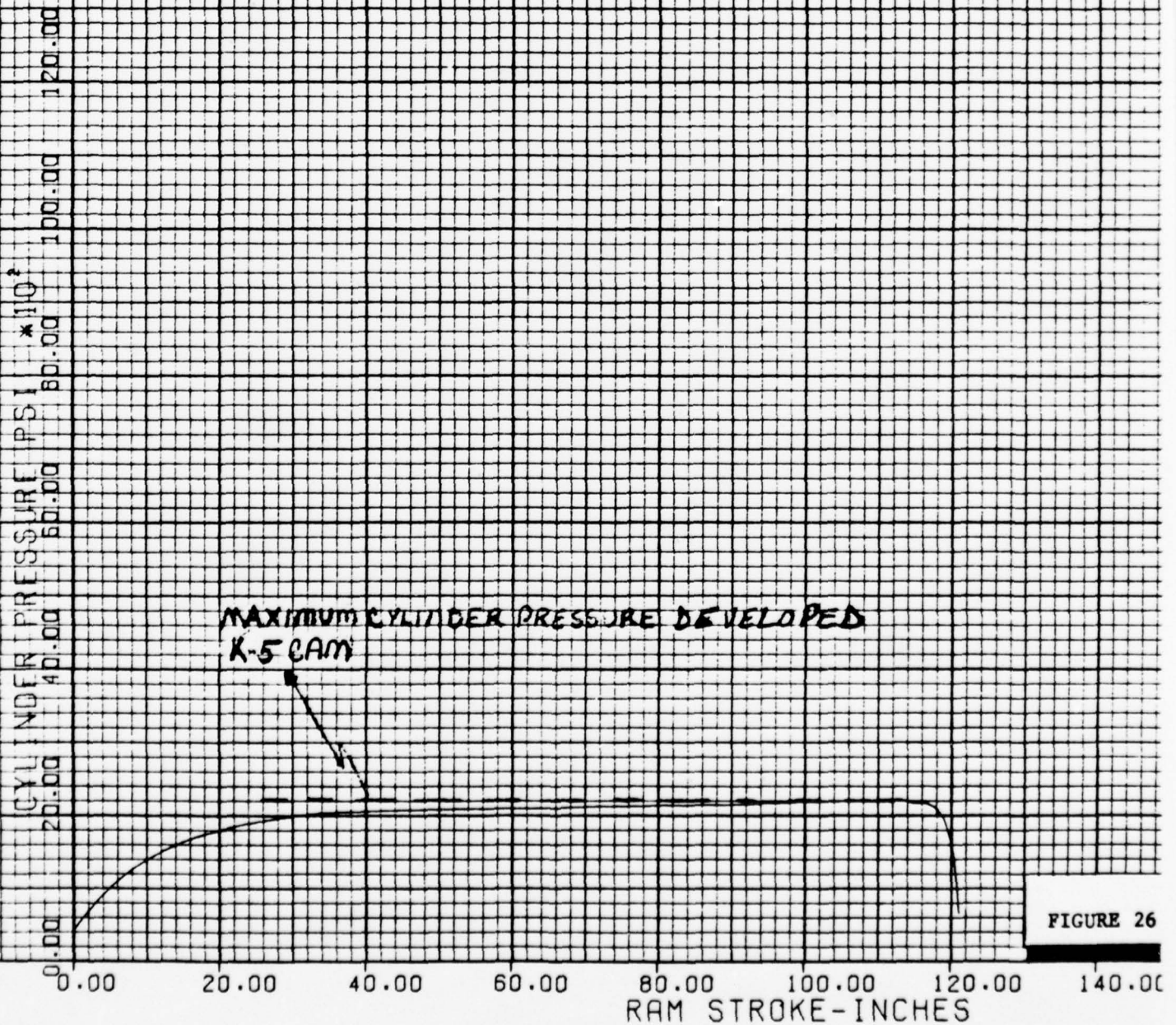


FIGURE 26

CYLINDER PRESSURE VS. RAMSTROKE  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A/C WEIGHT-20000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-1.80

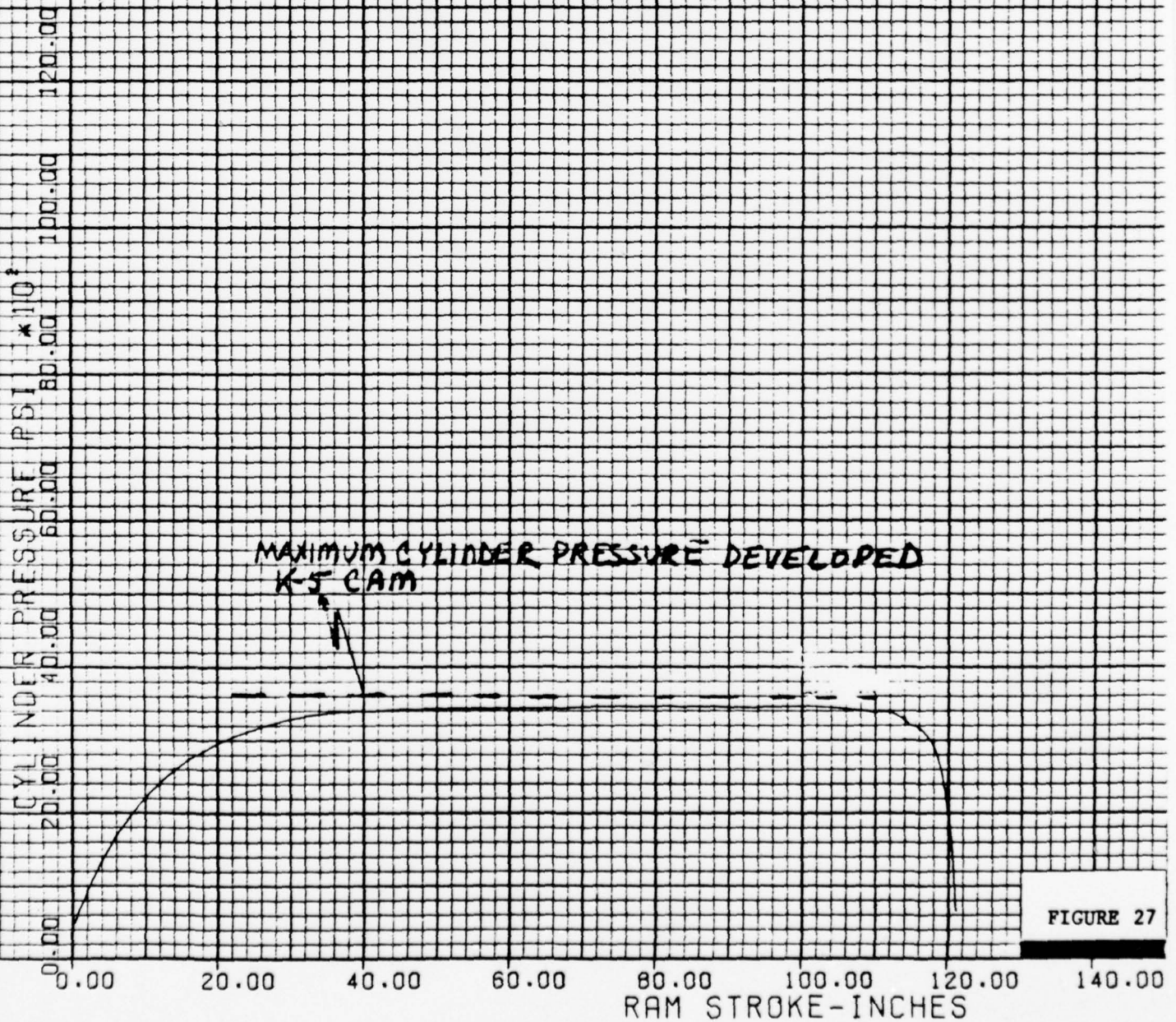


FIGURE 27

CYLINDER PRESSURE VS. RAMSTROKE  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A/C WEIGHT-30000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-2.4

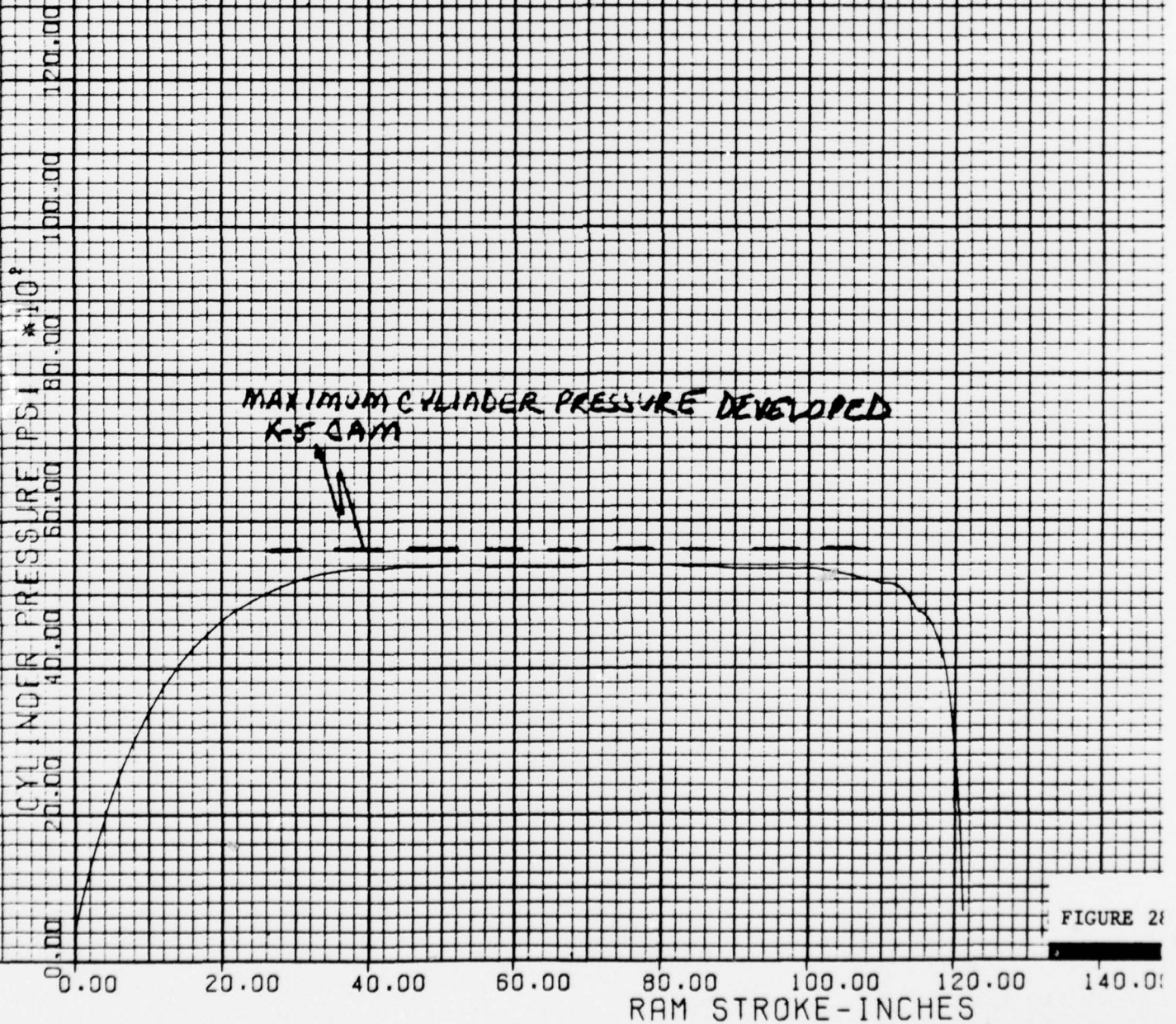


FIGURE 28

CYLINDER PRESSURE VS. RAM STROKE  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
A/C WEIGHT-40000 LBS.  
ENGAGING VELOCITY-110.0 KNOTS  
DIAL SETTING-2.9

