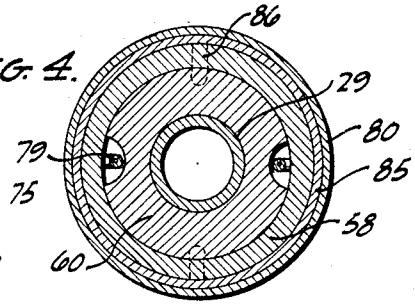
July 28, 1953 C. A. CARPENTER ET AL 2,647,196

APPARATUS FOR HEATING OIL WELLS

Filed Nov. 6, 1950

FIG. 4.



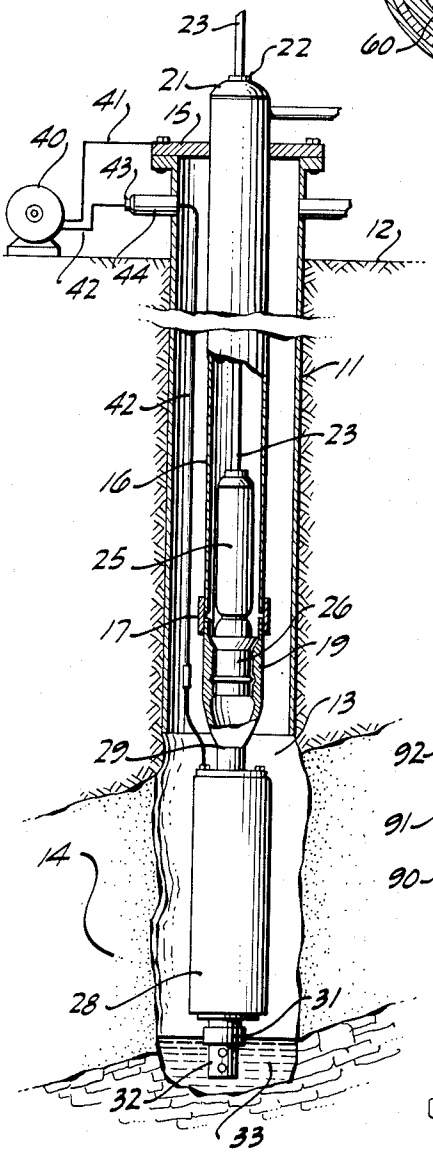


FIG. 1.

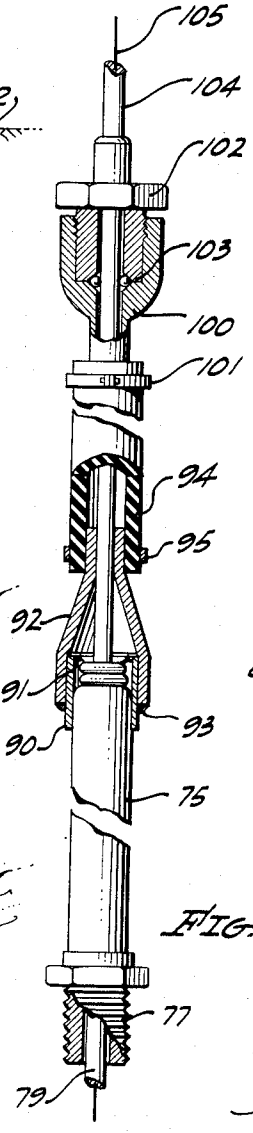
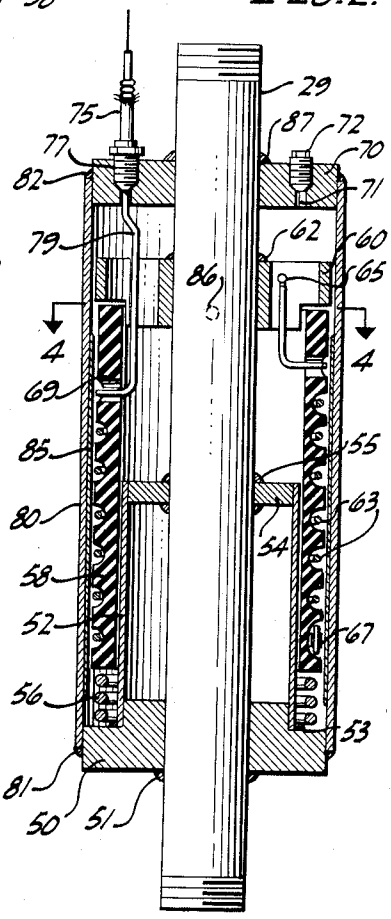


FIG. 3.

