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SUMMARY REPORT

ON

TASK ORDER NO. AA

ASA, WALL GROVING

December 31, 1958

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Rec'd 4/29/59 10:30 ED

April 28, 1959

Dear Sir:

Enclosed is the Summary Report on Task Order No. AA that describes the activity under this Task Order from May 1 through December 31, 1958.

As a result of this activity, a variety of cutting tools have been evaluated and found suitable to some degree for slotting brick and marble. Also, design parameters related to an implement for slotting brick and marble were studied, and the requirements of a suitable slotting implement were generally defined. This feasibility study did not result in the selection of a specific cutting tool and power source to perform the slotting operation of interest. However, the direction of future work to accomplish this purpose has been defined. The cutting tools evaluated in this program have been sent to the Sponsor for further evaluation.

We have enjoyed working on this project and believe that the effort performed has brought you closer to your goal. We would appreciate any comments that you or your associates might care to made in regard to the research under Task Order No. AA.

Sincerely,

[redacted] 25X1

ABW:mlm

In Triplicate

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SUMMARY REPORT

ON

TASK ORDER NO. AA

A.A, WALL GROUND [illegible]

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December 31, 1958

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SUMMARY REPORT

ON

TASK ORDER NO. AA

December 31, 1958

INTRODUCTION

Task Order No. AA was undertaken on May 1, 1958, directed toward the selection and evaluation of a cutting tool or combination of tools that might ultimately be incorporated in an implement to facilitate the concealment of wire in the interior of buildings. A device had been developed for drilling holes through masonry-type building materials under specialized conditions; but, there remains the problem of concealing the wire in those cases where it must traverse a room. If a means were available for cutting a slot in walls, primarily, and also in floors and ceilings, it appears that the ease of wire concealment would be increased significantly. It is believed that if a device could be developed for cutting a slot 1/8 inch wide and 5/16 inch deep in brick and marble at a rate of 1 foot per minute, such a unit would be quite useful.

Based on a cursory survey of probably applicable, commercially available cutting tools, it was felt that the best approach to the development of a suitable implement for slotting brick and marble satisfactorily was to select first a cutting tool or combination of tools that was capable of cutting or routing these materials rapidly, under the conditions of reasonable applied force, power requirements, and life expectancy. To provide a basis for such a selection, it was believed necessary to conduct an evaluation study of different types of available cutting tools under simulated-service conditions. Such a study was also expected to provide information on the design parameters pertinent to the development of a suitable slotting implement; the parameters of particular interest were considered to include slotting rate, rotational speed, pushing force, and power requirements.

In accordance with the above thoughts, the objective of the Task Order No. AA research program was to conduct research directed toward the selection and evaluation of a cutting tool or combination of tools for use in cutting grooves approximately 1/8 inch wide by 5/16 inch deep in brick and marble at a rate of about 1 foot per minute without the application of water as a lubricant and flushing medium. This report summarizes the research performed under Task Order No. AA, during the period May 1 through December 31, 1958.

DETAILED SUMMARY

The investigation was begun by surveying the cutting tools and equipment employed in the stone-cutting industry and construction field. It was learned that abrasive blades, diamond wheels, tungsten carbide cutting tools, pneumatic tools, air-abrasive equipment, and a number of miscellaneous tools and equipment were utilized depending on the work material, location, and desired results.

The abrasive blade, diamond wheel, and air-abrasive equipment are widely used and appeared to show the most promise relative to the slotting operation of interest. Therefore, these items were investigated first, and then small tungsten carbide tools were studied.

In the evaluation of the various potentially applicable slotting tools and equipment, it was found that the abrasive blade could be used for dry cutting masonry materials; if a 1/3 to 1/2-horsepower implement were employed as the power unit, a slotting rate of 1 foot per minute could be obtained in cutting a slot 1/8 inch wide by 5/16 inch deep. However, the noise and dust associated with the operation of the abrasive blade were objectionable.

The diamond wheel also cuts various types of masonry materials without the use of a lubricant; but, this type of wheel is expensive, easily damaged by heat, and easily broken when used with a portable power unit. Also, the noise and dust from the operation of the diamond wheel are comparable with those from the abrasive blade.

The cutting action of the tungsten carbide end mill and midget bur results in less noise than does the operation of the abrasive blade, and there is no associated dust problem. However, these tungsten carbide tools provide a low slotting rate and have a short life, although these can be resharpened with some sacrifice of tool diameter.

The air-abrasive equipment can be used to cut a slot in masonry materials; but, the equipment necessary to obtain a reasonable slotting rate is too large and bulky to be feasible for this purpose.

This was also true of a number of miscellaneous tools, equipment, and methods that were investigated.

A study was performed on the design parameters pertinent to a slotting implement which would incorporate a suitable cutting tool. Appropriate measurements made by means of an electric dynamometer and special test table showed that a slotting tool would require from about 1/3 to 1/2 horsepower and an average pushing force (on the workpiece relative to the tool or vice versa) of approximately 5-1/2 pounds in order to cut a 1/8-inch-wide by 5/16-inch-deep slot in marble at the rate of 1 foot per minute. A similar slot could be obtained with less power, dust, and noise by cutting two parallel narrow slots appropriately spaced; if the intermediate material did not break out in the normal course of slotting, as is frequently the case, then the material could be removed by means of a simple hand tool.

