Design of the Salt Water Gathering System

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GENERAL

This discussion is limited to salt water disposal systems where the salt water is to be injected into a subsurface formation. The subsurface formation may be the same formation from which the water was produced or some other one. The injection of salt water may be solely a means of disposal or it may be injected as a part of a waterflood or pressure maintenance project.

Systems for subsurface disposal of salt water will usually include the injection well, injection plant, treating plant and the salt water gathering system. The injection wells, injection plant and treating plant, as well as the source and disposition of the water, will be discussed only as they may influence and require consideration in the mechanical design of the salt water gathering system and the time for initiating such design.

The salt water gathering system shall include the gravity gathering lines, collection tanks, pumps and other equipment necessary to transport salt water from the tank batteries to the water treating plant. The facilities at each tank battery should include equipment that will adequately separate the oil and water so that oil skimming in the gathering system is limited to that necessitated by ocassional upsets. Such upsets will occur and provisions for handling the oil must be included.

Produced salt water may be formation water or water which has previously been injected in a waterflood or pressure maintenance project. If formation water, the design of the systems will usually be initiated after sufficient quanties of water are being produced so as to create a pollution or contamination problem. If, however, the salt water is from a waterflood or pressure maintenance project the design of the salt water disposal system should be made concurrently with the design of the water injection facilities. The actual installations can then be made so as to be available as needed.

There are two primary reasons for this simultaneous design. First, salt water production will result from a waterflood project and the cost of disposal facilities should be included to give the accurate economics of the project. Second, the simultaneous design will result in a more flexible design of the injection facilities so that, where possible, the produced water may be reinjected as a part of the flood, thus minimizing the need for extraneous make up water, additional equipment and/or operating requirements.

The location of the injection wells and the injection plant will determine the point to which the gathering system must transport water when the injection wells are a part of a water injection pattern or when they are the only wells available or suitable for injection. If a choice of injection wells exists, the gathering system design which makes the maximum economical use of gravity flow will determine the location of the injection wells, injection plant and treating plant.

When considering the source and disposition of salt water production it should be borne in mind that this salt water may provide the extraneous make up water for a future waterflood project in the same general locality. Therefore, the system design should be such that the minimum revision is required to deliver suitable water to the adjoining project.

Plants for teating salt water fall into general classification as the "open" system and the "closed" system. The "open" system is one where no attempt is made to prevent oxygen (air) from coming in contact with the produced water. In fact, the water is aerated and chemically treated prior to filtration and injection. In the "closed" system every effort is made to prevent oxygen from coming in contact with the salt water. The object of the "closed" system is to make possible the minimum of treatment prior to injection and is usually limited to filtration. See Fig. 1.

The "closed" system is generally accepted as the more economical method of handling salt water; therefore, it should be used where feasible. When the treating plant is to be an "open" system it is advisable to install a "closed" gathering system to prevent premature precipitation of solids and the possible plugging of lines. The discussion contained herein is directed to the design of a "closed" gathering system. With such a system either type treating plant may be utilized, depending upon future developments.

Regardless of the source of the produced salt water, such water must be considered to be corrosive. All equipment installed must, therefore, be of corrosion resistant materials or must be protected from corrosive action.

GRAVITY LINES AND PRESSURE LINES

The topography of an area is one of the more important factors for consideration in the design of a salt water gathering system; therefore, one of the first needs is a topographic map of the entire area to be considered. Topographic maps are not generally available; it will, in all probability, be necessary to construct one. This can be accomplished readily with the information available in most field offices, supplemented with field observation.

First, obtain an area base map of the area under consideration which shows all wells, injection wells, tank batteries and producing equipment located accurately. Since tank batteries do not plot to scale satisfactorily, the point of discharge of water should be clearly marked. This map should be to a scale which will lend itself to handling and at the same time possess a good degree of accuracy. A scale of 1 inch 2000 feet will usually prove most practical.

The derrick floor elevations of all wells in the field are entered on the map and the results contoured to produce a topographic map. Field observations will provide the location of the isolated high and low elevations as well as the nature of abrupt changes which are not apparent from the contour procedure.