FIG. 2.



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APPARATUS FOR HEATING OIL WELLS

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Application November 6, 1950, Serial No. 194,270

5 Claims. (Cl. 219—33)

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This invention relates to an apparatus for heating oil wells whereby the rate of oil flow and the net yield of oil can be increased. More particularly, this invention relates to an apparatus for the simultaneous heating and pumping of oil wells.

Many methods have been employed in the prior art for heating oil wells such as by electrical means, injecting heat transfer agents into the well such as steam, hot oils, etc. and by burning natural gas in the well bore. In general such methods have met with little or no commercial success due in part to the low efficiency of the apparatus employed and to the relatively large amounts of energy that were required to operate such equipment.

It is an object of this invention to provide an electric heater for heating a limited portion of an oil-bearing formation surrounding an oil well bore wherein a highly efficient mode of heat distribution is employed.

It is another object of this invention to provide a unitary electrical heater which is readily assembled and which requires a minimum of maintenance.

It is another object of this invention to provide an electric heater for heating oil wells which is easily run in and out on the tubing of a conventional well and wherein a minimum of preparation is required to install the heater in a conventional existing well.

It is another object of this invention to provide an electric heater for oil wells of a unitary construction wherein there is a maximum transfer of heat away from the longitudinal axis of the heater and a minimum transfer of heat toward the oil flowing along the longitudinal axis.

It is another object of this invention to provide a well heater comprising a spring-loaded mechanism for compensating for differential expansion of one member of the heater relative to a second member.

Other objects of this invention will become apparent to those skilled in the art as the description thereof proceeds.

In general, the present invention relates to a new electric heater for oil wells which is of a rugged unitary construction. In the oil well heaters of the prior art considerable difficulty has been experienced in maintaining the heater fluid-tight to prevent the entry of the bore hole fluids into contact with the heating elements. Oil well brine causes severe corrosion of any of the exposed fittings and often produces short circuiting of the entire heater. The heater of this

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invention is carried on the tubing and is easily run in or out with only minor adaptation of the existing equipment. Electrical energy is supplied to the heater through a single insulated cable and is returned through a grounded connection to the metal parts of the tubing. The heater mounting is attached to the pump and the core of the heating unit is a central oil conducting pipe which serves the function of a "skeeter bill." Above the heater mounting in the tubing string is a pump shoe lock which accepts a conventional pump shoe and retains the pump above the heater in a semi-rigid position. The pump takes suction on a pipe coaxially disposed and passing downwardly through the heating element to below the liquid level in the bore hole. Removal of the heater is effected by removing the rods and pump in a conventional manner and withdrawing the tubing upon which the heater is carried.

Figure 1 shows a partly cross-sectional view of an oil well wherein an electric heater of this invention is employed for the simultaneous heating-pumping of a well and wherein the surface of the oil pool is maintained somewhat below the bottom of the heater in the oil sand to permit a major portion of the heat to be transferred from the heater through the gaseous phase above the liquid level of the pool. The feature of transferring heat from the heater to the formation surrounding the bore via an intervening gaseous phase rather than via the pool of liquid oil forms no part of the present invention but is disclosed and claimed in my copending application Serial No. 177,926, filled August 5, 1950.

Figure 2 shows a partial cross-sectional view of the heater assembly of this invention together with the central pipe which serves as the "skeeter bill."

Figure 3 shows a partial cross-sectional elevation view of a means for passing the insulated electrical conductor through a suitable seal to prevent entry of oil into the heater proper and to protect the electrical conductor from the high ambient temperatures surrounding the heater.

Figure 4 shows a cross-section of Figure 2 through the plane 4—4.

Referring now more particularly to Figure 1, well casing 11 extends downwardly from earth surface 12 into bore hole 13 to the vicinity of the upper boundary of oil-bearing sand 14; well casing 11 is capped with tubing head 15. Tubing 16 is suspended through tubing head 15 and passes downwardly through casing 11. Tubing 16 is fitted with coupling 17 to which is attached pump lock shoe 19. At the earth surface tubing

16 is fitted with stuffing box 21 and stuffing ring 22 through which sucker rod 23 is permitted to reciprocate. Sucker rod 23 is attached to a rod hanger and walking beam assembly not shown.

