Tank Battery Consolidation in the Dollarhide Unit

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INTRODUCTION

The Dollarhide Field was discovered upon completion of Magnolia Petroleum Company's (Mobil Oil Company) E. P. Cowden 1 in September, 1945. Subsequent development drilling was completed in 1952, with 284 producing wells in what is now the Dollarhide Unit. Location of the Unit is in Block A-52 and A-55, Public School Land Survey, in Southwest Andrews County, with the western boundary of the unit being the Texas-New Mexico state line.

Unitization was effected on June 1, 1959, with The Pure Oil Company designated as the Unit Operator. Under the unit agreement, 6,182.58 acres, covering the Ellenburger, Silurian, Devonian, and Clearfork Fields, were placed in the Unit. Of these 4 fields, the Devonian and Clearfork extend beyond the unit boundaries to the north and west where Cities Service Oil Company and Gulf Oil Corporation are the respective operators.

All 4 producing zones have pressure maintenance programs in operation to some degree. Two zones, the Devonian and Clearfork, are being water-flooded, using a 5-spot pattern with a total injection rate of 60,000 BPD. In the other 2 zones, produced water is being injected below the respective water-oil contacts.

Although full response has yet to be achieved in the Devonian and Clearfork, daily oil production for the unit is approximately 6,000 BPD. Production is from 154 producing wells, with 101 wells having been converted to water injection wells. Of the total injection wells, 38 are Clearfork, 61 are Devonian, and there is one each in the Silurian and Ellenburger.

Although the Dollarhide Unit is not exceedingly large, there are 60 separate royalty tracts, which range in size from 40 to 160 acres. In several cases, there are 40 acre tracts with production from all 4 zones. Due to the 4 producing zones and the divided royalty interests, there were 144 tank batteries with over 400 tanks in the Dollarhide Unit before tank battery consolidation.

All of the tank battery equipment was from 10 to 15 years old, with a rapidly increasing frequency of repairs and need for replacement. In addition to being old, some of the tank batteries did not have adequate well test facilities, with well tests disrupting regular production, making them most inconvenient. Consequently, proper surveillance of the individual wells, especially in the water-flood areas, was difficult. With the problems of increasing maintenance costs, 144 scattered tank batteries and 2 waterflood projects, some action had to be taken at Dollarhide.

Of these problems, several could be eliminated through tank battery consolidation. Consolidation of the tank batteries was justified by reducing the operating costs, improving the gravity of the pipeline oil, and minimizing the cost of the field electric and water gathering systems. The field produced water gathering system, along with an electrical system, would be required because of the 2 waterfloods. It was decided that some automation would be necessary, but automation for the sake of automation would not be used. Therefore, each degree of automation was weighed against its cost before being incorporated in the final design. To reduce the investment cost of tank battery consolidation, old equipment was salvaged and used where possible.

RESULTS OF TANK BATTERY CONSOLIDATION

Since tank battery consolidation, the field operating personnel requirements have been reduced substantially. Part of the personnel that were formerly occupied with pumping are now being used to reduce the amount of roustabout contract labor employed. Repair and maintenance costs have been considerably reduced. Previously, 2 men were continually occupied with cleaning tank bottoms. This expense has been eliminated completely. Another operational expense which has been nearly eliminated is repairing flow line, heater treater, and tank leaks. Besides being expensive to repair, these leaks were wasting oil. Prior to tank battery consolidation, the amount of paper work created by 144 tank batteries was excessive. Since consolidating the batteries, the clerical requirements have been reduced. The field electric and produced water gathering systems now extend to 8 locations. Whereas, before tank battery consolidation, there would have been 34 locations.

The direct amount of savings attributed to the automation installed in the consolidated batteries is difficult to ascertain. For example, the number of well tests now obtained are furnishing valuable data on the individual reservoirs. Although it is impossible to place a number on this information, it is definitely of value. Better well test data, as well as other automation efficiencies, have allowed us to realize a large reduction in gas lift costs.

Pipeline gravity of the oil has been increased approximately one half of a degree by the new batteries. The gravities of the 3 commingled zones range from 35.0° to 40.0° API. With this range of gravities, a more substantial increase in gravity was anticipated. It now would seem that the oil is stabilized when it reaches the run tank.

Tests on the run tank did not indicate that many vapors were being vented. Subsequently, one small vapor recovery unit was installed, which verified these tests. During December, 1963, the vapor recovery unit recovered 3.06 cubic feet of gas per stock tank barrel of oil. Content of the gas was only 3.96 GPM, as determined with a test car.

PRODUCTION EQUIPMENT

Several different tank battery consolidation systems were investigated before deciding to build 11 separate batteries. Ellenburger oil was not commingled with the other zones because of the premium price it receives. Accordingly, the 11 tank batteries occupied only 8 locations. This system was the most economical, based on present and future unit operating conditions.

Other than some streamlining and moving the chokes to the battery header, the well heads were not changed. Having the chokes at the battery required that all flowlines be high pressure. By high pressure, we mean 640 psig, which is the maximum gas lift pressure available. Some of the old flowlines were salvaged and reused, with the remainder of the flowlines being new pipe. All of the flowlines, new and old, were pressure tested to 1000 psig before they were put in use. In some flowlines, new pipe internally coated for paraffin control was used. These internally coated flowlines were primarily used on Devonian and Clearfork wells where paraffin had been a problem. Length of the flowlines varied from a few hundred feet to over a mile. The shorter flowlines were 2-7/8 in. pipe, while the longer flowlines were 4-1/2 in. pipe.

