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AD 918296

⑥
COMPARISON OF LIQUID AND SOLID PROPELLANT AIRCRAFT GUN
PHYSICAL AND PERFORMANCE CHARACTERISTICS.

⑨ INTERIM TECHNICAL REPORT

⑪ 24 Sep 1969

⑫ 44 p.

⑮
Prepared under Contract N00123-69C-1928
for

COMMANDER, NAVAL WEAPONS CENTER, CODE 3012
CHINA LAKE, CALIFORNIA 93555

by
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I. NON-HYPERGOLIC BIPROPELLANT (NHBP) GUN DESIGN

Pulsepower Systems Incorporated (PSI) NHBP gun design is basically a modular, hydraulically-operated liquid propellant gun directed toward the attainment of high performance with relatively modest size and weight.

The basic gun module, consisting of a barrel and receiver assembly, is shown in Figures 1, 2, 3, 5, 6, and 7 for the various performance levels. The modular configuration allows a wide variety of installation configurations and is basically directed towards providing a high degree of flexibility in aircraft installation, particularly in the retrofit of existing aircraft. The gun modules can be arranged in a cluster (20mm, 4-barrel cluster, Figure 4; and 30mm, 3-barrel cluster, Figure 8), in a side-by-side flat pack arrangement, or installed separately as an individual gun.

The NHBP propellant system uses JP-4 and RFNA as the propellant. Each component is non-explosive and is kept separate until injected into the chamber of the gun. Thus the propellant is stored as a non-explosive, effectively eliminating the explosive hazard. The JP-4 and RFNA propellant combination has a high measured impetus ($\sim 401,000$ ft-lb/lb at a 4.6/1 acid to fuel ratio), thus allowing attainment of high muzzle velocity at a relatively low mass ratio. The liquid propellant combination heat transfer characteristics have not yet been determined but should provide the low erosion and heating characteristics that have been found to be inherent in all liquid propellant gun systems tested thus far, because of the effects of film cooling.

The NHBP gun is an hydraulically-operated, cam-controlled system. Hydraulic power is used to perform the primary gun functions, projectile loading, and propellant pumping, with the cam providing the control functions. Since the cam forces are not great, cam size, and therefore, gun envelope, are minimized.

The operational features of the NHBP gun can be discussed by considering one of the gun modules. Each gun module consists of a barrel and receiver assembly. In the receiver is located the bolt-lock mechanism, projectile loader, the hydraulic control-valve assembly, a bolt assembly (which contains the spark ignitor-fuel and acid injectors) and the propellant-metering chambers. In the cluster arrangement, a single cylindrical cam controls the hydraulic valve assemblies of each gun module. In the single module or side-by-side flat-pack arrangement, a flat articulated track cam is used to provide the control function.

The gun module is operated from an open breech position. When the firing circuit is energized, the hydraulically-operated projectile loader loads a projectile. The bolt assembly is driven forward and pushes the projectile into the chamber. The bolt is then locked. The fuel and acid injectors are driven forward hydraulically, injecting the fuel and acid simultaneously into the chamber.

Injection of the propellant forces the projectile forward into the forcing cone. This method of propellant loading avoids air entrapment with its attendant ullage problem. The spark circuit is then energized, which fires the gun. The bolt is unlocked and retracted. The cycle is then repeated.

It should be noted that to increase the muzzle velocity, the chamber and propellant-injection mechanism are increased in size. The projectile-loading and bolt-locking mechanisms remain reasonably constant for each projectile size. Therefore, considerable increase in muzzle velocity can be attained without a corresponding increase in receiver size, such as would be the case in solid propellant ammunition gun systems.

Several safety features have been incorporated into the NHBP gun design. In the event of misfire, the chamber is purged of propellant with a JP-4 purge with the bolt closed; the bolt is then drawn back and held open. The malfunctioning module is shut down while the other modules in the cluster remain in operation.

↓
The NHBP Design provides certain operational and design features which are not available to solid propellant gun systems. These are as follows:

- (1) High gun performance can be achieved at relatively moderate gun sizes since the receivers need not be sized to handle large cartridge cases.
- (2) Since only the projectiles are stored and transported, the ammunition supply system weight, volume, and power requirements are considerably less than comparable performance solid propellant system. (The acid and, in some cases, the N_2 pressurizing tank, is stored in the ammunition drum internal to the projectile storage volume.)
- (3) The stationery barrels do not introduce tangential velocity components into the projectile trajectory.
- (4) Rapid acceleration to full firing rate is achieved because of the small masses that are rotated. If desired, the drive cam can be continuously rotated with the hydraulic system locked out so that almost instantaneous full firing rates can be achieved.
- (a) Variable speed drive can be incorporated, permitting a variable firing rate.
- (5) The NHBP combination eliminates the propellant explosive hazard in the ammunition storage system. ←

all
(Non-hypergolic bipropellant)

II. NHBP PHYSICAL CHARACTERISTICS AS A FUNCTION OF PERFORMANCE LEVEL

A. Gun System Physical Characteristics

The physical characteristics of the NHBP gun system and the equivalent performance solid propellant gun system are tabulated in Table I (20mm bore size; 3300, 3800 and 4300 ft/sec muzzle velocity). The 20mm 4300 ft/sec muzzle velocity 4-barrel cluster is illustrated in Figure 4 and the 30mm 3800 ft/sec muzzle velocity 3-barrel cluster is illustrated in Figure 8. In addition, single NHBP gun modules in each of the above performance levels are illustrated in Figures 1, 2, 3, 5, 6, and 7.

The physical characteristics of the NHBP gun system were determined from scaling study performed under Contract N00123-69C-1928 using the proprietary PSI NHBP gun design as the basis for the study. In order to provide means of comparison between the NHBP gun design and present conventional solid propellant technology, appropriate solid propellant ammunition was scaled to equivalent muzzle performance. The M-61 Gatling gun system was then scaled up to handle these rounds. Results are tabulated in Tables I and II. The method of approach will be subsequently discussed.

The advantages attained through the NHBP approach is evident by comparing specific physical characteristics at equivalent performance levels in Tables I and II. Of particular interest for aircraft gun applications is the weight characteristics of the NHBP gun system. Since the NHBP approach eliminates the cartridge case required in conventional solid propellant technology, the NHBP gun receiver is sized only to handle the G.P. projectile and pumping requirements of the propellants. This results in a considerable reduction in the receiver size with an attendant reduction in overall gun size. Note that at the 20mm level and a muzzle velocity of 3300 ft/sec (see Table I), the gun system

weight (includes barrels, receiver, drive cam and motor, projectile feeder and transfer mechanism) is 237 lb for the NHBP gun, compared to 578 lb for the equivalent performance solid propellant case.

In the NHBP gun, increases in muzzle velocity can be accomplished by modifying the chamber length and propellant injector mechanism to accommodate the larger quantities of propellant. The increase in receiver size (and therefore gun system size) is quite modest in relation to the increase in performance. In Table I, the muzzle velocity increase from 3300 ft/sec to 4300 ft/sec results in the gun system weight changing from 237 lb to 281 lb, an increase of only 44 lb. Because of the requirements for handling a much larger cartridge case, the corresponding solid propellant gun system weight changes from 578 lb to 712 lb, or an increase of 134 lb.

At the 30mm level, the weight differences between the NHBP gun and conventional solid propellant gun systems are considerably more pronounced (see Table II). For a muzzle velocity of 2800 ft/sec, the NHBP gun system weight is 372 lb. Increasing the muzzle velocity to 3800 ft/sec results in an NHBP gun system weight of 512 lb (increase of 140 lb). The corresponding solid propellant gun system weight at 2800 ft/sec muzzle velocity is 1028 lb, and 1813 lb at 3800 ft/sec (increase of 785 lb).

Elimination of the cartridge case also results in rather significant weight reduction in the ammunition supply system and ammunition weight. The NHBP system ammunition supply (includes storage drum, ammunition conveyor, and the N_2 pressurizing tank) is sized to handle only the projectile supply and the RFNA tank. In the solid propellant gun system, the ammunition storage drum must be sized to handle the entire round. For the high performance round, such as the 30mm 3800 ft/sec performance level, the solid propellant ammunition supply system weight of 1559 lb. and ammunition weight of 3109 lb (for 1091 rounds) is quite excessive and

results in a total system weight of 6141 lb, which is impracticable for present aircraft applications. By contrast, the NHBP total system weight is 2353 lb for equivalent muzzle performance.

The advantageous features of the NHBP gun system is also reflected in the other significant physical parameters. Note that the volume and envelope size are considerably less in the NHBP case when compared with their equivalent performance solid propellant counterparts. For example, at the 20mm 4300 ft/sec performance level, the gun envelope is 7.5 in x 7.5 in x 93 in long, the gun system volume is 1.65 ft³ and the ammunition system volume is 6.0 ft³. By comparison, the equivalent performance solid propellant gun envelope is 17.7 in x 16.6 in x 143.7 in long, the gun system volume is 5.62 ft³ and the ammunition system volume is 24.8 ft³.

B. NHBP Design Study Procedure

The procedure followed in establishing the physical characteristics of the NHBP gun system are as follows:

1. For each muzzle velocity, the mass ratio was established for the NHBP combination. For this study, a 4.6/1 and to fuel ratio with a measured impetus of 401,000 ft-lb/lb was used.
2. At each combination of projectile weight and muzzle velocity, the propellant charge size and the chamber length was determined. The results are tabulated in Table III.
3. An engineering layout was then made for each bore size and chamber length to establish the receiver size. The receiver weights were then established from the engineering layouts.
4. Expansion ratios were then selected at each muzzle velocity. (Expansion ratios are based on previous experimental liquid propellant firings) With the charge size and expansion ratio established, the barrel length was then determined. The results are tabulated in Table IV.
5. For each bore size and barrel length, barrel weights were calculated. In the weight calculation, the following criteria were used.

a) A wall/radius ratio (barrel wall thickness/bore radius) approximating that which is used in the M-61 gun barrel was utilized. These are:

chamber end - wall/radius ratio = .96

muzzle end - wall/radius ratio = .287

b) In the NHBP gun barrel, the chamber end O.D. was extended and maintained constant for the first 40% of the total barrel length. (In liquid propellant guns, some propellant burning occurs down the barrel, thus necessitating heavier barrel sections during initial projectile travel.) From that point, the O.D. was tapered down to the muzzle end O.D. The resulting barrel weights are tabulated in Table IV.

6. At the 20mm level, the design firing rate of each module is 1500 shots per minute. Four modules are clustered together to provide a 6000-shot-per-minute firing rate. The physical characteristics of the 20mm and 30mm gun systems, which include the clustered gun modules (barrel and receiver), drive cam, drive motor, projectile transfer and feeder units, are tabulated in Table V.

7. The ammunition supply system characteristics, which consist of the ammunition storage drum and projectile conveyor, was determined by scaling up from an existing PSI liquid propellant ammunition system design. Results are as shown in Tables I and II.

C. Equivalent Performance Solid Propellant Gun System Scaling Procedure

In order to illustrate the advantages provided by the NHBP gun system design, it is desirable to compare the NHBP design with equivalent performance solid propellant gun systems. Since there does not presently exist directly comparable solid propellant gun systems, it was decided to scale up the 20mm M-61 gun to the desired performance levels, using muzzle energy as the basis for comparison. At the 20mm level, the 6-barrel scaled-up gun system with a firing rate of 6000 shots per minute is used and at the 30mm level, a

3-barrel version with a 3000-shots-per-minute firing rate is used. The study was performed in two phases: (1) existing solid propellant ammunition was scaled to the desired performance level; (2) the M-61 gun was then scaled up to handle these various rounds. The procedure utilized is as follows:

1. Solid propellant ammunition with approximately the desired performance level (muzzle energy) was selected.

2. In each of the selected solid propellant ammunition, the appropriate general purpose projectile was substituted for the standard projectile. Corrections were made for the propellant volume change due to use of the G.P. projectile. Each round was then scaled to provide the desired performance level. Table VI. illustrates the solid propellant ammunition characteristics.

