Turning Biological Waste Treatment Plant Sludge into a Fuel Source

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TURNING BIOLOGICAL WASTE TREATMENT PLANT SLUDGE INTO A FUEL SOURCE

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Abstract

North Carolina, as part of its landfill regulations, banned all waste treatment plant sludges from general landfills in March, 1989. Cranston Print Works Company was producing approximately 20 tons per day of 18% solid non-hazardous sludge in its extended aeration activated sludge waste treatment plant. Sludge disposal costs were $10,000 per week after the ban took effect.

This paper traces the process used in the selection of a sludge disposal method, and a full report on the chosen method, its installation, and long term operating characteristics.

The method chosen was to burn the biological waste treatment sludge as a fuel source, blended with coal in a pulverized coal fired boiler operated by the plant.

To transform the sludge to a usable form, an indirect steam heated Komline-Sanderson/Nara Paddle Dryer was selected. This machine produces a 99.5% solid pellet like material readily compatible with the pulverized coal boiler.

The sludge drying operation has been in full production on an automated, low manpower basis since January, 1990. A review of the operating characteristics is included.

The use of the sludge as a fuel source has proven successful in the pulverized coal fired boiler. The parameters considered in determining the suitability as a fuel are reviewed.

TURNING BIOLOGICAL WASTE TREATMENT PLANT SLUDGE INTO A FUEL SOURCE

North Carolina enacted a ban on wastewater treatment plant (WWTP) sludges from disposal in solid waste landfills to take effect in March, 1989.

The justification of this ban was that ordinary landfill material would decay at a faster rate than surrounding material when mixed with sludge. The more rapid decay would create voids in the landfills. This would in turn create depressions in the top cover, causing rainwater to collect and leach through the landfill. This would create the potential for groundwater contamination.

Cranston Print Works Company, Fletcher North Carolina Division, is a commission textile print works operating a bleaching, dyeing, printing, and finishing operation. They were using the Henderson County landfill for the disposal of 20 tons per day of WWTP sludges, and was to be affected by this ban.

The investigation for a solution to the problem of sludge disposal led to the method now employed, of indirect steam drying, then burning of the sludge in a pulverized coal fired co-generation boiler.

The Wastewater Treatment plant operated by Cranston Print Works (CPW) is permitted at 2.5 mgd average flow, and is normally operated at 2.0 mgd average. The plant consists of two (2) 3.75 million gallon aeration basins with six (6) 50 HP gear reduced aerators per basin. The flow from the aeration basins goes to two (2) 60 foot diameter clarifiers with a 0.25 million gallon capacity each. The sludge collected from the clarifiers is returned to the aeration basin at a normal rate of 1.15 mgd per basin with approximately 0.06 mgd of the return sludges routed to the sludge wasting system. A sketch of the plant layout is shown in Figure 1 on page 2.

The sludge wasting system consists of a Komline-Sanderson GMD 2-meter belt filter press that was installed in 1983. The sludge cake produced by this machine varies from 18 to 23% solids, depending on the solids content of the return sludge being processed. The sludge cake is then conveyed to a Komline-Sanderson/Nara NPD Model 9W indirect steam heated paddle dryer installed November, 1989. The sludge is dried by this machine to a consistent 99.5% solid content. The sludge is then transported to the boiler house where it is blended with coal at an approximately 25 to 1 ratio (coal to sludge), pulverized, and burned as fuel.

Options Studied

The means of sludge disposal chosen at the Cranston Plant was based on an investigation of several technologies available for this purpose. Sirrine Environmental Consultants, Greenville, SC were chosen by Cranston to aid in the method selection process. They were requested to work primarily in investigating known technologies of sludge disposal, and in examining them in relation to the situation at Cranston.

Several methods of sludge disposal were examined by Sirrine and Cranston, and each was evaluated utilizing the following factors: technology, economics, and risk.

