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ON THE POSSIBLE APPLICATION OF SOME OILFIELD TECHNIQUES TO THE STIMULATION OF WATER BORES.

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SUMMARY

A simple method of treating old water bores which are producing from calcareous rocks and whose production has declined, is described. The process is easy to apply and can be carried out without previous experience and using equipment which can be made or obtained cheaply a and locally.

INTRODUCTION

Some water bores completed in limestones, calcareous sandstones or dolomites have shown, over a period of years, a gradual reduction of water influx. This reduction could be due to the build-up of calcium carbonate deposit in the rock fractures and even in the perforations or slots of the casing itself.

It is possible to remove such water-blocking deposits by the application of relatively small volumes (5 to 15 gallons) of hydrochloric acid, which dissolves the calcium carbonate and "stimulates" the water bore to regain part or all of its original production rate, or even to exceed it.

Hydrochloric acid has been used, since about 1930, to promote oil and gas recovery efficiency in wells where the producing formation is predominantly calcareous.

Diluted hydrochloric acid of 16% strength (16gm. hydrogen chloride in 100 ml. water) is capable of dissolving approximately 2 lb or 20 cu. in. of calcium carbonate (limestone) per one imperial gallon of acid used.

The acid used may be pure hydrochloric acid or the commercial acids known as "spirits of salts" or "muriatic" acid. The strength of acid preferred will depend on the type of formation to be treated, and the amount of water standing in the bore.

THEORETICAL ASPECTS

1. The successful application of hydrochloric acid (HCl) in a water bore depends on its ability to dissolve limestone or calcium carbonate ($CaCO_3$), according to the following equation:

$$2\ HCl + CaCO_3 \longrightarrow CaCl_2 \downarrow + CO_2 \uparrow + H_2O \quad ..(1)$$

2 HCl	$CaCO_3$	$CaCl_2$	CO_2	H_2O
Hydrochloric Acid	Calcium Carbonate	Calcium Chloride	Carbon dioxide	Water

From this balanced equation we may determine:

(a) The amount of limestone that can be dissolved by a known quantity of HCl of known strength.

(b) The amount of $CaCl_2$ which will be produced and which must be removed from the bore.

(c) The volume of CO_2 which will evolve and exert pressure in the sealed bore casing.

(a) Dissolving power of 16% HCl

Using equation (1), the dissolving power of the HCl may be determined as follows:

2 HCl is equivalent to $CaCO_3$

Substituting atomic weights for the chemical symbols, we may write:

2(1+35.5) gm. HCl is equivalent to 40+12+(16)3 gm $CaCO_3$

Therefore 73 gm. HCl is equivalent to 100 gm $CaCO_3$

or 1 gm. " " " " 1.370 gm. $CaCO_3$

The 16% HCl contains 16 gms. HCl per 100 cc. water or 727 gm. per imperial gallon, therefore we may write:

727 gm. HCl is equivalent to (727 x 1.370) gm $CaCO_3$

or 1 gal. of 16% HCl will dissolve 996 gm. (2.20 lb) $CaCO_3$

THEREFORE ONE GALLON OF 16% HCl WILL DISSOLVE 2 POUNDS OF LIMESTONE

(b) Quantity of $CaCl_2$ produced

From equation (1),

2 HCl is equivalent to $CaCl_2$, and by substituting atomic weights as in (a) we may write:

2(1 + 35.5) gm. HCl is equivalent to 40 + (35.5) 2 gm. $CaCl_2$

Therefore 73 gm. HCl is equivalent to 111 gm. $CaCl_2$

or 1 gm. HCl is equivalent to 1.521 gm. $CaCl_2$

16% HCl contains 727 gm. HCl per imperial gallon. We may therefore write:

727 gm. HCl is equivalent to 727 x 1.521 gm. $CaCl_2$

or 1 gal. of HCl will produce 2.44 lbs. $CaCl_2$

THEREFORE ONE GALLON OF 16% HCl WILL PRODUCE 2.4 LBS. OF CALCIUM CHLORIDE

(c) Volume and pressure potential of CO_2 produced

From equation (1),

2 HCl is equivalent to CO_2

Therefore as before,

2(1 + 35.5) gm. HCl is equivalent to 12 + (16 x 2) gm. CO_2

Therefore 73 gm. HCl is equivalent to 44 gm. CO_2

However, the gram molecular weight of any gas occupies 22.4 litres at standard temperature and pressure (S.T.P.). Standard temperature is 0 deg. Centigrade and standard pressure is 760 mm. mercury.

