UNDERGROUND DISPOSAL OF MILL TAILINGS IN MINED-OUT AREAS OF FMC WYOMING CORPORATION TRONA MINE [1]

by

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Abstract. Faced with the possibility of constructing a new surface impoundment area for mill tailings, FMC decided to evaluate other more cost effective and environmentally acceptable tailings disposal alternatives. During this process, underground tailings disposal was conceived and selected as the most cost effective and environmentally acceptable alternative. Corporate funding was approved for installation of a test tailings disposal system (Phase I) whereby 40% of the facility's annual output of tailings would be injected into abandoned mine areas. The risks inherent to this patented, "state of the art", underground injection system (Phase I) were to be evaluated while continuously injecting 750 GPM of slurry. The three major identified and evaluated risks include the ability to: (1) continually pump slurry through 14,000 feet of surface pipeline; (2) maintain minimum hole deviation (less than 4 feet) while drilling and to drill and complete injection wells in areas of high mine closure; and, (3) continuously inject slurry into the mine without plugging the injection well. During the first twelve months of operation the three major risks were evaluated and determined to be negligible. Subsequently, Phase II was completed and the remaining 60% of the tailings were injected underground. Two key factors responsible for the expedient completion and success of these projects were: first, a large anticlinal geological structure cutting through the mine creating two large natural basins; and secondly, this anticlinal structure was mined-out. FMC not only resolved their tailings disposal issues by implementing the phased tailings disposal project, but also was able to solution mine previously unrecoverable sodium carbonate values as the slurry liquor dissolved the trona pillars which were left for roof support during the conventional mining era.

Introduction

FMC Wyoming Corporation (FMC), the first and largest producer of natural soda ash in the world, began mining and processing trona ore in the Green River Basin of southwestern Wyoming in 1947. Trona is a naturally occurring, soluble, sodium sesqui carbonate, mineral ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$). The trona beds in the Green River Basin are between 800 and 1550 feet deep and contain a varying mixture of trona and oil shale. Once mined, the trona ore must be processed to remove the insoluble oil shale and convert the trona to sodium carbonate (Na_2CO_3).

In the past, the insoluble oil shales (tailings) in the ore were stockpiled on the edge of an old playa lake basin which was used to store and evaporate the waste water used to convey the tailings. With the increasing environmental and economical liabilities associated with surface placement of tailings, FMC committed to resolve these issues by installing a more environmentally acceptable disposal method. After thorough evaluation, only one method met both the environmental and economic criteria required. This method was an underground tailings disposal system designed to inject a low concentration slurry into previously mined-out areas and

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[1] Oral presentation at the 1993 National Meeting of the American Society for Surface Mining and Reclamation, Spokane, Washington, May 16-19, 1993.

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Proceedings America Society of Mining and Reclamation, 1993 pp 447-454
DOI: 10.21000/JASMR93010447

https://doi.org/10.21000/JASMR93010447

return the liquor to the surface for re-use. Preliminary engineering studies of the proposed disposal area revealed a large anticlinal structure with two natural basins which would enhance the success of the injection system. Adding to the success of the project was an underground tailings injection model, already developed by the U. S. Bureau of Mines (Carlson 1973 and 1975).

After corporate funding was approved the test phase (Phase I) was brought on line to evaluate the operational risks. During the first twelve months of operation, three major risks were evaluated, determined to be negligible, and Phase I was deemed a success. Subsequently, Phase II was constructed and brought on line. To date the two systems have injected 1.1M tons of tailings underground. This innovative system not only disposes of tailings underground, but solution mines trona reserves which were previously considered unrecoverable. Because of the uniqueness of this tailings disposal/solution mining process, FMC was granted a Soda Ash Production Patent in August of 1991 (Frint, Bithell, Fischer, 1991).

