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PRECISION GRINDING OF DIALLYL PHTHALATE THERMOSETTING PLASTIC

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MOUND LABORATORY

MIAMISBURG, OHIO

OPERATED FOR

UNITED STATES ATOMIC ENERGY COMMISSION

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ABSTRACT

A semiautomatic grinder was designed and built at Mound Laboratory to grind molded plastic detonator heads to close tolerances. It uses a vertical spindle, dry grinding technique to decrease grinding time of some diallyl phthalate (DAP) detonator heads with wire inserts and to eliminate the problem of error in repeatability which is characteristic of the manual grinding process. The semiautomatic grinder is essentially air-operated with electrical control and was primarily designed using standard components for ease of manufacture and maintenance. As development of the semiautomatic grinder progressed, DAP detonator heads with wire inserts ground using the manual surface grinder were evaluated along with the same type of detonator heads ground using the semiautomatic grinder. Also, a time study was conducted to determine the cost savings of grinding miniature DAP detonator heads with wire inserts using the semiautomatic grinder. Inspection and analytical results and radiographic sections of ground detonator head surfaces from each grinding technique indicated that the semiautomatic grinding technique provides acceptable ground DAP detonator heads with wire inserts at a cost savings of 83.5% and a significant reduction in grinding time.

INTRODUCTION

The molding process for miniature DAP detonator heads with wire inserts requires an excess of thermosetting plastic in order for the mold section to withstand molding pressure. Removal of the excess DAP thermosetting plastic material by the manual grinding process (a technique using fixtures on a surface grinder) is time-consuming and is characterized by possible human error in repeatability introduced by the operator. A faster, more efficient grinding process was therefore needed for the removal of the excess plastic material left by the molding process. Consequently, a semiautomatic grinder (see Figure 1) was designed and built at Mound Laboratory using a vertical spindle, dry grinding technique to decrease the grinding time and to eliminate the problem of error in repeatability. As development of the semiautomatic grinder progressed, DAP detonator heads with wire inserts ground using the manual surface grinder were evaluated along with DAP detonator heads with wire inserts ground using the semiautomatic grinder. Inspection and analytical techniques and radiographic sections were used to compare the quality of the ground detonator head surfaces from each grinding technique. Also, a time study was conducted to determine the cost savings of grinding miniature DAP detonator heads with wire inserts using the semiautomatic grinder.

DESIGN OF SEMIAUTOMATIC GRINDER

The primary design considerations that were used for the semiautomatic grinder are as follows:

1. Loading the Head   A typical detonator head with wire inserts to be ground in the semiautomatic grinder is shown in Figure 2. The 4-in. (101.6-mm) wire extension complicated the automatic loading of detonator heads with wire inserts. To simplify loading the detonator head is placed in a nest device by the operator. After loading the machine cycle is automatic.

2. Design of Nest Device   The nest device developed to automatically nest and clamp the head for grinding is shown in Figure 3. The nest device is designed so that the head will drop downward when the nest is fully opened, thus automatically removing the head after grinding.

3. Type of Grinding The vertical spindle, grinding wheel and vacuum head of the semiautomatic grinder are shown in Figure 4. Moore jig grinder spindles were used because of their accuracy, compactness of design and unlimited speed control. The spindles are air-operated, and speeds can therefore be varied from 0 to 45,000 rpm. The unknown effects of the vertical spindle grinding of plastics provide a useful variable in the development of the grinding parameters. Dry grinding was accomplished by using a wax-impregnated wheel to retard the tendency of the wheel to load.

4. Machine Operation The semiautomatic grinder is air-operated and electrically controlled. The required switches are at a convenient location on the operating panel for efficient operation. A timer is provided in the main control box to control the grinding and dressing cycle. The timer can be set from 0 to 1000 heads. The dressing cycle for these heads was established at 200 heads after which the semiautomatic grinder stops automatically. The grinding wheel is then dressed by the operator; the cycle is reset; and grinding is resumed.

