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ELEC, Drilling

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19 March 1957

March 19, 1957

Dear Sir:

Enclosed is the Summary Report on Research Order No. 30, which describes the activity under this Research Order from March 8, 1956, through January 31, 1957.

As a result of this activity and in accord with recent discussions, we sent you a proposal, dated January 22, 1957, covering the further evaluation of 3/16-inch-diameter diamond drills and the preparation of another Type 2 Prototype Drilling Kit. This effort is currently being implemented under Work Order No. XI, Task Order No. A. Another proposal, concerned with the preparation of 10 Type 2 Prototype Drilling Kits, specifications, drawings, and an operator's manual, is being written and will be transmitted to you in the near future.

We would appreciate any comments that you or your associates might care to make with regard to the effort under Research Order No. 30.

Sincerely,

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ABW:dp

Enclosure

In Triplicate

SUMMARY REPORT

ON

RESEARCH ORDER NO. 30

January 31, 1957

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SUMMARY REPORT

on

RESEARCH ORDER NO. 30

January 31, 1957

INTRODUCTION

This report describes the work performed under Research Order No. 30 from March 8, 1956, through January 31, 1957.

The prime objective of the research program, as originally proposed, was to evaluate 5/16-inch-diameter diamond drills. The second objective was to prepare 10 experimental drilling kits for field testing by the Sponsor; each would include: (1) a 50-cycle, 110 - 220-volt motor, (2) a flexible shaft, (3) a drilling head, (4) collectors for dust and water, (5) sets of diamond, and possibly carbide, drills for drilling holes up to 30 inches in depth, (6) an axial loading device, (7) water and air supply systems, and (8) a cheap carrying case. The third objective was to prepare drawings and specifications of the experimental drilling kit and the drills, and an operator's manual covering the use of the drilling kit.

As a result of discussions with the Sponsor, the original objectives were modified, by Supplement No. 1 dated September 28, 1956. The second and third objectives of the proposed program were replaced with two others. One of the new objectives was to conduct an investigation directed toward developing a prototype drilling unit equipped with a lightweight, relatively quiet, electric motor integral with the drilling head, to replace the separate electric motor and flexible-shaft drive of the prototype drilling unit developed under Research Order No. 21; this included the design and development of suitable collecting devices for dust and water. The other proposed objective was to conduct a study of drilling with 1/8-inch-diameter diamond drills in granite, plaster, concrete, brick, marble, and other mutually agreed upon materials.

This report presents a detailed description of the evaluation of 5/16-inch-diameter diamond drills; the design, development, and evaluation of a lightweight drilling unit; the design, development, and testing of a suitable device for collecting dust and water; and the cursory evaluation of 3/16-inch-diameter diamond drills. Diamond drills of 3/16-inch rather than 1/8-inch diameter were evaluated because the smaller drills could not be obtained commercially in practical configurations.

DETAILED SUMMARY

In order to evaluate 5/16-inch-diameter diamond drills, drill manufacturing companies were contacted and representative drills were purchased; suitable test equipment was designed and constructed; and the drills were tested under predetermined conditions. Twenty-eight drill manufacturers were contacted and 10 types of drills were received from 9 companies. It was hoped that the test equipment that had been developed under Research Order No. 21 would be satisfactory for the evaluation of the 5/16-inch-diameter drills. However, even after some modification of the original equipment, it was necessary to design and construct a special assembly to hold the material being drilled. With this assembly it was possible to measure the torque that was imparted to the material from the drills by means of an arm incorporating a strain gage.

Tests were made to determine the drilling rate of the test drills in marble at 1/10 and 1/5 horsepower for speeds of 1,000, 2,000, 3,000, and 4,000 rpm. Because of difficulties from plugging, overheating, or inadequate cooling and/or flushing, the drilling tests with five of the 10 drills could not be completed. In tests with the five remaining drills, the fastest drilling rates were obtained with two core drills, and the third highest drilling rate was obtained with a non-coring drill. It is recommended that all three of these drills be field tested by the Sponsor, so as to ascertain which are the best drills from the standpoint of the Sponsor's applications. The non-coring drill should be the easiest to use, but the core drills should provide a higher drilling rate.

The drilling rates for these three 5/16-inch-diameter diamond drills were determined in plaster, brick, blue stone, marble, concrete, and granite with a 1/10-horsepower input. The rates obtained varied from 1/2 inch per minute in granite and 2 inches per minute in concrete, to 50 inches per minute in plaster.

The primary problem connected with the design of a lightweight drilling unit was the selection of an electric motor which would fit into a hand drill, provide sufficient power, and be relatively quiet. Electric-motor manufacturing companies were contacted to determine the feasibility of redesigning high-speed motors presently used in hand tools, in order to obtain quieter operation. It was the opinion of these companies that the noise of these units could not be materially reduced. A discussion of the problem was held with Robbins and Myers, Springfield, Ohio, and a 1/8-horsepower, 2,500-rpm, shunt-wound d-c motor was selected as a unit that would provide the best combination of power, low weight, and little noise.

Tests with this motor in our laboratory were satisfactory and a lightweight drilling unit incorporating this motor was designed. This unit consisted of a drilling head and a power supply. The drilling head included the electric motor, a lightweight housing, and a water swivel for supplying water to the diamond drills. The power supply included the necessary electrical cords and a rectifying unit to supply the motor with direct current. The appearance of the lightweight drilling unit is very similar to that of commercial 1/3-horsepower hand drills.

Several devices were designed and tested before a suitable unit was found for collecting both dust and water. The satisfactory unit used two rubber seals in contact with the drill shank to restrict the flushing medium. A chamber between these seals contained grease, which lubricated the drill shank. As the grease was used up, the grease chamber was reduced in size by turning a threaded plug. The collector was designed to be held against the wall by a plastic anchor such as the one developed under Research Order No. 21.

A drilling kit was assembled from the units developed under Research Order No. 30 and those which had been developed under Research Order No. 21. The components of this kit, called the Type 2 Prototype Drilling Kit, consist of a carrying bag, 20 feet of electrical connecting wire, a rectifier, a drilling unit, a water-filled tank, a CO_2 cylinder, a dust and water collector, the necessary tubing, and three 5/16-inch-diameter diamond drills. The entire kit weighs 15 pounds and has the appearance of an overnight bag.

Subsequent to the development of the lightweight drilling kit, 3/16-inch-diameter diamond drills were purchased from one of the drill manufacturing companies. The drills were fitted with 1/8-inch-diameter shanks and drilling tests were made in brick, bluestone, concrete, marble, and granite. At first it appeared that three 3/16-inch-diameter drills would be necessary in order to drill a hole 30 inches deep; during drilling, each drill would have a maximum unsupported shaft length of 10 inches. However, it was possible to drill with an unsupported shaft length of 15 inches if the operator was careful during the first 3 or 4 inches of drilling. Cursory tests with the 3/16-inch-diameter diamond drills were so successful that we believe that the 5/16-inch-diameter diamond drills could be replaced by the smaller drills for many of the Sponsor's applications.

ENGINEERING ACTIVITY

The engineering activity required to accomplish the objectives of this project was divided into four phases. The first phase consisted of the purchase of 5/16-inch-diameter diamond drills, the construction of test equipment, and the evaluation of the purchased drills. The second phase comprised the selection of a suitable motor for the lightweight drilling unit, and the design and fabrication of a unit incorporating the motor. The third phase was concerned with the design, development, and evaluation of the dust and water collector, and the fourth phase, with a cursory evaluation of the 3/16-inch-diameter diamond drills.

The Evaluation of 5/16-Inch-Diameter Diamond Drills

Procurement of Drills

In general, there are two types of 5/16-inch-diameter diamond drills: the type which produces a core, and the non-coring type. Either of these types can be made with surface-set diamonds or with a matrix impregnated with diamond chips. Because each drill manufacturing company has developed its own type of drill, it was not considered practical to eliminate any particular drill on the basis of visual examination. Therefore, two drills of each type were purchased from each company for evaluation. Of the 28 drill manufacturers that were contacted (see Appendix I), nine supplied drills; the rest of the companies were unable to furnish drills, for various reasons. Figure 1 shows the drills which were received and Table 1 lists the manufacturing companies and the types of drills.

