

Investigation and redesign of Mark 51, Model 7
bomb rack. (Final Report No. ES-6688.) C. E.
Csgood. OEMsr-1435. Douglas Aircraft Com-
pany. November 24, 1944.

DIV. 12-1820-M2

Results:

The results of these tests, and the special conditions applying to each sample, are given in the following table:

TABLE IV (Samples 1-10)
Results - Static Tests of Hooks

<u>Sample No.</u>	<u>Description of Sample</u>	<u>Base Metal Hardness Rockwell C</u>	<u>Load at Failure (Lbs.)</u>
1	Original Pollak Hook. Machined at $7\frac{1}{2}^{\circ}$ angle. No additional hardening.	38 - 39	21,000
2	Same as Sample 1.	30 - 33	17,900
3	Original Pollak Hook. Machined at $7\frac{1}{2}^{\circ}$ angle. Additional local induction hardening of throat section to Rockwell "C" 59 to 61. Lower portion chrome plated after hardening.	39 - 40	8,400 no yield
4	Same as Sample 3	40	9,900 no yield
5	Same as Samples 3 and 4. Retempered at 550°F . to surface hardness of Rockwell "C" 50-52.	43	9,900 no yield
6	Original Pollak Hook. Machined at $7\frac{1}{2}^{\circ}$ angle. Additional local induction hardening of lower bearing surface only to Rockwell "C" 57.	37 - 38	19,000
7	Same as Sample 6 except hardness of local area Rockwell "C" 53-54.	33	16,800
8	Same as Sample 7	37.5	19,900
9	Original Pollak Hook. Not machined. Entire hook hardened to Rockwell "C", 54. Oil quenched at 1525°F . Tempered at 400°F .	54	12,800 no yield
10	Same as Sample 9, except originally machined at 15° angle.	54	12,800 no yield

Analysis Mk 51-11 Rack
Prepared by C. E. Osgood
Date 11-24-44

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El Segundo Plant

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Discussion of Results

1. The results of these tests show the following points definitely:
 - a. Local induction hardening of the throat section of the hook weakens it to approximately half its original strength, causing it to fail at below 10,000 pounds, which is unsafe.
 - b. Local induction hardening, if confined to the lower portion of the hook section, below the throat section, as in Samples 6 and 8, will not affect the strength of the hook and will accomplish the desired purpose of preventing brinelling of the hook by the bomb lug.
 - c. Full hardening of the hooks as in Samples 9 and 10 is not recommended, as it makes the metal too brittle. These samples failed at 12,800 pounds which is unsafe.
2. The critical point at failure of the normal hooks of proper core strength (38-42 Rockwell "C") (Samples 1, 6, and 8) was shown to be the shearout through the pivot pin hole.

The addition of a bushing at this point would reduce the amount of shear material and would weaken the hook. For this reason, we do not recommend the addition of a bushing at the hook point.
3. It was later found that hook samples 9 and 10 had been tempered for only 45 minutes. A 2-hr. tempering time is recommended.

REPORT OF STATIC PULL TESTS
OF BOMB RACK HOOKS

Date of Tests: Wednesday, Friday and Monday,
August 2, 4, and 7.

Location of Tests: El Segundo Static Test Laboratory.

Samples: (11-18) All samples tested were original hooks
from Pollak racks of forged 3140 steel,
Rockwell "C" 38-42, machined at $7\frac{1}{2}^\circ$ angle.
Other conditions described under
"Description of Sample" in table of re-
sults below.

Purposes of Tests: 1. To check effect of bushing on strength
of hook.
2. To check effect of through hardening of
hook, from Rockwell "C" 45-54, on
strength of hook.
3. To check effect of tempering time on
strength of hook.

Equipment and Procedure: Same as in hook tests previously described

Results:

The results of these tests, and the special conditions applying to each sample, are given in the following Table:

TABLE V - Results - Static Tests of Hooks

Sample No.	Description of Sample	Metal Hardness When Tested Rockwell C	Load at Failure (Lbs.)
11	Aluminum Bronze Bushings at both pivot holes. No other local hardening.	36	15,400
12	Same as 11.	46	17,300
13	Entire hook heat treat hardened to hardness noted. Tempered $1\frac{1}{2}$ hours in salt bath.	45	22,000
14	Same as 13	49	25,000 (did not break)

15	Same as 13.	51	18,000
16	Same as 13.	53	22,000
17	Same as 13 except tempered for 30 minutes only.	53	13,000
18	Same as 13 except tempered for 2 hours	51	27,100

Discussion

1. Tests of Samples Nos. 11 and 12 hooks with bushings showed that the bushings weakened the hooks, as shown by the following comparison:

	<u>Sample No.</u>	<u>Rockwell C</u>	<u>Load at Failure (lbs)</u>
<u>With Bushings</u>	11	36	15,400
	12	46	17,300
<u>Without Bushings</u>	2	33	17,900
	1	39	21,000

2. Tests of Samples Nos. 13 and 14 showed an amazingly high degree of ductility for the hardness to which they had been heat treated. Sample No. 14 held a load of 25,000 lbs. and did not break, although it opened up about 1/4" and considerable necking down at the throat occurred. A minute crack is visible at the upper portion of the throat section, where it probably would have failed with further increase of load.
3. Samples Nos. 15 and 16 showed high loads at failure but little if any yield or ductility; when they failed they snapped.
4. Samples Nos. 17 and 18 showed to an amazing degree the effect of tempering time, No. 17, with the 30 minute temper, failing at 13,000 lbs., and No. 18, with the 2-hour temper, failing at 27,000 lbs. This result well justified the Process Laboratory general recommendation of a 2-hour tempering time.
5. The striking thing about the comparison of Samples Nos. 17 and 18 is that no physical measurement of the sample could reveal that one had been tempered for too short a time; the Rockwell readings were very close and nothing short of destruction of the samples revealed their difference.
6. We believe that these tests of hook samples have been worth while as examples of the action of metal under unusually high degrees of heat treating.

REPORT OF STATIC PULL TEST ON BUORD HOOK
FOR MARK 51 MOD. 11 BOMB RACK

Sample: One of ten hooks received from Naval Aircraft Factory, September 13, 1944

Sample was stamped "SK 142987".

Sample appeared to be hogged out of bar stock to dimensions of BuOrd Drawing No. 438459-1, which calls for SAE 4340 steel hardened to Rockwell "C" 39-43, and which calls for additional local induction hardening of upper surface of lower lip of hook to Rockwell "C" 54-58, penetration $1/8" \pm 1/64"$.

Sample contained bushings in both pivot holes as called for on BuOrd Drawing No. 438459-1.

Date of Test: September 21, 1944.

Location of Test: El Segundo Static Test Laboratory.

Purpose of Test: To measure strength of hook under static load and to check the depth and extent of the induction hardened portion.

Equipment & Procedure: The same test jig and method as previously described were used.

Results of Test:

1. Load at failure: 16,800 pounds.
2. Location of fracture: In approximately vertical plane $5/8"$ from lower tip of hook.
3. Rockwell hardness survey shows
 - a. Induction hardened region "C" 58 over entire lower tip of hook.
 - b. Heat affected zone "C" 30-36, through a portion of which the failure occurred.
 - c. Base metal hardness "C" 42.
4. FIG.17 Page 141 shows the Rockwell survey.

Analysis Mk 51-11 Rack
Prepared by C.E. Osgood
Date 11-24-44

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Discussion

The following discussion was written by one of the metallurgists of the Douglas Process Laboratory:

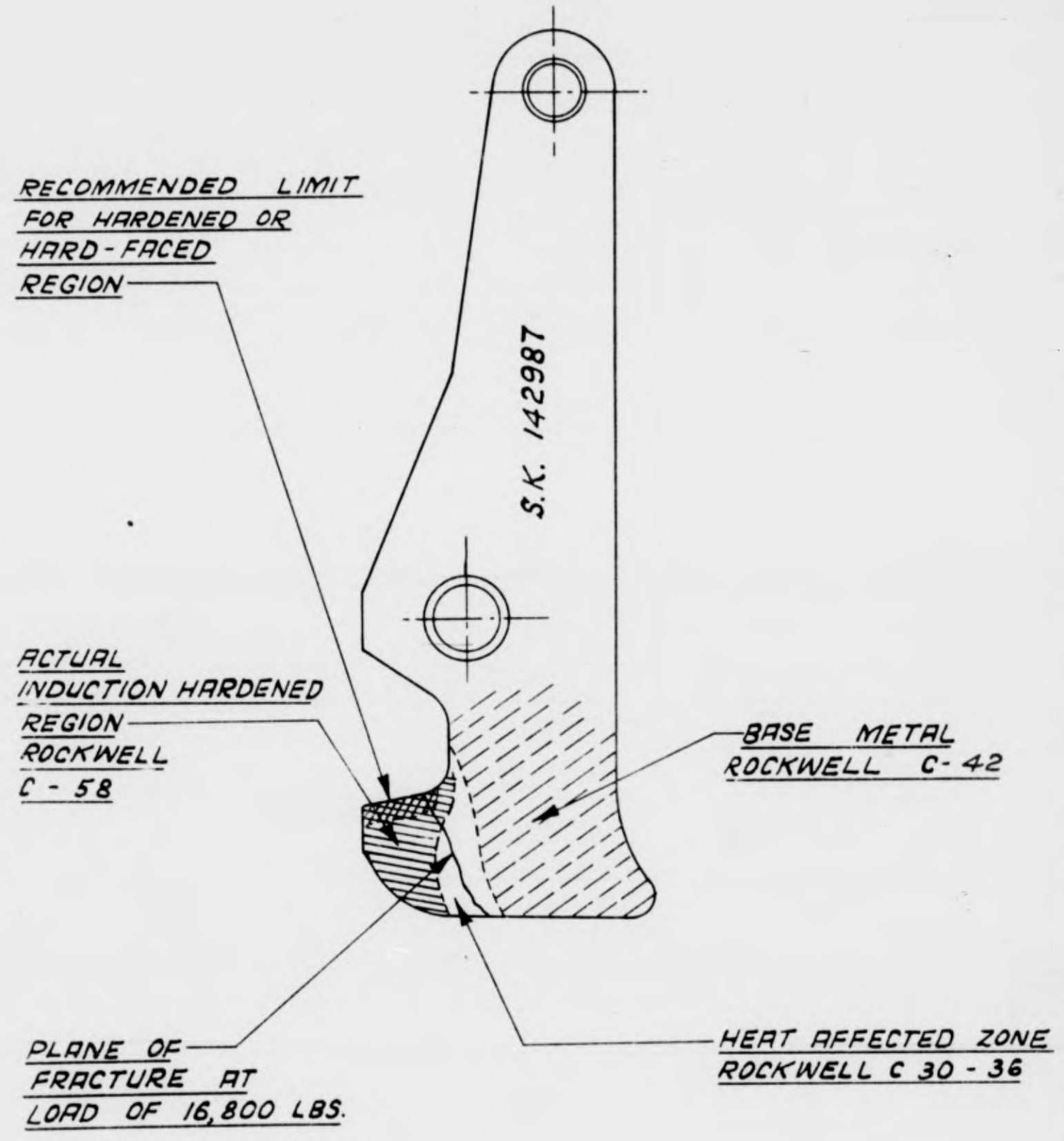
The fracture occurred outside of the zone where fractures are normally expected on this part. In spite of the fact that the failure at 16,800 pounds is above the design load, the fracture is brittle and unsatisfactory.

The Rockwell survey indicated the probable cause of the condition. The drawing required the lip of the hook to be induction hardened to a depth of 1/8". The hook evidently was hardened over an area greatly in excess of the requirement. This resulted in a rather broad heat affected zone, adjacent to the hardened zone, where the base metal hardness was reduced from 42 Rockwell "C" to from 30 to 36 Rockwell "C". The fracture occurred through the heat affected zone.

Apparently the induction hardening operation was improperly conducted. Possibly the coil design and the type of induction hardening unit were not suited to produce the required result on the part. Probably a Tocco 9600 cycle induction unit was used.

Satisfactory results were obtained in the Douglas Plant by using a 30 KVA Lepel induction unit (100,000 to 300,000 cycles per second). By this means we were able to obtain the local surface hardening required for this part.

FIG. 17



STATIC TEST AND ROCKWELL SURVEY
BU.ORD. HOOK FOR MK. 51-11 BOMB RACK

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MARK 51 MOD. 11 BOMB RACK - DOUGLAS ARMING SOLENOID

Results - No. 34 Wire Coil Pull Test
(60° Plunger Taper)

Date of Test: Tuesday, August 15, 1944
Location of Test: El Segundo Research Laboratory
Conditions of Test: 1. Housing block, core, and end pieces are fabricated of Armco iron, not hydrogen annealed.
2. Coil: No. 34 wire, 19 layers, approximately 132 ohms resistance at 78°F.

TABLE VI

Summary of Results

<u>Voltage</u>	<u>Stroke (Inches)</u>	<u>Gross Pull (Ounces)</u>
19.0	1/32	55.7
19.0	1/16	28.9
19.0	3/32	18.0
19.0	1/8	11.9
22.8	1/32	63.1
22.8	1/16	41.6
22.8	3/32	23.9
22.8	1/8	17.3
26.7	1/32	71.1
26.7	1/16	51.1
26.7	3/32	33.4
26.7	1/8	24.1
32.2	1/32	77.2
32.2	1/16	61.7
32.2	3/32	42.5
32.2	1/8	32.2

The above results are plotted graphically in Fig. 18, Page 143.

DOUGLAS ARMING SOLENOID GROSS PULL - OUNCES
FOR COIL OF #34 WIRE 19 LAYERS. 132 OHMS AT 78°F
60° PLUNGER TAPER. ARMC0 - NOT HYDROGEN
ANNEALED FIG. 18