Therefore 73 gm. HCl will produce 44 gm. CO_2, which will occupy 22.4 litres at S.T.P.

The 16% HCl used contains 727 gm. HCl per imperial gallon and the gas volume produced is:

$$\frac{727}{73} \times 22.4 = 223 \text{ litres } CO_2 \text{ at S.T.P.}$$

ONE GALLON OF 16% HCl WILL PRODUCE 223 LITRES OR 7.9 CU. FT. OF CO_2 AT S.T.P.

2. We will now assume that the bore to be treated is 100 ft. deep and is lined with 5 in. I.D. casing.

The 5 in. dia. casing has a capacity of 0.14 cu. ft./ft.

Therefore 100 ft. of casing will contain a volume of 14 cu. ft. or 396 litres.

Using the gas equation, we may now determine the pressure that will be exerted by the CO_2 produced from 1 gallon of acid if this CO_2 is confined within the casing.

Gas equation .... $\frac{P.V.}{T.} = \frac{P_1V_1}{T_1}$

where:
P = press. at S.T.P. = 760 mm. Hg
V = vol. at S.T.P. = 223 litres
T = absolute temp at S.T.P. = 273 deg.
P_1 = pressure of gas when confined in casing
V_1 = vol. of gas in casing = 396 litres
T_1 = absolute, average temp in casing = (273+20) deg.

Substituting in the gas equation:

$$\frac{760 \times 223}{273} = \frac{P_1 \times 396}{293}$$

From which P_1 = 459 mm. Hg

but 760 mm. Hg = 14.6 p.s.i.

Therefore $P_1 = \frac{459}{760} \times 14.6 = 9$ p.s.i.

THEREFORE THE PRESSURE EXERTED BY CO_2 PRODUCED FROM 1 GALLON OF 16% HCl, REACTING WITH LIMESTONE, WHEN CONFINED IN 100 FT. OF 5 IN. CASING, IS 9 P.S.I.

For example, a 15 gallon application would result in a pressure of 135 p.s.i.

Hydrostatic and overburden pressure

The hydrostatic pressure exerted by water at a depth of 100 ft. would be approximately:

$$100 \times 1.01 \times 0.433 = \underline{44 \text{ p.s.i.}}$$

The overburden pressure at the same depth, created by the pressure of overlying formation, would be approximately:

$$100 \times 2.25 \times 0.433 = \underline{97 \text{ p.s.i.}}$$

PRACTICAL APPLICATION

Initially, samples of detritus from the bottom of the bore, preferably pieces up to ½ inch, should be obtained and used for solubility tests which are described later. Normally, when the bore is bailed, flakes and fragments of formation or scale consisting of carbonate or oxide, are found inside the bailer, especially if it has reached the bottom of the bore.

Observations should be made during bailing to see whether the bore can be bailed dry or whether the influx of water is such that a steady water level in the bore is maintained.

After bailing stops, fluid levels should be taken every five minutes to determine the rate of influx of the water. Levels should be noted until a static level is obtained. This information will be important in determining the strength of acid to be added to provide the required concentration at the bottom of the bore.

Acid solubility tests should now be carried out on the scale and rock detritus collected from the bore. If it is proposed to use a 16% HCl acid, then a weighed amount of the detritus should be placed in a beaker and treated with 16% HCl. After effervescence has stopped, the beaker is filled with water and allowed to stand until all solid material has settled; the clear liquid should then be poured off. The beaker should then be filled again with water. This washing procedure must be carried out 5 or 6 times, after which the beaker containing the residue is placed in an oven to dry. After drying, the residue is weighed and the percentage of detritus soluble in 16% acid concentration is calculated.

The percentage solubility will give an indication as to whether acidization treatment is likely to be successful.

It may be that the scale and detritus collected is an oxide insoluble in HCl; in this case it is unlikely that any improvement in water flow would result from acid treatment. However, the scale may be a carbonate which is readily soluble in acid, which would indicate that the application of acid to the correct position in the bore might result in the cleaning of perforations and fractures, and thus obtain some increase in water production.

The minimum solubility of the scale or detritus which would indicate that acid could be successfully used is yet to be determined by practical experience; it is suggested, however, that even a 10% solubility may leave voids in the encrustation, enabling non-reactive pieces to come away from water passages where they have been restricting water flow.

