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R-RR-S-4-63-73

ANALYSIS OF A 105MM CLOSED BREECH GUN DESIGN WITH RECOIL CANCELLATION AND A 105MM DAVIS TYPE GUN DESIGN

U.S. ARMY ARMAMENT COMMAND

TECHNICAL REPORT

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THOMAS J. REDLING

AUGUST 1973

AIRCRAFT AND AIR DEFENSE WEAPON SYSTEMS DIRECTORATE

GENERAL THOMAS J. RODMAN LABORATORY

ROCK ISLAND ARSENAL

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TECHNICAL REPORT

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Commander
Rock Island Arsenal
Attn: SARRI-LW
Rock Island, Ill. 61201

ANALYSIS OF A 105MM CLOSED BREECH GUN DESIGN WITH RECOIL CANCELLATION AND A 105MM DAVIS TYPE GUN DESIGN

BY

THOMAS J. REDLING

AUGUST 1973

DA 1F163206D050 AMS Code 513.F.12.05014.01

[redacted]

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ABSTRACT

This report is a design study of large caliber weapons for helicopter application. The tables and graphs presented in this report provide a convenient tool for conducting trade-off evaluations.

Two weapon systems considered were a 105MM closed breech weapon with recoil cancellation and a 105MM Davis type gun. The results indicate that a greater combat load can be carried by a helicopter mounted 105MM closed breech gun design with recoil cancellation.

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INTRODUCTION

Present requirements exist for arming light aircraft and helicopters with larger caliber weapon systems which will provide improved kill capability against armored vehicles, gun emplacements, hardened bunkers, small surface craft, and personnel. The major problem associated with mounting large caliber weapons to helicopters is the excessive recoil stresses encountered by the airframe. The proposed use of recoilless rifles has also proven unsatisfactory because of the damaging breech blast. Recoilless technology investigations to reduce or control the breech blast have been unsuccessful to date.

Other approaches which can be used to achieve non-damaging recoilless operation are a closed breech weapon with recoil cancellation (impulse generator) or a Davis type gun design. The impulse generator is a rocket motor which is used to accelerate the cannon's recoilling parts to a specific velocity when the gun is fired. The rocket continues to burn and balance the gun recoil forces until projectile exit. The Davis gun is basically two gun tubes pointing in opposite directions with a common propellant chamber at midpoint. An ammunition load consists of a case, propellant charge, projectile and a disintegrating reaction mass. The weapon is recoilless when the projectile and the reaction mass exit their respective barrels simultaneously with equal momentum.

The purpose of this study is to investigate 105MM closed breech gun designs with recoil cancellation and 105MM Davis type gun designs for helicopter application.

DISCUSSION

The first step in this investigation was to select 105MM projectile weights of 25 and 30 pounds and determine gun weights, charge weights and muzzle velocities that could be obtained at different chamber pressures and tube lengths. A computer program developed at Watervliet Arsenal was used for this analysis and the results are shown in Table 1. Muzzle velocity versus gun chamber pressure at different tube lengths for 25 and 30 pound projectiles are shown in Figures 1 and 2 respectively.

The gun weights calculated by the program did not vary significantly with pressure for equal tube lengths since the computer program assumed a minimum wall thickness of 0.500 inches unless the pressures required greater thickness. The maximum pressures used for this analysis did not require wall thicknesses greater than the minimum.

Using the muzzle velocity results, exterior ballistic trajectories were calculated for firings from a helicopter at 1,000 feet and hover conditions. The range versus quadrant elevation and intersecting time of flight to range for various conditions are shown in Figures 3, 4, 5, and 6. These figures can be used in determining minimum muzzle velocity requirements for a specific range if the time-of-flight and maximum quadrant elevation are restrictive.

Closed Breech Design with Impulse Generator

Having calculated the gun weights and gun propellant charge weights for various muzzle velocity, the next steps involved calculating cartridge case weights, impulse generator propellant and motor weights. The cartridge cases were assumed to be made from steel and an assumption (based on past designs) was used that the case weight equals twice the propellant charge weight.

W_{CA} (Case Weight) = $2W_C$ (Gun Charge Weight)

The impulse generator's rocket propellant weight required to cancel out the gun recoil forces was calculated by dividing total gun impulse by the propellant specific impulse. An Isp of 230 was assumed for these calculations.

MV (Gun) = MV (Projectile) + MV (Propellant Gases)

$$Wp \text{ (Propellant Weight)} = \frac{MV}{Isp}$$

Since the back blast associated with the rocket motor impulse generator is directly related to the mass rate of discharge and ignition rise rate, these parameters were held constant for each case even though the total impulse changed. This design parameter can be controlled by varying the propellant grain geometry and burn time. The back blast overpressure associated with each impulse generator would then be the same and based on previous testing would be about 1 to 2 psi 20" aft and 25" right or left of the nozzle exit cone.

The rocket motor inert metal parts weight was calculated from the relationship:

$$\frac{Wp \text{ (Weight Propellant)}}{W_{RM} \text{ (Weight Rocket Motor)}} = .75$$

This ratio is based upon previous experience in designing rocket motors and is fairly realistic since the rocket motors are expendable and are furnished one for one with each projectile.

Having made the necessary individual component weight calculation, the overall round weight can now be calculated.

$$\begin{aligned} W_{TR} \text{ (Total Round Weight)} = {} & W_{PJ} \text{ (Projectile Weight)} \\ & + W_{CA} \text{ (Gun Charge Weight)} \\ & + W_{P} \text{ (Rocket Propellent Weight)} \\ & + W_{RM} \text{ (Rocket Motor Weight)} \end{aligned}$$

The total gun system weight was calculated from the gun weight plus a constant weight of 250 pounds, which accounted for mount weight, adapter weight and feed system weight.

$$\begin{aligned} W_{GS} \text{ (Gun System Weight)} = {} & W_{G} \text{ (Gun Weight)} \\ & + W_{ADP} \text{ (Adapter Weight)} \\ & + W_{FS} \text{ (Feed System Weight)} \end{aligned}$$

To obtain total weapon system weight, it was necessary to add to the gun system weight, a constant weight of 300 pounds for the fire control.

$$W_{TWS} \text{ (Total Weapon System Weight)} = W_{GS} \text{ (Gun System Weight)} + W_{FC} \text{ (Fire Control Weight)}$$

Assuming a helicopter payload capability of 2500 pounds, the weight available for an ammunition combat load can be calculated by subtracting total weapon system weight from 2500 pounds.

$$W_{AV} \text{ (Available Combat Load)} = 2500 - W_{TWS} \text{ (Total Weapon System Weight)}$$

The number of rounds that can then be carried by the helicopter will be equal to the available combat load divided by total round weight.

$$N \text{ (Rounds)} = \frac{W_{AV} \text{ (Available Combat Load)}}{W_T \text{ (Total Round Weight)}}$$

The results of these calculations are shown in Table 2 and the combat load versus muzzle velocity for a closed breech gun design with an impulse generator is shown in Figure 7.

Another important factor that must be considered in a closed breech gun design is the muzzle overpressures associated with these designs. Using the work of M. J. Salsbury[1], the muzzle overpressures were calculated

1. Salsbury, M. J., Polar Blast Field of 105MM Howitzer, Measured and Predicted, RE TR71-11, Artillery Systems Laboratory, U. S. Army Weapons Command, Rock Island, Illinois, Jan 71.

at various distances from the muzzle for the different muzzle velocities. The results are shown in Table 3 and Figures 8 and 9 show plots of ΔP overpressure versus muzzle velocity at two locations from muzzle. The location of the gun on the helicopter will be a key factor in determining the effects of muzzle blast overpressure.

