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FINAL REPORT

OLIN SPIW LAUNCHER

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12 July 1965 thru 12 June 1966

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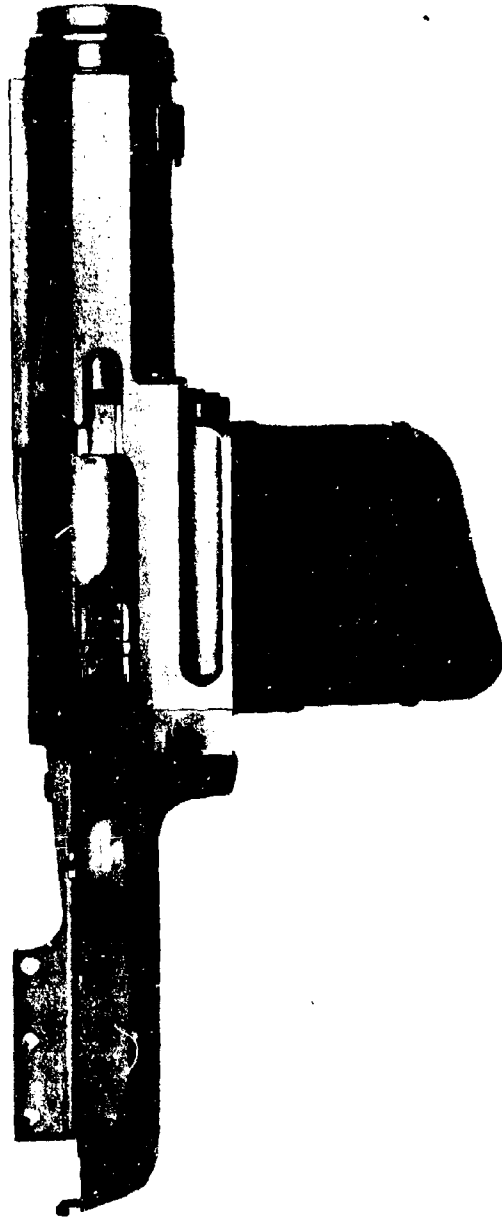
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NH-2604

TABLE OF CONTENTS

<u>SECTION</u>	<u>Page</u>
I. INTRODUCTION	4
II. SUMMARY	6
III. TECHNICAL DISCUSSION	15
IV. MAJOR LAYOUTS AND ASSEMBLIES	40

APPENDIX

- A Engineering Calculations
- B Illustrations
- C Human Factors Engineering
- D Reliability, Quality Assurance, Standardization
and Maintenance Engineering
- E Value Engineering

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I. INTRODUCTION

This contract involved the design, development, and delivery to Springfield Armory of ten 40mm semiautomatic grenade launchers. The launchers are designed to be mounted on point fire weapons of Springfield Armory design, for test during 1966. In response to the Springfield Armory RFQ T-M5-37, a proposal for an improved launcher, embodying the principal advantages of the previously developed Olin SPIW launcher, was proposed on 10 May 1965.

The technical basis of the proposal was to retain the previously demonstrated advantages of the forwardly moving barrel concept, while eliminating known structural shortcomings of the previous launcher. By retaining the forward moving barrel concept, an advantage is gained in overall length of the weapon system, since the weapon is of conventional length only at the time required, that is, at the time of feeding. The other advantage of the forward moving barrel is on weight, since the required moving mass is combined with the barrel or tube, which is necessary in any event.

The technical proposal involved the use of the pod type magazine system which had been used on the previous launchers. The proposed power system was the same floating chamber system as had been proven to be feasible on the previous launchers.

Several feature changes resulted from a period of investigation and discussion with Springfield Armory representatives as follows:

- . The pod type magazine system was replaced by a detachable box magazine, disposed vertically under the launcher.
- . The launcher trigger system was changed from a second trigger to a trigger/connector system which enables the launcher to be fired with the trigger of the point target element.
- . Investigation of the original floating chamber type of power system, as well as several other alternative power systems, resulted in the selection of the simple blow-forward system in preference to the original system.

Before the end of this contract a three months delay in the point target element portion of the program was instituted. A supplementary contract for the purpose of upgrading the launcher

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NH-2604

performance was awarded as a result. Completion of this work was scheduled to fit within the extended schedule on the point target elements, and will be covered in detail in a separate report following the end of that work.

-5-

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II. SUMMARYA. Development History

In response to the Government Request for Proposal, a preliminary design was submitted which was based on the best features of previous launcher development at Winchester-Western. The design which was submitted in the Winchester proposal included the original pod type feed system and the floating chamber method of powering the weapon. The forward moving barrel concept was maintained. The new design differed from earlier developments principally in that the basic structure was a one-piece aluminum design instead of the previous composite plastic/aluminum structure which had proven in tests to be insufficiently rigid. For purposes of the proposal, the firing mechanism was essentially the same as was previously used, although an alternative design was shown in which the cocking was done early in the cycle rather than at the end. The earlier method of extraction and ejection was also retained.

Following the award of the contract, approximately six to seven weeks were used for the purpose of more detailed establishment of basic design features through the cooperation of Winchester-Western, Springfield Armory, and various other government agencies. During this period of time, the general method of feeding was considered and discussed extensively, as was the location of the launcher on the parent weapon, the type of trigger system, and various human factors aspects. The discussions and conferences on these subjects were supported by design studies at Winchester which explored the mechanical and human factors implications of the various recommended types. During this period studies were begun on the basic power system in order to insure that the power system was the best for the purposes of this program. Investigation of the power system and various other functional areas was supported by the fabrication of test rigs and similar devices to give dynamic information, and an evaluation of the various parameters which affected each function. Throughout this early phase, human factors engineering personnel worked closely with the Product Engineering designers to thoroughly survey the human factors aspects of each proposed variant. The feed system in particular was subjected to close scrutiny from a human factor viewpoint, and resulted in an essentially independent evaluation of the various proposed feed system configurations.

As a result of the various design studies, conferences, and modifications to the required design features, the original design was modified to include a detachable box magazine, disposed vertically below the weapon. Other modifications to the proposed design included positioning the launcher further forward on the basic weapon in order to provide a more adequate handhold. During this period the method of mounting the launcher with three cross bolts was agreed upon. A new type of sight was also conceived, which was essentially a ramp type of sight, intended to allow the use of a linear range scale and a somewhat more compact construction than previous types which were studied.

As a result of the inputs from the human factors personnel and HEL, it was decided to change the trigger system from the separate type of trigger proposed to a common trigger with the point target element. In this type of trigger the launcher is connected to the point target trigger by means of a connector lever mounted on the rear of the point target receiver.

Following the establishment of the basic design features, layouts and detail design began on the first prototype weapons. The first weapons included a receiver design which was intended to be fabricated by impact extrusion. As a result of inability to obtain access to the necessary heavy presses, the prototype receivers had to be machined from solid. The first firing mechanism incorporated a sear which was combined with the cocking lever.

The tube return spring was designed to be a Negator type spring, to take advantage of the lightweight and compactness of the Negator spring and to reduce the peak force required to manually open the weapon. The magazine also incorporated a Negator spring, in this case to act as both follower and follower spring. The magazine was designed to be basically an aluminum extrusion, with integral T-slots for cartridge guides, and a stamped steel cartridge retainer in lieu of conventional feed lips. This was necessary because of the fact that the cartridge is not rammed in the conventional sense but is instead fed straight upward in front of the standing breech.

The extractor-ejector system was designed so that the extractor performs both extraction and ejection functions by pulling straight to the rear on the rim of the cartridge to eject the empty case. This permitted elimination of an ejector which protrudes from the bolt face, which would cause

interference with feeding. Another feature which was incorporated during this early development was provision to permit the action to automatically close and load upon insertion of a loaded magazine.

Sufficient hardware was fabricated at this time to permit the assembly of three prototype weapons for development purposes. Two of the prototypes were assembled and the first prototype was submitted after preliminary testing to the Springfield Armory, as stipulated by the contract for the end of Phase I. This launcher functioned well enough to demonstrate the validity of the mechanical principle, but did not function satisfactorily from an overall viewpoint.

Phase II began with redesign of the firing mechanism to eliminate the dual function of the cocking lever. The new design of firing system utilized a conventional type of sear and a separate cocking lever. The previous design had demonstrated that the conditions for safety were contradictory to the conditions which were necessary in order to obtain a low trigger pull force. During this period work continued on development of the blowforward power system, to improve the reliability of energy output. At this time, the government requested that modifications be made to the system to improve the appearance of the combined package. The criticism was made that the weapons did not look sufficiently integrated, and were prone to brush catching between the two weapons. Supplementary funds were granted for the purpose of the necessary redesign and modification. The blending of the two systems involved redesigning the receiver and certain other areas, and completion of new detail drawings. During the course of this work, the effort of mounting the receiver was simplified.

Virtually all functional components of the weapon system were redesigned during this period, based on test data obtained from the prototype weapons. The second of the early prototype weapons was delivered after upgrading early in Phase II. Development work during Phase II was centered principally about certain functional areas: feed system reliability, power system consistency, and general improvement of the mechanical efficiency of the system so as to reduce excessive loss of operating power. The most critical area was the trade-off between operating energy and muzzle velocity, the trade-off being complicated by the large number of variables involved. As during Phase I, maximum use was made of time-displacement records and high speed motion pictures.

To assist in studying the maximum range capability, a tripod mount was adapted and a number of outside maximum range tests were fired.

Liaison was maintained with Springfield Armory on various interface areas and administrative matters. This was particularly necessary in the matter of the trigger system, which was mounted partly in the point target weapon and partly in the launcher.

Throughout the development process, difficulty was encountered in ammunition consistency, since a larger percentage of the ammunition which was supplied was of a type having an obsolete crimp on the cartridge case. This caused considerable difficulty and limited the amount of operating energy which could be reliably obtained with the blowforward system. Since this was an obsolete type of cartridge, development work during the latter part of Phase II proceeded using smoke type ammunition having the latest type of crimp.

Sufficient hardware was fabricated during Phase II to permit assembly of the ten basic delivery weapons, plus one extra weapon, plus approximately eighty per cent of a twelfth weapon. The final phase of the program consisted of the assembly of the delivery weapon, final tests and adjustments, and delivery to Springfield Armory. A considerable number of minor modifications were made to the launchers during the final test phase, and the majority of the sources of malfunctions were pinpointed. At this time, it was understood that a supplementary contract would eventually be made for the purposes of final upgrading and improvement of these launchers. This was made practical by the extension of the Springfield schedule by some three months.

Following delivery of the basic ten launchers, Winchester-Western supported the week of acceptance tests conducted by Springfield.

B. Conclusions

1. Feasibility of the present design: The mechanical principles utilized in the present design are practical. Experience during development has shown that the system requires the usual tolerance studies, a large percentage of the malfunctions which were encountered being traceable to tolerance buildups in the mechanical components. The very small number of breakages encountered during

development testing is evidence that generally there are few critically stressed components.

2. Potential for development: The design is capable of further development in two areas, because of the duration of the development contract: conventional machining practice has been used to fabricate most components, where stamping, molding, and extrusions were envisioned for any regular production. As a result, any further development for production should include re-processing for more economical methods of manufacture. Such a re-processing is facilitated by the fact that most components were designed with this in mind. Secondly, certain functional areas are capable of being simplified, with the result of reducing the total number of components in the system. Much of this simplification would be centered about the striker housing assembly and the trigger connection components. Since for the most part the weapon is not critically stressed, deliberate attention to reduction of weight can result in a measurable improvement in that area. Likewise, the method of construction of the receiver, which was of necessity machined in the prototypes, can be improved for production purposes. For a discussion of this and other areas of potential improvement for production, see Appendix E (Value Engineering).
3. The weapon is readily adaptable to modifications to change the magazine capacity from zero rounds (single shot) to a capacity greater than the present three round magazine.
4. In conclusion, the normal process of final refinement can be expected to result in a weapon which meets or exceeds the requirements which are expected for this type of weapon.

C. Recommendations

It is recommended that this weapon be continued in development, to take advantage of the potential simplicity and reliability of the system.

D. Description of Weapon

The area target weapon is a semiautomatic three shot grenade launcher, which is blowforward operated, air-cooled and fed by detachable vertical box magazine. It utilizes standard 40mm M406 fragmentation cartridges, as well as practice (smoke, M407) rounds. The launcher is designed to utilize

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NH-2604

the trigger of the point target element, by means of a connector system which permits firing either element at will. The launcher is fabricated basically of aluminum alloy in order to conserve weight. The use of the blowforward type of action permits the system to be shorter than more conventional actions. It is of conventional length only at the time of feeding. In this system the barrel is also the primary mass (energy storing) member. This allows the system to be light in comparison to systems which require a separate moving mass such as a bolt. The use of a detachable box magazine permits the weapon a high rate of sustained fire as long as loaded magazines are available, since rounds do not have to be individually loaded into the weapon. To assist in this, the weapon has been designed so that it automatically closes and loads upon insertion of a loaded magazine. The sight is a separate member mounted on the point target element.

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NH-2604

E. Tabulated Characteristics

Area Target Element

Length, action closed	17.5 in.
Length, action latched open	21.5 in.
Width	3.2 in.
Height, with magazine in place	7.0 in.
Height, without magazine	3.2 in.
Weight, without magazine	3 lbs. 4.6 oz. (incl. sight)
Weight, with empty magazine	3 lbs. 11.4 oz. (incl. sight)
Weight, fully loaded (3 rounds)	4 lbs. 2.8 oz. (incl. sight)
Method of Actuation	Blowforward
Feed	Three round detachable, vertical box magazine
Firing System	Striker type, semiauto- matic only
Manual Safety	Mechanical, locks striker directly
Cooling	Air
Sight	Front: flat post Rear : aperture Sight Radius: 4.35 inches Range scale: linear divi- sions on side and top of sight bar, range in 25 meter increments
Length of Tube	10.0 in. - overall 8.0 in. - rifled length
Ammunition	HE fragmentation, M406 Smoke, M407 Proof, XM387 Illuminating Signal
Ejection	To right

F. Controls1. Charging Handle

This is on the right side of the action, mounted on the rear of the tube. It is pushed forward to open the action.

2. Tube Latch

Mounted on the top left side of the receiver, above the magazine. Depressing the latch allows the action to close under the force of the tube return spring.

3. Safety Lever

Mounted on the top left of the receiver, above the handgrip. When pressed fully forward, the action is ready to fire. When fully to rear, the action is on "safe".

4. Magazine Catch Button

Mounted at the rear of the magazine well, immediately forward of the handgrip. Can be pressed from either side to release magazine for removal.

5. Tube Lock

Mounted at front of magazine well, below receiver. Used to lock the action in the closed position if desired.

6. Elevation Slide

Mounted on the sight bar. To change elevation setting, squeeze the slide and move it along the sight bar until the range indicator pointer is at the desired setting. Releasing the slide allows it to lock at the selected setting.

7. Deflection Zeroing Screw

Mounted below rear aperture of sight. Must be loosened to permit rear aperture to be moved for zeroing in deflection.

8. Elevation Zeroing Screw

The front sight post may be raised and lowered by screw driver from the bottom of the sight bar.

9. Connector Lever

Mounted at the left rear of the PTE receiver cover. This is used to disconnect the PTE and simultaneously connect the ATE firing system to the PTE trigger. To do so, the lever is depressed by the thumb and held there as long as the ATE is to be fired. Returns by spring when released.

III. TECHNICAL DISCUSSIONA. Evolution of the Proposal Design

Previous launcher development at Winchester on a weapon utilizing the forward moving barrel approach was critiqued while the present design was in the proposal stage. The critique information consisted of detailed notes from both participating designers and test personnel, plus the test reports which resulted from the government tests on that program. A survey of the approach showed that while the forward moving barrel concept was valid, the general construction used in the previous launchers, a composite fiber glass metal arrangement, was not rigid enough to allow the launcher components to maintain reliable alignment during cycling. This lack of rigidity caused the breech face and the bore axis to be misaligned during the period of high pressure, and consequently, considerable side thrust and binding of the tube assembly during forward motion resulted. The method of cocking the earlier design was considered to be inadequate, since cocking took place at the final forward portion of the tube stroke, which permitted the operator on occasion to inadvertently load without cocking. The floating chamber power system, previously used, was able to supply more than adequate operating energy. As a matter of design, however, the floating chamber system had the disadvantage of requiring a larger diameter of tube assembly than was felt desirable. Test information also indicated that leakage of propellant gases around the floating chamber assembly could be a problem.

The pod type magazine system which had been employed was a practical system as long as a sustained fire rate was not the principal objective. The particular advantage of that system was the ability of the operator to replenish the magazines while the action was either closed or open. A major disadvantage of the system was the overall width, which tended to intrude into the sight line.

As a result of the critique of the previous approach, it was decided to retain the forward moving barrel concept, and a striker firing system, but to redesign the weapon so that the main assembly was one homogeneous member rather than a composite structure. Although it was decided to retain a striker firing system, it was apparent that the action should be altered to cock early in the opening stroke, to prevent accidental loading without cocking. For proposal purposes,

it was decided to retain the pod type of magazine system, since at that time no mention had been made by the users of a desire for a different type of magazine. As a result of this critique of the earlier design, the proposed design retained the basic features of the forward moving barrel, floating chamber, striker firing, and pod type magazine, but was centered about the use of a one-piece aluminum receiver, a modified system for cocking, and relocation on the point target element in accordance with expressed requirements.

B. General Development of the Concept

1. Selection of Features and Requirements

At the beginning of the program, it was apparent that it would be desirable to revise the particular design features in accordance with views expressed by the various using and evaluating agencies. The discussions, conferences, and supporting investigations of the various features took place over the first six to seven weeks of the program, and centered primarily around the magazine system and configuration, the location of the launcher on the parent weapon, and the operating controls. The initiation of layouts for the prototypes had to be delayed until the particular feed mechanism type was agreed upon.

The result of these discussions and investigations was agreement that the launcher should incorporate a detachable box magazine, disposed vertically under the weapon. The use of this arrangement allows a higher rate of sustained fire than was possible with the older pod system, and permits ejection to be horizontally to the right instead of vertically downward. The downward ejection of the older design was a cause for concern where limited clearance was available below the weapon, as when firing from fox holes or from behind cover. The detachable magazine also permits the weapon to be utilized as a single shot launcher if three round capacity is not necessary. It was also requested that the launcher be moved far enough forward to permit a longer handhold between the magazines of the two elements. During this time, engineering tests had been performed on various methods of supplying operating power, including the original floating chamber system. As a result of these studies, it was decided that a simple blowforward system would permit adequate operating energy while allowing a measurable reduction in the overall bulk

of the system. Also during this period, a concept of striker mechanism was evolved which was felt to meet the requirements of early cocking, and a method of ejecting by using the extractor was also developed.

The features which were expected to result from these changes were a relatively high rate of sustained fire, minimal exposure of the weapon and shooter to observation, ease of adaptation as a single shot weapon, and relative ease of training the shooter to use the weapon. During this time, it also was agreed to combine the trigger of the launcher with the point target element trigger.

2. Subsequent Development

Once the final design features had been settled upon, basic layouts and preliminary details were made for the first prototype weapons. By instruction, the emphasis was on functional practicality, with lesser emphasis on utilization of advanced production methods. However, the designers were instructed to bear in mind that a production fabrication technique should be readily applicable to any final development. The design work commenced by breaking the weapon into functional areas. These functional areas were feed system, operating energy, firing system, attachment and location, trigger connection, sights, and general construction. In practice, the design personnel responsible for the firing system also were responsible for the trigger connection means and the sight design, while the feed system, operating energy, attachment and location and general construction comprised the other group of functional areas.

During this initial detail design stage, human factors engineering personnel continued to work closely with the designers to insure implementation of human factors recommendations within the limits of mechanical feasibility.

3. The Final Design Concept

After testing and submission of the first prototype weapon, certain changes in the shape of the weapon were requested by the government in order to improve the general appearance of the total weapon package. Implementation of this requirement meant that virtually all

major components had to be redetailed, particularly those relating to the receiver. Additionally, it was found possible to simplify the method of attachment to the point target element by removing an auxiliary stud which had been previously been used for added rigidity. Testing showed that this auxiliary stud was unnecessary and it was removed in the newly restyled design. The new set of details also incorporated a new striker system, since the earlier one, although simple, was difficult to adjust. Other modifications in the new set of details included the incorporation of studs for mounting the bipod when the launcher is mounted on the point target element. This second series of weapons constituted the final design which, with minor modifications, was submitted to the government at the end of the contract.

During the development of the final design, Winchester Quality Assurance personnel participated by a program of inspection of the final fabrication hardware. Throughout this phase, liaison was maintained with Springfield Armory design personnel on the interface areas, principally the trigger connection means and the means of mounting the launcher sight.

The design activities throughout the development period were supported by almost continual testing, which was of two principal types: Tests to investigate the effects of various parameters and factors necessary to the actual design, and tests to trouble-shoot and aid in adjustment of the delivery weapons. As a rule, all tests were under the direct control of the interested design personnel. During the final test and adjustment phase, Quality Assurance personnel assisted by surveillance and recording of the test operations, and by compiling the necessary quality assurance and reliability engineering data.

C. Power System

At the beginning of the program, the original floating chamber type of power system was studied through surveillance of previous test data and by the construction of a single shot test rig which could be adaptable to a variety of power systems. The floating chamber power system had the advantage of assurance of adequate operating power and the fact that during the initial acceleration of the tube forward, the

chamber was held rearward over the cartridge case during the initial stages. The operating energy output could be controlled by variation of the diameter of the chamber section, by variation of the length of chamber stroke within the tube, and by variation of the tube and chamber masses, rifling configuration, and other means. The system had the disadvantage of requiring a larger overall diameter of the barrel assembly, a complexity in that it required three of four components for the barrel assembly. Other disadvantages of this system are that obturation means should be provided between the chamber and the tube, and the tube is not as well aligned with the breech face, in general, as with systems having the chamber integral with the tube.

Two general types of floating chamber systems were investigated: the original type, in which the chamber was mounted internally within the tube, and an external type in which the reverse was true. Analysis of time-displacement records from tests in which the various masses, power strokes, and effective piston areas were varied, showed that although the floating chamber did gain operating power from the interface between chamber and tube, a heavy proportion of the realized power came from the effort of engraving on the rifling. That is, the system in actuality derived much of its operating energy from the simple blowforward effect.

Another general type of power system which was studied with the use of the test rig was a system which utilized a chamber which was longitudinally fluted to permit propellant gases to pass outside of the cartridge case and to the rear of the tube. In this system the gases acted on the rear surface of the tube to give a gas assist to the blowforward action. Two variants were considered, one in which the tube was extended past the base of the cartridge to provide a place for a breech block which intruded into the chamber, and a second variant which was the reverse of this, in that a normal length of tube was used, but the entire tube was seated into breech face which extended forward over the outer walls of the tube. In both of these systems, since propellant gases were permitted to move outside of the cartridge case, a separate obturation means had to be provided between the tube and the breech block. Although this was not a great complication, the obturator had to be of the self-energizing type in order to be effective. Testing disclosed that the self-energizing obturator generated sufficient radial force on the tube to inhibit the initial forward tube motion. This meant that the system was inherently self-limiting, in that the condition necessary for adequate obturation was exactly the

condition which retarded the forward tube motion. Extensive studies were made during this time in order to determine the exact nature of the tube-versus-projectile motion. As a result of these studies and those on the floating and fluted chamber systems, it was decided to investigate the potential of the straight blowforward system, and to determine what variations in chamber and bore configuration would be necessary for successful operation with this type of action. Tests on the blowforward action disclosed the following characteristics: A relatively large diameter of chamber is required, in order to prevent undue retardation of the forward tube motion due to the expanding case. Other things being equal; the operating energy which was obtained was inversely proportionate to the weight of the tube assembly. Again, other things being equal; the energy output which is attained is directly proportionate to the number of lands in the bore. As expected, the primary energy input to the forward moving tube takes place during the initial engraving of the projectile rotating bands. Further studies disclosed that the energy exchange between the projectile and the tube was at a relatively low absolute efficiency. As an example, at this range of projectile velocities, one foot-per-second differential in projectile velocity corresponds to approximately 30 inch-pounds differential in projectile kinetic energy. The tests showed that when the system parameters were varied to change the maximum tube energy by 30 inch-pounds, the projectile velocity dropped somewhat more than one foot-per-second -- in some cases, in early tube configurations, as much as 20 feet-per-second. As development work proceeded on the tube design, this inefficiency was much reduced, but always remained a factor of concern. At this period of development it was assumed that the cartridge case did not permit any serious leakage of propellant gas even with the larger diameter of chamber, since tests with a special chamber showed that the cartridge case expanded dynamically as much as .030 in diameter when unsupported.

The effect of the number of rifling lands was studied by fabrication of 6, 8, 10, and 12 groove barrels having the same nominal rifling land dimensions. During these studies, experiments were also performed on the effect of free-boring the tube from the muzzle end, on the theory that without the rotating bands during the final portion of projectile travel, acceleration of the projectile would be unimpeded, resulting in higher muzzle velocity. For this latter purpose, tubes were free-bored for distances of 2, 3, 4, and 6 inches from the muzzle, the final 6 inch free-bore resulting in only

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NH-2604

2 inches of rifling remaining in the tube. An increase in muzzle velocity was realized by this method, the maximum being attained at approximately 4 inches of rifling. Although the tubes had been rifled with a more rapid twist than the standard used in the M79, in order to compensate for the forward motion of the tube, the free-bored tubes did not give reliable functioning with smoke type ammunition. In any event, the free-boring yielded at best only a small increase in muzzle velocity. In addition to the inadequate spin rate achieved by the free-bored tubes, it was felt that the angular jump of the weapon in recoil might result in the projectile impacting laterally on the free-bored section of the tube, causing excessive yaw at launch.

It was considered that the free-bored system may have potential for future development, but time did not permit exhaustive study of the various parameters involved, and it was decided to use a fully rifled tube and the simple blow-forward system for the development weapons. The parameters laid down for the prototype weapons included a 10 groove barrel, a moving mass approximating .5 to .6 pounds, and the large diameter chamber. Test rig work indicated that this combination could be expected to yield maximum kinetic tube energies in excess of 60 inch-pounds, which was deemed adequate for the system.

During the design of the first prototype weapons, tests were performed to assess the effect of the method of supporting and guiding the tube within the receiver. It was initially assumed that the tube should be closely guided, without perceptible clearance within the receiver. Tests on the first prototype weapons, however, indicated that the tube should not be tightly guided in the transverse plane, but should be relatively loose. Deliberate studies were made of the effect of lateral clearance, and the maximum tube energy which was realized invariably declined as the tube guidance was tightened. Tests on the prototype weapons showed that, although the trade-off between muzzle velocity and tube energy seemed to take place as expected, the effect was obscured by large variations in operating energy apparently not due to reduced muzzle velocity. It was later found that contrary to expectation, considerable leakage took place around the cartridge case, making the energy output susceptible to small variations in ammunition diameter, ellipticity, and chamber diameter. It was found that the cartridge case expanded during the highest portions of the pressure time curve, but was sufficiently strong to contract away from the

CONFIDENTIAL

CONFIDENTIAL

NH-2604

walls of the chamber as pressure decayed within the bore prior to muzzle exit. Development was also impeded by the fact that the inert warhead ammunition used in development was of an obsolete type, having a full circular crimp to retain the projectile. This crimp does not straighten out during firing, but simply cams the outer walls of the cartridge case against the tube wall and then relaxes inward after the projectile has started. The result was an erratic amount of chamber friction and, in general, less operating energy than that resulting when ammunition having the newer type of staked cartridge case was used. Since the full crimp design was stated by the government to be obsolete and no longer produced, it was decided that all subsequent development would take place employing the smoke ammunition on hand, or with inert warhead ammunition having the same staked cases.

The problem of leakage around the chamber was attacked by incorporation of a piston ring type obturator, inlaid into the wall of the chamber. This obturator was intended to lightly grasp the cartridge case, but not to act as a self-energizing obturator. The expectation was to reduce leakage without increasing friction between the cartridge case and the chamber wall. Early tests of this system showed an immediate increase in muzzle velocity, without apparent loss of operating energy. Later tests showed that if the obturator was adjusted so as to be too efficient, the muzzle velocity remained high, but the operating energy was degraded. Analysis of this situation seems to indicate that the reason for this is that the amount of force between the projectile and the tube is approximately constant, but when the leakage was stopped, the projectile reached muzzle exit more quickly and was thus in the tube for a shorter time. The result of this is that the impulse transmitted to the tube is lower, resulting in a considerable reduction of tube energy, since the tube energy is a second order function of the impulse transmitted to it.

To assess the potential maximum range capability of the system, outside firing tests were performed on certain weapons, and the results weighed against predicted maximum range/initial velocity tabulation. The results were approximately the same as prediction, the maximum range attained averaging slightly more than prediction.

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NH-2604

The refinement of the power system was complicated by the fact that there are several sources of energy loss within the system which, concurrently, had to be eliminated or reduced. These energy losses frequently obscured the relationships between the various parameters and the energy output, and also strongly affected the motion of the tube following muzzle exit. Principal sources of energy loss included cocking, misalignment of the operating rod and tube return spring, operation of the cutoff actuator, and interference with the extractor cocking lever. As these areas were progressively improved, the operating characteristics of the system became more uniform and the relationship between operating energy and other factors was more apparent. During development of the power system, extensive use was made of time-displacement records, chronograph records of muzzle velocity, and high speed motion pictures.

Another characteristic which was encountered was the accumulation of rotating band material on the rifling lands. This takes place within the first two inches of projectile motion, being heaviest immediately forward of the origin of the rifling. On occasion the buildup would reach a thickness of some .010 to .020 within a relatively few rounds. The result of this buildup is effectively an increase in shot start pressure, and an apparent improvement in ballistic efficiency. While this improvement has advantages from a maximum range viewpoint, the resultingly low time to muzzle exit adversely affects the operating energy. Investigation of the cause of this aluminum buildup seems to indicate that the tube walls are sufficiently thin to allow a measurable radial expansion of the tube in the area of the rifling origin, as much as .010 to .020 inches. This reduces the initial depth of engagement of the rotating bands in the rifling and results in a skidding motion, so that in effect the rotating band is engraved more gradually, while being subjected to high radial forces as the tube contracts. The engraving inclines to be more of an abrasion process, instead of a matter of shearing of the bands. Later investigations showed that application of a suitable silicon based oil or light grease inhibited the adherence of the aluminum to the bore to a considerable degree, so that it is felt that the condition can be effectively controlled if it arises during tests.

Midway in the course of development, the government expressed concern over the reliability of fuze functioning in the weapon, since several fuze malfunctions had been encountered during a demonstration at Aberdeen Proving Ground. This

CONFIDENTIAL

demonstration had been performed with a weapon having some four inches of free-bore from the muzzle, and the projectile spin rate was actually lower than on fully rifled tubes, since the projectile was angularly accelerated throughout only part of the bore travel. Subsequent tests at Aberdeen Proving Ground with a fully rifled barrel showed that the spin rate was entirely adequate, and that reliable fuze functioning was attained with both HE and smoke rounds.

Since one requirement of the weapon was the capability to handle the developmental signal and illuminating types of ammunition, a small quantity of this type of ammunition was obtained in order to perform function tests. The concern was that the short cartridge case of this special ammunition might cause considerable venting of gas at the breech, since the tube moves forward approximately one inch at the time of muzzle exit when using conventional ammunition. The tests indicated that this was no danger, since the recoil impulse of the special ammunition was relatively low, and the projectile had no rotating band in the usual sense. When firing this type of ammunition, the tube motion is almost imperceptible. Although this type of ammunition cannot be loaded in the magazine, it can be loaded into the chamber singly.

D. Feed System and Cartridge Control

Development of the feed system and cartridge control means was made under the following implications of the user and human factors requirements which had been laid down: The magazine should be detachable by manipulation of the magazine catch from either the left or the right side. The action should stay open automatically when the weapon is empty, and close and load automatically upon insertion of a loaded magazine. Loading the magazine outside of the weapon should not require special tools or chargers. The magazine system should provide a control which prevents the rounds in the magazine from interfering with the forwardly moving barrel. The cartridges should be released to feed vertically upward only after the tube has completed its forward motion. Timing of the feed system should involve a stepped sequence of mechanical functions, rather than relying on velocities or relative motion timing. The ejection system cannot involve ejectors which protrude from the bolt face in such a manner as to interfere with the vertically feeding cartridge. Extraction and ejection should preferably be arranged so that the ejecting cartridge is removed as soon as the forward moving tube clears it, although the requirement still exists that a loaded and unfired cartridge can be manually ejected

by moving the tube fully forward. Additional requirements included the capability to remove the magazine at any time, regardless whether the action was open or closed.

To achieve these objectives, the feed system which was selected involved the use of a cartridge cutoff, mounted on the magazine bodies, and actuated to release cartridges by the final forward motion of the tube. To provide for mechanical sequencing of the feed operation, a tube latch was incorporated which locked the tube in the full forward position until released by the vertically rising cartridge. In the early prototype, this tube latch took the form of a bell crank, mounted in the vicinity of the breech face and engaging the slide arm which ties the tube to the tube return spring. This method of operation was eventually shown to be unreliable, and this type of tube latch was replaced by a flat cantilever latch, mounted in the breech face and extended forward, acting as its own spring. An external lever was provided to permit manual release of the tube when desired.

The cutoff took the form of a flat stamping, mounted on the rear of the magazine body. This cutoff is actuated to release cartridges by a cutoff actuator or rocking lever, one end of which engages the operating rod, the other end engages the cutoff on the magazine. As the tube reaches the final portion of its forward motion, the operating rod rotates the cutoff actuator which in turn springs the cutoff to the rear and so disengages it from the rim of the cartridges in the magazine. The cutoff is disengaged only momentarily, and in practice, double feeding is prevented by the fact that the vertical motion of the cartridges upward is at a relatively low velocity. Later in the development period, a secondary cutoff system was incorporated so as to prevent double feeding when the weapon was manually cycled (as in immediate action following a misfire). This secondary cutoff, while desirable from a human factors viewpoint, caused interference with the feeding rounds and occasional failures to feed from the magazine. Consequently, the secondary cutoff was removed in the delivery weapons. Dynamic feeding is unaffected by this.

Since the blowforward type action did not require that the ammunition be rammed from the magazine in a conventional manner, it was necessary to design a different means of retaining the rounds in the magazine when the magazine was not in the weapon. This was accomplished by making a second

retaining arm on the stamping at the rear of the magazine body. When the magazine is loaded outside of the weapon, the top most round is retained by this round retaining arm. When the magazine is inserted in the weapon, the final upward motion causes the retainer to engage a cam which is fixed in the weapon, releasing the top round to feed. When the feeding round strikes the tube latch, the tube is released and the action closes automatically, chambering the first round. With only minor dimensional modifications this method of controlling the cartridges during feeding has been retained.

The extraction/ejection system consists basically of a sliding extractor which is spring loaded rearwardly, and a cocking lever which, on one end, engages the striker, and on the other end engages a cam surface on the operating rod. The sequence of operation is: on closing the extractor is cammed forward against its spring to engage the rim of the chambered cartridge. When the cartridge is almost completely chambered, the extractor lever slips off of the surface on the operating rod and the extractor then snaps to the rear, urging the rim of the cartridge to the rear. The breech face is undercut to a diameter somewhat less than that of the base of the cartridge. As a result, when the weapon is fired and the tube moves forward off of the cartridge case, the extractor pulls the cartridge rim to the rear and pivots it about the breech face and out of the ejection port. This arrangement has been generally satisfactory, however, it is important to insure that the extractor spring is not statically stronger than the tube return spring, since the tube return spring has to overcome the other spring during the closing stroke. It is felt that future development might permit modification of the weapon to allow a conventional type of spring loaded ejector to be used. The breech face in this case would have to be set to the rear far enough to permit the rising cartridges to clear the protruding ejector. One difficulty with this arrangement is that the ejector would tend to force the base of the cartridge away from the standing breech, and possibly cause difficulty with the primers. The present type allows the extractor to hold the base of the cartridge firmly to the rear against the breech face so that this is no problem. Future development should also consider the possibility of converting the present cutoff system to a simple rocking type of escapement, thereby obtaining the ability to manually cycle the weapon without particular care to prevent double feeding. This is not considered to be a major design problem.

The use of a Negator type spring for both a magazine spring and follower permits the follower to engage the lower cartridge in the magazine in point contact. This makes the system less sensitive to foreign material. The T slots in the present magazine are necessary to reliably position the cartridges and direct their motion upward into line with the chamber. The other advantage of the T slots is that they permit the cutoff motion to be relatively small, only enough motion to engage and disengage from the cartridge rims being necessary. Feeding reliability has been found to be sensitive to the accumulation of foreign matter in the T slots of the magazines. It was necessary to provide a special shape of rivet to hold the Negator spring in order to prevent the rotation of the cartridges in the magazines, which tends to occur at the moment of firing, from deforming the aluminum T slot.

Special arrangement had to be made to prevent the entire magazine from rotating and displacing forward relative to the launcher during firing. As a result, the magazine catch system provides three latches, one at the rear and two at the front of the magazine. All three latches are operated by the same cross button.

The incorporation of a magazine feed system on the launcher causes some complication, and a considerable increase of mass to the weapon. As is usual with feed systems, the magazine system on the launcher can be expected to be the source of perhaps 30 percent or more of any malfunctions. When used in the single shot, semiautomatic mode, general functioning reliability will obviously be higher than when using the magazine. In such a case, the fact that the weapon stays open for loading will still allow the operator to maintain a higher rate of sustained fire than that which is attainable in a completely manually operated launcher. It is felt that a launcher designed specifically for this mode of operation can be lighter in weight by more than the mere weight of the feed system components involved in the existing design. Much of the complication of the existing firing system is the result of the necessity of timing the feed system and having it meet other requirements imposed by the use of a magazine.

