Recommended Practice for Shale Shaker Screen Cloth Designation

API RECOMMENDED PRACTICE 13E (RP13E)
THIRD EDITION, MAY 1, 1993

American Petroleum Institute
1220 L Street, Northwest
Washington, DC 20005

Issued by
AMERICAN PETROLEUM INSTITUTE
Production Department

FOR INFORMATION CONCERNING TECHNICAL CONTENTS OF THIS PUBLICATION CONTACT THE API PRODUCTION DEPARTMENT, 1201 MAIN STREET, SUITE 2535, DALLAS, TX 75202-3994 — (214) 748-3841. SEE BACK COVER FOR INFORMATION CONCERNING HOW TO OBTAIN ADDITIONAL COPIES OF THIS PUBLICATION.

Users of this publication should become familiar with its scope and content. This publication is intended to supplement rather than replace individual engineering judgment.

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

TABLE OF CONTENTS

Attention Users of this Publication: Portions of this publication have been changed from the previous edition. The location of changes has been marked with a bar in the margin. In some cases the changes are significant, while in other cases the changes reflect minor editorial adjustments. The bar notations in the margins are provided as an aid to users to identify those parts of this publication that have been changed from the previous edition, but API makes no warranty as to the accuracy of such bar notations.

Note:
This third edition supersedes the second edition of RP 13E dated May 1, 1985 and represents changes adopted at the 1992 Standardization Conference, and subsequently approved by letter ballot.

FOREWORD

a. This recommended practice is under the jurisdiction of the API Committee on the Standardization of Drilling Fluid Materials.

b. The purpose of this practice is to provide standard procedures for the labeling of shale shaker screen cloths. It is not a manual on solids control procedures. It provides a method for the direct comparison of the majority of the currently available screen cloths, independent of the type of machine on which they are installed or the type of screen configuration (i.e. square weave, oblong weave, layered, or panel design).

c. This recommended practice is organized such that the recommended label, its position and the information required to be included on the label are described first. The procedures used to obtain the information for the label are then described and example calculations are shown.

d. Use of the practice will allow direct comparison of screens on parameters such as separation potential, the ability of a screen to pass fluid, and the amount of area available for screening. From these values other comparative performance characteristics can be calculated at the discretion of the user. With this information, the user can select the screen type that most adequately suits the needs of the operation.

e. Additional publications under the jurisdiction of this committee include:

Spec 13A	Specification for Drilling Fluid Materials
RP 13B-1	Recommended Practice Standard Procedure for Field Testing Water Based-Drilling Fluids
RP 13B-2	Recommended Practice Standard Procedure for Field Testing Oil Based-Drilling Fluids
Bul 13C	Bulletin on Drilling Fluids Processing Equipment
Bul 13D	Bulletin on the Rheology of Oil Well Drilling Fluids
RP 13G	Recommended Practice for Drilling Mud Report Form
RP 13I	Recommended Practice for Laboratory Testing of Drilling Fluids
RP 13J	Recommended Practice for Testing Heavy Brines
RP 13K	Recommended Practice for Chemical Analysis of Barite

POLICY

(1) API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

(2) API IS NOT UNDERTAKING TO MEET DUTIES OF EMPLOYERS, MANUFACTURERS OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHER EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

(3) NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

(4) GENERALLY, API STANDARDS ARE REVIEWED AND REVISED, REAFFIRMED, OR WITHDRAWN AT LEAST EVERY FIVE YEARS. SOMETIMES A ONE-TIME EXTENSION OF UP TO TWO YEARS WILL BE ADDED TO THIS REVIEW CYCLE. THIS PUBLICATION WILL NO LONGER BE IN EFFECT FIVE YEARS AFTER ITS PUBLICATION DATE AS AN OPERATIVE API STANDARD OR WHERE AN EXTENSION HAS BEEN GRANTED, UPON REPUBLICATION. STATUS OF THE PUBLICATION CAN BE ASCERTAINED FROM THE API AUTHORING DEPARTMENT (TEL. 214-748-3841). A CATALOG OF API PUBLICATIONS AND MATERIALS IS PUBLISHED ANNUALLY AND UPDATED QUARTERLY BY API, 1220 L ST., N.W., WASHINGTON, D.C. 20005.

(5) HEALTH AND SAFETY CONSIDERATIONS. THIS PUBLICATION DOES NOT ADDRESS HEALTH AND SAFETY PRECAUTIONS FOR THESE PROCEDURES. PLEASE REFER TO THE U.S. DEPARTMENT OF LABOR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION REGULATION "OCCUPATIONAL EXPOSURE TO HAZARDOUS CHEMICALS IN THE LABORATORY." 29 CFR (CODE OF FEDERAL REGULATIONS) 1910.145.*

SEE ALSO, OSHA PERMISSIBLE EXPOSURE LIMITS (PELS) FOR BARIUM AND OTHER MATERIALS REFERENCED: 29 CFR 1910.1000 AND AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS, THRESHOLD LIMIT VALUES® (TLV's).** INFORMATION CONCERNING SAFETY AND HEALTH RISKS AND PROPER PRECAUTIONS WITH RESPECT TO PARTICULAR MATERIALS AND CONDITIONS SHOULD BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

(6) AMERICAN PETROLEUM INSTITUTE (API) SPECIFICATIONS ARE PUBLISHED AS AIDS TO THE PROCUREMENT OF STANDARDIZED EQUIPMENT AND MATERIALS, AS WELL AS INSTRUCTIONS TO MANUFACTURERS OF EQUIPMENT OR MATERIALS COVERED BY AN API SPECIFICATION. THESE SPECIFICATIONS ARE NOT INTENDED TO OBVIATE THE NEED FOR SOUND ENGINEERING, NOR TO INHIBIT IN ANY WAY ANYONE FROM PURCHASING OR PRODUCING PRODUCTS TO OTHER SPECIFICATIONS.

(7) THE FORMULATION AND PUBLICATION OF API SPECIFICATIONS AND THE API MONOGRAM PROGRAM IS NOT INTENDED IN ANY WAY TO INHIBIT THE PURCHASE OF PRODUCTS FROM COMPANIES NOT LICENSED TO USE THE API MONOGRAM.

(8) API SPECIFICATIONS MAY BE USED BY ANYONE DESIRING TO DO SO, AND DILIGENT EFFORT HAS BEEN MADE BY THE INSTITUTE TO ASSURE THE ACCURACY AND RELIABILITY OF THE DATA CONTAINED THEREIN. HOWEVER, THE INSTITUTE MAKES NO REPRESENTATION, WARRANTY, OR GUARANTEE IN CONNECTION WITH THE PUBLICATION OF ANY API SPECIFICATION AND HEREBY EXPRESSLY DISCLAIMS ANY LIABILITY OR RESPONSIBILITY FOR LOSS OR DAMAGE RESULTING FROM THEIR USE, FOR ANY VIOLATION OF ANY FEDERAL, STATE, OR MUNICIPAL REGULATION WITH WHICH AN API SPECIFICATION MAY CONFLICT, OR FOR THE INFRINGEMENT OF ANY PATENT RESULTING FROM THE USE OF AN API SPECIFICATION.

(9) ANY MANUFACTURER PRODUCING EQUIPMENT OR MATERIALS INTENDED TO CONFORM TO AN API SPECIFICATION IS RESPONSIBLE FOR COMPLYING WITH ALL THE PROVISIONS OF THAT SPECIFICATION INCLUDING ALL THE APPLICABLE PROVISIONS OF API SPEC Q1, *SPECIFICATION FOR QUALITY PROGRAMS,* REQUIRED BY THE PRODUCT SPECIFICATION. THE AMERICAN PETROLEUM INSTITUTE DOES NOT REPRESENT, WARRANT OR GUARANTEE THAT SUCH PRODUCTS DO IN FACT CONFORM TO THE APPLICABLE API STANDARD OR SPECIFICATION.

