SME Mining Engineering Handbook

In Two Volumes

Volume 1

ARTHUR B. CUMMINS

Chairman, Editorial Board

IVAN A. GIVEN

Editor

Sponsored by

Seeley W. Mudd Memorial Fund of AIME
Society of Mining Engineers of AIME
U.S. Bureau of Mines, Dept. of the Interior

Society of Mining Engineers
of
The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.

New York, New York

1973

the mining engineer is to extract the minerals presently needed in the most efficient way for the greater well-being of society.

1.6—CONSERVATION IN MINING

Mineral deposits are a wasting asset. The minerals are irreplaceable, so that as the deposit is mined it decreases in value. The miner, unlike the manufacturer or the farmer, must discover new sources of raw materials to remain in business.

The prudent miner conserves his ore by planning mining in such a way as to maximize his profit from it over the life of the deposit. In mining, it is essential to view the financial outcome on the basis of the full life of the operation as nearly as this can be anticipated, which is not necessarily the case in other businesses. The economics of mining are influenced by efficient extraction. This usually means taking out ore of lower metal content to the greatest extent possible along with better grade ore.

Mineral conservation is achieved through several different approaches. The foregoing refers to the economic approach, which is an important technique. A second technique is competent geologic analysis to map the deposit and locate new ore. This is done so successfully that many mines are able to replace the ore mined year after year by the discovery of new reserves.

Technical research has played a tremendous role for generations in conserving minerals. New methods and new machines make it possible to extract ores of lower and lower grade. It is well known that the waste piles of old mines and metallurgical facilities are reworked to remove metals that formerly could not be recovered. Mining techniques, such as improved roof support, permit the reduction in size of pillars composed of ore so that more complete extraction is possible. The use of leach solutions at mines permits recovering metal from material which is too low grade to process in any other way. Metal is also extracted from natural mine drainage water.

Technology has increased conservation of minerals by enabling such minute metal values as molybdenum and rhenium to be recovered from copper ores. There are many other examples of byproducts, scarce in volume, being taken from ores.

The provident miner attempts to utilize as much of the material he extracts as he can. Rock refuse may be prepared for construction use, and mill sand often is returned to an underground mine to prevent caving. Even the opening may be used subsequently for storage of gas or other materials.

Less spectacular as an aid to conservation but of extreme importance is the day-to-day good operation of a mine as a result of experienced supervision, a stable work force and the avoidance of work interruptions.

1.7—ENVIRONMENTAL INFLUENCES AND MINING

It is not usually possible to extract minerals from the earth without changing the natural environment in some way (see Sec. 8). A mine requires access roads, power and water. An opening in the ground must be made. Usually, in the case of underground mines, the surface disturbance is small compared to open-pit mines. Mine site acreage must be devoted to processing facilities, shops, offices, changehouse and storage facilities. The waste materials from processing operations must be disposed of. These may be solid, liquid or gaseous. In addition, there is the atmosphere in the mine and other facilities that must be controlled to safeguard the workers' health.

Environmental controls have been applied to operations for decades. These include land restoration, water purification, dust suppression and diffusion of noxious gases. The techniques for these controls have been developed over a long period of time and, as the technology improves, the adverse effects of mining on the environment will continue to be reduced. At the present time, environmental legislation being proposed and enacted poses a problem to mine operators of a greater

or lesser magnitude depending c
problems are the availability of
pollution control, the time factor
of the additional cost.

Since the demand for minera
because of population but also
and underdeveloped areas, it wil
with the extractive industries. Pa
required in environmental control r

In the controversy over utiliz
there is the plausible solution of
practice, minerals are extracted i
followed by restoration for other
and phosphate mining where the
urban use, recreation, timber or gra

1.8—FUTURE OF MINING

Dependence of man on his m
indefinitely. Requirements of tech
upon the mineral industry to pro
This demand will be met by gre
better understanding of the genesis
of locating the presence of minera
in technology will make ore out of
Methods will change in a way
mental impairments.

The technology of the explor
metallurgist is benefiting the work
For example, great benefits to othe
ments in environment made by mi
of air conditioning.

The mining community at the s
in other fields. This cross pollinatio

Research is going on in gover
and in industry. A substantial a

The arts and sciences of the
rapidly in this period but assure
on earth.

