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DESIGN OF A HIGH-SPEED NONELECTRIC DETONATOR LOADING, ASSEMBLY, INSPECTION, AND PACKAGING SYSTEM

Kenneth Iles, et al

FMC Corporation

Prepared for:

Picatinny Arsenal

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DESIGN OF A HIGH-SPEED NONELECTRIC DETONATOR LOADING, ASSEMBLY, INSPECTION, AND PACKAGING SYSTEM

FINAL REPORT

by
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Max Tronik
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Prepared for
PICATINNY ARSENAL
Dover, New Jersey 07801
Contract DAAA21-73-C-0211

[redacted]

The findings in this report are not to be construed as an official Department of the Army position.

Prepared by
FMC CORPORATION
Engineered Systems Division
Santa Clara, California 95052

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CONTENTS

ILLUSTRATIONS

I. INTRODUCTION AND SUMMARY

FMC Corporation Engineered Systems Division (ESD) was awarded Contract DAAA 21-73-C-0211 to develop new concepts and to complete a preliminary design for a high-speed (1, 200 units per minute) automatic, remotely controlled system for loading, assembling, sealing, inspecting, and packing detonators. This final report describes the work performed under this contract and provides a systems concept recommended for implementation.

The major accomplishment of this project was the development of techniques for charging, tamping, and crimping detonators.

This final report presents proven principles gained through bench-model verification of the feasibility of producing M55 nonelectric detonators at a rate of 1, 200 per minute, using live powder, in the following areas:

- Metering of charges
- Consistency of charge weight
- Loading of charges
- Consolidation of charges
- Crimping
- Elimination of powder bridging.

This report also presents a final, overall system design incorporating practical improvements to the initial concept. The fully automated system includes the following features:

- Bulk feeding of cups
- Variable volume metering
- Safety during metering
- Elimination of propagation of explosion to metering hopper during consolidation
- Seal blanking and inserting
- Rapid tooling changeover to accommodate other sizes
- Packaging of finished detonators.

The basic advantages of the proposed system are:

1. Detonator transport is achieved by a standard 1-inch-pitch hollow-pin chain carrying simple holders that may be quickly changed if necessary.

2. Metering of each charge is accomplished on a separate turret for maximum safety and simplification of equipment.

3. Loading and consolidation of each charge is made on a separate turret to simplify equipment.

4. Powder bridging in the metering hopper is prevented by pneumatic agitation.

5. Charge weights are accurate and easily variable.

6. All functions can be computer controlled.

In conclusion, the major operations have been proven by bench-model testing. The packaging operation is now being investigated by FMC and feasible approaches have been developed. The major unproven area is sealant application. The proposed single supply roll system has been analyzed and we feel confident that this approach can be successfully implemented.

II. SYSTEM DESCRIPTION

A. GENERAL

The detonator assembly line will consist of 12 turrets linked by a carrier chain, cup-feeding equipment, and detonator-packaging equipment. (Figure 1 illustrates the general layout schematic.) In addition to the main carrier chain, three auxiliary powder-transport systems, synchronized with the fill turrets, will maintain a powder supply from the magazine to the assembly line.

All functions required for assembly of M55 and other size detonators will be performed on rotary turrets; therefore, the system will operate continuously rather than intermittently. Turret functions and principal items of equipment are described in the following paragraphs.

B. CARRIER CHAIN (Figure 2)

The chain is a standard Number 80 hollow-pin, self-lubricating, 1-inch-pitch chain and will contain a detonator carrier every fourth pitch. The hardened carrier will float freely within the sintered steel hollow pin of the chain, and the head diameter will be precision ground so that the bore can be accurately located on the tooling centerline of a turret work station. The bore will accept the outside diameter of the detonator cup; a D-shaped spring (Figure 3) protruding very slightly into the bore through a slot in the side of the carrier head will prevent the cup falling through. The amount of protrusion will be insufficient to cause interference with the lower anvil punch which, in operation, will move the spring aside.

A number of air-escape holes in the carrier head will prevent compressed-air disturbance of the empty detonator cup on the initial rapid rise of the anvil punch in the close-fitting carrier bore. A generous lead-in at the bottom of the carrier bore will permit alignment with the lower anvil punch on entry. The carrier will be free to move axially so that the carrier head may be accurately located in the tooling die register, pushed into position by a shoulder on the lower anvil punch. Return of the carrier to the normal position in the chain will be accomplished by a conical spring at the bottom of the carrier, retained by a small ring.

C. TURRETS

All turrets will be approximately 36 inches in diameter, designed basically around a 96-tooth, 1-inch-pitch chain sprocket of 30.563-inch pitch-circle diameter. Each turret will contain 24 tooling stations, spaced 4 inches apart around the circumference, with tooling station centerlines on the chain roller centerlines. The turrets will rotate at 50 rpm, and output will be 1,200 parts per minute.

Each turret will be driven through a 10-to-1 gear reducer beneath the turret. The gear reducers will be driven through a 2-to-1 gear belt drive from a common shaft extending the length of the machine. A variable-speed DC electric motor will drive the shaft. A torque-limiting feature, built into the spring-loaded chain idler mounts at each turret, will initiate shutdown of the equipment should an overload condition occur at any point on the line. Also, an adjustable and easily reset torque limiter will be provided at the main drive.

Turrets will be provided as follows:

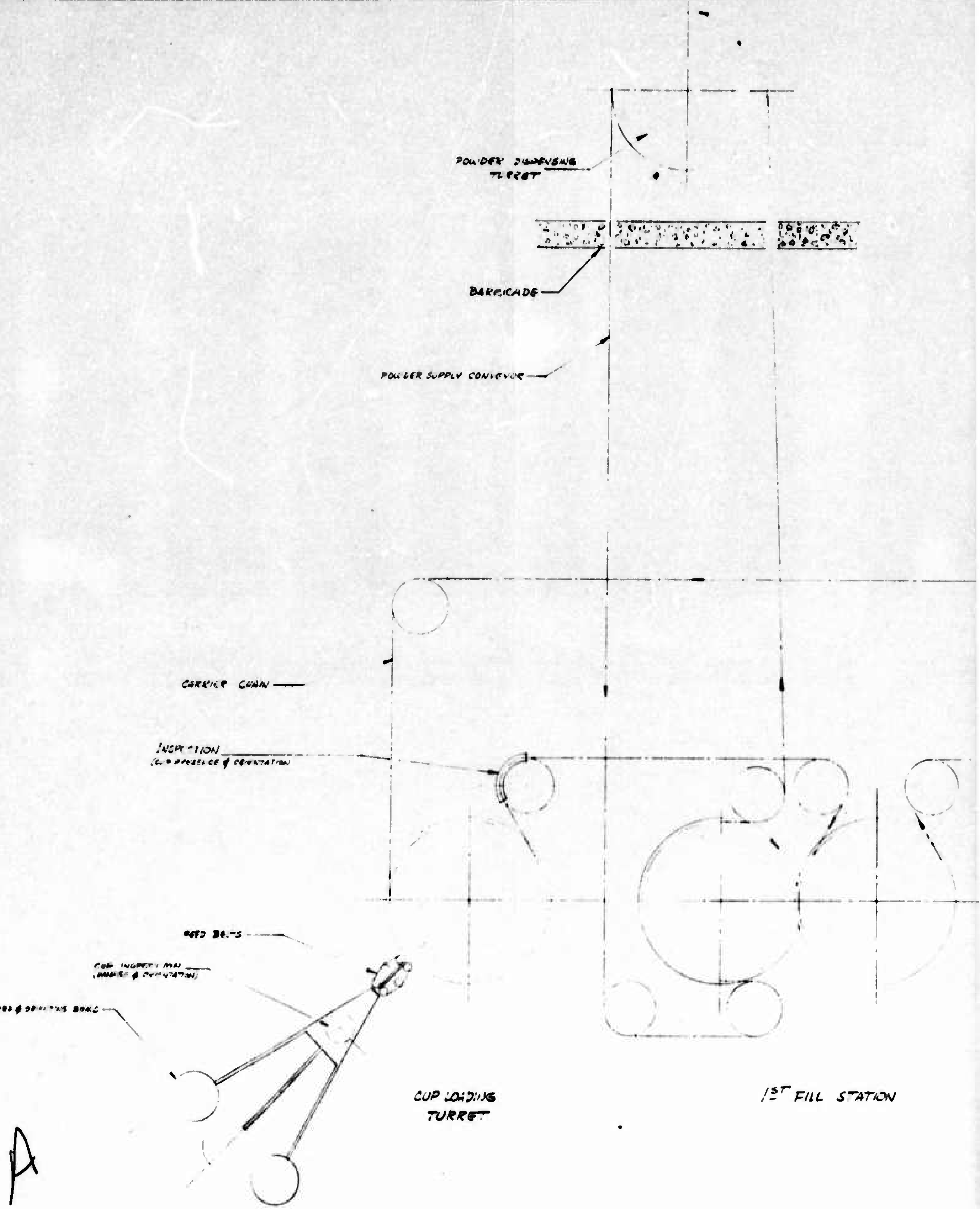
- Loading Station (1)
- Filling Stations (3)
- Brushing and Aspirating Turrets (3)
- Disc Blanking and Inserting Station (1)
- Crimping Turrets (2)
- Sealant-Application Turret (1)
- Unloading Turret (1).

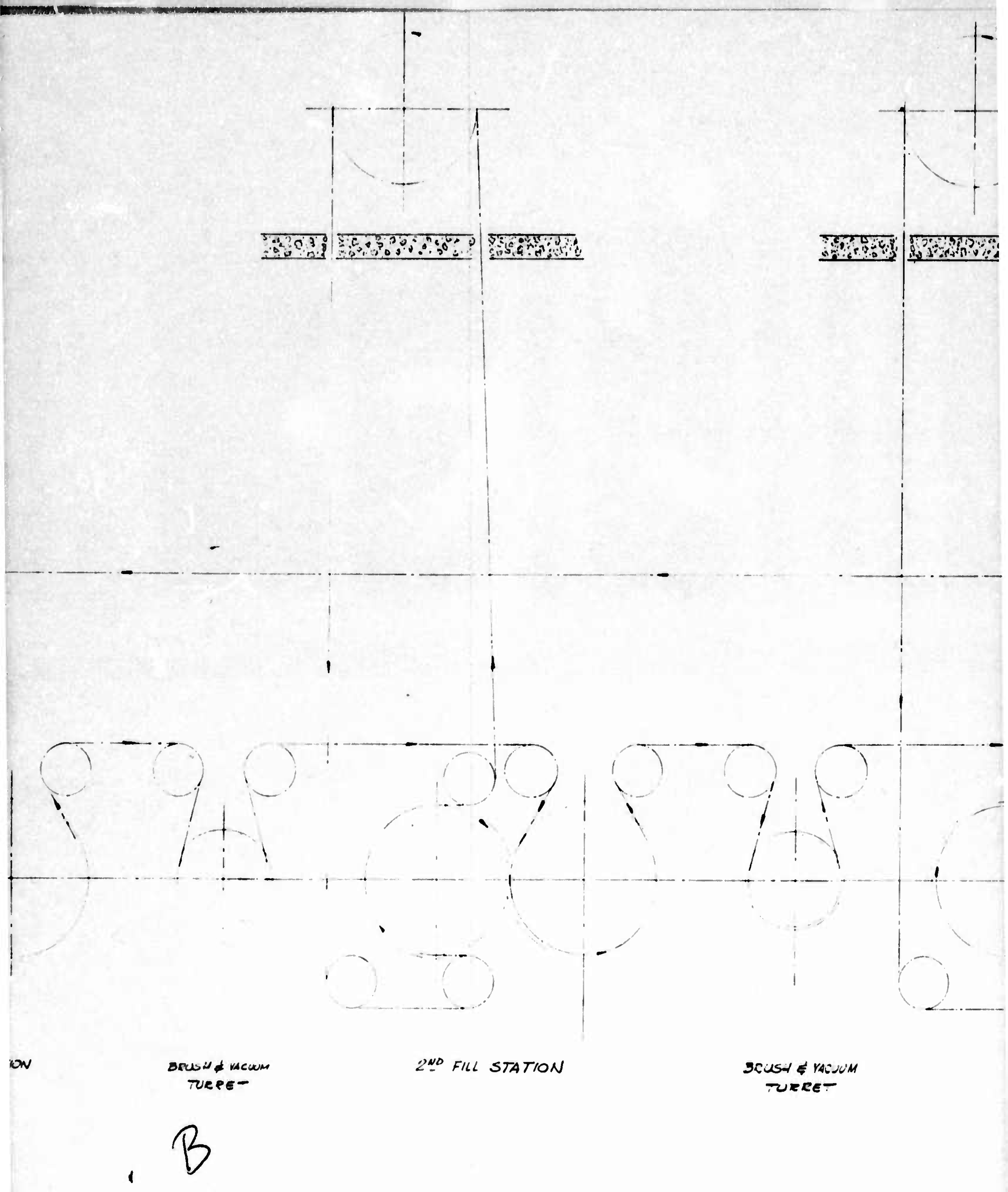
In many cases turrets are of identical construction, and many parts are duplicated, to minimize manufacturing costs, engineering effort, and spare parts inventory. The number of turrets can be reduced if turrets to perform multiple functions are employed, e.g., both the crimping stages on one turret, as outlined in the initial Phase I proposal. However, based on extensive experience with similar equipment, FMC ESD has found it is often beneficial, especially in high-volume production equipment, to reduce a complex, combination operation to separate and simple functions.

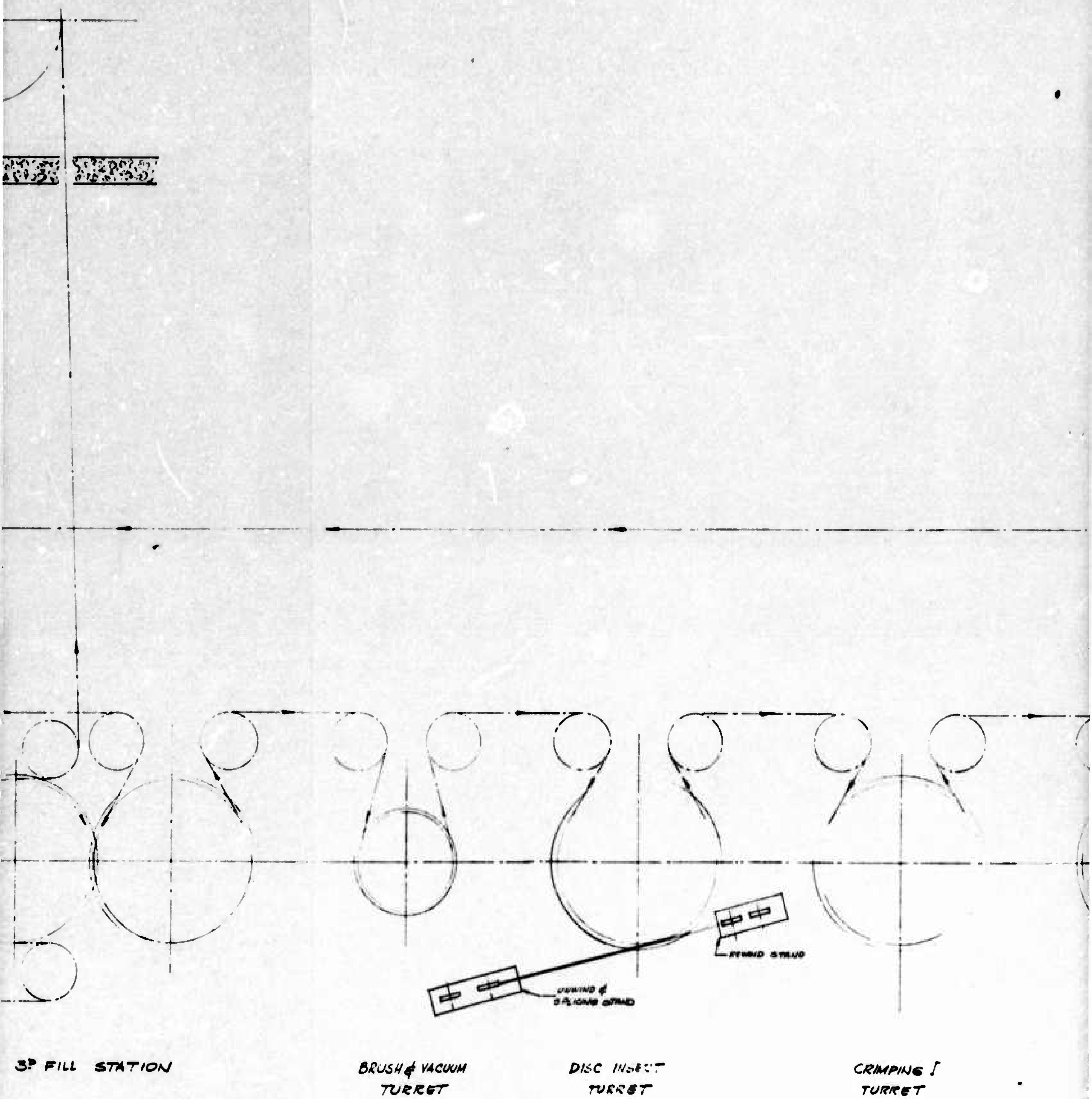
This design philosophy was applied to arrive at the number of turrets shown above. Each is described herein.

D. LOADING STATION

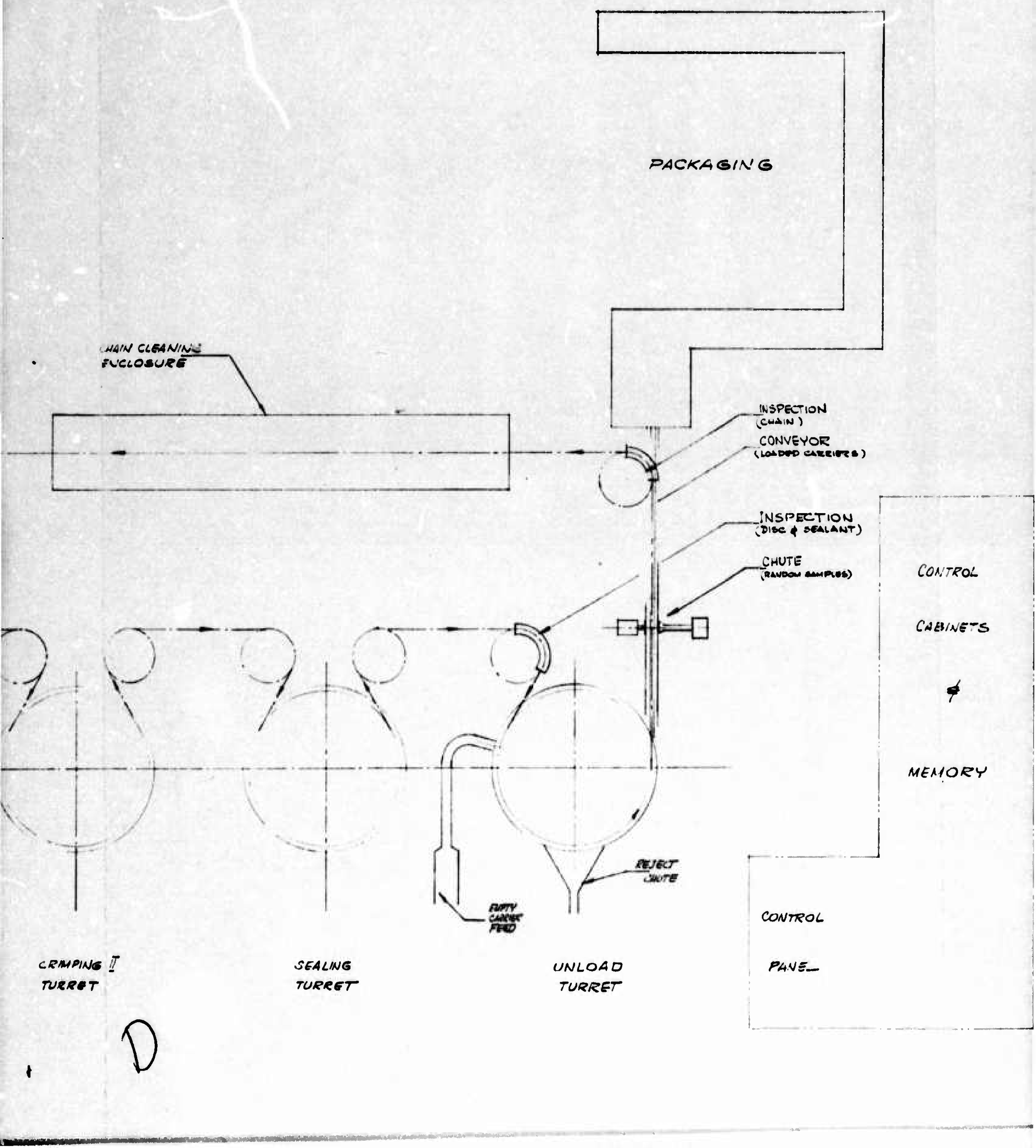
The first station of the machine comprises a cup-supply system and a loading turret. Three vibrator-feeder bowls will dispense oriented cups--open end up--at the required rate, to a collecting area. Two V-belts, set at 45 degrees, will gently direct the cups in a single line onto a star-wheel for inspection. A scanning device incorporating a laser beam, with a capacity for several thousand parts per second, will inspect the cups and reject misoriented and damaged parts. The cups will be conveyed to the turret by a set of pinch belts and a narrow slide bar; the pressure required to ensure a continuous supply of cups at the turret takeoff will be exerted at the lower portion of the cups where radial strength is greatest. This system is similar to that employed for the feeding and inspection of primers for the primer-insert equipment built for Frankford Arsenal (Figures 4 and 5).

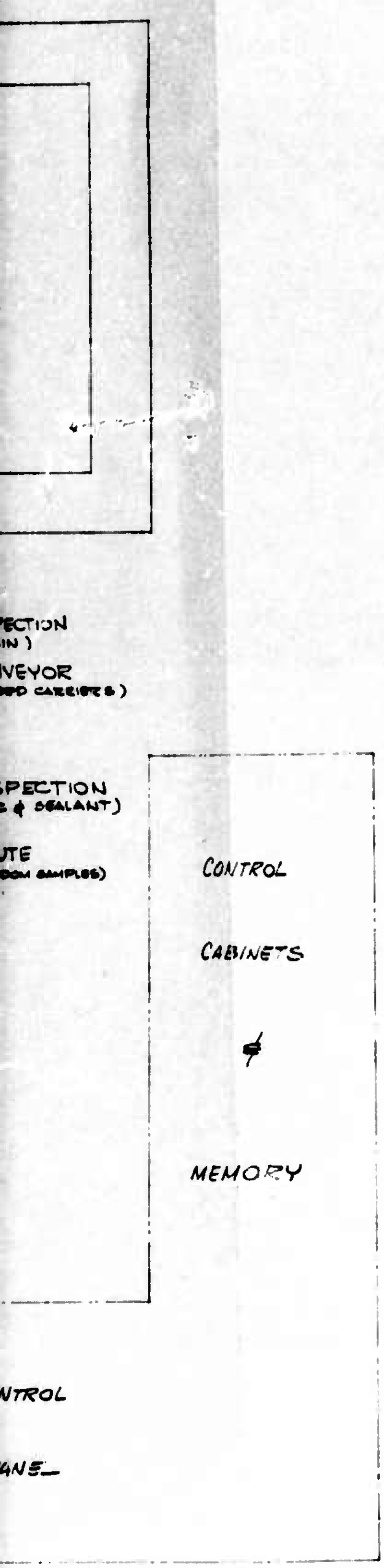

POWDER DISPENSING TURRET
BARRICADE
POWDER SUPPLY CONVEYOR
CARRIER CHAIN
CUP LOADING TURRET
1ST FILL STATION
A


ION
BRUSH & VACUUM
TURRET
2ND FILL STATION
BRUSH & VACUUM
TURRET
B


REWIND STAND
UNWIND & SPLICING STAND
3P FILL STATION
BRUSH & VACUUM TURRET
DISC INSERT TURRET
CRIMPING I TURRET

1 C


PACKAGING
CHAIN CLEANING ENCLOSURE
INSPECTION (CHAIN)
CONVEYOR (LOADED CARRIERS)
INSPECTION (DISC & SEALANT)
CHUTE (RANDOM SAMPLES)
CONTROL CABINETS & MEMORY
REJECT CHUTE
EMPTY CARRIER FEED
CONTROL PANEL
CRIMPING II TURRET
SEALING TURRET
UNLOAD TURRET
D



E

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Engineered Systems Division

Figure 1 DETONATOR ASSEMBLY LINE GENERAL LAYOUT SCHEMATIC (FMC Drawing 5102622)

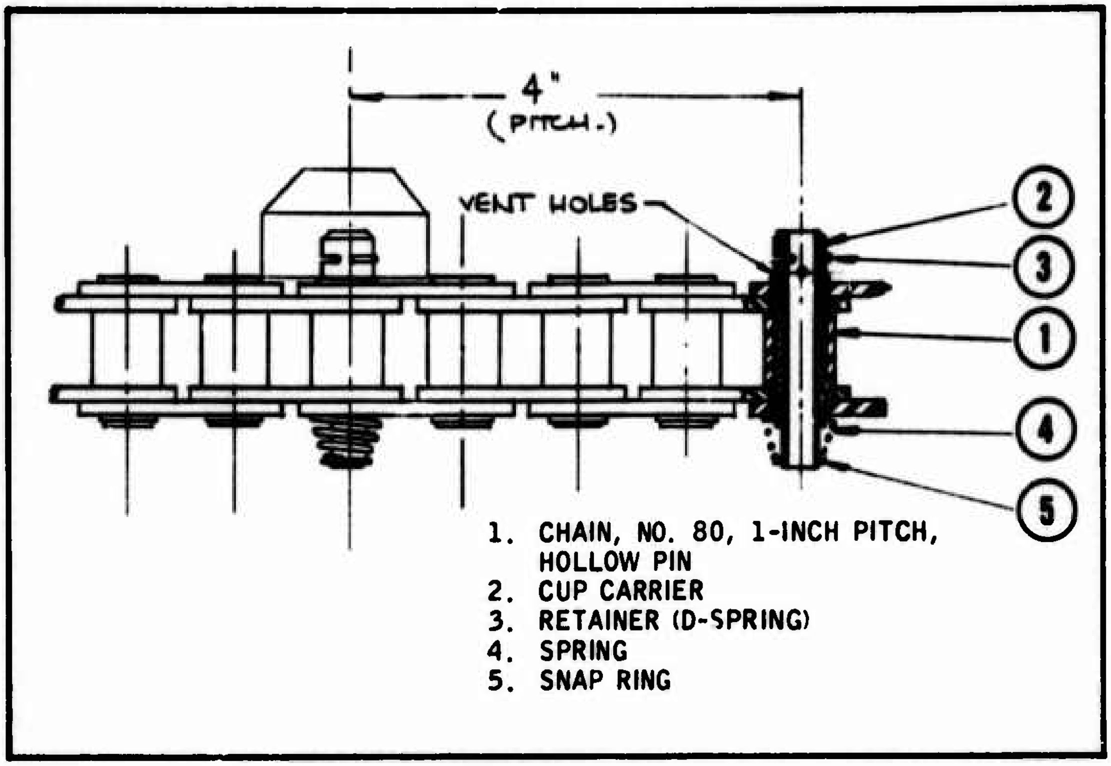

Figure 2 CARRIER CHAIN ASSEMBLY (FMC Drawing 5102520)

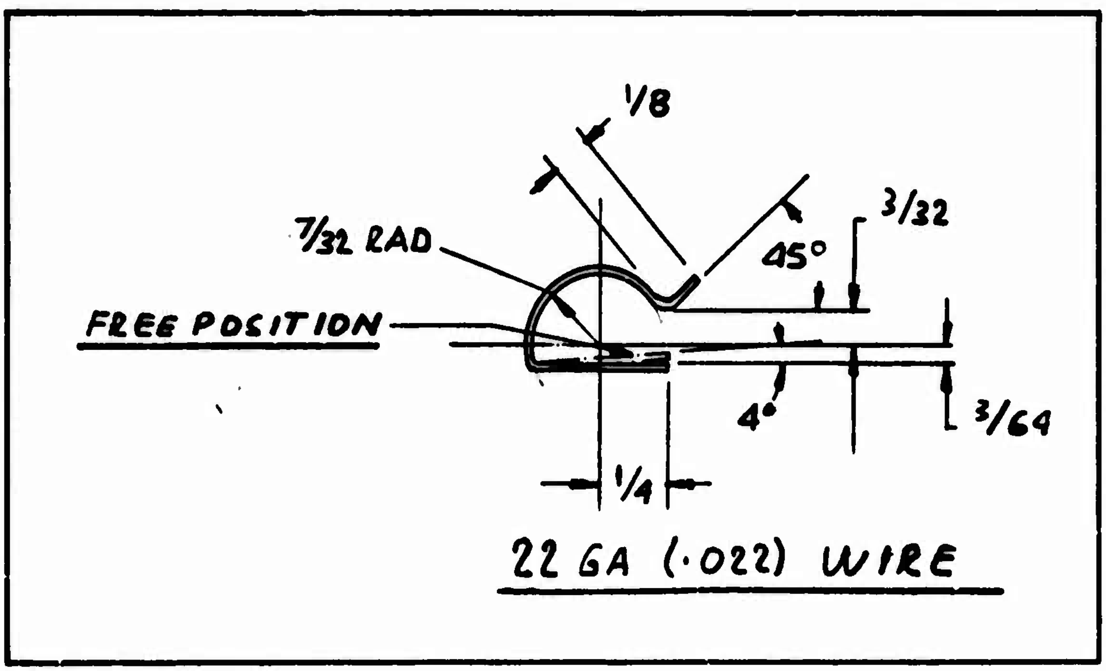

Figure 3 SPRING-POWDER FILL TURRET (FMC Drawing 5100586)

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The loading turret will consist of a 96-tooth, 1-inch-pitch chain sprocket running beneath a starwheel, with detonator cup nests every 4 inches around the circumference. The nest centerlines will match those of the carriers in the transport chain. A set of 24 bottom punches on the same centerlines will raise and accurately align the carriers immediately beneath the starwheel nests.

A similar set of top punches will push the cups downward out of the nests where they will be held by a stationary spring blade similar to that shown as Item 21, Figure 5.

An alternate concept would provide for application of vacuum through the top set of hollow punches, to hold the cup to the punch. With this method, stationary spring blades, which can cause scratches on the outside surfaces of the detonator cups, would be unnecessary. The vacuum would be applied intermittently, and a slight positive air pressure could be applied during top punch withdrawal to assure retention of the cup in the carrier.

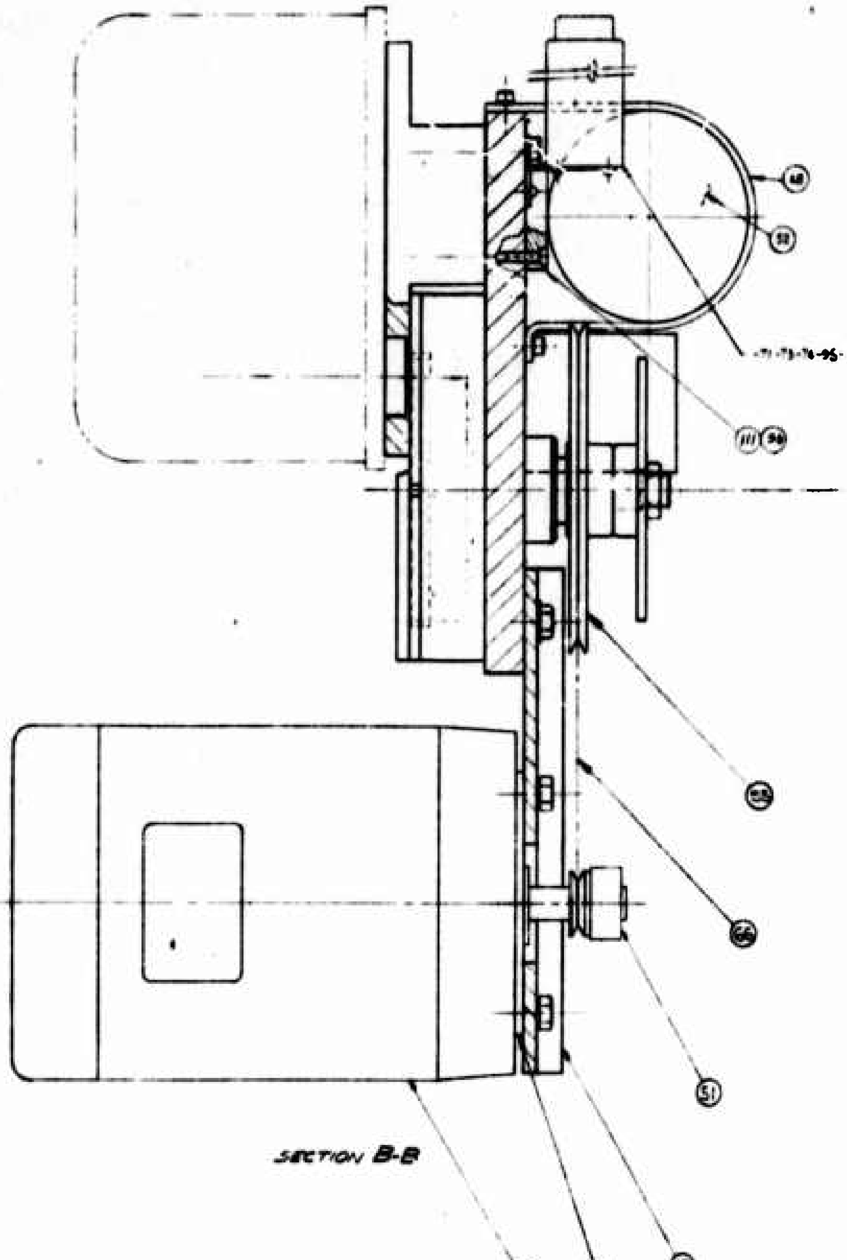
E. FILLING STATIONS

The three filling stations are of identical construction, differing only in type of powder loaded and adjustment of the punch pressures, consolidation height, and powder volume as appropriate. Figure 6 depicts the component parts of the prototype loader; it is representative of the two turrets which comprise each of the three loading stations.

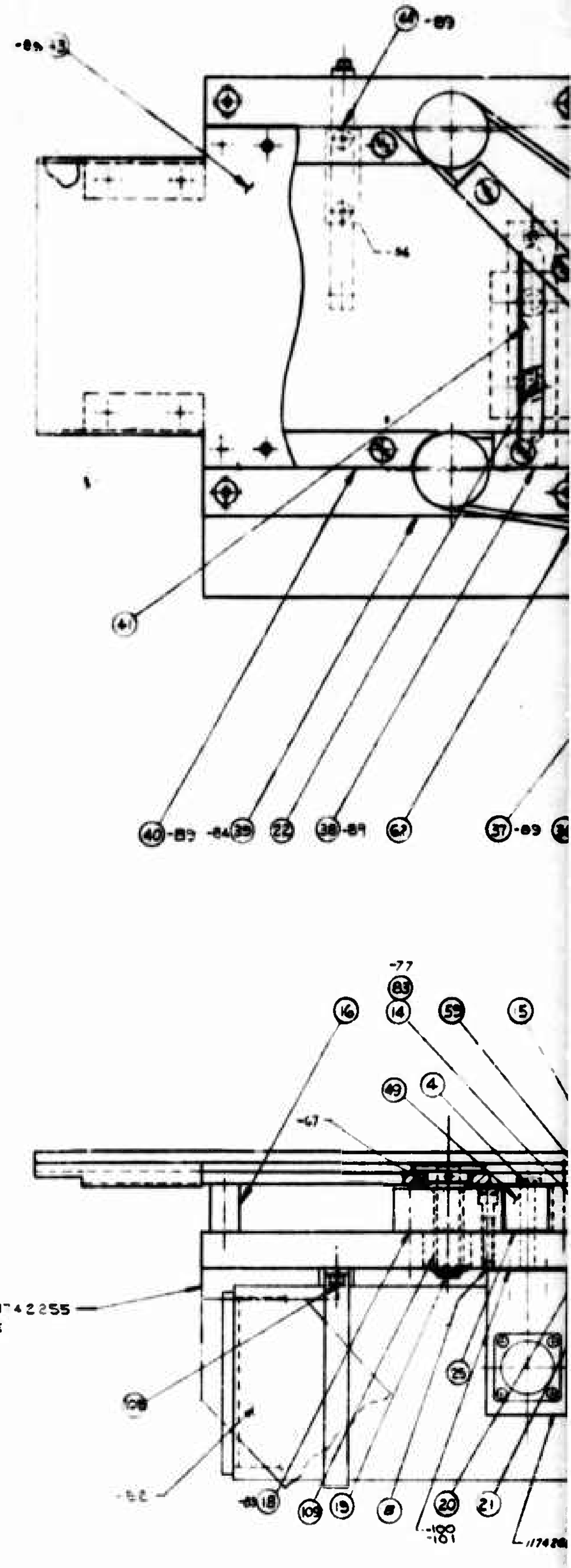
The proposed equipment (Figure 6) consists of two separate turrets on a common machine table top, one operating as a rotary press for charge consolidation, the other utilized for metering and dispensing powder into the powder funnels of the rotary press. Each turret will be driven by a 10-to-1 gearbox beneath the machine table top which derives power, through timing belts, from a common drive shaft extending the length of the line. The two turrets will rotate at 50 rpm in opposite directions, each incorporating 24 stations around the periphery. They will be synchronized through the drive components so that the stations converge on rotation in a manner similar to the meshing of the teeth of gear wheels; however, no physical contact of the rotating turrets will occur.

1. Rotary Press

This is a conventional rotary press design, with a top set of 24 punches and a lower set of 24 anvil punches. The punch stroke movements will be made by means of side-mounted cam followers working in stationary cams mounted at the top and the bottom of the turret, the top cam supported by columns. A dial between the quick-release punch sets around the turret will carry 24 tooling dies accurately located above the pitch circle diameter of a 96-tooth, Number 80 chain sprocket. This chain sprocket will carry the main transport chain between turrets of the overall assembly system.



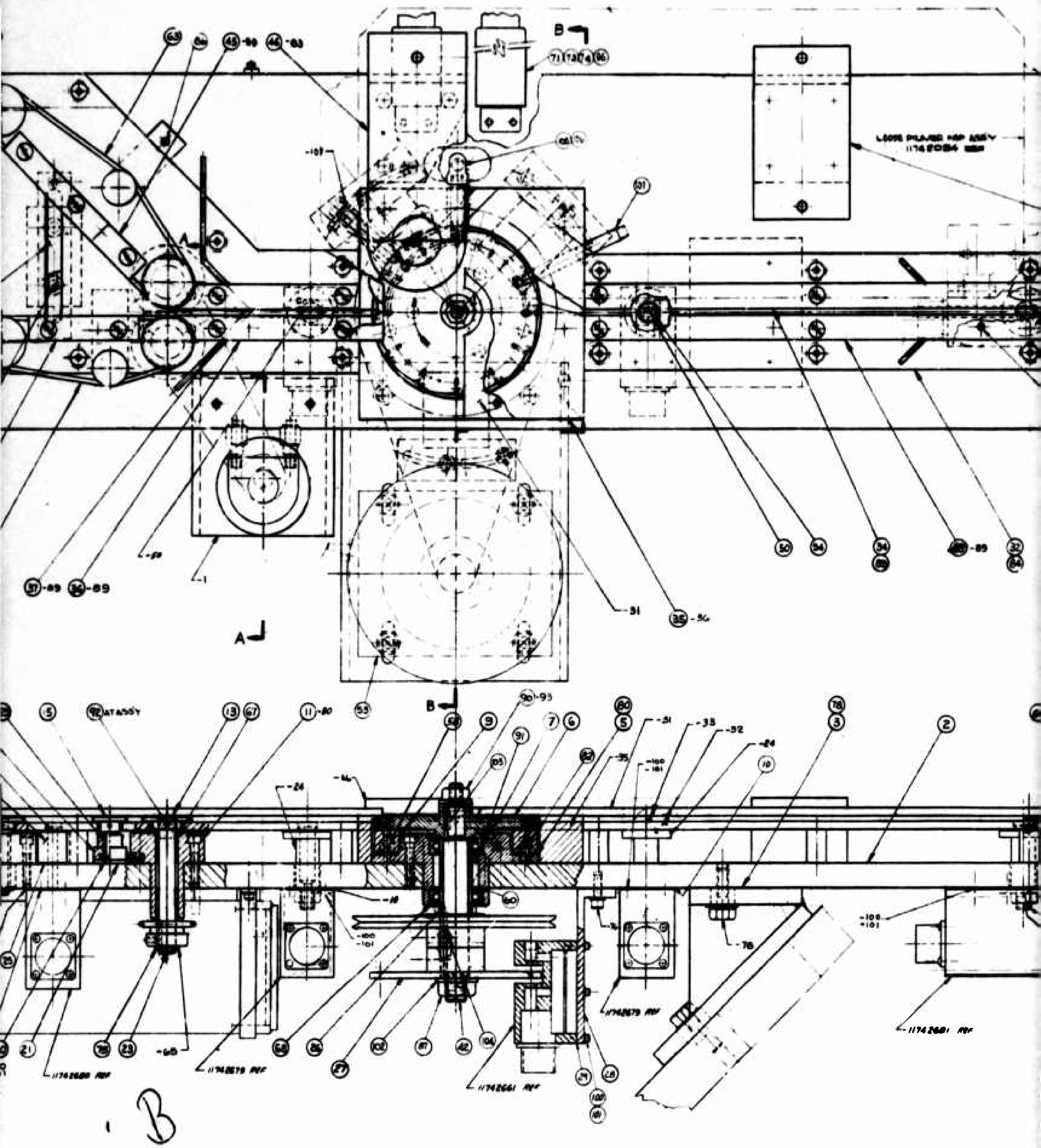
SECTION B-B

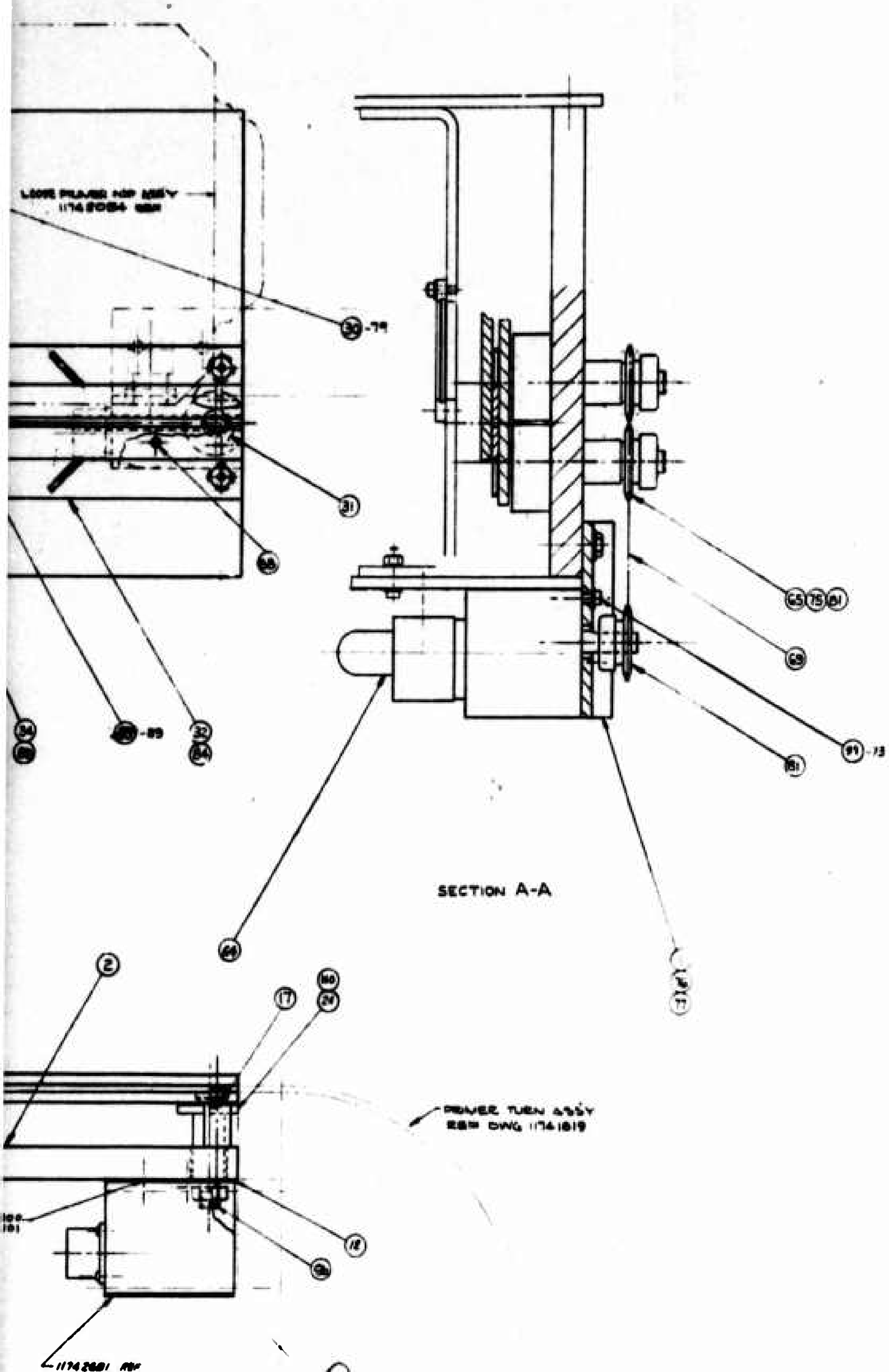


NOTES:

1. VALVE - CAT NO. 211-3- , 1/8 NPT, EXP. PROOF, 3 WAY WITH BRACKET No.10768 - MAC INC., DETROIT, MICH. 48237
2. GEARMOTOR - CAT. No # 1AM-NRV-56-GR11 GAST MFG. - BENTON HARBOR, MICH. 49022
3. # 35 CHAIN - 54 PITCHES, W/CONN. LINK BOSTON GEAR, QUINCY, MASS. 02171
4. SPROCKET - KSA12-1 - 1/2 BORE W/KEYWAY & DOUBLE SET SCR BOSTON GEAR, QUINCY, MASS. 02171

A


B
A
B
11742680 REF
11742679 REF
11742661 REF
11742681 REF
AT ASSY



ZONE	FIND NO	QTY REQ'D	CODE IDENT	PART NO OR IDENT NO	NOMENCLATURE OR DESCRIPTION	MATERIAL OR SPEC
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	110	11		[illegible]	SOC FL HD SOC CAP	CAD PL STL
	109	2		[illegible]	[illegible]	[illegible]
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	103	1		[illegible]	KEY	STL
	102	1		[illegible]	WASHER, FLAT	CAD PL STL
	101	24		[illegible] NOM	WASHER, LOCK	CAD PL STL
	100	22		[illegible]	SOC HD CAP SCR	CAD PL STL
	99					
	98					
	97	3		[illegible]	SOC HD CAP SCR	CAD PL STL
	96	3		[illegible]-14	NUT-HEX	STL
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	94	6		[illegible]	HEX HD CAP SCR	CAD PL STL
	93	2		[illegible]	FLAT WASHER	CAD PL STL
	92	3		[illegible]	ROLL PIN	STL
	91	1		[illegible]	RETAINING RING	[illegible]
	90	1		[illegible]	HEX NUT, LOCKING	CAD PL STL
	89	12		[illegible]	[illegible] FLT HD MACH SCR	CAD PL STL
	88	2		[illegible]	SOC HD CAP SCR	CAD PL STL
	87	1		[illegible]	LOCK NUT	[illegible]
	86	4		[illegible]	SOC HD CAP SCR	CAD PL STL
	85	4		[illegible]	HEX HD CAP SCR	CAD PL STL
	84	17		[illegible]	FLAT HD CAP SCR	CAD PL STL
	83					
	82	2		[illegible]	DOWEL PIN	STL
	81	6		[illegible]	SOC SET SCR	CAD PL STL
	80	18		[illegible]	SOC HD CAP SCR	CAD PL STL
	79	30		[illegible]	HEX HD CAP SCR	CAD PL STL
	78	2		[illegible]	HEX HD CAP SCR	CAD PL STL
	77	8		[illegible] NOM	FLAT WASHER	CAD PL STL
	76	11		[illegible]	HEX HD CAP SCR	CAD PL STL
	75	2		[illegible]	KEY	CAD PL STL

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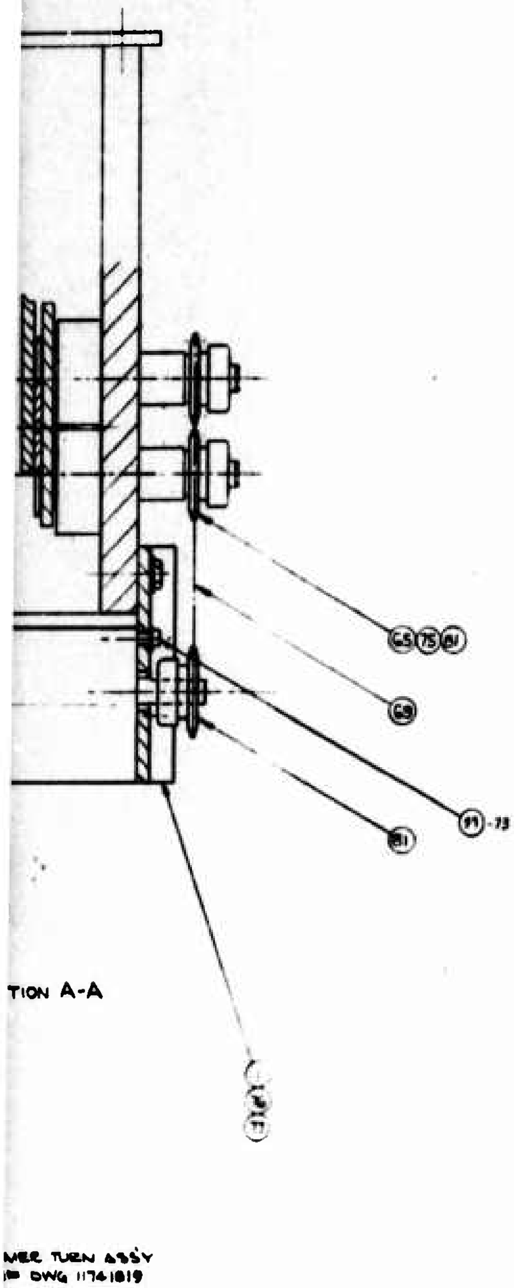
Figure 4 PRIMER
ASSEMBLY (FMC

C



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	108	4		[illegible]	SOC HD SCR	CAD PL STL
	107	[illegible]	[illegible]	115-P	LONG NIPPLE	[illegible]
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	105	1	[illegible]	770E	ELBOW	[illegible]
	104	1		[illegible]	KEY	STL
	103	1		[illegible]	KEY	STL
	102	1		[illegible]	WASHER, FLAT	CAD PL STL
	101	34		#4 NOM	WASHER, LOCK	CAD PL STL
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	98					
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	92	2		[illegible]	ROLL PIN	STL
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	90	1		[illegible]	HEX NUT, JOURNAL	CAD PL STL
	89	10		[illegible]	[illegible] FLT HD MACH SCR	CAD PL STL
	88	9		[illegible]	SOC HD CAP SCR	CAD PL STL
	87	1		[illegible]	LOCK NUT	[illegible]
	86	4		[illegible]	SOC HD CAP SCR	CAD PL STL
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	82	3		[illegible]	DOWEL PIN	STL
	81	6		[illegible]	SOC SET SCR	CAD PL STL
	80	10		[illegible]	SOC HD CAP SCR	CAD PL STL
	79	30		[illegible]	HEX HD CAP SCR	CAD PL STL
	78	2		[illegible]	HEX HD CAP SCR	CAD PL STL
	77	5		¼ NOM	FLAT WASHER	CAD PL STL
	76	11		[illegible]	HEX HD CAP SCR	CAD PL STL
	75	3		[illegible]	KEY	CAD PL STL

PARTS LIST

ZONE	ITEM NO	QTY REQ'D	CODE IDENT	PART NO. OR IDENT NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR SPEC
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	72					
	71					
	70	1		M-07[illegible]	MOTOR	HOOD'S
	69	1		[illegible]	CHAIN	BOSTON
	68	2		[illegible]	BEARING	[illegible]
	67	6		[illegible]	BRG.	[illegible]
	66	1		8M 650	POLYFLEX BELT	GATES
	65	2		[illegible]	SPROCKET	NOTE 4
	64	1		[illegible]	MOTOR	GAST
	63	1		[illegible]	POLYFLEX BELT	GATES
	62	1		8M400	POLYFLEX BELT	GATES
	61					
	60	1		[illegible]	WASHER, SPRING	[illegible]
	59	4		[illegible]	BEARING	OILITE
	58	3		[illegible]	COMP SPRING	LEE
	57					
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	55	1		[illegible]	SHEAVE	
	54	3		[illegible]	GASKET, WINDOW	
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	52	1		[illegible]	TUBE, VACUUM	
	51	1		[illegible]	SHEAVE	
	50	3		[illegible]	WINDOW	
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	48	2		[illegible]	BRACKET	
	47	1		[illegible]	BRACKET	
	46	1		[illegible]	SUPPORT	
	45	1		[illegible]	BELT GUIDE	
	44	1		[illegible]	GUIDE	
	43	1		[illegible]	COVER	
	42	1		[illegible]	SHAFT, STARWHEEL	
	41	1		[illegible]	WINDOW	
	40	1		[illegible]	GUIDE	
	39	1		[illegible]	SLIDER PLATE	
	38	1		[illegible]	BELT GUIDE	
	37	1		[illegible]	GUIDE	
	36	1		[illegible]	GUIDE	
	35	1		[illegible]	TOP PLATE	
	34	1		[illegible]	GUIDE - L.H.	
	33	1		[illegible]	GUIDE - R.H.	
	32	1		[illegible]	SLIDER PLATE	
	31	1		[illegible]	COVER	
	30	1		[illegible]	SUPPORT	
	29	1		[illegible]	GASKET	
	28	2		[illegible]	BRACKET	
	27	1		[illegible]	DISC - INSPECTION	
	26	1		[illegible]	SPACER	
	25	1		[illegible]	GASKET, SPACER	
	24	1		[illegible]	HOUSING	
	23	2		[illegible]	SHAFT, IDLER	
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	21	2		[illegible]	SPACER	
	20	2		[illegible]	PIN	
	19	2		[illegible]	SHAFT, IDLER	
	18	2		[illegible]	BRG. HOUSING	
	17	3		[illegible]	MTG. BOARD	
	16	17		[illegible]	SPACER	
	15	2		[illegible]	SHEAVE	
	14	2		[illegible]	SUPPORT	
	13	4		[illegible]	SHEAVE	
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	9	1		[illegible]	SLIP RING	
	8	1		[illegible]	GASKET	
	7	1		[illegible]	SPACER	
	6	1		[illegible]	STARWHEEL	
	5	1		[illegible]	BRG. HOUSING	
	4	1		[illegible]	MTG. BOARD ASS'Y	
	3	1		[illegible]	SUPPORT	
	2	1		[illegible]	BASE	
	1	1		[illegible]	BRACKET	

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Figure 4 PRIMER INSPECTION STATION ASSEMBLY (FMC Drawing 11742091)

