Economics of Stock Tank Vapor Recovery

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Historical

The advent of complete, economical utilization of crude oil has changed the field handling of production from open-pit storage to a nearly complete lease processing of produced hydrocarbons. In conventional installations the well stream is divided into stabilized hydrocarbon fluid, gas, water and residue. The hydrocarbon fluid is collected by a final separation in stock tanks which are atmospheric-pressure, ambient-temperature receiving vessels. Water and residue are removed at the battery site. Impurities, such as sulfur and carbon dioxide, are removed by sweetening and stripping equipment. The resulting crude storage, being under atmospheric control, experiences losses of volatile components in many installations. During warm periods vapor is expelled, through evaporation, with a loss in saleable hydrocarbons. During cool periods air is inhaled by the tank and creates a corrosive and more explosive atmosphere. In addition, this vapor loss results in gravity reduction of the stabilized oil. There have been reported several techniques that aid in the reduction of vapor loss and gravity reduction; and of these techniques, vapor recovery through the use of auxilary skid-mounted compressor-operated recovery units have received considerable acceptance.

Purpose of Study

It is then advantageous to examine factors concerned with the economics and design of such equipment and to ascertain any advantage available in the installation and operation of various types of vapor recovery processes in various lease operations. Essentially, utilization of vapor recovery equipment is dependent upon the following:

(1) Size, type and condition of existing tank battery installations
(2) Well stream composition and composition of tank vapor
(3) Market demand for various fluids and vapors available from the battery.
(4) Cost and maintenance of vapor recovery equipment, viz., "payout"
(5) Terms of existing gas contracts
(6) Processing temperature and pressure at the battery
(7) Pressure requirements of the gas-gathering system
(8) Safety reasons, fire and explosion hazards and nuisance considerations

Definition

To further pursue this subject it is to be understood that a vapor recovery process is any technique or techniques that conserve vapors and gas liquid content of a produced hydrocarbon liquid. This conservation effort may be introduced at any point in the handling or processing of the hydrocarbon (since this loss is a function of volatility), but more specifically the conservation measure is initiated at the tank battery or well.

BASIC PRINCIPLES

Stock-tank Vapor Composition

To provide attractive "payout" periods, crude oil systems adaptable to vapor recovery should be relatively rich in natural gas liquids. Crude oils usually have a predominant amount of these heavier volatiles; whereas condensates are often poor in these fractions. Table 1 illustrates the predominance of the heavier fractions in crude oil (1, 2).

TABLE 1
Selected Values of Gas-Condensate and Oil-Field Hydrocarbon Systems

Component	Mole Percent[1]					
	A	B	C	D	E	F
C_1	48.83	64.36	76.90	77.41	87.07	95.85
C_2	02.75	07.52	07.70	11.48	04.39	02.67
C_3	01.93	04.74	03.35	05.31	02.29	00.34
C_4	01.60	04.12	03.50	02.30	01.74	00.52
C_5	01.15	02.97	02.10	00.97	00.83	00.08
C_6	01.59	01.38	01.50	00.54	00.60	00.12
C_7	42.15	14.91	00.36	00.10	03.80	00.42

Component	Weight Percent[2]	
	G	H
C_1, C_2, C_3, C_4	15.2% @ 3000 psig and 01.19% @ 12 psig	03.11
C_5, C_6, C_7+	84.8% @ 3000 psig and 98.9% @ 12 psig	96.89

	A	B	C	D	E	F
mol-wt of C_7+	225	181	130	116	112	157
GOR in SCF/BSTO	625	2000	--	--	182000	105000

Tank Gravity;
API 34.3 50.1 -- -- 60.8 54.7 -- 52.3

A - black oil sample
B - volatile oil sample
C - condensate sample, Bacon Lime formation, East Texas
D - condensate sample, Paradox formation, test made on non-commercial reservoir, San Juan County, Utah

E - dry gas sample
G - midcontinent crude oil sample, values taken at 3000 psig and 12 psig
H - crude oil sample, Regasus, Texas, 8 psig RVP

[1] Mole percent data taken from Tables 2.1 and 2.7, Craft and Hawkins, Applied Petroleum Reservoir Engineering, Prentice-Hall, 1959, pp. 60 and 87

[2] Weight per cent data extracted from Table 4-5, Nelson, Petroleum Refinery Engineering, 4th ed., McGraw-Hill, 1958, p. 93

Table 2 shows an analysis of separator gas produced in the Goldsmith, Texas area. It is noted that this separator gas is predominantly methane and ethane with some propane, but these light fractions are removed prior to storage. Table 2 also shows an analysis of

Table 2

Fractional Analysis of Hydrocarbon Well Streams

SAMPLE	ANALYSIS, VOLUME PER CENT				
	C_1	C_2	C_3	$C_{4's}$	C_5+
Goldsmith Separator gas [1]	75.04	10.99	5.63	2.22	1.29
Stock tank vapor Azalea-Strawn Field, Midland Co., Texas[1]	3.08	16.05	39.76	29.57	10.69

[1] Analysis provided by Phillips Natural Gasoline Department, Odessa, Texas.

