PDHonline Course C285 (3 PDH)

Procedures for Soil Sampling in Borings

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be mounted on casing or a framework of drill pipe which has been driven into the overburden. Land-type drill rigs mounted on barges, floating platforms supported by pontoons of oil drums, or the fixed platforms supported by piles or spuds are used for most nearshore marine work. Although a barge or floating platform is more common than a fixed platform, the disadvantage of the barge or float is that it moves with tide and wave action, whereas the disadvantage of the fixed drilling platform is its expense.

g. Ancillary equipment. A number of small tools and miscellaneous equipment are needed for the drill rig. Driving weights, such as the 63.5 kilogram (kg) or 140 pound (lb) hammer for the SPT test and perhaps a larger hammer, i.e., 113 to 181 kg (250 to 400 lb) range, for driving and removing casing are integral components of the drill rig. Fishing tools for recovering drilling equipment which has been lost in the borehole, bypass and pop-off valves for the fluid circulation system, assorted safety hooks and hoisting tools, tools for coupling and uncoupling drill strings or augers, and spiders and forks for holding sections of drill rods or augers in the borehole should always be carried on the drill rig. A short piece of casing which can be driven into the ground prior to commencing the drilling operations should also be carried on the drill rig; the casing can be used as a collar to prevent erosion or sloughing at the top of the borehole caused by the action of the drilling fluid. Other equipment may include racks for stacking drill rods and samples. A number of small tools such as hand-held hammers, punches, adjustable wrenches, pipe wrenches, pliers, vise grips, screwdrivers, allen wrenches, and hacksaws and hacksaw blades, as well as hard hats, first aid kits, and this manual, should always be carried on the drill rig.

3-3. Types of Drills

Drill rigs are designed to perform a certain type of operation. Rotary, churn, and percussion drill rigs are the most common, although a number of other types of rigs have been designed and developed to perform site-specific tasks, such as drilling shot holes in quarries. Of these rigs, the rotary drill rig is widely used for geotechnical engineering investigations, whereas churn and percussion rigs are used more extensively for drilling water wells and for construction operations, such as drilling holes for cast-in-place piles.

a. Drills for wash borings. The wash boring refers to a process by which the borehole is advanced by a combination of chopping and jetting to break the formation and washing to remove the cuttings. The principal use of the wash boring method is to advance the hole between samples. The cuttings are not acceptable for sampling because of the breakdown of the particles due to the chopping action, the loss of fines during transport of the cuttings to the surface, and segregation of the cuttings in the sump tank. However, an experienced operator may be able to distinguish changes of stratigraphy by the action of the chopping bit as well as by changes of the characteristics of the cuttings.

The equipment to advance holes by the wash boring method consists of a motor which is used to drive a cathead for raising and lowering the tools in the borehole, a derrick with a sheave through which a rope from the cathead is passed to the drilling tools, and a water pump for jetting and washing the cuttings from the borehole. During drilling operations, the drill string is lowered into the borehole. Drilling fluid is pumped under pressure through the drill rods and bit to the bottom of the hole as the chopping bit is raised and dropped. Each time the rods are dropped, they are rotated either manually by a wrench or lever or mechanically by the rotary drill-rig drive. The rotation of the drill rods helps to break the material at the bottom of the borehole. The resulting cuttings are carried to the surface by the drilling fluid which flows in the annulus between the drill pipe and the walls of the hole. Cuttings which are not removed from the borehole when the circulation of the drilling fluid is stopped tend to settle and become the upper part of the next sample. The hole can usually be cleaned satisfactorily by raising the drill string slightly and circulating the drilling fluid until it is free of cuttings. Casing may be used, if necessary, to stabilize the walls of the borehole.

b. Churn drills. The churn drill was one of the first types of drilling machines to be manufactured. Churn drills are used extensively in the water well industry. They are economical to operate and are useful for advancing a boring through boulder or rubble zones and can be used for obtaining disturbed drive samples in soil and soft shale. However, they can not be adapted to undisturbed sampling operations.

The churn drill has no rotary features. Churn drilling which is often called cable-tool drilling is accomplished by the up and down hammering or churning action of a chisel-shaped or a cross-shaped drill bit for spudding or chopping. The drill bit is attached to a heavy steel weight on the drill string which frequently exceeds 450 kg (1,000 lb). The drill string is suspended by a cable and tends to act like a plumb bob when it is raised and dropped. The churning action is accomplished by a walking beam on the drill rig. Churn drills may be truck or trailer mounted and are generally powered by gasoline or diesel engines.

The procedures which are used to advance the borehole depend on the location of the water table and the type of soil which is encountered. Above the water table, a small amount of water should be poured into the borehole to form a slurry with the cuttings. When the carrying capacity of the slurry is reached, it can be removed by bailing. After the cuttings have been removed, more water is added to the borehole and the procedure is repeated. When drilling below the water table, it is not necessary to add water for the slurry. For clays, a small amount of sand may be placed in the borehole to enhance the cutting action of the bit. For sands, clay may be placed in the borehole to enhance the carrying capacity of the slurry. For unstable soils, casing may be added as the borehole is advanced; in soft or cohesionless soils, the borehole can frequently be advanced by bailing inside of the casing. The diameter of the borehole typically ranges from 10 to 30 cm (4 to 12 in.).

