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AFATL-TR-75-120



LINEAR LINKLESS FEED SYSTEM TECHNOLOGY

GENERAL AMERICAN RESEARCH DIVISION
GENERAL AMERICAN TRANSPORTATION CORPORATION
NILES, ILLINOIS 60648

SEPTEMBER 1975

FINAL REPORT: JUNE 1974 - JUNE 1975

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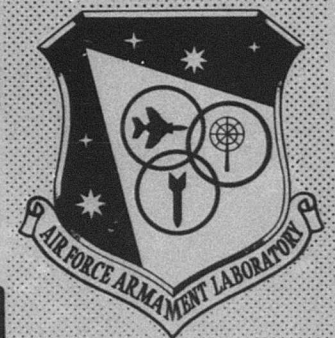
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFATL-TR-75-120	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LINEAR LINKLESS FEED SYSTEM TECHNOLOGY	5. TYPE OF REPORT & PERIOD COVERED Final Report, June 1974- 30 June 1975	
6. AUTHOR(s) R. H. Jacobson V. P. Milenkovic	7. PERFORMING ORG. REPORT NUMBER GARD-1623	8. CONTRACT OR GRANT NUMBER(s) F08635-74-C-0161 <i>new</i>
9. PERFORMING ORGANIZATION NAME AND ADDRESS General American Research Division General American Transportation Corporation Niles, Illinois 60648	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBER Project No. 161 AF-2560 GARD-16 Task No. 17 2560 01 Work Unit No. 024	
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida 32542	12. REPORT DATE September 1975	13. NUMBER OF PAGES 121
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified	
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied September 1975. Other requests for this document must be referred to the Air Force Armament Laboratory (DLDG), Eglin Air Force Base, Florida 32542.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available in DDC.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Linear Linkless Feed System F-15 Air Superiority Fighter F-16 Feed System F-16 Air Combat Fighter F-15 Feed System GAU-7 Gun System Gatling Gun M-61 Gatling Gun		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Design studies were performed for a 25mm linear linkless feed system for the F-15 air superiority aircraft and then for a 20mm system for the F-16 air combat fighter. Although the installation configuration and caliber size of the systems differed, the F-16 system employed most of the mechanism designs and principles of operation which evolved from the F-15 system study. Because of greater Air Force interest in the F-16 system, it is described in greater detail. The system is comprised of (1) loading mechanism, (2) storage		

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> conveyor, (3) accelerating and transfer mechanism, (4) merging conveyor, and (5) gun feed mechanism. It has a total capacity of 750 rounds in the F-16 installation and weighs 420 pounds exclusive of rounds. The optimum F-15 system was selected from several alternate design concepts investigated. For purposes of demonstrating feasibility of principles of operation and critical components of the system, a modified prototype system was designed and detailed for fabrication. <

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PREFACE

This is the final report on a linear linkless feed system technology study conducted by General American Research Division (GARD) of General American Transportation Corporation, Niles, Illinois 60648. The study placed particular emphasis on feed systems for the F-15 air superiority aircraft and the F-16 air combat fighter.

The program, designated as GARD Project No. 1623, was performed under Contract No. F08635-74-C-0161 with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida, during the period from 17 June 1974 to 30 June 1975. The program manager for the Air Force Armament Laboratory was Major Robert F. Grasmeder (DLDG).

The GARD program manager was Mr. R. E. Stern. Other GARD personnel who contributed materially to this program include Messrs. R. H. Jacobson, V. P. Milenkovic, and J. F. Reader.

This technical report has been reviewed and is approved for application.

FOR THE COMMANDER:



GERALD P. D'ARCY, Colonel, USAF
Chief, Guns, Rockets, and Explosives Division

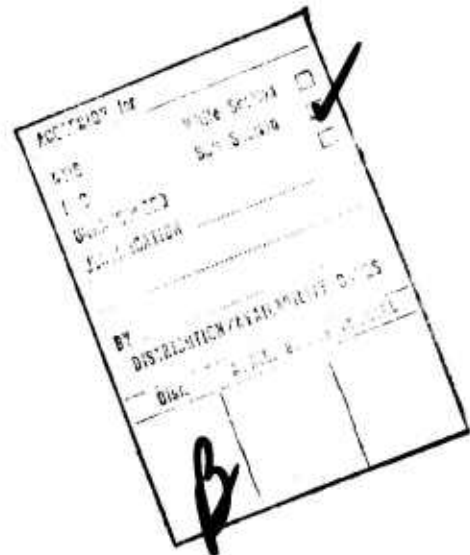


TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
II	F-16 FEED SYSTEM	3
	2.1 Design Objectives/Approaches	3
	2.2 System Description	5
	2.2.1 Loading Mechanism	9
	2.2.2 Storage Conveyor	11
	2.2.3 Accelerating and Transfer Mechanism	16
	2.2.4 Merging Conveyor	17
	2.2.5 Gun Feed Mechanism	22
	2.3 System Installation	23
	2.4 Drive Train	23
	2.5 System Weight and Power Requirements	26
III	F-15 FEED SYSTEM	31
	3.1 Design Objectives/Approaches	31
	3.2 System Description	32
	3.2.1 Storage Magazine	32
	3.2.2 Retrieval System Concepts	35
	3.2.2.1 Concept B	35
	3.2.2.2 Concept A	37
	3.2.2.3 Concept C	37
	3.2.3 Recommended System	41
	3.3 Partial Prototype Design and Fabrication	50
Appendix A	PARTIAL PROTOTYPE DRAWINGS	55

LIST OF FIGURES

Figure	Title	Page
1	General Layout of Complete F-16 Feed System	6
2	Identification of Major Subsystems and Components	7
3	Paths, Spacing, and Relative Positions of Rounds through Feed System	8
4	Loading Mechanism	10
5	Storage Conveyor Round Carriers	13
6	Round Carrier Mockup (A) Empty, (B) with Round in Straight Configuration, and (C) with Round in Folded Configuration	14
7	Merging Conveyor Round Carriers	19
8	Side Elevation through Midplane	24
9	Plan View of Feed System Installation	25
10	Ammunition Storage Compartment Layout	33
11	Storage Compartment Conveyor Details	34
12	Concept B Retrieval System	36
13	Concept A Retrieval System	38
14	Intermediate Conveyor Round Carriers	39
15	Concept C Retrieval System	40
16	Concept C Transfer Wheel Detail	42
17	Concept C Cam Details	43
18	Concept C System - Top View	44
19	Side View of Recommended Tunnel System	45
20	Positions of Rounds in Passage Through Tunnel	46
21	Merging Conveyor Details	47
22	Storage Compartment Conveyor Chain Detail	48
23	Drive Train Gearing Layout	49
24	Storage Container Loop of Partial Prototype Feed System	51
25	Container End of Tunnel Conveyor for Partial Prototype Feed System	52
26	Gun End of Tunnel Conveyor for Partial Prototype Feed System	53

SECTION I

INTRODUCTION

The objective of this program originally was a three-month design study of a linear linkless feed system to interface with the F-15 air superiority aircraft and a 6000 shot-per-minute (SPM) 25mm Gatling-type gun. Earlier it had been intended that the F-15 aircraft would incorporate the GAU-7 gun system which fired 25mm caseless ammunition; its feed system included a caseless ammunition storage container and transfer unit/conveyor but had no provision for retention of spent cartridges. However, because of a combination of technical difficulties, chiefly involving the caseless ammunition, the Air Force terminated the GAU-7 development program in March 1974.

Since the requirement to provide a 25mm gun system for the F-15 aircraft still existed, plans were made to modify a more conventional gun system to fire 25mm aluminum-cased rounds, and the linear linkless feed system design study was initiated to obtain a system which would feed the newly modified gun and retain the spent cartridge cases. The feed system would store the maximum number of rounds within the fixed volume available and would provide the functions of transferring the rounds to the gun and restoring all fired cases and dud rounds in the storage container. Since specific gun details were unknown, the feed system/gun interface was defined to be at a hand-off sprocket, sufficient to demonstrate functionality of the system. Several system concepts were designed by the contractor, and their theoretical feasibility was shown.

The contract scope subsequently was extended to provide for detail design of the optimum feed system defined by the design study and also for the fabrication and demonstration testing of a functional model. The model or partial prototype would be full scale and would include all critical elements, such as the conveyor's interface with the storage container and with the transfer/merging mechanism, so that the functional feasibility of the system could be demonstrated.

The above work was carried forward until 14 March 1975. At that time the contract scope was modified to discontinue efforts, including hardware fabrication, on the 25mm feed system for the F-15 aircraft and instead to concentrate on design studies for a 20mm feed system for the F-16 air combat fighter. The requirements for the 20mm feed system were generally similar to the previous ones; however, the feed system would now interface with the 6000 SPM, M-61 Gatling-type gun, and a storage capacity of 750 rounds of 20mm, M-50 series ammunition was desired.

In accordance with this redirection, GARD's efforts during the final months of the contract were devoted to design of a 20mm, F-16 feed system. Several system concepts were identified, an optimum system was selected, and additional design effort was concentrated on optimizing the system and its integration into the F-16 aircraft.

Because the F-16 feed system is of greater interest to the Air Force at the present time, this system is presented first in this report. All parts of the system, their major components, their modes of operation, and the flow of rounds through the system are described in detail in Section II.

It is pointed out that the F-16 feed system evolved from the earlier work devoted to the F-15 system. Although the installation configuration and the caliber size differ, the principles of operation and the mechanism designs were essentially alike. Because these principles and mechanisms are discussed thoroughly in Section II, they are summarized briefly in Section III where the F-15 feed system is described. Instead the successive concepts generated for the F-15 system are presented, and areas of difference with the F-16 system are pointed out.

SECTION II
F-16 FEED SYSTEM

2.1 Design Objectives/Approaches

The feed system is to be fitted into the F-16 aircraft to feed 20mm rounds to the six-barrel M-61 automatic gun firing 6000 rounds per minute. The primary objective is to store within the limited available space a substantially larger number of rounds than could be stored in the earlier feed system. The increased storage capacity is to be achieved while maintaining high reliability of operation, low total weight, and low power consumption. The rounds are to be handled without links attached to them, and the system must also handle and store the spent cartridge cases.

The basic functions of the feed system are: (1) loading of rounds into the system, (2) storage of rounds, (3) feeding of rounds to the gun, and (4) removal and retention of spent cartridges. The system capable of performing these functions must fit within an envelope of specified size and shape. This shape and particularly the prescribed relative position of the point of loading, of the storage area, and of the gun impose limits on the feasible configuration of the system.

With regards to loading, the prescribed point of entry for the rounds is some distance away from the bulk of the space available for storage, and the size of the passageway between the loading region and the storage space is restricted. For this reason, the loading function entails a considerable amount of transport, with a part of the system specifically devoted to that purpose.

The storage compartment must utilize the space in an efficient way in order to meet the prescribed capacity requirements. The dimensions of the available space are such that for efficient placement of rounds in storage, the rounds cannot be confined to a single plane. Instead, rounds must be stored in some form of a three-dimensional array. Ultimately, however, rounds must be fed to the gun in a single file, moving perpendicularly to their long dimension. Since the spacial pattern of rounds entering the gun will differ from the pattern of rounds in storage, suitable components of the system must be provided to alter the pattern by imparting the necessary motions to the rounds. These components have to be interposed between the storage mechanism and the unit which feeds the rounds into the gun.

The simplest linkless feed system is one in which all of the rounds in the system move when feeding occurs. This is also the most natural approach if spent cartridges are to be stored in the places left empty by the withdrawal of rounds. Rounds in the storage area can be moved forward in a single file, the ones in front being fed to the gun, while cartridges are being entered in the rear of the file. However, the full set of rounds within the system represents a sizeable inertia load to be brought up to speed rapidly when firing is initiated. Even during firing at a constant rate, substantial power is expended in overcoming the mechanical losses if many rounds are in

rapid motion. By moving all rounds at the full feeding velocity, the power consumption could become prohibitively large. One of the design objectives is to reduce the required power to an acceptable level.

In order to conserve power, it is possible to divide the number of rounds in storage into two or more groups and to move only one group at a time. If only one-half of the rounds were moved at full speed at any one time, the power would be reduced in half. However, if all of the rounds were moved at half speed, the power would be reduced to approximately one quarter of what it would have been otherwise. The lower speed can be achieved by dividing the total number of stored rounds into two equal groups, by removing rounds simultaneously from each group at one-half the firing rate, and then by merging the two streams of rounds into a single stream prior to entry into the gun. Incorporation of a power reducing feature is particularly important since the system is required to store a greater number of rounds than previous systems, and hence there is a greater mass to be moved.

The most advantageous arrangement of rounds into groups is one which simultaneously fulfills two objectives: (1) reduction of speed and power, and (2) maximization of the number of rounds which can be stored. The storage arrangement must not only have a high packing density but must also permit the use of a simple and reliable retrieval mechanism, which does not occupy much space.

The operation of bringing the rounds from storage to the gun is similar to, but the reverse of, the operation of taking either spent cartridges or unfired rounds from the gun back to storage. In the feed system it is necessary either to provide a mechanism capable of performing both operations simultaneously, or else to use a separate mechanism for each of the two operations. The efficiency and the space effectiveness of the necessary retrieval and return devices has a significant effect on the potential benefit of any particular storage arrangement.

In summary, a feed system which satisfies the design objectives can be functionally and, to a large extent, physically divided into the following subsystems:

1. A loading device, serving to transport the rounds from an external source into the storage area of the system. Another part of this subsystem, preferably within the same device, will serve to remove the spent cartridges from storage, either during or prior to loading of live rounds.
2. A storage subsystem, holding an adequate supply of rounds divided into two or more groups. This subsystem must simultaneously dispense rounds and accept spent cartridges during firing. The division into groups serves to reduce the driving power needed for the system.
3. A retrieval subsystem, serving to transfer the rounds from storage to the point of entry into the gun and to transfer empty cartridges the opposite way. Depending on the spacial arrangement and the grouping of rounds while in storage, this subsystem must impart the necessary motions to the rounds in order to line them up into a single stream. Insofar as the rounds in storage are divided into groups and they move at a velocity which is slower than the

velocity of entry into the gun, the retrieval subsystem must accelerate the rounds, change their spacing (pitch), and perform merging of two or more streams into one stream. Simultaneously, the subsystem must separate a single stream of spent cartridges emerging from the gun into two or more streams prior to their storage and must also change their velocity and pitch to that of the storage mechanism.

2.2 System Description

The system concept which was found to be both simple and most effective in utilizing the available space is one in which all rounds are oriented parallel to the axis of the gun and stored in two layers, one behind the other. The longitudinal dimension of the available space will accommodate two separated layers since this dimension is larger than twice the length of a round, but there is insufficient room to place three layers behind one another.

During retrieval rounds must be moved both laterally and longitudinally until they form a single stream prior to entry into the gun. However, the direction of the longitudinal axis of a round is never changed. The mechanical implementation of the action by which the rounds are rearranged from two layers to a single stream is relatively simple. It is accomplished by mechanisms which occupy only a small part of the total available space. Even this space contributes to the storage of a certain number of rounds but only in a single layer instead of in two layers.

The complete feed system, in its version adapted to the F-16 aircraft, consists of: (1) a loading mechanism, (2) a storage conveyor, (3) an accelerating and transfer mechanism, (4) a merging conveyor, and (5) a gun feed mechanism. A general layout of the complete feed system viewed in a vertical transverse cross section through the aircraft (without supporting structures or driving mechanisms) is shown in Figure 1. The individual subsystems, their relative positions, and drive train members are identified in Figure 2. In both figures the longitudinal axes of all rounds contained in the system are perpendicular to the plane of the figure.

The first three mechanisms listed above occupy more than 80 percent of the total space and contain 93 percent of the rounds. The rounds are placed in two layers behind each other, and they move only in the transverse plane. In the loading mechanism and in the storage conveyor the rounds are closely spaced and move at a uniform velocity of approximately 5 feet per second when the gun fires at a rate of 6000 rounds per minute. They are conveyed at 3000 pitches per minute and fed two at a time, one from each layer (longitudinally in line with each other).

The spacing and relative positions of the rounds and spent cartridges through the feed system are illustrated in Figure 3. In the accelerating and transfer mechanism, the rounds remain in their respective layers but move at a variable velocity. One function of the mechanism is to accelerate the rounds and thereby expand their pitch, as well as to change the relative alignment of the rounds in the two layers. Rounds enter the mechanism in longitudinally aligned pairs, i.e., the round in the aft layer is precisely behind the round in

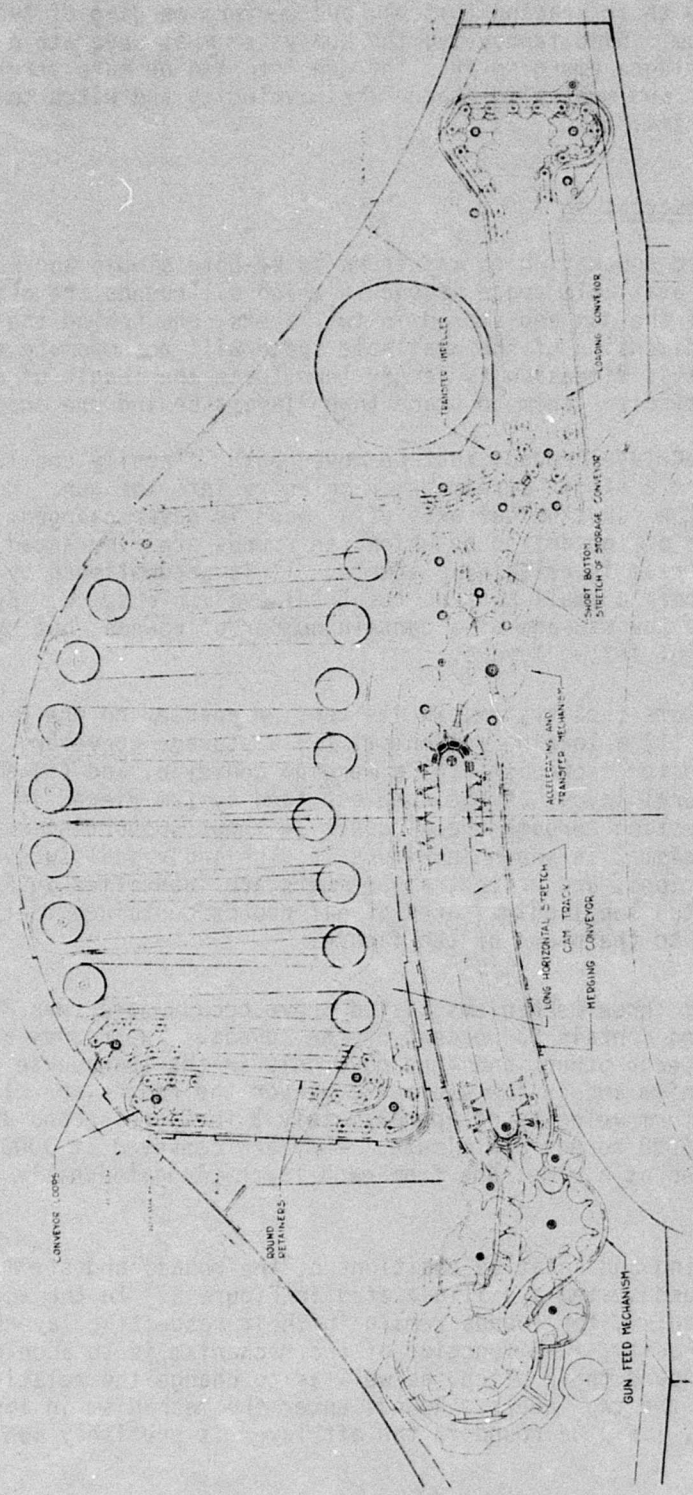


Figure 1. General Layout of Complete F-16 Feed System

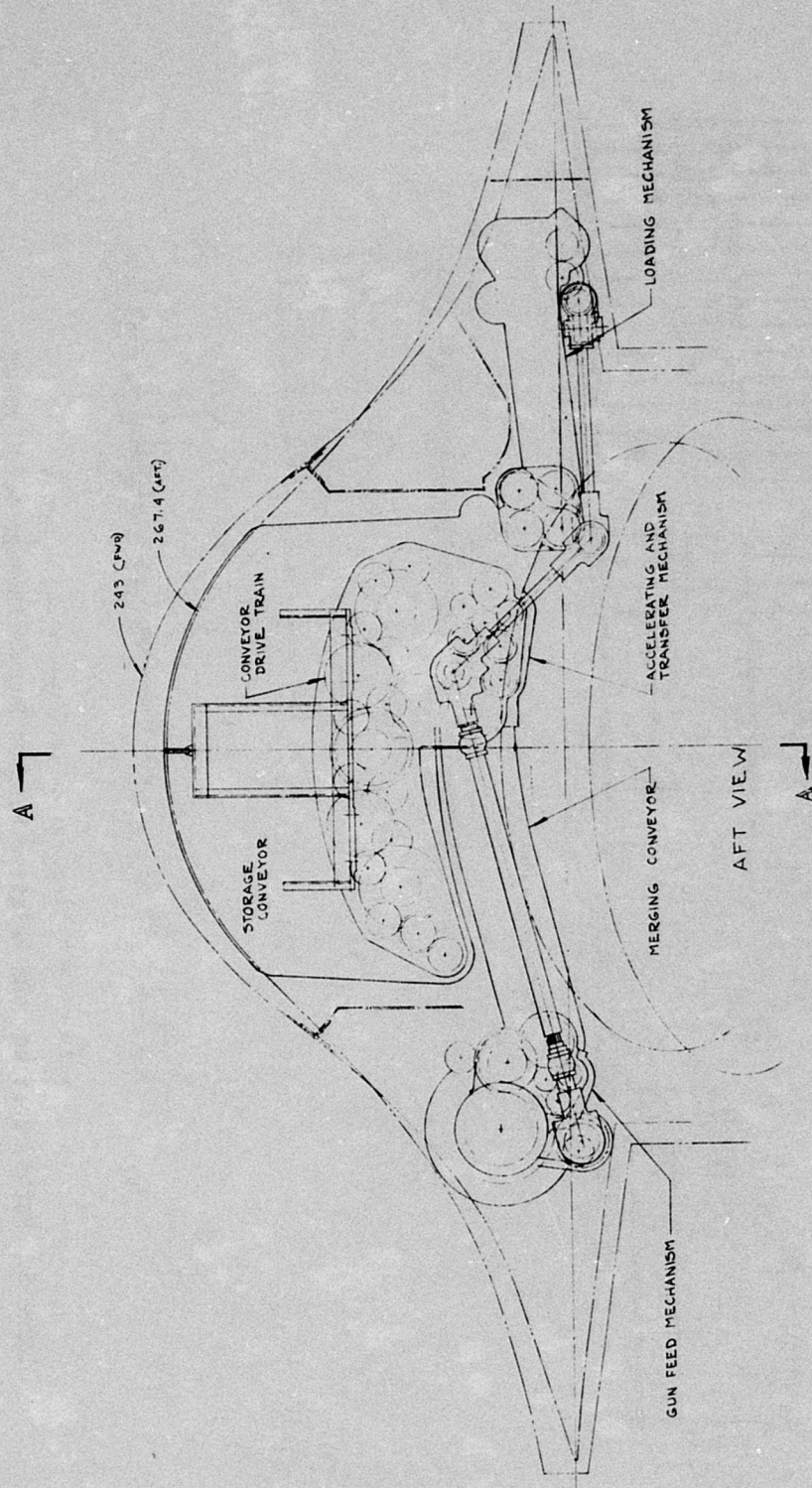
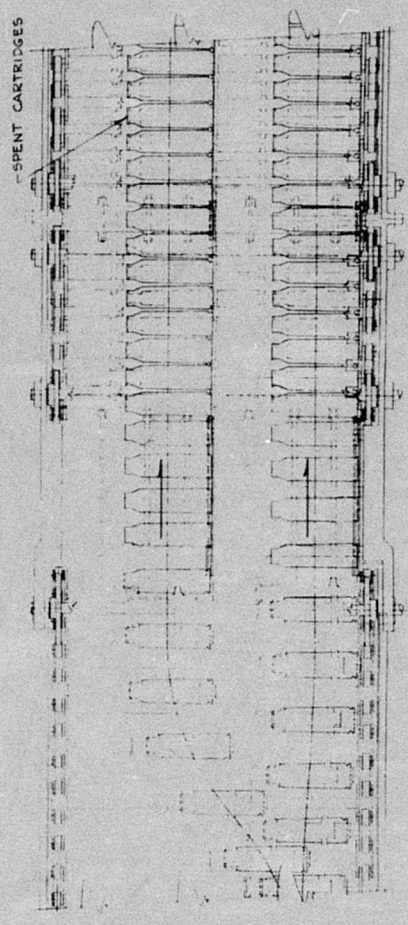


Figure 2. Identification of Major Subsystems and Components



(a) ROUND ACCELERATION, MISALIGNMENT, MERGING AND FEEDING



(b) SPENT CARTRIDGE SEPARATION, DECELERATION AND ALIGNMENT

Figure 3. Paths, Spacing, and Relative Pass of Rounds through Feed System

the forward layer. When they leave, the pitch between consecutive rounds in the same layer is approximately doubled, and their position is offset by half a pitch with respect to rounds in the other layer. Thus, there is an empty space in the aft layer directly behind a round in the forward layer and vice versa. This is illustrated in Figure 3(a). Another function of the mechanism is to rearrange spent cartridges or unfired rounds in precisely the reverse way: starting from double pitch and offset relationship to bring them closer together and into alignment. This action is shown in Figure 3(b).

The merging conveyor is the only part of the system in which rounds move both longitudinally and transversely. They do this in a horizontal plane [see Figure 3(a)]. In so moving, rounds coming from both layers are merged into a single stream, in which alternate rounds have originated from the same layer. The upper part of the conveyor handles rounds in the manner described, whereas the lower part handles spent cartridges [see Figure 3(b)] in precisely the reverse way; i.e., it separates a single stream of cartridges coming from the gun by moving alternate cartridges into one layer, and the ones in between into the other layer.

The gun feed mechanism serves to transfer rounds from the merging conveyor to the gun and spent cartridges (or unfired rounds) the other way. Here the rounds and cartridges move within a single transverse plane. This plane is approximately in line with the aft layer of the storage conveyor.

When the system is filled, it contains 78 rounds in the loading mechanism (39 in each layer), 604 in the storage conveyor (302 per layer), 16 in the acceleration and transfer mechanism (8 per layer), 36 in the merging conveyor, and 16 in the gun feed mechanism and within the gun itself. The total is 750 rounds. Those rounds which are initially in the outgoing side of the gun feed mechanism and those in the underside of the merging conveyor (the side which normally handles spent cartridges) will make the full circuit through all the other mechanisms. These rounds will then come back to the gun and be the last ones fired.

The system is designed to run in one direction only, without either the feed system or the gun being reversed. However, in order to fill the system to capacity, it is necessary to allow some rounds to pass unfired through the gun during loading. This is made possible by a feature of the gun which allows passage of rounds through the gun without being rammed into the barrel.

The individual subsystems are discussed in detail in the following subsections.

2.2.1 Loading Mechanism

The loading mechanism is shown in Figure 4. It consists of a loading receptacle with a hinged door, a short chain conveyor, and a pair of transfer impellers which serve to transfer rounds and cartridges to and from the main storage conveyor.

The loading mechanism is designed to operate in either of two modes: (a) loading or (b) firing. In the loading mode the hinged door is opened,

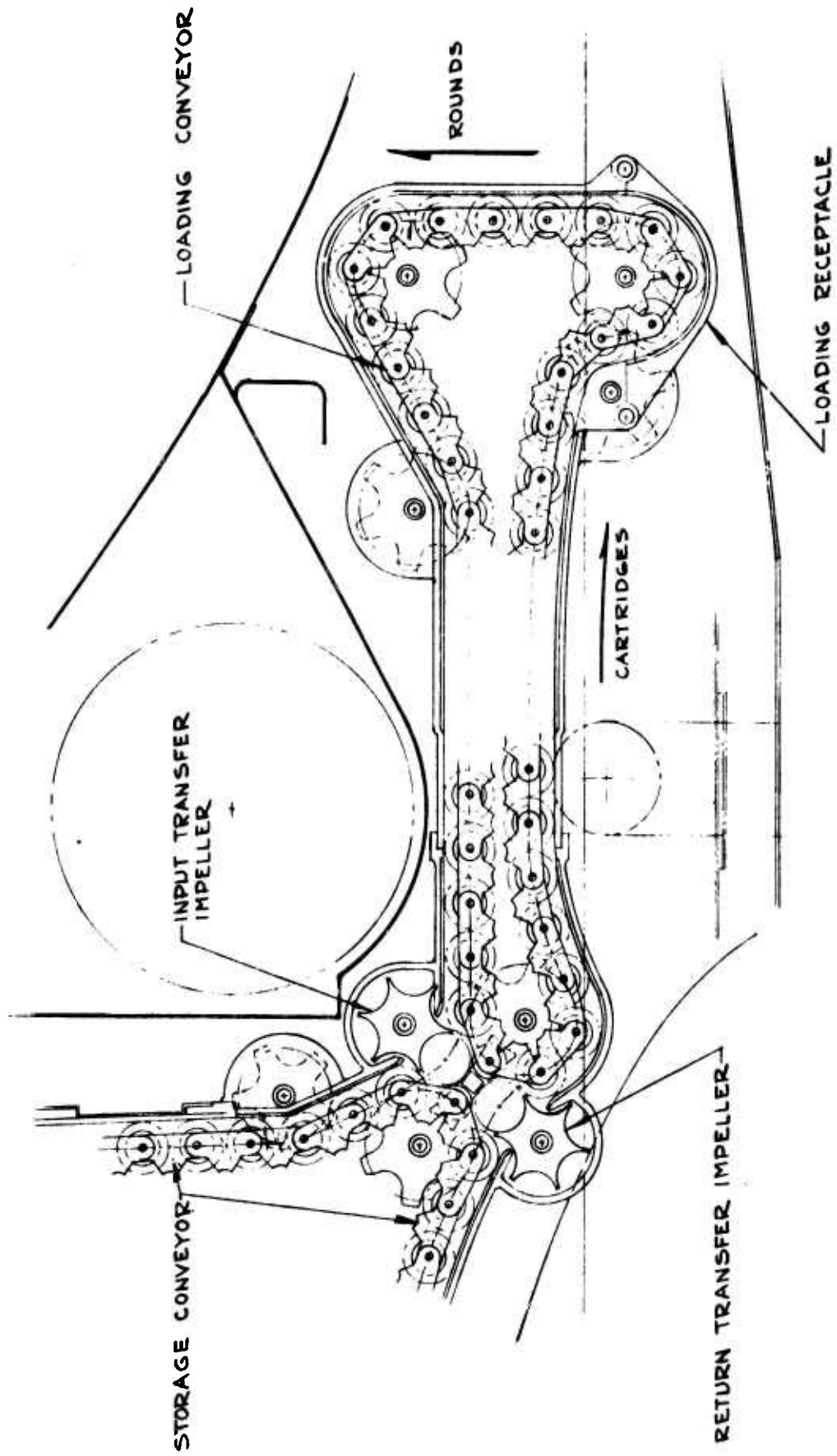


Figure 4. Loading Mechanism

and an external supply device is temporarily attached at the loading receptacle. The attachment establishes a path for the externally supplied rounds to enter the feed system. At the same time a mechanical power connection is established at the receptacle. During loading, the external device supplies the power to drive the entire feed system through the loading mechanism.

Loading of rounds into the system and removal of spent cartridges from the system proceed simultaneously. Rounds enter at the receptacle, they are carried from there by the upper part of the loading conveyor, and from there they are transferred by one of the impellers to the storage conveyor. At the same time, spent cartridges are transferred from the storage conveyor to the lower part of the loading conveyor by the other transfer impeller. The conveyor brings the cartridges to the receptacle, where they exit from the feed system to the outside.

During loading, the first pair of rounds which were entered will travel one conveyor pitch behind the pair of cartridges which will be the last ones to exit. The first pair of rounds will traverse the entire feed system: upper loading conveyor, the major length of the storage conveyor, upper acceleration and transfer mechanism, upper side of the merging conveyor, gun feed, through the gun (without ramming), outgoing side of gun feed, lower side of merging conveyor and of the acceleration and transfer mechanism, a short bottom part of the storage conveyor, and the lower part of the loading conveyor. Loading is completed when the first loaded pair of rounds appears at the side of the receptacle where cartridges have been ejected.

Upon completion of loading, the external supply device is disconnected, and the hinged door is closed. The door contains guides which prevent the rounds from leaving the conveyor at the loading station when the door is closed. The loading mechanism is now ready for the firing mode of operation in which this mechanism functions as an extension of the storage conveyor. In this mode, either rounds or cartridges enter the conveyor by means of the return transfer impeller, traverse the entire loading conveyor (without interruption at the loading station), and are transferred to the storage conveyor by the input transfer impeller.

The links of the loading conveyor are identical to the links of the storage conveyor, which will be described in the following subsection. The reason for using a separate loading conveyor is to facilitate the installation of the feed system into the aircraft. From a functional standpoint, the storage conveyor could have been extended through the loading mechanism.

