# Dehydration and Development of Dry - Desiccant Wellhead Adsorption Units

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ABSTRACT

Vapor-phase water in low-enough concentrations is relatively harmless in a natural-gas gathering and transporting system. It is the liquid-phase water which causes all of the difficuties experienced. The usual trouble caused by liquid water is the formation of gas hydrates; everyone is familiar with the so-called freezing of gas lines and equipment in cold weather. Another trouble which is somewhat more obscure than hydrate formation is internal corrosion of the pipe. Elimination of liquid water from a gas-handling system effectively prevents the formation of hydrates and corrosion.

Extensive laboratory research and field testing have resulted in the development of a new, small, short-cycle, dry-desiccant adsorption unit for gas wellhead applications. A fully automatic, self-contained and skid-mounted unit may be used to dehydrate the gas. No external source of energy, other than the gas stream which is to be dehydrated, nor external cooling medium, such as water or gas, is needed.

## INTRODUCTION

The problems of the oil field are basic. Petroleum is a natural resource. Its occurence can be explained. It can be prospected for and found. It can be identified and classified. Once it has been found and classified, the extent of its occurence can be determined. When the character and the extent are known, it can be brought to the surface pretty well as required by demand. Once on the surface, its actions and personalities can be told. The market exists. The buying specifications are known. The price can be arrived at. Economics fall into place. With the growth of the natural gas market, dehydration and methods of dehydration have become a major consideration of the industry.

## LIMITATIONS OF CONVENTIONAL METHODS

### Simple Heater and Separator

This wellhead production process is basic and is the conventional production assembly on most natural-gas wells. The gas stream from the well is heated in order that the pressure may be reduced to that in the separator without the formation of hydrates. The temperature of hydrate formation is the limiting condition of such a system.

Gas from the separator of such a system is saturated with water and hydrocarbons at the temperature and pressure of the separator, and any further reduction in the temperature will result in the condensation of liquids, both water and hydrocarbon, in the pipeline. Considering the example of a separator operation at 1000-lb pressure, the lower limit of temperature at which it may operate is something of the order of 70 F. The produced gas will contain 25 lb of water vapor per million cubic feet, (See Fig. 1), and the liquefiable hydrocarbon content will range up to 400 gallons per million cubic feet. Such gas cannot meet pipeline requirements.

### Low-Temperature Separation Units

By removing liquid water from a high-pressure gas stream before dropping the pressure into a separator and by providing heating coils in the separator to melt hydrates, relatively low temperatures of separation may be achieved. Considerable water vapor and additional hydrocarbons are thus condensed; so the gas produced through a low-temperature system has a lower water and condensible hydrocarbon content than that produced through a conventional separator. When pressure conditions at the wellhead are high, sufficient pressure drop is available to permit cooling to the degree that dehydration to pipeline specification is accomplished. Later in the productive life of the well when pressures are lower, sufficient pressure drop is not available to produce pipeline-specification gas. At this time, additional equipment must be installed to enable dehydrated gas to be produced.

One of the advantages of a low-temperature separation system at the wellhead is that additional hydrocarbon-liquid recovery in the stock tank over that of conventional separation is considerable, making low-temperature separation economically attractive. However, studies indicate that the actual removal of liquefiable hydrocarbons from the vapor phase in low-temperature separators is limited and that it decreases rapidly as the operating temperature increases. Fig. 2 is a plot of tail-gas analyses from low-temperature separation units in 20 fields. The quantity of pentanes plus found to be in the gas after its processing by these units represents stable liquid that could be recovered by adsorption.

Thus, the capacity of a low-temperature separator to remove water vapor from gas is limited by the temperature at which it may operate, and this temperature is dependent upon the pressure drop available. Any material that is not condensed from the vapor phase in the separator is carried out by the tail gas, and thus is not recovered. This fact is sometimes not fully appreciated.

Much effort and expense are sometimes entailed in an effort to minimize flash losses in transferring the liquid condensed in a low-temperature separator to the stock tank, usually by the use of stabilizer columns. In most instances, efforts to reduce flash losses from low-temperature separators result in a net gain of a very small amount of additional stable liquid in the stock tank over what would have normally been recovered. In the same installation, more recoverable hydrocarbons might be going down the line in the tail gas than the low-temperature separator was recovering in addition to that possible by a conventional separator.

The losses inherent in low-temperature separation can only increase with declining wellhead pressure. This disadvantage can be partially offset by the use of glycol injection and extensive heat exchange. However, even by these techniques, at least 700 to 1000 psi of pressure drop should be available to make the process practical. Losses in uncondensed hydrocarbon fractions in the tail gas are the same in a glycol-injection system as they are in any other low-temperature separation system operating at the same temperature.

### Glycol Dehydrators

Dehydration of natural gas by contacting with glycol may be evaluated from theoretical considerations. Absorption of water vapor by glycol follows definite equilibrium relations, and any other performance of a glycol-water mixture simply cannot happen. On the basis of the processed gas containing not over 7 lb of water vapor per million cubic feet, the re-

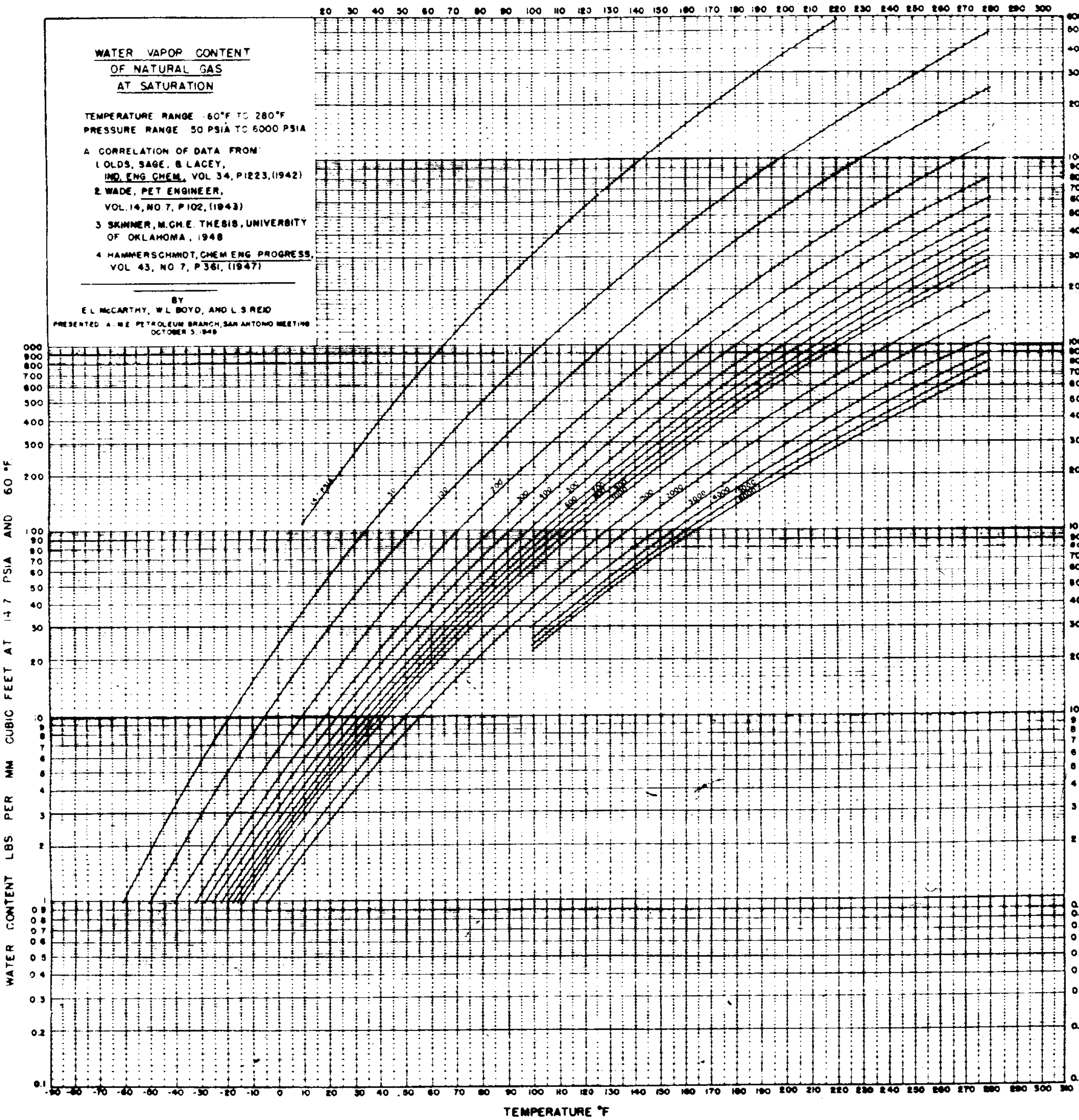
WATER VAPOR CONTENT OF NATURAL GAS AT SATURATION
TEMPERATURE RANGE -60°F TO 280°F
PRESSURE RANGE 50 PSIA TO 6000 PSIA
A CORRELATION OF DATA FROM:
1. OLDS, SAGE, & LACEY, IND. ENG. CHEM., VOL 34, P1223, (1942)
2. WADE, PET. ENGINEER, VOL. 14, NO 7, P 102, (1943)
3. SKINNER, M.CH.E. THESIS, UNIVERSITY OF OKLAHOMA, 1948
4. HAMMERSCHMIDT, CHEM ENG PROGRESS, VOL 43, NO 7, P 361, (1947)
BY
E. L. McCARTHY, W. L. BOYD, AND L. S. REID
PRESENTED A.I.M.E. PETROLEUM BRANCH, SAN ANTONIO MEETING OCTOBER 5, 1949
WATER CONTENT LBS. PER MM CUBIC FEET AT 14.7 PSIA AND 60 °F
TEMPERATURE °F