Based on the limited number of tests on a wide variety of cutting tools and equipment, the following recommendations are directed toward the potential development of a useful slotting implement. A device comprising two small, thin diamond discs spaced apart on a spindle, a vacuum dust-recovery system, and a power unit represents a promising implement; in the development of such a device, additional effort would have to be performed in studying disc sizes and different types of bonding agents in an attempt to increase the life and reduce the cost of the diamond disc. The tungsten carbide midget-bur and end-mill rotary tools are also promising items for use in the implement of interest; to exploit the advantages of these tools, some additional research would have to be performed on flute design, cut, and operating speeds in an effort to increase slotting rate and tool life.

The various cutting tools and appropriate adapters were sent to the Sponsor for further evaluation. Based on our findings, additional research is suggested that would be directed toward the further evaluation of selected cutting tools and the application of a suitable power unit, in order to provide the basic components of an appropriate implement for use in performing the desired slotting operation.

ENGINEERING ACTIVITY

The engineering activity on this research program comprised an investigation of commercial slotting methods, an evaluation of commercial slotting tools and equipment, and a study of slotting-tool design parameters. Also, consideration was given to recommendations directed toward the potential development of a useful slotting implement.

Investigation of Slotting Methods

An investigation of the methods used in cutting, carving, and slotting masonry-type building materials resulted in the study of the various tools and equipment. These included abrasive blades, diamond wheels and discs, tungsten carbide cutting tools, air-abrasive equipment, and a number of miscellaneous tools and equipments.

Abrasive Blades, and Diamond Wheels and Discs

A preliminary investigation of the stone-cutting industry and the construction field showed that abrasive blades and diamond wheels are widely used in the cutting and finishing of marble. Abrasive blades are also frequently employed in special equipment designed to cut brick and to slot concrete. The abrasive blades and diamond wheels involved in this type of work are generally 12 inches or more in diameter, are used with a water lubricant, and are designed to cut specific materials. The initial cost of a diamond wheel is considerably more than that of an abrasive blade; but, with proper care used in applying the diamond wheel, this difference in cost is offset by increased life. The abrasive blade can be used in the dry cutting of masonry-type materials; under dry cutting conditions, the life of the blade is reduced. However, the diamond wheel is not recommended for dry cutting operations unless an extremely short wheel life is acceptable.

Abrasive blades are manufactured commercially from a variety of abrasives and bonding materials; these determine the blade characteristics of softness or hardness and the resulting wear rate of the blades when used for specific materials and particular cutting and/or machining operations. In general, a soft abrasive blade is recommended for working on hard material, and a hard blade for soft material. The operating speed for an abrasive blade depends on the type of bonding agent involved, but is usually within the range of 5,000 to 10,000 surface feet per minute (sfpm).

Two types of general-purpose blades are manufactured for use with portable equipment in working on masonry-type materials. These blades consist of a silicon carbide grit bonded with a resinoid, and an aluminum oxide grit bonded with rubber; they are 6 to 10 inches in diameter, and have a glass-fiber matt bonded to the surface or molded in, as a safety measure to prevent disintegration of the blade if breakage should occur during the cutting operation.

Diamond wheels suitable for slotting operations are manufactured in standard sizes ranging from 3 to 24 inches in diameter and consist of natural diamonds in a variety of grit sizes and concentrations, and various bonding agents. Three general types of construction are normally used in these diamond wheels: (1) the diamonds are in a matrix bonded to the periphery of a metal disc, (2) the diamonds are retained in radial slots spaced around the periphery of a metal disc, or (3) the diamonds are bonded to segments which are mounted around the periphery of a metal disc. Also, small diamonds are bonded to the surface of small-diameter metal discs which are employed in the dental field to cut ceramic materials. Such discs are particularly useful for slotting operations on or for cutting precious material where waste must be minimized.

The manufacturers recommend the use of water or a lubricant with the diamond wheels because the heat generated during dry cutting is likely to destroy the bond and consequently the diamonds may be lost from the wheel. Further, diamond wheels with the diamonds bonded to the periphery are not recommended for use in hand tools; a twist or binding of the wheel in the slot is likely to separate the diamond-bearing section from the metal disc. The recommended operating speed for diamond wheels ranges from 6,000 to 15,000 sfpm.

Tungsten Carbide Cutting Tools

A survey of solid tungsten carbide and tungsten carbide - tipped cutting tools revealed that these items are used to some extent in the stone-cutting industry. However, they cannot compete with diamond wheels and abrasive blades in production work, except perhaps in turning operations, because the tool life is short, the cutting rate is low, and the cost of the tool is high. The tungsten carbide rotary cutting tools which appeared to be suitable for slotting operations were of two general types: (1) the end mill or the midget bur, either of which could be used in a router-type operation, and (2) the slitting-saw-type cutter which could be mounted on the shaft of a drill motor or similar portable implement. These rotary cutters are designed to operate at high speeds, and lubrication of the tools is important in order to achieve reasonable tool life. These tools can be resharpened after they have become dull; however, as a result, the diameter of the tools would be decreased and narrower slots would be cut.