D

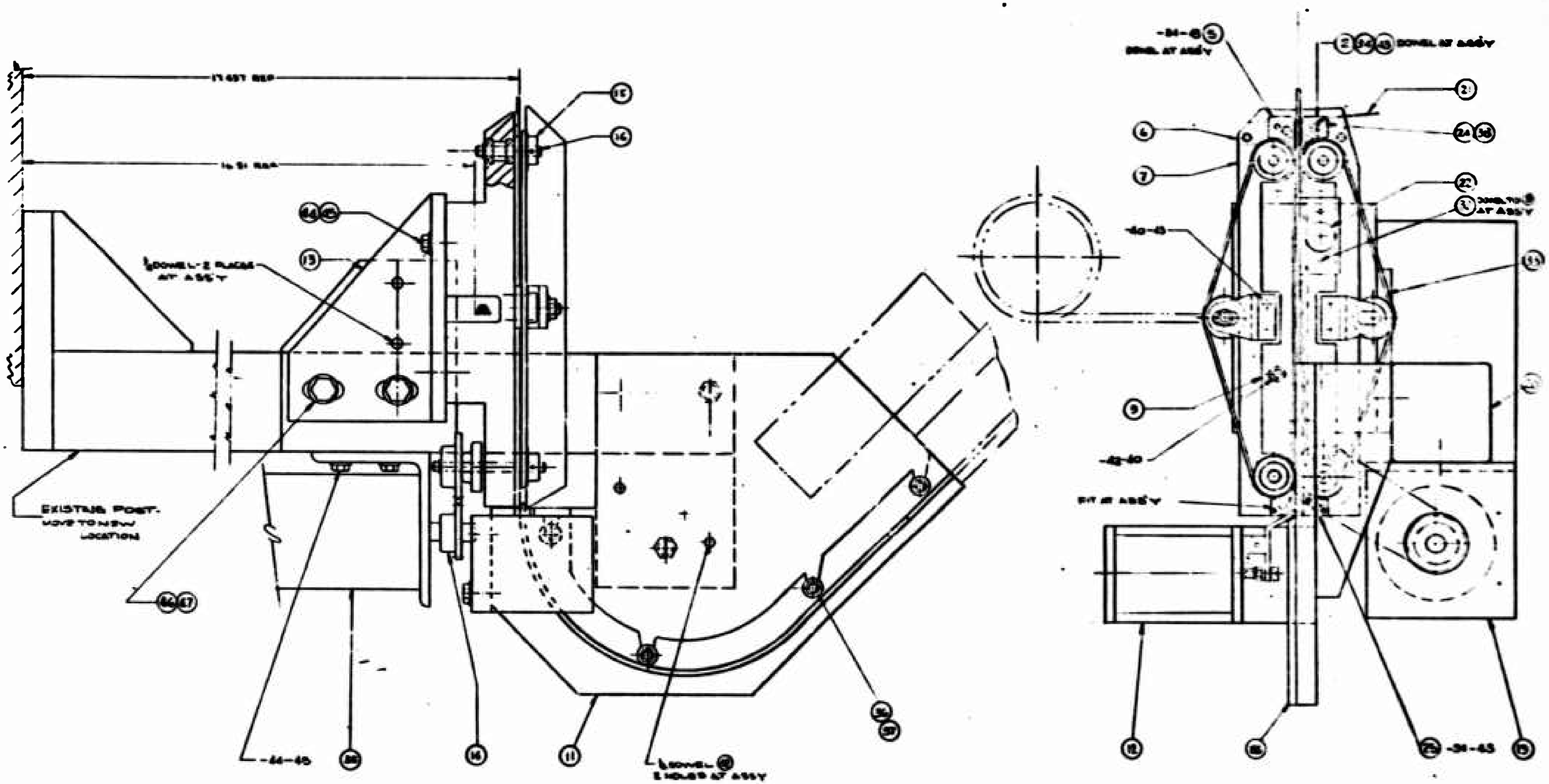

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Figure 5 PRIMER FEED ASSEMBLY — PRIMER INSERT MACHINE (FMC Drawing 11742969)

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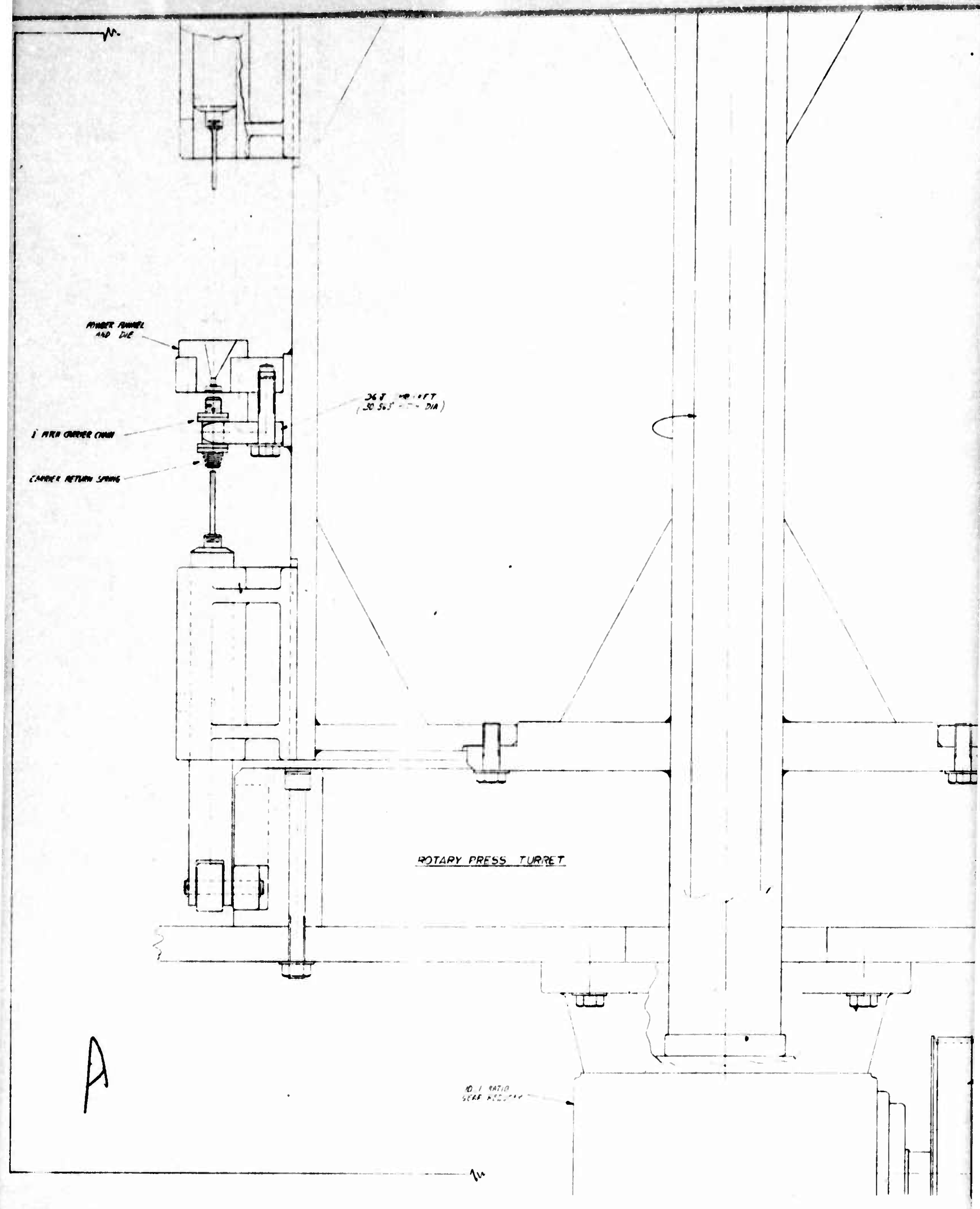
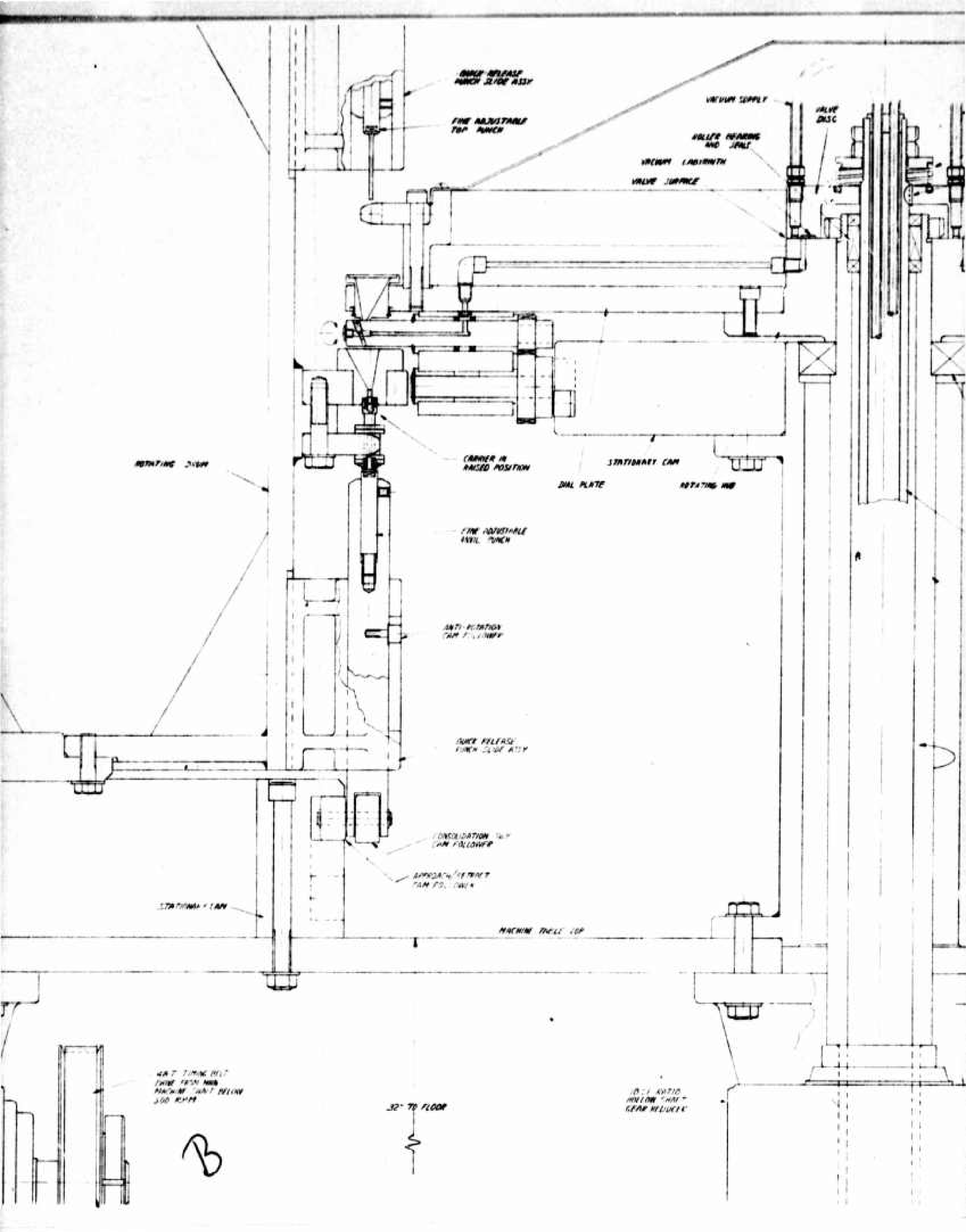

POWDER FUNNEL AND DIE
CARRIER RETURN SPRING
ROTARY PRESS TURRET
10 : 1 RATIO
A



QUICK RELEASE PUNCH SLIDE ASSY
FINE ADJUSTABLE TOP PUNCH
VACUUM SUPPLY
VALVE DISC
ROLLER BEARING AND SEALS
VACUUM LABYRINTH
VALVE SURFACE
ROTATING DRUM
CARRIER IN RAISED POSITION
STATIONARY CAM
DIAL PLATE
ROTATING HUB
FINE ADJUSTABLE ANVIL PUNCH
ANTI-ROTATION CAM FOLLOWER
QUICK RELEASE PUNCH SLIDE ASSY
CONSOLIDATION TOP CAM FOLLOWER
APPROACH/RETRACT CAM FOLLOWER
STATIONARY CAM
MACHINE TABLE TOP
32" TO FLOOR
HOLLOW SHAFT
GEAR REDUCER
B

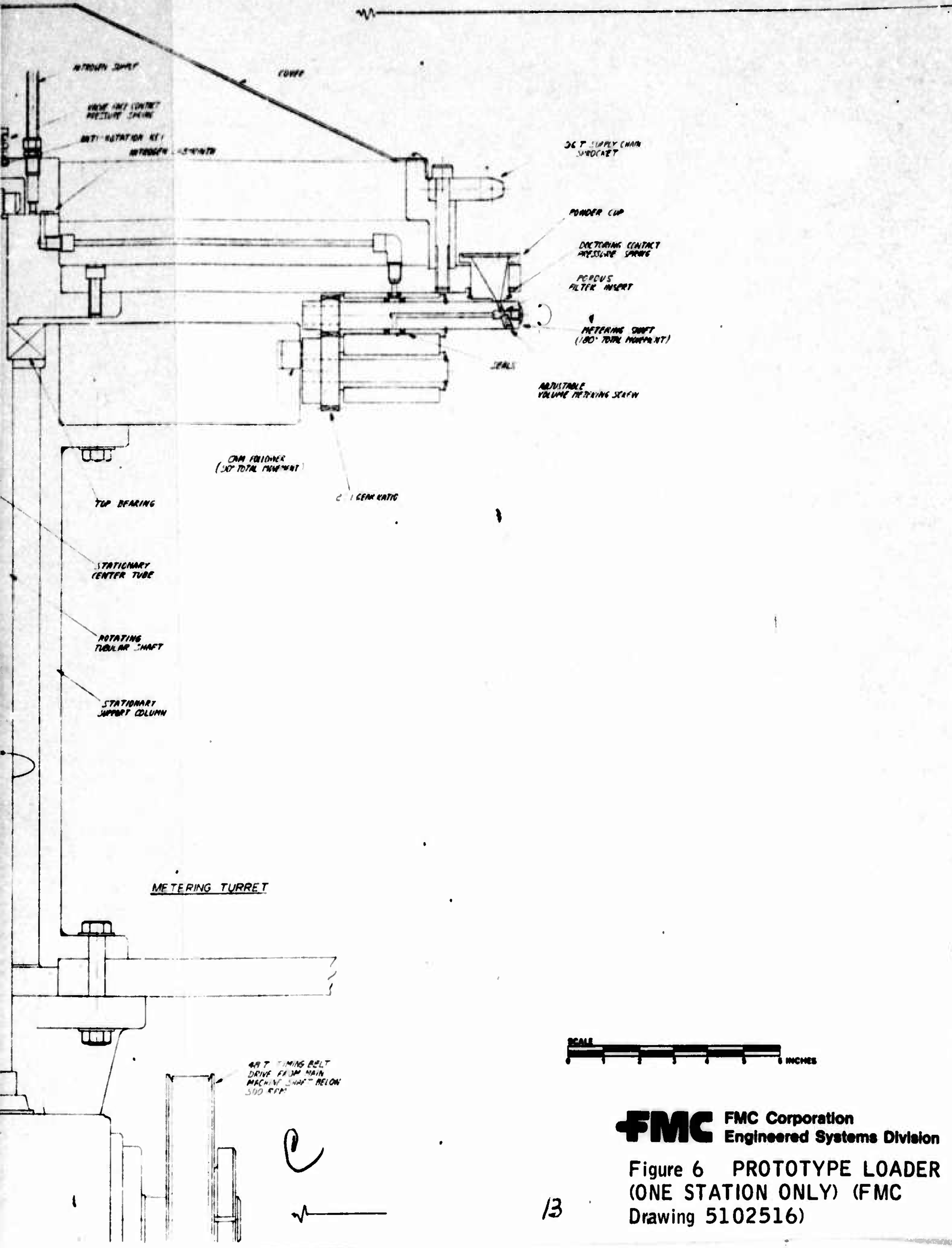


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Figure 6 PROTOTYPE LOADER (ONE STATION ONLY) (FMC Drawing 5102516)

Another cam follower will be mounted on the same centerline of each punch assembly; it will be used solely for providing the axial thrust necessary for the heavy consolidation pressures required. During movement around the turret, the cam follower will enter stationary special cam sections (not shown on Figure 6) also mounted at the top and bottom of the turret. The top cam section will carry the slow and final consolidation slopes and dwell periods required, and the lower section will act as a straight reaction component for the top punch pressure. The stationary top special cam section will be spring mounted to provide a definite consolidation pressure, and provided with an LVDT (Linear Variable Differential Transformer) gage head to monitor movement of the cam section to indicate fill condition. (The signal from this LVDT will be stored for subsequent rejection, if necessary, on the unload turret of the overall assembly system.)

All punches on the rotary press will be capable of fine adjustment and may be easily referenced to the machine table top during setup. Suitably angled powder funnels on the tooling dies will compensate for the centrifugal force on the powder. At the bottom of the funnel, a parallel section, no longer than required for the maximum charge volume of loose powder, will preclude the possibility of an unnecessary compression of air and resulting powder "puff" loss on rapid punch approach, a technique successfully verified on the bench-model tests.

An accurately ground register incorporated on the underside of the tooling die will precisely locate the head diameter of the transport chain carrier. A small recess in this register is designed to accommodate only .030 inch of the detonator cup rim.

2. Metering Turret

This turret comprises a stationary support column, with a cam and a large top bearing mounted on top of the column. A tubular shaft rotates in the bearing; the lower end is borne by the bearings of the gearbox that drives the shaft. A hub at the top of the rotating tubular shaft carries a dial plate on which is mounted a 96-tooth, Number 80 chain sprocket and 24 Delrin powder cups.

The powder cups contain angled funnels, and are spring loaded against a metering shaft beneath each cup to provide positive doctoring. The metering shaft contains a metering cavity angled so that when facing upward, the powder in the funnel may be transferred directly into the cavity. The metering shaft may be rotated 180 degrees by means of a cam follower which moves a 20-tooth gear through 90 degrees. This gear then rotates a 10-tooth gear attached to the metering shaft, allowing the cavity to be rotated 180 degrees. A snug-fitting porous ceramic plug within the cavity of the metering shaft may be moved axially in either direction by means of a screw to vary the cavity volume as required. Only one size metering shaft should, therefore, be required for all three charges on the M55 and other detonators, and adjustment of fill volume may be made manually. On rotation of the metering shaft

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to the downward dump position, the adjusting screw will clear the doctoring area above because of its angled slope. This arrangement also compensates for any adverse centrifugal effect when dumping the powder. Vacuum filling of the cavity and nitrogen pressure dumping directly into the die funnel will be achieved through small-bore pneumatic circuitry to the rotating hub. The top valve face of the hub will contain 24 holes connected to the metering apparatus.

A stationary valve disc mounted immediately above this valve face will be free to move axially on a stationary center tube and prevented from rotating by a key. A labyrinth system of valve ports on the valve disc face will provide vacuum or nitrogen as required for operation of the equipment at the appropriate times. The valve disc, manufactured from Delrin, will be maintained in a sealed contact condition by a wear-compensating adjustable spring mounted above it.

Vacuum and nitrogen stationary inputs will be connected to this valve disc, with the respective tubing led through the bore of the stationary center tube which is anchored on the machine base. Concentric tracking of the valve disc will be maintained by a sealed roller bearing at the top end of the stationary center tube. The vacuum line will pass to an aspirator bottle containing kill solution, then to the vacuum pump. Nitrogen pressure and vacuum level will be constantly monitored. The machine will be automatically shut off whenever pressure and vacuum readings are beyond preset limits.

3. Operational Description (Figures 2, 3, 6, 7, and 8)

The transport chain (Figures 2 and 8) will enter the rotary press turret (Figure 7) with empty detonator cups loosely resting in the carriers. The cups will be prevented from falling through the carrier bore by the D-shaped spring (Figure 3) which protrudes a few thousandths of an inch into the bore. The amount of protrusion will be insufficient to interfere with the upward travel of the anvil punch which will move the spring aside. Continuing its movement around the press turret, the lower anvil punch will rise and enter the bottom of the carrier above it, which has limited freedom to float in the hollow pin of the chain; this action will center the carrier. The possibility of compressed-air disturbance of the detonator cup by the rapid rise of the close-fitting punch in the bore of the carrier will be eliminated by the air-escape holes in the carrier head, as successfully demonstrated in the bench-model tests. The final movement of the anvil punch will accurately locate the head of the carrier in the register of the tooling die above. The carrier head will be moved upward by the anvil punch shoulder and compress the carrier spring.

Simultaneously, the tip of the anvil punch will raise the detonator cup out of the carrier by 0.030 inch, effectively sealing the detonator cup rim to the 0.030-inch recess in the tooling die register to prevent powder loss during transfer from the funnel. This anvil punch action will be completed just prior to convergence of the tangent points of the rotating press turret and the metering turret (Figure 7).

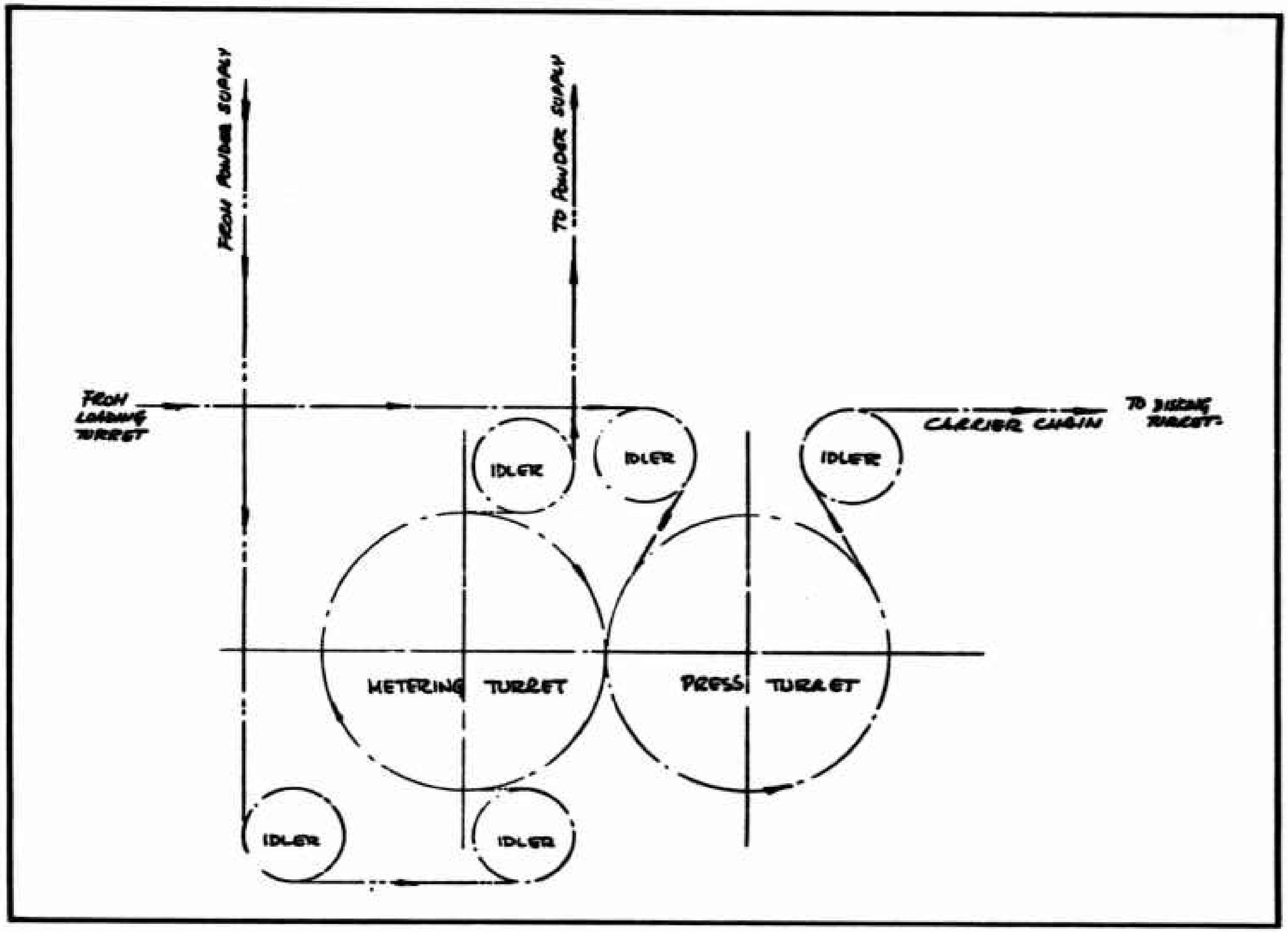


Figure 7 METERING AND PRESS TURRETS SCHEMATIC (FMC Drawing 5102522)

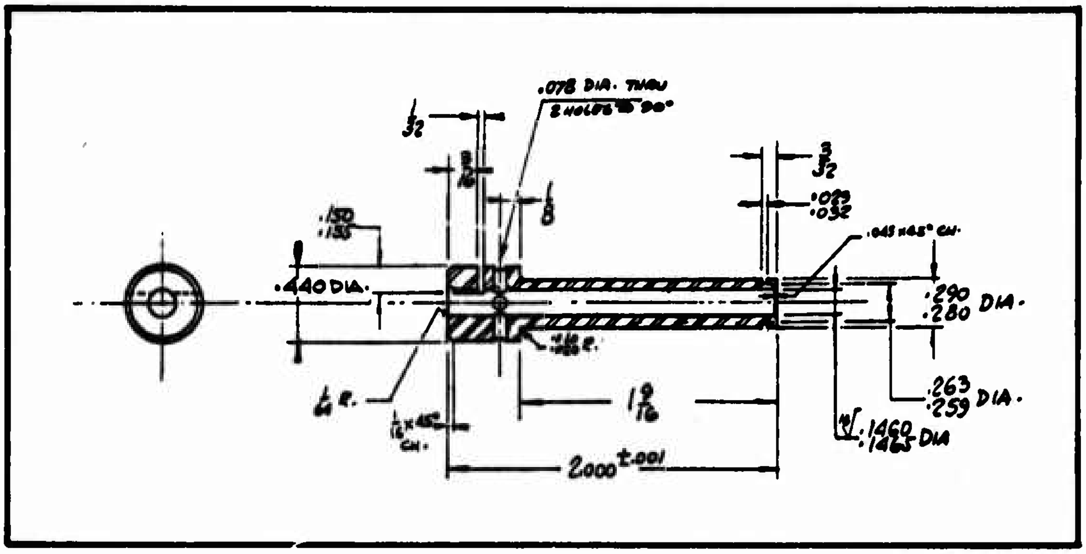
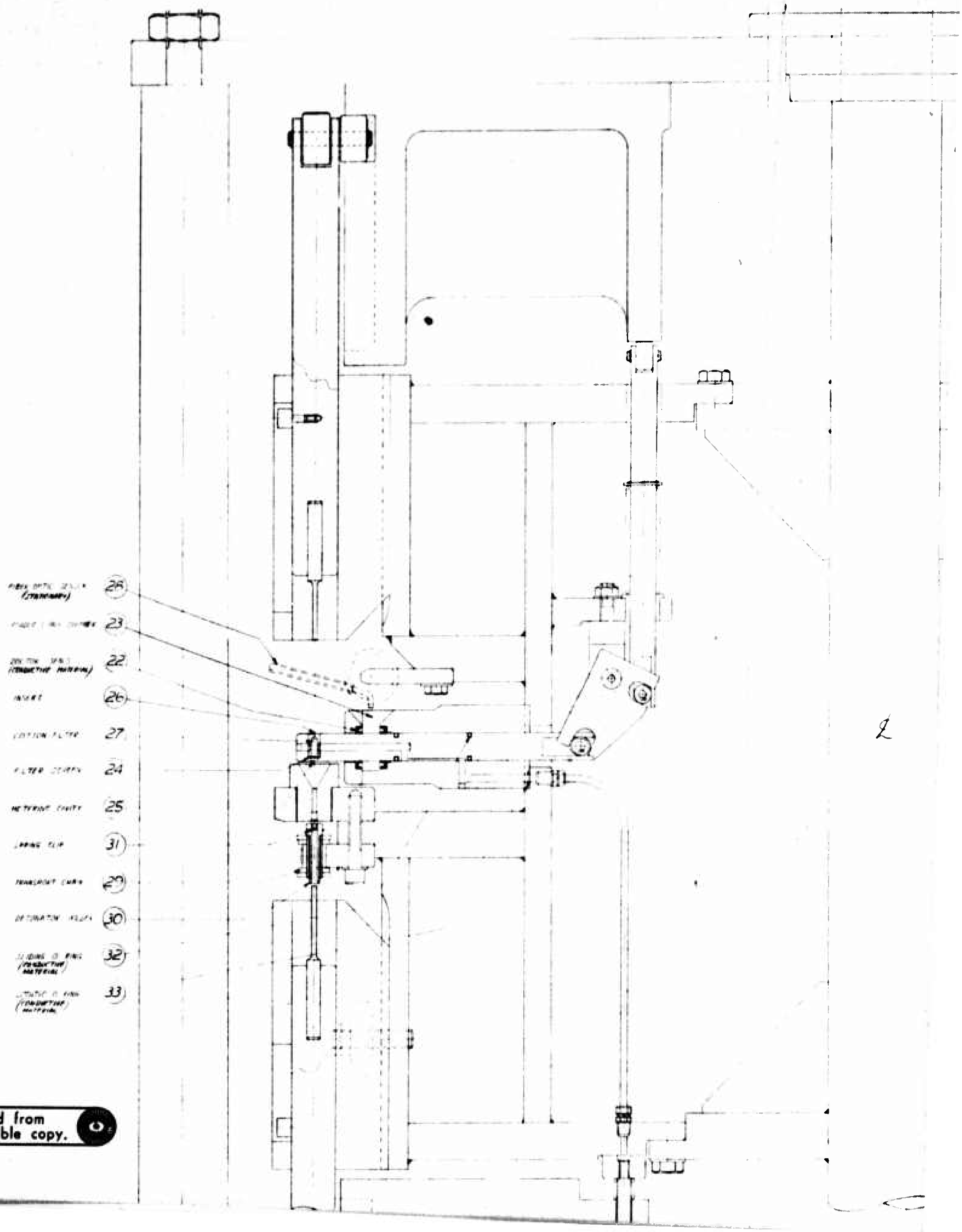


Figure 8 CUP CARRIER (FMC Drawing 5100587)

At this point (shown as "carrier in raised position" on Figure 6), the doctored and metered powder charge held by vacuum in the metering shaft of the metering turret will be transferred to the press turret. The transfer will be accomplished by the automatic valving system turning off the vacuum and applying a short sharp pulse of compressed nitrogen to the metering cavity. ESD has determined, through bench-model tests, that a pulse of approximately 50 milliseconds duration at 15-pounds-per-square-inch pressure will result in clean removal of the entire cavity powder content with no "dusting" normally associated with a flow of air or gas. Continued rotation of both turrets will then permit the transfer points to diverge and the turrets to function independently for the remainder of the revolution. The functions of the turrets are described in the following paragraphs.

a. Rotary Press Turret

With the powder cup and metering shaft of the metering turret free of interference, the top punch will rapidly descend, compressing the charge in the cup within approximately 0.090 inch of final consolidation. At this point the consolidation cam followers will enter the special cam sections which allow a powerful but gentle application of thrust necessary to finally consolidate the charge to 70,000 pounds per square inch, the maximum required consolidation pressure. The upper cam section (not shown on Figure 6) will be adjustable spring loaded to provide the necessary pre-load thrust as previously mentioned, and will be equipped with fill height measuring capability through an LVDT gage head. A short dwell period will follow consolidation, then the consolidation cam followers will leave the special cam sections and both top and bottom punches will be rapidly withdrawn. (The arrangement of the special cam section and LVDT are similar to that shown on Figure 9, Items 2, 3, and 4.)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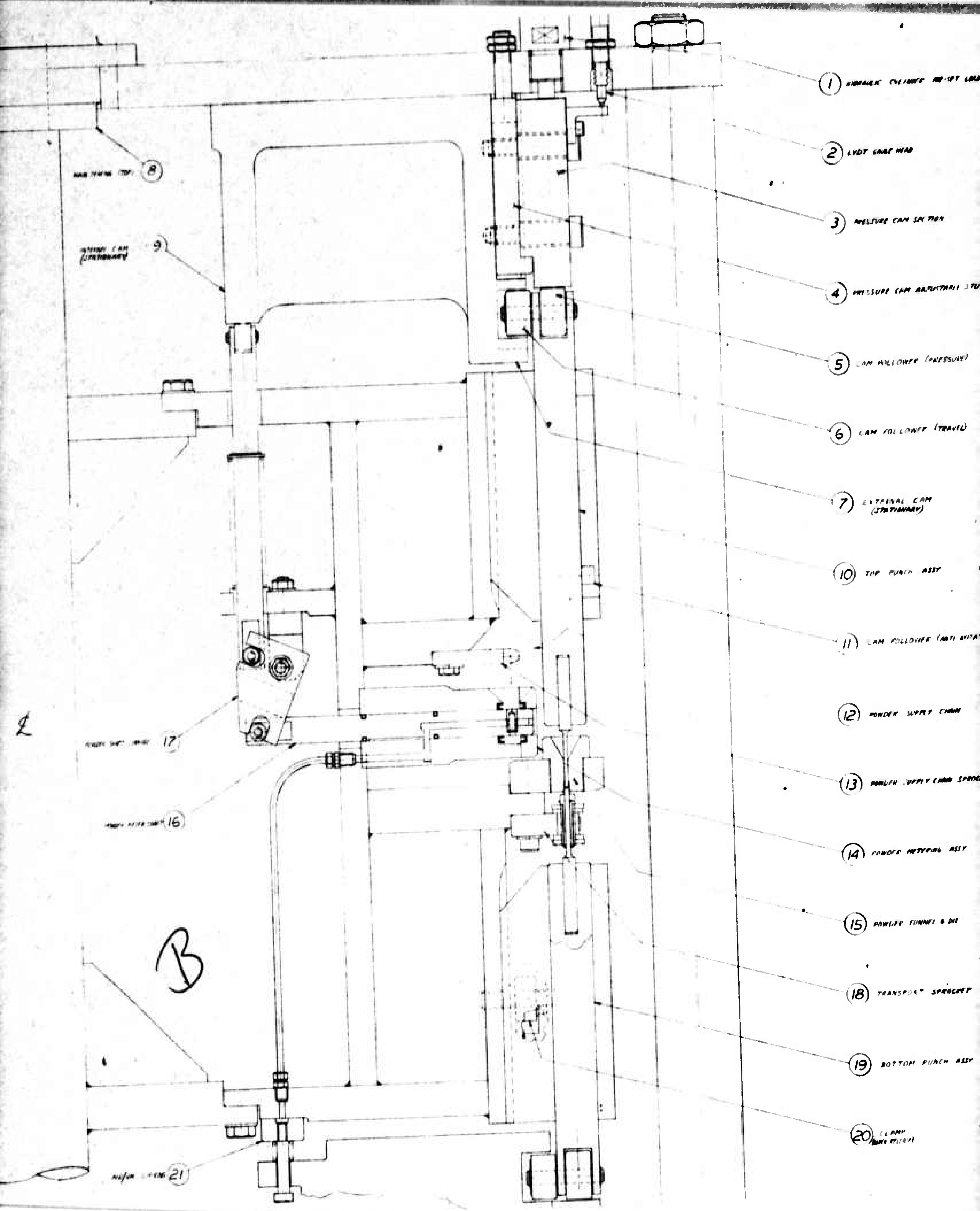
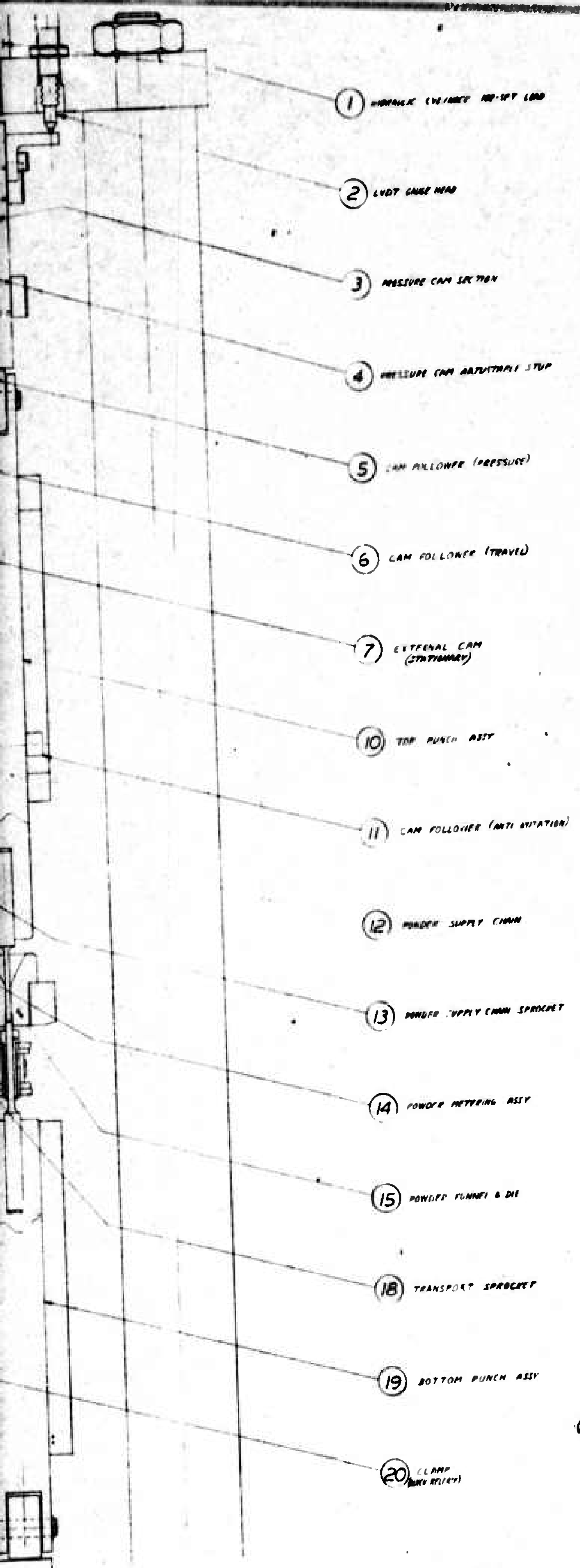


1
2 LVDT GAGE HEAD
3 PRESSURE CAM SECTION
4
5 CAM FOLLOWER (PRESSURE)
6 CAM FOLLOWER (TRAVEL)
7 EXTERNAL CAM (STATIONARY)
8
9
10 TOP PUNCH ASSY
11 CAM FOLLOWER
12 POWDER SUPPLY CHAIN
13 POWDER SUPPLY CHAIN
14 POWDER METERING ASSY
15 POWDER FUNNEL & DIE
16
17
18 TRANSPORT SPROCKET
19 BOTTOM PUNCH ASSY
20 CLAMP
21
B



SCALE 0 1 2 3 4 5 6 INCHES

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Figure 9 LAYOUT — POWDER FILL TURRET (FMC Drawing 4793170)

The spring of the carrier will allow the locating head to withdraw from the tooling die, and the carrier will return to the normal floating position in the hollow pin of the chain. The detonator cup will remain in the consolidated position in the carrier, with the rim protruding 0.030 inch. This position will be maintained for all subsequent operations in the entire detonator assembly system, including crimping, and will minimize the possibility of surface scratches on the outside diameter of the cup through linear movement in the carrier. The cup will be held in this position in the carrier by the radial compressive force from the first charge consolidation. With both punches retracted, and the carrier out of the tooling die, the carrier chain will leave the rotary press turret for the next operation.

b. Metering Turret

As the metering shaft and powder cup move away from the rotary press after transferring the charge, the metering shaft will rotate through 180 degrees so that the cavity is immediately beneath the bottom opening of the powder cup.

At this time the valving system will cause a short period of alternate vacuum/nitrogen pulses which will fluidize the powder in the cup, breaking up any bridging which may have occurred. Bench-model tests proved that this procedure is essential for consistently accurate charge weight, especially with NOL 130. Also, the nitrogen pressure, used frequently and passed through the porous filter in a reverse direction to the vacuum on every turret revolution, will serve to purge the filter free of any clogging of porous surfaces.

Continued rotation of the turret will cause the valving system to turn on the vacuum continuously, drawing the powder into the metering cavity. With the vacuum still on, the metering shaft will start to rotate through 180 degrees, doctoring the powder in the cavity, and position the cavity facing downward, ready to dump, with the vacuum still securely retaining the powder. The metering turret and the pressing turret, rotation synchronized, will converge on the appropriate metering shaft and tooling die, ready to repeat the operation.

4. Powder Supply Conveyor

The metering turrets of the three fill stations are to be regularly supplied with powder on an 11-increments-at-a-time basis. At 11-revolution intervals each of the 24 cups of the turret will receive a metered amount of powder consisting of slightly more than 11 increments.

The amount of powder in each cup will be constantly monitored and when a preset level is exceeded, the supply to the particular cup will be inhibited. The supply conveyor will extend from the metering turret to a rotary powder-dispensing and doctoring device isolated from the machine by a barricade. The basic component of the conveyor is the same 1-inch-pitch, hollow-pin standard roller chain used for the main carrier. The filling sequence will be determined by the spacing of the powder containers at 11-turret-pitch intervals (44 chain pitches). The containers are cam-actuated, hinged scoops; the entire assembly will be mounted on a single link, using both hollow pins as guides for vertical motion (Figure 10).

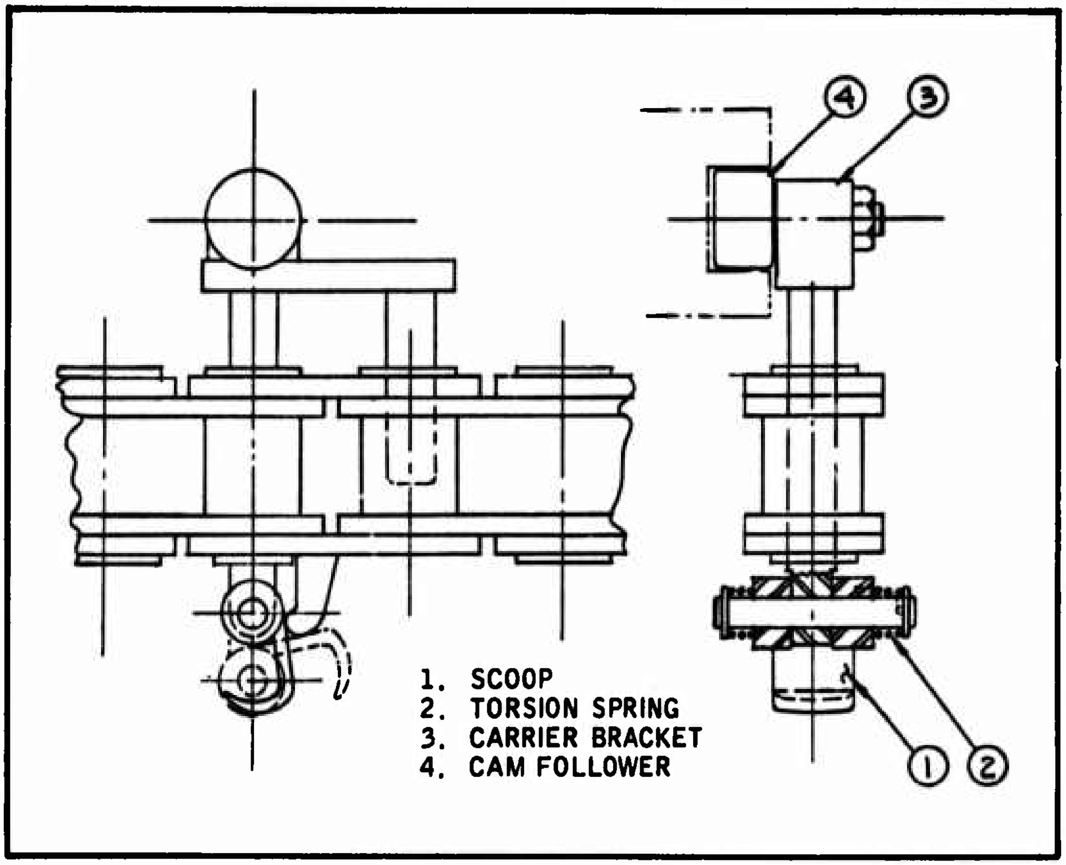


Figure 10 POWDER DISPENSER (FMC Drawing 5102641)

As the conveyor chain enters the metering turret, the scoop-actuating rod wil be cammed down; the scoop will rotate 90 degrees to a vertical position and empty into the funnel-shaped powder cup beneath it. During this dumping phase, vibration will be induced into the scoop through the cam track.

Behind the barricade, powder will be dispensed from a rotary trough, with the scooping motion described above somewhat reversed. Stationary plows in the pickup station of the trough will stir and mix the powder and maintain a powder level slightly higher than in the remainder of the trough.

Rotating doctor blades will move radially outward to remove any excess powder in the scoops. When refilling is to be inhibited because of too high a level in a cup on the metering turret, the scoop-lowering mechanism will be actuated and the powder will be dumped back into the doctoring area.

5. Inspection

Satisfying the scope of work requires inspection after each fill and consolidation; three inspection turrets could be included to perform this task. Each would consist of 24 lower anvils to raise the detonator and carrier to a reference level, where a top set of 24 LVDT gage heads would descend to measure the consolidation height. An unsatisfactory signal from any of the LVDTs, sent to a central memory system, would cause rejection of the defective component at the unload turret. A considerable cost saving is possible, however, if the three inspection turrets are eliminated and the one stationary LVDT gage head on each consolidation turret is utilized to perform the fill-height inspection. The details of this process are included in the filling station equipment description. FMC ESD strongly recommends adoption of this simple method, which could also be incorporated on the final crimping turret to monitor final assembled height of the detonators.

F. BRUSHING AND ASPIRATING TURRET

Following the principle of simplicity, FMC ESD proposes separate turrets to brush and aspirate the cups and chain after each consolidation, rather than incorporation of a system of brushes operated by linkage and added to each consolidating turret station.

The turret will consist of a lower section carrying 24 anvil punch stations, operated by a stationary cam. A 96-tooth sprocket above will carry the transport chain with the cups in the carriers. On the same centerline as and immediately above the carriers, a set of 24 small annular brushes will rotate on a small vertical shaft. A gear wheel on the top of each shaft will mesh with a large stationary gear wheel at the top of the turret. The rotation of the turret around the stationary gear will produce a speed of 1,280 rpm for each brush shaft.

Aspiration will be provided by small tubes inside and around each brush, connected to the aspiration vacuum. All such shrouds will be continuously open to the atmosphere, even at stations not in operation, and a slip ring-type coupling from the stationary vacuum to the rotating turret will be necessary. As an alternate method, aspiration could be provided by a stationary nozzle very close to the brush tip. The nozzle would be only as long as the section of the turret where brushing takes place, so the vacuum connection would be considerably simplified. Preliminary aspirating will be performed on the press turret to prevent any buildup of powder on the chain.

G. DISC BLANKING AND INSERTING STATION

1. Alternate Equipment Concept

The proposed closing disc blanking and placing equipment (Figure 11) comprises a 24-work-station rotary turret equipped with a stationary (aluminum) foil tapefeed system. The tape-feed system will be positioned in a plane tangential to the pitch circle of the rotating work stations.

The tape-feed system will advance the tape at a speed equal to that of the rotary turret, for the short time during which the disc is blanked, and allow short-duration travel of the tape at a slower speed while the next disc-blanking punch approaches.

2. Reels and Capstans

The new foil tape will be unwound from the reel by the payout capstan, at a rate equal to the takeup speed. To achieve minimum tape consumption, the tape will be advanced only 3/8 inch between blanking operations. The chain carrying the loaded cups will travel in a rotary path during the blanking operations, resulting in a differential between the velocity of the work stations and the velocity of the tangentially moving tape.

The takeup capstan and rotary turret will be driven at the same speed; therefore, the capstan radius must be approximately 1/10 the turret radius to produce tape advance not exceeding 3/8 inch. This size appears reasonable, and the takeup capstan drive can be directly coupled to the rotary turret drive to assure a constant proportion between average tape speed and turret speed.

This motion is comparable to that of the film in some high-speed movie cameras that is brought to a complete stop 500 times per second or 30,000 times per minute. We will require the same result at a much slower rate, i.e., 1,200 per minute.

The mechanism for accomplishing this motion is described in the Rotary Table and Punch Assemblies discussion. The takeup reel drive will be driven at a speed higher than that of the takeup capstan and will be equipped with a slipclutch to accommodate the takeup speed change resulting from coil radius growth as the scrap foil tape is wound on the reel much like a movie projector takeup reel. In an ideal situation the two capstans (takeup and payout) would consistently advance an equal length of tape; therefore, the length of tape between the two capstans would remain constant. However, the two capstans will not operate equally, and control of one of the capstans will be necessary to avoid excessive tension buildup or slack buildup of the tape. The slack-loop control will perform this function.

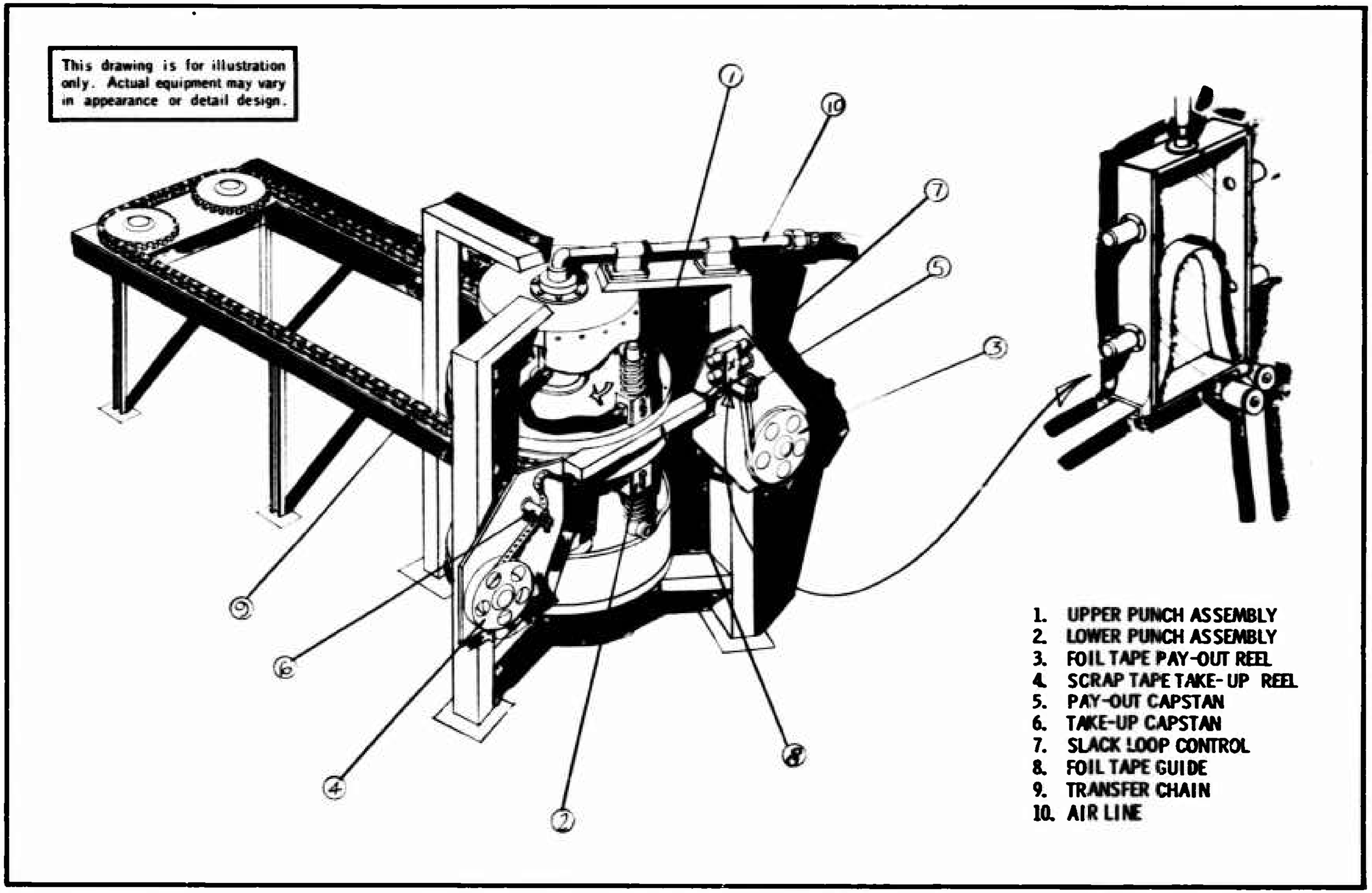


Figure 11 EXPERIMENTAL MODEL CLOSING DISC BLANKING AND PLACING TURRET
(FMC Drawing 5102126)

3. Slack Loop Control

To prevent tearing of the foil tape during the short-duration speedups (when the tape speed matches the speed of the blanking punch), a slack loop will be maintained in the tape on the payout side as in movie projectors. The length of the slack loop will be reduced when the tape speed exceeds the payout capstan feed rate and will be enlarged when the tape speed is less than the payout capstan feed rate. The tape speed will differ from the payout capstan speed each time a blanking punch operation is performed, or in the event the takeup capstan feed rate changes.

The change of the slack-loop length will be continuously monitored by the tape slack-control unit. When the loop length reaches a maximum or minimum limit, the payout capstan drive will be decelerated or accelerated accordingly. The tape slack-control unit will monitor the loop length through the use of two photoelectric cells in the plane of the loop. Interruption of the light beams of both photocells will indicate a loop length exceeding the maximum limit, and both light beams unobstructed will indicate a loop length less than the minimum limit.

The signals from the slack-control unit will initiate action to correct the slack loop length. Through a phaser gearbox driven by a stepping motor, the payout capstan will be advanced or retarded as necessary to bring the loop length within the allowable limits. FMC ESD has successfully utilized an identical slack-control device in an automatic winder for 8-channel tape decks (Figure 12).

Figure 12 SLACK-CONTROL DEVICE FOR WINDING TAPE DECKS

4. Rotary Table and Punch Assemblies

The proposed rotary-turret work station will consist of a die and an upper and lower punch assembly straddling a rotary table. The functions of these elements are as follows:

- The rotary table will register the carriers holding the detonator cups in line with the upper punch assembly to allow blanking and placement of the closing disc in a direct straight line. (This operation will require two separate punch strokes, as explained later.) The rotary table will be equipped with blanking die inserts. Proper registration of the detonator carrier sleeves with the die inserts will be maintained through a 96-tooth, 1-inch-pitch roller chain sprocket. The transfer chain with the carrier sleeves on 4-inch centers will wrap around the sprocket for a minimum arc of 180 degrees; therefore, the pitch circle diameter of the rotary table will be identical with that of the 96-tooth sprocket.

  The action of the upper and lower punch assemblies along the 180-degree active arc of the rotary turret is shown schematically in Figure 13.

- The upper punch clamping sleeve will be faced with polyurethane that will momentarily clamp the foil tape to the rotary table and bring the tape to the same speed as that of the table just preceding the blanking action of the descending inner punch. This feature will assure that the tape is moving at the same velocity as the rotary table when the upper punch shears out the closing disc.

  Immediately after the closing disc is severed from the tape, the punch will retract with the tip rising above the top surface of the foil tape, and the clamping sleeve will release the tape, allowing continued rotary motion of the punch without tearing the tape. To reduce acceleration forces developed within the tape during the clamping operation and to assure tape synchronization with the punch velocity, a cam roller will be placed at a point in the outfeed path of the tape from the turret. The tape will pass over the cam which will make one revolution per station, or 1,200 revolutions per minute. The cam will develop a sinusoidal tape-acceleration curve, minimizing tape stresses during the acceleration portion of the cycle. This action will assist the polyurethane clamping ring to maintain a tape velocity equal to the tangential velocity of the punch.

