Application and Operating Characteristics of Submersible Pumps In Water-Supply and Oil Wells

By JERRY F. BOUTWELL
Byron Jackson Tools, Inc.

ABSTRACT

While not applicable to all existing well conditions and requirements, submersible pumps, properly selected and applied, offer a useful tool to the oil industry. Ultimate economic efficiency -- a combination of all factors including mechanical and electrical efficiency, initial and operating cost -- is of important magnitude in our competitive business. Submersible pumps contribute toward the achievement of this goal.

Description of Submersible Pumps

Submersible pumps used in oil and water supply wells consist of the following basic elements:

A. Electric Motor, 2-Pole, 3-Phase
B. Multi-stage Centrifugal Pump
C. Seal Section (to include well fluid from motor)
D. Electric Cable
E. Control Panel or Switchboard

In normal applications first in the well is the motor, then the seal section and pump. The electric cable is clamped at intervals to the tubing, and the entire pumping unit is supported by the tubing. To perform various functions required in the particular installations, the control panel is equipped with manual and/or automatic controls such as float switch control, high or low lead line pressure shutdown, automatic re-start in the event of shutdown due to pump-off or power interruptions, etc. As required, auxiliary items -- such as well heads, cable reels, tubing check, transformers and cable guide wheels -- are normally supplied as a part of the pumping unit.

Fig. 1 shows a typical installation.

The ability to produce large volumes of fluid from common oilwell casing sizes is one of the most widely known features of submersible pumps. Fig. 2 shows capacities and lifts available from various casing sizes. Figures shown are for single pumping units, although in cases where pumping requirements exceed the ranges shown, tandem or parallel submersible pumping units can be installed. This paper will be confined to the discussion of single pumping unit installations because of the special requirements for tandem or parallel units because of their infrequent use.

Applications of Submersible Pumps

Being primarily high capacity equipment, submersible pumps are most commonly used where the pumping rate is from 50 BPD to 20,000 BPD, and for net lifts up to 13,000 ft. Because of the rapid increase in the size and number of waterflood and pressure maintenance projects and of the steady increase in well spacing, the use of submersible pumps has grown accordingly.

Typical operations are the following:

A. Water Supply Wells

Since most waterflood engineers prefer salt water instead of fresh water, and because of the need to conserve fresh water for other uses, most water for waterfloods is obtained from relatively deep wells. Here the engineer must determine not only the amount of water required and the depth and capacity of possible water producing horizons, but must also determine the required number of wells, cost per well, casing size, degree and method of well stimulation, character of the water, dependability of the producing zone or zones for long-term supply, optimum well spacing to limit well interference, and the proper pumping equipment.

The proper decision on these and other items determines the ultimate cost per barrel of water and, to a great degree, the ultimate economic efficiency of the project.

The ability to produce relatively large volumes of water from common oilwell casing sizes and from a wide range of depths is of great economic importance (Fig. 2)

