ACCESS TUBE INSTALLATION FOR STUDY OF SUBGRADE MOISTURE VARIATION

By

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SUBGRADE MOISTURE VARIATION

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PREFACE

The engineering use of nuclear equipment for field measurement of soil moisture and density has been explored by many research groups. The majority of the work has been concerned with use of surface instruments. In part, the hesitancy to use depth instruments has been associated with the problem of field installation of test sites. Several methods of installation discussed in this thesis were devised for the specific soil types encountered. Therefore, it is suggested that future research groups conduct a preliminary survey to determine the best procedure for the soils to be investigated.

The author wishes to express his gratitude to the Civil Engineering Department at Oklahoma State University and the sponsoring agencies of his research, the Oklahoma Department of Highways and Bureau of Public Roads, U.S.D.C.

W. L. H.

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CHAPTER I

INTRODUCTION

The School of Civil Engineering at Oklahoma State University is engaged in a research project concerning the relation between moisture changes under highway pavement and its performance. This project is sponsored by the Oklahoma Department of Highways and the Bureau of Public Roads, U.S.D.C. It is within the scope of this report to describe the equipment and procedures used to install access tubes for subsurface soil investigation with nuclear probes.

In February, 1965, a letter of inquiry was sent to the highway research departments of the fifty states, the District of Columbia, Puerto Rico, and various other governmental agencies. The purpose of this letter was to establish the extent of work and the experience of these organizations in utilizing nuclear equipment for measuring subsurface moisture and density variations, with particular interest toward the installation of field test sites.

An excellent response to these letters was received. However, field installation appeared to be a major problem among the few agencies that had experience with nuclear instruments.

The Highway Research Board (Ref 1) suggested four techniques for access tube installation and listed the problems associated with each method:

1) Drilling a hole and inserting the access tube. Voids around the tube pose difficulties in obtaining accurate readings from nuclear probes.
2) Drilling with a small auger inside the access tube as it is inserted into the soil. This creates a problem of a scarred inner surface, which hinders the passing of the probe through the tube.
3) Forcing closed tubing to a desired depth. This is impossible with thin-wall tubing except in very soft material. Also, this procedure increases soil density.
4) Forcing open-end tubing for three to four feet, allowing material to enter the bottom of the tube. This results in less soil densification than 3) and allows measurement to approximately two-thirds the depth of the inserted tube. The main disadvantage to this method is the limited depth of insertion, four to five feet, and measurement of three feet.

The Colorado Department of Highways (Ref 2) has used two methods of installation:

1) For shallow depths, a steel tube may be

sharpened and driven into the soil with a sledge hammer and appropriate driving collar. The soil within the tube is removed from the top with a ship auger having an outside diameter slightly smaller than the inside diameter of the tubing. Although this method provides superior sidewall contact, it has been successful only in soils containing no rocks. Depths have been limited to four feet because of sidewall friction.

2) For deeper holes a ship auger (having an OD 0.10 inch larger than the OD of the tubing) was used to hand auger the material. The tubing slipped into these holes quite easily and, in time, the soil settled around the tube for good metal to soil contact. In harder materials a drill rig, utilizing air, was used to a depth of 22 feet.

A copy of the report "A Method of Installing Access Tubes for Soil Moisture Measurement by the Neutron Procedure" by John Kozachyn and J. Roger McHenry (Ref 3) was received from the United States Department of Agriculture. This report describes, in detail, the equipment and procedure used to install test sites in the Oxford, Mississippi area. Various other reports and suggestions were received, but were not applicable to the problem of field installation.

After giving consideration to the various methods of test site installation, it was initially decided to use the procedure outlined by Kozachyn and McHenry. The following equipment was purchased in December, 1964:

1) Acker lighweight earth auger kit, Model 940, 9 HP,
2) ten sections of McCullough auger, 2 1/8 inch OD and three feet in length,
3) fishtail cutter head, 2 1/8 inch OD,
4) adapter to connect the power shaft to the auger,
5) sections of two inch OD stainless steel tubing increasing in three foot intervals, and
6) aluminum tubing, two inch OD, in ten foot lengths.

The access tubing suitable for use with Troxler probes was standard class 150 aluminum irrigation pepe, 2.000 inch OD and 1.900 inch ID. This particular tubing was selected on the basis of availability and low cost.

After receiving the above equipment it was necessary to reduce the OD of the auger sections to 1.865 inch to fit inside the steel casing. Preliminary work with this unit proved unsatisfactory. The project personnel encountered several serious difficulties:

1) when drilling in clay the auger would frequently screw into the soil rather than cut and remove the material.

2) It was necessary to use a supporting device, an A-frame and chain hoist, to steady the drill and aid in removal of the auger sections from the hole.

3) The tubing fit very tightly. When water was used as a lubricant, a vacuum formed and made removal of the tube extremely difficult.

These problems limited the depth of installation to ten feet. Also, the time element for completion, six hours for one hole, was considered to be too long for field installation beneath highways. It was concluded that this method was unacceptable for the soil types encountered in this area.

In April, 1966, inquires were made concerning the cost of drilling holes for access tubing using contract labor and drilling equipment. An average of the quotations was:

1)	coring (portland cement and asphaltic concrete)	\$12.50/core
2)	drilling (soil only)	\$ 2.50/foot
3)	travel (truck and drilling equipment)	\$ 0.25/mile
4)	driving time for operator	\$ 5.00/hour

Using these quotations the estimated cost per site was \$250.00. This cost estimate did not include the price of the aluminum tubing or taking soil samples.

Further investigation revealed that a rotary drilling rig being used for the purpose of soil exploration work might be suitable for the project work. This unit had the capability of powering a core bit or an earth auger. After consulting with the owner, Mr. Bill Sheets, of Moore, Oklahoma, and receiving a demonstration of the machine's capabilities it was decided to build and use a similar drill rig for the project.

CHAPTER II

EQUIPMENT

The drilling unit was assembled by R. A. Young and Son, Inc., Oklahoma City, Oklahoma. This unit was a combination of three component parts:

1) Minuteman Multi-purpose Rotary Drill manufactured by Mobile Drilling, Inc.,
2) Quincy Air Compressor, Model 310, and
3) Hydraulic cylinder, four inch diameter and 42 inch length.

These parts were assembled into an integral drilling unit and mounted on a skid type framework suitable for use from a trailer or truck as shown in Fig 2.1.

The Mobile Minuteman drill was originally equipped with a recirculating ball bearing screw feed mechanism. Satisfactory performance can be obtained with this unit, however, this mechanism requires a great deal of time to raise, lower, or position the drill. On advice from Mr. Sheets, this feed mechanism was replaced with a double acting hydraulic cylinder to provide direct control of cylinder movement.

The air tank served as water storage and provided a pressurized water system-for use in core drilling, see Fig 2.2. A "wet-valve", consisting of a tube extending to

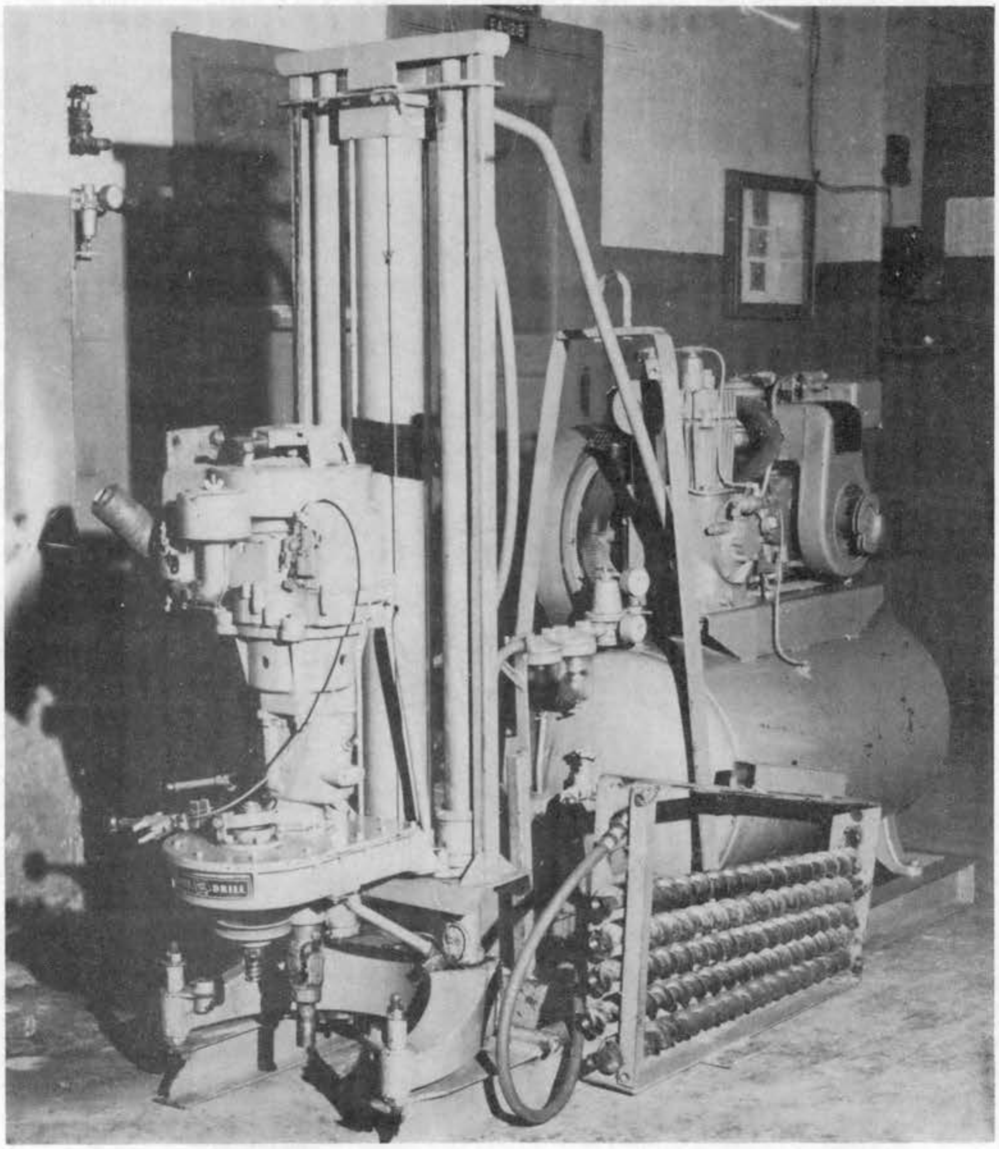

Fig 2.1. Drilling Unit

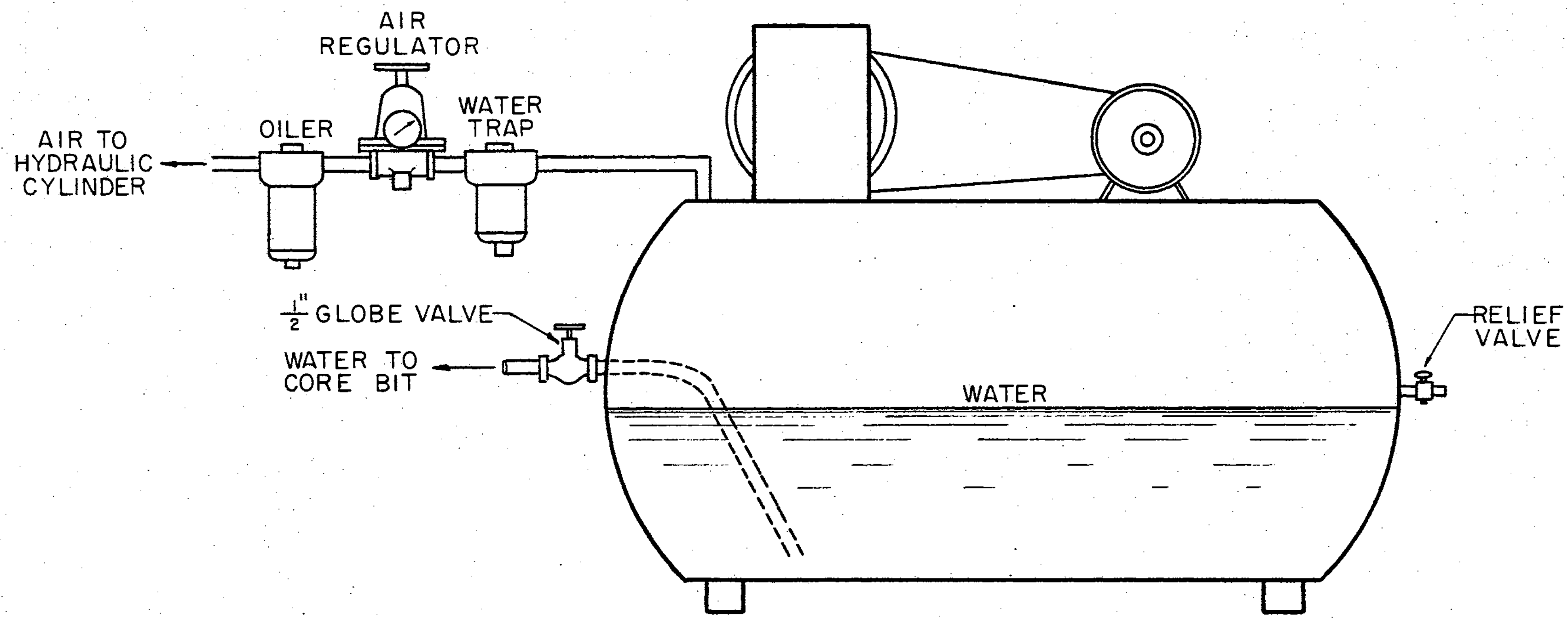

Fig 2.2. Pressurized Water System

the bottom of the air tank and a standard $\frac{1}{2}$ inch globe valve, was installed on the end of the air receiver. A relief valve was installed to release air when filling the tank with water. As a safety precaution the tank was not filled with water to more than half its capacity, approximately 30 gallons. This level was indicated by water flowing from the relief valve. Due to the presence of excess moisture in the system, the air line to the hydraulic cylinder was equipped with a water trap and oiler to prolong the working life of the hydraulic unit.