  After the turret has rotated sufficiently to permit the ascending blanking punch to clear the tangentially running foil tape, the punch will again descend. The closing disc will be pushed farther down into the detonator cup being held in the carrier in the chain. Several methods for mechanically stripping the disc from the punch may be employed. The usual commercial practice, providing the punch with a spring-loaded plunger that pushes the blanked disc off the end of the punch is considered inadvisable with the thin aluminum. The same general principle could be employed, but with the tip of the plunger normally spring loaded upward within the punch so that it is flush with the end of the punch. The stroke of the plunger would be very short, about 0.015 inch, and take place at the end of the stroke of the punch, just prior to or at the beginning of return movement. The plunger would be rod operated through the punch ram, the rod protruding from the top of the ram. On rotation of the turret, the top of the plunger rod would engage a stationary cam follower which would momentarily impart the necessary 0.015-inch stroke to the plunger, stripping the disc from the punch. The same action might be achieved by the mass inertia of the plunger movement against a very light return spring due to the rapid deceleration of the punch when reaching the end of the stroke. A subsequent turret will crimp the cup over the seal disc.

5. Concept Design Considerations

The proposed concept for blanking and placing closing discs in a continuous operation is based on proven movie-camera applications. The relatively slow-moving foil tape can be quickly accelerated to match the speed of the fast-moving blanking punch and die, and the blanking punch operation can be completed within a short time; the velocity vectors of the foil tape and the blanking tools are practically equal.

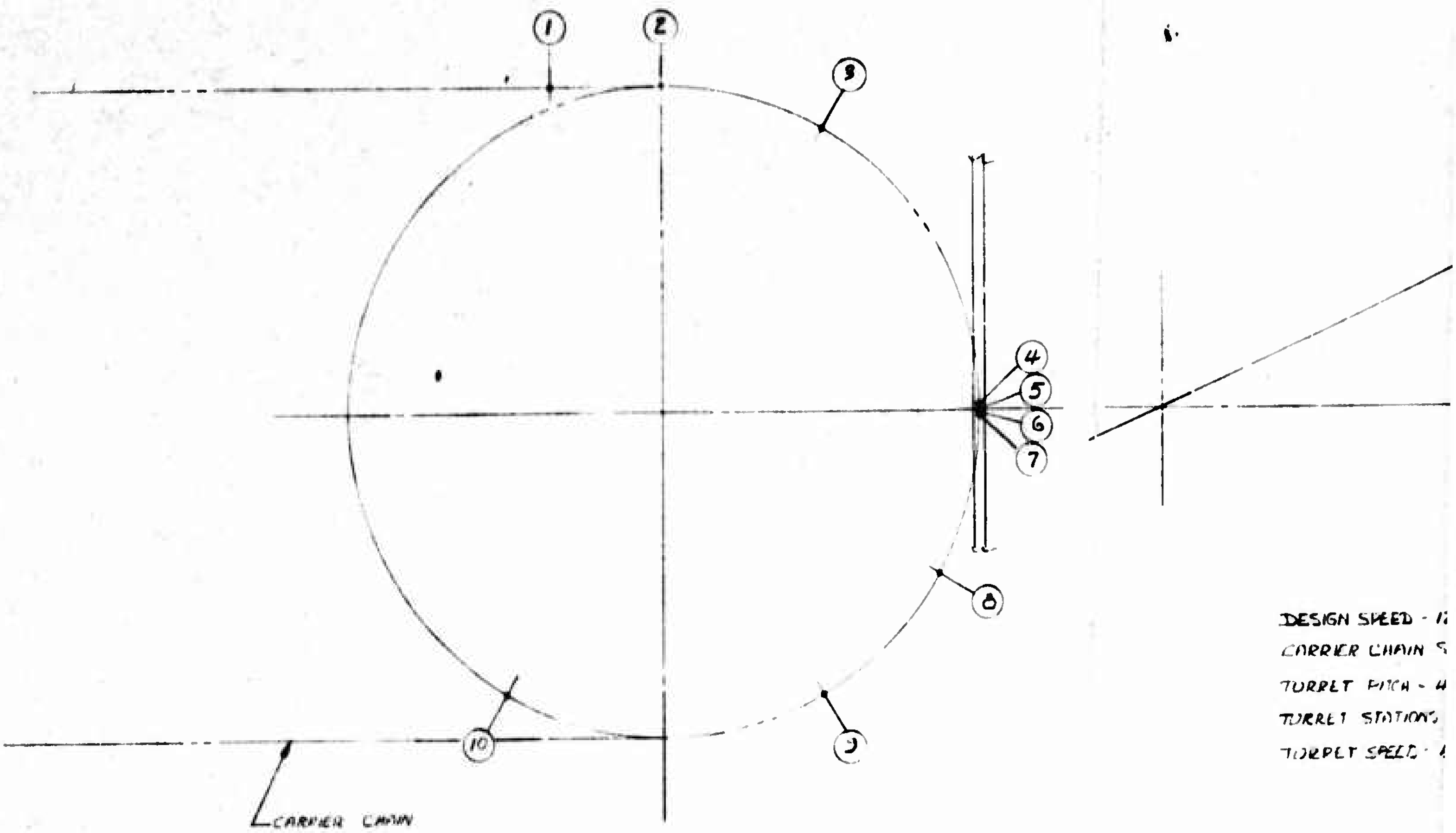
The proposed concept utilizes only one foil tape reel to supply the material for the closing disc blanking operation.

If, because of reel size limitations, the supply reels must be changed during operation, a commercially available automatic splicer can be incorporated in the design to automatically attach the new tape to the end of the exhausted tape reel, without stopping the system.

H. CRIMPING TURRETS

Crimping of the detonator cup requires two distinct operations, a 45-degree precrimp followed by a final flattening crimp. Both operations may be performed on one turret as described in detail in the Phase I report; however, FMC ESD recommends that two turrets be used to perform these functions, enabling a simple turret design for both, employing construction components similar to those used in other turrets. Utilization of an LVDT gage head and special cam section similar to those used in the consolidation turrets will permit monitoring of an accurate final crimp height. This system would be readily adaptable to a simple turret design.

A fixed aspirating station, as specified in the scope of work mandatory requirements, may be positioned between the two crimping turrets to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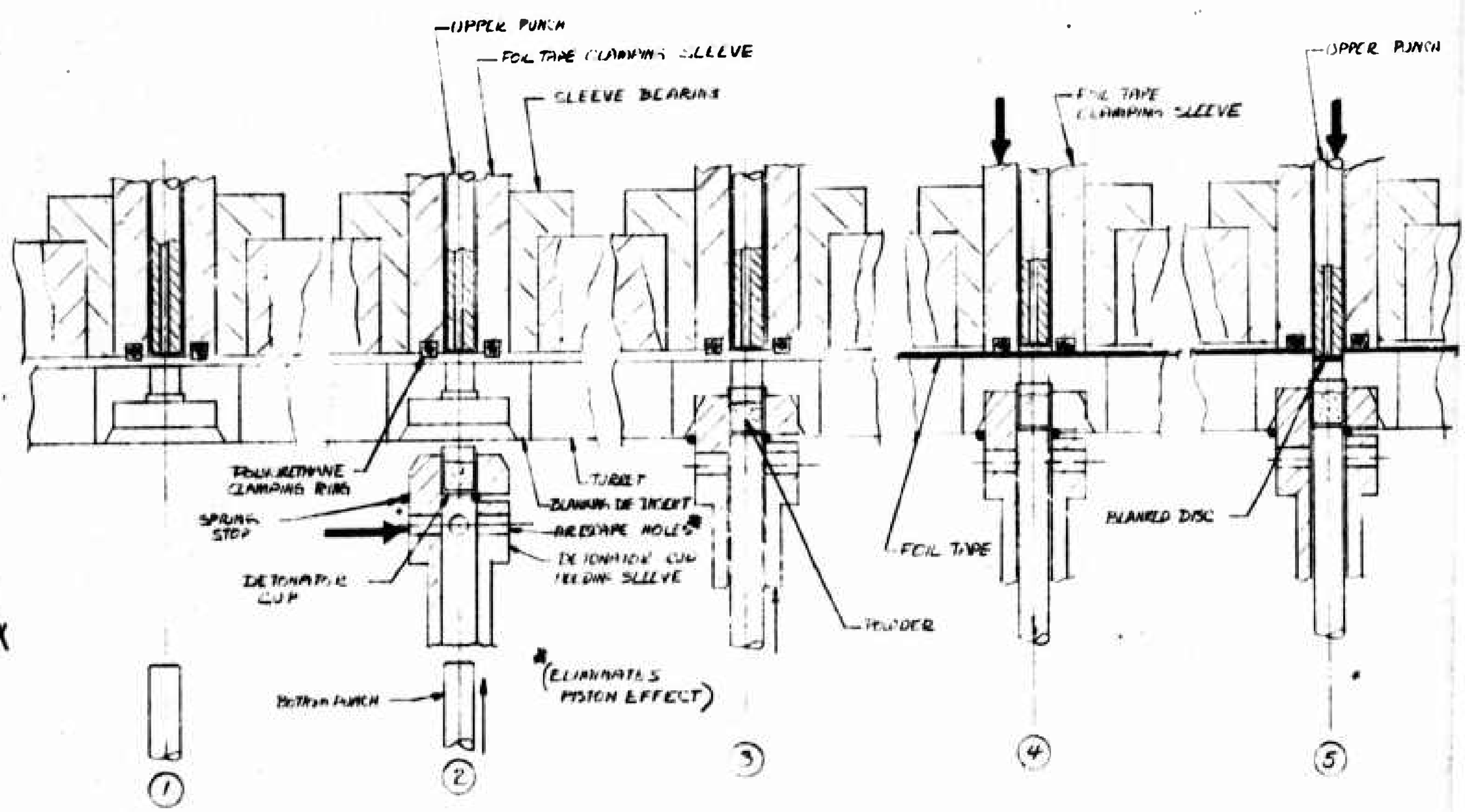
TURRET STATIONS
TURRET SPEED -


UPPER PUNCH
FOIL TAPE CLAMPING SLEEVE
SLEEVE BEARING
FOIL TAPE CLAMPING SLEEVE
UPPER PUNCH
POLYURETHANE CLAMPING RING
TURRET
BLANKING DIE INSERT
AIR ESCAPE HOLES*
SPRING STOP
DETONATOR CUP FEEDING SLEEVE
DETONATOR CUP
POWDER
FOIL TAPE
BLANKED DISC
BOTTOM PUNCH
*(ELIMINATES PISTON EFFECT)
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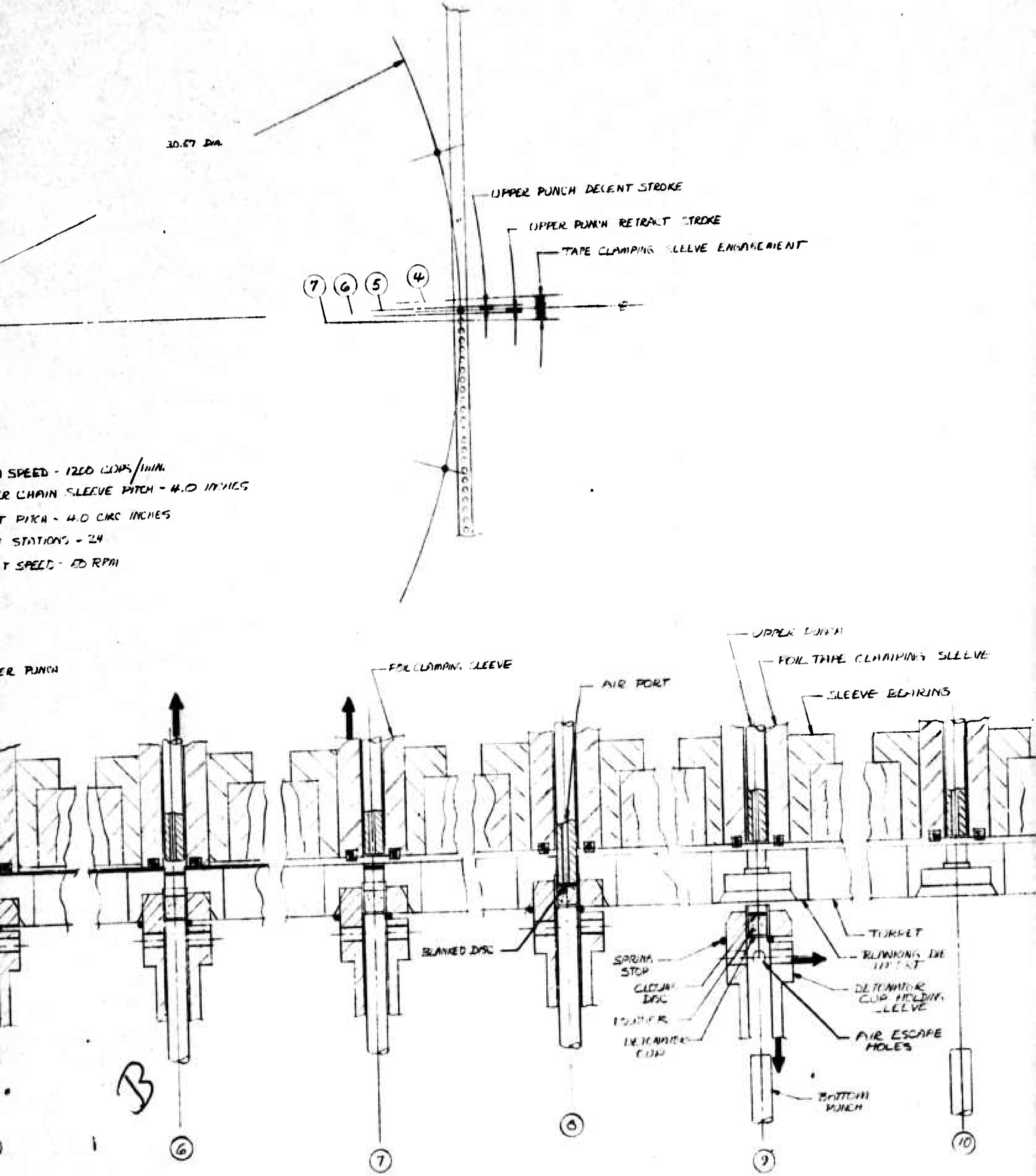
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UPPER PUNCH RETRACT STROKE
TAPE CLAMPING SLEEVE ENGAGEMENT
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SPEED - 1200 CUPS/MIN.
ER CHAIN SLEEVE PITCH - 4.0 INCHES
T PITCH - 4.0 CIRC INCHES
STATIONS - 24
T SPEED - RPM
ER PUNCH
FOIL CLAMPING SLEEVE
AIR PORT
UPPER PUNCH
FOIL TAPE CLAMPING SLEEVE
SLEEVE BEARING
BLANKED DISC
SPRING STOP
CLOSURE DISC
POWDER
DETONATOR CUP
TURRET
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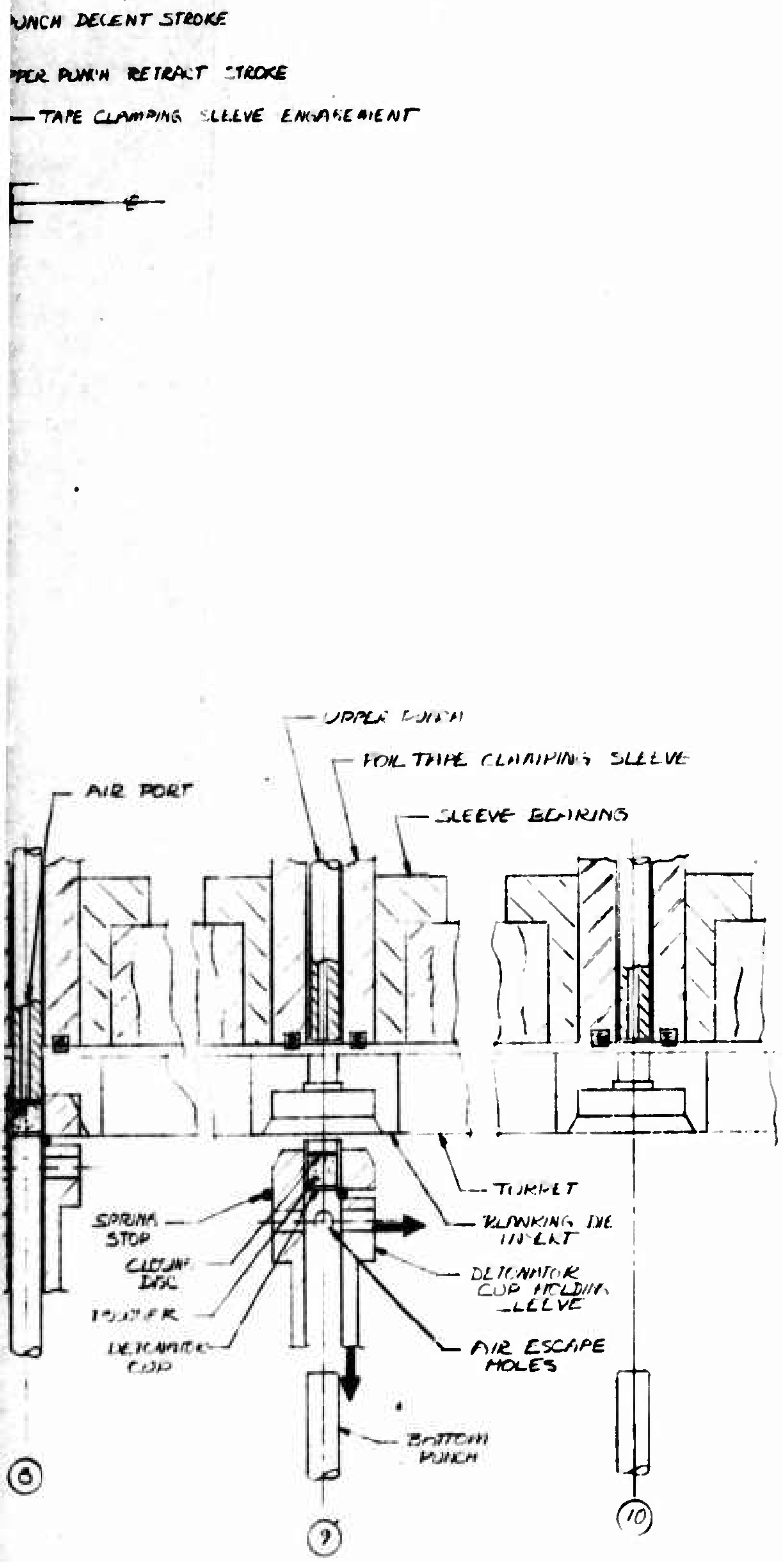

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Figure 13 EXPERIMENTAL MODEL CLOSING DISC BLANKING AND PLACING TURRET (FMC Drawing 5102187) remove any loose powder created from the 45-degree crimping operation as the crimped cups in the chain pass nearby. A possible alternative would be to provide the 45-degree crimp punches with hollow stems with a side port. On rotation of the turret, the port would pass close to a fixed aspirating head, transferring the vacuum directly to the crimp before the top punch rises.

I. SEALANT-APPLICATION TURRET

The sealant-application turret (Figure 14) consists of basic elements similar to those of other turrets, i.e., sprocket and upper and lower punches.

The lower punch will locate, raise, and support the work part for application of sealant. The upper punch will be equipped with a special polypropylene dabbing tip and a lacquer container. Container and tip will form a sealed unit; therefore, lacquer cannot dry out and will not clog. The tip, commercially available, is designed to meter the same amount of liquid each time the plunger is depressed, independently of pressure and time. The lacquer container is sufficiently large to accommodate a 1-day supply of sealant.

This concept is similar to a machine developed, built, and now operating satisfactorily at Frankford Arsenal for the sealing of primers with lacquer at a rate of 1,200 per minute.

An inspection is necessary to detect the presence of the sealing disc and of sealant. Both inspections may be made by stationary optical scanning means, the latter reacting to sealant color. Turrets for these inspections are not considered necessary.

Essentially, each inspection station will consist of a light beam directed at an angle onto the top surface of the finished detonator. A disc in the detonator will reflect the beam into an optical receiver.

The signal to start scanning for the reflected beam will be derived from the leading edge of the chain carrier, which is always the same distance from the cup. Thus, at a given chain speed, the time at which the scan should take place is easily established, so that the scan occurs when the detonator cup should reflect the beam if the disc is present.

Inspection for the presence of sealant application is accomplished in a similar manner, except that the optical system is sensitive to color. The reflected color of the sealant, or absence of reflected color, at the appropriate time of scan would result in acceptance or rejection as required at the unload/reject station.

J. UNLOADING TURRET

In this final turret of the machine, the finished detonators will be transferred into special carriers for packaging, and parts found unacceptable

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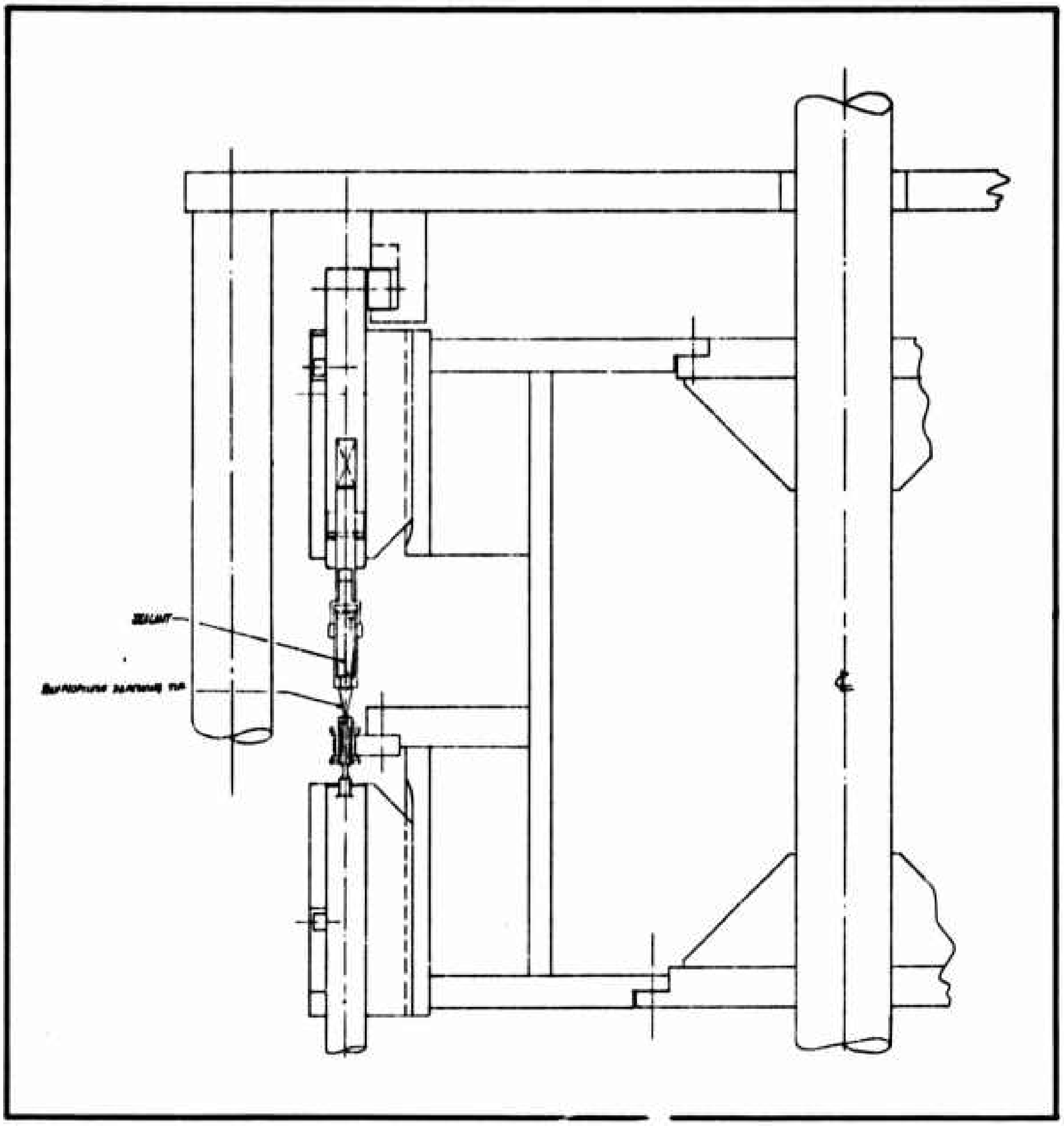
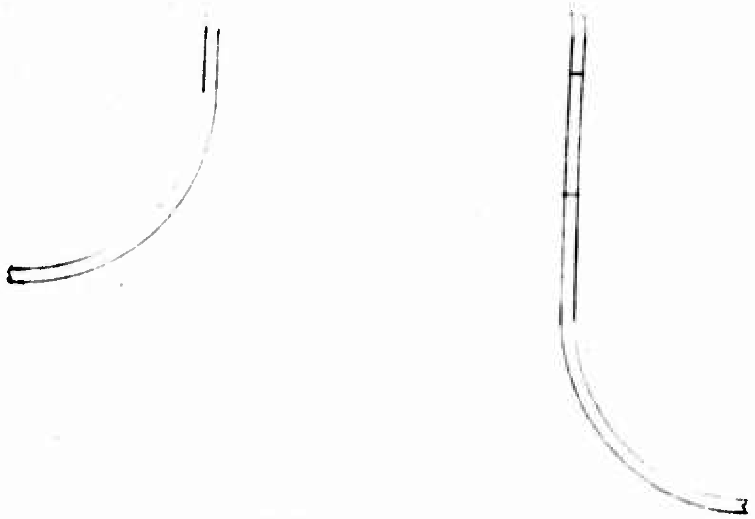


Figure 14 SEALANT-APPLICATION TURRET (FMC Drawing 5100213)

at any inspection station upstream will be ejected (Figure 15). The carrier rings (Figure 16) are flat collars in which the detonators will fit snugly because of the tight hole-diameter tolerance and be held firmly due to the springiness inherent in the split-ring configuration of the holders.

A starwheel, directly above the chain sprocket of the turret, is equipped with pitch diameter and nest centerlines which match those of the main



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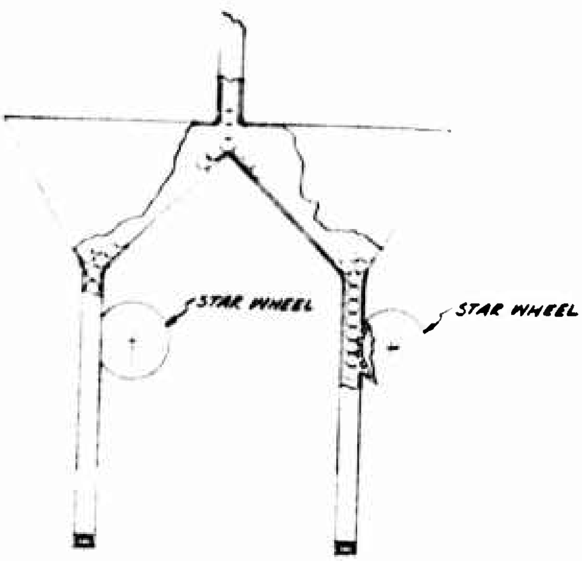
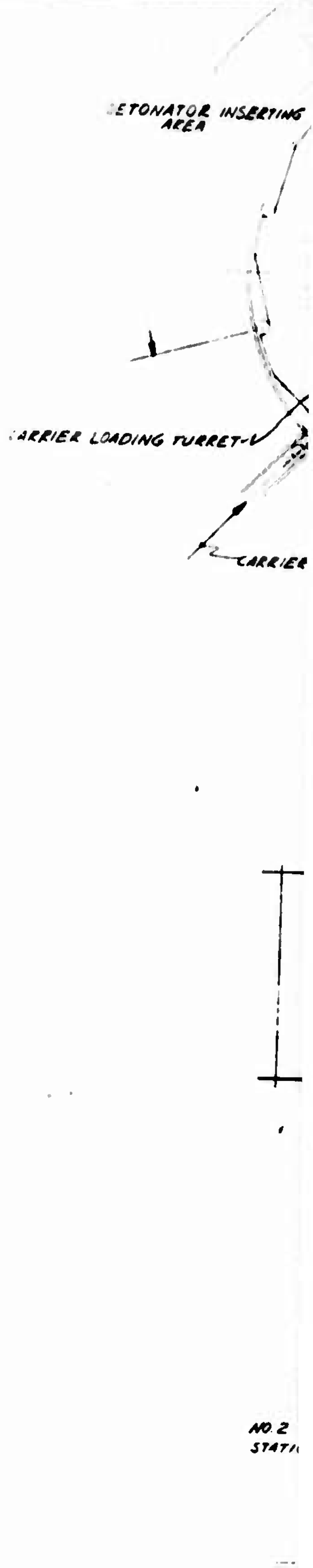


SECT. "B-B"



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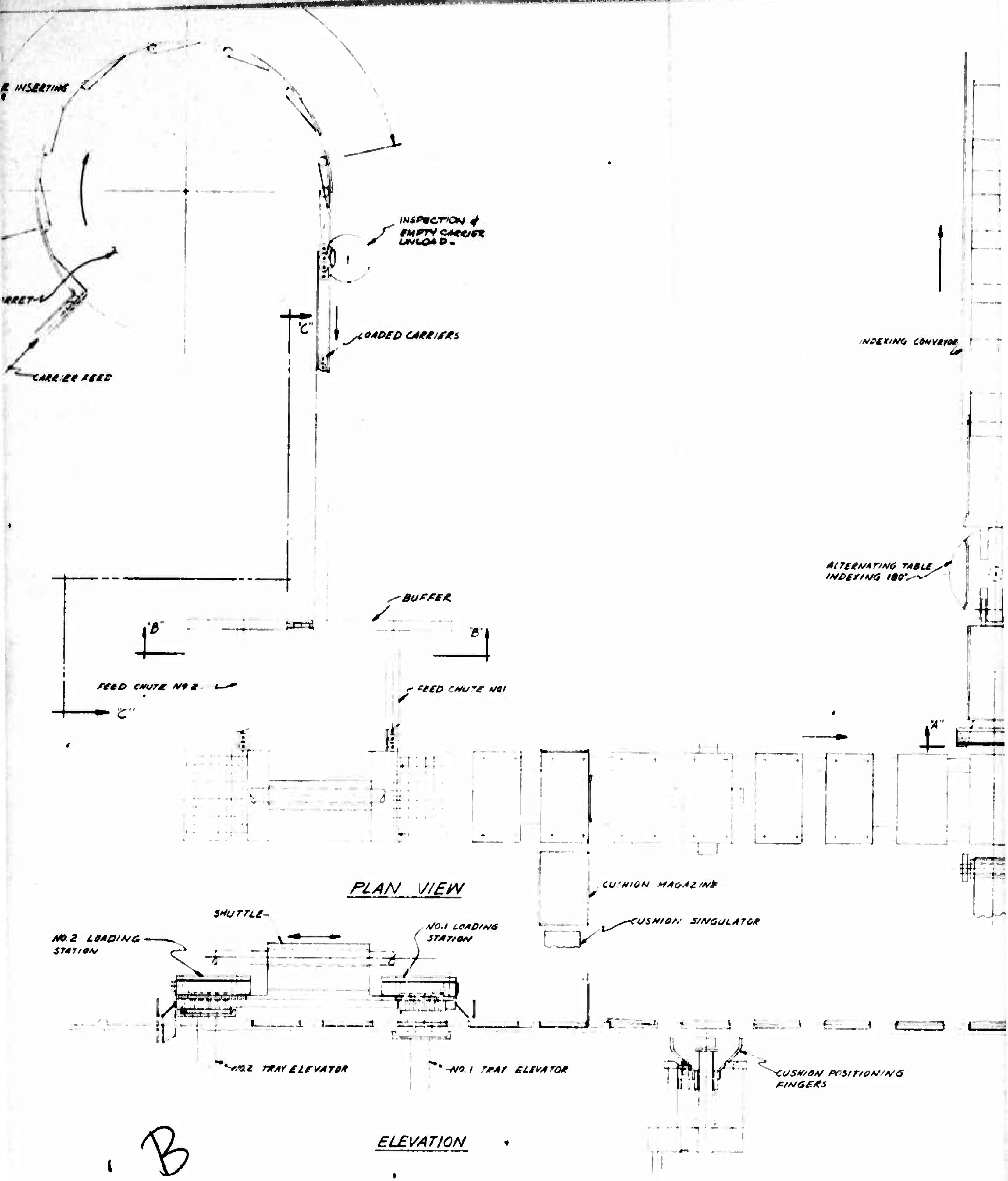
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RRET
"C"
LOADED CARRIERS
CARRIER FEED
INDEXING CONVEYOR
ALTERNATING TABLE INDEXING 180°
BUFFER
"B"
"B"
FEED CHUTE Nº 2
FEED CHUTE Nº1
"C"
"A"
PLAN VIEW
CUSHION MAGAZINE
SHUTTLE
NO. 2 LOADING STATION
NO. 1 LOADING STATION
CUSHION SINGULATOR
NO. 2 TRAY ELEVATOR
NO. 1 TRAY ELEVATOR
CUSHION POSITIONING FINGERS
ELEVATION

B

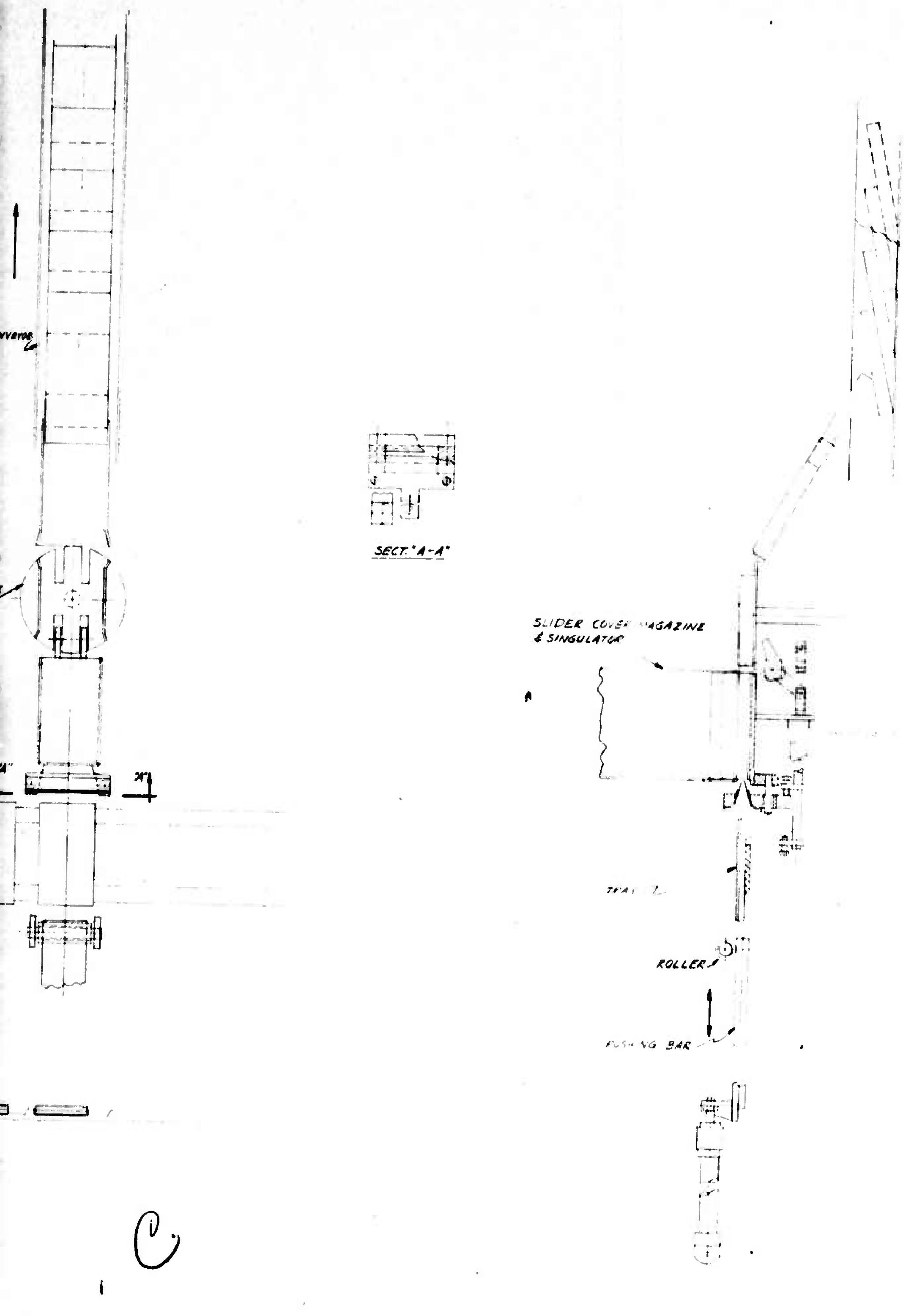

Figure
FIRST

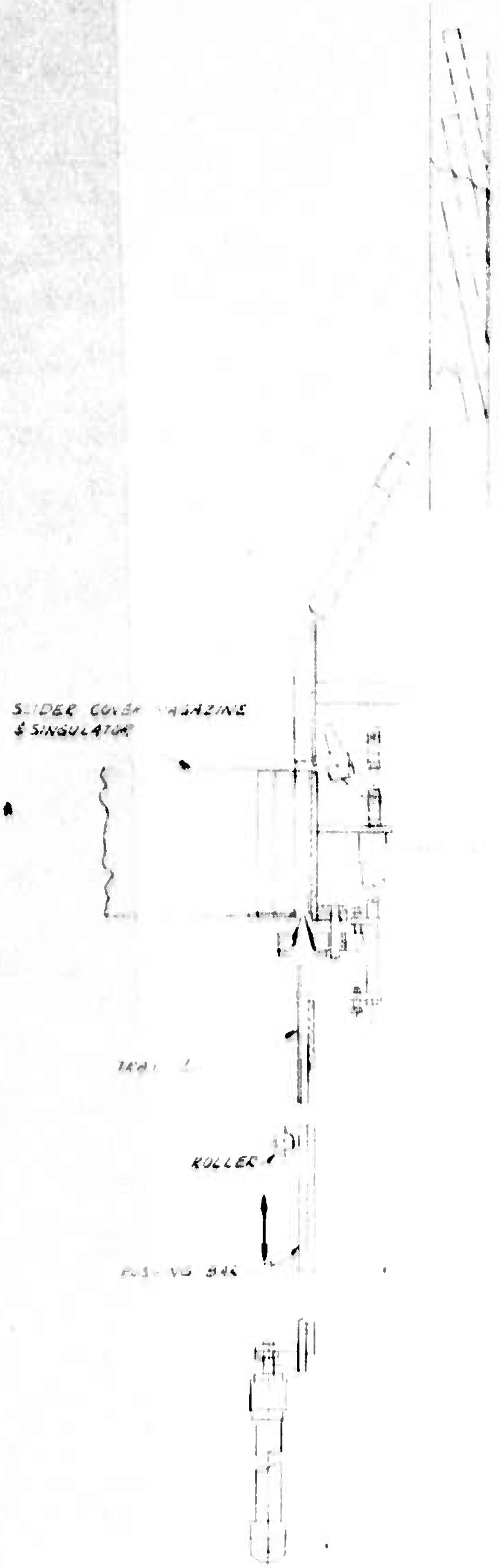

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Figure 15 PACKAGING LINE — FIRST STAGE (FMC Drawing 5102629)

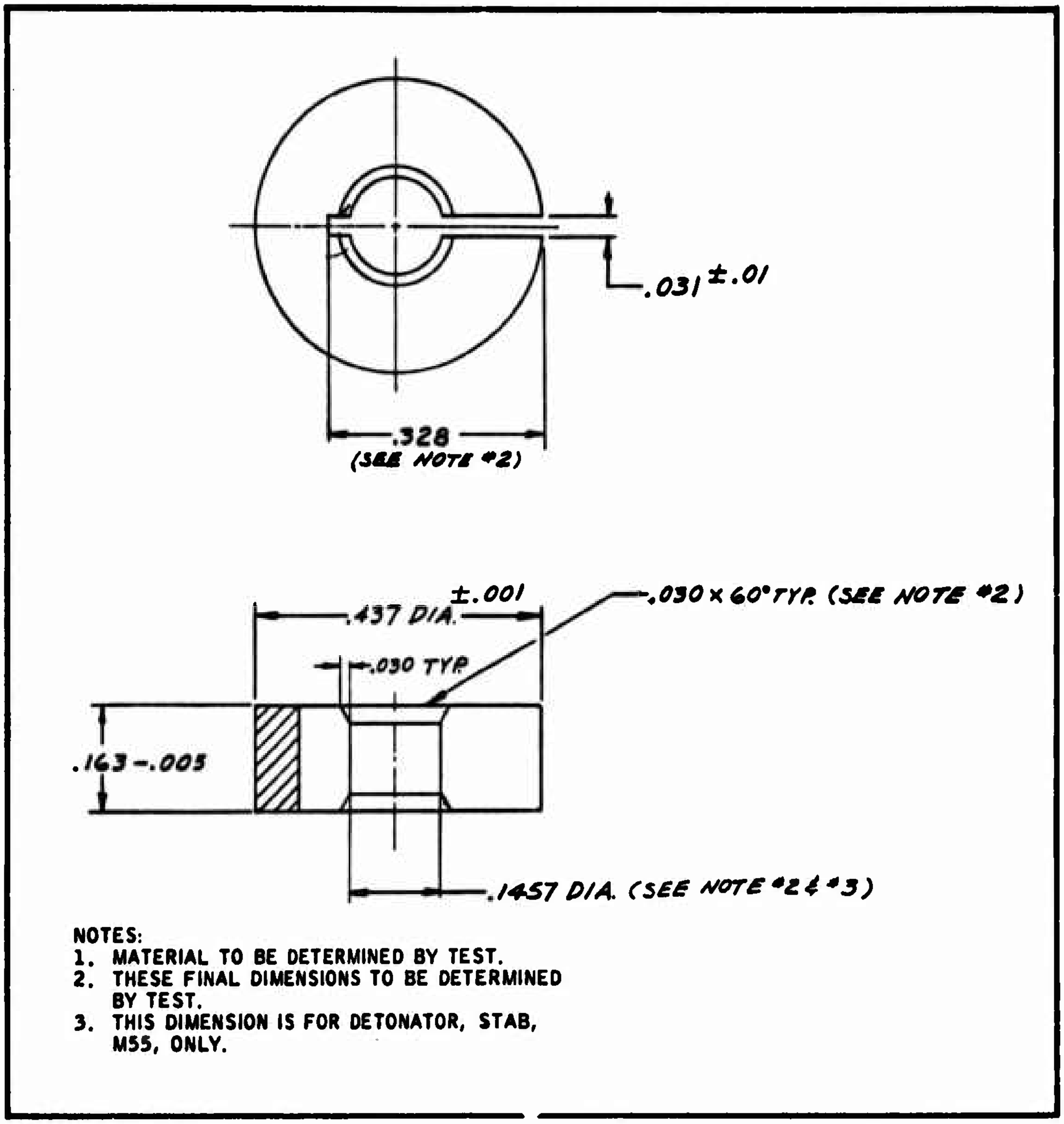


Figure 16 CARRIER RING, DETONATOR (FMC Drawing 5102190)

carrier chain. The carrier rings will be fed into the starwheel as are the cups into the loading turret. A circular plate above the starwheel will limit the upward motion of the carrier rings to a few thousandths of an inch.

Detonators will be transferred from the carrier chain into the rings by a set of lower punches moving all the way through the carriers, past the D-shaped spring. Ejection of defective detonators will be accomplished by inducing additional punch travel. The rejected parts will be pushed out of the carrier rings; openings in the top plate will allow for this motion. A rotating brush in the ejection area will send the rejected parts down a chute into a desensitizing container.

This momentary overtravel, about 3/16 inch, will be performed by a movable cam section adjacent to the main cam of the punches. An explosionproof solenoid will maintain the cam section removed from the path of the cam followers against spring pressure to satisfy the fail-safe requirement. In event of solenoid failure, all detonators would be rejected. Each punch will carry a central cam follower, which will ride the main cam track, and a cantilevered cam follower for the movable ejector cam section.

The carrier rings will be removed from the unload turret by a simple peel-off mechanism and proceed, in a solid single line, to the packaging area. An optical inspection system will locate and effect ejection of empty carrier rings.

K. RANDOM SAMPLE STATION

Sample detonators may be removed at random from the line following removal from the chain at the unload station. A simple gate moving laterally across the linear flow of detonators to the packaging operation will divert one or more detonators as required, still in the plastic carrier rings for safe handling.

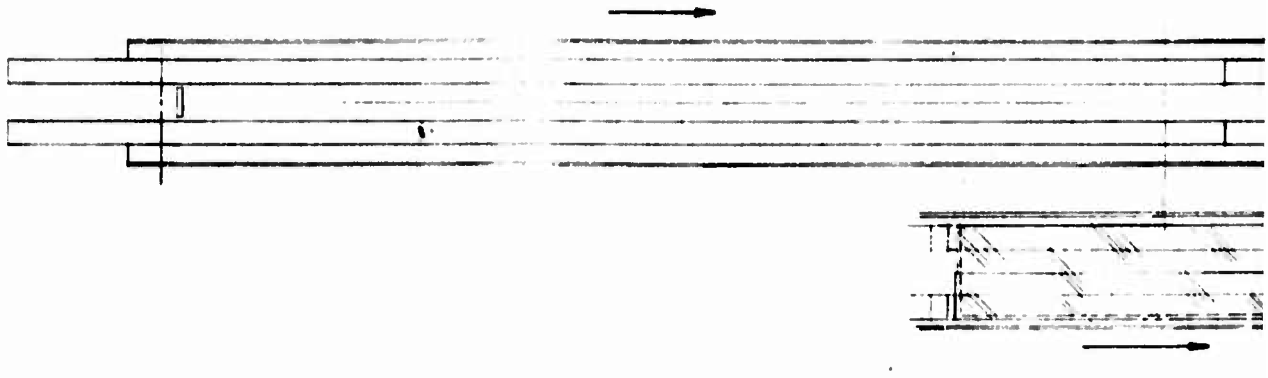
An alternate system would utilize the reject cam on the unload turret to remove a sample detonator, but divert the sample from the reject chute to the sample chute by means of a gate.

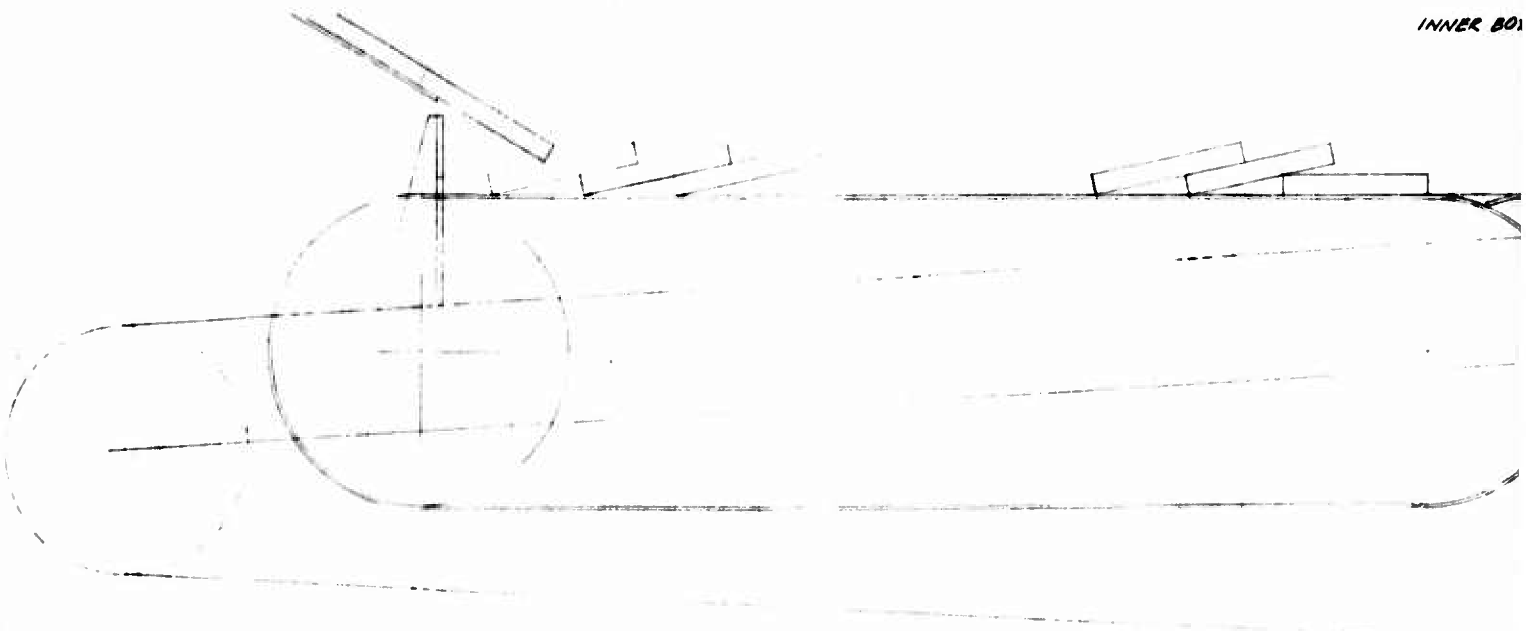
L. PACKAGING LINE (Figures 15 and 17)

Loaded carrier rings from the unload turret will be assembled in a buffer, then will proceed, in two lines, to the box-filling stations. The filling patterns, based on nest arrangement in the boxes, will be five rows of 10 detonators. The proposed carrier ring OD is exactly the same as the nest spacing (0.437 inch); therefore, when the carriers are squarely aligned and touching each other, the detonators will be in line with the nests in the boxes. At regular intervals, a shuttle bar will move one row of 10 carriers one index across (0.437 inch) over a dead plate. The shuttle bar will be located exactly between the two incoming lines of carriers and will operate the two lines alternately.

Empty boxes will be forwarded on an indexing conveyor, below the dead plate, and a tray elevator will raise the boxes against the dead plate. After five cross indexes, the detonator will be transferred into a box through clearance holes in the dead plate. This transfer will be accomplished by a cylinder acting on a spring-loaded pin pad. Both sides of the shuttle bar will be transferred simultaneously.

As the shuttle bar resumes motion, the empty carrier rings will be pushed into a chute by the oncoming rows of filled carriers and recirculated.





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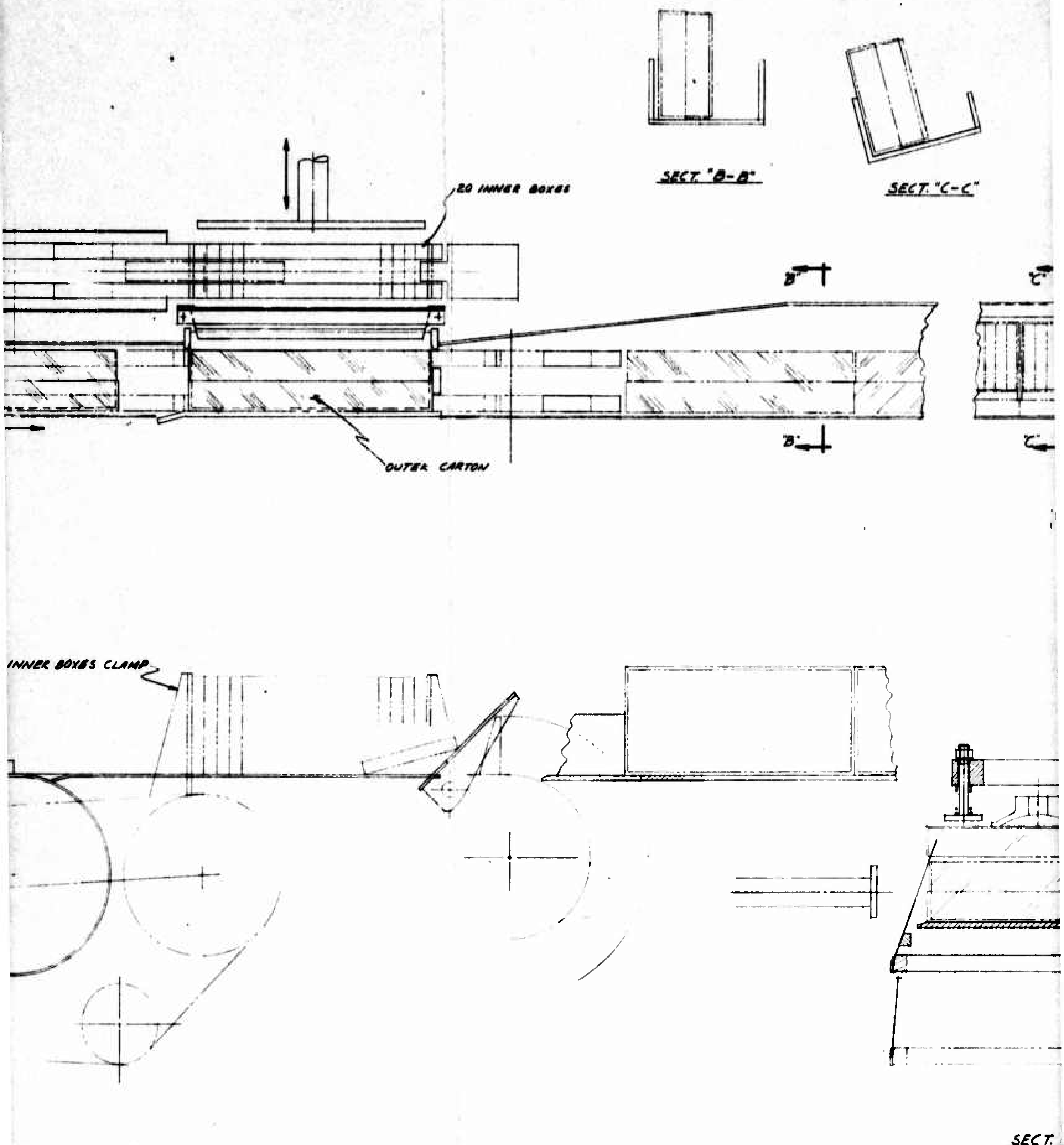
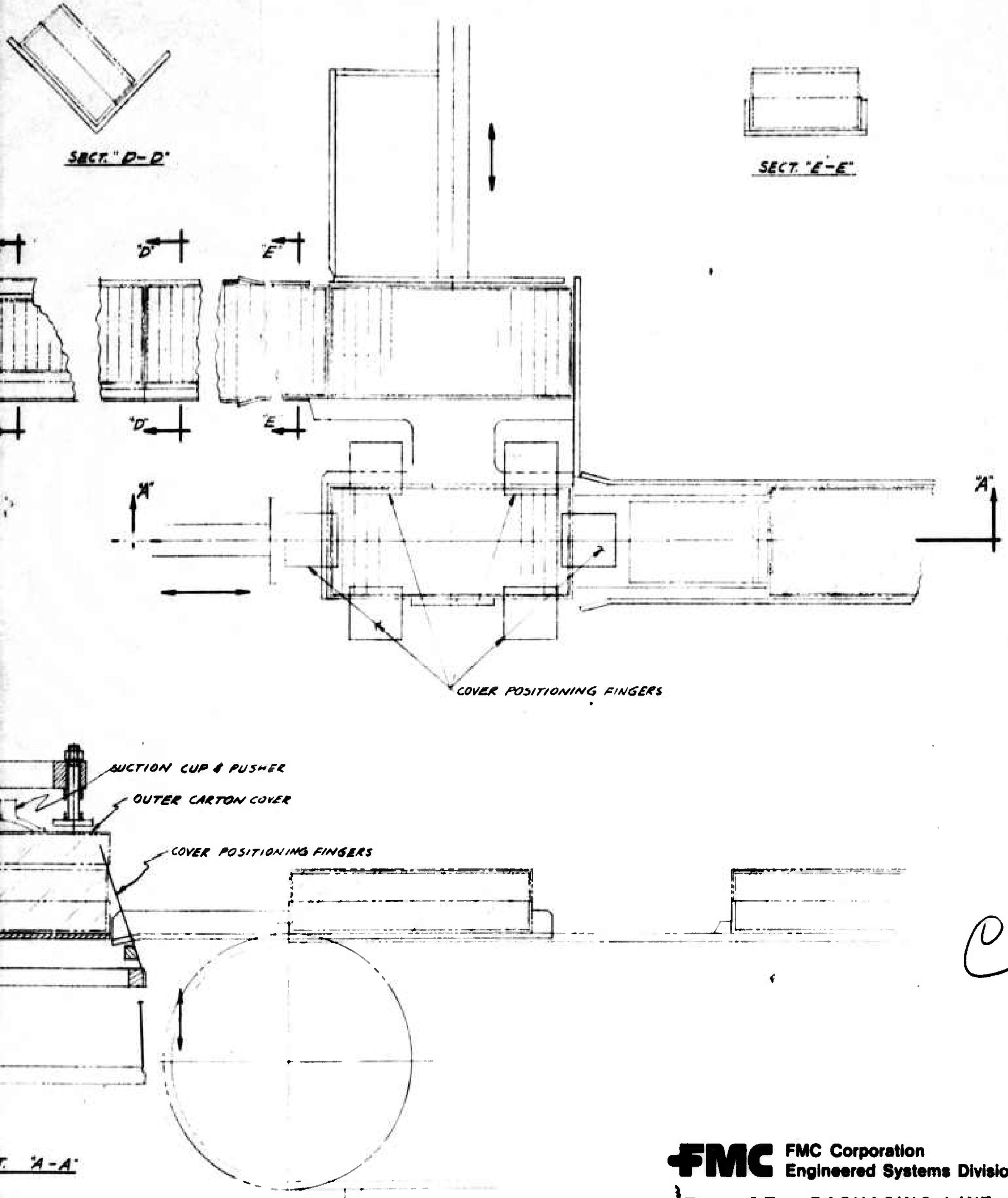

SECT. "B-B"
SECT. "C-C"
20 INNER BOXES
OUTER CARTON
INNER BOXES CLAMP
SECT.

