STEAM STIMULATION OF OIL-BEARING FORMATIONS

INVENTORS
MALCOLM F. McCONEEL
ROBERT P. CABEEN
WARREN W. HEDSTROM

BY: Sullivan, Patton, Halleck, Ali and Wecht

ATTORNEYS
STEAM STIMULATION OF OIL-BEARING FORMATIONS

Malcolm F. McConnell, 3940 Valley Meadow Road, Encino, Calif. 91316; Robert P. Cabeen, 4619 Grand Ave., La Canada, Calif. 91011; and Warren W. Hedstrom, Sunnyridge Road, Rolling Hills, Calif. 90274

Filed Apr. 1, 1966, Ser. No. 539,385
25 Claims. (Cl. 166-40)

ABSTRACT OF THE DISCLOSURE

Steam stimulation of oil bearing formations including the steps of forcing a gas through the annulus around the steam injection pipe at a pressure at least sufficient to prevent steam emerging from the lower end of the pipe from rising above a restriction in the annulus adjacent the oil strata, while restricting heat losses from the steam injection pipe with a column, surrounding the pipe, of a thin metallic sheet material that is locally confined. Steam injection pipe insulators incorporating such columns of thin metallic sheet that are loosely restrained by double-walled sleeves detachably connected to the steam pipe, or in an annulus permanently defined around the steam pipe, and with provision for fluid sealing ends of the insulators.

The present invention relates to the secondary recovery of hydrocarbons from subsurface formations, and more specifically, to apparatus and methods for such recovery by means of steam stimulation. It is recognized that steam injection is an effective thermal technique of recovery hydrocarbons from underground formations. The heat thus added to the formation lowers the viscosity of the oil which will then more readily flow into a well bored for production, which well bored may be the same through which the steam had been injected or a bored adjacent to the steam injection well. While the efficiency of steam injection as a method of secondary recovery is well recognized, difficulties are presented which inhibit its use even in shallow wells and which have previously been thought to prevent its use in deep wells. For example, there has heretofore always been present the danger of excessive thermal expansion of the well casing leading to casing collapse and consequent loss of the well. Also, excessive temperatures of the casing tend to deteriorate and destroy the cement bond between the casing and the formation. Another difficulty mitigating against economical steam injection is the high heat loss involved in the transfer of the steam from the generating equipment to the hole bottom. While techniques and apparatus for reducing such heat loss are available, the known measures are costly. Accordingly, their use is limited to relatively shallow wells and in most situations the use of the insulating measures is not economically justifiable or, at best, the prospect of profitable steam stimulation is rendered marginal.

An object of our invention is to provide an efficient method and apparatus for the recovery of hydrocarbons from sub-surface formations by steam stimulation without danger of casing collapse or cement bond failure, without limitation to shallow wells, and with minimum heat losses. Another important object of the invention is to provide a highly efficient insulated injection tubing string which will eliminate significant thermal growth in oil well casings and thus avoid the danger of casing collapse. The insulator means is further highly effective in reducing heat losses during the transmission of the steam from the steam generating equipment to the hole bottom so as to effectively inject steam at greater depths than have heretofore been possible. Accordingly, the insulator means of this invention permits the driving of maximum quantities of steam of the highest possible quality into the geological formations of oil wells.

It is also among the objects of the invention to provide a variety of insulator means which is economical from the standpoint of durability and reusability, assembly and disassembly in oil field use, and having a particularly facile mode of connection to the steam injection tubing.

A further object of the invention is to provide a method and apparatus for steam injection of underground formations in well bores having a standing head of oil or water in the bore at the time the steam injection string is installed and adapted to minimize heat losses in such an environment, and to avoid any intrusion of liquid into the insulator or damage to the insulator by said liquid head.

Yet another object of the invention is a method and apparatus permitting the utilization of steam injection as a secondary recovery technique which eliminates the need for a thermal packer.