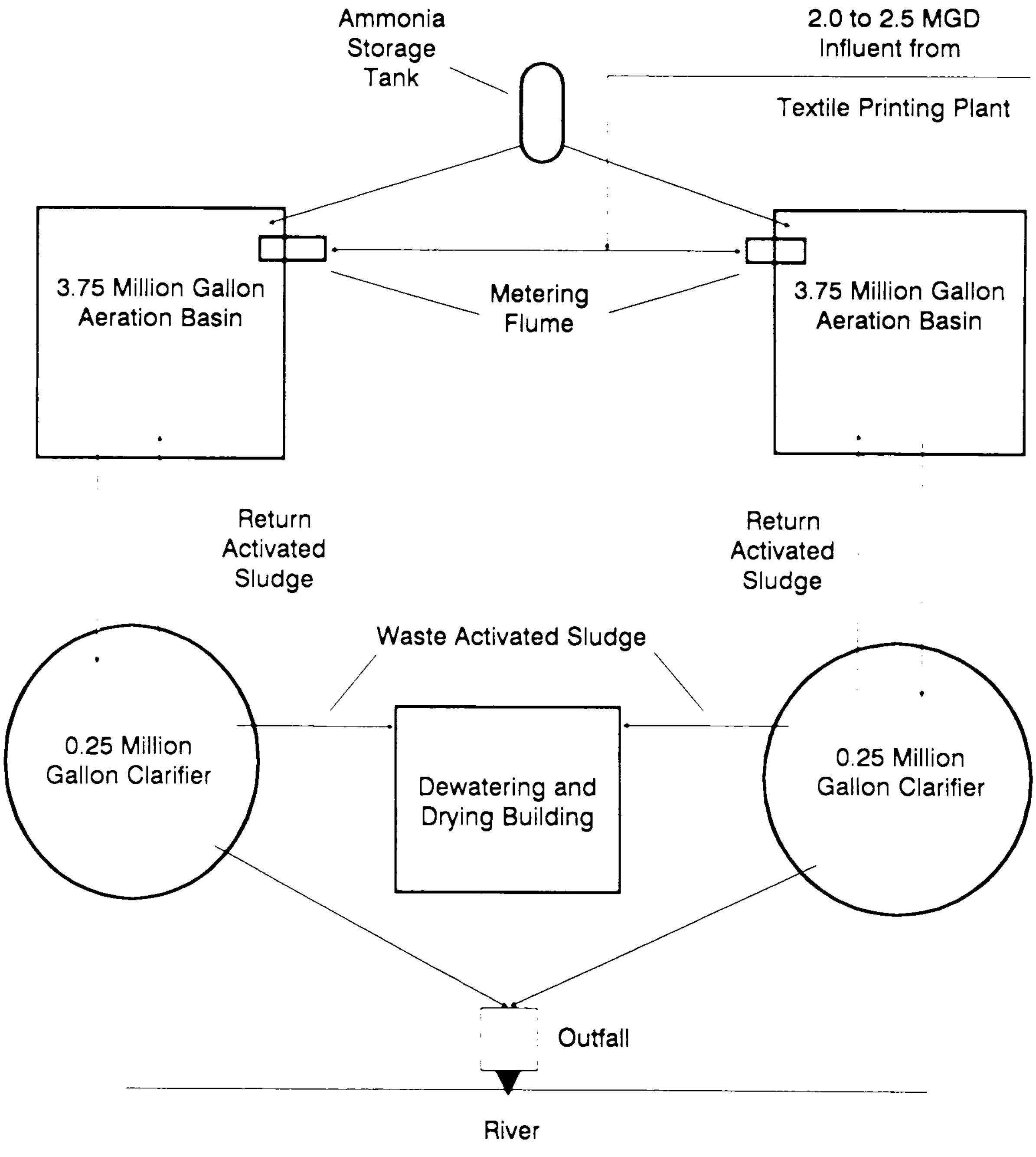


Figure 1

Plant Layout at Cranston Print Works, Fletcher, NC

Land Spraying (Spray Irrigation)

Cranston owns 3 tracts of land adjoining the main plant site totalling 95 acres. This land is well suited for spray irrigation due to its being relatively level, moderately permeable and already under cultivation with row crops. The only disadvantage to the sites is that they were subject to rare flood events.

The sludge to be applied has a high copper content (33 ppm) which would have severely restricted the quantity of sludge we could apply based on the Annual Pollutant Loading Rate limits. Copper removal was considered in the roller engraving area but was rejected.

The complexity of the system involved in spray irrigation was a consideration. The sludge contains a large amount of lint and fibrous material from the textile wet processes which causes some clogging of existing equipment. A spray system would be difficult to maintain under these conditions.

The cost of a spray irrigation system was also determined to be relatively expensive. The estimates by Sirrine were $1,658,000 for capital cost, plus $66,000 per year in operating costs.

The major disadvantage with a spray irrigation system is the liability problem. The long term risks associated with a changing regulatory climate were determined to be unacceptable. The cradle to grave responsibility associated with any wastes caused the feeling that owning a permanent waste site is a liability, even though by present standards spray irrigation is an acceptable means of sludge disposal.

Land Application (Land Spreading)

Many of the factors favoring Spray Irrigation also came into consideration with this alternative. The availability, suitability, and close proximity of the land application sites were favorable factors. The costs involved in this method were the most favorable of all methods considered. The capital costs involved were estimated to be $498,000 with operating costs to be $76,000 per year.

It was felt that a permanent waste site would be created along with all of the associated risks, both in the short term with public perceptions, and in the long term with changing regulations.

On-Site Landfill Disposal

The regulations imposed by the North Carolina Department of Environmental Management did allow landfill disposal of sludge in an approved monofill, and this method was examined. It was felt that in general terms the monofill would have been the most controllable method examined in relation to possible environmental impacts. A properly constructed and operated monofill would have had the advantage of being a tightly controlled, small site.

However, this method was eliminated due to several factors. The major concern was lack of suitable land for a landfill to be constructed. The plant site, and the surrounding properties, are in a flood plain area. Therefore, landfill construction and permitting at this location is very difficult. The purchase of a suitable site near the plant would have been difficult and also subject to public perception problems.

Another major factor considered was once again the permanent liability factor. The company does not wish to own a large amount of sludge inventoried in a landfill that at some point in the future could be deemed hazardous in a changing regulatory environment.

The capital costs of this method were estimated to be $792,000 if the monofill could have been permitted and constructed on site. The annual operating costs were not pursued due to the doubt about permitting.

Off-Site Landfill Disposal

This option for sludge disposal was considered and put into operation for a brief period of time after the ban went into effect and before the equipment was installed. The 20 tons per day of 18% solid sludge was trucked from Fletcher, NC to Pinewood, SC where it was placed in a secure landfill.

The costs involved in this operation were prohibitive for long term use. The fees involved in disposal and transportation were $10,000 per week. This option is still available if problems ever develop in burning the sludge as a fuel source.

Separate Sludge Incineration

This option of disposal was briefly considered and deemed not suitable.

The dryness of our existing sludge cake (18%) make additional dewatering equipment necessary for successful, fuel efficient incineration. There was also some concern about obtaining the permits necessary to operate such a facility. The company operates and is permitted for numerous stacks and sources. It was determined that none of these could be placed at risk of permit limitations in order to operate an incinerator.

The capital costs of such a system were not projected due to the quick elimination of this option.

Boiler Incineration

This alternative was the one most favored by Cranston and was explored in depth for positive aspects. The combustion of coal and sludge mixtures in industrial boilers is a common and well known practice. The most important factors generally considered are how to obtain a homogeneous mix of sludge and coal, and how much BTU value can be afforded for removing the water in the sludge. All of the operating installations known to Cranston or the consultants use stoker or grate type boilers. No case could be found where a pulverized coal boiler was being used as a sludge disposal means.