1 B



C

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Figure 17 PACKAGING LINE — SECOND STAGE (FMC Drawing 5102630)

The use of expendable (plastic) carriers, which would be loaded in a modified box, has been suggested. The plastic carriers would act as cushions during shipment and could be utilized in an automated assembly line, then discarded or returned in bulk to the detonator plant.

The filled boxes will be lowered to the conveyor and, two indexes downstream, a cushion pad will be slid onto each box, sideways from a stack, by a shuttle plate. The pad will be located accurately by four flexible fingers actuated by an air cylinder.

Farther down, the boxes and pads will be pushed into outer wrappers through a funneling gate. The boxes will then move at right angles to the loading conveyor. A rotating table will turn every second box 180 degrees to stagger the detonators when packed in 20-box cartons. The boxes will slide down an incline onto another, slower conveyor. As a result of the velocity differential, the boxes will overlap as they are moved along to a dead plate. At the end of the dead plate, a pivoting end plate will gently raise the first box on end. A vertical bar, moving in from the other end when 20 boxes have reached the dead plate, will cause the overlapping boxes to slide, one onto another, until the stack is vertical.

A pusher bar will transfer the 20 boxes into a carton. The open container will move down a helical chute which will turn it gradually until it is placed, open side up, at the next station. An overhead arm equipped with suction cups will pick up a lid and lower it onto the carton, with the assistance of four positioning fingers.

The junction between carton and lid will be taped at the next station by a rotary tape-dispensing and wetting device, a set of pressure rolls, and a cutter.

The closed carton will then be enclosed in a special plastic-coated bag; this operation will be performed at the last station of the packaging line. The bags, supplied in stacks, will be singulated and one bag will be lifted by suction cups and moved next to a carton. The bag mouth will be held open by a combination of vacuum bars and flexible fingers until the carton is completely pushed inside the bag. As before, the flexible fingers will act as guides. The bag mouth will be clamped shut, except for a small-diameter vacuum tube extending a couple of inches inside the bag, approximately at the center of the opening.

Vacuum will be drawn until the bag is molded around the carton. As the tube is withdrawn, two heated bars will clamp the bag near the end and seal the package.

M. FINAL INSPECTION

A final inspection will be made after the unload turret operation to ensure that all detonators are removed from the chain carriers. The equipment for this inspection will be similar to that used for disc-presence inspection, except that the scanning beam will pass through the carrier to verify that no detonators remain within. A signal from this inspection station indicating that the carrier is not free from obstruction will result in the immediate shutdown of the line so that corrective action may be taken.

N. CHAIN CLEANING AND ASPIRATING

After leaving the unload turret and clearing the packaging area, the transport chain will pass through a cleaning tunnel. Rotary brushes, on vertical and horizontal shafts, will remove all powder dust and other particles the chain may have gathered in the various work stations. Vacuum heads around the brushes will remove the dust as soon as released.

O. SAFETY

Because of the high production rate--1,200 detonators per minute--safety is of primary importance. The equipment will be designed to meet the following requirements:

- Satisfactorily low velocities of powder in contact with rubbing surfaces
- Avoidance of steel-on-steel condition of such surfaces
- Avoidance of unnecessarily large operational volumes of powder
- Nonpropagation of accidental detonation
- Sanitary powder handling.

The rate of consumption of potentially hazardous powder will be higher than with slower conventional equipment. To preclude frequent stops for refilling, a large basic supply of powder will be required. Even with the basic supply safely housed behind a magazine barricade, a system for transporting small amounts of powder to the metering and pressing equipment will be required. Adequate spacing must be maintained between these small volumes to avoid propagation of accidental detonation to the main supply of powder at the pressing station.

To achieve repeatedly accurate metered charges, the system will utilize a method of volumetric metering immediately prior to charge consolidation. The entire metering system will be carried on a separate turret to preclude close proximity of the loose powder of the metering apparatus to the potential hazard of consolidation and pressing. The close engagement proximity and metered charge transfer of the turret to that of the pressing turret takes place as far as possible from the point of pressing, maximizing safety of the operation. Another advantage of the method is the resulting simplified, economical design of both turrets. A large proportion of the metering turret rotation will be now devoted to metering only, and the actual velocities of metering surfaces will be considerably lower than those of the combined metering and pressing turret originally proposed. This method has been proven feasible by bench-model tests. The punch velocities of the pressing turrets have similar advantages, enabling a larger portion of rotation to be devoted to pressing and consolidation only.

The design of the metering shaft through a separate turret is compatible with a semirotary movement rather than the linear action first envisaged. Semirotary movement will reduce rubbing velocity by further reducing the length of surface travel necessary, and increase available time. The semirotary action will also allow the powder in the powder-metering cup to fall directly to the metering cavity of the shaft, beneath which it will be pulled by vacuum and assisted by gravity. This method offers a considerable advantage in overcoming powder bridging to that of pulling powder upward into the cavity. The pneumatic-agitator system successfully demonstrated in the bench-model tests is incorporated in the equipment design, providing a high level of confidence in repeatable accuracy of charge weights. Doctoring of the metered charge will be performed by Delrin/steel surfaces, wear compensated by spring pressure. Dumping of the charge into the die funnel of the pressing turret will be performed by dry nitrogen which assists in the maintenance of thoroughly dry powder considered essential for consistently accurate metering and equipment operation. All possible precautions will be taken against accidental spillage of powder, with vacuum aspirators employed around powder working areas.

In addition, all plastic components will be made conductive and grounded. Nonsparking materials will be used, wherever necessary, throughout the machine.

P. DETONATION DETECTION

The detonation-detection system uses an audio-frequency microphone housed in a dustproof enclosure and a frequency-selective amplifier. The voltage at the microphone is in the order of millivolts and thus is intrinsically safe; therefore, a complete explosionproof enclosure is not necessary even in the most hazardous areas.

Experiments will be made using the microphone and a storage oscilloscope to determine the predominant frequency generated in a detonation. The design of the amplifier will then be modified to amplify that frequency and reject all others. The output of this amplifier can then be used to operate a relay, sound an alarm, and stop operation if required.

Q. CONTROL DISPLAY

A display panel will continuously indicate the cycle rate of the equipment together with information on the total number of parts processed, number of parts rejected, and number of samples. Indicators will readily identify a source of malfunction, including detonation and parts out of tolerance.

III. WORK PERFORMED

The objective of this project was to develop a concept for an automatic system to produce nonelectric detonators at a rate of 1,200 units per minute. The program consisted of the following steps:

- Engineering study of present production system
- Development of new concepts for performing the required operations
- Manufacture of bench models of the charging, tamping, and crimping modules
- Testing of these bench models with inert and explosive material
- Final report.

A. ENGINEERING STUDY

FMC ESD personnel visited Lone Star Army Ammunition Plant, Texas, and Picatinny Arsenal, New Jersey, to observe the present operations of loading, assembling, sealing, inspecting, and packing detonators. These methods are relatively slow and manual. Discussions with knowledgeable personnel provided an understanding of the hazards now entailed in handling sensitive explosives. This information contributed to the development of the recommended systems concept to meet Government requirements.

B. DEVELOPMENT OF NEW CONCEPTS

Conceptual drawings were prepared for each operation required to produce and package nonelectrical detonators. Each concept was reviewed by Government personnel. As required, the concepts were modified to overcome any objections. Drawings of these concepts are included with this report.

C. MANUFACTURE OF BENCH MODELS

Bench-model equipment was designed to accomplish the following tasks:

- Metering of charges
- Loading of charges
- Consolidation of charges
- Crimping.

The equipment was designed to perform at the same speed required to meet the 1,200-per-minute production rate. Because of the need to process sensitive explosives, appropriate procedures were followed. The equipment was procured and manufactured.

D. TESTING OF BENCH MODELS

Using simulated charging material, the bench model (Figure 18) was operated. By changing tools, the metering, dispensing, consolidating, and crimping functions were satisfactorily performed. The equipment was then moved to enable operation with actual explosive materials. With the equipment safely housed in the FMC pressing block-house, a program of live powder metering, dispensing, and consolidation was conducted using NOL 130, lead azide, and RDX at appropriate consolidation pressures. As shown in Figure 18, an LVDT attached to the upper consolidation punch monitored the velocity and movements of the punch with the output signal connected to a graph recorder. The times were referenced to a 1-second pulse on the recorder which confirmed that the approach, consolidation, dwell, and retraction times were within the timing sequence designed to produce 1,200 detonators per minute on a 24-station rotary press at 50 rpm. Metering and dispensing of the charge was successfully accomplished within the time allocated for this function at this output rate, with a consistent weight of charge dispensed after several hundred operations. Based on this performance, and the fact that no detonations occurred, a high level of confidence in the system design is possible. Figure 19 shows a graph trace from a typical live test using NOL 130.

All tests were documented, and the following observation summaries were made:

1. Metering

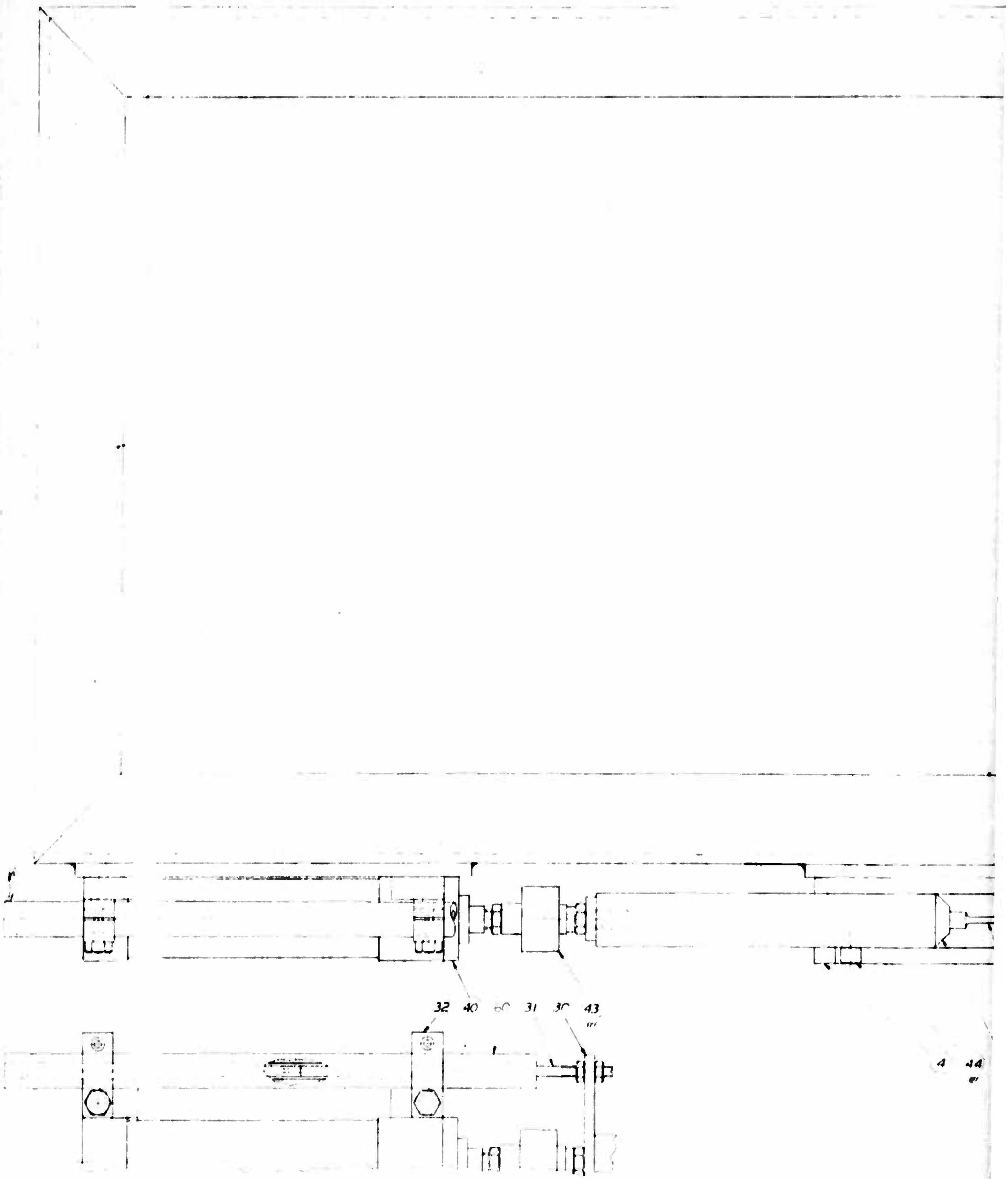
Doctoring of the metered charge by Delrin doctor blades on steel is satisfactory at the calculated speed of 1.08 feet per second or less.

- The vacuum fill/nitrogen eject volumetric filling method is highly satisfactory, provided the eject pulse is sharp and short to eliminate any dust. Repeatable accuracy is good.

- Vacuuming powder into a metering cavity tends to promote bridging in the powder supply. The proposed funneling of the supply downward to the cavity and pulling the powder down, assisted by gravity, is preferable.

- Pneumatic agitation was found satisfactory to prevent the supply powder from bridging, and is essential when using NOL 130.

- A substantial increase of vacuum at the metering cavity increases the charge weight only marginally, if at all. As a means of finely adjusting charge weight, varying the vacuum is not satisfactory. A quick and simple physical adjustment of volume is preferable and is presented in the report.



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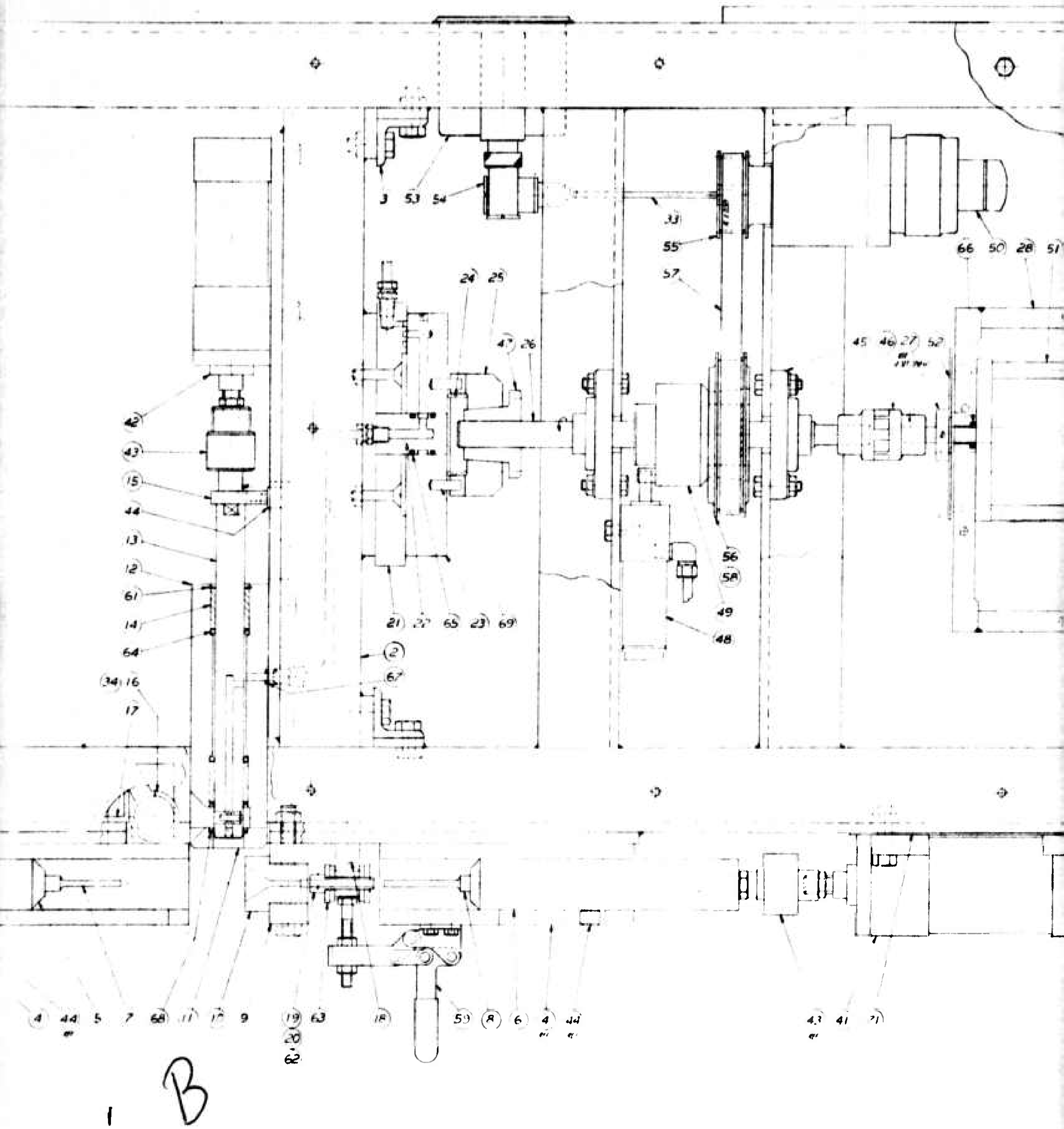

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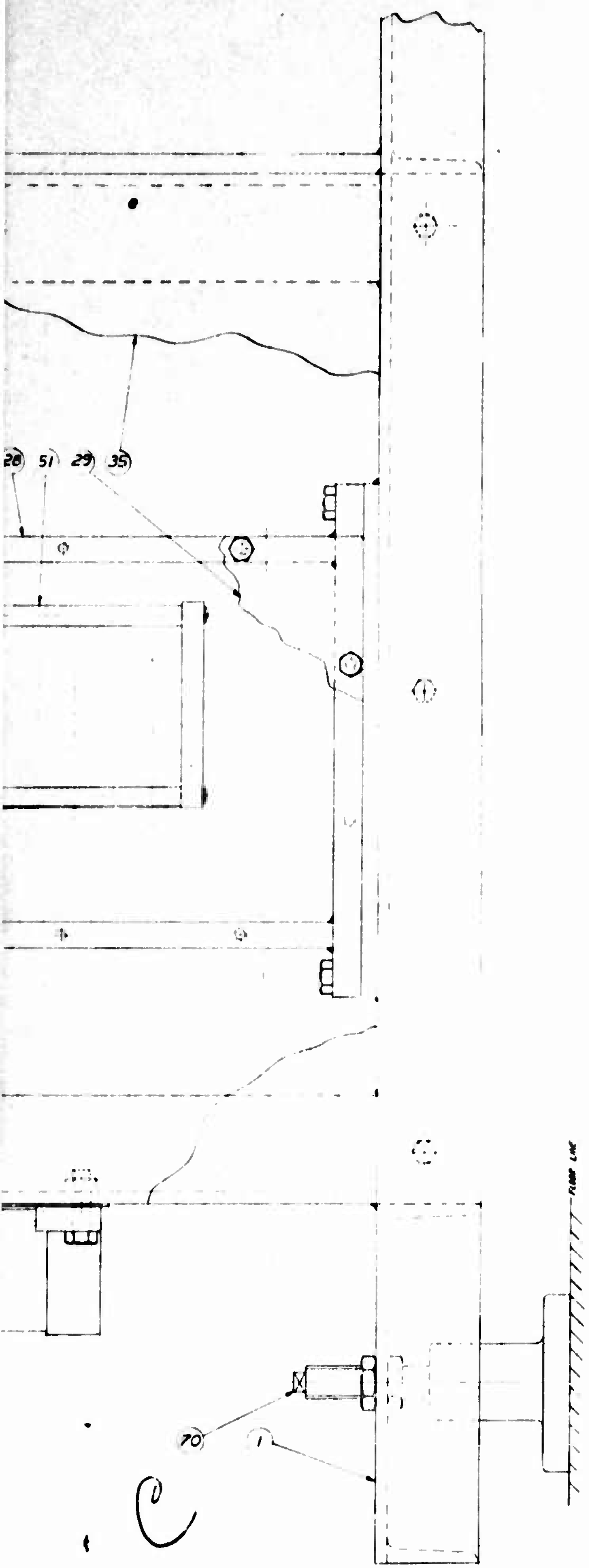

NOTES

1. SUPPLY HARDWARE TO SUIT
2. HYDRAULIC COMPONENTS & EQUIPMENT NOT SHOWN. THIS WILL BE MOUNTED AS REQUIRED
3. PNEUMATIC COMPONENTS & EQUIPMENT NOT SHOWN. THIS WILL BE MOUNTED AS REQUIRED
4. CAM PROGRAMMING AND TIMING TO BE SET UP PER DWG. E5100230-1-2 AND ENGINEERING INSTRUCTIONS
5. PROCURE FROM EXISTING STOCK IN MODEL SHOP STK.
6. RUBBER COMPONENTS MUST BE MADE OF CONDUCTIVE MATERIAL
7. ALL MOVING PARTS MUST BE GROUNDED
8. NO BRONZE, [illegible] MATERIALS TO BE USED
9. ALL ELECTRICAL [illegible] TO BE EXPLOSION PROOF
10. ASPIRATOR WILL BE [illegible] FOR CLEAN UP OF EXCESS [illegible]

SCALE

2	A	[illegible]		MOUNTING PAD		
3	B	5100599	2	ANGLE BAR		
4	B	5100596	2	SLEEVE		
5	A	[illegible]	1	PUNCH SHAFT-UPPER		
6	A	5100530	1	PUNCH SHAFT-LOWER		
7	A	5100577	1	PUNCH - UPPER		
8	A	5100576	1	PUNCH - LOWER		
9	A	5100579	1	HOLDER DIE		
10	A	5100591	1	POWDER FILL DIE		
11	A	5100593	1	[illegible]		
12	B	5100592	1	POWDER FILL BLOCK		
13	B	5100593	1	POWDER METER SHAFT		
14	A	5100588	2	BUSHING		
15	A	5100574	1	PLATE		
16	A	5100601	1	CUP		
17	B	5100600	1	CUP HOLDER		
18	A	5100578	1	SPROCKET ROTATION		
19	A	5100587	1	DETONATOR CUP RETAINER		
20	A	[illegible]	1	SPRING CLIP		
21	C	5100603	1	VALVE PLATE		
22	A	[illegible]	1	PIN		
23	B	[illegible]	1	VALVE PLATE ROTATING		
24	A	[illegible]	1	SPRING		
25	A	[illegible]	1	COUPLING HALF		
26	A	[illegible]	1	SHAFT		
27	A	[illegible]	1	DIE MOUNTING		
28	C	[illegible]	1	BOX		
29	B	[illegible]	2	BOX COVER		
30	A	5100575	1	PLATE		
31	A		1	LVDT CORE MOUNT		
32	A	5100572	2	CLAMP - LVDT		
33	A	[illegible]	1	TACHOMETER SHAFT		
34	B	5100602	1	CUP HANDLE		
35			2	FRONT COVER PLATE		
36	A	[illegible]	1	PLUG		
37	A	[illegible]	1	SCREEN		
38	A	[illegible]	1	FILTER		
39						
40			1	HYDRAULIC CYLINDER	1" STROKE	
41			1	HYDRAULIC CYLINDER	[illegible]	
42			1	HYDRAULIC CYLINDER	[illegible]	
43			1	ROD ALIGNER	[illegible]	BOSTON
44			1	CAM FOLLOWER	[illegible]	[illegible]
45			2	[illegible]	[illegible]	BOSTON
46			1	[illegible] COUPLING	[illegible]	BOSTON
47			1	[illegible]	[illegible]	BOSTON
48			1	[illegible]	[illegible]	[illegible]
49				[illegible] CLUTCH		
50			1	[illegible]	[illegible]	[illegible]
51				CAM PROGRAMMER	[illegible]	[illegible]
52			1	[illegible]	[illegible]	[illegible]
53			1	[illegible]	[illegible]	[illegible]
54			1	[illegible] DRIVE	[illegible]	[illegible]
55				PULLEY	[illegible]	[illegible]
56			1	PULLEY	[illegible]	[illegible]
57			1	TIMING BELT [illegible]	[illegible]	[illegible]
58				[illegible] BEARING	[illegible]	[illegible]
59				[illegible]	[illegible]	[illegible]
60				LVDT	[illegible]	[illegible]
61				RETAINING RING	[illegible]	[illegible]
62				RETAINING RING	[illegible]	[illegible]
63				[illegible]	[illegible]	BOSTON
64				[illegible]	[illegible]	
65			2	[illegible]	[illegible]	
66			1	[illegible]	[illegible]	
67			1	O RING [illegible]	[illegible]	
68			2	[illegible]	[illegible]	[illegible]
69			2	DOWEL PIN	[illegible]	
70			4	POST	[illegible]	
71				SHIM	[illegible]	
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76	A	[illegible]		[illegible]		
77	B	[illegible]		[illegible]		
78	B	[illegible]		[illegible]		
79	B					
80						

NOTES

1. [illegible]
2. HYDRAULIC COMPONENTS & EQUIPMENT NOT SHOWN. THIS WILL BE MOUNTED AS REQUIRED
3. PNEUMATIC COMPONENTS & EQUIPMENT NOT SHOWN. THIS WILL BE MOUNTED AS REQUIRED
4. CAM PROGRAMMER AND TIMING TO BE SET UP PER DWG E5100234-1-? AND ENGINEERING INSTRUCTIONS
5. PROCURE FROM [illegible] IN MODEL SHOP [illegible].
6. RUBBER COMPONENTS MUST BE MADE OF CONDUCTIVE MATERIAL
7. ALL MOVING PARTS MUST BE GROUNDED
8. NO BRASS, [illegible] MATERIALS TO BE USED
9. ALL ELECTRICAL EQUIPMENT TO BE EXPLOSION PROOF
10. [illegible]

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SCALE

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Engineered Systems Division

Figure 18 EXPERIMENTAL MODEL NONELECTRIC DETONATOR (FMC Drawing 5100859)

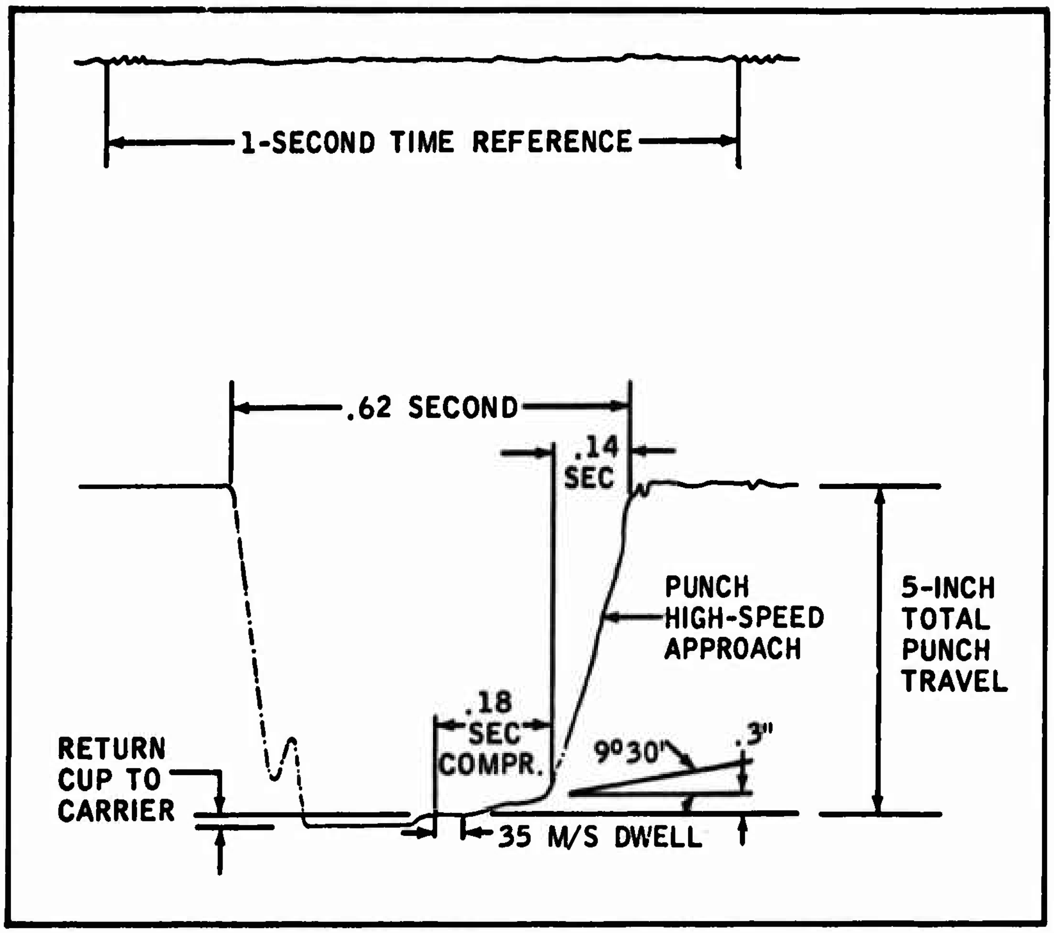

Figure 19 GRAPH TRACE FROM LIVE TEST 1, CUP 1, USING NOL 130

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- The filter medium must be capable of withstanding the abrasive effect of continued powder metering. Porous ceramic is used in industry for this purpose.

2. Consolidation

Data obtained from a typical graph trace on consolidation of NOL 130 (Live Test Number 1; see Figure 19) shows the following:

- Punch approach speed to within 0.3 inch of final consolidation: 4.7 inch in 140 milliseconds equals 2.8 feet per second.

- Punch consolidation speed, including 35 milliseconds dwell: 0.3 inch in 180 milliseconds equals 0.139 foot per second.

- Punch consolidation speed, not including dwell: 0.3 inch in 145 milliseconds equals 0.172 foot per second.

- Effective consolidation pressure is 70,000 pounds per square inch (derived from 1-inch-diameter hydraulic cylinder at 1,390 pounds per square inch hydraulic pressure, producing 1,090 pounds of thrust).

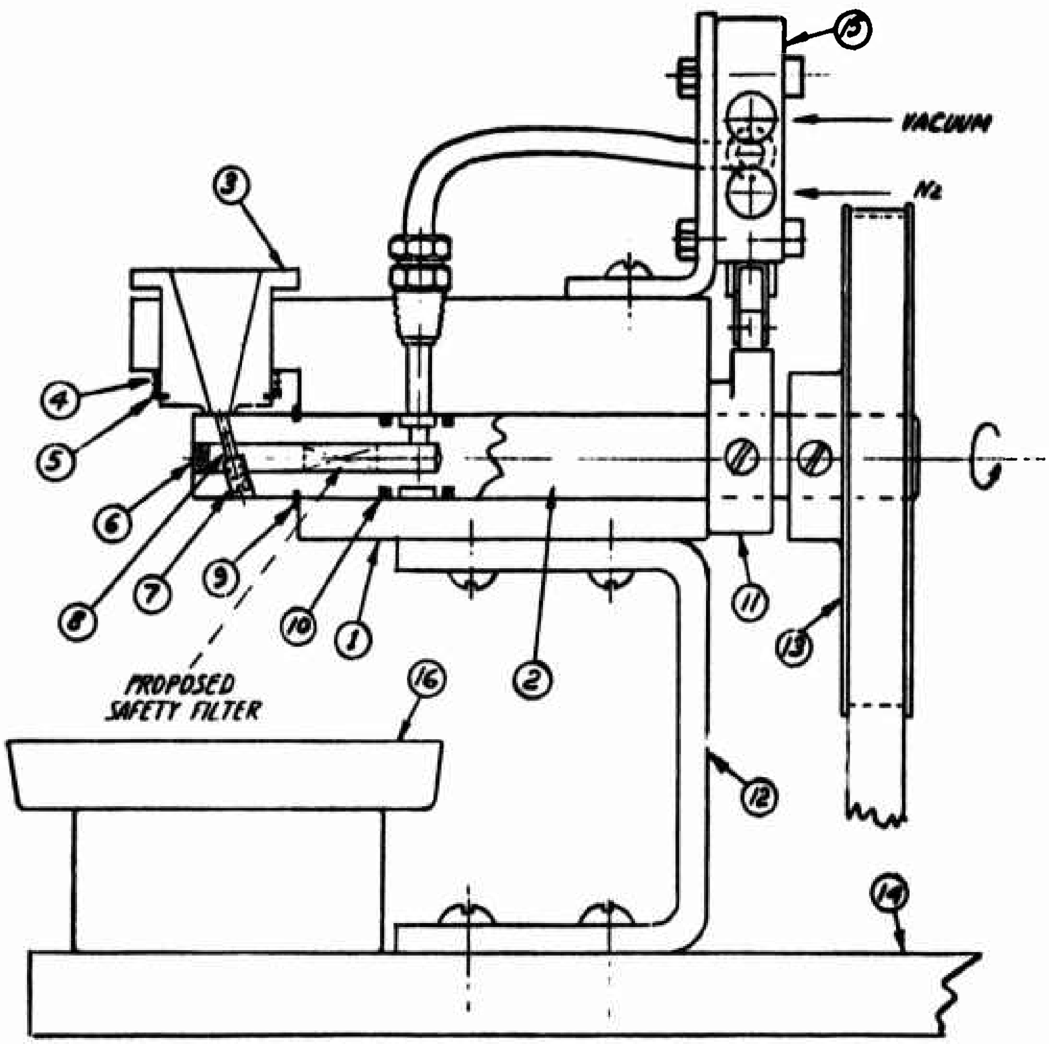
- Slope of this graph trace for consolidation equals 9 degrees, 30 minutes. This slope allows design of the mechanical cam track of a rotary press which can be operated without fear of detonation.

- The parallel portion of the powder funnel should be as short as possible to avoid an unecessary compression of trapped air on the fast approach of the punch. Air-escape holes must be provided in the carrier for detonator cups to prevent disturbance of the cup by a pump action on the rapid approach of the lower punch.

E. ROTARY DISPENSING TEST

1. Equipment Description

In order to test the feasibility of dispensing powder by a rotary technique rather than that of the linear method used on the bench model, a jury rig was constructed as shown in Figure 20. For simplicity of construction, the metering shaft was continuously rotated at 60 RPM rather than given a semi-rotary action, thus dispensing one powder charge every second. A cam, fitted to the shaft, operated a three-way valve which was provided with air pressure in one port and vacuum in another. The third port, being alternately common to both supplies, was connected to the metering cavity so that at any one time the cavity was subjected to either vacuum or air. A sharp lobe on the cam provided a short pulse of eject air when the metering cavity was at bottom center, thus dumping the charge. Vacuum was applied at the cavity for the remainder of the revolution. A mechanical revolution counter was included to enable a record to be made of the number of charges dispensed. The jury rig was also used to



1. Metering Body Block
2. Metering Shaft
3. Powder Hopper (Delrin)
4. Doctoring Spring
5. Retaining Ring
6. Plug
7. Filter Screw (Adjustable Volume)
8. Micronite Filter
9. Retaining Ring
10. "O" Ring Seals
11. Cam
12. Metering Bracket
13. Drive Pulley (60 RPM)
14. Base Plate
15. Three-Way Valve, Vacuum/Nitrogen Input, Roller Operated
16. Dish

Figure 20 ROTARY DISPENSING TEST

determine consistency of charge volume by weight, and if possible clogging of the "micronite" porous plastic filter would occur after repeated operation of several thousand cycles. Baby powder (talc) was used as a simulant of NOL 130, being recognized as the most difficult powder simulant to handle.

2. Procedure

The apparatus dumped 1,000 charges into a dish and the contents were weighed. This was repeated every few thousand operations and weights compared. Results:

Charges Dispensed	Weight
1,000	150 m/g
3,000	159 m/g
5,000	205 m/g
10,000	96 m/g
15,000	83 m/g

3. Observations

The small, but progressive increase in weight up to 5,000 charges showed that no clogging was occurring. The abrupt change in weight after 10,000 charges, and even less after 15,000 charges, indicated a malfunction. The filter was removed and found to be half eroded away.

4. Conclusions

Although baby powder is usually considered soft and gentle, it is nevertheless a finely divided mineral silicate talc or mica, and despite being the softest of all abrasives (Moh's Scale I), it appeared to have sufficient capability to seriously abrade the soft porous plastic. As the material was eroded, the cavity volume increased, as evidenced by the gradual increase in weight up to 5,000 operations. Further erosion allowed the powder to be sucked directly into the vacuum line. This caused the air to channel, resulting in a partial volume fill as shown by the reduced weight at 10,000 to 15,000 operations.

The test was abandoned and considered inconclusive at that time, especially as the abrasive qualities of live powders were unknown. Experiments prior to the live test showed that vibration was inadequate to ensure a fully filled and doctored cavity, the pneumatic agitation method being a successful technique.

5. Recommendations

A porous ceramic filter should be substituted for the porous plastic filter to resist any abrasiveness of live powders, and to provide filter longevity. This is standard practice for the industry. A further ceramic filter should be incorporated in the vacuum aspirator system, preferably in the metering shaft prior to the rubbing surfaces of the seals. This is a safety consideration, preventing the ingress of powder to the vacuum system in the event of a metering filter failure.

An increase in dump pressure for a shorter time would be beneficial to:

- Prevent "dusting" through excessive air flow
- Discourage clogging of ceramic pores
- Result in a clean, loose, slug of powder charge
- Provide clean removal of all residual powder on cavity walls.

F. FINAL REPORT

This document constitutes the final report for work under contract DAAA21-73C-0211. Included are the concept drawings of the total system recommended for development by FMC.

IV. ESTIMATED COST

The estimated cost is based on costs of the 5.56-mm primer-insert equipment previously developed, built, and installed by FMC and now successfully operating at Twin Cities Army Ammunition Plant, Minnesota. The six rotary turrets of the primer-insert line and the associated carrier chain system, primer-feeding equipment, primer-insertion equipment, LVDT depth inspections, crimping, sealant application, and controls generally follow the same basic operation requirements as those for the nonelectric detonator assembly line. The estimate also reflects the use of stainless-steel fabrication to satisfy the requirements concerning washdown capability, nonsparking materials, and saltspray tests.

The cost estimate is as follows:

Engineering	$1,804,140
Fabrication and Assembly	$4,734,560
Total Equipment Cost Estimate	$6,538,700

Note: Freight, installation, acceptance testing, spares, manuals, travel, safety analysis, training, human engineering, reliability and similar studies, are not included in the above estimate. Planning for further phases of this program should include costs for any such items which may be desired.

A project schedule is shown in Figure 21.

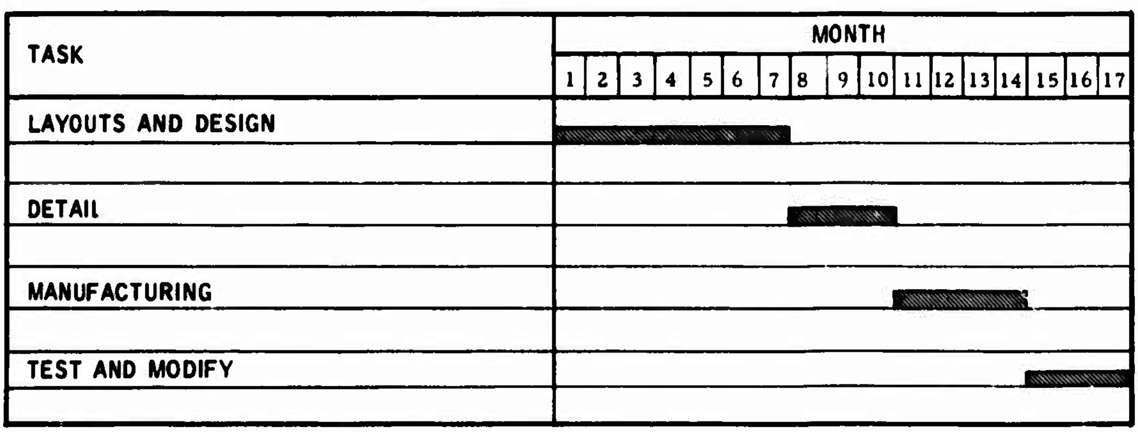


Figure 21 PROJECT SCHEDULE

Appendix A
PHASE I REPORT

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DESIGN OF A HIGH SPEED NON-ELECTRIC DETONATOR LOADING ASSEMBLY, INSPECTING AND PACKAGING SYSTEM

PHASE I REPORT

Prepared For
PICATINNY ARSENAL
Dover, New Jersey

Contract: DAAA21-73-C-0211
AMCMS Code: 49320540001

March 1, 1973

Prepared By
FMC CORPORATION
Engineered Systems Division
Santa Clara, California 95052

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I. SUMMARY

A. This report presents practical principles in the following areas for non-electric detonator production at a rate of 1200 per minute:

1. Overall System Design.
2. Transport of Detonators.
3. Metering, Loading and Consolidation of Charges.
4. Crimping.
5. Rapid Change-Over of Equipment Components.

The transport chain is standard and has simple holders that accurately locate the cups and are quickly changed when necessary.

The metering, loading and consolidation of the charge is accomplished all on one turret for each charge. The powder handling components are all easily and quickly changed when necessary, and the velocity of the moving parts in contact with the powder is satisfactorily low.

Both crimping operations are performed on one turret.

Other operations such as seal blanking, inspection, sealing, etc. are "state-of-the-art" techniques already employed on current FMC equipment built for Frankford Arsenal.

B. Experimental verification of conceptual design was successfully conducted in the following areas, with appropriate simulants:

1. Metering of charge.
2. Consistency of charge weight.
3. Loading of charge.
4. Elimination of powder "bridging".

II. SYSTEM DESCRIPTION

The detonator filling line (lay-out drawing R-5100207) will consist of 11 (eleven) turrets linked by a carrier chain. In addition, three auxilliary conveyor chains will continually supply the filling turrets with powder.

Carrier Chain

The carrier chain is a standard hollow-pin, 1" pitch (#80 HP) equipped at 5" intervals, with detonator cup holders. These holders sit loosely in the chain; they are accurately centered in the turret by the lower punches. The holder bore diameter allows for a sliding fit with the detonator cups. The latter are prevented from falling out by spring clips mounted in such a way that they will temporarily deflect when the lower punches move up to raise the cups (see drawing R-4793170).

Turrets

The turrets are about 36" in diameter and have 20 stations, 5" apart. The following turrets are planned:

1	loading turret (drawing R-5100208)
3	inspection turrets (drawing R-5100211)
3	filling stations (drawing R-4793170)
1	disc blanking and inserting turret (drawing R-5100210)
1	crimping turret (drawing R-5100209)
1	sealant applicating turret (drawing R-5100213)
1	unloading turret (drawing R-5100214)

Loading Turret (Drawing R-5100208)

Cups are bulk-fed into two 12" vibrator-type feeder-orienters. They emerge standing, opening up, and are forwarded by conveyor belt to a set of horizontal belts which move them in one single line, to the pick-up point. There, they are transferred to the 1st turret whose dial acts as a star wheel. The transport chain comes in on a sprocket underneath the dial. The lower punches enter the chain holders and thus aligns them accurately. The upper punches push the cups into the chain holders. Inside the mounting frame of this turret is the main drive of the line. It consists of a variable speed motor (D. C.), a right angle gearbox, two timing belt trains and hand cranking arrangement.

Inspection Turrets (Drawing R-5100211)

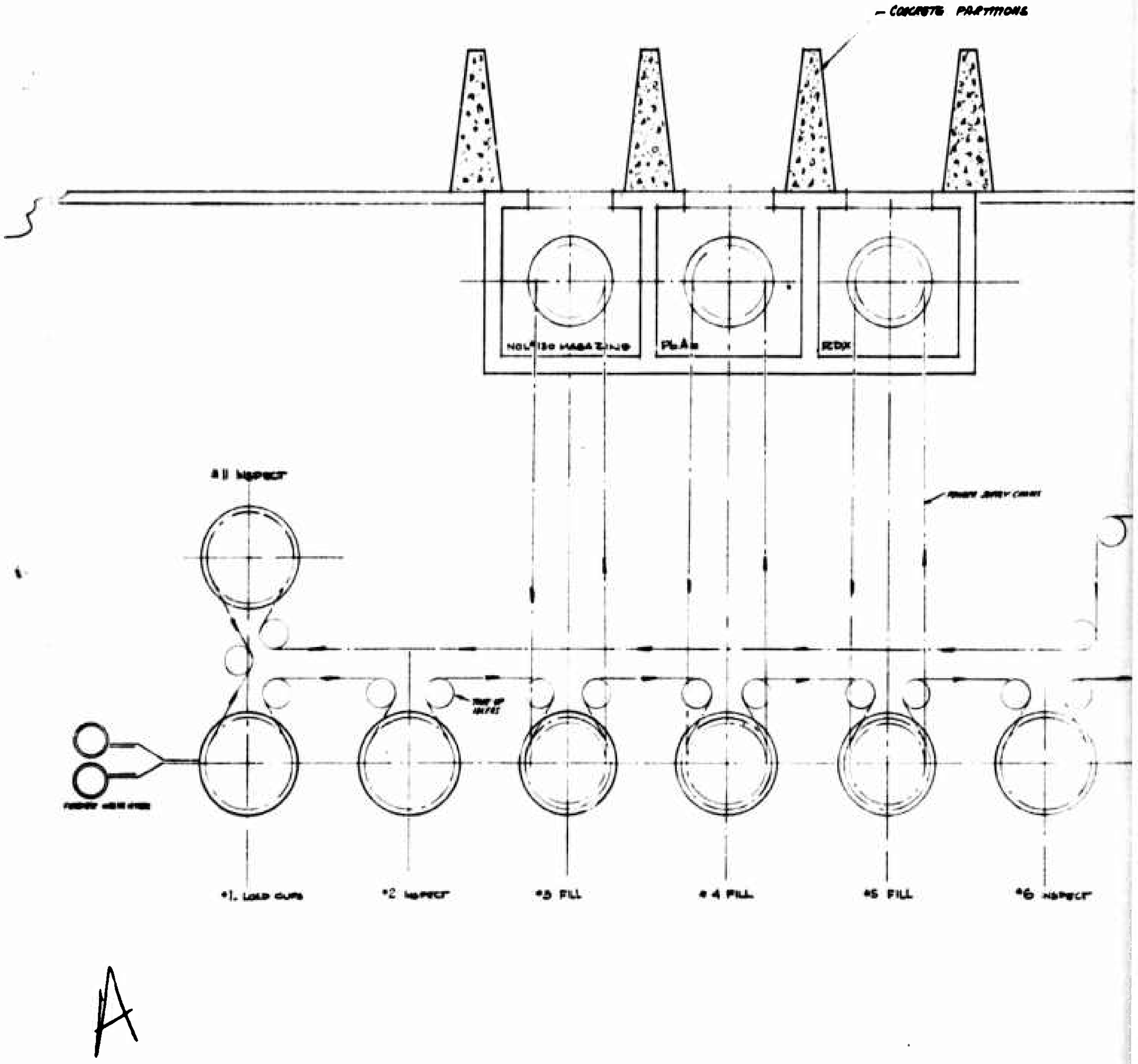
The three inspection turrets will check -

a) Presence and orientation of cup (turret # 2)

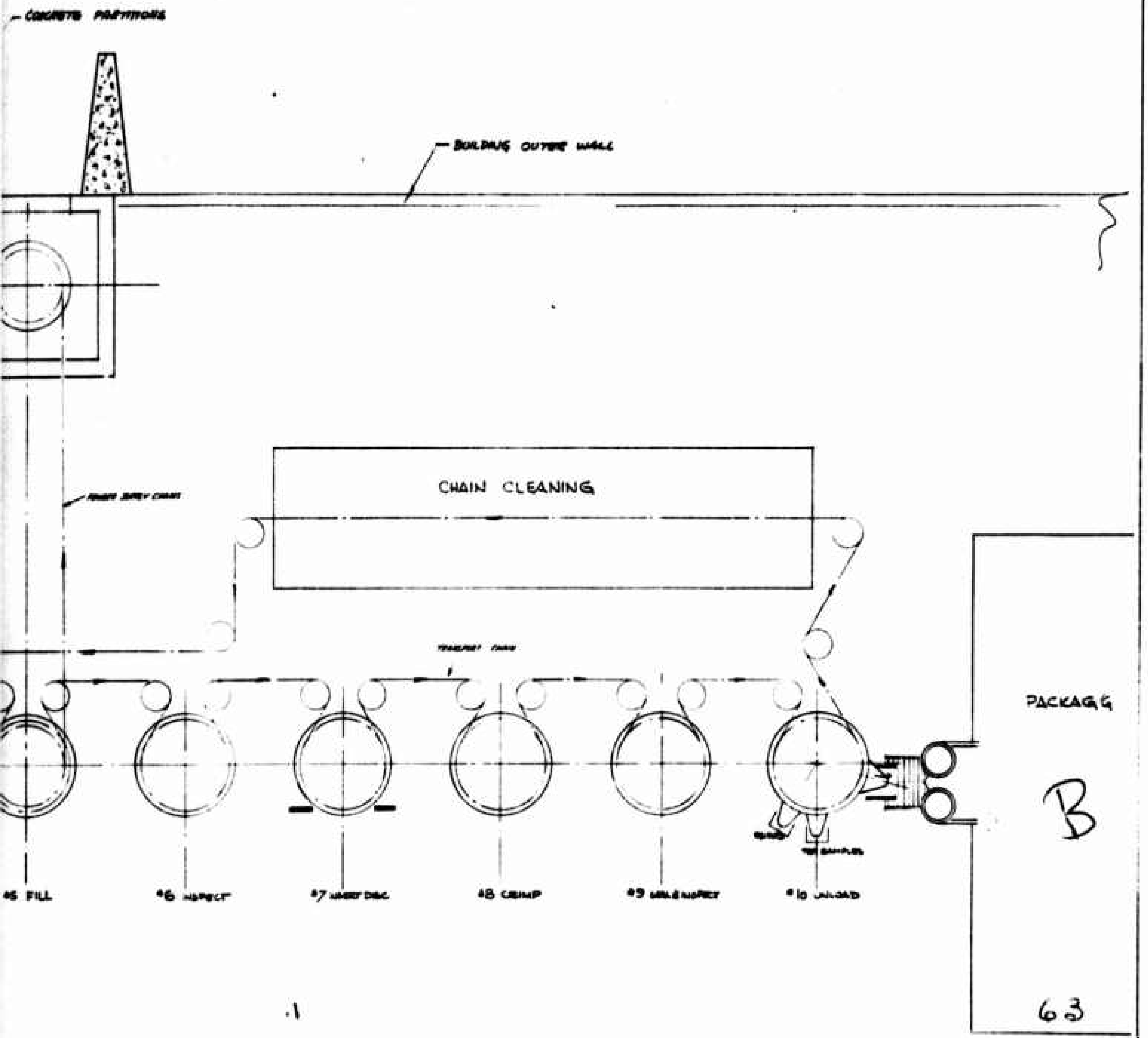
b) Height of powder increments (turret # 6)

c) Removal of all detonators (turret # 11)

In all three cases, probes connected to L. V. D. T. (Linear Variable Displacement Transformer) gages are used to perform the task. The detection of a defective part will either shut down the line (turret #11) or will be entered in a central memory thus inhibiting the actual filling operation (turret # 2) and rejecting the parts at the unloading turret (turrets # 2 and # 6). Sealant inspection will take place on the sealant applicating turret. It is an optical device reacting to color. It will also monitor the presence of a disc in each detonator. These will duplicate turrets already satisfactorily built by FMC for Frankford Arsenal to inspect primers inserted in cartridges at the rate of 1200 per minute.