Figure 1

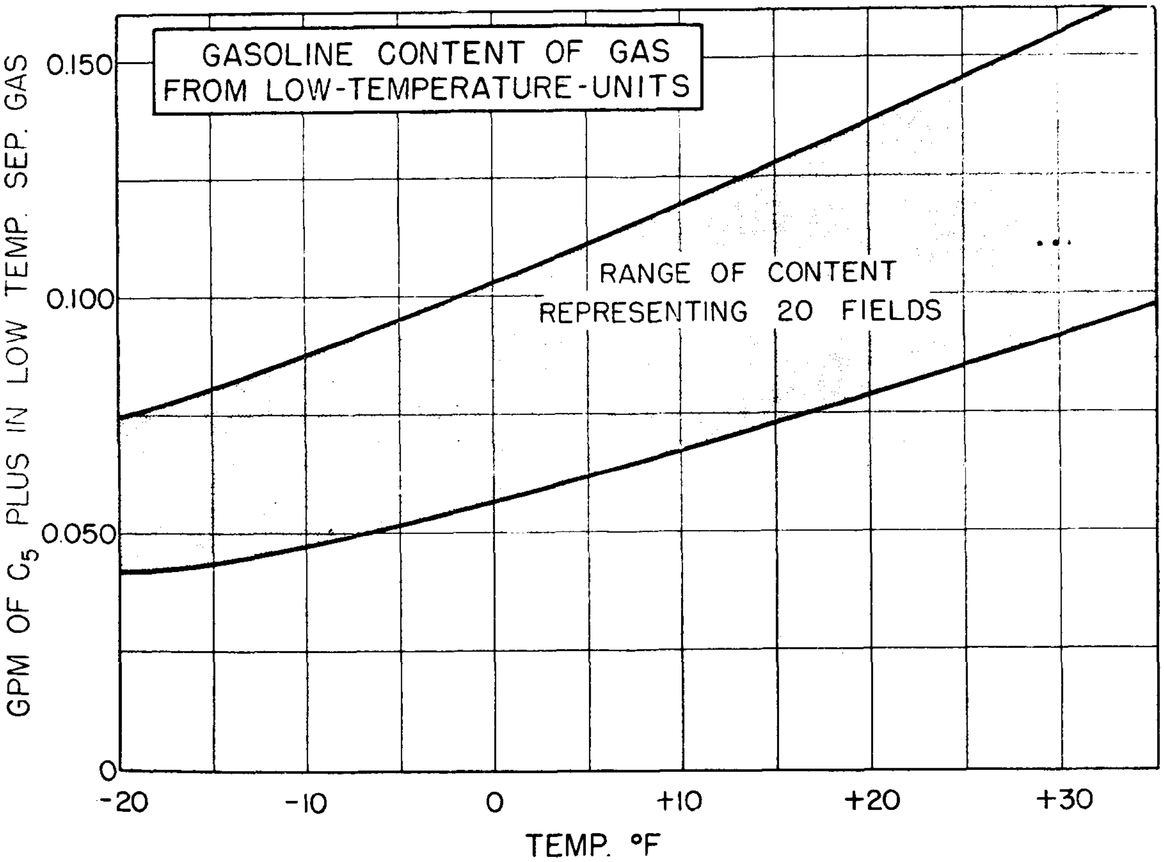


**Figure 2**

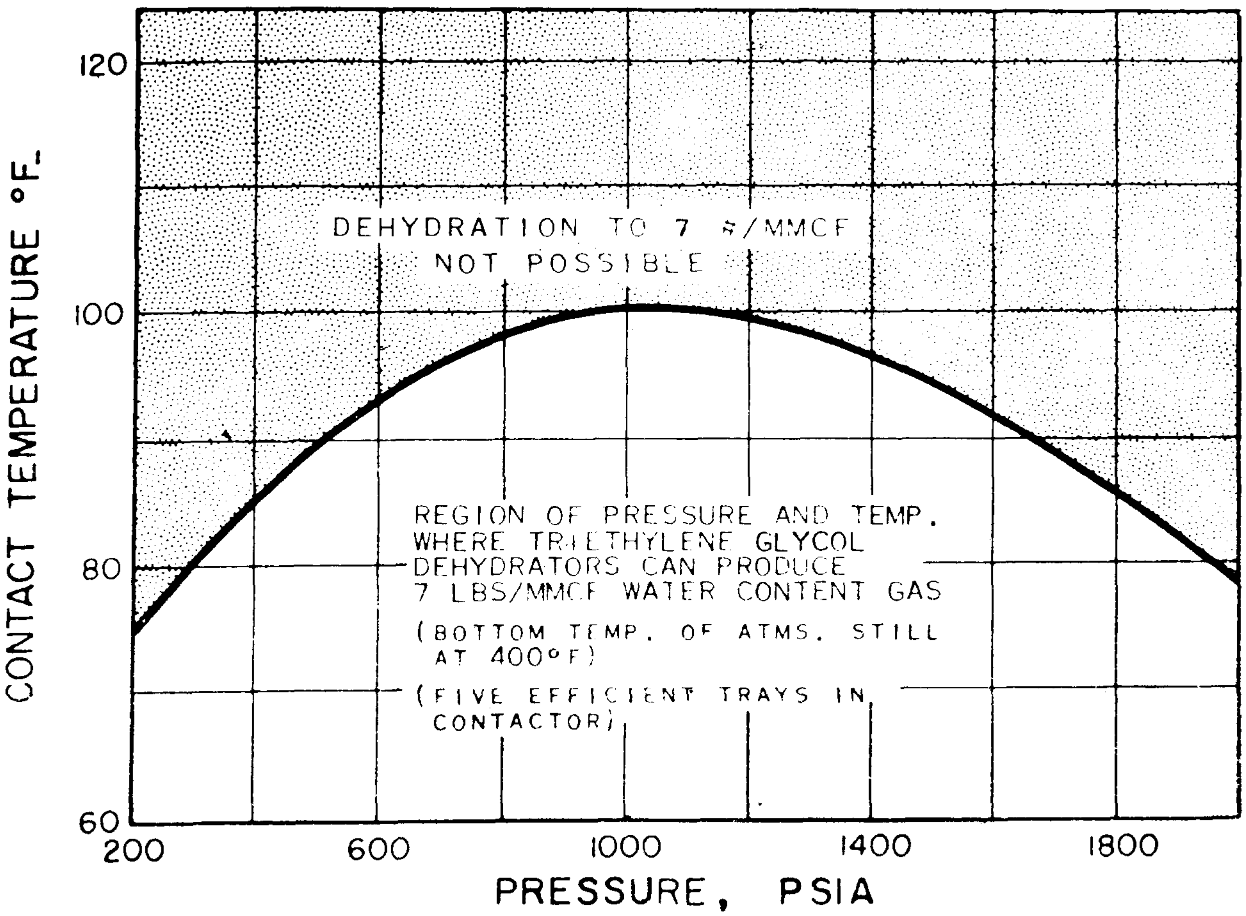


**Figure 3**

gions of pressure and temperature within which dehydration by glycol contact may be accomplished is set forth in Fig. 3.

Wellhead glycol units dehydrate the gas to a low-enough water content to avoid numerous production and gathering problems caused by hydrate formation. Liquid glycol which may escape from the unit into the pipeline can cause internal corrosion just as readily as liquid water can.

Obviously, dehydration of gas by glycol cannot recover any hydrocarbon liquid from the gas stream. Any economic benefit could only be the premium paid for dehydrated gas by a purchaser.

### Conventional Dry-Desiccant Dehydrators

Within the range of temperatures and pressures encountered in the production and handling of natural gas, the adsorption of materials from the vapor phase directly on the surface of a desiccant may be accomplished with varying degrees of efficiency. Dry-desiccant dehydration plants are very common throughout the industry, but for practical reasons they are made only in large sizes.

Conventional dry-dehydration processes are not suitable for wellhead installations. Conventional units are too large and too expensive in initial cost and in operating costs, and they do not permit flexible operations. Several thousand pounds of desiccant are required to dehydrate even small gas streams of 5 MMCF/D or less. The operation of conventional units is not efficient at varying flow rates if cooling water is not available. Units with gas-to-gas heat exchangers to condense the vaporized water cannot be operated efficiently at gas-flow rates lower than about 50 percent of the maximum design flow rate.

## DEVELOPMENT OF WELLHEAD ADSORPTION EQUIPMENT

### Selection of Basic Process

The major limitations of the dry-desiccant adsorption process for wellhead applications are high costs, large size, and inflexible operation. Inasmuch as there are no fundamental limitations of the basic method, this process was chosen as the one for development into a low-cost and practical wellhead unit. Hydrocarbon-recovery considerations made this a logical choice. Dry desiccants are capable of adsorbing the heavier hydrocarbon fractions from a gas stream in the same manner that water vapor is adsorbed. The adsorption of hydrocarbons on a desiccant is somewhat more complex than the adsorption of water vapor, but the process has no inherent limitations, as does the low-temperature separation process. To remove some 50 percent of the stable hydrocarbon fractions from a gas by adsorption at usual pipeline conditions of temperature and pressure is easily possible.

Dehydration of natural gas by the adsorption of water vapor was the primary objective of the development program in the beginning, but as the work progressed, the prospect of recovering hydrocarbon liquid in paying quantities appeared to be as attractive as the simple dehydration of gas for sales purposes, if not more so. The apparatus necessary for the removal of the maximum quantity of hydrocarbons from the gas may have to be modified somewhat from that of the standard dehydrator, but in any situation where an adsorption unit is operated for maximum hydrocarbon recovery, water vapor is removed to the point where the dew point cannot be detected by conventional methods.

