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A MOVING DETONATOR STAB SENSITIVITY TESTER

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Stab
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Apparatus has been conceived, designed, developed, and constructed in which stab sensitive items are tested by impact between moving detonators and stationary firing pins, permitting higher impact velocities and lighter firing pins than in drop weight tests.

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RSLR 74-13

A MOVING DETONATOR STAB SENSITIVITY TESTER

INTRODUCTION

Stab detonators are frequently used in fuze applications where the energy or momentum available for their initiation is quite limited and where an increase in this energy or momentum can be obtained only by compromising other desired features of the fuzes.

Although the sensitivity of a stab initiator is usually referred to in terms of energy (the unit used is the "inch ounce") a quantitative specification must also include precise descriptions of several details of the test apparatus and procedures used. The firing pin point configuration is usually specified as is the weight to be dropped and the height from which it is to be dropped. In addition, sampling and data collection and analysis procedures are usually specified. In general, such specifications have, apparently, served their purpose of assuring that fuzes, incorporating detonators made and tested in accordance with applicable specifications, will function as required. However, conditions to which an initiator is subjected in a fuze when it is expected to fire often differ substantially from those of the specification test which formed the basis for its acceptance. Although it is generally assumed that this difference is in a direction such as to increase the conservativeness of reliability estimates, this is not necessarily always true. It is possible that in some cases modifications of priming mixtures or loading pressures (for example) which increase sensitivity under test conditions may decrease sensitivity under fuze operating conditions. The rational design of stab initiation systems requires quantitative data relating the design variables at the disposal of the designer to the reliability of initiation. These variables may include the composition, quantity, and loading pressure of the priming mix, the material and thickness of the end closure to be pierced by the firing pin, the firing pin configuration and material, the path of movement of the firing pin, and its mass and velocity, and the support afforded to the priming charge by the other explosive charges, and the inert components of the initiator and the supporting inert fuze components. In most cases, the designer's latitude of choice is severely limited by such requirements as the use of "shelf item" initiators, the costs of close tolerances, space and weight limitations, and material compatibility considerations. By the time he considers the stab initiation system as such, he has, at his disposal, only a few adjustable variables with which to offset or augment the effects of the other "fixed" factors. If, at this point, he had available quantitative data relating all of the factors including those which have been "fixed" by other considerations and those at his disposal as "design variables," he could, rather quickly assess the feasibility of designing a reliable system within the limitations imposed and, if it proves feasible, design the optimum system for maximum reliability at minimum cost. A better understanding of the interactions of these variables is necessary to the rational design of stab initiation systems. Such understanding is attainable only on the basis of experimental data relating these variables.

The most seve limitations which have inhibited such effort in the past have been those of the drop weight apparatus used in the sensitivity testing of stab initiators. Ordinarily the drop weight is separate from the firing pin. As a result, the firing pin in the short time interval after it has been struck by the drop weight moves in a very complex manner due to the reverberation of elastic waves in the firing pin and the drop weight and the attenuation of these waves by plastic deformation and other dissipative mechanisms. If the firing pin is combined with the drop weight, a marksmanship problem is introduced which becomes increasingly difficult as the drop weight becomes lighter and the height increases. If the drop is guided, friction becomes a source of error which increases with decreasing mass. A new type of apparatus has been developed which will simplify these problems and extend the range of velocities (and hence masses) substantially beyond that attainable with drop weight apparatus.

The effort described herein included the design, construction, and calibration of this apparatus.

TECHNICAL DISCUSSION

As has been pointed out in the Introduction, the principal impediment to the acquisition of data relating firing pin mass to the threshold velocity for initiation of a stab initiator is the drop weight apparatus used in the measurement of threshold conditions for initiation of such devices. Both the use of a separate weight and firing pin, which results in a complex equation of motion of the firing pin, and the problem of hitting the sensitive area of a detonator with the firing pin dropped over a large distance limit the ranges of masses and velocities over which such data can be obtained.

These difficulties are eliminated in the apparatus schematically illustrated in Figure 1. In this apparatus the detonator is mounted on a relatively massive mechanical element (such as a flywheel or reciprocating plunger, in an attitude such that, at some point in its movement, the axial movement of the detonator is vertically upward with the input end forward (up). The firing pin is so mounted that it can

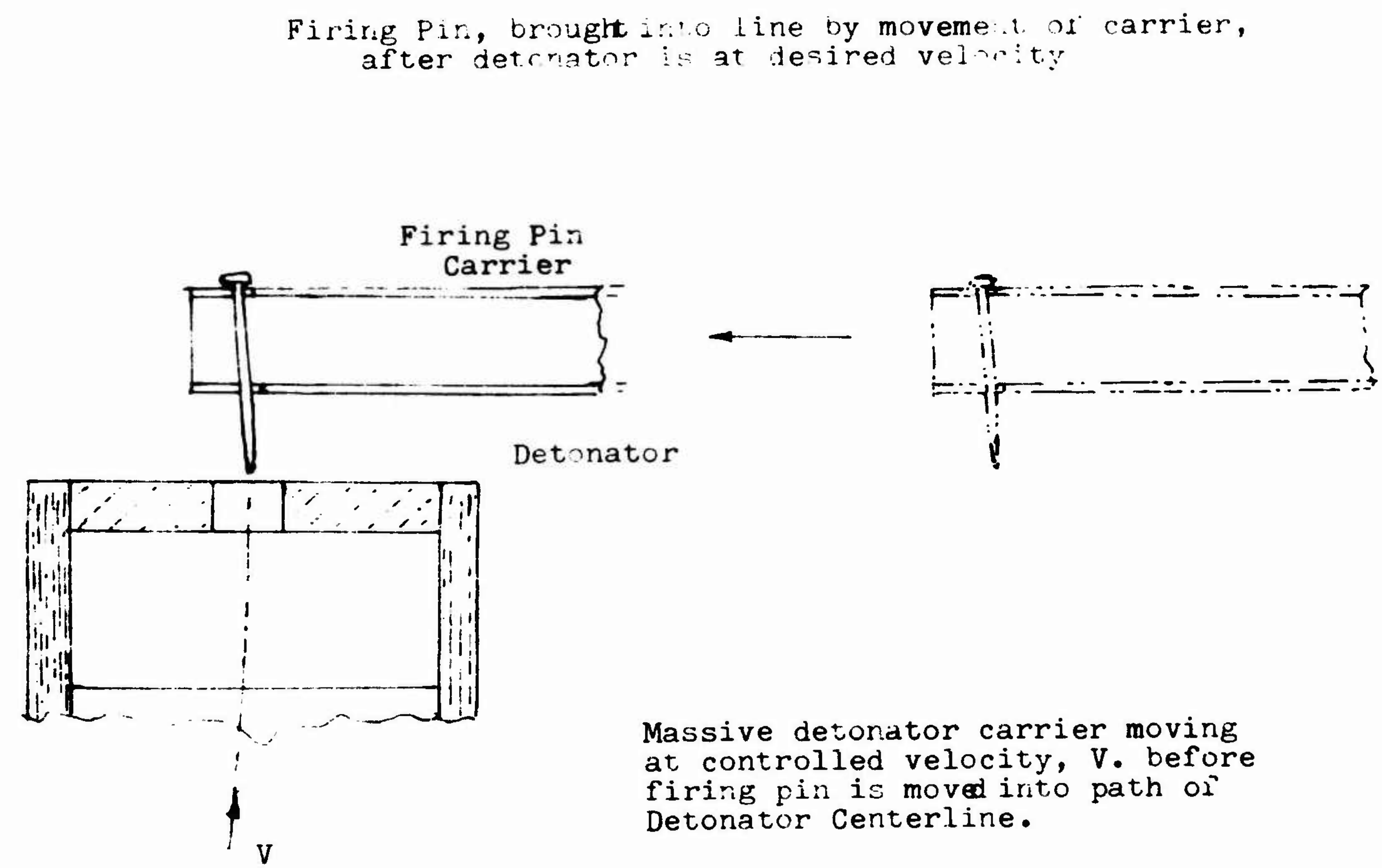
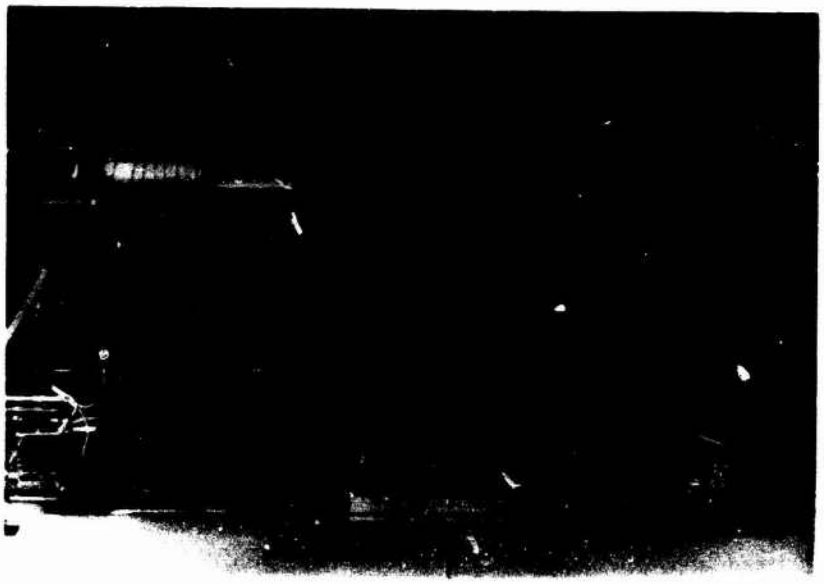