— CONCRETE PARTITIONS
PbA
RDX
#1 LOAD CUPS
#2 INSPECT
#3 FILL
#4 FILL
#5 FILL
#6 INSPECT
A



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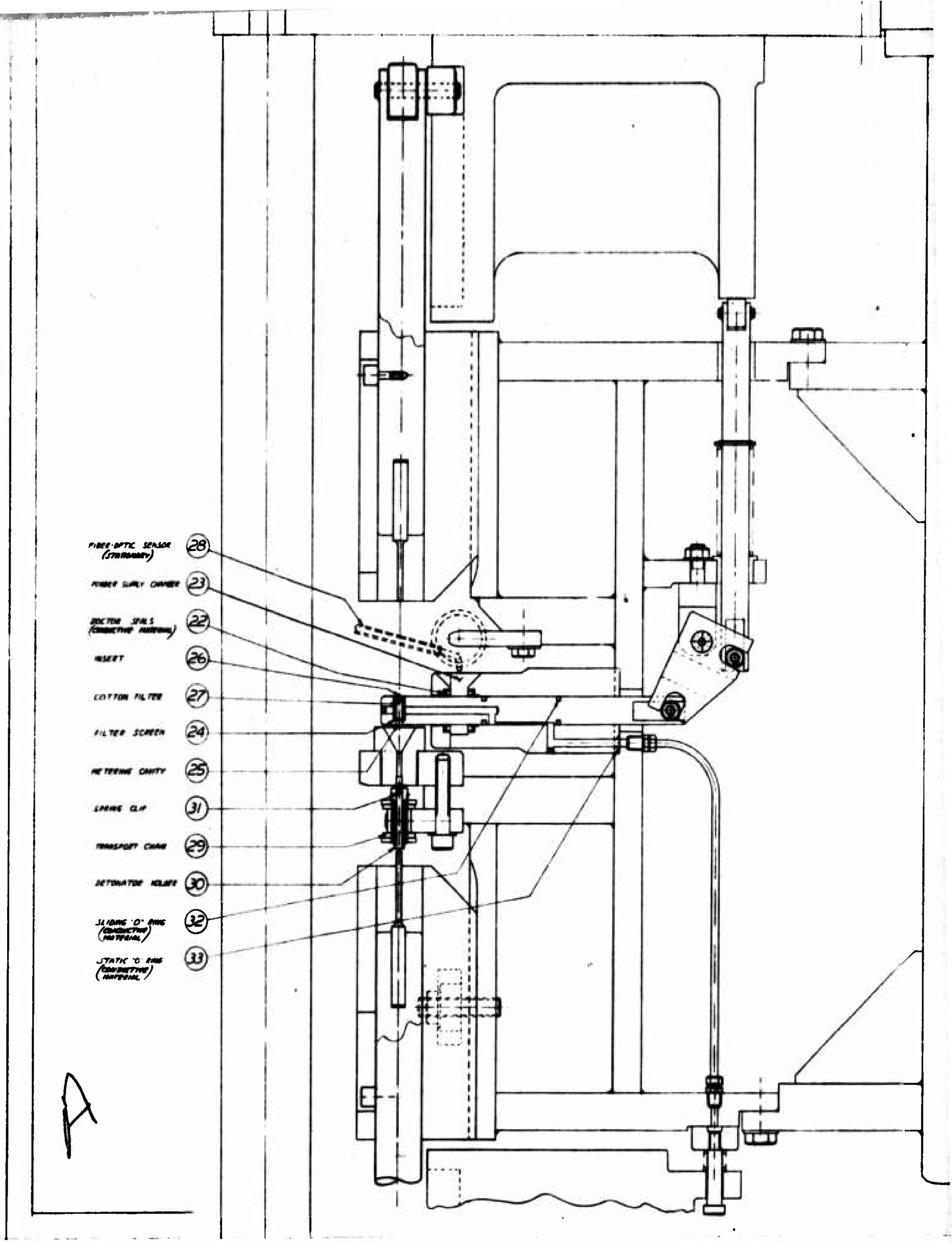
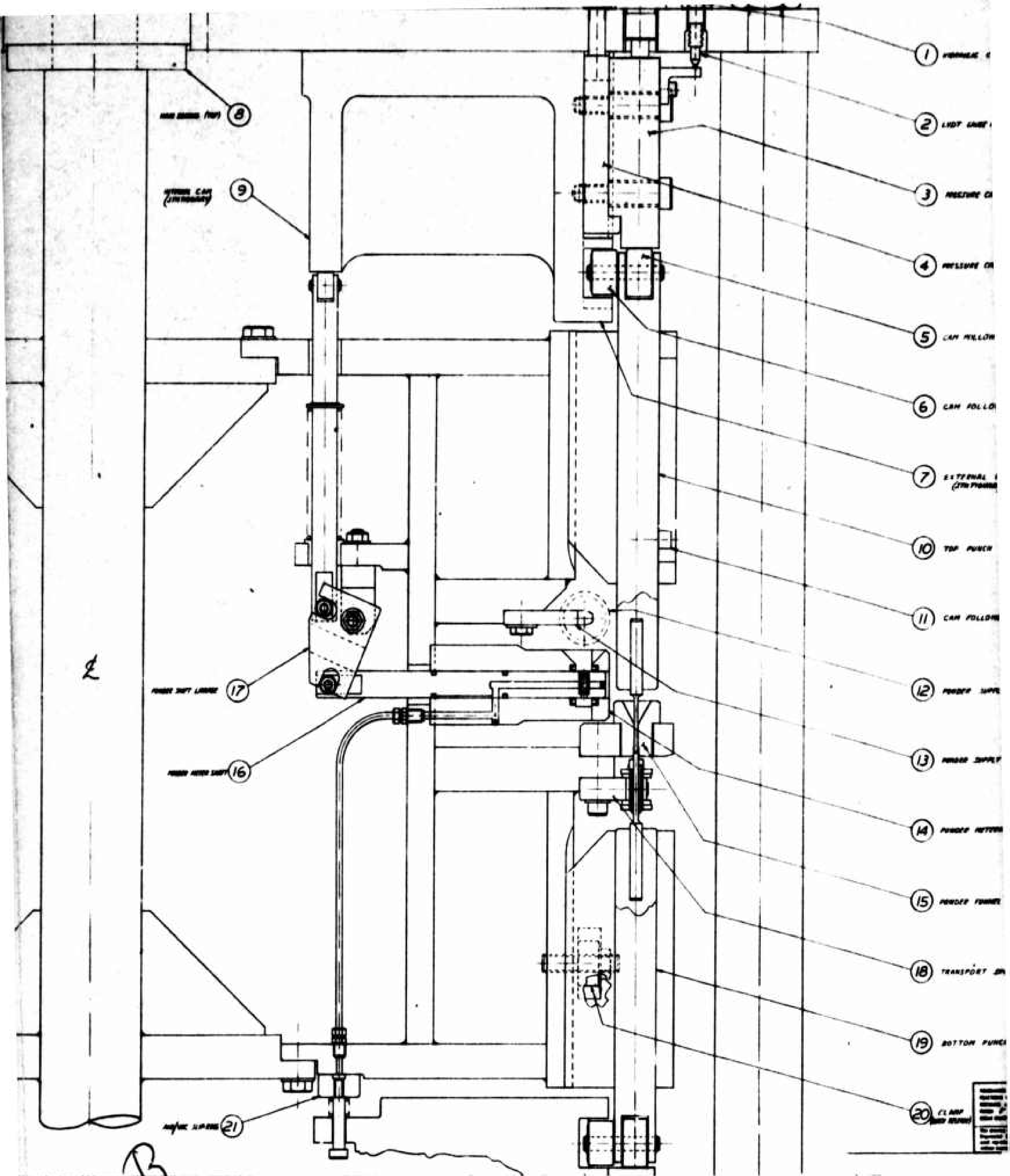
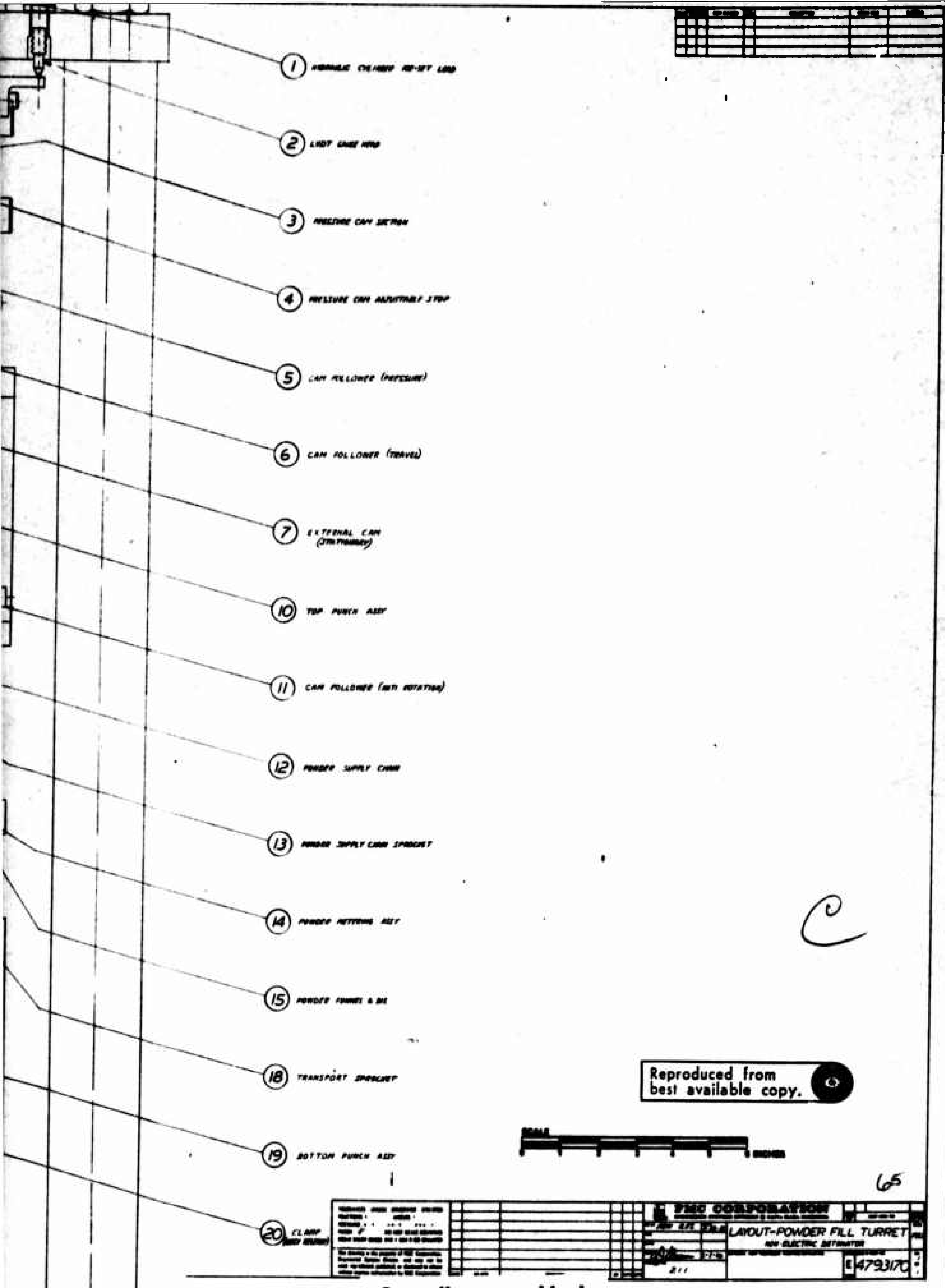
NON ELECTRIC DETONATOR FILLING LINE. B'DG LAY OUT

211

5100207


FIBER-OPTIC SENSOR (STATIONARY) 28
POWDER SUPPLY CHAMBER 23
DOCTOR SEALS (CONDUCTIVE MATERIAL) 22
INSERT 26
COTTON FILTER 27
FILTER SCREEN 24
METERING CAVITY 25
SPRING CLIP 31
TRANSPORT CHAIN 29
DETONATOR HOLDER 30
SLIDING "O" RING (CONDUCTIVE MATERIAL) 32
STATIC "O" RING (CONDUCTIVE MATERIAL) 33


1
2
3
4
5 CAM
6 CAM
7 EXTERNAL
8
9
10 TOP PUNCH
11 CAM
12 POWDER
13
14 POWDER
15 POWDER
16
17
18 TRANSPORT
19 BOTTOM
20 CLAMP
21
B



29?

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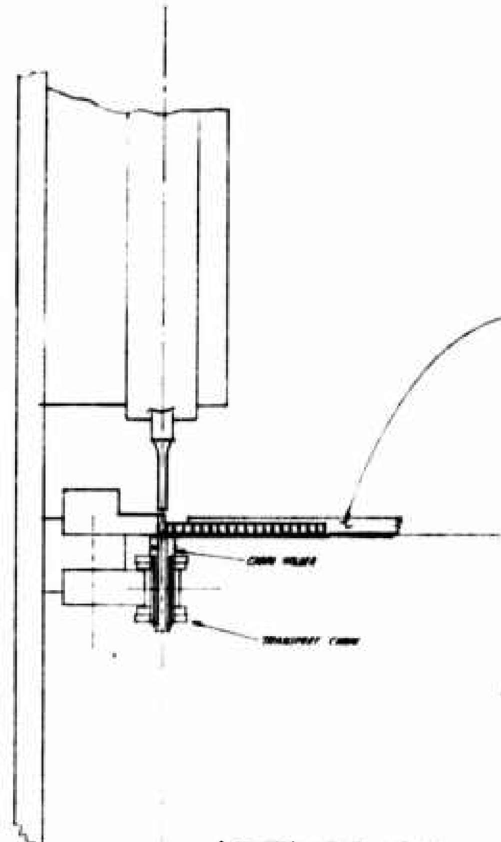
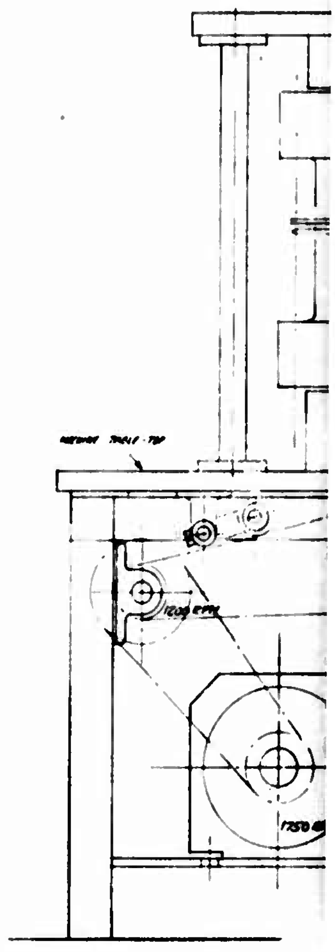
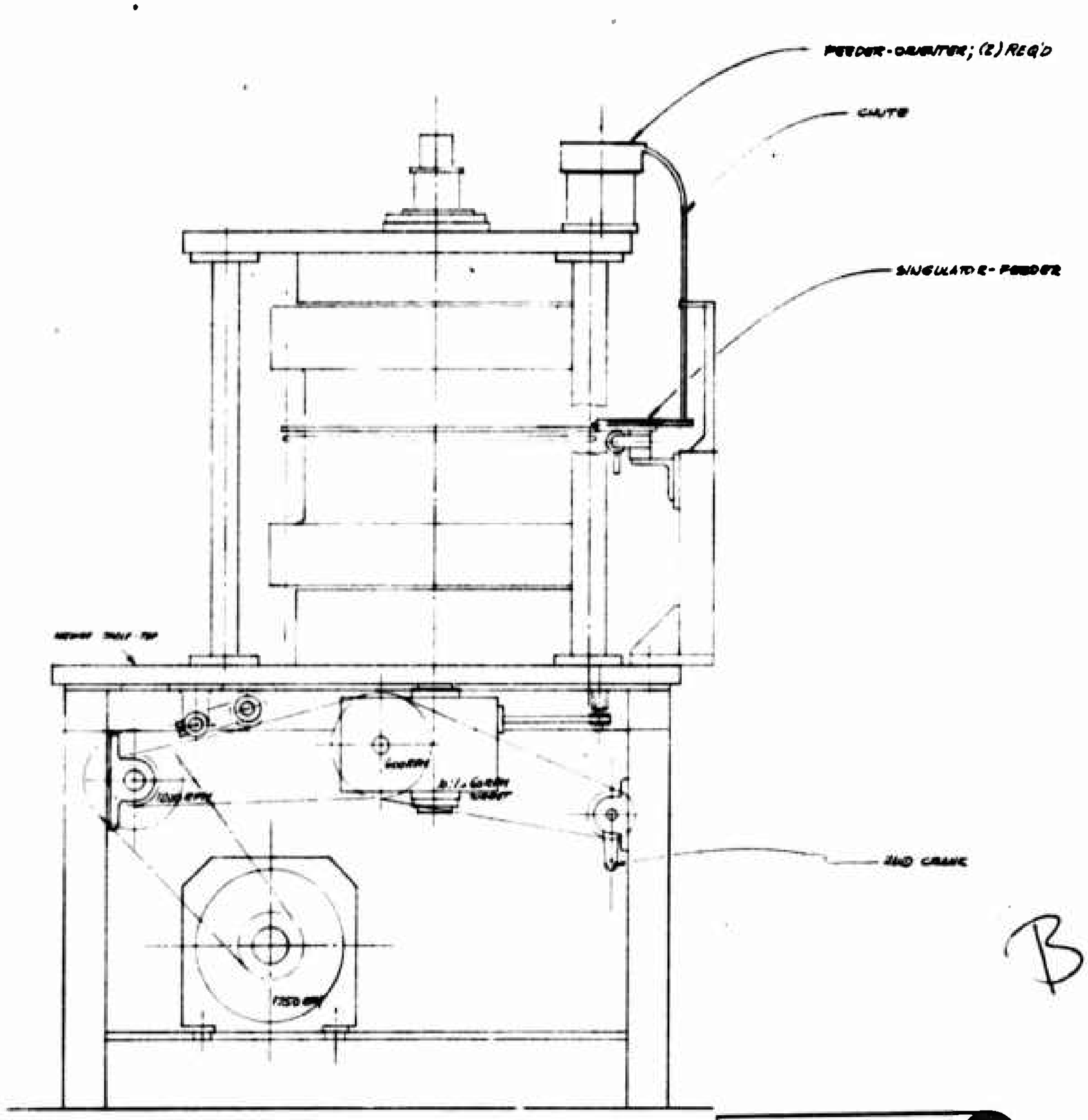


CUP TRANSFER DETAIL





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NON ELECTRIC DETONATOR CUP LOADING TURRET

211

5100208

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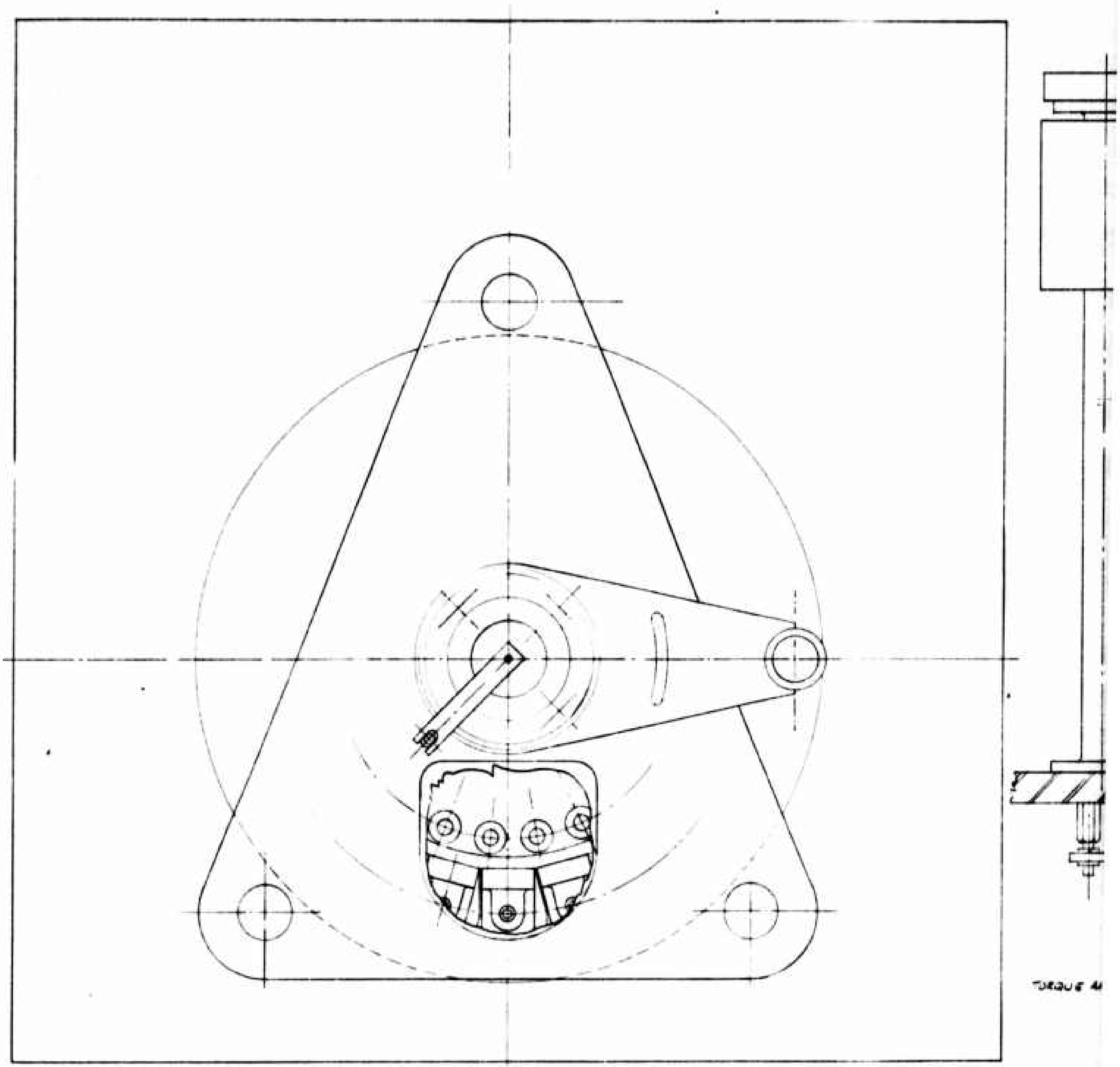

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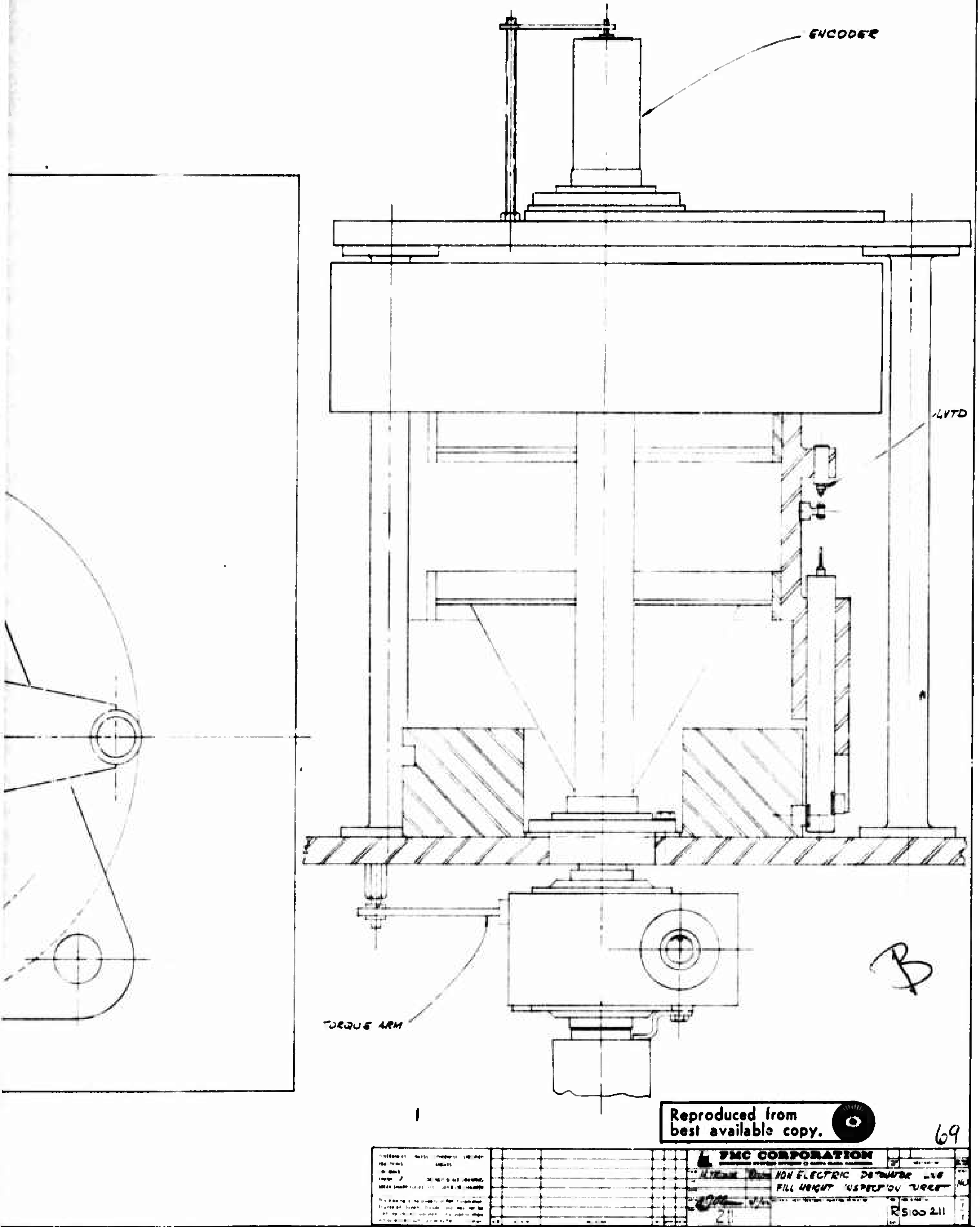

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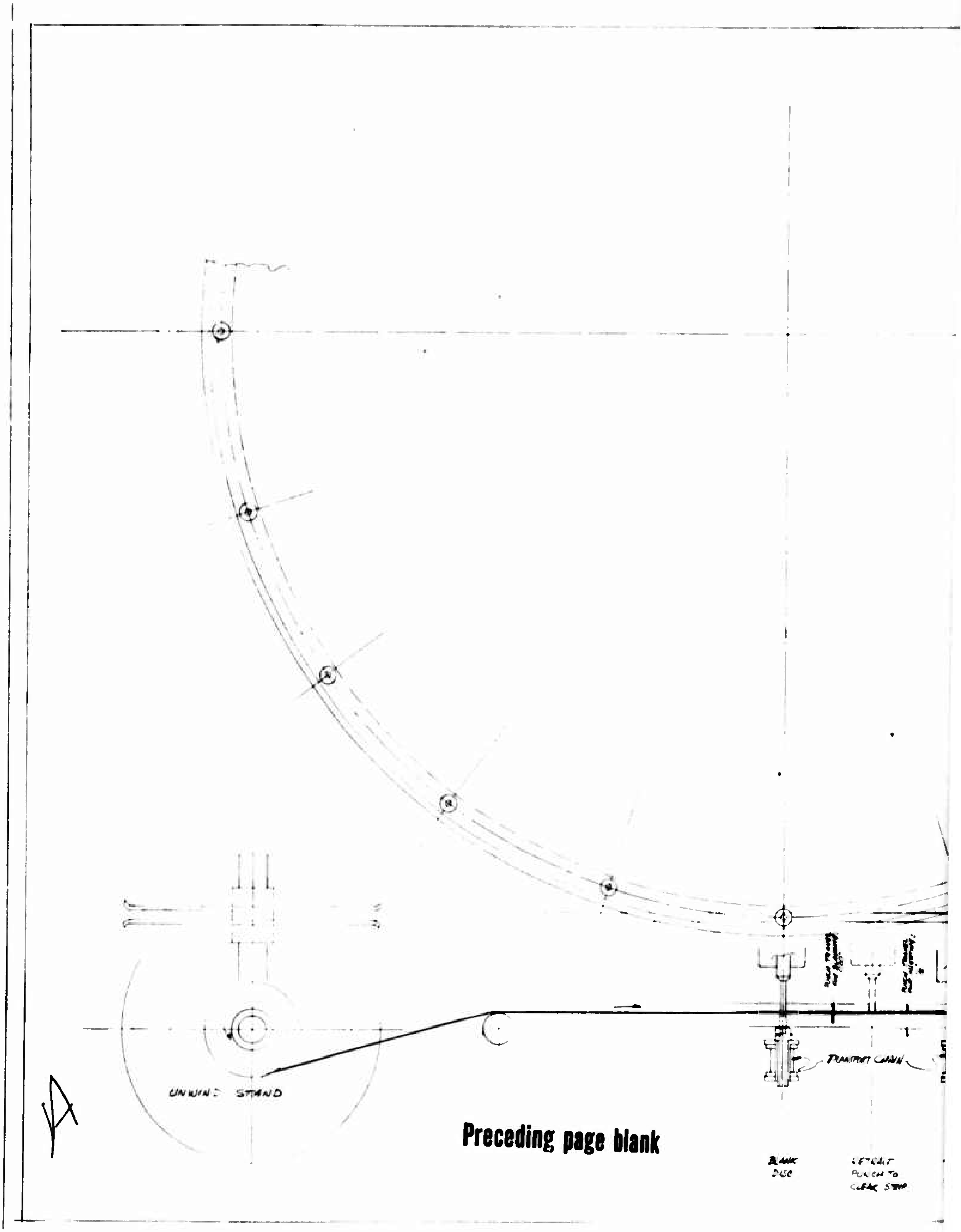

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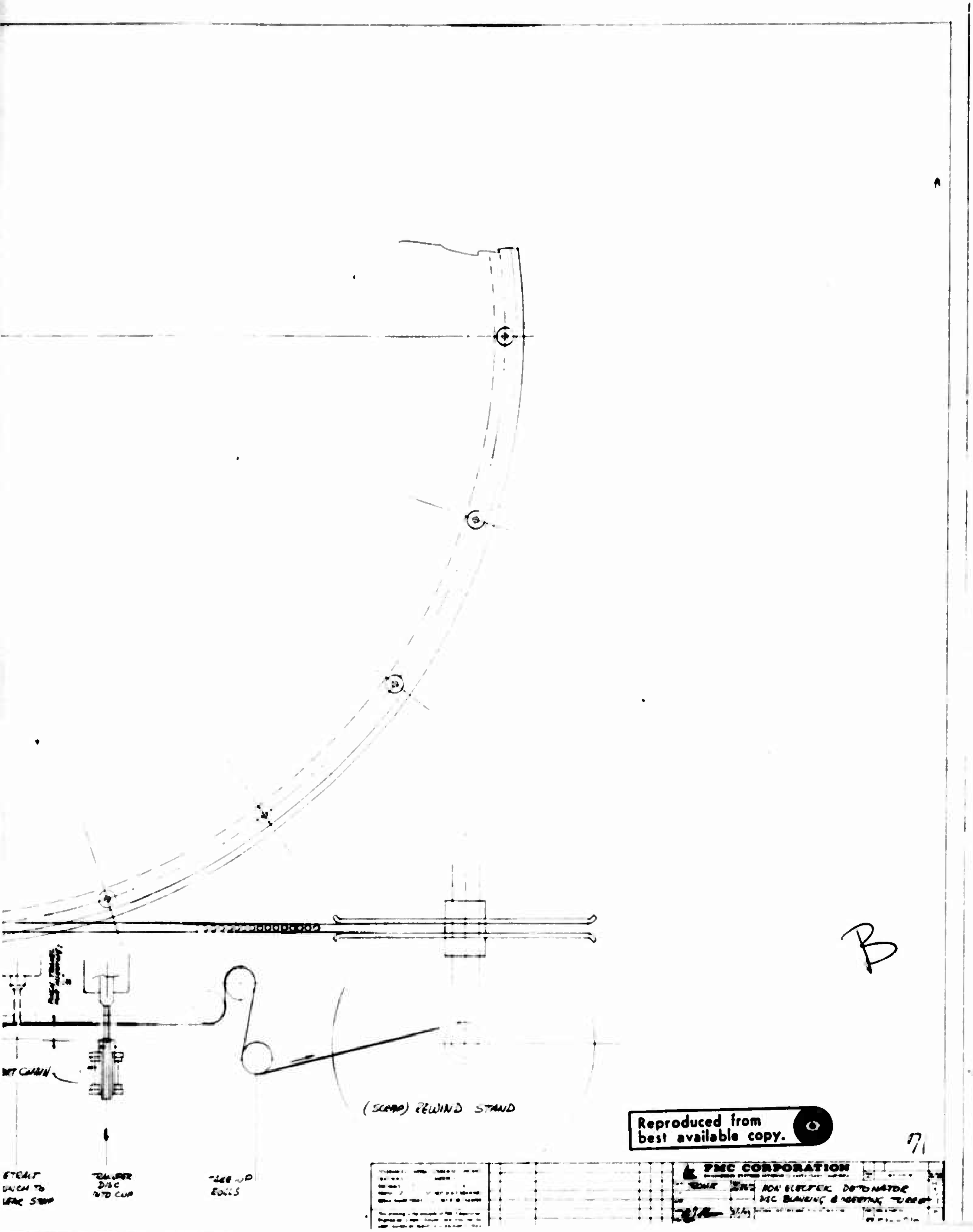
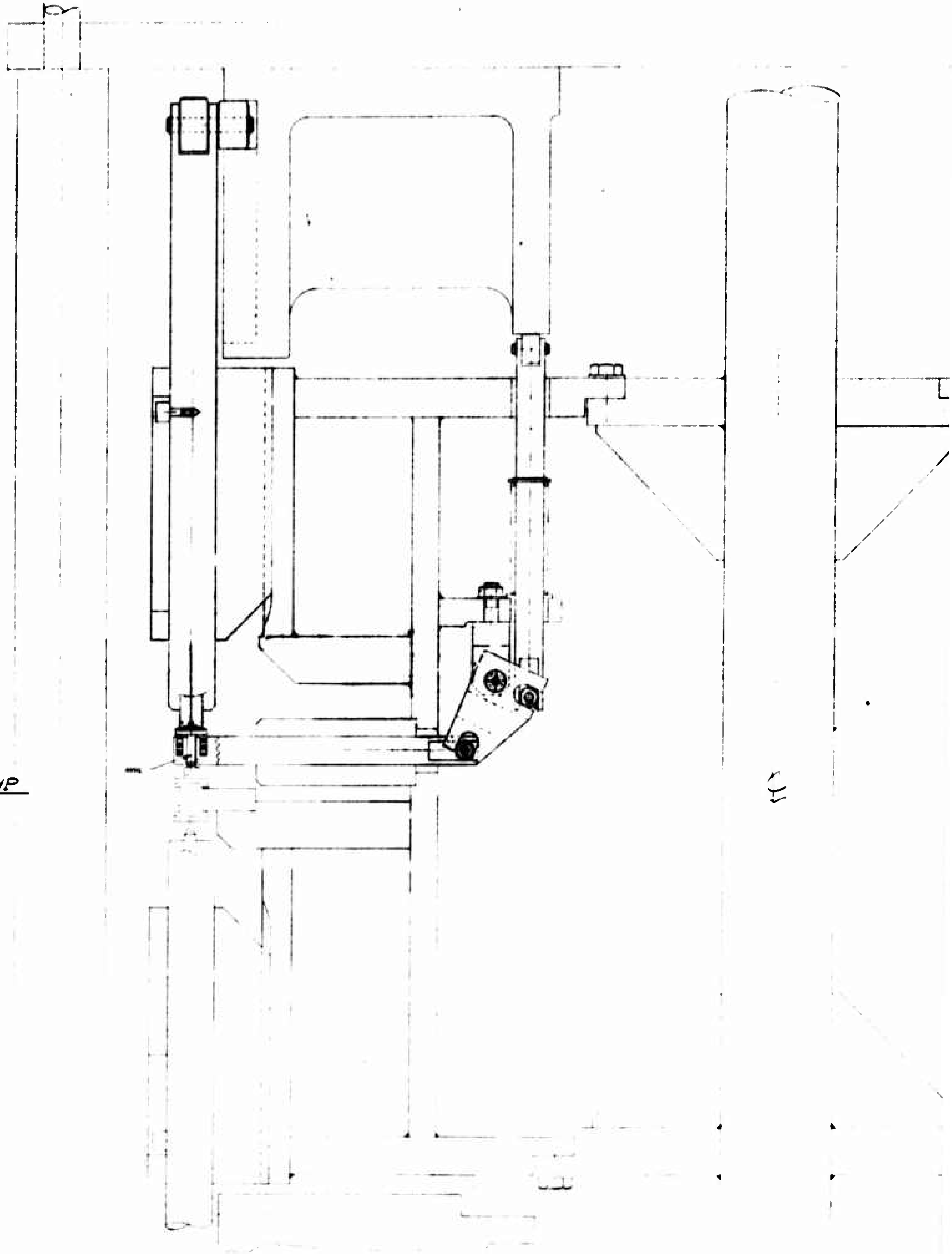
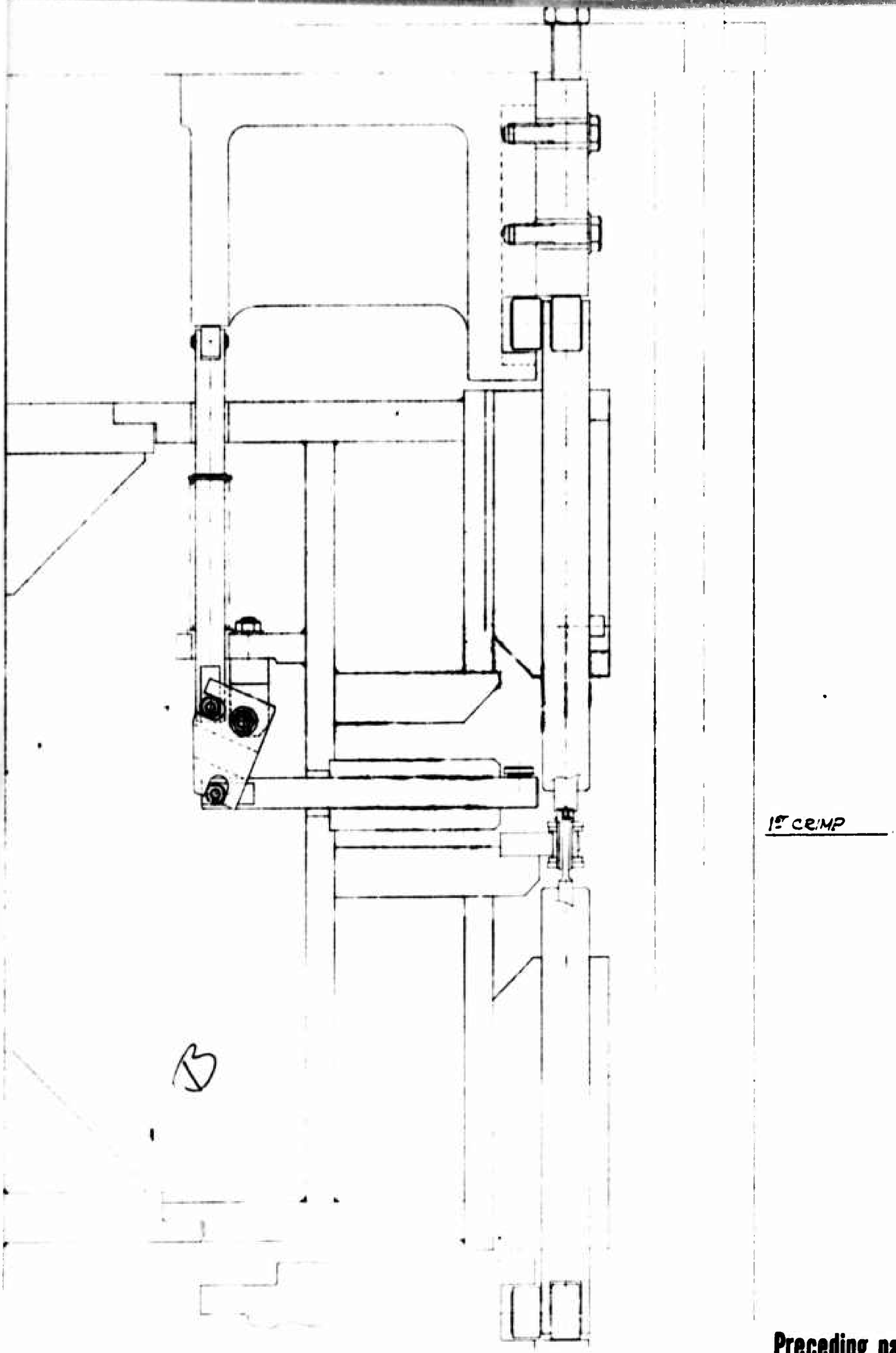


(SCRAP) REWIND STAND
TRANSFER DISC INTO CUP
TAKE UP ROLLS
B
71
FMC CORPORATION
NON ELECTRIC DETONATOR DISC BLANKING & INSERTING TURRET



2ND CRIMP



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Disc Blanking and Inserting Turret (Drawing R-5100210)

In addition to this basic turret (upper and lower punches, dies) the disc blanking operation requires an unwind and rewind stand mounted outside the rotating turret. The discing material strip, in large coils, runs from the unwind stand tangentially across the turret. The punctured strip (scrap) is collected at the rewind stand. Quick change provisions can be provided for new tapes.

As the chain engages the sprocket on the turret, the lower punches move up and locate the cup holders in line with the blanking dies inserted in the dial directly above the chain and the upper punches. At the place where the strip's center line is tangent to the dial's (and chain's) pitch circumference, the actual blanking occurs: The upper punch moves down about .020 in., barely engages the die and retracts. The blanked disc is left in the die. As a result of the minuteness of the stroke the operation could be performed in about one millisecond. However, this time will be increased so that the amount the strip has to travel with the dial due to punch engagement, equals the indexing pitch (about 1/4"). Some 15° turret rotation later, the upper punch comes down again and pushes the disc all the way through die into the detonator on top of the three powder increments.

Crimping Turret (Drawing R-5100209)

Two crimping operations are performed here. In addition to the upper and lower punch assemblies and the chain sprocket, this turret is equipped with a radially moving shuttle similar to the powder metering shaft on the filling turrets. The lower punch enters the detonator cup holder, locates it accurately and then raises the cup 1/32 in order to expose the edge for crimping. During both crimping operations, the lower punch remains at that level to support the cup. The upper punch comes down directly and performs the first crimp. Its face is shaped so as to bend the cup's lip at 45°.

The punch retracts high enough to make room for the shuttle to be moved in place between the punch and the work piece. This shuttle has a hardened, spring loaded anvil. As the upper punch moves downward for the second crimp, it pushes the anvil against the cup thus flatening out the pre-crimped edge. This procedure eliminates the need for two crimping turrets.

Sealant Applicating Turret (Drawing R-5100213)

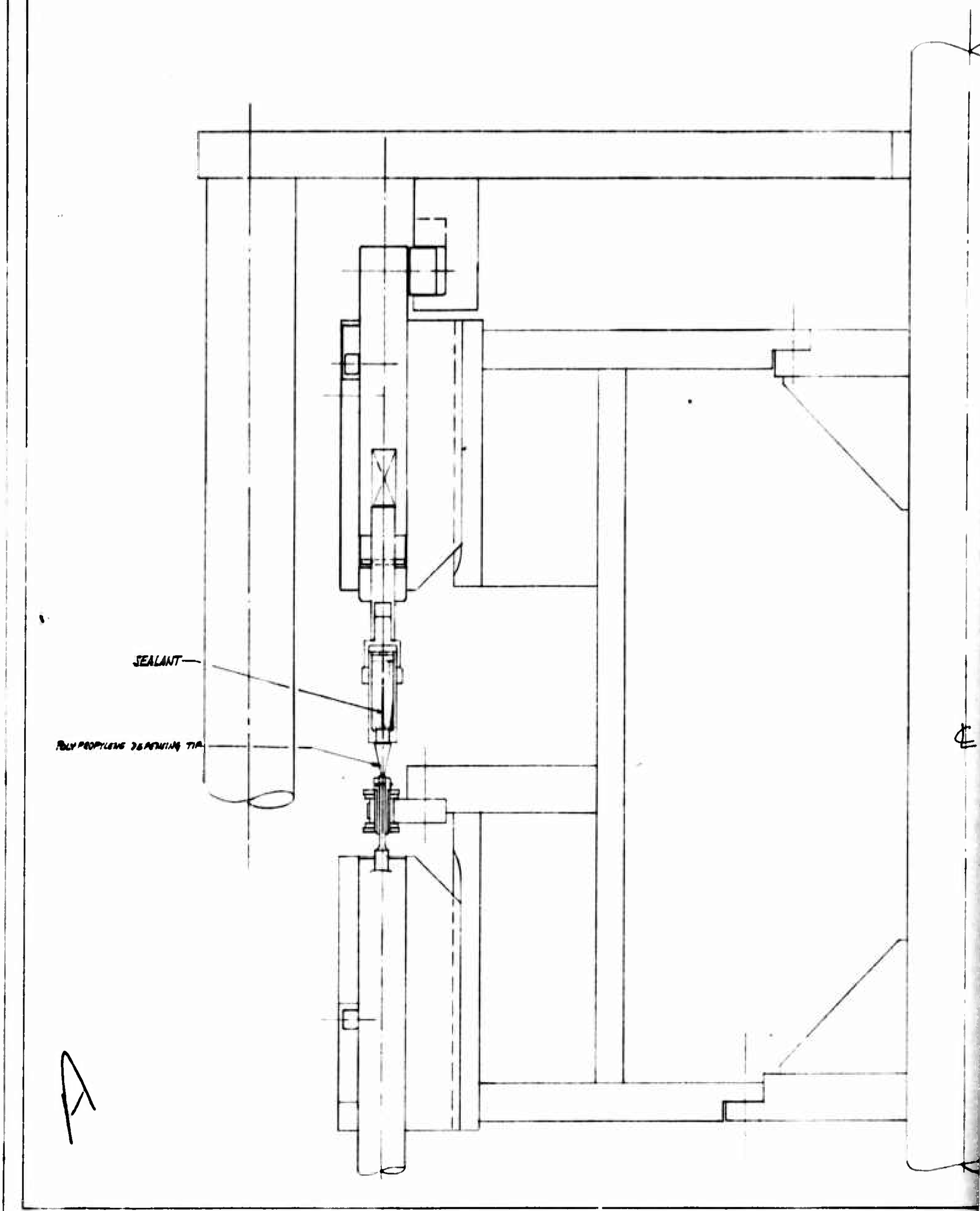
This turret consists of the similar basic elements, i. e., sprocket, upper and lower punches. The lower punch locates, raises and supports the work part for the sealant application. The upper punch is equipped with a special polypropylene dabbing tip, and a lacquer container. Container and tip form a sealed unit. The lacquer cannot dry out and thus will not clog. The tip is commercially available. It is designed to meter out the same amount of liquid each time its plunger is depressed independently of pressure and time. The lacquer container is large enough to hold a day's supply of sealant.

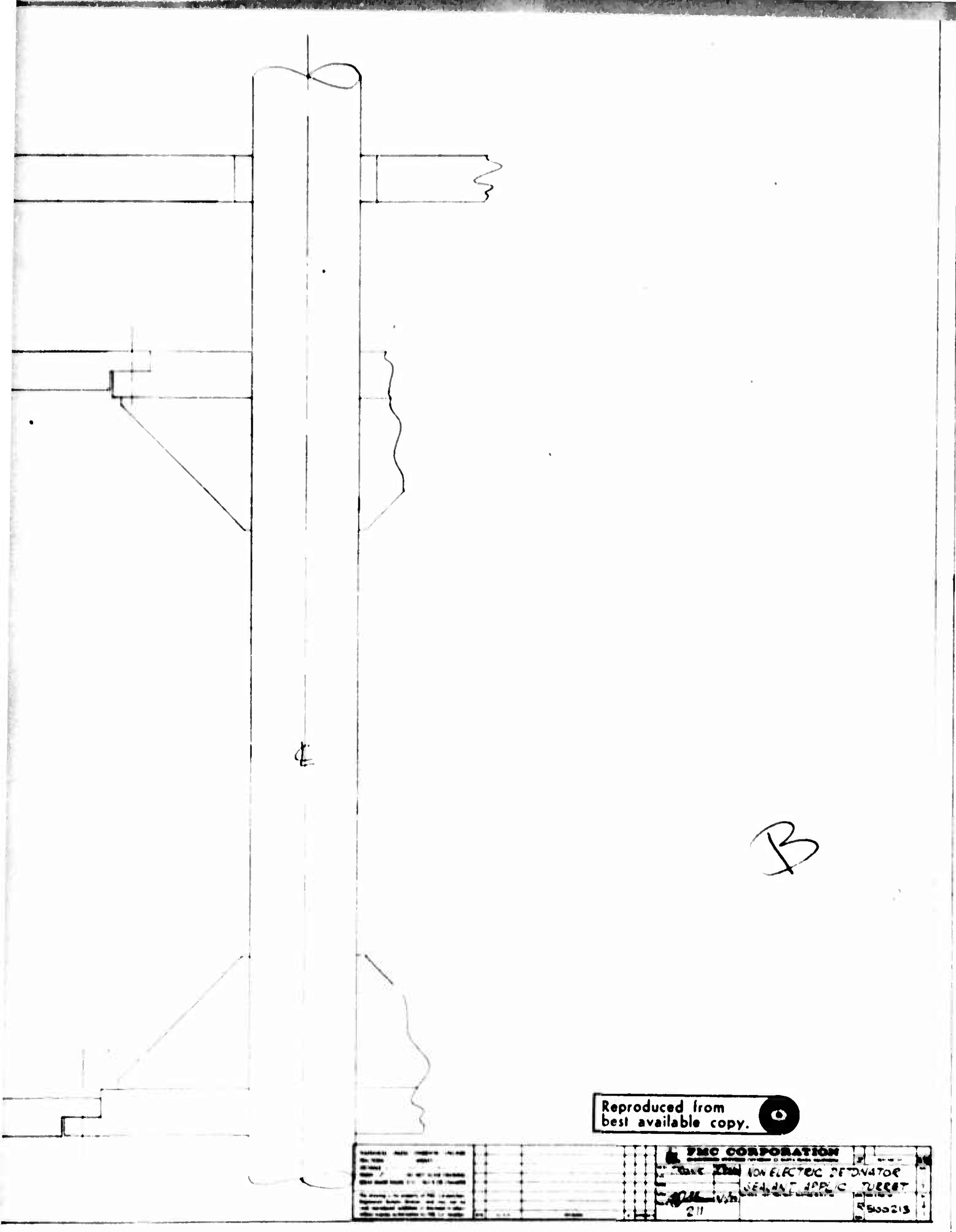
This concept is similar to a machine developed, built, and satisfactorily operating in FMC's shop for the sealing of primers with lacquer at a rate of 1, 200 per minute.

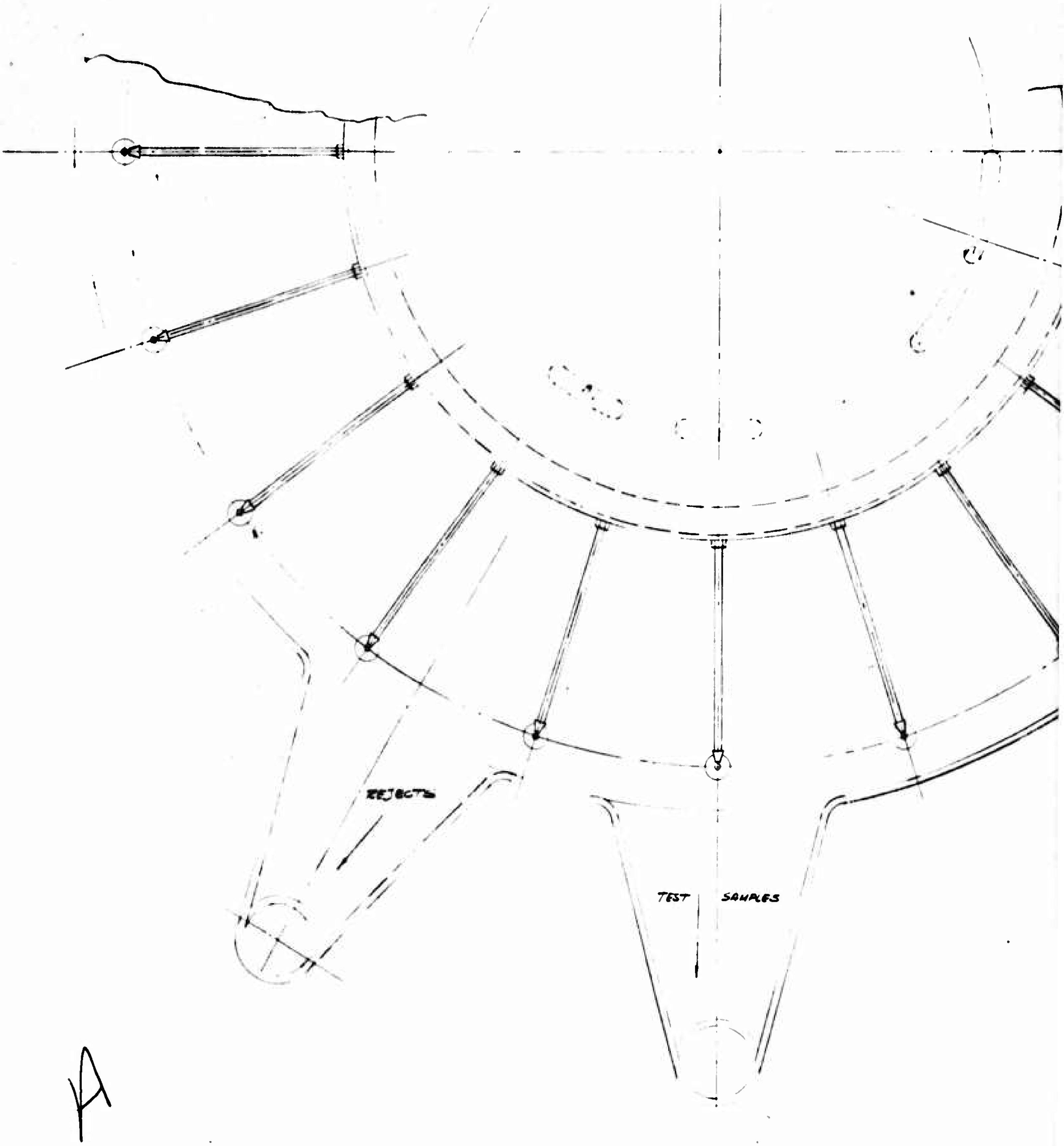
Unloading Turret (Drawing R-5100214)

All parts, good and bad, are carried to this turret on the conveyor. Parts are pushed out of their seats and ejected at either one of the three exits for:

1) Rejects
2) Test samples
3) Good detonators


SEALANT
POLYPROPYLENE DISPENSING TIP
A
℄


℄
B
FMC CORPORATION
NON ELECTRIC DETONATOR
SEALANT APPLIC TURRET
211
5100213



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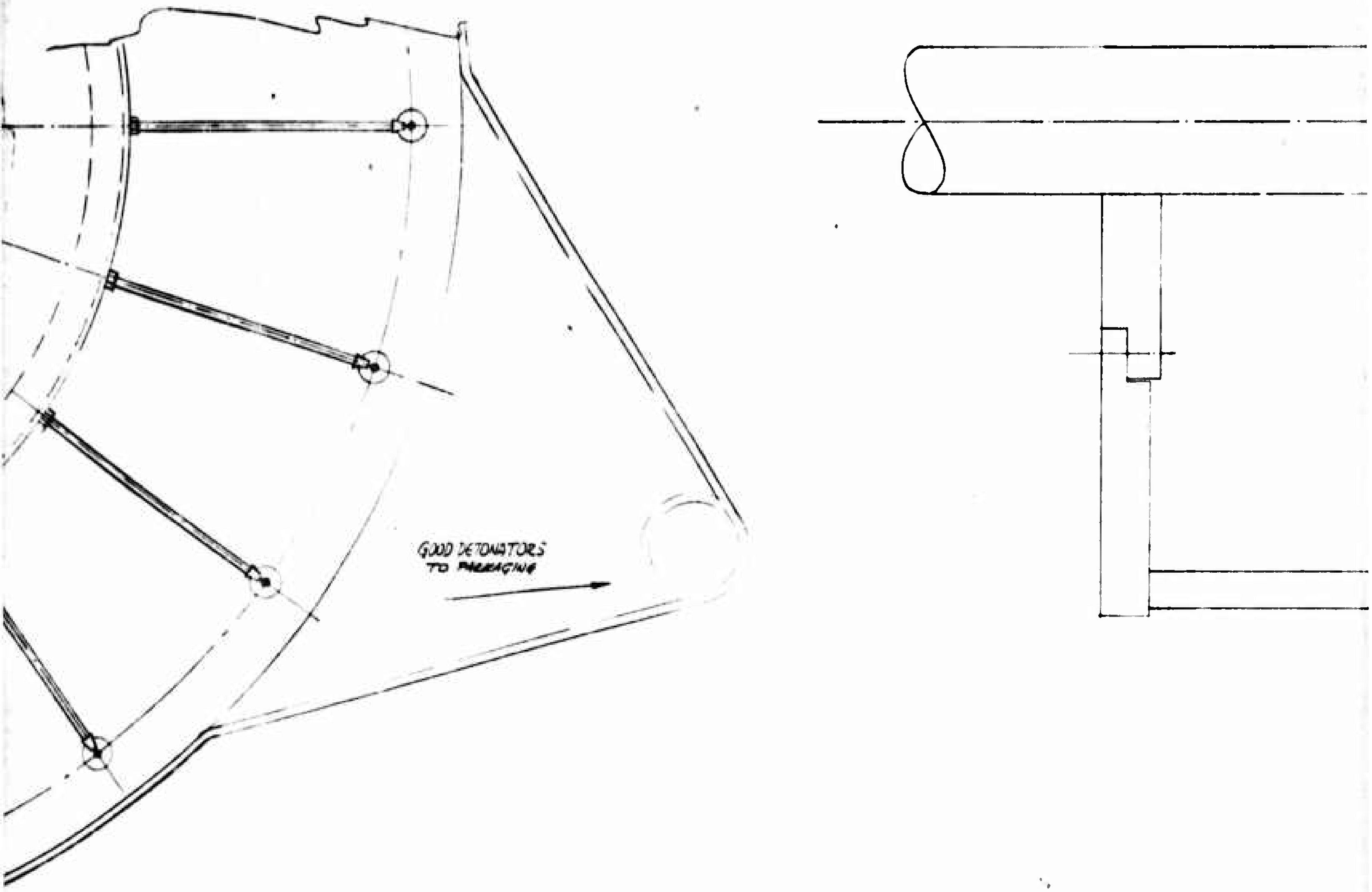

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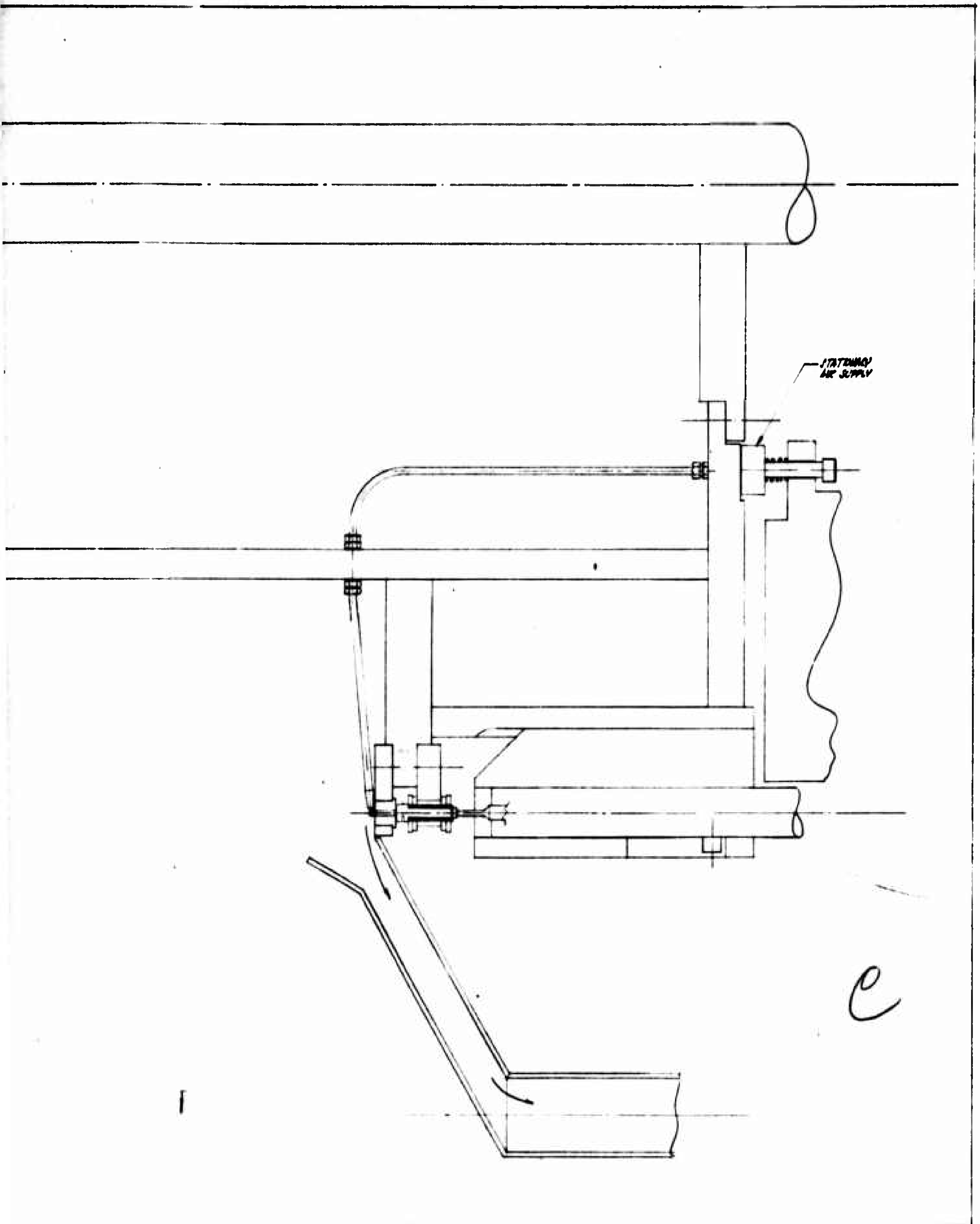


FMC CORPORATION

NON ELECTRIC DETONATOR UNLOADING TURRET

The turret has a sprocket, 20 lower punch sets and 20 air nozzles connected to zonal and controllable air supply very similar to the one designed for the filling turrets. The lower punch pushes the finished detonator <u>almost</u> completely out of its holder on the chain. The reason for keeping the cup lightly seated is to compensate for the centrifugal force.