* Government printing office, Superintendent of documents, Washington, D.C. 20402.

**Trademark term of American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Bldg. D-5, Cincinnati, OH 45211.

SECTION 1
SHAKER SCREEN LABELING

1.1 Description

a. Oil field shaker screens are manufactured in a number of configurations. This diversity in manufacturing causes considerable confusion about the performance characteristics of each type of screen. Consequently, selecting the proper screen for a particular application frequently becomes a matter of trial and error.

b. In order to provide a common ground for comparing the separation characteristics of different types of screens, a tag will be affixed to the screen in such a position that it will be both visible and legible after the screen is installed in the shaker. The exact placement of the tag and its material composition are left to the discretion of the supplier. The information contained on the tag will be recorded in such a manner that it will remain indelible for the life of the screen.

c. The components of the designation system provide a complete description of the screen's identification and performance parameters. The designation system consists of the following elements:

Manufacturer's Designation

Separation Potential (d_{50}, d_{16}, d_{84} "Cutt" points)*

Flow Capacity (Conductance and Total Non-Blanked Area)

1.2 Manufacturer's Designation

The manufacturer's designation is the combination of letters and numbers used by the manufacturer to describe the screen. The information contained in this designation will depend upon the individual manufacturer and may contain the screen panel type, composition, and other information deemed essential by the manufacturer.

1.3 Separation Potential

a. The separation potential of the screen is recorded in terms of the d_{50}, d_{16}, and d_{84} "Cutt" points. The "Cutt" points are the spherical diameters corresponding to the ellipsoidal volume distribution of the screen's opening sizes. The separation potential of a screen is presumed to be directly related to this distribution. This is usually a valid assumption since the <u>relative separation efficiency</u> of shaker screens must be related to the size of their openings. "Cutt" point measurements are described in Section 3.

***NOTE:** *The terminology "Cutt" (pronounced "koot") point is used to differentiate separation potential from the traditional particle size cut points normally associated with separation devices. The terminology recognizes the efforts of the individual who first applied the technique to shaker screen cloths and published the results in SPE Paper #22570, "Shaker Screen Characterization Through Image Analysis."*

b. The term "separation potential" is used because the experimentally determined grade separation efficiency curve will not necessarily agree with the separation potential curve. Factors such as solids loading, fluid viscosity, shaker dynamics, and drill cuttings shape will have a considerable effect on the experimentally determined grade separation efficiency. However, the ranking of each screen's <u>relative</u> separation ability under similar conditions will be in agreement between the two methods. Because separation potential is a function of only the screen composition, it provides a constant scale by which to rank the separation performance of shaker screens.

c. The d_{50} "Cutt" point is the median, volume distribution of the opening (aperture) sizes, in microns. In relation to grade separation efficiency, the d_{50} "Cutt" point is comparable (but not identical) to the d_{50} cut point commonly used to represent the size of solid that has a 50% probability of removal by a device. Because of its importance, it is listed before the d_{16} and d_{84} values.

d. The d_{16} and d_{84} "Cutt" point values are used to indicate the range of screen aperture sizes present in the screen. They represent the size of the 16th and 84th percentiles of the volume distribution of the aperture sizes in the screen.

As the difference between these two values increases around a common d_{50} point, the slope of the separation potential curve becomes less vertical. This implies that a larger total volume percentage of finer solids will be removed and that a larger percentage of solids coarser than the d_{50} size will not be removed. Triple-layer screens will <u>generally</u> have a larger spread between the d_{16} and d_{84} points than a single square mesh screen with the same d_{50} size. These values can be significant when the removal of fine solids from an unweighted mud is important or when the unwanted removal of barite from a weighted mud is a concern.

e. Flow capacity is the rate at which a shaker can process mud and solids. It is a function of many variables including shaker configuration, design and motion, mud rheology, solids loading, and blinding by near size particles. This is an extremely complex system for which no satisfactory model currently exists. However, for a given shaker under constant conditions, flow capacity is largely controlled by the screen parameters of conductance and area.

Conductance, measured in units of kilodarcies/ millimeter, defines the ease with which fluid can flow through a unit area of screen. In very simplistic terms, it can be thought of as the permeability of the screen. Conductance is calculated from the mesh count and wire diameters of the screen.

The area available for screening is the net unblocked area, in square feet, that will permit the passage of fluid. Some screen designs may eliminate as much as 40% of the gross screen panel area from fluid flow due to backing plate and bonding material blockage. The total non-blanked area of a shaker screen panel is therefore important when considering the flow capacity of the screen.

SECTION 2
SHAKER SCREEN SEPARATION POTENTIAL

2.1 Description

a. This procedure is a method for determining the separation potential of shale shaker screens through the visual analysis of their openings, or apertures.

b. Definitions

Aperture	the opening between the wires in a screen cloth.
Martin's Radii	the distance from the centroid of an object to its outer boundary. The direction of this measurement is specified by the azimuthal orientation of the line (The radii in the 0°, 90°, 180°, 270° angle from horizontal).
pixel	the smallest unit of a video picture, composed of a single color or grey level.
separation potential	the relative potential grade efficiency of a screen composition as defined by the ellipsoidal volume distribution of its openings as a function of spherical diameter, also called the "Cutt" point distributions.
shute	in a woven cloth, the direction of the wires running perpendicular to the loom.
warp	in a woven cloth, the direction of the wires running parallel with the loom.

2.2 Equipment

a. Image Analyzer System: An image analyzer processes and dimensionally analyzes the raster graphics images produced by a video camera and captured by a video image converter (frame-grabber). Most image analyzer systems use two monitors: one for viewing the video image of the subject material and the second for display of input/output test data of the PC software.

Several PC-based image analyzer systems are commercially available. For this application, the image analyzer software must provide the capability to simultaneously measure the Martin's Radii dimensions of up to 50 screen apertures per image. This dimensional data must be made available in an ASCII or spreadsheet-compatible format for subsequent manipulation. The camera, frame-grabber and display monitor must provide a minimum resolution of 512 x 512 pixels.

b. Microscope: The resolution of the image analyzer system is primarily linked to the microscope magnification. For accurate dimensional analyses of typical screen cloth samples with up to 460 openings per lineal inch, a wide field microscope such as the Olympus SZH Zoom Stereo Microscope equipped with a phototube and the following optics is required:

Specifications:	Objective:	1x, 2x
	Zoom:	7.5 to 64x
	Photo eyepiece:	2.5x, 3.3x, 5.0x

c. Illuminator Table: A light table with sufficient illuminated area to support and backlight the screen sample is required to enhance contrast between the wires and the apertures in the cloth.

d. Video Camera: The video camera captures the magnified image from the microscope and feeds a raster graphics image to a frame grabber board within the minicomputer for image processing and display on a television monitor. The frame grabber is usually supplied as part of the image analysis system. Refer to the image analysis system manufacturer's recommendations regarding minimum camera requirements for this application.

e. Example Equipment List: The following equipment or equivalent can be used for this procedure:

Computer:	IBM-Compatible 386 MHz with
	- 2Mb RAM, Math Coprocessor
	- VGA Monitor
	- Frame Grabber Board with 512 x 512 pixel resolution
Software:	Olympus Cue-2 Image Analyzer
	Lotus 123 Spreadsheet
Microscope:	Olympus Model SZH
	Olympus MTV 3 Phototube Boom Mount
Optics:	Olympus DF Plan 1x Objective
	Olympus DF Plan 2x Objective
	NFK 2.5x Photoeyepiece
	NFK 3.3x Photoeyepiece
	NFK 5.5x Photoeyepiece
Video Camera:	Dage-MTI CCD72
Video Monitor:	Sony PVM 1910 Color Video Monitor
Illuminator Table:	Aristo HF-810

2.3 Procedure — Image Analyzer Calibration

Calibrate the image analyzer to the microscope magnification prior to analyses in both the x and y direction using standard microscope calibration slides. Refer to the calibration instructions for the specific image analysis system in use.