Figure 1 Moving Detonator Stab Tester

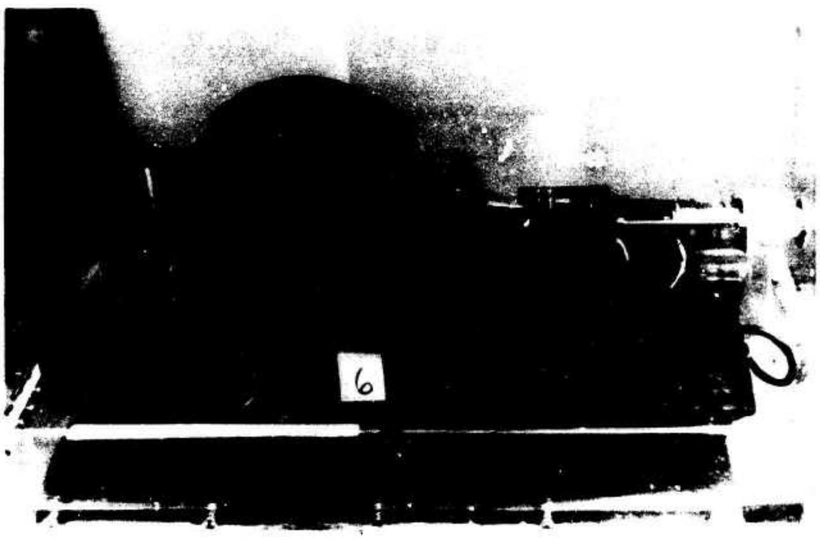
be lifted from below by a surface impinging upon its tip or point. The mounting of the firing pin is such that it can be moved into the path of the detonator at the point where its motion is vertically upward so that the sensitive end of the detonator impinges upon the point of the firing pin lifting it upward. Upon reflection, it will be seen that the impact between the firing pin and the detonator in this device is exactly equivalent to that which would occur if the firing pin were falling freely at the upward velocity of the detonator. Since the bearings of the moving element carrying the detonator the linkage or other mechanism used to move the firing pin into the path of the detonator can be made as rigid and precise as is necessary, the concentricity of the firing pin with respect to the detonator can be controlled to any specified tolerance.

The test apparatus, as it was reduced to practice, is shown in Figures 2, 3, 4, 5, and 6. The detonator is mounted in the bracket on the edge of the rotor (Figure 4). The firing pin is supported and guided in a transverse hole in length of plastic tubing (" Dairy Queen" plastic drinking straws), which is, in turn mounted on a cam controlled reciprocating member which, when triggered, carries the firing pin from a position clear of the path of the detonator and its mountings to a position concentric with path of the



Moving Detonator Stat Sensitivity Tester
(front view)

Figure 2



Moving Detonator Stab Sensitivity Tester
(rear view)

Figure 3

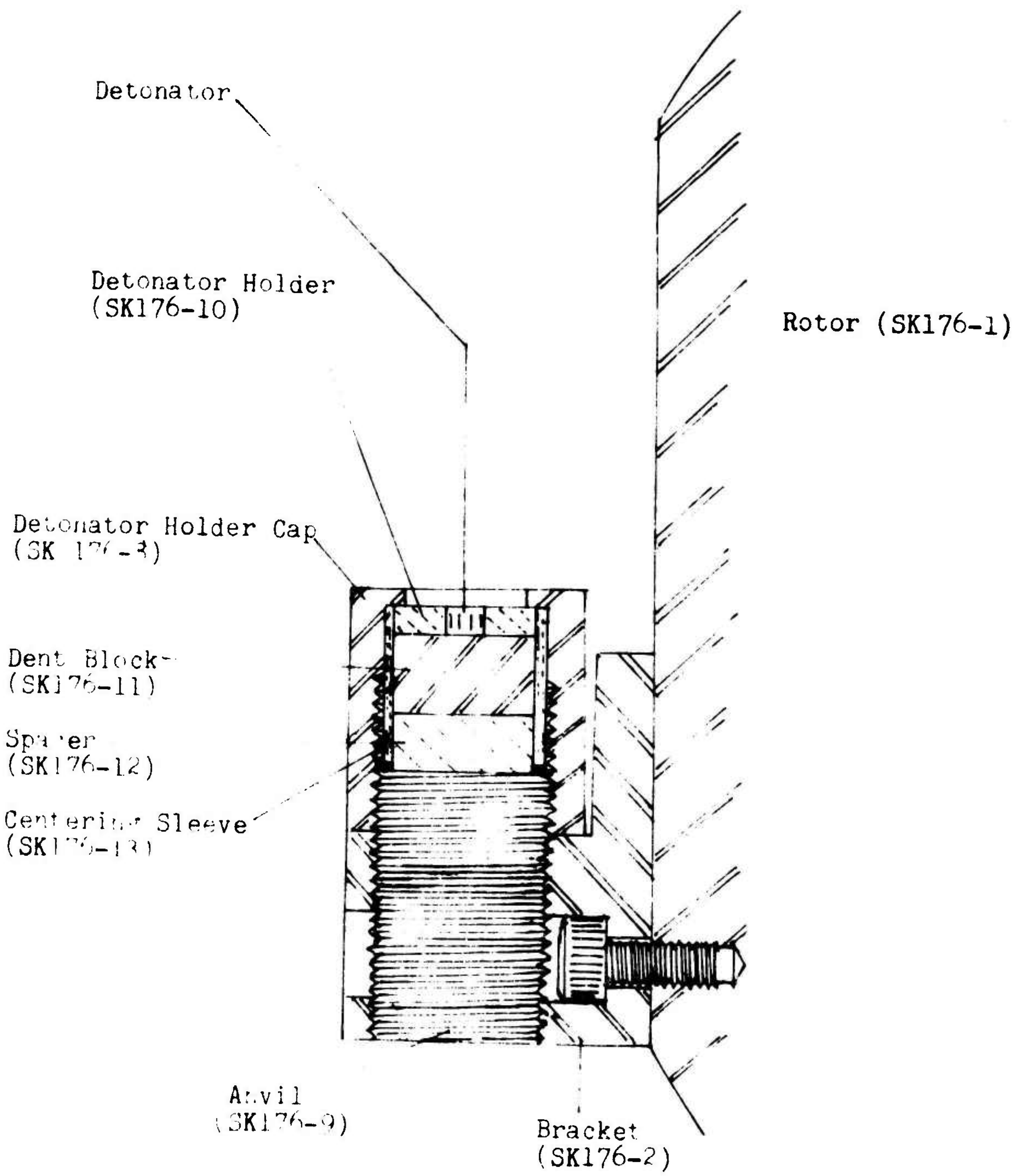
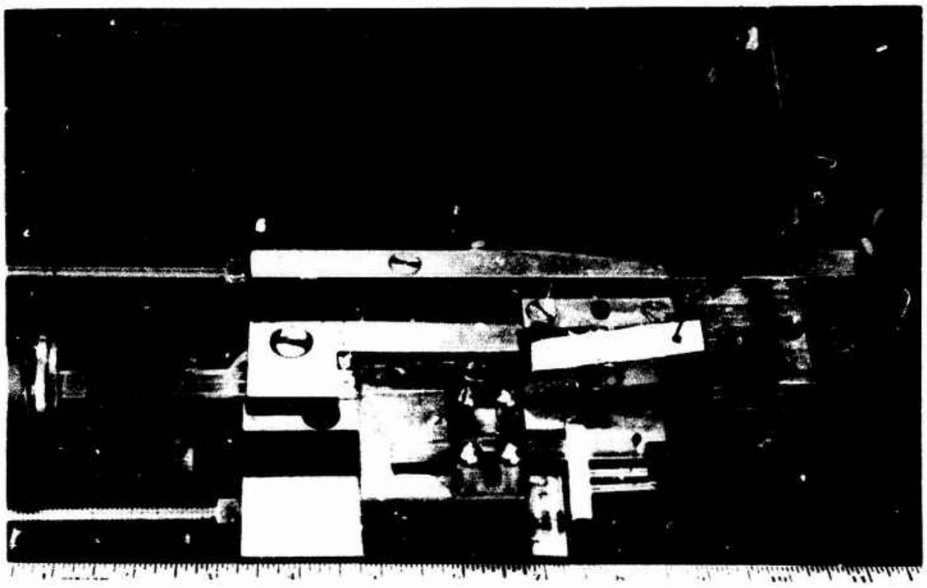
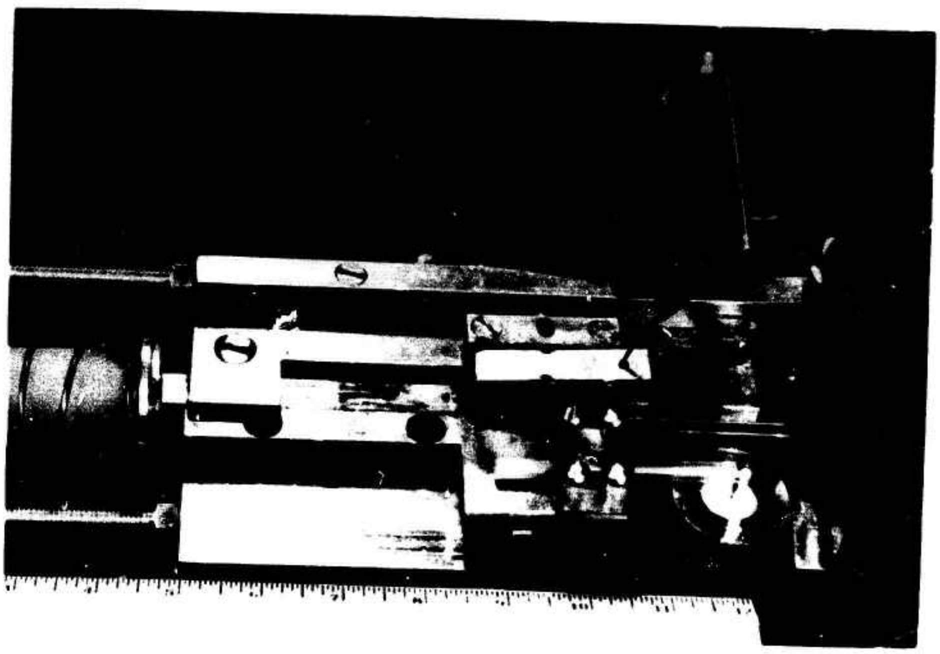