Cranston operates a 200,000 lbs/hr Babcock & Wilcox (B&W) pulverized coal firedboiler at an average rate of 90,000 pounds of steam per hour. It was determined that any BTU loss involved in wet sludge burning would be insignificant in relation to boiler capacity. The existing stack scrubber system had a performance history that demonstrated a large margin to stay within compliance if sludge burning caused any problem in that area.

The consultants were of the opinion that the sludge cake (18%) could be blended with the coal and pass through the pulverizers. The most important part of this would be achieving a homogeneous blend of sludge and coal. Babcock & Wilcox did not recommend this, and the Cranston boiler operators concurred. The opinion of Cranston was that if the moisture content of the sludge could be reduced to less than 50%, it would pass through the pulverizers without any adverse effects.

The capital cost estimates produced by Sirrine ranged from $100,000 to $500,000 for the drying of sludge to the degree that was desired. The costs were directly linked to the type of equipment chosen for the project, but were considered to be acceptable in comparison to other options considered. The expense of steam was not a major factor in dryer selection due to excess boiler capacity, and co-generation benefits of additional steam use.

It was at this point that a search for a means to dry the sludge started that ultimately resulted in the installation of an indirect steam heated sludge dryer.

Indirect Drying

Before proceeding further, we should define the indirect drying process so as to separate it from other drying processes. Indirect drying for the purpose of this paper and most other purposes, places a metallic barrier between the process mass being dried and the heat transfer medium, such as condensing vapor (steam) or liquid. These barriers are the jacket wall of the process vessel, the wall of the hollow shaft and the wall of the hollow paddles mounted on the shaft. This is in contrast to the direct drying process where the process mass is directly contacted by the heating medium, hot gases. During the drying process for biological sludges some low boiling odoriferous vapors are released. The problem of air pollution abatement is increased if these vapors are diluted by mixing them with the copious quantities of gases required to provide the heat requirements for the drying process. The odoriferous gases produced by indirect drying mix only with the limited volume of gases that leak into the dryer either as part of the feed sludge or through the feed and discharge mechanisms. The indirect drying process is normally more efficient than the direct process since the energy is directly passed by conduction into the process mass.

The extended aeration activated sludge passes through a number of phases during the drying process. The first stage is called cohesive. During this stage the sludge will be very sticky, tending to remain together as a single mass. Fouling of the heating surfaces may take place during this stage of the drying cycle. In the next phase, called shearing, resulting from the further loss of moisture, balls are created which continue to break down in size passing through the wet and dry granular phases. With the removal of moisture, the volume occupied by the sludge is reduced to as little as a third of the original volume.

Equipment Selection

A major factor considered in the development of this project was the lack of operating experience with the units proposed for the drying of biological sludges. Any available work in the field that could be found by the company or its consultant was based on pilot work rather than full scale operation.

Sirrine, through its parent company CRS Sirrine, did have material drying experience with other products. The most common of these methods involved variations of heated air dryers. These dryers are relatively inexpensive, but have one major disadvantage; i.e. treating the large the amount of off gases from the drying process.

The use of indirect steam heated dryers in pilot work was known, and their use for this purpose was being proposed by their manufacturers. It was decided that indirect steam heated drying would be the method of choice due to their efficiency and small volume of off gases provided their suitability could be demonstrated.

The course of action chosen was to examine the continuous disc type dryers and the discontinuous, paddle type dryers that were available for pilot testing. The appropriate contacts were made to conduct the pilot tests, and the following method was used to evaluate the dryers.

Pilot Testing

Since the data used in the study of technology was based on the best estimates of potential equipment or service suppliers, it was in Cranston's best interest to pilot test the sludge drying process to confirm the proposed design parameters. Each potential candidate had to be checked because every sludge exhibits its own distinctive handling characteristics and each dryer has its own processing idiosyncrasies. The test procedure was similar in all cases since the equation $Q = UA\Delta T$ applies to them all. The terms are defined as:

Q = total amount of heat required per hour to dry sludge including sensible heat of liquid and solids, heat of vaporization of liquid, etc; BTU's/hour.

U = Rate of heat transfer coefficient. This factor is peculiar to each sludge and each manufacturers design; BTU/hr-sq.ft.-°F.

A = Total heat transfer area; sq. ft.

ΔT = Temperature driving force between heat transfer medium and process mass; °F.

Cranston studied two (2) different types of indirect dryers-multiple shafted paddle and single and multiple shafted disc. Figure 2 on page 7 shows a cutaway of both the paddle and disc type dryers.

The indirect paddle dryer utilizes a segmental (usually 120-150° arc) hollow paddle mounted in pairs on opposite sides of a hollow shaft. The paddle can be placed on the shaft with a pitch to propel the mass through the dryer. The disc type dryers use a full 360° hollow disc mounted on a hollow shaft. The discs are mounted perpendicular to the direction of flow. Tabs are mounted on the outer periphery of the disc so as to impart flow.

While the segmental paddle dryer operates with the heat transfer surface fully flooded, the disc type dryer normally operates only partially flooded. The multiple shafted units tested were designed so that the paddles or discs intertwined. The path swept by the paddles or discs mounted on one shaft came very close to the shaft on which the blades or disc of the other agitator were mounted.

A picture of the K-S Nara Paddle Dryer pilot unit is shown in figure 3 on page 8. This unit has a simple air pollution package attached to it. These units are typically available for lease or use in the equipment manufacturer's laboratory.