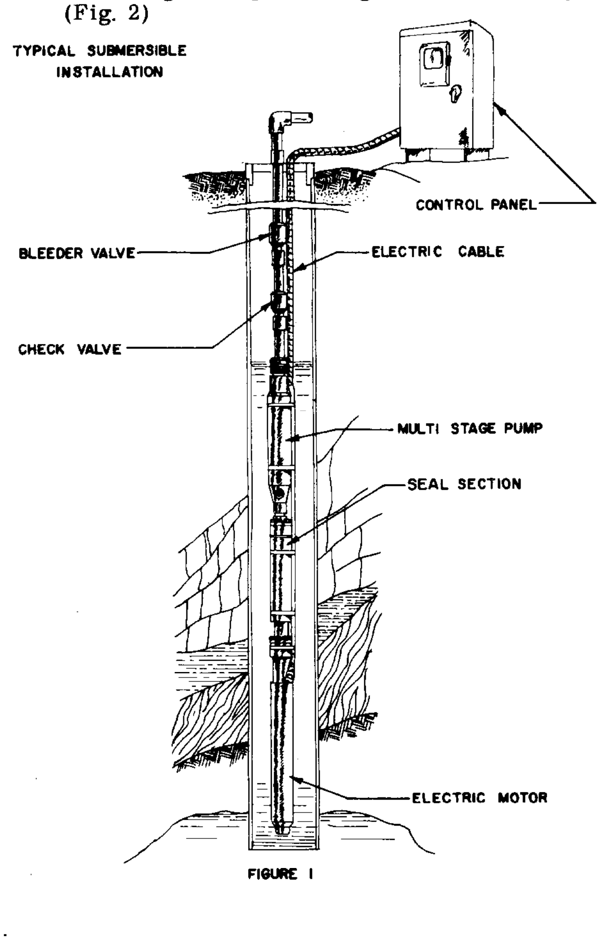

FIGURE I

SUBMERSIBLE PUMP CAPACITY AND LIFT RANGES IN VARIOUS CASING SIZES — SINGLE UNITS ONLY

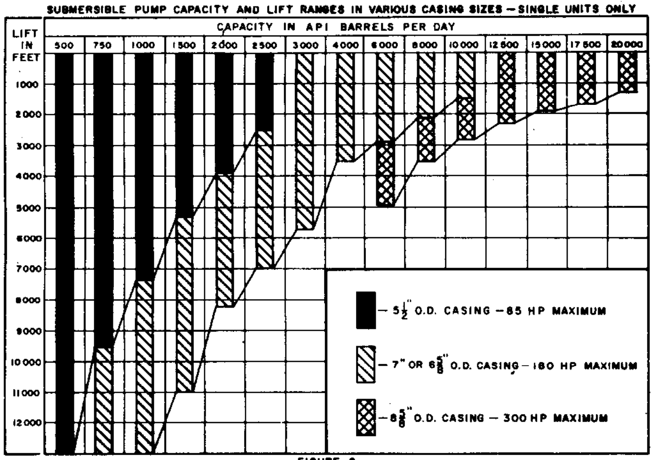

FIGURE 2

Therefore, submersible pumps are usually a factor in the mechanical, electrical, and economic studies on waterflood or pressure maintenance projects. Such studies usually result in the use of 8-5/8 in. casing, but 5-1/2 in. O D cased wells are sometimes used when the economics justify this practice. While in most applications the submersible pump is used to produce from the supply well to surface storage it is also used to inject water into the input wells and thereby eliminate surface pumps. It may also be used in a closed system where the water zone and oil producing horizon are open in the same well.

Oil Producing Wells on Waterfloods

Since most reservoir engineers, on secondary recovery projects, prefer to keep oil producing wells in a "pumped down" condition, submersible pumps are useful in wells having a capacity of about 500 BPD or more.

On projects where alternate producing wells are converted to injection wells, and the effective well spacing thereby doubled, submersible pumps are often used.

Submersible Pumps are Primary Production

In oil producing reservoirs having an active water drive one finds another type of application for submersible pumps.

Ability to produce the allowed amount of oil is of great importance to the operator, but of equal and sometimes greater importance is the fact that high withdrawal rates from water drive reservoirs usually result in greater ultimate recovery, a result chiefly because of two factors. High withdrawal rates reduce the cost per barrel of fluid lifted by spreading all fixed costs per day over more barrels per day; these costs include depreciation, labor, supervision and overhead. Variable costs per barrel, such as repairs and well servicing, are not directly proportional to pump horsepower or capacity, and are, therefore, lower per barrel at high withdrawal rates. When producing rates are increased, many producing horizons respond favorably to the reduction in bottom hole pressure, particularly irregular limestone or similar conditions where entrapped oil may be released when the bottom hole pressure is reduced to less than bubble point pressure.

Selection of Submersible Pumps

The design of any pump installation can be done most efficiently and economically only if there is a reasonably accurate estimation of the pumping requirements and conditions, including:

A. Casing size, weight and setting depth.
B. Liner size, weight, depth to top and bottom.
C. Open hole or perforated intervals.
D. Tubing size, thread and length.
E. Productivity index of the well, in barrels per PSI or per ft.
F. Specific gravity of the well fluid.
G. Bottom hole temperature.
H. Bubble point pressure.
I. Specific gravity of produced gas.
J. Gas-oil or gas-fluid ratio.
K. Surface discharge pressure at well head.
L. Electric power supply.

Consideration should be given to any well conditions such as sand, deposition or severe corrosion to determine what steps -- chemical treatment, protective coatings or screen liners -- may be taken to control these conditions.

With the above information available, a proper pumping unit can be selected from engineering data supplied by the manufacturer. For example, it may not be necessary to set the pumping unit near the bottom of the well; therefore, one would save initial cost in electric cable and tubing, and save operating cost by having less tubing friction loss and voltage drop.

In wells where the producing bottom hole pressure will be less than bubble point pressure, a gas separator should be specified, and the pump setting depth should be near bottom. In undersaturated wells the setting depth would be at that point in depth where the submersible pump pressure, while pumping would be equal to or greater than the bubble point pressure.

Most electric power companies offer a variety of power rate schedules that are based largely on the amount of power consumed per month and also allow for various load factors, power factors and/or demand charges. However, since these conditions usually vary or change throughout the life of a producing oil property, periodic checks should be made to determine the most economic power schedule. Substantial savings may result from such action.