When making field observations of an area it should not be viewed up hill or down but across the slope and slightly off of the perpendicular. When the map has been revised as necessary from field observations it should be drawn as a positive or original so that copies may be made for use as work maps throughout the development of the design.

Using this topographic map, the layout of all the gravity gathering lines and the location of the collection centers can be made. The location of the treating plant and injection wells may be entered and the location of the pressure lines necessary to connect the collection centers to the treating plant determined. The differences in elevations shown, and the lengths of the lines as scaled from the map will be accurate enough to make line size calculations and calculations of pump requirements. Similar layout maps may be made of all alternate plans to facilitate economic analyses.

If a more accurate profile is required, this map will provide an excellent guide for the field alignment plan and profile survey. Where no alignment and profile survey is to be made, a few spot checks of elevations should be obtained before the design is considered complete. The engineer should also walk out the lines so that he is well acquainted with the terrain prior to ordering materials. This layout map will also provide a basis for preliminary right-of-way negotiations so that necessary revisions can be made.

The next information required is the maximum volume of water which shall be produced from any tank battery at any time. It is also necessary to know the maximum volume to be produced concurrently from a group of batteries by any one line. Water production data will, at best, be an estimate; however, consideration of the direction and rate of approach of a flood front and the economic limit of water production from any well will assist in making this estimate. Having arrived at estimates of water production, the maximum volumes to be handled by each line should be entered on the layout map.

From the layout map the line number, difference in elevation, length of line, volume and the available head per 1,000 feet should be prepared, in tabular form, for each section of line. The volume and available head per 1,000 feet of line should be entered in adjacent columns. These are the data necessary to size the lines and make pump calculations.

Various Pipe Sizes

The Hazen-Williams formula is generally used in calculations of this type; however, rather than make calculations for each line, a series of curves for the various pipe sizes to be considered should be obtained. Curves of this type are available in the engineering data books of many companies. If not on hand, curves for the various sizes and weights of steel pipe cement lined may be obtained from Permian Enterprises Incorporated, Odessa, Texas; curves for asbestos cement pipe may be obtained from South Chester Tube Co. or Johns-Manville.

If preferred, a set of curves may be prepared using roughness factors and other data applicable to the specific installation under consideration. When preparing a set of friction loss curves, calculations at three or four different rates for each pipe size will usually be adequate.

With these friction loss curves and the tabulated data, the size of each line may be selected using the smallest pipe size available which will carry the required volume with the difference in head. Selection of line sizes may be made either by starting at the extremities of the system and working to the collection center or by starting at the collection center and sizing out to the laterals. The closeness of line size selections is dependent upon the stage of water production and the reliability of estimates of water production.

The selection of pipe sizes for pressure lines and the selection of pump and motor requirements must be made simultaneously. This problem will generally take either of two forms: 1. where the water must be pumped upgrade for the full length of the pressure line and 2. when the water must be pumped to the top of a ridge from whence it may gravitate to the destination.

The pump must overcome the static head difference between the pump setting and the highest elevation, plus the friction loss in the line from the pump to this high elevation, and possibly a part of the friction loss in the gravity section of the line. The line size is selected on the basis of the economics of installing a larger line versus the cost of horse power to overcome the friction loss. The curves which were used in selecting the pipe sizes for the gravity lines may be used to determine the friction loss for these calculations. Pump selection is further discussed in conjunction with Collection Center Design.

These procedures may be followed in preparing estimates for comparison of the economics of alternate plans. After the decision as to which layout is to be used, an alignment and profile survey may be made and the resulting data used in this same procedure.

At such time as the sizes of the lines are determined, the materials of which these lines are to be constructed must be selected. Lines constructed of many materials have been used in salt water disposal systems with varying success. Asbestos-cement pipe, cement lined steel pipe and plastic lined steel pipe are most commonly used.

Materials for Lines

Until recently most systems were constructed using standard weight steel pipe, cement lined for the pressure lines and asbestos-cement pipe for the gravity lines. The asbestos-cement pipe is more economical than the standard weight steel pipe cement lined. Also, the cement lining reduced the cross sectional area of the standard weight steel pipe so that larger sizes were required to handle volumes comparable with a given size of asbestos-cement pipe.

