USE OF ELECTRIC IMMERSION HEATING ELEMENTS IN OILFIELD-TREATERS*

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INTRODUCTION

The ever decreasing supply of fossil fuels in the world is prompting the oil and gas industry to seek alternatives to emulsion treating methods which utilize natural gas for heating purposes in heater treaters. Due to this decreasing availability of natural gas, the search for an alternate treating method is warranted. This paper describes a case history on the performance of an electric immersion heater conducted in an uninsulated C. E. Natco 6' x 20' vertical heater-treater at the Waples-Platter battery in the Amoco Production Company's Wasson, N. E. Clearfork Field, Yoakum County, Texas (reference Figure 1). The electric heating element is, of course, designed on the well established principle of resistive heating, that as electricity flows through a conducter, thermal energy is produced. The heating element was installed January 19, 1979 and the monitoring equipment was connected on January 26, 1979. During the one year test period, the heater power consumption, the ambient and incoming crude temperatures, and the corresponding time (to monitor when the unit was off and on) was recorded daily. Also, samples of crude oil and produced water were taken at different demand temperatures. The produced water was analyzed for oil carryover, dissolved solids and total ions. The fluid temperature in the treater was monitored and found to vary a maximum of ±10° with the electric heating element. (This fluctuation could be reduced, if desired, to any temperature differential.) After a one year period, the heater treater was converted to a conventional gas firetube heater for comparison under similar pumping and climatic conditions. The fluid temperature in the gas-fired treater during its test period however, was too erratic to pinpoint.

This paper contains a discussion of the design and operation of the electric immersion heating element as well as the results and interpretation of the field test that was conducted.

DESIGN

The electric heater assembly illustrated in Figure 2 is a 'Low Watt Density', thermostatically controlled electric heating unit consisting of 21 tubes (3" O.D. x .065 stainless steel welded tubing). Each tube unit contains an electric heating element assembly consisting of a nickel-chromium alloy resistance wire, wound in coils. These elements are supported by specially designed high temperature 'coil-lock' ceramic insulators which are suitable for supporting the resistance heating element. For testing purposes, only 15 of the 21 tubes were utilized; that is, only 15 tubes contain an open coil electric resistance heating element of the coil-lock design sited in Figure 3. Each heating element is rated at 5 KW, 480 volt, three phase, with each element being one phase of a Detla connected, balanced, three phase circuit shown in Figure 4.

Another integral part of the heater assembly consists of the automatically

* Study conducted while employed by AMOCO Production Company.

operating electric control panel. The panel in Figure 5 shows selected switchgear properly rated for the electric heater load involved, and factory wired so that the user need only bring power to the lugs provided inside the panel. If so desired, by adjusting the circuitry of the pre-wired control panel, specific heating elements may be turned on or off for the particular region of fluid medium to be heated. Also, the amount of heat input can be easily adjusted for a specific type of emulsion, flow rate or quantity of fluid to be treated.

The control panel also includes contactors for each 'heating stage' (group of elements) and fused protection for each heater in the unit. The inline fuses will open the circuit in any particular tube should a leak or short develop, thus protecting the entire system. This protection also eliminates the need to pull the entire unit because of an element failure. It should be possible to continue normal operations indefinitely with a tube shorted out and fuse blown.

OPERATION

The two heating stages are controlled by means of a high quality thermostat utilizing two pointers - one showing the temperature of the material being heated, the other showing the desired fluid or emulsion temperature, thus providing convenient readings, or settings, at a glance. Also, because of the dual thermostat arrangement and the electrical control panel devices, any variation of heat, either through quantity, temperature variations, timing, or internal temperature, can be obtained and still be completely automatically controlled. When the two pointers come together, the No. 2 stage of the heating element is switched to the 'on' control mode. If the No. 2 stage cannot hold the desired temperature, or the temperature drops below the desired preset incremental temperature (in this case 5°F), the No. 1 stage heater is energized by means of the 2-stage thermostat and the entire heater is then in the 'on' mode. As the fluid temperature increases, the No. 1 stage drops out, leaving the No. 2 stage to continue to serve the heater-treater until the preset temperature has been reached, and then it is dropped out of service.

In the initial stages of the test, the demand temperature was set at 120°F and all five circuits were being utilized, yielding the maximum output of 75 KW (256,050 BTUH) at 480 volt, three phase. At that particular setting, power consumption and costs were exceedingly high (cited in Table 1) and a lowering of the gravity of the oil also resulted. Therefore, the demand temperature was lowered, and eventually the fuses in circuits No. 1 and 4 were pulled, thereby removing them from operation. This yielded an output of 45 KW (153,585 BTUH), which was maintained at various demand temperatures for several weeks between 80°F and 95°F (inclusive) throughout the test. Circuits No. 1 and 4, were disposed of to create a greater overall heat-transfer exchange. This eliminated the structural interference present (a support plate on the heating element) that passed through these two circuits consisting of six heater tubes.

Throughout the test, samples of crude oil and produced water were taken at the different demand temperatures. The produced water was analyzed for oil carryover, dissolved solids and total ions. This was done to help determine the most economical and feasible temperature required to maintain acceptable oil-water separation, with the intention of keeping a minimal amount of oil carryover in the water, lowering scaling tendencies and also maintaining the desired oil gravity. From eight different samples taken, it was found that the demand temperature should be maintained between 84°F and 87°F (given in Table 2).

RESULTS

Data was collected on a daily basis during the periods the vessel was electrically operated and gas-fired. The fluid temperature in the treater was continually monitored and found to vary a maximum of ±10° with the electric heating element. The fluid temperature in the gas-fired treater was too erratic to pinpoint due to the difficulty of keeping the pilot lit on a continuous basis. This was caused by the frequent high winds in the vicinity and the fuel gas regulator malfunctioning due to low gas supply in the casing-tubing annulus (since there is no gasoline plant in the vicinity, treater fuel consisted of raw gas from the casing-tubing annulus of the only producing well on the lease). The frequency of pilot blowouts during this time caused numerous upsets in the treater.

