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Report 2388

CONVERSION OF ROME PLOW, KGBA7E CLEARING BLADE, TO MINEFIELD-CLEARING PLOW; DESIGN DATA PACKAGE

August 1983

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U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND MERADCOM

U.S. ARMY MOBILITY EQUIPMENT
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This final report describes the design effort, from parameter establishment to prototype design, required for the conversion of the KGBA7E Rome Plow to a minefield-clearing plow as requested by the Armor Engineer Board, Fort Knox, Kentucky.

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PREFACE

The Engineer Support Laboratory (Systems and Engineering Division, Engineering Branch) of USAMERADCOM was requested to provide technical assistance to the Armor Engineer Board, Fort Knox, in the design of a modification kit for the KGBA7E Rome Plow which would adapt this system for minefield-clearing capabilities. Adapting the Rome Plow will not result in a plow as efficient as one specifically designed for mine clearing; however, MERADCOM agreed to assist the Armor Engineer Board in this effort. In response to this request, the author was tasked to generate a baseline design package from which a preliminary prototype could be fabricated. This report documents the scope of the work performed and the design data generated which presently serve as a Technical Data Package for the item fabricated at Fort Knox. Sections I through III summarize the design effort of the author from 26 through 28 October 1981 and implemented at Fort Knox. The remaining sections summarize the follow-up effort performed subsequently by MERADCOM.

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ILLUSTRATIONS

CONVERSION OF ROME PLOW, KGBA7E CLEARING BLADE, TO MINEFIELD-CLEARING PLOW; DESIGN DATA PACKAGE

I. BACKGROUND

The Armor Engineer Board, Fort Knox, requested the Engineer Support Laboratory of MERADCOM to provide the services of a design engineer who could, within a short period of time, generate a workable design to convert the KGBA7E Rome Clearing Blade used for heavy-duty forestry operations (see Appendix A) into a minefield-clearing plow. The following constraints were set forth by the Board to serve as a guide, or baseline, for the design effort:

- Minimum tine or tooth depth = 6 inches.
- Maximum spacing between teeth = 4.75 inches.
- Provision of a flotation device to keep the plow from "digging in."

Upon arrival at Fort Knox, the author of this report found no preliminary design effort had taken place and that the full effort was to be accomplished by MERADCOM. In addition, this was to be a current and future effort involving several distinct and related phases:

- **Phase A** — Modify the existing plow (KGBA7E) to accept mine-excavating teeth (tines) and a flotation device.
- **Phase B** — Widen the existing plow to 5.5 m (18 ft 0.516 in.) and include the modifications as described by Phase A.
- **Phase C** — Adapt Phase B to the M60 series tank.
- **Phase D** — Upgrade and finalize the existing designs to enable the system to withstand appropriate mine blast effects.

Phases A and B, as described above, are to be utilized on existing Army bulldozers; Phase C involves the M60 tank and implies frontline use. Recent directives from the US Army Engineer School, however, indicate a behind-the-lines, non-offensive mission for the Rome Plow System. Thus, speed and heavy armor protection are not requirements for the prime mover.

In addition to the above requirements and constraints the designer or design team leader must be aware of the resources available to him in order to determine the full scope of his effort and in what direction he is to proceed. A cursory survey of what was needed, why it was needed, and the resources available revealed the following:

a. In order to generate a valid and realistic design, a team effort is required—not a one-man strike force. For the most part, this capability was not available at Fort Knox. That is not to say that the personnel are not engineering oriented; indeed, they are. However, a venture such as this requires designers with experience and expertise in related areas of mine clearing and earth moving.

b. The success of any design is based on three aspects: sound engineering practices, past experience, and a good file of technical data and historical background. Without the history resources immediately available (as at MERADCOM), much design effort is usually expended in "reinventing the wheel." In addition to the historical background, a true design analysis requires a great deal of multi-variable calculations. A computer is available to this author; however, the simulations and necessary programs are not.

c. A "begin-fabrication" date of 30 October 1981 was established, and as this directly relates to material availability, a survey of in-hourse material was conducted. Obviously, the material required must possess excellent strength (100+ K/in.^{2} yield) and hardness (HRC of 20+) characteristics and yet possess reasonable ductility. In-house supplies constituted steel sheets in sufficient quantity but of marginal (at best) thickness (up to 1 in.) and sub-standard mechanical propeities for their intended usage (AISI 1020 to 1040). Thus, it was apparent that the start date of 30 October 1981 would slip markedly.

d. While the welding capability of Fort Knox is adequate to facilitate the necessary assembly of the modification, the overall fabrication facilities are limited and would certainly be overtaxed by such an undertaking. The end result would be a contractor effort which must be closely monitored and which could produce undo delays.

There were some apparent misgivings in dealing with the utilization of a "skid shoe" as a flotation device, as personnel of the Armor Engineer Board strongly suggested utilization of the clearing blade itself for flotation. This type of approach has one major strong point over the skid shoe and, as such, merits consideration. As a rule, skid shoes are mounted external to the plows making the shoes highly subject to damage by an inadvertent mine detonation causing the plow to "dig in," possibly haulting the prime mover in its tracks. Another consideration is that, for the most part, a bulldozer will serve as the prime mover. A dozer has excellent control over plow depth and thus would not need as heavy a counter-reactive surface as would M60, which has little to no such control. This, however, is a relatively new approach with little historic documentation; thus an alternate approach using the skid shoe concept should be kept in mind.

II. DESIGN DATA AND ASSUMPTIONS

As accurately as could be determined from field measurements and all available data, the overall configuration of the KGBA7E Rome Clearing Plow is as shown by Figure 1. Note that this in no way attempts to describe the internal configuration which must be known if the blade is to be extended to clear a 5.5-m path.

As described by cognizant staff members of the Armor Engineer Board, constraints imposed by modern mine configurations (both threat and friendly) suggest a tine-to-tine configuration as depicted in Figure 2. From this configuration the following design base may be determined:

$$t = \text{Tine thickness}$$

$$= 6.00 \text{ in.} - 4.75 \text{ in.}$$

$$= 1.25 \text{ in.}$$

By Armor Engineer Board direction, the tine must engage and direct upward a mine located 6 in. below the ground's surface (Figure 3). This author feels the tip depth required should be 12 in., which is selected as the required tip depth.

The angle of attack (see Figures 4 and 5) should be within the range of 30° to 45° as measured from the ground plane to the attack surface of the tine. The most practical angle must be determined through a review of historical data files.

Material selection should be a high-grade alloy steel, such as T-1 manufactured by U.S. Steel. This steel combines high strength and moderate hardness with a reasonable ductility and it retains most of these properties at cold temperatures. In addition, this alloy, as opposed to other fine alloy steels, requires no heat treating to achieve these properties and it readily welds to almost all steels.

Regardless of the angle to which the blade's forward edge is set with respect to a perpendicular in the direction of travel, the tines should be parallel to the direction of travel (Figure 6). If not, a great deal of energy will be expended by the prime mover to keep on the right path rather than in the direction the tines are pointed.

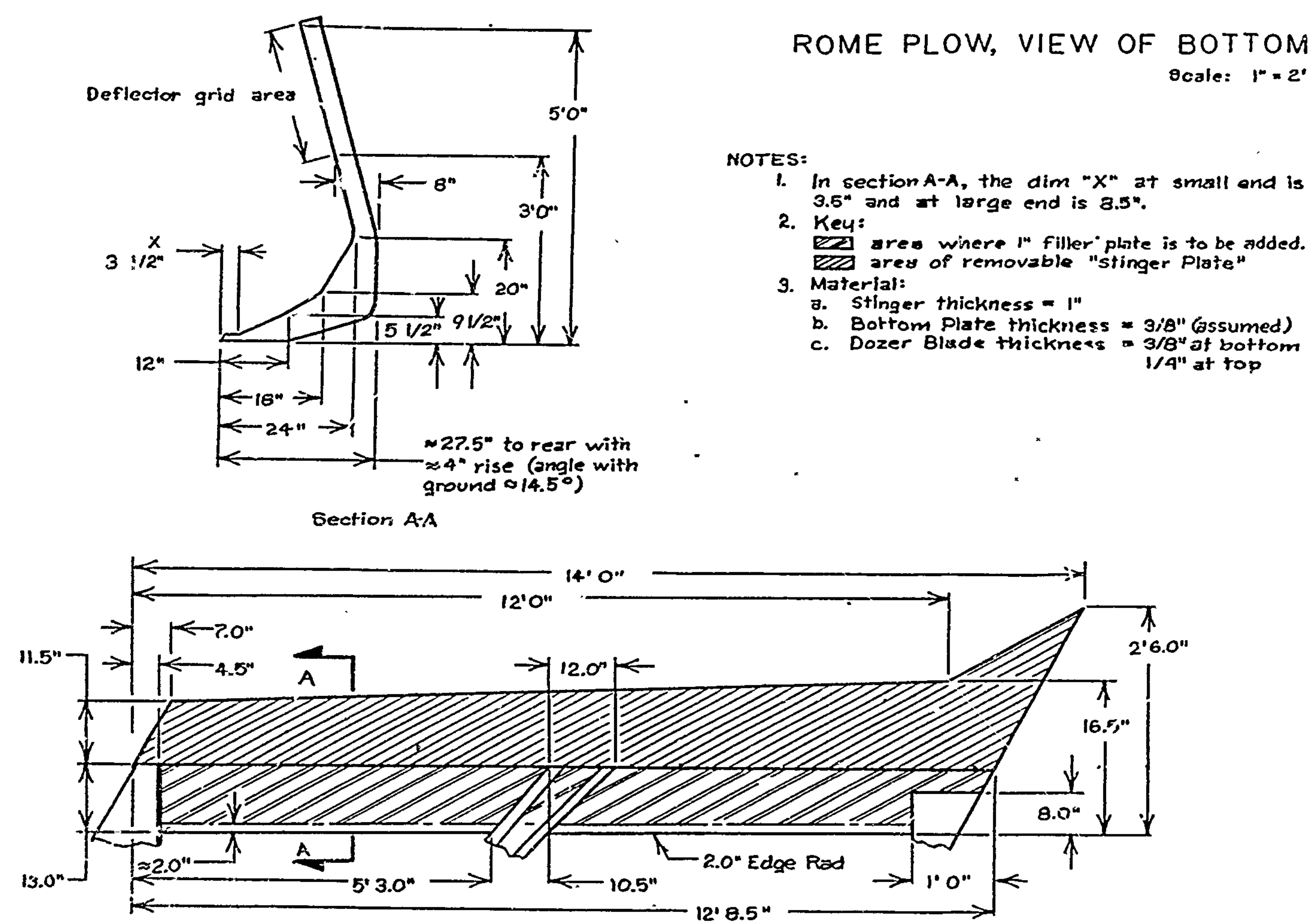


Figure 1. Rome Plow, bottom view.

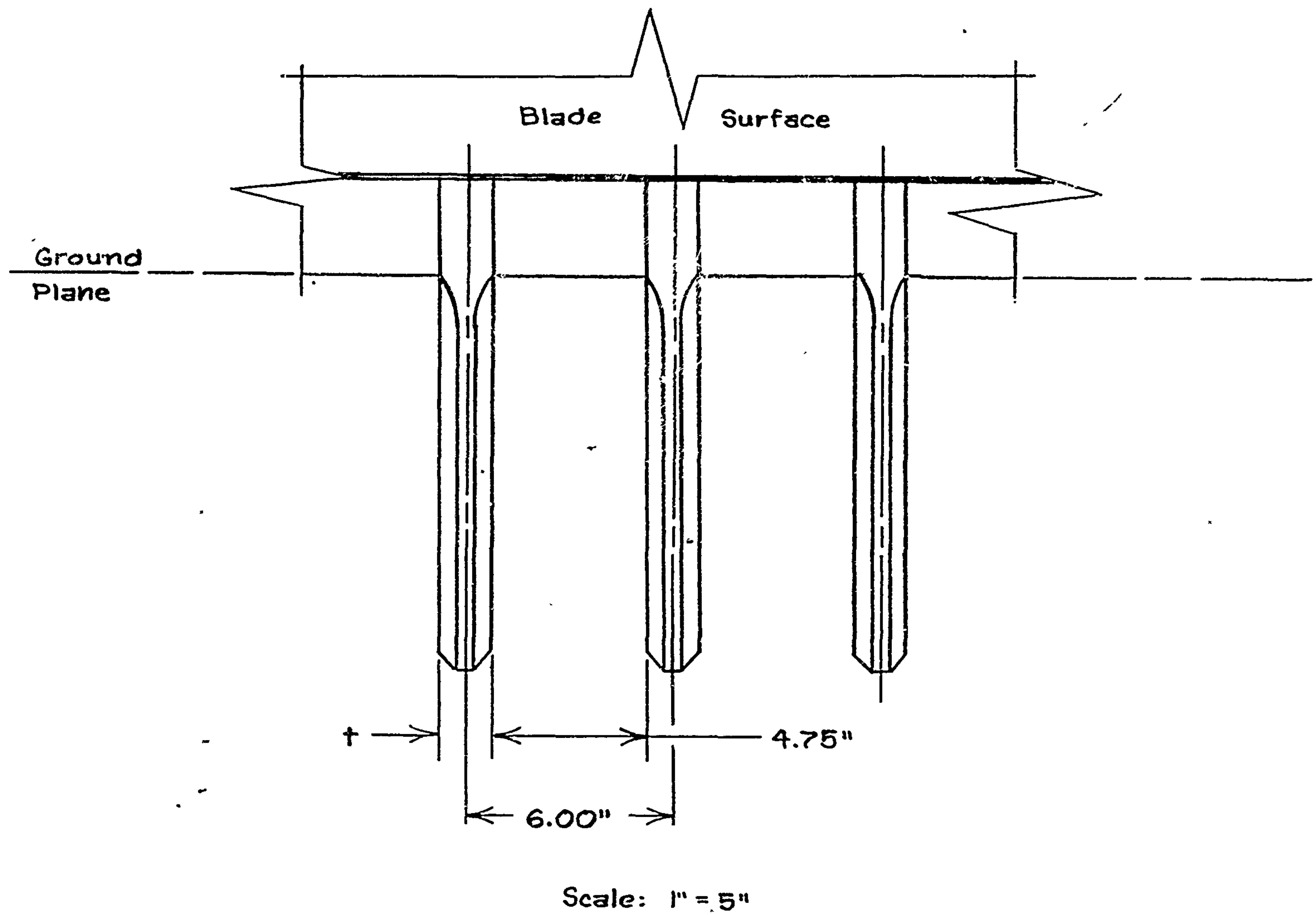


Figure 2. Configuration, tine-to-tine.