INDUSTRIAL EMPLOYEE

365 Days in Year
-104 Weekend days
-10 Vacation days
-10 Holidays

---

241 Days of Work

CSM PROFESSOR

365 Days in Year
-124 Academic days

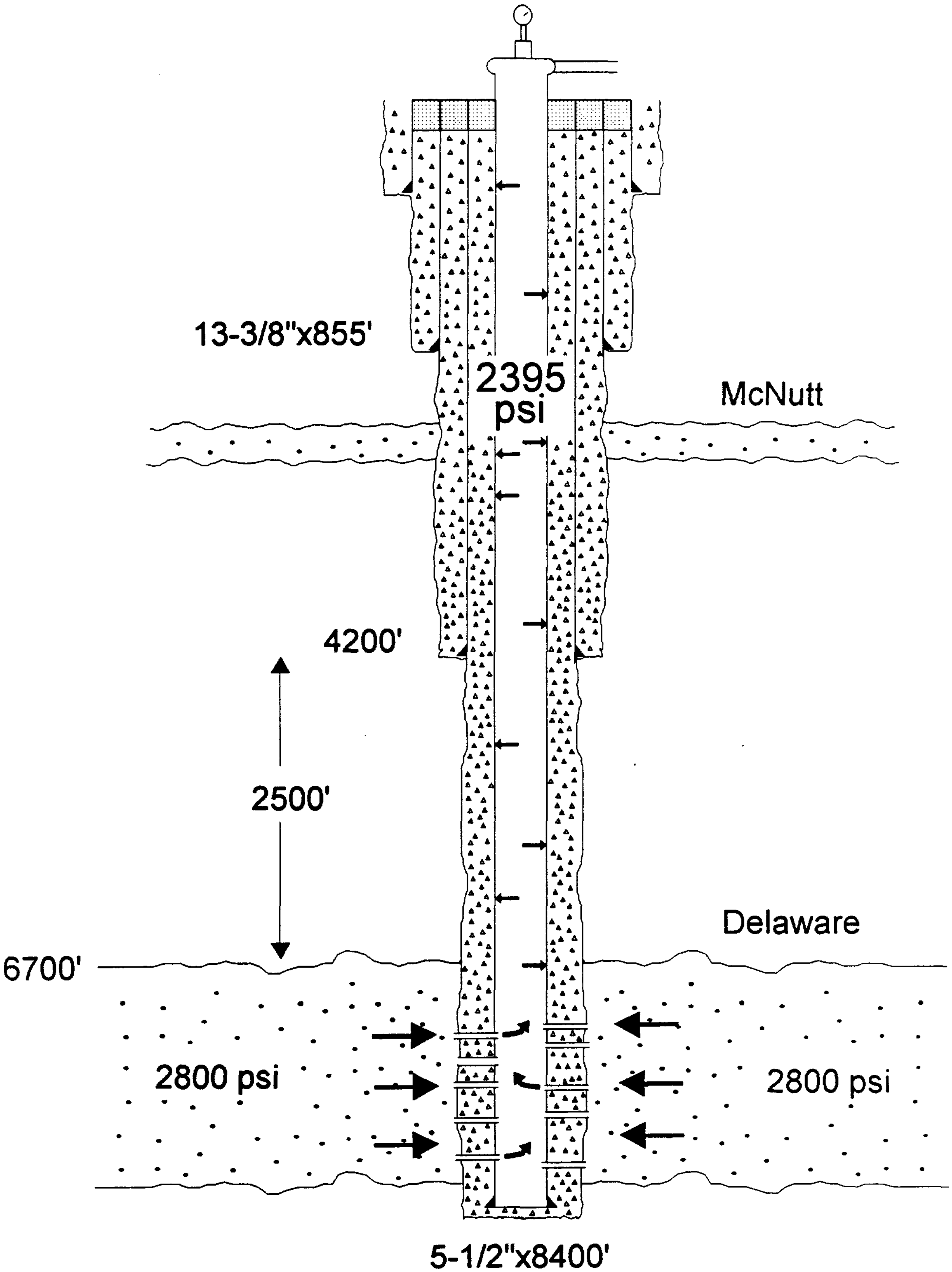
---

240 Days for Work

EXHIBIT 37

EXHIBIT #1

Exhibit #2a



DELAWARE WELL

Expected Natural Gas Pressure in the Well Bore at the McNutt

$Pb := 2800$ Delaware bottom hole pressure; psi

$Pt := 700$ Well bore pressure at the McNutt zone; psi

$G := .9$ Gravity of the natural gas

$T := 550$ Flowing temperature of the natural gas in the annulus; deg.R

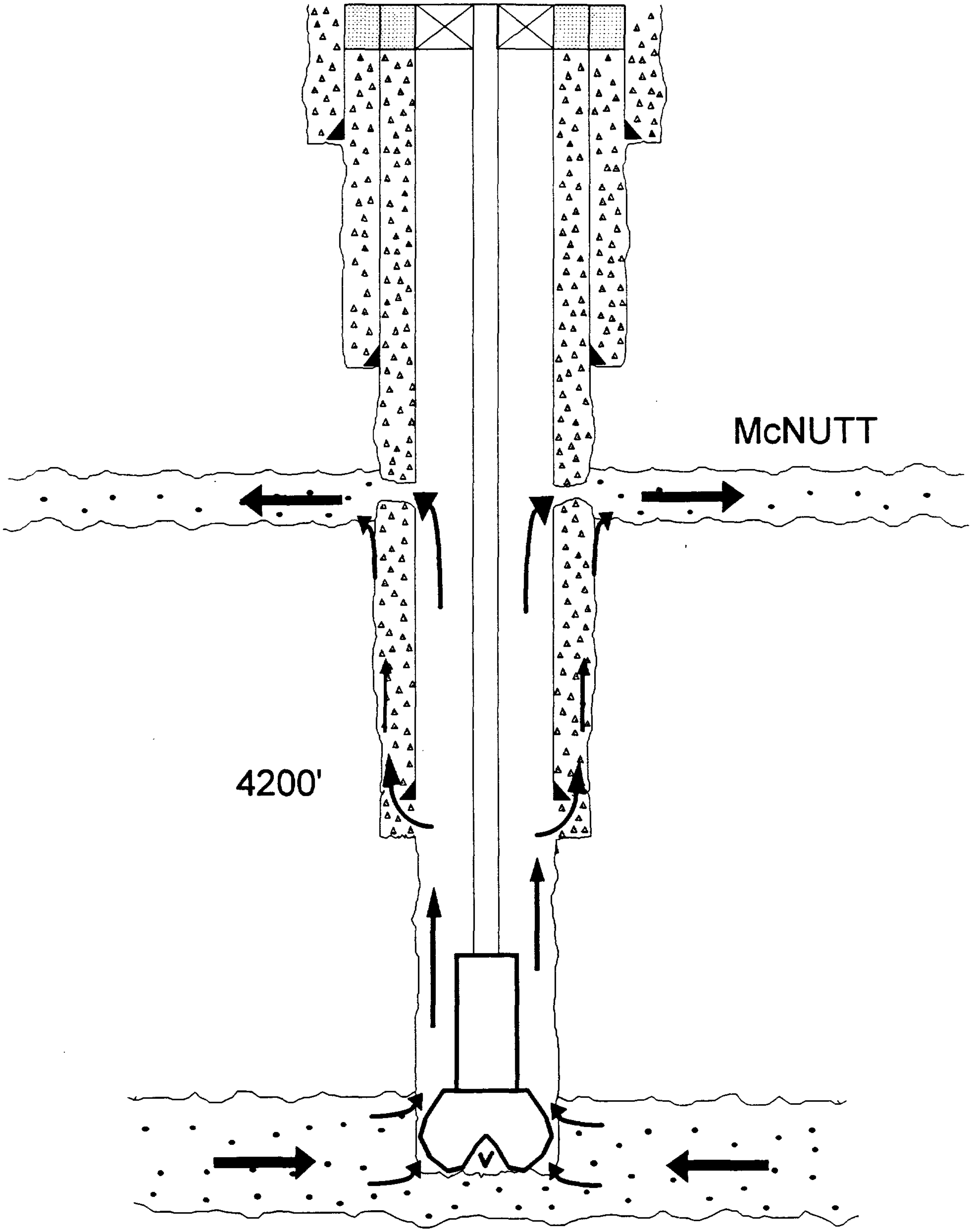
$L := 5000$ Length of natural gas column; feet

Gas Column Equation:

$$Pt := Pb \cdot e^{-0.0000347 \cdot G \cdot L}$$

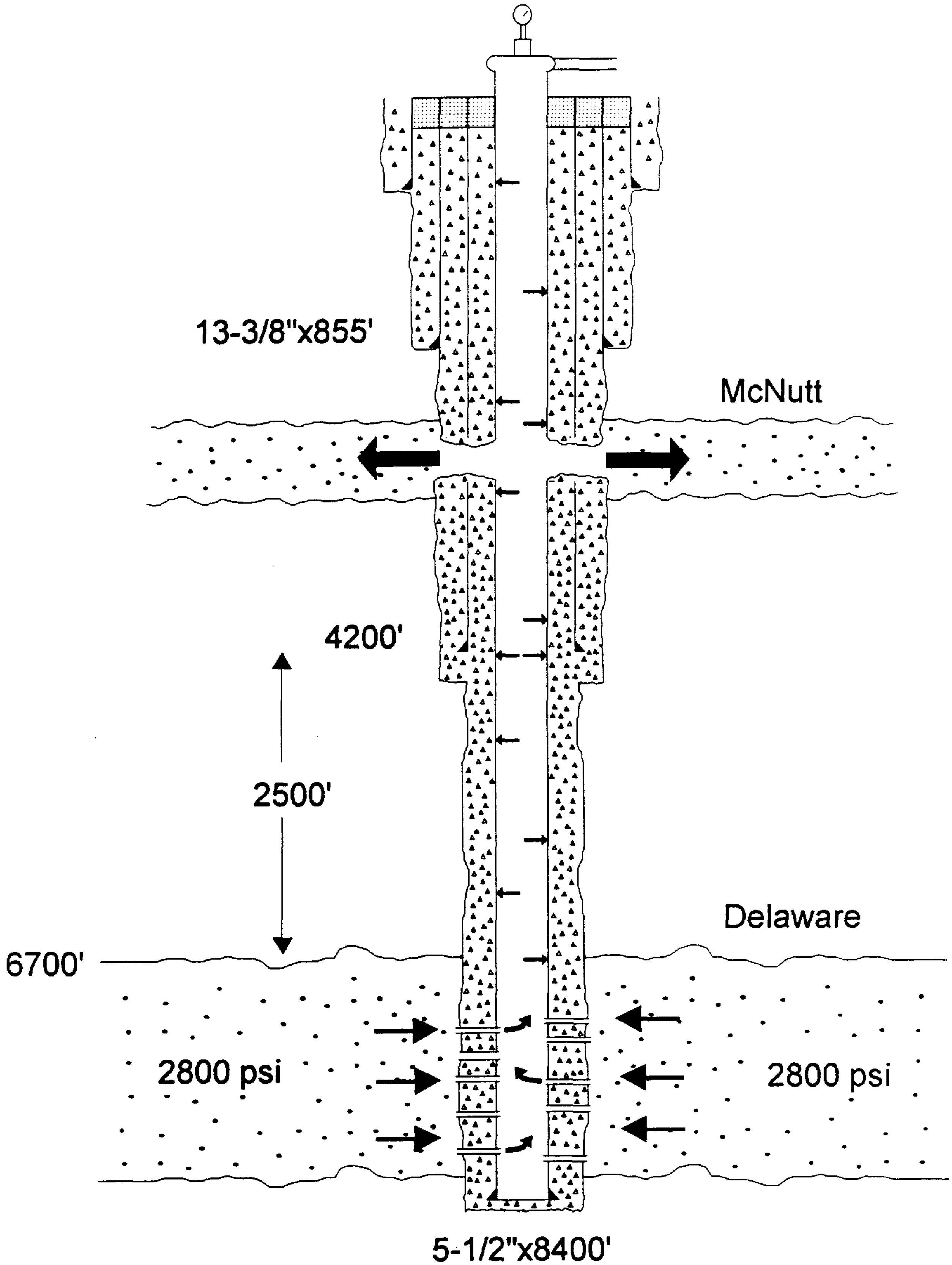
$Pt = 2395$ psi Expected pressure within the well bore adjacent to the McNutt zone.