Asbestos-cement pipe is manufactured and sold as "Transite" by Johns-Manville and as "Century" by Keasbey-Mattison. The "Century" asbestos-cement pipe is distributed to the oil industry by South Chester Tube Company. The pipe manufactured by both companies is very similar, the primary differences being in the machining of the joint and the coupling design. Asbestos-cement pipe may be obtained in sizes 3 inch through 12 inch and in Class 100, 150 and 200 with the Class designation being the recommended working pressure. The standard joint is 13 feet long with one-half joints and one-quarter joints available and shipped as a per cent of the order for use in making short radius turns and tie-ins. The short joints may be obtained machined each end or machined overall. The machined overall joints may be field cut to give any desired joint length.

Detailed instructions for the installation of asbestos-cement pipe may be found in manuals supplied by both manufacturers. The manual provided by Johns-Manville is quite complete. The fittings required for use with asbestos-cement pipe have been constructed from different materials but the fittings fabricated from asbestos-cement appear most satisfactory. Asbestos-cement fittings are available from Corrosion Proof Fitting Co., Odessa, Texas and Rice Engineering, Great Bend, Kansas.

In recent years the steel pipe mills have been manufacturing what is commonly called "thin wall" pipe. This pipe has found wide acceptance in the gas gathering, transmission and distribution industries. The techniques of manufacture and testing have been improved so that the pipe is very satisfactory. The "thin wall" construction has reduced steel tonnage requirements; therefore, the cost of the pipe has been reduced to as little as 46 per cent of the cost of standard weight steel pipe.

The development of the "thin wall" pipe makes possible the cement lining of steel pipe that will have the same inside diameter and same capacity as comparable sizes of asbestos-cement pipe. The lower cost of the steel pipe makes it possible to obtain the pipe, have it cement lined and externally coated and wrapped and ready to lay for the same or less cost than asbestos-cement pipe.

In areas where the pipe is to be installed in earth, the cost of laying the cement lined steel pipe will be some greater than laying the asbestos-cement pipe; however, in rocky areas or where laying on top of the ground is permitted, the cost of laying the cement lined steel pipe will be less.

Cement lined "thin wall" steel pipe can be used in pressure lines, except for extremely high pressure injection lines, and it may also be used in constructing a gravity gathering system. The gravity gathering system may be installed for the same or less overall cost than an asbestos-cement system and the resulting system will have a higher allowable working pressure. The exact cost comparison and working pressures are dependent upon the wall thickness of the steel pipe selected.

"Thin wall" steel pipe is usually electric resistance weld pipe and is available in a wide selection of sizes and wall thickness which meet API specifications. Depending upon the size and wall thickness, the joints may be connected by welding or mechanical joints. This pipe is marketed through the usual sources of supply as well as by many distributors more or less specializing in "thin wall" pipe.

In the West Texas-New Mexico area, cement lining of steel pipe is performed by Permian Enterprises, Incorporated and Plastic Applicators, Incorporated. Permian Enterprises has permanent cement lining plants in Odessa and Snyder, Texas and a portable plant which can be moved to any area where the size of the job justifies the move. Plastic Applicators Incorporated completed the construction of a plant in Odessa about January 1, 1959.

Lining Processes

The lining processes used by these concerns are somewhat different. Permian Enterprises prepares the mix as a slurry. After one end of the join has been capped, the amount of slurry required for the pipe size, joint length and lining thickness is dumped into the joint. The other end of the joint is capped and the joint placed inside the pipe. The joint is rolled from the machine, the end caps removed and the excess water drained. The lining is inspected, the ends are hand finished and the joint placed on a dolly for movement into the steam kiln.

The humidity of this area is maintained at a point sufficient to prevent premature drying. The loaded dolly is rolled into a concrete block kiln where it is steam cured for a minimum of 12 hours. This steam curing gives the cement lining the properties usually associated with "28 day" concrete. On removal from the kiln, the lining is inspected and the ends of the lining buffed smooth with the end of the pipe. The cement lined pipe is then ready for coating and wrapping and/or laying.

