OPERATION MANUAL FOR THE RADIOACTIVE SEDIMENT DENSITY PROBE

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This operation and maintenance manual was intended to be focused primarily upon the practical needs of Engineers directly engaged in reservoir sedimentation investigation and their operating field personnel. Many of the concepts presented concerning operational techniques or trouble-shooting procedures have evolved through practical experience gained from a wide variety of density probe operations by Omaha district personnel since 1959.

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FOREWORD

This operation and maintenance manual for the radioactive sediment density probe was prepared by the U. S. Army Engineer District, Omaha in accordance with a request from the Office of the Division Engineer, Missouri River Division, dated November 1964. It was intended that its scope should be focused primarily upon the practical needs of Engineers directly engaged in reservoir sedimentation investigations and their operating field personnel. Many of the concepts presented concerning operational techniques or trouble-shooting procedures have evolved through practical experience gained from a wide variety of density probe operations by Omaha District personnel since 1959.

The original draft of this manual was prepared by Robert H. Livesey, Supv. Hydr. Engineer in December 1964. After review by MRD, CERC and OCE, plus Technical Operations, Inc., and several other interested government agencies, this first edition was prepared to reflect the general views of most of the current users of the density probe. Other Omaha District personnel who contributed directly to the development of many of the technical procedures included in this manual were Clifford J. Armstrong, Donald A. Bauer, Isaac Shepherdson and Dave S. Shields. The cooperation of the manufacturer of the probe, Technical Operations, Inc., must also be acknowledged for their continuing assistance and the training that Mr. Livesey received at their laboratory in September 1962.

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OPERATION MANUAL FOR THE RADIOACTIVE SEDIMENT DENSITY PROBE

Introduction

1. This manual was prepared primarily for the guidance of personnel engaged in sedimentation operations where the radioactive sediment density probe is employed for the measurement of in situ densities of saturated sediment deposits. Numerous and varied methods, techniques, and procedures have been utilized in past field work but no attempt has been made to standardize these proceedings or provide adequate guidance for maintenance and repair of the equipment. This manual in its present form is considered to be only the first edition in the development of a final, authoritative document. Currently there are too many unanswerable questions or unproven relationships to attempt to establish final techniques and standards. Some of the criterion presented in this edition are admittedly based upon vague presumptions, particularly the calibration relationships and techniques, but they reflect the current thoughts of most of the density probe users including the developers of the instrument. As time and experience dictate logical changes, it is imperative that such corrections or additions be incorporated into this manual. Only a brief resume will be included in this edition concerning the theoretical background or other similar aspects related to the development of the density probe since such details are readily available in the published references listed in the appendix.

SECTION I - DESCRIPTION OF PROBE AND ACCESSORY EQUIPMENT

2. General. The radioactive sediment density probe discussed in this manual was developed under the Civil Works Investigation Program of the Office, Chief of Engineers. The project was assigned to the staff of the Beach Erosion Board with actual development by contract with Technical Operations, Inc. of Burlington, Mass. The probe is presently designed to measure the in situ density of fresh water sediment deposits within the range of 62.4 to about 110 pounds per cubic foot. (The measurement of saline deposits is also practical if additional minor design and calibration requisites are met). The density measurement is accomplished by the gamma-ray scattering principle where it is assumed that the mass absorption coefficient of all sediment particles (basic elements) within the exposure range of the probe are the same. The emission source is 3 millicuries of Radium 226 which has a half life of 1800 years. No AEC license is required for operation but registration of the instrument is necessary in certain Sates. Specific responsibility and accountability regulations apply for Corps of Engineers radiological safety.

3. Two primary components, the density probe and a counting scaler, are necessary to obtain a density measurement. See Photo 1. The probe is a waterproof, cylindrical shaped stainless steel tube containing the radium source at one end and radiation detection tubes, plus integral amplification elements, near the opposite end. The scaler, attached to the probe by a coaxial cable, contains the remote reading radiation counting circuitry and basic power supply. The complete density probe component, including 100 feet of coaxial cable and protective storage or

transportation box (See Photo 2), is available from Technical Operations, Inc. at a list price of about $2,100.00. Several portable scalers are commercially available but the instrument referred to in this manual (Model 2800) is manufactured by the Nuclear-Chicago Corp. of Des Plaines, Illinois, and retails for about $1,250.00. Additional and necessary accessory equipment will be discussed later.

4. Density Probe. The probe body is cylindrical in shape with a streamlined nose at the source or lower end. Currently three known variations in the design of the suspension or upper end exist. On the initial design, the upper body portion of the cylinder flares from a 1.5 inch diameter to 2.5 inches to allow space for the watertight O-ring seal and the coaxial cable connector plus eyelets for cable suspension and threads for the attachment of tubing or pipe for a rigid suspension. The lower 1.5 inch diameter shell is 0.065-inch stainless steel. A lead insert two inches in length fills the tip end of the sheath to provide a radiation shield and additional sinking weight. The over-all length is 25 inches and the total weight about 12 pounds. Due to limitations in deposit penetration, caused by the flare of the upper body, the outer shell for the second design was streamlined to a uniform diameter of 1.5 inches with threads at the upper end to permit attachment of an adaptor for either cable or pipe suspension. The third design was necessary to alleviate a maintenance problem involving nicking of the O-ring seals during assembly or dis-assembly of the internal components and to provide a greater wall thickness where the exterior screws fasten the outer shell to the O-ring and coaxial connector body plug. Frictional resistance on the outer shell during retrieval of the probe from very dense material had caused a rupture of the exterior screw holes on the modified streamlined model. In the latest design the upper three inches of the sheath was again flared to 1.875 inches O.D. to provide sufficient wall thickness and allow full expansion of the O-rings as they passed the screw holes in the outer sheath.

5. The internal units of the probe are mounted on a chassis which fits into the outer steel sheath. See Photo 3. Mounted successively from the tip end of the chassis are (1) the radium source supported on a stud and surrounded by a lucite shroud, (2) a lead plug six inches long, (3) an aluminum cap and lucite spacer, (4) three halogen filled gamma counter tubes, (5) a transistorized, cathode-follower type pre-amp including a 1.3 volt mercury battery, and (6) an upper body plug with grooves for two watertight O-ring seals, exterior threads for the suspension adaptor and the connector for the coaxial cable. See Plate 1. In normal position the radium capsule is located 2.5 inches from the tip of the probe, on the cylindrical centerline, between two lead plugs. These plugs minimize the deflection of the gamma rays in a longitudinal direction, both toward and away from the counter tubes, but permit transit in a general perpendicular direction through the thin steel sheath into the surrounding medium to be measured. The back scatter of a gamma ray or a count, by this medium toward the probe is detected by the counter tubes which induce a pulse or count into the pre-amp and counting circuitry. Further details on the theory of radiation measurement will be given in Part II. The scaler power supply provides the necessary operating voltage for the counter tubes through a coaxial cable. The transistorized pre-amp in the probe

provides the necessary amplification to deliver a pulse of sufficient amplitude back through the long coaxial cable to the scaler for counting. Power for the pre-amp is provided by the 1.3 V mercury battery from which a transistor draws about three micro-amps.

6. Portable Scaler. The purpose of the scaler is to provide the operating voltage to the counter tubes in the probe, via a coaxial cable, and to record the radiation pulses or counts as measured by the tubes. The Nuclear-Chicago scaler is a portable instrument powered by rechargeable wet cell batteries and designed for continuous recording of the radiation counts. This scaler can also operate from an A.C. power supply if desired and contains an automatic battery charging unit for recharging the wet cell batteries whenever plugged into an A.C. line. Variable high voltage output of from 700 V to 1500 V is controllable from the instrument panel for operation of the probes counter tubes. The scaler weighs about 30 pounds.

7. The radiation counts are continuously accumulated and recorded on five glow tube decade counters for visual reading after a given time period. A reset button positions the dots of light in the glow tubes to the zero position before a count is started. Both mechanical and electrical timing switches are available for automatic counting and timing. A test-use switch permits the operator to count either (1) an A.C. line frequency or an internal vibrator frequency (to determine if the scaler is functioning properly), or (2) the actual radiation count.

8. Accessory Equipment. Field operation of the density probe requires the use of certain accessory equipment. The more important items will be briefly discussed here. Further details will be covered later in the appropriate sections.

a. Electrostatic Volt Meter. The counting rate (and consequently the apparent density of the measured medium since it is a function of the counting rate) is dependent upon the high voltage applied to the counter tubes. Calibration of the probe, and also subsequent operation, requires that a known and constant voltage output be supplied by the scaler. Although both the probe and scaler design incorporate certain stabilizing features to limit inherent errors, it is necessary to periodically check the scaler voltage output to assure accurate results. Since most common voltmeters are limited in accuracy, it is recommended that voltage checks be made by a reliable, claibrated electrostatic voltmeter.

b. Suspension Tubes or Cable. The measurement of an in situ density requires that the probe be suspended in the deposit material. For shallow depth operation (usually less than 50 feet), lengths of lightweight tubing can be attached as needed to provide a rigid support for the probe. See Plate 1, Part 47. This method permits the forcing of the probe into the denser deposits but also requires adept handling to avoid bending the tubing. The probe should never be driven into a deposit since neither the sheath nor the internal components were designed for such use. For deep water operations over 50 feet, it is necessary to suspend the probe from a cable with additional weight attached above the probe to obtain penetration. A section of tubing filled with lead and fitted with threads on one end for attachment to the probe, plus a suspension ring on the other end, should provide a sufficient penetration weight for deposits up to about 90 PCF wet density. See Plate 1, Parts 45 and 46. The cable suspension also requires a boom or crane and a reel mounted on the operating boat or launch.

c. Operating Craft. Due to the compactness and portability of the probe-scaler combination the physical space requirements in a boat are minimal; however, these requirements are inconsequential in relation to the stability required for placing the probe into the deposit material and maintaining its vertical position during the counting period. Movement of the operating craft by wind or wave action is probably the most disrupting influence that will limit field operations. It is very important that recognition be given, during the initial planning stages for a proposed operation, to the need for a suitable and adequately equipped operating craft. Since numerous types of craft and equipment can satisfy the operating conditions, the following guides are proposed as the minimum requirements for an operating craft:

(1) The craft must meet safe navigation limits for the proposed operating load, including anticipated wind and wave conditions.

(2) It must be of sufficient size to provide a reasonably stable operating platform during normal wind and wave conditions.

(3) The craft should be equipped with

(a) suitable gear for suspension of the probe

(b) at least three anchors of adequate weight and design

(c) sufficient anchor line to permit placement of all three anchors at one time

(d) a capstan when the operation is from a launch and depths or anchor weights are excessive

(e) a storage space for the probe when not in use.

SECTION II - PRINCIPLE OF OPERATION

9. Theory of Operation. The measurement of the density of saturated sediment deposits, by use of the sediment density probe, is dependent upon (1) the homogenous character of sediments possessing almost the same mass absorption coefficient, (2) the random emission, penetration, and scattering of gamma rays and (3) the statistical measurement of non-absorbed or returning rays when the geometry between the source and the detection system remains constant. In simple terms, when a radioactive source, such as radium, is placed in a material, such as soil, the emitted ray or photon collides with an orbiting electron in an atom of the material, gives up some of its energy and changes its direction of travel. Such a collision causes further random or secondary scattering of the photon until the energy of the photon is either reduced to a level where it is absorbed by the material or it encounters a detector mechanism such as a Geiger tube. The potential for a collision and further scattering increases proportionally with the density of the material (e.g., the number of electrons increases with the unit mass of the material); however, as the number of electrons increase, the probability also increases that the photon will be absorbed before it reaches a detector. Thus, as the density of a saturated sediment deposit becomes greater, a relatively fewer number of photons will be available for detection; and also the quantity of material representing the "sensitive volume" of measurement decreases. Since the density of most soils is proportional to the number of electrons present in a unit volume, this relative number of photons available for detection becomes through correlation a means for the direct measurement of the density of the material.

10. It must be recognized at this point that the physics of this phenomenon are much more complicated than described and that in reality the relationship between the counts measured by a detector and the density of the material is an empirical one. In nature the common constituents of sediments are generally similar enough both geologically and geographically throughout the United States to permit the development of calibration curves that are applicable for most fresh water deposits. A more detailed explanation of the exponential relationship of photon attenuation can be found in the various reference publications listed in Appendix B.

11. How it Works. The measurement of the saturated density of a reservoir deposit requires placement of the probe into the deposit and maintaining a constant position during the time period necessary to measure a minimum number of counts at the scaler. Physically, the probe is suspended by either a rigid pipe or wire cable. A separate non-supporting coaxial cable provides an electrical transmission line between the probe and scaler. High voltage power generated by the scaler is supplied via this cable to operate a battery of three halogen-filled gamma detection tubes in the probe. Since the gamma source is in a continuous decaying state (emitting photons constantly at a random rate), it is only necessary to energize the detection tubes and record a statistically adequate number of photons or counts which reach the detection tubes over a given time period. The photons or counts recognized by the detection tubes vary both in energy strength and rate of

occurrence. (The tubes are capable of registering a maximum rate of about 10,000 counts per second). As these counts are recognized, the detection tube induces individual pulses into the electrical circuit connecting the scaler and the probe. To drive these pulses through the coaxial cable to the scaler, a transistorized pre-amplifier is built into the probe unit and powered by the internal mercury cell. Thus, the heights of these pulses are amplified to a fairly uniform and sufficient size to be accepted by the scaler discriminator and passed on through to the decade counting circuits. (The scaler is also provided with a sensitivity adjustment which determines the minimum pulse voltage acceptable to produce a count. This control regulates the counting efficiency by the elimination of extraneous high voltage or other noise counts inherent in the equipment.) Five glow tubes or decade indicators are mounted on the scaler panel to record any quantity from 0 through 99,999. These tubes accumulate the total number of pulses passing the discriminator in a series of glow lights positioned and numbered clockwise from 0 through 9 around each glow tube. To measure a count rate it is only necessary to (1) reset the decade indicator tubes to zero, (2) energize the scaler counting circuit (the probe-scaler circuit being previously in operation), and (3) record a statistically adequate number of counts during a known time period. Applying this observed count rate to a previously defined calibration curve of density vs. count rate, applicable to the type of material being measured, will give the in situ saturated density of the deposit material. Conversion to dry density values is a simple mathematical chore if the specific gravity of the measured material is known. However, it should again be emphasized that the count rate vs. density relationship is an empirical one which must be defined by calibration of the instrument.

12. Counting Errors. The reliability of individual measurements obtained by the probe is dependent upon the calibrated count rate vs. density relationship plus the techniques and accuracy employed to define this calibrated curve. There are several sources that can introduce "mechanical errors" during field operations (these will be discussed individually later), but there are also inherent counting or statistical errors that must be recognized in order to define the accuracy of any measurement. In general, these counting errors are related to:

a. Pregressive decay of the source material.

b. Background radiation.

c. Timing accuracy.

d. Degree of confidence or probability selected.

13. Decay Rates. As previously noted, radioactive materials are continuously in a decay or disintegration process but the actual disintegration of individual atoms occur at random intervals and not in any predictable manner. The theory of probability and the laws of statistics provide the means for establishing a level of confidence when measuring less than an infinite number of such disintegrations.

Applying this knowledge to determine the probable life expectancy of a source material (normally expressed in terms of its "half life"), probable decay rate values can be computed and periodically applied to correct this source of error. However, since Radium 226 has a half life of about 1800 years, the progressive decay rate value represents a relatively insignificant annual deviation. If, for instance, cesium 137 with a half life of 30 years were being used as a source, the calibration curve would require a correction at least annually to avoid such an accumulative error.

