A DB RILEY TECHNICAL PUBLICATION

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Presented at
POWER-GEN International Conference & Exhibition
December 9-11, 1997
Dallas, Texas

RST-145

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## *ABSTRACT*

*In today's competitive marketplace for electrical power, utilities must optimize the use of their capital resources while continually providing system improvements. One way to do both of these is to convert an existing wet fly ash handling system to a dry fly ash handling system. This conversion replaces the large cost and real estate associated with maintaining an ash pond with a dry fly ash storage silo. The primary issues involved in determining the feasibility of a wet to dry conversion are: environmental impact, revenue potential, technical capability, capital investment, and outage requirements. This paper describes the actual technical and economic issues and decisions that were made for the dry fly ash system conversion of Northern Indiana Public Service Company's Michigan City Generating Plant in 1997.*

## ASH HANDLING SYSTEMS BACKGROUND[1]

The earliest ash handling systems were simple in cost and design as befits a boiler-related auxiliary that was merely viewed as a necessary but unsophisticated waste handling system. Ash that was generated by a coal fired boiler was often handled in one overall system. Ash that fell to the bottom of the boiler *(i.e. bottom ash)* was often openly sluiced to a sump and then pumped to a pond or was directly pumped to a pond using a venturi type water jet pump. The fly ash (then often called *top* ash) that was collected in economizer, air heater, mechanical collector, electrostatic precipitator (ESP) or baghouse hoppers was pulled by vacuum from the many collection hoppers or pick-up points to a central elevated tank. The vacuum producer was a water jet exhauster that channeled high pressure water through nozzles surrounding a venturi section to create the vacuum. The result is an air, ash and water mixture that accumulated in an air separator tank. After the air was vented, the ash and water slurry drained by gravity to storage pond(s). Periodically, the pond(s) needed to be drained and the fly ash slurry sent to disposal facilities. These pond based systems have been phasing out for decades due to several outside influences:

1. If an existing pond experienced any kind of containment failure, the resultant run off into area streams, rivers and wetlands was quickly labeled an environmental hazard (water pollution). The lighter and often floating fly ash, in particular, was prone to not only breach the pond walls but even dry out on the water surface and be swept off by drying winds to create air pollution.

2. Various wholesalers of road bed materials and concrete additives began to approach utilities and offer to buy their "waste" products and recycle them into usable products in the construction industries.

3. Newer plants being designed had larger megawatt ratings with higher coal burn rates and higher ash content fuels. When the associated ash percentages were applied to increased coal burn rates, the required pond sizes began to exceed the available real estate, which was becoming even more costly to buy and maintain.

4. The chemistry of the coals and ash became more important as the net emissions output of acid rain producing pollutants came under more stringent government regulations.

5. After several oil embargoes and the volatility in oil prices took effect, many plants that were burning cleaner oil fuel were converted or reconverted to coal. However, pond space was not available at these existing plants, many of which were in the urban areas along the east coast of the United States.

6. The economics of electrical production, especially the difference between gross megawatt output and net megawatt output, made many plant engineers and economists study all energy-draining services within the plant. The motors on the high pressure water pumps sending 250-350 psig water to the "simple" venturi jets came under scrutiny. If these *larger, inefficient* water pumps could be replaced with *smaller, more efficient* horsepower vacuum blowers, then the net drain on plant electrical production could be reduced.

7. The increased use of lower sulfur coals, such as Powder River Basin (PRB) coal, to avoid the generation of acid rain-producing components also led to the increase in the use of coals that created caustic water and ash slurries that attacked metal components in the ash systems. The ash itself was given to stickiness even when dry, but certainly the use of hydraulic systems to handle the ash needed to be considered carefully.

8. The *manufacturers* of mechanical (not venturi) vacuum pumps increased the level of technology in their key component to be able to create higher and dependable vacuum levels (e.g. 18" Hg vacuum) without the use of a water ring seal. These totally dry vacuum pumps were efficient and economical so they eliminated replacing one form of water pollution with another while offering noticeable horsepower savings. Likewise, the manufacturers of pulse jet bag filters were upgrading the dependability of their designs to operate under the elevated vacuum levels and high temperatures (up to 400°F) of dry systems.

