19 th & 20 th November 2002
Sir Francis Drake Hotel
San Francisco, Ca., USA

IN CO-OPERATION WITH CEMENT DISTRIBUTION CONSULTANTS

DRIVE THROUGH DOME STORAGE FACILITIES

Lane Roberts
Vice President Marketing
Dome Technology
USA

Biography

Lane Roberts
Vice President Marketing
Dome Technology
USA

- Graduated with a degree in Financial Planning and Counseling from Brigham Young University.
- Served on civic and industry board of directors for such organizations as Kiwanis International, Junior Achievement International, American Chamber of Commerce and A.R.M.A. International.
- Began marketing domes for Monolithic Constructors in 1989.
- Began work for Dome Technology in 1996.
- Has written many articles that have been published in various trade magazines.
- Frequently speaks at various industry conferences on the subject of bulk storage and reclaim handling systems.
- Vice President of Marketing for Dome Technology

Drive through domes as a means to reduce terminal capital costs

Presented to INTERCEM Workshop "Terminal Operations" by Lane Roberts, Dome Technology, Inc.

Introduction:

The backbone of cement marketing strategy is a good cement terminal distribution system. This article presents the costs of common terminal configurations in tabulation form. The method of the tabulation will allow a reader to customize the cost framework to most any terminal project.

Costs not considered here are land costs and transportation system costs. The costs of docks, unloaders, self-unloading vessels, ships and barges, rail cars, etc. should be considered outside of the costs discussed in this article.

We will investigate in detail the costs of six different terminals ranging from steel bins and concrete silos to dome storage systems. In order to view these costs, we look at the items and issues usually found in a terminal construction project. As we assemble these costs, we will compare the terminals directly on a spreadsheet and evaluate the costs against the various arrangements.

Cost Study Parameters:

We will discuss the three areas of cost in our analysis. These three are generally titled:

1. Core Terminal Costs
2. Site Improvement Costs
3. Construction Costs

Normally, core costs are the first costs we consider in a terminal system. These major items are the silos, bins, domes, conveyors, dust collectors and truck scales. Core costs are the main costs associated with a terminal project.

A second group of costs that should be considered are the site improvement costs. Any terminal that is constructed will have a group of costs that are necessary to the terminal but tend to be more site specific. Examples of site costs include capital for roads, railroad extensions, parking, fencing, utility service from the street to the terminal, night lighting, etc.

The last group of costs is the construction costs. These costs include taxes, freight, permits, engineering, contractor's risk and owner's risk. For example, a general contractor will sub-contract earthwork, plumbing, silo or dome construction, electrical and sometimes mechanical work. In this area of cost tabulation we add the general contractor's supervision of these contracts and include the cost of contractor risk of the work correctly and simultaneously being executed in a timely manner.

Throughout this discussion we will be looking at Table A, the detailed cost breakdown, located in complete form at the end of this presentation. Tables 1 through 4 are sections of Table A. Costs will be tabulated for six different terminal arrangements. We will compare one steel tank, multiple steel tanks, small slip-formed silos, large slip-formed silos and finally a mechanical dome terminal to a semi-mechanical dome terminal.

Let's discuss the construction costs and site costs before we get into the various differences in the terminals.

Construction Costs:

Included in the environmental study costs, is the cost to file for the appropriate city and state permits. The owner will hire a surveyor to provide a site plan with elevations. A stormwater study will be performed, and usually terminal sites are required to construct a stormwater retention pond. A civil engineer will detail site plans for roads, drainage, etc.

The owner will hire an engineering consultant to perform feasibility studies and project costs estimates for the terminal type and perhaps compare several locations. The engineer may issue bid packages with drawings and specifications as well as manage the construction through completion of the work. These costs are part of the construction costs.

	A	B	C	D	E	F
Terminal Project	**Steel Tank (single)**	**Multiple Steel Tanks**	**Slip-formed Silos**	**Slip-formed Silos**	**Dome Drive-Through Pneumatic**	**Dome Drive-Through Mechanical**
Construction Costs	detail of costs:					
Environmental Work	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
Stormwater Study	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
Geotechnical Work	$ 18.000	$ 18.000	$ 18.000	$ 18.000	$ 18.000	$ 18.000
Geotechnical QC	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000
Site Survey	$ 8.000	$ 8.000	$ 8.000	$ 8.000	$ 8.000	$ 8.000
Design Engineering	$ 105.000	$ 153.000	$ 291.000	$ 704.000	$ 466.000	$ 360.000
Construction Management	$ 87.000	$ 127.000	$ 242.000	$ 586.000	$ 388.000	$ 300.000
Construction QC	$ 9.000	$ 13.000	$ 24.000	$ 59.000	$ 39.000	$ 30.000
Taxes	$ 44.000	$ 64.000	$ 121.000	$ 293.000	$ 194.000	$ 150.000
Freight	$ 23.000	$ 33.000	$ 63.000	$ 152.000	$ 101.000	$ 78.000
Insurance and Bonds	$ 17.000	$ 25.000	$ 48.000	$ 117.000	$ 78.000	$ 60.000
Permits	$ 9.000	$ 13.000	$ 24.000	$ 59.000	$ 39.000	$ 30.000
Terminal Startup	$ 75.000	$ 75.000	$ 75.000	$ 75.000	$ 75.000	$ 75.000
Contractor OH and Profit	$ 262.000	$ 382.000	$ 727.000	$ 1.759.000	$ 1.164.000	$ 901.000
Owner's Contingency	$ 262.000	$ 382.000	$ 727.000	$ 1.759.000	$ 1.164.000	$ 901.000
Construction Costs Subtotal	**$ 984.000**	**$ 1.359.000**	**$ 2.434.000**	**$ 5.654.000**	**$ 3.797.000**	**$ 2.977.000**

Table 1: Construction Costs

Additional construction costs include the quality control of the construction work. For example, most deep foundation work requires a qualified professional to inspect and record the site work. Concrete testing and weld examination are common construction costs. Additionally, electrical inspection, plumbing inspection and pressure testing should be considered in terminal project costs.

The cost to obtain building permits and pay for taxes, freight, construction insurance and performance bonds are all part of these costs. The costs on Table 1 are either a fixed fee or a fixed percentage of cost, in an effort to keep the terminal arrangements as comparable as possible.

The two largest construction costs are the contractor's overhead and profit and the owner's contingency. You will recall that the construction business is consistently one of the most risky businesses. Protect your budget with a contingency to allow for some of your risk.

