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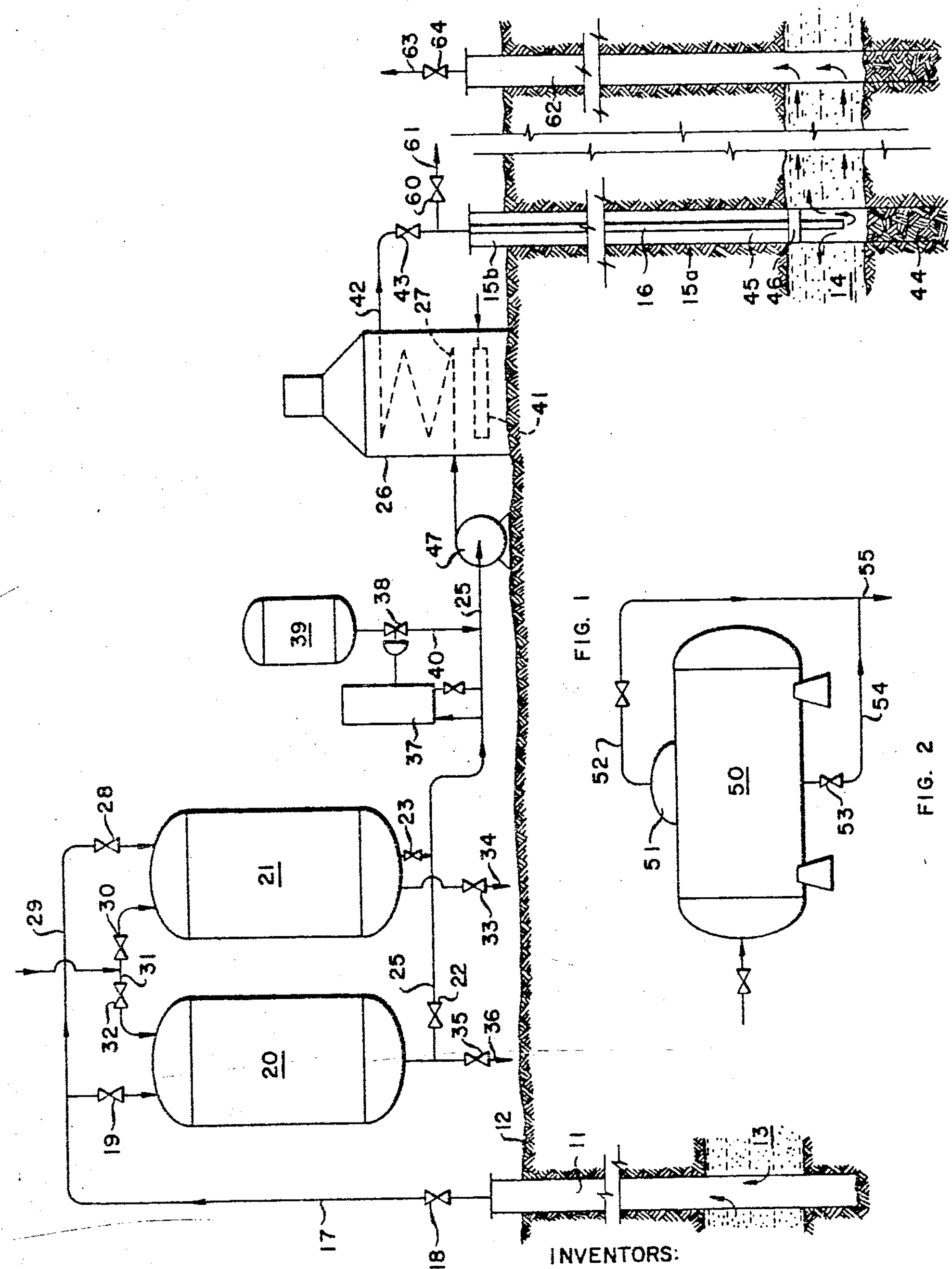

FIG. 1

FIG. 2

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USE OF LOW-GRADE STEAM CONTAINING DISSOLVED SALTS IN AN OIL PRODUCTION METHOD

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This invention relates to an improved method for recovering hydrocarbon material from an underground formation which may be in the form of oil sands, oil shale or tar sands. The invention pertains more particularly to a method for the secondary recovery of oil, particularly highly viscous oil, or other hydrocarbon materials that are substantially nonflowable under reservoir conditions.

