AFATL-TR-75-158

GFU-6/E 30mm AMMUNITION LOADER FOR GAU-8A GUN SYSTEM

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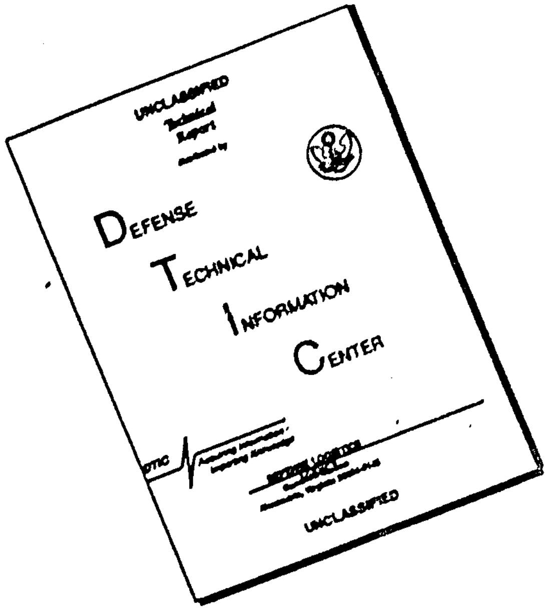

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This effort involved the technical evaluation of an engineering model; design, fabrication and testing of the prototype; delivery of the system to Eglin AFB, Florida for gun system interface and technical assistance during the test and evaluation at Edwards AFB, California. A single prototype was constructed. Descriptions and details of the system and its operation are included and safety, reliability and maintainability features are discussed. Recommendations for engineering changes for a production loader are also included.

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PREFACE

This report documents work performed during the period from September 1974 through October 1975 by the Wayne H. Coloney Company, Inc., 2111 North Monroe Street, Tallahassee, Florida 32303, under Contract F08635-75-C-0021 with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida 32542. CMSgt. Wesley H. Smith (DLDA) managed the program for the Armament Laboratory.

This report has been reviewed and is approved for publication.

FOR THE COMMANDER

ALFRED D. BROWN, JR., Colonel, USAF
Chief, Guns, Rockets and Explosives Division

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TABLE OF CONTENTS

LIST OF FIGURES

SECTION I

INTRODUCTION

The GAU-8/A 30mm gun system is undergoing full scale development in conjunction with the A-10 close air support aircraft. The gun system is a high rate of fire, gatling gun system with a capacity of 1350 rounds of ammunition. The gun system specifications require that the system be capable of being loaded by three men in not more than 15 minutes which includes connection and disconnection of the loading unit to and from the aircraft. In order to meet requirements regarding loading time and personnel requirements, an automated ammunition loading system was developed by the Air Force Armament Laboratory (AFATL). The AFATL loading system removes rounds from the M548 ammunition container and places them into a conveyor for transport to the loading system interface unit. The loader simultaneously accepts rounds from the interface unit, places them into a return conveyor for transport to the repackaging unit which inserts the unfired rounds into M548 containers. The loader also employes a device for separating spent cases from unfired rounds. The in-house development effort for the loading system included a design study and the development of an engineering model.

The objective of this effort was to develop a prototype automated 30mm ammunition loading system from the engineering model developed by the Armament Laboratory.

The effort was conducted in two phases. Phase I included a contractor design study of the AFATL engineering model of the loading system to simplify and improve the existing design, consolidate gear and drive mechanisms, conform the system to current military specifications, and interface the system with the GAU-8/A gun system. Phase II consisted of contractor construction of a prototype loading system incorporating Phase I design improvements.

The following technical requirements and tasks were made a part of the contractural effort:

Phase I:

a. The contractor shall perform a study on the existing AFATL engineering model of the automated 30mm loading system to determine design improvements, simplification of gear and drive mechanisms, and alterations for conforming the unit to MIL-S-008512 C (USAF).

b. The contractor shall design the automated loading system to interface with the GAU-8/A loader unit attachment.

c. The automated loading system shall be designed by the contractor to remove 30mm ammunition from the M548 ammunition container and place the ammunition into a conveyor element mechanism for transport to the GAU-8/A loader unit.

d. The contractor shall design the automated loading system to accept unfired 30mm ammunition and spent cases from the GAU-8/A loader unit and return the unfired ammunition to a repackaging unit which repackages it into the M548 container.

e. The automated loading system shall be designed by the contractor to accomplish simultaneous unpackaging and loading, and unloading and repackaging of 30mm ammunition.

f. The automated loading system shall separate unfired (unloaded) 30mm ammunition from unloaded spent cases.

g. The drive power required for the automated loading system shall be drived from (geared to) the gun ammunition feed system through the conveyor elements so no electrical power is required for control of the loading system.

h. The ammunition loading system shall contain a manual drive shaft. The drive shaft shall match the speed and rotation of the drive shaft present on the GAU-8/A gear box.

i. The ammunition loading system shall have the capability to load and unload 1350 rounds of 30mm ammunition into the GAU-8/A gun system in not more than 10 minutes (Exclusive of time required to attach and detach the loading system from the gun system).

j. The loading system shall be designed to provide high reliability and ease of maintenance.

k. The loading system design shall be cost effective, and use low cost government standard components wherever possible.

l. (Safety) The automated loading system shall be designed for maximum safety.

m. The loading system shall contain a device which disengages or stops the loading system in the event of a gun/feed system jam.

n. The loading system shall contain a device which disengages or stops the system during the simultaneous loading-unloading process in the event a round of ammunition remains in the M548 container after the unpackaging process of the loading cycle is complete, to preclude a round removed from the gun system from being inserted into a position in the M548 container which contains a round, which was not extracted during the load cycle.

o. The loading system shall contain a device which disengages or stops the system in the event of a malfunction in the ammunition can transport and indexing unit.

Phase II

a. Upon the approval by the sponsor of the design, the contractor shall construct a prototype automated loading system incorporating Phase I design improvements and simplifications.

SECTION II

ENGINEERING MODEL EVALUATION

Certain changes and modifications to the engineering model were made to the prototype as a result of the evaluation phase. These changes and modifications are as follows:

1. The container elevator indexer was changed from a geneva-cross mechanism to an incremental rotational clutch-brake with anti-backlash and without anti-overrun. Operation of the container elevator independent of the extractor/reload section required operation without the anti-overrun.

2. Locating the container discharge below the feed roller conveyor rather than on the side was recommended and utilized.

3. Actuation of the dump bar system through a 4-bar linkage and cam-cable trigger rather than through a double-series geneva-cross mechanism was used.

4. The extractor grippers and release were modified to hold the rounds horizontal and release them sequentially to expand the pitch to that of the conveyor elements used in the flexible chuting.

5. Conveyor elements used with the General Electric attachable load head and flexible chuting were incorporated into the horizontal conveyor of the loader to simplify the loader-chuting interface.

6. Five mechanical logic, safety stop systems were incorporated to detect malfunctions of the loader.

7. The feed container roller conveyors were positioned in such a way as to minimize the height through which the containers would have to be lifted.

8. A separate ammunition container receiver was designed and fabricated to collect misfires.

All other features of the engineering model were left unchanged in the prototype.

SECTION III

LOADER SYSTEM

LOADER DESCRIPTION BY SUBSYSTEM

The loader system as shown in Figure 1 is comprised of the following subsystems:

1. VERTICAL SYSTEM
   - a. Container Roller Conveyors
   - b. Container Elevator
   - c. Container Indexer
2. HORIZONTAL SYSTEM
   - a. Ammunition Extractor
   - b. Ammunition Pitch Expander
   - c. Ammunition Conveyor
   - d. Spent Case Separator
   - e. Dump Bar and Pitch Contractor
   - f. Ammunition Reloader
   - g. Misfired Ammunition Separator
3. DRIVE POWER INPUT
   - a. Load Head Element Sprocket and Element Train
   - b. Auxiliary Power Input Spline Shaft
4. EXTRACTOR/RELOAD DRIVE MECHANISM
5. SAFETY STOP
   - a. Extractor Test
   - b. Release Test
   - c. Vertical Elevator Index Test
   - d. Overload Test
   - e. Manual Emergency Stop

6. LOADER-FLEXIBLE CHUTE INTERFACE

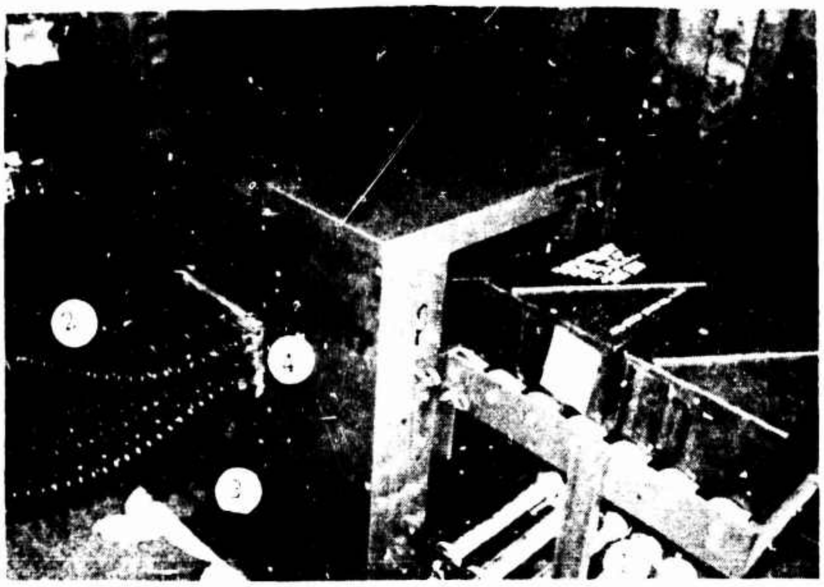

Figure 1. Final Loader Prototype

1. Container Roller Conveyors
2. Flexible Chuting
3. Spent Case Chute
4. Loader-Flex Chute Interface

LOADER OPERATION BY SUBSYSTEM

All components and materials used in the design and fabrication of the GFU-6/E loader were selected and/or tested to conform to MIL-STD-8512(c) for adherence to the high/low temperature extremes.

VERTICAL SYSTEM

The vertical system (Figure 2) consists of three sections;

1. The container feed/discharge roller conveyors
2. The container elevator
3. The container indexer.

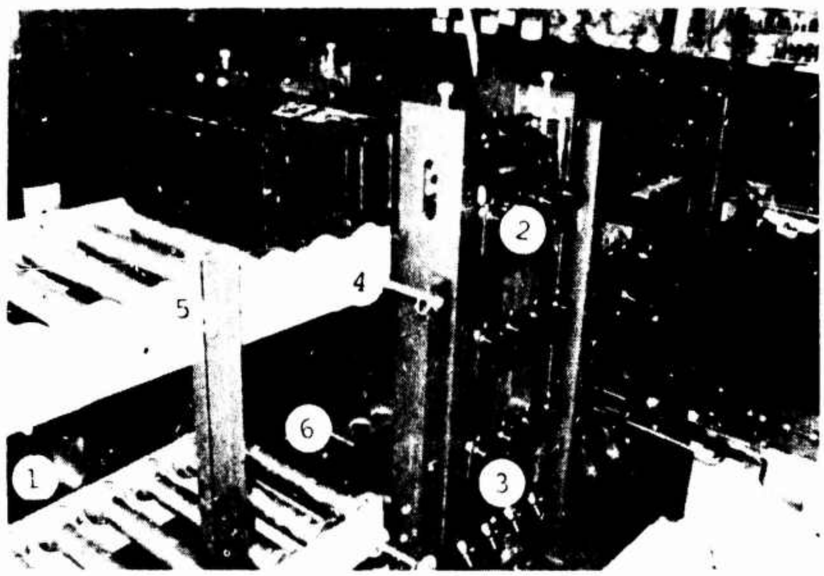

Figure 2. Vertical System

1. Container Roller Conveyors
2. Container Elevator
3. Container Indexer
4. Conveyor Hinge
5. Slope Adjuster
6. Container Support Cam Rollers

The feeder/discharge roller conveyor (Figure 3) consists of seven rollers each. Each roller is shaped in such a way that it supports the M548 container along its edge, beyond each stiffner rib. The inner edges of each roller are tapered inward to facilitiate positioning the container on the roller conveyor. The last roller of each conveyor can be locked into position to prevent the containers from rolling off the end of the conveyor. Due to exposure to the atmosphere, the rollers were cadmium plated to conform with MIL-STD-8512(c). Each conveyor has a two-container capacity beyond the container elevator. The conveyors are hinged at the container elevator frame and are adjustable to allow changing the slope of the conveyors relative to the container elevator (Figure 2). The adjustable conveyors used in conjunction with jackscrews provided at the conveyor end of the loader allow the loader to be positioned properly on an inclined ramp. This feature was also incorporated to conform with MIL-STD-8512(c).

