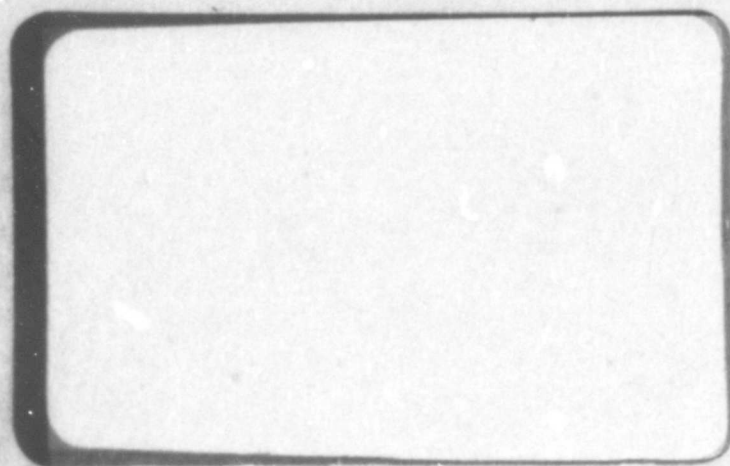
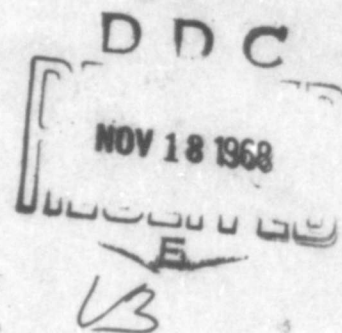


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**CONVAIR**

A DIVISION OF GENERAL DYNAMICS CORPORATION  
SAN DIEGO

GENERAL DYNAMICS/CONVAIR

DEPARTMENT 190-2 FINAL REPORT

DYNAPAK FORGING

P.R. 904

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ABSTRACT

Tooling concepts for forging and extrusion processes were developed. The developed tooling has demonstrated production practicality in the manufacture of test parts.

Detail test parts have shown grain size reduction in the forging process. The parts also demonstrated that precision forging and extrusion by the high energy rate process can be achieved in fewer stages than conventional processes.

Machine operating and safety procedures for the San Diego Dynapak unit were also established.

SUMMARY

Tooling concepts for forging and extrusion processes were developed. Two basic types of universal holders for both processes were evolved. One holder was pre-stressed and the other unstressed. The pre-stressed design was found to be more adaptable to extruding and the unstressed holder to the forging process. Sound, strong tooling developed for production capabilities has demonstrated operating practicability in the manufacture of test parts.

Detail parts made through the use of test tooling have shown grain size reduction in the forging process. An anticipated gain in strength due to the refinement of grain did not occur, however, a uniformity of material grain size was achieved. The detail parts demonstrated that precision forgings and extrusions can be effectively produced by the high energy rate process in fewer stages than required by the more conventional processes.

Machine operating parameters and safety regulations were established for the operation of the San Diego Dynapak unit.



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<u>TABLE OF CONTENTS</u>	<u>PAGE</u>
ABSTRACT	1
SUMMARY	11
INTRODUCTION	1'
CONCLUSIONS AND RECOMMENDATIONS	1
<u>General</u>	1
<u>Machine</u>	1
<u>Tooling</u>	2
DEVELOPMENT OF THE PROJECT	
<u>The Dynapak Machine and It's Operating Principles</u>	2
<u>Parts Manufacture</u>	
Selection of Parts	13
Manufacture	17
Lubricants	31
<u>Tooling</u>	
Design	32
Forging	35
Forward Extrusions	42
Backward Extrusions	53
Compacting	57
Materials	59

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TABLE OF CONTENTS  
(Cont'd)

	<u>PAGE</u>
<u>APPENDIX</u>	61
MACHINE OPERATING INSTRUCTIONS	
<u>General Operating Instructions</u>	
Safety Precautions	63
Test Firing	64
Machine Malfunction	70
Tool Installation	72
ACKNOWLEDGMENTS	77

GENERAL DYNAMICS/ELECTRONICS

LIST OF ILLUSTRATIONS

	<u>PAGE</u>
FIGURE 1 - SAN DIEGO DIVISION MODEL 1200 DYNAPAK INSTALLATION	3
FIGURE 2 - SAN DIEGO DIVISION MODEL 1205 DYNAPAK ILLUSTRATION	4
FIGURE 3 - MODEL 1205 DYNAPAK MACHINE FRAME MODIFICATION FOR 3RD SHOCK INSTALLATION	6
FIGURE 4 - CLOSE-UP OF "V" GROOVED MAIN RODS AND SQUARE BOLSTER PLATE	7
FIGURE 5 - CLOSE-UP OF SQUARE GROOVED MAIN RODS AND ROUND BOLSTER PLATE	8
FIGURE 6 - 1205 SERIES DYNAPAK MACHINE SCHEMATIC	9
FIGURE 7 - DYNAPAK AT REST AFTER POWER STROKE	10
FIGURE 8 - HYDRAULIC OIL RETURNS PISTON AND COCKS HYGE TRIGGER UNIT	11
FIGURE 9 - MACHINE READY TO FIRE	12
FIGURE 10- TRIGGER GAS ABOUT TO MOVE HYGE PISTON	14
FIGURE 11- DYNAPAK REACTION FRAME IN OPERATION	15
FIGURE 12 -FORGED SPRING TAIL HOOK FITTING AND BILLET(P/N 8-78732-7)	16
FIGURE 13- DYNAPAK FORGED ALUMINUM (2014) CLIP	18
FIGURE 14- DYNAPAK FORGED SAE 4130 BUSHING P/N 8-16512	19
FIGURE 15- DYNAPAK FORGED SAE 4340 BUSHING	20
FIGURE 16- OPEN BACK EXTRUSION SAMPLES	21
FIGURE 17- FOREWARD EXTRUSION SAMPLE	22
FIGURE 18- INITIAL SPRING TAIL HOOK TOOLING	23
FIGURE 19- EXAMPLE OF MATERIAL SEPARATION	24
FIGURE 20- PHOTOMICROGRAPH OF TAIL HOOK FITTING STRUCTURE AS FORGED	26

LIST OF ILLUSTRATIONS

	<u>PAGE</u>
FIGURE 21 - PHOTOMACROGRAPH OF SAE 4130 P/N 8-16512 WING SPAR BUSHING	28
FIGURE 22 - PHOTOMICROGRAPH (200X) OF BILLET MATERIAL GRAIN SIZE 7 FOR 8-16512 BUSHING	30
FIGURE 23 - PHOTOMICROGRAPH (200X) OF 8-16512 BUSHING GRAIN SIZE SMALLER THAN 8	30
FIGURE 24 - TYPICAL CLOSED FORGING DIE CROSS SECTION	33
FIGURE 25 - TYPICAL POCKET BLEED HOLE	34
FIGURE 26 - UNSTRESSED UNIVERSAL DIE HOLDER	36
FIGURE 27 - TYPICAL FORGE DIE DESIGN FOR UNSTRESSED DIE HOLDER	37
FIGURE 28 - UNIVERSAL HOLDER & STRIPPER RING	40
FIGURE 29 - BASIC HOLDER LESS STRIPPER RING	41
FIGURE 30 - BASIC HOLDER WITH STRIPPER RING IN UP POSITION	43
FIGURE 31 - TYPICAL BUSHING TOOLING	44
FIGURE 32 - FIRST PUNCH HOLDER BUILT	46
FIGURE 33 - PUNCH HOLDER FAILURE	47
FIGURE 34 - UNIVERSAL PUNCH HOLDER	48
FIGURE 35 - PRE-STRESSED EXTRUSION TOOL HOLDER	49
FIGURE 36 - TYPICAL FAILURE OF HIGH HARDNESS PUNCH	51
FIGURE 37 - TYPICAL UPSET FAILURE OF PUNCH	52
FIGURE 38 - EXTRUSION DIE BUTTON DESIGN	54
FIGURE 39 - EXTRUSION DIE BUTTON	55
FIGURE 40 - OPTIMUM BACK EXTRUSION PUNCH DESIGN	56
FIGURE 41 - FLATTENING DIES FOR COMPACTION ATTEMPT	58
FIGURE 42 - OPERATING CONSOLE CONTROLS	66

## GENERAL DYNAMICS/CONVAIR

### INTRODUCTION

Preliminary work conducted under RMDA SD-9-8 at the Pomona Dynapak site and the Precision Forge Company facility in Santa Monica, indicated that conventional forging and extrusion practices were not entirely applicable to the high energy rate process. Consequently upon the acquisition of the Model 1200 series Dynapak machine by Convair-San Diego this project was initiated.

The purpose of this project was the establishment of tooling and operating parameters as well as part design limitations consistent with the high energy rate Dynapak forging process.

### CONCLUSIONS AND RECOMMENDATIONS

#### General

The use of the Dynapak high energy rate process for forging and extrusion of metals is not only feasible but can be accomplished with closer tolerances and fewer stages than conventional processes.

#### Machine

It is recommended that the machine be "beefed up", to harness the tremendous forces generated, for production usage.

Ram guides should be further improved to provide accuracy and ram stability not available on present machines.

#### Tooling

Under no circumstances should a tool be bolted to the bolster plate from below.

Never use anything less than 1 inch bolts for hold-down usage.

Tool hardness should never exceed  $R_c$  50 or go below  $R_c$  46.

## CONCLUSIONS AND RECOMMENDATIONS

### Tooling (Cont'd)

Use an H-11 or equivalent shock resistant tool steel such as Durodi for part tooling. Do not use tool steels normally used for blanking and forming dies.

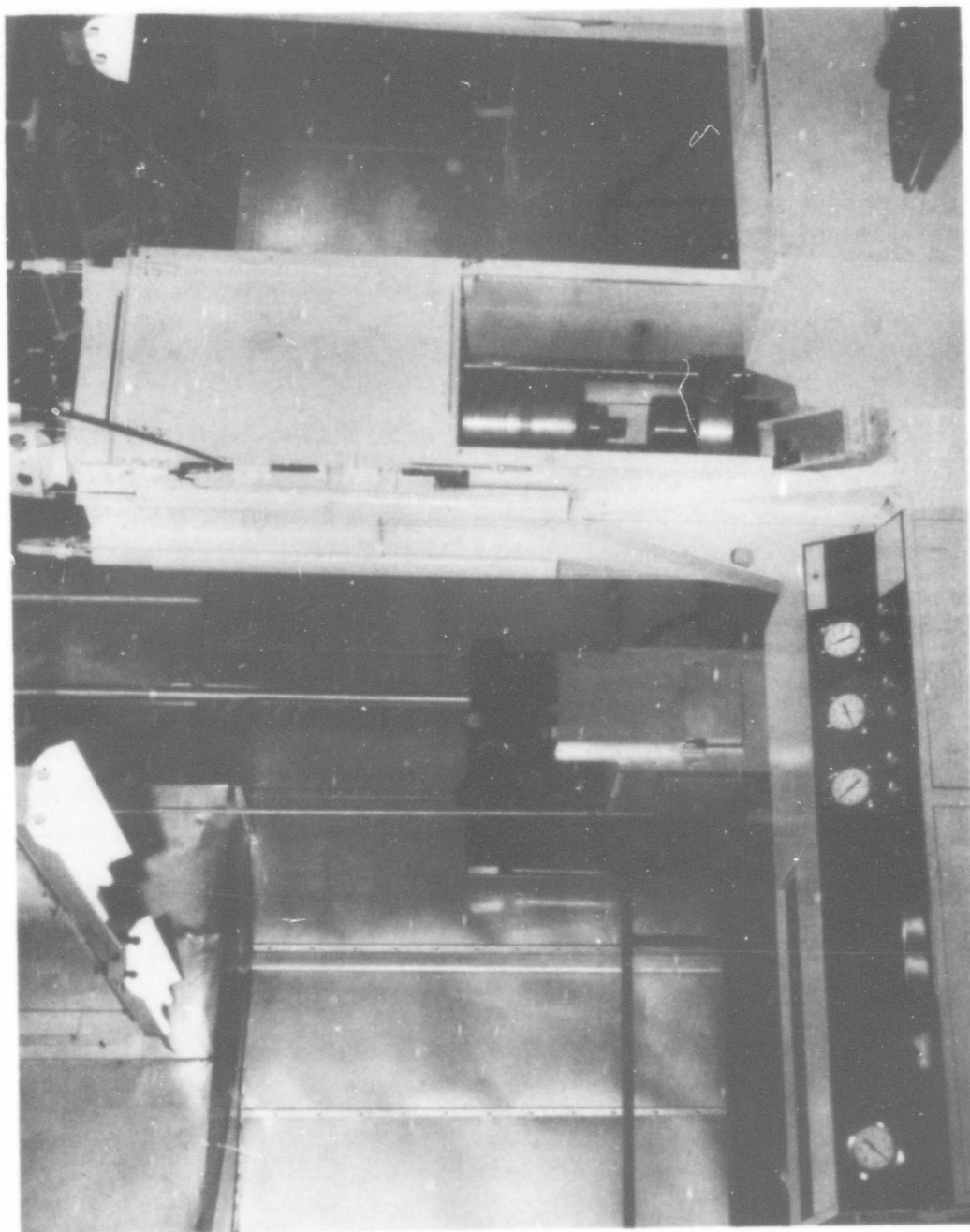
Maintain polished die surfaces to reduce the chances of material "pick up" during the operating cycle.

## DEVELOPMENT OF THE PROJECT

### The Dynapak Machine and It's Operating Principles

A Model 1200 Dynapak machine was utilized in the establishment of tooling and operating concepts. The original San Diego machine was adapted to operate in a vertical position since the machine was to be used in the forging application. An additional main rod foot arrangement was required to stabilise the machine since shock cylinders were mounted only on the two front main rods. Figure 1 illustrates the original unit as installed. The foot arrangement is seen beneath the bolster plate at the rear of the machine.

Initial work established that the machine was too lightly built to withstand constant forging operation. Information gained from the operation of the San Diego Division machine as well as others in the field resulted in machine modifications. A third shock cylinder was installed to eliminate the foot arrangement. All three shock cylinders were interconnected to insure a balanced gas pressure & uniformity of deflection. Square grooved main tie rods were replaced with "V" grooved units, and a heavier square bolster plate replaced the small round one. A front view of the modified unit is shown in Figure 2. A separate balance control console for shock cylinder pressures is mounted on the left side of the main frame of the machine.



Convair Photo 51311

Figure 1 - SAN DIEGO DIVISION MODEL 1200 DYNAPAK INSTALLATION



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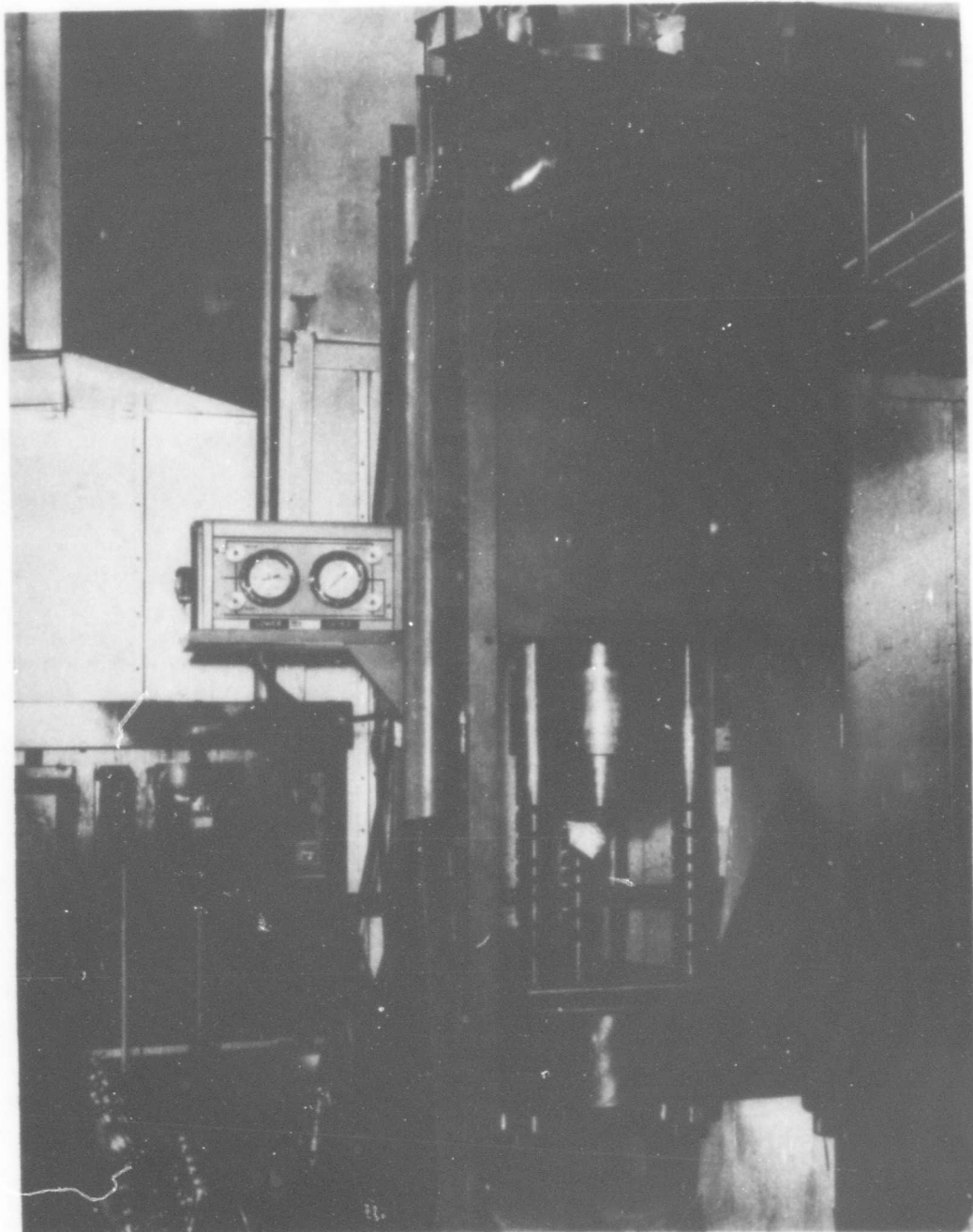


Figure 2 - SAN DIEGO DIVISION MODEL 1205 DYNAPAK INSTALLATION

Convair Print 62178

DEVELOPMENT OF THE PROJECT

The Dynapak Machine and It's Operating Principles(Cont'd)

A close-up of the modification of the main frame for the third shock cylinder can be seen in Figure 3. Figure 4 illustrates the change to "V" grooves on the main tie rods and the heavier square bolster plate which replaced the square grooved rods and small round bolster plate shown in Figure 5.

Figure 6 schematically illustrates the vertically mounted Dynapak unit. High pressure gas is stored in chamber A and low pressure gas in chamber B.