After sufficient data was collected and the performance evaluated, the heating element was replaced by a gas firetube. The average daily power consumption for the heating element was 644 KWH* (the equivalent of 1.61 MCFD when theoretically converted from KWH to MCFD of 1376 BTU per ft^3 gas, reference Appendix A) as compared with the conventional gas firetube consumption of 43.00 MCFD (measured).

In each case, the data was examined during a two week period in January 1979 for electricity and a two week period in January 1980 for gas, when ambient temperature during this time was 38°F with the demand temperature set at 120°F as shown in Figures 6-8. It is apparent that there is an appreciable difference between the measured amount of gas consumed and the amount of gas theoretically equated to the electricity consumed. It was thought that this difference in fuel consumption might be due to poor fuel efficiency resulting from excessive amounts of oxygen entering the firetube[1].

Results of adjusting air entry portals on gas fired heater-treaters indicate an average 12.5 percent reduction in metered fuel gas consumption when excess air entry is properly regulated. If a 12.5 percent reduction is applied to the fuel gas consumption of the Waples-Platter treater during the two week comparison period, the new daily average fuel gas consumption rate of 37.63 MCFD is still appreciably different from the gas equivalent of electricity consumed. It is apparent, therefore, the treater adjustment would not significantly decrease this difference.

It appears the heating element has a much greater efficiency when comparing the amount of heat which actually goes into heating the fluid to the heat generated per unit of power consumed. This last is a result of the fact that there are no stack losses and all heat generated must pass through the fluid in order to reach the vessel walls. Due to this greater efficiency, it should normally be possible to maintain the immersion heating unit at a lower temperature (84°F to 87°F) on a continuous; year-round basis under all climatic conditions than with a gas fired unit as shown in Figure 9.

The cost of the immersion heating element was $3,790 compared to $3,344 for a gas fired U-tube with necessary accessory equipment. Based on a 15 year operating life, the estimated annual cost of the gas fired U-tube (initial cost plus replacement parts plus maintenance) would be $817 while that of the immersion heater would be $253 ammortized over the 15 year life. This test did not determine the working life of the electric heating element, however, elements have lasted as long as 28 years in other industry applications. Based on 1979 average lease fuel gas costs of $0.50 per MCF (value to the lease) and $0.033 per KWH for electricity in this area, the annual fuel

*A check meter, with a multiplier of 160, for electrical consumption was installed on January 29, 1979 with a meter reading of 0000 (the start of the test period). On February 15, 1979, the test meter read 0069, for an average daily consumption of 649 KWH. The next meter reading was on March 6, 1979 and read 0140 or 640 KWH/Day for an overall average consumption of 644 KWH/Day.

costs would be $3,924 for gas and $3,913 for electricity (reference Appendix B). These energy costs will vary as to their availability and corresponding rates in effect. The fuel and power consumptions were determined with the treater, in both instances, set at 120°F operating temperature (even though the electric heating element can and did operate effectively in the 84°-87° range under all climatic conditions). Although the numbers are based on an estimated annual cost, the heater units operated approximately six months out of the year.

This field test was not designed to compare the cost of treating with electricity versus gas, however, at least in this area, they appear to be competitive. In areas where residue gas can be sold for a higher price, the fuel cost difference might be in favor of the electric heating element. The electric heating element would also be attractive in areas where treater gas has to be purchased from a utility or is not available at all, and in areas where it is impossible or undesirable to make daily checks for gas fired treaters.

One recommendation for modification to the heating element resulted from an incident that occurred as it was being removed. During this operation, part of its structure snagged on the bottom portion of the vertical heater-treater flange sited in Figure 10. Installation of a support guide (for sliding purposes) on the bottom of the heating unit probably would eliminate the problem.

The electric immersion heating unit displayed the following significant operational benefits: maintained uniform temperatures, distributed heat throughout the fluid medium and required a minimal amount of maintenance. Some additional advantages by using immersion heater's are: 1) Helps reduce the possibility of fire or explosion hazards since there are no open flames, 2) Eliminates all inconveniences created by the pilot light blowing out in a gas fired vessel thus having to be relit, 3) The quantity of heat can easily be fitted to the requirement of the job, giving a flexibility that cannot be obtained from usage of gas, 4) Coking or carbonization is avoided by the use of low wattage density (reference Figure 11), and 5) Due to greater efficiency, it should normally be possible to maintain the immersion heating unit at a lower temperature on a continuous; year-round basis under all climatic conditions than with a gas fired unit.

CONCLUSIONS

1. The electric heating element performed entirely satisfactorily during the test period.

2. Electric heat transfer is more efficient than gas firetube heat transfer. The electric heating element can approach 100 percent efficiency.

3. Maintenance of a more uniform temperature with electricity than with gas is possible.

4. The quantity of heat can be easily fitted to the requirements of the particular application[2].

5. Electric heat is safe. Immersion heaters help reduce the possibility of fire or explosion hazards since there are no open flames.

6. Electric heat is easily controlled, giving a flexibility that cannot be obtained from usage of gas.

7. Coking or carbonization of heater tubes is avoided by using low watt density elements.

8. The cost of treating oil with electric heat is competitive to heating with gas.

9. Existing gas-fired heater treaters can be retrofitted with an electric immersion heater.

10. By utilizing an insulated heater treater, reducing the overall cost of operation in heating the fluid in the vessel is possible.