3. The 20mm M-61 gun system (gun and ammunition supply system) is then scaled up to handle each of the scaled solid propellant rounds. Factors used for scaling the M-61 gun were based on the round length, diameter and weight ratios between the scaled-up solid propellant ammunition and the M-55 ammunition used in the M-61 gun. Results of the M-61 scaling are tabulated in Table VII.

III. SAFETY ASPECTS OF THE NHBP GUN SYSTEM

The use of the NHBP propellant system affords several advantageous safety features which are not generally associated in present solid propellant systems. Each of the NHBP components, JP-4 and RFNA, are non-explosive. JP-4 is already present in aircraft fuel systems. RFNA, properly packaged and handled, can be arranged to be of minimum hazard. The primary advantage of this propellant system is that it is not a propellant until the components are injected and mixed in the chamber of the NHBP gun. Therefore, the hazard due to explosion caused by fire or battle damage to the ammunition supply is reduced to a minimum.

The use of RFNA aboard aircraft requires special procedures and technique to reduce handling hazards. For example, complete pre-packaging and the use of zero leakage-quick disconnect fittings are desirable. RFNA storage tanks can be arranged to be jettisoned in the event of puncture due to battle damage.

In the design of the NHBP gun, the propellants are injected into the chamber through the bolt mechanism. Therefore, the propellant supply mechanism is thermally isolated from the hotter chamber except for the short interval (20 - 30 milliseconds) during which the propellant is injected and the gun is fired. The barrel is mounted to the receiver, using insulators to provide thermal isolation. In general, the design is directed toward isolating the hot chamber and barrel away from the remainder of the gun components.

TABLE I

COMPARISON OF EQUIVALENT PERFORMANCE LIQUID & SOLID PROPELLANT
20mm GUN SYSTEMS WITH GENERAL PURPOSE (2320 GR.) PROJECTILE

	NHBP (Liquid) Gun System			Solid Propellant Gun Systems (Based on scaled-up M-61)		
	3300	3800	4300	3300	3800	4300
Muzzle Velocity (ft/sec)	3300	3800	4300	3300	3800	4300
Muzzle Energy (ft/lb.)	56,000	74,200	95,000	56,000	74,200	95,000
Gun Arrangement	4-barrel Cluster			6 Barrels		
Rate of Fire (shot/min)	6000			6000		
Ammunition Type	NHBP	NHBP	NHBP	Scaled up HS-920	Necked down TRW6425	Scaled up & necked down TRW6425
Gun System Wt* (lb.)	237.6	252.8	281.2	578	589	712
Ammunition Supply System Wt** (lb.)	124	124	133	539	575	679
Total System Wt (w/o ammo) (lb.)	361.6	376.8	414.2	1117	1164	1391
ammunition Wt (1091 rds) (lb.)	454	494	551	906	1145	1364
Total System Wt (w/amm) (lb.)	815.6	870.8	965.2	2023	2309	2755
Gun System Volume (cu.ft.)	1.24	1.41	1.65	4.26 ⁽¹⁾	4.32 ⁽¹⁾	5.62 ⁽¹⁾
Ammunition System Vol. (cu.ft.)	4.9	5.1	6.0	17.4 ⁽²⁾	20.6 ⁽²⁾	24.8 ⁽²⁾
Gun Envelope						
Max. Height (in)	7.5	7.5	7.5	17.0	16.7	17.7
Max. Width (in)	7.5	7.5	7.5	16.0	15.8	16.6
Overall Length (in)	67.8	79.1	93	106.9	115.6	143.7
Ammunition Drum Envelope						
Diameter (in)	20.75	20.75	22.75	27.7	27.3	28.8
Length (in)	23	23	23	50	61	66
Power Requirements (hp) (based on est. force req'ts)	32	36	40			

*Includes barrel, receiver, cam, motor, feeder, transfer

**Storage drum, N₂ Tank, conveyor

(1) Does not include transfer unit

(2) Drum volume only

TABLE II

COMPARISON OF EQUIVALENT PERFORMANCE LIQUID & SOLID PROPELLANT
30mm GUN SYSTEMS WITH GENERAL PURPOSE (7200 GR.) PROJECTILE.

	NHBP (Liquid) Gun System			Solid Propellant Gun Systems (Based on scaled-up M-61)		
	2800	3300	3800	2800	3300	3800
Muzzle Velocity (ft/sec)	2800	3300	3800	2800	3300	3800
Muzzle Energy (ft.lb.)	125,000	174,000	231,000	125,000	174,000	231,000
Gun Arrangement	3-barrel Cluster			3 Barrels		
Rate of Fire (shot/min)	3000			3000		
Ammunition Type	NHBP	-NHBP	NHBP	Oerli- kon 304	Scaled up Oerli- kon 304	Scaled up & necked down Oerli- kon 35
Gun System Wt* (lb.)	372.4	442	511.9	855	1139	1473
Ammunition Supply System Wt** (lb.)	313	313	313	1005	1415	1559
Total System Wt (w/o ammo)(lb.)	685.4	755	824.9	1860	2554	3032
Ammunition Wt (1091 rds) (lb.)	1315	1413	1528	2200	2650	3109
Total System Wt (w/ammo) (lb.)	2000.4	2158	2352.9	4060	5204	6141
Gun System Volume (cu.ft.)	4.26	4.32	5.62	6.76 ⁽¹⁾	9.6 ⁽¹⁾	14.4 ⁽¹⁾
Ammunition System Vol. (cu.ft.)	14.6	14.6	15.0	40.6 ⁽²⁾	53.0 ⁽²⁾	66.6 ⁽²⁾
Gun Envelope Max. Height (in)	11.2	11.2	11.2	21.7	23.5	25.4
Max. Width (in)	11.2	11.2	11.2	21	22.5	24
Overall Length (in)	70.4	93.3	112.4	86.1	116.7	163.4
Ammunition Drum Envelope Diameter (in)	30	30	30	35.4	38.3	41.3
Length (in)	34.5	34.5	34.5	71.4	79.5	86
Power Requirements (hp) (based on est. force req'ts)	48	54	60			

*Barrel, receiver, cam, motor, feeder, transfer

**Storage Drum, N₂ Tank, Conveyor

(1) Does not include transfer unit

(2) Drum volume only

TABLE III
NHBP GUN PROPELLANT CHARGE AND CHAMBER SIZE

Bore	Proj. Wt. (grains)	Muzzle Velocity (ft/sec)	Mass Ratio*	Prop. Charge (grams)	Prop. Volume (cc)	Chamber Diameter (in)	Chamber Length (in)
20mm	2320	3300	.252	37.8	29.1	.834	3.26
20mm	2320	3800	.363	54.5	41.8	.834	4.7
20mm	2320	4300	.522	78.2	60.2	.834	6.7
30mm	7200	2800	.174	81.3	62.4	1.26	3.08
30mm	7200	3300	.253	118	91.	1.26	4.45
30mm	7200	3800	.363	170	131	1.26	6.32

*Based on Acid/Fuel Ratio of 4.6/1
Impetus of 401,000 ft-lb/lb

TABLE IV

NHBP BARREL LENGTHS AND WEIGHTS

Bore	Muzzle Velocity (ft/sec)	Prop. Volume (cc)	Expansion Ratio	Total Volume (cc)	Barrel Length (in)	Outside Diameter		Barrel Weight (lb)
						Chamber End (in)	Muzzle End (in)	
20mm	3300	29.1	14	406	48.7	1.61	1.05	17.0
20mm	3800	41.8	12	502	60.0	1.61	1.05	19.4
20mm	4300	60.2	10	602	71.7	1.61	1.05	21.0
30mm	2800	62.4	14	873	47.6	2.48	1.57	36.8
30mm	3300	91.0	14	1272	69.5	2.48	1.57	55.0
30mm	3800	131.0	12	1572	85.8	2.48	1.57	67.3

TABLE V-a
NHBP MODULE WEIGHTS

Bore Size	20mm			30mm		
	Muzzle Velocity (ft/sec)	3300	3800	4300	2800	3300
Receiver Weight (lb)	32.9	34.3	39.8	64.0	69.0	80.0
Barrel Weight (lb)	17.0	19.4	21.0	36.8	55.0	67.3
Module Weight (lb)	49.9	53.7	60.8	100.8	124.0	147.3
Overall Length (in)	67.8	79.1	93.0	10.4	93.3	112.4

TABLE V-b
NHBP GUN SYSTEM WEIGHTS

Bore Size	20mm			30mm		
	Muzzle Velocity (ft/sec)	3300	3800	4300	2800	3300
Arrangement	4-Barrel Cluster			3-Barrel Cluster		
Total Module Weight (lb)	199.6	214.8	243.2	302.4	372.0	441.9
Feeder	8	8	8	10	10	10
CLM	10	10	10	15	15	15
Motor	10	10	10	12	12	12
Transfer Unit	10	10	10	33	33	33
Total Gun System Wt. (lb)	237.6	252.8	281.2	372.4	442.0	511.9

TABLE VI

SOLID PROPELLANT AMMUNITION SCALING

Equivalent LP Performance	20mm			30mm		
	Muzzle Velocity (ft/sec)	3300	3800	4300	2800	3300
Proj. Wt. (grain) (General Purpose)	2320	2320	2320	7200	7200	7200
Muzzle Energy (ft/lb)	56,200	74,200	95,200	125,000	174,000	231,000
Comparable Solid Propellant Round with Standard Projectile	H.S. 820 (H.E.)	TRW 6425 (H.E.)		Oerlikon 304		Oerlikon 35
Total Round Length (in)	8.4	8.78		11.4		15.2
Case Diameter (mm)	29	38		44		55
Cartridge Case Lgth (in)	5.4	5.6		6.8		9.0
Propellant Volume (in ³)	3.37	5.24		8.65		21.4
Propellant Weight (lb)	.116	.201		.314		.75
Total Round Wt (lb)	.69	1.13		1.76		3.44
Muzzle Energy (ft/lb)	51,200	80,000		144,000		280,000
Comparable Solid Propellant Round with General Purpose Proj.	H.S. 820	TRW 6425 necked down to 20mm		Oerlikon 304		Oerlikon 35 necked down to 30mm
G.P. Proj. Lgth (in) (external to case)	2.6	2.6		3.88		3.88
Cartridge Case Lgth (in)	5.4	5.6		6.8		9.0
Total Round Lgth (in)	8.0	8.2		10.68		12.88
Case Diameter (mm)	29	38		44		55
Propellant Volume (in ³)	3.12	4.82		7.46		20.2
Propellant Weight (lb)	.107	.189		.271		.71
Total Round Wt (lb)	.75	1.05		2.02		3.10
Muzzle Energy (ft/lb)	47,000	75,000		124,000		263,000
Comparable Solid Propellant Round with General Purpose Proj.		TRW-6425	Scaled up TRW-6425 &		Scaled up	Scaled down Oerlikon 35