Illustrating the machine operation let us examine schematics of the various stages of the operating cycle. Figure 7 illustrates the unit in an "as fired" condition with the ram down. Recycling the machine is initiated by pumping hydraulic oil into chamber B. This forces the piston up to the orifice plate seal ring and simultaneously recompresses the gas into chamber A. The hydraulic pump then forces the double piston in the trigger unit in chamber A down against the orifice plate seal ring. These operations are shown completed in Figure 8. When both pistons are seated the gas trapped in the hole through the orifice plate between them is exhausted to the atmosphere. In the next step shown in Figure 9 the hydraulic oil is forced out of piston back-up areas by compressed gas at a pre-determined pressure. It should be noted that the pressure behind the ram piston is not identical to that separating the trigger unit pistons. The reasons for this are discussed in the operating instructions section. The machine is ready to fire at this point. It is only necessary to over-balance the lower trigger piston by admitting a spurt of high pressure gas

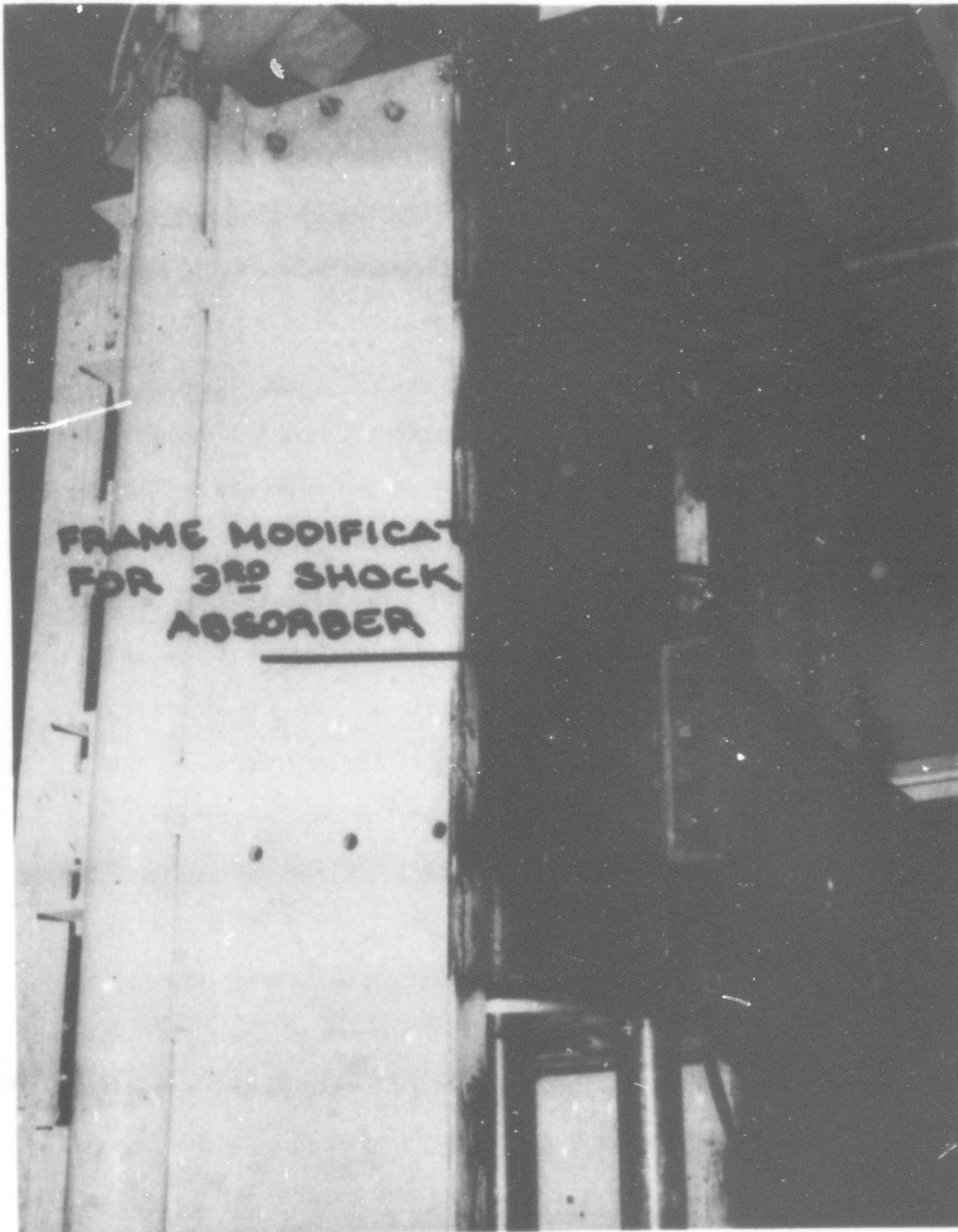


Figure 3 - MODEL 1205 DYNAPAK MACHINE FRAME  
MODIFICATION FOR 3RD SHOCK INSTALLATION

Convair Print 60581

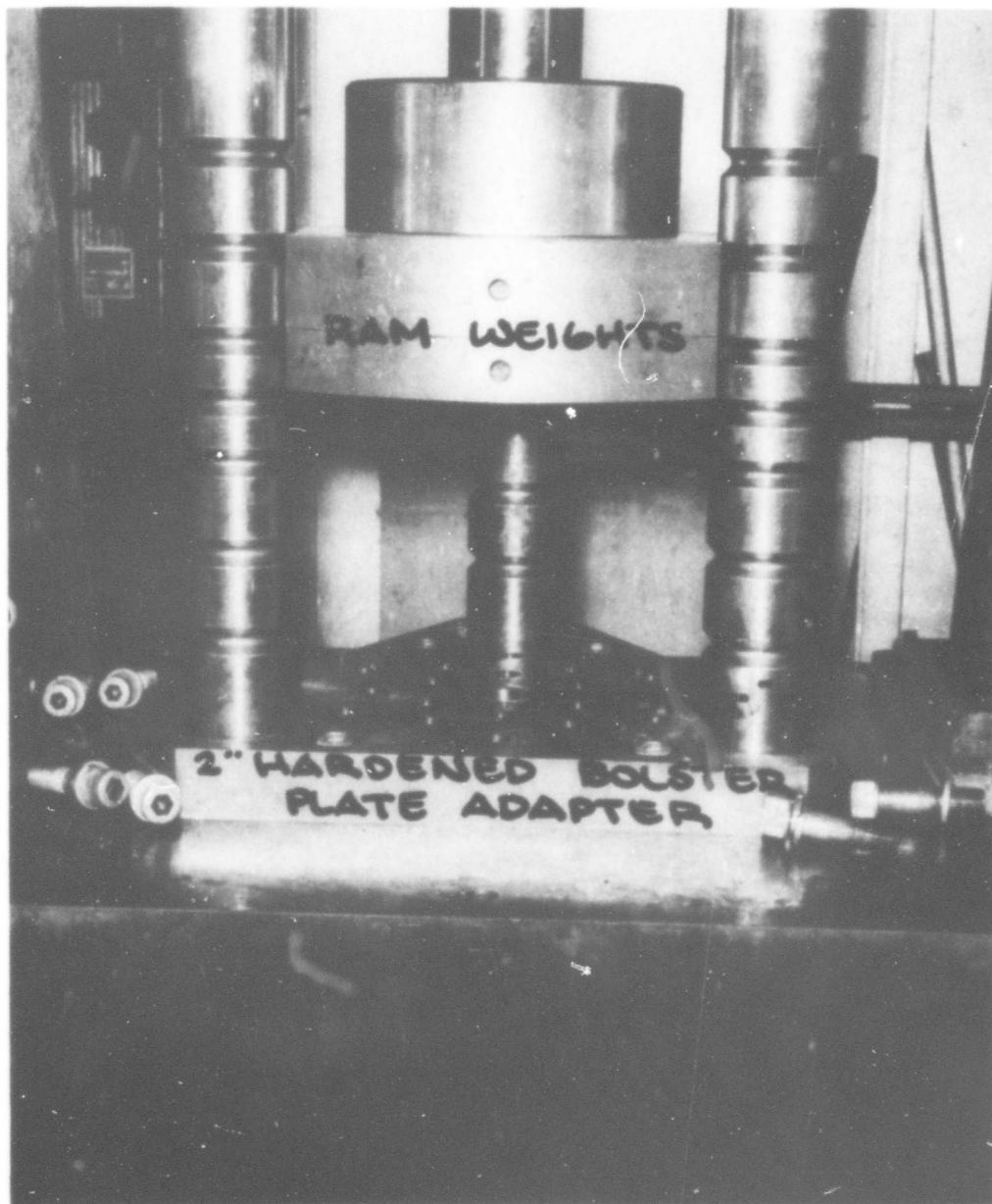


Figure 4 - CLOSE UP OF "V" GROOVED MAIN RODS AND SQUARE  
BOLSTER PLATE

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GENERAL DYNAMICS/CONVAIR

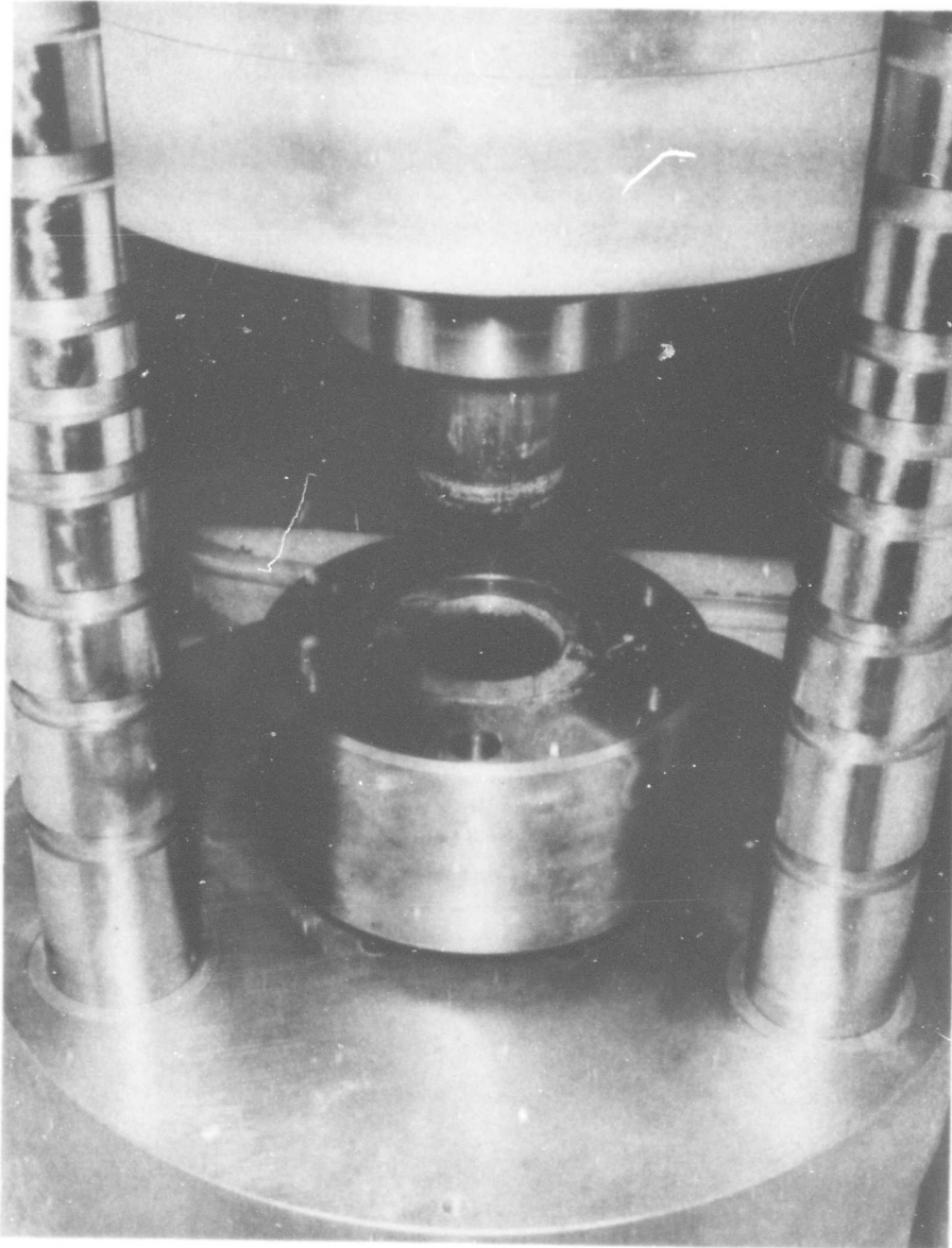


Figure 5 - CLOSE-UP OF SQUARE GROOVED MAIN RODS AND  
ROUND BOLSTER PLATE

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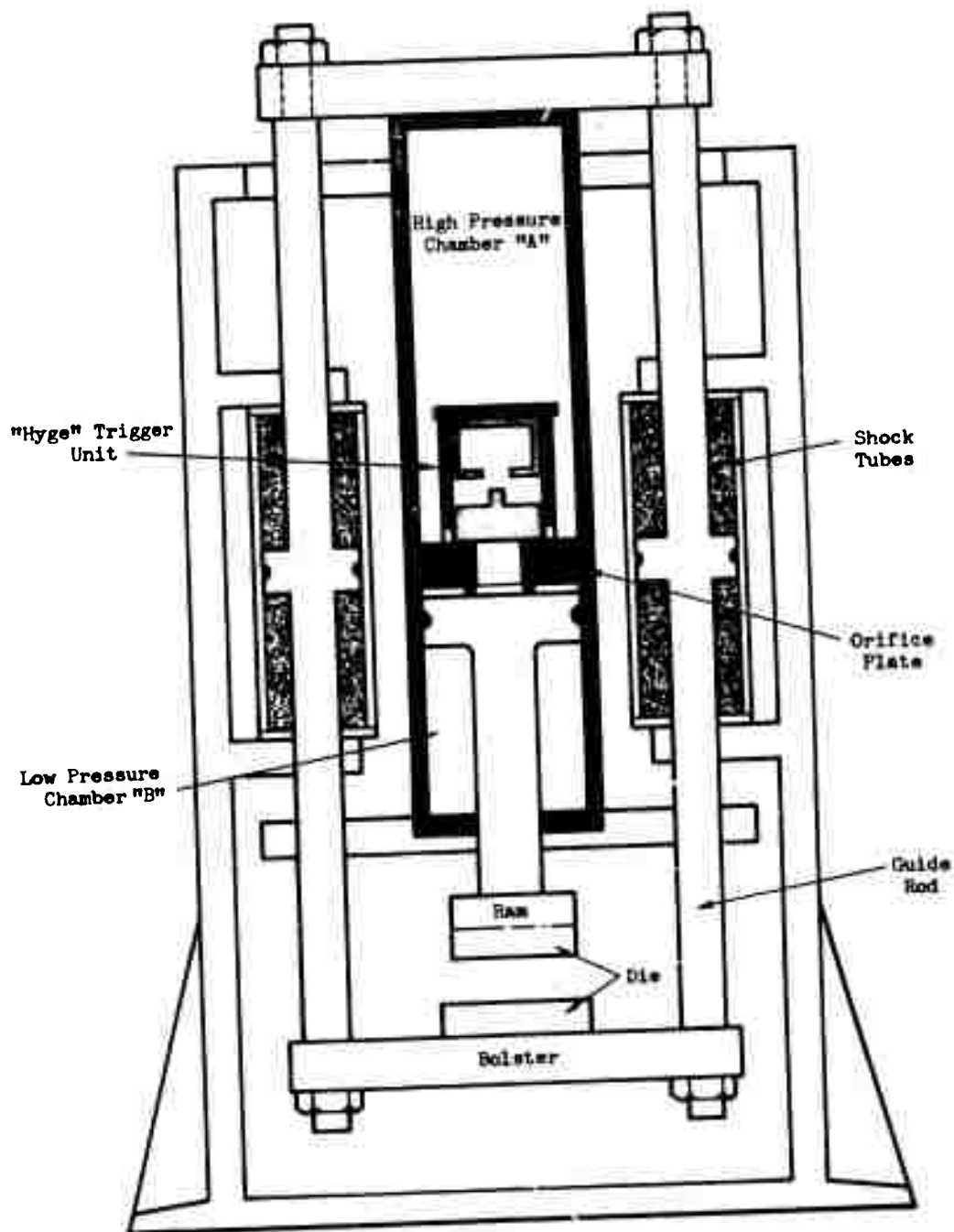


Figure 6 - 1205 SERIES DYNAPAK MACHINE SCHEMATIC

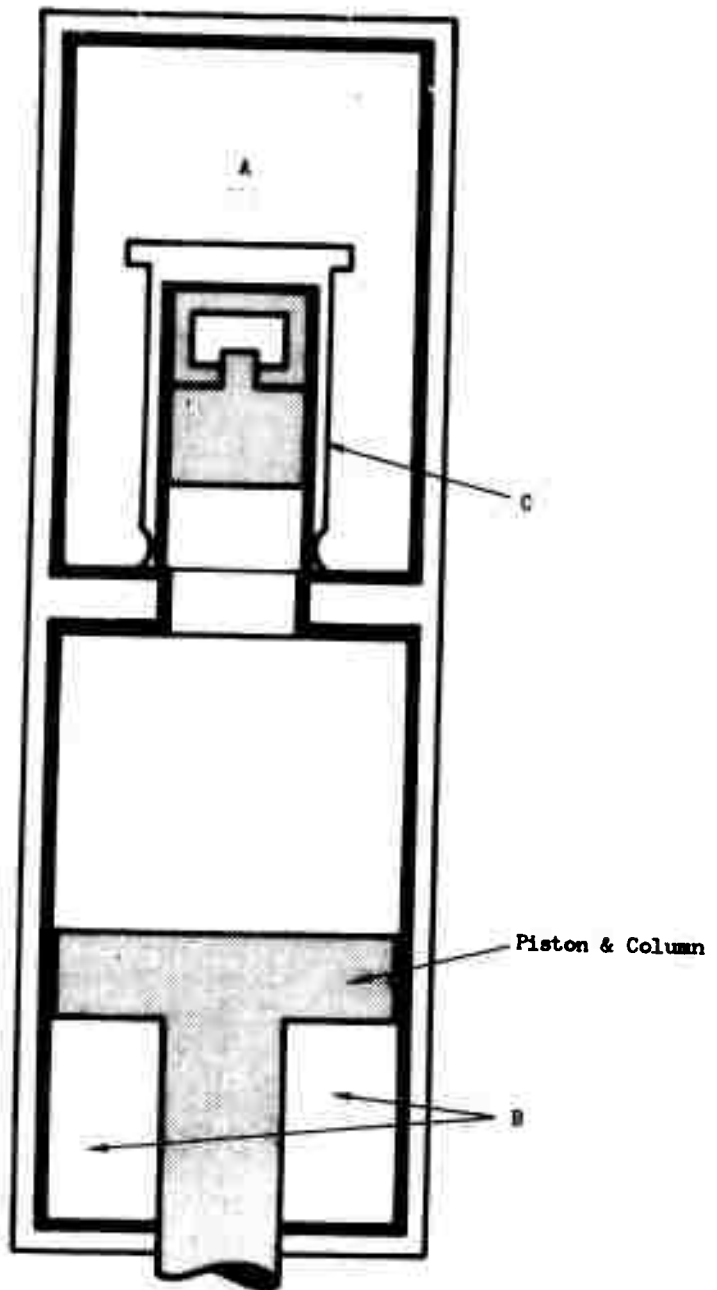


Figure 7 - DYNAPAK AT REST AFTER POWER STROKE  
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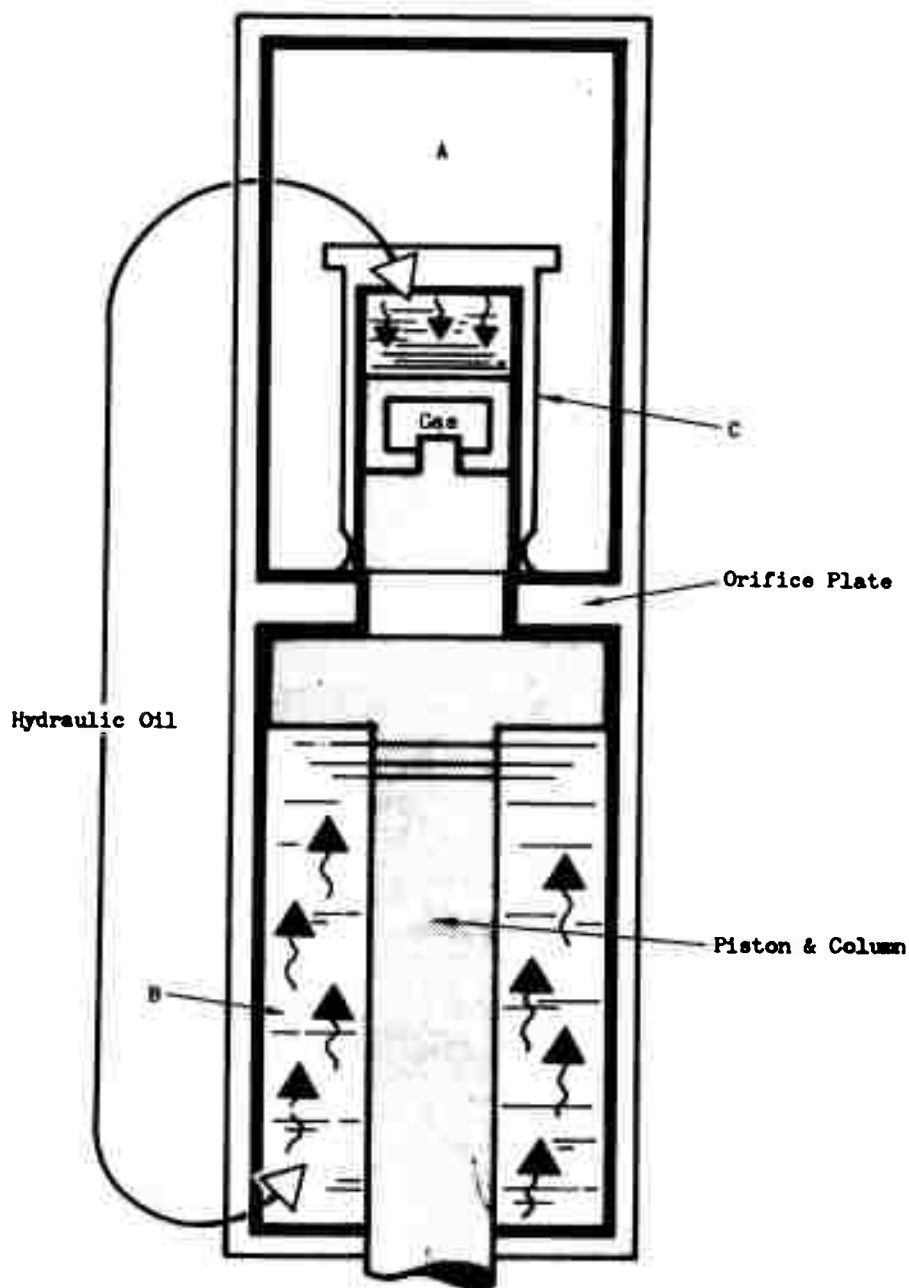


Figure 8 - HYDRAULIC OIL RETURNS PISTON AND COCKS HYGE TRIGGER UNIT  
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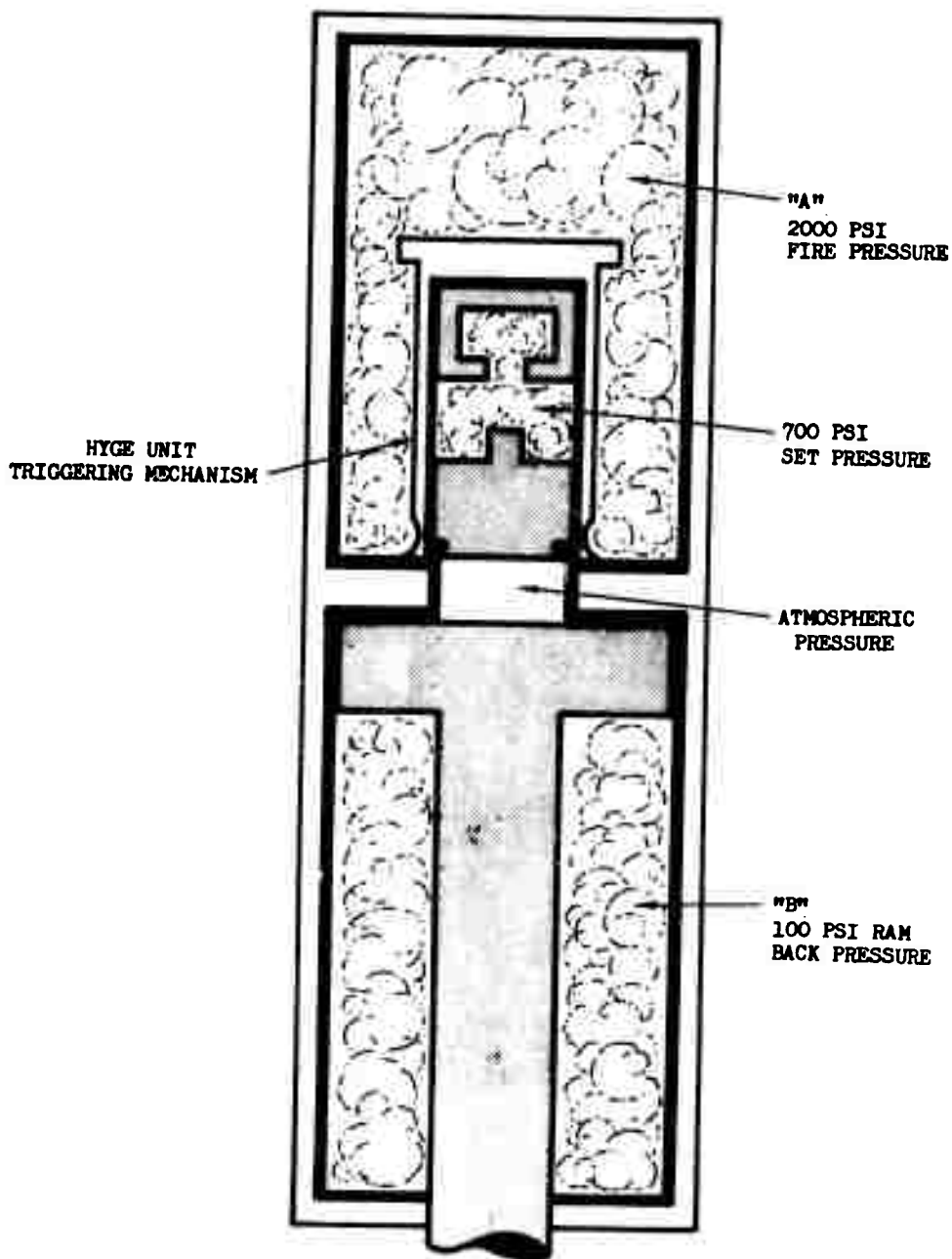


Figure 9 - MACHINE READY TO FIRE  
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## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### The Dynapak Machine and It's Operating Principles (Cont'd)

into the orifice areas as shown in Figure 10. This spurt of gas moves the small piston away from it's seat on the orifice plate and allows the high pressure gas in the upper cylinder to act against the ram piston driving it downward at high velocity. Note in Figure 11 that as the ram moves toward the bolster, the machine reacts in the opposite direction. The shock cylinders control machine reaction through their own piston system, as shown in Figure 6, thus preventing the forces from being transmitted to the floor. This unique feature allows the machine to produce exceptionally high impact forces and yet be installed without special floor mountings or pit arrangements required for conventional presses.