The foregoing and other objects and advantages of the invention will be clear from the following description when taken in connection with the annexed drawings.

FIGURE 1 is a schematic view showing in cross section a well bore extending into the earth and equipped with one form of the invention;

FIGURE 2 is an axial sectional view on the line 2—2 of a portion of the steam injection tubing and associated equipment in the well of FIGURE 1;

FIGURE 3 is a horizontal sectional view taken on the line 3—3 of FIGURE 2 showing one means of keeping injected steam from upward passage into the annulus between the casing and steam injection assembly;

FIGURE 4 is a schematic view of a well bore extending from the surface to an oil bearing formation and equipped with a steam injection apparatus employed in combination with a packer;

FIGURE 5 is an axial sectional view on the line 5—5 of FIGURE 4 and illustrating a species of insulator means such as may be employed in the upper portion of the steam injection string;

FIGURE 6 is a horizontal sectional view taken on the line 6—6 of FIGURE 5 and showing details of construction at one end of a section of insulator;

FIGURE 7 is a horizontal sectional view on the line 7—7 of FIGURE 5 and showing details of construction of an insulator section at another end of an insulator section;

FIGURE 8 is an axial sectional view on the line 8—8 of FIGURE 4 showing a species of fluid-tight insulator assembly, such as may be employed in the lower end portion of a steam injection string which is surrounded by a standing liquid.

Referring now to FIGURE 1 of the drawings, there is shown a well 10 that has been drilled from the surface 11 of the earth into a hydrocarbon bearing formation 12. The well 10 has a casing 13 which is typically cemented in place and which is provided at its upper end with a well
A steam injection tubing string 15 is centrally supported within the well 10, passing through the well head 14 and at its lower end is provided with an outlet pipe 16. The tubing string 15 is in fluid communication with a steam supply pipe 17 which, in turn, communicates with a source (not shown) of steam from a steam generating unit. Thus, the steam may be driven down through the tubing string to escape from the outlet pipe 16 for penetrating the formation 12.

From the well head 14 down to the formation 12, the tubing string 15 is enclosed in a plurality of insulators 18, groups of which are gravitationally supported by a plurality of clamps 19 coaxially affixed to the tubing string 15. An annulus 20 is thus defined between the inner wall of each insulator 18 and the surrounding section of string 15 and another annulus 21 is defined between the insulators 18 and the casing 13.

At the well head 14, the outer annulus 21 has communication via a pipe 22 with a source (not shown) of a gas of low thermal conductivity under pressure which may be, for example, air, nitrogen, natural gas or carbon dioxide. As the annulus 20 is not perfectly sealed by the insulators 18, it will also contain gas of low thermal conductivity and the gas will be substantially statically confined by the insulators. At the lower end of the tubing string 15, a restrictor in the form of an annular disc 23 is coaxially mounted on the steaming tube or to the bottom of a clamp and serves as a partial barrier against rising of steam emitted from the pipe 16. The compressed gas in the annulus 21 is at all times supplied at a pressure such that the gas pressure on the upper side of the annular disc 23 exceeds the pressure of the steam on the underside of the disc, whereby the steam cannot rise into the annulus 20 to effect thermal expansion of the casing 13. The disc 23 should be seam welded or otherwise sealed against the tubing string 15 to keep steam out of the annulus 20, also.

Referring to FIGURE 2, each of the insulators 18 comprises an assembly of an outer tube 26, an inner tube 25, a pair of end caps 27 and a sleeve 28, which assembly contains layers of thin metallic sheet 31. The rigid parts may be made of relatively inexpensive sheet metal, for example, 18 or 24 gauge steel, that is smoothly finished, polished or galvanized to be of low thermal emissivity. While light in weight, the insulators 18 are nevertheless such as to withstand rough handling in the field without injury to the fragile sheet 31 and will have a long service life. Further, the construction is such that the required number of insulators 18 can very quickly be installed and removed from the tubing string 15, these operations being accomplished without making any permanent connection to the tubing string.