Figure 4 Detonator Mounting



Moving Detonator Stab Sensitivity Tester
close up showing firing pin
located with point over center of detonator
(Step 4 of test sequence (p 18))

Figure 5



Moving Detonator Stab Sensitivity Tester
close up showing firing pin shuttle
latched per step 6 of test sequence (p 18)

Figure 6

centerline of the detonator. This movement is forced by the "driving spring" and controlled by the eccentric at the side of the rotor. The firing pin shuttle is latched in the out-of-line position until the solenoid is actuated (by the operator, when he is satisfied that the velocity is as desired). As may be noted, the solenoid is not directly attached to the latch, but its movement is transmitted, as an unlatching moment, through a cantilever wire spring. The unlatching moment is insufficient to release the latch while the latter is locked by the driving spring. The locking force is relieved each revolution as the eccentric momentarily engages its follower. Thus, the latch releases when the eccentric engages its rider after the solenoid has been actuated and the reciprocating member follows the eccentric bringing the firing pin into alignment just before the detonator collides with and lifts the firing pin.

The displacement (6.266 inches) of the centerline of the detonator from that of the flywheel is such that the detonator path length is exactly one meter so that the rotary velocity of the flywheel in revolutions per second is the impact velocity in meters per second. For measurement of this velocity, a magnetic pickup has been provided and ten (alnico) magnets have been mounted, equally spaced, in a circle near the perifery. The frequency output of the magnetic pickup is, of course, ten time the rotor speed.

The rotor is driven by an AC-DC motor rated at 10,000 rpm (no load) and 1/2 horsepower. The motor, acting through a two stage V-belt reduction, drives the countershaft at an approximate top speed of 750 rpm. A four step cone drive results in top speeds of the rotor of from 375 rpm (6.25 RPS) to 1500 rpm (25 RPS). A variable autotransformer is used to reduce and control the speed of the motor at speeds below the maximum. The output of the autotransformer is rectified and filtered to provide smooth operation of the motor at lower speeds. It was found possible to attain stable speeds as low as one RPS. Thus impact velocities are possible from one to twenty-five meters per second (corresponding with drop heights between about five centimeters (two inches) and thrity-two meters (one hundred feet)).

Four interchangeable driving springs are included. Although this is quite probably more than is necessary, a single driving spring would have been insufficient, since a driving spring capable of accelerating the reciprocating mass at the seventy times gravity necessary to follow the eccentric at its highest speed would affect the lowest velocity more than would be tolerable.

The firing pin is supported, in its carrier, by a head, similar to a nail head, or a shoulder or bushing, until it is lifted by impact with the detonator. Firing pins, of various weights could be machined from rod in the general pattern of common nails with points in accordance with the standard or other desired firing pin point configuration. The length of the pin, from the point to the bottom of the head or shoulder should be 1/2 inch. The firing pin weight can be predetermined by the choice of material and diameter.

For the initial tests of the apparatus, firing pins were made from two available items; steel phonograph needles and "sequin pins." Each of these items has a spherical point of one to three mils radius, but each point was flattened, by means of abrasive, to a flat of 0.005 diameter. The "sequin pins" have suitable heads. For the phonograph needles, short lengths of plastic "shrink" tubing served as support bushings or shoulders. The phonograph needles weighed about 185 milligrams and the "sequin pins" about 26 milligrams. It is suggested that a variety of common articles, including pins and needles of various kinds, wire nails, etc., can be modified to provide firing pins of almost any desired weight and configuration.

The firing pin carrier is a two and a half inch length of plastic (drinking straw - Dairy Queen) tubing 1/4 inch inside diameter. A hole is drilled 0.020 inches larger than the firing pin, about 0.075 inch from the end of the tube at an angle of about 85% from the axis. The reason for this hole size and orientation is the minimization of frictional or other interaction between the firing pin and support after the impact. As the result of the nearly sinusoidal motion of the firing pin carrier, the firing pin tends to lie against the side of the hole toward the end of the carrier. As illustrated in Figure 1 this position of the firing pin results in its being lifted away from the edge of the hole at impact.

A slip ring assembly is provided for instrumentation of detonators to measure functioning times, closure disc or fragment velocities, or transducer pressure-time signatures.

Recommended Test Procedure

The principal purpose of the subject apparatus is the investigation of the interaction of the relationship between firing pin weight and the threshold impact velocity for the initiation of a stab detonator. Such an investigation as contemplated by the writer could include a series of Bruceton tests, each with a firing pin of a different weight (and possibly other characteristics). In each Bruceton test, the variable is the velocity of the impact.

Before starting a test, a sufficient supply of detonators, firing pins, firing pin supports, detonator holders, and witness blocks should be at hand. On the basis of general knowledge regarding the sensitivity of the detonators and the weight of the firing pin, an estimate of the velocity range should be made. (The design of this apparatus makes metric units most convenient for operation, calculations, etc. For purposes of such calculations it may be borne in mind that the equation $K.E. = MV^2/2$ yields energies (KE) in joules when mass (M) is expressed in grams and velocity (V) in meters per second. One joule is equal to 141.5 inch ounces.) The apparatus should be set up for the estimated impact velocity range, approximately as follows:

Velocity Range M/sec	Cone Pulley	Driving Spring
10-25	Fastest	Stiffest
5-15	2nd "	2nd "
3-10	3rd "	3rd "
1-5	Slowest	Softest

At this point, a series of levels for the Bruceton tests should be established. Logarithmic step intervals (0.025 log units, referred to velocity seems to be appropriate) are recommended, since this functional relationship is retained in conversion to energy and since logarithmic (normal or logistic) distribution tend to fit explosive sensitivity data of many kinds. Having set the apparatus up and established a series of test levels, the control box is connected to the test apparatus by means of the cord with the "Jones" plugs, and the control box lead plugged into a 120V 60 cycle outlet. A frequency meter, or interval timer is connected to the "Banana jacks" which are connected, through a mating transformer to the velocity pickup. The test velocity levels should be converted to the units of the frequency meter (keeping in mind that the frequency output (in Hertz) of the velocity pickup is ten times the rotational rate in revolutions per second and that the impact velocity in meters per second is equal to the rotational rate. Before installing any detonators in the apparatus, it is well to try the control system and practice bringing the apparatus up to the speeds indicated by the series of steps. The rotor should be brought up to speed more or less gradually by means of the variable transformer. If the voltage is increased too rapidly the fuze may blow. When each such speed has been attained press the trigger switch and observe the action of the firing pin carrier. Ideally, it should make one excursion to the firing position and, if the switch is released at the right time, return and latch.

For each trial, the sequence is as follows:

1) Install the detonator and witness block as shown in Figure 4.

2) Release the reciprocating component and rotate the flywheel, by hand to the approximate impact position. Figure 5.

3) Insert a reenforcing tube in a firing pin carrier and insert both in the holder. Figure 5

4) Insert a firing pin in the carrier and adjust carrier so that firing pin point is centered with detonator. Lock set screw.

5) Rotate flywheel backwards one half turn, at which point latch will close and remain in clear position. (Figure 6) Close and lock shield.

7) Bring flywheel to speed as indicated by Bruceton procedure.

8) When speed is stabilized, depress trigger switch. Detonator will either fire or not. If detonator fires, record as "fire." If detonator does not fire, examine to assure that firing pin has struck near center. If positive, record as "misfire."

Test Results and Discussion

Two Bruceton tests were performed using firing pin masses of 185 mg and 26 mg. Results were as follows:[a]

α Also included are results of a standard drop weight test with a 1/4 oz drop average of detonation from the same lot as were tested in the moving detonator apparatus.