Within tubing 16 and attached to sucker rod 23 is pump 25 which is attached at the lower end to pump lock 26 insertable in and normally retained by pump lock shoe 19. Heater unit 28 is suspended on skeeter bill 29 which is threaded into the lower section of pump lock shoe 19. At the lower end of heater 28 the skeeter bill unit is fitted with coupling 31 which is in turn attached to perforated section 32 which is submerged below the liquid level of oil pool 33 in the bottom of bore hole 13.

Alternating current generator 40 at the earth surface generates an alternating current which flows through one lead 41 to a grounded connection at tubing hanger 15. The other line 42 from the alternating current generator 40 passes through a suitable packing gland 43 into normal gas production line 44 and thence to electric heater unit 28. The return element of heater 28 is grounded to skeeter bill 29.

Referring now more particularly to Figure 2 which shows a partial cross-sectional view of heater unit 28, skeeter bill 29 traverses the entire length of the heater unit and is an integral part thereof. The lower closure member 50 is welded to skeeter bill 29 at weld 51 which provides a circular seal around the skeeter bill 29. Tubular centering member 52 extends upwardly from an upper shelf of member 50 and coaxially with skeeter bill 29. Tubular aligning or centering member 52 is supported on member 50 by suitable welds 53. Upwardly from the lower member 50, tubular centering member 52 is maintained in coaxially alignment by supporting member 54 which is in turn welded to skeeter bill 29 by weld 55. Supporting member 54 slidably contacts the inner surface of tubular member 52 thereby permitting expansion or contraction of the tubular member relative to skeeter bill 29. Springs 56 press on their lower side against lower member 50 and on their upper side against tubular member 58.

Perforated disc 60 presses against the upper end of tubular member 58 and opposes the force of springs 56 attempting to push tubular member 58 upwardly. Perforated disc 60 is anchored to skeeter bill 29 by suitable welds 62 which also provide an electrical ground connection to skeeter bill 29.

Tubular member 58 on its outer surface is fitted with two series of spiral channels within which are wound heating coils 63. One terminal of the heating coil is grounded to perforated disc 60 by suitable contact 65. The coil grounded to contact 65 traverses one series of grooves to near the bottom of the tubular member 58 and at plug 67 it is transferred into the other series of grooves and winds upwardly on the face of the coil. It then passes through hole 69 in tubular member 58 and passes upwardly to the conducting cable 79 to be described hereinafter. By this method the heating coils 63 are wound non-inductively so as to minimize the electrical impedance thereof.

Somewhat above perforated disc 60 is mounted upper closure member 70 which comprises the top plate or upper closure of the heater. Closure member 70 is fitted with hole 71 which is in turn fitted with plug 72. Removal of plug 72 permits compressed air or other gas to be admitted to the inner chambers of the heater in order to test for leaks after the completion of the assembly. Member 70 is also fitted with flexible pipe 75 by means of nipple 77 which permits egress of electrical conductor 79 passing from hole 69 in tubular member 58.

The outer shell 80 of the heater is circularly welded to lower closure member 50 at weld 81 and is welded to upper closure member 70 at weld 82. Welds 81 and 82 completely seal the inner chamber of the heater. Shell 80 is coated on the inner surface with a ferro-enamel layer 85 such as is used commercially. Ferro-enamel layer 85 is firmly bonded to shell 80 and provides a non-conducting coating on the inside of the shell which prevents electrical contact between metallic shell 80 and the exposed coils 63.

Referring now more particularly to Figure 3 conductor 79 passes upwardly through nipple 77 attached to braided flexible pipe 75. The exposed metallic flexible joint of flexible pipe 75 is welded to inner sleeve 90 at weld 91. Outer sleeve 92 fits over inner sleeve 90 and is welded thereto at circular weld 93. The upper end of outer sleeve 92 fits into one end of rubber tubing 94 which is secured thereto by external clamp 95. At its upper end, rubber tubing 94 is fitted to sealing member 100 and is secured thereto by clamp 101. Threaded member 102 screws into the upper threaded end of sealing member 100 and the beveled face thereof compresses O ring sealing member 103 which is normally torus-shaped. Compression of O ring 103 provides a seal between insulation 104 covering conductor 105 thus preventing any possible oil flow downwardly between sealing member 100 and insulation 104 covering conductor 105.

