Oil Well Monitoring System

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INTRODUCTION

Many aspects of the oil producing and processing industry have been effectively measured and controlled by automatic means to improve efficiency and reduce operating costs. However, the complex factors affecting the performance of an operating oil well pumping unit make it very difficult to monitor with the devices commonly used for flow and pressure measurements. Nevertheless, one instrument, the well weighing dynamometer, has been shown to be capable of monitoring the pumping cycle and producing a record which can be analyzed to determine well performance. The mechanical dynamometer in present use is somewhat time consuming in operation and does not provide an output which is convenient for transmission to remote locations. However, a recently developed unit has been designed for permanent installation of the pumping unit and utilizes load cells with strain gages providing an electrical output suitable for transmission to other locations. This paper describes a system for efficiently instrumenting a large number of well pumping units and transmitting the data to a central location for analysis. Then, technical personnel may evaluate the performance of any individual well by electrically switching to that well and recording the data.

SYSTEM CAPABILITIES

A system has been designed to accomplish the well monitoring function simply and efficiently and for the most part with standard, commercially available equipment. In addition, the system has a built-in expansion capability which permits its usefulness to be extended many times. It may be expanded to monitor additional wells, to supplement the monitoring capability with simple control functions and eventually to connect to completely automatic computer analysis of the well data. A summary of the system capabilities then includes:

(1) Rapid evaluation of the static and dynamic status of each well in a group of wells.

(2) Remote monitoring of the performance of well equipment.

(3) The capability for expansion to automatic operation.

SYSTEM CONSIDERATIONS

The primary use of the system will be for remote monitoring of well operations during normal pumping cycles. A basic premise assumed in arriving at this system is that it would be desirable to monitor a relatively large number of oil wells, dispersed over an area of at least several sections, at one central control point. A significant economic factor exists in providing signal lines connecting these well sites to this central control point. In general, it appears probable that the use of one common line will provide the most economical way of connecting the well pick-up equipment to the central point. Since all the well sites are connected to one line, this method of transmission requires a means of selecting and identifying the data signal associated with each well.

Previously recorded and analyzed data of sucker rod load versus time, during the pump cycle, shows important transients, or changes of condition which must be duplicated accurately at the monitor site. Measurements of numerous wells indicate that frequencies up to five cycles per second must be reproduced to adequately present these transients for analysis of the well and pump operation.

The system has been designed to be capable of reproducing frequencies up to 35 cps, although a lower cut-off frequency is sometimes deliberately used to reduce normal extraneous noise, or insignificant frequencies, from the monitor output.

In addition to the basic dynamic load status waveform obtained during the pump cycle, important information can be obtained from the slow changes in well weight under static, non-pump conditions. Consequently, the system has been designed to accurately measure and transmit static as well as dynamic conditions.

SYSTEM DESCRIPTION

The system is comprised of two types of equipment. The monitor site contains a control unit which provides well selection signals affording individual access to many well installations, and which demodulates, or separates the well information signal, and provides the desired load waveform on a paper chart recorder. At each well site, an electronic dynamometer is permanently mounted on the polished rod and connected to a voltage controlled oscillator. The oscillator, well selection decoder, and required power supply are permanently installed on the well structure. The installed equipment does not interfere with normal pumping operations in any way.

