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MODIFICATION AND ANALYSIS OF THE 40MM SELECTIVE FEED SYSTEM

MAX L. COPPOCK
THOMAS J. DONAHUE

JANUARY 1977

TECHNICAL REPORT

AIRCRAFT & AIR DEFENSE WEAPONS SYSTEMS DIRECTORATE

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This report describes one approach to the problem of feeding several (more than two) types of ammunition of the same caliber into a single weapon. This system was designed primarily for use with an aircraft armament subsystem, however, there is no real reason for limiting its application to an aircraft.

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Block 20 continued:

A feasibility prototype using the M129, 40mm Grenade Launcher was designed and fabricated by a contractor. This report describes the design and how it was changed to give it added reliability of operation. It was concluded that considerably more work is required to obtain acceptable reliability for demonstration. In comparison to existing helicopter armament subsystems, this system will be limited to a relatively low rate of fire.

SUMMARY

General:

The Selective Feed Program was initiated to develop an ammunition feeder for a gun system which is capable of feeding several different types of ammunition (same caliber) into one gun. A weapon system of this type will allow an aircraft (helicopter) gunner to select and fire the round of ammunition which will best defeat the immediate target. The resulting effect will be to have more effective rounds, thereby, reducing the total number of rounds required to defeat a target.

This report describes the feasibility prototype which was designed and fabricated on contract by the Hughes Helicopters/Division of Summa Corporation. In addition, this report describes the design modifications made by the Aircraft and Air Defense Weapons Systems Directorate to improve the Selective Feed's operational reliability.

Conclusions:

Considerably more effort is required to obtain an acceptably reliable operation for the Selective Feed System. In addition, a design is required for the ammunition storage container, hand-off mechanism to the loader and the conveyor loading mechanism. The existing devices being used in this capacity are primative and not designed for an actual aircraft installation. The present Selective Feed design is limited to a relatively low rate of fire (approxi-

mately 325 spm). A family of 3 or more cartridges will maximize the benefits from using the Selective Feed System. Most current weapon systems use only two types of combat cartridges. However, use of the Selective Feed System will allow an effective use of the existing combat rounds.

Recommendations:

It is recommended that the following design changes and new designs be funded for implimentation:

a. Redesign the conveyor belt links to improve their strength, improve the round retention capability and reduce torque requirements.

b. Replace micro-switches and other electronic noise producing components with solid state components.

c. Redesign electronic circuitry to filter out as much electronic noise as possible.

d. Redesign the motor control circuit to provide better speed control.

e. Prepare a design for an ammunition storage and hand-off system. It is recommended that the present indicated design of a storage and hand-off unit for each type of round be discarded in favor of a single storage unit which has compartments for each type of round. The hand-off mechanism will be designed to remove rounds from each compartment and feed them into the proper links on the conveyor belt. This proposed change will greatly reduce the weight and space requirements of the present design.

f. Prepare a design to show the Selective Feed System as it would be applied to an actual installation.

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INTRODUCTION

A need presently exists for a weapon feed system which will allow an aircraft gunner to select and fire the round of ammunition which will best defeat the specific type of target being encountered. Designs for dual feed systems are in existence, however, they do not meet the need since it is desired to have the capability of selecting three or more different types of rounds.

An available feed system of this type will allow munition designers to develop families of rounds. Each of which would be designed for a special target. Thus, each round could be made to be more effective, thereby, reducing the number of rounds required to deactivate each target. In addition, existing rounds can be used to better advantage by selecting the one best suited for the target at hand.

The Selective Feed System was developed as a part of the D044 Program for aircraft armament gun type systems. CDOG item 512.b(7) is applicable.

The purpose of the Selective Feed Program was to determine the feasibility of a weapon feed system which would allow several types (more than two) of rounds to be fed into one gun. The purpose of this report is to describe Hughes Helicopter's system, the modifications made to it by Rock Island Arsenal and to analyze the resulting product. The system was basically designed for an aircraft armament weapon system, however, due to the nature of the design, it is expected to be applicable to most small and medium caliber weapon systems.

HISTORY

Requests for Proposals (RFP's) for Selective Feed concepts were sent to prospective contractors in April 1970. The four best proposals (Hughes Helicopters/Suma Division, AAI, Challenger Research, and Emerson Electric Company) were selected and funded for concept work. This work was completed in January 1971. From this effort, Hughes was selected to receive a contract to further develop their concept and to fabricate one working prototype to prove the feasibility of their design. A one-year contract was awarded to Hughes Helicopters on 1 July 1971. In July 1972, the contractor declared that the prototype did not operate as anticipated, therefore, the contract period was extended to give Hughes time to improve their hardware. The contractor conducted a demonstration firing at his plant on 12 October 1972. The selective feed mechanism, M129 Grenade Launcher and practice ammunition were used in the demonstration. Twelve rounds were fired before the mechanism jammed. This was the longest burst to this date that the contractor had ever achieved before the mechanism jammed. The hardware was received at RIA on 14 November 1972. The drawings received at this time did not adequately reflect the hardware and some drawings were missing. Several months were required to make drawing changes and obtain the additional ones required.

Familiarization with the hardware was begun in December 1972. It was evident that the system was highly unreliable. Jams were frequent, the system was velocity and timing sensitive and electronic problems were numerous. In-house redesign work was initiated in March 1973 to improve the operational reliability of the system.

The following activities were conducted from March 1973 through December 1973: System components were redesigned; the conveyor was shortened to a 24-round belt; redesigned parts were procured and some were installed; system analysis tests were conducted; and the electronic controls were tested. Additional parts were installed and tested from December 1973 to March 1974. An oscillograph was used to monitor all operational tests from March 1974 through June 1974. Studies for system improvements were made from July 1974 through October 1974 at which time all efforts were discontinued due to lack of funds.

DESIGN CONSIDERATIONS

The Selective Feed Program was minimum funded, thereby requiring a maximum use of materials already available. The 40mm, M129 Grenade Launcher Serial No. 698, was selected for this program since it was the only weapon readily available, and it was the only weapon for which there was a possibility of having four different types of cartridges available. The Selective Feed System required a side-stripping link but the 40mm link used with the M129 Launcher is end stripped. The 30mm, XM23 link was then selected for use with the 40mm round because it was nearly the correct size, was side strippable and was available in sufficient quantities. It had to be reshaped to fit the contour of the 40mm round (See Fig.1). The links had marginal holding force and after limited usage they became loose to the point that rounds were thrown out due to the centrifugal forces exerted at the end sprockets. Stiffeners were welded into the links which improved their holding ability but not enough to eliminate the problem. Many jams were caused by rounds being thrown out of the links and getting wedged into a moving part of the machinery.

The conveyor belt of ammunition consists of a repeated sequence of four different types of rounds. For this reason the conveyor belt must operate four times as fast as the gun fires. It appears that approximately 325 spm is the optimum gun speed for this system.

