ABSTRACT

Since the chronology presented at the 1974 National Conference, the Nashville Incinerator with Heat Recovery, has been started up, and with some temporary interruptions has been carrying its connected heating and cooling service load. This report discusses the major problems encountered during the start-up of incinerator operation.

A great deal has been learned from the Thermal plant. The purpose of this candid review of the status of the project is to relate the experience and it is hoped that it will be of some value to others involved with solid waste fueled plants.

INTRODUCTION

Nashville Thermal Transfer Corporation (THERMAL) is a not-for-profit, private corporation created pursuant to the Tennessee General Corporation Act, as amended, for the purpose of burning garbage and trash ("solid waste") and using energy recovered from such solid waste to provide low cost district heating and cooling services to various governmental and private buildings located in downtown Nashville, Tennessee (the "Project"). Though all of the property and assets of the Corporation will be transferred, without cost, to The Metropolitan Government of Nashville and Davidson County, Tennessee ("The Metropolitan Government") when the bonds issued by the Corporation have been fully paid, neither the Metropolitan Government nor the State of Tennessee is legally liable for the bonds or other indebtedness of the Corporation. With the exception of a $150,000 annual sum which the Metropolitan Government has agreed to make available to the Corporation for the sole purpose of meeting the Corporation's obligations under the indenture securing the bonds issued to finance its facilities, all of the income of the Corporation is derived from the sale of steam and chilled water.

The facilities of the Corporation (facilities) consist of a Heating Plant, a Cooling Building and a Distribution System. Housed in the Heating Plant are: (1) the solid waste storage pit into which raw, unprocessed solid waste is dumped by trucks belonging to, or directed by, the Public Works Department of the Metropolitan Government; (2) two large, water wall incinerator/boilers supplied by the Babcock and Wilcox Company, each incinerator/boiler consuming at full load a maximum of 360 tons of solid waste daily and producing steam at the rate of approximately 108,000 pounds of steam per hour; and, (3) a standby, fossil-fueled, package steam boiler capable of delivering 125,000 pounds of steam per hour.

Contained in the cooling building are two 7,000-ton steam-driven, centrifugal refrigerators, manufactured by Carrier Corporation, which are used to chill water to approximately 41°F for use in the distribution system. Associated with these refrigerating units are two Marly cooling towers with a joint water flow rate of approximately 34,000 gallons per minute.

The Distribution System consists of four pipes, a chilled water feed line, a chilled water return
line, a steam feed line, and a condensate return line. The steam lines vary in size from 3 to 20 inches and the chilled water lines from 10 to 42 inches. Both steam and chilled water are continuously available to heat and cool the buildings served. Funds for the construction of the facilities, including the Distribution System, were obtained by means of the issuance by the Corporation of First Mortgage Revenue Bonds in the aggregate principal amount of $16,500,000, the proceeds of which have been expended as follows: (1) approximately $390,000 for financial and legal fees connected with the issuance of the Bonds; (2) approximately $13,140,000 (plus interest earned during the construction) for the construction of the facilities; and $2,970,000 for the payment of interest accruing on the Bonds during construction and the establishment of a 1-year interest reserve fund.

Construction of the facilities was commenced soon after delivery of the Bonds in July of 1972, and was substantially complete by January of 1975. However, in an effort to obtain additional revenues, as early as February 4, 1974, several customers were provided steam service by means of the fossil-fueled, package steam boiler prior to completion and checkout of the two solid waste incinerator boilers. Cooling service, also by means of the package steam boiler, was initiated on May 8, 1974. Testing and checkout of the incinerator boilers did not occur until June and July of 1974. Thereafter, however, solid waste has constituted the primary source of energy for the Corporation's Facilities, except for a substantial number of instances (at least one of which was several weeks in duration) when it has been necessary to burn fossil fuels because of equipment malfunctions, system modification, or air pollution considerations.

At the present time, the Corporation provides either heating or cooling services, or both to 33 buildings located in downtown Nashville, including 14 buildings owned by the State of Tennessee and three buildings belonging to the Metropolitan Government.