### Size Reduction of Process Vessels

The cost of a pressure vessel assembly is a matter of size and weight of the components and of the complexity of the inter-connecting piping and valves. In order to bring the cost of a wellhead adsorption unit down to a reasonable level, the size of the vessels commonly used in dry dehydration processes had to be drastically reduced.

Because the quantity of the desiccant determines the size of the vessel containing it, consideration was given to the possibility of reducing the quantity of the desiccant without sacrificing overall plant capacity. Laboratory studies indicated that design criteria commonly used in the design of adsorption plants specified many times the quantity of desiccant that was actually necessary for a given capacity. These studies indicated that only a fraction of the amount of desiccant as specified by the accepted criteria could be used to dehydrate gas in a wellhead unit. To achieve this maximum capacity of adsorption from a dry desiccant requires the efficient application of what is termed "dynamic adsorption."

To substantiate the incredible results of the laboratory calculations and studies, field tests were made with beds of desiccant in pressure vessels operating under actual field conditions. Results from these tests were very encouraging, in that all question was removed that small bodies of desiccant could be made to do a relatively large job of adsorbing water.

Based on the results obtained from the tests, desiccant pack sizes were calculated for the range of dehydration requirements needed in wellhead units. Fig. 4 illustrates the contrast in the weight of desiccant required for a wellhead unit and that used in some conventional dehydration plants. Design for a wellhead unit specifies that the processed gas shall have a water content of less than 7 lb per million at at all times. To be safe, the quantity of desiccant actually required is doubled to allow for decreased efficiency of the desiccant with time.

Factors that determine the useful life of a desiccant are unknown with the exception of those that mechanically destroy the ability of the desiccant to function. The coating of the surface by tarry material, the disintegration of the desiccant by flooding of the bed with liquid, and the powdering of the desiccant are some of the obvious causes of desiccant failure.

The number of cycles of adsorption and regeneration is sometimes used as a yardstick of useful desiccant life. This is of extreme importance in the operation of a small well unit as short time cycles, two hours or less, are desirable. To study the effect of rapid cycling on a desiccant, samples of desiccant were taken from beds that were in continuous service. A sample of desiccant that had been subjected to 3000 cycles of adsorption and regeneration still had 90 percent of the capacity of new desiccant. Desiccant used in large conventional dehydration plants ordinarily is expected to last 500 to 1000 cycles before being renewed. Sufficient data have been taken on desiccant life in the wellhead units at this time to be certain that the number of cycles of saturation and regeneration is not the controlling factor in desiccant life.