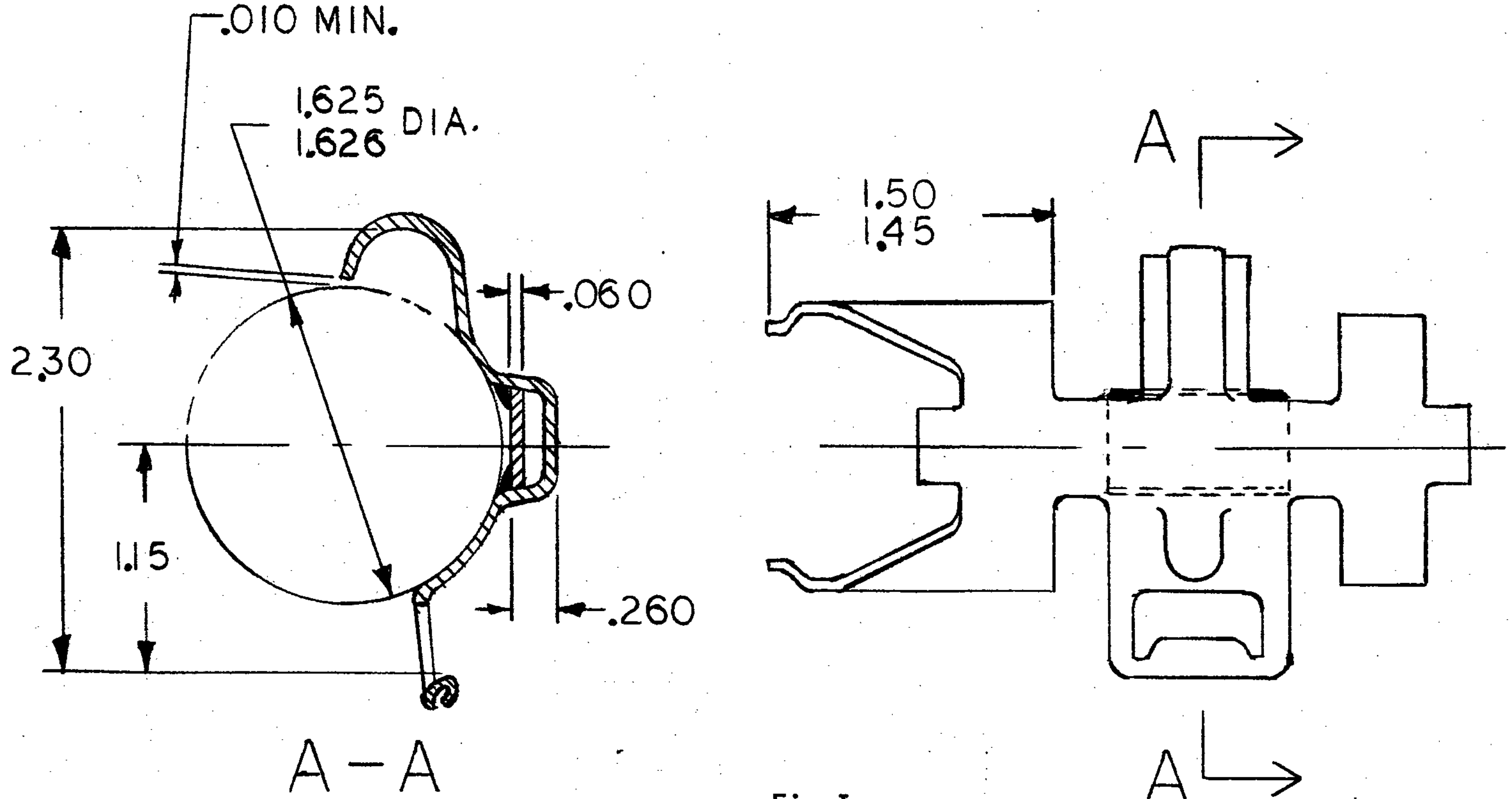

Fig I
Modified XM23 Link

SYSTEM DESCRIPTION

The Selective Feed Mechanism is basically an endless conveyor belt of ammunition with a selector mechanism at one end and up to four reloading mechanisms at or near the other end of the conveyor. Other components with the system are: a drive motor, power supply, control box, and interconnecting cable assemblies (See Fig II). The conveyor belt contains up to four different types of ammunition which are positioned in a fixed sequence. When in use, the selector removes every fourth round from the conveyor in accordance with the type of round selected.

A loader mechanism and ammo storage container is required for each of the four types of ammo. The contract with Hughes Tool Co did not provide for anything more than a rudimentary device which shows that rounds can be loaded into the moving conveyor belt. Only one loader was fabricated, therefore, only one type of round can be reloaded automatically on the demonstration model.

The loader provides a sprocket type roller around which the ammunition conveyor moves. The drive motor for the selector mechanism and weapon also operates this sprocket by means of a drive shaft and gearing. This keeps the loader properly synchronized with the selector. The loader end, also, has a cam, cam follower, feed pawl, round sensing arm, loading sprocket and ammunition holding magazine. As the ammunition in the conveyor approaches the sprocket-roller, the round sensing arm senses every fourth link (for one type of ammunition only) (see Figs. III and IV). This is accomplished by means of the cam, cam follower and two heavy springs. The cam follower is mounted on the same arm as the