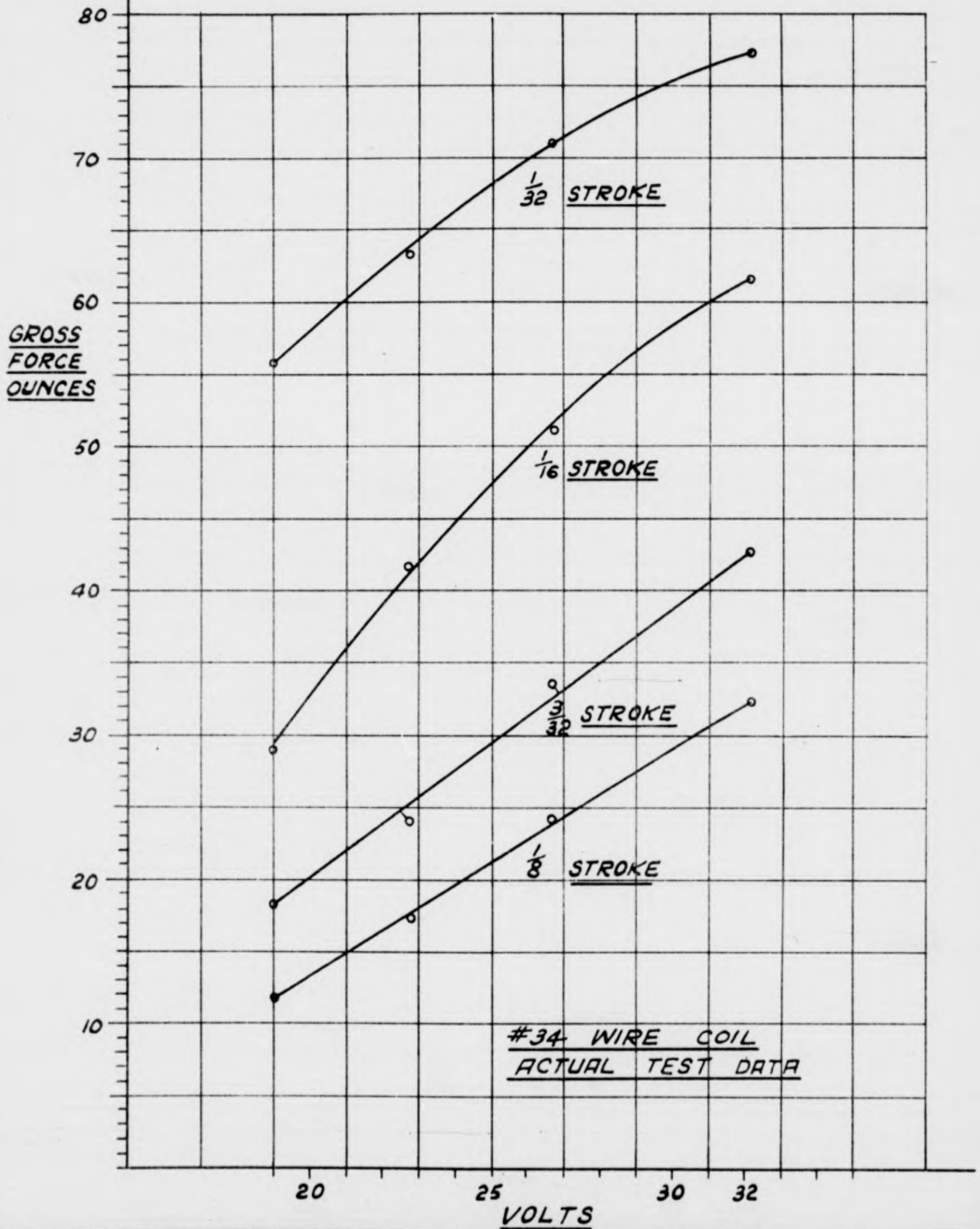


FIG. 19

ARMING SOLENOID - FINAL ARRANGEMENT
OF SAMPLE PARTS AFTER TEST

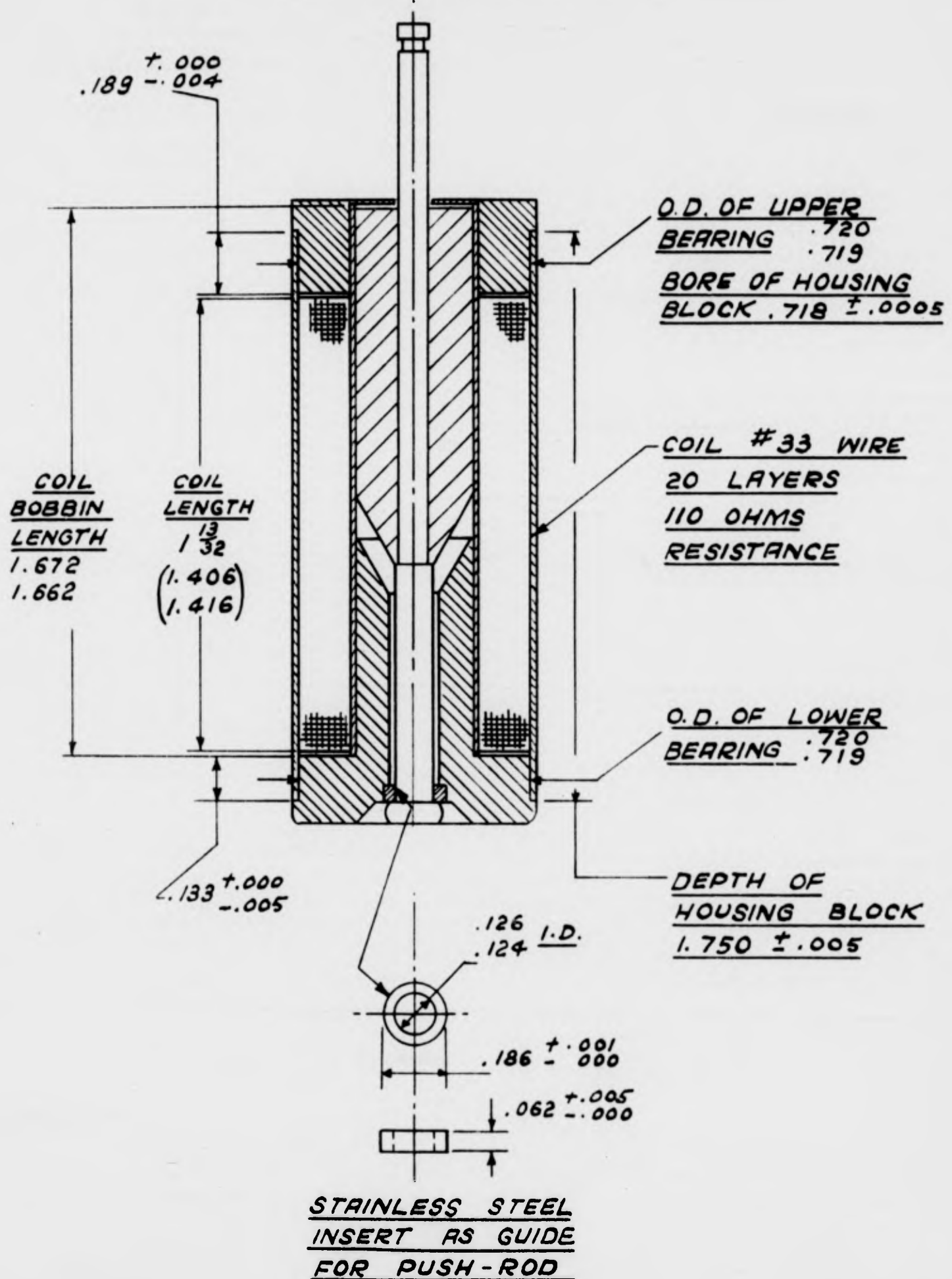
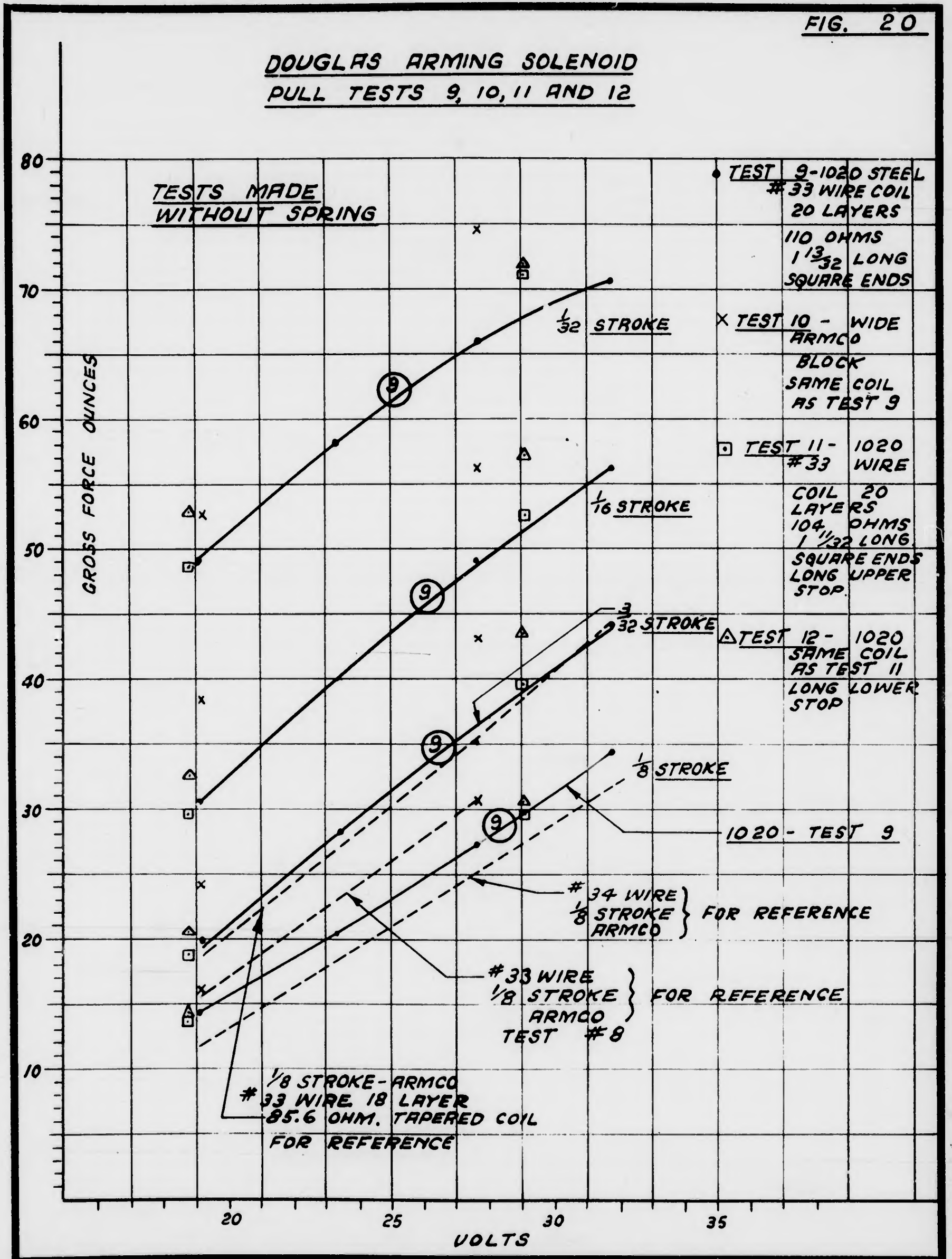


FIG. 20



Report of Pull Test No. 9 on Douglas Arming Solenoid

TABLE NO. VII

* PULL TEST No. 9 Tues, 8-29-44 Parts of 1020 STEEL
 Coil: #33 Wire, 20 layers, 1 13/32 long, square ends,
 same as used in Pull Tests 4 and 8 of Report No.22, and
 with block and end pieces of same dimensions as shown in
 SKETCH, Figure 19, page 144 ; except all parts are of 1020
 Steel instead of Armco. Test made without spring.

<u>Voltage</u>	<u>Current (Amperes)</u>	<u>Stroke</u>	<u>Gross Pull Ounces</u>
19.2	.172	1/32	49.2
		1/16	30.4
		3/32	19.8
		1/8	14.5
23.4	.206	1/32	58.2
		1/16	39.5
		3/32	28.0
		1/8	20.6
27.7	.244	1/32	65.7
		1/16	49.0
		3/32	35.2
		1/8	27.2
31.8	.278	1/32	70.9
		1/16	56.11
		3/32	44.2
		1/8	34.5
Coil R : 112.8 ohms @ 79° F.			