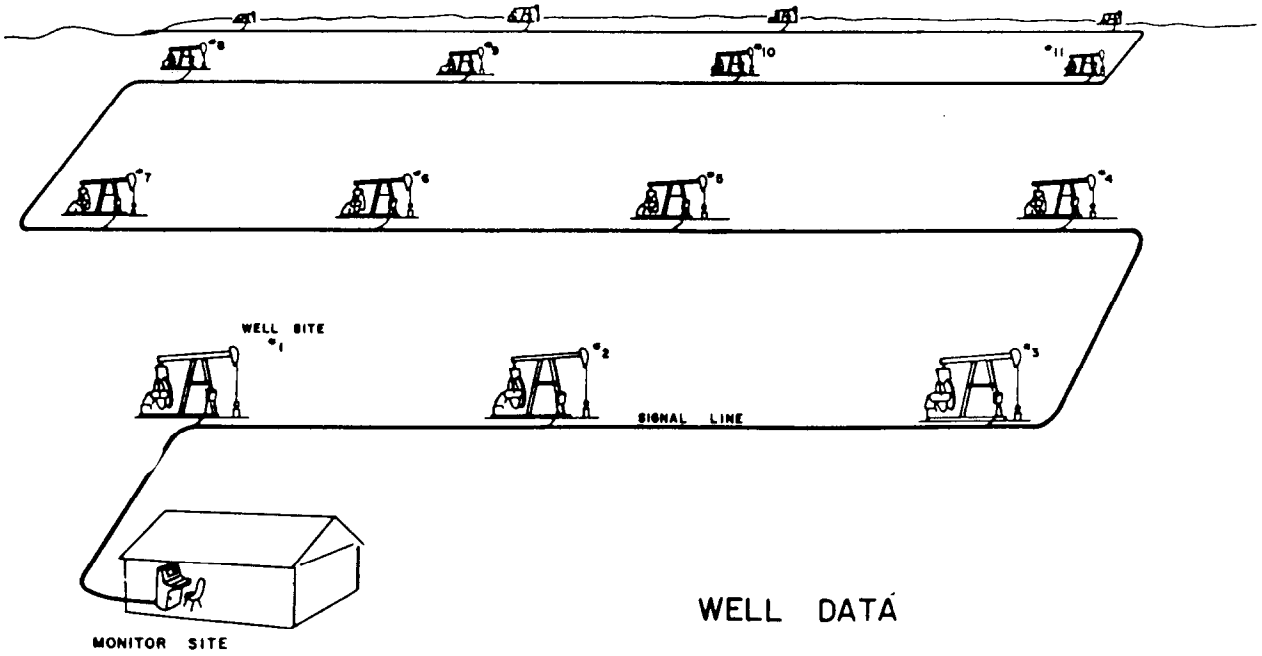
A single pair of wires, which may be a standard telephone pair or any line with similar characteristics, is used to connect all well sites in one group to a central control and monitoring point. See Fig. 1. At each well, a selection decoder, consisting primarily of two frequency sensitive relays, is permanently connected to this line and is continuously energized from the well site power line.

Each relay is tuned to respond only to a specific frequency, and is insensitive to any other frequency signal applied to it. Selection of the two proper frequencies, which are applied simultaneously on the signal line, will activate the decoder at the particular well containing the relays which respond to the two selected frequencies. A total of 20 selection frequencies are provided at the monitor site control panel and are used, two at a time, to select up to 100 different wells. See Fig. 2.

Recognition of its preset combination of frequencies results in a well decoder locking in a relay which in turn activates the transducer and transmission equipment. A third frequency sensitive relay, tuned to a single frequency different from any of the 20 selection frequencies, is used to recognize a "Turn Off" command. Momentary application of the shut-down frequency signal at the monitor control unit activates this third relay at the selected well and opens the relays previously locked in by the original selection signal. This action turns off the pump monitoring equipment, and thereby clears the line for selection of another well site.

The transducer provides an output voltage which is a continous representation of the weight on the polished rod, and represents the instantaneous loading throughout the pumping cycle. This voltage is on the order of from 0 to 0.02 volts.

A carrier oscillator operating at 2300 cps, which is a standard frequency widely used in both industrial and military telemetering sys



WELL DATA
TRANSMISSION SYSTEM

Fig. 1

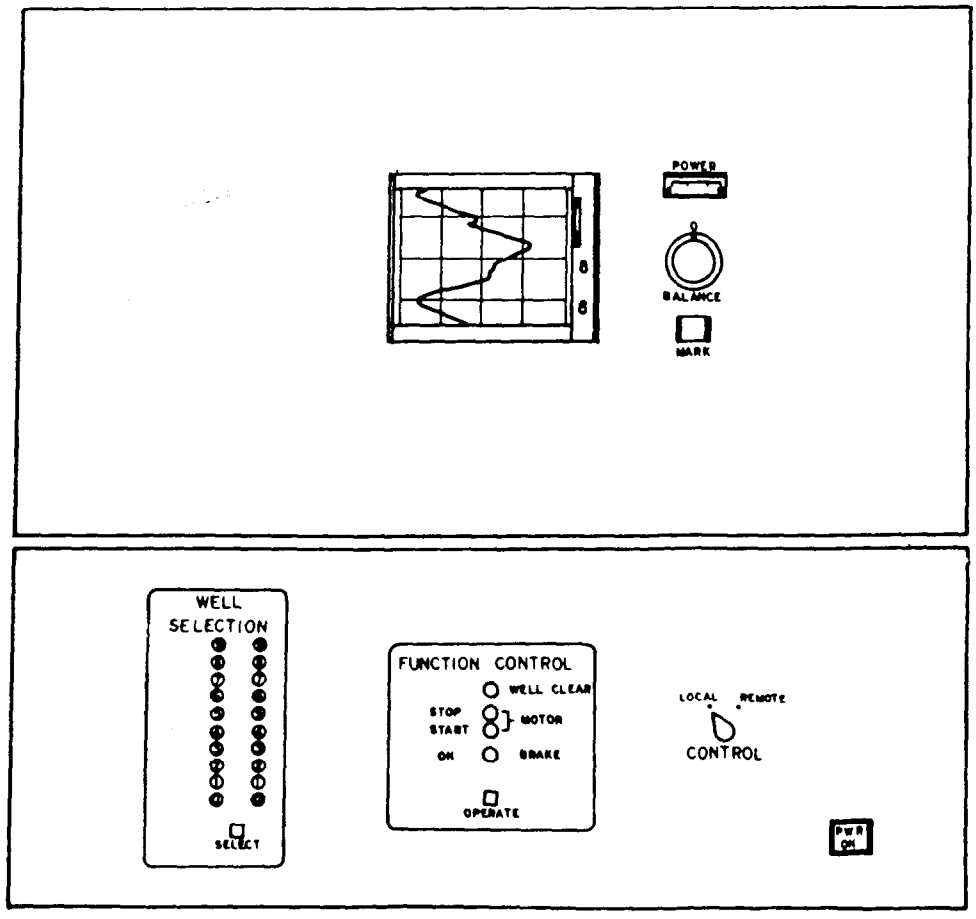
tems, converts the transducer voltage output into a frequency modulation of the carrier oscillator.

