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ENERGY CONSERVATION

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ENERGY UTILIZATION—MUNICIPAL WASTE INCINERATION

Final Report

March 27, 1981

Work Performed Under Contract No. AC02-80CS40400

J. E. Sirrine Company
Greenville, South Carolina

U. S. DEPARTMENT OF ENERGY

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ENERGY UTILIZATION - MUNICIPAL WASTE INCINERATION

FINAL REPORT

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GREENVILLE, SOUTH CAROLINA 29606

MARCH 27, 1981

PREPARED FOR

UNITED MERCHANTS AND MANUFACTURERS, INC.
GREENVILLE, SOUTH CAROLINA

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ABSTRACT

This report assesses the technical and economical feasibility of converting municipal waste into useful and useable energy. The concept presented involves retrofitting an existing municipal incinerator with the systems and equipment necessary to produce process steam and electric power. The concept is economically attractive since the cost of necessary waste heat recovery equipment is usually a comparatively small percentage of the cost of the original incinerator installation. In addition, the fuel, municipal refuse, is abundant in supply and free of charge. Technical data obtained from presently operating incinerators designed specifically for generating energy, documents the technical feasibility and stipulates certain design contraints.

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A. INTRODUCTION

On September 15, 1980 United Merchants and Manufacturers, Inc. commissioned J. E. Sirrine Company to serve as a subcontractor to accomplish a feasibility study and prepare a report on Energy Utilization from Solid Waste Incineration. The objective of this study and report was to assess the technical and economic feasibility of converting municipal waste into useful and useable energy by retrofitting an existing municipal incinerator with the systems and equipment necessary to produce process steam and electric power. The study and report includes an assessment of feasibility and a preliminary conceptual design for energy utilization from solid waste incineration.

This study includes a thorough investigation of similar projects and a literature search of background information sources. The assessment of feasibility includes the following considerations:

- An evaluation and assessment of the proposed site and facilities for compatibility with the proposed retrofit with respect to physical size, accessibility, availability of utilities, and down time schedule necessary for the conversion.
- Availability of competent personnel to staff the operating and maintenance functions of the facility after the proposed conversion.
- Environmental effects of the proposed retrofit on the ecology of the surrounding vicinity.
- Need and availability of alternate fuel sources to maintain steam and electrical generating capacity during periods of planned or forced outages of the incinerator, and plans for accomodating the surplus energy available during periods of low user demand.

A. INTRODUCTION - Continued

- o Seasonal variations in the characterization and quantities of refuse delivered to the incinerator and the resultant effects on the operation of the retrofitted facility, ability of the facility to meet energy demand, and any other effects such as corrosion due to changes in composition of the material being incinerated.
- o The effects and ways of dealing with the formation of slag on the steam generating surfaces of the retrofit boiler.
- o The effects and ways of dealing with fouling of these surfaces other than by slagging.
- o Method and practicality of final cleanup of the effluent gases to meet environmental standards.
- o Metal wastage of steam generating surfaces by erosive gas scrubbing.
- o Dew point corrosion of the generating surfaces.
- o Maximum or proper operating temperatures to prevent high temperature corrosion due contact with gases and compounds such as HCl, Cl2, K_2SO_7, NaCl, $ZnCl_2$, and $pbCl_2$, and the result of these constraints on the operability and capacity of the facility.

The preliminary conceptual design includes:

- o General arrangements and a flow diagram to identify and define the scope of the project.
- o A steam/electrical power balance of the composite facility.
- o A preliminary equipment list of all major components of the retrofit.

- o Based on the equipment list, vendors' quotes and other information, a cost estimate of the total project is presented which includes estimates of the cost of all engineering effort, spare parts inventory, sales tax, license fees and use permits in addition to the estimated cost of all site work, foundations, interplant connections, electrical, sewer, service water, compressed air and other piping work as well as structural steel fabrication and erection and the purchase, installation, and checkout of the components and acceptance testing of the completed retrofit.

All cost estimates are based on current costs. An escalation allowance is included based on the projected design and construction schedule. This schedule, with identifying milestones, is included as an intregal part of the preliminary design.