Comparison of ARMCO vs. 1020 - Test 8 vs. Test 9

<u>Voltage</u>	<u>Stroke</u>	<u>Gross Pull-Oz.</u>		<u>Difference</u>	<u>% Diff.</u>
		<u>Armco</u>	<u>1020</u>		
19.2	1/32	54.0	49.2	4.8	8.9
	1/16	34.1	30.4	3.7	10.8
	3/32	22.2	19.8	2.4	10.8
	1/8	15.6	14.5	1.1	7.1
27.7	1/32	72.3	65.7	6.6	9.15
	1/16	56.0	49.0	7.0	12.5
	3/32	41.3	35.2	6.1	14.7
	1/8	30.5	27.2	3.2	10.8

* The 60° Plunger was used in this test, as in Pull Tests 1 to 8 inclusive.

FIG. 21

ARMING SOLENOID ASSEM.
MK. 51-11 BOMB RACK
PRODUCTION DESIGN

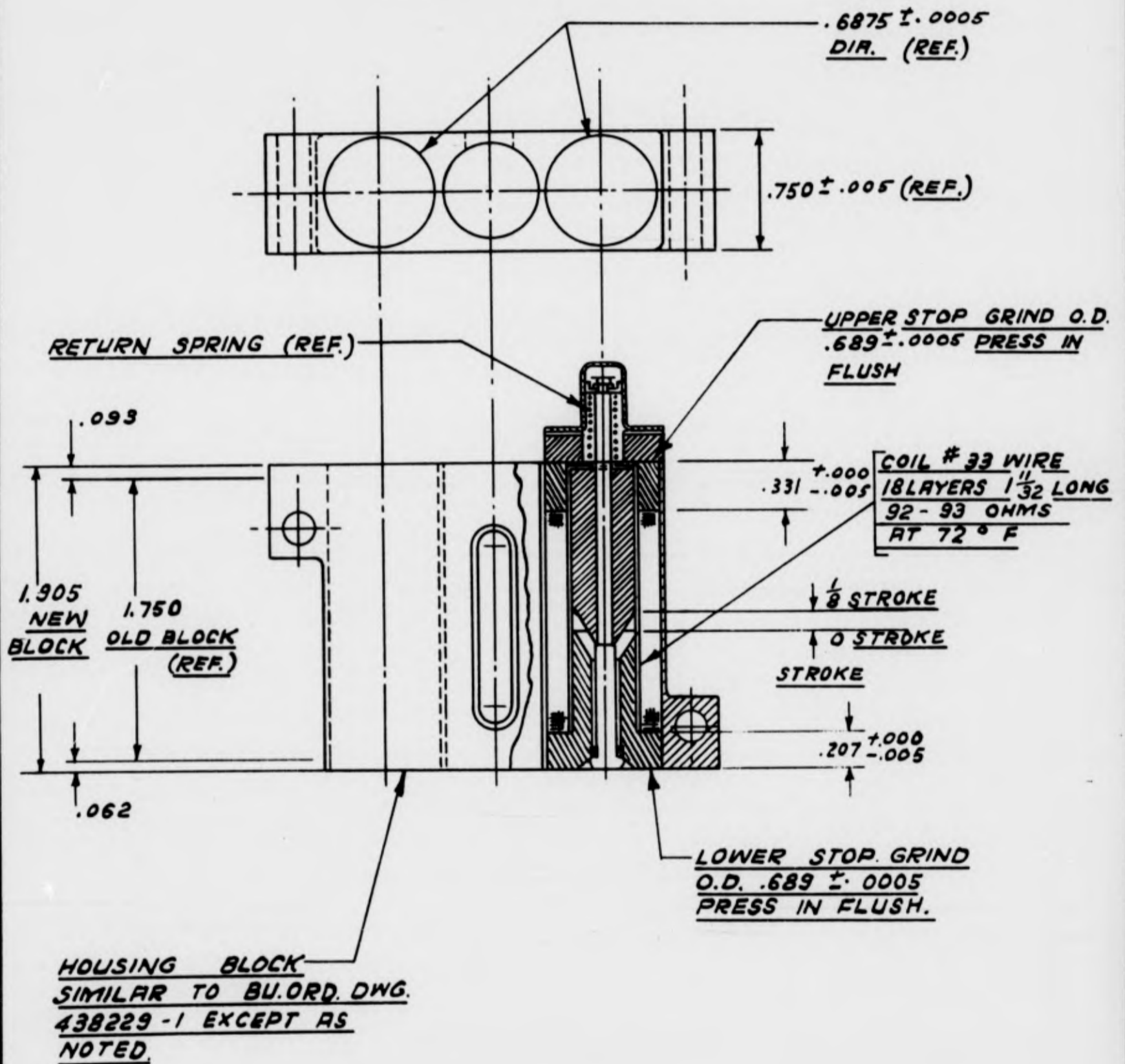
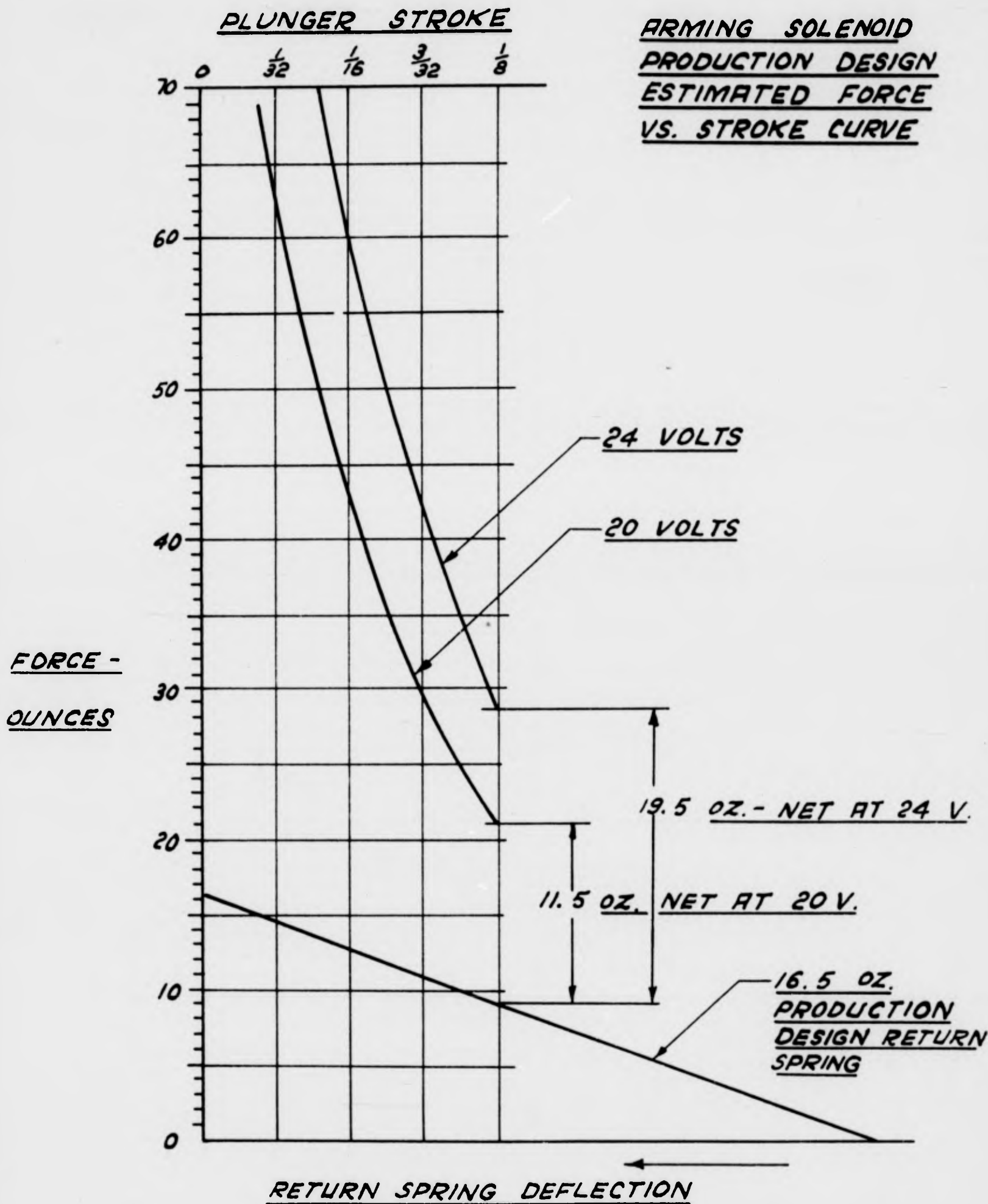


FIG. 22



LIST OF EXPERIMENTAL RACKS AND ARMING UNITS
DELIVERED TO NDRC OR BUREAU OF ORDNANCE
(Including Experimental Arming Units Not in Racks)

Date Delv'd	Rack No.	Serial No.	Arming Unit Serial No.	Arming Unit Type	Arming Block Material	Arming Coil	Approx. Ohms.
							Wire Size' Layers
June 3	1		2	2	1020		
" 22	2	69151	3	2	1020	32	-- 50
" 22	3	69152	4	2	1020	32	-- 50
" 22	4	69153	-	Aurex	----	33	20 123
" 22	5	69149	-	Aurex	----	33	20 123
" 23*		-----	5	2	1020	32	50
July 1		-----	6	3	1020	33	19 90
" 1		-----	7	3	1020	33	19 90
" 15 **		-----	-	4	1020	33	18 83
Sept. 15	6	76513	8	5	Armco (3/4")	33	20 110
" 15	7	76534	9	5	"	33	20 110
" 15	8	76522	10	5	"	33	20 110
" 15	9	76505	11	5	"	33	20 110
" 15	10	76519	13	5	"	33	20 110
" 15	11	76527	14	5	"	33	20 110
" 15	12	76548	20	5	"	33	20 110
" 15	13	76529	16	5	"	33	20 110
" 22***			17W	6	Armco (25/32")	33	20 110

* Unit taken East by Mr. R. Cocks for Bomb Rack Conference in Washington. Unit was returned to Douglas after conference.