E. Firing System

Development of a suitable firing system was controlled by the following requirements, both specific and implied: Primarily, safety in operation had to be maintained as in any weapon. The trigger pull characteristics which were required were essentially a low weight of pull, and a short length of pull. A suitable manually operated safety was also required, since the launcher is not affected by operation of the point target element safety. Based on experience with previous launcher development, cocking or powering of the firing system should be in a manner which prevents inadvertent loading of the weapon without cocking it. This implies that the cocking should take place early in the forward tube motion or, less desirably, during the closing motion of the tube. The latter method is less desirable since it requires that the tube return spring oppose the striker or hammer spring. A simple method of firing can be obtained, and has been demonstrated, by allowing the firing pin to permanently protrude from the breech face and firing the weapon from the open or partially position. It was agreed at the beginning of the program, that this mode of firing may be objectionable from the human factors viewpoint, and so firing from the closed action position was specified. An additional requirement, common to most firing systems, was to limit the mechanism so that the trigger or striker could not be activated unless the action was entirely closed. This is particularly important in the case of the launcher, which tends to have a fairly long cycle time, making it possible for an operator to pull the trigger a second time before the action has completely cycled.

The firing system design utilized on the first prototypes made use of a pivoted lever which was actuated by the forward motion of the operating rod. The other end of the lever cocked the striker to the rear and then, in its final position, acted as a sear. Firing was accomplished with this design by having a bell crank lever push the cocking lever out of the sear position. This caused the striker to go forward, pivoting the cocking lever at the same time. Test showed that this system, although simple in principle, had several disadvantages: First, it was necessary for the cocking lever to remain in contact with the operating rod throughout virtually all of the cycle. The resulting pressure of the cocking lever against the operating rod was a source of considerable energy loss. Secondly, the engage-

CONFIDENTIAL

NH-2604

ment of the tip of the cocking lever with the striker had to be correct as a sear engagement, but when the angles were correct for this purpose a heavy force was required to rotate the cocking lever and allow the striker to drive forward. Conversely, if the system was adjusted so that a low force was required to move the cocking lever out of the seared position, it was not reliable as a sear and frequently became disengaged and bore heavily on the operating rod, binding the action. Assessment of this system made it evident that the functions of cocking lever and sear should be separated. In this way, the conditions for searing could be made correct without affecting the function of cocking the weapon and vice versa. At this time, an alternative firing system was also considered which was, in effect, a single motion or double action type of system. Such a system had the virtue of safety and simplicity, but was incompatible with the amount of trigger stroke which was available in the point target element. Additionally, there were human factors objections to the customary long, relatively hard pull of a double action system. As a result, this concept was not carried further. Redesign of the firing system then took place about a separate sear and cocking lever concept. The final design involved a "slip sear" type of arrangement, similar in principle to that used originally on various Winchester rifles, and currently on several other weapons. For use on a launcher, the system was reversed in that the sear hook surface was forward of the pivot point, instead of behind it. The principle of operation and disconnecter action remain the same. With this design, the cocking lever became a separate member, although it continued to operate in similar fashion to the earlier design. To prevent undue shock to the firing system, the bell crank firing lever, which engages and activates the sear, was modified by a springably mounted extension, termed the disconnecter. In order to prevent firing the system when the action is not fully closed, a separate lever, called the interrupter, was mounted in the trigger housing assembly. This lever is arranged so that the sear motion is blocked unless the lever is aligned with a clearance cut on the operating rod, occurring only when the action is closed.

This firing system has been retained with slight modifications throughout the remaining development of the weapon.

The remaining element of the firing system is the connection system which couples the firing mechanism of the area fire element to that of the point target element. The feature of firing both weapons from a common trigger has undeniable

CONFIDENTIAL

CONFIDENTIAL

NH-2604

advantages from a human factors viewpoint, but it appears probable that the advantages which may be gained by this do not outweigh the potential for greater reliability if the trigger systems were separate. The point target element has provision for a connector lever mechanism which, when activated by the shooter, disengages the point target element trigger mechanism and engages the trigger to the area fire trigger mechanism. Since this arrangement necessarily took place after the general configuration of the point target element had been established, a considerable complication in the firing systems resulted. The original area fire trigger system provided for a connection to be made vertically downward to the rear of the area fire receiver area. Liaison with Springfield Armory, considering the space limitations within the system, resulted in a change in that the trigger connection was to be made through the rear of the area fire receiver. In order to accomplish this within the time available, it was necessary to add other components in the area fire system in order to reach the linkage within the point target weapon. This complication can be eliminated in the course of future design, but does not relieve the necessary complications within the point target element trigger housing assembly. It is recommended that future consideration of the trigger system take into account the considerable simplification and improvement in reliability which results in the use of separate triggers.

The basic striker housing unit also contains in it the extractor/ejection elements, and the cam or cartridge retainer actuator which serves to release cartridges upon insertion of a loaded magazine. While this results in a single, compact unit, removed from the weapon as one piece, it complicates the effect of tolerance buildups within the system, and consequently, affects the overall reliability and ease of adjustment. Future development should consider the separation of the extraction/ejection function and the round retainer actuation function from this assembly. No major engineering changes would be necessary in order to accomplish this.

F. Sights

From the viewpoint of hardware development, the sight design was virtually an independent area. In addition to the requirements outlined in the Technical Characteristic section of the contract, human factors engineering input indicated that it was very desirable to obtain a range scale which was

CONFIDENTIAL

CONFIDENTIAL

NH-2604

as long as possible physically, and one in which the range divisions were equally spaced in order to avoid confusion to the shooter. Previous human factors studies had indicated that a relatively short sight radius, 3 1/2 inches or more, would be suitable from an optical and precision viewpoint. In the course of the sight development, earlier human factors studies of the optimum location of the rear sight aperture to permit the sight to be useable when firing the weapon from the shoulder at all angles of elevation, was restudied and verified, using supplied point target element weapons and a suitable, adjustable dummy sight.

Although the intended configuration of the weapon system was such that the launcher line of recoil passes normally through the approximate center of the point target element butt plate, it was felt that a measurable amount of vertical jump might still occur in firing, since the entire system tends to recoil about the hips of the shooter. Additionally, lateral jump is expected to be considerable, since the shooter does not support the weapon centrally on his body. While the effect of jump is inconsiderable on small arms with conventional muzzle velocities, the low muzzle velocity of the grenade can logically be expected to cause relatively large effects on the point of impact. As a result of these considerations, it was decided to incorporate provision for automatic drift compensation, and to at least demonstrate in the sight design that some compensation for jump effects could be incorporated. Although ballistic tables supplied from BRL were useful for approximating the expected amount of ballistic drift, no information was available on the possible effects of jump, and development time did not permit testing in order to assess this effect in detail. Consequently, the zeroing adjustment in deflection, which is provided on the sight, was larger than that nominally necessary for simple compensation of drift at the maximum range. This extra range of adjustment is necessary in any event for bore sighting or collimation of the sight line with the weapon.

Several alternative types of mechanical configuration were considered in the course of sight development, a principal type being the so-called quadrant type, in which the range graduations are marked on a quadrant plate, the center of which is the pivot point for the sight bar. Other types of mechanical configuration included types where the rear aperture was kept at one point, while the front aperture or post was raised vertically along a track. The first design decision was that the sight should be mounted on a common

CONFIDENTIAL

CONFIDENTIAL

NH-2604

sight bar and pivoted together. This prevents distortion of the rear aperture as occurs in those types in which the aperture does not move.

The principal shortcoming of the quadrant sight, or one in which the range graduations are spread over a quadrant plate, is that the quadrant itself must be quite large in order to provide readable scale divisions.

Additionally, this sight of range scale is inherently non-linear, the range divisions for longer range being quite large relative to those for short ranges. As a result of these and other considerations, it was decided to develop a ramp type of sight, similar in operating principle to those commonly used on European military rifle sights. In the course of adapting this type of sight to the needs of the launcher, it was believed that with proper geometry, it would be possible to make the cam portion of the sight a true arc, instead of the more complex cam shapes usually employed. By manipulation on layouts of the location of the sight pivot point relative to the cam, and by varying the radius of the cam, it was found to be possible to achieve this result in a configuration which is considerably more compact than that of the conventional quadrant type. The only range tables available at this time for the 40mm cartridge, XM-385. Since the nominal ballistic characteristics were close to those of the M407, M406 ammunition, the resulting design should be a fairly close approximation of any final design. The final design should, of course, take into account the difference in initial ballistics when using the shorter tube of the semiautomatic launcher. Based on the ballistic drift data in the firing tables, automatic drift compensation was provided by inclining the cam plate in a manner such that when the range slide is moved to the rear for higher elevations, the sight line is displaced to the right relative to the bore axis. As a result of using this cam, or ramp type of construction, the range scale, from zero meters to 400 meters, is 2.66 inches long, the spacing being .665 inches per 100 meter, and the 25 meter marks are .166 inches apart and clearly distinguishable.

Adjustments in range are made by depressing the button on the range slide and sliding it to the rear to elevate the weapon. When the range slide is released, the sight bar is locked at the desired elevation, and cannot be knocked out of position unless the slide button is deliberately pressed.

CONFIDENTIAL

Adjustment for zeroing the weapon in deflection is provided by a movable rear aperture, which is locked in place by a screw. Adjustments for zeroing in range are provided by screwing the post type front sight up or down as desired. The sight assembly is attached to the receiver cover of the point target element, and is removed by simply pressing a button at the front of the mount and sliding the sight downward and off.

The horizontal distance of the sight bar from the center line of the weapon required a compromise, in that if the sight bar were to be located far enough out to permit the shooter to use the sight without interfering with the front or forward hand, the sight would have to be located so that the bar was almost two inches to the left of the outside of the point target weapon. It is felt that a sight located in this manner would protrude so far as to continually be caught in brush, etc., and would also make the whole weapon inconvenient to carry and more delicate. Likewise, to make the sight so that it was mounted on a hinged, or extensible arm would make it relatively complicated and more fragile. Consequently, the sight was mounted relatively close to the left side of the point target element, in a position where the sight line clears the weapon components, but which will require the shooter to move his thumb out of the line of sight at certain elevations.

Although the prototypes are fabricated of aluminum alloy, the long range production intention is that it be adapted to stamped, sheet metal fabrication. Although government recommendations included the use of a post type of front sight, it is felt that a considerable improvement in useability could result from the use of a properly designed front aperture type of front sight. It is understood that such a sight would require careful selection of the aperture diameters, and the radial thickness of the aperture mask. Future development of the sight assembly might profitably include consideration of a simple collimator type optical system. It should be noted that the elevating and adjusting means used on the present sight are readily adaptable to such a system.

G. Mounting

The location of the launcher assembly on the point target element was a subject of considerable discussion during the early phase of the contract. Previous Winchester launcher

design had included mounting the launcher at the forward end of the point target element, to permit the shooter to maintain a normal handhold on the basic weapon. Since this arrangement resulted in an increased moment of inertia for the entire weapon system, stability when firing bursts or full automatically was improved, but at the expense of the ability to bring the point target element rapidly to bear on surprise targets. As a result, government representatives felt that the launcher should be mounted as far to the rear as possible, to hold the moment of inertia to a minimum. An additional reason for doing so on the Springfield point target element is that it was felt that mounting the launcher on the forward section of the point target element would result in a considerable adverse effect on point target element dispersion. The original layouts of the launcher showed a launcher mounted as far to the rear as possible, the launcher at this time having a relatively short length from the rear of the magazine to the rear of the receiver. Discussion of this design, and manipulation of a mockup which was constructed in this manner, showed that the distance between the magazines of the two elements was too small to permit a convenient handhold with the forward hand. As a result, it was requested that the launcher magazine be moved approximately two inches further forward. The mounting bracket which was incorporated in the point target element could not readily be moved forward by this amount, so that the end result was a stretching of the launcher by approximately two inches, so that the magazine could be further forward, while the rear of the launcher remained in the same position. In the course of modifying the layouts to meet this condition, it was decided to take advantage of the increased length of receiver behind the magazine, by mounting the tube return spring in the rear portion of the receiver.

The method which was desired by Springfield for attaching the point target element to the launcher involved cantilevering the launcher from a bracket which is in the vicinity of the extreme rear of the area fire element. As a result of concern as to the reliability and ruggedness of this method of mounting, the initial prototype weapons also incorporated a bayonet lug type connection further forward, which locked the middle of the area fire receiver to the point target element. Test firing with this bayonet lug removed showed that this secondary attachment was unnecessary, and the cantilever arrangement was in fact adequate. As a result, the final launcher receiver design eliminated the bayonet lug.

Midway in the development process, inspection of the appearance of the mockups resulted in criticism from Weapons Command about the appearance of the combined weapon. Weapons Command pointed out that the weapon package looked like two separate distinct weapons, instead of one integrated unit. The reason for this is that there was a considerable gap between the top of the launcher receiver and the bottom surface of the point target element. This considerable gap made it possible for brush, etc., to become wedged between the two weapons. Additionally, it was stated that the overall height of the system should be reduced if possible. As a result of this, a supplementary agreement was made to permit Winchester to redesign the receiver and related elements so as to close the gap between the two weapons and give a more blended appearance. The resulting design, incorporated on the final delivery weapons, raised the center line of the launcher slightly, and provided wings along the top of the launcher receiver to mask the gap between the two weapons without making actual contact. A secondary modification made to the receiver at this time was the incorporation of suitable lugs on the launcher receiver to permit mounting the bipod on the launcher, instead of the point target element. The principal reason for this was that the bipod, when mounted on the point target element, interfered with the launcher ejection port when folded. Although the new bipod mounting position causes the bipod legs to miss the ejection port when folded, the folded bipod does make it less convenient to insert and remove the launcher magazine.

Regardless of the position of the launchers on the point target element, as long as the three round capacity is required, the launcher will continue to be approximately 3.5 pounds in weight, and will continue to make handling of the entire weapon package considerably more awkward than for a conventional rifle. It is recommended that, in the event that the launcher magazine capacity is reduced, or the magazine is eliminated, a reconsideration should be made of mounting the launcher further forward on the point target element.

H. Fabrication and Production Aspects

As previously noted, the first Winchester prototype launchers used a composite construction in which the breech assembly was of aluminum and the main receiver assembly was a fiber glass reinforced molded plastic. Since early in the present contract the decision was taken to make the receiver one

homogeneous member in order to obtain the necessary rigidity, aluminum alloy was the logical choice for prototype work. The choice of aluminum was also dictated by the time required to construct the necessary molds for plastic assembly. Various methods were considered for the fabrication process to be used in the prototypes, including that of stamping the receiver. Again, tooling for this type of fabrication was considered to take too long for the purposes of the present program. Several major aluminum suppliers and fabricators were conferred with on the possibility of forming the basic receiver by means of impact forging. The method envisioned involved impact forging both the main front cavity and the rear cavity in which the striker housing is mounted. The various vendors were supplied with receiver details, and hypothetical forging details. Each vendor then modified the supplied detail drawings to suit the needs of the process as they envisioned it. At least two of these organizations showed definite interest in the work, and quoted tooling and fabrication times which appeared to be within the scope of the program. At this time, because of changing war conditions within the aerospace industry, the necessary heavy forging presses, required for the prospective forging operations, became unavailable. Since other detail design had taken place about the impact forged receiver concept, at this point it was too late to convert the method of fabrication to some other method. As a result, it was necessary to obtain large forged cylindrical blanks and machine the receivers entirely from solid. The process or sequence used was as follows: First the blanks were bored to their major internal diameter at the front end, and the rear cavity was roughed out on a jigborer. Following this, the blanks were Eloxed to obtain the necessary tube guidance key ways, and to obtain the finished shape of the rear cavity. Following this, the external shape of the receiver was rough finished. Semi-finished, die cast magazine wells were then attached to the basic receiver by means of T-slots, epoxy resin, and aluminum screws. The aluminum screws served principally to insure good electrical connection between the magazine wells and the rest of the receiver. After the magazine well castings were assembled to the rough machined receiver, the remaining machine cuts were made, which included final finishing of the magazine well aperture. Following this, the entire receiver was hard coated as a unit.

As a result of the difficulty in obtaining access to heavy presses, and since the future availability of such presses are an unknown factor, the Value Engineering team turned attention to the receiver and reconsidered the practicality

of a stamped receiver. Studies showed that a stamped receiver was practical, as originally expected, and this became the basic recommendation for future fabrication.

Construction of the early prototype magazines was made in approximately the same manner as the prototype receivers, that is, the internal cavity was rough machined and finished by Eloxing. In this particular case it was convenient to machine the magazine floor plate as an integral part. The final delivery magazines were constructed in a different manner, in that the magazine bodies were extruded sections, appropriately cut to length and machined. The magazine floor plates were made as a deep drawn shape, spot welded to the magazine body. The assembly method for the magazine spring and the cartridge retainer stamping was by riveting. This was used in the first prototypes as well as in the final delivery magazines. In general, this final method of magazine fabrication is satisfactory, and is reasonably light. Since the main functional components of the magazine are the spring, the section of the magazine which contains the T slot, and the cartridge retainer, the magazine is capable of a variety of alternative methods of construction. For some of these alternative means, see Appendix E, Value Engineering.

The striker housing was envisioned from the very beginning as a die cast component. For practical purposes during development, the housings were machined from solid stock. As long as no basic changes in the general firing system are envisioned, die casting the striker housing, either in one or two pieces, would seem to be the best method for mass production.

Fabrication of the tube or barrel was from solid stock, for prototype purposes. The first tubes were constructed from rifled blanks, the rifling being done by an outside vendor. Early testing disclosed that the bore and rifling dimensions on these blanks was not uniformly within specification. Additionally, the unit cost was considered excessive. As a result of this experience, the Winchester Model Shop adapted a milling machine for the purpose of rifling blanks in-house. The adaptation used at Winchester was an improved one in that it provided better support for the rifling bar and the blank. These hook rifled tubes were used throughout the remainder of the project. The use of a one-piece tube has the advantage that the tube guidance lugs can easily be held correct relative to the bore and chamber. Since the tube is essentially a thin walled tube, it would appear that proper tooling

might allow fabrication of a tube as a linear extrusion. This could be done by two methods: In one method, the tube would be extruded in smooth-bore form, with the guide lugs rough formed on the outside. Another approach would be to extrude the tubes in thin walled forms, and by using an appropriate shape of central mandrel, formed as a rifling button, the tubes would be extruded with the rifling already finished. In such a case, it would be necessary to attach the guide lugs to the outside of the barrel afterward.

It is expected that, because of the nature of the weapon, the bulk of the fabrication cost in production would be centered about the receiver, the magazine well, the tube, and the striker housing. Although these components are few in number, they can logically be expected to be responsible for perhaps 75 per cent of the production cost. The remaining components of the weapon are on the average considerably simpler. On several areas, it has been possible to use more or less standard forms of fasteners such as roll pins, standard machine screws, and conventional rivets.

In the course of development only two or three small components have actually been broken due to overstressing. Since this and other information seems to indicate that some areas of the launcher are, as presently made, over-designed, it appears possible that future development can result in some lightening of the system. Since experience during the development has pointed the way toward some simplification of the functional areas, it may be concluded that the entire launcher is capable of considerable flexibility as to the method of fabrication, and may be potentially lightened and simplified. Virtually all of the potential simplifications and refinements are of an elementary nature, and do not require complete redesign of the system.

I. Conclusions on Technical Aspects

Some conclusions on the technical aspects of the design are as follows:

- . The basic mechanical design of the system is sound.
- . The primary source of malfunctions on the existing weapons appears to be due to tolerance buildups within the system. This is largely true since the present contract scope does not involve a formal tolerance study.

CONFIDENTIAL

NH-2604

- . In general, the principles of operation of the system lend themselves to a variety of methods of fabrication in production. The design is sufficiently flexible that future development and refinement will be relatively straightforward.
- . The system can be lightened to a certain extent in future development.
- . The design of the system is such that it can be readily adapted to a variety of methods of mounting, control, and tactical usage.

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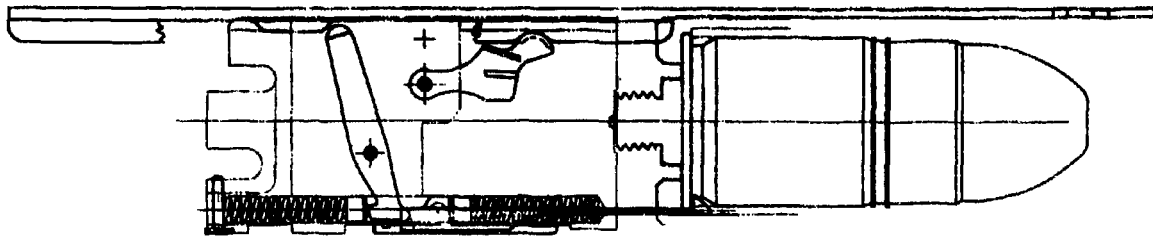
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SECTION IV

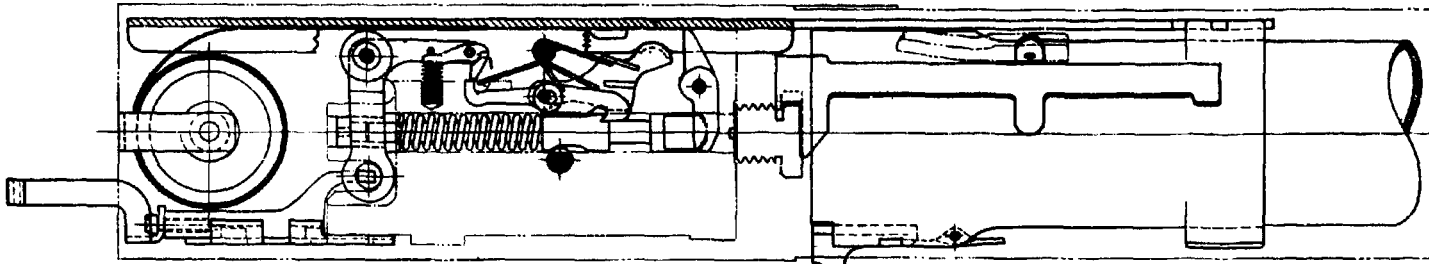
MAJOR LAYOUTS AND ASSEMBLIES

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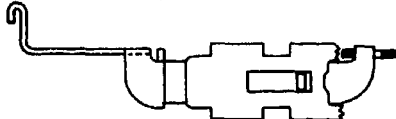
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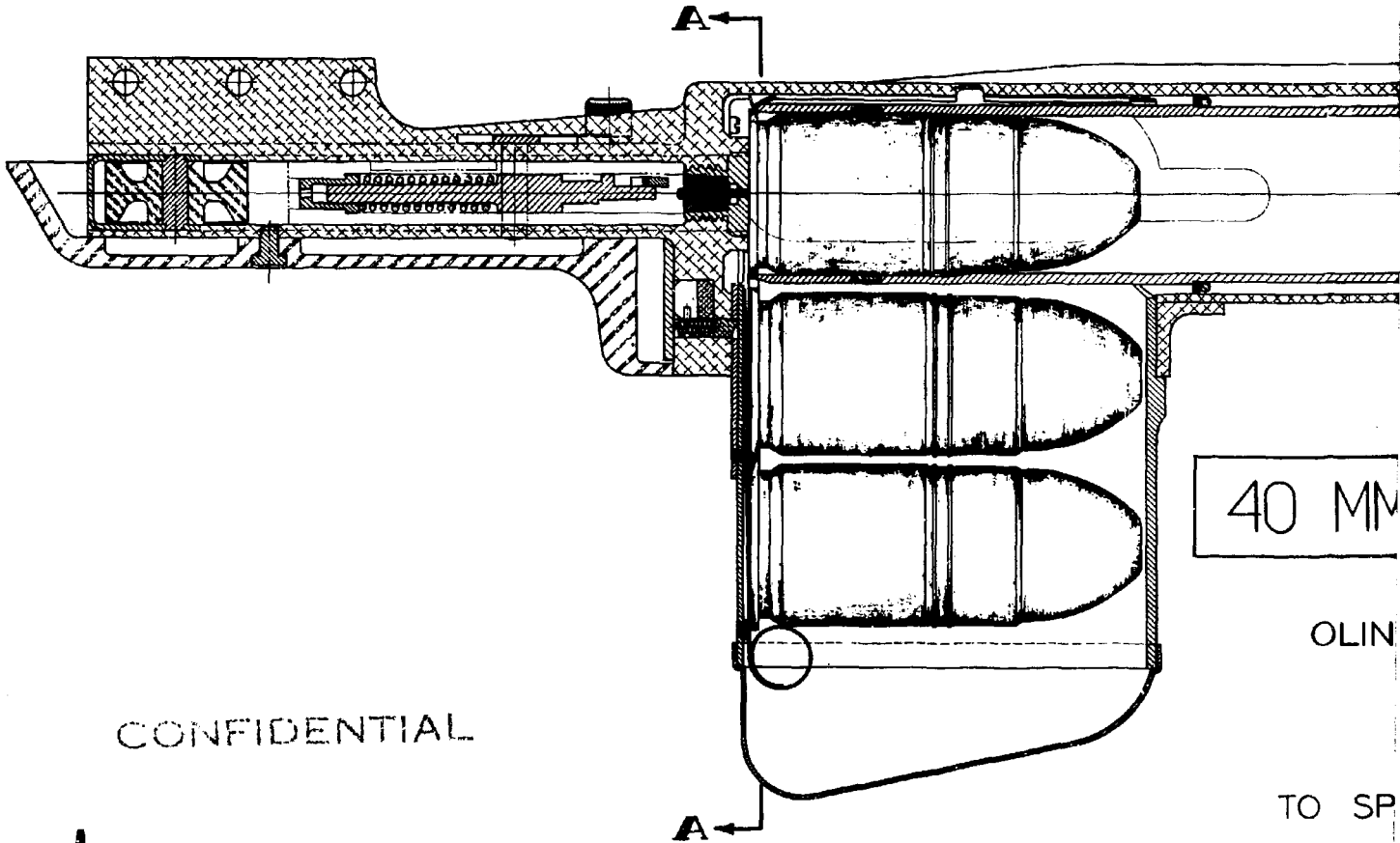
EXTRACTOR SYSTEM



FIRING SYSTEM



TRIGGER CONNECTOR ASSEMBLY



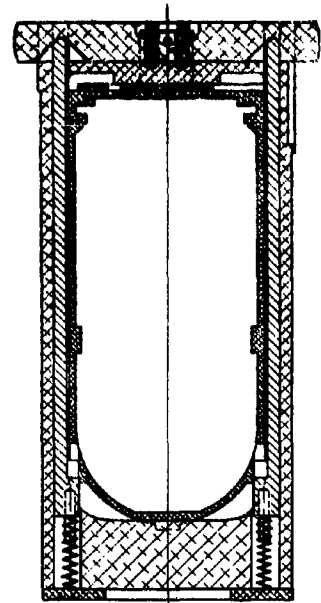
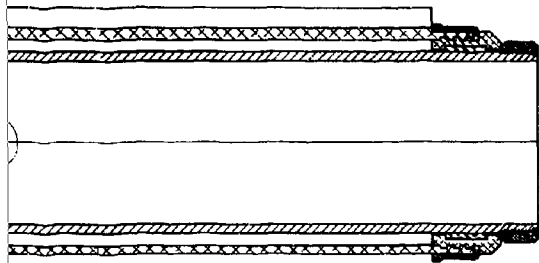
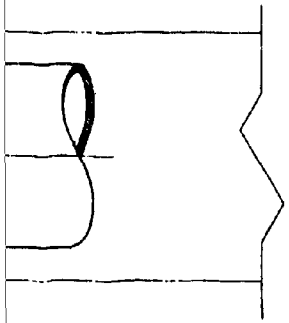
40 MM

OLIN

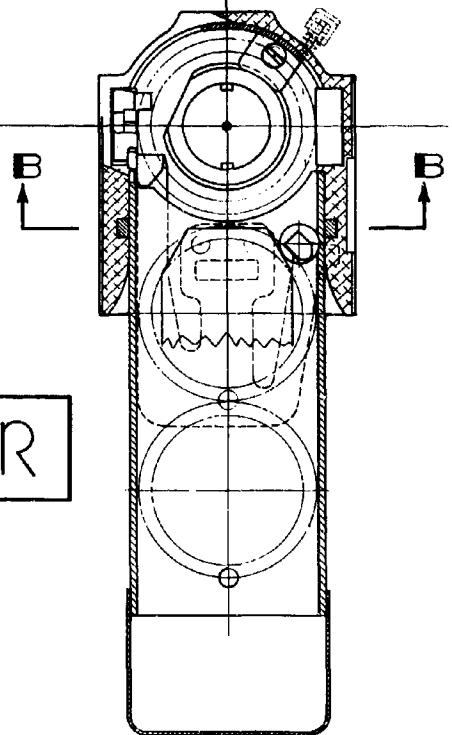
CONFIDENTIAL

TO SP

CONFIDENTIAL



SECTION **BB**
MAGAZINE LATCH SYSTEM



SECTION **AA**

30 MM SEMIAUTOMATIC LAUNCHER

WINCHESTER-WESTERN DIVISION
OLIN MATHIESON CHEMICAL CORPORATION

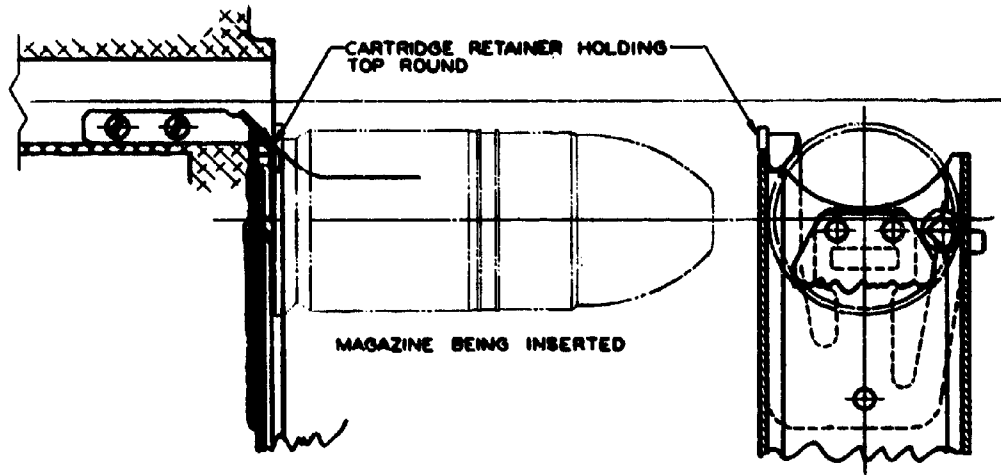
CONTRACT DA-19-058-AMC 1103
PO-19-058-M5-T5654
TO SPRINGFIELD ARMORY, SPRINGFIELD, MASS.

2

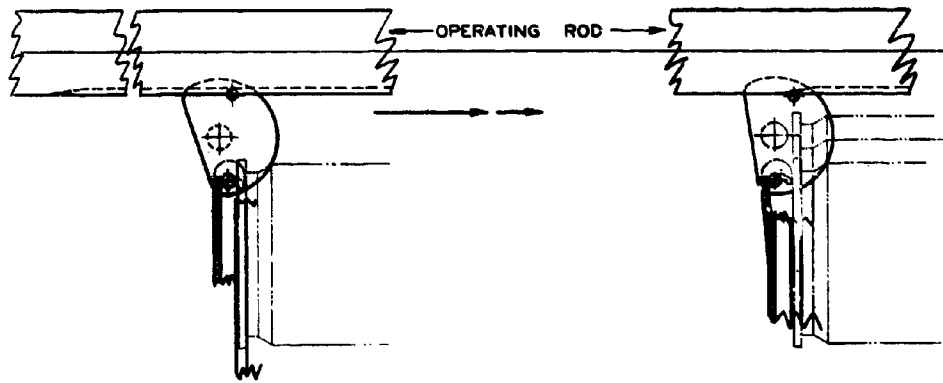
NH-2604

OPERATION OF FEED

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FUNCTION OF CUTOFF ACTUATOR



OPERATING ROD MOVING FORWARD.
ROUND IS RESTING AGAINST CUTOFF

OPERATING ROD FULLY FORWARD.
RIM STILL GUIDED BY GROOVE IN
MAGAZINE.
ROUND RELEASED

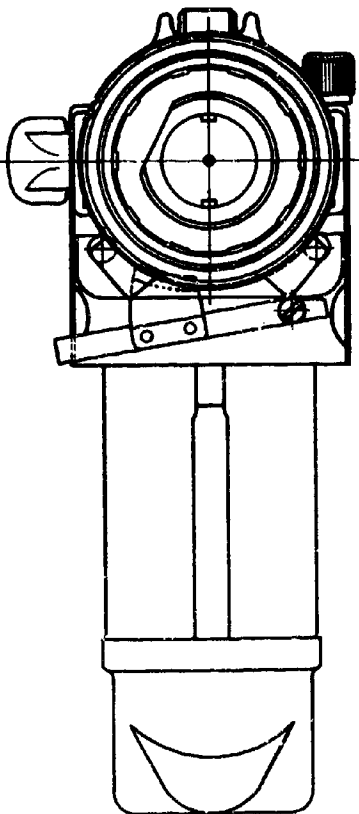
ED SYSTEM

RISING CARTRIDGE PUSHES TUBE LATCH UP

RETAINER CAMMED TO REAR
RELEASING TOP ROUND TO
RISE

MAGAZINE FULLY INSERTED, FEEDING FIRST ROUND

TRIDGE RETAINER AND TUBE LATCH



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2

NH-2604

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NOTES:

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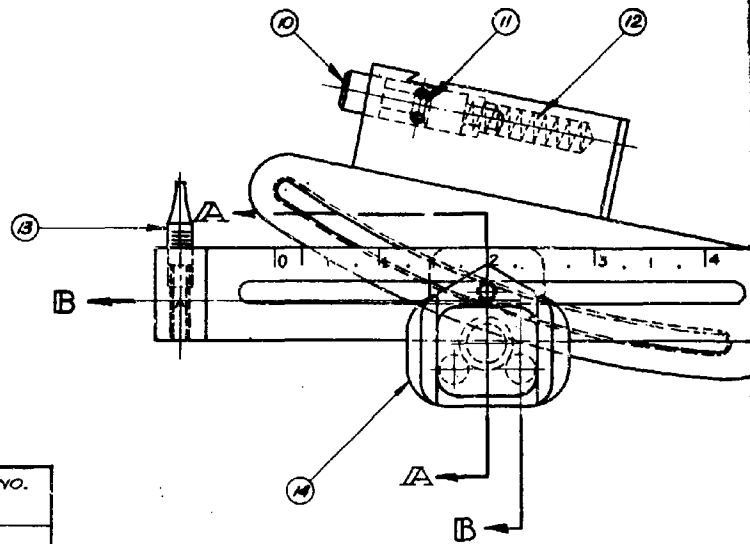
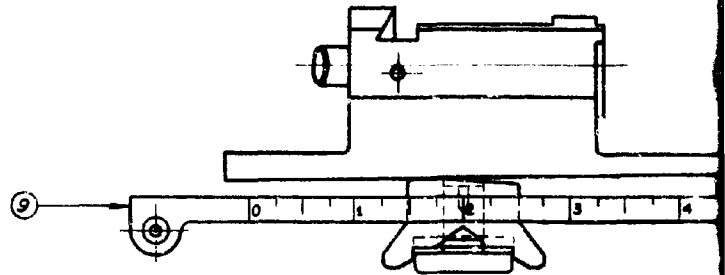
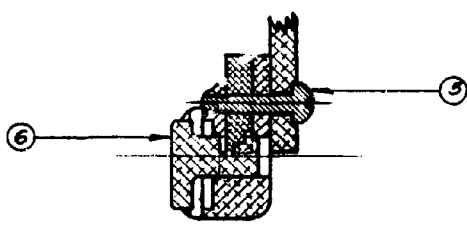
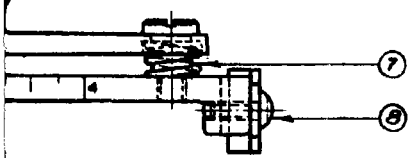


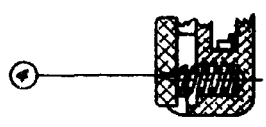
FIG. NO.	PART NO.	NOMENCLATURE	QTY. REQD.	DWS. NO.
1	51436	MOUNT	1	F 51436
2	51442	SCREW, PIVOT	1	B 51442
3	51440	APERTURE, REAR	1	B 51440
4	51445	SPRING, DETENT PLATE	2	B 51445
5	51441	SCREW, SLIDE	1	B 51441
6	51448	DETENT	1	C 51448
7	51450	SPRING, SIGHT BAR	1	B 51450
8	51449	SCREW, REAR APERTURE	1	A 51449
9	51439	BAR, SIGHT	1	C 51439
10	51449	LOCK, MOUNT	1	B 51449
11	51352	PIN, LOCK MOUNT, RETAINING	1	B 51352
12	51446	SPRING, MOUNT LOCK	1	B 51446
13	51443	POST, FRONT SIGHT	1	B 51443
14	51447	SLIDE	1	C 51447

MECHANICAL PROPERTIES	
YP	
TS	
EL 2	
RA	
BH	
RH	

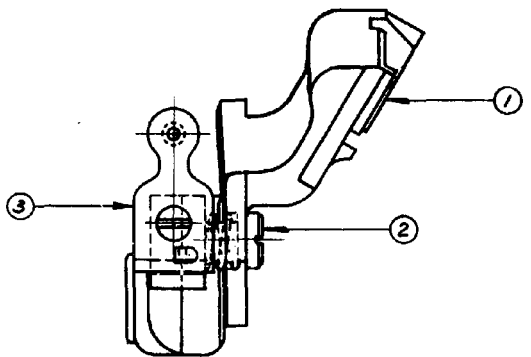
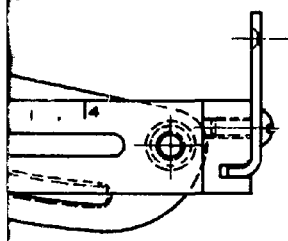
REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL



SECTION A-A
SEE ZONE 4-B



SECTION B-B
SEE ZONE 4-B



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PART NO. 51461

MECHANICAL PROPERTIES	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		ORIGINAL DATE OF DRAWING 6-28-66	SPRINGFIELD ARMOY U. S. ARMY WEAPONS COMMAND SPRINGFIELD 1, MASS. U. S. ARMY MATERIEL COMMAND	
	TOLERANCES ON DECIMALS ±	FRACTIONS ±	DRAFTSMAN BAZ	CHECKER	ASSEMBLY, SIGHT
SEE ENGINEERING RECORDS	ANGLES ±	MATERIAL -	TRACER	CHECKER	
NEXT ASSY USED ON	HEAT TREATMENT -	APPROVED	ENGINEER HF	ENGINEER	CODE IDENT NO. DWG SIZE 19205 D D51461
APPLICATION	FINAL PROTECTIVE FINISH -		SUBMITTED		
DO NOT APPLY PART NO					SCALE 2:1 UNIT WT SHEET / OF /
DO AO SPECIFIED					

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APPENDIX A

Engineering Calculations

A-1

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CALCULATIONS AND ANALYSIS

During the course of development several types of calculations were made, principally in the following categories:

- . Those necessary to analysis of the power system energy output.
- . Evaluation of the effect of the power system on muzzle velocity, range capability, and range dispersion characteristics.
- . Estimation of the energy and static forces required for feeding.
- . Those relating to projectile spin rate and required rifling twist rate.
- . Calculations on acceptable tube wall thickness and dynamic expansion.