#### Parts Manufacture

##### Selection of Parts

Part selection was based principally on the type of process which would be required to produce the configuration. Although the primary objective of the project was the establishment of tooling and operating parameters, consideration was given in the selection of parts to potential cost reductions, should production of the selected part be desired.

Two details were selected to demonstrate and determine draftless forging techniques. The first part, an F-106 spring tail hook fitting (P/N 8-78832-7) of aluminum (2014) alloy, was chosen for its angularity and side wall to front wall thickness ratio. Figure 12 illustrates the forged detail and round billet from which it was formed. The second part was an aluminum (2014) clip (P/N 22-18892) which was used to determine the boundaries of

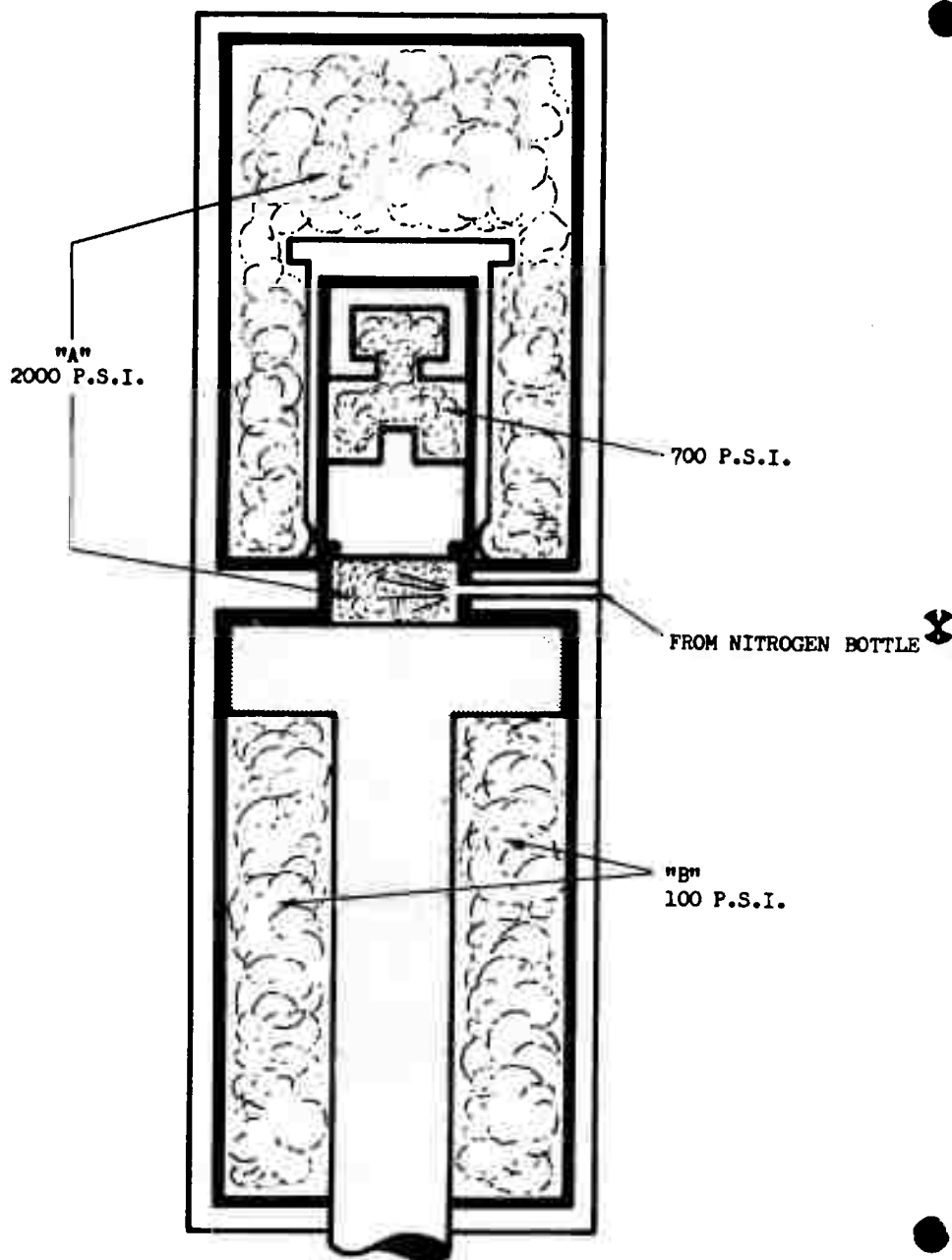


Figure 10 - TRIGGER GAS ABOUT TO MOVE HYGE PISTON  
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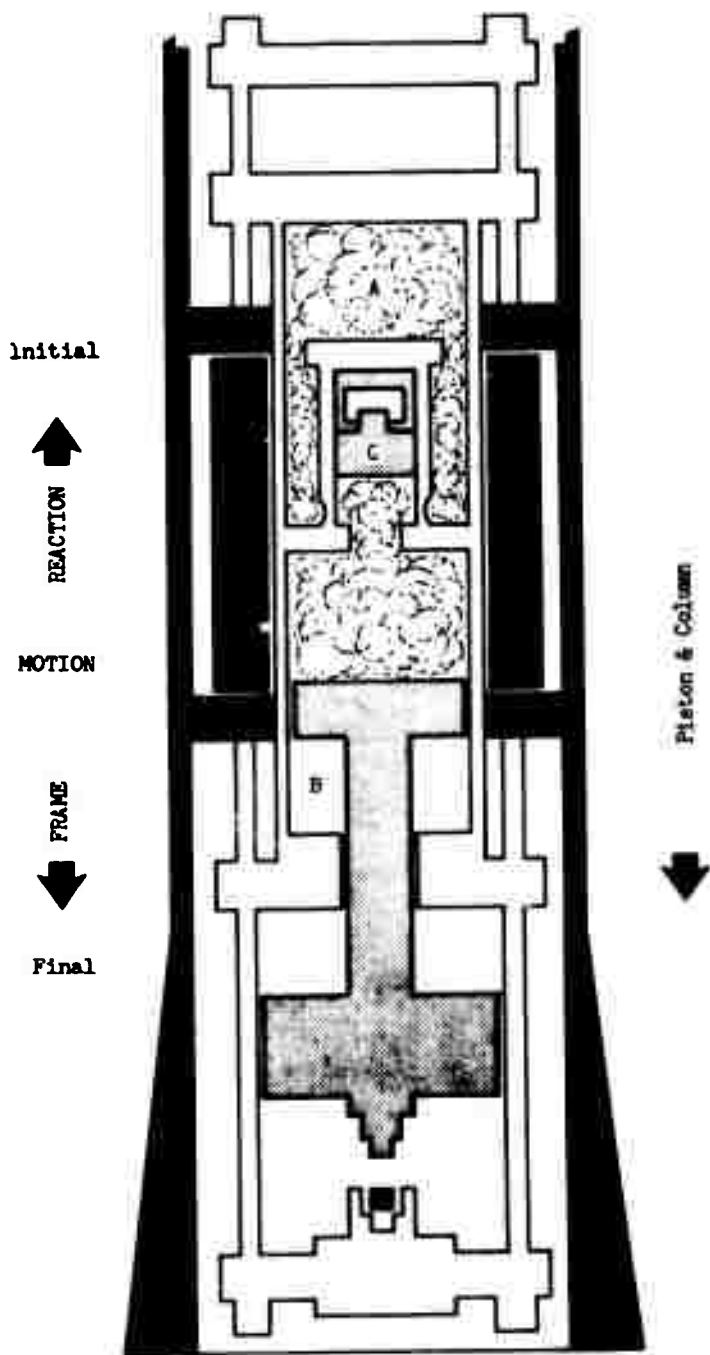
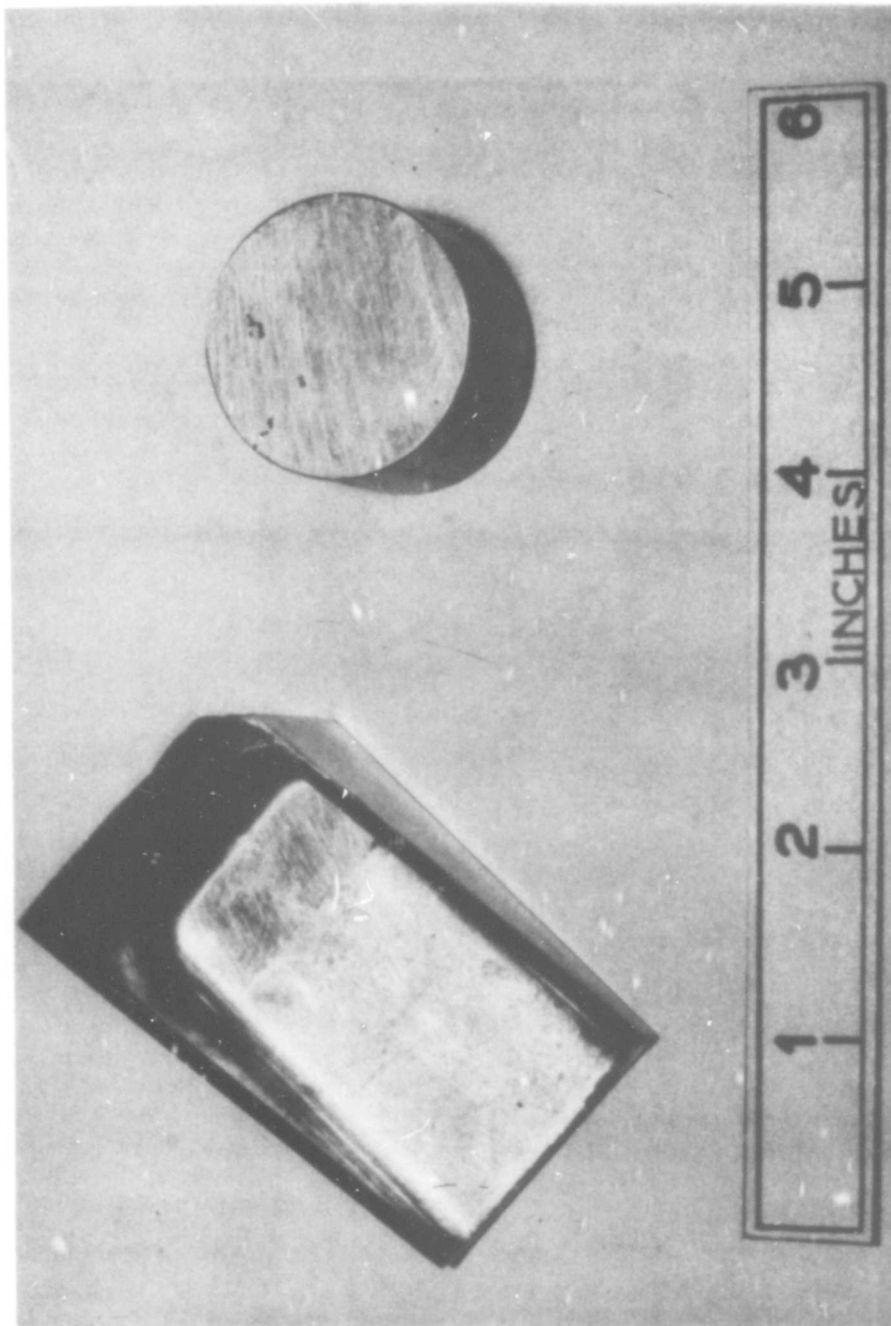


Figure 11 - DYNAPAK REACTION FRAME IN OPERATION  
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**FORGED PART AND BILLET**  
**P/N 8-78732-7**

Figure 12 - FORGED SPRING TAIL HOOK FITTING & BILLET  
(P/N 8-78732-7)

Convair Print 57008

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### Parts Manufacture

#### Selection of Parts (Cont'd)

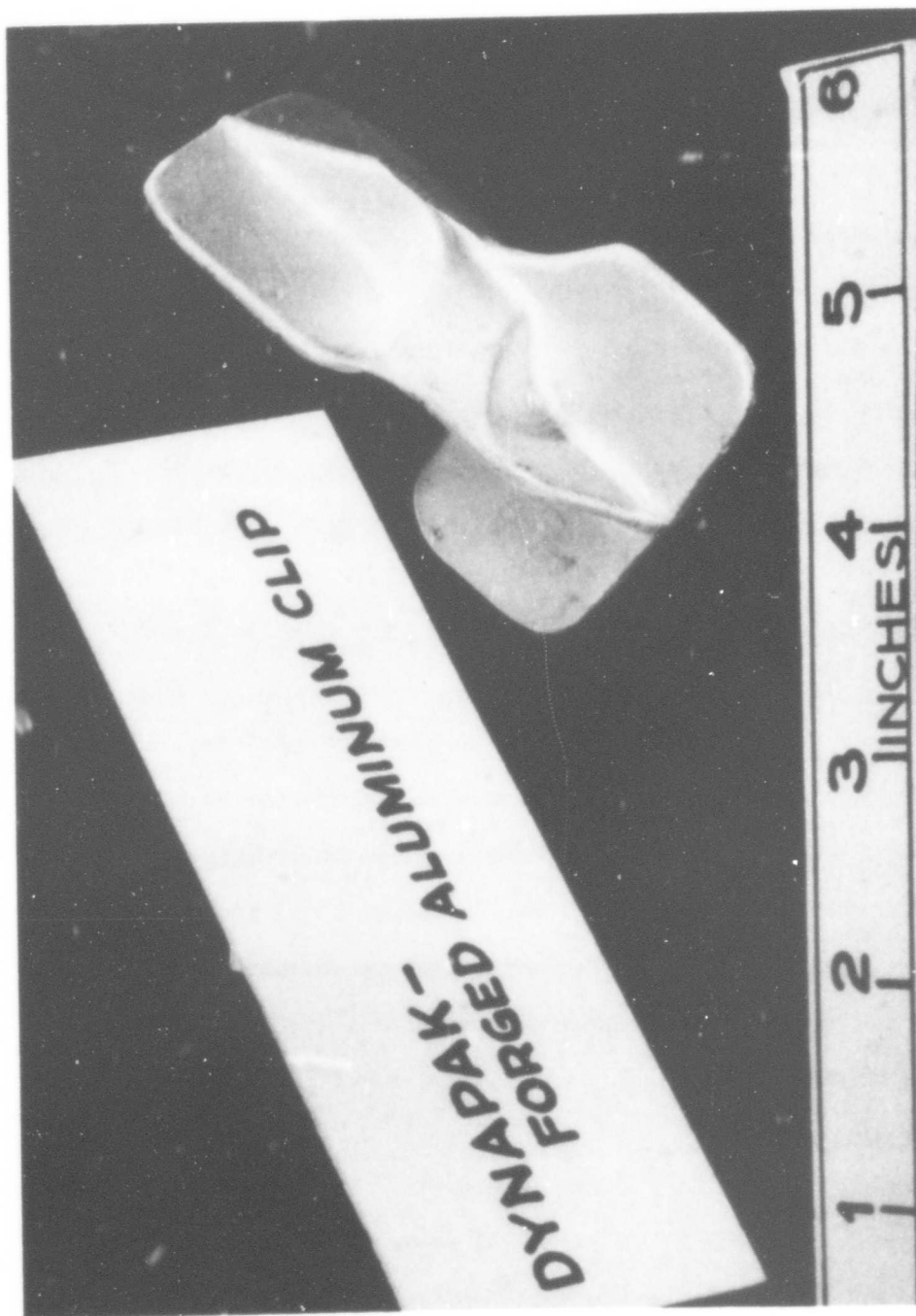
draftless thin wall forged details. Figure 13 illustrates the forged detail after trimming.

Two details demonstrating closed forging techniques were selected. The first selection was a small diameter deep cup and the second was a large diameter shallow cup. It should be noted that the cup bottom is removed in a machining operation. The small diameter bushing P/N 8-16512) made from SAE 4130 steel is shown with the initial billet in Figure 14. The second detail made from SAE 4340 steel is shown in Figure 15.

In addition to the forging applications previously mentioned, an open back extrusion test part was made to examine tool characteristics. The test pieces are shown in Figure 16. Forward extrusion tooling techniques were also evaluated. The cruciform shown in Figure 17 is an example of the test parts produced. Deformation of the extrusion resulted from contact with the floor, illustrating the impracticability of extruding with the machine mounted vertically and without special provisions for extrusion length.