2.4 Procedure — Sample Preparation

a. Oil field shaker screens can be composed of one to three layers of screen cloth. Include only the top two layers of any composition in the analysis. The third "backing cloth" does not significantly affect a triple-layer screen's separation potential. Its inclusion will cause errors and depth-of-field problems during analysis.

Include both layers when screens are composed of a single screening mesh over a backing cloth. Although the backing cloth will not normally influence separation potential, it can begin to have an affect as its mesh count begins to approach that of the top cloth.

It should therefore be included. Refer to Procedure 2.5 for additional information.

Cloth samples may be taken directly "from the roll" and layered as required. Analysis may also be performed on an existing screen panel. Remember that the third "backing cloth" layer must be removed from triple-layer screen panels prior to analysis.

b. The screen cloth sample should have a minimum area of 3 square inches for ease of handling and be approximately equal in width and length.

c. Layered screen compositions built from individual samples should be held between glass slides or otherwise fixed so the layers remain in contact and cannot shift during analysis.

Confirm under the microscope that the top layer is correctly oriented relative to the bottom cloth and that the warp and shute wires are perpendicular in both layers.

d. Orient the sample to align the screen wires with the x and y axes on the image analysis monitor. Maintain this orientation throughout the remainder of this procedure.

Position screen cloth with rectangular apertures so that the major axis orientation of both the apertures and the pixels are the same. Because the pixels are rectangular, this maximizes the measurement accuracy of the image analyzer for this style of cloth.

2.5 Procedure — Magnification Selection

a. Select a microscope magnification calibrated to the image analyzer so that the individual pixel dimensions are approximately 5% or less of the top cloth's aperture dimensions.

NOTE: *As a general guideline for establishing calibrated magnification settings, select a combination of optics which maximizes depth of field at a magnification that yields no more than 50 apertures of the top screen cloth visible on the monitor. Calibrate the image analyzer for this magnification if necessary. This usually provides sufficient dimensional accuracy without appreciable loss of depth-of-field resolution for most layered screen compositions.*

b. In some instances the mesh count and wire diameter difference between the two layers is great enough to cause problems in achieving visual resolution of both layers at a suitable magnification level for dimensional analysis. This usually occurs when the ratio of mesh counts between the top and bottom cloth exceeds 4:1. In this case, the infrequency of aperture interference caused by the backing cloth will not perceptibly affect the separation potential characteristics of the shaker screen. Use a magnification sufficient for accurate dimensional analysis of the finer cloth. Disregard a lack of resolution of the bottom cloth.

2.6 Procedure — Image Enhancement and Processing

a. The image analyzer displays the screen cloth on the monitor as an image composed of pixels of different gray level intensities. Before dimensional analysis can be performed, the image must be converted to a binary (black and white) image.

It may be necessary to use the image enhancement features of the image analysis system software to heighten the contrast between the wires and the apertures to improve edge definition. The enhancement functions are also used to "clean up" the image prior to binary conversion and analysis. The enhancement functions available and the specific procedures used for image enhancement and processing will depend on the image analysis system used.

b. To verify the accuracy of the enhancement and binary conversion process, measure the resultant wire diameters of the top screen sample at three locations in both warp and shute directions as they appear in the binary video image. Confirm agreement between the measured wire diameters and those specified by the manufacturer of the wire cloth, within the accuracy limits of the image analyzer at that magnification.

c. If the wire diameters measured in Par. 2.6b do not agree with the manufacturer's specified diameters, remeasure the wire diameters with the image analyzer at a higher microscope magnification. If agreement is reached at this higher magnification, repeat the image enhancement procedure at the original magnification using different grey level settings for the binary conversion until agreement with the manufacturer's diameters is obtained.

If the wire diameters are confirmed to deviate from the manufacturer's specifications at the higher magnification, repeat the image enhancement procedure at the original magnification using the wire diameters established at the higher magnification.

NOTE: *At any magnification, the accuracy of the image analyzer is limited to +/- one-half the pixel dimension in the measurement direction. During aperture analysis, the pixel size is dimensionally larger than that used when confirming the wire diameters because the magnification is generally less. Thus, the accuracy of wire diameter measurements at aperture analysis magnification will be less. However, the average of several measurements taken at different locations on the image should agree with the previously established wire diameters within the accuracy limitations of this magnification.*

2.7 Procedure — Analysis

a. Once suitable grey level values have been selected for conversion of the screen images to binary form, proceed with dimensional analysis of each screen aperture for Martin's Radii (in microns) at 0, 90, 180, and 270 degrees orientation.

b. Analyze a minimum of 1500 apertures in layered screen compositions to ensure adequate statistical representation of the sample apertures. This number includes the resultant apertures created by interaction of the two screen cloth layers. Single layer screen samples will require analysis of a minimum of 750 apertures.

c. Collect each subsequent image diagonally across the sample such that the line of images sampled on the screen forms an "X" pattern: One set of images totaling half the required number of apertures are collected sequentially in a diagonal line from upper right to lower left. The remaining images are collected in a line perpendicular to the previous line.

d. Store this dimensional data, the Martin's Radii, in a format suitable for import into a spreadsheet program for further processing.

2.8 Procedure — Spreadsheet Calculations

a. Import the file containing the Martin's Radii values for the screen composition into a spreadsheet as 4 columns of data consisting of the Martin's Radii, in microns, at 0, 90, 180, and 270 degrees orientation. Each aperture is represented by a row of data.

b. For each aperture, create columns to contain the following data, as shown in Tables 2.1 and 2.2:

1. Major, Minor Axis Length

   a. Compute the horizontal length of each aperture, x, as the sum of the 0 and 180 degree Martin's radii.

   b. The sum of the 90 and 270 degree Martin's radii yields the vertical length, y, of each aperture.

   c. The major axis length of each aperture, l_a, is the greater of the x and y dimensions. Conversely, the minor axis length, l_b, is the lesser of the x and y dimensions.

2. Ellipsoidal Volume

   The ellipsoidal volume, Ve, of each aperture is calculated by:

$$V_e = \frac{\pi \times l_a \times l_b^2}{6} \qquad \text{(a)}$$

3. Spherical Diameter

   Each aperture's spherical diameter is given by:

$$D_s = \sqrt[3]{6 \frac{V_e}{\pi}} \qquad \text{(b)}$$

c. Sort the entire spreadsheet by ascending ellipsoidal volume.

d. Enter into the spreadsheet the cumulative volume percent of each aperture, computed by:

$$\text{Cum Vol, \%} = \frac{\sum_{i=1}^{n} V_{e_1}}{\sum V_e} \times 100 \qquad \text{(c)}$$

where: n = n^{th} aperture for which the cumulative volume percent is desired,

i = i^{th} aperture in the data set. The last aperture in the data set has a cumulative volume percent value of 100. Table 2.2 is an example of a completed spreadsheet.

e. A plot of cumulative volume percent as a function of spherical diameter should yield a smooth curve as shown in FIG. 2.1.

f. The d_{50} separation potential of the screen sample is reported as the spherical diameter, in microns, corresponding to 50 cumulative volume percent. The d_{16} and d_{84} separation potentials are the spherical diameters corresponding to 16 and 84 cumulative volume percent respectively.