At the consolidated batteries, the flow of the oil is as shown in the diagram in Fig. 1. The headers contain a choke, diverter valve, and a check valve for each well. The diverter valve is a 3 way, 3 position valve with the positions being test, regular production, and shut in. An electrical solenoid valve is used to select the positions of the diverter valves. Arrangement of the gas supply pressures and solenoids were such that only 2 master solenoids and one solenoid per well were required for each header. Supply gas piping to each diaphragm was connected so that the diverter valve could be manually operated.

One point should be mentioned about the supply gas used throughout the battery. In the winter, if this gas supply freezes, all control of the battery is lost. Consequently, special attention was given the gas supply. Processed gas, which is very dry, is returned from the Dollarhide Gasoline Plant for gas lift purposes. This gas was used in all the supply gas systems and has eliminated any freezing problems.

Produced oil, water, and gas first go to the separators where the gas is removed and sent to the gasoline plant. Because of the volume of fluid and gas produced, most zones required 2 separators connected in parallel. Next, a heater treater is used to separate the produced oil and water. Both the separators and heater treaters used in the consolidated tank batteries were salvaged from the old batteries. Besides some minor repairs, the only new equipment on the heater treaters was a water meter and anodes. Produced water is gathered in a tank at each battery and pumped to a central location for injection in the Silurian and Ellenburger formations.

A variety of induced current anodes were installed and tested in the heater treaters. Results indicate that the graphite anodes gave the most consistant protection. This is probably due to the fact that chemicals are injected in the produced fluid stream.

As shown in Fig. 1, two tanks have been provided for each zone. One is the run tank and the other is for emergency storage. Only 2 controls are mounted on the run tank—a high level float and a pressure switch. The float prevents overflowing the tank, while the pressure

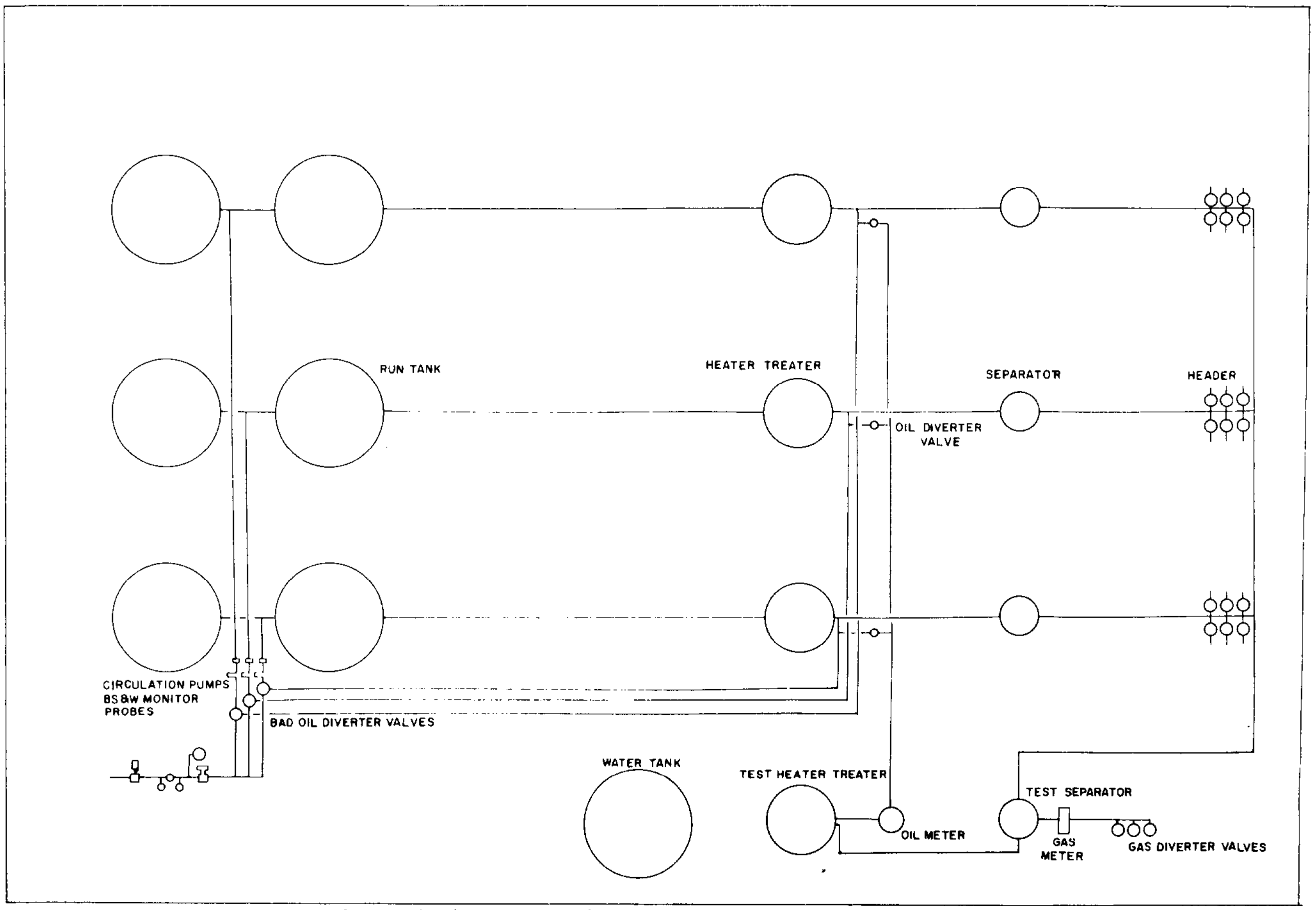

Figure 1. A typical flow diagram of a consolidated tank battery in the Dollarhide Unit.