Azalea Strawn stock tank vapor and indicates a high volume of heavier hydrocarbons. Hagen and Weldon (3) list the fractional composition of a typical stock tank vapor (Table 3). Their analysis indicates that more than three-fourths of the stock tank vapor tested was natural gas liquid (23.89 GPM). In addition Table 4 illustrates the low liquid recovery often obtained from condensate streams.

Table 3

Mol Percent Composition of a Typical Stocktank Vapor [2]

Component	Mol Percent		GPM
CO_2	0.08		
N_2	0.60		
C_1	6.56		
C_2	14.85		
C_3		38.38	10.52
iC_4		5.51	1.80
iC_4		21.32	6.71
iC_5		3.69	1.35
nC_5		5.06	1.83
C_6+		3.95	1.68
	22.09	77.91	23.89
	100.00		

G = 1.70

[1] after Hagen and Weldon (Ref. 3)

Table 4

API Gravity; and Liquid Recoveries Obtained from 172 Gas and Gas-Condensate Fields [1]

GPM	API	Number of Fields	Percentage
0.4		57	33.1
0.4 to 0.8		55	32.0
0.8 to 1.2		32	18.6
1.2 to 1.6		10	5.8
1.6 to 2.0		5	2.9
2.0		13	7.6
		172	100
	40	3	1.8
	40 to 45	6	3.6
	45 to 50	24	14.6
	50 to 55	47	28.5
	55 to 60	49	29.7
	60 to 65	30	18.2
	65	6	3.2
		165	100.0

[1] This material adapted from Table 2.2, Craft and Hawkins, "Applied Petroleum Reservoir Engineering, Prentice-Hall, 1959, p. 63

This table shows that, for 172 gas-condensate fields, 65.1 per cent of these fields yielded gas liquid recoveries ranging from less than 0.4 GPM to 0.86 GPM. 18.6 per cent of these fields yielded from 0.8 to 1.2 GPM recovery, but only 16.3 per cent of these fields yielded GPM values in excess of 1.2 (1).

Conventional Separation

Conventional separation techniques will not be considered in detail here. Suffice it to say that such techniques involve the surface handling of crude oil and gas including a combination of the following:

(1) Separation of water from oil
(2) Separation of hydrates from gas
(3) Separation (including staging) of gas and oil
(4) Storage of oil
(5) Metering and transfering of hydrocarbons from site

The significant observation is that, during these various separations and treatments, conventional handling of the fluids allows escape of gaseous hydrocarbons, especially in heater-treater operations and stock-tank storage; and if this loss is sizable an additional source of revenue has been overlooked. It might also be suggested that a hard look at the phase characteristics of the well-head fluid will dictate better separation of gaseous hydrocarbons through more efficient utilization of stage separation and crude stabilization. This latter consideration may be made in addition to those concerned with vapor recovery.

Hydrocarbon Losses

Because most storage facilities are equipped with near-atmospheric venting devices that expel vapor or inhale air to maintain tank rupture or collapse specifi cations, most vapor losses occur while crude is in storage This vapor loss is due primarily to evaporation; but in addition, strong prevailing winds can "trip" the venting devices and allow escape of appreciable volumes of vapor (4,5). In summary, vapor losses may occur as:

(1) Breathing (in and out) losses
(2) Standing-storage losses
(3) Filling losses
(4) Emptying losses
(5) Wetting losses
(6) Boiling or "rolling" (weathering) losses

When consideration is given to the effects of daily temperature and pressure changes on a typical storage tank it becomes evident that storage and breathing losses constitute the focal point on which to base vapor recovery and gravity conservation.

BASIC CONSIDERATIONS OF VAPOR RECOVERY SYSTEMS

Definition

The process has been defined and is schematically represented in Figure 1. Equipment-wise, the system may contain (1) vapor-gathering and discharge lines (2) auxilary vessels for liquid scrubbing and transfer (3) compressor and compressor drives, and (4) pressure and equipment-control devices.

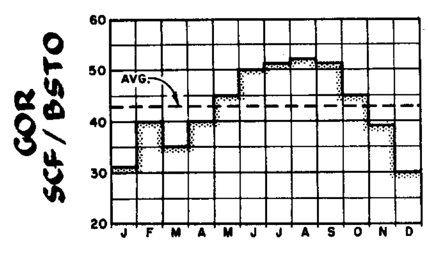

Fig 1 - Variation in stock-tank GOR (Ref. 3)

Requirements of a Vapor Recovery System

To provide optimum oil-field service, a vapor recovery system should meet the following conditions:

(1) Economical in purchase, installation and operation
(2) Automatic in operation under varying loads
(3) Easily and economically maintained with a long service life
(4) Resistant to corrosive elements
(5) Attractive payout
(6) Presentation of an additional source of revenue

On the basis of current figures, vapor recovery units generally payout original investment in 4 to 8 months By the same token, a tank battery losing vapors rapidly enough to pay out a recovery unit in 6 months, (an investment averaging \$3000 to \$3500) is then losing \$6000 to \$7000 revenue per annum.