In this manner, an adequate signal voltage is available from the oscillator for transmission over relatively noisy lines, while the information is carried in the actual frequency of the signal where it is essentially unaffected by the line noise. The accuracy of the system is thus maintained without the use of expensive DC amplifiers, and line losses in the long signal lines between the well sites and the monitoring control site are not important. A further extremely significant advantage is attained, in that this FM carrier signal may be applied to a telephone line linking the field control station with other remote office installations, if desired.

At the monitor site, a standard FM telemetry discriminator is used to demodulate the carrier oscillator. This discriminator converts the frequency modulation containing the well load information back into a voltage representing the output of the well transducer. This voltage is then applied directly to the chart recorder to provide an accurate reproduction of the transducer output and consequently, a true record of the actual load conditions during dynamic operations or in a static state. The technique is similar to that used in FM broadcasting. FM is used in this system due to its inherently noise and static free operation and its capability for high fidelity reproduction.

EQUIPMENT DESCRIPTION

All the monitor site equipment is housed in a compact and attractive console. See Fig. 3. This electrical enclosure is suitable for use in either home office or field office installations. The instrument panel contains the instrumentation recorder and the control panel mounts the selection and function controls which are on the proper level for optimum convenience and efficiency when the operator is seated. Fig. 2 shows details of the instrument and control panels.