2.2.2 Storage Conveyor

The storage conveyor serves to provide the storage space for more than 80 percent of all rounds which are loaded into the feed system. It is a continuous chain conveyor, arranged in ten vertical loops which fill all but the bottom 6 inches of the ammunition storage compartment space available in the F-16 aircraft (see Figures 1 and 2).

The pitch of the chain is 1-1/4 inches and the total conveyor length is 380 inches. The width of the conveyor accommodates two round lengths, so that

two rounds of ammunition can be stored in each pitch of the conveyor. The two rounds or two spent cartridges are stored in line with each other. The plan view of a portion of the storage conveyor loaded with rounds can be seen on the right side of Figure 3(a).

The conveyor consists of two 1-1/4 inch pitch roller chains, spaced approximately 14 inches apart. The two chains are connected by a set of round carriers which span the distance between them. Each round carrier is attached to a link of each chain, as illustrated in Figure 5. The conveyor forms a flexible ladder, in which the round carriers represent the rungs. Two rounds can be stored in the space between any two adjacent carriers.

The design of the storage conveyor is aimed at maximizing the packing density of rounds in storage. To achieve high density, the pitch between consecutive rounds, as well as the spacing between conveyor loops, should be made as small as possible. Since the maximum diameter at the base of the rounds is 1.165 inches, the chosen pitch of 1.25 inches gives a minimum gap of .085 inch between consecutive rounds near the base. This gap is just sufficient to accommodate the thickness of the part of the carrier which separates consecutive rounds. The carriers are profiled to the shape of the rounds, being thicker at the forward part where the diameter of the round is smaller. The shape of the carriers prevents the rounds from moving forward while being conveyed sideways.

A mockup of the round carrier for a single round is shown in Figure 6. The empty round carrier assembly and the assembly with a round in place in the straight and folded configurations are shown in views (A), (B), and (C), respectively.

During firing, rounds or spent cartridges coming from the loading conveyor are transferred by a transfer impeller to the storage conveyor at the bottom right side (see Figure 1). From there they are conveyed up and down the conveyor loops, progressing from right to left. Upon completing the last downward pass on the extreme left side of the storage compartment, they traverse the long horizontal stretch of the conveyor from left to right, and then they turn around a sprocket and enter the accelerating and transfer mechanism. At the same time, empty cartridges move from left to right through the bottom half of the accelerating and transfer mechanism, then traverse the short stretch of the storage conveyor on the bottom right side, and from there they enter the loading conveyor. Upon traversing the latter, the cartridges will re-enter the storage conveyor loops and will be stored there until the system is reloaded.

As shown in Figure 5, the round carriers are located in the storage conveyor toward one side, which is the closed side of the conveyor. Rounds enter the conveyor and exit from it on the other side, i.e., the open side of the conveyor. The carriers are continuous on the closed side but are interrupted by several slots on the open side. These slots serve to clear a set of stationary cam blades which reach through the slots to guide the rounds out of the conveyor at points of exit.

As seen in Figure 1, the conveyor loops around ten sprockets on top of the storage compartment, with the open side outward and the closed side

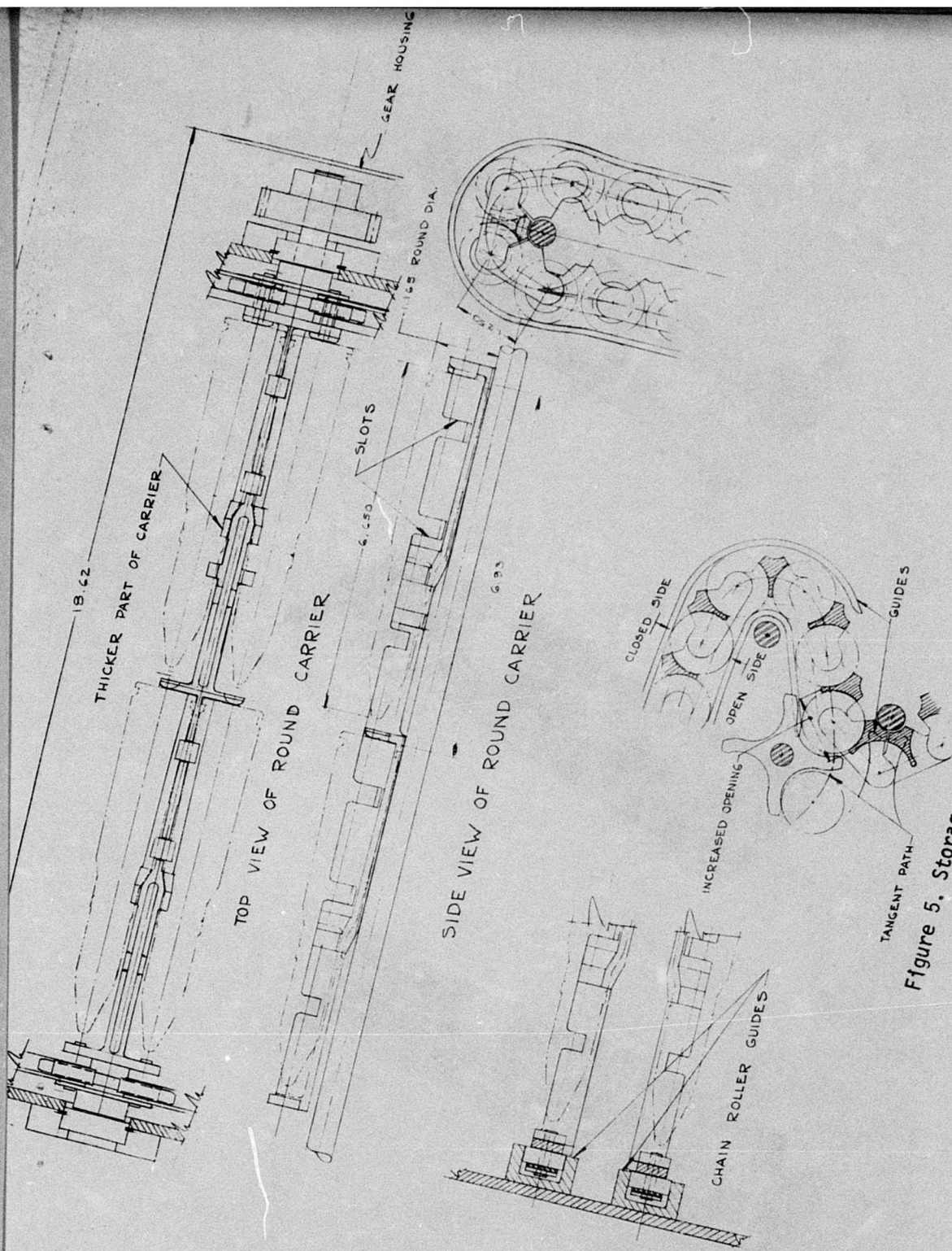


Figure 5. Storage Conveyor Round Carriers

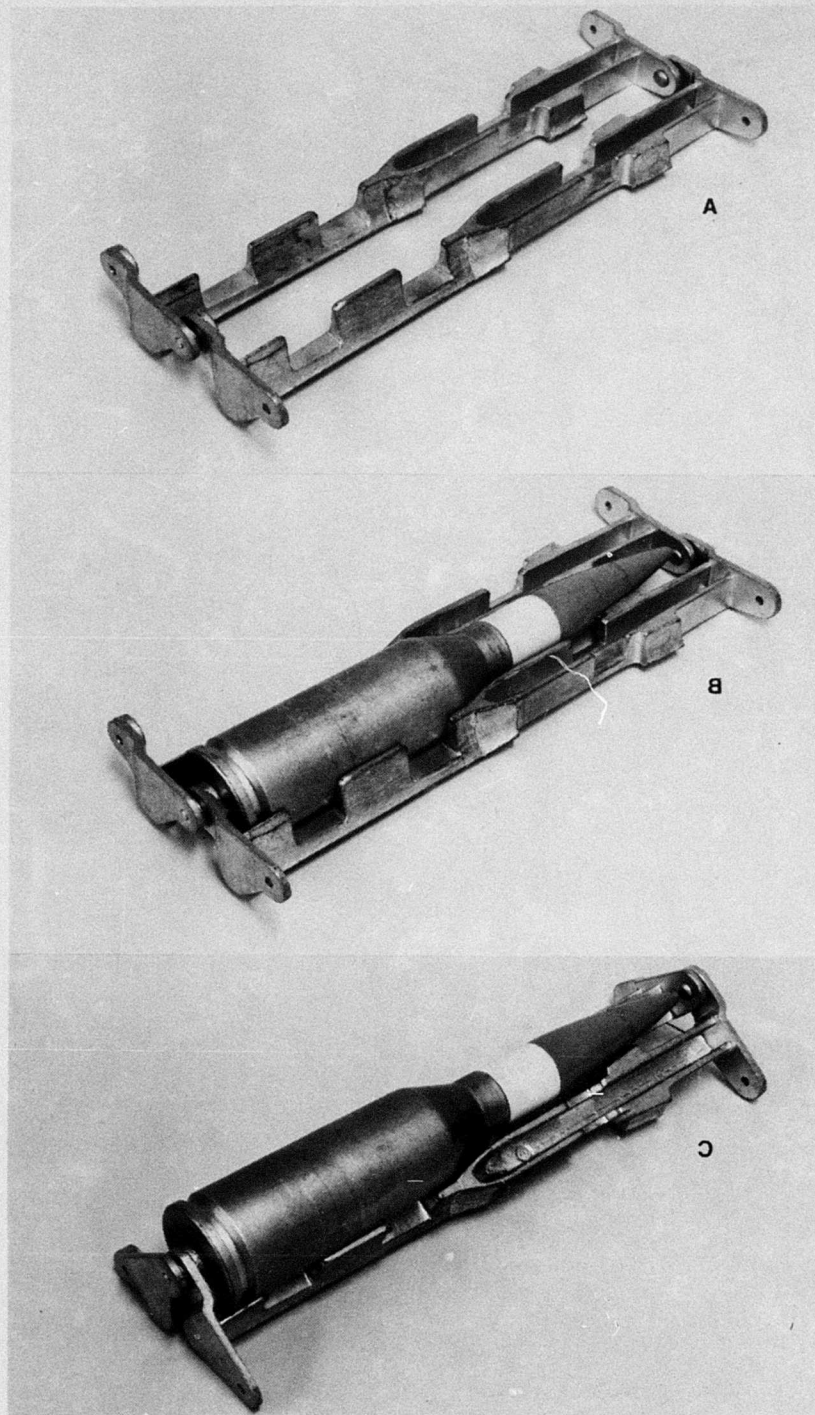


Figure 6. Round Carrier Mockup (A) Empty, (B) with Round in Straight Configuration, and (C) with Round in Folded Configuration

toward the shafts. It loops in the same way at the sprocket adjacent to the accelerating and transfer mechanism and at the sprocket adjacent to the loading conveyor. As the conveyor turns around the sprockets at the bottom of the vertical loops, its closed side is outward and the open side is toward the shaft. To ensure positive retention of rounds within the storage conveyor, stationary retention guides are provided at all turn-around sprockets except the two sprockets where rounds are required to enter or leave the conveyor. Guides are also provided on the open side of all straight portions of the conveyor.

The transfer of rounds to and from a conveyor at a turn-around sprocket is a feature which promotes reliability and freedom of motion of the rounds. One reason is that the curvature of the conveyor path causes the openings between round carriers to increase (Figure 5). The other reason is that the condition where the rounds leaving the conveyor follow a tangent path, whereas the empty conveyor follows a curved path, is dynamically far more favorable than if the rounds had to be deflected out of a straight part of the conveyor. The same type of transfer is also employed with the loading conveyor which is, in all respects, identical to the storage conveyor except for having a much shorter length.

The storage and loading conveyors are designed so that one round carrier member separates two consecutive rounds (Figure 5). One round is retained between two consecutive carriers attached to two consecutive chain links whose pivotal axis (roller centerline) coincides with the longitudinal axis of the round. In this arrangement, the center distance between consecutive rounds remains constant as the conveyor path changes from straight to curved in either direction. In any other arrangement, the distance would diminish on curves, and the pitch would have to be larger in order to ensure adequate clearance between rounds on curves. The pitch achieved in this design is practically the smallest pitch among those achievable in any design where rounds are stored and conveyed in separated pockets.

The size of the turn-around sprockets of the conveyor governs the packing density of rounds in the storage compartment. Five-tooth sprockets are used throughout the conveyor path. Figure 5 shows how this size provides just enough room between the rounds and the sprocket shaft to accommodate the structural part of the round carriers. Although a five-tooth sprocket will induce a nonuniform motion of the chain to some extent, this effect is minimized by guiding the rollers of the chain on their approach to the sprocket. Guides for the rollers are provided throughout the path of the conveyor, so that the chains are restrained from whipping sideways even when the conveyor runs empty.

In order to ensure smooth running of the conveyor through its multiplicity of loops, approximately one-half of the turn-around sprockets are positively driven by the drive train (Figure 2). Proper timing of the drive train will ensure that slack in the conveyor is uniformly distributed among various loops and not accumulated at one point. Driving through many points also reduces the tension in the conveyor and minimizes the power loss.

2.2.3 Accelerating and Transfer Mechanism

As indicated earlier, the velocity of rounds coming from the storage conveyor must be approximately doubled before the rounds from the two layers can be merged into a single stream. As the velocity is increased, the pitch between two consecutive rounds from the same layer is also increased until the space between them is sufficient to accommodate a round coming from the other layer. The mechanism described here serves to accelerate the rounds to double velocity and double pitch.

Since the rounds in the storage conveyor are transported two abreast instead of staggered, it is also necessary to advance the rounds of one layer by one-half pitch with respect to the rounds of the other layer. When this is done, the rounds coming out of the accelerating mechanism are staggered as well as spaced. Figure 3(a) shows this relationship, where on the left end (output end) of the mechanism there is a free space behind each round of the forward layer and a free space in front of every round of the aft layer.

The capability of the accelerating and transfer mechanism to shift the phase of the rounds in one layer relative to those in the other layer leads to great simplifications in the design of the long storage conveyor. If rounds already had to be staggered in the conveyor, the complexity and the weight of the conveyor would be substantially increased.

The accelerating and transfer mechanism consists of two essentially identical parts. In the upper part, rounds coming from the storage conveyor are accelerated, expanded in pitch, and transferred to the merging conveyor on the left. Figure 3(a) refers to this upper part. In the lower part, Figure 3(b), empty cartridges coming from the merging conveyor (which had separated them into two layers) are decelerated, moved closer together, aligned, and transferred to the storage conveyor on the right.

As shown in Figure 1, the path of the rounds passing from right to left through the upper part of the mechanism and the similar path of spent cartridges passing from left to right through the lower part of the mechanism are wavy lines composed of arcs of circles connected by straight-line segments. The motion of rounds or cartridges in each path is controlled by three impeller stages. Acceleration occurs when a round is transferred from one impeller stage to the next. The amount of acceleration depends on the number of teeth and on the tooth profile of the impellers.

The first and the last impeller stages use common shafts for both layers of rounds. The stage nearest to the storage conveyor has four-tooth impellers in both layers. The stage nearest to the merging conveyor has three-tooth impellers in both layers. In the middle stage, a hollow tubular shaft is used for the forward layer, with four-tooth impellers attached to it. Passing through the tube is a solid shaft which controls the aft layer, where three-tooth impellers are used in the middle stage. The upper part of the mechanism seen in Figure 1 shows only the impellers pertaining to the aft layer, and the lower part shows the impellers pertaining to the forward layer. If the same layer were shown in both places, the upper and lower parts would be mirror images of each other.

In the forward layer, pitch is expanded more slowly in the beginning (between the first and the middle stage) and more rapidly later. In the aft layer, pitch is expanded more rapidly in the beginning and more slowly later. The overall result is that the same double pitch is produced in both layers, but the rounds of the aft layer are ahead of the rounds in the forward layer by one-half of the double pitch.

All impellers are profiled to produce a smooth acceleration of rounds during transfer from impeller to impeller in the upper part of the mechanism and a smooth deceleration of cartridges or rounds returning from the gun. The position of every round is uniquely defined at each instant during transfer, being positively constrained by the impeller profiles and by the stationary guides. There is no free flight of a round at any time.

When firing at 6000 rounds per minute, all four-tooth impellers (first stage in both layers and middle stage in the forward layer) rotate at 750 rpm. All three-tooth impellers (middle stage in the aft layer and last stage in both layers) rotate at 1000 rpm. The pitch radii, relative center locations, and theoretically correct profiles have been established, using formulas developed on this project.

In this system, the pitch of the rounds in the storage conveyor is 1.25 inches, and the single pitch in the merging conveyor is 1.312 inches. Since consecutive rounds in the same layer of the storage conveyor are transferred to every other space of the merging conveyor, the pitch expansion effected by the accelerating and transfer mechanism is from 1.25 inches to 2 times 1.312 inches, which amounts to a ratio of 2.1 to one.

The velocity of rounds which pass through the accelerating and transfer mechanism varies from stage to stage as follows:

	Velocity, inches/second at full rate	
	<u>Forward Layer</u>	<u>Aft Layer</u>
Storage Conveyor	62.5	62.5
First Impeller Stage	76.2	76.2
Middle Impeller Stage	81.0	108.0
Last Impeller Stage	114.5	114.5
Merging Conveyor	131.2	131.2

The velocity of the spent cartridges varies in the reverse order as the cartridges are being decelerated.

2.2.4 Merging Conveyor

The merging conveyor serves to merge the rounds from the two layers into a single row prior to their entry into the gun and to separate into two layers the spent cartridges or unfired rounds coming from the gun. The

merging action is illustrated on the left side of Figure 3(a), which shows the upper part of the conveyor. Separation of cartridges is shown on the left side of Figure 3(b), which illustrates the lower part (the return part) of the conveyor.

The end view of the merging conveyor is shown in the lower end of Figure 1, between the accelerating and transfer mechanism and the gun feed mechanism (which is adjacent to the gun). The conveyor is of chain-link construction, running between two sets of sprockets. It consists of two roller chains of 1.312 inches pitch, spaced approximately 14 inches apart. Offset from the plane of the rollers is a set of rectangular bars. The ends of each bar are connected to a link of each chain. A round carrier (see Figure 7) is restrained to slide along the bar. One carrier per pitch of the conveyor is provided.

The width of the conveyor is such that when a carrier slides all the way toward the forward chain, the round contained in the carrier is aligned with the forward layer of the storage conveyor. Similarly, when a carrier slides all the way toward the aft chain, the round is aligned with the aft layer of the storage conveyor. For this purpose, the width of the merging conveyor must be the same as the width of the storage conveyor, i.e., equal to twice the length of the round plus the thickness of the chain links and rollers on both sides.

While being conveyed, the rounds travel in the transverse direction at a constant velocity of 131 inches per second when firing at 6000 rounds per minute. At the same time, sliding of the carriers along the bars causes the rounds to move in a longitudinal direction. Rounds of the forward layer which enter the conveyor from the accelerating and transfer mechanism must be moved rearward approximately 6 inches as they are conveyed toward the gun end. Rounds of the aft layer must be moved forward approximately 1 inch so that both groups of rounds are in the same plane when they reach the gun feed mechanism. By undergoing precisely the reverse motion, spent cartridges are alternately separated into two layers on the return side of the conveyor.

The fore and aft motion of the carriers is actuated by two sets of stationary cam tracks (see Figure 7). Cam rollers fastened to the underside of the carriers follow the cam tracks. A carrier dedicated to the forward layer will engage the 6-inch stroke cam track. This carrier will receive a round from the forward layer, move to the left through the length of the conveyor and simultaneously slide rearwards, deliver the round to the gun feed mechanism, turn around the sprocket, receive a spent cartridge from the gun feed mechanism, traverse the underside of the conveyor while sliding forward, deliver the cartridge to the accelerating and transfer mechanism, turn around the other sprocket, and be ready to receive another round. A carrier dedicated to the aft layer will perform a similar motion while its roller is running in the 1-inch stroke cam track.

This arrangement requires that there be an even number of carriers in the conveyor. One-half of them serves the forward layer, and the other half serves the aft layer. The two types are alternately placed along the conveyor. The location of the roller on one type of carrier differs from the location on the other type. As a result, the two cam tracks will nowhere

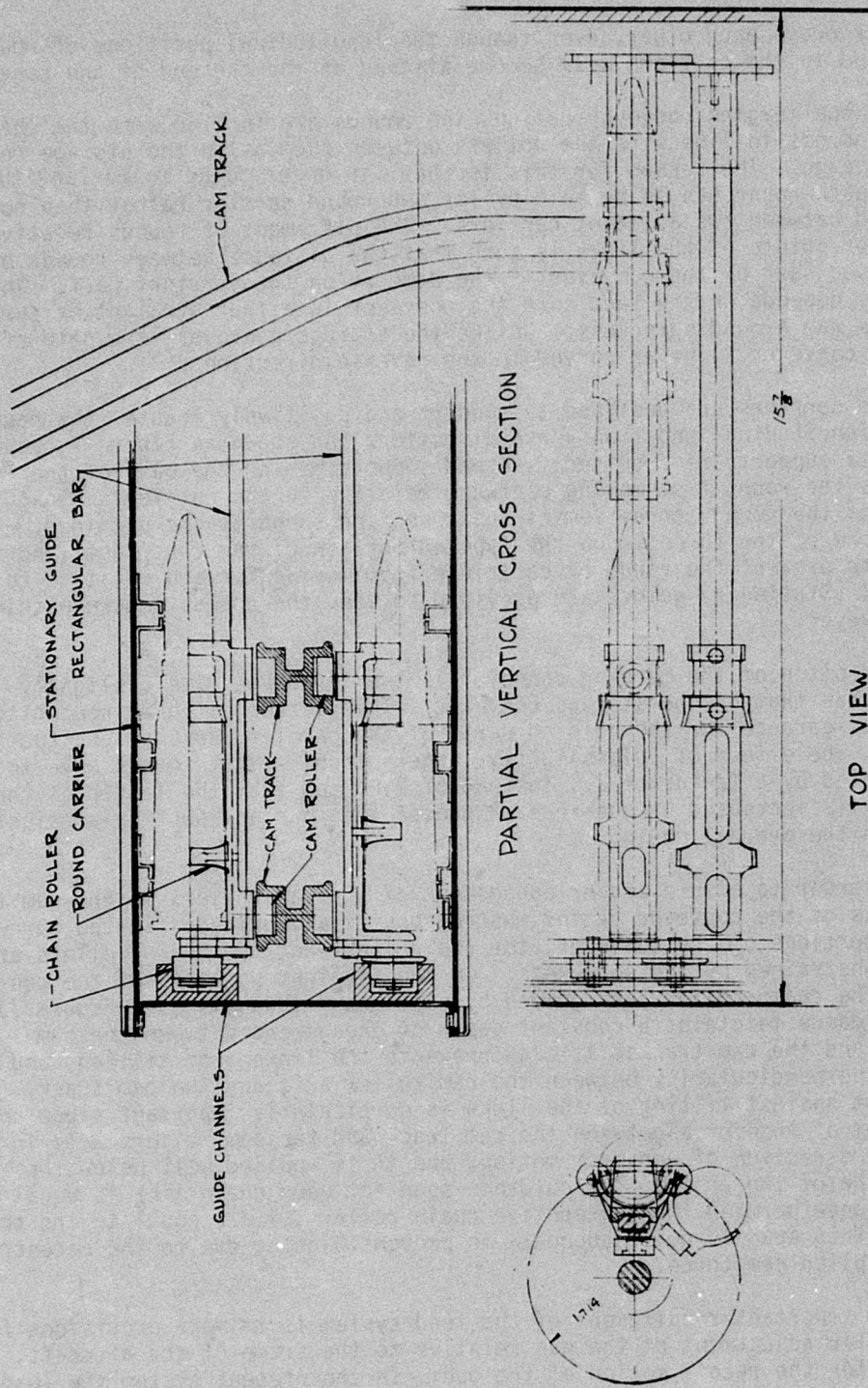


Figure 7. Merging Conveyor Round Carriers

merge or cross each other, even though the longitudinal positions of rounds contained in the carriers will become aligned at the gun end of the conveyor.

In the merging conveyor design, the rounds are in line with the chain links and not in line with the rollers between them as in the storage conveyor design. The reason for this is that, in order to be moved longitudinally, each round has to be held by its own round carrier rather than constrained between two adjacent carriers. The placement of rounds relative to the pivot points of the links is such that the distance between rounds on the curved part of the conveyor is the same as on the straight part. This geometry depends on the fact that the conveyor is either straight or curved only one way around sprockets. Unlike the storage conveyor, the path of the merging conveyor is never curved in the reverse direction.

The carriers are designed to support and positively locate the rounds in the longitudinal and transverse direction. As shown in Figure 7, several points of support are provided. An end support behind the base of the round prevents the round from moving rearward relative to the carrier. Along the length of the round, three semicircular nesting supports are provided. The middle one of the three is on the tapered portion of the cartridge, and it serves to prevent the round or cartridge from moving forward relative to the carrier. Stationary guides are provided to keep the rounds secure within the conveyor.

The pitch of the merging conveyor is $1\frac{5}{16}$ inches, i.e., slightly larger than that of the storage conveyor. This larger pitch is needed to provide clearance for the holding parts of the carriers during longitudinal motion. The effect of this slightly larger pitch is that rounds have to be accelerated by a factor of 2.1 instead of 2.0 and that the length of the conveyor is increased by one inch. None of this has any particular significance in the overall design.

In order to ensure proper engagement of the cam rollers in the cam track, the links of the conveyor chains must be positively guided. In the turn-around portions of the conveyor, the chain links and the chain rollers are fully constrained by the sprockets. On the straight portions of the conveyor, the chain rollers are guided by stationary channels (see Figure 7). This guidance maintains a constant depth of engagement between the cam rollers and the cam tracks; it also prevents the links from tilting, and thus ensures perpendicularity between the cam roller axis and the cam track. The restraint against tilting of the links is particularly important since one component of the force between the cam track and the cam rollers acts in line with the direction of conveyor motion, and it is applied well below the centerline of the chain. The guidance span for each chain link is equal to the distance between two consecutive chain rollers, i.e., equal to the chain pitch. This span is quite adequate to prevent binding due to the eccentrically applied cam force.

One important requirement of the feed system is to make provisions for the angular adjustment of the gun relative to the frame of the aircraft, as well as for the recoil motion of the gun. In the present system the loading mechanism, the storage conveyor, and the accelerating and transfer mechanism

all run on bearings that are fixed with respect to the frame. The gun feed mechanism will be fixed to the gun. The merging conveyor must then provide the flexibility to accommodate the displacements of the gun relative to the frame.

In the present design, the longitudinal position of the rounds is controlled by the cam tracks, while the chains of the conveyor remain in fixed planes. To ensure that the rounds enter the gun in the correct location as the gun undergoes recoil, it is only necessary to have the cam tracks, and not the entire conveyor, follow the recoiling motion of the gun. For this purpose, the structural member which contains the cam tracks is pivotally attached at the right end of the merging conveyor and allowed to move fore and aft relative to the chains and sprockets at the gun end of the conveyor.

The shaft with the two sprockets at the gun end of the conveyor is so mounted as to remain in a fixed lateral, vertical, and angular relationship with the gun during the aiming adjustment of the gun but not to follow the gun in its fore and aft motion during recoil. Only the cam tracks will follow that motion. In this fashion, the magnitude of the eccentrically placed reciling mass is minimized.

To accommodate aiming adjustments, a certain amount of flexibility is incorporated into the merging conveyor. By elongating the pivot holes in the chain links, the chains are made capable of stretching or contracting to a sufficient extent. Since the rollers are guided in channels, the chains will properly run even when slack. The structural support members for the stationary guides which keep the round within the conveyor will be attached in a manner which gives the entire assembly a certain degree of flexibility. In particular, the assembly will be free to twist and thus allow for some amount of nonparallelism between the sprocket shafts at the two ends of the merging conveyor.

To ensure sufficient flexibility as well as functional reliability, the length of the merging conveyor is made somewhat larger than the minimum necessary for the cam action to accomplish merging. The center distance between the shafts is slightly under 20 inches. This length will accommodate a cam of a 6-inch stroke with an action angle of 30° or less, designed to accelerate the rounds longitudinally at less than 3 g. Such a cam design is quite conservative. However, a steeper cam is considered inadvisable because of the additional motion of the rounds due to the recoil of the gun. If the length is shortened by one pitch (1.3 inches), there would be two less rounds in the merging conveyor and four more in the storage conveyor, for a net gain of two rounds. The possible gain in storage capacity is minor, compared with possible functional disadvantages if the conveyor is shortened.

To avoid an accumulation of slack on one side of the conveyor and to ensure positive synchronism of round transfer at both ends of the conveyor, the sprocket shafts at both ends of the conveyor are externally driven. Thus, the conveyor chains will transmit no power other than the power to drive the rounds which are within the conveyor.

2.2.5 Gun Feed Mechanism

The purpose of this mechanism is to transfer the aligned single stream of rounds from the merging conveyor to the gun and to transfer the empty cartridges from the gun to the return side of the merging conveyor. The mechanism is designed to accommodate the geometry of the installation, in particular the location of the gun and the orientation of its ammunition entry and exit passages relative to the ammunition storage compartment in the aircraft.

The gun feed mechanism adapted to the available passage geometry and the gun location in the F-16 aircraft is illustrated in Figures 1 and 2. It consists of five transfer impellers: two of them next to the merging conveyor, two next to the gun, and one intermediate impeller, located in between the others.

Referring to the lower left side of Figure 1, rounds are propelled from the merging conveyor to the gun by the upper impeller near the conveyor, by the intermediate impeller, and finally by the gun input impeller. Spent cartridges follow a somewhat longer path below the path of the rounds. They are taken out of the gun by the gun exit impeller, they follow an arc around the intermediate impeller, and from there they are transferred to the merging conveyor by the lower impeller near the conveyor.

The design of the gun input and exit impellers, in terms of impeller profiles and center locations, exactly follows the design that has been used before. The present design employs the three additional impellers because of space limitations which prevent terminating the merging conveyor close to the gun. The limitations are related to the fact that the merging conveyor has a large width in order to provide access to two layers of rounds in storage.

There are obstructions in the aircraft which prevent bringing a wide conveyor any closer to the gun than the left side wall of the storage compartment. It is considerably simpler to use the three additional impellers in the gun feed mechanism than to construct a tapered merging conveyor, wide at the storage end and narrow at the gun end. The use of the conveyor whose width is constant is the preferred approach.

In the present gun feed mechanism, the intermediate impeller has nine teeth, and the other four impellers have five teeth.

Up to this point, the flow of rounds/spent cartridges through the feed system and the mechanisms by which this flow is generated and controlled are described. In the following sections the feed system installation in the F-16 air combat fighter, the drive train for providing power to the various parts of the system, and weight and power requirements of the system are discussed.

2.3 System Installation

The placement of the feed system relative to the aircraft is shown in Figures 2, 8, and 9. Figure 2 is a transverse elevation, in which the locations of the major subsystems are identified. A side elevation view through the midplane of the aircraft (line A-A in Figure 2) is shown in Figure 8. Figure 9 shows in major outlines the plan view of the system as seen from the top.

As seen in these figures, most of the feed system is located in the storage compartment. Located outside of the compartment is the gun feed mechanism, on the left adjacent to the gun, and the loading mechanism which is on the right side.

To facilitate installation, the gun feed mechanism and the loading mechanism can be separated from the remainder of the system. These two mechanisms must be installed first when installing the feed system in the aircraft.

The gun feed mechanism is attached to the gun. The loading mechanism is installed in place at the opposite side of the aircraft. Because of obstructions and narrow passages found in the aircraft (see Figure 4), it may be necessary to split and then splice the loading conveyor chain in order to install the loading mechanism.

After this, a box which contains the storage conveyor, the accelerating and transfer mechanism, and the merging conveyor is lowered into place from the top of the storage compartment. This box is shown cross-hatched in Figure 8. Mounting flanges projecting from the box are fastened to support shelves which project from the forward and the aft walls of the storage compartment.