Background

FMC Wyoming Corporation (FMC) began mining and processing trona ore ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ plus oil shale) in the late 1940's. During processing, the oil shale contaminants (tailings) are separated from the trona ore in dissolving circuits. Prior to 1979, the tailings were slurried and pumped to the edge of a previously dry playa lake basin located adjacent to the processing facilities. This large playa lake basin functioned primarily as an evaporation pond for the waste process water being used to slurry the tailings. Over the 30 year period of depositing tailings in this manner, the coarse components of the tailings would rapidly settle out and remain on the lake basin shore line at the point of deposition. The fine components were carried in suspension and, subsequently, deposited on the lake bottom. By 1979, the fine tailings deposited in the lake had reduced the lake volume to an unacceptable level. To rebuild the lake volume and increase the evaporative surface area, FMC applied for and received a permit from the Wyoming Department of Environmental Quality (WDEQ) to remove undisturbed topsoil from the lake basin perimeter and to raise the elevation of the lake to the maximum allowable limit. To avoid filling the newly increased evaporation lake volume with the fine tailings, in 1980 FMC permitted and constructed a 350 acre tailings impoundment on the shoreline of the lake basin to collect tailings. Based on 1980 plant production rates this impoundment was designed to accommodate tailings deposition for approximately 10 years.

Several volume expansions of the impoundment were accomplished over a ten year period by raising it's containment dike. Toward the end of the tailings impoundment's useful life, FMC began investigating the permitting requirements for construction of an additional tailings impoundment. New environmental regulations and concerns associated with ground water seepage and fugitive dust generation from the existing tailings impoundment made the cost of a new impoundment prohibitive and provided an economical advantage to pursuing other more environmentally acceptable tailings disposal alternatives.

FMC committed to evaluate and select an alternate tailings disposal method based on: (1) long term environmental impact, performance bonding requirements, and compliance requirements; (2) capital and operating costs; and, (3) technical risks. Of the seven disposal methods reviewed only two were both economically feasible and also in compliance with the environmental standards set by WDEQ. Both methods involved disposing of slurried tailings in previously mined-out areas of underground mines.

The first method selected is commonly used in multi-level underground mines to dispose of mill tailings by backfilling the stopes (vertically mined-out openings) as they are mined. This method requires a 60% slurry (by weight) to be pumped to the underground disposal site and selectively deposited. The water used to transport the solids is collected in sumps and pumped back to the surface for re-use in the process. Although this disposal method is environmentally acceptable and risk free, the system would require mine personnel to continually monitor and move underground high pressure pipelines and pump systems. Ultimately, this type of system would not be cost effective.

The second option involved injection of a low concentration slurry via an injection well, into abandon, mined-out areas of a flat-lying ore body. Water draining off the

