Underground LPG Storage, Development And Operation

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INTRODUCTION

This paper is presented as a reference for drilling, washing and completion of storage wells in the Salado Salt Section of the Eastern New Mexico-West Texas Area. The discussion and recommendations expressed herein are based on the experiences and problems encountered by the El Paso Natural Gas Products Company in its operation of the Odessa complex LPG storage wells.

The producer in this area is fortunate to have a relatively shallow and extensively developed salt section for storing products for his plant or complex operations, for this permits the operator to drill these wells using conventional rotary equipment and complete the underground storage facility at an appreciable savings to that of above ground vessel storage. The comparative cost of drilling, completing and equipping an underground storage well is $3.40 per barrel to that of $10 per barrel for vessel storage based on 50,000 bbl capacity. But the economical aspect is only one of the many advantages of using underground storage; safety of handling and producing the products, the utilization of the surface area for plant facilities, and the physical properties of the product itself (ethylene) warrant the development of underground storage wells.

Although storage wells are not considered strictly producing wells, they, as any well drilled in Texas or New Mexico, must have the proper State clearance and approval. (Rules and Regulations of The Texas Railroad Commission, Oil & Gas Divn. Prepared by R. W. Byram & Co. Rule No. 705- Rules & Regulations of the New Mexico Conservation Commission. Prepared by R. W. Byram & Co).

Also, the operator generally does not have the mineral lease with the surface lease where his plant is located and he must obtain subordination agreements between the mineral owners and the lessee of the minerals to protect his ownership of the subsurface stored product. Storage wells differ also from oil and gas wells in that they may be located and spaced for ease and convenience of the operator to his plant and facilities, with the prime consideration being safety to his operation.

PRINCIPAL PROBLEMS ENCOUNTERED IN OPERATING STORAGE WELLS

The Salado Salt Section of Permian Geological Age, unlike the massive and relatively pure salt domes of the Gulf Coast, is composed of salt deposits interbedded with shales, anhydrites and red beds. These impurities in the salt section create the first principal problem in that the anhydrites are relatively hard insolubles to that of the salt, and consequently, anhydrite ledges are formed when the supporting salt is dissolved. These ledges will creep or slough and crush, bend or block the exposed, unportected tubing string in the cavern of the well.

The second problem is that of washing the cavern, which, if not controlled, can erode the supporting salt and cement around the production casing and permit the product to channel and become lost, requiring workover to the well to recover the product and repair damage to the casing.

The third problem is preventing tubing leaks which result also in workover to the well if proper circulation of brine and product can not be maintained.

SAFETY

The successful utilization of the underground well is dependent on safe and cautious operation in drilling, storing and especially workovers of the LPG storage well. The personnel involved with the various phases of drilling and completing a storage well should be well experienced, for the safety of the plant is directly related to their ability to perform work in an area of extreme caution. The safety department of the plant should be given a complete explanation of the project being performed and precautions followed to minimize any hazard which may be present. The physical properties of the LPG products, low vaporization pressure and relatively low ignition temperature create an ever present fire hazard and it is imperative that safe, modern equipment be utilized in the drilling and completion of the storage well

DRILLING

Conventional rotary equipment generally is used to drill the 2800 ft storage wells in the West Texas-Eastern New Mexico Area. Normal drilling procedures and practices are used with emphasis on safety in the plant or complex area. Under normal conditions, 8 days are required to drill the storage well, with brine being used as the circulating medium to reduce washout and undesirable leaching. The State Regulatory Body will advise the depth to which surface casing must be set to protect the surface potable water zones and in general, 13-3/8 in. casing is set at approximately 500 ft, with cement circulated. The production string of 9-5/8 in. casing is set through the Rustler Anhydrite Formation into the top of the Salado Salt Section to an anhydrite stringer casing seat at approximately 2100 ft. It is imperative that the production casing be circulated with cement to prevent voids or channels from occuring that might result in unintentional charging of unprotected formations with products. A blend of saturated salt cements which is lightweight and shock resistant and is designed to afford maximum bonding, is used to circulate the production casing.