Test Equipment

The equipment shown in Figure 2 had been developed under Research Order No. 21 for use in evaluating various sizes and types of drills. The material to be drilled was contained in the barrel at the left, the drill was loaded and driven from the table which was mounted on the two parallel shafts, and the values of the different variables were indicated on the instruments mounted on the panel. The load on the drill was applied through the drill table by an air cylinder, part of which can be seen below the parallel shafts. The drill was driven by a variable-speed transmission

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Figure 1. 5/16-Inch-Diameter Diamond Drills Tested
(See Table 1 for identification of drills)

TABLE 1. MANUFACTURING COMPANIES AND TYPES OF TEST DRILLS

Drill No.	Manufacturer	Type
1	Wheel Trueing Tool Company	Surface-set non-coring drill
2	Anton Smit and Company	Impregnated core drill
3	Fish-Schurman	Impregnated core drill
4	Triangle Equipment Company	Impregnated core drill
5	Koebel Diamond Tool Company	Surface-set and impregnated core drill
6	J. K. Smit & Sons	Surface-set core drill
7	Diamond Wheel and Instrument Company	Impregnated core drill
8	Hoffman Brothers Drilling Company	Surface-set core drill
9	Hoffman Brothers Drilling Company	Impregnated core drill
10	F. F. Gilmore and Company	Surface-set non-coring drill

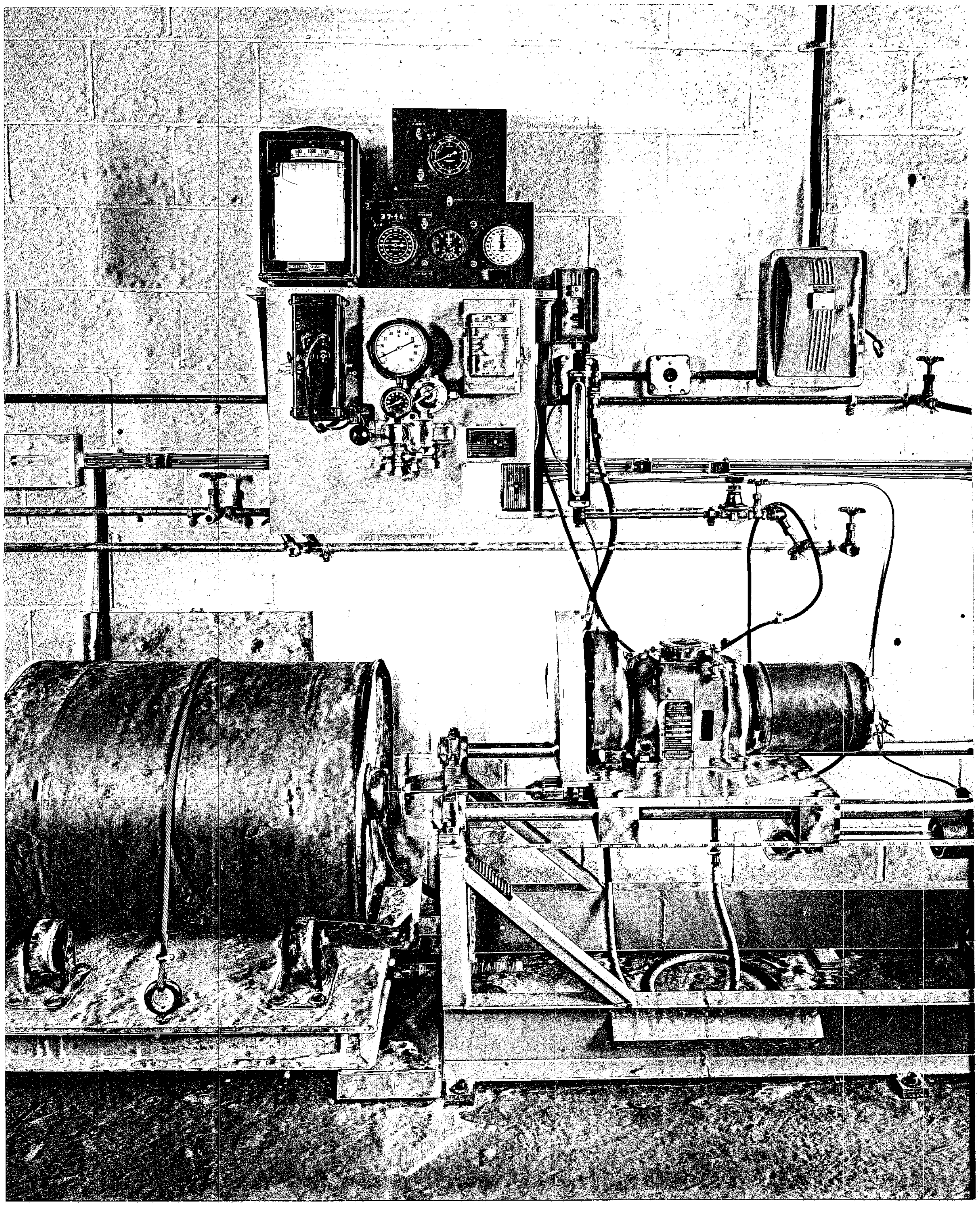

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Figure 2. Drilling Test Equipment

mounted on the table and the depth of drilling was measured on the steel tape mounted below the drill table.

In order to make this equipment more sensitive, the original parallel shafts were replaced with special hardened-steel shafting and other related parts were re-machined to provide better alignment. A gear box was used with the transmission to provide a speed range of 0 to 5,400 rpm and an aluminum platform was substituted for the steel platform.

During subsequent conferences with the Sponsor concerning the proposed use of the test equipment, it was decided that the drills should be evaluated on the basis of power inputs of 1/10 and 1/5 horsepower. Unfortunately, the test equipment modified as indicated above could not measure within ±5 per cent of these power inputs, and it was decided that additional equipment would have to be designed and built to provide the necessary accuracy of measurement.

Several different means were studied for evaluating the 5/16-inch-diameter diamond drills. These included different types of strain-gage applications, a cradle dynamometer, a torque meter using a changing air gap in a magnetic field, and an electronic speed-control unit. These methods required either expensive equipment or equipment with a long delivery date. Finally, a simple method was evolved that permitted the measurement of the reaction torque. Thus, most of the equipment shown in Figure 2 could be used, but the barrel was replaced by the test-material-holding assembly shown in Figures 3 and 4. During drilling, the torque that was imparted to the material from the drill was resisted by an arm