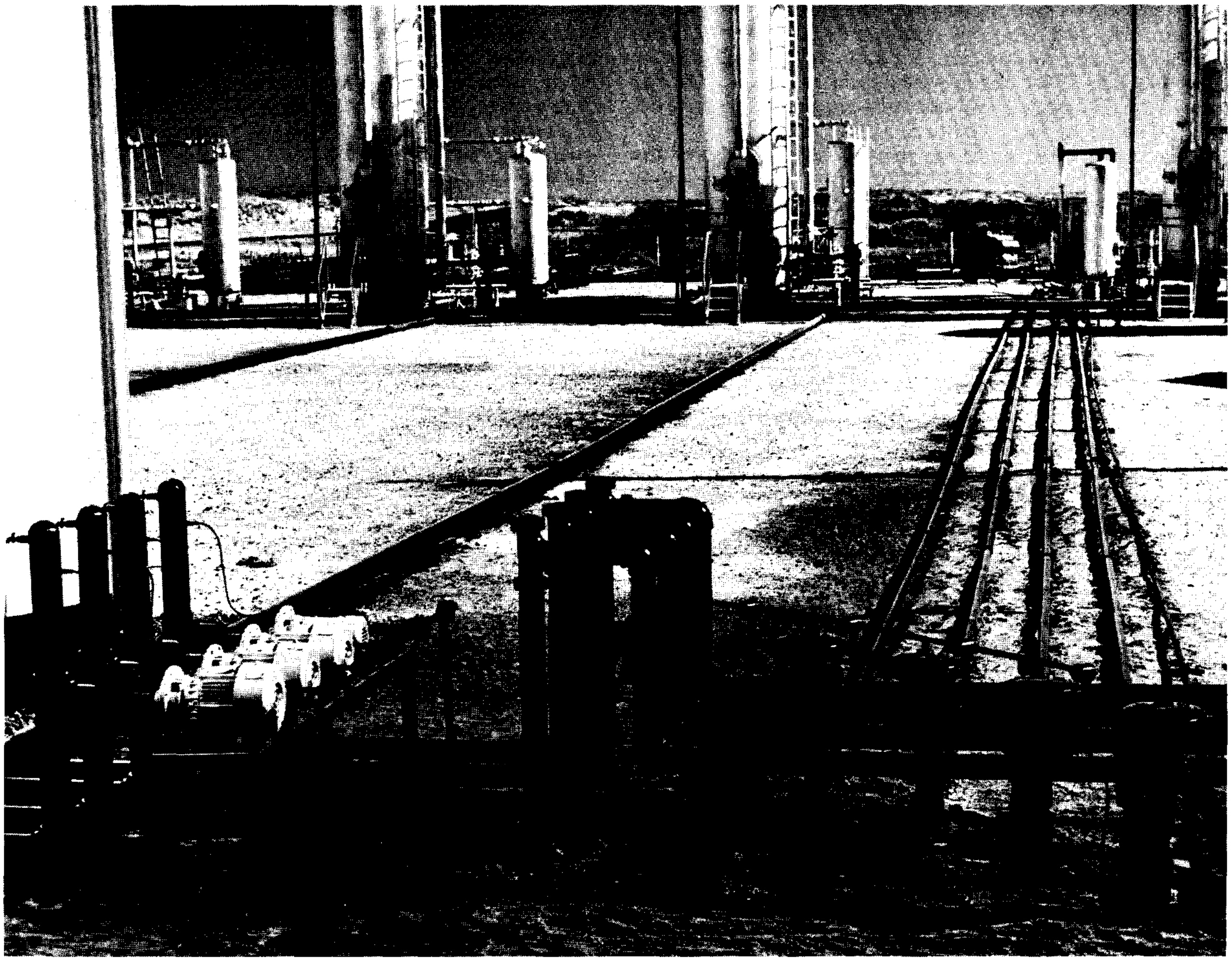

Figure 2. Centrifugal pumps, BS & W probes, and diverter valves between the run tanks and LACT skid.

switch starts and stops the selling process. Each tank has a draw-off line connected to its pump so that periodically, the bottoms can be circulated. So far, this arrangement has been very effective in eliminating bottom sediments and reducing bad oil recirculation.

Between the run tank and the LACT skid, each zone has a centrifugal pump, BS & W monitor, diverted valve, and sampler, as shown in Fig. 2. The centrifugal pump is used to move the oil to the LACT pump or to circulate bad oil. When bad oil is obtained, the diverter valve sends the oil back to the regular zone heater treater. A 30 second delay was incorporated in the BS & W monitor so that small amounts of bad oil would not disrupt the oil selling process. Under normal operating conditions, precaution is taken, so the oil is seldom diverted back to the heater treater. It has been found that excessive recirculation of the oil reduces the oil's pipeline gravity.

