1987 SCA Conference Paper Number 8704

RESERVOIR PETROPHYSICS OF POORLY CONSOLIDATED ROCKS

I. WELL-SITE PROCEDURES AND LABORATORY METHODS

by

A. E. Worthington, J. Gidman, and G. H. Newman
Chevron Oil Field Research Company, La Habra

ABSTRACT

A new set of procedures is described for handling poorly consolidated rocks at the well site, for preserving and slabbing them for description, and for obtaining their petrophysical properties by laboratory measurements on core plugs. Cores are retrieved at the well in a plastic liner fitted inside the inner core barrel. Novel procedures are employed for handling the inner barrel and liner to avoid gross mechanical disruption of the core by distortion of the liner. The core is stabilized at the well site by filling the annular space between the core and the liner with a self-polymerizing liquid plastic. It is chilled to ice temperature to reduce oil viscosity and fluid evaporation, but not frozen. A thin slab is cut from the top of the core for description and photography. The plastic secures the soft rock to the plastic liner, resulting in exceptionally good slabs. Sampling points are selected by examination of the slabs or the photos. Plugs are plunge cut, and transferred to a pressure vessel without any form of jacketing. The plug is returned to net effective reservoir stress and then cleaned and resaturated with brine by miscible displacement. The plug is maintained at stress throughout all the subsequent measurements. Brine flow and resistance are measured and then the plug is desaturated with air to obtain resistance at one or two levels of partial saturation. The remaining water and salt are removed by solvents and the plug air dried. Air flow and pore volume are measured. Stress is removed from the sample, and the grain volume and density determined on the dry residue. Porosity, grain density, air and brine permeability, and the Archie a, m, and n parameters are calculated from the measurements.

This sequence of operations results in less damage to a poorly consolidated core and in fewer uncertainties in the measured quantities than the more conventional techniques of freezing and jacketing. Major advantages of the procedure are the reduction in well-site damage, preservation of the morphology of fragile beds and bedding contacts, elimination of grain rearrangement by freezing, elimination of the grain crushing that results when a cleaned, jacketed sample is restored to reservoir stress, and improvements in the monitoring of sample behavior during laboratory manipulation.

INTRODUCTION

Detailed geological descriptions of cores and petrophysical measurements on core samples play important roles in formation evaluation. This paper presents a procedure for obtaining cores with well-preserved geological detail and a method for obtaining the parameters required for formation evaluation for reservoirs in which the rock is sufficiently unconsolidated that contacts between thin sand and shale beds are usually mechanically disrupted in slabs from frozen cores and in which a cleaned core sample does not retain its mechanical integrity when subjected to minor physical disturbance. For many years, the industry has adopted the practice of freezing the core, often followed by packaging of a frozen core plug, as the preferred method of coping with the mechanical fragility of such rocks (Mattax et al., 1975). That procedure, and the accompanying core handling methodology, has proven unsatisfactory for a number of reasons:

- Rough treatment of the core prior to freezing results in irreversible macroscopic damage to the core.
- Bedding contacts between thin sand and shale beds are almost always disrupted in slabs made from frozen core.
- Formation of ice in the pore space results in particle reorientation (Hancock, 1986).
- Packaging of the frozen core plug, followed by cleaning without applied stress, results in free space in the package which permits the grains to move about.
- Application of stress to a rock with reoriented grains results in grain breakage.
- Repeated passage of vapor/liquid interfaces through the core plug maximizes the chance of reorientation and movement of fine particles (Heaviside et al., 1983; Pallatt et al., 1984).

This paper describes a procedure which attempts to avoid these problems in the following manner:

- Every step of the coring and well-site core handling procedure is designed to minimize mechanical damage to the core.
- The core is mechanically stabilized at the well site by filling the annular space between the core and the liner of the inner core barrel with a rigid material.
- The core is chilled with ice at the well site and preserved at that temperature, but not frozen.
- Core plugs are plunge cut and placed directly into a Hassler sleeve, and returned to net effective reservoir stress.

The plug is cleaned, brine saturated, and permeability and electrical properties measured. It is then desaturated and resistivity index measured, and then recleaned and dried and permeability and pore volume measured. All these operations are performed while the restored stress is maintained. Miscible displacement is used whenever possible when changing saturating fluids.

WELL-SITE PROCEDURES

Large diameter cores in poorly consolidated sands are less likely to be damaged by the coring process than those of small diameter (Webb and Haskin, 1978); therefore, the core diameter should be as large as practical. A plastic liner about 0.25 in. larger in inside diameter than the outside diameter of the core is placed inside the inner core barrel. In order to limit damage to the core by compressional failure under its own weight, it is necessary to cut short cores: 20 feet or even less, depending on the nature of the rock. Damage during drilling and surfacing is often evidenced by the filling of the annular space that should exist between the core and the liner with shifted or reworked core material. When the core fails in compression, it usually exhibits a high-angle slip plane that can be seen when the core is slabbed. The annulus may still be present away from the region of failure and in some parts of the adjacent region. Under such circumstances, plugs of undisturbed material can be obtained by careful selection. If the annulus is totally absent, and there is no evidence of a slip plane, then there is a possibility that the entire core has been reworked or remolded to fill the liner. The other possibility is that the core has expanded from stress relief so that it fills the liner. However, a 0.25 in. annulus corresponds to 14% of the cross-sectional area of a 3.75 in. diameter core. Therefore, that explanation requires a very large amount of radial expansion, and would presumably be accompanied by a correspondingly large, or even larger, vertical expansion. When no annulus is present, measurements of properties dependent on grain orientation should not be made unless thin-section examination of rock taken from the core immediately adjacent to the specific plug shows no evidence of reworking.

The selection of the coring assembly, drilling and circulation rates, weight on the bit, and other drilling parameters must be tailored to the specific rock. Full recovery of an undamaged core is critically dependent on those factors and the skill of the core driller. The core must be surfaced carefully, particularly during the last part of the trip when expansion of gas within the core can cause severe damage if the pressure is reduced too rapidly. Coring and well-site handling of unconsolidated rocks were thoroughly discussed by McCollough (1972).