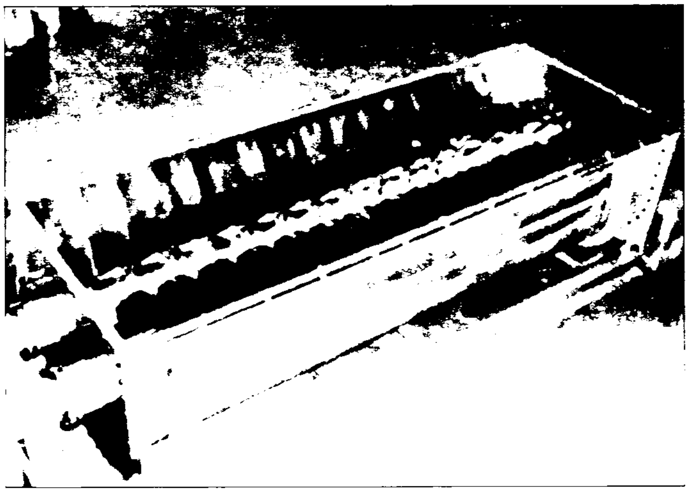


Figure 2a

Section through dual shafted paddle dryer

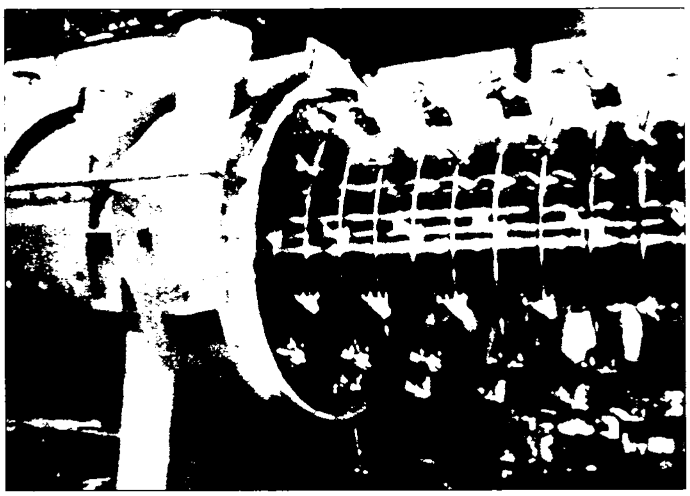


Figure 2b

Section through single shafted disc type dryer

A heat transfer rate (U) is established by collecting data at a specific time from several points along the length of the pilot dryers during a period of stability. Stability is achieved when the following are constant: feed rate, feed moistures, heat transfer medium temperatures, and discharge moisture. The data one must collect is the bed temperature, bed moisture, bed handling condition, and amount of heat transfer surface covered at these various points. Also horsepower and agitator speeds should be noted at this time. Figure 4 on page 9 shows a typical plot of the data collected during the test. A typical plot of the heat transfer rate versus moisture level is found in figure 5 on page 10. For a more detailed explanation of the test procedure, please refer to the article entitled "Indirect Drying of Solids", published in the May 2, 1983 issue of Chemical Engineering Page 52-64 inclusive.

The primary factor leading to the selection of the paddle type dryer is its greater ability to physically 'knead' the sludge. During the pilot testing with two of the three potential suppliers of the dryer, in order to assure proper operation of their equipment recycle---returning and mixing a portion of the dried product with the fresh dewatered cake---was required. The paddle type dryer, as a result of this kneading action, did not require recycle. This capability produced a smaller ball of sludge at an earlier

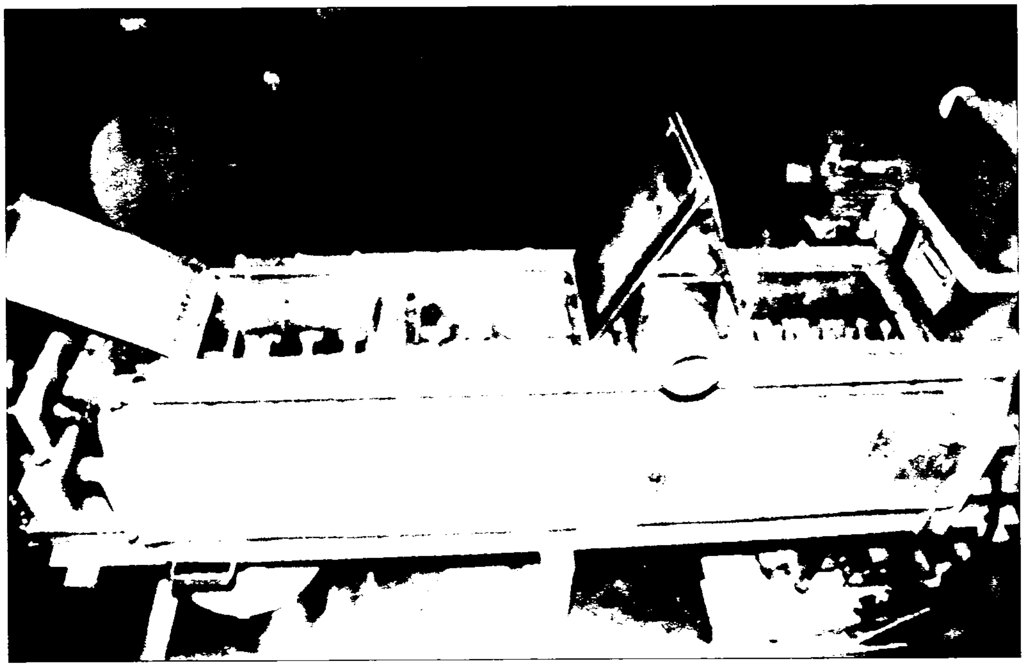


Figure 3

Picture of K-S/Nara Pilot Padle Dryer used to obtain drying parameters

stage in the process. The greater surface area generated in the sludge mass allowed more contact with the heat transfer surfaces of the dryer. This kneading ability of the paddle dryer also reduced the tendency of the sludge to bridge over the interior heated areas of the rotating shafts, especially in an overload condition. As a result, the paddle dryer system was the simplest because it allowed the elimination of the return dried sludge conveyors and pre-mixers for the combined sludge and their associated installation and maintenance.

Based on the physical factors in handling the sludge, it was determined that the paddle dryer installation would be smaller than the disc type. This was an important advantage due to pricing of the system, and the limited space available for installation.

Permitting Aspects

After the method of drying and fuel blending was selected Cranston then investigated the permitting aspects.