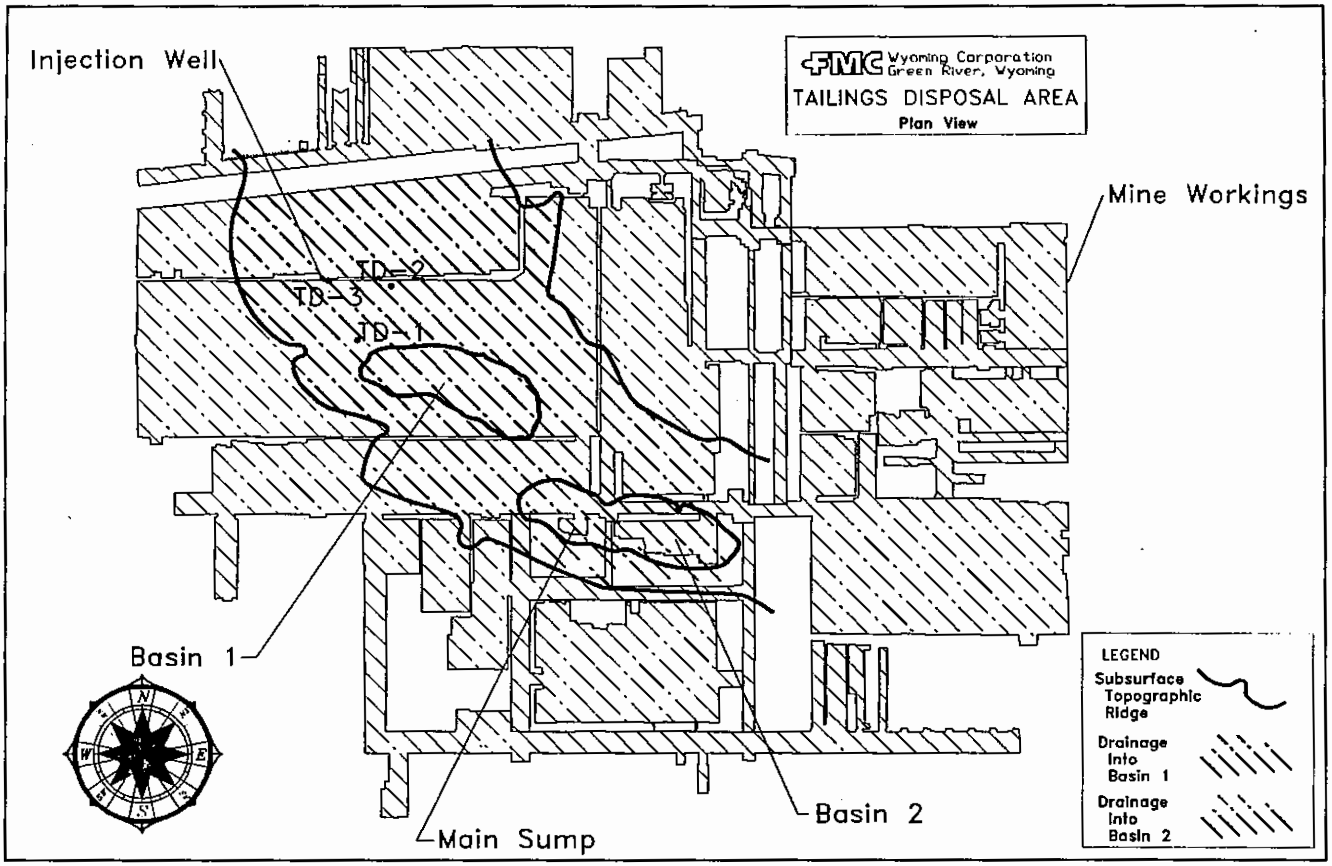

Figure 1. Plan view of underground mine showing anticlinal structure with ridges and basins.

tailings is collected in an underground sump and pumped to the surface. A similar system was tested by the U. S. Bureau of Mines to backfill shallow underground coal mines in an attempt to reduce surface subsidence problems (Carlson 1973). Although the U. S. Bureau of Mines test physically worked, the material injected would not completely fill the mined-out openings and therefor did not provide support for the mine roof. Instead, the injected material randomly migrated throughout the mine, an outcome which would promote the success of FMC's system. This system appeared to be environmentally and economically superior; however, the higher risks inherent to this system needed further evaluation.

Geological Features

A geological feature unique to FMC's trona mine is an anticlinal structure which cuts through the mine on a N 45° W bearing (Figure 1). Adding to the uniqueness of this structure is: (1) two large mined-out basins located along the axis of the anticline; and, (2) two ridges which parallel both east and west sides of the anticlinal axis and isolate the basins. This previously mined-out geological structure supplied FMC with a natural containment area for depositing the tailings. Over the past 20 years, Basin 1 (mined-out and abandoned) gradually filled with naturally occurring mine water; during the past 10 years, this sodium carbonate enriched water (liquor) has been overflowing at the saddle between Basins 1 and 2 (Figure 1).

By locating the injection well between the two ridges and north of Basin 1's shoreline, the mined-out areas above the basin are used for placement of tailings and the inundated basin is used for clarification of the slurry liquor (Figure 1). This geological structure gave FMC the ability to utilize these mined-out areas and, consequently, avoid a three year mine development program designed to excavate an area for placement of tailings underground.