Another procedure that could conceivably enhance the successful application of acid to calcareous rocks is that of fracturing the rocks by the application of pressure. This operation is known as "fraccing". Pressure in excess of over-burden pressure is applied to the formation, through the bore, so that existing fractures are widened. The pressure created by CO_2 evolved in the acidizing process could be utilized for this purpose, but may have to be augmented by use of pressure from a pump.

During "fraccing" in a water bore, solid material along with the liquid in the bore, may be forced into opened crevices and fractures, so that on release of pressure, the openings do not return to their original state but are kept open by the solid material.

If it is decided to acidize the bore, the strength of the acid to be used must be determined. If the water flow has completely stopped or is such that it will fill only a few feet in the bottom of the bore in a period of ten minutes, then the acid to be used would probably be 16% HCl which could be mixed in plastic buckets at the bore site. If on the other hand, production of water is sufficient to fill the bore to half of its volume in ten minutes then the concentrated (32%) acid should be used and should be added directly to the bore, allowing the bore water to dilute the acid.

As an example of acidizing procedure, we will assume that 32% acid is to be used; in which case, the following steps should be carried out:

Carry the acid bottle to the casing head and remove the stopper while the bottle is in an upright position. Rapidly invert the bottle, resting the neck of the bottle on the casing rim, so that the bottle shoulders form a seal in the casing tip.

When the bottle has been emptied or when the required amount of acid has been added, remove the bottle and quickly screw on the casing cap. Refer to Fig. 1.

With the casing cap tightened and the two casing cap valves closed, screw in the appropriate pressure gauge and slowly open the gauge valve. If several gauges are available, use one with the largest pressure range, replacing with one having a smaller range if it is found that the pressure is not great.

The second valve on the casing cap should have a hose of suitable length connected to it so that any effluent from the bore may be run off into a large drum or pit when the valve is opened.

The pressure in the bore is regulated by this second valve. If it is desired that only the casing ports and material adjacent to the bore are to be cleaned, then the pressure should be maintained at a value between the overburden pressure and the hydrostatic pressure, which would have been calculated previously.

If it is known that the production is from fractured formation and it is desired to widen these fractures, then the pressure obtained when the CO_2 is evolved from acid attack on limestone should be allowed to increase above the calculated overburden pressure. However, any increase of pressure above overburden should only be attempted in bores having well cemented casing.

A pressure high enough to overcome overburden pressure may not be possible if permeable passages are opened sufficiently to allow the pressure built up by CO_2 to be dissipated away from the well bore.

As the acid is spent and the well-head pressure drops, the outlet valve may be closed and the bore allowed to stand for about one hour. After this period the pressure may be bled off and the casing cap removed. The bailing of the spent acid solution, which will contain calcium chloride, should now begin and while this is being done, it should be noted whether improvement in water influx has resulted.

If there has been little or no improvement, a second acid application should be made in the same manner as described above. However, it is suggested that after the second addition of acid and after pressure adjustments have been made, the bore should be left sealed for some hours, preferably overnight, before bailing again.

Following an acid treatment, the water produced should not be used until several casing volumes, depending on the volume of acid used, have been discarded into a pit where later, after drying out, the $CaCl_2$ may be scraped up and removed.

A simple method for determining when the water is fit for use is to test it with strips of "Hydrion" pH paper. These strips are inexpensive and will indicate the pH of the water from pH-1 to pH-11 in steps of one pH unit.

If the water still contains acid this will be clearly indicated when the test strip is compared with the colour chart provided. It is more likely, however, that all acid will be spent and the first production from the well will be strongly alkaline due to the concentration of calcium chloride; this also will be indicated by the test strip and colour chart.

Water produced from the well should be discarded until the test strip shows that near neutrality or the pH of the original water has been reached.

SAFETY PRECAUTIONS

The acid purchased must be of the inhibited type containing a compound which will prevent it attacking the steel casing and causing corrosion. Imperial Chemical Industries (I.C.I.) market a 33% inhibited HCl acid known as "Norocene"; this product does not attack mild steel, many stainless steels, copper and admiralty metal.

Hydrochloric acid generally comes in 5 gallon bottles packed firmly in a wooden crate with only a short neck of about 2 inch diameter protruding.