Times pulses triggered by the central memory or by the programmed sampling pattern will release an air jet whenever a recognized faulty detonator or one selected for testing reaches the reject or the sample exits respectively. The third nozzle remains activated as the parts pass in front of the packaging input station and all remaining detonators are ejected there. A conveyor belt forwards them into a singulator-orienter; from there they are fed into a customized tablet packaging machine (LAKSO Model 49 or similar).

<u>Powder Supply Chain (Drawing R-5100212)</u>

In order to keep the filling turrets consistently supplied with powder while maintaining the total amount of explosives below the permissible maximum, the supply system is based on refilling each chamber on the turrets once every 20 revolutions with the equivalent of 20 increments of each powder charge. Taking into account an additional 20% to keep the chambers from being completely empty at any time, we obtain the following figures for the resupply charge weight.

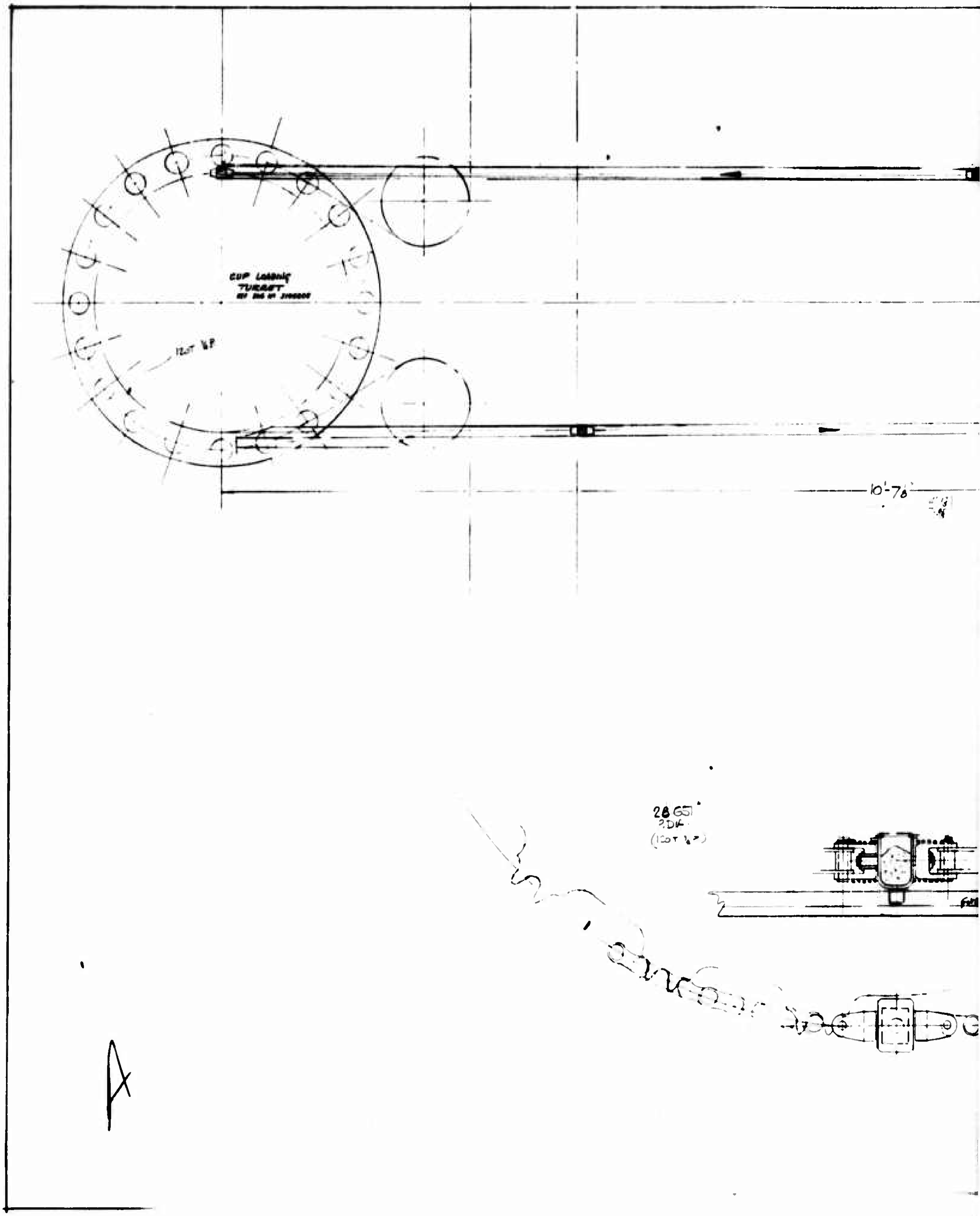
NOL # 130 - $\frac{.015g \times 20 \times 20}{2}$ 20% of .015 x 20 x 20 4.2 gram

Lead Azide: $\frac{.062 \times 20 \times 20}{2}$ 20% of .062 x 20 .17.4 gram

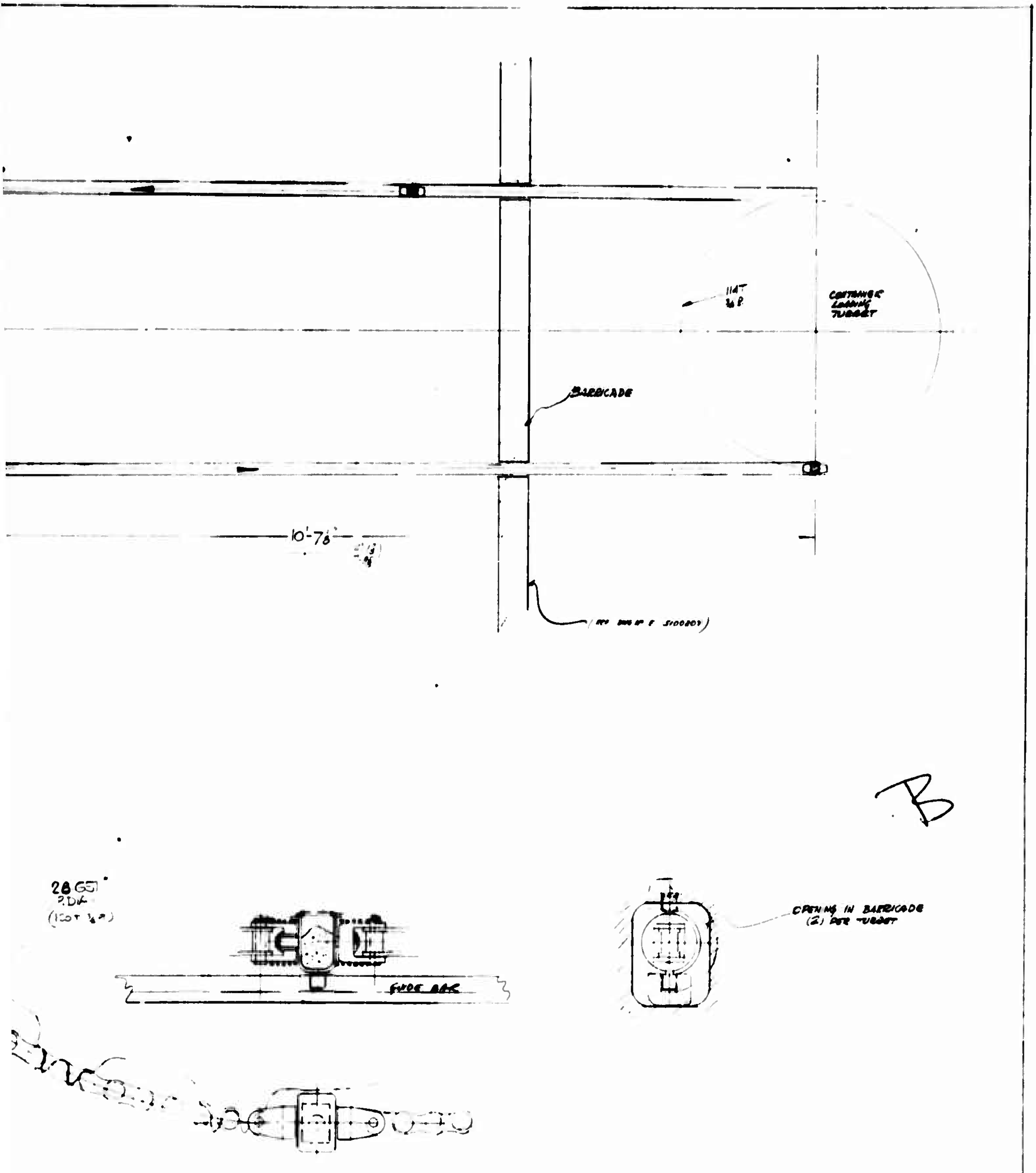
RDX: $\frac{.019 \times 20 \times 20}{2}$ 20% of .015 x 20 x 20 4.8 gram

In the plan view, the conveyors run perpendicularly to the main chain between the turrets and the main powder supply rooms, behind barricades. They consist of standard #60 roller chain loops and cylindrical containers accurately spaced. The latter are equipped with trunions allowing them to rotate about the chain's axis, and cam followers engagine a stationary guide bar. The container's opening is facing up for most part of its travel, but as it engages the sprocket on the turret, a spring mechanism is released and causes the container to pivot briskly 180° over the loading chamber. As the container leaves the turret, it engages the guide bar again. The latter has a semi-cylindrical portion with a helical groove. There, the container is turned "face-up" again and its springs are rewound.

The container is filled in a loading turret (behind the barricade) by a metering shuttle arrangement similar to the one described above (R-4793170). The filling sequence, on both ends, is determined by sprocket size, chain length and spacing between containers. With the "overfill" built in, the powder height sensor (item #28, drawing E-4793170) will occasionally cause the container not to be filled in the supply room.



CUP LOADING
TURRET
10'-7"
A



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FMC CORPORATION

NON ELECTRIC DETONATOR LINE POWDER SUPPLY CONVEYOR

POWDER FILL TURRET

III DESCRIPTION OF EQUIPMENT AND OPERATION

Drawing E4793170

General

The Powder Fill Turret shown in the above drawing is identical in construction for the Lead Azide, NOL 130 and RDX charges, the only variation between these turrets being in their powder charge quantities achieved by a different powder metering shaft embodying the appropriate metering cavity.

The same basic turret construction is used in the crimping operation, and a similar design for the sealant application, closure insert and inspection station allows maximum economy of design and manufacture.

All turrets are driven by a common line shaft through a gearbox under the vertical shaft of each turret, thus relieving the transport chain of any drive function. This is the same construction satisfactorily used on the primer insert machine (1200 per minute) built for Frankford Arsenal.

Construction

The turret is composed of a central shaft on which is mounted an integral inner and outer drum. The drum shaft runs in flange bearings (8) in a frame consisting of the machine table-top and a top plate supported by columns. The turret rotates at 60 RPM and has 20 stations around its periphery equally spaced on a 100" circumference. Each station is composed of a top and bottom punch assembly (10 and 19), both of which are secured by quick-release clamps (20) and are located by axially machined grooves on the outer drum, thus assuring accurate punch alignment. In addition, each station has a consolidated die with a powder funnel (15) and also a powder metering assembly (16) mounted by similar quick release clamps on the inner drum.

The air passages through this assembly are sealed by sliding "O" rings (32) and static "O" ring (33), the doctoring seals (22) of conductive material in the powder supply chamber (23) being lip seals to minimize friction and to provide a clean powder cut-off when doctoring. The bore around the metering shaft (16) in this area is relieved so that at no time is the powder subjected to a "steel-on-steel" condition, this lessening the possibility of detonating the powder through friction. (The maximum linear speed of the powder shaft as it moves radially in and out is 1.08ft/sec., this further reducing the danger of detonation, being below the maximum acceptable speed of 1.2 ft/sec. for a lead azide steel-on-steel condition, according to a study by Cadillac Plastics provided us by Picatinny Arsenal).

The tip of the metering shaft carries a fine screen (24) consisting of .006" dia. conical holes spaced at .022" centers, this screen held in place above the metering cavity (25) by an insert (26) filled with a cotton filter material (27) which prevents the ingress of powder to the vacuum system. The top of the insert is highly polished to provide a reflective surface for a fiber optic photo-reflective scanning sensor (28) which is used for an overfill powder level detection in the powder supply chamber. The self-cleaning of the polished surface as it moves through the doctor seals assures reflectivity.

A 100 tooth 1" pitch sprocket (18) is mounted on the outer drum, this carrying the transport chain (drawing No. 5100207) from the turret to turret. A 120 tooth 3/4" pitch sprocket (13) also mounted on the outer drum carries the powder supply chain (12) (Drawing No. R5100212) from the powder supply hopper behind a barricade.

The punches are moved mechanically by means of cam followers (6) which are operated by a stationary external cam (7) which provides only the approach and retraction of the punches, the heavy consolidation pressure with very short stroke being achieved by the larger cam follower (5) mounted on the thrust centerline of the punches. This final pressure is applied by a separate short section of cam (3) mounted on the external cam close to one of the columns, and free to move over a small vertical distance. It is held in its consolidation position against an adjustable stop (4) by a hydraulic cylinder (1) with its pressure pre-set to provide the required consolidation force. Mounted on this cam section is a bracket which operates a L. V. D. T. precision gage head (2), signals from which indicate the condition of the fill height.

The lower part of the turret is fitted with a stationary air/vacuum slip ring (21) (Drawing No. B5100234 - Sheet 1) which supplies the alternate vacuum and air pressure requirements for accurate metering of powder in the powder metering assemblies rotating above. The slip ring also embodies a means of rapidly alternating the air pressure/ vacuum in the powder supply chamber of the powder shaft assembly to break up any "bridging" which may occur there. We have proven this principle by experiment in the laboratory.

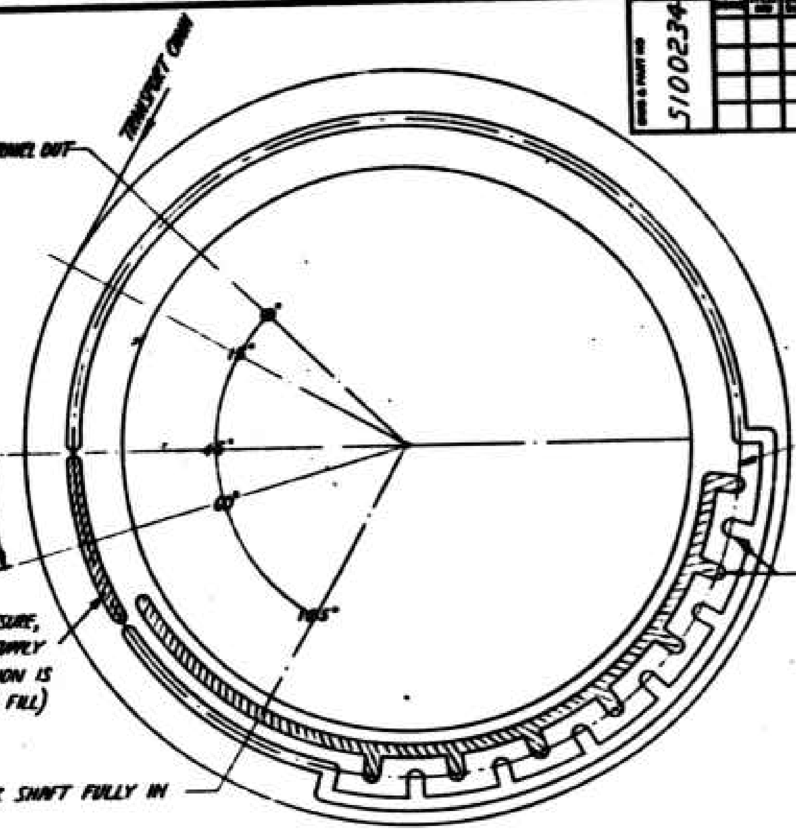
An internal cam (19) operates the powder meter shaft (16) through a linkage (17) mounted on the inside of the inner drum.

Operation

On entering the turret, the transport chain(29) carrying empty detonator cups is roughly located on the pitch line of the punches which is the same as that of the sprocket. Every 5" pitch of the hollow pin chain carries a small floating detonator holder (30) the bore of which accepts the outside dia. of the detonator. A small "D" shaped spring clip (31) prevents the detonator from falling through but allows the lower punch to pass by freely. The lower punch starts to rise and enters the radiused mouth at the bottom of the detonator holder. Continued upward movement of the bottom punch, the outside dia of which is the same as that of the detonator, now precisely locates the floating holder, finally transferring the detonator into the die (15) above.

The extended metering shaft (16) carrying a doctored and metered charge held in its metering cavity (25) by vacuum now has its vacuum abruptly changed to air pressure, and the powder charge is dumped directly into the powder funnel of the die. The metering shaft now retracts radially inward and its air pressure reverts to vacuum ready to pick up another charge after entering the powder chamber (23) of the powder metering assembly through the doctoring seal.

The top punch now descends by means of cam follower (6) which brings it close to its consolidation position. The stationary external cam track (7) now opens in slight clearance around the cam follower (6) and the pressure cam follower (5) engages cam section (3) which continues the downward movement to final consolidation position. As this cam section is held in position by a pre-set hydraulic cylinder pressure (1) the consolidation pressure in the detonator is automatically assured, the only variable being the height of consolidation. This height is monitored via a precision L. V. D. T. gage head (2) the output signals of which indicate an acceptable or unacceptable condition. These signals are stored in a shift register for subsequent rejection.



NOTE :- THE ALTERNATING AIR/VAC PULSES ARE NECESSARY ONLY FOR NOL 130 POWDER TO AGITATE AND SETTLE IT DOWN AND TO PREVENT "BRIDGING" IN ITS SUPPLY CHAMBER

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± ANGLES ±
DECIMALS .X=± , .XX=± , .XXX=±
FINISH √ DO NOT SCALE DRAWING
BREAK SHARP EDGES .010 ±.005 X OR CHAMFER

SYM	REVISION		BY	APPD	DATE
Ø	2H 31-1-102			4	3-3-73

FMC CORPORATION
ENGINEERED SYSTEMS DIVISION, SANTA CLARA, CALIFORNIA

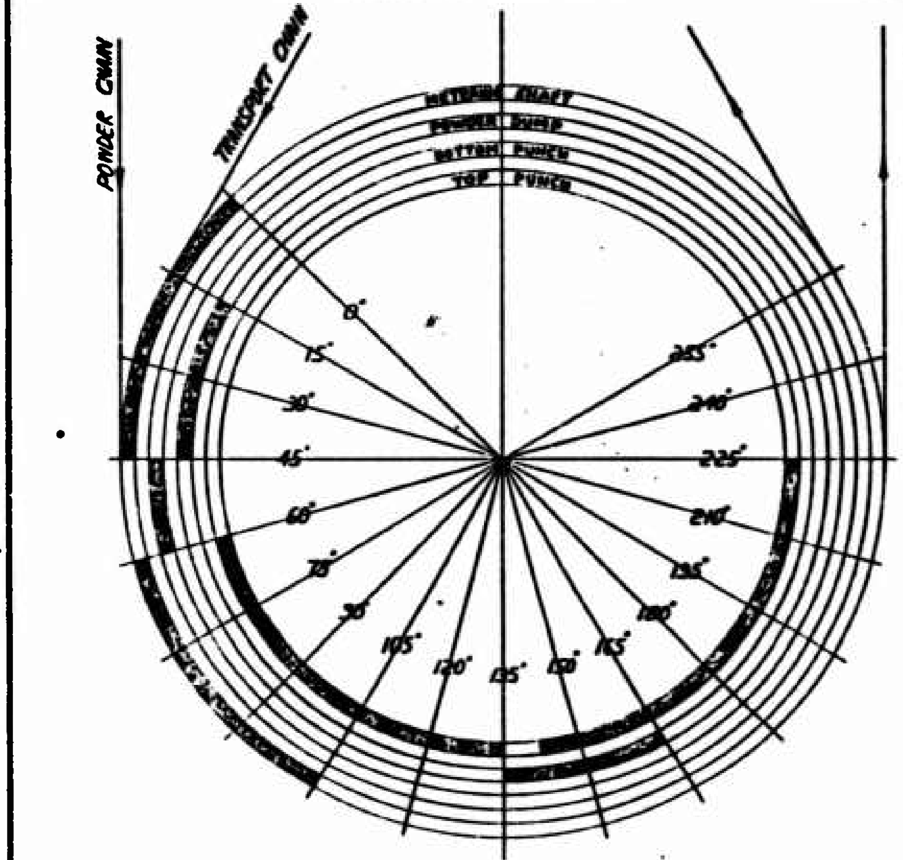
DRAWN: R. ILES — DATE: 2-28-73
APPD: A. J. Allen — 3-1-73
PROJECT NO: 211

TIMING LAYOUT - AIR/VAC SLIP-RING.
FILL TURRET
NON ELECTRIC DETONATOR

NEXT ASSY NO: E 5100859
SIZE: B
DWG & PART NO: 5100234
SCALE: NONE
SH 1 OF 2

DWG & PART NO: 5100234 (SH 1 OF 2)

S1



CAM SEQUENCE OF OPERATIONS

0° — METERING SHAFT STARTS OUTWARD TRAVEL

15° { TRANSPORT CHAIN ENTERS SPROCKET; BOTTOM PUNCH STARTS TO RISE }

45° { POWDER CHAIN ENTERS SPROCKET; METERING SHAFT FINISHES OUTWARD TRAVEL; BOTTOM PUNCH IS FULLY RAISED; POWDER STARTS TO BE DUMPED }

60° { POWDER FINISHES DUMP; METERING SHAFT STARTS INWARD TRAVEL; TOP PUNCH STARTS TO DESCEND }

105° — METERING SHAFT FINISHES INWARD TRAVEL

135° { TOP PUNCH REACHES CONSOLIDATION POSITION. BOTTOM PUNCH STARTS TO DESCEND }

140° — TOP PUNCH STARTS TO DESCEND AGAIN (TO RELOAD CHAIN HOLDER)

150° — TOP PUNCH REACHES BOTTOM OF STROKE AND IMMEDIATELY STARTS TO RISE AGAIN

165° — BOTTOM PUNCH IS FULLY LOWERED

225° { TOP PUNCH IS FULLY RAISED; POWDER CHAIN LEAVES SPROCKET }

255° — TRANSPORT CHAIN LEAVES SPROCKET

DWG & PART NO. 5100234

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS ± ANGLES ±
DECIMALS .X=± .XX=± .XXX=±
FINISH √ DO NOT SCALE DRAWING
BREAK SHARP EDGES .010 ±.005 R OR CHAMFER

SYM	EO/ECN	REVISIONS	BY	APPD	DATE
Ⓐ	2413M502	MF			4/23/73

FMC CORPORATION
ENGINEERED SYSTEMS DIVISION ☐ SANTA CLARA, CALIFORNIA

DR BY K. ILES DATE JUNE 3 '72
APPD 3/1/73
PROJ 211

TIMING LAYOUT - CAM
FILL TURRET
NON-ELECTRIC DETONATOR

NEXT ASSY NO E 5100233
SCALE NONE
SIZE B DWG & PART NO 5100234
SH 2 OF 2

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The bottom punch now starts to descend to its lowest position, and is immediately followed by a further short descent of the top punch which returns the detonator cup to its holder in the transport chain. The top punch now returns to its uppermost position and the transport chain leaves the turret for the next turret function.

No Cup-No Fill Protection

In the event that the previous inspection station detects the non-presence or improper position of a detonator cup, a fluidic logic shift register signal prevents the powder fill from taking place at the appropriate fill station. Although all the mechanical functions take place normally and the powder metering shaft advances to the powder tunnel with its metered charge ready for dumping, the dump is inhibited by changing the air pressure to vacuum in the section of the air/vac slip ring that causes the powder to dump. This is simply achieved by means of a fluidic interface 3 way change over valve connected to the slip-ring section, and even though mechanical valving still takes place on the slip ring when the appropriate fill station port reaches this position, no change of vacuum in the powder metering cavity occurs. The powder metering shaft merely returns the powder to the supply chamber and normal functioning is resumed.

Powder Level Detection - Powder Meter Assembly

The powder supply chain, drawing No. R5100212, and its function is described in detail, but the means for level detection in the supply chamber of the powder metering assembly is now described.

Since the turret is rotating and the level of powder must not be excessive, direct scanning of the powder level itself is desireable. Due to the dark nature of some powders, little light reflection is possible

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from the powder itself, thus making a simple optical scan impractical, or at least unreliable. However, the high polish of the top of the meter shaft insert (26) reflects light to a stationary photo-reflective fiber-optic pipe (28) at every pass of the powder meter assembly, this assuring the associated logic that the powder is below the level, and that operation is normal. If the powder level becomes too high, however, it will cover the shaft and prevent sufficient reflected light passing into the fiber-optic receiver pipe. The self cleaning action of the doctoring seals (22) continually present a reflective surface to the light pipe therefore, as long as the powder level does not cover the shaft. Since the powder supply chain is set to a slight over-fill condition, no powder starvation in the supply chamber should occur. However, if an insufficient amount of powder is deposited in the detonator cup due to chamber starvation for some reason, the L. V. D. T. gage head (2) would detect the improper height of the cam section (3) and singal accordingly.

IV DESCRIPTION

Powder Metering

Probably the most important function of the fill turrets is the accurate metering and powder delivery to the consolidation dies, therefore the major effort in jury rig and laboratory testing was devoted to this problem.

As the high production requirements of 1200 Fills/minute was considered too high to weigh each charge before consolidation, a volumetric metering approach was made. However, even tiny voids in such small quantities of powder in each charge would make a large percentage variation, therefore, emphasis was placed on methods of ensuring:

a. Each volume metered was free from voids.

b. Doctoring of the volume was consistent.

c. Discharge from the metering cavity was complete with no residual powder.

d. The weights of each charge remained consistent.

Drawing No. E473170 Item 14 shows the general arrangement of the method used for powder transfer to the dies and for its accurate metering. A jury rig test block similar to this was constructed shown in Figure 3, and various test metering shafts with differing metering cavities and filter arrangements made to determine the most acceptable configuration, these shafts shown in Figure 4.

An operator filling the powder supply chamber of the jury rig block is shown in Figure 5, and Figures 1 and 2 show the general

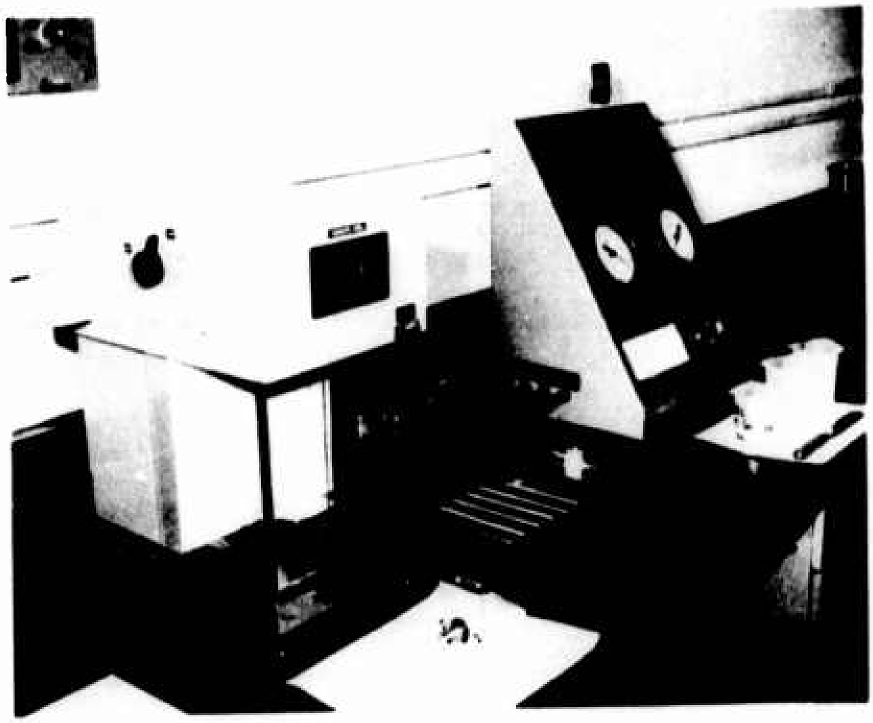


Figure 1

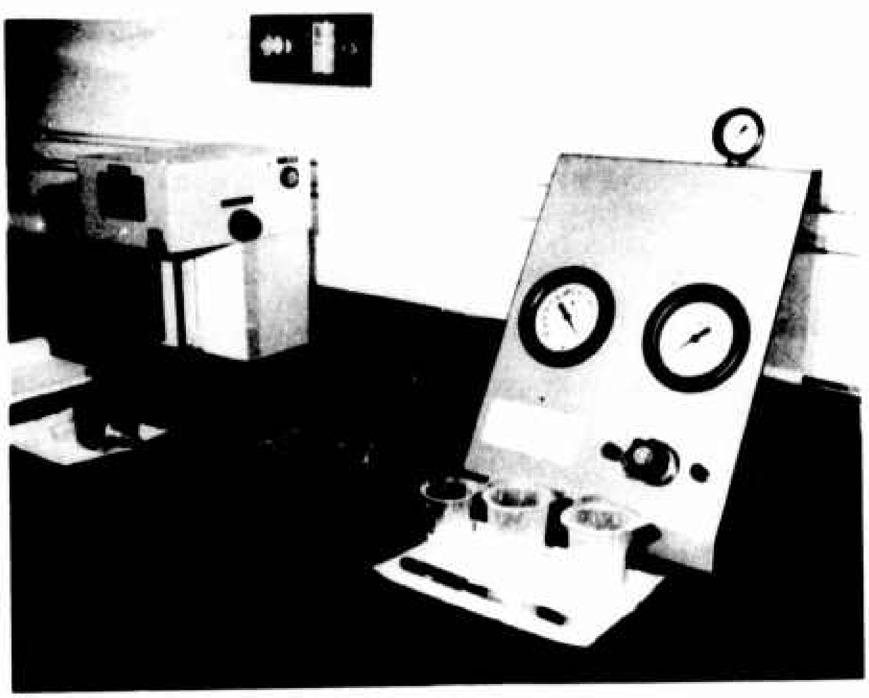


Figure 2

arrangement of the equipment used. This equipment was composed of a electric balance reading to 0.1 milligram, and a pneumatic consol with vacuum and pressure gages fitted with capability to infinitely adjust the vacuum and air/pressure outlet levels. These outlets were connected to a manually operated 3 way poppet valve which changed the vacuum to air pressure at a touch of the button, the output of this valve connected to the metering shaft is under test.

Three simulants were supplied: - lead azide, NOL 130, and RDX. The latter however, had extremely large granular particles which varied in size so much that the large variations in bulk density resulted in large weight variations. (See Sheet 2 & 3 of Appendix "A"). Permission was obtained to screen this through a No. 28 seive, whereupon results were satisfactorily. Baby talc was used as the simulant for NOL 130.

Several preliminary tests were conducted which showed up some unfavorable methods with results not warranting documentation. One of these (as an example, Sheet 1 - Appendix "A"), was conical dimple on top of the metering shaft which was rotated 180° after doctoring, which dumped the charge by gravity. Haphazard powder adherence to the cavity after dumping was the major cause of the poor results in this case.

Procedure was adopted as follows:

The powder metering shaft under test was fitted in the block which was then filled with a simulant. The shaft was then drawn into the supply chamber where the vacuum, normally on, sucked powder into

Figure 3

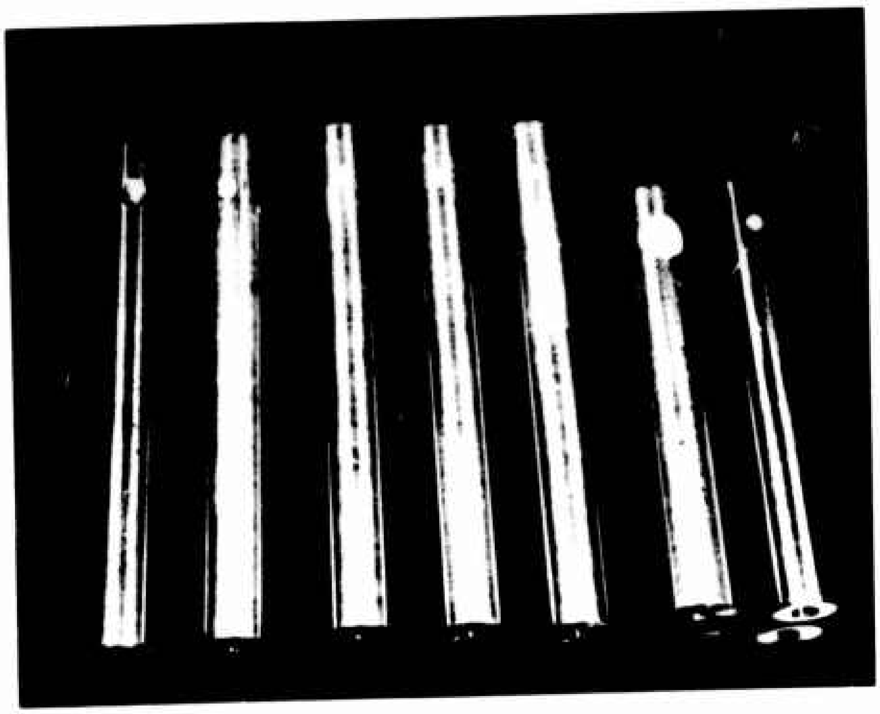


Figure 4

its metering cavity filling any voids. The shaft was then moved outward which doctored the powder off before emerging, the valve was then pressed which changed the vacuum to air pressure, this dumping the charge into a glass dish.

The charge was then weighed and the process repeated and the results tabulated. This procedure was repeated for all simulants.

Different metering shafts were tried, some of which were poor, the best of which appeared to be of the construction shown on Drawing No. E4793170. Pages 3 and 4 of Appendix "A" show results, with the coarse screen .010" dia. conical holes at .022" spacing being the most satisfactory, giving an average weight variation of:

± 1% for lead azide simulant.
± 1.2 % for NOL 130 simulant.
± 1.2 % for RDX simulant.

Observations

From the previous experiments, it was noted that the best results were achieved when:

a. The powder metering cavity was cylindrical, not conical.
b. The cavity should be highly polished.
c. Ejection air pulse was short and sharp, not sustained.
d. Vacuum level was 12" - 15" hg.
e. Air pressure approx. 15' P.S.I.

It was also noted that in the case of NOL 130 simulant (baby talc)

Figure 5

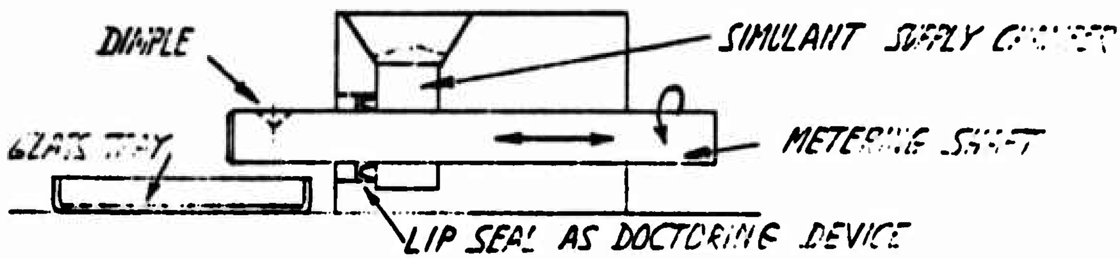
occasional agitation was required to ensure that no large voids occur in the supply chamber of the block through "bridging ". This was effectively achieved without mechanical aid by rapidly fluctuating the air pressure/vacuum while the metering shaft has its metering cavity in the chamber. This pneumatically shakes down the powder without the risk of stratification likely with a vibration system.

Sheet 1 - Appendix "A"

Powder Metering Data

Jan. 31st.

Jury rig set-up using 3/8 drill point dimple in 3/4 dia. shaft and rotating 180° for gravity drop.



	Lead Azide Simulant (White)			RDX Simulant (RED)	
	9.925			9.940	
	9.923			9.939	
	9.923			9.940	
	9.922			9.940	
	9.922			9.938	
	9.922			9.941	
	9.921			9.941	
	9.922			9.942	
	9.921			9.941	
	9.920			9.939	
	9.922	Average		9.940	Average
Less	9.894	Tray weight	Less	9.894	Tray weight
	.028	Gr. Av. Weight		.046	Gr. Av. weight

Widest Wt. Diff: 5 m/g. (± 8.9%)   Widest Wt. Diff. 4 m/g (± 4.4%)

Test conducted without shock or jolt to free any remaining powder in dimple when dropping into tray.

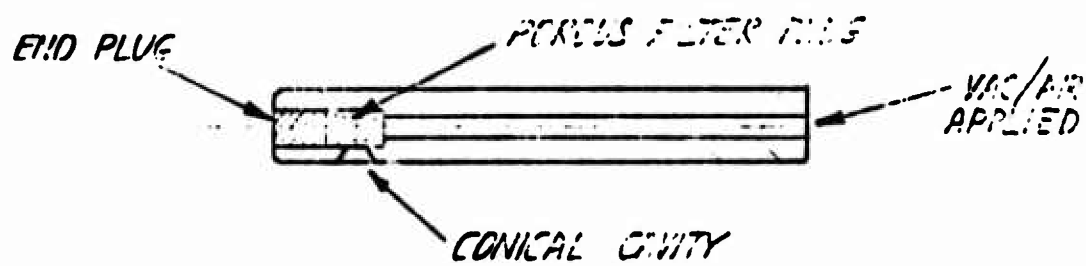
Pages 102-104 blank

Sheet 2- Appendix "A"

Feb. 2, 1973

Test conducted with 3/4" dia shaft with 5/16 dia dimple cone 90° angle and with 1/8 dia porous bottom.

Vacuum applied to fill cavity, (approx. 26" hg) and air pressure applied to remove powder from cavity. (Air pressure just sufficient to prevent "dusting").



SHAFT USED IN SAME BODY AS PREVIOUSLY , - NOT ROTATED.

Lead Azide Simulant (White)

	9. 9309	
	9. 9309	
	9. 9309	
	9. 9304	see note
	9. 9299	
	9. 9299	
	9. 9289	
	9. 9294	
	9. 9294	
	9. 9299	
Av. wt.	9. 3005	
Tray	9. 8962	
Av. charge	. 0338 g	33. 8 m/g

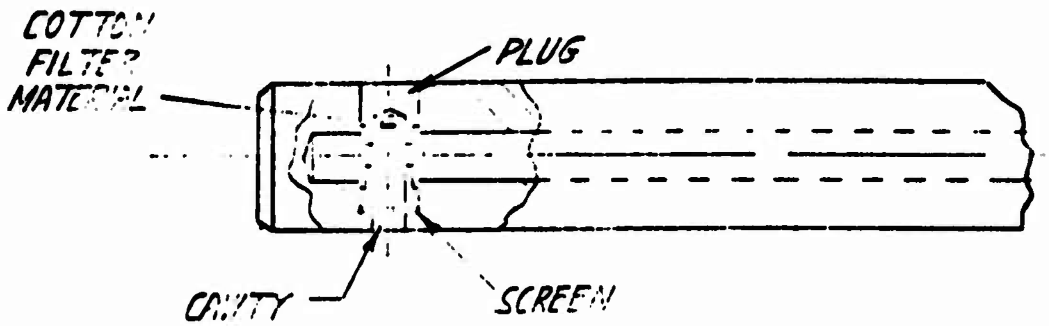
Widest differential 2 m/g (2. 9 %)

RDX Simulant (Red)

This simulant would not be picked up by the vacuum, it appears that the large sand-like granules of the simulant do not allow the powder to "self-seal" in the cavity.

Note: - A small amount of simulant started to adhere or build up onto the edge of the cavity dia, even after polishing (which seems to be an important factor).

POWDER METERING -PERF. SCREEN METHOD



The cavity is a 3/16 dia polished hole. The plug has an anular groove and cross holes for air flow, and it also serves as a screen retention. The screen is .005" thick stainless disc with .006 dia. straight sided holes spaced at .010 centers.

Results

	(vac @ 10 " hg.)		(Vac @ 20 " hg.)	
	Lead Azide Sim.	N0L 130SIM.	#28 Screened RDX Sim.	Unscreened RDX Sim.
	33.6	49.4	52.3	56.7
	33.5	49.5	51.8	57.5
	34.1	50.4	51.8	53.7
	33.4	47.8	51.5	54.7
	33.2	49.1	51.2	53.2
	33.3	49.2	51.3	53.5
	33.5	48.9	50.9	53.9
	34.4	49.6	51.1	51.7
	34.4	50.4	51.6	52.8
	34.1		50.8	
			51.5	
Av. Wt.	33.8 m/g	49.3 m/g	51.4 m/g	54.2 m/g
Widest Diff.	1.2 m/g	2.6 m/g	1.5 m/g	5.8 m/g
	± 1.8 %	± 2.5 %	± 1.5 %	± 5.3 %

Sheet 4 - Appendix "A" Feb. 15, 1973

PERFORATED SCREEN METHOD - LARGE SCREEN

This test was conducted with the same apparatus as that shown on page 3 but with the following differences:

a. Screen Disc: - .008 St. Stl .010" dia cone hole (large dia. toward cavity) spaced on .022 centers.

b. 3 way poppet type valve used (instead of rotary previously) to give short burst of eject air after vacuum.

c. Air pressure increased to approx. 15 P. S. I.

d. Vacuum at 10" hg for all simulants.

	Lead Azide Sim.	NOL 130 Sim. *	RDX Sim. (#28 seived)
	33.6	48.0	51.0
	33.6	47.2	51.0
	34.3	47.2	50.5
	34.1	46.9	49.8
	33.9	47.0	50.5
	34.0	47.7	50.4
	34.0	47.5	50.0
	33.9	47.4	49.8
	33.8	46.9	50.1
	33.6	47.7	50.1
Average wt.	33.9 m/g	47.7 m/g	50.3 m/g
Widest Diff.	0.7 m/g	1.1 m/g	1.2 m/g
	±1.0 %	±1.2 %	±1.2 %

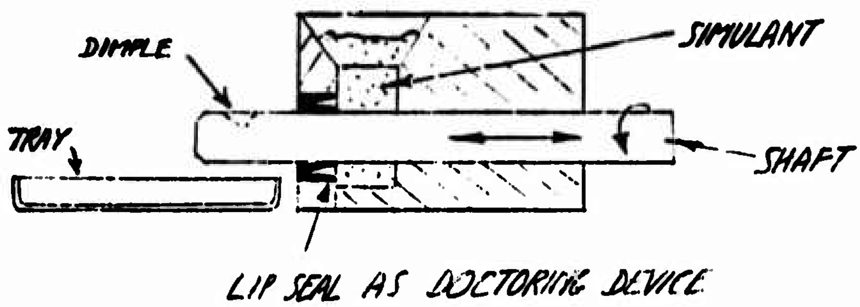
Note: - The NOL130 simulant required occasional agitation to prevent "bridging".

This was achieved by a rapid pulsing of the valve while the metering cavity was in the powder supply chamber causing a pneumatic powder settling.

Appendix B
LABORATORY NOTEBOOK

POWDER METERING DATA Jan.31, 1973

Jury rig setup using 3/8 drill point dimple in 3/4 diameter shaft and rotating 180° for gravity drop.



LEAD AZIDE SIMULANT (WHITE)	RDX SIMULANT (RED)
9.925	9.940
9.923	9.939
9.923	9.940
9.922	9.940
9.922	9.938
9.922	9.941
9.921	9.941
9.922	9.942
9.921	9.941
9.920	9.939
9.922 Average	9.940 Average
Less 9.894 Tray Weight	Less 9.894 Tray Weight
.028 Gr. Av. Weight	.046 Gr. Av. Weight
Widest Wt. Diff.=5 mg (±8.9%)	Widest Wt. Diff.=4 mg (±4.4%)

Test conducted without shock or jolt to free any remaining powder in dimple when dropping into tray.

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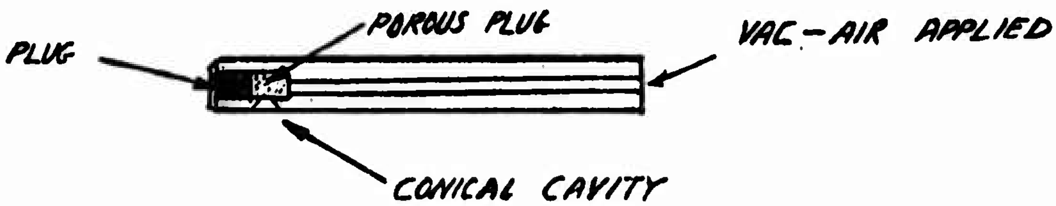
POWDER METERING DATA Feb. 2, 1973

Test conducted with 3/4 diameter shaft with 5/16 diameter dimple
Cone 90° angle and with 1/8 diameter porous bottom
Vacuum applied to fill cavity (approximately 26" Hg) and air pressure applied to remove powder from cavity. (Air pressure just sufficient to prevent "dusting".)



Shaft used in same body as previously — not rotated.

LEAD AZIDE SIMULANT (WHITE)

9.9309
9.9309
9.9309
9.9304*
9.9299
9.9299
9.9289
9.9294
9.9294
9.9299
9.3005 Average
Less 9.8962 Tray Weight
.0338 Gr. Av. Charge = 33.8 mg
Widest Wt. Diff. = 2 mg (±2.9%)

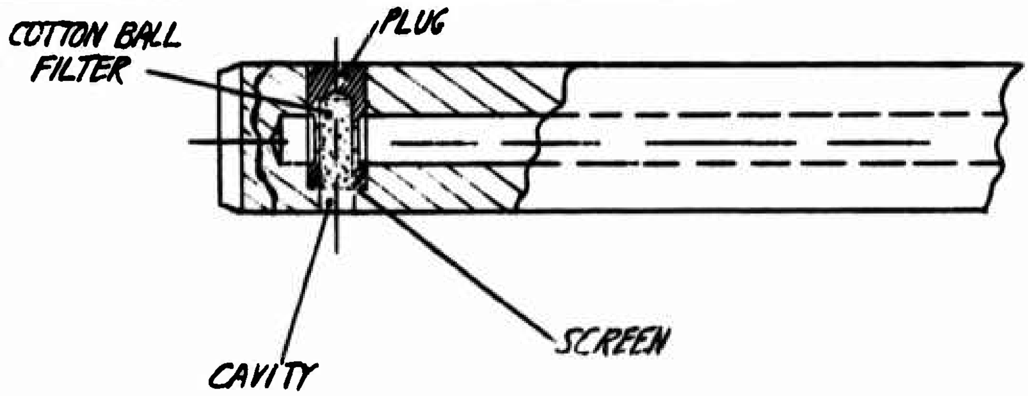
RDX SIMULANT (RED)

This simulant would not be picked up by the vacuum. It appears that the large sand-like granules of the simulant do not allow the powder to "self seal" in the cavity.

*A small amount of simulant started to adhere or build up onto the edge of the cavity diameter, even after polishing (which seems to be an important factor).

POWDER METERING — PERF. SCREEN METHOD

Feb. 13, 1973



The cavity is a 3/16 diameter polished hole. The plug has an annular groove and cross holes for air flow, and it also serves as a screen retention. The screen is .005" thick stainless disc with .006 diameter straight sided holes spaced at .010 centers.

Results:

	(Vac at 10" Hg)		(Vac at 20" Hg) RDX SIM.	
	Lead Azide Sim.	NOL 130 Sim.	#28 Screened	Unscreened
	33.6	49.4	52.3	56.7
	33.5	49.5	51.8	57.5
	34.1	50.4	51.8	53.7
	33.4	47.8	51.5	54.7
	33.2	49.1	51.2	53.2
	33.3	49.2	51.3	53.5
	33.5	48.9	50.9	53.9
	34.4	49.6	51.1	51.7
	34.4	50.4	51.6	52.8
	34.1		50.8	
			51.5	
Av. Wt.	33.8 mg	49.3 mg	51.4 mg	54.2 mg
Widest Diff.	1.2 mg	2.6 mg	1.5 mg	5.8 mg
	= ± 1.8%	= ± 2.5%	= ± 1.5%	= ± 5.3%

PERFORATED SCREEN METHOD — LARGE SCREEN Feb. 15, 1973

This test was conducted with the same apparatus as that shown on page 3, but with the following differences:

1. Screen Disc: .008 st. stl. .010 diameter cone hole (large diameter toward cavity) spaced on .022 centers.
2. 3-way poppet-type valve used (instead of rotary previously) to give short burst of eject air after vacuum.
3. Air pressure increased to approximately 15 psi.
4. Vacuum at 10" Hg for all simulants.

	LEAD AZIDE SIM.	NOL 130 SIM.*	PINK RDX SIM. (# 28 SCREENED)
	33.6	48.0	51.0
	33.6	47.2	51.0
	34.3	47.2	50.5
	34.1	46.9	49.8
	33.9	47.0	50.5
	34.0	47.7	50.4
	34.0	47.5	50.0
	33.9	47.4	49.8
	33.8	46.9	50.1
	33.6	47.7	50.1
Av. Wt.	33.9 mg	47.4 mg	50.3 mg
Widest Diff.	0.7 mg	1.1 mg	1.2 mg
	= ±1.0%	= ±1.2%	= ±1.2%

*This NOL 130 Simulant required occasional agitation to prevent "bridging." This was achieved by a rapid pulsing of the valve while the metering cavity was in the powder supply chamber, causing a pneumatic powder settling.

CAM FOLLOWER DIMENSIONS — FILL TURRET

Jan. 19, 1973

Diameter of Detonator	.147 inch
Area	.0169 square inch
Compression of Powder	70,000 pounds/square inch
Compressive Force	1,188 pounds (say, 1,200 pounds)
Turret Diameter	32 inches
Circumference	100 inches
Speed	60 RPM (20 stations)
Circumferenential Speed	6,000 inches/minute

(Ref. McGill Catalog, Pages 20 and 21)	2-inch Roller	1-inch Roller	1-3/8-inch Roller
Circumference	6.28 inches	3.14 inches	4.32 inches
Speed of Roller	955 RPM	1,910 RPM	1,388 RPM
Load	1,200 pounds	1,200 pounds	1,200 pounds
Life	500 hours	500 hours	500 hours
FL	1	1	1
FS	2.8	3.4	3.1
Required Bearing Capacity	3,360 pounds (1,200 x 2.8 x 1)	4,080 pounds (1,200 x 3.4 x 1)	3,720 pounds (1,200 x 3.1 x 1)
			Page 20 states that 1-3/8-inch diameter capacity is 3,930 lbs. ∴ This diameter is adequate.

TRIAL NO. 1 OF LOADING FIXTURE

Nov. 2, 1973

Johnson's Baby Powder (NOL Simulant 70,000 psi)

Air Pressure	3 psi
Vacuum	15 in. Hg
Upper Cylinder Pressure	200 psi (should be 1,390 psi)
Automatic Cycle (Airmotor @ 250 RPM)	

Detonator	Tare Wt. (mg)	Filled Wt. (mg)	Load Wt. (mg)	
1	16.6	19.1	2.5	Powder sticks to tip of upper punch.
2	16.1	19.8	3.7	
3	16.6	24.4	7.8	
4	15.9	20.7	4.8	Punch cleaned after each run.
5	16.1	19.8	3.7	
6	16.1	19.1	3.0	
7	16.4	20.6	4.2	
8	16.2	19.2	3.0	
9	16.1	20.5	4.4	
10	15.9	20.1	4.2	

Plunger area $= .0155\ in^2 =$ (1,090 lbs. required)

With 1-inch bore cylinder $P = \frac{1,090}{.785} = 1,390$ psi.