**Douglas Design on detail dwgs forwarded to N.D.R.C.

***Made slightly wider to permit more iron around coil to improve solenoid pull.

Notes

1. Coils in arming units, Serial Nos. 2 to 7 inclusive, were taper end coils.

Coils in arming units, Serial Nos. 8 to 17W inclusive, were square end.

2. Hooks of Racks 6 to 9 inclusive were Pollak hooks induction hardened locally, and marked "3140".

3. Hooks in Racks 10 to 13 inclusive were BuOrd design, received frm gun factory, marked "S.K. 142987", with bushings at both pivot points.

APPENDIX VMARK 51 MOD 11 MODIFIED RACKReference List of Drawings

<u>BuOrd Dwg. No.</u>	<u>Brief Title</u>	<u>Submitted 6-23-44</u>	<u>Douglas Dwg. No.</u>	
			<u>Sample Racks 9-13</u>	<u>Production Design</u>
438222	General Assem.	3250541	3250541-A	3250541-A
438223	Outline			
438510	Frame Assem.	3250553	3250553-A	3250553-A
328760	Frame Details			
Sh. 1, 2, 3	-			
300651	Hook and Details			
328763	Hook and Link, Assem. and Details	3250547	3250547-A	3250547-A
438459	Hooks and Details (Bushings)			{ 2252817 2252818
438459-1	Hook (Assem.) Modified	4250537	4250537-A	4250537-A
-4	Washer - Hook	2250807	2250807-A	2250807-A
-5	Plate - Wire Protector	2250552	2250552-A	2250552-A
-6	Cover - Wire	2250549	2250549-A	2250549-A
-7	Grommet	2250550	2250550-A	2250550-A
438455	Arming Solenoid - Comp. Assem.	4250539	4250539-B	4250539-B
438227	Arming Solenoid Assem.	4219637	SK. 89	4219637-B
438228	Arm.Sol.Sec. - 10 times Size			
438229-1	Housing - Arming Sol.	4250803	4250803-A	4252807
-2	Plunger	2250597	2250597-B	2250597-B
-3	Lower Stop(Bearing Assem)	2250800	SK 90	2250800-A
-4	Coil Assem.	2250594	SK. 88	2250594-B
-5	Push-Rod	2250598	2250598-B	2250598-B
-6	Upper (Nose) Bushing	2250593	SK.74	2250593-A
-7	Upper (Tail) Bushing	2250593	SK.74	2252813
-8	Coil Bobbin	2250594	SK.88	2250594-B
438230-1	Cap - Arming Solenoid	2250590	2250590-A	2250590-A
-2	Spring - Arming Push Rod	2250596	2250596-A	2250596-A
-3	Insulator - Bomb Rack Arming (Disc)	2250801	2250101-A	2250801-A
-4	Cup - Arming Spring Ret.	2250592	2250592-A	2250592-A
-5	Ring-Arming Spring Re- tainer Lock	2250812	2250812-A	2250812-A
-6	Washer -Arming Sol.Ins.	2250588	2250588-A	2250588-A
-7	Washer-Arming Sol.Re- taining	2250591	2250591-A	2250591-A
-8	Insul.Tubing (Arming)	2250599	2250599-A	2250599-A
438231-1	Disc -Solen.Insulating	2250815	2250815-A	2250815-A
-2	" " "	2250815	2250815-A	2250815-A
-3	" " "	2250815	2250815-A	2250815-A
-4	" " "	2250815	2250815-A	2250815-A
-5	Guide -Arming Sol.Push- rod	-	2252810	2252810

BuOrd Dwg. No.	Brief Title	Submitted 6-23-44	Sample Racks 9-13-44	Production Design
438456-1				
-2				
-3				
-4				
-5				
-6	Mkr-Rel.Solenoid Lead	2250834	2250834-A	2250834-A
-7	" " " "	2250834	2250834-A	2250834-A
-8	" " " "	2250834	2250834-A	2250834-A
-9	" " " "	2250834	2250834-A	2250834-A
-10	" " " "	2250834	2250834-A	2250834-A
438457-1	Arming Solenoid Side Pl.			
	" " " LH	4250525	4250525-B	4252809
-2	" " " RH	4250526	4250526-B	4252808
-3	Rivet - Arm. Sol.Attach.	2250528	2250528-A	2250528-A
-4	Bushing -Arm.Sol.Upper	2250538	2250538-A	2250538-A
-5	" " " Lower	2250546	2250546-A	2250546-A
438458-1	Manual Arming Cable	2250536	2250536-B	2250536-B
-2	" " " Sleeve	2250536	2250536-B	2250536-B
-4	Plunger - Manual Arming	2213898	2213898-A	2213898-A
-5	Pin - Manual Arm.Plunger	2250535	2250535-B	2250535-B
438512	Arming Retainer Assem. (BuOrd Dwg.not rec'd)	4250531	4250531-A	4250531-A
438513	Arming Retainer Hsg(Orig) (Revised) Arming Ret.Hsg.	3213896 3250898	- 3250898-A	- 3250898-A
N.A.F. 142981	Substitute Part Revised -Die Cast -Arm.Ret. Housing			
438514-1	Retainer -Arming Wire	2250532	2250532-C	2250532-C
-2	Bushing-Arm.Wire Retn'r	2250534	2250534-B	2250534-B
-4	Pin-Arm.Cable Retaining Spring-Arm.Wire Retainr.	2250527 2250533	2250527-A 2250533	2250527-A -
438224	Release Sol.Assem.Comp.	4250548	4250548-B	4250548-B
438225-1	Rel.Sol.Assem.	2250558	2250558-B	2250558-B
-2	Coil Assem.-Rel.Solen.	2250589	2250589-B	2250589-B
-3	Case -Rel.Solenoid	2250572	2250572-A	2250572-A
-4	Plunger -Rel.Solenoid	2250577	2250577-A	2250577-A
-5	Lower Stop-Rel.Solenoid	2250581	2250581-A	2250581-A
-6	Insulator -Rel.Solenoid	2250578	2250578-A	2250578-A
-7	Upper Stop -Rel.Solenoid	2250573	2250573-A	2250573-A
-8	Coil -Rel.Solenoid	2250589	2250589-B	2250589-B
438226-1	Release Solenoid Nut	2250582	2250582-A	2250582-A
-2	Ins.Tube -Rel.Solenoid	2250583	2250583-A	2250583-A
-3	Plug -Sol.Terminal	2250579	2250579-A	2250579-A
-4	Washer -Sol.Plunger Re- taining	2250580	2250580-A	2250580-A
	Washer - Insulating	2218371	2218371	2218371

BuOrd Dwg. No.	Brief Title	Douglas Dwg. No.		
		Submitted 6-23-44	Sample Racks 9-13-44	Production Design
438515-1-11	Release Wiring-Assem. & Details	4250833	4250833-A	4250833-A
328766-2	Details - Arming Unit (Spring)			
-6	Spring			
-9	Switch with Spring			
328768-6	Indicator Sw.Actuator			
328770	Details-Release Assem.			
-1	" " "			
-2	" " "			
-3	" " "			
-4	" " "			
-5	" " "			
-6	" " "			
328771-1	Details - Release Unit			
-2	" " "			
-3	" " "			
-4	" " "			
-5	" " "			
-6	" " "			
-7	" " "			
-8	" " "			
-9	" " "			
-10	" " "			
-11	" " "			
-12	" " "			
422719-1	Hoist-Brket.-Assem.&Details			
-2	" " " " "			
328773-2	Hoist Brkt.& Details (Sh.1)			
-3	" " " "			
-32	" " " "			
-5	" " " "			
-6	" " " "			
-7	" " " "			
328773-12	Recep.Assem.& " (Sh.2)			
-13	" " " "			
-14	" " " "			
-15	" " " "			
-16	" " " "			2252827
-17	" " " "			
-18	" " " "			
-19	" " " "			
-20	" " " "			
328773-25	Details (Sheet 3)			
-26	"			
-28	Arming Cable Bushing	2250595	2250595-A	2250595-A
-33	" " "			