That a small body of desiccant could perform the adsorbing job required, and that the life of the desiccant would not

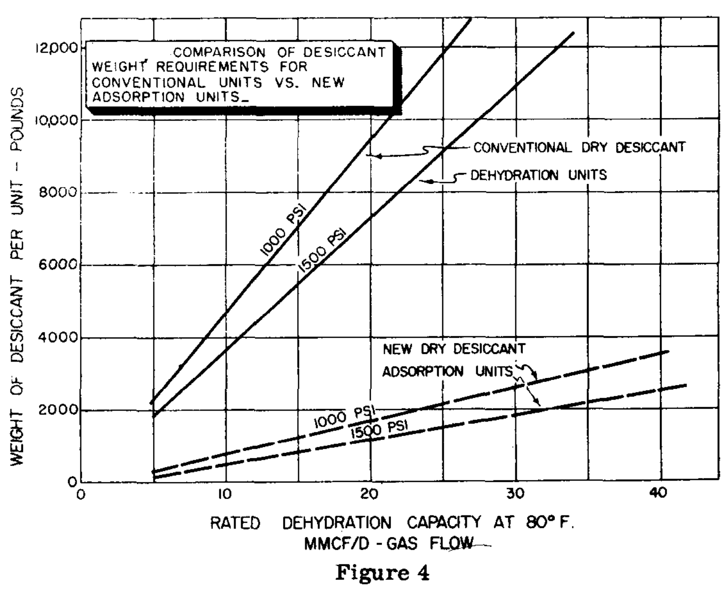


Figure 4

## TABLE I

## SIZE AND CAPACITY OF WELL-HEAD DEHYDRATORS

| TOWER DIAMETER | PRESSURE CLASS | CAPACITY AT 80 F & DESIGN PRESSURE MMSCFD | WEIGHT OF DESICCANT | FUEL COMBUSTION MCFD |
|---|---|---|---|---|
| 12" | 1200# | 6.6 | 300 | 2.2 |
| 16" | 1200# | 10.1 | 600 | 3.2 |
| 24" | 1200# | 14.6 | 1300 | 7.1 |
| 30" | 1200# | 19.1 | 2500 | 11.0 |
| 36" | 1200# | 25.0 | 3800 | 15.8 |
| 12" | 2900# | 9.7 | 280 | 2.2 |

be shortened by the unusual treatment in the wellhead unit, having been determined, designs were made for twin desiccant pack adsorption units, using the desiccant bed sizes as shown in Table I.

Reduction in the weight of the desiccant vessels not only reduces the manufacturing cost, but also reduces the overall heating and cooling requirements.

### Vessel Assembly

In the usual dehydration plant, several pressure vessels are required, and these in turn, must be inter-connected by piping and valves. Pressure vessels are costly, as is the piping required to connect them in the final assembly. One of the most expensive items is the large, high-pressure motor valve required for switching the main gas flow and the regeneration gas flow.

The numerous valves with the attendant complex piping cannot be eliminated in the design of a conventional dehydration, twin-desiccant bed plant. The cost of valves and piping is such a large fraction of the total cost of the assembly that merely reducing the size of the vessels does not effect much real reduction in cost. Fig. 5 shows one of the wellhead units as manufactured today.

The multiple vessels required for conventional design have been combined into one single vessel; part of the vessel is horizontal and part is vertical. No valves of any kind allow parts of the vessel to be isolated from the others. It is truly a single, unitary vessel containing an inlet gas-liquid separator, a liquid accumulation chamber with liquid dumping control, two desiccant packs, a regeneration gas cooler and condenser, and a provision for separating the liquid condensed from the regeneration stream and dumping this liquid.

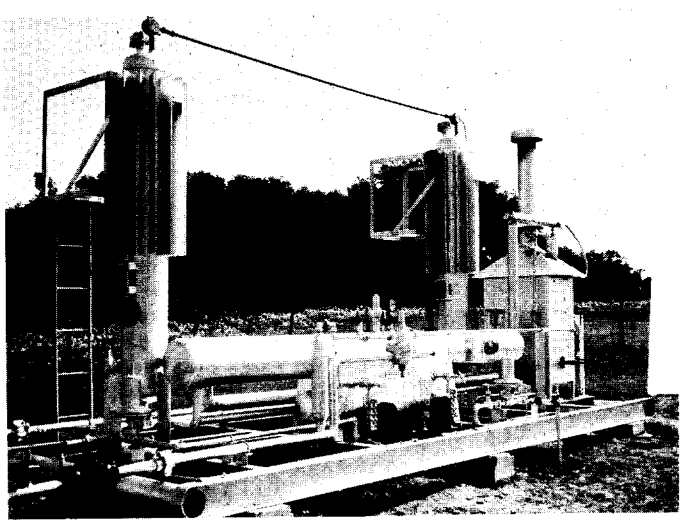

Figure 5

By the use of such a unitary vessel, the expense of the inter-connecting piping and valving disappears; none is required. A full-opening, zero-leakage, three-way valve located at the junction of the outlet lines from the two desiccant packs serves to direct flow through the tower which is adsorbing. A small, high-temperature, three-way valve serves to switch the flow of hot gas from the heater through the bed that is regenerating. These three-way valves constitute the entire valving required.

Fig. 6 is a schematic flow diagram of the arrangement of the parts of the unitary vessel which minimizes inter-connecting piping and valving.

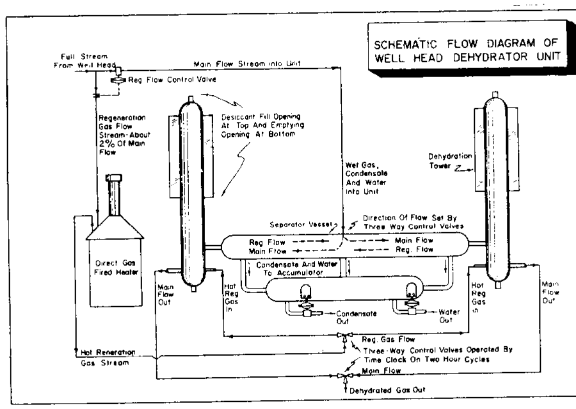


Figure 6

### Heat Balance

Perhaps the one greatest drawback to the conventional, dry-desiccant unit is the inflexibility of operation. The basic design of such units requires a large stream of gas for the heating of the packs for regeneration, and this stream of enerating gas must be cooled after having passed through pack. Such cooling of the regeneration gas stream may accomplished by heat exchange with the gas flow leaving unit. If the main flow is reduced by one half, then only f enough cooling gas is available, and the result is that regeneration gas is inadequately cooled.

Under such conditions, the hot, saturated gas which contains a relatively immense quantity of water, goes into the main stream entering the tower being saturated. This addition increases the water load on this tower and also increases the gas temperature, with the net result that efficiency may be reduced to the point where the dehydration process practically stops. A large part of the water adsorbed in the towers may thus be shuttled back and forth between the towers in the hot regeneration gas stream with very little dehydration of the stream flowing through the unit.

The solution to this problem is to use a water-cooling system, but this necessitates a source of water and power to circulate it through the cooler. Neither the water nor the power is ordinarily available at an isolated well. Thus, a better system, other than by heat exchange, had to be developed for cooling the hot regeneration gas. Complete flexibility of a wellhead unit from zero flow to maximum is a must, and water cooling was out of the question.

The approach to the heat-balance problem consisted of two parts: first, to reduce the quantity of heat used for regeneration so as to minimize the cooling problem and, second, to find a means of disposing of the heat contained in the hot regeneration stream without heating the gas stream entering the pack being saturated.