The drilling rig was supplied with a six inch diameter "oriented" diamond core bit, water swivel, extension rods, adaptors, and couplings, as shown in Fig 2.3. Oriented bits differ from "random set" bits in that the diamonds are carefully positioned so that cutting stresses and abrasion are borne by the hard edge or rib of each stone, Because wear and cleaving of the diamonds is substantially reduced, better performance and longer life is obtained.

Considerable difficulty was encountered in obtaining an auger suitable for drilling a two inch diameter hole. The auger furnished by Mobile Drill, Inc., see Fig 2.4, was totally unsatisfactory for drilling clay soils. The auger stem diameter was too large to allow sufficient auger flight surface for removal of the material. When drilling a hole with this auger, the soil was displaced rather than removed, and this increased the soil density around the periphery of the hole. Upon notification that the auger would not

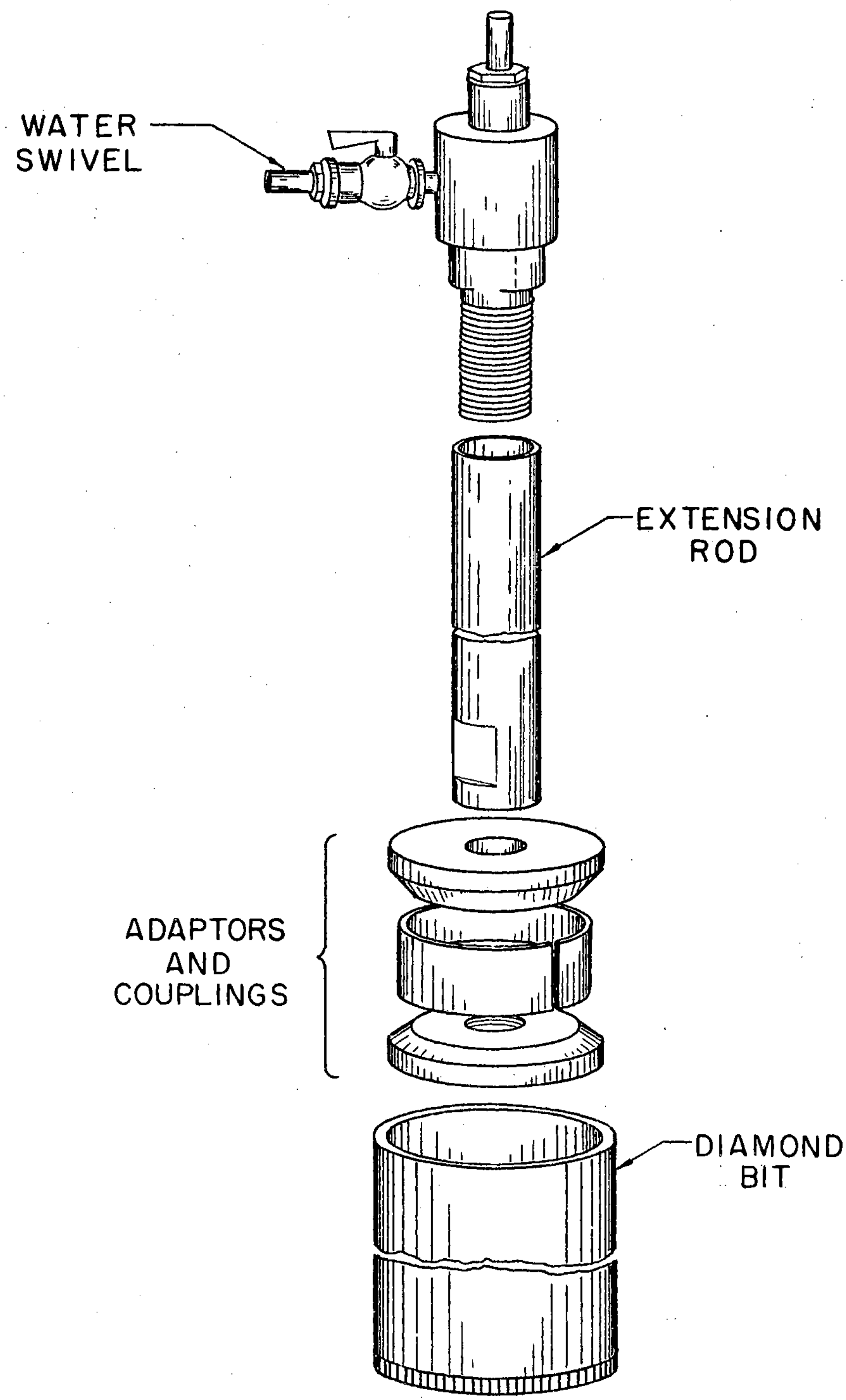

Fig 2.3. Core Drilling Apparatus

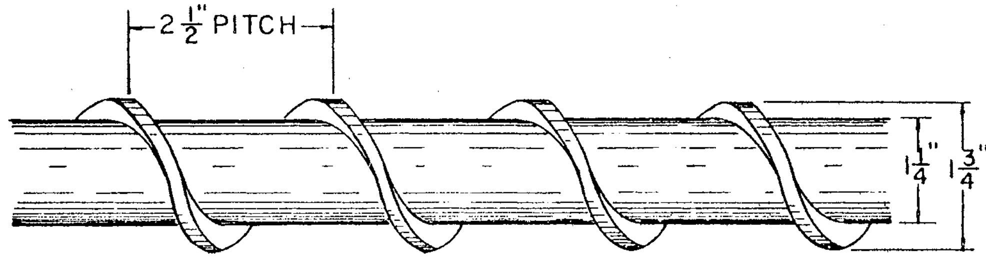

Fig 2.4. Mobile Drill Auger

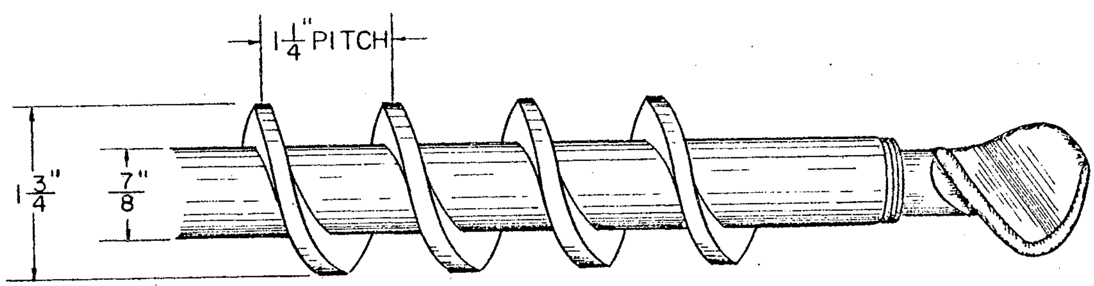

Fig 2.5. Acker Drill Auger

perform properly, Mobile Drill, Inc. sent another set of augers. The only difference from the original auger was a hard surfacing applied to the auger flight. As would be expected, this auger was also unsuitable.

An attempt was made to adapt the auger purchased with the Acker auger kit to the Mobile drill. This auger was not suitable because the auger flight was not continuous at the joints and at the connection of the fishtail bit to the auger stem, as shown in Fig 2.5. Since the flight was discontinuous, cohesive soils had to be forced past these points and onto the next section of auger. This forcing effect increased the density of the soil by displacement rather than removal of the material.

Consideration was given to the use of a section of ship auger, see Fig 2.6. To use this type auger, it would be necessary to remove the entire length of drill stem from the hole after advancing 18-24 inches. This process would undoubtly enlarge the upper portions of the hole and consume a great deal of time.

An extended effort was made by the Oklahoma City Branch of R. A. Young and Son, Inc. to locate and obtain a continuous flight two inch diameter auger with small diameter stem. An auger fitting this description, shown in Fig 2.7, was purchased from Haynes Manufacturing Co., Livingston, Texas. After adapting this auger to the Mobile drill, it was possible to drill and remove clay soils with a minimum of disturbance to the material adjacent to the hole.

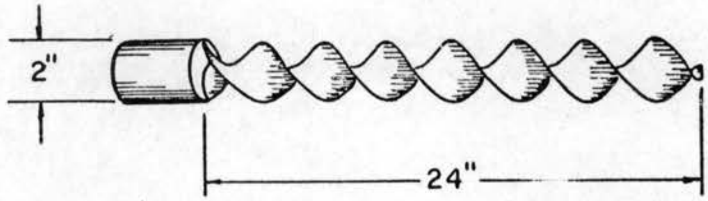

Fig 2.6. Ship Auger

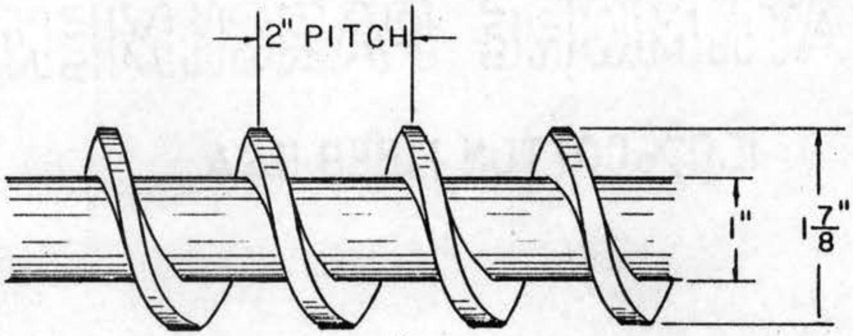

Fig 2.7. Auger from Haynes Manufacturing Company

After receiving the drilling unit, a number of minor modifications were made by project personnel. Excess vibration of the drill motor caused failure of the straps supporting the fuel tank. The two straps were replaced with a steel plate. The fuel line was re-routed to avoid excess heat from the exhaust manifold and possible "vapor lock." A 45° ell was placed between the exhaust manifold and the muffler to discharge exhaust gases away from the drilling crew.

A secondary water storage system was used to supplement the water required by the core drilling process. This system included a portable air tank and a 30 gallon sealed container, see Fig 2.8. The portable air tank was connected to the air compressor and charged to 175 psi. By connecting an air line from the portable air tank to the auxilliary water tank, another pressurized water system was formed. This system could be used to force water into the air receiver, after relieving the pressure, or directly to the water swivel. As the secondary system did not provide a constant high pressure and regulated flow rate, it is not recommended for continuous core drilling.

Nuclear Equipment

The nuclear equipment used by the project was purchased from Troxler Electronics Laboratories, Inc., Raleigh, North Carolina. The equipment was:

1) Model 200B, Electronic Scaler,

2) Model 504, Depth Density Probe, and

3) Model 104, Depth Moisture Probe.

Access Tubes

The access tubes were constructed from standard Class 150 seamless aluminum irrigation tubing, 2.000 inch OD and 1.900 inch ID. The tubes were inspected by passing a "dummy probe" through them. The "dummy probe", a metal shaft of 1.875 inch diameter and 15 inches in length, revealed any damage to the tube that would prevent passage of the nuclear probes.

One end of the tube was sealed with a metal plug and a rubber O-ring, see Fig 2.9. By casting a lead alloy in a section of aluminum tubing and subsequently removing the tube, a lead shaft with an OD of 1.900 inch was obtained. This stock was cut into discs 3/4 inch thick, and a groove was machined in each disk to receive the O-ring. The plug was driven into the end of the access tube and tested for leakage. As an additional precaution against leads, the end of the aluminum tube and the metal plug were externally sealed with epoxy paint.