9. The distances that the ash needed to be conveyed to the on-site area of temporary collection simply became too great for not only a simple gravity drain line (the air separator tank would need to be higher than the boiler roof), but also for all efficient hydraulic and even pneumatic vacuum systems. At some point in the matrix of increased distances and conveying rates, pneumatic *pressure* systems need to be used. These can often be most effective when used as part of a vacuum-pressure combined system. This allows all the advantages of a dry vacuum system over a wet vacuum system. Instead of having the vacuum collection equipment on top of the storage silo, it is located at grade and merely transfers the ash down into a dilute phase or dense phase conveying line(s) for additional conveying to a silo.

10. More automated and continuous systems were being designed[2,3] which meant horsepower and water savings over a full shift became important.

## THE MICHIGAN CITY SPECIFICS

The Michigan City generating plant of Northern Indiana Public Service Company, (NIPSCO), is a coal and gas fired power plant located directly on the southern shore of Lake Michigan. NIPSCO is based in Hammond, Indiana, and owned by NIPSCO Industries, Inc. Unit 12 has a single Babcock & Wilcox coal fired cyclone boiler that went into commercial operation in 1974. Its gross megawatt rating is 520 MW with a net output of 480 MW. The fly ash system was originally designed to pull all precipitator and gas recirculation ash by vacuum to a water jet exhauster (Hydrovactor®) which uses high pressure water sprayed through an annulus of spray nozzles to create the vacuum. The air, ash and water mixture is collected into a nearby 4 foot diameter round air separator tank located on a platform at elevation 71'-0" in the plant. The air is vented to atmosphere and the ash water slurry drains by gravity approximately 2400 feet to one of two 2.3-acre fly ash ponds. The ash ponds are periodically switched. The “closed” pond is emptied and the waste products are sent to landfills for disposal. By 1997, however, NIPSCO was spending about $2,000,000 per year emptying the ash ponds. Increasing disposal costs and more stringent environmental regulations caused them to evaluate alternatives for their ash disposal. The entire fly ash disposal issue had become a major concern at the plant and utility management level.

Due to fuel cost concerns in addition to the emissions restrictions, NIPSCO fuel buyers wanted to start using higher blends of Powder River Basin coal along with high sulfur coals. Plant engineers had checked with existing users of PRB coal and were made aware of the unique problems with burning this coal, many of which are associated with the chemistry and consistency of the ash that is produced. Adding water to PRB coal ash greatly compounds the ability to move it and can cause eroding and corroding of ash handling components.

At the same time, NIPSCO was aware of the newer markets for PRB fly ash as a substitute for cement in concrete and as a soil stabilizer. An ash marketing firm was contacted to estimate the potential value of selling fly ash. Preliminary market values for Michigan City’s fly ash were put at about $500,000 par year. This triggered a more detailed economic study of ways to reduce plant operating costs by turning the waste disposal system into a *revenue producing* arm of NIPSCO.

## THE ENGINEERING AND ECONOMIC STUDY

In 1996, NIPSCO contracted with Burns & McDonnell Engineering, Inc. to conduct a feasibility study for Michigan City to determine the environmental, economic, and engineering impact of converting Michigan City's wet fly ash system to a revenue producing dry fly ash handling system. While many of the hoped-for benefits were already being anticipated, Burns & McDonnell also needed to study the potential problems, such as:

