New LACT Project Features Remote Off-Lease Supervisory Equipment*

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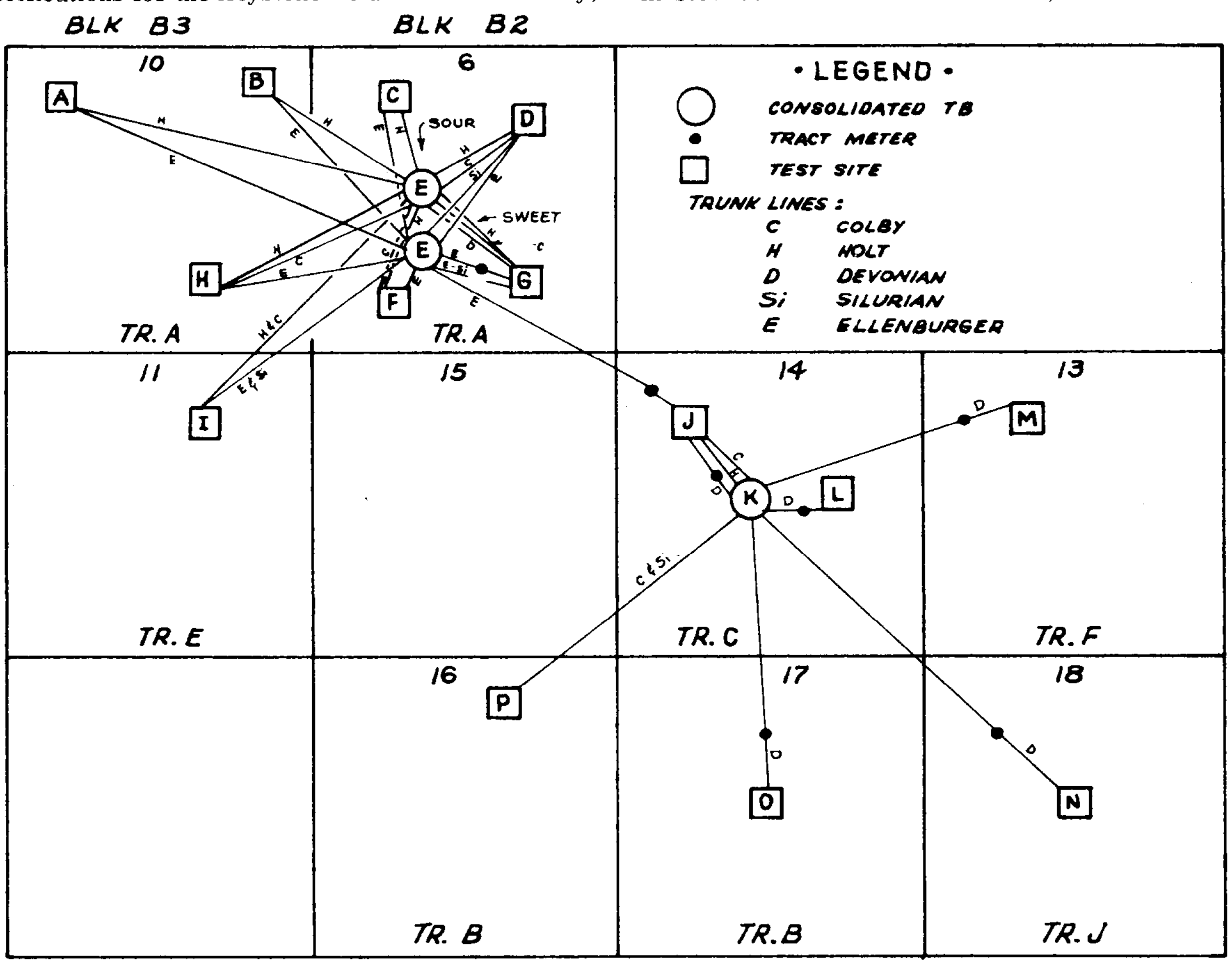
INTRODUCTION

The rather severe profit squeeze experienced by the oil industry in recent years has necessitated a more aggressive application of technology to production activities. In helping to offset the economic blow resulting from declining product prices and from increasing labor and material costs, the progressive application of new ideas, methods and materials has helped to restore profits by increasing productivity and reducing production expenditures. Improved technology in oilfield production operations has paved the way for adoption of more efficient operating and data-processing procedures. One example of this is the automation project designed to Gulf Oil Corp.'s specifications for the Keystone field in Winkler County, Tex. This project applied recent technical developments to reduce operating costs through updated operations, to improve revenues and to preclude expenditures due to inadequate treating facilities, severely corroded equipment and the lack of a produced-water disposal system.

A portion of the Keystone field, consisting of 148 wells producing approximately 3,000 BOPD from 5 reservoirs underlying 6 different royalty tracts, was completely automated in Oct., 1961. The automation includes battery consolidation, automatic custody transfer to the pipeline, automatic well tests, remote control of well tests, and supervisory monitoring of production data, well-test data and trouble alarms.