The predominant technological risks concerning this project involve both high and low temperature corrosion, slag and fouling of heat transfer surfaces, and metal wastage by erosive gas scrubbing. A literature search failed to produce documentation of an operating, retrofit WHRS on a solid waste burning incinerator. Much has been written on municipal incinerators designed specifically for energy generation from solid waste refuse. High temperature, high pressure systems suffer severe problems related to corrosion, fouling and slagging. Low temperature, low pressure systems operate within a temperature range that minimizes corrosion and slagging. Metal wastage resulting from erosive gases are minimized by wide gas passes. The low temperature, low pressure WHRS presented in this report is the result of an indepth study of existing systems considered adaptable or pertinant to energy utilization from solid waste incineration.

A. INTRODUCTION - Continued

The major systems studied were firetube and water tube waste heat recovery boilers, heat pipe waste heat recovery boilers, Organic Rankine Cycle turbine-generators, a steam Rankine cycle topping turbine, a steam Rankine cycle condensing turbine, and a steam Rankine cycle turbine with atmospheric exhaust. An assessment of feasibility considering each system and/or a combination of systems resulted in a concept comprised of heat pipe waste heat recovery boilers for steam generation and the traditional steam Rankine cycle turbine-generator with atmospheric exhaust.

The conceptual WHRS would be comprised of waste gas ductwork and a damper system to bypass waste gases from the incinerator into heat pipe waste heat recovery steam boilers and back into the existing exhaust gas system. The steam generated by the WHRS (62,300 pph at 350 psig-460°F) would be divided with approximately half of the steam being piped from the incinerator facility to the existing steam system at the textile complex. The other half of the steam generated by the WHRS would be piped to a multistage, backpressure steam turbine and electric generator located at the incinerator facility. The electricity would be routed to the textile complex by transmission cable. The firing rate of the incinerator is erratic and totally independent of steam demand. Therefore, the process steam requirements would be met first and the turbine generator would then modulate on the remainder. The amount of electricity generated would depend on process steam requirements and the firing rate of the incinerator.

To properly operate and maintain the WHRS and meet the codes for the State of Massachusetts three (3) class II operators and one (1) first class mechanic would be required. At current labor rates including

fringe benefits, the total annual wage costs would be $86,965/year. Individuals at the above competency level are available in the local area.

The proposed design and equipment selection is compatable with the existing facility and site in respect to physical size, accessibility, availability of utilities, and the down time schedule necessary for the conversion. The retrofit WHRS would be installed in a by-pass duct arrangement which would neither help nor hinder the present environmental status. The method and practicality of final cleanup of the effluent gases to meet environmental standards would involve an independent study, totally unrelated to waste heat recovery and not included in the scope of the contract.

The estimated total energy generated from incinerating 10 tons of municipal solid waste per hour is 93.5 x 10^6 BTU/hr. Considering losses from radiation, unburnable materials, waste gas leakage around dampers, and miscellaneous unaccountable losses, it is estimated that 92.026 x 10^6 BTU/hr. would be available for waste heat recovery. The waste heat recovery system (WHRS) would be 71.43% effective, therefore, the recovered energy would be 65.734 x 10^6 BTU/hr. This energy savings can quite readily be converted to its fuel oil equivalency.

Considering No. 6 fuel oil with a heating value of 149,600 BTU/gallon, the incinerator operating 108 hours/week, 52 weeks/year, the annual energy recovery converted to No. 6 oil at 85% efficiency is 2,903,100 gallons/year.

B. SUMMARY

At the Fall River, Massachusetts municipal incinerator flue gases from the combustion of municipal solid waste are vented to the atmosphere comprising a gross energy loss of approximately 93,500,000 BTU/hr. A retrofit Waste Heat Recovery System (WHRS) installed at the incineration facility could recover and effectively utilize energy equivalent to an estimated 2,903,100 gallons of No. 6 fuel oil per year.

The WHRS would generate steam and electricity. The recovered energy would provide space heating for the incinerator facility during cold weather. In addition, the WHRS would provide 100% of the process steam requirements, and approximately 50% of the annual average electrical requirements for the adjacently located United Merchants and Manufacturers textile complex.