#### Manufacture

The F-106 tail hook detail P/N 8-78732-7 being the first part selected... was the basic trial part for both machine operation and forging evaluation. The initial tooling made from SAE 52100 tool steel and heat treated to RW/c 48-50 did not prove to be sufficiently shock resistant for general usage. Figure 18 illustrates the cracked female die. It should be



Convair Print 403-61

Figure 13 - DYNAPAK FORGED ALUMINUM (2014) CLIPS

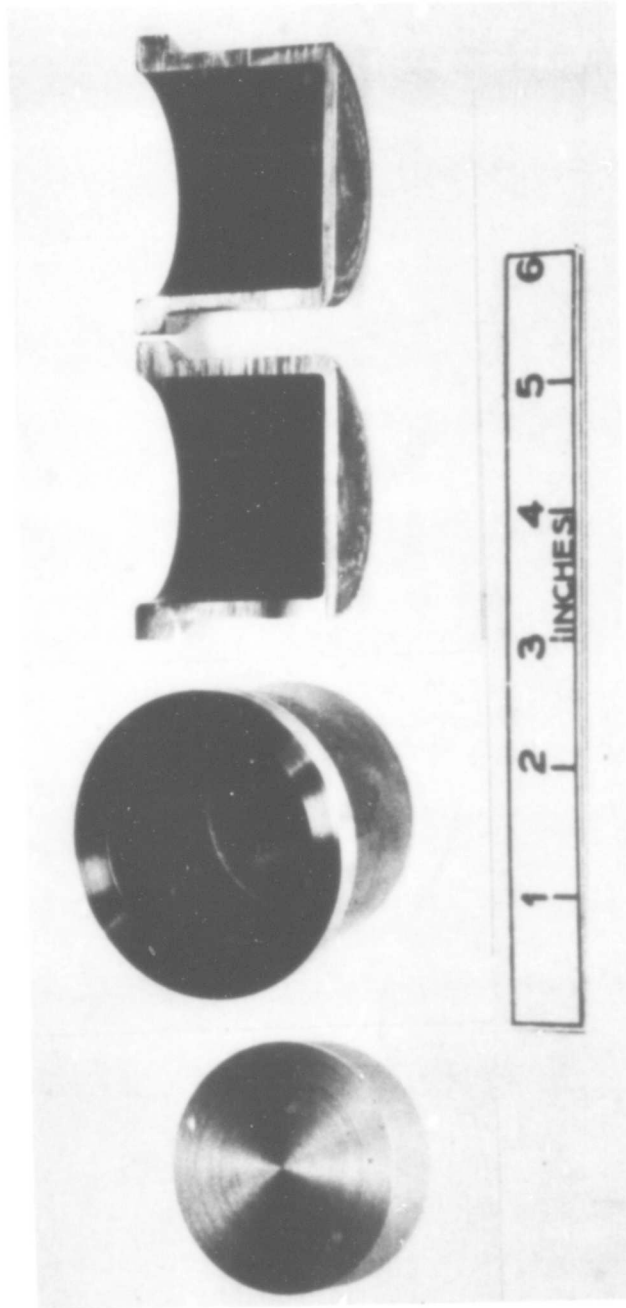


Figure 14 - DYNAPAK FORCED SAE 4340 BUSHING P/N 8-16512 Convair Print No. 57334



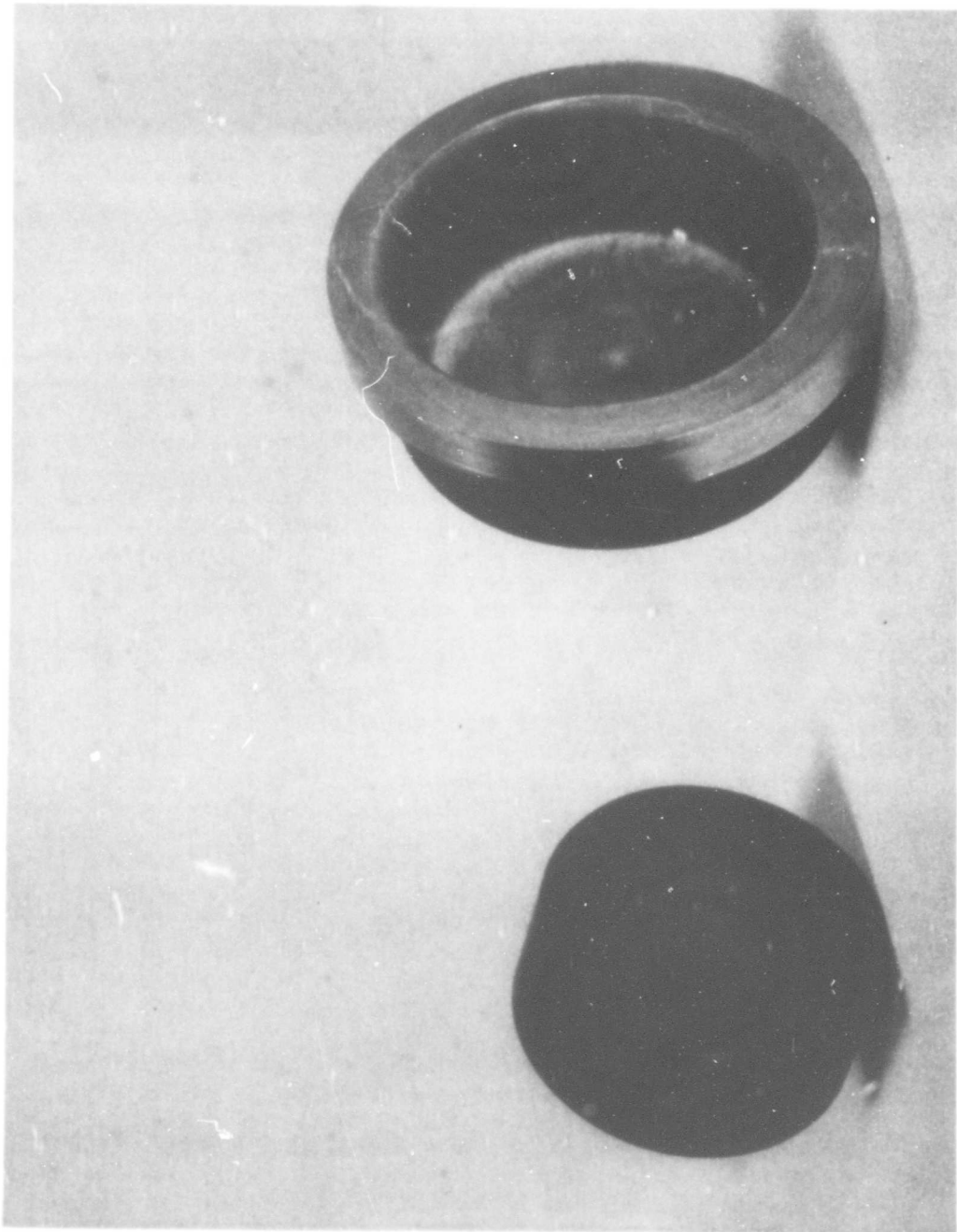
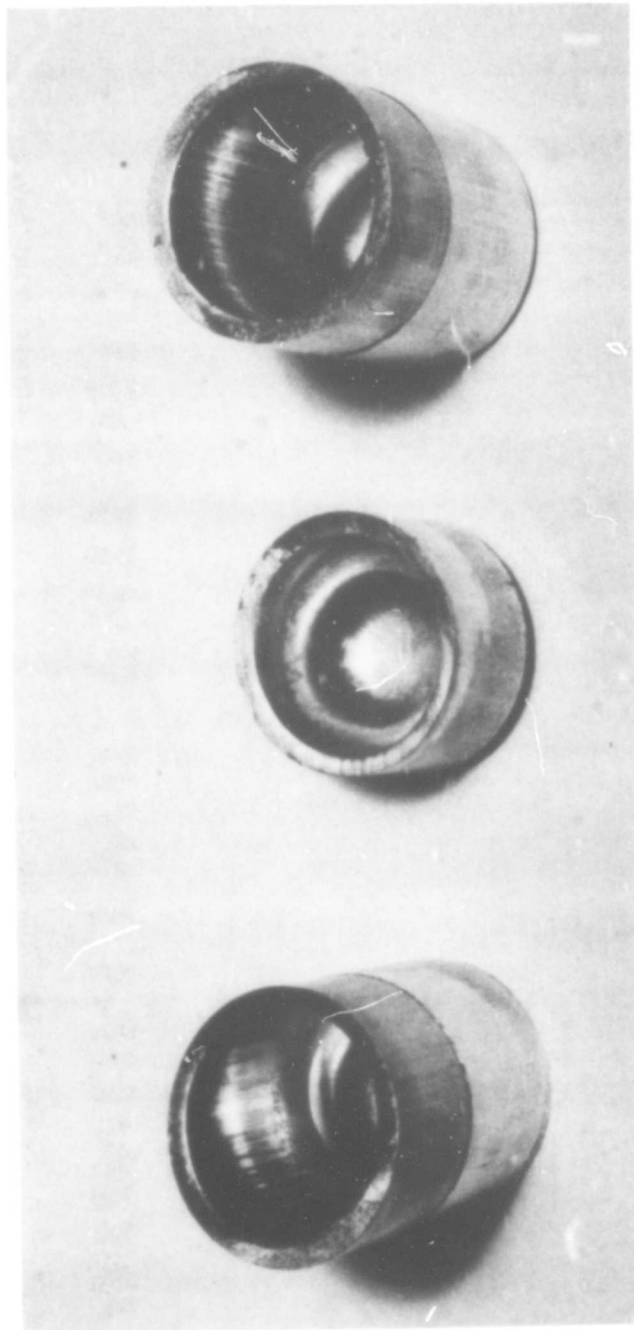


Figure 15 - DYNAPAK FORGED SAE 4340 BUSHING

Convair Print 51616



# ALUMINUM BACK EXTRUSION

Convair Print 54925

Figure 16 - OPEN BACK EXTRUSION SAMPLES



## ALUMINUM FWD. EXTRUSION

Figure 17 - FOREWARD EXTRUSION SAMPLE

Convair Print 54922

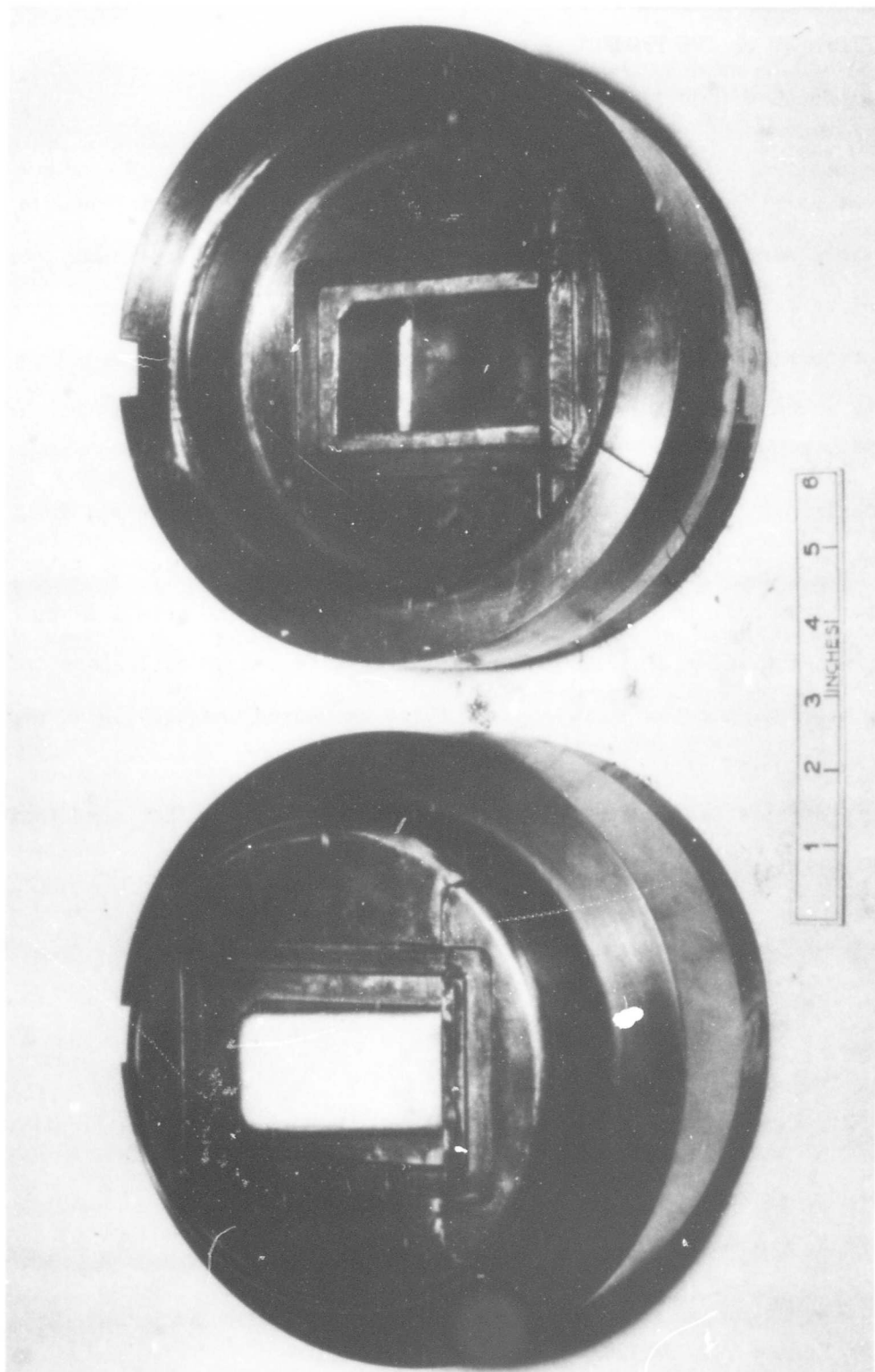


Figure 18 - INITIAL SPRING TAIL HOOK TOOLING

Convair Print 57007

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### Manufacture (Cont'd)

noted that the female die, contrary to general practice, was not radiused in the corners. This was done to determine if such a design practice was feasible since many precision detail parts do not have large radii normally required for conventional forging practice.

A second female die was made from Durodi tool steel which proved to be quite successful. This steel heat treated to RW/c 48-50 outlasted the SAE 52100 male punch.

Preliminary efforts conducted with the required part material, 2014 Aluminum alloy, established the critical nature of the speed of material flow. It was found that without traps, built up in the trim area to restrain the material flow, the material mass tended to pull apart indicating that the momentum resulted in a force exceeding the tensile strength of the material at the particular temperature.

Considerable difficulty was experienced in the bottom flat area indicated in Figure 19.

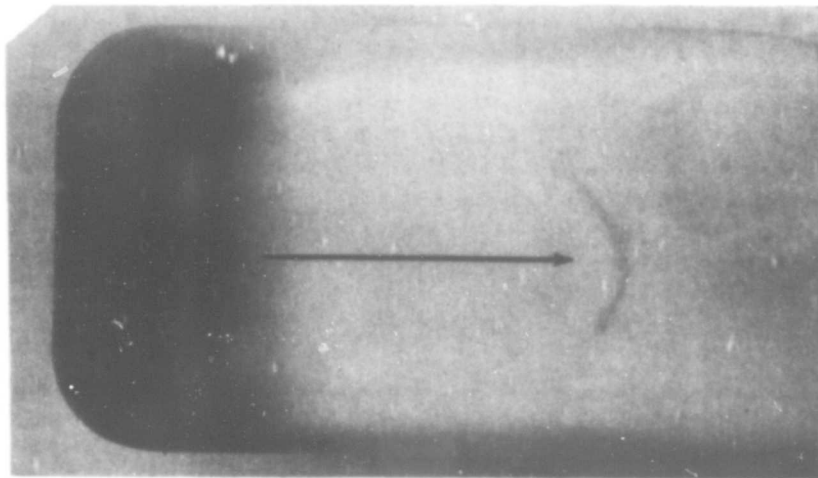


Figure 19 - EXAMPLE OF MATERIAL SEPARATION

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

Trap areas were added to further restrain the material flow, with success. Billet configurations were altered in attempts to control the flow. Wedges, squares, rectangular and round billets were utilized. The round extruded billet material, it was found, provided the maximum amount of separation free parts.

Several difficulties were encountered which could be traced to machine functions. First the bounce or rebound encountered often trapped flash material and embedded it into the forged detail on the rebound hit. A second feature which caused trouble was the slow retraction of the ram after the forming stroke. Prolonged contact between the forged detail and the dies resulted in heat checks and short tool life. In addition, part shrinkage due to cooling resulted in parts contracting on the punch requiring heat to remove the part from the tool.

The forged fitting was produced in one operation requiring a secondary trim operation to remove flash. Part dimensions were to blue print specifications in all respects. Metallurgical examination revealed excellent flow characteristics in the vertical walls and bottom sections of the non-separated (round billet) parts as shown in Figure 20.

The aluminum clip (P/N 22-18892) was produced from a round billet (extrude' bar stock). Three different billet lengths were used in attempts to fill the tool cavity in one operation without success. An excessive length billet was then struck, trimmed and then restruck completely filling the cavity. The excessive depth to width relationship in the vertical fin areas was a source of trouble in two ways. First; since there was no draft allowance on one face; there was a predominate tendency for the metal

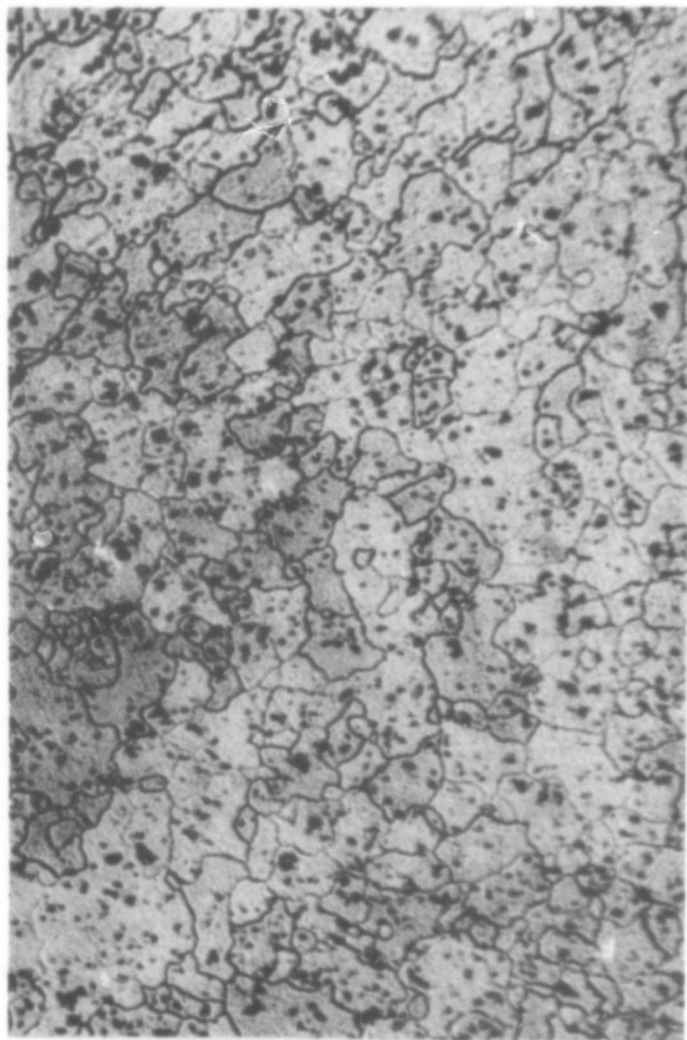


Figure 20 - PHOTOMICROGRAPH OF TAIL HOOK FITTING STRUCTURE  
AS SHOWN

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

to stick in the die cavity. Second; the machine bounce coupled with the tendency of the material to stick in the die cavity frequently tore the forged detail in half.

Various lubricants were used to provide less friction in the vertical fin areas but results were unsatisfactory. Although the part can be made on the Dynapak machine without draft on the deep fin areas, the scrap rate is excessive. Therefore it is concluded that draft will have to be added to achieve production efficiency.

A wing spar bushing (P/N 8-16512) was the first production forging attempted in a closed die. Tooling was designed to include a floating stripper arrangement which was also a portion of the closed die cavity. A complete discussion of the particular tool is found in the tooling section.

SAE 4130 steel was used for the first time in the forging evaluation in producing this part. Some scaling was encountered due to lack of atmospheric control in the billet heating furnace. For the most part the billets were heated to approximately 2100 F for effective material flow. Scale formed during the heating, to forging temperature, was removed by a sharp blow against the bolster prior to positioning the billet in the die opening. Excess material was left in all areas for final machining and grinding. It is believed that if adequate furnace controls were available, net parts could be produced since allowances would not have to be made for removal of scaled areas by machining operations.

Engineering Laboratory Analysis was made on representative parts. Photomicrographs of sectioned parts indicated that flow characteristics in the vertical wall were satisfactory (Figure 21.)



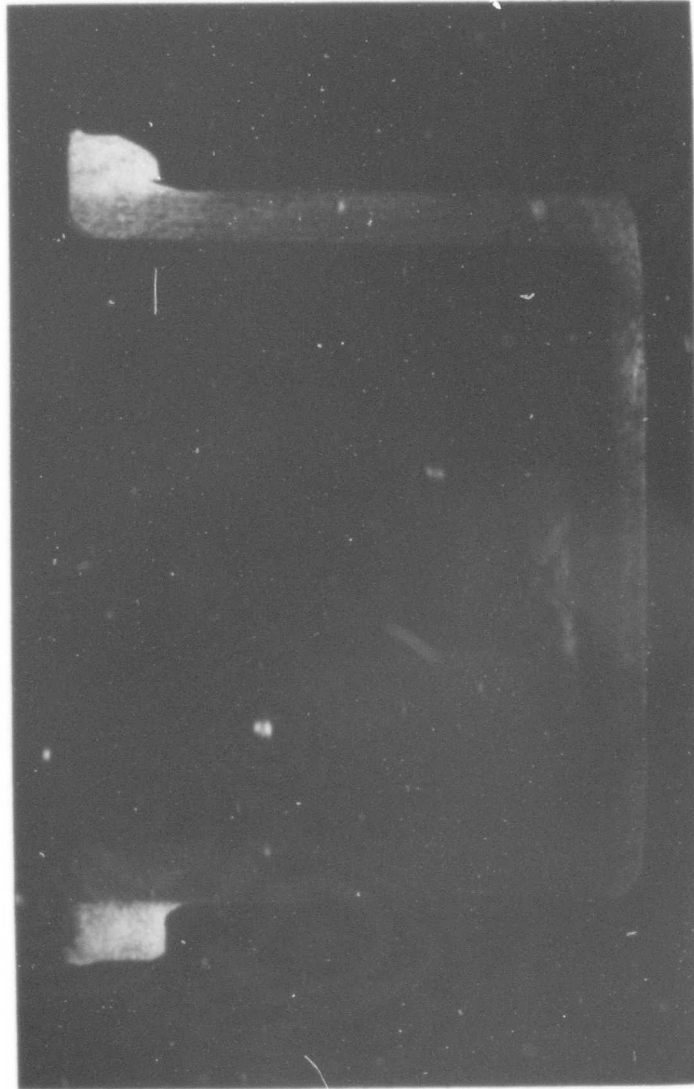


Figure 21 - PHOTOMICROGRAPH OF SAE 4130 PN 8-16512 WING SPAR BUSHING  
ENGINEERING TEST LAB 0-1812

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

Flow in the bottom of the cup could be improved through tooling modifications but since this area was to be cut away in these parts, no attempt was made to rework the tooling. The flange area shown on the right side of Figure 21 illustrates a lap; indicating flow problems in this area. A modification of the radius in the area of the lap to provide better flow would be required if the flange is to be produced without excess clean-up stock.

Photomicrographs taken of both the billet and the finished part illustrate the marked reduction of grain size achieved in the Dynapak operation. Figure 22 shows the grain size of the billet at 200 x and Figure 23 shows the grain size of the forged part at 200 x.

Mechanical property tests showed that the Dynapak part as forged was approximately equal to the properties of the hardened and tempered non-forged material. The results are as follows:

#### Dynapak as forged

198,500 psi ultimate	20% elongation
190,900 psi ultimate	17.5% elongation

#### Billet - hardened and tempered

191,500 psi ultimate	25% elongation
----------------------	----------------

#### Dynapak - hardened and tempered

187,700 psi ultimate	10% elongation
176,000 psi ultimate	20% elongation

The hardened and tempered Dynapak part, however, fell short of the hardened and tempered properties of the non-forged material. Further evaluation will have to be made to verify the above findings if it is desired to eliminate further heat treatment of Dynapak forged parts.