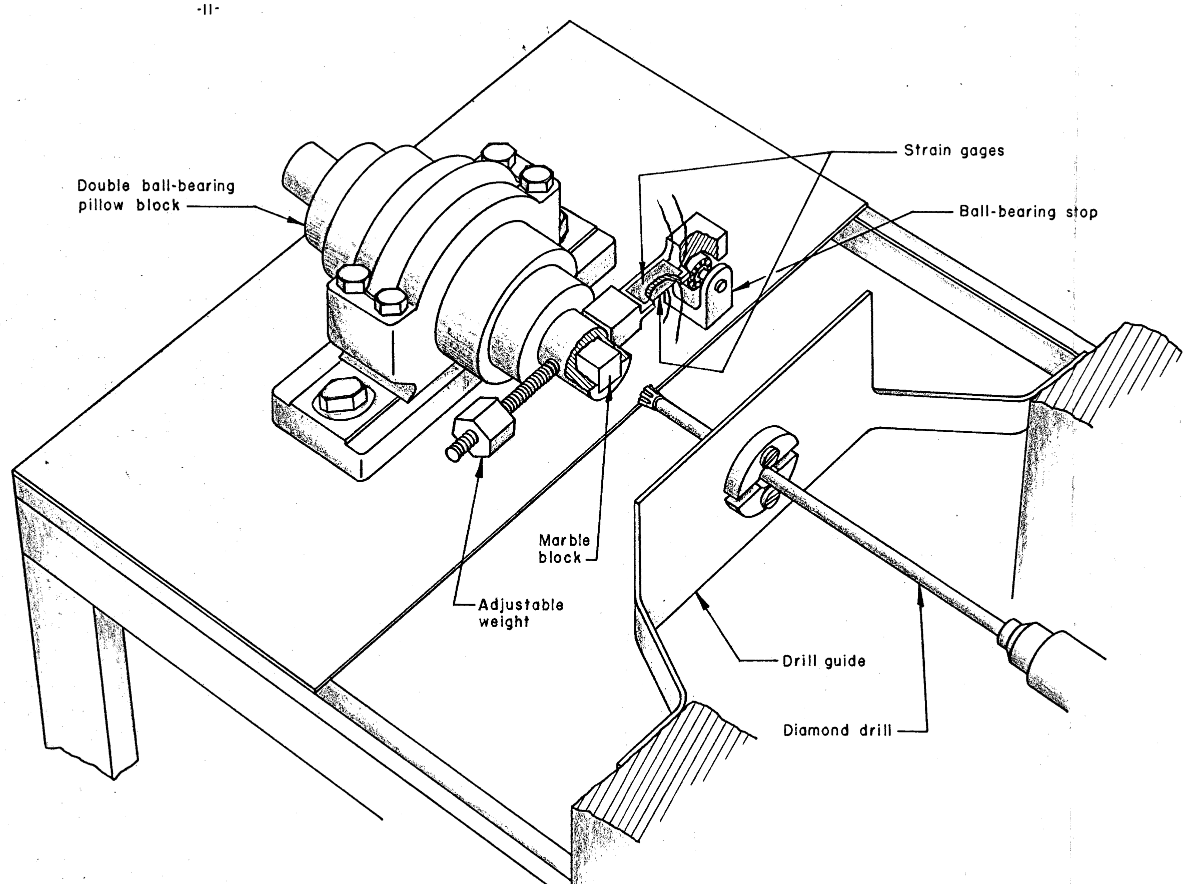

FIGURE 3. SCHEMATIC DRAWING OF EQUIPMENT FOR MEASURING THE POWER INPUT TO THE TEST DRILLS

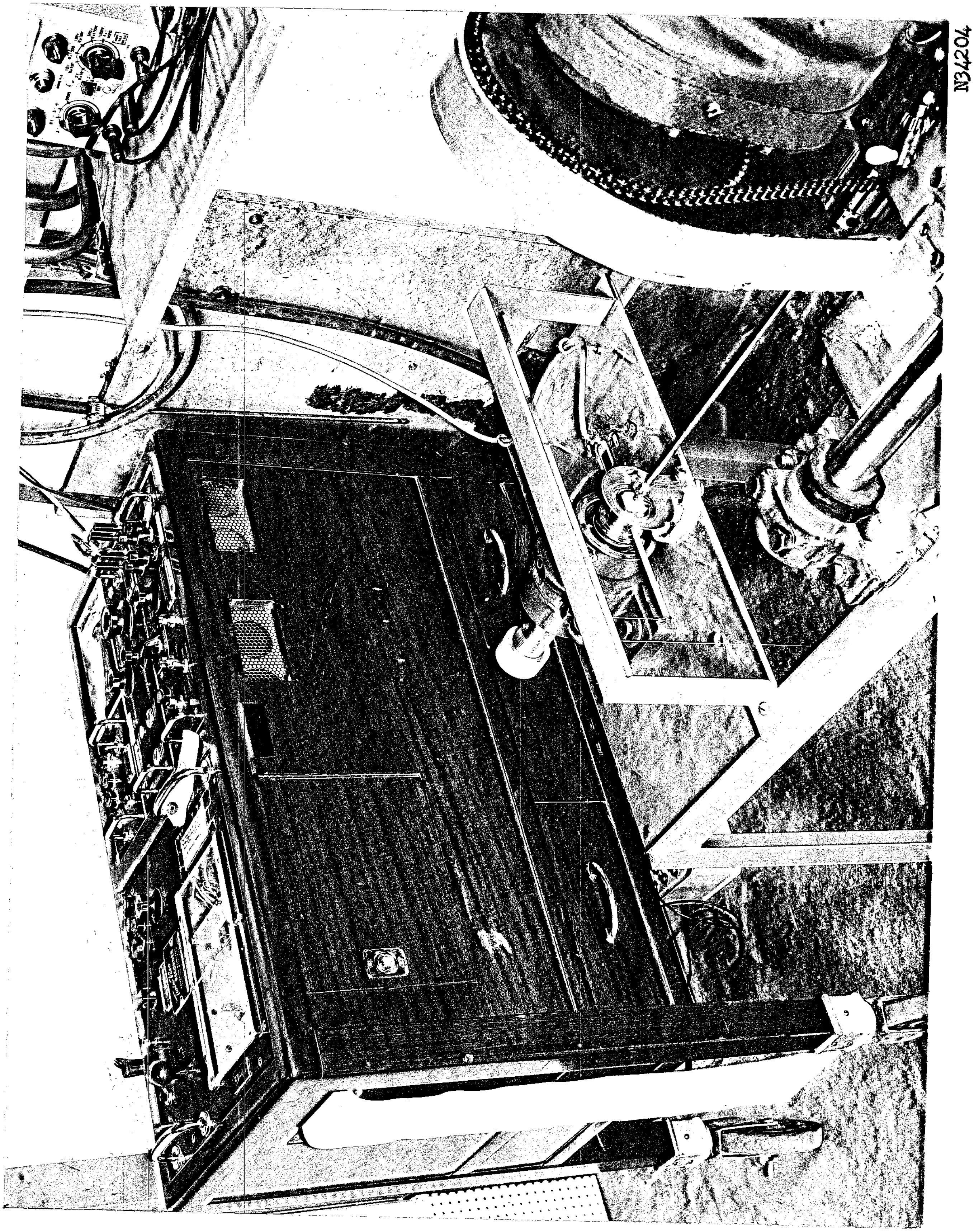

Figure 4. Equipment for Measuring the Power Input to the Test Drills

incorporating a strain gage. To simplify the apparatus and maintain a constant moment of inertia, only one hole was drilled in each piece of test material. Pieces of marble 3/4 inch square by 3 inches long were used as the test material, and the torque on the marble was calculated from the strain data obtained on a Sanborne recording instrument.

Test Procedure

During a discussion with the Sponsor, it was decided that drilling rates should be measured at 1/10 and 1/5 horsepower for drill speeds of 1,000, 2,000, 3,000, and 4,000 rpm. From these tests the best speed for each drill could be chosen for each horsepower level, and the drilling rates of the different drills could be compared. Thus, the drills yielding the best drilling rate at 1/10 and 1/5 horsepower could be selected.

At the beginning of each day of testing, a warm-up period of approximately one hour was required to stabilize the recording equipment. After warming up was completed, the test equipment was calibrated by balancing the strain-gage amplifier used with the Sanborne recording equipment and free loading the strain gages with various amounts of weight. When the equipment was calibrated, a marble test block was inserted and drilled, with the drill rotated at one of the predetermined test speeds.

In order to determine the axial load required so as to use 1/10 and 1/5 horsepower at each test speed, it was necessary to make preliminary tests during which the axial load was varied and the resulting torque was observed. When the proper axial load for each torque was determined, three tests were made for each horsepower rating at each test speed. The average of the results from the three tests was then calculated.

Test Results

The tests showed that the diamond-impregnated core drills were less efficient and less rugged than the diamond-surface-set core drills. During drilling, the impregnated core drills cut out cores of approximately the same diameter as the ID of the drills. Because these cores reduced the flow of water to the drill tips, the drill tips became hot and the drilling rates decreased.

The surface-set core drills, due to the irregular spacing and high peaks of the diamonds, produced cores which were smaller in diameter than the ID of the drills. No trouble with reduced water flow was encountered while drilling with this type of core drill.

The prescribed test program could not be completed with Drills Nos. 2, 3, 7, 9, and 10 for different reasons. For example, in some instances, the core drills plugged readily, and, as a result, either the drill tips overheated and "burned" or the drilling rate decreased very rapidly; in other cases, the drills with water holes located on the shank behind the tip were not cooled and/or flushed adequately by the water and, consequently, the above-indicated difficulties were encountered. The drilling rates and axial loads for the remaining drills at 1/10 and 1/5 horsepower are shown in Figures 5 and 6, respectively. Although Drills Nos. 6 and 8 gave the highest drilling rates, it is recommended that Drill No. 1 be considered also for use by the Sponsor because it produces