Owners often forget the costs of startup until they realize that the computer program somebody wrote for a similar terminal just doesn't reflect the needs of their new facility. The costs of debugging the new equipment and programming the owner's protocol into the new terminal should be included here. Cement terminal budgets should include the cost to water-hose test the terminal for leakage.

Terminal projects are always different and should have an owner's contingency to cover the costs of the unexpected. Contingency percentages should be as high as 40% in the conceptual stage of the project and fall throughout the project until it completes. The tabular sheet entry is a 10% contingency, which is generally used as a minimum contingency at the point in the project where a competent engineer has assembled bid packages and the owner has obtained firm equipment prices and labor quotations.

The construction costs in the example terminals presented here generally range from 33% to 36% of the total project costs. In other words, if a direct project cost is a complete and firm bid of $100, the total project construction cost is $36 more (i.e. $136, total project cost by our tabulation here).

Site Improvement Costs:

Each site will have costs unique to the location. The largest costs are for railroad extensions and roadways. No modern city will allow terminals to operate trucks on unpaved site roads. Indeed, many metropolitan officials will require a pavement sweeper and if so, include this equipment cost in your budget.

Figure 1: Stormwater Culverts **Figure 2: Soding Stormwater Pond**

Terminals are no exception when it comes to stormwater drainage. Even terminals located on major waterways generally require an extensive retention pond and drainage ditch system. Our terminal costs do not include land, and owners should keep in mind that additional land will be used for retention ponds. It is not unusual to need an extra 2 or 3 acres specifically for retention ponds and embankments. By the way, the sod on the sandy site pictured in Figure 2 did need to be watered and mowed during construction.

	A	B	C	D	E	F
Terminal Project	**Steel Tank (single)**	**Multiple Steel Tanks**	**Slip-formed Silos**	**Slip-formed Silos**	**Dome Drive-Through Pneumatic**	**Dome Drive-Through Mechanical**
Site Improvements Direct Cost			detail of costs:			
Site Grading	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Fencing	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Roads & Parking	$ 180.000	$ 180.000	$ 180.000	$ 180.000	$ 180.000	$ 180.000
Rail Improvements	$ 200.000	$ 200.000	$ 200.000	$ 200.000	$ 200.000	$ 200.000
Grading and Seeding	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Storm water Structures	$ 50.000	$ 50.000	$ 50.000	$ 50.000	$ 50.000	$ 50.000
Utilities: Street to Terminal	$ 70.000	$ 70.000	$ 70.000	$ 70.000	$ 70.000	$ 70.000
Distribution of Construction Costs	$ 307.000	$ 290.000	$ 274.000	$ 263.000	$ 267.000	$ 270.000
SubTotal =	**$ 852.000**	**$ 835.000**	**$ 819.000**	**$ 808.000**	**$ 812.000**	**$ 815.000**

Table 2: Site Improvements

Utility costs come in several forms. The terminal is an operating a business, so you need water and sewer systems. Few terminals on navigatable water have sewers that will operate without the owner providing a lift station. We include cost for a phone and data communications. Some owners prefer gas heating, which will require additional piping costs.

Figure 3: Transform Utility Voltage

Hidden costs abound. Some municipalities will require the electrical service to be buried, thus raising your wire sizes and possibly requiring you to place the cables in duct bank. The transformer in Figure 3 costs $11,500, but this doesn't include underground wiring. A second transformer that costs $5,500 is used inside the terminal to convert 480 volts to single phase (lighting) power. Questions to consider are…Did you order your air conditioner to operate at 480 volts, or did you pay extra to upsize your inside transformer to handle the extra 220 volt single phase air conditioner? Whose contract selected the voltage? Did the HVAC contract also include the electrical installation work that coordinated a correctly sized inside transformer? Your final spreadsheet should tabulate the costs of these issues.

For our illustration in Table 2, site costs have been held constant for each terminal. The Table 1 construction costs have been distributed in Table 2 by a percentage distribution added to the tabulated estimate. In summary, a reasonable cost for a cement terminal for these site improvements is between $725,000 and $750,000.

Core Terminal Costs:

For the purpose of illustrating the differences in the terminal arrangements, we will now look in depth at the six different terminal arrangements. We have chosen these arrangements because they are the most common in the cement distribution industry. By using this system of cost tabulation, an owner can create an accurate budget for variations for his unique terminal.

Terminal Project	A	B	C	D	E	F
	Steel Tank (single)	Multiple Steel Tanks	Slip-formed Silos	Slip-formed Silos	Dome Drive-Through Pneumatic	Dome Drive-Through Mechanical
Core Terminal Direct Costs			detail of costs:			
Storage Vessel	$ 175.000	$ 550.000	$ 2.200.000	$ 5.500.000	$ 2.050.000	$ 1.800.000
Tunnels Stairs Platforms	$ 25.000	$ 90.000	$ 125.000	$ 500.000	$ 2.400.000	$ 1.900.000
Vessel Installation	$ 80.000	$ 256.000	incl above	incl above	incl above	incl above
Deep Foundations	$ 120.000	$ 208.000	$ 340.000	$ 1.200.000	$ -	$ -
Foundations	$ 55.000	$ 100.000	$ 450.000	$ 600.000	$ 450.000	$ 250.000
Dewatering for Pits	$ 3.000	$ 3.000	$ 3.000	$ 3.000	$ -	$ 5.000
Office	$ 139.000	$ 139.000	$ 139.000	$ 139.000	$ 139.000	$ 139.000
Electrical / Compressor room	$ 5.000	$ 5.000	$ 40.000	$ 40.000	$ 40.000	$ 20.000
Compressor / Dryer	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000
Conveyors	$ 45.000	$ 60.000	$ 60.000	$ 350.000	$ 715.000	$ 150.000
Elevators	$ 90.000	$ 15.000	$ -	$ 850.000	$ 75.000	$ 322.000
Pumps	$ -	$ 80.000	$ -	$ -	$ -	$ -
Load out Spout / Flow Control	$ 35.000	$ 35.000	$ 300.000	$ 250.000	$ 35.000	$ 100.000
Scale	$ 50.000	$ 50.000	$ 85.000	$ 150.000	$ 100.000	$ 100.000
Driver Access / Loadout Safety	$ 20.000	$ 20.000	$ 20.000	$ 60.000	$ 20.000	$ 20.000
Dust Collector	$ 25.000	$ 28.000	$ 40.000	$ 60.000	$ -	$ 35.000
Other Items	$ 20.000	$ -	$ -	$ 140.000	$ 350.000	$ -
Mechanical Installation	$ 78.000	$ 78.000	$ 133.000	$ 471.000	$ 330.000	$ 188.000
Electrical Installation	$ 120.000	$ 151.000	$ 240.000	$ 575.000	$ 350.000	$ 300.000
Electrical Instruments	$ 15.000	$ 20.000	$ 20.000	$ 60.000	$ 20.000	$ 20.000
PLC	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
MCC	$ 25.000	$ 35.000	$ 25.000	$ 70.000	$ 25.000	$ 30.000
PLC program	$ 20.000	$ 20.000	$ 20.000	$ 60.000	$ 55.000	$ 20.000
Lightning Protection	$ 5.000	$ 7.000	$ 8.000	$ 50.000	$ 5.000	$ 8.000
Phone System	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000
Furniture	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000
Distribution of Construction Costs	$ 680.000	$ 1.070.000	$ 2.160.000	$ 5.390.000	$ 3.530.000	$ 2.710.000
SubTotal =	**$ 1.880.000**	**$ 3.070.000**	**$ 6.460.000**	**$ 16.570.000**	**$ 10.740.000**	**$ 8.170.000**