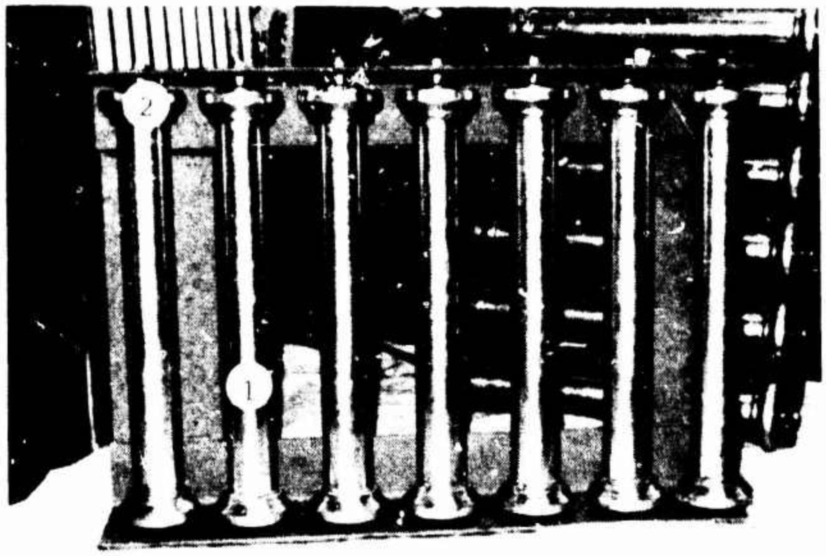

Figure 3. Roller Conveyors

1. Conveyor Roller
2. Roller Taper

The container elevator accepts the containers from the top roller conveyor and indexes the containers down to the extract and/or reload positions (See Figure 2). The containers are supported along their edges by eight cam rollers (four each side) as shown in Figure 4.

The containers are indexed down one row at a time, allowing enough time in each indexed position for the extractor to extract each row of nine rounds and the reload bar to push nine unfired rounds back into the containers. The elevator double indexes every fourth index to allow for the space between containers. The container is then pushed onto the lower roller conveyor by the push bar shown in Figure 4. During operation, the elevator contains two containers. Rounds are being extracted from the upper container while rounds are being reloaded into the lower container during a simultaneous upload-download operation or rounds are being extracted from the upper container while the lower container is empty during an upload operation with spent cases being separated.

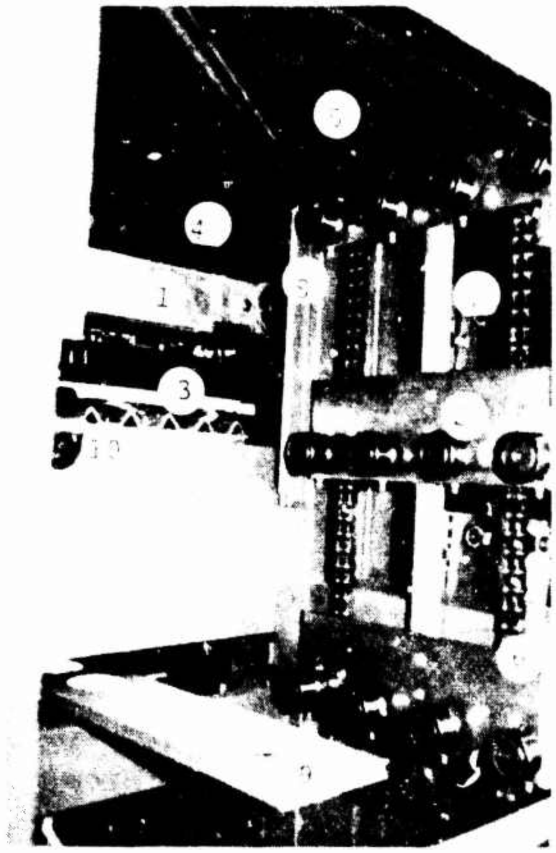

Figure 4. Container Elevator, Extractor and Reload Section

1. Horizontal Conveyor
2. Cam Rollers
3. Reload Push Bar
4. Extracted Rounds
5. Supported Container
6. Guide Plate
7. Guide Plate Guide Track
8. Container Guide Bars
9. Container Push Bar
10. Reload Tray

The containers are held in position and guided down the elevator by the guide bars shown in Figure 4.

The cam rollers which support the edges of the M548 container are mounted on guide plates (Figure 5) which in turn are mounted on two strands of RC 45 roller chain. The chain is driven by sprockets located at the bottom and top of each side of the container elevator. A guide track with two cam rollers is provided behind the guide plates to stabilize the plates during their downward movement in the container elevator.

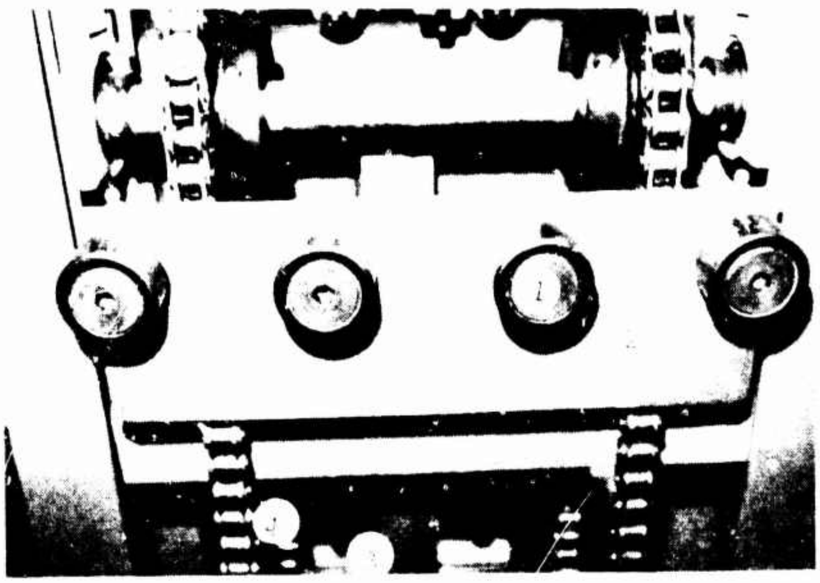

Figure 5. Container Elevator Guide Plates

1. Can Support Cam Rollers
2. Guide Plate
3. Plate Guide Tract
4. Roller Chain
5. Sprockets

The sprocket shafts are linked by a worm shaft (Figure 6) which is driven by a chain from the loader main drive shaft through a Warner clutch-brake incremental rotational control package with anti-overrun. The clutch-brake package was used because of its higher reliability and simpler construction. The clutch-brake was tested and found to qualify for operation at both temperature extremes. One revolution of the worm shaft indexes the containers down one ammunition row. The rotational roller is triggered by a central cam system. This cam system is shown in Figure 23.

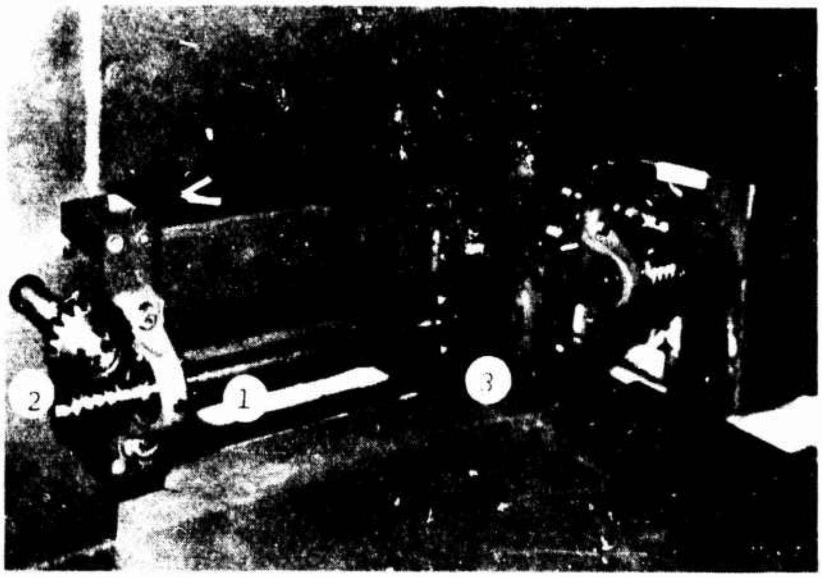

Figure 6. Worm Shaft and Indexer

1. Worm Shaft
2. Worm Gears
3. Clutch-Brake

The double index operation is actuated by a mechanical sensor located on the container elevator system to allow for the space between containers.

HORIZONTAL SYSTEM

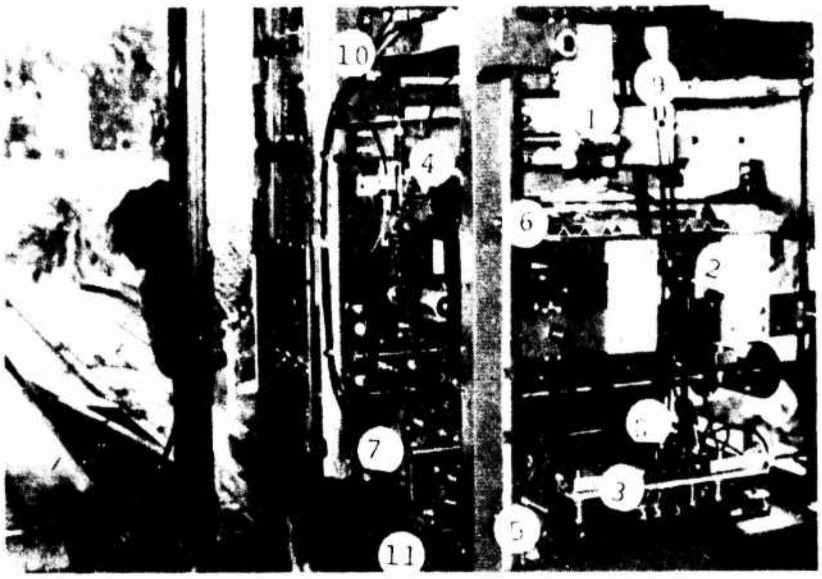

Figure 7. Horizontal System

1. Auxiliary Input Power Spline
2. Reload Tray
3. Safety and Dump Bar Cams
4. Overload Safety Stop Sensor
5. Re-Engage T-Handle
6. Dump Bar
7. Input Power Jack Shaft
8. Main Power Drive Shaft
9. Extractor/Release Safety Stop Drive Cables
10. Extractor/Release Safety Stop Trigger Cables
11. Dump Bar Override Pull Handle

The horizontal system is shown in Figure 7 with the major subsystems identified by name and number.

Ammunition Extractor

The extractor system is a multi-gripper unit which is inserted into the M548 container, extracts a row of nine rounds, pulls them out of the container and holds them horizontally above the horizontal conveyor. Figures 8 and 9 illustrate this operation.

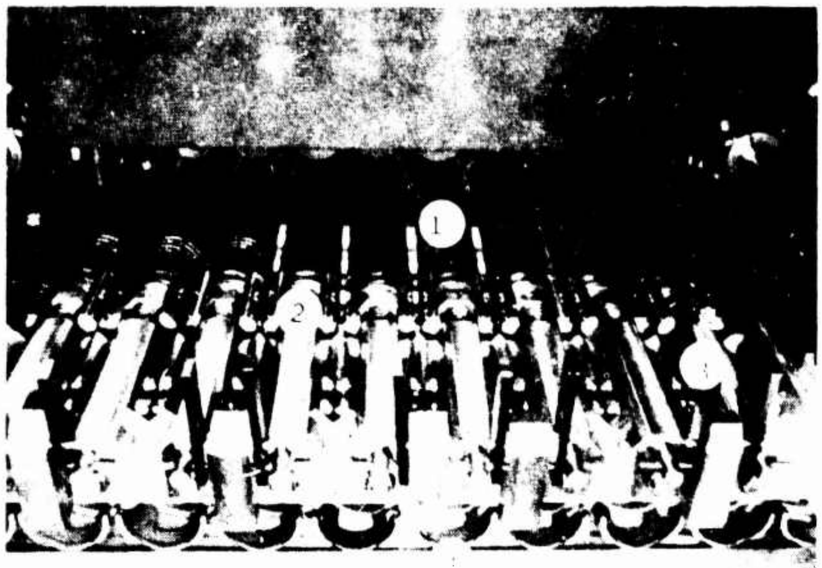

Figure 8. Ammunition Being Extracted

1. 30mm Ammunition
2. Grippers
3. Release Triggers
4. Conveyor Elements

The rounds are then dropped sequentially onto the horizontal conveyor (Figures 10 and 11), thus expanding the pitch of the rounds from 1.854 inches (container pitch) to 2.12 inches, thus conforming to the element train pitch.

The extractor head consists of nine individual assemblies (Figures 11 and 12). Each assembly consists of two grippers, two bottom support fingers, a spring tension base plate to hold the rounds horizontal and a release plate to raise the grippers and to back up the bottom fingers. The release plate is actuated through a shaft by a release lever on the back of the extractor assembly which is actuated by the rotary cam system. The rotary cam system is timed to sequentially release the rounds to expand the pitch. The rounds are released and dropped vertically into the element cradles shown in Figure 10.