1. A dry fly ash system has the potential to cause dusting problems. Due to the location of the Michigan City Generating Station, dusting needed to be minimized to the greatest extent possible.
2. The markets for fly ash may not be as consistent over time as they appear to be at the time of the conversion. What needs to be done in periods when there is no market for the ash and no landfill disposal points are available? What could be done to provide alternate disposal in this situation?
3. The dry fly ash will need to be transported off the site with trucks that will increase traffic on a daily basis into the plant to unload the silo. This affects many plant issues such as the condition of existing access roads, the possible need to add truck weigh scales and more plant labor to monitor and manage the increased traffic.
4. A potential location for the storage silo must be identified as well as identification of the existing underground utilities and soil conditions. The location of the silo should minimize the risk of harming existing plant operations. In addition, the silo should be located as close as possible to the ash sources to minimize ash piping runs and allow as much reuse of the existing piping as possible.
5. Even with maximum reuse of existing equipment, the installation of a new silo and the larger pieces of ash conveying or collection equipment require time and resources best suited for a total plant outage. The scheduling of a convenient and *least costly* outage is a major undertaking.
6. Getting budget prices from ash handling system suppliers for the new ash handling components only begins to identify all the expected and hidden costs associated with a total plant conversion. Previous experience in this area is a great asset in providing a check list of items to study and address.
7. The ash handling system controls are no longer stand-alone controls in the world of Distributed Control Systems (DCS). Even with modest changes and/or increases in total ash system input/output (I/O) signals, the integration of the new controls into an existing DCS provided by another party creates another logistical problem. Michigan City has a Foxboro DCS system.
8. After the main construction and installation phase, the remaining issue is the training and/or retraining of plant operators and maintenance personnel. Operators with possibly decades of experience with a wet system will find many different aspects in running a dry system. The best system in the world will not work if it is not properly maintained and operated.

## THE CONCLUSIONS OF THE STUDY

After several months of studying the unique aspects of Michigan City's situation, the conclusions reached by both the owner and the engineer were:

1. The existing 24 precipitator hoppers and the attached material handling valves were operating in acceptable fashion and no changes were required by the two main parties. Because of the specific design of the material handling valve, which has a straight *horizontal* feed into branch lines several feet away, ash handling system suppliers needed to be experienced with using this type of valve. Alternate designs of material handling valves involve a more pronounced dropping of the ash *diagonally down* into a lower branch line. The eight existing gas recirculation hoppers and valves were also found to be acceptable. All 24 precipitator hoppers have vibrators.

2. The use of the wet system would be retained as a fully operational back up system to the new dry system in case the market for the dry ash is temporarily not available or if on-line maintenance on the new system is required. The changeover from the wet system to a dry system would be left as a manual operation that could be performed in a short time frame (less than 24 hours).

3. The existing ash conveying lines, including branch lines, headers, and risers could be reused to the maximum extent possible. These lines were made of chrome iron alloy pipe and fittings, but it was deemed acceptable to use hardened steel pipe for any new extensions as long as the thicker alloy fittings with replaceable wearbacks were used on the bends.

4. The new storage silo was best located on the *opposite* side of the main boiler building where the riser to the existing water jet exhauster and air separator tank were located. This was necessary to obtain good truck access to the silo and to minimize underground utility interferences, but it necessitated a longer run of ash conveying pipe.

5. The silo would be a steel fabricated structure. It would hold 1000 tons of fly ash at a density of 65 pounds per cubic foot. Because it was on the Lake Michigan side of the plant and exposed to winds coming directly off the lake, an enclosed penthouse on top of the silo would be used to protect the ash collection equipment (the filter/receiver separators) from the effects of the weather.

6. The silo would have access platforms and walkways leading from the boiler building to make it more convenient for plant personnel to perform preventative maintenance inspections.

7. The new silo would need ash collection equipment on the roof, a fluidizing system for the floor of the storage area, and two telescoping dry dust chutes to unload the stored ash into enclosed bulk tanker trucks. These chutes require a venting system to return displaced air from the trucks back into the silo.

8. The engineer's experience with ash conveying systems led it to recommend a minimum pick-up velocity for the vacuum system that will be conveying PRB coal ash to be 3800 feet per minute (fpm). This is significantly higher than the range of 1800-2300 fpm used in the original design of the existing system, which was satisfactory for the coals expected at the time and has been adequate for many years.

