HYDROCARBON VAPOR RECOVERY SYSTEMS

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INTRODUCTION

Many improvements have been made in production techniques and equipment design in the past few years. These refinements have made recovery of low pressure hydrocarbon vapors practical, both from an ecological and economical standpoint.

Conservation of resources has been a continuing aim of both the crude oil producer and government. Awakening interest in pollution reduction, problems in ecology, and the arrival of an energy shortage have resulted in improved production practices to allow capture and utilization of all produced hydrocarbons.

It is no longer simply a question of economics to justify vapor recovery since government agencies, as a matter of policy, are insisting on conservation of hydrocarbon vapors. Therefore, we must accomplish this as economically as possible. To do this, skid-mounted, completely automated, packaged units become extremely attractive. All engineering and design is provided by the supplier, with minimal installation time and costs.

Experience shows that a rotary compressor has advantages over reciprocating compressors in the compression of wet, sour gas, such as exists in the vapors emitted from storage tanks. It also offers the desired operational characteristics for systems of this type. If high discharge pressures are required (due to higher pressure gathering systems), the use of reciprocating compressors is usually considered. The systems are basically the same. For simplicity, we will discuss only systems using rotary compressors.

BASIC REQUIREMENTS

In the past, two of the more important conditions necessary for design of a profitable vapor recovery system have been: (1) availability of a gas sales outlet with a favorable contractual schedule, and (2) sufficient volume of vapor to justify purchase, installation and operation of equipment.

With the trend toward centralization, larger volumes of vapor are available for processing, and the economic factor has motivated the installation of a number of vapor recovery units. However, an even more influential factor behind the recent upsurge in vapor recovery has been the supplementation of stringent government laws for air pollution and for conservation of hydrocarbons.

Other factors that influence volume of vapor (and consequently whether a vapor recovery unit would be an economic feasibility) are: (1) operating conditions of upstream equipment - higher temperatures and pressures cause higher stock tank vapor volumes, and (2) gravity of crude - vapor losses usually increase as crude gravity increases.

ECONOMIC ANALYSIS

The accurate determination of the amount of vapor available is one of the most difficult problems in the economic analysis of a vapor recovery system. In applications such as recovery of glycol reconcentrator or crude stabilizer overheads, reasonably accurate calculations can be made. However, calculations for determining stock tank vapor rates are subject to variables such as temperature, API gravity and composition of the crude. To facilitate preliminary estimates of stock tank vapor recovery systems, two published methods for determining these rates are presented.

The following equation can be used for preliminary estimate of stock tank vapor rates.

$$Q = C \times Ps$$

Q = Amount of stock tank vapor (SCF/STB).
Ps = Pressure (psig) of last separation stage.
C = Value from Table 1.

TABLE 1

API° GRAVITY	C
35	1.0
40	2.0
45	3.0
50	4.0

Figures 1 and 2 are also provided for the same type of preliminary estimate. Figure 1 is a plot of SCF of vapor recovered per STB crude oil. The data was taken on 23 tank batteries utilizing vapor recovery systems. Although there is wide variation of vapor emissions from lease to lease, the curve does show a trend toward higher emissions as crude gravities increase. Figure 2 is a plot of horsepower requirement vs volume of hydrocarbon vapors compressed for three discharge pressures. Although the curves are smooth, actual horsepower must be selected from standard sizes.