BuOrd Dwg.No.	Brief Title	Submitted 6-23-44	Sample Racks 9-13-44	Produc- tion Design
328774-3	Manual Rel. Trigger & Details			
-4	" " " " "			
-5	" " " " "			
-6	" " " " "			
-7	" " " " "			
-8	" " " " "			
-9	" " " " "			
-10	" " " " "			
-11	" " " " "			
-12	" " " " "			
328785-37	Misc. Details			
-38				
-39	Pin - For Bomb Hook	-	2250806-A	-
-40				
-41				
-70				
-71				
-72				
329209-21	Misc. Details			
-32				
-41				
-42				
-61				
-71				
-92				

FIG. 23

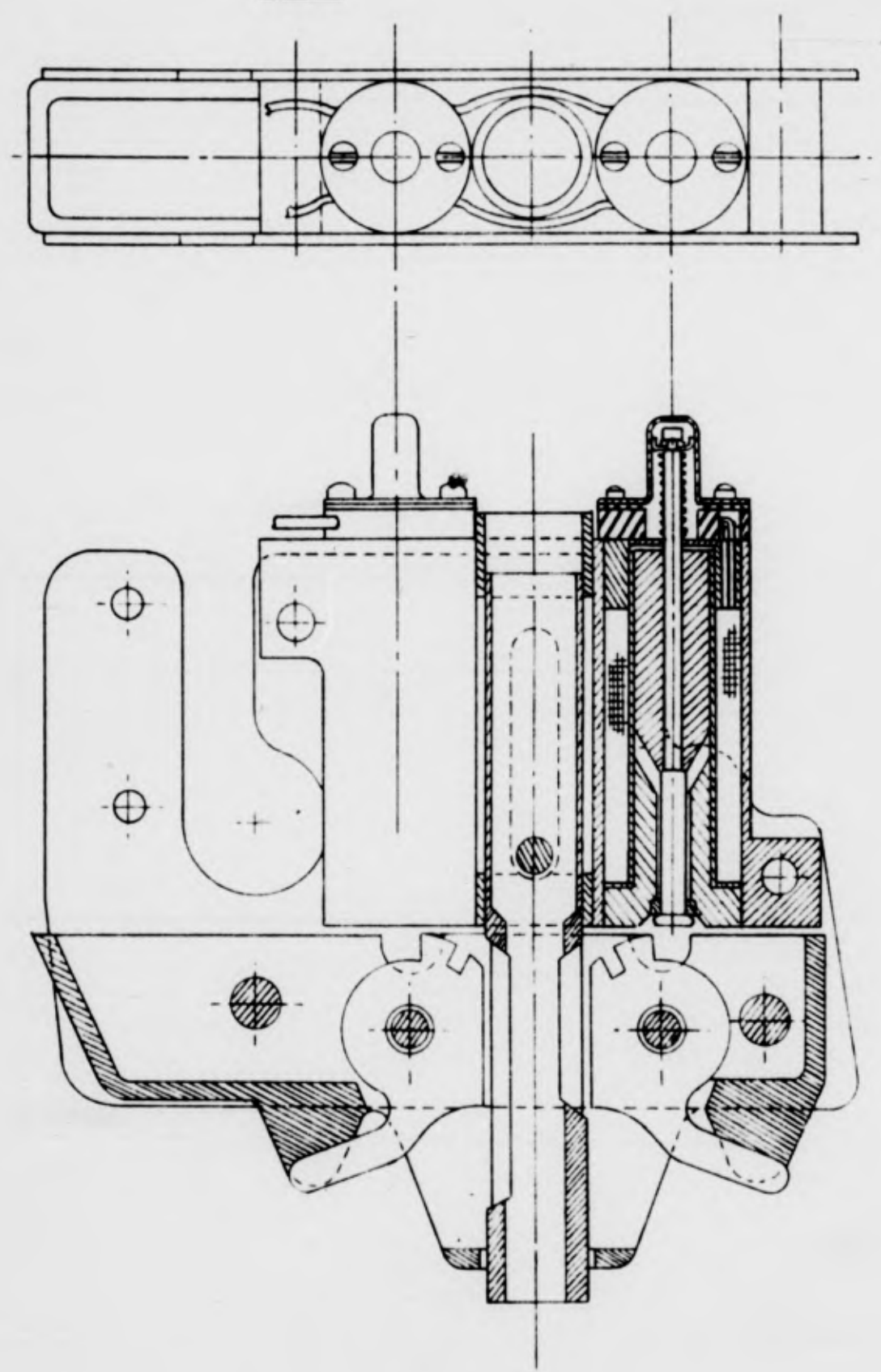
ARMING UNIT COMPARISON

REDESIGNED UNIT

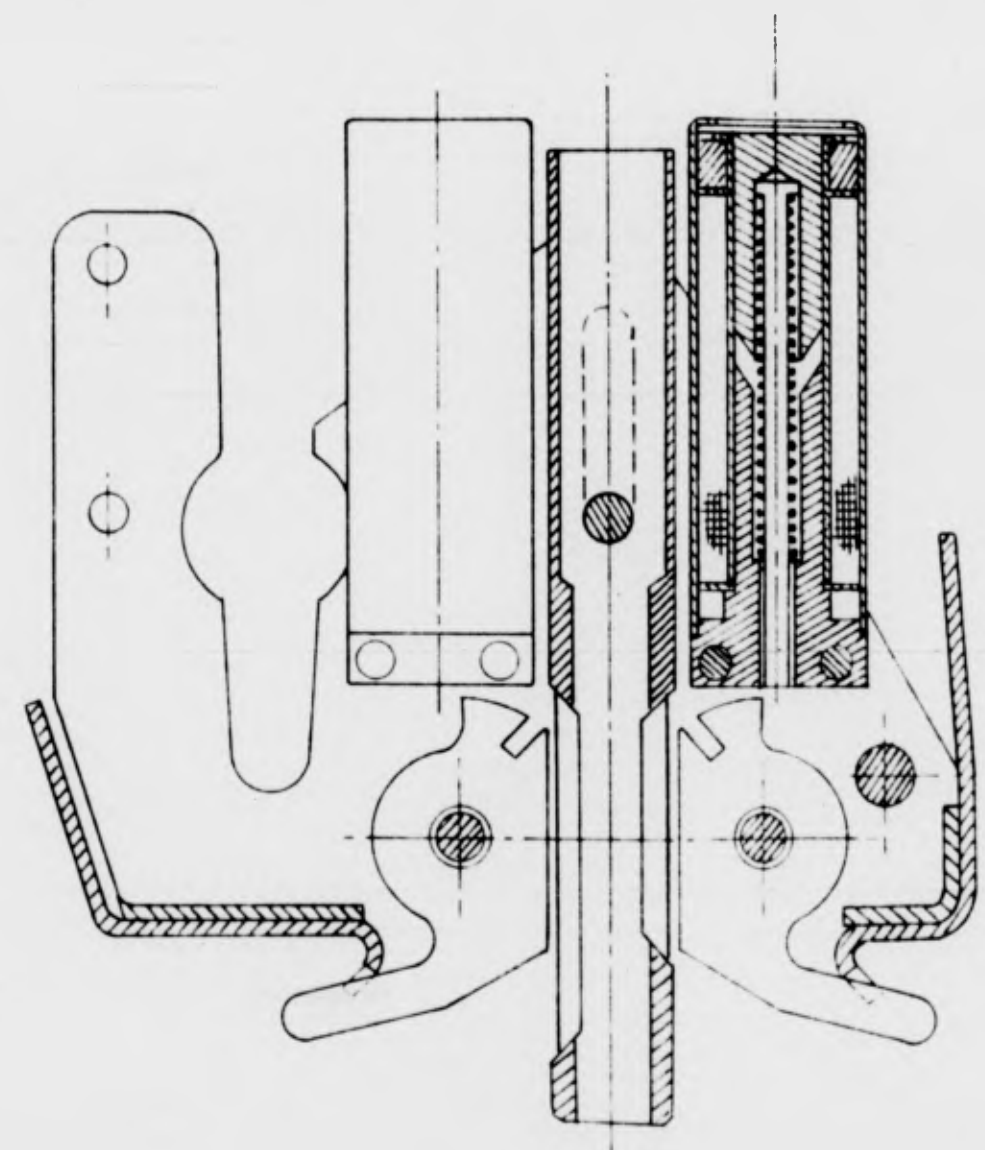