Air-Abrasive Equipment

The stone-cutting industry employs impact-type cleaning equipment to remove material from the surface of masonry-type materials. In stone-cutting plants, stationary equipment is used to cut grooves in the form of letters, numbers, and borders in stone work; portable equipment is used to do the same job in the field. Aluminum oxide grit or sand, suspended in air at 80-psi pressure, constitutes the abrasive and propellant. The grit size and composition, and the nozzle diameter vary in accord with the type of material to be worked and the quality of cut desired. The contour of the slot is achieved by masking with a resilient material, and the depth of cut is controlled by varying the rate and uniformity of movement of the nozzle.

Similar equipment was found to be used in the dental field and in specialized commercial operations where very fine cuts are required. Cylinder nitrogen gas is used to propel an aluminum oxide abrasive, and the amount of material removed is kept to a minimum. The nozzle and grit sizes are varied depending on the type of cut desired and the type of material being slotted.

Miscellaneous Tools and Equipment

In addition to the survey of stone-working tools described in the previous section, consideration was given to the use of several miscellaneous types of tools and equipments, in an effort to uncover other methods which might prove to be applicable to the slotting operation of interest. These included percussion-type tools, electro-arc equipment, the plasma torch, acid, and ultrasonic impact grinding.

The percussion-type tools and the use of ultrasonics were not evaluated in the laboratory because these were found to provide a low cutting rate, and also the associated equipment is large, bulky, and expensive. The plasma torch with a flame temperature of between 15,000 and 30,000 F probably could be used to gouge a slot in masonry-type materials. However, the associated electric-arc-generating equipment is also large, bulky, and expensive, and consequently this tool is probably not readily applicable. The use of acid on marble to produce a slot was considered to be impracticable because this operation would require the application of concentrated acid over long periods of time.

Evaluation of Slotting Tools and Equipment

On the basis of the information obtained in the initial investigation of potentially applicable cutting tools and methods, the following items were selected for evaluation in the laboratory: abrasive blades, diamond wheels, diamond discs, tungsten carbide cutting tools, and air-abrasive equipment. The various rotary tools are illustrated in Figure 1. To facilitate the evaluation of these tools, several types of equipment were used, including a table saw, a portable heavy-duty power saw, a standard drill motor, a special electric drill motor (from the Task Order No. 0 drilling unit), an electric grinder motor, a drill press, and a router.