Protective Covering

Figure 2.10 shows a combination of plumbing supplies used to provide a water-tight, non-obstructive covering for the access tube. A standard cast-iron sewer clean-out was leaded into a three inch cast-iron hub section to form an

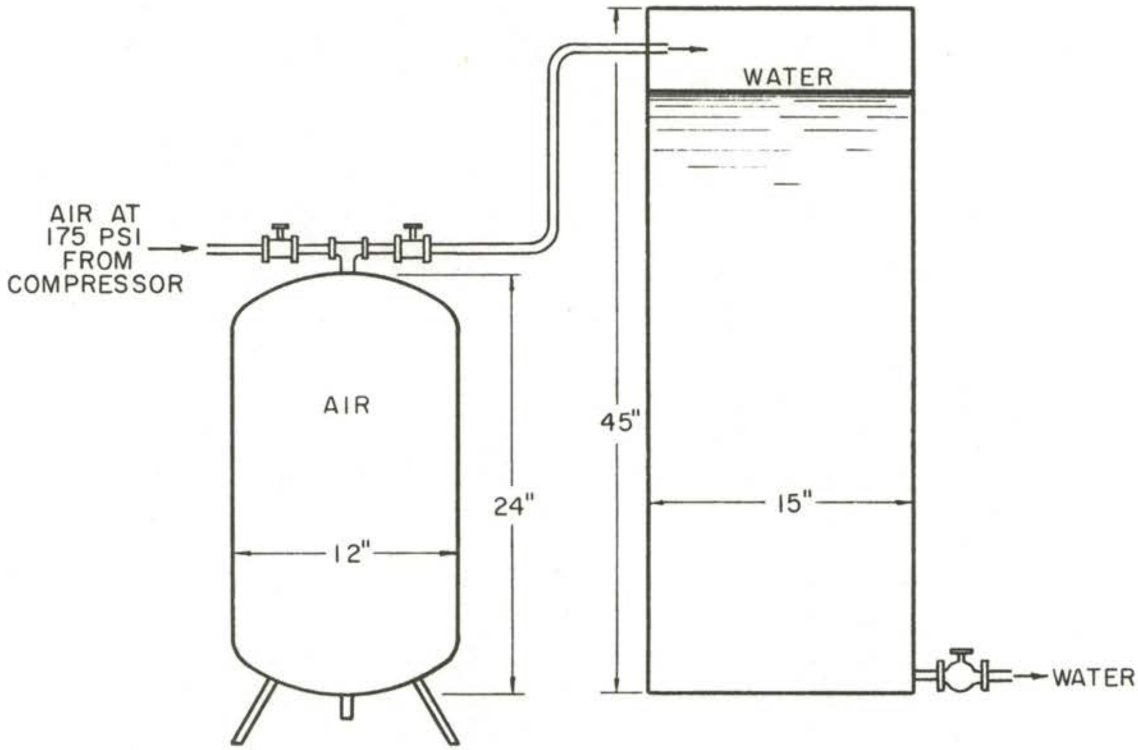

Fig 2.8. Secondary Water System

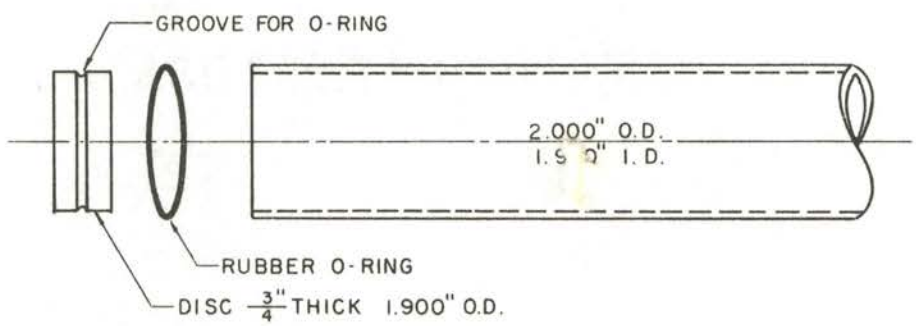

Fig 2.9. Sealed End of Access Tube

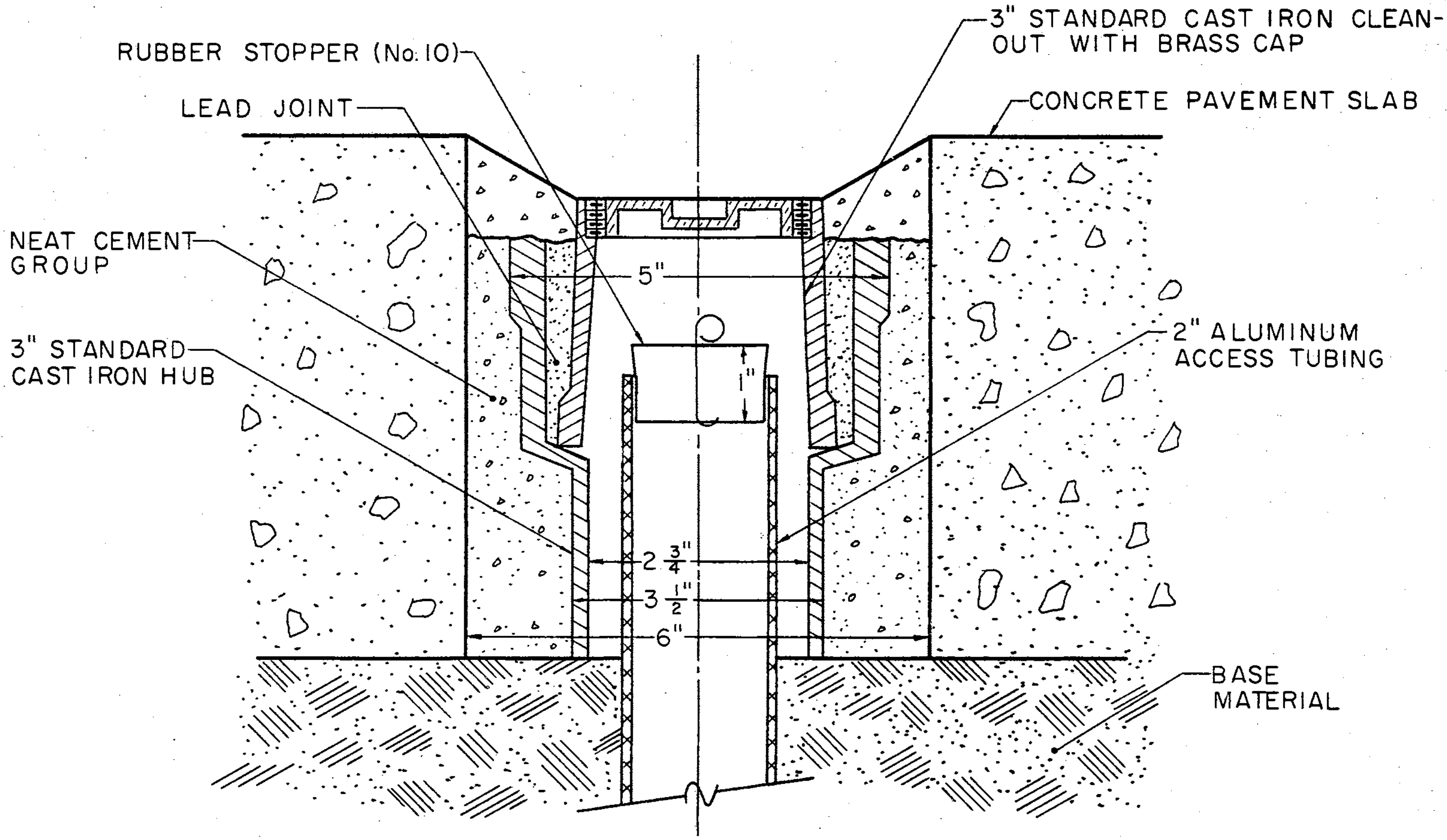

Fig 2.10. Protective Covering

integral unit. This assembly was held in position around the access tube by a cement grout mixture.

Miscellaneous Hand Tools

An assortment of small hand tools was required for the purpose of maintenance and minor adjustments to the equipment. Several "special" tools, seen in Fig 2.11, were required:

1) an auger retriever to remove dropped or broken auger sections from the hole,
2) a strap wrench to aid in break-down of the core barrel and accompanying adaptors,
3) a "square-drive" wrench to use when removing brass caps, and
4) star-drill and cold chisel to break away the top of cores greater than 12 inches thick (depth of core barrel) to allow further penetration of core bit assembly.

Vehicle

A Ford F-100 step-side pickup was used to transport the equipment described in this chapter, see Fig 2.12. It was necessary to remove the tailgate and rear bumper to allow the proper positioning of the drilling unit. Several storage boxes and racks were installed to carry the tools and equipment required for field test site installation.