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NOMENCLATURE

SCF= Standard Cubic Feet

BTU= British Thermal Unit

KWH= Kilowatt-Hour

1 KWH= 3413 BTU

REFERENCES

1. Ferguson, K. R. and Stechmann, R. H.: "Improving Heater Treater Fuel Efficiency," SPE 8304 paper presented at the SPE 54th Annual Fall Technical Conference and Exhibition, Las Vegas, Nevada, September 23-26, 1979.

2. Industrial Power and Heating Group, "An Introduction to Industrial Electric Heating, Edison Electric Institute, New York (1962).

APPENDIX A

Electric Power Conversion to Cubic Feet of Gas

1367 BTU Per Cubic Feet Gas

$$\frac{KWH}{Day} = \frac{SCF}{Day} \times \frac{BTU}{SCF} \times \frac{1\ KWH}{3413\ BTU}$$

$$\frac{SCF}{Day} = \frac{KWH^{(a)}}{Day} \times \frac{SCF^{(b)}}{BTU} \times \frac{3413\ BTU}{KWH}$$

Given: $\frac{644\ KWH}{Day}$; $\frac{1367\ BTU}{SCF}$

Find: $\frac{SCF}{Day}$

Solution: $\frac{644\ KWH}{Day} \times \frac{SCF}{1367\ BTU} \times \frac{3413\ BTU}{KWH} = \frac{1608\ SCF}{Day}$

[a]Power Consumed

[b]Gas Analysis

APPENDIX B

Economic Calculations

Annual Cost Analysis

	Ammortized Cost[a]	Fuel [b]		Total
Gas-Fired U-Tube:	\$816.65	\$3924.00	=	$\frac{\$4740.65}{\text{Yr}}$
Electric Immersion Element:	\$252.67	\$3913.00*	=	$\frac{\$4165.67}{\text{Yr}}$

(a) Original cost ÷ Life expectance = Ammortized cost

Gas-Fired U-Tube (Stack assembly + Flame arrestor assembly + Scrubber + U-tube w/o flange + Recoating firetube)

$$\frac{\$344.41}{15\text{ Yr}} + \frac{\$1130.47}{15\text{ Yr}} + \frac{\$394.24}{7\text{ Yr}} + \frac{\$1476.00}{3\text{ Yr}} + \frac{\$170.00}{1\text{ Yr}} = \frac{\$816.65}{\text{Yr}}$$

(like parts deleted)

Electric Immersion Element: (Heating unit w/o flange w/control panel)

$$\frac{\$3790.00}{15\text{ Yr}} = \frac{\$252.67}{\text{Yr}}$$

(there are similar immersion heaters that have been in service for over 28 years without failure)

(b) Based on \$0.50/MCF for natural gas and \$0.0334/KWH for electric energy charge, with the demand temperature set at 120°F.

*Note: Fuel cost for Electric Immersion Unit will be \$3030.00 when operated between 84°F and 87°F.

Monthly Production and Electrical Operating Costs - 1979

	J	F	M	A	M	J	J	A	S	O	N	D
Crude (Bbls)	362	371	382	350	374	346	340	339	349	329	319	277
Water (Bbls)[1]	1457	1316	1550	1620	1612	1500	1395	1426	1410	1457	1350	1395
Total Fluids (Bbls)	1819	1687	1932	1970	1986	1846	1735	1765	1759	1786	1669	1672
Actual Net Crude (BPD)	10	11	10	10	10	10	9	9	10	9	9	7
KWH (Heating Element)	7548[2]	19124	13097	11984	—	—	—	—	—	3450	5300	5920
Demand Temperature (°F)	120°	120°	120°	120°	120°	110°	110° 17th[3]-100°		5th-85°	2nd-82° 19th-88°	9th-95° 20th-85° 30th-87°	9th-80° 14th-84°

[1] Estmated

[2] Immersion Heating Element Installed (January 19)

[3] Date of Thermostat Setting Change

Waples Platter Crude and Water Analysis

Temperature of Sample (°F)	84	87	41
Heating Device	Element	Element	Firetube
Oil in Water (ppm)	72	97	750
Shake Out - Cold	4/10% Paraffin	1 2/10% B.S.	2/10 Water 6/10 B.S.
Hot	Trace Paraffin	Trace Water 2/10 B.S.	2/10 Water
API Gravity	34.97	33.23	32.65
Dissolved Solids			
Cations			
	mg/l	mg/l	mg/l
Sodium, Na (calc)	56,097	46,713	82,156
Calcium, Ca	25,824	5,133	3,168
Magnesium, Mg	4,568	788	3,888
Anions			
Chloride, Cl	145,200	83,200	143,200
Sulfate, SO_4	600	280	600
Carbonate, CO_3	0	0	0
Bicarbonate, HCO_3	59	110	102
Total Dissolved Solids (calc) (ppm)	232,348	136,214	233,114
pH	5.9	7.4	6.9
Specific Gravity, 60/60 F	1.160	1.110	1.160