The current estimated total installed cost of the proposed WHRS is $4,023,400. The total escalated project cost is estimated to be $4,523,000. The pretax Return On Investment (ROI) is 51% and the payback is 2.2 years. Start-up of the WHRS would be approximately 18 months after start of detailed design.

C. COST SUMMARY

Equipment	$1,810,450	
Equipment Erection	449,150	
Equipment Foundations and Other Structural Costs	18,600	
Buildings and Structures	418,000	
Electrical Installation Costs	320,200	
Instrumentation Installation Costs	18,000	
Piping Costs	150,000	
Area Costs	500	
TOTAL DIRECT COST	$3,184,900	
Contingency	318,100	
TOTAL CURRENT DIRECT COST PLUS CONTINGENCY		$3,503,000
Engineering	$ 228,000	
Soil Tests	6,000	
Construction Management	15,000	
Spare Parts Allowance	45,000	
Sales Tax Allowance	72,500	
Start-Up Assistance	1,500	
Preparation of Operating & Training Manuals	2,400	
Project Coordination & General Overhead	150,000	
TOTAL CURRENT INDIRECT COST		$ 520,400
TOTAL CURRENT PROJECT COST		$4,023,400
Escalation Allowance		499,600
TOTAL ESCALATED PROJECT COST		$4,523,000

D. DESCRIPTION OF PROCESS AND FACILITIES

The Fall River Massachusetts municipality owns and operates a solid waste incineration facility comprised of two identical solid waste refuse incinerators. Presently one incinerator at a time is in operation with the second unit serving as a spare. The energy generated from the combustion of municipal solid waste in the incinerators is not being recovered.

Each incinerator is rated to consume 300 tons of refuse per day, however, the units are presently operated at 240 tons per day. The incinerators operate 108 hours per week. Normal operating hours are from midnight Sunday until noon Friday 52 weeks per year. The incinerators are subject to unscheduled outages due to equipment failures. However, following an outage the firing rate is increased and the units may be operated through the weekend to eliminate the accumulation of refuse.

Unsorted refuse is trucked from the Fall River municipality to the incinerator and dumped directly into a concrete holding pit. An overhead travelling crane with a clamshell bucket transfers the refuse from the holding pit to the feed chute. The refuse gravity feeds via the feed chute onto oscillating grates in the furnace area. Once ignited by natural gas burners the refuse sustains combustion and the gas burners are extinguished. Undergrate forced draft air supports primary combustion. Overfire air fans force ambient air through ducted ports near the roof of the furnace. The overfire air serves two purposes. First, the overfire air supports secondary combustion of volatile gases liberated during primary combustion of the refuse. Second, a high volume of secondary air at ambient temperatures attemperate the 1725°F gases to 1400°F.

D. DESCRIPTION OF PROCESS AND FACILITIES - Continued

The 1400°F gases traverse over a bridge wall into a fourteen foot square secondary combustion chamber. The gases flow downward through the secondary combustion chamber. At the bottom of the secondary combustion chamber the gases turn and are ducted horizontally through a water spraying ring (sparging duct) which reduces the temperature of the gases to approximately 250°F. From the sparging duct the gases are drawn through a Peabody wet scrubber and enter the induced draft fan at a temperature of approximately 150°F. The gases exit the induced draft fan, pass through a series of ionizing scrubbers, then to the smoke stack, and finally discharged to atmosphere.

The ashes, metal and other materials not burned drop from the end of the grate into one of two flight conveyor troughs. The flight conveyor transfers the material to a dumpster where salvageable metal is recovered and sold for scrap iron. The remaining material is trucked to landfill.

Adjacent to the incinerator facility United Merchants and Manufacturers, Inc., (UMM) owns and operates a textile complex that employs 584 people. The complex operates 24 hours per day five days per week. On an annual average basis the facility requires 2,000 kw/hr. of electricity and 33,500 pph steam for space heating and process uses (See Appendix K1). Steam for the textile complex is generated by three fossil fuel fired boilers. Two of the boilers fire No. 6 oil and one boiler fires either No. 6 oil or natural gas. If a WHRS project were implemented the existing boilers would be retained for stand-by service.

