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CONVERSION OF THE CENTRAL WAYNE COUNTY SANITATION AUTHORITY INCINERATOR TO A MODERN WASTE-TO-ENERGY FACILITY

by

Len Kriesky, P.E., David Moore, P.E., and Keith Statler, P.E.
Black and Veatch, Kansas City, MO

and

William Boyle, P.E. and Mark Gibson, P.E.
DB Riley, Inc., Worcester, MA

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DB RILEY

DB Riley, Inc.
Post Office Box 15040
Worcester, MA 01615-0040
http://www.dbriley.com

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INTRODUCTION

The Central Wayne Energy Recovery Project resulted from the commitment of five Michigan communities to incinerate their domestic solid waste rather than send it to local landfills. The Central Wayne Sanitation Authority was created in 1955 by the communities that are now the Cities of Dearborn Heights, Wayne, Westland, Garden City, and Inkster. In 1961, the Sanitation Authority agreed to build an incineration plant for the disposal of solid waste. In late 1964, two 250 ton per day incineration trains began operation. In 1970, due to the increased population of the communities, the capacity of the incineration plant was increased by the addition of a third train with a capacity of 300 tons per day. During the middle to late 1970s, the Sanitation Authority upgraded the incinerators to comply with the Clean Air Act of 1970. Additional air quality upgrades were implemented in 1984 and the operation of two of the three incinerators was continued until June 1998; the commencement date for this Energy Recovery Project. In addition to the air quality control upgrades discussed in this paper, the Sanitation Authority also upgraded the dedicated residual ash storage site.

In 1991, the Sanitation Authority, Constellation Power, Inc., a subsidiary of Baltimore Gas and Electric Company, and DB Riley Incorporated entered an agreement to develop a waste-to-energy facility at the incinerator site. The developed facility would meet all current new source performance standards for municipal solid waste combustors and include modern control equipment that would allow operation of the plant far into the next century. The facility will use the existing yard waste transfer facility, tipping hall, refuse storage pit, charging chutes, and combustion grates as well as the Sanitation Authority's administrative and operations facilities. The energy recovery portion will replace each incineration train with a steam generator (boiler), an air quality control system for the boilers, and a complete thermal electric energy system. The air quality control system consists of a spray dryer absorber (SDA); a pulse jet fabric filter, selective non-catalytic reduction system (SNCR); and activated carbon injection systems to control sulfur dioxide, nitrogen oxide, hydrogen chloride, particulate, and other criteria pollutants to meet air permit requirements. The thermal electric energy cycle consists of a steam turbine generator, condenser/cooling tower heat rejection system, and a plant distributed control system.

The Central Wayne Energy Recovery Project posed significant design and engineering challenges. Retaining the existing fuel feed and combustion grates created a challenge in the design and support requirements for the new boilers. The combination of three combustion trains into a single air quality control system also resulted in engineering challenges. The single turbine using steam from three boilers posed complex requirements for the electric energy generation system and its control.

This paper discusses the interesting engineering work that will be required for the conversion of the incineration facility to a waste-to-energy facility. The goal of the project is to recover and efficiently use the heat released from the existing combustion grates to produce steam for electric energy production. The design of the steam generator required the boiler to physically match the existing stoker configuration. It was also necessary to ensure that the design and supply of the combustion air to the stokers was sufficiently distributed to provide complete combustion of the municipal solid waste (MSW), and control of combustion related emissions. The structural engineering challenge resulted from the need to support the new boilers that are larger than the incinerators they will replace in essentially the same "footprint" as the original structure. This paper will also describe design features of the steam electric generation system that must respond to the variable operating conditions inherent in a facility burning MSW fuel with three separate steam generators. The site arrangement is shown on Figure 1 and the plant elevation is shown on Figure 2. The existing plant facilities that will become part of the new facility are indicated by lighter gray line work.

COMBUSTION AND STEAM PRODUCTION

Innovative boiler and auxiliaries

Three major boiler design issues arose from the requirements of this project and were addressed to ensure optimum boiler and air quality control system performance. These issues were: induced draft (ID) fan control and turndown, maintaining SDA inlet temperature under varying operating conditions, and rehabilitation and upgrades to the existing stoker grates for good combustion air distribution.