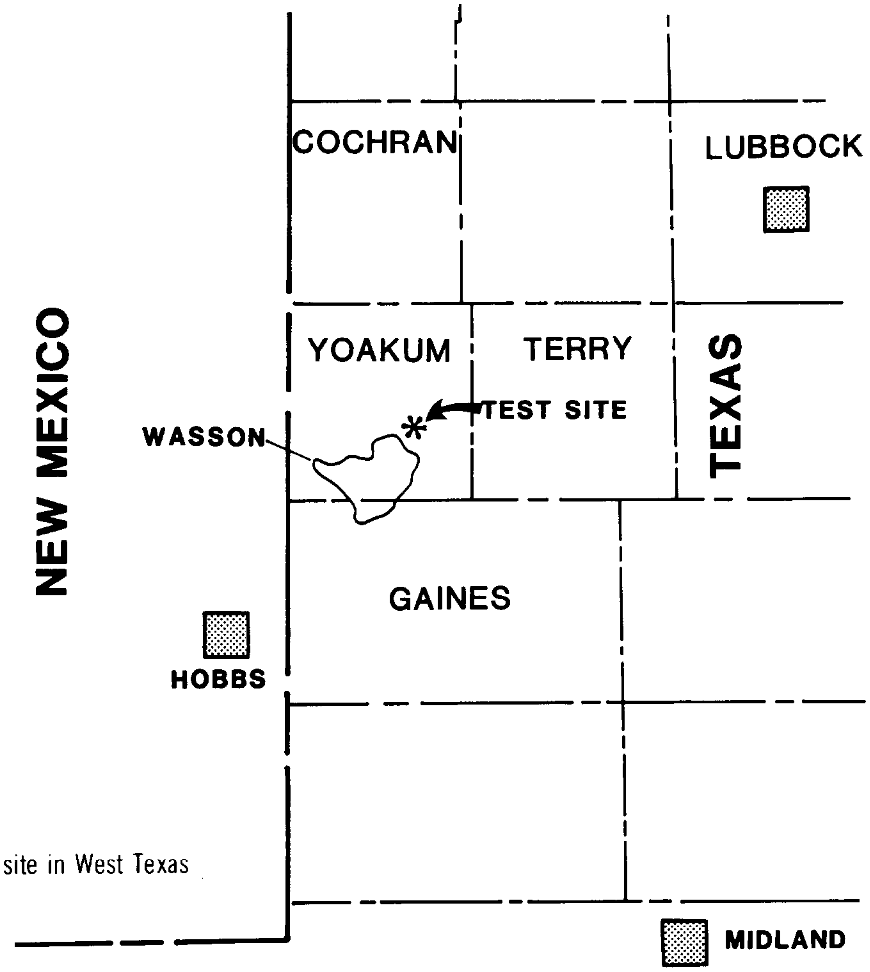

FIG. 1 — Location of test site in West Texas

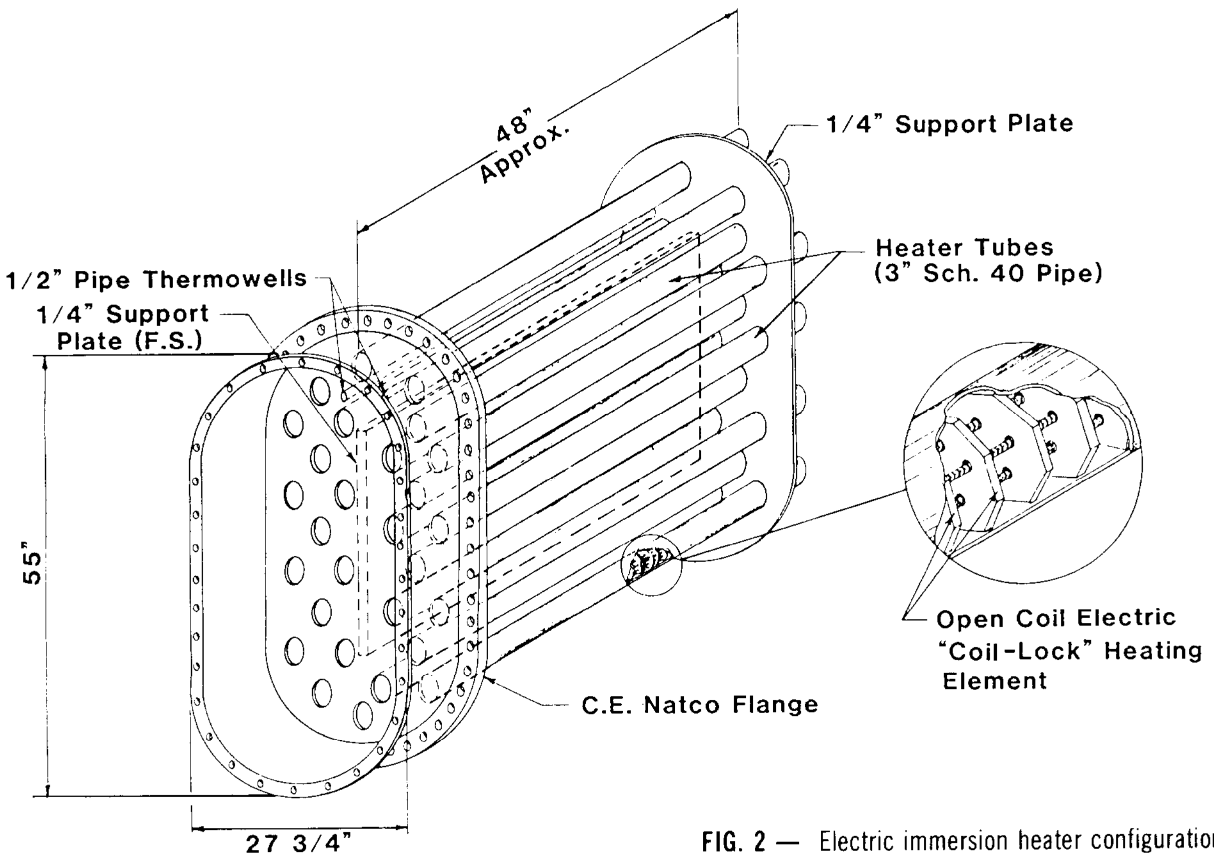

FIG. 2 — Electric immersion heater configuration

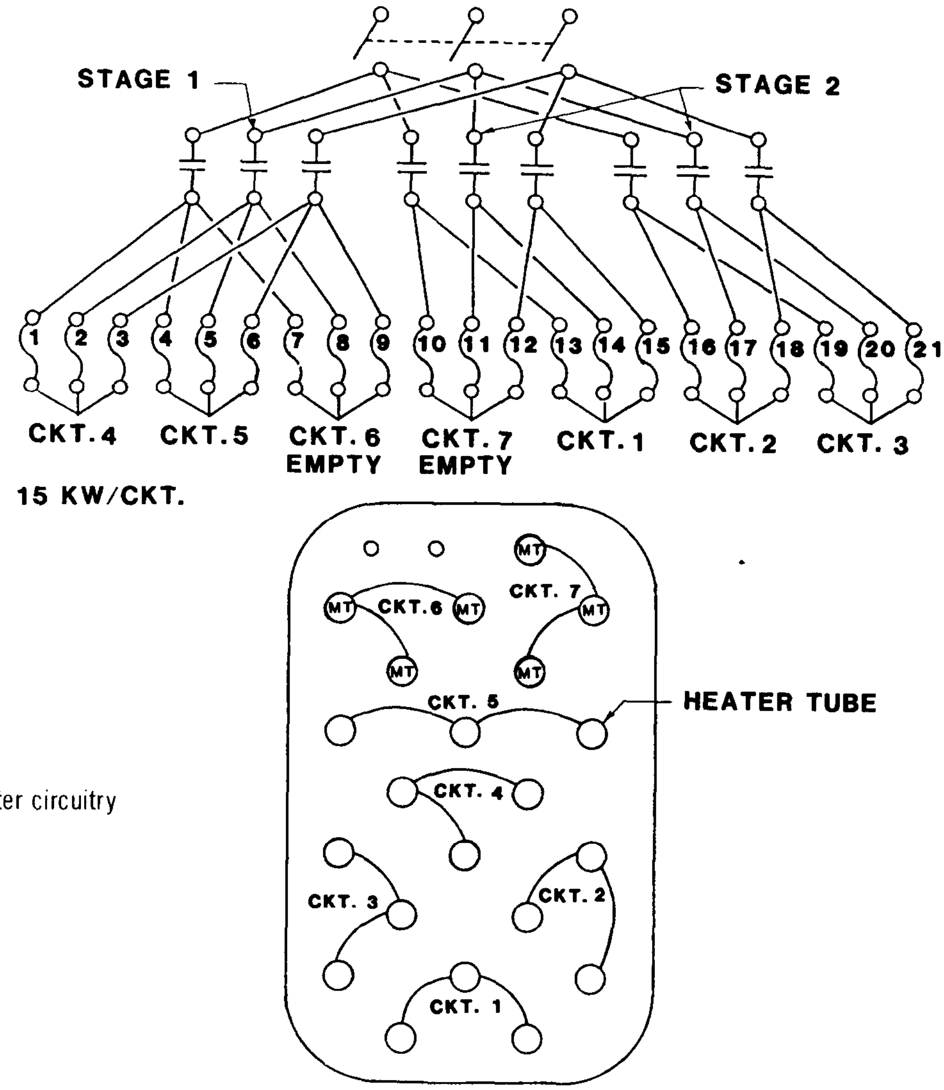