The inner barrel is withdrawn vertically from the core barrel and set down on the catwalk very gently and without rotation. This is accomplished by attaching a pulley to the bottom end of the inner barrel and running a catline through the pulley, attaching it to the far end of the catwalk. The top end of the inner barrel is lowered and, at the same time, the pulley and catline are used to raise the lower end of the barrel, allowing it to move toward the end of the catwalk. The arrangement is shown schematically in Figure 1. The inner barrel must be blocked against rotation immediately it touches the catwalk. If the barrel rotates, the core may fracture internally as the core rolls around inside the liner. If it is necessary to reposition the inner barrel on the catwalk, this must be done without rotation. The barrel can be moved by wrapping one or more garrottes around the barrel and then lifting it vertically, moving it horizontally and then setting it down again vertically, with two persons handling each garrotte.

The inner liner is withdrawn by pulling it out horizontally onto a track that forms a continuation of the catwalk, as shown in Figure 1. There must be perfect vertical alignment of this track with the catwalk as the plastic liners are sufficiently flexible that the core can be damaged if the liner is allowed to bend. The track can be made from a one-third section of casing welded to supports. A gap must be provided in the track about 3 feet from the catwalk end to allow for cutting of the liner. The core catcher is removed and the liner pulled out of the inner barrel by grasping the exposed end with vice grip pliers. If additional pulling force is required, a garrotte can be wrapped around the end, or if that is insufficient, a come-along can be used. In the latter situations, the vice-grip pliers prevent the wire pulling cable from sliding off the end of the liner. Under no circumstances may the core and liner be pumped out by applying fluid pressure to the other end.

The liner is marked in the conventional manner, but with two sets of markings. One set of orientation lines, depths, and well identification is placed on the center top of the core, the other along the side. After the core is slabbed, one complete set will be on the slab, the other on the larger piece of core.

The top of the core is located by probing from the top of the liner, and any empty liner cut off. The liner is positioned over the gap in the track so that a 3-foot section can be cut off. Wooden blocks are clamped to the liner on either side and as close as possible to the cutting point. The blocks are provided with holes that exactly fit the outside diameter of the liner, and are made in two parts and hinged so that they can be quickly clamped around the liner or removed (shown schematically in Figure 1). The rigid block maintains the circular cross-section of the liner and prevents distortion during cutting, particularly when a tubing cutter is used. (The passage of the cutting wheel sends a wave of radial distortion around the liner and severely damages the core material.) The liner is cut with a tubing cutter and the cut carried through the core with a deep throat hacksaw fitted with a coarse blade.

Each cut section is then carried, without rotation, to a conveniently located wooden stand where it rests in a rack on the top of the stand at an angle of 10 to 20° from the horizontal. Promptly, after any remaining mud has drained from the annulus, a rubber cap is fitted over the lower end of the section, and a short section of scrap liner is taped to the upper end. The caps are provided with a hole in the side, next to the flat end. This hole is oriented to the top and the cap slid on the liner as far as possible without closing the hole. The cap is then taped or clamped to the liner.

Liquid plastic is then poured into the hole in the cap until no more is accepted. Positioning and filling of the core sections on the stand are shown schematically in Figure 2. The preferred method is to use a plastic which is formed by the reaction of two liquid components, an isocyanate and a polyol-carbon black mixture. These two liquids are pumped by separate chambers of a proportioning pump to a mixing gun and run out of the nozzle as a thin liquid. This low viscosity liquid quickly fills all openings in the core and between the core and the liner. Within 5 to 15 minutes, this liquid mixture sets to a hard plastic. As soon as the plastic in the end cap has set, the core segment is tipped without rotation to an almost vertical position in a second rack on the side of the stand. Plastic is poured into the top until the core is covered and no more plastic is accepted by the annulus or by breaks in the core. As soon as the plastic sets, the cores are placed in an insulated chest and packed with ordinary ice for transportation from the rig site.

Wax has been used instead of the plastic resin. The only advantages are ready availability and the simplicity of handling. The disadvantages are several: the wax solidifies by cooling instead of by chemical reaction; therefore, it cools and solidifies before it can enter the finest cracks in the core or the thinnest annular spaces. The wax contracts slightly on cooling and does not adhere well to the plastic liner; therefore, the core is not firmly anchored in the tubing and the resulting slab section is easily damaged by handling. Oil bleeding from the core may soften and deteriorate the wax rather quickly during storage. Components of the wax dissolve in the liquid phases of the core and diffuse to all parts of the core, so that the core cannot be used for geochemical tests and is probably unsuitable for tests involving wettability or surface tension effects.

Preliminary tests show that the plastic results in much less contamination of the core. However, until further studies are conducted, it is recommended that geochemical samples be taken from the exposed end of core sections prior to plastic injection, and that wettability tests be performed on one-foot sections of core cut prior to plastic injection and hand-carried to the measurement laboratory without any stabilizing agent in the annular space.

The procedures outlined here were performed by Petroleum Testing Service, Inc. (PTS), Santa Fe Springs, California, at the request of, and in cooperation with, Chevron U.S.A., Chevron Oil Field Research Company, and the authors and their colleagues.

CORE MANAGEMENT

The purpose of maintaining the core at ice temperature is to increase the viscosity of the oil phase and thereby inhibit grain movement, and to reduce the loss of fluids by evaporation. It is highly recommended that the core be slabbed and examined before sampling. The slabbing should be done off the top (the side that was up when the plastic was injected), using a horizontal band saw with a diamond blade. The slab should be only thick enough to yield a cut rock surface wide enough for examination and description. After the core has passed through the slab saw, the two pieces are removed together, placed on a table, rotated together 90° so that the cut is vertical, then simultaneously rotated away from each other about the lower exposure of the cut, so that both pieces are turned cut side up. This procedure protects both sections of core in the event that any of it is not well anchored into the liner. Slabbing and handling of the pieces are shown schematically in Figure 3. Attempting to slab off the bottom of the core may result in mechanical failure of the larger section; some of these cores are so weak that they will develop internal fractures from the tension developed across the unsupported face of the downward facing cut. The larger piece must be immediately wrapped for preservation. The slab can be scraped clean, examined, photographed, and described. There is no need to keep the slab chilled unless it is desired to maintain its moisture content.

The isocyanate-polyol resin does an exceptionally good job of filling the annular space between the core and the plastic liner and even very fine, coring-induced fractures. However, the resin is under insufficient pressure to impregnate the sandstone itself. As a result, the slabs are very well cemented into the liner and the bed contacts are well preserved. Even in consolidated formations, cores tend to break at bed contacts so that detailed information about the nature of a contact is lost. The slabs are well stabilized by the resin, retaining their integrity more than a year after slabbing (Gidman et al., 1987).