A large portion of the calculations dealt with empirical data. Although the design as a whole is relatively simple, in the area of power system operating energy, a large number of parameters affect the system, and as variations were made in the system on one parameter at a time, it was usual to plot the parameter versus output so as to obtain at least an approximation of the optimum values.

The most frequently used analytical aid was the time-displacement chronograph (film-drum type). Records from this device were used in two ways: particular values of velocity (and consequently, energy) were obtained by analysis of the film with a direct reading goniometer. Secondly, familiarity with the characteristics of the time-displacement traces permitted the designers to correlate particular inflections of the curves with certain mechanical functions (or malfunctions) in the course of studying mechanical functioning. Typical of this was a tell-tale disjunction of the tube trace when excessive energy was lost in engagement of the striker cocking lever with the forward moving operating rod. Another example is the characteristic inflection at front impact of the tube. Since front impact was necessary to the operation of the magazine cutoff, inspection of the curve could indicate whether a failure to feed from the magazine was due to lack of operating energy or to some cause within the feed system proper.

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A Fastax high-speed motion picture camera was frequently used for studying ejection and feeding. Since the drum chronograph is generally superior for obtaining quantitative displacement and velocity data, the high speed pictures are used for the purpose only on special cases. The exception on this program was in using the Fastax camera to relate projectile muzzle exit to forward tube motion. The Fastax camera was convenient for this because of the low muzzle velocity.

A-3
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SAMPLE CALCULATIONS AND CURVES

PROJECTILE SPIN RATE AT LAUNCH

Rifling Twist: 1 turn in 42 inches (3.5 ft)

Spin Rate in RPM is:

$$\begin{aligned} N &= \frac{V_p - V_{\text{tube}}}{3.5} \times 60 \\ &= (V_p - V_{\text{tube}}) \times 17.143 \quad (\text{RPM}) \end{aligned}$$

Projectile Velocity, V_p :

V_p and V_{tube} were measured simultaneously (chronograph and drum camera)

$$\bar{V}_p \text{ (5 round mean) } = 231.05 \text{ ft/sec}$$

(Individual velocities were 229.2, 227.3, 235.0, 231.3, and 235.0)

These correspond to T-D records 511-515 inclusive.

Fastax pictures of muzzle exit were then taken on 3 shots, showing the tube displacement relative to the receiver at the instant of muzzle exit. The pictures showed this displacements as 1.1, 1.2, and 1.3 inches. Analysis of the tube velocity at this point (using the T-D curves) showed values of V_{tube} as 19, 20, 21, 21, and 22 ft/sec, averaging 20.6 ft/sec.

The spin rate is then

$$N = (231 - 20.6)(17.43) = 3670 \text{ RPM } \pm$$

Rate specified for M79: 3750 mean, 3000 min.

A-4

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UNCLASSIFIED Launcher Tube Strength
(sample)

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WALL THICKNESS REQUIRED

From
$$\text{Min } r_2 = r_1 \left[\frac{\Sigma T + P_i(1-\mu)}{\Sigma T - P_i(1+\mu)} \right]^{1/2}$$

and using

μ for steel of 0.30
 μ for Aluminum of 0.35,

and Max tangential stress ΣT of

180,000 lb-in⁻² for steel
and
60,000 lb-in⁻² for Al. alloy

Then at P_i (internal pressure) of 4000 lb-in⁻²,

the minimum wall thickness is

$$t_{\text{MIN}} = .011315 D_i \text{ for steel and}$$

$$t_{\text{MIN}} = .03538 D_i \text{ for Alum. alloy}$$

At $P_i = 2000 \text{ lb/in}^2$,

the minimum wall thickness is

$$t_{\text{MIN}} = .0056056 D_i \text{ for steel and}$$

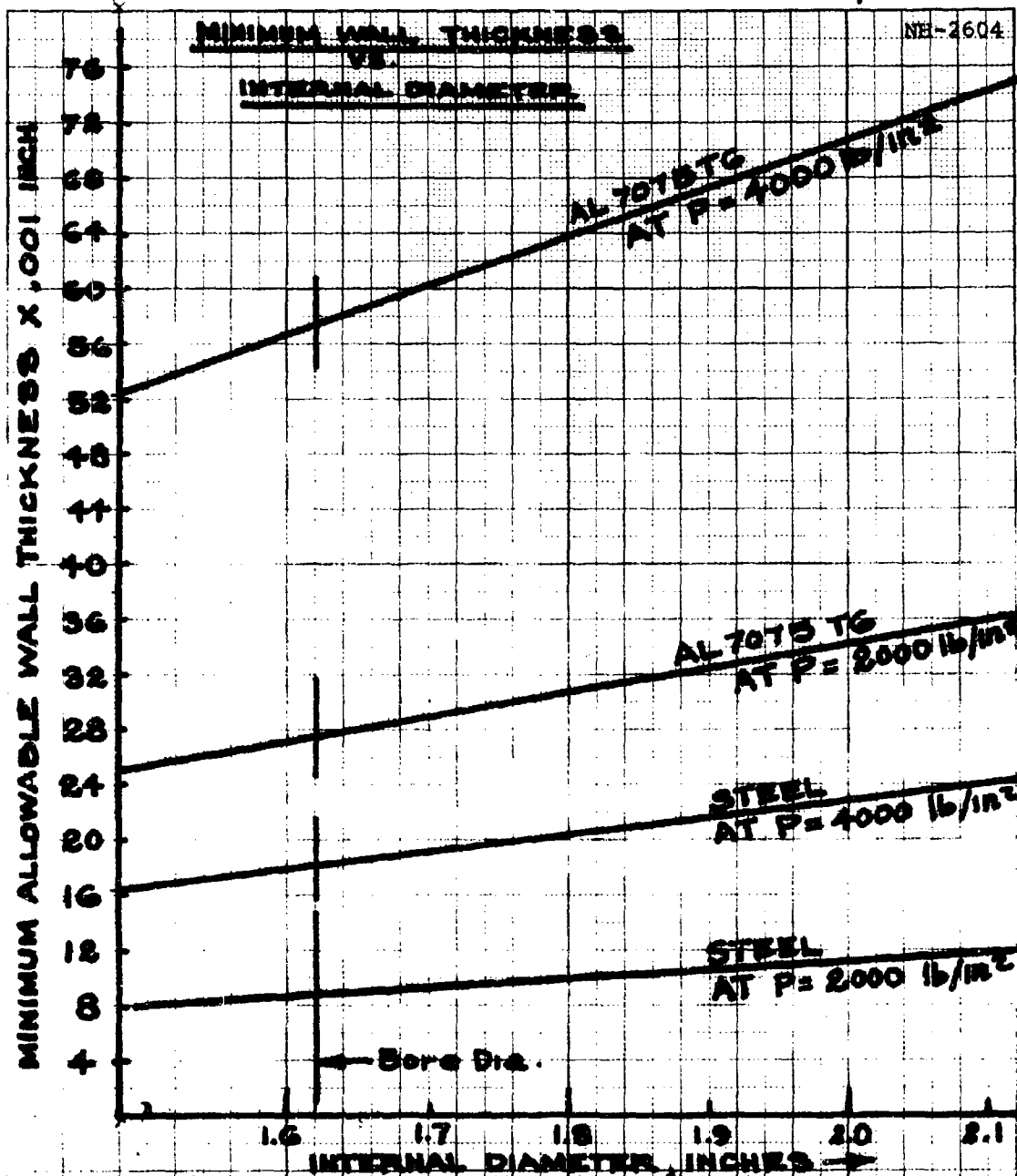
$$t_{\text{MIN}} = .0171576 D_i \text{ for Alum. alloy.}$$

(D_i = internal diameter, r_i = internal radius, etc)

A-5
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J. J. July 65

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40 MM BARREL THICKNESS, ETC.



For ΣT , Max tan stress of $\begin{cases} 150,000 \text{ lb/in}^2 \text{ for steel, and} \\ 60,000 \text{ lb/in}^2 \text{ for 7075-T6} \end{cases}$

Using $\mu = 0.30$ for steel | From: $\text{Max } \sigma_2 = \tau \frac{[\Sigma T + P(1-\mu)]^{1/2}}{[\Sigma T - P(1+\mu)]^{1/2}}$

$\mu = 0.35$ for 7075-T6

Jef 6/05

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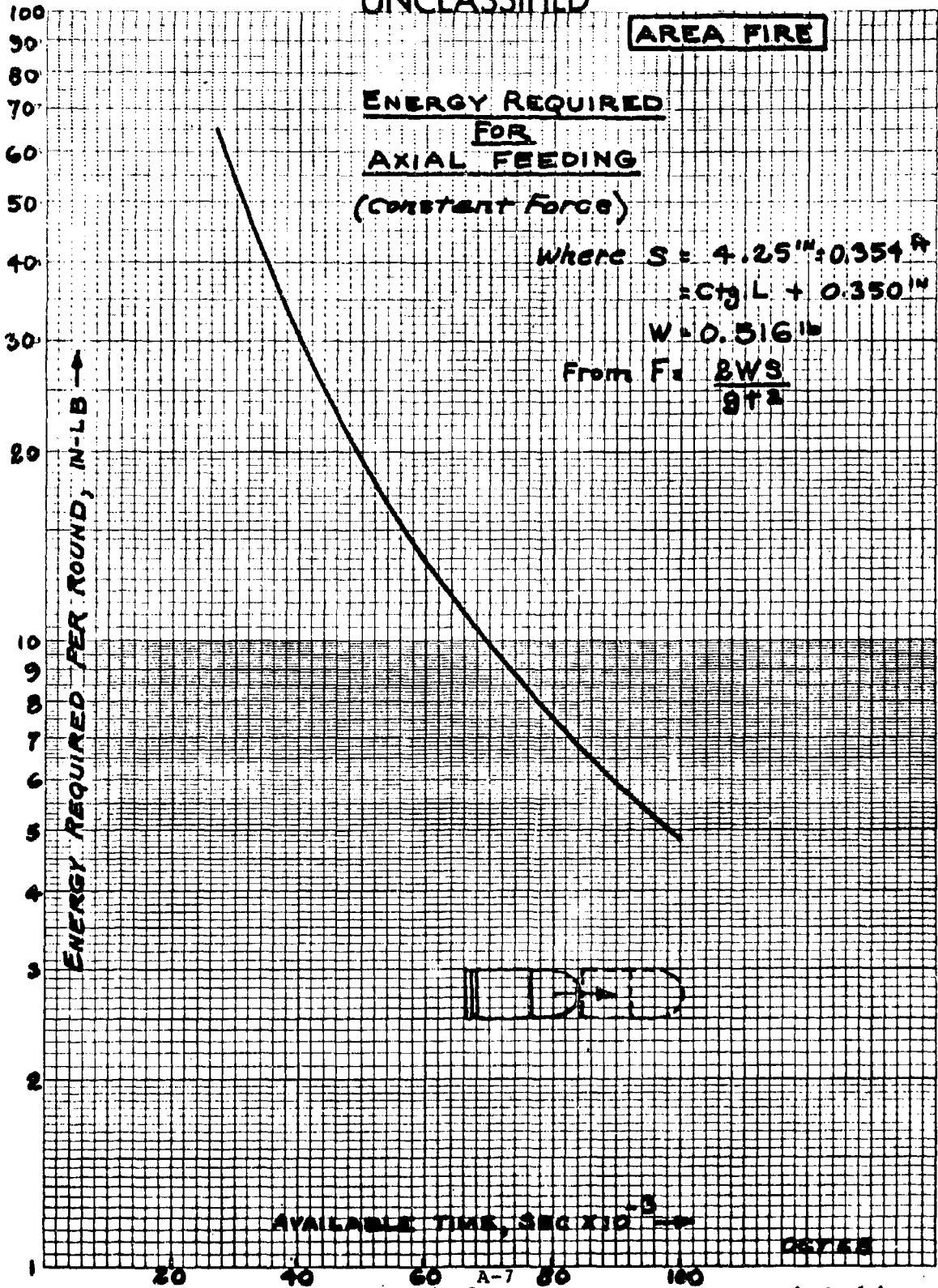
AREA FIRE

ENERGY REQUIRED
FOR
AXIAL FEEDING
(constant force)

Where $S = 4.25'' \pm 0.354''$
 $= C_1 L + 0.350''$
 $W = 0.316''$
From $F = \frac{2WS}{g t^2}$

EUGENE DIEZBEN CO.
MADE IN U.S.A.

NO. 340-L210 DIETZBEN GRAPH PAPER
SEMI-LOGARITHMIC
2 CYCLES X 10 DIVISIONS PER INCH

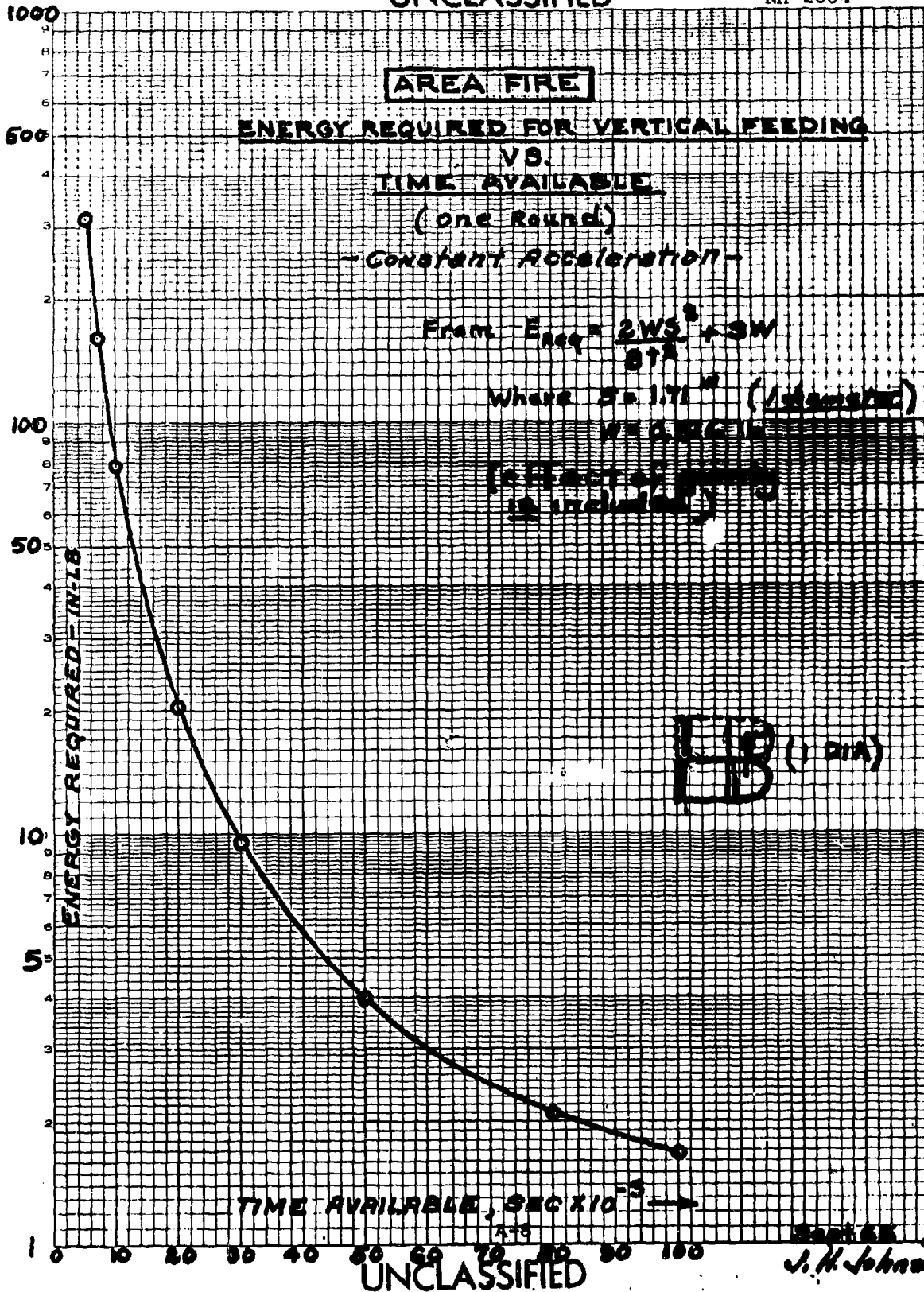


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EUGENE DIETZGEN CO.
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NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

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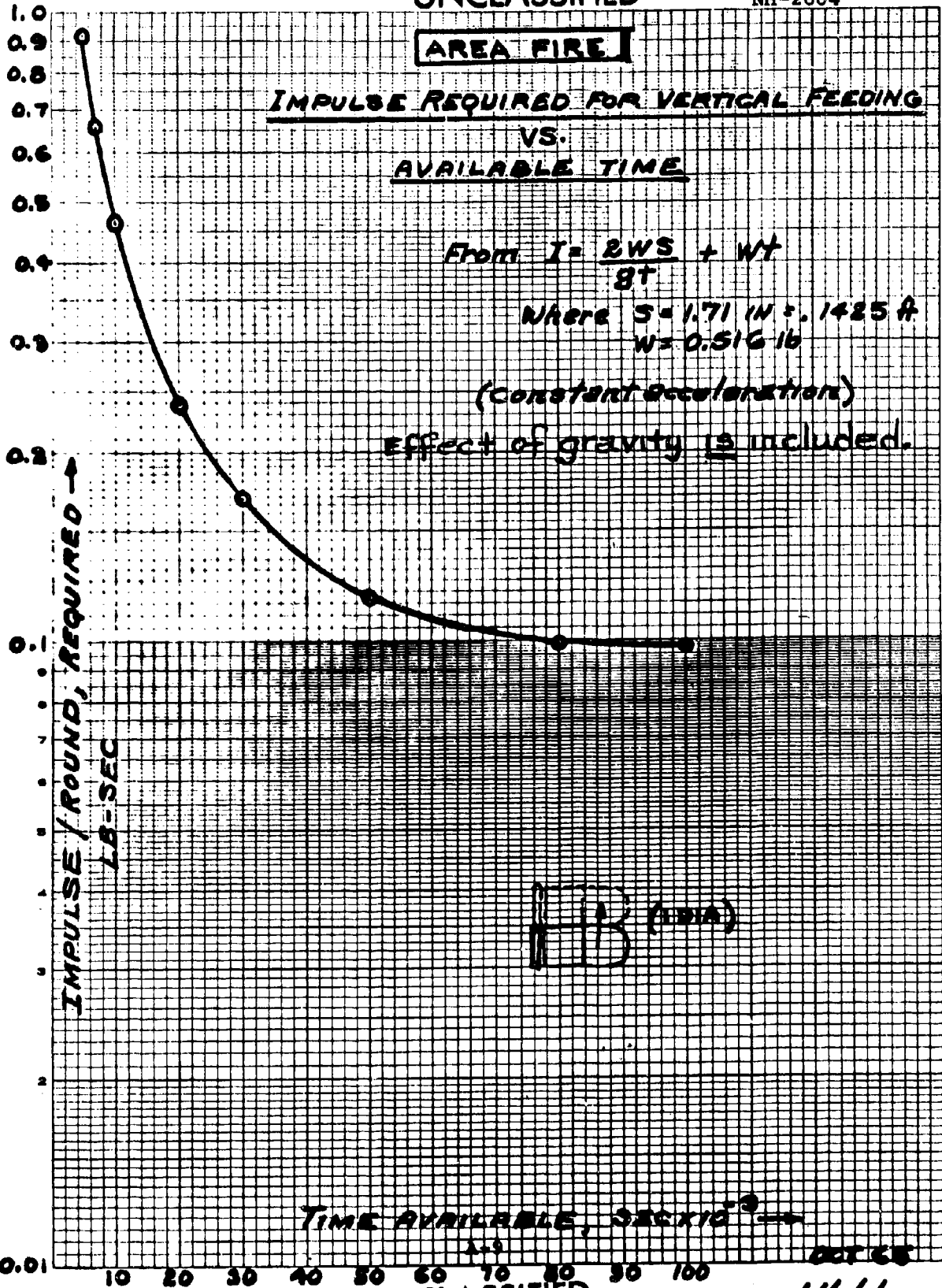
AREA FIRE

IMPULSE REQUIRED FOR VERTICAL FEEDING
VS.
AVAILABLE TIME

From $I = \frac{2WS}{gt} + Wt$

Where $S = 1.71 \text{ IN} = .1425 \text{ ft}$
 $W = 0.516 \text{ lb}$

(constant acceleration)
effect of gravity is included.



STANDARD DIETZGEN CO.
MADISON, WIS.

NO. 340-L210 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
2 CYCLES X 10 DIVISIONS PER INCH

TIME AVAILABLE, SECS →

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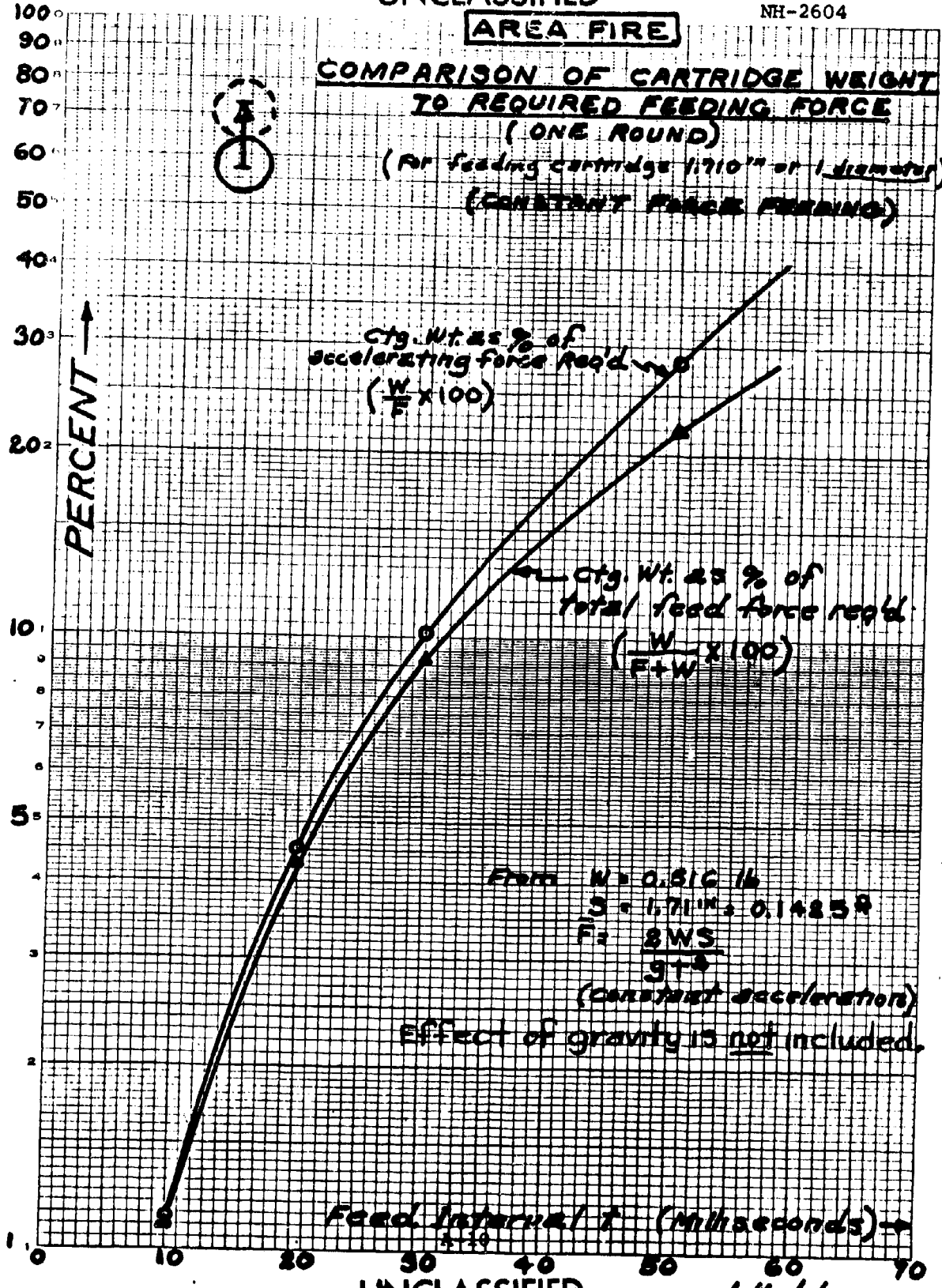
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AREA FIRE

COMPARISON OF CARTRIDGE WEIGHT TO REQUIRED FEEDING FORCE (ONE ROUND)

(For feeding cartridge 1.710" or 1 diameter)
(CONSTANT FORCE FEEDING)



Cty. Wt. as % of accelerating force req'd.
 $(\frac{W}{F} \times 100)$

Cty. Wt. as % of total feed force req'd.
 $(\frac{W}{F+W} \times 100)$

From $W = 0.516 \text{ lb}$
 $S = 1.710'' = 0.1485 \text{ ft}$
 $F = \frac{8WS}{9T^2}$

(constant acceleration)

effect of gravity is not included.

Feed Interval t (milliseconds) →

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2 CYCLES X 10 DIVISIONS PER INCH

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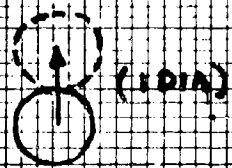
AREA FIRE ROUND

Accelerating Force Per Round
to translate 1 rd. a dist. of 1 ctg. DIA

where $W = 0.516$ lb
and $S = 1.710$ in = 0.1425 ft.

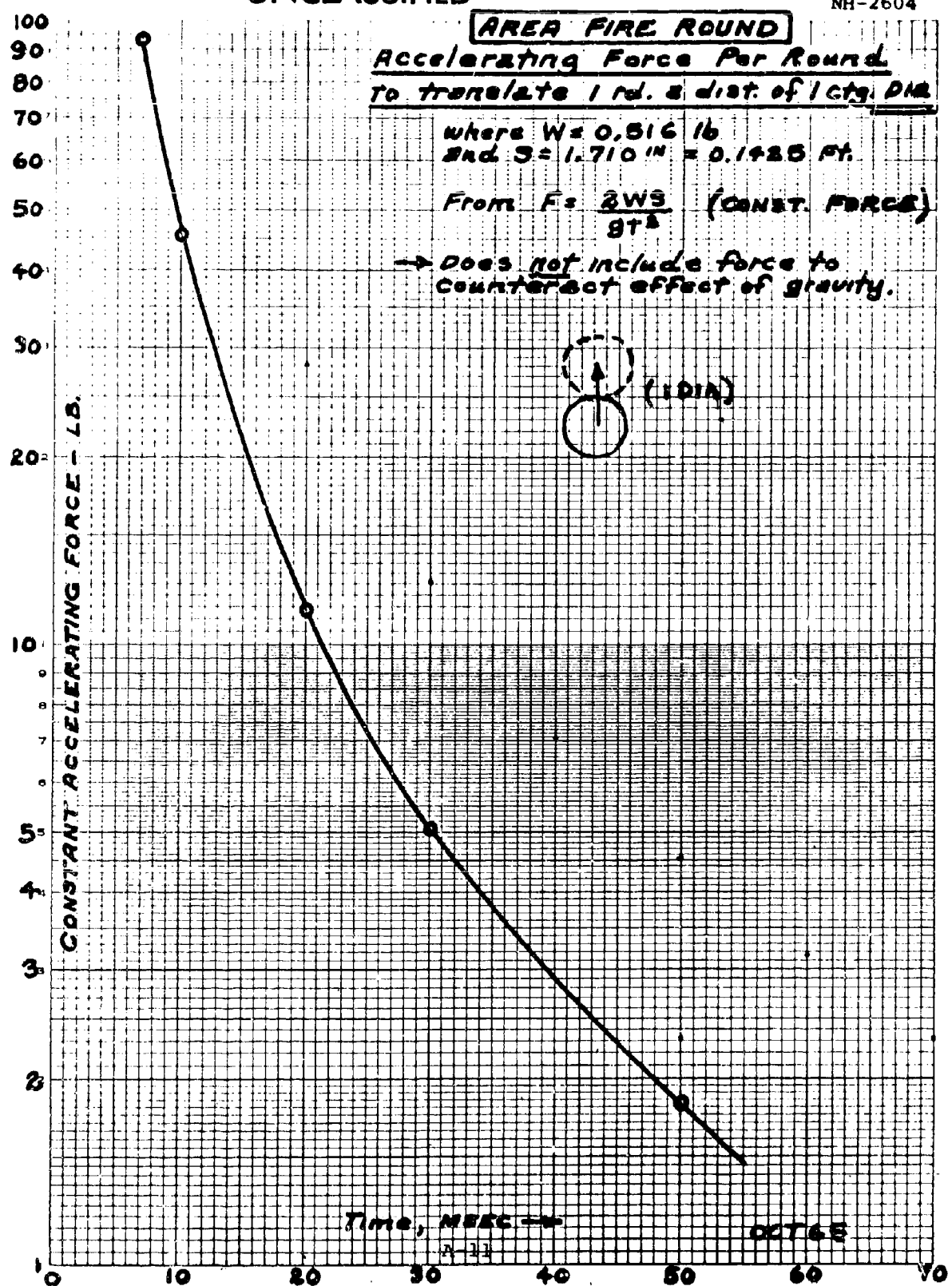
From $F = \frac{2WS}{gt^2}$ (CONST. FORCE)

→ Does not include force to counteract effect of gravity.



EUGENE DIETZGEN CO.
MADE IN U.S.A.

NO. 340-L210 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
2 CYCLES X 10 DIVISIONS PER INCH

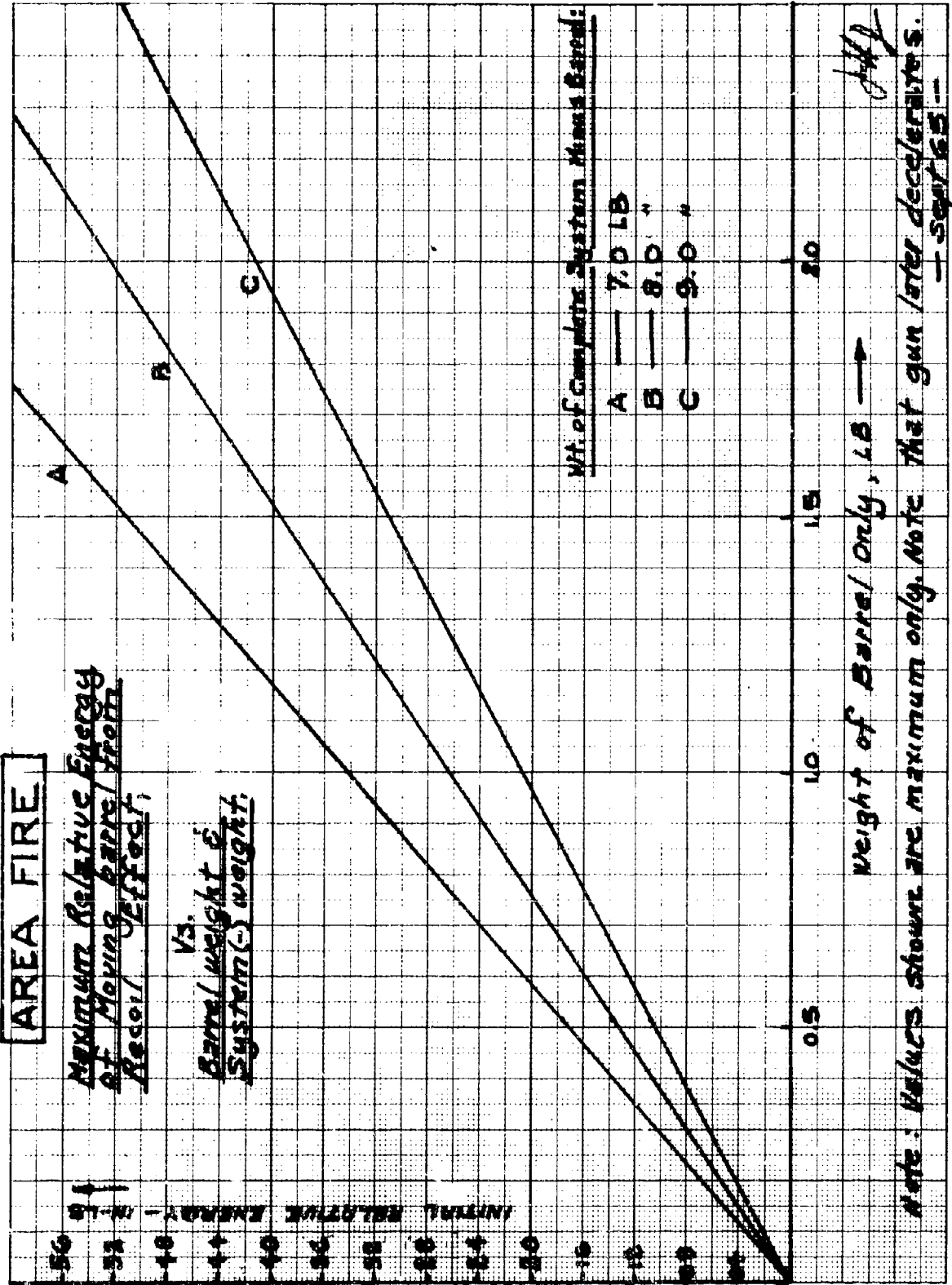


Time, MSEC →

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A-12

STATISTICAL DATA REDUCTION

SUBJECT: Projectile Vel. - Tube B D PROJ: 4850 BY: JHJ DATE: 23AP66

NO.	X	R	R ²	VARIANCE	σ	RELATIVE DIFFERENCE	PRECISION	NH-26D4
X	UNIT:	($\bar{x} - x$)		$\frac{\Sigma R^2}{N-1}$	$\sqrt{\text{Var.}}$	$\frac{\sigma}{\bar{x}}$	$\sqrt{\frac{1}{25^2}}$	
1	235.0	+4.3	18.49					
2	218.0	-12.7	161.29					
3	231.5	+0.8	0.64					
4	236.0	+5.3	28.09					
5	235.0	+4.3	18.49					
6	235.5	+4.8	23.04					
7	233.0	+2.3	5.29					
8	226.6	-4.1	16.81					
9	222.5	-8.2	67.24					
10	234.2	+3.5	12.25					
$\bar{x} =$	230.73		$\Sigma R^2 = 351.63$	39.07	6.25	(2.7%)		
	ft-sec ⁻¹				ft-sec ⁻¹			

- SAMPLE -

(P.E. = 4.22 ft-sec⁻¹)

Rds 1-5: with single band of 5 mil tape around case.
 Rds 6-10: " double width " " " " " " "

REF. [Same tube with no tape;
 Mean $v_0 = 207.9$ ft-sec⁻¹ avg of 4 rds:
 (210.2 - 207.8 - 208.9 - 209.6)

Rds 1-10:	Dev. R	no	no Ambles	%
	-12.7	1	1	10
	-8.2	1	2	20
	-4.1	1	3	30
	+0.8	1	4	40
	+2.3	1	5	50
	+3.5	1	6	60
	+4.3	2	8	80
	+4.8	1	9	90
	+5.3	1	10	100

see Att. for plot.