**OPERATIONAL PROBLEMS**

**ATMOSPHERIC EMISSIONS**

For reasons not yet fully determined, when the incinerator/boilers are burning solid waste, the atmospheric particulate emissions from the incinerator/boilers considerably exceed the level originally projected. After extensive testing and study, it has been determined by the Corporation that although operation adjustments, equipment modification or replacement, and other technical changes can and have reduced the amount of particulate emissions from the original level of 0.41 grains per standard cubic foot to approximately 0.17 grains per standard cubic foot - attainment of the 0.08 grains per standard cubic foot maximum level specified in the Regulations of The United States Environmental Protection Agency will require complete replacement of the original low energy, wet system (and its successor interim equipment) with a different type of emissions control equipment.

The Corporation, on the advice of S&T Western, Inc., an engineering firm retained by the Corporation, has chosen to install an electrostatic precipitator to control the particulate emissions from one of the two incinerator/boilers, and, concurrently, to institute a testing program of two "baghouse" pilot units in order to determine whether such units can successfully and reliably control particulate emissions from incinerator/boilers of the type installed at the Corporation's facilities. If the test of one or more of these pilot units is successful, the Corporation intends to install a "bag house" type system to control particulate emissions from the second incinerator/boiler, thereby possibly realizing a significant saving in projected capital and operational costs compared to other possible types of emission control equipment, including electrostatic precipitators. If, however, such tests and system evaluation are not successful, the Corporation will purchase and install a second electrostatic precipitator.

This emissions control program, i.e., the purchase of one electrostatic precipitator, the testing of baghouse pilot units, and the installation of either a second electrostatic precipitator or a baghouse system, has been incorporated in a Consent Compliance Order ("Compliance Order") issued by the United States Environmental Protection Agency on April 7, 1975. This compliance Order also requires that the Corporation take certain interim measures to limit particulate emissions pending installation and checkout of the definitive emissions control equipment.

Pursuant to the provisions of the Compliance Order, installation and checkout of the first electrostatic precipitator will be completed by August 15, 1976. Tests of the baghouse pilot units are scheduled for completion on February 15, 1976,
and, depending upon the results of these tests, either a baghouse emissions control unit will be installed and operational by January 1, 1977, or a second electrostatic precipitator by January 15, 1977. With the exception of certain delays in the acquisition of equipment, etc., the Corporation is substantially in conformance with the schedules set forth in the Compliance Order.

INCINERATOR/BOILER

Beginning in the Fall of 1974, a number of sporadic, but apparently isolated failures occurred in certain portions of the water wall incinerator/boiler tubing located in the lower combustion areas. After both incinerator/boilers were simultaneously disabled by such failure in late April 1975, all of the boiler tubing in the lower combustion areas was subjected to thorough ultrasonic testing. As a result of such tests, it was discovered that the wall thickness of the boiler tubing located immediately above the burning grate of each of the two incinerator/boilers had been reduced to an extent requiring immediate replacement of all such tubing. The two incinerator/boilers were, therefore, removed from operation on May 1, 1975, and heating and cooling services provided by means of the backup, fossil-fueled, boiler. At the present time, the Corporation believes that the probable cause of this tube deterioration was a combination of: (1) insufficient air for thorough combustion in certain areas of the incinerator/boiler; (2) the absence of any protective coating on the outside of such tubing; and, (3) a thin "scale" accumulation on the inside of the tubing which accelerated the initial wasteage phenomenon.

Solid waste operations resumed on June 22, 1975, using one of the two incinerator/boilers, after completion of the following repairs and modifications to such unit: (1) replacement of all boiler tubes located in the lower combustion areas; (2) modification of the combustion air system; (3) acid cleaning of scale from the inside of all boiler surfaces; and (4) other minor modifications to the solid waste feed and combustion air systems.

Similar repairs have now been completed on the second incinerator/boiler; and this incinerator/boiler resumed solid waste operations in early 1976.

In addition to failures in the boiler tubes located in the lower combustion areas of the incinerator/boilers, the Corporation has experienced a similar failure in the super heater tubes of both of the incinerator/boilers. These failures are the result of sootblowing and corrosion. The superheaters on both units were replaced and the expected life hours of operation perhaps substantially greater depending on the impact of new sootblowing techniques and new design changes.

CHILLERS

Until recently, it has been impossible to operate one of the Corporation's two centrifugal chillers because of the occurrence of intense, intermittent vibrations, in the chiller building steam supply piping whenever the unit was placed in operation. The Corporation, however, has now ascertained that these vibrations are caused by technical problems in the "excess steam condenser", which is also located in the refrigeration building. Certain temporary measures, including vibration shutdown protective instrumentation, have been instituted to control this problem and a permanent redesign of the piping and control valve has been completed to resolve the problem. Though initially refusing to fully warrant this particular centrifugal refrigerator because of possible damage to such equipment as a result of these vibrations, the manufacturer of the two centrifugal chillers has now agreed to extend its usual warranty to this unit also.

