COLLECTION OF CASING HEAD GAS WITH THE USE OF ROTARY COMPRESSORS

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Although the oil industry has long been concerned with the efficient production and recovery of oil and natural gas, present-day regulations, conservation practices, and gas values necessitate review, on a lease by lease basis, of the feasibility of efficiently recovering very small quantities of gas which may be gathered at several ounces of pressure. The rotary gas compressor, which is readily adaptable to compressing very small volumes of gas, provides a means for the recovery for use or sale, of gas at very low pressure.

For efficient use of a low pressure recovery system all possible sources of low-pressure gas from the casing head to the stock tank must be evaluated for quantity and liquid hydrocarbon content. Whether low-pressure gas is sufficient to justify an installation is present must be determined. This gas, though small in volume, is usually rich in liquid hydrocarbon content. In some fields where the bottom-hole pressure is very low and the formation permeability is very high, a reduction in formation back pressure may result in an increase in oil production rate. This reduction in back pressure can be accomplished by elimination of flow-line back pressure on the casing head by installation of a separate gas-gathering system.

MEASUREMENT

The most critical and often the most neglected aspect of determining the feasibility of a casing head gas gathering system is determining what volume of gas is present. Some people make the mistake of not conducting an exhaustive per-well measurement under the same conditions that the system will operate. A casing head gas gathering system was installed on a unit in West Texas on 120 wells producing from the San Andres formation. A spot check of the wells showed that all of the wells combined would produced 840 MCFPD. This estimate was based on tests conducted on only a limited number of the wells that were considered to be representative of the unit. After the system was installed, only 90 MCFPD was found to be being produced. Two errors in design criteria were made: 1) Not all of the wells had been tested, and 2) on those that had been tested, the tests were not conducted for a sufficient length of time for the gas production to stabilize. Therefore, the tests gave erroneously high results. Another source of error in testing arises when a vacuum is used on the casing head because air can enter the tester and give erroneously optimistic results.

The most useful tool which can be used to determine the volume of gas being produced is a portable orifice well tester with a 0-10 inches of water bellows. The tester can be tied directly into the casing head and can measure volumes as small as 500 CFPD. This meter is also suitable for measuring stock-tank vapors because it does not require pressure high enough to cause damage to tanks.

Determination of the volume of gas that will be available for sale should be based on the best possible prediction of future gas production. One thing that can greatly reduce the volume of gas produced is waterflooding. In all waterfloods, after the peak production has been reached, the GOR will decline as water cut increases. If installation of a gas-gathering system is being contemplated in a field that is being water flooded, and the volume of gas being produced at present does not justify the installation, installation of the system would be impractical.

When an evaluation of a gas collection system is being conducted, the liquid content of the gas can have more of an impact on the profitability of a system than does the actual gas itself. Several uncontaminated samples of the produced gas should be obtained and analyzed for GPM and oxygen content.

ECONOMICS

Once the volume of gas production and the liquid content of the gas have been determined and forecasted, the next step is determination of whether or not installation of a gathering system is feasible. Two factors play a key role in this determination: 1) price of the system, and 2) revenue generated by the produced gas.

The price of the system depends on the overall design and is discussed at length later in this paper. The revenue of the produced gas is determined by the volume and price of both the gas and gas-plant liquids.

On the Dora Roberts Lease in Howard County, Texas, a casing head gas gathering system was installed to gain compliance with RRC Rule 36 and to increase the recovery of low pressure natural gas.

The system was installed on 60 wells producing from two different reservoirs on 480 acres. The oil and water is produced to a central consolidated battery. The casing heads were all left open because of the very low reservoir pressure, approximately 250 psi. No gas was being sold from this lease prior to installation of the gathering system because only 84 MCFPD was being vented from the separation vessels. A gas measurement test was conducted to determine the amount of gas being vented from the casing heads and the stock tanks. This test was conducted on each individual well. It was determined that approximately 360 MCFPD was being released from all of the wells combined and that an additional 90 MCFPD was being vented from the oil stock tanks and water tanks. The combined natural gas vapors that could be gathered by use of a low-pressure gathering system was 450 MCFPD. This amount in conjunction with the 84 MCFPD being vented from the separation vessels totaled 534 MCFPD of gas that could be recovered.

The contract with the gas pipeline company was negotiated with a provision that the price per MCF of vapor delivered would be equal to 33 percent of the value of the gas plant liquids and 75 percent of the value of the residue gas.