III. PRELIMINARY DESIGN EFFORT

Based on assumptions and recommendations presented later in Section IV, a preliminary or baseline design was generated in an effort to get this program off dead center. It should be noted that this was an initial effort involving only two full working days and based strictly on the experience, judgement, and plain "gut feeling of the author." However, it was a maximum effort for the time alloted. The design does not lack refinement (producing good strength/weight ratios and, thereby, cost effectiveness); however, there are questions which should be answered prior to finalization of this design package. Some of these questions can be answered only through field trials; others can be solved empirically. It is rare that a baseline design results in a fielded item. Some of the more pertinent questions are:

a. What effect does the "pull down" caused by the tines have on the plow; i.e., is the flotation device sufficient to counteract these forces?

b. What effect does the resistance caused by the modification have on the supporting push rods, frame, and pins; i.e., do they need to be modified?

c. What effect does the angle of attack (see Figures 4 and 5) have on the system?

d. What effect does the modified plow have on the mobility of the prime mover (HD16)?

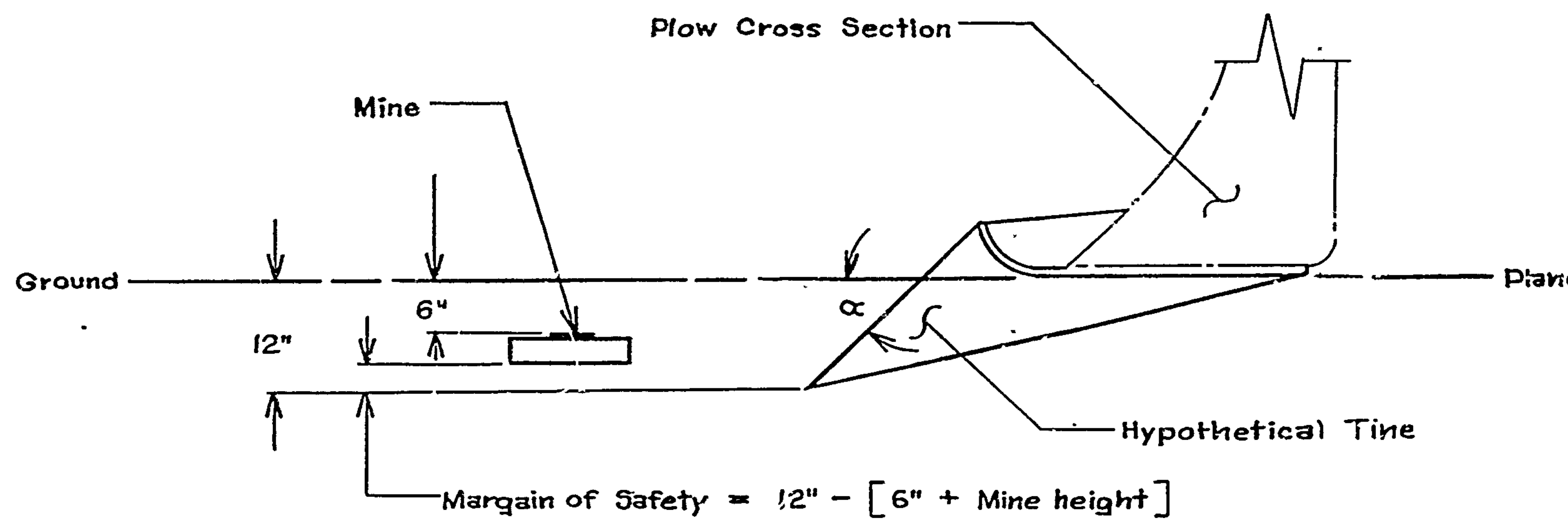
e. What effect do varied soiled properties and irregularities have on the attack surface of the tines? Is surface wear and deterioration a significant problem? The steel selected (T-1) is fairly hard (HRC > 21), but it may be somewhat soft for this application. If so, it is suggested that a flame spraying of tungsten or carbide (Eutectic Process) over the attack surface be done. This produces a permanent finish which can be applied easily.

With these thoughts in mind, the Armor Engineer Board was presented an initial design package and a step-by-step method of modification prior to the departure of this author from Fort Knox. This modification package was based on a 23-tine arrangement as shown in Figure 6 and as set forth as follows:

a. Remove by flame cutting that portion of the "Stinger" which extends forward of the plow/stinger interface. See Figure 7.

b. Add buffer plates (Figure 8). As is seen in Figure 8, eight separate plates (labeled A_R through H_R) are utilized in this assembly, providing a maximum weld interface between the buffer and the existing plow. All plates are 1-in. stock. Weld details are also covered by the same figure.

c. Add 23 tines in accordance with those guidelines set forth by Figure 6. Note that the direction and spacing are extremely critical to the design. Tine design is based on those guidelines set forth by Figures 9a and 9b. Basic tolerances for these dimensions are ±0.06 in. Weld details for tine/plow interface are covered in Figure 9b.



Scale: 1" = 20"

Figure 3. Tine/mine interface.

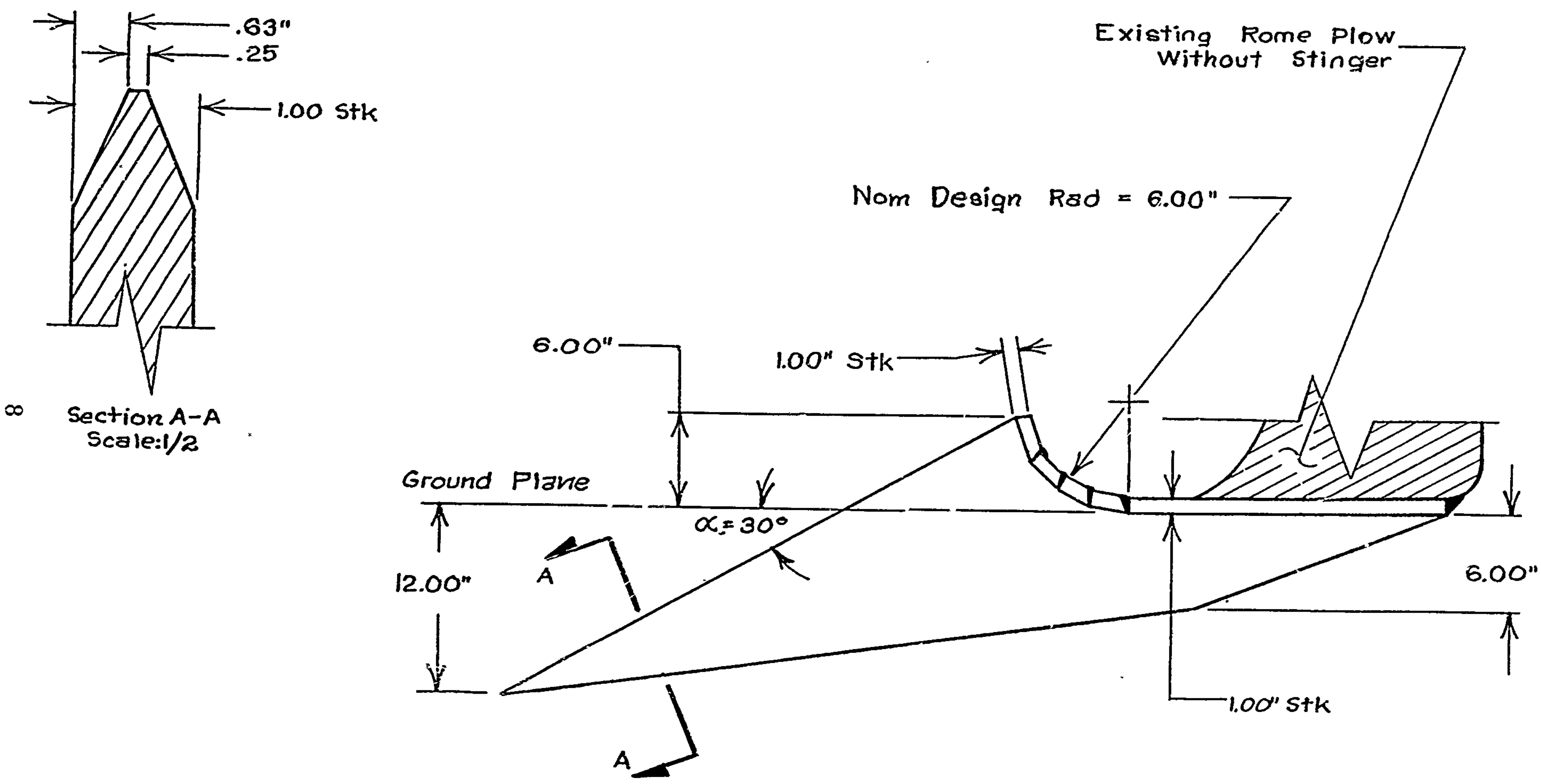


Figure 4. 30°α Configuration.

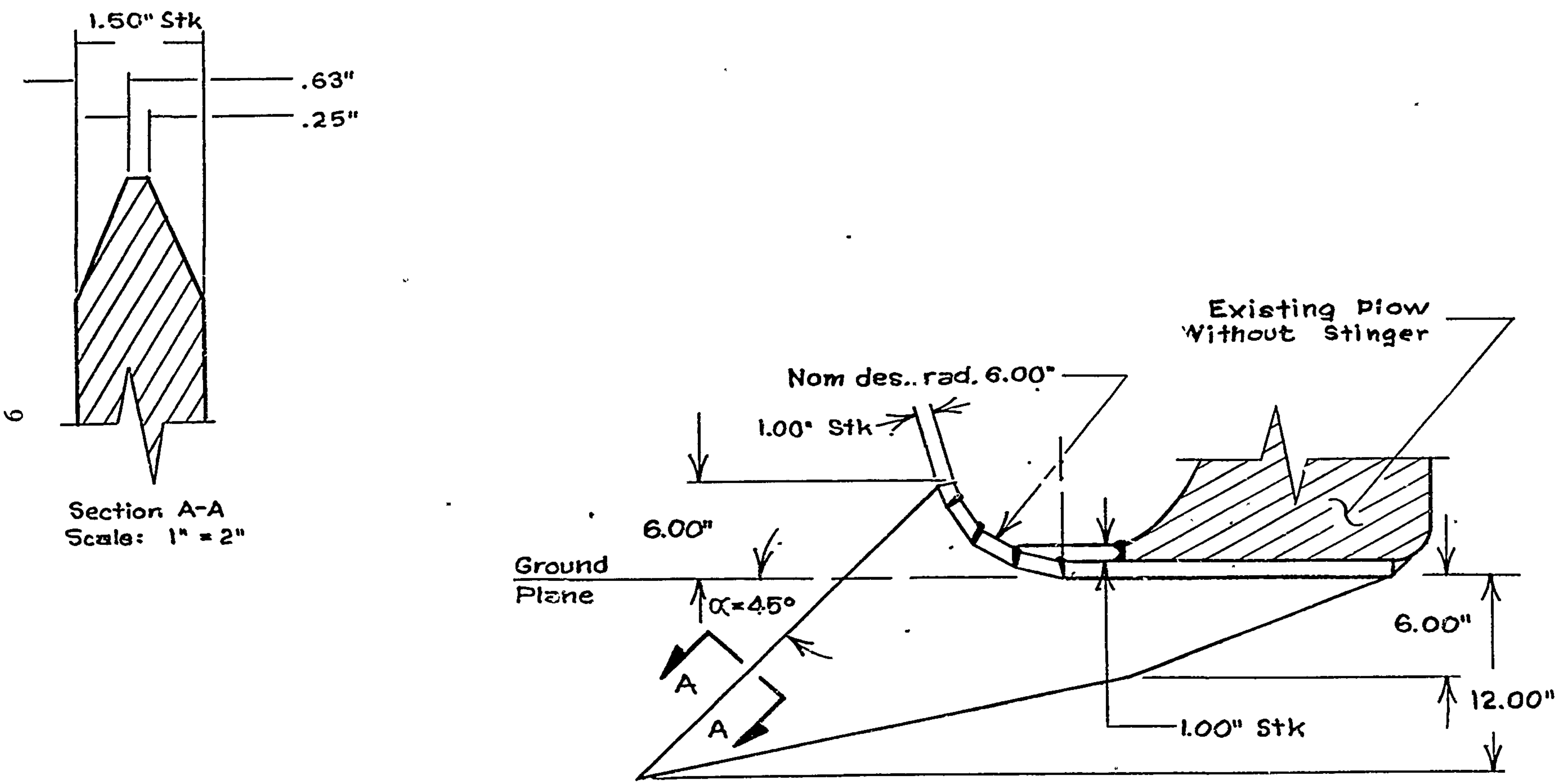


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Figure 5. 45°α Configuration.