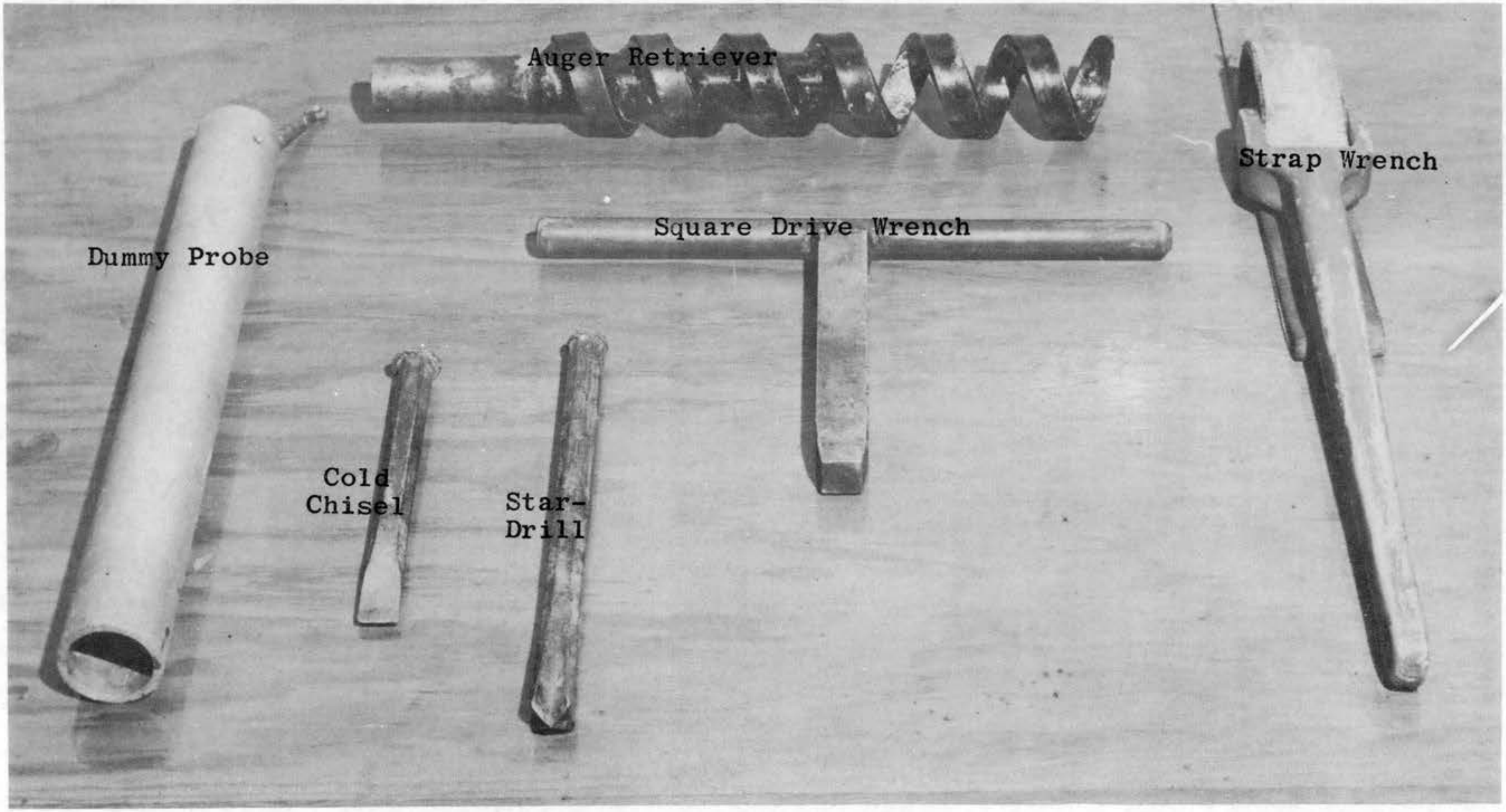

Fig 2.11. Special Tools

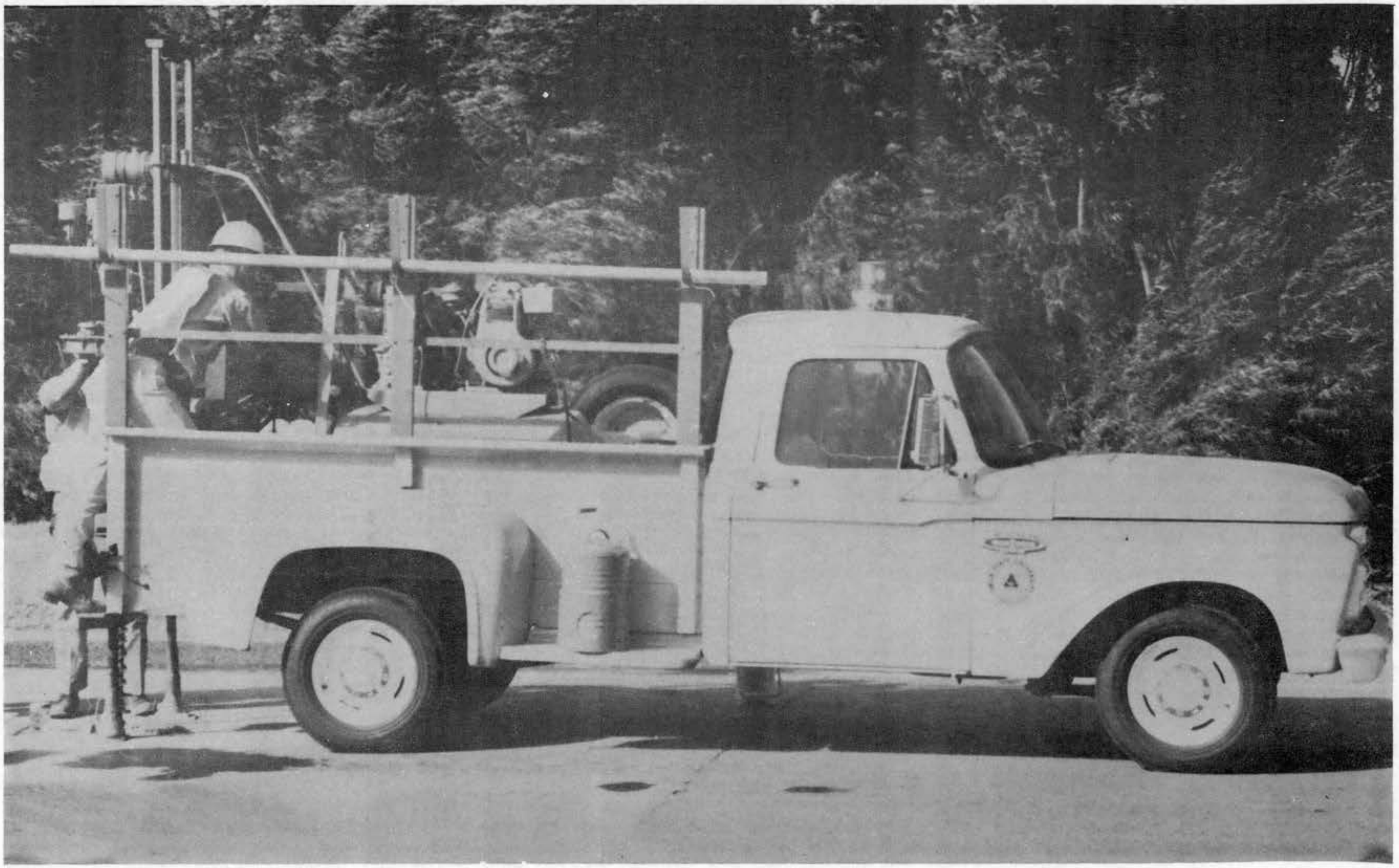

Fig 2.12. Drill Rig mounted on Vehicle

CHAPTER III

CRITERIA FOR SITE SELECTION

Preliminary test site selection was made in the office. The location of each site was within 10 miles of the nearest U.S. Weather Bureau Climatological Recording Station. The northeast region of the state was chosen for the first 30 sites. A general pattern that would facilitate the drilling and data collection operation and give complete coverage of the area was established.

Final selection of each site was made by traveling to the general area and picking an exact location for the installation. The test sites were designated by hanging an orange and black marker on a nearby fence. Prime consideration was given to highway safety. Sight distance was one of the governing factors for location of most sites. When possible, test sites were located on four-lane highways with a second choice of two-lane highways with improved shoulders. There was no discrimination with respect to type of pavement, asphaltic or portland cement concrete. Test sites were located in both creek botton and up-land regions. Fill sections and deep cuts were avoided to reduce the complexity of relating the physical factors to the moisture variation within the subgrade. The selected test sites were subject to relocation by the drilling crew when undesirable sub-surface conditions, such as rock or gravel, were encountered.

Old and new sections of pavement were selected for investigation. Old sections of pavement in good condition were chosen to determine possible tolerable levels of moisture accumulation. By observing sections of new pavement, the phenomenon of moisture collection could be studied and related to pavement performance.

To investigate the subgrade moisture variation at each test site, three test holes were augered to a maximum depth of 10 feet and a minimum depth of 4 feet. A hole at each edge of the pavement and one hole in the center was installed to permit observation of any transverse moisture gradient. Pertinent data recorded for each test site included

1) exact location,
2) terrain and vegetation,
3) type of pavement, subgrade, and sub-base, and
4) width and condition of pavement and shoulders.

A review of previous work (Ref 4) indicated that moisture variations below depths of 10 feet were almost non-existent. The maximum depth of 10 feet was established on this basis.

Site descriptions, pavement evaluations, and soil classifications will be presented in a later report.

CHAPTER IV

SAFETY

Although the radioactive sources used with the nuclear probes have a relatively low strength of 3 millicuries, film badges were worn by project personnel. The badges used were sensitive to alpha, beta and gamma radiation. Studies by Professor Robert Stone (Ref 5), Agronomy Department of Oklahoma State University, indicate that an over-exposure to alpha radiation occurs before over-exposure to neutron radiation when using Ra^{226}. For this reason, the wearing of neutron sensitive badges was deemed unnecessary. Additional badges were carried with the nuclear instruments and issued to visitors. A log book containing the visitor's name, date of visit, and badge serial number was kept on a daily basis.

Monthly film badge service was provided by Tracerlab, Inc., Waltham, Massachusetts. Their reports have not revealed any measurable radiation exposure.

The radium sources of the probes are tested for leakage by performing a swipe test at six month intervals. The results of these tests are reviewed by the Oklahoma State University campus radiological safety officer.

The storage box used for transporting the probes was located three feet from the passenger cab of the vehicle and three feet from the working area of the drilling crew. The storage box was adequately identified as containing radioactive materials.

Highway safety was one of the governing factors concerning local test site location. Adequate sight distance, a minimum of 1,000 feet, was a prime prerequisite. To provide minimum interference and congestion from local traffic, test sites were located away from roadside business establishments, residences, and secondary road intersections. Figures 4.1 and 4.2 demonstrate the traffic routing procedure used when installing test sites on highways of various widths. Excellent cooperation was received from the Oklahoma Department of Highways in providing the necessary flagmen, advance warning signs, and barricades for effective traffic control.

Safety caps and vests were worn by the drilling crew, and a first-aid kit was carried with the drilling unit to provide treatment for minor injuries. Standard safety equipment on the vehicle included I.C.C. warning lights. Other safety equipment, seen in Fig 4.3, included 1) traffic cones, and 2) Dietz emergency light.

The color of the equipment, a tan vehicle and orange drilling unit, was chosen on the basis of easy visibility and recognition. Two 3x4 foot signs, painted orange and lettered in black, served the dual purpose of identifying the sponsoring agencies and as a protective barricade for the drilling crew. An all-purpose fire extinguisher, class