Firing Pin Mass (mg)	50% Point V(M/S)	50% Point Energy mg	50% Point in oz	Standard Deviation Log Units (ref to energy)	Standard Deviation in oz (approx)
26	12.195	1.933	0.272	0.025	0.02
185	7.82	5.65	0.798	0.031	0.025
1/4 oz[a]			0.688		0.125

It is of interest to compare these data with values predicted using the equations on page 30 of Reference 1. For a 26 mg firing pin, these equations predict a threshold energy of 0.25 inch ounce or 11.65 M/sec. In view of the fact that the equations of Reference 1 are based on data obtained with a minimum firing pin mass of 1.75 grams, this agreement is quite remarkable. In contrast, the predicted threshold conditions for the 185 mg firing pin mass are an energy of 0.34 inch ource or a velocity of 5.1 M/sec, rather poor agreement at best. As to whether this inversion (note that the threshold energy for the 185 mg firing pins is larger than this with the 1/4 oz drop weight) is due to some experimental aberration or the result of a pecularity of response characteristics of the detonator too few data are available to make the distinction. Similar inversions have been observed in earlier investigations.[2,3]

a Also included are results of a standard drop weight test with a 1/4 oz drop average of detonation from the same lot as were tested in the moving detonator apparatus.

The relatively small standard deviations observed seem to the writer to indicate that friction and other random sources of error are negligible in the operation of the apparatus.

CONCLUSIONS AND RECOMMENDATIONS

It may be concluded that the mvoing detonator stab sensitivity apparatus is a potentially useful tool for the investigation of interaction of firing pin dimensions and masses and loading variables as it affects stab sensitivity.

It is recommended that a comprehensive investigation of such interactions be developed and performed for M55 detonators and other stab initiated items. More specific recommendations will be made if requested.

REFERENCES

1. Dalrymple, E. W. and W. E. Voreck, "Development of an Improved Stab Sensitivity Test and Factors Affecting Stab Sensitivity of M-55 Detonators," PATR 4263, Picatinny Arsenal, Dover, New Jersey, June 1972.

2. Fuze Explosive Train Designers Handbook, NOLR 1111, Naval Ordnance Laboratory (White Oak), April 1952.

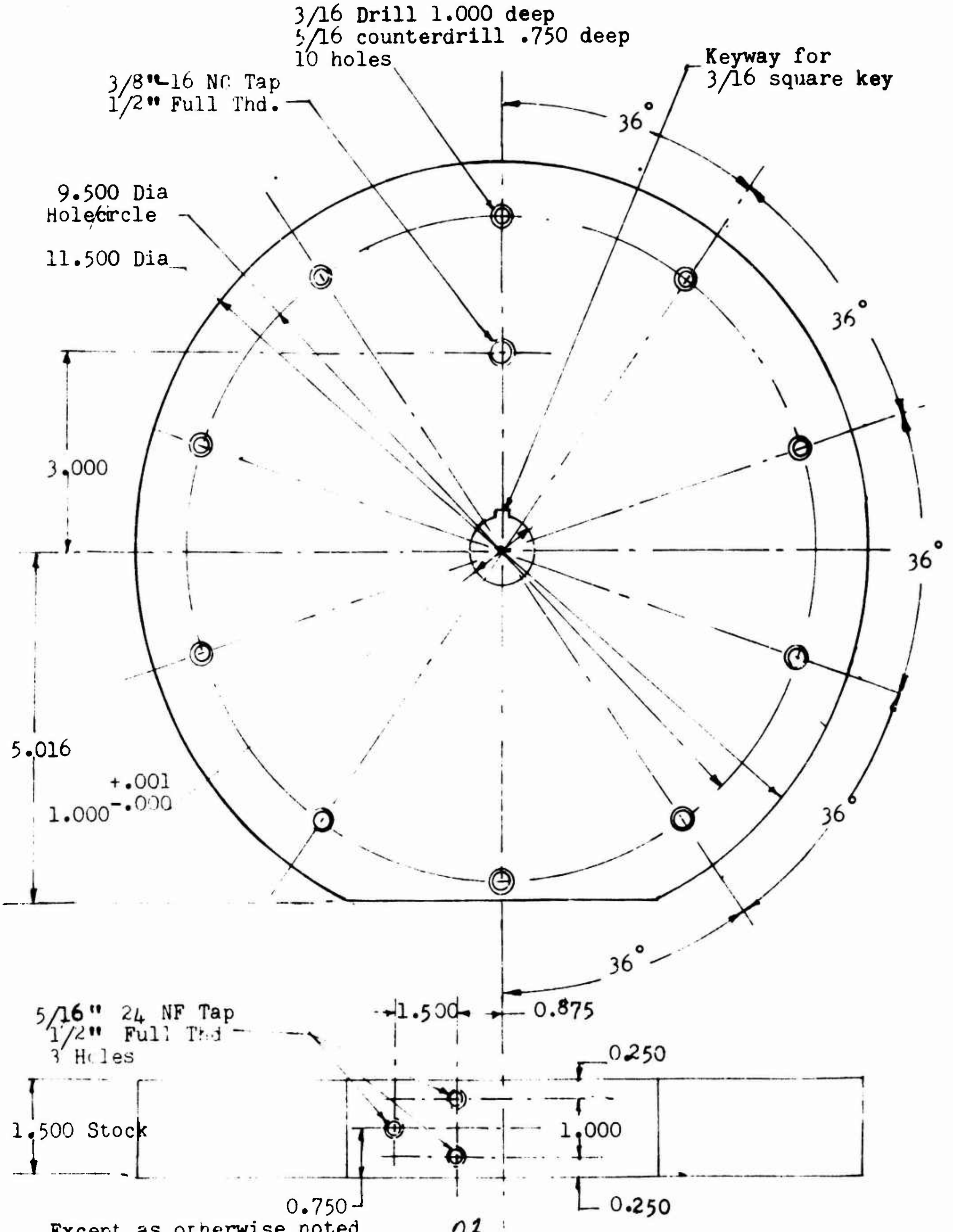
3. Forsyth, A. C., R. C. Ling, and J. V. R. Kaufman, "Effects of Various Parameters on the Stab Sensitivity of Primary Explosives," Navord Report 5746, Proceedings of the Gilbert B. L. Smith Memorial Conference on Explosive Sensitivity, dated September 16 and 17, 1958, page XXXIV-244.

APPENDIX A

DETAIL SKETCHES

Note: The larger parts and some expendible components (destroyed or damaged by detonator output) of the apparatus were procured from subcontractors, after which it was assembled and completed by personnel of this laboratory. Components of the release mechanism and other auxiliaries were fabricated and hand fit, and some of the parts made by subcontractors were modified in the course of assembly and completion. This appendix includes the sketches which were used in procurement from subcontractors as well as a few sketches of expendible components made by this laboratory. Sketches have not been made of hand-fit parts or of catalog items used as components.

Appendix A



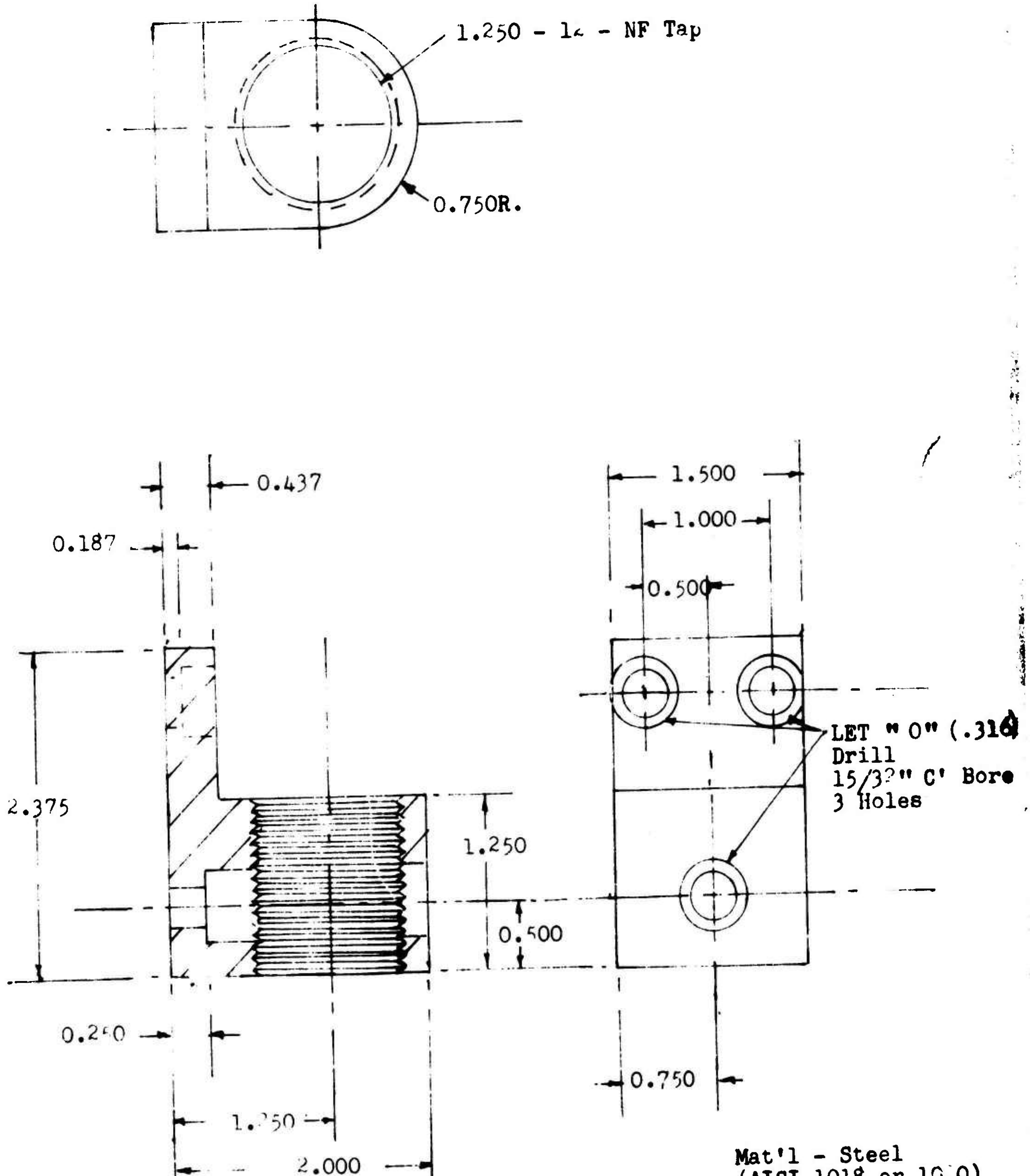
Except as otherwise noted
Tolerances ± .005