The extractor assembly is guided horizontally on two one inch shafts by four Thompson rectilinear ball pillow blocks mounted to the extractor assembly. One of the shafts floats in the horizontal plane to allow for expansion of the extractor over the operating temperature of the loader. The sequential

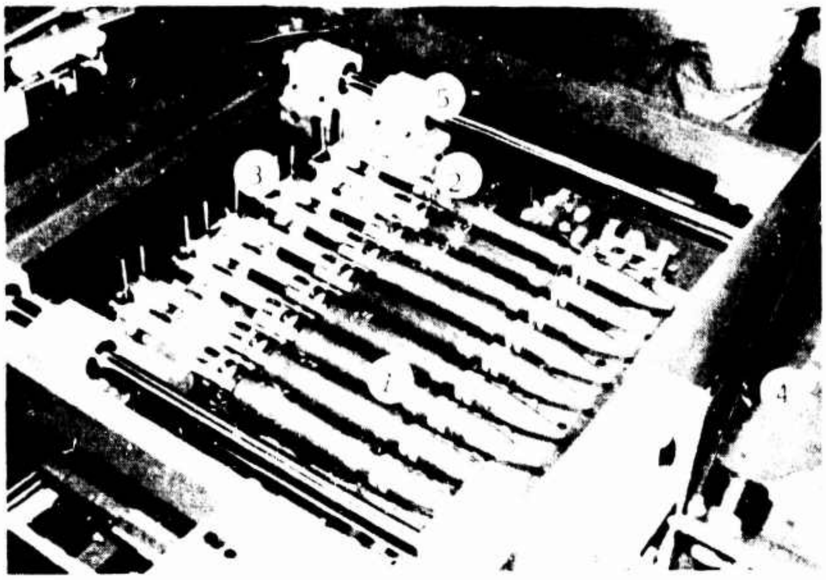

Figure 9. Ammunition Release Position

1. 30mm Ammunition
2. Grippers
3. Release Triggers
4. Container
5. Rectilinear Ball Pillow Block

release is accomplished by cams on a cam shaft that contact the release levers when the extractor assembly is in its rear position. The extractor assembly is retained in the rear position for one-fifth of the loader cycle.

Ammunition Pitch Expander

The extractor is driven by a dwell linkage (Figure 14) located on the base of the horizontal system. The extractor is connected by a series of chains to the linkage output. The release cam shaft is driven by a chain linked to the main drive shaft.

Ammunition Conveyor

The horizontal conveyor is a track for the conveyor elements. The box ends on the flexible chuting from the aircraft connect to one end while the drive sprocket connects to the other end (Figures 15 and 16).

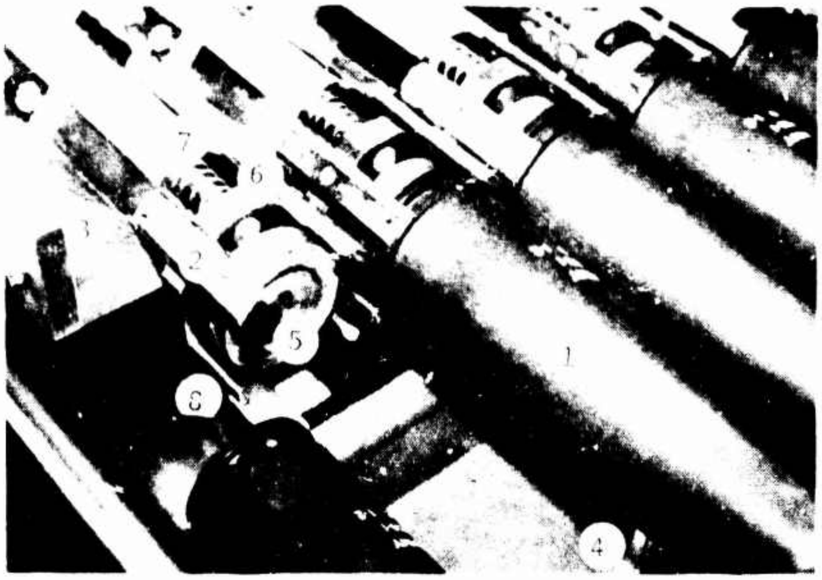

Figure 10. Sequential Release of Rounds

1. 30mm Ammunition
2. Grippers
3. Extractor Bar
4. Conveyor Element
5. Pressure Plate
6. Release Plate
7. Compression Spring
8. Support Fingers

As the elements and rounds enter the bottom of the conveyor, the spent cases are dropped and the unfired rounds ride onto the dump bar and are dropped through the pitch change chute onto the reload tray. If the dump bar has been overridden, the misfired rounds will ride across the dump bar and drop into a container on the opposite side of the loader (See Figure 30). The elements fit the contour of the element sprocket, rotate about this sprocket and enter the track on the top side of the horizontal conveyor. The extracted rounds are dropped onto the conveyor (See Figure 17) and transferred to the aircraft on these elements through flexible chuting which interfaces directly with the GFU-6/E loader. The horizontal conveyor system is driven from the load head element sprocket shown in Figure 18.

Figure 11. Extractor and Horizontal Conveyor

The element turnaround sprocket (See Figures 16 and 17) in the horizontal conveyor system is driven by the element train as well as the auxiliary power input drive shaft. It is noted at this point that the flexible chuting and element train between the loader and the gun system in the aircraft experiences interface and operating difficulties.

Spent Case Separator

The spent case chute shown in Figure 15 allows the spent cases to drop from the elements and transfer into a spent case hopper located at the side of the loader. The spent case separator was designed to allow the spent cases to drop from the elements which were in an inverted position, thus allowing them to drop by gravity through the spent case chute into the hopper. A spring steel stripper was installed behind the elements in such a way that a downward force was applied to the spent cases as they passed into the loader, ahead of the dump bar assembly. This stripper was installed to compensate for expansion of the cases when the rounds were fired.

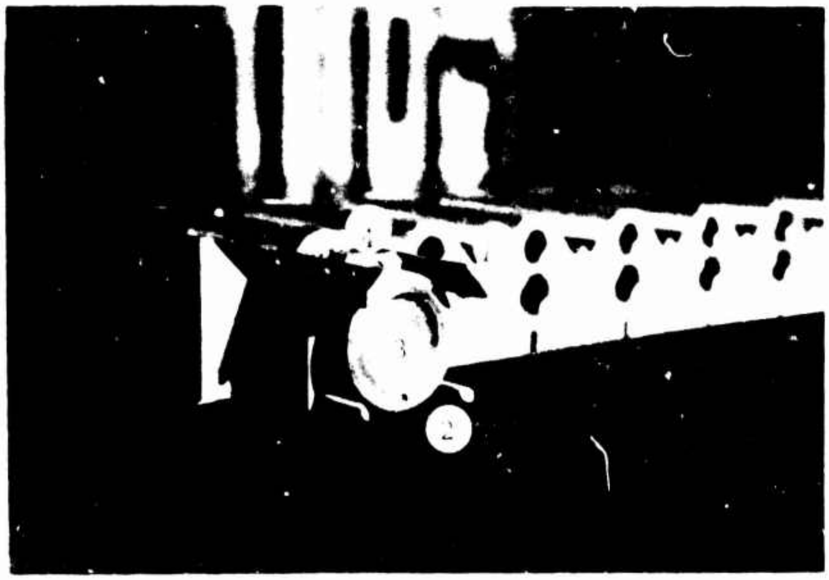

Figure 12. Extractor Head

1. Grippers
2. Support Fingers
3. Base Plate
4. Release Plate

Dump Bar and Pitch Contractor

The dump bar system consists of two bars, one which supports the base of the rounds and one which supports the nose of the rounds. Both bars are pivoted through a four-bar linkage which is actuated by a cam through a pull cable. When the linkage is actuated, the bars pivot away from the nose and base of the round and allow them to drop by gravity through a pitch contractor onto the reload tray.

The rounds fall through a sheet metal guide chute which acts to contract the pitch between the rounds to match the pitch within the M548 container. The pitch contractor is configured in such a way that it compensates for the horizontal and vertical velocity of the rounds as they drop from the dump bar assembly. The dump bar assembly is timed so that it opens and closes before the round following behind the last round in the pitch change contractor reaches the dump bar assembly. The design of the dump bar and pitch change assembly was predicated on the information that the rounds are loose in the elements and are free to drop by gravity onto the reload tray (See Figure 19).

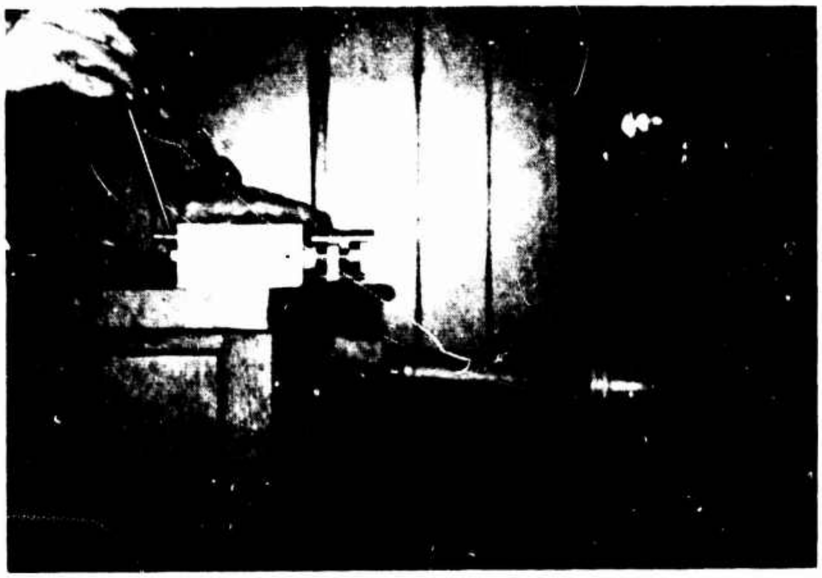

Figure 13. Round Release

Ammunition Reloader

Figure 19 illustrates the reload operation. When the rounds are dropped onto the reload tray, the reload push bar is in the full retracted position at the rear of the loader. The reload bar is driven by a dwell linkage which is a mirror image of the linkage which drives the extractor (See Figure 14). After the rounds have been deposited on the reload tray, the push bar pushes the rounds along the tray into the empty row of the M548 container which is in the proper position on the container elevator. After the container has been filled with ammunition, it is indexed into the position shown in Figure 19 where the cam rollers which support the container along its edges are in line with the lower roller conveyor system. The container push bar then pushes the container out onto the discharge roller conveyor. After the ammunition is repackaged, the reload push bar is retracted to the rearward position, another nine rounds are dropped from the dump bar through the pitch change contractor, onto the reload tray and the cycle is repeated.

Figure 14. Dwell Linkage

1. Worm Shaft
2. Input Crank
3. Chain Drive Output
4. Container Elevator Indexer Drive Sprocket

Misfired Ammunition Separator

The misfired ammunition separator is designed to accept misfired ammunition from the horizontal conveyor system and deposit it into a misfired ammunition container. This container is designed to accept a maximum of 12 rounds and is actuated by overriding the dump bar operation. The dump bar override is actuated by shifting the dump bar cable, cam-lever beyond the dump bar cam lobe. When this occurs, the dump bar fails to operate, thus allowing the rounds to proceed across the dump bar and into the misfired ammunition container. The dump bar override T-handle is shown in Figure 7.

DRIVE POWER INPUT

There are two power inputs to the GFU-6/E loader system. Both power inputs are derived from the hydraulic system which drives the gun system. The minimum power requirement for the GFU-6/E loader is approximately 1/3 horsepower.

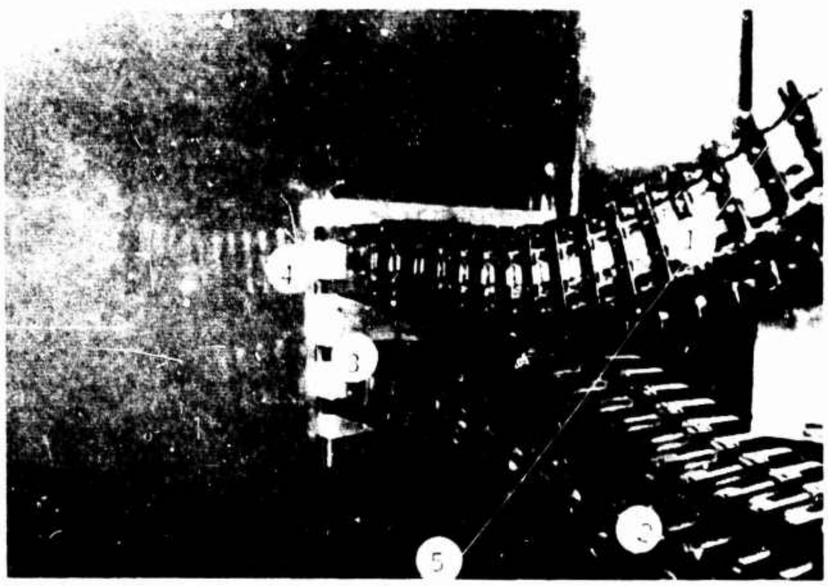

Figure 15. Horizontal Conveyor - Flex Chute Interface

1. Upload Ammunition Flexible Chuting
2. Download Ammunition/Spent Case Flexible Chuting
3. Box Ends
4. Flex Chute Connect
5. Spent Case Chute

Load Head Element Sprocket and Element Train

The operation of this drive power input system was briefly discussed in an earlier section of this report. The element sprocket in the load head of the flexible chute system is driven directly from a set of gears on the gun system shown in Figure 18. This element sprocket drives the twist-lock ammunition elements of the horizontal conveyor system. They in turn drive the element sprocket of the GFU-6/E horizontal conveyor shown in Figures 16 and 17. In effect, they operate as a chain drive on a conventional chain sprocket drive system. However, the power derived from this system is inadequate to drive the entire loader system. Therefore, additional power is necessary and an auxiliary spline shaft was designed.