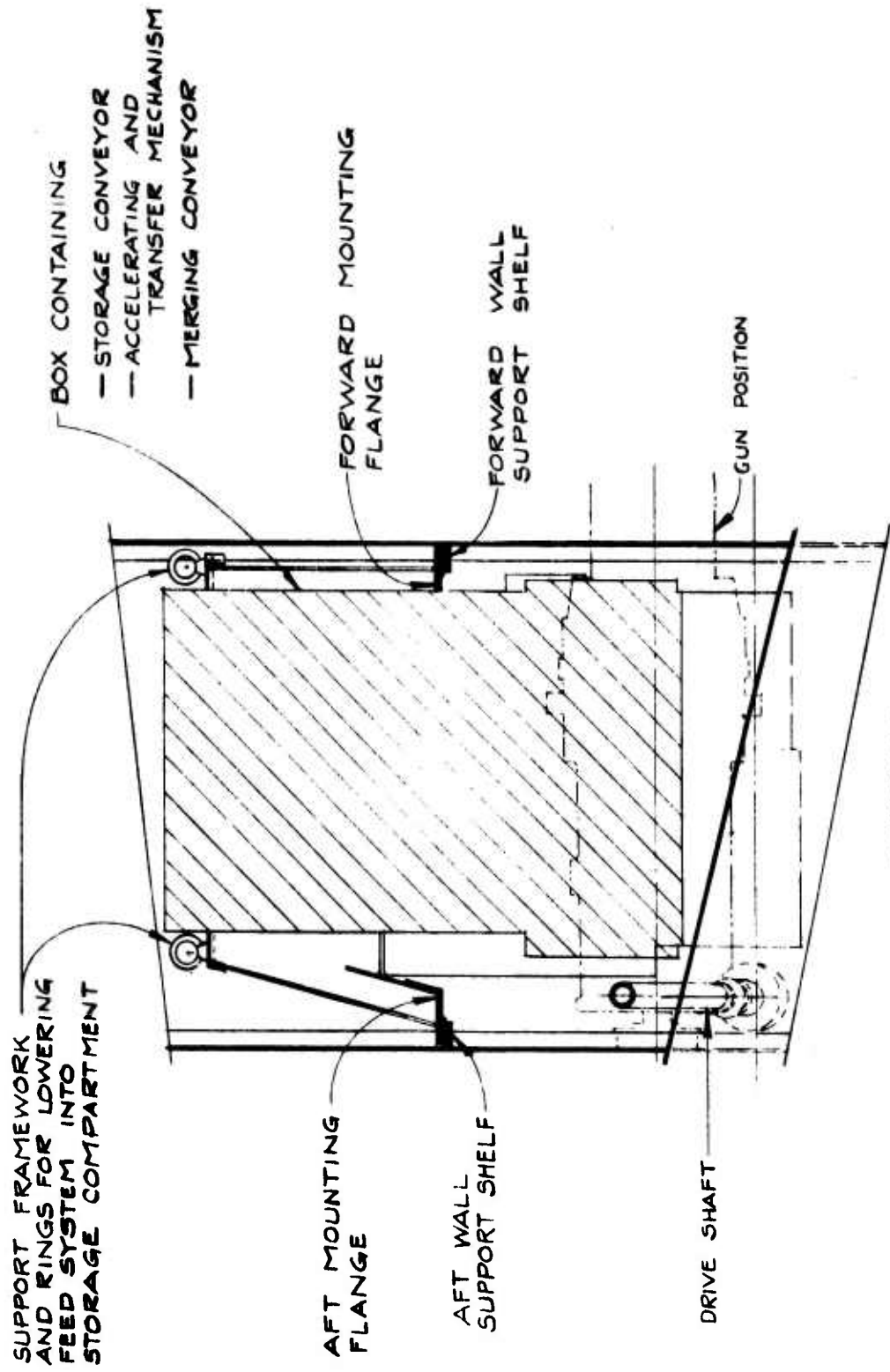
With all parts of the system in place, connections are secured between the gun feed mechanism and the merging conveyor mountings on the left, and between the storage conveyor and the loading mechanism mountings on the right. In addition, parts of the drive train are interconnected.

2.4 Drive Train

The major elements of the feed system drive train are shown in Figure 2. Seen on the left is a set of intermeshing gears which drive the shafts of the impellers of the gun feed mechanism and the left end sprocket shaft of the merging conveyor. This set is driven off of a gear on the gun.

A right-angle drive connects this set to a shaft running transversely towards the center plane of the aircraft. From there, another right-angle drive brings the power to the six impeller shafts of the accelerating and transfer mechanism. Gears which drive these shafts are in mesh with one another and also with the gear which drives the right end sprocket of the merging conveyor. From this area, power is distributed by the conveyor drive train to the shafts which drive the lower end of all loops of the storage conveyor.

FWD →



SECTION A-A

Figure 8. Side Elevation Through Midplane

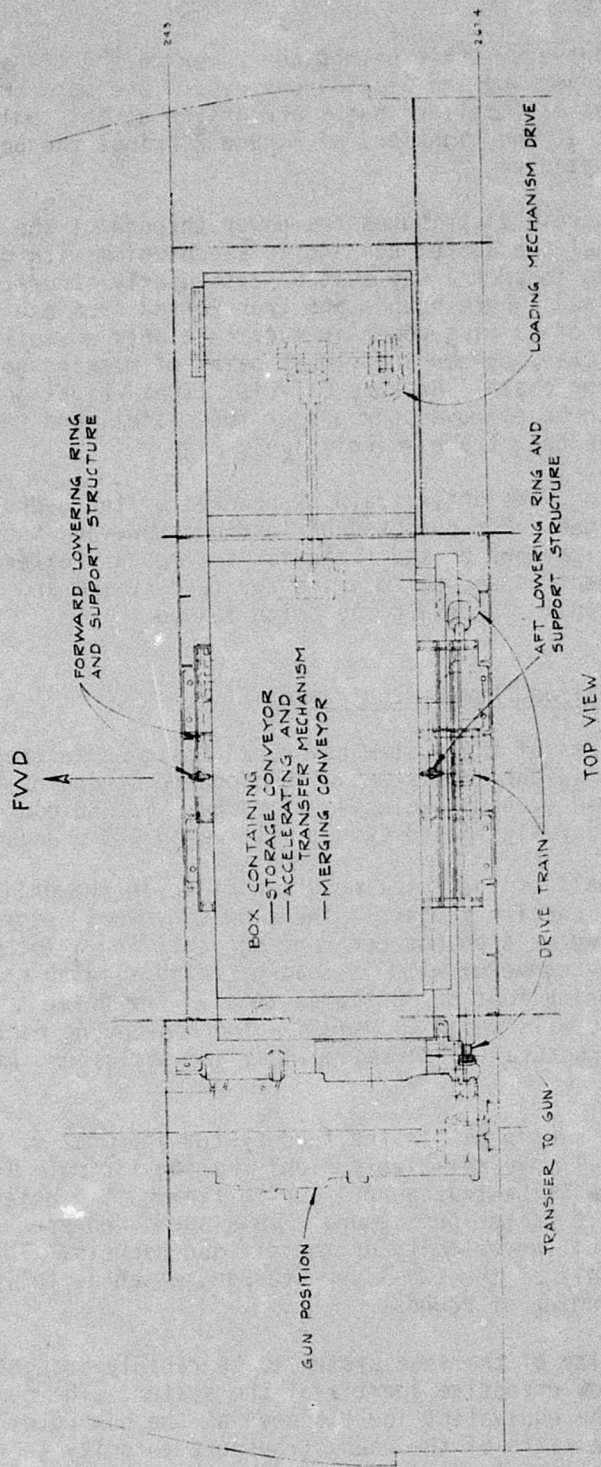


Figure 9. Plan View of Feed System Installation

A short transverse shaft brings the power to the transfer area between the storage conveyor and the loading conveyor. One sprocket of each conveyor and the two transfer impeller shafts are driven at this point. The last transverse shaft at the right end of Figure 2 brings the power to the area of the loading receptacle.

This drive train distributes the power throughout the feed system and keeps all parts of the system running in synchronism with one another. The train is designed in such a way that a particularly accurate synchronism is maintained in places where rounds are transferred from one conveyor to another. The distribution of driving power is such that only a small part of the total power is transmitted between individual pairs of meshing gears or along any part of a conveyor chain. Because of this, light-weight gears and light-weight chains can be employed throughout the system, and the overall power efficiency of the gear train is relatively high.

During firing, the drive train is powered by the hydraulic motor which also drives the gun. For purposes of loading, however, there is a provision at the extreme right end of the train for a temporary external power connection. This connection serves to drive the feed system and the gun from an external source while the system is being loaded.

2.5 System Weight and Power Requirements

When all parts of the system have been designed in their final form, aimed at minimum weight consistent with adequate strength, the estimated total weight of the feed system, exclusive of rounds, is 350 pounds. The 750 rounds stored within the fully loaded system will weigh 420 pounds.

About one-half of the total weight will be in the chain-link conveyors with their round carrier members. The slow conveyors (storage and loading conveyors) will weigh 4 pounds per running foot, for a total of 140 pounds. The short merging conveyor with its cam-operated sliding carriers will weigh 8 pounds per running foot or 30 pounds total. The drive train, including rotary impellers, will weigh 40 pounds. The non-moving part of the system, consisting of structural supports, guides, and enclosure, will weigh 140 pounds.

Most of the rounds within the feed system and most of the moving parts of the system will move relatively slowly during firing. The typical speed at which rounds will be transported during firing at a rate of 6000 rounds per minute is 62.5 inches per second. This speed represents less than one-fourth of the orbiting velocity of the six gun barrels. The low transport speed is the result of the two-layer storage, which is followed by pitch expansion and merging of rounds.

The capability of the feed system to be rapidly brought up to speed is related to the low effective inertia of the system. The contribution of the feed system to the equivalent inertia seen at the gun rotor is proportional to the square of the ratio of the round transport velocity to the rotor velocity. The inertial effect of loading 750 rounds into this feed system is equivalent to the effect which would be produced if 5 pounds were added to the weight of

each gun barrel. Thus, the rounds in the feed system will increase the inertia of the overall gun system by 15 to 20 percent.

The gun and the feed system will both be powered by a hydraulic power supply rated at 26 gpm at 2600 psi. The theoretical torque produced at a rotor which will run at 1000 rpm when the hydraulic actuator draws 26 gpm is 2482 in-lb at 2600 psi. The actual torque may be on the order of 2000 in-lb. The power corresponding to 2000 in-lb at 1000 rpm is 31.75 hp.

Calculations have shown that in order to reach 6000 rounds/minute in 0.4 second this fully loaded feed system will require between 14 and 15 hp at the instant prior to reaching the full rate. To maintain the rate under steady state conditions, between 10 and 11 hp will be required.

These calculations are based on an estimated drive train efficiency of 75 percent. The necessary output torque of the drive train, in a shaft whose rpm is the same as the gun rpm, is 250 in-lb at low speeds and 500 in-lb at rated speed under steady-state conditions. The average additional torque to accelerate the feed system to full rate in 0.4 second is 220 in-lb. The results of calculations are summarized in the Tables 1, 2, and 3.

TABLE 1. INERTIA OF MOVING MASS REFLECTED TO SHAFT WHICH ROTATES AT 1000 RPM (FIRING RATE OF 6000 SPM)

	Number of Rounds	Weight (lb)	Speed (in/sec)	Reflected Inertia (lb-in ²)
Slow Moving Rounds	690	386.4	62.5	138*
Fast Moving Rounds	60	33.6	158 (ave)	77
All Rounds	750	420	74.8 (ave)	215
Slow Conveyors		140	62.5	50
Merging Conveyor		30	131	47
Sprockets, Impellers, Gears		40	60 (ave)	13
All Moving Parts		210	75.7 (ave)	110
Total		630 lb		325 lb-in ²

To accelerate this inertia from zero to 104.72 rad/sec (1000 rpm) in 0.4 seconds:

$$\text{Angular acceleration} = 104.72/0.4 = 261.8 \text{ rad/sec}^2$$

$$\text{Average acceleration torque, } \frac{325 \text{ lb-in}^2}{386 \text{ in/sec}^2} \times 261.8 \text{ sec}^{-2} = 220.4 \text{ in-lb}$$

It is assumed that the acceleration torque varies, starting from 250 in-lb at rest and ending with 190 in-lb as the maximum velocity is reached. The acceleration is higher at the start and lower near the end because the resistance torque is lower at the start and higher at the end, whereas the full driving torque of the hydraulic motor is approximately constant.

*Note:

$$\text{Inertia Reflected to Shaft} = \text{Weight of Conveyor} \times \left(\frac{v}{N} \cdot \frac{60}{2\pi} \right)^2$$

$$\text{Example: } 386.4 \text{ lb} \times \left(\frac{62.5 \text{ in/sec}}{1000 \text{ rpm}} \times \frac{60}{2\pi} \right)^2 = 137.6 \text{ lb-in}^2$$

TABLE 2. TORQUE AT 1000 PRM SHAFT TO OVERCOME LOSSES IN FEED SYSTEM

	Static		Dynamic		Total Torque (in-lb)
	Force, (lb)	Torque (in-lb)	Force (lb)	Torque (in-lb)	
Slow Conveyors (62.5 in/sec)	335	200*	135	81	281
Fast Conveyors and Transfers	40	50	70	88	138
Gun Feed Mechanism		<u>0</u>		<u>81</u>	<u>81</u>
Total		250		250	500

*Note:

If a shaft rotates at N rpm, and a conveyor moves at v in/sec,

$$\text{Torque on Shaft} = \text{Force on Conveyor} \times \left(\frac{v}{N} \cdot \frac{60}{2\pi} \right)$$

$$\text{Example: } 335 \text{ lb} \times \left(\frac{62.5 \text{ in/sec}}{1000 \text{ rpm}} \cdot \frac{60}{2\pi} \right) = 200 \text{ in-lb}$$

TABLE 3. ACCELERATION AND RUNNING TORQUE AND POWER

1. Starting Torque (at zero speed)

Input to Gear Train	667 in-lb
25 Percent Gear Train Loss	<u>- 167 in-lb</u>
Gear Train Output	500 in-lb
Static Friction in Feed System	<u>- 250 in-lb</u>
Initial Acceleration Torque	250 in-lb

2. Terminal Torque and Power (at 1000 rpm)

Input to Gear Train	920 in-lb	14.6 hp
25 Percent Gear Train Loss	<u>- 230 in-lb</u>	<u>-3.65 hp</u>
Gear Train Output	690 in-lb	10.95 hp
Static Friction	<u>- 250 in-lb</u>	-7.93 hp
Dynamic Losses	<u>- 250 in-lb</u>	
Final Acceleration Torque	190 in-lb	3.02 hp

Average Acceleration Torque: $1/2 \cdot (250 + 190) = 220 \text{ in-lb}$

Average Acceleration Rate of 325 lb-in^2 Inertia:

$$220 \text{ in-lb} \times \frac{386 \text{ in/sec}^2}{325 \text{ lb-in}^2} = 261.3 \text{ sec}^{-2}$$

Time to reach 104.72 rad/sec (1000 rpm, 6000 rounds /min):

$$104.72 \text{ sec}^{-1} / 261.3 \text{ sec}^{-2} = 0.40 \text{ sec}$$

3. Steady State Torque and Power (at 1000 rpm)

Input to Gear Train	667 in-lb	10.59 hp
25 Percent Gear Train Loss	<u>- 167 in-lb</u>	<u>-2.65 hp</u>
Gear Train Output	500 in-lb	7.94 hp
Static and Dynamic Loss	<u>- 500 in-lb</u>	<u>-7.94 hp</u>
Acceleration	0	0

SECTION III

F-15 FEED SYSTEM

3.1 Design Objectives/Approaches

The initial work under the contract was devoted to the design of a linear linkless feed system for the F-15 aircraft. The basic approach in this design was very similar to the approach employed in the F-16 system, described in Section II. In fact, the latter F-16 design evolved from the earlier work accomplished on the F-15 system.

This feed system is required to fit into the F-15 aircraft to feed 25mm aluminum-cased rounds to a modified GAU-8/A type multi-barrel automatic gun firing 6000 shots per minute. The system must store a large number of linkless rounds, feed them to the gun, and remove and store the spent cartridges. The primary objectives of the design are: large storage capacity, high reliability of operation, low total weight, and low power consumption.

As in the F-16 system described in Section II, the basic functions are: (1) loading of rounds into the system; (2) storage of rounds; (3) feeding of rounds to the gun; and (4) removal and retention of cartridges. The size and shape of the specified envelope within which the system must be emplaced differs considerably from the envelope of the F-16 system. Many features of the system, including its basic configuration, are governed by the geometry of the envelope. In this case, the envelope consists of an approximately rectangular storage area and a relatively long and narrow horizontal tunnel leading from the storage area to the gun.

The geometry permits loading of rounds directly into the storage area from underneath the aircraft. This eliminates the need for a separate subsystem that is entirely devoted to the loading function. The system is therefore divided into only two major subsystems:

1. A storage subsystem which fits in the storage or magazine area. This subsystem stores the rounds and spent cartridges in two bays located one behind the other. The two-bay arrangement serves to increase the storage capacity, while lowering the required driving power for the same reasons which were discussed in connection with the F-16 design in Section II. During firing, this subsystem simultaneously dispenses rounds and accepts spent cartridges at the entry to the transport tunnel. During loading, the subsystem accepts rounds and rejects cartridges through a door located at the bottom of the magazine.

2. A retrieval subsystem which fits in the tunnel and serves to transfer rounds from storage to the point of entry into the gun and to transfer spent cartridges in the opposite direction. During transfer, certain motions must be imparted to the rounds, and similar but reverse motions must be imparted to the cartridges. Insofar as the rounds in storage are divided into

two groups (i.e., two bays), and they move at one-half the gun entry velocity and one-half the overall dispensing rate in each group, the retrieval subsystem must accelerate the rounds and increase their spacing (pitch), and then merge two streams of rounds into a single stream. The reverse of these motions must be imparted to the spent cartridges on their way from the gun to the storage magazine.

3.2 System Description

In this system, as well as in the system for the F-16 aircraft, the concept found to be most feasible stores all rounds in two layers, one behind the other, with rounds oriented parallel to the axis of the gun.

Again, the rounds move both laterally and longitudinally during retrieval, until they form a single stream prior to entry into the gun. The direction of the longitudinal axis of a round is never changed. To accomplish this motion in the most effective way, in terms of simplicity of implementation, reliability, serviceability, and additional storage capacity within the tunnel space, several concepts were investigated. All these concepts will work in conjunction with a single concept which was developed for the storage magazine design.

The work accomplished on (1) one final storage magazine design and (2) several retrieval concepts (transport, pitch expansion, merge, and gun entry) is described in the following subsections. Among the several concepts under (2), one was finally chosen as the recommended approach. For the chosen approach, a functional prototype was designed and partially fabricated.

3.2.1 Storage Magazine

The layout of the storage magazine is shown in Figure 10. One chain conveyor in each of two bays contains and transports the rounds in storage. The conveyor path forms six vertical loops and a horizontal stretch across the bottom of the magazine. The chain pitch is 1.812 inches, and the spacing of the rounds is the same. The rollers of the chain as well as the rounds themselves are guided throughout the path. The velocity of the conveyor is 7.55 feet per second when firing at 6000 rounds per minute.

The reason for the relatively coarse pitch of the chain is that in such a chain the distance between rounds does not become shortened as the chain loops around the turn-around sprockets. This is important since the distance is small in order to ensure maximum storage capacity. For the same reason, the loops are very tight. Each turn-around sprocket has four teeth. To prevent velocity fluctuations of the chain driven by 4-tooth sprockets, the path of the chain around each sprocket is guided in such a manner that uniform chain motion is ensured. The shape of the guided path is shown in Figure 11 (left side). The right side of Figure 11 shows the geometry of the round carriers in the chain and the rounds nested between the carriers.

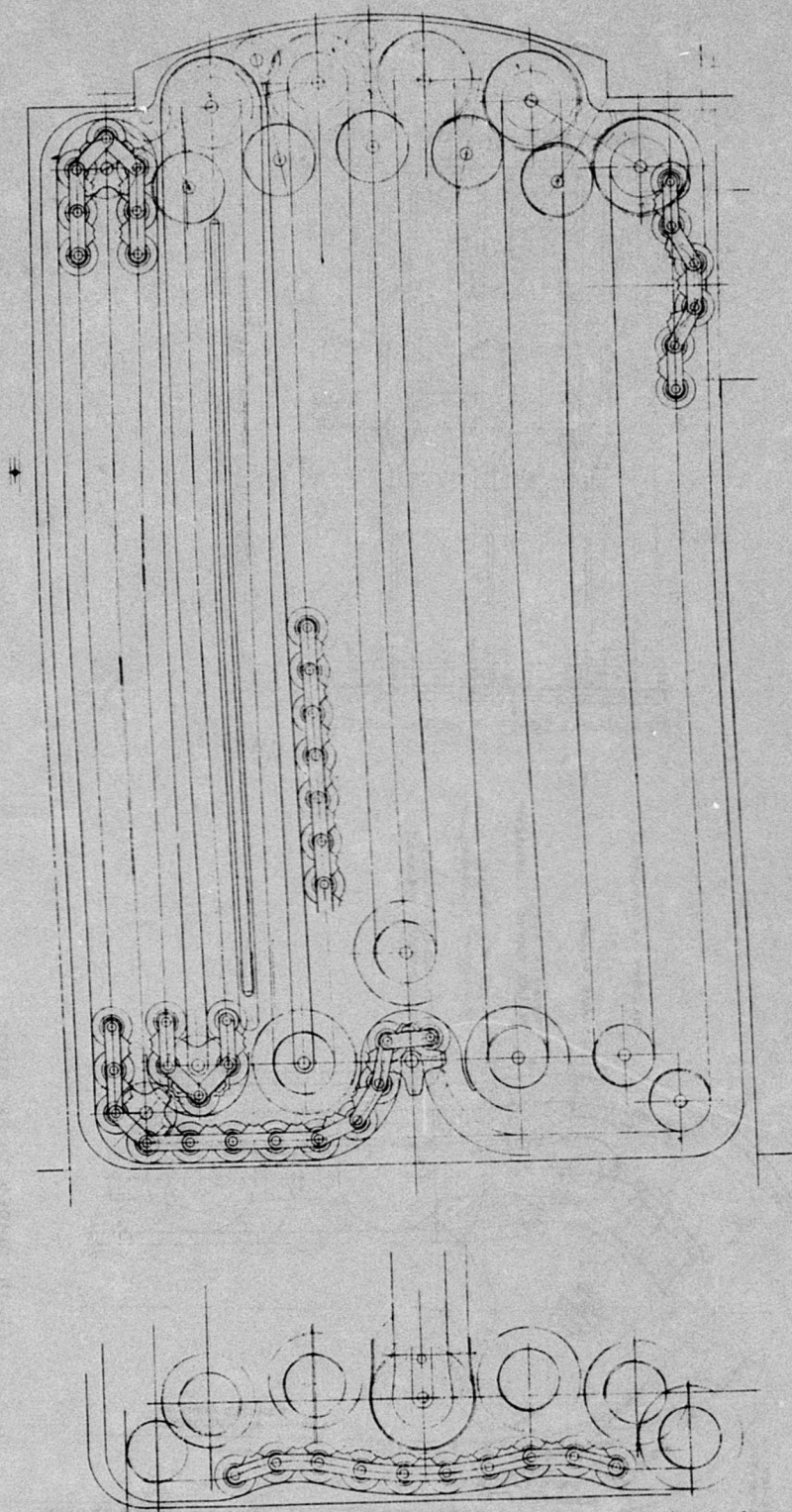
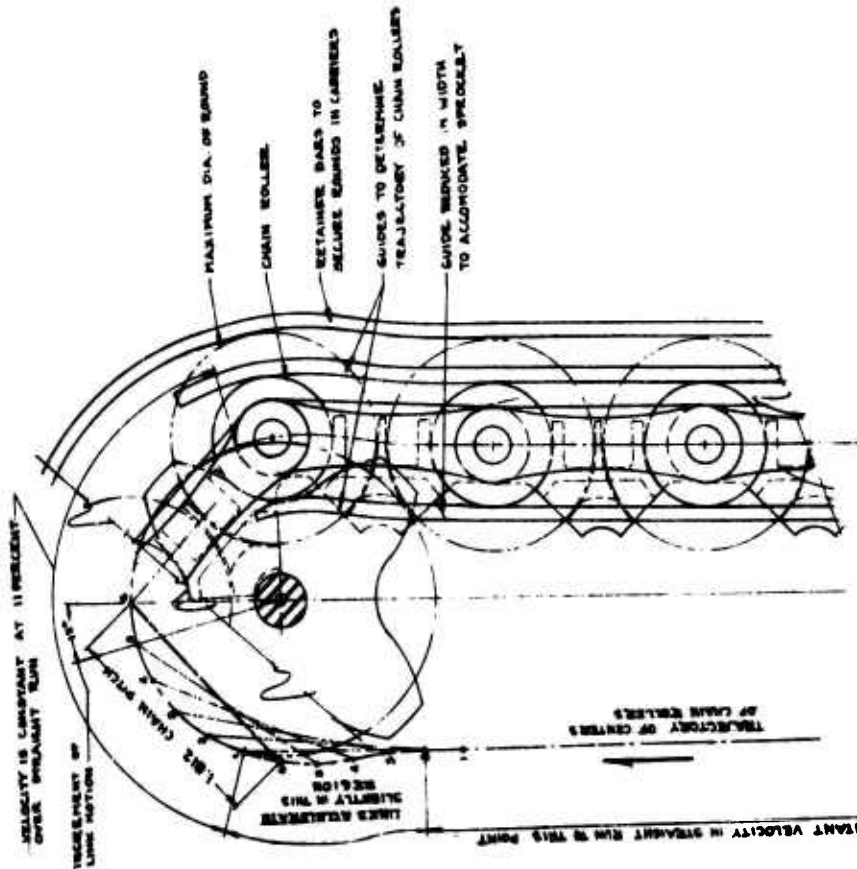
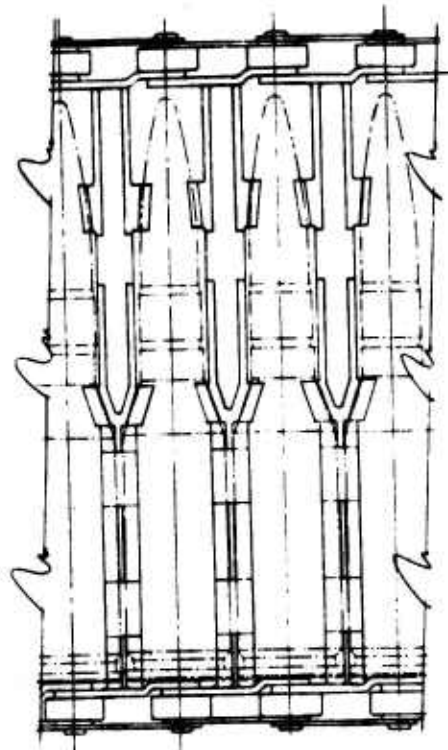


Figure 10. Ammunition Storage Compartment Layout
33



CHAIN GUIDES TO FACILITATE
 USE OF 4 TOOTH SPROCKET
 2 X SIZE



FRONT VIEW OF VERTICAL CHAIN
 FULL SIZE

Figure 11. Storage Compartment Conveyor Details

All the sprockets located on the upper side of the magazine are driven by the drive train. This ensures uniformity of motion and a uniform distribution of tension along the conveyor. Since the 25mm F-15 rounds are longer and heavier than the F-16 rounds, and since the effort to store as many rounds as possible limited the size of the system drive shafts, the F-15 storage system was driven in the center between the two bays of the magazine. Also unlike the F-16 design, a separate chain is used here for the rounds in each bay. This permits timing the two chains with one-half pitch offset relative to one another, so that rounds are retrieved alternately from the two bays. The process of merging two streams is thereby simplified; it does not require an offsetting mechanism as in the F-16 system. Another reason for separate chains is that the 25mm round is relatively long, so that a chain of double width would become structurally weak. The use of two chains also permits each sprocket shaft to be supported in the middle between the two bays. This support increases the rigidity and the strength of the system.

3.2.2 Retrieval System Concepts

3.2.2.1 Concept B

This design approach is illustrated in Figure 12. It uses a circular pitch-expanding wheel, a merging conveyor, and a transfer wheel, all centrally located along the tunnel. These elements handle the rounds entering the gun on one side and on the other side the returning spent cartridges. A number of separate transfer impellers serve to transfer rounds and cartridges between the magazine conveyor and the pitch expander, between that and the merging conveyor, between the latter and the transfer wheel, and finally into and out of the gun.

The pitch-expanding wheel contains five arms, each capable of carrying a round or a cartridge. The arms rotate about a common shaft at a nonuniform velocity. This motion is controlled by an eccentric drive. The result of the motion is that the pitch between two consecutive arms is smaller when the arms are on the side near the magazine, and it is larger (expanded) when the arms are on the merging conveyor side.

The method of operation of the merging conveyor is identical to that employed in the F-16 system, described in Section II. The transfer wheel is also similar, and it serves a similar purpose. The width of the entire merging conveyor is governed by the space occupied by two layers of rounds before merging, which amounts to at least twice the length of one round. The exit end of the tunnel is somewhat narrower than the conveyor. For this reason, the conveyor must be terminated before the narrower exit of the tunnel. The transfer wheel handles a single stream of rounds which are already merged, and it serves to carry the rounds and cartridges across the narrower opening in the tunnel.

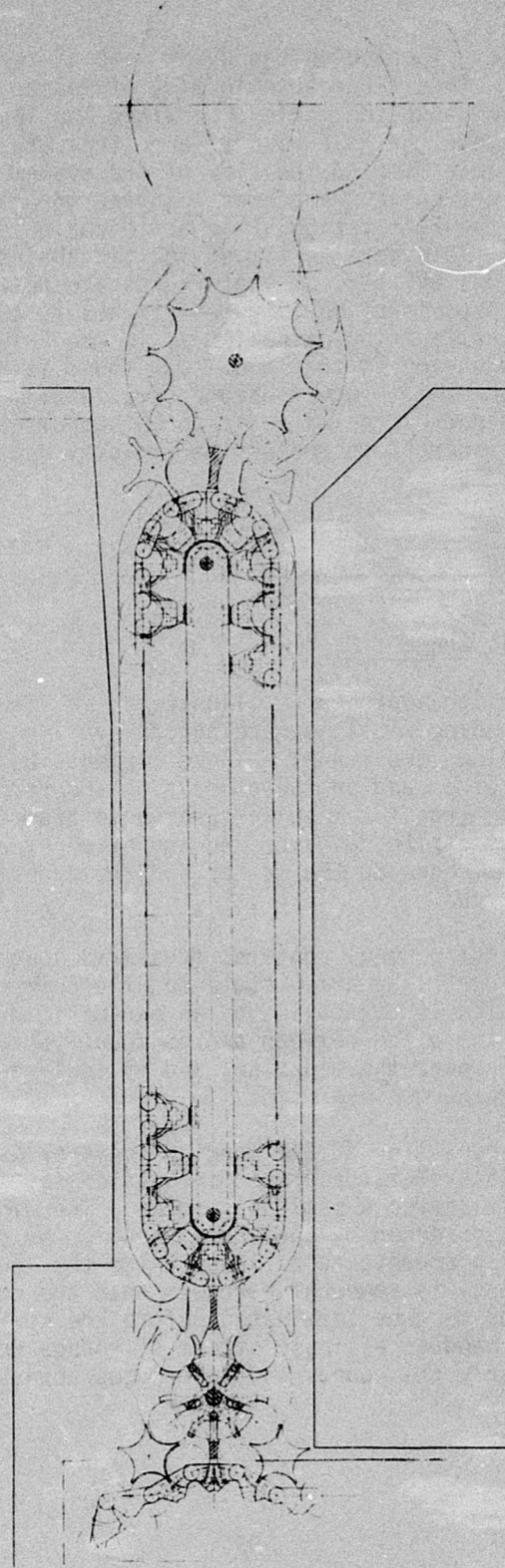


Figure 12. Concept B Retrieval System

3.2.2.2 Concept A

The total storage capacity of the system can be somewhat increased if the point of pitch expansion is located closer to the gun. A concept in which the pitch expanding wheel is placed near the midpoint of the tunnel is shown in Figure 13. An intermediate conveyor is placed between the wheel and the storage magazine conveyor. The pitch between rounds in the intermediate conveyor is not expanded, and thus more rounds are stored in the part of the tunnel occupied by this conveyor than in the same space of the concept described previously (Concept B).

In the magazine, rounds in the two layers are longitudinally separated by about 2-1/2 inches to accommodate the chains, sprockets, shaft support, and drive gearing between the two bays. The intermediate conveyor is equipped with a mechanism to move the rounds longitudinally until the tips of the rounds in the aft layer are in the same plane as the cartridge bases of the rounds of the forward layer. This motion somewhat reduces the width required for the merging conveyor, allowing the latter to pass through the end of the tunnel, and thus eliminates the need for the transfer wheel.

The construction and the round carrier details for the intermediate conveyor are illustrated in Figure 14. This concept has somewhat more complexity than the previous one. It also has the disadvantage that a critical mechanism, the pitch-expanding wheel, is located in a place which is not readily accessible for maintenance.

3.2.2.3 Concept C

This concept represents a simplification over the previous one by using only one instead of two conveyors in the tunnel. It also eliminates the transfer of rounds near the middle of the tunnel, where maintenance problems may arise because of inaccessibility. This concept is shown in Figure 15.

Using three impeller stages, the pitch of the rounds is partially expanded. This permits a partial merging in the conveyor. The conveyor is similar to the intermediate conveyor used in the previous concept, except that it has a slightly larger pitch. Rounds are so spaced in this conveyor that consecutive rounds can be brought to partially overlap lengthwise, utilizing the fact that the projectile diameter is substantially smaller than the diameter of the case.