To obtain a sample, the drill bit and the short-stroke drilling jar are replaced with a hollow steel barrel and long-stroke fishing jar for drive sampling. The long-stroke jars provide a slip joint link in the drill string that allows the top half of the jar and the drill string to be lifted and dropped while the bottom half of the jar and the sampler remain stationary. Holes which are drilled and sampled tend to be vertical because of the plumb bob action of the drill string.

c. Rotary drills. Rotary drill rigs are the workhorses of most geotechnical engineering drilling and sampling operations. In general, boreholes are advanced by rotary action coupled with downward pressure applied to the drill bit plus the cleaning action of the drilling fluid. Samples may be obtained by rotary coring or by pushing a thin-walled tube into the foundation material at the desired depth. The rated capacity of rotary drill rigs, unless otherwise noted, is usually based on the performance in a 75-mm or a 3-in.-diam (NX) hole. Most drill rigs are mounted on a truck, trailer, tractor, or all-terrain vehicle or on skids, although post-mounted drill rigs or portable units are sometimes used in remote or inaccessible areas.

Most truck-mounted rotary drill rigs can be used for drilling, sampling, and in situ testing. Generally, rotary drill rigs are driven by the power takeoff from the truck engine, although some drill rigs are equipped with independent engines. Two general types of pulldown mechanisms are normally used. Truck-mounted rotary drill rigs equipped with a chain pulldown drive mechanism are capable of drilling to depths of 60 to 300 m (200 to 1,000 ft). Hydraulic feed drive rotary drill rigs are capable of drilling to depths of 150 to 750 m (500 to 2,500 ft). A total thrust capacity of approximately 45 kilonewtons (kN) or 10,000 lb is required for undisturbed sampling in very stiff materials. Although the total thrust on chain pulldown rigs may not be sufficient for undisturbed sampling in resistant soils, these rigs can be used for disturbed sampling and vane shear testing.

In addition to rotary drilling and sampling, rotary drill rigs can be used for bucket-auger drilling and reverse-circulation drilling. For bucket-auger drilling, the rig must be provided with a derrick for lowering and lifting the bucket and an arm to convey the bucket away from the borehole to the dumping area. Telescoping kelly bars and a rotary table opening large enough to pass the bucket permit drilling to depths of 12 m (40 ft) or more without adding extra drill stem. Rigs equipped for reverse circulation must have a large rotary table opening that will allow the passage of 10- to 15-cm- (4- to 6-in.-) diam flange-connected drill pipe.

A number of other types of rotary drill rigs are available, depending on the requirements of the drilling operations. One of the most popular is the skid-mounted rotary drill rig, which is merely a smaller version of the truck-mounted rig. Skid-rigs are powered by air, electricity, diesel, or gasoline. A skid-rig can be moved by its own wireline winch, although the skids are usually arranged for easy mounting on the frame of a truck. Skid-rigs normally employ a hydraulic pulldown drive mechanism and may be equipped with a derrick. Derricks for skid-rigs are lightweight and sometimes can be moved independently of the rig. The drill head can be rotated 360 deg for drilling horizontal or inclined holes. Skid-rigs are used primarily for rock coring, although they may be used for soil sampling in areas inaccessible to trucks. Large rotary drill rigs are usually trailer-mounted and equipped with independent power units. The trailer-mounted rigs are generally less mobile and less convenient for soil sampling than truck-mounted rigs. Tractor-mounted rotary drill rigs may be used in rough terrain, whereas rigs mounted on heavy duty all-terrain vehicles can be used for drilling in marshy and swampy areas. In areas of extremely difficult accessibility, such as nearshore sites and marshy and swampy areas, lightweight post-mounted rotary drill rigs, powered by electricity or gasoline, have been used. For drilling in mines or tunnel shafts and drifts, rigs mounted on double-end bearing posts may be used.

d. Hammer drills. Hammer drilling consists of driving or rotating plus driving a drill to advance the borehole. Hammer drilling is analogous to an air-operated jackhammer with an attached bit. It works well in medium to hard rock that is somewhat friable and brittle. Borings advanced by hammer drilling are satisfactory for taking disturbed samples provided that the material in the bottom of the borehole can be considered as representative. However, undisturbed samples should not be obtained from boreholes advanced by hammer drilling. Hammer drill rigs may be truck-, trailer-, or wagon-mounted. Bits usually have carbide blade inserts or carbide button inserts attached to the cutting edge. The diameter of the boreholes ranges from 10 to 40 cm (4 to 16 in.).

(1) *Becker hammer drill*. A special type of hammer drill, called a Becker hammer drill, was devised specifically for use in sand, gravel, and boulders by Becker Drilling, LTD., of Canada. The Becker hammer drill utilizes a diesel-powered pile hammer to drive a special double wall casing into the ground without rotation. As the casing is driven by the pile hammer, drilling fluid is pumped to the bottom of the hole through the annular space between the two pipes. Either air or water can be used as the drilling fluid. A toothed bit which is affixed to the bottom of the casing is used to break material with blows of the hammer. Broken fragments or cuttings are returned to the surface through the center of the casing. At the surface, the return flow is ejected through a vent in the casing to a hose which leads to a cyclone or to collector buckets. The cuttings which are collected can be observed to give an idea of the materials which have been drilled. If necessary, drilling can be stopped and sampling can be done through the inner barrel using a split- barrel sampler or coring techniques. The outside diameter (OD) of the casing ranges from 14 to 61 cm (5-1/2 to 24 in).