Auxiliary Power Input Spline Shaft

An input spline shaft and chain-sprocket speed reducer was designed, fabricated and installed on the loader as shown in Figures 7 and 20. This auxiliary power input spline shaft assembly and speed reducer was designed to reduce the input flexible drive shaft speed by a ratio of 9-1/2:1. This was accomplished by utilizing two sets of chain sprocket arrangements of 16:32 ratio and one set of 15:35 ratio sprockets. The opposite end of the flexible drive shaft shown connected to the gun system in Figure 18 was connected to the input spline shaft on the loader shown in Figures 7 and 20.

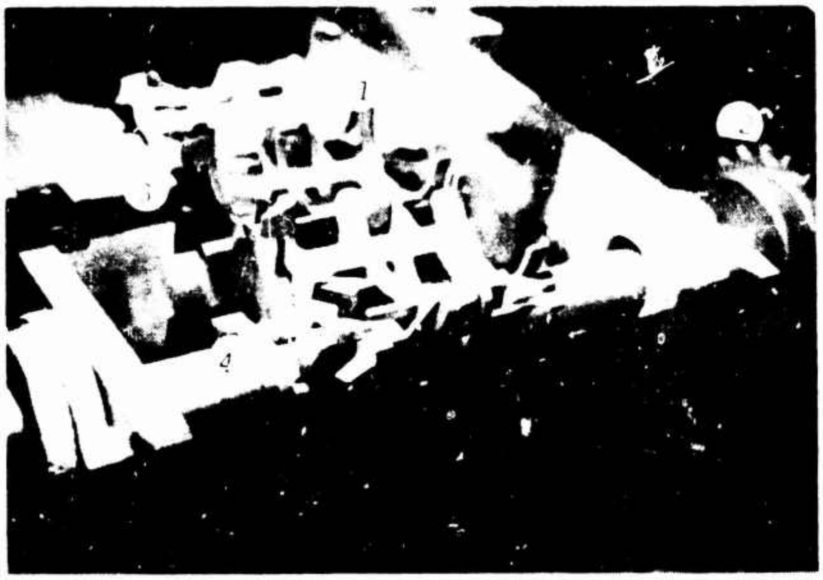

Figure 16. Element Turnaround Sprocket

1. Conveyor Elements
2. Drive Sprocket
3. Conveyor Element Guide Track
4. Element Sprocket

EXTRACTOR/RELOAD DRIVE MECHANISM

The input power to the loader system was derived from the auxiliary power input spline shaft and element sprocket through the input chain-sprocket assembly shown in Figure 7. The input drive chain operates the sprocket which is keyed to the jack shaft shown in Figure 21. The bevel gear on the jack shaft shown in Figure 21 drives a second bevel gear on the main drive shaft shown in Figures 7 and 21. The safety test and dump bar cam system, release cam system, container elevator indexer drive system and the extractor/reload mechanism are all powered from this main drive shaft.

The bevel gear located on the input jack shaft is keyed in such a way that it can slide to the left as shown in Figure 21. Whenever disengagement of the power source is required, the throwout lever is actuated and the compression springs drive the yoke which holds the bevel gear engaged to the left. This disengages the power to the main drive shaft, thus stopping the loader operations. The horizontal conveyor continues to operate until the operator releases the hydraulic lever shown in Figure 18.

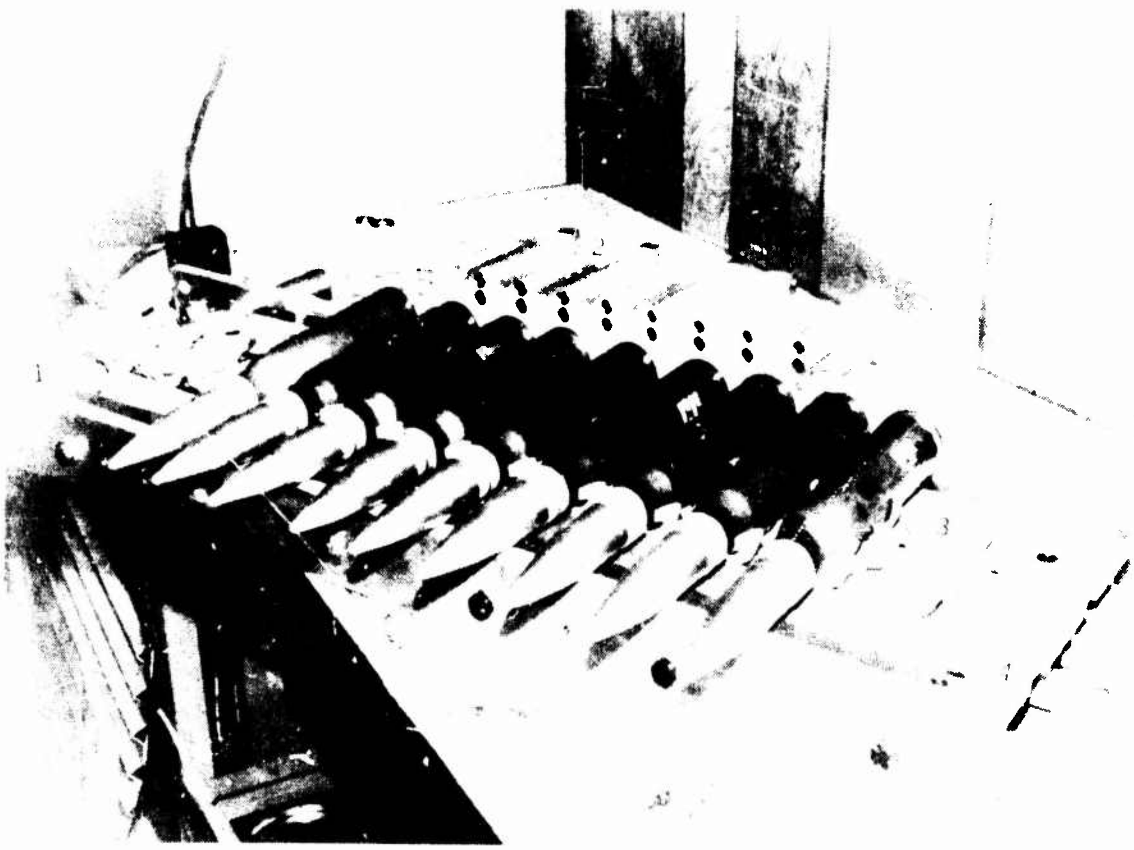

Figure 17. Horizontal Conveyor

1. Element Sprocket
2. Extractors Block
3. Ammunition Elements
4. Element Guide Track

The extractor-reload bar assembly drive mechanisms are shown in Figure 14. The input crank of this eight-bar linkage is driven from the main drive shaft through a chain and sprocket assembly. The extraction and reload bar assemblies are driven by separate linkage assemblies which are mirror images of one another. They are designed specifically to generate 16 inches of output travel and also provide a dwell at the extreme end of travel, equivalent to one-fifth of the total loader cycle.

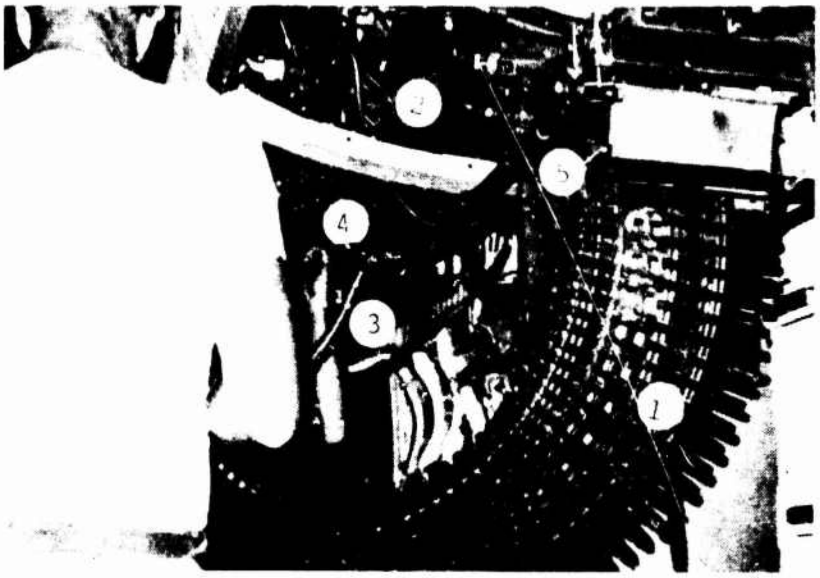

Figure 18. Load Head

1. Flex Chuting
2. Drive Gears
3. Flexible Drive Shaft
4. Hydraulic Control Lever
5. Element Sprocket

SAFETY STOPS

The GFU-6/E ammunition loader contains five safety stop subsystems which will disengage the input power drive system. These safety stop subsystems detect malfunctions of individual operations of the loader and prevent the loader from continuing to operate under the malfunction condition. The requirement that they be entirely mechanical adds some complexity to the system; however, it does reduce the complexity in the input power requirements to the loader.

Extractor Tests

The extractor tests are designed to detect a failure in the extractor mode whereby one or more of the rounds are not extracted from the container. The feelers shown in Figure 22 are lifted by the rounds when they pass under them. They in turn lift a yoke which rides in a slot on the upper portion of the mechanical sensor. If all nine yokes are raised, the slotted slide bar inside the mechanical sensor system is allowed to shift to the left when it is actuated by the drive cable connected to the cam lever shown in Figure 23. If, however, one or more of the yokes is down, indicating missed rounds on extraction, the slide bar is prevented from moving to the left, thus causing the left half of the slide bar assembly to separate relative to the slide bar, thus pulling the actuation cable shown in Figures 21 and 22. This actuation cable triggers a clutch-brake assembly which is driven from the input power jack shaft. This clutch-brake pulls the actuation lever on the bevel gear throwout assembly shown in Figure 21. Thus, the loader input power is disengaged from the main drive shaft and the loader operation is halted.

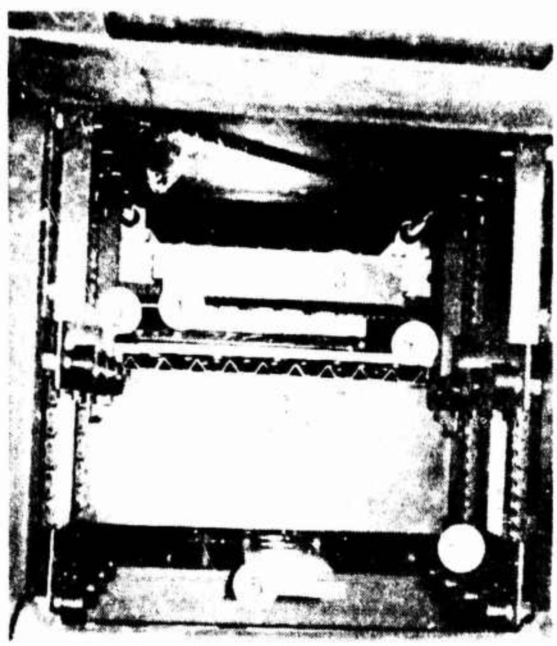

Figure 19. Reload Section

1. Dump Bar
2. Pitch Change Chute
3. Reload Tray
4. Reload Push Bar
5. Container Push Bar
6. Discharge Roller Conveyor
7. Container Edge Support Cam Rollers
8. Horizontal Conveyor