14. Background Radiation. In our present stage of development of the density probe background radiation is one counting error that has been superficially recognized but deserves considerably more attention. The source of this error is nature's minute accumulation of radioactive elements in all types of physical matter. Its influence on the counting rate was generally considered to be either negligible or relative until a few years ago. The error introduced by an increase of say 75 background counts out of 18,000 counts per minute observed by the probe would be insignificant; or it would be relative if the same range of background counts occurred in both the calibration material and the reservoir deposits. Unfortunately this simple solution is no longer valid due to the recent increase of radioactive fallout. Water is perhaps the greatest collector of this fallout and the sediment deposits comprising a stream, lake or ocean bed, the final accumulation place for this residue. The significance of this random accumulation by nature is not completely known. It may become necessary in the future to measure this background radiation with a sourceless probe and then apply a correction factor to the observed count before reading density values from the calibration curve.

15. Timing Accuracy. Timing errors may be introduced through the method or mechanism used to define the period of count observation, or by the resolution time of the probe and scaler system itself. But the more important of these two is the accuracy in which repetitive counting intervals are determined. For instance, a normal count rate when the probe is immersed in water might be 18,000 counts per minute. This is equivalent to 300 counts per second or for an error of 1 percent, a repetitive timing accuracy of at least one-half second for each minute of counting time. The several methods available to produce this desired timing accuracy will be discussed in more detail later. The other source of timing error, termed resolution, is built into the detection system and while this error does not influence the count rate vs. density relationship obtained by calibration, it should be recognized that such resolution or coincidence errors exist.

16. Confidence and Probability Levels. It has been established that the decay rate, and subsequently the rate of radioactive emissions, is a random process which can be defined by statistical methods. It happens that the dependable degree of confidence in this instrument, and its relative accuracy, is principally limited by the inherent error that occurs in counting a relatively small number of emissions. Statiscally this error is a function of the total number of counts observed and tends to become less as the total number of accumulated counts

becomes greater. For example, the "true" rate of decay emissions, or similarly the probe counting rate, can be determined only by timing an infinite number of such counts. Logically, the instrument cannot be calibrated nor operated by observing such very long term values, so a probability theory is employed to define a "workable" limit of error if only a practical number of counts are observed.

17. It can be shown through this theory that such an error can be readily determined from the equation:

$$E = \pm \frac{K\sqrt{C}}{t} \qquad (1)$$

Where, E = the error in counts per minute for any observed counting rate

C = the total number of counts observed

t = the time interval in minutes required to accumulate C

K = the degree of confidence desired.

When K = 1.00 the computed error value is defined as the Standard Error and it can be assumed that the values observed in 68 out of 100 individual measurements will not vary by more than plus or minus this Standard Error value from the "true" rate. If a higher degree of confidence is desired, the value of K must be increased and a larger number of counts must also be observed to attain an equivalent plus or minus deviation from the "true" rate. At a 90 percent level of confidence, K shculd equal about 1.64; for the 95 percent level, about 2.00; and for the 99 percent level, about 2.60. Thus, for a two minute time interval where 10,000 counts were accumulated and a confidence level of 95 percent is desired, the expected limits of error in the <u>counting rate</u> would be:

$$E = \pm \frac{2\sqrt{10{,}000}}{2} = \pm 100 \text{ CPM}$$

and the percentage of error involved in this measurement would be:

$$\% \text{ Error} = \frac{E}{\frac{C}{t}} \times 100 = \frac{100}{5000} = 2\% \qquad (2)$$

18. Reference is made to Table I, below, in order to clarify the interrelationship of these equation factors. Here, tabulated for illustrative purposes is a series of synthetic values in which the only observation parameter that varies is the total count. (Time is a function of this value.)

TABLE I

Line	Total Count (C)	Time Interval (t)	Count Rate (C/t)	$\sqrt{C}$	K	Counting Rate Error CPM (E)	Counting Rate Error % (E)
1	1000	1 Min.	1000	32	1.00	± 32	3.2
2					1.64	± 52	5.2
3					2.60	± 83	8.3
4	5000	5 Min.	1000	71	1.00	± 14	1.4
5					1.64	± 23	2.3
6					2.60	± 37	3.7
7	50,000	50 Min.	1000	224	1.00	± 4	0.4
8					1.64	± 7	0.7
9					2.60	± 12	1.2

First, compare the values on lines 1, 4 and 7. Note particularly that when the total count increases, the plus or minus limits of the counting rate error decreases for any constant K value. Also note that the percentage error for a constant counting rate likewise decreases. Next compare the values for t, K and %E on lines 4, 5, and 6. Note first that when a greater confidence level, K, is desired for any constant total count, C, the percent error in the counting rate increases rapidly. Now compare the same values on line 4 with line 9. Note that a very substantial increase in counting time must occur to achieve equivalent accuracy in terms of percent error for different values of K. The significance of this discussion will become apparent later when it can be recognized that by calibration, a certain counting rate reflects a given density value and that it is intended to measure an unknown density at a desired confidence level with only one total count in a minimum amount of time.

19. At this point two factors of conflicting interest should be recognized. First, the selection of a confidence value K should depend primarily upon the purpose for which the observations are being made. For instance, an Engineer should not handicap his operations by requiring 99 percent confidence level observations during a reconnaissance type density survey where Standard Error limits might be adequate. Secondly, frequent changes in K values can lead to confusion in defining the accuracy of a variety of measurements, particularly when an interpretation of basic results is necessary. This further demonstrates the need for a standardization of methods and establishment of specific operating procedures before attempting a comprehensive density survey.

20. Mechanical Limitations. Before the statistical relationships can apply for the development of a calibration curve we need to recognize certain mechanical limitations associated with the detection of a count. As previously noted, a count is first recognized by the detection or gamma counter tube. This pulse is then amplified, transmitted to the scaler and recorded on the decade indicator tubes. However, satisfactory

accomplishment of this counting is dependent upon four prime factors -- correct voltage applied to the counter tubes; transmission of adequate pulses from the probe; the recording of valid counts by the scaler; and, repetitive timing accuracy. The first and last of these factors are more important from an operation viewpoint due to their exposure to external adjustment. The other two, which are internally controlled, are more consistent and require less attention.

21. Operating Voltage. The effectiveness of a counter tube in recognizing a photon is dependent upon the individual voltage requirements of that tube. Each tube has its own unique characteristics. Thus, in our application to the density probe which contains three such counter tubes wired in parallel, the voltage required is dependent upon their composite characteristics. In order to select an optimum operating voltage, this composite operating characteristic must be defined in terms of count vs. voltage. Graphically, this relationship is called a "plateau curve." Several examples for materials of different densities are shown on Plate 2. The plateau curve originates at a "threshold voltage" (about 800 V) where the first indication of counts are noted, raises rapidly to a fairly constant "plateau" for a wide range of voltage and then continues another rapid climb as the counter tubes become unstable due to internal saturation at higher vaoltages. The optimum voltage for operation is selected from the "plateau" portion of this curve where the percentage change is near a minimum. Generally, this point is between 100 to 150 volts from the bottom of the plateau. After calibration of the probe at the selected operating voltage, all subsequent measurements which are dependent upon this calibration must be made while the designated voltage is being applied to that specific set of counter tubes. If either a change in operating voltage or counter tubes should occur, the calibration relationship is no longer valid.

22. Transmission of Count Pulse. There are also other 'mechanical" changes which can influence the validity of calibration. The amplification of the pulse generated in the counter tube and its transmission to the scaler is an important one. This is a function of the probe pre-amp and scaler circuitry with their relatively stable component parts. As long as an adequate output voltage or pulse height (representing individual counts originating at the counter tubes) can be delivered from the probe to the scaler via the coaxial cable, a valid count will be recorded. A discriminator control in the scaler permits all pulses of a minimum amplitude or greater to continue through to the decade counting circuit. Weaker pulses are rejected. The earlier designs of the probe pre-amp circuit required a balance of impedence to accomplish this transmission through the 100 foot length of cable. In this manner the type and length of coaxial cable used also became anotherllimitation for probes with serial numbers 1 through 5 that employ pre-amp circuit designs A and B as shown on Plate 3. This can be effectively demonstrated, if desired, by a comparison of plateau curves for different cable lengths. Later pre-amp circuit designs C, D and E, for probes with serial numbers 6 through 9 and shown on Plate 4, supposedly correct this deficiency by producing a 175 millivolt input to the scaler through 300 feet of cable. However, field tests have not been reported to confirm the validity of this design.

23. Timing Accuracy. This subject has been previously discussed with regard to counting errors and it was found that to achieve not more than a 1 percent error, a repetitive accuracy of at least one-half second for each minute of total counting time was necessary. This can be efficiently accomplished by the use of an electronic timer to start and stop the decade counting circuit at accurate time intervals. Spring wound time clocks are also available to perform this on-off function but the accuracy of such devices are limited and erratic. A 30 second sweep-hand stop watch is probably the best alternate to an electronic timer. Personal coordination between instantaneous starting and stopping of both the counting switch and stop watch will approach or exceed most minimum requirements.

24. Calibration Criteria. Either directly or indirectly most of the integral traits that tend to define the operating characteristics of the sediment density probe have been discussed. In review, we know that the calibration relationship will be subject to the following limitations:

a. The material used for calibration must contain a homogenous mixture of sediments that are common to the reservoir deposits to be measured, i.e., similar specific gravity.

b. It must be in a saturated condition.

c. The determination of its reference density will be dependent upon standard laboratory analyses or compatible volume - weight measurements.

d. The volume of material representing a specific counting rate will vary dependent upon density, i.e., a higher rate will pertain at low density values and vice versa.

e. The geometric shape of this effective volume will be similar to an spheroid with axes lengths of about 16" and 30" or less.

f. The precision of the counting rate - density correlation will be primarily dependent upon the length of count in accordance with the theories of probability.

g. In order to obtain repetitive measurements (for determination of unknown density values), the density probe must be operated at a specific voltage with the scaler set at a specific sensitivity. Also, the type and length of the coaxial cable must be within design limits.

Now, assume that a counting rate - density relationship has been determined, as indicated by the curve on Plate 5, per the criteria outlined above. (The symbols represent actual calibration data as observed by techniques discussed in Section VII.) This curve defines the calibration relationship to a relatively fine degree of probability and for ideal conditions that do not always obtain in the field. From a practical standpoint, then, field measurements will not be attempted at this same precision, but at some lesser degree.

25. Defining the Calibration Curve. Equation 1 established working limits of error in terms of counting rate only. Now that this counting rate is also a function of density, the error limits must be redefined in equivalent terms or counts per minute per pound per cubic foot. To accomplish this the factor "s", representing the slope of a line tangent to the calibration curve at a given saturated density value, is introduced to equation 1 so that the

$$\text{error (PCF)} = \frac{\pm K\sqrt{C}}{ts} \qquad (3)$$

For example, assume that the total count observed by the probe in a reservoir deposit was 40,260 for 3 minutes, a Standard Error confidence level was desired, and the curve on Plate 3 represented the calibration relationship. Computing the counting rate C/t, or 13,420 CPM, and referring to the calibration curve will give a wet density value of 87.3 PCF. The slope tangent to the calibration curve at this density value is about 159 CPM/PCF. Thus the error in this measurement would be:

$$E = \pm \frac{1\sqrt{40,260}}{3 \times 159} = \pm 0.4 \text{ PCF}$$

or the density of the reservoir deposit at this point would range between 86.9 and 87.7 PCF at a 68 percent confidence level. If a 95 percent confidence level were desired, the error would be ± 0.8 PCF so the density of the deposit probably ranged between 86.5 and 88.1 PCF. A simple graph can be prepared as shown on Plate 6 to define the minimum number of total counts that must be observed for various combinations of E and K. Whether it is preferable to limit the number of total counts accumulated for any given density to the values designated by such a curve (thereby reducing observation time to a minimum), or establish a minimum count value for all observations (which will require more time in certain instances), is a criteria that should be established in the standard operating procedures. Since maintaining the probe at a stationary position within a deposit for appreciable lengths of time can be critical during marginal operating conditions, it is recommended that the total counting time per individual observation be kept to the minimum that is consistent with the degree of measurement accuracy desired. The development of a graph similar to Plate 6 will provide the party chief with a reference for determining this minimum total count. It is important to realize that the total number of counts limits the measurement accuracy but that constant intervals of observation time are only a convenience, not a necessity.

26. The Standard Count. The purpose of the standard count is twofold; first, to provide a physical reference mark for evaluating satisfactory performance of the probe and two, to provide a similar measure of confidence that the calibrated phenomenon of radioactive emission and recording has remained consistent. The one calibration value which can be measured most conveniently and perhaps most accurately is a large body of clear, fresh water. The combination of conveniency and relative stability makes this an ideal point of reference for the standard count. If it is assumed that the density of fresh, clear water

is constant, then the standard count value becomes theoretically, the calibration curve value for water. However, experience has demonstrated that all bodies of fresh clear water do not reflect counting rates that fall within the desired limits of statistical error. These deviations are generally very minor and only amount to perhaps one or two percent of the calibration curve count rate. The specific cause is unidentified at present but such variations become significant when trying to establish any overall limit of error. Thus, it is the current practice to establish a standard count for each body of reservoir or lake water and to use this value to verify the consistent operation of the probe. The procedures for establishing a standard count are outlined in Section IV - Operation Techniques.

27. Sediment-water Ratio. The reliability of the standard count for a body of clear, fresh water might also serve another very useful purpose. By computing the ratio of counting rates, between the calibration value observed for various densities of sediment and the standard count for water, or the

$$\text{Sediment-water Ratio (S/W)} = \frac{\text{counting rate in sediment}}{\text{counting rate in water}} \qquad (4)$$

a relationship can be obtained that appears to be interdependent to a limited extent between such external variables as background radiation, operating voltages, counting tube efficiency, etc. However, the validity or extent of this mutual dependency has not been completely demonstrated.

28. Dry Density Computations. Equivalent dry density values can be computed directly from the wet density values, provided the specific gravity of the deposit material is known or assumed. The equation for this conversion is:

$$D\ (\text{PCF}) = \frac{G\ (W-62.4)}{G-1} \qquad (5)$$

where D = the dry density or dry weight per unit volume, G = the specific gravity of the material and W = the wet or saturated density as determined by the density probe. Since the normal specific gravity of soil mixtures is about 2.65 this value can be conveniently used for approximate determinations. The sampling of reservoir deposits for specific gravity determinations provides an important check as to the validity of using the existing calibration curve for probe measurements. If a significant difference is noted between the specific gravity values obtained by sampling of the deposit material and the value used for calibration, recalibration of the probe may be necessary using material comparable with that sampled. Thus, some pre-survey investigation of the reservoir is recommended to confirm what type of material has accumulated in the deposits.

SECTION III - RADIATION SAFETY

29. General. The sediment density probe is not a dangerous instrument that should be avoided due to its radioactive characteristics. Like many other instruments developed for engineering or scientific use, operation of the probe is not a hazardous occupation providing a little common sense is combined with a few simple safety rules. Since an Atomic Energy Commission registration and licensing is not required for radium sources of this low magnitude, the prime controls governing the possession, handling and use of the probe by Corps of Engineer offices are outlined in ER 385-1-80 - Radiological Safety. In some instances a form registration may be required by certain State Departments of Health prior to use within their State boundaries.