Sampling locations are determined by examination of the slabs. Plugs are cut from the preserved core by plunge cutting. The plunge cutter is shown in expanded view in Figure 4. The cutting edge is designed to deflect most of the force of penetration to the sides, away from the downward direction, thereby minimizing the force on that part of the core which is yet to become part of the plug. The plunge cutting is done in a 3 to 4 in. section of core which has already been cut out from the main core with a small band saw. This prevents the plunge cutting from possibly fracturing a long section of the preserved core, and minimizes radial distortions generated in the uncut core in the otherwise least constrained axial direction. The section is clamped between metal plates and mounted on a drill press beneath the plunge cutter, as shown schematically in Figure 5. The cut should be in the middle of the core piece. The cutter is not rotated during cutting. If one attempts to cut more than one plug from a section, the second plug is severely distorted because of the tendency of the core to expand freely in the direction of the open plug hole under the applied cutting force.

The plunge cutter is provided with a liner made by shrinking heat-shrinkable Teflon (R, DuPont) tubing over a steel mandrel with a diameter a few thousandths of an inch larger than the opening in the cutter. This tubing serves as a protective jacket during handling of the plug and as a guide for shaping the ends of the plug just before placing it in a pressure vessel.

PETROPHYSICAL MEASUREMENTS

Summary of the Procedures

Figure 6 is a flow diagram of the steps required to obtain the petrophysical measurements. Detailed descriptions of the steps follow.

Mounting in the Pressure Vessel

In preparation for mounting in a pressure vessel, the core plug is slid to one end of the Teflon (R, DuPont) tubing and squared off with a razor blade. It is then slid to the other end and cut to the desired length. The cut off pieces are used for thin-section, SEM, CEC, and chemical and mineralogical analysis. Plug length is measured as accurately as can be done without pressing against the ends of the plug with a caliper. Great care must be taken in handling the plug. Many of these cores are so soft that they can be molded by slight finger pressure. The lower electrode of the apparatus shown in Figure 7 is removed and the plug tipped out onto a 180 mesh, fine silver screen which sets on the electrode. A similar screen is laid on the top of the plug. The elastomer sleeve that confines the cylindrical surface of the sample is retracted by applying a slight vacuum to the hydraulic pressure system. The electrode assembly is moved into position in the apparatus by use of a lab jack. The pressure vessel is closed by screwing in the end fitting that carries the lower electrode. The vacuum is released and the sleeve allowed to relax around the plug. The hydraulic system is then slowly pumped up to the calculated net effective reservoir stress and maintained at that value until the very end of the experimental cycle.

Cleaning

Use of chloroform/acetone, or a similar polar solvent, is essential if black oil is to be removed from a core. Toluene leaves a substantial residue of heavy ends in most reservoir rocks. Unfortunately, polar solvents attack most materials which could be used to jacket the plug or to form a Hassler sleeve. The sleeve is made of KalRez (R, DuPont), a fluorocarbon-based elastomer that is sufficiently elastic to serve as a sleeve, but is resistant to all the solvents used in the cleaning process and is impermeable to hydraulic oil and brine. This is the only material found so far to have the required properties. It is exceedingly expensive, in part because of the technical difficulties in manufacturing tubing goods.

The plug is cleaned first by flowing toluene. The solvent flow rate is set at 0.05 ml/min and the pressure limit set at 30 psi for a typical plug. The initial flow rate may be determined by the pressure limitation because of the viscosity of the oil being displaced, but, after solvent breakthrough occurs, the pressure drop will be reduced and the flow rate will increase to the set value. When the toluene effluent appears colorless, the solvent flow is stopped and the plug allowed to soak for a few hours or overnight. The flow is then restarted and the color of the effluent noted after an estimated one-half pore volume of fresh solvent has flowed. If the effluent is noticeably colored, flow is continued until it appears clear. The plug is again set to soak, and the process repeated until no discoloration appears on resuming flow.

The solvent is changed to methanol and the process repeated until no discoloration of the methanol is noted and a sufficient volume has flowed to have removed the remaining salts. The solvent is then changed to chloroform/acetone azeotrope and the process of flow and soak is repeated until the solvent coming out of the soak cycle is clean.

Saturation and Measurement of Formation Factor and Brine Permeability

The chloroform/acetone mixture in the cleaned plug is replaced with methanol. The methanol is then replaced by a series of methanol/brine mixtures: starting with 90% methanol and 10% brine, continuing in steps of 10%, ending with 10% methanol and 90% brine, and finally 100% brine. Approximately one pore volume of mixture is passed through the plug in each step. Brine flow is then measured for three values of hydrostatic head or pump pressure. Electrical resistance and phase is measured with a Hewlett-Packard LCR Meter at 11 frequencies from 100 Hz to 100 kHz.

Dimension Changes

The length changes of the plug are continuously monitored by a linear variable differential transformer mounted on the upper, movable electrode. This value includes the closure between the apparatus and the plug; therefore, the actual compression of the plug is unknown, but less than the observed value.

Desaturation and Measurement of Resistivity Index

Free brine in both electrode stems is removed using a hypodermic syringe equipped with a flexible plastic tube that just fits inside the bore of the steel tube. The plug is then desaturated by applying air pressure. The air is humidified by bubbling through water and then by passing through a tube containing cotton wool immersed in the same brine as in the plug. Pressure is increased until a very slow flow of brine drips from the lower electrode. The effluent brine is captured in a tared flask. Evaporation is retarded by placing a plastic film seal around the neck of the flask and the electrode stem. Brine expulsion is continued until air breaks through or until the saturation is reduced to an estimated 60% of the total pore space. After shutting off the air, any remaining brine in the lower electrode stem is removed and that brine combined with the effluent in the tared flask. The expelled brine is weighed and its volume calculated.

Electrical resistance is again measured and the plug left to equilibrate. Measurements are repeated over at least 24 hours. Desaturation is then resumed until air breakthrough, or for as long as significant volumes of brine are being produced. The volume of air allowed to flow after breakthrough is kept low to minimize evaporative transport of water. When significant brine production has ended, the air flow is terminated, the lower electrode stem cleared of brine, and the measurement process repeated.

Pore Volume and Air Flow

When the electrical measurements are completed, the plug is flushed with pure methanol to remove the remaining brine. The methanol is allowed to evaporate in a tared Teflon (R, DuPont) beaker and the weight of the residue recorded. The soluble residue may be taken up in distilled water and analyzed for chloride. The methanol is replaced with acetone, and then the acetone displaced with air. Dry air is blown through the plug until all the acetone has evaporated. Gas flow is then measured by connecting the apparatus to a gas permeameter.