If this type of bottle is held horizontally when the acid is being added to a bore, the acid flows spasmodically and is likely to splash. It is far safer to place the neck of the bottle over the casing centre and completely invert the bottle; the acid is then confined to the inside of the casing and the concentration of irritating acid fumes in the area of the bore is minimized.

Some spillage of acid does occur, due mainly to the overflow of bubbles from the casing top before the casing cap can be fitted and for this reason rubber boots and gloves should be worn by those working near the casing top.

The main danger in using acid lies in splashes of the acid reaching the eyes. With proper care this should not occur but for safety, goggles should be worn and a water hose should be left running nearby. In the event of acid reaching any part of the skin, the effected party should be thoroughly washed immediately with large volumes of water.

It is reasonable to expect that any pressure produced as a result of the acid treatment would be dissipated into the formation through the casing perforations and the channels by which water had been entering the bore. However, to avoid any possibility of a blow-out, the following precautions should be taken:

(a) The cap sealing the casing-head should have two valves welded into it - one for the release of pressure if this should be necessary, and the other for the mounting of a pressure gauge to show the build up of pressure inside the bore.

(b) On no account should acid be sealed in the bore if it is known or suspected that the outside of the casing is not firmly held in place in the formation.

(c) If this type of water bore stimulation proves to be successful and is used extensively, it may be possible to design a system where a pumping unit could be used to place acid in the bore through the casing cap valve thereby avoiding any human contact with the acid. See Fig. 2.

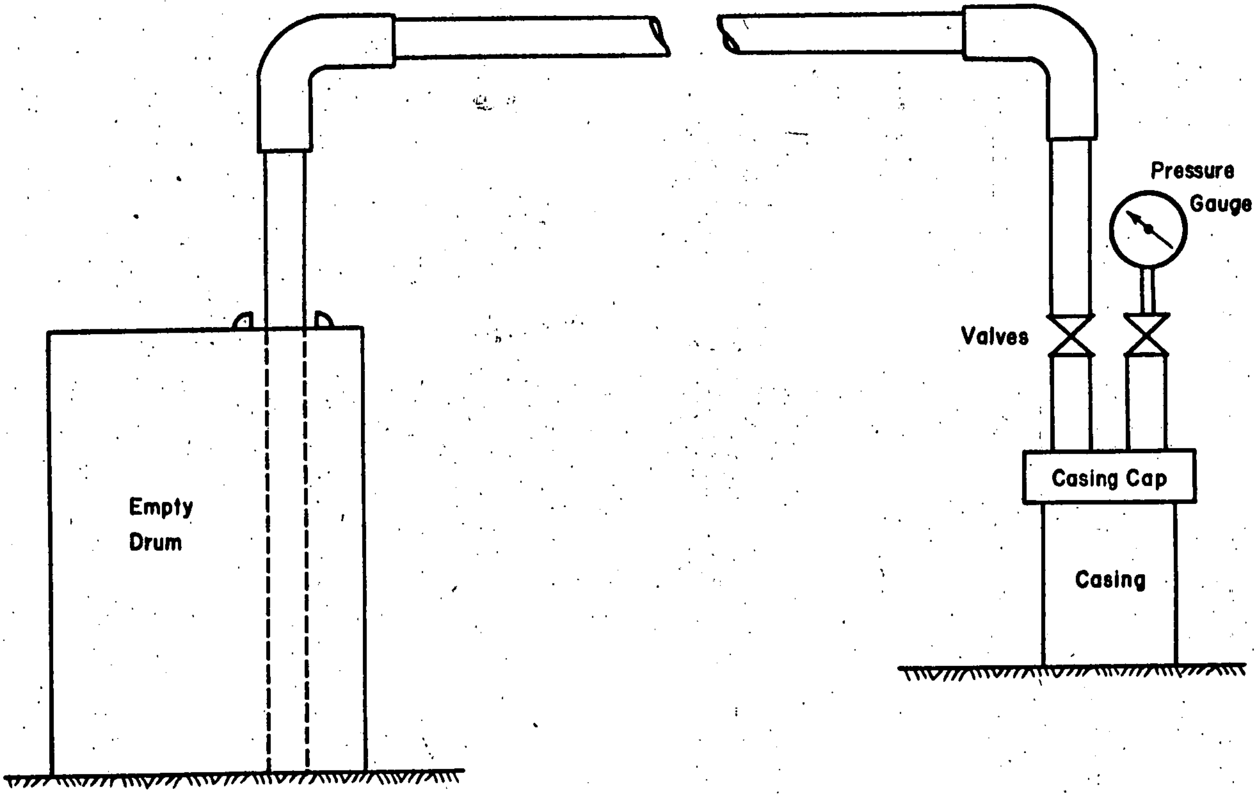

Fig. I Equipment required where pressure of evolved gas only is used.