30. Radiation Monitoring. Even though the probe is a relatively safe instrument to use when properly handled, all operating personnel should be familiar with the basic facts of radiation safety, organizational safety regulations and the instruments to be used in monitoring personal radiation exposure. The exposure normally accumulated during proper handling and operation of the density probe should be well within the allowable dosage rate of 3 rem per quarter or about 100 millirem per week. Experience has shown that normal operation exposure rates are less than 10 millirem per month. Exposure measurements on an unshielded probe indicate rates as follows:

Distance from Source in Inches	Approximate Exposure in mr/hr
1	1000
6	90
12	25
24	6
39	2

As a basic minimum for operating personnel, each operator should be provided with at least one film badge and a pocket dosimeter in order that the accumulation of exposure may be determined during the periods of probe use. Rates of exposure should be maintained for inclusion in the individual's personnel file as a permanent record. Periodic evaluation of the total accumulated exposure is necessary to assure that maximum permissible doses are not exceeded. Film badge service is available from both government or commercial sources. Pocket dosimeters with portable charging devices are available from several commercial sources.

31. Standard Operating Procedures. The direct responsibilities for complying with the safety provisions outlined in ER 385-1-80 are usually assigned by the District Engineer to the operating supervisor who utilizes the density probe. Guidance, assistance and inspection for compliance with regulations are provided by the District Radiation Protection Officer. However, the field party chiefs or individual operators have the immediate responsibility of conducting a safe and proper reservoir density survey.

It is at this level that guidance must be directed in a specific, clear and detailed manner. This can be accomplished by the establishment of standard procedures for use when operating the density probe. The SOP should be prepared under the direction of the operating supervisor. He is best qualified to incorporate the necessary safety requirements into a feasible plan of operation. For guidance in preparing an SOP, the following items related to radiation safety are considered pertinent. Other operational procedures are covered in Section IV.

a. Responsibility. Outline the specific areas of individual responsibility including those of the District Radiation Protection Officer.

b. Accountability. Clearly define who will be deemed accountable for the physical custody of the probe during actual operations, field or office storage, maintenance or repair, shipment, etc.

c. Accidents or emergencies. List procedures to be followed in case of personal over-exposure, leakage, damage, theft, fire, etc.

d. Radiation monitoring. Indicate the type and number of monitoring devices needed including wearing instructions.

e. Records of exposure. Establish method and frequency of recording exposure rates both in the field and office. Procedures must also be defined for transmittal of film badges, interpretation of exposure results, filing records, etc.

f. Maximum permissible exposures. These values are well defined by regulations but procedures should be clear as to how such exposure values are determined. A table showing actual exposure rates at given distances from the source is helpful.

g. Training of personnel. Outline training procedures for operating personnel. Include necessary qualifications for both operators and maintenance or repair technicians. A continuing program for periodic training in radiation safety is also necessary.

h. Places of use. The authorized places of use should be defined plus instructions for informing the District Radiation Protection Officer and Area or Project offices of working schedules and locations. In some instances, notification to the local State Department of Public Health will also be necessary.

i. Inspections. Outline the procedures for inspection of the instrument after initial receipt or return from loan or repair, how wipe tests will be performed, what routine inspections should be made, etc. If the probe is to be used for salt water operations, such as in estuarial deposits, special instructions and procedures for wipe tests should be established in the event that internal water leakage occurs.

j. Instrument operation. List operating procedures including maintenance or repair instructions. Define radiation working area. Establish transportation procedures between work sites.

k. Storage. Designate official locations for prolonged storage. Outline requirements for temporary storage at field offices or in transportation vehicles. Stress need for protection from fire or theft and placement of adequate warning signs or labels.

l. Administrative reports. Outline report requirements and assign responsibilities.

SECTION IV - OPERATION TECHNIQUES

31. General. Density observations can be accomplished at the time of the reservoir re-survey sounding work but usually it is more desirable to evaluate the general pattern of deposition and select representative or special points for observation. In the scheduling of such observations, two particular items can adversely effect the forward progress of such work or exhaust a carefully prepared budget. The first and most important concerns inadequate preparation. Do not attempt a comprehensive density measurement operation without first securing the proper accessory equipment, particularly a seaworthy boat or launch complete with a qualified, experienced operator and sufficient anchoring gear. Prior to the initial departure from the docking area, assemble and test operate all equipment. Many valuable hours have been lost back-tracking from the first observation point due to a surprise malfunction or a forgotten piece of equipment. Second, anticipate that periods of either inclement weather or high winds and waves will occur during the survey. Be particularly prepared for that sudden blow that might isolate you in a protective but remote cove overnight or perhaps longer. If the operations are interrupted by continuing rough water, or time consuming equipment repair, have a reserve of other productive tasks that can be accomplished during such idle periods.

32. Operational Log. A chronological record or daily operational log concerning the probe should be faithfully maintained. It is not intended that this log would duplicate all observation data such as that outlined in paragraph 41 but that it include information pertinent to the physical operation of the equipment. Typical entries could include:

a. Location and date of operations.

b. Number of daily observations, number of breakdowns, source of trouble, difficulties experienced, how standard count checked, length of cable in use, operating voltage, etc.

c. Any maintenance or repairs accomplished.

d. Unusual conditions encountered such as excessive background count, change in plateau curve, erratic counting rates, etc.

33. Preparation of Equipment. Assuming that the operating personnel are equipped with film badges and/or dosimeters, the storage box can be unlocked and the coaxial cable uncoiled from the brackets in the lid. See photo 2. If the probe is to be fastened to the suspension tubes (Part 47), determine the number of tube lengths required to cover the depth of operation and thread the cable (Part 44) through each tube length, being sure that the thread connections match between tubes and with the probe, and that the depth markings on the tube are in sequence. Next remove the storage holding bracket securing the connector end of the probe and tilt the probe sufficiently to connect the coaxial cable but avoid withdrawal of the source end of the probe from the protective storage shield. If this connection is a threaded type (probably an Amphenol connector) fill the cavity of the male end with a small quantity of

silicon grease and securely tighten and tape the connector. If the connection is a molded pressure type fitting (Parts 42 and 43) remove the short protective tube (Part 40) from the probe threads and <u>use caution</u> when slipping the connector together to assure that the protruding pin on the probe enters the female socket on the cable without damage. After this cable connection is made, connect the first section of tubing to the probe. The probe may now be withdrawn from the lead shield and placed in such a position that operating personnel cannot accidently become exposed to the source end. This can be effectively accomplished by resting the suspension tube on the boat gunwale with the probe projecting out over the water. The remaining sections of tubing may now be added individually as desired. (It is not recommended that several sections of tubing be connected, the cable threaded through the tubes, the coaxial cable connection made and then the tubing fastened to the probe. Experience has shown that friction contact between the cable and the interior of the tubing can be sufficient to damage the cable due to twisting as the tubing is threaded.) The free end of the coaxial cable (Part 49) can now be secured to the scaler.

34. The practical limits of a normal suspension tube operation are about 40 to 50 feet. If suitable accessory equipment and a stable working platform are available, observations at greater depths can probably be accomplished with greater ease and accuracy by this method than by cable suspension. When a cable suspension operation is intended, the coaxial cable is threaded through an adaptor (Part 45) prior to making the connection between the cable and the probe. After the connection is secure, the adaptor can be threaded onto the probe and the weighted section of pipe (Part 46) threaded to this adaptor. After the suspension cable is attached, the probe can be carefully removed from the storage shield and suspended over board from the boom. By lowering the probe immediately into the water below the draft of the boat, it is inaccessible for accidental radiation exposure and not exposed to damage as when swinging free. After the coaxial cable is coiled for free play, the cable can be connected to the scaler.

35. <u>Establishing a Standard Count</u>. The first observation to be made at any reservoir site concerns establishing a standard count for clear water. After the scaler has warmed up, adjust the scaler output voltage to the value designated as the calibration voltage. (It is assumed that an electrostatic volt meter has been plugged into the scaler circuit to permit this adjustment. If this type of volt meter is not available for field use, the voltage output should have been previously adjusted, under operating load conditions, and the potentiometer locking ring on the scaler secured to prevent accidental disturbance of this setting. Do not rely on the voltage correction table furnished with the scaler. Also see Section V Voltage Checks. Suspend the probe in clear water, not closer than three feet from the boat hull or any submerged matter or the reservoir bottom. Using either the electronic timer built into some scalers or a reliable 30 second sweep-hand stop watch, proceed to establish a standard count as follows:

a. Obtain a series of five individual observations that total at least 65,000 counts each.

b. Sum these total counts and divide by the total observation time to determine a probably long term count rate. (This value should normally be within a few percent of the calibration curve value for water).

c. Using ± 1.0% of this count rate, determine the acceptable limits of error for the standard count. (The use of a ± 1.0% deviation for establishing these limits is a descretionary choice but this value seems adequate. Other percentages can also be used but remember that this operation is not a calibration check, its only purpose is to evaluate whether the probe system is functioning properly or not.)

d. Compute the count rate for each of the individual observations. If all of these rates fall within the acceptable ± 1.0% deviation limits, it is assumed that the standard count is verified and the probe is functioning properly.

e. If any individual count rate exceeds the ± 1.0% limits, repeat items a through d to verify a standard count. If an error exceeding ± 1.0% still occurs, the probe system is probably functioning erratically and servicing is necessary.

A typical example of defining the standard count is noted below:

Total Counts	Time in Minutes	Count Rate (CPM)	Deviation From Mean (CPM)
73396	4	18,349	+ 81
72670	4	18,168	-100
73026	4	18,257	- 11
73612	4	18,403	+135
72662	4	18,166	-102
365366	20	18,268 = Mean Count Rate	

Error Limits = ± 1.0% of Mean = ± 183 CPM

Calibration Curve Value for Water = 18,485 CPM.

36. Measurement Procedures. Upon arrival at an observation site, the first problem encountered is establishing the location of the measurement vertical and anchoring or positioning the boat near this point. For the inexperienced this operation can become very time consuming; it is here that the experience and skill of the boat operator plus the use of adequate anchoring gear will pay dividends. Consideration must also be given to the acceptable horizontal limits within which the measurement must be taken. If relatively accurate or repetitive positioning is desired, the setting of buoys at the selected positions prior to anchoring is advised. Usually a general area in the vicinity of a range line is designated as an observation location, the launch anchored within this area and then the exact position of the measurement vertical defined as necessary in terms of range stationing or offset from such stationing.

This positioning method permits the use of reasonable judgment both in locating the area by sight and the maneuvering necessary to set the anchors at proper angles. This is particularly important when long anchor lines are needed to hold during windy weather or in deposits of soft muck. If the water depths and wind permit, spuds can be used to hold the boat on station. Under relatively calm wind conditions in deep water, two anchors placed fore and aft will suffice but whenever choppy waves develop, three or more anchors become a necessity. Heed the advice of an experienced seaman when employing or developing anchoring techniques.

37. Water Count. The first measurement to be made with the probe is a water count to establish that the instrument is functioning properly. Standard count techniques are used except that only a single observation of at least 65,000 counts need be obtained if this count rate falls within the standard count limits. If a greater departure occurs, obtain several more water counts or check the standard count to define the extent of any difference from the established standard. Although not common, such differences have been observed. The reason for these variations are not always clear but often it can be traced to either equipment malfunction or a change in background radiation.

38. Background Radiation. Any significant increase of background radiation, over that which obtained during calibration, will influence the validity of all density measurements as long as such an increase continues. This is one of the major reasons for frequent water counts, to confirm that a background change has not influenced the standard count or the relationship of the sediment-water count ratio. However, this check will not indicate any background change that must be expected to accumulate by natural circumstances in the deposits themselves. Currently it is assumed that such background variations are either insignificant or are constant with conditions that existed during calibration. When the significance of these variations are better understood, it is possible that measurements with a sourceless probe will be necessary to determine what corrective factors to apply to the observed density count before consulting the calibration curve. Occasionally an increase in the standard water count will occur for no apparent reason. This variation could have been preceded by normal standard counts at another location and might be followed by similar normal standard counts at still another location. If the occurrence of a temporary counting malfunction can be eliminated, the cause of this change can conveniently be identified as unknown background radiation. If use of the measurement data is necessary, approximate density values can be determined by correcting the observed counts by the difference between the established standard count and the observed high water count. Such data should always be identified as approximately correct but questionable.

39. Positioning Probe in Deposit. The techniques used to position the probe in the deposit are not complicated but sometimes determining the surface elevation of the deposit or maintaining a static vertical position during the counting period will be difficult. The sonic sounder is perhaps the most versatile method of locating the surface elevation of deposits whose wet density is less than about 75 PCF. Other positive methods can also be used but "feeling" with the probe generally results in lost time or inaccurate determinations. When the suspension tube

technique is used in such light deposits it will be necessary to secure the probe to the boat to maintain a constant vertical position. For this purpose a simple holding device can be fabricated as shown in photo 4. When the frictional resistance on the probe and tubing within the deposit reaches a "floating" point, a positive vertical support from the boat is not always necessary. This can be very advantageous at times, particularly when waves induce movement in the boat. In these circumstances always maintain a line contact with the tubing and make sure that the probe does not settle during the observation. For deeper penetration apply vertical pressure on the tubing. This requires some dexterity when operating from a small boat to maintain a vertical movement of the probe, while avoiding undue bending of the tubing which could damage the thin probe sheath. Do not attempt to drive the probe into a deposit - the stainless steel sheath and internal components are not designed for this type of handling.

40. When positioning the probe from a cable suspension, the degree of penetration is dependent entirely upon the added weight. Usually no penetration difficulties are experienced until the deposits approach a density of 85 to 90 PCF. Further penetration can usually be accomplished, providing the entire probe is submerged below the deposit surface, by raising the suspension cable by hand not more than two feet and allowing the probe to fall free to a new depth. Gentle penetration movements of this nature can produce additional obesrvation points with a minimum of disturbance. Do not attempt to achieve penetration by allowing the probe to fall free more than two feet or into the bed surface; the desired vertical penetration will not occur due to the top-heavy, unbalanced distribution of weight.

41. Obtaining a Density Count. Since the geometry of the probe dictates a fixed separation between the gamma source and the detection tubes, the minimum vertical range of sensitivity for any measurement is limited to about 13 inches. Thus, several measurements in a vertical spaced 12 inches apart would theoretically overlap at the top and bottom. Due to the lead shield in the nose of the probe, a minimum depth penetration of about 15 inches is necessary to obtain a representative measurement. It is apparent that the definition of thin lenses of deposits or interface changes are restricted by these limitations; however, a rough evaluation is sometimes possible by obtaining overlapping measurements at vertical intervals less than 12 inches. Whatever the interval, it is very important to record the vertical limits or mean depth of the sensitivity range for each observation. This can be accomplished very simply by "zeroing" the depth markings on the suspension tubing, or reel, to the vertical center of the probe sensitivity range. All measured and recorded depth values will then reflect the center of this sphere. Another popular method is to "zero" the location of the source or the probe tip and correct mathematically for this vertical difference. In this case indicate in the field notes whether or not the recorded data reflects such corrections. A typical record of field observations should include the following information:

a. Project or reservoir name

b. Observation location by range or mile number

c. Date of observation

d. Probe operator

e. Probe serial number

f. Operating voltage and how determined

g. Stationing on range line or offset

h. Water surface elevation

i. Water depth

j. Depth of observation (center of sensitive spheriod)

k. Depth of observation below deposit surface

l. Total depth of deposit

m. Total count for each observation

n. Time interval for observation and how determined

o. Counting rate in counts per minute

p. Wet density value from calibration curve

q. Date of calibration curve

r. Sediment - water ratio

s. Computed dry density (show specific gravity)

t. Remarks. Include here comments on standard counts, weather or lake surface conditions, reliability of observations, etc.

u. Notations of radiation exposure including film badge numbers, dosimeter readings, length of exposure, etc., are normally maintained in a separate record.