INSTRUMENT AND CONTROL PANEL
MONITORING EQUIPMENT

Fig. 2

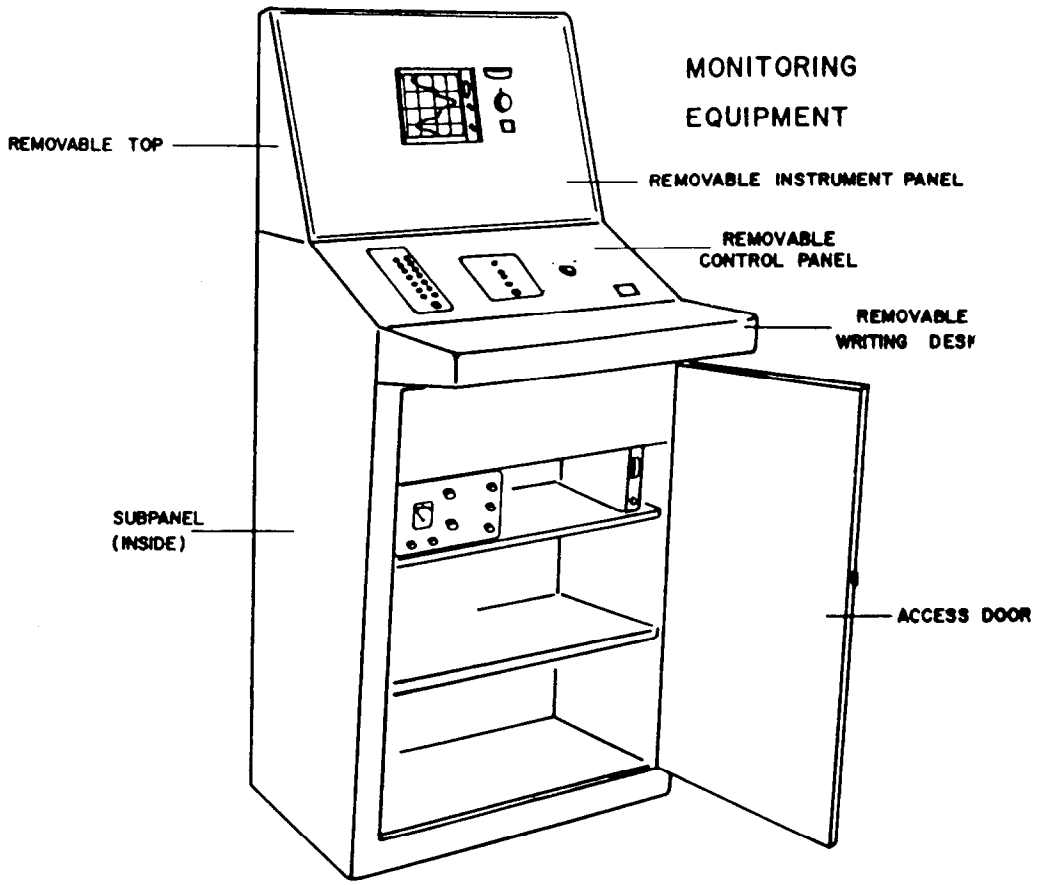


Fig. 3

Twenty-one tone encoders are utilized at the monitor facility. These units have been used extensively in remote control systems, telemetering, data transmission and similar applications.

The recorder supplies a strip chart of load versus time at a constant maximum speed of 30 in. per min. providing excellent resolution for analyzing even the fastest wells. Simple front panel controls allow operating personnel to obtain maximum accuracy with very little training.

The FM discriminator features accuracy, high input sensitivity, compactness and low output noise. It is also a standard commercial item. The FM discriminator is mounted on supports behind the front access door.

Maximum height of the electrical enclosure is 36 in., width is 36 in., and depth, including writing surface, is 30 in. Power and signal connectors are located on the rear panel.

The well site equipment consists of the electronic dynamometer, a well site equipment assembly and the connecting cable.

The Lockheed Electronics Dynamometer, which is used as the transducer, was especially developed for mounting on the polished rods of pumping oil wells. The unit is currently being used by several major producers to obtain dynamic and static load characteristics from their wells. It consists of load sensitive resistance elements, mounted on precision made load rings. Compression loads on the ring are converted into electrical signals with an accuracy and sensitivity of two per cent of full load rating. The assembly is mounted on top of the hanger bar, and a clamp is then tightened over the transducer. A replaceable cable carries the excitation and signal lines from the transducer to the walking beam arm, and then to the structure mounted equipment. The cable is subjected to a certain degree of flexing during pumping cycles, and will require replacement as determined by the particular well's pumping rate and activity. Proper installation of the cable so that flexure is minimized, and the use of high quality cable will provide at least one year of operation before replacement is necessary. Exclusive of the load tranducer and the re-

quired connecting cable, all well site components including power supply, power control relay voltage controlled oscillator, well select and clearing decoders, and associated circuitry are mounted inside a National Electrical Manufacturers Association (NEMA) "Type 4 Watertight" panel enclosure. This rugged assembly is 16 in. high, 12 in. wide and 6 in. deep. See Fig. 4. The millivolt transistorized subcarrier oscillator utilized in the well site panel enclosure will be a small plug-in type oscillator with no internal or external adjustments. Open or shorted input leads will not damage the unit. Long term stability is 1 per cent for a six-month period.

The well site assembly also contains the required decoders, which are complementary assemblies of the encoders used at the monitor site, a power control relay and the power supply.

MONITOR SITE EQUIPMENT

The basic monitor site equipment in block diagram form is illustrated in Fig. 5. Well selection is initiated by two rows of 10 push-button switches, one row determining well identification number UNITS, and the second row determining identification number DECADES. Each push-button is associated with a specific frequency of tone oscillator. Depressing the button connects its oscillator to a common line. As previously stated, a two-tone selection system is utilized, thus requiring that one UNIT and one DECADE button be engaged. The two tones which can be preset at any convenient time, are transmitted simultaneously to an amplifier.

The amplifier output is connected to the oil field signal line by momentarily depressing the select button. The reception of the two tones at the selected well turns on the monitoring equipment, and transmits the well data waveform back to the monitor site until the well is again turned off. The monitoring equipment is turned off by depressing the WELL CLEAR pushbutton and SELECT button.

