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CONSIDERATIONS IN THE CHOICE OF CARBON ADSORPTION SYSTEMS FOR GOLD HEAP LEACHING

Presented at the First International Symposium on Precious Metals Recovery – Reno, Nevada, USA – June 1984

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ABSTRACT

This paper is a discussion and comparison of the three principle carbon adsorption systems: cascading system (open-top), closed-top system and tower-type adsorption columns.

INTRODUCTION

Carbon adsorption has become the most common approach for recovering gold (and silver, if present) from heap leach liquors and other precious metal-bearing solutions. The majority of the gold/carbon adsorption plants use fluidized or fixed carbon beds contained in multiple tanks or stages for obtaining intimate carbon/solution contact. These systems operate in the counter-current “continuous/batch” mode, although truly continuous systems are presently being developed and improved. The continuous/batch mode means that the pregnant solution continuously passes through a series of carbon batches or stages. As the solution contacts the carbon, the precious metal values are adsorbed onto the carbon. Solution exiting the last stage is very low in gold and silver content and is termed “barren solution.” As each batch of carbon becomes loaded with gold and silver, it is sequentially moved to the immediate upstream stage. The carbon from the leading stage is removed from the adsorption circuit, stripped of gold and silver (desorption), possibly acid-washed and/or heat regenerated, and then returned to the last (downstream) stage in the adsorption circuit.

Several designs exist for providing continuous solution flow and separation of the carbon batches. These include:

- A multiple-tank cascading system utilizing gravity flow between stages;
- A multiple-tank system using pump pressure to force solution through closed-top tanks; and
- A multi-stage tower with continuous up-flow of solution through all stages.

This paper will describe the three systems in some detail and will explore the advantages and disadvantages of each one in relation to the others.

CASCADING SYSTEM

One of the first carbon adsorption circuits used in a major gold heap leach operation was at the Cortez Mine in east-central Nevada. This system successfully employed a five-stage cascading system and was the model for many of the existing operating plants (1). Examples of major heap leach operations in the western United States using this type of system include Carlin Gold Mining Company’s Maggie Creek Operation (2,500 tons per day), Amselco Mineral’s Alligator Ridge Project (3,000 tons per day), and Goldfield Mining Corporation’s Ortiz Mine (2,000 tons per days as of 1980) (2). The Pinson Mine in Nevada incorporates a series of carbon stages for recovery of gold from the thickener overflow in their 1,200 ton per day carbon-in-pulp plant (3). There are many other gold/silver operations world-wide employing this type of design, such as the 600 ton per day heap leaching operation of Minera Macacona in Costa Rica. This indicates the degree of acceptance that cascading-type systems enjoy in the industry. Some cascading-type systems are pictured in Figures 1, 2, and 3.

Diagrams of a typical cascading-type system and an individual tank are presented in Figures 4 and 5. Solution enters the bottom of each tank and flows through a distribution plate of some type and up through the carbon bed. The overflow from each tank then flows by gravity to the bottom of the next tank, etc. Several methods are employed to feed solution to

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each tank. The design in Figure 5 shows the feed solution entering the tank through a down-comer in the center of the tank and discharging below the distribution plate. The down-comer is fed by a launder with a dart valve to control flow so as to eliminate air entrainment in the solution as it flows down into the tank. Air entrainment in entering feed solutions can cause channeling of solution and carry-over of carbon out of the system. This factor must be seriously considered in the design of a cascading system. The feed launder contains another dart valve to allow an operator to by-pass the tank by directing solution to the overflow launder and then to the next tank in the series. Other designs pipe the feed solution through the side of each tank below the distribution plate. The advantage of the down-comer system is the ease of by-passing an individual tank without extensive piping as is required in the side-entry design.

Another advantage of the cascading-type system is the relatively easy access to the inside of the tanks. Often it is necessary to check each tank for proper carbon level, extent of fluidization, or cementing of carbon to the bottom or sides of the tank. It may be necessary to replace or repair the bubble caps or distribution system. This can be accomplished quite easily through the open top tank. Carbon and solution sampling are also accomplished quite easily with this system.

On the other hand, easy access to an open-top tank can be a security risk in that carbon theft is a possibility. Some cascading systems have a lockable hinged screen over the top of each tank to reduce this risk.

A major disadvantage of the cascading system are the structural requirements for raising the tanks to the elevation necessary to obtain the pressure head for proper flow through the system.

Walkways and working platforms must be constructed at each level to provide for ease of operation and maintenance. This increases capital and installation costs for the series of tanks and also increases building costs if the tanks are to be enclosed. Portability of the adsorption system also becomes quite expensive, although this may not be a factor in the conception of the project.

The large structures involved with cascading systems increase the operating costs associated with heating a large building during colder months. The possible exposure of operators to hydrogen cyanide vapors and solution in the tanks and launders along with the high moisture content of the air when processing cold solutions in an enclosed building lead to a poor working environment and possible building maintenance problems.

There are several other minor disadvantages or operating problems associated with a cascading system. One is the need for operators to climb up and down stairs or ladders in order to properly attend to their duties. Minor problems can develop into major ones if operators are too lazy to perform regular checks, and stairs contribute to this situation. It should also be noted that access to the drain valves on the bottoms of the upper tanks can also become difficult. Also, the use of windows or viewports in the sides of the tanks is pre-empted unless further walkways are installed. A final problem related to this system is that carbon movement between cascading stages requires the use of eductors. It can be argued that the use of eductors contributes to carbon attrition, although the severity of the attrition has not been quantified.

CLOSED-TOP TANK SYSTEM

Figures 6 and 7 depict actual closed-top tank systems utilizing relatively low pump pressure to force the gold/silver-bearing solutions through a series of tanks with closed and sealed tops at the required flowrate. With these systems all tanks can be at ground level since gravity is not required as a driving force. Examples of operating closed-top systems include Whim Creek Consolidated's Haveluck Mine (500 tons per day heap leach) in Meekatharra, Western Australia (4), Saga Exploration's Sterling Operation in southern Nevada (250 tons per day) (5);, and E & B Exploration's El Plomo Project in southern Colorado (300 tons per day). Closed-top type systems have been used at several other mining operations, and are typical in the chemical industry.

Figures 8 and 9 are diagrams of a typical four-stage closed-top system and an individual stage, respectively. Solution enters the bottom of each tank below a baffle or distribution plate, much the same as in a cascade system. General operation is also quite similar during the adsorption phase since flowrate control, degree of fluidization, carbon levels, etc., are all critical. However, the basic characteristics of the closed-top system allow much more flexibility in the amount and type of process variations available when designing the overall adsorption-desorption-recovery (ADR) circuit.