Figure 3-4 is a photograph of the Becker hammer drill. Figure 3-5 is a schematic of Becker hammer drilling and/or sampling operations using reverse air circulation. A schematic diagram of the double-wall casing with reverse air circulation for removal of cuttings is illustrated in Figure 3-6. Figure 3-7 is a photograph of several open bits. Typically, the OD of Becker bits ranges from 14 to 23 cm (5.5 to 9.0 in.), although the 17-cm (6.6-in.) diameter is commonly used for the Becker penetration test (BPT). Figure 3-8 is a photograph of a plugged bit which is being connected to the double-wall casing. Plugged bits are used to obtain Becker penetration resistance which is discussed in Appendix C (Appendix H of Geotechnical Investigations manual). Soil, which is collected by a cyclone during drilling operations, is shown in Figure 3-9.

The elements of the Becker hammer drill include an air compressor, mud pump, either a double- or single-acting diesel pile hammer, rotary drive unit, hydraulic hoist, casing puller, mast, and cyclone. The double-wall threaded casing is specially fabricated from two heavy pipes which act as one unit. It has flush joints and tapered threads for making and breaking the casing string. The standard casing is 14.0- to 16.8-cm (5-1/2- to 6-5/8-in.) OD by 8.3- to 8.7-cm (3-1/4- to 3-7/16-in.) inside diameter (ID). The chisel-type bits are made of a tempered steel and nickel alloy. The principal advantage of the Becker hammer drill includes a rapid and inexpensive method for drilling bouldery materials. The principal disadvantage of this method of drilling is that when compressed air is used, the pressure at the bottom of the casing is reduced far below the hydrostatic pressure from the groundwater table. Hence, the flow of groundwater into the borehole can disturb the material at the bottom of the boring. If a boulder is encountered, sand surrounding the boulder may be sucked into casing. As a result, the sample is nonrepresentative, and the recovery ratio could exceed 100 percent.

(2) *Becker CRS drill.* A modification of the Becker hammer drill is the Becker CRS drill. This drill uses twin-tube drill rods with a modified tri-cone roller bit at the bottom of the rods. To advance the borehole, the drill string is hammered and simultaneously rotated. Air is normally used as the drilling fluid, although water or an air-water mixture can be used. The drill bits have an open center to obtain samples. The Becker CRS drill is a fast, economical method for drilling holes or casing through overburden to obtain rock. The Becker processes are patented. Work can be performed under contract with Becker Drilling, LTD.

(3) *Eccentric reamer system.* Another patented hammer drilling system is the eccentric reamer, or ODEX, system. Drilling action consists of rotation plus percussion. The principal drilling equipment consists of a pilot bit with a bearing surface on which the reamer rides and an eccentric reamer which is used to drill the borehole larger than the OD of the casing. Both the reamer and the pilot bit are fitted with carbide cutting inserts for drilling purposes. An eccentrically placed hole in the reamer permits the reamer to be twisted in or out (with respect to the pilot bit shaft), depending on the direction of rotation of the shaft. Stop lugs are used to hold the reamer once it has been positioned. Foam drilling fluid is sometimes used to lubricate the sidewalls of the borehole so that the casing, which follows the bit and reamer, will slide more easily into the borehole. Foam may also enhance the removal of cuttings from the borehole.

Two types of air hammers are available. A downhole hammer is attached directly to the pilot bit. For this system, a special casing shoe is required to transfer the energy from the hammer to the casing to "pull" it down. Center rods which are the same length as the casing sections are used to rotate the pilot bit and reamer during drilling operations. Rotation of the casing is prevented, although the hammer, casing, and drill bits move downward in unison. If a top hammer drive is used, the hammer is attached at the top of the casing string and is connected to the pilot bit and reamer by drill rods. During drilling operations, all components are moved downward in unison. However, only the pilot bit and reamer are rotated; rotation of the casing is prevented.

To operate, the bit is rotated clockwise to swing the reamer to the correct position; a sharp counterclockwise rotation of the drill bit through the drill string swings the reamer back over the pilot bit for removal from the borehole. No samples are obtained by this method of drilling, although a rough idea of the material can be obtained by observing the cuttings. This method of drilling is useful for penetrating loose overburden material to access more competent underlying formations.

e. Auger drills. Auger rigs employ a basic rotary drilling technique in conjunction with various types of augers to advance the borehole. The parts of an auger rig are virtually the same as rotary drilling rigs except a kelly is not needed. The auger is attached directly to the rotary drive or spindle. When an auger rig is needed for rotary work, a chuck is installed above or below the spindle and a kelly rod is inserted through the hollow rotary spindle. Most auger rigs use an hydraulic pulldown drive mechanism. These rigs are usually equipped with long or telescoping hydraulic cylinders which permit a drive or stoke of 1.8 m (5 ft) or more.