The salt section is drilled using an 8-3/4 in. bit below the production casing point, again with brine as the circulating fluid, to total depth and a Gamma-Acoustic type log is run on the open hole section of the well. This type log best describes the lighology changes in the salt section and is used for selection of a starting point for underreaming the open hole. The salt section is hydraulically underreamed starting approximately 100 ft below the 9-5/8 in. production casing seat to total depth. The advantages of underreaming are (1) increased area for a more efficient wash, (2) increased primary cylinder volume to afford more area to accomodate sloughing of the insoluable formations and to decrease the formation of anhydrite ledges, (3) increased protection to the base of the 9-5/8 in. production string, which will help to prevent washouts and pockets behind the production casing.

It is very important that in all phases of drilling the storage well that the hole be maintained as straight (vertical) as possible. This will help to insure good cementation of the casing strings and will permit subsequent raising and lowering of the wash strings with ease of entry into the cavern section.

WASHING THE SALT SECTION

Figure 1, diagramatic sketch, represents the hole conditions prior to washing. A cavern is created in the salt section by dissolving the salt formation in fresh water until the desired volume is obtained necessary for storing the product. The optimum size of the cavern is 50,000 bbl capacity. This volume or size has been selected from experience as the most economical and efficient for this area. Larger size caverns do not have enough support and the frequency of ledge formation and collapse is increased and result in an increase in workovers of the storage well. The shape of the cavern is designed to be that of a pear -- large on bottom, small on top -- to afford as much support and protection to the production casing as possible. The pear shape of the cavern is derived by 3 subsequent washings of the salt section in which fresh water is pumped down the 2-7/8 in. tubing string and returned as brine to the surface via the 5-1/2 in. return tubing string. Generally, each of the 3 washings cover a 200 ft interval with each subsequent wash, starting from the bottom, forming a smaller volume. Figures 2, 3 and 4 schematically show the washing operation with the relative position of the tubing wash and return strings.

Calculation of the volume of fresh water needed to dissolve the salt to the desired storage volume is derived from the solubility of saturated salt water to the density of salt. This results in a ratio, that 6.1 units of fresh water is required for 1 unit of saturated salt water. Consequently, 1 bbl of storage in the salt formation requires 6.1 barrels of fresh water. The size of each stage of the cavern is then determined by multiplying the number of barrels of fresh water pumped by the percent salinity of the returned brine divided by the ratio factor of 6.1. Experience has shown that the maximum efficiency of the wash is obtained at lower pump rates (4000 BPD) in each initial washing operation, with increased pump rate governed by the salinity of the returned wash water. Each stage of cavern should be reversed circulated before proceding to the next subsequent wash so as to remove and clean the cavern of insoluble materials which, due to low anular velocities, were not circulated out. A final reverse circulation with brine should be made when the 5-1/2 in. tubing is landed in position to receive products at a rate, approximately 15 bbl/min. which will not be exceeded during pumping operations of LPG products.

COMPLETING THE STORAGE WELL

Upon completion of the washing operation the 2-7/8 in. water injection tubing is removed from the well and the 5-1/2 in. brine return tubing is lowered into position to receive products. Figure 5 illustrates the completed storage well.

The casing used as the producing tubing string, designed to afford the maximum protection against creep or sloughing damage from the insoluble ledges, is 5-1/2 in. OD 23#/ft Grade J-55 intergal joint casing. Each joint or connection is protected from leaking and torque back-off by the application of a specially developed thread locking compound. This compound is an epoxy or resin which is insoluble in liquid hydrocarbons, but can be broken and vaporized by the application of 400° F heat.