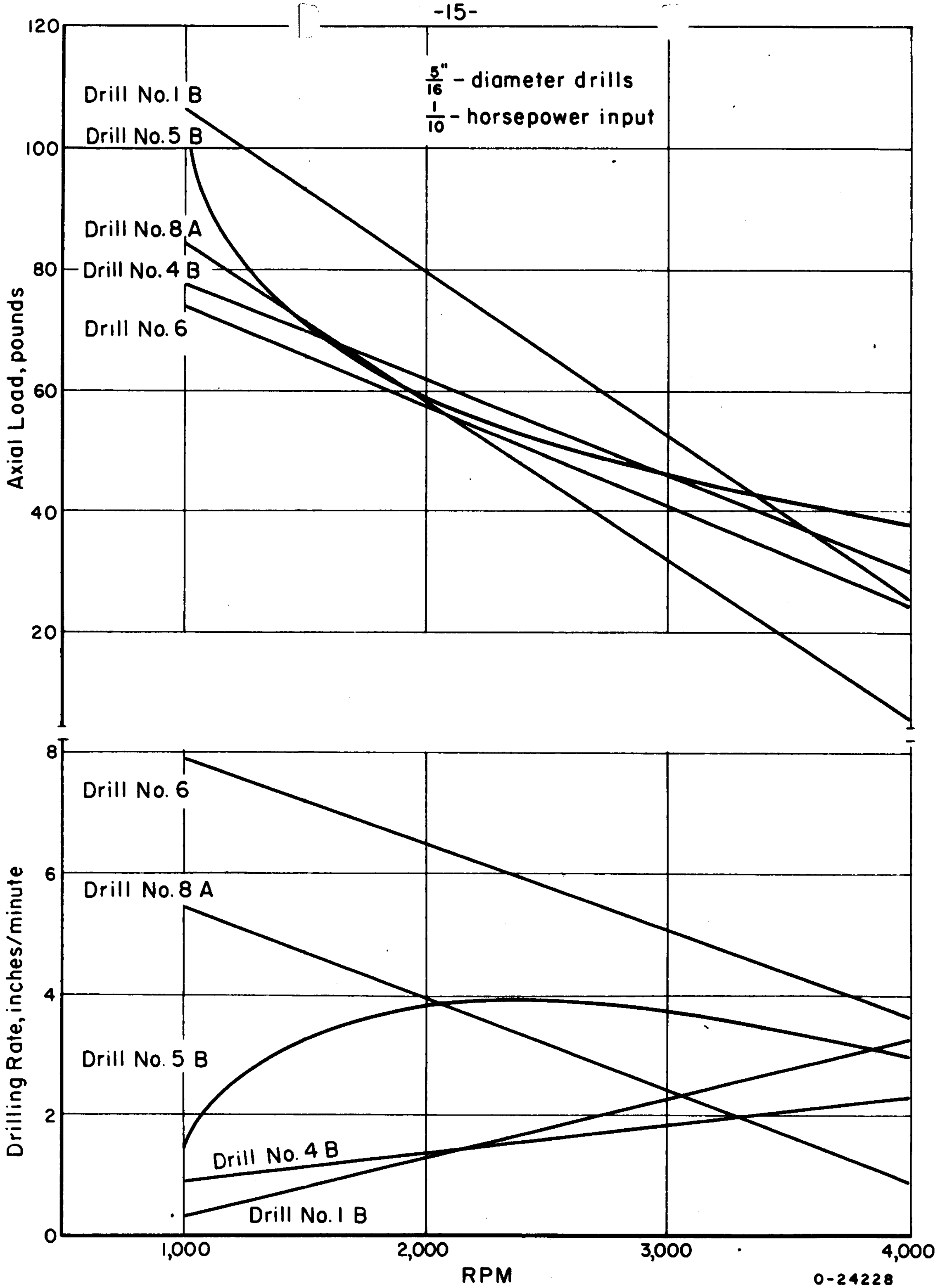

FIGURE 5. DRILLING RATES AND AXIAL LOADS WITH $\frac{1}{10}$-HORSEPOWER INPUT

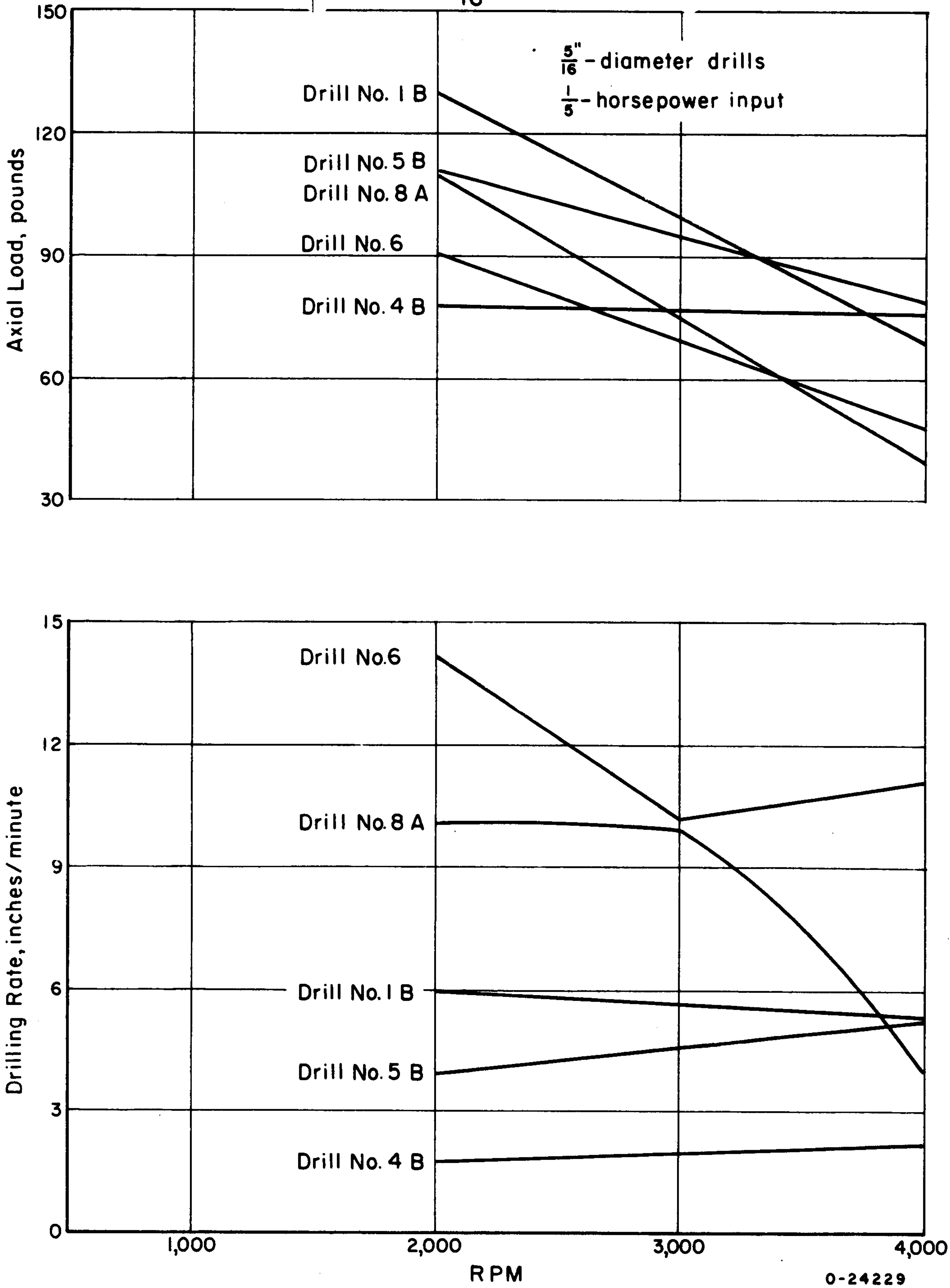

FIGURE 6. DRILLING RATES AND AXIAL LOADS WITH $\frac{1}{5}$-HORSEPOWER INPUT

no core. Thus, during an operation, Drill No. 1 would not have to be removed from the material in order to extract the core; it may well be that, in the drilling of deep holes, the over-all drilling rate with Drill No. 1 may approach those obtained with Drills Nos. 6 and 8.

Drilling Rates in Other Materials

Following the evaluation work, tests were then made to determine the drilling rates of the three recommended drills in plaster, brick, blue sandstone, marble, aggregate concrete, and granite when using 1/10 horsepower. These values are given in Table 2. The tests were made by using the experimental hand-held drilling unit which is described in the next section of the report. An ammeter was connected in the circuit with the drill, and the drilling rates were measured while the operator maintained the drill load necessary to give an ampere reading corresponding to 1/10 horsepower.

TABLE 2. DRILLING RATES AT 1/10 HORSEPOWER FOR 5/16"-DIAMETER DRILLS

Drill No.	Drilling Rate, inches per minute					
	Plaster	Brick	Blue Stone	Marble	Concrete	Granite
1	27.50	8.50	3.50	1.50	2.25	0.50
6	52.25	24.25	4.50	6.75	2.25	0.25
8	31.00	14.50	5.00	3.25	2.25	0.50

Development of a Lightweight Drilling Unit

The hand-drilling unit developed under Research Order No. 21 was tested by the Sponsor and was found to be satisfactory in many respects. However, the unit, which weighed 30 pounds, was too heavy to be carried easily. It consisted of a 1/4-horsepower, 1,725-rpm electric motor which was connected to the drilling head by a flexible shaft.

Because the 5-foot length of flexible shafting weighed 9 pounds, it appeared that any significantly lighter unit would necessarily have the motor located in the drilling head in order to eliminate the weight of the shafting. Thus, the primary problem in developing a drilling unit which would weigh 12 pounds or less involved the selection of a lightweight motor which would develop sufficient power without being excessively noisy.

Selection of the Electric Motor

It was realized that most types of electric hand drills which develop approximately 1/4 horsepower are quite noisy. It was hoped, however, that the noise could be greatly reduced by maintaining closer tolerances or exploiting other factors which might not be of paramount importance in commercial hand drills. Manufacturers of fractional-horsepower motors and electric hand drills were contacted in order to determine whether the noise originating in electric hand drills could be reduced appreciably. Most commercial units use a high-speed series-type motor with a reduction gear box. The combination of high speed (10,000 to 20,000 rpm), the gear box, the commutator brushes, and the cooling fan causes most of the noise. In the opinions of the manufacturers, it was not feasible to bring about an appreciable reduction in the noise level of such units.

A trip was made to the Robbins and Myers Company, Springfield, Ohio, a major manufacturer of fractional-horsepower motors. After considerable discussion, it was decided that a shunt-wound d-c motor driving the drill directly would provide the most power for the least amount of noise and weight. A shunt-wound d-c motor was then run in their laboratories at different speeds to obtain some indication of the different noise levels. The noise at 2,500 rpm was low, but at 3,000 rpm the noise level increased very appreciably, and at 4,000 rpm the noise was definitely too loud. On the basis of these tests, it was decided that the electric motor for the drilling unit should run at approximately 2,500 rpm. Robbins and Myers manufactures a 2,500-rpm, shunt-wound, 1/8-horsepower, d-c motor which weighs 6 pounds. It was believed that with this motor a suitable drilling kit weighing 12 pounds could probably be prepared; consequently, an order was placed for the motor.