Large auger rigs are usually mounted on a crane or truck. Augers and belling buckets are used for drilling large-diameter holes. If a crane is used, no downward force can be applied to the auger. The borehole is advanced by relying on the weight of the bucket plus the digging of the teeth. Drilling operations are controlled from the cab of crane. If a truck-mounted rig is used, drilling operations are controlled from a position on or at the end of the rig. Downward force is applied by a chain or hydraulic pulldown mechanism. During drilling operations, the auger is pulled to the surface after it has been filled. To empty, the drill is pivoted on a turntable on the truck bed. When it has been moved away from the borehole, the auger is spun rapidly to discharge the cuttings.

Small motorized auger drills are used in inaccessible areas. They are useful for obtaining a limited number of holes in a hurry. These drills are handheld or can be mounted on a mobile stand. Most portable drills are capable of reverse augering.

The bucket auger rig, which is a form of the rotary drill rig, uses a ring gear drive to supply rotary torque to the bucket. The ID of the ring must be sufficient to allow the bucket to pass through. The drive bar in which the kelly slides fits into two slots at 180 deg apart on the drive ring. Torque from the kelly is transmitted through the drive bar to the drive ring. For this type of drilling rig, the kelly is usually square with two or three telescoping sections which can be extended to 25 m (82 ft) or more. To fill, the bucket is rotated. When it is full, the bucket is raised and pulled through the drive ring by a cable. A dump arm is used to pull bucket away from the rig. A photograph of a bucket auger drill in operation is presented in Figure 3-10. A variety of types of bucket augers are available for specific tasks. A discussion of the types of buckets is presented in paragraph 7-2*d*.

f. Other drills. A large number of other drills, including electric arc and electric beam drills, explosive and jet drills, implosion drills, and laser drills are in experimental stages of development and therefore are not discussed herein. Details of these drills are reported by Maurer (1980) and other references. Only those drills which are currently used for civil engineering purposes are discussed.

(1) *Remote control drill*. Drilling by remote control methods has received much interest, especially for investigations of sites such as munitions dumps or areas which are suspected of being contaminated by hazardous or toxic wastes. For remote control drilling operations, air cylinders or electric motors are attached to the operating levers of the rig and to the remote console. The function of the remote control system is to advance or withdraw drilling tools or samplers from the borehole. Other drilling functions such as making or breaking the drill string must be performed by the crew at the rig.

(2) *Electric motor drill.* Electric motor rotary drills are available for use with thin-wall diamond core bits for obtaining samples of concrete and rock from difficult locations. These portable drills can be mounted on a pipe or casing or attached to a rack and base. They can also be bolted to a wall or ceiling, such as in a tunnel or drift. Although these drills are generally not adaptable for soil sampling operations, they can be used to drive small augers. This type of drill is also available in air or gas driven models.

(3) *Air track drill.* Air track drills are used for drilling shot holes in quarries. These maneuverable drills are operated by air motors and move about on steel tracks. They are air-operated and use percussion plus rotary drilling techniques. These drills employ a chain pulldown feed mechanism for advancing the borehole. Air track drills can be used to drill blast holes at any angle.

3-4. Accessories and Appurtenant Equipment

Various types of accessories and appurtenant equipment are required for soil sampling and drilling. This equipment includes, but is not limited to, drill rods, drill bits, casing, portable sumps or mud pits, augers, bailers and sand pumps, and miscellaneous pieces of small equipment. The following paragraphs describe the equipment normally required, excluding hand tools.

It should be noted that a great deal of time and consequently, money can be saved during the actual drilling operations if a little forethought is given to the physical layout of the site and the placement of the equipment in a convenient manner to permit easy access during the drilling operations. Besides the work area required for the drill rig and circulation system, consideration should also be given to the storage and/or stacking of drill rods, casing, and other miscellaneous equipment as well as work areas for inspection, logging, and temporary storage of samples. No standard configurations are offered, however, as the layout of each site is dependent on the equipment involved and the terrain. It is suggested that the driller and engineer or geologist should inspect and plan the layout of the site before drilling begins.

a. Standard nomenclature. Two standards are used for the designation of drilling tools, including drill rods, casing, drill bits, and core barrels. Metric standards predominate in Europe. The Diamond Core Drill Manufacturers Association (DCDMA) standards were developed in United States, Canada, England, South Africa, and Australia. It is estimated that DCDMA standards account for about 80 percent of the equipment which is sold throughout the world (Acker 1974). Therefore, only the DCDMA standards are discussed herein.

A two- or three-letter designation is used to describe drilling equipment according to DCDMA standards (Diamond Core Drill Manufacturers Association, Inc. 1991). The first letter in the DCDMA standard designation, such as E, A, or N, indicates the approximate borehole diameter for standard steel drill pipe. The second letter, i.e., X or W, is the group standardization of key diameters and the design standardization of dimensions affecting interchangeability. For example, "W" is used to designate flush joint casing, whereas "X" is used to designate flush coupled casing. The "X" casing is relatively lightweight tubing with fine threads and is not flush along its ID. The "W" casing is heavier walled than the "X" casing and is machined with coarse threads. It has a box thread at one end and a pin thread at the opposite end. Box and pin threads on tubular members refer to the placement of threads on the inside surface and threads on the outside surface, respectively. The casing is flush along its ID and OD and does not require a coupling. The "W" standard casing is relatively new.

