

The Solid State Pipeline Gauger

By R. A. HINCHLIFFE*

(17th Annual Technical Meeting, The Petroleum Society of C.I.M., Edmonton, May, 1966)

ABSTRACT

Automatic receiving and delivery facilities have been installed by Federated Pipe Lines Ltd. at all gathering points where power is available. This equipment reduces the frequency of visits by operating personnel and, barring component failure, provides reliable control of pipeline facilities.

The "Fieldgate" operational technique now being employed by producing companies requires that the pipeline provide the most efficient handling possible. In the past, crude from a field was received at perhaps a dozen or more locations; now the entire production may be received at one "Fieldgate" battery. This resulting high throughput from a single location must not be held up, and down time of pipeline facilities has to be kept to a minimum.

Remote control of pipeline facilities at these locations of high throughput permits continuous monitoring, and equipment malfunction is indicated at the operating control center. Remedial action can be initiated much quicker by this monitoring than by the visual inspection of a passing operator.

The installation of remote control equipment must be considered carefully, bearing in mind that the automatic equipment at the battery is accomplishing the over-all function of accepting, metering and shipping crude.

The essential requirements of the remote control system are to provide an indication of equipment status and equipment on-off control. Digital read-out of the metering equipment is required to determine periodic throughput. Alarm indications are to be registered whenever a condition arises which affects the operation of the pipeline facilities. Reset control is a requirement to rectify power failure conditions once power has been restored.

INTRODUCTION

THE gathering system installed by Federated Pipe Lines Ltd. serves various crude oil producers in an area some 60 miles long and, at one point, 30 miles wide. Until ten years ago, this region of Alberta was an isolated wilderness and the only surface access was over a few forestry trails. The current producing fields of Swan Hills, Judy Creek, Carson Creek, Virginia Hills, Morse River, Inverness, Deer Mountain and House Mountain lie within this area. The present road network provides reasonable access within the various fields, but surface travel between

the fields is sometimes difficult and indeed can become impossible during wet periods and break-ups.

Lease Automatic Custody Transfer equipment has been installed by Federated at all locations where power is available. With certain reservations, the L.A.C.T. units permit unattended operation and provide product quality control and equipment protection. Still in abeyance is a decision on what equipment should be employed to give us a continual record of B.S.&W. content and provide us with the diversion or re-cycle of unacceptable crude. Once a suitable unit is selected and added to the L.A.C.T. units, we will have automatic control at the battery. In other words, the pipeline facilities will determine when to ship crude, accept only crude of acceptable quality, meter the crude and pump it into the pipeline system.

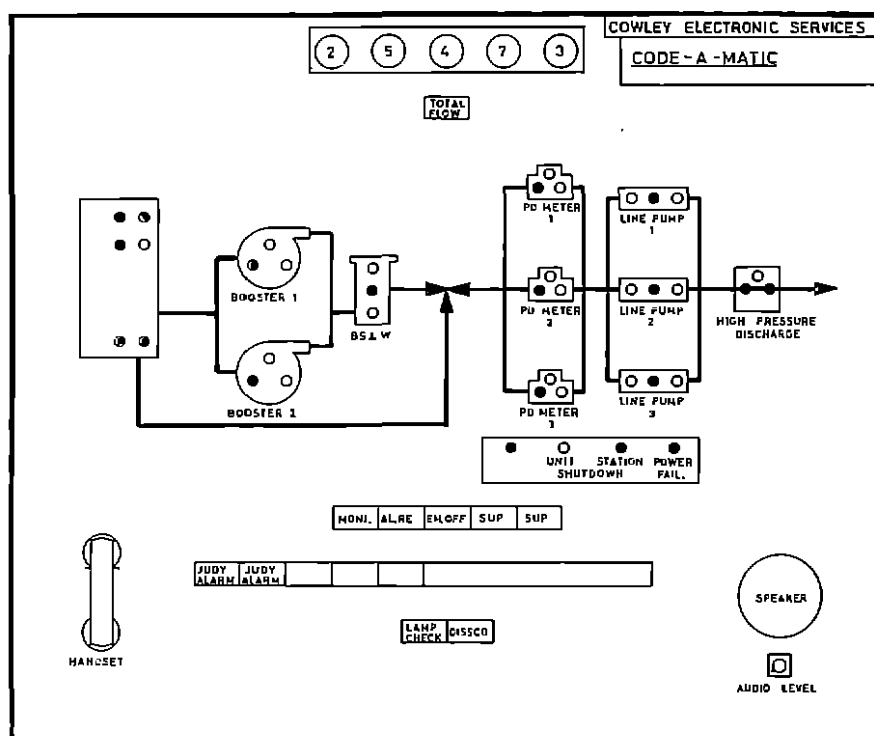
Most devices, be they men or machines, require some degree of supervision. In the case of L.A.C.T. equipment, remote supervision of a number of locations from a central or master control station improves the operation