ID fan control and turndown

Selection of the ID Fan and fan controls required special consideration to accommodate the system operating pressure and flow turndown requirements. The use of one double width double inlet (DWDI) ID fan was a requirement of the project. The operation of a single ID fan to control the furnace pressure in each of three parallel boilers was achieved by using fan inlet dampers to maintain a common pressure set point at the common economizer outlet plenum, prior to the SDA inlet duct. Each individual boiler's furnace pressure is maintained by a damper upstream of the common plenum.

The turndown of the ID fan has to accommodate a system with three boilers tied to a single air quality control train. To complicate matters, any combination of one to three boilers could be in operation at any given time. Turndown requirements were needed for the full range of boiler operation (i.e., minimum purge airflow on light off of a single boiler up to and including full load test block conditions with all three boilers in service).

Various alternatives were considered, including variable speed drive, two-speed drive, gas recirculation from the outlet to inlet of the fan, inlet vanes, inlet louver dampers, and combinations of the above.

The selected fan arrangement consists of a two-speed fan and specially designed, dual inlet louver type dampers. The unique feature of this arrangement is the drive and linkage design. Each damper has seven louvers. One louver in each damper (2 total) are driven by a

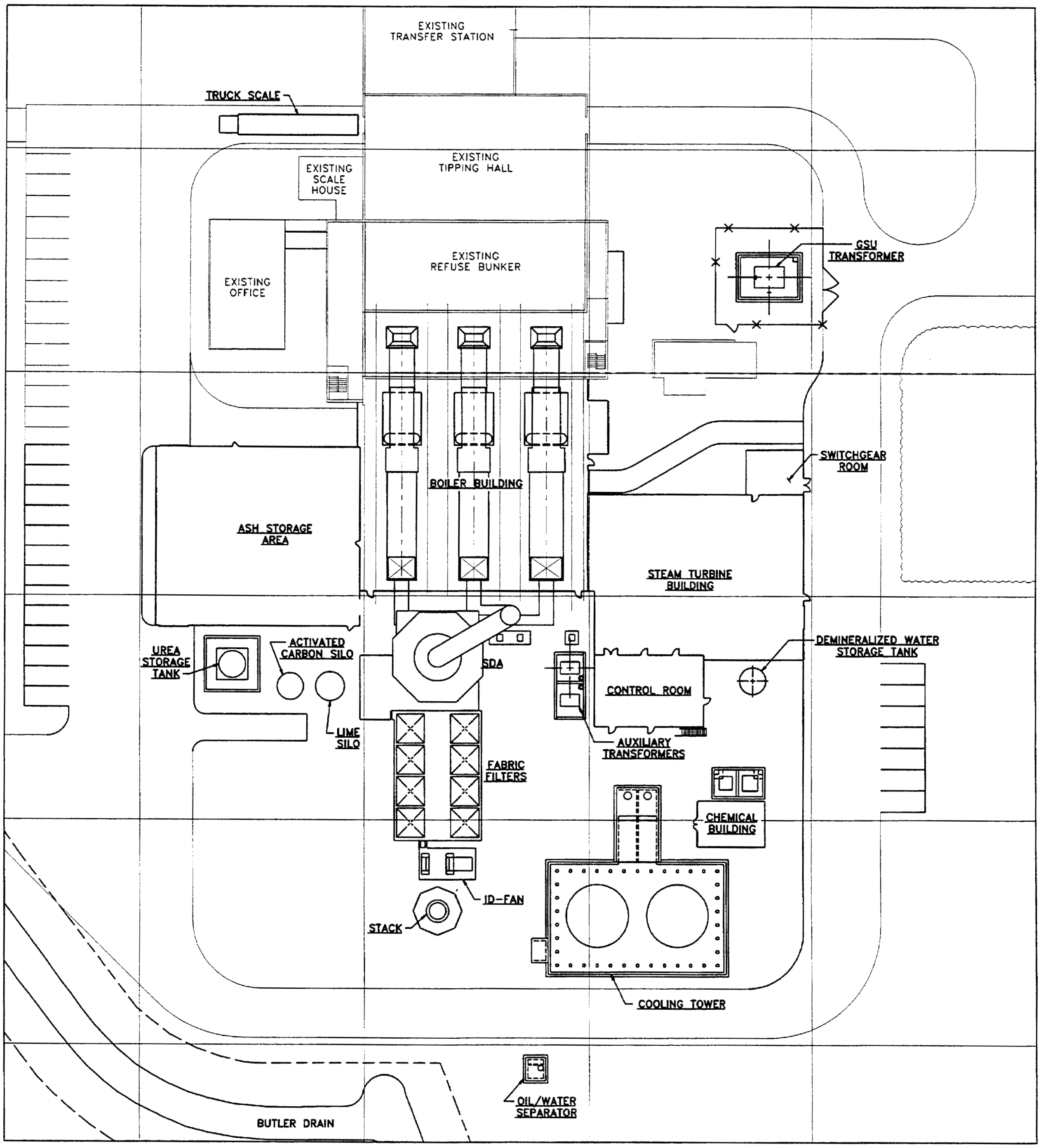

Figure 1 Plan View

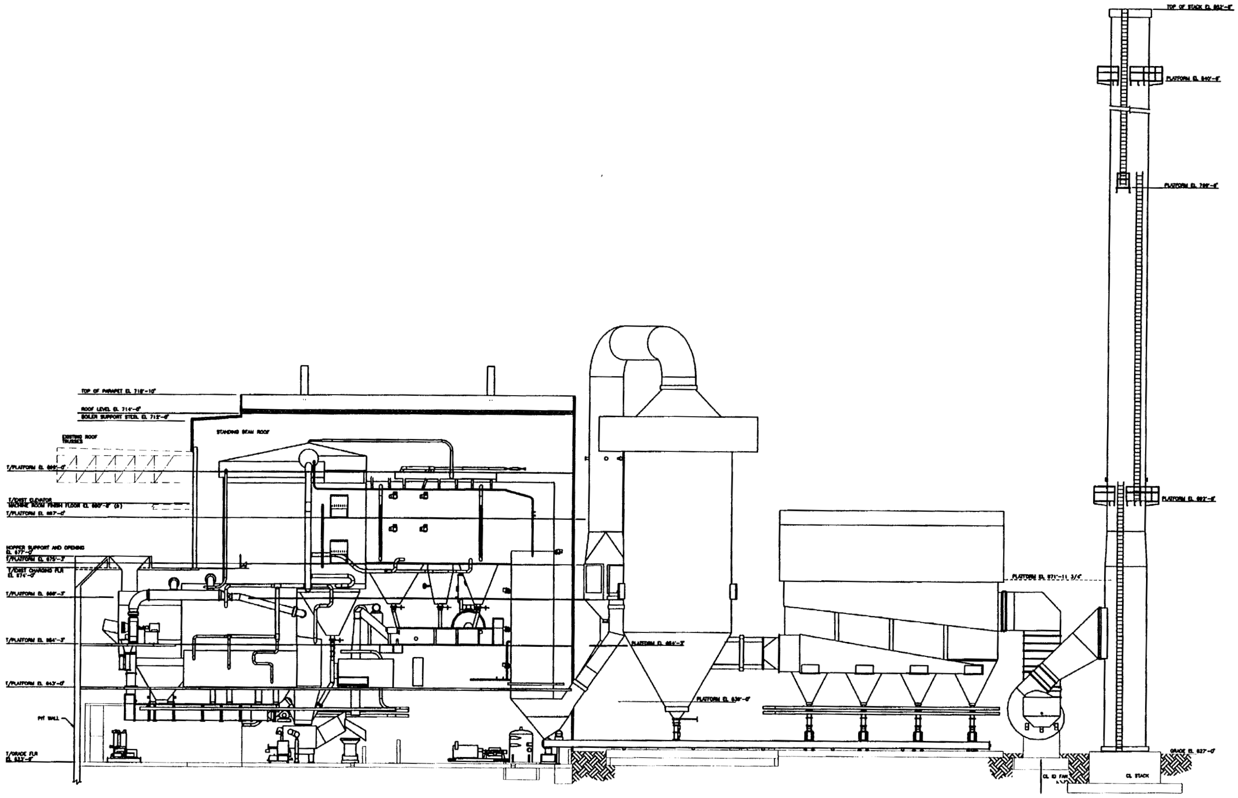

Figure 2 Elevation

single electric drive. The remaining 6 louvers in each damper (12 total) are driven by a second, independent electric drive.