Rotor

Mat'l
Steel (AISI 1020)
Cold Finished

SK 176-1

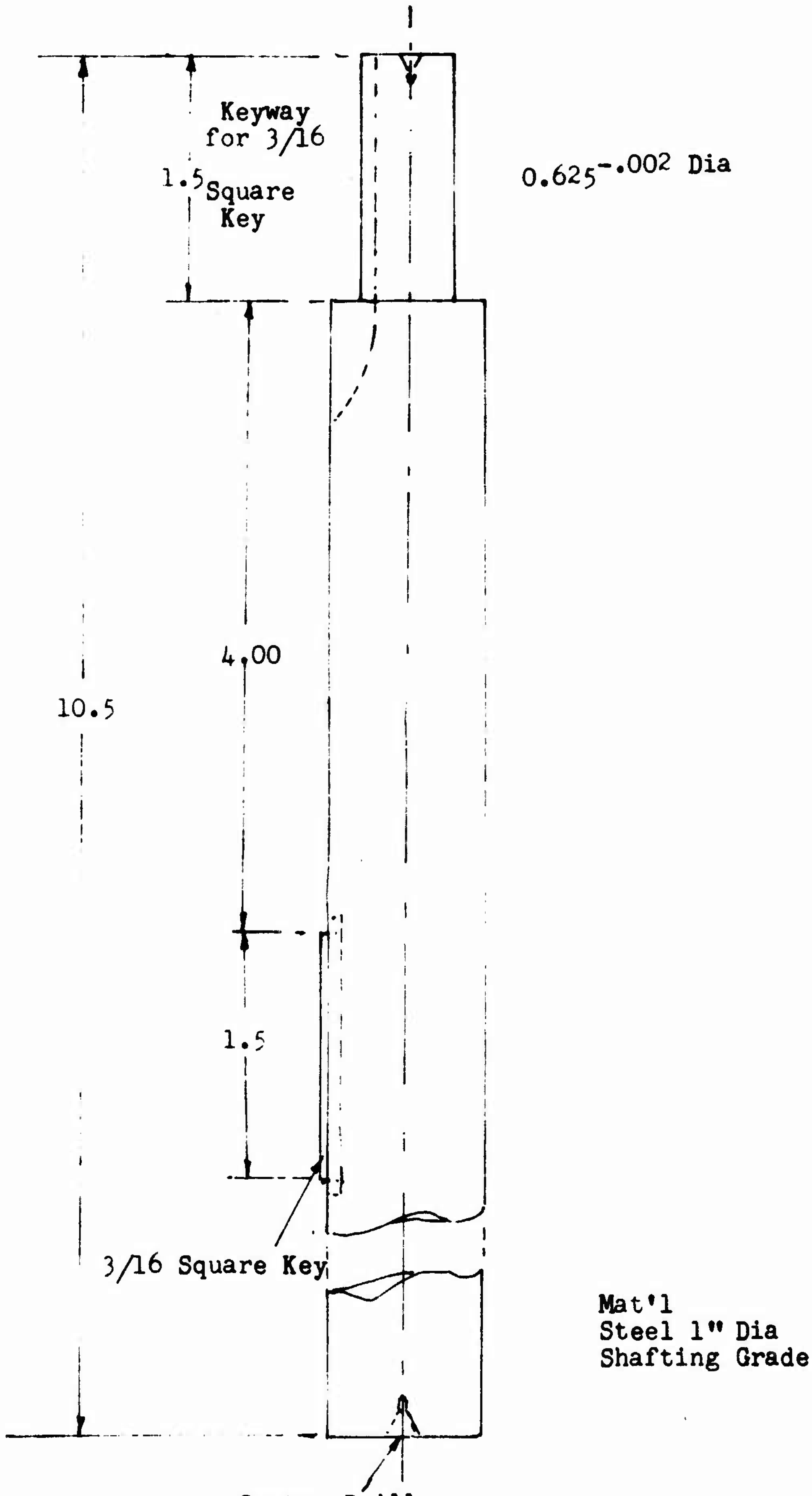
Appendix A



Mat'l - Steel
(AISI 1018 or 10?0)