considerably. A remote control and monitoring system enables a single pipeline gauger to supervise and operate a considerable number of L.A.C.T. facilities. This reduces unproductive travelling time and, therefore, reduces the wear and tear on vehicles. An alarm system must be an integral part of the remote control equipment. This alarm facility will make the pipeline operating personnel aware of equipment failure or malfunction much sooner than visual observation by field personnel.

HISTORY

In 1959, Federated Pipe Lines Ltd. began delivering crude oil from Swan Hills to the Edmonton area. Lease Automatic Custody Transfer equipment was installed at all batteries with power in order to provide the most reliable means of receiving the crude in the field. At this stage of development, Federated realized that a remote control system to monitor

*Home Oil Company Limited, Calgary, Alta.



Typical Pipeline Battery Facility Flow Sheet. HALLIBURTON EXHIBIT 1026
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00557, Page 1

and control the L.A.C.T. installations would be an aid to operations. The roads within the Swan Hills area at that time were in very poor condition and vehicle movement was always difficult. Six batteries were connected to a remote control system, with the master station located at the Swan Hills Terminal. The communications link between the master station and L.A.C.T. equipment at the various batteries consisted of multi-pair style "B" cable strung on the power poles. This system enabled the master station operator to determine the battery status; i.e., tank levels, pipeline pump on-off, recycle or shipping and meter readout. In addition, the operator could stop and start the pipeline pump. The remote control equipment was based on impulse codes utilizing electro-mechanical devices.

This initial remote control system immediately established itself as a device of considerable value. The only problem was that the communications link was vulnerable to damage. Of necessity, the cable was strung some distance below the power transmission lines on the power poles. At this elevation, it was frequently torn down by falling trees and by the movement of equipment along roads and right-of-ways. The frequency of cable breaks sometimes averaged two a week. As a result, operating personnel became disenchanted with the system and the high cost of maintenance eventually led to virtual abandonment.

This remote control system was in intermittent operation during 1959 and 1960. During this time, two factors contributed to the lack of improvement and development of the system. They were: first, the rapidly expanding pipeline gathering system was reaching locations which would require considerable expenditure to connect, using cable for communications; second, the road network within the area covered by the remote control system had improved considerably.

A number of investigations were carried out to determine the best way to restore existing remote control equipment to a state of serviceability, bearing in mind that the pipeline would be serving locations far remote from the Swan Hills Terminal Control Centre. During 1963, Federated began operating an unattended, remotely controlled 1,400-hp mainline pump station. This pump station was located in the Judy Creek area, some 20 miles from the Swan Hills Ter-

minal. The communications link in this application was a multi-channel V.H.F. radio link, and the supervisory functions were coded through telephone-type relays. Several months of operation developed considerable faith in the use of radio as a communications link.

The use of radio equipment was decided upon for the remote control of L.A.C.T. facilities in the pipeline gathering system. The type of radio employed to run the mainline pump station was, of course, expensive and provided far more facilities than would be required at an L.A.C.T. installation. The use of frequency shift equipment on single channel radio reduces the cost of the communications link and provides a reliable path for the transmission of the required signals to control an L.A.C.T. installation.

The required reliability of the communication link can certainly be supplied by a radio system. In addition, the range of a radio system will permit economical transmission of signals throughout the pipeline gathering system when the cost of coverage in the same area by land line would be prohibitive.