FIG. 3 — Electric heater circuitry

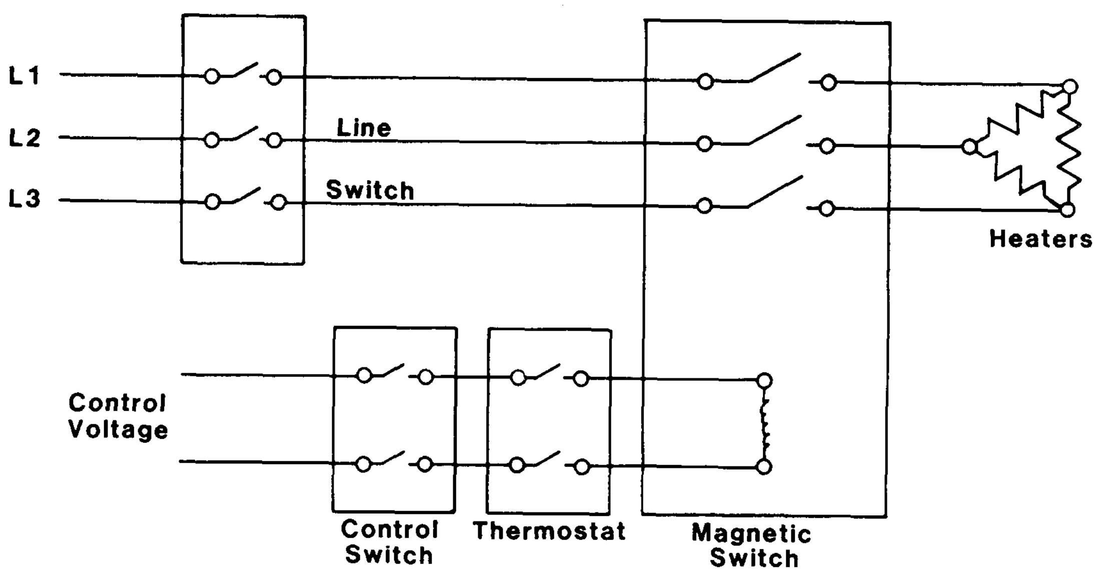

FIG. 4 — Three-phase a-c heater circuit with separate control circuit

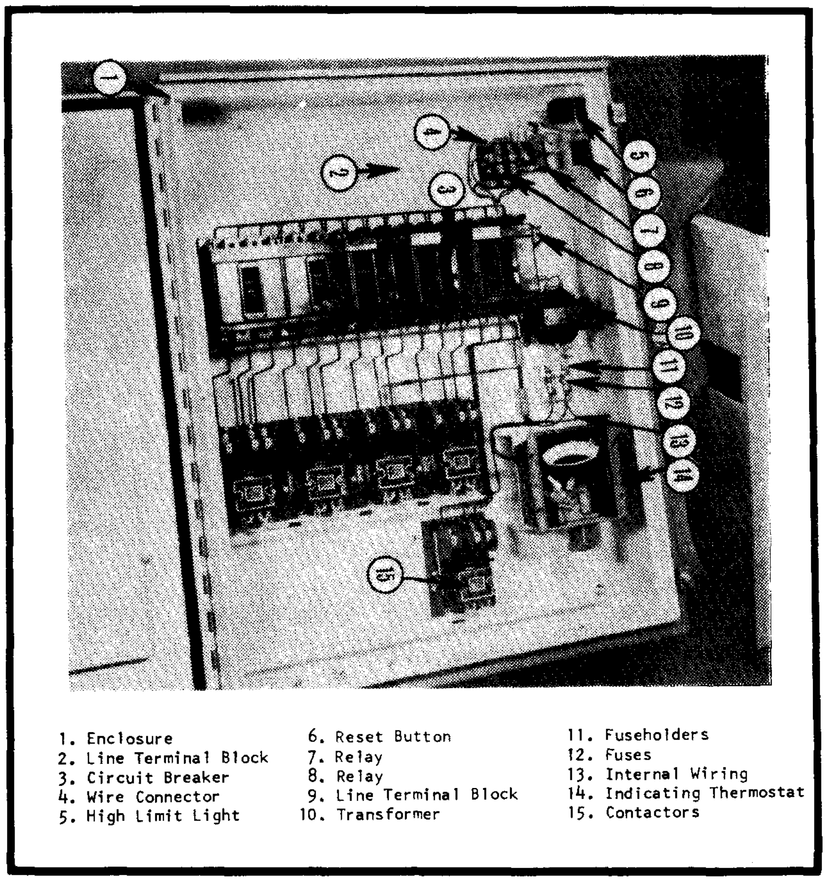

FIG. 5 — Electric control panel