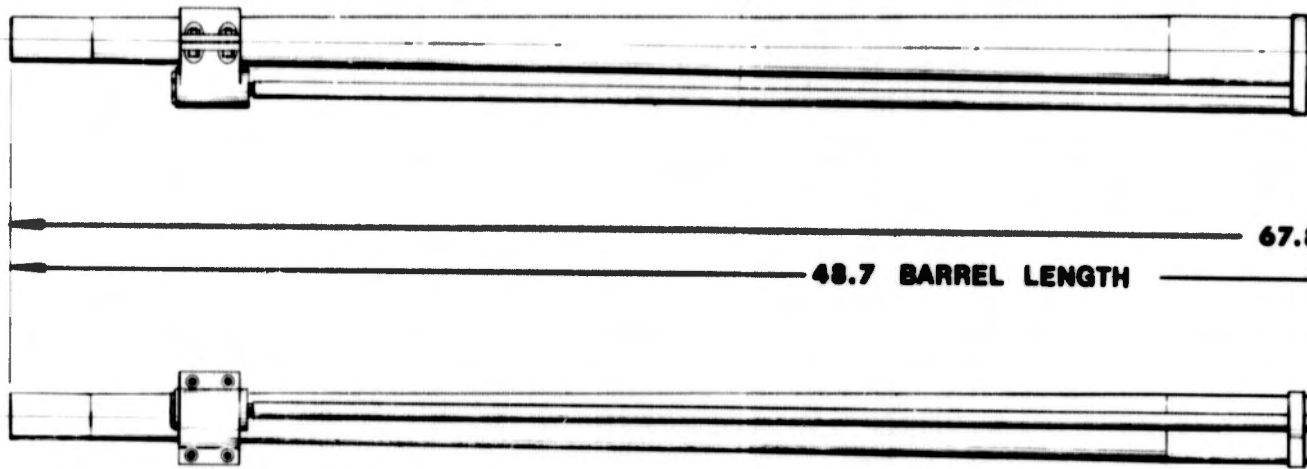
Case Diameter (mm)	29	38	44	55
Cartridge Case Lgth (in)	5.4	5.6	6.8	9.0
Propellant Volume (in ³)	3.37	5.24	8.65	21.4
Propellant Weight (lb)	.116	.201	.314	.75
Total Round Wt (lb)	.69	1.13	1.76	3.44
Muzzle Energy (ft/lb)	51,200	80,000	144,000	280,000
Comparable Solid Propellant Round with General Purpose Proj.	H.S. 820	TRW 6425 necked down to 20mm	Oerlikon 304	Oerlikon 35 necked down to 30mm
G.P. Proj. Lgth (in) (external to case)	2.6	2.6	3.88	3.88
Cartridge Case Lgth (in)	5.4	5.6	6.8	9.0
Total Round Lgth (in)	8.0	8.2	10.68	12.88
Case Diameter (mm)	29	38	44	55
Propellant Volume (in ³)	3.12	4.82	7.46	20.2
Propellant Weight (lb)	.107	.129	.271	.71
Total Round Wt (lb)	.75	1.05	2.02	3.10
Muzzle Energy (ft/lb)	47,000	75,000	124,000	263,000
Comparable Solid Propellant Round with General Purpose Proj. Scaled for Equivalent LP Performance	Scaled up H.S.-820	TRW-6425 Necked down to 20mm	Oerlikon 304	Scaled down Oerlikon 35 necked down to 30mm
G.P. Proj. Lgth (in) (external to case)	2.6	2.6	3.88	3.88
Cartridge Case Lgth (in)	5.72	5.6	6.8	8.62
Total Round Lgth (in)	8.32	8.2	10.68	12.50
Case Diameter (mm)	31	38	44	53
Propellant Volume (in ³)	3.72	4.82	7.46	17.8
Propellant Weight (lb)	.128	.189	.271	.63
Total Round Wt (lb)	.83	1.05	2.02	2.85
Muzzle Energy (ft/lb)	56,200	75,000	124,000	231,000

TABLE VII

SCALING UP OF M-61 GUN TO EQUIVALENT LP PERFORMANCE LEVELS

Gun Components (Weights)	Basic M-61 1540 Grain Projectile 3300 ft/sec		20mm 6-Barrel Gun - 2320 Grain G.P.P.		30mm 3-Barrel Gun - 7200 Grain G.P.P.	
	3300 ft/sec	3800 ft/sec	3300 ft/sec	4300 ft/sec	2800 ft/sec	3300 ft/sec
	3300 ft/sec	3800 ft/sec	3300 ft/sec	4300 ft/sec	2800 ft/sec	3300 ft/sec
Barrels (lb)	110*	184	167	233	143	196
Stationary & Rotating Members (less barrels) (lb)	155	296	310	349	510	685
Storage Drum (lb) (doubled-ended)	240	427	410	506	768	1200
Exit Unit (lb)	11	21	18	26	38	65
Entrance Unit (lb)	14	27	28	33	49	83
Conveyor Unit (lb)	64	100	83	114	150	211
Transfer Unit (lb)	33	64	66	77	115	195
Drive Unit (lb)	24	45	35	53	87	123
Total System Weight (less ammunition) (lb)	651	1164	1117	1391	1860	2554
Ammunition Weight 1000 Rds in Storage 91 Rds in Conveyor (lb)	610	1145	906	1364	2200	2650
Total Weight (lb)	1261	2309	2023	2755	4060	5204
						6141

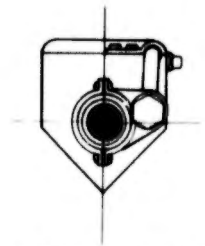
*6 Barrels



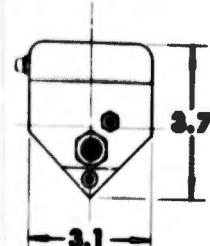
67.0

48.7 BARREL LENGTH

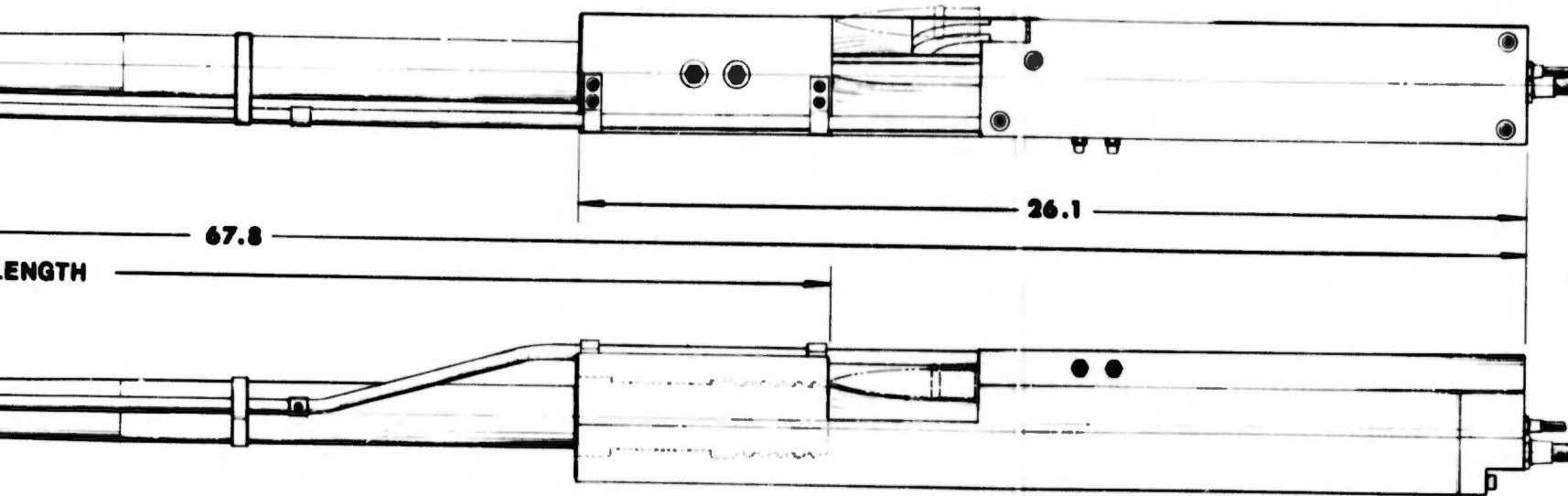
1



MUZZLE VIEW



BREECH VIEW



67.8

26.1

LENGTH

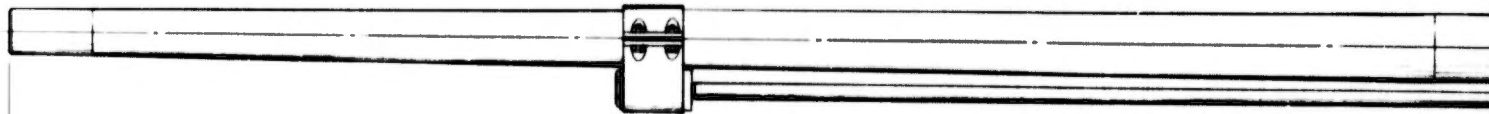
WEIGHT ■ 50 LBS.