ORIGINAL MOD. 7 UNIT

LEFT

RIGHT



REDESIGNED
ARMING UNIT



MODEL 7 RACK
ARMING UNIT

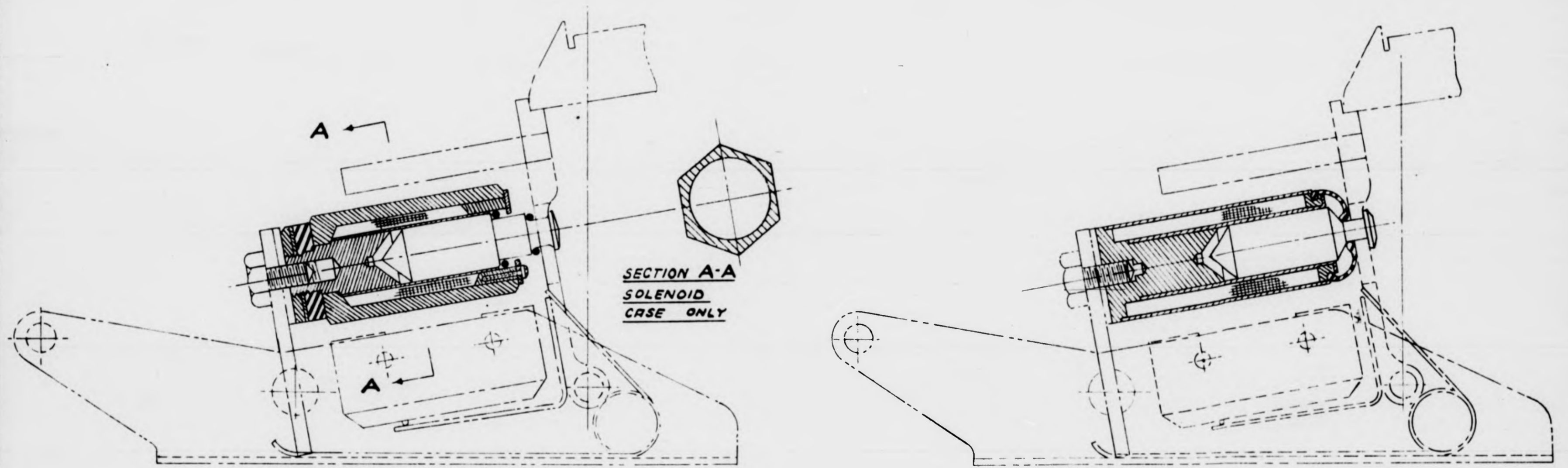
SCALE :- FULL SIZE

FIG. 24

RELEASE SOLENOID COMPARISON

REDESIGNED UNIT
LEFT

ORIGINAL MOD. 7 UNIT
RIGHT

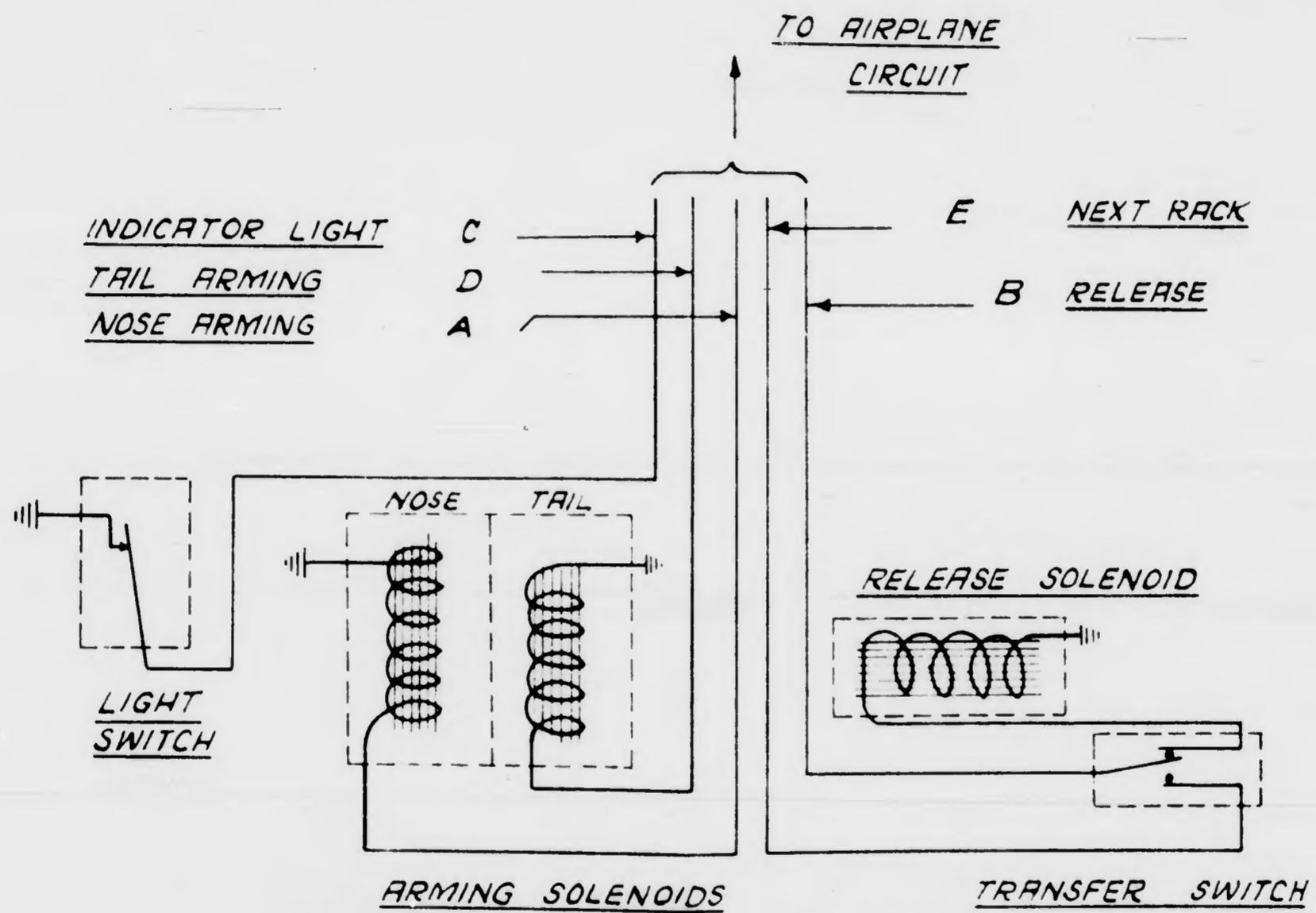


REDESIGNED RELEASE SOLENOID

MODEL 7 RELEASE SOLENOID

SCALE :- FULL SIZE

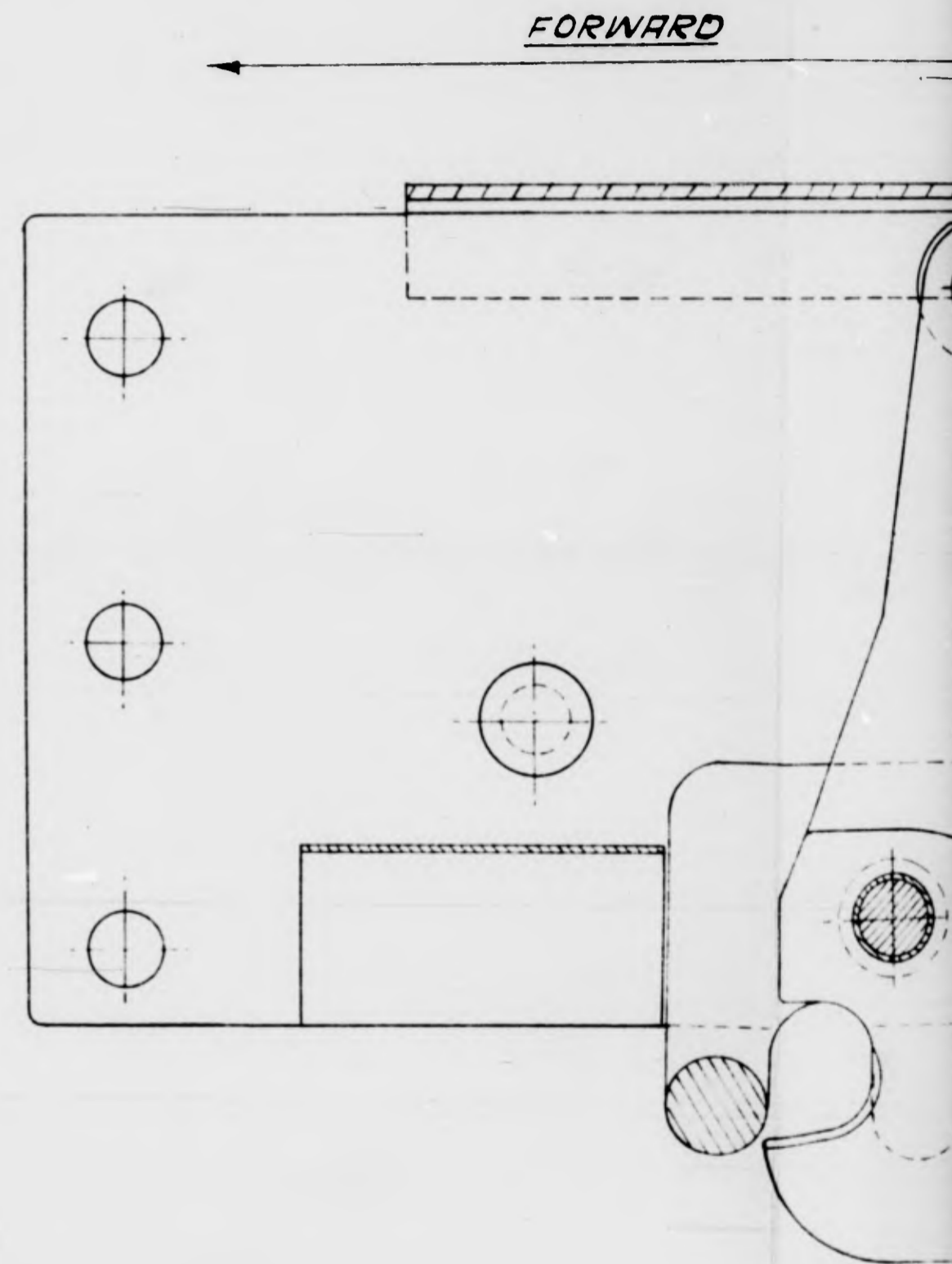
RACK CIRCUIT
MUST BE GROUNDED
TO AIRPLANE



SCHEMATIC WIRING DIAGRAM

CURRENT AT 24 VOLTS :-

RELEASE SOLENOID 4.8 AMPS
NOSE ARMING SOLENOID 0.26 AMPS