9. Mechanical vacuum pumps from a recommended list of approved vendors would be used.

10. A design coal was determined that would have 5.55% ash content. The resultant design fly ash generation rate was 9.07 tons per hour at 65 pounds per cubic foot. Normally this rate is merely doubled to determine a minimum required convey-

ing rate, but in this case a required conveying rate of 25 TPH was selected. The 1,000 ton storage silo effectively has 110 hour storage capacity.

11. A complete fly ash handling specification would be written and sent out to all major suppliers of such equipment for a complete competitive bid cycle even though timing was becoming crucial.
12. It would take about one year to design and construct a complete dry fly ash handling system.

## THE DESIGN OF THE DRY FLY ASH SYSTEM

All four domestic suppliers of ash handling systems who received the bid package had to comply with the stringent specification, but they each had to individually resolve several major design issues. Any pneumatic conveying system requires a complete energy balance analysis that takes into account:

a. Maximum and minimum lengths of horizontal run of pipe from all pickup points to the silo.

b. Maximum vertical lift in the system.

c. Maximum number of equivalent ninety degree bends in the system.

d. Initial and final pipeline internal diameters with minimum velocities maintained throughout all conditions and when conveying from all pickup points.

e. Maximum and nominal differential pressures from pick-up points to disposal point.

The bid documents required each ash handling system supplier to determine where the tie-in to the existing ash handling system would be located. The existing lines under the precipitator hoppers have an 8-inch inside diameter (I.D.) followed by an increase to 10-inch I.D. in a header running back to the boiler and the air separator tank. For a given volume of air, an increase in line size decreases the velocity by the inverse ratio of the squares of the diameters, so any velocity in the 8-inch line drops by 64/100 as soon as the air moves into the 10-inch line. If a 12-inch line were to be used as well, the velocity at that transition point decreases by 100/144. However, actual line velocities increase from the pick-up point, under ambient pressure in a vacuum system, to the point of maximum vacuum level at the vacuum producer, so only a detailed analysis can calculate the actual velocities at all changes in line size. The required 25 TPH conveying rate at a relatively high minimum pick-up velocity made the selection of the actual tie-in point quite important in the bid stage. Higher line velocities, other things being equal, decrease conveying capacity because more energy is lost to line friction than with lower velocities. The best design uses the *lowest* velocity that still guarantees all material will be picked up and maintained in suspension all the way to the disposal point.

The successful bidder on the NIPSCO Michigan City dry fly ash handling system specification was Ash Conveying Technologies (ACT) a division of DB Riley, Inc. ACT determined that a three port, 45 degree lateral could be installed in the vertical riser leading to the Hydrovactor® with the straight-through vertical ports maintaining the existing path to the water jet and pond system. The 45 degree leg would lead to a 45 degree elbow that would turn the new header into a straight horizontal run across the boiler building and out through a new wall opening to the new silo location. Since the tie-in point was close to the end of the existing lines, all velocity concerns in the 8-inch and 10-inch lines were addressed sufficiently that a 10-inch hardened steel pipe header could be used for the new horizontal run to the silo. The total number of equivalent ninety degree bends was maintained at an acceptable level, even from the farthest precipitator hopper. There are four hoppers on eight existing branch lines, including the gas recirculation hoppers.

The two alternate disposal paths are now separated by manual line isolation valves that need to be properly aligned to the desired path at the beginning of any ash conveying cycle. A tie fitting was added in the existing ash line header to allow the fly ash to be routed to either the ash pond using the Hydrovactor® or to the new fly ash silo using the new vacuum pump system. The control system is designed to run either system. To change systems, the plant needs only to open and close two manual isolation valves. See Figure 1.