These tables and figures represent some of the trade-offs that can be considered in selecting closed breech gun design with an impulse generator for helicopter application.

Davis Type Gun Design

The results obtained in Table 1 were considered applicable to a Davis type gun design and were used in calculating additional parameters.

The Davis gun weight was calculated by doubling the closed breech gun weight.

W_{DG} (Davis Gun Weight) = $2W_G$ (Gun Weight)

Since a weight equal to the projectile will be fired rearward to balance the recoil forces, the weight of gun propellant charge was doubled.

W_{DC} (Davis Charge Weight) = $2W_C$ (Gun Charge Weight)

Applying the previous assumption for steel cartridge cases, the Davis gun cartridge case weight would be equal to twice the Davis gun charge weight.

W_{DCA} (Davis Case Weight) = $2W_{DC}$ (Davis Charge Weight)

The total round weight would be equal to twice the projectile weight plus the Davis charge weight plus the Davis case weight.

W_{TDR} (Total Davis Round Weight) = $2W_{PJ}$ (Projectile Weight) + W_{DC} (Davis Charge Weight) + W_{DCA} (Davis Case Weight)

The total Davis gun system weight was calculated from the Davis gun weight plus a constant weight of 250 pounds, which accounted for mount weight, adapter weight and feed system weight.

W_{DGS} (Total Davis Gun System Weight) = W_{DG} (Davis Gun Weight) + W_{MO} (Mount Weight) + W_{ADP} (Adapter Weight) + W_{FS} (Feed System Weight)

To obtain total weapon system weight, it was necessary to add to the gun system weight a constant weight of 300 pounds for the fire control system.

W_{TDWS} (Total Davis Weapon System Weight) = W_{DGS} (Davis Gun System Weight) + W_{FC} (Fire Control Weight)

Again, assuming a helicopter payload capability of 2500 pounds, the weight available for an ammunition combat load can be calculated by subtracting total Davis weapon system weight from 2500 pounds.

W_{AV} (Available Combat Load) = 2500 - W_{TDWS} (Davis Weapon System Weight)

The number of rounds that can then be carried by the helicopter will be equal to the available combat load divided by total round weight.

$$N \text{ (Rounds)} = \frac{W_{AV} \text{ (Available Combat Load)}}{W_{TDR}}$$

The results of these calculations are shown in Table 4 and the combat load versus muzzle velocity for a Davis type gun design is shown in Figure 10.

Since the same muzzle velocities as the closed breech gun system were considered in the Davis type gun design, the muzzle overpressures will be the same as those shown in Table 3 and plotted in Figures 8 and 9.

CONCLUSIONS

The tables and figures presented in this report provide a tool for conducting trade-off evaluations of large caliber weapons systems in helicopter applications.

The results indicate that a greater combat load can be carried by a helicopter mounted 105MM closed breech gun design with recoil cancellation than one with a 105MM Davis type gun design.

The muzzle blast overpressure associated with both designs is considered a significant problem. By using the closed breech gun system, one half of the problem can be eliminated, since it does not appear that the blast from the impulse generator will be significant. Diffusers or barrel extensions will be required to reduce the peak muzzle blast overpressure or move it further away from the helicopter structure.

Additional trade-off design studies will be required once the overall weapon system requirements (range, time-of-flight, lethal effectiveness, accuracy, etc.) have been more adequately defined.

TABLE I

105MM CANNON DESIGN AND INTERIOR BALLISTIC DATA

CONDITION NO	PROJECTILE WEIGHT W_{PJ} POUNDS	CHAMBER PRESSURE P_{MAX} PSI	MUZZLE VELOCITY V FT/SEC	GUN CHARGE WEIGHT W_C POUNDS	CHAMBER VOLUME V_C CU. IN.	GUN LENGTH L_G INCHES	BREECH WEIGHT W_{BR} POUNDS	GUN WEIGHT W_G POUNDS
1	25	10,000	1328	1.36	58	110	76	314
2	25	15,000	1598	1.97	84	110	78	311
3	25	20,000	1815	2.55	108	110	79	313
4	25	25,000	1998	3.09	131	110	80.5	320
5	25	30,000	2156	3.59	153	110	82	332
6	25	10,000	1205	1.12	48	90	76.5	271
7	25	15,000	1451	1.63	69	90	78	269
8	25	20,000	1650	2.10	90	90	79	272
9	25	25,000	1818	2.55	109	90	80.5	277
10	25	30,000	1963	2.98	127	90	82	288
11	30	10,000	1216	1.37	58	110	76.5	314
12	30	15,000	1464	1.99	85	110	78	312
13	30	20,000	1665	2.57	109	110	79	314
14	30	25,000	1883	3.12	133	110	80.5	321
15	30	30,000	1980	3.64	155	110	82	333
16	30	10,000	1102	1.13	48	90	76.5	271
17	30	15,000	1329	1.64	70	90	78	269
18	30	20,000	1512	2.12	90	90	79	272
19	30	25,000	1667	2.58	110	90	80.5	278
20	30	30,000	1801	3.01	128	90	82	289

TABLE 2

105MM CLOSED BREECH GUN DESIGN WITH IMPULSE GENERATOR

CONDITION NO	CASE WEIGHT W_{CA} POUNDS	GUN IMPULSE MV LB. SEC.	PROPELLANT WEIGHT W_P POUNDS	ROCKET MOTOR WEIGHT W_{RM} POUNDS	TOTAL ROUND WEIGHT W_{TR} POUNDS	GUN SYSTEM WEIGHT W_{GS} POUNDS	TOTAL WEAPON SYSTEM WEIGHT W_{TWS} POUNDS	AVAILABLE COMBAT LOAD W_{AV} POUNDS	NUMBER OF ROUND N
1	2.72	1201	5.25	7.00	41.33	564	864	1636	39
2	3.94	1528	6.64	8.85	46.40	561	861	1639	35
3	5.10	1782	7.75	10.35	50.75	563	863	1637	32
4	6.18	2001	8.71	11.61	53.59	570	870	1630	30
5	7.18	2195	9.55	12.73	58.05	582	882	1618	27
6	2.24	1097	4.76	6.35	39.47	521	821	1679	42
7	3.26	1369	5.95	7.94	43.78	519	819	1681	38
8	4.20	1587	6.90	9.20	47.40	522	822	1678	35
9	5.10	1782	7.75	10.35	50.75	527	827	1673	32
10	5.96	1960	8.53	11.36	53.83	538	838	1662	30
11	2.74	1332	5.80	7.74	47.65	564	864	1636	34
12	3.98	1655	7.20	9.60	52.77	562	862	1638	31
13	5.14	1925	8.37	11.18	57.26	564	864	1636	28
14	6.24	2220	9.65	12.85	61.86	571	871	1629	26
15	7.28	2417	10.5	14.00	65.42	583	883	1617	24
16	2.26	1168	5.06	6.75	45.20	521	821	1679	37
17	3.28	1478	6.42	8.55	49.89	519	819	1681	33
18	4.24	1720	7.47	9.95	53.78	522	822	1678	31
19	5.16	1929	8.39	11.19	57.32	527	828	1672	29
20	6.02	2120	9.21	12.30	60.54	539	839	1661	27