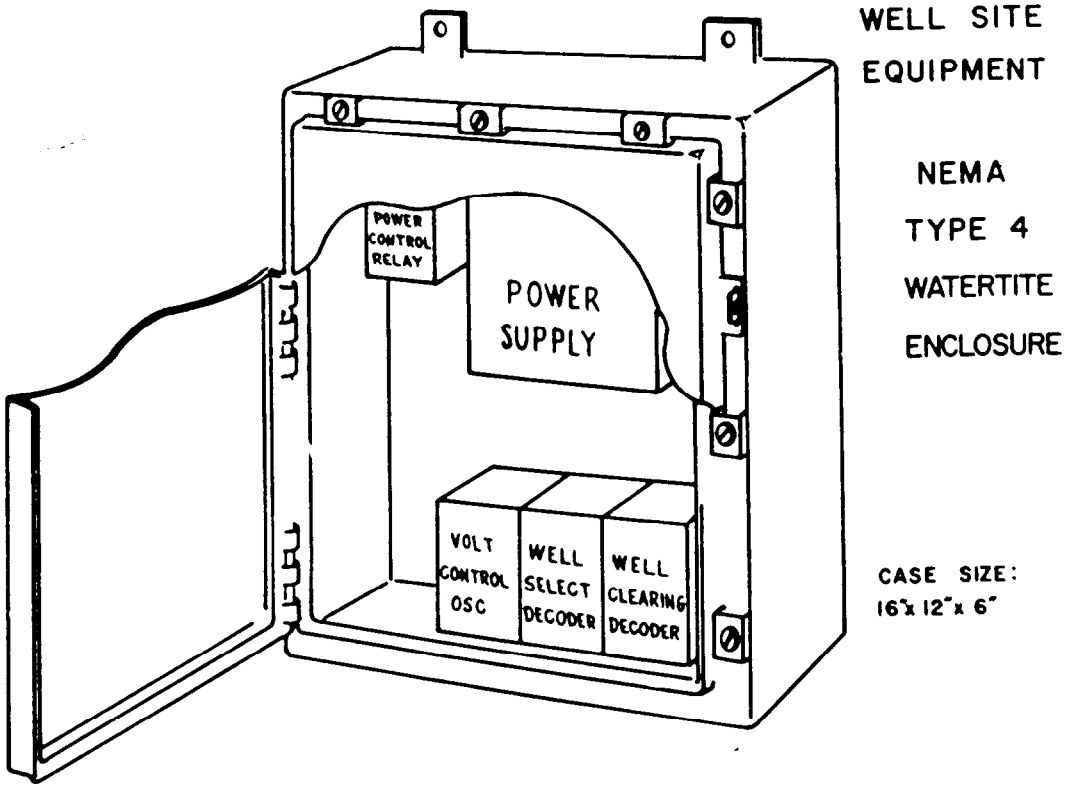


Fig. 4

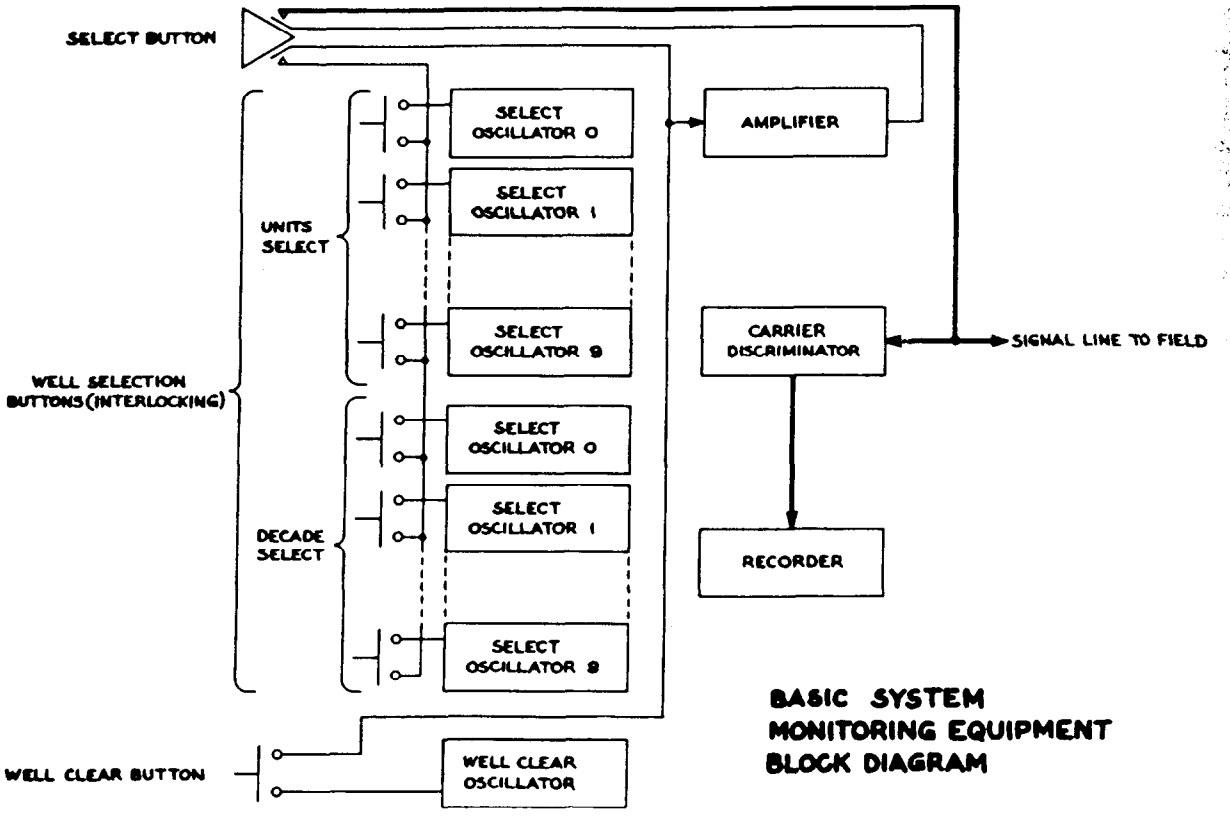


Fig 5

During the "ON" period, the signal from the well is applied to the CARRIER DISCRIMINATOR at the monitor site. This unit extracts the well pump dynamic waveform from the carrier, and feeds it to the chart recorder for visual display, as well as for a permanent record of well operation during this monitoring period.

A second set of monitor site equipment may be located at a remote point, such as a main field office, etc., and connected by means of a standard telephone pair to the first monitor site equipment, as indicated by the block diagram. A REMOTE-LOCAL switch is provided to transfer control to the remote site, while retaining the monitoring capability at the local site.

WELL SITE EQUIPMENT

The individual well site basic equipment is illustated in Fig. 6 in block diagram form. A single phase transformer is connected to the well power line to provide power to the equipment. A power supply continuously operates from the transformer output, and maintains the WELL SELECT DECODER in a receptive condition at all times. Standby power consumption is only three watts, mainly consumed in the power transformer.

Operation of the decoder by the momentary presence of the two specific selection tones associated with the particular well site actuates the POWER CONTROL RELAY. This relay applies AC power to the well pump transducer and carrier oscillator power supply, connects the signal line to the output of the carrier oscillator, and provides holding power to the relay coil through the normally closed contacts of the WELL CLEARING relay.

The monitoring equipment will remain on until a WELL CLEAR tone pulse is transmitted to the well site. This provides as long a period as desired for observing operation of a well. This period may be short in automatic well monitoring, and recordings of an entire field can be completed as rapidly as adequate recording time per well permits. Conversely, the system may be left actively monitoring a particular well as long as desired.