An example of this flexibility is the fact that a simple feed-pump change can allow the use of a complete new range of process flowrates. This may be desirable to compensate for design errors or different carbon size selection. Cascading systems do not allow this capability since the driving force (pressure drop) for flow through the system is limited by the elevation difference between each tank.

Another example of this flexibility is that a properly designed adsorption tank can double as a stripping vessel and be used for acid-washing the carbon. In addition, a four or six tank system can be operated as either a single series of tanks or two parallel sets. The Whim Creek tanks (Figure 6) were originally designed to operate as six tanks in series, but were later set up as two sets of three tanks with the circuits operating in parallel. As shown in Figure 6, all the Whim Creek tanks are mounted on a carousel stand which is rotated to place each tank in the required position. The Sterling tanks (Figure 7) operate as fixed-bed units with two sets of two tanks operated in parallel. Stripping and acid-washing are conducted in the same tanks with the carbon continuously cycled through these various steps for over a year before it is transferred out of its respective tank and replaced. This flexibility can serve to reduce the amount of tanks required for the various operations in an ADR circuit as well as reduce the degree of carbon handling.

Along these lines, another factor to consider in favor of closed-top systems is potential portability. Costs and difficulty for moving ground-level tanks are much reduced compared to tanks mounted two or three stories high. For smaller production facilities and entire ADR plant can be installed in a 40-foot semi-trailer for ultimate portability. Larger plants can be constructed by joining two trailers together. The Sterling plant is an example of a trailer-mounted ADR plant.

In comparison with the cascading tank system, other advantages of the closed-top system include major capital cost savings in support structures and building size along with savings in heating costs during winter months. Operators are not exposed to cyanide-bearing solutions since the leach solutions are not exposed. Also, the possibility of air entrainment in the solution fed to each tank is eliminated. Because the tanks can be pressurized, carbon can be transferred out of a tank using direct water pressure rather than sucking the carbon through an educator. This can cut down on carbon losses due to the attrition and can simplify the transfer system.

Windows mounted in the side of the tanks at a convenient viewing height allow operators to view the behavior and level of carbon inside the tanks. This eliminates some operating headaches in adjusting both column flowrate during adsorption and carbon levels during carbon transfer. Also, since the tanks are all mounted at ground level, operators are not required to climb stairs or ladders to perform their duties.

Access to the inside of the tanks in the closed-top type system is much more difficult than for the open top cascading system. Although this is advantageous from a security standpoint, it can cause problems and delays when performing maintenance on distribution plates, etc. Proper design should include manholes to make access easier. Obtaining carbon samples can also be difficult, especially if the carbon is never transferred out of a given tank. Inter-stage solution samples are easily obtained through a valved sample port.

The previous discussions regarding the inherent flexibility of closed-top tanks do not mention the costs associated with this flexibility. While structural costs are much lower, a properly designed adsorption system for simple series operation must include provisions for by-passing individual tanks for maintenance purposes. This piping would be somewhat more extensive than the simple launders used when by-passing a cascade-type tank.

If a closed-top system is constructed to incorporate stripping and acid-washing in the adsorption system design, piping and installation costs can become high and operation of the plant can become complicated and sophisticated. However, if this is the case, direct comparisons with an adsorption-only cascading system cannot be made since a cascading tank system does not offer the flexibility for this arrangement.

Although the gold/silver industry is quite familiar with pressurized operations such as pressure filtration and compressors, an important point to remember when considering this type of system is the safety factor encountered when operating closed tanks under pressure. The tanks must be designed to withstand operating pressures which are relatively low (<20 psi), but the possibility always exists for over-pressurization by pumping against a closed tank discharge valve. To avoid unpleasant consequences, safety pressure relief valves and/or rupture discs should be employed and operators must be well trained in performing the various tasks requiring pressurization. The tank depicted in Figure 9 is designed with both relief valves and rupture discs.

TOWER TYPE ADSORPTION COLUMNS

The final style of a continuous/batch adsorption system to consider is the multi-stage adsorption tower or column. This system incorporates several stacked sections each containing a batch of carbon and separated only by a distribution plate. There are several operations in the western United States that use this type of adsorption system. The Carlin Gold Mining Company employs a five-stage carbon column for processing tailings overflow water before recycling it to their milling circuit (6). Fischer-Watt's Hayden Hill property in California uses a five-stage tower for processing solutions from their 1000 ton per day heap leach. Western United States Mining's Goldstrike Mine in eastern Nevada uses two sets of two four-stage columns to process their heap leach liquors and they are presently building another heap leach plant at their Drum Mountain property in western Utah using tower-type adsorption columns.

A diagram of a typical five-stage adsorption column is presented in Figure 10, and the Hayden Hill and Goldstrike columns are pictured in Figures 11, 12, 13 and 14. Operation of these columns is straight-forward. As Figure 10 shows, the pregnant solution is pumped into the bottom of the tower and overflows from the top over a carbon catch screen before flowing to the barren pond. Eductors are located between each stage to transfer carbon down the column as it gradually becomes loaded (for smaller columns, simple gravity-flow carbon transfer is possible). Windows are located in each stage for observation of carbon behavior. Valved sample ports are properly located to obtain both solution and carbon samples.

A major selling point of this type of system is the low capital cost. Structural and piping costs are reduced significantly, although a solid concrete foundation is required. Floor space requirements are very small, but height requirements usually result in outdoor operations. Portability is somewhat simplified since only a single piece of equipment must be moved for each multi-stage adsorption system. Semi-portable ADR plants capable of processing 1000 tons of ore per day have been built.

As mentioned previously, the height of the tower usually means that the tower will be installed out of doors. During periods of colder weather, a certain amount of freeze protection is required to protect educator and water supply lines. Insulation and heat tape can help here, especially in conjunction with a positive draining educator system. However, it should be pointed out that this type of system lends itself much more easily to outdoor processing since inter-stage piping or launders are not involved.

There are several inherent disadvantages to this type of system. Foremost is the lack of flexibility. If maintenance of any kind is required on one of the stages, the entire adsorption operation must be shut down. If the required repair work is major, this could result in a very substantial loss of production although good heap leach system design includes enough pond volume flexibility to handle certain amounts of downtime. Also, access to the inside of the individual stages is very difficult and dangerous, even with properly designed manholes in each section.

Operating an adsorption tower presents certain headaches. A major problem is the necessity of the operator to climb up and down the ladder to perform sampling and carbon transfer duties. Some operations have employed remote-operating valves so that inter-stage carbon transfer can be initiated from ground level. However, it is still necessary to verify positive carbon transfer and to determine when correct carbon levels are attained in each stage. If an operator becomes lazy, it is possible to end up with a double batch of carbon in one stage while another stage is completely empty. Also, since eductors tend to become plugged on occasion, valves are required to isolate the educator for removal and repair without draining the entire column. These valves are also necessary to prevent short circuiting of a portion of the leach solution through the educator lines.