RELIABILITY

Through solid waste has provided its primary source of fuel since July of 1974, the Corporation, because of various equipment and operational problems, has been unable to reliably and continuously sustain solid waste operations for extended periods of time. Thus, the longest, continuous period that the facilities have operated using solid wastes, instead of fossil fuels, is approximately 35 days during March and April of 1975. The Corporation believes, however, that continuous solid waste operation is technically feasible and will, upon completion of contemplated equipment modifications, ultimately be attained.

GENERAL PROBLEMS

The solid waste as received is usually dry enough to incinerate without difficulty. The average heat value of the solid waste has been
KEY

Distribution Lines & Customers

Proposed Distribution Expansion

Thermal Plant

THERMAL

Downtown Distribution
May, 1974
about 6,000 Btu a pound, which compares with 12,000 Btu per pounds for coal or 19,300 Btu per pound for fuel oil. The solid waste has occasionally, following large rainfalls, become too wet to burn alone. In these cases a mixture is made by the crane operator of dry and wet solid waste, which is stored separated in the storage pit so that when wet solid waste is delivered a burnable mixture can be adjusted accordingly. On one occasion, the storage pit was practically empty and the previous day had recorded 5 inches of rainfall within 24 hours. All the solid waste which was delivered was too wet to sustain combustion and required the use of supplementary fossil fuel in order to continue the operation. Now, a sufficient amount of dry solid waste is stored to burn wet solid waste whenever it is delivered.

Underfire/overfire combustion air comes from within the plant, thereby creating a slight vacuum. This prevents the radiation of odors from the plant. When the incinerator/boiler was originally installed this volume of overfire air was insuffucient and caused a reducing atmosphere just above the grate levels. This problem was solved by installing larger capacity front and side air nozzles and changing the direction of the nozzles.

When the ash which resulted from combustion was dumped from the ash hopper into the dump trucks, a virtual dust storm was created which caused complaints from neighbors. This problem has been partially solved by confining the dumping area during ash dumping operations. An automatic quench system has also been installed to settle the flyash and cool down the hot discharge.

The plant was constructed with most auxiliary equipment driven, steam turbines; the induced draft fans, boiler feedwater pumps, cooling tower circulating pumps and chilled water distribution pumps for the chilled water, were driven by 400 psi 600°F non-condensing steam turbines. This required a large load on the boiler to sustain plant operation and the plant did not have a sufficient operating flexibility. For example, a solid waste boiler could not be brought on line unless the package boiler was first underway and producing enough steam to run the auxiliaries. Also, if the solid waste boiler experienced a major increase in demand during operation, the fire could not respond rapidly enough because of the nature of the fuel and therefore the pressure would drop. A drop in pressure would slow down the combustion air fans and feedwater pumps, which would result in an uncontrollable situation.

As a solution to the problem, electric motors have been placed at critical locations so that the primary functions will continue unaffected by changes in load and thereby increase the overall plant reliability and flexibility.

Under normal operating conditions the plant produces an excess supply of steam to accomodate load changes. The control of steam rate with the nonhomogeneous fuel is not always possible and there is a 15-minute time lag between stoker changes and changes of steam rate. Therefore, minor load changes are provided for by producing more steam than is required and condensing the surplus in a heat exchanger. Steam supply pressure is thereby maintained within a ± 5 percent tolerance.

Thermal has two manholes on the underground steam distribution system which are below the crest of the adjacent Cumberland River. Consequently, there have been problems with flooding which short circuits the steam and produces large quantities of condensate which overload the steam traps. This was a serious problem, since a severe water hammer could result. The solution of this problem involved welding a watertight bellows to the pipe and manhole.

CUSTOMER RELATIONS

INTRODUCTION

Of the 33 buildings now served by the Corporation, four - including the new, Nashville Hyatt House Hotel - have no independent source of coolant. Furthermore, the complex of 14 buildings owned and occupied by the State of Tennessee, now furnished heating and cooling services by the Corporation, were formerly provided steam for heating from a central coal burning facility which has been decommissioned, although most of the necessary equipment is still in place. All other buildings served by the Corporation have alternative in-building sources of heating and cooling.