Plastic Applicators prepares the mix as a slurry. A length of 1-1/4 inch tubing is inserted into the joint to be lined. A mud pump pumps the slurry through the tubing as it is withdrawn from the joint. The speed at which the tubing is withdrawn controls the amount of slurry placed inside the joint. When the slurry has been placed, the ends of the joint are temporarily capped and the joint moved to lining machine. There, the temporary caps are removed and the spinning caps placed on the ends. The pipe is then rotated until the lining is placed inside the pipe.

On removal from the lining machine, the spinning caps are removed and the excess water drained. The ends are repaired as necessary and covered with plastic bags to prevent premature drying. The joints are then racked over two steam headers, covered with a tarpaulin and steamed for a minimum of 12 hours. After steaming, the ends of the pipe are again covered with plastic bags and the pipe moved to yard storage ready for coating and wrapping and/or laying.

The various fittings such as tees, ells, weld neck flanges etc., that are necessary for installing a pipe line system are cement lined by Permian Enterprises at the Odessa plant.

Preparation of the bill of material for a salt water gathering system should be given considerable attention so that all materials needed are delivered on schedule. At the same time, the surplus should be held to the minimum. Many of these materials require special order and any surplus is not readily usable in other operations.

The bill of material for each line should be prepared separately and the station number location of each fitting noted. These data should then be cross listed so as to accumulate all like items. Both records should be filed until completion of the project when the cost distribution will be made to the various accounts.

Particular attention should be given to locations where the ditch cannot be economically cut to grade so that a hump is created. An automatic air release valve should be installed at such locations to vent any gas and prevent a gas lock.

The number and location of valves is dependent on the particular system. Valves may be gate valves, plug valves or butterfly valves which are available in corrosion resisting Ni-Resist cast iron, ceramic lined etc. Flanged end valves should be used for both asbestos-cement lines and cement lined steel lines. The companion flanges for these valves should be flat faced to prevent breaking of the flanges on the valves.

COLLECTION CENTER DESIGN

The collection center will be located at a low elevation where it can receive water from one or more gravity trunk lines. It may also receive water from another collection center through a pressure line. From each collection center the salt water will be transferred to another collection center or the treating plant. In some cases, the pressure line from a collection center may discharge into a gravity trunk line which terminates at another collection center.

The entire salt water gathering system must be designed to operate unattended and oxygen must be excluded throughout if a "closed" system is to be maintained. The collection center facilities should include corrosion resistant surge tanks, pumps and motors with automatic starters, electric power supply, level controls and controls, fittings and media for excluding oxygen.

Power failures will occur and it is probable that for short isolated periods the water input to a given collection center will exceed the pump capacity. It is, therefore, necessary that some surge and overflow facilities be installed and that the tanks, pumps and other equipment be enclosed with a dyke or retaining wall. See Figs. 2, 3, 4 and 5.

Steel tanks are preferred for the proposed type of installation as they are more adapted for installing the required controls and maintaining a slight gas pressure. Also, steel tankage is being made surplus by the installation of automatic lease equipment and is probably on hand. Tanks may be either bolted or welded but should be low tanks to permit the maximum use of gravity feed. Low 500 barrel tanks are very adaptable.

The tanks should be set with the chime ring centered on a concrete ring foundation which extends from solid footing to about 9 inches above finish grade. A concrete splash ring about 18 inches wide should be installed around the periphery of the tank. The top of this splash ring should be about 4 inches above finish grade and slope toward the tank except for a spillway.

The area inside the concrete ring should be filled to about 6 or 7 inches above grade with thoroughly compacted caliche which is then covered with 2 or 3 inches of pea gravel. Small diameter tubes may be inserted through the concrete ring at the top of the caliche to allow seepage and detection of leaks which may develop in the tank bottom. Building felt may be placed between the tank bottom and the pea gravel and is necessary if the external tank bottom is to be coated to prevent leakage of cathodic protection.

The inside of the steel tank should be thoroughly sand blasted and coated with Tarset, Arocoat or other acceptable coating materials. If cathodic protection is to be installed, the plastic coating should not be applied to the internal tank bottom or to the side walls from the bottom up to a point approximately 8 inches below the lowest fluid level. All entries into tank should be made and all welding completed prior to applying coating.