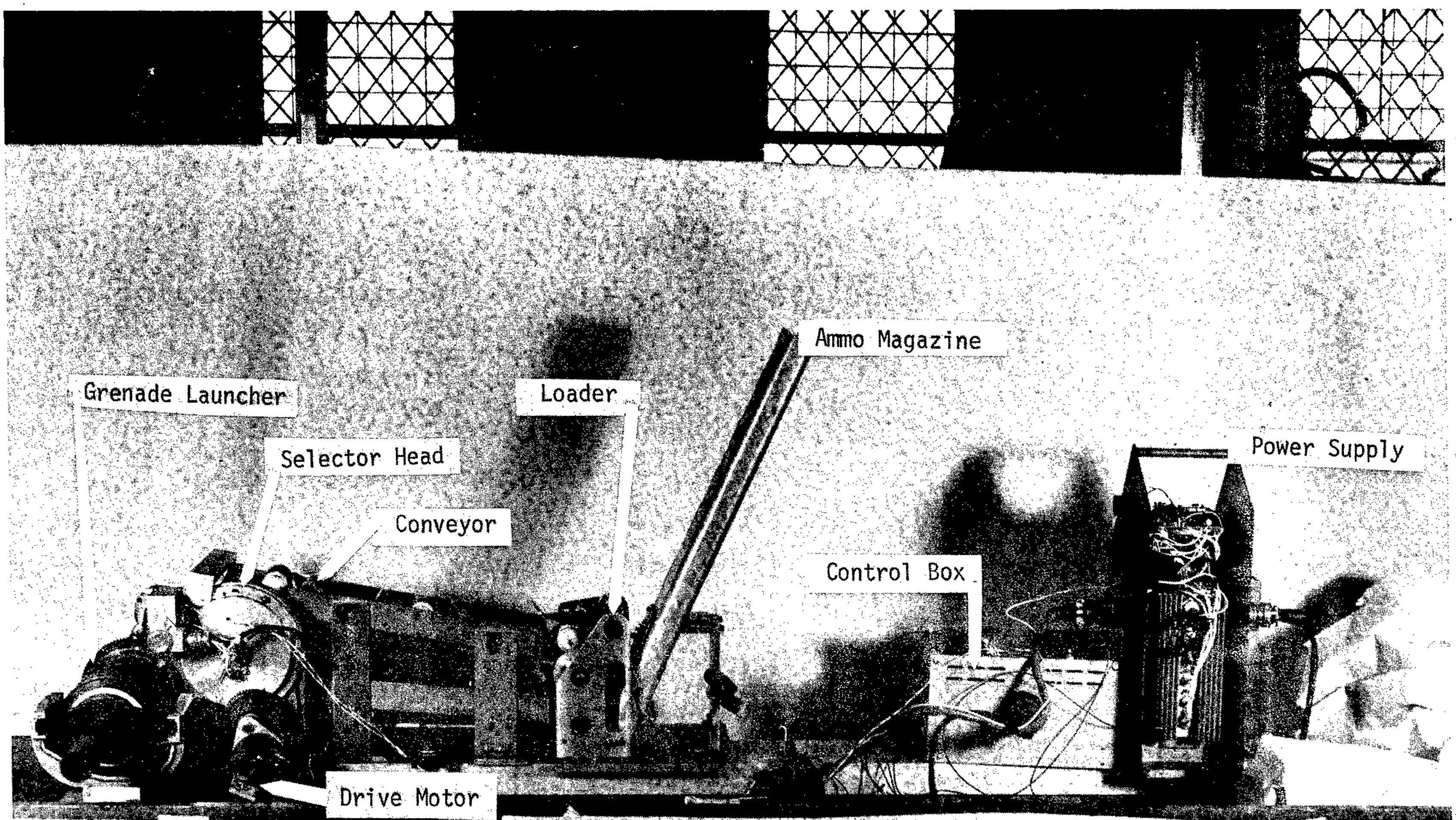

Fig. II
Selective Feed Assembly

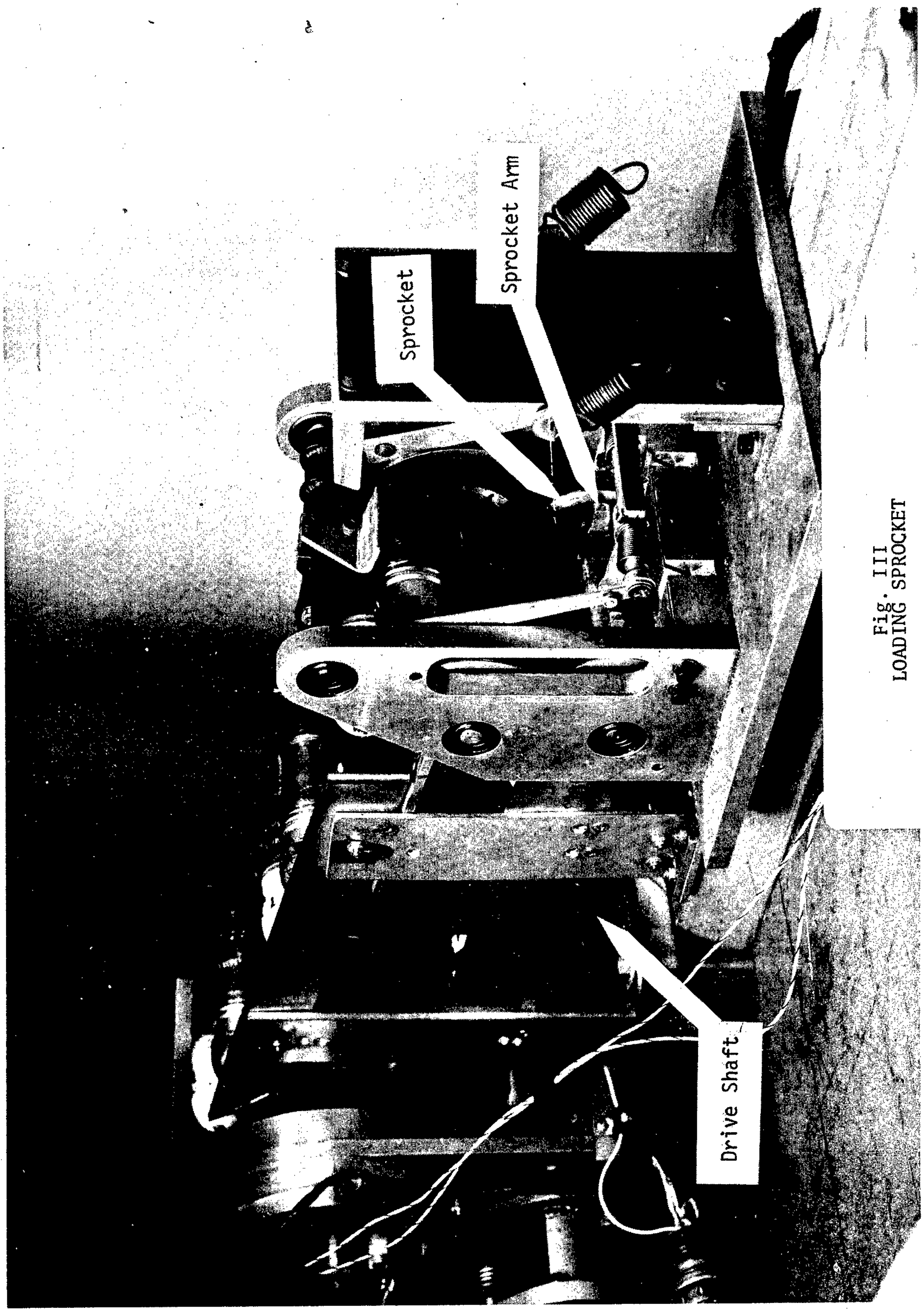

Fig. III
LOADING SPROCKET

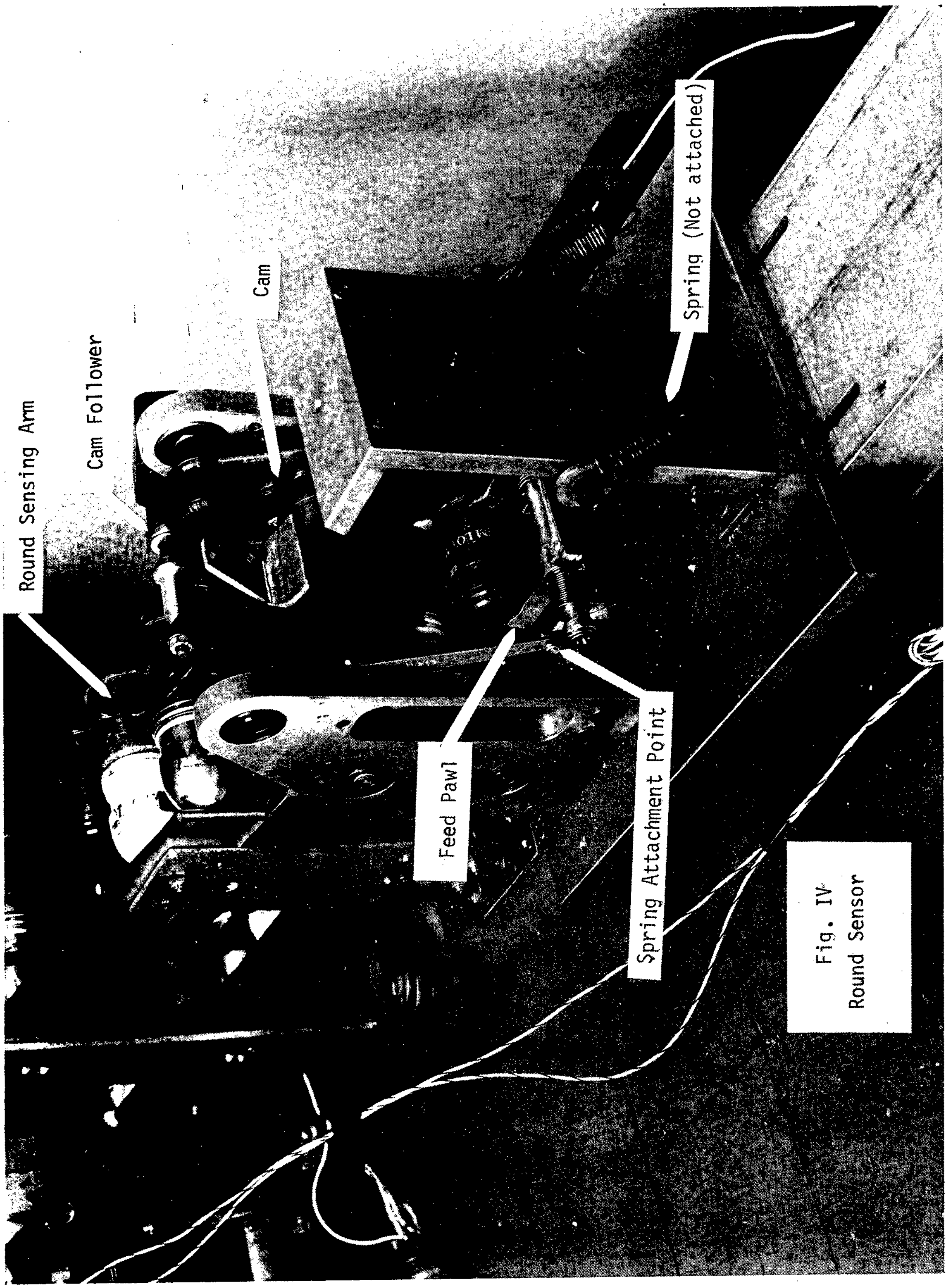

Fig. IV
Round Sensor

round sensor. The cam is so designed and geared that it only allows the cam follower and round sensor to sample every fourth round. Two heavy springs hold the cam follower to the cam surface. When the round sensor finds an empty link, it drops a short distance into the link which causes the feed pawls to move backward allowing one round in the magazine to drop down one position. The cam then forces the cam follower and feed pawls back into the normal position. During this action the feed pawls push the dropped round into a position where the loading sprocket will pick it up and force it into the empty link as it comes into position. The feed pawls and a spring activated panel on the magazine prevents rounds from getting into the loading position at the wrong time.

The selector mechanism is composed of two concentric rotating drums. The belt of ammunition rides around 180° of the outer surface of the outer drum. Each drum has a large ring gear on one end. These two gears are connected by a solenoid operated clutch. Ejection arms inside the innermost drum are controlled by a cam at the end of the two drums. As the cam rotates, it causes the ejection arms to move in and out through slots in the two concentric drums (see Fig V). As they move out, they eject a round from the conveyor belt. The round is caught by the feeder and moved into the breech of the gun. A brake in the system is applied when the firing function is stopped so that the ejector arms are always stopped in the neutral position (arms retracted into drum). When a change in round selection is made, the solenoid is activated. This releases the clutch which allows its inner and outer drums to operate separately from

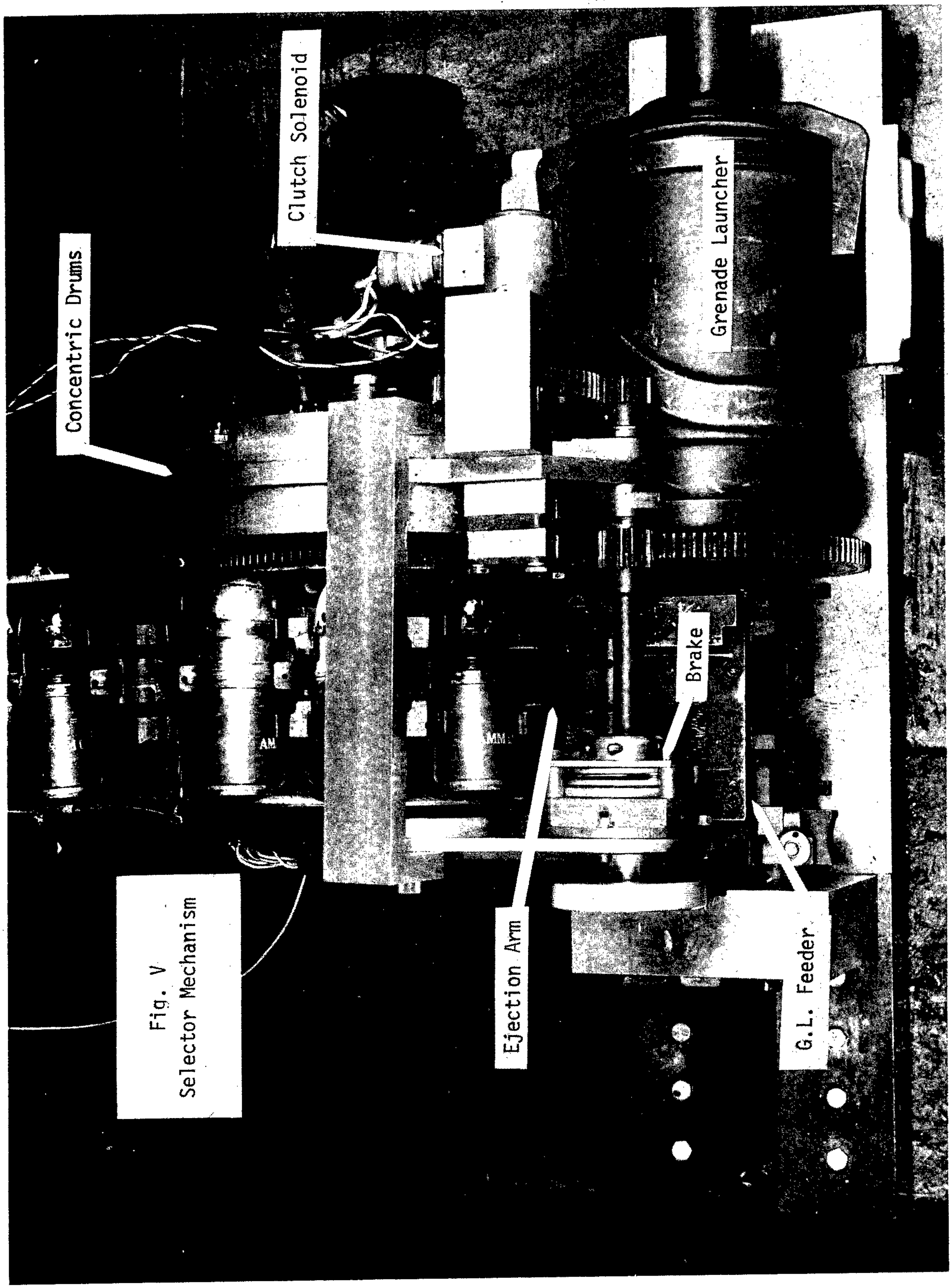

Fig. V
Selector Mechanism

each other. The inner drum then rotates to a new position with respect to the outer drum causing the ejection arms to remove a different round in the sequence of rounds.