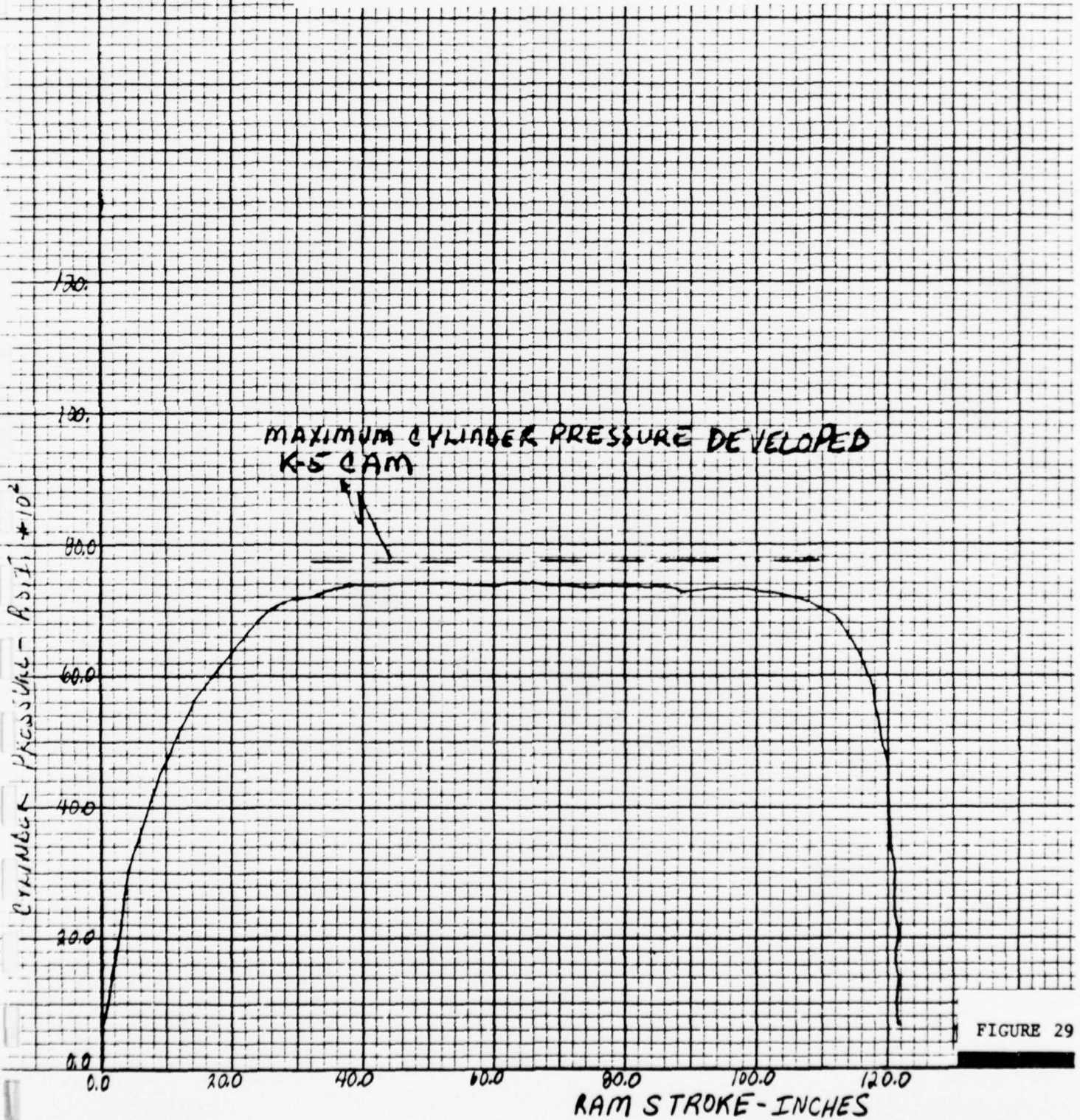


FIGURE 29

CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.75  
THRUST-.4 WEIGHT

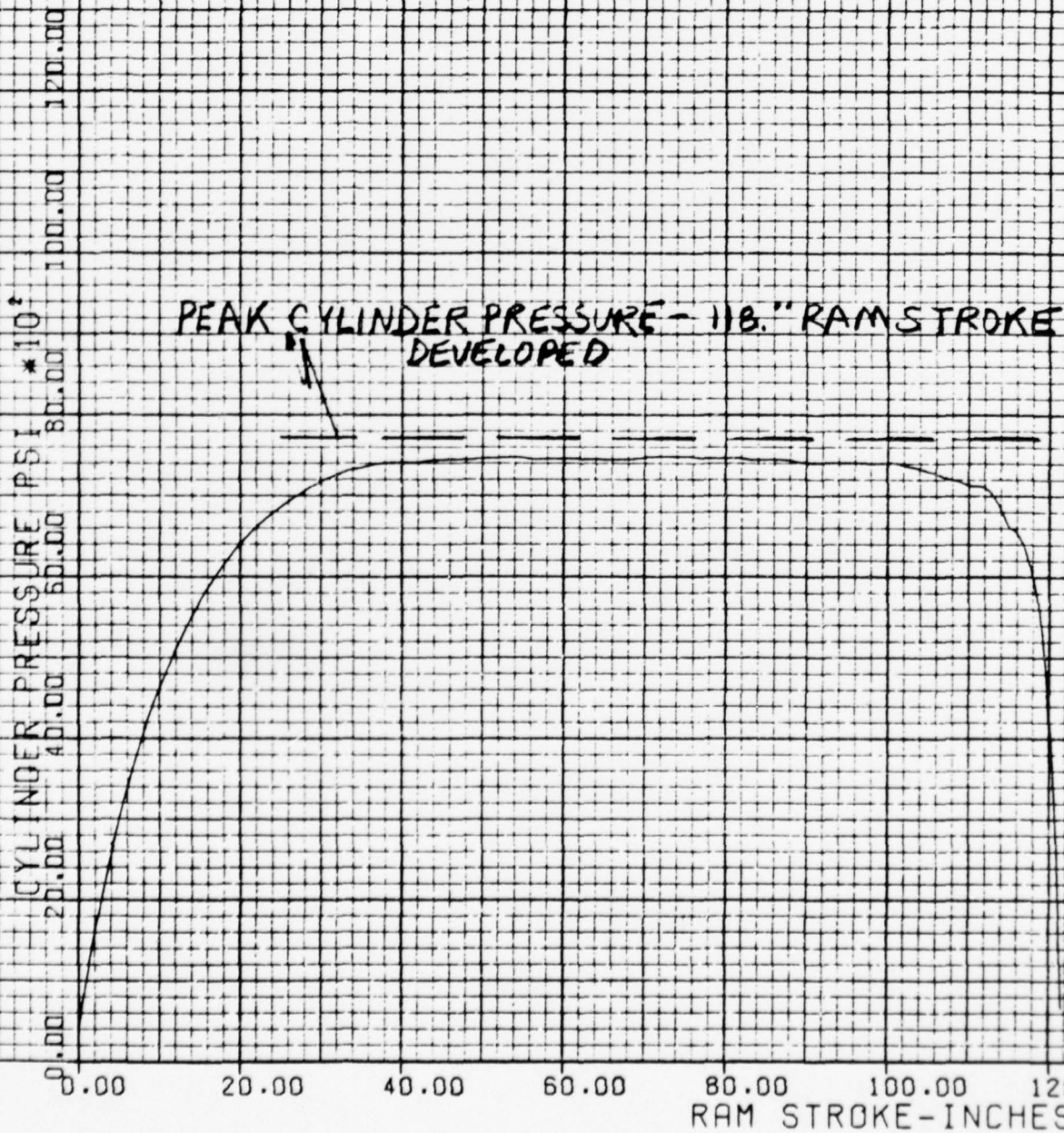


FIGURE 30

CYLINDER PRESSURE VS. RAM STROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTINGS-2.75  
THRUST-.63 WEIGHT

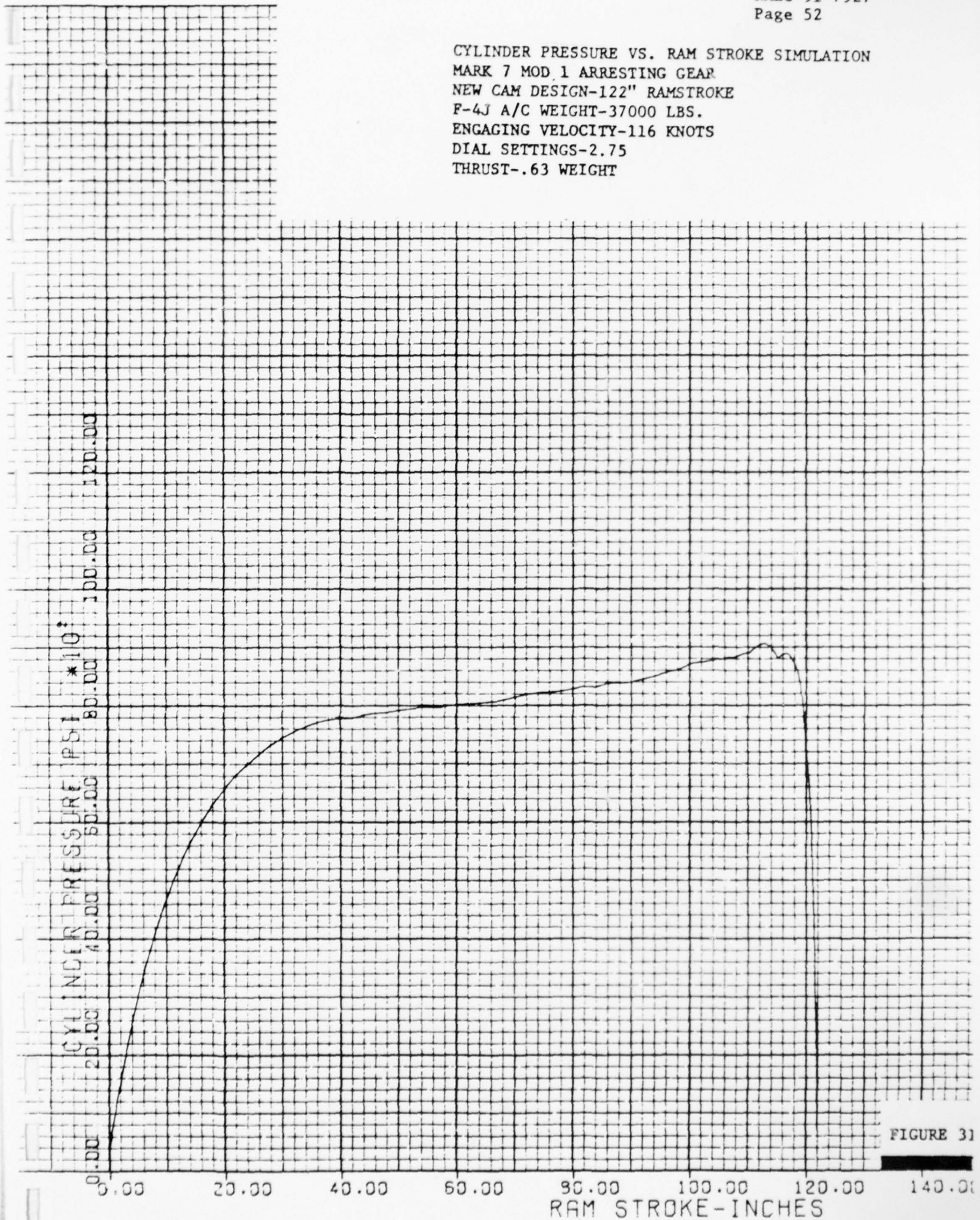


FIGURE 31



CYLINDER PRESSURE VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
K-5 CAM ROTATED 4" ONTO DWELL-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.55  
THRUST-.63 WEIGHT