Tanks and Pumps

At least two tanks should be installed at each collection center. All incoming lines, the pump suction, level controls etc., should be installed in the surge tank. A second tank or overflow tank should be connected to the surge tank by an open overflow line near the top of each and should have a valved equalizing line near the bottom. If emergency overflow is to be provided by an open pit, the overflow tank should have an overflow line with a liquid seal leading to the pit. The overflow tank will also provide temporary storage for oil which may accumulate in the surge tank. Both tanks should be provided with sight gauge glasses. See Figs. 2, 3 and 4.

The pumps installed at collection centers should be centrifugal pumps direct coupled to the electric motor drive and mounted on a base which can be well anchored. The units selected should be manufactured for allweather service. Pumps constructed of alloys such as Worthington's Worthite have given very satisfactory performance in salt water service. Similar alloys are available from the Mission and Goulds Pump Companies. There are other materials which may be used; however, it appears that the aforementioned ones will give better long range service though the initial cost may be somewhat greater.

The selection of a pump and motor size is somewhat difficult because the initial requirements may represent only a small fraction of an ultimate volume and head that will not be reached for several years. The pump should be selected for a volume and head requirement which may be anticipated within a short period of time, i.e., 50 percent of ultimate.

In selecting any pump, consideration should be given to a pump with cut down impellers and operating at low revolutions per minute. When additional capacity and head output is required, larger impellers may be installed, the revolution per minute increased and the motor changed to provide the additional horsepower and speed. These changeouts can be made in stages so as to gradually bring the pump to the desired ultimate performance.

The selection of a pump by application of these considerations will prevent the rather costly changeouts of piping. All pumps should be selected to operate at low revolutions per minute so that a motor changeout alone will give increased performance. Pumps should be slightly oversize and installed to operate intermittently through control by level controls on the surge tank.

If the pump and motor required for the ultimate capacity are in the smaller size range, such a pump should be installed initially. The difference in cost of pumps in the smaller sizes is not great enough to justify any changeouts.

The pump and motor unit should be set on a concrete foundation which will elevate the motor above the water level which would occur in the event of a tank overflow. The required height is dependent upon the height of the dyke installed around the collection center. The pump suction piping should be fabricated from pipe one or two sizes larger than the pump suction flange. The piping should be installed with a slight rise from the tank to the pump and terminate with an eccentric reducing spool adjacent to the pump suction flange. See Figs. 3 and 5.

The pump motor starter may be controlled by any of several type of level controls mounted on the surge tank. Separate controls should be used for the starting and stopping operation. The single controls commonly available for performing both the starting and stopping operation have short vertical travel and cause more cycling of the motor than when individual controls are used and spaced farther apart.

This is especially true when the initial pump installations are oversized. The increased cycling will cause wear of relays, starters, etc., which have a usable life rating in terms of cycles, and bring about increased maintenance costs. See Figs. 3 and 5.

One of the most promising controls for this type of service is the capacitance probe. The capacitance probe operates on the difference in the dielectric constants of the two media forming the interface. The difference in the dielectric constants of oil and water is quite large; therefore, when perfected, these controls should be very useful for maintaining oil seals. Some difficulty has been experienced with installations made to date; however, it is very likely that the problems will be eliminated in the near future. See Fig. 3.

Type of Blanket

In "closed" systems, oxygen is prevented from coming in contact with the salt water by using either an oil seal or a gas blanket. There are many advocates and opponents to each type of blanket. When there is a dependable supply of gas, the gas blanket is preferred. An oil seal is going to be present at the collection centers when a gas blanket is used because some oil will find its way to the collection center; thus when designed for a gas blanket, both will be present.

The pressure for the gas blanket should be maintained at about 2 ounces which may be controlled by using an Enardo vent line valve installed as on stock tanks. The inlet gas control may be accomplished by a Fischer Type 733 regulator or equal which will give a regulator outlet pressure of from 3 inches to 8 inches of water. If the gas supply pressure at the sources of supply or immediately supply pressure is above 25 pounds a second regulator may be installed at the sources of supply or immediately upstream of the final regulator. See Figs. 2 and 4.

When only an oil seal is to be used, the low level in the tank should be carried somewhat higher than when using a gas blanket. That is, there should be a greater distance between the level where the water enters the tank and the oil blanket-water interface. This is necessary since the entering water will tend to roll the tank and break the oil seal.