42. The mechanics of obtaining a density count are similar to those used for the standard count or the water count. With the scaler at operating temperature and correct output voltage, and the probe at desired observation depth, accumulate a significant number of counts. Reduce this total accumulated value to a count rate per minute before consulting the calibration curve for a density value. Check this result for continuity with previous measurements in the vertical. If unexplainable variances are noted, a check count might be in order before advancing to the next depth. This constant appraisal for probable valid counts can also be very useful in making operation decisions. For example, if a continuing buildup of waves causes increased vertical movement of the suspended probe (due to pitching of the launch), at some point it must be determined whether this movement is disturbing the deposited sediments sufficiently to discontinue operations. One guide to use in making this decision is an appraisal of the apparent continuity of the measurements. Generally the degree of vertical movement is less critical in low density deposits than in high density material.

43. Comparative Samples. The need for comparative density values through sampling observations depends upon the confidence placed in the probe and its calibration or the degree of measurement accuracy desired. Since samples of the reservoir deposit are needed to ascertain the particle size distribution, specific gravity, etc., it requires little additional effort to select portions of the more representative (least disturbed) samples for a density analysis. A nominal number of such comparative results will tend to express confidence in any final report.

44. Salt Water Operation. Prior to operation of the probe in saline water, such as for the measurement of tidal estuary deposits, two important details must be considered. First, the radium source capsule should be protected from salt water corrosion in the event that internal leakage occurs. A light plastic coating over the capsule would probably be sufficient protection but it is recommended that this modification be performed by the manufacturer. Second, due to the slight difference in the specific gravity between fresh and salt water, a recalibration of the probe may be desirable. In any event, several points on the current calibration curve, including water, should be verified to establish the degree of any departure from this curve. Operational techniques discussed in this manual are generally applicable to salt water observations. Maintenance techniques are also applicable except for the complications introduced by salt water corrosion. In general, if salt water leakage is not immediately detected and its corrosive action halted, the replacement of most internal components will be necessary. Special consideration must also be given to radiological wipe test inspections in the event of salt water leakage.

SECTION V - MAINTENANCE

45. General. Continuing satisfactory performance of the density probe will depend considerably upon the frequency and degree of preventative maintenance inspections. This section covers suggested procedures for such inspections. When engaged in such operations CAUTION MUST BE EXERCISED IN TWO AREAS. FIRST, dangerous HIGH VOLTAGES are present when the scaler and probe are in operation. Avoid inspection of the scaler or probe interior components if a possible grounding potential exists. This is particularly important when operating in a small boat or from a steel deck launch. SECOND, accidental RADIATION EXPOSURE hazards increase during close handling of the probe. Whenever practical, leave the probe in its protective lead shield while servicing or testing. If disassembly of the probe is necessary, disconnect the inner lead shield and source as a unit and confine it in protective storage until reassembly is necessary.

46. Scaler Servicing. Detailed maintenance instructions for servicing the portable scaler can be found in the scaler instruction manual. The following items are discussed briefly due to their importance in normal operation.

a. Battery. During field operations make a daily inspection of the battery condition both for charge and electrolytic level. Generally this can be accomplished at the end of each day's operation when the scaler is plugged into a 110 volt A.C. circuit for a recharging period. When the probe is in non-use storage, a periodic recharging is necessary about every 30 days. The normal life for this battery is about 24 months.

b. Voltage Checks. If an electrostatic voltmeter is not a unit of the normal operating equipment, it is recommended that the voltage potentiometer dial be checked and/or set at the desired operating voltage, under operating load, prior to departure for field measurements and rechecked upon return. The importance of knowing that the scaler is being operated at the calibrated voltage cannot be overemphasized. Do not attempt to use conventional type voltmeters since they will load the circuit, causing erroneous voltage indications. Maintain a continuing record of such checks and/or changes to substantiate the validity of any field observation.

c. Spurious Counts. This is another validity check to assure that the scaler circuitry is not introducing fake or spurious counts to the glow tubes. Since this check involves a voltage change, it can be conveniently made in conjunction with voltage checks or when making plateau curve observations. Follow the scaler manual instructions and be sure the scaler is operating on battery power.

d. Sensitivity Check. The scaler sensitivity setting determines the minimum negative pulse voltage that is acceptable through its circuits to produce a count indication on the glow tubes. This internal setting is usually considered a factory adjustment but its value, like the potentiometer voltage, has a direct bearing on the calibrated count rate-density relationship. Experience indicates that a setting of 150 millivolts will permit satisfactory operation of the probe with 100 feet of cable. Regardless, the setting that obtained during calibration must also be maintained for valid measurement counts. Although any sensitivity setting should remain stable for a long time period, verification of this value is suggested at least once a year and always prior to any serious calibration work. Detailed instructions for checking and/or adjusting the sensitivity control can be found in the scaler manual. It is possible to replace the sensitivity potentiometer with a fixed resistor to maintain a constant sensitivity level; however, this limits any fine tuning for a given pulse amplitude and voids versatile use of the scaler.

47. Probe Servicing. Design modifications over the past several years have greatly improved the water tightness of both the probe and the coaxial connectors. Thus, the frequency of internal maintenance inspection can now be reduced to the probable minimum of two or three times a year. Prior to any disassembly of the probe, providing it is in operable condition, take a standard water count. A similar comparative count after reassembly will verify immediately that the probe is still in operable condition or that perhaps a recalibration is necessary due to the recent repair. When disassembly of the probe is necessary proceed as follows:

a. Release the "tie down" collar in the storage case and tilt the probe into a vertical position with the source remaining at the desired protective location within the lead shield.

b. Discharge the pre-amp capacitors by grounding the inner coaxial lead at the connector (Part 42) to the chassis body plug (Part 38).

c. Connect either the suspension cable adaptor (Part 45) or a short piece of tubing (Part 40) to the threads on the probe.

d. Remove the four set screws (Part 2) at the top of the sheath.

e. Tilt the probe to a convenient working angle and grasp the flanged top end of the probe sheath (Part 1) with one hand and the adaptor with the other. With a slight twisting action on the adaptor end, push against the sheath while pulling upward on the adaptor until both "O" rings (Part 37) appear free of the sheath casing. Stop at this point.

f. Next grasp the upper portion of the probe sheath with a pair of long handled tongs or pliers, then quickly but gently withdraw the probe chassis (Parts 3 through 42) from the sheath casing.

g. Quickly remove the sheath from the lead shield. Tilt the shield to a vertical position and place a small block of wood under the shield to keep it vertical. Replace the source end of the probe chassis (Parts 3 through 7) back into the protective shield and secure it in a vertical position. (If the probe has been used for saline water operations and leakage is suspected, a wipe test should be made immediately to ascertain that chemical deterioration of the silver solder that seals the radium source within the capsule has not occurred. Proceed per Section VI, Item C-4. If the wipe test is negative, carefully rinse the entire unit in fresh water before storage.)

h. Grasp the cylindrical lead plug (Part 8) about two inches below the counter tubes (Part 12) with the tongs. Unscrew the upper chassis section and remove it to a suitable location for inspection or repair. Exercise caution in the handling and storage of this section to avoid puncturing or damaging the exposed counter tubes.

i. Confine the area surrounding the probe box and semi-exposed source or remove the source to a suitable storage vault if the probe is to remain disassembled for a lengthy time.

48. Routine inspection of the internal probe should include the following:

a. Inspect for moisture condensation, particularly on the counter tubes (Part 12) and sockets (Part 15). If traces of moisture are found also proceed as indicated in Section VI under paragraph 51, item C - 3.

b. Inspect battery terminals (Parts 22 and 30) for corrosion and test the battery voltage (Part 24). If replacement is necessary, remove the battery support bracket (Part 25) and loosen the terminal nut (Part 34) (not the screw) at the top of the battery. Remove the battery and check the terminal contacts for corrosion. Replace the new battery and reassemble. After tightening the terminal nut, place a drop of quick drying liquid cement on the exposed threads (Part 35) to prevent possible loosening due to vibration.

c. Verify that the counter tubes are clean and free of surface pits or holes. If removal of a tube is necessary, loosen the three long chassis tie rods (Part 9) sufficiently to permit withdrawal of the tube from its socket. Replace each tube in its proper socket without intermixing.

d. Make a general inspection of all electrical components for worn or damaged parts and loose connections.

e. Check "O" rings (Part 37) for nicks and apply a small quantity of silicone grease for lubrication.

49. To reassemble the probe, proceed as follows:

a. Make a re-check to assure that the counter tubes are secure in their sockets, the battery has been replaced if necessary and contacts are clean and that the "O" rings are lubricated.

b. Remove the source end of the probe from the storage vault, inspect the plastic shroud (Part 3) covering the radium source for damage or deterioration and if satisfactory replace the lower source section into the storage box protective shield. (This is a convenient time to make a "wipe test" if necessary.)

c. Refasten the upper chassis section to the lower source section.

d. Quickly remove the chassis and source section from the shield, insert the sheath into the shield and grasp it with tongs, and then lower the chassis section into the sheath up to the "O" rings.

e. Rotate the inner section until the "match marks" on the top of the sheath case and the body plug are aligned. Grasp the upper portion of the sheath and with a slight twisting action, firmly force the inner section into the sheath until the screw holes match.

f. Replace the screws, connect the coaxial cable and make a bench check to assure the probe is operating.

g. Check for a satisfactory standard water count.

50. External servicing of the probe is limited to visual inspection of the coaxial cable connectors (Parts 42 and 43) for replacement and cleaning of the sheath or suspension gear. During operations, cleaning of the probe sheath can be easily accomplished without danger of radiation exposure by repeated swabbing with a long handled straw broom.

SECTION VI - TROUBLE SHOOTING

51. General. This section will deal primarily with suggesting methods for locating the cause of probe or scaler malfuncfions and recommend appropriate corrective measures. It should be recognized that while many of these suggested procedures have evolved through practical field experience, they are not necessarily the only solution to the problem. Likewise, symptons will possibly develop which are not discussed in the following trouble shooting table. In such instances do not immediately give up and return to the office. Use some initiative to try to locate the source of trouble, within a reasonable time limit, while it is occurring. Carefully document the sequence of inspection checks for future reference. It is these unexperienced and indefinite failure causes that are so difficult to analyze or reproduce in a bench check. With a few concise notes from which to gain clues, the probability of developing a corrective technique could advance rapidly from an impossible to practical situation. Occasionally the probe may return to working order without knowing which particular inspection technique caused the cure. This probability alone is worth a reasonable delay before quitting the field due to equipment failure.

52. Trouble Shooting Guides. The following guides were developed primarily for quick reference in the field to evaluate the probable cause or extent of scaler or probe malfunctions. The defects noted for each sympton are purposely listed in a given sequence with the more probable and less time consuming corrective actions first. Following this sequence of checks will probably conserve time if the general source of the trouble is unknown.

Item	Sympton	Defect	Corrective Action
A	Scaler will not count either probe or test pulses at calibration voltage.	Internal scaler trouble, probably faulty tubes.	Proceed per instructions in scaler operation manual.
B	Scaler will count test pulses but not probe pulses.	1. Scaler output voltage low.	1. Check and/or reset scaler voltage to proper calibration value (usually 900 V.).
		2. Coaxial cable not connected to probe or scaler	2. Connect cable.
		3. Poor connector contacts.	3. Check Mecca connector (Part 42) for bent or damaged male pin. Also check scaler connection contact pins (Part 49).

Item	Symptom	Defect	Corrective Action
B	Scaler will count test pulses but not probe pulses (cont.)	4. Moisture in cable connectors.	4. Dry thoroughly and fill voids around high voltage contact with silicone grease.
		5. Probe inoperative	5. Check continuity in probe by grounding male coaxial connector pin (Part 42) to discharge pre-amp capacitor. Then using ohmmeter (on 40 meg scale), observe slight deflection in meter as capacitor is recharged. If only a monetary deflection is noted, the probe interior is dry and the pre-amp circuit probably functioning properly. If a continuing deflection is noted, internal repairs are necessary.
		6. Scaler tubes faulty.	6. Proceed per scaler manual instructions.
C	Water leakage into probe sheath.	1. "O" rings nicked or severed.	1. Replace "O" ring (Part 37). Check for sharp or burred edges causing damage to ring and correct. Check for lubricant on rings. Dry probe chassis per item C-3.
		2. Improper connection at probe or inadequate water-tight seal.	2. Make proper connection or replace connectors if faulty. Male connector on probe does not have internal coaxial seal and relies entirely on coverage by female portion to prevent interior water leakage. Dry probe chassis per item C-3.
		3. Fresh water leakage.	3. Whenever fresh water leakage occurs, proceed as follows to dry and check internal components:

Item	Symptom	Defect	Corrective Action
C	Water leakage into probe sheath (Cont)	3. Fresh water leakage.	a. Disassemble the probe including removal of the lower source and shield section. Using tongs, drain any water from the source shroud, wipe the exterior dry and allow remaining moisture to evaporate. Store section in vault or shield until needed for reassembly.
			b. Using a dry, absorbent cloth, carefully wipe as much moisture as possible from the probe chassis and the sheath interior. If available, air pressure can be used to remove the excess moisture but care must be exercised to avoid damage to the probe components, particularly the counter tubes.
			c. Unscrew the chassis tie rods sufficiently to remove all three counter tubes. While the rods are loose, check each spacer tube for trapped water and then retighten the rods.
			d. Check for internal moisture at the base of each counter tube. Using an ohmmeter, if any continuity is indicated between Pin 3 (the cathode or steel wall of the tube) and Pin 1 (the anode) or Pin 2 (a no contact pin), moisture exists under the tube wall at the base. Remove as may drops as possible by shaking. Then dry in an oven at not more than 130°F. temperature until the ohmmeter indicates zero continuity between the pins. Do not replaces tubes yet.

Item	Symptom	Defect	Corrective Action
C	Water leakage into probe sheath (Cont)		e. Remove, check and replace the mercury battery if necessary. Be sure contact points are dry and clean before replacement.
			f. If air pressure is available, direct a stream of air into the chassis body cavity to dry the lower portion of the male Mecca connector. If air pressure is not available, or complete removal of moisture is impossible by this method, the coaxial and ground leads coming from the Mecca connector must be unsoldered at their chassis connection points and the connector removed for cleaning. Before reassembly check the connector "O" ring (Part 41) for damage and apply a trace of silicone grease for lubrication.
			g. Inspect all pre-amp connections and components for moisture or damage. Particular attention must be given to the counter tube sockets (Part 15) due to moisture or corrosion accumulating in the female pin sleeves. Continuity between sleeves will indicate a faulty socket. Replacement of the socket may be necessary in some instances. If this is unavoidable, remember that the collar of these minature sockets must be removed in order to fit. This can be easily accomplished by grinding or with a file.

Item	Symptom	Defect	Corrective Action
C	Water leakage into probe sheath (Cont)		h. After the removal of all moisture has been accomplished and pertinent checks made, replace the counter tubes. Check for continuity in the probe per item B-5. If satisfactory, reassemble probe, test for operation and then check standard water count to verify the current calibration curve.
		4. Salt water leakage.	4. Whenever salt water leakage occurs, the following special action is necessary in addition to C-3 above: a. During disassembly of the probe exercise caution for possible radiological leakage due to salt water corrosion of the silver solder sealing the radium capsule. b. Retain the salt water within the probe sheath when withdrawing the inter chassis from the casing. c. Make a wipe test immediately to ascertain whether radiological leakage has occurred. If the results of this test are negative, drain the water from the sheath and proceed with cleanup and repair. If the test is positive, quarantine the area and inform the Radiation Protection Officer.
D	Intermittent Counting.	1. Varying output voltage from scaler.	1. Correct per scaler manual instructions.