The working gas of the permeameter is replaced with helium and the pore volume measured by attaching a helium porosimeter to the electrode system. The dead volume in the electrode stems and the silver screens is measured either before the plug is put in the apparatus or after it is removed.

Grain Volume and Grain Density

The pressure is then released with the vessel upside down and the lower electrode is lifted out from the top. The vessel is inverted and the plug tipped into a tared beaker. Very unconsolidated plugs will fall from the vessel as a shower of sand. All sand grains are swept from the electrode assemblies and the inside surface of the sleeve using a brush. All, or a weighed fraction, of the plug is transferred to a matrix cup and the grain volume measured using a helium pycnometer.

Calculations

The length of the plug can only be visually estimated, not calipered before placing in the apparatus, and only the relative, not the absolute, length can be measured during the time under pressure. One can assume that the initial visual length measurement is correct and calculate a diameter from the bulk volume; or assume the plug diameter was originally equal to the inside diameter of the plunge cutter throat and calculate a length from the bulk volume. The difference between these two estimates is a measure of the uncertainty in the sample dimension. These minor errors affect only the calculated value of the formation factor.

Grain density is calculated from the grain volume and mass of the plug remains used for measurement, and grain volume computed from the total mass of recovered grains. Bulk volume is the sum of the grain volume and the measured pore volume. Formation factor and resistivity index are calculated from plug dimensions and resistance and brine resistivity. Saturation is calculated from the measured mass of produced brine. The final saturation may be checked against the measured mass of chloride removed from the plug by methanol extraction.

DISCUSSION

The well-site core handling procedure has been successfully applied to over 1400 feet of core from a well in the Inglewood Field, Los Angeles, California, with over 94% recovery. Contacts between sand and shale laminae are preserved in undisturbed condition, unlike the contacts observed in slabbed sections of cores handled in more usual manners and frozen at the well site. The slab is well anchored in the piece of tubing by the plastic and so there is very little disturbance or fall-out of pieces during sawing. The slab, after cleaning the sawing waste from the surface by scraping, presents an excellent surface for examination, photography under illumination by both visible and ultraviolet light, and description of geological features. This field method is being applied to improve preservation of poorly consolidated rocks in other fields and other areas.

The laboratory procedures were developed using core material from the Inglewood Field. The method has been free of serious problems right from the beginning; the procedure described is essentially the same as that used for the first attempt. The cleaning process is very much more rapid than the modified Soxhlet or Dean Stark methods, requiring a few days instead of a few weeks. The length changes and electrical properties of the plug are monitored continuously and provide a continuous indication of the approach to equilibrium during all of the procedures that involve brine. Equilibrium is reached rapidly in these plugs, and the properties of the plug remain stable for weeks if the conditions remain unchanged.

Very poorly consolidated rocks disaggregate at the slightest disturbance after removal of the confining stress from the cleaned and dried plug. Techniques are being developed to stabilize the plug so that it can be removed from the measurement vessel and placed in another apparatus in which it can be impregnated with epoxy and then be sampled for thin-section preparation. By temporarily filling the pore space with a material which can be solidified or melted at will, it may be possible to stabilize the grains well enough that no grain or particle movement occurs while the sample is transferred between vessels. Development of such a method is necessary for full evaluation of alteration to the fabric of the plug which may occur as a result of the techniques described here. Evaluation of the petrophysical measurements is hampered by the absence of any known way, regardless of cost or difficulty, of obtaining in the laboratory a piece of poorly consolidated rock which is with certainty in its original reservoir condition. When sufficient data have been accumulated, porosity comparisons with the density log and resistivity comparisons in wet sands will be attempted. Evaluation of sample integrity and data reliability are the planned subjects of a future paper. Presentation of these methods at this time is made with the hope of stimulating and encouraging others to experiment with these and similar procedures, and to evaluate and publicly comment on them.

One important observation has come from this work concerning the behavior of fines during the various plug handling processes. Some migration was noted during cleaning, although the quantity of material that was observed to flow out of the plug was minute. No movement of fines was noted during miscible displacement of the methanol with an NaCl brine, or during the brine flow and permeability procedures. However, on displacement of brine with air, substantial fines migration occurred, resulting in severe and instant reduction in permeability. Experiments with a brine composed of potassium and calcium chlorides showed only minor loss of permeability on displacement of the brine with air. This demonstrated a susceptibility of the fines in this Inglewood rock to migrate under interfacial stress. It is unlikely that this effect would have been noted during electrical measurements in which the plug was removed from the apparatus in order to change saturation. Such effects may be common in poorly consolidated rock.

The ability to constantly monitor the electrical and flow properties of the plug during preparation and measurement is an important feature of the laboratory procedures. It provides assurance that measurements are made at equilibrium and that the plug properties have not been altered by the process.

CONCLUSIONS

1. The described well-site core handling technique results in exceptionally well-preserved cores.
2. Core chilling and plunge cutting of plugs can be used to replace freezing and drilling of plugs and has the advantage of not causing grain rearrangement by the formation of ice crystals.
3. Grain rearrangement and consequent grain breakage can be minimized by transferring the plug directly to a restored stress apparatus and leaving it at stress for all cleaning, saturating, and measurement functions. This procedure does not require packaging and thereby avoids the problems and errors associated with the package and its fit to the plug.
4. All the desired petrophysical measurements can be obtained on a core handled by the described procedure.

ACKNOWLEDGMENTS

Jack Hillman (then employed by PTS), Deborah Lerner, and Jim Spencer all contributed to the development of the well-site procedures. Mike Carlo, Jim Leather, and Phil Maddux spent many hours in unsuccessful attempts to develop a packaging technique for the core plugs that would withstand the cleaning solvents while meeting all the other requirements. Jim Leather first suggested that it might be possible to transfer the naked plug directly to the pressure vessel, and Mike Carlo perfected the technique.

REFERENCES

Gidman, J., Worthington, A. E., and Newman, G. H., 1987 Well-site Handling of Poorly Consolidated Core; Inglewood Field, Los Angeles Basin, Poster Session, AAPG, Los Angeles, June 9.

Hancock, N. J., 1986, Private communication.

Heaviside, J., Langley, G. O., and Pallatt, N., 1983, Permeability Characteristics of Magnus Reservoir Rocks, Eighth European Formation Evaluation Symposium, London.