The design of the piping for water entry into the tank and for the pump suction are very important. The water entry should be near the bottom of the tank but high enough so that after passing through the tank the entry can ell down. The downcomer should rest on the tank bottom and be cut at an angle which will cause the water to be discharged toward the tank bottom and wall. A riser should be installed on the top of the ell and should extend above the operating high level in the tank. The riser will vent any slugs of gas which may enter the tank and prevent rolling. See Fig. 4.

The pump suction piping on the outside of the tank was discussed under setting the pump. The internal suction piping should extend in toward the center of the tank. If there are to be several entries into the tank, and if they are scattered around the wall, the pump suction should end in the center of the tank.

The suction piping should either ell up or be joined at right angles to a riser or well of a larger size pipe which extends from bottom up to the desired low level. All joints must be sealed so that the only outlet is through the top of the well, so as to break any syphon which may be created. A syphon will empty the tank and lose the oil blanket, if used, and/or coat the anodes with oil when cathodic protection is used.

The electric power supply to the collection center will usually be brought in overhead. It is a good idea to bring primary lines to the collection center and set the transformers where they may be accessible for servicing. The power supply and control circuit from the last pole should be conduited with conduit protected from corrosive action of the salt water. A master switch should be installed outside the dyke so that power may be shut off in case of flooding because of overflow.

CONCLUSION

The purpose of this paper is to present some design techniques, installation procedures and information regarding materials of construction which may be of assistance to persons responsible for the design and/or installation and operation of salt water gathering systems. The practices suggested are not all original and certainly do not answer all of the questions which may arise in connection with such designs.

In most cases, the suggested practices represent time saving techniques when compared with the design practices currently being used and, at the same time, produce equal or better results. The installation procedures are, in general, corrective actions which have been made or can be made to improve design of existing installations and are based on observations of actual field occurences.

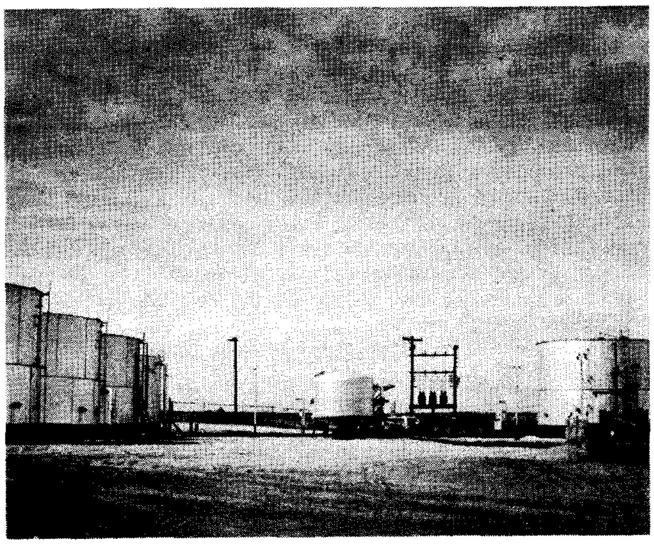


FIG. 1: Closed salt water treating plant. Pictured from left to right are: 3 tank receiving and surge system with entries and controls mounted on the third tank, filter backwash tank, filters, clear well or injection pump surge tank and the injection pumps are located in front of the clear well.