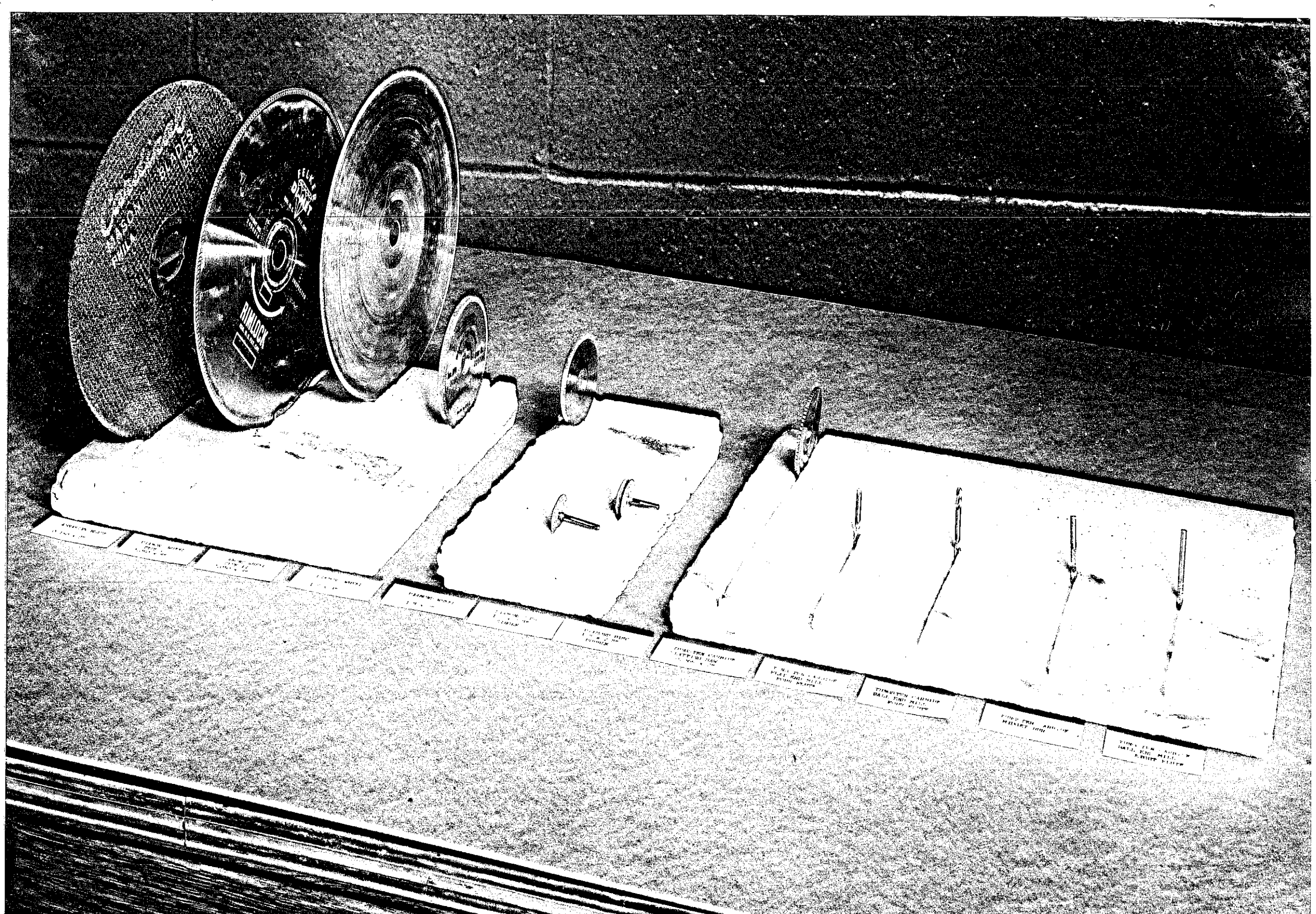

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Figure 1. Abrasive Blade, Diamond Wheels and Discs, and Tungsten Carbide Rotary Cutting Tools Which Were Investigated

Early in the course of those evaluation experiments which involved the portable above-mentioned power devices and abrasive blades, or diamond wheels or discs, it was noted that the extent to which the cutting action was readily controllable depended on the direction in which the slot was cut in relation to the direction of rotation of the cutting blade, wheel, or disc. The direction of rotation of the cutting tools, when attached to these portable implements, was clockwise as viewed from the implement side of the tool; it was found that the cutting action of the tools could be controlled most readily by slotting from right to left. With this relationship between direction of slotting and direction of tool rotation, the tool tended to push away from the workpiece; in order to achieve a slot, the operator had to force the tool continually back against the workpiece, and, consequently, by manually varying the force exerted on the tool, the operator was able to control the cutting action readily. When slotting from left to right was attempted with the above-described combinations of portable implements and cutting tools, the tools tended to "move into" the workpiece and to seize and gouge; consequently, it was extremely difficult to control the slotting operation. As a result of this experience, all of the slotting tests performed with abrasive blades, and diamond wheels and discs were arranged so that the above-described optimum relationship was maintained between the direction of slotting and the direction of rotation of the cutting tool.

Abrasive Blades, and Diamond Wheels and Discs

The abrasive blades which were selected for slotting tests in brick and marble were general-purpose, break-resistant blades consisting of a silicon carbide grit in a resinoid bonding material; they ranged from 5 to 8 inches in diameter and were 1/8 inch thick. Limited slotting tests were made with a blade comprised of an aluminum oxide abrasive in a rubber bonding material; however, the results obtained with this type of blade were not so good as those with the silicon carbide - grit blade. The slotting data presented in Table 1 were obtained using silicon carbide - grit blades attached to a table saw, a portable power saw, a standard drill motor, and the motor from the special drilling unit developed under Task Order No. 0; the slotting operations were all performed dry.

In the above-described tests, the wear of the abrasive blades was negligible; it is anticipated that this would be so also in the course of an average field operation. As indicated by the data in Table 1, with sufficient power available, a slotting rate of 1 fpm could easily be achieved with this abrasive blade. A 6-inch-diameter break-resistant blade mounted on a small portable power saw provides a workable unit. However, the Sponsor indicated that the noise and dust resulting from the cutting action of the abrasive blade could not be tolerated under field conditions.

Consequently, a solid wax lubricant and a mist-type spray consisting of water, a water-soluble lubricant, and air were used

TABLE 1. SLOTTING DATA FOR SILICON CARBIDE - GRIT BLADES

Power Unit	Abrasive-Blade Diameter, inches	Slot Dimensions, inch	Test Material	Slotting Rate, fpm
Table saw, 3/4 hp at 3,425 rpm, 9.8 amp, 120 volt	7	1/8 wide by 5/16 deep	Marble	2.0
8-inch heavy-duty power saw, 4,500 rpm, 9 amp, 115 volt	7	1/8 wide by 5/16 deep	Marble	2.5
	6	Ditto	Marble	2.0
	8	"	Marble	3.0
	8	"	Concrete	4.5
	8	"	Brick	8.0
Special drill motor, 0.1 hp at 2,100 rpm	8	1/8 wide by 1/4 deep	Marble	0.3
	6	1/8 wide by 5/16 deep	Brick	2.0
	6	1/8 wide by 1/4 deep	Concrete	1.0
1/4-inch drill motor with saw attachment, 3,000 rpm, 2 amp, 115 volt	5	1/8 wide by 1/4 deep	Concrete	0.3

Note: All of the tests were conducted dry.

with the abrasive blades in an effort to reduce the noise and dust from the slotting operation. The lubricating and cooling effects resulting from the use of these lubricants would undoubtedly increase the life of the blades, but the reduction in noise and in dust was negligible. Also, when either lubricant was applied in quantity, excess wax or water was deposited on the workpiece; this would probably be undesirable under service conditions.