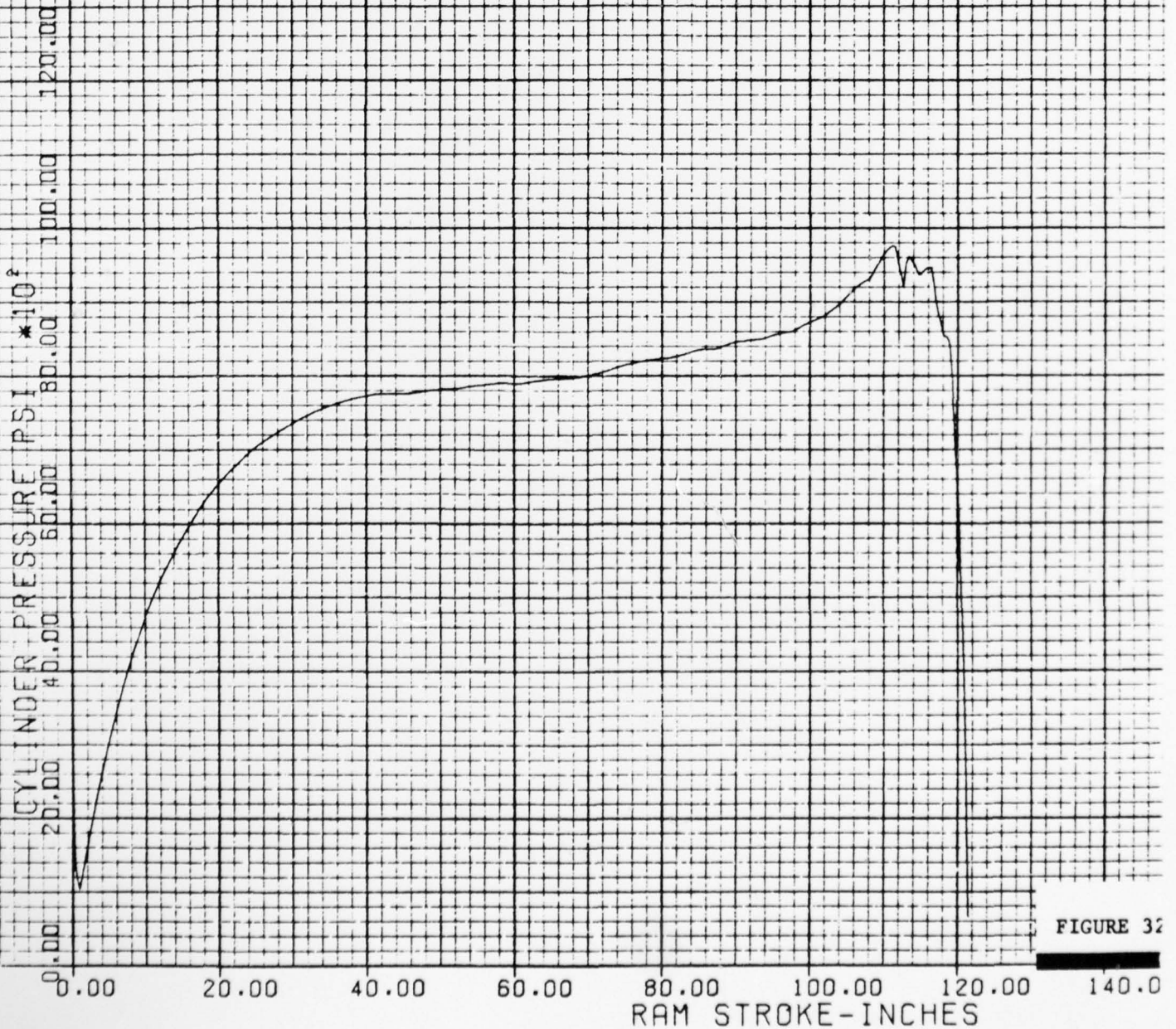


FIGURE 32

CABLE TENSION VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.75  
THRUST-.4x WEIGHT

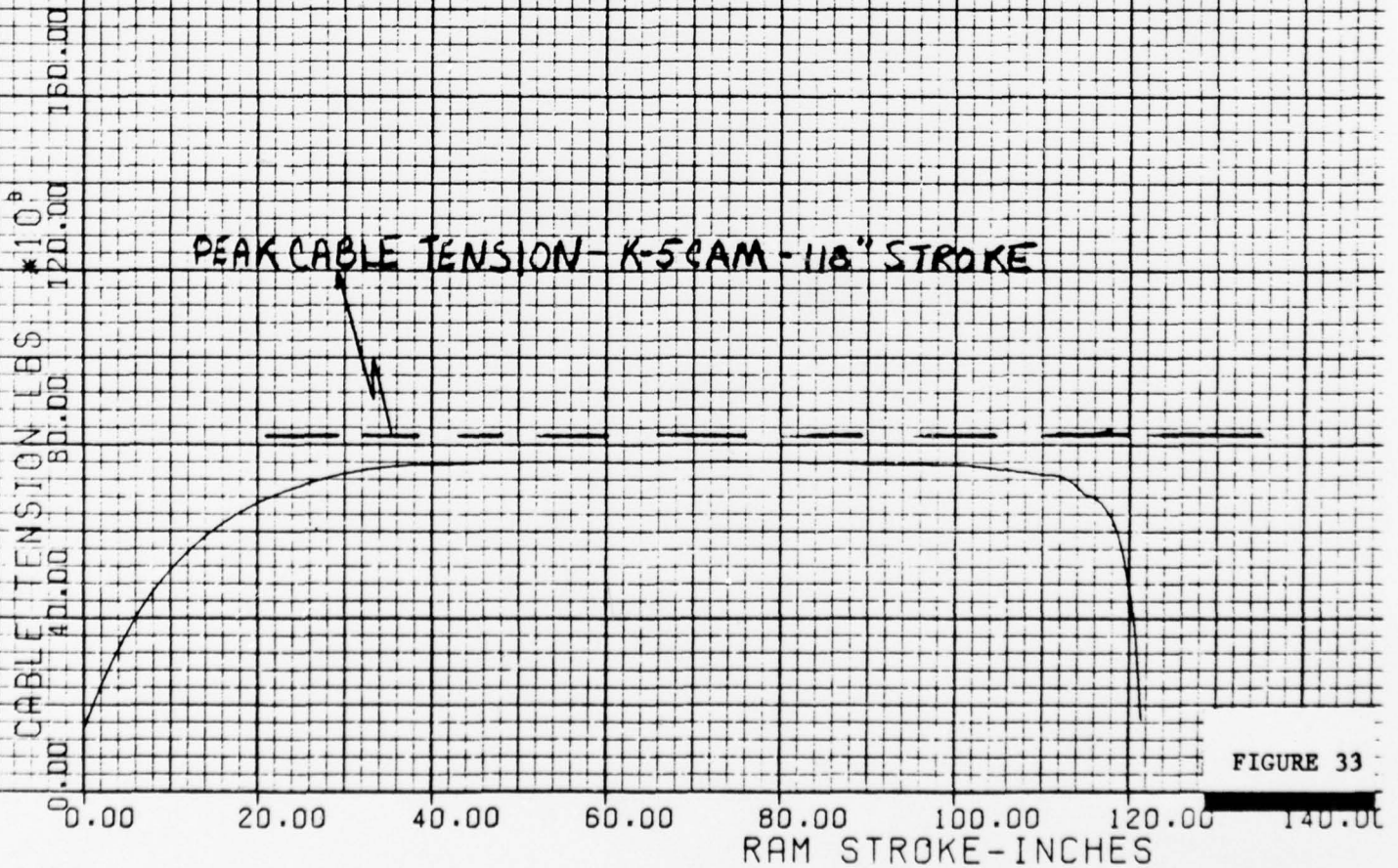


FIGURE 33

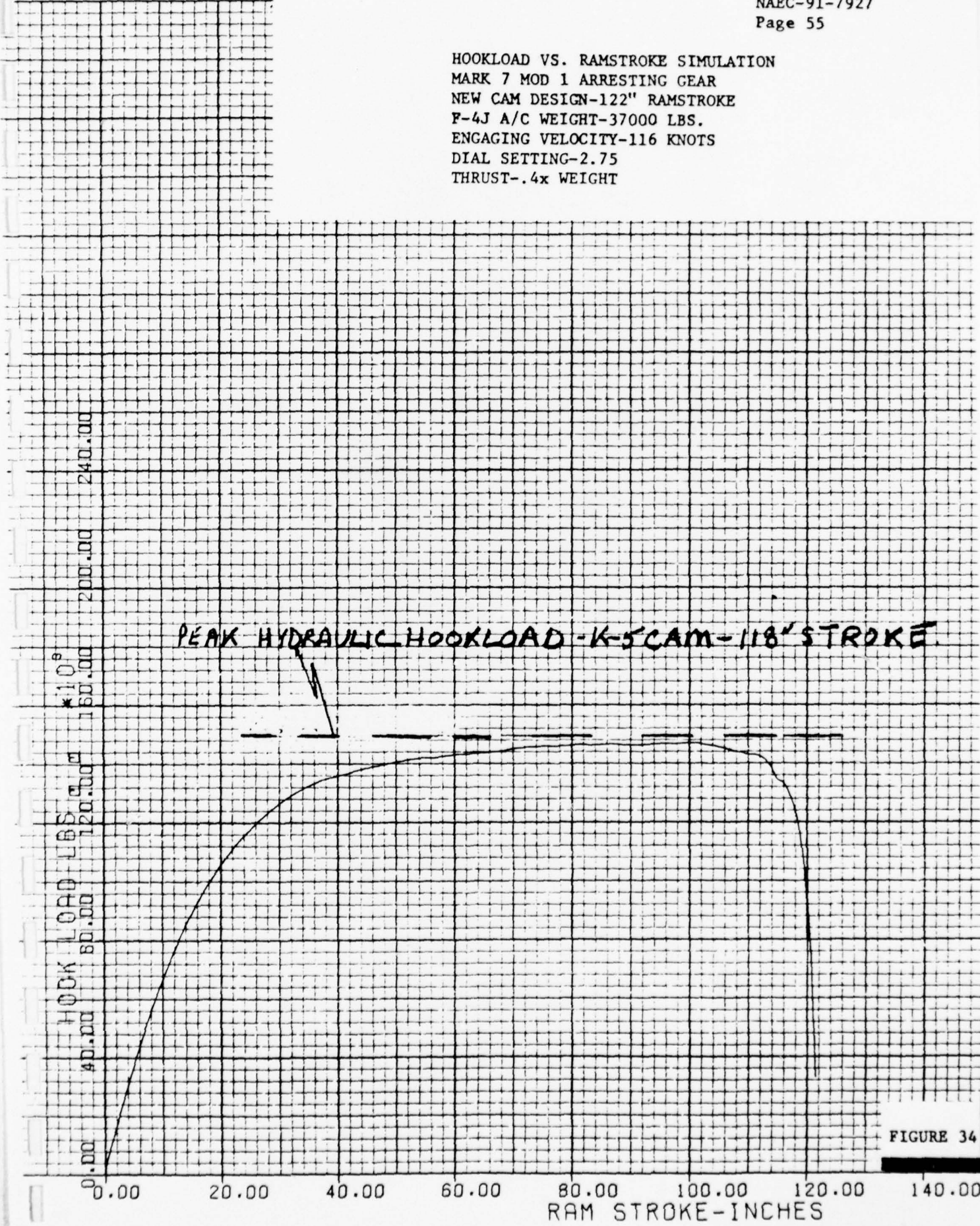
HOOKLOAD VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.75  
THRUST-.4x WEIGHT