Tests With the Electric Motor

There was considerable question concerning the temperature rise and the associated problems that might be encountered with the 1/8-horsepower motor during drilling. Because this motor furnished only half the horsepower of the motor in the original drilling unit, and because the original motor could be stalled, it was realized that the 1/8-horsepower motor would be stalled frequently during drilling. The manufacturing company expressed doubts concerning the suitability of the motor for our application.

Nevertheless, an experimental hand-drilling unit was designed to permit the use of the 1/8-horsepower motor for actual drilling tests. This unit is shown in Figure 7. During drilling tests with the experimental hand-held unit, the temperature of the motor rose to 156 F in 20 minutes of constant drilling. A motor that is this hot cannot be held in the hand; however, it was decided that the temperature rise was not great enough to militate against the incorporation of the motor in a satisfactory hand tool, since 20 minutes of constant drilling would be encountered only occasionally in service. Furthermore, it was considered possible to reduce the temperature rise by means of a more efficient fan or to mount the motor so that the heat generated would not bother the operator.

The Sponsor drilled with this experimental unit in marble, concrete, and granite, and the weight, power, and noise level of the motor appeared to be satisfactory. Therefore, a lightweight drilling unit incorporating this particular electric motor was designed.

Design of the Lightweight Drilling Unit

The lightweight drilling unit consisted of a drilling head and a suitable power-supply unit. The drilling head included the electric motor, a lightweight housing, and a water swivel for flushing the diamond drills. The power-supply unit comprised a rectifying unit to supply the motor with direct current and the necessary electrical connecting cords.

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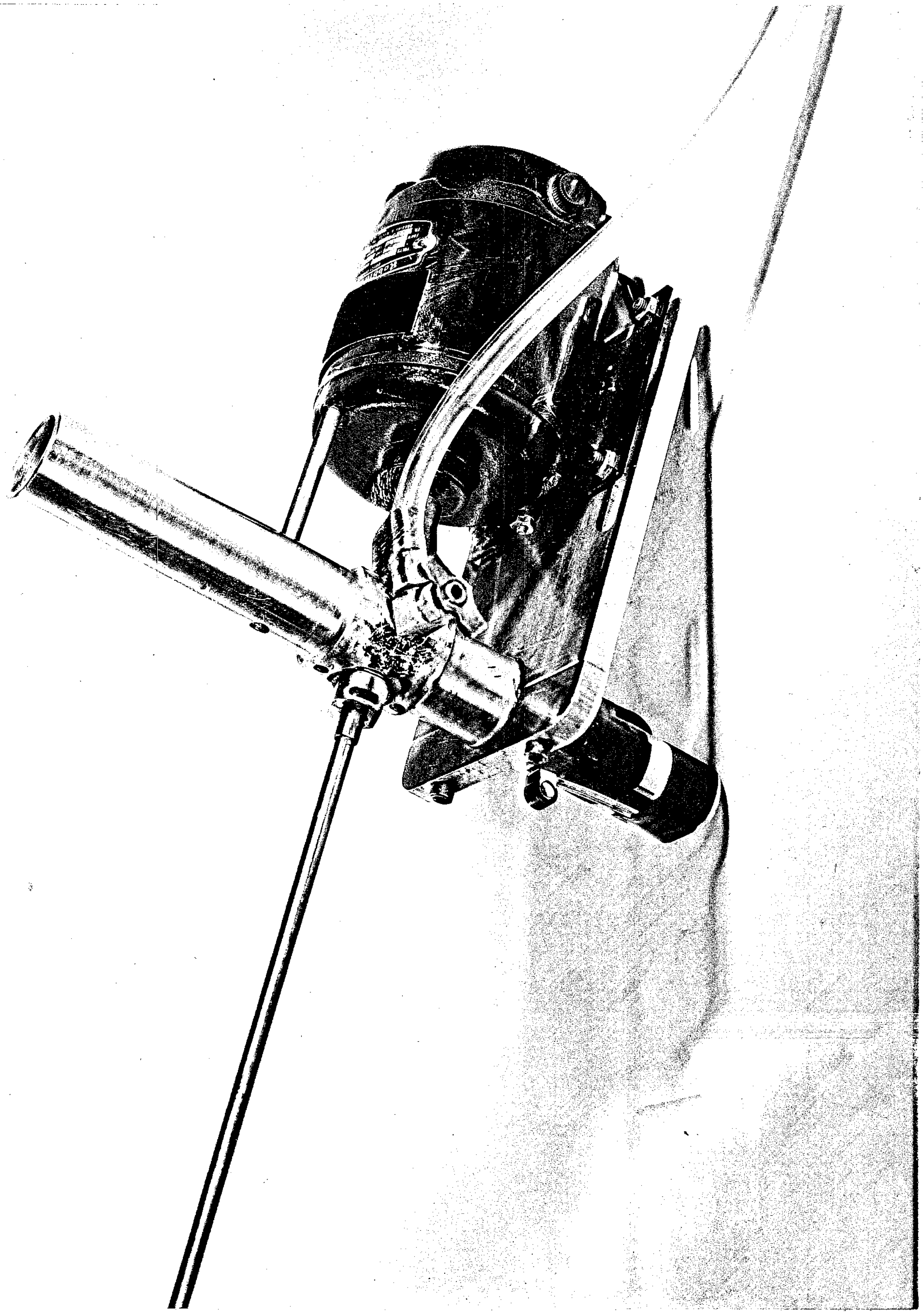

Figure 7. Experimental Hand-Held Drilling Unit

Lightweight Drilling Head. During discussions with Robbins and Myers, they indicated that a Model 281 Skil electric drill was designed for the motor frame which was used for this electric motor. Therefore, the necessary parts were purchased and the motor with ball bearings was mounted in the rear housing of the electric drill. This fortunate turn of events facilitated the fabrication of a satisfactory motor and housing unit with existing production parts.

In previous drilling units, water had been supplied to the drills through swivels which used O-rings. Because of the low horsepower of the lightweight electric motor, it was necessary to use a lower friction type of seal in the lightweight drilling unit. Therefore, a water swivel incorporating two carbon-faced seals was designed, fabricated, and adapted to the drill housing. Included in the water swivel were a small metering valve and a bayonet fitting for the drill similar to that used on previous units. The completed drilling head is shown in Figure 8.

Power-Supply Unit. Because the motor used in the lightweight drilling unit was a d-c unit, it was necessary to supply a suitable rectifying unit. The current supplied to the motor when stalled was 3 amperes. A full-wave rectifying unit with a 5-ampere capacity was fabricated with four silicon power rectifiers connected in a bridge circuit, in a perforated aluminum and plastic housing. This unit was designed to be used with 110-volt current, either 50 or 60 cycles. A diagram for the circuit used is shown in Figure 9.