More specifically, the insulators 18 may be made up into lengths of approximately 10 ft., for example, for use with tubing strings made up of about 30 ft. lengths of tubing. As can be seen from FIGURE 2, the end caps 27 are generally U-shaped in radial cross section to provide a confronting pair of spaced walls between which ends of the cylindrical tubes 25 and 26 are received. Thus, the inner tube 25 has its opposite ends telescoped around the inner walls of the end caps 27 while the outer tube 26 has its opposite ends telescoped received within the radially outer walls of the pair of end caps 27. Preferably, the ends of the inner tube 25 are not soldered or welded to the end caps 27, nor otherwise secured, so as to allow differential thermal expansion between tubes 25 and 26. In order to hold the end caps 27 and tubes 25 and 26 in assembled relationship, it is preferable to merely spot weld or spot under opposite ends of the end caps 27, as indicated, for example, at 30. At the upper end of the insulator 18, spot welding 30 may also be employed to secure a sleeve 28 to the assembly, this sleeve being of an internal diameter such that its lower end telescopically receives the upper end cap 27, whereby the sleeve 28 coaxially projects upwardly to telescopically slidably receive therein the lower end of another insulator assembly 18. Adjacent insulators 18 are thus axially interconnected and supported one upon another.

The insulators 18 provide a substantially dead gas space in the annular area between the inner tube 25 and the outer tube 26, thus inhibiting transfer of conductive thermal energy from the inner shell to the outer shell. Transfer of thermal energy by radiation is inhibited by wrapping the inner tube 25 in a layer or layers of a very thin sheet material 33 of a metallic sub鶯o be highly polished on at least one side. For example, ordinary aluminum foil of a few mils thickness, e.g., 2–3 mils, such as employed for kitchen use, may be used with very satisfactory results. In assembling an insulator 18, a length of the sheet material 33 of the same length as the inner tube 25 is wrapped around the inside shell. The inner tube 25 is loosely wrapped in the sheet 31 to achieve several spaced layers of the sheet 31 as indicated in FIGURE 2, or at least to achieve discontinuous surface contact between adjacent layers of the sheet 31. The desired effect will be enhanced by inducing wrinkling in the metallic sheet 31 during the wrapping operation, thus minimizing contact points and maximizing the inclusion of static gas spaces between adjacent layers of the sheet. Thereafter, when the wrapped inner tube 25 is surrounded by the outer tube 26, the sheet 31 is confined and restrained into elongated tubular configuration against significant bending when the insulator 18 is placed in a vertical position.

Each of the support clamps 19 preferably comprises a pair of split-collar castings 32, whose plane configuration is shown in FIGURE 3. Each split-collar 32 is of a substantially uniform wall thickness providing an almost semi-circular flat port 34 and 35, disposed in diametral planes. The casting is also integrally formed with three angularly spaced apart axially and radially extending web portions 36, 37 and 38 extending outwardly from the inner wall 33 and between the flat portions 34 and 35. These webs 36, 37 and 38 extend radially outwardly beyond the flat portions 34 and 35 to merge into axially elongated portions defining a diameter around these flat portions 34 and 35, such as to telescopically receive the upper and lower ends of adjacent insulators 18. The webs 36 and 37 also form four buffers which serve to keep the tubing and insulator assembly approximately centralized within the casing.

When a pair of the castings 32 are placed on opposite sides of the tubing of the string 15 they can be clamped together and onto the tubing by a suitable fastener means 39, such as pairs of nuts and bolts passing through suitably located holes formed in the webs 36 and 38, thus defining the support clamp assembly 19. As will be apparent, as the tubing string 15 is made up at the well head a support clamp 19 may be connected thereto immediately above the outlet pipe 16 and the annular restrictor disc 23. Thereafter, the tubing string 15 as it is made up has successive sections of the insulators 18 sleeved thereover and sleeved together until an appropriate number of the insulators 18 are gravitationally supported by the clamp 19. For example, it has been found that each clamp 19 can very readily support approximately 100 ft. of slip-on insulator sections 18 after which a new clamp 19 is affixed to the injection string 15 to support another 100 ft. or so of insulators 18. The assembly of the tubing string 15 and insulators 18 is thus continued until the tube 26 is sealed against the outlet pipe 16 opposite the formation 12 is achieved.