Item	Symptom	Defect	Corrective Action
D	Intermittent counting (Cont)	2. Poor coaxial connector contacts.	2. Correct per item B-3.
		3. Moisture in connectors or probe.	3. Correct per item B-4. Remember only a trace of moisture in connectors can cause trouble.
		4. Interior ground wire loose between male Mecca connector and probe chassis.	4. Disassemble probe. Unsolder both coaxial lead and ground wire entering chassis from chassis body. Unscrew male coaxial connector from chassis body. Check and/or resolder ground wire to connector.
		5. Scaler battery low.	5. Recharge battery.
		6. Probe pre-amp circuit faulty.	6. Check for broken wires or unsoldered connections. Check circuit voltages and resistances. Correct as necessary.
E	High standard count	1. Incorrect output voltage from scaler. (Higher than calibration value.)	1. Reset scaler voltage to desired output value using electrostatic voltmeter.
		2. Timer or stopwatch inaccurate.	2. Check internal scaler timer by counting 110 V AC 60 cycle frequency on glow tubes. Check stopwatch against reliable time piece.
		3. One or more gamma counter tubes bad. (Standard count erratic and can be either high or low.)	3. Using electrostatic voltmeter, increase output voltage to about 1000 V and check for any fluctuation in output voltage. If unstable voltage is noted, disassemble probe and after removing one counter tube at a time, recheck for voltage fluctuations until the faulty

Item	Symptom	Defect	Corrective Action
E	High standard count. (Cont)		tube is located. Since such tube failures are usually the result of internal water leakage, and the other tubes have probably been exposed to the same degree of deterioration, the replacement of all tubes is recommended. The cost is insignificant when considering total recalibration costs. See item E-6 below before attempting repair.
		4. Scaler sensitivity control changed.	4. Check per scaler manual instructions and reset to calibration value.
		5. Scaler producing spuratic counts.	5. Check and/or correct per scaler manual instructions.
		6. Radium leakage from sealed capsule contaminating interior probe components. Usually a standard count check will exceed the norm by at least 20%.	6. Although uncommon such leakag has occurred. As a precautio follow SOP for radiological leakage during disassembly of the probe. (This also applies to item E-3 above). A wipe test will immediately verify whether leakage exists. Retur probe to manufacturer for decontamination & repair.
F	Low Standard count.	1. Incorrect output voltage from scaler (lower than calibration value).	1. Reset scaler voltage to desired output value using electrostatic voltmeter.
		2. Scaler not warmed up to operating temp.	2. Allow at least 5 minutes warm up before starting counts.
		3. Ditto items E-2, E-3 and E-4 above.	3. Correct per items E-2, E-3 or E-4 above.
		4. Scaler battery voltage low.	4. Recharge battery.

Item	Symptom	Defect	Corrective Action
F	Low standard count. (Cont)	5. Probe pre-amp battery voltage low.	5. Replace battery.
		6. Counter tube faulty.	6. Disassemble probe. Test counter tubes per item E-3. If bad tube is not located, remove all tubes and insert a known good tube. Replace source section and with probe suspended clear of all objects, obtain a standard count <u>in air</u>. Remove source section and then replace good tube with questionable one in the same tube socket. Repeat sequence until all three tubes have been tested individually. Compare standard count results. If satisfactory, each tube count should agree with the count of the known good tube, i.e., within the limits of the standard error.
G	Scaler decade tubes not operating in sequence.	1. Loose connection in scaler circuit.	1. Check panel assembly circuit carefully, particularly those ground lugs secured by a bolt or nut.
		2. Connecting cable between scaler panel assembly and lower chassis exerting pressure on internal components.	2. Check cable position to assure that it is not forced against either panel assembly chassis or lower chassis components when the panel assembly is secured in place.
H	Adjustment of scaler output voltage erratic or ineffective.	1. Control knob slipping on shaft	1. Turn potentiometer shaft to a convenient voltage value, as determined by an electrostatic voltmeter, and tighten Allen setscrew with control knob indicating this value. Then dial to voltage values at both ends of the scale for a check.

Item	Symptom	Defect	Corrective Action
I	Shape of plateau curve changes or shifts.	1. See items D, E and F.	1. Correct per appropriate comment in items D, E or F. Remember that the threshold voltage for a set of counter tubes should remain almost constant for a given cable length.
		2. Impedance mismatch due to change in coaxial cable length or type.	2. Replace with type and length of coaxial cable in use during calibration.

53. Radiation Problems. Any unusual problems which may develop concerning the radium source or radioactive protection should be referred immediately to the Radiation Protection Officer for his concurrence or approval of the anticipated method of solution. If the source suspension rod or capsule are damaged, or radium leakage is suspected, the vicinity and equipment should be immediately quarantined pending further instructions or inspection by the DRPO. Such repairs should be performed only by qualified personnel or commerical companies. Replacement of the plastic shroud is not considered to fall within this category but should be performed only under the guidance of the DRPO.

54. Miscellaneous Procedures. The following list includes miscellaneous procedures that might be helpful in operational or trouble shooting circumstances:

a. Before making the scaler-probe cable connection, take a turn around some stable object to prevent upsetting the scaler should someone trip on the cable.

b. When connecting the suspension weight adaptor (Part 45) to the probe, pause occasionally and remove the twisted kinks in the cable by turning the probe within the lead shield.

c. When difficulty is experienced in retrieving the probe and support tubing from a deposit, try a rapid up and down pumping action to induce a fluid condition in the adjacent material.

d. Additional penetration can some times be accomplished by retrieving the probe and cleaning the accumulation of material from the probe and suspension tube surfaces.

e. If the bow anchors drift on windy days try positioning with a stern quarter into the wind from two stern and one bow anchors. This may cause more spray over the stern but usually prevents yawing of the bow and less pitching with the waves.

f. If the anchor fails to hold in a soft deposit, add more weight such as a heavy log chain, or attach a couple of expendable, weighted buckets forward of the anchor on a lighter bridle line.

g. The length of any anchor line should be at least three times the anchoring depth.

h. If the male Mecca connector "O" ring (Part 41) does not fit tight when compressed into the chassis body, place one or two turns of a narrow piece of electrician's tape into the bottom of the "O" ring slot as a filler. Be sure the ring is lubricated before assembly.

i. If a scaler glow tube which registers either the tens, hundreds or thousand decades goes bad and no spare is available, replace the defective tube with the ten-thousand decade tube and accumulate this value by pencil notation. The unit decade glow tube is not an acceptable replacement.

j. For a quick check of the scaler count circuit, reduce the voltage to 700 V, place test-use switch in use position and tickle pin C in the output plug with a piece of fine <u>insulated</u> wire. Counts should register if the circuit is okay.

k. The scaler can be operated from any 6 V battery source in an emergency.

l. The flatter slope of most plateau curves should range between 2 percent and 5 percent. If the slope exceeds about 7 percent the current drain required for counter tube operation is probably above normal and some circuit defect needs correction. Check counter tubes and/or transistor first.

m. Counter tubes can be conveniently checked with a short cable lead from the scaler and a small radioactive source such as the radium dial on a watch. Connect leads to counter tube with clips, place watch at a given distance from the tube and run a plateau curve using air as the density medium. The plateau slope should not exceed 5 percent. All tubes will not give an identical curve but deviations should be small if the tubes are good.

n. Assuming the probe is functioning properly, if the scaler operates in the "test" position but not in the "use" position, check scaler tubes V1 and V2 first. They are not included in the test circuit.

o. The transistor leads (Part 51) are very delicate. If water leakage occurs, dry thoroughly and check for evidences of corrosion.

p. The threshold voltage of #309 Anton counter tubes is about 800 V. If this voltage point varies more than ± 25V it is an indication of trouble either in scaler output voltage, the coaxial cable or connectors, or one or more counter tubes.

If spurious or noise counts are suspected in the probe circuit, remove the gamma counter tubes (Part 12) from their sockets and then slowly increase the voltage through the poteniometer range while observing for counts on the scaler. If satisfactory, no counts should be recorded.

r. If spurious or noise counts are suspected in the scaler circuit, disconnect probe and slowly increase voltage as above. If counts are noted within 500 volts of the operating voltage, discontinue operations until scaler repairs are made. If counts are noted above this 500 volt limit, their influence is probably not significant but corrective action should be taken at the first opportunity.

s. When scaler decade tubes do not count in sequence, a bias shorting in a resistor lead to one of these tubes has probably occurred. Check the position of the internal cable lead to the top panel assembly -- it has probably been wedged against a chassis lead forcing it out of proper position.

t. If background radiation in a deposit becomes a serious problem, its rate can be measured with the probe after removing the source and lead shielding cylinder from the inner chassis. Exercise caution to avoid collapse of the non-reinforced thin-walled sheath.

SECTION VII - CALIBRATION

55. General. The statistical criteria necessary to define a calibration relationship for the density probe has been previously discussed in Section II. This section will be devoted to the physical procedures involved in the calibration. From a technical viewpoint it is felt that the current practices are generally inadequate to properly define all of the parameters associated with the calibration curve. There are too many unanswered questions: Is the true calibration relationship a curved or a straight line? What are the dimensions of the "sensitive spheroid" that represents various densities? How important is the background count in reservoir deposits? How do we measure it? Do we need a separate calibration for different coaxial cable lengths? What influence does changes in water salinity have on the calibration? etc. From a practical viewpoint, however, a logical calibration curve can be developed which permits an almost undisturbed measurement of the density of submerged reservoir deposits. This capability of measuring the density of an almost undisturbed sample is perhaps the most significant feature of the probe. It is not improbable that the probe density values will eventually prove to be a more accurate method of density determination than standard sampling or laboratory techniques.

56. Calibration Sediments. The sediments used for calibration work should be representative of the reservoir deposits to be measured. They should be in a saturated condition and at the highest density possible. Since a considerable volume of material is needed (over 200 gallons), it might be more practical to make the calibration measurements in the vicinity of the reservoir deposits. Several samples should be obtained for the determination of its specific gravity and particle size distribution. A representative background radiation count for the material should also be determined.

57. Container. The size of the container for the sediment mixture is critical. It should be of sufficient depth and diameter to contain the "sensitive spheroid volume" for clear water if a large body of water is to be measured. The size of this spheroid has been approximately determined at 16" vertically x 30" horizontally, or less, dependent upon the density of the material.. The most popular container used to date for this operation has been a 55 gallon barrel, basically due to convenience, even though the dimensions were not the optimum for low density material. For serious calibration work a cylindrical container not less than 3' high and 5' in diameter is recommended.

58. Density of Calibration Sediments. A method for determining the density or weight per unit volume of the calibration material must be selected. Two methods are popular. The first, and perhaps most convenient, involves sampling of the various densities of material for analysis by standard laboratory methods. This technique is not completely void of errors, particularly when obtaining representative samples at very high densities. The other involves the measurement of weights and volumes, both total and incremental, for computation of the density values. This method requires adequate weight scales and the determination of large liquid volumes.

59. Calibration Sequence. The procedures of calibration are not complicated but the preparation and observation of probe measurements is very time consuming. The sequence involves:

a. Determination of calibration techniques including a plan of operation. This should include selection of the calibration voltage, scaler sensitivity, cable length, sampling and laboratory analysis methods, etc.

b. Preparation of equipment, obtaining a standard count, making a dry run of the operations, etc.

c. Placement of the calibration material into the container. The material should be in as high a density condition as practical.

d. Stirring this material to obtain a homogenous mixture. If this is not practical some dexterous method of obtaining representative samples for lab analyses might be necessary.

e. Submergence of the probe into the material. Usually this places the source at least 15" below the surface at the center of the container.

f. Observing a series of total counts in accordance with the plan of operations. (Three individual counts, of five minutes duration each, is a suggested minimum.)

g. Sampling of the material for density determinations.

h. Dilution of the mixture with a pre-determined quantity of water that will produce the next density value. (Removal of some of the original material will be necessary.)

i. Stirring to produce a homogenous mixture.

j. Repeating the sequence of measurements through the range of density values desired.

60. Preparation of the Calibration Curve. While the density values are being determined by the laboratory, or the wet density by weight per unit volume for each measurement is being computed, the total count data compiled by the probe observations can be evaluated. The counting rate for each total count should be computed; and its error for a 99 percent confidence level. When the density values are known they can be plotted versus the individual counting rates. Using these points, with their error limits defined, a best fit line can be drawn to reflect the calibration relationship. There are other sophisticated methods for defining this line but until more is known about the various parameters that can influence this relationship, this method will adequately define the calibration curve.

61. Miscellaneous Procedures. Many minor problems will be encountered during calibration that have not been discussed. To assist the unexperienced, a few miscellaneous suggestions are noted below:

a. Consider the possibility of calibrating two or more probes. The prorating of expensive calibration costs between several probe owners is worth the effort.

b. Run a plateau curve at several, separated density values. This should verify whether a proper operating voltage is being used.

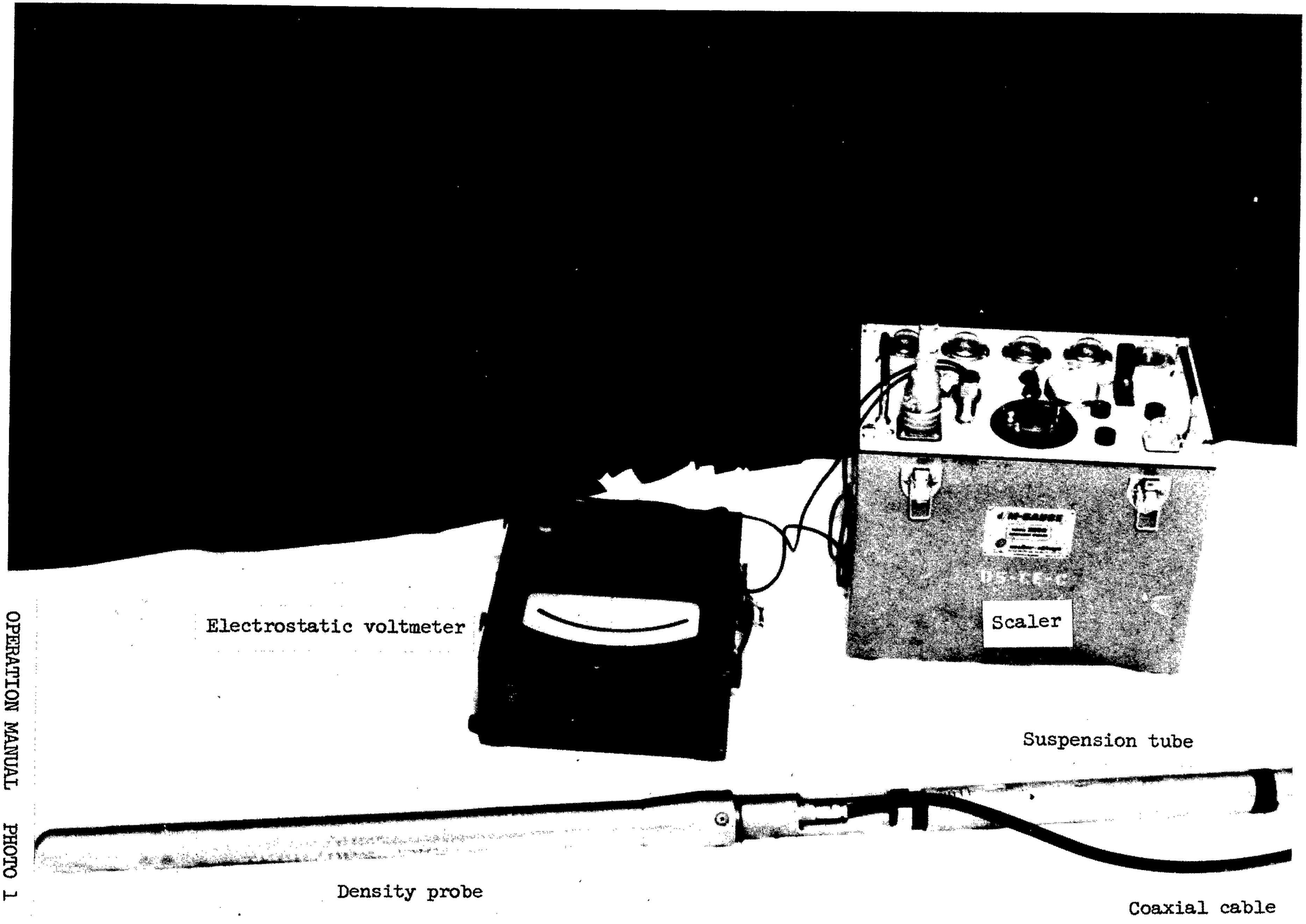
c. Stirring of the sediment mixture by hand should not be attempted. Power mixers or a stirring device mounted on a large electric drill will perform much better and easier.

d. Some test is necessary to determine whether a density change will occur in the mixture during the count period, i.e., sands setting to the bottom. Try a series of two-minute counts after mixing is completed. If a significant change occurs in the counting rate, the mixture is probably not homogenous.

e. Settling of the coarser sediments in the mixture will occur at lower density values. Try adding bentonite to the mixture to deter this action.

