Fire Flooding Ignition Techniques

By JON T. MOSS

Tor Developments, inc.

During the recent development of the fire-flood oil recovery processes, one of the first problems that had to be answered was how to initiate combustion. It was found that quite often certain crude oils were difficult to ignite even in the laboratory experiments, and the problems were magnified in field cases. Just why certain oils are more or less susceptible to combustion than other oils of oil bearing formations is not precisely known; but because of this, several ignition methods have been developed and ignition equipment has been improved. Designed temperature levels can be obtained and the heat generating capabilities of ignition equipment is sufficient to meet almost any reservoir condition.

The planning of project ignition is actually more important than the many operational details associated with initiating combustion. If, for this discussion, the problems of well array and injection well locations are omitted the specific problem then is just where should combustion be initiated to realize maximum oil recovery. Questions that usually arise are: (1) single or multiple sand section, (2) permeability variations, (3) shale separations between zones, (4) shale or impermeable separation within particular zones, (5) reservoir and oil characteristics, (6) fluid saturation distributions, etc. The detailed study of these and other related factors usually makes the injection completion interval fairly obvious.

The injection well can then be designed. For example, a consolidated uniform sand can be completed as (1) in open hole, (2) liner across the sand, or (3) casing set through and perforated. Since the ignitor is usually operated at 800 - 1000°F, the problem of thermal expansion of the pipe can arise in (3), above. Experience with numerous perforated completions indicates that possible well damage due to thermal expansion of the short heated pipe section does not normally interfere with subsequent operations. In fact, heaters have been run in and out of high temperature holes at various sand face positions with less than 0.5 in. maximum clearance between the heater and the pipe of other equipment in the well bore.

As a general rule, regular oil field tubular goods may be used in injection well completions. Since the high temperature zone is limited to the completion interval, any need for heat resistant pipe, such as stainless steel, is restricted to the heated section. It is often convenient to equip the injection well with small pipe strings to serve as thermo-wells for temperature observations during ignition. The lower section of this small diameter pipe should be of stainless steel.

Injection wells are designed for two purposes, i.e. to conduct air from the surface to the formation and to confine the air to the desired formation intervals. Sometimes, old wells are suitable or can be reworked as injectors. High temperature cement in completions is desirable particularly where formations with this vertical separations must be isolated in the heated region.

Many different techniques have been used to initiate combustion. Air has been heated at the surface an injected down-hole for this purpose. Similarly, steam has been used to elevate formation temperatures to promote ignition when contacted by air. Chemical methods and sometimes reactive oils have been used to start combustion, and spontaneous combustion occurs in many oil reservoirs. Perhaps the most widely used ignition method employs down-hole heaters to heat the injected air to ignition temperature.

Igniter operations are usually conducted at 800 to 1000°F and these temperatures are maintained for the desired heating period. Electrical heaters used for this purpose are usually 10 to

40 KW in size. The heater temperature is controlled by means of thermocouples on the heater or in a thermowell pipe beside the heater. By positioning the heater at various depths, all sections of the well bore can be heated.

In the gas burner system, gas is injected down the tubing while air (about 80 to 90 per cent excess air) is injected down the casing annulus. The gas is ignited and burns inside a heat-shield, thus protecting the well casing from damage. Air flows around and through the heat-shield transferring heat down the hole to the formation. Numerous safeguards are observed and explosive limits of a gas-air mixture are never approached at any time during the operation.

Gas ignitions can be conducted at high pressure and have been carried out at depths of at least 7000 ft. The heat generation rate is controlled by the air and gas injection rates, with a maximum heat release of 10 MMBTU Day recommended. With constant air rates the air temperature at down-hole conditions is controlled by adjusting gas rates, or if using electrical heaters, by adjusting the power supply. After well bore temperature stabilizes, the air temperature below the heater is very near the adiabatic temperature estimated from heat supplied by the igniter. Maximum temperature control can be obtained from down-hole temperature measurements and these are recommended wherever possible.