In addition to economic considerations, a vapor recovery system must offer flexible automatic operation so that wide variations in vapor volumes may be handled. An example of this variation is shown in Figure 2. Automatic operation, as shown in Figure 3, must be controlled by a very small pressure range that does not exceed collapse or rupture pressures of the tank.

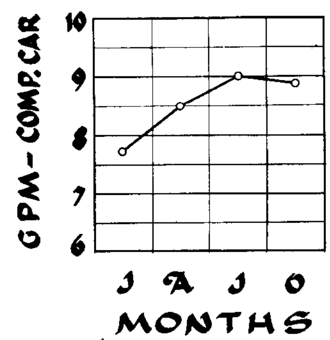

Fig 2-Variation in Stock-tank GPM (Ref. 3 also)

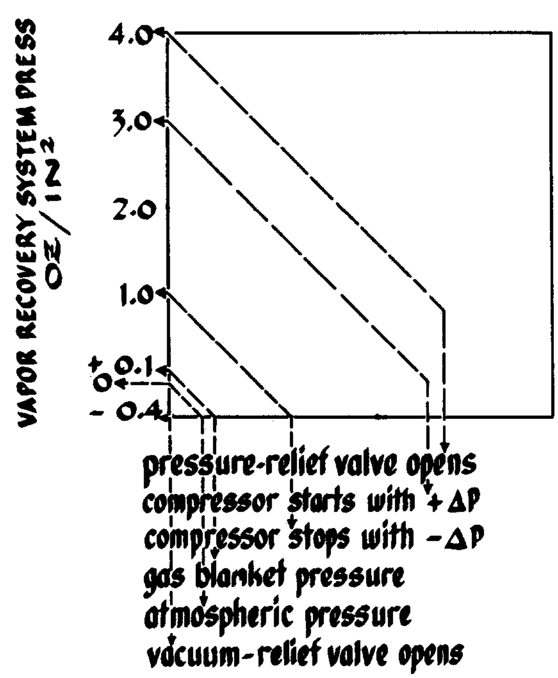

Fig:3 VRU Pressure Control Levels, (After Ref. 7)

A vapor recovery unit should be flexible not only so it will be adaptable to another tank battery, but also so belt, sheave, and motor changes will provide changes in compressor capacities.

Because vapor recovery systems are essentially small auxiliary process equipment, careful design must be applied to sizing and equipment selection. To insure optimum compressed vapor delivery, a compromise must be made between peak and minimum volumes. The two design factors of most importance are (1) the vapor volume, and (2) the GPM content of the vapor.

Justification for Installation of Vapor Recovery Equipment

Economic justification of vapor recovery equipment rests upon the net gain resulting from comparison of sales revenue with investment and operating costs of recovery equipment. Sources of revenue are:

(1) Residue gas sales resulting from vapor collection
(2) Natural gas liquid sales resulting from vapor recovery
(3) Removal of pipe line penalty from sales of stabilized oil by gravity increase or decrease
(4) Additional revenue from non-prorated recovery.

However, factors that can deduct from such revenue are:

(1) Excessive gravity reduction because of vapor collection
(2) Installation cost of vapor recovery equipment
(3) Cost of equipment maintenance and operation
(4) High and low API gravity fluids and their respective vapor yields.

The factors that govern revenue received from vapor recovery sales are:

(1) Vapor volume available
(2) Amount of natural gas liquids available from vapor
(3) Accuracy by which volume and GPM is measured
(4) Contractual agreement and/or market demand.

Additional factors that contribute to justifying utilization of vapor recovery equipment are:

(1) Reduction or elimination of deck corrosion of a stock tank by eliminating oxygen from the vapor space
(2) Removal of undesirable and/or harmful gases from the surrounding atmosphere
(3) Elimination of atmospheric venting contributing to the distribution of hydrocarbons that might cause explosions in the stock tank vapor space and/or low-lying areas near the battery
(4) Conservation of energy sources previously lost to the atmosphere.