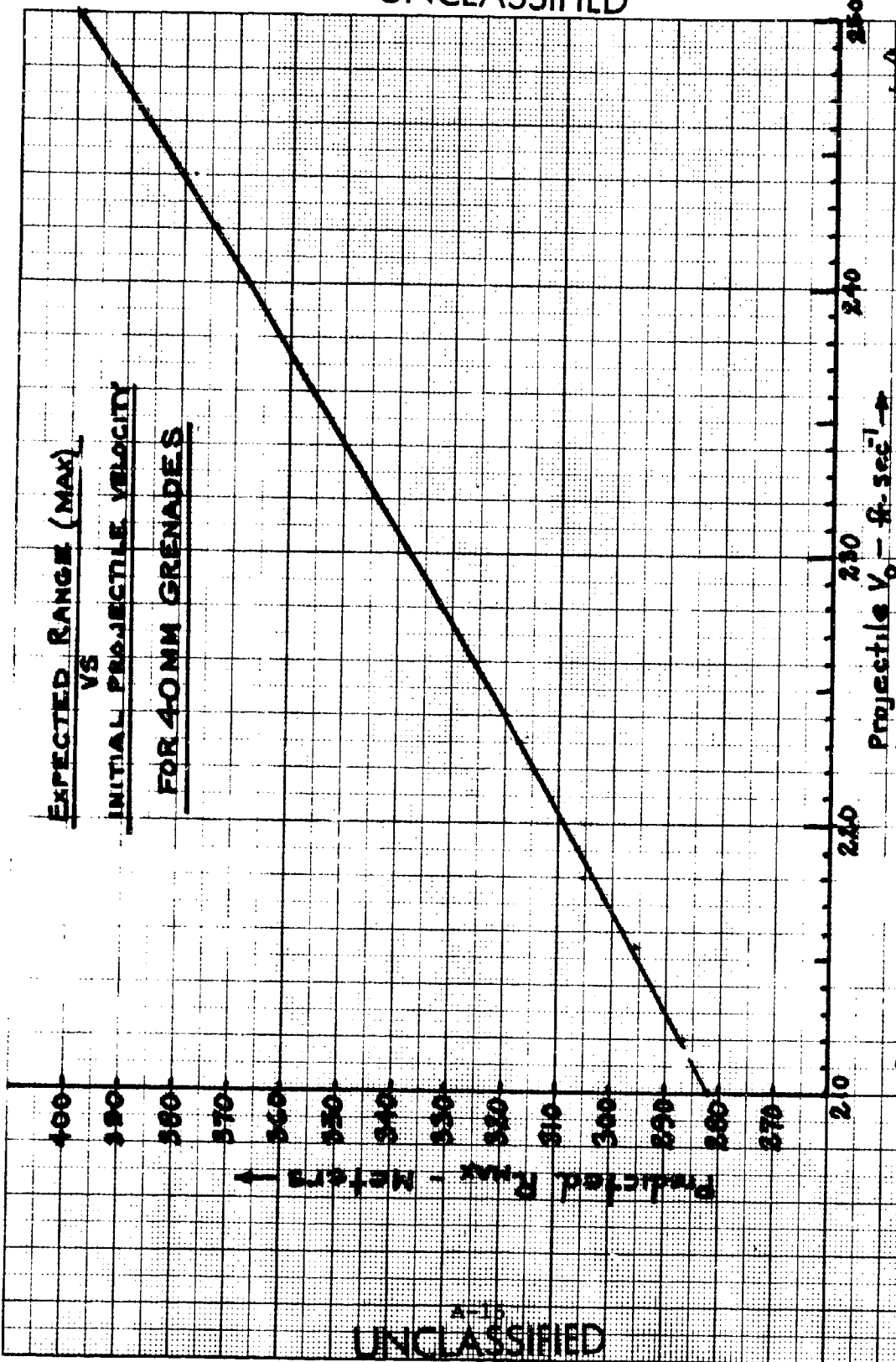
- SAMPLE WORKSHEET -

STATISTICAL DATA REDUCTION

SUBJECT: V_0 with Obstructor Tube BD PROJ: 4850 BY: JHJ DATE: 21AP66

	NO.	X	R	R ²	VARIANCE	σ	RELATIVE DISPERSION	PRECISION	NH-2604
	X	UNIT:	$(\bar{X}-X)$		$\frac{\sum R^2}{N-1}$	$\sqrt{\text{Var.}}$	$\frac{\sigma}{\bar{X}}$	$\frac{1}{\sqrt{20^2}}$	Array of Dev.
SMOKE ↓	1	230.9	-0.7	0.49					-3.5 10
	2	232.0	+0.4	0.16					-2.6 20
	3	232.0	+0.4	0.16					-0.7 30
	4	232.0	+0.4	0.16					+0.1 40
	5	228.1	-3.5	12.25					+0.4 40
	6	231.7	+0.1	0.01					+1.4 50
	7	235.5	+3.9	15.21					+3.9 100
	8	232.0	+0.4	0.16					
	9	233.0	+1.4	1.96					
	10	229.0	-2.6	6.76					
	\bar{X}	231.6	$\sum R^2 =$	37.32	4.14	2.04	0.88%		
		ft/sec				ft/sec			
Array of Dev.									
Proof ↓	1	235.0	-0.3	0.09					-3.8 10
	2	237.3	+2.0	4.00					-2.5 20
	3	238.9	+3.6	12.96					-0.3 30
	4	235.0	-0.3	0.09					+0.2 40
	5	231.5	-3.8	14.44					+2.0 50
	6	232.8	-2.5	6.25					+2.2 60
	7	232.8	-2.5	6.25					+3.6 100
	8	235.5	+0.2	0.04					
	9	237.5	+2.2	4.84					
	10	237.5	+2.2	4.84					
	\bar{X}	235.3	$\sum R^2 =$	53.80	5.98	2.45	1.04%		
		ft/sec				ft/sec			

-SAMPLE WORKSHEET-



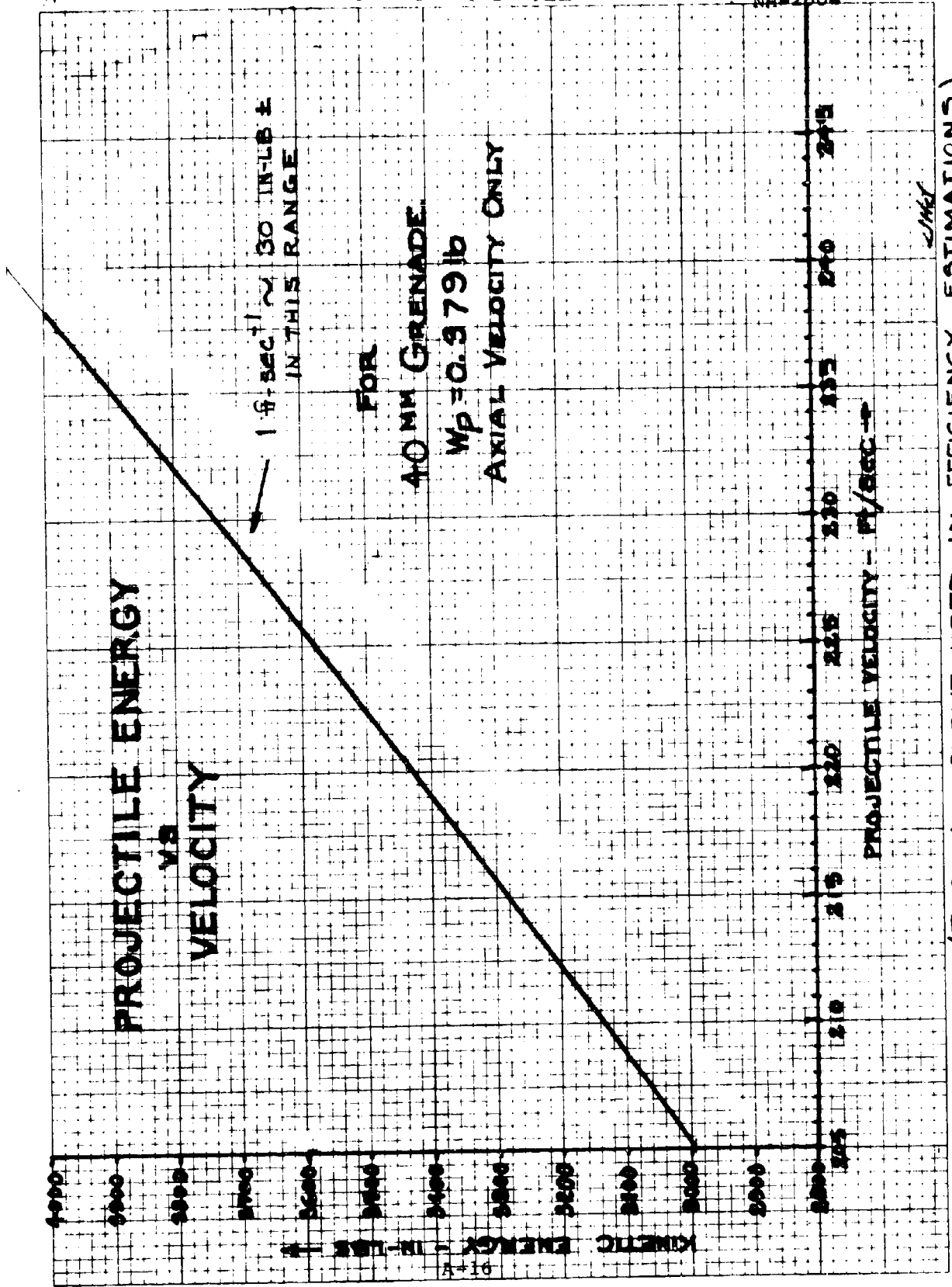
PLOT: $R_{max} = \frac{V_0^2}{15.656}$ (meters) where V_0 is in ft. sec⁻¹, derived from assumptions below.

ASSUMPTIONS: ① True $R_{max} = V_{ac}$. Parabolic fig. x a const. over small ΔV , ② const. from Aberdeen firing results, giving $R_{max} = 350 M$ for $V_0 = 247 ft/sec$

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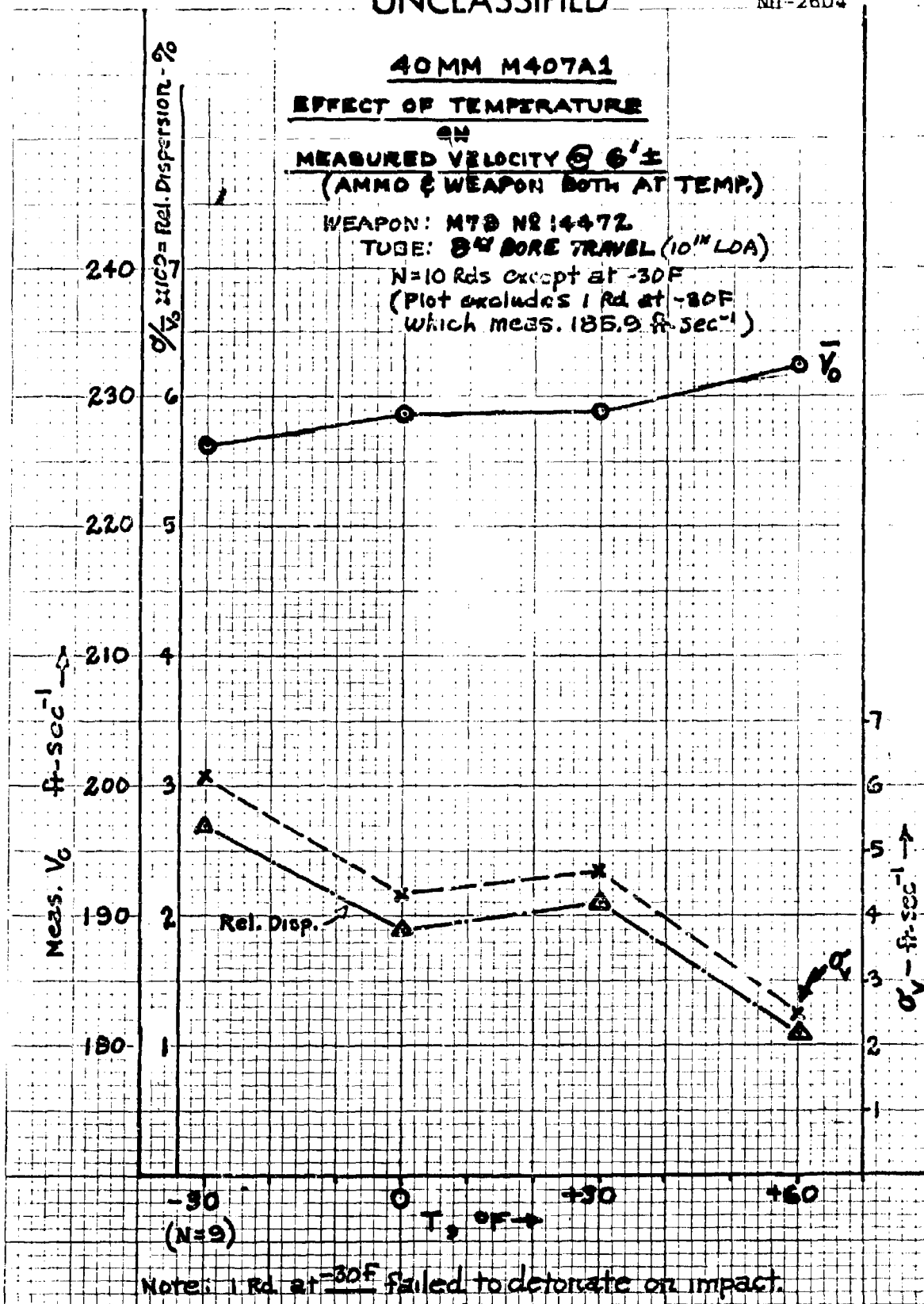


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(TYPICAL CURVE USED IN EFFICIENCY ESTIMATIONS)

40MM M407A1
EFFECT OF TEMPERATURE
ON
MEASURED VELOCITY $\bar{V}_0 \pm \sigma$
(AMMO & WEAPON BOTH AT TEMP.)

WEAPON: M78 N2 14472
 TUBE: 8" BORE TRAVEL (10" LDA)
 N=10 Rds except at -30F
 (Plot excludes 1 Rd at -30F
 which meas. 185.9 ft-sec⁻¹)



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APPENDIX B

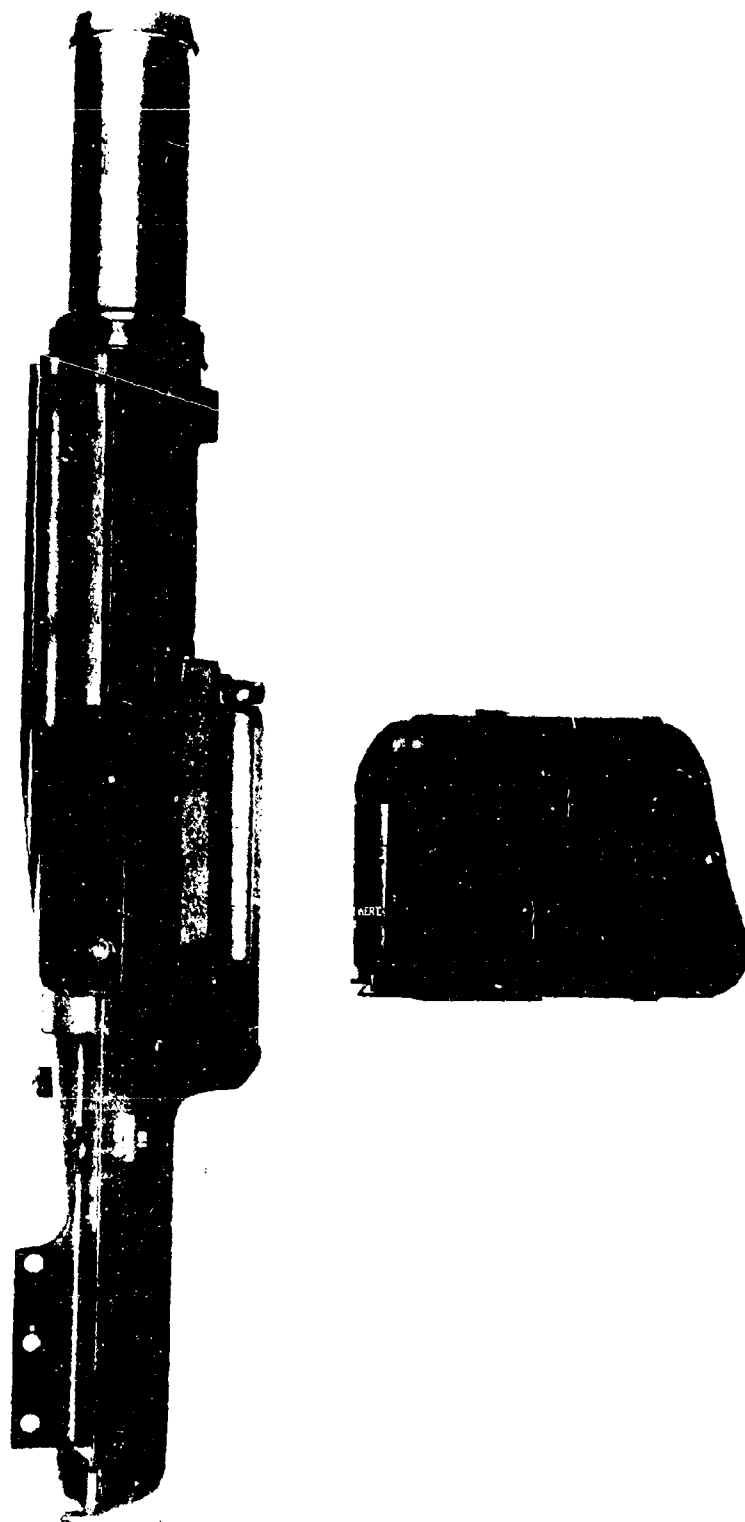
Illustrations

B-1

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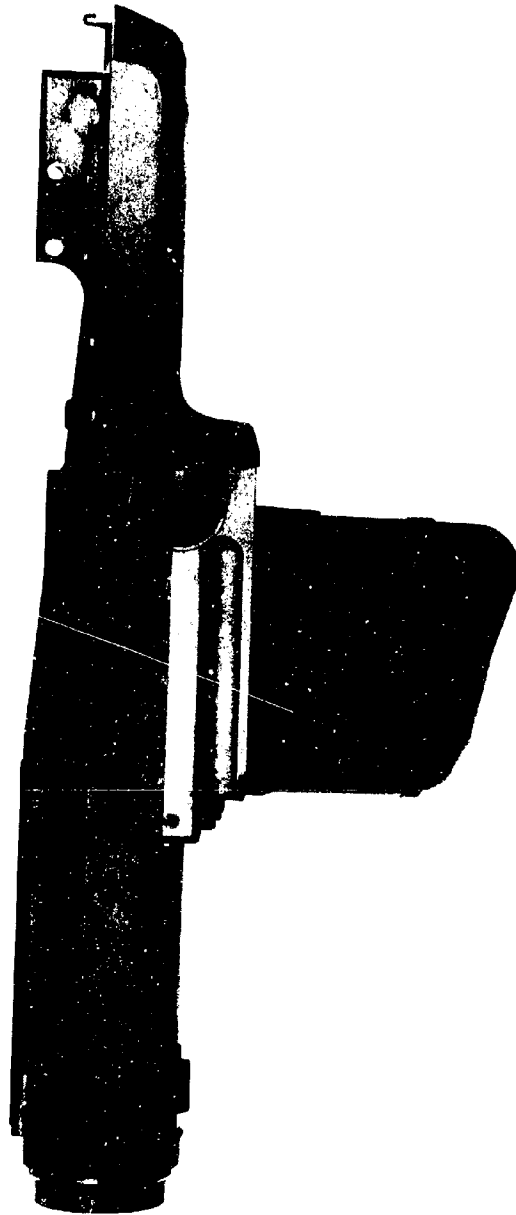
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LAUNCHER, RIGHT SIDE, ACTION LATCHED OPEN, MAGAZINE OUT

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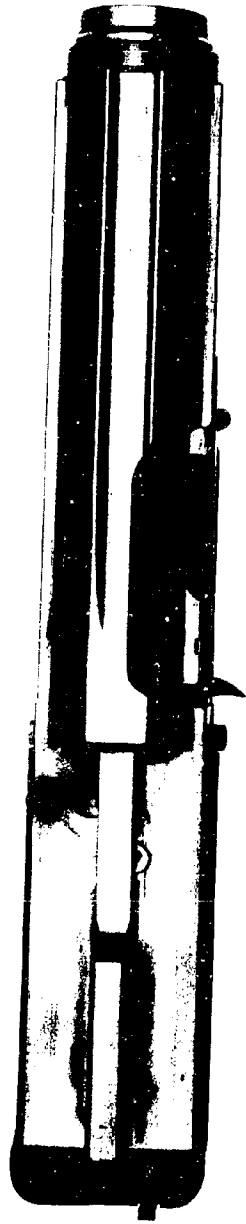


LAUNCHER, LEFT SIDE

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LAUNCHER, TOP VIEW

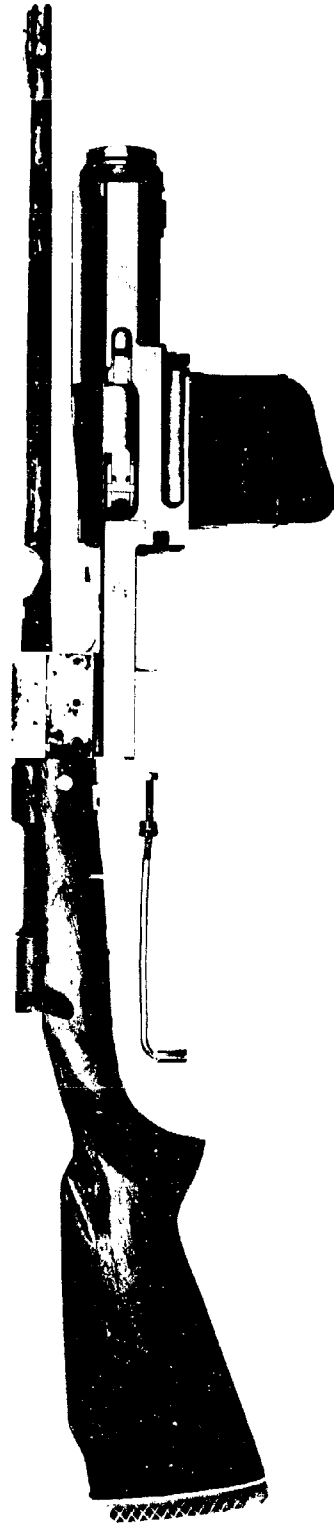


LAUNCHER, TOP VIEW

LAUNCHER, TOP VIEW

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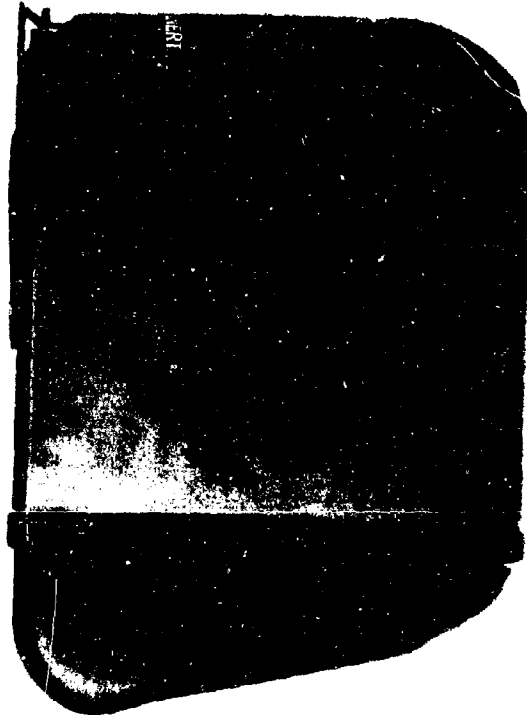
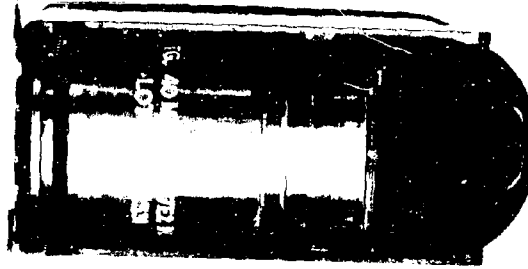


LAUNCHER ON M70 TEST MOUNT

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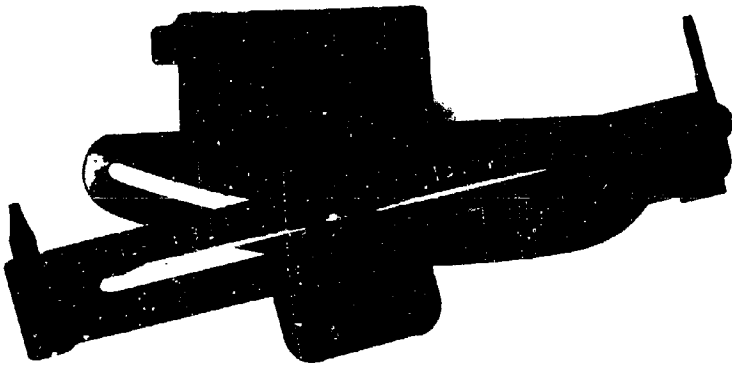
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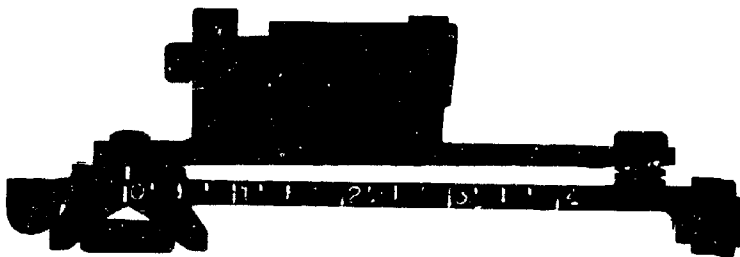
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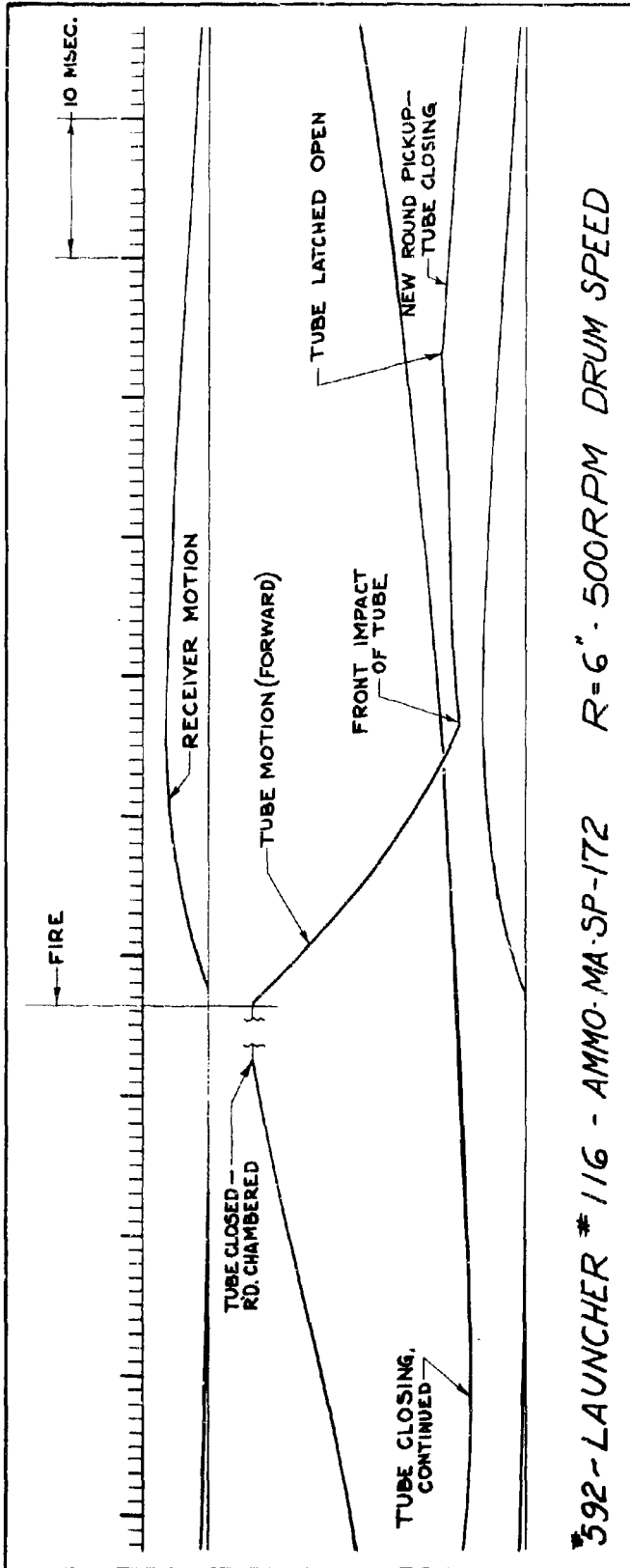


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TYPICAL T. D. RECORD
AREA FIRE WEAPON

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APPENDIX C
Human Factors Engineering

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Prepared for:

Olin-Mathieson Chemical Corporation
Winchester-Western Division
New Haven, Connecticut

HUMAN FACTORS ENGINEERING FOR THE
SPECIAL PURPOSE INDIVIDUAL
WEAPON (SPIW) LAUNCHER (U)

Final Report

Purchase Order NHW 98486

30 June 1966

Prepared by:

Dunlap and Associates, Inc.
Darien, Connecticut

C-2

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TABLE OF CONTENTS

	<u>Page</u>
I. Introduction	C-4
II. Approach	C-5
III. Summary of Human Factors Recommendations	C-6
IV. Technical Analysis and Results	C-8
A. Feed System Design	C-8
1. Configuration	C-8
a. Selection of Alternate Designs	C-8
b. Criterion Selection and Weighting	C-9
c. Design Evaluation	C-12
2. Associated Components	C-16
a. Cartridge Retainer	C-16
b. Magazine Insertion/Removal	C-16
c. Magazine Latch	C-16
d. Charger Handle	C-20
e. Manual Tube Latch	C-20
f. Manual Tube Lock	C-20
B. Trigger/Safety Design	C-21
1. Trigger	C-21
a. Selection of Alternate Designs	C-21
b. Criterion Selection and Weighting	C-23
c. Design Evaluation	C-24
2. Field Safety	C-26
C. Sight Design	C-27

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HUMAN FACTORS ENGINEERING FOR THE SPECIAL PURPOSE INDIVIDUAL WEAPON (SPIW) LAUNCHER

I. Introduction

This report presents the human factors engineering studies and design recommendations provided by Dunlap and Associates, Inc., to the Arms Product Engineering Department, Winchester-Western Division of the Olin-Mathieson Chemical Corp., on the Special Purpose Individual Weapon (SPIW) program. The scope of this effort was confined to the launcher (area fire) subsystem of the total weapon system.

The report is organized to present, successively, the human factors approach and general guidelines, a summary of the human factors design recommendations, and the technical analyses and results supporting the recommendations.

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II. Approach

The human factors approach to launcher design is best characterized by a series of guidelines which styled the work effort during the entire program.

- Utilize the experience available from the previous SPIW program--
The human factors project team reviewed all reports relative to human factors on the previous program and actively encouraged comment and critique of its work by personnel from: the Human Engineering Laboratory, Aberdeen Proving Ground, Md. (HEL); Springfield Armory, Springfield, Mass. (Springfield); and the Arms Product Engineering Department of Winchester.
- Allow equal consideration to all alternate designs--Design evaluation was not compromised in its scope by the technical experience and hardware which resulted from the first SPIW programs.
- Subject all alternate designs to a systematic comparative evaluation--
In each major design area, a definitive evaluation was performed using a technique which permitted a quantitative assessment of each design and an objective comparison of their relative merits.
- Maintain the required independence of the human factors effort--
All initial human factors analyses were performed in relative isolation from detailed engineering and other system constraints.
- Maintain close coordination with the engineering effort--Over 90% of the technical work was performed at the Winchester facility, thereby facilitating the interface between human factors and engineering personnel so essential to design selection and implementation.

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III. Summary of Human Factors Recommendations

Listed below are summary statements of the human factors recommendations for the basic launcher design and major associated components. Technical studies and other rationale supporting the recommendations may be found in Section IV.

- . Feed System Configuration
Recommendation: In-Line Tube design, ref. Fig. 1
- . Cartridge Retention in Magazine
Recommendation: Retainer latch design (on magazine)
- . Magazine Insertion/Removal
Recommendation: Direct vertical insertion/removal
- . Magazine Latch
Recommendation: Dual pushbutton controls, on rear of magazine well
- . Charger Handle
Recommendation: Integral with tube, over ejection port area
- . Manual Tube Latch
Recommendation: Lever control, forward of field safety
- . Manual Tube Lock
Recommendation: Lever control, underside of barrel, forward of magazine well
- . Trigger
Recommendation: Combined triggers with connector lever

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- Field Safety

Recommendation: Lever control, above launcher keyway

- Sight

Recommendation: Ramp type, side mounted, short sight radius

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IV. Technical Analysis and Results

This section presents and discusses the technical analysis and results which support the human factors design recommendations. The presentation reflects the compartmentalization of the total study area into three relatively independent topics--feed system design, trigger/safety design, and sight design.

A. Feed System Design

1. Configuration

Overall configuration design for the feed system was judged to be the most critical area for human factors study. Accordingly, the major effort for the first seven weeks of the project was concentrated here. As discussed below, the approach taken involved a systematic evaluation of several design candidates. A battery of human factors criteria was prepared, and each design was given a relative rating score on each criterion. The criteria were weighted to reflect their relative importance and the rating scores were multiplied by the weights to provide a weighted rating score for each design against each criterion. The scores were summed to yield a composite rating for each design. Finally, the composite ratings were ranked to provide an ordering of the human factors design preferences.

Summary results and recommendations for feed system configuration design are given in Section III. Presented below, in chronological order, are the initial analysis and the successive iterations of the analysis, which resulted from comments, critiques and directives from HEL and Springfield.

a. Selection of Alternate Designs

The initial goal of the study was to develop generic configuration designs. Several designs were in hand when the human factors specialists joined the project team. These designs had been suggested by the engineering staff and were obviously most responsive to engineering-type criteria. The list of candidates was extended by developing other concepts based exclusively on human factors considerations. Accordingly, task requirements and relevant operator skills and capabilities were reviewed. The question was asked--what will be required of the man; e. g., aiming, pointing, firing, loading, carrying, etc. Similarly, what are his relevant skills and limitations; e. g., reaction time, field of view, anthropometry, etc. These requirements, capabilities

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and constraints were loosely documented and catalogued. The process served a dual purpose--to stimulate design ideas and to grossly screen and evaluate these ideas. The intent was not to establish a final design but to generate a family of design candidates, all of which showed at least initial human factors promise.

Several alternate designs were developed by this method. They were submitted to the engineering staff for screening against criteria associated with mechanical complexity, reliability, etc. Similarly, design concepts developed by the engineers were evaluated against human factors criteria. The end result was the selection of eight candidates for further study, all of which were characterized by at least marginal compliance with initial human factors and engineering criteria.

Figure 1 shows the general configuration for each design. It should be emphasized that at this point in the study a requirement still existed for a magazine fixed in place. Thus, loading refers to single round replenishment.

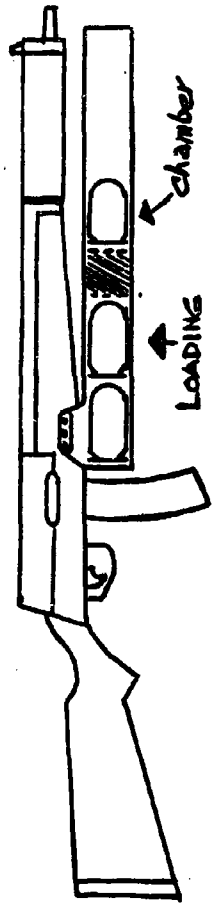
b. Criterion Selection and Weighting

Preliminary criteria, used for the initial design screening, served as baseline inputs to the preparation of a final battery. Every effort was made to give an unambiguous operational definition to each criterion--relate it to specific tasks, and to maintain independence between criteria--relate them to different tasks. The result was a criterion battery of eleven items, as shown below.

- Forward Hand Support--provides good support for the off hand during aiming, pointing and firing in both area and point fire modes.
- Loading--facilitates rapid loading of a) first round, b) replenishment of magazine, and c) single rounds when maintaining sustained fire.
- Concealment--permits minimum conspicuity of the shooter under all conditions of concealment.
- Carrying--allows for comfortable, balanced carrying with a) two-hands, b) sling, and c) one-hand.