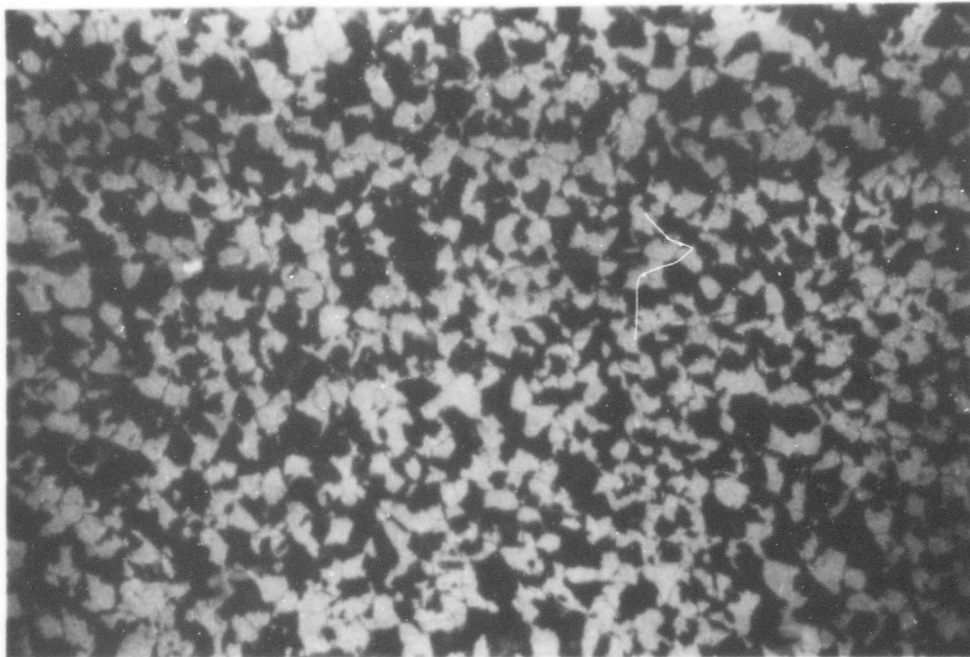


Figure 22 - PHOTOMICROGRAPH (200X) OF BILLET MATERIAL  
GRAIN SIZE 7 FOR 8-16512 BUSHING

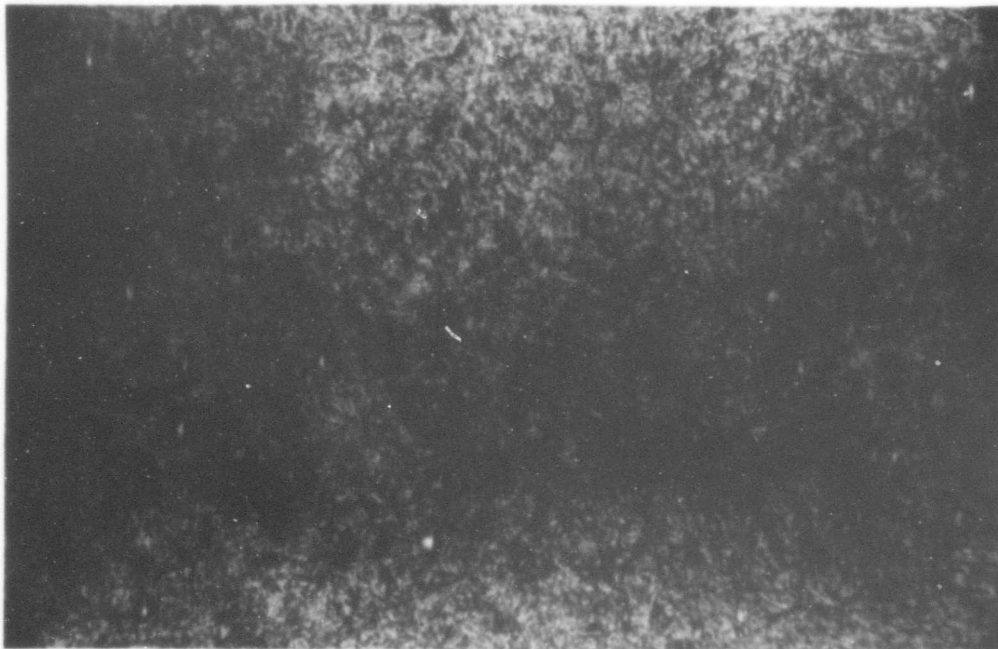


Figure 23 - PHOTOMICROGRAPH 200X OF 8-16512 BUSHING  
GRAIN SIZE SMALLER THAN 8.

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

Repair bushing 22-51001 (REQ 1660) also utilized the universal die holder and punch holder. AISI 4340 steel used in the part presented the same scale problems as were encountered with the SAE 4130 evaluation. Again most of the scale flowed into the flash area where it was removed in the rough trimming operations. The remaining scale was on the part surfaces where allowances had been made for finish machining and consequently did not present any problems. Flow characteristics were basically the same as encountered in the previous bushing indicating that the size difference was of very little consequence.

#### Lubricants

Maintenance of a lubricating media between the part material and die material is essential in the Dynapak process. Poor lubrication leads to galling of punches and dies and increased tool loadings. In addition it can also lead to the requirement of increased fire pressure and billet temperature. It also should be noted that lubricant ineffectiveness necessitates frequent tool polishing. Too much lubricant leads to a dieseling effect and die checking from high intensity local heat zones.

Of the lubricants tested, a mixture of peanut oil and graphite was found to be satisfactory for aluminum alloy forging. The use of higher temperatures for steels required a mixture of litharge and glycerine.

Lubricants ordered for evaluation did not arrive in time for testing but information obtained from other Dynapak users indicates that colloidal graphite dispersions (Dag dispersions) are effective in the 1800-2300 F forging range.

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### Tooling

#### Design

#### (Forging-General Notes)

Forging die design is similar in many respects to press closed die forging design even though the Dynapak technique is more closely related to drop forging. Die blocks are not as large as the typical drop forging tool and in general are heat treated to  $R_c$  48-50 in contrast to normal practice of  $R_c$  45 maximum.

Due to press limitations, lead-in must be provided on forging dies to insure proper mating of punch and die upon impact. In general it was found that a one inch lead-in was required. Figure 24 illustrates a cross section of a typical closed forging die and the lead-in required. A secondary use of the "lead-in" is the prevention of side thrust in some part configurations. Parting lines, for punch & die, should be designed whenever possible to balance side thrust.

Closed, deep pocket areas where lubricants and air may be trapped during a forging cycle should, whenever possible, have small holes in the bottom area in which lubricant and air may be compressed without retarding the part material flow. Figure 25 illustrates such a pocket area and the bleed hole. Without such provisions the inherent high compression and dieseling effect may prevent the part from filling the die. The bleed hole may be either tapered or straight.

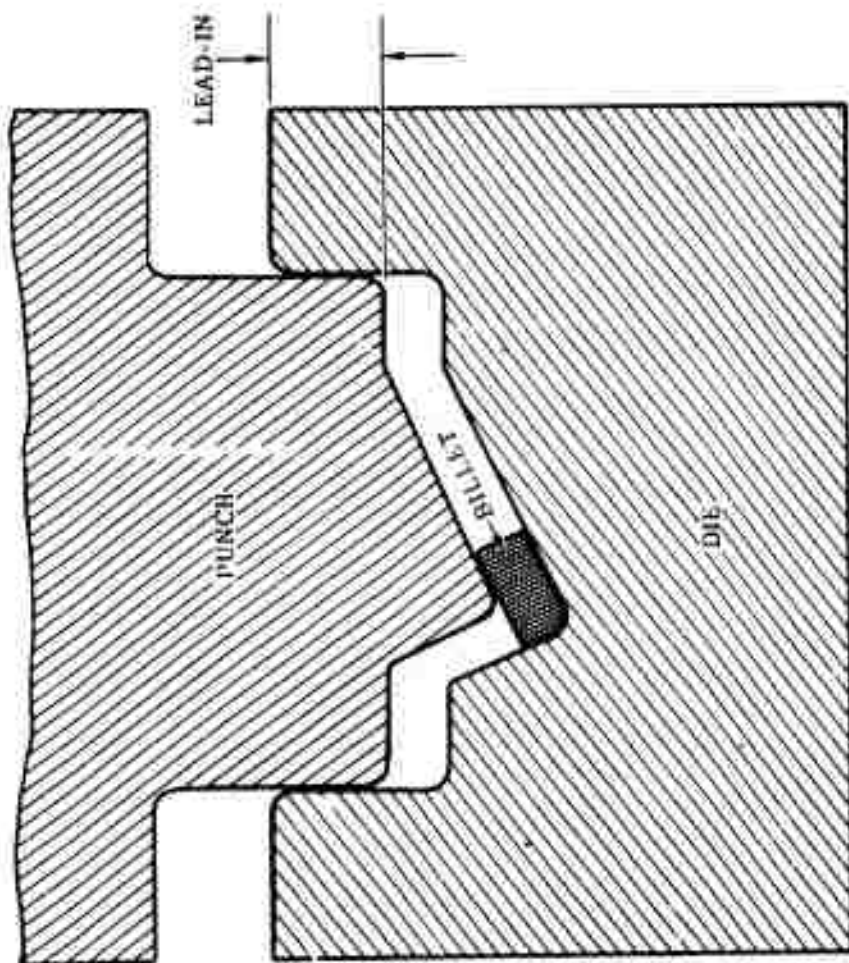


Figure 24 - TYPICAL CLOSED FORGING DIE CROSS SECTION

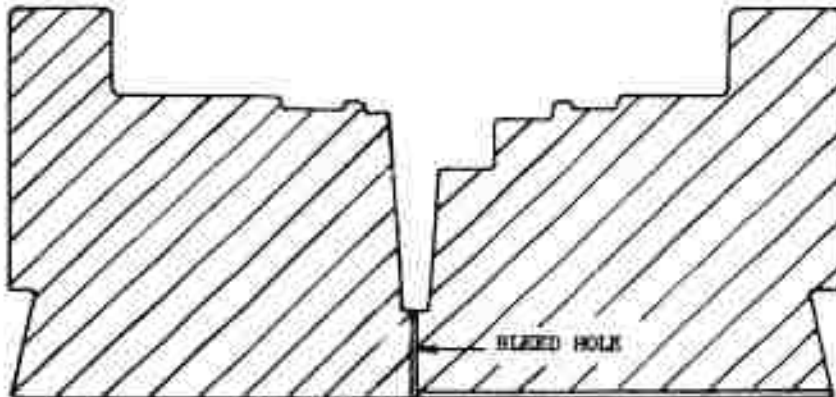


Figure 25 - TYPICAL POCKET BLEED HOLE

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### (Forging - Tool Development)

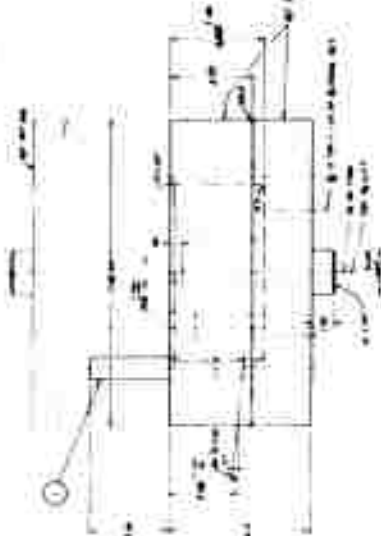
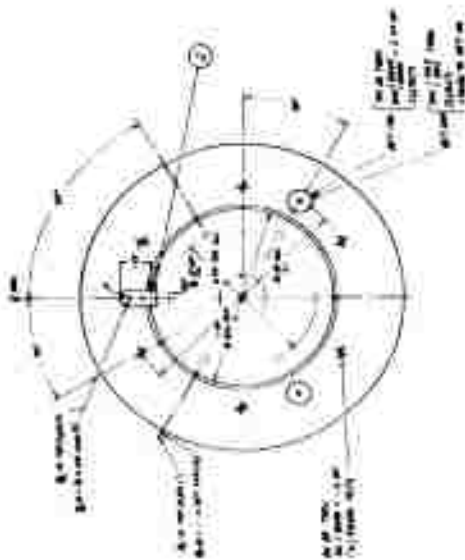
Two universal punch and die holders were developed to provide short tool change time and standardize forging tool block dimensions. The first basic type was unstressed, the second prestressed. The unstressed tool holders were used in all forging tests since detail part dies were made to fit the first set of holders.

The unstressed holders are satisfactory for a major portion of forging applications which fall within a four inch diameter circle. Larger parts up to 5 inches in diameter require the pre-stressed design to prevent die breakage.

The unstressed die holder shown in Figure 26 was made from SAE 52100 heat treated to  $R_c$  48. The weld joint noted on the drawing was omitted in both holders and the guide pins were removed after original trials. The original intent was to bolt the holder to the bolster plate from below; however, constant bolt failures required a re-evaluation of the machine action. Analysis disclosed that to achieve a bolt mounting free from compression loading at any time the bolting must be from the top into the bolster plate. High speed movies were used to provide the desired information on the machine action. The change to top bolting eliminated bolt failure.

Typical of the forging die design for the unstressed holder is the F-106 fitting die MDA-146 shown in Figure 27. The tapered undercut area in both punch and die is used to retain the tool members in the tool holders by set screws. This taper provides an adequate lock for forging work. Keys are used in both punch and die to assure matching when mounting in the tool holders.





720 TOP INSERT HOLDER  
IDENTICAL EXCEPT AS NOTED

100 BOTTOM INSERT HOLDER SAME

FUNCTION OF TOOL	MACHINE USED ON
TEST TOOL	DYNAMAC

STAMP NOTES

[illegible][illegible][illegible]

1984	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	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Figure 26 - UNSTRESSED UNIVERSAL DIE HOLDER.

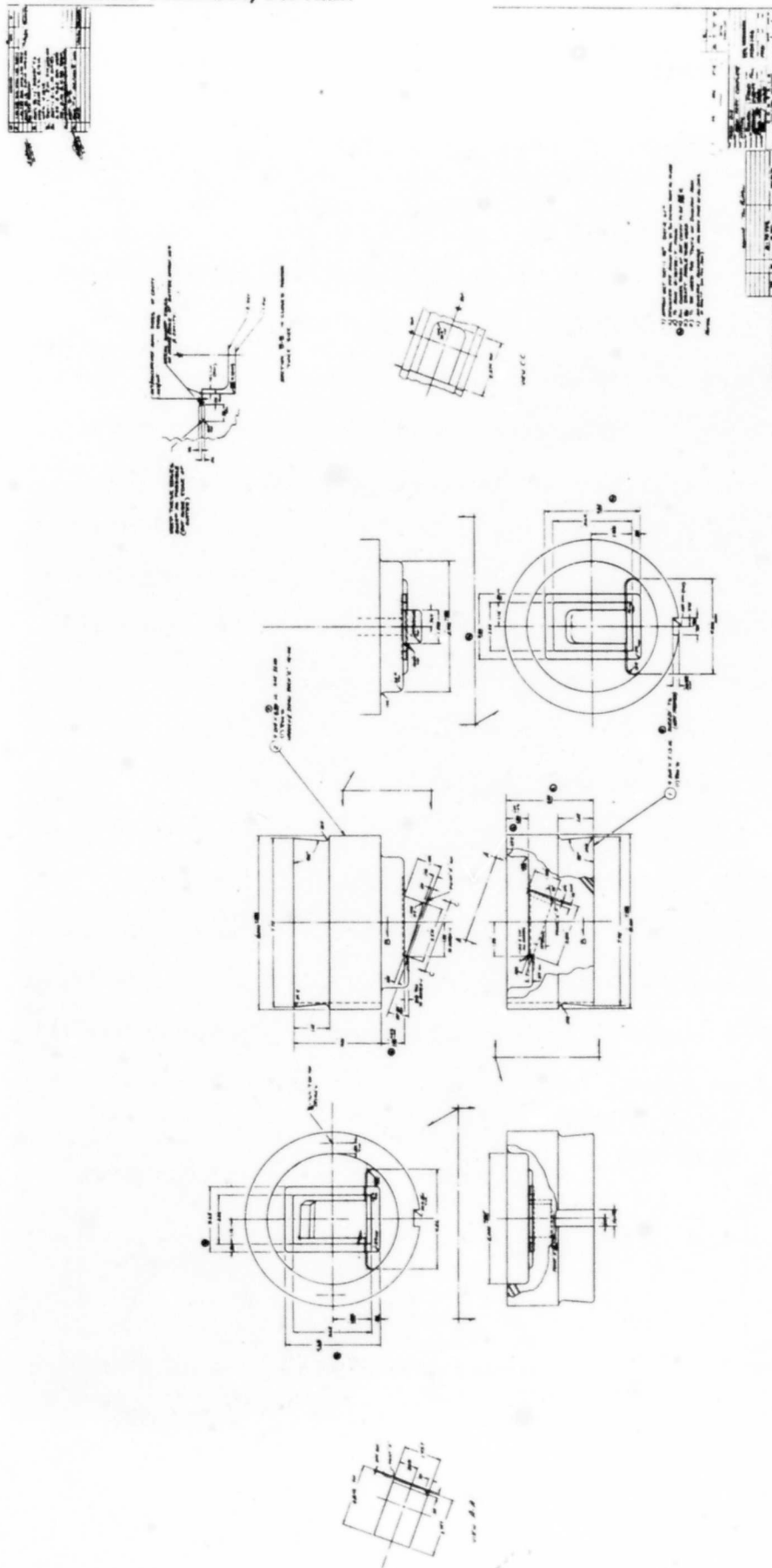


Figure 27 - TYPICAL FORCE DIE DESIGN FOR UNSTRESSED DIE HOLDER

## GENERAL DYNAMICS/CONVAIR

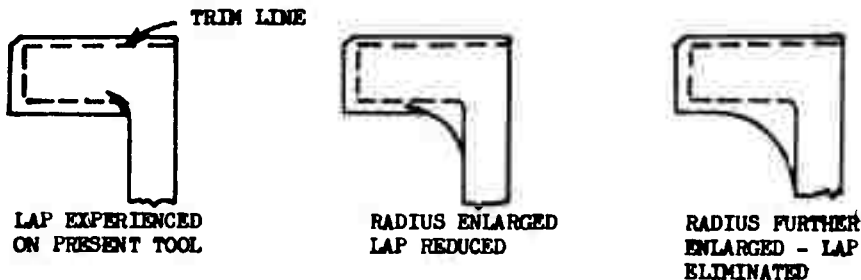
### DEVELOPMENT OF THE PROJECT

#### (Forging - Tool Development)

Note the use of the lead-in on the die member to eliminate side thrust and provide a close tolerance matching of punch and die.

Control of material flow in forming is of great importance. Since the Dynapak technique involves speeds considerably beyond the normal forging rates, material flow must be closely controlled. The tool noted in Figure 27 allows a maximum of .010" in the trim area of the part. It was found during the tests that the area had to be reduced to trap the material and thus retard material flow in order to keep the part in one piece. The final proof out of tooling generally resolves itself into a cut-and try method to control flash and insure filling the die.

In closed die forging, where no flash provisions are made, flow control to prevent laps and voids is critical and may at times require design changes. An example of the type of problem is the bushing 8-16512 discussed earlier under part fabrication. The lap found in the upper flange area can be reduced or eliminated by a change in the flange radius. A larger radius in the area will improve the material flow and should a lap occur it will be in the part trim area (shown below).



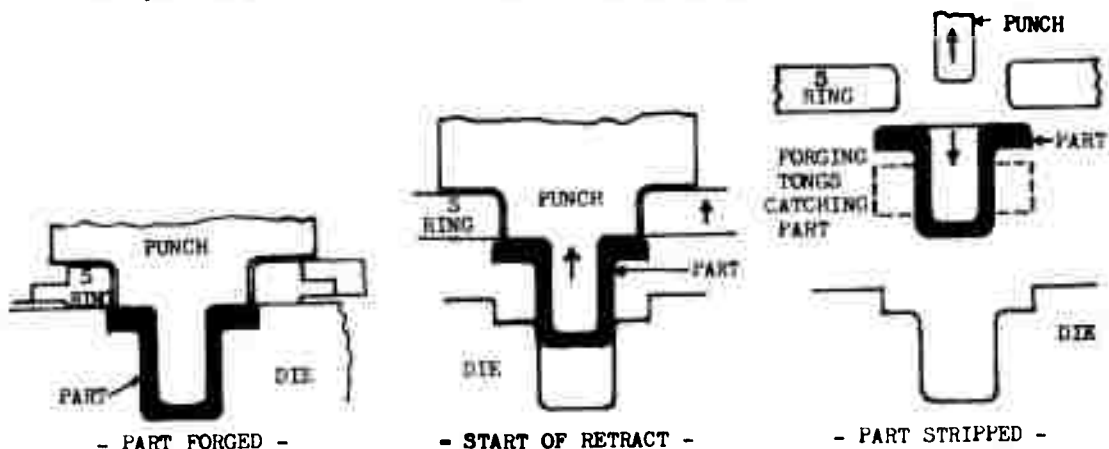
# DEVELOPMENT OF THE PROJECT

## (Forging - Tool Development)

A new forge die holder was made for the closed die forging trials. The holder provided for a stripper ring arrangement to strip the parts from the punch on the return stroke of the ram. The universal holder and stripper ring are shown in Figure 28. A view of the basic holder in Figure 29 shows the three additional stripper bolt holes, side slots and release knob modifications to the basic design.

Inserts were used in the stripper ring so that only one stripping ring would be required. Inserts were then made to fit the outer ring and the particular part for which they were intended. Since the actual stripper portion of the ring would become part of the die it was made of Durodi while the outer ring was made from SAE 52100.