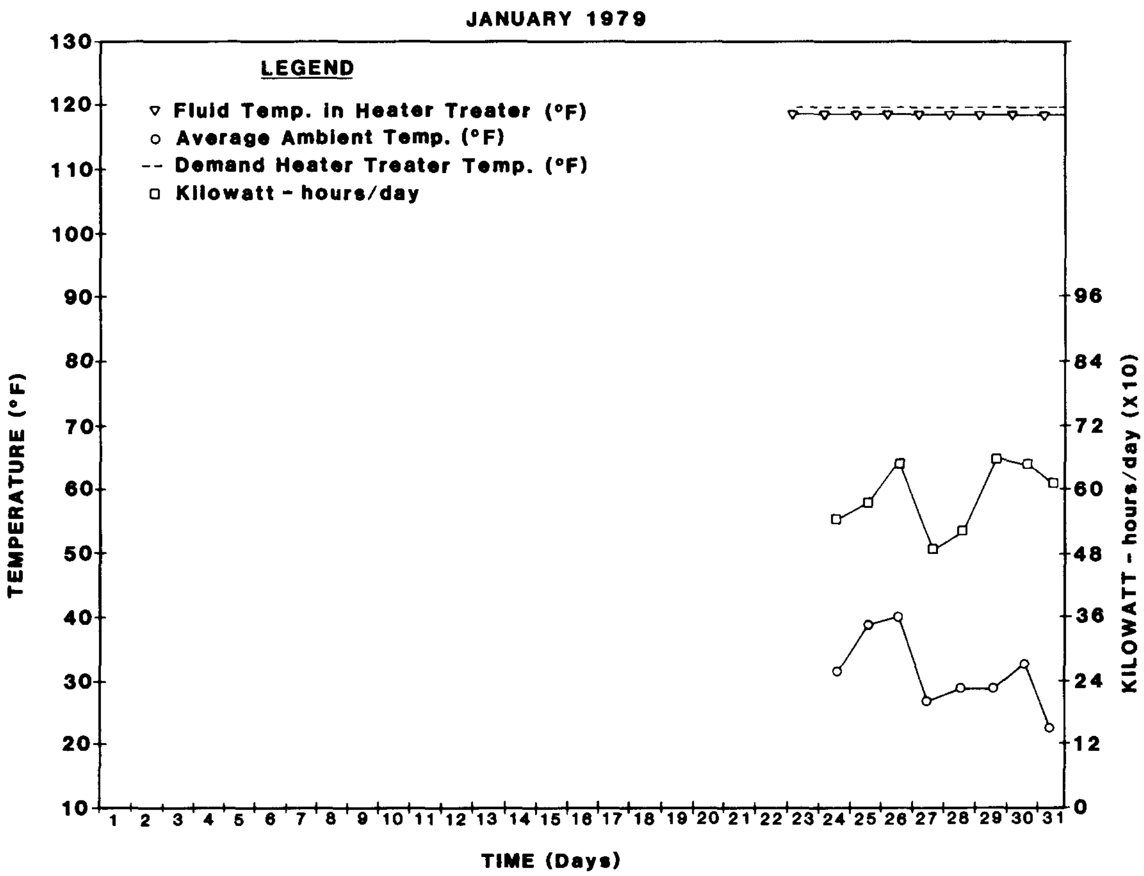

FIG. 6 — Temperature - electrical power consumption data for immersion heater

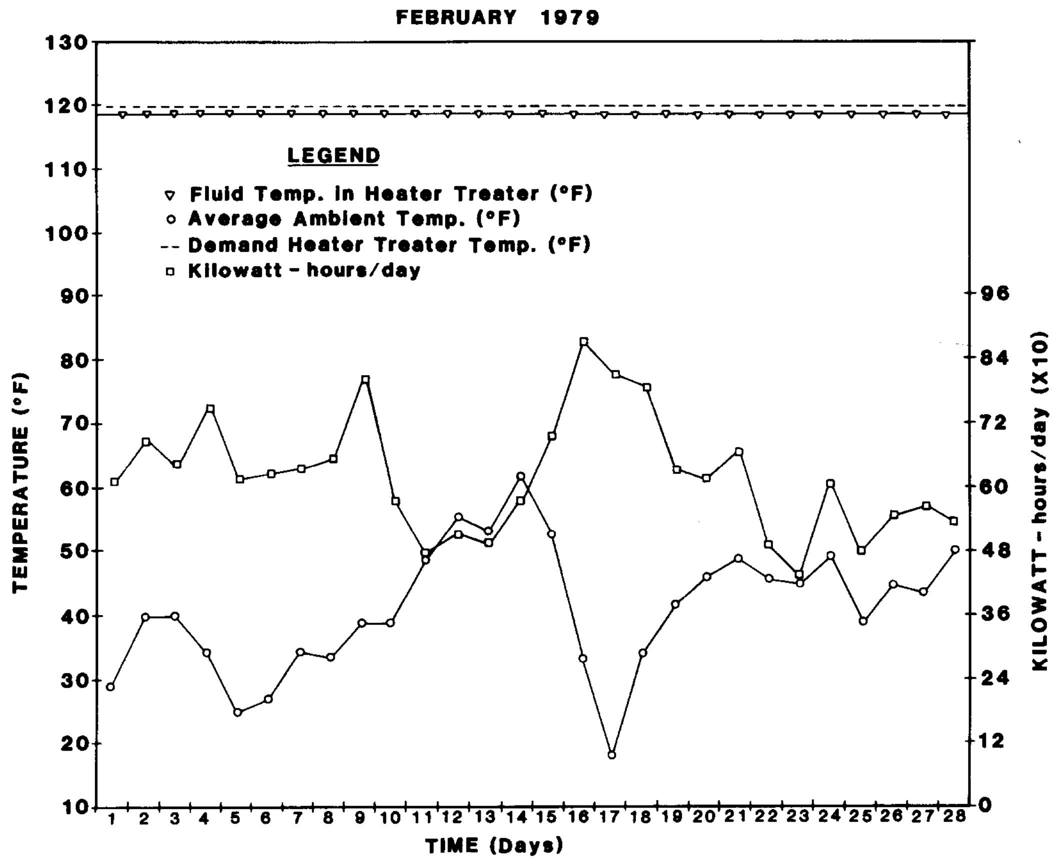

FIG. 7 — Temperature - electrical power consumption data for immersion heater