Due to the fact that some unit participants do not have an interest in all of the producing zones, a special revenue allocation factor was conceived. Total revenue for each battery is based on the commingled oil volume and gravity, as measured at the LACT skid. This revenue is then divided, based on an allocation factor between the commingled zones in the battery. The allocation factor for each zone is derived from the individual zone's oil volume and gravity. By using this method, the additional revenue derived from commingling the oil could more equitably be divided between the commingled zones.

First commingling of the individual zones takes place at the LACT skid. These skids contain the standard components, strainer, meter, sampler, back pressure valve, and pump. The positive displacement meter is equipped with a print out head, temperature compensator, right angle drive, and impulse switch. The impulse switch is a set of contacts which are reversed as one barrel of oil is metered. This important set of contacts is used in several electrical circuits in the production control panel. Besides driving the individual zone counters, the meter impulse contacts are used in the meter failure and the "Full Barrel Shut Down" circuit.

As mentioned previously, the oil's pipeline gravity is measured at the LACT skid sampler. In the batteries where there is commingling of the oil, the oil's pipeline gravity is less than 40 API. Due to the fact that a maximum pipeline gravity would be economically advantageous, an expensive sampler was used on the LACT skid. This sampler allows the oil's gravity to be measured without removing the oil from the sampler.

On the larger LACT skids, a gear type pump rated at 250 psig and 90 gal. per min. is used. Both the pressure and volume rating are anticipated as the oil production from the waterfloods increase. On the smaller LACT skids, the same type pump is used but is only rated at 50 gal. per min. at 250 psig.

The equipment used to produce the oil from the wells to the pipeline is not different from many other consolidated tank battery systems. Control, especially the electrical control panels, is the feature that distinguishes the Dollarhide consolidated tank batteries from others. The very nature of the operations required that someone be in attendance at least part of the time. Therefore, partial automation was used to reduce the operating personnel and still improve operational efficiency.