Mattax, C. C., McKinley, R. M., and Clothier, A. T., 1975, Core Analysis of Unconsolidated and Friable Sands, Journal of Petroleum Technology, v. 27, December, p. 1423-1432.

McCollough, C. N., 1972, Innovations in Handling and Processing Unconsolidated Cores, Journal of Petroleum Technology, v. 24, October, p. 1191-1195.

Pallatt, N., Wilson, J., and McHardy, B., 1984, The Relationship Between Permeability and the Morphology of Diagenetic Illite in Reservoir Rocks, Journal of Petroleum Technology, v. 36, December, p. 2225-2227.

Webb, M. G. and Haskin, C. A., 1978, Pressure Coring Used in Midway-Sunset's Unconsolidated Sands, Oil and Gas Journal, v. 76, April 10, p. 51-55.

Soft Core Handling at Wellsite

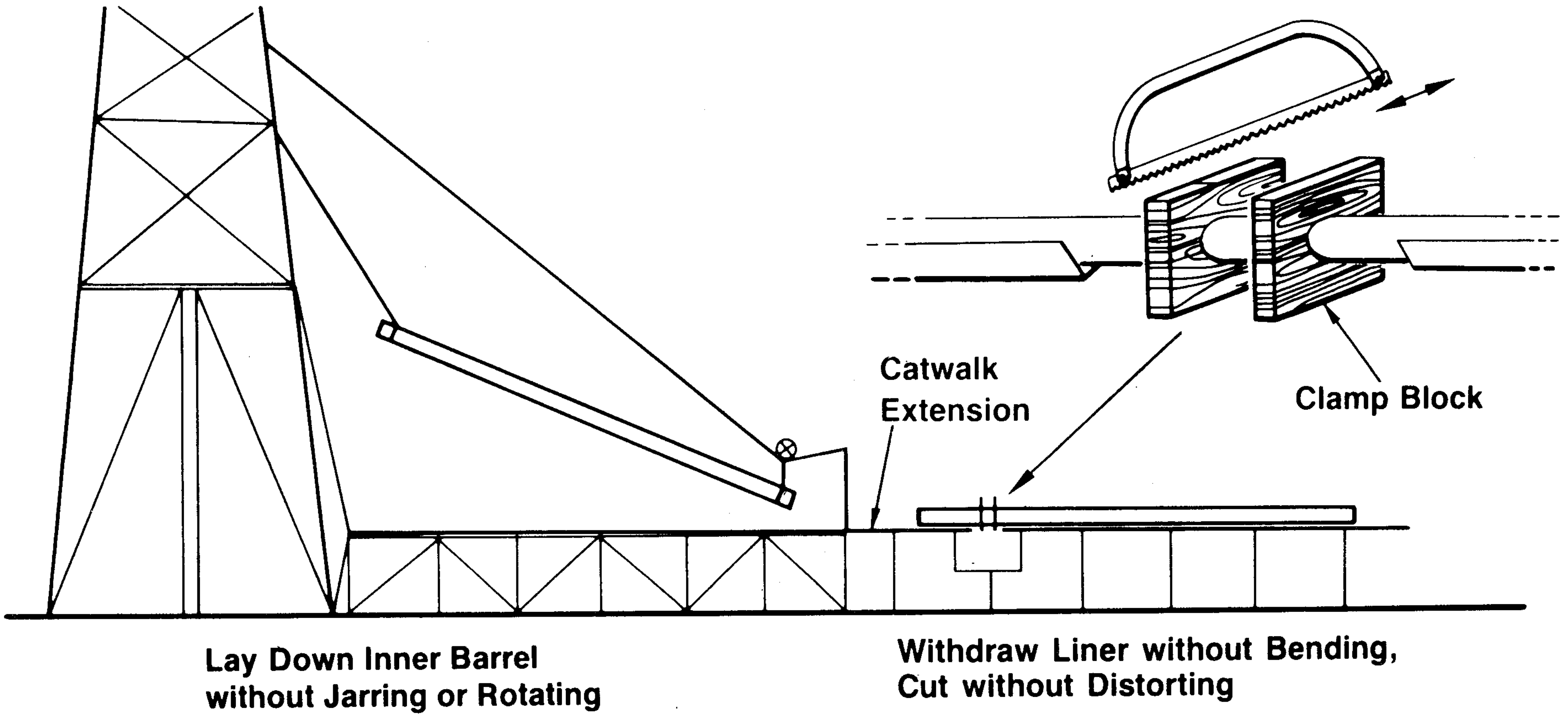
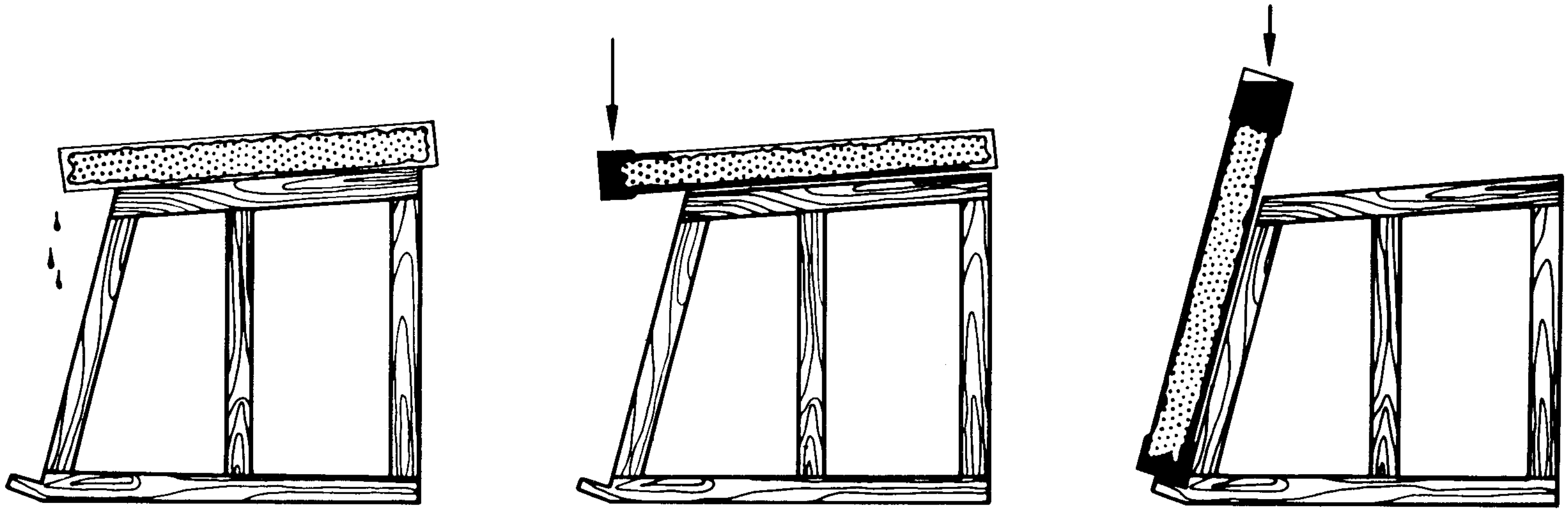