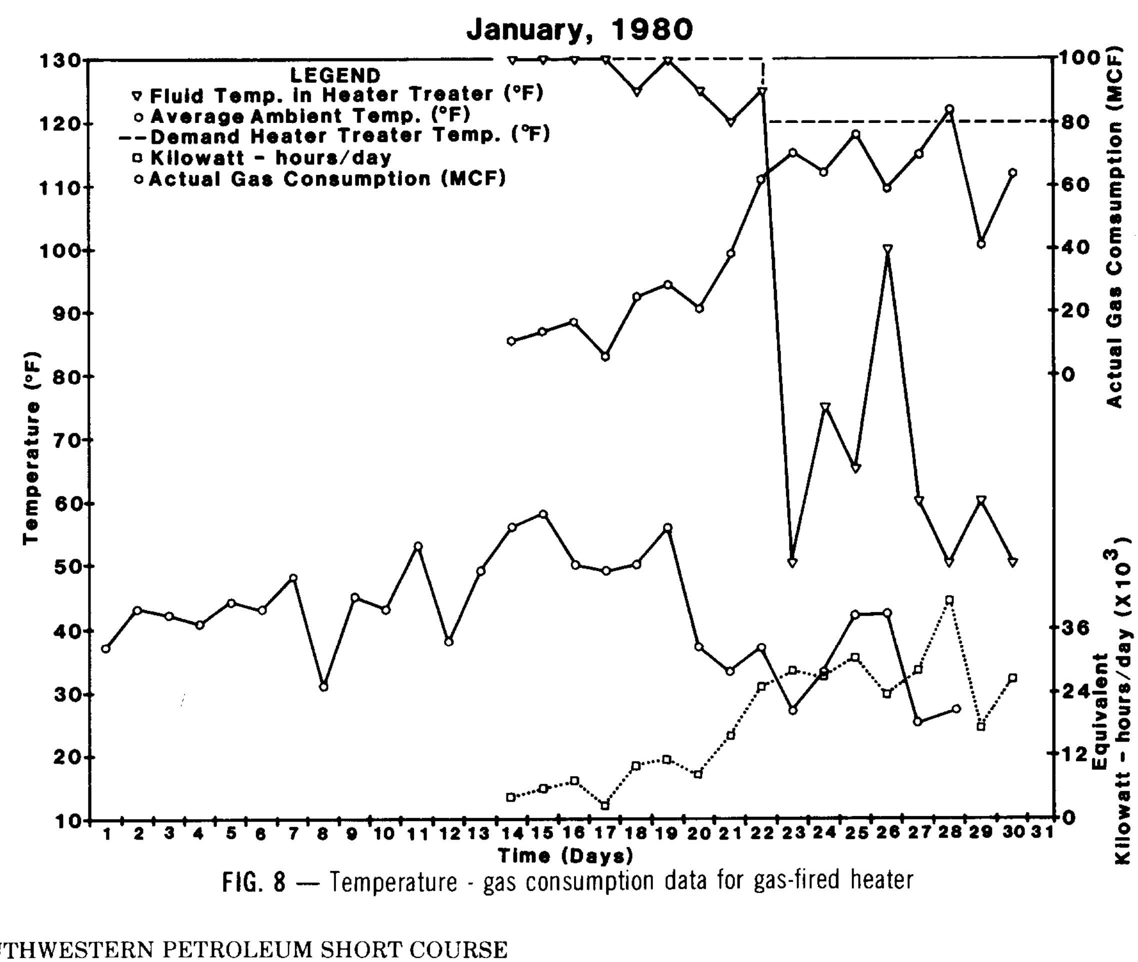

FIG. 8 — Temperature - gas consumption data for gas-fired heater

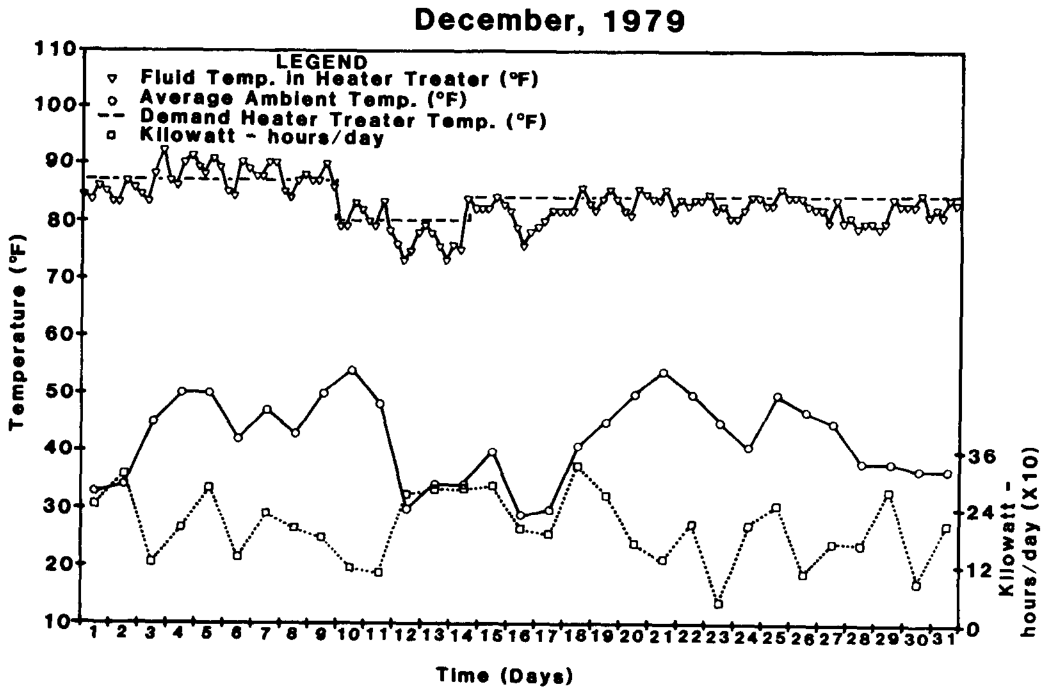

FIG. 9 — Temperature - electrical power consumption data for immersion heater