DISCUSSIONS OF COMPARISONS

The preceding descriptions contained some comparisons between and among the three systems. In general, the cascading system would be the most expensive but would be preferable from a tank maintenance point of view. Operating problems are not excessive and, based upon the number of these systems presently in use, the design is quite successful. It is noted that the cascading-type design is used in virtually all of the larger processing plants (greater than 1000 tons per day), probably because the designers wanted to draw on the experience of the earlier models and operators. However, that traditional hesitation by the mining industry to accept new or unfamiliar technology is evident.

The closed-top tank system would be in the middle of a cost comparison and has the advantage of extreme flexibility regarding flow rate, multi-function potential of the tanks, and method of carbon transfer. Operating problems are minimal, but maintenance on the inside of the tanks would be somewhat difficult. This system can also be made much more portable that the cascade system.

The tower adsorption column is by far the cheapest of the systems for flowrates above 100 gallons per minute and is the most straight-forward to operate during the adsorption cycle. However, flexibility is extremely limited and operating problems exist during carbon transfer. Maintenance on the inside of the tower is very difficult and potentially dangerous. Cold-weather operation of an outdoor adsorption system would present fewer problems with this system. Portability of this system is relatively good.

It is difficult to recommend any one system since so many factors must be included in the decision-making process. Certainly, operator preference must be considered since people tend to have more faith in a familiar system. However, proper design of any of the systems will yield a functional and cost-effective plant. If flexibility is considered important, the closed-top system cannot be surpassed. This is especially true if the adsorption system was designed integrally with the stripping and electro-winning systems. As far as maintenance and operating problems are concerned, none of the systems stand out as clear winners. Cost tends to be a major factor in choosing equipment designs and styles, but in this case the most expensive system is the industry favorite, especially in the larger plants. It is felt that this will change as more of the other types of designs are put into production on larger-scale projects.

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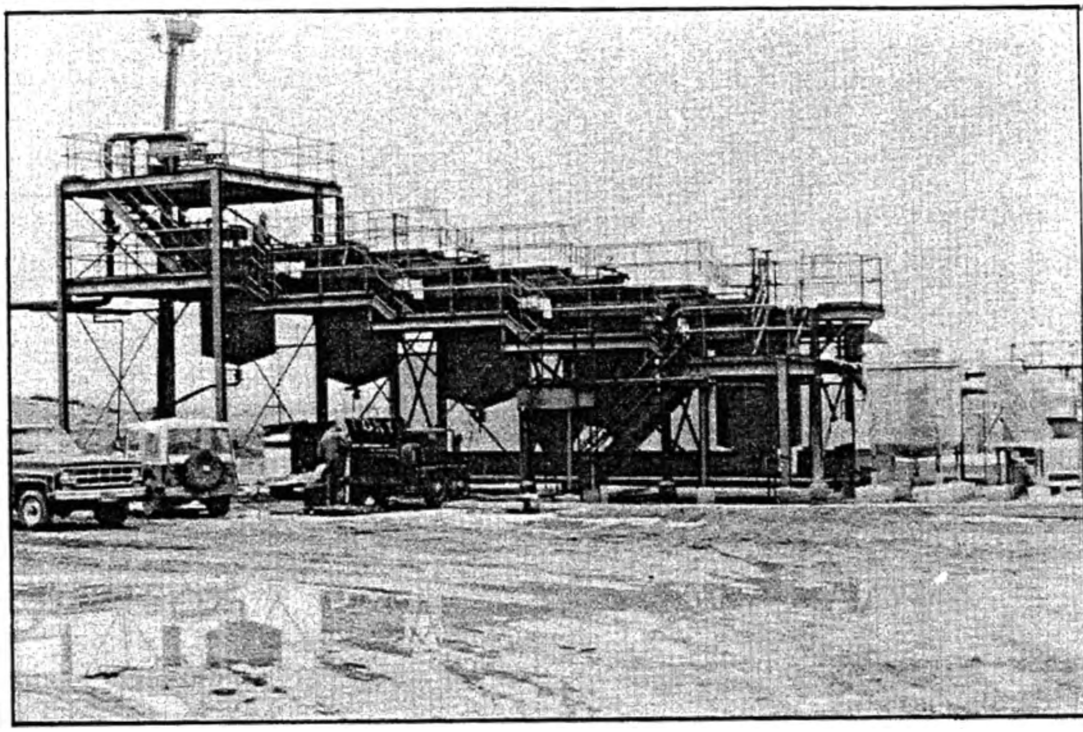