Figure 1

Stabilize Core with Resin



Drain

Cap, Pour Resin
Into Lower End

Extend Tube, Fill
Annulus with Resin

Figure 2

Soft Core Slabbing and Preservation

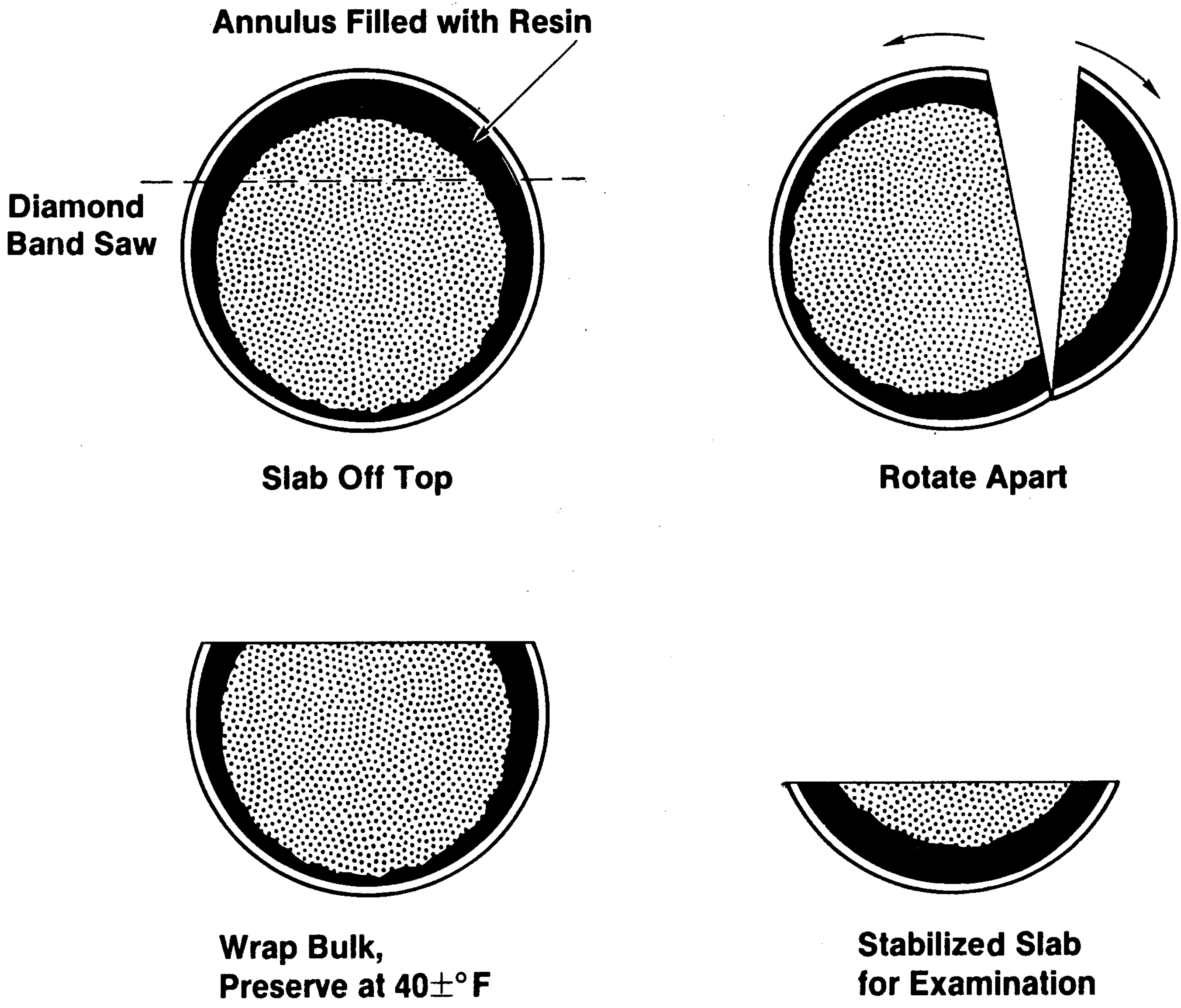