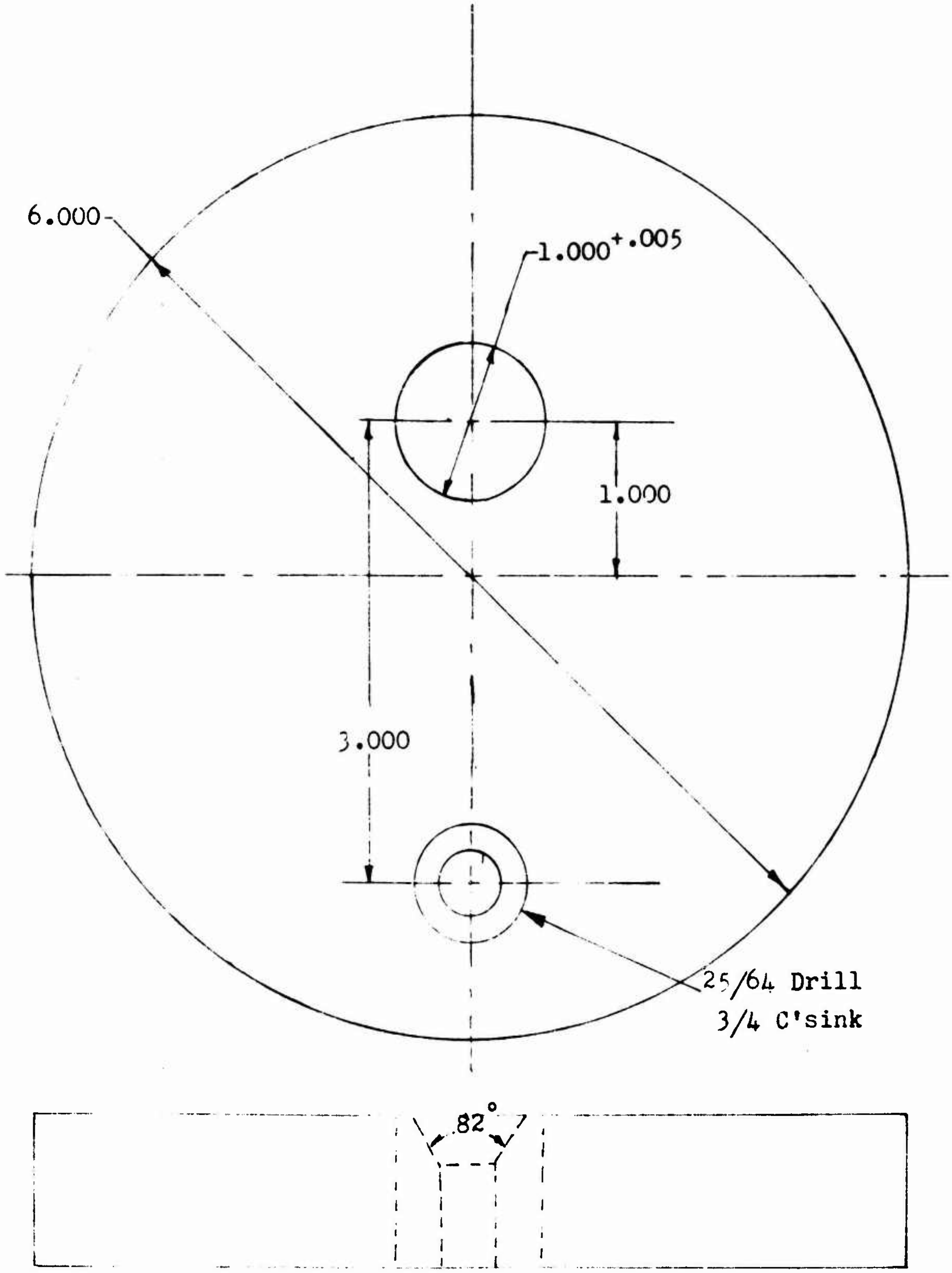
Bracket

SK 176-2



Shaft 25 SK 176-3

Appendix A

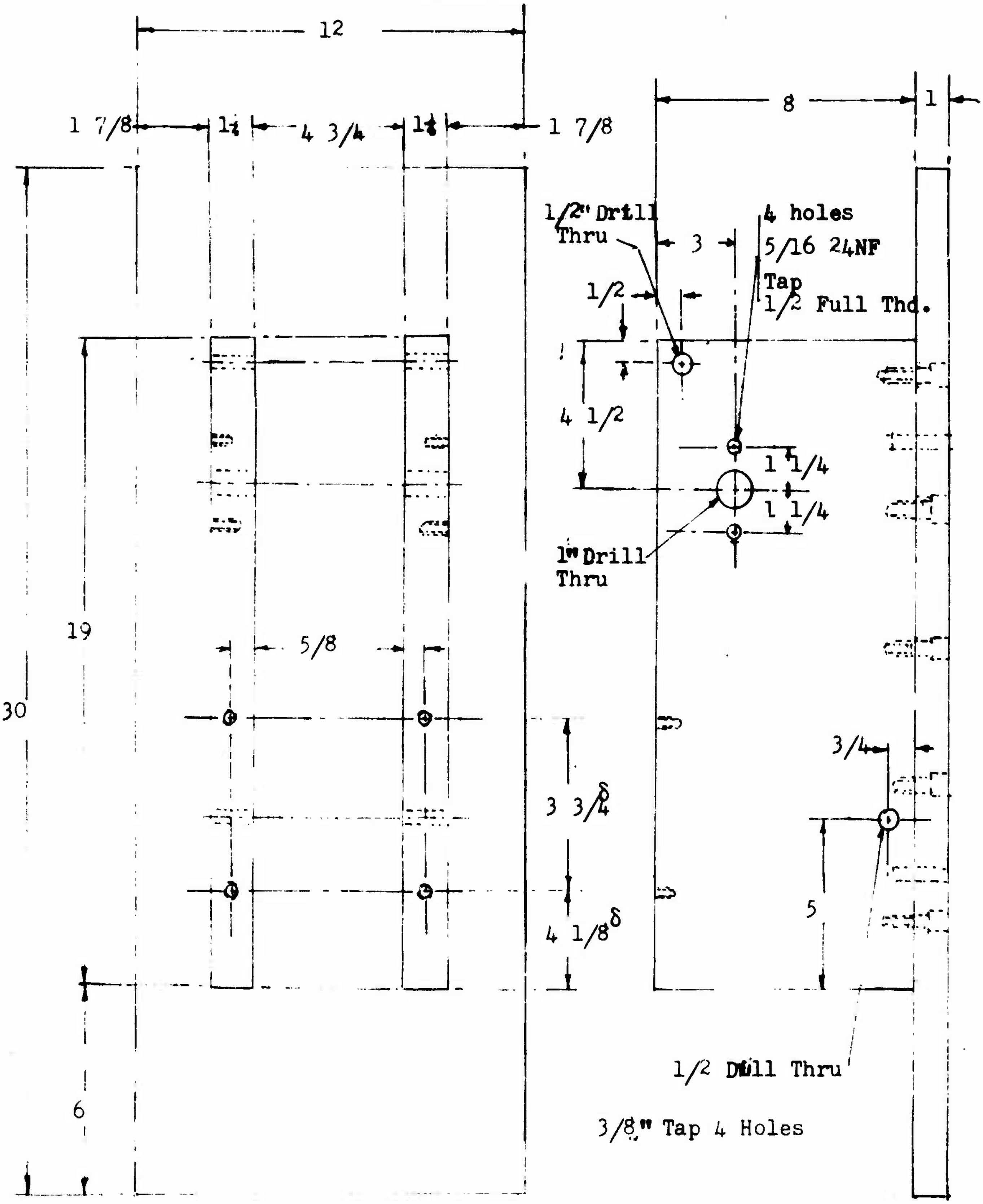


Mat'l
Liner Base Phenolic

Cam

SK 176-4

Appendix A

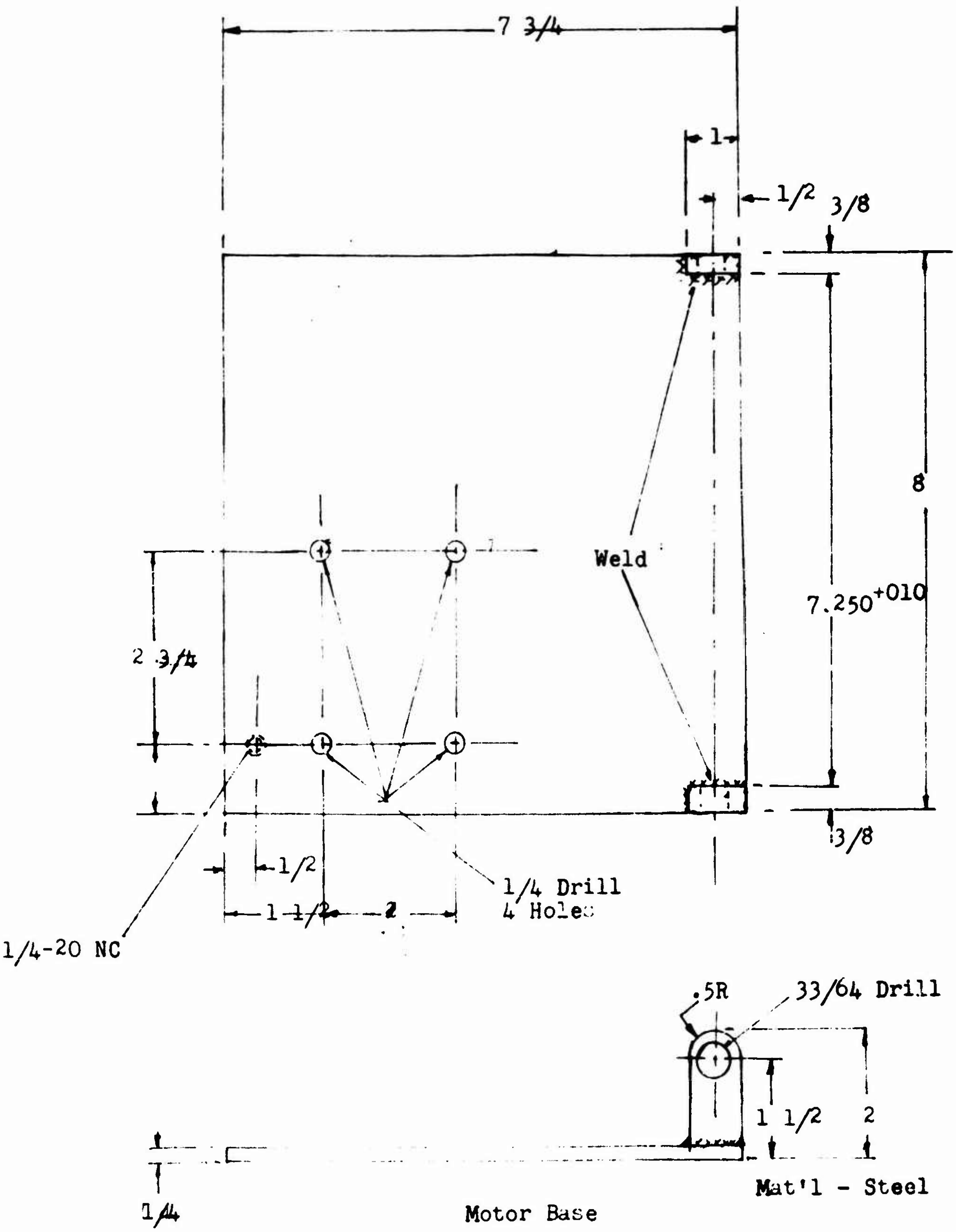


δ not drawn to scale

Base

SK 176-5

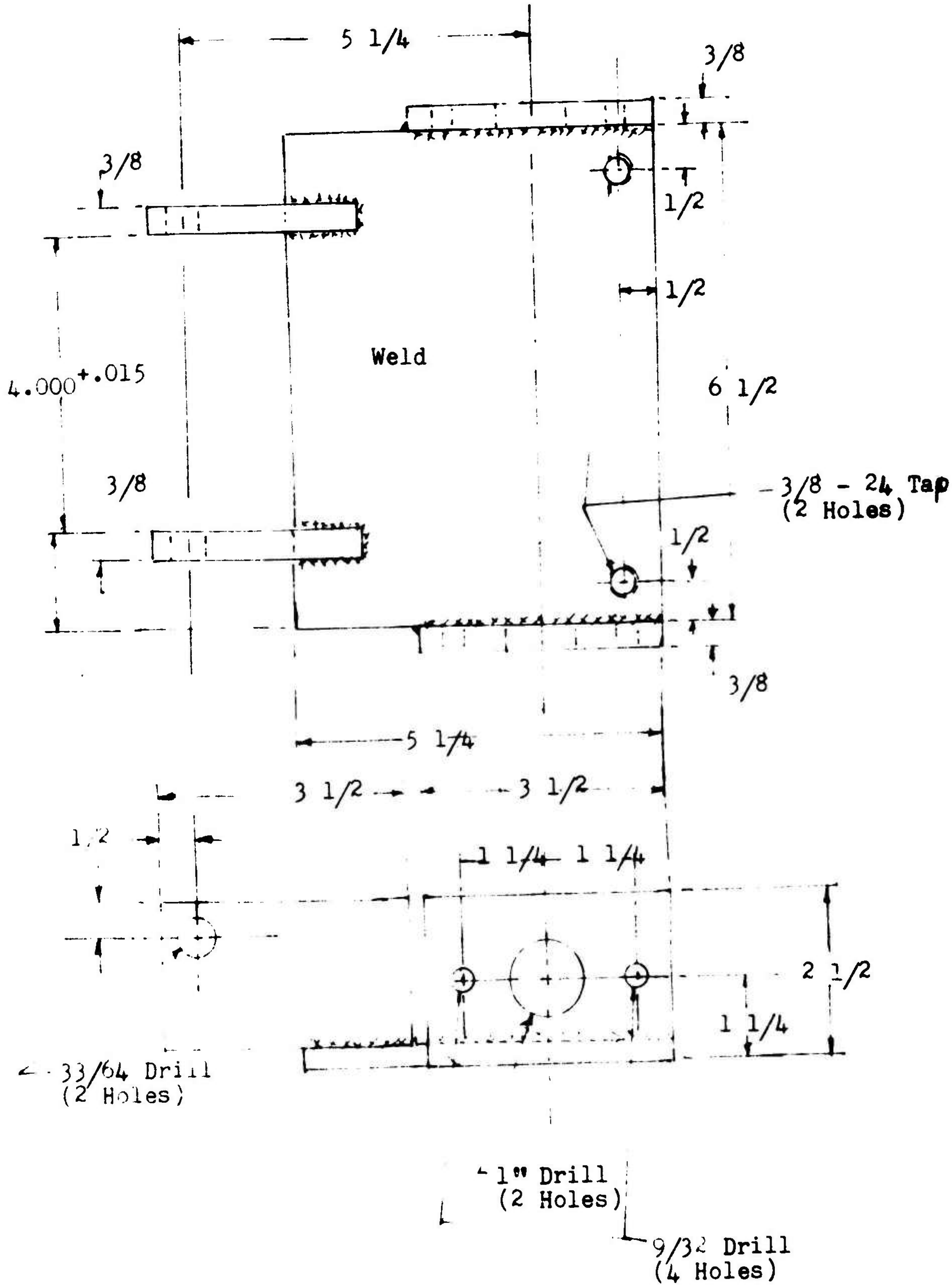