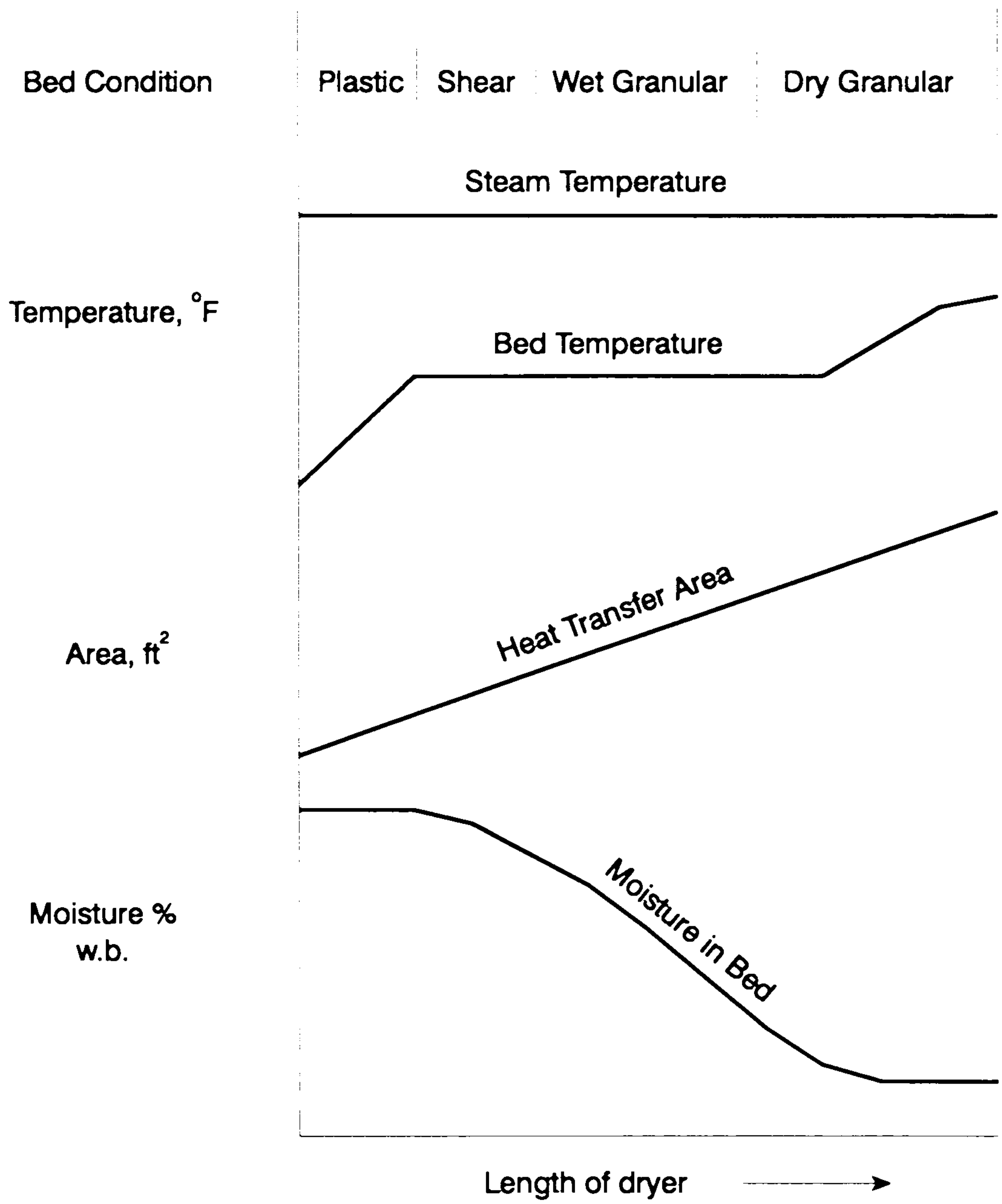


Figure 4

Pilot data typically used in designing a dryer

The North Carolina Department of Natural Resources and Community Development (N.C. DNRCD) had never permitted such a facility, but were very cooperative in establishing the necessary parameters. The decisiveness they exhibited was very beneficial in allowing the company to design the facility with firm parameters in place.