After the insulated tubing string 15 is made up, the steam line 17 is connected to a source of steam at a suitable pressure for penetrating the formation 12 and the gas pipe 22 is connected to a source of a suitable gas under pressure for injection into the annulus 21. The pressures of injected steam and gas on opposite sides of the re-
strictor disc 23 are such that the steam is prevented from escaping upwardly around the annular disc 23. Further, the higher pressure of the injected gas passing through the annulus augments the steam pressure thus encouraging the penetration of high quality steam into the formation 12.

FIGURE 4 illustrates another embodiment of the steam injection system of our invention. In this case, a well bore 10' extends from a ground surface 11' down to a formation 12'. The well is provided with the usual casing 13' which is capped by a well head 14' through which tubing string 15' passes. The upper end of the string is connected to a pipe 17' communicating with a source of steam. At the lower end of the string 15' just above the formation 12' desired to be stimulated, a packer 40 is set in the casing 13' and through which the injection string 15 passes to communicate with the outlet pipe 16'.

The system of FIGURE 4 differs from the system of FIGURE 1 in that the lower end of a section such as above the formation 12' is sealed off by the packer 40 and the annulus 21' is not communicated to a source of gas under pressure. Rather, the annulus 21' may be vented to the atmosphere at the well head 14' or the annulus may be evacuated if desired. For economy of illustration, the tubing string 15' is illustrated in FIGURE 4 by two types of insulator 41 and 42, the former being shown in FIGURE 5 and the latter in FIGURE 8. However, it is to be understood that the system of FIGURE 1 or 4 may be employed with the insulators 10, insulator 41 or insulator 42, or any combination thereof.

For convenience of description, it will be assumed that the system of FIGURE 4 is provided with the insulators 41 in upper portions of the string and that the lower end of the well bore is provided with a standing head of fluid, in which environment the use of the insulators 42 of FIGURE 8 is preferable.

The insulator 41 of FIGURE 5 is of a type which is mounted integrally with the individual sections of pipe making up the tubing string 15' but which may be so mounted without the necessity for any permanent connection of the insulating means to the pipe and particularly without necessity for any welding such as could be locally injurious to the sections of pipe. In many situations welding of the insulator to the tubing is permissible and may be preferable from the economic standpoint. Functioning of the insulation system is not adversely affected. While the insulating means 41 may more conveniently be integrated with the sections of pipe in a shop, the construction such that the insulator may be mounted to the sections of pipe at the well site.

In FIGURE 5, there are shown two sections of conventional pipe, 44 and 45, fastened together by a coupling 46. The insulator 41 includes an elongated cylindrical outer shell 47 which at its lower end, externally mounts an axially slideable sleeve 48. This assembly is hung at its upper end adjacent the upper end of a section, such as the pipe 44 of the string 15' in the following manner. A strip 49 of an insulating material, for example, asbestos tape, is wound circumferentially around the section of pipe 44 approximately 2 ft. beneath the area of a coupling 46. The shell 47 is L-shaped in radial section, is placed around the strip 49 with the cylindrical portion of the collar 50 embracing the tape. At the confronting ends of the split collar 50, a pair of radially and axially disposed ears 51 are affixed thereto, as by welding, and are formed with a pair of aligned holes or notches, a portion of a suitable fastener means 52 which, upon tightening, securely but detachably clamps the collar 50 in place.