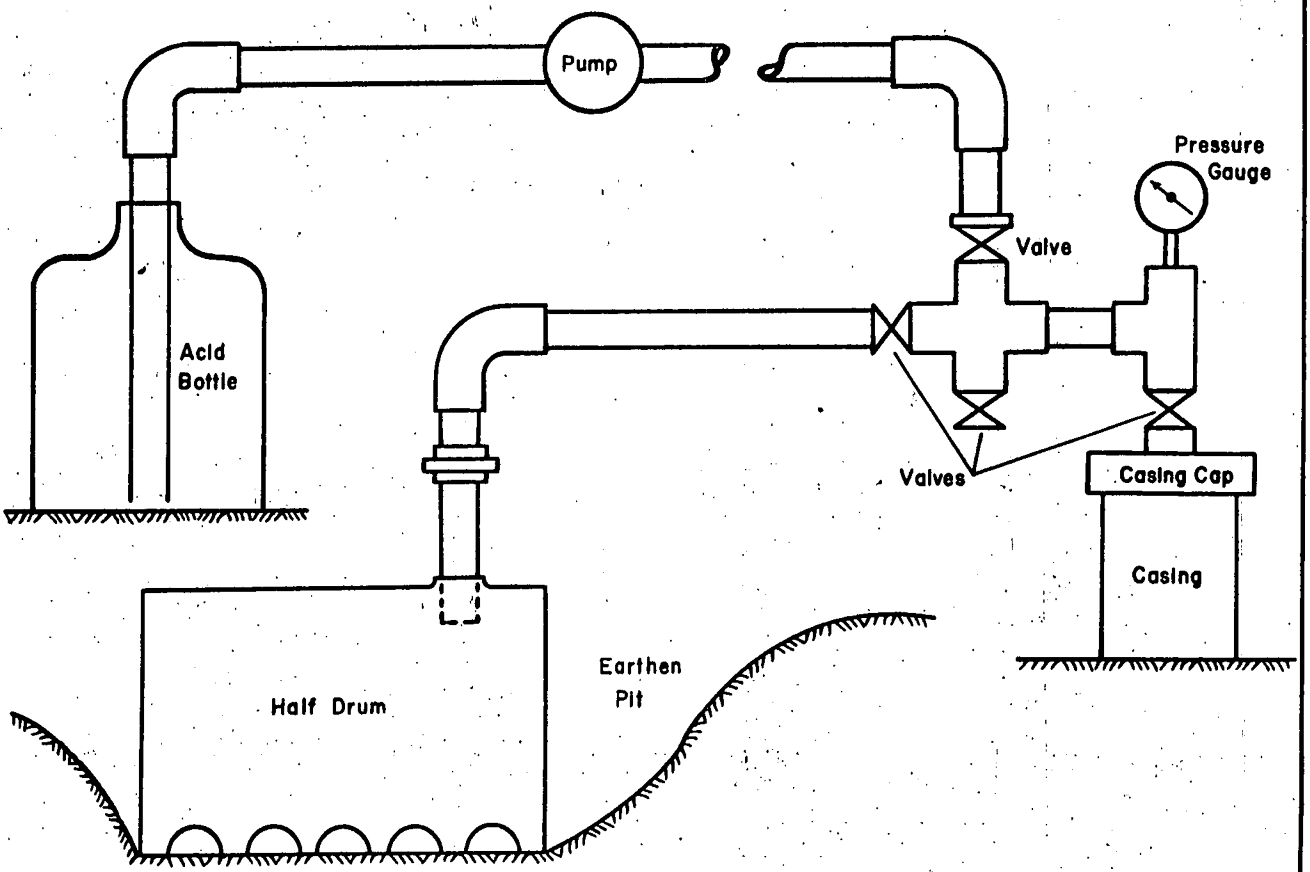

Fig.2 Equipment required where pump is employed to place the acid and supplement pressure if required.