SDA inlet flue gas temperature

The inlet temperature to the SDA must be maintained at a level that ensures the total evaporation of the lime slurry mixture. If the inlet temperature is allowed to drop below a minimum level, total evaporation in the vessel will not occur and that may cause damage to the downstream fabric filter.

There are two key factors that affect the minimum SDA inlet temperature. The first factor is that the percent of sulfur (S2) in the MSW fuel, and the subsequent sulfur dioxide (SO_2) formed by combustion can vary significantly based on fuel content. The higher the SO_2 content in the flue gas the greater the quantity of lime slurry that must be injected. This results in reduced SDA outlet flue gas temperature due to the increased evaporation of the slurry by the flue gas.

The second factor is that the flue gas temperature exiting the boiler varies over time as a function of the cleanliness of the boiler sections. The exit temperature is lower when the boiler tubes are "cleaner," because more of the flue gas heat energy is transferred in the boiler. The system's greatest challenge for design occurs when the SO_2 content in the flue gas is high and the SDA inlet temperature is low due to "clean" boiler conditions.

The original approach to controlling and maintaining minimum SDA inlet temperature was to use a flue gas bypass around the economizer. This system provided a means of controlling the SDA inlet temperature by varying the percent of the total flue gas flow bypassed around the economizer. Another design evaluated was a water side economizer bypass. The air permit requires a Continuous Emissions Monitoring system (CEMs) at the outlet of each boiler as well as at the stack. The individual boiler exit CEMs would have complicated a flue gas bypass because the CEMs could not be bypassed. The water side bypass design was used to facilitate the instrument installation and operation of the individual boiler outlet CEMs.

Each of the three boilers has an economizer that consists of four modularized tube bundles. Various permutations of boiler heat transfer design cases were analyzed under both clean and fouled conditions to determine the optimum bypass arrangement. This analysis concluded that a waterside bypass of two of the four bundles on each boiler would provide the flexibility needed to control the SDA inlet temperature.

Each economizer bypass is designed for on/off control. The bypass valves were arranged so that the bypassed economizer sections are connected via an intermediate header. This design feature ensures that the modules are never isolated from water. The flue gas temperatures passing through the bypassed bundles are below the allowable tube metal temperature to ensure that no damage to the tube's metallurgy will result when operating on bypass.

REHABILITATION AND UPGRADES OF THE EXISTING STOKER GRATES

Multiple inspections were performed to assess the extent of work required to refurbish each grate to "as new" condition. A 24-hour throughput capacity test was performed with the grate in a worn condition prior to the start of the project. These tests confirmed that throughput and carbon burnout target values were achievable. With these basics established, grate system enhancements were designed to make the conversion from operation as a municipal incinerator to the tightly controlled system required for a modern waste-to-energy facility.

The grate acts in concert with the furnace design to achieve proper combustion. To achieve the level of combustion performance required by the air permit from these grates, a new, redesigned air supply system and undergrate air control philosophy was required. The new system increased the number of undergrate air zones to six per unit, with individual flow monitors and control dampers for each zone. The use of six distinct air zones was deemed necessary for proper control of the combustion process on the grate surface.

The damper control system is based on air flow measurement and visual feedback, and is an automatic system with manual biasing capabilities for each air zone. The plant's distributed control system (DCS) will monitor each zone's air flow and will position zone dampers to satisfy the air flow set point required by the combustion process. The system allows the operator to modify the air distribution to each zone according to his observations.

Another grate system enhancement was the redesign of the undergrate siftings hoppers. The previous hopper design had insufficient slope and required manual on-line observation and raking through access doors. This practice allowed tremendous air in-leakage that could not be tolerated in the new system. Excessive air in-leakage would not allow for proper control of the combustion process on the grate and in the furnace.