TABLE 3

MUZZLE BLAST OVERPRESSURE

CONDITION NO	ΔP_1 20" FWD 25" R or L PSI	ΔP_2 20" FWD 30" R or L PSI	ΔP_3 20" FWD 40" R or L PSI	ΔP_4 20" FWD 50" R or L PSI	ΔP_5 20" FWD 62" R or L PSI
1	33.6	22.8	16.2	12.1	8.1
2	48.6	33.0	23.4	17.5	11.7
3	63.5	43.0	30.4	22.8	15.2
4	76.5	51.9	36.8	27.6	18.4
5	89.2	60.5	42.8	32.2	21.4
6	34.8	23.6	16.5	12.4	8.3
7	50.4	34.2	24.0	18.1	12.1
8	65.0	44.2	30.9	23.3	15.6
9	79.2	53.8	37.9	28.4	19.0
10	95.4	64.8	45.6	34.2	22.9
11	33.8	23.0	16.3	12.2	8.2
12	49.5	33.5	23.7	17.8	11.9
13	63.5	43.0	30.4	22.8	15.2
14	75.5	51.3	36.2	27.2	18.1
15	90.2	61.2	43.4	32.5	21.7
16	35.3	24.0	16.9	12.7	8.6
17	50.9	34.6	24.3	18.2	12.2
18	65.8	44.7	31.4	23.6	15.8
19	80.1	54.5	38.3	28.8	19.2
20	93.5	63.5	44.6	33.5	22.4

TABLE 4

105MM DAVIS TYPE GUN DESIGN

CONDITION NO	GUN WEIGHT W_{DG} POUNDS	GUN CHARGE WEIGHT W_{DC} POUNDS	CASE WEIGHT W_{DCA} POUNDS	TOTAL ROUND WEIGHT W_{TDR} POUNDS	GUN SYSTEM WEIGHT W_{DGS} POUNDS	TOTAL WEAPON SYSTEM WEIGHT W_{TDWS} POUNDS	AVAILABLE COMBAT LOAD W_{AV} POUNDS	NUMBER OF ROUNDS N
1	628	2.72	5.54	58.16	878	1178	1322	22
2	622	3.94	7.88	61.82	872	1172	1328	21
3	626	5.10	10.20	65.30	876	1176	1324	20
4	640	6.18	12.36	68.54	890	1190	1310	19
5	664	7.18	14.36	71.54	914	1214	1286	18
6	542	2.24	4.48	56.78	792	1092	1408	24
7	538	3.26	6.52	59.78	788	1088	1412	23
8	544	4.20	8.40	62.60	794	1094	1406	22
9	554	5.10	10.20	65.30	804	1104	1396	21
10	576	5.96	11.92	67.88	826	1126	1374	20
11	628	2.74	5.48	68.22	878	1178	1322	19
12	624	3.98	7.96	71.94	874	1174	1328	18
13	628	5.14	10.28	75.42	878	1178	1322	17
14	642	6.24	12.48	78.72	892	1192	1308	16
15	666	7.28	14.56	81.84	916	1216	1284	15
16	542	2.26	4.52	66.78	792	1092	1408	21
17	538	3.28	6.56	69.84	780	1088	1412	20
18	544	4.24	8.48	72.72	794	1094	1406	19
19	556	5.16	10.32	75.48	806	1106	1394	18
20	578	6.02	12.04	78.06	828	1128	1372	17

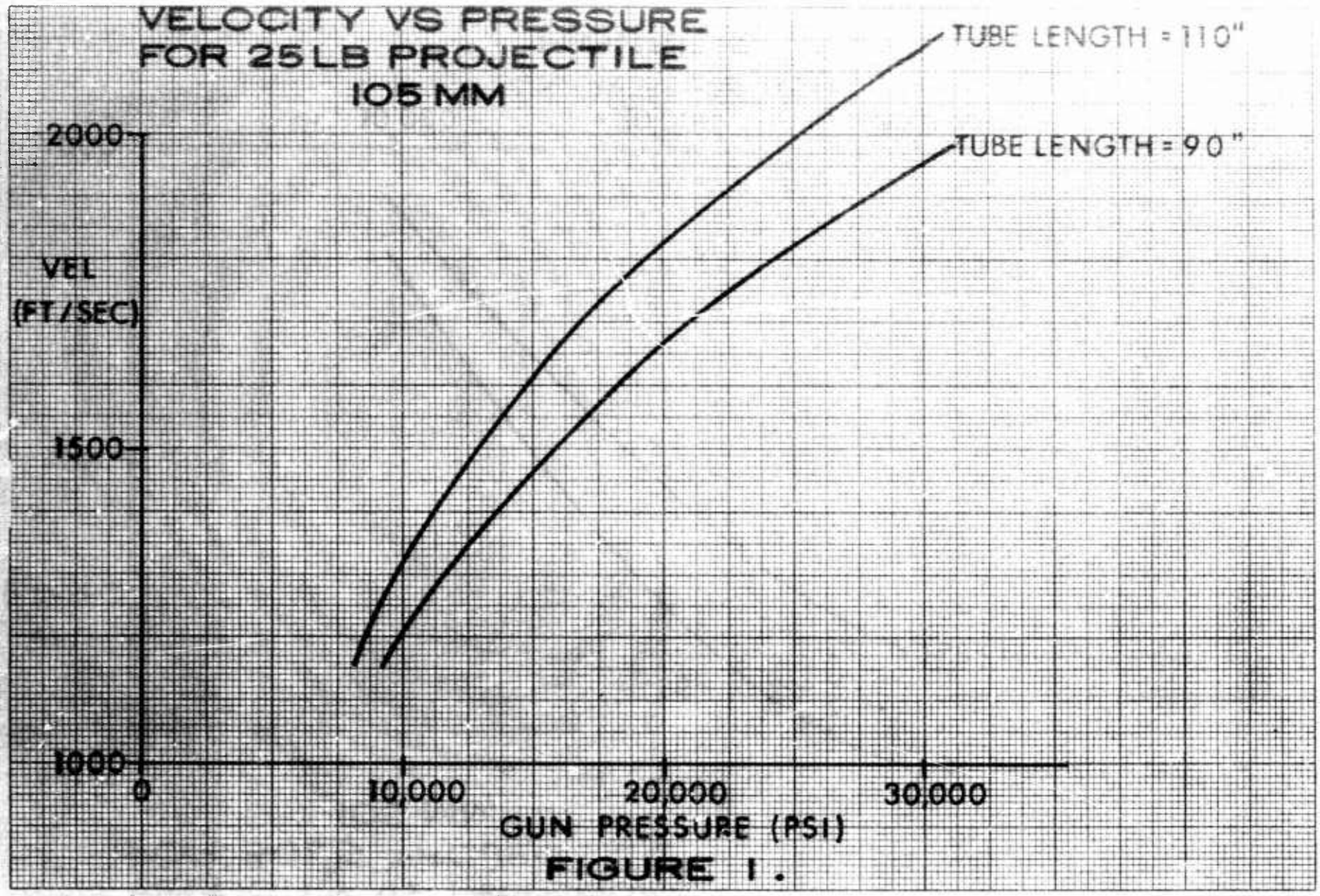

VELOCITY VS PRESSURE
FOR 25 LB PROJECTILE
105 MM
TUBE LENGTH = 110"
TUBE LENGTH = 90"
2000
VEL
(FT/SEC)
1500
1000
0
10,000
20,000
30,000
GUN PRESSURE (PSI)

FIGURE 1.