Figure 1. Cascading System – Newmont's Maggie Creek Operation

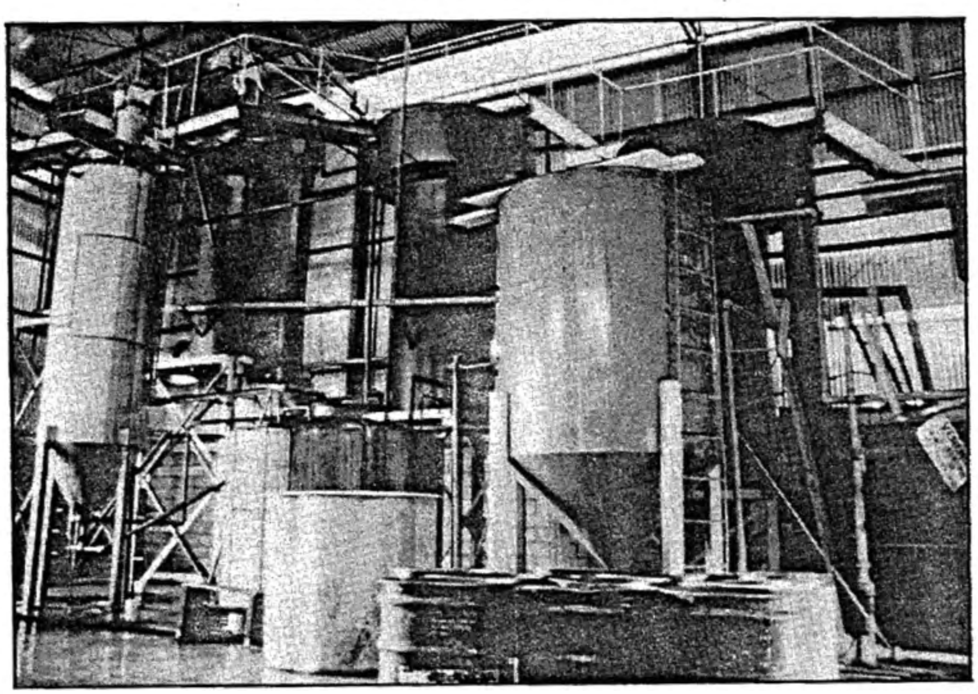

Figure 2. Cascading System – Minera Macacona, Costa Rica

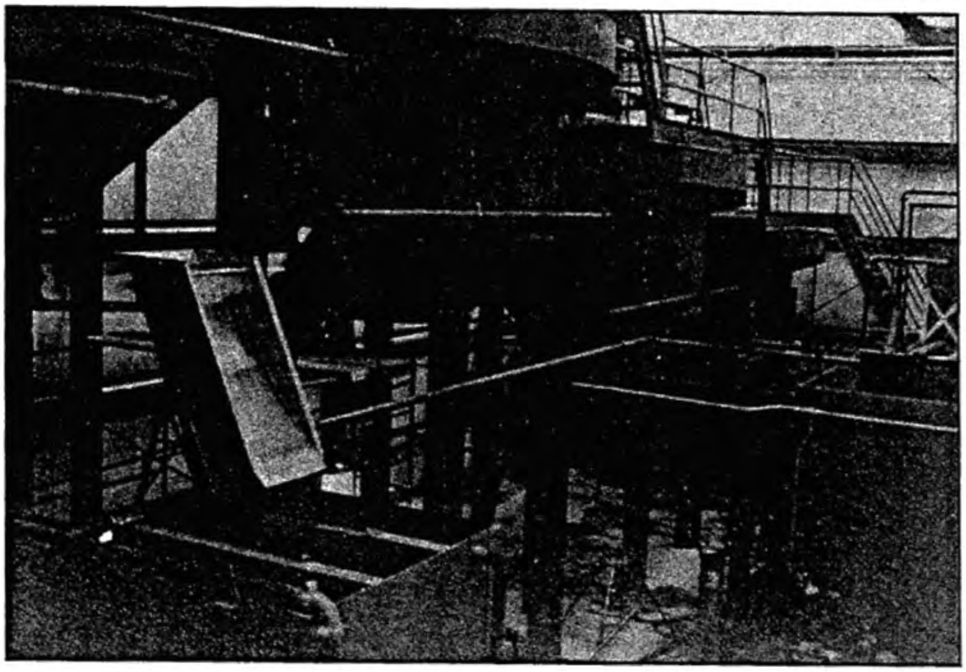

Figure 3. Cascading System – Goldfields' Ortiz Operation