Table 3: Core Costs

Table 3 tabulates the costs of terminals with storage from 1,000 stons to 45,000 stons. Our terminal costs range from $3 million to $18 million, exclusive of land and ship (or barge) unloading costs.

Description of Terminal A: 1,000 Ton Steel Tank:

Terminal A is a common arrangement used for rail distribution. The rail system includes a main track switch; two site switches and a length of sidetrack so that the terminal operators can shuffle full and empty rail cars over an unloading pit. The cost of the rail system, $200,000, is included in the site costs of all six terminals. We include in this system a $20,000 rail shed, under-rail unloading and conveying system to a bucket elevator. The elevator discharges into a single steel tank with an integral dust collector.

Our completely full steel tank weighs too much for a mat foundation, and our geotechnical solution is to construct a concrete mat upon a group of driven piles to stabilize the settlement. We do not put the truck scale system on piling. We integrate a circular access stair into the tank to provide access to the maintenance floor above the truck filling location and access to the tank roof for maintenance of the dust collector and bucket elevator.

The truck filling system consists of a loading spout with integral dust collection and a silo aeration system to insure consistent flow. An air compressor is located in a ventilated room near the tank to provide dry, high-pressure air for the automatic operations.

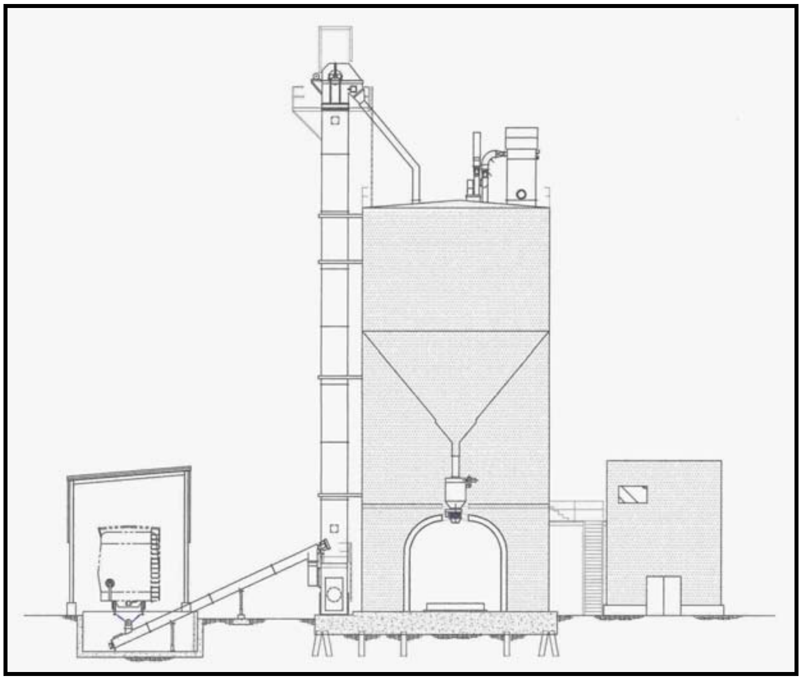


Figure 4: Rail to Truck Terminal

The control room is a modest 20' by 30' building. Our arrangement is a two-story structure. The lower floor is used for the motor control center (MCC or electrical starters) the upper floor allows the terminal operator good visual contact with the truck loading spout operation.

At the heart of the control system is a programmable logic controller (PLC), with a specialized program written for this application. This system will be electrically tied to a personal computer (PC) with modem contact to the corporate billing office. Include in the project the costs of lightning protection, electrical grounding and automatic power controls (APC) for all the electronic office equipment.

You will note that changing the storage size from 1,000 to 2,000 tons, will effect the costs of the tank, tank erection, foundation, deep foundation, bucket elevator, installation and electrical cost. However, the overall project cost certainly will not be doubled.

You can also see that lowering the tank size from 1,000 to 500 tons may allow the terminal to be placed on a site with poor bearing soils, but the minor cost savings may not offset the distribution and operational problems of the decreased storage.

Description of Terminal B: Multiple Steel Tanks:

Terminal arrangements with multiple steel tanks are very common. One of the most practical arrangements is to place two fairly large tanks in a series. The discharge point of the tanks is raised to allow for the height of a conveyor to discharge into a single loading point. A second alternate is to lower one tank near the ground and to convey the cement to the bucket elevator and into the first loading tank. A third alternate version is to pneumatically convey the cement into truck loading tank.

Figure 5: Bins Elevated over one Loadout

More mechanical devices drive up hidden costs in electrical installation, MCC, and sound resistive mechanical rooms to house noisy pneumatic blowers. Our table includes the costs for a simple mechanical solution with two storage bins.

For simplicity, we ignore the dust collector upsizing for pneumatics, and we intervent the silos together to save the cost of a second dust collector. The terminal owner and local code did not prohibit a circular stair tower. The generous platforms allow good maintenance access, but this type of tank is prone to rainy day loading problems.

Figure 6: Office / Control Room

This terminal is substantially similar to the terminal arrangement A, and by spending an additional $1.3 million; we have increased the stored volume by a factor of four.

Description of Terminal C: Slip-formed Concrete Silos—Medium:

A pair of slip-formed concrete silos with a drive-through arrangement is reasonably cost efficient. For our example here, the materials are pneumatically unloaded and conveyed from the dock to the silos. We have not included the cost of a barge unloader, nor a cost of a self-unloading vessel. We have included some costs for piping the cement into the silos and for valves that distribute the cement into the various silo bins.