2

INTERPRET THIS DRAWING
PER STANDARD 800-0-100

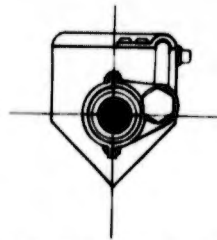
REV	DATE	BY	CHKD

NEXT ASSY USED IN APPLICATION

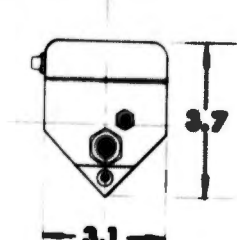


60.0 BARREL LENGTH

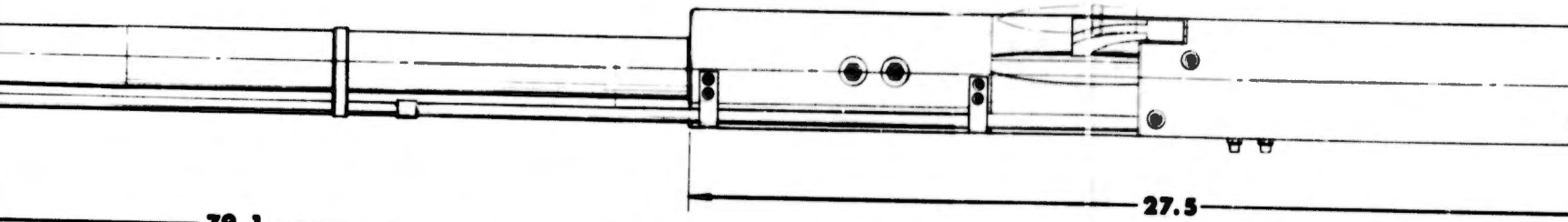




MUZZLE VIEW

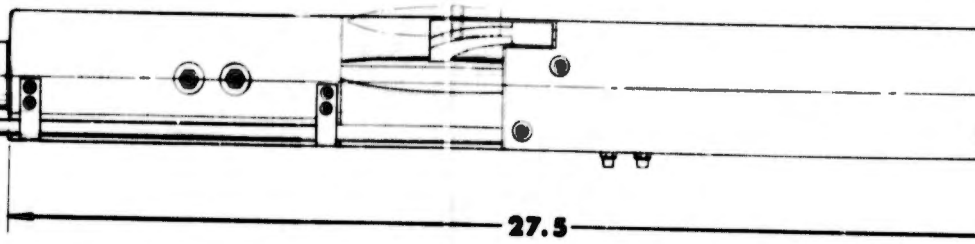


BREECH VIEW

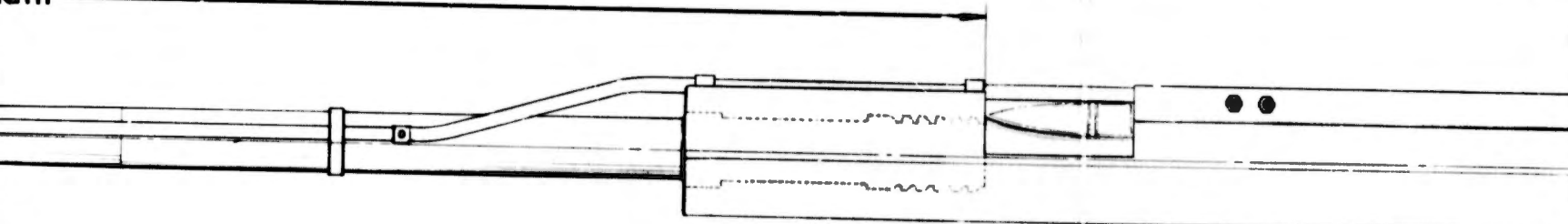


79.1

LENGTH

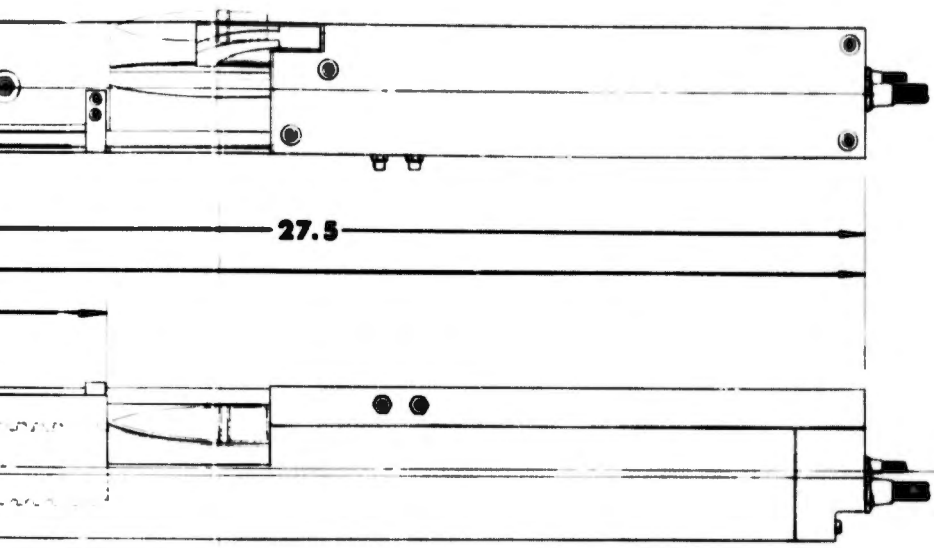
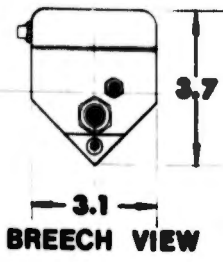


27.5



WEIGHT = 54 LBS.

2

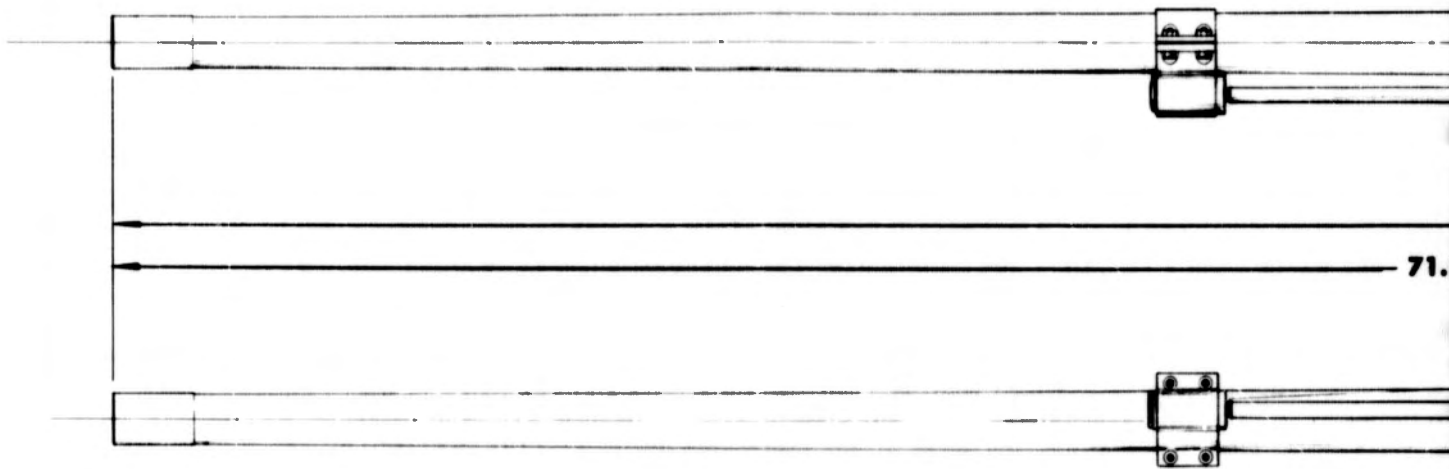


WEIGHT = 54 LBS.

INTERPRET THIS DRAWING PER STANDARD MIL-0-1000		QTY REQD	PART NUMBER	DESCRIPTION	CODE IDENT NO	ITEM NO
DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES						
UNLESS OTHERWISE SPECIFIED						
MATERIAL SPECIFICATIONS						
SURFACE FINISH						
TOLERANCES UNLESS OTHERWISE SPECIFIED						
APPROVED						
APPROVED						
APPLICATION						
DR. [Signature] CHK. [Signature] PROJ. ENG. [Signature]				LIST OF MATERIAL PULSEPOWER SYSTEMS INCORPORATED MODULE - 20MM NHBP GUN 3800 FPS - MV SIZE CODE IDENT NO. DRAWING NO. R 3001-202 SCALE 1/2 WT SHEET OF		

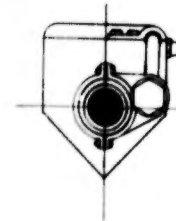
3

FIGURE 2

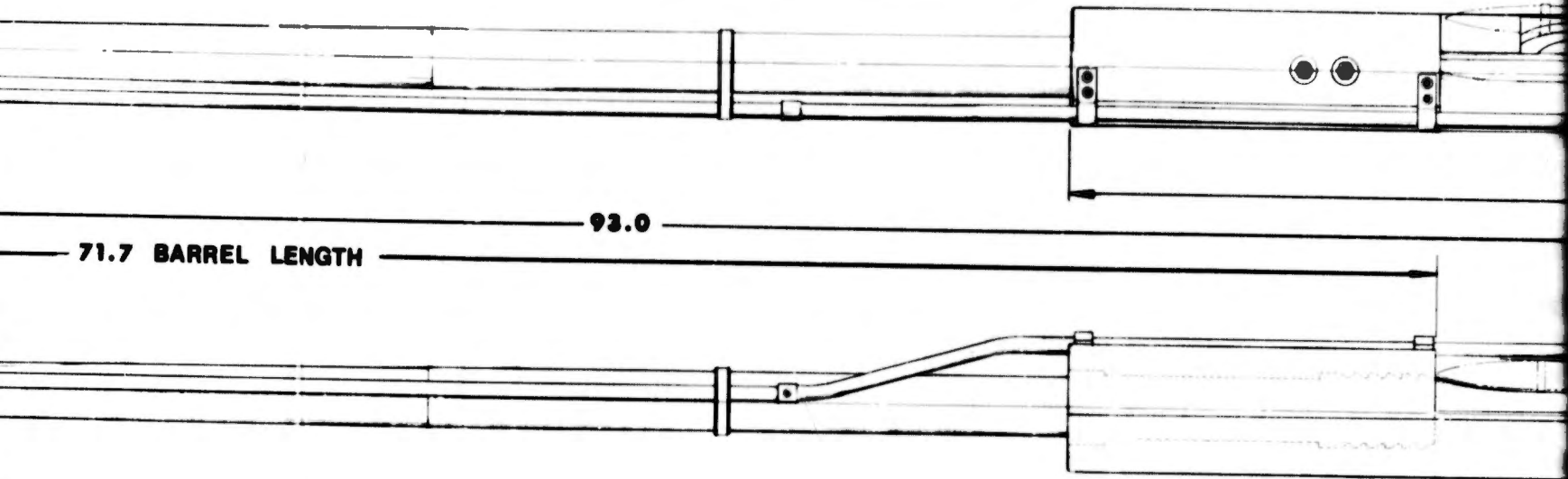


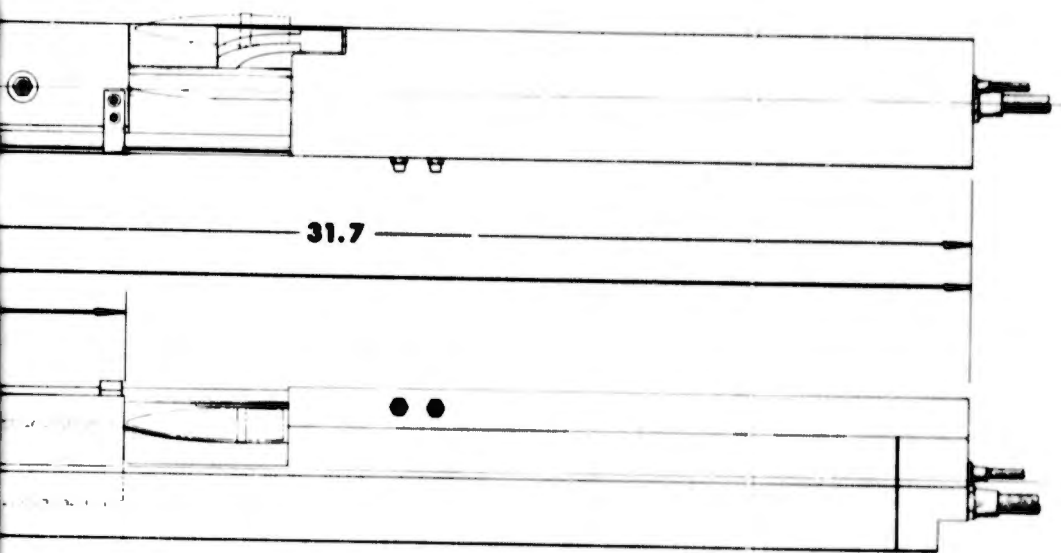
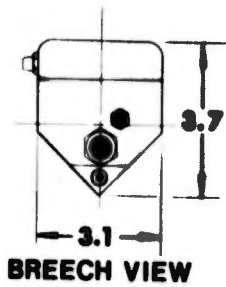
71.

1



MUZZLE VIEW



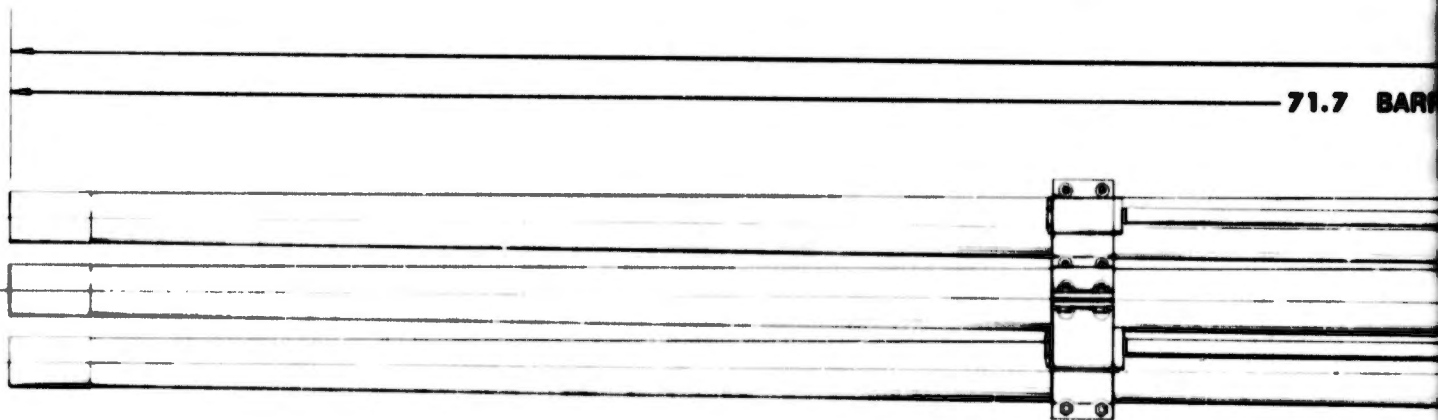
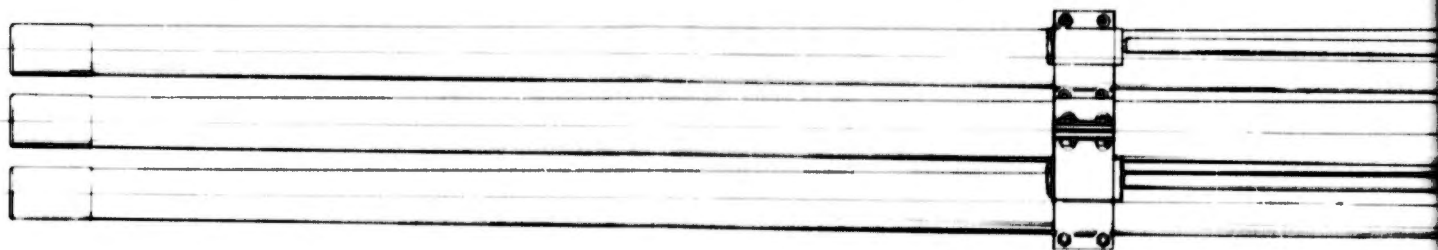


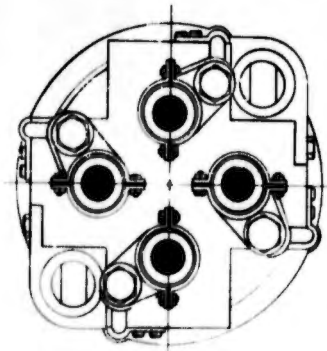
WEIGHT = 61 LBS.