Appendix A



Motor Base

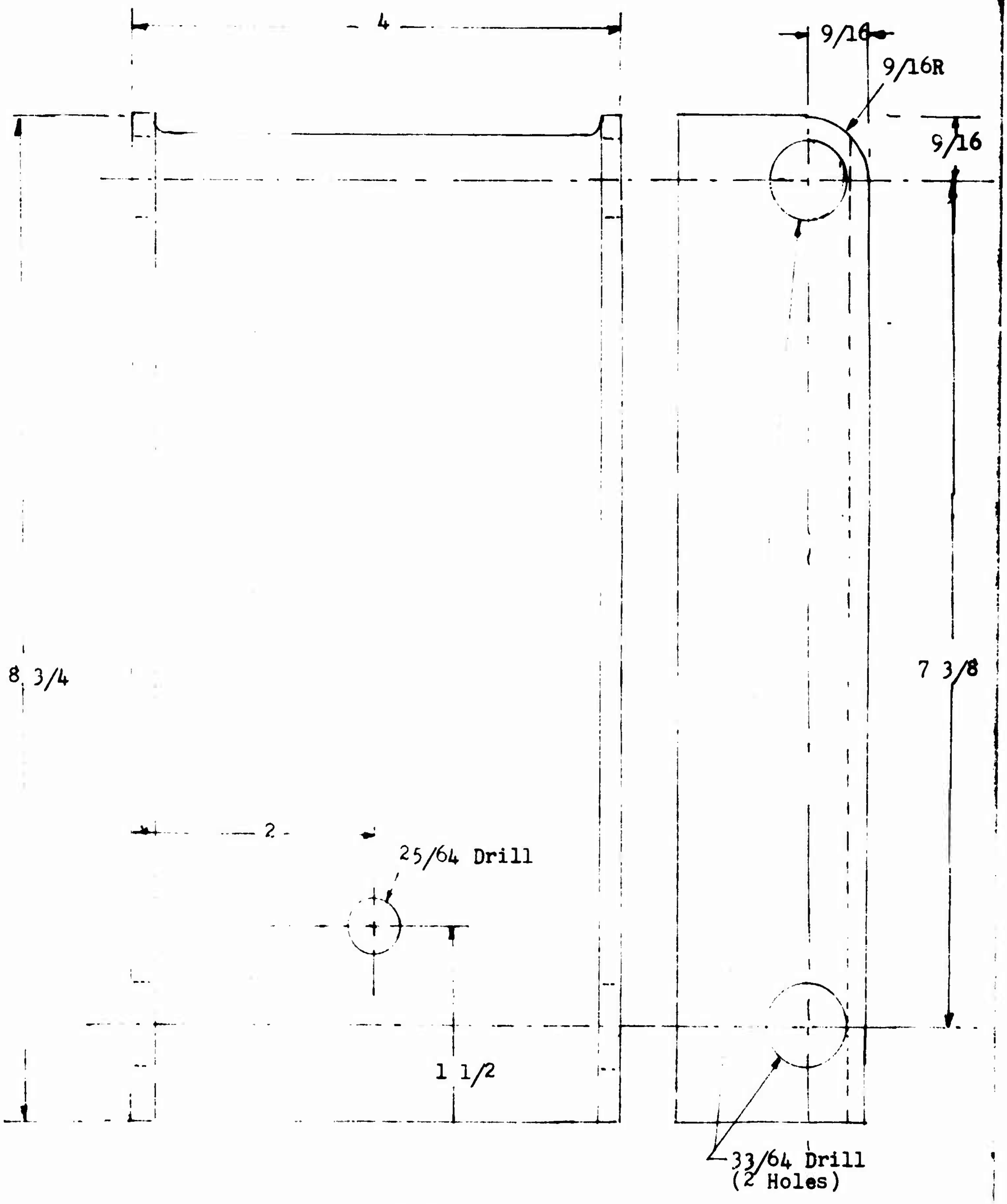
SK 176-6

Appendix A



Countershaft Bracket

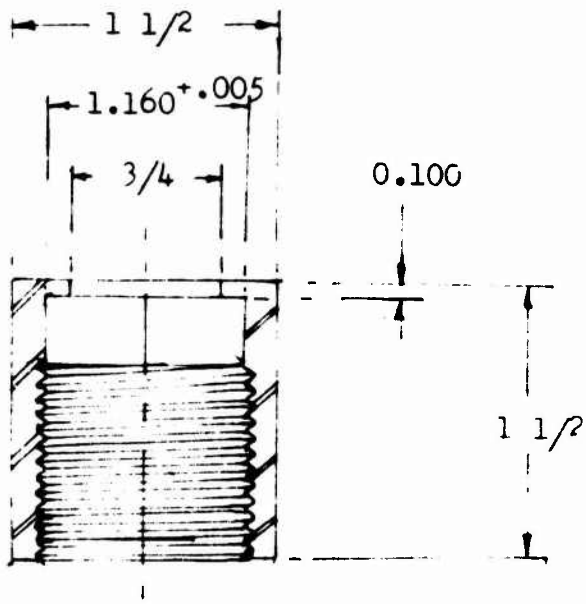
SK 176-7



Countershaft Bracket Link

SK 176-7L

Appendix A



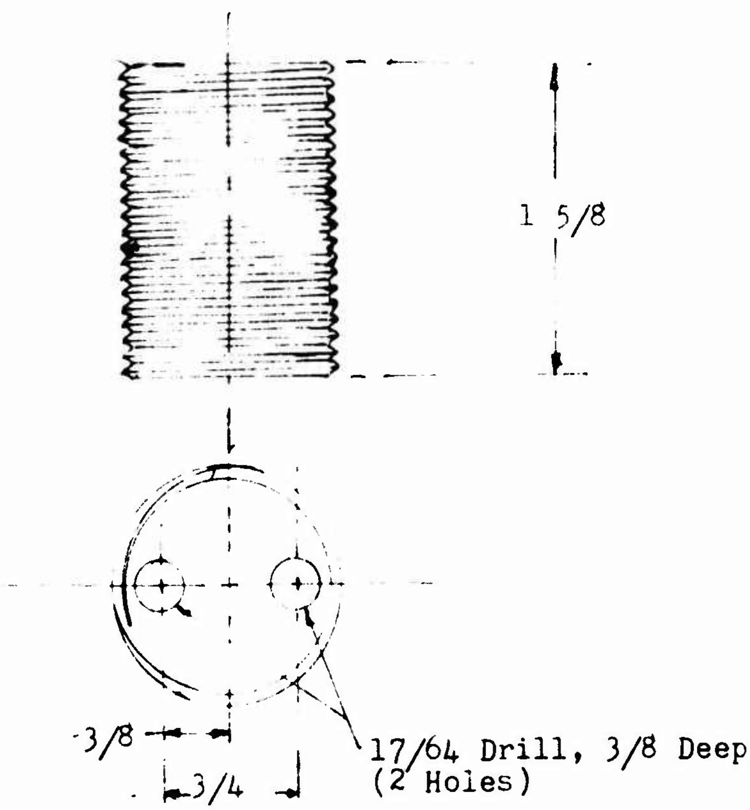
1 1/4 - 12 Tap
0.500 Full Thd.