When the three-letter designation is used, the second letter, i.e., X or W, indicates the group of tools with which the equipment can be used. This feature allows for nesting of casing and tools to reach a greater

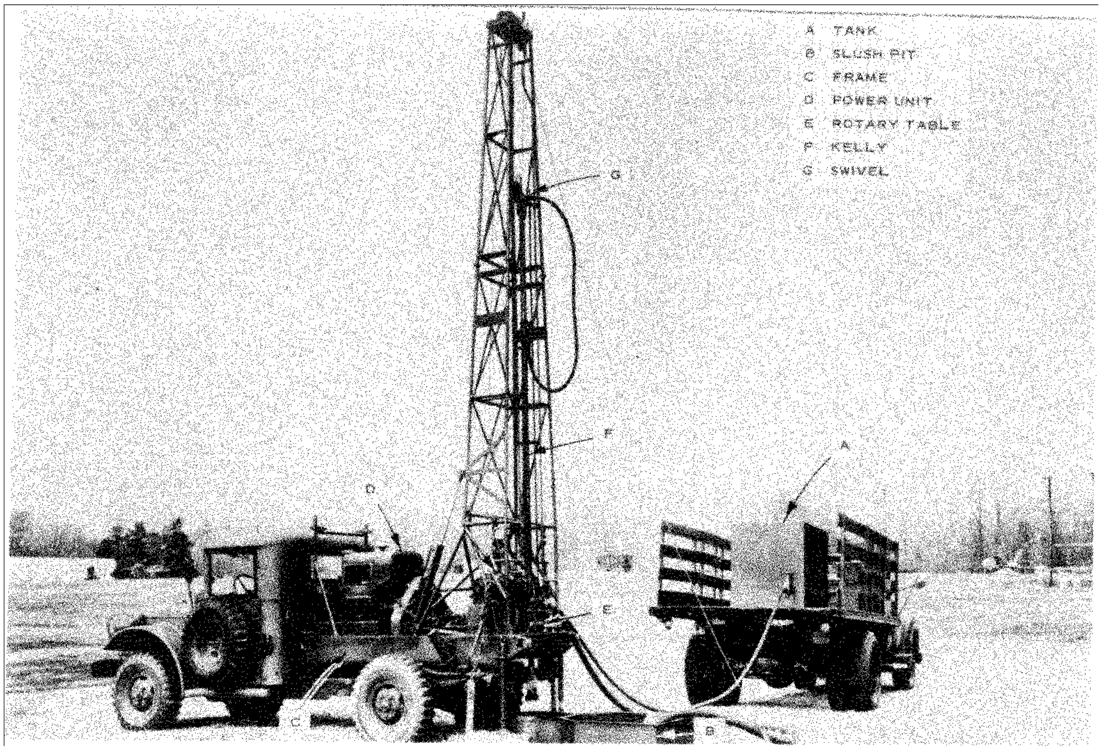