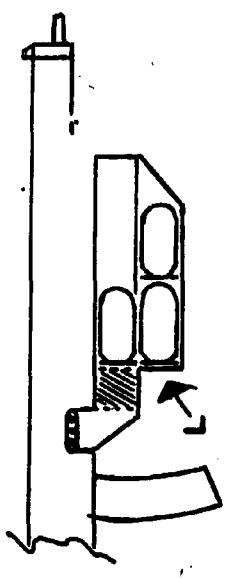
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A. IN-LINE TUBE

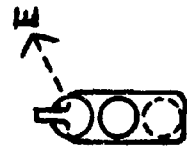
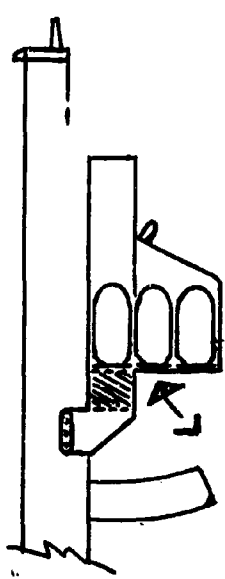


REAR VIEW
LAUNCHER ONLY

B. DOUBLE TUBE



C. BOX, DOWN



D. ROTARY, DOWN

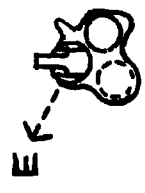
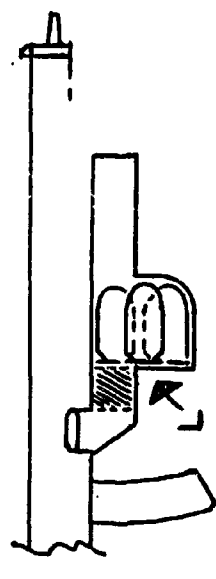


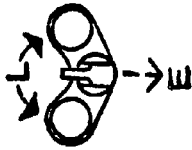
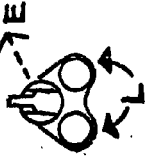
Figure 1. Alternate Feed System Configuration Design.

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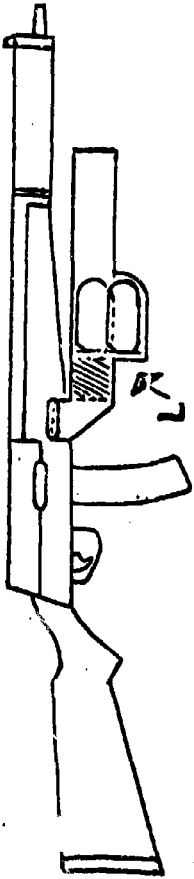
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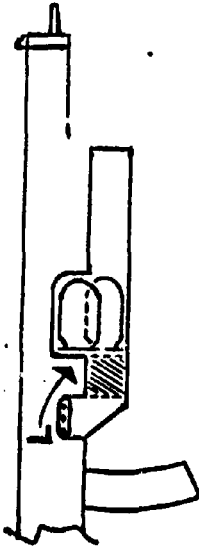
REAR VIEW
LAUNCHER ONLY



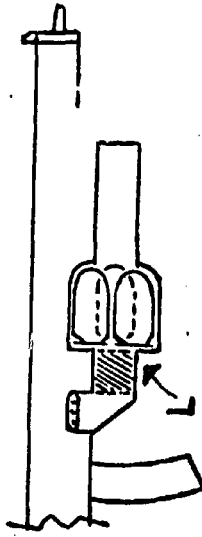
E. PODS, DOWN



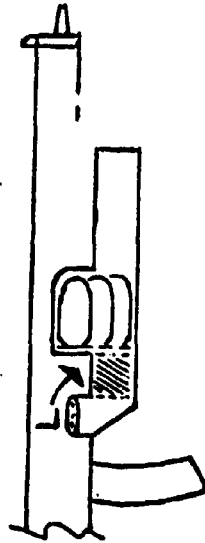
F. PODS, UP



G. ROTARY, SIDE



H. BOX, SIDE



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Figure 1. Alternate Feed System Configuration Design (continued)

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- . Compatibility with Area Fire Sights--has minimum protrusion into the preferred sight line of the area fire sights.
- . Environmental Protection--affords good protection for muzzle and ports from sand, dirt, mud, etc.
- . Ejection Envelope--provides for shell ejection in a manner that will not degrade visibility or constrain firing position.
- . Protrusions--has minimum number of protrusions that could break off, snag in brush, etc.
- . Forward Hand Safety--provides protection for the off hand from ejection port and ejected shells.
- . Left Hand Operation--permits fast and accurate operation by the left-handed shooter.
- . Ammunition Status--facilitates optimum positioning of an ammo status indicator.

Obviously, all criteria were not of equal importance. Therefore, each was weighted to reflect its appropriate contribution to the total evaluation. A ten-point scale (10 highest → 1 lowest) was used for the weighting. Two human factors specialists and a senior design engineer prepared independent weightings after agreeing on a baseline point, i.e., the criterion "Forward Hand Holding" was weighted 10. Other criteria were weighted relative to the base point and the average weight for each was used for the evaluation.

c. Design Evaluation

All candidate designs were rated against the criterion battery. A five-point scale was used with 5 assigned to the design(s) most responsive to each criterion. Remaining concepts were rated on each criterion by asking the question: How responsive to the criterion is the design relative to the design(s) rated 5? To illustrate: designs A, B, C and E were all rated 5 on the criterion "Ejection Envelope" because they ejected shells away from the right-hand shooter and did not constrain firing position; concepts D, G and H were rated 4 because they ejected shells toward the right-hand shooter; and concept F was rated 2 because it had downward ejection, thereby requiring the shooter to adopt a firing position which must always provide considerable ground clearance.

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The matrix of ratings permitted all design concepts to be compared against any individual criterion. However, they did not allow a comparison of all designs across all criteria. To permit this comparison, each rating was weighted in accordance with the associated criterion weight. The resulting weighted rating scores were obtained by multiplying each rating and the associated criterion weight.

Finally, the weighted scores were summed and then ranked to yield the ordering of human factors design recommendations for feed system configuration.

Table I shows the evaluation matrix with the eleven criteria, the criterion weights, the eight candidate designs, the rating scores (first entry in each cell) and the weighted rating scores (second entry in each cell). Also, the table shows the composite ratings and their rank-order. As indicated, the In-line Tube (Design A) was the preferred human factors design.

The above evaluation was presented for review and comment to human factors personnel at HEL. Based on their review and further study by the project team, a second, similar analysis was undertaken. The major change in the evaluation was removal of "Ammo Status" as a major human factors criterion and inclusion of "Moment of Inertia" as a new criterion. This criterion was associated primarily with the effect of each design, i. e., the design's c. g., or swing fire ability. Also, some of the criterion weights and design ratings were altered. The results of this second evaluation are shown in Table II. As indicated, the preferred human factors design, and the first alternate design, remained as determined from the first analysis.

On 19 August 1965, the results of these analyses were presented to Springfield Armory personnel. After review of human factors, engineering and systems considerations, the human factors effort was directed to focus on design refinement of the "Box, down" design (Design C) with the following changes:

- . the magazine would be removable
- . the requirement for reloading the magazine while in position would be eliminated
- . the configuration would be moved approximately 2 inches forward of the original position

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Table I. Initial Evaluation of Feed System Configuration Designs

Human Factors Criteria	Weight	Designs							
		A In-line Tube	B Double Tube	C Box, down	D Rotary, down	E Pods, down	F Pods, up	G Rotary, side	H Box, side
1. Forward Hand Support	10	5-50	3-30	4-40	4-40	3-30	3-30	4-40	4-40
2. Loading									
a) first round	4	4-16	3-12	4-16	4-16	3-12	3-12	4-16	5-20
b) magazine	3	4-12	5-15	3-9	3-9	4-12	4-12	3-9	3-9
c) sustained fire	3	4-12	3-9	4-12	4-12	3-9	3-9	4-12	5-15
3. Concealment	8	5-40	4-32	3-24	4-32	4-32	4-32	5-40	5-40
4. Carrying									
a) 2-hands(walk- ing & crawling)	3	5-15	4-12	4-12	4-12	4-12	4-12	4-12	3-9
b) sling	2	5-10	4-8	5-10	4-8	2-4	2-4	5-10	5-10
c) 1-hand(walk- ing & crawling)	2	4-8	4-8	5-10	4-8	4-8	4-8	2-4	2-4
5. Compatibility with Area Sights	6	5-30	5-30	5-30	4-24	4-24	3-18	5-30	4-24
6. Environmental Protection - muzzle & ports	5	3-15	5-25	5-25	5-25	4-20	1-5	3-15	3-15
7. Ejection Envelope	3	5-15	5-15	5-15	4-12	5-15	2-6	4-12	4-12
8. Protrusions	3	5-15	4-12	4-12	4-12	4-12	4-12	4-12	3-9
9. Forward Hand Safety	3	5-15	5-15	5-15	5-15	5-15	5-15	5-15	4-12
10. Left Hand Operation	3	4-12	5-15	5-15	4-12	5-15	5-15	2-6	2-6
11. Ammo Status	2	4-8	5-10	5-10	5-10	5-10	5-10	5-10	5-10
Composite score		273	248	255	247	230	200	243	235
Rank		1	3	2	4	7	8	5	6

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Table II. Second Evaluation of Feed System Configuration Designs

Human Factors Criteria	Weight	Designs							
		A In-line Tube	B Double Tube	C Box, down	D Rotary, down	E Pods, down	F Pods, up	G Rotary, side	H Box, side
1. Forward Hand Support	10	5-50	3-30	4.5-45	4.5-45	3-30	3-30	5-50	5-50
2. Loading									
a) first round	4	4-16	4-16	4-16	4-16	4-16	4-16	5-20	5-20
b) magazine	2	3-6	5-10	3-6	3-6	4-8	4-8	2-4	2-4
c) sustained fire	4	4-16	4-16	5-20	3-12	3-12	3-12	4-16	5-20
3. Concealment	8	5-40	4-32	4.5-36	4-32	4-32	4-32	5-40	5-40
4. Carrying									
a) 2-hands(walk- ing & crawling)	3	5-15	4-12	5-15	5-15	3-9	3-9	4-12	4-12
b) sling	2	5-10	4-8	5-10	5-10	3-6	3-6	5-10	5-10
c) 1-hand(walk- ing & crawling)	2	4-8	4-8	5-10	5-10	4-8	4-8	3-6	3-6
5. Compatibility with Area Sights	4	5-20	5-20	5-20	4-16	4-16	3-12	4-16	4-16
6. Environmental Protection - muzzle & ports	2	3-6	5-10	5-10	4-8	4-8	2-4	3-6	3-6
7. Ejection Envelope	2	5-10	5-10	5-10	4-8	5-10	2-4	4-8	4-8
8. Protrusions	2	5-10	4-8	4-8	4-8	4-8	4-8	4-8	4-8
9. Forward Hand Safety	2	5-10	5-10	5-10	5-10	5-10	5-10	5-10	4-8
10. Left Hand Operation	2	4-8	5-10	5-10	4-8	5-10	5-10	2-4	2-4
11. Moment of Inertia	4	5-20	4-16	4-16	4-16	4-16	4-16	5-20	5-20
Composite score		245	216	242	220	199	185	230	232
Rank		1	6	2	5	7	8	4	3

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Accordingly, human factors analysis proceeded with minor evaluations and trade-off studies associated with launcher components.

2. Associated Components

Design of components associated with the feed system, such as magazine latch, charger handle, etc., were subjected to human factors study. Design recommendations and supporting rationale for these components are presented below.

a. Cartridge Retainer

Two basic cartridge retainer designs were subjected to a comparative evaluation: 1) a retainer latch magazine, and 2) a Mendoza single feed lip magazine. Both designs can be made adaptable to clip loading when detached and afford good portability and handling characteristics. Characteristics of human factors relevance which tended to differentiate the designs are summarized in Table III.

Based on the trade-off as shown in Table III, the on balance recommendation was for a retainer latch magazine. The recommendation was put forth with the understanding that the engineering design implementation would provide for reliability compatible with total system reliability requirements, and that the bottom of the magazine cover would be rounded and canted upward to attenuate the problem of downward protrusion.

b. Magazine Insertion/Removal

Five methods of inserting and removing the magazine were investigated--pivoting the magazine in each of the four primary directions and straight vertical insertion/removal. The assets and liabilities of each, in terms of operator functions, are summarized in Table IV.

From the trade-off analysis as shown in Table IV, the human factors design recommendation was for a straight vertical method of insertion and removal. To enhance the ease of magazine insertion, it was further recommended that sizable lead-in lips be provided on all sides of the magazine well.

c. Magazine Latch

The recommendation for magazine latch control was:
location - on both sides of the magazine well at the rearmost position;
action - pushbutton action, at right angles to base centerline. In this location,

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Table III. Cartridge Retainer Design
Human Factors Trade-Off

Magazine Design	Pros	Cons
1. Retainer Latch	<ul style="list-style-type: none">. Can insert partially full magazine independent of tube position.. Can remove magazine independent of tube position.. Fast recharging of weapon from partial to full capacity.. Charger loading of magazine possible when detached.. One hand loading of detached magazine is possible.	<ul style="list-style-type: none">. Protrudes downward $\approx 1/2''$ more than Mendoza type magazine.. Less inherent reliability than Mendoza type magazine.
2. Mendoza - Single Feed Lip	<ul style="list-style-type: none">. Less protrusion ($\approx 1/2''$) than retainer latch magazine.. Design offers inherently high reliability.	<ul style="list-style-type: none">. Magazine insertion - removal possible only with tube forward.. Slow recharging.. Charger loading of detached magazine not possible.. Requires two-hand loading of detached magazine.. Requires more bulk in breech area.

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Table IV. Magazine Insertion/Removal - Human Factors Trade-Off

Method of Insertion/Removal	Pros	Cons
1. Vertical	<ul style="list-style-type: none"> . Allows for rapid insertion (use of long-deep lead-ins). . Equally adaptable to left and right hand loading. . Compatible with point fire magazine insertion and removal. . Minimum complexity. . <u>If</u> must handle magazine for removal, pull is compatible with body-hand support. 	<ul style="list-style-type: none"> . Direction of insertion not fully compatible with body-hand support.
2. Pivot-Front	<ul style="list-style-type: none"> . Lead-ins should allow for reasonably fast insertion. . Equally adaptable to left and right hand loading. . Very compatible with most common magazine catch designs. . Direction of insertion compatible with body-hand support. 	<ul style="list-style-type: none"> . <u>If</u> must handle magazine, not fully compatible with body-hand support. . Would require complex movement and/or complex engineering to allow top round to clear breech face. . Not compatible with point fire magazine insertion and removal.
3. Pivot-Rear	<ul style="list-style-type: none"> . <u>If</u> must handle magazine for removal, pull is compatible with body-hand support. . Should permit reasonably fast insertion. . Equally adaptable to left and right hand loading. 	<ul style="list-style-type: none"> . Direction of insertion not fully compatible with body-hand support. . Not compatible with point fire magazine insertion and removal. . Requires two distinct movements for insertion.

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Table IV (continued)

Method of Insertion/ Removal	Pros	Cons
4. Pivot-Left	. (No relative advantages)	<ul style="list-style-type: none">. Not compatible with point fire magazine insertion and removal.. Pivot side (left) obscured from view.. Not equally adaptable to left and right hand loading.. Requires two distinct movements for insertion.
5. Pivot-Right	. Insertion should be relatively fast, i. e., pivot side is visible.	<ul style="list-style-type: none">. Not compatible with point fire magazine insertion and removal.. Not equally adaptable to left and right hand loading.. Requires two distinct movements for insertion.

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the control can be quickly operated by the thumb of the off hand and by the right- or left-handed shooter. Upon activation, the empty magazine is expected to fall clear, thereby facilitating rapid three-round loading. It was further recommended that the hand grip material, added to the underside of the negator spring housing to improve off-hand holding, protrude directly behind the latch control to afford protection against accidental activation.

d. Charger Handle

Three positions were considered for location of the charger handle: 1) forward of the magazine and under the barrel, 2) forward of the magazine and on the right side of the barrel, and 3) in-line with the magazine on the ejection port area of the tube. Position 1 is most suitable to left or right-hand operation; however, both positions 1 and 2 require excessively long reach. Accordingly, position 3 was recommended. In this location, arm reach is minimal and operation by the thumb of the trigger hand provides ample room for ejection of an empty case or unfired round.

e. Manual Tube Latch

Two positions for the manual tube latch were given serious consideration: 1) forward of the field safety and above the magazine well on the left side of the barrel, and 2) on the barrel, forward of the ejection port. Position 1 has a decided advantage in terms of speed of operation--the weapon can be held with the left hand, loaded with the right hand, and closed immediately upon loading by activating the control with the left thumb. Conversely, position 2 has some advantage in the inherent safety it offers against inadvertent activation while loading a single round. The safety problem in this context was not judged to be critical and, therefore, position 1 was recommended.

f. Manual Tube Lock

A manual tube lock may be required because of the relatively short case on flare rounds. If required, it was recommended that tube locking be controlled by a lever located on the barrel underside, just forward of the magazine well. In this position, the control is well protected against accidental movement. It has minimum protrusion, but can be seen from the rear in either position because it will extend slightly beyond the machined grooves of the magazine well. While the location does

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not permit the most rapid control activation, it was judged to be sufficient for the task and the frequency with which it will be performed.

B. Trigger/Safety Design

Human factors study of design options for the area fire trigger were inextricably associated with the general problem of area fire safety. One of the major design criteria affecting trigger selection was safe, unambiguous operation. Accordingly, trigger and safety design was subjected to a combined analysis. The analysis and results are presented below; first, for the trigger design and the implication for safety associated with firing the weapon and, second, for the one relatively independent aspect of safety--the field or traveling safety.

1. Trigger

In establishing human factors recommendations for trigger design, the approach taken was similar to that used in establishing design recommendations for the feed system configuration. Alternate designs were evaluated against a battery of human factors criteria. A weighted rating technique was used to establish an ordering of human factors design preferences. Summary results and recommendations are presented in Section III. Presented below are the initial analysis and the successive iterations, which again resulted from comments, critiques and directives from HEL and Springfield.

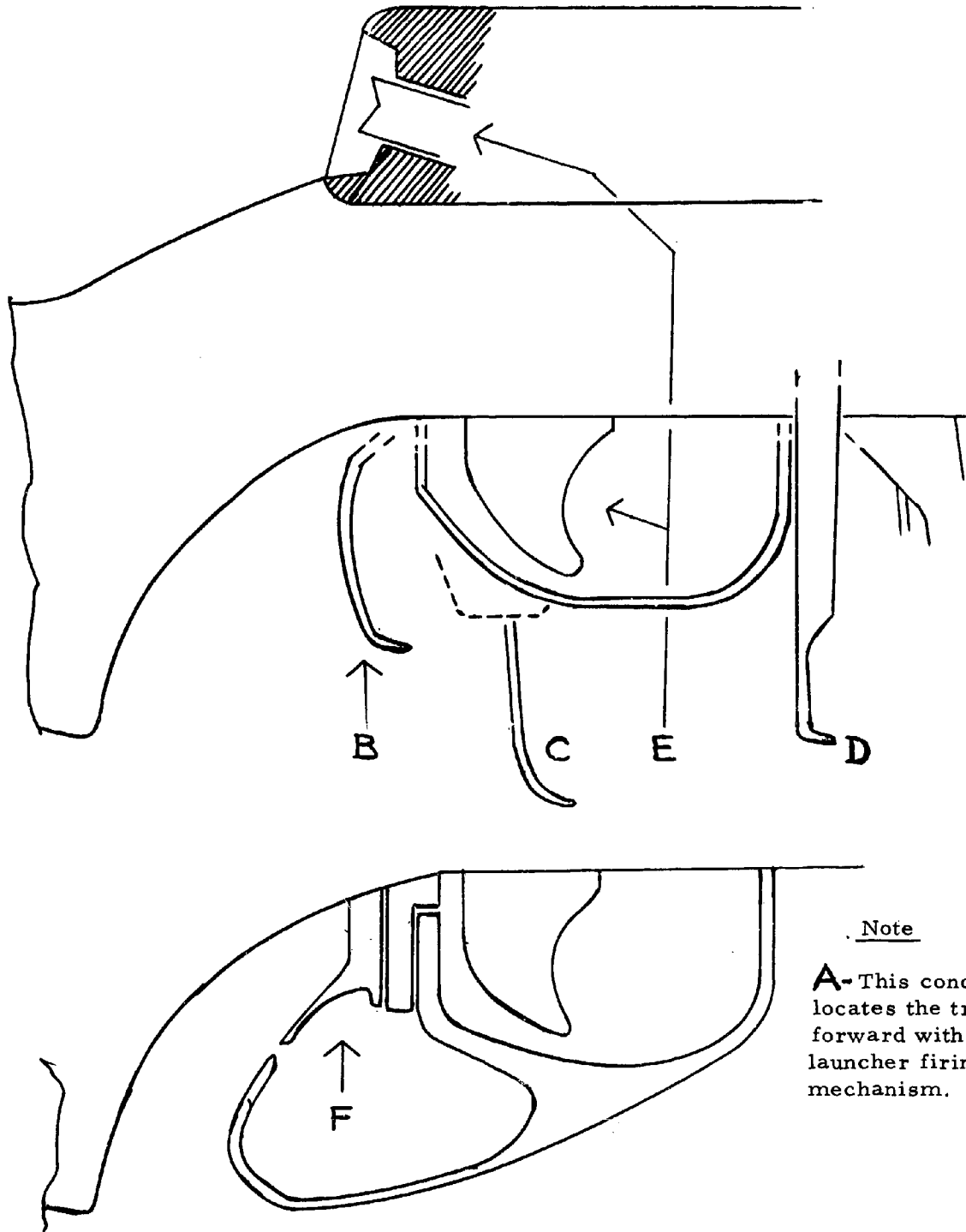
a. Selection of Alternate Designs

A preliminary list of human factors criteria was prepared and this, in combination with a review of the earlier SPIW program, facilitated generation of alternate trigger designs. Other designs were suggested by the engineering staff. All designs were subjected to initial screening against human factors and engineering criteria. Six designs, all of which were reasonably responsive to the criteria in hand, were selected for definitive evaluation. A composite sketch of their location relative to the point fire system is shown in Figure 2.

Major characteristics of the triggers shown in Figure 2 are:

Design A: Forward of Point Fire Magazine--this trigger is located 2" to 3" forward of the point fire magazine; it has a folding cover which eliminates protrusion when not in use and protects the point fire magazine from area fire recoil.

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Note

A- This concept locates the trigger forward with the launcher firing mechanism.

Figure 2. Alternate Trigger Designs.

C-22

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Design B: Rear of Point Fire Trigger Guard--this trigger is located 1" to 2" rearward from the point fire trigger guard; it is spring loaded forward toward the point fire trigger guard when not in use and is further secured in the safe position by a sliding cover mounted on the point fire trigger guard.

Design C: Point Fire Trigger Guard--this trigger is the horizontal section of the point fire trigger guard; it is spring loaded to the horizontal position and can be secured in that position by a sliding cover mounted on the forward section of the guard; it is also hinged to swing into position when the entire trigger guard is pivoted 90°, i. e., for firing with arctic mittens.

Design D: Forward of Point Fire Trigger--this trigger is located in line with the forward section of the point fire trigger guard and displaced 1/2" - 3/4" to the right of it; it is swung approximately 180° into position from a stowed location along the right side of the weapon.

Design E: Combined Triggers--this trigger is identical with the point fire trigger; it requires a connector control which must be operated simultaneously with the trigger to effect area fire; the connector control is a "dead-man" button located directly below the point fire trigger sight.

Design F: Plunger--this trigger is also located directly behind the point fire trigger guard; it is unique in its direction of pull--vertical, into the stock; it has a trigger guard and provides ample clearance for the fingers of the trigger hand when using the weapon in point fire mode.

b. Criterion Selection and Weighting

Again, the preliminary criteria were used to aid in the generation and screening of alternate designs, serving as baseline inputs for the final criterion battery. After several successive refinements, a battery of ten criteria was assembled. The items and their operational definitions are listed below.

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- Forward Hand Support--provides good support for the off hand during aiming, pointing and firing in both area and point fire modes.
- Trigger Location--Anthropometry--provides for a firm grip and smooth pull.
- Trigger Selection--Speed--provides for minimum delay in selecting either area or point fire mode.
- One-hand Operation--trigger location permits firing weapon using hip or shoulder and one hand.
- Environmental Protection--trigger is well protected against accidental activation by branches, vines, etc.
- Physical Interface--Point Fire Trigger--allows for uninhibited operation of point fire trigger.
- Physical Interface--Area-Sight--does not interfere with area fire sight line.
- Physical Interface--Point Fire Magazine--allows for uninhibited insertion/removal of point fire magazine.
- Recoil Protection--permits shooter to absorb recoil with hands and shoulder in the normal proportionate amounts.
- Trigger Selection--Ambiguity--provides for minimum probability of selecting unintended firing mode.

The criteria were weighted to reflect their relative importance using a ten-point scale. Independent weighting was completed by two human factors specialists and one design engineer after agreeing on the baseline point, i. e., the criterion, "Trigger Selection--Ambiguity," was weighted 10. Other criteria were weighted relative to the base point and the average weight for each was used for the evaluation.

c. Design Evaluation

Each design was rated on each criterion in the same manner as per the feed system configuration design evaluation. Similarly,

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weighted rating scores, composite scores and/or preference ranking were obtained. The evaluation matrix is shown in Table V.

Each cell entry contains the rating and weighted rating. As indicated from the final ranking, the Combined Triggers (Design E) was the preferred design.

The results of this analysis were submitted for review to HEL and Springfield. Human factors personnel were directed to continue work on design implementation of the combined triggers concept.

After study of the constraints imposed by the current design for the point fire trigger mechanism, it was obvious that a connector button, located below the point fire rear sight, was not feasible. Reviewing the limited number of options available, it was determined that a paddle-type connector lever was the best human factors design. The connector was to be spring loaded to a safe position against the right side of the receiver. For operation, the shooter would draw the paddle backward with his right thumb until it cleared the receiver (vertical position), then he would depress the paddle across the back of the receiver until it lay horizontal on the small of the stock. The connector could be maintained in this position by the thumb and still allow a firm grip and smooth trigger pull.

In May 1966, further engineering study of the connector control indicated that the above design could not be implemented. Accordingly, a vertical operating lever, located directly below and left of the point fire rear sight, was recommended. Further, in response to another engineering problem--the excessively high trigger force required to operate the trigger in the area fire mode--it was recommended that a "set" trigger concept be used. In this concept, the force required to depress the connector lever would "set" the trigger, thus reducing the trigger pull requirements to an acceptable level.

2. Field Safety

In addition to the safety inherent in a connector system-combined trigger design, a field or traveling safety was also provided. The safety is located on the upper left side of the launcher and rearward of the breech. A lever type control was used with the forward position being FIRE. This location facilitates rapid thumb activation by the off hand. Also, the launcher keyway and the forearm of the point fire stock protect the control from inadvertent operation.

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Table V. Evaluation of Area Fire Trigger Designs

Human Factor Criteria	Weight	Designs					
		A Fwd. Pt. Fire Mag.	B Rear Pt. Fire Trigger Guard	C Pt. Fire Trigger Guard	D Fwd. Pt. Fire Trigger	E Combined Triggers	F Plunger
1. Forward Hand Support	9	4-36	5-45	5-45	5-45	5-45	5-45
2. Trigger Location - Anthropometry	10	4-40	5-50	3-30	3-30	4-40	5-50
3. Trigger Selection - Speed	4	4-16	4-16	4-16	4-16	5-20	4-16
4. One-hand Operation	1	5-5	2-2	2-2	1-1	1-1	2-2
5. Environmental Protection	10	5-50	4-40	3-30	3-30	5-50	4-40
6. Physical Interface - Point Fire Trigger	8	5-40	5-40	4-32	5-40	5-40	4-32
7. Physical Interface - Area Sight	3	4-12	5-15	5-15	5-15	5-15	5-15
8. Physical Interface - Point Fire Magazine	4	4-16	5-20	5-20	3-12	5-20	5-20
9. Recoil Protection	4	2-8	5-20	3-12	3-12	4-16	5-20
10. Trigger Selection - Ambiguity	10	5-50	4-40	3-30	4-40	5-50	4-40
Composite Score		273	288	232	241	297	280
Rank		4	2	6	5	1	3

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C. Sight Design

Several basic types of sights (arc, tangent, ramp, drum, etc.) were given initial screening against applicable human factors criteria. The resulting candidates for further study were arc type sights (frequently referred to as quadrant sights) and ramp type sights. The additional study indicated a marked preference for the ramp type sight. Major reasons for this preference are:

- . Allows for a linear range scale
- . Permits easy implementation of duplicate scales - side reading and top reading
- . Provides more design latitude in developing an interchangeable (left - right) sight

In addition, the ramp type sight is more compact and rugged. In particular, its smaller size enhances the probability of good sight location on the right side of the weapon, where controls and other protrusions will present relatively greater design/location problems. Recommendations for sight location, sight radius, and eye relief were based on human factors studies conducted on the previous SPIW program.

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NH-2604

APPENDIX D

**Reliability, Quality Assurance, Standardization
and Maintenance Engineering**

D-1

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NH-2604

RELIABILITY SUMMARY - 40MM LAUNCHER

The Reliability activity for this contract was structured to implement paragraphs 3.5.12b and d of Mil-R-27542A in accordance with contract requirements.

The program provided for a review of all weapon components and an evaluation of critical areas for potential failure which would affect the weapon reliability. It also provided for surveillance of weapon testing and reporting system. A form for reporting failures was designed to meet the requirements of paragraph 3.5.12b of the above Mil specification.

Failure reporting, per agreement with Springfield personnel and the Olin Mathieson Reliability Engineer, was only to include the instances of part breakage or those malfunctions which would make the weapon inoperable. It was also established that the reporting function would not take effect until the design had been stabilized. This status was considered to be reached upon fabrication of the final ten delivery weapons.

The weapon testing was performed under Quality Control and Reliability surveillance. Quality Control personnel recorded the final detailed test results. These test results were analyzed by the Reliability Engineer, and each malfunction was evaluated for the effect the operation of the weapon.

During the testing of the delivery weapons, one component broke. This occurred on the sixth round fired in weapon No. 108. The secondary cutoff plunger broke, preventing rounds from being fed from the magazine. The weapon remained operable by manual operation even with this part broken. A failure report defining the breakage, the cause, and the corrective action taken to prevent recurrence was completed and included with the Reliability Report.

No malfunction occurred during the testing which prevented any weapon from being operable manually.

During the term of the contract, monthly reports were submitted indicating the progress of the program. A final report was issued on 10 May 1966 on each of the ten weapons and included the failure report and corrective action for the breakage on weapon No. 108.

D-2

UNCLASSIFIED

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NH-2604

QUALITY ASSURANCE SUMMARY - 40MM LAUNCHER

The Quality Assurance responsibility involved the inspection of weapon components and assemblies, and surveillance of weapon testing. Development of historical data on each component, preparation of a Quality Assurance Study Sheet on each part and determining those part characteristics necessitating 100 per cent inspection were also required. In addition, final inspection reports for components in each of the delivery weapons and inspection data on the end item were required to accompany each weapon on delivery.

Inspection characteristic sheets were developed on each component and revised as necessary to meet the design changes. These sheets were used for recording inspection results as well as defining the inspection points. A copy of the inspection results for the components in each weapon accompanied the final delivery.

Analysis and evaluation of dimensional requirements, fabrication methods, and historical data from that development testing which was monitored by Quality Assurance personnel was the basis of preparing the Quality Assurance Study Sheet. This sheet was prepared for each part of the weapon and reviewed by Product Engineering.

Each final part print was reviewed with Product Engineering, and a list of those part characteristics requiring 100 per cent inspection was developed. The method of fabrication and the functions of the parts were considered. Those characteristics were selected where the dimensional integrity was critical to the function of the weapon, and the anticipated fabrication process would require close control to provide reliable repeatability of product. Five parts involving nine characteristics were placed in the 100 per cent inspection category.

Detail parts for the final delivery weapons were inspected; the results recorded. Copies of these results accompanied each weapon on delivery and included notation of dimensions which exceeded print tolerances. All variations from specifications were reviewed for disposition by Product Engineering and Quality Engineering.

The final delivery weapons were inspected for firing pin indent, trigger and safety forces, and firing pin intrusion and protrusion. These results were included with the inspection data accompanying each weapon. Quality Assurance personnel monitored and recorded the results of all firing on each of the delivery weapons and cooperated with the Springfield Armory representatives to insure completeness.

D-3

UNCLASSIFIED

UNCLASSIFIED

NH-2604

STANDARDIZATION

The use of stock commercial items on the design was done as a matter of procedure. The launcher design is such that most of the expected production cost is in the receiver, magazine body, tube, and striker housing. These components are necessarily of special design, and not adaptable to the use of stock hardware. Of the remaining components, many are fasteners or pivot pins. In the case of the latter, most are intended to be screw-machine products, although with minor redesign some can be converted to standard drive pins where normal maintenance does not require removal.

Conventional machine screws are used in several areas, notably for mounting the launcher, and for retaining the sight aperture, magazine latch components, handguard, and safety spring. Roll pins are used on both the sight base and the striker assembly. The magazine assembly uses three rivets which, with some adaptation of the magazine, can be made with standard heads.

The final design, as delivered, is an improvement over the first prototypes with regard to the use of standard types of hardware, since the standardization aspects were reviewed during subsequent design activities. When it appeared practical to do so, parts were converted from special to standard type. Additionally, it was possible on at least one area, to convert from some different standard screws to one type.

A basic premise of the design was to utilize conventional methods of fabrication and finish. The principle departure from common practice was the projected use of a double ended impact forging for the receiver. As discussed previously, although this method was agreed upon as practical by the vendors who worked on it, the lack of availability of the necessary presses made it necessary to machine the receivers in a conventional manner, and to consider alternate, more common methods for production. (See Appendix E, Value Engineering)

Surface finish processes are considered to be non-critical for the design, with the exception of the bore surface which demands the use of hard-coat type anodizing. The surface finish of the other aluminum components could be conventional anodizing instead of the hard-coat anodizing which was used. Likewise, Parkerizing or equivalent finishes are useable on all steel components except music wire springs. In summary, no special protective finishes are required on the design.

UNCLASSIFIED

NH-2604

MAINTENANCE

The maintainability of the launcher was considered throughout the development, with first consideration given to maintenance by the operator. The early design studies showed that the firing mechanism components would not lend themselves to easy disassembly by the shooter. As a result, it was decided to place these more sensitive elements in a single unit which can be simply removed and reinserted from the receiver. This allows these relatively small elements to be removed and reassembled to the weapon without disturbing their adjustment. It is recognized that, ideally, no tools should be required for field disassembly and assembly, and the design is such that this is possible, although it is not convenient if disassembly is carried beyond a certain point.

Disassembly into principle groups is simple: after removing the magazine, the charging handle is removed by depressing a latch. Following this, the tube assembly is removed by simply unscrewing the cap and pulling the tube forward far enough to allow it to be disengaged from the operating rod and removed. Removal of the operating rod assembly and the striker housing assembly can then be done after first removing the handguard. The handguard and the rear of the receiver cover the striker housing and the tube return spring elements, and it is expected that only breakage or exceptionally heavy accumulations of foreign material would require these two elements to be removed from the weapon. As stated, to do so requires removal of the handguard, which presently is retained by a machine screw. If all major assemblies (tube, operating rod, and striker housing) are removed from the weapon, reassembly requires that the operating rod be pulled to its position against the resistance of the tube return spring. While this can be done without tools, it is less difficult if done with an L-shaped hook.

During the course of development, some changes were made in the original design to aid in assembly and disassembly. Two major ones were: riveting the tube return spring to the operating rod, which eliminated a difficult operation in making them connect when in the weapon, and the addition of a yoke to house the return spring and drum, which eliminated a difficult pin-and-hole alignment during assembly.

The magazine is a permanent, riveted and spot welded assembly. Although minor maintenance such as straightening and de-burring can be done without disassembly, it is recommended that magazines having major damage be replaced rather than repaired.

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UNCLASSIFIED

NH-2604

Maintenance on the striker housing assembly should be a matter of replacement rather than repair. Disassembly and assembly can be done with the aid of a drift and a screw driver, although it can be speeded by the use of one or two simple special tools for insertion of the springs.

Experience on the present contract points to certain improvements which should be considered in future developments. The two principle ones are elimination of the screw attachment of the hand-guard so that a screw driver is not required for disassembly into major groups, and modification of the operating rod/tube joint to correct the awkwardness of pulling against the tube return spring in order to position the operating rod during reassembly.

D-6

UNCLASSIFIED

UNCLASSIFIED

NH-2604

APPENDIX E

VALUE ENGINEERING

E-1

UNCLASSIFIED

TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>	
I.	<u>Introduction</u>	3	
	Objective	3	
	Scope	3	
	Approach	3	
	Assumptions	4	
	Master Planning Schedule	8	
II.	Report of Value Engineering studies on cost areas classified major	9	
	<u>Project No.</u>	<u>Description</u>	
	#2.1.1	Receiver	10
	#2.2.1.2	Tube	15
	#2.3.1	Housing, Striker	21
	#2.1.3	Assembly, Magazine	26
	#2.2.2.1	Rod, Operating	34
	#2.1.3.2	Retainer, Cartridge	39
	#2.3.8	Extractor	41
	#2.3.18	Lever, Firing	46
	#2.3.2	Striker	48
	#2.4	Sight Group	52
III.	Report of Value Engineering studies on cost areas classified minor	59	
IV	<u>Cost Summary of Value Engineering recommenda- tions</u>	65	

UNCLASSIFIED

NH-2604

SECTION I - INTRODUCTION

A. OBJECTIVE

Purpose of V. E. Effort

To effect design and engineering studies which will result in lowering the total overall cost to the Government of the Launcher and Sight System without impairing any of its essential characteristics.

To produce, at lower cost, an equivalent or improved functioning product, with an equal or extended service life.

B. SCOPE

All components as illustrated by the current design were subjected to an intensive and critical review of all elements of design, as related to operational requirements, to insure that only necessary functions were retained and that these were supplied at the minimum cost consistent with the preservation of essential operational and maintenance characteristics.