Exhibit #3a

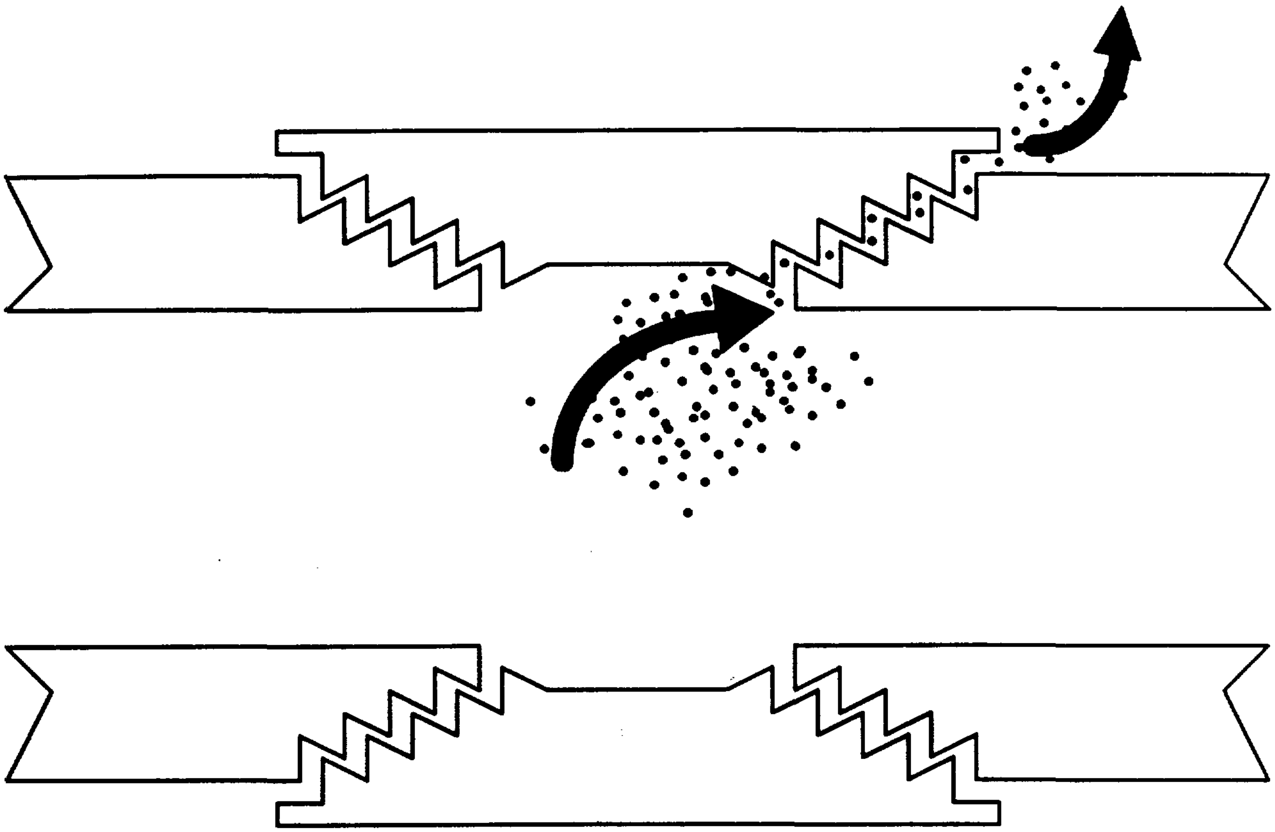


BLOWOUT & CLOSURE

Exhibit #3b



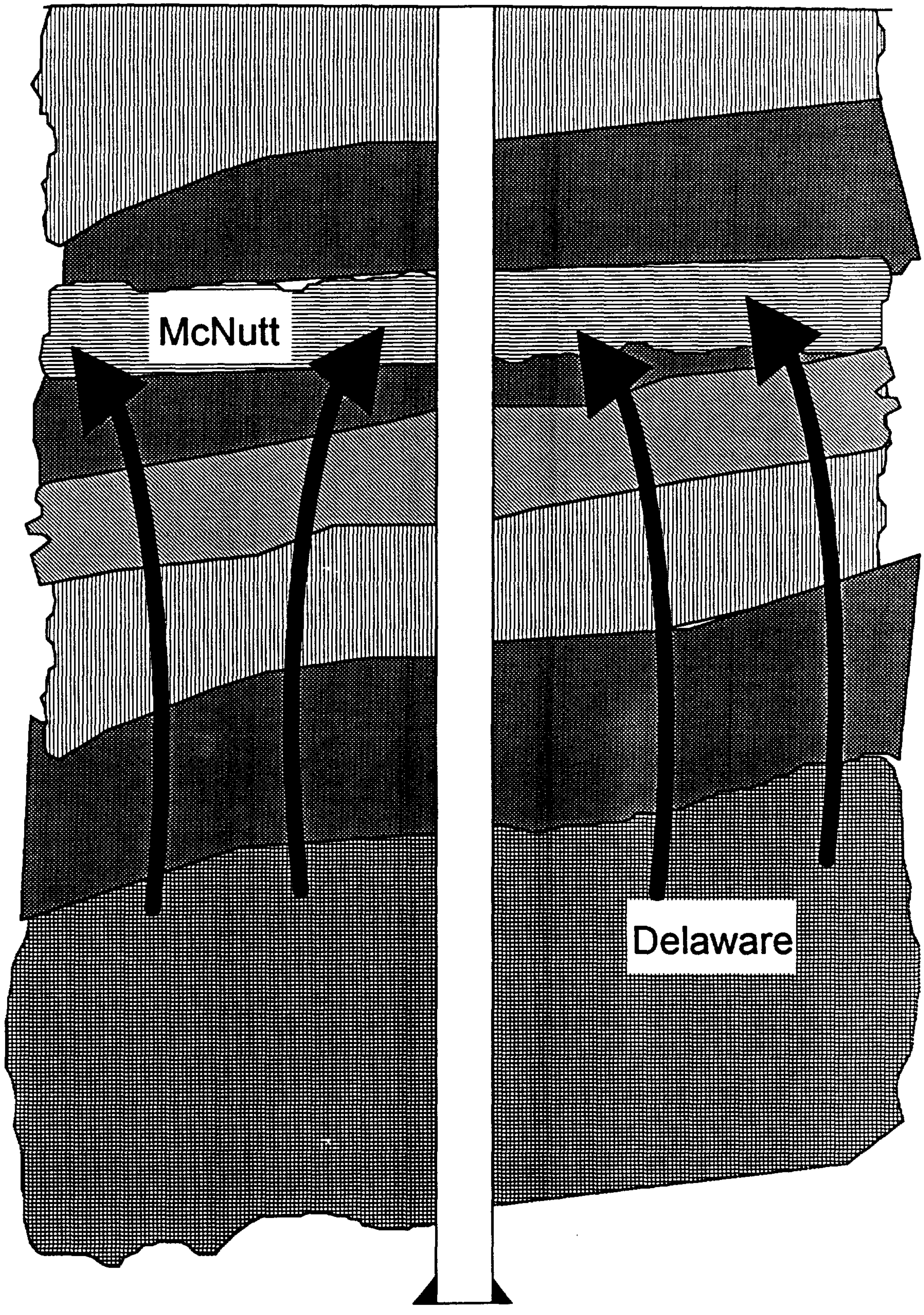
HOLES IN CASING



COUPLING GAS LEAKAGE

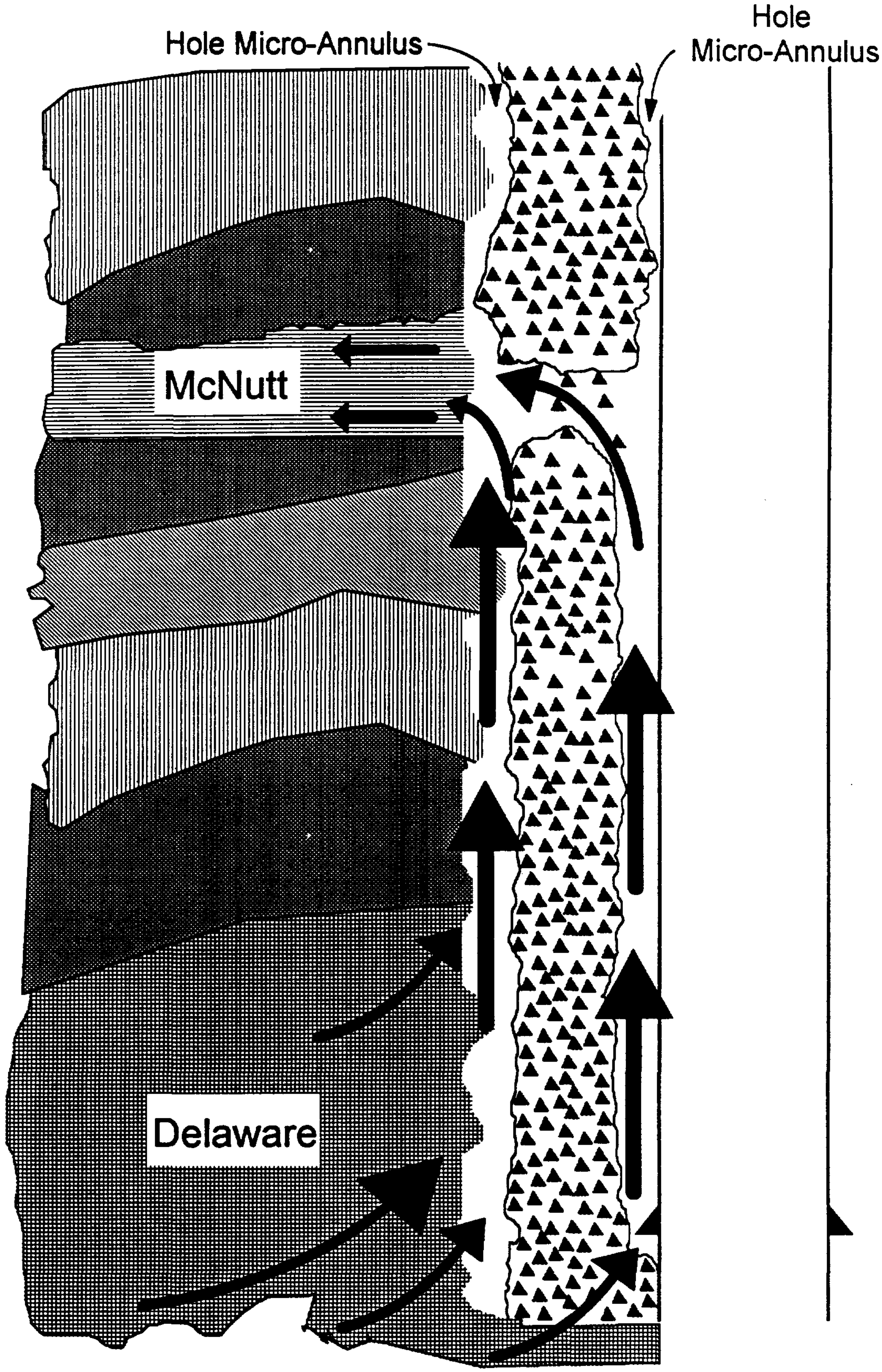
EXHIBIT #4

Exhibit #5



NATURAL MIGRATION OF GAS
FROM THE DELAWARE TO THE McNUTT

Exhibit #6a



MICRO ANNULI PATHS

Expected Natural Gas Flow Rate Through Micro Annulus

$Pb := 2800$ Delaware bottom hole pressure; psi

$Pt := 700$ Well bore pressure at the McNutt zone; psi

$G := .9$ Gravity of the natural gas

$T := 550$ Flowing temperature of the natural gas in the annulus; deg.R

$L := 5000$ Length of annulus; feet

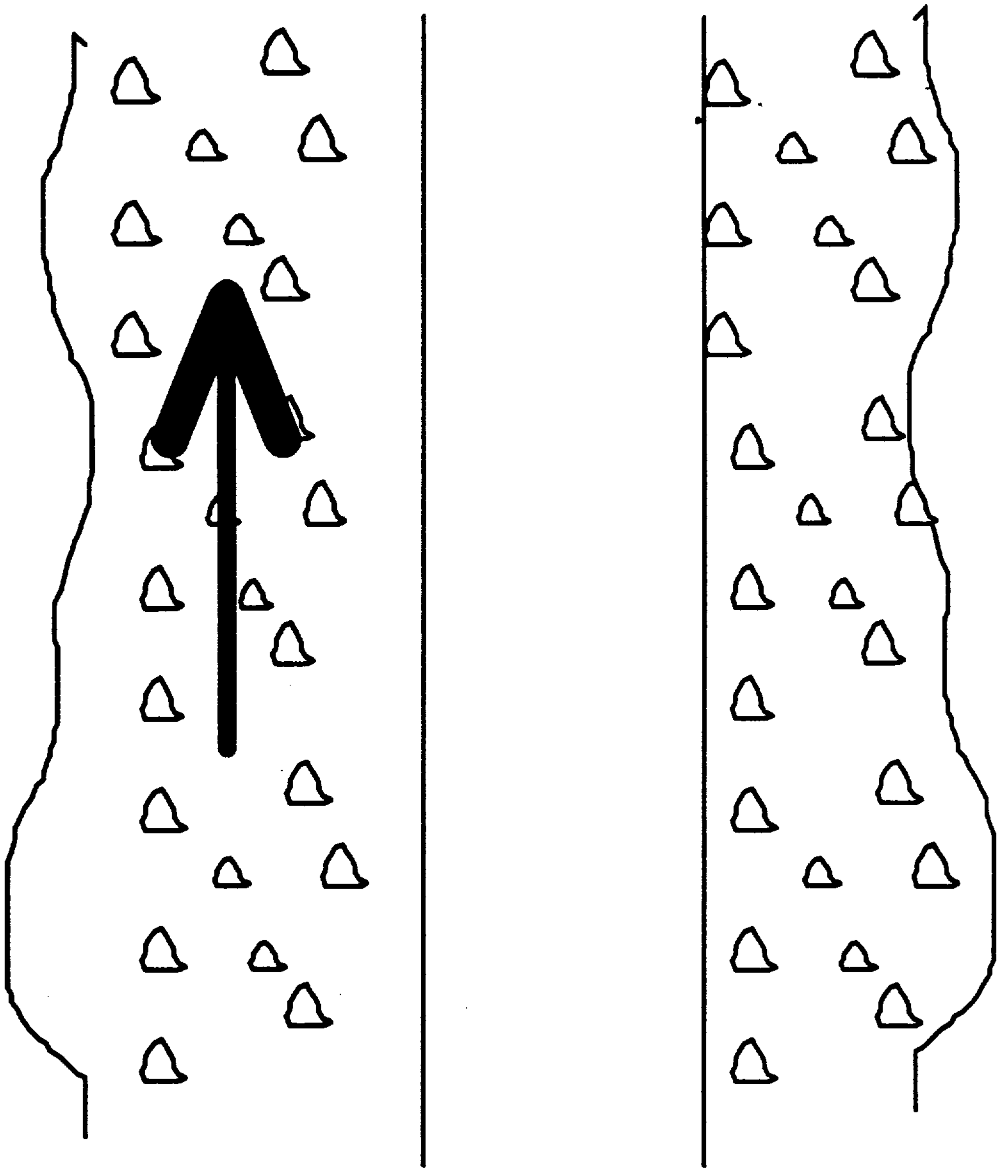
$gap := .015$ Radial width of the annulus; inches

Weymouth's Equation:

$$q := 1000000 \cdot \sqrt{\frac{\left(Pb^2 - Pt^2\right) \cdot gap^{5.33}}{.81 \cdot G \cdot T \cdot L}}$$

$q = 26.387$ scf/d Volume of standard natural gas which is expected to flow through the micro annulus in one day.

EXHIBIT #6b



GAS FLOW THROUGH CEMENT

GAS FLOW THROUGH CEMENT IN THE 7-7/8" BY 5-1/2" ANNULUS

$Pb := 2800$	Pressure at the bottom of the cement column; psi
$Pt := 700$	Pressure at the McNutt depth; psi
$Tflow := 550$	Gas flowing temperature; deg.R
$Pbase := 14.65$	Base pressure for standard gas volume; psia
$Tbase := 520$	Base temperature for standard gas volume; deg. R
$z := .85$	Gas deviation factor
$ug := .011$	Gas viscosity; cp
$k := .0001$	Permeability of neat cement after 28 days; Darcys
$L := 5000$	Length of cemented annulus
$A := \frac{\pi}{4} \cdot \frac{7.875^2 - 5.5^2}{144}$	Cross-sectional area of cemented annulus.