In 1964, an evaluation of the original remote control system components indicated that the "state of the art" with respect to electronic equipment had progressed to such a degree that our equipment was obsolete or at least old-fashioned. As a consequence, a new system design was indicated.

In 1965, the "pilot" remote control system was installed at the Imperial Judy Creek Fieldgate battery. This "pilot" system consists of a "Code-A-Matic" supervisory section which is solid state in make-

up and is harnessed to a transistorized radio installation. This equipment acts as a resident operator with 'round-the-clock observation capacity and some operational ability. As such, it has been dubbed — "The Solid State Pipeline Gauger."

The requirements of design for the "pilot" system, its operation and proposed extension to other locations are described in the following section.

SYSTEM REQUIREMENTS

The requirements of a remote control system vary with the individual pipeline operators. Federated's requirements were laid down as being the following:

- 1.—Tank levels — lo-tank, shipping and hi-tank. These various levels are to be indicated on the master control panel by means of lights.
- 2.—Provision for indication of high B.S.&W. Utilization of this provision is deferred until an acceptable monitor is installed.
- 3.—Provision for indication of the recycle of unacceptable crude, based on the operation of a B.S.&W. monitor.
- 4.—Indication of meter operation. This facility is to be connected to an automatic meter switching device which will initiate a transfer to a standby meter as a result of failure of the running meter.
- 5.—Indication of booster pump operation. This indication will advise the master station operator which booster pump is "on line." As a result, he will know if the standby

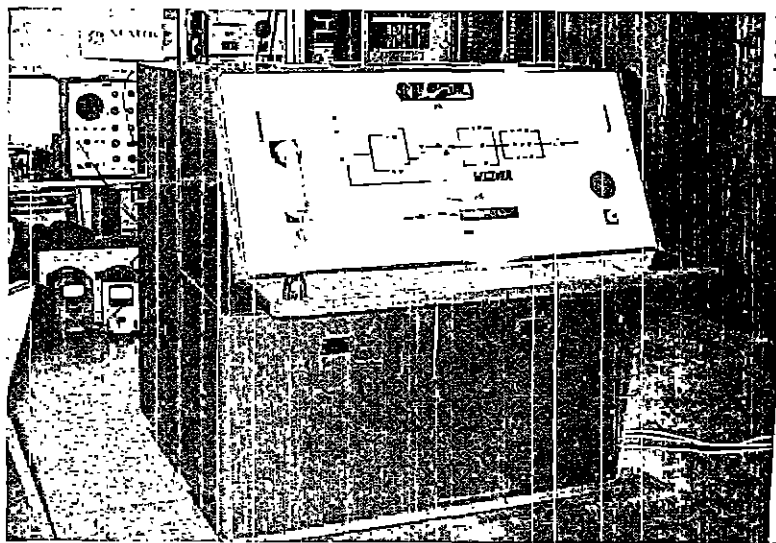


Figure 1.—The master station control cabinet during tests prior to installation.

HALLIBURTON EXHIBIT 1026

- equipment has been activated as a result of unit failure.
- 6.—Indication of main pump operation, showing which main pumps are "on line."
 - 7.—Meter read-out, providing a cumulative digital indication of the total throughput in barrels.
 - 8.—Alarm indications to advise the master station operator of unit failure, an unsatisfactory condition or station shutdown.
 - 9.—Control functions: 1. to permit the operator to reset the remote station to correct a power failure shut-down; 2. to provide emergency stop of the remote station and reset to permit automatic start when required.
 - 10.—Voice communication between master station and remote stations.

Cowley Electronic Services (1961) Ltd., of Edmonton, were authorized to proceed with the design, manufacture and installation of a "pilot" remote control system to meet these requirements. The Imperial Oil Judy Creek Fieldgate battery was selected for the remote station installation, with the master station at the Swan Hills Terminal Control Centre. The selection of this battery was based on the following:

- 1.—The throughput from this battery is the largest handled by the Federated Gathering System.
- 2.—The battery is actually a double facility serving two fields — Judy Creek and Judy Creek West. The crude streams are handled separately by the pro-

ducer. The pipeline employs two L.A.C.T. units, and remote control of two separate locations is possible using a single radio installation.