C. APPROACH

The nature of the work contracted dictated the amount and type of Value work to be accomplished. This called for the design of a Launcher and Sight System and the manufacture of a limited number of functioning units in a relatively short period of time. It was concluded that with the compressed work schedule, sufficient time would, in most cases, not be available to implement the V.E. suggestions. During most of the Phase I portion of the contract, firm prints and specifications were not available for detailed study. Hence, Value Engineering input was provided at the drawing-board level by V.E. trained designers and discussions with members of the Value Engineering team. Formal V.E. meetings were also held to plan the approach which would be taken during Phase II and to review the Launcher and Sight System in broad scope to determine whether the Government requirements were realistic when compared to intended use.

As the Launcher began to take its first form and part definition became firmer, a preliminary cost analysis was conducted to reveal the areas where emphasis should be directed and to evolve an overall planned approach to the V.E. opportunities present in the design. An operating plan was then developed which designated the studies to be undertaken, their priority, timing, and the amount of effort to be expended on each. (See V. E. Master Schedule, Page E-8.)

The following components and/or functional areas were identified as major cost locations, comprising approximately 80% of the cost of the Launcher and Sight (in order of priority.)

E-3

UNCLASSIFIED

C. APPROACH (continued)

1. Receiver
2. Tube
3. Housing, Striker
4. Assembly, Magazine
5. Rod, Operating
6. Retainer, Cartridge
7. Extractor
8. Lever, Firing
9. Striker
10. Assembly, Sight

It followed that all other components comprised the remaining 20% of cost and that, due to sheer numbers of parts, less in-depth study could be afforded here if we were to maximize the results of the Value Engineering effort.

Accordingly, time spent on each of these two categories was allocated at about the same rate -- 80% on the major items and 20% on the minor items.

A system for identifying projects was established as shown on pages E-5, E-6 and E-7 of this report. This was particularly necessary in view of the potential for part number changes in the earlier stages.

D. ASSUMPTIONS

The growth stage of the product being studied was such that prior cost information, in most cases, was non-existent. As a result, production costs of the "Before" as well as "After" had to be estimated. The accuracy of these figures is a function of the optimum production situation as envisioned by the estimator utilizing the existing prints and proposed sketches together with sound engineering principles and practices. Opinions regarding the type of equipment, special machinery and tooling to be used could conceivably cause some variation in the absolute cost values derived for either the "Before" or "After." The relative change in cost would, therefore, appear to be a better measure of accomplishment. Since the existing prints were developed for purposes of fabricating prototypes, Product Engineering's production-design intent was requested in all cases to provide a closer benchmark for assessing Value Engineering effectiveness. In keeping with contract guidelines, the present or "Before" costs are predicated upon the existing prints. Manufacturing cost data contains material, labor and full factory burden (G & A and profit not included.)

As per contractor's instructions, production volume is assumed to be 100,000 Launchers and Sights per year with magazine volume based upon a 5:1 ratio, or 500,000 units per year.

Production contract duration was estimated at one (1) year for purposes of setting limits on investment in facilities.

UNCLASSIFIED

NH-2604

GRENADE LAUNCHER

IDENTIFICATION OF FUNCTIONAL GROUPS FOR V.E. STUDY

Projects have been identified by the numbers assigned in this breakdown.

2.1 Receiver Group

- 2.1.1 Receiver
- 2.1.2 Magazine Well
- 2.1.3 Magazine Assembly
 - 2.1.3.1 Magazine
 - 2.1.3.2 Cartridge Retainer
 - 2.1.3.3 Cartridge Retainer Rivets (3)
 - 2.1.3.4 Magazine Spring
- 2.1.4 Cutoff Actuator Assembly
 - 2.1.4.1 Actuator Plate
 - 2.1.4.2 Stud, Long
 - 2.1.4.3 Stud, Short
 - 2.1.4.4 Cutoff Spring
 - 2.1.4.5 Cutoff Screw
- 2.1.5 Safety Shaft Retainer
 - 2.1.5.1 Safety Shaft Retainer Screw
- 2.1.6 Magazine Latch Mechanism
 - 2.1.6.1 Magazine Latch Button
 - 2.1.6.2 Magazine Latch Rear
 - 2.1.6.3 Magazine Latch Rear Springs (2)
 - 2.1.6.4 Magazine Latch Rear Pin
 - 2.1.6.5 Magazine Latch, L.H.
 - 2.1.6.6 Magazine Latch, L.H. Spring
 - 2.1.6.7 Magazine Latch, R.H.
 - 2.1.6.8 Magazine Latch, R.H. Spring
- 2.1.7 Plate, Front
 - 2.1.7.1 Plate, Screws
- 2.1.8 Hand Guard
 - 2.1.8.1 Hand Guard Screws (2)
- 2.1.9 Tube Latch
 - 2.1.9.1 Tube Latch Shaft

E-5

UNCLASSIFIED

UNCLASSIFIED

NH-2604

GRENADE LAUNCHER (continued)

IDENTIFICATION OF FUNCTIONAL GROUPS FOR V.E. STUDY (continued)

2.1 Receiver Group (continued)

2.1.9 Tube Latch (continued)

- 2.1.9.2 Tube Latch Spring
- 2.1.9.3 Tube Latch Plunger

2.2 Tube Group

2.2.1 Tube Assembly

- 2.2.1.1 Tube
- 2.2.1.2 Cap
- 2.2.1.3 Shield
- 2.2.1.4 Ring
- 2.2.1.5 Buffer
- 2.2.1.6 Charging Handle
 - 2.2.1.6.1 Charging Handle Retainer
 - 2.2.1.6.2 Charging Handle Retainer Pin
 - 2.2.1.6.3 Charging Handle Retainer Spring

2.2.2 Operating Rod Assembly

- 2.2.2.1 Operating Rod
- 2.2.2.2 Return Spring
- 2.2.2.3 Return Spring Rivets (2)
- 2.2.2.4 Return Spring Drum
- 2.2.2.5 Return Spring Yoke
- 2.2.2.6 Return Spring Pin

2.3 Striker Mechanism Group

- 2.3.1 Housing (Trigger)
- 2.3.2 Striker
- 2.3.3 Striker Spring
- 2.3.4 Striker Pin
- 2.3.5 Sear
- 2.3.6 Sear Pin
- 2.3.7 Sear Spring Retainer
- 2.3.8 Extractor-Ejector
- 2.3.9 Ejector Spring
- 2.3.10 Ejector Cocking Piece
- 2.3.11 Ejector Cocking Spring
- 2.3.12 Ejector Cocking Plunger
- 2.3.13 Safety Pin
- 2.3.14 Safety Actuator
- 2.3.15 Safety Actuator Button
- 2.3.16 Round Retainer Disconnecter
- 2.3.17 Round Retainer Disconnecter Screws (2)
- 2.3.18 Firing Lever

E-6

UNCLASSIFIED

GRENADE LAUNCHER (continued)

IDENTIFICATION OF FUNCTIONAL GROUPS FOR V.E. STUDY (continued)

2.4 Sight Group

2.4.1 Base

2.4.2 Base Rivets (2)

2.4.3 Mount

2.4.3.1 Spring Mount Lock

2.4.4 Screw, Pivot

2.4.5 Screw, Detent

2.4.6 Bar, Sight

2.4.6.1 Aperture, Rear

2.4.6.2 Aperture, Rear, Screw

2.4.6.3 Post, Front Sight

2.4.6.4 Slide

2.4.6.4.1 Plate, Detent

2.4.6.4.2 Plate, Detent, Springs (2)

2.4.6.4.3 Screw, Detent, Springs (2)

2.4.7 Spring, Sight Bar

VALUE ENGINEERING MASTER SCHEDULE

PROJECT #2 - S.P.I.W. LAUNCHER

REVISION #1 1-14-66

WEEK #	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	
DATE - W/E	12/17	12/24	12/31	1/7	1/14	1/21	1/28	2/4	2/11	2/18	2/25	3/4	3/11	3/18	3/25	4/1	4/8	4/15	4/22	4/29	5/6	5/13	
COMPONENTS					REC. TUBE	STKR HSG	STKR HSG	FIC. HSG	STKR HSG	STKR HSG	MAG BODY	MAG BODY	OPR ROD	OPR ROD	CLEA -UP	CTG RET EXTR	CTG FRNG LEV STKR	REMAINING PARTS					

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<p><u>V.E. JOB PLAN</u></p> <p><u>I INFORMATION PHASE</u></p> <p>1. What is it?</p> <p>2. What does it cost?</p> <p>3. What is its function?</p> <p><u>II CREATION PHASE</u></p> <p>1. What else will do the job?</p> <p><u>III EVALUATION PHASE</u></p> <p>1. What are the best ideas?</p> <p>2. What does that cost?</p> <p><u>IV INVESTIGATION PHASE</u></p> <p><u>V RECOMMENDATION PHASE</u></p>																							

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NH-2604

E-8

UNCLASSIFIED

NH-2604

SECTION II - REPORT OF VALUE ENGINEERING STUDIES ON COST AREAS CLASSIFIED MAJOR

COMPONENTS - MAJOR COST AREAS

<u>PART NUMBER</u>	<u>NOMENCLATURE</u>
51335	Striker
51346	Lever, Firing
51355	Housing, Striker
51361	Extractor
51371	Receiver
51386	Well, Magazine
51407	Tube
51422	Body, Magazine
51423	Spring, Magazine
51424	Rivet, Magazine
51425	Floor, Magazine
51426	Retainer, Cartridge
51429	Rod, Operating
51436	Mount
51437	Base
51438	Rivet, Base
51439	Bar, Sight
51440	Aperture, Rear
51441	Screw, Slide
51442	Screw, Pivot
51443	Post, Front Sight
51444	Screw, Rear Aperture
51445	Spring, Detent Plate
51446	Spring, Mount Lock
51447	Slide
51448	Detent
51449	Lock Mount
51450	Spring, Sight Bar

E-9

UNCLASSIFIED

A. DESCRIPTIONProject #2.1.1Project Name: ReceiverComponents

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
51371	Receiver	1	1
51386	Magazine Well	1	1

B. FUNCTION

<u>Basic</u>	<u>Secondary</u>
Contain Parts	Contain Parts
	Position Parts
	Locate Magazine
	Control Feed
	Guide Tube
	Support Cartridge Case
	Provide Attachment
	Latch Tube
	Transmit Force

C. EXISTING DESIGN DESCRIPTION -(Refer Sketch #1)

Present (prototypes) - Machine from bar stock in the following sequence:

- (1) boring of front section
- (2) preliminary drilling of rear section
- (3) Elox (electric discharge machining) of front and rear sections to give guides for the tube and recess for striker housing.
- (4) preliminary machining of external shape
- (5) mounting magazine well (T-slot and epoxy resin to fasten)
- (6) final machining

(Note: Original intent was double impact extrusion to give the same results as steps 1 through 4 above.)

Contains all operative components except sight and magazines.

D. MAJOR ALTERNATE DESIGNS CONSIDERED1. Die Cast

This process would appear to have certain cost advantages and probably warrants further investigation. However, there exists a question as to the structural integrity of this process.

D. MAJOR ALTERNATE DESIGNS CONSIDERED (continued)2. Extrusions

This approach has merit. However, the degree of risk regarding tolerances and the state of the art precludes a favorable recommendation at this time.

E. RECOMMENDED DESIGN - (Ref. Sketch #2)

The recommended design utilizes a complete stamped aluminum envelope plus support components consisting of a machined breech face, die cast magazine well filler, and a secondary stamped mounting filler. The stamping has been designed to permit minimum visual clearance with it's mounting.

F. DESIGN COMMENTS1. Receiver

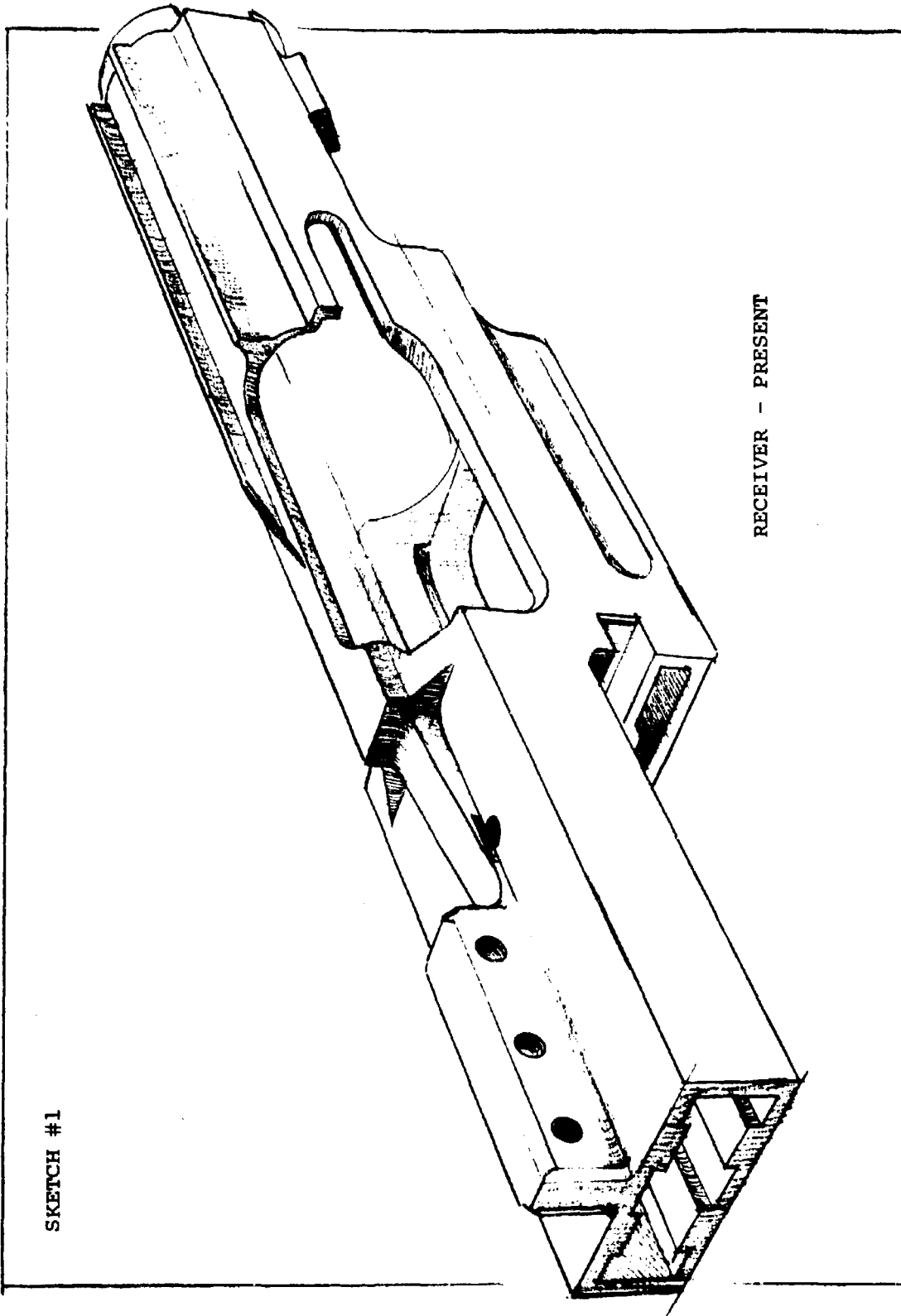
The proposed stamped or pressed method of fabrication is feasible but will require design study and probable changes in the method of attachment, mounting of the breech block and in the magazine catch arrangement. From the viewpoint of simplicity, the use of two stampings (left and right) should be considered, especially since it facilitates mounting the breech block and incorporation of a solid member for mounting.

The final estimated cost of \$51.90 is still high and additional effort should be directed towards further reduction.

UNCLASSIFIED

NH-2604

B-12



SKETCH #1

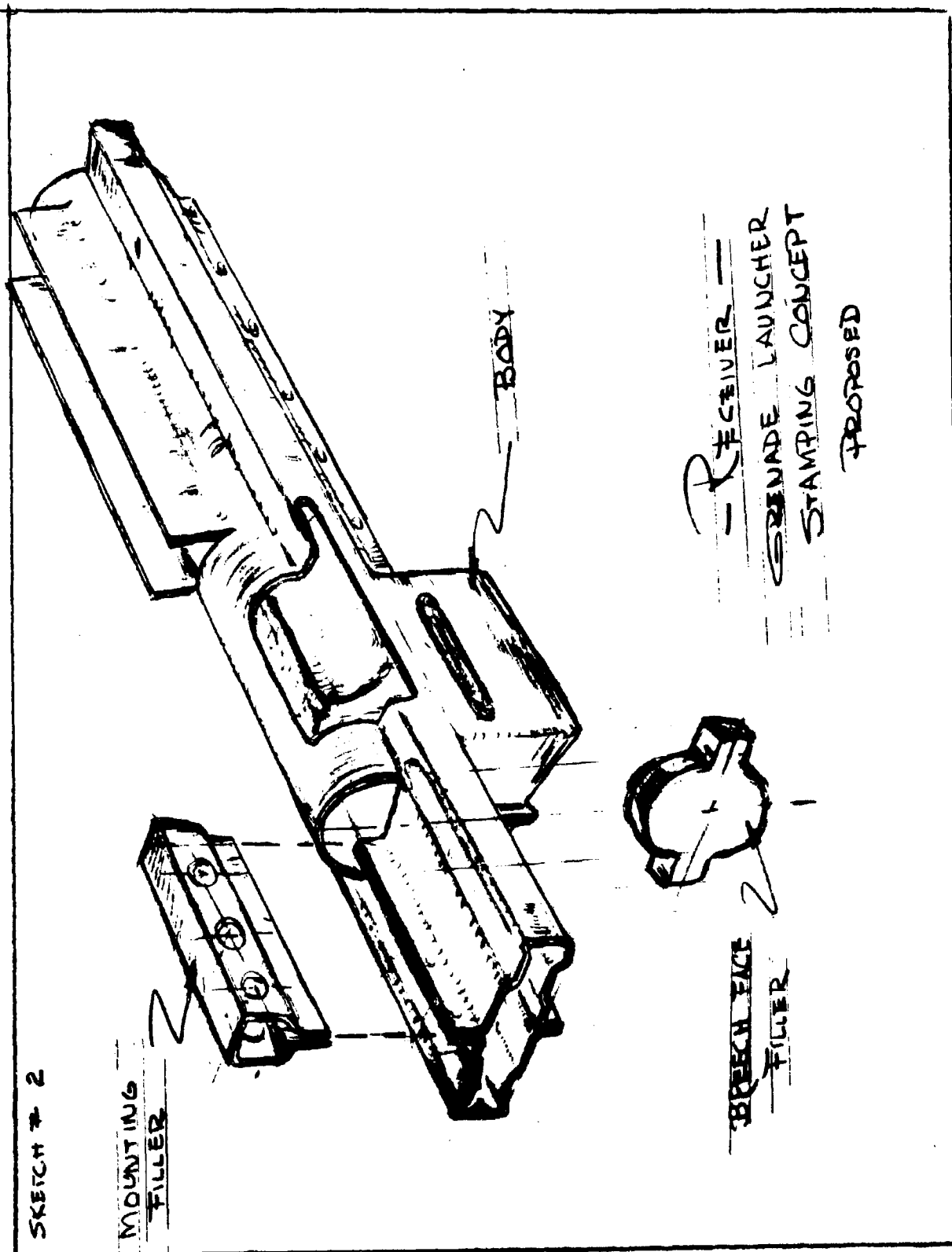
RECEIVER - PRESENT

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NH-2604

E-13



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G

COST SUMMARY - RECEIVER

Present Method		Proposed Method		Potential Savings	
Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
\$ 85.90	\$ 8,500,000	\$ 51.90	\$ 5,190,000	\$ 3,310,000	\$ 2,325,000
	Investment \$ 3,100,000		Investment \$ 775,000		

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NH-2604

E-14

UNCLASSIFIED

A. DESCRIPTIONProject #2.2.1.2Project Name: TubeComponents

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Assembly</u>
51407	Tube	1	1

B. FUNCTIONSBasic

Direct projectile

Secondary

Provide rotation
 Retail pressures
 Transmit energy
 Provide connection
 Provide obturation

C. EXISTING DESIGN DESCRIPTION (Refer Sketch #3)

Machined from bored cylindrical blanks. Present process sequence: final boring, rifling, external machining, chambering, and inletted for obturator.

External configuration has provision for:

Mounting of changing handle (T-slot on external lug)
 Mounting of muzzle reinforcing ring
 Guidance in receiver (in the form of lugs, integral with the tube)
 Attachment of the operating rod
 Clearance for extractor
 Mounting of changing handle retainer, spring and pin.

D. ALTERNATE DESIGNS CONSIDERED

1. Tube with stamped lugs (refer sketch #4)
2. Tube with stamped lugs and integral operating rod (refer sketch #5)
3. Among the alternate processes costed out were impact extrusions. This was found to be more costly than the recommended approach.

E. RECOMMENDED DESIGN

A comparison of costs on four different alternatives covering all basic alternate designs as well as the original process indicated that the current design (fabrication from linear extrusion) accomplished the desired functions at the lowest overall cost. On a production basis we would use drawn tubing as raw material rather than solid cylindrical stock. No change is recommended.

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F. DESIGN COMMENTS

Tube:

The recommended method of construction is satisfactory as long as those dimensions on the guide lugs are machined so as to insure concentricity and centrality of the chamber and bore with the lugs. Future development of the obturator (inletted into the chamber) may point to a more economical method of fabrication, but it is unlikely that a gross change in the obturator design will actually be required, or that a magnitude reduction in fabrication cost would result. The present construction, with integral guide lugs, offers the most secure method of resisting the large torque due to rifling reaction. This is important to assurance of preventing binding the tube in the receiver.

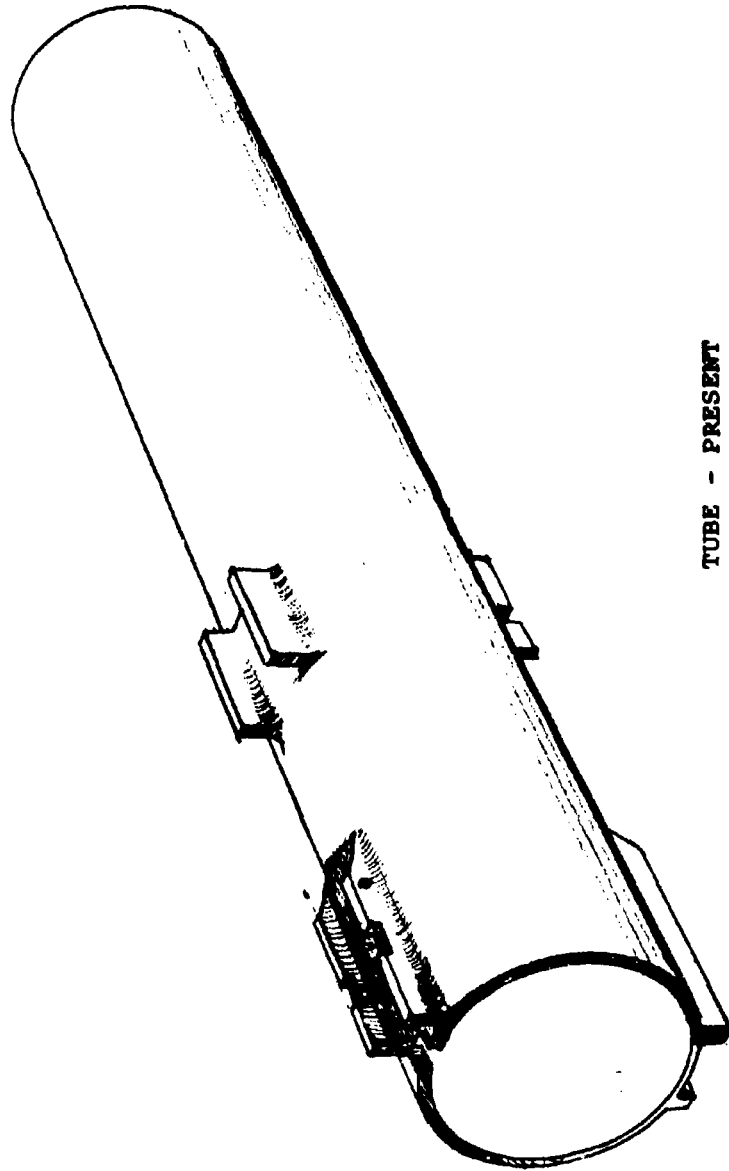
E-16

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E-17

TUBE - PRESENT

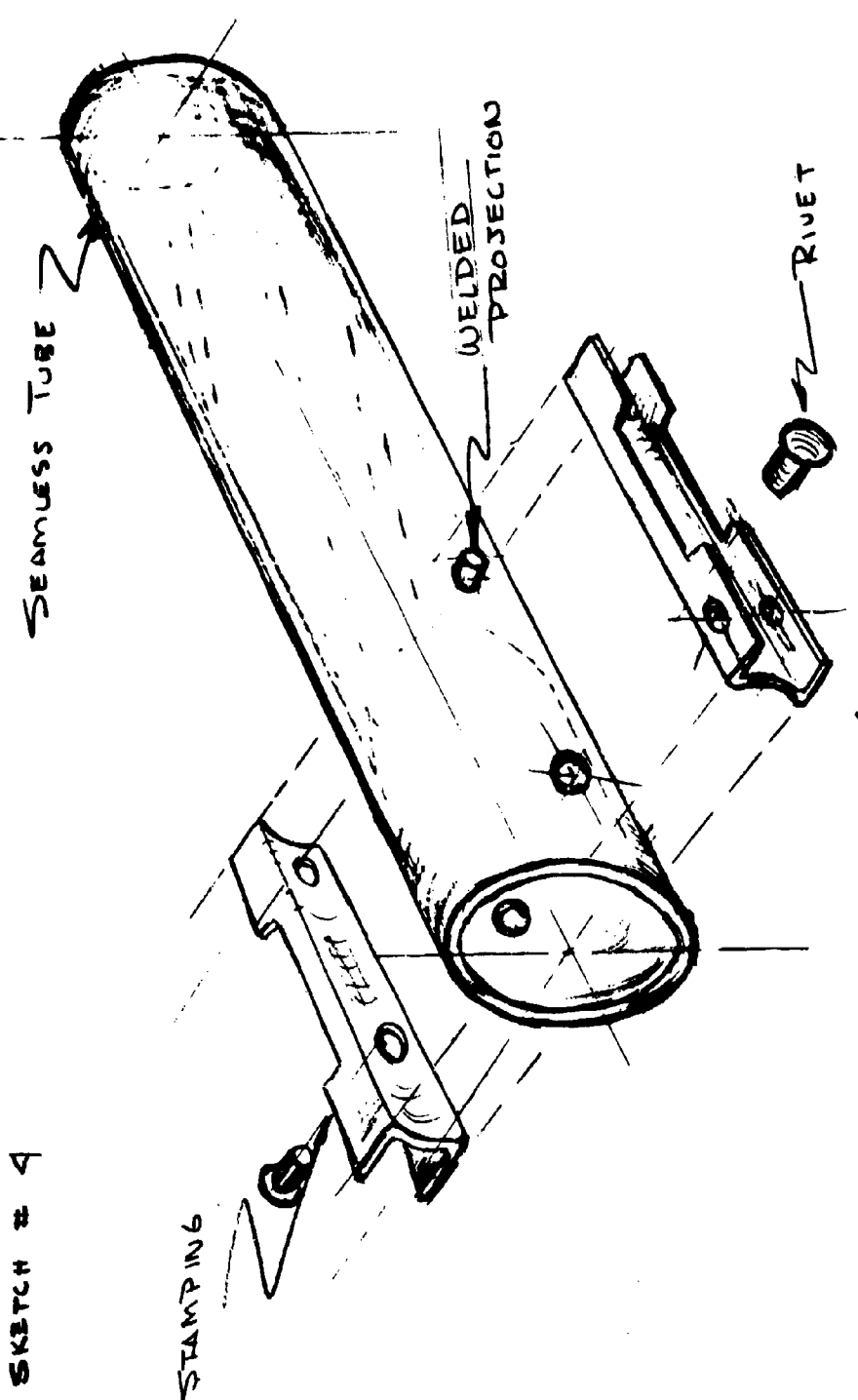


SKETCH #3

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E-18



SKETCH # 4

STAMPING

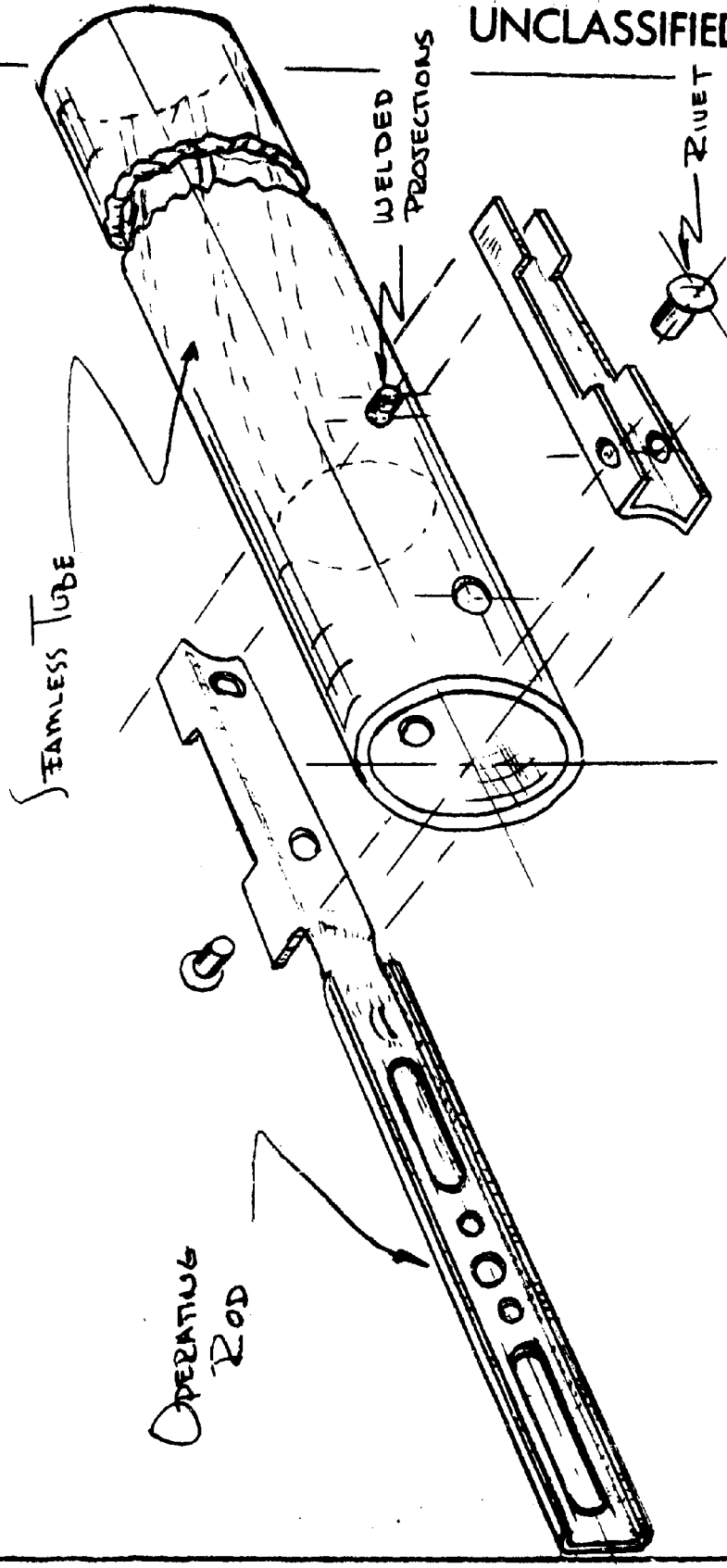
TUBE - GRENADE LAUNCHER
 SEAMLESS TUBE & STAMPINGS CONCEPT
 PROPOSED

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NH-2604

B-19



GRENADE LAUNCHER
 TUBE & OPERATING ROD ASSEMBLY
 SEAMLESS TUBE & STAMPINGS
 PROPOSED

SKETCH # 5

OPERATING
ROD

SEAMLESS TUBE

WELDED
PROTECTIONS

RIVET

UNCLASSIFIED

G.

COST SUMMARY Tube

PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
\$ 7.06	\$ 706,000	\$ 7.06	\$ 706,000	-0-	-0-
	Investment*		Investment*		Investment
	\$ 94,000		\$ 94,000		

* Reflects special tooling only

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NH-2604

E-20

UNCLASSIFIED

A. DESCRIPTIONProject #2.3.1Project Name: Striker HousingComponents

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Assembly</u>
51355	Housing, Striker	1	1

B. FUNCTIONBasic

House Parts

Secondary

Position parts
 Contain parts
 Resist force
 Transmit force
 Provide connection
 Contain force
 Limit weight

C. EXISTING DESIGN DESCRIPTION (refer sketch #6)

Prototypes machined of bar stock (7075T6)

Contains or holds the following:

Extractor assembly, including lever, springs, etc.
 Striker components
 Sear assembly
 Firing lever assembly
 Cartridge retainer disconnecter
 Guide roller for tube return spring
 Safety shaft and spring
 Interlock assembly

D. ALTERNATE DESIGNS CONSIDERED

1. Multiple-piece construction. Among the alternatives evaluated were:

- a. Die cast sections
- b. Investment cast sections
- c. Injection molded plastics
- d. Stamped members
- e. Powdered metal sections
- f. Combinations of all above

2. Single-piece construction:

- a. Machined from solid
- b. Investment cast + secondaries
- c. Die Cast + secondaries
- d. Plastics + secondaries

E. RECOMMENDED DESIGN (refer to sketch #7)

The recommended design consists of an upper and lower half constructed of aluminum investment castings. These halves would be permanently joined by riveting. It was felt that this approach will minimize necessary secondary machining operations, specifically in internal areas.

F. LONG TERM RECOMMENDATIONS

During supplemental discussions involving the extractor, striker, etc., it was suggested that there exists a possibility of elimination or greatly simplifying this component and its related parts. Amplification of this possibility is contained in the section on future developments. (Section III^b Technical Discussion)

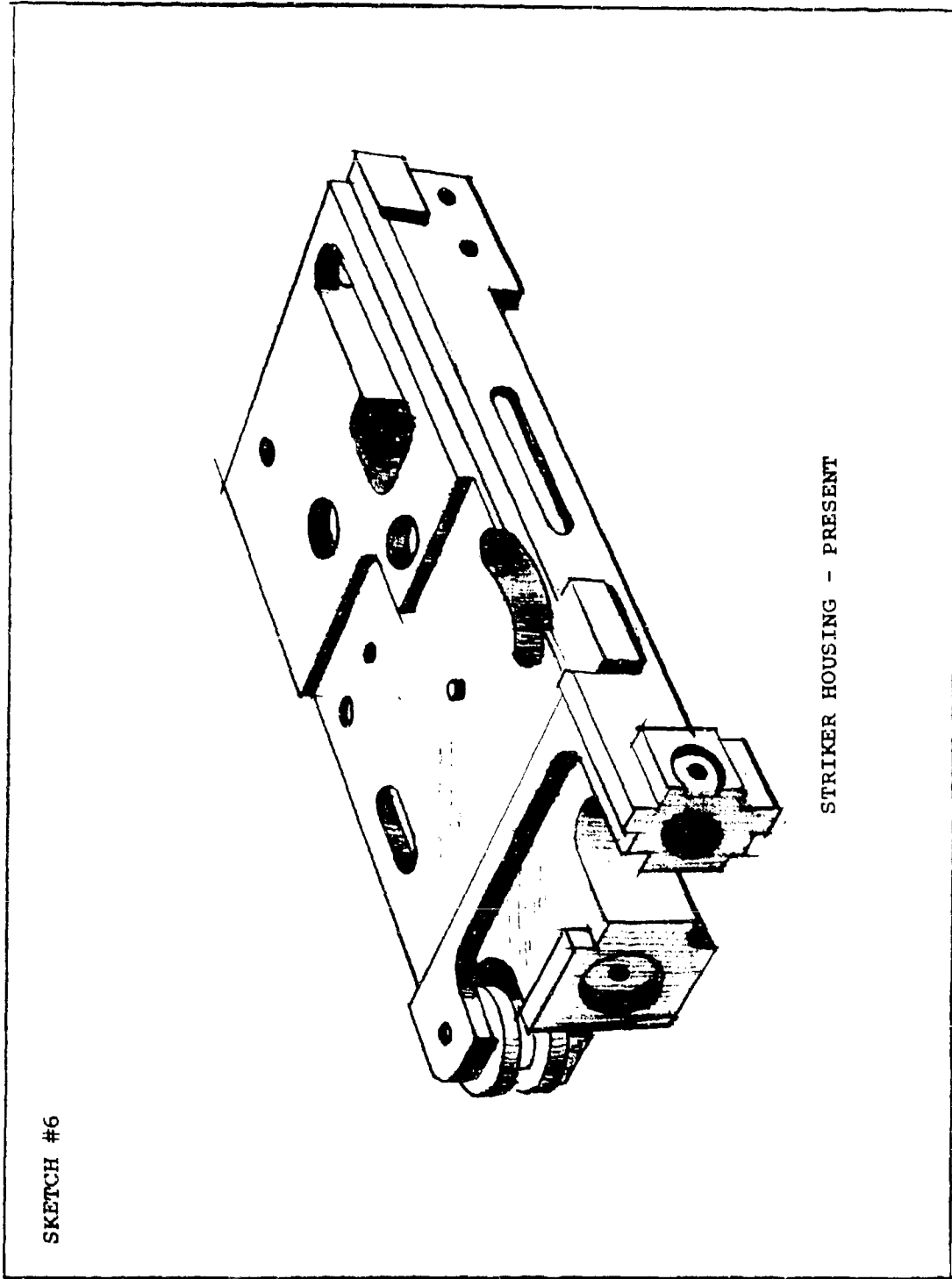
G. DESIGN COMMENTSStriker Housing:

The cast housing offers no difficulty from the functional viewpoint. Thinking on future development includes study of a different type of firing mechanism which could eliminate the need for a striker housing, but as long as a striker or hammer system is retained, the cast design is preferred. It may become practical to use a one piece casting instead of a two piece.