Figure 7: Site Fence, two Slip-formed Concrete Silos

Silo bins have interesting ways to increase our costs. We pay to plumb the piping and instrument the individual silo sections, and we pay to rejoin the cement under the silo arrangement into a central loading location. We do have the ability, however, to store separate cements in this silo configuration. If we did however, we would have a higher dust collection cost in order to keep fly ash or masonry cement from contaminating portland cement.

The dust collector sized for pneumatic unloading is larger, and the interventing costs may be hidden in the roofing bid or the mechanical contractor's scope. Structurally, a slip-formed silo will need a separate stair tower structure for foot access. We have not included the cost of an elevator or a jib-crane beam.

Figure 8: Rail and Truck Loading, during track construction

Concrete silos of this capacity almost certainly need deep foundations. Even when founded upon rock, the seismic engineer will probably want tall thin silo foundations bolted down. The deep foundation costs are a big variable in the project costs. Good coordination between the geotechnical consultant and engineering can often completely pay for itself and yield project-dollar dividends. For example, sometimes a terminal is located back from a dockface to save structural costs only to forever be plagued by high conveying costs to move the cement further from the dockface.

Our example includes a combination truck / train scale and loadout system.

Popular in the United States are terminal configurations, which include the need for large amounts of compressed air to pneumatically convey materials into storage. When you consider the cost of compressors, you must automatically include the costs of the compressor cooling system and a building with foundation. The location of the building is generally a trade-off between the costs of electrical power and wiring, noise abatement and pipe routing costs. Pneumatic compressor related costs are not included in our examples, except in Terminal E.

As you compare Terminal C, the concrete slip-formed silo, you begin to understand why it is popular. For a modest increase of $3 million, the storage capacity is again up by nearly four times.

Description of Terminal D: Larger Slip-formed Concrete Silos:

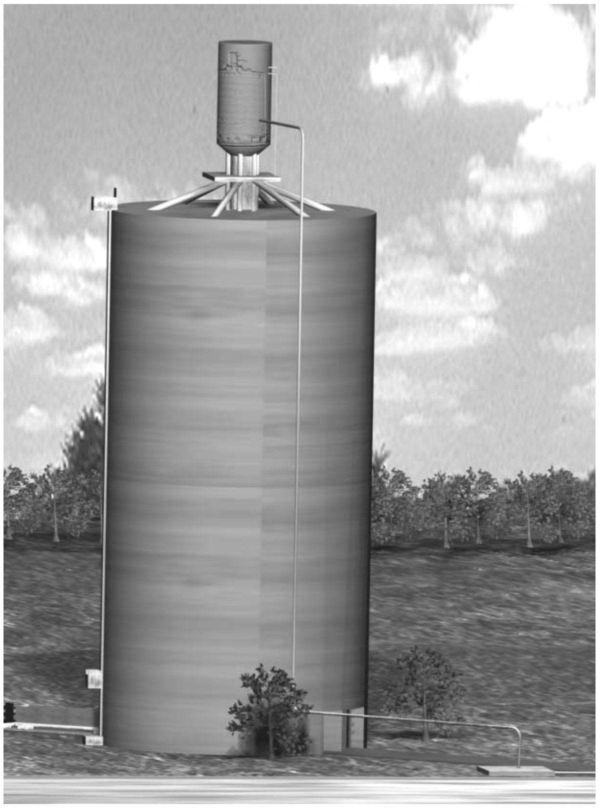


Figure 9: Similar Silo to Terminal D; this one is not filled with bucket elevator.

There is no real limit to the amount or number of slip-formed silos a terminal project can have. We all know examples of some very major silo projects. A popular silo design today is the 30,000-ton arrangement like the one in Figure 9. This is outwardly a single cylinder 100 feet in diameter and 200 feet tall. Internally, the configuration is a single 70-foot central silo surrounded by six satellite silos that share walls and reinforce the structure.

A typical silo system like this is located near a dock where a ship mechanically unloads to a telescoping conveyor belt. Our system includes a shore belt that conveys cement from the ship to a bucket elevator. The elevator discharges into an air-gravity conveyor distribution system on the silo top. Our costs reflect the fact that the elevator system is some 70 feet taller that the silo group in order to accommodate the distribution system. Because of the now considerable height, we have included an elevator to the roof to assure that the system will have operator maintenance.

Under the silos, these arrangements have air-gravity conveyor systems to join the cements into the loading systems. We have included costs for three truck scales or two combination rail / truck lanes in our system.

This particular mechanical arrangement has a definite cost disadvantage because of the tall silo and the much-taller bucket elevator necessary to distribute the cement nearly 100 feet across to the farthest satellite compartment. The massive elevator and elevator stabilization system has a high first cost, and it costs more to operate and maintain than simpler solutions. Nonetheless, it remains more popular today than some other configurations of groups of smaller silos and the additional mechanical systems they entail.

Owners often argue that the mechanical elevator operates at a lower cost than the equivalent pneumatic systems. As we account for these mechanical requirements, the cost per stored ton is higher than in Terminal C.

Description of Terminal E: Dome Storage with Drive-through Loading:

The traditional dome storage approach has been a dome with an adjacent terminal loading facility. A dome with a cylinder wall under the hemisphere will allow the system to increase the stored volume and decrease the interior mechanical system costs associated with unloading the system. Domes inherently have stable fat footprints and generally do not require deep foundations. With good geotechnical information, the dome design engineer can model on a finite elements program the interaction of the dome/tunnel to an owner's soil conditions and design appropriately for settlement.

Figure 10: Terminal within a Dome Storage System

The reduced mechanical requirements and increased storage capacity provide a doubling positive effect on terminal budgets. Let's look at the mechanical arrangement of a drive-through dome system.