H  
O  
O  
K  
L  
O  
A  
D  
L  
B  
S  
\*110°  
160.00  
120.00  
80.00  
40.00  
0.00

PEAK HYDRAULIC HOOKLOAD - K-5 CAM - 118" STROKE

0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00  
R  
A  
M  
S  
T  
R  
O  
K  
E  
-  
I  
N  
C  
H  
E  
S

FIGURE 34



CABLE TENSION VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.75  
THRUST-.63x WEIGHT

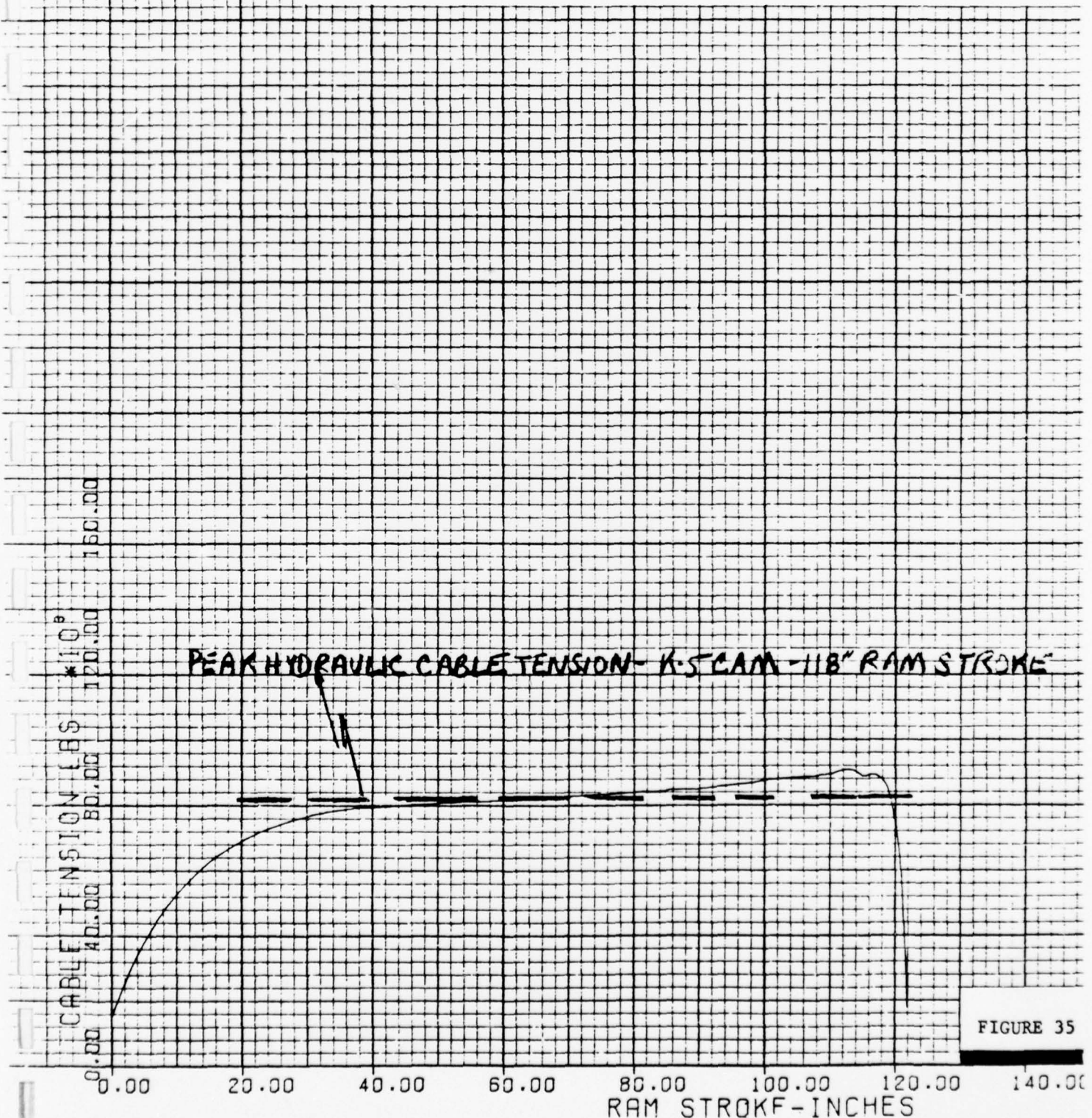


FIGURE 35

HOOKLOAD VS. RAMSTROKE SIMULATION  
MARK 7 MOD 1 ARRESTING GEAR  
NEW CAM DESIGN-122" RAMSTROKE  
F-4J A/C WEIGHT-37000 LBS.  
ENGAGING VELOCITY-116 KNOTS  
DIAL SETTING-2.75  
THRUST-.63x WEIGHT

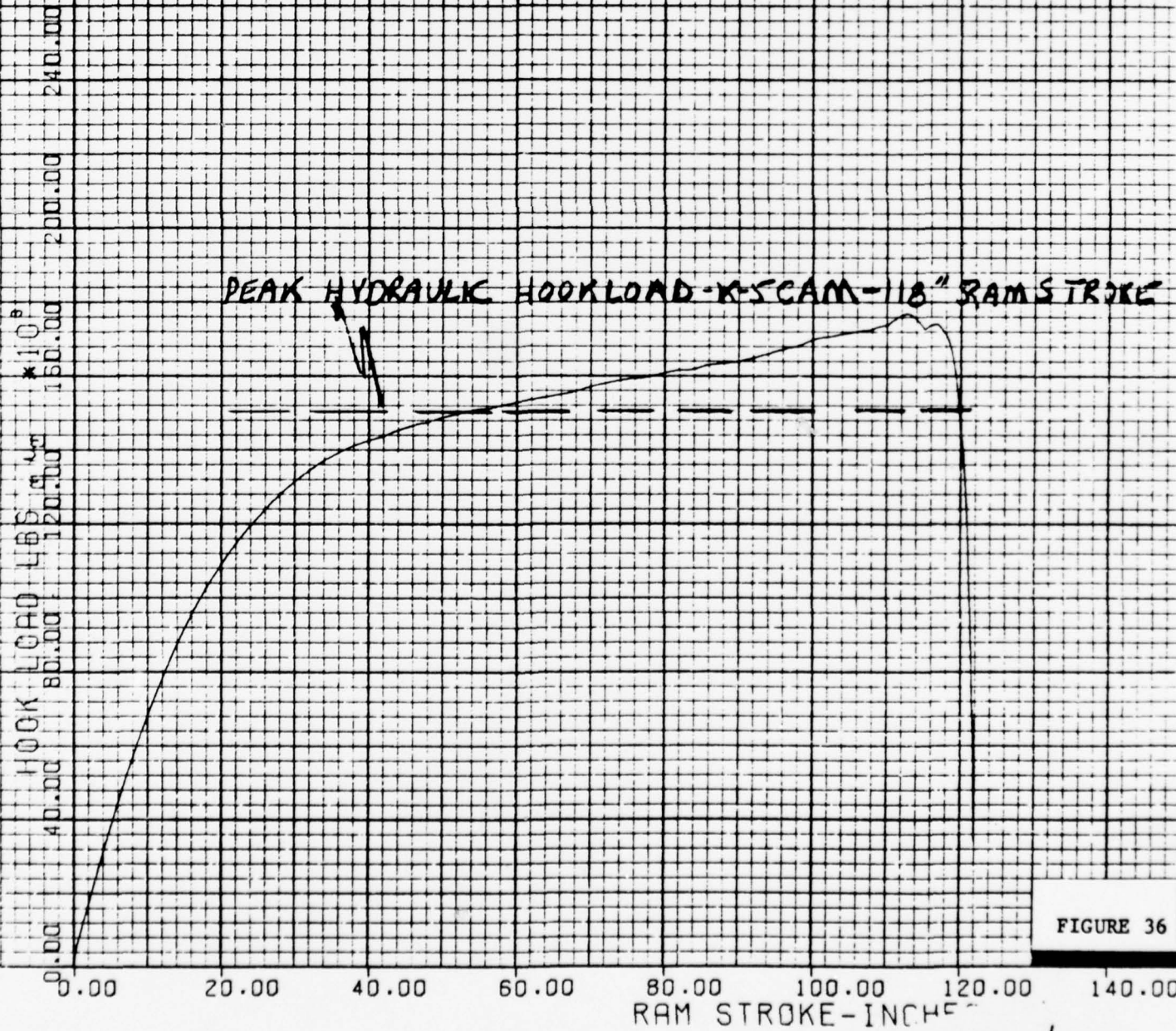


FIGURE 36

MARK 7 MOD 1 ARRESTING GEAR  
VALVE STEPLIFT VS. RAMSTROKE  
K-5 CAM-118" STROKE  
NEW CAM DESIGN-122" STROKE  
ROTATED K-5 CAM-122" STROKE  
REEVE RATIO-18:1  
DECKSPAN-95"