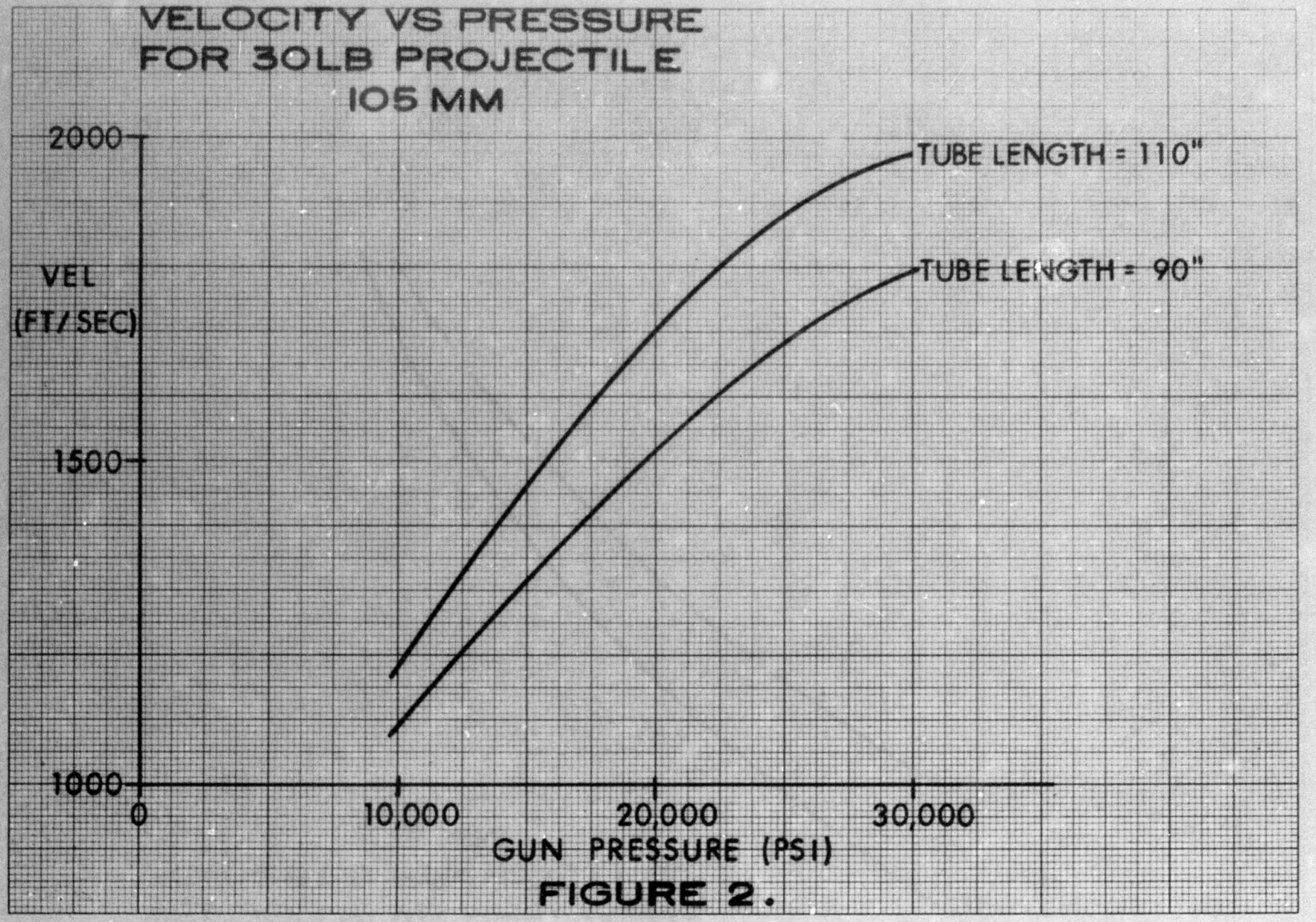

VELOCITY VS PRESSURE
FOR 30LB PROJECTILE
105 MM
2000
1500
1000
VEL
(FT/SEC)
TUBE LENGTH = 110"
TUBE LENGTH = 90"
0
10,000
20,000
30,000
GUN PRESSURE (PSI)

FIGURE 2.

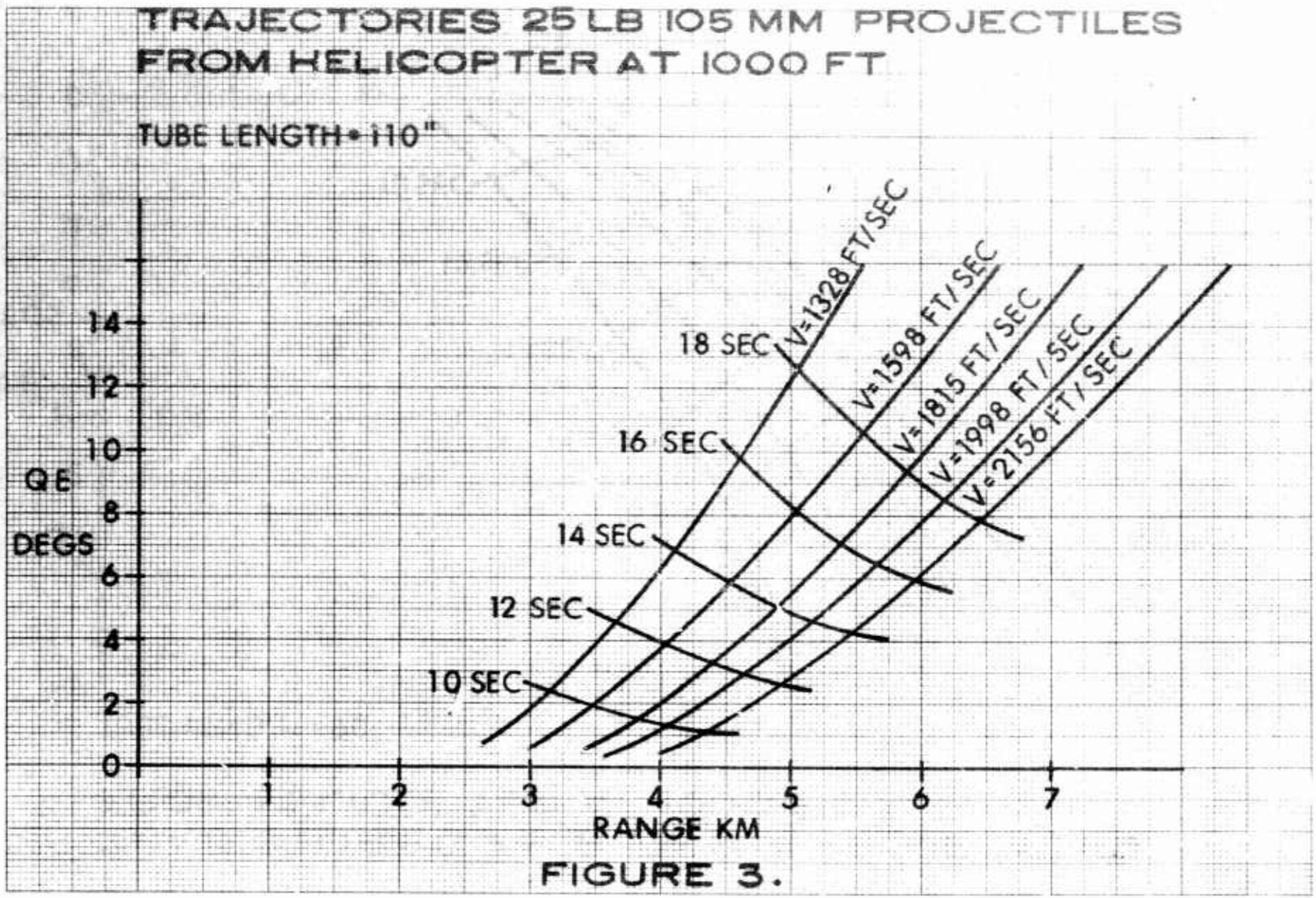

TRAJECTORIES 25 LB 105 MM PROJECTILES
FROM HELICOPTER AT 1000 FT
TUBE LENGTH = 110"
QE
DEGS
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
RANGE KM
10 SEC
12 SEC
14 SEC
16 SEC
18 SEC
V=1328 FT/SEC
V=1598 FT/SEC
V=1815 FT/SEC
V=1998 FT/SEC
V=2156 FT/SEC

FIGURE 3.