In the lower end portion of the section of pipe, approximately 2 ft. above and adjacent the coupling 46, another piece of insulating tape 53 is wrapped around the circumference. The axial spacing of the wrap of tape 53 beneath the wrap of tape 49 is approximately equal to the length of the cylindrical shell 47 to be sleeved over the piece of pipe 44. Thereafter, the piece of pipe 44 is wrapped in a length of thin metallic sheet material 54 throughout the area between the pairs of tapes 49 and 53, in the same manner as previously described in connection with the insulator 10. Thereafter, the shell 47 is sleeved over the loosely wrapped and wrinkled layers of sheet material 54 until the upper end abuts the underside of the radially disposed portion of the collar 50. The shell 47 is then tack-welded at its upper end to any sparsely apart portions of the underside of the split collar 50, so that when the section of pipe 44 is in the vertical position, the shell 47 hangs from the collar.

At the lower end of the shell 47, a ring 55, which may be made up of separate segments, is affixed by as tack-welding 56 within the shell to close its lower end. The internal diameter of the ring 55 is such as to provide a close or sliding clearance at 57 on the surface of the piece of tape 53. The axial dimension of the tape 53 should be at least great enough to cover the full range of difference in thermal elongation between the piece of steam injection pipe 44 and the shell 47 so that despite the greater elongation of the steam injection pipe 44, caused by its higher temperature, the piece of tape 53 will at all times be disposed as an insulating barrier between the steam injection pipe and the ring 55.

As is shown in FIGURE 5, after sections of the string 15 have been coupled together the area between the insulators 41 and including the coupling 46 may be insulated by pulling the slidable sleeve 48 into the position shown so that a tapered or crimped lower end 58 of the sleeve gravitationally rests on the radially disposed portion of the collar 50 therebelow. In order to provide clearance for such abutment, the crimped portion 58 is notched, as indicated at 59, to receive the ears 51 of the collar therebelow. While not essential for most applications, if desired, a layer or layers of metallic sheet material 54 may be loosely wrapped around the coupled ends of the pipes but care should be taken so as to avoid creating convenient conduction paths through tightly packed layers for the transfer of heat from the coupling to the sleeve 48. The sleeve 48 should be freely slidable on the shell 47 when heated so that its weight will, at all times, cause it to bear on top of the collar 50. If desired, a plurality of outriggers 60 may be tack-welded in equally circularly spaced apart relationship to the upper end of the shell 47 to maintain the string and insulator 41 in central coaxial relationship to the casing 13'.

The insulator 41 of FIGURE 5, like the insulator 10 of FIGURE 2, may have its rigid parts made of relatively light gauge sheet metal, preferably galvanized steel, and accordingly, is extremely light in weight and relatively inexpensive while at the same time constituting a highly efficient insulator which eliminates any significant thermal stress in the casing 13' during steam injection. In this connection, as compared to the double wall insulator 10, it will be observed that the single wall insulator 41 provides an arrangement to dispose a great number of layers of metallic foil or sheet in loosely wound columnar form of smaller diameter. While the insulator 41 is not sealed against the penetration of liquids as is standing in the bottom of the well bore, its construction and advantages may be realized in a fluid tight construction by the modification shown in FIGURE 8.

The insulator 42 is of a construction permanently integrated with the tubing string 15'. As shown in FIGURE 8, the tubing string 15' includes conventional pipe sections 65 and 66 coupled together at 67 and each incorporating an insulator means 42. Each pipe section, at its upper end approximately 2 ft. beneath the coupling 67 has a ring 63 coaxially affixed thereto as by continuous welding 68. At its lower end approximately 2 ft. above the coupling area, each pipe section is wrapped with a length of insulating tape 53' spaced from the ring 63 a distance approximately the same as the length of an outer cylindrical shell 69. The shell 69 preferably com-
prizes a length of seamless pipe, whose internal diameter is such as to enable the upper end of the tube to be telescopically slideable over the periphery of the ring 63 and permanently affixed thereto by a continuous seam-weld 70, such connection taking place after the pipe section has been loosely wrapped in a layer or layers of metallic foil or sheet 71 in the length of the tube between the ring 63 and the tape 53. At its lower end, the cylindrical shell internally mounts a ring 55, which may also be of a segmental construction, the ring being welded in place and like the ring 55 having a close fit or sliding engagement with the insulating tape 53' which the ring surrounds.