Two general types of diamond wheels were used in slotting experiments on brick and marble. In one type (Type II), the diamond matrix was bonded to the periphery of a steel disc, and in the other type (Type I), the diamonds were embedded in radial slots spaced at approximately 1/8-inch intervals around the periphery of a steel disc. Diamond-coated steel discs, 7/8 inch in diameter by 1/32 inch thick, that are used to cut ceramic material in the dental field were also evaluated. Although the manufacturers recommend that a lubricant and a rigid, accurate, spindle mounting be employed when using the diamond wheel on masonry-type materials, the slotting tests were conducted dry with intermittent operation of the wheels or discs on fixed spindle mountings and on portable hand tools. Representative data are presented in Tables 2 and 3; a few noise-level measurements were made and are included in Table 3.

The results of the tests using the diamond wheels indicated that the larger diameter (8 inch) Type II wheels, when run dry at the recommended speeds, cut the various types of masonry material. However, it should be emphasized that these wheels must be used intermittently in order to allow for wheel cooling; otherwise, they must be

TABLE 2. SLOTTING DATA FOR DIAMOND WHEELS AND DISCS

Power Unit	Type of Diamond Wheel or Disc	Slot Dimension, inch	Material	Slotting Rate, fpm
Table saw, 3/4 hp at 3,425 rpm, 9.8 amp, 120 volt	8-inch diameter by 0.050 inch thick; Type II; grit size 100, grit concentration 100	1/16 wide by 5/16 deep	Marble	0.30
			Hard brick	0.58
			Soft brick	4.0
8-inch heavy-duty power saw, 4,500 rpm, 9 amp, 115 volt	8-inch diameter by 0.050 inch thick; Type II; grit size 100, grit concentration 100	1/16 wide by 5/16 deep	Marble	1.00
	8-inch diameter by 0.050 inch thick; Type I	Ditto	Marble	Damaged by generated heat; unsatisfactory
Special drill motor, 0.1 hp at 2,100 rpm	3-inch diameter by 1/8 inch thick; Type II	1/8 wide by 5/16 deep	Marble	0.10, but damaged by generated heat; unsatisfactory
Special drill motor, 0.1 hp at 2,100 rpm	2-inch diameter by 1/8 inch thick; Type II	1/8 wide by 5/16 deep	Marble	Unsatisfactory; grabbed and was erratic in operation
Electric grinder motor, 0.1 hp at 22,000 rpm	7/8-inch diameter by 1/32 inch thick; 2 spaced discs; grit size 180 to 250	3/32 wide by 1/4 deep	Marble	0.17
			Hard brick	0.05
			Soft brick	1.20
Special drill motor, 0.1 hp at 2,100 rpm	7/8-inch diameter by 1/32 inch thick; 2 discs spaced 3/64 inch apart	1/8 wide by 1/4 deep	Marble	0.12

Note: All of the tests were performed dry; the wheels or discs were operated intermittently, in an attempt to minimize overheating.

TABLE 3. COMPARATIVE SLOTTING-RATE AND NOISE-LEVEL DATA FOR DIAMOND WHEEL AND ABRASIVE BLADE

Power Unit	Type of Wheel	Slot Dimensions, inch	Material	Slotting Rate, fpm	Noise Level, db
Table saw, 3/4 hp at 3,425 rpm, 9.8 amp, 120 volt	Diamond; 8-inch diameter by 0.050 inch thick; Type II; grit size 100, grit concentration 100	1/16 wide by 5/16 deep	Marble	0.3	91
	Abrasive; 8-inch diameter by 1/8 inch thick	1/8 wide by 5/16 deep	Marble	1.3	99

Note: The tests were conducted dry.

lubricated during operation. The noise and dust from the action of the diamond wheels were comparable to those from the abrasive blades. When operated in a hand implement, these diamond wheels must be handled very carefully, to prevent breakage of the diamond matrix; this might occur readily if inadvertently the edge of the wheel were bound or twisted in a slot. The 8-inch-diameter Type I diamond wheel was not too "touchy" when used in a hand implement; but, in dry slotting tests, this wheel overheated quickly and was considered unsatisfactory. In each particular test, the 3-inch-diameter Type II diamond wheel initially cut, but rather quickly became loaded and overheated. The 2-inch-diameter Type II diamond wheel did not slot very far before it grabbed and became erratic in operation; this wheel also overheated quickly. On the basis of the results from these tests, the small-diameter Type II diamond wheels were considered unsatisfactory for dry slotting masonry-type materials.

The small-diameter diamond discs showed promise; they provided a fair cutting rate, and caused less dust and noise during slotting than did the larger diamond wheels or abrasive blades. However, these discs have a very limited tool life, because the bond fails readily and diamonds are lost from the disc.