Poiseuille's equation for linear viscous flow of gas:

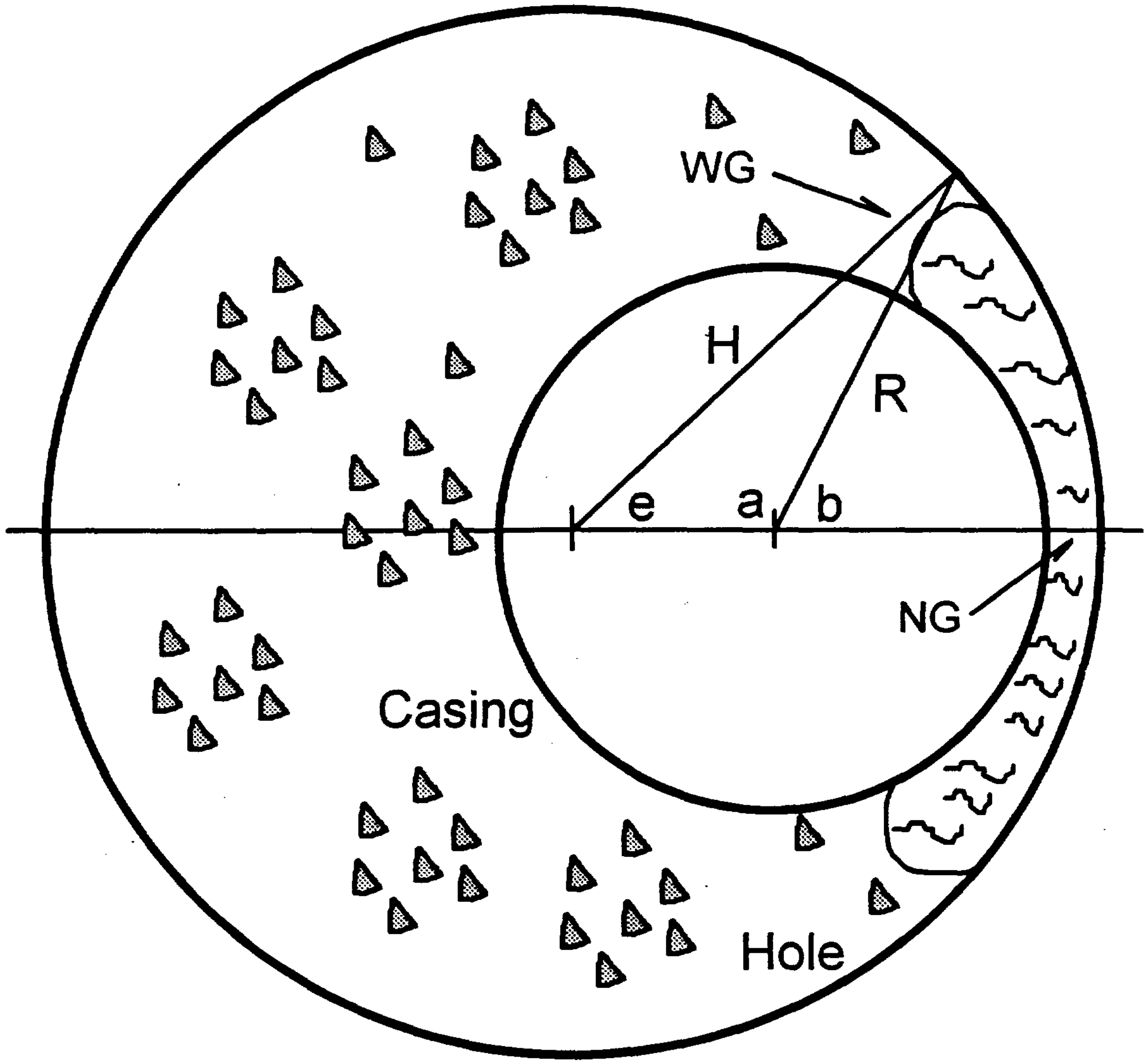
$$q := \frac{\pi \cdot Tbase \cdot k \cdot A \cdot \left(Pb^2 - Pt^2\right)}{Tflow \cdot z \cdot ug \cdot L \cdot Pbase}$$

$q = 0.552$ Expected gas flow rate in scf/d through cement in the annulus.

$k := .01$ Permeability of neat cement after 28 days; Darcys

$$q := \frac{\pi \cdot Tbase \cdot k \cdot A \cdot \left(Pb^2 - Pt^2\right)}{Tflow \cdot z \cdot ug \cdot L \cdot Pbase}$$

$q = 55.226$ Expected gas flow rate in scf/d through cement in the annulus.



MUD CHANNEL

EXHIBIT # 8a

Expected Natural Gas Flow Rate Through Channel in Annulus

$Pb := 2800$	Delaware bottom hole pressure; psi
$Pt := 700$	Well bore pressure at the McNutt zone; psi
$G := .9$	Gravity of the natural gas
$T := 550$	Flowing temperature of the natural gas in the annulus; deg.R
$L := 5000$	Length of annulus; feet
$H := \frac{7.875}{2}$	Bit diameter / 2; inches
$R := \frac{5.5}{2}$	Casing outside diameter / 2; inches
$NG := .25$	Narrow side of gap; inches
$WG := .5$	Wide side of gap; inches

Hydraulic radius of the channel

$$a := \left[\frac{H^2 - (R + WG)^2 - (H - R - NG)^2}{2\cdot(R + WG)\cdot(H - R - NG)}\right]$$

$a := \mathrm{acos}(-a)$	$a = 2.301$	Angle a; rad
$b := \pi - a$	$b = 0.841$	Angle b; rad
$Pr := 2\cdot b\cdot R$	$Pr = 4.626$	Perimeter of casing segment: inches
$e := \mathrm{asin}\left(\frac{R + WG}{H}\cdot\sin(a)\right)$		Angle e; rad
$Ph := 2\cdot e\cdot H$	$Ph = 5.218$	Perimeter of hole segment; inches
$WP := Ph + Pr + 2\cdot WG$	$WP = 10.844$	Wetted perimeter of flow area; inches
$Ah := e\cdot H^2$	$Ah = 10.274$	Area of hole segment; in^2
$Ar := b\cdot R^2$	$Ar = 6.361$	Area of casing segment; in^2
$At := \frac{H}{2}\cdot(H - R - NG)\cdot\sin(e)$	$At = 1.136$	Area of triangles; in^2
$Af := Ah - Ar - 2\cdot At$	$Af = 1.642$	Area of flow; in^2
$HR := \frac{Af}{WP}$	$HR = 0.151$	Hydraulic radius; inches

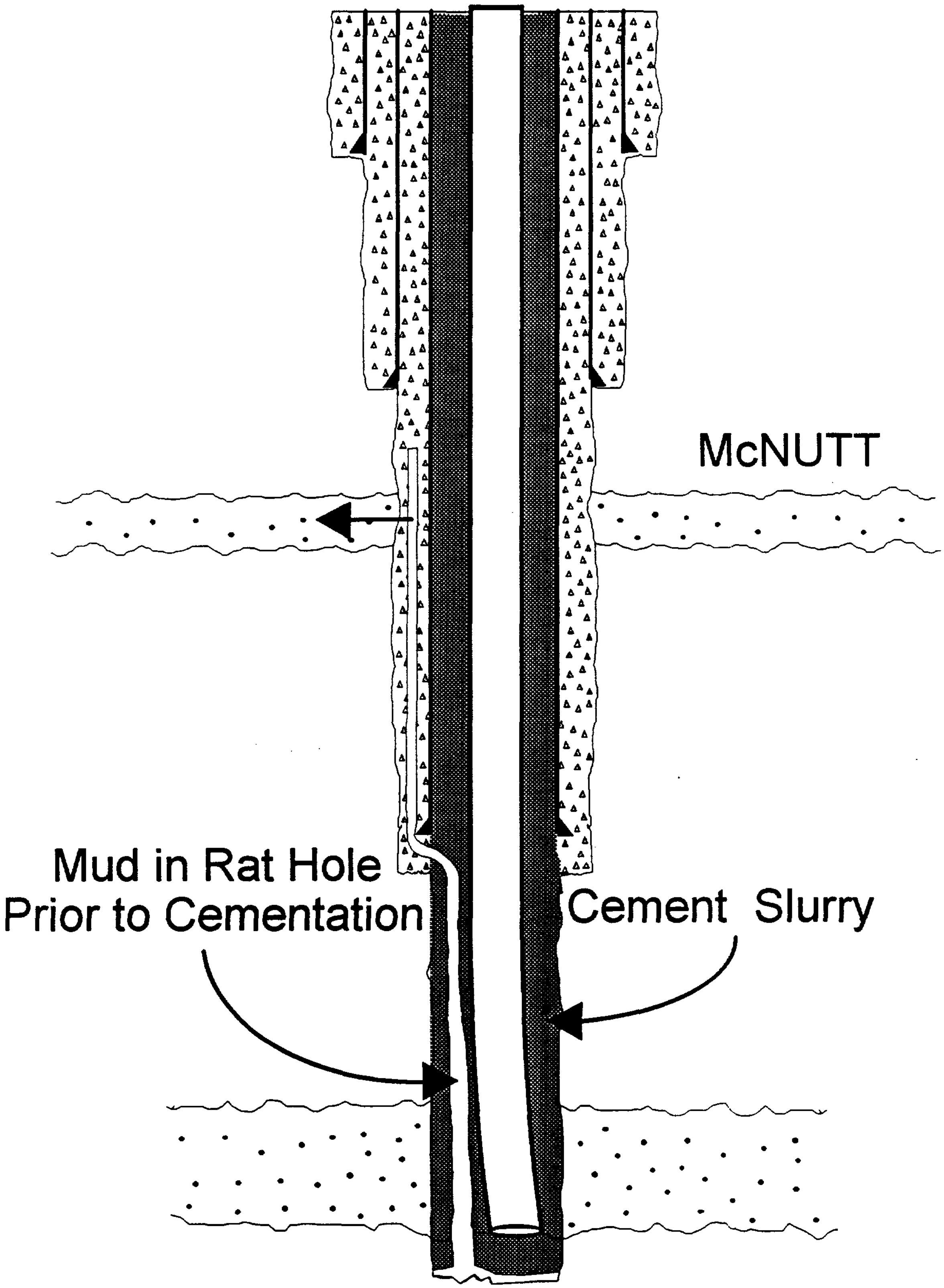
Weymouth's Equation:

$$q := 1000000\cdot\sqrt{\frac{(Pb^2 - Pt^2)\cdot(HR\cdot 4)^{5.33}}{.81\cdot G\cdot T\cdot L}}$$

$q = 503385$ scf/d — Volume of standard natural gas which is expected to flow through the channel in one day.

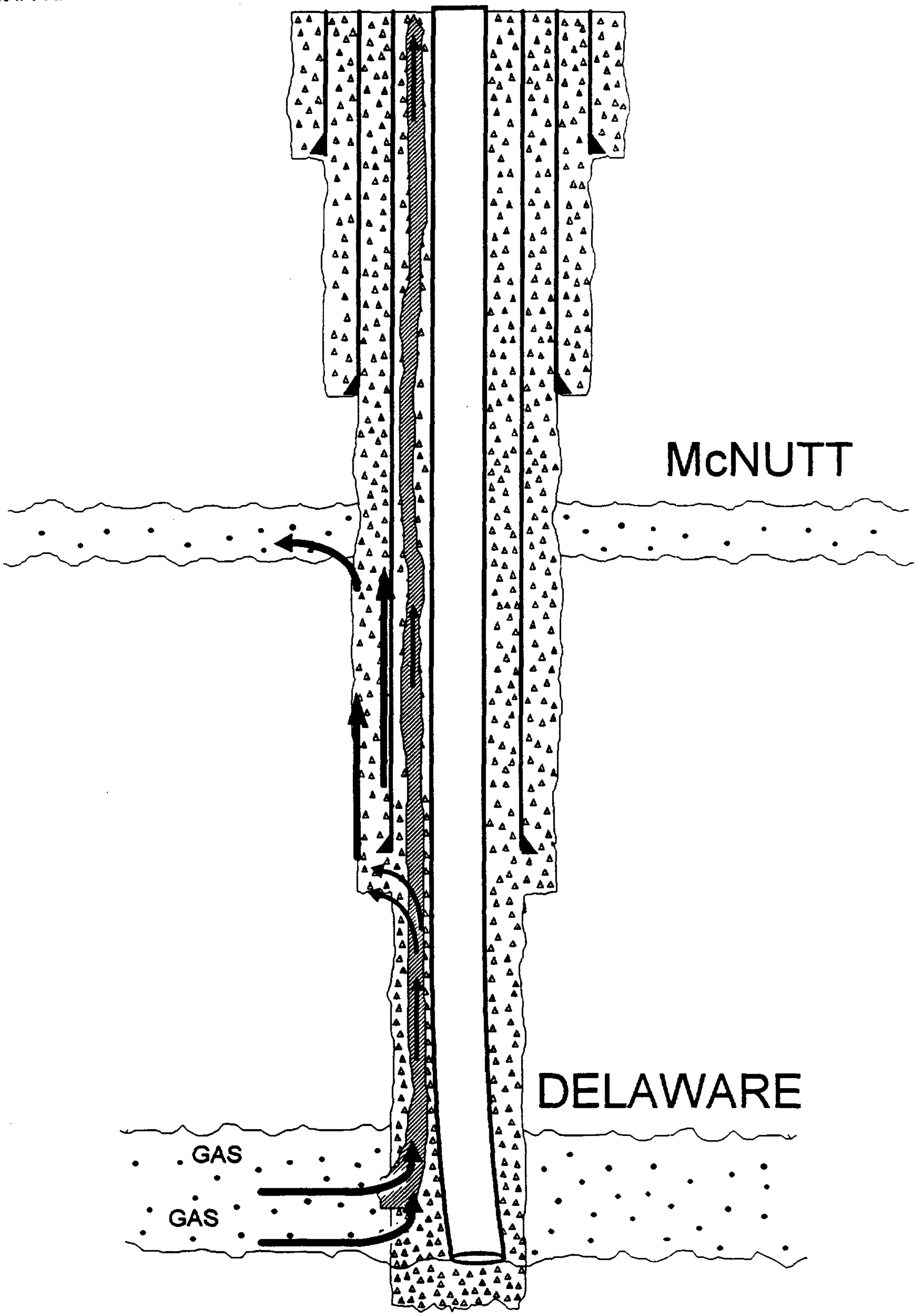
EXHIBIT # 8b

Exhibit #9



SWAPPING OUT

Exhibit #11a



GAS PERCOLATION

Expected Natural Gas Flow Rate Through A Percolation Channel

$Pb := 2800$	Delaware bottom hole pressure; psi
$Pt := 700$	Well bore pressure at the McNutt zone; psi
$G := .9$	Gravity of the natural gas
$T := 550$	Flowing temperature of the natural gas in the channel; deg.R
$L := 5000$	Length of annulus; feet
$Dia := 0.75$	Diameter of the percolation channel; inches

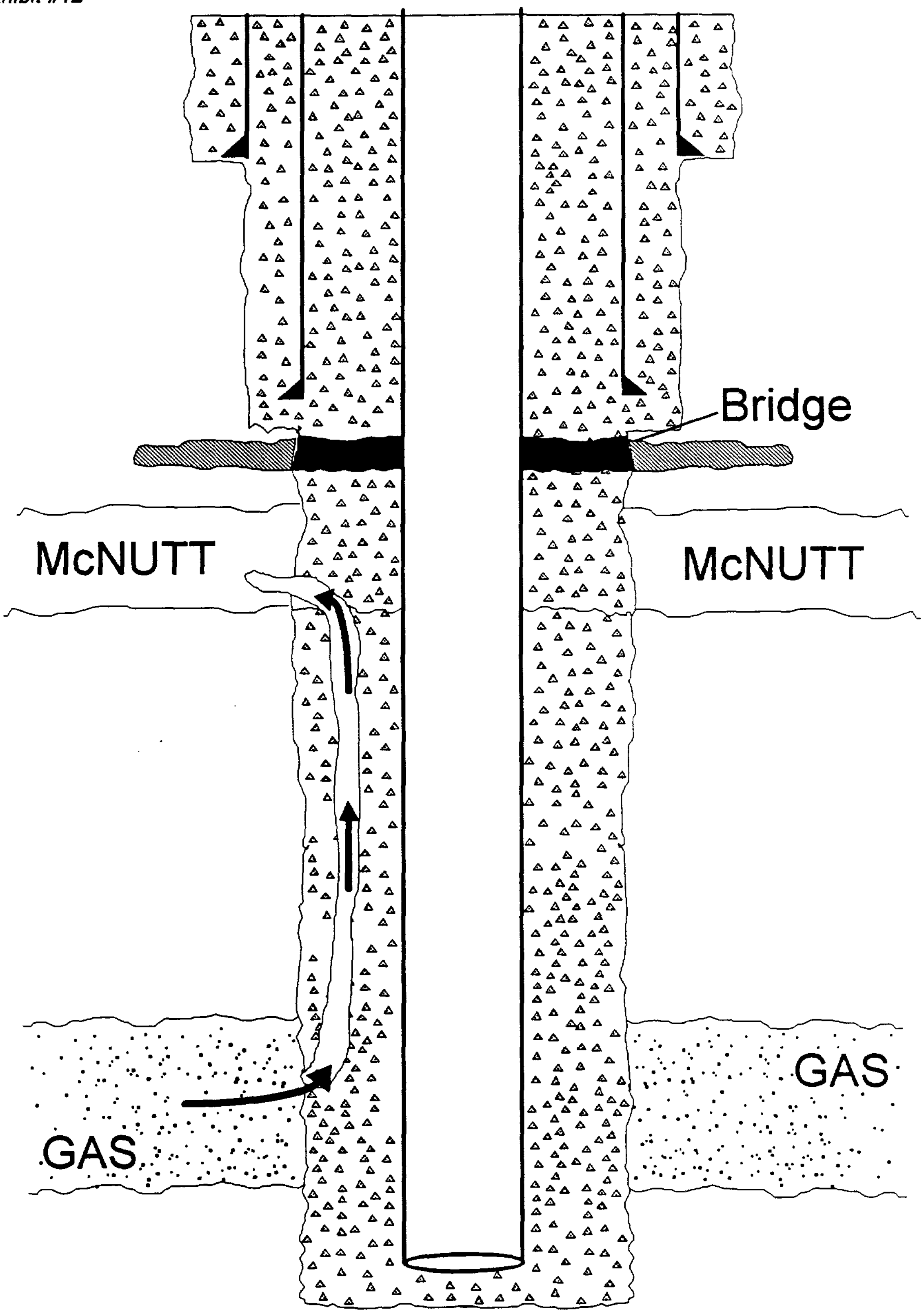
Weymouth's Equation:

$$q := 1000000 \cdot \sqrt{\frac{\left(Pb^2 - Pt^2\right) \cdot Dia^{5.33}}{.81 \cdot G \cdot T \cdot L}}$$