The wellhead assembly is designed to handle liquid and gaseous products in the working pressure of 1440 psi and test pressure of 2170 psi, series 600 ASA code. The wellhead assembly is protected against corrosion with use of stainless steel ring gaskets, internal and external flange protectors. The production tubing (5-1/2 in. casing) is suspended from the threaded tubinghead flange and is packed off with a compression activated seal unit. The production valves used with the wellhead are also 600 series ASA with stainless steel trim and Teflon seats. The product is generally pumped into the side out-let valves and brine displaced through the master or 5-1/2 in. tubing valve; however, this process may be reversed as the wellhead assembly is manifold to allow circulation in any direction, as illustrated in Figure 6 of a typical LPG wellhead installation. The completed well is now ready to receive and store LPG products which are pumped at a controlled rate of approximately 10 bbl/min, and displace the brine into approved storage facilities through a closed pipeline system which prevents vaporization and eliminates the need of refrigeration to control the products.

WORKOVER OF STORAGE WELLS

Elimination of the costly workover to the storage wells has been of major consideration in design of the primary drilling and completion of the storage wells; however, occasionally it is necessary to rework the well to maintain it as a storage facility.

In most instances of workover, product has been stored; and either because of (1) parted or inoperative tubing or (2) lost products, it is necessary to remove the production tubing from the well. This is accomplished by stripping the tubing after displacement of product with brine through a series of blow-out preventors, one which is a ram type and the other a bag type stripper, both of which are equipped with synthetic rubber elements to withstand the sub-freezing temperatures created in vaporization of the product.

Frequently it is necessary to re-drill portions of the cavern section with a bit attached to the producing tubing string. This is accomplished with the use of a power rotating swivel, stripper head, and reverse circulating unit in conjunction with the workover pulling rig. The cavern is re-drilled with brine circulating both conventionally and in the reverse method. Each joint of casing is made up by using the epoxy resin to resist torque back-off and to prevent thread leaks. The bit is removed from the casing by shooting it free with a jet charge cutter or in some