Chromatographic analysis of a vapor sample considered to be representative of the commingled gas showed a liquid content of 5.731 gas/MCF, as shown in Table 1.

TABLE 1—VAPOR ANALYSIS

LIQUID COMPONENT	*GAS/MCF*
Propane	1.970
I-Butane	1.024
N-Butane	0.930
I-Pentane	0.730
N-Pentane	0.220
Hexanes	0.341
Hexanes plus	0.516
Total	5.731

On the basis of a field-average oil price of $5.20 per barrel, the entrained liquids are worth $0.23 per MCF. The average value of the residue gas in $0.51 or a net of $0.38 per MCF to the lease. Therefore, the net price of the produced gas in $0.61 per MCF. With the lease producing 534 MCF of vapors per day, the gross revenue being generated is $326 per day. With a total system cost of $117,000, an income interest of 87.5 percent, and operational expenses at 10 percent of net income, the system will have a payout of 455 days.

The data presented may leave the impression that this type of system works only on a rather large lease or facility. This is not the case, as the following example indicates.

A casing head and stock-tank gas-gathering system was installed on another lease in Howard County, Texas, that had 10 producing wells on 80 acres. The producing wells had the casings vented, and the battery consisted of a gun barrel and stock tanks which were also vented. After testing to establish the amount of gas being vented, the entire lease was found to be producing 88 MCFD. This gas had a composite natural-gas liquids content of 7.837 GPM. With an oil price of $5.20/bbl, the liquids are worth $0.32 per MCF. With the residue gas worth $0.38/MCF to the lease, the net price of the produced gas is $0.70 per MCF. This figure results in a daily gross income of $61.60 for the lease. The installed system cost was $22,000. With an income interest of 87.5 percent and operating expenses of 10 percent, the system will pay for itself in 453 days.

A casing head gas gathering system can sometimes be used to increase crude-oil production by reducing back pressure on a formation. This type of installation generates income based on an oil and gas production increase rather than on recovery of vented gas. Only such a system works where the formations have very low bottom-hole pressures — approximately 300 psi or less — and high permeability. Another criterion necessary for this type of installation to work is that the lift equipment must be capable of handling the additional fluid production. If not, the reduction in casing pressure is offset by an increase in fluid level.

Other applications which may make the installation of rotary compressors economical are as follows: 1) on single well gas well, tubing or casing to flowline to reduce wellhead pressure; 2) treater or separator gas to gas gathering system, second stage compression, with stock tank vapor compressed on first stage; 3) crude oil stabilizer, central crude oil-gas separation, pressure vacuum control, gas to gathering system, continuous stream system; 4) casing head gas to be used for fuel gas supply when outside purchase in unavailable or costly; 5) casing head gas to be used for feed stock in on-site process system; or 6) crude-oil gravity variance controlled by storage vessel vapor pressure control.

SYSTEM DESIGN

The best time for installation of any system is after all the wells are drilled and completed and after tests indicate that the system is justified. Fortunately, a gas-gathering system of the type being described in this paper is usually installed in older depleted fields where only a minimal amount of development takes place. As with any system, this one should be designed to allow for expansion if any is being contemplated.

The capacity of a system should be of prime concern and should receive first consideration. The original design should be for a minimum of 150 percent of the maximum anticipated volume and pressure, particularly in the case of the main gathering or trunk lines. Very high design factors allow for additional development and help compensate for pressure drops due to the accumulation of water or liquid hydrocarbons.

One key factor should be taken into account in the design of a casing head or stock-tank gas-gathering system, and that is it will be operating at very low suction pressure, on the order of several ounces or inches of water. This factor is what makes rotary compressors so attractive. They are designed on the positive displacement principle, yet the only load the compressor experiences is due to the differential pressure it creates. This asset allows for use of the same compressor under a wide range of conditions.

Compressors are air cooled for up to 30 psi of differential pressure and water cooled for up to 50 psi differential. The compressor is multivaned and is equipped with a force-feed lubrication system. Oil is distributed to the seals, bearings and cylinder. The lubricator is driven by compressor shaft with a positive belt drive. The compressor is driven by an electric motor and is coupled by V belt drive, allowing for flexibility to operate at maximum efficiency. All units are also equipped with suction scrubbers, high liquid-level shutdown, high discharge and low suction-pressure shutdowns, automatic bypass valve and safety-shutdown thermal sensors to monitor the temperature of compressor bearings (see Figure 1).