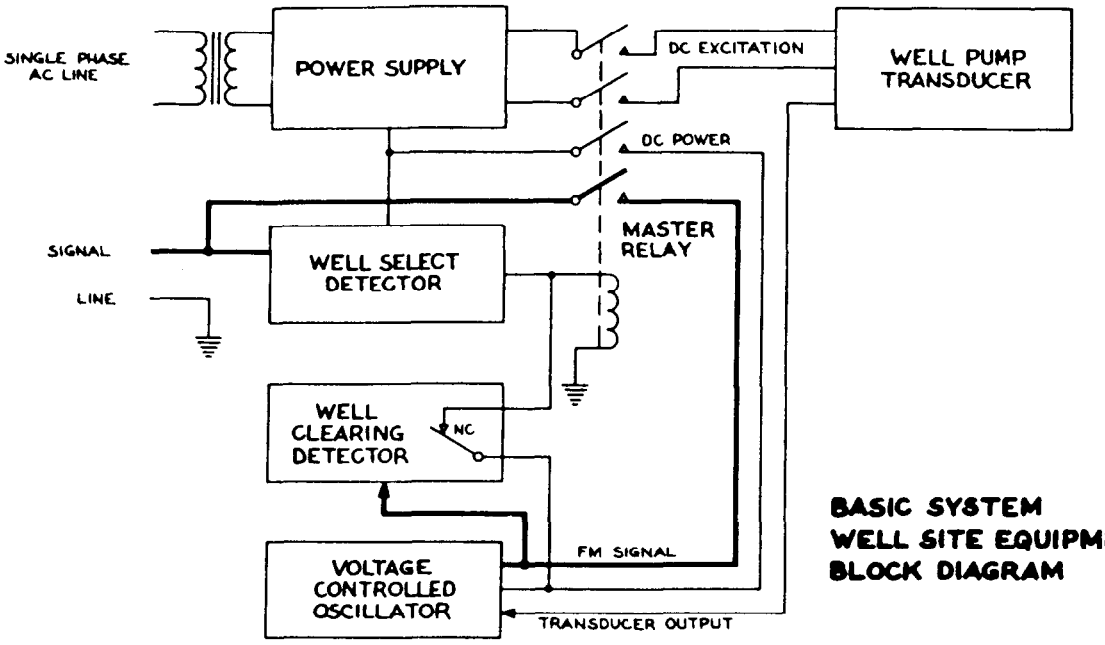


Fig. 6

SYSTEM ACCURACY AND DEPENDABILITY

The system described above has been designed with the telemetering techniques developed by the aerospace industry and utilizes the equipment designed for use in the extreme environments encountered in missile and spacecraft applications to ensure long life and high dependability. The monitoring link comprised of the carrier oscillator at the well site and the discriminator at the office monitoring control site will maintain a transfer accuracy of better than 95 per cent under all environmental conditions anticipated. This accuracy includes static load measurements, and will be significantly better with respect to dynamic load variation measurements during pumping cycles. Static calibration checks may be made at specified intervals, by comparing the remote control link measurements with measurements taken directly from the transducer output at the well site.

TRANSMISSION MEANS

As described above, a single pair of wires is utilized to connect the monitor site with all of the well sites. Since only one line is required, it can be supplied just as effectively by a standard telephone line or by a common voice radio link. The telephone line is particularly useful when it is desired to monitor wells from a distant city as a backup or confirmation of the local field monitor site. It permits instantaneous consultations on well performance between distant locations or it may be used to transmit well data to a home office computer for data processing.

The radio link is more useful as a special purpose transmission medium. Occasionally, isolated wells pose difficult problems for visits of maintenance personnel and are too remote for economical wire laying. In these cases, radio links can be employed to connect the well to the monitor site.

CONTROL FUNCTIONS

Basic control functions may easily be added to the monitoring system. Additional encoding and decoding units are provided in the monitor and well site equipment respectively. The added units are connected as shown in the block diagrams of Figs. 7 and 8. The operational control features illustrated in Fig. 7 operate similarly to the selection controls previously described. Facilities for stopping the pump motor, starting the motor, and for applying a pump brake actuate signal are illustrated. A unique frequency tone oscillator is associated with each of the push-button switches for these functions and this signal is applied to a common line when the button is depressed. The signal is then transmitted to the selected well site equipment by momentarily depressing the FUNCTION OPERATE button. The

installation of corresponding optional control detectors and relays at the well site makes it possible to perform these functions from either the remote or local monitoring sites, as determined by the position of the REMOTE-LOCAL selector switch in the local site office.

A greater number of optional controls may be incorporated in the system to expand its capability by adding the required tone oscillators at the monitoring site, and corresponding detectors and relays at the well site. Additional monitoring

