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(71) Applicant
John Samuel Bradley
3355 South Braden
Tulsa
Oklahoma 74135
United States of America
(72) Inventor
John Samuel Bradley
(74) Agent and/or Address for Service
Potts Kerr & Co
15 Hamilton Square
Birkenhead
Merseyside L41 6BR

(54) Disposing of fluid wastes

(57) Toxic liquid waste, eg liquid radioactive waste, is disposed of by locating a sub-surface stratum which, before removal of any fluid, has a fluid pressure in the pores thereof which is less than the hydrostatic pressure which is normal for a stratum at that depth in the chosen area, and then feeding the toxic liquid into the stratum at a rate such that the fluid pressure in the stratum never exceeds the said normal hydrostatic pressure.

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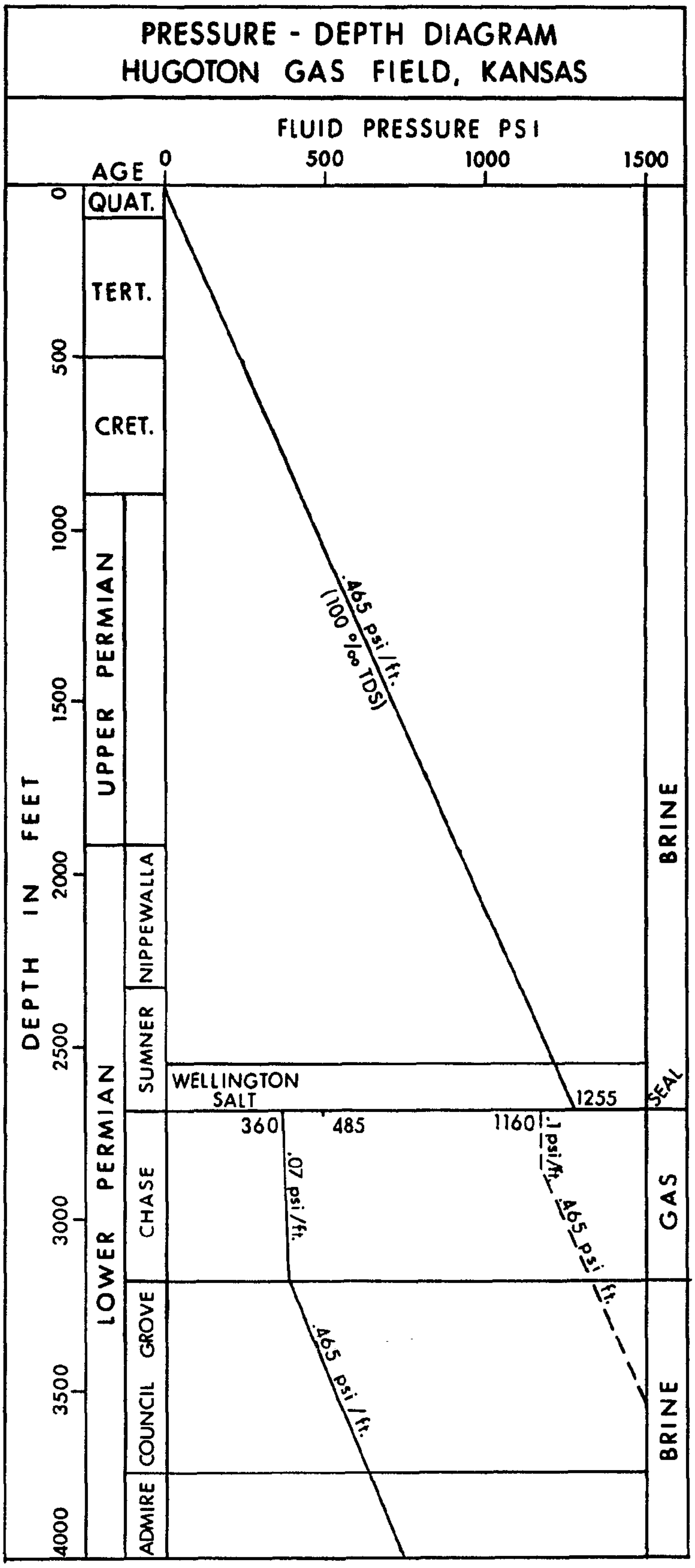
The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.


PRESSURE - DEPTH DIAGRAM
HUGOTON GAS FIELD, KANSAS
FLUID PRESSURE PSI
0
500
1000
1500
AGE
DEPTH IN FEET
QUAT.
TERT.
CRET.
UPPER PERMIAN
LOWER PERMIAN
NIPPEWALLA
SUMNER
CHASE
GROVE
COUNCIL
ADMIRE
WELLINGTON SALT
.465 psi/ft.
(100 ‰ TDS)
1255
SEAL
360
485
1160
.07 psi/ft.
.1 psi/ft.
.465 psi/ft.
.465 psi/ft.
BRINE
GAS
BRINE
0
500
1000
1500
2000
2500
3000
3500
4000

SPECIFICATION

Disposing of fluid wastes

The invention primarily concerns the disposal of fluid waste. It relates especially to the underground disposal of toxic liquid waste.