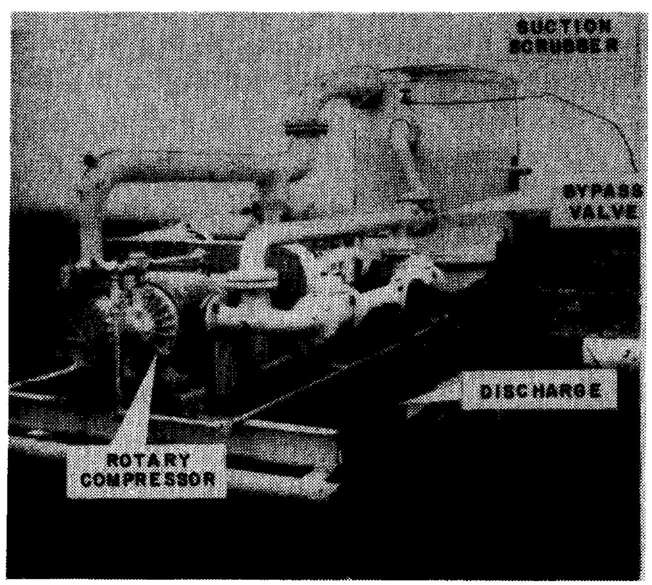


FIG. 1—PREFABRICATED SKID MOUNTED UNIT BEING USED TO GATHER CASING HEAD GAS ON THE DORA ROBERTS LEASE. UNIT SHOWN HAS CAPACITY OF 370 MCFPD.

The units can be designed to run intermittently, to start and stop at a predetermined pressure, or to operate continuously, maintaining a constant suction pressure. The units designed to operate intermittently are used for stock-tank vapor recovery.

When pressure in the stock tanks reaches a set point, the compressor starts and runs until pressure in the tank is decreased to another set point. At this point, the unit shuts down. To prevent the unit from cycling unnecessarily, an automatic bypass valve is opened for several minutes prior to unit shutdown and bypasses gas from the discharge to the scrubber, allowing stock-tank pressure to increase. The units used on casing head gas-gathering systems are usually designed to operate continuously. The automatic bypass valve is used to throttle sufficient gas back to the scrubber to maintain a constant suction pressure.

The units used on the Dora Roberts Lease collect both stock-tank vapors and gas from the casing heads (see Figure 2). This is accomplished with the use of a control pilot on the stock tanks which controls the operation of a motor valve which regulates the flow of gas from the tanks into the gathering system. The sytem is operated with a vacuum which permits the tank vapors under 2 ounces of pressure to enter the gathering lines. *All states have regulations which prohibit the application of a vacuum to any oil- or gas-bearing* formation. However, in some states, such as Texas, a permit can be obtained to gain exception to this rule.

When the gathering lines for a low-pressure gas system are being designed, pressure containment is not a key factor. Therefore, pipe such as fiberglass or PVC which is considerably less expensive than steel pipe may be used. The prime emphasis should be placed on the size of the pipe because this will detemine the pressure drop through it. Figure 3 is a nomograph which can be used to determine the pressure drop in pipes due to low pressure vapor flow. If the lines are not of sufficient size to keep frictional pressure loss to a minimum, wells at the outer edge of the system will have back pressure held against them, which reduces production. This problem can be compounded by liquid accumulation in the lines. Liquid lying in a line will reduce the effective diameter of the pipe, causing unnecessary pressure drops in the system. This situation can be remedied with the installation of drips or low-point drains in the low places in the lines, since that is the natural place for liquids to accumulate. The drips should be of sufficient size to contain all accumulated fluid and should be emptied at regular intervals to assure that liquids will not collect in the line. Since collection of fluid at certain points in a line is not always foreseeable installing them after the system is put in operation may be desirable. Several drips should be installed in regional low areas in conjuction with installation of the system. When the lines are laid they should not