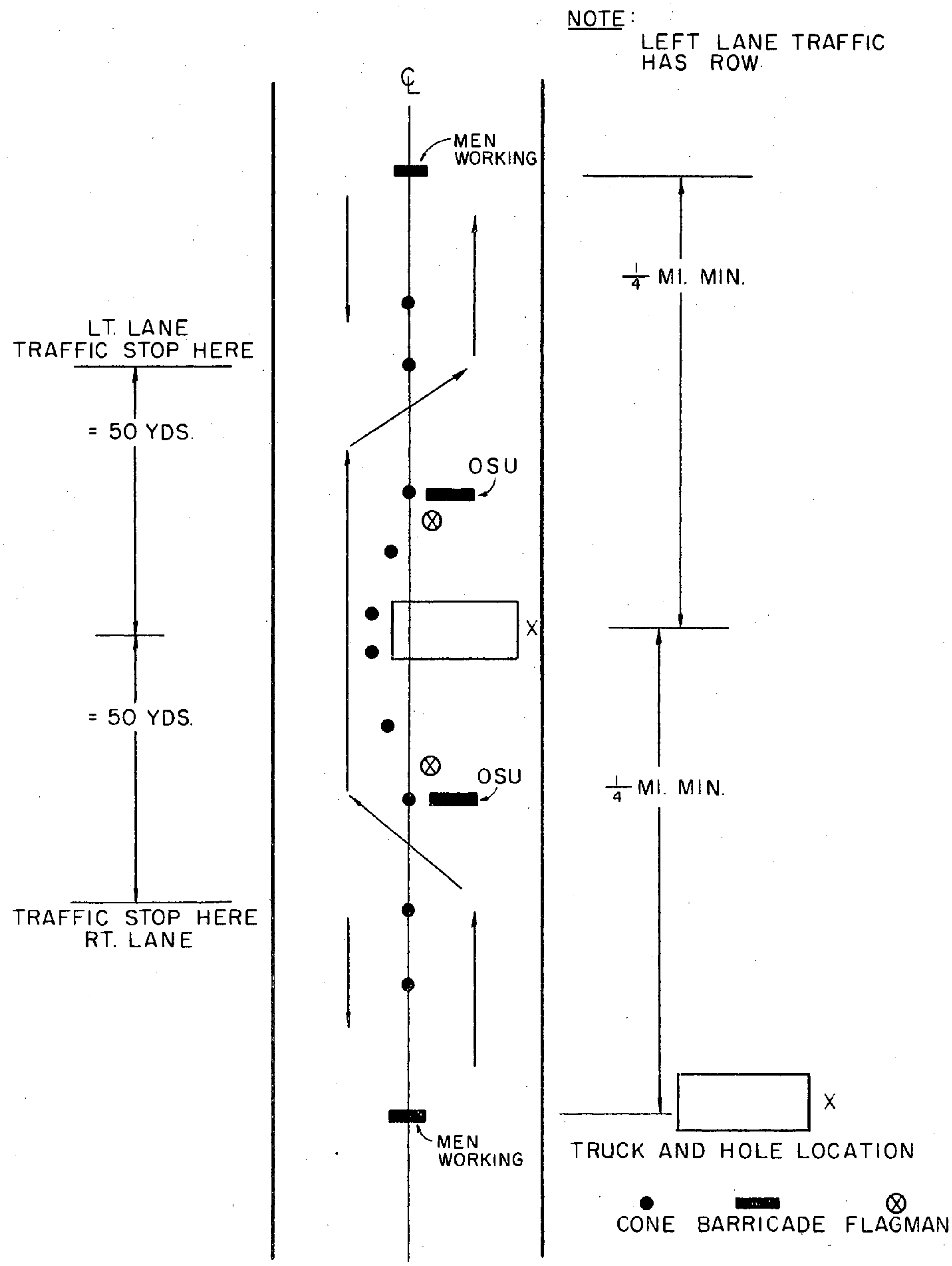

Fig 4.1. Traffic Routing When Drilling in Shoulders

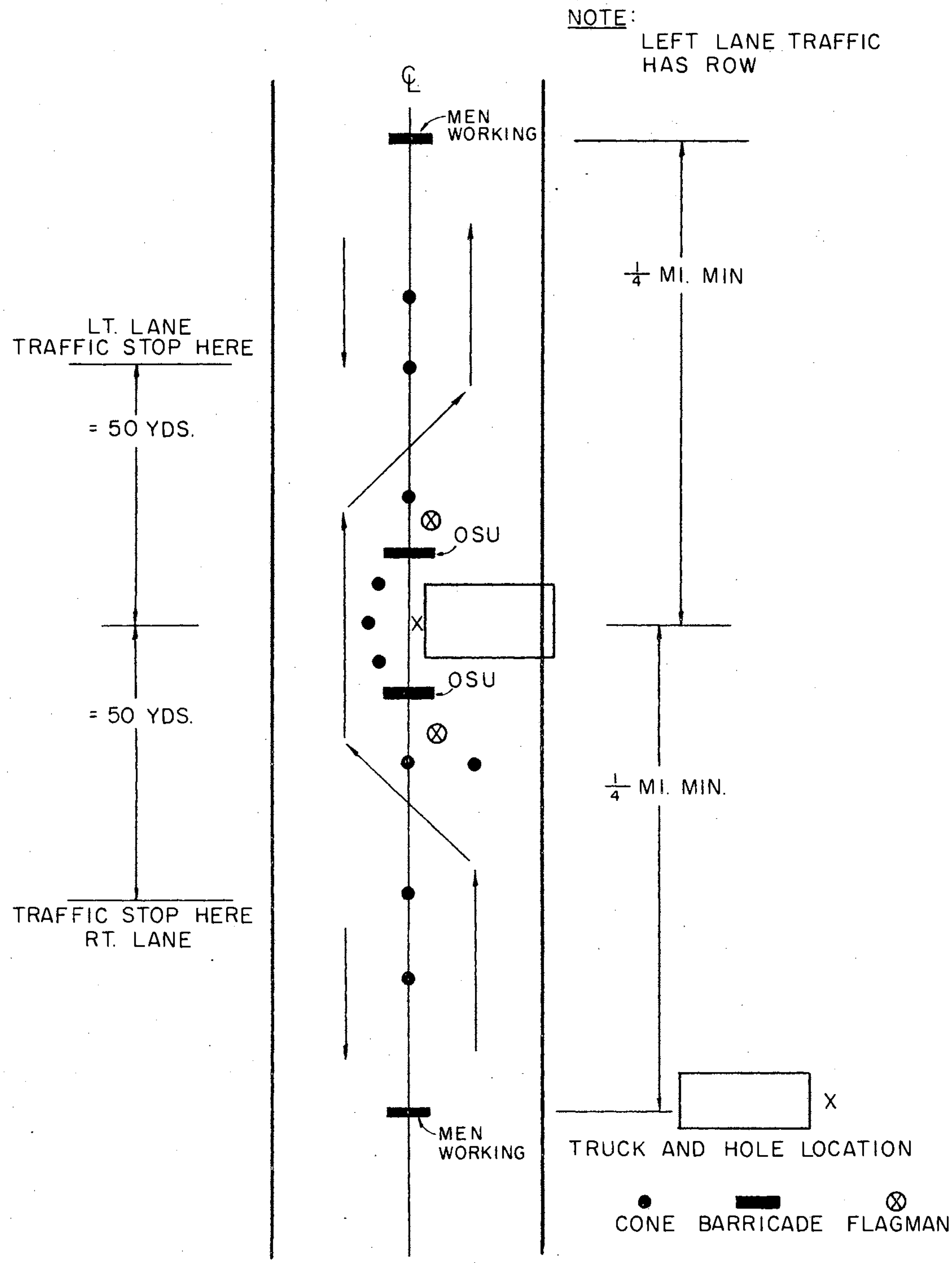

Fig 4.2. Traffic Routing When Drilling in Center of Pavement

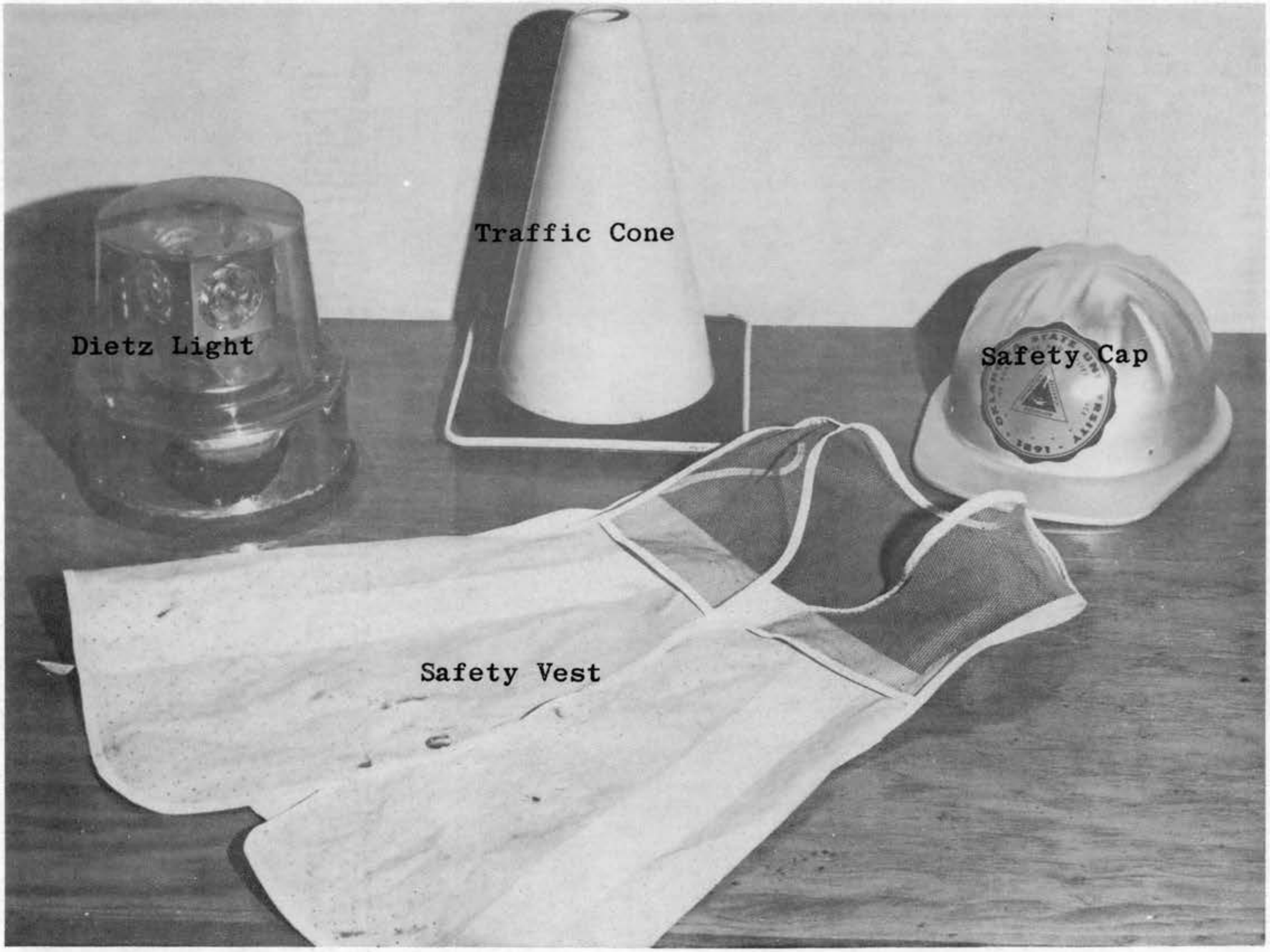

Fig 4.3. Safety Equipment

A, B, and C, was mounted in an easily accessible location within the cab of the vehicle. The fuel tanks of the drilling unit were more than sufficient to install one site of three holes, thereby eliminating the hazard of carrying a spare gasoline container.

CHAPTER V

INSTALLATION AND DATA COLLECTION PROCEDURE

Core Drilling

The core drilling process was the same for either asphaltic or portland cement concrete. The recommended procedure was as follows:

1) level the vehicle with out-riggers, and
2) adjust the air pressure on the cylinder to 50 psi. At this pressure, sufficient downward force can be applied to the core bit without damage.
3) Connect the core bit assembly to the high-speed spindle of the drill.
4) Adjust the water folw rate to 1/2 gallon per minute. A higher flow rate, 1 gallon per minute, is necessary for asphaltic concrete due to the increased friction and drag of the asphalt binder.
5) Lower the core bit into a template to align and hold the core barrel when starting the hole, shown in Fig 5.1. When the bit is "seated" remove the template and increase

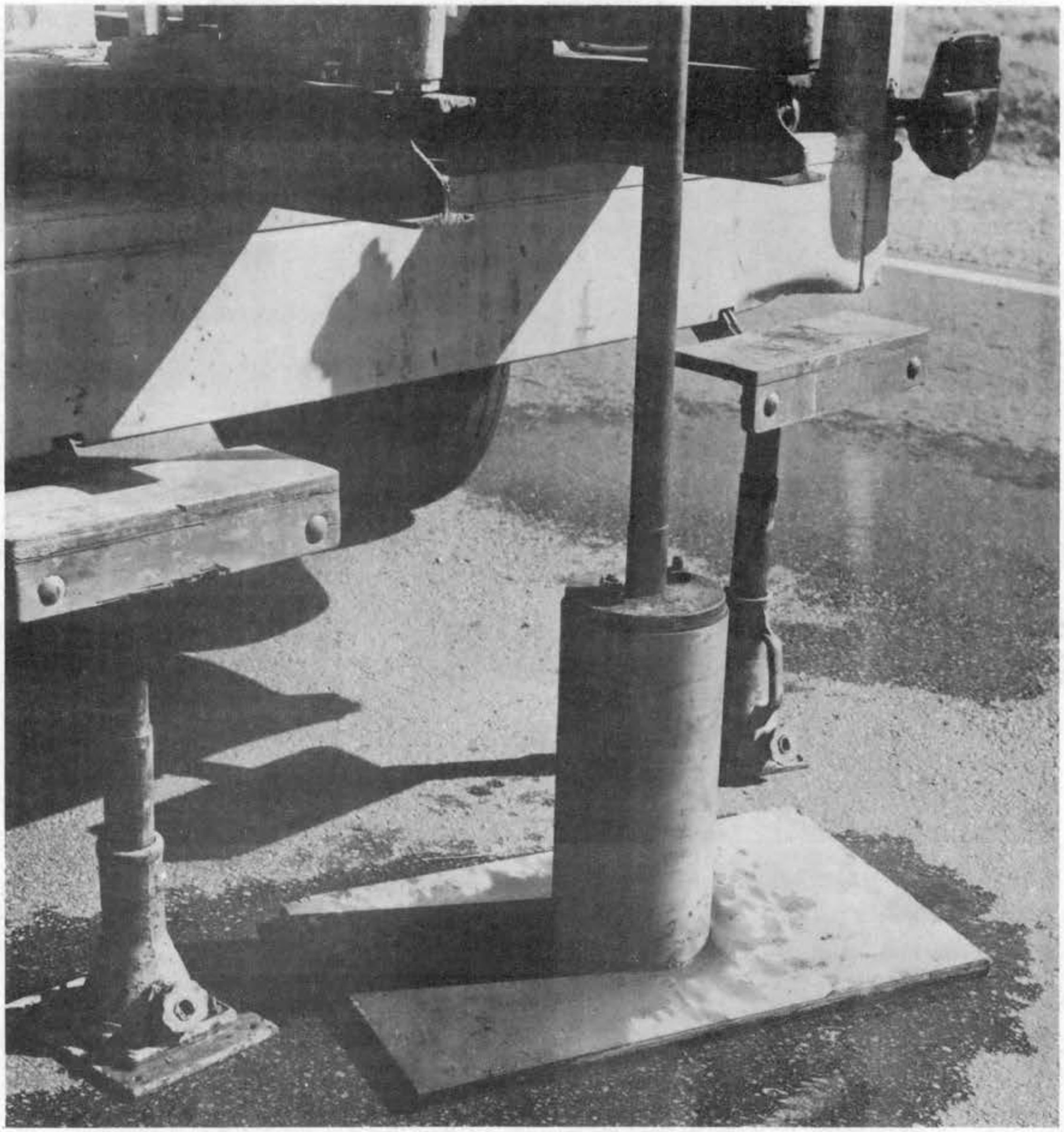

Fig 5.1. Core Bit and Template

the engine speed, as seen in Fig 5.2. With the transmission in first gear and maximum engine speed, the core bit rotates at 350 rpm.

The coring feed was applied at a constant rate and the bit "crowded" just as fast as it could cut. Holding back and allowing the bit to ride on the material would polish the diamonds and impair cutting ability -- particularly when cutting steel reinforcing in portland cement concrete.

It was very important to watch the water circulation during the coring operation. Much information was gained by observing the waste water. The amount of residue contained in the out-flowing water was a function of the cutting rate. Also, it was obvious when steel was encounted because the metal cuttings collected on the pavement around the bit.

When core drilling a portland cement concrete pavement with an asphaltic concrete overlay, it was important to remove the overlay when it separated from the original pavement. This small core of asphaltic concrete would act as a plug and restrict the flow of water to the cutting edge of the bit.

Any movement of the vehicle caused misalignment and subsequent binding between the pavement and the core bit. Excess wear and possible damage to the core bit was a result of this occurrence.

Occassionally, asphaltic concrete pavements greater than 12 inches in thickness were encountered. By using a cold chisel, star-drill, and hammer, the top of the core

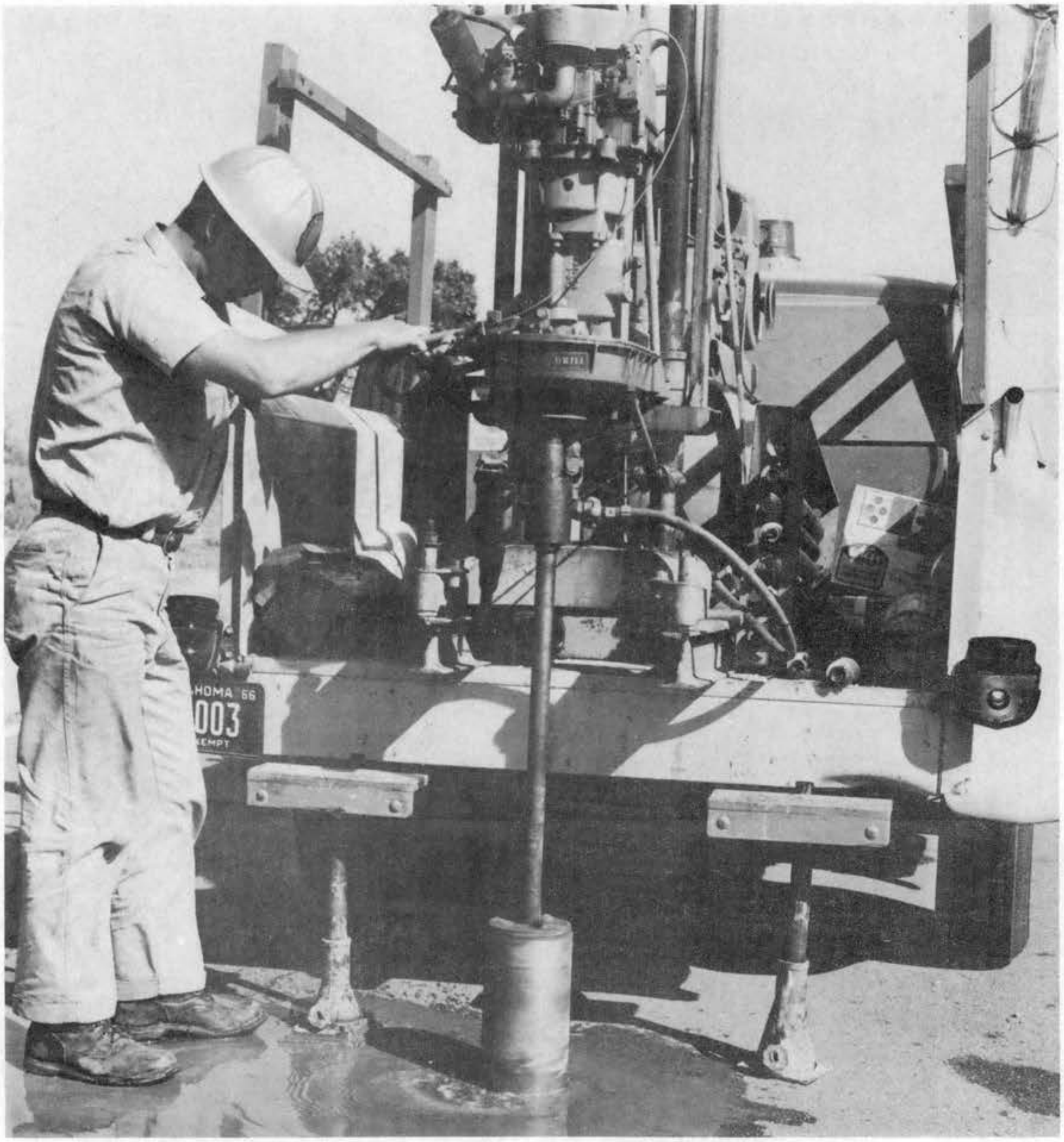

Fig 5.2. "Seated" Core Bit

could be removed and depths greater than 12 inches could be bored, as shown in Fig 5.3.