Reduction in the quantity of heat required resulted from a reduction in the physical size of the pack and the vessel, plus more efficient use of the heat used in the regeneration process. Where conventional dry-desiccant units may require 10 percent of the throughput gas for supplying the regeneration heat, heat requirement has been reduced in the wellhead unit to the point where less than 2 percent of the maximum throughput is required for regeneration. This leaves only a fifth of the cooling problem that the conventional unit has.

The use of a double-walled vessel to contain the desiccant bed makes possible the direction of the hot gas flow from the pack into intimate contact with the outer wall of the vessel, which is finned for heat dissipation to the atmosphere. Considerable heat is removed at this point. Flow of the partially cooled regeneration stream, directed into the end of the horizontal section of the vessel, moves toward the center to rejoin the incoming stream of gas. If this were done simply as stated, the result would obviously be the same as that with a large, conventional unit with inadequate cooling of the regeneration gas. Considerable water and heat would be added to the incoming stream at exactly the wrong point in the system. Adding heat to the incoming stream in the zone where the separation of the gas and the liquid occurs would result in a net increase in temperature before the separation of the gas and the liquid. An increase in temperature would enable the gas to carry more water in the vapor phase. Such a cycle would actually increase the load of the pack being saturated and would raise the temperature of adsorption. Both factors would serve to decrease the capacity of the desiccant bed. This is exactly what occurs in a conventional dehydration unit with gas-to-gas cooling; a small unit cannot afford this self-inflicted decrease in capacity.

The solution is this: The heat contained in the hot regeneration gas stream from the bed is stored in a mass of material located in the end of the horizontal section of the vessel and is not carried by the gas to the center of the vessel to increase the temperature of the incoming stream. Thus, the hot gas stream from the pack being regenerated is cooled to the temperature of the main stream before admixing with it. The water content is the same, and there is no increase in temperature or water load of the gas going to the saturating pack.

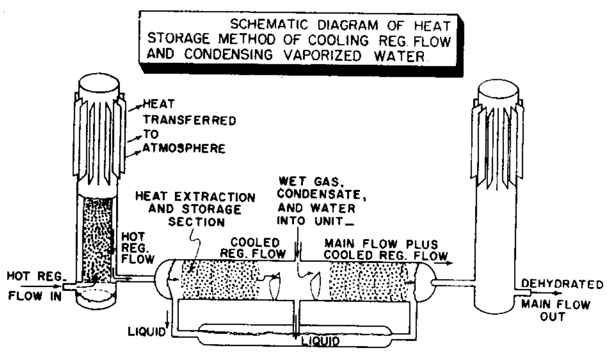


Figure 7

The stored heat has not been removed from the system; it is only stored and must ultimately be removed. The schematic drawing, Fig. 7, shows that there are twin heat-storage masses in the horizontal-vessel section; and as the cycle switches, flow reverses direction from the central point of entry of the wet gas. The hot gas from the pack being regenerated enters the horizontal section at the end and flows toward the center. As the main flow switches direction in this horizontal section, it goes through the mass that has just had a quantity of heat stored in it and sweeps the heat

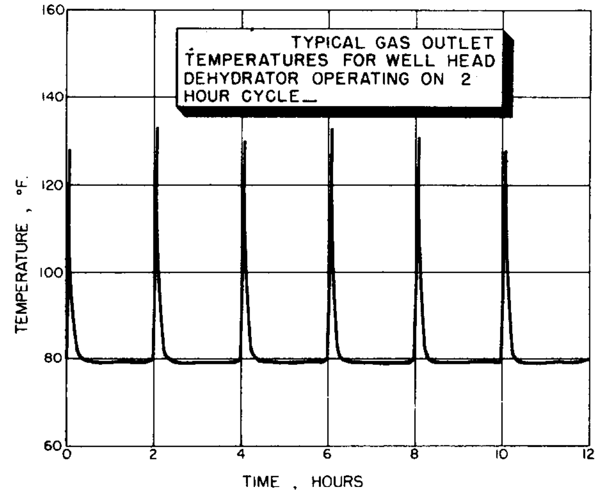


Figure 8

out in a very short time. The temperature of the gas going through the adsorbing bed is relatively high for a few minutes. (See Fig. 8), but in the wellhead unit, this mass of hot gas has a negligible effect on the adsorptive capacity during this time.

In the conventional unit, the hot regeneration stream cannot be completely cooled by heat exchange and must be combined with the main stream ahead of the point of liquid-gas separation. This increases the water load in the gas and raises the temperature, thus decreasing the adsorptive efficiency. In the wellhead unit utilizing heat storage, the regeneration gas is cooled to the extent that the temperature of the main gas stream is not increased after the point of combination; the efficiency is thus unaffected. Following the switching of cycles, the main stream is heated in the process of sweeping out the heat from the heat storage, and it goes into the desiccant pack at this elevated temperature for a short period. The heat is added to the main flow after it has had the liquid separated from it; so the increase in temperature adds no water to the gas stream going into the desiccant bed.

The adsorptive capacity is momentarily reduced by the increase in temperature; but this increase in temperature is of very short duration, and it comes at a time when the pack is freshly regenerated with adsorptive capacity at the maximum. There is very little if any disturbance in the overall adsorptive efficiency of the unit.

## Controls

Some control problems in the operation of the wellhead adsorption unit are unique and cannot be satisfactorily solved by the use of standard control instruments as manufactured.

For realization of the maximum performance from a bed of desiccant, the heating and cooling cycles must be properly controlled, much more accurately than is ordinarily done in a conventional plant using a large mass of desiccant.

It is imperative that the desiccant bed in a wellhead unit be completely regenerated during each cycle. If insufficient heat is applied to the pack to accomplish this regeneration, part of the bed is left in a saturated condition, which reduces the effective size of the desiccant bed for the subsequent saturating cycle. Reduced bed size means reduced adsorbing capacity.

The continued application of heat to the desiccant bed after regeneration is complete may be equally bad for the overall efficiency of the wellhead unit. Carried to the extreme, such excess heat would overload the heat-storage section: heat would spill over into the incoming stream of gas to increase the temperature of the gas going to the pack then adsorbing. This action would result in a decrease in efficiency.

Several types of controls for the basic heating and cooling cycle, both electric and pneumatic, have been tested. Each system has advantages and disadvantages. Most of the units presently in the field are equipped with combination pneumatic/electric control systems. The electric power is generated by a commercial thermopile incorporated in the pilot burner of the heater. The thermopile output also serves as a safety cut-off for the heater fuel in the event of a pilot burner outage.

A time-cycling controller driven by a clock has been used to switch flow and to start the heater burner at the beginning of a regeneration cycle. A temperature-sensing element, located within the desiccant pack, signals the time at which regeneration is complete, and this signal cuts off the fire in the heater. When the pack has cooled, the time clock switches flow and starts a new cycle.

The rate of heat input into a bed during regeneration is a function of the rate of regeneration-gas flow and its temperature. Thus, it is important that this rate be held to the required amount in respect to the flow of the main gas stream through the unit. The temperature of the gas from the heater is controlled by a thermostat in the heater outlet line.

In conventional dehydration plants, the rate of regeneration-gas flow is held constant by a rate-control instrument actuated by an orifice in the regeneration-gas line to the heater. The output from the instrument positions a throttle valve situated in the line carrying the incoming gas into the unit. The degree of throttling determines the flow through the regeneration system. Such a system delivers a constant flow through the regeneration system.