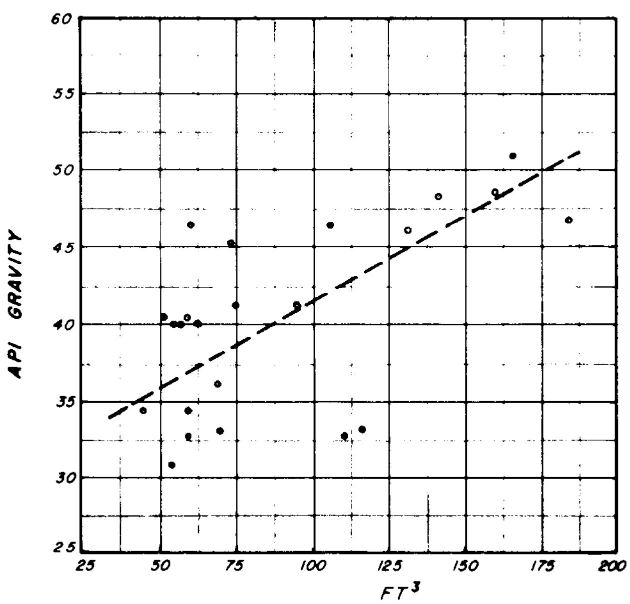

FIG. 1—STOCK TANK VAPOR EMITTED PER BARREL OF CRUDE OIL

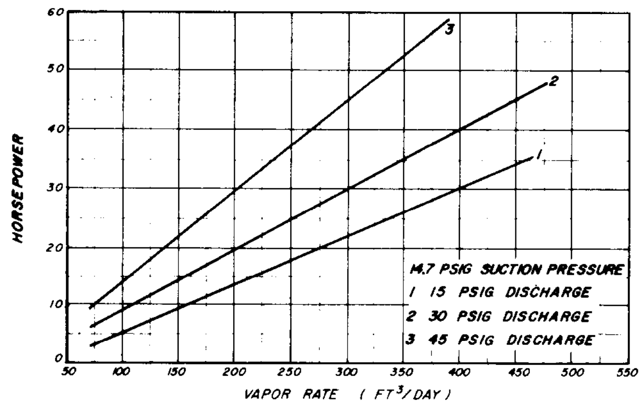

FIG. 2—HP REQUIREMENTS FOR COMPRESSION USING SMALL ROTARY COMPRESSORS

When estimates are complete, field tests should be made, especially in marginal cases. This can be done in two ways.

The first type of test is a 24-hour test under normal operating contitions using a low range recording manometer with an orifice well tester. This method is better than calculation but is open to many errors due to the difficulty of measuring gas flows when the static pressure is in inches of water.

A second method of testing requires the use of a "rental" vapor recovery unit. This method is far superior to other approaches. The gas is compressed to 20-25 psig which greatly improves meter accuracy. Unusual battery conditions can be observed; e.g., fluctuating flows of gas even with steady production of oil, metering, and analyzing of liquids that are carried over with the vapors. This leads to accurate specifications for the required vapor recovery equipment.

Extreme care should be taken to eliminate vapor losses during these tests to ensure that the total volume of vapor available is measured.

APPLICATIONS

While the recovery of vapor from tank batteries is the largest application for these systems, they do have other applications.

These systems may be used for the recovery of all low pressure hydrocarbon or sour vapors within a gas plant or refinery; e.g., glycol regenerators and vent tanks are a source of both H_2S and water vapor. These vapors are a pollution hazard year around and a freezing hazard in winter. Utilizing a vapor recovery unit, these gases can be boosted in pressure and fed to either the fuel gas system or to

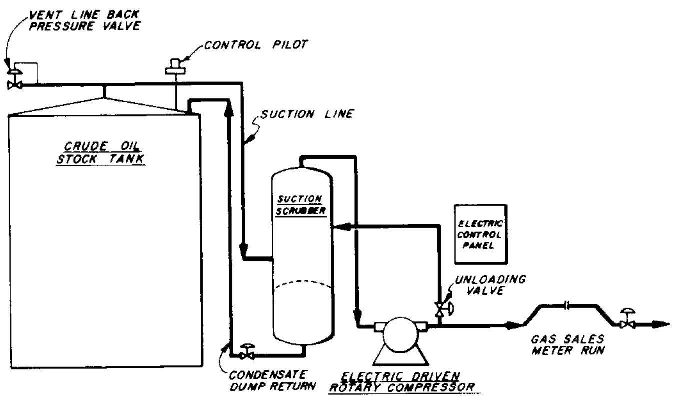

FIG. 3—TYPICAL STOCK TANK VAPOR RECOVERY SYSTEM

the sulphur plant. Similarly, gases from condensate storage tanks can be recovered and boosted to low pressure treaters.

Recovery of overhead vapors from crude stabilization units is another vapor recovery application. Crude oil gravity is controlled and weathering losses in stock tanks are eliminated. A vapor recovery system has an advantage over other methods of processing overhead vapors in that it allows lower operating pressures and temperatures in the stabilizer.

HOW EQUIPMENT WORKS

Most vapor recovery units are available as packaged units, designed to fit the specific operating conditions of the lease on which they are installed. Actual installation normally requires only connection of the suction and discharge piping and addition of necessary power and control circuits. Figure 3 is a typical stock tank vapor recovery flow sheet.

Since horsepower requirements to drive the compressors are in the 5-200 hp range, the use of electric motors, where possible, offers the lowest cost on the initial installation and allows the greatest degree of automation.

Normally, vapor recovery starts when tank pressure reaches a predetermined level, in the range of 2.0 inches of water. The units are designed for the compressor to start at this pressure and continue as long as the pressure is maintained. If the tank pressure drops to a predetermined minimum pressure (in range of 0.5 inches of water), a second pressure switch will shut the compressor down. It is important that positive pressure be maintained in the stock tanks to prevent air from entering the system and also to eliminate the hazard of the tank imploding under vacuum.