Detonator Holder Cap

Mat'l
Cold Rolled Steel

SK 176-8

Appendix A

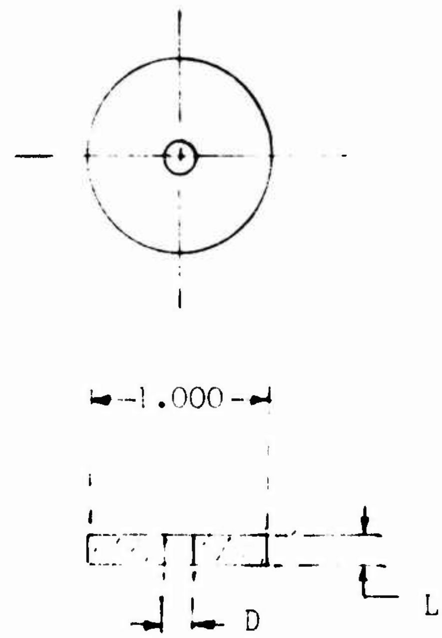


Mat'l
1 1/4 - 12 Threaded Rod

Anvil

SK 176-9

Appendix A



L Length of detonator (see table)
D Diameter of detonator (see table)

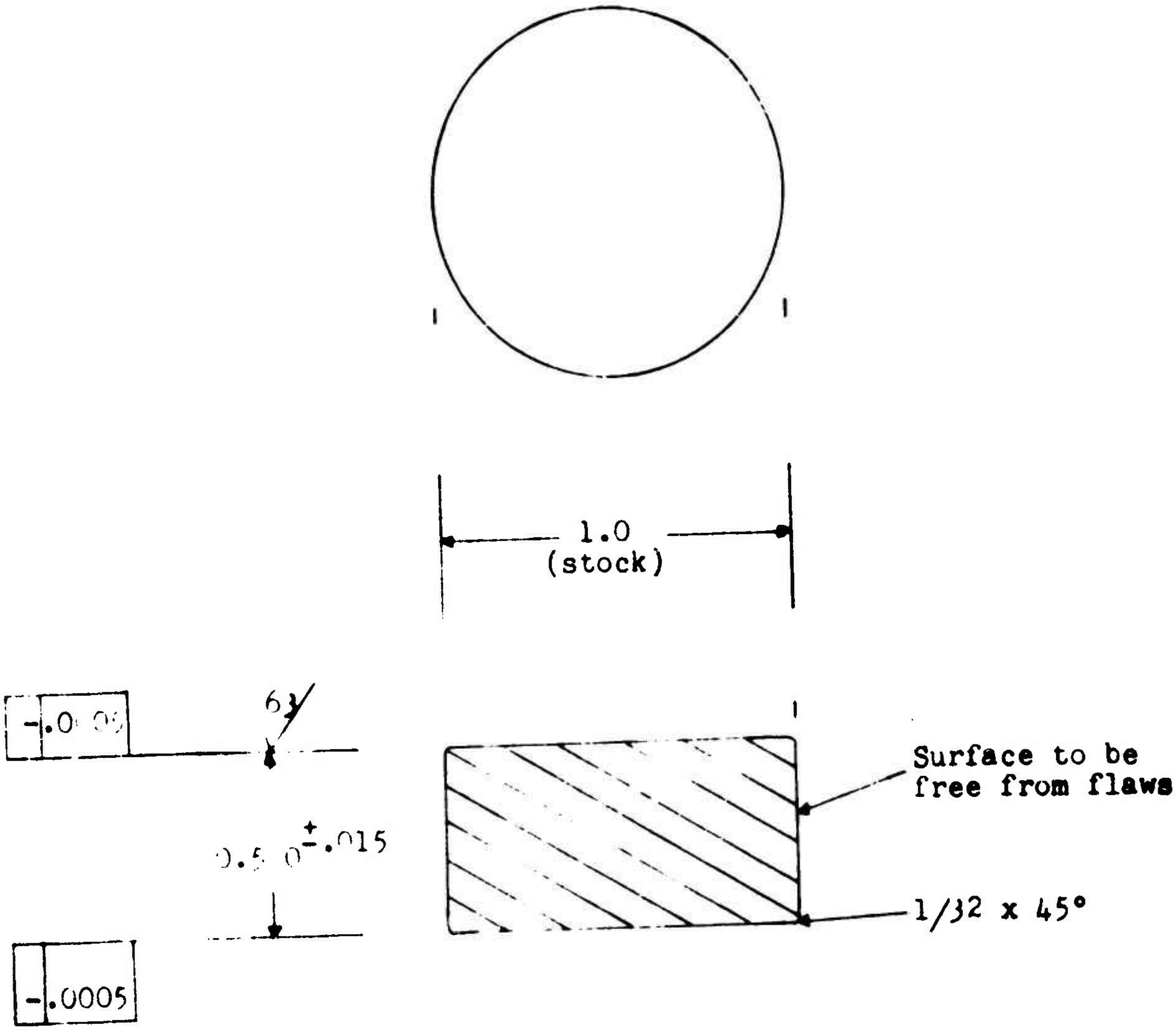
De[illegible] D[illegible]
M [illegible]

Mat'l [illegible]
De[illegible]

Holder, Detonator

 SK176-10

Appendix A

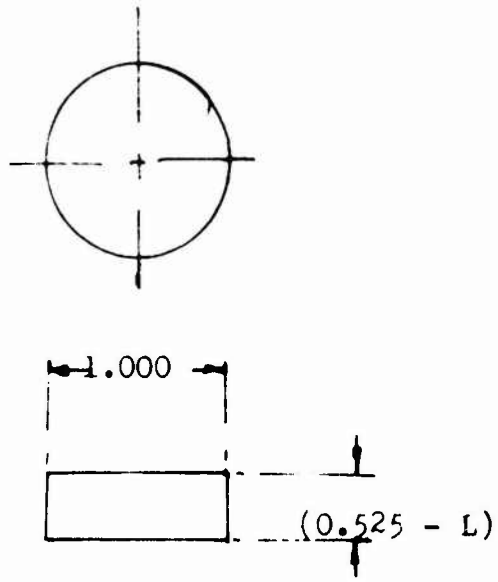


Material: Steel, 1018
Or, where "hard" blocks are required:
Steel, Drill Rod
Hardened and Drawn
to Rockwell C49-53

Block, Dent

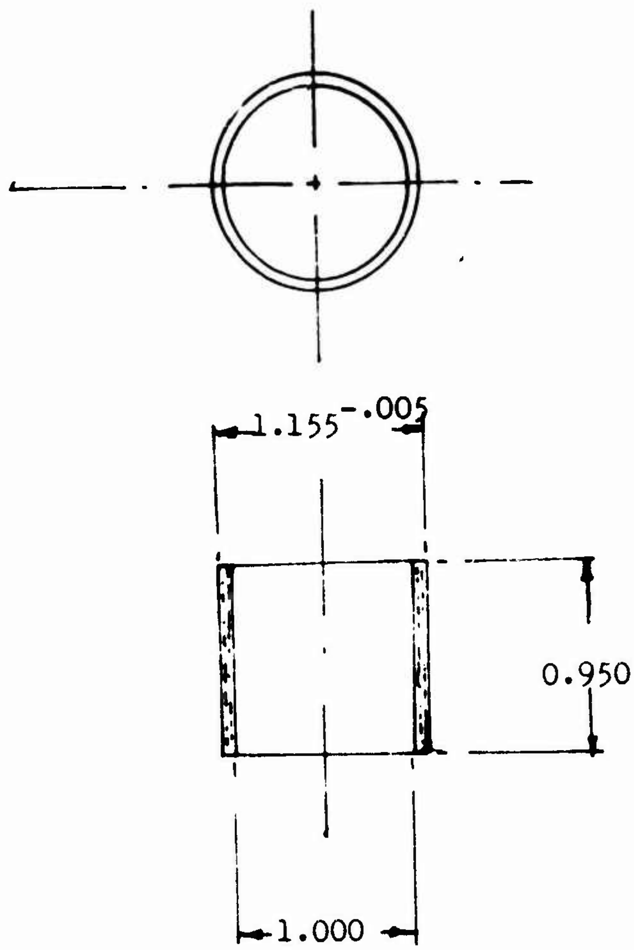
SK176-11

Appendix A



L = Length of detonator (See SK 176-10)

Appendix A



Mat'l
Polyethylene tubing
1.25 O.D. x 1.000 I.D.

Sleeve, Centering

SK 176-13