D. DESCRIPTION OF PROCESS AND FACILITIES - Continued

The WHRS would produce 1,650 kw however, during normal operation the WHRS itself will require approximately 300 kw to operate attemperating gas fans and pumps. This energy is required for both start-up and continuous operation of the WHRS. Therefore, it must be supplied by the local utility.

E. CONCEPTUAL DESIGN

The proposed waste heat recovery system (WHRS) presented in this report entails a conceptual design. The concepts presented, equipment proposed, and related costs reflect basic engineering concerns not a detailed design. The concept presented is technically feasible, however, the final design may vary considerably from the proposed concept.

The technical feasibility of a WHRS involves an in-depth analysis of the types of waste heat recovery equipment presently available, compatibility of proposed equipment with respect to site arrangement, environmental effects of the proposed retrofit, and considerations to minimize slagging, fouling, metal erosion and corrosion. We have investigated the applica- of an Organic Rankine cycle turbine (see Appendix K2). However, considering the quantity and temperatures of the waste gases the most effective system would be the traditional steam Rankine cycle system comprised of WHRS steam generators and a steam powered turbine driving an electric generator.

Presently, there are two popular types of WHRS steam generators on the market. They are the traditional scotch marine firetube boiler adapted for waste heat recovery by replacing the fossil fuel burner assembly with a refractory lined inlet duct and the water wall steam generator used for waste heat recovery from very high temperature applications such as gas turbine exhausts. Neither one of these systems meet the requirements for waste heat recovery from a refuse incinerator.

The firetube boiler cannot be cleaned on-the-run and would tend to accumulate slag and suffer from particulate fouling on the tube surfaces. The

E. CONCEPTUAL DESIGN - Continued

unit(s) must then be taken out of service, opened up and cleaned manually then put back into service with all new gaskets and seals. A firetube WHRS boiler would require manual cleaning approximately every 60 to 80 days. The cleaning operation would require four men working an estimated twenty hours per unit. In addition to slagging and fouling the gas side pressure drop through a firetube boiler is 3.5 to 4.5 in. w.g. for a clean unit. The system, therefore, would require an induced draft booster fan and drive.

Water tube WHRS boilers can be cleaned on-the-run. However, standard units are built primarily for high temperature applications. High temperature corrosion is a very serious concern when recovering energy from municipal incinerators. The gases must be attemperated to not more than 900°F (See Appendix K3). The water tube boilers have extremely thick wall boiler tubes and as a result the units themselves are expensive. The units are heavy necessitating expensive structural support and foundations. Considering cost effectiveness, alternative boiler designs were studied.

The heat pipe WHRS boilers appear promising (See Appendix K4). The heat pipe coil is comprised of hermetically sealed heat pipes which require external cleaning only. The coil bank can be cleaned readily on-the-run by either hand lancing with steam, compressed air, water or a permantly mounted soot blowing system can be purchased as an integral part of the unit. The heat recovery coil bank induces a maximum gas side pressure drop of 2.5 in. wg. In most retrofit applications, as in this particular case, an induced draft booster fan would not be required. The unit weight is comparable to a firetube boiler. Therefore, required

structural support and foundations are nominal. Both firetube and water tube boilers depend on a turbulent gas flow to induce greater heat transfer. Turbulent gas flow means high velocity resulting in excessive erosion of metal surfaces. The heat pipe boiler is dependent upon exposure time of the coil bank to the hot gases. Therefore, the slowest possible gas velocity yields the highest heat transfer effectiveness. Metal wastage of steam generating surfaces by erosive gas scrubbing would be minimized. The heat pipe boiler arrangement is compatible with the proposed changes in the incinerator system.

An initial concept considered installing a WHRS within the confines of the secondary combustion chamber (See Drawings Appendix J). The secondary combustion chamber is 14 feet square with a usable height of 16 feet. It is not possible physically to place sufficient heat recovery surface within these confines and maximize energy recovery. In addition, the gases must somehow be attemperated from 1400°F to not more than 900°F before entering the waste heat recovery system. Finally, if the system were located in the secondary combustion chamber and a problem, such as a tube leak in the boiler, developed then the entire incineration operation would have to be shutdown for the required repairs. The conclusion is that a simple waste gas duct system bypassing the secondary combustion zone would be more compatible.