Both the final pitch expansion and the final merging is accomplished in a wheel which is located between the conveyor and the gun. The motion of the round carrier buckets of the wheel is controlled by two stationary cams. One cam controls the circumferential spacing between the buckets, thus controlling the pitch. The other cam controls the axial motion of the buckets to complete the merging process. The length of path within the wheel is sufficient to complete the necessary motions, since the pitch has previously been partially expanded and the rounds have been partially merged in the conveyor. Details of the construction of the wheel, cam action during merging,

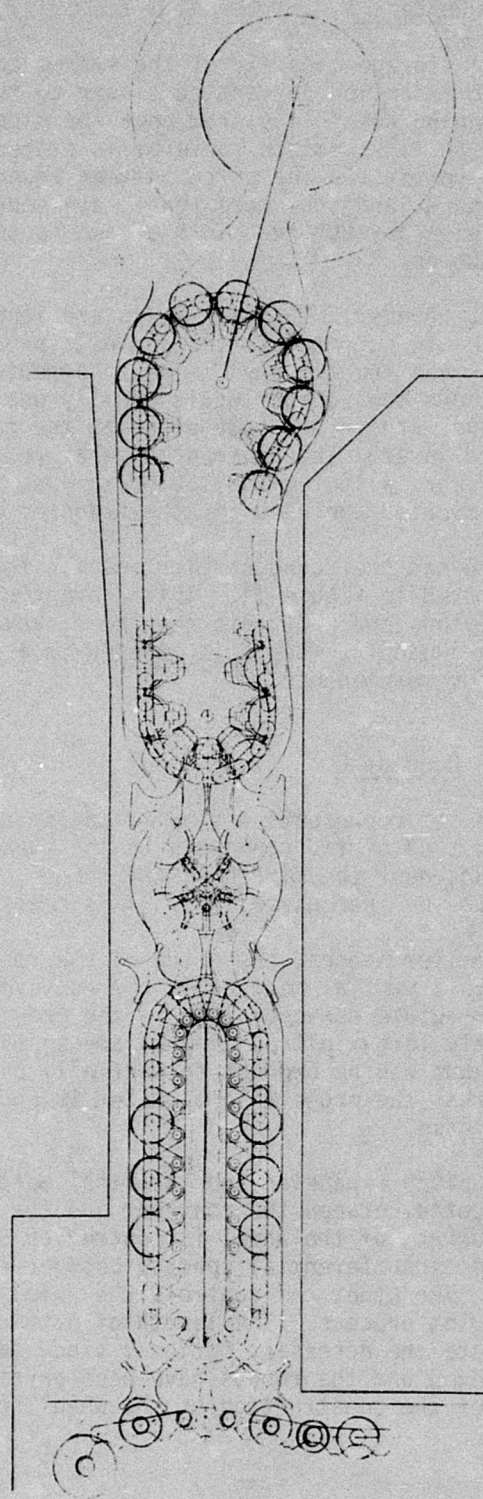


Figure 13. Concept A Retrieval System

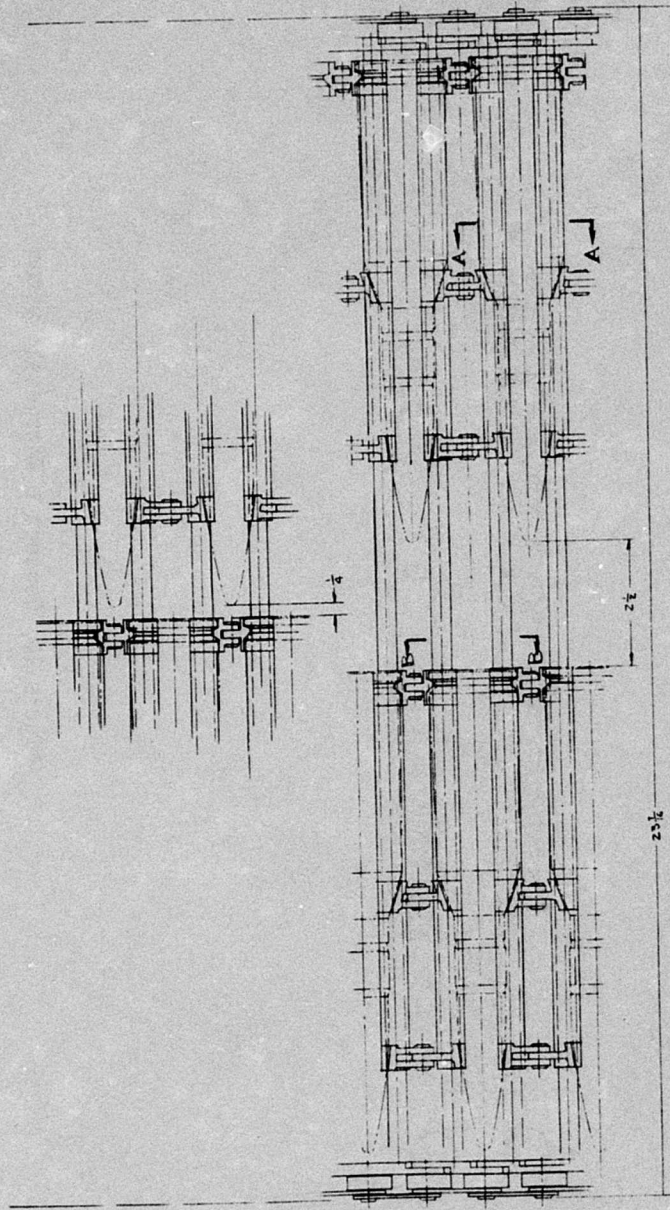
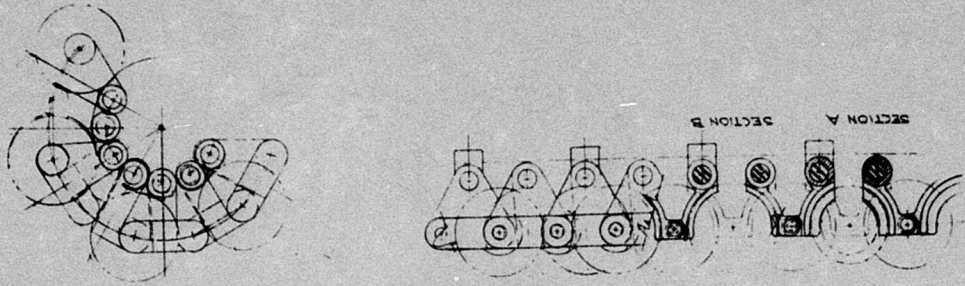


Figure 14. Intermediate Conveyor Round Carriers

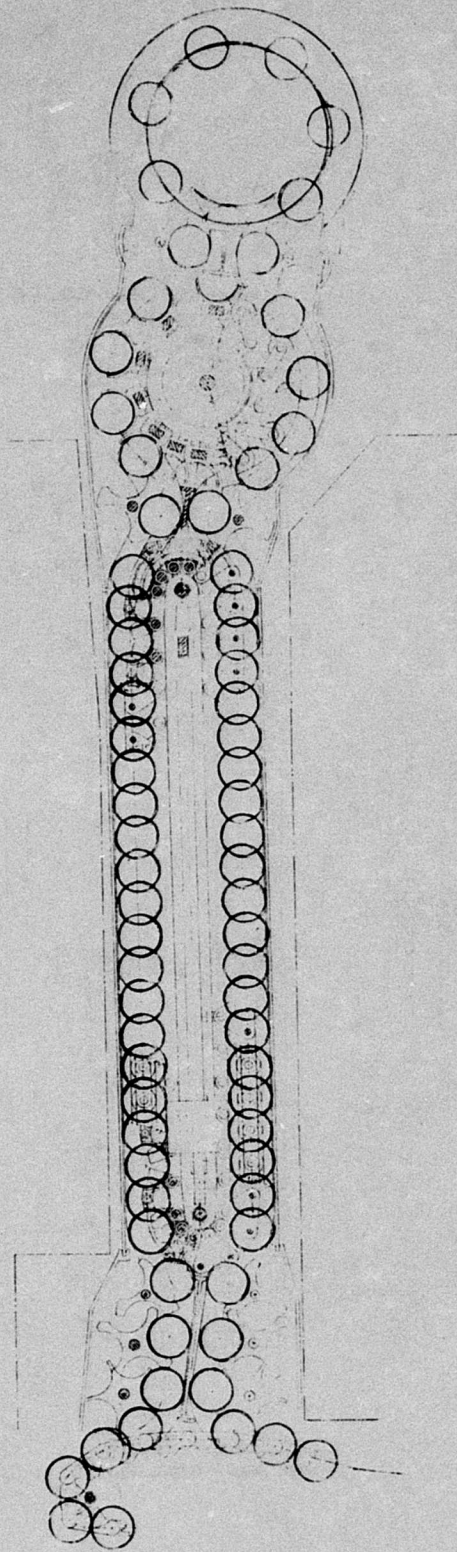


Figure 15. Concept C Retrieval System

and the path of entry into the gun are shown in Figures 16 and 17. The top view of the system, including the motion of the rounds in their passage through the tunnel, is shown in Figure 18.

In terms of the number of rounds, this concept is comparable to Concept A, perhaps very slightly better. The fact that only one conveyor is used in the tunnel represents an advantage. The wheel, which both varies in pitch and moves the rounds longitudinally, adds to the complexity of the system to some extent.

3.2.3 Recommended System

By considering all factors in the design trade-off analysis, the recommended system is a refinement of Concept B. It is considerably simpler and thus more reliable than the concepts discussed previously. The total number of rounds stored is only about 3 percent less than that achievable with Concepts A or C.

The recommended system includes the storage magazine, as shown in Figure 10, and the tunnel conveyor design shown in Figure 19. Rounds are removed from the magazine chain, and then they loop around a set of three impellers. These impellers gradually accelerate the rounds and increase their pitch. During this motion, a small longitudinal displacement is given to each round by the stationary guiding system until the 2-1/2-inch gap between the two layers is closed. The rounds then enter the merging conveyor which has a constant pitch and velocity. By the use of stationary cam tracks, the round carriers are moved longitudinally (i.e., transversely with respect to the conveyor transport motion), until the rounds from both layers end up in a single layer, halfway between the two original layers. This action is illustrated in Figure 20, which shows the top view of the entire path of the rounds in passing through the tunnel.

A set of two impellers is used to transfer the rounds from the merging conveyor to the gun. These impellers impart a small additional increase of speed and pitch to the rounds in order to match the conditions in the gun. These impellers can be seen at the right side of Figure 19.

Figure 21 shows the merging conveyor in cross-section, with the round carriers and cam tracks shown in some detail. Figure 22 shows the magazine chain round carrier details. Figure 23 illustrates the gearing layout of the drive train, including the gears which drive all the impellers and conveyor sprockets in the tunnel, and the interface with the magazine drive train.

The flexibility to allow for aiming adjustments of the gun relative to the aircraft frame is incorporated into the merging conveyor. However, since the round carriers are free to move longitudinally relative to the conveyor, i.e., from side to side of the conveyor, and since this motion is controlled by the cam tracks, the conveyor need not follow the recoil motion of the gun. Instead, the cam tracks are pivoted at the magazine end and constrained to follow the recoil at the gun end.

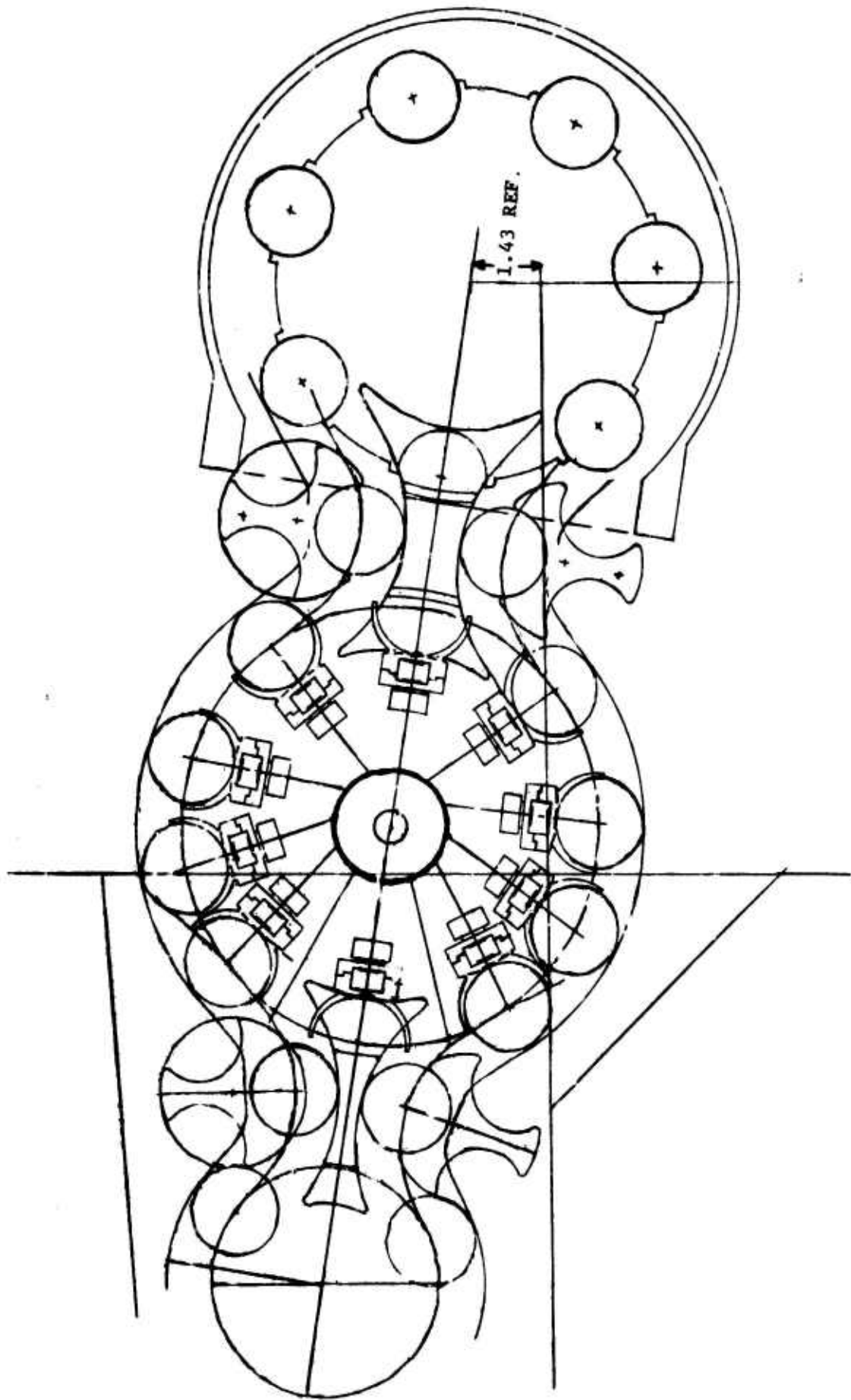


Figure 16. Concept C Transfer Wheel Detail

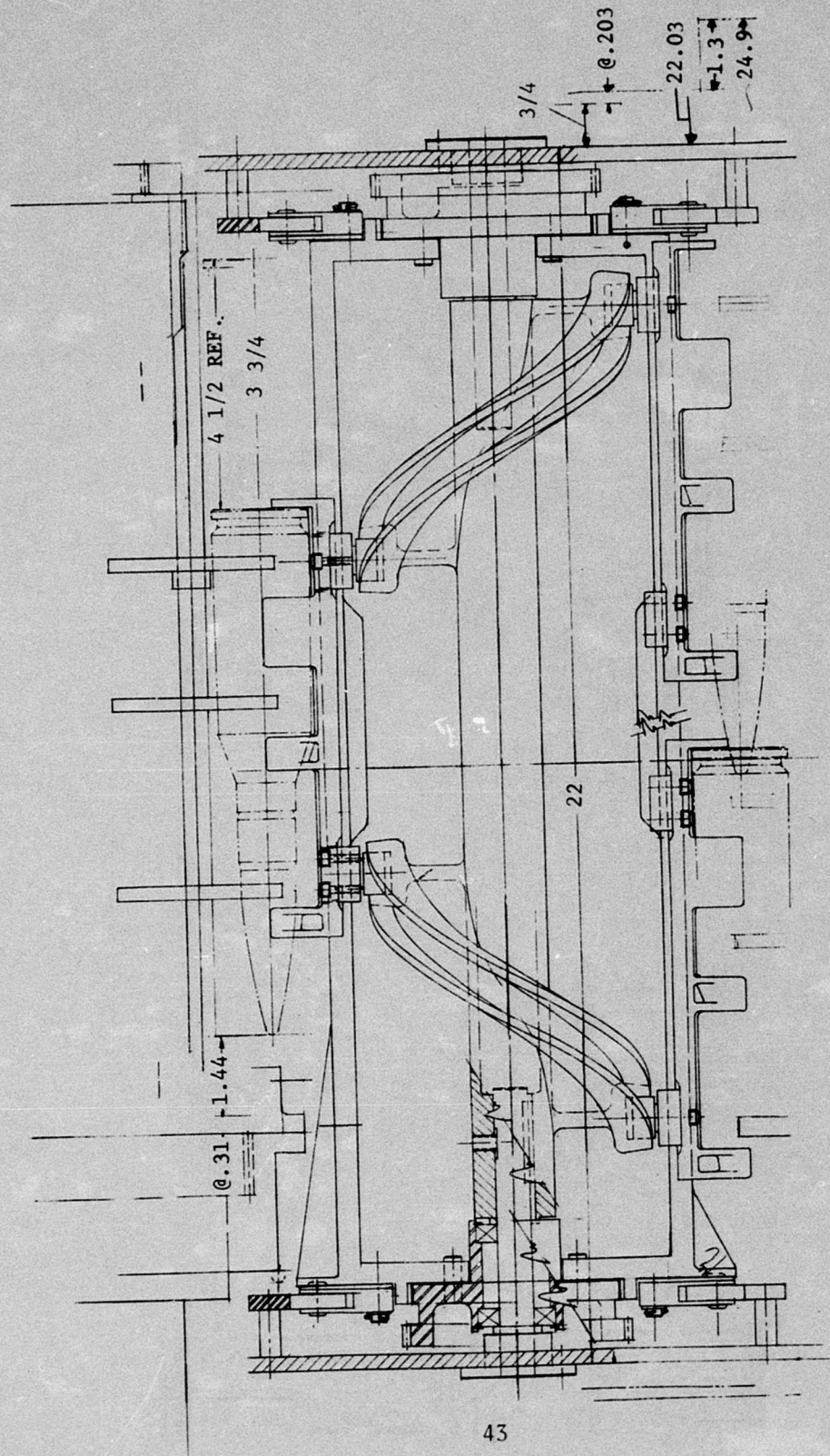


Figure 17. Concept C Cam Details

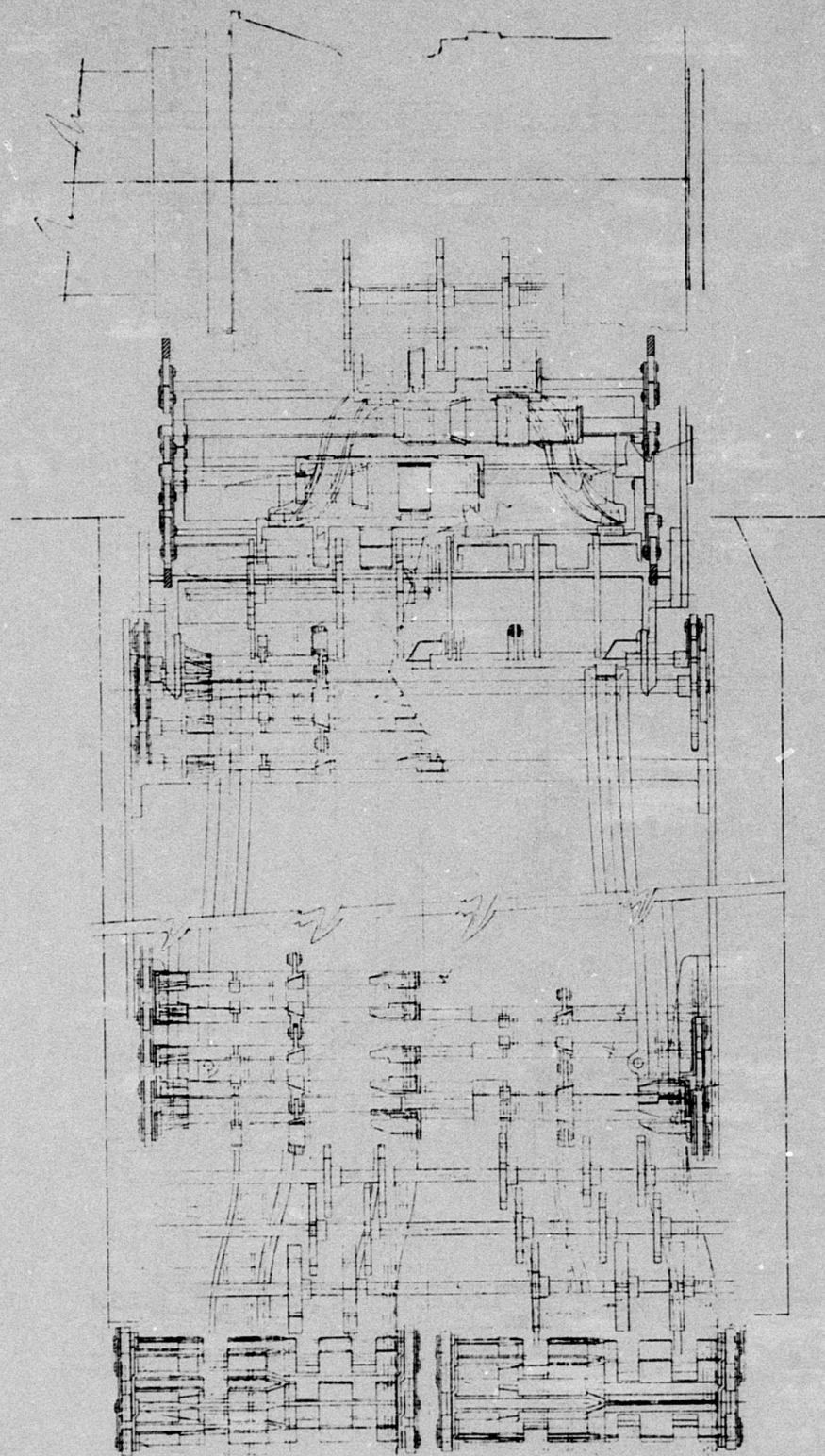


Figure 18. Concept C System - Top View

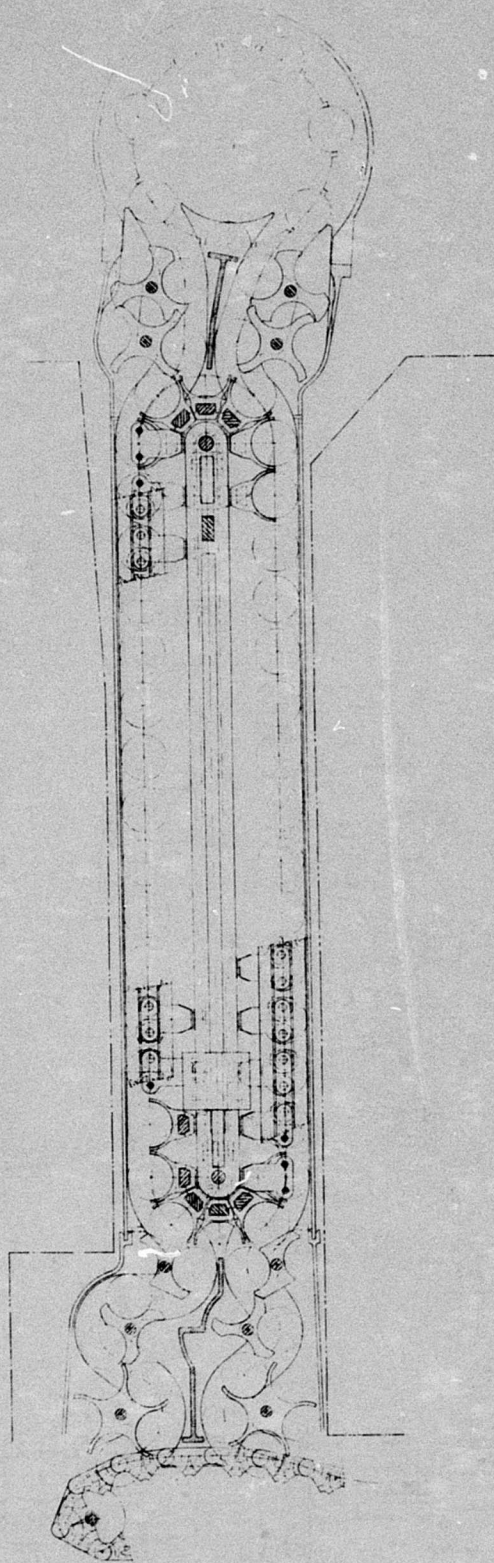


Figure 19. Side View of Recommended Tunnel System

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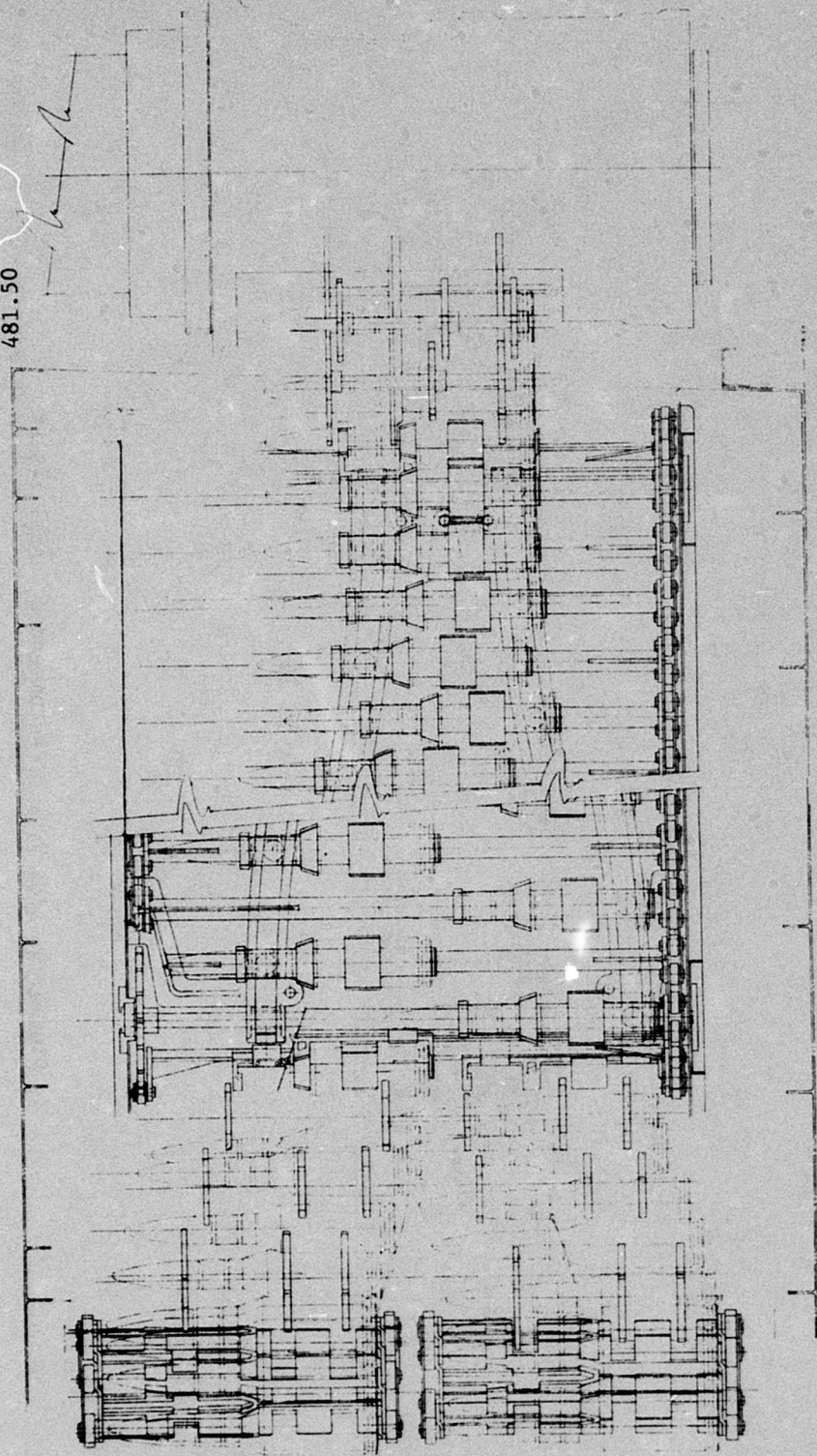


Figure 20. Positions of Rounds in Passage Through Tunnel

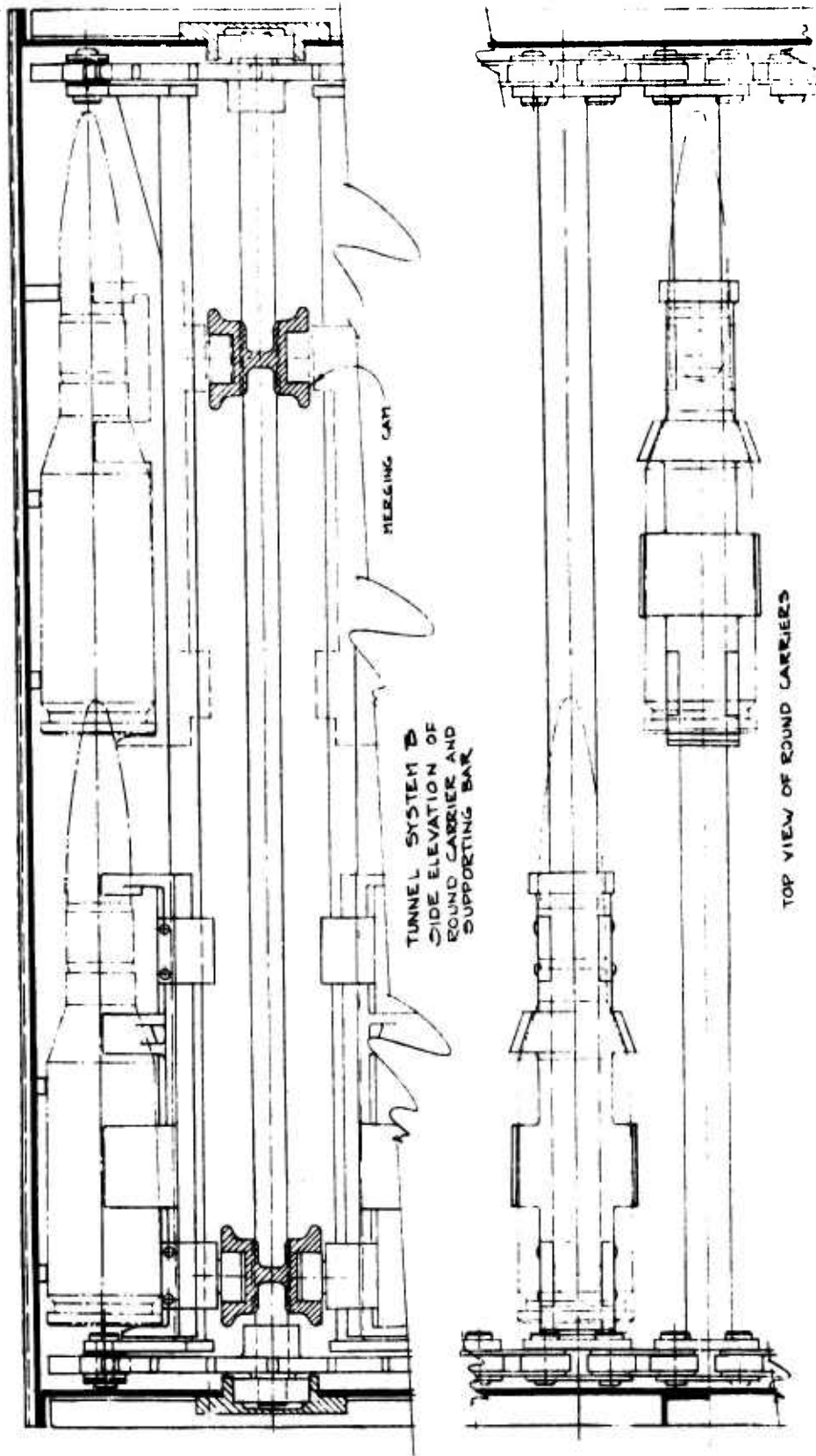


Figure 21. Merging Conveyor Details

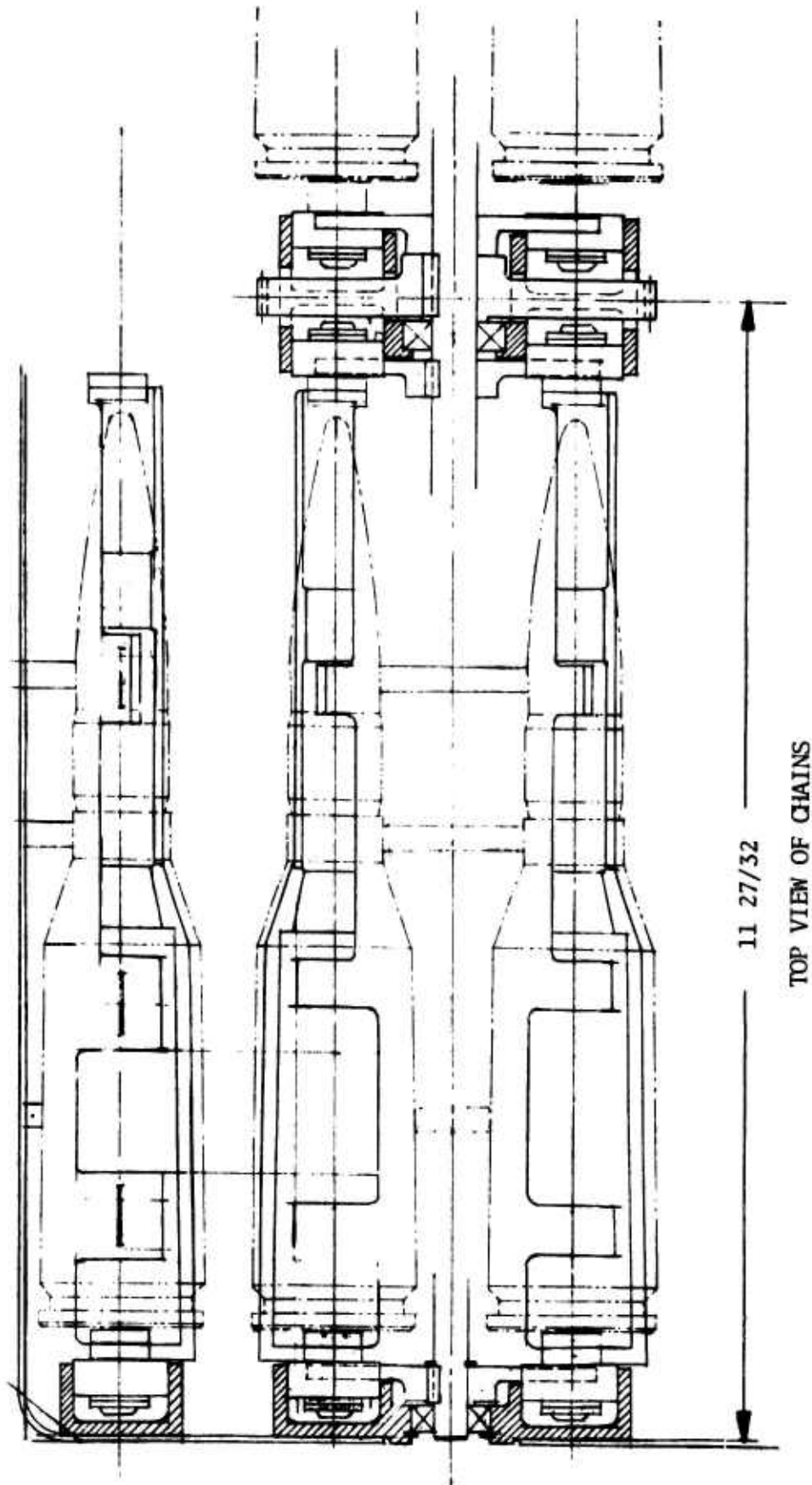


Figure 22. Storage Compartment Conveyor Chain Detail

Many basic features of this feed system are similar to the features of the system for the F-16 aircraft. Allowing for the difference in the dimensions (length and diameter) of the rounds, the shape of the magazine conveyor path and its round carrier details are similar. The merging conveyor design, including the fact that one side of the conveyor carries the rounds and the other side carries the cartridges, are similar. The layouts of the pitch-expanding impellers for the rounds and of the corresponding set of pitch-contracting impellers for the cartridges are quite similar to the accelerating and transfer mechanism of the F-16 feed system. The treatment of the gun recoil motion is similar.