The drive motor is geared directly to the outer drum which in turn drives the gun through intermediate gearing.

PHYSICAL ARRANGEMENT

The main power supply is connected directly to a 110 VAC supply line. This unit contains the main power switch. A cable connects the main power supply to the control box. A second cable connects the power supply to the drive motor and other electrical components on the selector mechanism.

The control box contains the master armament switch, the ammunition selector switch, the safe/arm switch, the firing button and a power-on indicator lamp.

The selector mechanism, M129 Grenade Launcher, ammunition conveyor belt and loading mechanism are all mounted on a T shaped platform made of aluminum channels (See Fig VI). The weapon is located beside the selector mechanism. The drive motor, concentric drums, drive motor, slip clutch, solenoid clutch, system brake and conveyor belt all form a part of the conveyor belt, loading mechanism and ammunition magazine.

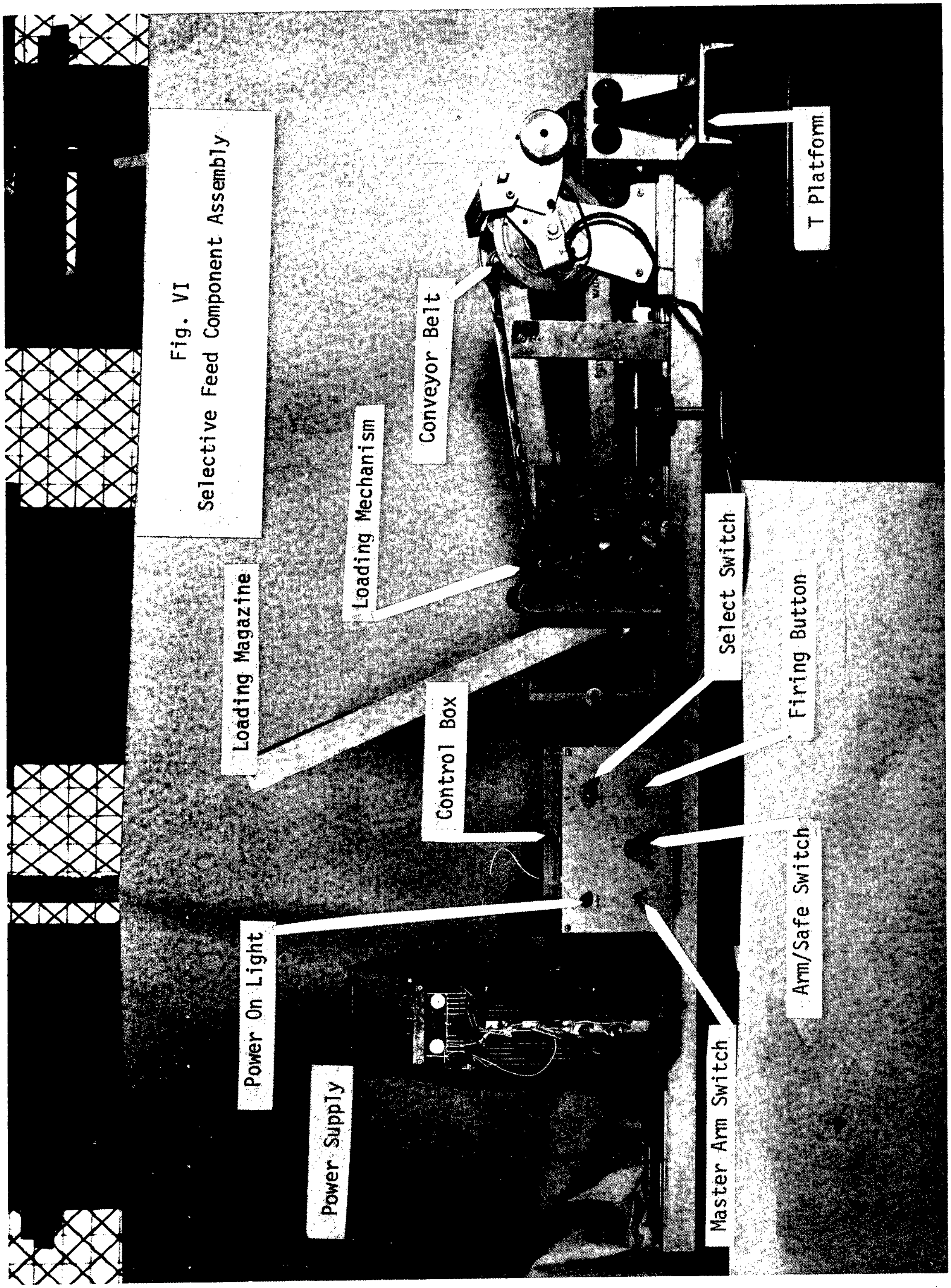

Fig. VI
Selective Feed Component Assembly

OPERATIONAL PHILOSOPHY

The sequence of events to operate the Selective Feed System after it has been connected to 110 VAC power line as taken from the contractor's report[1] is as follows:

a. Turn on main power switch (power supply)

b. Turn on master arm switch (control box)

c. Move safe switch to arm position (control box)

d. Select desired type of ammunition (choice of 4 types on control box).

e. Depress trigger switch (control box).

When the trigger switch is depressed the following chain of events is initiated:

a. The clutch solenoid is energized to disengage the clutch which allows the two concentric drums to rotate independently from each other.

b. After a 25 millisecond delay the brake is energized to release and the drive motor is simultaneously energized.

c. One-hundred and fifteen milliseconds later the select circuits are energized.

d. The appropriate switch in the group of selector switches is closed. This switch corresponds to the type of ammunition selected.

e. Power is removed from the clutch solenoid permitting the clutch to engage and again tying the inner drum to the outer drum.

NOTE: 1 Ammunition Sequential Selector Conveyor, HH 74-134, Hughes Helicopters - Division of Summa Corporation, Culver City, CA July 1974.

f. The concentric drums, ejector arms, and weapon, rotate, firing the ammunition as required.

When the trigger switch is released the following events occur:

a. The system continues to operate until the rotation causes the neutral indicator switch to close.

b. The solenoid is immediately energized which causes the clutch to disengage the inner drum, ejectors and weapon from the outer drum and conveyor belt.

c. Twenty-five milliseconds later the motor is de-energized and the brake coil is de-energized to permit brake application.

d. The weapon, inner drum, and the ejectors are all stopped in the neutral position by the brake.

e. The motor, outer drum and the conveyor belt, decelerate until stopped by friction.

f. One second after initial closure of the neutral indicator switch, the clutch solenoid is de-energized causing the clutch to re-engage the inner and outer drums thus completing system shutdown. See the Logic Flow Chart (Fig. VII).

To change from firing one type of round to another, it is necessary that the system be stopped. Therefore, if the system is being fired the process is as follows:

a. Release the trigger

b. Physically change the selector switch on the control box to the desired type of ammunition.

c. Depress the trigger.

If the system is not being fired, follow instructions b. and c. above.