Each seal 69 at its lower end externally mounts an axially slideable sleeve 73, which in view of the differential pressures to which the device may be subjected is also preferably made of a length of pipe greater in length than the space between adjacent ends of pipes 65 and 66, so as to span this area and the coupling 67. The sleeve 73, adjacent its lower end, is internally provided with a metal bumper ring secured in place by brazing, for example, and spaced from the lower edge of the sleeve a sufficient distance so that when the sleeve is lowered to telescopically receive the upper end of a lower adjacent shell therein, a generous overlap is provided sufficient to give a range of movement great enough to accommodate relative movement of the parts upon thermal expansion.

At its opposing ends, the sleeve 73 is encased in a pair of axially elongated tubular seals of an elastomeric material as, for example, neoprene, of a relaxed diameter smaller than the diameter of the cylindrical shells 69. As the joint at 67 is made up, it will be appreciated that the sleeve 73 is raised from the position shown in FIGURE 8 with its bumper 74 abutting the lower end of its associated shell 69. At this point, the pair of seals 75 are in a position rolled back upon the sleeve 73. Then, after the joint has been made up to interconnect the pipes 65 and 66 and after, if desired, an additional layer or layers of metallic foil or sheet 71 have been loosely wrapped around the exposed area, between insulators 42, the sleeve 73 can be lowered to a position shown in FIGURE 8. In this connection, because of the small clearance between the bumper 74 and the enlargement at the coupling 67, it is preferable that no layers 71 be placed around the coupling 67. After the sleeve 73 is in position with its bumper 74 abutting the upper end of the adjoining shell 69, the pair of seals 75 have their roller back portions rolled onto the adjacent surface of a cylindrical shell, thereby sealing the joint. Thereafter, each of the seals 75 has a hoseclamp 76 wrapped around each of its ends to insure the integrity of the seal.

Referring to FIGURE 4, if it be assumed that a standing head of liquid is in the lower portion of the well bore, the steam injection tubing string can be made up with an appropriate number of the sealed insulators 42 for the lower portion of the string exposed to the standing head of liquid while the upper portion of the string may be made up using the insulators 41. The packer 40 being set whereby to seal off the producing length of the well bore from the annulus 21 therefrom, steam may now be introduced through the steam pipe 17 for injection into the oil bearing strata 12. For example, assuming a steam temperature of 450° F. the cylindrical shell 69 and sleeve 73 of the insulator 42 will not rise more than about 55° F. above the normal ambient temperature of the surrounding liquid in the well bore. Further, if no liquid is present in the well bore, the temperature of the casing 13 may be held within about 20° of the ambient geothermic temperature.

The systems and apparatus illustrated and described herein are to be taken only as typical examples of the practice of our invention and are not to be taken in a limiting sense. While we have set forth what we considered to be the best modes of our invention, various modifications of the systems and apparatus described will undoubtedly occur to those skilled in the art to whom equivalents will occur. Accordingly, we do not wish to be limited except in accordance with the spirit and scope of the following claims.

We claim:

1. A process of raising the temperature of hydrocarbons in a subsurface formation by steam injection through a well bore from the surface to the formation, including: defining steam conduit means, in a casing of the well bore, from the surface to the formation and spaced from the casing; forcing steam downwardly through the conduit means to be released adjacent the formation; forcing a gas downwardly through the space between the casing and the conduit means; restricting the flow of the gas at a position within the casing just above the formation; maintaining a pressure of the gas sufficient to prevent steam emerging from the conduit means from rising above the position of restriction of the gas flow; and maintaining a steam pressure sufficient to force steam emerging from the conduit means into the formation.