The need to eliminate tramp air infiltration at the interface of the boiler and stoker required many mechanical enhancements to form an adequate seal. The downward thermal expansion of the boiler relative to the fixed grate required a flexible seal.

THE SUPPORT STRUCTURE: OLD AND NEW

The existing incineration facility

The existing three incinerators and their associated systems were housed in a steel frame structure enclosed by clay masonry. The roof trusses acted with the building columns to create a moment frame. The structure had neither the interior nor perimeter steel vertical bracing system to resist any horizontal environmental load, such as wind. Consequently, the horizontal wind loads were carried by the exterior clay brick enclosure acting as shear walls. Long span trusses supported the roofing system. Each incinerator system was supported on its own steel frame. A concrete suspended floor distributed horizontal forces generated by the operating incinerator system. This floor also separated the high humidity and corrosive bottom ash operation from the furnace-operating floor. In short, the incinerator systems were enclosed by a structure very similar to other 1960s era structures of nearby industry, such as the automotive assembly plants.

With the exception of the administration building, the tipping floor structure, and the stoker/grate supports, the entire site was razed to ground level. The removal of the existing incinerators, building steel, and masonry was required for the erection of the new higher and longer boilers. The existing stoker grates were refurbished in place and their steel frames were retained. The precipitators and their associated ductwork were razed to ground level. The chimney anchor bolts were found to be reusable but the chimney itself was of insufficient height and its modification too costly to keep. It was demolished in a planned, dramatic free fall.

Foundations

The footprint of the boiler building was influenced by the access loop road, the location of the new turbine building, the existing administration building, the tipping floor structure, and the existing stoker/grate equipment. The access loop road could not be moved without interfering with an existing drainage ditch, the forested areas that served as a buffer to the surrounding neighborhood, and the existing power lines. The new steam turbine building was placed inside the loop access road to minimize steam piping and cable lengths. To minimize the length of the ash conveyors, the ash handling area was arranged to be an extension of the boiler building. The existing administration area, tipping floor, and feed chute structure limited the available space to expand the boiler footprint to the west and north. The interior column row locations were determined by the top-hung boiler support requirements and the existing stoker/grate equipment The structure was essentially confined to the footprint of the existing incinerator building.

The new electric generating facility has many heavy loads that greatly overstressed the existing foundations and the supporting soil. The foundation support for the main facilities were on belled, drilled piers. This included the structure supporting the three steam generators and their associated building, the spray dryer absorber (SDA), and steam turbine generator. A combination of drilled piers and existing foundations support the SDA and fabric filter. Mat foundations, placed on compacted soil, support the cooling tower, lime and activated carbon silos, ash storage building, and steam turbine building. Spread footings on compacted soils will be adequate for support of other structures such as the generator step-up transformer, chemical building, and tank foundations.

Structural steel support of the new boilers

The three long and narrow boilers and their stoker/grate systems extend from inside the existing structure through to the end of the new building and occupy the full building height and create three impenetrable volumes within the boiler building. This made it difficult to provide an efficient bracing system for the new boiler structure. In the east/west direction, the horizontal bracing system is functional but irregular due to the column row locations, hoist access requirements, equipment interferences, and the boiler support grid steel. The horizontal bracing in the north/south direction is regular but is limited to shallow depth trusses with short panel points acting between narrow column rows. The new structure could only be vertically braced on three external faces. The stoker/grate and boiler equipment size and location make it impossible to place vertical bracing on the common face between the existing and new structure. The vertical bracing on the south face of the boiler building is irregular to avoid the interferences caused by the three boiler exhaust ducts.

The new configuration

An assessment of the existing structure included the larger loads from the new boilers and indicated that the existing structure would need to be modified to support the new loads. However, the existing structure could not be modified because of an interference with the existing feed chutes. The new structure is designed to act independently of the existing tipping floor structure and is designed so that only gravity loads are introduced to the existing structure from lightly loaded incident beams. The structure was weakest perpendicular to the boiler centerline. Therefore, the column strong axes are oriented perpendicular to the boiler centerline to give added strength to the structure in resisting horizontal loads. Eight interior columns had long, unsupported lengths and were heavily loaded. These columns were strengthened by tying each of the two sets of four columns with diagonal bracing. Egress from the facility required a stair tower be placed in the northeast quadrant of the structure. The addition of the stair tower, the column diagonal bracing, and the orientation all added stiffness to the structure and reduced the horizontal deflection. The boilers had a great number of large horizontal pressure loads acting at the upper elevations. This resulted in high overturning moments, which had to be resisted by the structure. A box truss system was used to hang the boiler that extended into the existing structure over its stoker/grate. The boiler building height was increased to provide for adequate clearance between the boiler support steel and the roof grid steel.