Figure 3-3. Truck-mounted rotary drill rig with a chain feed drive system

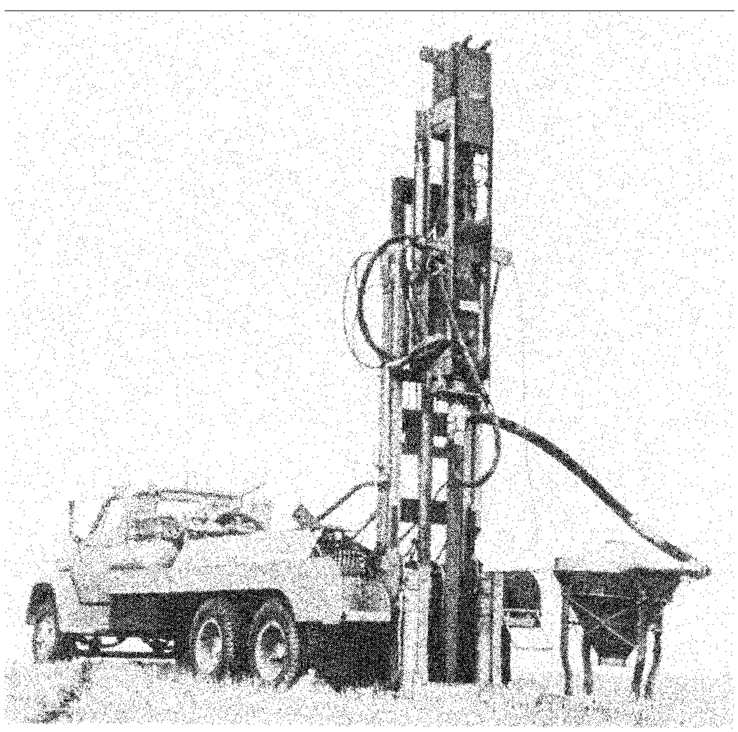

Figure 3-4. Photograph of a Becker hammer drill

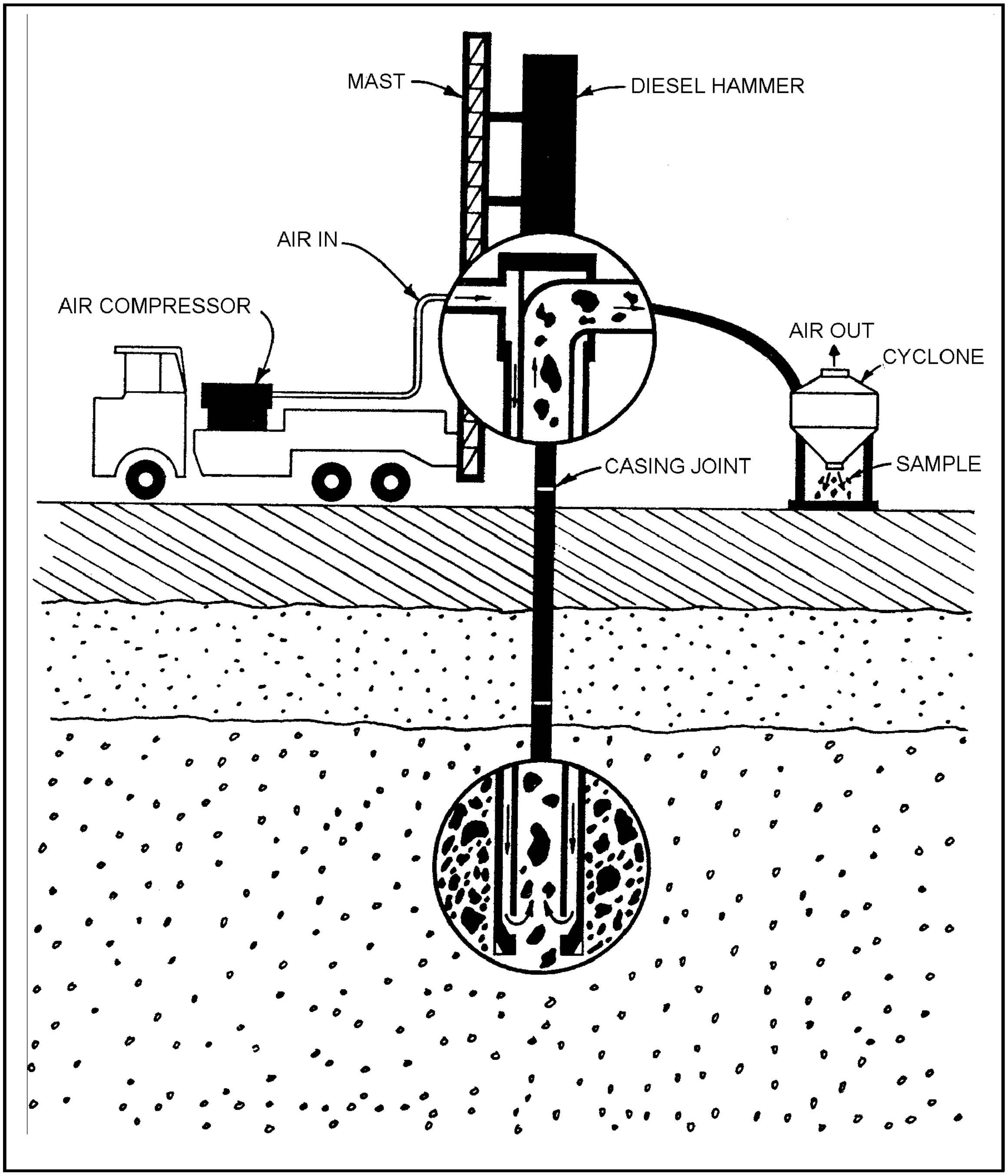

Figure 3-5. Schematic of Becker hammer drilling and/or sampling operations using reverse air circulation (Harder 1993)