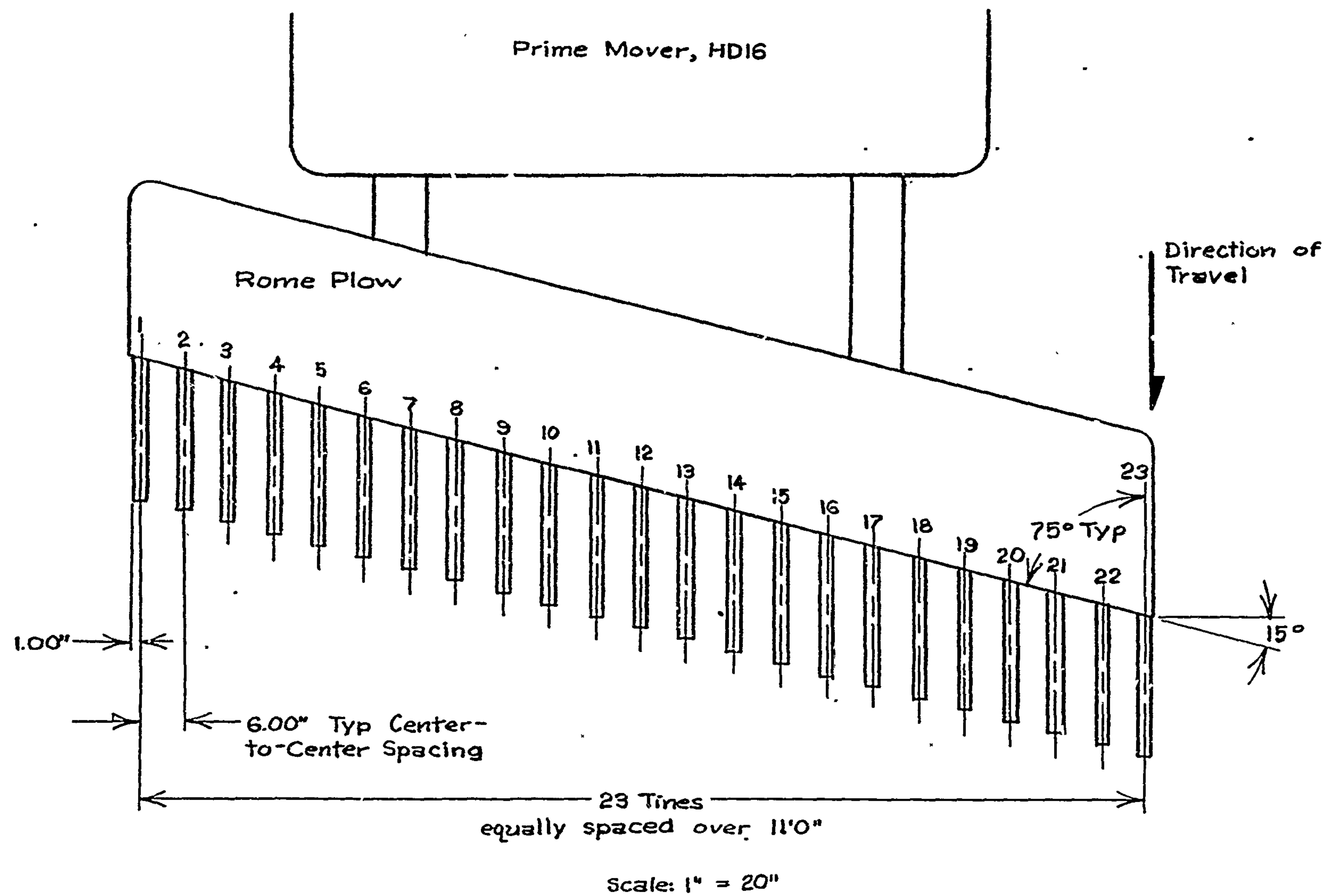

Figure 6. Tines to parallel direction of travel.

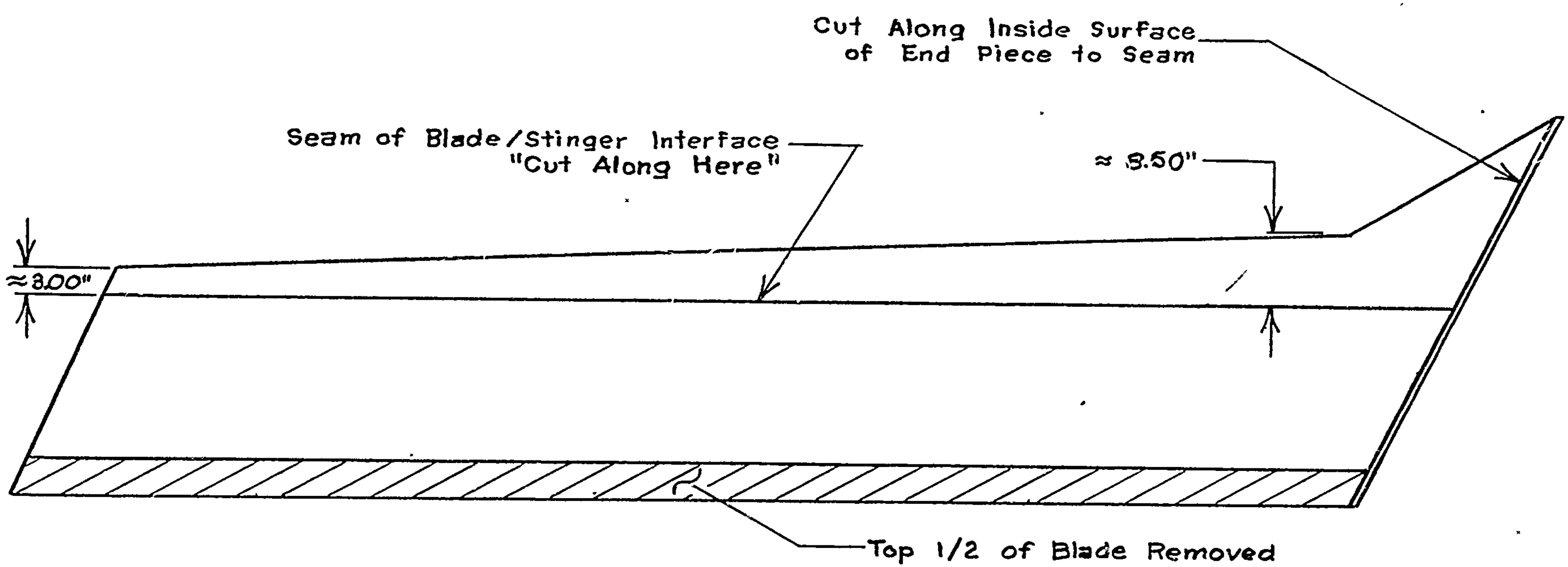

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Figure 7. Step A.

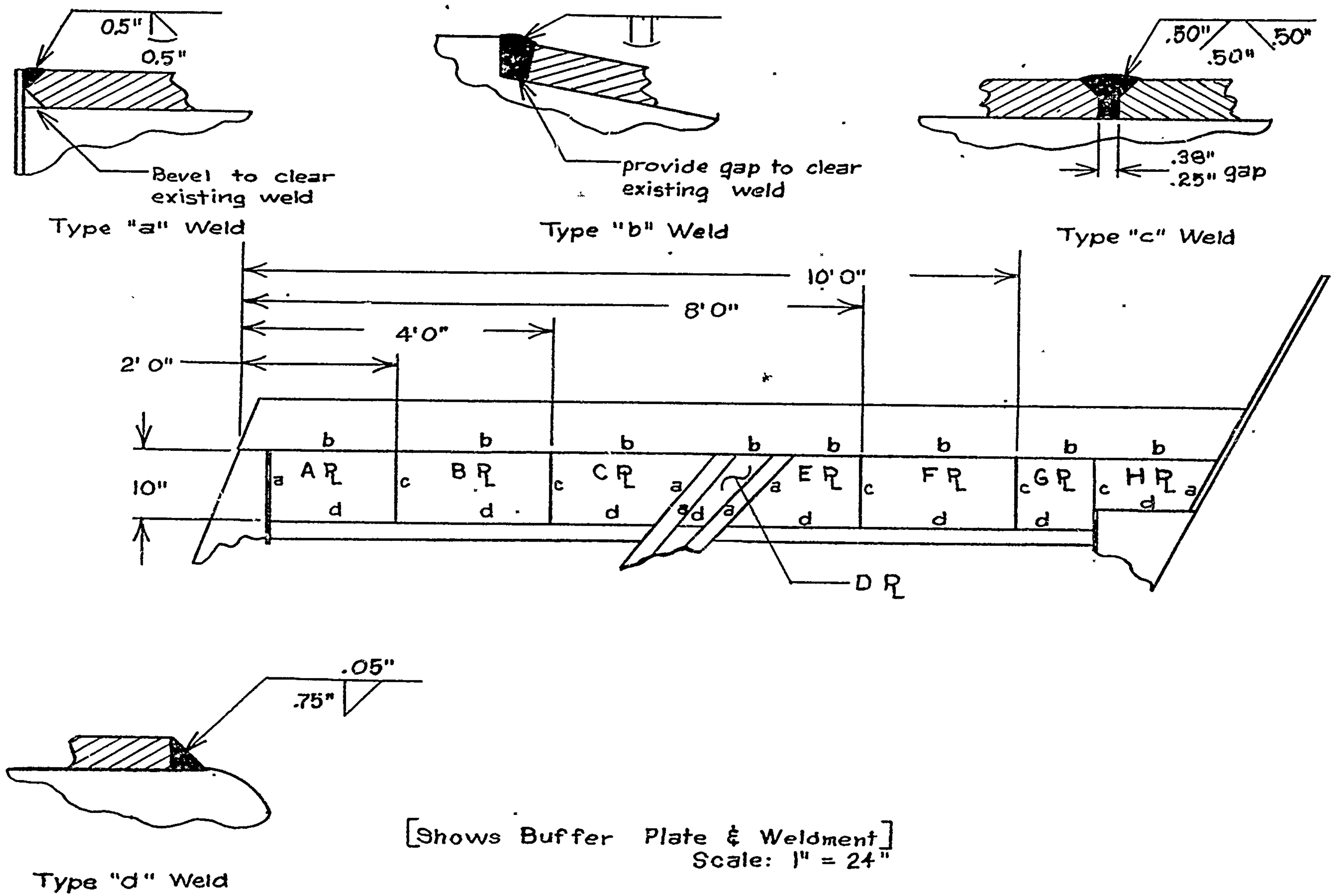

Figure 8. Bottom view of Rome Plow, showing buffer plate and weldment.

d. Add the flotation plates as shown by Figures 10 and 11 and which are fabricated from 1-in. stock. Note: prior to installation of these plates, the end of the stinger referred to as the "tree splitter" must be cut to allow the plates to fit the total outside edge-to-outside edge distance. Lengths are approximate and may vary somewhat from one plow to another; therefore, they should be cut oversized and finished flush with the plow sides. It is suggested that the flotation plates be fabricated from 1-in. by 6-in. bar stock.

e. Install counter braces. In general, these must be hand fitted into place with each one centered over and in line with a tine. Therefore, there are 23 such braces. Basic weld detail is shown in Figure 12. These braces are required to add resistance to the downward pull of the tines on the flotation plates. This may pose some objection because debris or a small mine might be trapped in the pockets created along the lower edge of the blade. The author feels that this is no problem; however, should it become a problem, it could be rectified easily by adding ¼-in. plate between the braces and flush with their upper surfaces.

f. It is recommended that the open areas in the upper 2 ft of the Rome Plow be filled in with a heavy gauge screen. This would prevent mines from jumping through these spaces and becoming a threat to the dozer.

g. Normal welding procedures and electrodes presently utilized at Fort Knox should be sufficient for this assembly. Normally, MERADCOM uses the 1018 series rods for T-1 steels.

Again, it should be pointed out that this is an initial effort and is subject to change. It should also be noted that the KGBA7E Rome Plow dimensions utilized in this design were measured by this author, using a 12-in. wood ruler, from several plows lying on top of each other in a muddy field. Care should be exercised when the various components are fabricated. It would be a good idea to use templates to verify dimensions. A list of the material requirements generated by this design is provided as Appendix B of this report.