Removal of the core from the pavement was accomplished by stopping the flow rate and rapidly moving the core bit upward. A vacuum was forned and the core lifted readily from the hole, as seen in Fig 5.4. When this was not possible, a wire loop was used for removal. When asphaltic concrete cores adhered to the base material, a lateral movement was used to break the bond.

Extraction of the pavement core from the core barrel was often difficult. By applying the maximum water pressure, 175 psi, most cores were forced out of the core barrel. Thin asphalt cores of 2 to 4 inch thickness were broken and removed in separate pieces. The removal of the most difficult cores required disassembly of the core bit and couplings. When this was necessary, a strap wrench was used to prevent crushing and damage to the core barrel.

Auger Drilling

The auger was connected to the low speed spindle and lowered to the soil. At this point it was important to adjust the air regulator to deliver maximum air pressure, 175 psi, to the cylinder. Also, it was imperative that the out-riggers be positioned securely. These two precautions were necessary to prevent the auger from advancing too rapidly and screwing into the soil.

The auger was slowly advanced into the soil in 1 foot

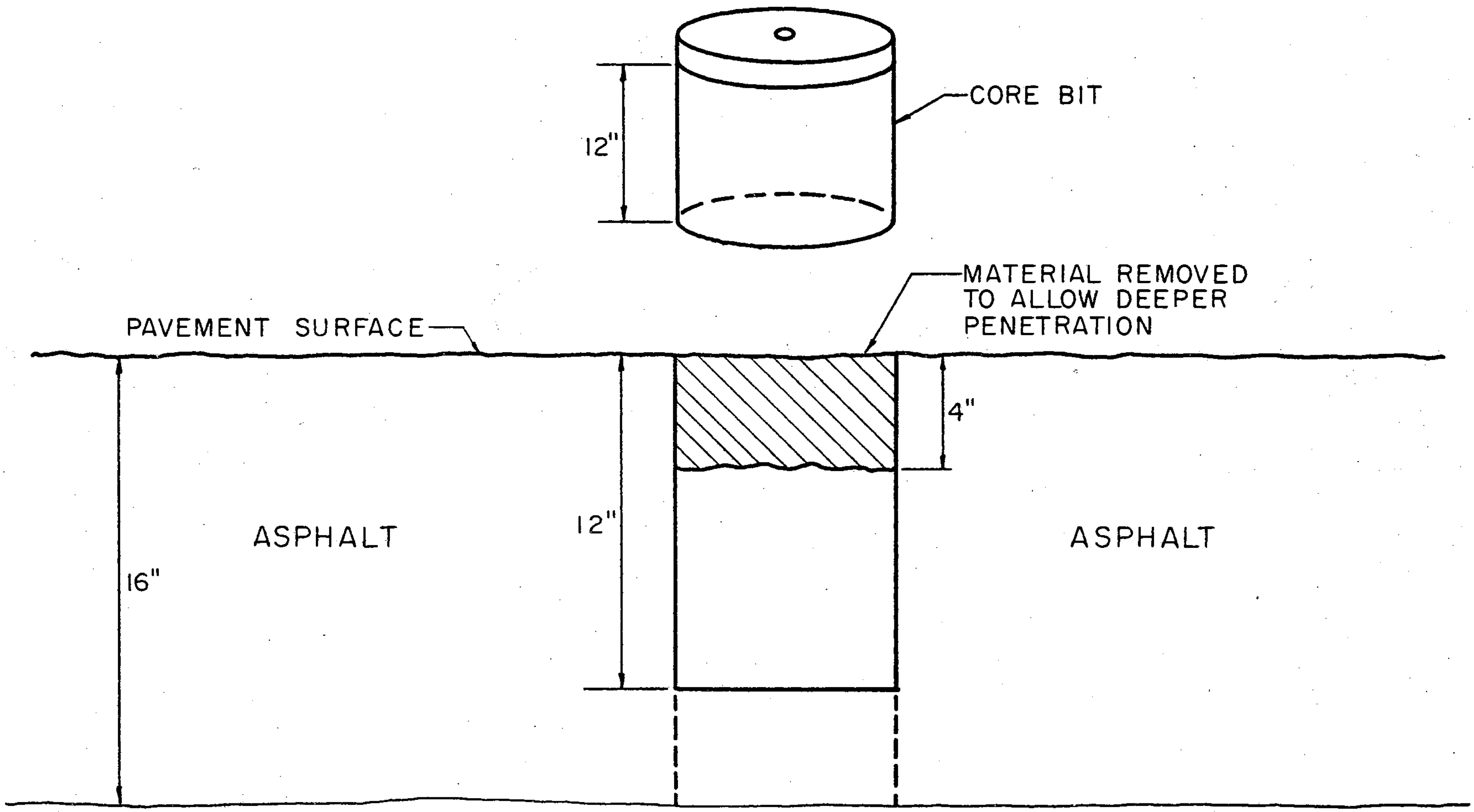

Fig 5.3. Coring Thick Pavements

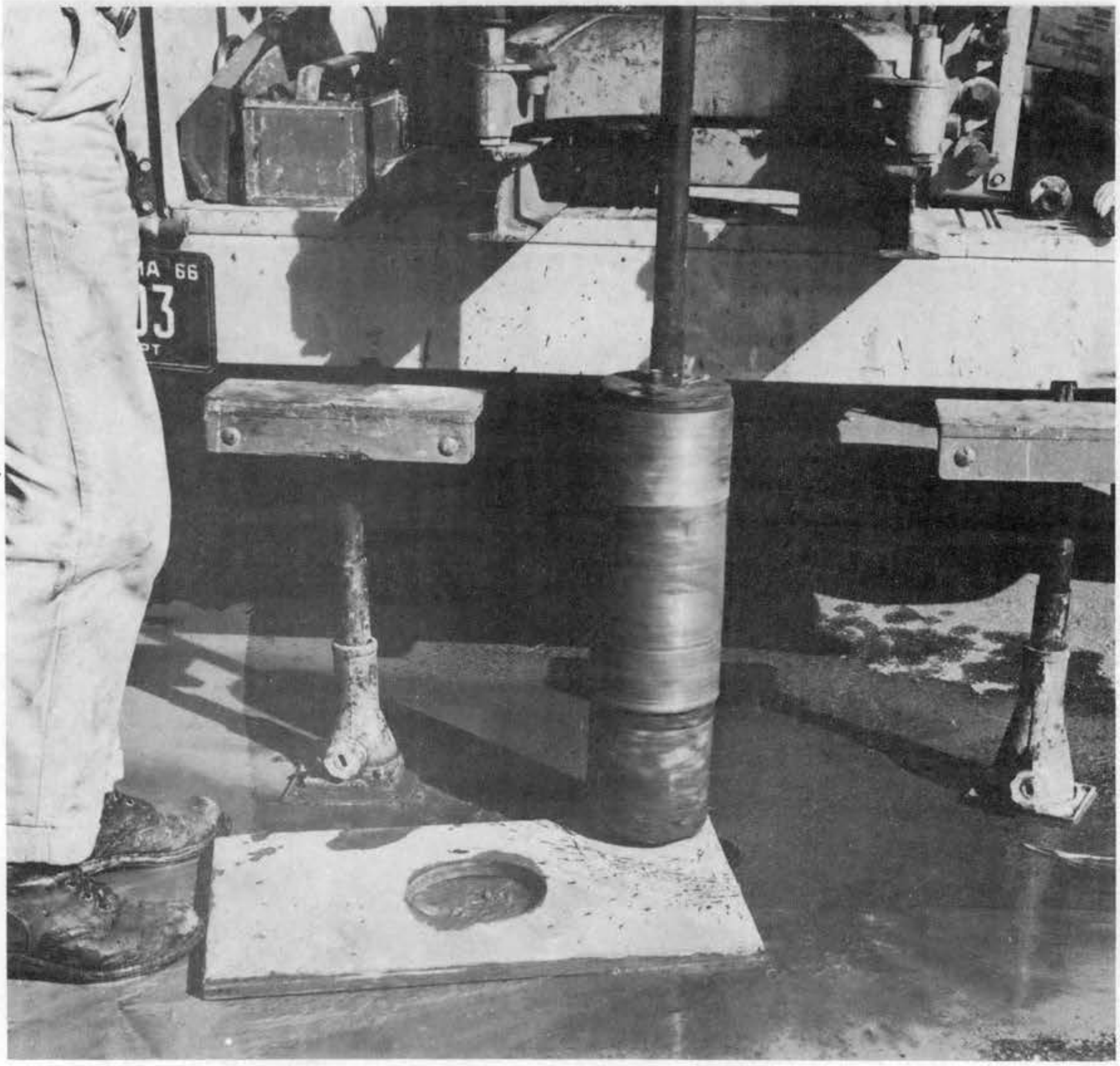

Fig 5.4. Vacuum Removal of Core

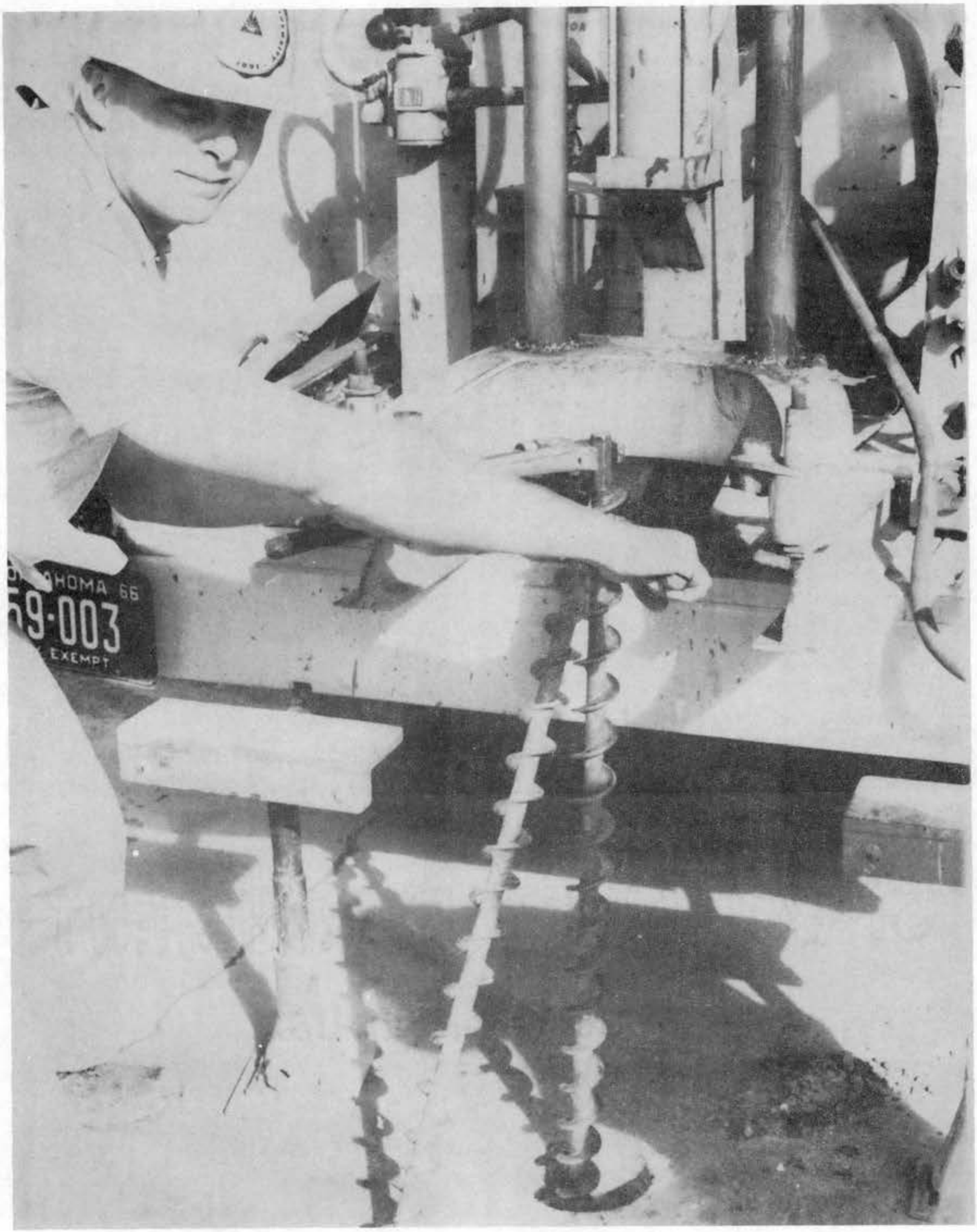

Fig 5.5. Removing an Auger Section

increments. After each advance, the auger was allowed to rotate for a short time to move the soil sample to the surface. Vibration of the auger string was noticed when the majority of the soil had been removed. It was necessary to advance the auger slowly to allow the bit to cut and remove the soil rather than screw itself into the material. With precaution, a stiff and moist clay could be removed. The hole was drilled approximately 12 inches deeper than the desired depth. Soil fell into the hole when removing the auger, and material was dislodged from the sidewalls when inserting the access tube.