5. Types of Grinding Wheels The grinding wheel that proved to be most acceptable for grinding some threaded detonator heads with copper wire inserts was Type 49CG-46-J7-VCPT; grinding wheel Type 49CG-60-J7-VCPT proved to be most acceptable for a plain (unthreaded) detonator head with phosphor-bronze wire inserts (see Table 1). Both types of grinding wheels are silicon carbide wheels that have been impregnated with wax.

   The results of various types of grinding wheels with varying grit size and hardness that were tried in the semiautomatic grinder are listed in Table 1. The type of grinding wheel to be used in the semiautomatic grinder for grinding DAP detonator heads with wire inserts is dependent upon the specific material used for the wire insert, e.g., copper versus phosphor-bronze.

Design of the semiautomatic grinder involved the construction of temporary tooling so that the nest device of the proposed design could be mounted on a Moore jig grinder to simulate conditions that would be encountered on the final machine. Also, various types of grinding wheels (Chicago Wheel and Manufacturing Co., Chicago, Ill.) were tried at varying speed and feed rates using the Moore jig grinder to determine the optimum rates for final use. A final design was chosen after the proposed design was tested and proved to be feasible. When possible standard components were used in the final design for economy and ease of manufacture.

DESCRIPTION OF SEMIAUTOMATIC GRINDER

The semiautomatic grinder is essentially air-operated with electrical control and is primarily designed using standard components for ease of manufacture and maintenance. A standard rotary indexing table is used as a mounting base for a specially designed nest plate. The nest plate consists of eight cam-operated fixtures for nesting and clamping. The detonator head that is to be ground is provided with eight nesting pads to ensure nesting pressure during clamping. The accuracy required for the semiautomatic grinder was in the range of 0.0005 TIR (Total Indicator Reading). This accuracy was necessary due to a ±0.001 in. (0.025 mm) tolerance of some DAP detonator heads with wire inserts. The cam-operated nests are actuated by suitable cams mounted beneath the nest plate, while the cams that operate the nesting pads are mounted on an overarm which is in turn mounted to the machine base. Two standard Gilman slides were used to convey the transverse motion of the grinding wheel to the grinding head. The slides are air-operated with hydraulic speed control. A hand-operated slide with an angle mount for the grinding head is mounted perpendicular to the transverse slides to provide vertical adjustment of the grinding wheels. The diamond wheel dressers are mounted relative to the nest plate; therefore, with the grinding wheel being adjusted to height and dressing it will always be dressed according to the finished head dimension. A set block is provided to set the diamond dresser to height. The standard base on which the semiautomatic grinder is mounted contains the control panels and filter lubricator, both of which are mounted beneath the mounting plate.

Preventive maintenance is essential for the semiautomatic grinder and is easily accomplished, since the spindles are lubricated by air flow. The six grease fittings on the slides and rotary table require lubrication only once a week. The only additional requirement would be cleanliness which is essential for any machine tool. The vacuum heads and pressure cleaning nozzle located over the nests provide most of the cleaning necessary.

RESULTS AND DISCUSSION

A wheel speed of 28,000 rpm and a feed rate of 8 in./min (203.2 mm/min) yielded the best results in preliminary trials of the proposed design and also in final operation of the chosen design. The results of machine operation are favorable according to the inspection data listed in Tables 1, 2 and 3. The data listed in Table 4 compare the required dimensions and the results obtained for ground DAP detonator heads with wire inserts. Figure 5 shows Tallysurf charts for the ground heads. The data indicate that the results of the semiautomatic grinding technique are within the required specifications with a cost savings of 83.5%.

A slight smear of wax was evident at the wire inserts on the surface of some ground heads due to the wax-impregnated grinding wheels. This is probably due to the melted wax caused by heat generated while the wire insert is being ground. The ground heads must be cleaned by a degreasing technique regardless of the type of grinding method; degreasing the ground head will remove the wax smear. Therefore, the presence of the wax smear at the wire inserts should not be detrimental to the ground head surface. As a further attempt to reduce or eliminate the problem of wax smear at the inserts, grinding wheels with a silicone impregnation instead of wax will be tried which should reduce the possibility of smear. An additional approach to solving the problem of wax smear is the design of a carbide-inserted cutter of the same diameter as the grinding wheels. Two cutters were made, and 200 heads were machined. The results using these cutters showed an improved ground head surface without wax smear which might imply a change from grinding to machining. However, further investigation will be required to determine cutter life and comparative cost.