Data and instructions between field points and the master control in the area office, 7 to 9 mi distant,



KEYSTONE CONSOLIDATION
BLK B2 & B3 WINKLER CO., TEX.
FIGURE 1

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are transmitted over a 4 wire, voice-frequency telephone circuit. The telemetered information includes tank gauges, production-meter readings, trouble alarms and well-test data. In addition to data gathering, the system allows the operator in the area office to place any well on test, either selectively or by a pre-set, programmed schedule. Telemetered data are recorded by an electric typewriter, and if desired by the operator, are also automatically punched onto tape for subsequent computer processing.

The installation of this supervisory equipment grew directly from a successful pilot operation on the Ida Hendrick "A" lease, Kermit field, Winkler County, Texas. There, many of the basic components and operating procedures were evaluated and perfected during a year's run. This 12 well test installation has been incorporated into the new installation, resulting in a 160 well hookup. Data transmitted from the Ida Hendrick "A" lease, however, have been restricted to trouble alarms and production readings from the run tanks, 2 royalty tract meters and the LACT meter.

A preliminary investigation of remote leases reveals that expansion of the telemetering system also may be economically feasible, for batteries having LACT equipment alone or even for conventional batteries with manual pipeline runs. The master control at the area office will permit its adaptation for additional batteries at rather low costs.