DIAGRAMMATIC SKETCH OF L.P.G. STORAGE WELL

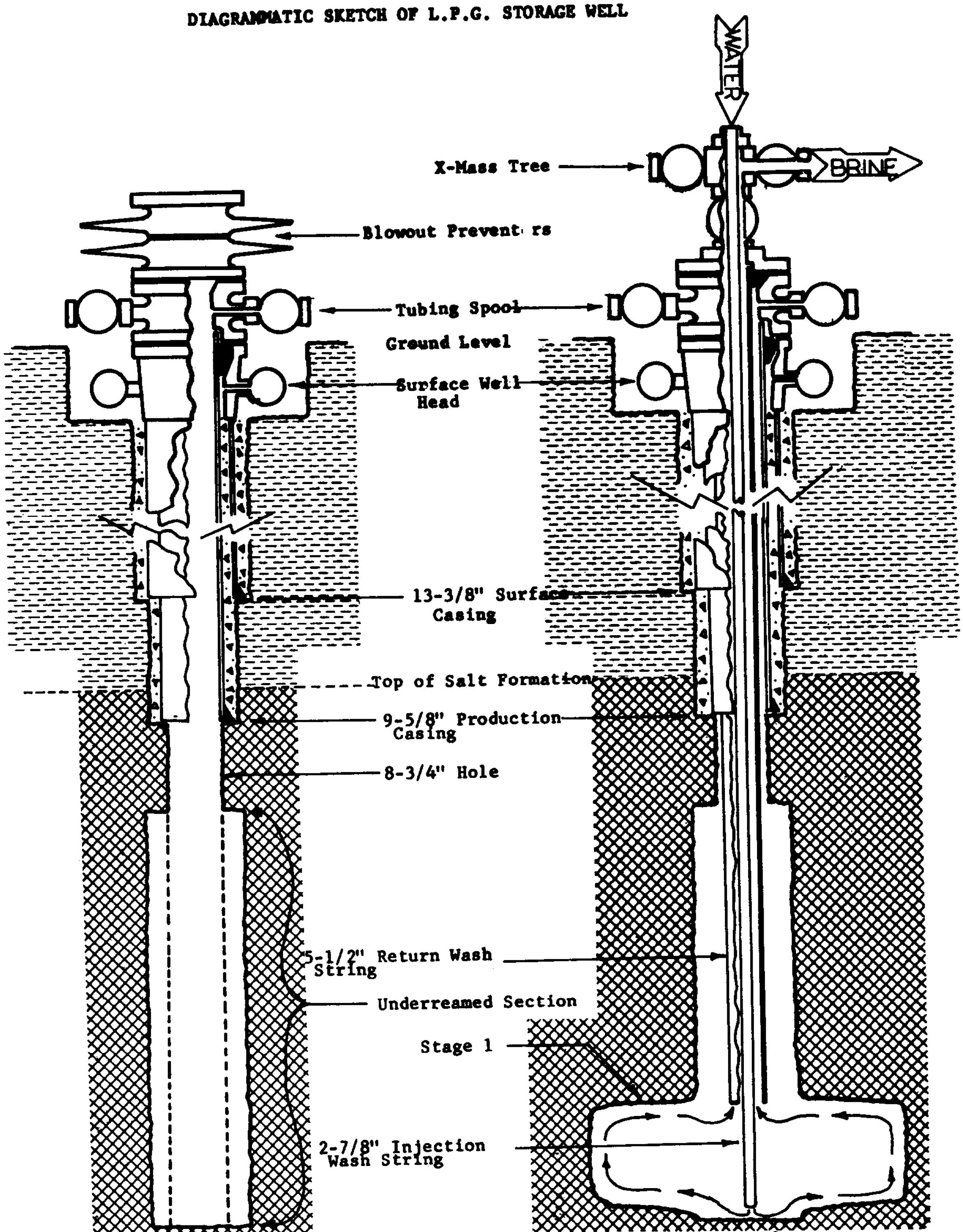

Fig. 1

Fig. 2

DIAGRAMMATIC SKETCH OF L. P. G. STORAGE WELL

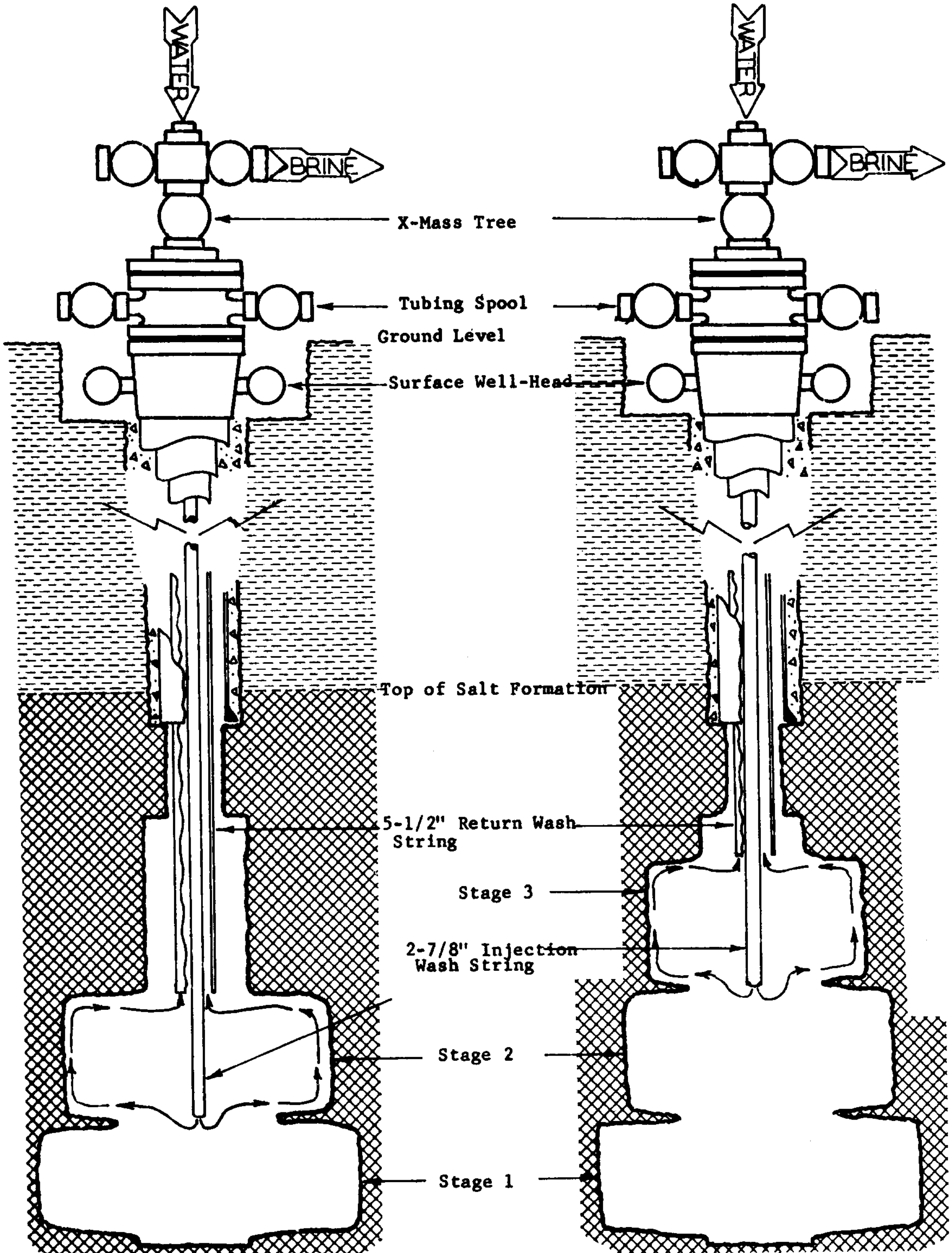

Fig. 3

Fig. 4

DIAGRAMMATIC SKETCH OF L. P. G. STORAGE WELL

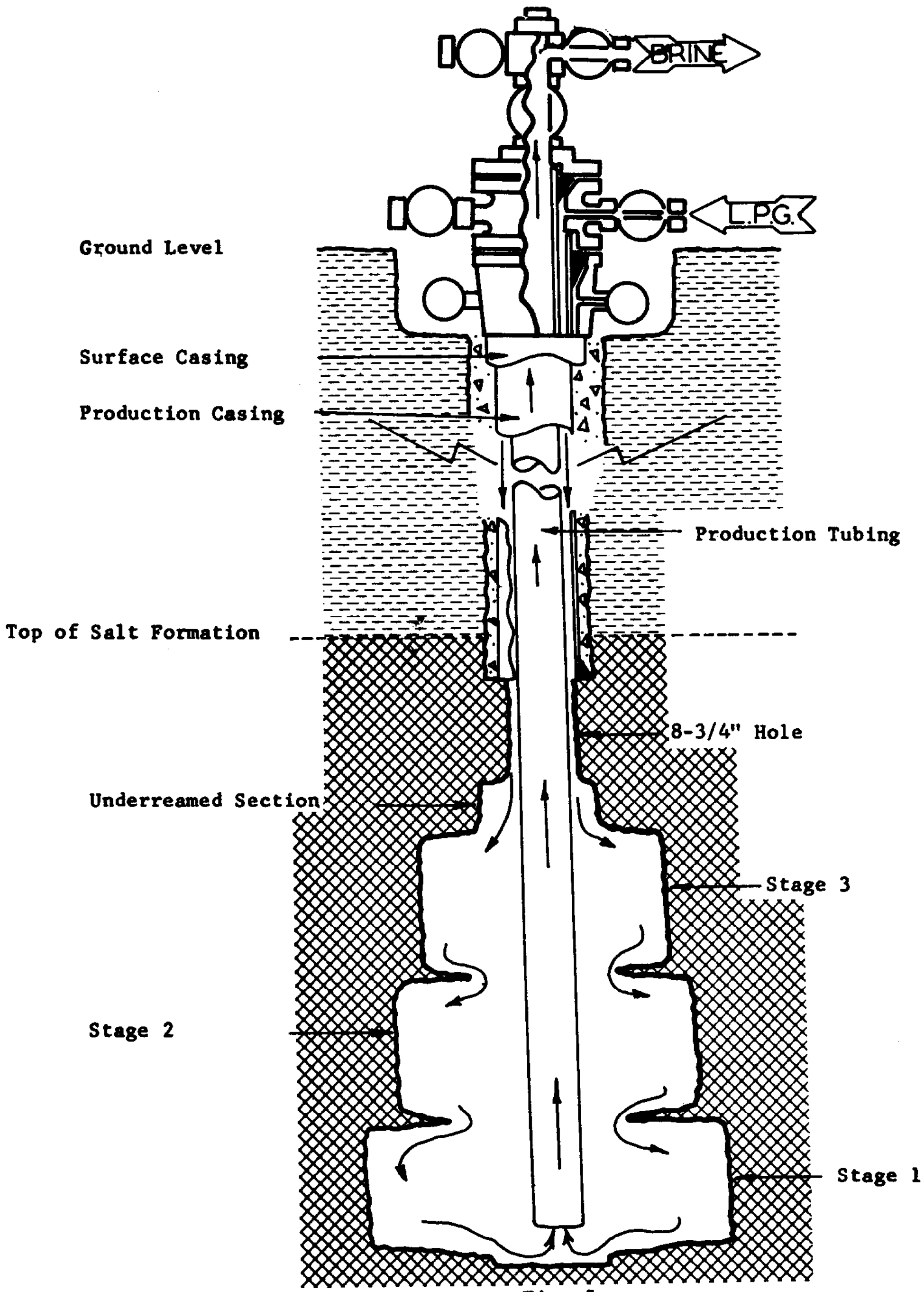

Fig. 5

DIAGRAMMATIC SKETCH OF TYPICAL LPG WELL HEAD INSTALLATION

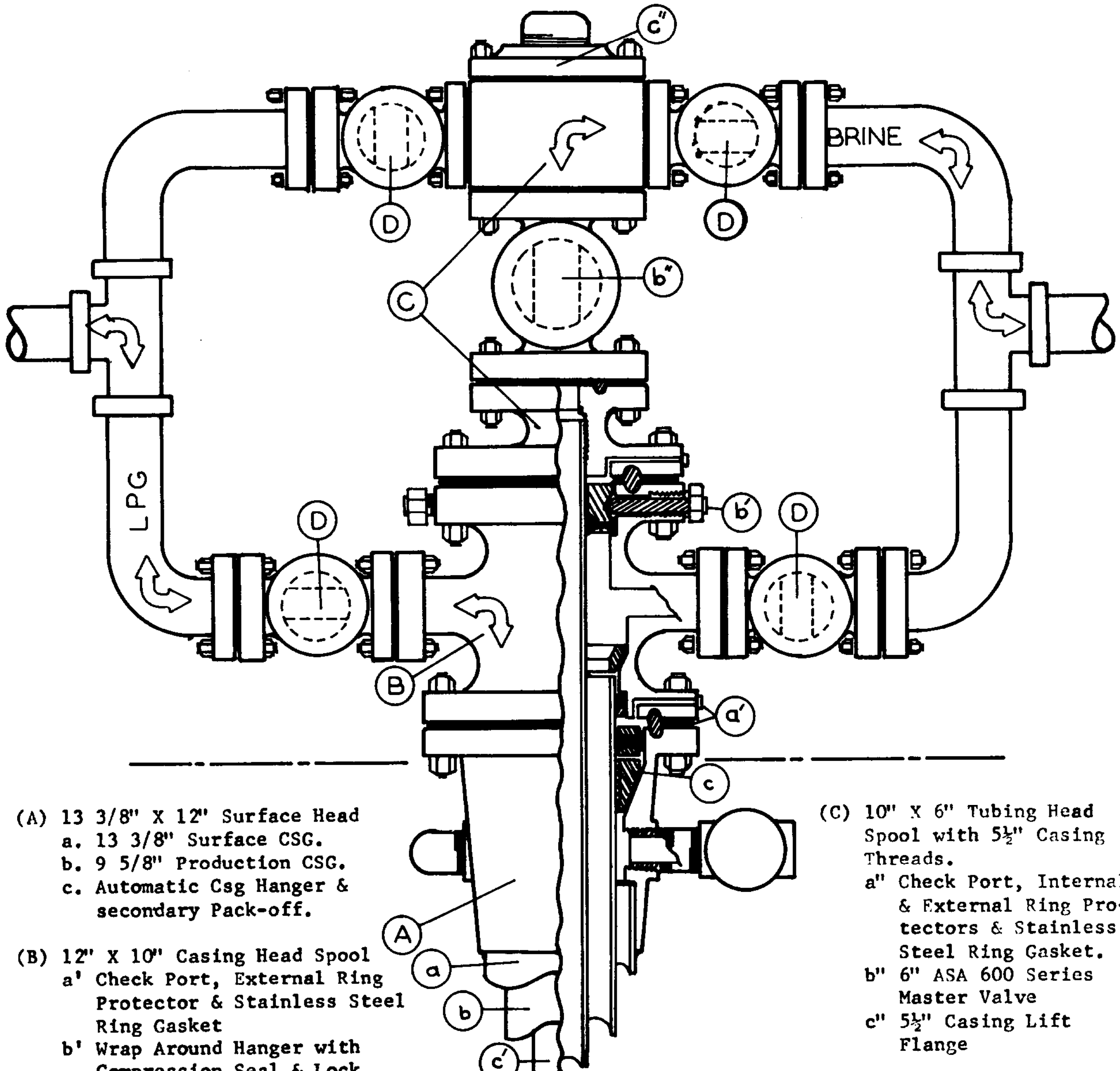

Fig. 6

(A) 13 3/8" X 12" Surface Head
   a. 13 3/8" Surface CSG.
   b. 9 5/8" Production CSG.
   c. Automatic Csg Hanger & secondary Pack-off.

(B) 12" X 10" Casing Head Spool
   a' Check Port, External Ring Protector & Stainless Steel Ring Gasket
   b' Wrap Around Hanger with Compression Seal & Lock Down Screws