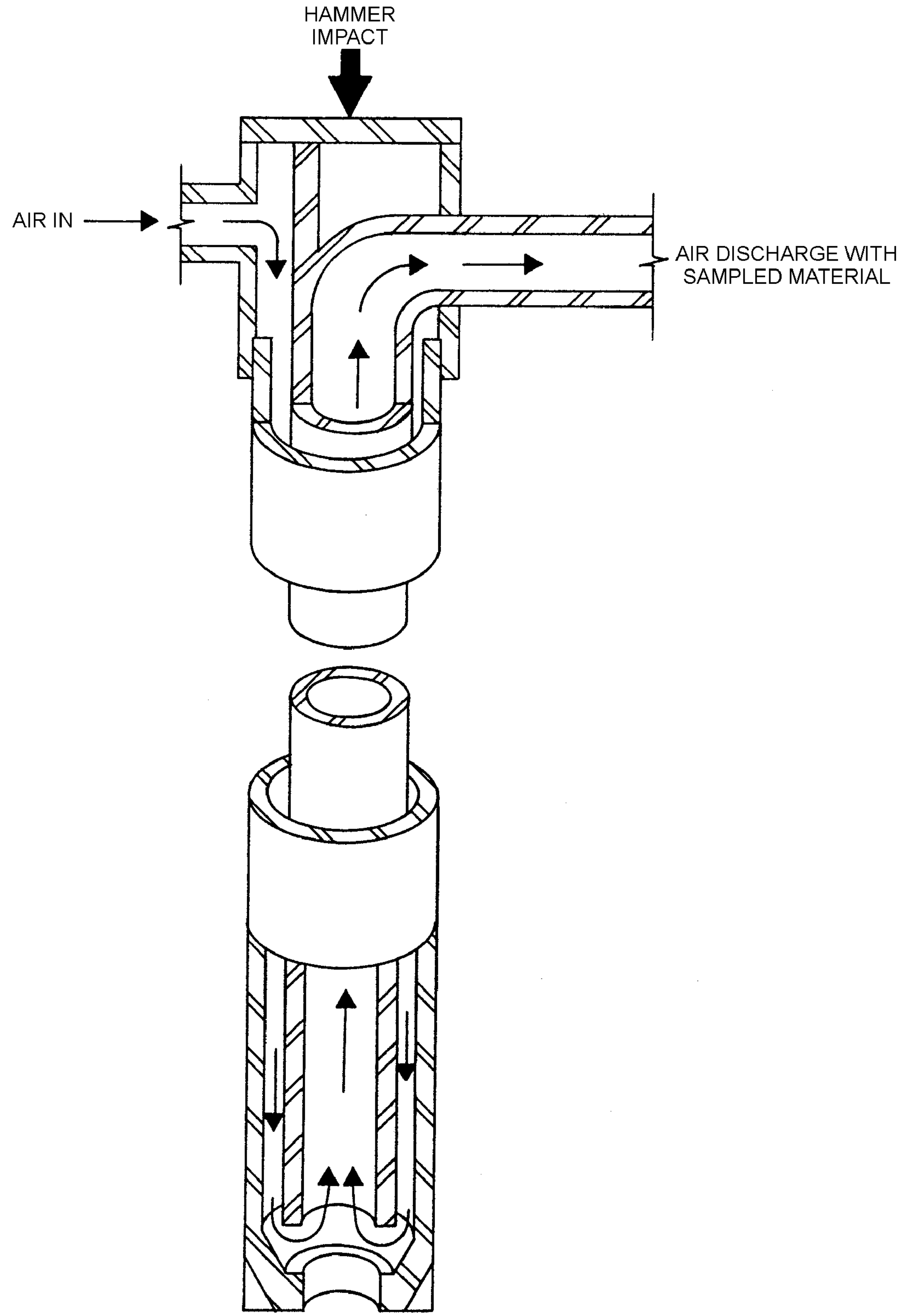

Figure 3-6. Isometric diagram of the double-wall casing with reverse air circulation for removal of cuttings (Harder 1993)

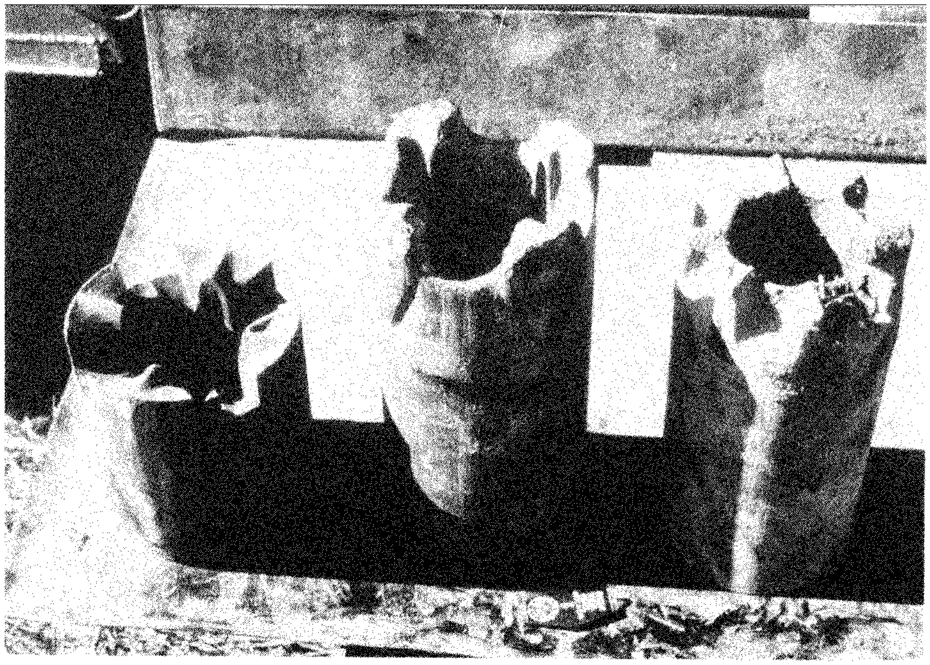

Figure 3-7. Photograph of several open-type Becker bits (Harder 1993)