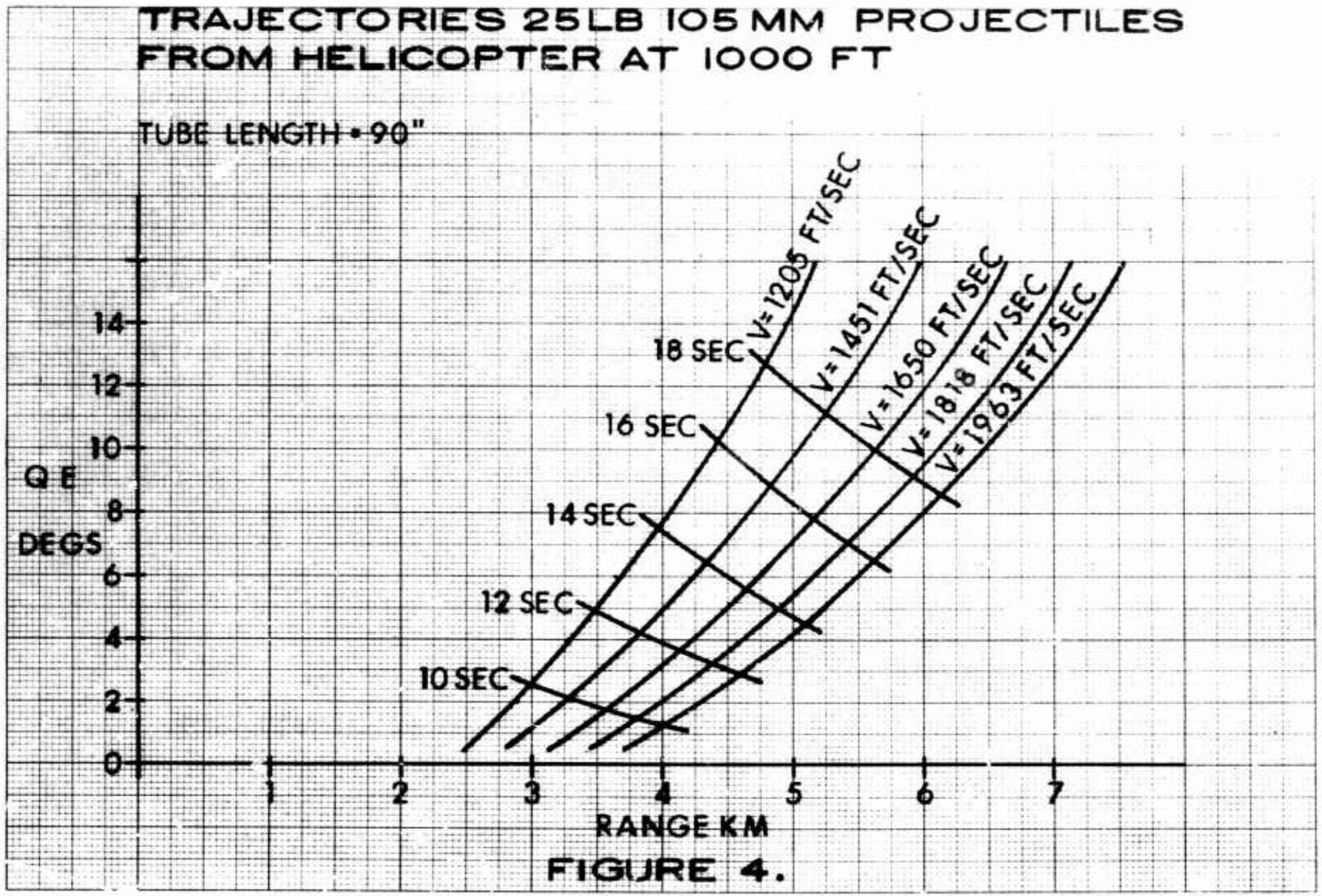

TRAJECTORIES 25LB 105 MM PROJECTILES
FROM HELICOPTER AT 1000 FT
TUBE LENGTH = 90"
V=1205 FT/SEC
V=1451 FT/SEC
V=1650 FT/SEC
V=1818 FT/SEC
V=1963 FT/SEC
18 SEC
16 SEC
14 SEC
12 SEC
10 SEC
Q E
DEGS
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
RANGE KM

FIGURE 4.

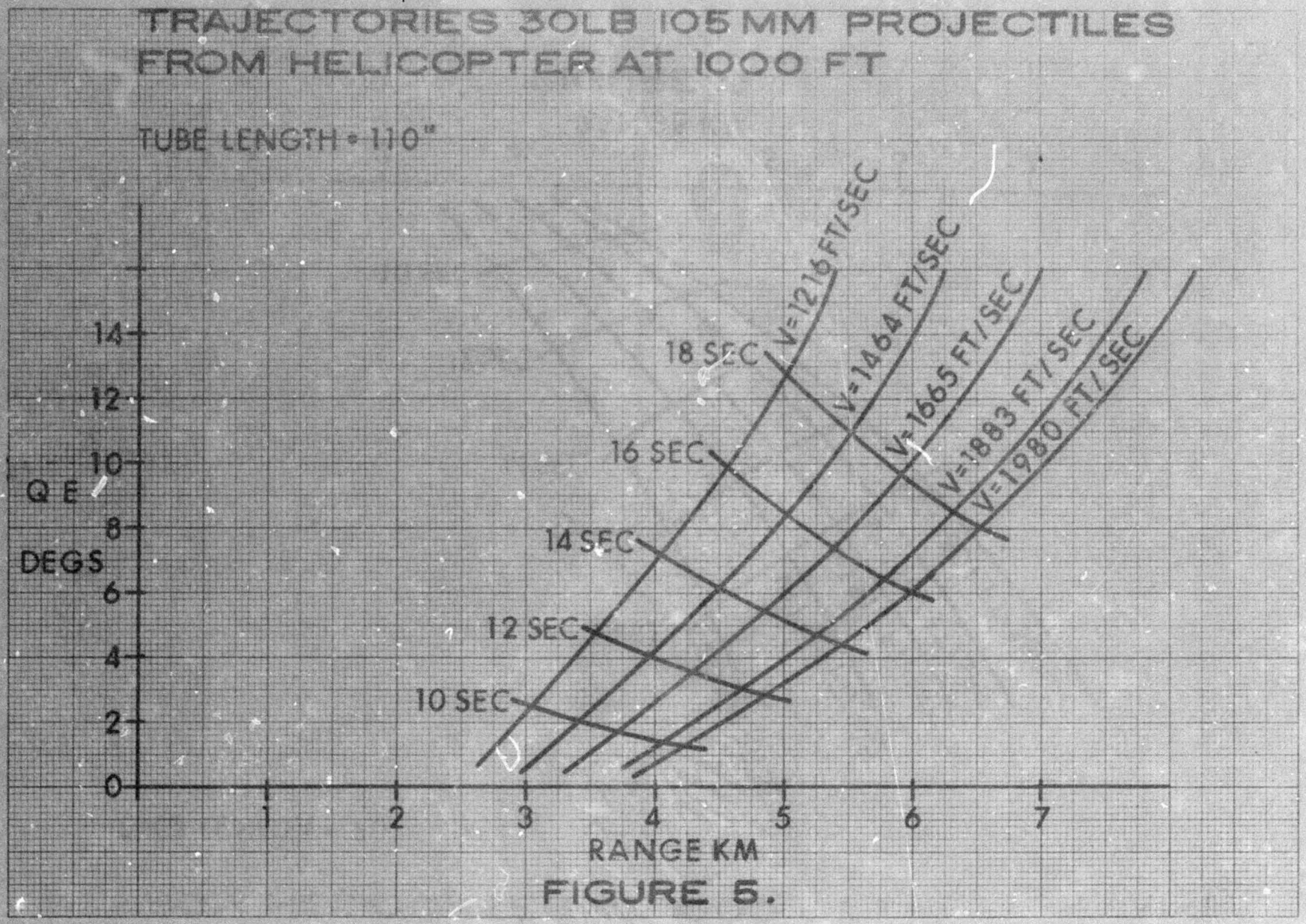

TRAJECTORIES 30LB 105MM PROJECTILES
FROM HELICOPTER AT 1000 FT
TUBE LENGTH = 110"
Q E
DEGS
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
RANGE KM
10 SEC
12 SEC
14 SEC
16 SEC
18 SEC
V=1216 FT/SEC
V=1464 FT/SEC
V=1665 FT/SEC
V=1883 FT/SEC
V=1980 FT/SEC

FIGURE 5.