For the complete flexibility of operation required of the wellhead unit, such a constant-flow device is not suitable. A combination rate-sensing and flow-throttling device was developed with the characteristic of varying the rate of the regeneration-gas flow to meet the requirement of changing the main gas flow through the unit. The cost of the controller is not much greater than that of a simple motor valve such as would be used with a standard rate-control instrument. Thus, the cost of a rate-control instrument is saved.

A combination pneumatic and clock system of control is used in maintaining the dehydration cycle. Each tower has a special, temperature-sensing element installed in the desiccant pack. These elements actuate pilot mechanisms which are in the top of each tower. The pilots transmit signals to the central control panel.

At the start of a cycle, hot gas starts to flow into the bed that has been saturated; the bed is cool. When sufficient heat has been put into the pack to regenerate it completely, the temperature-sensing element in the pack cuts off the fire in the heater, and the cooling period begins. The clock then switches towers at a predetermined set point. In the hydrocarbon recovery unit, the clock is not required. When the pack has been cooled, the temperature-sensing element acts to switch flow through the bed and at the same time to start the fire in the heater. Thus, flow of heat to the desiccant bed is cut just at the point of complete regeneration, and the cycle is switched just as soon as the bed has been cooled.

The only adjustments to be made with such a control system is the setting of the temperature within the bed where heating stops and cooling starts. With experienced operators, the proper setting of these devices may be made in the shop before the unit is sent out. The rate of the regeneration-gas flow which is not critical, would then determine the time of the cycle.

Early in the testing period of twin-bed units, it became apparent that stock three-way valves would not be suitable for wellhead unit flow control. Some of the valves available had restricted flow areas that would cause undue pressure drop; others used metal-to-metal seats which would invariably leak to some extent. In all cases, conventional three-way valves complicated piping assembly, especially when the piping had to be arranged for dismantling to enable the lower seat of the three-way valve to be serviced.

Full-opening, three-way valves were designed for this service. They are equipped with resilient seats to assure zero leakage, they have unrestricted flow passage, and all of the internal parts of the valve may be removed through the top opening of the body.

It may appear that the importance of valve leakage was being unduly emphasized. This is not the case. In the operation of wellhead dehydration units, the stream of gas used for regeneration is frequently less than 2 percent of the flow through the unit. The importance of supplying the correct quantity of heat to the pack for regeneration has been discussed. The heat supplied is directly dependent upon the amount of gas flowing through the pack to effect regeneration. If 2 percent of the throughput were being used for regeneration, in a unit, valve leakage of only 0.5 percent of the throughput would cause the pack to be only 75 percent regenerated. Large conventional dehydration plants require about 10 percent of the throughput for regeneration, and they can better tolerate valve leakage.

Wellhead adsorption units are frequently installed in isolated places, with the rate of flow through the unit being controlled from a point on the line some distance from the well. If, for any reason, flow through a unit should be stopped, the heater should not be allowed to come on, as overheating of the heater tubes could result.

The most satisfactory and fool-proof control system has proved to be a pneumatic device. A temperature-sensing element is installed in a deep well located inside the inlet pipe to the heater. The well and sensing element are of sufficient length to extend well inside the heater firebox. Under normal flow conditions, the incoming regeneration-gas stream maintains the temperature-sensing element at line temperature. Should flow through the regeneration system stop and the fire remain on, this section of the inlet pipe to the heater would immediately start to heat. The control is set to block the burner fuel when a relatively slight rise in temperature occurs at this point.

Devices that sense a rise in stack temperature were abandoned, as experience showed that by the time sufficient rise in stack temperature had occured to cause the controller to cut off the burner fuel, damage to the heater tubes might already have been done.

### Heater

Design and development of a heater of suitable characteristics for use in the wellhead adsorber required considerable time and effort. Field-test data indicated that higher regeneration efficiency could be had by heating the regeneration gas to a temperature somewhat higher than that commonly used in conventional dehydration plants. It was decided to use a regeneration-gas temperature of 600 F.

The use of salt-bath or vapor-type heaters was not practical; so a direct-fired heater was developed. By-passing of the heater during the cooling period was not desired. This required that the heater have a very low mass to retain heat, both in the fire tube and in the heater housing. In effect, the heater must be such that gas at regenerating temperature must flow from the heater soon after the fire has been started, and the temperature of the gas from the heater must drop to essentially line temperature shortly after the fire has been cut. Fig. 9 shows typical heater outlet temperatures.

All efforts have been made to minimize losses in the heater. The entire combustion chamber is surrounded by an insulated box; the outer wall of the box never becomes too hot to hold a hand against. The burners are designed and constructed especially for these heater requirements. Heaters have been built in capacities ranging from 50,000 to

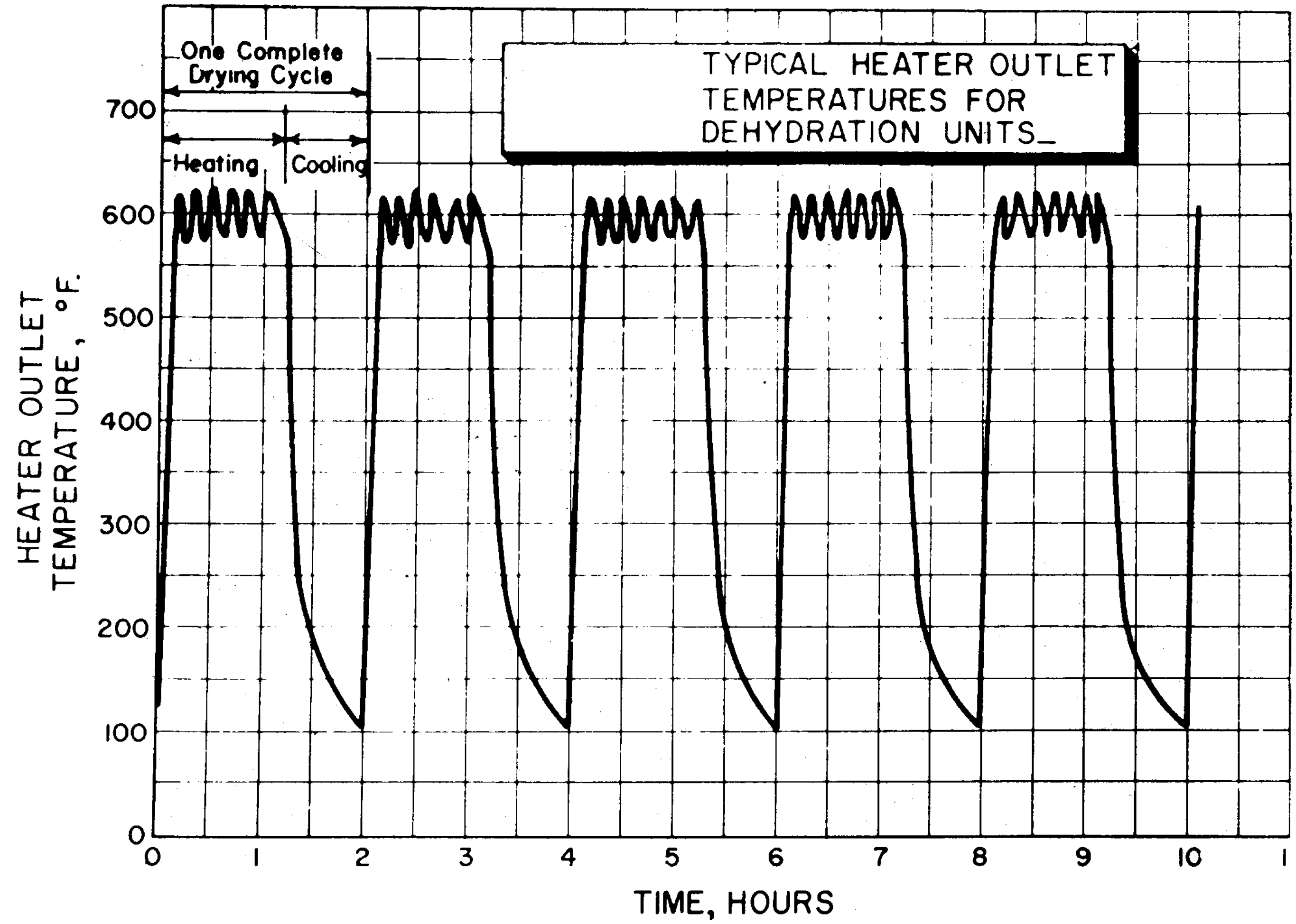


Figure 9

1,000,000 Btu per hour.