To ensure accurate interpretation of the results, the separation potential values should be taken from the spreadsheet database rather than from a graphical display. Report the separation values to the nearest micron.

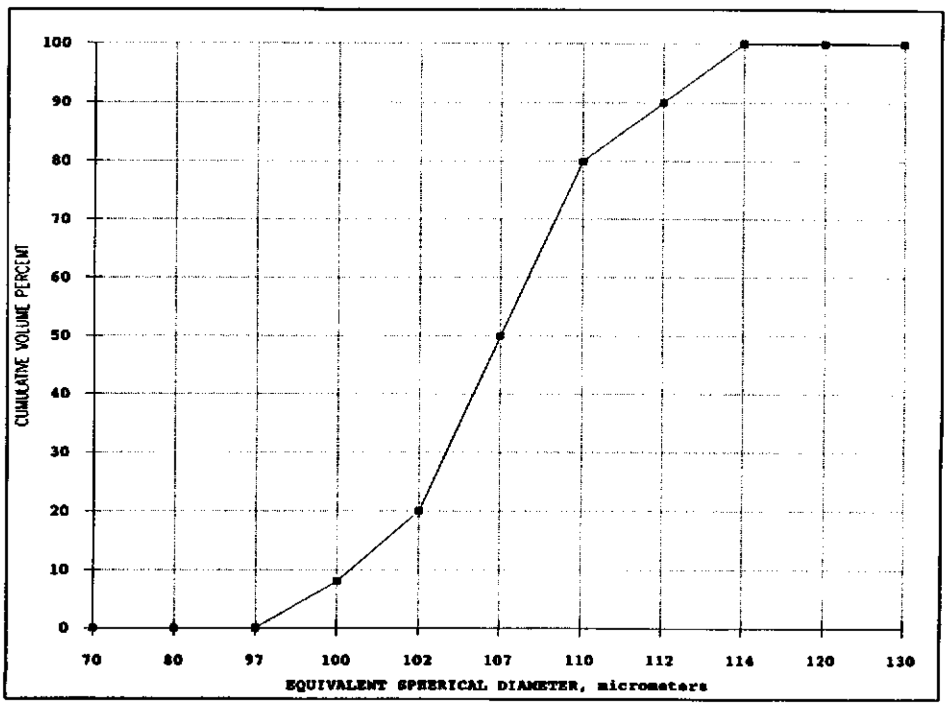

FIGURE 2.1
SEPARATION POTENTIAL CURVE
MARKET GRADE 150 X 150

TABLE 2.1
SAMPLE SPREADSHEET DATA, UNSORTED

MRTN 00	MRTN 90	MRTN 180	MRTN 270	MAJOR AXIS	MINOR AXIS	ELLIP. VOLUME	CUM. VOL. %	SPHERD IA.
49	54	49	57	111	98	559976		102
53	56	51	57	113	104	640056		107
49	56	47	59	115	96	553394		102
57	56	55	54	112	110	705655		110
51	52	51	54	106	102	579459		103
53	54	49	52	106	102	579459		103
55	52	53	57	110	108	669937		109
49	51	45	56	106	94	492128		98
51	56	49	56	111	100	583066		104
51	54	49	59	113	100	591768		104
55	56	55	56	111	110	705509		110
49	54	47	59	113	96	545374		101
49	54	47	56	110	96	529333		100
53	54	53	49	106	103	589354		104
53	51	49	56	106	102	579459		103
53	56	51	54	110	104	621231		106
49	54	49	54	108	98	543261		101
50	50	50	50	100	100	523599		100

TABLE 2.2
COMPLETED SPREADSHEET

MRTN 00	MRTN 90	MRTN 180	MRTN 270	MAJOR AXIS	MINOR AXIS	ELLIP. VOLUME	CUM. VOL. %	SPHER. DIA.
49	51	45	56	106	94	492128	4.5	98
50	50	50	50	100	100	523599	9.6	100
49	54	47	56	110	96	529333	14.6	100
49	54	49	54	108	98	543261	19.7	101
49	54	47	59	113	96	545374	24.9	101
49	56	47	59	115	96	553394	30.1	102
49	54	49	57	111	98	559976	35.4	102
53	54	49	52	106	102	579459	40.8	103
51	52	51	54	106	102	579459	46.3	103
53	51	49	56	106	102	579459	51.8	103
51	56	49	56	111	100	583066	57.3	104
53	54	53	49	106	103	589354	62.9	104
51	54	49	59	113	100	591768	68.4	104
53	56	51	54	110	104	621231	74.3	106
53	56	51	57	113	104	640056	80.4	107
55	52	53	57	110	108	669937	96.7	109
55	56	55	56	111	110	705509	93.3	110
57	56	55	54	112	110	705655	100.0	110
							TOTAL 1.06e+07	

SECTION 3
CONDUCTANCE

3.1 Description

a. Conductance is a measure of the ease with which fluid can flow through the screen per unit area. The conductance of square mesh or rectangular mesh screen cloth is calculated from the screen's mesh count and wire diameter in both the warp and shute direction. The equations are valid for most standard open-weave oil field screens with the exception of some non-standard polyester weaves and coated screen cloths. The conductance of these non-standard weaves can be measured experimentally by the procedure outlined in the Appendix A.

The equations used to calculate the conductance in this procedure are identical to those used in the literature for the calculation of conductance with one exception. The 4095 constant used for these calculations was determined experimentally by measuring the conductance of various oil field screens by the procedure mentioned in the Appendix A. Use of this constant provides much better agreement between measured and calculated conductance values than the constant previously reported in the literature. No matter which constant is used, the relative ranking of one screen to another is not affected. Only the absolute value of the volume throughput will be affected by changing the constant. While this absolute value may have significance in other engineering calculations, it is not critical for the comparison of screens relative to each other.

b. Nomenclature

- A = Wire surface area to mesh volume ratio, inches^{-1}.
- C_1 = Conductance of the first layer of screen cloth, kD/mm.
- C_2 = Conductance of the second layer of screen cloth, kD/mm.
- C_n = Conductance of the nth layer of screen, kD/mm.
- C_t = Total conductance of a layered screen composition, kD/mm.
- d_s = Shute wire diameter, in. (nominal)
- d_w = Warp wire diameter, in. (nominal)
- E = Void fraction.
- l_s = Length of shute wire, in.
- l_w = Length of warp wire, in.
- N_s = Mesh count in shute direction, wires per inch.
- N_w = Mesh count in warp direction, wires per inch.
- t = Screen thickness, in.
- V_s = Volume of shute wire, inches^3.
- V_w = Volume of warp wire, inches^3.