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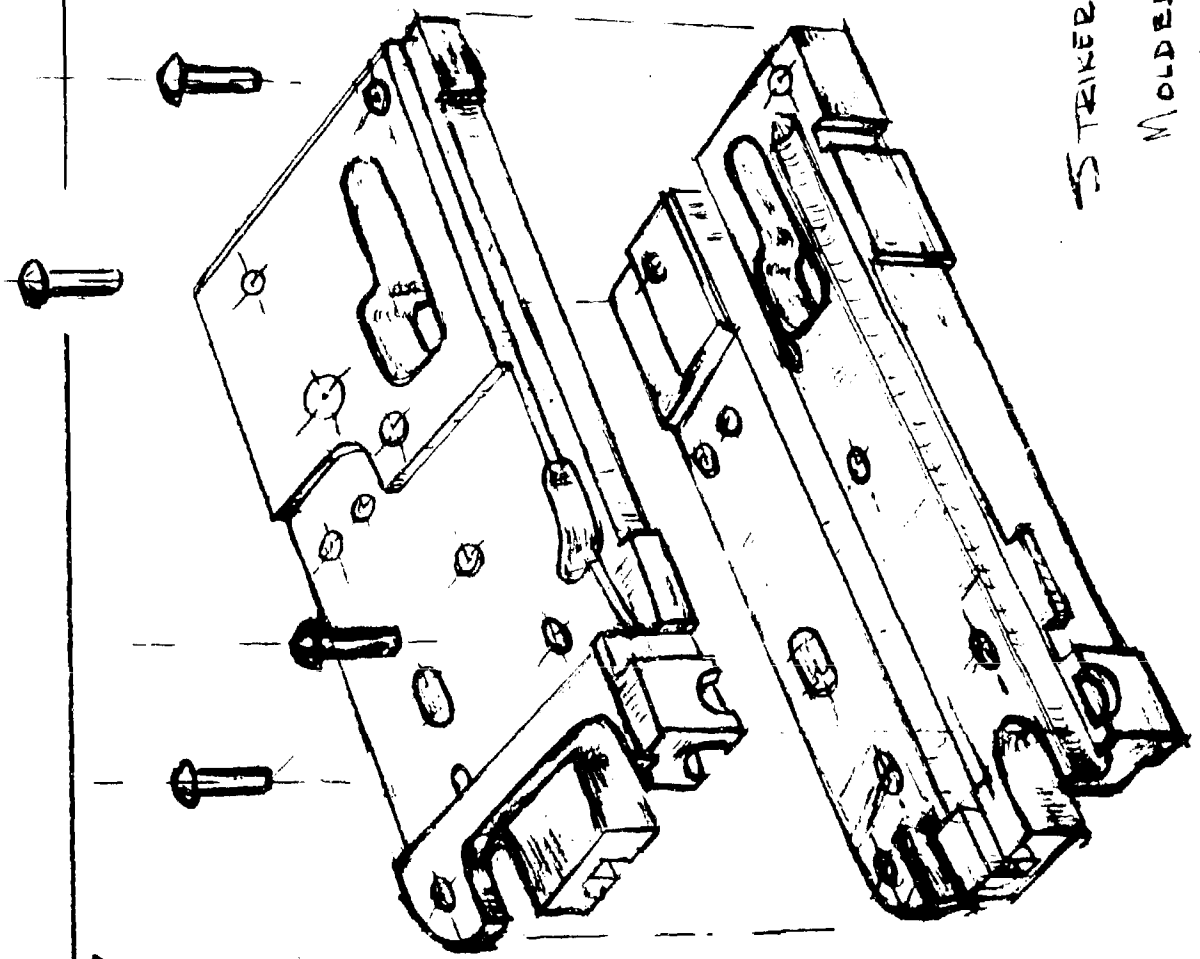
E-23



SKETCH #6

STRIKER HOUSING - PRESENT

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STRIKER HOUSING
MOLDED HALVES
PROPOSED

SKETCH #7

H.

COST SUMMARY - STRIKER HOUSING

PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Cost Per Year Investment	Unit Cost	Cost Per Year Investment	Cost Per Year	Investment
\$ 5.48	\$ 548,000	\$ 4.38	\$ 428,000	\$ 110,000	\$ 145,000

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NH-2604

E-25

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NH-2604

A. DESCRIPTION

Project No. : 2.1.3.1

Project Name: Magazine Assembly

Components:

<u>Part No.</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher *</u>
51422	Body, Magazine	1	5
51425	Floor, Magazine	1	5
51424	Rivet, Magazine	3	15
51426	Retainer, Cartridge	1	5
51423	Spring, Magazine	1	5

* One (1) Basic w/launcher + Four (4) support

B. FUNCTIONS

Basic

Store Parts
Feed Parts

Secondary

Guide Cartridges
Position Cartridges
Protect Cartridges
Provide attachment

C. EXISTING DESIGN DESCRIPTION (Ref. sketch #8)

The existing design consists of an extruded aluminum casing with a drawn aluminum bottom cover spot welded to the casing. The casing contains a negator spring which acts as both follower and energy source to feed cartridges. The magazine contains the cartridge cut-offs and cartridge retainer as an integral part of the magazine. The magazine capacity is three rounds. This design permits either left hand or right hand loading, convenience in use, storage, and is totally detachable from launcher. From a human factor's viewpoint, it is easy to use, and provides for positive positioning even in the dark, or with gloves. Weight of the magazine is 7 oz.

Cost of the magazine in its present configuration is estimated at \$2.94 ea.

D. ALTERNATE DESIGNS CONSIDERED

1. Style #1

Ref. Sketch #9

This design consists of a composite sheet metal and plastic structure. The rear of the magazine case is a steel stamping forming a "T" slot cartridge guide. This is completely enclosed by a plastic shell. The end of the integral negator spring is formed to comprise a cartridge retainer. The cartridge cut-off function is integral with launcher and is made once for each launcher rather than with every magazine. Cost is estimated at \$.98/pc.

E-26

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D. ALTERNATE DESIGNS CONSIDERED (continued)1. Style #1 (continued)Advantages

1. Lower initial tool cost
2. Lower unit cost, from a user's viewpoint
3. In all respects, same as original design
4. Disposable magazine

Disadvantages

1. Reduced service life, but reusable three to five times minimum
2. Slightly more susceptible to deformation

Reason for Discard

Basic function can be performed by another design at lower cost

2. Style #2

In all respects identical with style #1, except that the plastic body is eliminated and a steel strip bottom is added. This one will require a magazine body as an integral part of the launcher. Cost is estimated at \$.51/pc.

Advantages

1. Lower unit cost
2. Lower initial tool cost
3. Disposable magazine

Disadvantages

1. Requires a fixed magazine housing.
2. Increases command height in certain circumstances.
3. Increases overall distance from weapon in loading

Reason for Discard

Basic function can be performed by another design at lower cost.

3. Style #4Ref. Sketch #10

Hinged magazine type considered but discarded as unwieldy from a human factor's viewpoint.

E. FINAL DESIGN - RECOMMENDEDStyle #3Ref. Sketch #11

Sheet metal stamping in the form of a "T" slot with negator spring integral and performing the function of cartridge retainer.
Cost estimated at \$.41/pc.

Advantages

1. Lowest overall unit cost
2. Low initial tool cost
3. True throw-away
4. Less storage space for empties
5. Reduce overall length of magazine

Disadvantages

1. Less protection outside of launcher
2. Increases command height under certain circumstances
3. Initial design has slight advantages from a human factor's point of view.

F. DESIGN COMMENTSMagazine

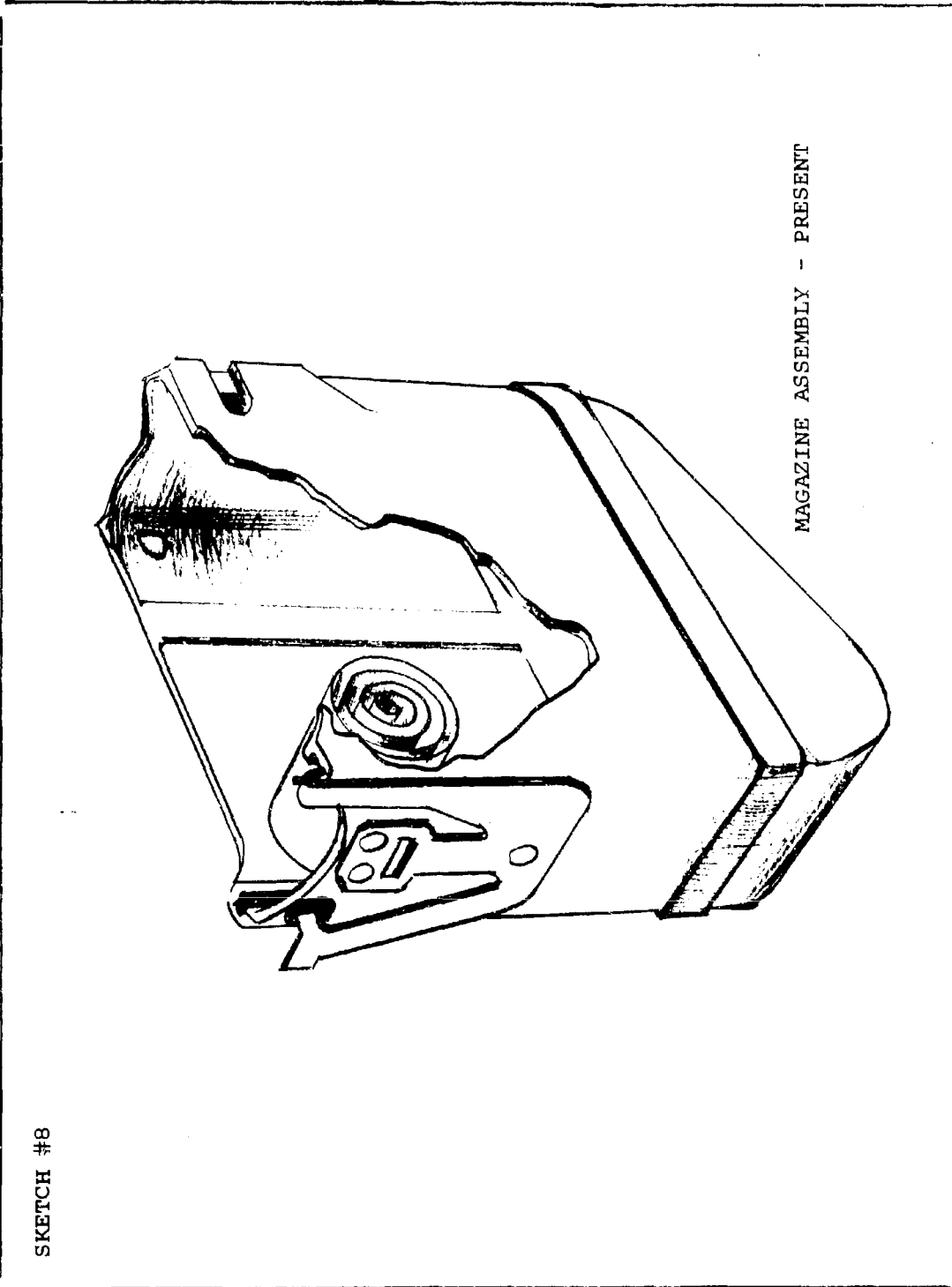
The proposed magazine construction is feasible from the engineering viewpoint, but incorporation should await careful study of the human factor's aspects. A task analysis on loading is required, and assessment should be made of the effect of having the main magazine body always attached to the weapon.

Note: These comments apply to the "clip" type arrangement,
not to the composite type of box.

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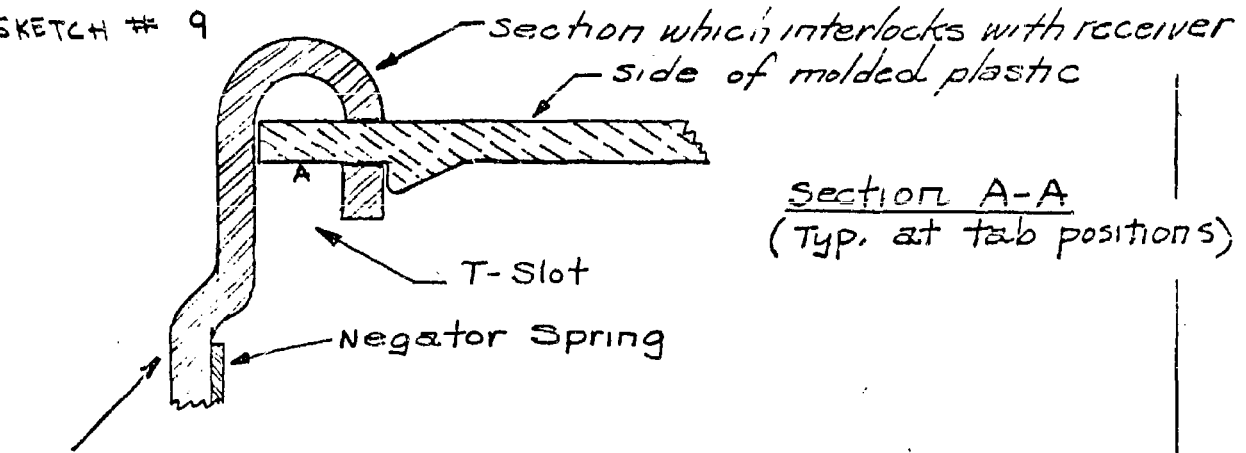
NH-2604

E-29

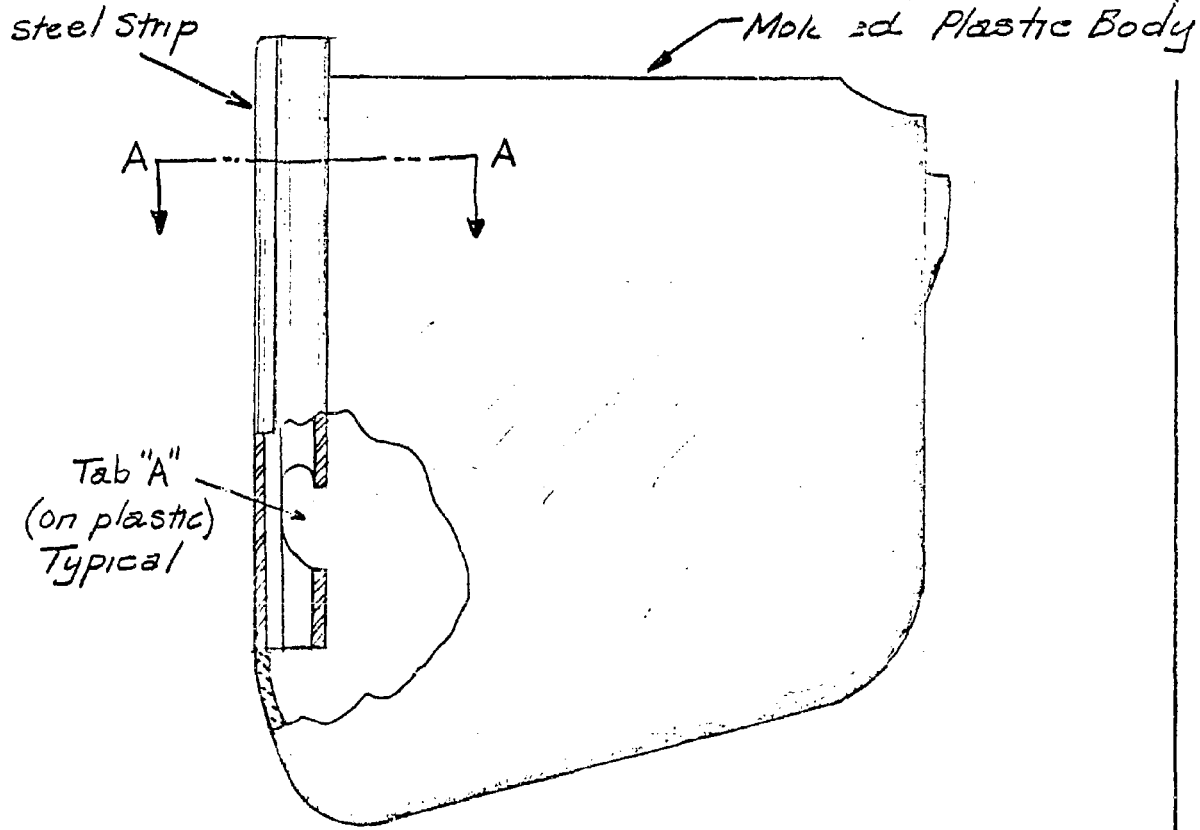


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SKETCH # 9



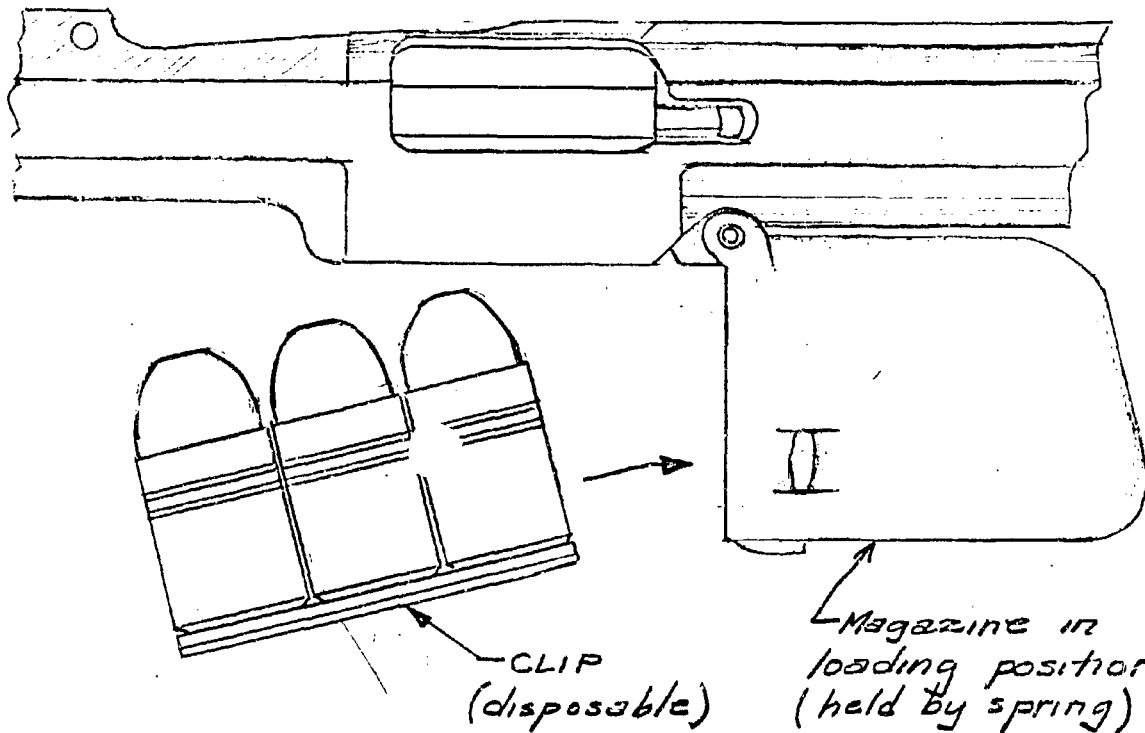
Section A-A
(Typ. at tab positions)



Composite Magazine -
Molded Plastic / Steel

(Plastic not to take recoil forces)

PROPOSED - STYLE #1



*Use of Broda Type Magazine,
permanently attached to receiver.*

PROPOSED - STYLE # 3

SKETCH # 10

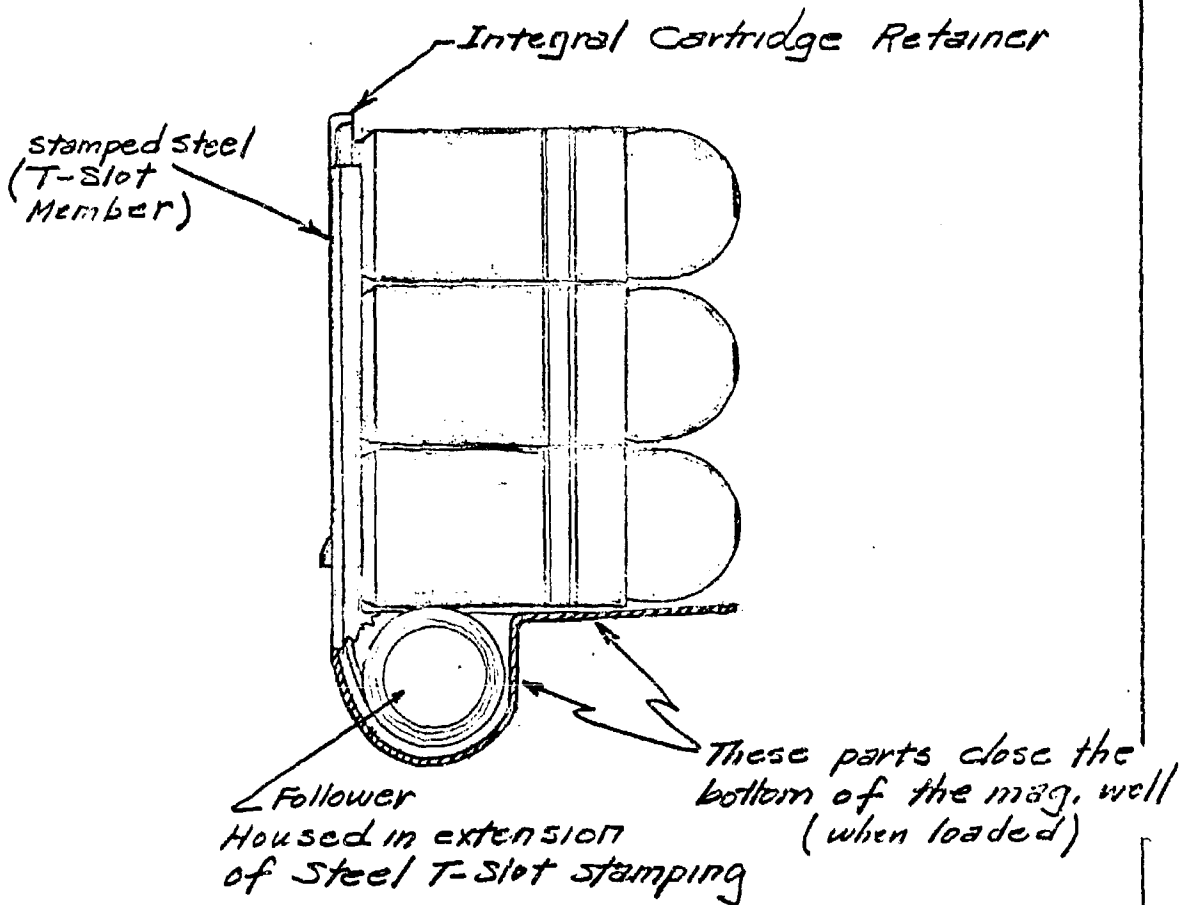
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NH-2604
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SKETCH # 11

DISPOSABLE MAGAZINE
(includes follower and retainer)

PROPOSED STYLE # A



Skeleton Magazine, for insertion into deep magazine well (which protects the sides and front)

- can be designed for insertion from rear or bottom of magazine well.

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E-32

G.

COST SUMMARY - Magazine Assembly

		PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Per Year *	Investment	Unit Cost	Per Year*	Investment	Cost Per Year *	Investment
\$ 2.94	\$ 1,470,000	\$ 26,250	\$.51	\$ 255,000	\$ 5,250	\$ 1,215,000	\$ 21,000

* Based on 500,000/Yr.

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NH-2604

E-33

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A. DESCRIPTION

Project #2.2.2.1

Project Name: Rod, Operating

Components:

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
51429	Rod, Operating	1	1

B. FUNCTION

Basic

Transmit forces
Provide connection

Secondary

Actuate cutoff
Cock striker
Prevent rotation
Actuate extractor
Provide safety
Actuate secondary cutoff
Provide timing
Limit mass
Guide tube

C. EXISTING DESIGN DESCRIPTION (Ref. Sketch #12)

Prototypes are machined from bar stock, including integral cam surfaces to operate the cocking lever, extractor lever, cutoff actuator, secondary cutoff lock, and the interrupter. Notches are provided for engagement with the tube, and rivet holes are provided for attachment of the tube return spring. Because of the necessity to maintain straightness, heat treatment was done with the operating rod clamped to a rigid block.

D. DESIGN RECOMMENDED (Ref. Sketch #13)

The recommended design provides a shape that is compatible with a stamping process. By reverting to this shape, it was possible to form all the working surfaces necessary to its function in one machine handling.

Advantages

1. Lower unit cost
2. Productivity improved

E. DESIGN COMMENTS

Operating Rod

The proposed method corresponds to that envisioned by the designers

E. DESIGN COMMENTS (continued)

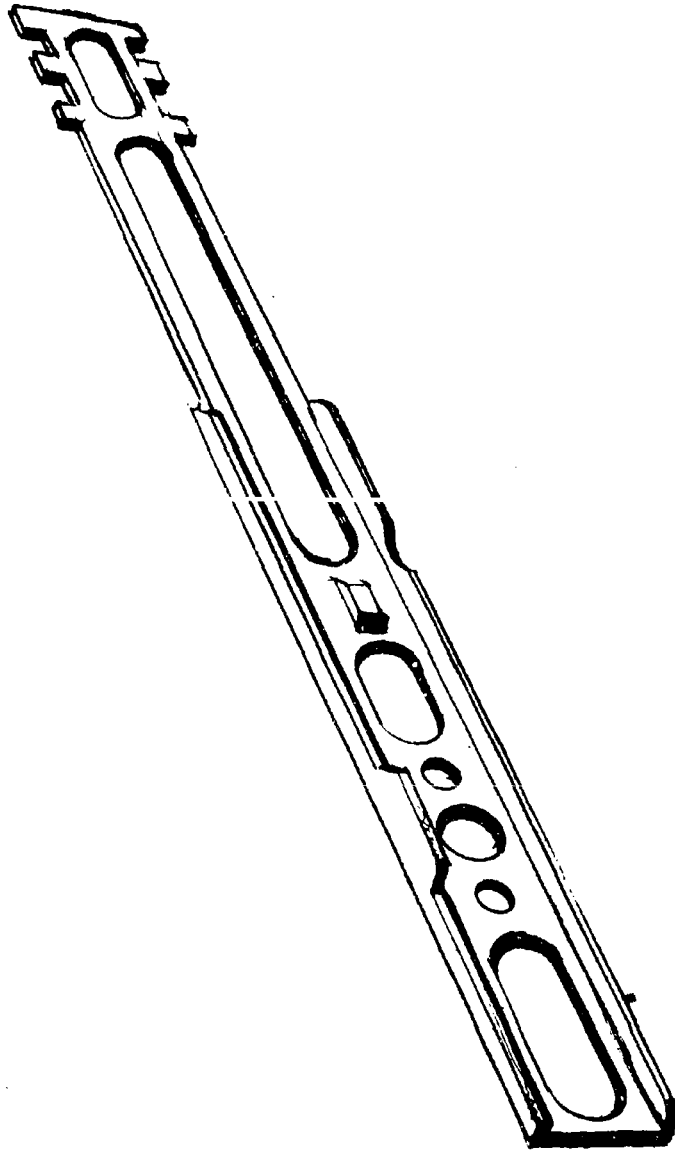
Operating Rod (continued)

and is practical. Modifications may be required in order to give satisfactory cam surfaces for the various functions. Qualification of height and width may have to be made after stamping. The operating rod would probably be shortened some three inches in the course of any future development, and this aids in making a stamping more usable.

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NH-2604

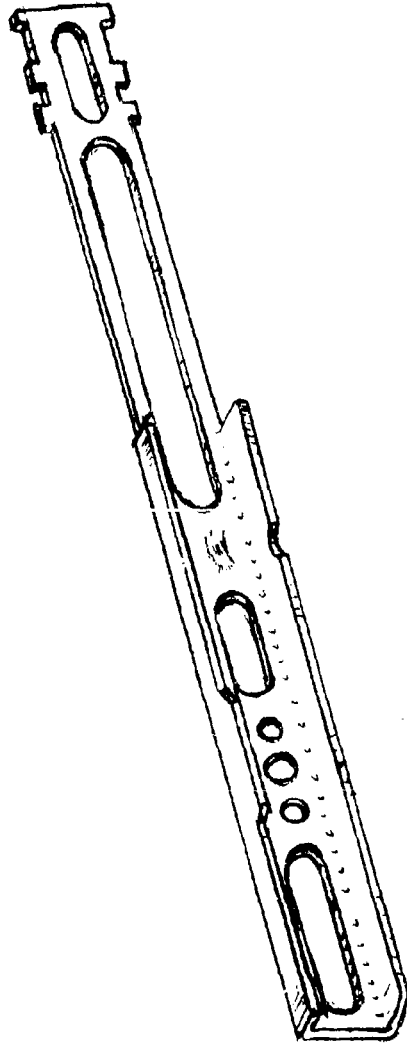
E-36



ROD OPERATING - PRESENT

SKETCH #12

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ROD - OPERATING
STAMPING CONCEPT
PROPOSED

SKETCH # 13

F.

COST SUMMARY - Operating Rod

	PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
	Unit Cost	Investment	Unit Cost	Investment	Cost Per Year	Investment
	\$ 1.54	\$ 27,600	\$ 0.77	\$ 16,000	\$ 77,000	\$ 11,600

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NH-2604

E-38

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A. DESCRIPTIONProject: #2.1.3.2Project Name: Retainer, CartridgeComponents:

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
51426	Retainer, Cartridge	1	1

B. FUNCTIONS

<u>Basic</u>	<u>Secondary</u>
Controls, Cartridge	Provide escapement Engage latch Position magazine

C. EXISTING DESIGN DESCRIPTION

Present design is a stamping, riveted outside the rear wall of magazine body. The stamping provides:

1. A spring leaf type catch to retain cartridges when the magazine is not in the weapon.
2. A second spring leaf catch which acts as a cutoff, releasing cartridges to rise (feed) when the action is open, but which holds the cartridges down out of contact with the tube at all other times.
3. A recess which is engaged by the rear magazine latch.

D. RECOMMENDED DESIGN

Certain design changes were made in the magazine assembly study which affect this component. See Project #2.1.3.1 for further detail.

E. DESIGN COMMENTS1. Cartridge Retainer

Present (and recommended) design is satisfactory functionally except that the stock thickness is too great, with the result that too much force is required to disengage the cutoff arm from the cartridge rim. This can be corrected easily by reducing the thickness.

F.

COST SUMMARY Cartridge Retainer

PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
\$ 0.19	\$19,000	\$ 0.19	\$ 19,000	-0-	-0-

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NH-2604

R-40

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NH-2604

SUMMARY REPORT

GRENADE LAUNCHER

A. DESCRIPTION

Project No.: 2.3.8

Project Name: Extractor

Components:

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
D-51361	Extractor	1	1

B. FUNCTIONS

<u>Basic</u>	<u>Secondary</u>
Expel Case	Remove case Control case Position case Resist force Clear case Restrain lever

C. EXISTING DESIGN DESCRIPTION (Ref. Sketch #14)

The existing extractor design consists of a machined steel component produced from bar stock with an integral "leaf-type" extractor section.

The extractor is mounted in the striker housing. It is energized rearward by a spring for cartridge ejection and moved forward by a lever which, in turn, is linked with the operating rod.

This linkage provides engagement of the extractor hook with the cartridge rim during action closing.

Ejection is not synchronized with the tube position.

The ejector spring force is not critical.

The breech face is clear of protrusion such as ejectors, thereby permitting an unobstructed path for the feeding round.

D. DESIGN RECOMMENDED (Ref. Sketch #15)

The recommended design maintains all intended functions. However, the shape has been modified in order that maximum utilization of the stamping process can be realized.

E-41

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E. DESIGN RECOMMENDED (continued)Advantages

1. Lower unit cost
2. Producibility

F. LONG TERM DESIGN RECOMMENDATION

The long term design recommendation involves a simple leaf extractor and separate spring plunger type ejector.

This design requires that the breech face be moved rearward approximately 1/4" to prevent interference with feeding rounds. The amplification of this approach is contained in the section on future development efforts.

Advantages

1. Component simplification
2. Timing (mechanism) less critical
3. Extractor acts as secondary cartridge retainer

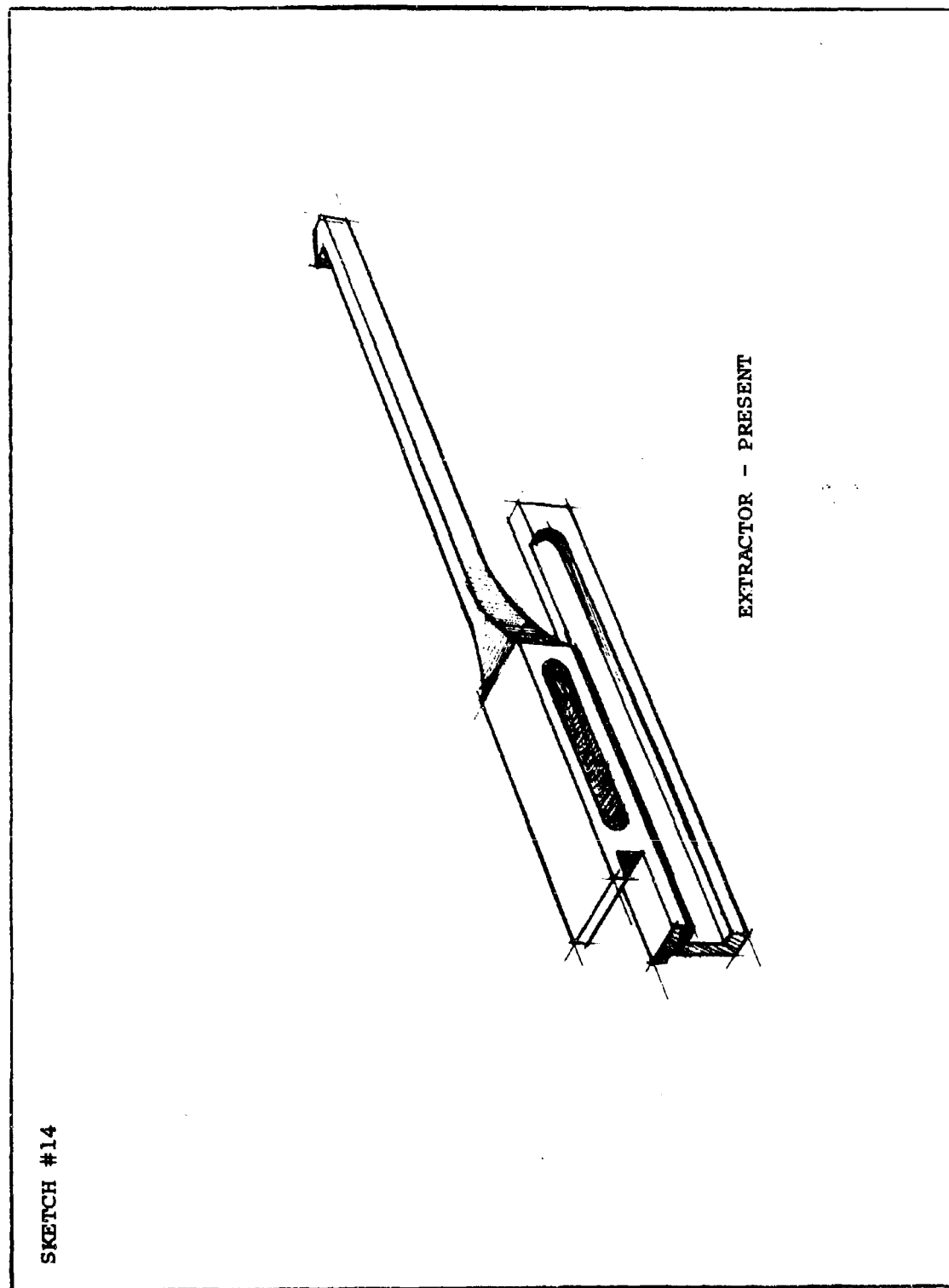
G. DESIGN COMMENTSExtractor

The extractor in the present system is not inherently highly stressed, and the stamped construction is probably feasible, with appropriate alterations in associated parts. Although the present design meets the functional requirements, it is felt that sufficient familiarity has been gained on the functioning to permit the use of a simpler method of extraction and ejection, with relatively little development effort. As a result, the view of product design is that redesign is preferable to the reprocessing of the existing extractor.