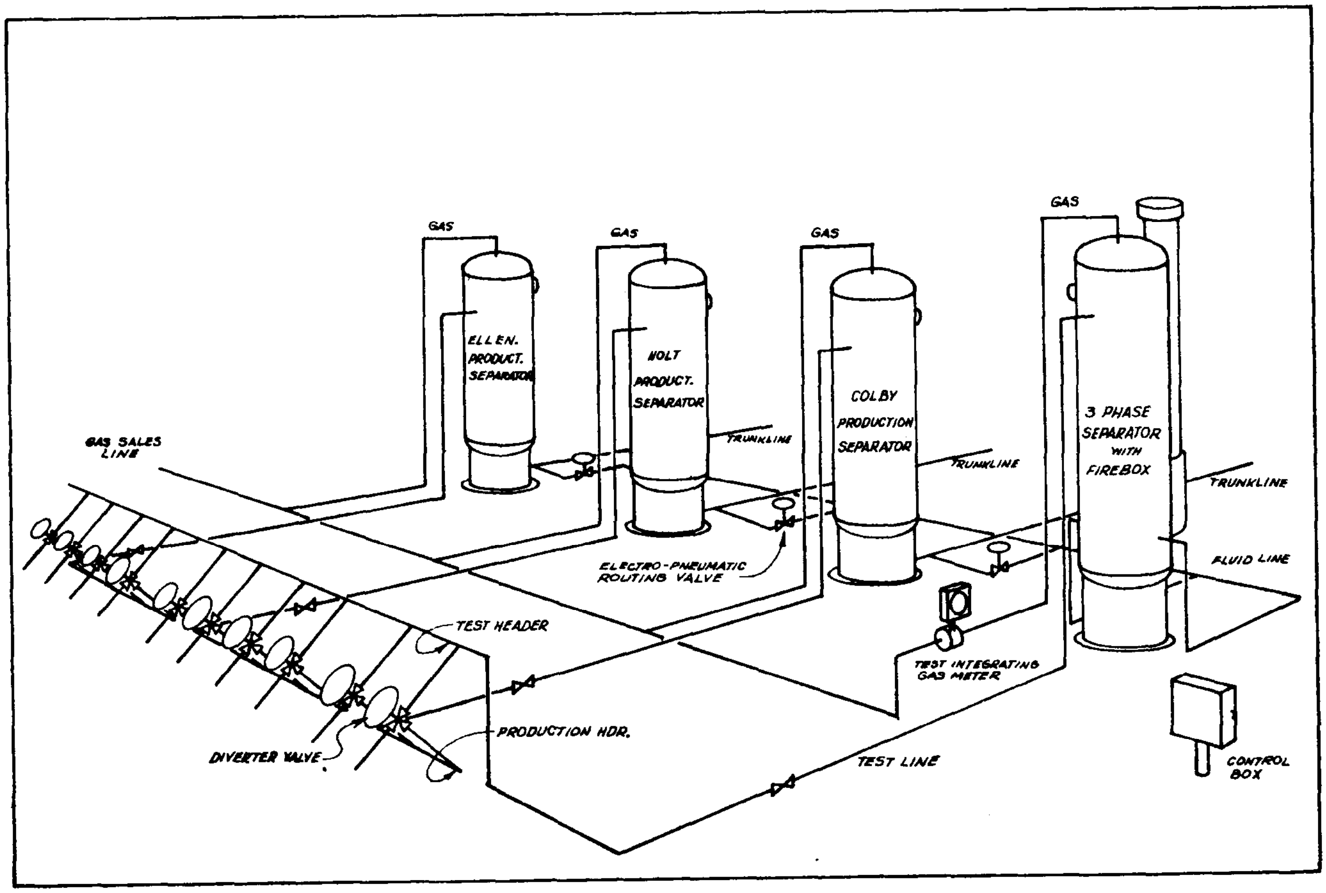
KEYSTONE FIELD CONDITIONS
PRIOR TO AUTOMATION

Prior to consolidation and automation, production from 148 wells producing from the Ellenburger, Silurian, Devonian, Holt and Colby pays was stored in over 100 stock tanks located in 40 batteries. Many of the stock tanks and much of the allied equipment were corroded from years of service under mildly corrosive conditions. Water encroachment was rendering some of the treating facilities inadequate. Moreover, increasing water production coupled with proposed waterflood operations in some of the reservoirs was requiring immediate installation of brine facilities to collect produced water from the widely scattered batteries. Furthermore, production—gauged and run manually—required 250 to 300 run tickets per month, consuming time for both Gulf production and pipeline personnel.

FIELD LAYOUT AND EQUIPMENT
AFTER AUTOMATION

Figure 1 shows central-battery and test-station sites. Of the three central LACT batteries located at two sites ("E" and "K"), two handle sour crude and one handles sweet crude. Trunk lines and underground communication cables link 14 remote automatic test stations to the central batteries; and, to minimize flowline rearrangements, a "satellite" system with test-station sites at old battery locations was used.

Figure 2 shows schematic details of a typical



DETAILED SCHEMATIC DRAWING OF A TEST STATION

FIGURE 2

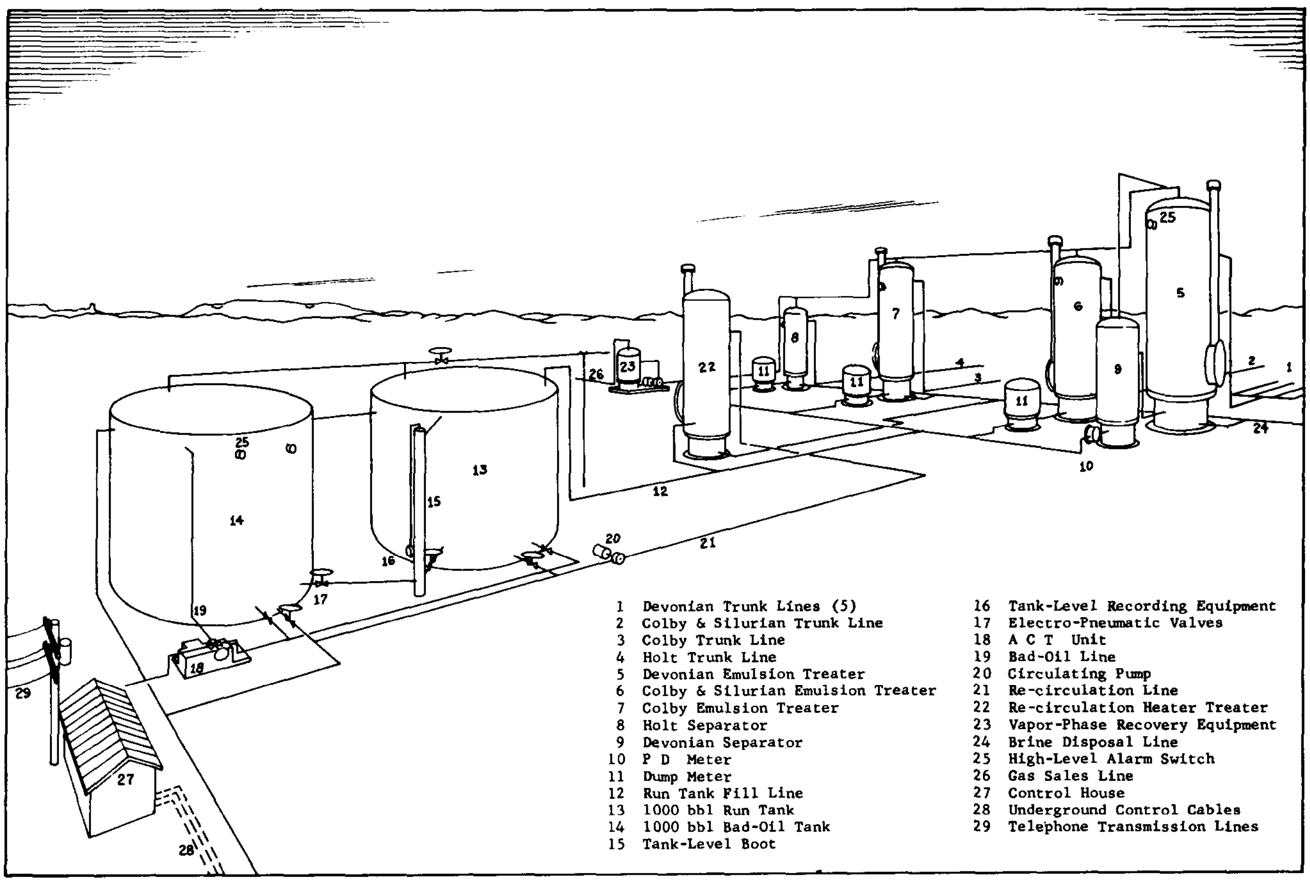
test station. As illustrated, the wells produce directly through individual flowlines into test stations consisting of production separators, test separator and/or a three-phase separator equipped with a firebox (installed at test stations where the wells produce water), integrating gas meter, and inlet-well manifold equipped with 3 way, 2 position diverting valves. Some of the test stations are also equipped with royalty-tract meters. Liquids leaving the production vessels are directed into appropriate trunk lines for the different pays. In most cases, both oil and water are moved to the central battery by the dump pressure of the vessel. At 5 stations, however, liquids are dumped into a transfer tank and then are moved automatically to the central battery by an electrically-driven transfer pump actuated by high- and low-level switches. Free gas from all vessels is passed into gathering systems leading to gasoline plants.