IV. COMPARATIVE DESIGN ANALYSIS

A comparison of different methods for the removal of ground-implanted mines by earth-moving equipment must be based on calculations of power required and draw-bar pull. These calculations are basically accomplished in three parts: the power required to raise the soil to a height necessary to deposit it in a ridge on the side of the ditch toward which the blade will feed; the power required to overcome the friction between the soil and the various parts of the plow; the power required to break up the moved earth into small particles (1-mm cubes are said to be a good estimate; however, for ease of calculation, ⅓-mm cubes are considered adequate).[1]

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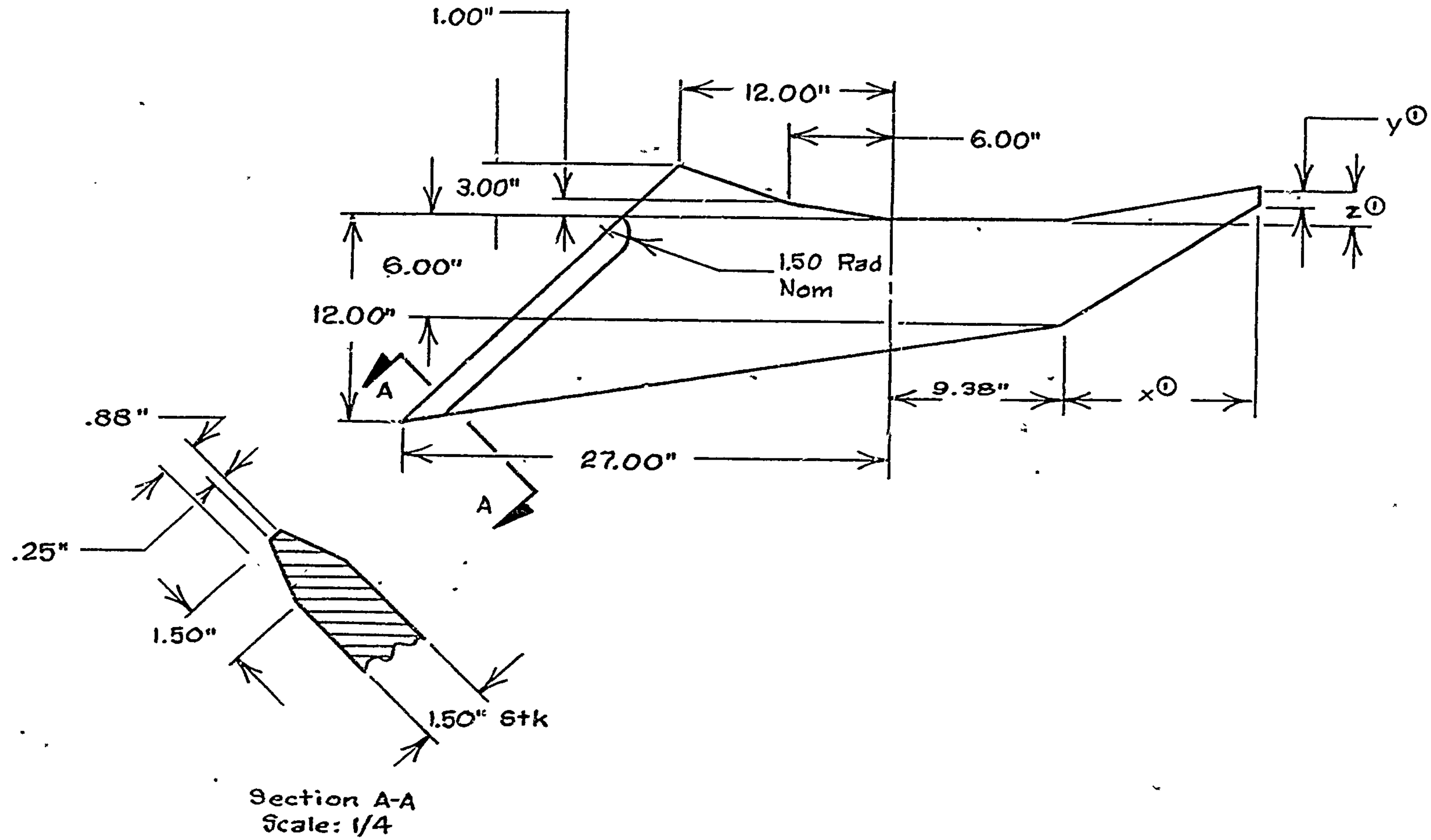
[1] "Basic Studies—Detecting, Destroying or Inactivating Mines." Penn. State U., Dept. of Engr. Res., Final Report Contract DA-44-009-Eng-1773, p. 101 (18 Nov 53).



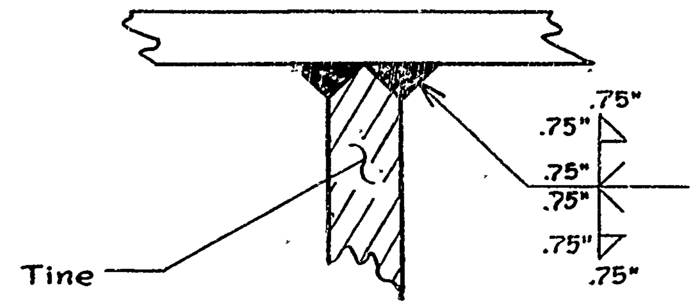
Notes:
1. dimension to be verified by use of template

Scale: 1" = 10"

Figure 9a. Tine Design.

DIMENSION TABULATION

Tine #	x	y	z	Tine #	x	y	z
1	0	—	—	13	10.50"	1.00"	2.00"
2	8.00"	1.00"	1.50"	14	10.50"	1.00"	2.00"
3	10.50"	1.00"	2.00"	15	10.50"	1.00"	2.00"
4	10.50"	1.00"	2.00"	16	10.50"	1.00"	2.00"
5	10.50"	1.00"	2.00"	17	10.50"	1.00"	2.00"
6	10.50"	1.00"	2.00"	18	10.50"	1.00"	2.00"
7	10.50"	1.00"	2.00"	19	10.50"	1.00"	2.00"
8	10.50"	1.00"	2.00"	20	10.50"	1.00"	2.00"
9	10.50"	1.00"	2.00"	21	10.50"	1.00"	2.00"
10	10.50"	1.00"	2.00"	22	5.00"	1.00"	.88"
11	10.50"	1.00"	2.00"	23	5.00"	1.00"	.88"
12	10.50"	1.00"	2.00"				



Weld Design
Tine to buffer, to remaining stringer, to new flotation plates

Figure 9b. Weld detail tine to buffer/remainder of stinger/new flotation plates.

NOTES:
1. x_1, x_2, x_3 dependent on location of tine

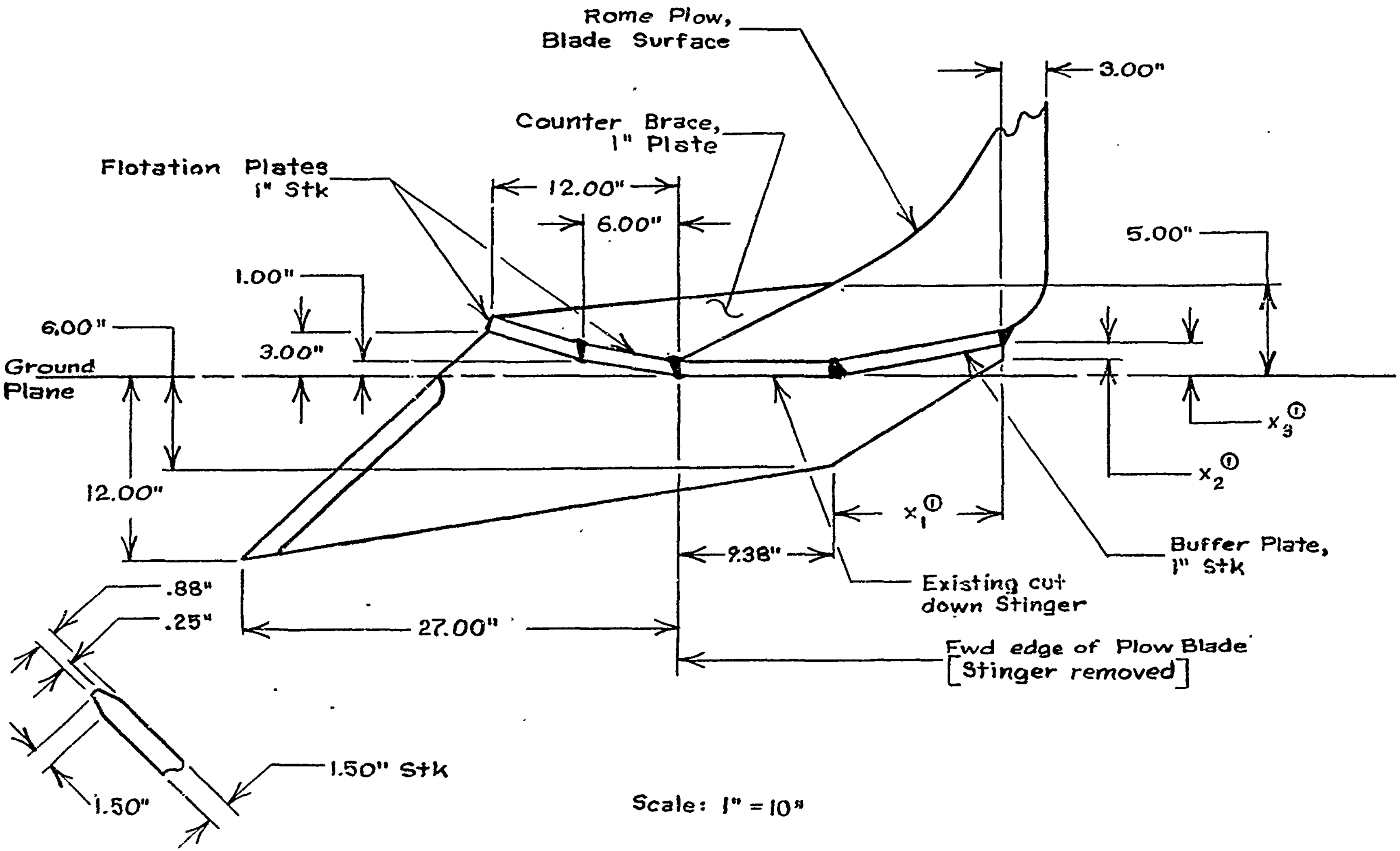


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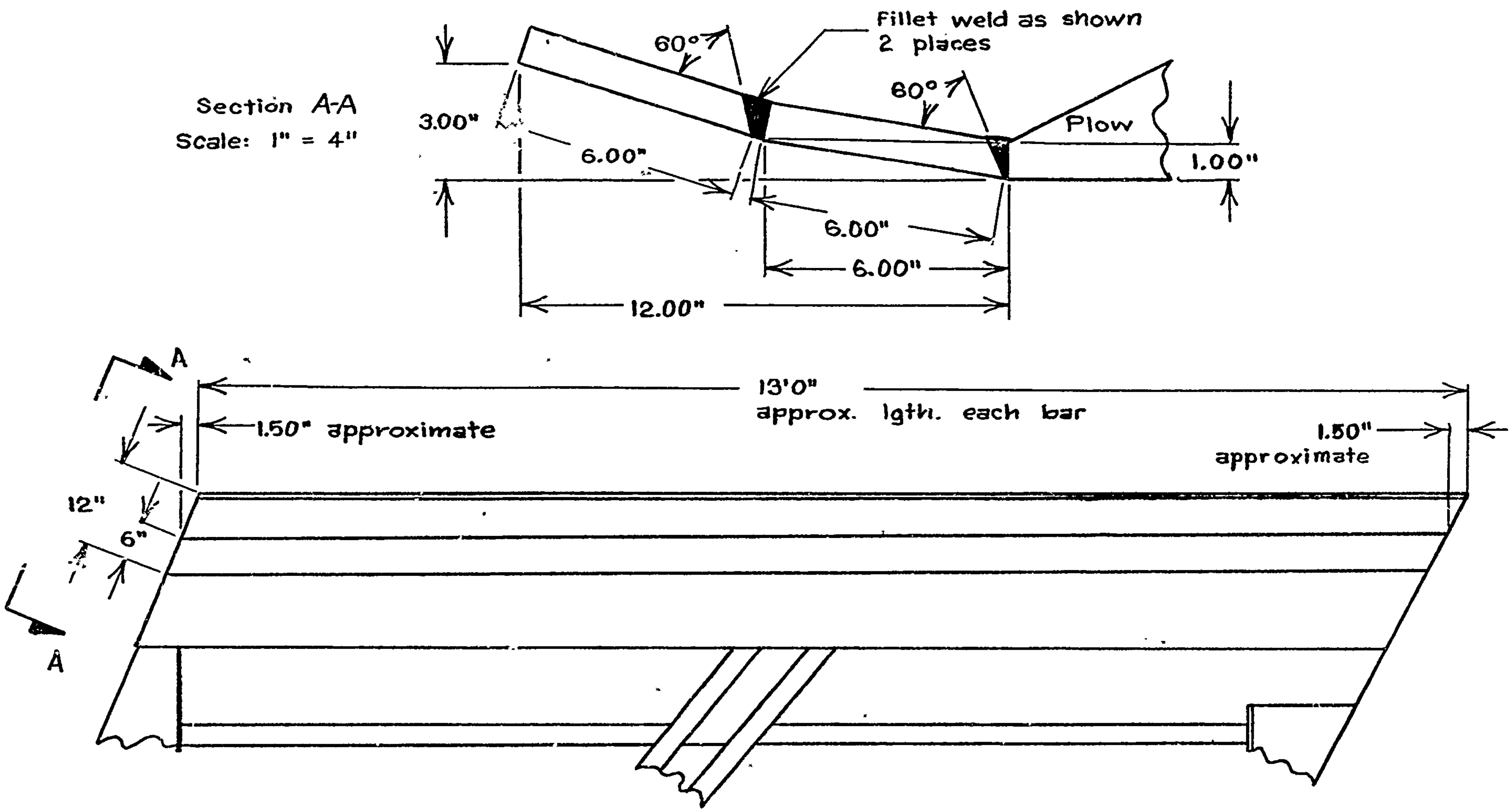
Figure 10. Nominal tine configuration.



Scale: 1" = 20"

Figure 11. Flotation plates.

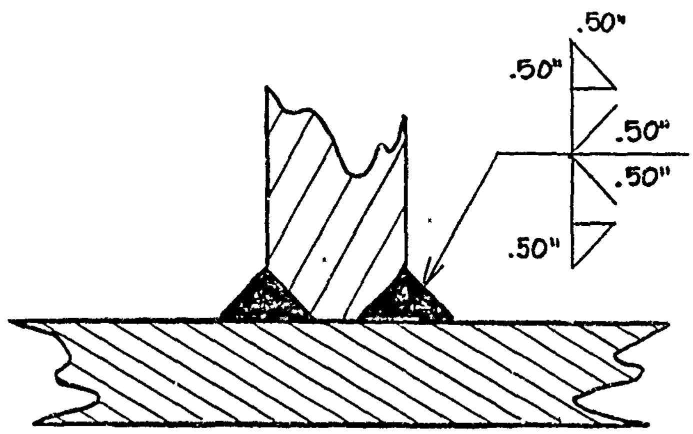


Figure 12. Basic weld detail of counter braces.

As all calculations of this nature are only approximations, the following approximations and/or assumptions have been made:

- 1 mi/h ≈ 90 pm.
- Soil density ≈ 100 lb/ft³.[2]
- Coefficient of friction = M ≈ 0.5.[3]
- Power required to break up soil into ⅛-mm cubes ≈ 100-gm calories/ft³.[4]
- 1-gm calorie ≈ 3.1 ft-lb.