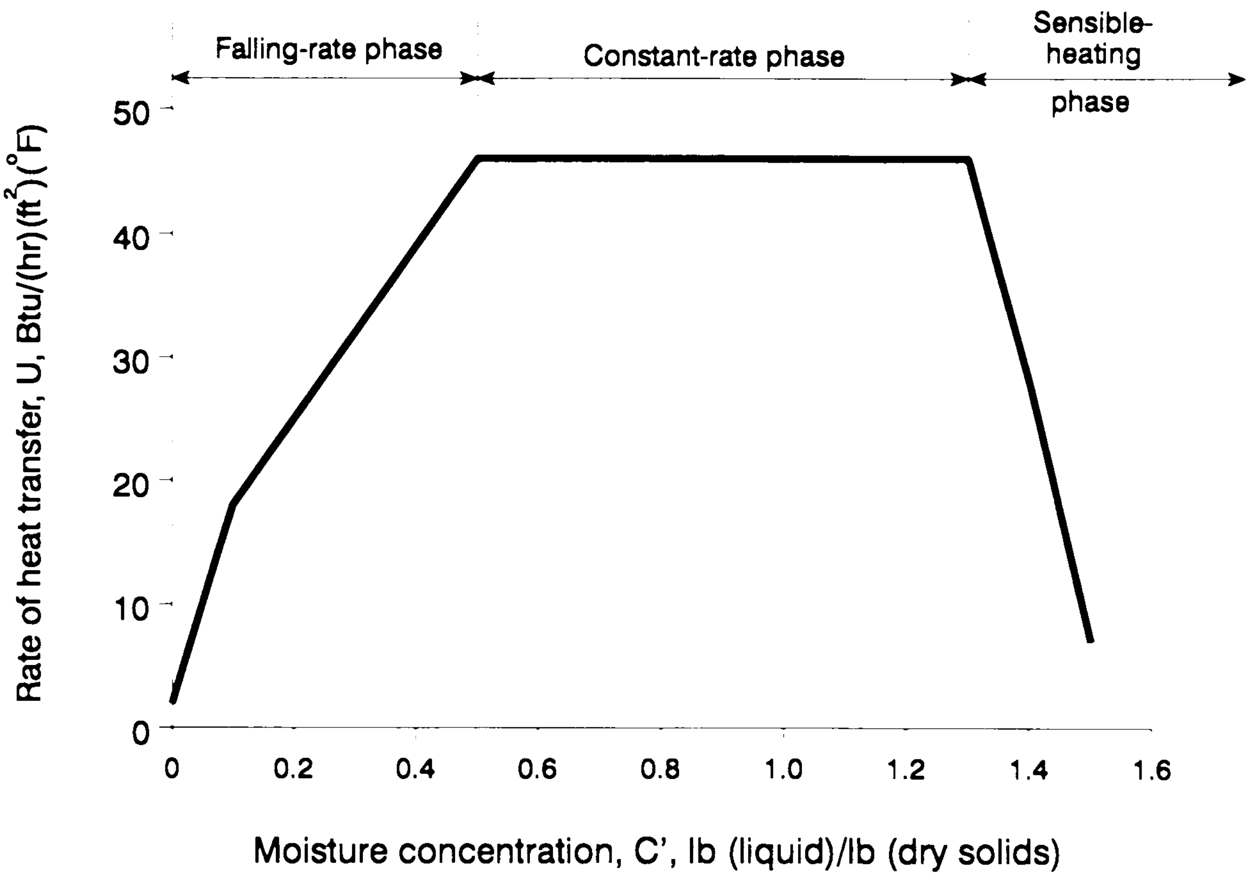


Figure 5

Typical heat transfer curve for drying

The first consideration was assuring that the sludge would continue to be classified as non-hazardous. The company had maintained a continuous testing program to insure that both the waste water and sludge were non-hazardous, but a full test of the sludge was done again. The standard tests of sludge most commonly employed was based on leachate analysis for toxic metal content. The small amount of data available from that test was deemed inadequate for the fuel burning program. The sludge was analyzed for leachates, total metals, organics and ultimate analysis of combustion discharges to insure a non-hazardous ruling could be established.

The off gases from the dryer were then considered and determined to be non-hazardous due to the sludge determination itself. It was known that some odor could be generated by the process, but it was not known to what extent that would be a problem. The N.C. DNRCD allowed a start-up to determine the necessity and degree of control needed, with the agreement that any control method needed would be employed by the company for continuous operation.

The permit for the boiler itself was not changed except for the following four parameters:

1. The existing particulate (0.169 lbs/million BTU) would not be exceeded.
2. The existing SO_2 limit (2.11 lbs per million BTU) would not be exceeded.
3. The amount of sludge burned would not exceed 10% of the total BTU input of the fuel burned.
4. The sludge would maintain its non-hazardous classification.

Considerable efforts were expended on the permitting aspects of the project since everyone involved agreed that no large capital expenditure would be made until all aspects of permitting were explored.

Fuel Value of Sludge

The value of the dried sludge as a fuel was not as major a consideration in the evaluation of the project as was the disposal of the sludge itself. However, some considerations did have to be made for boiler compatibility.

The sludge was evaluated as a fuel using the following factors:

1. The BTU Value - The sludge has a BTU value of 6500. This was important since the North Carolina standards are 5000 BTU or above to be considered a fuel.
2. Metals Content - These tests were important to insure that the sludge, its off gases from combustion, and the resulting ash would remain non-hazardous.
3. Ash Content - This test determined that the additional ash from the sludge would not overload the existing ash handling systems or scrubbers.
4. Ash Softening and Fusion Temperature - There was a great deal of concern by the B&W and CPW boiler personnel about the possibility of fouling in the combustion chamber, and on the boiler tubes by the burning of sludge. The softening and fusion temperatures of the ash from the sludge was determined to be very similar to that of coal, so no problems were expected in that area.

Equipment Installation

The existence of the sludge wasting equipment that was installed in 1983 played an important part in the options available for dryer installation.

The desire to have the dryer on the same floor of the building with the belt press made the physical size of the dryer an important factor, and one that was considered in the machine selection process. The smaller size of the K-S machine, and the ability to operate without recycle, aided in locating the machine in the desired position.

The adaptation of the dryer to the belt filter press system was accomplished through the use of a conveyor system (see figure 6 on page 13). This system was designed by CPW personnel along with New England Conveyors. The actual delivery of sludge into the dryer is accomplished by the use of a belt conveyor which feeds a screw conveyor with a short auger section with a flight removed to create an air lock. This is important in maintaining proper air flow through the dryer.

The decision was made early in the project that the plant would run automated and unmanned during the evening hours. The design and installation layout was done with this in mind.

The sludge wasting control system at the waste treatment plant was designed by Cranston and Control Products Sales, Inc. of Charlotte, NC using Bailey Sequence Command and Loop Command controllers. For each step in the sludge system a failure detector was specified and installed. The automated shutdown of the system and its sequences are determined by the controller. An example would be the failure of the conveyor belt from the belt press to the dryer screw conveyor. If such an event occurred the sequence commander would detect it. The belt press, sludge feed pump, polymer, and wash pump would shut down. The dryer itself, and its discharge auger would continue to run, but in a shutdown mode. The dryer would run for one hour with the steam on, then one more hour with the steam off to cool down. The discharge auger and the dryer would shut down at the same time.

Figure 7 on page 14 shows the process flow diagram around the K-S/Nara Paddle Dryer. Table I on page 16 provides a summation of operating data and cost.