Stripping action is provided by the return stroke of the press. As the ram returns the part, shrunk on the punch due to cooling, carries the stripper ring with it until the guide bolts stop the ring, stripping the part from the punch. A typical stripping sequence is shown below.



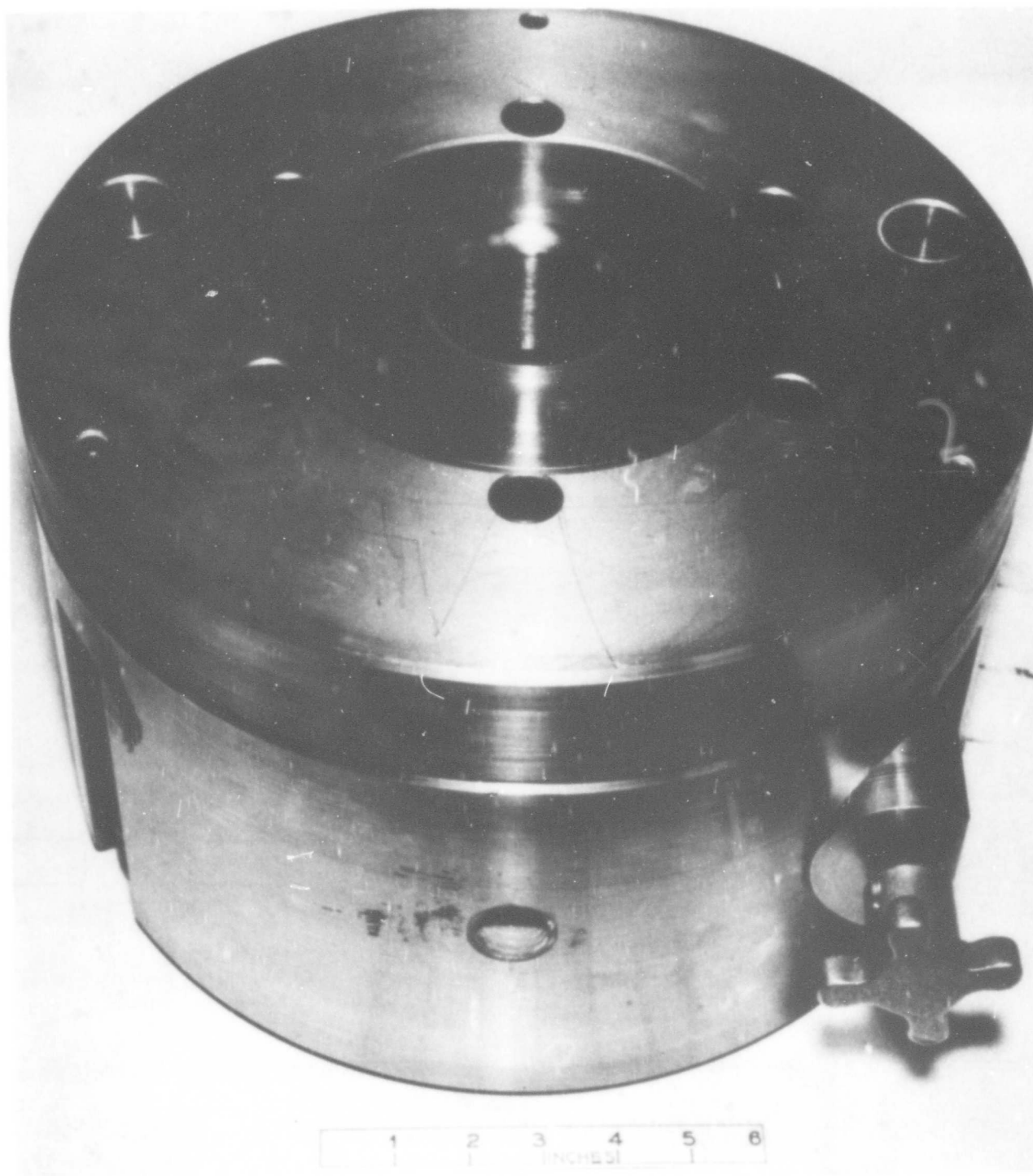


Figure 28 - UNIVERSAL HOLDER & STRIPPER RING

Convair Print 57028

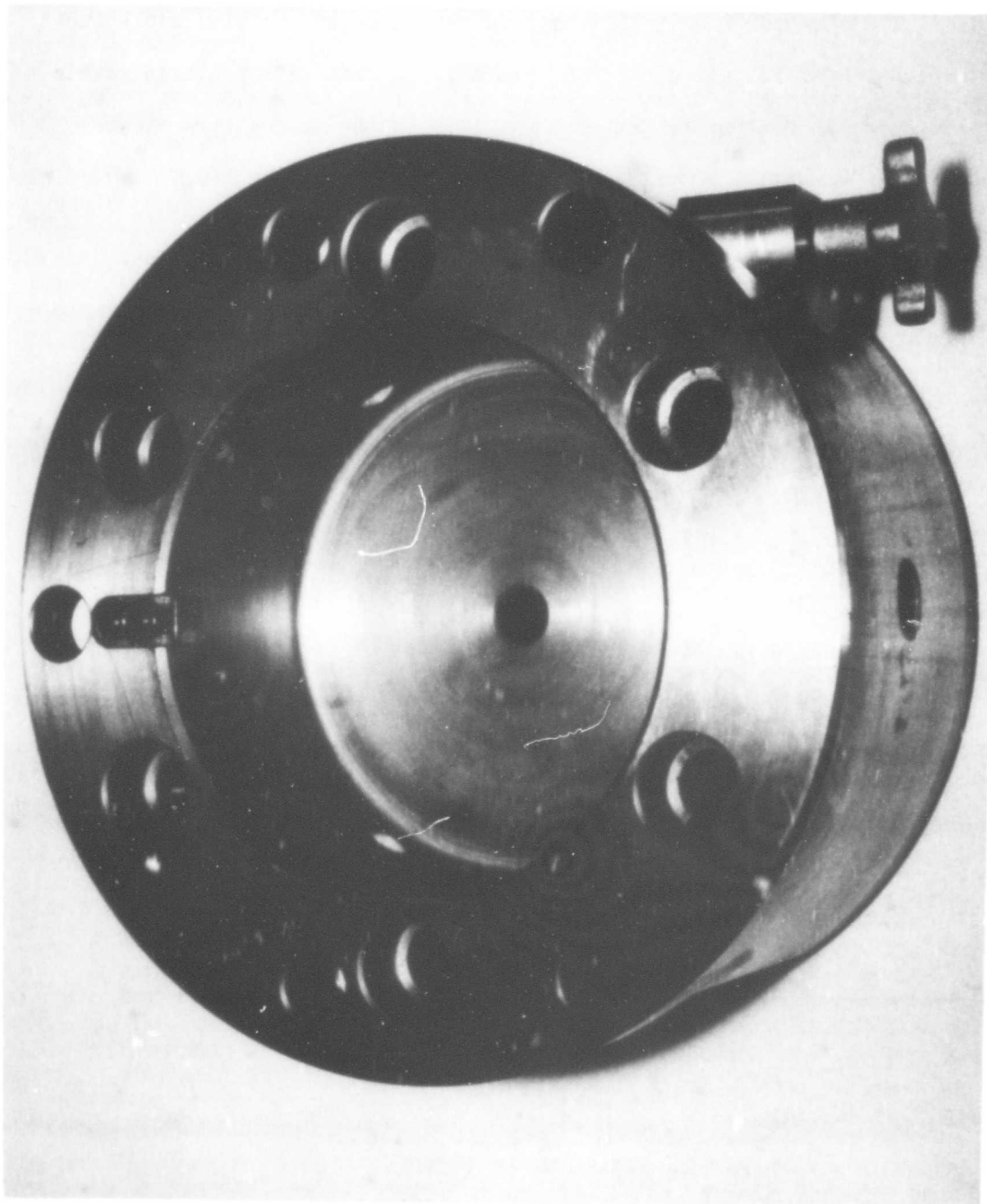


Figure 29 - BASIC HOLDER LESS STRIPPER RING

Convair Print 57027

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### (Forging - Tool Development)

The stripper ring will remain in the extended position until the release knob is pulled, allowing the ring to drop into position on the holder. In most cases the ring was left in the up position shown in Figure 30 until the next billet had been placed in the die cavity. The ring was then released and the machine fired.

Since the holder and outer stripper ring were standardised it was necessary only to make a punch, die and stripper for a detail part. Typical of the tooling required are the components for the bushing. P/N 22-51001-21 shown in Figure 31.

#### (Foreward Extrusions-General Notes)

The Dynapak extrusion button varies from the convention. button in that it appears that no lead-in is required to achieve the desired extrusions. A ring of metal is left in the scalp of the extrusion billet and often is separated from the scalp due to material flow during the extrusion stroke.

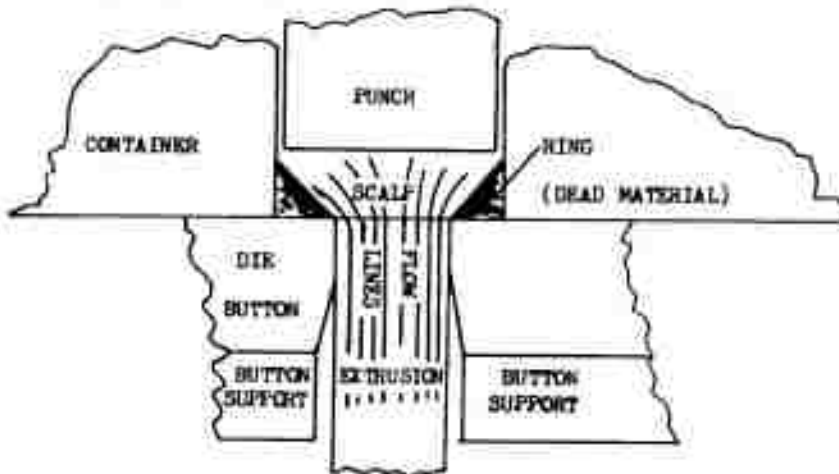
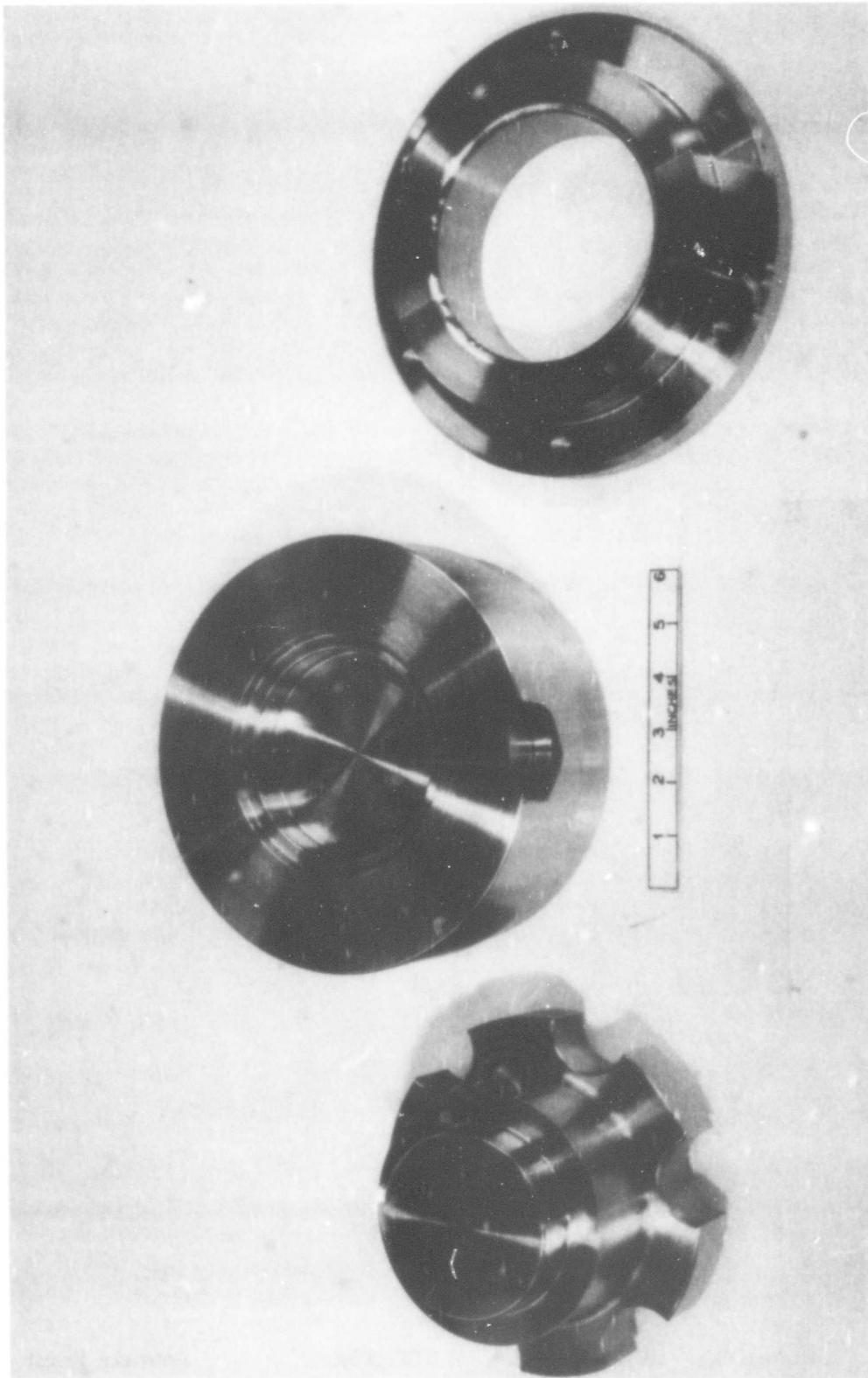




Figure 30 - BASIC HOLDER WITH STRIPPER  
RING IN UP POSITION

Convair Print No. 57029





Convair Print 57335

Figure 31 - TYPICAL BUSHING TOOLING

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

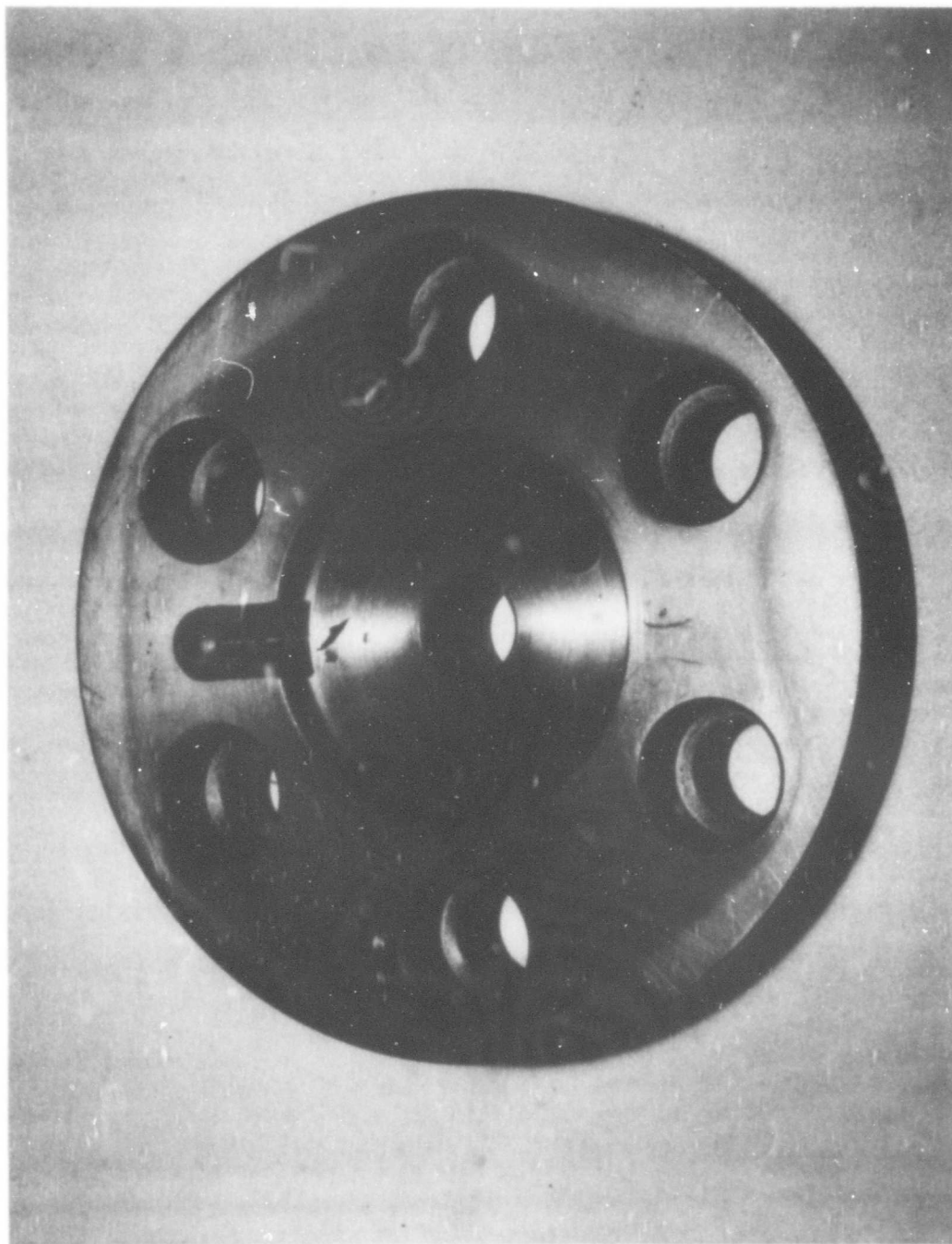
#### (Foreward Extrusions-General Notes)

Attempts to duplicate the dead material ring in the container design have not been fruitful and it is felt that the limited improvement, if any at all, would not warrant the increased complexity of extrusion button design and manufacture.

#### (Tool Development)

Punch holders were developed in the same manner as the die holders, by test. The first punch holder, MDA 500 shown in Figure 32, was made from SAE 52100 tool steel heat treated to  $R_C$  48. This holder failed when used in a forging attempt and is seen in Figure 33 after removal from the machine. As a result of this failure a new holder, incorporating sub plates hardened to resist the high compression loads, was made. The first plate was heat treated to  $R_C$  58-62 which proved to be too hard and brittle. A subsequent plate was tooled from Durodi steel, heat treated to  $R_C$  45-46. This choice was made as a result of the excellent showing of Durodi in the forging tools. The new sub plate has been used in forging, extruding and compacting tests and still is in good working condition. The new universal punch holder MDA 501 is seen in Figure 34.

In addition to the punch holder development a pre-stressed extrusion tool holder was developed. The design seen in Figure 35 is unique in that both the billet container and the die button are independantly pre-stressed in the same tool. The design also allows the billet container to be removed without bothering the die button. In addition the die button is backed up heavily to prevent failure.