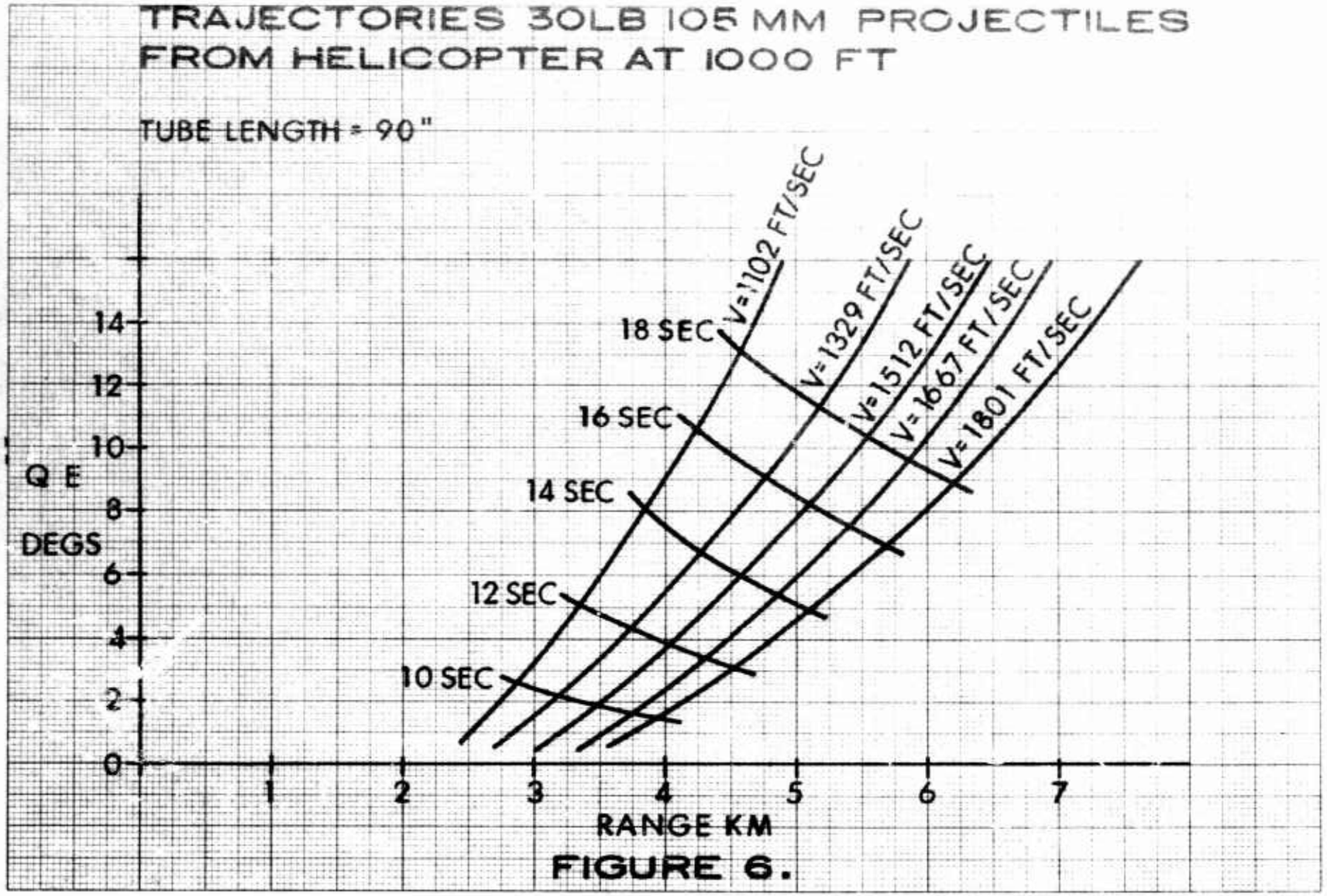

TRAJECTORIES 30LB 105 MM PROJECTILES
FROM HELICOPTER AT 1000 FT
TUBE LENGTH = 90"
V=1102 FT/SEC
V=1329 FT/SEC
V=1512 FT/SEC
V=1667 FT/SEC
V=1801 FT/SEC
18 SEC
16 SEC
14 SEC
12 SEC
10 SEC
Q E
DEGS
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
RANGE KM

FIGURE 6.