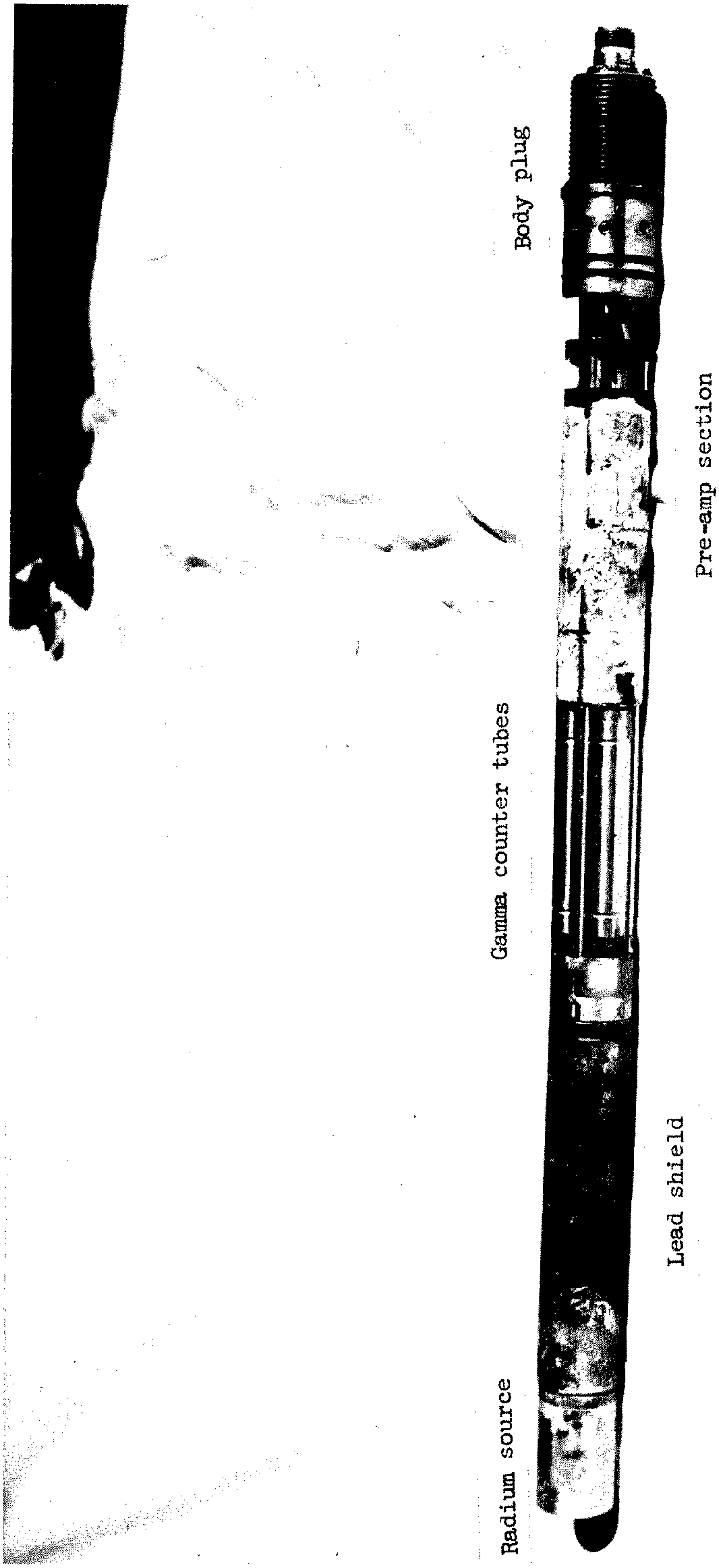
f. Take at least three samples for each density determination. The Foerst sampler works well except at the higher densities.

g. Prior to calibration verify that the probe is functioning properly and if possible, determine the sensitivity setting for the scaler.



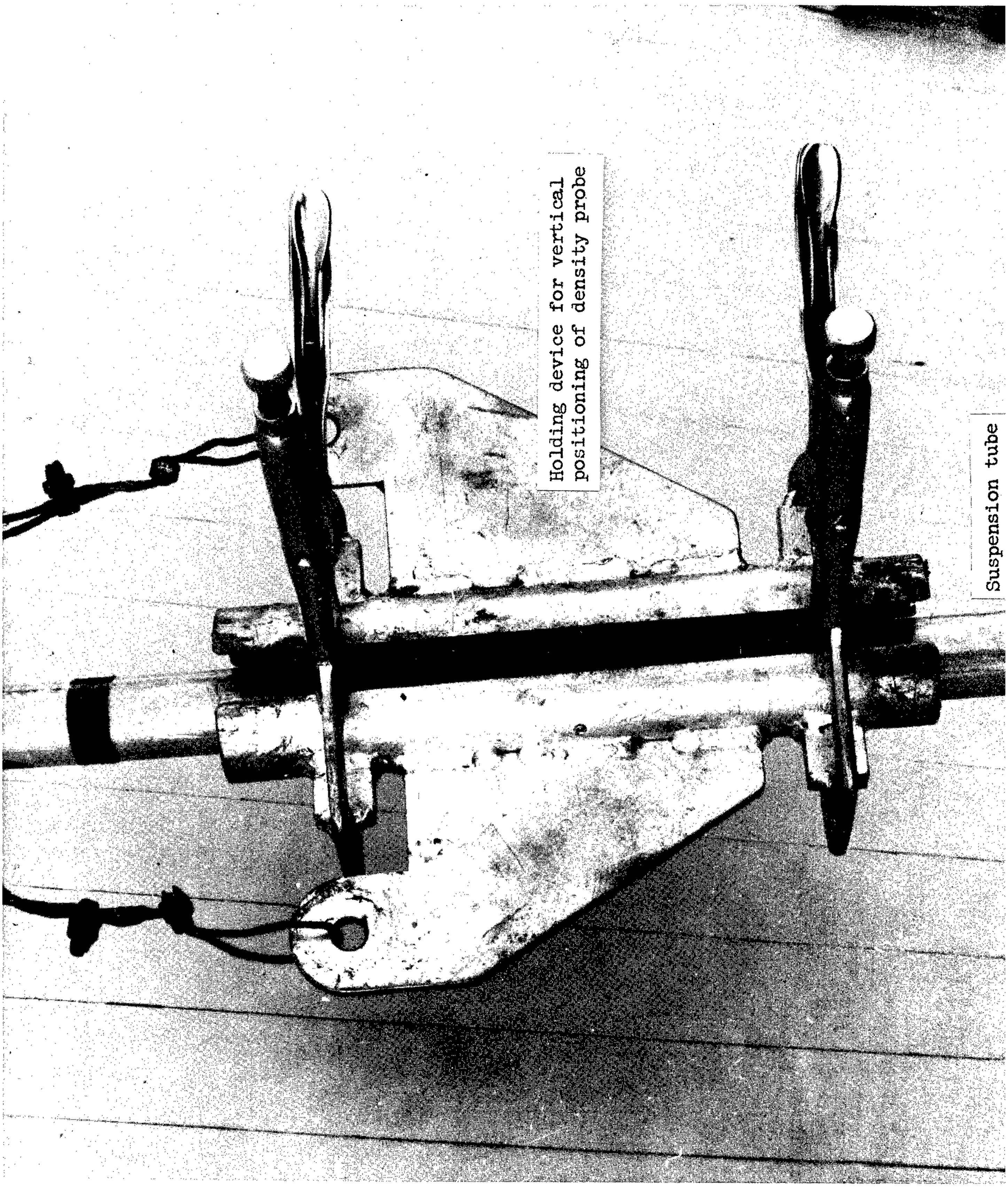
OPERATION MANUAL PHOTO 1

Sediment density probe with cable & storage case

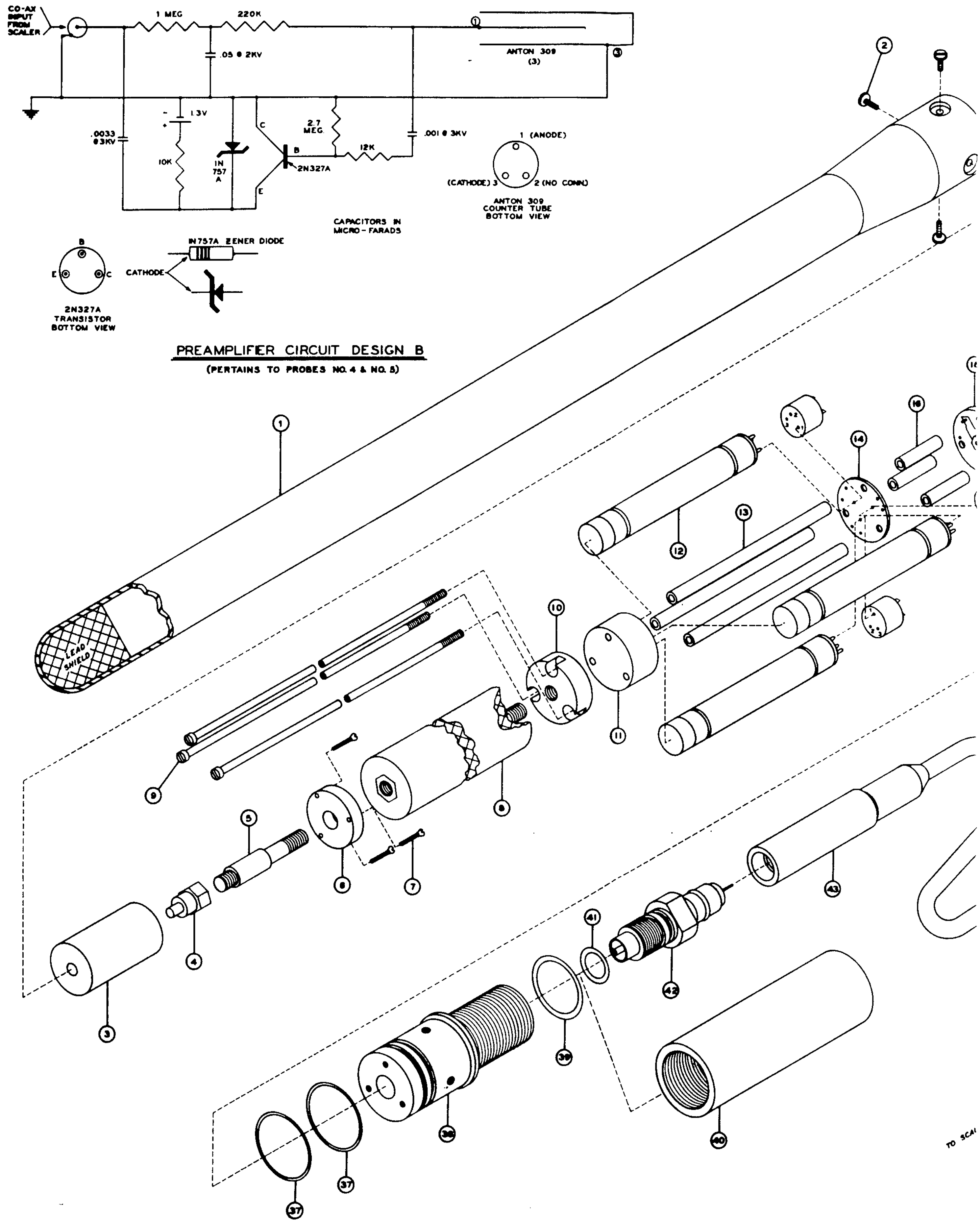


View of interior chassis

OPERATION MANUAL PHOTO 3

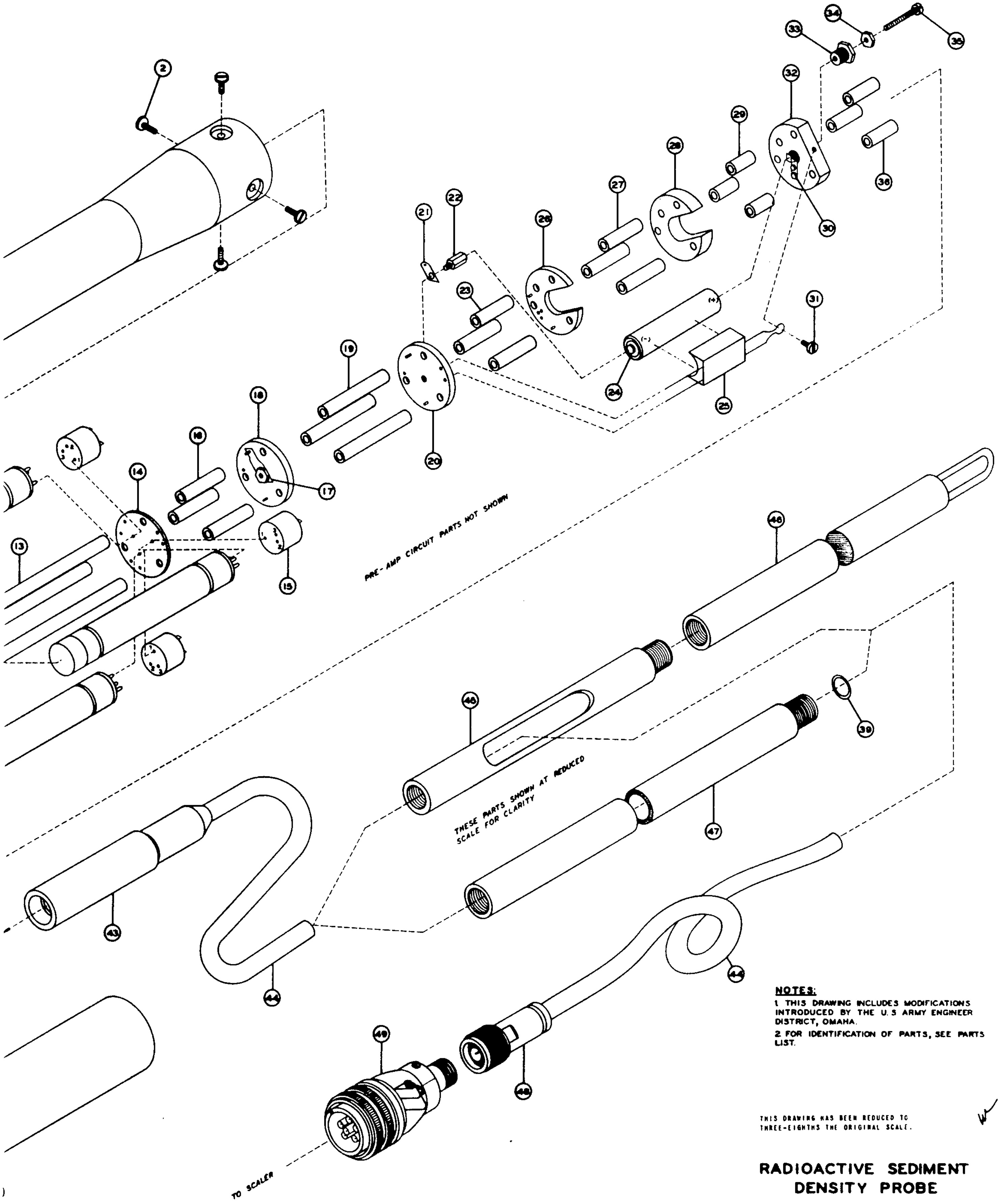


OPERATION MANUAL PHOTO 4



PREAMPLIFIER CIRCUIT DESIGN B

(PERTAINS TO PROBES NO. 4 & NO. 5)