An unwanted by-product of our industrial society is toxic liquid waste. This toxic liquid waste must be disposed by some safe means. However, in most cases there appears to be no such disposal means readily available. In some cases it has been placed in tar-sealed barrels and buried in shallow graves, or dumped to the ocean floor or pumped into shallow wells. This appears satisfactory until the barrels start to leak or until displaced fluids or waste itself is pumped into aquifers or to the surface.

No prior art is known to the applicant which teaches to search for and find a sealed, sub-surface reservoir by detecting an abnormally low fluid pressure, then drilling a disposal well into it, and disposing of fluid in a manner and rate so as not to disturb the seal.

This concerns a system and method for the disposal of fluid waste and especially toxic or radio-active liquid waste. First located is convenient, porous, permeable, sub-surface strata which, before any fluid has been removed therefrom has fluid pressure in the pores which is less than the normal hydrostatic pressure of the water for that depth of strata in that area. This may be called a sealed underpressured reservoir. Industrial fluid waste is then flowed by gravity into such strata at a rate so that the fluid pressure never exceeds the normal hydrostatic pressure.

Various objects and a better understanding of the invention can be had from the following description taken in conjunction with the accompanying drawing which is a Pressure-Depth Diagram of the Hugoton Gas Field in Kansas.

The problem of liquid-waste disposal, particularly that of toxic or radioactive wastes, has become a major technical and political problem of our society. If the technical problem of safe waste-disposal through time can be solved, the political problem might be much alleviated.

Liquid wastes may be safely disposed of by utilizing underpressured reservoirs, a natural phenomenon, as a repository for the wastes. By the very fact of being under pressured; i.e., below the normal hydrostatic pressure for its depth, the reservoir indicates that it is, and has been, sealed off from the surface and from surrounding normally pressured reservoirs. The fact that the pore fluid pressure is below normal hydrostatic pressure for its depth is *prima facie* evidence that such strata are sealed. The age of the seal cannot always be determined, but where it can be, the ages are on the geological time scale, hundreds of thousands to millions of years, and thus may be considered a "permanent" seal in our usual time frame, and fluid can neither enter or escape.

In accordance with the invention a well is drilled into such underpressured reservoir and lined with proper casing and cement. The liquid waste is then disposed of into the reservoir under conditions so that the effective fluid pressure in the reservoir never exceeds the normal hydrostatic pressure. This way the natural seal is never disturbed or broken.

In accordance with the invention this permanently-sealed, underpressured reservoir can be filled with liquid waste until the reservoir approaches normal pressure without disturbing the seal or displacing any fluids outside the seal. By "normal pressure" is meant that pressure equal to the pressure exerted by the formation fluids from the surface to the specific depth within the underpressured reservoir. It is found by multiplying the depth by the pressure gradient (psi/ft) of the formation water column. This can be obtained by obtaining samples of the water from the strata and determining its density. A "normal" hydrostatic gradient is assumed to be .465 psi/ft which corresponds to a 100 parts per thousand total dissolved solid (TDS) brine or a density of 1.075 gm/cm^3. While this is a good average value, the pressure calculated for a shallow hole may be up to 50 psi too high, and for a deep hole with heavier brines may be as much as 150 psi too low. Thus, one should make an accurate determination from the measured density of the sample fluid of the strata into which fluid is to be disposed. To be safer, the abnormally-low pressure zone should be beneath an upper zone which has fluid in its pores at a normal hydrostatic pressure. This will avoid some near-surface (e.g., a few hundred feet) effects like perched water tables which could give low pressure without proving a pressure seal.

The conventional disposal through an injection well into a normally pressured reservoir displaces freely-migrating reservoir fluids, eventually to the surface, which can pollute the natural fluids and perhaps enter the food chain. However, even if, in using my invention, the seal of an underpressured reservoir were breached, as by improperly cemented or abandoned wellbores or by tectonic events, the normally pressured fluids from surrounding reservoirs would merely flow into the breach until pressures became normal. There would be no tendency to force the liquid waste to escape from the reservoir.

Underpressured reservoirs are known throughout the world and are widespread in North America. An example of the underpressured field would be the Hugoton Gas Field, chosen here because of the ready availability of data from an article by John W. Mason, "Hugoton

Panhandle Field, Kansas, Oklahoma and Texas," published in 1968 by the American Association of Petroleum Geologists in *"Natural Gases of North America, Volume Two"*. The field contains five and a half million acres. Wells are patterned on a mile grid; i.e., 640 acre spacing. The Permian Wolfcampian Chase Group, limestones, dolomites, and shales, are gas productive. In the Kansas portion of the field the following averages apply:

permeability	5 md
porosity	14%
water saturation	25%
productive thickness	45 feet

The initial reservoir pressure was 485 psia and the 1965 reservoir pressure 360 psia. The present pressure is even less. The average formation temperature is 90° F and the average depth to the formation is 2700 feet. The shale, anhydrite, and salt of the Wellington formation provide the upper seal and reduced permeability and the bottom water provide the lateral and bottom seals.