INTERPRET THIS DRAWING PER STANDARD MIL-D-1000		QTY REQD	PART NUMBER	DESCRIPTION	CODE	ISSY NO	ITEM NO
DIMENSIONS APPLY OVER FINISH AND ARE UNBORED							
LIST OF MATERIAL		PULSEPOWER SYSTEMS INCORPORATED MODULE - 20MM NHBP GUN 4300 FPS - MV					
NEXT ASSY		USEL ON	APPROVED	DATE	CODE	ISSY NO	DRAWING NO
APPLICATION			APPROVED	SCALE	VR	WT	SHEET OF

3

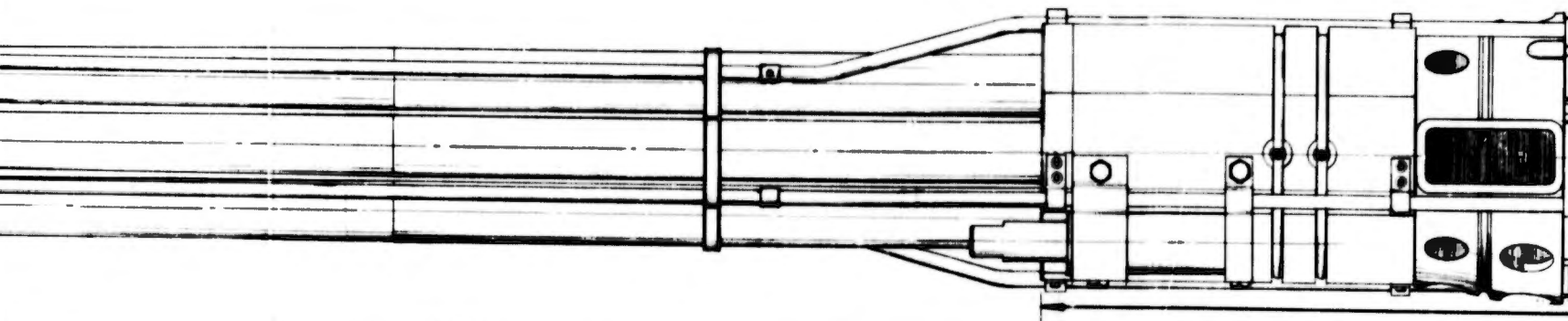
FIGURE 3





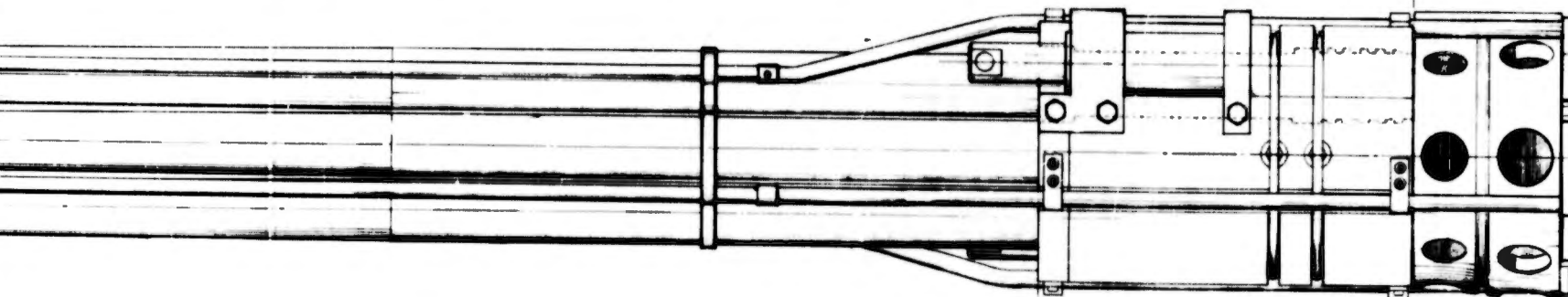
7.5

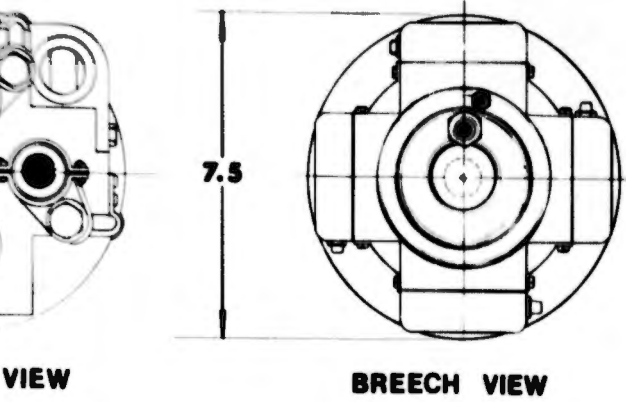
MUZZLE VIEW



93.0

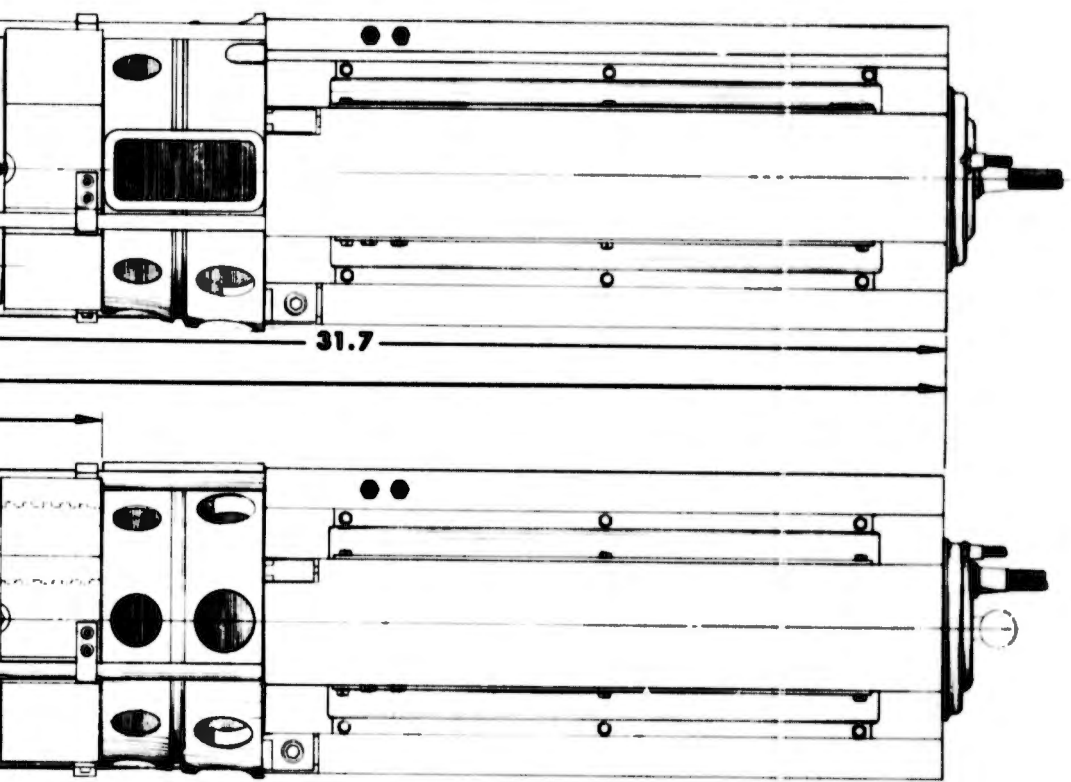
71.7 BARREL LENGTH





VIEW

BREECH VIEW



VOLUME = 1.65 CU. FT.
GUN WEIGHT = 253.2 LBS.

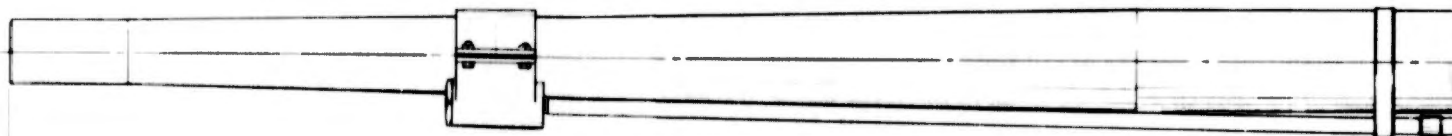
QTY	REQD	PART NUMBER	DESCRIPTION	CODE	ISSUE NO	FIG NO
LIST OF MATERIAL						
			INS. <i>[Signature]</i>			
			PROJ ENG <i>[Signature]</i>			
			DESIGNERS APPLY OVER FINISH AND ARE IN DIMS			
			UNLESS SHOWN OTHERWISE			
			PROJ. ENG. <i>[Signature]</i>			
			APPROVED			
			APPROVED			
			NEW ADDY			
			USED ON			
			APPLICATION			
			SCALE			
			GT			
			SHEET			
			OF			