3.2 Procedure — Conductance Calculation, Single Screen*

a. Compute the conductance, C, in units of kilodarcies/millimeter for a standard weave screen cloth from the following equation:

$$C_1 = \frac{4095 \times E_2}{A^2 \times t} \quad \text{(a)}$$

where: E = the void fraction of the screen and is calculated by:

$$B = \frac{\frac{1}{N_s} \times \frac{1}{N_w} \times t - (V_w + V_s)}{(\frac{1}{N_s} \times \frac{1}{N_w}) \times t} \quad \text{(b)}$$

b. The screen thickness, t, in inches, is calculated by:

$$t = d_s + d_w \quad \text{(c)}$$

c. The length of the warp and shute wires l_w, l_s, in inches are calculated by:

$$l_w = \sqrt{(\frac{1}{N_s})^2 + d_s^2} \quad \text{(d)}$$

$$l_s = \sqrt{(\frac{1}{N_w})^2 + d_w^2} \quad \text{(e)}$$

The volume of the warp and shute wires, V_w and V_s, in inches^3 are computed by:

$$V_w = (\frac{\pi d_w^2}{4}) \times l_w \quad \text{(f)}$$

$$V_s = (\frac{\pi d_s^2}{4}) \times l_s \quad \text{(g)}$$

d. The wire surface area to volume ratio, A, is computed by:

$$A = \frac{\pi d_w l_w + \pi d_s l_s}{(\frac{t}{N_s N_w})} \quad \text{(h)}$$

3.3 Procedure — Conductance Calculation, Layered Screens

a. For screens composed of two or more layers, the conductances are calculated for each layer individually.

b. The total conductance of the layered screen composition is then calculated by:

$$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_a} \quad \text{(i)}$$

---

* See for example: Armour, J.C., and Cannon J.N., "Fluid Flow Through Woven Screens", AIChE Journal, Vol. 14, No. 3, May 1968, pp. 415-420 and Hoberock, L.L., "Shale Shaker Selection and Operation", Oil and Gas Journal, Series of articles beginning Nov. 23, 1981 and ending Feb. 1, 1982.

3.4 Example Calculation

a. Given a screen panel with the following composition:

	Mesh Count, Openings/inch		Nominal Wire Diameter, inches	
	N_s	N_w	d_s	d_w
Top Layer	160	160	0.0014	0.0014
Middle Layer	130	130	0.0017	0.0017
Bottom Layer	30	30	0.0065	0.0065

The conductance of each layer is computed independently. Detailed calculations are provided for the top layer. The conductances of the middle and bottom layers in this example are not shown but are computed in the same manner.

b. The screen thickness, t, of the top layer is calculated from the nominal wire diameters:

$$t = d_s + d_w = 0.0014 + 0.0014 = 0.0028 \qquad (a)$$

The actual length of the warp wires, in inches, is computed as follows:

$$l_w = \sqrt{\left(\frac{1}{N_s}\right)^2 + {d_s}^2} = \sqrt{\left(\frac{1}{160}\right)^2 + (0.0014)^2} = 0.006405 \qquad (b)$$

NOTE: *If d_s=d_w and N_s=N_w, then l_w=l_s. Therefore, a separate computation for l_s is not necessary. This will always be the case for square mesh wire cloth where the warp and shute diameters are equal.*

c. Now that l_w and l_s are known, the volume of the warp and shute wires, V_w and V_s, in inches³ can be computed:

$$V_w = \left(\frac{\pi {d_w}^2}{4}\right) \times l_w = \frac{\pi(0.0014)^2}{4}\ 0.00641 = 9.86 \times 10^{-9} \qquad (c)$$

Again, since the wire diameters and lengths are equal in both the warp and shute directions, $V_w = V_s$.

d. The wire surface area to volume ratio, A, is now computed for the top layer of cloth:

$$A = \frac{\pi d_w l_w + \pi d_s l_s}{\left(\frac{t}{N_s N_w}\right)} = \qquad (d)$$

$$\frac{\pi(0.0014)(0.00541) + \pi(0.0014)(0.00641)}{\frac{0.0028}{(160)(160)}} = 515$$

e. The void fraction of the screen, E, is calculated:

$$E = \frac{\left(\frac{1}{N_s N_w}\right)t - (V_w + V_s)}{\left(\frac{1}{N_s\ N_w}\right)t} =$$

$$\frac{\frac{1}{(160)(160)}(0.0028) - [(9.86\times10^{-9}) + (9.86\times10^{-9})]}{\frac{1}{(160)(160)}(0.0028)} = 0.8192$$

f. The conductance of the top layer is now computed:

$$C_1 = \frac{4095 \times E^2}{A^2 \times t} = \frac{(4095)(0.8192)^2}{(515)^2(0.0028)}\ 3.698$$

The conductance of the middle and bottom layers are calculated similarly. In this example, their respective conductances are 4.25 and 24.33 kD/mm.

g. The conductance of the total screen composition is calculated from the equation of Par. 3.3:

$$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Solve for C_t:

$$C_t = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} = \frac{1}{\frac{1}{3.69} + \frac{1}{4.25} + \frac{1}{24.33}} = 1.83$$

Thus, the conductance of this screen composition to be reported on the screen designation tag is 1.83 kD/mm.

SECTION 4
CALCULATION OF TOTAL NON-BLANKED AREA OF A SHALE SHAKER SCREEN PANEL

4.1 Description

This procedure is a method for determining the total non-blanked area of a shale shaker screen panel using direct measurement and calculation techniques.

4.2 Equipment

a. A dial or digital caliper, graduated in millimeters to measure smaller perforated panel or pretensioned panel openings.

b. An accurate rule, marked in millimeters, to measure the larger open hook strip type screen panels

4.3 Procedures

a. Pretensioned or Perforated Panel Type Screens

1. Obtain data from and make all calculations with information gathered from "regular or ordinary" production run screen panels. Do not use "show", "test", or "special" panels.
2. Randomly choose two panels from a production run of at least 25 screened panels.
3. Mark all panel openings for measurement, and number the openings consecutively (see Example — Calculation of Total Non-Blanked Area for a Perforated Panel Mount Screen).
4. Measure the necessary dimensions of each panel opening to the nearest millimeter. These measurements are critical to obtain accurate and repeatable results. Do not include the space occupied by adhesive or bonding materials. Measure only the unoccluded panel opening space located between the panel webs.

b. Open Hook Strip Panels

1. Obtain data from and make all calculations with information gathered from "regular or ordinary" production run screen panels. Do not use "show", "test", or "special" panels.
2. Randomly choose two panels from a production run of at least 25 screened panels.
3. Measure the width of each screen panel from the inner edge of the hoop strips on either side, to the nearest millimeter.
4. Measure the length of each screen panel from the inside of the top of the non-blanked wire cloth area to the inside of the bottom non-blanked cloth area, to the nearest millimeter (see Example — Calculation of Total Non-Blanked Area for an Open Hook Strip Screen).

4.4 Calculations

a. Pretensioned or Perforated Panel Type Screens

1. Calculate the area of each panel opening, in square millimeters.
2. Sum the unoccluded areas of all panel openings to obtain the total non-blanked area of that particular panel in square millimeters.
3. Convert the total non-blanked area from square millimeters to square feet by dividing by 92,903.
4. Calculate the total non-blanked panel area by summing the individual panel total non-blanked area and dividing by two.

b. Open Hook Strip Panels

1. Calculate the total non-blanked area of each panel, in square millimeters.
2. Convert the total non-blanked area from square millimeters to square feet by dividing by 92,903.
3. Calculate the total non-blanked panel area by summing the individual panel total non-blanked area and dividing by two.

4.5 Examples

a. Total Non-Blanked Area for a Panel Mount Screen, as shown in Figure 4.1.