- 3.—The motor control centers and L.A.C.T. equipment at the battery were readily adaptable to the addition of the remote control system.

THE PILOT SYSTEM

The "pilot" system supplied was designed using available components to perform the requirements established by Federated. The final configuration for the supervisory section of the system has been named "Code-A-Matic" by the supplier.

The system supplied is a quiescent type with respect to its monitoring ability. Monitoring of the L.A.C.T. status is on a command basis. Alarm status is reported to the master station immediately by the remote station. An alarm status is initiated by any one of the following conditions: 1. *Hi-tank level*, which might indicate that the L.A.C.T. did not start shipping the crude at the proper time. 2. *Meter failure*. At the same time as the occurrence of the alarm condition the L.A.C.T. automatically transfers to a standby meter. 3. *High B.S.&W.* A time delay will be incorporated in the L.A.C.T. before recycle or station shutdown occurs, but during the delay the operator will be aware of high B.S.&W. 4. *High discharge pressure*. The main pump unit will automatically shut down on high discharge pressure, switch to standby equipment and initiate the alarm. If the standby equipment also develops high dis-

charge pressure then it too shuts down and a second alarm is initiated. 5. *Unit shutdown* is incorporated in the alarm status as a back-up function to ensure that meter and pump failure alarms are reported to the master station. In addition, the booster pumps' performance is incorporated in unit shutdown and their failure will be determined by a subsequent monitoring operation. 6. *Station shutdown* acts as a back-up function which indicates failure of the standby equipment and shows that the L.A.C.T. facilities are inoperative.

The detecting devices for the foregoing conditions are connected in series. In this manner, the master station operator receives a single alarm condition indicating the L.A.C.T. location involved. To determine precisely what caused the alarm the operator then monitors the station. If the alarm has originated as a result of meter failure, unit shutdown or station shutdown, this is visually illustrated on the control panel. The specific meter which failed can be determined by comparing the operating meters indicated against the meters which were operating prior to the alarm. Booster pump and main pump failure can be determined in the same manner. High tank level is indicated by observation of the tank-level indicating lights. High B.S.&W. and high discharge pressure will be indicated by indicating lights. There has been no provision made to date for standby power at the L.A.C.T. As a result, if power failure does occur an alarm condition will not be initiated. Without standby power the only indication that the operator has of power failure will be his inability to contact the remote station. An alarm will be initiated as soon as power has been restored. The operator can then monitor the remote station to ensure that the L.A.C.T. has resumed normal operation.

Federated's L.A.C.T. equipment has been standardized as much as possible, but some variations have developed. In laying out the graphic representation of the master station control panel a composite display was achieved. This display shows all the equipment pertinent to any particular L.A.C.T. location. Some locations will not have all the equipment shown on the display. To avoid confusion, indicating lights for each component at a specific location are illuminated, thus giving a representation of equipment installed at that parti-

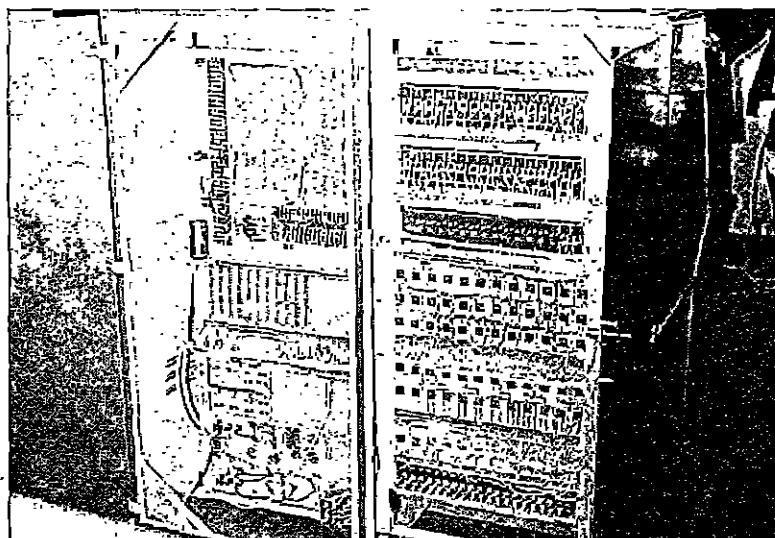


Figure 2.—A view of the rear of the cabinet, with the cover doors open.

cular L.A.C.T. This representation appears upon selection by the operator of a specific L.A.C.T. location.