Underground Depositional Theory

The basic theory behind underground deposition of slurried tailings predicts that tailings are initially deposited radially around the wellbore (donut shaped pile) until the tailings reach the mine roof. The simplified underground depositional theory is represented by Figure 2. Initially, the tailings are deposited radially around the wellbore in a donut shaped accumulation near Break-out 1. When this donut shaped collection of tailings reaches the mine roof all break-outs plug off except Break-out 2. Break-out 2 will continue to deposit tailings in a semi-circular fashion until the distance between the wellbore and the perimeter of the semi-circular buildup of tailings becomes so great the hydrostatic head developed in the well will no longer supply the driving force required to convey the tailings. Once Break-out 2 plugs off, Break-out 3 will occur and begin depositing tailings semi-circularly outward. Again, this deposition will continue until the distance between the wellbore and the perimeter of the semi-circular deposited pile of tailings becomes so great the hydrostatic head developed in the well will no longer supply the driving force required to convey the tailings. This depositional cycle will continue, as represented in Break-outs 4 through 7, until the hydrostatic head developed in the well will no longer produce new break-outs. At this time, the injection well will become plugged with tailings and underground deposition will cease.

Phased Tailings Disposal Project

Phase I Process Description

After reviewing the U. S. Bureau of Mines case studies (Carlson 1973 and 1975), FMC began designing Phase 1, a test system for disposing of tailings underground, whereby 40% of the facility's tailings would be injected into a previously mined-out and barricaded area of the mine. Phase I was used to evaluate the risks associated with underground tailings disposal. During preliminary engineering three major risks were defined: (1) the ability to pump the slurry through 14,000 feet of surface pipeline during the long cold Wyoming winters; (2) the ability to drill and complete injection wells in areas of high mine closure and to control hole deviation (less than 4 feet) to ensure hitting the mine openings; and, (3) the ability to continuously inject slurry into the mine without plugging the injection well. With the completion of engineering and risk analysis, corporate funding was allocated and construction began.

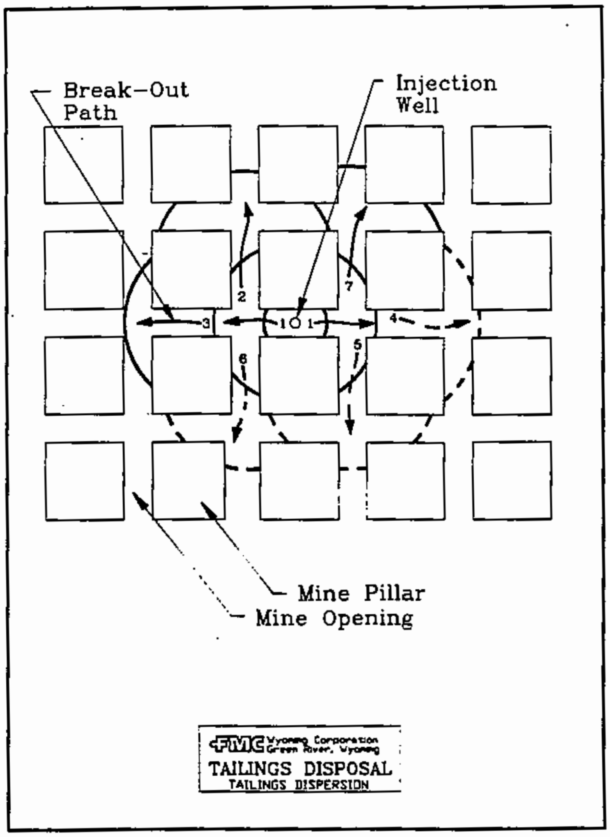

Figure 2. Plan view of mined out underground panel with simplified depositional theory showing break-out sequence.

Phase I was designed and constructed to continuously inject 750 GPM of slurry and discharge a maximum of 1100 GPM of mine liquor. To reduce the problem with constructing and operating a system physically separated by 1550 feet of overburden, the process was divided into two sub-systems, the surface injection system and the mine dewatering system. Figure 3 is a simplified process flow diagram for Phase I and Phase II which depicts the surface injection, disposal and mine dewatering processes. (Phase I's mine dewatering was omitted for clarity.)