1. Measure the length and width of panel opening #1 with a dial or digital caliper to the nearest millimeter. If, for example, it measures 24 mm wide by 25 mm long, its area is as follows:

$$24mm \times 25mm = 600mm^2$$

2. Perform a similar calculation for all panel openings on both screens used in the analysis, and sum the individual results to obtain the total non-blanked area of each panel mount screen in square millimeters. In this example, the resultant sums are 626,400mm², and 618,734mm², respectively.
3. Convert the total non-blanked area to square feet using a conversion factor:

$$626{,}400mm^2 / 92{,}903 = 6.74\ ft^2$$

$$\text{and } 618{,}734mm^2 / 92{,}903 = 6.66\ ft^2$$

4. Average the two non-blanked area results to obtain the final answer for total non-blanked area of a panel, as follows:

$$[(6.74\ ft^2) + (6.66\ ft^2)] / 2 = 6.70\ ft^2$$

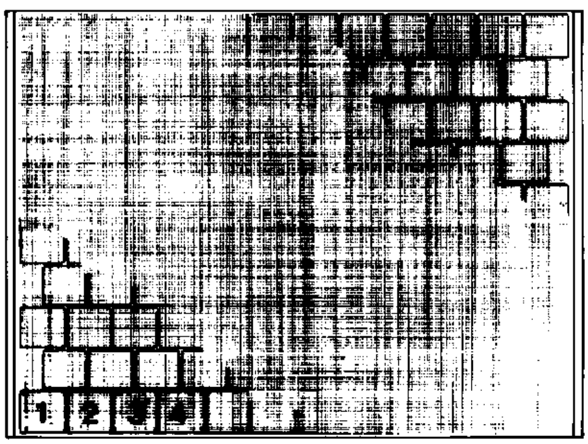

FIGURE 4.1
NON-BLANKED AREA FOR PANEL MOUNTED SCREEN

b. Total Non-Blanked Area for an Open Hook Strip Screen Panel, as shown in Figure 4.2.

1. Measure the width of each screen panel from the inner edge of the hook strips on either side.
2. Measure the length of the non-blanked area of each screen panel, starting from the inside edge of the top cloth fold and extending to the inside edge of the bottom cloth fold.
3. Calculate the total non-blanked area (mm^2) of each screen panel as follows:

   Screen Panel #1
   $1160mm \times 1520mm = 1{,}763{,}200mm^2$

   Screen Panel #2
   $1156mm \times 1522mm = 1{,}759{,}432mm^2$

4. Convert the total non-blanked area of each screen panel from square millimeters to square feet by performing the following calculation:

   Screen Panel #1
   $1{,}763{,}200mm^2 / 92{,}903 = 18.98\ ft^2$

   Screen Panel #2
   $1{,}759{,}432mm^2 / 92{,}903 = 18.94\ ft^2$

5. Average the two non-blanked panel area results to obtain the final answer for total non-blanked area of one open hook strip panel, as follows:

   $[(18.98\ ft^2) + (18.94\ ft^2)] / 2 = 18.96\ ft^2$

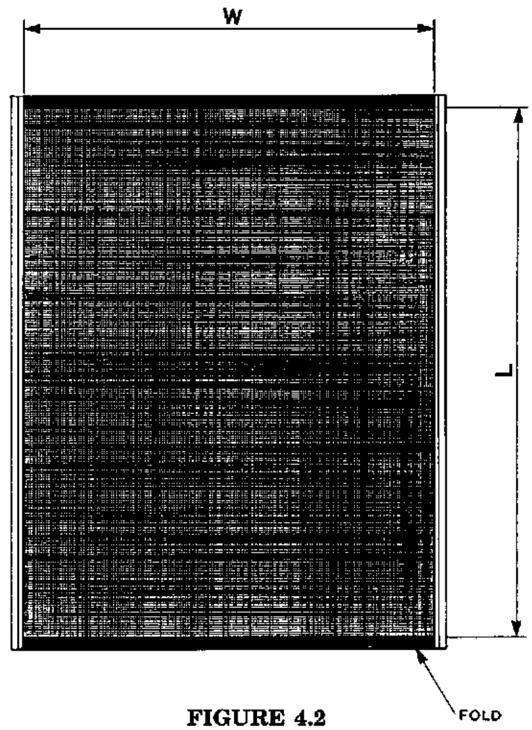

FIGURE 4.2
NON-BLANKED AREA FOR OPEN HOOK STRIP SCREEN

APPENDIX A
EXPERIMENTAL PROCEDURE FOR MEASURING SCREEN CONDUCTANCE

A.1 Description

a. Screen conductance is a measure of a Newtonian fluids ability to pass through a screen. Screen conductance has units of permeability per unit length, kilodarcy/mm.

b. The measurements made which allow screen conductance to be calculated are screen cross sectional area, flow rate, fluid viscosity, and pressure drop across the screen.

A.2 Equipment

a. Construct a flow loop as shown in Figure A.1. The components of the flow loop include:

1. Fluid Reservoir: construct the reservoir in the shape of a cone with the return fluid from the system entering so that it moves slowly across the reservoir and allows any entrained air to escape.
2. Pump: flow rates up to twenty gallons per minute. A MOYNO pump, or equivalent, could be substituted for the centrifugal.
3. Flow meter: calibrated over the flow range of 1 to 20 gpm. For example, a FISHER PORTER one inch magnetic flow meter, or equivalent, calibrated using time and weight over several flow rates between 1 and 20 gpm.
4. Pressure transducer: capable of making differential measurements between 0 and 1 psi to ±0.0001 psi, such as a Beta Products Model 320 pressure transducer, or equivalent.
5. Temperature sensor: precision of 0.1 °F.
6. Cooling coils: for accurately regulating the fluid temperature are necessary to maintain the flow loop temperature to ± 1/2 °F.
7. Screen holder: construct as in Figures A.2-A.4.
8. Viscometer: capable of measuring viscosity to ± 0.2 cP, such as a Cannon-Ubbelohde Tube Viscometer, Size 200, or equivalent.

A.3 Procedure

a. Formulate a glycerin and water mixture which has a viscosity of approximately 35 cP. Measure the viscosity of the fluid to +0.2 cP using the tube viscometer at the mean temperature of the flow loop.

b. Mount the screen in the holder. If the screen element has a high conductance mount two or more layers of this screen until the differential pressure is at least 0.2 psi at a flowrate of 2 gpm. Circulate the fluid through the screen at 2, 4, 6, 8 and 10 gpm. Measurements may also be made in increments of 2 gpm up to 20 gpm. Measure and record the pressure drop at each flowrate. Insure that the fluid temperature is constant within ±0.25 °F.

1.4 Calculation

a. Calculate the conductance of the screen cloth as follows:

$$C = \frac{0.014375\, n\, Q\, \mu}{A\, \Delta P} \qquad \text{(a)}$$

where: Q = flow rate, gpm

μ = viscosity, centipoise

A = screen cross sectional area, square inches

ΔP = pressure drop, lb/square inch

n = number of identical screen layers tested

C = conductance of each screen layer, kilodarcy/mm

Calculate the conductance for each flow rate. If the measurements were all perfect, the value of conductance at all flowrates would be the same. Average at least four consecutive measurements which are within ten percent of each other. Repeat the measurement if four consecutive values are off more than 10%. Report the average of these four values.