If we assume the averages above for the Chase Group and assume the water table at the base of the Chase, the pressure regime can be represented as in Fig. 1 of the drawing. If liquid wastes were injected into the reservoir to raise the pressure from 360 psi to 1160 psi, still well below the "normal" hydrostatic pressure of 1255 psi, the amount of liquid waste injected per well can be calculated as follows:

$$D = hA\phi \left\{ S_w C_L (P_2 - P_1) \left[1 + E_v (T_1 - T_2) \right] + S_G \left[1 - \left(\frac{P_1}{P_2}\right)\left(\frac{Z_2}{Z_1}\right)\left(\frac{T_2}{T_1}\right) \right] \right\}$$

where:

D is disposal volume, ft^3

h is reservoir thickness, ft

A is the reservoir area, ft^2

ϕ is porosity (decimal)

C_L is liquid compressibility, $\frac{ft^3/ft^3}{psi}$

S_w is water saturation (decimal)

S_G is gas saturation (decimal)

E_v is volume coeffiecient of expansion $\frac{ft^3/ft^3}{°F}$

P is pressure, psi

z is CH_4 gas correction

T is temperature °R

For the Hugoton reservoir:

$h = 45$ ft (effective, out of 500 ft total)

$A = 640 \text{ acres} \times 43{,}560\ ft^2/\text{acre} = 27.9 \times 10^6\ ft^2$

$$\phi = .14 \left(\frac{\text{volume pores}}{\text{volume total}} \right)$$

volume of reservoir is $h\,A = 1255.5 \times 10^6\ ft^3$

volume of pores is $h\,A\,\phi = 175.77 \times 10^6\ ft^3$

And

$S_w = .25$

$S_G = .75$

And

volume of brine is $h\,A\,\phi\,S_w = 43.94 \times 10^6\ ft^3$

volume of gas is $h\,A\,\phi\,S_G = 131.83 \times 10^6\ ft^3$

And

$P_1 = 360$ psi

$P_2 = 1160$ psi
$P_2 - P_1 = 800$ psi
$T_2 = T_1 = 90°\ F = 500°\ R$

$$C_L = 3 \times 10^{-6} \ \frac{ft^3/ft^3}{psi}$$

$$E_v = 400 \times 10^{-6} \ \frac{ft^3/ft^3}{°R}$$

$Z_1 = .96$
$Z_2 = .90$
$T_2/T_1 = 1$
$P_1/P_2 = .31$
$Z_2/Z_1 = .94$
$460°\ R = 0°\ F$

Thus, for these sample assumptions,

$$D = 45 \cdot 27.9 \cdot 10^6 \cdot .14 \left\{ .25 \cdot 3 \cdot 10^{-6} \cdot 800[1 + 400 \cdot 10^{-6} \cdot 0] + .75 \left[1 - \left(\frac{360}{1160}\right)\left(\frac{.90}{.96}\right)\left(\frac{550}{550}\right)\right] \right\}$$

$D = 93.58 \times 10^6$ ft^3/well
or
$D = 16.67 \times 10^6$ bbl/well
If the reservoir well were all liquid ($S_w = 1$),
$D = 75{,}139$ bbl/well
If the reservoir well were all gas ($S_G = 1$),
$D = 22.2 \times 10^6$ bbl/well

This difference is due to the difference in compressibility of the brine and the methane. To inject large volumes of liquid into a liquid-filled reservoir would require a thicker, more porous reservoir; i.e., a higher pore volume per well, than this example calculates.

CLAIMS

1. A method of disposing of fluid industrial waste which comprises locating a porous, permeable, sub-surface stratum which, before any fluid has been removed therefrom, has fluid pressure in the pores thereof which is less than normal hydrostatic pressure for that depth of the stratum in that area, flowing industrial fluid into the stratum at a rate so that the fluid pressure never exceeds the normal hydrostatic pressure.

2. A method as claimed in claim 1, in which the waste is flowed through wells drilled into permeable strata, having original fluid pressure in the pores which is less than normal hydrostatic pressure.

3. A method as claimed in claim 1 or 2, in which the strata is beneath an upper zone which has fluid in its pores at a normal hydrostatic pressure.

4. A method as claimed in claim 1 or 2, in which the normal hydrostatic pressure is determined by measuring the density of sample fluid from the strata and using such density and strata depth to obtain the normal hydrostatic pressure.

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