3

FIGURE 4



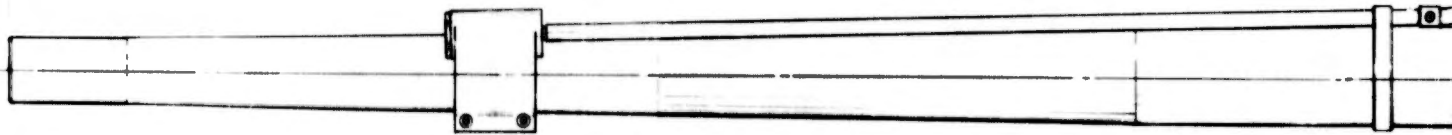
MUZ



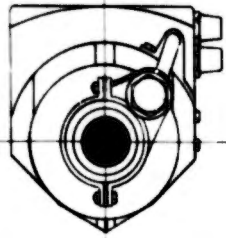
70.4



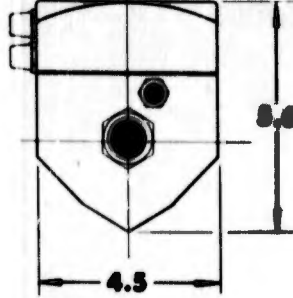
47.6 BARREL LENGTH



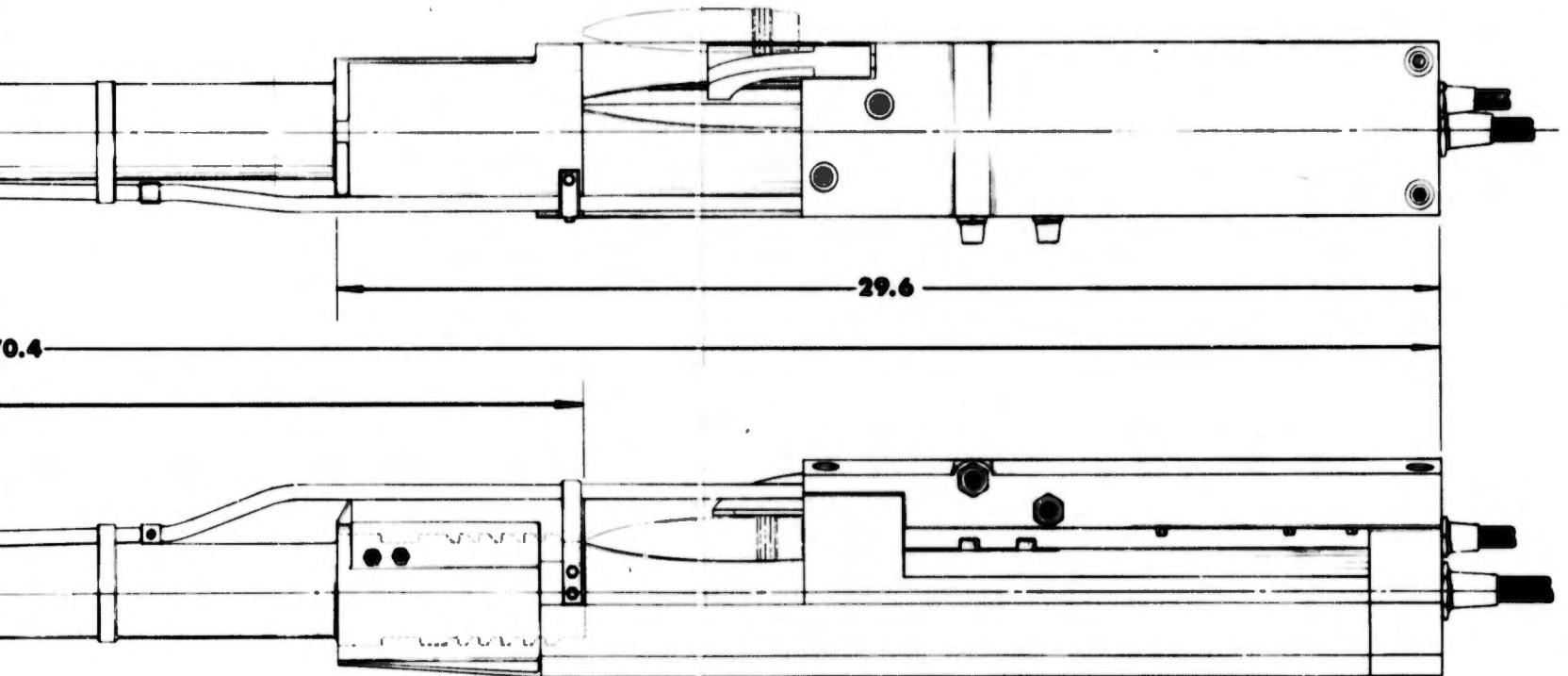
1



MUZZLE VIEW



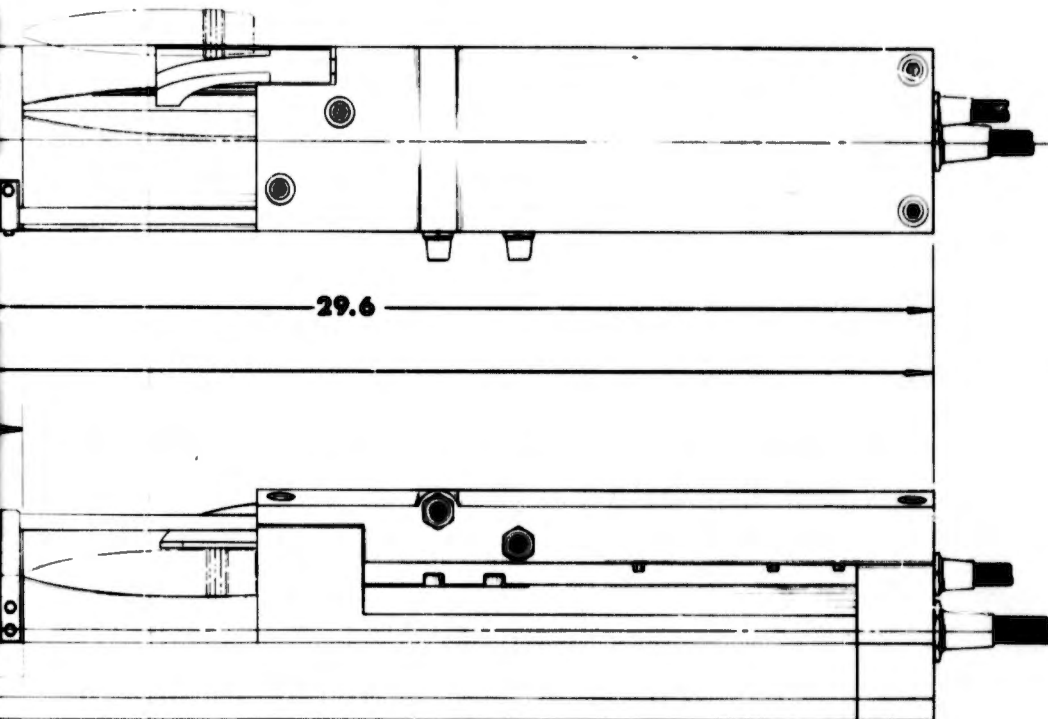
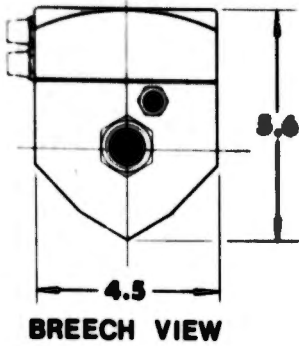
BREECH VIEW



WEIGHT = 101 LBS.

INTERPRET 1:48 DRAWING PER STANDARD MP-9-1000		QTY REQD	PART NUMBER	DESCRIPTION
DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES				LIST OF MAT'L
	UNLESS SHOWN OTHERWISE			DATE
	CONC. AND TOL			BY
	FOR PLAT. OR FOR W.			APPROVED
	EDGES AND SURF			APPROVED
	FILLET RADIUS			SCALE

2

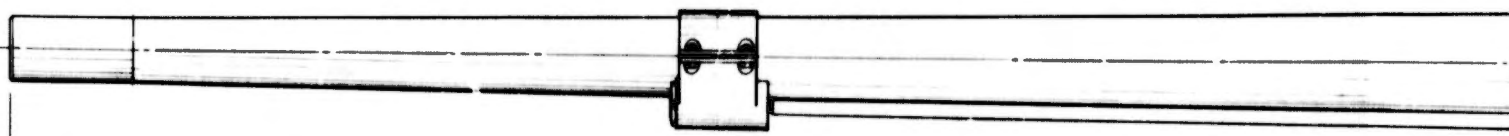


WEIGHT = 101 LBS.

QTY	PART NUMBER	DESCRIPTION	CODE	ITEM NO
INTERPRET THIS DRAWING PER STANDARD MIL-D-1000				
LIST OF MATERIAL				
DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES				
UNIT: DEC. INX.01 ANG: 2 8" CONC: 0.0125 PDR: 0.015 EDGES: 0.015 RAS FILET: 0.015 RAS				
NEXT ASSY APPLICATION	USED ON	APPROVED APPROVED	PULSEPOWER SYSTEMS INCORPORATED MODULE - 30MM NHBP GUN 2800 FPS-MV R SCALE 1/2"	DRAWING NO. 3001-205 OF