Presently, only one or the other of the two incinerators operates at any one time. The retrofit would therefore require no down time since number two unit could be totally retrofitted while the number one unit remains in operation. The number two unit could then come on line with the WHRS in operation. The number one unit would be isolated by duct dampers

E. CONCEPTUAL DESIGN - Continued

while it is tied into the WHRS. By-pass dampers could be placed in the secondary combustion chamber which would allow the waste heat recovery system to be bypassed and the units would function just as they are doing now. However, a recent quotation considering the 1400°F gas temperature and the corrosive environment requires Inconel or equal construction of the dampers and the quoted price is $236,000 each. A more practical concept is a carbon steel frame with firebrick forming a semi-permant diaphram divider across the secondary combustion chamber. The cost estimate includes $135,000 for each chamber for installing either a semi-permanent firebrick divider or a locally fabricated carbon steel-firebrick constructed drawbridge type damper. If a semi-permanent divider was installed and a problem developed with one of the waste heat recovery boilers, that particular boiler could be isolated and the other boilers would continue to function. The incinerator operator would probably have to reduce the firing rate proportionately until the problem is resolved. In the unlikely event that the entire waste heat recovery system suffers a prolonged outage, the incinerator could be temporarily shutdown, the semi-permanent firebrick divider removed, and the unit could be brought back on line functioning as it is now.

As of May 1979 the average hourly rate of refuse incineration at the Fall River facility was 9.25 tons per hour. The present firing rate is 10 tons/hr. and the capacity of each unit is 12.5 tons per hour. Considering pending legislation imposing strict design and operational requirements for landfills the anticipated hourly rate of incineration is expected to increase to 12.5 tons per hour by the time this proposed WHRS starts up - approximately Spring 1983. The proposed equipment is sized for 12.5 tons per

hour, the design capacity of one incinerator. An economic analysis for both 10.0 and 12.5 tons refuse incinerated per hour is included.

Considered in the design is expansion potential to maximize recovery of energy from both incinerators operating simultaneously at rated capacity. This would be accomplished by extending the ductwork, the elevated platform, and boiler configuration both to the north and south of the presently proposed system. The number of boilers presently proposed would double and some duct damper rearrangement would be necessary, however, the duct size would remain the same.

The design criteria for equipment selection and sizing is based on the following analysis for as fired, unprepared municipal refuse:

Moisture	29.50%	HHV = 4,675 $\frac{BTU}{Lb.}$
Carbon	25.58	
Hydrogen	3.59	
Oxygen	18.76	
Sulfur	0.17	
Nitrogen	0.24	
Ash	22.03	
Chlorine	0.13	
	100.00	

Based on Higher Heating Value of 4,675 BTU/Lb. of refuse, 12.5 tons refuse per hour, the gross heat input would be 116.88×10^6 BTU/hr. According to charts published by the American Boiler Manufacturing Association the calculated radiation and unaccountable losses would be approximately 1.1% of the total gross heat input. Approximately 0.5% of the heat input would be absorbed by unburnable materials. The net heat input would be $(116.88 \times 10^6) \times (.984) = 115.01 \times 10^6$ BTU/Hr.

E. CONCEPTUAL DESIGN - Continued

The gas flow rate from primary combustion air would be 248,000 pph. at 1725°F. Overfire air is injected near the roof of the incinerator to induce turbulence, burn off volatile gases and attemperate the exhaust gases from 1725°F to 1400°F. Approximately 67,000 pph of overfire air at 70°F is injected into the incinerator. The result is 315,000 lb. per hour of waste gases at 1400°F. The anticipated loss in the secondary combustion chamber from gas leakage around the diaphram divider or damper is 3.4%. The net mass flow rate of waste gases to the heat recovery system would be (315,000 lb./hr.)(.966) = 304,290 pph at 1400°F.

The waste heat recovery system would reduce the temperature of the gases from 1400°F to 400°F. Therefore, the overall heat recovery effectiveness would be: $\frac{1400 - 400}{1400} \times 100 = 71.43\%$. Multiplying this effectiveness factor times the net heat input (0.7143) x (115.01 x 10^6 BTU/hr.) = 82.152 x 10^6 BTU/hr. heat recovery. Using the net mass flow rate and the formula $Q = \dot{m}\ cp\ (T_1 - T_2)$ to check: Q = (304,290) (0.27) (1400-400) = 82.158 x 10^6 BTU/hr. Considering the order of magnitude of the numbers the calculations check.