Convair Print 57001

Figure 32 - FIRST PUNCH HOLDER BUILT

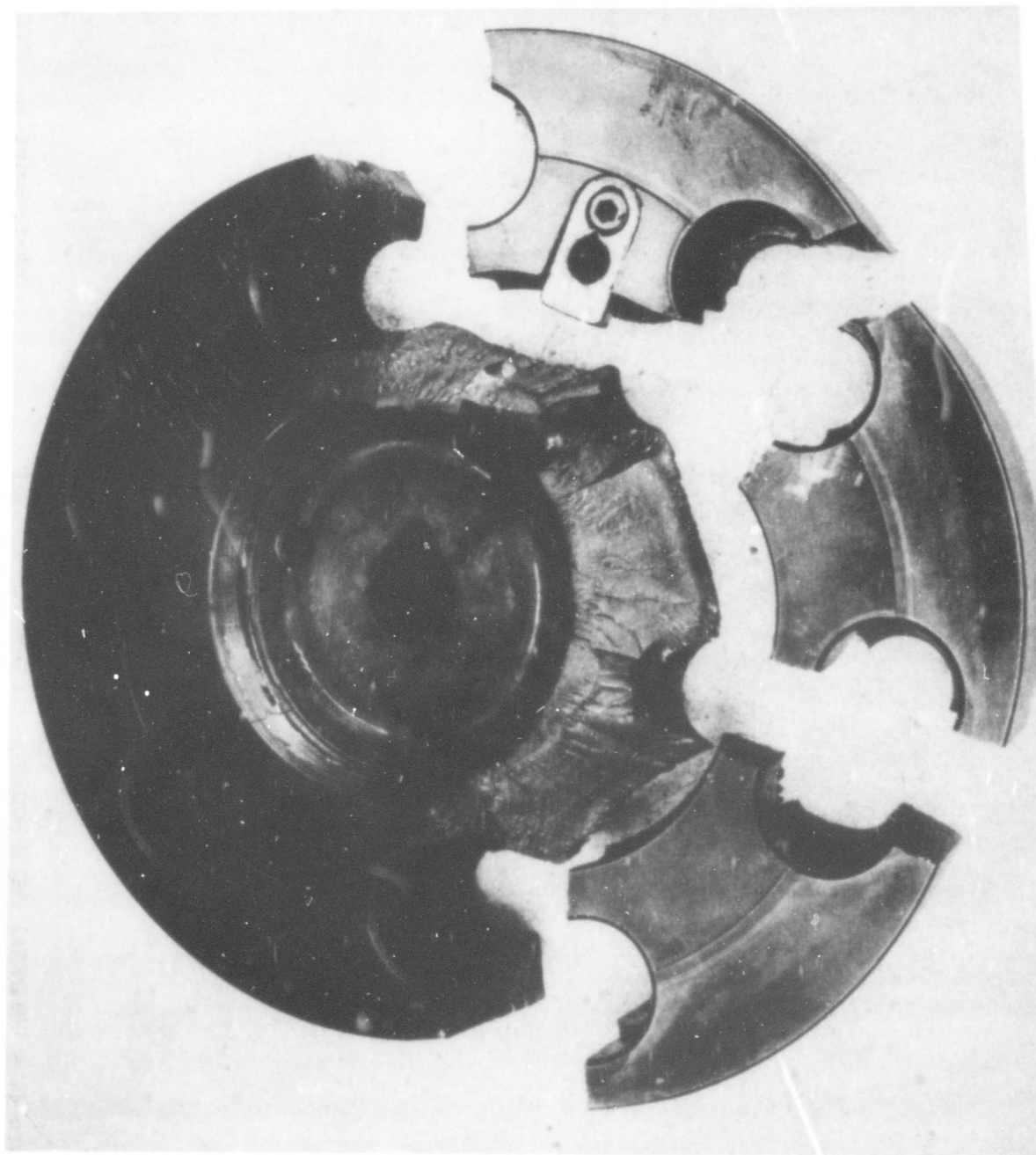


Figure 33 - PUNCH HOLDER FAILURE

Convair Print 58862

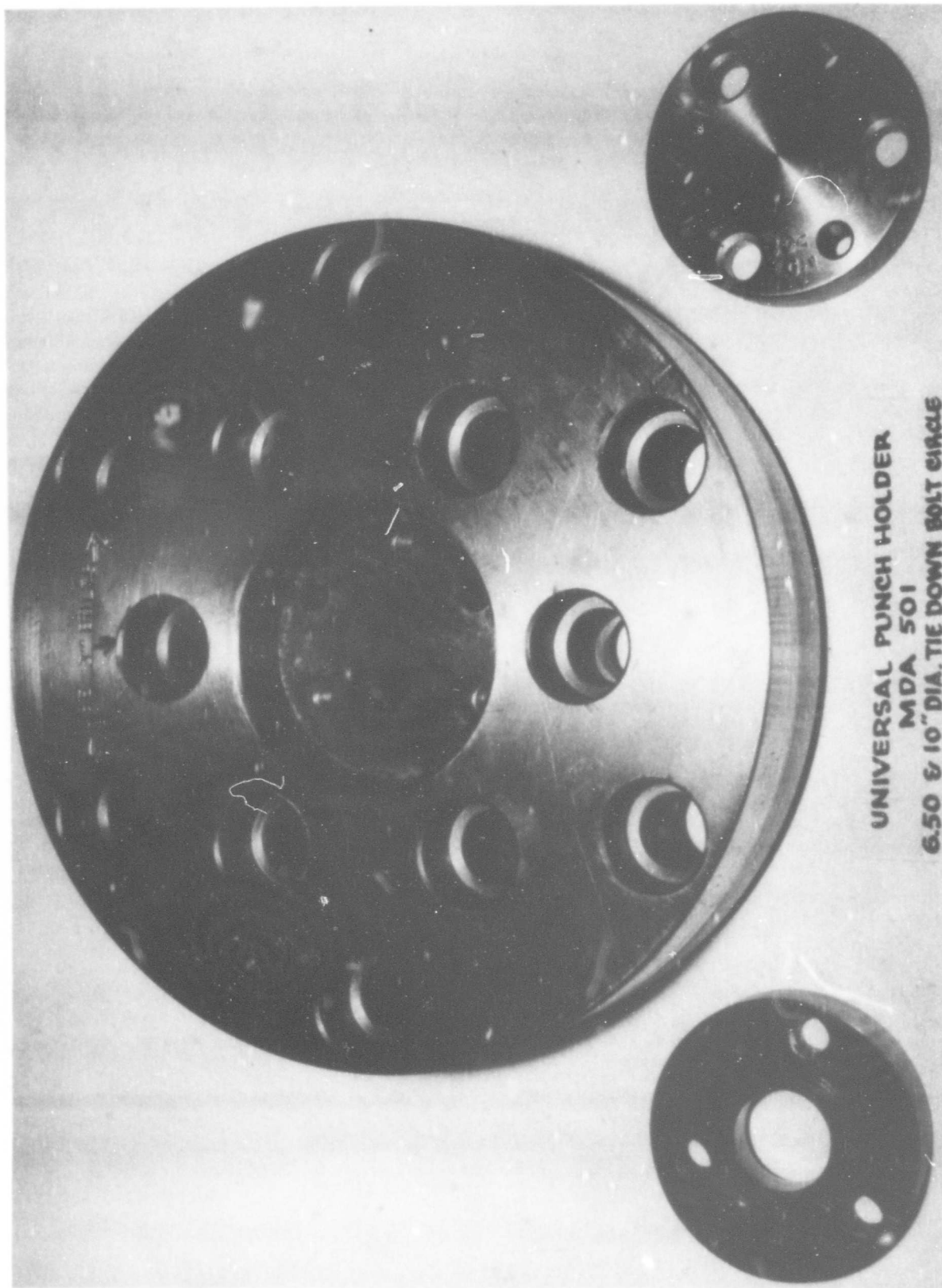


Figure 34 - UNIVERSAL PUNCH HOLDER

Convair Print No. 57002

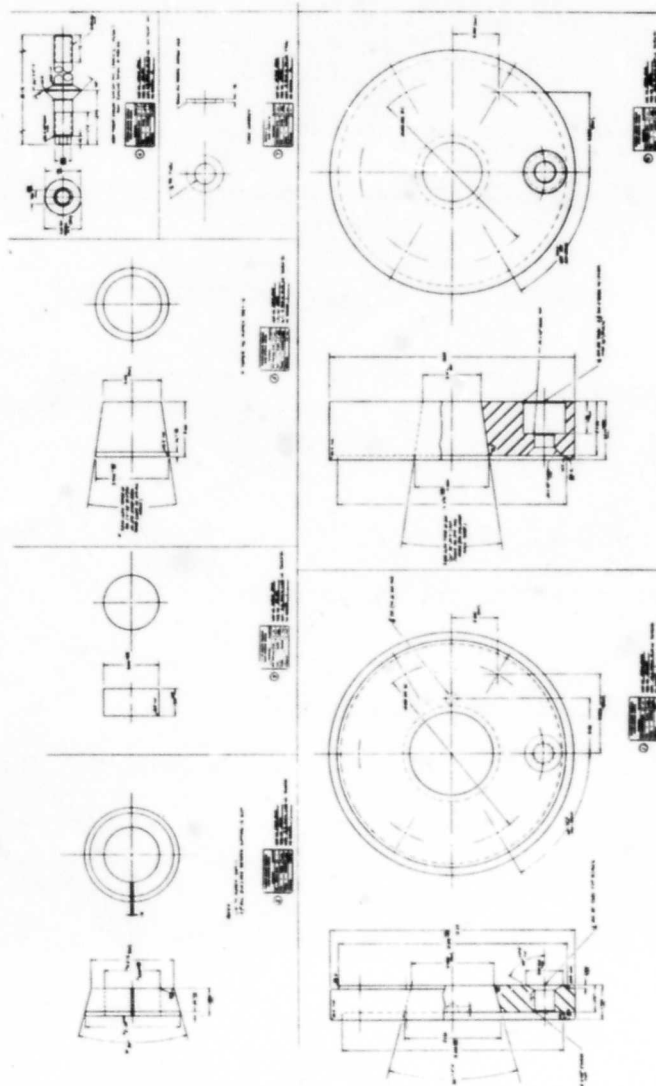


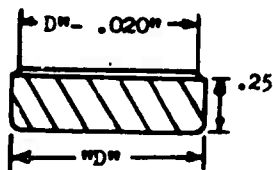
Figure 35 - PRESTRESSED EXTRUSION TOOL HOLDER

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

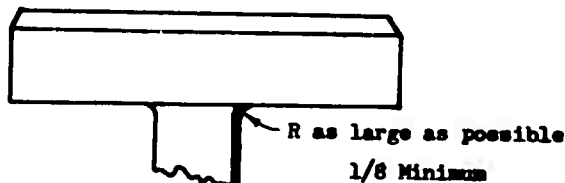
#### (Tool Development)

Punch design is more or less determined by the part. There are however some basic design features common to all punches. On all straight punches it is best to relieve the punch about .020 on the diameter starting from approximately 1/4 inch behind the contact face. The contact face may be



separate so that replacement may be made without scrapping the whole punch.

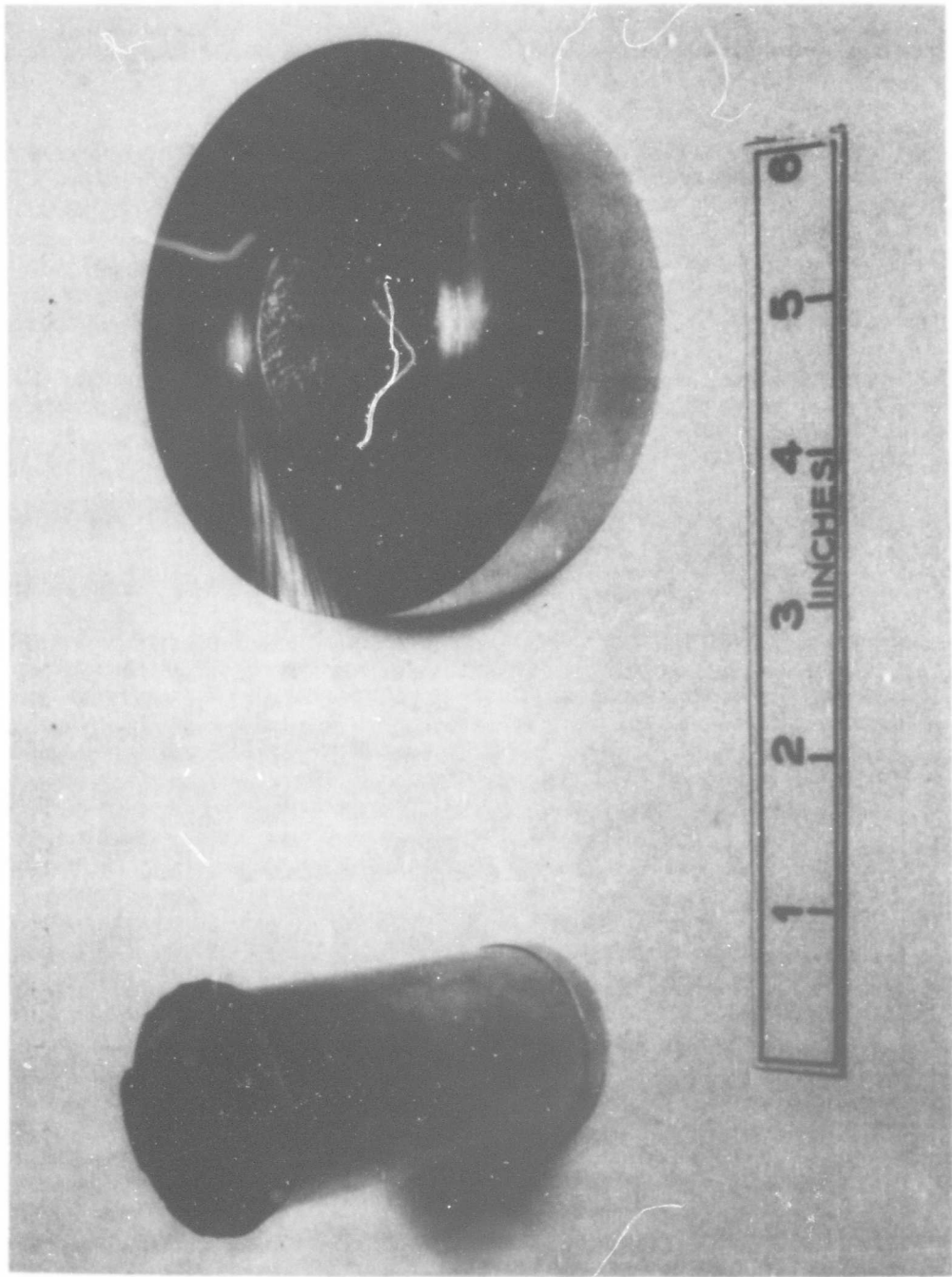
If at all possible a large radius should be used between the shank & butt.



In most cases radii of between 1/8 and 1/4 are satisfactory however, the smaller the punch diameter the greater the need of a large radius for strength.

Test evaluations established that punches hardened in excess of  $R_c$  50 were too fragile for normal use. Machine side play and slight billet unevenness resulted in broken punches. Typical of the failures experienced in the punch shown in Figure 36. However as the punch hardness was reduced a tendency to mushroom on impact was noted. Figure 37 illustrates





Convair Print 54924

Figure 36 - TYPICAL FAILURE OF HIGH HARDNESS PUNCH



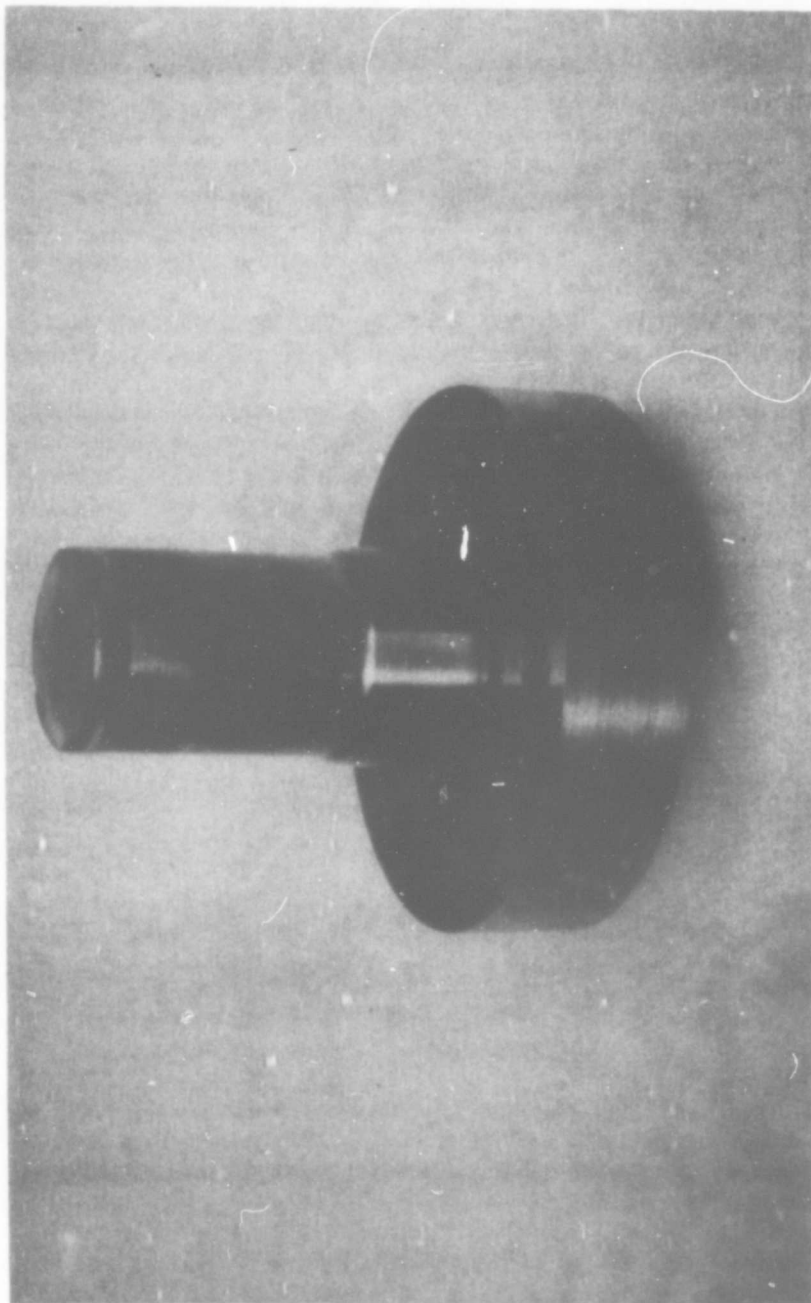


Figure 37 - TYPICAL UPSET FAILURE OF PUNCH

Convair Print No. 54865

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### (Tool Development)

a typical punch upset from excess compression loading. It is believed that the best hardness range for punches is between  $R_c$  46-48. There will still be a tendency to upset the punch when excessive fire pressures are used. No set figure can be given for punch size to fire pressure relationships since it will vary from material to material, by forging temperature, by reduction ratio etc. however information in this area for extrusion application is being developed by the Dynapak project personnel.

Extrusion button design is quite simple when no lead-in is provided. The desired cross section is cut into the round button and is relieved below the first  $1/4$  inch. Reference Figure 38. A view of the button is shown in Figure 39. Although the die button thickness of  $1-1/2$  inches seems sufficient, tests established that a heavier back up around the desired cross section is mandatory to prevent button failure.

#### Backward Extrusion

Only a limited amount of work was done with back extrusion; however, the tooling developed in the forward extrusion testing was found to be satisfactory for general usage. The punch was rounded rather than flat to achieve a better flow of material and reduce the punch loading upon impact. Flat bottom punches should be avoided since they retard the flow of metal directly below the punch face. For optimum metal flow and reduced punch loading the punch should have a cone angle of from one to seven degrees with a minimum radius blend in to the punch land of .032." (Figure 40)