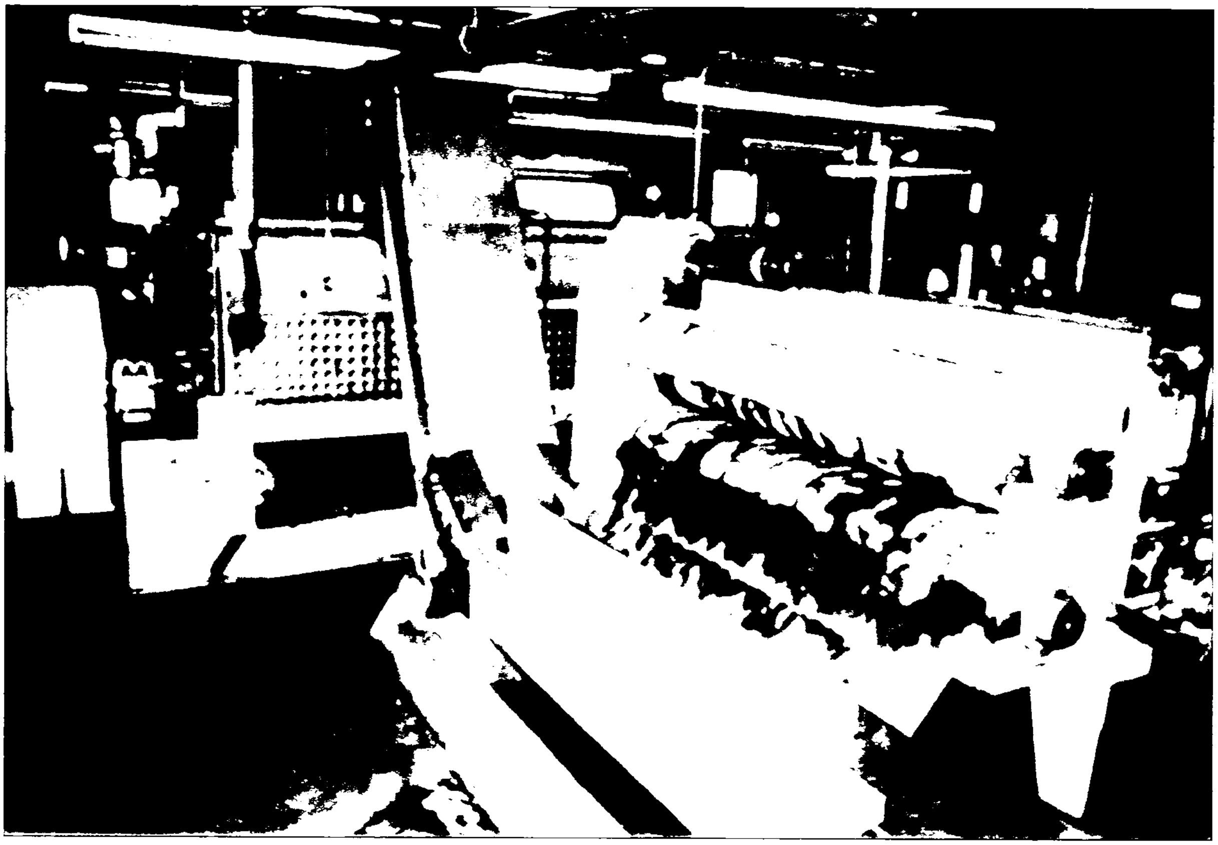
Start-Up

The start-up of the project was less complicated than expected on a new system that was unknown to the operating personnel. The primary factors aiding in this were the efforts put into design and layout, and the simplicity and reliability of the entire system.

The existing belt press operation was well known, but had to be adapted to the dryer system. Before the dryer was installed, the belt press was operated approximately 6 hours per day with the remaining time devoted to polymer mixing and cleanup. With the dryer operating, the belt press must process the same amount of sludge on a 24 hour per day basis. The primary consideration was changing from a manual to a continuous polymer mix system. Liquid emulsion polymer from Callaway/Exxon was chosen, along with their automated blend system.

During the early phases of start-up, before the control system was in place, the dryer system was operated during the day only. This made one facet in dryer operation very obvious. The dryer did not run well on a discontinuous basis. The heat retained in the mass of sludge was great enough that it would dry into a cake, making restart of the machine very difficult. It was discovered that by reheating the machine for one hour before attempting to start it the sludge cake would break up allowing the dryer to restart easily. After the machine was placed in continuous operation no additional problems developed in that area.

The dust generated by the machine in the early stages was not a major problem, but did indicate that the machine was not being properly operated. It was determined that dust was primarily a factor of the machine not being fully loaded during the start-up period. Also it was found that the machine would



Discharge end of belt filter press and feed end of dryer

generate more dust if it was not being properly loaded while in operation, or was allowed to operate too long during the shutdown phase.

Odor problems were another concern that quickly became apparent during the start-up phase. This problem was solved by the installation of a packed column scrubber fabricated on site. The scrubber utilizes 2" fiberglass reinforced packing saddles from Norton Industries. Cooling water was provided by pumping 60 gpm of effluent water through the packed column.

The burning of the sludge at the boiler house is not a problem. The physical nature of the dried sludge as a dry pellet has made handling much less of a problem than anticipated. The sludge is mixed with coal on the ground with a front end loader, loaded in the coal handling elevators, and transported by bucket elevators to the day bunkers. After this degree of mixing action, the sludge is not readily distinguishable from the coal itself. The sludge/coal mix is fed through the pulverizer from the day bunker, and has caused no problems.

The boiler stacks were tested for any problems, and none were found. These tests were conducted under the supervision of the N.C. Department of Environmental Management by Sirrine Environmental Consultants and Pace, Inc.

The process automation system that was installed works very well. Some adjustments were made during the start-up phase, both for sensitivity and timing of shutdown sequences, but the system is successful. The high degree of planning and design has proven to be a positive factor in this area.