The power-supply unit included 10 feet of electrical cord from

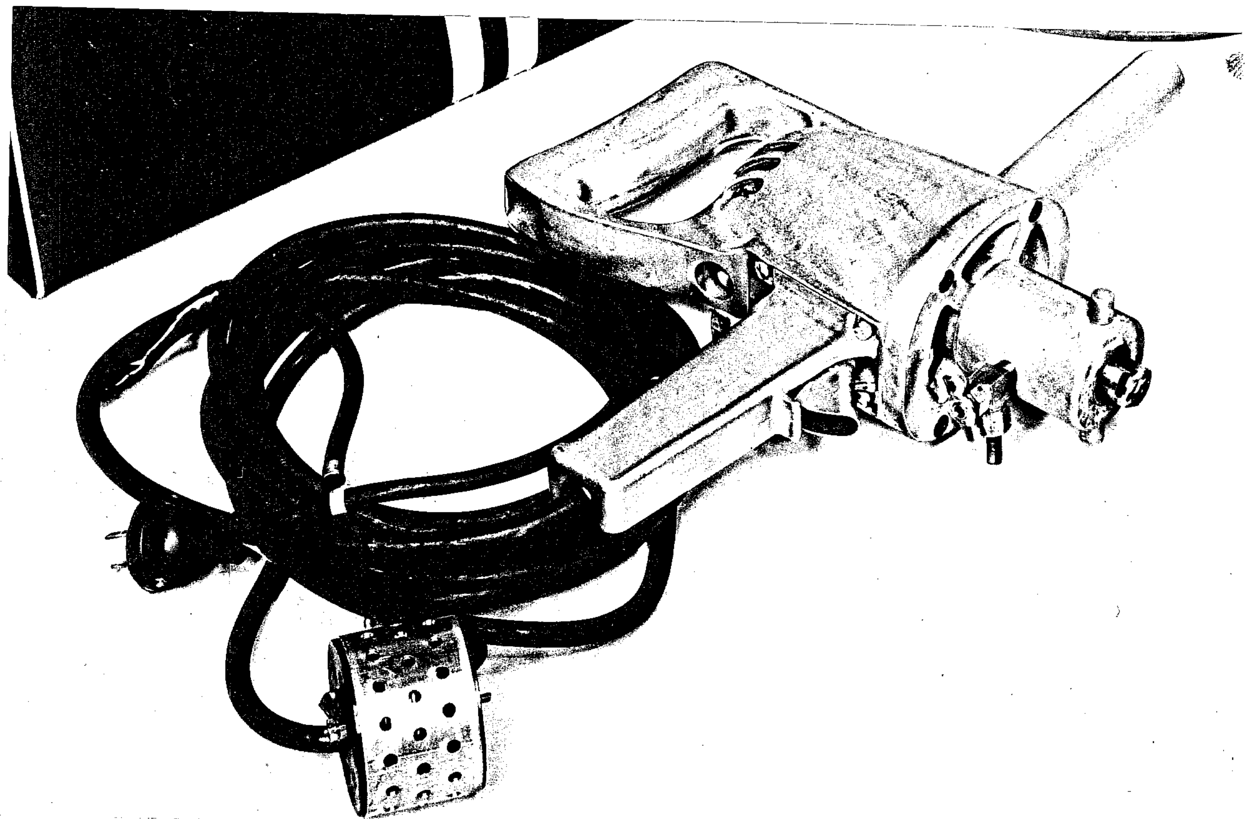

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Figure 8. The Lightweight Drilling Unit

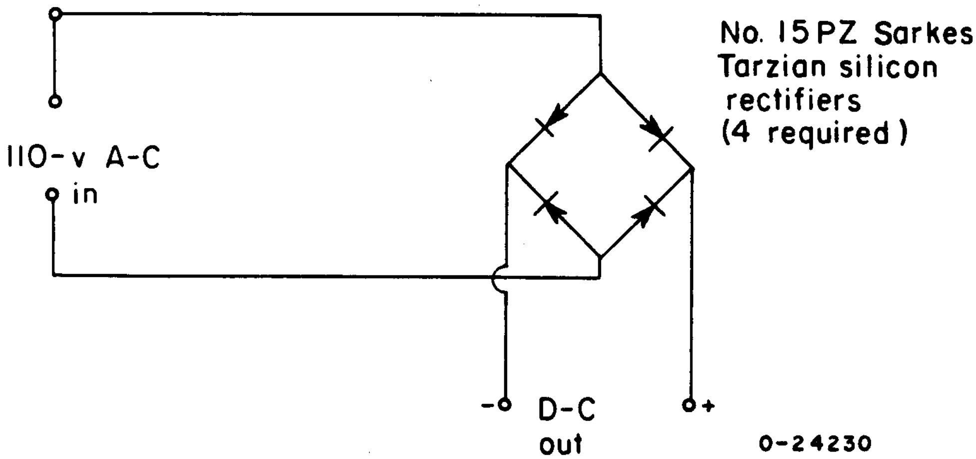

FIGURE 9. CIRCUIT DIAGRAM OF THE FULL-WAVE BRIDGE RECTIFYING UNIT

the wall plug to the rectifier and 10 feet of cord from the rectifier to the drilling head. A ground wire was supplied for the protection of the operator.

The Dust and Water Collector

Several collectors were designed and tested before a device was constructed that satisfactorily collected both dust and water. The unit shown in Figure 10 consisted of a metal chamber which was sealed against the wall. The drill passed through the chamber and into the wall, and it was expected that the flushing water would be confined within the chamber as a result of the small clearance between the diameter of the chamber and of the drill shank. This collector was based on a commercial collector design, but it was unsatisfactory because during drilling water seeped out of the chamber along the shank of the drill.

The collectors shown in Figures 11, 12, and 13 were similar to the first design except that rubber was used as a seal around the drill shank. In the design shown in Figure 11, the rubber shank seal was separate from the rubber used to seal the collector against the wall. In the design shown in Figures 12 and 13, the rubber shank seal was also used to seal against the wall. Both of these designs worked satisfactorily with water if the operator exercised some care to maintain a film of water between the drill shank and the rubber seal. However, if the water film was not maintained, the rubber quickly overheated and eroded. These designs were completely unsatisfactory for use with compressed air as the flushing medium because of the absence of a lubricating film between the

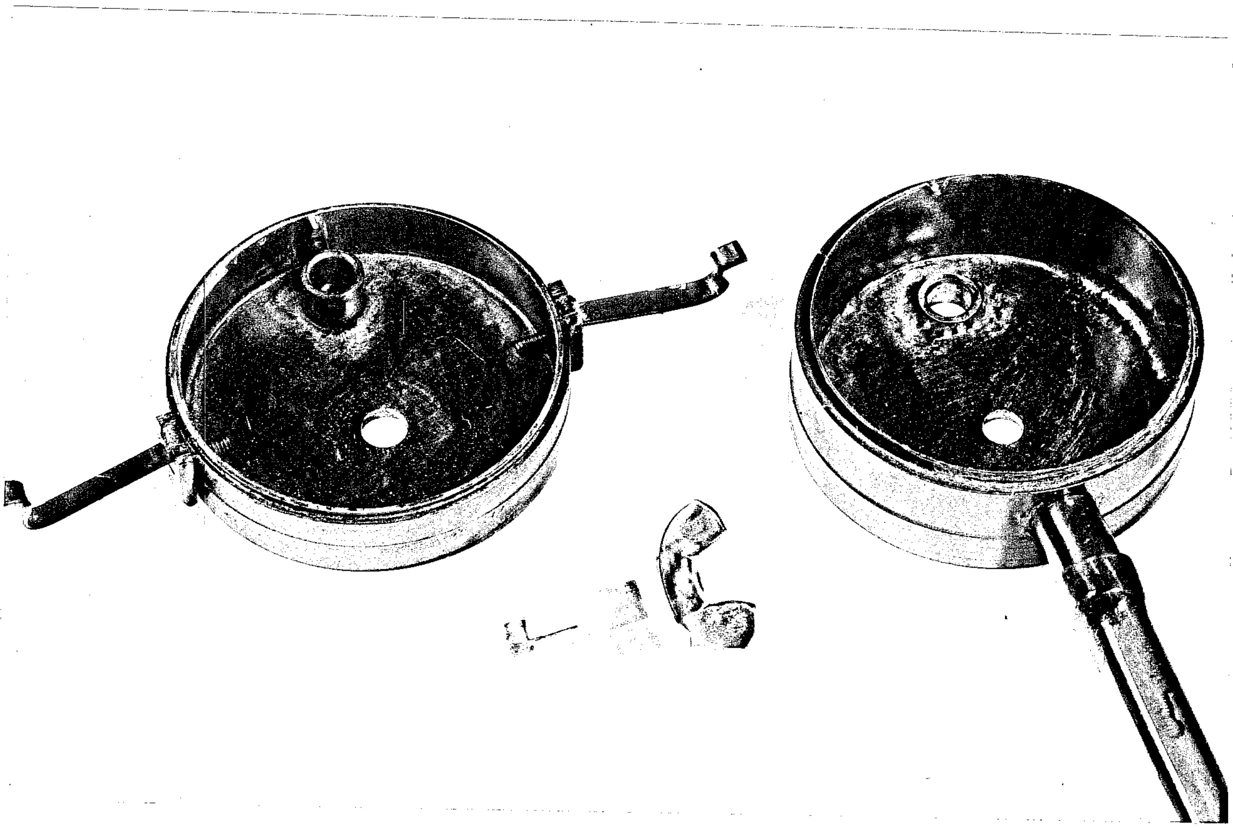

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Figure 10. Water-Collector Design No. 1, Disassembled

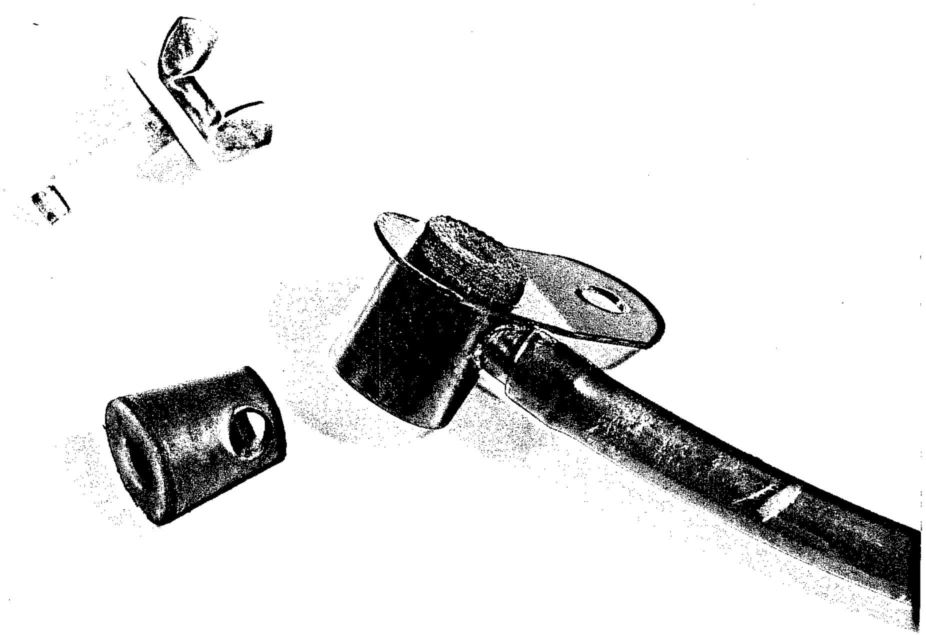

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Figure 11. Water-Collector Design No. 2, Disassembled