As four of the 14 test stations have dual test facilities, the stations will test 18 wells simultaneously and will permit 24 hr tests on all 148 wells within a 12 day period. Where common test facilities serve wells producing from different horizons, electropneumatic routing valves direct production from the test vessel into appropriate trunk lines. Malfunction detectors on these valves signal the master control in the area office in the event of a valve failure.

A small control box at each test station is linked directly to the central battery by communication cable. The box, containing a decoder, translates the transmitted message to place the appropriate well on test, as instructed by the operator at the master control. Well-test instructions from the central battery to each test station are encoded to reduce the number of wires required in the communication cable.

Figure 3 schematically illustrates the equipment at one of the central batteries. Each of the central batteries consists of a 1,000 bbl steel run tank, a 1,000 bbl steel bad-oil tank, water knockouts (at only 1 battery), production heater treaters, recirculation heater-treater, automatic circulating pump, zone and some tract meters, vapor-phase recovery equipment, produced-brine facilities, control house with display panel and supervisory equipment and a skid-mounted LACT unit consisting of a centrifugal pump, BS&W monitor, diverter valve, strainer, PD meter, master-meter by-pass and sampler. All vessels at the central batteries and at the test stations, a total of 74, are equipped with high-level alarms.

Tank-level recording equipment, mounted on an outside boot between the run tank and the bad-oil tank, controls the high and low fluid levels in the run tank by actuating the shut-in valve and by starting and stopping the pump on the LACT unit. Shaft position encoders are mechanically attached to the tank-level recorder and the LACT meter. Their position at any time accurately reflects the tank gauge or cumulative production run to the pipeline; this data can be transmitted on demand to the master control. In the interest of economy, the boot is equipped with 2 electropneumatic valves with malfunction detectors. The valves, when actuated by the operator at the master control,



SCHEMATIC DRAWING SHOWING DETAILS OF A CENTRAL BATTERY

FIGURE 3

will permit gauging of the bad-oil tank utilizing the same tank-level recording equipment.

Underground communication cables from the test stations tie into controls at each central battery site, thereby providing a means for remote control of well tests and for transmission of well-test data, tract meter readings and alarms.

A data accumulating console (Figure 4) in the control house contains electronic accumulators or "memory units" for all meters except the LACT meters. The console also houses the set-stop counters for all tract, zone and LACT meters. Lights on the panel of the console depict any wells on test and identify specific alarm conditions such as high levels, valve failures, vapor-recovery-equipment failure, bad oil, meter failures and allowable produced. When pressed, buttons on the panel display tract meter readings, zone meter readings and oil, water and gas meter readings for well tests.

A terminal unit cabinet contains solid-state circuitry which is used throughout the telemetering system to receive and transmit data. Modular construction on a swing-out chassis makes all circuits readily accessible.

Fluid production can be rapidly traced through the central-battery facilities. When the production arrives at each battery in trunk lines from the test stations, it enters a water knockout and/or an emulsion heater-treater for eacy pay. There, water is separated from the oil. The produced water is subsequently utilized as flood water for 2 of the pay zones. Oil from different zones is measured separately with either a dump or PD meter as it leaves each heater-treater. It then is commingled and passed to the run tank from where it is automatically run to the pipeline by the tank-level recording equipment.

The BS&W monitor on the LACT unit constantly checks the oil for excessive BS&W. It diverts the bad oil into a tank where it is automatically recirculated through a heater-treater and then into the run tank. The bottom of the run tank is automatically circulated at pre-set intervals to preclude the build-up of high bottoms.