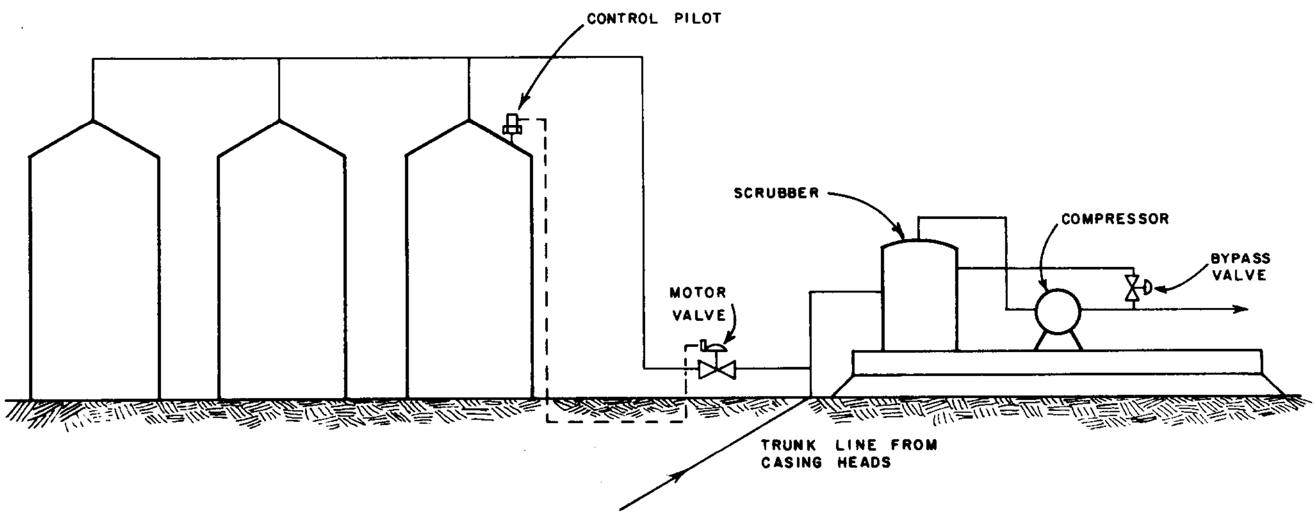
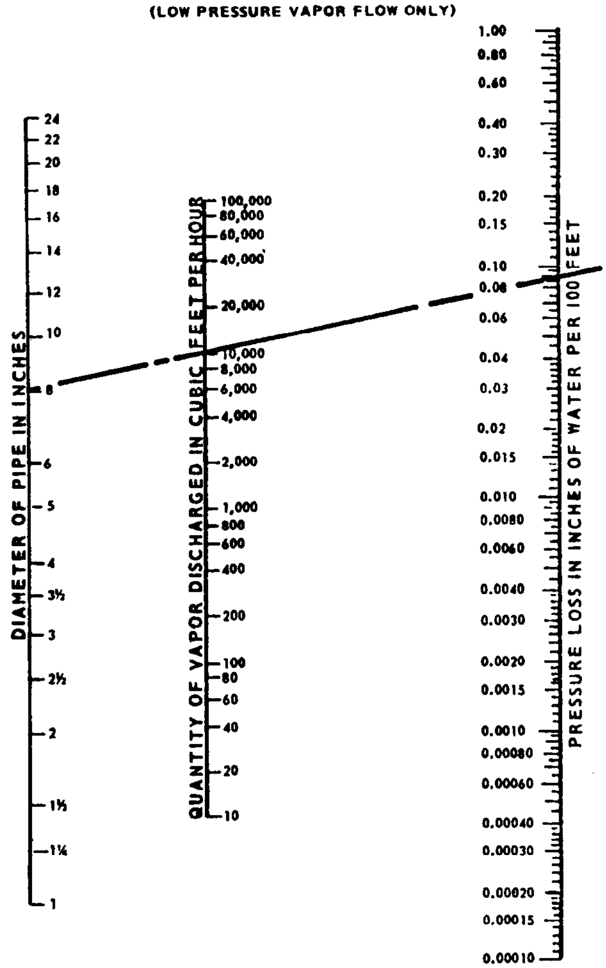


FIG. 2—MOTOR VALVE AND CONTROL PILOT REGULATES GAS AT 2 OUNCES OF PRESSURE TO ENTER GATHERING LINE WHICH IS UNDER A VACUUM.

have any unnecessary rises or dips. If all lines are laid on the surface, care should be taken that they do not have low places under road crossings. If low places are unavoidable, a drip or drain should be installed adjacent to the road. Also when the lines are laid on the surface, the gas lines should pass under any existing lines to avoid any additional low places for fluid to accumulate.