Results of the development program on the heating unit are not immediately visible; the benefit is in the form on unburned gas that goes into the pipeline. Fig. 10 lists the fuel requirements for the wellhead dehydration units as compared with those for conventional dehydration units. Generally, the fuel cost of the wellhead unit is about $0.06 per day per million cubic feet of gas dried.

### Pressure Drop

The design of a small adsorption unit for use at the wellhead involves some practical considerations other than the function of the individual parts of the assembly.

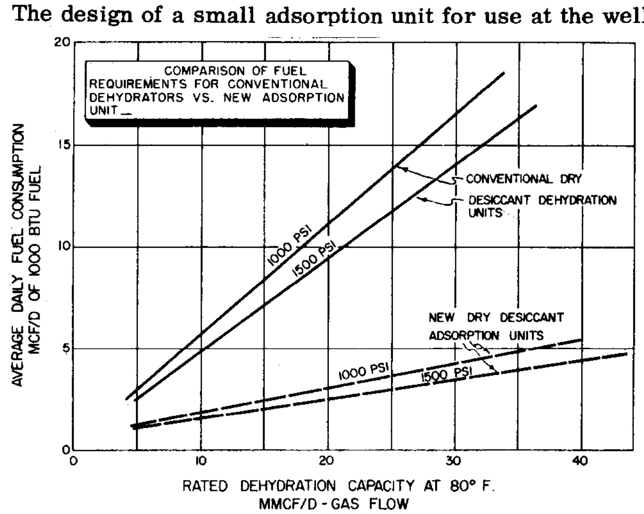


Figure 10

The use of equipment employing small beds of desiccant raises the question of pressure drop under operating conditions. When pressure drop through a dehydration plant is mentioned, the tendency is to visualize the drop as occuring through the desiccant bed with very little, if any, consideration being given to pressure drop through the piping and the valves. Analysis of the pressure drop through several plants indicated that this impression is erroneous. The greater part of the total pressure drop across a plant is in the piping and the valving.

In one large conventional dehydration plant operating at the rated capacity, pressure drop through the bed was 3 psi; overall plant loss of pressure was 18 lb. A similar study of a large wellhead unit showed a 5-lb drop across the bed, with an overall pressure drop of 12 1/2 lb across the unit.

The explanation of the low overall pressure drop through the wellhead unit is that simplified piping and a single, full-opening, three-way valve to control flow instead of the multiple valving necessary in conventional plant flow patterns are used. Pressure drop through the heat exchanger of the conventional dehydration plant was 4 lb. In heat exchange equipment, pressure drop is necessary for efficient heat exchange. The wellhead unit has no heat exchanger; thus this addition to the overall pressure drop is zero.

Small adsorption units are ordinarily used on individual wells where pressure drop is not critical. It is in the dehydration of compressed gas that pressure drop becomes of major importance, and it is in this application that larger volumes of gas may be handled.

TABLE II

SUMMARY OF OPERATING CONDITIONS AND RESULTS OF FIELD INSTALLATIONS

| | OPERATING CONDITIONS | | | PRESSURE DROP | | |
|---|---|---|---|---|---|---|
| Size of Unit | Flow | Pressure | Temp. | Across Bed | Across Unit | General Performance |
| 12"-1500 psi 400 lbs Desiccant | 1/2 to 1-1/2 MMCF/D | 500 to 700 psi | 80 F | 4 psi | 25 psi | Outlet humidity about 1 lb/ MMCF. Recovered 2 bbls/ MMCF additional liquid. |
| 12"-3500 psi 300 lbs Desiccant | 4 to 6 MMCF/D | 3100 psi | 95 F | 10 psi | 22 psi | Outlet humidity about 3 to 6 lbs/MMCF |
| 30"-1000 psi 2600 lbs Desiccant | 5 to 10 MMCF/D | 500 psi | 90-95 F | 4 psi | 15-22 psi | Outlet humidity about 2 to 6 lbs/MMCF. |
| 12"-850 psi 460 lbs Desiccant | 1 MMCF/D | 250 psi | 85-90 F | 5 psi | 15 psi | Outlet humidity less than 2 lbs/MMCF. 1 to 2 bbls per day of liquid recovery. |
| 16"-1000 psi 700 lbs Desiccant | 4 MMCF/D | 800 psi | 105-115 F | 4 psi | 20 psi | Outlet humidity about 4 to 7 lbs/MMCF. |
| 12"-1000 psi 420 lbs Desiccant | 1-1/2 MMCF/D | 800 psi | 90-95 F | 2 psi | 7 psi | Outlet humidity about 1 lb/ MMCF. |
| 10"-850 psi 320 lbs Desiccant | 1-1/2 MMCF/D | 500 psi | 75-80 F | 7 psi | 11 psi | Outlet humidity 1 to 2 lbs/ MMCF. |

## APPLICATION OF WELLHEAD UNITS

Out of this development program have evolved some basic components for adsorption-unit applications at the wellhead. The components may be modified and arranged to suit specific requirements. A summary is given in Table II of the operating conditions of the field installations and of their results.

Simple dehydration of natural gas by the use of a wellhead unit requires no variation in the combination of the basic elements which comprise the complete unit. The quantity of gas to be dehydrated, with its inherent water-vapor load fixed by temperature and pressure, determines the size of the equipment. Thus, dehydration equipment may be designed on the basis of gas volume, temperature, and pressure. (For illustration of unit capacity and for dehydration as a function of temperature, see Fig. 11.)

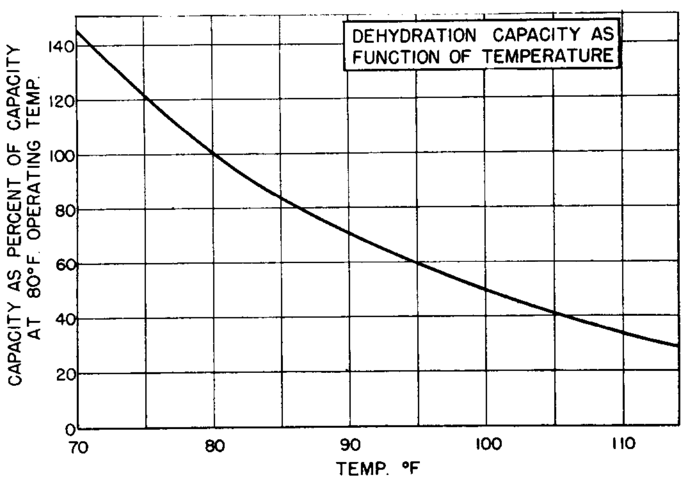


Figure 11

The mechanics of adsorption and recovery of hydrocarbon fractions from natural gas are very complex as compared with those of simple dehydration. In dehydration, the water adsorbed from the vapor phase is only a few gallons per million cubic feet of gas, whereas hydrocarbon recoveries are usually a matter of barrels of liquid per million cubic feet of gas. A body of desiccant can adsorb only a given quantity of liquid per cycle, whether the liquid be water or hydrocarbon; so the rating of a hydrocarbon-adsorption unit must be dependent upon the total liquid load carried in the vapor phase of the gas and not upon the volume of gas to be processed. The stable hydrocarbon fraction of gas streams differs widely.