The basic differences of the two systems are:

1. Because of the size, a separate magazine conveyor chain for each bay is used here instead of one double-width conveyor for both layers.
2. Being in separate conveyors, the rounds in the two layers are half a pitch offset with respect to each other, and consequently no pitch offsetting feature is needed in the transfer impellers.
3. No separate loading conveyor is required since the magazine area is directly accessible for loading from underneath the aircraft.

3.3 Partial Prototype Design and Fabrication

The refined Concept B system is recommended as the overall optimum F-15 linear linkless feed system to evolve from the design studies performed. This system is capable of storing 650 rounds. The best which can be done with an alternate system (Concept C) is on the order of 670 rounds. This represents an increase of 3 percent in capacity at a considerable penalty in the complexity of the system.

A partial prototype of the recommended feed system was designed for purposes of fabricating and then demonstrating design feasibility of critical components of the system. To minimize the fabrication effort and expense involved, the system was not complete but it was sufficient for demonstrating the operation of all key subsystems. For example, a single storage compartment conveyor loop was provided instead of the complete storage compartment shown in Figure 10. However, all components were full scale.

The partial prototype includes the complete mechanism in the tunnel, with pitch expansion and merging of rounds, and the return of cartridges or unfired rounds from the gun to the magazine. The magazine conveyors in the prototype include only one typical single loop of the multi-loop conveyor for the final system. Except for the total length and storage capacity, the prototype conveyors are designed exactly as the conveyors in the final system. The inertia and drive friction of the missing length of the conveyors can be simulated by a flywheel and a brake which is provided in the prototype.

Design layouts of the partial prototype are shown in Figures 24, 25, and 26. Figure 24 illustrates the single loop storage container conveyor. The

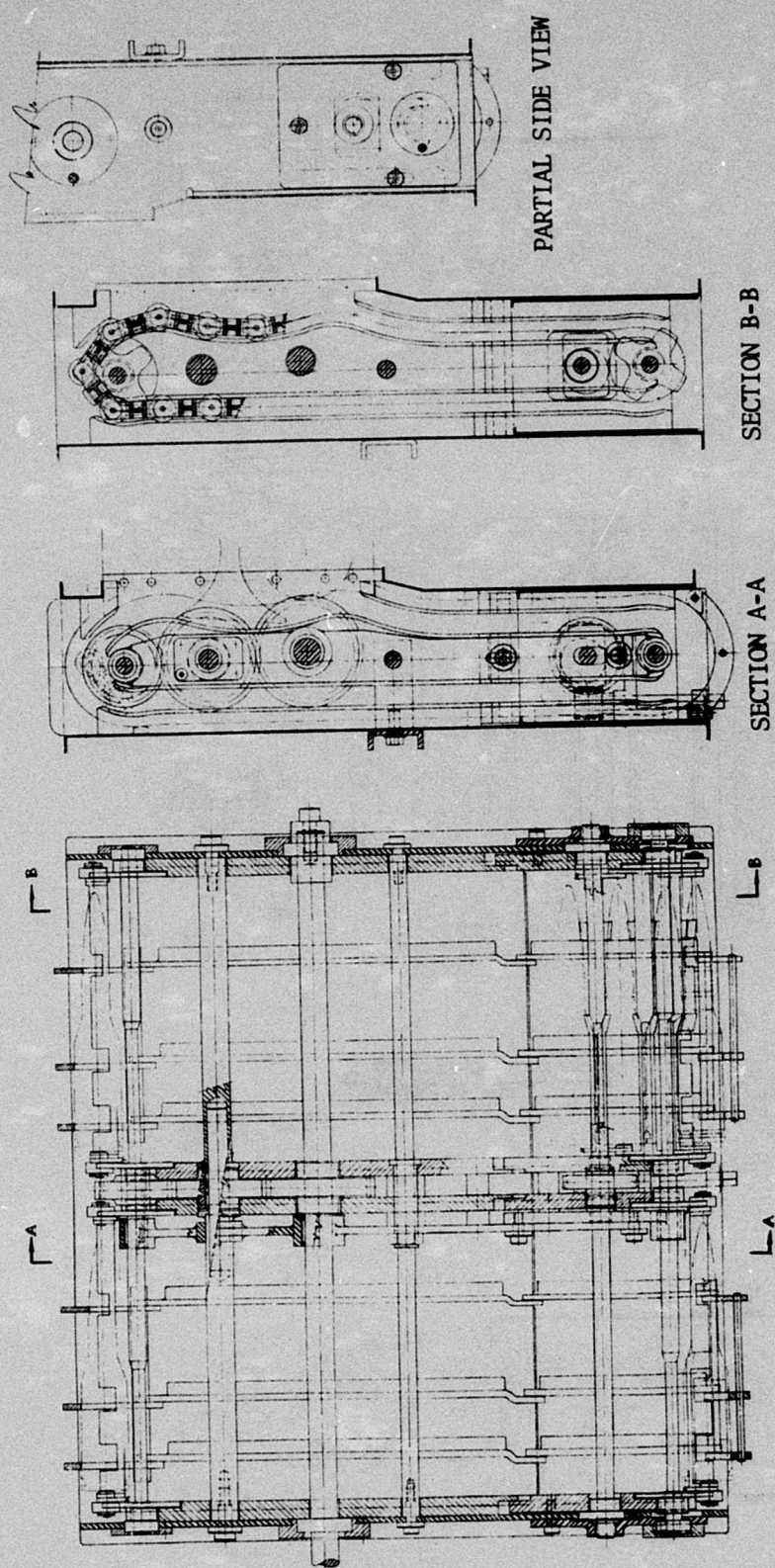


Figure 24. Storage Container Loop of Partial Prototype Feed System

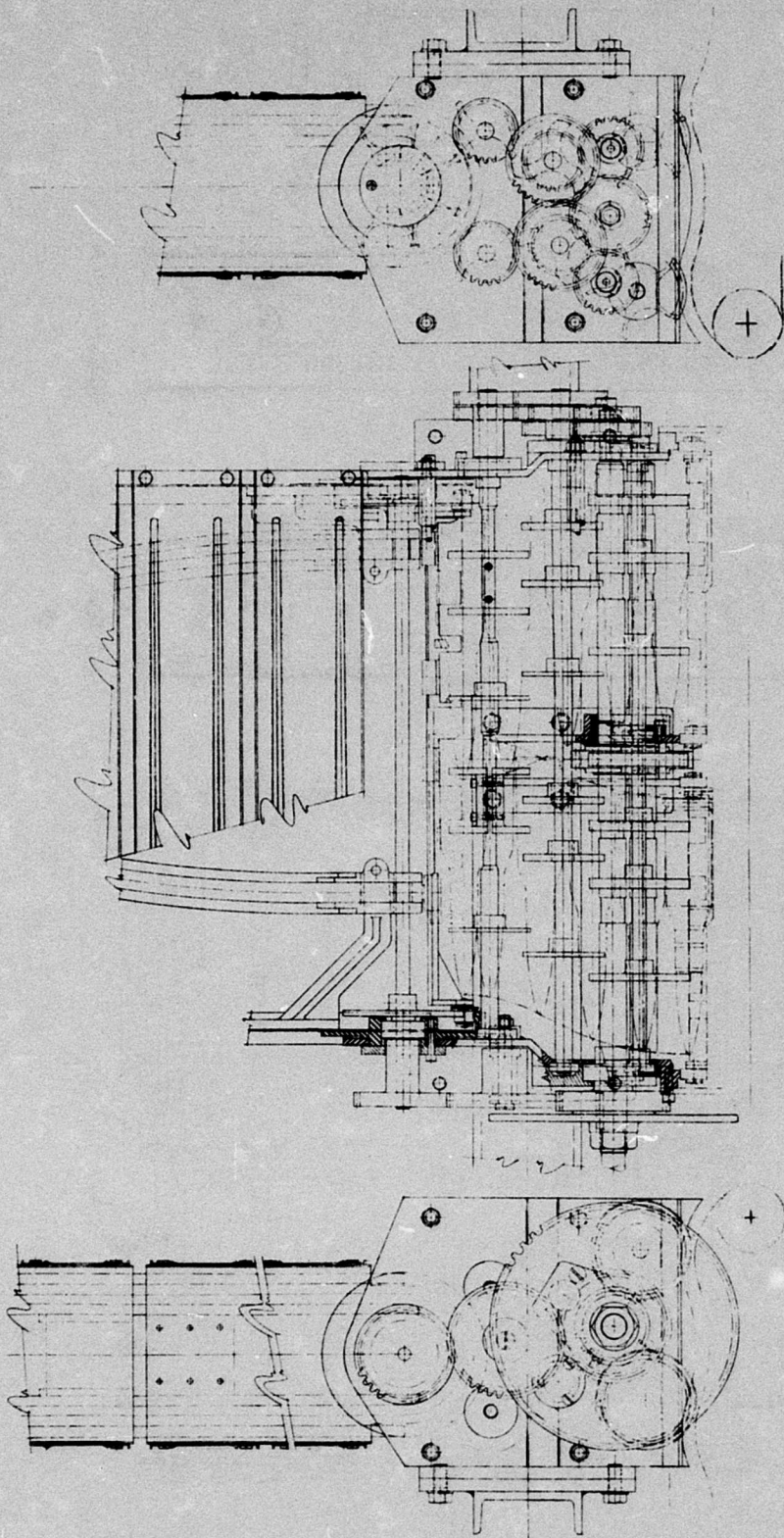


Figure 25. Container End of Tunnel Conveyor for Partial Prototype Feed System

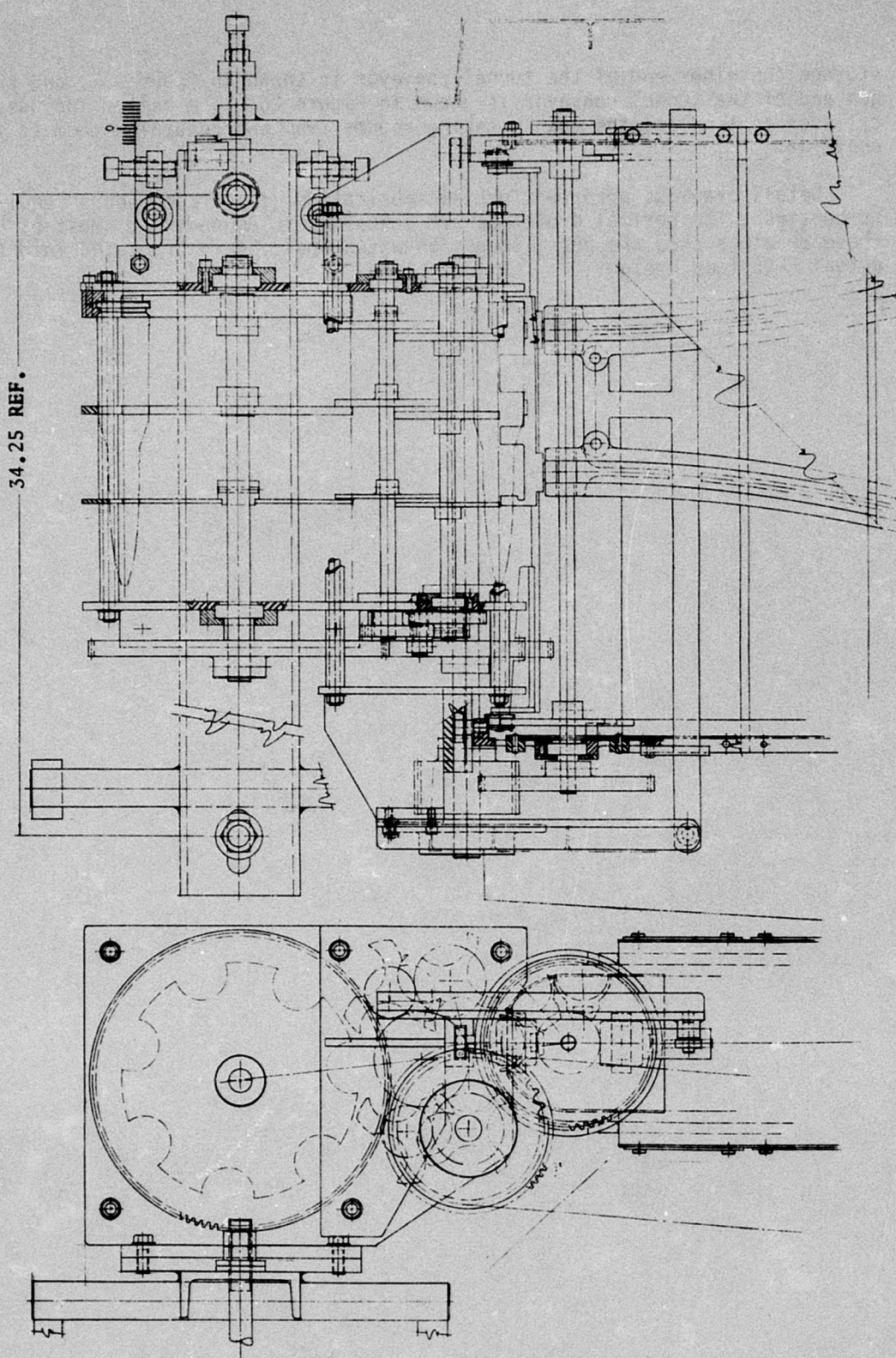


Figure 26. Gun End of Tunnel Conveyor for Partial Prototype Feed System

storage container end of the tunnel conveyor is shown in Figure 25, and the gun end of the tunnel conveyor is shown in Figure 26. The latter includes a cylinder to simulate the gun in taking rounds from and returning them to the conveyor.

Detail drawings prepared for the fabrication of all components required to construct the partial prototype are contained in Appendix A. Most of these drawings show the detailed design which would be incorporated into the actual F-15 feed system.

APPENDIX A

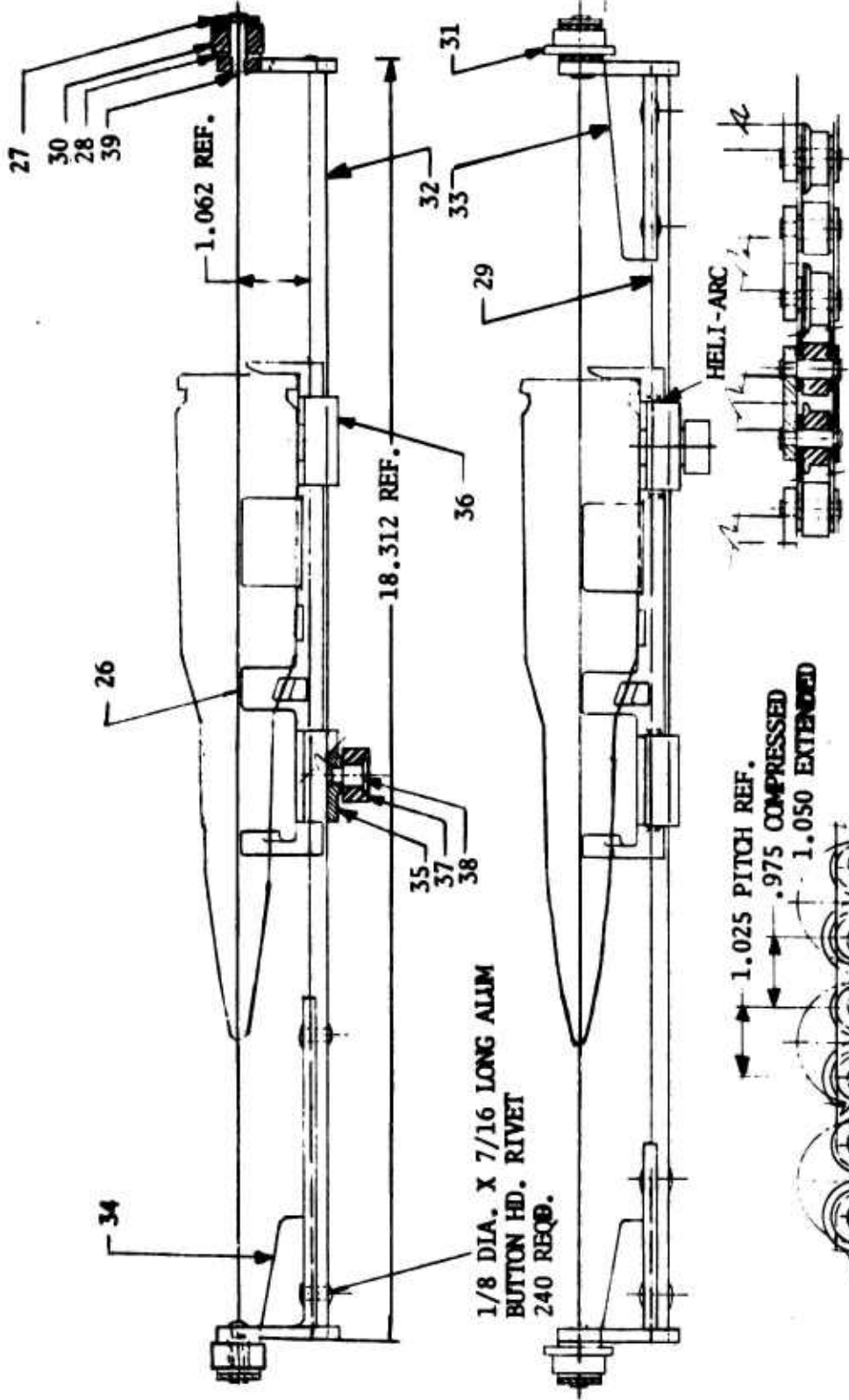
PARTIAL PROTOTYPE DRAWINGS

1623-6	Gun End Support Weldment - Tunnel Conveyor
1623-7	Elevation Gage And Pointer - Tunnel Conveyor
1623-8	Rotation Gage - Tunnel Conveyor
1623-12	Inboard Foreward Side Plate - Tunnel Conveyor
1623-13	Inboard Aft Side Plate - Tunnel Conveyor
1623-14	Inboard Bearing Plate - Tunnel Conveyor
1623-15	Outboard Bearing Plate - Tunnel Conveyor
1623-16	Foreward Center Chain Guide - Tunnel Conveyor
1623-17	Aft Center Chain Guide - Tunnel Conveyor
1623-25	Round Carrier Assemblies - Tunnel Conveyor
1623-26	Round Cradle - Tunnel Conveyor
1623-27	} Chain Side Plates - Tunnel Conveyor Chain
1623-28	
1623-29	Cross Bar - Tunnel Conveyor
1623-30	} Rollers - Tunnel Conveyor Chain
1623-31	
1623-32	Cross Bar Weldment - Tunnel Conveyor Chain
1623-33	} Cross Bar Ends Weldments - Tunnel Conveyor Chain
1623-34	
1623-35	} Cradle Retainers - Tunnel Conveyor
1623-36	
1623-37	Cradle - Cam Follower - Tunnel Conveyor

1623-38		Pivot - Cam Follower - Tunnel Conveyor
1623-39		Pin - Tunnel Conveyor Chain
1623-40		Cross Bar End Weldment - Tunnel Conveyor Chain
1623-50		Container Conveyor Chain Detail
1623-51		Round Carrier - Container Conveyor
1623-52		Bushing - Tunnel Conveyor Chain
1623-53		Roller - Container Conveyor Chain
1623-54		Pin - Container Conveyor Chain
1623-55	}	Chain Side Plates - Container Chain
1623-56		
1623-57		Washer - Container Conveyor Chain
1623-58	}	Upper And Lower Bearing Support - Container
1623-59		
1623-61	}	Center Chain Guides - Container (sheet 1 of 2)
1623-62		
1623-63		
1623-64		
1623-65		
1623-66		
1623-61	}	Center Chain Guides - Container (sheet 2 of 2)
1623-62		
1623-63		
1623-64		
1623-65		
1623-66		

1623-67	}	Side Chain Guides - Container
1623-68		
1623-69		
1623-70		
1623-71		
1623-72		
1623-73		Side Plate - Container
1623-74		Lower Bearing Plate - Container
1623-75		Worm Gear Support - Container
1623-76		Cross Bar, Center Chain Guide - Container
1623-77		Spacer, Center Chain Guide - Container
1623-78	}	Round Retainer Angles - Container
1623-79		
1623-80		
1623-81		
1623-82		
1623-83		
1623-84		Bottom Round Retainer Assembly - Container
1623-85		Upper Sprocket Shaft - Container
1623-86	}	Round Retainer Angle - Container
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1623-88		
1623-89	}	Top, Round Retainer - Container
1623-90		
1623-91		

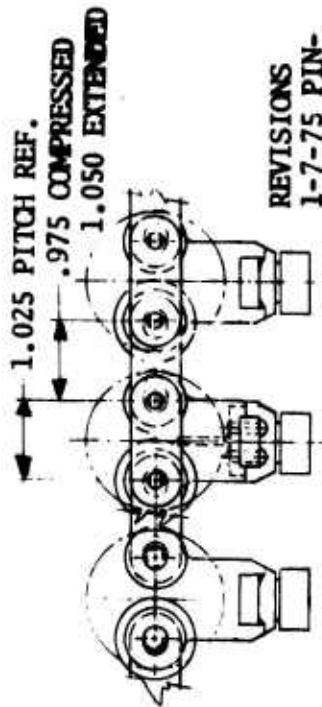
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1623-93		Chain Length Adjustment Shaft - Container
1623-94		Idler Gear Shaft - Container
1623-95		Cross Tie Rod - Container
1623-96		Container Drive Gear Shaft
1623-97		Bearing Retainer - Container Drive Shaft
1623-98		Bearing Retainer - Upper Sprocket Shaft - Container
1623-99		Bearing Retainer - Lower Sprocket Shaft - Container
1623-100		Washer - Idler Shaft
1623-101		Washer - Container
1623-102	}	Spacer - Tie Rod - Container
1623-103		
1623-104	}	Sprockets - Container Chain
1623-105		
1623-106		
1623-107		
1623-108		
1623-109		Chain Drive Gear - Container
1623-110		Idler Gear - Container
1623-111		Container Drive Gear
1623-112		Cam Chain Length Adjustment - Container
1623-113		Thrust Washer Idler Gear - Container



TOP VIEW OF CHAIN

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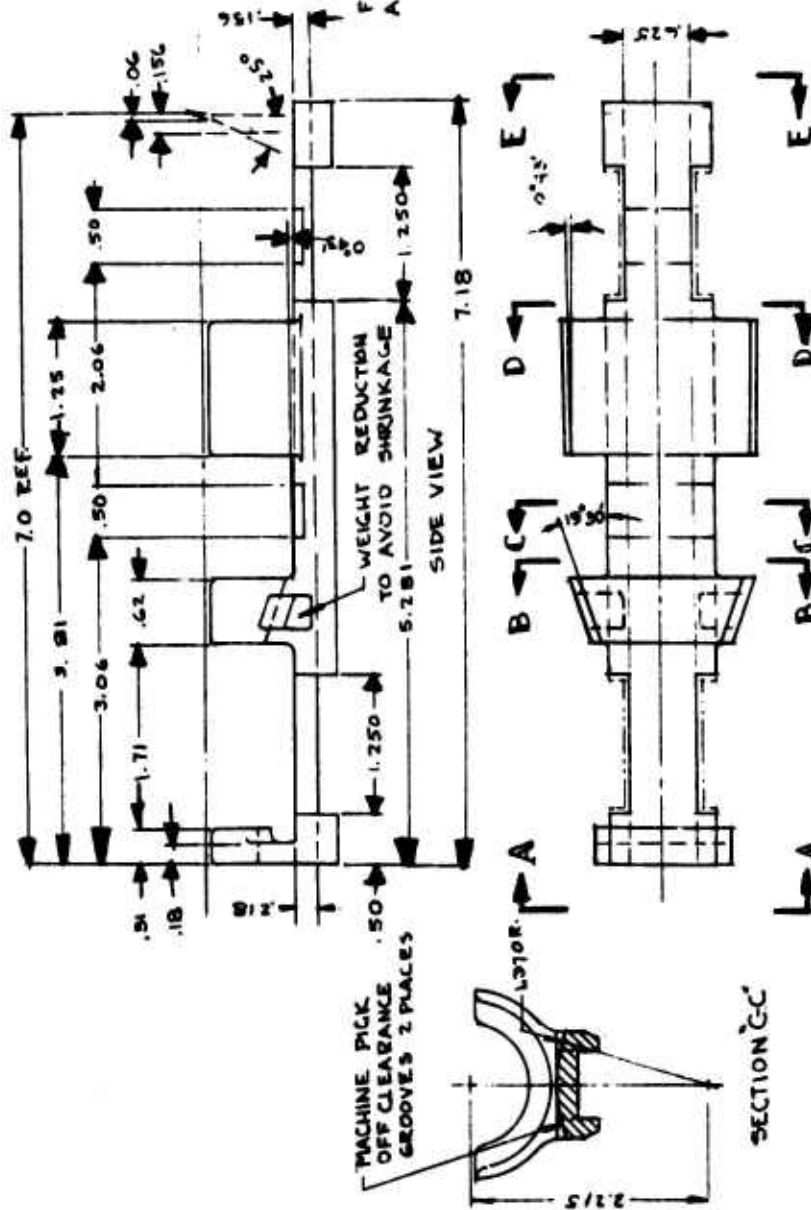
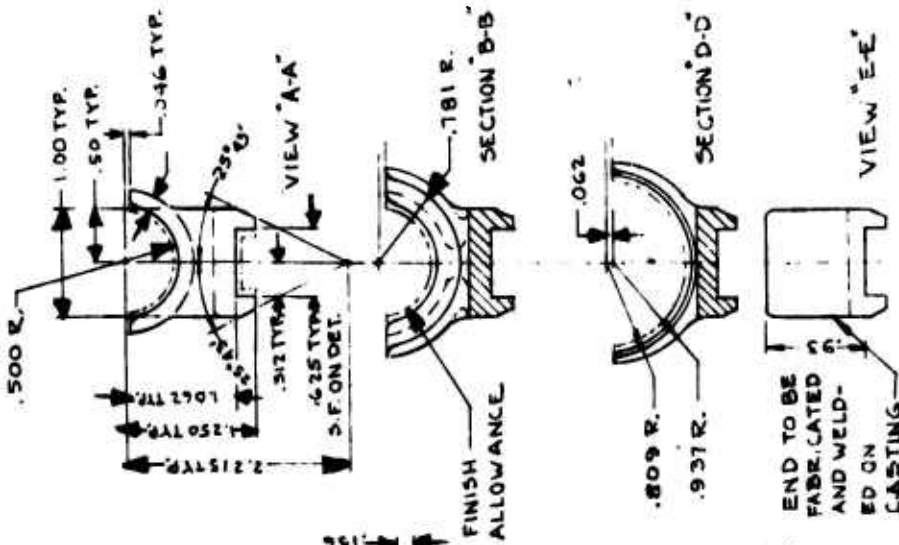
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END VIEW

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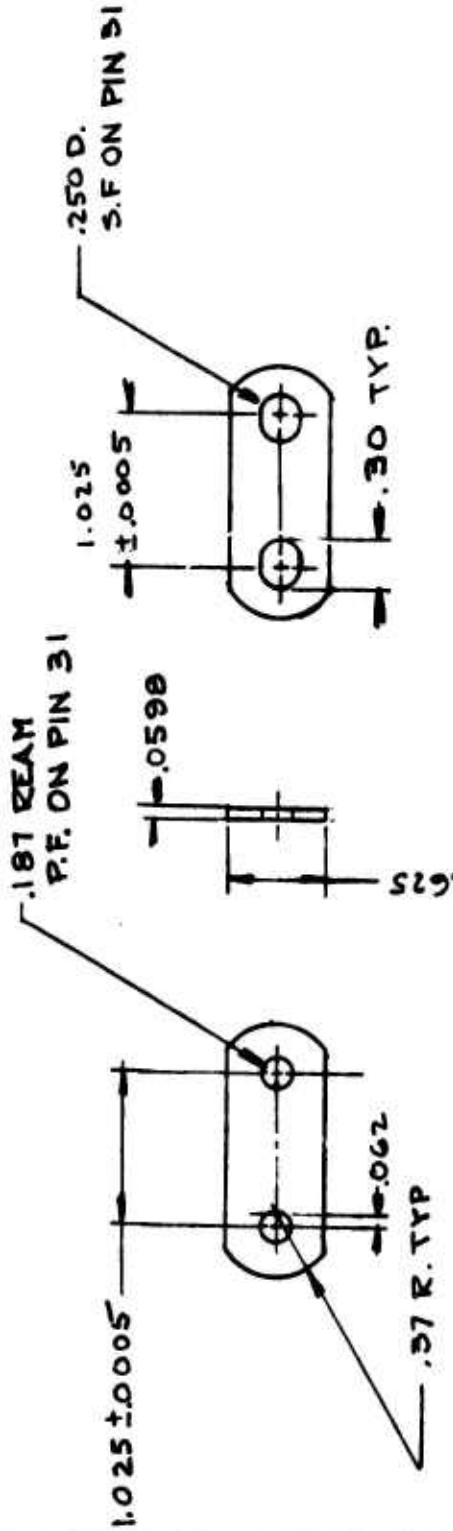
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PART NO. 1623-26	REV. 0001
QUANTITY 1	DATE 12-18-74
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DED.	APPROVED BY

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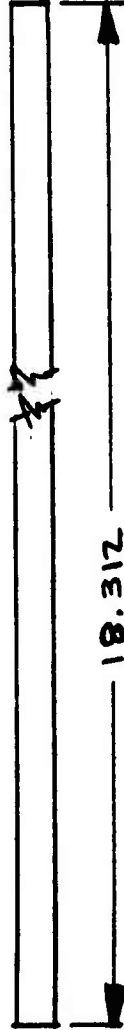
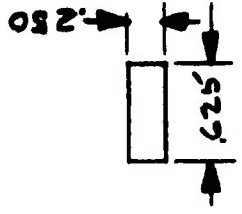


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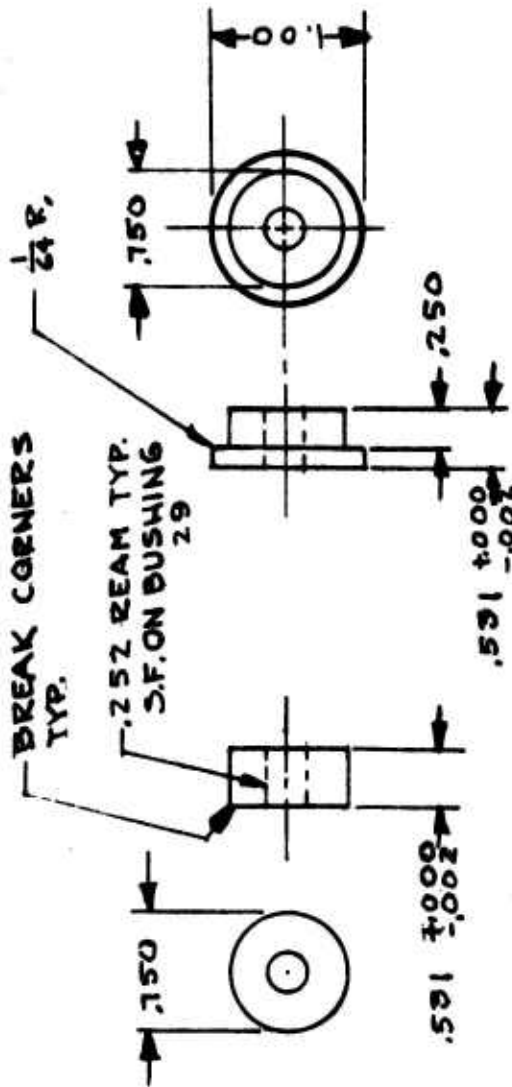
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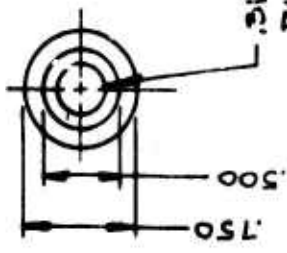
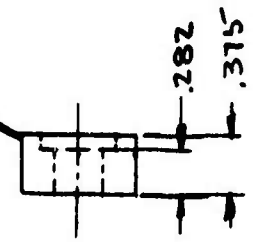
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DET 31
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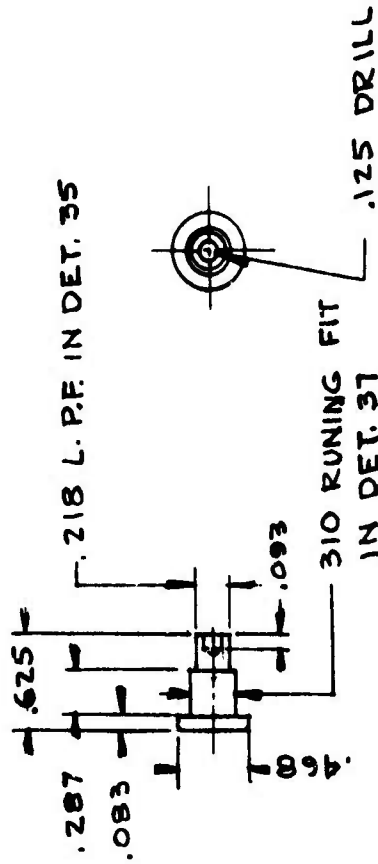
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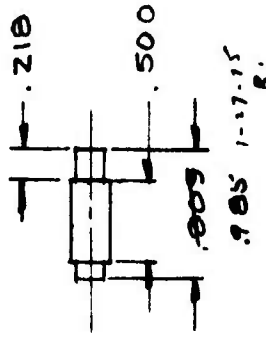
40 REQD.