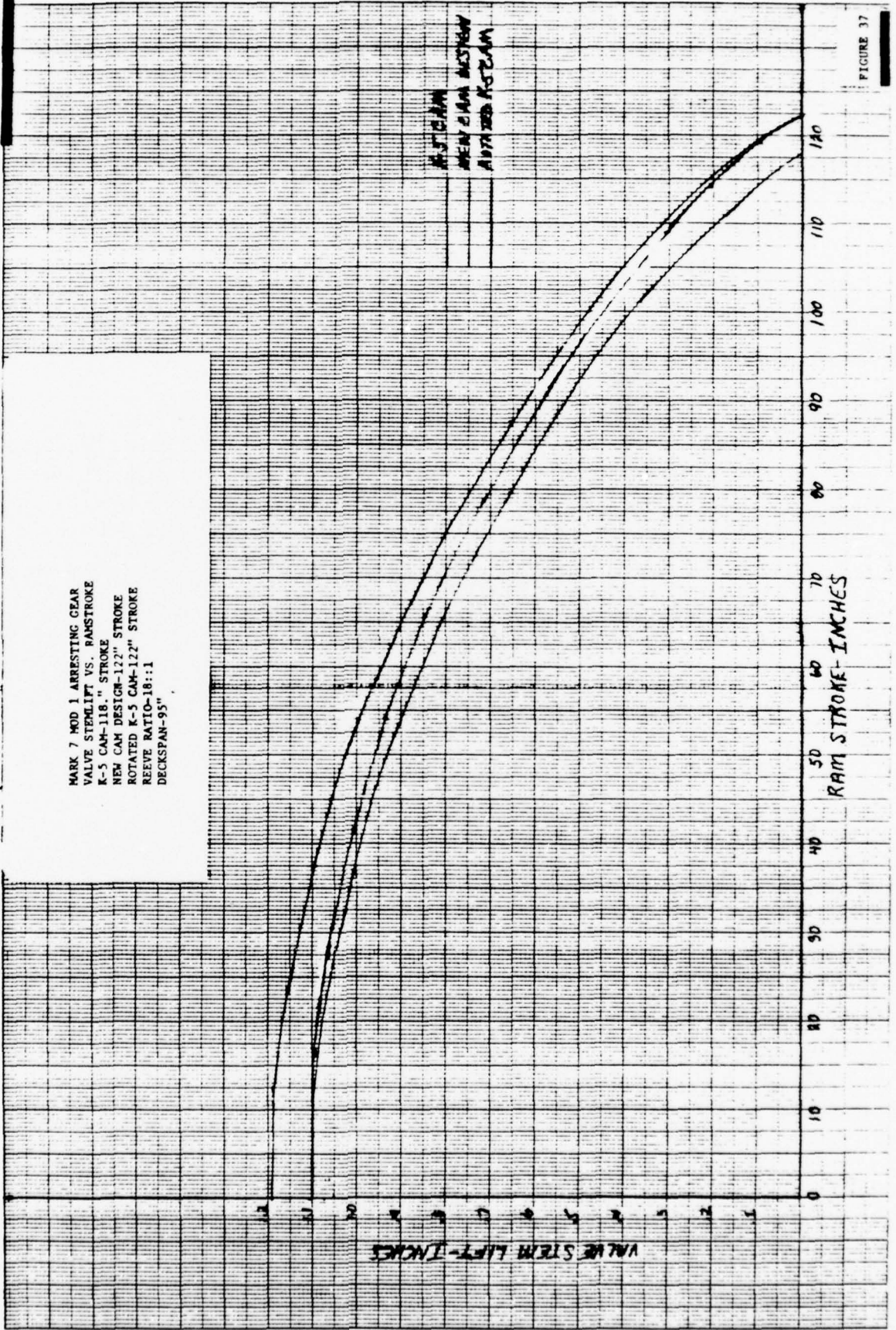


FIGURE 37

TABLE 1

MARKT MOD 1 ARRESTING GEAR  
 VALVE STEM LIFT VS RAM STROKE CO-ORDINATES  
 STANDARD K-5 CAM - 118.1 STROKE DECK SPAN 95'

STROKE	LIFT	STROKE	LIFT	STROKE	LIFT
0.0	1.10	60.42	.353	112.03	.190
2.00	1.10	62.50	.336	111.67	.170
4.17	1.10	64.58	.313	112.50	.150
6.25	1.10	66.67	.290	113.33	.135
8.33	1.10	68.75	.276	114.17	.115
10.42	1.099	70.83	.253	115.0	.090
12.50	1.095	72.92	.231	115.03	.070
14.58	1.090	75.0	.209	116.67	.045
16.67	1.085	77.08	.188	117.98	.030
18.75	1.080	79.17	.164	117.50	.015
20.83	1.072	81.25	.139	117.9	.005
22.92	1.056	83.33	.117	116.1	.000
25.0	1.059	85.42	.1590		
27.08	1.050	87.50	.1565		
29.17	1.040	89.58	.1540		
31.25	1.031	91.67	.1512		
33.33	1.021	93.75	.1485		
35.42	1.012	95.83	.1454		
37.50	1.002	97.9	.1423		
39.58	.995	100.0	.1389		
41.67	.986	102.08	.1352		
43.75	.973	104.17	.1316		
45.83	.960	105.0	.1299		
47.92	.948	105.83	.1282		
50.0	.933	106.67	.1265		
52.08	.918	107.5	.1249		
54.17	.902	109.85	.1235		
56.25	.889	109.17	.1220		
58.33	.871	110.0	.1205		

TABLE 2

MARK 7 MOD 1 ARRESTING GEAR  
VALVE STEM LIFT VS RAM STROKE COORDINATES  
NEW CAM DESIGN - 122" STROKE DECK SPAN - 95'

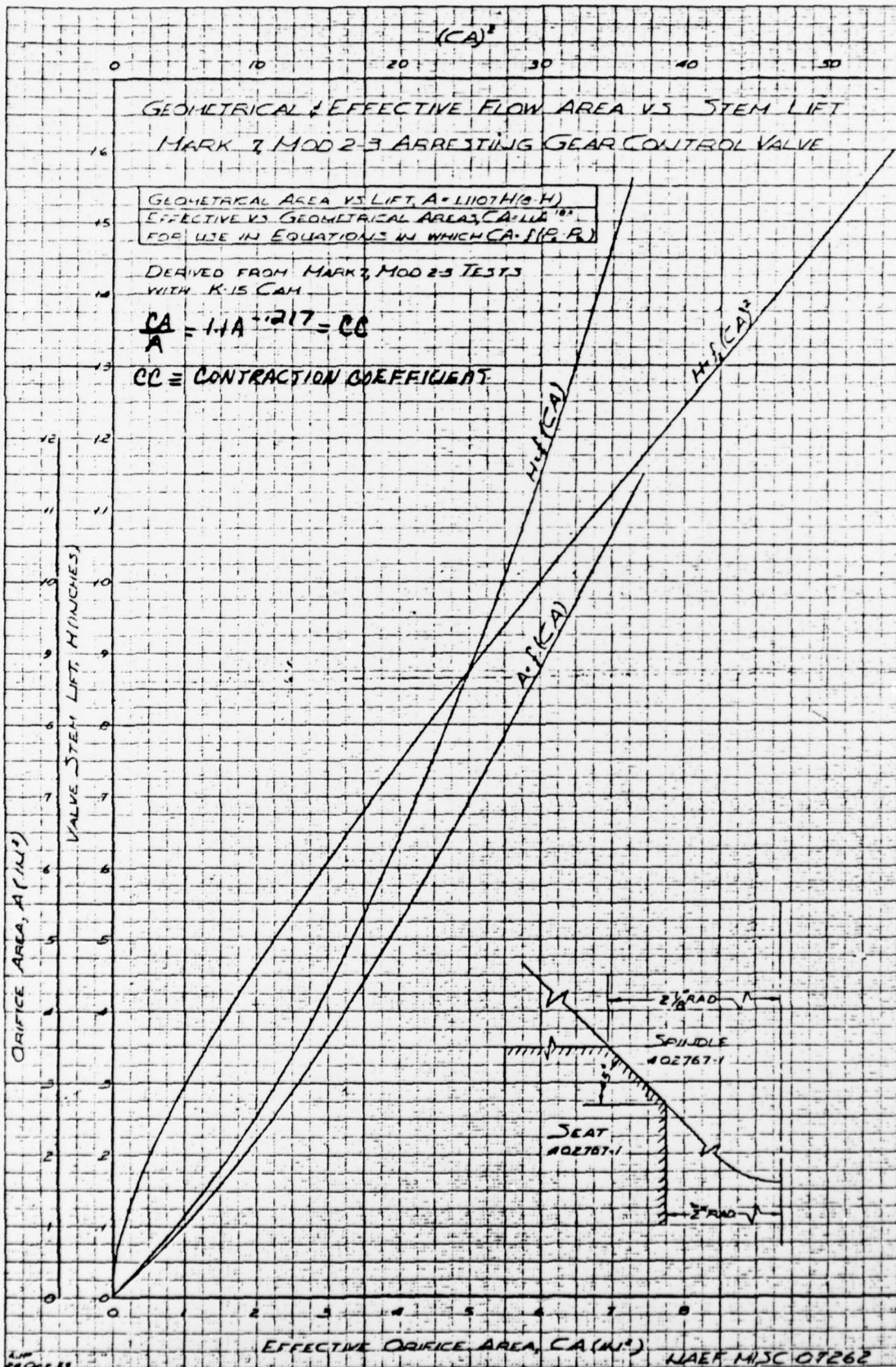
STROKE	LIFT	STROKE	LIFT	STROKE	LIFT
0.0	1.19	60.42	.943	121.5	.032
2.03	1.19	62.50	.926	122.0	.000
4.17	1.19	64.43	.908		
6.25	1.19	66.67	.888		
8.33	1.19	68.75	.866		
10.42	1.189	70.83	.843		
12.50	1.185	72.92	.821		
14.58	1.180	75.0	.799		
16.67	1.175	77.08	.778		
18.75	1.170	79.17	.754		
20.83	1.162	81.25	.729		
22.92	1.156	83.33	.707		
25.00	1.149	85.42	.680		
27.08	1.140	87.50	.655		
29.17	1.130	89.58	.630		
31.25	1.121	91.67	.602		
33.33	1.111	93.75	.573		
35.42	1.102	95.83	.543		
37.50	1.092	97.92	.513		
39.52	1.085	100.0	.480		
41.67	1.076	102.5	.442		
43.75	1.063	105.0	.402		
45.83	1.050	107.5	.360		
47.92	1.038	110.0	.314		
50.0	1.023	112.5	.262		
52.08	1.008	115.0	.213		
54.17	.992	117.5	.150		
56.25	.979	120.0	.082		
58.33	.961	121.0	.049		



TABLE 3

MARK 7 MOD 2 ARRESTING CLAR VALVE STEM LIFT VS RAM STROKE CO-ORDINATES ROTARY K5 CAM 122° STROKE - DECK SPAN - 95'							
STROKE	LIFT		STROKE	LIFT		STROKE	LIFT
0.0	1.10		56.08	.918		111.5	.249
1.0	1.10		58.17	.902		112.83	.235
2.0	1.10		60.25	.887		113.17	.220
3.0	1.10		62.33	.871		114.0	.205
4.0	1.10		64.42	.853		114.83	.190
6.08	1.10		66.50	.836		115.67	.176
8.17	1.10		68.58	.818		116.50	.150
10.25	1.10		70.67	.798		117.33	.155
12.33	.40		72.75	.776		118.17	.115
14.42	1.099		74.83	.753		119.0	.100
16.50	1.095		76.92	.731		119.83	.070
18.58	1.090		79.0	.709		120.67	.045
20.67	1.085		81.08	.688		121.50	.030
22.75	1.080		83.17	.664		121.50	.015
24.83	1.072		85.25	.639		121.9	.005
26.92	1.066		87.33	.617		122.0	.000
29.0	1.059		89.42	.590			
31.08	1.050		91.50	.565			
33.17	1.040		93.58	.540			
35.25	1.031		95.67	.512			
37.33	1.021		97.75	.485			
39.42	1.012		99.83	.454			
41.50	1.002		101.92	.423			
43.58	.995		104.0	.389			
45.67	.986		106.08	.352			
47.75	.973		108.17	.316			
49.83	.960		109.0	.299			
51.92	.948		109.83	.282			
54.0	.933		110.67	.265			