The standard width of the surface of Type 49CG-46-J5-VCPT grinding wheel that comes in contact with the head during grinding was found to be detrimental to the surface of the head. Consequently, the grinding wheel surface was machined at a 30° angle leaving a 0.0312-in. (0.7925-mm) land width. Figure 6 is a sketch of the modified (machined) wheel which yielded the best grinding results. The land width was found to be critical, i.e., too wide a land will affect the surface finish of the head and too narrow a land will affect wheel life. A wheel dresser was designed to retain the shape of the grinding wheel; consequently, the wheel when dressed will always be the same dimension. This should ensure a similar head surface condition at all times.

CONCLUSION

Although the quality of the ground DAP detonator head was not improved, the semiautomatic grinding technique provided acceptable ground DAP detonator heads with wire inserts at an 83.5% cost savings. The semiautomatic grinding technique for grinding miniature DAP detonator heads with wire inserts is less time-consuming and eliminates the human factor of repeatability which is characteristic of manual grinding.

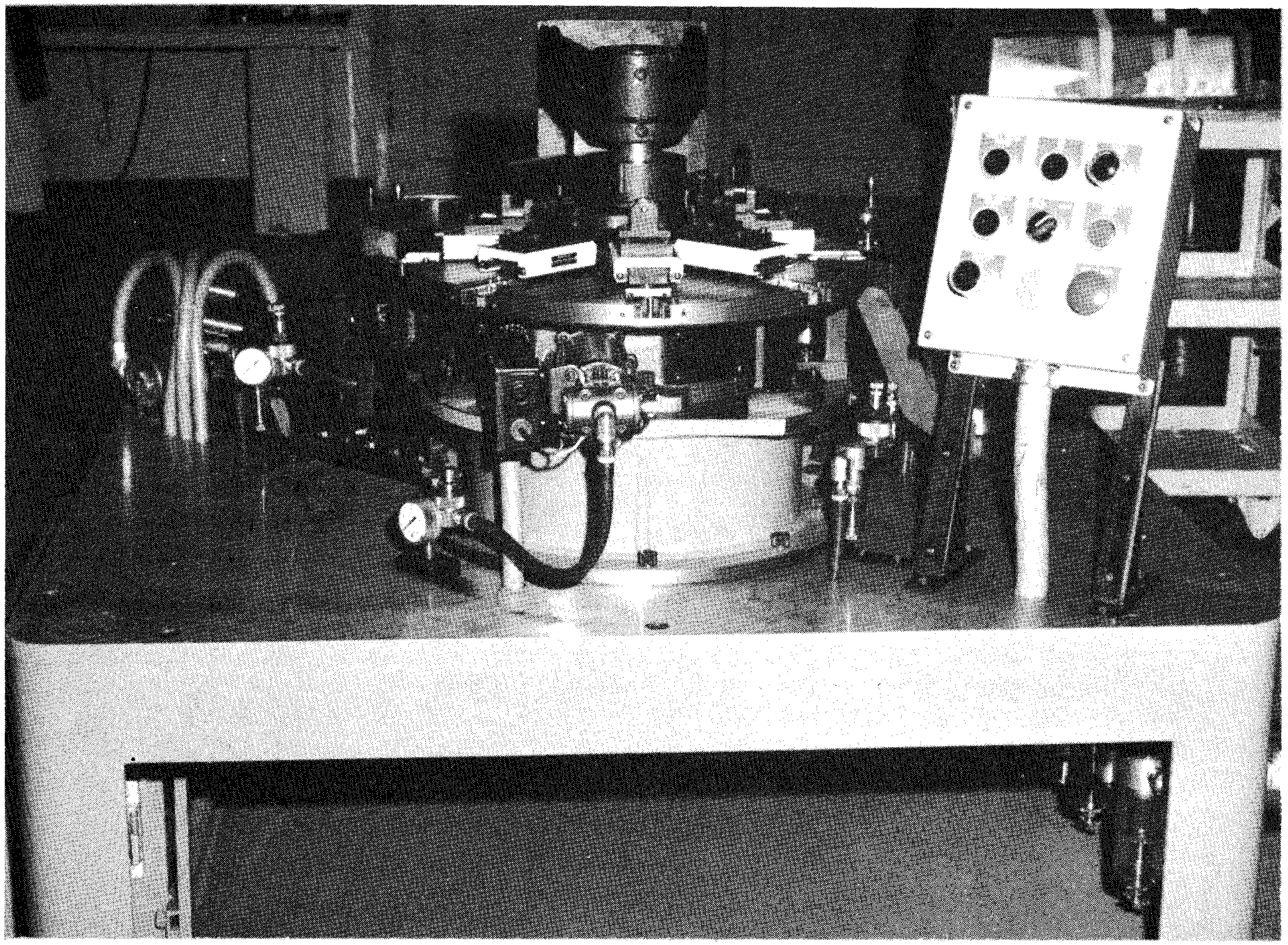

FIGURE 1 - Overall view of the semiautomatic grinder.