After the pipeline design and velocity profile was established, it was rather straightforward to request pricing on an integrated set of vacuum pumps and bag filter/receivers. Due to the large air flow in the 8-inch and 10-inch lines, Gardner Denver Model 9CDL23 mechanical dry vacuum pumps were selected. Two 100% capacity pumps are being used, each with 100 HP motors. The system design vacuum level is 15" Hg. Using an appropriate air-to-cloth ratio (3.5:1) a Mikro Pulsaire circular (5'-6" diameter) pulse jet filter/receiver was selected. Two 100% capacity filter/receivers are mounted on the silo roof (shown in Figure 2). Each one can continuously receive the 25 TPH of ash and transfer it down through an ACT airlock into the storage silo. A stone box design is used to block the path of the fast moving air and ash mixture as it enters the receiver section. The ash drops down to the airlock while the air is directed down, over, and up to the pulse jet bag filter. After passing through the bag filter, the air path is monitored by a photocell detector to alarm if any bag breakage causes excess carryover to the vacuum pumps. Automatic vacuum breaker valves also protect the system from any line pluggage or event that would damage the pumps or bag filters.

A fully integrated silo system was designed (see Figure 2). The height to diameter ratio chosen for any required storage volume in a silo affects the aeration air requirement to fluidize the stored ash. Air is vented out of the silo through the use of a silo vent filter (another Mikro Pulsaire model). The system at Michigan City required additional air to be vented from the truck enclosure. The area where the ash conveying trucks load with the ash was enclosed with a building to minimize the risk for any dusting problems. The truck enclosure required that the area be vented back to the silo and out through the vent filter. The silo is maintained near ambient pressure to prevent pressure build-up in the silo.

For Michigan City, a 30-foot diameter by 60-foot high flat bottom silo was selected. A 40-foot high penthouse protects the collection equipment. Two 2-stage 100% capacity Sutorbilt aeration blower packages with 20 and 25 HP motors send 20 psig aeration air into the silo through an array of porous stones on the floor of the storage area. The 380 SCFM of air is heated by an in line 30 KW circulation air heater. The ash is unloaded through one of two telescoping dry dust chutes complete with hoists and mounted vent fans that return displaced air from the trucks into the silo. A third vent fan serves the truck bay. A 24-inch diameter vacuum/pressure silo relief door is also mounted on the roof for backup protection. Silo level protection is provided by high and low level capacitance type indicators mounted in the roof and wall of the silo. In addition, continuous silo level information is obtained from an ultrasonic level detector mounted in the roof. The system was designed with several redundant systems for the main components to provide reliable service to NIPSCO.

The fly ash system employs an Allen-Bradley Programmable Logic Controller (PLC) to control the operation of all system components except the truck enclosure equipment.

Modifications to system control logic can be made through the logic programming software. The PLC and associated equipment is housed in two control cabinets. Control room operator interface is provided via the Foxboro Distributed Control System (DCS). All normal system alarm signals are accounted for in the control system logic.

## THE SCHEDULE

The main contract was awarded to Burns & McDonnell Engineering, Inc. as a Design-Build Contract. NIPSCO was concerned with quality, cost, and schedule which fit well with a Design-Build approach with Burns & McDonnell. The award of the ash handling system contract was on March 10, 1997. Construction at the site began in June 1997 with minor utility relocations and foundation construction. Most ash system construction materials, including the silo, arrived on site in September 1997. Almost all major equipment was on site by the end of October. Erection of the ash conveying equipment and silo began in September with an expected completion date of December 15, 1997. Training for plant operators and maintenance personnel is scheduled for mid December. Start-up and testing will begin in mid-December with an expected commercial operation date in early 1998.

## THE CONCLUSION

Most existing wet fly ash handling systems will have to be converted to dry fly ash handling systems once competitive and compliance pressures come to bear fully on the economics of any existing power plant. On the positive side, the market value of fly ash can be an additional source of revenue for a plant.

All plants should initiate a controlled study of their existing ash handling systems to determine how to better handle the various ash sources in the modern era. For plants with larger, older ash ponds, the conclusion to convert to a dry fly ash system will probably be straightforward, but budgeting the time and expense will not be such an easy decision. However, a growing number of utilities, consulting engineers, and suppliers of ash handling systems have experience with such fast track and tight budget projects. This is a subject all utilities may face.