The 1400°F waste gases would be ducted from the upper section of the secondary combustion chamber through another attemperating zone. Exhaust gases from the boiler feed water economizers at approximately 400°F would be circulated by an attemperating gas fan back to the outlet of the secondary combustion zone. The 400°F gases plus ambient air would attemperate the 1400°F gases to 900°F. The amount of ambient air induced into the duct would be minimized for two reasons. First, cold ambient air could cause a cold spot in the duct resulting in acid dewpoint

corrosion. Secondly, any volatile gases carried into the duct could be ignited by an oxygen rich atmosphere of ambient air. A flash fire in the duct could severely damage the heat pipe coil bank.

The 1400°F waste gases would exit the secondary combustion chamber at the rate of 304,000 pph and enter an attemperating section of new ductwork. During start-up of the incinerator and WHRS ambient air (203,000 pph at 70°F) would be used to attemperate the 1400°F gases to 900°F. After a few minutes of operation the ambient air inlet damper would start to close and exhaust gases from the boiler feedwater economizers (304,000 pph at 400°F) plus 14,000 pph of ambient air at 70°F would be used to attemperate the 1400°F gases to 900°F. After the system has stabilized from start-up, waste gases at the rate of 622,000 pph and 900°F would be ducted and equally distributed to three waste heat recovery boilers (the final design may require four boilers, smaller in size). The waste gases would enter the waste heat recovery boilers at 900°F and exhaust from the boilers at approximately 500°F. The 500°F gases would elevate the feedwater from 200°F to 400°F. From the economizer the waste gases at 400° would be ducted back to the lower section of the secondary combustion chamber and drawn by the existing induced draft fan through the existing water sparging ring and Peabody scrubber and exhausted through the existing system.

The waste heat recovery boilers would generate a calculated 62,300 pph at 350 psig-saturated temperature. The saturated steam would flow through a coil bank in the waste gas inlet duct and pickup approximately

25°F superheat. The superheat would protect the steam turbine from blade erosion from moisture impingment. The superheated steam would be piped to the south side of the incinerator complex and divided into two flow streams.

One stream would be piped approximately 740 feet to the UMM textile complex for process purposes. The process steam would be pressure reduced from 350 psig to 150 psig at the UMM existing power house then tied into the existing steam header and distributed via the existing piping system. A desuperheating station may be required downstream of the pressure reducing station depending upon the temperature rating of the existing steam valves and associated equipment. The weekly average steam flow for process ranges from a low of 18,000 pph in the summer to a high of 45,000 pph in the winter with peaks up to 60,000 pph (see Appendix K1).

The second steam flow stream would service a new turbine-generator located at the south side of the incinerator facility. The steam turbine would be a multistage unit driven by inlet steam at 350 psig-460°F. The turbine would exhaust at approximately atmospheric pressure resulting in an estimated turbine efficiency of 55%. Two other turbine-generator alternatives were considered.

One alternative would be a topping turbine where all of the steam generated by the WHRS would be piped to the turbine at 350 psig-460°F. The turbine would exhaust at 150 psig and the exhaust steam would be piped to the UMM textile complex or other users in the near vicinity. This concept was rejected because within the geographical region

surrounding the incinerator, including UMM, there is insufficient users of 150 psig steam. The excess steam would have to be either vented to atmosphere or condensed which could amount to as much as:

$$62{,}300 \text{ pph} - 18{,}000 \text{ pph} = 44{,}300 \text{ pph}$$

The second alternative we studied involved the same steam distribution as presently proposed but the turbine would exhaust to a vacuum condenser. The generator kw output would be almost doubled, however, we estimate that the initial cost of the condensing turbine-generator would more than triple to include the T-G, condenser water pumps, piping, and pumping station. The operating and maintenance costs would increase significantly. The condenser would require approximately 2,000 gpm of cooling water. The area presently has severe water table problems. An additional drain on the stream and pond for condenser cooling water purposes would aggravate an already severe ecological problem and in fact may not be available.