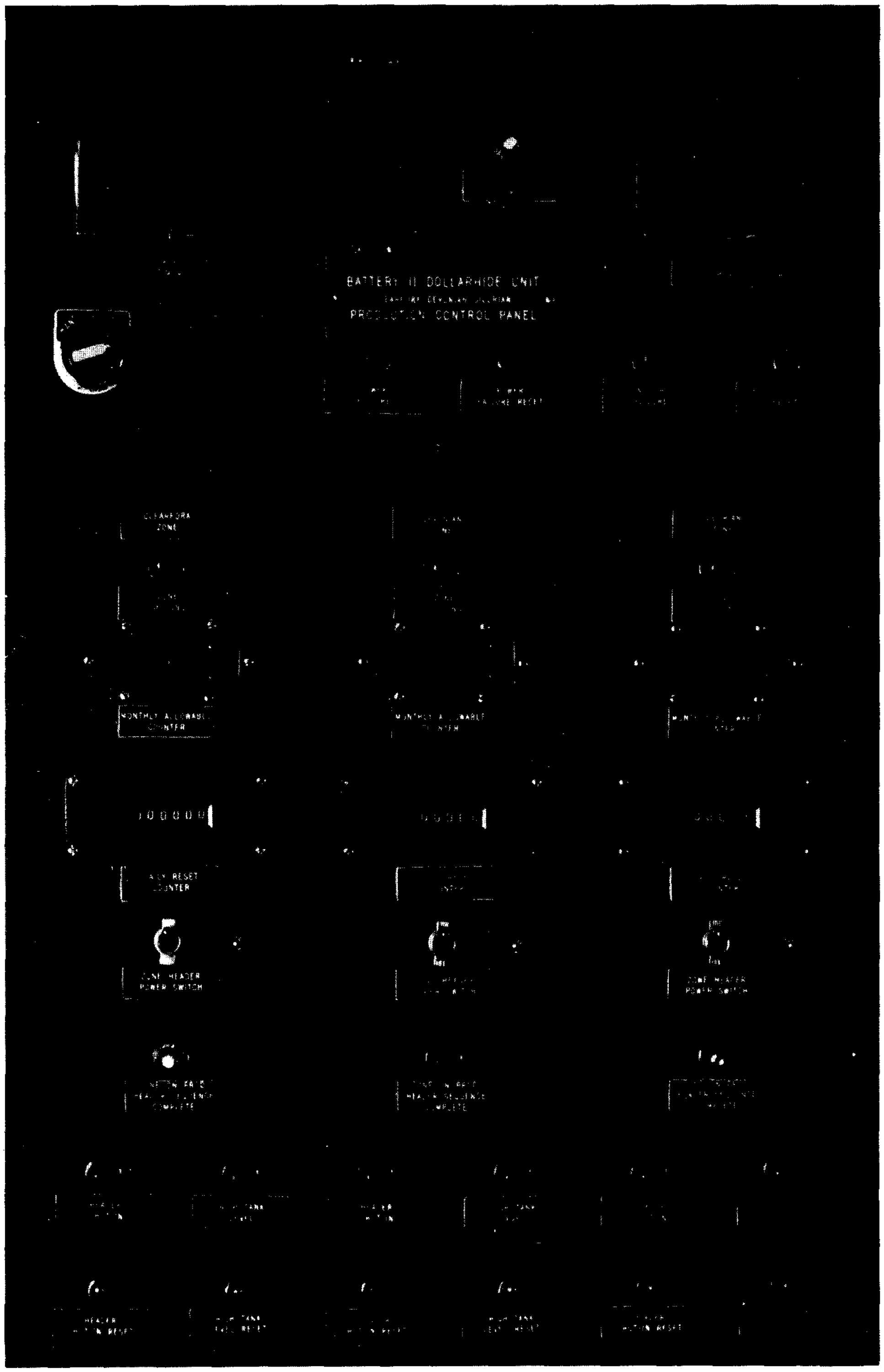

Figure 3. Production control panel

PRODUCTION EQUIPMENT CONTROLS

Control of each consolidated tank battery is centralized in the production control panel (Fig. 3). Only 2 points of control exist in the battery; they are at the header and run tank. The header can be automatically closed or opened as the situation requires. From the run tank, oil is automatically transferred to the pipeline. Other controls are used to test the wells and will be discussed later. The control panels, BS & W monitors, and motor starters are located in the battery control house. The decision to use a control house was based on safety, convenience, and savings incurred by not having to weatherproof the electrical panels.

To shut in the header, a set of contacts are opened in the production panel which de-energizes the header's 2 master solenoid valves. With both master solenoid valves closed, the gas pressure bleeds from both sides of the diverter valves and shuts in the header. This procedure is typical of how an electrical-pneumatic system is used to control the operations of the batteries.

Only a high level in the run tank or a power failure will shut in the header. Other situations, such as a meter failure or completion of selling the allowable, will only keep the LACT unit from running; which, in turn, causes a high level in the run tank. When the header does shut in, a cam timer in the production panel is used to place the wells back on regular production. If the header is shut in for only a short period of time, approximately one minute, the cam timer will open all diverter valves instantaneously. On the other hand, if the header has been shut in long enough to allow excessive pressure to be trapped in the flow lines, then the cam timer opens the diverter valves one at a time. By using a sequence device to divert the wells back to regular production automatically, a safety feature has been provided.

To sell oil to the pipeline, 3 sets of contacts, indicating 3 conditions are satisfied, must be closed in an electrical circuit. There must be a run level in the tank, no excessive BS & W, and allowable still unsold on the set-stop counter before the LACT unit will run. When the run tank reaches a low level, or if there is some malfunction, the LACT unit stops selling.

As mentioned previously, only one meter is used for all of the zones. This meter is located on the LACT skid and sends electrical impulses to the production control panel as oil is sold. These electrical impulses drive a set-stop and daily counter for each zone. As a particular zone starts the selling process, the correct set of zone counters is automatically selected.

This brings up another consideration, because only one meter is used for all commingled zones. It would be possible to sell part of a barrel of oil from one zone and yet not have it recorded on the zone counter in the production control panel. This could happen, due to the fact that an electrical impulse is only sent to the zone counter in the production panel after a full barrel has been registered on the LACT meter. To prohibit this inaccuracy, a special full barrel shut down circuit was incorporated in the production control panel. Whenever the LACT unit stops for any reason, other than a power failure, it does so only on a full barrel. As a barrel of oil is being sold, an electrical circuit, other than the one containing the BS & W Monitor, low level and allowable contacts, furnishes power. When a full barrel is reached on the LACT meter, the electrical circuit containing the above mentioned three contacts is tested. If any contact is open, the LACT unit pump stops running. In the same manner, this control will not let oil be diverted to the heater treater except after a full barrel has been registered.

Selling each zone singularly and separately created the possibility of several adverse conditions. One such condition was having one zone reach an emergency high level while another was selling. When a zone begins selling oil to the pipeline, an adjustable timer starts. Upon timing out the zone selling oil stops, and the other zones are checked for run levels in the tanks. If another zone is ready to sell, the timer is reset and the second zone begins selling oil. By not finding another zone ready to sell, the original zone will resume selling oil through the LACT unit.

In the production control panels, as in the well test panels, 110 volt AC sealed plug in relays were used. Part of the relays were instantaneous and part were time delayed. Several of the instantaneous relays were connected with a resistor in series and a capacitor in parallel. This modification of the instantaneous relays actually made them operate with a slight delay. The reason for this modification was instantaneous power dips that occur on the power lines. Also, a pulse limiter circuit was provided in the production control panel to eliminate any stray counts due to power failures.

The positive lock outs are provided for in the relays. Each relay contains 2 sets of contacts; one set is open when the relay is de-energized and the other set is closed. Upon energization of the relay, the contacts are reversed. To operate a diverter valve in one zone, a relay is energized which completes the electrical circuit to the solenoid valve. The set of contacts in the relay which are open on energization are included in the electrical circuits to the other zone's diverter valves. Therefore, if one zone relay is energized, the other zones are automatically locked out.

WELL TEST SYSTEM

The test system for a single zone battery is shown in Fig. 4. Production is diverted to the test system at the header by the solenoid controlled diverter valve. The separator and heater treater are of a conventional type, but with the appropriate meters for measuring the produced oil, water, and gas. Oil is measured with a half barrel dump type volume meter at the heater treater. A positive displacement meter on the heater treater measures the produced water. A positive displacement meter measures the produced gas at the separator. This type of meter was selected so that surges of gas from the gas lift wells could accurately be measured. In the batteries that have more than one zone using the test system, diverter valves are used to route the oil and gas back to the proper zone. On each meter, a micro-switch was attached to send an electrical impulse to the well test control panel. A counter in the panel is driven by the electrical impulses from the individual meters.