The use of an arrangement consisting of two thin diamond discs appropriately spaced apart on an arbor would result in two thin slots with intermediate unremoved material. In experimental slotting operations with this setup, the intermediate material frequently broke out; if not, it was readily broken out with a simple hand tool.

With such an arrangement, less material is removed than is the case when a single thicker diamond disc is employed; consequently, it is probable that a higher cutting rate can be achieved with the spaced discs, possibly with the use of less power.

The use of a small battery-operated vacuum cleaner was effective in catching and removing most of the dust resulting from the slotting operation with the diamond disc. It is of interest that at least one manufacturer is known to be working on a better bond, in an attempt to retain the diamonds on the base metal disc and thus increase the life of the diamond disc.

Tungsten Carbide Cutting Tools

Slotting tests were made in marble with solid tungsten carbide rotary cutting tools. Representative results are given in Table 4. The rate data are based on the removal of a specific volume of material, since in some cases the full depth was obtained by making two or three cuts in the same slot.

In the application of this type of cutting tool, it is necessary to utilize a router or similar device to provide the means of control necessary in order to cut a relatively straight slot of uniform depth. In some of these slotting tests, the router speed was varied while using a ball-end-mill rotary cutting tool; a speed of approximately 10,000 rpm seemed to provide an optimum combination of slotting rate and tool temperature, and, therefore, relatively good tool life. The noise levels associated with the cutting action of the end-mill-

TABLE 4. REPRESENTATIVE SLOTTING DATA FOR TUNGSTEN CARBIDE ROTARY CUTTING TOOLS

Power Unit	Speed, rpm	Type of Tool	Slotting Rate, fpm
Drill press, 1/3-hp motor	2,500	Ball end mill, 4 flutes	0.12
Ditto	2,500	Square end mill, 4 flutes	0.15
"	2,500	Midget bur, 4 flutes	0.8
"	5,000	Ball end mill, 4 flutes	0.15
"	5,000	Square end mill, 4 flutes	0.18
"	5,000	Midget bur, 4 flutes	0.12
"	5,000	Ball end mill, 8 flutes	0.20
Router, 5/8 hp	22,000	Ditto	0.18
Ditto	10,000	"	0.22
Special drill motor, 0.1 hp	2,100	Slitting saw, 2-inch diameter by 1/16 inch thick	0.06

Note: All of the tests were conducted dry on marble, in cutting the "standard"-sized slot, 1/8 inch wide by 5/16 inch deep.

and midget-bur-type rotary cutting tools were lower than those of the abrasive blades evaluated. Also, the cuttings remained loose in the slot, and the dust problem was minimized. The slitting-saw rotary cutter, however, was quite noisy and control of the dust was a problem. This cutter had a relatively low and erratic slotting rate.

These tungsten carbide tools are expensive and the tool life is relatively short. However, such tools can be resharpened, with some sacrifice of tool diameter and, therefore, of slot width.

Air-Abrasive Equipment

Two kinds of commercial impact-cleaning type of equipment were evaluated in slotting tests run in brick and marble. One unit (No. 1) used aluminum oxide abrasive propelled by nitrogen gas and was designed for slitting or cleaning small and delicate parts. The second unit (No. 2) was a shop-type sand-blast apparatus designed to clean and finish medium-sized machine-shop items. A steel grit propelled by compressed air is normally used in the operation of the sand-blast unit, but in our tests in brick and marble, sand was employed as the abrasive; the brick and marble were masked with resilient material in order to define the slot width.

The No. 1 unit with a 0.019-inch-diameter nozzle cut a very narrow slot in brick and marble, and used relatively small amounts of nitrogen gas and abrasive. However, this equipment was large and the slotting rate was low. A slotting rate which approached acceptability was achieved with the No. 2 unit using the standard 1/4-inch-diameter nozzle. Representative slotting data obtained with the two air-abrasive units on marble are presented in Table 5.

TABLE 5. SLOTTING DATA FOR AIR-ABRASIVE EQUIPMENT

Unit	Nozzle Diameter, inch	Abrasive	Propellant	Material	Slotting Rate, fpm
No. 1	0.019	Aluminum oxide, 0.004 lb/min	Nitrogen, 0.2 cu ft/min	Marble	0.001
No. 2	0.250	Sand, 2.6 lb/min	Air, 12-1/2 cu ft/min	Marble	0.030

Based on the information from these slotting tests and the knowledge that a standard paint-spray electric motor-compressor unit would deliver 3-1/2 cu ft/min of air at 100-psi pressure, special nozzles, 1/8- and 3/32 inch in diameter, were fabricated for the No. 2 unit in an effort to obtain an acceptable slotting rate with less air and abrasive. Although the air consumption with the 3/32-inch-diameter nozzle was reduced to approximately 6 cu ft/min, the slotting rate in marble was reduced to 0.010 fpm. As a result of the low slotting rate and the apparent bulkiness of a combined motor-compressor and abrasive-handling unit, air-abrasive equipment was considered to be impracticable as a slotting tool.