In summary, a vapor recovery system may be justified on the basis of all or any one of the following reasons:

(1) To prevent volume loss of stock tank oil. This loss is reduced because weathering is reduced since "weathered" crude may then release its vapor to a gathering system rather than to the atmosphere.
(2) To prevent API gravity loss due to venting
(3) To increase low API gravity by re-charging scrubber ends from a vapor recovery unit back to stock tank
(4) To reduce high API gravity by vacuum stripping of separator liquid in conjunction with a vapor recovery system
(5) To recover gas, previously vented
(6) To increase the GPM content of the sales gas by mixing compressed vapor with separator gas
(7) To use, initially, a vapor recovery unit as test equipment for determining other applications of vapor recovery systems
(8) To constitute vapor recovery as unprorated production, additive to established allowable production.

Basic Types of Vapor Recovery Systems

Basically, vapor recovery systems are compressor-operated systems. Eduction techniques are the exception and such methods are still experimental. The compressor systems available for tank battery service are basically:

(1) Dry-seal systems for gravity conservation and control
(2) Wet-seal systems for gravity conservation and control
(3) Vacuum stripper equipped wet-or-dry sealed systems for gravity control
(4) Casing annulus systems for well-head fluid level reduction.

Figures 4 and 5 show schematic diagrams of the dry-seal and wet-seal recovery units.

In general, three types of compressors are in use:

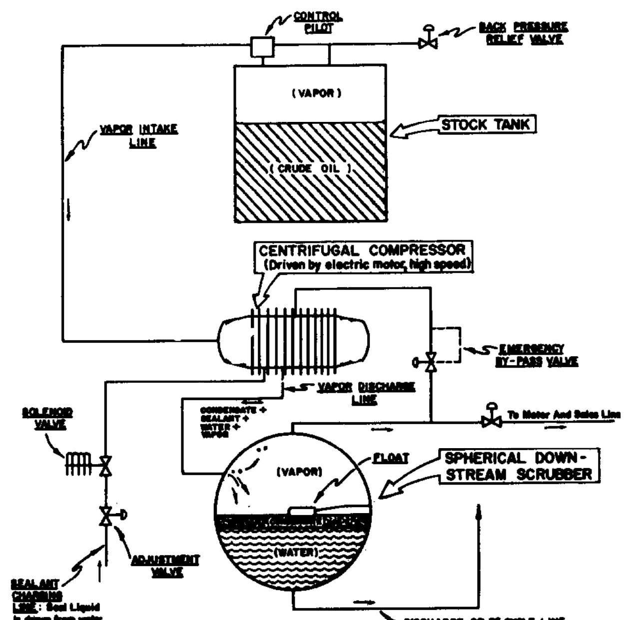

Fig. 4
Wet-Seal Recovery Unit

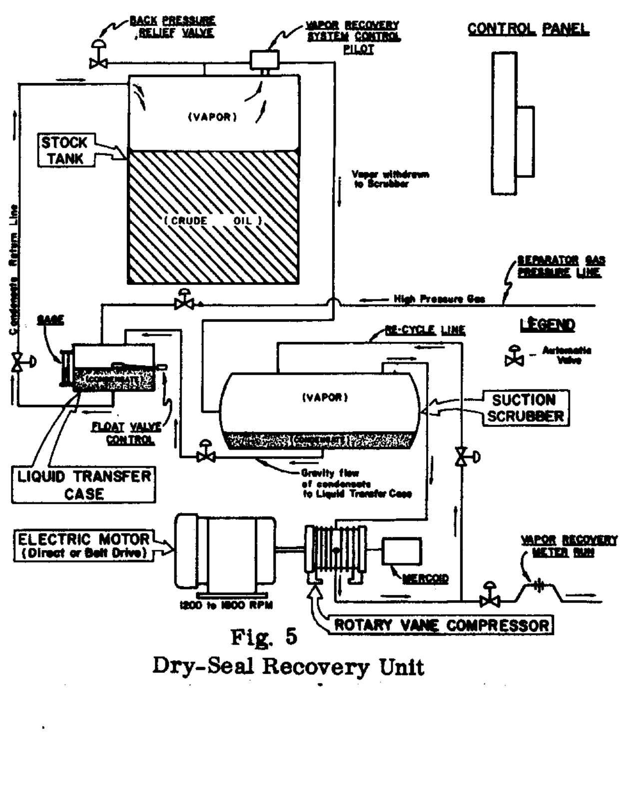

Fig. 5
Dry-Seal Recovery Unit

(1) Centrifugal fluid-seal compressors (wet-seal)
(2) Rotary-vane positive-displacement gas-seal compressors (dry-seal)
(3) Reciprocating compressors

Wet-seal compressors require stock-tank sealant for operation, while dry-seal rotary compressors move gas by positive displacement. For small vapor recovery units the centrifugal and rotary compressors are often employed. For field-size gathering requirements large reciprocating compressors are often used. However, prevelant liquid "slugging" may damage these units. The prime movers for these compressors include (1) electric motors, (2) gas-driven turbines, and (3) internal combustion engines. Electric motors are more often used while the availability of high pressure separator gas affords utilizing the turbine. The undesired use of rich vapor-laden gas as fuel sometimes discounts the use of internal combustion engines.