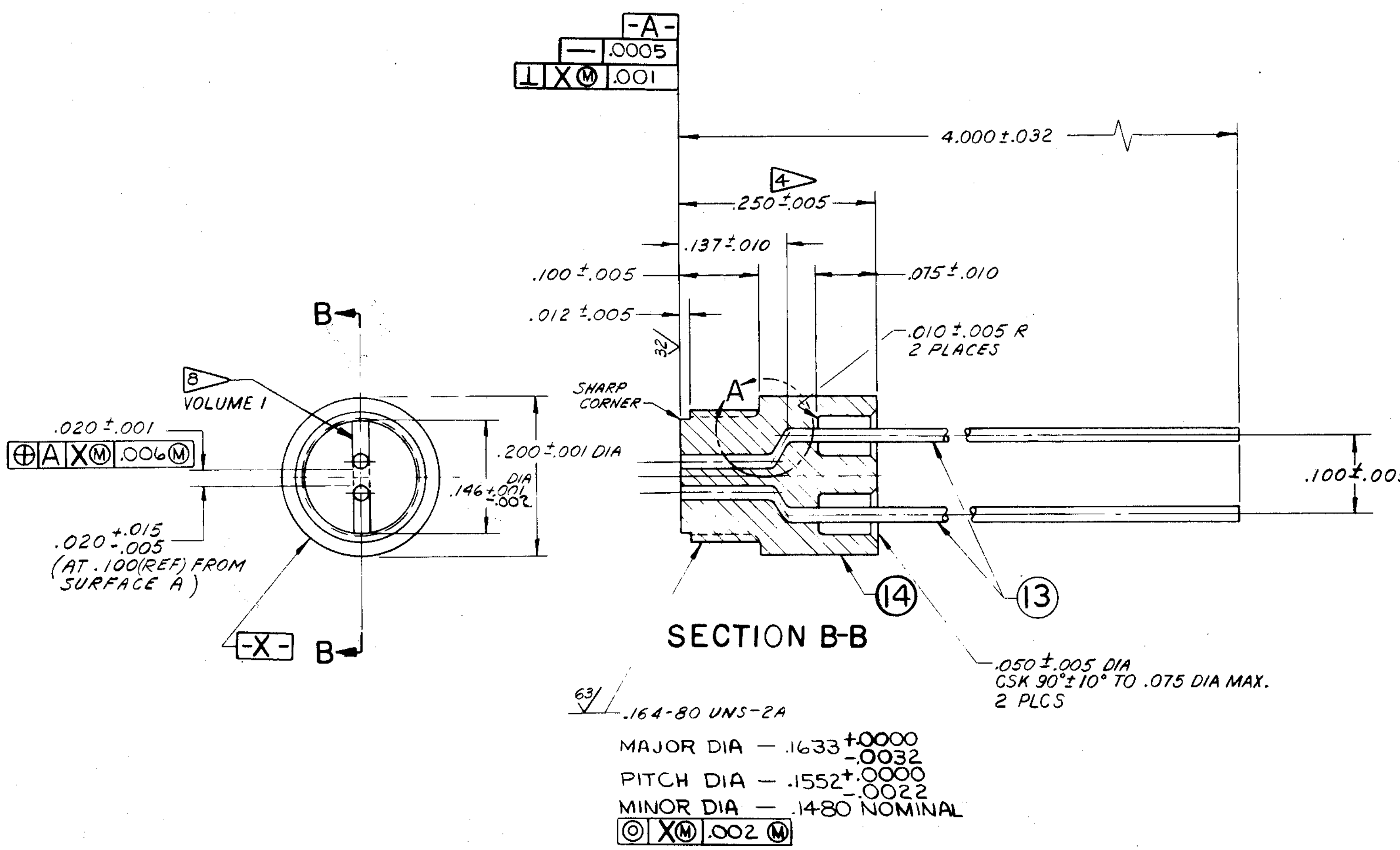

FIGURE 2 - Detonator head engineer drawing showing 4-in. (101.6-mm) wire extension.

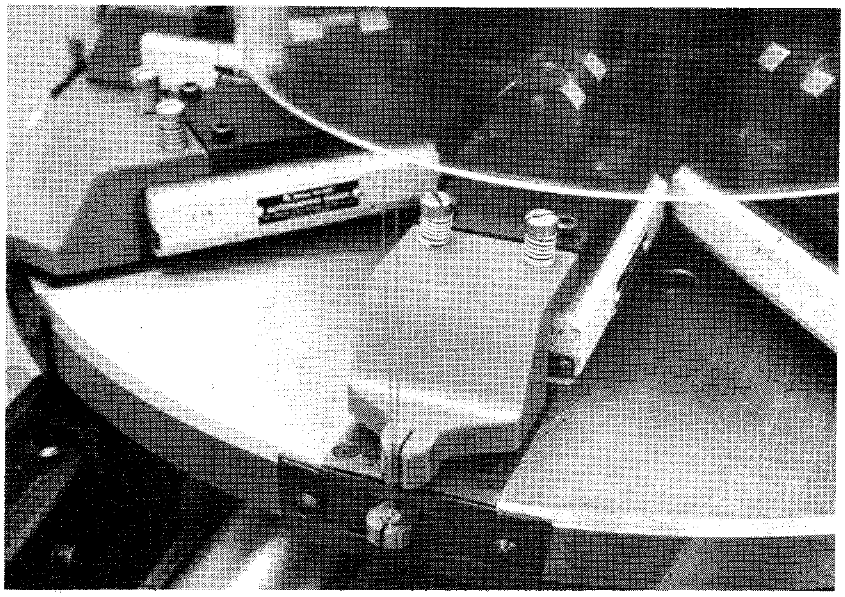

FIGURE 3 - View of semiautomatic grinder showing nest device clamping DAP detonator head with wire inserts.

FIGURE 4 - View of semiautomatic grinder showing vertical spindle, grinding wheel and vacuum head.