NOTES:

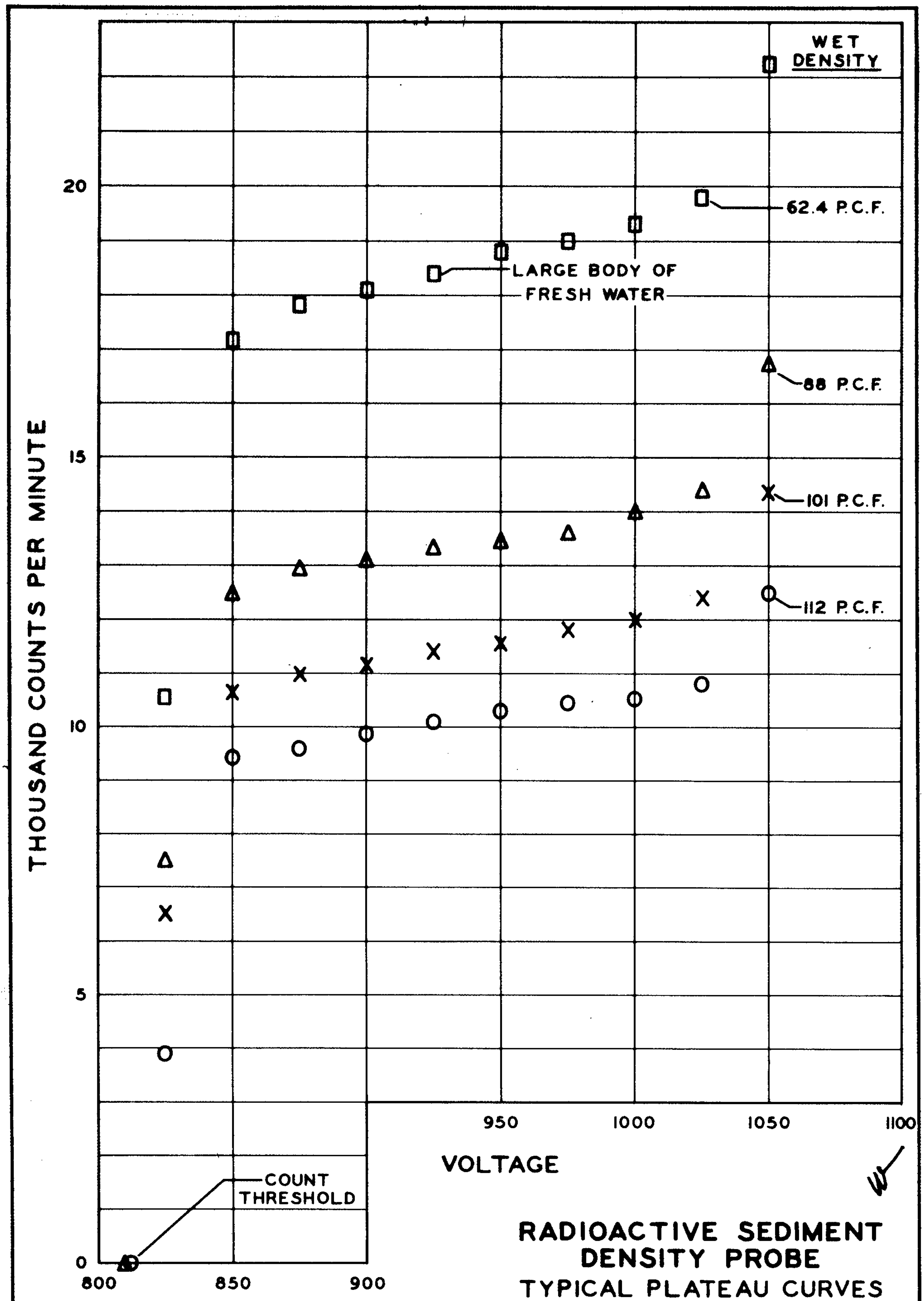
1. THIS DRAWING INCLUDES MODIFICATIONS INTRODUCED BY THE U. S ARMY ENGINEER DISTRICT, OMAHA.
2. FOR IDENTIFICATION OF PARTS, SEE PARTS LIST.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

RADIOACTIVE SEDIMENT DENSITY PROBE

EXPLODED ASSEMBLY DRAWING

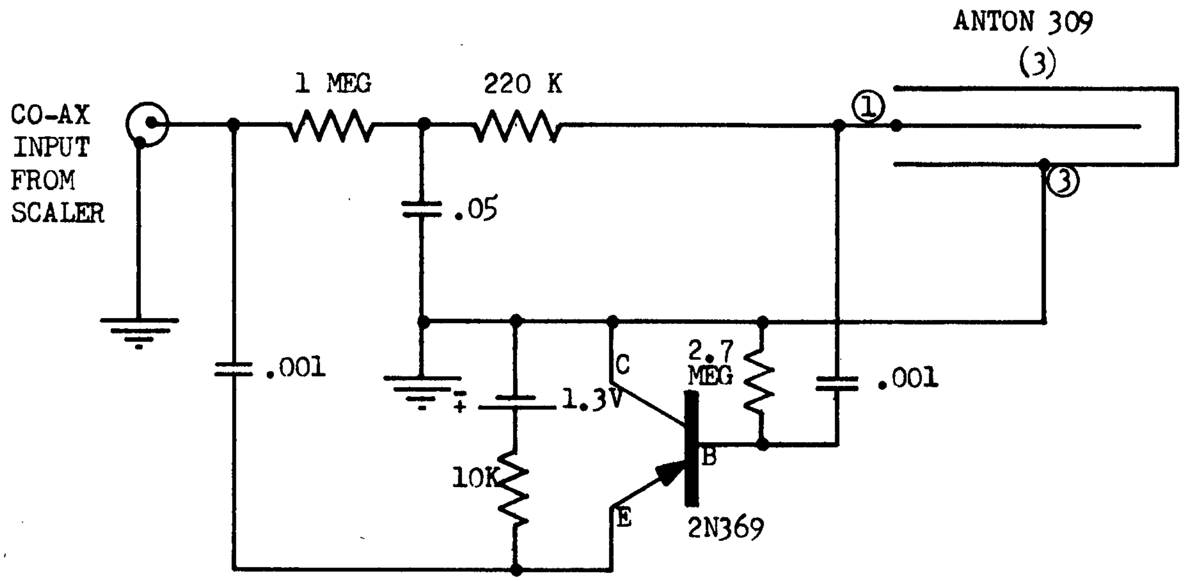
JANUARY 1965



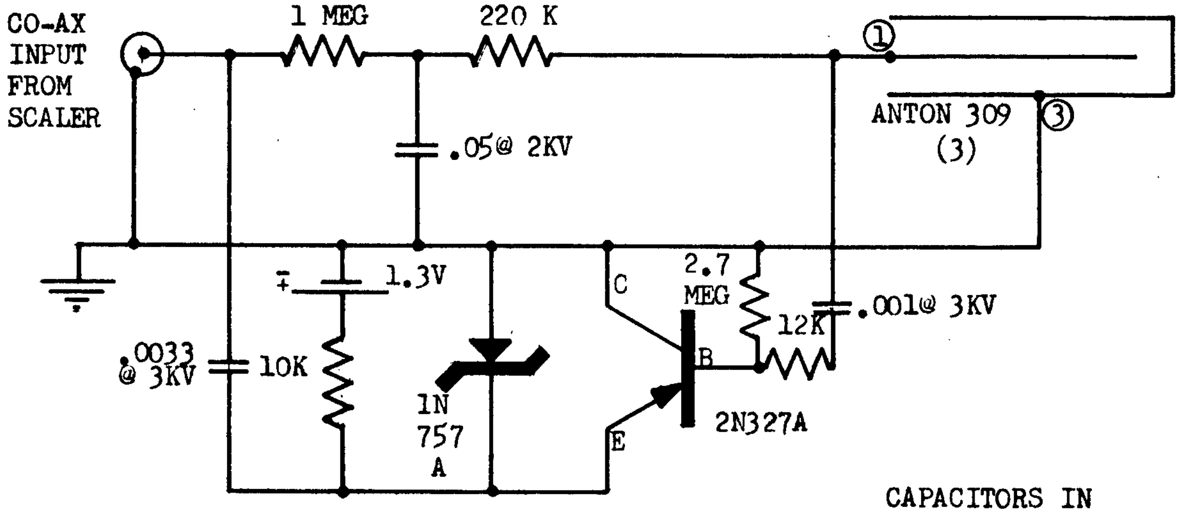
RADIOACTIVE SEDIMENT DENSITY PROBE

TYPICAL PLATEAU CURVES FOR VARIOUS DENSITIES

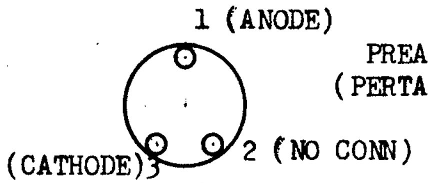
JULY 1965



PREAMP CIRCUIT DESIGN A
(PERTAINS TO PROBES #1, #2 & #3)



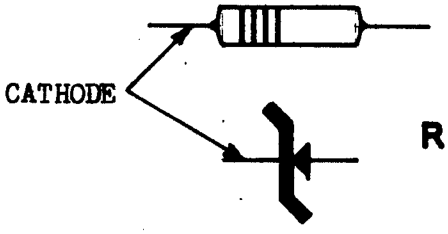
CAPACITORS IN
MICRO-FARADS

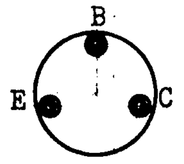


PREAMP CIRCUIT DESIGN B
(PERTAINS TO PROBES #4 & #5)

ANTON 309
COUNTER TUBE
BOTTOM VIEW

1N 757A ZENER DIODE



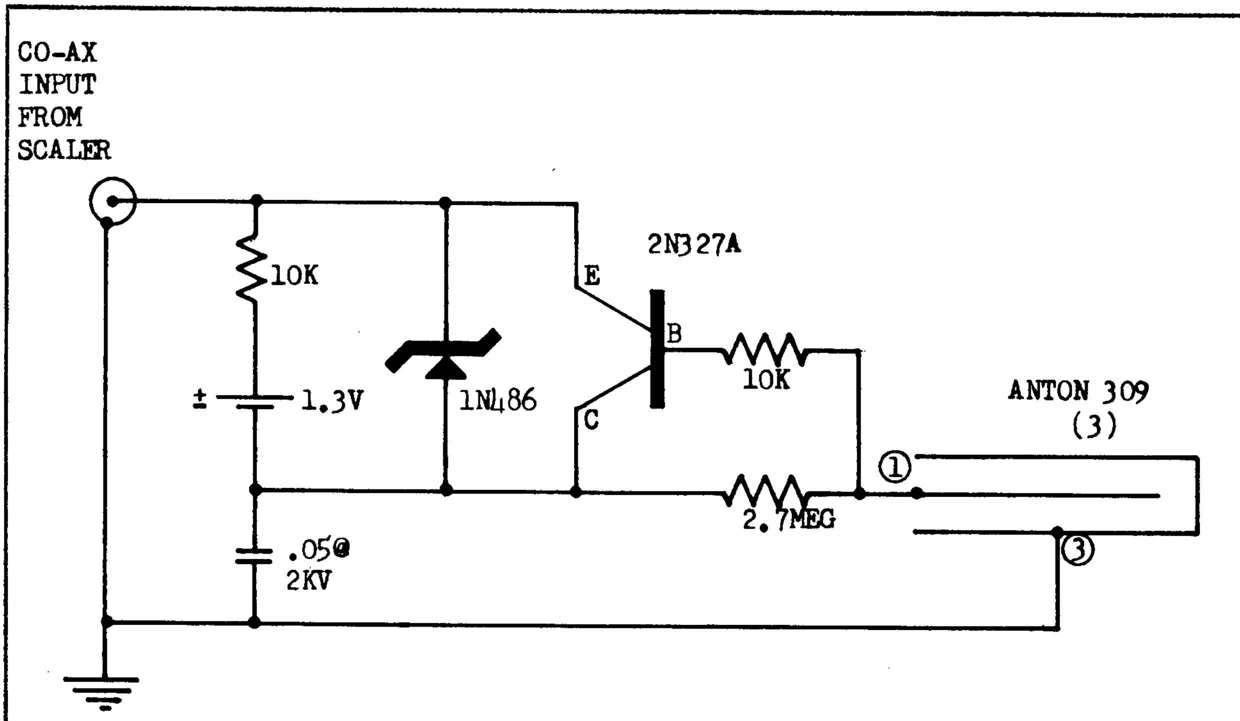


2N369 & 2N327A
TRANSISTOR
BOTTOM VIEW

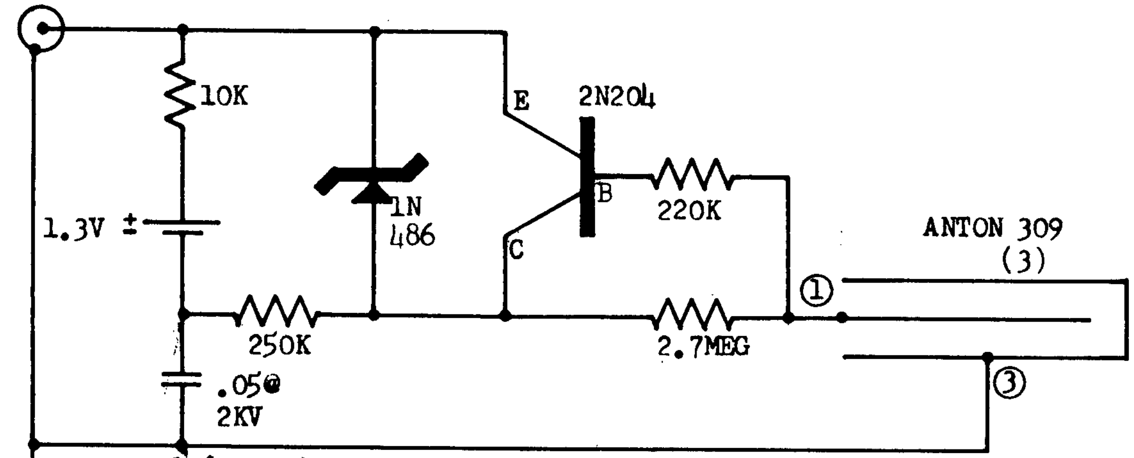
RADIOACTIVE SEDIMENT DENSITY PROBE

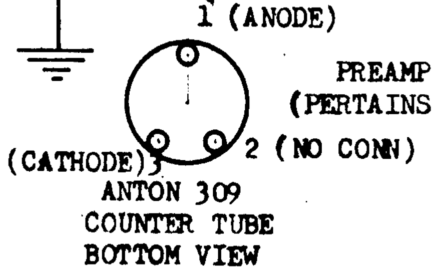
PREAMPLIFIER CIRCUIT DESIGNS A & B

JULY 1965



PREAMP CIRCUIT DESIGN C
(PERTAINS TO PROBE #6)