Dry-seal units require upstream scrubbing. Displacement is directly proportional to pressure and maintenance costs are not extreme. The rotary-vane compressor also has a wide range of optimum efficiency and is driven at a relatively low rpm.

The wet-seal units require heavy oil as a power fluid and are hampered by a narrow range of reasonable efficiencies. In addition, they require high rpm speeds; and scrubbing of sealant is required downstream.

Casing annulus units are designed to reduce foaming fluid heads and thereby reduce back pressure on the well. Vacuum units are utilized to place produced fluid under vacuum and thus reduce API gravity of the stock tank in conjunction with commingling this fluid with lower gravity production. The vapor recovered by vacuum withdrawal is then collected by a conventional vapor recovery unit.

The eductor, or jet pump technique, is still experimental. It appears that the motive gas (separator gas) requirements are too great for the average installation. It is reported (6) that 5 lb of motive gas would be required per pound of suction gas (stock-tank vapor) at 150 psig separator gas pressure, 20 psig discharge pressure, and 14.7 psia suction pressure.

In summary, a "standard" vapor recovery unit will consist of the following equipment: (1) compressor and prime mover; (2) pilot controls, pressure relief valves, switches and control panel; (3) scrubber, upstream or downstream; (4) liquid transfer case (dry-seal); (5) force-feed lubricator, and (6) skid and piping.

DESIGN OF VAPOR RECOVERY SYSTEMS

Factors Favorable for Installations

Conditions favorable for the installation of vapor recovery systems include (1) tank battery consolidation because of unitization, replacement, etc.; (2) automatic custody transfer; (3) richness (GPM) and volume of vapor; (4) market demand; and (5) elimination of atmospheric venting. Of these considerations the last two are the most important. Automatic custody transfer enhances consolidation, but in any event market demand establishes price.

Measurements

Vapor volume is usually estimated by venting vapors through an orifice well tester. It is an understatement that this test is inaccurate, for the 24 hr test period, i.e., in winter time, may not be representative of vapor delivery. Furthermore, leakage of tank hardware contributes to low readings. The four-ounce back-pressure during testing yields an unrealistic volume estimate because vapor expulsion will occur at lower pressures, and thus deliver greater vapor volume. Usually a design factor of 1.5 to 2.0 must be used as a multiplyer of test volumes for proper unit sizing. There is evidence that positive displacement meters, pressure and temperature compensated, may provide more accurate readings.

Richness of a vapor is established by either standard charcoal or test car results. However, because the upper limit of the charcoal test is around 1.26 GPM, use of the compression test car measurement is more satisfactory. Richness, hence, price, is based on GPM.

In estimating vapor volumes it is well to anticipate field expansion, penalty GOR wells, utilization of miscible recovery processes, increase or decrease in number of wells serviced by a battery, changes in field allowable, utilization of secondary well equipment such as gas lift, and alterations in quality of the vapor because of a change in overall received oil content.

Selection of Vapor Recovery Units

Selection of vapor recovery equipment centers around compressor capacity and required horsepower. This selection should be based on:

(1) Volume requirements (with necessary design allowances)
(2) Discharge or differential pressure
(3) Type of liquid in vapor stream, especially with regard to liquid and corrosive element content
(4) Availability or necessity of proper compressor sealant.

Design Criteria

The vapor gathering system, especially piping, should be kept at a minimum to avoid excessive pressure reduction requirements. The system must usually operate between 4 oz/sq in. and -0.4 oz/sq in. (7), as illustrated in Figure 3. Hagen and Weldon (7) suggest that total pressure drop of the system not exceed one-tenth of the maximum operating pressure of the recovery system. They further suggest utilizing a variation of the Spitzglass formula for estimating pressure losses in vapor recovery systems:

$$h = \frac{0.0794\ Q^2 SL\ (1 + \frac{3.6}{d}) + 0.03d}{d^5}$$

where:

h = pressure drop in in. of water column
Q = vapor flow rate, MCF per hr
S = specific gravity of vapors, $G_{air} = 1.0$
L = length, in ft, of gathering line
d = inside diameter of gathering line, in.

To prevent blocking from accumulations of liquid slugs, lines should slope from the stock tanks toward the compressor. Location of motor controllers, etc., should be such that no safety hazard is developed.

The liquid scrubber should be sized so gas velocities on it suction side are low; and it should be equipped with automatic dumping controls and a liquid-level shut-down switch. To prevent icing, it may be necessary to provide a heating cable for the dump valve. Selection of an upstream or downstream scrubber depends on compressor selection, as previously described.

The control panel and auxilary equipment constitute.

the "nerve-center" for a recovery unit. The compressor and its drive constitute the "heart" of the system.