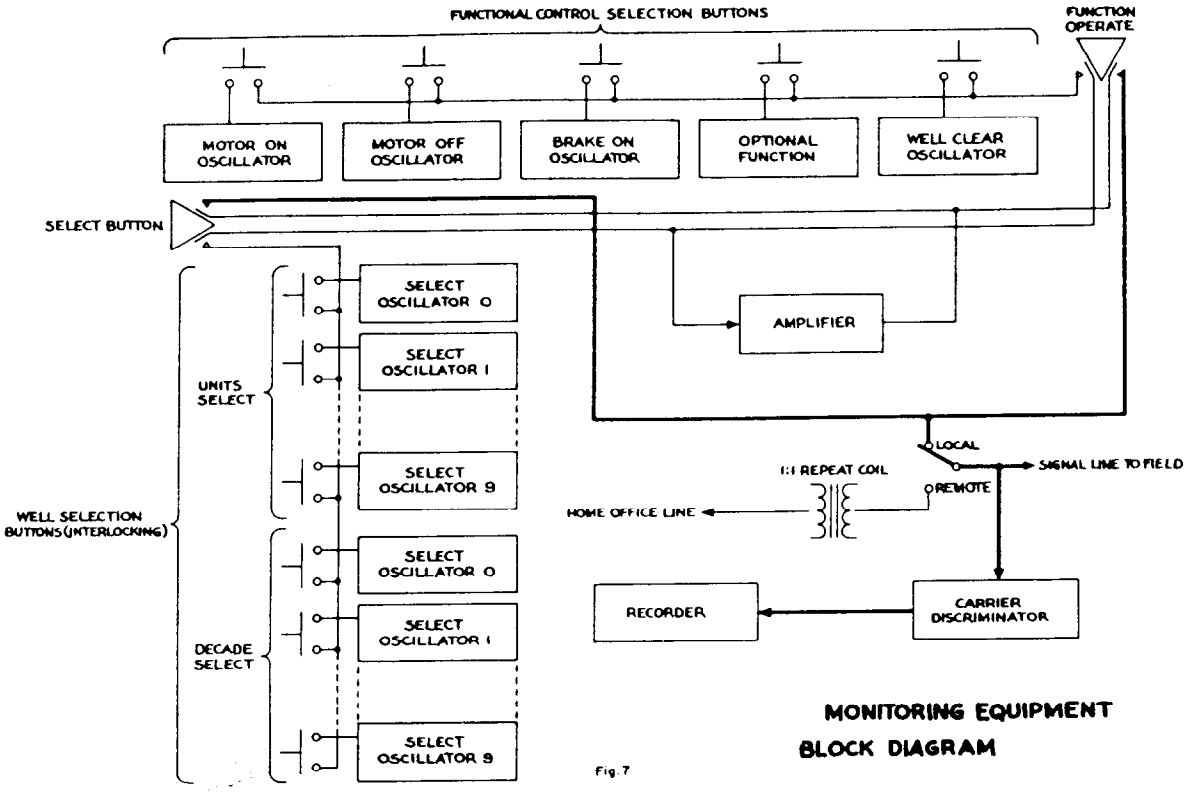


Fig. 7

MONITORING EQUIPMENT BLOCK DIAGRAM

WELL SITE EQUIPMENT BLOCK DIAGRAM

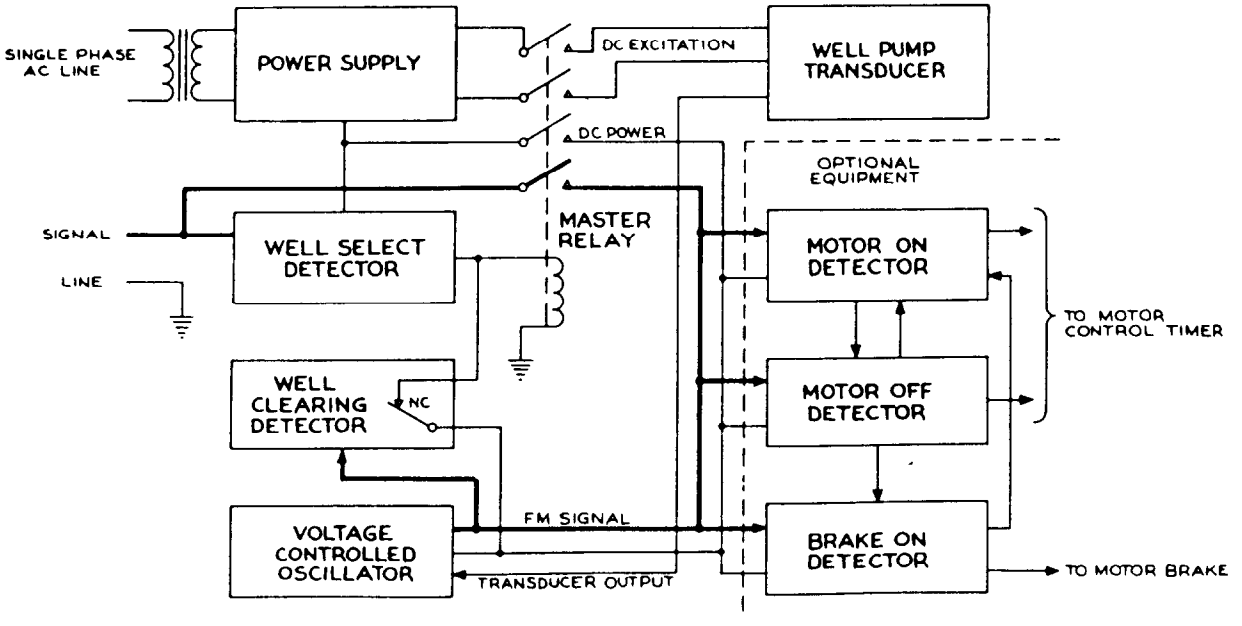


Fig. 8

functions can also be added to the system, if future requirements arise, by including a second carrier oscillator, operating at 1700 cps, at the well site and providing a second discriminator at the monitoring control site.

AUTOMATIC MONITORING

Automatic monitoring is another feature which may be provided with the system. When so equipped, the system continuously sequences through the wells, monitoring each in turn, on a 24-hr basis. Automatic failure-sensing detectors are activated should well operation change significantly during this period.

Automatic sequencing provides an almost immediate indication of impending or actual conditions of damage or failure, as well as providing the current performance characteristics of each well on site. The recorder is not required to run continuously. It can be programmed to start recording at a predetermined time before technical personnel are scheduled to arrive at the facility containing the control monitoring equipment, and would provide a record ready for immediate analysis or comparison with the previously recorded data.

COMPUTER PROCESSING

Computer processing of the well weight waveform is used to automatically analyze pump performance and thereby improve operating efficiency. A major petroleum producer has developed a computer program for this purpose. The monitoring system output can be connected to a computer for this purpose by means of interfacing equipment.