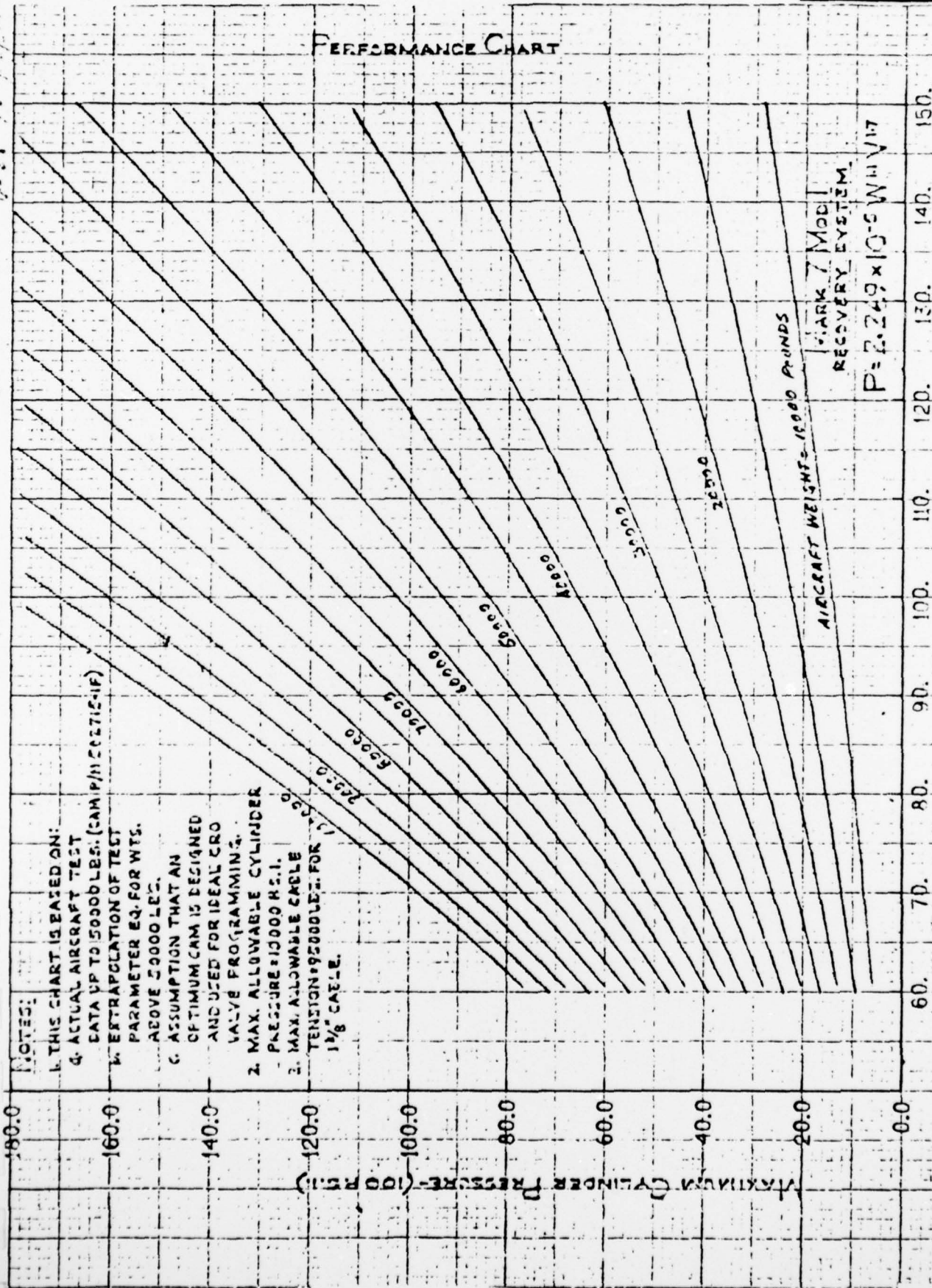
Geometrical vs. Effective Flow Area, MK 7 Mod 1 Arresting Gear



MISC 07262

FIGURE 38

PERFORMANCE CHART



NOTES:

- 1. THIS CHART IS BASED ON:
  - a. ACTUAL AIRCRAFT TEST DATA UP TO 5000 LBS. (CAM/IN CERTIFIC-IF)
  - b. EXTRAPOLATION OF TEST PARAMETER EQ. FOR WTS. ABOVE 5000 LBS.
- 2. ASSUMPTION THAT AN OPTIMUM CAM IS DESIGNED AND USED FOR IDEAL CRO VALVE PROGRAMMING.
- 3. MAX. ALLOWABLE CYLINDER PRESSURE = 10000 H.S.I.
- 4. MAX. ALLOWABLE CABLE TENSION = 95000 LBS. FOR 1 1/8" CABLE.

AIRCRAFT WEIGHTS = 10000 POUNDS  
MARK 7 MOD I  
RECOVERY SYSTEM

$$P = 2.249 \times 10^{-5} W^{0.17}$$

ENGAGING VELOCITY - (KNOTS)

(SHEET 3 OF 4)

NAEC MISC. 09334

IMG 5/23/72

FIGURE 39

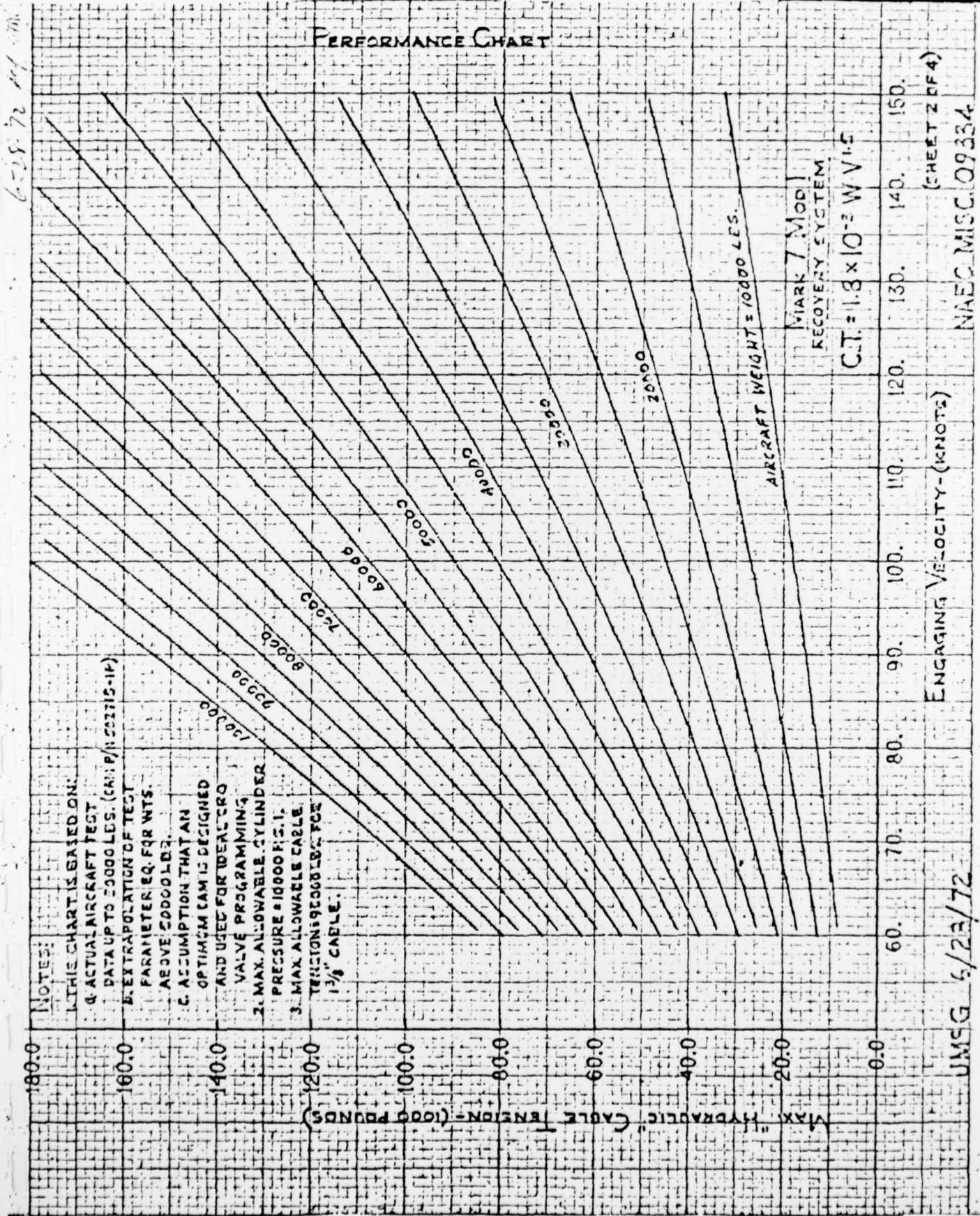


FIGURE 40

(SHEET 2 OF 4)

ENGAGING VELOCITY - (KNOTS)