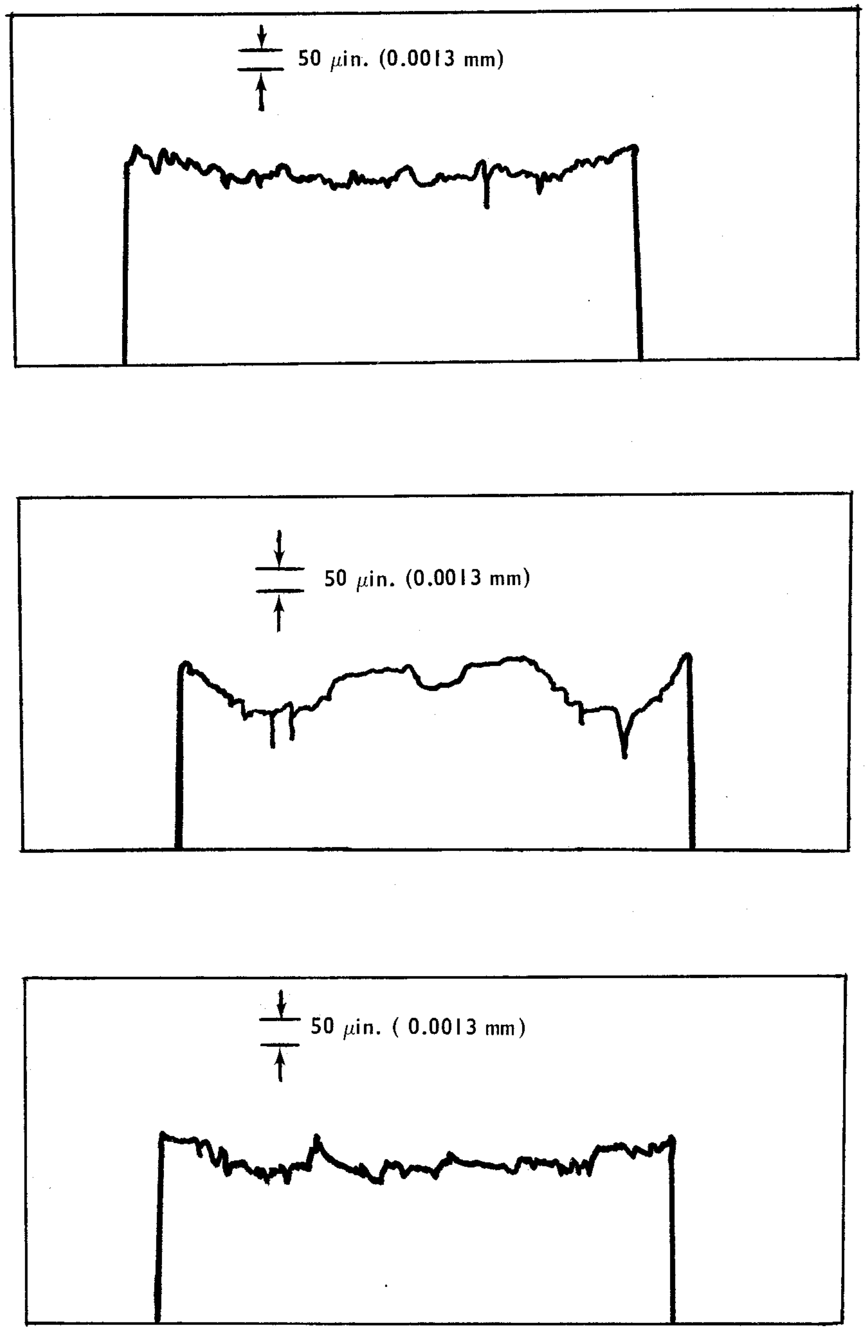

FIGURE 5 - Tallysurf charts of DAP detonator head surfaces ground with the semiautomatic grinder.

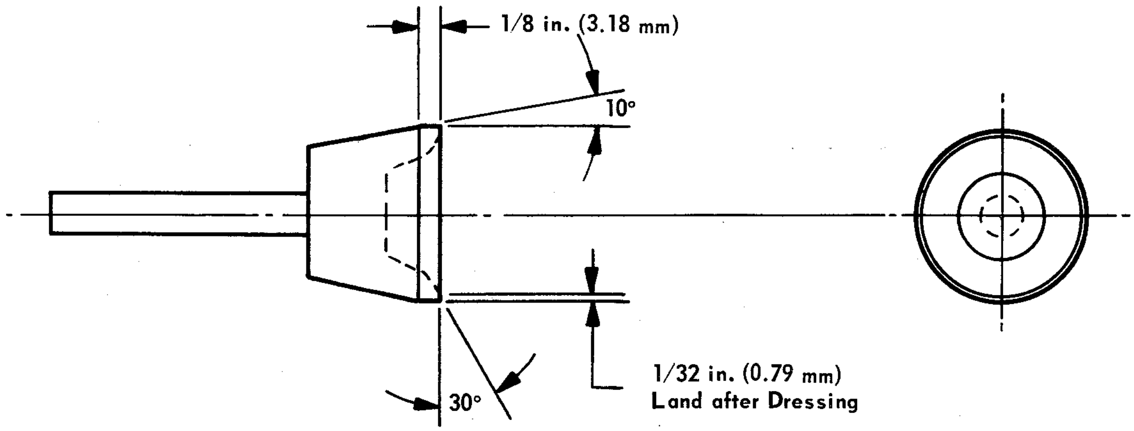

FIGURE 6 - Sketch of modified standard 49-CG-J5-VCPT grinding wheel shape showing land width.