The auger was removed from the hole by the upward motion of the drill. A three foot auger section was removed from the string, as seen in Fig 5.5, and the drill lowered and fastened to the remaining auger. This process was repeated until remaining sections of auger could be removed by hand. Lifting the auger by hand prevented unnecessary enlargement of the top of the hole.

Soil Sampling

Soil samples were taken at one foot intervals, as the auger was advanced. Samples were sealed in glass jars and marked for identification. A boring log was kept indicating sample number and corresponding depth for each hole.

The actual depth of the auger and the corresponding soil sample at the top of the auger flight was subject to variation. It was found that sandy soils cleaned from the auger flight very well and advanced readily to the top of the auger. These samples were within 12 inches of the actual depth of the auger. Clay soils were the most difficult to sample. To advance these soils to the surface, the drill was rotated for several minutes without vertical advancement. When drilling a 10 foot deep hole, the deeper soil samples could have been 24 inches from the indicated depth. Under these conditions, the last 2 or 3 soil samples were taken from the auger when it was removed from the hole.

Access Tube Installation

The access tube was inserted by hand. The top of the tube was positioned 4 inches below the pavement surface. An extension tube, see Fig 5.6, was connected to the access tube to aid in centering the hub and to prevent debris from falling into the access tube. Soil was placed around the tube to a level that would support the hub. The top of the hub was set below the surface of the pavement to avoid obstruction to traffic, snowplows, and other maintenance equipment.

A rapid-set cement was used to make a grout mixture for holding the hub in position around the tube. A rich mixture of 3 parts cement, one part sand, and water was combined to form a stiff paste. Adherence of the grout to the cast iron was excellent, but the smooth concrete surface produced by the core bit presented slight bonding problems when subject to heavy impact loads.

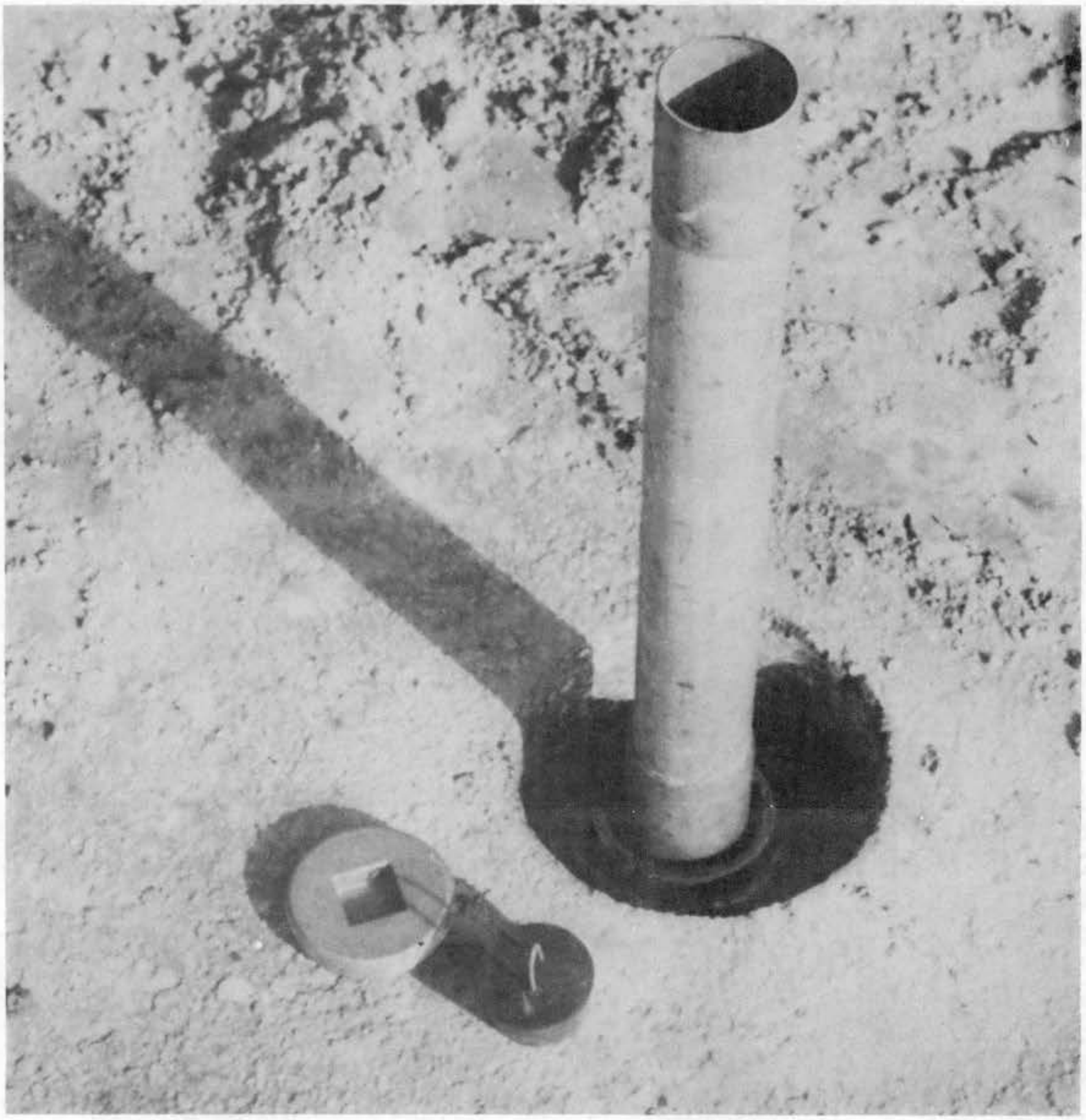

Fig 5.6. Hub in Place and Ready for Grouting

A number 10 rubber stopper was used to seal the open end of the access tube. A wire loop or chain facilitated removal of the stopper from the tube. If moisture condensation occurs inside the tube, a small container of desiccant should be inserted between inspection periods.

Initial Data Collection

The nuclear probes were used to collect data from the test hole immediately after completion. Ten readings were taken with the instrument in the shield. This provided the standard to use when calculating the count ratio. By connecting an extension tube to the access tube, the shield could be placed on the extension tube and the probe lowered into the access tube, as seen in Fig 5.7. Two readings were taken for each one foot interval. The one foot increment was established by calculating the probable sphere of influence for the probes, (Ref 6). The basis of two readings per interval was used to obtain the desired accuracy in the 95% confidence level, (Ref 7).

To provide a minimum obstruction to traffic, the layout of operations, shown in Fig 5.8, was 1) drill - A, 2) read - A, drill B, 3) read - B, drill C, and 4) read - C. It was possible for one man to drill a hole and install an access tube in the time required to take a set of readings from another hole.

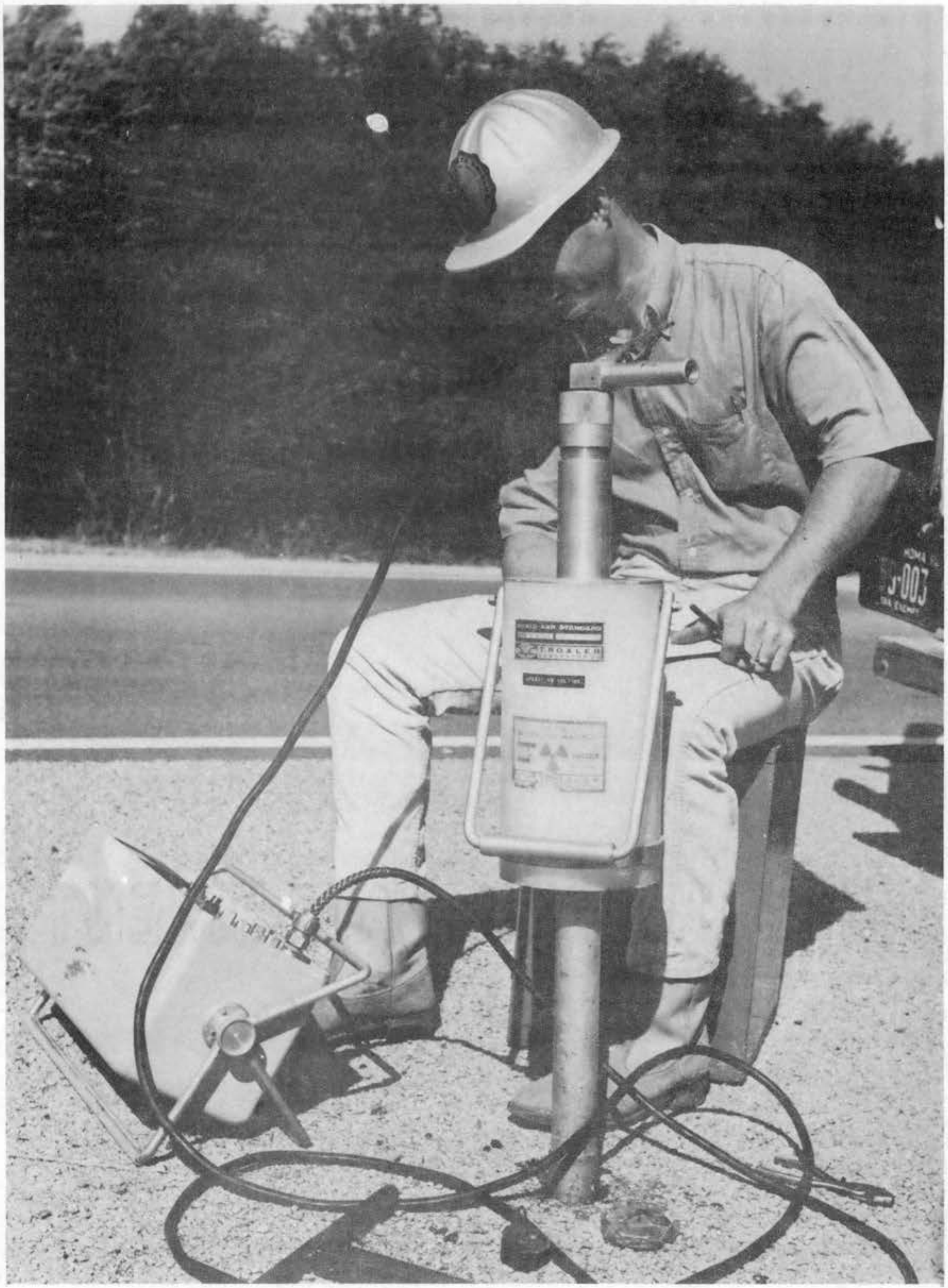

Fig 5.7. Initial Data Collection

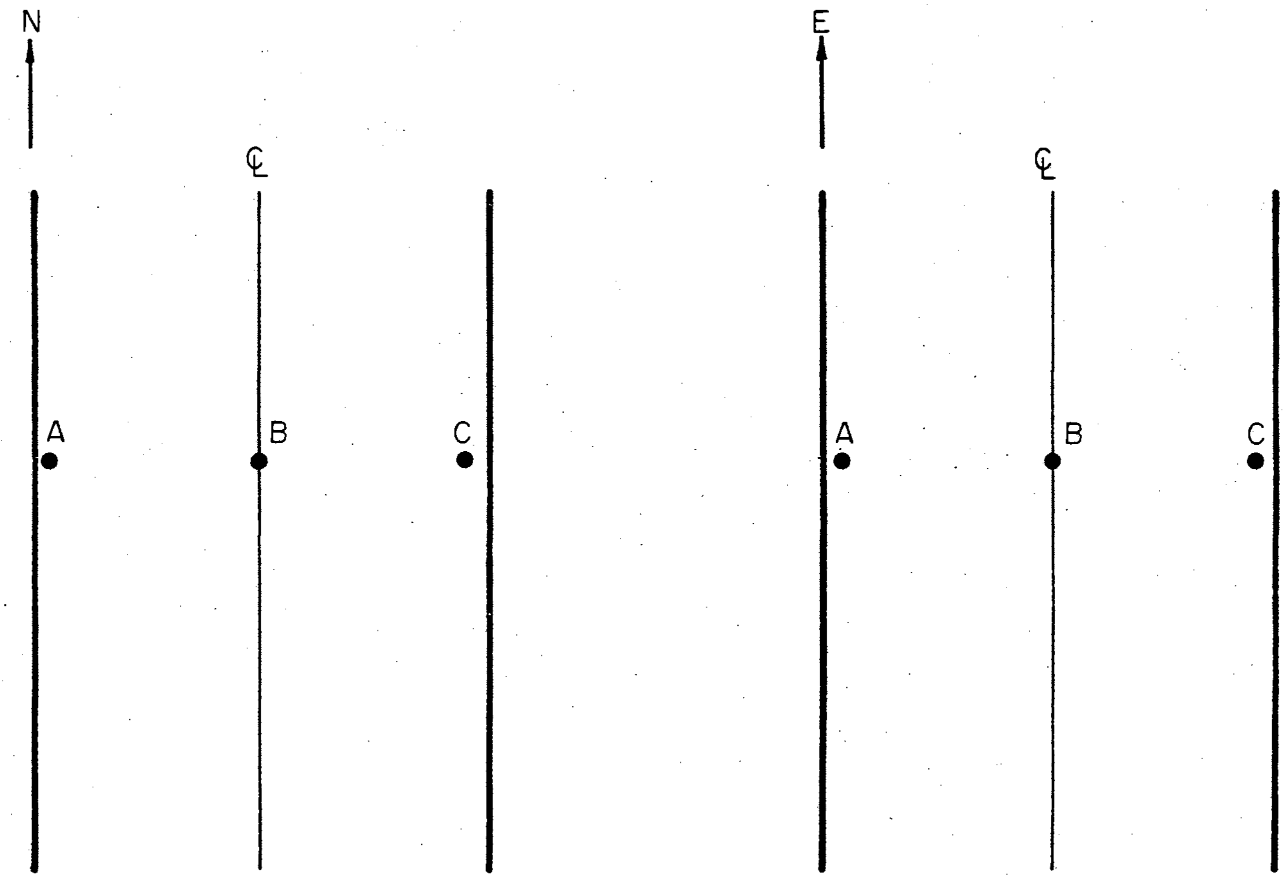

Fig 5.8. Layout of Operations

CHAPTER VI

PROBLEMS ENCOUNTERED AND SUGGESTED MODIFICATIONS

After using the drilling unit to install 30 test sites, several possible modifications of the drilling equipment became apparent.