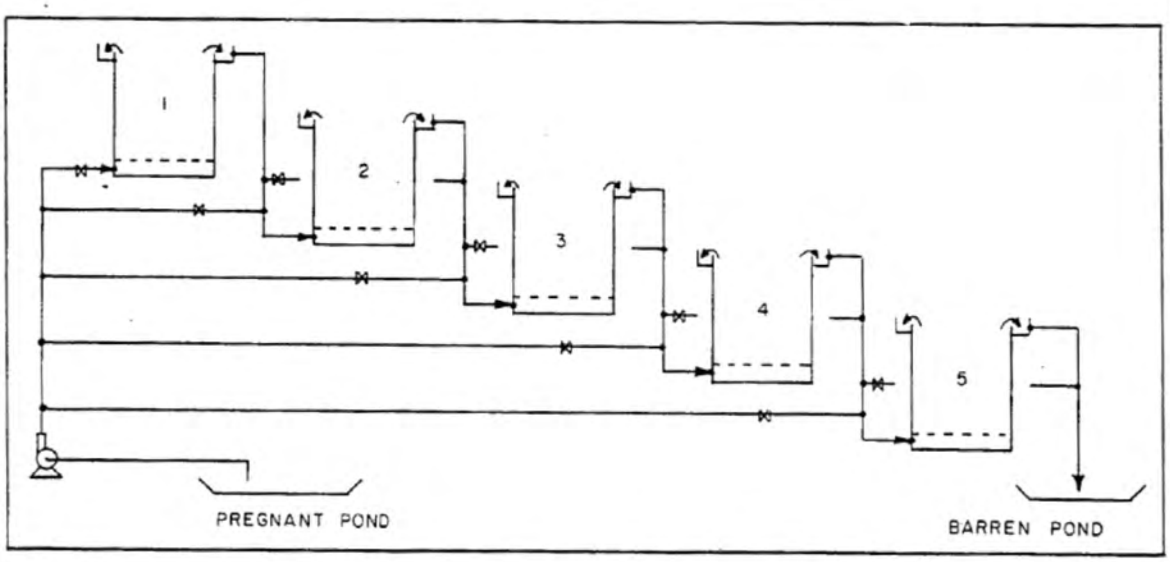

Figure 4. Typical 5-Stage Cascading System

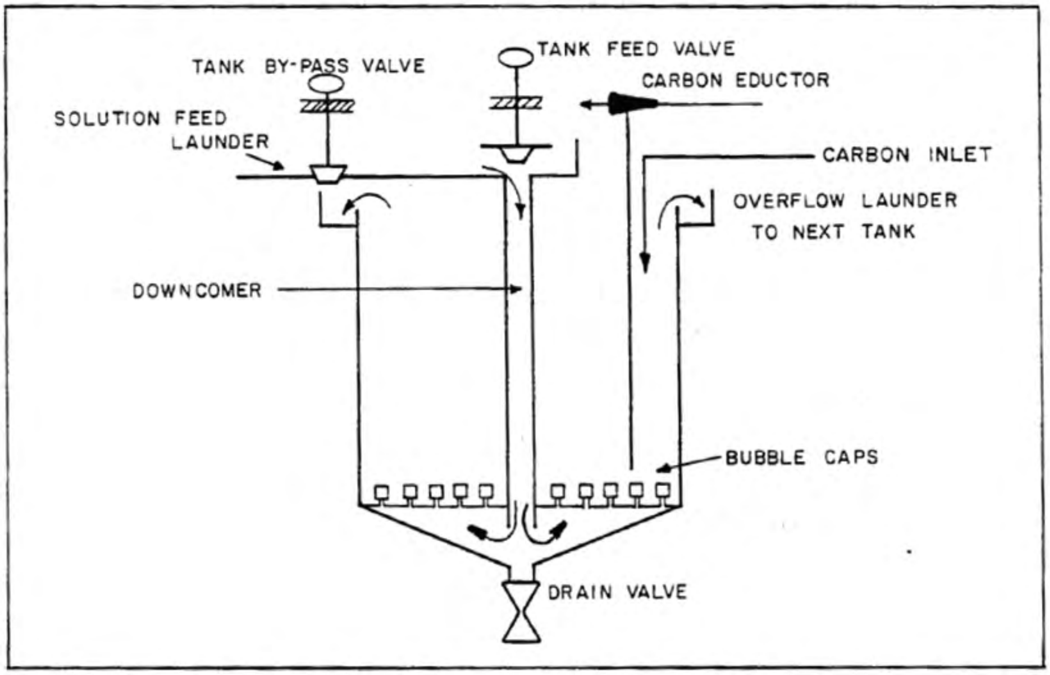

Figure 5. Typical Cascade-Type Tank

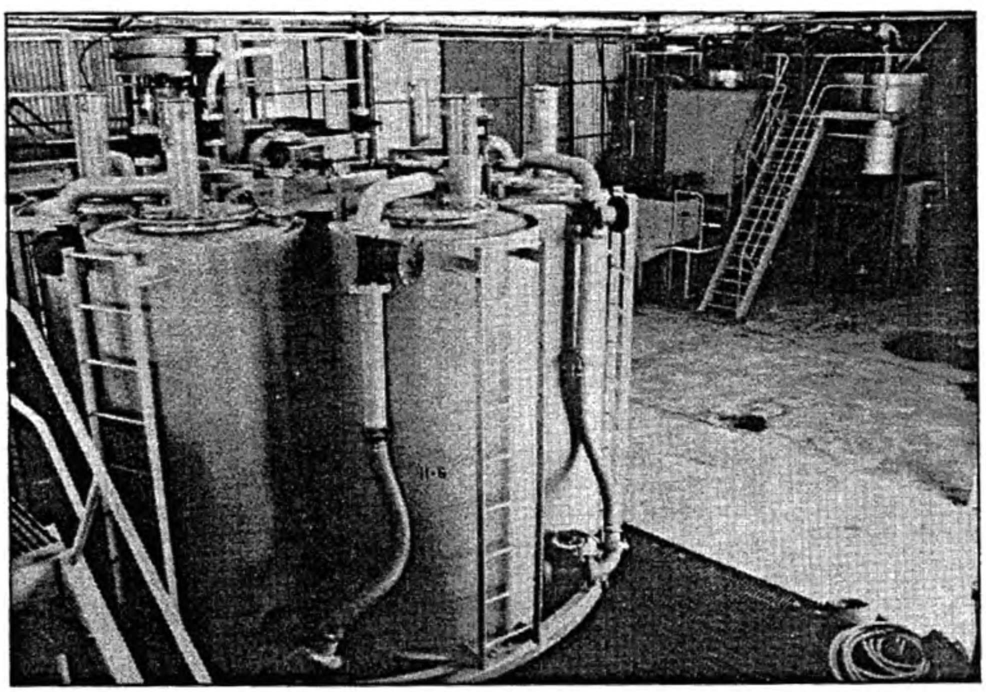

Figure 6. Closed-Top System – Whim Creek