In addition to these assumptions, the desired ditch cross-section is shown in Figure 13.

a. The first consideration of the following three-part calculation deals with the power required to raise the soil against the force of gravity. In general, it deals with two basic types of systems: a plow which removes all of the earth from the desired ditch depositing it in a ridge as shown in Figure 13, and a plow/tine arrangement (referred to as a "Potatoe Digger" by Pennsylvania State University). All calculations will be made assuming an operational speed of 5 mi/h (450 ft/min).

(1) Basic Plow System:

$$\text{Horsepower}_G = (\text{wt of earth moved/min})\ (\text{ht raised to})$$
$$= (\text{conversion of ft-lb/min to hp})$$

$$= \frac{\left(11\ \text{ft} \times 1\ \text{ft} \times \frac{1\ \text{ft} \times 1\ \text{ft}}{2}\right)(450\ \text{ft/min})\left(100\ \frac{\text{lb}}{\text{ft}^3}\right)(3\ \text{ft})}{33{,}000\ \text{ft-lb/min-hp}}$$

$$= 47.045\ \text{hp}.$$

(2) Plow/Tine System. Because this system must still lift dirt to almost the same height, the required horsepower for this action will be assumed to be the same as for the basic plow:

$$= 47.045\ \text{hp}.$$

The number of tines utilized will have little or no bearing on this figure.

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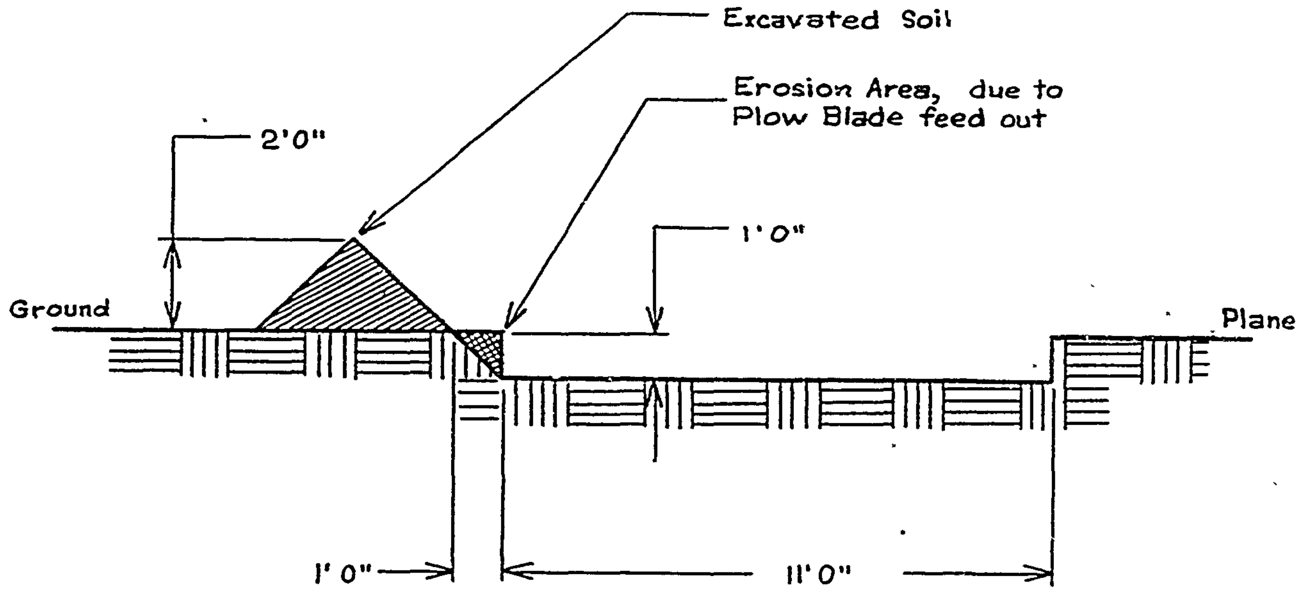
2 "Basic Studies—Detecting, Destroying or Inactivating Mines," Penn. State U., Dept. of Engr Res., Final Report Contract DA-44-009-Eng-1773, p. 101 (18 Nov 53).

3 Ibid, p. 101.

4 Ibid, p. 101.



Scale: 1" = 48"

Figure 13. Cross section of desired ditch.

b. The second consideration of this three-part calculation deals with the power required to overcome sliding friction.

(1) **Basic Plow System.** It is assumed that the surface of the plow which will carry the soil is 3.5 ft long in the direction of motion:

$$\text{Horsepower}_{f1} = \frac{(\text{soil load over plow})\ M\ (\text{speed})}{33{,}000}$$

$$= \frac{(11 \text{ X } 3.5 \text{ X } 100)\ (0.5)\ (450)}{33{,}000}$$

$$= 26.25 \text{ hp}_{f1}.$$

Since this load also rests on the bottom surfaces of the plow, a second, lower surface, frictional force is encountered equal to the above:

$$\text{Horsepower}_{f2} = 26.25 \text{ hp}_{f2}.$$

In addition, a third frictional load also exists due to the weight of the plow itself which is assumed to be 5000 lb:

$$\text{Horsepower}_{f3} = \frac{(5000 \text{ lb})\ (0.5)\ (450 \text{ ft/min})}{33{,}000 \text{ ft-lb/hp-min}}$$

$$= 34.09 \text{ hp}_{f3}.$$

Therefore, the total frictional horsepower is expressed as:

$$\text{Horsepower}_f = 26.25 + 26.25 + 34.09$$
$$= 86.59 \text{ hp}.$$

(2) **Plow/Tine System:** The frictional losses for this type system are similar to those of the basic plow, and the power required would not differ significantly from that calculated above. $\text{Horsepower}_f = 86.59$ hp.

c. The final consideration of this three-part calculation centers around the power requirements to break up the moved soil.

(1) **Basic Plow System:**

$$\text{Horsepower}_B = \frac{\text{(cross section are ditch) X 100 X 3.1 ft/min}}{33{,}000}$$

$$= (11.5)\ (100)\ (3.1)\ (450)/(33{,}000)$$

$$= 48.614 \text{ hp.}$$

(2) **Plow/Tine System (23-tine model):** Since the tines are 1.5 in. wide and assuming broken soil exists 1.5 in. on either side of the tines:

$$\text{Horsepower}_B = \frac{(23 \text{ X } 4.5/12)\ (100)\ (3.1)\ (450)}{33{,}000}$$

$$= 36.46 \text{ hp.}$$

(3) **Plow/Tine System (14-tine model):** The same assumptions hold true here as for the 23-tine model:

$$\text{Horsepower}_B = \frac{(14 \text{ X } 4.5/12)\ (100)\ (3.1)\ (450)}{33{,}000}$$

$$= 22.19 \text{ hp.}$$

(4) **Plow/Tine System (12-tine model):** The same assumptions hold true here as for the 23-tine model.

$$\text{Horsepower}_B = \frac{(12 \text{ X } 4.5/12)\ (100)\ (3.1)\ (450)}{33{,}000}$$

$$= 19.02 \text{ hp.}$$

Since the total horsepower requirement is a summation of all three of its parts (i.e., horsepower to lift, horsepower friction, and horsepower to break-up), the final horsepower requirements for the prime mover are:

- Basic Plow = 182 hp.
- Plow/Tine System, 23 Tines = 170 hp.
- Plow/Tine System, 14 Tines = 155 hp.
- Plow/Tine System, 12 Tines = 153 hp.

From these figures, the draw-bar pull requirements based on a plowing speed of 5 mi/h may be calculated by the equation:

$$\text{Force}_{\text{pull}} = \frac{33{,}000 \text{ (horsepower).}}{\text{(speed in ft/min).}}$$

Therefore, the total draw-bar pull requirements for the prime mover are:

- Basic Plow = 13,300 lb.
- Plow/Tine System, 23 Tines = 12,500 lb.
- Plow/Tine System, 14 Tines = 11,400 lb.
- Plow/Tine System, 12 Tines = 11,200 lb.

These values along with other pertinent data are summarized in the table on page 24.

Based on input from Captain Given of the Armor Engineer Board, Fort Knox, Kentucky, data derived from items presently undergoing evaluation by the USMC, Quantico, and based on studies documented in a Pennsylvania State University College of Engineering research report which verified that a "tine type" mine-clearing device required approximately one-sixth less draw-bar pull than did the basic plow device (which compares favorably with the 14-tine model documentation), the best cross between adequate earth movement and power requirements appears to be an item which would produce one-sixth the draw-bar pull of a basic plow. Thus, experience (based on past and present technology) dictates the 14-tine model.

V. COMMENTS, COMPARATIVE DESIGN ANALYSIS

All basic data, formulae, and assumptions used in the previous analysis were taken from the Pennsylvania State University report.[5] Another Pennsylvania State report[6] yields values approximately 40 percent higher than calculated values. Since the apparatus and soil conditions are not exactly comparable, this could be considered a fair corroboration of the calculated values. Where the soil does not behave in a predictable manner or boulders and other obstacles are encountered, the Agricultural School values would be valid. In sandy or fine aggregrate soil conditions, the calculated values would be high. It is felt that the calculated values provide an excellent baseline estimate.

Since both Pennsylvania State reports show a significant reduction in power requirements of the tine or "potatoe digger" type mine-clearing device over the basic plow of approximately one-sixth, and since the 14-tine model and 12-tine model exhibit similar percentage reductions, an alternative design utilizing 14 tines has been prepared and is shown in Appendix C. This design is also based on tine spacing of an item presently undergoing test and evaluation at Quantico, Virginia. Appendix D provides a new material list for the alternative design.

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5 "Basic Studies—Detecting, Destroying or Inactivating Mines," Penn. State U., Dept. of Engr. Res., Final Report Contract DA-44-009-Eng-1773, pp. 95-103 (28 Nov 53).

6 "Technical Features of Tillage Tools," Penn. State U., School of Agriculture, Bulletin 465, Part 2.

Tine Spacing Evaluation Summary Chart

Device	Value	Estimate Range	
		Calculated	Agricultural
Basic Plow	Horsepower req	182 hp	262 hp
	Draw-Pull req	13,300 lb	19,100 lb
23-Tine Mod	Horsepower req	170 hp	245 hp
	Draw-Pull req	12,500 lb	18,000 lb
14-Tine Mod	Horsepower req	155 hp	223 hp
	Draw-Pull req	11,400 lb	16,400 lb
12-Tine Mod	Horsepower req	153 hp	220 hp
	Draw-Pull req	11,200 lb	16,100 lb

VI. OVERALL SYSTEM INTEGRITY

Utilizing previously derived data pertaining to draw-bar pull and prime mover horsepower requirements as a data base for stress level calculations, it is possible to generate equations yielding approximate values of weld stress where the tines join the lower surface of the plow blade (Figure 14). All calculations are based on the 14-tine model utilizing the agricultural figures for draw-bar pull (16,400). It is assumed that all the load is witnessed solely by tines and that each tine, under normal conditions, bears an equal share of the load, or 1200 lb. All calculations are based on the No. 1 tine which has the least weld area.

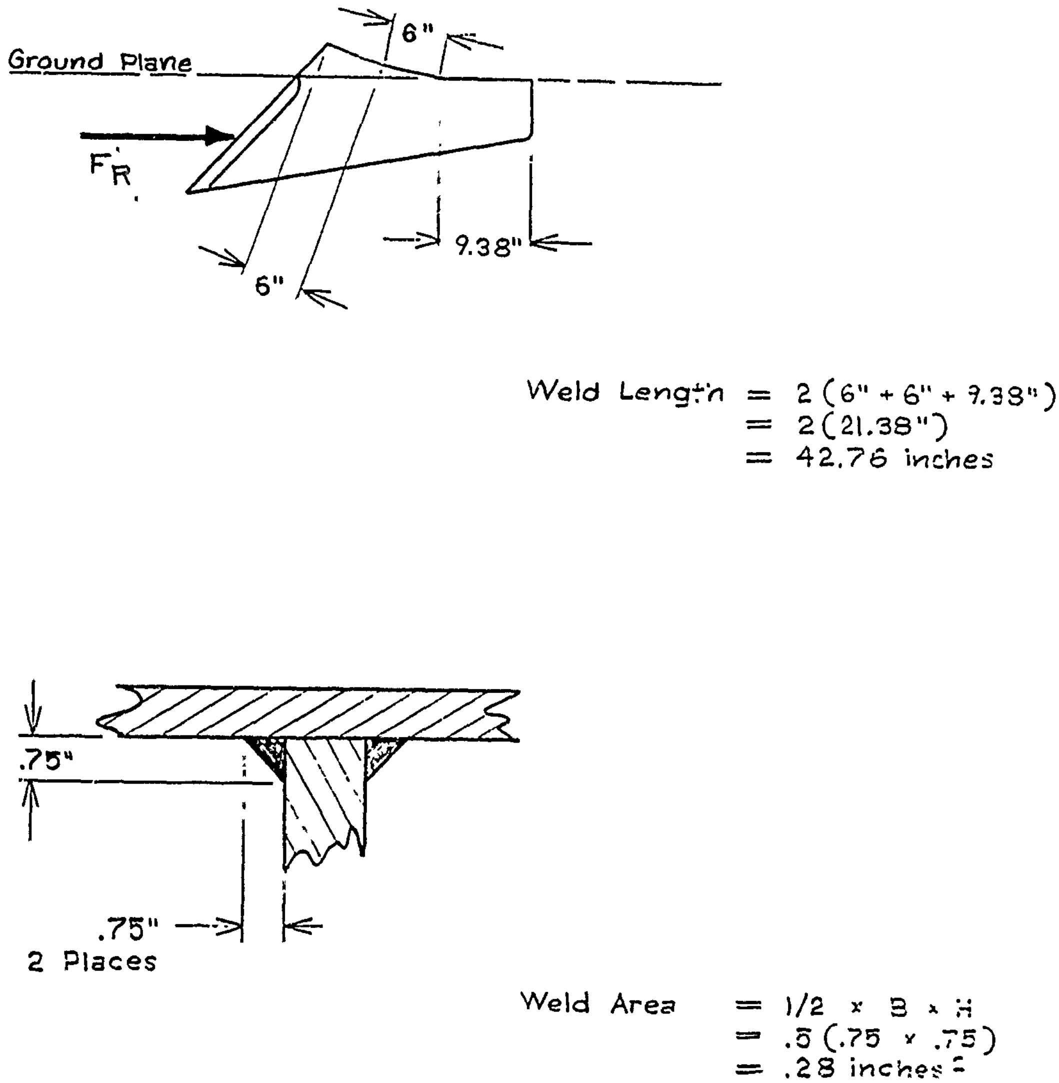


Figure 14. Typical tine loading at weld interface.