Being essentially similar to motor-driven centrifugal pumps with which are all familiar, submersible pumping units respond in a similar manner: the amount of fluid produced is determined by a combination of rotative speed, pump size and number of stages, total operating head and variations therein. Power requirements are determined by efficiency of the system, including transformers, electric wire or cable, motor, pump and discharge pipe or tubing. As standard practice, centrifugal pumps are usually shop-tested in fresh water, and performance curves produced therefrom. Therefore, with published data based on a specific gravity of unity, corrections must be made in direct proportion for power consumption at any other specific gravity. Viscous liquids, such as 15 API crude will reduce pump output and increase power consumption. However, where the average oil or oil-water mixture at pump suction conditions does not exceed 150 SSU corrections are not normally made, but for higher viscosities the manufacturers recommendations should be obtained.

Shown as Figs. 3, 4 and 5 are typical performance curves of submersible pumping units.

The type Q-60 (Fig. 3) is for use in 5-1/2 in. OD

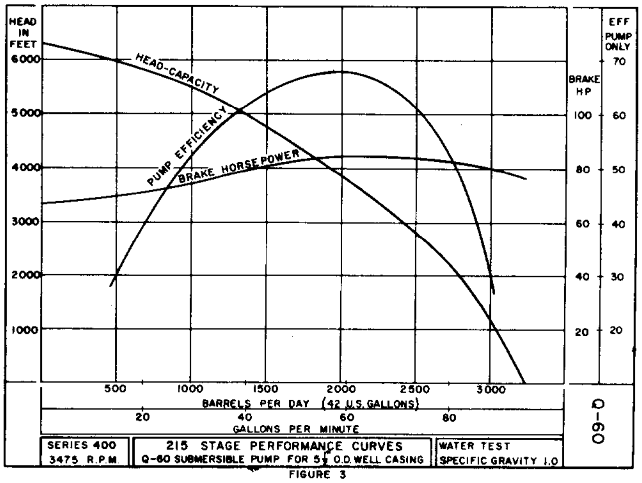

FIGURE 3

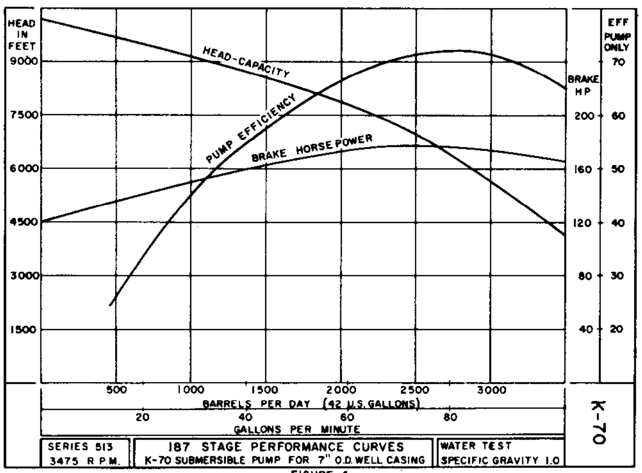

FIGURE 4

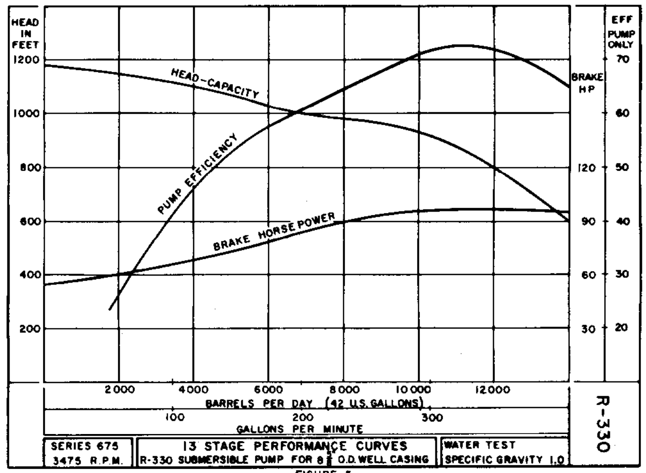

FIGURE 5

casing. Common to all centrifugal pumps is the ability of each to operate over a comparatively wide range of capacity with little loss of efficiency; but the available lift or head changes with capacity. Therefore, with a loss of not more than five points of efficiency at the lowest point, this pump can be used over the range of 1,400 BPD at 4,900 ft to 2,500 BPD at 2,800 ft, with peak efficiency at 2,000 BPD and 3,850 ft. Power consumption changes very little throughout this range. Type K-70 (Fig. 4) is for use in 7" O D casing, or larger. Operating characteristics are similar to type Q-60 in that capacity changes with head and the pump can be used over a comparatively wide range of capacity, from 2,000 barrels per day to about 3,400 barrels per day.

Type R-330 (Fig. 5) is for use in 8-5/8 in. OD casing, or larger, and covers a capacity range frequently produced from water supply wells on waterfloods.