2. A process as in claim 1 in which the pressure of the gas is high enough to force the gas downwardly past the position of restriction and into the formation.

3. The process of claim 1 which includes: defining the conduit means by coupling together several lengths of pipe; surrounding the pipes of the conduit means between the surface and the position of gas flow restriction with a column for each pipe of a metallic sheet material having a smooth finish on at least one side and of a material thickness incapable of vertically supporting the column length, each column having a minimum length, approximately, co-extensive with the uncoupled area of the pipe; and supporting the columns of thin metallic sheet material against buckling and against displacement out of a position in which the columns are in spaced relation to the casing.

4. A thermally improved process of raising the temperature of hydrocarbons in a subsurface formation by steam injection through a well bore from the surface to the formation, including: defining steam conduit means in a casing of the well bore, from the surface to the formation and spaced from the casing by coupling together sections of conduits; reducing heat losses from the steam conduit means by surrounding each of the sections of conduits, throughout approximately at least the length of the sections other than their coupled areas, in that portion of the conduit means from the surface down to a location immediately above the formation, with a column of a metallic sheet material having a smooth finish of low thermal emissivity on at least one side and of a material thickness incapable of substantially exactly supporting the column; loosely confining the column of thin metallic sheet material of each of the sections against collapsing under its own weight and against displacement out of a position in which the column is in spaced relation to the casing; forcing steam downwardly through the conduit means to be released adjacent the formation; preventing rising of steam emerging from the conduit means beyond the location immediately above the formation to force the steam into the formation.

5. The process of claim 4 which includes surrounding each of the sections of conduit with a plurality of layers of the thin metallic sheet column material successively loosely enclosing one another, the adjacent layers being arranged to have areas of separation to provide capacity for reception of a gas of low thermal conductivity between successive layers of the sheet material.
6. A process as in claim 5 which includes:
defining an annular space between the column and the section of conduit and substantially completely enclosing the volume around each section of conduit that is occupied by the column and the annular space with a sheet material that is impervious to the passage of fluids to substantially statically confine a gas of low thermal conductivity.

7. The process of claim 5 which includes substantially completely sealing the space around each section of conduit that is occupied by the group of layers of thin sheet metal column material to confine the column and contain a gas of low thermal conductivity.

8. A process as in claim 4 that includes:
limiting the length of the column of thin metallic sheet material to the circumferential area of the section of conduit exclusive of the coupled areas of adjacent sections of conduit and enclosing an annular volume between adjacent ends of a pair of the columns and around the coupled areas of the corresponding sections of conduit with a rigid sheet material that is impervious to the passage of fluids to contain a substantially static volume of a gas of low thermal conductivity.

9. A process as in claim 8 that includes:
sealing the rigid sheet material and the static volume of gas enclosed therein against penetration thereto by a liquid.

10. An insulator for inhibiting heat losses in an oil well steam injection pipe comprising:
a sheet arranged in elongated tubular form and made of metallic material having opposite surfaces adapted for a low rate of thermal emissivity and of a thickness incapable of substantially withstand buckling of the tubularly arranged sheet when vertically disposed; and an elongated rigid means of substantially tubular configuration arranged coaxially with said tubularly arranged sheet and adapted to loosely restrain the sheet into tubular form in order to minimize areas of contact between said sheet and said rigid means.

11. An insulator as in claim 10 that includes:
a section of steam injection pipe extending coaxially inside of the tubularly arranged sheet, the wall of said pipe comprising a portion of said rigid means restraining the sheet in tubular form.

12. An insulator as in claim 10 in which:
the rigid means restraining the sheet includes an elongated tubular member having smooth surfaces to be adapted for a low rate of thermal emissivity, the tube coaxially surrounding the tubularly arranged sheet, and a connecting means supporting one end of the tube and adapted for coaxially connecting to a steam pipe therethrough to support the tube in coaxial relationship to the steam pipe.