Lead Azide simulant should be 197 psi.

TRIAL NO. 1 OF LOADING FIXTURE Oct. 22, 1973

RDX Simulant (15,000 psi)
Powder -- Pink #80 Mesh

Pressure	3 psi
Vacuum	15 in. Hg
Upper Cylinder Pressure	200 psi (should be 298 psi)
Automatic Cycle (Airmotor @ 250 RPM)	

Detonator	Tare Wt. (mg)	Filled Wt. (mg)	Load Wt. (mg)
1	16.2	18.6	2.4
2	16.3	18.8	2.5
3	16.2	18.4	2.2
4	15.9	19.3	3.4
5	16.0	18.2	2.2
6	16.4	19.7	3.3
7	16.1	17.6	1.5
8	16.2	19.2	3.0
9	15.8	17.2	1.4
10	15.7	17.6	1.9

.0155 in^2 punch area (234 lbs. required)

$\frac{234}{.785}$ =298 psi gauge pressure.

Oct. 23, 1973

1. Began fabricating a new metering slide for a larger charge volume.
2. Moved the jury rig to a new area to improve accessibility.
3. Increased the hydraulic pressure to the newly calculated compacting force valves.
4. Tried to load primers using the new pressure setting (1,300 psi) and found that the cups were being destroyed by excessive plunger speed. The higher speed also caused the lower plunger to get out of adjustment.
5. Tests were discontinued to upgrade the jury rig.
   a. A new cam is being made to improve the secondary deceleration time length.
   b. The lower and upper cylinders will be doweled to prevent the plungers from getting out of adjustment.
   c. Flow control valves were ordered to provide speed control on all cylinders.
6. Completed the installation of the air line dryer.

Oct. 24, 1973

1. Completed the secondary deceleration cam modification.
2. Completed the adjustment and doweling of the lower cylinder.
3. Began the doweling of the upper cylinder.
4. Still looking for a source for immediate delivery of the flow control valves.

Oct. 25, 1973

1. Completed and installed the new metering rod.
2. Completed the doweling of the upper cylinder.
3. Found a source for three flow control valves. Delivery promised for today.
4. Fabricated a vacuum trap.

Oct. 26, 1973

1. Installed the three flow control valves; two in the return lines for the upper cylinder and one in the pressure line preceding the four selector valves.
2. Adjusted the lower punch.

Oct. 29, 1973

1. Reinstalled the old metering rod. The new rod deposited too much powder.
2. Started fabricating a third metering rod with a volume increase of twice the original volume.
3. Demonstrated the filling operation for general and other army personnel.
4. Added a sight glass to the vacuum trap.

Oct. 30, 1973

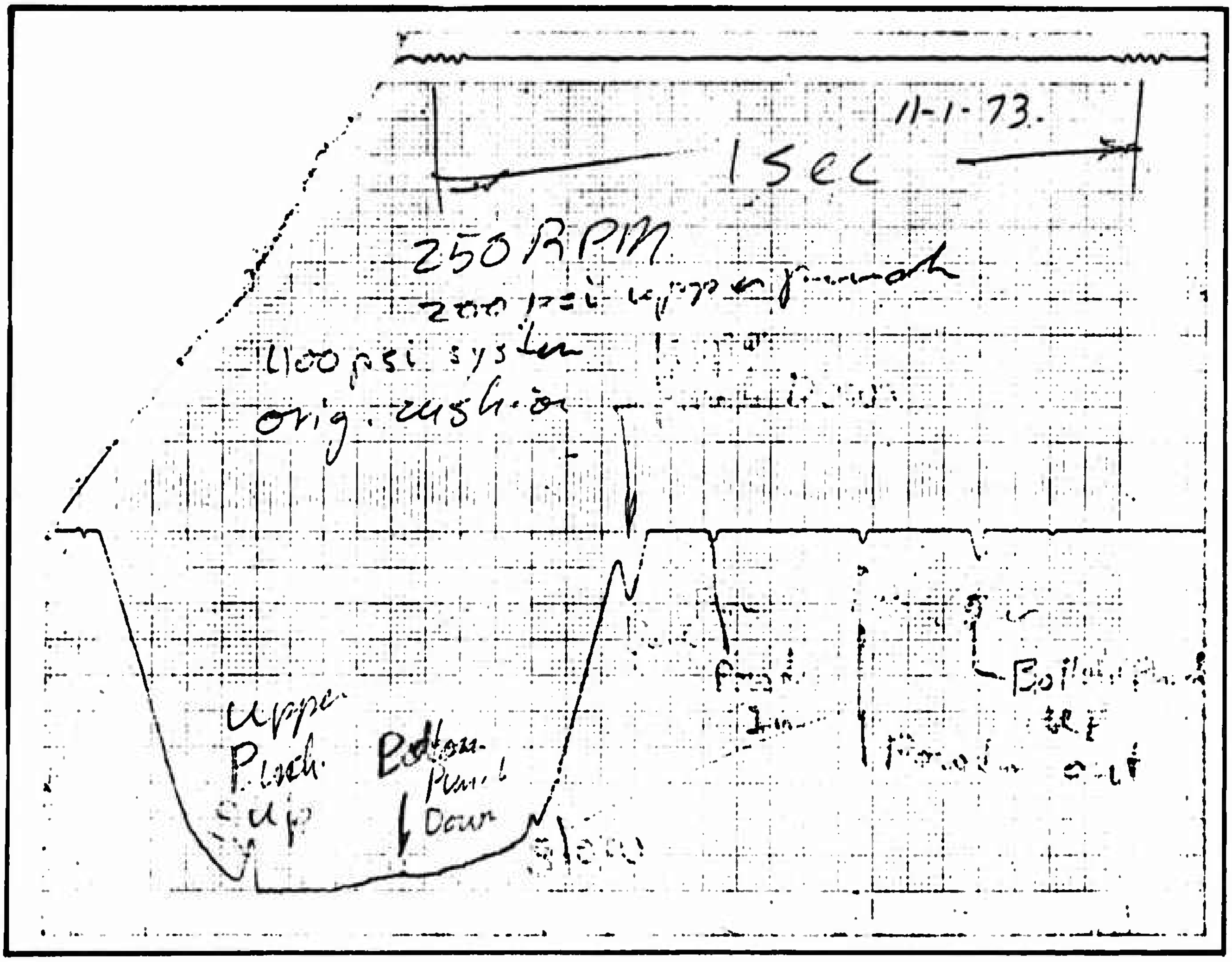
1. Installed vacuum trap to system.
2. Made filling trials using #80 mesh pink powder.
3. Demonstrated the filling function for the Picatinny Arsenal representative, making the hazard analysis.

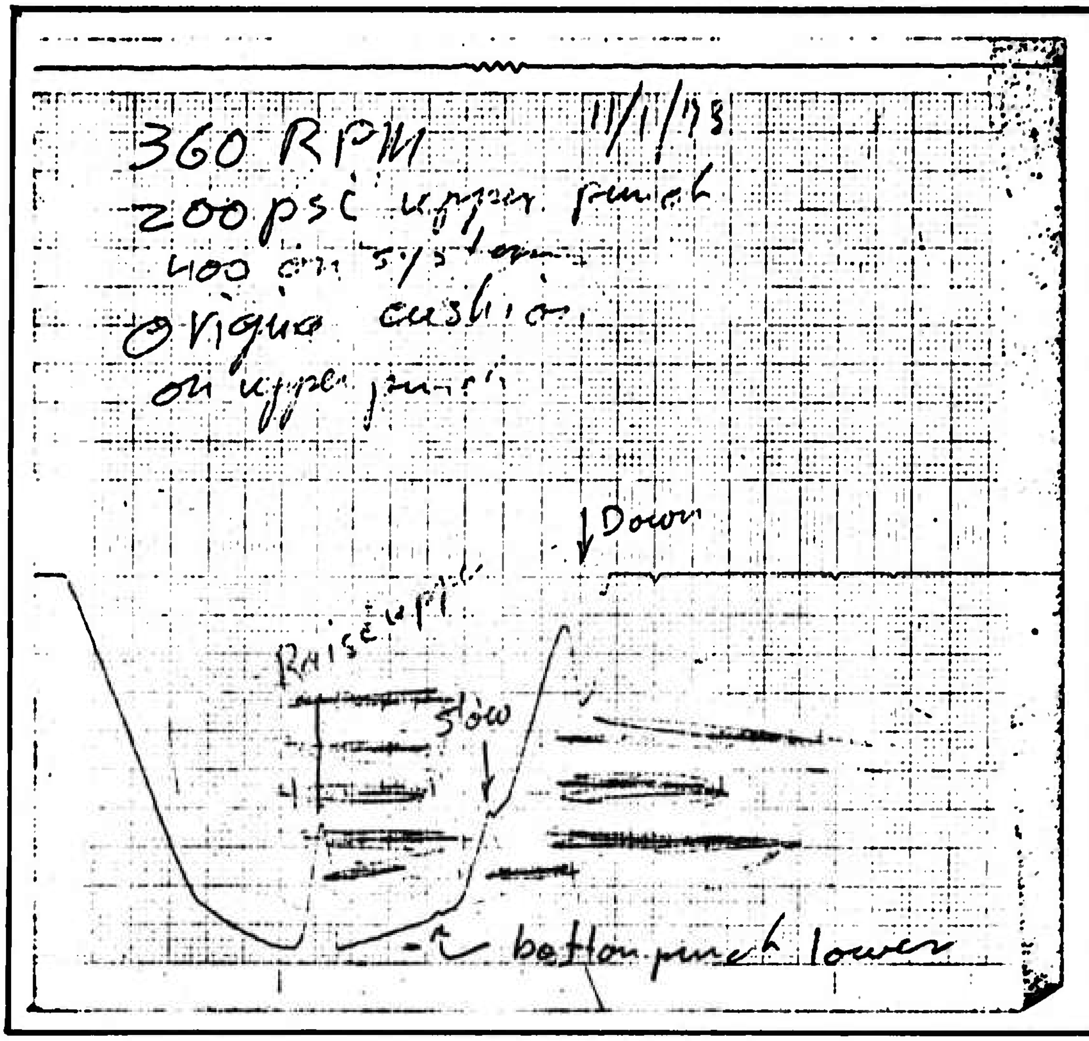
Oct. 31, 1973

1. Set the three speeds for the top punch. Hydraulic pressure 400 psi.
2. Recorder was too slow to register the speeds during the automatic cycle. A more sensitive recorder is being wired in.

Nov. 1, 1973

1. Completed the recorder hookup.
2. Made several trial runs (see samples).

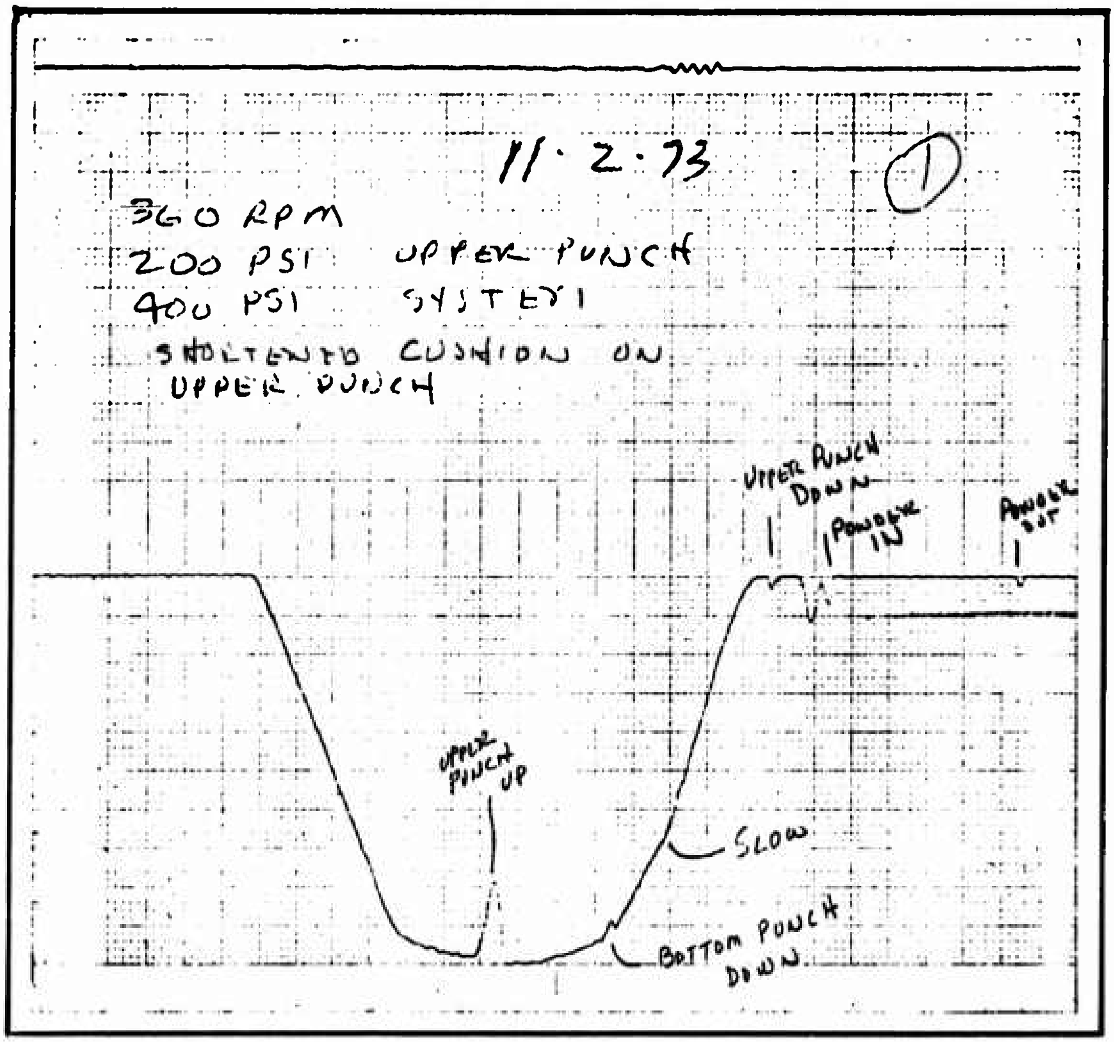




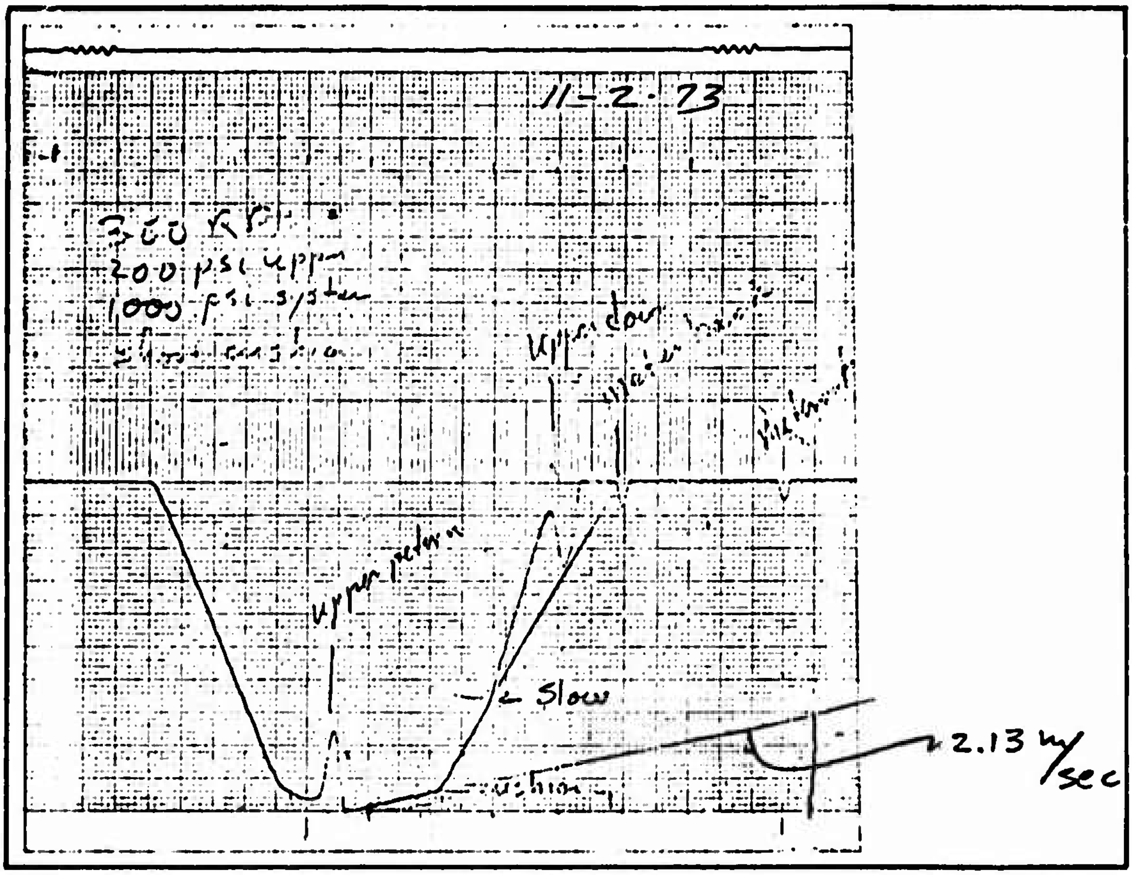
3. **Final cushion too long. Cylinder removed and modified to shorten cushion.**

Nov. 2, 1973

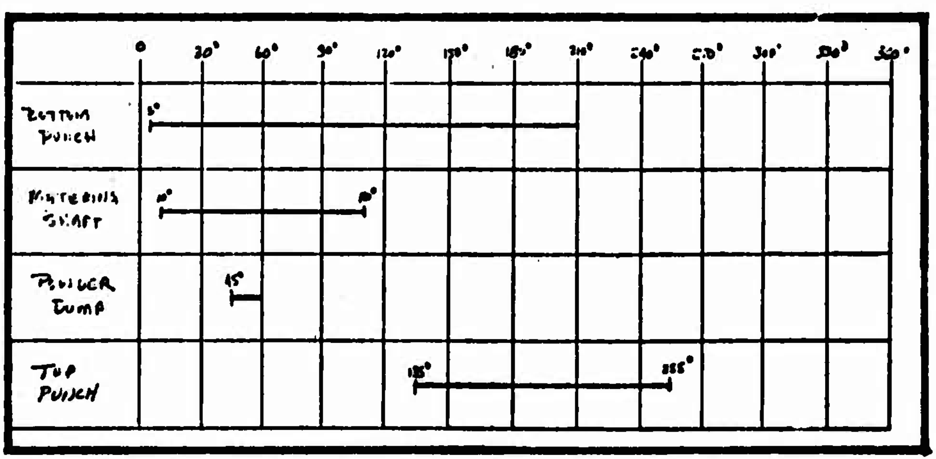
1. Completed cushion modification.



2. Cycle time too long. Increased the system hydraulic pressure from 400 psi to 1,000 psi.



3. Cycle time shortened some, but not enough. Decided to change the cam timing to shorten dwell times and close up the sequencing of the functions.



Nov 5, 1973

Put in larger volume plunger
10-inch Hg vac.
2 psi dump pressure
1,350 psi system pressure
Airmotor 200 RPM (38 psi)
200 psi upper punch press
Pink simulant #80 mesh.

Detonator		Tare Wt. (mg)		Filled Wt. (mg)	Load Wt. (mg)	Mg. Diff.
1		16.0		29.4	13.4	
2		16.0		18.7	2.7	
3		15.9		21.0	5.1	
4		16.2		21.2	5.0	
5		16.2		20.0	3.8	
6	5" Hg	16.0	Est.	20.0	4.0	
7		16.0		21.2	5.2	1.2
8		16.0		19.4	3.4	1.8 max
9		16.0		21.0	5.0	1.6
10		16.0		20.0	4.0	1.0

Inspected screen: it was plugged except for 2 holes.

Cleaned screen and turned vacuum off between shots.

10" Hg, 3 psi

1	16.0	Est.	22.3	6.3
2	16.0		24.1	8.1
3	16.0		24.2	8.2
4	16.0		24.0	8.0
5	16.0		26.1	10.1

Air 2 psi
Vac. 10-inch Hg.
28 Mesh

1	16.0		34.0	18.0	Mg. Diff.
2	16.0		27.1	13.1	6.0
3	16.0	Est.	37.2	19.2	
4	16.0		32.4	16.4	
5	16.0		32.0	16.0	

$\frac{6}{13}$ = 50% variation.

Nov. 7, 1973

Installed new plunger with micronite.

Nov. 8, 1973

Test 1 — 1 psi, 10-inch Hg

Cup	Wt. (cup and powder)
1	20.2
2	15.8
3	18.7
4	15.1
5	15.3

Test 2 — 4 psi, 10-inch Hg

Cup	Wt. (cup and powder)
1	17.5
2	17.3
3	17.5
4	18.2
5	17.5

$\frac{.3}{1.5}$ = 20% mg

Run 3 — Baby Powder

Note 1 - Built up on funnel.
Note 2 - 60 percent relative humidity.
Note 3 - Powder not hitting center of funnel.

Cup	Wt.	
1	25.1	
2	25.8	
3	23.2	} 8 mg Diff.
4	24.4	
5	29.8	
6	27.3	
7	17.4	
8	26.5	
9	30.0	
10	17.2	

Nov. 9, 1973

Cleaned filter with acetone.
Replaced one O-ring.

4 psi air, 10-inch hg vac, pink sim. 28 mesh.

Run 1		Run 2	
Cup	Wt. Filled (mg)	Cup	Wt. Filled (mg)
1	35.0	1	29.0
2	31.1	2	33.0
3	32.0	3	32.3
4	33.2	4	36.5
5	32.0	5	36.1
6	33.4	6	35.1
7	33.3	7	27.0
8	32.5	8	32.0
9	32.8	9	34.5
10	32.0	10	35.4

Humidity, 62 percent. Fine powder sticks to side of funnel.

Nov. 12, 1973

28 mesh pink simulant.
Humidity, 65 percent.
Temperature, 67 degrees.
Varied time 25 seconds to 1 minute.
4 psi air, 10-inch hg vac.

Run 1		Run 2 (same as above except timed 30 seconds each)	
Cup	Loaded Wt.(mg)	Cup	Loaded Wt. (mg)
1	35.3	1	34.3
2	35.3	2	33.4
3	33.5	3	34.2
4	31.2	4	33.7
5	33.3	5	33.8

Flow control added to metering shaft cylinder (exhaust) to control outward speed of shaft and help control powder spill*. (Controls set at 5 white.)

Humidity, 60 percent.
Temperature, 72 degrees.
30 seconds each.
4 psi air, 10-inch hg vac, air motor 200 RPM.

Detonator	Tare Wt(mg)	Loaded Wt(mg)	Load	RUN 1
1	16.5	37.6	20.1	
2	16.7	31.4	14.7	
3	16.3	26.5	10.2	
4	16.5	29.6	13.1	
5	16.6	29.3	12.7	
6	16.3	33.3	17.0	
7	16.8	30.9	14.1	
8	16.8	31.2	14.4	
9	17.0	32.7	15.7	
10	16.3	27.7	11.4	*Spill not noticeably reduced.

Cleaned screen, Flow control set at 5 blue.* 4.5 psi air, 8-inch hg vac.

RUN 2

Detonator	Loaded Wt(mg)	Detonator	Loaded Wt(mg)
1	26.4	6	24.7
2	22.1	7	21.7
3	25.2	8	26.9
4	25.7	9	26.3
5	27.3	10	24.3

*Amount of spill greater than above setting.

Nov. 12, 1973 pm

Pressure side of agitation closed off.
4 psi air, 10-inch hg vac.
Time, 30 seconds.
Air motor 200 RPM.
200 psi gauge.

RUN 3 (28 mesh)

Detonator	Loaded Wt(mg)
1	24.3
2	25.6
3	27.7
4	20.7
5	23.2
6	20.3
7	20.3
8	19.8
9	27.5
10	23.4

+spills.

Nov. 13, 1973 am

Cleaned filter and screen with acetone.
Reversed outer lip seal.
Meter shaft flow control set at 0 white.
Time, 30 seconds.
Air motor 240 RPM.
Temperature, 70 degrees; humidity, 68 percent.
4 psi air, 10-inch hg vac.
200 psi gauge.
28 mesh.

Run 1

Detonator	Loaded Wt(mg)
1	30.4
2	32.8
3	34.6
4	36.5
5	29.1
6	25.7
7	29.0
8	31.1
9	31.4
10	35.3

Spill 26.0 mg

Run 2 (same as above except 10 psi air and 8-inch hg vac)

Detonator	Loaded Wt(mg)
1	32.4
2	33.5
3	34.2
4	28.8
5	34.3

Run 3

8-inch hg vac, 10 psi air, 200 RPM

Powder spills caused by speed and shock of outstroke of meter shaft.

Nov. 14, 1973 pm

Shortened metering shaft travel by 13/16 inch by moving powder fill block closer to powder fill die.
12-inch hg vac, 6 psi air, air motor 200 RPM, 200 psi gauge.
Meter shaft flow control set at 6 gold.

Run 1 (28 mesh) Timed 20 seconds

Detonator	Loaded Wt(mg)
1	35.0
2	35.3
3	34.5
4	34.1
5	35.0

12-inch hg vac, 6 psi air, air motor 200 RPM, 200 psi gauge.
Meter shaft flow control set at 6 gold.

Run 2

Detonator	Loaded Wt(mg)
1	33.7
2	34.7
3	34.7
4	35.8
5	35.9

18-inch hg vac, 5 psi air, otherwise same as above.

Run 3 Timed 20 seconds

Detonator	Loaded Wt(mg)
1	27.8
2	28.9
3	32.0
4	33.0
5	32.9
6	33.4
7	30.3
8	31.7
9	35.0
10	33.0

Nov. 15, 1973 am

12-inch hg vac, 6 psi air, air motor 200 RPM, 200 psi gauge. 28 mesh, pressure side of agitator closed, timed 30 seconds.

Run 1

Detonator	Loaded Wt(mg)
1	35.4
2	33.7
3	33.6
4	33.4
5	32.4
6	36.4
7	33.8
8	34.6
9	34.9
10	34.4

Run 2 (same except 10-inch hg vac & 5 psi air)

Detonator	Loaded Wt(mg)
1	30.7
2	35.8
3	31.1
4	36.4
5	34.8
6	35.3
7	36.2
8	24.2
9	35.3
10	35.8

Run 3 (same except 16-inch hg vac & 8 psi air)

Detonator	Loaded Wt(mg)	
1	21.7	
2	19.0	
3	22.0	
4	22.3	Spill is dust only.
5	21.4	
6	20.8	
7	21.8	
8	22.1	
9	20.0	Screen was plugged.

Nov. 15, 1973 pm

Changed metering shaft: has filter only with no screen.
Flow control - meter shaft 6 gold.
10-inch hg vac, 4 psi air, air motor 200 RPM, 200 psi gauge.
28 mesh pink, timed 30 seconds.

Run 1

Detonator	Loaded Wt(mg)	
1	36.5	
2	36.1	
3	36.0	
4	36.4	
5	36.9	
6	37.0	
7	36.3	Spill reduced to dust only.
8	36.7	
9	36.7	

Run 2 (same as Run 1 except:
8-inch hg vac
timed 20 seconds)

Detonator	Loaded Wt(mg)
1	35.8
2	35.5
3	35.6
4	35.9
5	36.3
6	35.5
7	36.2
8	36.1
9	35.5
10	35.8
11	33.7
12	35.3
13	34.6
14	35.3
15	35.2
16	34.1
17	34.6
18	35.0
19	34.0
20	34.6

Run 3 (same as Run 1 except:
6-inch hg vac
timed 30 seconds)

Detonator	Loaded Wt(mg)
1	35.4
2	35.1
3	34.5
4	35.4
5	35.4
6	34.6
7	34.6
8	34.7
9	34.3
10	35.0
11	34.0
12	34.0
13	34.0
14	34.4
15	34.6
16	34.0
17	33.8
18	34.0
19	34.3
20	34.3

Nov. 15, 1973 pm (contd.

10-inch hg vac, 5 psi air, air motor 200 RPM, 200 psi gauge.
28 mesh pink.
Filter only - no screen.

Run 4

Detonator	Loaded Wt(mg)	
1	34.0	
2	33.9	
3	33.8	low
4	34.1	
5	34.0	
6	33.8	
7	33.8	
8	34.3	
9	34.5	high
10	33.7	

$$\begin{array}{r} 34.5 \\ -33.8 \\ \hline .7 \end{array} \qquad \begin{array}{r} 33.8 \\ -16.0 \\ \hline 17.8 \end{array} \text{ cup}$$

$$\frac{.7}{17.8} = \pm 2\%$$

Nov. 16, 1973 am

Meter shaft has filter only, no screen.
Flow control meter shaft 6 gold.
Agitator action not used (pressure side).
White simulant powder, timed 30 seconds.
6-inch hg vac, 4 psi air, air motor 200 RPM, 200 psi gauge.
Temp ambient, humidity 72 percent.

Run 1

Detonator	Loaded Wt(mg)
1	28.2*
2	28.4*
3	28.5
4	28.6
5	28.9
6	28.7
7	28.9
8	28.8
9	29.0
10	28.9
11	28.7
12	29.0
13	29.0
14	29.0
15	30.1
16	29.1
17	28.5
18	30.2
19	28.6
20	29.8
21	28.6
22	28.6
23	28.5
24	28.5
25	29.5

*Light charge may be from first cycle after changeover from 28 mesh to white sim. powder.
Small amount of powder blown out around funnel. Also a film of powder sticking to sides of funnel.
Noted powder on botton punch after each cycle. Cleaned funnel & punches.

Run 2 (same except 5-inch hg vac & 3 psi air)

Detonator	Loaded Wt(mg)	
1	29.2	
2	28.8	
3	28.7	
4	27.3*	
5	30.3	
6	26.5	
7	32.3	
8	26.5	
9	28.5	
10	27.2	
11	29.3	
12	29.4	
13	29.0	
14	30.0	
15	28.9	
16	30.6	
17	29.3	
18	27.4	
19	28.9	
20	27.4	
21	29.5	
22	27.5	
23	26.0	
24	25.0	
25	*	
26	28.3	Cleaned funnel, ran slow cycle.

*#25 - bottom pushed out of cup.
#4 - out of round.
All cups hard to remove from holder.

Nov. 16, 1973 am
(continued)

Filter only in meter shaft.
No pressure on agitator.
Clean funnel.
6-inch hg vac, 4 psi air, air motor 200 RPM, 200 psi gauge.
Humidity 72 percent.
White simulant, timed 30 seconds.

Run 3

Detonator	Loaded Wt(mg)
1	29.4
2	28.9
3	29.5
4	28.4
5	28.6
6	28.0
7	28.8
8	29.0
9	28.7
10	29.1
11	29.4
12	29.0
13	26.3
14	28.6
15	29.3
16	30.7
17	28.8
18	28.9
19	27.4
20	28.9

Small amount of dust blowing out around funnel.

Nov. 16, 1973 pm

Raised top punch .085.
Charge: white sim. over pink sim.
6-inch hg vac, 4 psi air, air motor 200 RPM, 200 psi gauge.

Loaded with Pink sim. powder			2nd Charge loaded with white			Total
Detonator	Loaded Wt(mg)	Powder Wt(mg)	Detonator	Loaded Wt(mg)	Powder Wt(mg)	Powder Wt(mg)
1	35.7	19.7	1	48.7	13.0	32.7
2	34.0	18.0	2	46.7	12.7	30.7
3	35.5	19.5	3	48.5	13.0	32.5
4	34.0	18.0	4	46.5	12.5	30.5
5	35.9	19.9	5	47.4	11.5	31.4
6	35.9	19.9	6	48.8	12.9	32.8
7	35.7	19.7	7	48.3	12.6	32.3
8	34.2	18.2	8	47.8	13.6 ←	31.8
9	35.7	19.7	9	48.2	12.5 ←	32.2
10	34.0 ←	18.0 ←	10	47.1	13.1	31.1

±5%

$\frac{2.1}{11.5} = \pm 10\%$

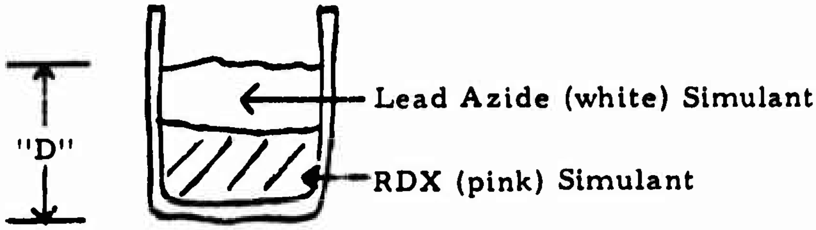
Ran 60 more white over pink at same setting as above.
Noted small amount of powder on top of bottom punch after each cycle.

Pink sim. over white, gauge psi 295, otherwise same settings as above.

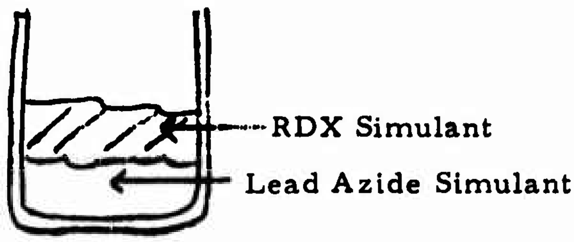
Detonator	White Powder Loaded Wt(mg)	+Pink Powder Loaded Wt(mg)	Detonator	White Powder Loaded Wt(mg)	+Pink Powder Loaded Wt(mg)
1	29.4	46.0	11	29.4	49.0
2	28.9	47.4	12	29.0	48.0
3	29.5	47.3	13	26.3	48.8
4	28.4	45.7	14	28.6	48.5
5	28.6	51.9	15	29.3	48.0
6	28.0	45.4	16	30.7	48.7
7	28.8	51.1	17	28.8	48.3
8	29.0	45.0	18	28.9	45.5
9	28.7	47.6	19	27.4	48.0
10	29.1	46.0	20	28.9	46.8

Preceding tests run with metering shaft flow control set at 6 gold.
Top punch flow controls: hi speed, 9 yellow; lo speed, 7 yellow.

Nov. 19, 1973 am



"D"	
.114	#1
.114	#2
.114	#3



.102	#1
.102	#2
.105	#3

White over pink.
Top punch flow contols set: hi speed, 9 yellow; lo speed, 7 yellow.

Hydraulic pump pressure 500 psi.

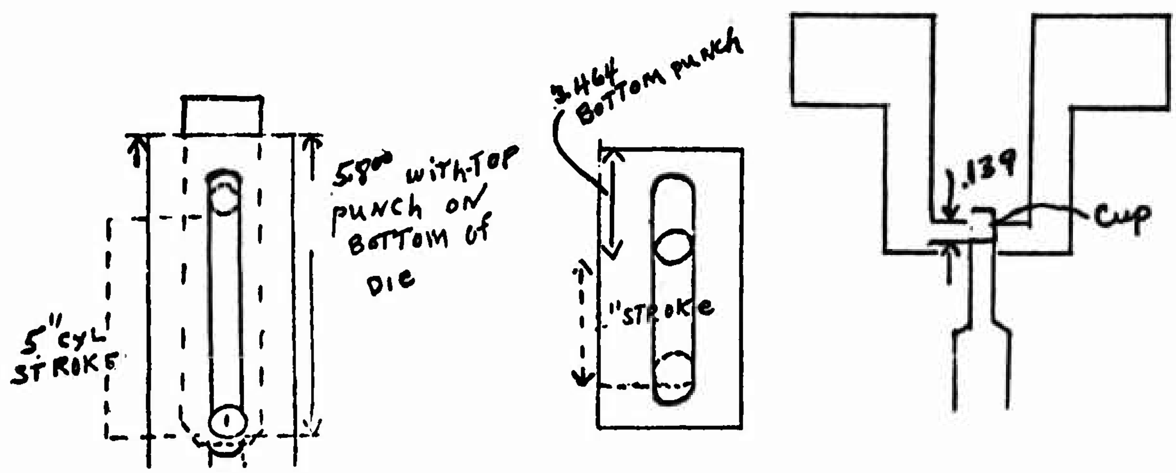
Top punch gauge pressure 310 psi.

Top punch set on bottom of crimping die.

Bottom punch at end of cylinder stroke is .139* below top punch.

Air motor 200 RPM.

*Flattening punch is .004 shorter than crimping punch.

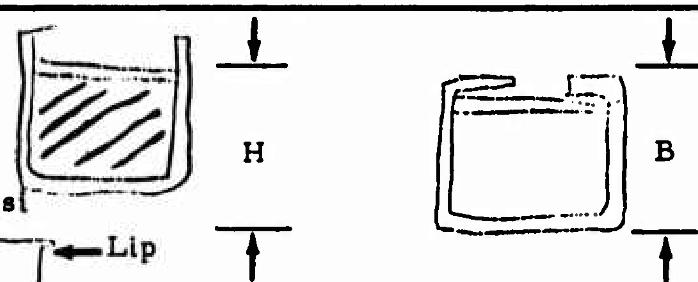


Nov. 26, 1973

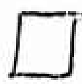
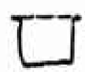
New holder for rod scraper seal ---- done
Longer chamfer and seal punches with new drawings
10 new chains and holders without chamfer on top
1 new funnel with smaller diameter hole (.147 max) ---- done

Nov. 29, 1973

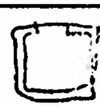
Precrimp?



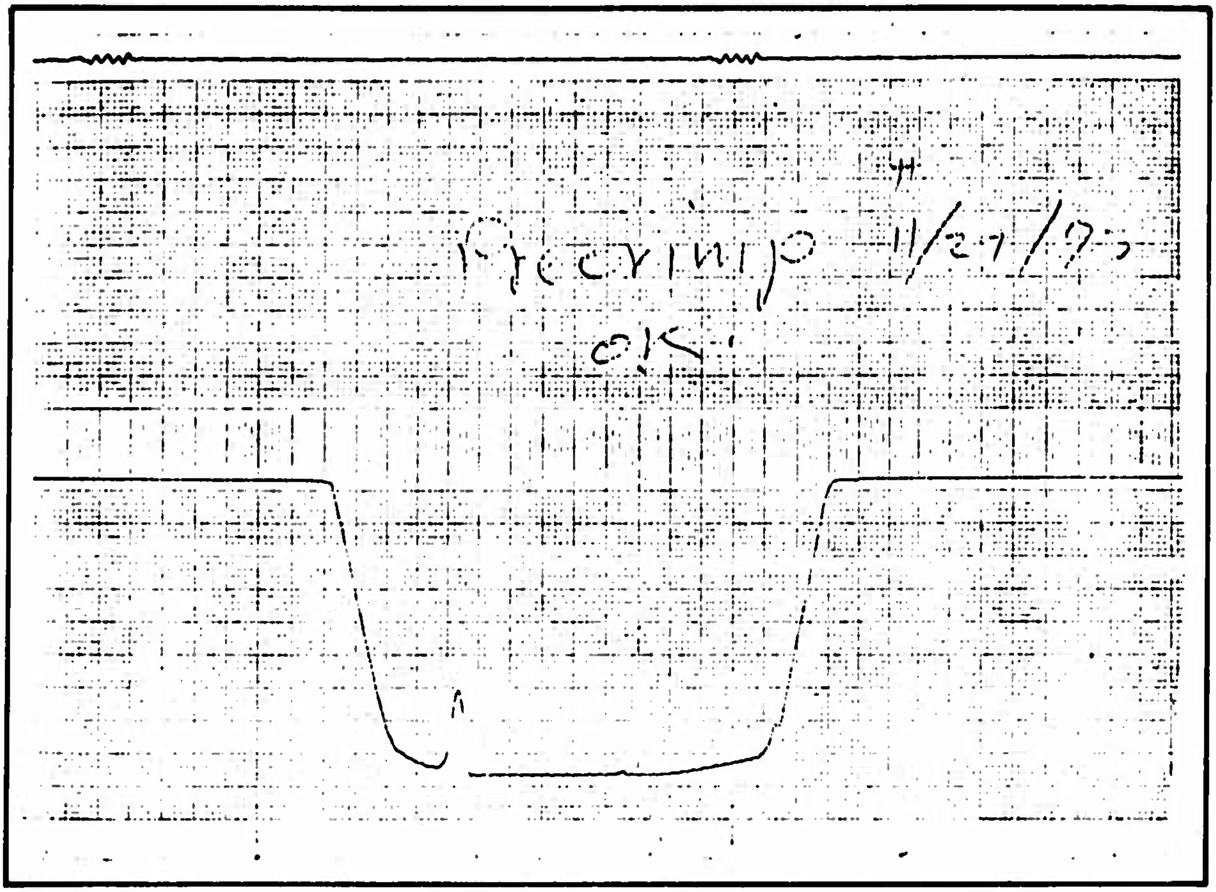
310 psi

	"H"	"B"		
1	.129		 ←Lip	
2	.133	.139	 ←Lip	
3	.135	.140	 ←Lip	Lowered lower punch
4	.130	.140		Lowered lower punch .003
5	?			Lower lower punch another .005

Inspected housing and found chamfer.
Removed chamfer:

	"H"	"B"		
6	.130	.143	 ←	Very slight bulge (OK)
7	.130	.144	.148→  ←.147	Very slight bulge (OK)

Nov. 29, 1973
(continued)



Nov. 30, 1973

CRIMPING OPERATION

Ten new cup retainers and chains made:
Cup length 1.797 and flat on top.

Two new crimping (lower) punches made:
One 1.682 long, one 1.676 long (from shoulder to tip).
The longer punch to be used with the 45° crimp upper punch and the shorter one with the flattening punch (upper). *

First trial detonator looks acceptable on crimp operation, but bottom of cup is out of round and oversize .0005 at bottom.

Hydraulic pressure 450 psi. Gage pressure, top punch, 290 psi.

Second trial shows crimp acceptable but detonator has slight bulge around top.

Third trial also has slight bulge (002 oversize) at top.

*For this operation top and bottom punches were changed but no adjustment was made on stroke length.

Bottom punches sent to be hardened.

Dec. 3, 1973 am

28 Mesh pink simulant.
8-inch hg vac, 4 psi air.
Hydraulic pressure 1,000 psi, gauge pressure 297 psi.

No. 1	one charge	33.6 mg - 17.6	
No. 2	two charges	54.3 mg - 20.7	Slow Speed
No. 3	three charges	73.3 mg - 20.0	

Run 2 as above (slow speed):

Cup	Loaded Wt(mg)	Est. Load
1	34.0	18.0
2	34.2	18.2
3	34.5	18.5
4	34.1	18.1
5	33.7	17.7

Run 3*-28 mesh, pink simulant
hydraulic pressure 1,000 psi, gauge pressure 290 psi
air motor 200 RPM
8-inch hg vac, 4 psi air. Not Timed.

Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)
1	33.5	6	35.3
2	34.9	7	35.2
3	34.7	8	35.3
4	35.0	9	36.2
5	35.0	10	35.1

Run 4* ^-^8 mesh, pink simulant
hydraulic pressure 1,000 psi, gauge pressure 290 psi
air motor 200 RPM
10-inch hg vac, 4 psi air. Timed 30 seconds

Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)
1	36.4	6	36.3	11	34.9
2	36.2	7	35.6	12	35.7
3	35.8	8	36.6	13	36.4
4	35.6	9	36.1	14	35.0
5	36.3	10	34.4	15	35.2

*Used one chain and holder only. Other holders tend to damage cup.

Dec. 3, 1973 pm

Deburred and cleaned all holders.

28 mesh pink simulant.
10-inch hg vac, 5 psi air, air motor 200 RPM.
Hydraulic pressure 1,000 psi, gauge pressure 295 psi.
Timed 30 seconds.

Run 5

Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)
1	35.3	6	34.2
2	34.4	7	34.6
3	35.1	8	34.7
4	35.1	9	34.6
5	Damaged	10	34.4

Same as Run 5 except 16-inch hg vac and timed 15 seconds:

Run 5

Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)
1	33.6	6	35.2
2	34.4	7	35.0
3	35.7	8	35.2
4	34.4	9	35.1
5	33.7	10	34.3

Attempts made to duplicate Run 4 (morning of Dec. 3)
See results of Run 4:

Run 6

Cup	Loaded Wt(mg)	Cup	Loaded Wt(mg)
1	34.7	6	34.3
2	34.2	7	33.4
3	34.2	8	34.4
4	33.7	9	34.4
5	34.6	10	34.0

Dec. 4, 1973

28 mesh pink simulant.
10-inch hg vac, 4 psi air.
Hydraulic pressure 1,000 psi, gauge pressure 297 ± psi.
Reference Drawing 8798331.
"H" compressed height Note 4.

Ran 3 charges with above settings and checked compressed height (ref. .133 ± .002)
Heights below are with closing disc (.003)= (.136 ± .002).

1	.1375	.148 dia	6	.133	.148 dia	11	.1295	.148 dia	16	.146	.1475 dia
2	.133	All pcs	7	.121		12	.131		17	.144	.1472
3	.1355		8	.130		13	.133		18	.142	
4	.1375		9	.131		14	.131		19	.147	
5	.131		10	.1295		15	.113		20	.1395	

At No. 16 adjusted top punch (shorter .06) to keep from pushing cup into holder too deep.

21	.140	.148 dia	26	.119	.148 dia	31	.142		36	.143	.048 dia
22	.136		27	.132		32	.143		37	.141	
23	.1385		28	.142		33	.134		38	.140	
24	.136		29	.140		34	.144		39	.139	
25	.139		30	.142		35	.144		40	.128	
									41	.108	

All cup diameters are .148 (oversize .001).

Making new funnel with .146 diameter hole for die.

Dec. 5, 1973 am

Pink simulant 28 mesh.
500 psi hydraulic pressure
290 gauge pressure top punch
4-inch hg vac, 4 psi air.

Reference Drawing 8798331. "H" height .133±.002.
Includes three charges of pink simulant mesh plus closing disc .003 thick*.

1	.123	11	.133
2	.134	12	.139
3	.135	13	.135
4	.137	14	.138
5	.139	15	.136
6	.142	16	.139
7	.130	17	.144
8	.137	18	.138
9	.133	19	.140
10	.133	20	.143
		21	.134

Cups are pushed too deep into retainer.
Sides of some cups are damaged whether by retainer spring or misalignment between filling die and retainer.

All diameters of cups are .148+.

*all heights.

Dec. 6, 1973

Tried new metal scraper seal with 28 mesh pink simulant.

Decided that seal was doing a better job than original seal. Also that most spill was coming from cavity not emptying completely and was spilling when metering shaft retracts.

Metering shaft being reworked with cavity smaller in diameter, but deeper.

Dec. 7, 1973

Reworked metering shaft with cavity .100 diameter and .25 deep.
Filter only -- no screw.
Set up and used with small diameter funnel and new rod scraper seal.

28 mesh, 500 psi hydraulic pressure, 290 gauge
10-inch hg vac, air 8 psi.

Run 1 (Slow speed - hand)

	Loaded Wt(mg)
1	39.6
2	37.0
3	36.4
4	37.5
5	36.1

Noted dusting condition all over and around funnel.

Run 2 14-inch hg vac
air motor 200 RPM

	Loaded Wt(mg)
1	37.5
2	37.4
3	35.5
4	35.7
5	37.4

Excessive dusting.

Run 3 14-inch hg vac, air reduced to 6 psi, air motor 200 RPM

	Loaded Wt(mg)
1	36.3
2	35.9
3	36.1
4	35.8
5	36.4

Still excessive dust around funnel.

Run 4 10-inch hg vac, air 3 psi

	Loaded Wt(mg)
1	35.8
2	35.7
3	34.6
4	18.2
5	16.8

Dust reduced, loaded weight also reduced.

Changed to larger mouth funnel to check dusting problem:
Hydraulic pressure 500 psi, top punch gauge 290 psi
14-inch hg vac, air 6 psi, air motor 200 RPM
28 mesh pink simulant.

Run 1

	Loaded Wt(mg)		Loaded Wt(mg)
1	35.2	6	37.5
2	35.8	7	36.5
3	36.8	8	36.0
4	35.0	9	36.3
5	35.6	10	35.5

Still dust around sides and on top of funnel.

Dec. 7, 1973
(continued)

Metering shaft cavity .100 diameter, .25 deep
Hydraulic pressure 500 psi, top punch gauge 290
6-inch hg vac, air 5 psi, air motor 200 RPM.

Run 1 (White simulant powder)

	Loaded Wt(mg)
1	29.0
2	28.6
3	28.7
4	27.5
5	28.4
6	29.5
7	29.1
8	27.5
9	28.6
10	28.3

Dust on and around funnel.

Hydraulic pressure 500 psi, top punch pressure 200 psi
8-inch hg vac, air 4 psi, air motor 200 RPM.

Run 2 (White simulant powder)

	Loaded Wt(mg)
1	28.0
2	28.0
3	28.3
4	28.3
5	29.3
6	28.4
7	28.2
8	28.0
9	29.1
10	28.4

Dec. 11, 1973 am

Small mouth funnel, .145 diameter die
.100 diameter cavity, .25 deep metering shaft
Brass rod scraper seal
New carrier .1455 diameter ID
500 psi top punch, 600 psi gauge
6-inch hg vac, 6 psi air, air motor 200 RPM
White simulant powder, two consecutive charges.

	Loaded Wt(mg)		Loaded Wt(mg)
1	40.3	11	40.1
2	41.2	12	39.8
3	40.3	13	40.0
4	39.8	14	40.2
5	40.6	15	40.0
6	40.2	16	40.5
7	40.0	17	40.0
8	39.8	18	40.3
9	41.2	19	40.4
10	39.6	20	41.0

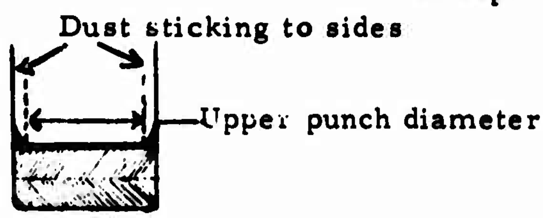
Flow control valves: high, 2 yellow; low, 9 gold.

Dec. 13, 1973 am

Filled 60 detonators with 2 consecutive charges of white simulant powder.

Hydraulic pressure 600 psi, top punch pressure 500 psi
6-inch hg vac, 5 psi air, air motor 200 RPM
Meter shaft flow control: 8 gold
High speed flow control, 6 blue; Lo speed, 2 yellow
Small mouth funnel and brass rod scraper seal.

Noted dusting condition on and around funnel -- powder sticks to sides of cup.



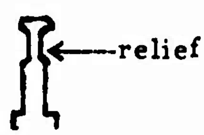
Spot Check of Loaded Wt(mg)

	White (2)	Plus Pink (1)		White (2)	Plus Pink (1)
1	40.6	58.9	36	40.3	59.6
5	40.9	59.3	41	41.1	60.6
10	40.5	58.5	44	40.6	59.5
16	40.3	58.2	48	40.3	58.8
19	40.4	58.7	51	40.9	59.6
23	41.6	59.8	55	39.7	57.8
24	41.0	60.8	60	39.2	57.2
30	39.6	58.4			

Added 1 charge of pink 28 mesh simulant to above cups (6-inch hg vac and 8 psi air).

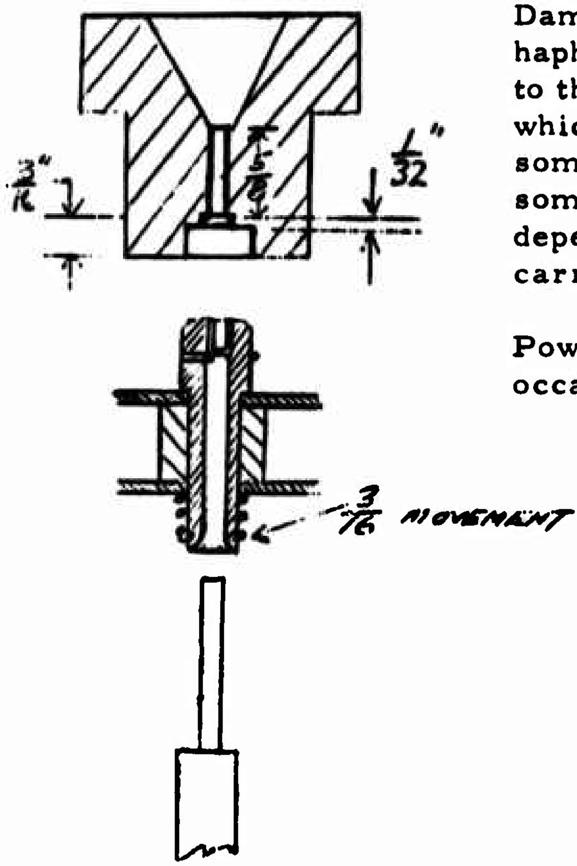
White simulant powder
Hydraulic pressure 1,400 psi, top punch 1,370 psi
Main flow valve open enough to assure delivery of powder when meter shaft flow control is open: hi pressure flow control - 2 blue
lo pressure flow control - 8 aqua
6-inch hg vac, air 6 psi, air motor 200 RPM.

Have trouble with top punch sticking in cup and pulling it part way back into funnel each time. Relined top punch .015 about 1/32 from end. Noted very little improvement.



Jan. 14, 1974

Redesigned die and carrier to allow the cup to move 1/32 inch only in carrier. The entire carrier is pushed up by lower punch into a recess approximately 3/16 inch deep in the bottom of die. Lower punch also raises cup 1/32 inch out of carrier and into a very small recess about .001 inch larger in diameter than the cup, and 1/32 inch deep.

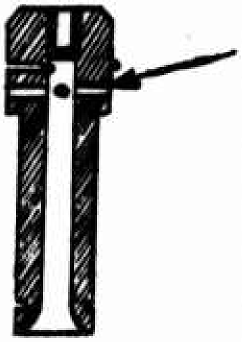


<u>Results:</u>

Damage occurred to the cup edges in a haphazard manner. This was attributed to the "pump" action of the lower punch which pushed a column of air ahead of it, sometimes forcing out the cup completely, sometimes halfway, sometimes not at all, depending on the degree of cup fit in the carrier.

Powder simulant was spilled on numerous occasions due to the above.

Jan. 15, 1974



1/16" dia. air holes (4) drilled under spring clip of carrier.

Purpose:

To allow escape of air from bore of carrier and reduce the "pump" effect of the lower punch, thus leaving the cup in place.

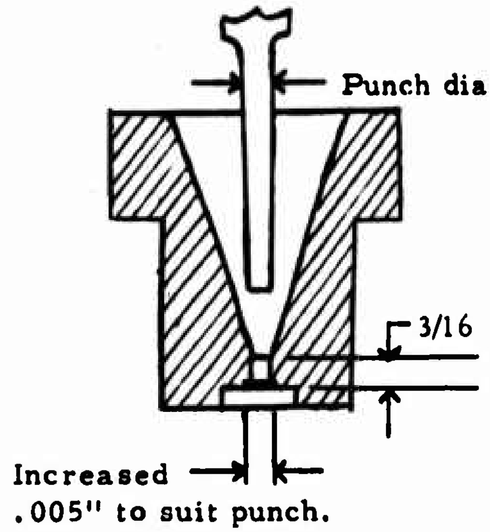
Result:

Cups retained continually and no further damage occurred.

Furthermore, no powder spill on top of carrier occurred after this modification.

Some powder sticking to punch.

Jan. 16, 1974



Die modified to provide less "pump" effect in parallel portion of funnel.

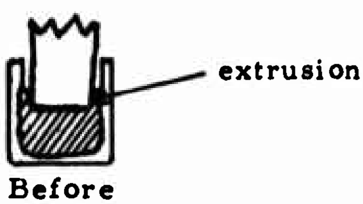
Object:

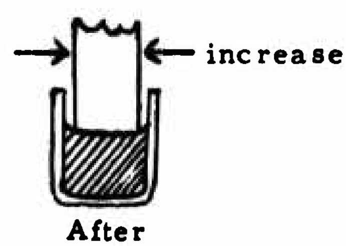
To lessen chance of dusting of baby powder up on punch on high speed descent.