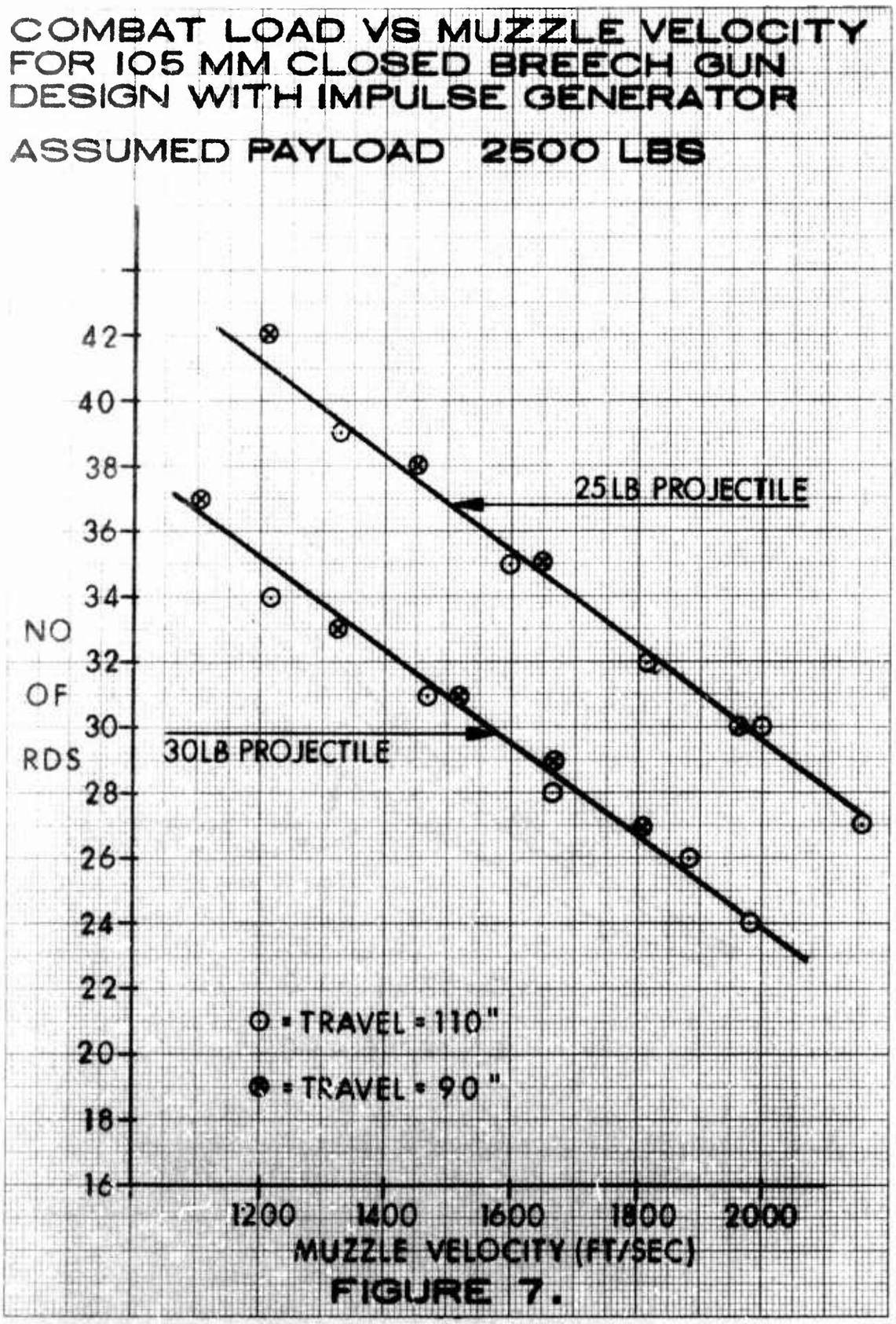

COMBAT LOAD VS MUZZLE VELOCITY
FOR 105 MM CLOSED BREECH GUN
DESIGN WITH IMPULSE GENERATOR
ASSUMED PAYLOAD 2500 LBS
NO OF RDS
42
40
38
36
34
32
30
28
26
24
22
20
18
16
25LB PROJECTILE
30LB PROJECTILE
⊙ = TRAVEL = 110"
⊗ = TRAVEL = 90"
1200
1400
1600
1800
2000
MUZZLE VELOCITY (FT/SEC)

FIGURE 7.

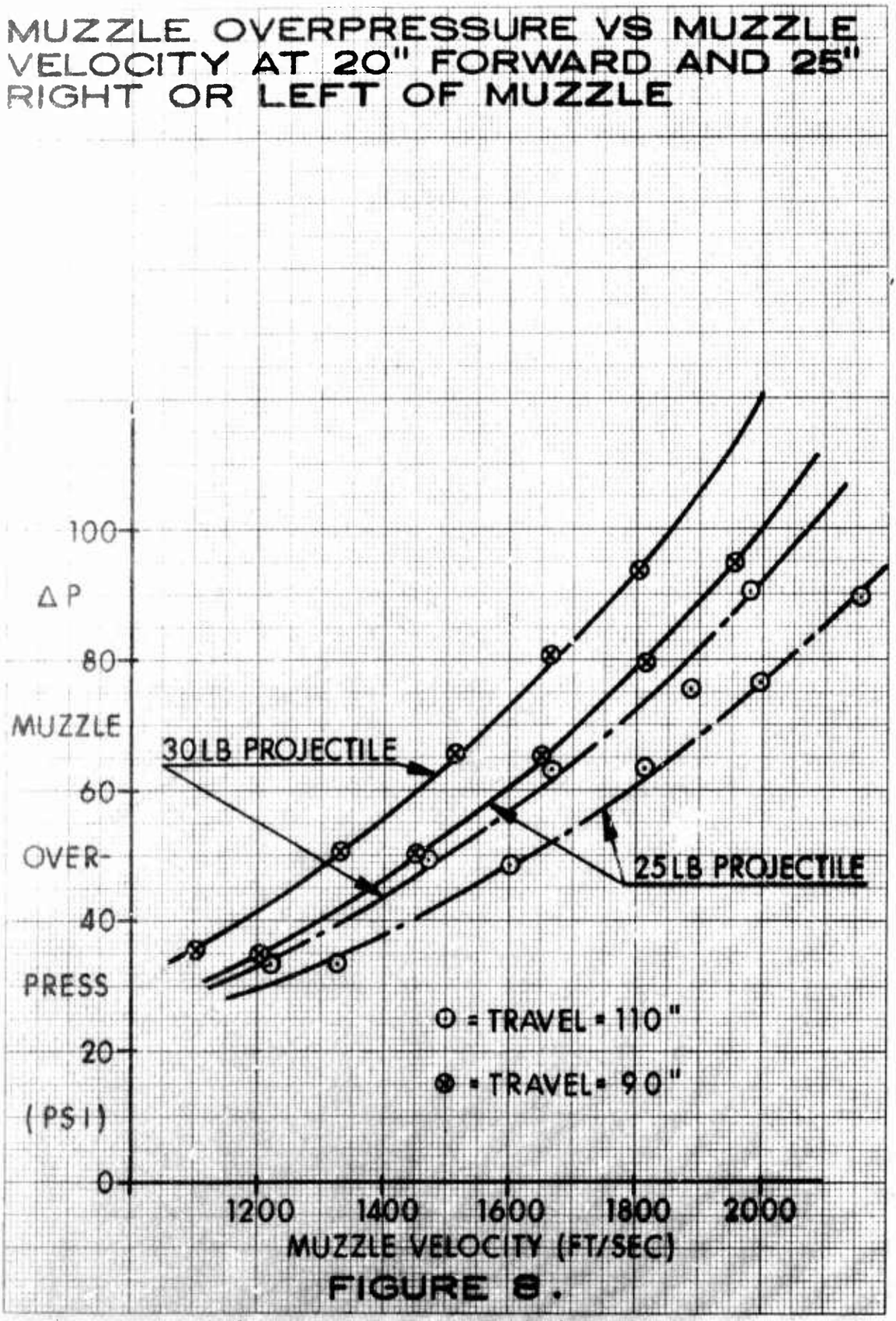
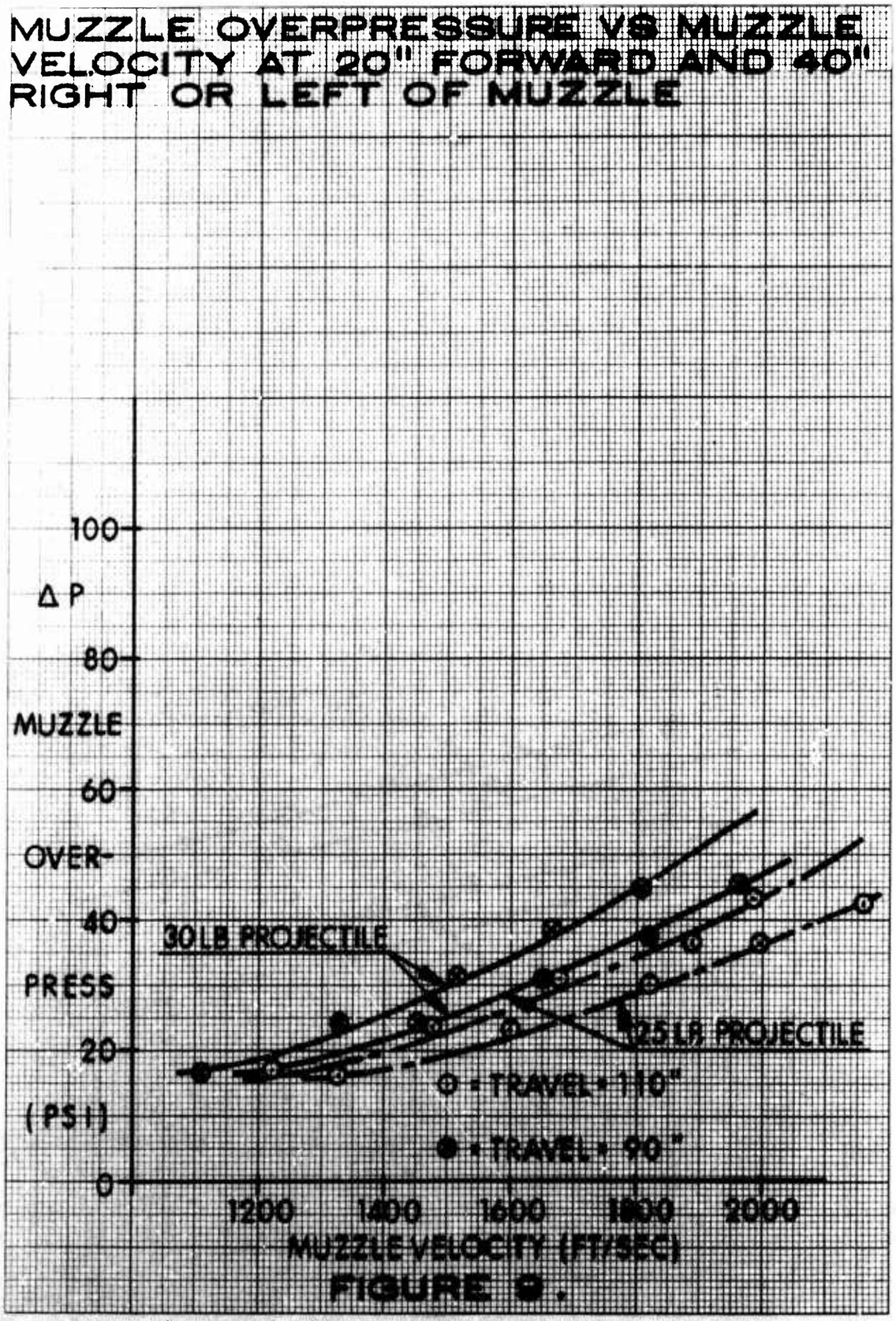