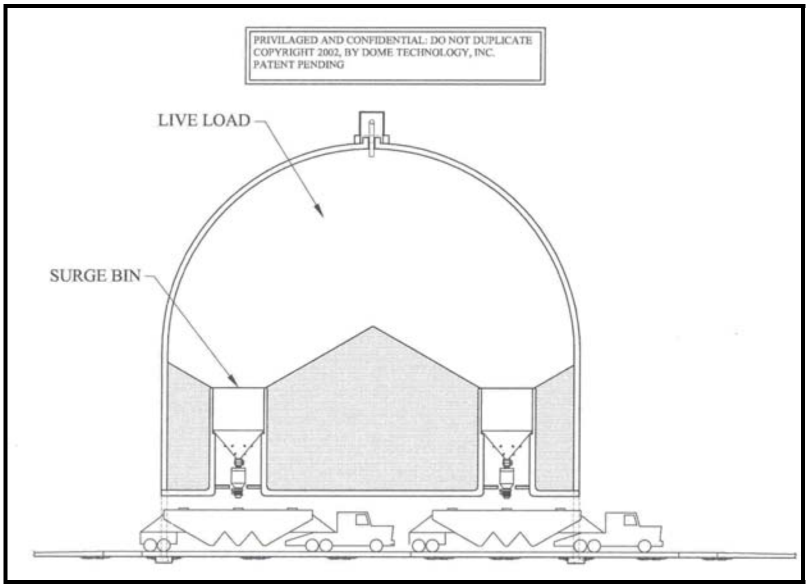


Figure 11: Truck Loading in Tunnel, with Surge Bins

The Terminal Arrangement E is a comparable 33,000-ton system to the slip-formed silo system D. Physically, the dome is a 54-foot-tall cylinder with a 109-foot hemisphere on top. Internally, we use a 16-foot-wide tunnel to provide a drive-through lane. The interior of the dome is fitted with two truck (or rail / truck) loading surge bins over the center tunnel. If the dome were nearly full, the surge bins would feed from the live load. As the cement draws down, the complete floor is outfitted with air-gravity conveyors and pneumatic conveying pods. This live floor system will keep the truck loading surge bins full of cement.

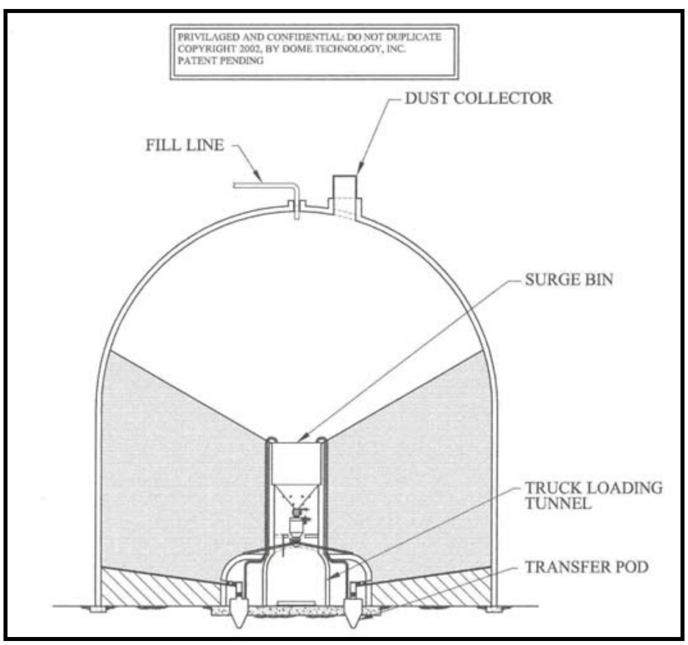


Figure 12: Pressure Pods used to keep Surge Bin Full

As before, the cement is transferred into the dome pneumatically. The roof-mounted dust collector would be accessed by ladder. No other working mechanisms are on this simple roof arrangement. In this dome arrangement, the routing of the pneumatic piping follows the dome shell from the base to the head-house area. Some pumping arrangements require only horizontal and vertical piping runs. The additional costs for the pipe support bent and truss system would be an additional cost to tabulate in this type of system.

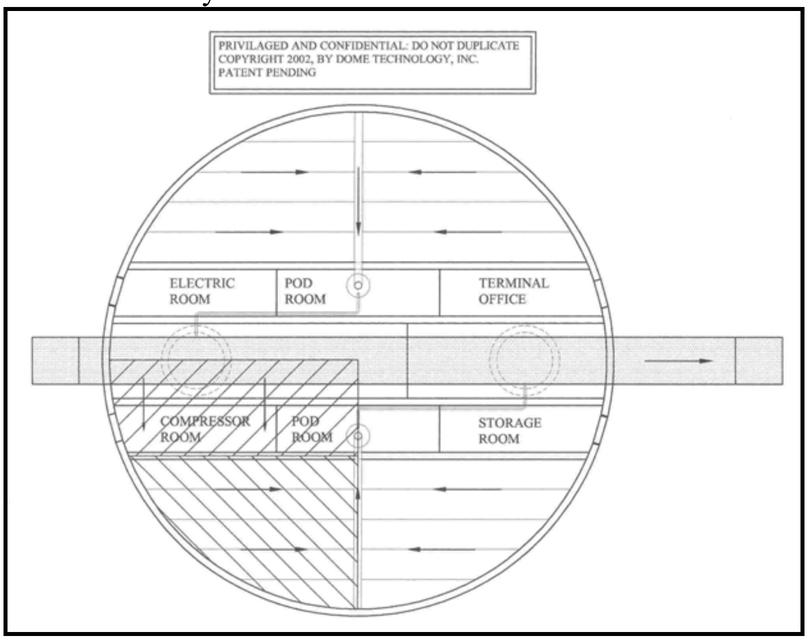


Figure 13: Pneumatic Floor Designed for 100% Reclaim

We have included a one lane tunnel with two loading positions along the same tunnel.

Dome Technology has applied for a US patent on this terminal system, and we believe it can be adapted to several useful alternate arrangements. The cost of the facility is moderately in the middle of the terminal prices, but because of the storage capacity of a dome, the arrangement is very inexpensive when viewed as a cost-per-stored ton.

Description of Terminal F: Dome Storage with Drive-through Loading, Mechanical Unloading:

In many parts of the world, cement is “warehoused” on a flat floor and scooped into a conveying system for truck and rail loading. Because of safety issues with the scoop, the best configuration is a lower, flatter dome. As the available equipment for scooping has changed, warehouse

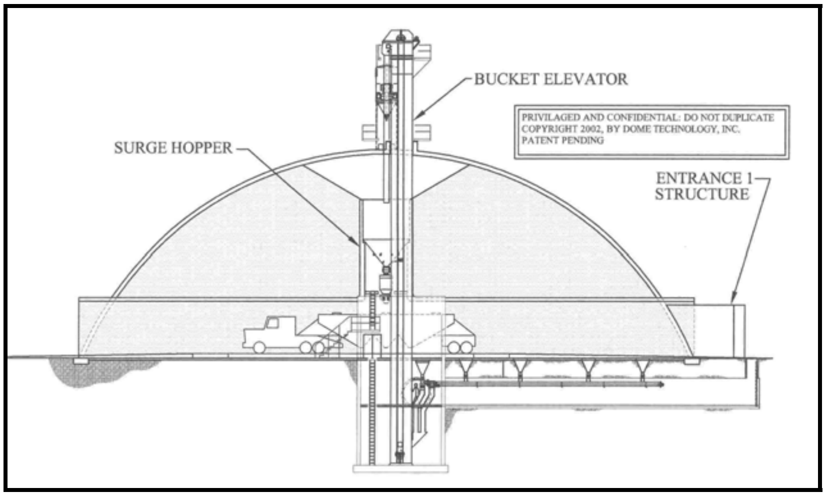


Figure 14: Elevation of Drive-through Mechanical Dome

operators have been gravitating from an end-loader to a telescoping scoop or to a larger end-loader. This configuration minimizes the costs of the truck-loading terminal with a warehouse scoop. The Terminal F dome is 175 feet in diameter, but only 70 feet tall.
In Arrangement F, the dome can be filled with cement by pneumatic conveying, or the cement could be mechanically conveyed to the surge bin’s bucket elevator system. The central tunnel