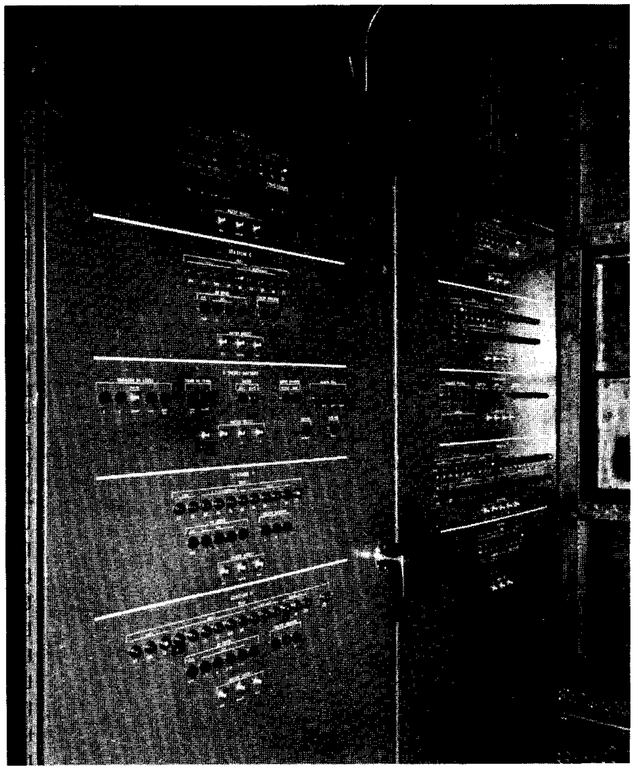
Lucrative vapors from tanks, heater-treaters and water knockouts are collected by vapor-phase recovery equipment for sale to a gasoline plant.

MASTER CONTROL EQUIPMENT IN THE AREA OFFICE

All commands to field equipment originate from the master control, at which point data are accumulated as printed and punched-tape records. Also, all abnormal equipment conditions are received there for subsequent transmittal by 2 way radio to operating personnel. Equipment at the master control consists


Fig. 4

of the terminal unit, well-test control unit, control console, electric typewriter and tape punch (Figure 5). As this equipment is relatively noise-free, it does not require a special room apart from an office where other personnel are working.



The terminal unit, consisting of compact solid-state circuitry is housed in three cabinets, 6 ft high x 2 ft wide x 1 ft deep. This unit includes equipment for encoding and transmission of commands to the field, and for receiving and decoding messages from the field stations.

The well-test control unit contains equipment for control of automatic or manual well-test sequencing of 148 wells. There are 18 well-test programmers for the 14 test stations, 4 test stations being equipped for 2 simultaneous tests. Each programmer has 4 positions: (1) manual position to start, stop or switch tests; (2) lockout position; (3) sequencing position for a zero to 4 hr timer; and (4) sequencing position for a 0.5 to 30 hr timer. The well-test control unit also provides means for exclusion of wells from test as well as selective testing of individual wells.

All data requests, alarm signals and instructions except well-test control commands, which are performed by the well-test control unit, are functions of the control console. By pressing the appropriate combination of buttons on the console, the operator can transmit coded commands for production data, well-test data and identification of alarms. He can also control functions to switch valves connected to the boot at each central battery, permitting subsequent gauging of the bad-oil tank, or to switch manifold valves on the dual or "split" test manifolds at four of the test stations. This console also contains alarm lamps that indicate which central battery originated the trouble alarm. On demand, additional lamps specify the type of alarm such as bad oil, high level, meter failure, valve failure, or production-allowable fulfillment.

All production and well-test data are recorded by an electric typewriter on a data-printout format (Figure 6). Run tanks, bad-oil tanks and production

STATION K

TIME	DATE	ACT	DEV.	O - DEV.	J - DEV.	L - DEV.	M - DEV.	N - DEV.	COLBY & SIL	HOLT	COLBY	TANK
Ø7ØØ	Ø1JUN62	ØØ3Ø1/ØØØØØ	2Ø7Ø3/ØØØØØ	4Ø1Ø5/ØØØØØ	4Ø2Ø7/ØØØØØ	4Ø3Ø9/ØØØØØ	4Ø411/ØØØØØ	4Ø513/ØØØØØ	2Ø815/ØØØØØ	2Ø917/ØØØØØ	21Ø19/ØØØØØ	26925/ØØØØØ

STATION E - SWEET

TIME	DATE	ACT	SIL.	SIL - Tr C	SIL & ELL	ELL - Tr C	ELL.	TANK
Ø7ØØ	Ø1JUN62	ØØ1Ø1/ØØØØØ	2Ø1Ø3/ØØØØØ	4Ø6Ø5/ØØØØØ	2Ø2Ø7/ØØØØØ	4Ø7Ø9/ØØØØØ	21111/ØØØØØ	26923/ØØØØØ

All tank identifiers shown indicate the run tank. The bad-oil tank identifiers are as follows:

STATION K - 26924

STATION E

SWEET - 26922

SOUR - 2692Ø

STATION E - SOUR

TIME	DATE	ACT	HOLT	COLBY & HOLT	DEV.	COLBY	TANK
Ø7ØØ	Ø1JUN62	ØØ2Ø1/ØØØØØ	2Ø3Ø3/ØØØØØ	2Ø4Ø5/ØØØØØ	2Ø5Ø7/ØØØØØ	212Ø9/ØØØØØ	26921/ØØØØØ

WELL TEST DATA

TIME	DATE	SITE & WELL NO.	TEST OIL	TEST GAS	TEST WATER
Ø7ØØ	Ø1JUN62	M178	TOØØØ	TGØØØ	TWØØØ

DATA PRINTOUT FORMAT

FIGURE 6

meters are assigned identifying numbers for computer processing. Print-out of well-test information shows time, date, test station, actual well number, barrels of oil, barrels of water and thousand cubic feet of gas. When desired, the production information is simultaneously punched onto a 5 channel tape for subsequent transmission by teletype or mail to the Accounting and Services Dept. for processing by electronic computers.

COMMUNICATION SYSTEM

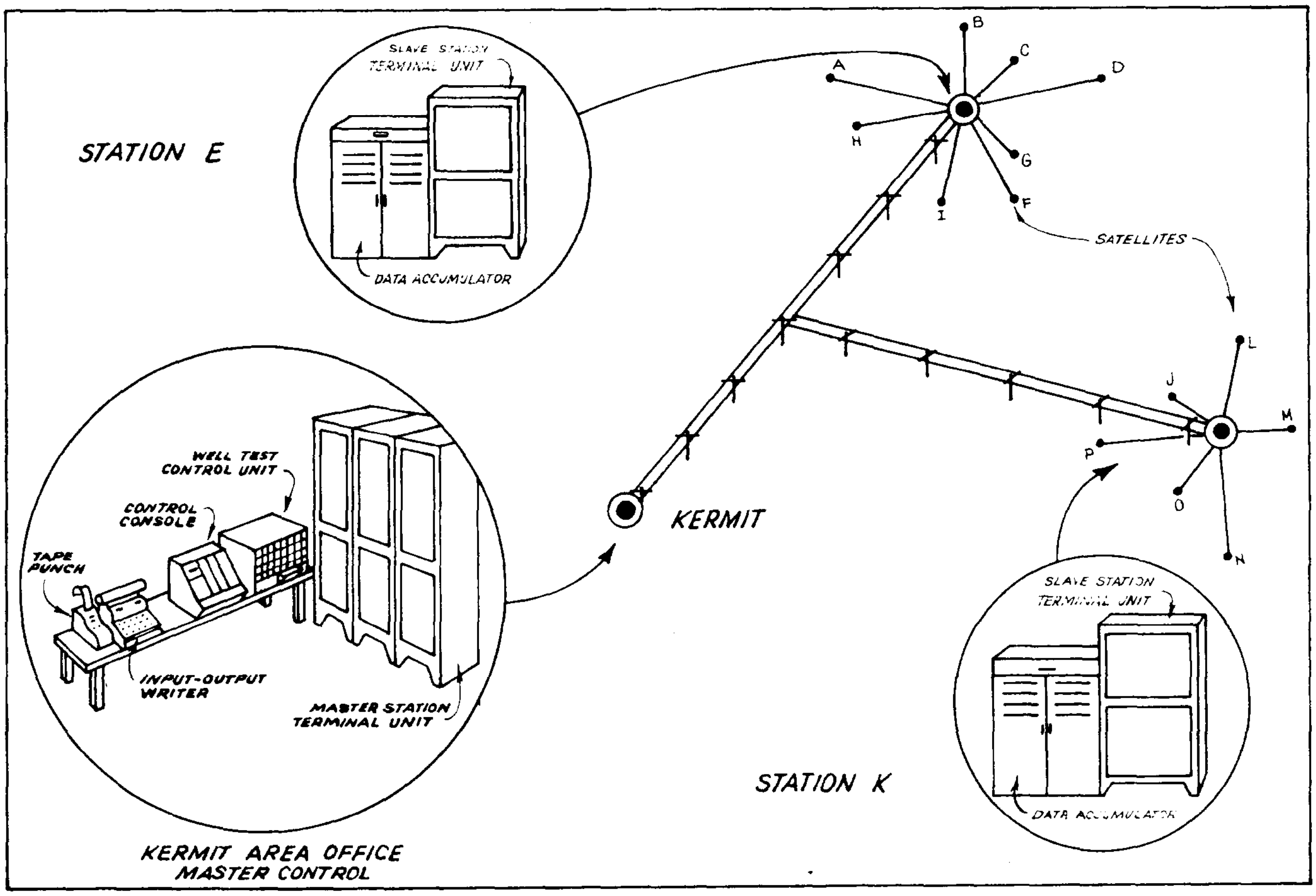
Figure 7 depicts the complete, automatic, production-data monitoring and control system. This schematic drawing shows major supervisory equipment and the communication pathway from each test station to the central battery, and from each central battery to the master control in the area office.