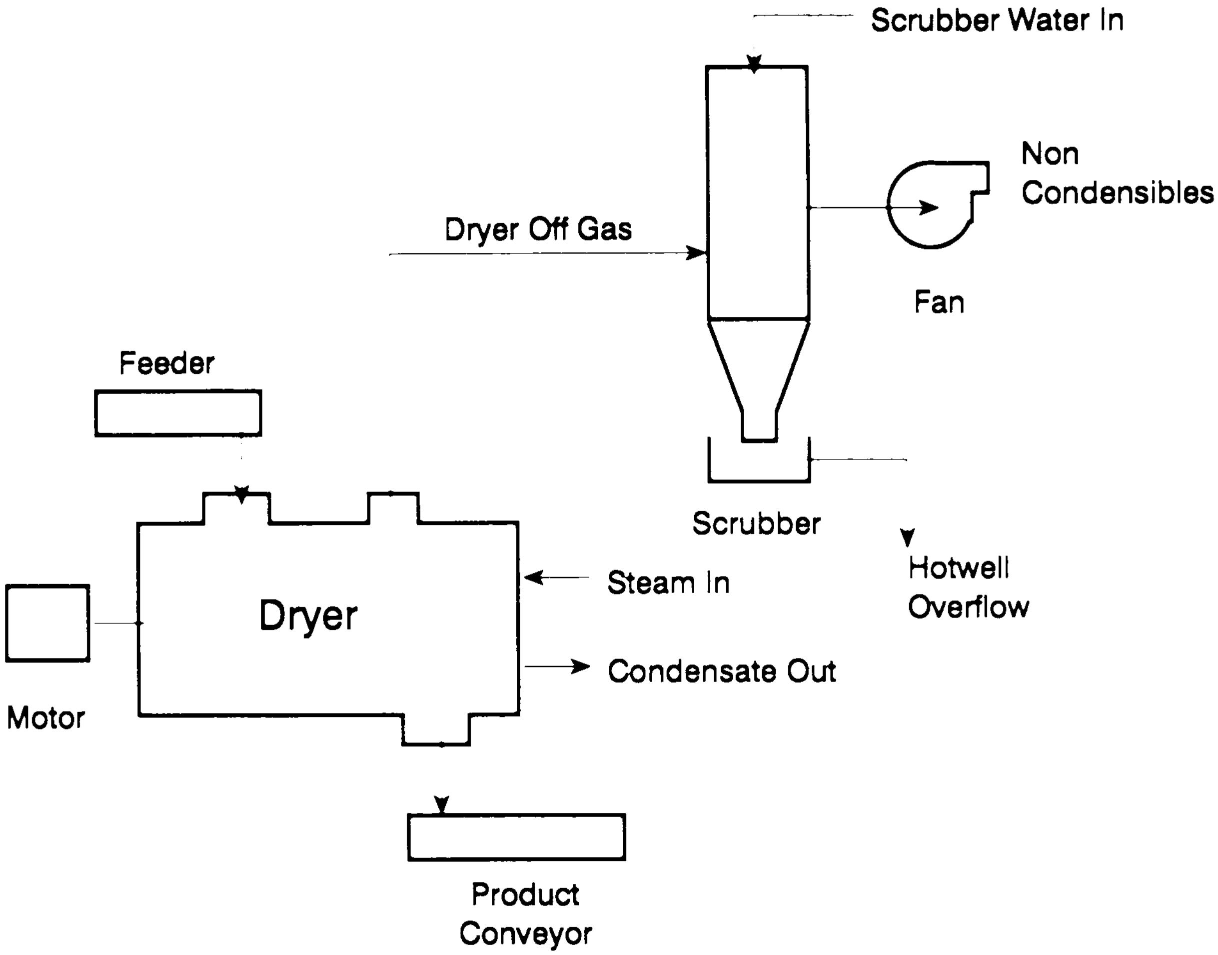


Figure 7

Process Flow Diagram

Operation/Maintenance

The long term experience that has been gained by the sludge drying and burning operation has proven to be positive. The equipment itself has proven to be relatively trouble free. The only maintenance problems that have surfaced have been normal seal and packing replacement items.

The boiler was recertified and completely inspected after operating one year with the sludge/coal blend. No evidence of any problems associated with sludge combustion were found.

The Komline-Sanderson Kompress® Belt Filter Press, Komline-Sanderson/Nara Paddle Dryer and its associated equipment is normally started up on Monday morning, and is not shut down until Friday afternoon. This schedule of operation is best for avoiding any problems with start-up and shutdown. Lubrication and clean-up are usually done after shutdown on Friday.

CRANSTON PRINT WORKS
Fletcher, NC

I. To dewatering

(Assume 2% T.S. feed sludge)
(Assume 24 hours/day and 7 day/week operation)

- 0.06 MGD - Sludge (liquid)
- 2,325 lbs/hr - cake @ 15%
- Polymer conditioning cost (estimated): $30,000/year

II. To drying

- 15% T.S. Cake-------90% T.S. product
- 2,325 lbs/hr Cake-----388 lbs/hr product
- Steam Required: 2,700 lbs/hr @ 150 psig (saturated)
- Cooling Water Required: 60 gpm @ 70° F

III. Miscellaneous

- Maintenance per year: $3,000 (lubrication and packing)
- Approximate Connected HP: 20 HP dewatering
60 HP drying

Table I

Operating Conditions and cost for Cranston Print Work Dewatering and Drying System

The Authors

Donald L. Greene is the Environmentalist for Cranston Print Works, Fletcher Division, Fletcher, NC 28732. He has held this position since 1983. Prior to this, he was the plant chemist. Don holds a Bachelor of Science degree in Natural Sciences and a minor in chemistry from Mercer University. He is a member of the North Carolina Textile Manufacturers Association and serves as chairman of their Water Quality Committee. He also is a member of WPCF and AWWA.

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Robert J. Fortier is Senior Product Manager for Komline-Sanderson Engineering Corporation. He has more than twenty years of experience in the area of design engineering involving mechanical equipment. Many of these years were spent in a supervisory capacity. He has published several articles concerning Potable Water Treatment. He received a BSCE from Newark College of Engineering and a MBA from Fairleigh Dickinson University. In addition he has completed several graduate courses in Environmental Engineering. He is a member of WPCF.

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