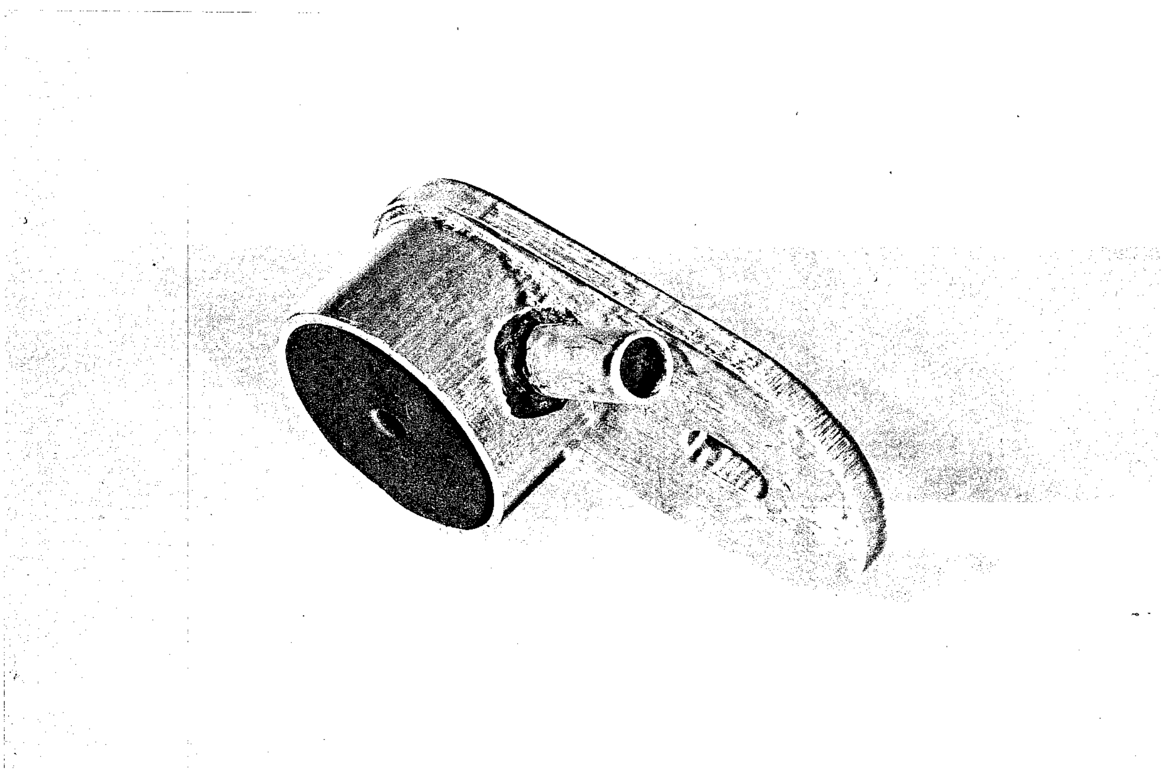

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Figure 12. Front View of Water-Collector Design No. 3

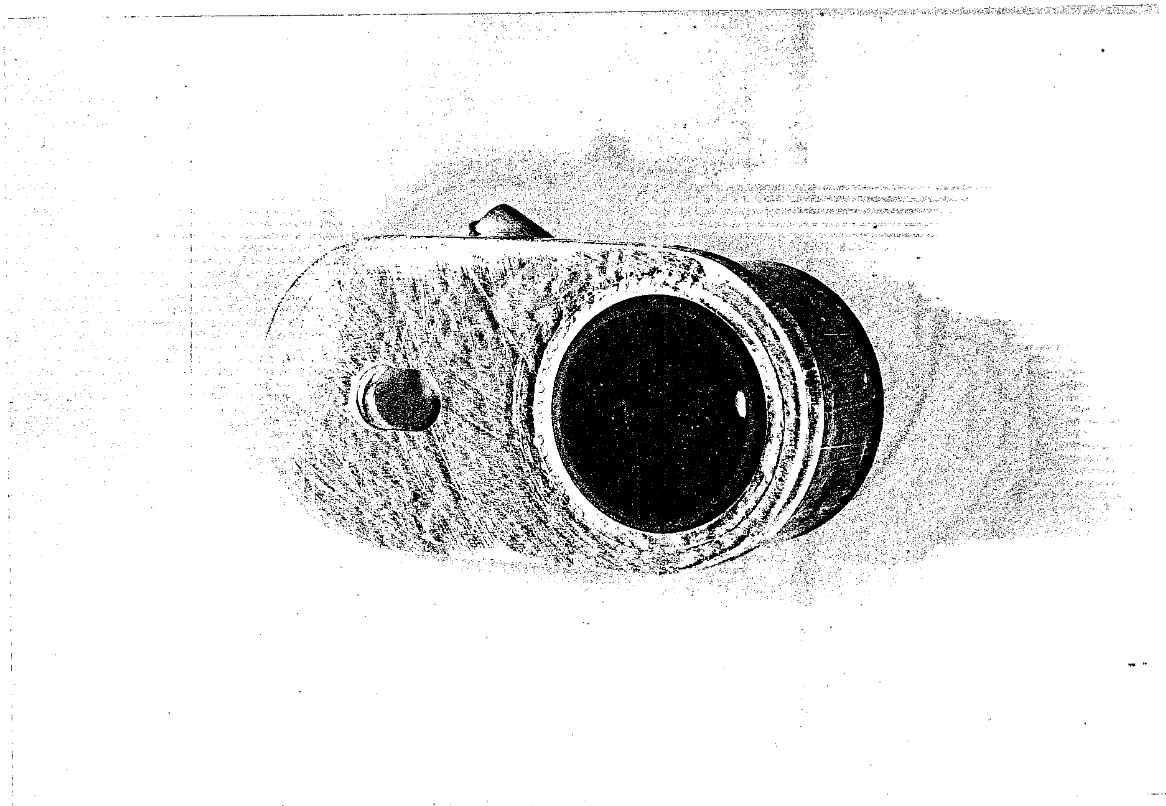

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Figure 13. Rear View of Water-Collector Design No. 3

rubber seal and the drill shank.

The design shown in Figure 14 provided a grease chamber which furnished a grease film to the drill shank, so that either water or compressed air could be used as the flushing medium. Prior to drilling using this device, the operator removes a threaded plug, fills the chamber with grease, and partially reinserts the plug. With the plug in this position, there is a rubber washer at each end of the grease chamber. When this collector is used, the drill passes through the first rubber washer, through the grease chamber, through the second rubber washer, and then into the wall. As the hole is drilled, the volume of the grease chamber can be reduced by turning the threaded plug; thus, the drill shank is continuously lubricated with a film of grease. Tests with this device have shown that it will collect both water and dust very satisfactorily. It is believed that the use of grease will not inconvenience the operator because only one filling of the grease chamber is necessary in connection with the drilling of several 30-inch-deep holes.