WELL TEST CONTROLS

Special consideration was placed on the well test system in the consolidated tank batteries. Control of the two waterflood projects would require periodic well test data. Also, the produced oil and gas would have to be allocated to the individual royalty tracts based on well tests. Achievement of these 2 pre-

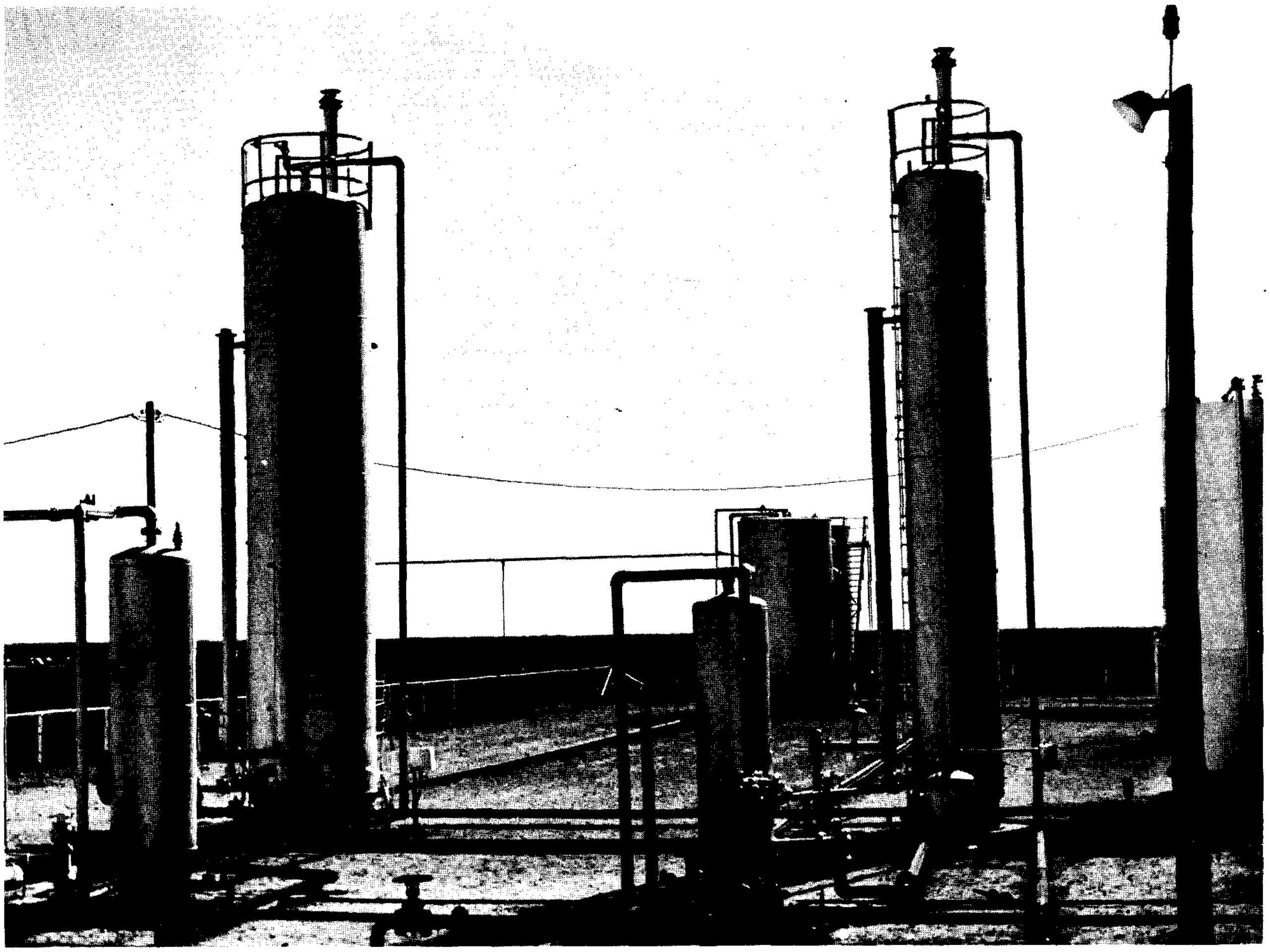

Figure 4. A single zone battery with the test facilities to the right and regular production to the left.

requisite goals required more well tests than would normally be taken. Consequently, a well test system was designed by the unit engineers to provide the advantages of an automated system but without a permanent print-out device. Selection of the wells to be tested and the accumulation of test data is centralized at the well test panel in the battery control house.

Each well test control panel (Fig. 5) has from 2 to 5 sets of counters, depending on the number of wells in the test system. Each set of counters consists of 3 individual counters—1 each for the oil, water, and gas. Corresponding to each set of counters are from 4 to 6 wells. Duration of the well tests is predetermined by an adjustable timer. A selector switch above each set of counters is used to select the particular well for testing. After selecting the well, an electrical circuit is completed to the well's solenoid valve at the header. Production is then diverted into the test system. At the same time, the contacts between the meter's microswitches and the counters are closed. Thus, the well has been placed on test and the panel is ready to record the production data. Well test data remains on the counters until they are zeroed and another well is selected.