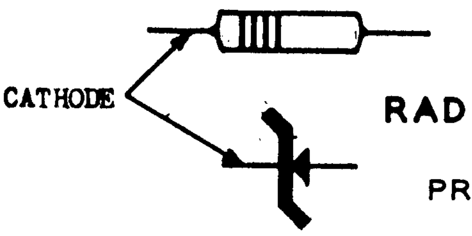


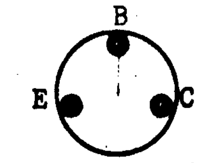
ANTON 309
COUNTER TUBE
BOTTOM VIEW

PREAMP CIRCUIT DESIGN D
(PERTAINS TO PROBES #7, #8 & #9)

CAPACITORS IN
MICRO-FARADS

1N 486 ZENER DIODE



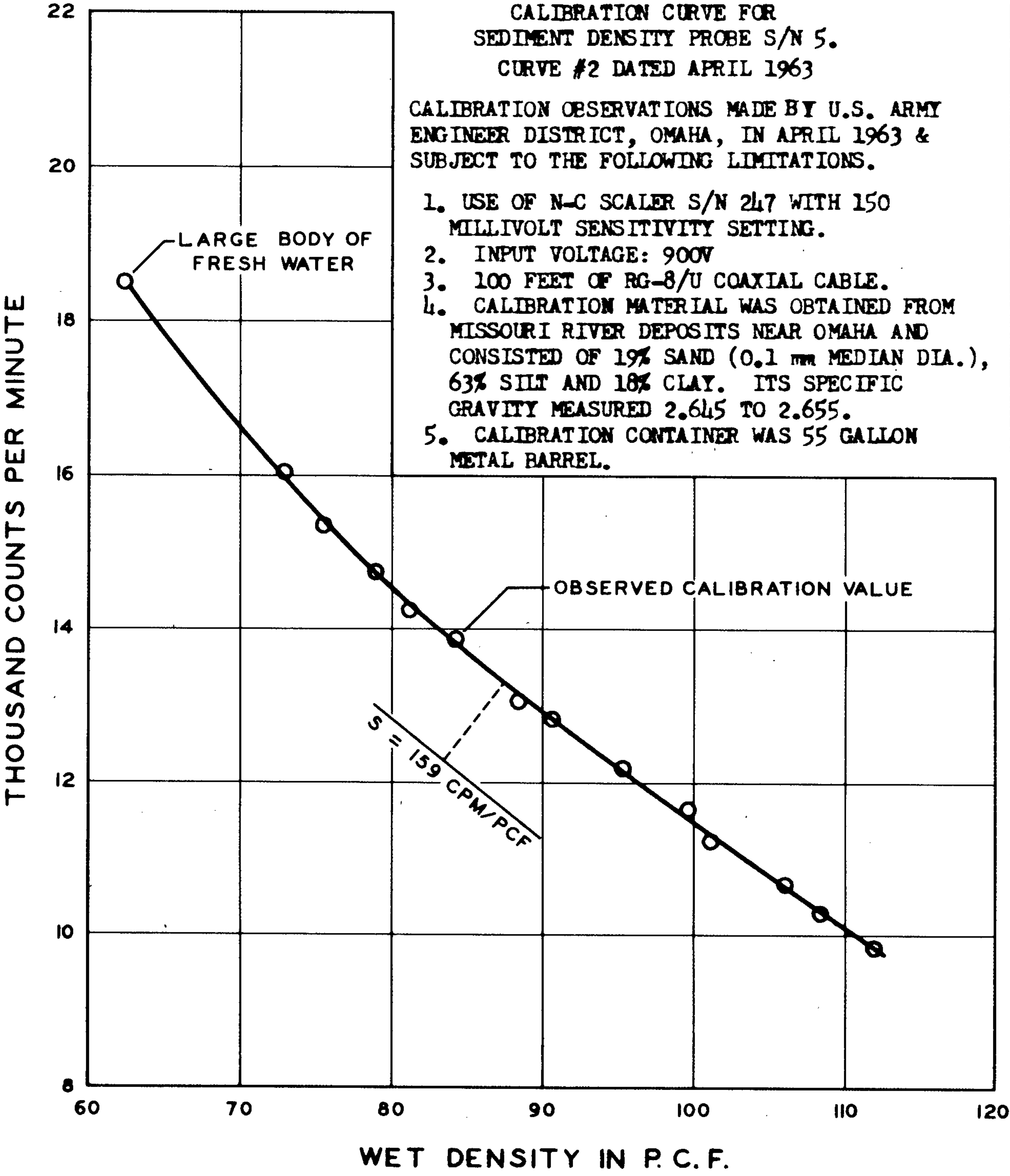


2N327A & 2N204
TRANSISTOR
BOTTOM VIEW

RADIOACTIVE SEDIMENT DENSITY PROBE

PREAMPLIFIER CIRCUIT DESIGNS C & D

JULY 1965

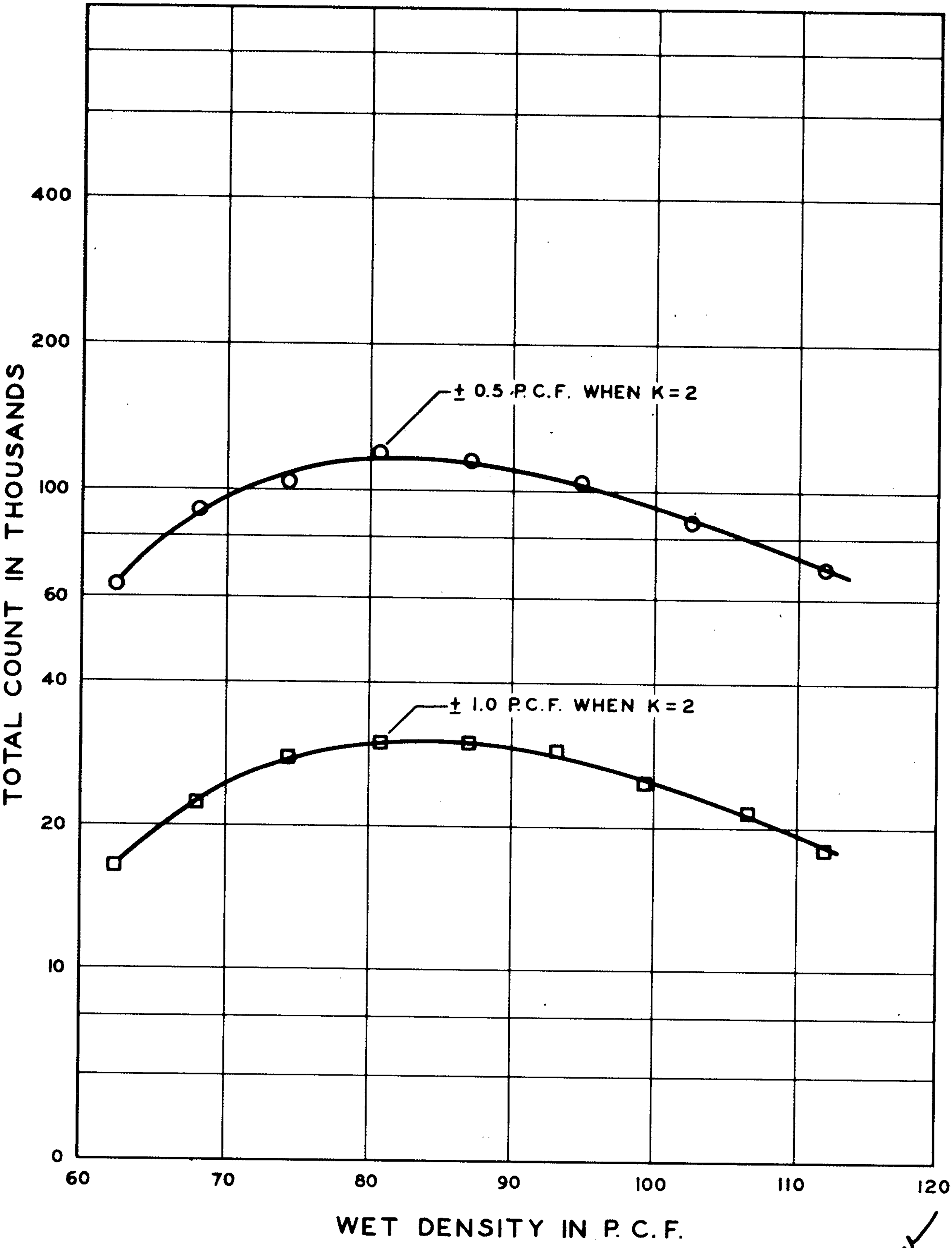


CALIBRATION CURVE FOR
SEDIMENT DENSITY PROBE S/N 5.
CURVE #2 DATED APRIL 1963

CALIBRATION OBSERVATIONS MADE BY U.S. ARMY ENGINEER DISTRICT, OMAHA, IN APRIL 1963 & SUBJECT TO THE FOLLOWING LIMITATIONS.

1. USE OF N-C SCALER S/N 247 WITH 150 MILLIVOLT SENSITIVITY SETTING.
2. INPUT VOLTAGE: 900V
3. 100 FEET OF RG-8/U COAXIAL CABLE.
4. CALIBRATION MATERIAL WAS OBTAINED FROM MISSOURI RIVER DEPOSITS NEAR OMAHA AND CONSISTED OF 19% SAND (0.1 mm MEDIAN DIA.), 63% SILT AND 18% CLAY. ITS SPECIFIC GRAVITY MEASURED 2.645 TO 2.655.
5. CALIBRATION CONTAINER WAS 55 GALLON METAL BARREL.

RADIOACTIVE SEDIMENT
DENSITY PROBE
TYPICAL CALIBRATION CURVE
JULY 1965



RADIOACTIVE SEDIMENT DENSITY PROBE

RELATIONSHIP OF MEASUREMENT
ACCURACY TO TOTAL COUNT
JULY 1965

APPENDIX A

PARTS LIST

(SEE PLATE 1 FOR EXPLODED ASSEMBLY VIEW)

Part No.	No. Req'd	Description
1	1	Probe sheath, 1-1/2" O.D. x 0.065" thick stainless steel tube with 2" lead shield insert in tip
2	4	Sheath screws, #8 - 32 N.C. x 3/8" long, stainless steel
3	1	Lucite shroud, 1-1/4" O.D. x 1-3/4" long
4	1	Radium 226 source, 3 millicuries, double sealed into Tech/Ops A-411 holding capsule
5	1	Capsule support rod, with 3/8" - 16 N.C. thread
6	1	Shroud support plate, metal, 1-5/16" O.D. x 1/4" thick
7	3	Shroud screws, flat head machine screw #8 - 32 N.C. x 1/2" long
8	1	Lead shielding cylinder, 1-5/16" O.D. x 6" long with 3/8" - 16 N.C. tap and stud threads
9	3	Chassis tie rods, stainless steel, #10 - 32 N.F. special flat head machine screw 11-1/4" long
10	1	Bottom chassis plate, metal, 1-5/16" O.D. x 3/8" thick, with 3/8" - 16 N.C. tap
11	1	Plexiglas spacer, 1-5/16" O.D. x 5/8" thick
12	3	Gamma counter tube, Lionel/Anton type #309
13	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 3-7/8" long
14	1	Chassis plate, Micarta or similar insulating material, 1-5/16" O.D. x 1/16" thick
15	3	Counter tube sockets, modified from Amphenol miniature connector #78 - S3S
16	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 1" long

PARTS LIST (Cont'd)

Part No.	No. Req'd	Description
17	1	Solder lug and capacitor nut
18	1	Chassis plate, Micarta or similar, 1-5/16" O.D. x 1/8" thick
19	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 1-1/2" long
20	1	Chassis plate, Micarta or similar, 1-5/16" O.D. x 1/8" thick
21	1	Solder lug
22	1	Battery ground pin
23	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 13/16" long
24	1	Mercury battery, Burgess #Hg 502R or equivalent
25	1	Battery support bracket and pin
26	1	Chassis plate, Micarta or similar, 1-5/16" O.D. x 1/8" thick
27	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 13/16" long
28	1	Chassis plate, Micarta or similar, 1-5/16" O.D. x 1/4" thick
29	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 7/16" long
30	1	Battery contact lug with holding screws
31	1	Binding-head screw, #6 - 32 N.C.
32	1	Chassis plate, Micarta or similar, 1-5/16" O.D. x 1/4" thick
33	1	Threaded bushing with #6 - 32 N.C. tap
34	1	Machine screw nut, #6 - 32 N.C.
35	1	Battery contact screw, #6 - 32 N.C. x 3/4" long

PARTS LIST (Cont'd)

Part No.	No. Req'd	Description
36	3	Chassis spacer tube, stainless steel, 1/4" O.D. x 5/8" long
37	2	"O" ring, neoprene, 1-7/32" x 1-11/32" x 1/16"
38	1	Chassis body plug, with 1-1/4" - 12 N.F. threads
39	1	"O" ring, neoprene, 1-3/16" x 1-7/16" x 1/8"
40	1	Protection tube for male coaxial pin, 1-1/2" O.D. x 4" long with 1-1/4" - 12 N.F. tap
41	1	"O" ring, neoprene, 5/8" x 27/32" x 7/64"
42	1	Coaxial connector, male, Mecca #2437
43	1	Coaxial connector, female, Mecca #2228
44	1	Coaxial cable, 100 feet, #RG-8/U
45	1	Adaptor, for cable suspension weight, 1-1/2" O.D. x 12" long with 1-1/4" - 12 N.F. threads
46	1	Cable suspension weight, 1-1/2" O.D. x 30" long or as required with 1-1/4" - 12 N.F. tap
47	8	Rigid suspension tubes, 1-1/2" O.D. x 6' long with 1-1/4" - 12 N.F. threads
48	1	Coaxial connector, male #UG 21 C/U
49	1	Scaler coaxial connector, #PM 6S/HV - 3108B20 with female adaptor, UG 680/U
50	1	Storage case, for probe and coaxial cable, complete with protective radiation shield

Notes:

1. Pre-amplifier circuit parts are not listed due to their common identification and the occasional modification of circuit design. See various pre-amp schematics for identification of individual components.

2. Certain standard parts have been modified to meet the dimension requirements of this instrument. In these instances a complete description of the part may be lacking.

APPENDIX B

REFERENCE PUBLICATIONS

1. Final Report on Development of a Sediment Density Probe by Dr. I. L. Kofsky, Project Scientist with Technical Operations, Inc. Burlington Mass., furnished as report No. TOI 58-5 to the Ohio River Division Laboratories, Corps of Engineers, U.S. Army in March 1958.

2. Development and Tests of a Radioactive Sediment Density Probe by J. M. Caldwell. Published as Technical Memorandum #121 by the U.S. Army Coastal Engineer Research Center in September 1960.

3. Instruction Manual for Technical Operations Model 497B Silt and Sediment Density Probe.

4. Operation and Maintenance Manual for Nuclear - Chicago Portable Sealer, Model 2800.

5. Determination of Densities of Reservoir Sediments <u>In Situ</u> with a Gamma Probe by J. R. McHenry, Sedimentation Laboratory, Agricultural Research Service, Oxford, Mississippi.