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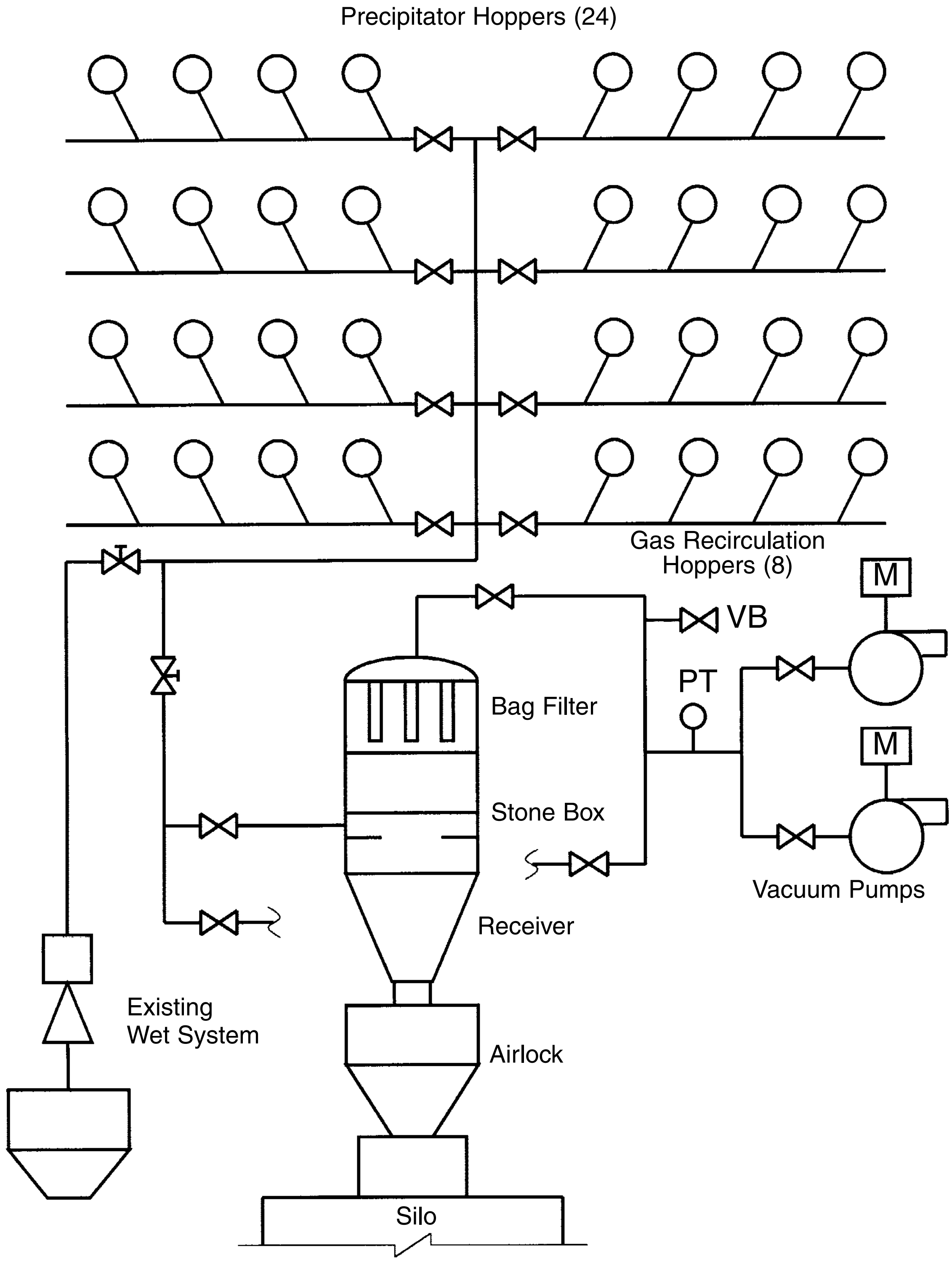