$q = 889512$ scf/d — Volume of standard natural gas which is expected to flow through the percolation channel in one day.

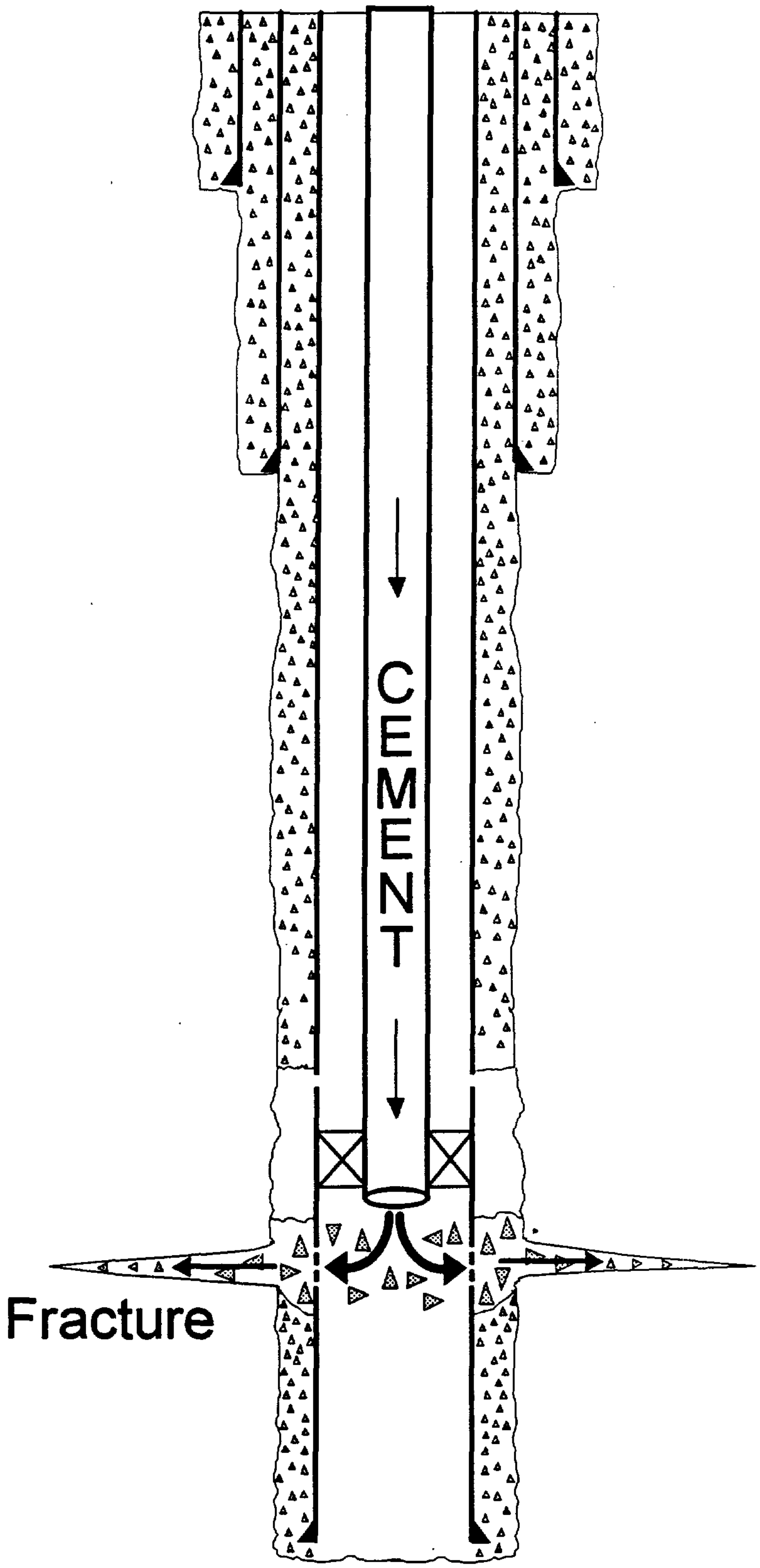
EXHIBIT #11 b

Exhibit #12



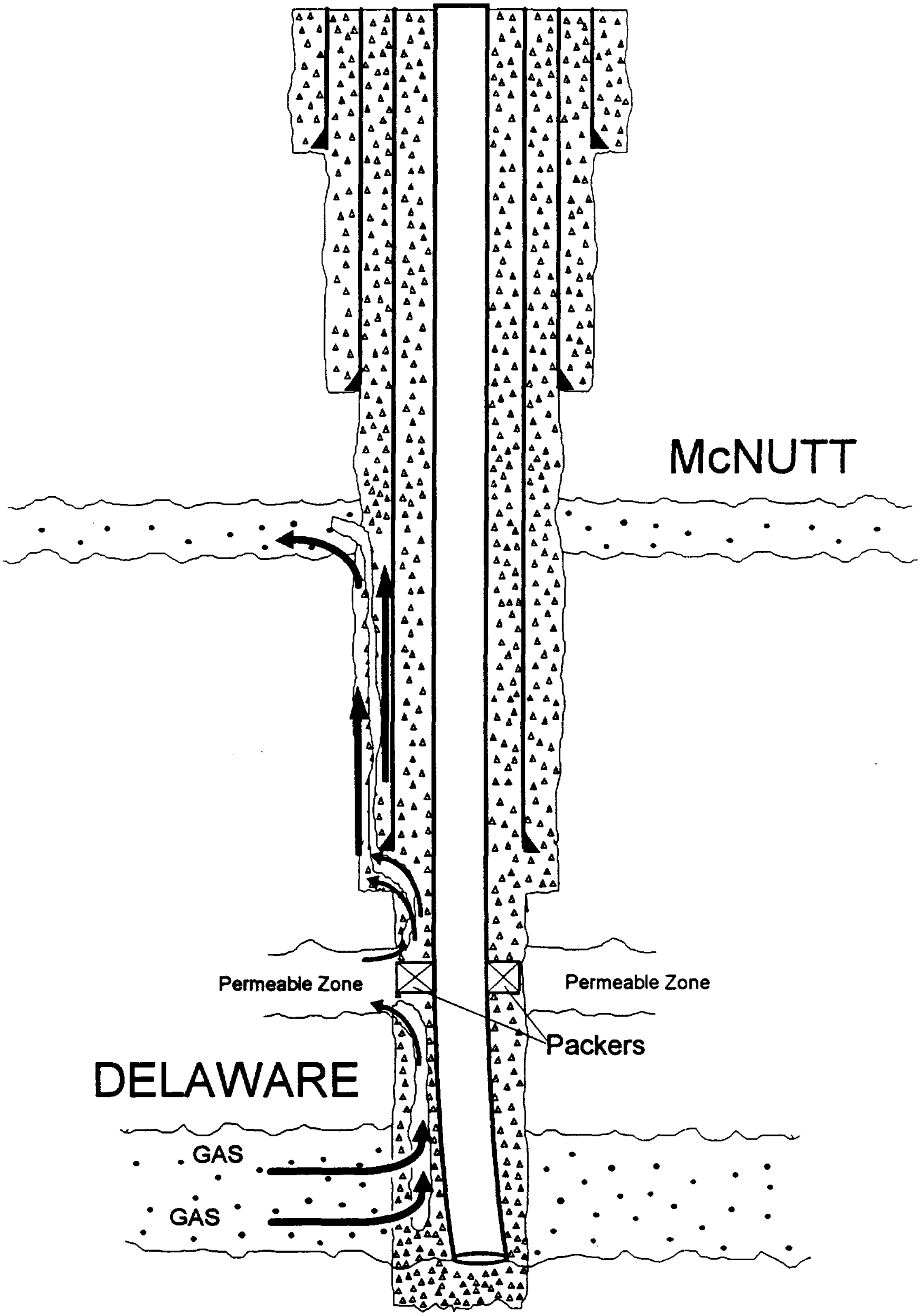
GAS CUT CEMENT & BRIDGING