Study of Slotting-Implement Design Parameters

A special test table was designed, constructed, and mounted on an electric dynamometer, to facilitate the study of design parameters that would be useful in the ultimate development of a slotting implement. The experimental setup is shown in Figure 2. The design parameters investigated were power requirements, pushing force on the workpiece, rotational speed of the cutting tool, and slotting rate.

Description of Test Equipment

The test equipment comprised a spindle for the test blade or wheel and an adjustable table top to support and guide the test material or workpiece. The direction of rotation of the spindle was such as to permit maintaining the previously described optimum relationship between the direction of slotting and the direction of rotation of the cutting tool (abrasive blade or diamond wheel). In the performance of the experiments, the test material, brick or marble, was pushed against the rotating blade or wheel while data pertaining to the following design parameters were recorded: (1) the force required to feed the workpiece, (2) the speed of the cutting tool, (3) the power required to cut a slot 1/8 inch wide by 5/16 inch deep, and (4) the rate of the slotting operation. Abrasive blades and diamond wheels were used with this equipment.

Evaluation of Test Results

In general, the abrasive blades and diamond wheels provided similar results. Table 6 lists representative data obtained with the

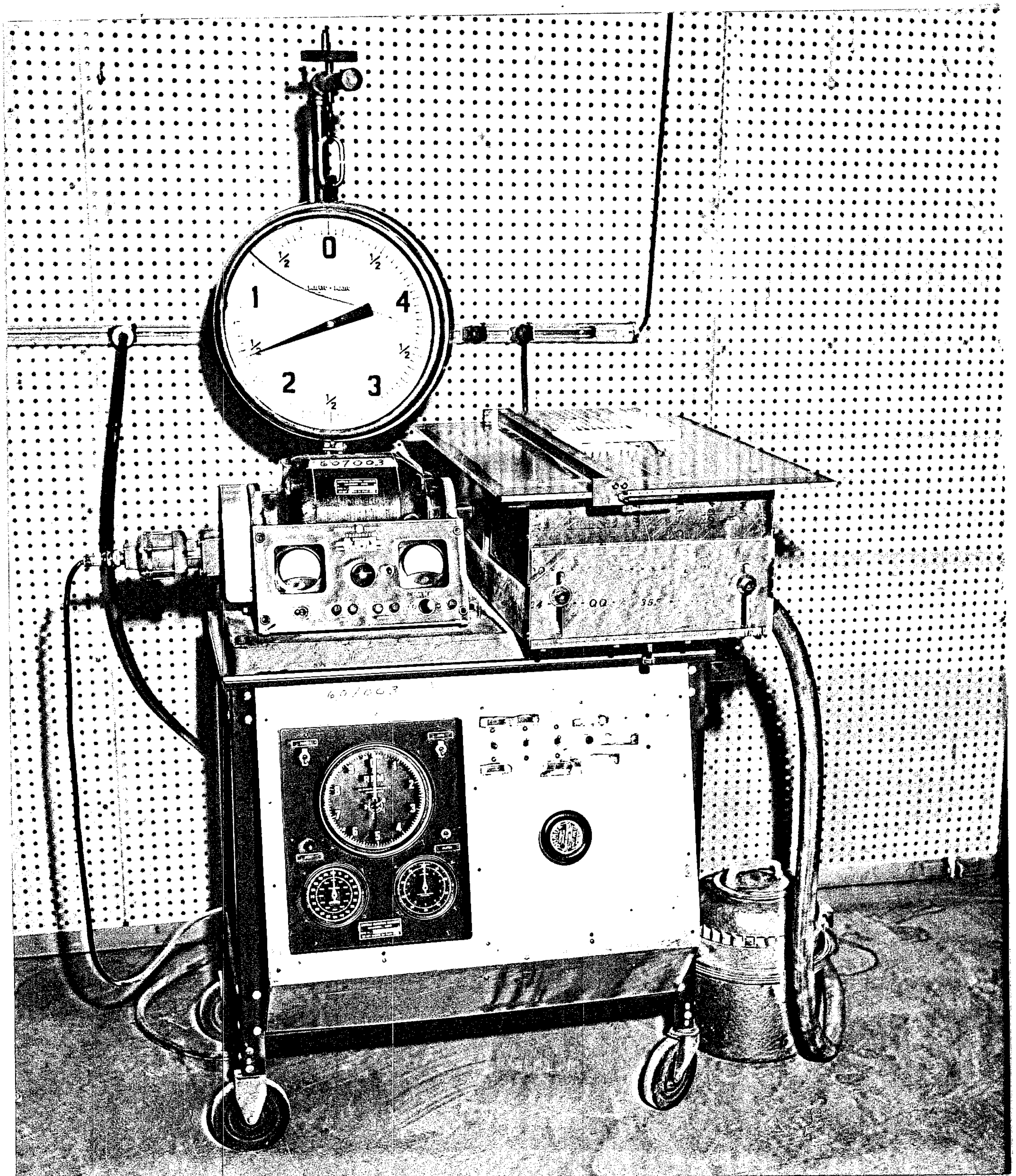

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Figure 2. Electric Dynamometer With Special Table

TABLE 6. REPRESENTATIVE SLOTTING DATA FROM DYNAMOMETER - TEST TABLE EXPERIMENTS

Abrasive-Blade Speed, rpm	Horse-power	Abrasive-Blade Diameter, inches	Slotting Rate, fpm
1,800	0.3	6	0.3
2,900	0.4	6	0.6
3,000	0.4	6	0.8
3,200	0.8	6	1.1
3,400	0.4	6	1.0
3,400	0.6	6	1.2
3,400	0.8	6	1.7
3,000	0.4	8	1.1
3,400	0.7	8	1.3
3,400	0.6	8	1.8
3,400	0.8	8	2.4
3,400	0.8	8	2.7

Notes: 1. The slot cut was 1/8 inch wide x 5/16 inch deep.