Upon completion of a test, a stepper switch automatically moves to the next selected well. Provisions were made so the test sequence could automatically skip wells, retest wells, or stop after completing a test. The only restriction is that 2 wells under the same selector switch cannot be automatically tested consecutively.

Electrical circuits in the well test panel were designed to accommodate several conditions of operation. As in all the controls in the consolidated batteries, a fail safe design was used in the well test system. Positive lock outs were built in the test panel to assure that no commingling could take place. When a well from one zone is being tested, contacts are open in the electrical circuits to the other zones' oil and gas diverter valves.

If, during a test, there is a power failure or header shut in, two special features are provided in the test panel. A pulse limiter device was used in all the counter electrical circuits, so extra counts would not be recorded because of power failures. When the test is stopped for any reason, the test timer stops and does not start again until the well is actually diverted to the test system. A deliberate delay has been built into the sequence cam timer that opens the header diverter valves. This delay allows the well to blow down gas and fluid trapped in the flowline before it goes back on test.

To date, the test system has operated very satisfactorily. The only malfunctions were found upon initial installation and have been of a minor nature, such

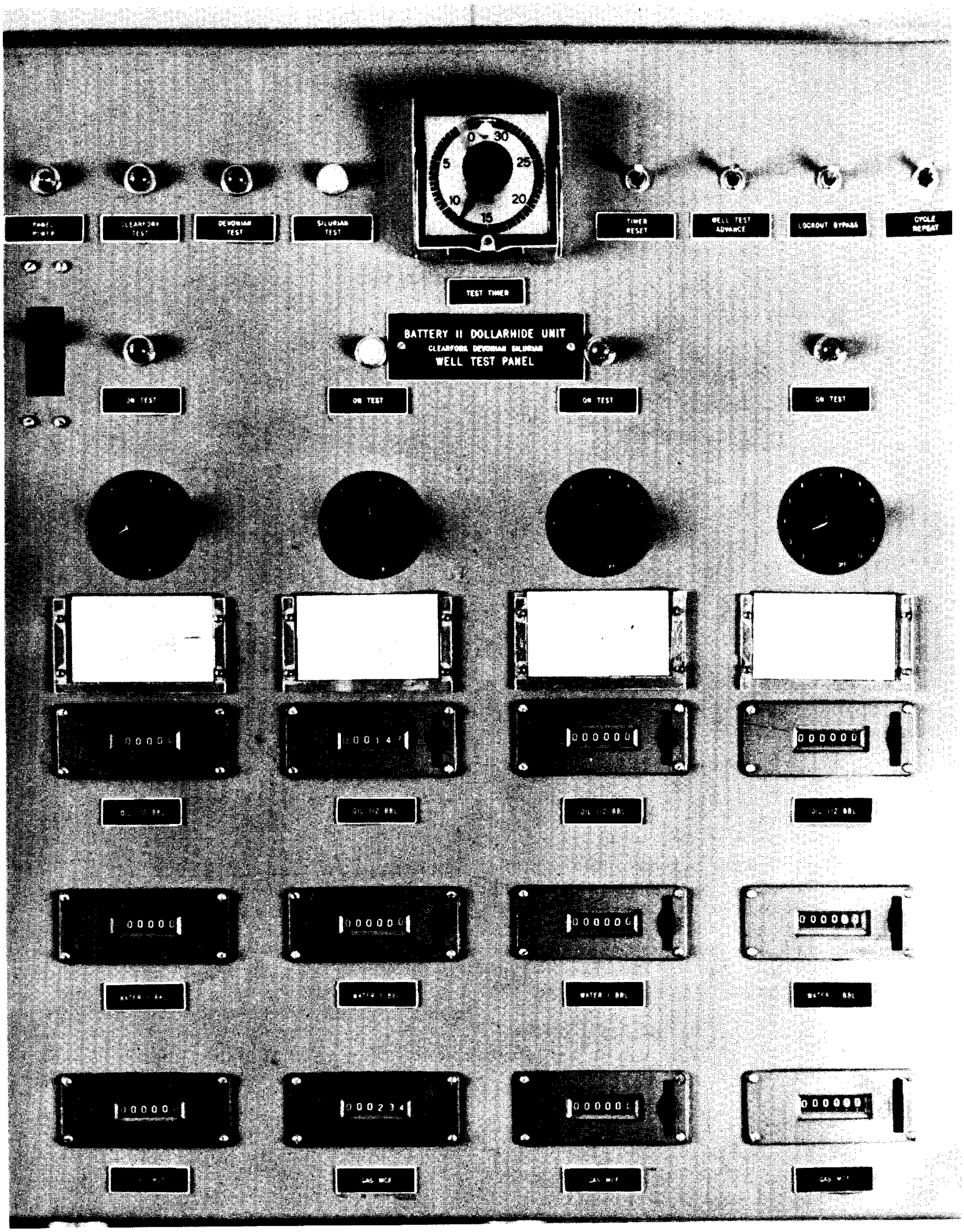

Figure 5. Well test control panel

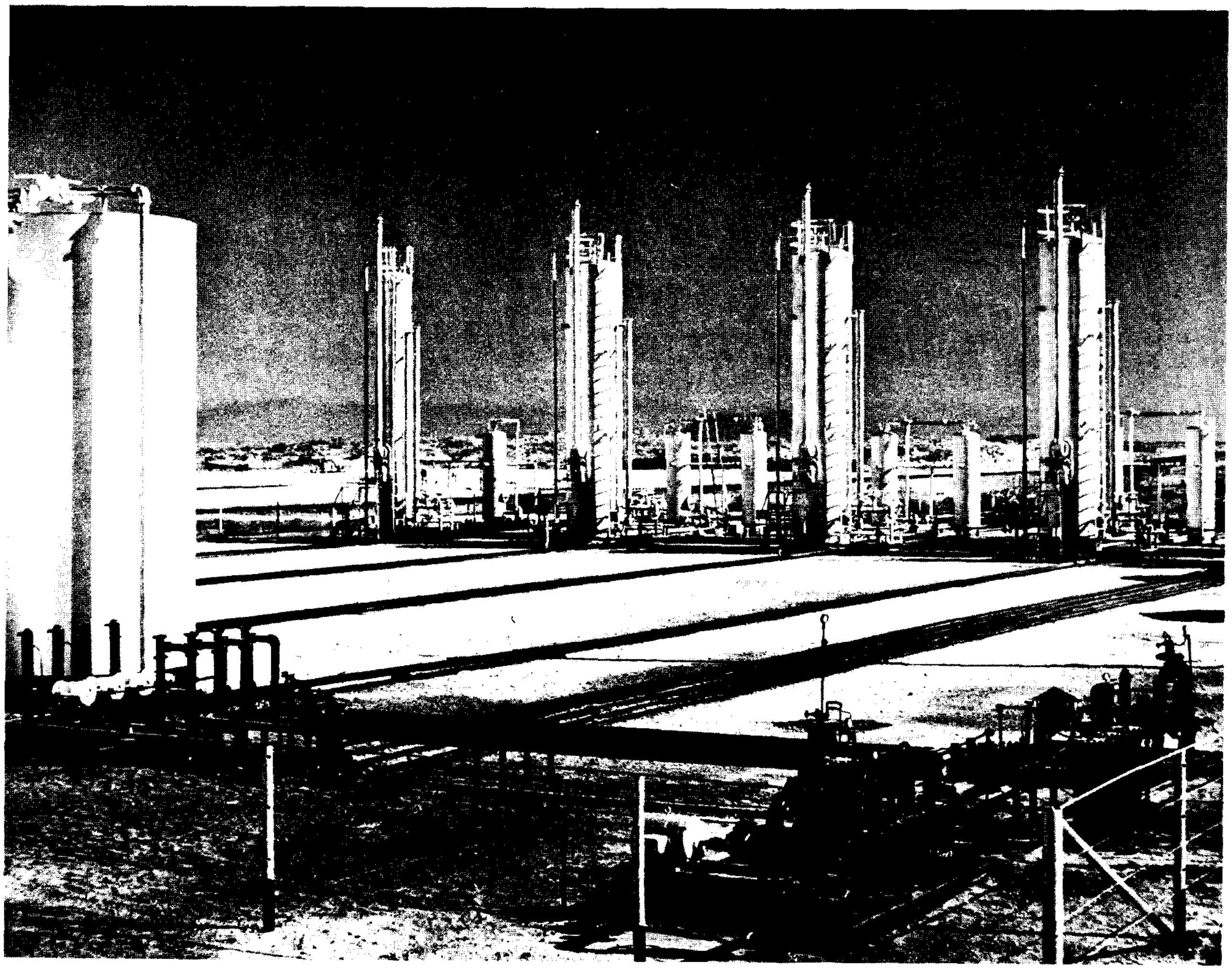

Figure 6. Photograph of four zone battery. The LACT skid to the left is for the three commingled zones.