This invention constitutes an improved method for supplying heat and/or other energy in the form of a driving medium to an underground formation containing tar sands, oil sands or oil shales for the purpose of increasing the oil recovery therefrom. The method is applicable to formations containing oil of high viscosity which may be nonproducible, i.e., nonflowable under original conditions and to those containing low to medium viscosity oils of which varying amounts may have been recovered by conventional primary means.

The primary production of petroleum hydrocarbons from oil-bearing formations is usually effected by drilling through or into the oil-bearing sand and providing access to the formation around the borehole so as to permit oil to flow into the borehole from which it may be recovered by conventional methods. If the formation contains an oil of low or medium viscosity at reservoir conditions, the well may be produced either by flowing or pumping in a manner well known to the art. If on the other hand the formation contains a highly viscous oil at reservoir conditions, it may be necessary to heat the formation in the vicinity of the borehole to reduce the viscosity of the oil so that the oil may flow into the borehole. In time, even the wells containing free flowing oil become depleted although a substantial amount of oil still remains in the producing formation underground. The residual oil left in the formation underground is very difficult to produce and considerable research has been carried out on secondary methods of recovering this residual oil. Various methods have been devised such as heating, underground combustion, flooding with water or a miscible fluid, etc.

The flooding of underground formations for the primary or secondary recovery of a hydrocarbon material such as oil presents many problems. In the water flooding of oil-bearing underground formations, it is necessary to employ flood water free of clays, colloidal material, undissolved salts, etc., which would tend to plug the face of the oil formation and perhaps within the oil formation itself when the water is injected thereinto. In addition, many producing formations being flooded contain a certain amount of swelling clays in the form of a bentonite or montmorillinite clay, which upon swelling, reduces the permeability of the formation. Saline water tends to prevent the swelling of clays of this type and its use is often preferred in water flood projects. Whatever water is used, it should be compatible with the formation into which it is injected so as not to reduce the permeability of the formation.

Unfortunately, the water available in or around many oil fields is usually hard and contains alkaline earth metal salts such as those of calcium and magnesium. In the event that hot water or hot water and steam are to be injected into the producing formation, the use of ordinary oil field water normally available containing calcium and

magnesium salts would cause the formation of considerable scale in steam generation equipment. The water could be treated in a conventional manner with phosphate to precipitate the calcium and magnesium salts as a non-scaling phosphate sludge within the steam generation equipment. This phosphate sludge however is of a form that readily plugs a formation when the water is being injected into it.

It is therefore a primary object of the present invention to provide a method of recovering hydrocarbon material from underground formations by heating them with a material which is compatible with the formation and may be readily injected thereinto.

A further object of the present invention is to provide a method of flooding an underground oil-producing formation with a hot fluid that has no tendency to scale equipment nor any tendency to plug an underground formation into which it is being injected.

Still another object of the present invention is to provide a method of flooding with a hot fluid an underground formation to recover hydrocarbon material therefrom wherein the water phase of the flood fluid contains dissolved salts that are compatible with the formation being flooded and have a tendency to prevent the swelling of certain clays which may be in the formation.

A further object of the present invention is to provide a method of flooding an underground formation with a hot fluid for the recovery of hydrocarbon material therefrom wherein the treatment of the flood fluid is relatively inexpensive.

These and other objects of this invention will be understood from the following description taken with reference to the drawing, wherein:

FIGURE 1 is a schematic view illustrating three wells taken in cross section and extending into the earth with associated equipment diagrammatically illustrated on the surface of the earth; and

FIGURE 2 is a schematic view of another form of steam generation equipment for use with the equipment of the present invention.