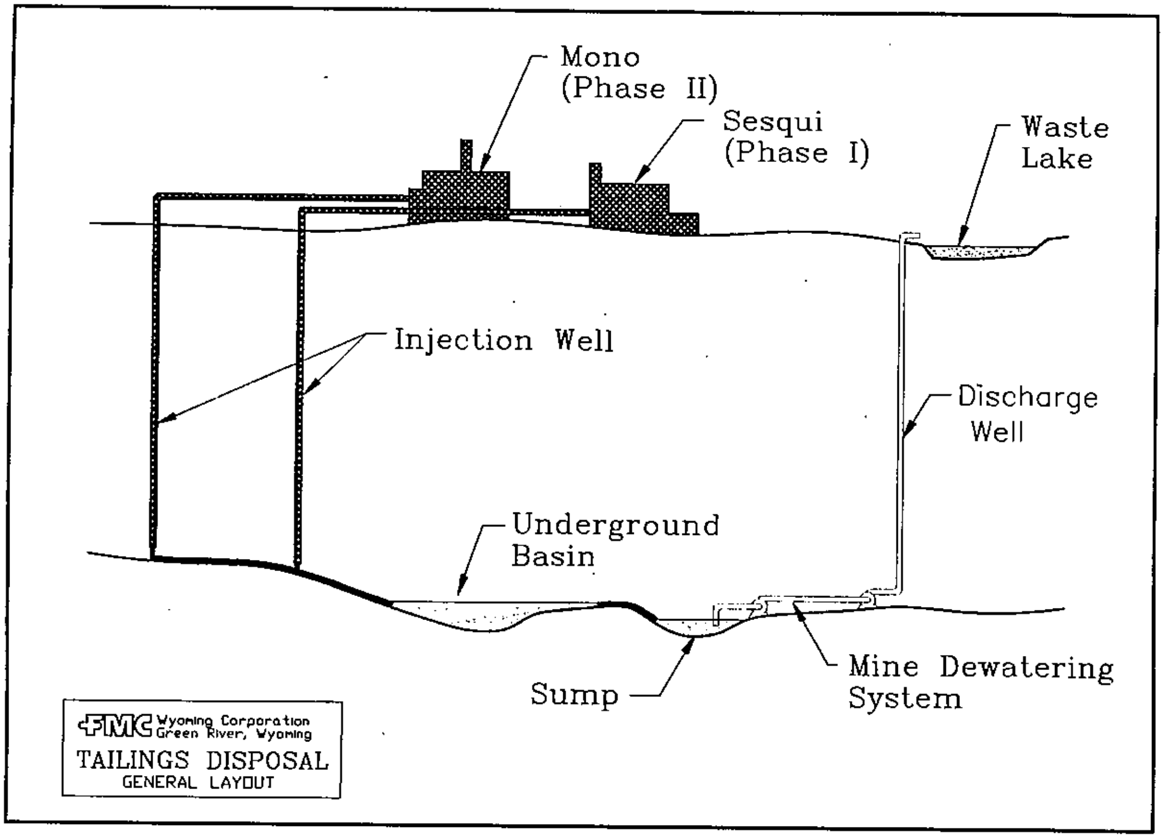

Figure 3. Cross sectional view of Phase I and Phase II surface injection systems and mine dewatering system.

Surface Injection System. The surface portion of Phase I was constructed adjacent to the Sodium Sesqui Carbonate (Sesqui) plant (Figure 3) to house two parallel sets of five Warman slurry pumps connected in series. To ensure the pumping system will be continuously operational one set of pumps is an installed spare. Slurry feed to the pumps is supplied by a large capacity mixing tank with dilution control instrumentation to constantly monitor and adjust slurry density. The slurry then exits the pumps at 620 PSIG and flows through 14,000 feet of surface pipeline which is connected to the injection well. As the slurry enters the 1,550 foot deep injection well, the pressure required to produce flow in the pipeline decreases to zero and the well begins to siphon (vacuum).