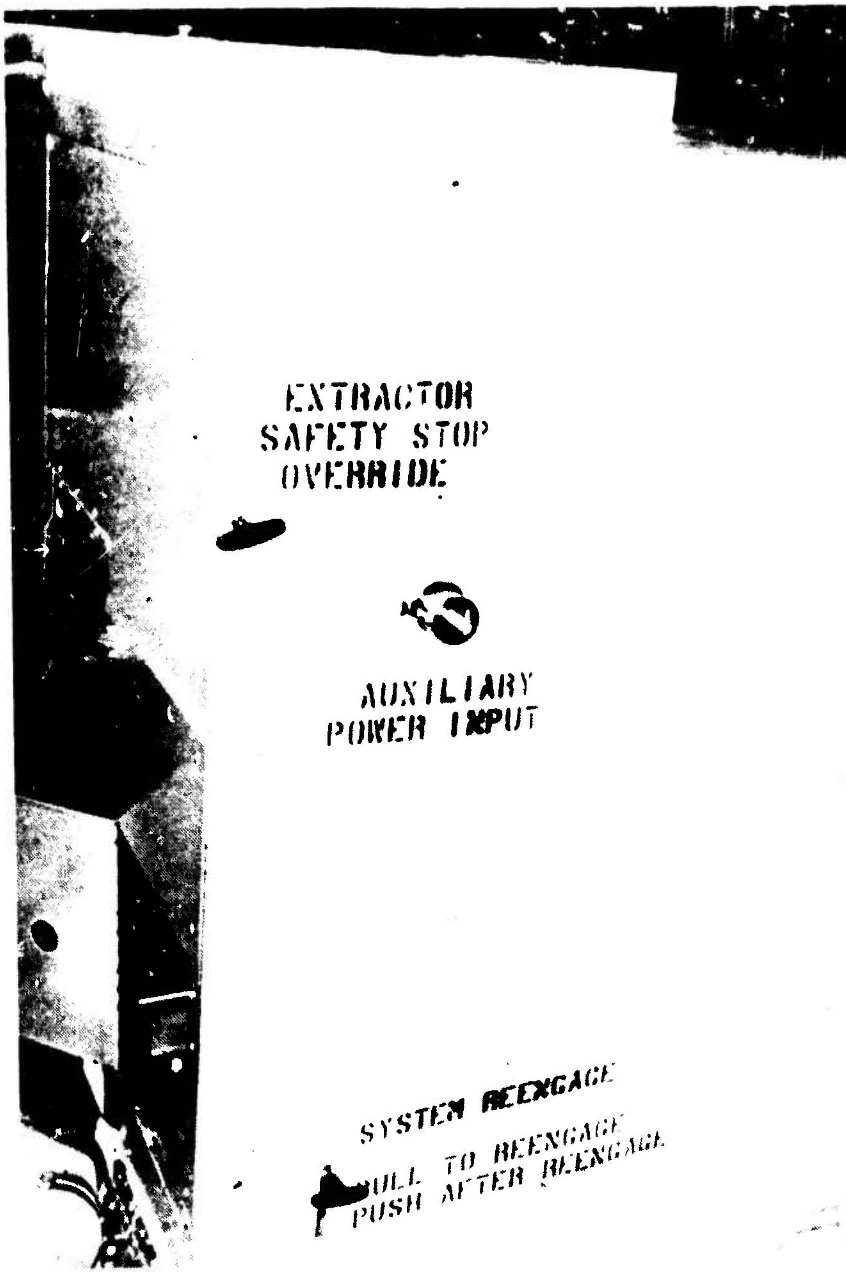

Figure 20. Auxiliary Power Input

Release Test

The release test is operated similar to the extractor test. After the rounds have been released onto the horizontal conveyor elements and prior to movement of the extractor assembly toward the container, a lower slide is actuated to the left by the drive cable shown in Figures 22 and 23. If all rounds have been released from the extractor grippers, the feelers and yokes are allowed to drop and the lower slide bar is allowed to move to the left. However, if one or more rounds are left in the extracor grippers, the lower portion of the yoke(s) is in one or more of the lower slots, thus preventing the lower side from moving to the left. Consequently, a separation in the left-hand portion of the slide assembly occurs, thus actuating the trigger cable to the clutch-brake throwout assembly. As in the extractor tests, the clutch-brake disengages the input drive power to the main drive shaft of the loader and the loader operation is halted.

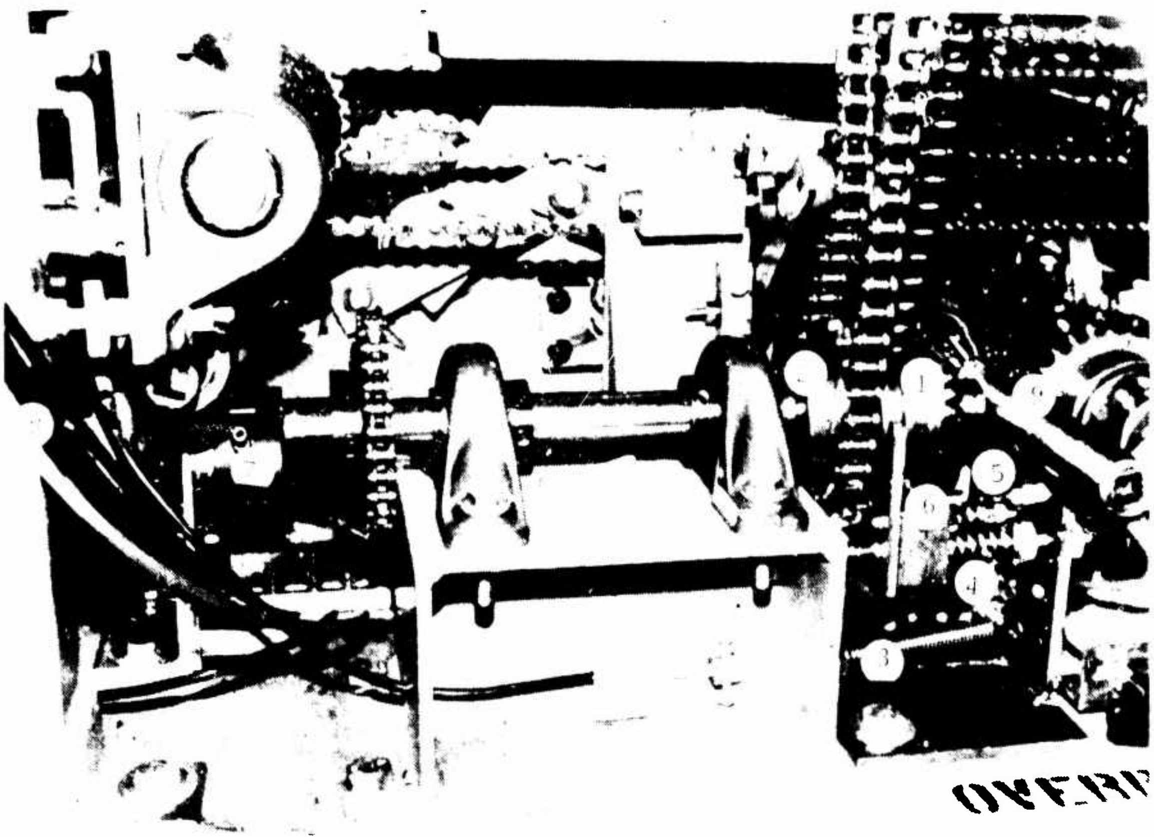

Figure 21. Jack Shaft Throwout

1. Bevel Gear with Timing Marks
2. Input Drive Sprocket
3. Throwout Latch
4. Compression Springs
5. Re-Engage Cable
6. Yoke-Slide Assembly
7. Throwout Clutch-Brake
8. Throwout Trigger Cables
9. Main Drive Shaft

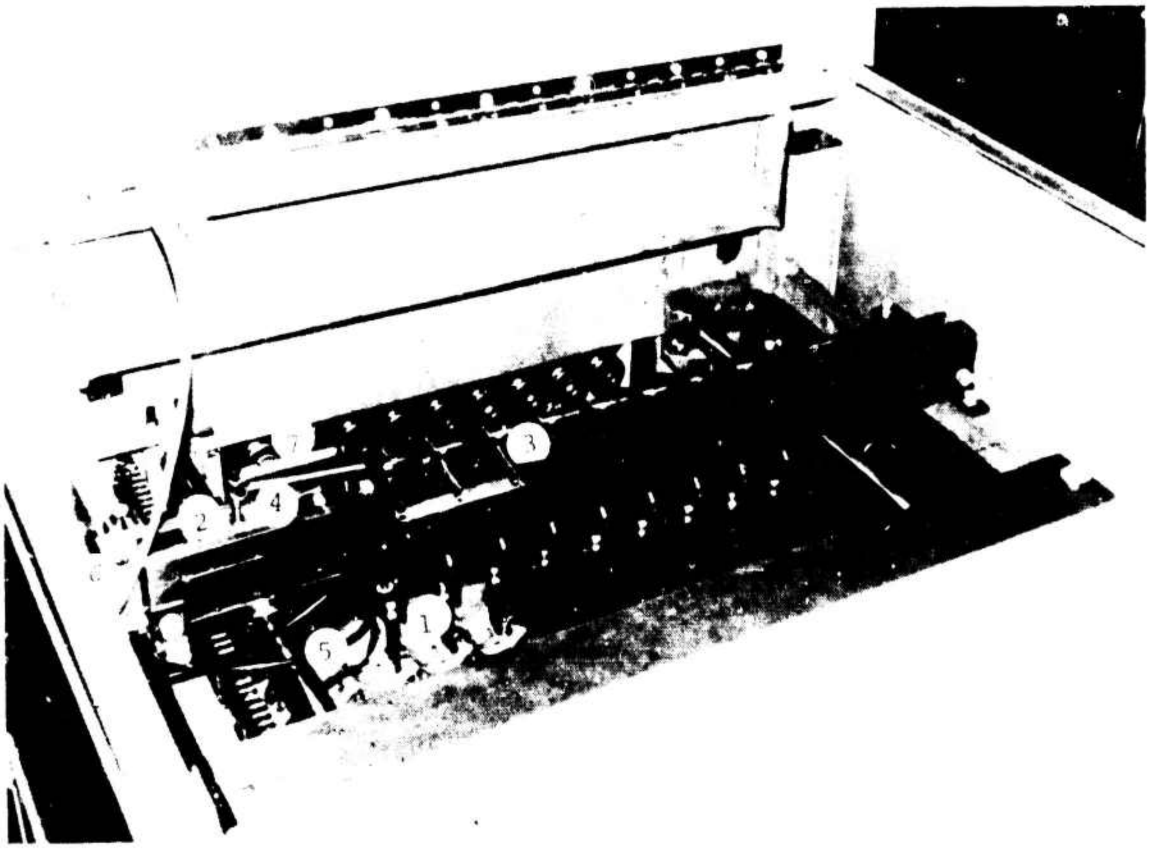

Figure 22. Extractor/Release Safety Check

1. Safety Feelers
2. Mechanical Sensor
3. Yoke
4. Extractor Sensor Slide Return Spring
5. Trigger Cables
6. Drive Cables
7. Extractor Sensor Trigger Cable Return Spring
8. Manual Stop Trigger Cable

Container Elevator Indexer Test

The container indexer test is utilized to test whether or not the container elevator has been properly indexed. A cam which is mounted on the worm shaft of the container elevator indexer rotates and displaces the sensor lever shown in Figure 24, pulling the push-pull cable shown mounted at the bottom of this lever in Figures 23 and 24.

When this cable is pulled, it pulls the container elevator index test cam lever shown in Figure 24 to the right, holding it in that position while the container elevator indexer sensor cam passes by this lever. If the container elevator is not properly indexed, the sensor lever is not pulled to the right, and the sensor cam depresses this lever, thus pulling the trigger cable shown in Figures 21 and 24. Consequently, the clutch-brake throwout assembly is actuated and the input drive to the main drive shaft is disengaged.

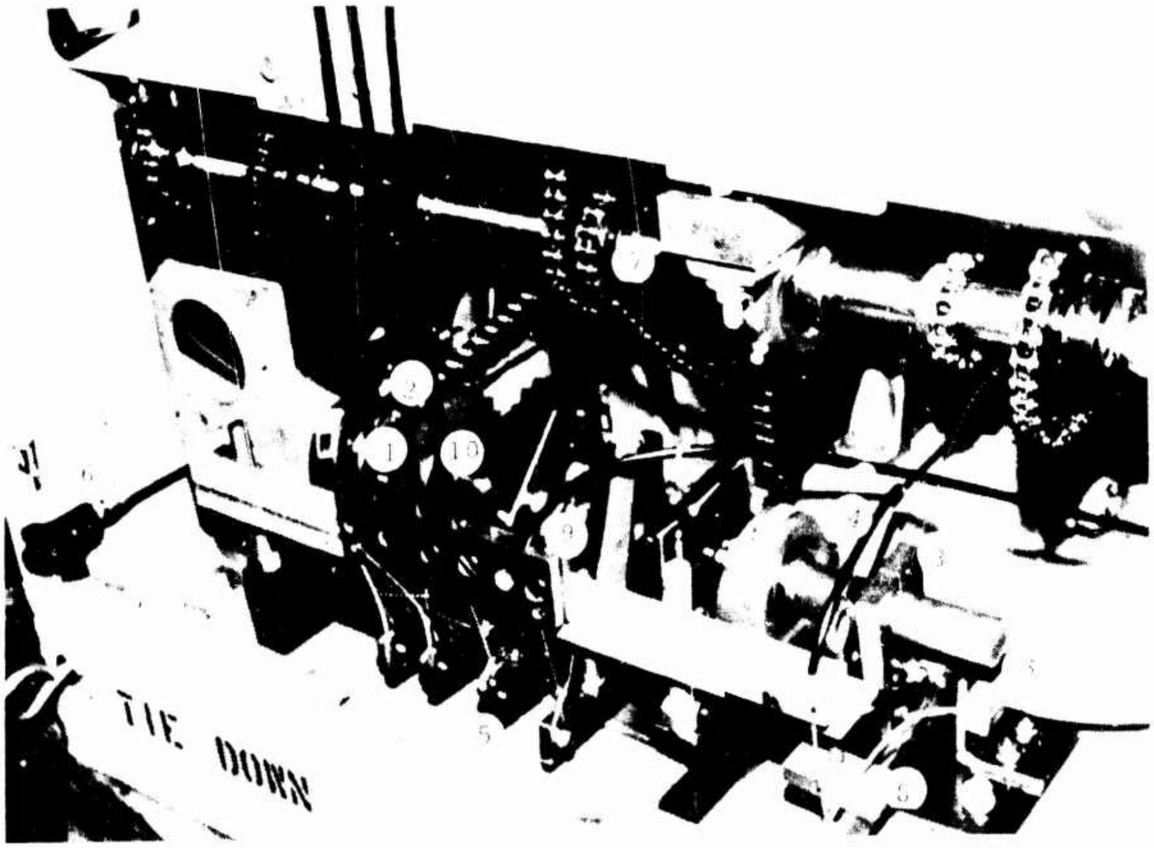

Figure 23. Safety Stop Drive Cams and Cables

1. Extraction Safety Test Slide Drive Cable and Cam
2. Release Safety Test Slide Drive Cable and Cam
3. Container Elevator Indexer Test Cable and Cam
4. Container Elevator Indexer Trigger Cable
5. Dump Bar Actuation Cam and Cable
6. Bevel Gear Re-Engage T-Handle
7. Release Cam Drive Chain-Sprocket
8. Container Elevator Test Cam Lever
9. Container Elevator Index Trigger Cable and Cam
10. Dump Bar Actuator Cable and Cam

Overload Test

The overload test is performed by an idler sprocket arrangement shown in Figure 25. The idler sprocket is mounted on a pivot bar and is pulled against the tight side of the input drive chain by a compression spring shown in Figure 25. If an overload in the system occurs, this idler sprocket is depressed, thus compressing the spring. When this occurs, the trigger cable is pulled and the clutch-brake throwout disengages the loader drive system.