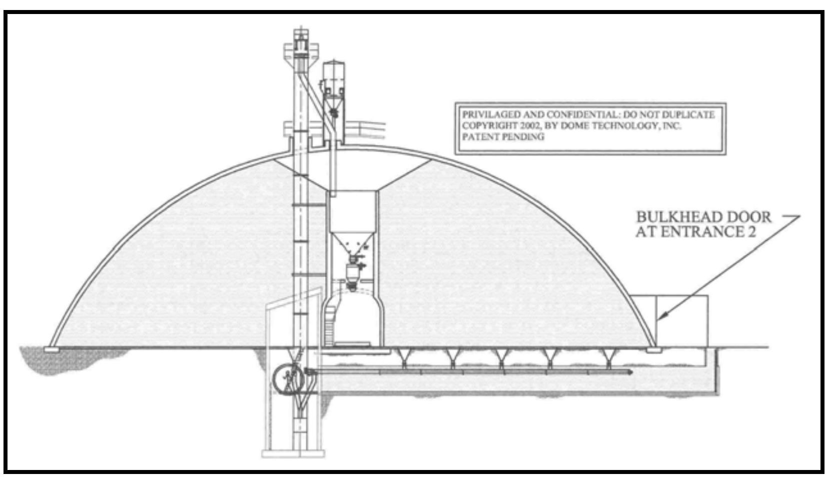


Figure 15: Elevator and Under-floor screw conveyors charge Truck Surge Bin

creates two sides to the dome. An under-floor tunnel system with a screw conveyor and in-floor grates designed to recover cement into the bucket elevator. The automation is programmed to keep the surge bin full of cement.

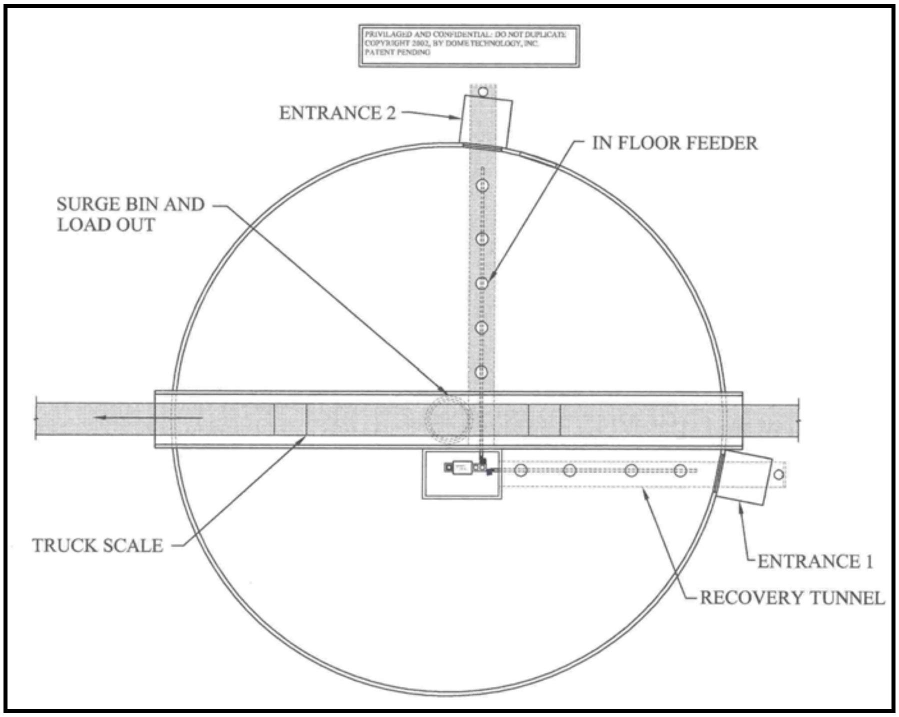


Figure 16: Plan View, Drive-through Mechanical Dome System

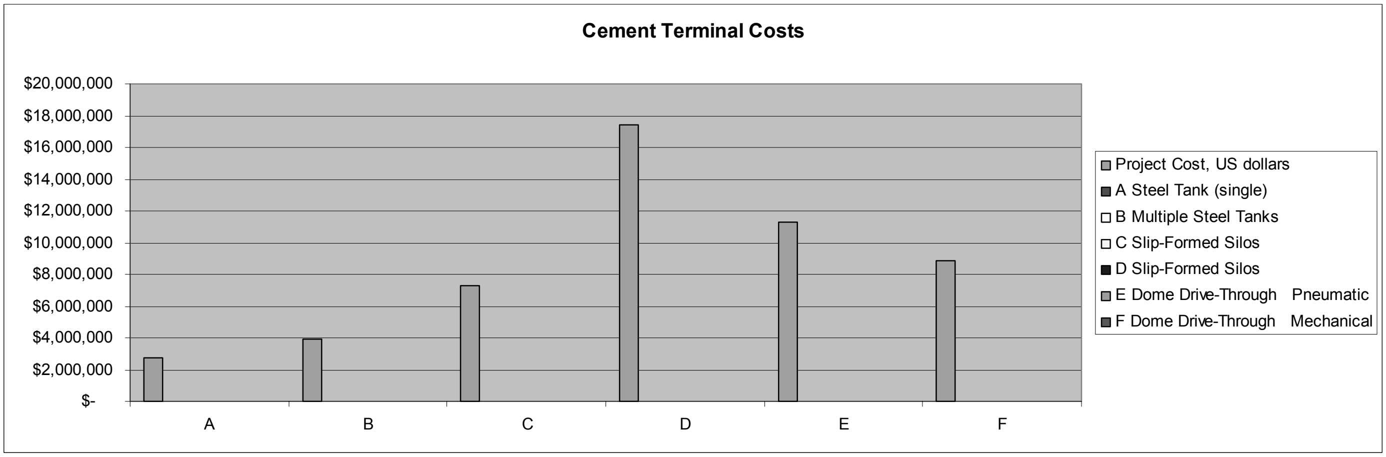
As the cement reserves draw down, a bulkhead door on each side of the tunnel can be opened, and a scoop will have access to the warehoused cement. In our design, we have changed the dust collector to a conventional collector with hopper so that we have better control of the dust falling into the dome than a directly mounted bag-house.