To prevent excessive compressor starting and stopping, a well-designed unit utilizes a third pressure switch. This switch, on a pressure reduction to the range of 1.0 inch of water, opens an automatic bypass valve back to the suction scrubber, maintaining system pressure for a short period of time to prevent shutdown. This bypass cycle is controlled by a 3-10 minute timer that will then shut the compressor down if tank pressure does not increase to the design 2.0 inches of water column.

These three pressure switches are incorporated as part of single control pilot. The set pressure of each switch is accurately set by the use of weights (similar to a dead weight gauge). The use of weights eliminates the inaccuracy associated with bourdon tubes and other less sensitive pressure transducers. The pressure pilot is mounted on the top of the tank to eliminate any possibility of pressure drop, liquid sealing, or freezing between the pressure source and the pilot.

Liquid condensation and accumulation in the stock tank vapor lines can be hazardous if they drain directly into the compressor. Therefore, an inlet suction scrubber should be included in each vapor recovery unit. Automatic dump controls and high liquid level shutdown devices are usually incorporated on the suction scrubber to handle this accumulated liquid and to protect the compressor if excessive liquids are encountered.

Compressors are either air cooled or water cooled depending upon the comparison ratio requirements of the individual installation. The compressor design should be such that it will pass some free liquid in normal operation in order that those stock tank gases having high GPM content can be successfully handled. Rotary compressors are designed to pass free liquid at the rate of one gallon for every 35 cubic feet of gas entering the compressor at normal peak efficiency.

Protective and shutdown devices normally employed with this type of fully automated system include controls for high discharge pressure on compressors, high temperature on compressor bearings, and low oil level on force feed mechanical lubricators.

The content of packaging of vapor recovery units starts with a basic design incorporating: (1)

compressor; (2) lubrication system; (3) prime mover; (4) drive, coupling or pillow block jackshaft; (5) water cooling system (if required); and (6) fabricated steel skid.

Options which are available and that will vary for each application are: (1) sour gas modification to compressor design; (2) inlet scrubber (epoxy-coated for sour gas); (3) liquid transfer system; (4) compressor control bypass system for stock tank control; (5) high-level safety shutdown control system for inlet scrubber; (6) in-line speed reducer (in lieu of v-belt drive); (7) steel building constructed on skid; (8) discharge check valve; and (9) control and annunciator panel—electric explosion-proof or pneumatic complete with (a) start/stop push button, (b) power reset button, (c) gauges (high-low suction pressure, high-low discharge pressure, and high-low discharge temperature), and (d) annunciators (power on, outboard bearing temperature, inboard bearing temperature, compressor jacket water temperature, low lube oil, high-low suction pressure, high-low discharge pressure, high-low discharge temperature, H.L.L.S.D. scrubber, vibration, bypass and timer, and spare).

OPERATIONS

Operating problems encountered with this type unit are usually associated with excessive compression ratios, which in turn cause discharge temperatures in excess of 300°F, resulting in premature bearing failure. Where it is not practical to reduce the discharge within the maximum prescribed limit for single-stage compression, a second compressor can be added for two-stage operation. Rotary compressors operate trouble-free at maximum discharge pressures of 45 psig. Single-stage rotaries are still a first choice up to 50 psig; however, increased maintenance costs can be expected.

Proper lubrication is essential for good compressor operation. It is recommended that prelube of the lubricating system be made by manual rotation of the lubrication pump for three minutes prior to any startup after six hours downtime.

The most important maintenance requirement for a rotary gas compressor is correct and proper lubrication; therefore, it is important that the oil used for compressor lubrication be compatible with the hydrocarbon vapor being compressed. A breakdown of the lubricant can result in premature bearing failure and buildup of deposits on the sliding vanes of the compressor to the point of excessive sticking of the vanes and loss of compressor capacity.

We cannot emphasize too much the necessity of sampling and analyzing of wet sour gas that is to be recovered and compressed. The results of the analysis should be presented to the supplier of the lubricant to ensure that the compressor lubricant is compatible with the particular hydrocarbon vapor being compressed.

Through extensive research and development, Hy-Bon Engineering in Midland, Texas has designed and perfected a mechanical method for sealing the main bearings in a rotary designed compressor, thereby allowing this equipment to function in extremely wet and sour gas. The gas compressor is normally furnished of cast iron construction; however, where required, nodular iron is available.

The utilization of a rotary-type gas compressor with internal design for wet sour gas, furnishes an inexpensive method of single-stage compression of low pressure gas, which normally is within the range of 20-50 psig. In conjunction with proper instrumentation, the units are normally installed for unattended operation at crude oil lease storage facilities, although many field gas gathering operators are utilizing the basic design to facilitate gas gathering line booster service.

The automatic features and few moving parts coupled with low investment costs are making low pressure vapor recovery compressors a common sight in the oil and gas industry.