Figure 3

Soft Core Plunge Cutter Exploded View, Half Size

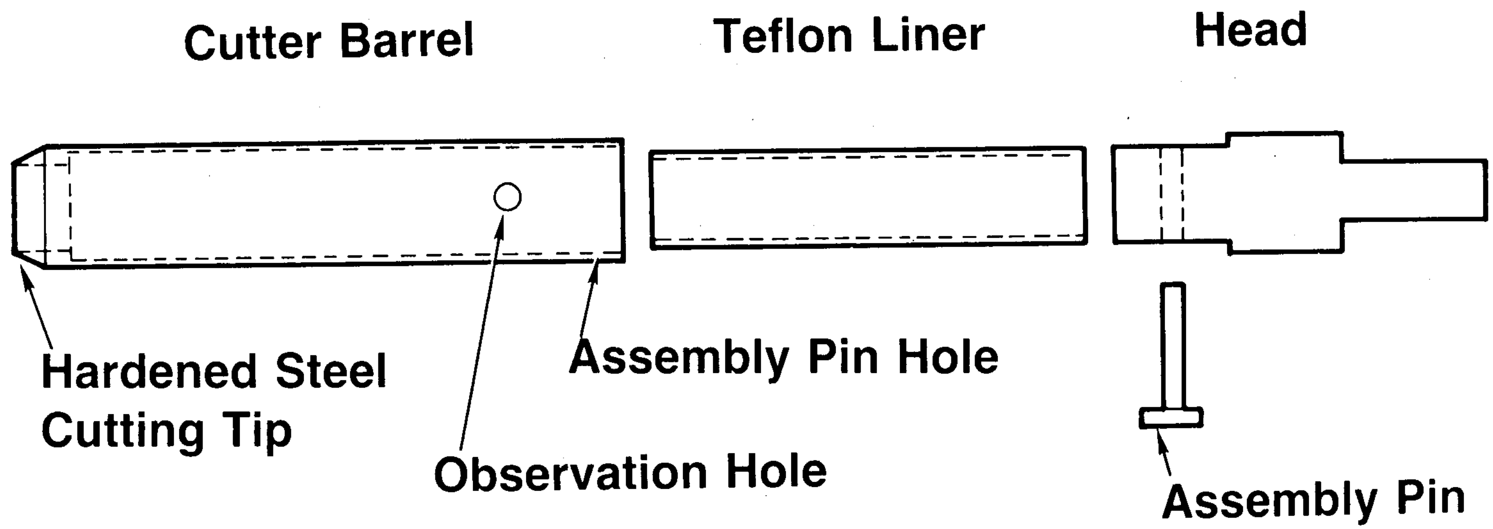


Figure 4

Plunge Cut Plug from Section of Bulk Core