Table 1

RESULTS OF VARIOUS GRINDING WHEELS
TRIED IN SEMIAUTOMATIC GRINDING MACHINE

Type of Grinding Wheel	Wheel Speed (rpm)	Feed Rate[a] (in./min)	Ground Detonator Head Surface Results		Conclusions
			Finish	Chipping	
49CG-46-J7-VCPT[b]	29,000	8	Good	None	Recommended Wheel
49CG-46-G7-VCPT	25,000 to 29,000	6 to 10	Fair	Slight	Wheel Breakdown
49CG-46-I7-VCPT	25,000 to 29,000	6 to 8	Fair	Slight	Wheel Loading
49CG-60-J7-VCPT[c]	25,000 to 29,000	6 to 8	Fair to Good	Slight to None	Approved
49CG-60-G7-VCPT	25,000 to 29,000	6 to 8	Fair	Slight	Wheel Breakdown
49CG-60-I7-VCPT	25,000 to 29,000	6 to 8	Rough Cupping Effect	Slight	Wheel Loading
49CG-80-G7-VCPT	25,000 to 29,000	6 to 8	Rough	Excessive	Wheel Loading
49CG-80-I7-VCPT	25,000 to 29,000	6 to 8	Rough	Slight	Wheel Loading

[a] The average feed rate was 8 in./min (203.2 mm/min).

[b] Grinding wheel Type 49CG-46-J7-VCPT was selected for grinding a plain (unthreaded) detonator head due to its phosphor-bronze wire insert.

[c] Grinding wheel Type 49CG-60-J7-VCPT was selected for grinding some threaded detonator heads due to their copper wire inserts.

Table 2

INSPECTION DIMENSIONAL RESULTS USING
VARIOUS NEST DEVICES IN SEMIAUTOMATIC GRINDER

Tolerance[a]	Tolerance Dimension[b] (in.)	Sample Size	Dimensions[c] (in.) for Nest Device Numbers: 9	10	11	12	13	14	15	16
Perpendicularity	0.001	1	0.0004	0.0004	0.0005	0.00055	0.0004	0.0002	0.0004	0.0004
Perpendicularity	0.001	2	0.00015	0.00025	0.0006	0.0004	0.0006	0.0004	0.00045	0.00055
Flatness	0.0005	1	0.00025	0.0003	0.0004	0.0003	0.0004	0.0005	0.0006	0.0004
Flatness	0.0005	2	0.00034	0.0004	0.0005	0.0003	0.00045	0.0004	0.0004	0.0005

[a] Perpendicularity tolerance represents the degree to which Surface A is perpendicular to Surface X (see Figure 2); flatness tolerance represents the degree of flatness of Surface X (see Figure 2).

[b] 0.001 in. (0.025 mm) and 0.0005 in. (0.0127 mm).

[c] Average dimensions for nest devices are 0.00736, 0.00864, 0.01270, 0.00991, 0.01168, 0.00965, 0.01168 and 0.01168 mm for nest devices numbers 9 through 16.

Table 3

INDUSTRIAL ANALYSIS[a] OF MANUAL VERSUS SEMIAUTOMATIC GRINDING TECHNIQUE

Grinding Technique	Time/1000 Heads (hr)	Cost/hr ($)	Cost/1000 Heads ($)
Manual	32.1	3.45	110.75
Semiautomatic	5.3	3.45	18.29

[a] The analysis reveals that when considering only the direct labor costs, the proposed semiautomatic grinding technique presents an 83.5% cost reduction.

Table 4

COMPARISON DATA FOR GROUND DAP DETONATOR HEADS WITH WIRE INSERTS

	Dimensions[a]	
	Required	Obtained
Length (in.)	0.100 ± 0.005	0.100 ± 0.0005
Finish (μin.)	32	8 to 15
Flatness (in.)	0.0005	0.0002
Squareness (in.)	0.001	0.0002

[a] 0.100 in. (2.54 mm) and 0.0002 in. (0.0051 mm).