2. The force required to feed the marble test material into the blade averaged 5-1/2 pounds.

electric dynamometer and test table using an abrasive blade to cut a slot in marble.

The test results were comparable with those obtained with the abrasive blade on hand-operated portable power implements. The higher surface speeds resulted in higher slotting rates, and also smoother cutting action of the blade. The data also indicated that, to obtain a slotting rate of 1 fpm with a tool that removed all of the material from a 1/8-inch-wide by 5/16-inch-deep slot would require between 1/3 and 1/2 horsepower. The force required to feed the work, about 5-1/2 pounds, did not vary appreciably with the different test materials or blades and also no problem was encountered in feeding the workpiece.

General Considerations

In connection with the ultimate development of a slotting implement, the speed of the cutting tool used would depend on the type of tool and material to be slotted. In the tests performed, the abrasive blades operated at speeds of from 5,000 to 8,000 sfpm provided satisfactory dry slotting without damage to the blades as a result of excessive generated heat. However, since the design parameters are dependent on the amount of material to be removed, it appears worth while to consider the advantages of minimizing the amount of material to be removed by employing some arrangement like the previously discussed setup with two thin diamond discs spaced appropriately apart on an arbor; it is recognized that the uncut material remaining between the two thin slots obtained by using such a setup might have to be broken out, but this operation could be done quickly with a simple hand tool. Thus, as a result of decreasing the amount of material to be cut, it would be possible to reduce the power requirement and the pushing force, and also the amount of dust and noise "generated" in the course of the slotting operation.

FUTURE WORK

The results of the findings under this research program indicate that the factors which would affect the design of a combined slotting tool and power source are the power required, the rate of cut desired, the control of the drive, the tolerable level of noise and amount of dust, and the tool life. On the basis of consideration of these factors, the diamond disc and the tungsten carbide rotary cutting tools show the most promise for application in a slotting implement. It is believed that both of these types of cutting tools should be investigated further, in an effort to determine which might be superior for this particular application.

Diamond Disc

If a program were to be undertaken to develop a slotting implement using the diamond-disc cutter, we recommend that the initial effort be concerned with working closely with the manufacturer of diamond discs, in an attempt to develop a specialized diamond disc;

a desirable diamond disc would be 2 or 3 inches in diameter and would be produced using an improved bonding agent that would significantly increase the service life of the tool. As currently contemplated, it would be advantageous for the implement of interest to employ two diamond discs spaced apart on a common arbor so as to cut two narrow slots. It is likely that the material between these slots would break out in the normal course of slotting, and, if not, this material could be removed readily with a simple hand tool, in order to obtain a slot 1/8 inch wide x 5/16 inch deep.

A further investigation should be made to determine the disc operating speed which would provide for an optimum combination of slotting rate and tool life. To complete the slotting-implement development, a small electric motor should be selected for use as the power unit. Also, it is contemplated that a vacuum-type dust collector should be used with the slotting implement, to facilitate the removal of the dusty cuttings. This dust collector could either be an independently operated unit or could be incorporated as an integral part of the implement. Since the slotting action of the diamond disc is relatively quiet, it is expected that an electric-motor power source, two diamond-disc cutters, and a vacuum-type dust collector could be combined in an implement which could operate at an acceptable noise level.

Tungsten Carbide Rotary Cutting Tools

In a potential program to develop a slotting implement using a tungsten carbide end mill or midget bur, we recommend first, working closely with the manufacturer of solid tungsten carbide rotary cutting tools in an effort to obtain a cutter which would provide an acceptable slotting rate and tool life. In this connection, the flute design, number of flutes, type of cut, and operating speed should be investigated because these factors control the cutting action and the heating up of the tool. It is contemplated that specialized cutters would be required for this development program.

Subsequently, an appropriate electric-motor powering implement should be developed or prepared by modifying an available device; this unit should operate like a router-type tool, so as to provide the necessary control of slotting depth and direction. The noise associated with the cutting action of the tungsten carbide midget bur or end mill would probably be acceptable. Since the loose cuttings remain in the slot cut by these tools, it appears that there would be no dust problem. However, if these tools should require high operating speeds, as was suggested by some of the results of this initial investigation, then consideration should be given to the development of a sound-dampening system for reducing the operating noise to an acceptable level.

The cutting tools which were evaluated under this research program have been submitted to the Sponsor for further evaluation. If the Sponsor indicates an interest in the development of a slotting implement, we shall submit an appropriate proposed program of research.