CITY P-CGD	DWG OR PART NO.	TITLE OR DESCRIPTION	ITEM
FRACTIONS : 1/32 X.II ± 0.015 X.III ± 0.005	GENERAL AMERICAN RESEARCH DIVISION GENERAL AMERICAN TRANSPORTATION CORPORATION 7448 NORTH WATCHEZ AVENUE MILES, ILLINOIS 60048 312/647-9000	GATX	
ANGULAR ± 1/2° R	PIVOT-CAM FOLLOWER TUNIJEL CONVEYOR		
WT.	SCALE	A	1623-38
FINISH	DRAIN	CHECKED	APPROVED
TREATMENT	STL.		
MATERIAL	YP	RA	IN
	TS	IN	IN
	EL2		
NEXT ASSEMBLY	NO. RECD		
			SHEET

DIETZGEN 1904

LTR	REVISIONS	DATE	APPR
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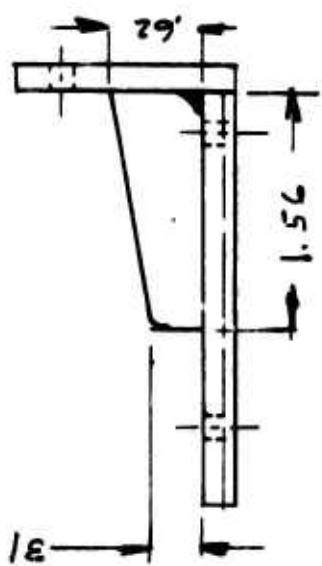
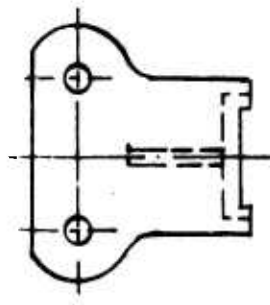
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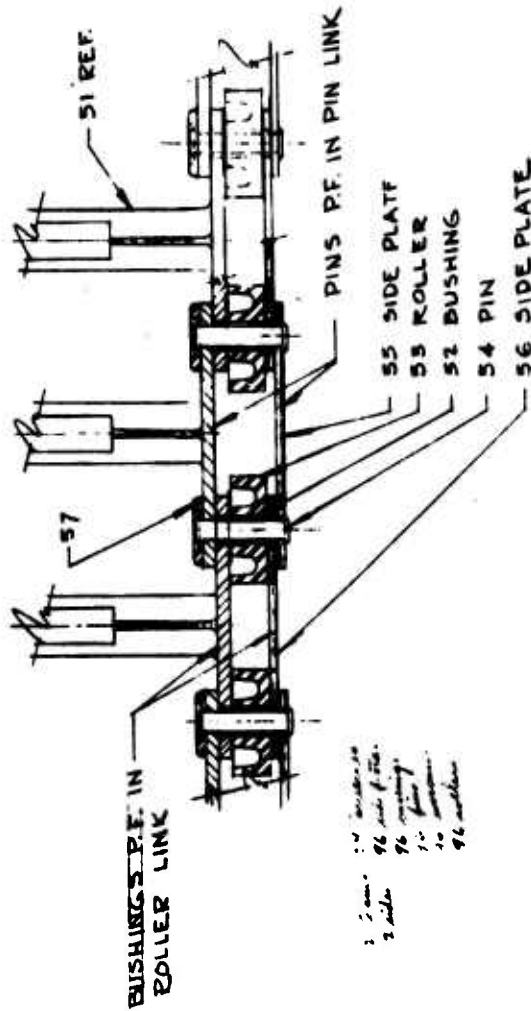
144 REQD.

CITY REC'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM
FRACTIONS : 1/32		DRAWN		GENERAL AMERICAN TRANSPORTATION CORPORATION		SHEET
X.II ± 0.015		CHECKED		GENERAL AMERICAN RESEARCH DIVISION		
X.III ± 0.005		APPROVED		7448 NORTH MATCHEZ AVE. NILES IL 60648 312/647-8000		
ANGULAR : 1/2°		MATERIAL		PIN		
R		STL		TUNNEL CONVEYOR CHAIN		
NO. REC'D		SCALE		A		
NEXT ASSEMBLY		SCALE		16 23 - 39		

DIETZEN 1004

	REVISIONS	DATE	APPR
LTR			
		<p style="font-size: 2em; margin: 0;">ZD REQD</p>	
<p style="font-size: 1.2em; margin: 0;">SEE DWG 1623 33 & 34 FOR DIM. NOT SHOWN</p>		<p style="font-size: 0.8em; margin: 0;">CITY REC'D</p> <p style="font-size: 0.8em; margin: 0;">FRAXIONS : 1/32</p> <p style="font-size: 0.8em; margin: 0;">X.XI ± 0.015</p> <p style="font-size: 0.8em; margin: 0;">X.XII ± 0.005</p> <p style="font-size: 0.8em; margin: 0;">ANGULAR : 1/2</p>	<p style="font-size: 0.8em; margin: 0;">DWG OR PART NO.</p> <p style="font-size: 1.5em; font-weight: bold; margin: 0;">GATX</p> <p style="font-size: 0.8em; margin: 0;">GENERAL AMERICAN TRANSPORTATION CORPORATION GENERAL AMERICAN RESEARCH DIVISION 7448 NORTH MATCHEZ AVE NILES IL 60048 312/647-9000</p>
<p style="font-size: 0.8em; margin: 0;">FINISH</p> <p style="font-size: 0.8em; margin: 0;">TREATMENT</p> <p style="font-size: 0.8em; margin: 0;">MATERIAL ALUM</p>	<p style="font-size: 0.8em; margin: 0;">NO. REC'D</p> <p style="font-size: 0.8em; margin: 0;">NEXT ASSEMBLY</p>	<p style="font-size: 0.8em; margin: 0;">DRAWN</p> <p style="font-size: 0.8em; margin: 0;">CHECKED</p> <p style="font-size: 0.8em; margin: 0;">APPROVED</p>	<p style="font-size: 0.8em; margin: 0;">SCALE</p> <p style="font-size: 1.5em; font-weight: bold; margin: 0;">A</p> <p style="font-size: 1.5em; font-weight: bold; margin: 0;">1623-40</p>
<p style="font-size: 0.8em; margin: 0;">ITEM</p>		<p style="font-size: 0.8em; margin: 0;">TITILE OR DESCRIPTION</p> <p style="font-size: 1.2em; font-weight: bold; margin: 0;">CROSS BAR END WELDMENT TUNNEL CONVEYOR CHAIN</p>	
<p style="font-size: 0.8em; margin: 0;">SHEET</p>		<p style="font-size: 0.8em; margin: 0;">SHEET</p>	

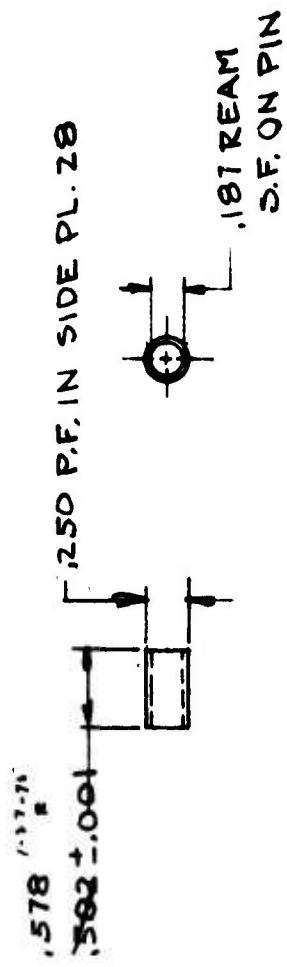
DIETZEN 1084



3 Pins
2 rollers
2 rollers
96 pins of roller
96 pins of roller
96 pins of roller
96 pins of roller

PART		TITLE OR DESCRIPTION	
PART NUMBER		GENERAL TRANSPORTATION CORPORATION	
GENERAL		GENERAL AIRCRAFT RESEARCH DIVISION	
17		748 NORTH HATFIELD AVE. WILMINGTON, DEL. 19380	
18		DATE: 3/15/50	
19		SCALE: B 1623-50	
20		BY: [Signature]	
21		CHECKED: [Signature]	
22		APPROVED: [Signature]	
23		DRAWN: [Signature]	
24		PART NUMBER: 1623-50	
25		PART DESCRIPTION: CONTAINER CONVEYOR CHAIN DET.	
26		SCALE: B	
27		BY: [Signature]	
28		CHECKED: [Signature]	
29		APPROVED: [Signature]	
30		DRAWN: [Signature]	
31		DATE: 3/15/50	
32		SCALE: B 1623-50	
33		BY: [Signature]	
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35		APPROVED: [Signature]	
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38		SCALE: B 1623-50	
39		BY: [Signature]	
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45		BY: [Signature]	
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51		BY: [Signature]	
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63		BY: [Signature]	
64		CHECKED: [Signature]	
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81		BY: [Signature]	
82		CHECKED: [Signature]	
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84		DRAWN: [Signature]	
85		DATE: 3/15/50	
86		SCALE: B 1623-50	
87		BY: [Signature]	
88		CHECKED: [Signature]	
89		APPROVED: [Signature]	
90		DRAWN: [Signature]	
91		DATE: 3/15/50	
92		SCALE: B 1623-50	
93		BY: [Signature]	
94		CHECKED: [Signature]	
95		APPROVED: [Signature]	
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146		SCALE: B 1623-50	
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151		DATE: 3/15/50	
152		SCALE: B 1623-50	
153		BY: [Signature]	
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158		SCALE: B 1623-50	
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164		SCALE: B 1623-50	
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174		DRAWN: [Signature]	
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176		SCALE: B 1623-50	
177		BY: [Signature]	
178		CHECKED: [Signature]	
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184		CHECKED: [Signature]	
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200		SCALE: B 1623-50	

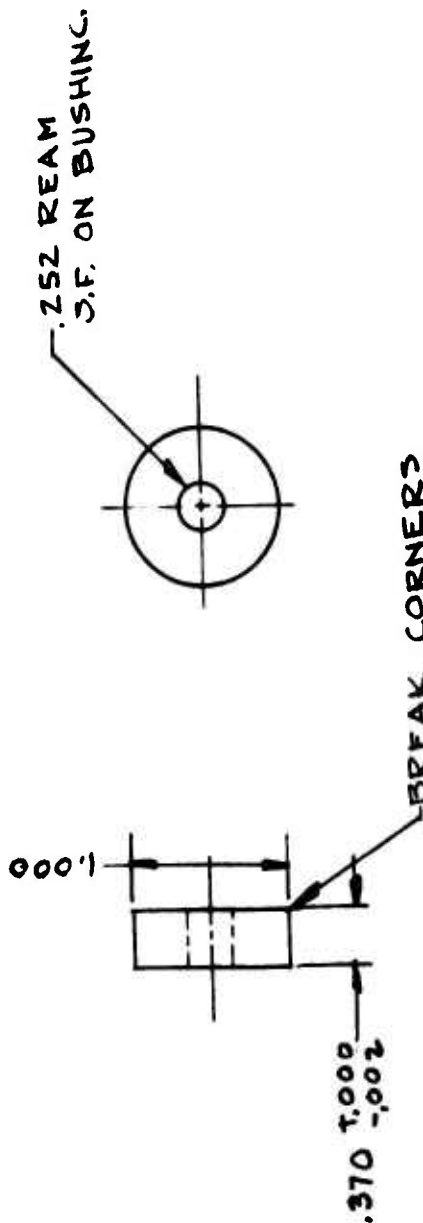
LTR	REVISIONS	DATE	APPR
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96 REQD.

QTY. REC'D		DWG OR PART NO.	TITLE OR DESCRIPTION	ITEM
FRAXIONS : 1/32		GENERAL AMERICAN RESEARCH DIVISION GATX		
X.XI ± 0.015		GENERAL AMERICAN TRANSPORTATION CORPORATION		
X.XIX ± 0.005		7408 NORTH WATCHEZ AVENUE		
ANGULAR : 1/2°		MILES, ILLINOIS 60048 312-647-0000		
R 12-23-74		BUSHING		
STL. TUBE		TUNNEL CONVEYOR CHAIN		
YP	NA	WT.	A	SCALE
TS	RM	1623 - 52		
EL2	RM	SHEET		
NEXT ASSEMBLY		NO. REC'D		
		APPROVED		
		DRAWN		
		CHECKED		
		FINISH		
		TREATMENT		

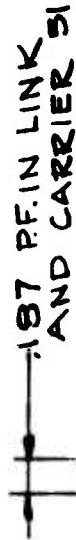
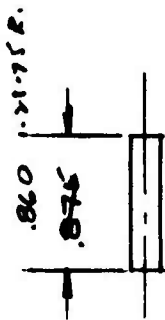
LTR	REVISIONS	DATE	APPR
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96 REQD

CITY REC'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM	
FINISH		FRACTIONS : 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		GENERAL AMERICAN TRANSPORTATION CORPORATION	
TREATMENT		X.IX : 0.015		GENERAL AMERICAN RESEARCH DIVISION		GENERAL AMERICAN RESEARCH DIVISION	
MATERIAL		X.IX : 0.005		7448 NORTH MATCHEZ AVE. NILES, IL 60048		7448 NORTH MATCHEZ AVE. NILES, IL 60048	
STL.		ANGULAR : 1/2		ROLLER		CONTAINER CONVEYOR CHAIN	
IP	RA	DR	DR	WT.	A 1623-53		
TS	RM	CH	CH	SCALE	SHEET		
EL2	RM	AP	AP				
NO. REC'D							

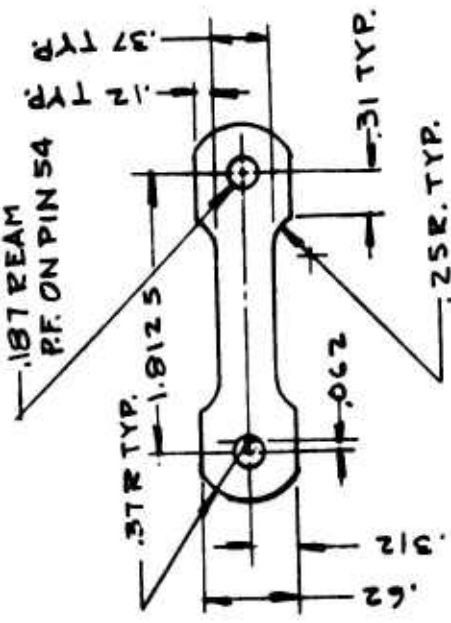
LTR	REVISIONS	DATE	APPR
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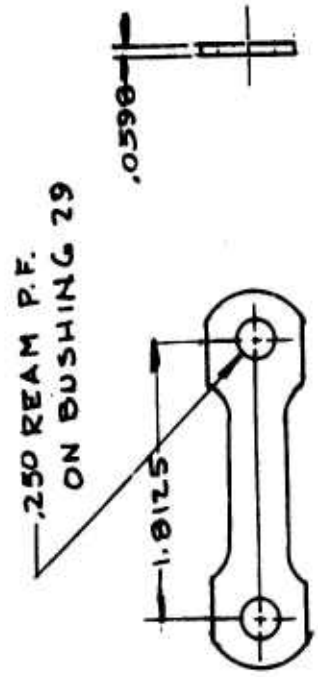
96 REQD.

CITY		SIZE	DWG OR PART NO.	TITLE OR DESCRIPTION	ITEM
NO. REC'D					
FINISH		GENERAL AMERICAN TRANSPORTATION CORPORATION GENERAL AMERICAN RESEARCH DIVISION 7448 NORTH MATCHEZ AVE. NILES, IL 60048 312/647-8000			
TREATMENT		GATX			
MATERIAL		PIN CONTAINER CONVEYOR CHAIN			
FRACTIONS : 1/32	X.II : 0.015	WT.		SCALE	
X.XIX : 0.005	ANGULAR : 1/2"	A		1623-54	
R	R	12-26-74		SHEET	
YF	DA	DRAWN			
TS	RM	CHECKED			
EL2	RM	APPROVED			
NO. REC'D					
NEXT ASSEMBLY					

LTR		REVISIONS		DATE	APPR
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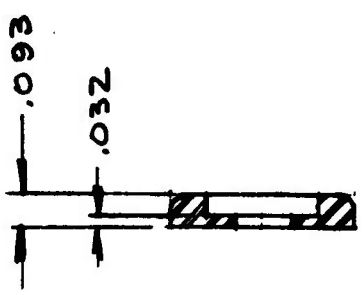
DET. 55
48 REQD



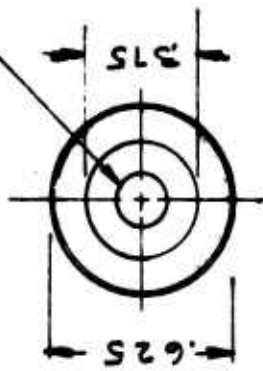
DET. 56
48 REQD

QTY REC'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM	
FRACTIONS : 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		CHAIN SIDE PLATES		SHEET	
X.IX : 0.015		GENERAL AMERICAN RESEARCH DIVISION		CONTAINER CHAIN		BUSHING	
X.IXX : 0.005		7448 NORTH HATCHEZ AVE NILES, IL 60048		SCALE		A 1623 - 55 & 56	
ANGULAR : 1/2		R		WT.		A	
R		12-26-74		SCALE		A	
FINISH		MATERIAL		STL.		NO. REC'D	
TREATMENT		TP		RA		NEXT ASSEMBLY	
MATERIAL		TB		BH		NO.	
TP		EL2		BH		NO.	
TB		APPROVED		APPROVED		NO.	
EL2		APPROVED		APPROVED		NO.	
BH		APPROVED		APPROVED		NO.	

LTR	REVISIONS	DATE	APPR
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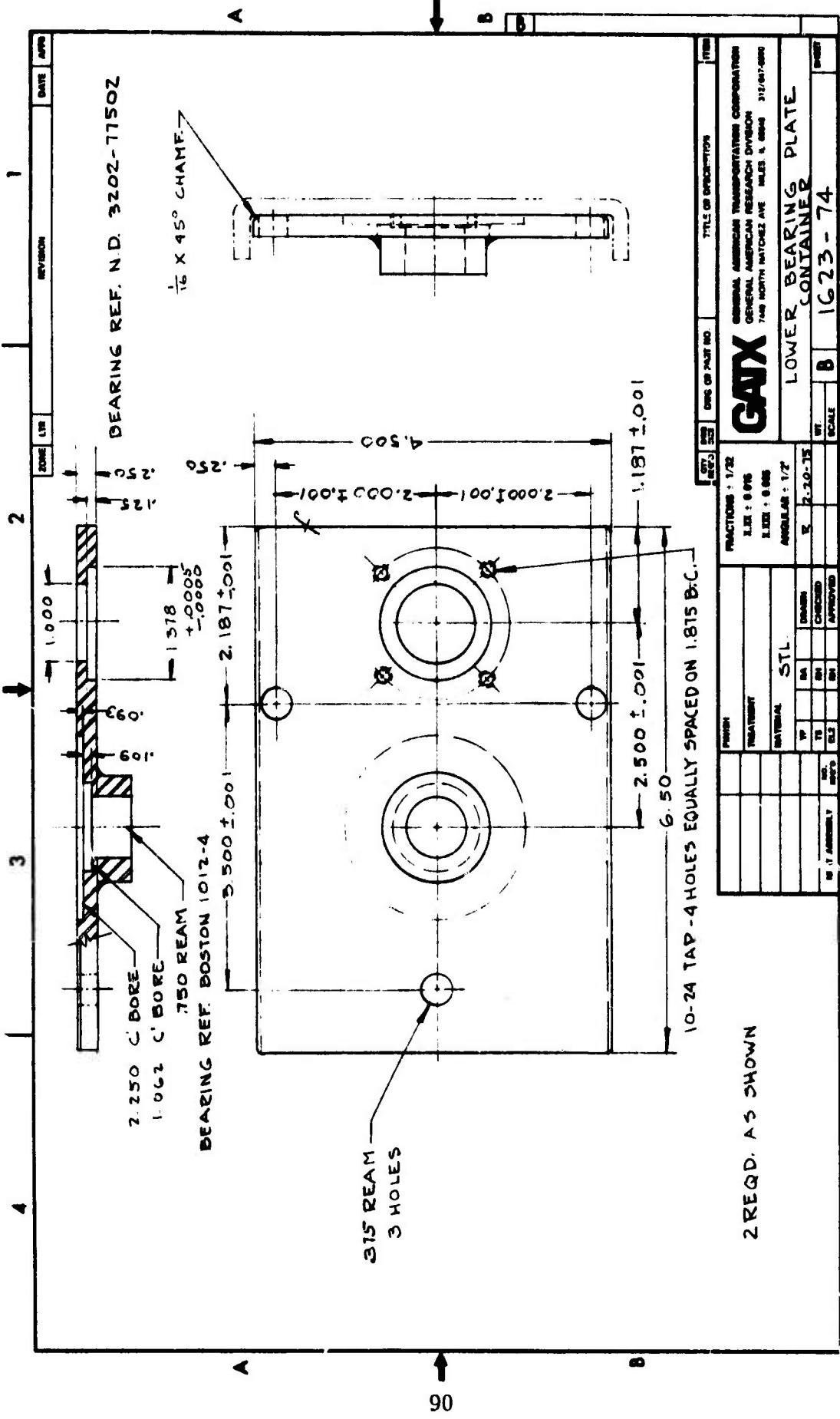
.184 REAM



ACTUAL SIZE

100 REQD.

QTY. REQ'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM
100				WASHER CONTAINER CONVEYOR CHAIN		SHEET
FINISH		FRACTIONS : 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		
TREATMENT		X.IX : 0.015		GENERAL AMERICAN RESEARCH DIVISION		
MATERIAL		X.XXX : 0.005		7449 NORTH MATCHEZ AVE. NILES, IL. 60548		312/647-8000
STEEL		ANGULAR : 1/2"		SCALE 2-1/2" = 1"		623-57
YP	RA	DRAIN	R	WT.		
TS	BH	CHECKED		SCALE 2-1/2" = 1"		
EL2	BN	APPROVED				
NEXT ASSEMBLY	NO. REQ'D					



REV.	DATE	APP.

ZONE	REV.	DATE	APP.

REV.	DATE	APP.	DESCRIPTION

FRACCTIONS: 1/32	FLER: 0.015	ANGULAR: 1/2
LKER: 0.005		

DATE	BY	CHECKED	APPROVED
7-20-75			

NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS

NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS

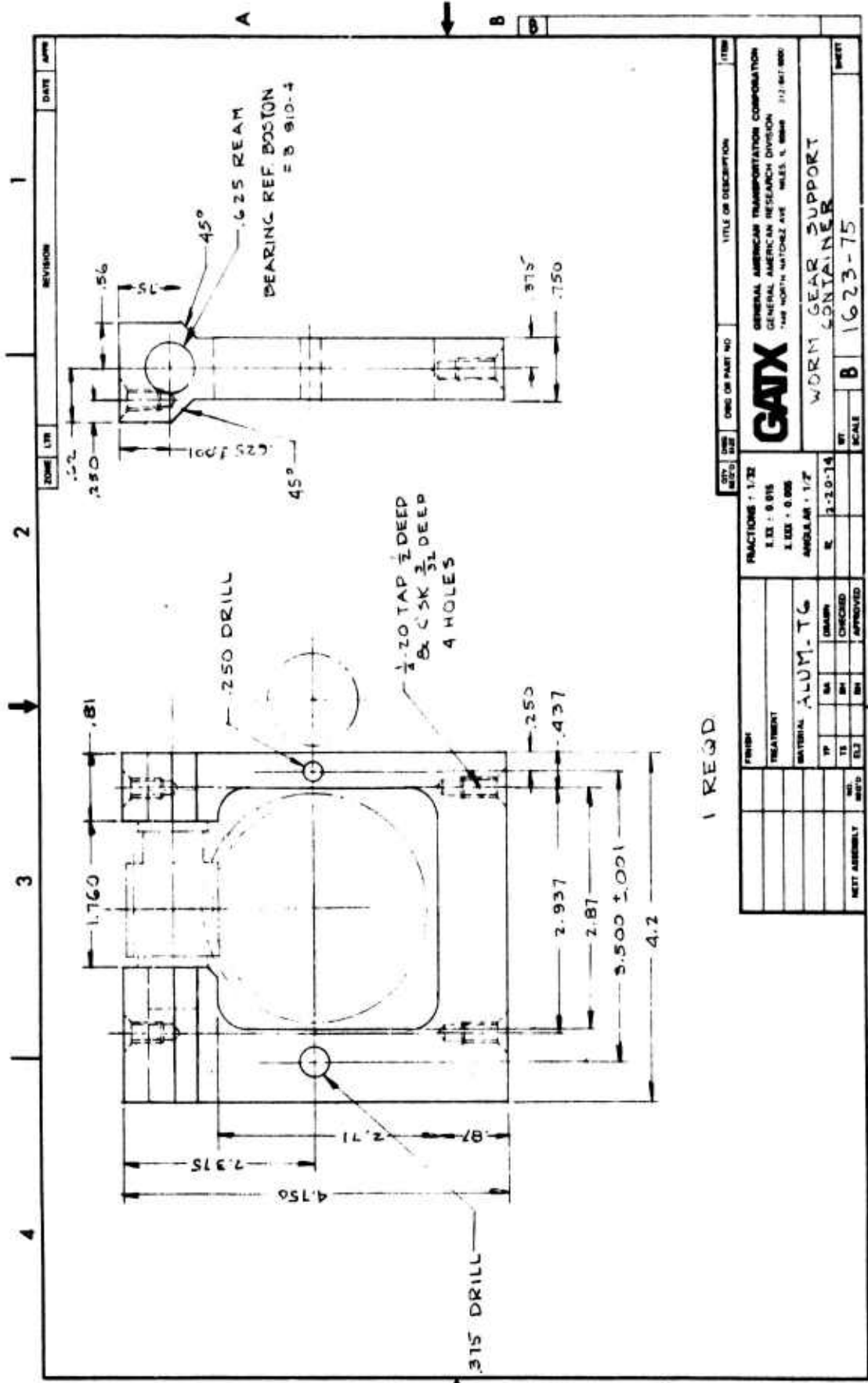
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NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS

NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS

NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS

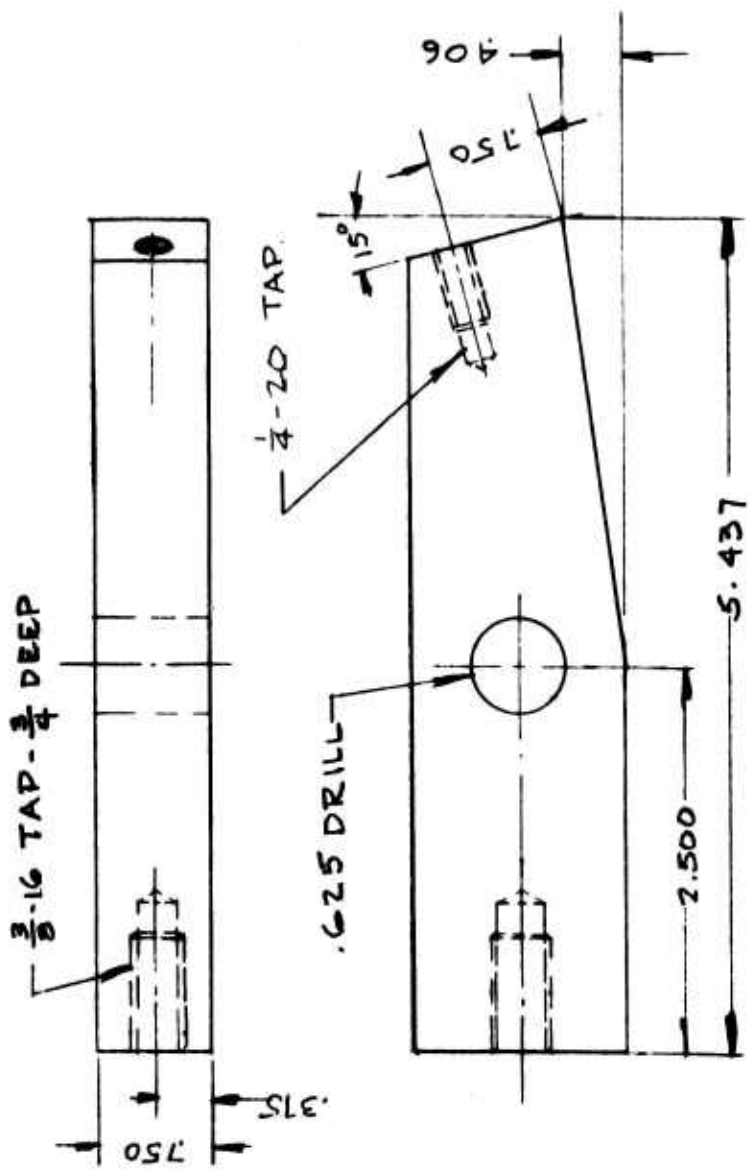
NO. OF ASSEMBLY	NO. OF PARTS	NO. OF HOLES	NO. OF TAPS



1 RECD

DATE	REVISION	ZONE	DATE	APP
TITLE OR DESCRIPTION		ITEM		
GENERAL AMERICAN TRANSPORTATION CORPORATION		GENERAL AMERICAN TRANSPORTATION CORPORATION		
GENERAL AMERICAN RESEARCH DIVISION		GENERAL AMERICAN RESEARCH DIVISION		
100 NORTH WATFORD AVE WELLS R. MASS		100 NORTH WATFORD AVE WELLS R. MASS		
SCALE		WT		
B 1623-75		B 1623-75		
TITLE OR DESCRIPTION		ITEM		
WORM GEAR SUPPORT		WORM GEAR SUPPORT		
CONTAINER		CONTAINER		
SCALE		WT		
B 1623-75		B 1623-75		
TITLE OR DESCRIPTION		ITEM		
FRACTIONS: 1/32		FRACTIONS: 1/32		
DEC: 0.015		DEC: 0.015		
ANGULAR: 1/2		ANGULAR: 1/2		
SCALE		WT		
B 1623-75		B 1623-75		
TITLE OR DESCRIPTION		ITEM		
MATERIAL		MATERIAL		
ALUM. T6		ALUM. T6		
FINISH		FINISH		
TREATMENT		TREATMENT		
DRAWN		DRAWN		
CHECKED		CHECKED		
APPROVED		APPROVED		
NET ASSEMBLY		NET ASSEMBLY		
WT		WT		
B 1623-75		B 1623-75		