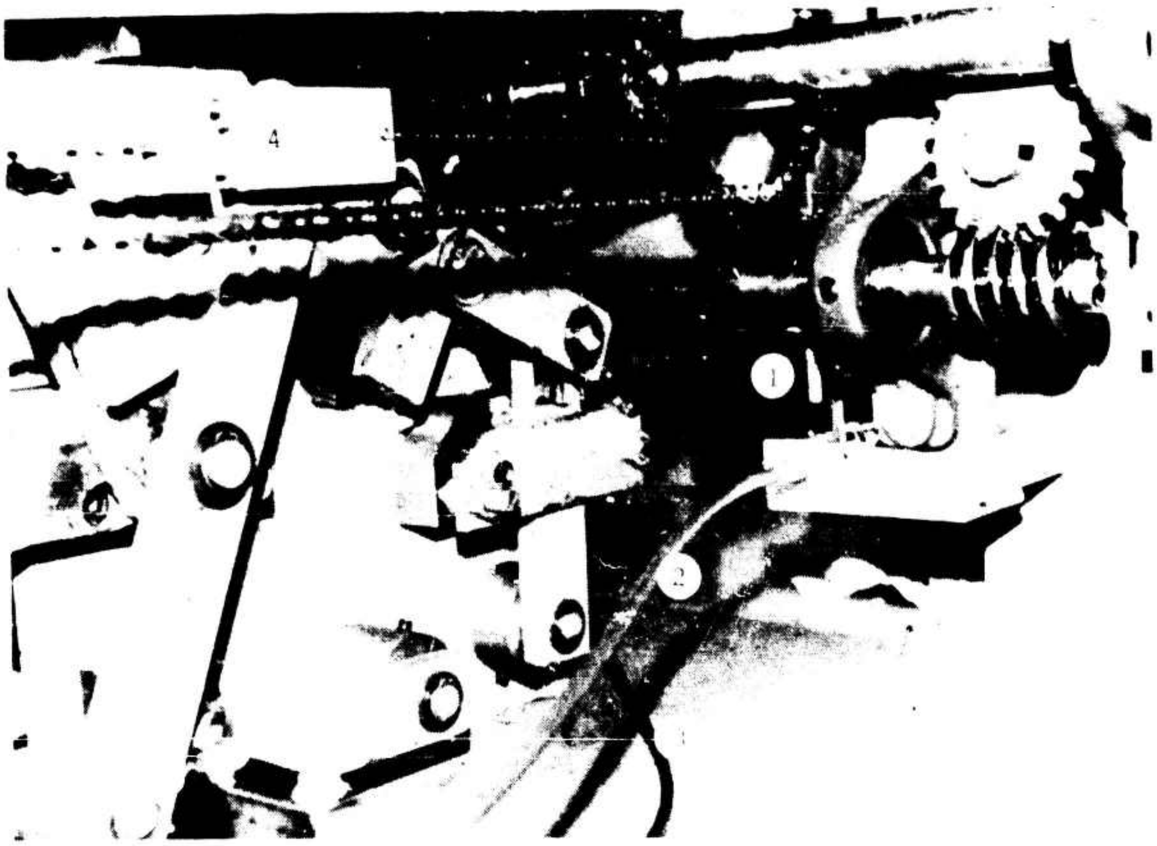

Figure 24. Container Elevator Index Tester

1. Worm Shaft Cam
2. Sensor Lever
3. Push-Pull Cable
4. Reload Push Bar Drive Mechanism Connection

Manual Emergency Stop

The manual emergency stop is a red knobbed pull cable located at the upper right-hand corner of the container roller conveyor system and is a direct cable connection to the clutch-brake throwout assembly. Whenever this knob is pulled, the clutch-brake is actuated and the bevel gear throwout assembly is actuated and the loader is stopped.

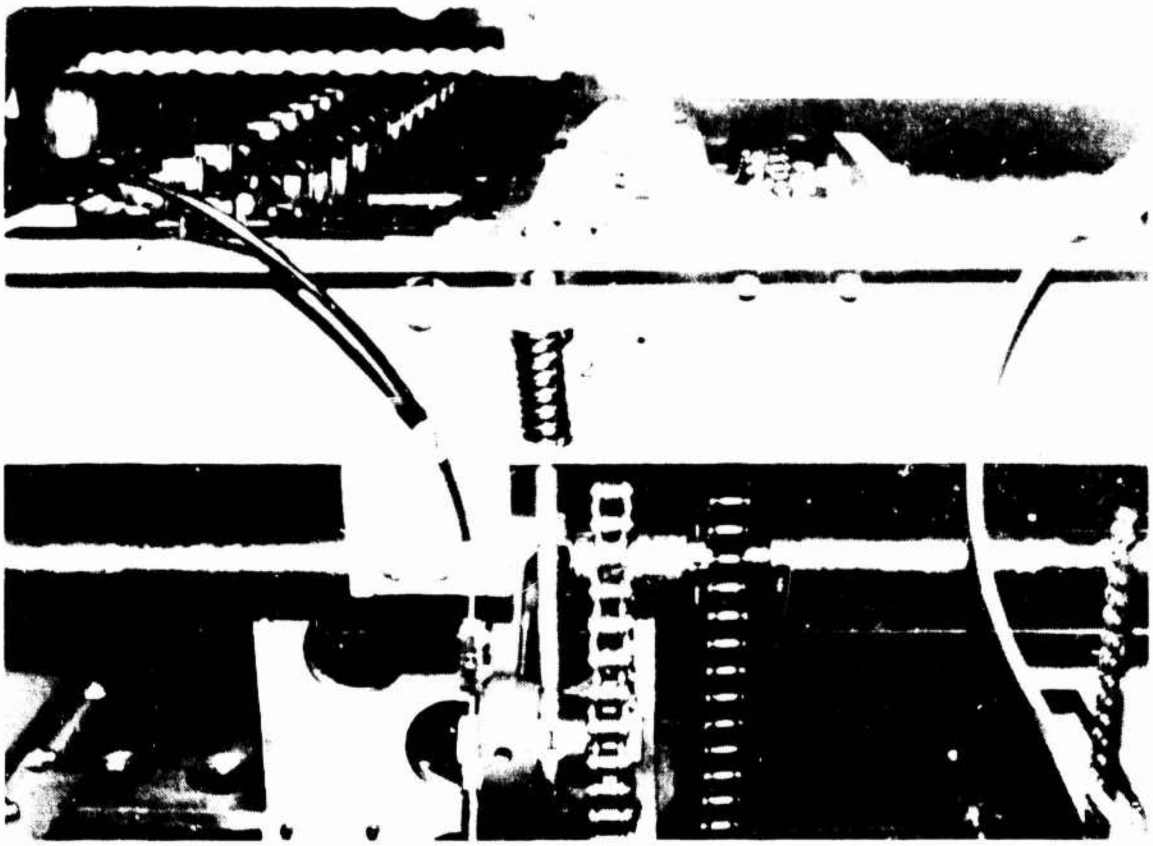

Figure 25. Overload Sensor

1. Idler Sprocket
2. Compression Spring
3. Trigger Cable

Re-engagement of the drive system is accomplished by correcting the overload or throwout condition and reversing the horizontal conveyor for approximately three elements to re-engage the clutch-brake assembly. After this has been performed, the teeth of the two bevel gears are realigned for the timing marks and the re-engage handle shown in Figures 20 and 23 is pulled until the bevel gear and yoke assembly is relatched in the engaged position.

LOADER-FLEXIBLE CHUTE INTERFACE

The loader-flexible chute interface is shown in Figure 15 and is designed to conform to the shape and element configuration of the box ends attached to the G.E. flexible chuting. Two holder keys (pins) go through the flex chute connect to hold the box ends in position on the loader. The interface connection is designed in such a way that the element tracks are properly aligned between the loader and the fexible chuting.

SECTION IV

TESTING AND DEBUGGING

As in all machine development projects, there were many malfunctions in the initial prototype which required redesign and modifications of various subsystems of the loader. Only those problems of major proportions will be discussed in this section.

SAFETY STOP, DUMP BAR AND CONTAINER INDEXER TRIGGER ACTUATOR

The original system proposed for these subsystems called for a cam follower configuration. However, it was decided that a direct trigger system as shown in Figure 26 would work as well and be less complicated and expensive. The result was that the trigger failed to function adequately and imposed very large loads on the drive system.

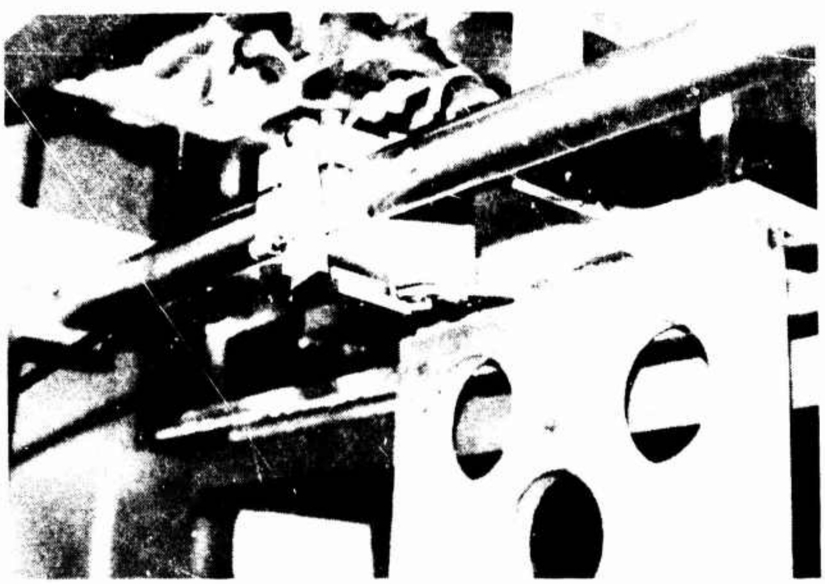

Figure 26. Sensor, Cam, Indexer Trigger

The original design concept was incorporated as shown in Figure 23. This corrected all of the problems experienced with the original prototype system.

JACK SHAFT MAIN DRIVE SHAFT THROWOUT

The original concept incorporated a PSI clutch-brake on the right side of the two drive bevel gears. The jack shaft bevel gear was held engaged with the main drive shaft bevel gear by the yoke-latch shown in Figure 27. The bevel gear on the clutch-brake on the right remained engaged with the main shaft bevel gear at all times. Whenever one of the trigger cables was pulled it would pull the latch to the right, release the yoke-slide which would be forced to the left by the compression springs. When this occurred, the right hand clutch-brake would engage, thus stopping the loader.

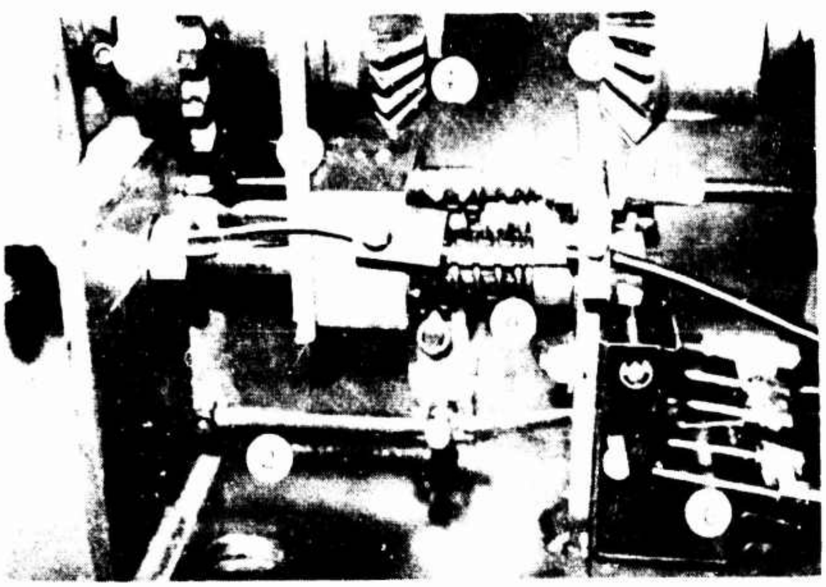

Figure 27. Original Throwout

1. Latch
2. Return Spring
3. Clutch-Brake Bevel Gear
4. Jack Shaft Bevel Gear
5. Clutch-Brake Bevel Gear
6. Trigger Cables
7. Drive Sprocket
8. Yoke
9. Compression Springs
10. Re-Engage Cable

It was discovered that the force required to release the latch was far too great, imposing too large a force on the sensor system and main drive. Other minor problems were also discovered as well.