Mine Dewatering System. Once the slurry exits the wellbore, the tailings begin to settle-out and the liquor begins to migrate through the mined-out openings. While traveling to Basin 1, the liquor dissolves the soluble trona pillars, thus becoming enriched in sodium carbonate values. Once in the inundated basin (Basin 1), the enriched liquor becomes clarified as it migrates to the basin overflow where it drains into a 1.7M gallon collection sump (Figure 3).

Two 1100 GPM Worthington sump pumps connected in parallel were installed at the collection sump to pump mine liquor to the main mine dewatering station. To ensure continuous pumping, one sump pump is an installed spare and used only in case of emergency. Two 6 inch diameter pipelines connect the sump pumps to the surge tanks at the main mine dewatering station. The two large in-line surge tanks add another degree of control in maintaining a steady state process. Two 1100 GPM, five stage, Gould main mine dewatering pumps connected in parallel draw their make-up liquor from the surge tanks and then discharge into a 8 5/8 inch discharge well. Once again, to ensure continuous system reliability, one main mine dewatering pump is an installed spare. When the mine return liquor reaches the surface it flows through 3200 feet of 12 inch buried surface pipeline and then discharges into the playa lake basin.

Phase II Process Description

After successful completion of Phase I, Phase II was implemented to dispose of the remaining 60% of the tailings generated by the facility. The Phase II system was designed and constructed to continuously inject 1350 GPM of slurry and discharge 2200 GPM of mine liquor. The combined discharge flow of Phase I and Phase II is 3300 GPM (Phase I, 1100 GPM and Phase II, 2200 GPM). Again, to reduce the problems with constructing and operating these separated systems, the project was divided into surface injection and mine dewatering systems (Figure 3).

Surface Injection System. The slurry pumping facility for Phase II was constructed adjacent to the Mono Hydrate (Mono) process plant, which generates the remaining 60% of the facility's tailings (Figure 3). Phase II's slurry injection process begins in a large surge tank where the density is continually adjusted and monitored by dilution control instrumentation. The continuous stream of slurry exiting the tank feeds two parallel sets of seven GIW pumps, which are connected in series to produce 650 PSIG. To maintain a continuous pumping operation, one set of GIW pumps is designated as emergency spares. The constant density slurry is pumped through a 16,000 foot surface injection pipeline which is connected to a 1550 foot deep injection well. Once the slurry enters the well, the pressure required to cause flow in the pipeline decreases to zero and the well begins to siphon (vacuum).

Mine Dewatering System. Underground deposition, liquor migration, and clarification occurs as in Phase I. At the collection sump, Phase I and II liquor streams are collected for pumping to the main mine dewatering pumps. With the addition of Phase II, the mine dewatering capacity was increased from 1100 GPM to 3300 GPM. Under normal operating conditions, Phase II's 2200 GPM mine dewatering system has sufficient pumping capacity to continually dewater the mine while Phase I's system (1100 GPM) is used as an emergency back-up. Phase II's sump pumping system is comprised of two 1100 GPM A-C sump pumps connected in parallel to pump 2200 GPM to the main mine dewatering pumps via two 8 inch diameter parallel pipelines. The two 1100 GPM, three-stage, Bingham-Sulzer main mine dewatering pumps connected in parallel supply the head required to pump 2200 GPM, 1550 feet vertically and, finally, through 9400 feet of 12 inch diameter surface pipeline. As in Phase I, the liquor discharges into the playa lake. The Phase II system has been in operation for 11 months without any problems.

Summary

Because the tailings impoundment at the FMC Wyoming Corporation facility had reached maximum capacity, the company committed to develop a new and more environmentally compatible tailings disposal method. In addition to long and short term environmental advantages, the underground tailings disposal system was also the most cost effective. This innovative process, which was patented in 1991, allowed FMC to deposit tailings underground and simultaneously solution mine substantial amounts of previously unrecoverable trona.

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