The design solutions to the challenges of this retrofit project were in many cases inefficient, but unavoidable. As a result, the steel tonnage for this boiler building was higher than that of a conventional fossil fueled boiler. At the Central Wayne Energy Recovery Facility, there are three boilers supported in the space that usually supports only one boiler. Typically, a boiler occupies no more that 35 percent of the volume of the structure. At Central Wayne Energy Recovery, the three boilers occupy 67 percent of the structure volume. This high percentage means there was a limited choice of boiler support options.

The existing stoker/grate support steel configuration resulted in boiler support columns having long unsupported lengths and subsequent large size. The confined space also increased the vertical and horizontal bracing steel tonnage. To meet the aggressive construction schedule, the structure had to be designed with preliminary and therefore conservative loads.

STEAM TO ELECTRIC ENERGY

Steam cycle

Superheated steam is generated in each of the three MSW boilers at the conditions of 630 psig and 752°F at the superheater outlets. A combined total of 232,100 lb/h of steam is routed in a common pipe header to the steam turbine throttle valve. The steam turbine is a single flow, multi-stage condensing machine with an axial exhaust and two extractions for feedwater heating designed for a gross output of 24.7 MW at design fuel conditions. One low-pressure feedwater heater and a deaerator provide feedwater at a temperature of 265°F to the economizer inlet.

At full load, the steam turbine operates at a speed of 4,200 rpm and is gear reduced to 1800 rpm to drive a four pole, totally enclosed water to air cooled (TEWAC) generator rated at 27.67 MVA. A generator transformer steps-up the voltage from 13.8 kV to 40 kV for transmission by Detroit Edison to a nearby substation.

Turbine bypass system

During steam turbine outages, the facility has been designed with a steam bypass system that allows continued operation of the MSW boilers to avoid the costly option of bypassing the waste to landfill. The exhaust of the turbine is joined to the condenser inlet through a stainless steel bellows expansion joint. For turbine outages, this expansion joint is removed and a blanking plate is provided for bolting to the condenser to isolate it from the turbine.

A steam conditioning valve is used to reduce pressure and to desuperheat main steam to an enthalpy 1,200 Btu/lb, (120 psia/358°F) according to EPRI guidelines. A specially designed "dump hood" is provided on top of the condenser to further breakdown the energy in the steam through a series of perforated plates before passing over the stainless steel condenser tubes.

The bypass system is sized to pass the full steam capacity of the two 250 ton per day boilers (Units lA and lB) operating in the "clean" condition. The decision to size the bypass system using the two 250 ton per day boilers was based on two simple principles. The first was that the five member communities contributed nominally 500 tons per day prior to renovation to an 800 ton per day facility, and the other 300 tons per day of waste would be "spot" marketed, and therefore easier to cut off during these outages. The second reason was that the total heat load to the condenser during bypass operation of these two smaller boilers is nearly equivalent to the heat load on the condenser during full load condensing with the turbine in operation. Therefore, the condenser and cooling tower were not oversized for bypass operation.

CONCLUSION

The Central Wayne Energy Recovery Facility, now under construction, is scheduled to be in commercial operation in December 1999. The engineering of the facility required innovation in boiler design and an unconventional approach to the support of the boilers; both requirements necessitated by the reuse of the combustion grates and MSW fuel feed systems.

The "new" plant will meet the stringent air permit requirements with the design of the new steam generators and Air Quality Control System. The design will also include modern control equipment that will allow efficient operation of the facility. The municipal solid waste that was previously incinerated with no heat recovery will be used to generate useful electricity for the future, without direct reliance on fossil fuels.