TAIL ARMING SOLENOID 0.26 AMPS

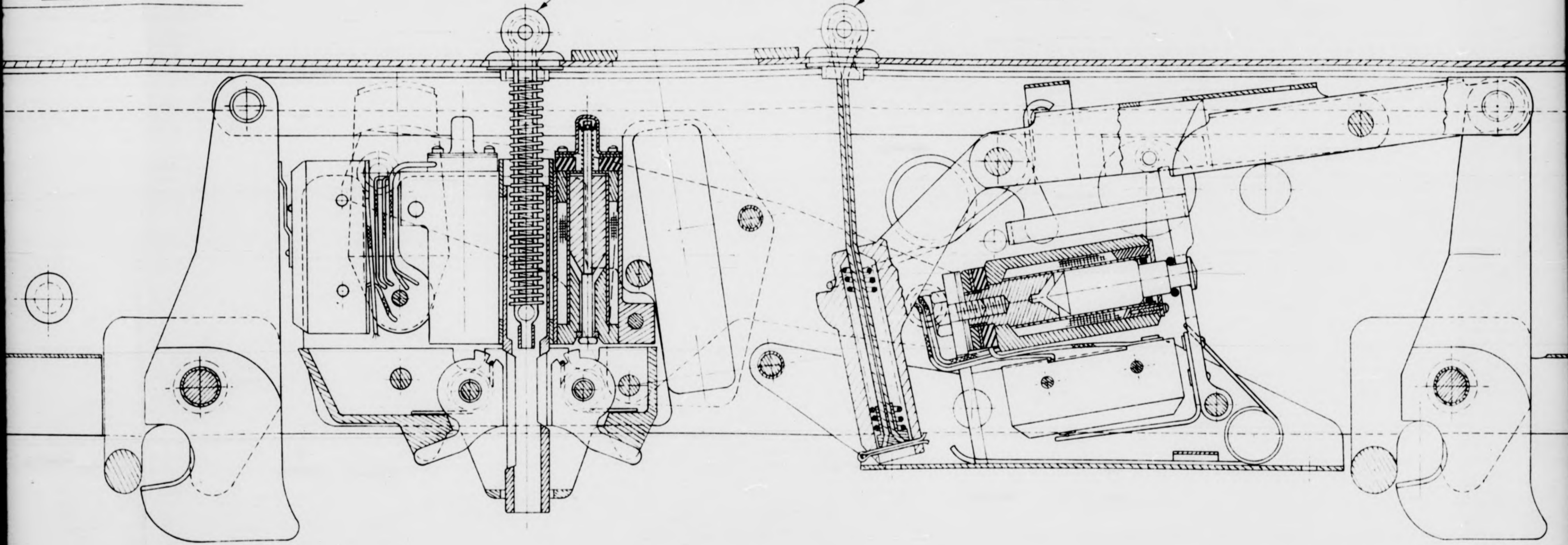


LAY

FORWARD

MANUAL ARMING
CONTROL

MANUAL RELEASE
CONTROL



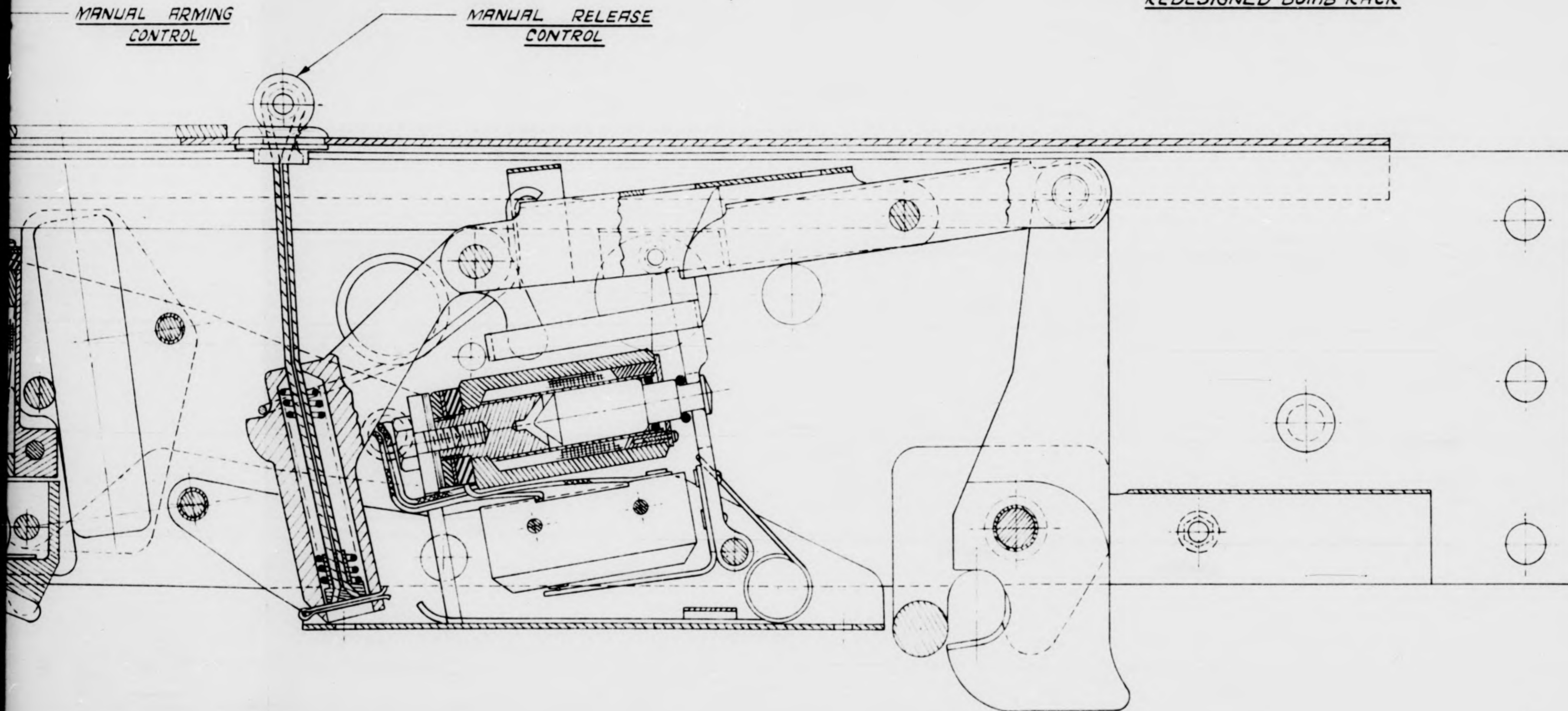
MK. 51 - 11 REDESIGNED BOMB RACK
(MODIFICATION OF MK. 51 - 7)

SCALE :- FULL SIZE

FIG. 25

LAYOUT AND WIRING DIAGRAM

REDESIGNED BOMB RACK



II REDESIGNED BOMB RACK

(MODIFICATION OF MK. 51-7)

SCALE :- FULL SIZE

DIVISION 12

**TRANSPORTATION
DEVELOPMENT**

DECLASSIFIED

BY THE AUTHORITY OF THE

SECRETARY OF DEFENSE MEMORANDUM

DATED AUGUST 2, 1960

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