Exhibit #13



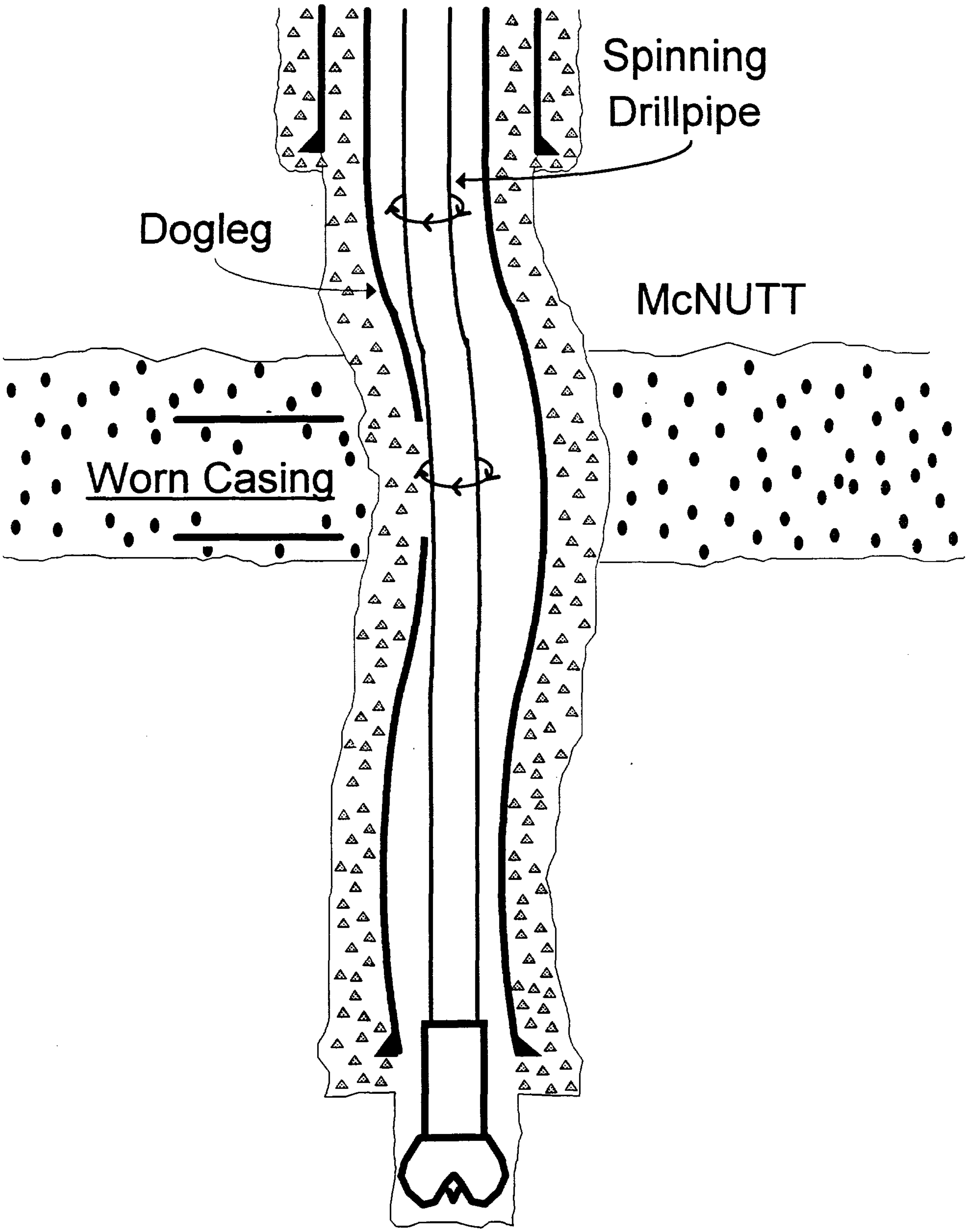
SQUEEZE CEMENTING

Exhibit #14



EXTERNAL CASING PACKER

Exhibit #15



WORN CASING and DOGLEGS

INCLINATION SURVEY GRAHAM AKB STATE #1

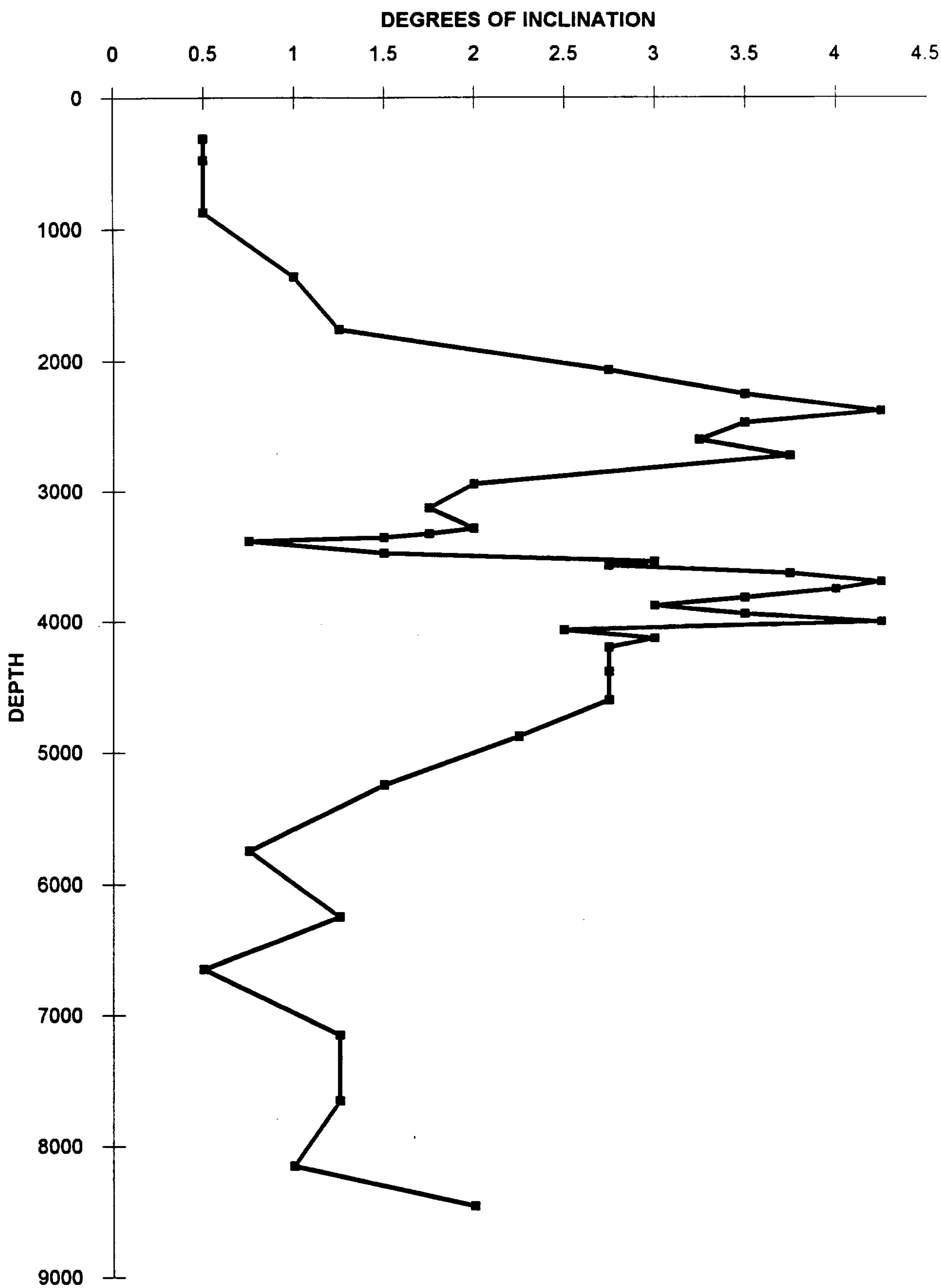


EXHIBIT #16