*Figure 1  Schematic of NIPSCO Michigan City Dry Fly Ash System*

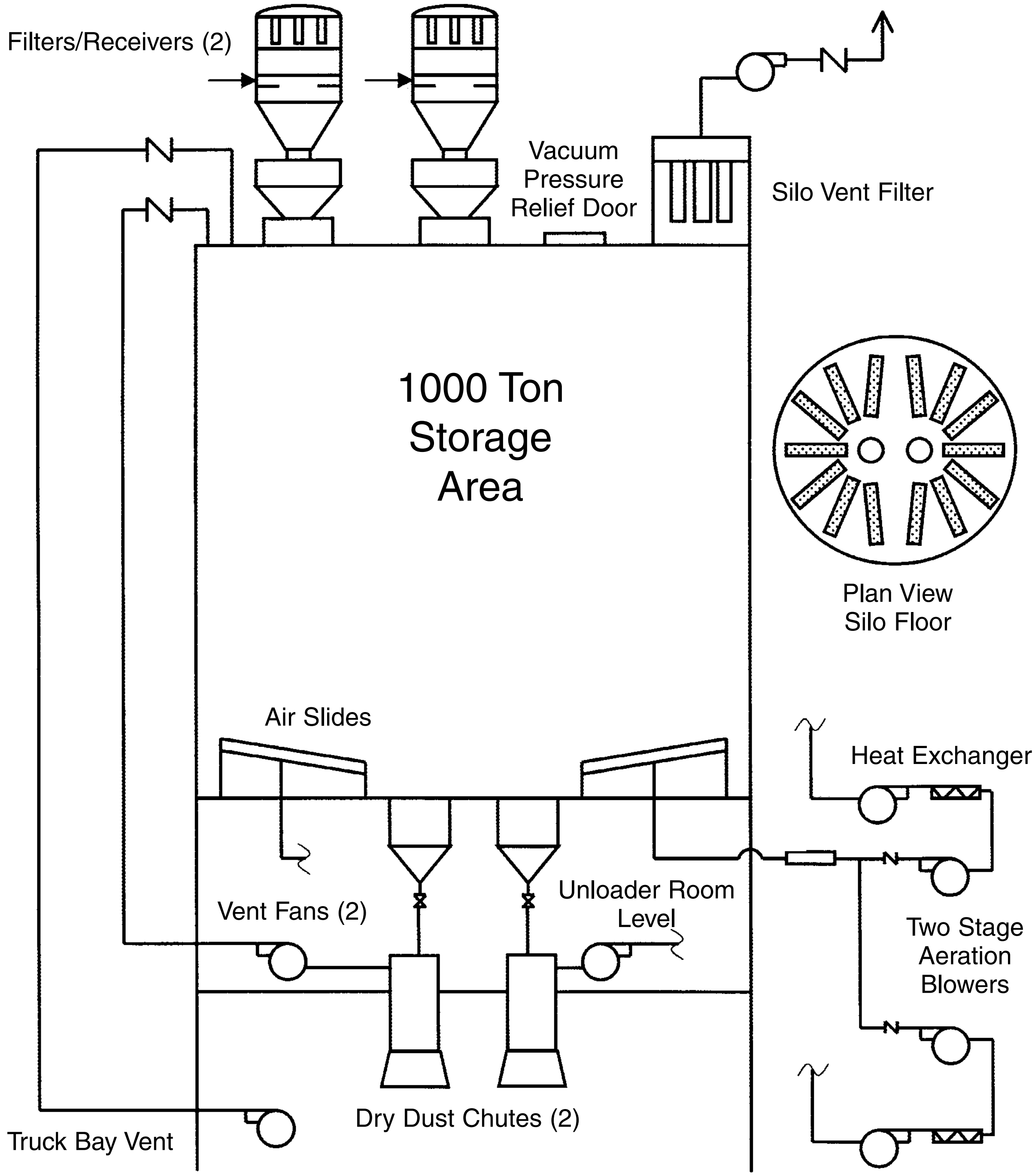


*Figure 2  Schematic of NIPSCO Michigan City Silo System*