Shear Loading = $\sigma_s = F_A/A$

$= 1{,}200$ lb/.56 in.^{2}

$= 2{,}140$ lb/in.^{2}.

And the possible elongation through the weld, ϵ_s

$= \sigma_s\ 1/E$

$= 2{,}140 \times 21.38/30 \times 10^6$

$= 0.001$ in.

These values are well within the working stress for welding T-1 steel (115,000 lb/in.^{2}/5 or 23,000 lb/in.^{2}).

In addition to the above calculations, another set of calculations is provided assuming the same tine strikes an immovable object (zero deformation) stopping the prime mover instantly (no pivot type motion or other form of energy absorption), in which case this tine would witness all 16,400 lb of load. Welds are assumed to fail in direct horizontal shear.

a. Basic Shear Loading at 0 mi/h, σ_s

$= F_R/A$

$= 16{,}400/0.56$

$= 29{,}285$ lb/in.^{2}

b. Possible Weld Deformation at 0 mi/h, ϵ_s

$= \sigma_s\ 1/E$

$= 29.285 \times 21.38/30 \times 10^6$

$= 0.020$ in.

c. Maximum velocity of the plow without shearing the tine, V. Given:

Maximum Yield of T-1 = 135.000 lb/in.^{2} =

0 velocity stress = 29,285 lb/in.^{2} =

0 velocity deformation = 0.02 in. =

h = $V^2/2g$ where g = 32.16 ft/s^2

$$= \frac{2h}{e}$$

$$\text{Thus: } V = \frac{\sigma_1^2 \times \epsilon \times 2g}{2}^{1/2}$$

$$= \left[\frac{135{,}000^2 \times .02 \times 2 \times 32.16}{29{,}285^2}\right]^{1/2}$$

= 5.23 ft/s or 314 ft/min or 3.6 mi/h.

for two tines striking simultaneously, the maximum velocity would increase to:

$$V = \left[(135{,}000^2 \times .02 \times 2 \times 32.16)/(15{,}000^2)\right]^{1/2}$$

= 10.2 ft/s or 612 ft/min or 7 mi/h.

In general, these calculations substantiate the design strength of the redesigned system. It is felt that this system will survive an impact with a large solid object at a design speed of 5 mi/h, even though the calculations show safe speeds approaching 4 mi/h for a single tine impact. It should be noted that the equations assume contact with a totally immovable object and no energy absorption other than in failure of the weld. This condition could never exist.

Therefore, it is recommended that:

a. System design be fixed as shown by Appendix C.

b. Weld sizes shown are minimum.

c. Maximum allowable plowing speed is 5 mi/h.

VII. NEED FOR SUPPORT PLATE STIFFENER

For calculation purposes, it is assumed that the flotation plate acts as a 12-in. long cantilever beam, 10.25 in. wide, uniformly loaded.

$$F_R \times 6 = W \times 6$$

$$W = F_R = 16{,}400 \text{ lb (worst condition).}$$

From that, the deflection, y, and stress σ, may be calculated as follows:

$$Y = \frac{Wl^3}{8EI} = \frac{(16{,}400)(12)^3(12)}{8(30 \times 10^6)(10.25 \times 1^3)}$$

$$= 0.14 \text{ in.}$$

$$\sigma = \frac{Mc}{I} = \frac{Wlc}{2I} = \frac{(16{,}400)(12)(½)}{2(10.25 \times 1^3)}$$

$$= 4{,}800 \text{ lb/in.}^2$$

Upgrading these figures to impact loading characteristics where V = 5 mi/h or 7.33 ft/s:

$$h = V^2/2g = (7.33)^2/(2 \times 32.16)$$

$$= 0.835.$$

Utilizing this figure, the new deflection, y', and the new stress, σ', due to the impact may be calculated:

$$Y' = Y\frac{2h}{Y} = (0.14)\left[(2 \times 0.835)/(0.14)\right]^{½}$$

$$= 0.48'$$

$$\sigma' = \sigma\sqrt{\frac{2h}{Y}} = (4{,}800)\left[(2 \times .835)/(.14)\right]^{½}$$

$$= 16{,}578 \text{ lb/in.}^2$$

These values indicate adequate strength without stiffeners. However, warpage in this area would prove detrimental. Therefore, it is suggested that the stiffners and cover plate be utilized as shown in Appendix D.

APPENDIX A

SPECIFICATIONS FOR KGBA7E ROME CLEARING BLADE

Series KGBA

K/G CLEARING BLADES for ROME C-FRAMES

SPECIFICATIONS

CATALOG NUMBER	DESCRIPTION	Overall Length Trunnion to Stinger Tip Ft.' In." (m)	Overall Width Mounted Ft.' In." (m)	Height Ft.' In." (mm)	Net Weight Lbs. (kg)
	FOR CATERPILLAR D5 AND D6 TRACTORS EQUIPPED WITH BULLDOZER C-FRAME				
KGBA6B consisting of:	For Caterpillar D5 and D5B Tractors–74" (1880 mm) Gauge –	16' 7" (5.06)	10' 4½" (3.16)	4' 4½" (1283)	3,360 (1524)
KB 6100A Blade Assembly	equipped with Cat C-Frame				2,530 (1148)
KAB-6A Brace Group	Group No. 6J0679.				830 (376)
	For Caterpillar D6 and D6B Tractors–74" (1880 mm) Gauge – equipped with Cat C-Frame Group No. 8F8912.				
KGBA6C consisting of:	For Caterpillar D6C Tractors-74" (1880 mm) Gauge - equipped with	17' 3" (5.26)	10' 4½" (3.16)	4' 4½" (1283)	3,380 (1533)
KB-6100 Blade Assembly	Cat C-Frame Group No. 3J4615.				2,530 (1148)
KAB-61 Brace Group	Effective dozer serial numbers 44E1-up.				850 (386)
KGBA6CA consisting of:	For Caterpillar D6C and D6D Tractors–74" (1880 mm) Gauge–	17' 3" (5.26)	10' 4½" (3.16)	4' 4½" (1283)	3,380 (1533)
KB-6100 Blade Assembly	equipped with Cat C-Frame Group				2,530 (1148)
KAB-61A Brace Group	No. 9J9469, effective dozer serial Nos. 44E1-11306-up.				850 (386)
	FOR CATERPILLAR D7 TRACTORS EQUIPPED WITH BULLDOZER C-FRAME				
KGBA7E consisting of:	For Caterpillar D7E Tractors equipped with Cat C-Frame	18' 2" (5.54)	11' 2" (3.40)	5' 1" (1549)	5,180 (2350)
KB-7100 Blade Assembly	Group No. 5J5634 or 2J8606.				4,010 (1819)
KAB-71 Brace Group					1,170 (531)
	For Caterpillar D7F and D7G Tractors equipped with Cat C-Frame Group No. 7J4951.				
	FOR CATERPILLAR D8 TRACTORS EQUIPPED WITH BULLDOZER C-FRAME				
KGBA8 consisting of:	For Caterpillar D8H Tractors equipped with Cat C-Frame	22' 5" (6.83)	12' 4" (3.76)	5' 4½" (1644)	6,820 (3094)
KB-8100 Blade Assembly	Group No. 3J5606, 3J3840 or				5,580 (2531)
KAB-81 Brace Group	3J3516 S/N 28E-2251 and up.				1,240 (562)
	For Caterpillar D8K Tractors equipped with Cat C-Frame Group No.8J9856.				
	For Caterpillar D8H Tractors equipped with Cat C-Frame Group No. 2J2457: Specify OM-00068 ball studs in lieu of standard ball studs. (optional equipment)				

NOTES.

1. *All series KGBA CLEARING BLADES can be used with either cable or hydraulic operation if available on tractor. No sheaves, cable, hydraulic cylinders or components are furnished by ROME.*
2. *Tilt Cylinder Arrangements available on Special Order. Prices, specifications, and delivery information on request.*
3. *When ordering Series KGBA CLEARING BLADES for Caterpillar Track-Type Tractors, specify C-Frame Group Number.*

Series KGB

K/G CLEARING BLADES for CATERPILLAR C-FRAMES

SPECIFICATIONS

CATALOG NUMBER		DESCRIPTION	Overall Length Trunnion to Stinger Tip Ft.' In." (m)	Overall Width Mounted Ft.' In." (m)	Height Ft.' In." (mm)	Net Weight Lbs. (kg)
		FOR CATERPILLAR D6 TRACTORS				
KGB6CA		For Caterpillar D6C Tractors	17' 3" (5.26)	10' 4½" (3.16)	4' 4½" (1283)	5,030 (2282)
consisting of:		(74" Gauge), Serial Numbers				
KB-6100	Blade Assembly	74A, 76A, 99J, 10K–Dozer				2,530 (1148)
KD-62C	C-Frame	Serial Numbers 44E 11306-up				1,650 (748)
KAB-51A	Brace Group	For Caterpillar D6D Tractors,				850 (386)
		Serial Nos. 3X1-up & 4X1-up				
KGB6CLGP		For Caterpillar D6CLGP Tractors, Serial Number 69U	18' 4" (5.59)	12' 4" (3.76)	4' 4½" (1283)	5,950 (2699)
consisting of:						
KB-6100LGP	Blade Assembly	For Caterpillar D6DLGP Trac-				2,990 (1356)
KD-62LGP	C-Frame	tors, Serial Numbers 6X1-up				2,100 (953)
KAB-61LGP	Brace Group					860 (390)
		FOR CATERPILLAR D7 TRACTORS				
KGB7F		For Caterpillar D7F Tractors,	18' 2" (5.54)	11' 2" (3.40)	5' 1" (1549)	7,530 (3416)
consisting of:		Serial Numbers 93N1 and				
KB-7100	Blade Assembly	94N1 and up				4,010 (1819)
KD-72F	C-Frame	For Caterpillar D7G Tractors,				2,350 (1066)
KAB-71	Brace Group	Serial Numbers 91V1-up and				1,170 (531)
		92V1-up				
• KGB7FTCA		For Caterpillar D7F Tractors,	18' 2" (5.54)	11' 2" (3.40)	5' 1" (1549)	7,840 (3556)
consisting of:		Serial Numbers 93N1-up and				
KB-7100TCA	Blade Assembly	94N1-up, equipped with Cat-				4,010 (1819)
KD-72FHC	C-Frame	erpillar Tilt Cylinder Group				2,700 (1225)
KAB-71TCA	Brace Group	No. 7J1353 (Tilt Cylinder				980 (445)
KD-7500HC	Hyd. Lines & Guard Group	not furnished by Rome – order from Caterpillar)				150 (68)
•KGB7FLGP		For Caterpillar D7GLGP Tractors, Serial Numbers 72W1-up	21' (6.40)	13' (3.96)	5' 1" (1549)	8,310 (3769)
consisting of:						
KB-7100LGP	Blade Assembly					4,460 (2023)
KD-72FLGP	C-Frame					2,650 (1202)
KAB-71LGP	Brace Group					1,200 (544)
		FOR CATERPILLAR D8 TRACTORS				
KGB8		For Caterpillar D8H Tractors,	22' 5" (6.83)	12' 4" (3.76)	5'4¾" (1644)	11,380 (5162)
consisting of:		Serial Numbers 36A and 46A				
KB-8100	Blade Assembly					5,580 (2531)
KD-8200A	C-Frame					4,560 (2068)
KAB 81	Brace Group					1,240 (562)
KGB8K		For Caterpillar D8K Tractors,	22' 5" (6.83)	12'4" (3.76)	5' 4¾" (1644)	11,380 (5162)
consisting of:		Serial Numbers 76V1-up and				
KB-8100	Blade Assembly	77V1-up				5,580 (2531)
KD 8200K	C-Frame					4,560 (2068)
KAB-81	Brace Group					1,240 (562)

NOTES. *Series KGB CLEARING BLADES are furnished as a complete unit for mounting on the trunnions of a Caterpillar Track-Type Tractor. No trunnions, hydraulic cylinders or components furnished by ROME. Maximum usable track width same as recommended by Caterpillar Tractor Company for C-Frames.*

• *Special Order Only*

APPENDIX B

MATERIEL REQUIREMENTS (PRELIMINARY DESIGN)

28 October 1981

Alloy Steel, T-1, produced by U.S. Steel:

a. Plate: 1½ in. thick

4 ft by 8 ft — 5 required

b. Plate: 1 in. thick

4 ft by 4 ft — required

c. Bar Stock: 1 in. by 6 in.