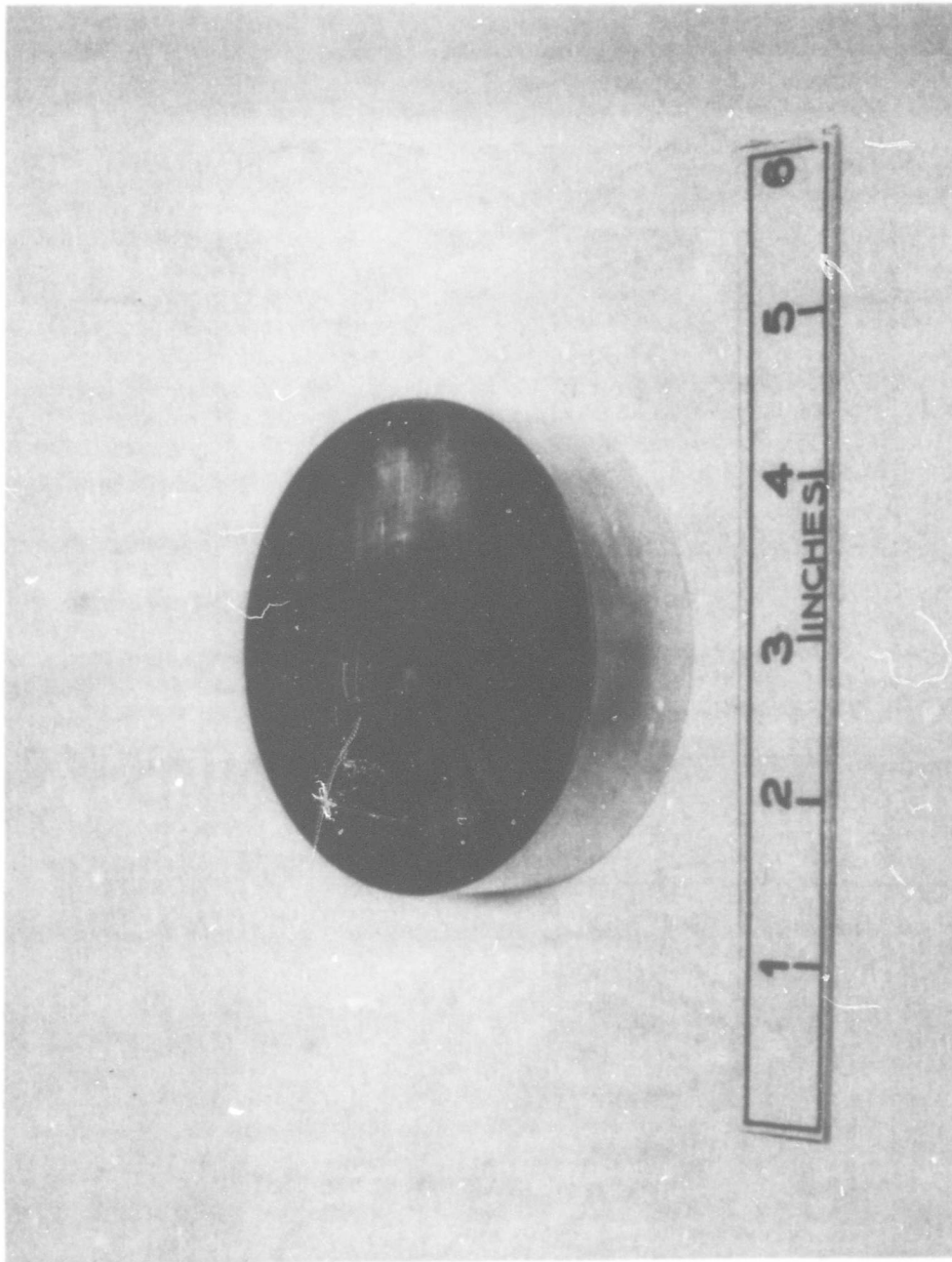


Figure 39 - EXTRUSION DIE BUTTON

Convair Print 54923

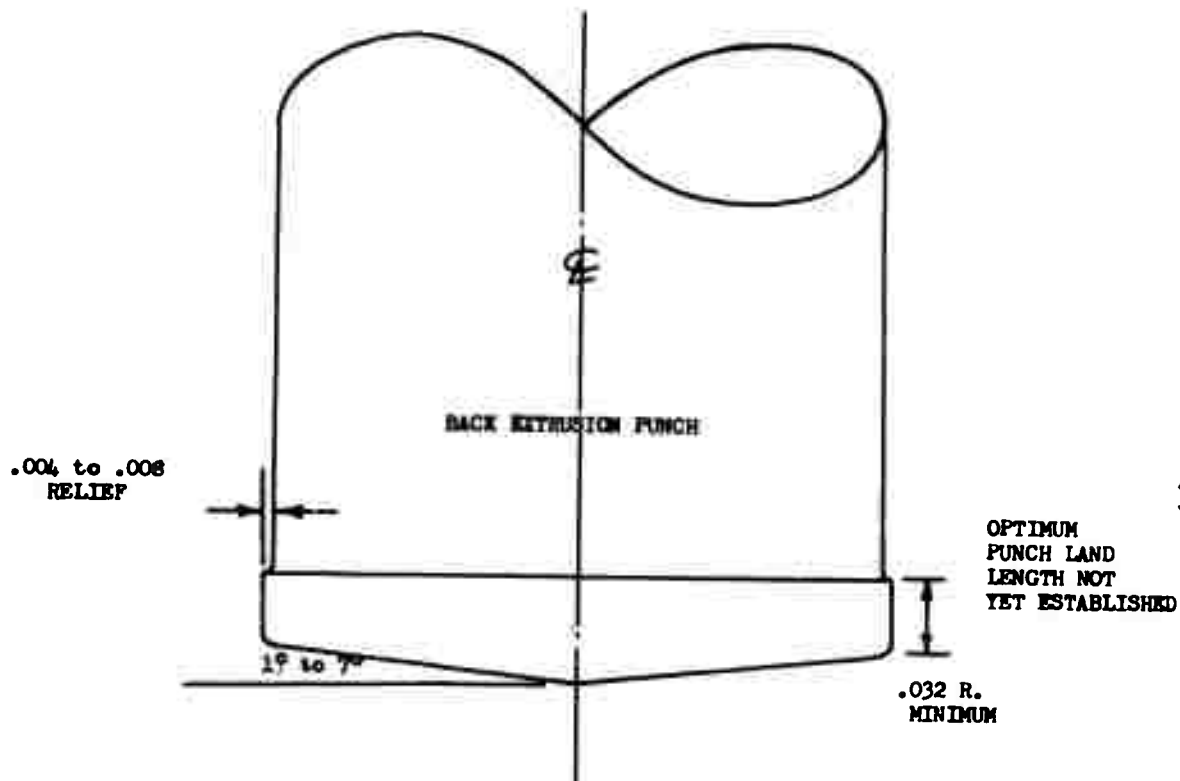


Figure 4.0 - OPTIMUM BACK EXTRUSION PUNCH DESIGN

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### Backward Extrusion

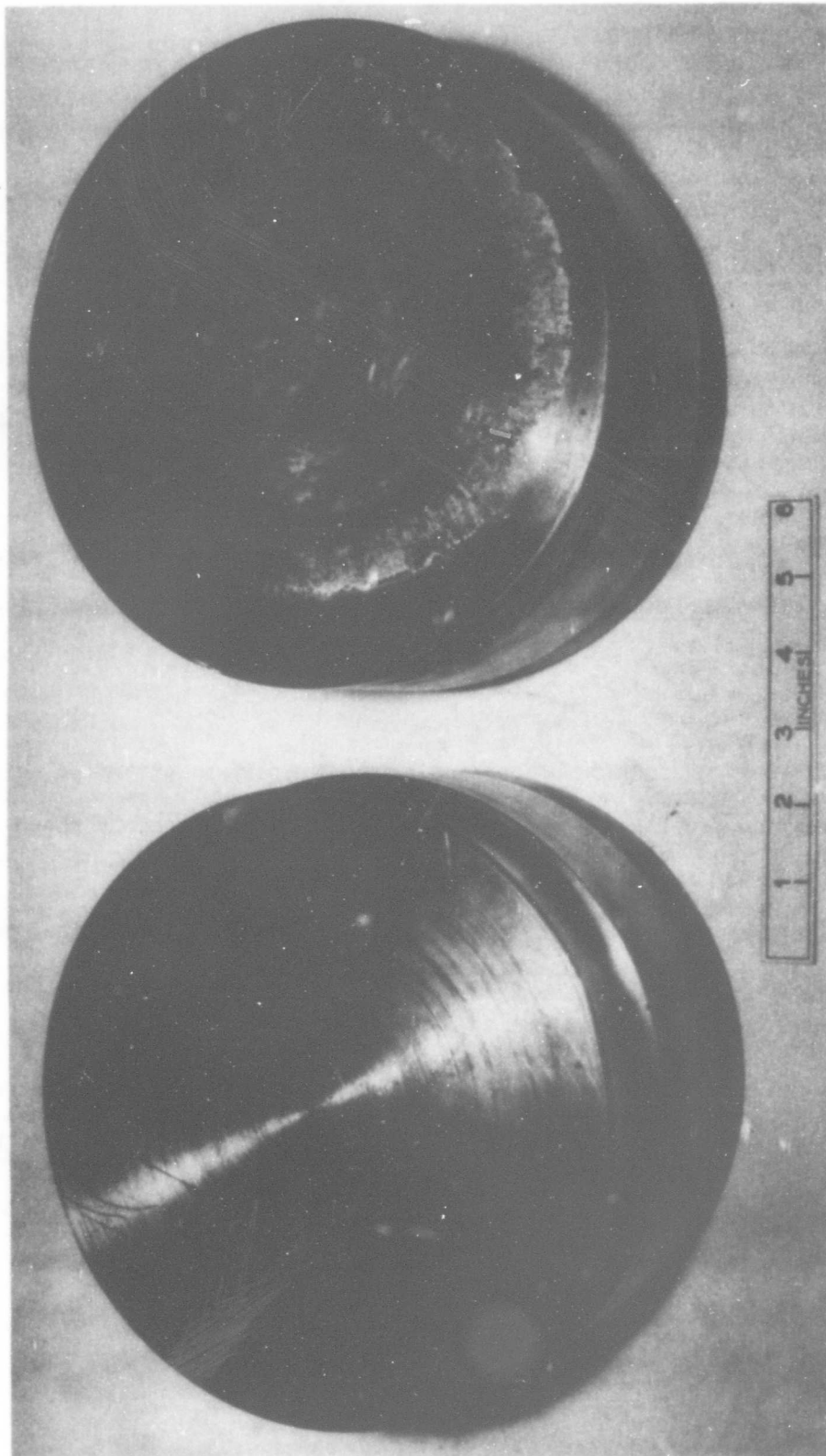
It was found that a .004" to .008" relief in contrast to the .020" used on the forward extrusion was necessary to control size. Secondly the length of the non-relieved section was found to be important. A short length of the land is best, since side friction is reduced. If the land is too short, size tolerances are lost. There was insufficient work done in this area to establish a minimum land size. It is believed that the land size will depend to a great extent on punch size and material to be extruded.

As with all tooling which is used in the forging and extruding areas, surface finish is extremely important. A mirror finish on the punches and dies is a definite asset.

#### Compacting

A preliminary evaluation of compacting by Dynapak was attempted using tungsten carbide pre-pressed powders. A flatter die assembly shown in Figure 41 was used in the trials.

A rectangular shape was cut in a piece of hot rolled steel. The opening was filled and the powder pre-pressed prior to the forging stroke. The steel and powder pre-pressed prior to the forging stroke. The steel and powder were then hit and reduced in thickness. Powder density was increased but the stresses set up by the forged steel holder cracked the compact before the piece could be sintered.



Convair Print No. 57004

Figure 41 - FLATTENING DIES FOR COMPACTION ATTEMPT

## GENERAL DYNAMICS/CONVAIR

### DEVELOPMENT OF THE PROJECT

#### Compacting

Although the results were somewhat disappointing, the tests did lay the groundwork for Project 348, a compaction study.

#### Materials

It was found that Durodi, a shock resistant tool steel, was an excellent all around material. The SAE 52,100 material was found to be satisfactory for holders and holder rings but was not sufficiently shock resistant for the forging die or punch section. Punches made of Graphite tool steel were tried but proved susceptible to brittle failure due to side loads.

It was found that high hardness was not necessary to satisfactory punch performance. In general it may be said that hardnesses exceeding  $R_c 50$  should not be used in the tools subject to impact and shock loads. Tool steels selected for Dynapak use should be capable of withstanding high thermal shock and impact loads and yet retain the strength level required. The Durodi material does fairly well but many improvements can be made. As yet there are no tool steels manufactured that meet the drastic requirements of the Dynapak operation.



GENERAL DYNAMICS/CONVAIR

A P P E N D I X

## MACHINE OPERATING INSTRUCTIONS

General Operating Instructions

## Safety Precautions

The Dynapak machine is a safe machine when handled with respect. It's ability to release tremendous forces in milliseconds requires that each action be thought out prior to initiation. A careless operator will find it an extremely dangerous machine unless he follows the simple and logical rules which follow:

NEVER put the hands under the ram unless it is held up by hydraulic oil pressure. Without the oil under the ram piston, even the "safe" position of the control switch is unsafe.

WATCH the fire pressure and set pressure gauges and be sure that the ratios are maintained 3 to 1. NOTE: Fire pressure may gradually build up from trigger gas or set pressure leakage could make the machine misfire.

REMEMBER the PANIC BUTTON is the fire pressure bleed valve on the console. Opening this valve dumps the fire pressure to the atmosphere and the machine cannot fire.

When energizing the machine, ALWAYS put the fire pressure in last.

When de-energizing the machine, ALWAYS dump the fire pressure first.

When the machine is left unattended it should be in the safe position with oil under the piston. All electric power and the nitrogen gas supply to the console should be cut off.

In the event of a electrical power failure if the rotary switch is in the fire return, or cock position, the machine will dump the fire pressure to the atmosphere thus, making it safe automatically. If the machine is in the safe or ready position, it cannot be fired electrically, but it does remain energized and will misfire if the 3 to 1 fire pressure to set pressure reaches 4 to 1.

## MACHINE OPERATING INSTRUCTIONS

General Operating Instructions

## Safety Precautions

All bolts, nuts and other structural parts of this machine are made of heat treated alloy steels. (DO NOT SUBSTITUTE).

Never attempt to disassemble the machine unless all gas is dumped, all bleed valves excepting back pressure bleed valve are open and the high pressure gas supply is shut off.

When firing, stay out of splatter area or use the safety door.

Test Firing

The (6) end caps on each end of the (3) shock absorbers should be turned counterclockwise with a spanner wrench to be sure they are tight against the (6) bearing feet.

Insert the six inch spacer adjustment bolt between the top of the lower cover plate and the bottom of the right front bearing foot.

Turn on the utilities as follows:

110 Volt AC to the console

Nitrogen manifold gas supply to the console

440 Volt 3 phase current to the pump unit

Open the pressure "X" valve above the left gauge on the left side of the machine. It will take about 750 psi to raise the machine to obtain the 6" dimension from the frame.

Close pressure "X" valve and open pressure "Y" valve above right hand gauge on left side of machine. Admit 250 psi to the upper shocks.

Close pressure "Y" valve and remove 6" bolt for established (6") neutral position before firing.

## GENERAL DYNAMICS/CONVAIR

### MACHINE OPERATING INSTRUCTIONS

#### Test Firing

The machine is now ready for test firing, and it can be shot against a high back pressure so that the column will move only a few inches.

Close the set pressure bleed valve on the console and open the set pressure to build a pressure of 35 psi in the MYGE unit.

Check the back pressure bleed valve (It should never be opened or hydraulic oil will be exhausted onto the floor under the console.) Turn the back pressure fill valve to the right and build up a gas pressure under the piston of 100 psi. This is a diaphragm valve. It opens to the right and is left open to maintain the pressure selected, automatically.

Close the fire pressure bleed valve, and very slowly open the fire pressure fill valve and reach a pressure of 100 psi.

IMPORTANT: Never exceed a three to one pressure ratio between fire and set pressures or the machine ~~may~~ misfire automatically. From this time on until firing the machine is energized, so do not approach it bodily. Use tongs to place or move parts in the work area.

Start the pump with the manual switch to the right of the oil pressure gauge at the left end of the console.

Set the rotary switch to the "Ready" position (pointing straight up)

Turn the 110 volt toggle switch to "on" and the machine is ready.

As the rotary switch is turned counterclockwise the following events take place:

Fire - The machine should fire and the column moves out very rapidly, but for a short distance, because the back pressure is high enough to stop it.

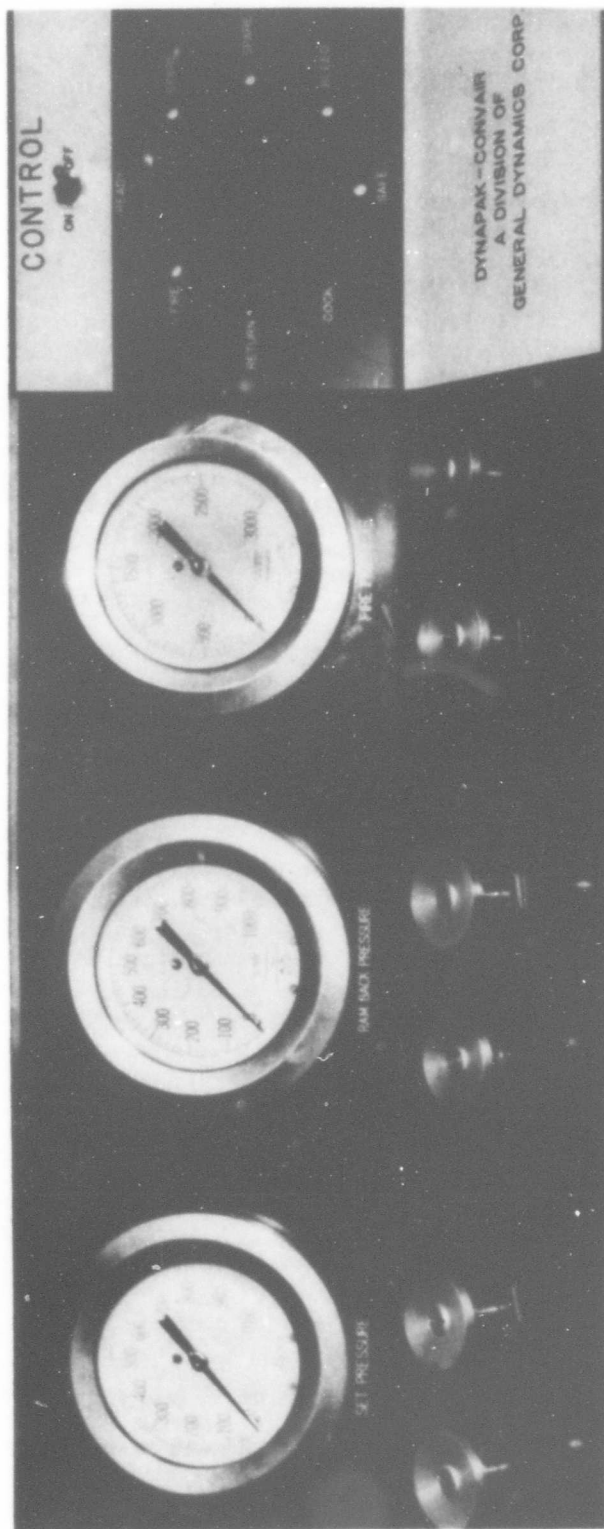


Figure 42 - Operating Console Controls

## MACHINE OPERATING INSTRUCTIONS

Test Firing

Return - This position energizes a solenoid valve which then allows hydraulic oil to be pumped under the ram piston and returns it to the starting position. When the green light comes on and the hydraulic oil pressure gauge reads approximately 2300 psi the piston is up against the seal plate and the operator may move the rotary switch to the next counter-clockwise position.

NOTE: On the first run, the pump must purge itself, and this may take some time.

The "cock" position pumps oil into the set pressure system of the Hyge unit and returns the seal base to its starting position. Allow a minimum of five seconds in this position. When the green light comes on, the operator may move the rotary switch counter clockwise to the "safe" position.

Safe - At this point the machine has been re-cocked, but the hydraulic oil is still under the piston, hence the piston could move but a very short distance even if accidentally fired. This is the safe position for changing tools, etc. This is also the position to leave the machine in when it is not to be operated for a short time. If there is no need to have the machine in "safe" position (as with rapid firing) this position is passed through without stopping at all.

Bleed - With the rotary switch in the bleed position the hydraulic oil is returned to the reservoir and the machine is again ready to fire. The operator must hold this position until the red light comes on indicating the bleed is complete.

GENERAL DYNAMICS/CONVAIR

MACHINE OPERATING INSTRUCTIONS

Test Firing

Spares - Two spare positions are included in the cycle to be used as desired. These positions can be used for such purposes as regulating purge gas, tripping an automatic billet feeder, or blasting a forging die with gas to remove scale.

NOTE: If the machine is in the "ready" position and it is desired to return to the "safe" position without firing, turn the rotary switch CLOCKWISE to the return position. The pump will then fill the piston back pressure chamber "B" full of oil. The normal, counterclockwise, rotary switch sequence through to the "safe" position should then be followed.

IMPORTANT: The set pressure and the ram back pressure gauge readings are erroneous for gas pressure indication when there is oil in the machine. For this reason a spare or ready position of the rotary switch is necessary for setting pressures desired. Always work from left to right adjusting the set pressure to 1/2 the desired fire pressure; then adjust the diaphragm fill valve to maintain 100 psi ram back pressure. (This pressure is used for all fire pressures above 300 psi.) Next adjust the fire pressure to twice the set pressure. Lastly, open the set pressure bleed valve on the console slowly and drop it to 1/3 the fire pressure. If this ratio is exceeded the machine will automatically misfire without movement of the rotary switch. Set pressure gas fills a small area in the hyge unit and very little is wasted for the additional safety obtained as outlined above.

MACHINE OPERATING INSTRUCTIONS

Test Firing

CAUTION: NEVER allow anyone near the machine when gauge pressures are being set or adjusted.

Machine Malfunctions :

Going back through the preparations for firing, and the test firing the following list covers most malfunctions and their probable causes.

One of the fill valves on the console is opened to raise a pressure in the machine and nothing happens.

(Probable Cause)

The valve on the nitrogen gas bottle was not opened.

Remedy: Open the valve on the gas bottle.

Nitrogen pressure in the bottle is too low.

Remedy: Close the valve on the bottle and open a valve on a bottle containing more pressure.

Should the bottle pressure be less than the machine pressure, the machine will bleed into the bottle until the pressures are equalized. This principle can be utilized to conserve gas in many cases. For example, rather than exhaust fire pressure to the atmosphere the excess gas may be bled into a near empty bottle thus saving the gas for future use.



MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

The fire pressure valve is opened to introduce fire pressure and the gas exhausts to the atmosphere:

(Probable Cause)

The Hyge unit is not seated.

Remedy: Increase set pressure gauge reading to possibly 800 psi.

If there is dirt on the actual seal, actuation of the machine may blow it out. If permanent damage to the seal has been done the machine must be disassembled to correct the condition.

The rotary switch is moved to the fire position and nothing happens:

(Probable Cause)

110 volt toggle switch on the console in off position

110 volt power to the console off: at the fuse box

Fuse block on the 110 volt system has blown

The nitrogen gas supply was not turned on at the bottle.

The trigger gas solenoid valve mal-functioned.

Remedy:

There may be a short in a wire from the console to the solenoid mounted on the left side of the machine.

MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

After firing, the rotary switch is moved to the return position and nothing happens.

(Probable Cause)

440 Volt 3 phase power to the pump unit was not turned on

The 110 volt AC power from the machine console to the hydraulic pump solenoid valve is disconnected.

The 440 volt circuit breaker at the hydraulic pump has opened.

Remedy:

Turn on the power.

The hydraulic pump returned the ram piston to the seal plate but the green light did not come on to indicate a completed cycle.

(Probable Causes)

Signal light bulb burned out.

Improper adjustment on pressure switch in the signal light circuit.

The rotary switch is moved to the "SAFE" position and the fire pressure starts exhausting to the atmosphere.

(Probable Cause)

Hyge unit not seated.

Remedy:

Quickly return the rotary switch to the fire position. This closes a solenoid valve and prevents further exhaust and loss of fire pressure gas. Move on to "Cock" position and start the hydraulic pump and hold at full pressure for ten seconds. Return to "Safe".

## MACHINE OPERATING INSTRUCTIONS

Machine Malfunction

Having passed the "Bleed" position on the rotary switch the machine is ready for use. After repeated cycling it is observed that the fire pressure is changing. If this condition is not rapid, it would be advisable to correct for it periodically by adding or bleeding gas as required to restore the desired value. If on the other hand rapid changes occur the time delay relay inside the right front end of the console should be adjusted. This relay is timed to put in as much gas on firing the machine as is lost on recocking it. When the timing is correct, the fire pressure will remain nearly constant. Increasing the delay will put in more gas (increase fire pressure) and decreasing the delay will put in less gas. Because the bottled gas supply pressure is not constant some variation in fire pressure is unavoidable.

Tool Installation

Punch and die alignment can be checked by advancing the ram toward the bolster at low velocity and under positive control. To do this the following procedure is required:

Energize the set pressure to a moderately high value. If the machine is empty of all gas pressure charge the set pressure to 400 to 500 psi.

Adjust the ram back pressure to 100 psi.

Adjust the fire pressure to 100 psi.

Bleed the set pressure back to 35 psi.

Fire the machine by advancing the rotary switch to the fire position. Because of the balanced back pressure and fire pressure the ram will advance a short distance and stop. NOTE: Leave the control switch at the fire position.

MACHINE OPERATING INSTRUCTIONS

Tool Installation

Bleed off all set pressure to guarantee that the set pressure unit will not close during subsequent maneuvering.

Advance the ram into the tooling by adding fire pressure manually.

Retract as required by bleeding fire pressure manually.

When tool check out is complete, adjust the set pressure to a value of 400 psi or more, advance the control switch to return and complete the operating cycle to the ready position. The machine may then be recharged to the operating conditions.

GENERAL DYNAMICS/CONVAIR

#### ACKNOWLEDGMENTS

## GENERAL DYNAMICS/CONVAIR

### ACKNOWLEDGMENTS

Operating Instructions for the 1200 Dynapak were obtained from General Dynamics/Advanced Products Department. The instructions given in this report were modified for the Convair updated machine.

Credit is due to Mr. J. T. McCormick and Mr. T. J. Critton (General Dynamics/Advanced Products Department) for their ideas and efforts which contributed greatly to the success of this project.