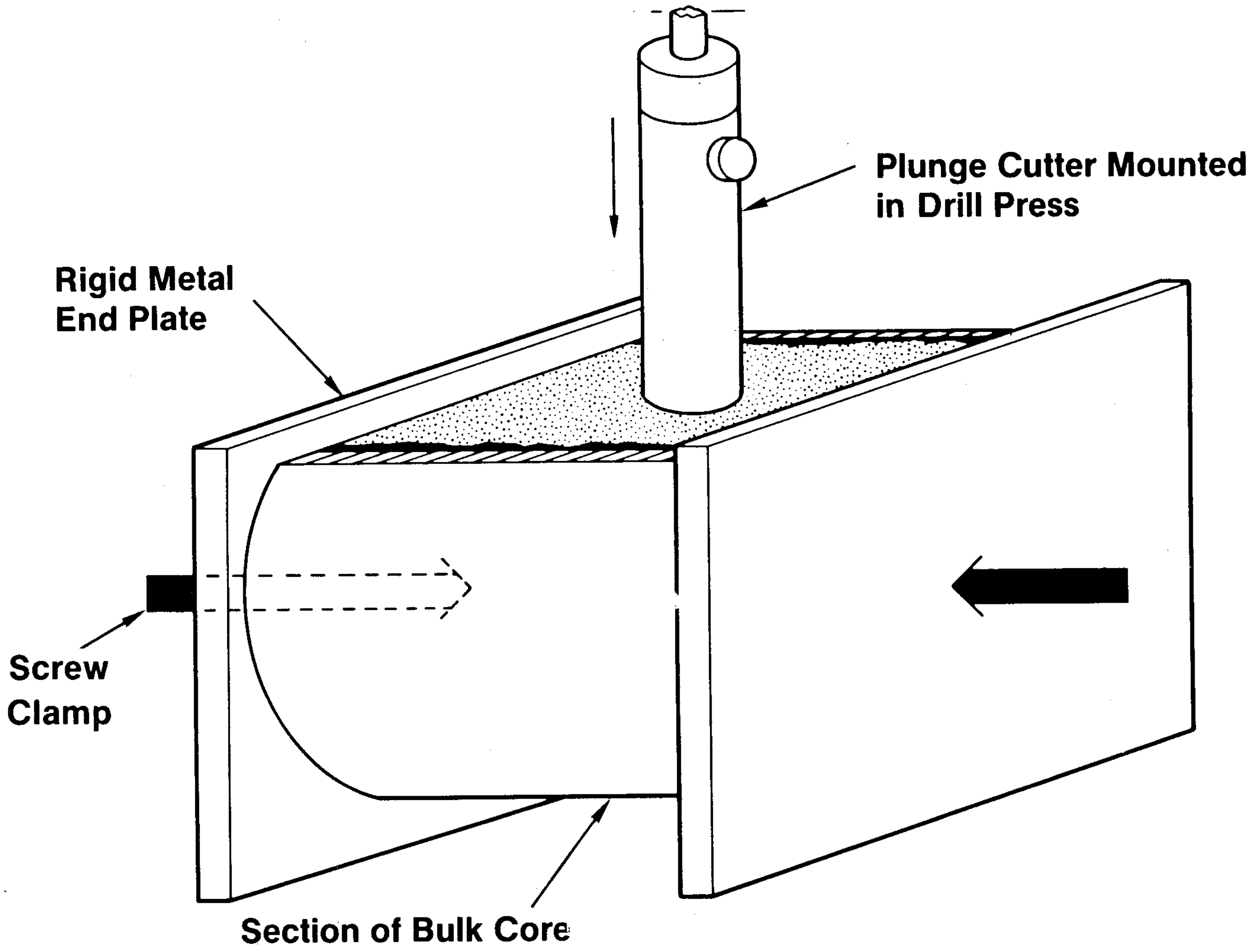


Figure 5

Soft Core Analysis Procedure

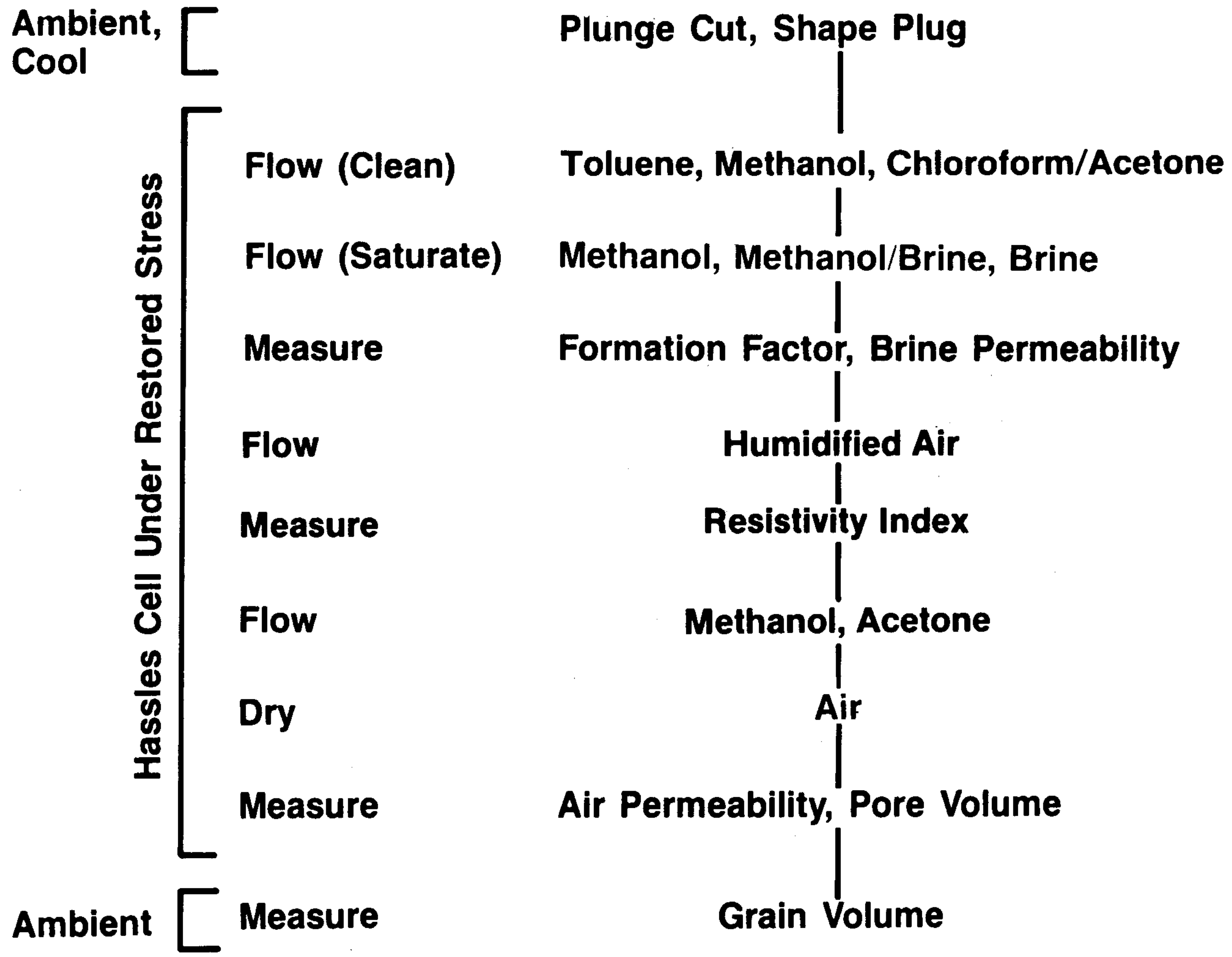


Figure 6

PKFSI Cell

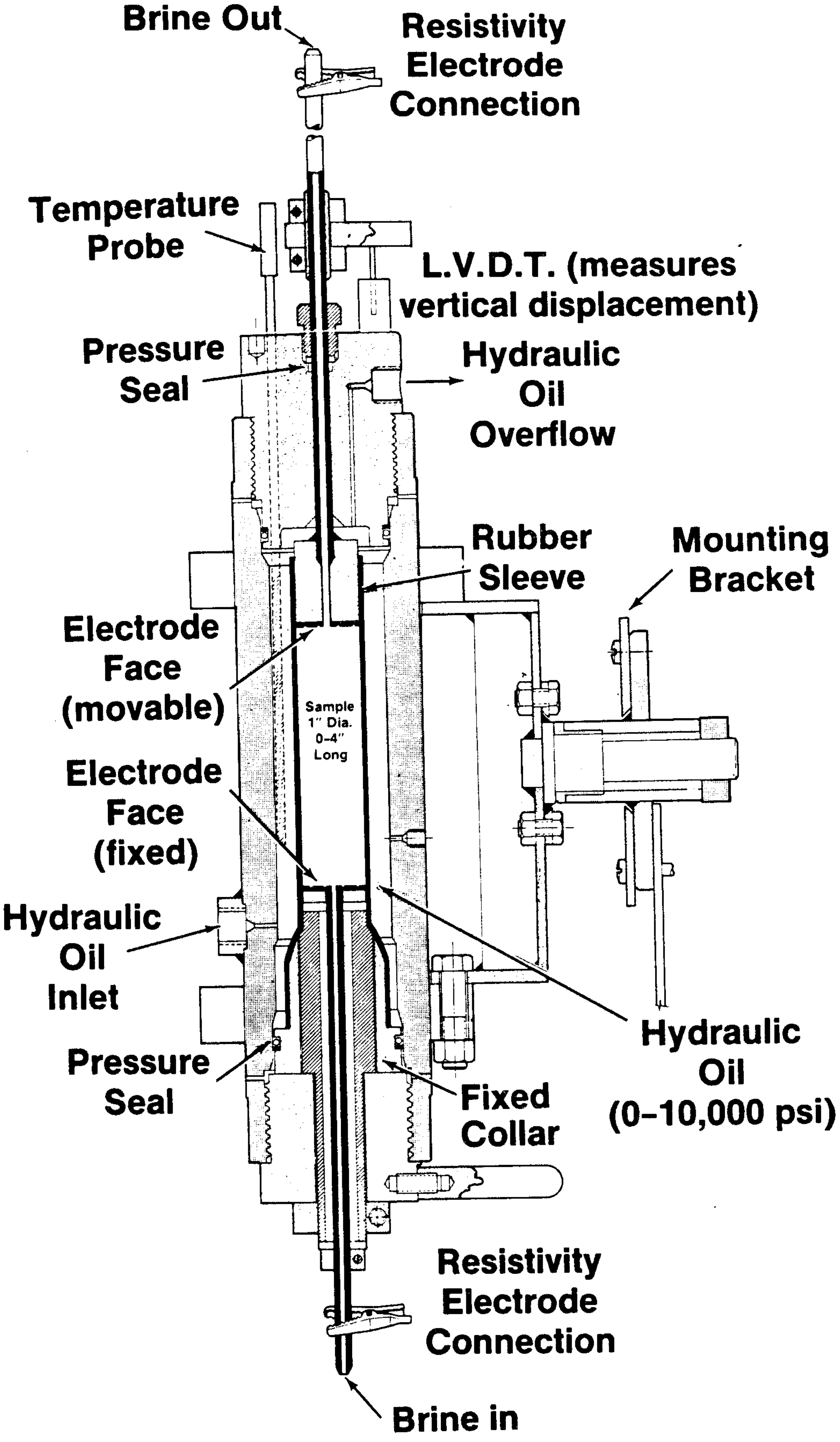


Figure 7