In general, an adsorption unit designed to recover the maximum of hydrocarbon from a gas stream will have much larger beds of desiccant than will units designed to dehydrate the same volume of gas. The capacity of any quantity of desiccant to remove hydrocarbons from the vapor phase is a function of the bulk of the bed and of the frequency with which it is saturated and regenerated. For maximum hydrocarbon recovery, it is necessary to operate on as rapid a cycle of saturating and regenerating as possible. Rapid cycling requires a high rate of heat input to the desiccant bed to shorten regeneration time. Cooling the hot regeneration stream requires a corresponding increase in the rate of heat dissipation.

In general, it is desirable to operate a hydrocarbon-recovery unit at pipeline pressures, 500 to 1200 psi, and not at higher pressures in order to obtain the maximum amount of natural condensation of hydrocarbon liquid. The additional recovery of liquid hydrocarbons results from the adsorption of hydrocarbon vapors from the separator gas by the dry-desiccant beds. Depending upon the flowing pressures and temperatures of each individual well, it may be desirable to install a high-pressure dehydrator, a line heater, or a gas-to-gas heat exchanger upstream of the hydrocarbon-recovery unit. In some cases it is possible to throttle directly into the hydrocarbon-recovery unit.

In the application of the wellhead unit to field operations, apparently the type of installation most attractive to the operator is a combination dehydration and hydrocarbon-recovery unit. This involves the installation of a wellhead unit which is over-sized for the dehydration requirement with the additional adsorption capacity of the unit recovering stable stock-tank liquid. The cost of extra capacity in a unit is small in comparison to the value of the additional liquid recovery. Wellhead hydrocarbon adsorption units can recover from 2 to 4 bbl more of condensate per million cubic feet of gas than can conventional wellhead separators.

## SUMMARY AND CONCLUSIONS

Fifty adsorption units have been placed in operation with applications ranging from straight dehydration to maximum hydrocarbon recovery. These units have proved the basic dehydration and hydrocarbon-recovery performance of the adsorption process.

The development program as initiated was directed to the problem of dehydration of natural gas at the wellhead. As the work progressed, the importance and possibility of additional hydrocarbon recovery from the gas stream became evident. Dehydrating gas for sales purposes is obligatory. The prospect of doing this at a profit from additional liquid recovery is attractive. A hydrocarbon adsorption unit can recover from 2 to 4 bbl more of condensate per million cubic feet of gas than can conventional wellhead separators.

Sufficient basic work has been done and operating experience on dehydration units has been gained to provide for the complete design of a plant for any natural-gas dehydration requirement. There is no size limitation on the basic dehydration design principles.

## REFERENCES

(1) W. M. Dow and A. S. Parks. "Development of Dry-Desiccant Wellhead Adsorption Units," API Divisions of production, Spring Meeting, Southern District, March 7, 1956.

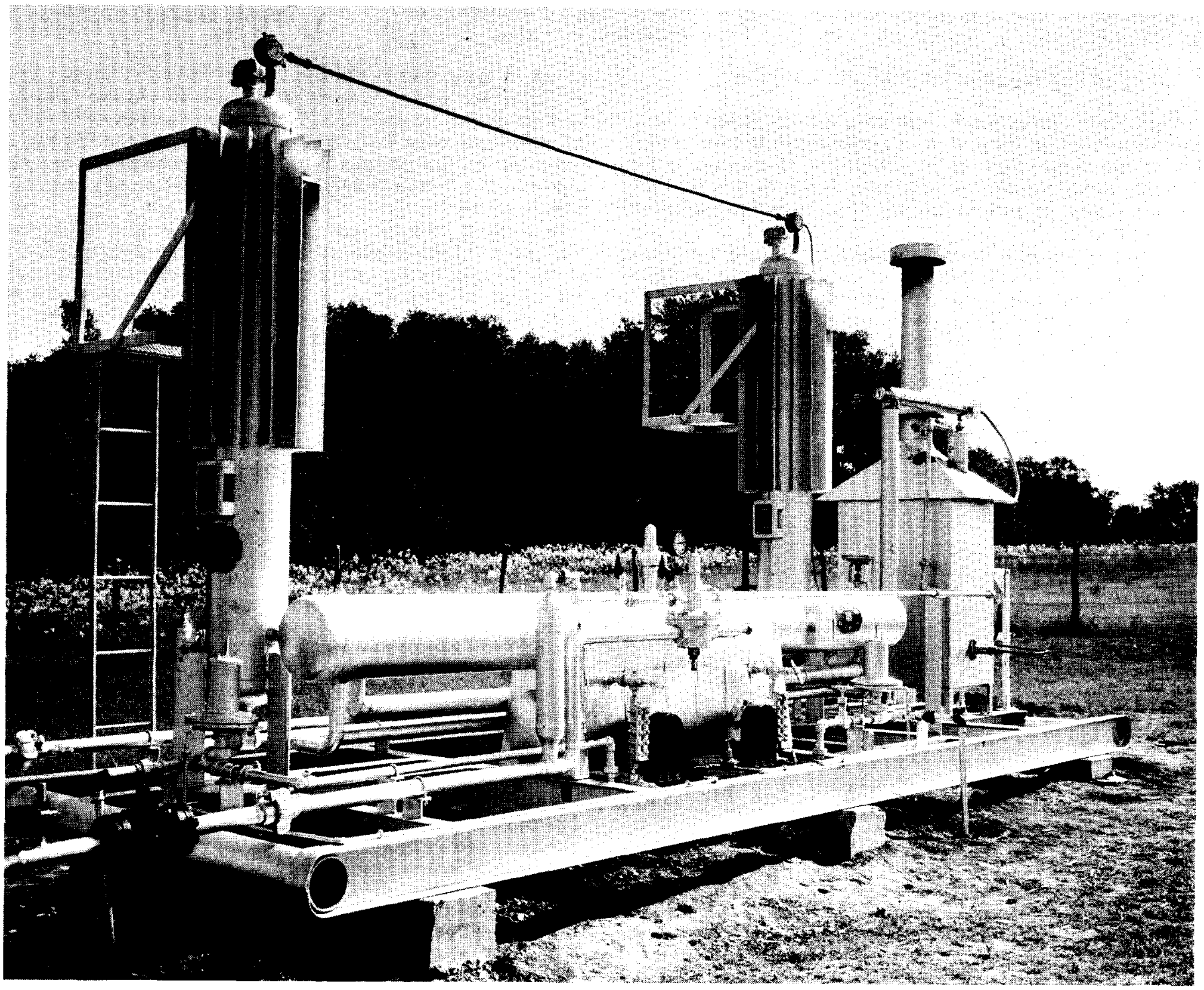

Figure 12