When possible, it is prudent to vent low-pressure residue gas to the stock tanks to provide an oxygen-free, corrosion-free atmosphere for tank vapor space. In most cases, this residue gas blanket will be unavailable, especially when producing and when plant properties are separately owned or geographically remote, or when sour gas is produced. However, vapor-space filling by stock tank vapor evolution should, in most cases, provide more corrosion protection, in conjunction with a recovery system, than will an oxygen-vapor vapor space.

Economic Considerations In the Design and Selection of Vapor Recovery Systems

For rotary, air-cooled compressor-operated systems, initial cost versus capacity is a linear function with approximately $2500.00 representing base price. On the other hand, the data for centrifugal compressor-operated units is not linear. Also, centrifugal compressor rpm requirements show a need for more horsepower per unit mcf of vapor discharged. This need adds to the cost.

Contractual agreements and market demand decide all other economic considerations. No set contract price exists; however, it is prudent to seek petrochemical outlets.

Design Schedule

The following considerations may be made when selecting a vapor recovery unit:

(1) Using a suitable orifice well tester design factor (1.5 to 2.0), estimate vapor volume, including surge, continuous, intermittent flow, etc. into the battery
(2) Establish discharge pressure requirements for the battery
(3) Determine compressor capacity, horsepower requirements, etc. and select compressor motor and auxilary equipment
(4) Calculate horsepower cost under continuous load:
Dollar cost/month =
$$\text{hp}\ (.746)\frac{\text{kw}}{\text{hp}} \times \frac{720\ \text{hr}}{\text{month}} \times \frac{\text{dollar rate}}{\text{kwh}}$$
(5) From contractual agreement, etc., estimate anticipated vapor sales, e.g.,
$$1.00\ \frac{\text{contract price}}{\text{MCF}} = .15\ \frac{\text{residue gas}}{\text{MCF}} + .85\ \frac{\text{natural gasoline}}{\text{MCF}}$$
(6) Estimate payout for unit:
$$\text{Net Payout} = \frac{\text{(Cost of unit)}}{\text{(Revenue-operating costs - royalty)}}$$
For a 69 MCFPD vapor volume, using a 25 hp motor with a $4897.61 unit (including installation), gross payout would be 7.39 months and net payout would be 8.7 months.

Profitability

The producer's value of vapor sales is a product of MCF, GPM, plant efficiency, percentage share, and price per gallon variables. The seller's share may range from 25 to 60 per cent. Total value of recovered vapor will generally be based on total liquid content and any residue gas remaining. Test content may be based on test car analysis or fractional analysis.*

One contractual agreement, with an example calculation, in use is as follows:

Premises	Example
Volume of stock-tank vapor recovered	46 MCFPD
Test car liquid content	6.08 GPM
Price, per gallon of gasoline, as based on casinghead contract	6.95¢/gal (36° API basis)
API gravity of raw gasoline (use factor of 18.5 per cent per API regulator paragraph 7-A-3)	130°
Plant size factor (between 30,000 and 40,000 test gal)	30%

Payment:

(15.50¢ per MCF)

$$\frac{¢}{\text{MCF}} + \frac{¢}{\text{MCF}}\ \text{Plant Size Factor} + \text{gravity or LPG payment in ¢/MCF} = \text{Total content payment per MCF}$$

thus:

15.60¢ + 4.68¢ + 8.74¢ = 29.02¢

also:

Total content payment per MCF x Vapor Volume, MCF = $/day for test content of vapors

thus:

(29.02¢) (46 MCFPD) = $13.85/day

ROLE OF STATE REGULATION

In philosophy and in practice, the collection and utilization of stock tank vapors constitute a relatively new form of petroleum conservation. No statutory stopgap, hindering vapor recovery, is evident at this time. Only condensate returned to the stock tank is charged against allowable, and this volume of liquid is relatively small and is often balanced by fluid shrinkage because of vapor withdrawal. To date there have been no regulatory directives related to gravity reduction or increase.

INDUSTRY APPLICATION OF VAPOR RECOVERY SYSTEMS

The following paragraphs describe various installations utilizing stock tank vapor recovery.

A West Texas operator is presently handling between 2600 to 2700 bbl of 52° gravity production per day. By combining 5 in. of mercury vacuum pressure with heat treating, a gravity reduction of 2° has been obtained. This reduction in gravity has changed the stock tank crude price from $2.81 per bbl to $2.85 per bbl, based on pipeline penalty postings. In addition, a 35¢ per MCF price is being received for vapor sales (tank GOR is 30:1), or an additional $.0105 per bbl. The per barrel increase is $.0605 over original sales and represents a $101 dollar increase in sales. At present this operator plans to combine his vacuum stripping-vapor recovery system with commingling of low and high gravity crudes.