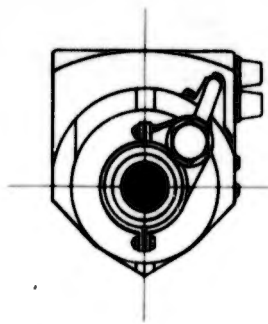
FIGURE 5

3

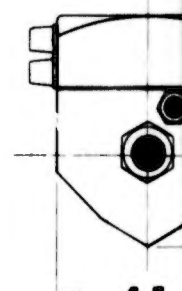


69.5 BARREL LENGTH

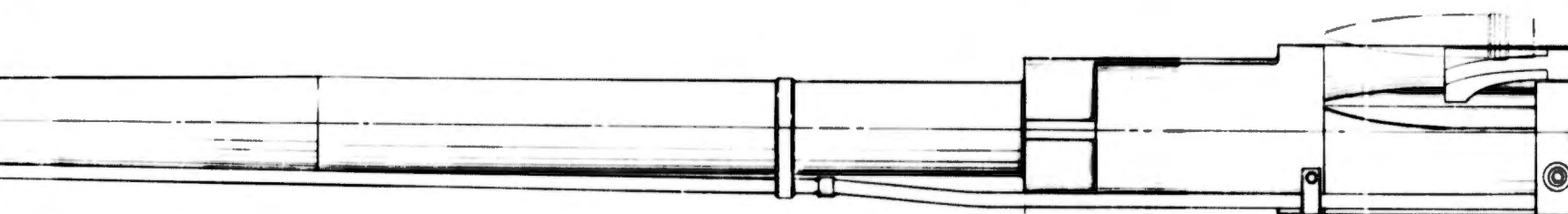




MUZZLE VIEW

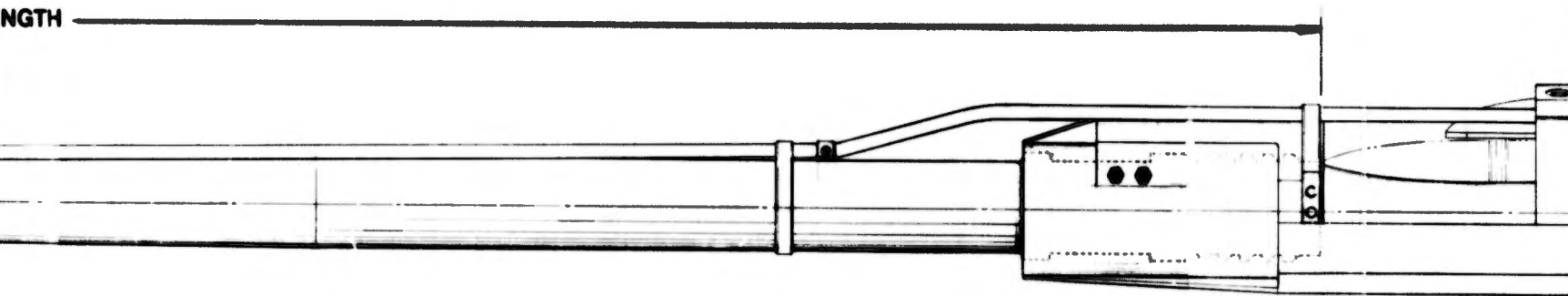


4.5
BREECH VIEW

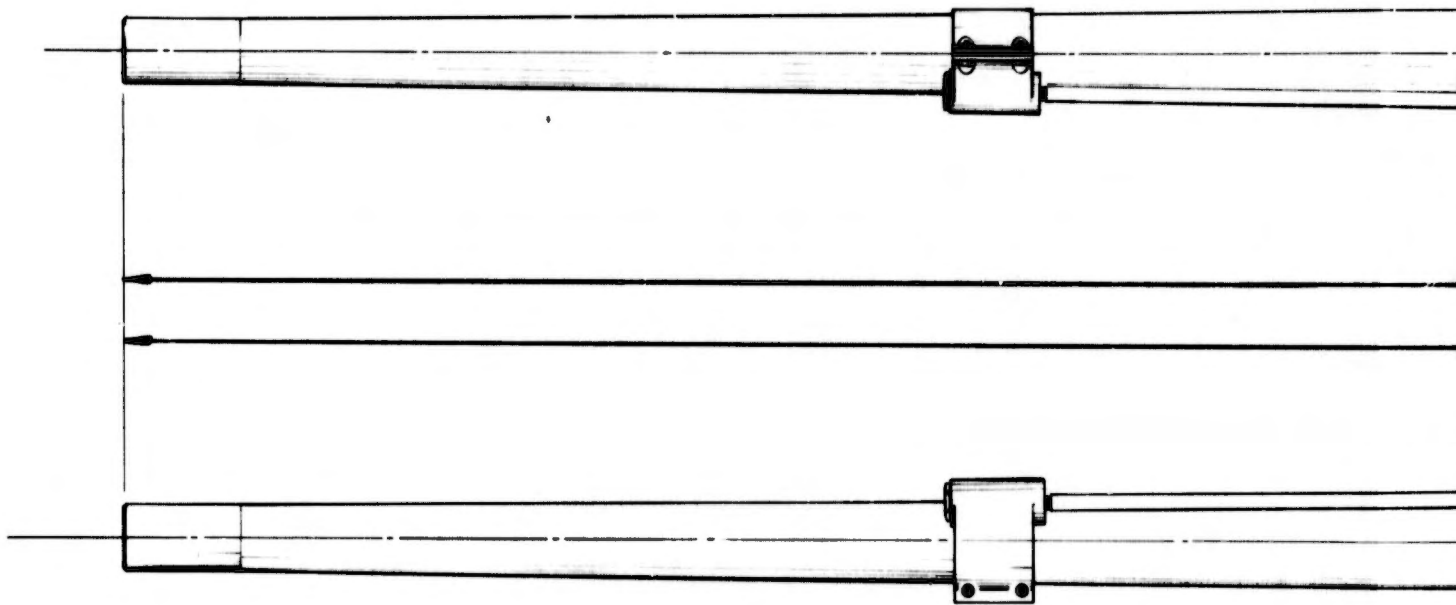


93.3

LENGTH



2



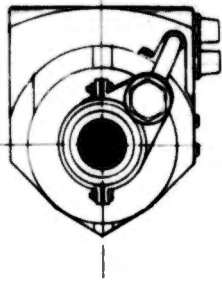


112.4

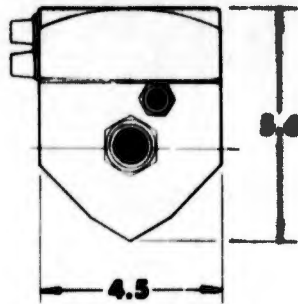
85.8 BARREL LENGTH



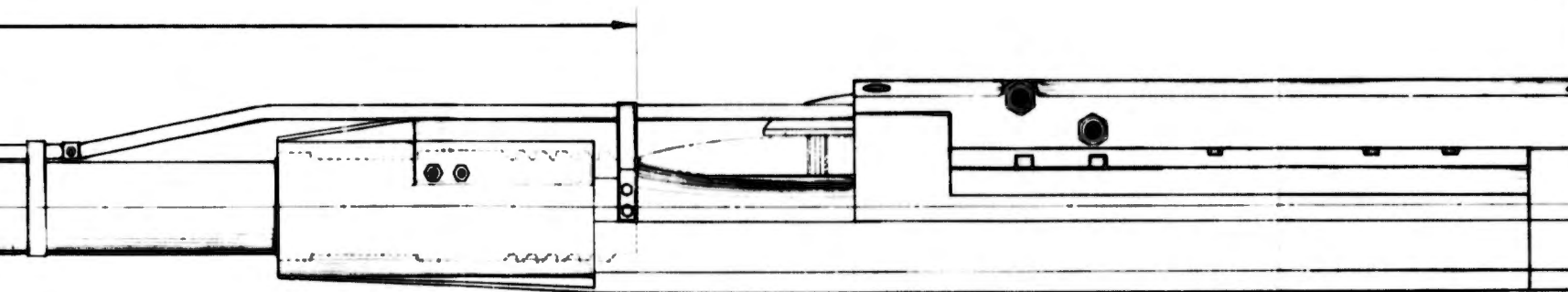
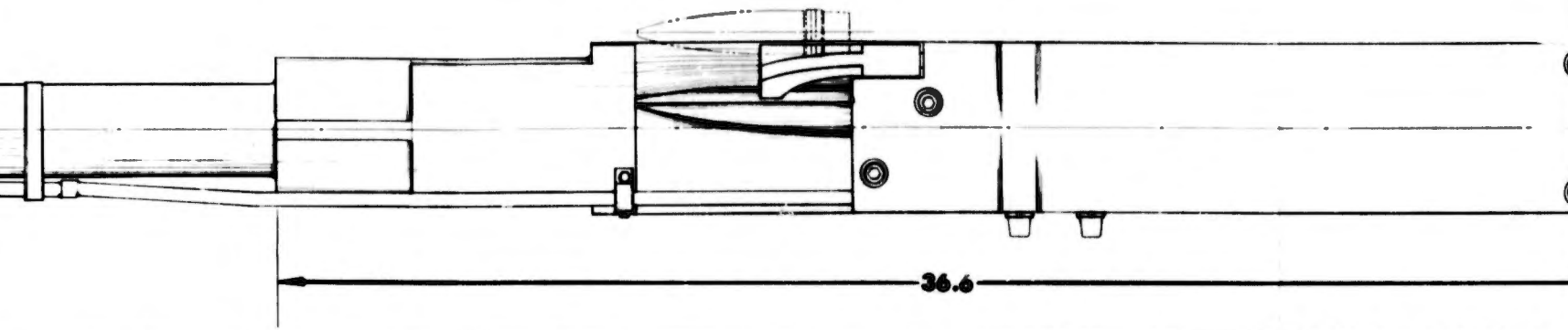
2



MUZZLE VIEW



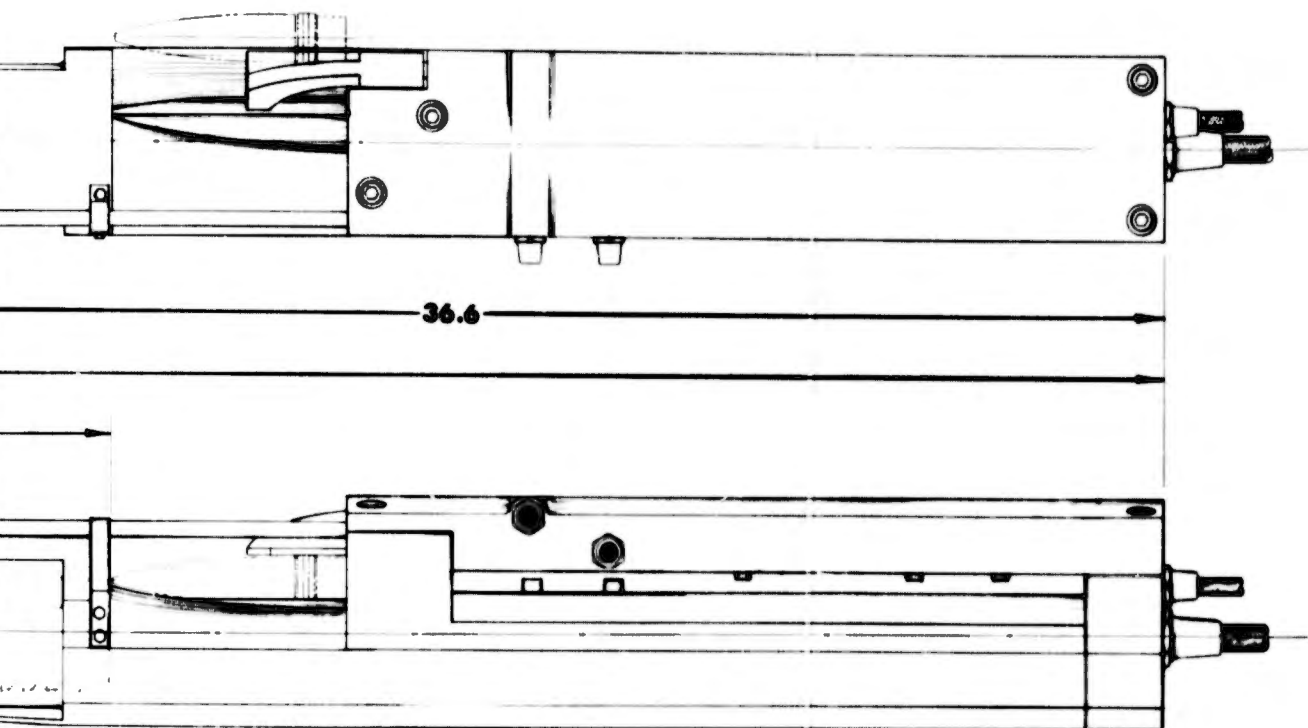
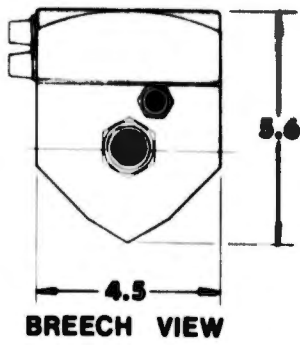
BREECH VIEW



WEIGHT • 147 LBS.

INTERPRET THE ORDERS PER STANDARD MIL-D-1000		QTY REQD	PART NUMBER	DE
DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES				DR: [Signature] CHK: [Signature] PROJ ENG: [Signature]
MILX2 008 .1X2.01 ANG 2°				APPROVED
CONC GUN TOR				APPROVED
PAR PLAT. DR. 008/10				APPROVED
EDGED DR MAX				APPROVED
FILLET RAD. .05				APPROVED
NEXT ASSY	USED ON			
APPLICATION				