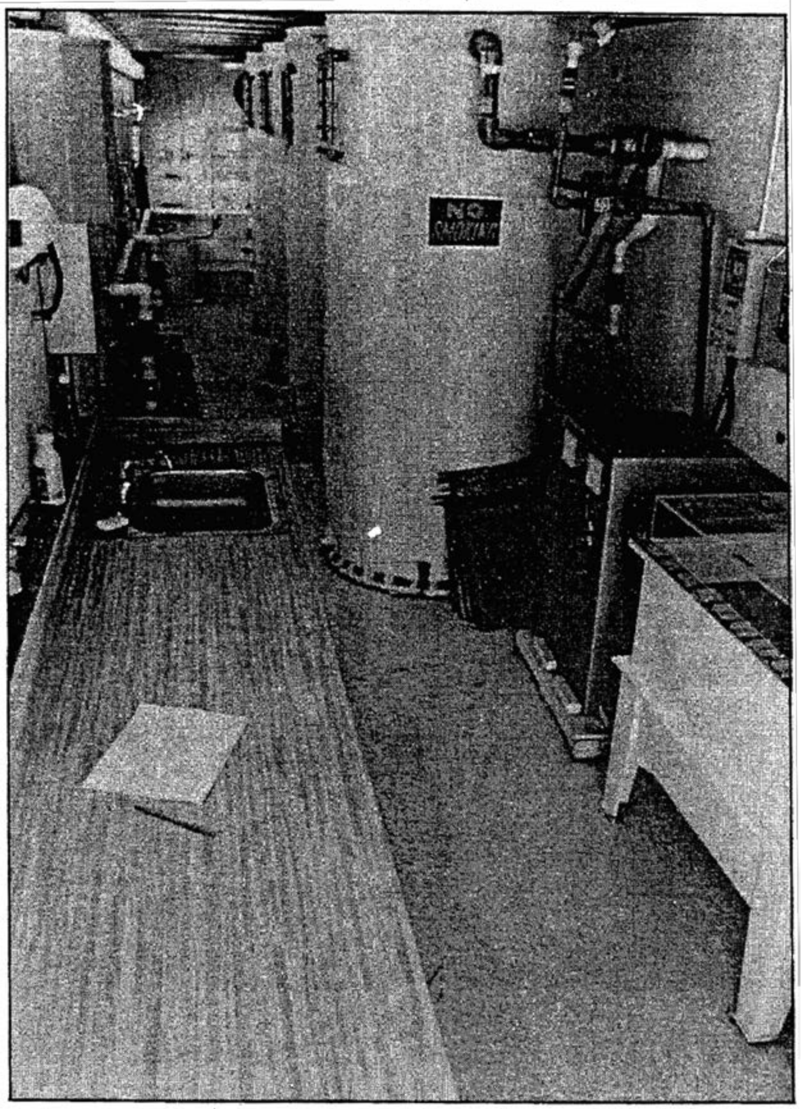

Figure 7. Closed-Top System – Sterling Mine

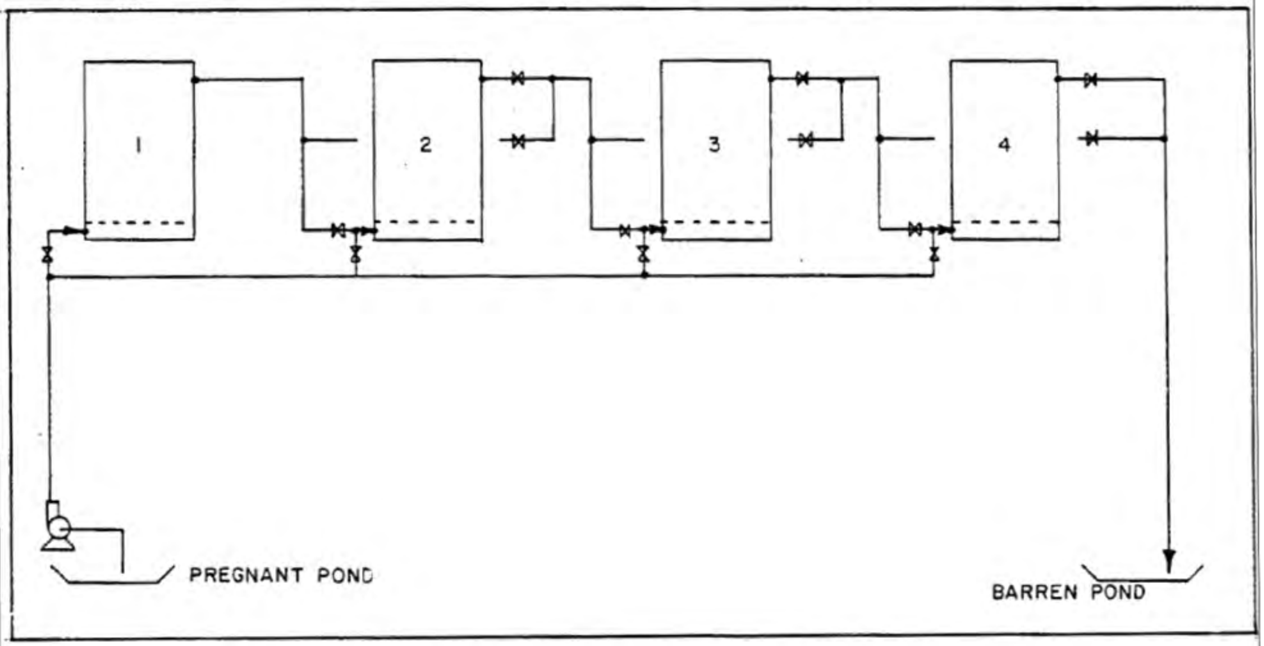

Figure 8. Typical 4-Stage Closed-Top System

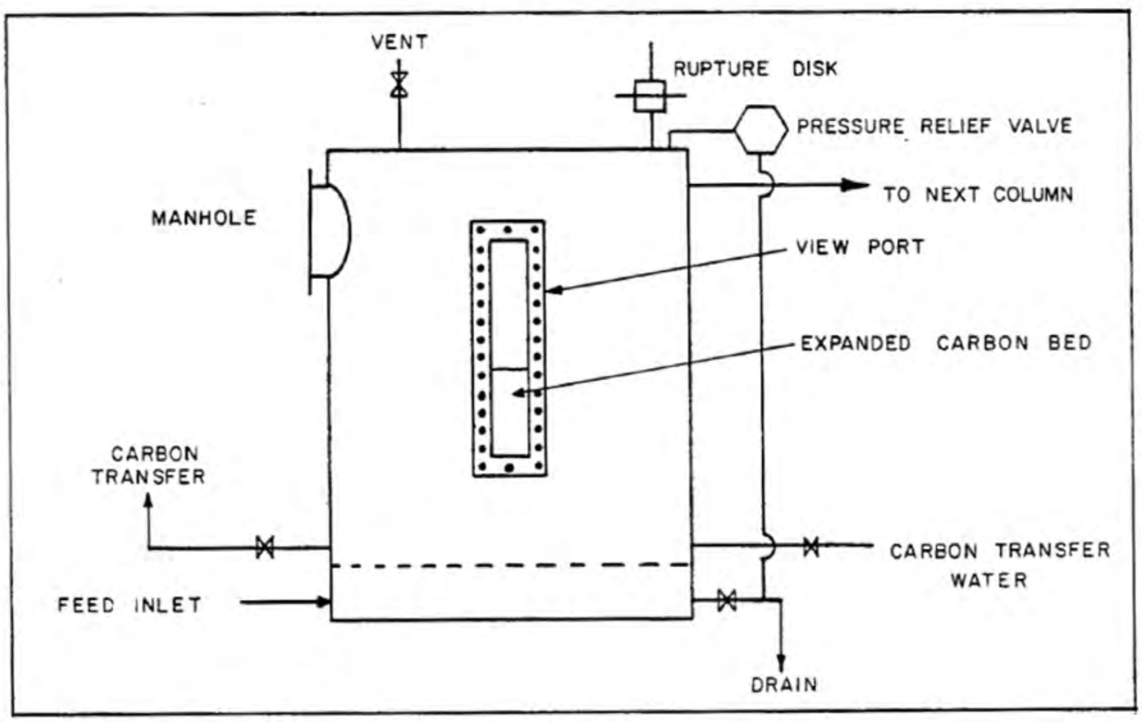

Figure 9. Typical Closed-Top Tank