13. An insulator as in claim 12 in which:
the elongated tube at one end coaxially supports a tubular sleeve extending beyond the one end of the tube for contact with an adjacent end of a second tube.

14. An insulator as in claim 13 in which:
the sleeve is telescopically slidably connected to one end of the tube to allow relative movement therebetween in response to differential thermal elongation of the sleeve and tube and to be adapted for coaxial extendability from the tube to be engageable with an adjacent end of a second tube.

15. An insulator as in claim 14 in which:
a sealing means is provided on one end of the sleeve for circumferentially sealing the one end of the sleeve and the tube against penetration by fluids when the sleeve is in coaxially extended position.

16. An insulator as in claim 12 that includes:
a section of steam injection pipe extending coaxially inside of the tubularly arranged sheet, the wall of said pipe comprising a portion of said rigid means restraining the sheet in tubular form, the section of steam pipe having a circumferential area of predetermined axial length carrying an insulating layer of a material of low thermal conductivity, the other end of the tube internally coaxially mounting a diametrically disposed ring whose radially inner edge closely confronts the insulating layer of the steam pipe, the axial dimension of the insulating layer being sufficient to maintain a portion of the insulating layer disposed between the ring and the steam pipe when the tube and steam pipe are differently thermally elongated.

17. An insulator as in claim 12 in which:
the connecting means supporting the tube comprises a clamping device adapted for fastening to a steam pipe and to extend circumferentially and radially outwardly from the steam pipe, the clamping device and the lower end of the tube having matingly engageable portions adapted to gravitationally support the tube on the clamping device and in coaxial spaced relationship to a steam pipe, and one end of the tube mounts a sleeve adapted and arranged for telescopically coaxially interconnecting the adjacent end of a pair of tubes whereby a plurality of the tubes can be gravitationally supported on one of the clamping devices.

18. An insulator as in claim 12 in which:
the connecting means comprises an annular ring internally secured to the upper end of the tube and connected to a steam pipe that extends coaxially inside the tube and comprises a portion of the rigid means restraining the sheet in tubular form, the tube depending gravitationally from the ring in coaxially annularly spaced relationship to the steam pipe.

19. An insulator as in claim 10 in which:
the rigid means restraining the sheet in tubular form comprises a cylinder of an internal diameter adapted to define an annular gas space with a steam pipe to be coaxially extended therethrough.

20. An insulator as in claim 10 in which:
the rigid means comprises a coaxially telescoped pair of metal cylinders defining an annular gas space in which space the metallic sheet of elongated tubular form is loosely and substantially coaxially confined; and a cap is mounted at each of the opposite ends of the pair of cylinders to substantially close the opposite ends of the annular gas space.

21. In an oil well steam injection apparatus, the combination comprising:
a steam injection tubing string comprising coupled sections of pipe; a plurality of rigid elongated cylindrical heat shields made of a sheet material of low thermal conductivity that have been smoothly finished to be adapted for low thermal emissivity; and a plurality of connecting means vertically spaced along the tubing string and each connected between one of the pipes and one of the shields to support a shield in annularly spaced relationship to the pipe.

22. An apparatus as in claim 21 in which each of the connecting means gravitationally supports a plurality of the heat shields.

23. An apparatus as in claim 21 in which:
there is one of the connecting means between each pipe and each shield and each shield is shorter than and disposed between opposite ends of the associated pipe.

24. An apparatus as in claim 21 having a plurality of sleeves each of which is mounted coaxially on an end of
one of the shields in annularly spaced relationship to the string and is adapted for engagement with the adjacent end of another shield.

25. An apparatus as in claim 21 in which each of the shields encloses a tubularly arranged sheet of metallic material having smooth surfaces and of a material thickness incapable of substantially withstanding buckling of the tubularly arranged sheet when vertically disposed, the sheet being loosely confined in tubular form in the annulus between the shield and the pipe to surround the pipe and divide the annulus into gas spaces.

STEPHEN J. NOVOSAD, Primary Examiner.