Also to allow more time for slow action because microswitch was lowered by 1/4".

All compression testing and setups from this date to 21st of January conducted with this setup.

Punch increased .005 in diameter to give less powder extrusion up sides of punch inside cup when pressing.

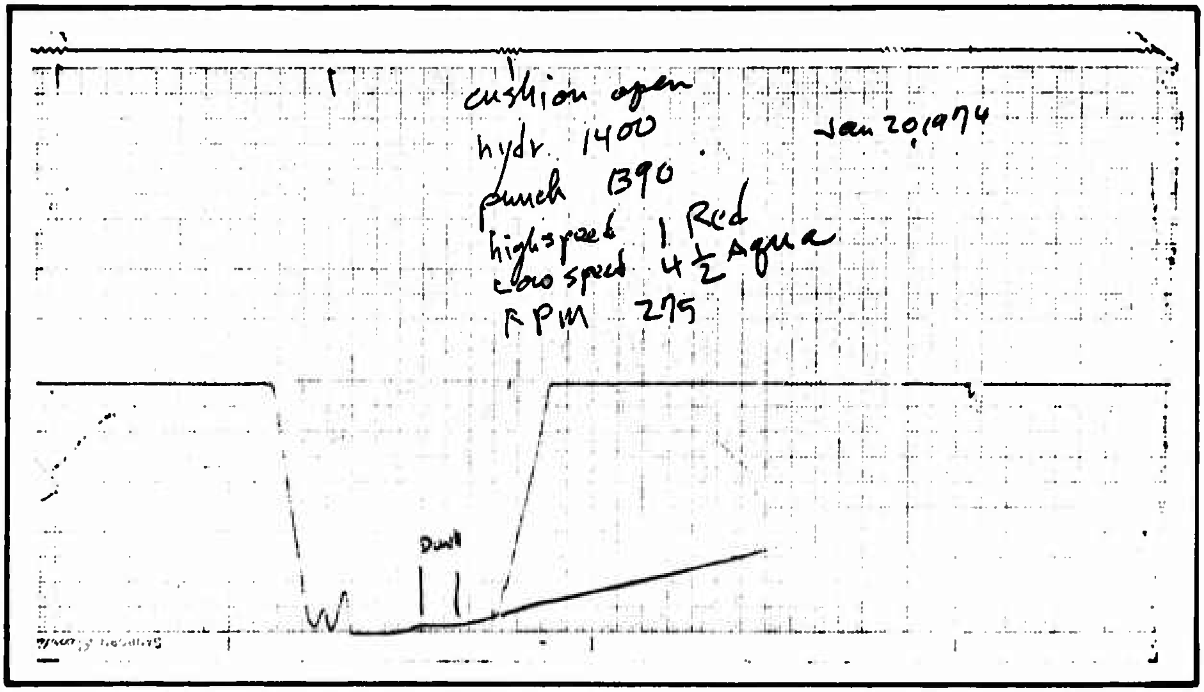


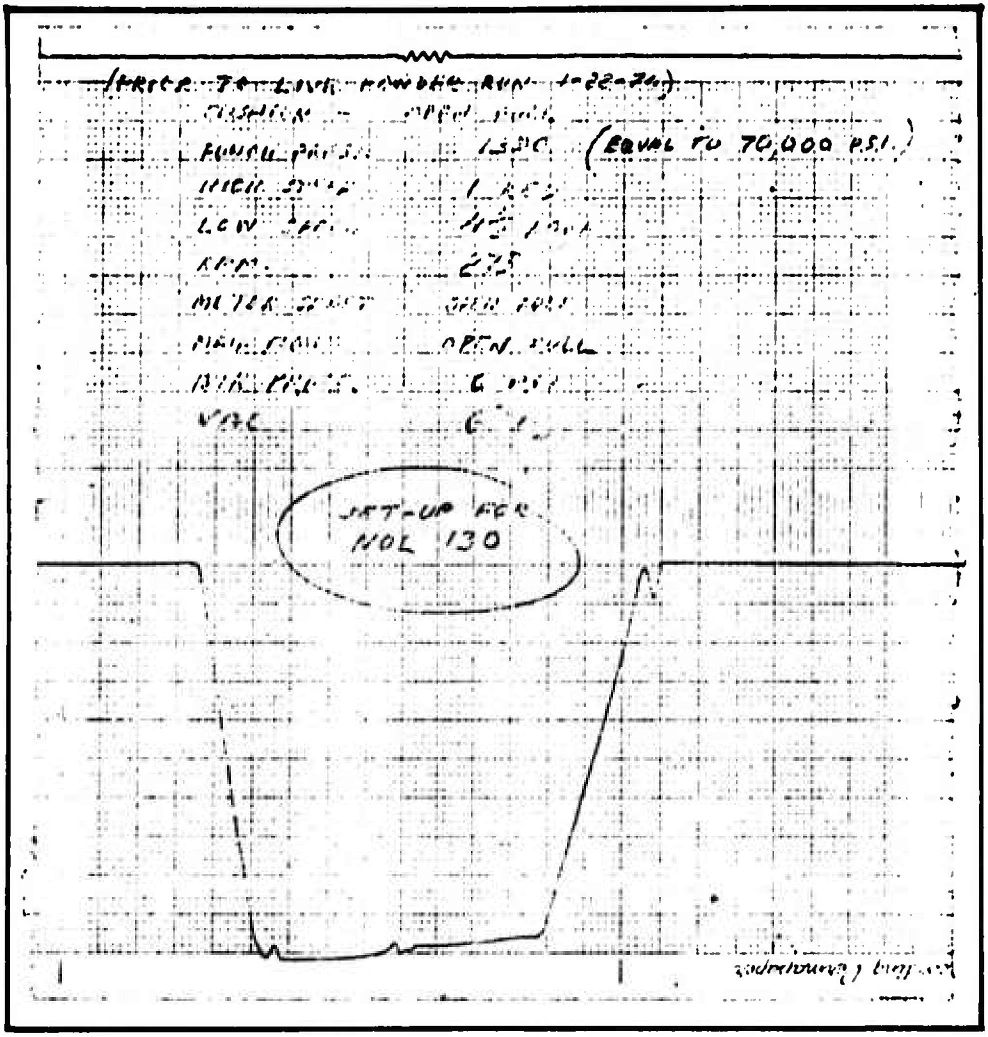


Jan. 21, 1974

Setup for first compression to provide graph slopes on attached trace.

Cushion (top punch)	Fully Open
Hydraulic Pressure	1,400
Punch Pressure	1,390
High Speed Regulator	1 Red
Low Speed Regulator	4-1/2 Aqua
RPM	275
Time Cycle	.6 seconds.




(EQUAL TO 70,000 P.S.I.)
OPEN FULL
SET-UP FOR
NOL 130

Jan. 22, 1974

LIVE TEST NOL 130

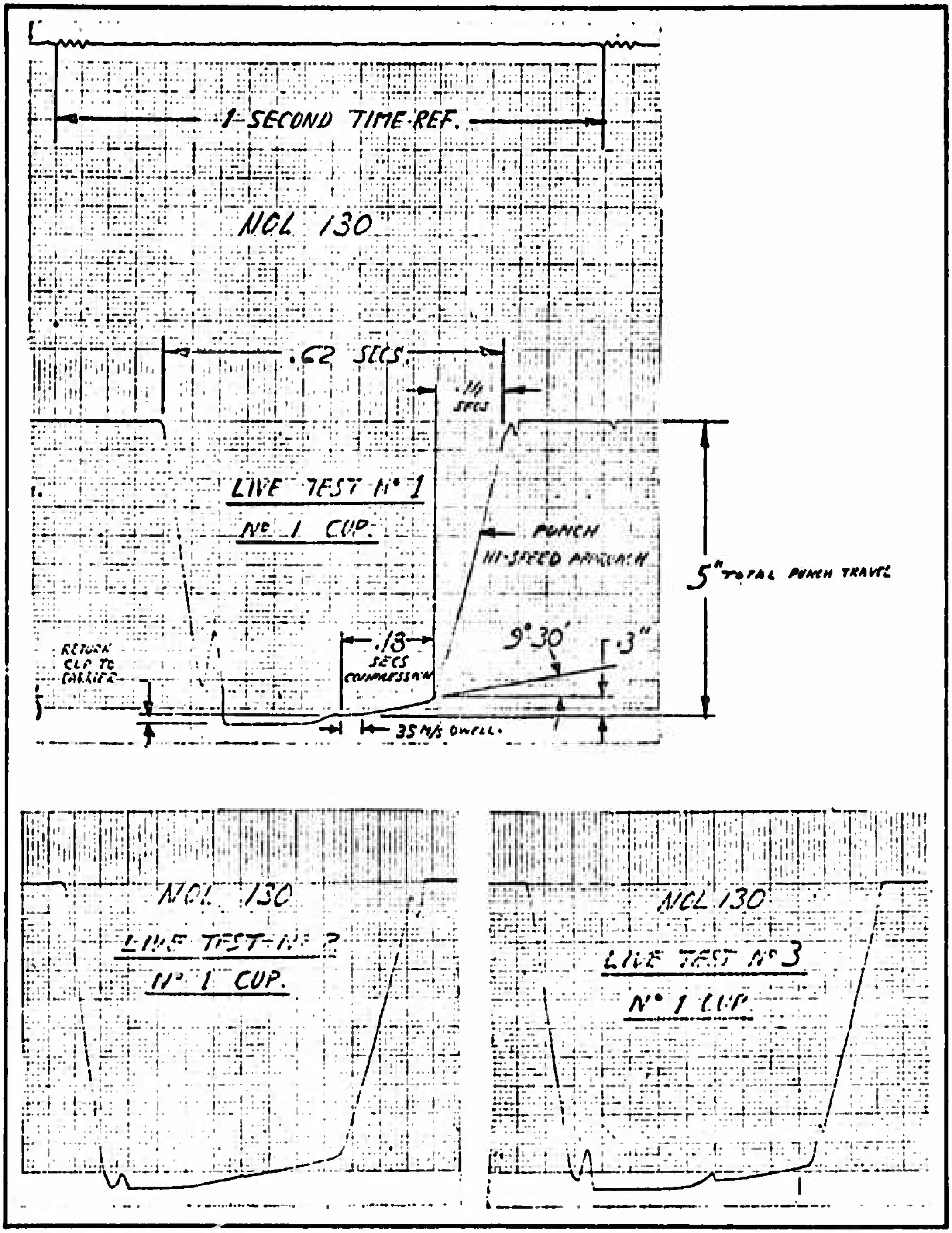
The first of a series of live tests was performed using 10 carriers and compressing the first charge of NOL 130. Carriers were numbered for fill identification. Settings used on the equipment were as follows for all 10 fills.

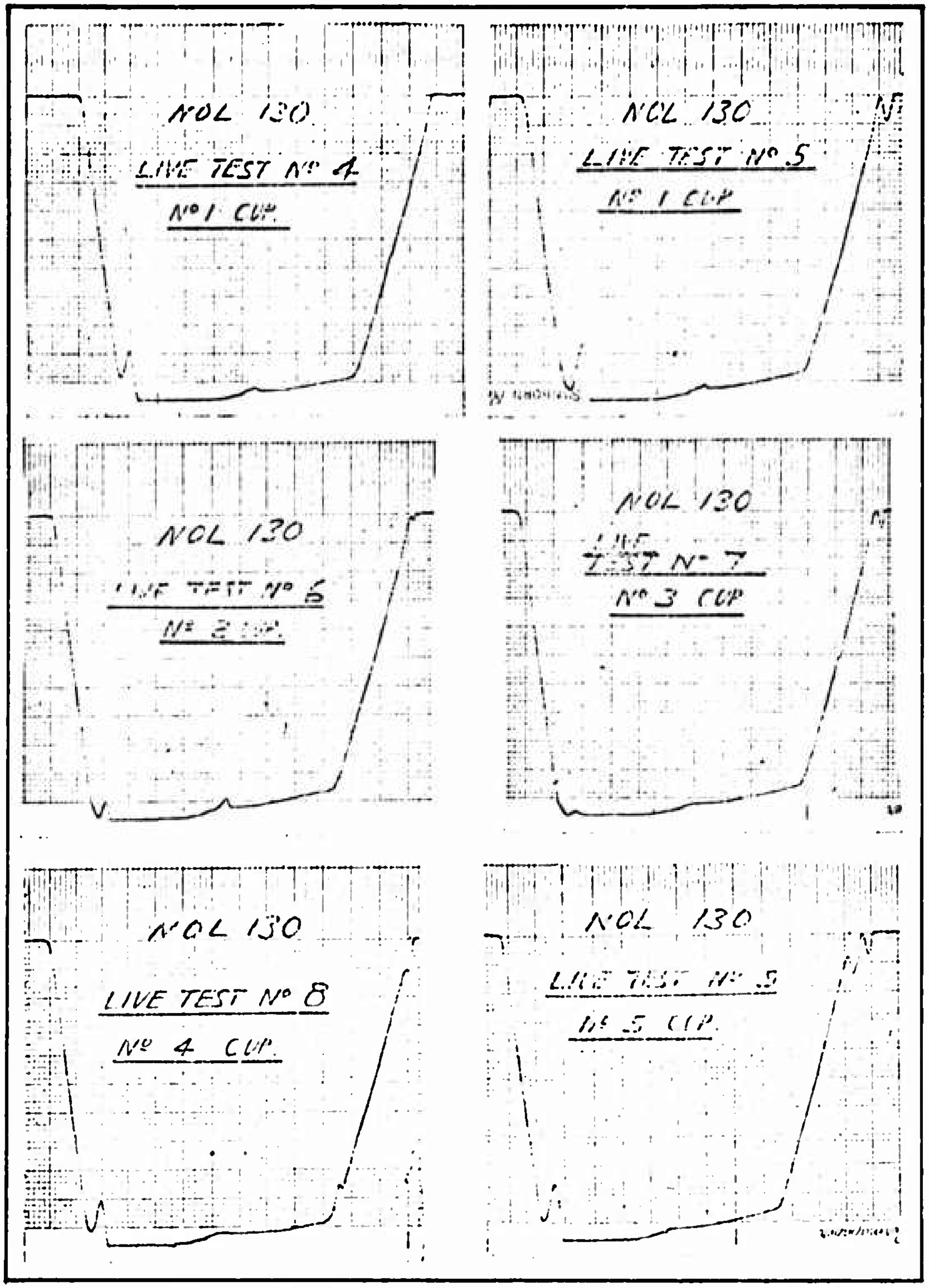
Punch Pressure	1,390 lbs.
Cushion - Top Punch	Fully Open
Main Flow Valve	Fully Open
Meter Shaft Flow Valve	Fully Open
Punch High Speed Valve Flow Setting	1 Red
Punch Low Speed Valve Flow Setting	4-1/2 Aqua
RPM of Cam Shaft	275
Vacuum	6-inch Hg
Nitrogen Pressure	6 psi.

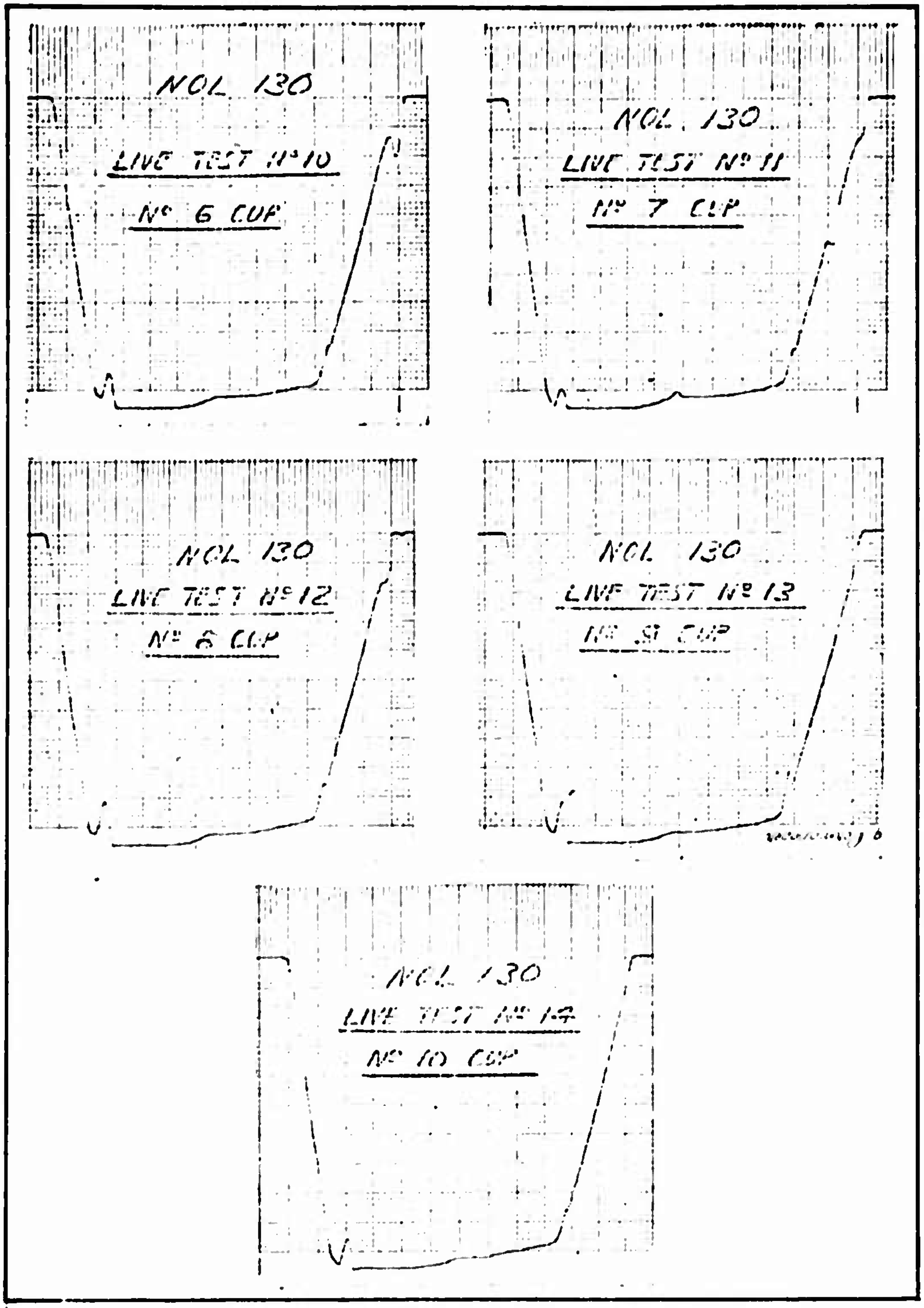
The powder hopper was slowly filled with 250 mg NOL 130 and Test No. 1 attempted. No powder in the cup resulted due to insufficient powder level in the hopper. The hopper quantity of NOL 130 was gradually increased, approximately 5 grams being necessary for correct metering and cup fill. Tests No. 1 through No. 4 using No. 1 cup were made to establish hopper fill requirement -- no cup fill resulting until Test No. 5. These first few tests without cup fill showed that the speed of the metering shaft was adequate for operation without danger of frictional detonation.

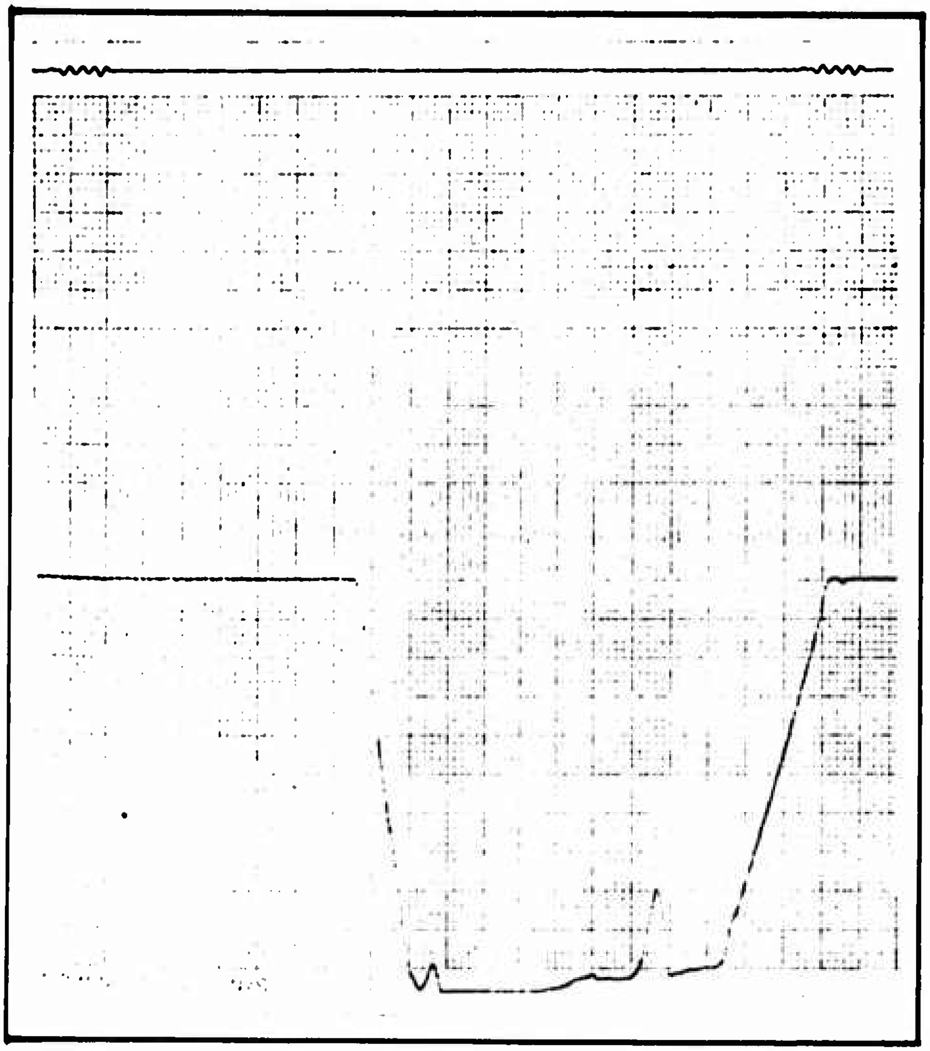
Test No. 5 through Test No. 14 produced 10 filled cups without detonation. These cups were then oven dried prior to weighing for uniformity of charge weight.

A record of the punch speed pattern was made with each test. The graph trace for these are on the following pages. Times were identical for all tests — .62 seconds time elapse from start of punch descent to finish of its return. (See 1-second time reference on graph trace of Test No. 1.) This time reference was consistent for all tests and are therefore not included on remaining traces.


1-SECOND TIME-REF.
NOL 130
.62 SECS.
.14 SECS
LIVE TEST No 1
No 1 CUP.
PUNCH
HI-SPEED APPROACH
5" TOTAL PUNCH TRAVEL
9°30'
.3"
.18 SECS COMPRESSION
RETURN CUP TO CARRIER
35 M/S DWELL
NOL 130
LIVE TEST No 2
No 1 CUP.
NOL 130
LIVE TEST No 3
No 1 CUP.


NOL 130
LIVE TEST N° 4
N° 1 CUP
NOL 130
LIVE TEST N° 5
NOL 130
LIVE TEST N° 6
N° 2 CUP
NOL 130
LIVE TEST N° 7
N° 3 CUP
NOL 130
LIVE TEST N° 8
N° 4 CUP
NOL 130


NOL 130
LIVE TEST Nº 10
Nº 6 CUP
NOL 130
LIVE TEST Nº 11
Nº 7 CUP
NOL 130
LIVE TEST Nº 12
Nº 6 CUP
NOL 130
LIVE TEST Nº 13
NOL 130
LIVE TEST Nº 14
Nº 10 CUP



Live Test No. 15
No. 11 Cup

Jan. 24, 1974

LIVE TEST DATA
NONELECTRIC DETONATOR

NOL 130 Detonator Cup Charging

The results of the 10 detonator cup fills, according to the procedure on Live Test NOL 130 dated January 22, 1974, were as follows.

It should be noted that no agitation of the hopper powder was taking place.

	1 Charge per Cup — No. 1 Test				
Cup No.	Tare Wt.	Total Wt.	Charge Wt.		Comments
1	.0155	.0611	.0456		
2	.0159	.0642	.0483		
3	.0149	.0650	.0501		
4	.0155	.0663	.0508		
5	.0155	.0657	.0502		
6	.0160	-	-		Bad Cup
7	.0151	.0640	.0489		
8	.0150	.0622	.0472		
9	.0153	.0500	-		Cup dropped during removal
10	.0150	-	-		Out-of-round cup
11	.0159	.0363	.0204	*	
12	.0161	.0203	.0042	*	
13	.0150	-	-	*	Out-of-round cup
14	.0150	.0203	.0053	*	

*Cups 11-14 were run after 40-minute shutdown.

Conclusions

Individual metering shots with a fairly long time period between them (changing cups, resetting controls, etc.) was disadvantageous to accurate metering without agitation. Note the considerable change after 40-minute shutdown and hopper bridging started. This test was the very first with live powder, performed by Ordnance personnel unfamiliar with good or bad cups for this equipment, and no calculations were made due to the variable weights obtained.

The next test, No. 2, was a metering test — 100 successive cycles indicated that the mechanical shocks from fairly rapid machine cycling helps bridging somewhat, but the gradual decrease in weight shows that it progressively became worse until serious bridging occurred during the fill of Dish No. 10. The single shots into Dishes Nos. 11-20 exhibit similar problems without agitation.

Jan. 24, 1974
(contd.)

Dish No.	Tare Wt.	Total Wt.	Charge Wt.		Comments
	10 Charges Per Dish — No. 2 Test				
1	1.4096	1.8451	.4355		
2	1.3996	1.8338	.4342		
3	1.3982	1.8292	.4310		
4	1.3980	1.8367	.4387	+	
5	1.4012	1.8291	.4279		Hopper ran low, was refilled.
6	1.4028	1.8271	.4243		
7	1.4040	1.8258	.4218		Note gradual decrease in weight.
8	1.4049	1.8154	.4105	-	
9	1.3982	1.8103	.4121		
10	1.3991	1.6309	.2318		Serious bridging, this line omitted.
	Average Weight		.4262 (1 - 9)		
	Widest Difference		.028		
	Maximum wt. variation		± 3.3%		
	1 Charge Per Dish — No. 3 Test				
11	1.4064	1.4131	.0067	-	Continued Bridging
12	1.4067	1.4288	.0221		
13	1.3984	1.4137	.0153		
14	1.4086	1.4159	.0073		
15	1.3974	1.4068	.0094		
16	1.4025	1.4232	.0207		
17	1.4144	1.4422	.0278	+	
18	1.4178	1.4299	.0121		
19	1.4076	1.4153	.0077		
20	1.3959	1.4051	.0092		
	Average Weight		.0138		
	Widest Difference		.0211		
	Maximum wt. variation		— exceeds average weight.		

The above two tests were both conducted without the pneumatic agitation of the hopper powder. Serious bridging and haphazard metering occurred. Dish No. 10 weight was so obviously low that it was omitted from average weight calculations.

Recognizing the reason for the poor results of the last three tests, the agitation was connected (it had been disconnected because of the difficulty of achieving an adequate vacuum reading and sufficient nitrogen pressure reading at the same time due to a leakage path between the port routes of the common valve).

Jan. 24, 1974
(contd.)

Although the vacuum on the following test was low, and the nitrogen pressure also lower than desirable, the results of the single charge per dish repeat test, with agitation show great improvement.

	1 Charge per Dish — No. 4 Test				
Dish No.	Tare Wt.	Total Wt.	Charge Wt.		Comments
11	1.4049	1.4448	.0399	*	This line omitted
12	1.4029	1.4459	.0430		
13	1.4068	1.4496	.0428	-	
14	1.4086	1.4520	.0434		
15	1.4066	1.4497	.0431		
16	1.3980	1.4421	.0441		
17	1.4013	1.4445	.0432		
18	1.4046	1.4489	.0443		
19	1.3997	1.4434	.0437		
20	1.3939	1.4393	.0454		
	Average Weight		.0436 (12 - 20)		
	Widest Difference		.0026		
	Max. Weight Variation		±2.9%		

*The charge weight on this first shot after previous bridging problems is so obviously low that it is omitted from average weight calculation. It is attributed to the existing lack of fill condition without agitation still being present until a complete metering cycle had taken place, i.e., from Dish No. 12 onward.

Vacuum on No. 4 Test	5.4-inch hg
Nitrogen Pressure	4 psi
Hydraulic Pressure (for metering only)	500 psi

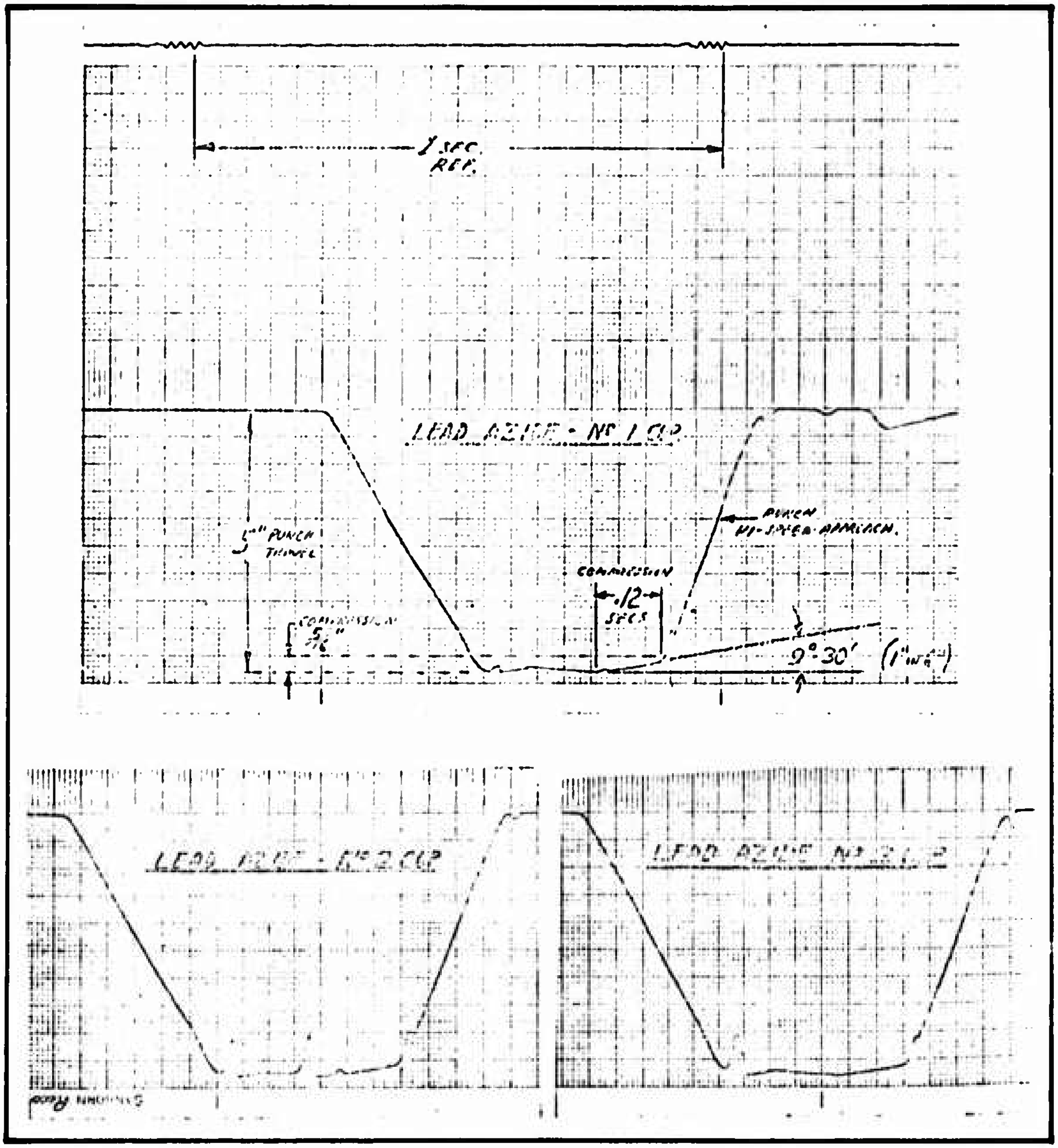
No detonation took place.

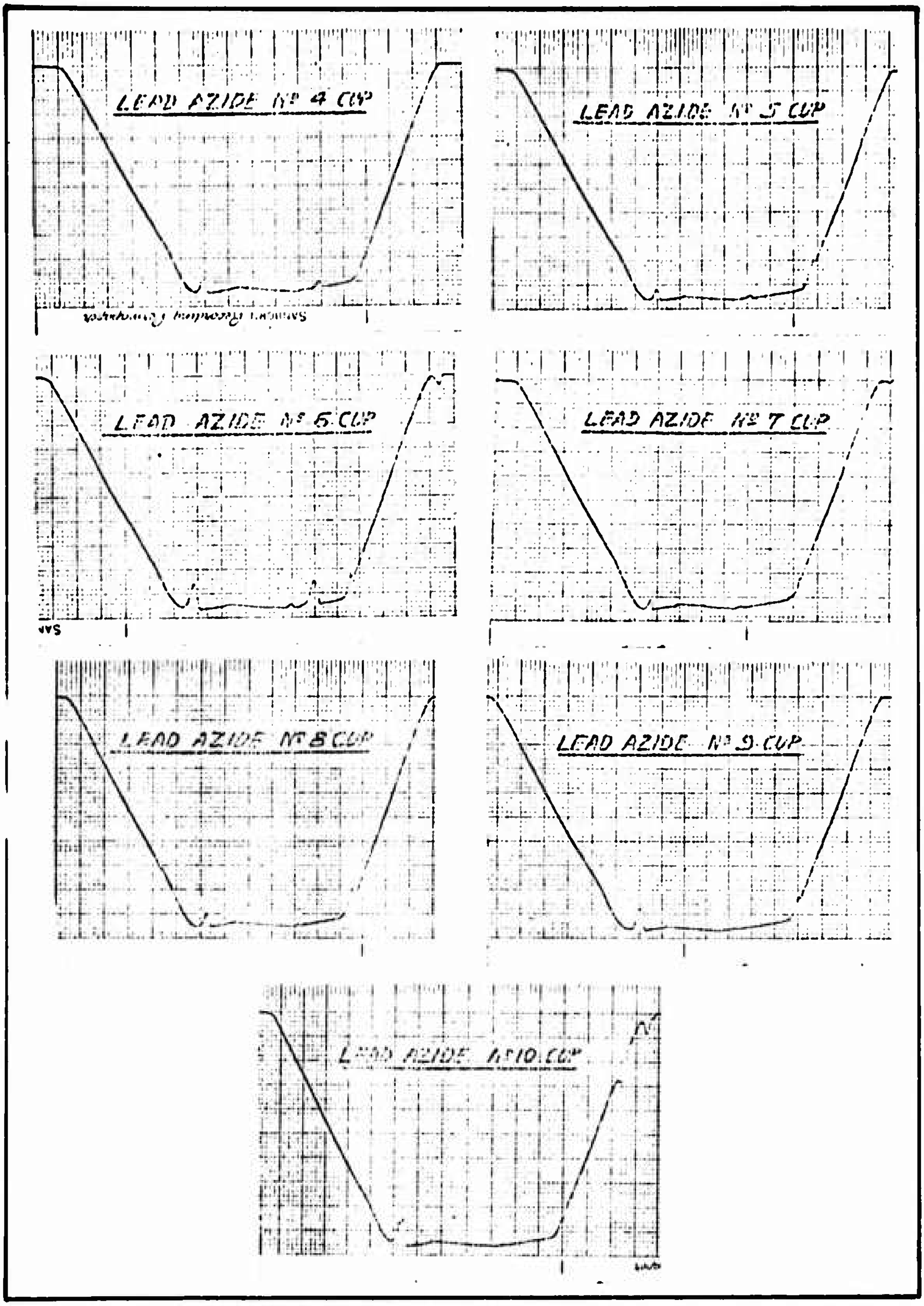
Jan. 24, 1974

LIVE TESTS — LEAD AZIDE

Graph Traces for Detonator Cup Fills

Machine settings as on data sheet.
Slower approach and retract slopes of punch is due to lower hydraulic pressure (197 lbs/sq in) than that of the NOL 130 slopes (pressure 1,390 lbs/sq in).




LEAD AZIDE No 4 CUP
LEAD AZIDE No 5 CUP
LEAD AZIDE No 6 CUP
LEAD AZIDE No 7 CUP
LEAD AZIDE No 8 CUP
LEAD AZIDE No 9 CUP
LEAD AZIDE No 10 CUP

Jan. 24, 1974

LIVE TEST DATA
NONELECTRIC DETONATOR

Lead Azide Live Testing

	Detonator Cup Fill — No. 5 Test				
Cup No.	Tare Wt.	Total Wt.	Charge Wt.		Comments
1	.0155	.0656	.0501		
2	.0160	.0648	.0488		
3	.0165	.0662	.0497		
4	.0163	.0646	.0483	-	Slight spill on carrier
5	.0158	.0658	.0500		
6	.0158	.0657	.0499		
7	.0158	.0651	.0493		
8	.0164	.0650	.0486		
9	.0155	.0658	.0503	+	
10	.0166	.0668	.0502		
	Average Weight		.0495		
	Widest Difference		.002		
	Max. Wt. Variation		±2.02%		

Equipment Settings:

Hydraulic pressure on punch	197 psi
Punch cushion	Fully open
Main flow valve	Fully open
Meter shaft flow valve	Fully open
Agitation	Off
Punch high speed valve setting	Fully open
Punch low speed valve setting	4-1/2 Red
Tachometer reading	275 RPM
Vacuum	6-inch hg
Nitrogen	6 psi

Lead azide requires little agitation compared to NOL 130. Cup fills were good, compression looked good. No detonation took place.

Jan. 24, 1974

LIVE TEST DATA
NONELECTRIC DETONATOR

Lead Azide Live Metering Test

Dish No.	Tare Wt.	Total Wt.	Charge Wt.	Comments
	10 Charges per Dish — No. 6 Test			
1	1.4122	1.9153	.5031	
2	1.3686	1.8748	.5062	
3	1.4008	1.9070	.5062	
4	1.4011	1.9091	.5080	+
5	1.4012	1.9068	.5056	
6	1.3974	1.9013	.5039	
7	1.4058	1.9088	.5030	-
8	1.4059	1.9120	.5061	
9	1.4130	1.9197	.5067	
10	1.4063	1.9139	.5076	
	Average Weight		.5056	
	Widest Difference		.005	
	Max. Wt. Variation		±0.49%	
	1 Charge per Dish — No. 7 Test			
11	1.4050	1.4556	.0506	
12	1.4042	1.4543	.0501	
13	1.3946	1.4451	.0505	
14	1.3953	1.4455	.0502	
15	1.4124	1.4626	.0502	
16	1.4100	1.4594	.0494	-
17	1.3318	1.3826	.0508	
18	1.4087	1.4586	.0499	
19	1.4013	1.4605	.0502	
20	1.4081	1.4598	.0517	+
	Average Weight		.0504	
	Widest Difference		.0023	
	Max. Wt. Variation		±2.28%	

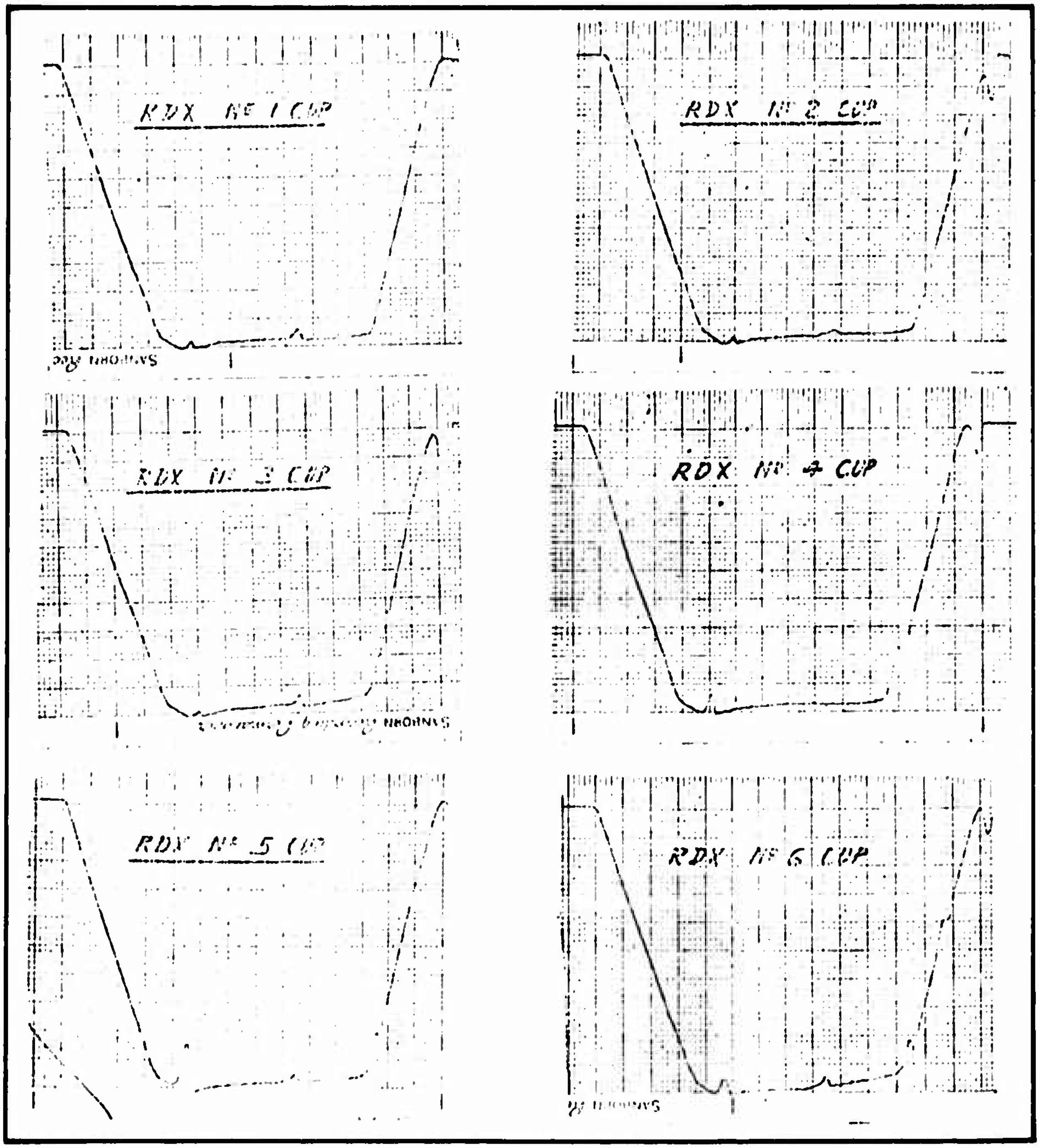
Equipment settings same for No. 5, 6, and 7 Tests.

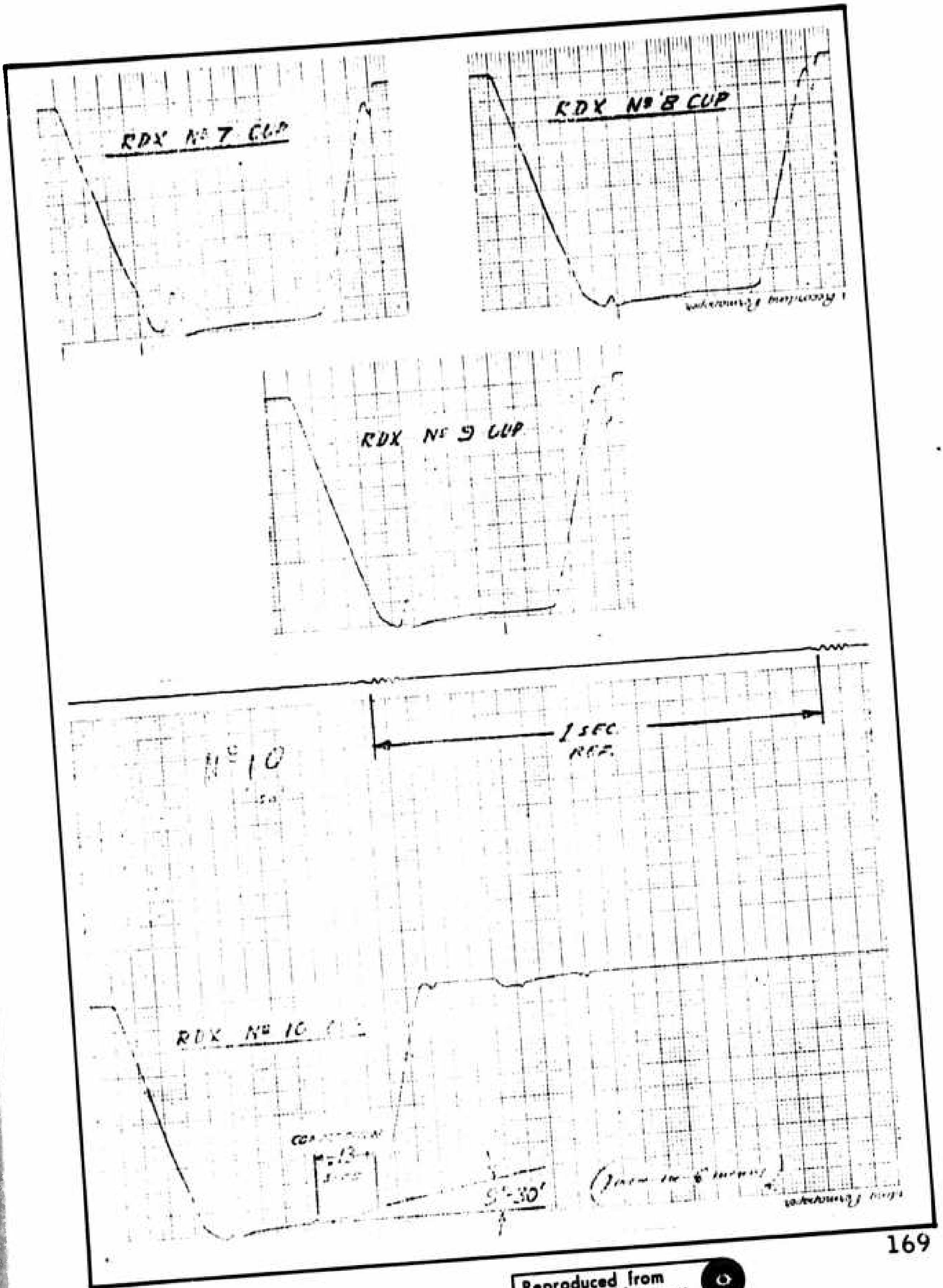
Jan. 29, 1974

LIVE TESTS — RDX

Graph Traces for Detonator Cup Fills

Machine settings as on data sheet.
Note slope of punch descent (ascent is slightly faster due to hydraulic pressure increase [to 298 psi] over that of lead azide pressure at 197 psi).




RDX Nº 7 CUP
RDX Nº 8 CUP
RDX Nº 9 CUP
Nº 10
1 SEC.
REF.
RDX Nº 10
5'-30'

Jan. 29, 1974

LIVE TEST DATA
NONELECTRIC DETONATOR

RDX Live Testing

Detonator Cup Fill — No. 8 Test

Cup No.	Tare Wt.	Total Wt.	Charge Wt.	Comments
1	.0158	.0433	.0275	-
2	.0160	.0440	.0280	
3	.0157	.0441	.0284	
4	.0162	.0445	.0283	
5	.0165	.0451	.0286	
6	.0157	.0446	.0289	
7	.0170	.0457	.0287	
8	.0155	.0447	.0292	
9	.0162	.0456	.0294	+
10	.0155	.0443	.0288	
	Average Weight		.0286	
	Widest Difference		.0019	
	Max. Wt. Variation		±3.3%	

The RDX was screened through a No. 48 sieve before use.

Equipment settings for Nos. 8, 9, and 10 Tests were as follows:

Hydraulic punch pressure	298 psi
Punch cushion	Fully open
Main flow valve	Fully open
Meter shaft valve	Fully open
Agitation	On
Punch high speed valve setting	Fully open
Punch low speed valve setting	4-1/2 Red
Tachometer reading	275 RPM
Vacuum	4-1/2-inch hg
Nitrogen	4 psi

Fill in cups looked good. No detonations occurred. Compression looked good. Two extra cycles were run because two carriers were inadvertently cycled without cups. The fill assumed a pellet shape in the carrier and had to be pushed out before reloading with a detonator cup. No detonation occurred.

Jan. 29, 1974

LIVE TEST DATA
NONELECTRIC DETONATOR

RDX Metering Tests

	10 Charges per Dish — No. 9 Test				
Dish No.	**Tare Wt.**	**Total Wt.**	**Charge Wt.**		**Comments**
1	1.3982	1.6883	.2901	-	
2	1.3955	1.6882	.2927		
3	1.3975	1.6923	.2950		
4	1.3987	1.6918	.2931		
5	1.4012	1.6951	.2939		
6	1.3960	1.6283	.2323	*	Hopper ran out of powder and needed refilling.
7	1.3952	1.6894	.2942		
8	1.3958	1.6920	.2962	+	
9	1.3938	1.6895	.2957		
10	1.3980	1.6923	.2943		
	Average Weight		.2939 (omitting No . 6)		
	Widest Difference		.006		
	Max. Wt. Variation		±1.03%		

*The obviously low figure of No. 6 dish is due to the hopper running dry. The calculations for average weight do not include this dish.

	1 Charge per Dish — No. 10 Test			
11	1.3976	1.4272	.0296	
12	1.3957	1.4256	.0299	+
13	1.3960	1.4258	.0298	
14	1.3975	1.4272	.0297	
15	1.4003	1.4288	.0285	-
16	1.4030	1.4320	.0290	
17	1.4056	1.4350	.0294	
18	1.3991	1.4284	.0293	
19	1.3954	1.4250	.0296	
20	1.4008	1.4300	.0292	
	Average Weight		.0294	
	Widest Difference		.0014	
	Max. Wt. Variation		±2.38%	

Feb. 27, 1974

LIFE TEST OF MICRONITE FILTER ADJUSTABLE VOLUME METHOD

A jury rig was built as shown in Sketch K.1. 2/6 to prove feasibility of method of metering as well as to determine if filter would clog after repeated operation.

Charges were weighed after several thousand operations to see if filter was clogging. Baby powder was used (talc).

Results:

1,000 operations	150 mg
3,000 operations	159 mg
5,000 operations	205 mg
10,000 operations	96 mg
15,000 operations	83 mg

Observations:

Up to 5,000 operations, the volume by weight showed an increase but dropped off when measured at 10,000, and a similar decrease was apparent at 15,000 operations.

Filter was removed and it was practically half eroded away. This erosion probably accounted for the gradual increase in volume by weight as the cavity increased. However, the total breakdown and consequent clogging allowed only a small amount of powder in the cavity later.

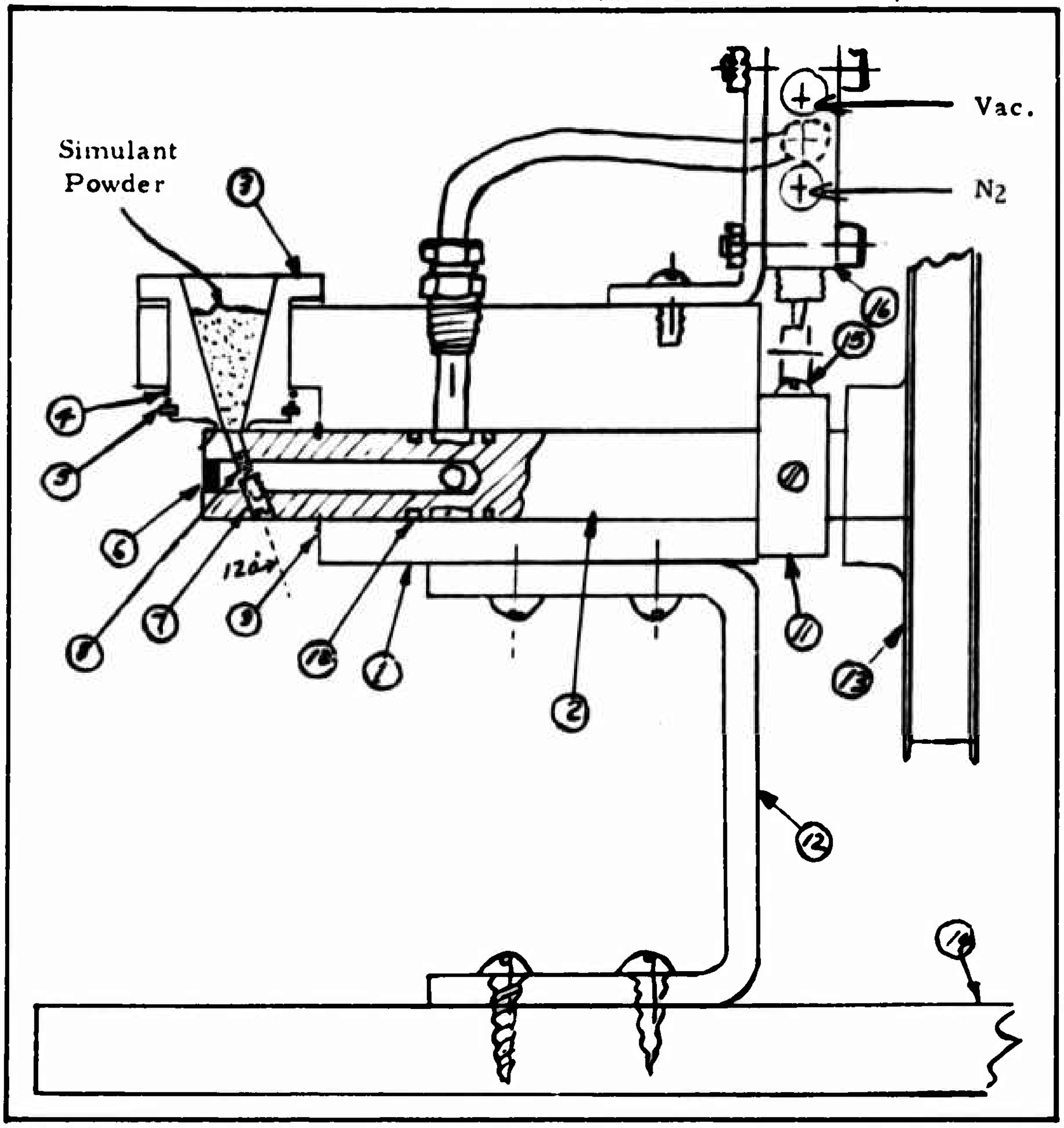
Conclusions:

Use a ceramic filter rather than the porous plastic micronite to resist the abrasive effect.

Also, an increase in dump pressure for a shorter dump time would elp to prevent clogging.

Test is considered inconclusive using plastic filter and abrasive baby powder (talc or mica) as the abrasive qualities of NOL 130, Lead Azide and RDX are unknown.

Sketch K.I. 2/6 BENCH TEST JURY RIG (Needs Variable Speed Motor Drive, also Rev. Counter)



1. Metering Body Block
2. Metering Shaft
3. Powder Hopper (Nizon or Delrin)
4. Doctoring Spring
5. Retaining Ring
6. Plug
7. Filter Screw (adjustable volume)
8. Micronite Filter
9. Retaining Ring
10. "O"-Ring Seals
11. Collar
12. Mtg. Bracket
13. Drive Pulley (shaft to rotate at 60 RPM)
14. Base Plate
15. Screwhead Cam to Operate Roller of Valve 16 (sharp "blip" to valve required)
16. 3-way Valve, Vacuum and Nitrogen Input, roller operated