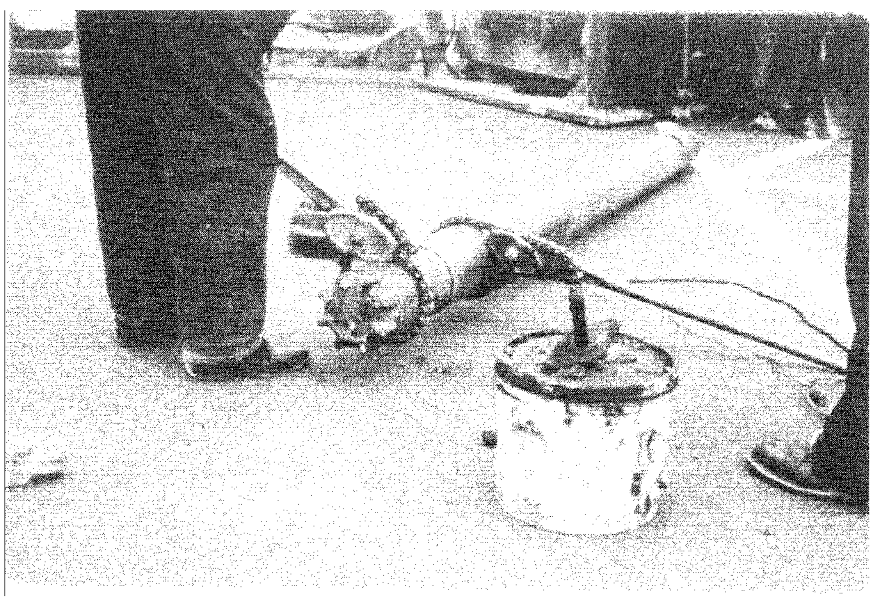

Figure 3-8. Photograph of a plugged bit which is used to obtain Becker penetration resistance (Harder 1993)

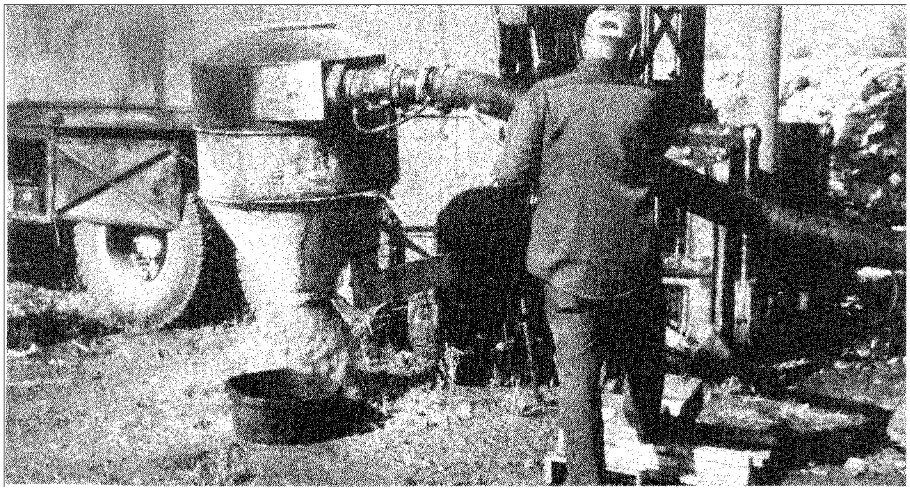

Figure 3-9. Soil is collected by a cyclone during Becker hammer drilling operations (Harder 1993). Note: Safety is a very important consideration for Corps of Engineers projects. Safety items, including hardhats, gloves, safety shoes, protective clothing, and dust or vapor masks, should be worn, as appropriate, for the particular drilling and sampling operations

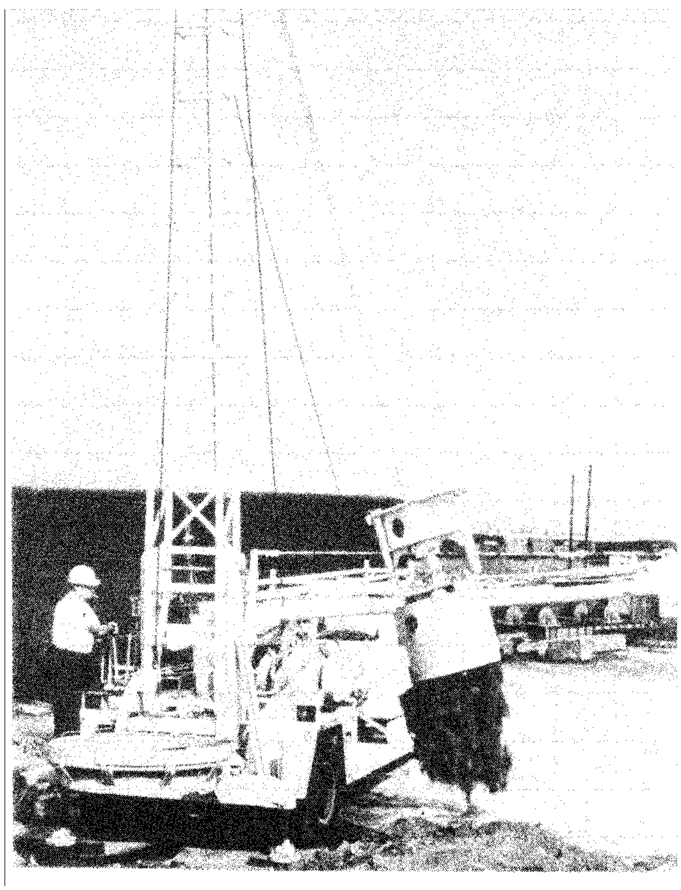

Figure 3-10. Photograph of a bucket auger drill in operation