Bracing — 15-ft length = 2 required

Flotation — 15-ft length — 2 required

Optional

a. Brace Cover Plate:

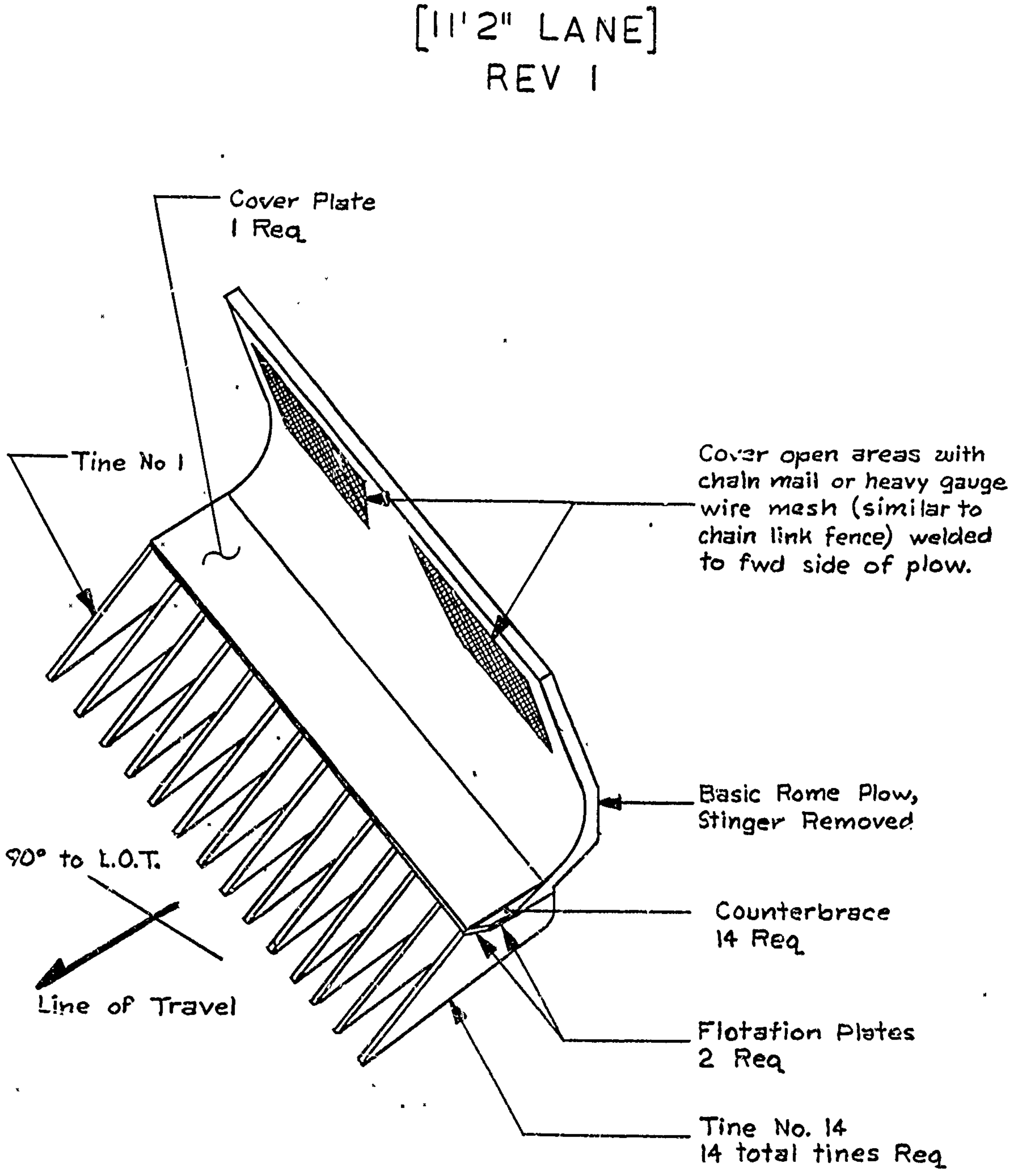
Steel alloy, T-1, 4 ft by 2 ft by ¼ in. stk — 1 required

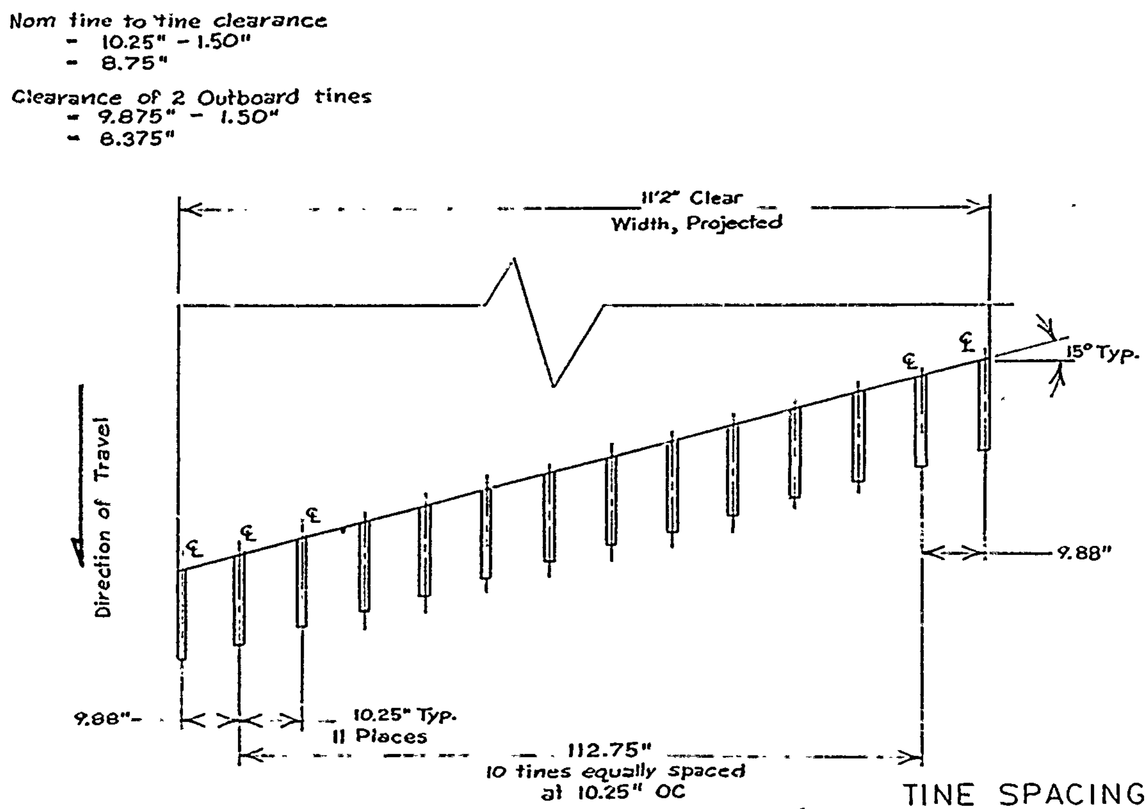
b. Wire Mesh or Screening:

Suggest material similar to chain link fencing — 1 sheet 8 ft by 2 ft

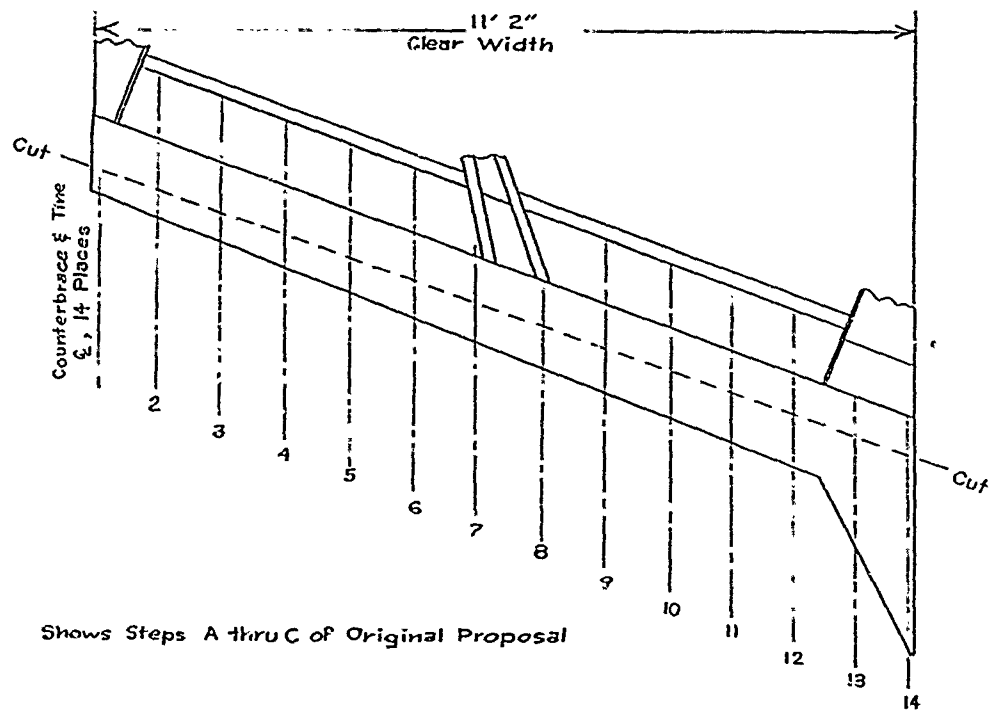
APPENDIX C

ROME PLOW, MINE, FULL WIDTH





TINE SPACING OF PLOW
(Based on USMC data provided by Ft Knox)
Rev 1 - dtd 1/13/81
Scale 1" = 2'



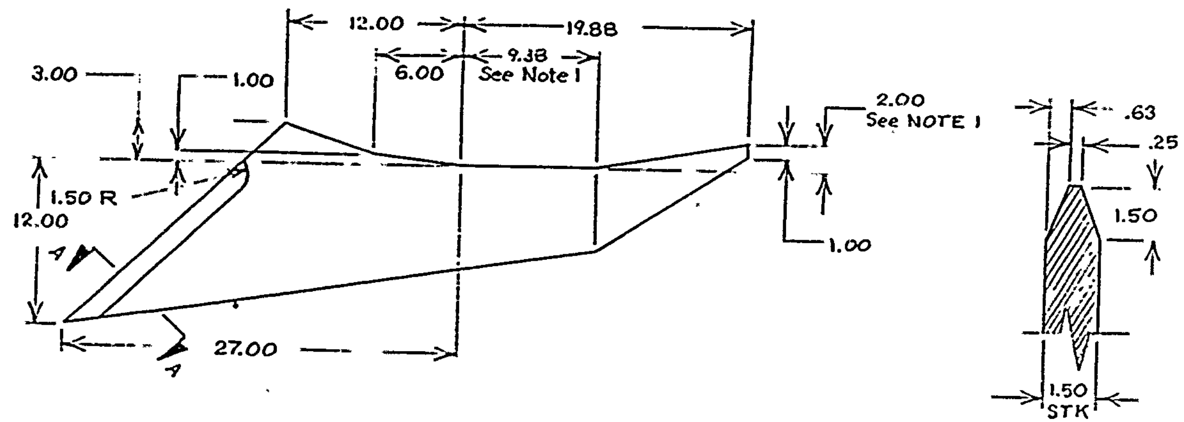
Shows Steps A thru C of Original Proposal

TINE/PLOW INTERFACE

Rev1 - dtd 11/17/81
Scale 1" = 2'

. NOTES:

1. Verify these dimensions by use of template.
2. 9 required.
3. Max overall block size is 15" x 47"
4. Std tolerance is ± 06"



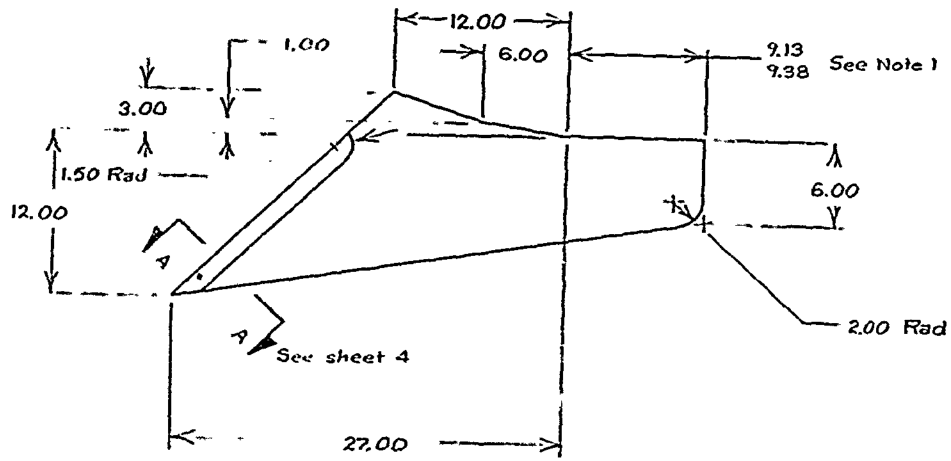
Section A-A
1/4 Scale

TINE DESIGN

[For Tine No's 2-6 & 9-12]
Rev 1 - dtd 11/17/81
Scale: 1"=10"

NOTES:

1. Verify these dimensions by use of template.
2. 4 required.
3. Max overall block size is 15" x 37".
4. Std Tolerance is ±.06".