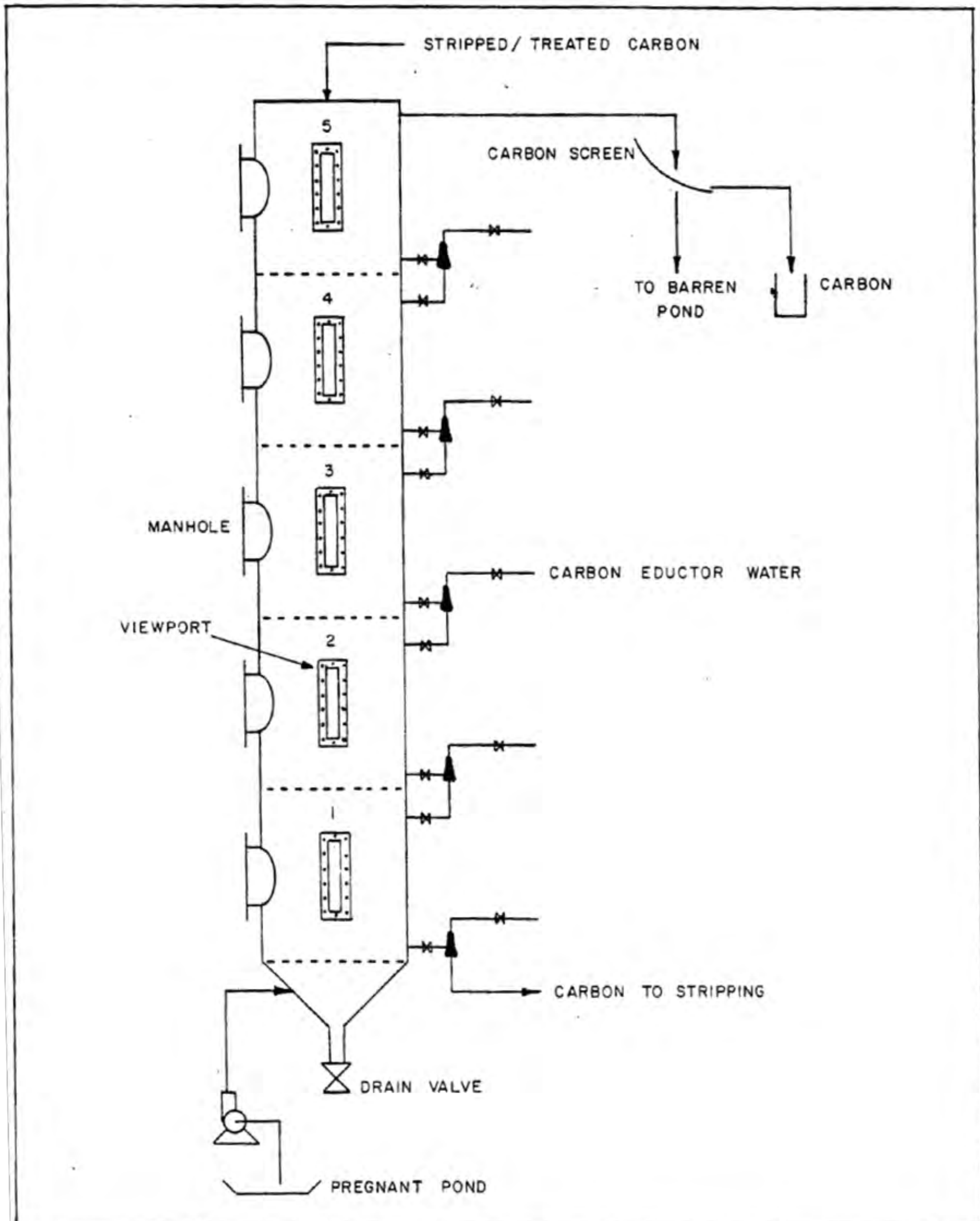

Figure 10. Typical 5-Stage Adsorption Column

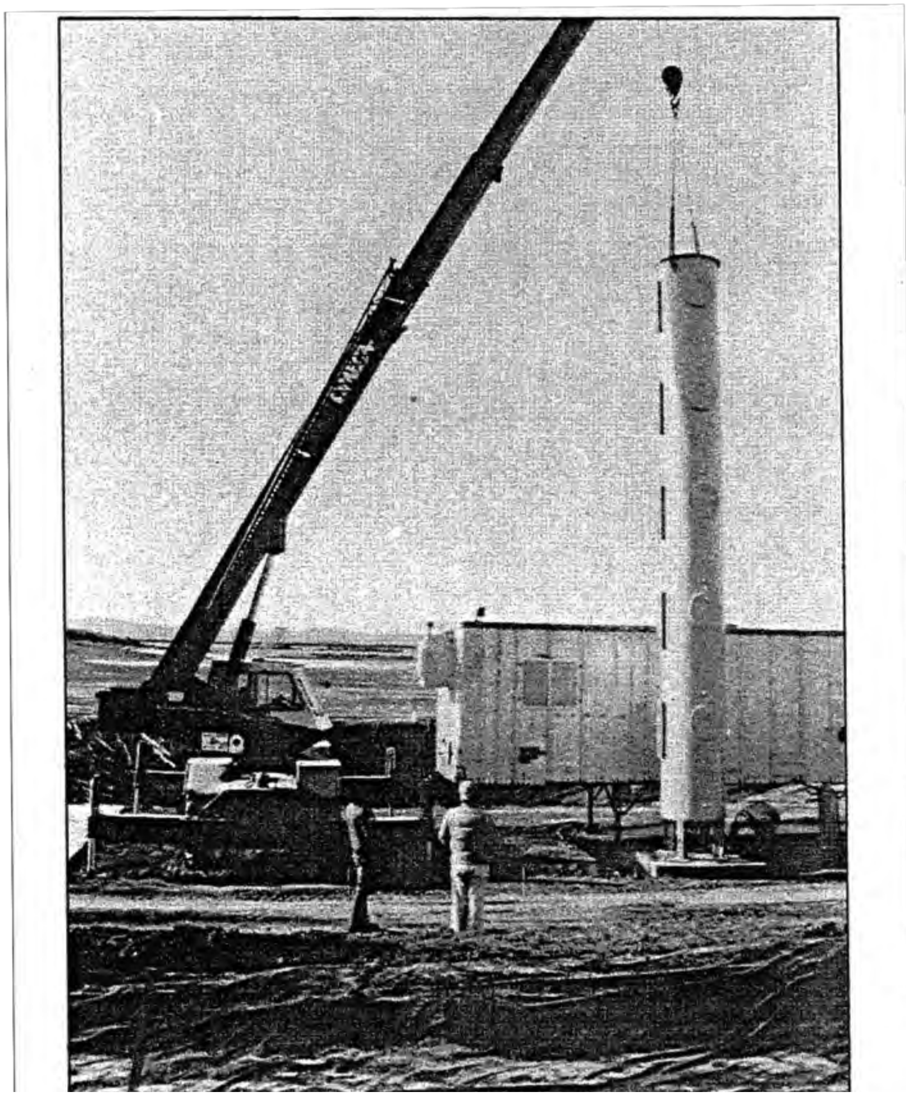

Figure 11. Installation of Adsorption Column – Hayden Hill

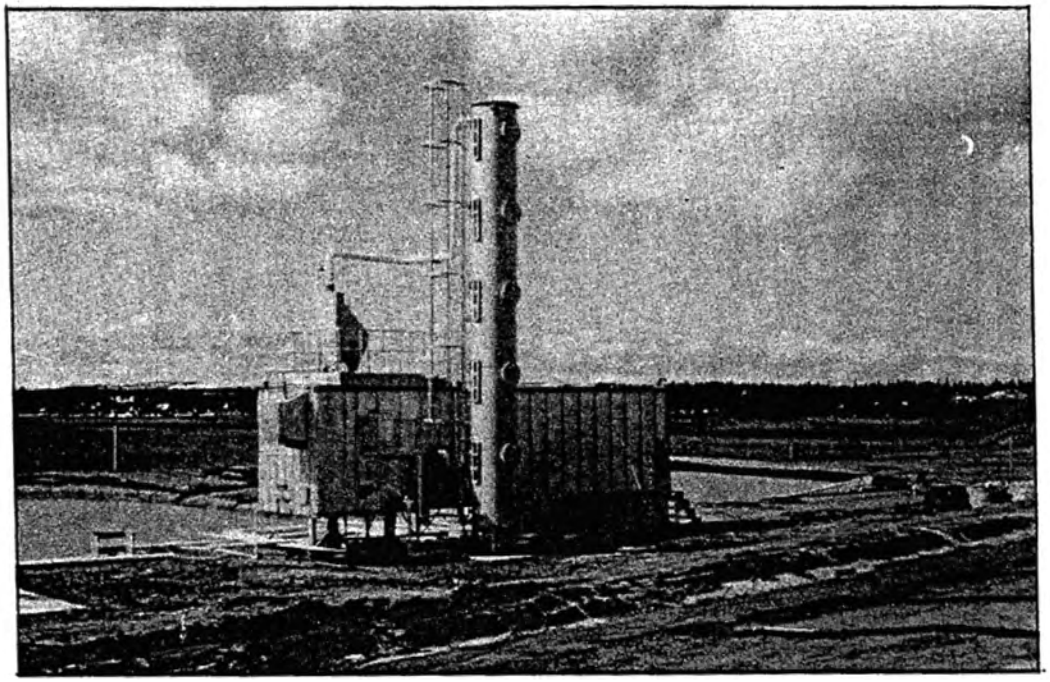