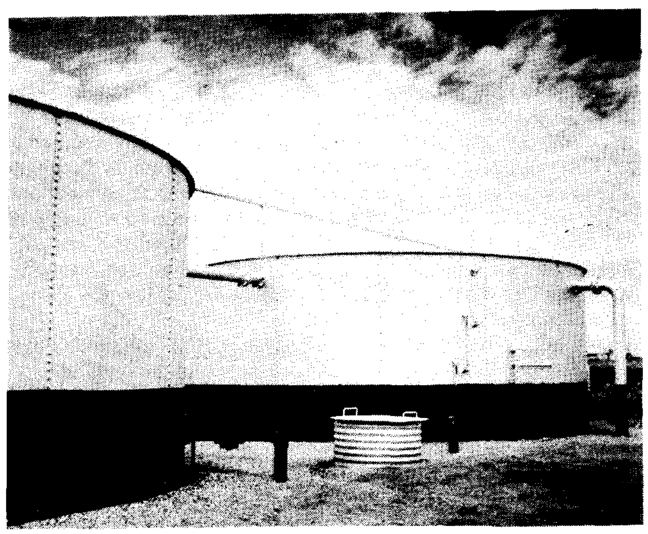
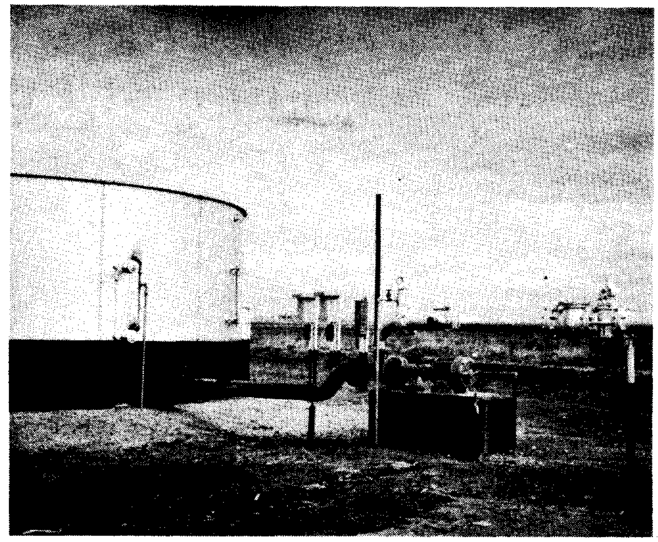


FIG. 2: Tank to the left is the surge tank. Pictured are the interconnecting overflow line near the top of the tanks, the valved equalizing line near the bottom and the emergency overflow line from the overflow tank to the earthen overflow pit. Also shown are the sight glasses, cathodic protection anodes, and the gas blanket relief line with the vent line valve located above the overflow tank.

FIGS. 2, 3 and 4: Pictured is a two tank Collection Center. It may be noted that the tanks are set on a concrete rung foundation but do not have the splash ring recommended in text. The earthen retaining wall may be seen in the background. All piping is cement lined steel.

FIG. 3: Tank to the left is the surge tank. Pictured are the pump and motor setting with suction and discharge piping, separate level controls for starting and stopping operation of pump, sight glasses and cathodic protection anode. In the background from right to left are the pump motor controller and rectifiers for cathodic protection.



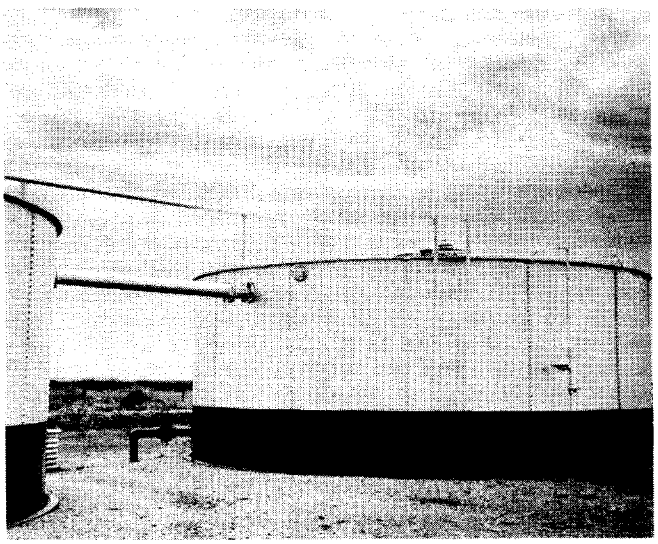


FIG. 4: Tank to the right is the surge tank. Pictured are the gas blanket inlet line and gas regulator, the gas blanket relief line to the vent line valve, Fig. 2, the interconnecting overflow line and equalizing line, Fig. 2, and at the extreme right the water entry into the surge tank.

FIG. 5: Tank to the right is the surge tank. Pictured are all of the items noted in Fig. 2, 3, and 4. The float control is a single control that starts and stops pump motor. The pump is set on grade level and can be flooded in the event of overflow. The pump discharge piping is cement lined steel and all other piping is asbestos-cement. The earthen retaining wall may be seen in background.