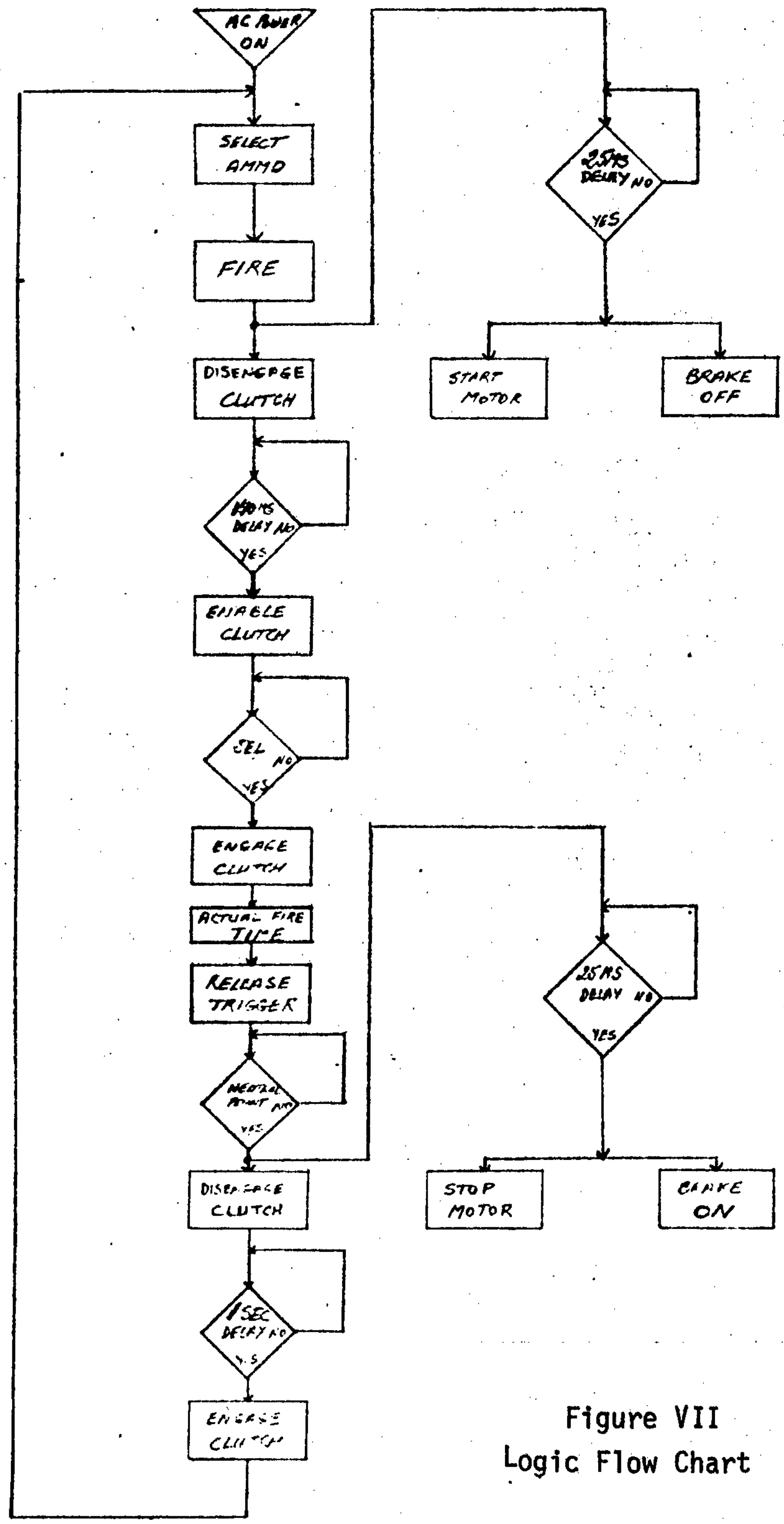

Figure VII
Logic Flow Chart

DISCUSSION OF CHANGES MADE

It was discovered that several hard stoppages of the selector mechanism caused the shaft on each cam follower to bend. New cams were selected which increased the shaft diameter from .25 inch to .375 inch. The larger cam shaft resulted in an increase in the cam follower diameter from .50 inch to .75 inch. It then became necessary to redesign the cam plate and several other parts used directly and indirectly with the cam followers. They are as follows:

Selector Ejector Cam	73D40049
Cam Follower Slider	73C40050
Gear Adapter	73B40051
Selector Solenoid Bracket	73C40052
Cam Spacer	73B40053
Ejector Assy Bracket	73C40055
Joining Hardware	

The conveyor belt is constructed of modified M23 Links which ride in a stainless steel tray coated with a graphite type lubricant. The electric drive motor used with the system is the original drive motor for the M129 Grenade Launcher and was selected because it was available, not because of the power requirements. As it turned out the motor was slightly underpowered.. The conveyor belt was shortened from 52 to 24 rounds to reduce the friction and required torque.

The drive motor, which is mounted directly on the selector mechanism, was connected directly to the loader end by a pair of bevel gears on each end of a long rigid shaft. This shaft was supported at each end by a bearing block. This arrangement required that both ends be perfectly aligned to prevent binding and/or friction. To avoid this situation, the shaft was cut in half and joined by a universal joint. A pillow block bearing was added at the universal joint to support the shaft on the selector end.

The system as received from the contractor was speed sensitive. When the conveyor was full of ammunition, it would run at one speed. As ammunition was removed from the conveyor during a firing sequence, the system would gain speed. A speed adjustment was provided on the power supply, however, it is manual, not automatic. Once it is set, the speed of the system will vary depending on the number of rounds in the conveyor. The original drive motor was series wound. A compound motor of slightly higher horsepower (1.5 HP, Western Gear No. 318 GC3) was located and used to replace the series wound motor (1.25 HP, Western Gear No. 318 GC2.) The compound motor and the increase in horsepower combined to reduce the speed variations in the system (ammunition conveyor). Speed is critical for two reasons: (1) When the launcher operates faster than 325 rpm it tends to throw rounds out of the conveyor before they are ejected which results in a jam and (2) a change in speed will change the round selection causing an incorrect round to be selected for the next firing burst. This can be either an early or a late selection. The motor control circuits were also changed to accommodate the differences between the series and compound motors.

Two heavy springs at the loader hold the cam follower to the loading cam. This constant pressure is strong and creates a large resisting torque at the loader continuously. These springs were replaced with a cam and spring operated system (See Fig VIII). It is so designed that a pin in the side support structure restrains the cam follower for most of each cycle without putting a strain or resisting torque on the system. As the loading cam approaches the point where the cam follower and attached round-sensing arm must follow the flat surface of the cam to sense if every fourth link is empty, a spring load is applied to the cam follower to insure that the cam surface is followed and that the loading procedure is carried out. This applies a momentary torque load to the system which is easily overcome by the momentum of the conveyor belt.

Power supply wiring changes were made to improve the operation of the total system. These changes were incorporated in a new schematic drawing for the power supply (74C40235). The drawing changes and explanation for each change is given as follows:

a. 10K ohm resistor was added (total of 3 places) from base to emitter of the 2N2222 Transistor. These resistors were added to reduce the transient effects of the motor, brake and clutch when power is turned on.

b. The 30S2 Diode was added across the shunt field of the drive motor to suppress transient spikes from the shunt field.

c. The C60A SCR was changed to a type T500024005AQ74 because the C60A did not have an adequate dv/dt rating and would become energized due to transient spikes at the anode. The 47 ohm resistor was added between the gate and the cathode of this SCR to reduce its sensitivity.

d. The 1.0 micro-farad capacitor was added between the base and the emitter of the 2N2222 Transistor to reduce the effects of noise on the operation of the clutch.

e. A 100 ohm resistor and an 0.01 micro-farad capacitor (2 places) were added across each of two branches of the bridge rectifier to insure that commutator noise from the motor does not falsely trigger any associated components.

f. A 10 ohm resistor was added to the gate circuit leading from each of the two C60A SCR's in the bridge rectifier. This was done to compensate for any inequality of gate turn-on characteristics.

g. Resistors of 3 ohms, 12 ohms, 3.3K ohms and 100K ohms; capacitors of 25 micro-farads and 0.1 micro-farad; and a 4E20-28 avalanche breakdown diode were added to the SCR firing circuit which incorporates feed-back from the motor armature to help stabilize the motor speed under varying load conditions.

h. Drive motor was changed from a series wound to a compound wound motor to provide a more constant torque-speed characteristic.

i. The following components were added to provide the excitation for the shunt field of the motor: 4.7K ohm resistor, 0.33 micro-farad capacitor, 2N2907 transistor, 2N1845A SCR, 18K resistor and 1N1186 diode (2 each). No changes were made to the control logic unit. All new electronic components were packaged in the power supply unit.