things as not having the micro-switches exactly positioned to function properly. One of the outstanding benefits of the test system has been the excellent gas measurement. Previously, a gas-oil ratio test was made semi-annually; now, the gas-oil ratio is measured on each test. These tests have been of significant value in controlling the waterfloods and improving gas lift efficiency.

Fig. 6 illustrates a four zone battery utilizing a skid-mounted LACT unit to handle three commingled zones.

CONCLUSIONS

Old equipment and secondary recovery made tank battery consolidation in the Dollarhide Unit a necessity. The whole problem was the amount of automation that would be used. On one end of the scale was automatic transfer of the oil and manual battery control. The other extreme was complete automation of the batteries for unattended operation. It was felt that manual control of the battery, especially in the test system, would not produce the desired flexibility. On the other hand, it was not believed that complete automation was required. Therefore, the unit engineers designed the battery controls so they were somewhat in between manual and unattended automation.

So far the tank battery consolidation program at Dollarhide has improved operations and at the same time reduced operating costs. Operation of the batteries has been relatively trouble free, which, to a large extent, is due to the ability of the pumpers. At the outset of consolidation, every effort was made to familiarize the pumpers with how and why automation works. Dividends from this training have been well worth the time spent.

The tank battery consolidation program with its automation, as used at Dollarhide, is by no means recommended for all leases. Rather, the principle of designing for each individual lease is recommended.

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