Atlantic's Block 31 vapor recovery system adds approximately $200,000 in revenue per year. Richfield oil in the North Coles Levee Field reported 17,000 MCF of tank vapors contained 244,800 gal of liquid from 524 bbl of crude during January 1951. In the Russell Rank Unit, Cuyama Valley, California, 8500 MCF of vapor were recovered from 484,600 bbl of crude, yielding 91,800 gal of liquid. Stock tank GOR

*Fractional analysis basis for test content is relatively new and is being used by newer gasoline plants.

was 18 SCF/BSTO and a 25 hp motor, driving a 12 x 9 horizontal, single-cylinder compressor was used in the collection system.

A summary of these and other operations is shown in Tables 5 and 6.

Table 5

Summary of Vapor Recovery System Operations (Selected)

Type of Operation	Remarks	Economics
Vacuum Stripper (5-in. Hg.) with rotary compressor-operated vapor recovery system	52° API oil reduced to 50 API oil oil plus vapor sales	4¢ increase in crude price per bbl plus 35¢ per MCF vapor tested at 30 SCF /BSTO. Total revenue increase was reported as 4.1¢ per BSTO or $101 increase per 2000 bbl run
Atlantic, Block 31 Project		$200,000 additional revenue per year
Richfield Oil Corp., North Coles Levee Field, Calif.	17,000 MCF vapor from 524,000 bbls crude for 32 SCF/ BSTO[1]	244,800 gal. nat. gas liquid recovery. Avg. liquid content: 14.4 GPM, ZIRVP (3.75 gal. gasoline) 4.55 gal. butanes, 6.10 gal. propanes)
Russell Rank Unit, Cuyama Valley, Calif. VRU was 25 hp-operated compressor, operating between 5-in. vac. & 30 psi discharge, using 12 x 9 horiz., single-cylinder unit	8500 MCF vapor recovery from 484,600 bbls crude (Jan. 1951) 18 SCF/ BSTO	91,800 gal. liquid recovery. Contained 3.90 gal. of 21 RVP gasoline, 3.40 gal. butanes, 3.50 gal. propanes (10.80 GPM)
Newhall-Portero Field, Calif. (Sunray), conventional VRU plus stage separation	13149 MCF vapor recovery from 254,800 bbl crude, Oct 1951, 52 SCF/BSTO	
Guijarrel Hills Field, Calif.	March 1960- Jan. 1951 136,900 MCF vapor recovery, 1,446,157 gals. isobutanest.	liquids: $86,769 Stripped gas: $14,238 $101,007
Oak Canyon Field, Calif. (Western Gulf Oil Co.)	212,400 MCF recovery containing 2,010,000 gals. C_4t+ liquid, April 1946 - Sept 1950	
Magnolia-Smackover Field, Ark., (Atlantic)	17,500 bbls prodn per day on LACT, 40° oil, 15 psig - 75° F separation 700 MCFPD recovery of vapor from 38 SCF/ BSTO per day	Unit cost: $15,000 Net Income: $125,000 first year
Atlantic State "T", Denton Field, N.M.,	1100 bbls of 45° oil per day, 35 SCF/BSTO 15 psig - 110 °F separation, 40 MCFPD recovery	VRU cost: $4700 payout: 2 months Net Income: $9000 for 1st year operation
Phillips Refinery Okmulgee, Okla. liquid-seal rotary compressor	3 - 55,000 bbl (gasoline) cone roof tanks, 8-13 RVP finished fuel	$40,000 income 1st year
Goldsmith, Texas 175 MCFPD capacity dry-seal unit @ 18 psig discharge	37° API crude, 5000 BSTO/D, 8GDM test est. at 69 MCFPD vapor recovery	32¢/MCF net payout: 8.2 months $41.00 vapor recovery revenue per day

1 GOR values apply to stock-tank oil only, not well head fluid.

Table 6[1]

Economic Features of Stock-Tank Vapor Recovery in the Denver Basin (9)

Table 6A

Equipment, Operating Conditions and Costs

Area	VRU [2]	Production
Little Beaver "D" Sand Unit	5 HP Sliding-vane, direct-drive, 100 MCFPD design capacity, 4 oz suction to 8 psig discharge	2000 BPD, gas granity - 1.900
Big Beaver, Unit	30 HP Sliding-vane direct-drive Unit, 415 MCFPD design capacity, 15 psig suction to 39 psig discharge	1900 BPD, gas gravity 1.335
Plum Bush Creek Unit (2 VRU)	20 HP Sliding-vane, belt-drive unit, 250 MCFPD design capacity, 4 oz suction to 24 psig discharge	9100 BPD, gas gravity 1.710