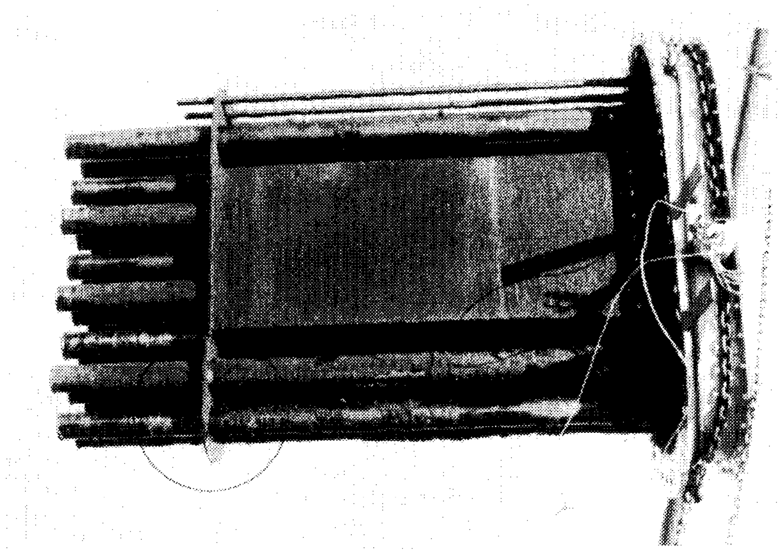

FIG. 10 — Area in question for flange structure modification

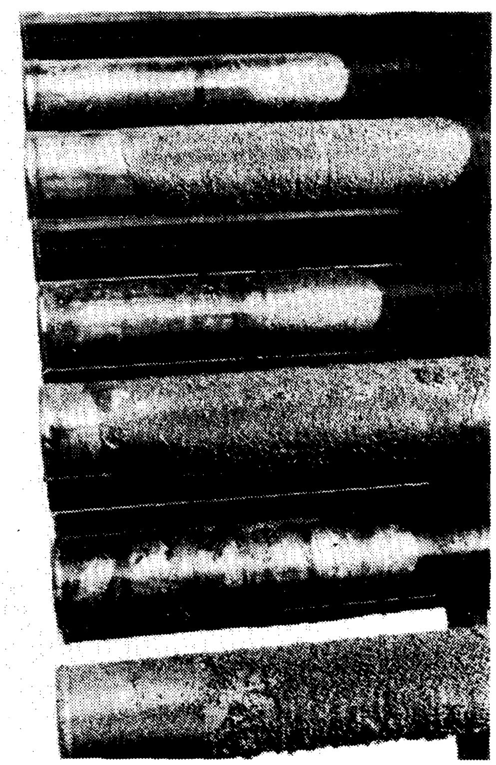

FIG. 11 — Some Carbonization occurred at temperatures greater than 100°F