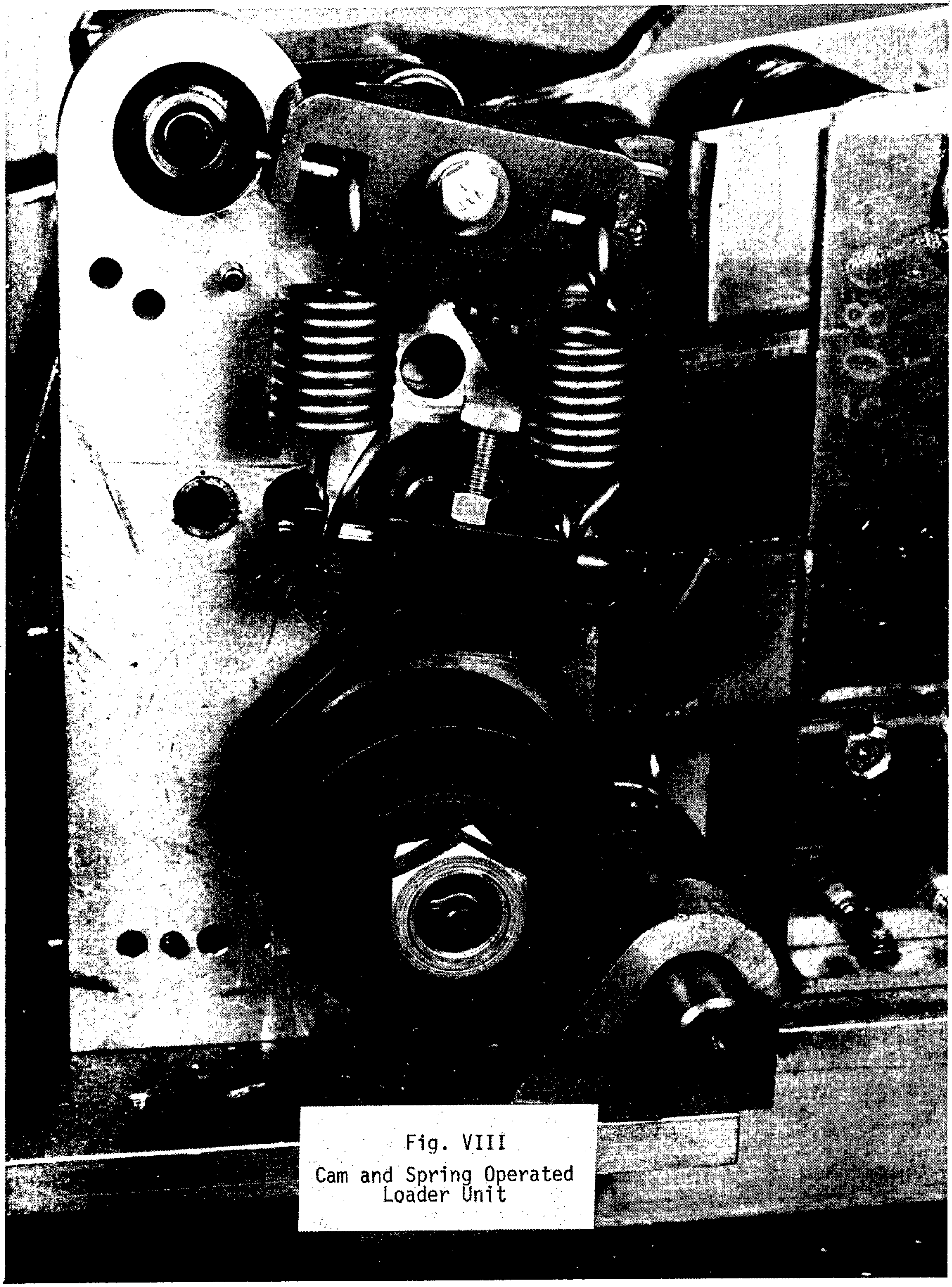

Fig. VIII
Cam and Spring Operated Loader Unit

EVALUATION OF TEST RESULTS

No data was recorded prior to the design modifications described in the main body of this report. System testing was conducted for three different configurations of the Selective Feed System as follows: (1) Feed System without Grenade Launcher and without loading Magazine, (2) Feed System with the Grenade Launcher but without loading magazine and (3) Feed System with both the Grenade Launcher and Loading magazine. All the data taken for the three configurations is given in Tables C-I, C-II, and C-III.

An oscillograph was used to record the fire signal, motor brake power signal, clutch enable signal, selection pulse, motor brake SCR signal, stop signal, neutral signal, clutch engage signal and clutch SCR signal. See Fig D-I for a simulated trace. Determination of correct round selection from the oscillograph record was based on whether or not the front surface line of the first round selection pulse coincides with the end of the clutch disengage pulse (see Fig D-I). If the clutch disengage pulse did not coincide with the front surface of the round selection pulse, it was considered either an early or late selection depending on where the clutch disengage line ended.

The round selection pulses (obtained from the oscillograph) and the actual round selection (obtained from first hand observation) are tabulated in Table C-IV. In comparing the actual selections with the oscillograph records it appears that there are more correct round selections than the selection pulses indicated. This could indicate that the criteria used for evaluating the selection pulses was in error. However, an evaluation of the data did not reveal any trend regarding early, late, or wider selection band widths. It was also found that some selections which appeared to be correct on the oscillograph were actually incorrect. Examination of the oscillograph records indicates the presence of electronic noise. The electronic circuits were checked and analyzed, however, no obvious incorrect wiring or shorts were discovered. It would appear that some electronic problem(s) still exist which causes the SCR and ultimately the drive clutch to activate occasionally in an incorrect time frame. A few loose connections have been found. Correcting these connections did improve the round selection reliability, however, it did not correct the total problem. Due to the extreme amount of vibration of the total Selective Feed Mechanism, it is suspected that other loose connections exist but have not been found. In addition, it is theorized that stray voltage spikes are causing erratic round selection. The number of stoppages vs rate of fire was examined but no correlation between the two could be found. The stoppages appeared to be completely on a random basis.

The Mean Rounds to Stoppage (MRTS) for each test condition was determined by the point average method. The extremely low MRTS values are a result mainly of the stretched 30mm links and the primative type loading mechanisms.

MRTS = 71.6 (for system w/o Grenade Launcher and Loading Magazine.)

MRTS = 19.9 (for system with Grenade Launcher but without Loading Magazine)

MRTS = 8.2 (for system with Grenade Launcher and Loading Magazine.)

MRTS = 26.4 (overall point average, with all firings combined)

Most of the stoppages were caused by the links. The links either broke or stretched enough to cause the rounds to be thrown out by centrifugal force jamming the mechanism. A few jams were caused by reusing the dummy rounds to the point that they developed burrs which caused the rounds to jam in the rim guide of the grenade launcher's feed tray. Also, a few jams were caused by electronic errors which caused the mechanism to stop in some position other than neutral. The stoppage occurs when the mechanism is started from a non-neutral position.

CONCLUSIONS & RECOMMENDATIONS

This report will terminate all efforts on the Selective Feed System since the funds have been exhausted. Due to the limited funds available for the Selective Feed Program, it was not possible to make all the changes to the system which were considered necessary for more reliable operation nor was it possible to prepare a concept brochure to show how the system could be applied to a 20mm or 30mm armament subsystem.

The operational reliability of the Selective Feed System without the Grenade Launcher, loader, and ammo storage magazine has been improved over the reliability of the contractor provided hardware. Many jams still occur when the grenade launcher is attached to the selective feed mechanism and even more jams occur when the ammunition storage magazine is attached. The jams which occur when the grenade launcher is in the system are caused mainly by weak conveyor links which allowed rounds to be thrown out by centrifugal force before being ejected. These rounds then became twisted or stuck in the weapon feed mechanism. It is believed that redesigned links will greatly improve the reliability in this area. The ammunition magazine and loading mechanism requires considerable design work. The feed pawls are too flimsy and the round release mechanism does not operate correctly. Both of these problems cause rounds to get cocked and jam at the loading sprocket. The following specific areas will require design or redesign efforts:

a. Ammunition links should be designed specifically for conveyor belt usage and should be designed for the round which is to be used with the system.

b. The selector micro-switches and other electronic noise producing components should be replaced with solid state components or switching devices. In addition, the declutching SCR should be replaced with a transistor circuit. This will reduce the effects of electronic line noise on the round selection process which will result in more accurate selections. Additional filter circuits should be made mechanically secure. Noise in the circuits and loose electrical contacts are presently causing incorrect round selections.

c. A design for an ammunition storage and hand-off system is required. The contractor provided only a 12 to 13 round magazine in which the rounds were pushed down by a heavy lead weight when the release mechanism activated the loading sequence. The concept for the Selective Feed System as developed by the contractor will, by the nature of its design, be a relatively heavy system. To be useful it will require 3 or 4 ammunition storage containers each of which will require a separate round sensing mechanism, loading mechanism and hand-off mechanism. It would appear that a better approach would be to design one ammunition container which would house 3 or 4 types of ammunition. Use a one round sensing mechanism, loader, and hand-off mechanism which can be indexed to a different type round at the same time that the round selector mechanism is changed.

The Selective Feed System should be applied to some existing turret using a 20mm or 30mm weapon for the purpose of determining the changes or design modifications required for applying this system to a fully flexible turret.

A family of 3 or more cartridges should be available to maximize the benefits provided by using the Selective Feed System. The Vehicle Air Defense System (VADS) is the only known current system which has the possibility for utilizing 3 or more rounds (20mm). Most current weapon systems use only 2 types of combat cartridges. Incorporation of the selective feed system into these weapon systems will allow maximum utilization of each of the two rounds. It will allow both types of rounds to be carried with the weapon system and will permit a quick change to firing the round most suited for attacking the target at hand.

REFERENCE

Ammunition Sequential Selector Conveyor, HH 74-134, Hughes Helicopters - Division of Summa Corporation, Culver City, CA, July 1974.

NOTE: Figs. I, VII, A-I, D-I and the Operational Philosophy were taken from the above report.