	30 HP Sliding-vane, belt-drive-unit, 400 MCFPD design capacity, 4 oz. suction to 24 psig discharge	
Little Beaver East Unit	5 HP Double - impeller belt drive, 50 MCFPD design capacity, 4 oz. suction to 7 psig discharge	1200 BSTO, gas gravity - 1.840
Kejr Unit	5 hp double - impeller belt - drive unit, 50 MCF/D design capacity, 4 oz suction to 7 psig discharge	1200 BSTO, gas gravity - 1.775

Vapor Production	VRU Cost
88 MCFPD	$1975, $395/HP
415 MCFPD	$3980, $133/HP
210 MCFPD	$4450, $222/HP
430 MCFPD	$5300, $177/HP
740 MCFPD	$9750.00
43 MCF/D	$620.00 @ $124/HP
48 MCF/D	$600.00 @ $124/HP

Table 6B

Economics and Profitability

Area	Plant Costs	Plant Income	Producers Cost	Producer Income
Little Beaver "D" sand Unit	Investment $1525 Installation 450 $1975 Operating Costs/Mo. $ 30 Total $2005	LACT gas vol. 88 MCFPD Test Content 25 GPM LPG Price 4.5 ¢ gal Residue Gas 16 ¢/MCF Gross LPG Income $2250.00/Mo Gross Residue Gas Income $140.00/Mo. Total Gross Income 2390.00/Mo.	$0	After royalty: Gas Volume 88 MCFPD Test Content 25 GPM LPG Sales 4.5 ¢/gal. Residue Gas Sales 14.0 ¢/ MCF Gross LPG Income $660.00/Mo. Gross Residue Sales $105.00/Mo. Total $765.00/Mo.
	VRU Payout period (before taxes and depreciation) 0.8 mo.			
Plum Bush Creek Unit	Investment $8750 Installation $1020 $9770 Operating Costs/Mo $ 230 $10,000	LACT gas vol 210 MCFPD Treater gas vol 430 MCFPD (Vapors) LACT test content 27.8 GPM (Vapors) Treater tes content 9.9 GPM LPG Price 4.5 ¢/gal Residue Gas Price 16.0 ¢/MCF Gross LPG Income $10,355/mo. Gross Residue Income $1010/mo. Total Gross Income $11,365/mo.	$0	After Royalty: LACT gas vol. 210 MCFPD Trtr gas vol. 430 MCFPD LACT vapor test content 27.8 GPM treater vapor test content 9.9 GPM LPG Sales 4.5 ¢/gal Residue Sales 16 ¢/MCF Gross LPG Income $3020/mo. Gross Residue Income $775/mo. Total $3795.00/mo.
	VRU payout period (before taxes and depreciation) 0.9 mo.			
Little Beaver East Unit	Investment $470 Installation $150 $620 Operating Exp. per mo. $ 30 $650	LACT gas vol. 43MCFPD Test Content 26.5 GPM LPG price 4.5 ¢/gal. Residue gas price 16.0 ¢/MCF LPG Gross Income $1170/mo. Residue Gross Income $70/mo. Total $1240.00/mo.	$0	LACT Gas Volume 43 MCFPD LACT test content 26.5 GPM LPG price 4.5 ¢/gal. Residue gas price 14.0 ¢/MCF LPG Gross Income $340/mo. Residue Gross Income $ 50/mo. Total $390.00/mo.
	Payout Period for VRU before taxes and depreciation 0.5 mo.			

1. Data based on Blevins and Van Matre's paper, Reference 9, published in Oiland Gas Journal and originally presented at NGPA meeting, Billings, Montana, September 1961 as "Lease Stock Tank Vapor Conservation".

2. VRU - Vapor recovery unit

SUMMARY

Vapor recovery systems are generally economical, afford a new means of petroleum conservation, and are fast approaching the point of becoming standard equipment on most large tank batteries.

The economic feasibility of this form of recovery is dependent upon the quantity and quality of vapor, on contractual agreements, on market demand for natural gas liquids, on the limiting consequence of base price for a recovery system with respect to vapor volume, on transmission costs, and on reasonable payout.

The recovery system must be economical in installation and operation and must offer continuous, automatic operation. Tank batteries, so equipped, must likewise be kept in good condition. The use of the system will enhance the life of the battery.

Justification of vapor recovery units is generally based on economic factors. Units, in some cases, may also be fully justified on the basis of safety and the presence of obnoxious or unhealthy fumes released by venting.

At present, five basic systems, as described, offer reasonable field adoption. These systems include wet-seal and dry-seal compressor units, adjunct vacuum stripping equipment, compressor units, and casinghead units.

The design and installation of recovery units are enhanced by battery consolidation, automatic custody, large volumes of rich vapor, and market demand.

If payout is used as an index of economic justification, net payout should be appraised in preference to gross payout in order to include operating expenses and royalty payment.

Since the 1920's vapor recovery systems have been used in some form or fashion and with continuing success. These systems are now being introduced into West Texas, and every effort should be made to economically adapt the systems to various tank batteries.

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