TRANSMISSION CODE AND ACCURACY CHECKS

The telemeter coding used throughout the system is termed a "binary coded decimal". This means that the code format is laid out with five bits representing a complete digit, and with each bit assigned a weight or value of 8, 4, 2, 1 and parity. Bits, therefore, are transmitted for each digit with a total of 16 digits in every message leaving the master control. Codes are transmitted and received at 50 bits per second, which is equivalent to 120 words per minute.

There are 2 methods used to assure accurate transmission of information. One method is termed the "parity" check, which is used primarily for checking against changing of a message by a burst of noise, temporary transmission-line failure, or something of that nature. The equipment always transmits an odd number of mark (1) bits for each digit. Whenever either a slave station (central battery) or the master control receives a message, it counts the bits of each digit for an odd number. If an odd number is present for each digit of the entire message, the equipment is permitted to act in accordance with the message. If any digit does not have an odd number of bits, the entire message is disregarded.

The second method for assuring accuracy is called the "loop" check, which is used to check equipment at each slave station for component failure. In this check, a message received by the slave station is stored temporarily and then transmitted back to the master control. Upon its receipt by the master control, the code is compared digit by digit in the error detector with the message originally transmitted. If they are identical, the master control encodes a "Start" code instructing the slave station to act upon the message. The fact that the slave station received the "Start" code and acted accordingly is acknowledged by the slave through transmission of the original message back to the master control for comparison. If the comparison checks, the master control acknowledges the completed message. If an error is detected at any



AUTOMATIC PRODUCTION DATA MONITORING & CONTROL SYSTEM

FIGURE 7

time during the "loop" check, the master control will automatically initiate the entire message the second time. If the message is not acted upon by the second attempt, the "no action" lamp on the control console will flash to indicate that the particular function requested did not happen.

TELEMETERING SYSTEM OPERATION

The operation of the telemetering system can be divided into three basic functions: (1) automatic alarm detection, (2) interrogation for measured data and (3) well-test operation.

Automatic Alarm Detection

A program at the master control alternately scans Central Battery Stations "E", "K" and Ida Hendrick "A" for abnormal conditions during the time that no control command or request for data is being transmitted. When a malfunction occurs, a signal from an alarm transducer causes the station alarm lamp on the control console to illuminate and a buzzer to sound. A manual request is then initiated to identify the specific type of alarm by transmission of a "read alarm" signal to the indicated station. Upon receipt of the reply, the associated lamp is illuminated to identify the specific type of alarm. The operator of the master control then alerts proper operating personnel to the abnormal condition by radio. Operating personnel check the lights on the panel at the indicated central battery for location of the specific malfunction. The station alarm lamp on the control console remains illuminated until the malfunction is corrected.

Interrogation For Measured Data

Interrogation of field accumulators or "memory units" for stored data, which is a function of the control console, is accomplished automatically or by manual requests of the master-console operator. Production information is printed automatically at 7:00 a.m. each day or manually at any time that specific data are requested by the operator. By pressing 4 buttons, the operator can initiate action to gauge the bad-oil tank at each central battery to account for stock as required at the end of each month. This operation will switch 2 electropneumatic valves connected to the boot located between the run and bad-oil tanks, thus permitting the fluid level in the bad-oil tank to equalize in the boot equipped with a tank-level recorder. The operator can then request and receive a gauge of the bad-oil tank.

Complete production readings are thus available at any time for the operator to check production from the various royalty tracts and zones against the allowables to assure proper producing rates. If rates need changing, he can notify the proper pumper of the needed adjustments by short-wave radio. This operating technique, coupled with computer processing of monthly production reports, will virtually relieve pumpers of all paper work.

Well-test data are printed out at the beginning and end of each test or at any time that a printout is manually requested during the test.

Well-Test Operations

Automatic or manual well-test sequencing is controlled exclusively by the well-test control unit at the master control. Field personnel desiring to test a specific well can have the well immediately placed on test by notifying the master-control operator via radio communications.

When a well test is begun, the operator has a choice of 3 positions on the test-station programmer. If he selects the lockout position, the test will continue until manually ended. If he chooses the zero to 4 hr timer, the well will be removed from test when the time expires, and the next well in the pre-set sequence will be placed on test. On the 0.5- to 30 hr timer, the same procedure will be followed as occurs with the 0 to 4 hr timer. Printout of test oil, test gas and test water data is made at the beginning and end of each well test. All electronic accumulators or "memory units" are re-set to zero when each test is begun.

The same procedure occurs for all 18 test-station programmers. As tests terminate, data are printed and a test begins at the next well on program at each station associated with the timer.

If the operator decides to conclude testing at a given test station, he switches that particular programmer to the manual position and presses the stop button, which removes the well from test. He then moves the switch on the programmer to the "lockout" position.