APPENDIX A

TESTING

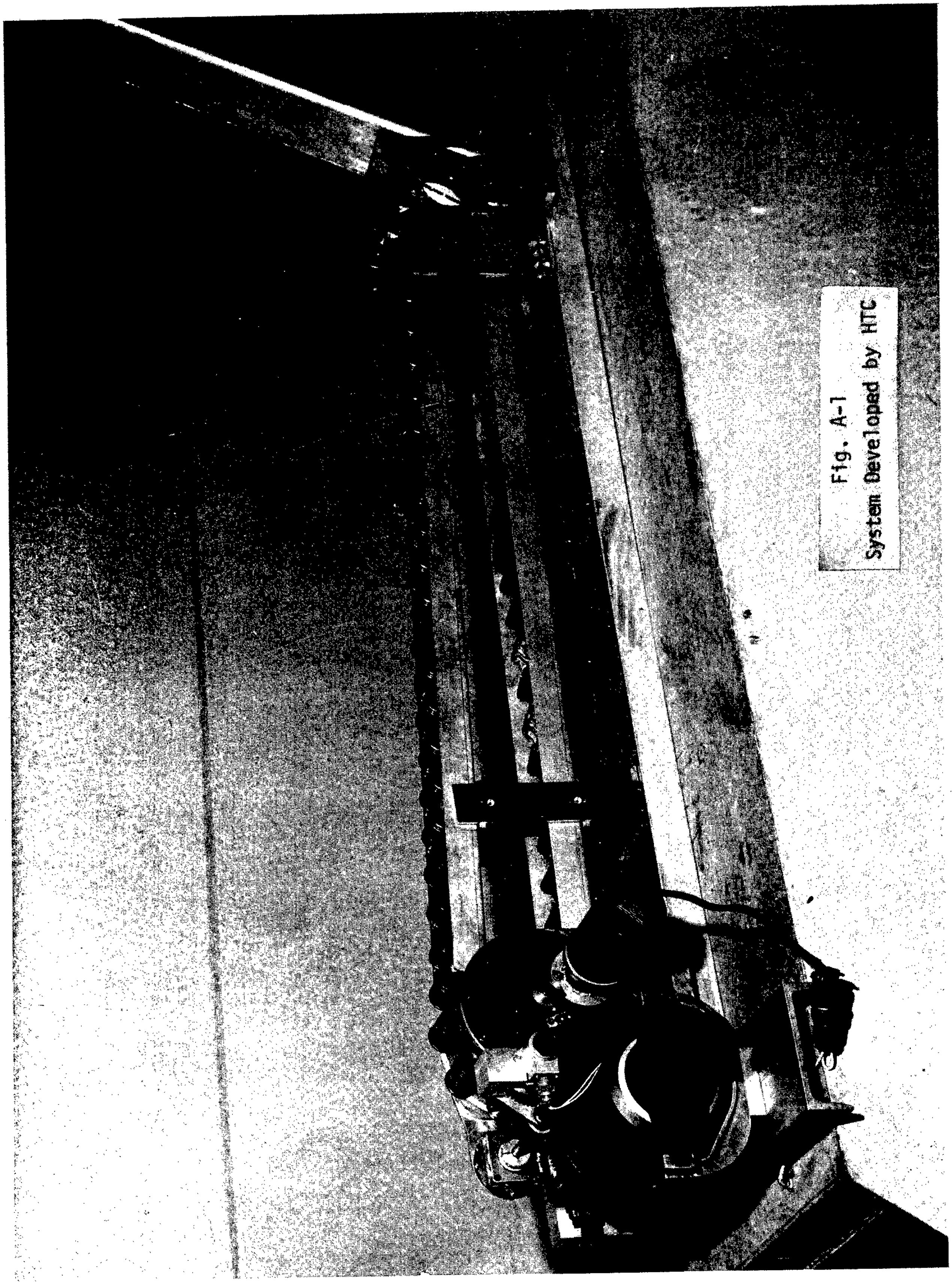

Fig. A-1
System Developed by HTC

APPENDIX A

TESTING

The selective Feed System as received from the contractor (see Fig A-1) was mounted on a shop table on 20 Nov 72. Operational tests were run without the M129 Grenade Launcher or the loading magazine through Feb 73. This testing showed that the conveyor could not be emptied of the four types of rounds without several stoppages and incorrect selection of rounds. Stoppages included: rounds thrown from the links causing the conveyor to jam and clutch disengagement during round ejections causing the ejectors to jam.

The period from Mar 1973 through Dec 1973 was used to redesign system components, change the conveyor to a 24 round belt length and conduct tests on it, procure redesigned parts and analyze their operation and test the electronic controls. Parts for the ejector redesign were installed and tested in Jan 1974. The compound motor and motor control circuits were, also, installed in Jan 1974 and tested. Operation of this revised system with the compound motor showed that the control circuits were affecting the selection circuits. At this point a Honeywell 906C Oscillograph was obtained, and set up to monitor various points in the circuitry. Initial instrumented channels are given in Appendix B.

Clutch control circuits were analyzed with the oscillograph, oscilloscope and a digital voltmeter. A solenoid external to the system was substituted for the clutch solenoid so that the ejector could be cycled without rounds in the conveyor and without changing the round selector so that correct selection signals could be determined. This testing resulted in selection of an SCR for clutch control which had optimum operating characteristics. The original GE C60A SCR used by the contractor was found to be inadequate for the job required of it. As a result a Westinghouse 251D SCR was selected as having more desirable characteristics.

Tests in which the oscillograph was used to monitor various system circuits were initiated on 19 March 1974. The system at this time included only the Selective Feed hardware without the grenade launcher and without the loading magazine. The M129 Grenade Launcher, Serial No. 698, was added to the system for the oscillograph tests which started on 10 April 1974. The total system which included the loading magazine was used for the oscillograph tests that started on 26 June 1974.

APPENDIX B

INSTRUMENTATION

APPENDIX B

INSTRUMENTATION

<u>Equipment</u>: A Honeywell 906C Oscillograph with ten channels was set up to monitor the various Selective Feed Circuits as follows:

Channel #1: Fire Signal; Pin #3 of Integrated Circuit (IC) D-3 of the logic printed circuit (PC) card.

Channel #2: Motor Brake Power; Pin #1 of N7400 IC on the power control PC card.

Channel #3: Clutch Enable Signal; Pin #15 of IC D-3 on logic PC card.

Channel #4: Not used.

Channel #5: Power to clutch solenoid; SCR base.

Channel #6: Stop or Brake Signal; Pin #11 of IC D-1 on the logic card.

Channel #7: Neutral Signal; Pin #12 of IC C-3 on the logic card.

Channel #8: Clutch Engage Signal; Pin #15 of IC D-4 on the logic card.

Channel #9: Clutch Engage Signal; Pin #6 of IC N7400 on Power Control.

Channel #10: SCR (clutch) Gate Signal: Point #7 on the Power Card.

APPENDIX C

TEST RESULTS

TABLE C-I

ROUND SELECTION TEST WITHOUT GRENADE LAUNCHER

AND WITHOUT LOADING MAGAZINE

DATE	BURSTS	Selection* Pulse; C, E, L,(?)	System Selection;** Correct/Error	Stoppages	No. of Rds Fired	Rate of Fire, SPM	Cumulative Total of Rds Fired
19 Mar 74	12	4C,7E,1L	12/0	1	72	300-316	72
22 Mar	26	16C,8L,(2?)	8/12 (6?)	5	156	292-316	228
25 Mar - 2 Apr	77	14C,23E,4L,(36?)	25/22 (30?)	4	462	270-316	690
3 Apr	12	2C,9E,1L	5/4 (3?)	2	72	316	762
4 Apr	21	2C,11E,1L, (7?)	14/6 (1?)	0	126	300	888
5 Apr	15	2C,7E, (6?)	15/0	2	90	279-316	978
8 Apr	5	5E	4/1	0	24	308-316	1002

NOTES:

* In the Selection Pulse column (determined from oscillograph readings) C, E, L and (?) stand for Correct, Early, Late and Questionable respectively. On the questionable bursts either the oscillograph chart was not readable or a stoppage occurred prior to a pulse indication.

** In the System Selection column, ? represents questionable bursts in actual selection of rounds by the system. Causes for some bursts being questionable are: (1) The rounds of the type selected were not in the conveyor and therefore no ejections could occur, (2) Data on the oscillograph was not recorded or (3) Operator error (clutch lockout device was not removed or the selector switch was not tightened sufficiently to prevent movement.)

TABLE C-II

ROUND SELECTION TEST WITH GRENADE LAUNCHER

BUT WITHOUT LOADING MAGAZINE

DATE	BURSTS	Selection * Pulse; C,E,L, (?)	System Selection;** Correct/Error	Stoppages	No. of Rds Fired	Rate of Fire, SPM	Cumulative Total of Rds Fired
10 Apr 74	3	1C,2L	1/0 (2?)	3	6	300	1008
19 Apr	6	2C,4E,	3/3	0	24	279-300	1032
23 Apr	—	—	—	—	Cycled w/o Rds	300-308	1032
23 Apr	4	1C,3E	Cycled w/o Rds	0	Cycled w/o Rds	292-300	1032
24 Apr	23	13C,2E,2L,(6?)	17/3 (3?)	4	126	266-300	1158
25 Apr	13	10C,3E	10/3	2	56	Not Recorded	1214
26 Apr	8	2C,1E,5L	5/3	1	42	Not Recorded	1256
29 Apr	4	2C,2L	Cycled w/o Rds	0	Cycled w/o Rds	292-300	1256
30 Apr	4	4C	4/0	0	24	266-285	1280
1 May	6	2C,4L	5/1	1	31	261-286	1311
2 May	10	7C,2E,1L	7/3	0	48	261-285	1359
3 May	8	Not Recorded	Cycled w/o Rds	0	Cycled w/o Rds	300	1359