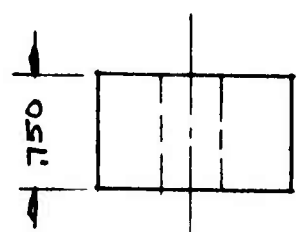
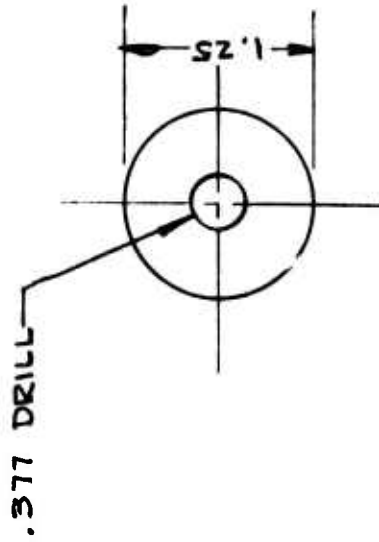
LTR		REVISIONS		DATE	APPR
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1 REQD

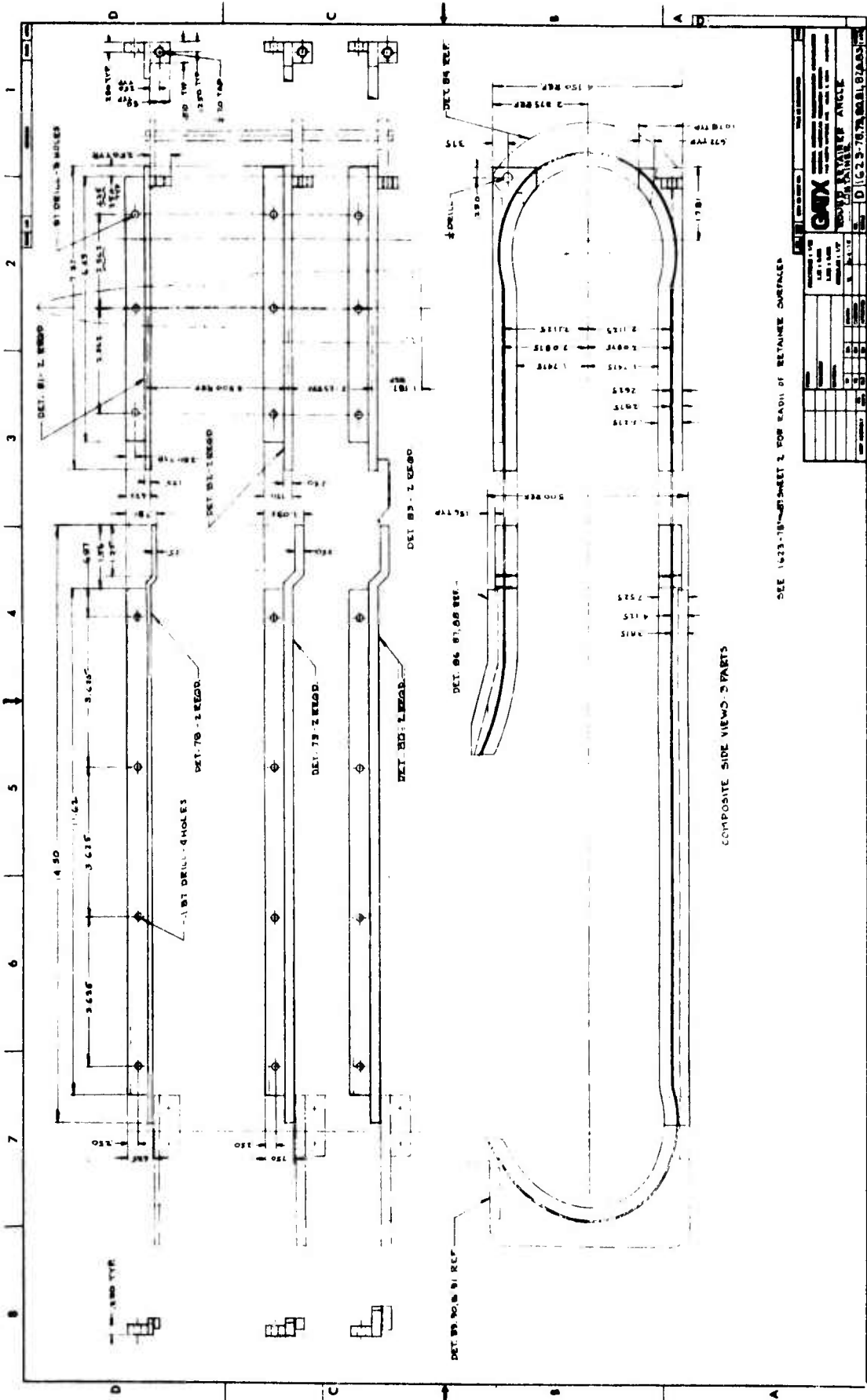
QTY REQ'D		DRG OR PART NO.		TITLE OR DESCRIPTION		ITEM	
FRACTIONS : 1/32		GAX		GENERAL AMERICAN TRANSPORTATION CORPORATION		GENERAL AMERICAN RESEARCH DIVISION	
X.XI : 0.015		GENERAL AMERICAN RESEARCH DIVISION		1-49 NORTH NATCHEZ AVE		MILES IL 60648 312/647-9000	
X.XII : 0.006		CROSS BAR CENTER CHAIN GUIDE		CONTAINER		A 1623-76	
ANGULAR : 1/2"		R		WT.		SCALE	
R		2-20-75		SHEET		SHEET	
FINISH		TREATMENT		MATERIAL		ALUM.	
Y.P.		R.A.		D.R.A.		D.R.A.	
T.S.		B.H.		C.H.K.		C.H.K.	
E.L.Z.		R.H.		A.P.R.		A.P.R.	
NEXT ASSEMBLY		NO. REQ'D		NO. REQ'D		NO. REQ'D	

LTR REVISIONS DATE APPR



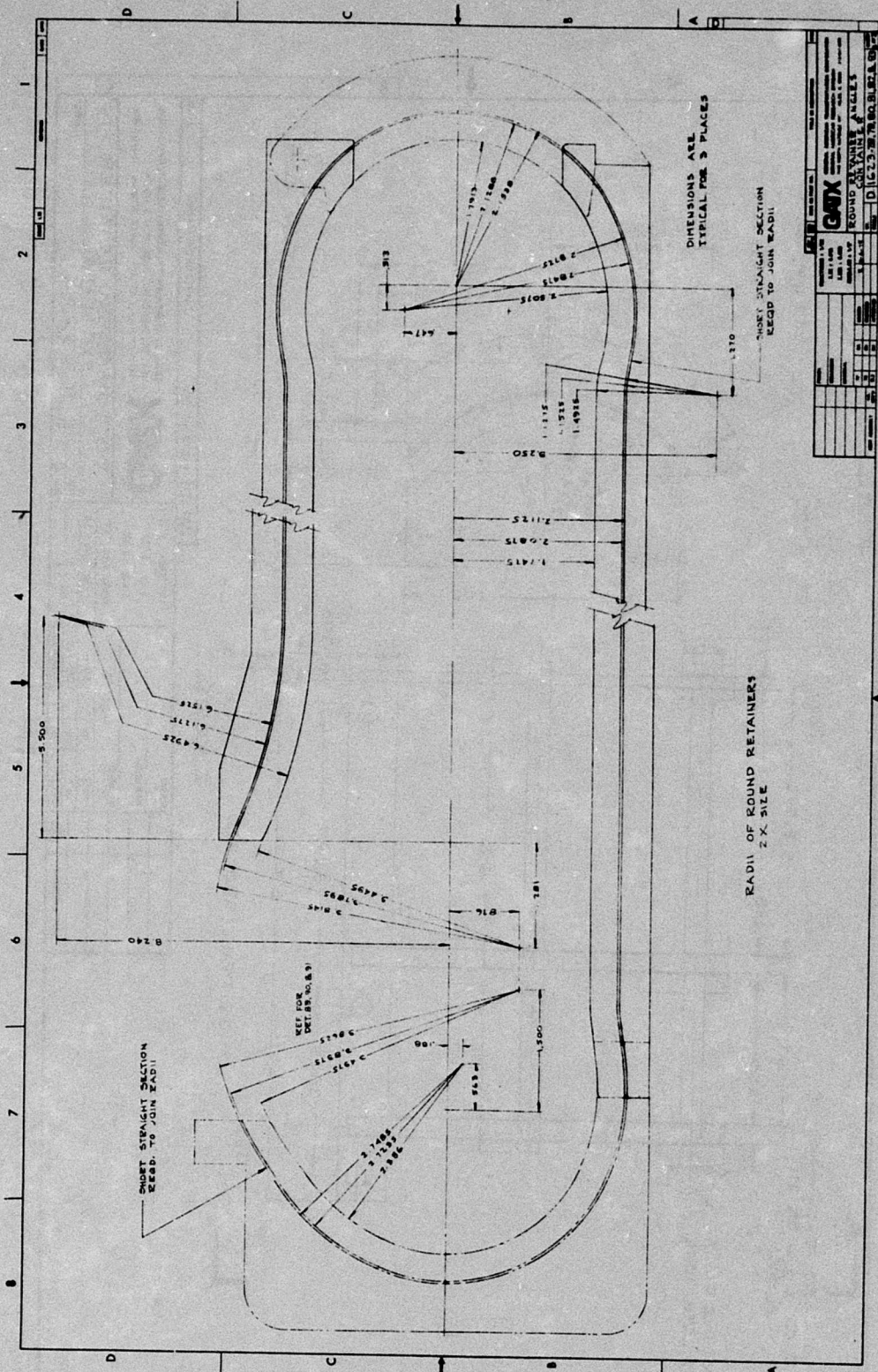
1 REQD.

QTY. REQ'D		DNG OR PART NO.		TITLE OR DESCRIPTION		ITEM
FRACOINS : 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		SPACER CENTER CHAIN GUIDE		SHEET
X.XI : 0.015		GENERAL AMERICAN RESEARCH DIVISION		CONTAINER		
X.XXX : 0.005		7448 NORTH NATCHEZ AVE. NILES IL 60048		A 1623-77		
ANGULAR : 1/2°		GATX		SCALE		
R 2-20-73		MATERIAL ALUM		WT.		
FINISH		YP		RA		
TREATMENT		TS		BH		
MATERIAL ALUM		EL2		MH		
DRAWN		CHECKED		APPROVED		
NO. REQ'D		NEXT ASSEMBLY		NO. REQ'D		

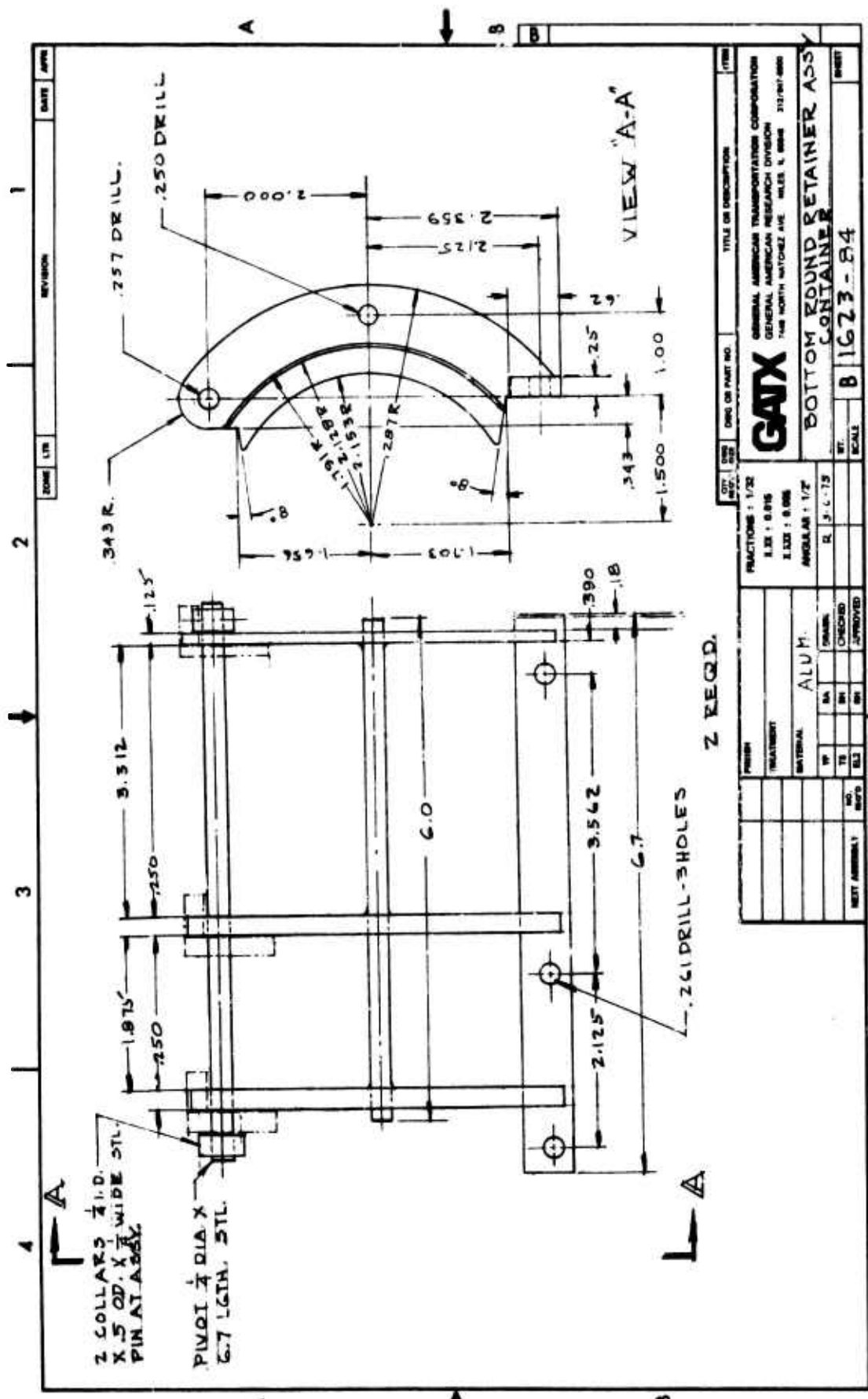


COMPOSITE SIDE VIEW - 2 PARTS

SEE 1623-18-10 SHEET 2 FOR RADII OF RETAINING SURFACES

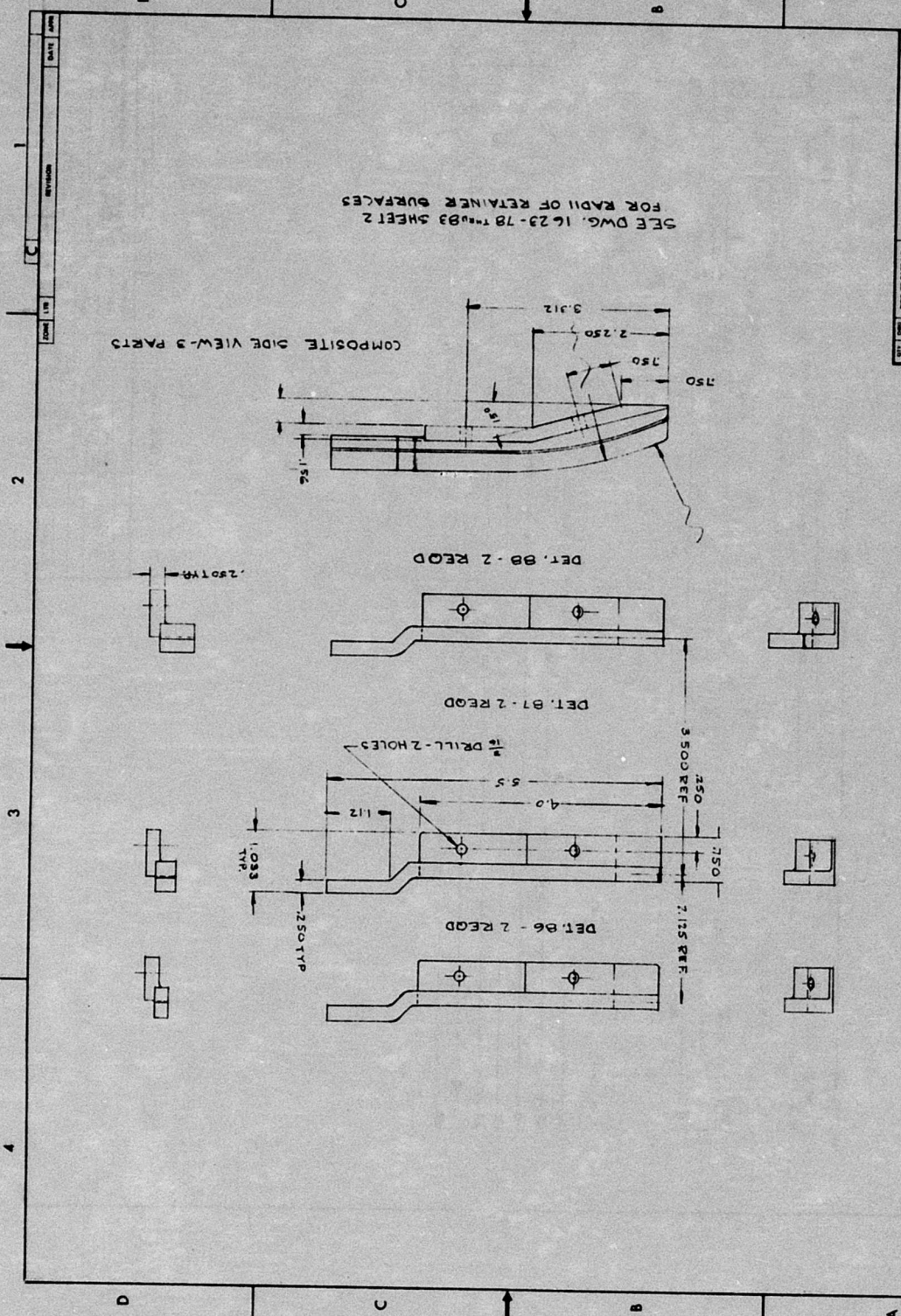


GATX	
ROUND JOINTS & RIGLES	
1.115	
1.015	
0.915	
0.815	
0.715	
0.615	
0.515	
0.415	
0.315	
0.215	
0.115	
0.015	
0.000	



REV. NO. 1
 DATE APR 1
 REVISION
 ZONE LTR
 TITLE OF DESCRIPTION
GATX
 GENERAL AMERICAN TRANSPORTATION CORPORATION
 GENERAL AMERICAN RESEARCH DIVISION
 7408 NORTH WATCHEZ AVE. WILKS, N. CAROLINA 27177-0000
BOTTOM ROUND RETAINER ASSY
CONTAINER
 WT. SCALE B 1623 - B4
 SHEET

FRAC. 1/32	FRAC. 1/32	FRAC. 1/32	FRAC. 1/32
1.32 : 0.815	1.32 : 0.815	1.32 : 0.815	1.32 : 0.815
1.32 : 0.815	1.32 : 0.815	1.32 : 0.815	1.32 : 0.815
ANGULAR : 1/2	ANGULAR : 1/2	ANGULAR : 1/2	ANGULAR : 1/2
DR. J. C. 79	DR. J. C. 79	DR. J. C. 79	DR. J. C. 79
DESIGNED	CHECKED	APPROVED	
BY SA	BY SA	BY SA	
BY TE	BY TE	BY TE	
BY EL	BY EL	BY EL	
BY IN	BY IN	BY IN	
BY AP	BY AP	BY AP	
BY ME	BY ME	BY ME	
BY AS	BY AS	BY AS	
BY OT	BY OT	BY OT	
BY DR	BY DR	BY DR	
BY MA	BY MA	BY MA	
BY SC	BY SC	BY SC	
BY SW	BY SW	BY SW	
BY TL	BY TL	BY TL	
BY TR	BY TR	BY TR	
BY VA	BY VA	BY VA	
BY VE	BY VE	BY VE	
BY VI	BY VI	BY VI	
BY VJ	BY VJ	BY VJ	
BY VK	BY VK	BY VK	
BY VL	BY VL	BY VL	
BY VM	BY VM	BY VM	
BY VN	BY VN	BY VN	
BY VO	BY VO	BY VO	
BY VP	BY VP	BY VP	
BY VQ	BY VQ	BY VQ	
BY VR	BY VR	BY VR	
BY VS	BY VS	BY VS	
BY VT	BY VT	BY VT	
BY VU	BY VU	BY VU	
BY VV	BY VV	BY VV	
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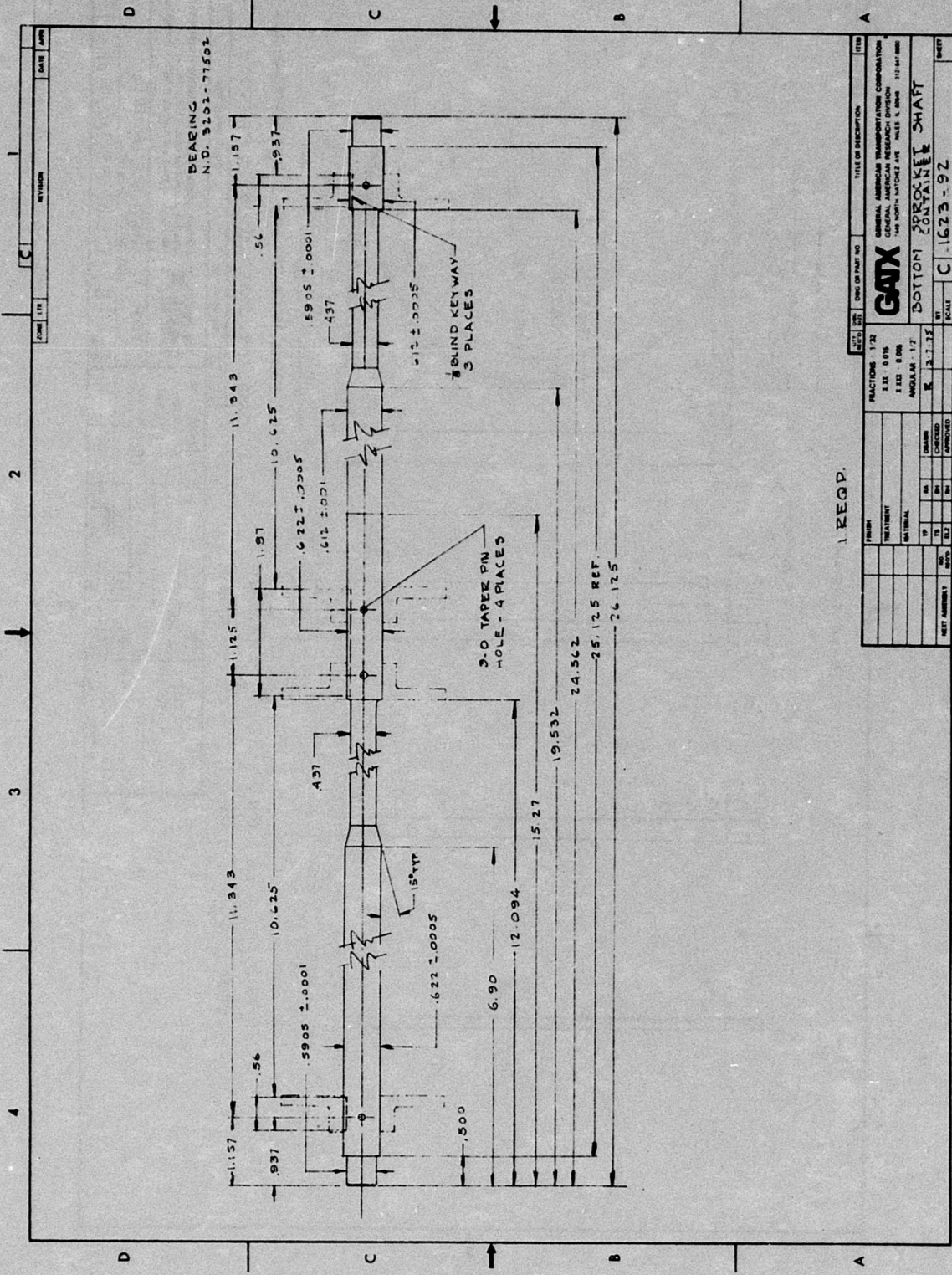


DATE	BY	REVISION
		C

PART NO.		TITLE OR DESCRIPTION	
1623-86	87	ROUND RETAINER ANGLE	88
1623-86	86	ROUND RETAINER ANGLE	87
1623-86	85	ROUND RETAINER ANGLE	86
1623-86	84	ROUND RETAINER ANGLE	85
1623-86	83	ROUND RETAINER ANGLE	84
1623-86	82	ROUND RETAINER ANGLE	83
1623-86	81	ROUND RETAINER ANGLE	82
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1623-86	79	ROUND RETAINER ANGLE	80
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1623-86	13	ROUND RETAINER ANGLE	14
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1623-86	11	ROUND RETAINER ANGLE	12
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1623-86	9	ROUND RETAINER ANGLE	10
1623-86	8	ROUND RETAINER ANGLE	9
1623-86	7	ROUND RETAINER ANGLE	8
1623-86	6	ROUND RETAINER ANGLE	7
1623-86	5	ROUND RETAINER ANGLE	6
1623-86	4	ROUND RETAINER ANGLE	5
1623-86	3	ROUND RETAINER ANGLE	4
1623-86	2	ROUND RETAINER ANGLE	3
1623-86	1	ROUND RETAINER ANGLE	2

GENERAL AMERICAN TRANSPORTATION CORPORATION
 GENERAL AMERICAN RESEARCH DIVISION
 1400 W. MICHIGAN AVE. WEEHAWKEN, N.J. 07094

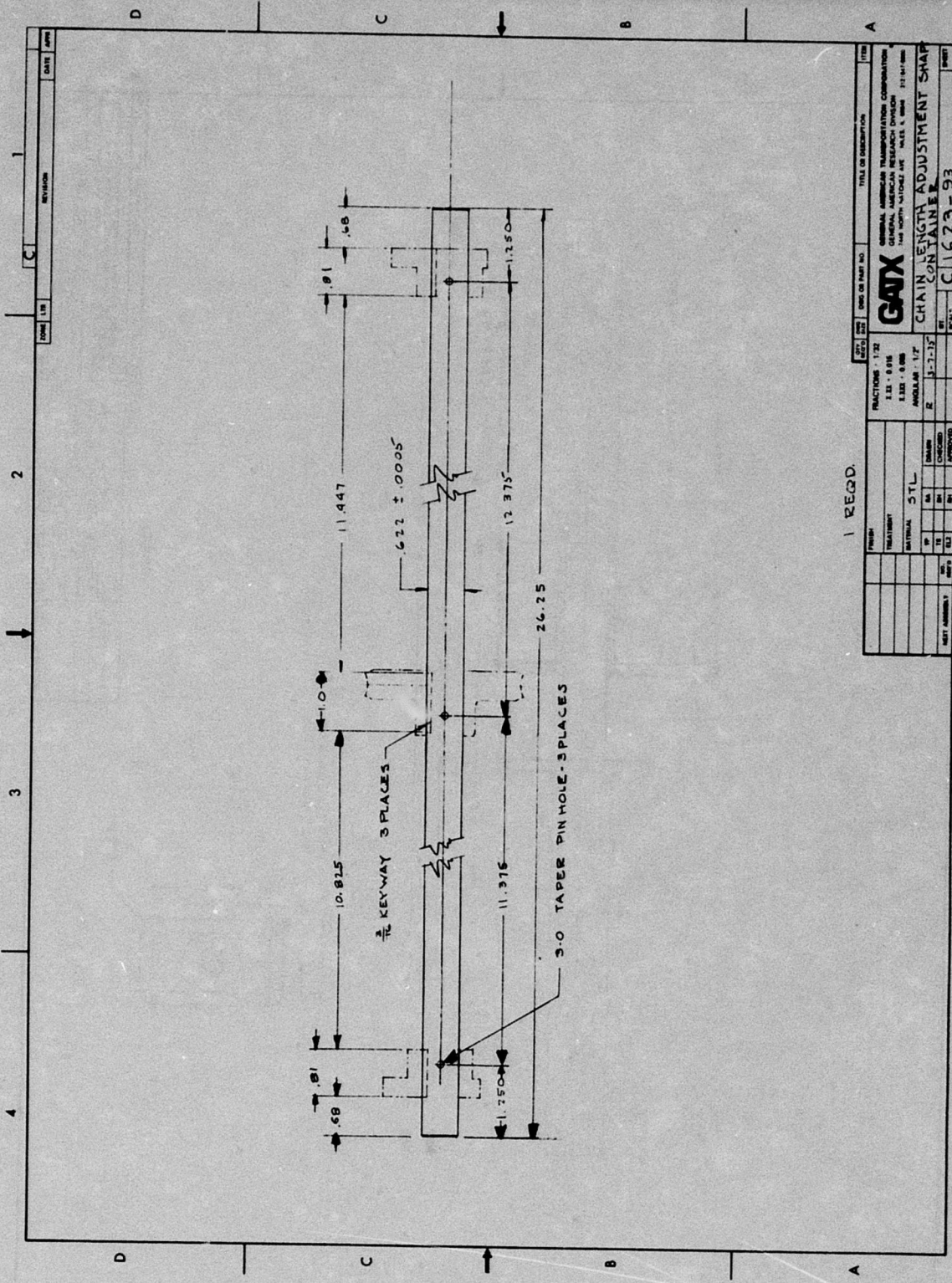
SCALE: C 1623-86, 87, 88



100

1 REQP.

FIG. NO.	100	TITLE OR DESCRIPTION	BOTTOM BRACKET SHAFT
REV. NO.		DATE	
DESIGNER		SCALE	C 1:625 - 92
CHECKED		APPROVED	
DRAWN			
MATERIAL			
TREATMENT			
FINISH			
FRACCTIONS	1/2		
1/16	0.015		
1/32	0.008		
ANGLES	1/2		
R	3.175		
NET AMOUNT	100		
NO.	100		
DATE			
BY			
CHECKED			
APPROVED			
GENERAL AMERICAN TRANSPORTATION CORPORATION			
100 NORTH AVENUE, NEW YORK, N. Y.			