A shortcoming of this cost-effective system is that the site of the dome must allow for the construction of a pit to house the bucket elevator. At some sites, this may mean additional cost for construction dewatering.

The terminal operation is simple, straightforward and presents a very attractive cost for cement storage.

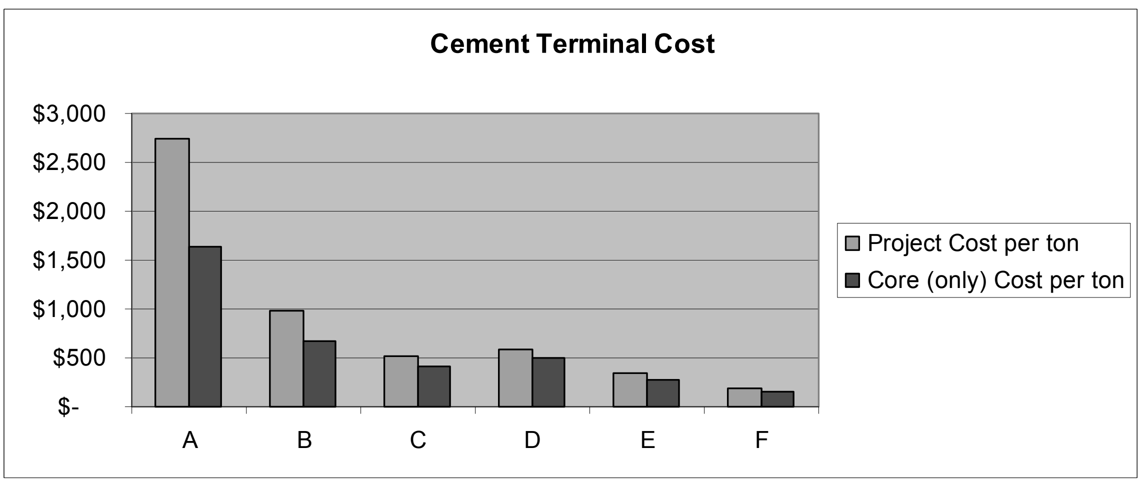
Discussion of Terminal Costs:

The parameters that make up these typical terminals have been assembled here to be as comparable as possible between the various Arrangements A through F. The simplest terminal is the small steel bin (Terminal A), which costs between $2 and $3 million is compared to the largest, a 45,000-ton dome (Terminal F), at just over $8 million.



Examining the chart, Terminal D (the slip-formed 30,000 ton system), is the most capital-intensive arrangement.

A second way to compare the efficiency of a terminal project is to compare the cost per stored ton of product. There are actually two costs to compare. The project cost, which includes the site costs and the core costs, which are just the storage system costs. In our examples, both costs properly include the construction costs.



The cost per ton in the above chart falls into three distinct ranges. The steel bin projects are smaller and cost between $2,700 and $1,000 per stored ton. The concrete silo projects are between $600 and $500 per stored ton. The dome projects are between $350 and $200 per stored ton. Table 4 tabulates the actual costs for these various options:

	A	B	C	D	E	F
	Steel Tank (single)	**Multiple Steel Tanks**	**Slip-formed Silos**	**Slip-formed Silos**	**Dome Drive-Through Pneumatic**	**Dome Drive-Through Mechanical**
Capacity in stons	1.000	4.000	14.000	30.000	33.000	45.000
Project Cost, US dollars	**$ 2.730.000**	**$ 3.910.000**	**$ 7.280.000**	**$ 17.380.000**	**$ 11.560.000**	**$ 8.980.000**
Project Cost per ton	$ 2.733	$ 977	$ 520	$ 579	$ 350	$ 200
Core (only) Cost per ton	$ 1.881	$ 768	$ 462	$ 552	$ 326	$ 182

Table 4: Summary of Costs

Dome suppliers are developing additional configurations for systems involving larger material storage volumes. The role of the dome supplier has been evolving so that as projects enter the concept stage, systems designers want to obtain input from the dome supplier.

Also apparent in the assembly of costs is the need for the professionals to work well together. The investigative costs for interfacing geotechnical consultants and the dome structural designer, heavily favor the owner who chooses a good professional team. The costs associated with deep foundations or mechanical systems that have to elevate cement 270 feet in the air (Type D) cost owners money in both initial capital and in higher operational costs throughout the life of the terminal.

Conclusions:

Projects for storing cement have been evolving considerably in the favorable economic climate in which we live. The movement of cement from points around the globe has caused designers to build larger storages indeed sized to accommodate ships laden with 75,000 stons of cement (Panomax shipping size). The same facilities that once only served as small, local distribution points are now conceptualized to maximize the size and turnaround time of the ocean-going freighters.

High-capacity storage terminals have evolved along with this economic change. Domes allow for larger capacity storage to be placed upon conventional soils. By utilizing the dome supplier in the conceptual development of the terminal, an owner may save deep foundation costs and mechanical system costs.

We have tabulated the terminal sizes and types from steel to concrete to dome and from several million dollars to nearly $20 million. We have demonstrated that the most cost-effective approach remains the simple approach— one large storage dome has very distinctive cost advantages:

1. The lower height to fill the dome means lower costs and faster unloading rates.
2. The wider storage footprint of a dome means a much lower chance of needing deep foundations (piling), thus saving substantial costs.

3. The combination of a drive-through loading tunnel (patent pending by Dome Technology) means that fewer mechanical parts are needed to load trucks and rail cars.
4. The warehouse storage concept, where the final terminal cleanout is done in conjunction with a scoop, has real capital cost advantages over more mechanized systems.

The cement storage industry is growing, and the use of domes in cement storage terminals seems to have a large future!