To select a location, the operator presses the call button for that location. This operation initiates the transmission of a discreet code applicable to that location only. Upon receipt of this code, the remote location answers back to the master station. At this point, the master station determines that it is connected to the correct remote station. This is indicated by the illumination of the call button on the panel for that location. Simultaneously, the display board is illuminated, representing the L.A.C.T. equipment installed.

Once connected to the L.A.C.T. location desired, the operator monitors the status of the location by pushing the monitor selector. The display board then presents a visual indication, by means of lights, as to each component's status, i.e., on or off, normal or not. To obtain the cumulative read-out of throughput in barrels from the positive displacement flow-meters, the operator presses the flow read-out button. The total flow is presented on an in-line digital display, using Nixi tubes.

If a control function was required, this could be obtained as soon as the operator received the answer back from the remote station. During this period when the master station is connected to a specific remote station, no other remote station can be contacted. This prevents accidental data transmission, or function determination at a remote station other than the one being monitored. Alarm indications cannot be received by the master station during this period. The master station will not receive signals from any other remote station while it is still connected to the station being monitored. When the operator has completed his monitoring of an L.A.C.T. location, he presses the disconnect button. The disconnect operation returns the master station to a quiescent state and the display panel illu-

mination is turned off. The master station can now be directed to a new location, or, if an alarm condition has occurred, it will be received and indicated as previously described.

The code used in this remote control system is eight bit, polarized return to zero. A discreet code has been designated for each function, each remote station and each remote station answer-back. This permits the use of the same function codes for all remote stations, because the discreet remote station and answer-back codes ensure connection to the remote station desired. Any future installation, of course, can use the function codes already designated.

The digital read-out of meter throughput is accomplished using a four-bit binary coded decimal and transmitting two digits at one time. In order to obtain the required five-digit reading it is necessary to send three transmissions.

The security of the system is provided by four features: 1. The polarized return to zero coding. 2. Answer back on command by the remote station. 3. Master station interlock which ensures that the proper remote station is connected. The master station must receive the correct code from the remote station in answer to the command. 4. Total bit parity requires that eight bits have to be received in a predetermined time. This time period depends on the size of the bits.

The speed of transmission is forty bits per second. This rate can be termed as medium speed. The encoders and decoders are capable of operating at 5 kilocycles, with a resulting speed of 5,000 bits per second. Transmission of 5,000 bits per second requires an entire voice band. A high-speed system is not a requirement for the Federated application. The use of a forty-bit-per-second rate requires only one tone channel. Voice transmission is performed in the 0- to 2,400-cycle range, and the remote control system operates on a frequency shift of 170 cycles centered on 2,975 cycles.

CONCLUSION

The "pilot" remote control system, as installed, has satisfied all the requirements originally specified.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Home Oil Company Limited of Calgary for permission to prepare and publish this paper.

The design, fabrication and installation of the Code-A-Matic was carried out by Canadian General Electric and their subsidiary, Cowley Electronic Services (1961) Ltd. of Edmonton. Their interest and cooperation in the project and their capacity to supply the equipment to satisfy the requirements is hereby acknowledged.

The author also wishes to thank Mr. K. R. Fowler, who presented this paper at the Seventeenth Annual Technical Meeting, The Petroleum Society of C.I.M.



R. A. Hinchliffe attended public and high school in Edmonton, Alberta, and served five years in the R.C.A.F. He then attended the Northrop Aeronautical Institute in Los Angeles, and graduated in aeronautical engineering, class of 1952. Returning to Canada, he worked in the aircraft industry until 1958.

Since 1958, Mr. Hinchliffe has been employed in the petro-chemical industry, and has spent the last seven years with the Pipeline Department of Home Oil Company Ltd. His current position is as operations engineer, Cremona Pipe Line Division, Home Oil Company Limited, Calgary.