Figure 12. Adsorption Column with Stripping and Recovery Plant – Hayden Hill

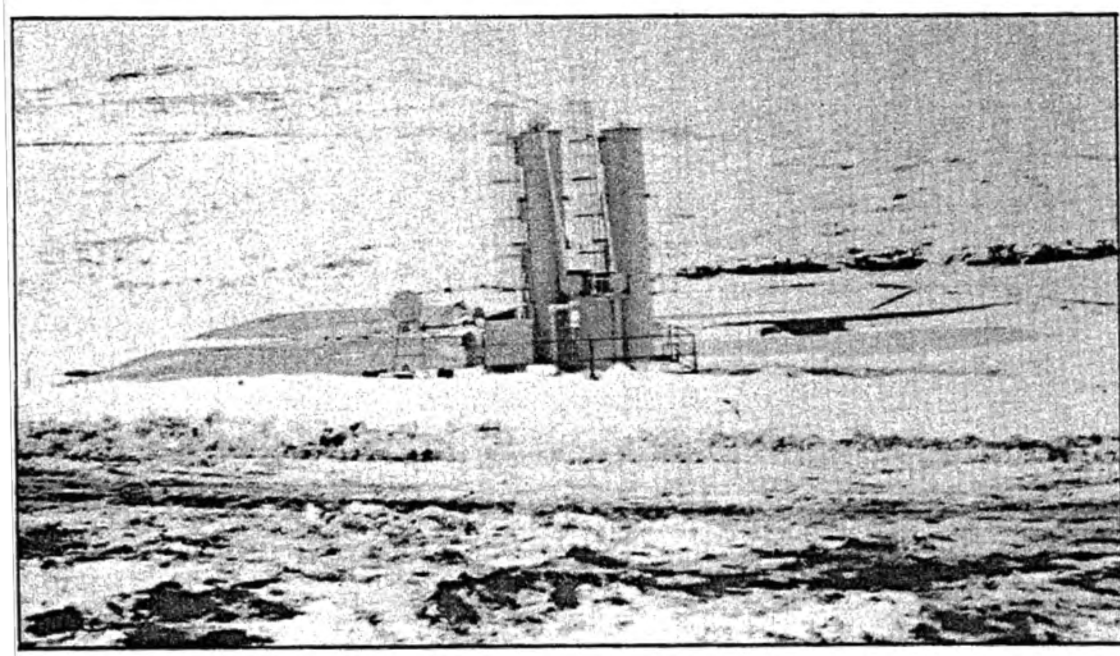

Figure 13. Adsorption Columns – Western States' Goldstrike Mine

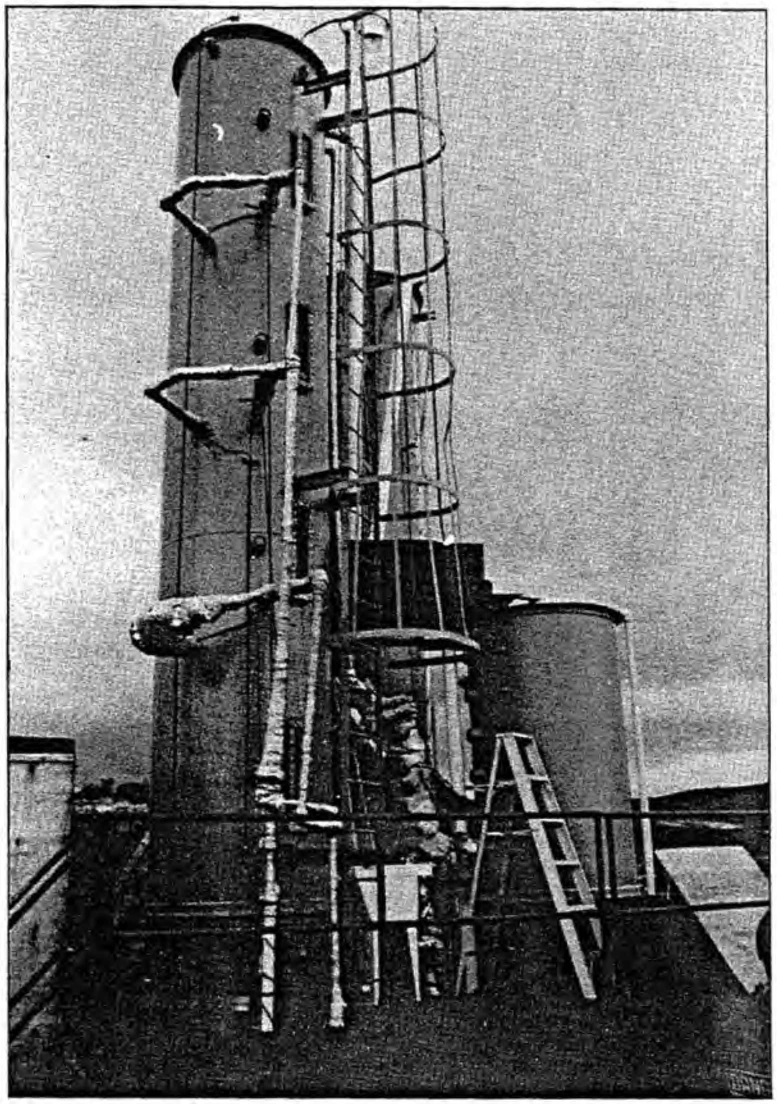

Figure 14. Adsorption Columns – Western States' Goldstrike Mine