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NH-2604

E-43



EXTRACTOR - PRESENT

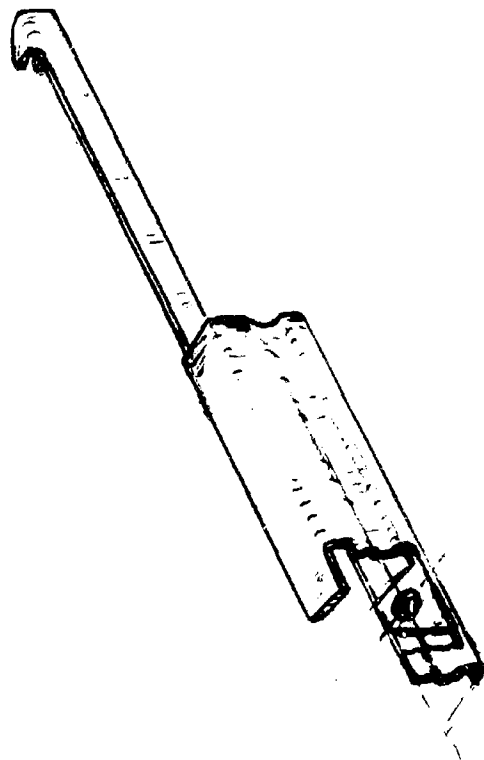
SKETCH #14

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NH-2604

E-44



EXTRACTOR
STAMPING CONCEPT
PROPOSED

SKETCH # 15

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H.

COST SUMMARY Extractor

PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
\$ 1.24	\$ 124,000	\$ 0.45	\$ 45,000	\$ 79,000	\$ 30,500
			Investment		
	\$ 45,500		Investment		

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NH-2604

E-45

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UNCLASSIFIED

NH-2604

A. DESCRIPTION

Project : #2.3.18

Project Name: Lever, Firing

Components

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
51346	Lever, Firing	1	1

B. FUNCTION

Basic

Transmit force

Secondary

Provide connection
Actuate Sear
Carries disconnector

C. EXISTING DESIGN DESCRIPTION

The present firing lever is a stamped bell-crank lever. One arm engages the linkage to the PTE trigger (pulling rearward.) The other arm carries the disconnector which, when the lever turns, presses the sear out of engagement with the striker. The firing lever and attached disconnector are mounted on the striker housing.

Present material: Aluminum, 7075-T6

D. DESIGN RECOMMENDATION

No change

E. DESIGN COMMENTS

Firing Lever

The present design is satisfactory functionally and from a process viewpoint. The lever is subject to redesign in the event the basic firing system is altered, but would remain a stamping of approximately the same type and complexity.

E-46

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F.

COST SUMMARY Firing Lever

	PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
	Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
	\$.166	\$ 16,600	\$.166	\$ 16,600	-0-	-0-
		\$ 7,500		\$ 7,500		

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NH-2604

H-47

A. DESCRIPTIONProject: #2.3.2Project Name: StrikerComponents

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
C-51335	Striker	1	1

B. FUNCTIONS

<u>Basic</u>	<u>Secondary</u>
Transmit energy	Stores energy Position sears

C. EXISTING DESIGN DESCRIPTION (Ref. Sketch #16)

Present striker is turned, with secondary milling cuts added to provide a notch to engage the sear, and a shoulder which is engaged by the cocking lever. A turned shoulder is provided to engage with the safety shaft when the safety is in the "safe" position.

The present design does not include the firing pin.

D. DESIGN RECOMMENDED (Ref. Sketch #16)

The recommended design provides a shape that is compatible with a stamping process. By reverting to this shape, it was possible to form all the working surfaces necessary to its function in one machine handling.

Advantages

1. Lower unit cost
2. Producibility improved

E. LONG TERM DESIGN RECOMMENDATION

An alternate type of firing mechanism has been considered involving a fixed firing pin (integral with the breech face) and firing from a partially open action.

This would permit simplification of the firing system and, together with proposed changes in the extractor system, elimination of the striker housing as an assembly. Amplification of this alternative design is contained in the section on future developments (Section III).

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NH-2604

F. DESIGN COMMENTS

Striker

The proposed stamping is preferred in principle over the prototype design, especially in that the tendency of the striker to rotate and bind the cocking lever, operating rod and tube is completely eliminated with a flat striker.

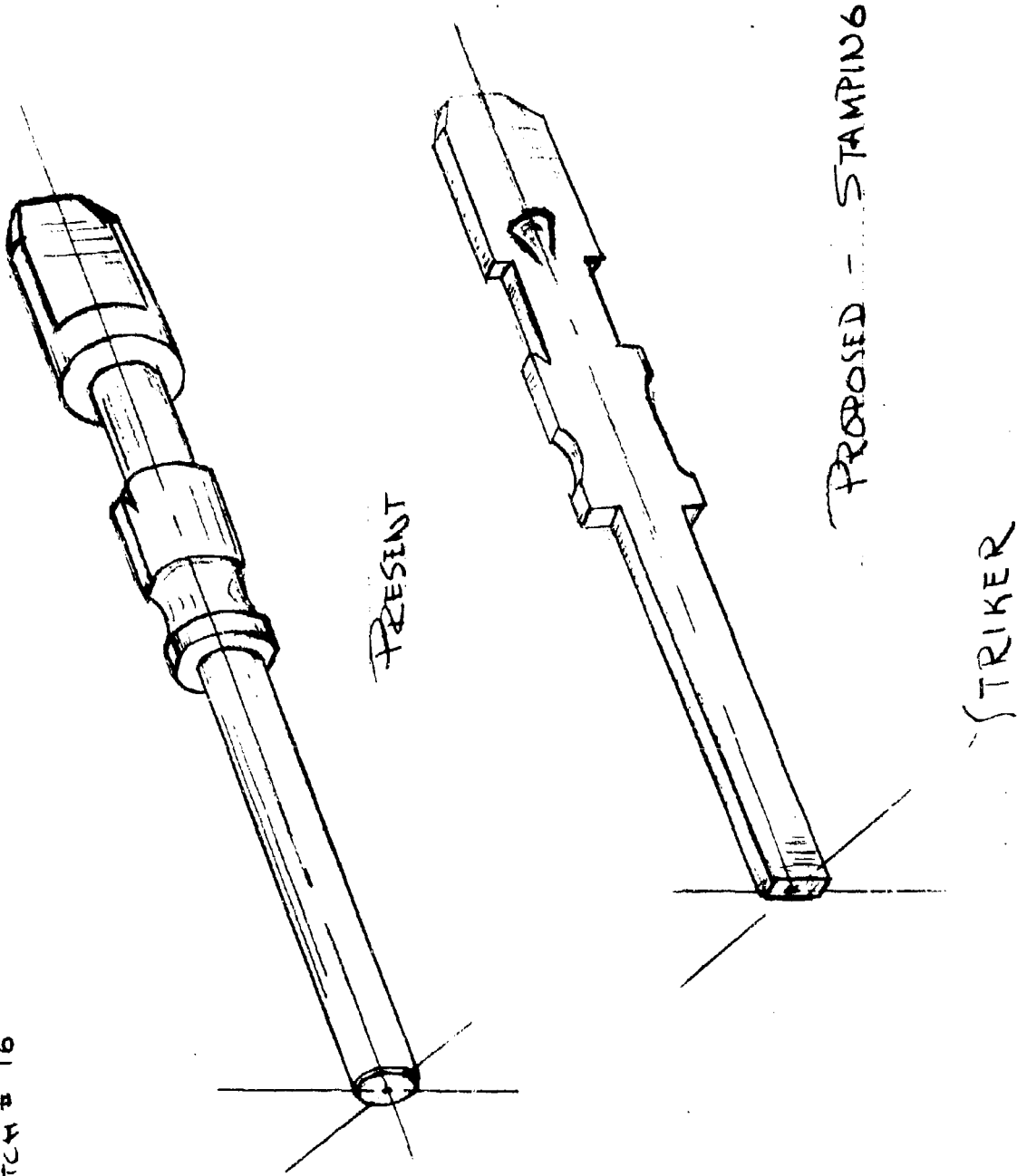
E-49

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NH-2604

E-50



SKETCH # 16

UNCLASSIFIED

G.

COST SUMMARY Striker

PRESENT METHOD		PROPOSED METHOD		POTENTIAL SAVINGS	
Unit Cost	Cost Per Year	Unit Cost	Cost Per Year	Cost Per Year	Investment
\$.90	\$ 90,000	\$.253	\$ 25,300	\$ 64,700	\$ 27,500
	\$ 36,000		\$ 8,500		

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UNCLASSIFIED

NH-2604

E-51

UNCLASSIFIED

A. DESCRIPTIONProject: #2.4Project Name: Sight GroupComponents:

<u>Part #</u>	<u>Part Name</u>	<u>#/Assembly</u>	<u>#/Launcher</u>
51436	Mount	1	1
51437	Base	1	1
51438	Rivet, Base	1	1
51439	Bar, Sight	1	1
51440	Aperture, Rear	1	1
51441	Screw, Slide	1	1
51442	Screw, Pivot	1	1
51443	Post, Front Sight	1	1
51444	Screw, Rear Aperture	1	1
51445	Spring, Detent Plate	1	1
51446	Spring, Mount Lock	1	1
51447	Slide	1	1
51448	Detent	1	1
51449	Lock, Mount	1	1
51450	Spring, Sight Bar	1	1

B. FUNCTIONBasic

Align Weapon

Secondary

Provide connection
 Provide easy removal
 Resist shock

C. EXISTING DESIGN DESCRIPTION (Ref. Sketch #17)

Present design (prototypes) are basically fabricated from aluminum. The mount and slide are castings with subsequent machining. The sight bar is machined from bar stock; the rear aperture is a stamping, and the front sight a screw machine post. The basic sight is the ramp type, with a linear range scale, provision for zeroing in range and deflection, and automatic composition for ballistic drift. A push-button latch is provided to allow removal from the PTE receiver cover.

D. DESIGN RECOMMENDED (Ref. Sketch #18 & 19)

Analysis of the current assembly and functional requirements indicated that there was considerable room for simplifying the design from a user and producibility point of view.

From the user point of view, the sliding mechanism was judged overly complicated and did not provide the optimum indexing features desirable for night operation when selecting the desired point on the range scale. It was also felt that the ease with which the

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D. DESIGN RECOMMENDED (continued)

launcher sight is affixed to the point fire weapon could be improved upon.

The Value Team concluded that less expensive processing techniques could be employed, and that these processing improvements would be compatible with improvements needed from the user point of view.

An alternate design was conceived (see sketch) utilizing the following:

1. A gear and rack type principle to facilitate indexing the sight to desired range locations. This is expected to improve night sight-adjustment capabilities through a more positive movement sensing and reaction device plus reduced visual demands on the user.
2. A simplified means for affixing the sight to the weapon utilizing a quick acting friction type toggle clamp.
3. Improved fabricating techniques, such as stampings, powdered metal, shelf items, etc.

Acceptance of this design will result in an improved functioning assembly at a lower total cost.

<u>Part #</u>	<u>Part Name</u>	<u>Present Design</u>	<u>Quantity Required</u>	<u>Proposed Design</u>	<u>Quantity Required</u>
51436	Mount	Machined	1	Stamping	1
51437	Base	Machined	1	Stamping	1
51438	Rivet, Base	Screw machine	2	Screw machine	2
51439	Bar, Sight	Machined	1	Stamped	1
51440	Aperture, Rear	Stamped	1	Stamped	1
51441	Screw, Slide	Screw machine	1	Eliminate	1
51442	Screw, Pivot	Screw machine	1	Screw machine	1
51443	Post, Front sight	Screw machine	1	Screw machine	1
51444	Screw, rear aperture	Std. screw	1	Std. screw	1
51445	Spring, Detent plate	Coil spring	1	Eliminate	1
51446	Spring, Mount lock	Coil spring	1	Eliminate	1
51447	Slide	Machined	1	Stamping	1
51448	Detent	Screw machine	1	Stamping	1
51449	Lock, Mount	Screw machine	1	Stamping	1
51450	Spring, Sight Bar	Coil spring	1	Eliminate	1
New	Wheel, Sight Adjust.	None	0	Powdered Metal	1
New	Shaft, Sight Adjust Wheel	None	0	Screw machine	1
New	Washer, Retaining	None	0	Standard item	3
New	Pin, Toggle pivot	None	0	Wire pivot	1

E. DESIGN COMMENTSSight Assembly

The proposed stamped sight assembly corresponds with the original

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NH-2604

E. DESIGN COMMENTS (continued)

Sight Assembly (continued)

intent of Product Engineering for long range development, although the execution, as shown in the sketches, is subject to variation in any future development stage. It is recommended that through-hardening materials be used on the main components to maximize the resistance to abuse. The adaptation to stamping is contingent on the design of mounting and adjustment means which are inherently "self centering". Without this, the use of stampings is impractical since tolerance effects would cause unacceptable variations in alignment because of the short sight radius.

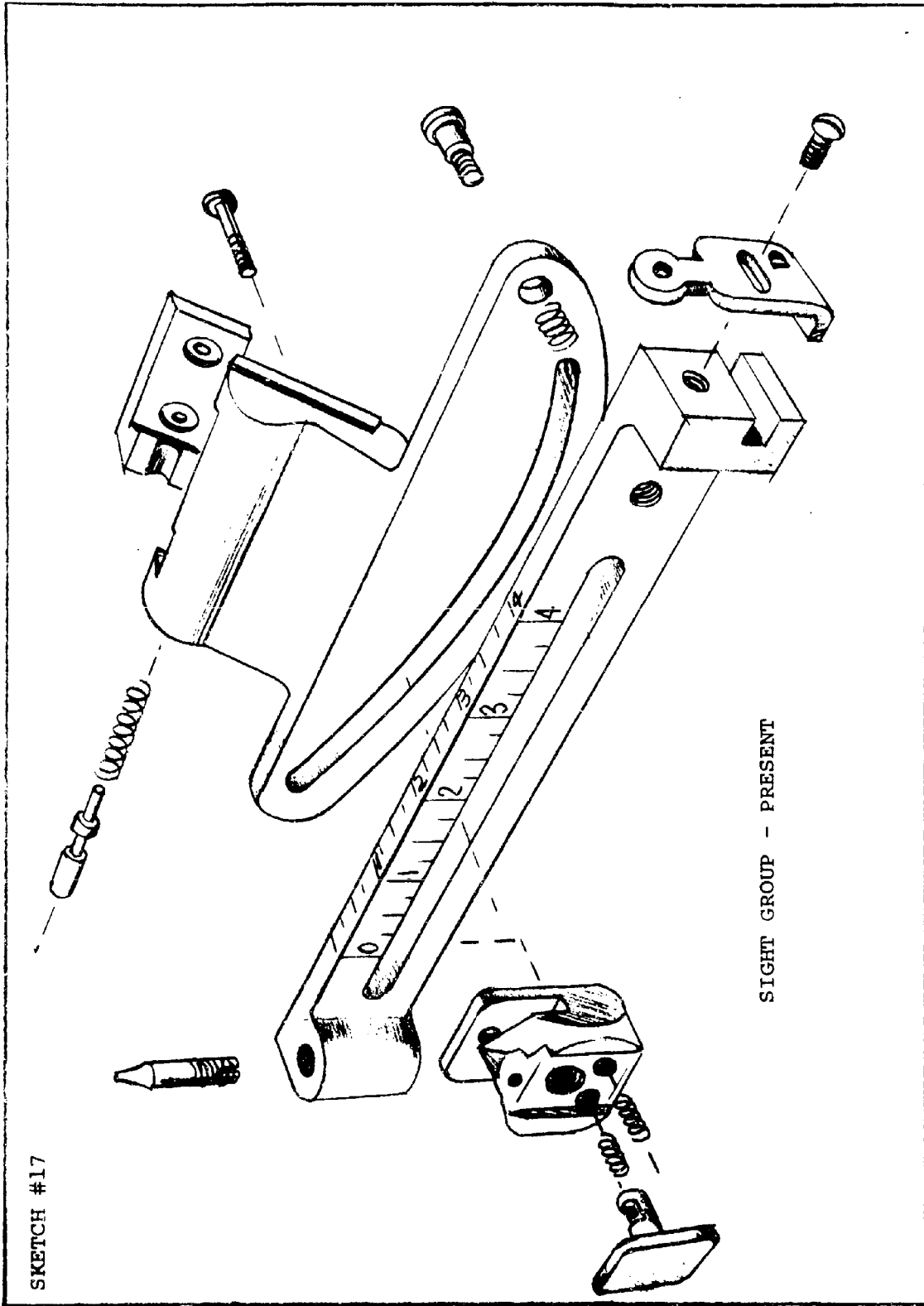
E-54

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NH-2604

E-55

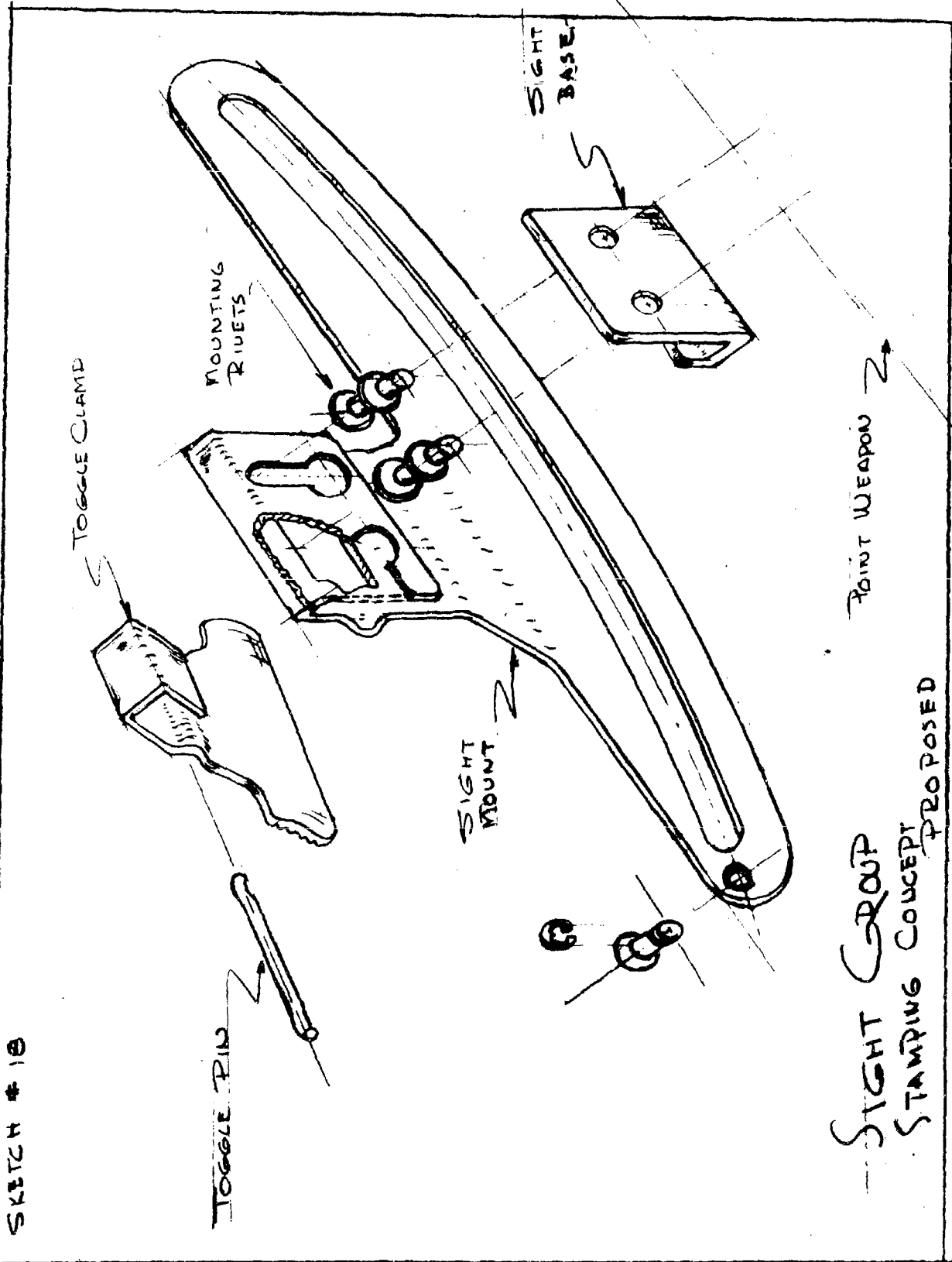


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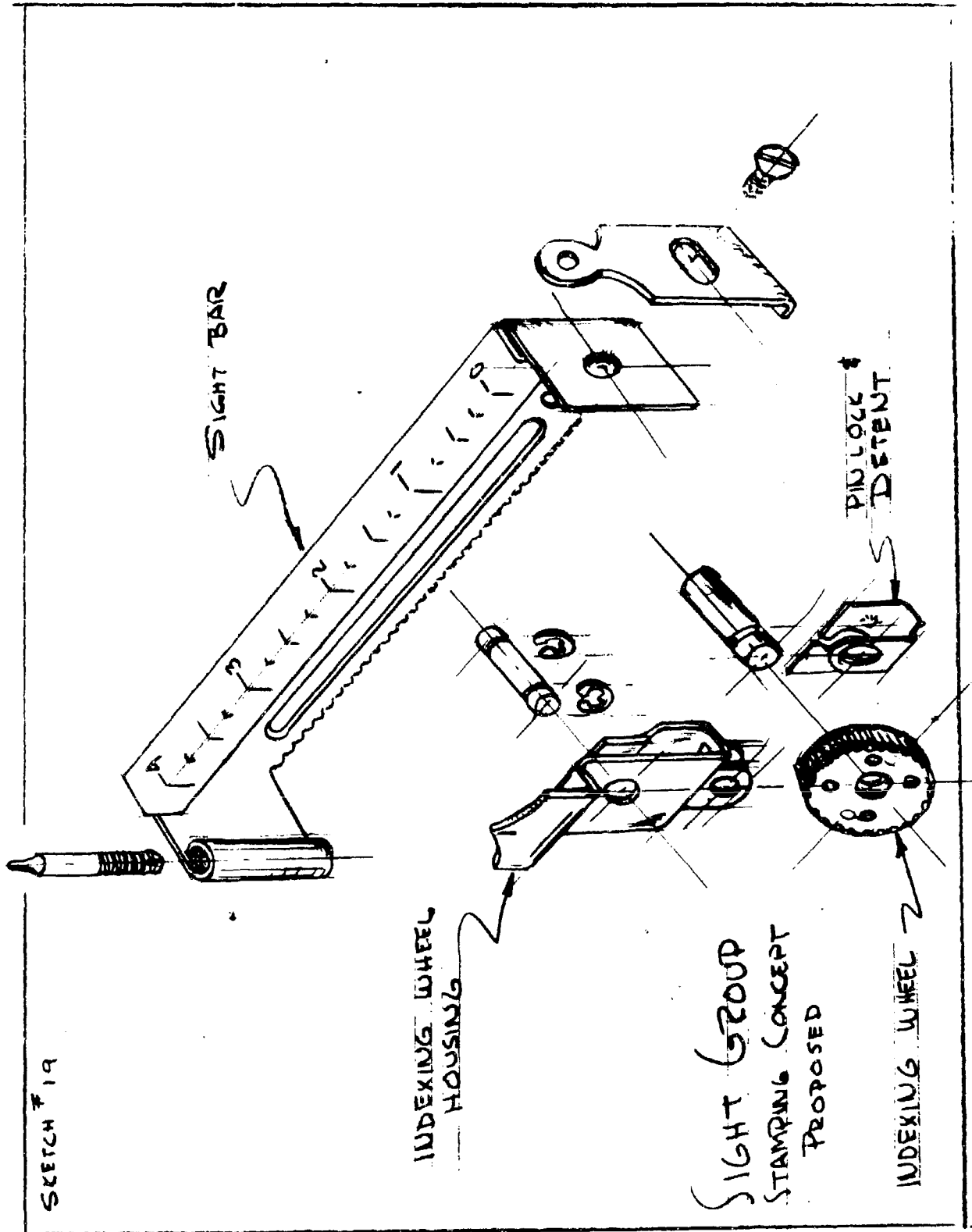
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NH-2604

E-56



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SKETCH # 19

INDEXING WHEEL HOUSING

SIGHT GROUP STAMPING CONCEPT PROPOSED

INDEXING WHEEL

PIN LOCK DETENT

SIGHT BAR

COST SUMMARY Sight Assembly

PRESENT METHOD			PROPOSED METHOD			POTENTIAL SAVINGS	
Unit Cost	Cost Per Year	Investment	Unit Cost	Cost Per Year	Investment	Cost Per Year	Investment
\$ 5.28	\$528,000	\$ 176,200	\$ 1.86	\$ 186,000	\$ 79,300	\$ 343,000	\$ 96,900

UNCLASSIFIED

NH-2604

E-58

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NH-2604

SECTION III. REPORT OF VALUE ENGINEERING STUDIES ON COST AREAS
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Detailed areas of investigation were made to:

1. Analyze commercial sources for products with similar use requirements and compare with Government Specifications to determine if substitution of commercial items would result in lower cost without reduction of quality or impairment of essential functioning and military serviceability.
2. Determine whether functions are required. If so, determine if the part can be simplified or if multiple parts can be combined into a single part and still maintain the combination of required functions.
3. Determine if the parts are designed and dimensioned to accommodate the most economically acceptable process; e.g., forging, casting, stamping, welding, extruding, etc.
4. Determine whether less expensive, more readily available, or light weight material can be substituted satisfactorily.
5. Determine whether tolerances and finishes are as liberal as possible.
6. Determine whether parts can be assembled more easily or economically by the use of quick release type or other specialty fasteners, and if maintenance and adjustment of the equipment can be readily performed.
7. Determine whether the Government Specifications for the equipment are realistic when compared to intended use.

E-59

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PART # NOMENCLATURE

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P.F.
LONG RANGE
PROCESS
DESCRIP-
TION
(ORIGINAL
INTENTION)

PRESENT
PROCESS
DESCRIP-
TION

PROCESS
DESCRIPTION

VALUE ENGINEERING RECOMMENDATION

NATURE OF CHANGE

AREAS OF
EXPECTED
IMPROVEMENT

ELIMINATION
CHG. TO STD.
SIMPLIFY
RELY ON POL.
CHG. MAT'L.
SHARP ENDS
NO CHG.

RELIABILITY
HUMAN FACTOR
WEIGHT
SPACE
COST
PRODUCTIVITY

51336	Spring, Striker	Coil Spg.	Coil Spg.	Coil Spg.	X														
51337	Lever, Cocking	Casting	Inv. Casting	Inv. Casting															
51338	Lever, Safety	Stamping Screw Machine	Stamping Non- Existent	Stamping Combine w/339	X														
51339	Knob, Safety	Drawn Machine	Screw Machine	Drawn Shape						X									
51340	Shaft, Safety	Stamp/ Mach. Machine	Machined Stamping Screw Machine	Stamp Screw Machine	X														
51341	Spring, Safety	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51342	Screw, Safety Spring	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51343	Sear	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51344	Pin, Sear & Sear Spring	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51345	Spring, Sear	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51347	Roller, Spring Guide	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51348	Lever, Interlock	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51349	Spring, Interlock	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51350	Disconnector	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51351	Pin, Disconnector Stop	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51352	Pin, Disconnector	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51353	Cocking Lever and Pin, Firing Lever	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51354	Spring, Firing Lever	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51356	Connector, Trigger Adapter	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51357	Base, Trigger Adapter	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51358	Adapter, Trigger	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51359	Screw, Adapter, Trigger	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														
51360	Screw, Trigger Connector Adapter	Machined Screw Machine	Inv. Cast. Screw Machine	Stamp & Washers Screw Machine	X														

PART # NOMENCLATURE

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PART #	NOMENCLATURE	PRESENT PROCESS DESCRIPTION	P.E. LONG RANGE PROCESS DESCRIPTION (ORIGINAL INTENTION)	VALUE ENGINEERING RECOMMENDATION								AREAS OF EXPECTED IMPROVEMENT				
				PROCESS DESCRIPTION	ELIMINATION	CHG. TO STD.	SIMPLIFY	RELAX TOL.	CHG. MATE.	SHAPE SIMP.	NO CHG.	RELIABILITY	HUMAN FACTOR	WEIGHT	COST	PRODUCTIVITY
51362	Plunger Retaining	Screw Machine	Screw Machine	Standard Roll Pin				X							X	X
51363	Spring, Extractor Lever	Coil Spg. Screw Machine	Coil Spring Screw Machine	Coil Spring								X				
51364	Plunger, Extractor Spring	Screw Machine	Screw Machine	Screw Machine												
51365	Screw, Disconnector Cartridge Retainer	Std. Screw Stamp	Std. Screw	Stamp												
51366	Disconnector Retainer	w/ Machine	w/ Machine													
51367	Spring, Cocking Lever	Wire Form	Wire Form	Wire Form												
51368	Stop, Striker	Screw Machine	Screw Machine	Screw Machine												
51369	Spring, Extractor	Coil Spg.	Coil Spring	Coil Spring												
51370	Lever, Extractor	Machining	Stamping	Stamping								X				X
51373	Actuator, cutoff	Stamped	Stamping	Stamping								X				X
51374	Cutoff, Secondary	Machined	Inv.Cast.	Drawn Shape												X
51375	Mount, Secondary Cutoff	Machined	Inv.Cast.													X
51376	Lock, Secondary Cutoff	Stamped	Stamping	Stamped												X
51377	Stud, Secondary Cutoff Lock	Screw Machine	Screw Machine	Screw Machine												X
51378	Plunger, Secondary Cutoff	Screw Machine	Screw Machine	Screw Machine												X
51379	Spring, Secondary Cutoff Lock	Torsion Spring	Torsion Spring	Torsion Spring												X
51380	Spring, Secondary Cutoff Plunger	Coil Spring	Coil Spring	Coil Spring												X
51381	Pin, Secondary Cutoff	Spiral Pin	Spiral Pin	Spiral Pin												X
51382	Stud, Cutoff Short	Screw Machine	Screw Machine	Screw Machine												X
51383	Stud, Cutoff Long	"	"	"												X
51384	Spring, Cutoff Actuator	Wire Form	Wire Form	Wire Form												X
51385	Screw, Cutoff Actuator	Std. Screw	Std. Screw	Std. Screw												X
51387	Plate, Retaining, Front	Stamping/Mach.	Stamping	Stamping												X

F-01

84-4

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PART #	NOMENCLATURE	PRESENT PROCESS DESCRIPTION	P. E. LONG RANGE PROCESS DESCRIPTION (ORIGINAL INTENTION)	PROCESS DESCRIPTION	VALUE ENGINEERING RECOMMENDATION											AREAS OF EXPECTED IMPROVEMENT					
					NATURE OF CHANGE											RELIABILITY	HUMAN FACTOR	WEIGHT	SPACE	COST	PRODUCTIVITY
					PROCESS CNG.	ELIMINATION	CHG. TO STD.	SIMPLIFY	RELAX TOL.	CHG. MAT'L.	SHAPE SIMP.	NO. CNG.									
51388	Plate, Retaining, Rear	Stamping	Stamping	Stamping																X	X
51389	Screw, Retaining Plate, Rear	Std. Screw Screw Machine	Std. Screw	Std. Screw								X									
51390	Screw, Retaining Plate, Front	Screw Machine	Std. Screw Mach. from Square Stock	Std. Screw Machine	X																
51391	Button, Magazine Latch																				
51392	Pin, Magazine Latch, Rear	Std. Roll Pin	Std. Roll Pin	Std. Roll Pin																	
51393	Latch, Magazine, Rear	Machined	Machined	Machined																	
51394	Latch, Magazine, Left	Machined	Machined	Machined																	X
51395	Latch, Magazine, Right	Machined	Machined	Machined																	X
51396	Spring, Magazine Latch, Rear	Coil Spg.	Coil Spg.	Coil Spg.																	
51397	Spring, Magazine Latch, Front (L & R Side)	Coil Spg.	Coil Spg.	Coil Spg.																	
51398	Latch, Tube	Stamping	Stamping	Stamping																	
51399	Lever, Tube Latch	Machined	Die Cast	Stamping																	X
51400	Spring, Tube Latch Lever	Coil Spg. Std.	Coil Spg.	Coil Spg.																	
51401	Pin, Tube Latch Lever	Roll pin Screw Machine	Roll Pin Screw Machine	Std. Roll Pin Screw Machine																	
51402	Screw, Tube Latch	Screw Machine	Screw Machine	Screw Machine																	X
51403	Plug, Breech Face																				
51404	Pin, Firing	"	"	"																	X
51405	Spring, Firing Pin	Coil Spg. Screw Machine	Coil Spg. Screw Machine	Coil Spg. Screw Machine																	
51406	Bushing, Firing Pin																				
51408	Arm, Tube Lock	Stamping Screw Machine	Stamping Screw Machine	Stamping Screw Machine																	X
51409	Pivot, Tube Lock	Machined Screw Machine	Machined Screw Machine	Machined Screw Machine																	X
51410	Lock, Tube																				
51411	Ring, Tube																				X

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PART #	NOMENCLATURE	PRESENT PROCESS DESCRIPTION	P.E. LONG RANGE PROCESS DESCRIPTION (ORIGINAL INTENTION)	PROCESS DESCRIPTION	NATURE OF CHANGE							AREAS OF EXPECTED IMPROVEMENT				
					ELIMINATION	CHG. TO STD.	SIMPLIFY	RELAX TOL.	CHG. MAT'L.	SHAPE STAMP.	NO CHG.	RELIABILITY	HUMAN FACTOR	WEIGHTS	SPACE	COST
51412	Obturator	Stamp Machine	Machine from tubing	4-Slide Screw Machine	X										X	X
51413	Cap	Screw Machine	Screw Machine	Screw Machine						X						
51414	Shield	Screw Machine	Screw Machine	Screw Machine												X
51415	Buffer	O-Ring	O-Ring	O-Ring												X
51416	Support, Buffer	Stamping	Stamping	Stamping					X							X
51417	Handle, Charging	Machined	Cast	Die Casting	X											X
51418	Pin, Charging Handle Catch	Std Roll Pin	Std Roll Pin	Std Roll Pin												X
51419	Latch, Charging Handle	Machined	Stamping	Stamping	X											X
51420	Spring, Charging Handle Latch	Coil Spg.	Coil Spg.	Coil Spg.												X
51427	Hand Guard	Inj. Mold	Inj. Mold	Inj. Mold												X
51428	Screw, Hand Guard	Standard	Standard	Standard												X
51430	Spring, Tube	Shell Special	Shell Special	Shell Special												X
51431	Yoke, Return Spring	Stamp	Stamping	4-Slide Screw Machine	X											X
51432	Rivet, Tube Spring	Screw Machine	Screw Machine	Screw Machine												X
51433	Drum, Tube Spring	Screw Machine	Comp. Mold	Inj. Mold	X											X
51434	Pin, Tube Spring Drum	Screw Machine	Screw Machine	Screw Machine												X
51435	Assembly, Safety Lever															
51457	Pin, Magazine Latch, Right & Left	Standard Roll Pin	Standard Roll Pin	Standard Roll Pin												
51458	Guard, Secondary Cutoff	Screw Machine	Screw Machine	Screw Machine					X							

PART # NOMENCLATURE
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VALUE ENGINEERING RECOMMENDATION			AREAS OF EXPECTED IMPROVEMENT															
P.E. LONG RANGE PROCESS DESCRIPTION (ORIGINAL INTENTION)	PRESENT PROCESS DESCRIPTION	PROCESS DESCRIPTION	NATURE OF CHANGE															
			PROCESS CHG.	ELIMINATION	CHG. TO STD.	SIMPLIFY	RELAX TOL.	CHG. MAT'L.	SHAPE SIMP.	NO CHG.								
			RELIABILITY	HUMAN FACTOR	WEIGHT	SPACE	COST	PRODUCIBILITY										
51453	Assy. - Mag. Latch Rear	Mech. Assy.	Mech. Assy.						X									
51455	Assy. - Tube Lock	"	"						X									
51472	Screw- Rec. Sub Assy.	Screw Machine	Screw Machine			X											X	X
51454	Assy. - Actuator Cutoff	Mech. Assy.	Mech. Assy.			X												
51452	Assy. - Firing Pin	Mech. Assy.	Mech. Assy.													X	X	X
51456	Assy. - Magazine	Reversible	Reversible							X								

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SECTION IV. - COST SUMMARY OF VALUE ENGINEERING RECOMMENDATIONS

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Part or Assembly	PRESENT METHOD			PROPOSED METHOD			POTENTIAL SAVINGS		
	Unit Cost	Cost Per Year	Estimated Investment	Unit Cost	Cost Per Year	Estimated Investment	Cost Per Year	Investment	Investment
Tube	\$ 7.060	\$ 706,000	\$ 94,000	\$ 7.060	\$ 706,000	\$ 94,000	\$ -0-	-0-	
Receiver	85.000	8,500,000	3,100,000	51.900	5,190,000	775,000	3,310,000	\$ 2,325,000	
Striker housing	5.480	548,000	340,000	4.38	438,000	195,000	110,000	145,000	
Magazine assembly	2.940	1,470,000	26,250	.510	255,000	5,250	1,215,000	21,000	
Operating Rod	1.540	154,000	27,600	.770	77,000	16,000	77,000	11,600	
Retainer Ctge	.190	19,000	8,500	.190	19,000	8,500	-0-	-0-	
Extractor	1.240	124,000	45,500	.450	45,000	15,000	79,000	30,500	
Lever, Firing	.166	16,600	7,500	.166	16,600	7,500	-0-	-0-	
Striker	.900	90,000	36,000	.253	25,300	8,500	64,700	27,500	
Sight Assembly	5.280	528,000	176,200	1.860	186,000	79,300	342,000	96,900	
		\$12,155,600	\$ 3,861,550		\$6,957,900	\$1,204,050	\$5,197,700	\$ 2,657,500	

NH-2604

E-65

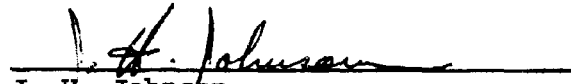
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Respectfully submitted,

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Prepared by:


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