The use of rubber tubing 94 serves to provide a junction for splicing high temperature insulated conducting wire 79 with the low temperature, general purpose insulated conductor 105 insulated by insulating sheath 104. In the usual method wire 79 is brought out of the heater 28 through nipple 77 and flexible pipe 75 fitted with inner sleeve 90 and outer sleeve 92. The high temperature conductor is then spliced to the low temperature conductor fitted through the seal provided by sealing member 100 and rubber tubing 94 is then fitted over the splice and clamped into position.

Referring now more particularly to the method of assembling the heated unit shown in Figure 2, the following method has been found most suitable. A pipe of suitable dimensions is selected for skeeter bill 29 and the lower closure member 50 with a suitable opening for insertion of skeeter bill 29 is slid over the skeeter bill and is welded at weld 51. Supporting disc 54 is thereafter welded to skeeter bill 29 by weld 55 a suitable distance upwardly from lower closure member 50. Thereafter the tubular aligning member 52 is fitted into place and welded at 53 and compression springs 56 are next fitted over skeeter bill 29 and placed in contact with lower member 50. Coil form 58 with mounted coils 63 is fitted over tubular member 52. Perforated disc 60 is fitted over skeeter bill 29 and is pressed downwardly against coil form 58 so as to put compression springs 56 under partial compression. With compression being maintained against springs 56, weld 62 is made, thereby fastening perforated disc 60 to skeeter bill 29. If desired, suitable transverse pins 86 may be employed to pin coil form 58 to perforated disc 60 to prevent rotation of coil form 58 relative to skeeter bill 29. The appropriate

coil terminals are brought out through the perforations of perforated disc 60 and contact 65 is established and the other coil terminal is brought out from the lower chamber. Upper closure member 70 is next fastened to skeeter bill 29 by weld 87. The coil terminal from coil form hole 69 is brought out through flexible pipe 75 and through the apparatus shown generally in Figure 3. Tubular shell 80, maintaining bonded ferro-enamel on its inner face, is then slid over the two end closures and welds 81 and 82 are made thereby completely sealing the inner chambers of the heater. Compressed gas is introduced through unplugged opening 72 in order to check the walls against leaks. Following the leak testing, plug 72 is replaced and the apparatus is ready for installation in the well bore.

In the installation of heater 28 in the manner shown in Figure 1, perforated pipe 32 and nipple 31 are attached to the lower end of heater 28. The tubing string made up of pump lock shoe 19, coupling 17 and tubing 16 is attached to the upper end of heater 28 and the whole is lowered into the well bore by conventional means with suitable provision being made for paying out conductor cable 42. Suitable means are used for clamping the cable to the tubing. The pump 25 and bottom pump lock 26 are run in on sucker rods 23 in a conventional manner.

In the Cut Bank, Montana, area a well which was producing about twelve barrels per day of 38° API gravity, highly paraffinic crude oil was selected for electric heating experiments. When the well was produced without heating, the temperature of the oil pool was 70° F. and the formation temperature at a point removed from the well pool was determined to be about 84° F. The thickness of the formation was about 9 feet. Upon the installation and operation of the electric heater at a steady power rate of only about 7 kilowatts, the well produced quite uniformly an average of 45 barrels per day for a period of 30 days during the continuance of the heating operation. When the heater was removed and the production of the well was resumed without any heating whatsoever, the production declined within a week to only about 25 barrels per day.

While the exact reasons for the success of this experiment are not known with certainty, it is possible that the relatively small amount of heating was merely sufficient to overcome the slight cooling of the oil flowing into the oil pool and to permit it to carry its normal complement of wax from the formation without deposition on the bore hole wall of the formation.

In the particular experiment the temperature of the heated oil pool was determined by measurements to be 130° F. and that of the gaseous phase above the oil pool and in the proximity of the heater was found to be 170° F. The temperature of the oil under these conditions is such that little or no coking occurs on the heater shell.

According to a preferred mode of operation, only a limited amount of heat is applied to the oil-bearing formation. It has been found that heaters operating at a power level of about 0.02 to 2.0 kilowatts per foot of formation are most efficient for wax-bearing wells.