NAEC MISC. 09334

UMSG 6/23/72

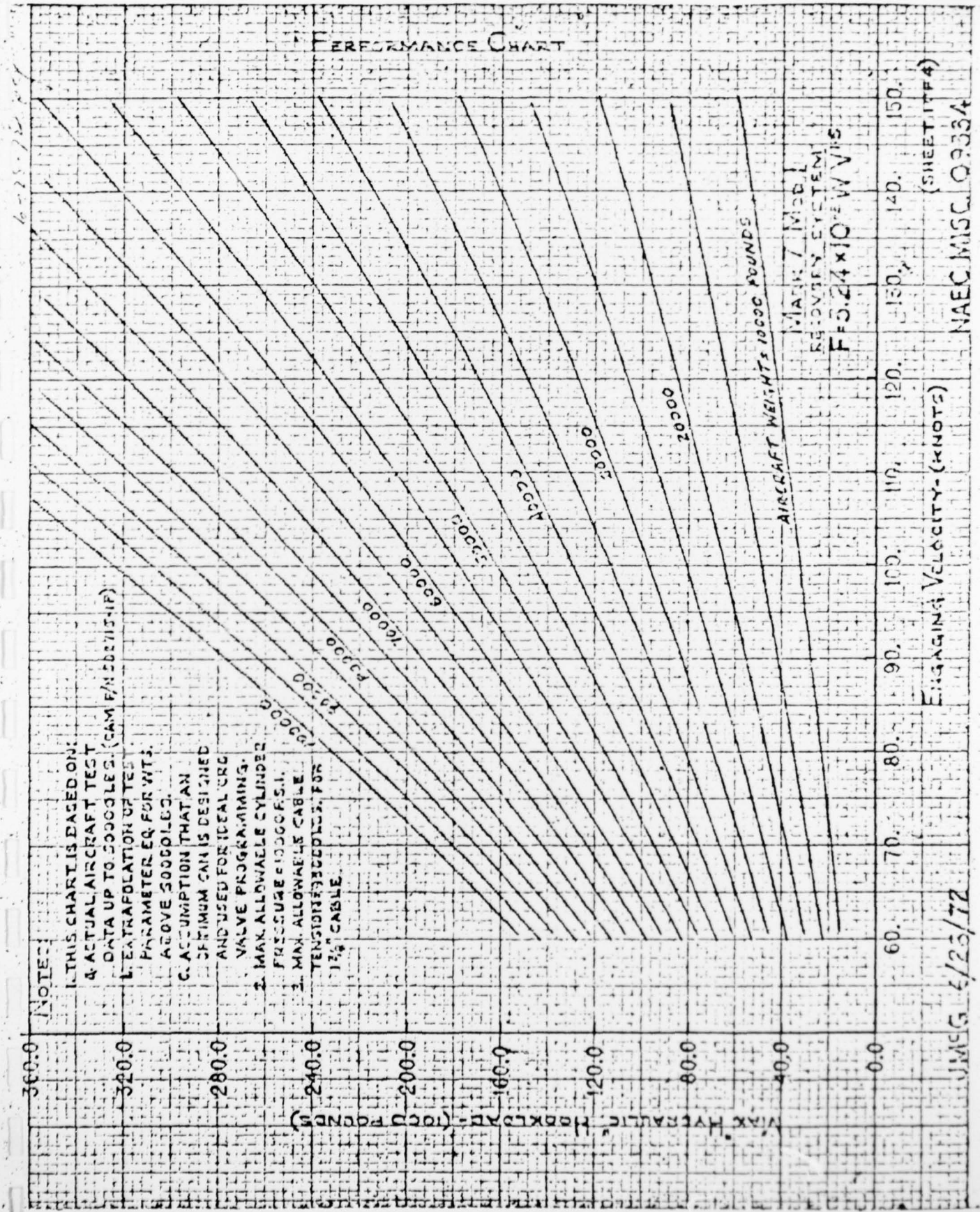
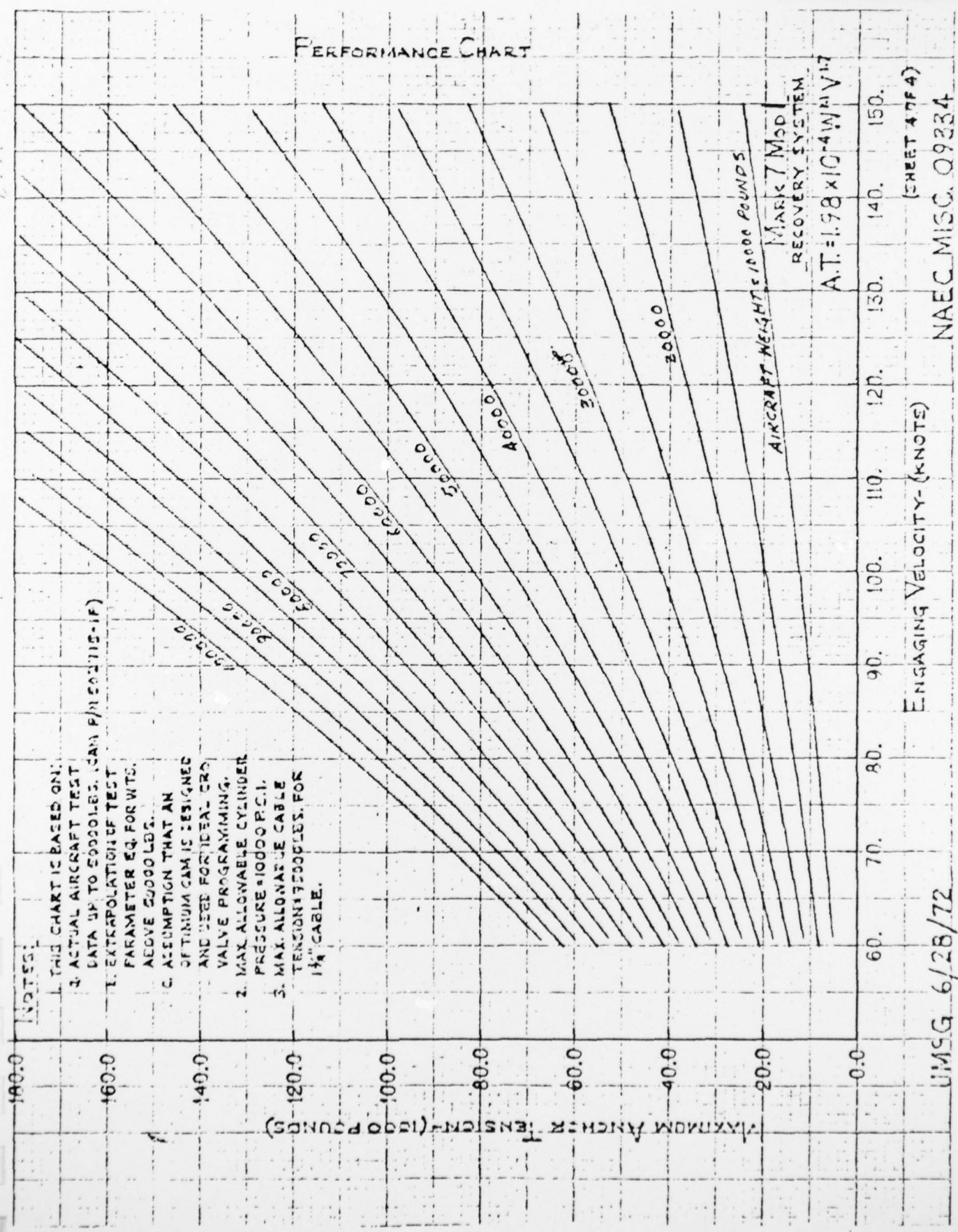


FIGURE 41

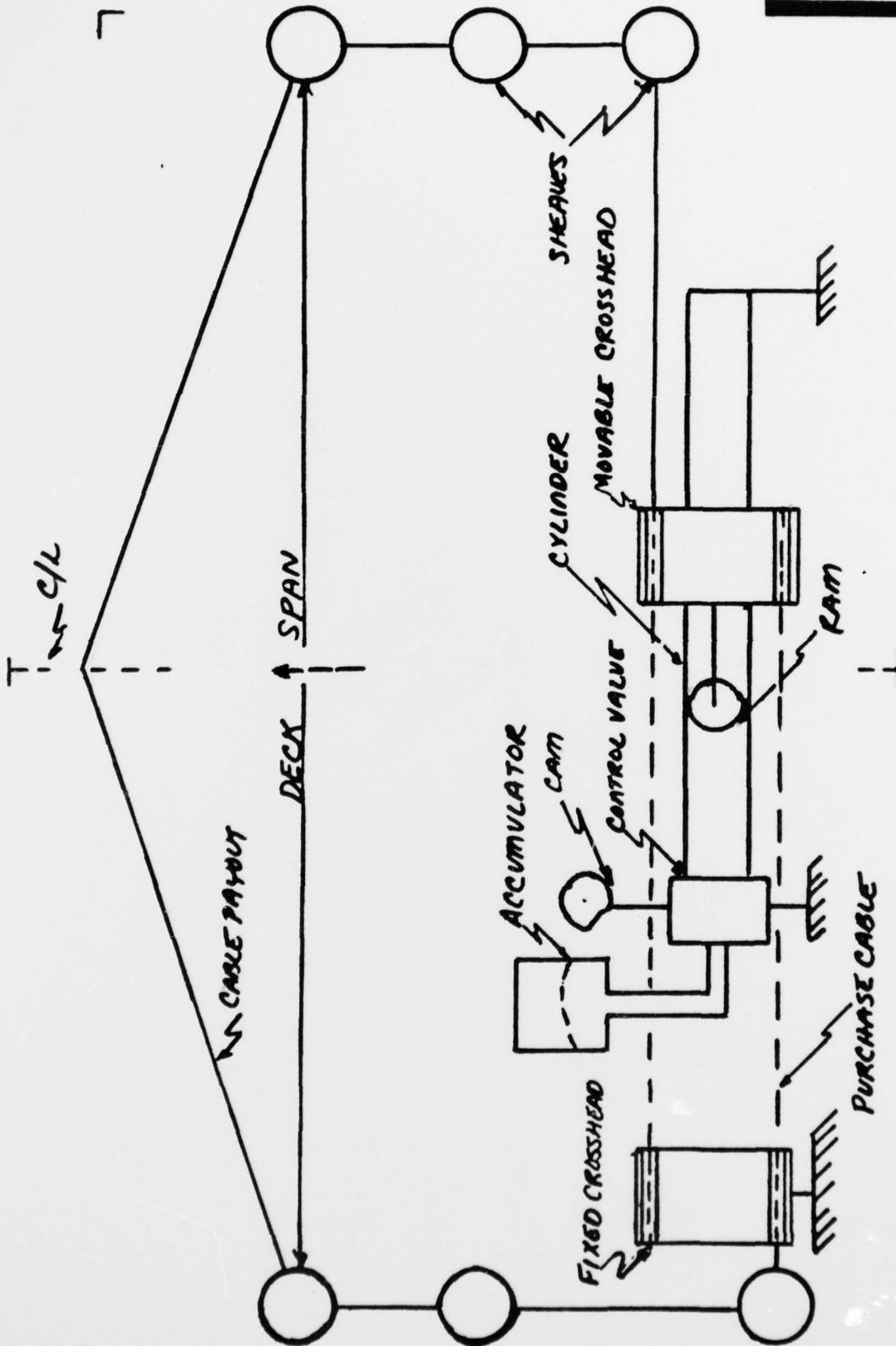
PERFORMANCE CHART



NOTES:

1. THIS CHART IS BASED ON:
  3. ACTUAL AIRCRAFT TEST DATA UP TO 5000 LBS. (CAN P/N 20115-1F)
  1. EXTRAPOLATION TEST PARAMETER EQ. FOR WTS. ABOVE 5000 LBS.
  - C. ASSUMPTION THAT AN OPTIMUM CAM IS DESIGNED AND USED FOR IDEAL CRG VALVE PROGRAMMING.
2. MAX. ALLOWABLE CYLINDER PRESSURE = 10000 P.S.I.
3. MAX. ALLOWABLE CABLE TENSION = 7500 LBS. FOR 1 1/4" CABLE.

FIGURE 42



SIMPLIFIED MARK 7  
ARRESTING GEAR LAYOUT.