b. Calculate the conductance of dissimilar layered screen cloths as follows:

$$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_a}$$

where: C_t = total conductance of the layered cloth

C_1 = conductance of the first layer of screen

C_2 = conductance of the second layer of screen

C_n = conductance of the n^{th} layer of screen

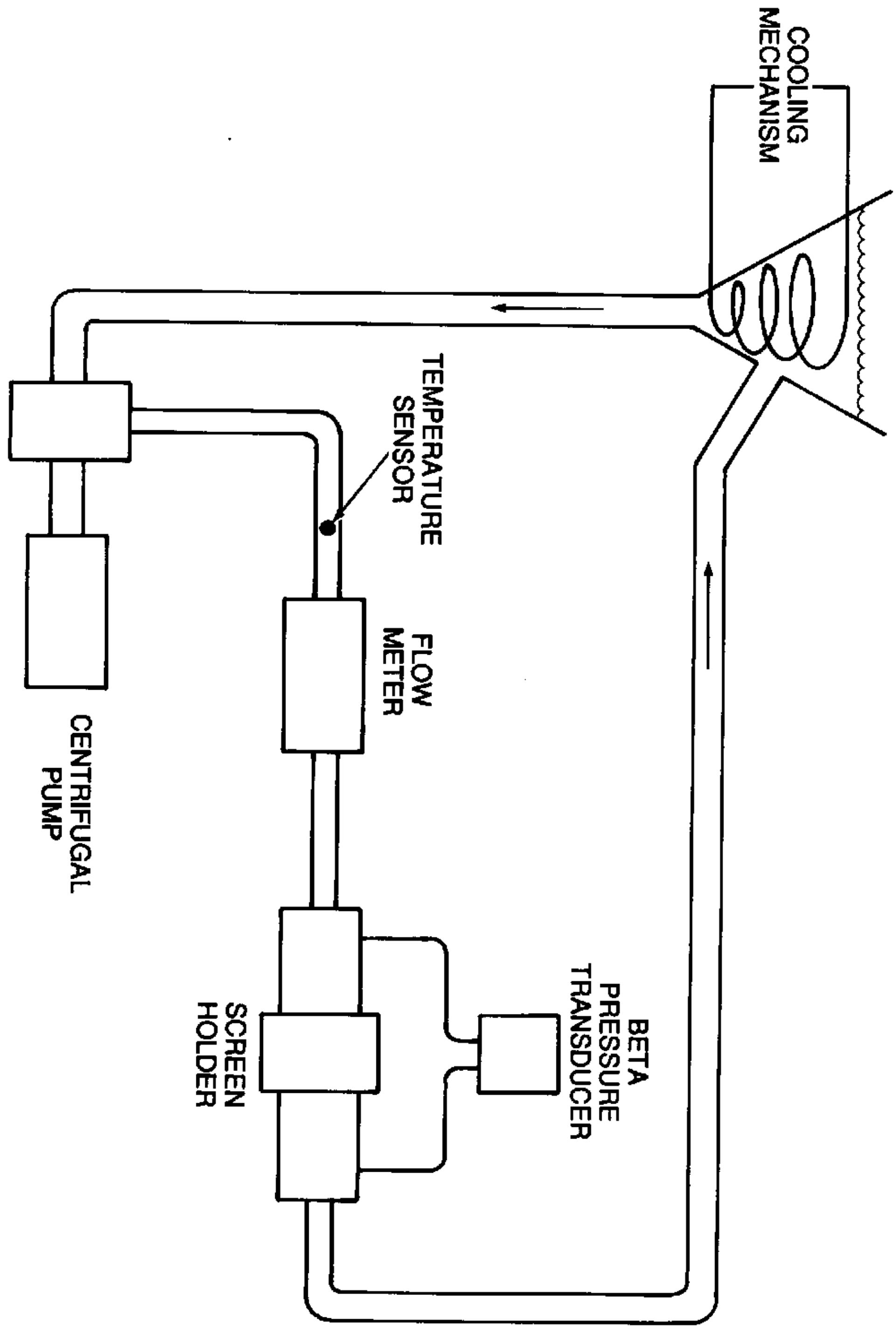

FIGURE A.1