   c' 5 ½" Production Tubing

(C) 10" X 6" Tubing Head Spool with 5½" Casing Threads.
   a" Check Port, Internal & External Ring Protectors & Stainless Steel Ring Gasket.
   b" 6" ASA 600 Series Master Valve
   c" 5½" Casing Lift Flange

(D) 4" ASA 600 Series Valve

cases it may be necessary to perforate the casing or drill pipe. In that case, the perforation should be made with expendable guns with hole size and pattern density great enough to equal the area of the pipe. This will then allow free unrestricted circulation through the tubing string.

When large volumes of product are unaccountable, it is usually found that the product is trapped behind the 9-5/8 in. production casing in unintentional washouts which always can be correctly located by means of a neutron type log. Once the washouts are located in relation to the depth of the casing, the production tubing is re-run into the well, with the bottom of the tubing hanging a few feet above the top of the washout area. An expendable jet perforator, run through the bore of the tubing, is positioned opposite the area of washout behind the 9-5/8 in. casing. The casing is perforated and the tubing, with tubing head assembly, is immediately lowered into producing position and flanged up to control the product which, because of density differences, will rise to the surface within seconds after perforating. The perforating line is protected by means of a line stripper or blow out preventer on a lubricator above the master valve. The product is displaced from behind the casing with brine in the conventional recovery method.

SUMMARY

Economical storage for LPG products has been successfully accomplished by the use of the shallow Salado Salt Section as an underground storage facility. The salt formation is ideal for storage and a minimum of cost is required for maintenance to the underground storage well if necessary precautions are used during the drilling, washing and completion of the well. The scope of this paper has been to acquaint the operator with the major problems and their corrections encountered in drilling and completing storage wells in the West Texas Area.

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