With the exception of one customer who is provided steam pursuant to an “interruptible” contract allowing termination of service by the Corporation whereby such customers agree to obtain their entire heating and cooling requirements (or heating only in one case) from the Corporation for a 30-year period.

Though the schedule of rates originally charged by the Corporation for its services is included in an appendix to these contracts, such contracts also
contain an express provision authorizing the Corporation to make “whatever rate adjustments that are necessary to insure the fulfillment of its bond covenants.” Pursuant to this authorization, the Corporation on February 1, 1975, and again on May 1, 1975, increased its service rates. Together, the two rate adjustments increased the projected revenues of the Corporation originally established in 1970 by approximately 100 percent.

Thermal, as stated earlier, is a not-for-profit corporation, which provides heating and cooling services at cost using solid waste as the primary fuel. Based on operating experience during 1975 it became obvious that the original projections on costs and revenues were not realistic.

The unbudgeted expenses relating to the emissions problem and other aforementioned problems have overburdened the original rate schedule. The rate schedule has been increased to $6.88/1000# of steam and $.076/ton hour for cooling.

The rate increase does not include revenues for expansion since any expansion will be funded by additional contracts and in a fashion similar to the original plant. If in the future the operating costs stabilize or decrease then the decrease will be passed on to the customers. Thermal’s energy is still comparable with its nearest competitor. Rates for other systems in the country are $7.00/1000 lbs steam and $.10/ton hour cooling and the Thermal rates are, concerning Thermal’s current competitive situation, comparable to these. The 14 State-owned office buildings in downtown Nashville heated on fossil fuel would cost $700,000, while the same energy from Thermal would cost $613,000, which includes the rate increase.

But these are being worked out and after another year of shakedown/startup the project will be technically correct and operating well.

FINANCIAL

In order to begin making payments on the new electrostatic precipitator and to meet Thermal’s other financial requirements, the corporation will need to market additional bonds. Once these funds are secured, the Thermal plant will be able to achieve all of its original objectives.

The project has a bright future because the concept is so well-founded. There are many hurdles yet to be cleared but Thermal is in the vanguard of new energy technology and it is this fact, together with the energy crisis and the solid waste disposal problem, that will propel it to success.

CONCLUSION

There has been a lot of written reports and discussions in recent years on combustion of solid wastes with heat recovery. There has however been a lack of hard facts particularly in relation to operating and maintenance costs resulting from actual experience and candid discussion of problems. These subjects are of particular importance in the current economic and social climate, when recovery and re-use of the resources contained in urban and industrial waste are becoming a must in our energy and materials-short nation.

Experience of the Thermal plant shows, in the author’s opinion, that energy recovery from the combustion of solid waste can be a practical and viable operation, provided the inherent problems of using such a variable and difficult fuel are recognized in the design stage and in the operating phase as well. Corrosion rates on boiler tubes, compared with conventional coal and oil-fired plant, seem impossible to avoid in refuse incinerators with integral boilers. Plant down time for maintenance will therefore inevitably be greater than with conventional fuels. One lesson to be drawn from experiences at Thermal is the utmost importance of qualified competent operating staff at a plant of this kind. The fact that the Thermal plant is how operating satisfactorily despite the many problems experienced in the early stages is in no small measure due to the ability of the engineering and operating personnel to adapt and modify operating procedures to get optimum results and to assist in introducing necessary modifications.
A great deal has been learned from the Thermal plant, and it is hoped that by making a review of its status, as has been attempted in this paper, will be of value to others planning for, or operating solid waste fueled plants.

ACKNOWLEDGEMENTS/NOTES

Interim Status Report, Nashville Thermal Transfer Corporation dated August 21, 1975.

I. C. Thomasson and Associates are the design engineers for the Thermal project. Babcock and Wilcox Company supplied the incinerator boilers and Carrier supplied the chiller units - see attached simplified flow diagram and distribution system diagram.

The author was the General Manager and Chief Engineer for Thermal from July 1972 until November 1975 and is now a consulting engineer associated with Ellers, Fanning, Oakley, Chester & Rike, Inc., Memphis, Tennessee.

Key Words

Thermal
Nashville Thermal Transfer Corporation
Particulate Emissions
Baghouse
Boiler Tube Failures
6000 Btu Fuel
Underfire/Overfire Air
Steam Sales $6.88/1000 lb.
Cooling Sales .076¢/ton hr.