Referring to FIGURE 1 of the drawing a water well **11** is shown as being drilled in the earth **12** and into a water-producing formation **13** to serve as a supply for water in a flood project for the recovery of hydrocarbon from a hydrocarbon-producing formation **14** which is traversed by a well **15*a***. The well **15*a*** is provided with casing **15*b*** which may have a tubing string **16** therein. It is to be understood that instead of using well **11** as a source of water that the water could be supplied from any other source. The well **11** is provided with a discharge line **17** having a control valve **18** therein. The water line **17** leads through valve **19** into the top of a chemical treatment tank **20** which is preferably mounted in side-by-side arrangement with a second chemical treatment tank **21** in the event that it is necessary to re-generate the chemical in one tank while the other tank is being used.

In accordance with the method of the present invention, a method of treating waters containing calcium and/or magnesium salts is to pass them through a tank containing sodium ion exchange resin (e.g., sodium zeolite) which carries out an ion exchange so that calcium and magnesium salts are converted to sodium salts which are discharged in the fluid stream through valve **22** in line **25** to a suitable steam generation unit **26** having coils **27** therein for example.

When the flow of hard water is through valve **19** into chemical treatment tank **20** and it is necessary to regenerate the chemical in treatment tank **21**, valve **28** in the other line **29** going to tank **21** would be closed while valve **30** in line **31** would be open with valve **32** closed so that sodium chloride brine could be flushed through the other tank **21** to regenerate the sodium zeolite in tank **21** with the salt water being discharged through valve **33** and line **34**. Tank **20** would be provided with a similar valve **35** and discharge line **36**.

The system may be provided with a water hardness analyzer **37** adapted to actuate the valve or other mechanism **38** from a chemical injection tank **39** which is connected to line **25** by line **40**. Thus, in the event that a small amount of calcium or magnesium salts were still present in the water, the hardness analyzer **37** could control the injection, through valve **38** from tank **39**, of a small amount of a chelating agent to form water soluble calcium and magnesium salts. One suitable chelating agent is an aqueous solution of the tetrasodium salt of ethylene diamine tetra-acetic acid.

The steam generation unit for heating the water may be in the form of a spiral set of coils **27** through which the water flows with a suitable burner **41**, such as a gas or oil-fired heater, positioned in the bottom to heat the coils.

The low grade steam from the steam generating unit **26** is discharged through line **42** and valve **43** and thence down through well tubing **16** to be discharged preferably adjacent to the producing formation **14**. The bottom of the well **15*a*** may be closed in any suitable manner, as by cement **44**. The annular space **45** between the well casing **15*b*** and the tubing string **16** may be closed by a packer **46** of any suitable type at a level close to the top of the producing formation **14**.

A water pump **47** is provided in the line **25** to the steam generating unit **26** which may be in the form of a boiler, steam generator or field heater. By adjusting the pump rate and the setting of the burner **41**, the water content of the steam in the discharge line **42** can be controlled. Since the water coming into the boiler, steam generator **26** or field heater carries with it soluble salts, it is essential that these salts remain in solution while the steam is being formed and while the steam and water are being discharged from the boiler, steam generator or field heater through line **42** and into well **15*a***. Preferably, the liquid phase of the low grade steam being produced by the field heater, boiler or steam generator **26** has from 5 to 25 percent water in it depending on the amount of salts that it is necessary to carry from the boiler, field heater or steam generator and down into the well. If a boiler **50** of the type shown in FIGURE 2 is employed, where pure steam is discharged out the dome **51** through line **52**, a valve **53** in the water discharge line **54** from the bottom of the boiler **50** can be adjusted, either manually or automatically, to periodically or continually bleed a small amount of water laden with soluble salts out line **54** and down line **55** with the steam. The dissolved salts concentration in the water carried by either line **42** or line **55** is several fold greater than the dissolved salts concentration in the water supply.

Although the apparatus of the present invention has been operated between from about 150 to 600 p.s.i.g. steam generating unit pressure, the same equipment could be operated at 2500 p.s.i.g. or more. The operating pressure generally depends on various well characteristics such as well depth and well pressure since it is necessary to force the steam and hot water to the bottom of the well or to the point adjacent a producing formation. Both the steam and water are injected into the formation at high temperatures to reduce the viscosity of the hydrocarbons therein and/or vaporize the lighter components. If the producing formation is of varying permeability, the water in the steam has a tendency to block the larger interstices between the sands to prevent fingering of the steam into the formation thus giving a more uniform rate of movement of heat through the formation. The presence of concentrated soluble salts in the injection water reduce the tendency of clays to swell.