Lightweight Drilling Kit

A drilling kit was assembled from the units developed under Research Order No. 30 as described above and from those which had been developed under Research Order No. 21. The components of this kit, called the Type 2 Prototype Drilling Kit, are shown in Figure 15. They consist of a carrying bag, 20 feet of electrical connecting wire, a rectifier, a drilling unit, a water-filled tank, a CO_2 cylinder, a collector, the necessary tubing, and three 5/16-inch-diameter diamond drills. This kit weighs

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Figure 14. Dust and Water Collector Incorporating a Grease Chamber

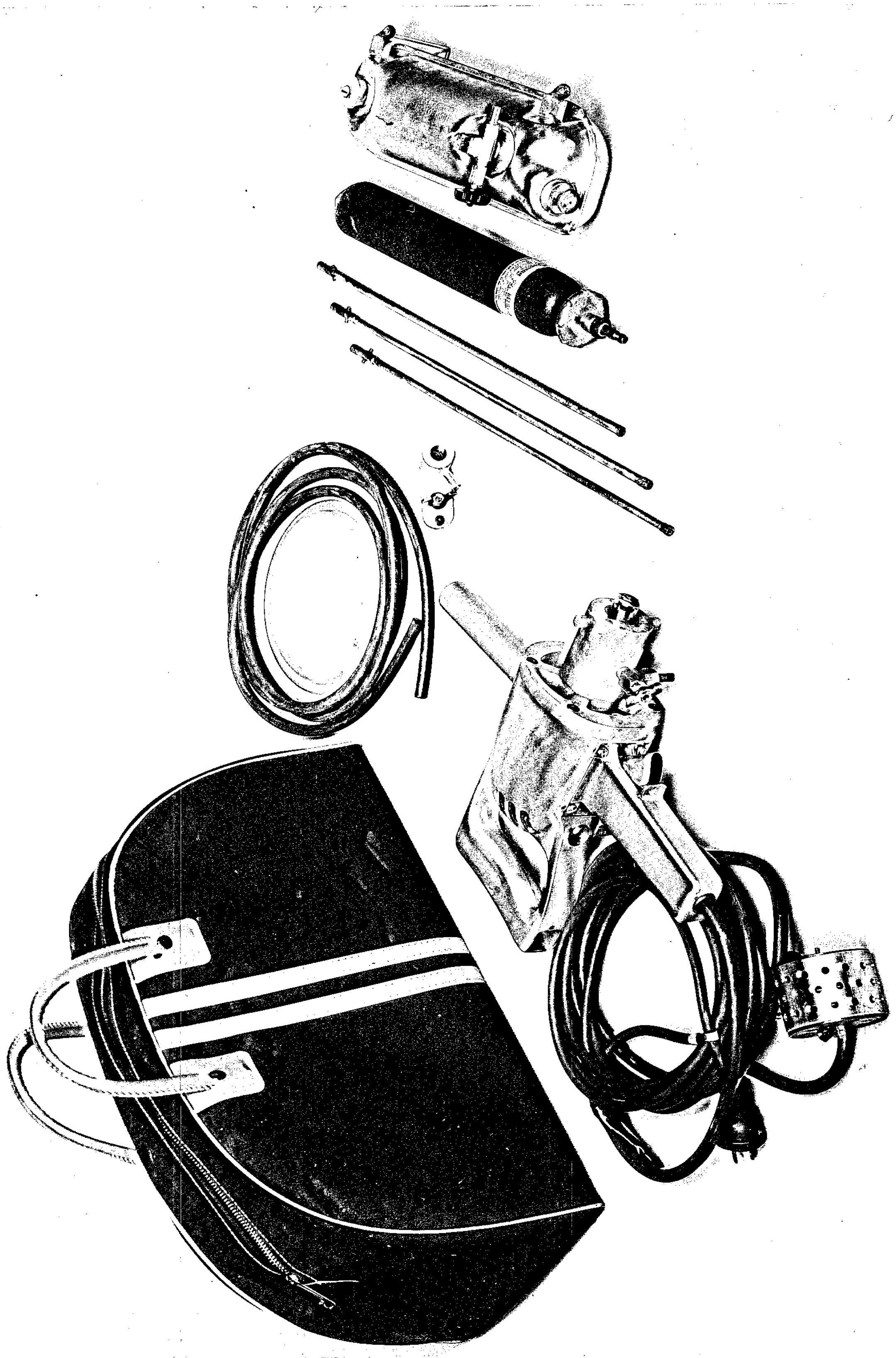

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Figure 15. The Type 2 Prototype Drilling Kit

15 pounds. Although this is more than the desired weight of 12 pounds, it is believed that the kit will be satisfactory.

Cursory Evaluation of 3/16-Inch-Diameter Diamond Drills

One objective of this program was to conduct a cursory evaluation of 1/8-inch-diameter diamond drills for drilling 30-inch-deep holes in granite, plaster, concrete, brick, and marble. The nine manufacturing companies that supplied 5/16-inch-diameter diamond drills for evaluation were contacted concerning the manufacture of 1/8-inch-diameter diamond drills for use in drilling to a depth of 30 inches. All of these companies said that it was not practical to drill holes deeper than a few inches with 1/8-inch-diameter diamond drills. In fact, only one company, the Hoffman Brothers Drilling Company, offered to supply even 3/16-inch-diameter diamond drills. Because a 3/16-inch-diameter hole has only about 1/3 the area of a 5/16-inch-diameter hole, it appeared that the 3/16-inch-diameter diamond drill would probably drill faster than the larger drill and should be evaluated.

Two 3/16-inch-diameter diamond drills were purchased and fitted with 1/8-inch-diameter shanks. At first, it was believed that three drill lengths and therefore three drills would be necessary in order to drill a hole 30 inches deep; thus, each drill would have a maximum unsupported shaft length of only 10 inches. However, it was actually feasible to use an unsupported shaft length of 15 inches if the operator exercised some care during the first 3 or 4 inches of drilling. Thus, only two drill lengths were needed to drill 30 inches.

Drilling rates with the 3/16-inch-diameter diamond drills were established for brick, blue stone, concrete, marble, and granite, as shown in Table 3. On the basis of cursory drilling in plaster with diamond drills of this size, it is estimated that the drilling rate in this material is probably as high as or higher than that in brick.

TABLE 3. DRILLING RATES WITH 3/16-INCH-DIAMETER DIAMOND DRILLS WHEN USING THE TYPE 2 PROTOTYPE DRILLING UNIT

Material	Drilling Rate, inches per minute
Brick	13
Blue stone	4-1/2
Concrete	3-1/4
Marble	2-3/4
Granite	1

The drilling was accomplished with the lightweight drilling unit shown in Figure 15. Unfortunately, it is not certain that, during these drilling tests, the rectifiers were supplying full power to the drilling unit, and there were not sufficient funds available to permit these tests to be repeated. Therefore, it is very possible that higher drilling rates can be obtained with 3/16-inch-diameter diamond drills and the lightweight drilling unit than are indicated in Table 3.

FUTURE WORK

During discussions with the Sponsor, two proposals have been requested. One is concerned with the further evaluation of 3/16-inch-diameter diamond drills and the preparation of another Type 2 Prototype Drilling Kit. The second proposal involves the fabrication of 10 Type 2 Prototype Drilling Kits and the preparation of specifications, drawings, and an operator's manual. These proposals will be forwarded in the near future.

APPENDIX I

CONFIDENTIAL

Companies Contacted in Connection With Drill Procurement

1. Acker Drill Company, Inc.
   725 West Lackawanna Avenue
   Scranton 3, Pennsylvania

2. Action Diamond Tool Company
   4547 Grand Avenue
   Chicago, Illinois

3. Blanchard Diamond Tool Company
   735-41 East 87th Place
   Chicago 19, Illinois

4. Chicago Pneumatic Tool Company
   8 East 44th Street
   New York, New York

5. Christensen Machine Company
   1937 South 2W
   Salt Lake City, Utah

6. Cle-Cut Products, Incorporated
   1921 Main Street
   Santa Monica, California

7. Clipper Diamond Tool Company, Inc.
   21 West 46th Street
   New York 36, New York

8. Diamond Drill Carbon Company
   244-246 Madison Avenue
   New York, New York

9. Diamond Wheel and Instrument Co., Inc.
   93 Elm Street
   Yonkers 2, New York

10. Felker Manufacturing Company
    Torrance, California

11. Fish-Schurman Corp.
    70 Portman Road
    New Rochelle, New York

12. Gateway Products Corporation, Inc.
    200 Main Street
    La Crosse, Wisconsin

13. General Industrial Diamond Company
    611-21 Broadway
    New York 12, New York

14. F. F. Gilmore and Company
    725 Boylston Street
    Boston 16, Massachusetts

15. Glenbard Tool Manufacturers, Inc.
    214-18 North Clinton Street
    Chicago, Illinois

16. Charles F. Haake
    47-49 Ann Street
    New York 38, New York

17. Hoffman Brothers Drilling Company
    Punxsutawney, Pennsylvania

18. Industrial Diamond Company
    2392 Wolcott
    Ferndale, Michigan

19. Koebel Diamond Tool Company
    9456 Grinnell Avenue
    Detroit 13, Michigan

20. E. J. Longyear Company
    Foshay Tower
    Minneapolis, Minnesota

21. Malco Drilling Machines, Inc.
    1100 20th Street, N.W.
    Washington, D. C.

22. Mott Machine and Manufacturing Co.
    Huntington, West Virginia

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23. Refinery Supply Company
625 East Fourth
Tulsa, Oklahoma

24. J. K. Smit & Sons
9105 Macomb Street
Grosse Ile, Michigan

25. Anton Smit & Company
333-49 West 52nd Street
New York, New York

26. Starlite Industries, Inc.
58th at Market Street
Philadelphia 39, Pennsylvania

27. Triangle Equipment Company
47 River Road
Nutley, New Jersey

28. United Diamond Tool Corporation
51 Prospect Avenue
Lynbrook, L.I., New York

29. Wheel Trueing Tool Company
3200 W. Davison Avenue
Detroit 6, Michigan