## TABLE 5

NAEC-91-7927  
Page 69

MARK 7 MOD 1 SIMULATION PROGRAM

DIMENSION S(100),H(100)

DIMENSION IR(9), IP(11),IV(8),IT(9),IF(7),IH(6),IS(6)

DATA IR/'RAM STROKE-INCHES '/,IP/'CYLINDER PRESSURE PSI '/

DATA IV/'VELOCITY-KNOTS '/

DATA IT/'CABLE TENSION LBS '/

DATA IF/'HOOK LOAD LBS '/

DATA IH/'LIFT-INCHES '/

DATA IS/'TIME-SECONDS '/

IC=0

OPEN 25,1,900,8

CALL PLOTS(0,0,6)

DO 70 I=1,100

READ(10,1)S(I),H(I)

IF(S(I).EQ.999.) GO TO 72

70 CONTINUE

72 READ(10,2)VAK,WT,D

READ(10,3)ST,CS,RR,AP,DIA,SW,G,SK

READ(10,5)M,TI

READ(10,6)C,EX

READ(10,12)JJ

READ(10,14)CV

READ(10,16)EFF

READ(10,18)FB

READ(10,20)TMS,CW

READ(10,22)THC

VAO=84000.0

L=1

PR=0.0

SR=0.0

SX=0.0

PX=400.0

PAO=400.0

RX=0.0

EAB=0.0

EFHL=0.0

FHR=0.0

FHL=0.0

DT=0.0

VX=VAK\*1.689\*12.0

PO=2.0\*TMS\*ST

RO=(((PO+DS/2.0)\*\*2-(DS/2.0)\*\*2)\*\*\*.5)/12.0

TH=THC\*WT

ETA=.0443\*WT\*(VAK\*\*2)+(TH\*RO)

FD=(1.0-EFF)\*ETA/(2.0\*PO/12.0)

CV=3.126\*(WT\*\*(-.111))

EFF=.201\*(ETA\*\*0.084)

DO 21 I=1,M

DT=DT+TI

RS=RX

RY=RS

RX=RX+(VX\*TI)

DRX=RX-RY

CL=(((RX\*\*2+(DS/2.0)\*\*2)\*\*\*.5)

```

SR= SX
SY= SR
SX= (CL- (DS/2.0)) / (2.0* TMS)
DSX= SX- SY
33 IF (S(L).GE.SX) GO TO 75
L= L+1
IF (L.GT. JJ) GO TO 54
GO TO 33
75 MH = H(L-1) + (H(L)-H(L-1)) * (SX - S(L-1)) / ((S(L)-S(L-1)))
HA= MH/D
COST= RX/CL
VLC= VX* COST
VRA= VLC / (2.0* TMS)
AO= 1.1107* HA * (2* (DIA)-HA)
CD= C* (AO**EX)* CV
PA= (PAO* (VAO**1.4)) / ((VAO- (SK * SX))**1.4)
DPX= (SW / (24.0* G)) * (VRA**2) * ((AP/AO)**2) / (CD**2)
PR= PX
PY= PR
PX= PA+ DPX
XPX= PX+ PY
76 FRA= PX* AP
CT= ((FRA) / (2.0* TMS* CW)) + FD
FHR= FHL
FHY= FHR
FHL= (2.0* CT* COST)
DFHL= FHY+ FHL
EFHL= EFHL + (DFHL* DRX*.5) / 12.0
VX= ((12.0* G) / WT) * TI * (TH- FE- FHL) + VX
VFT= VX / 1.689 / 12.0
EAB= EAB + ((XPX*.5) * DSX * (AP / 12.0))
51 WRITE (12,4) DT, SX, RX, PX, PA, CD, HA, VFT, AO, FHL, CT, EAB
IC= IC+1
WRITE (25(IC),4) DT, SX, RX, PX, PA, CC, HA, VFT, AO, FHL, CT, EAB
IF (VX.LT.0.) GO TO 54
21 CONTINUE
54 EFC= EAB/ETA
WRITE (12,8) TH, FD, RO, ETA, EFF, CV, EFC, EFHL
WRITE (12,2) VAK, WT, D
58 CONTINUE
CALL AXIS(0.,0.,IR , -17,10.0,0.,0.00,+20.)
CALL AXIS(0.,0.,IP , +21,6.0,90.,0.00,+2000.)
DO 101 K=1,IC
READ (25(K),4) DT, SX, RX, PX, PA, CD, HA, VFT, AO, FHL, CT, EAB
X= SX/20.
Y= PX/2000.
IF (K.EQ.1) CALL FLCT(X,Y,3)
101 CALL PLCT(X,Y,2)
CALL PLOT (12.0,0.0,-3)
CALL AXIS(0.,0.,IR , -17,10.0,0.,0.00,+20.)
CALL AXIS(0.,0.,IV , +15,6.0,90.,0.00,+40.)
DO 100 K=1,IC
READ (25(K),4) DT, SX, RX, PX, PA, CD, HA, VFT, AO, FHL, CT, EAB
X= SX/20.
Y= VFT/40.
IF (K.EQ.1) CALL PLOT(X,Y,3)
100 CALL PLOT(X,Y,2)
CALL PLOT (12.0,0.0,-3)
CALL AXIS(0.,0.,IT,+17,4.0,90.0,0.00,+40000.)
CALL AXIS(0.,0.,IR , -17,10.0,0.,0.00,+20.)

```

```

DO 102 K=1,IC
READ(25(K),4)DT,SX,FX,PX,PA,CD,HA,VFT,AO,FHL,CT,EAB
X=SX/20.
Y=CT/40000.
IF(K.EQ.1) CALL PLOT(X,Y,3)
102 CALL PLOT(X,Y,2)
CALL PLOT(12.0,0.0,-3)
CALLAXIS(0.,0.,IR,-17,10.0,0.,0.00,+20.)
CALL AXIS(0.,0.,IF,+17,10.0,90.0,0.00,+40000.)
DO 104 K=1,IC
READ(25(K),4)DT,SX,RX,PX,PA,CD,HA,VFT,AO,FHL,CT,EAB
X=SX/20.
Y=FHL/40000.
IF(K.EQ.1) CALL PLOT(X,Y,3)
104 CALL PLOT(X,Y,2)
CALL PLOT(12.0,0.0,-3)
CALLAXIS(0.,0.,IR,-17,20.0,0.,0.00,+10.)
CALL AXIS(0.,0.,IH,+17,10.0,90.0,0.00,+100)
DO 106 K=1,IC
READ(25(K),4)DT,SX,RX,PX,PA,CD,HA,VFT,AO,FHL,CT,EAB
X=SX/10
Y=HA/(.100)
IF(K.EQ.1) CALL PLOT(X,Y,3)
106 CALL PLOT(X,Y,2)
CALL PLOT(22.0,0.0,-3)
CALL AXIS(0.,0.,IS,-17,20.0,0.,0.00,+250)
CALLAXIS(0.,0.,IT,+17,10.0,90.0,0.00,+20000.)
DO 110 K=1,IC
READ(25(K),4)DT,SX,FX,PX,PA,CD,HA,VFT,AO,FHL,CT,EAB
X=DT/.250
Y=CT/20000.
IF(K.EQ.1) CALL PLOT(X,Y,3)
110 CALL PLOT(X,Y,2)
CALL PLOT(22.0,0.0,-3)
CALL AXIS(0.,0.,IS,-17,20.0,0.,0.00,+250)
CALLAXIS(0.,0.,IR,+17,10.0,90.0,0.00,+20.)
DO 112 K=1,IC
READ(25(K),4)DT,SX,FX,PX,PA,CD,HA,VFT,AO,FHL,CT,EAB
X=DT/.250
Y=SX/20.0
IF(K.EQ.1) CALL PLOT(X,Y,3)
112 CALL PLOT(X,Y,2)
CALL PLOT(22.0,0.0,-3)
CALL PLOT(0.0,999)
STOP
1 FORMAT(2F10.4)
2 FORMAT(F6.1,F6.0,7F6.3)
3 FORMAT(F6.1,F6.0,F3.0,FE.1,F4.1,F6.4,F6.2,F6.1)
4 FORMAT(F7.3,F11.3,3F10.0,2F10.4,2F10.4,3F14.0)
5 FORMAT(I4,F6.3)
6 FORMAT(2FE.3)
8 FORMAT(F8.1,3F14.0,3F9.3,F14.0)
12 FORMAT(I2)
14 FORMAT(FE.3)
16 FORMAT(F6.3)
18 FORMAT(F9.1)
20 FORMAT(F4.1,F3.1)
22 FORMAT(F5.3)
END

```

## A. LIST OF SYMBOLS IN ANALYSIS

<u>SYMBOL</u>	<u>DESCRIPTION</u>
A	Area of Pipe
ACGTY	Acceleration of Gravity
ACWGHT	Aircraft Weight
AREPTN	Area Piston
AREORF	Area Orifice
CBLPOU	Cable Payout
CBLTEN	Cable Tension
CONCOF	Contraction Coefficient
D	Diameter of Pipe
DECEL	Deceleration
DPMEC	Cylinder Pressure Drop
DSHCOF	Discharge Coefficient
FDRAG	Drag Force
FRAM	Ram Force
G	Acceleration of Gravity
HKLOAD	Aircraft Hookload
LIFT	Valve Stem Lift
MCHEFF	Mechanical Efficiency
MEC	Main Engine Cylinder
P	Pipe Pressure
PACCO	Initial Pressure Accumulator
PACC	Final Pressure Accumulator
PMEC	Pressure Main Engine Cylinder
Q	Discharge Rate
R	Reynolds Number
STROKE	Ram Stroke
THRUST	Aircraft Thrust
TIME	Time Increment
VALDIA	Constant Runout Valve Diameter
VELCOF	Velocity Coefficient
VELIN	Initial Velocity
VELOF	Final Velocity
VOLACO	Initial Accumulator Air Volume
VOLACT	Final Accumulator Air Volume
$v_{1t}$	Orifice Inlet Fluid Velocity
$v_{2t}$	Orifice Outlet Fluid Velocity
$\rho$	Density of Fluid

## B. LIST OF SYMBOLS AS USED IN COMPUTER PROGRAM

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
AO	Orifice Area	Square Inches
AP	Piston Area	Square Inches
C	Constant of Flow Equation	
CC	Contraction Coefficient	
CL	Cable Length	Inches
COST	Cosine ( $\theta$ )	
CW	Conventional Wrap	
CT	Cable Tension	Lbs.
CV	Velocity Coefficient	
D	Aircraft Dial Setting	
DIA	Valve Seat Diameter	Inches
DPX	Pressure Drop Across Orifice	PSI
DRX	Change In Runout	Inches
DSX	Change In Stroke	Inches
DT	Time Increments	Seconds
EAB	Energy Absorbed-Main Engine Cylinder	Ft.-Lbs.
EFC	Calculated Efficiency	
EFF	Mechanical Efficiency	
EFHL	Total Hookload Energy	Ft.-Lbs.
ETA	Total Energy of Engagement	Ft.-Lbs.
EX	Exponent of Flow Equation	
FB	Brake Force	Lbs.
FD	Drag Force	Lbs.
FHL	Hookload	Lbs.
FHR	Hookload	Lbs.
FRA	Ram Force	Lbs.
G	Gravitational Acceleration	Ft/SEC <sup>2</sup>
HA	Valve Stem Lift	Inches
HH	Valve Stem Lift	Inches
JJ	Dummy Variable # of Lift Inputs	
K	Aircraft Thrust Variable	
M	Number of Program Time Increments	
PAO	Accumulator Pressure	PSI
PAC	Accumulator Pressure	PSI
PO	Cable Payout	Feet
PR	Cylinder Pressure	PSI
PY	Cylinder Pressure	PSI
PX	Cylinder Pressure	PSI
RO	Runout	Feet
RX	Runout	Inches
RY	Runout	Inches
RS	Runout	Inches
RR	Reeve Ratio	

## B. LIST OF SYMBOLS AS USED IN COMPUTER PROGRAM (CON'T)

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
SK	Dummy Variable Accumulator Pressure	
ST	Ram Stroke	Inches
SR	Ram Stroke	Inches
SX	Ram Stroke	Inches
SY	Ram Stroke	Inches
SW	Specific Weight - Ethylene Glycol	Lbs./In. <sup>3</sup>
TH	Aircraft Thrust	Lbs.
THC	Aircraft Thrust Variable	
TI	Time Increments	Seconds
VAO	Accumulator Air Volume	Cubic Inches
VAK	Velocity of Aircraft Engagements	Knots
VLC	Cable Velocity	Inches/SEC
VRA	Ram Velocity	Inches/SEC
VX	Aircraft Velocity	Inches/SEC
WT	Aircraft Weight	Lbs.
XPX	Twice Cylinder Pressure	PSI