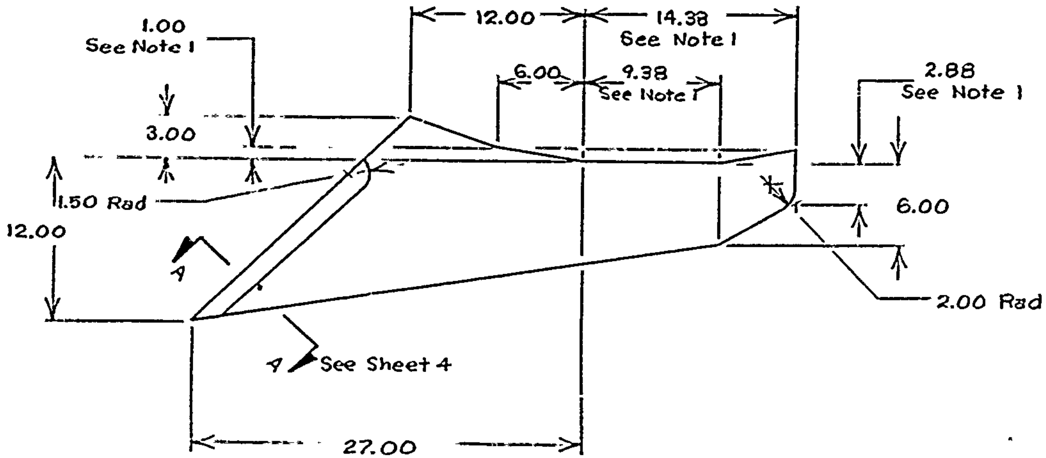


TINE DESIGN

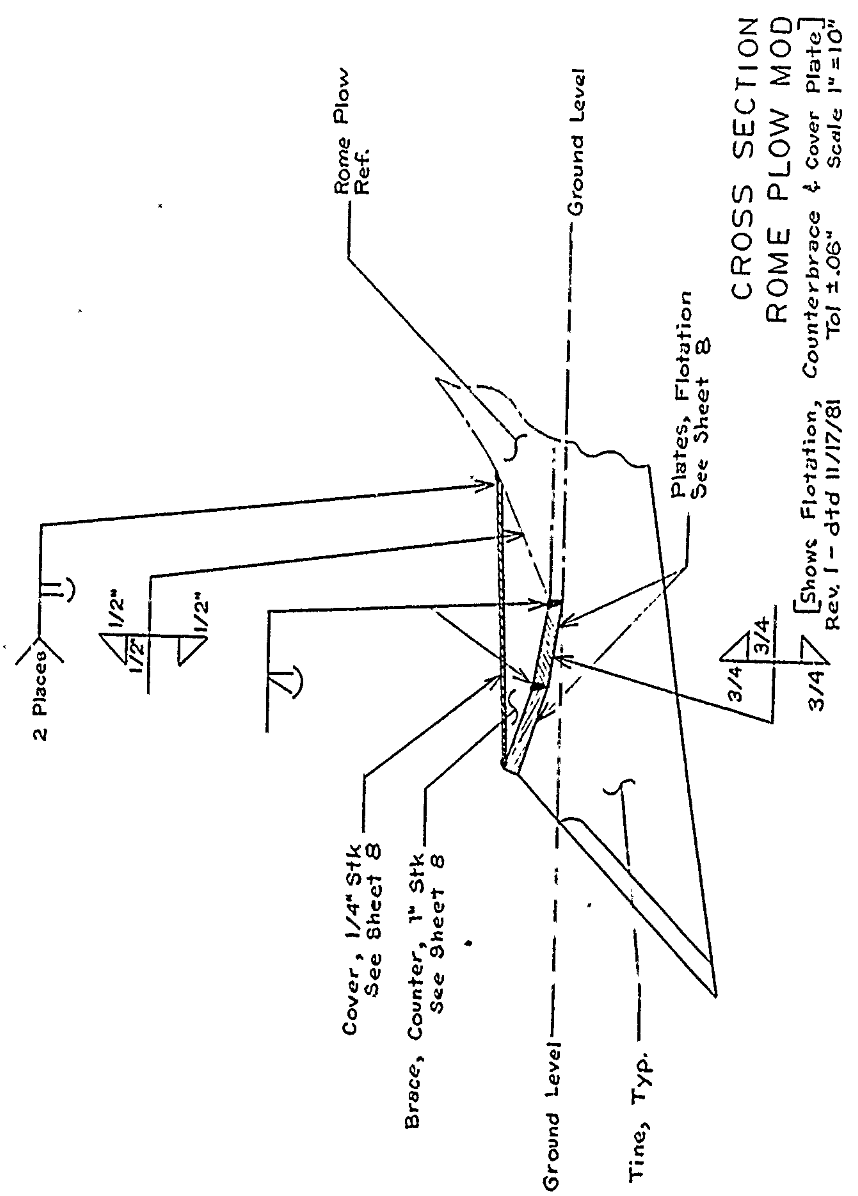
[For Tine No's 1, 8, 13 & 14]
Rev 1 - dtd 11/17/81
Scale: 1" = 10"

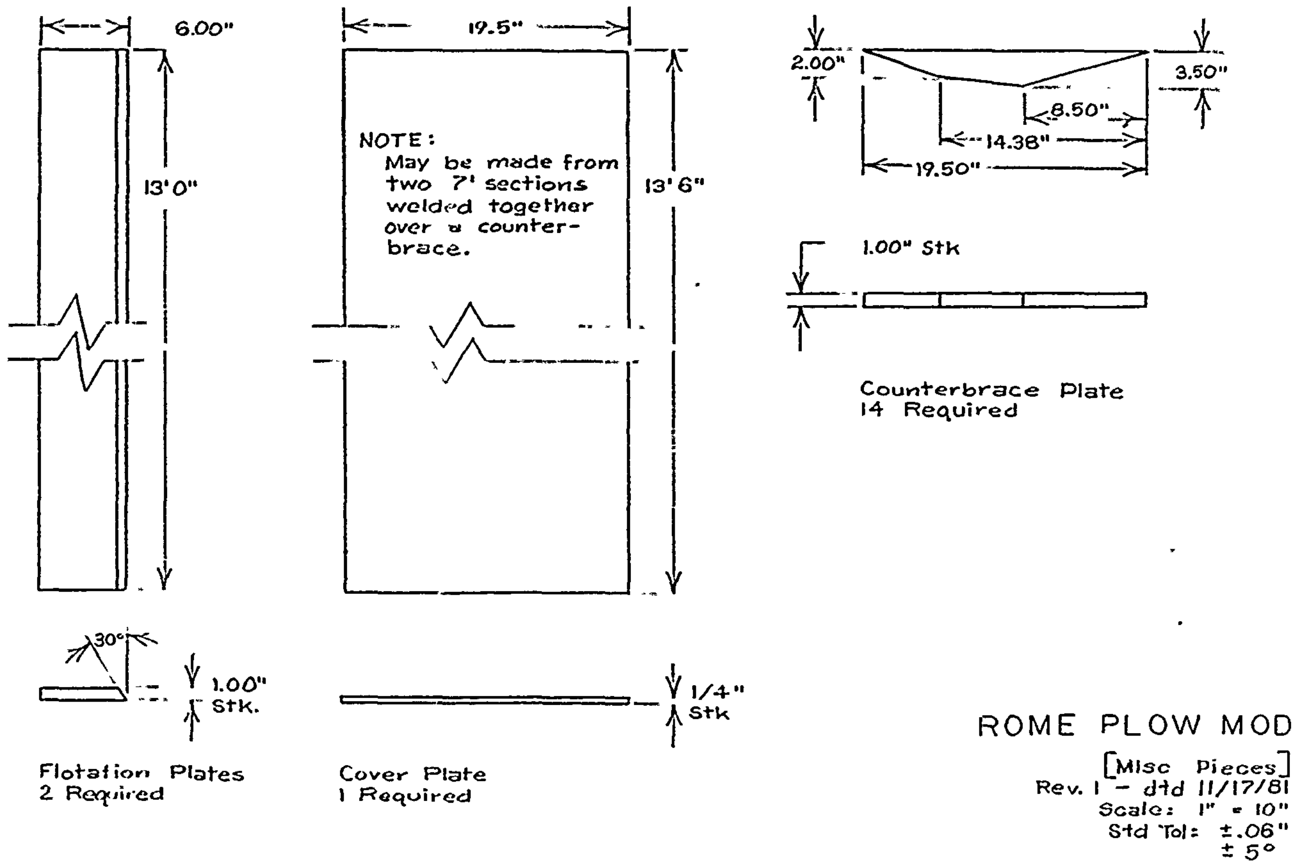
NOTES:

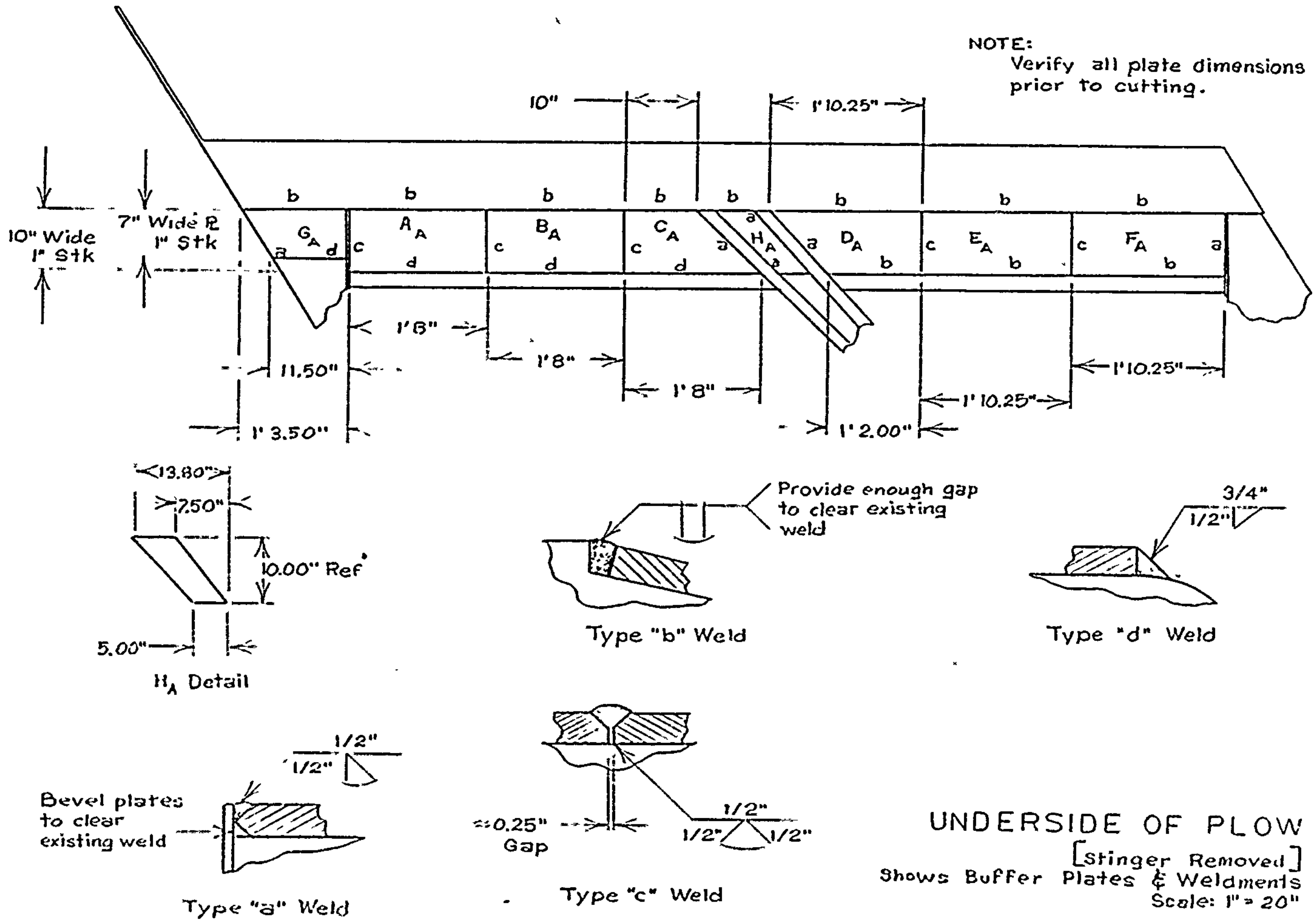
1. Verify these dimensions by use of template.
2. Max overall block size is 15" x 42"
3. Std Tolerance is ±.06".



TINE DESIGN
[For Tine No 7]
Rev 1 - dtd 11/17/81
Scale: 1" = 10"


CROSS SECTION
ROME PLOW MOD
Counterbrace & Cover Plate
Tol ±.06"
Scale 1" = 10"
[Shows Flotation, Rev. 1 - dtd 11/17/81]
Rome Plow Ref.
Ground Level
Plates, Flotation
See Sheet 8
2 Places
1/2"
1/2
1/2"
3/4
3/4
3/4
Cover, 1/4" Stk
See Sheet 8
Brace, Counter, 1" Stk
See Sheet 8
Ground Level
Tine, Typ.


6.00"
13'0"
1.00"
Stk.
30°
Flotation Plates
2 Required
19.5"
13'6"
NOTE:
May be made from two 7' sections welded together over a counter-brace.
1/4"
Stk
Cover Plate
1 Required
2.00"
3.50"
8.50"
14.38"
19.50"
1.00" Stk
Counterbrace Plate
14 Required
ROME PLOW MOD
[Misc Pieces]
Rev. 1 - dtd 11/17/81
Scale: 1" = 10"
Std Tol: ±.06"
± 5°



UNDERSIDE OF PLOW
[Stinger Removed]
Shows Buffer Plates & Weldments
Scale: 1" = 20"

APPENDIX D

MATERIAL REQUIREMENTS (UPGRADED DESIGN)

20 November 1981

Alloy steel, T-1, produced by U.S. Steel

a. **Plate:** 1½ in. thick

4 ft by 8 ft — 2 required
(Approx. weight 3920 lb)

4 ft by 4 ft — 1 required
(Approx. weight 1000 lb)

b. **Plate:** 1 in. thick

4 ft by 8 ft — 1 required
(Approx. weight 1320 lb)

c. **Plate:** ¼ in. thick

2 ft by 14 ft — 1 required
(Approx. weight 290 lb)

d. **Bar:** 1 in. by 6 in.

14-ft length — 2 required
(Approx. weight 820 lb)

Fabric, Steel Chain Link Fence, 11 gauge

1 piece 2 ft high by 8 ft long

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