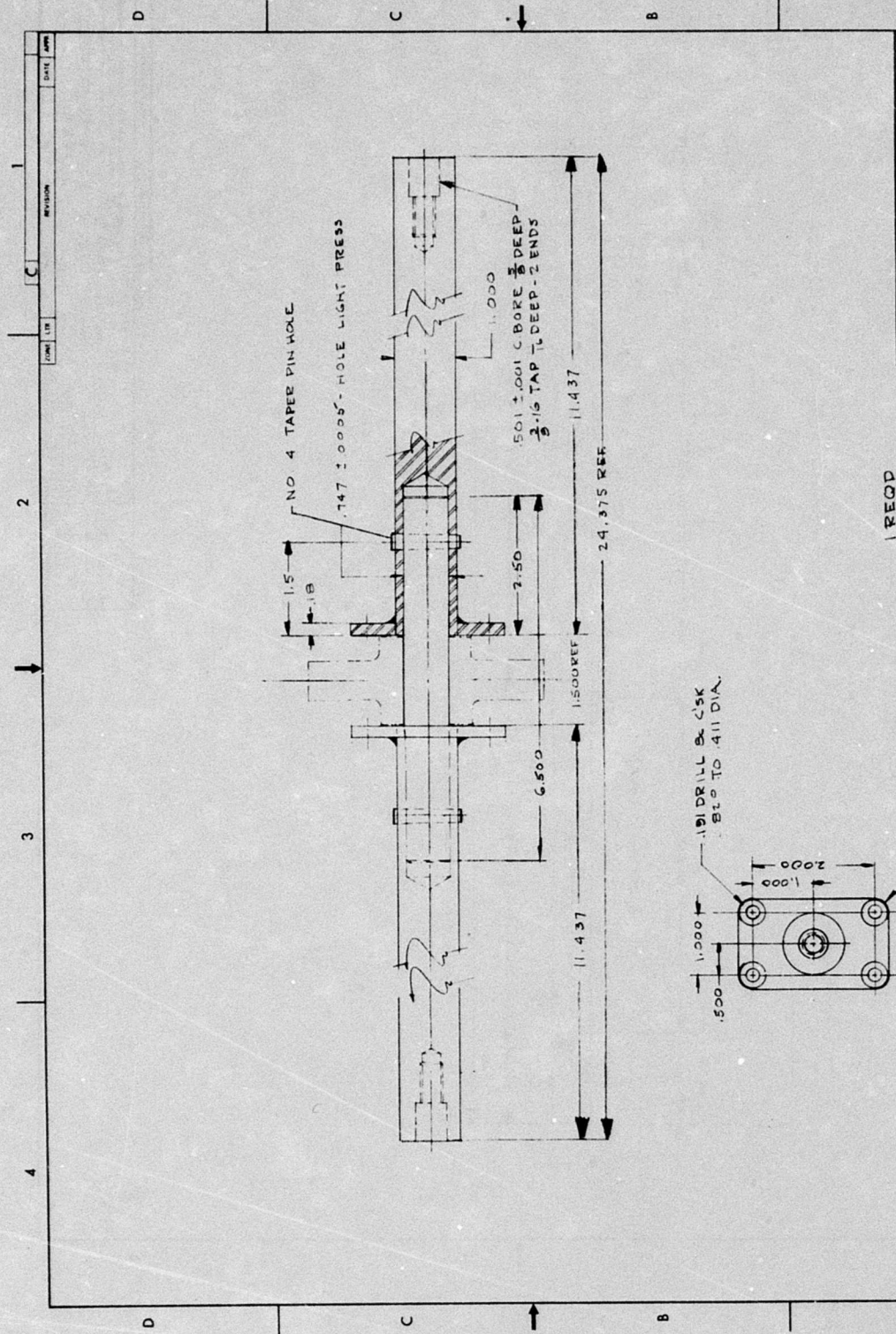


DATE	REVISED

1 REQD.

PROJ. NO.		QUANTITY	172	TITLE OR DESCRIPTION	
TREATMENT		FRACCTIONS	172	GENERAL AMERICAN TRANSPORTATION CORPORATION	
MATERIAL	STL	1.13	0.018	GENERAL AMERICAN RESEARCH DIVISION	
NO.		1.33	0.008	1400 NORTH WATKINS AVE. WALKER, ILL.	11-21-58
BY		APPROVAL	17	CHAIN LENGTH ADJUSTMENT SHAFT	
CHKD		DATE	3-7-57	CONTAINER	
APP'D		BY			
REV'D		APPROVED			
NO. OF SHEETS	1				
SHEET NO.	1				

C 1623-93

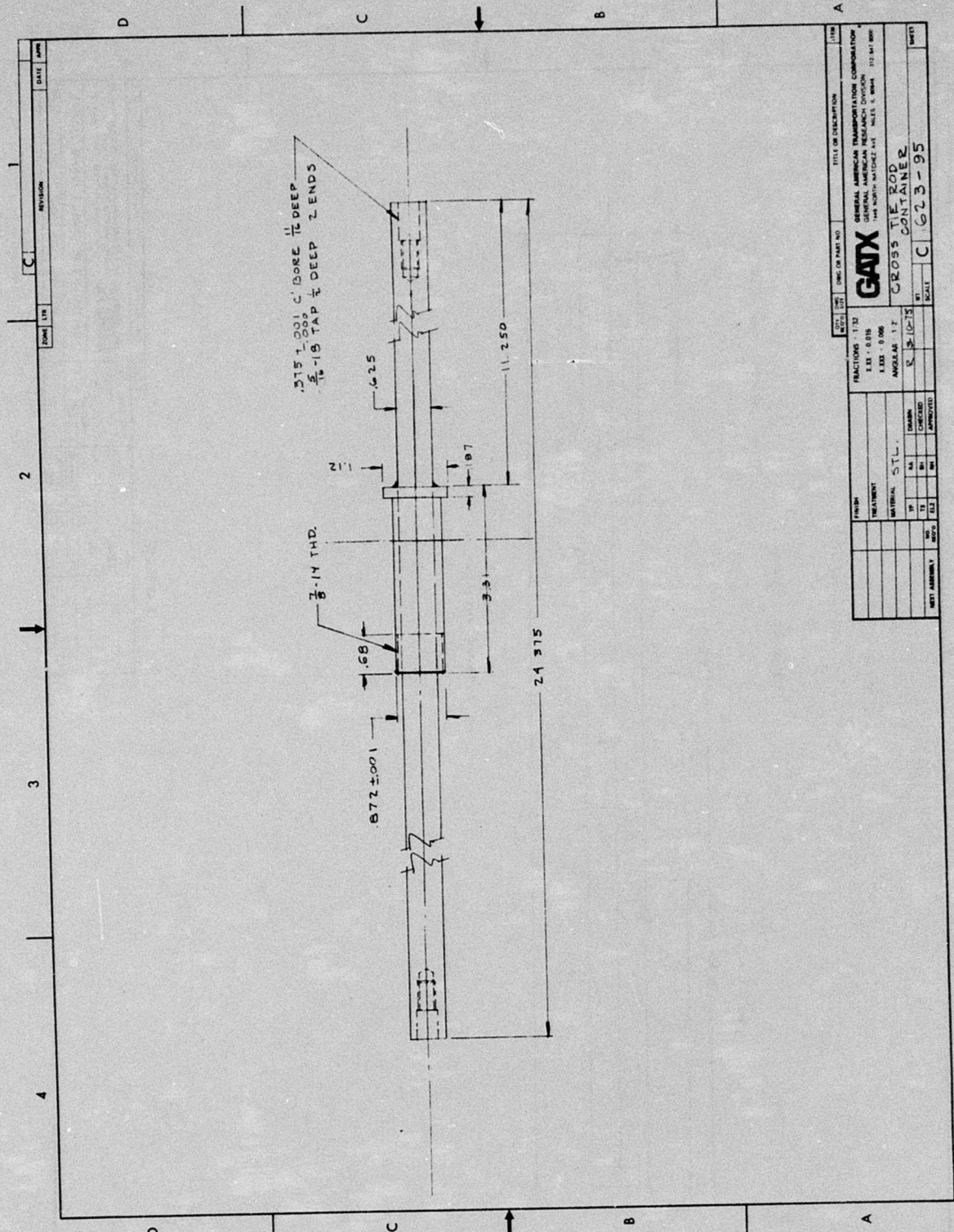


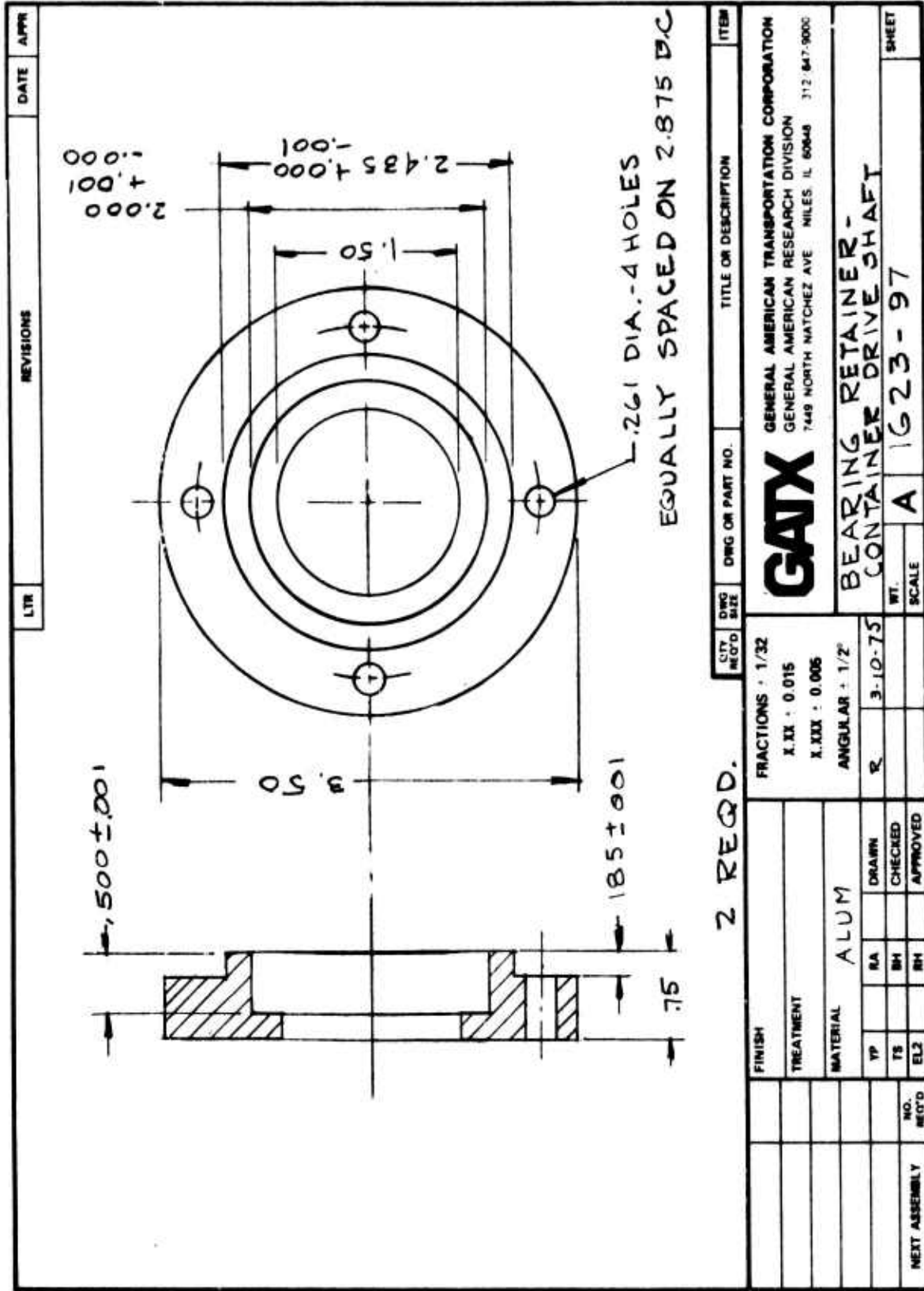
REV. NO.		REV. DATE		REV. BY		REV. APPR.	
1		11/1/54		J. L. BROWN		J. L. BROWN	
2		11/1/54		J. L. BROWN		J. L. BROWN	
3		11/1/54		J. L. BROWN		J. L. BROWN	
4		11/1/54		J. L. BROWN		J. L. BROWN	
5		11/1/54		J. L. BROWN		J. L. BROWN	
6		11/1/54		J. L. BROWN		J. L. BROWN	
7		11/1/54		J. L. BROWN		J. L. BROWN	
8		11/1/54		J. L. BROWN		J. L. BROWN	
9		11/1/54		J. L. BROWN		J. L. BROWN	
10		11/1/54		J. L. BROWN		J. L. BROWN	
11		11/1/54		J. L. BROWN		J. L. BROWN	
12		11/1/54		J. L. BROWN		J. L. BROWN	
13		11/1/54		J. L. BROWN		J. L. BROWN	
14		11/1/54		J. L. BROWN		J. L. BROWN	
15		11/1/54		J. L. BROWN		J. L. BROWN	
16		11/1/54		J. L. BROWN		J. L. BROWN	
17		11/1/54		J. L. BROWN		J. L. BROWN	
18		11/1/54		J. L. BROWN		J. L. BROWN	
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21		11/1/54		J. L. BROWN		J. L. BROWN	
22		11/1/54		J. L. BROWN		J. L. BROWN	
23		11/1/54		J. L. BROWN		J. L. BROWN	
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90		11/1/54		J. L. BROWN		J. L. BROWN	
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92		11/1/54		J. L. BROWN		J. L. BROWN	
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99		11/1/54		J. L. BROWN		J. L. BROWN	
100		11/1/54		J. L. BROWN		J. L. BROWN	

1 REQD

FRACCTIONS - 1:32		L.E. - 0.015		L.E. - 0.006		ANGULAR - 1:7	
TREATMENT		CENTRE PIN		RC-SB		MATERIAL	
STL		STL		STL		STL	
DRY		DRY		DRY		DRY	
CHECKED		CHECKED		CHECKED		CHECKED	
APPROVED		APPROVED		APPROVED		APPROVED	
NO. REQD		NO. REQD		NO. REQD		NO. REQD	
1		1		1		1	
DATE		DATE		DATE		DATE	
11/1/54		11/1/54		11/1/54		11/1/54	
BY		BY		BY		BY	
J. L. BROWN		J. L. BROWN		J. L. BROWN		J. L. BROWN	
SCALE		SCALE		SCALE		SCALE	
C 16 23 - 94		C 16 23 - 94		C 16 23 - 94		C 16 23 - 94	
SHEET		SHEET		SHEET		SHEET	
1		1		1		1	

END VIEW





CITY REQ'D	DWG SIZE	DWG OR PART NO.	TITLE OR DESCRIPTION
			GENERAL AMERICAN TRANSPORTATION CORPORATION GENERAL AMERICAN RESEARCH DIVISION 7449 NORTH NATCHEZ AVE NILES, IL 60048 312.847.9000
<p style="text-align: center;">GATX</p>			BEARING RETAINER - CONTAINER DRIVE SHAFT
FRACTIONS : 1/32		WT.	
X.IX : 0.015		SCALE	
X.XXX : 0.005		A 1623-97	
ANGULAR : 1/2°		SHEET	
R 3-10-75			
MATERIAL ALUM			
YP	RA	DRAWN	
FS	BH	CHECKED	
EL2	BH	APPROVED	
NEXT ASSEMBLY	NO. REQ'D		

DIETZGEN 1964

LTR		REVISIONS		DATE	APPR

2.462 ± 0.001
0.50

2.37

1.3780 ± 0.001

1.196 DIA. - 4 HOLES EQUALLY
SPACED ON 1.875 B.C.

GAIX

GENERAL AMERICAN TRANSPORTATION CORPORATION
GENERAL AMERICAN RESEARCH DIVISION
7449 NORTH NATCHEZ AVE NILES IL 60648 312/647-8000

**BEARING RETAINER -
UPPER SPROCKET SHAFT - CONTAINER**

WT. SCALE
A 1623-9B

QTY REQ'D	DWG OR PART NO.	TITLE OR DESCRIPTION	ITEM

FINISH	TREATMENT	MATERIAL	YP	RA	DRAWN
		ALUM			
			TS	BH	CHECKED
			EL2	RH	APPROVED

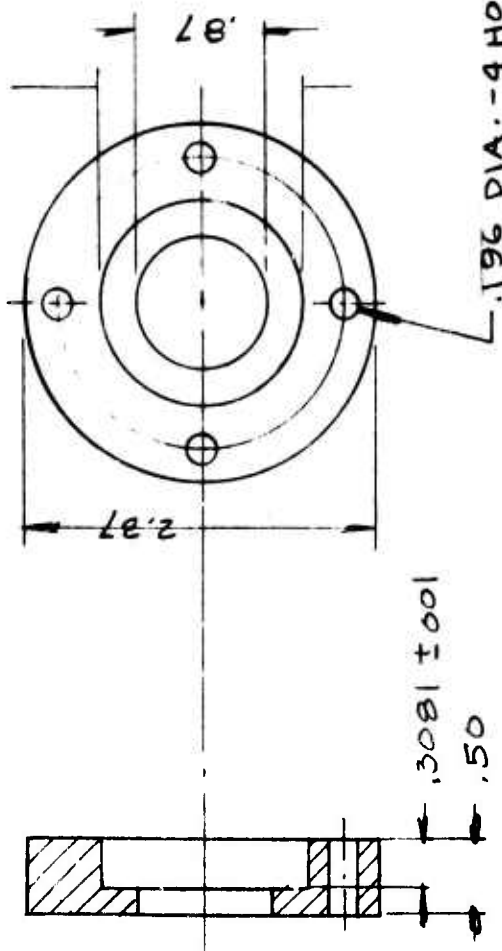
NEXT ASSEMBLY	NO. REQ'D	FRACTIONS : 1/32	R 3-10-15	WT.	SCALE	SHEET
		X.XX : 0.015				
		X.XXX : 0.005				
		ANGULAR : 1/2°				

2 REQD

DIETZGEN 188H

LTR	REVISIONS	DATE	APPR
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1.3780
+ .001
- .000

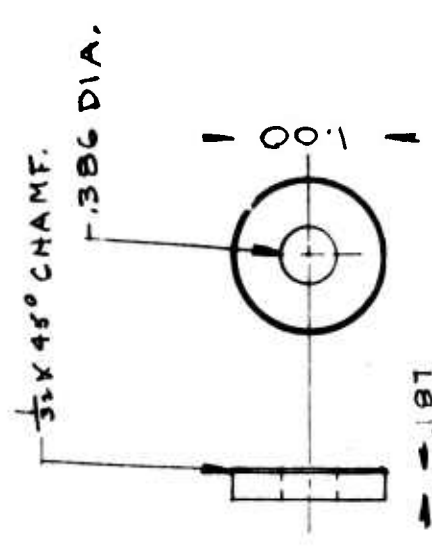


.196 DIA. - 4 HOLES EQUALLY SPACED ON 1.875 D.C.

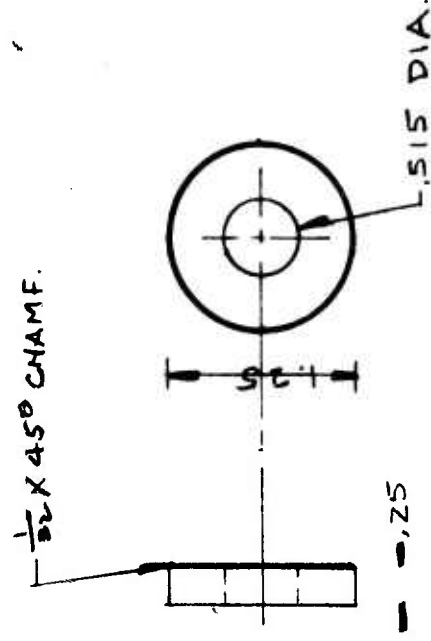
2 REQD.

DWT REQ'D		DWT OR PART NO.		TITLE OR DESCRIPTION		ITEM	
FRACTIONS : 1/32		GATX		GENERAL AMERICAN TRANSPORTATION CORPORATION			
X.XX : 0.015				GENERAL AMERICAN RESEARCH DIVISION			
X.XXX : 0.005				7449 NORTH WATCHEZ AVE NILES IL 60848		312/647-9000	
ANGULAR : 1/2°		BEARING RETAINER		LOWER SPROCKET SHAFT CONTAINER			
R 3-10-75		WT		SCALE		SHEET	
		A		1623-99			
FINISH		DRAWN		APPROVED			
TREATMENT		CHECKED		APPROVED			
MATERIAL ALUM		RH		RH			
YP		RH		RH			
TS		RH		RH			
EL2		RH		RH			
NEXT ASSEMBLY		NO. REQ'D		APPROVED			

LTR	REVISIONS	DATE	APPR
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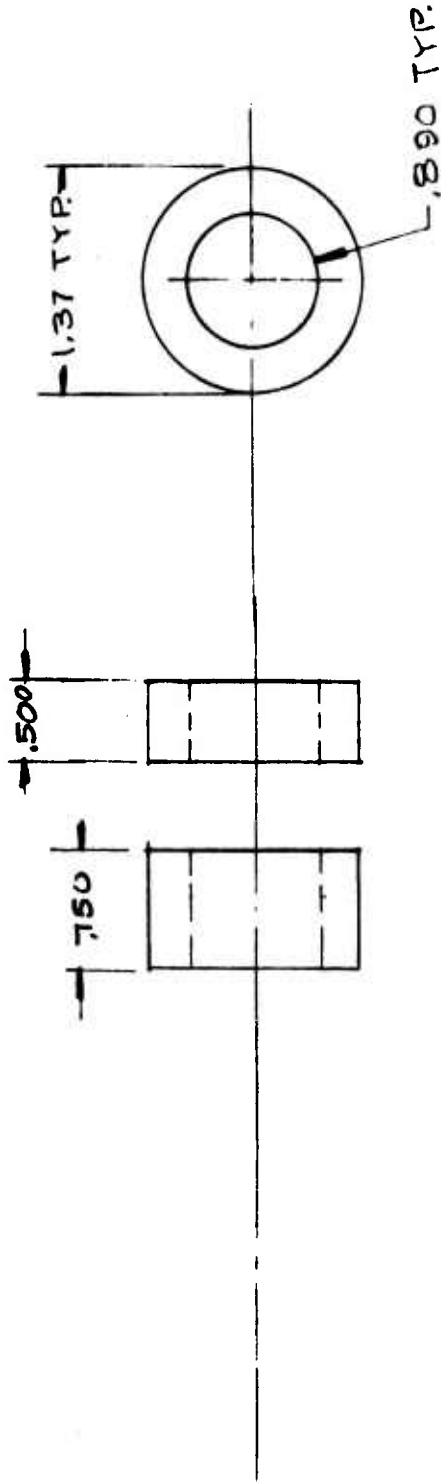
DET. 101
WASHER - CONTAINER
4 REQD.



DET. 100
WASHER - IDLER SHAFT
2 REQD.

QTY REQ'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM
FINISH		FRACTIONS ± 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		
TREATMENT		X.XI ± 0.015		GENERAL AMERICAN RESEARCH DIVISION		
MATERIAL		X.XXX ± 0.005		7449 NORTH NATCHEZ AVE NILES, IL 60648		312/647-9000
ANGULAR ± 1/2°		F 3-12-75		WASHER - IDLER SHAFT		
YP	RA	DRAWN		WASHER - CONTAINER		
TS	BM	CHECKED		A 1623-100 & 101		SHEET
EL2	RM	APPROVED		SCALE		
NEXT ASSEMBLY	NO. REQ'D					

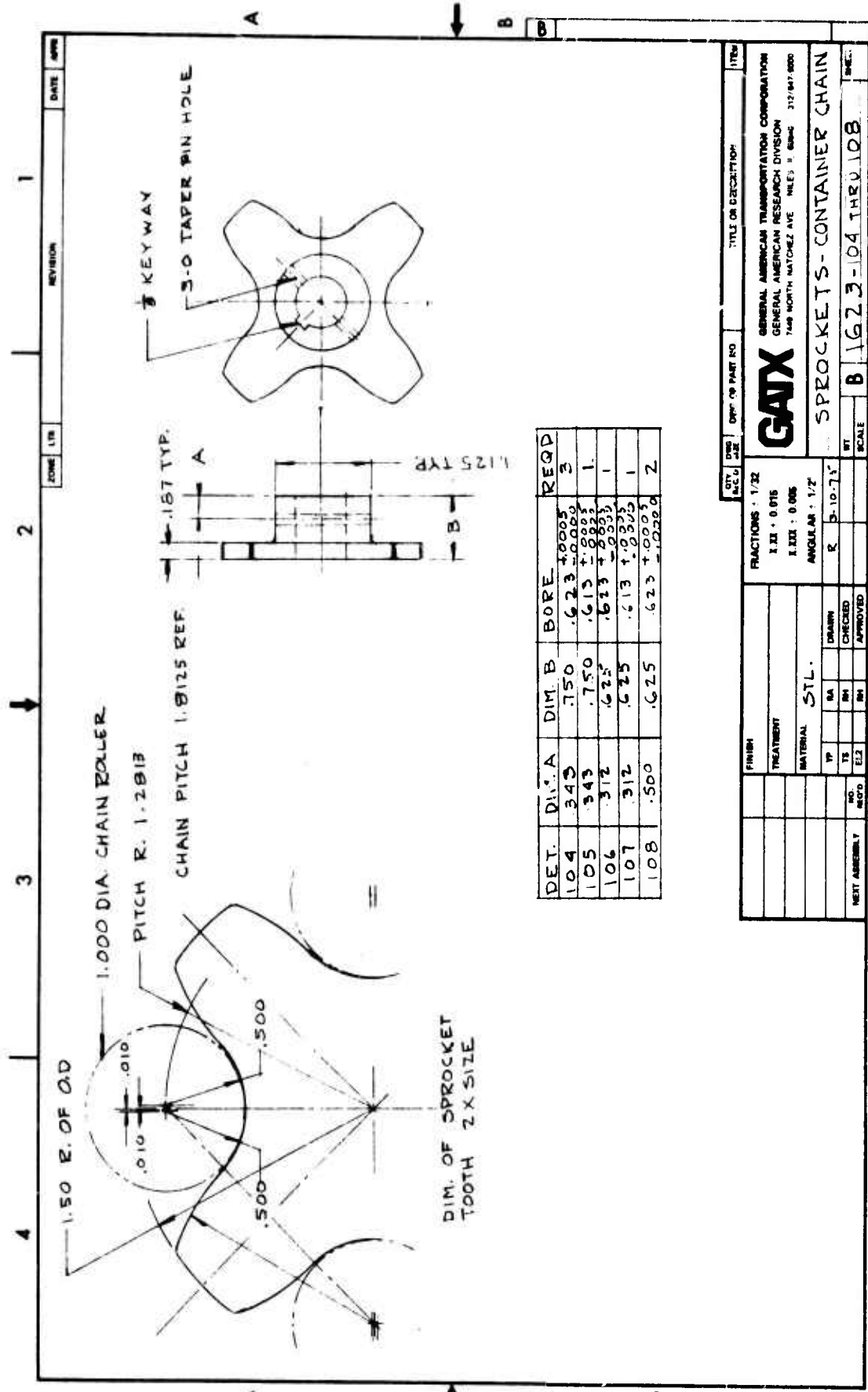
LTR	REVISIONS	DATE	APPR
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DET. 102
SPACER

DET. 103
SPACER

CITY, DWG. REG'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM
FRACTIONS : 1/32		GENERAL AMERICAN TRANSPORTATION CORPORATION		GENERAL AMERICAN RESEARCH DIVISION		312/647-9000
X.IX ± 0.015		7449 NORTH WATCHEZ AVE		NILES, IL 60648		
X.XIX ± 0.005		ANGULAR : 1/2°		SPACER - TIE ROD		
R 3-10-75		DRAWN		CONTAINER		
MATERIAL STL		CHECKED		A 16 23 - 102 & 103		
YF RA		APPROVED		WT.		
TS BH				SCALE		
EL2 RH				SHEET		
NEXT ASSEMBLY		NO. REG'D				



1
2
3
4

REVISION

DATE

APP

ZONE

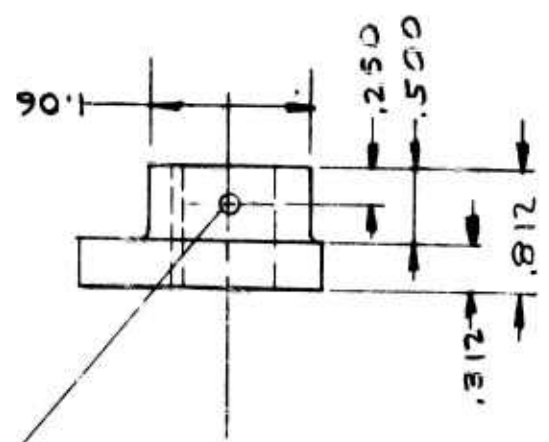
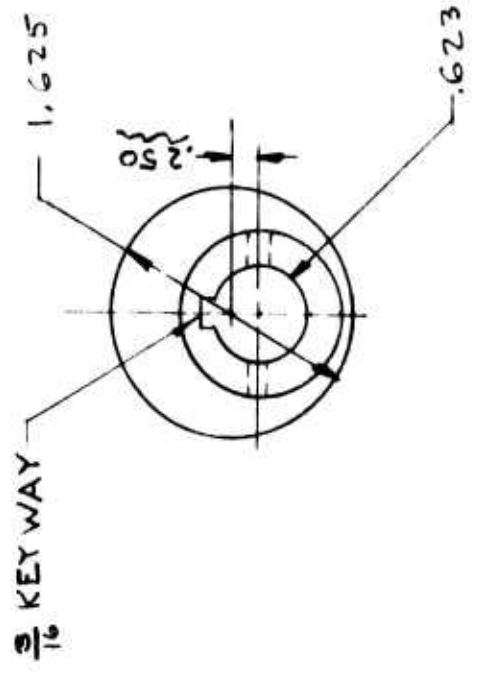
LIB

DET.	DIM. A	DIM. B	BORE	REQD
104	.343	.750	.623 ± .0005	3
105	.343	.750	.613 ± .0005	1
106	.312	.625	.613 ± .0005	1
107	.312	.625	.613 ± .0005	1
108	.500	.625	.623 ± .0005	2

CITY	STATE	DWG. OR PART NO.	TITLE OR DESCRIPTION	ITEM
GATX				
GENERAL AMERICAN TRANSPORTATION CORPORATION GENERAL AMERICAN RESEARCH DIVISION 7448 NORTH MATCHELZ AVE. NILES, ILL. 60062 312/847-8800				
SPROCKETS - CONTAINER CHAIN				
WT	SCALE	B 1623-04 THRU 108		INCH.
FINISH TREATMENT MATERIAL STL. IP MA DRAMM TS BN CHECKED ELZ BN APPROVED NEXT ASSEMBLY NO. MOD.				
FRACTIONS: 1/32 I. II: 0.015 I. III: 0.005 ANGULAR: 1/2° R: 5-10-7.5				

LTR	REVISIONS	DATE	APPR
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NO. 3-C TAPER PIN HOLE



2 REQD.

QTY REQ'D		DWG OR PART NO.		TITLE OR DESCRIPTION		ITEM
FRACTIONS : 1/32		GADX		GENERAL AMERICAN TRANSPORTATION CORPORATION		
X.XI : 0.015				GENERAL AMERICAN RESEARCH DIVISION		
X.XIX : 0.005				7449 NORTH NATCHEZ AVE NILES, IL 60648 312/647-9000		
ANGULAR : 1/2				CAM - CHAIN LENGTH ADJUSTMENT		
5				CONTAINER		
3-11-75				SCALE		
				A		1623-112
NEXT ASSEMBLY		NO. REQ'D		WT.		SHEET

INITIAL DISTRIBUTION

Hq USAF/RDQRM	2	AMXSJ-DS	1
Hq USAF/SAMI	1	US Army Material Comd	1
Hq USAF/XOXFCM	1	Nav Wpns Eval Fac/Code WE	1
Hq USAF/XOOWA	2	Office of the Chief of Nav Opns	1
AFSC/IGFG	1	OP-982E	1
AFSC/SDWM	1	USAF TAWC/AY	1
Hq AFSC/DLCAW	1	TAWC/TRADOCLO	1
AFML/DO/AMIC	1	AFATL/DL	1
AFIT/LD	1	AFATL/DLY	1
ASD/YEM	1	AFATL/DLOU	1
ASD/ENFEA	1	AFATL/DLOSL	2
ASD/ENAZ	1	AFATL/DL DL	1
TAC/DRA	1	AFATL/DL DA	1
Hq SAC/NRI/STINFO Lib	1	AFATL/DL DE	1
AUL/AUL-ISE-70-239	1	AFATL/DL DT	1
Redstone Science Info Ctr/Doc Sec	2	ADTC/WE	1
USA Wpns Comd/SAPRI-LW-A	1	AFATL/DL DG	20
AMXSJ-DD	1	Genrl Amer Rsch Div/Gen Amer	5
AMXSJ-A	1	Transportation Corp	1
AMXBR-TB	1	AFLW/LR	1
Frankford Arsenal/Lib	1	AFIS/INTA	1
Picatinny Ars/SARPA-TS	1	ASD/ENYEHM	1
USN Wpns Lab	1	WRAMA/MMEBL	1
USN Ord Lab/Tech Lib	2	Naval Rsch Lab/Code 2627	1
Nav Ord Stn/Tech Lib	1		
Nav Wpns Stn/20323	1		
Nav Sys Ctr/Tech Lib	1		
USN Wpns Ctr/Code 533	2		
Comdr/Code 4565	1		
AF Wpns Lab/Tech Lib	1		
Nav Air Sys Comd/Code AIR-5303	1		
Office Nav Rsch/Code 473	1		
NASA STINFO Facility	1		
Inst for Def Analysis/Class Lib	1		
Sandia Labs/Div 5625	2		
Rand Corp/Lib-D	1		
Harry Diamond Labs/AMXDP-TC	1		
DDC/TC	2		
USAF TFWC/TA	1		
Comdr/Nav Wpns Lab	1		
SARWV-RDT-L	1		
Comdr/Nav Wpns Ctr/Code 51102	1		
Ogden ALC/MMNOP	2		
AF Spec Comm Ctr/SUR	2		
Hq Dept of the Army/DAMA - WSA	1		
Picatinny Ars/SARPA-FS-S-A	1		