Terminal Project	A	B	C	D	E	F
	Steel Tank (single)	Multiple Steel Tanks	Slip-formed Silos	Slip-formed Silos	Dome Drive-Through Pneumatic	Dome Drive-Through Mechanical
Capacity in stons	1.000	4.000	14.000	30.000	33.000	45.000
Project Cost, US dollars	**$ 2.730.000**	**$ 3.910.000**	**$ 7.280.000**	**$ 17.380.000**	**$ 11.560.000**	**$ 8.980.000**
Project Cost per ton	$ 2.733	$ 977	$ 520	$ 579	$ 350	$ 200
Core (only) Cost per ton	$ 1.881	$ 768	$ 462	$ 552	$ 326	$ 182
Site Improvements Direct Cost			detail of costs:			
Site Grading	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Fencing	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Roads & Parking	$ 180.000	$ 180.000	$ 180.000	$ 180.000	$ 180.000	$ 180.000
Rail Improvements	$ 200.000	$ 200.000	$ 200.000	$ 200.000	$ 200.000	$ 200.000
Grading and Seeding	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000	$ 15.000
Storm water Structures	$ 50.000	$ 50.000	$ 50.000	$ 50.000	$ 50.000	$ 50.000
Utilities; Street to Terminal	$ 70.000	$ 70.000	$ 70.000	$ 70.000	$ 70.000	$ 70.000
Distribution of Construction Costs	$ 307.000	$ 290.000	$ 274.000	$ 263.000	$ 267.000	$ 270.000
SubTotal =	**$ 852.000**	**$ 835.000**	**$ 819.000**	**$ 808.000**	**$ 812.000**	**$ 815.000**
Core Terminal Direct Costs			detail of costs:			
Storage Vessel	$ 175.000	$ 550.000	$ 2.200.000	$ 5.500.000	$ 2.050.000	$ 1.800.000
Tunnels Stairs Platforms	$ 25.000	$ 90.000	$ 125.000	$ 500.000	$ 2.400.000	$ 1.900.000
Vessel Installation	$ 80.000	$ 256.000	incl above	incl above	incl above	incl above
Deep Foundations	$ 120.000	$ 208.000	$ 340.000	$ 1.200.000	$ -	$ -
Foundations	$ 55.000	$ 100.000	$ 450.000	$ 600.000	$ 450.000	$ 250.000
Dewatering for Pits	$ 3.000	$ 3.000	$ 3.000	$ 3.000	$ -	$ 5.000
Office	$ 139.000	$ 139.000	$ 139.000	$ 139.000	$ 139.000	$ 139.000
Electrical / Compressor room	$ 5.000	$ 5.000	$ 40.000	$ 40.000	$ 40.000	$ 20.000
Compressor / Dryer	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000
Conveyors	$ 45.000	$ 60.000	$ 60.000	$ 350.000	$ 715.000	$ 150.000
Elevators	$ 90.000	$ 15.000	$ -	$ 850.000	$ 75.000	$ 322.000
Pumps	$ -	$ 80.000	$ -	$ -	$ -	$ -
Load out Spout / Flow Control	$ 35.000	$ 35.000	$ 300.000	$ 250.000	$ 35.000	$ 100.000
Scale	$ 50.000	$ 50.000	$ 85.000	$ 150.000	$ 100.000	$ 100.000
Driver Access / Loadout Safety	$ 20.000	$ 20.000	$ 20.000	$ 60.000	$ 20.000	$ 20.000
Dust Collector	$ 25.000	$ 28.000	$ 40.000	$ 60.000	$ -	$ 35.000
Other Items	$ 20.000	$ -	$ -	$ 140.000	$ 350.000	$ -
Mechanical Installation	$ 78.000	$ 78.000	$ 133.000	$ 471.000	$ 330.000	$ 188.000
Electrical Installation	$ 120.000	$ 151.000	$ 240.000	$ 575.000	$ 350.000	$ 300.000
Electrical Instruments	$ 15.000	$ 20.000	$ 20.000	$ 60.000	$ 20.000	$ 20.000
PLC	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
MCC	$ 25.000	$ 35.000	$ 25.000	$ 70.000	$ 25.000	$ 30.000
PLC program	$ 20.000	$ 20.000	$ 20.000	$ 60.000	$ 55.000	$ 20.000
Lightning Protection	$ 5.000	$ 7.000	$ 8.000	$ 50.000	$ 5.000	$ 8.000
Phone System	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000
Furniture	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000	$ 5.000
Distribution of Construction Costs	$ 680.000	$ 1.070.000	$ 2.160.000	$ 5.390.000	$ 3.530.000	$ 2.710.000
SubTotal =	**$ 1.880.000**	**$ 3.070.000**	**$ 6.460.000**	**$ 16.570.000**	**$ 10.740.000**	**$ 8.170.000**
Construction Costs			detail of costs:			
Environmental Work	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
Stormwater Study	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000	$ 20.000
Geotechnical Work	$ 18.000	$ 18.000	$ 18.000	$ 18.000	$ 18.000	$ 18.000
Geotechnical QC	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000	$ 25.000
Site Survey	$ 8.000	$ 8.000	$ 8.000	$ 8.000	$ 8.000	$ 8.000
Design Engineering	$ 105.000	$ 153.000	$ 291.000	$ 704.000	$ 466.000	$ 360.000
Construction Management	$ 87.000	$ 127.000	$ 242.000	$ 586.000	$ 388.000	$ 300.000
Construction QC	$ 9.000	$ 13.000	$ 24.000	$ 59.000	$ 39.000	$ 30.000
Taxes	$ 44.000	$ 64.000	$ 121.000	$ 293.000	$ 194.000	$ 150.000
Freight	$ 23.000	$ 33.000	$ 63.000	$ 152.000	$ 101.000	$ 78.000
Insurance and Bonds	$ 17.000	$ 25.000	$ 48.000	$ 117.000	$ 78.000	$ 60.000
Permits	$ 9.000	$ 13.000	$ 24.000	$ 59.000	$ 39.000	$ 30.000
Terminal Startup	$ 75.000	$ 75.000	$ 75.000	$ 75.000	$ 75.000	$ 75.000
Contractor OH and Profit	$ 262.000	$ 382.000	$ 727.000	$ 1.759.000	$ 1.164.000	$ 901.000
Owner's Contingency	$ 262.000	$ 382.000	$ 727.000	$ 1.759.000	$ 1.164.000	$ 901.000
Construction Costs Subtotal	**$ 984.000**	**$ 1.359.000**	**$ 2.434.000**	**$ 5.654.000**	**$ 3.797.000**	**$ 2.977.000**
% Construction Cost of Direct Cost	36,0%	34,8%	33,4%	32,5%	32,9%	33,1%
Grand Total	**$ 2.730.000**	**$ 3.910.000**	**$ 7.280.000**	**$ 17.380.000**	**$ 11.560.000**	**$ 8.980.000**

Table A: Tabulation of Terminal System Costs