Drill Modification

Using oil rather than air to activate the hydraulic cylinder would eliminate many of the problems encountered with the original unit. The compressibility of air causes sudden uneven movements of the cylinder. By using oil, a positive displacement system would be obtained, thus eliminating these abrupt movements. This would allow a steady feed and extend the life of the core bit.

It has been mentioned previously that the auger has a tendency to screw itself into clay soils rather than cut and remove the material. When this occurs, the air on the bottom side of the piston has the pressure in the control system, 175 psi, and trying to counteract the unwanted downward movement by using the control valve reduces the pressure on the top side of the piston to atmospheric pressure, as shown in Fig 6.1. This unbalanced condition

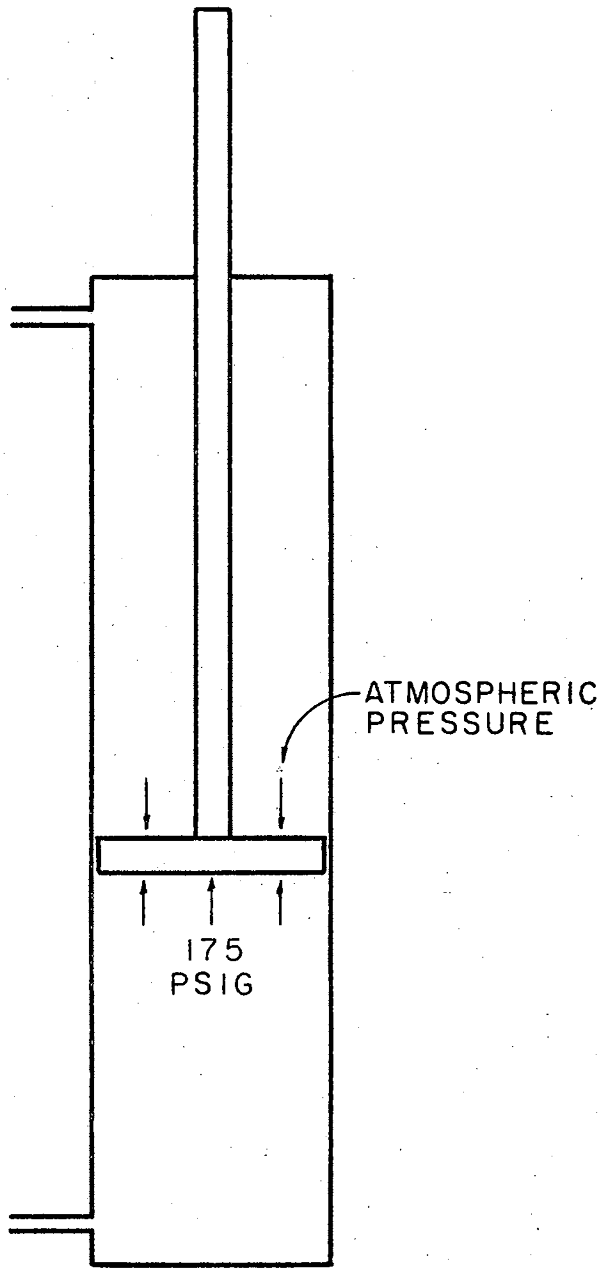

Fig 6.1. Unbalanced Air Cylinder

can be dangerous. Any failure of the auger or connections will allow a rapid movement of the drill in an upward directions, stopping abruptly at the end of piston travel. This could damage the Mobile drill and cause injury to the drilling crew. By using a positive displacement system, the problem of unwanted downward movement would be minimized and the possibility of sudden upward movement eliminated.

Introduction of a hydraulic oil system and subsequent removal of the air compressor introduces advantages and disadvantages. With the oil system, it would be possible to reduce the over-all drilling time by installing hydraulic out-riggers for stabilization. Absence of the air compressor poses the problem of supplying water for the core drilling process. A electrical pump, using the 12 volt system of the vehicle, would be more than adequate to supply the required flow rates.

There are several possibilities for providing a power source for the hydraulic pump:

1) a standard hydraulic system powered by a power-take-off shaft from the transmission of the vehicle,
2) a portable hydraulic system powered by a gasoline engine, or
3) a belt driven pump mounted in the engine compartment of the vehicle.

Core Drill and Auger Modifications

The use of an 8 inch diameter core bit would solve several minor problems. When using a 6 inch diameter bit, it is very difficult to take soil samples beneath pavement slabs greater than 9 inches thick. Due to the use of both spindles of the drill (see Chapter III), it is necessary to move the vehicle after coring the pavement, thus creating the problem of centering the 2 inch diameter hole in the cored section, as seen in Fig 2.10. When using a 6 inch core bit and a 3 inch hub, the allowable deviation was less than 7/8 inch. A larger core bit would allow more variation in centering and a better distribution of the grout mixture around the hub.

Although the auger performance was satisfactory when new, several undesirable effects appear after nominal usage. It becomes obvious that the auger is not made to be used with a large drill. The applied torque causes the shoulders of the threaded connections to flare out, as shown in Fig 6.2. This condition creates two serious problems:

1) the auger flight ceases to be continuous, and
2) the alignment of the auger sections is not straight and enlargement of the hole occurs.

In relation to these problems a moderate degree of success was accomplished by placing washers between the shoulders of the auger sections. With the threaded connection, it is not possible to use the reverse gear to

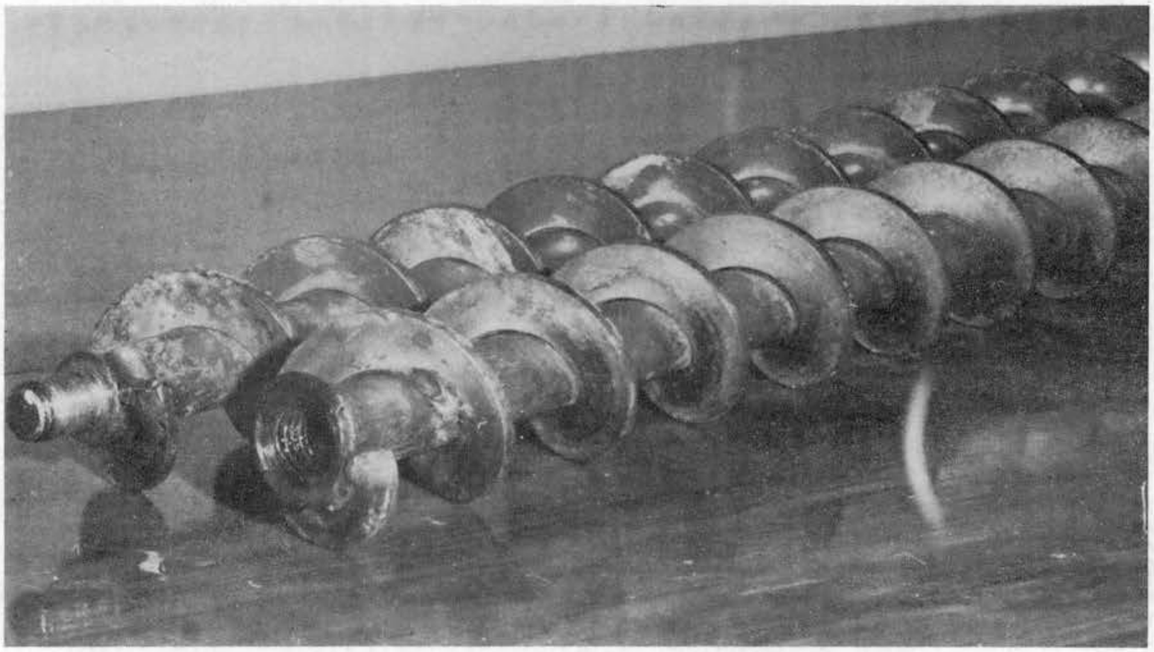

Fig 6.2. Flared Shoulders of Threaded Connections

remove the auger from binding positions, i.e., heavy clays, rock fragments, and roots.

The length of weld connecting the auger flight to the stem should be increased to develop more strength. It is imperative that any major changes of the auger be made by the manufacturer, because localized heating from welding would produce distortion of the auger.

The auger pieces are furnished in 3 foot and 3 1/2 foot lengths. The 3 1/2 foot sections contain the fish-tail bit. Rock is extremely detrimental to the bit, and it is necessary to replace the entire 42 inch section when the bit is ruined by rock. It is suggested that the manufacturer produce bits on auger lengths of 6 inches, thereby reducing the expense and allowing spare bits to be carried, as shown in Fig 6.3. The lead section of auger is subject to the most intense abrasion, therefore, it is desirable to rotate auger sections to obtain uniform wearing.

For test sites located in rocky terrain, it is helpful to drill a test hole adjacent to the pavement to determine if the minimum depth can be drilled.

Corrosion between the cast-iron hub and brass cap was encountered under field conditions. A coating of heavy grease on the threaded areas eliminated this problem.

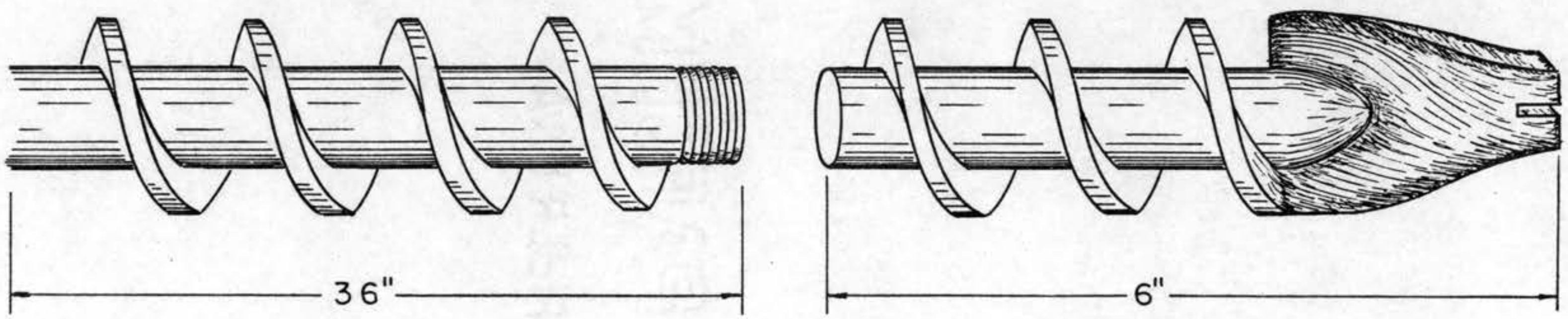

Fig 6.3. Spare Bit

CHAPTER VII

CONCLUSION

The equipment and procedures described in this report were used to install thirty test sites. The performance of the drilling equipment was satisfactory. The downtime of the equipment was negligible and there were only minor maintenance problems. When using the aforementioned procedures, it was possible to drill three holes, install access tubes, and take initial data readings in a 4 to 6 hour period.

The problem of voids due to an augered hole, as discussed in Reference 1, has been minimized by the expansive nature of the soils encountered and by the close tolerances of the drilled hole. Tubes that have been installed 60 days or more exhibit a tightness of fit with respect to the surrounding material. Results from the data collected to date indicate a slight increase in the dry density of the soil within 60 days of initial installation. At the present time, data collection is proceeding on an eight week interval.

It is concluded that this equipment provides a satisfactory method of installing test sites for measurement of subsurface soil moisture and density with nuclear instruments.

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