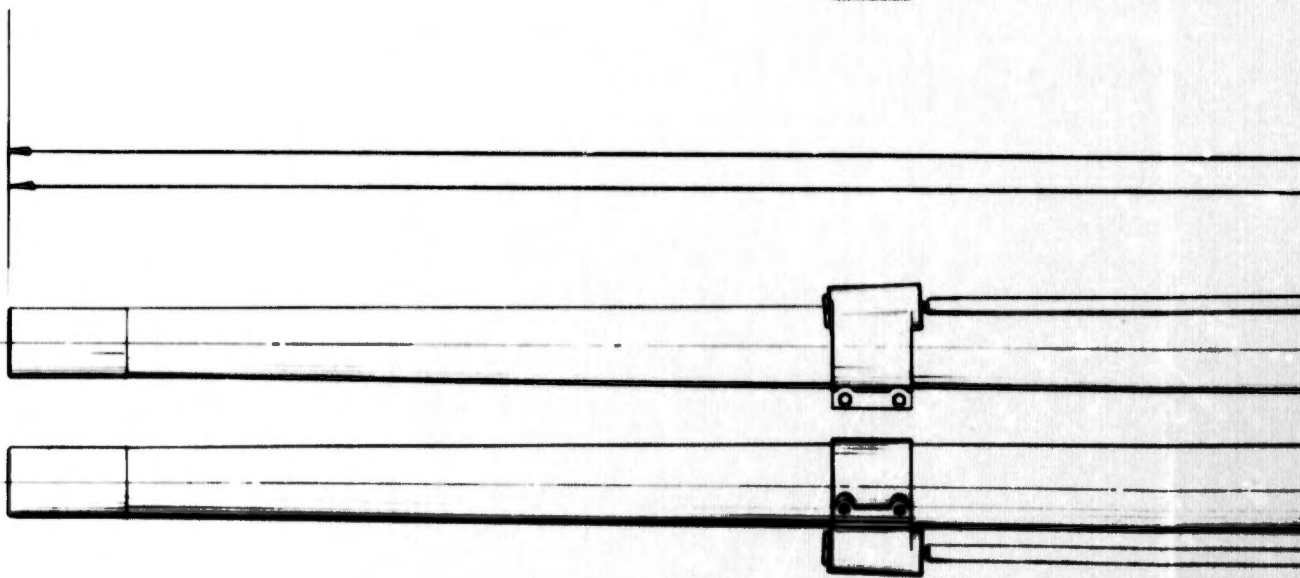
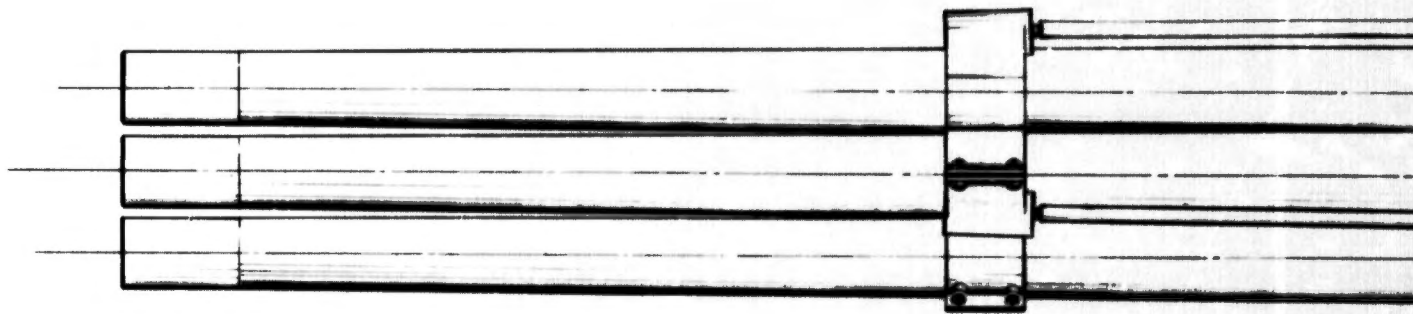
3

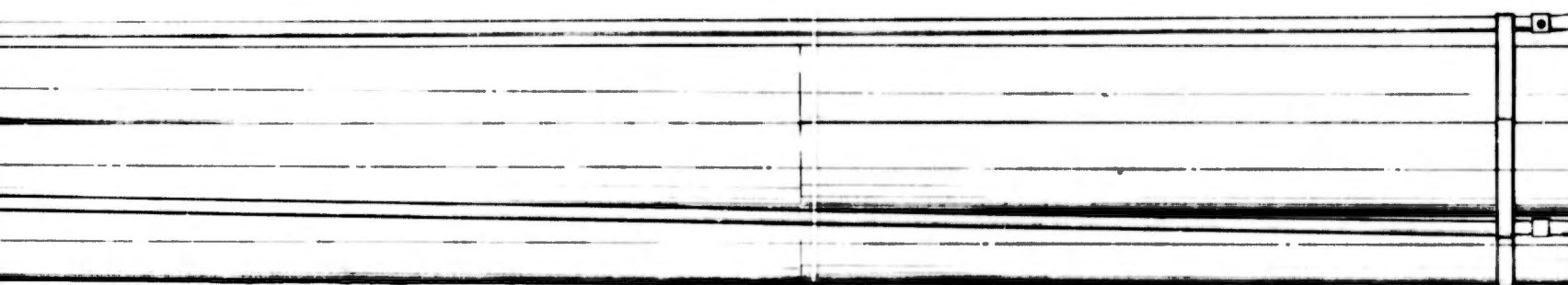


WEIGHT = 147 LBS.

QTY	PART NUMBER	DESCRIPTION	CODE	ITEM NO
INTERPRET THE DIMENSIONS PER STANDARD MIL-C-1000				
LIST OF MATERIAL				
DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES		DESIGNED BY: <i>[Signature]</i> CHECKED BY: <i>[Signature]</i> PROJ ENG: <i>[Signature]</i>	PULSEPOWER SYSTEMS INCORPORATED MODULE-30MM NHBP GUN 3800 FPS-MV	
DATE: 000 .XXX.XX	AND: 2 5"	APPROVED: <i>[Signature]</i>	SIZE: CODE: REV: NO.	DRAWING NO.
CONC. CENTER	EDGES: 0.03 MAX	APPROVED:	R	3001-207
NEXT ASSY:	USED ON:	APPROVED:	SCALE: $\frac{1}{2}$ "	WT: SHEET OF
APPLICATION:		FILLET RADIUS		

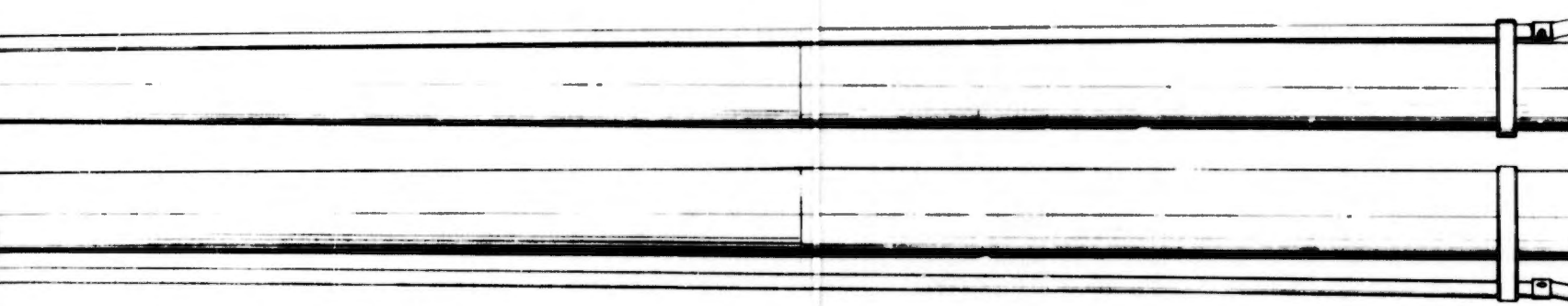
FIGURE 7

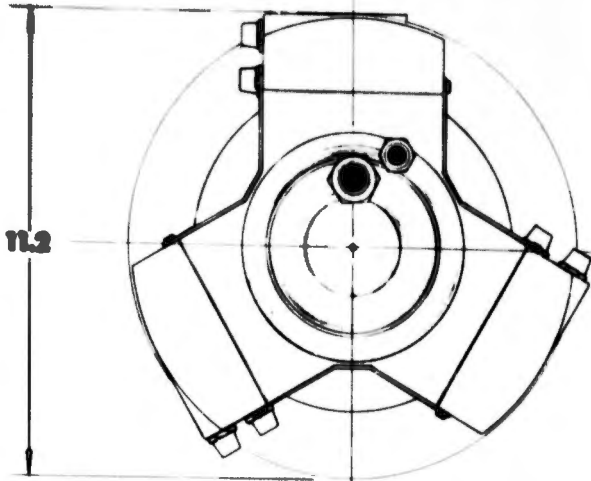




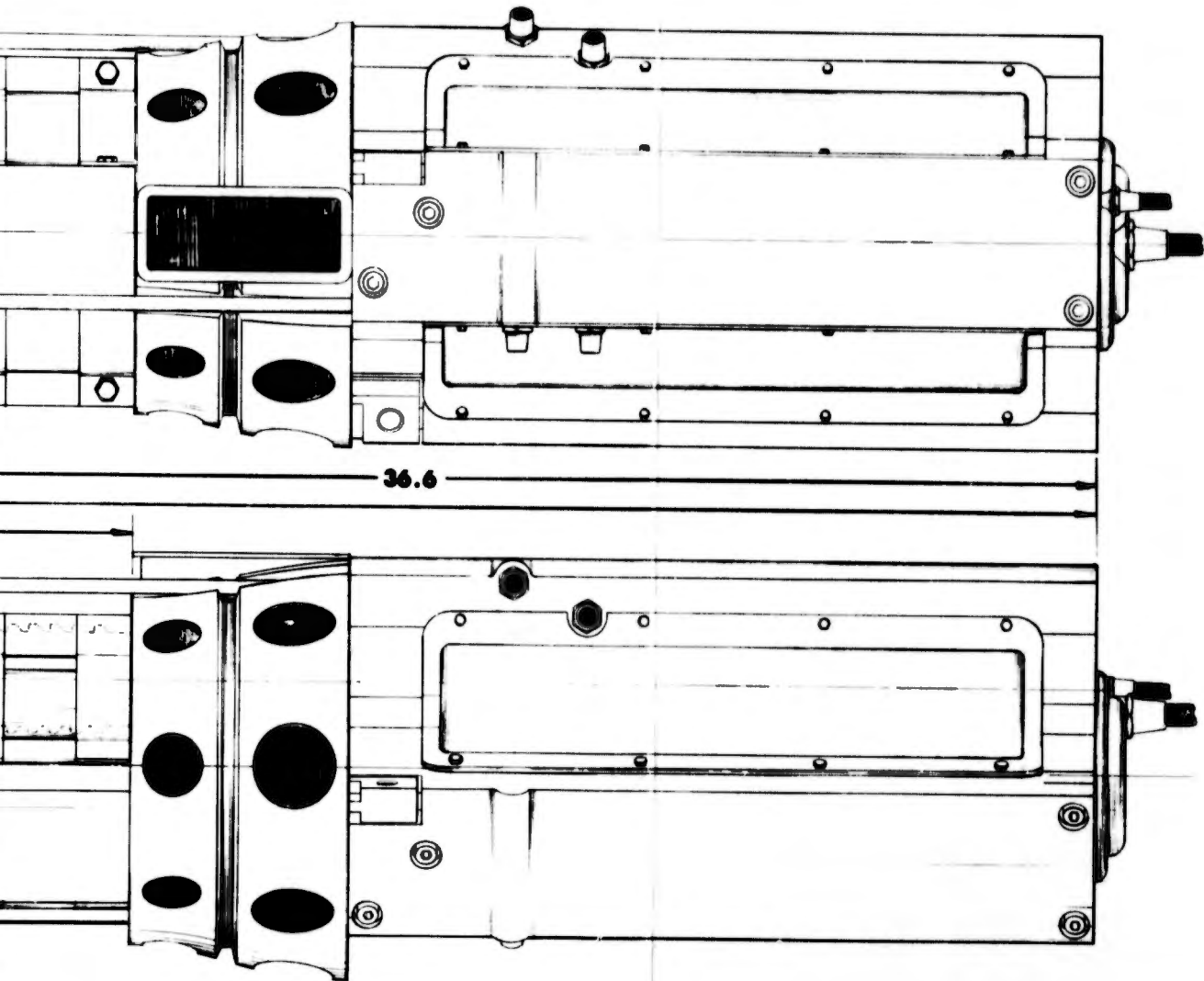
85.8 BARREL LENGTH

112.4





BREECH VIEW



VOLUME = 3.54 CU. FT.
GUN WEIGHT = 456.9 LBS.

QTY	PART NUMBER	DESCRIPTION	CODE	ITEM
REQD			IDENT NO	NO
LIST OF MATERIAL				
		DR. <i>[Signature]</i> DATE: <i>[Date]</i> GR. <i>[Signature]</i> P. FOR PROJ ENG. <i>[Signature]</i>	PULSEPOWER SYSTEMS INCORPORATED	
		DIMENSIONS APPLY OVER FINISH AND ARE IN INCHES UNLESS OTHERWISE SPECIFIED CONC. 0.0017 IN PER FLAT. 0.002 IN EDGES. 0.015 MAX FILLET RADII. 0.05	3 MODULE CLUSTER 30MM INHEP GUN 3800 FPS - MV	
TEXT ASSY	USED ON	APPROVED	SCALE	SHEET
APPLICATION		APPROVED	R	3001-208
			1/2	1/1

FIGURE 8

4