The solution was to take the clutch-brake, drive it in the un-engaged mode off of the jack shaft, attach a pull cable to the latch which was reversed from that shown in Figure 27, trigger the clutch-brake by the trigger cables and thus operate the throwout with the clutch-brake. This reduced the load requirements on the main drive by a factor of ten and made the safety stop throwout highly reliable, maintainable and effective.

CONTAINER ELEVATOR INDEXER

The requirement that the container elevator be operable independently of the extractor/reload section required that the clutch-brake used on the worm shaft be installed without an anti-overrun feature. The result was that the worm gears and shaft would overrun the input sprocket and come to an abrupt, impact halt with each index. The resulting bounce and shock would misposition the ammunition row so the extractor would be misaligned with the row and would fail to extract. In addition, the crash experienced from overload resulted from this feature.

First, a band brake was put on the worm shaft to keep the shaft from overrunning the input sprocket. However, the friction was too inconsistent for proper operation. The anti-overrun feature was reinstalled in the clutch-brake and the problem was resolved. As a result, the container elevator cannot be operated independent of the extractor/reload system.

SYSTEM OVERLOAD

During the testing phase, the overload safety stop was not in operation because of the test motor drive setup. The system was operating when the double indexer trigger failed to operate on the container elevator. This occurred when the worm shaft overran the input sprocket, triggered the double index too soon and it thus failed to trigger at all. The containers stopped with the top of one and the bottom of the other in the extract position. The extractor heads jammed into the container edges, the container elevator indexer triggered and the containers indexed down on the extractors. The resulting overload severely damaged the extractor drive mechanism and extractor assembly. Extensive repairs were made to the drive mechanism and sprockets were changed to provide overdrive to the extractor grippers to enter the containers adequately to grip the rounds.

CONTAINER AND PACKAGING

The most severe problems in the development of the GFU-6/E loader were with consistency of M548 container and packaging configuration and shape. The extractors were designed to allow for a moderate amount of misalignment to the depth of the rounds in the container of ± 1/8 inch and in the extract plane of 3/32 inch off of center. In aligning the stop position of the vertical elevator with a container full of rounds, it was found that it was possible for a row of rounds to have as much as 5/16 inch of sag (catenary). This resulted in 1/2 inch more than the allowed tolerance for the extractors. It was found that by bending the side of the container the sag could be overcome to some extent. If the container was used several times it would begin to sag again. The extractor would align and extract misaligned rounds to a certain extent; however, it required that the extractor be overdriven, thus requiring more power than normally needed. This caused an excessive load on the drive mechanism, causing excessive wear on the mechanism bearings and links and on the connecting chains and sprockets. By checking containers and overdriving the extractor, the misalignment was overcome, although the loader would not be run under these conditions for prolonged periods of time.

Problems with rounds sticking in the cardboard tubes were also encountered. This caused the rounds to not be extracted, which would overload or otherwise cause the loader to disengage. The extractor would also pull both the tube out with the round causing a jam in the conveyor system when the cardboard tube tried to enter the flexible chute.

SECTION V

GUN SYSTEM AND AIRCRAFT INTERFACE

The loader was delivered to Eglin Air Force Base and mated to the GAU-8/A gun at Range 74L. Figure 28 shows the loader connected to this gun system. The loader was functionally tested in this configuration. It was then found that it functioned properly even though the test stand in which the gun was mounted made it very difficult to connect the load head to the gun system.

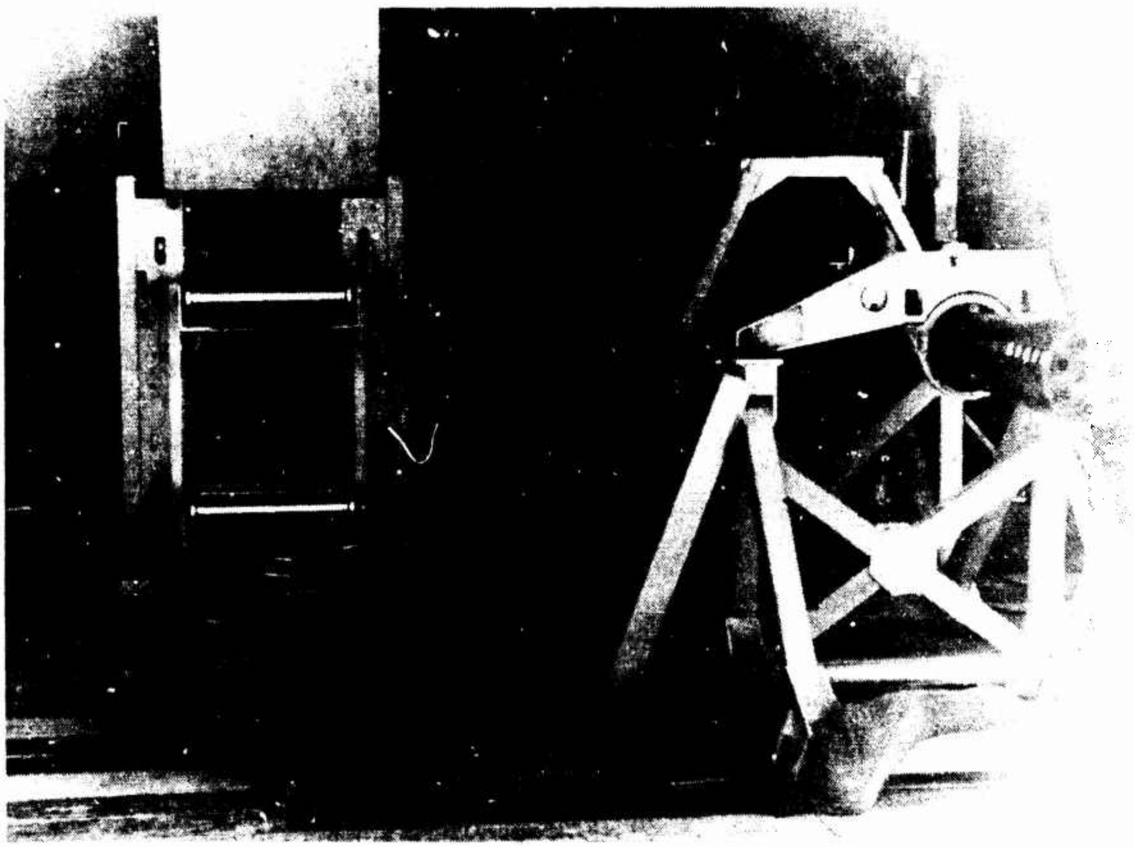

Figure 28. Eglin Test Gun/Loader Interface

The loader was then delivered to Edwards Air Force Base, California where it was tested while being connected to the A-10 Aircraft. The loader-trailer configuration is shown in Figure 29 while Figures 30 and 31 show the loader positioned at the aircraft during a test up/download operation. The actual, simultaneous up/download test time was 9-1/2 minutes while uploading 1350 rounds and simultaneously downloading and repackaging 1350 rounds. This time exceeded the design specifications by 1/2 minute.

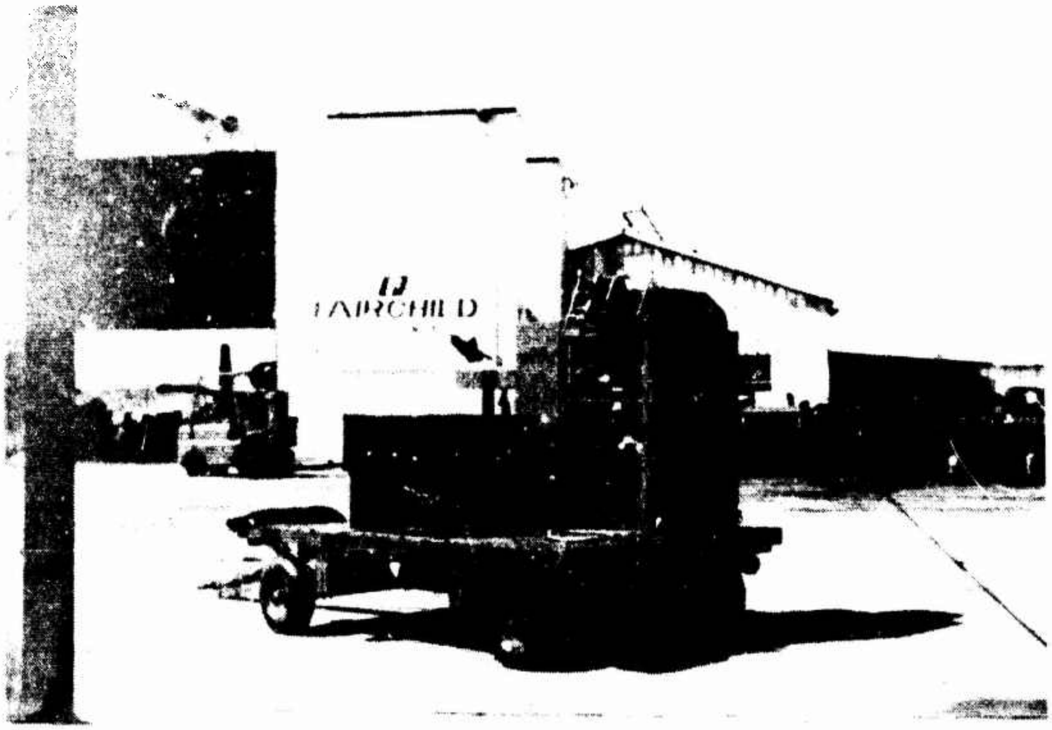

Figure 29. Loader-Trailer Configuration

The Development Test and Evaluation (DT&E) phase of the design program revealed some weaknesses in the design; however, it revealed even more weaknesses in the interface system between the loader and the actual gun system. Recommendations for improvements to the loader for use as a production loader are given in the next section.

These recommendations are based on results of the DT&E as well as direct observations of the loader operation and apparent areas requiring improvement as a result of actually operating the loader with the gun system. It is important to note that this contractor had no gun-system interface testing of the loader prior to its delivery to Eglin Air Force Base. Had this interface been provided during the duration of the contract, many of the difficulties incurred during the Eglin and Edwards testing programs would not have occurred.

Main difficulties experienced with the interface system (flexible chuting, ammunition elements and the load head with its turn-around sprocket) were associates with collapse (accordioning) of the flexible chuting under load conditions. Bending of the element cradle ends thus causing the rounds to jam in the elements, springout and jamming of the tabs of the flexible chuting, extreme difficulty in assembling of the flexible chuting on the loader with the proper number of elements installed in the conveyor system for proper operation and difficulty in positioning the loader next to the aircraft because of the length of the flexible chuting provided to interface with the loader. In addition, the flexible chuting and load head were difficult for the load crew to attach to the gun system because of its bulkiness, weight and semi-rigid nature when it was lifted into the connecting position.