NOMOGRAPH FOR PRESSURE DROP IN PIPES

(LOW PRESSURE VAPOR FLOW ONLY)



EQUIVALENT PIPE LENGTHS OF FITTINGS

KIND OF LOSS	DIAMETERS
Entrance	25
Exit	40
45° Elbow	15
90° Elbow, standard radius	30
90° Elbow, medium radius	25
90° Elbow, long sweep	20
Tee – used as elbow, entering run	60
Tee – used as elbow, entering branch	90
Tee – passing through run	20

FIGURE 3

It is unfortunate that most older wells have to be treated downhole for corrosion, scale or paraffin because this treatment along with condensation causes fluid to accumulate in gas-gathering lines. When chemicals are displaced down the annulus, a gassy well kicks some of the fluid back to the surface. When treatments are made, a procedure should be prepared for the person treating the wells to follow to minimize fluid lost to the gathering line.

Another problem that is encountered in rotary compressor installations is solids. When the system is being built, dirt, rust, slag, and pipe shavings inevitably get trapped in the lines and eventually pass through the compressor. The vanes in rotary compressor are made of phenolic-laminated asbestos. The vanes and the compressor case itself can be damaged, sometimes beyond repair, within several hours of start-up. Care should be taken to keep all foreign material out of all lines. Ideally, filters should be installed immediately in front of the compressors. Filter elements must be changed frequently in the early life of the system, but as time goes on they will not require much maintenance and can probably be removed altogether. The small expenditure required for installation of filters can save several thousands of dollars in equipment repair.

Another major problem encountered in a low-pressure or vacuum gas-gathering system is the problem of leaks. In a vacuum gathering system, leaks result in air being mixed with the gas — a mixture which can, with the heat of compression, become explosive. This mixture also creates inefficiency in operations and causes accelerated corrosion in the presence of hydrogen sulfide. Furthermore pipeline companies do not accept gas which has any substantial oxygen content.

Oxygen can find its way into a system through any opening, holes in the casing or gathering line, faulty packing in tubing heads, poorly made-up connections, open valves, etc. Therefore, all lines and connections in a gathering system should be tested to a minimum of 100 psi upon completion of installation. Connections such as tubing heads, that cannot be pressure tested should be pressurized and soaped to detect leaks. Often a system holds pressure but not a vacuum.

The first test for air in the system should be at the terminal point. If the presence of a leak is detected, samples can be tested from other points in the line until the leak is located. The best instrument for use in the field in determinations of oxygen content is a portable oxygen indicator which uses a self-generating, temperature-compensated, membrane-type electrolytic cell. A unit with the 0-5 percent scale has accuracy to ± 1/10 percent. If no oxygen content is indicated by this instrument, a gas sample should be obtained and analyzed in a lab chromotograph because chromatographic is much more accurate. A chromatograph is accurate to 1/100 of a percent. All field personnel should be educated to be conscientious and not allow air to enter the system. Well service crews should be instructed to close the casing valve on a gas line prior to working on a well and to examine tubing head packing every time it is removed and to replace it if necessary.

Several other important items that should be considered in the design of a gathering system are as follows: 1) installation and location of block valves to allow flexibility in isolating sections of the system for repairs; 2) location of controls and emergency shut-down devices so that if a gas line breaks on the compressor skid the unit may be shut down from a remote location; 3) installation of back-pressure and relief valves (where separation vessels are vented it is common practice to tie back-pressure valves and pop-off valves into the same vent line; when they are tied into the gathering system the pop-off valves must still be vented to the air); and 4) location of flares and measuring equipment. If all necessary equipment is installed in conjunction with construction of the system, savings of gas and convenience of operation result.

CONCLUSIONS

With gas-price situation as it is today, gathering small volumes of low pressure gas with the use of rotary compressors is often profitable. Sources from which gas can be collected are casing heads, single- or multiple-well producers, stock tanks, water tanks, and gun barrels. the combined volumes being vented from these sources represent a source of additional revenue. Rotary compressors can be used to increase production by lowering back pressure and to increase oil gravity by controlling storage tank vapor pressure. They can also be used to gain compliance with governmental rulings on recovery of sour gas.

As with any system, operational problems of the rotary-compressor system can be reduced by proper system design. Three items that cause most of the operational difficulties are fluids, oxygen, and solids that get into the system. Nearly all problems can be alleviated if the system is adequately engineered.