As previously mentioned, each of four test stations is equipped with a dual or "split" test manifold, a three-phase metering test separator and a 2 phase test separator equipped with a fluid meter to permit simultaneous testing of 2 wells. The dual manifold is split midway by an electropneumatic valve which separates Group 1 and Group 2 wells. Normally, Group 1 wells are tested through the three-phase metering separator to obtain oil, gas and water, while Group 2 wells are tested through the two-phase separator to obtain total fluid only. If the operator decides to meter all three phases of the Group 2 wells, they are diverted through the Group 1 test facilities by opening the manifold valve and by closing an electropneumatic valve on the input line to the two-phase separator. The command to open or close these valves is initiated by the operator pressing buttons on the control console. Prior to the performance of this control function, a printout of the data for the well on test is automatically made to prevent loss of test data. Group 1 wells are locked from test while Group 2 wells are using the 3 phase test facilities.

SYSTEM PERFORMANCE AND COST

The Ida Hendrick "A" pilot installation, which is of relatively simple design, cost $13,179. It has given 27 months of essentially trouble-free operation except for component malfunctions incurred during a severe thunderstorm. Approximately 400,000 bbl of oil have been accurately measured through the LACT meter and telemetered into the area office. This installation showed a payout on the investment in 1.1 yr. The lease contains 12 producing and 12 water-injection wells. As previously mentioned, this pilot operation is now incorporated into the newer Keystone system.

The over-all performance of the Keystone system during 12 months of operation can be classified as good. Some adjustments and component changes have been required, which is understandable considering the vast scope of the installation. Experience gained should be useful in eliminating nonessential functions and in simplifying the design of subsequent installations.

The electronic accumulators or "memory units", which store tract, zone and well-test data, have been the major sources of trouble. In fact, after extensive testing and redesigning of these units (which were of combination solid-state and mechanical-relay construction), they were proved unreliable and were replaced with 110-v stepping-switch accumulators. Preliminary testing of the new accumulators indicates good accuracy and reliability except when malfunctions occur in the pulsing circuits. Telemetering to the master control of information stored in the accumulators has been 100% accurate.

On the other hand, shaft position encoders, which are directly attached to the LACT meters and tank-gauge recorders, have proved extremely accurate and reliable. Approximately 1.15 million bbl of oil have been accurately measured and telemetered into the master control from the three LACT meters. Except for 3 instances when encoder discs became out-of-phase, 100% accuracy in transmission of LACT meter readings was sought and achieved. Malfunctions of this type are readily detected. Telemetered tank gauges normally check within 1/4 in. of those obtained by manual means.

Trouble alarms have been accurately telemetered and have resulted in quicker correction of malfunction, thereby reducing down-time and production losses due to high levels. The alarm detection system permits longer "free-wheeling" of production equipment between visits of operating personnel. During the few days of abnormal sub-zero weather occurring the past winter, the alarm panels proved extremely valuable in quickly pin-pointing equipment malfunctions, thereby assisting in maintaining production.

Efficient operation with the automated system required a new concept in lease operation. Many pumpers' duties associated with manual operation were adjusted to utilize the supervisory equipment. Under the revised operation, pumpers' duties primarily include adjustment and close-in of wells, filling chemical pumps, routine maintenance, correction of malfunctions and equipment repairs. Operation of the master control has required very little time, and the operator has been able to absorb this responsibility and still carry out his regular duties.

The entire project — including consolidation, automation, vapor-phase recovery equipment and telemetering — cost $464,000. This cost represents an expenditure of $3,135/well. Expansions to the supervisory system, consisting of telemetering of data only, should cost only a small fraction of this per-well cost.

A payout on the investment will occur in 2.13 yr based on tangible savings and increased revenue. A payout of 3.67 yr is indicated on tangible savings alone. Tangible savings were achieved in the reduction in cost of produced-water disposal facilities, lease equipment repair and oil-treating costs, operating labor, and in the salvage of corroded and, in some cases, inadequate equipment. Vapor-recovery equipment collecting vapors from knock-outs, heater-treaters and tanks accounts for increased revenue from the sale of approximately 22 MMcf of gas/month, having a monetary value of $3,520.

In addition to these tangible benefits, there are other values which enhance the value of the installation that have received no consideration for payout purposes. For instance, the facilities will handle production increases from any of the pay zones flooded with little or no additional expenditures. The automation will eliminate the expense to process 250 to 300 run tickets each month, and will preclude some production losses caused by high levels in separators due to early detection and correction of malfunctions.

CONCLUSIONS

The operating performance of the described experimental system illustrates that, in some cases, consolidation of producing facilities including remote supervisory equipment is both economically justifiable and technically feasible. Further improvements in technology and attendant system simplification will undoubtedly make future installations economically more attractive. Supervisory systems in the future will likely find limited application under varying degrees of oilfield automation dependent upon specific conditions and operating procedures. Although these systems are not "cure-alls" for indiscriminate application in oilfield operations, such equipment along with any other related technical developments should not be overlooked in the constant warfare against production costs.

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