It is now believed that the previous attempts to employ electric heating have generally met with failure for the reason that it was thought that a barrier of wax was built up over a considerable period of time and that if it were removed the well would thereafter continue to produce at a high rate for a considerable period of time. Accordingly, the prior art was wholly occupied with drastic heating during relatively short periods of time after which periods of heating the pumping equipment was reinstalled and the well produced. Furthermore, the heaters of the prior art caused extensive gas separation and coking of the oil because of the extremely high temperatures at which they were operated. The heater of the present invention operates at relatively low temperatures with highly uniform heat distribution and is preferably operated so as to transfer all or part of the heat through the gaseous phase rather than the liquid phase. The favorable results attained by the operation of this heater are of a type and magnitude which were not obtainable heretofore by employing the methods of the prior art.

In the use of the present heater alternating current is generally preferable to direct current for convenience of handling and availability. Electrolytic corrosion is generally greater when direct current is employed. The voltages employed in the case of alternating currents are generally between about 10 to 1000 volts and preferably between about 30 to 450 volts. Voltages between about 5 to 600 volts and preferably about 20 to 300 volts are employed in the case of direct currents.

With regard to the amount of heat required in order to sustain a high rate of flow from a given oil-bearing sand, it has been found that usually a heater operating at a power rate between 0.02 and 2.0 kilowatts of power per foot of formation to be heated is suitable. Preferably the power rate should be between about 0.1 and 1.0 kilowatt per foot. The gaseous phase above the oil pool should be heated at least to about 25° F. above the formation temperature and the oil in the well bore should be heated at least about 10° F. above the formation temperature. In general the gaseous phase should be heated to between about 100° F. and 200° F. and preferably to between 130° F. and 180° F.; the oil pool should be heated to between about 90° F. and 160° F. and preferably between about 110° F. and 140° F. Where the oil is heated to higher temperatures considerable and deleterious gas separation occurs and much coke and gum deposits on the equipment, which necessitates frequent removal. At appreciably lower temperatures no increase in the production rate is obtained.

It is thus apparent that there are many specific features of this invention which contribute to the overall favorable result. Thus by the use of ferro-enamel bonded to the metallic shell the heat transfer between the internal heating coils and the external heat radiating shell is markedly improved over conventional forms of insulation. Furthermore, the use of such ferro-enamels in layer form greatly facilitates the construction of heaters of this invention and such insulation requires a minimum of maintenance. While other forms of heat-conducting electrical insulation may be employed, the ferro-enamel type is by far the most favorable.

The ferro-enamel layer may be deposited on the iron or steel tube by any suitable conventional method. One method consists of plugging one end of the tube, pouring it full, or partially full, with a suitable clay-containing ferro-enamel mixture, pouring the mixture from the tube and thereafter firing it such as at 1100° F. to form a

hard ferro-enamel surface on the inside of the bore of the tube.

Another feature of this invention lies in the heat insulating barrier or barriers placed between the heating coils and the skeeter bill. It has been found that the greatest effectiveness of a unit of heat is realized when the heat is transmitted by radiation through an intervening gaseous phase to the exposed formation face. As has been stated hereinbefore, the gaseous phase interposed between the heater and the formation face is established and maintained by controlling the rate of pumping of the liquid level in the bore hole. It has also been found that the heat otherwise transmitted through the walls of the skeeter bill to the column of oil flowing upwardly therethrough to the pump is rapidly dissipated from the oil and contributes little to increasing the oil production of the well. In the preferred modification of the invention the coil form is of a heat insulating variety which transfers a minimum of heat from the heating coils to the inner surface of the coil form. Furthermore, the maintenance of dead air space between the inner face of the coil form and the skeeter bill also serves to minimize heat transmission therebetween.

In one modification of the invention a solid heat barrier may be employed between the windings and the central pipe or skeeter bill. Referring again to Figure 2, member **52** and member **54** may be deleted and coil form **58** may be fashioned so that it fits snugly over skeeter bill **29** and extends to within a short distance of insulation liner **85**. When the coil form is thusly fashioned of material having a low heat conductivity, the major portion of the heat generated in the coils is transferred to the tubular shell **80** and thence to the coil bearing formation.