SCREEN CONDUCTANCE TEST STAND

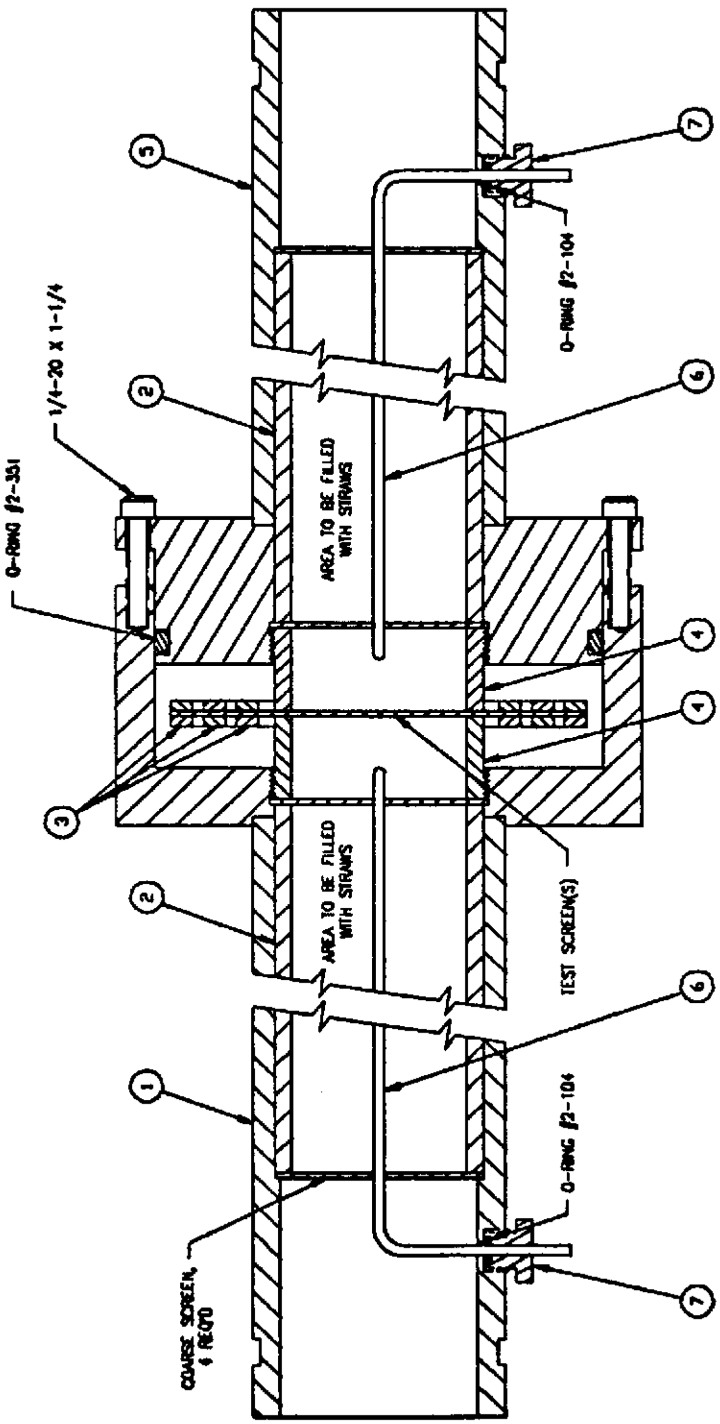

FIGURE A.2
SCREEN HOLDER AND SIDE VIEW

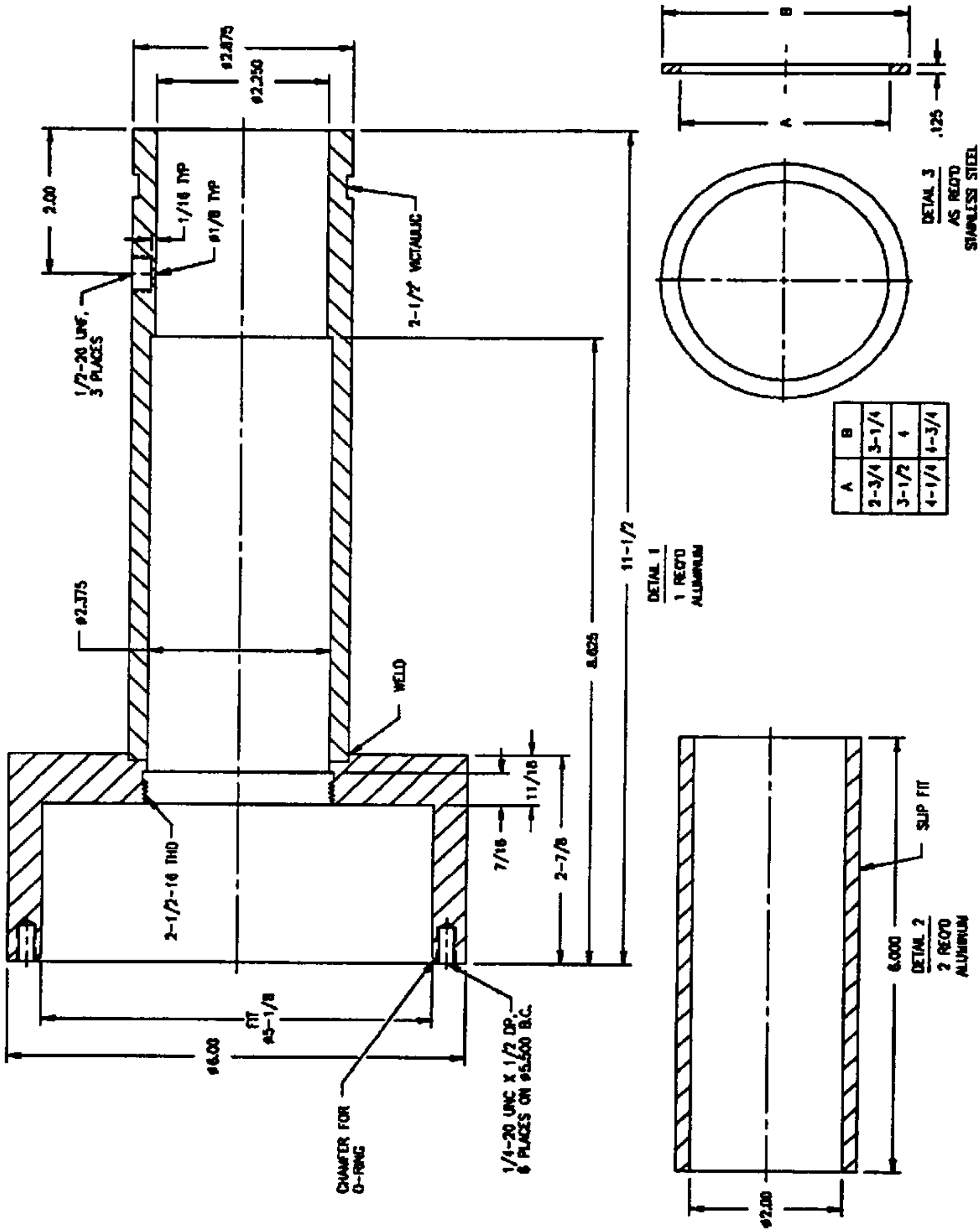

FIGURE A.3
SCREEN HOLDER

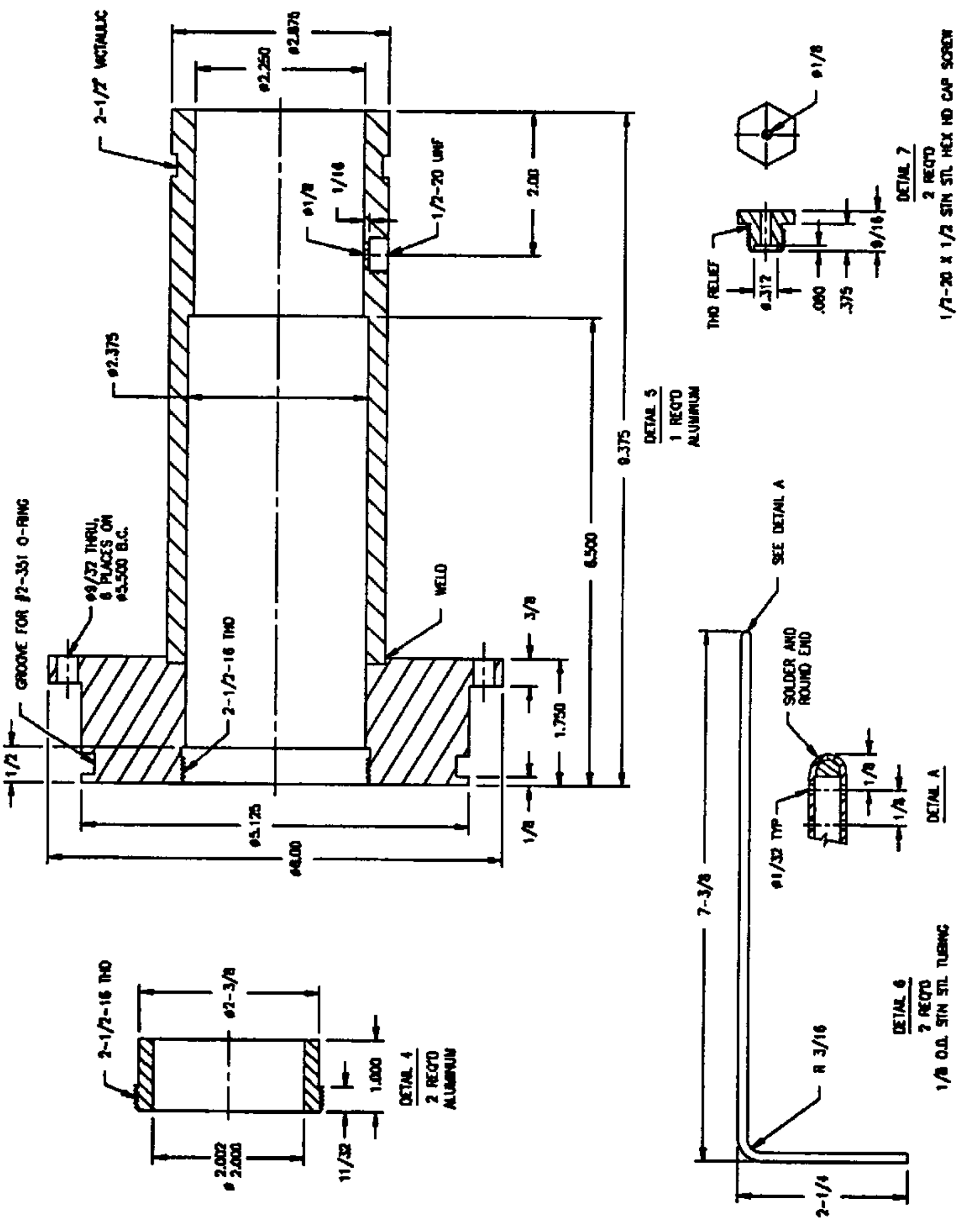

FIGURE A.4
SCREEN HOLDER

Order No. 811-07120

Additional copies available from
AMERICAN PETROLEUM INSTITUTE
Publications and Distribution Section
1220 L Street, NW
Washington, DC 20005
(202) 682-8375