After heating the formation **14** through well **15*a*** for a predetermined time, the well **15*a*** may be produced in any conventional manner through its tubing string **16** by

closing the steam injection valve **43** and opening valve **60** on production line **61** leading from the well. If a steam drive is to be carried out through the producing formation **14**, which must necessarily be of a permeability sufficient to allow the passage of steam therethrough, a second well **62** would be drilled in the formation **14** at some distance from the well **15*a***. The well **62** would be produced in any conventional manner through its production flowline **63** when valve **64** was open.

It is realized that most of the calcium and magnesium salts in the hard water coming from the supply source **11** may be converted to sodium salts in the chemical treating tanks **20** or **21**. Instead of removing small amounts (say a few parts per million) of residual hardness from the treated water by adding a chemical from tank **39** to form water soluble calcium and magnesium salts, the chemical addition from tank **39** can be omitted with the result that a small amount of scale formation in the field heater, boiler or steam generator tubes **27** will take place. This can be overcome by shutting the system down from time to time and removing the scale from the field heater, boiler or steam generator tubes in a conventional manner. In addition, it is to be realized that the water from the supply source **11** can be treated in one or more various ways, as needed, as by adding lime or lime-soda ash to reduce calcium and magnesium hardness, adding magnesium oxide to reduce silica content, adding sodium sulfite to remove oxygen from the water and hence prevent corrosion, adding suitable materials to re-saturate the water with bicarbonates to prevent scale deposition, etc., and that sodium ion exchange treatment may be deleted or used in conjunction with these treatments and when used may be conducted with parallel or series flow of the water through two or more tanks containing sodium ion exchange resin. All of these treatments are conventional and need to be only employed where the composition of water demands it. To date, low grade steam having at least 10 percent water in it has been employed successfully. Further, it is to be realized that low grade steam may be discharged down through the annular space **45** between the well casing **15*b*** and the tubing string **16** or down through both said annular space and tubing string **16**.

We claim as our invention:

1. In a method of recovering a hydrocarbon material from an underground formation in which it occurs, the steps of
   - drilling a well from the ground surface into said hydrocarbon-containing underground formation,
   - obtaining a supply of water containing ions of a scale-forming alkaline earth metal salt,
   - treating the water to convert the alkaline earth metal salt to a soluble alkali metal salt,
   - generating low-grade steam from said treated water, said steam having a quantity of water in liquid phase sufficient to maintain the soluble salts dissolved therein and in a concentration greater than the dissolved salt concentration of the water supply, and
   - injecting the low-grade steam and the soluble salts carried therein through said well and contacting the hydrocarbon-containing underground formation in communication therewith for a time sufficient to improve the flow characteristics of said hydrocarbon material.

2. The method of claim 1 including the subsequent step of stopping the injection of low-grade steam into the well, allowing the hydrocarbon of beneficiated flow characteristics to flow into the well, and subsequently producing said hydrocarbon up the well.

3. The method of claim 1 wherein said low-grade steam has from 5 to 25% water in the liquid phase.

4. The method of claim 1 wherein the water containing said scale forming alkaline earth metal salts is treated with sodium ion exchange resin to convert the salts to the sodium form.

5. The method of claim 1 wherein a chelating agent is added to the treated water to keep any residual alkaline earth salt in a soluble non-scaling form prior to employing the water to generate low-grade steam.

6. The method of claim 1 including the steps of
drilling a second well into said hydrocarbon-containing formation at a spaced interval from said other well,
injecting low-grade steam into the other well for a time sufficient to heat the formation and drive hydrocarbon to said second well, and
producing hydrocarbon from said second well.

7. The method of claim 1 wherein low-grade steam is injected through said well into the hydrocarbon-containing formation for a time sufficient to volatilize at least a least a portion of said hydrocarbon.

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