Another feature of this invention lies in the method of mounting the coil form which is generally fashioned of a material having a low thermal rate of expansion within the metallic elements which generally have a much higher rate of thermal expansion. Thus in the preferred form for mounting the coil form within the heater the top of the coil is suitably pinned directly or indirectly to the nearby section of the skeeter bill while the lower end of the coil form is pressed upwardly by the springs under compression, thereby maintaining a rigid mounting, Also, the use of the tubular aligning member further increases the rigidity of the coil form mounting.

Another feature of this invention lies in the use of a fluid-tight unitary heater construction wherein the electric conductor is passed through a sealing means and into the heater chamber itself. The sealing means provides for a fluid-tight seal between the conductor cable of the well bore and the conductor within the heater proper.

While only a single phase heater has been described hereinbefore, it is apparent that 3-phase or other polyphase heaters may be employed similarly. For three phase electric heating three coils are wound on a three coil form with the lower ends of the three coils being connected together and the upper ends being attached to the three leads from the current source. The same features of sealing, insulating, etc., may be applied thereto.

The foregoing disclosure of this invention is not to be considered as limiting since many variations may be made by those skilled in the art without departing from the spirit and the scope of the following claims.

We claim:

1. A well heating apparatus comprising a central oil-conducting conduit; an outer heat-radiating shell; an upper closure; a lower closure; said upper and lower closures providing a fluid-tight seal between said conduit and said shell, and maintaining said shell coaxially disposed around and spaced away from said conduit; a tubular coil-form disposed between said shell and said conduit, said coil-form having spiral grooves cut into its outer surface to receive an electrical resistance heating coil and being formed of an electrical- and heat-insulating material; a coil-form retaining member affixed to said conduit adjacent said upper closure and receiving the upper end of said coil-form; resilient means disposed between the lower end of said coil-form and said lower closure; an electrical resistance heating coil wound in the grooves of said coil-form; and sealing means for passing an insulated electrical conductor through the outer surface of said apparatus to said heating coil.

2. An apparatus according to claim 1 wherein that portion of the inner surface of the heat-radiating shell which is co-extensive with the heating coil bears a heat-conducting electrically-insulating coating.

3. A well heating apparatus comprising a central oil-conducting conduit; an outer heat-radiating shell; an upper closure; a lower closure; said upper and lower closures providing a fluid-tight seal between said conduit and said shell, and maintaining said shell coaxially disposed and spaced away from said conduit; a tubular coil-form disposed between said shell and said conduit, said coil-form having spiral grooves cut into its outer surface to receive an electrical resistance heating coil and being formed of an electrical- and heat-insulating material; alignment means affixed to said conduit and maintaining said coil-form spaced away from said conduit and in close proximity to said shell; a coil-form retaining member affixed to said conduit adjacent said upper closure and receiving the upper end of said coil-form; resilient means disposed between the lower end of said coil-form and said lower closure; an electrical resistance heating coil non-inductively wound in the grooves of said coil-form; and sealing means for passing an insulated electrical conductor through said upper closure to said heating coil.

4. An apparatus according to claim 3 wherein that portion of the inner surface of the heat-radiating shell which is co-extensive with the heating coil bears a heat-conducting electrically-insulating coating of ferro-enamel.

5. A well heating apparatus comprising a central oil-conducting conduit; an outer heat-radiating shell, the inner surface of which bears an electrical-insulating heat-conducting coating; an upper closure; a lower closure; said upper and lower closures providing a fluid-tight seal between said conduit and said shell, and maintaining said shell coaxially disposed around and spaced away from said conduit; a tubular aligning member having its lower end affixed to said lower closure and having its upper end slidably engaging a transverse disc-like support affixed to said conduit, said aligning member being coaxially disposed to and spaced away from said conduit; a tubular coil-form disposed between said aligning member and said outer shell, said coil-form having spiral grooves cut into its outer sur-

face for receiving an electrical resistance heating coil and being formed of an electrical- and heat-insulating material; a coil-form retaining member affixed to said conduit and receiving the upper end of said coil-form; resilient means disposed between the lower end of said coil-form and said lower closure; an electric resistance heating coil non-inductively wound in the grooves of said coil-form; and sealing means for passing an insulated electrical conductor through said upper closure to said heating coil.

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