MUZZLE OVERPRESSURE VS MUZZLE VELOCITY AT 20" FORWARD AND 25" RIGHT OR LEFT OF MUZZLE
100
ΔP
80
MUZZLE
60
OVER-
40
PRESS
20
(PSI)
0
30LB PROJECTILE
25LB PROJECTILE
⊙ = TRAVEL = 110"
⊗ = TRAVEL = 90"
1200
1400
1600
1800
2000
MUZZLE VELOCITY (FT/SEC)

FIGURE 8.


MUZZLE OVERPRESSURE VS MUZZLE VELOCITY AT 20" FORWARD AND 40" RIGHT OR LEFT OF MUZZLE
100
ΔP
80
MUZZLE
60
OVER-
40
PRESS
20
(PSI)
0
30LB PROJECTILE
25LB PROJECTILE
O = TRAVEL = 110"
● = TRAVEL = 90"
1200
1400
1600
1800
2000
MUZZLE VELOCITY (FT/SEC)
FIGURE 8.

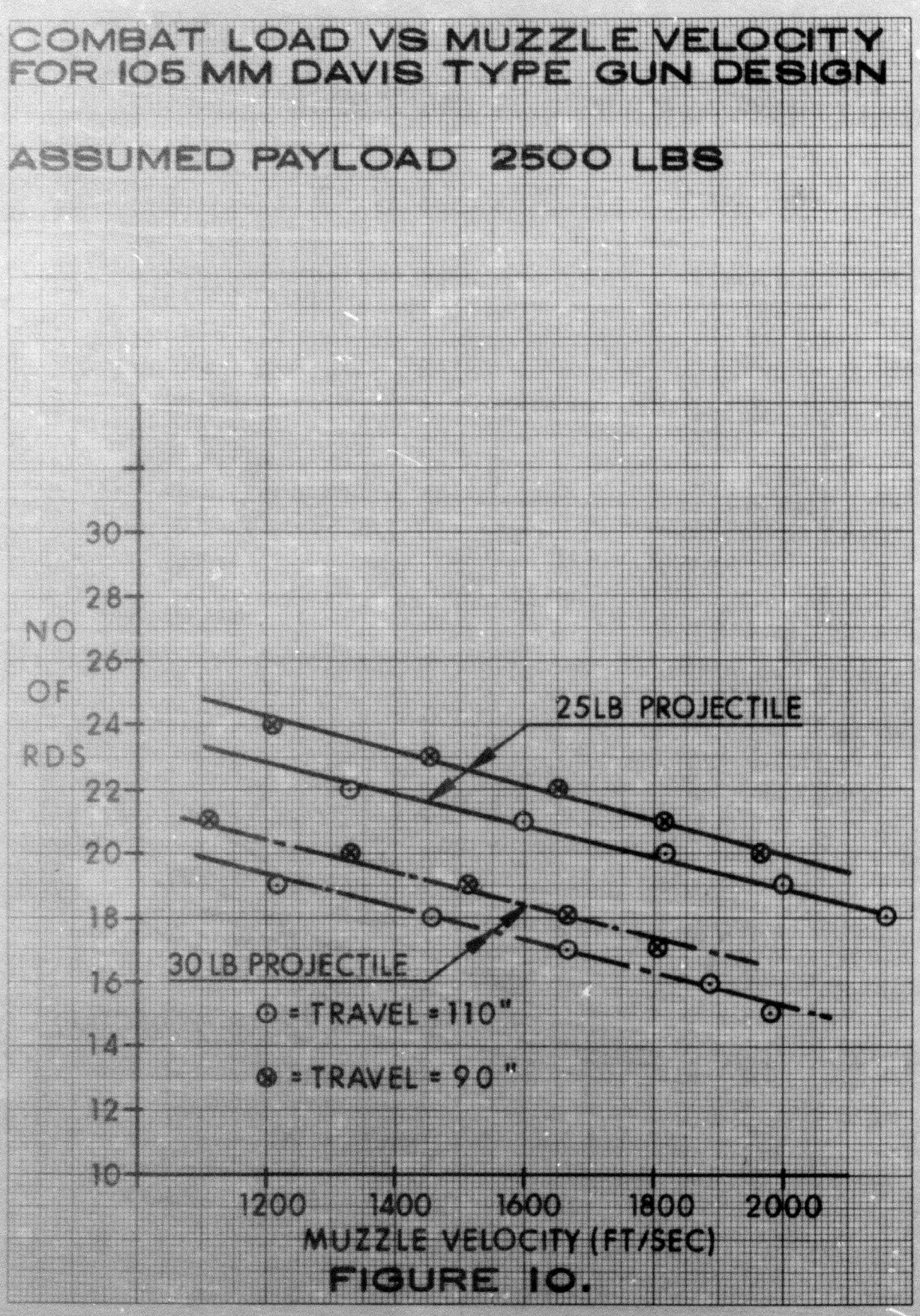

COMBAT LOAD VS MUZZLE VELOCITY
FOR 105 MM DAVIS TYPE GUN DESIGN
ASSUMED PAYLOAD 2500 LBS
NO OF RDS
30
28
26
24
22
20
18
16
14
12
10
25LB PROJECTILE
30 LB PROJECTILE
⊙ = TRAVEL = 110"
⊗ = TRAVEL = 90"
1200
1400
1600
1800
2000
MUZZLE VELOCITY (FT/SEC)

FIGURE 10.

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13. ABSTRACT

This report is a design study of large caliber weapons for helicopter application. The tables and graphs presented in this report provide a convenient tool for conducting trade-off evaluations.

Two weapon systems considered were a 105MM closed breech weapon with recoil cancellation and a 105MM Davis type gun. The results indicate that a greater combat load can be carried by a helicopter mounted 105MM closed breech gun design with recoil cancellation.

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Report R-RR-S-4-63-73, Aug 73, 26p. incl illus, tables, (DA Project 1F163206D050, AMS Code 513.F.12.05014.01) Unclassified report

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