TABLE C-II CONTINUED

DATE	BURSTS	Selection* Pulse; C,E,L,(?)	System Selection;** Correct/Error	Stoppages	No. of Rds Fired	Rate of Fire, SPM	Cumulative Total of Rds Fired
6 May 74	9	5C,2L (2?)	4/2 (3?)	0	24 rds + 3 bursts w/o rds	316-375	1383
7 May	7	1E, 6L	4/3	3	30	316-363	1413
8 May	10	4C,3E,3L	3/1 (6?)	0	24 rds + 6 bursts w/o rds	285-363	1437
10 May	9	4C,2E,3L	6/3	3	36	292-324	1473
13 May	4	1C,2L (1?)	3/1	0	24	292-316	1497
14 May	12	5C,2E,4L (1?)	5/3 (4?)	4	24 rds + 4 bursts w/o rds	279-363	1521
16 May	4	1C,2E,(1?)	Cycled w/o rds	0	Cycled w/o rds	307-332	1521
17 May	6	2C, 4E	4/2	2	28	300-324	1549
20 May	7	2C, 4E (1?)	4/3	4	24	266-300	1573
21 May	6	3C, 2E (1?)	2/0 (4?)	3	18 rds + 3 bursts w/o rds	285-324	1591
23 May	7	3C, 1L,(3?)	3/0 (4?)	2	20	297-300	1611
23 May	12	3C,4E,4L(1?)	4 cycles w/o rds 4/3 (1?)	2	42 rds + 4 bursts w/o rds	272-300	1653
24 May	12	2C, 10E	Cycled w/o rds	0	Cycled w/o rds	307	1653

TABLE C-II CONTINUED

DATE	BURSTS	Selection* Pulse; C,E,L,(?)	System Selection;** Correct/Error	Stoppages	No. of Rds Fired	Rate of Fire, SPM	Cumulative Total of Rds Fired
29 May 74	8	6C,1L (1?)	6/1 (1?)	1	44	285-307	1697
30 May	7	1C,1E,5L	6/1	3	227	285-307	1724
31 May	9	5C,3E (1?)	6/3	0	54	260-307	1778
7 Jun	10	3C,6E,1L	6/4	0	60	266-300	1838
10 Jun	16	6C,10E	14/2	3	84	255-307	1922
11 Jun	8	2C,5L (1?)	7/1	2	44	240-307	1966
11 Jun	9	2C,6E (1?)	7/2	2	46	255-300	2012
12 Jun	16	10C,1E,4L (1?)	13/2 (1?)	7	72	266-312	2084
18 Jun	7	6E,1L	Cycled w/o rds	1	Cycled w/o rds	316	2084
19 Jun	20	1C,19E	———	5	Cycled Only	250-300	2084
21 Jun	6	1E,5L	2/4	0	12	272-300	2096

NOTES:

* In the Selection Pulse Column (determined from oscillograph readings), C,L,E and (?) stand for Correct, Late, Early, and Questionable, respectively. On the questionable bursts either the oscillograph chart was not readable or a stoppage occurred prior to a pulse indication.

** In the System Selection Column, (?) represents questionable bursts in actual selection of rounds by the system. Causes for some bursts being questionable are: (1) The rounds of the type selected were not in the conveyor and, therefore, no ejections could occur, (2) Data on the selection was not recorded or (3) Operator failure (clutch lockout device was not removed or selector switch was not tightened sufficiently to prevent movement.)

TABLE C-III

ROUND SELECTION TEST WITH GRENADE LAUNCHER AND WITH LOADING MAGAZINE

DATE	BURSTS	Selection Pulse,* C,E,L,?	System Selection,** Correct/Error	Stoppages	No. of rds. Fired	Rate of Fire, SPM	Cumulative Total of Rds. Fired
26 Jun 74	10	1C,8E,(1?)	8/2	7	32	240-307	2128
27 Jun	15	3C,8E,(4?)	11/0 (4?)	7	45	279-300	3173
28 Jun	4	4E	3/1	1	46	292-307	2219

NOTES:

* In the Selection Pulse Column (determined from oscillograph readings), C,L,E and (?) stand for Correct, Late, Early and Questionable, respectively. On the questionable bursts either the oscillograph chart was not readable or a stoppage occurred prior to a pulse indication.

** In the System Selection Column, (?) represents questionable bursts in actual selection of rounds by the system. Causes for some bursts being questionable are: (1) The rounds of the type selected were not in the conveyor and, therefore, no ejections could occur, (2) Data on the selection was not recorded or (3) Operator failure (clutch lockout device was not removed or selector switch was not tightened sufficiently to prevent movement.)

TABLE C-IV

ROUND SELECTION ACCURACY

1. System w/o Grenade Launcher and Loading Magazine:	
a. Actual round selections	83/128 = 64.8% Correct*
b. Oscillograph record	40/117 = 34.2% Correct**
2. System with Grenade Launcher but w/o Loading Magazine:	
a. Actual round selections	161/218 = 73.8% Correct*
b. Oscillograph record	122/280 = 43.4% Correct**
3. System with Grenade Launcher and Loading Magazine:	
a. Actual round selections	22/25 = 88% Correct*
b. Oscillograph record	4/24 = 16.7% Correct**

NOTES:

* All figures were taken from the "System Selection" column of Tables C-1, C-II, and C-III. The questionable selections were not included.

** All figures were taken from the "Selection Pulse" column of Tables C-I, C-II, and C-III. The questionable selections were not included.

APPENDIX D

CONTROL LOGIC TIMING

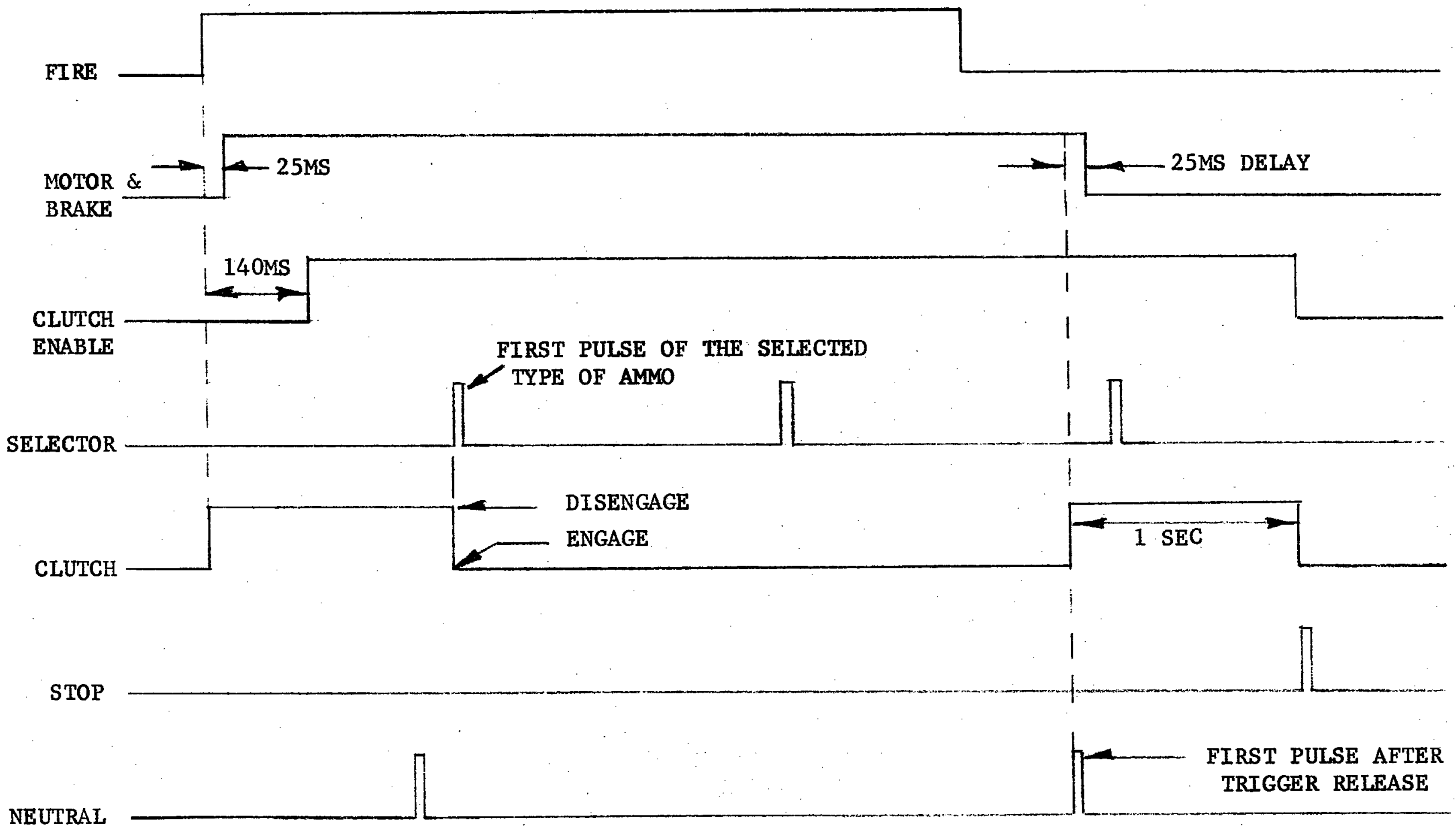

Figure D-1

CONTROL LOGIC TIMING DIAGRAM

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Unclassified report

This report describes one approach to the problem of feeding several (more than two) types of ammunition of the same caliber into a single weapon. This system was designed primarily for use with an aircraft armament subsystem; however, there is no real reason for limiting its application to an aircraft. A feasibility prototype using the M129, 40mm Grenade Launcher was designed and fabricated by a contractor. This report describes the design and how it was changed to give it added reliability of operation. It was concluded that considerably more work is required to obtain acceptable reliability for demonstration. In comparison to existing helicopter armament subsystems, this system will be limited to a relatively low rate of fire.

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