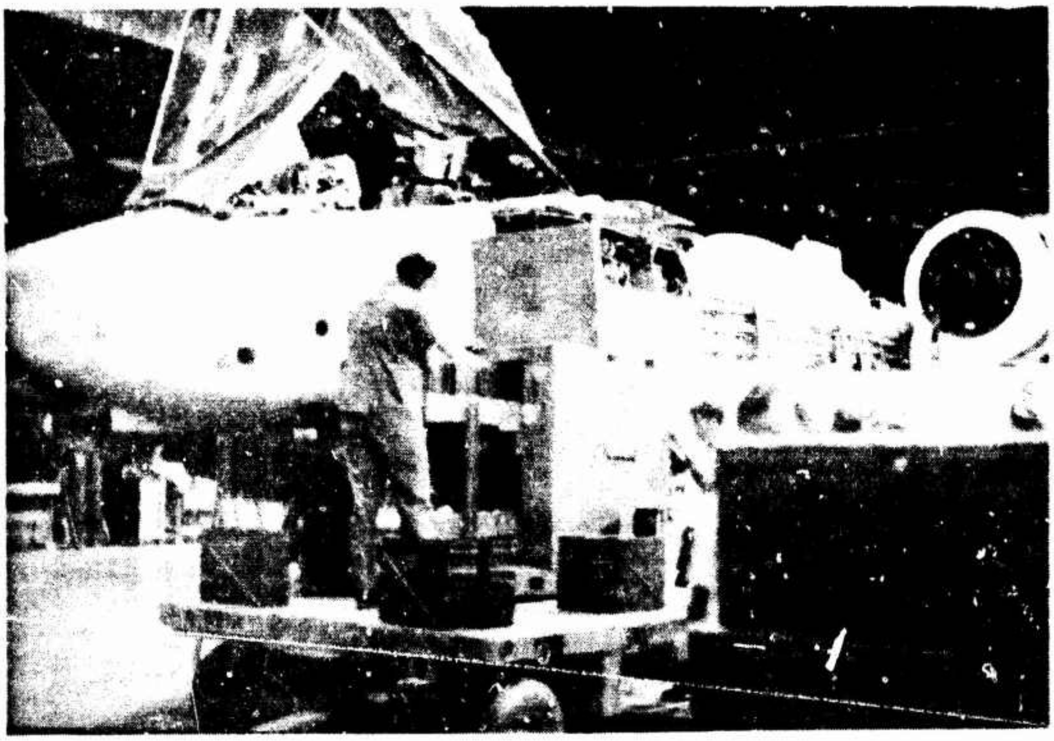

Figure 30. Loader-Aircraft Interface

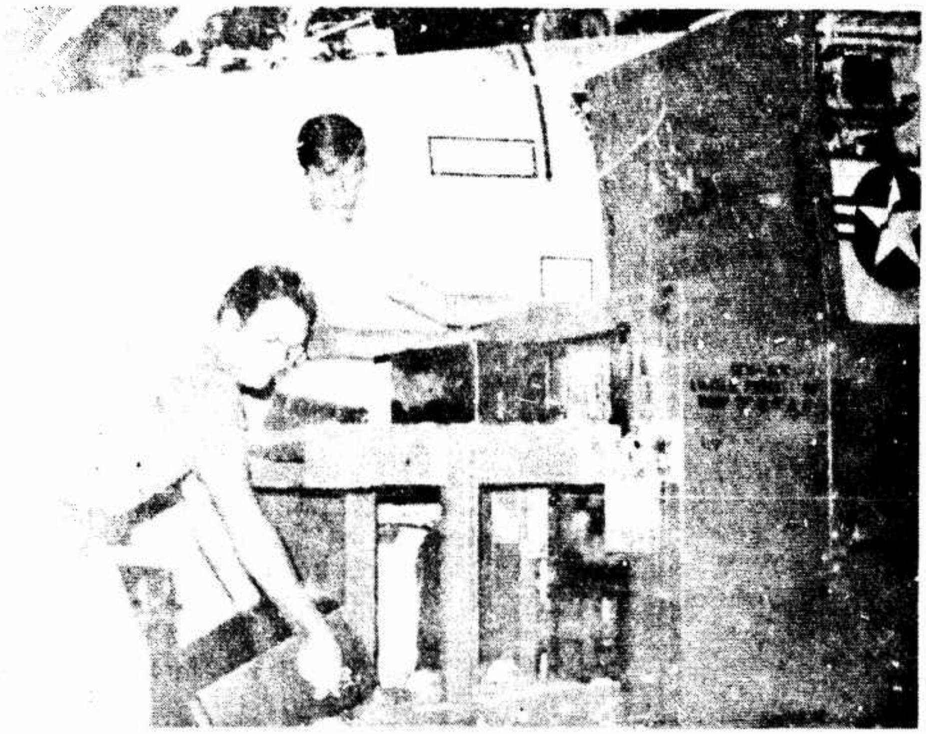

Figure 31. Up/Download with Aircraft

SECTION VI

RECOMMENDED ENGINEERING DESIGN CHANGES

The following list of changes, modifications and improvements to the prototype include recommendations from the contractor and the DT&E load crew, as well as representatives from the Tactical Air Command and A-10 SPO.

1. Redesign of the trigger cam assembly to use standard cams and roller-followers so the cams can be manufacturered from hardened casting resulting in longer durability and lower manufacturing costs.

2. Modify the dwell linkage drive system for extractor and reload push bar assemblies to assure true planar motion and allow the entire assembly to be removed if it is required.

3. Relocate the input drive shaft with the spline adapter to the opposite side of the loader so the shortest length of flexible drive shaft can be used when attaching the loader to the aircraft.

4. Modify the loader covers so that the panels are hinged, thus allowing them to be opened and closed more readily.

5. Provide draw-down cleats on the vertical elevator flights so that the containers are automatically drawn down into the vertical elevator system without requiring assistance from the load crew.

6. Decrease the size and complexity of extractor/release mechanical logic system and provide a linkage drive for this system rather than cables.

7. Provide a semi-rigid element chuting system to interface the loader with the load head and gun access unit. This arrangement would have a permanent 90-degree turn in the chuting system and would be so arranged that the load head would be gimbled for ease in attaching it to the gun system.

8. Provide a support arm upon which the load head and chuting system is supported to reduce the effort required by the load crew in interfacing the load head with the gun system on the aircraft.

9. Provide mesh wire or sheet metal guarding between the two container roller assemblies to prevent the load crew from being injured by containers which are discharged from the loader.

10. Modify the re-engage assembly to simplify the re-engagement procedure in such a way that the system will automatically adjust itself for phasing whenever it is reasonably close to being properly realigned.

11. Provide additional support bearings for the extractor bar and reload bar drive shaft.

12. Provide automatic tension take-up idler sprockets for those chain assemblies which will have normal expansion due to temperature and wear.

13. Mount the loader on a drop-axle assembly so that the bottom of the loader is approximately 3 inches above the traveling surface and in such a way that the steering assembly of the loader is at the opposite end from the ammunition container inlet and outlet roller assemblies.

14. Equip a MHU-12 trailer with spherical stock roller assemblies so that the ammunition containers can be arranged in rows along the trailer in such a way that they can be fed onto the input roller system of the loader without having to lift containers while they are full.

15. Provide a rail around the roller system so that the containers will remain on the trailer while it is being moved.

16. Provide a row shift-bar assembly to the roller system on the trailer so that the rows of ammunition containers can be shifted laterally on the trailer after each row is fed onto the loader.

In addition, it is recommended that a new, improved, lower cost container packaging (insert) be developed for the M548 container. Many of the problems which were encountered during the design and development of the GFU-6/E loader would be eliminated if this were done. Container sag, uneven alignment of the bases of the rounds in the containers, sticking of the rounds in the insert tubes, tube pull out and irregular container shape would all be minimized and/or eliminated by utilizing another type of packaging method.

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APPENDIX I

FAILURE MODES AND EFFECTS ANALYSIS

The failure modes and effects analysis was performed to identify potential system failures and to establish the procedure for correcting these failures.

SYSTEM VERTICAL ELEVATOR

COMPONENT	FUNCTION	FAILURE	EFFECT ON ASSEMBLY	EFFECT ON SYSTEM	METHOD OF DETECTION AND COMPENSATING PROVISION
Drive Clutch	Driving and stopping the vertical elevator	1. Drive spring breakage	Vertical Elevator may fail to index	Elevator safety would shut loader down	Failure of container to index. Probability of breakage nil.
		2. Brake spring breakage	Vertical elevator will fail to stop causing jam in loading system	Overload safety would shut loader down	Container would fall to bottom of elevator or jam if extractor or reloader caught container. Probability of breakage nil.
		3. Overrun spring breakage	Vertical elevator will drop containers but still stop in proper position	Loader may operate roughly due to container sitting on container pusher	Jerky operation of vertical elevator. Probability of breakage nil.
		4. Trigger failure no actuation	Vertical elevator will not index	Elevator safety would shut loader down	Failure of container to index.
		5. Trigger failure no stop	Vertical elevator would not stop	System jam would cause loader to shut down	Container jam or container at bottom of elevator.
Worm gears	Transfer elevator drive from clutch shaft to drive sprocket shaft	Breakage of worm or worm gear	Assembly jam	System jam would shut loader down	Failure of elevator to index. Replace broken gear.
Double index trigger	Actuate clutch to index between containers	Breakage of trigger or trigger cable	Elevator would not index when container edge was in extract position or reload position	Extractor system jam would shut loader down	Container edge in extract position. Replace broken part.
Side plate chains	To hold and index side plates of elevator	Broken chain	Elevator will jam	System jam will shut down loader	Failure to index container or container jam. Replace broken chain.

SYSTEM EXTRACTOR

COMPONENT	FUNCTION	FAILURE	EFFECT ON ASSEMBLY	EFFECT ON SYSTEM	METHOD OF DETECTION AND COMPENSATING PROVISION
Grippers	Grip rounds	Broken spring or catch	Failure to extract	Extract safety would shut loader down	Assembly would not extract. Replace gripper.
Fingers	Hold bottom of round	Broken	Round would not stay in extractor	Absence of round in extractor would shut loader down	Failure to hold round. Replace finger.
Back plate	Hold round horizontal	Bushing seizure or spring breakage	Failure to hold round horizontal	Extract safety would not sense round and shut loader down	Round would not be horizontal. Replace spring. Clean bushing.
Drop plate	Pull fingers back to drop rounds	Broken spring. Bushing seizure.	Failure to extract round	Failure to extract would shut loader down	No extraction. Replace spring. Clean bushing.
Drive	Drive extractor	Broken chain	Extractor would not extract all rounds or extractor would not move at all	Failure to extract would shut loader down	No extraction. Repair broken chain.
		Drive linkage	Extractor would not move	Failure to extract would shut loader down	No extraction. Repair drive linkage.

SYSTEM RELOAD

COMPONENT	FUNCTION	FAILURE	EFFECT ON ASSEMBLY	EFFECT ON SYSTEM	METHOD OF DETECTION AND COMPENSATING PROVISION
Front dump bar	Hold round nose up	Return spring breakage	Runner would not return to hold up round	System would jam and shut down loader	Jammed rounds in reload section of loader. Replace spring.
		Broken trigger cable	Runner would not trigger causing nose of round to drop slower	Would possibly cause loader to jam and shut down	Jammed rounds in dump bar. Reload system. Replace cable.
Rear dump bar	Hold round base up	Return spring breakage	Runner would not return to hold up round base	Loader would jam and shut down	Jammed rounds in reload section of loader. Clear out and replace spring.
		Trigger cable breakage	Dump bars would not operate	Rounds would come out and fall into misfired round container	Rounds in misfired container. Replace cable.
Pusher	Push rounds into container and push container out of elevator	Drive chain breakage	Record system jam - rounds not being put into container	Loader would overload and shut down	Rounds jammed under dump bar. Repair chain.
		Drive linkage failure	Record system jam - rounds not being put into container	Loader would overload and shut down	Rounds jammed under dump bars. Repair linkage.

SYSTEM SAFETY STOP

COMPONENT	FUNCTION	FAILURE	EFFECT ON ASSEMBLY	EFFECT ON SYSTEM	"ET OF DETECTION AND COMPENSATING PROVISION
Extract sensor	To sense whether or not there is a round in the extractor	Sensor breakage	Safety would not sense round in extractor	System would shut down	Shut down even though a round was in the extractor. Replace sensor.
		Slide breakage	Safety would not sense missed or not dropped round	System would not shut down when round was missed or not dropped	Failure for safety to function. Replace slider.
Trigger and drive cables	Transmit stop signal and sense signal to and from safety	Trigger cable breakage	Disengage. Drive clutch would not receive stop signal.	System would not shut down	Failure for safety to function. Replace cable.
		Drive cable breakage	Safety system would receive sense signal from cam assembly	System would not shut down	F ilure for safety to function. Replace cable.
Overload sensor	To sense an overload on the input drive	Spring breakage	Assembly would sense overload	Loader would shut down	Overload shut down for no reason. Replace spring.
		Bearing seizure	Assembly would sense overload	Loader would shut down	Overload shut down for no overload. Repair bearing or replace.
Vertical elevator index sensor	Sense vertical elevator index	Sensor breakage	Assembly would not trigger if elevator did not index	System would not shut down, or jam and shut down	Elevator not indexed and loader not shut down. Replace sensor.

SYSTEM DRIVE - INPUT

COMPONENT	FUNCTION	FAILURE	EFFECT ON ASSEMBLY	EFFECT ON SYSTEM	METHOD OF DETECTION AND COMPENSATING PROVISION
Spline shaft	Transmit power from input to reducer	Breakage	Drive would stop	Loader would stop flex chute will jam if gun system is not stopped	Power not transmitted to head shaft. Replace shaft.
Reducer	Reduce input RPM to headshaft RPM	Bearing seizure	Assembly would bind up	System would require greater power to run	Flex drive shaft wraps under heavy load. Replace worn bearing.
		Chain breakage	Drive would stop	Loader would stop flex chute will jam if gun system is not stopped	Power not transmitted to headshaft. Repair broken chain.
Headshaft	Drill horizontal conveyor elements	Bearing seizure	Conveyor would jam causing overload on input drive	System would stop	Flex drive shaft wraps under heavy load. Replace broken headshaft.
Loader Drive Chain	Transmit power from headshaft to throw-out shaft	Chain breakage	Drive stops	Loader stops while conveyor continues to run	Loader stops as if it was disengaged. Repair chain.
Disengaged system	Disconnect input drive from loader drive	Engage catch	System will not stay engaged	Will not run	Failure of bevels gears to stay engaged.
		Bearing seizure	Bevel gear would not slide back and disengage	System would not stop running until gun system was stopped	Failure for loader to stop when stop button was pulled. Fix or replace bearing.
		Drive chains to different systems	Drive assembly would keep running	Driven system would stop	Check drive on system w/failure. Replace or fix chain

INITIAL DISTRIBUTION

Hq USAF/SAMI	1
ASD/ENYEHM	1
ASD/ENFEA	1
AFWL/LR	2
AUL/AUL-LSE-70-239	1
DDC/TC	2
Ogden ALC/MMNOP	2
TAWC/TRADOCLO	1
AFATL/DL	1
AFWL/LR	2
AFATL/DLOSL	2
AFATL/DLOA	5
AFATL/DLDD	2
ASD/YXA	2

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