Chemically treated and deaerated feedwater for the WHRS would be piped from the existing UMM boiler facility to the turbine atmospheric condenser. New boiler feedwater pumps would supply water to the waste heat boilers. Steam purity would be controlled by a continuous surface blowdown system and an intermittantly, manually operated, bottom blow-off system.

To date there are no publicized municipal mass burning refuse incinerators in the United States that have been retrofitted to produce process steam and

electric power. Lacking historical documentation, the effects of corrosion has been a vital concern during the course of this study. The mass burning refuse waterwall incinerator offers a close corollary and much has been written describing the effects of corrosion in these units.

At least four recognized types of corrosion occur in mass burning refuse boilers. These are:

1. High-temperature, liquid-phase corrosion.
2. Corrosion due to non-uniform furnace atmosphere.
3. Halogen corrosion.
4. Low temperature or dew-point corrosion.

High-temperature, liquid-phase corrosion occurs in the temperature zone above 900°F and is most severe at approximately 1200°F (See Appendix K3). Above 900°F refuse constituents from sulfate, alkali and chloride compounds become entrained in the waste gas stream which stick, foul and corrode the heat transfer surfaces. For this reason, the proposed concept generates comparatively low pressure steam and uses attemperation to maintain the waste gas temperature at 900°F. The actual metal temperature of the heat transfer surface would be well below 900°F.

In the second type of corrosion, the products of partial combustion create a reducing atmosphere. Carbon monoxide, or hydrogen sulfide can be produced. These gases react with the iron oxide protective layer on the heat transfer surfaces, exposing them to corrosive attack. It is important that the combination of undergrate and overfire air systems provide the correct fuel-air ratio, proper distribution of air to fuel, and

sufficient turbulence to prevent stratification. The precautions are necessary to prevent a furnace atmosphere that fluctuates between reducing and oxidizing. The required mass flow of attemperating gases plus ambient air exceeds the flow from the furnace region, therefore, a blending of waste gases would tend to dampen any reducing and oxidizing fluctuations that may occur.

Concerning the third type of corrosion, the corrosive rate of low-alloy steel is increased markedly as the amount of polyvinyl chloride (PVC) in the refuse, and the metal temperature of the heat transfer surfaces increase (again see Appendix K3). PVC can contain chlorine in concentrations as high as 50%.

We anticipate Hcl concentrations between 50-200 ppm. Maintaining metal temperatures below 900°F will minimize the effects of Halogen corrosion.

The graph in Appendix K3 also shows the severity of dew point corrosion when waste gas temperatures fall below 300°F. The proposed exhaust gas temperatures would be maintained between 350°F and 400°F. The units would be air purged then water washed during weekend shutdowns.

Seasonal variations in the characterization of refuse delivered to the incinerator will occur. However, the effects on corrosion due to seasonal changes in composition are regarded to be minimal. Corrosion in the system will occur throughout the year and must be anticipated. The overall effects of corrosion can be minimized by temperature control, metallurigical considerations and proper operating techniques.

E. CONCEPTUAL DESIGN - Continued

The buildings and structures for this proposed concept are estimated on the following basis:

a. General

Design will comply with any State or other applicable building codes and ordinances, and will meet the requirements of the Insurance Underwriters and OSHA standards. Wind loading would be determined during detail design. Earthquake analysis is not contemplated at this time.

b. Foundations

The building foundations are estimated using steel H piles 40' long. Miscellaneous foundations have been estimated as reinforced concrete footings supported on soil capable of supporting 2 kips per square foot. Concrete for foundations shall develop 300 psi at 28 days. Concrete design will comply with ACI 318, latest edition. Soil borings will be required in the areas of new work.

c. Frames

Structural steel frames will be of ASTM A-36 steel. The design shall comply with AISC Code, latest edition.

d. Floors

Floors shall be either steel grating or reinforced concrete.

e. Sprinklers

No sprinklers are contemplated.

E. CONCEPTUAL DESIGN - Continued

The electrical design will comply with National Electric Code, OSHA Standards, any local applicable codes, and will meet the requirements of the Insurance Underwriters. The electrical costs estimated for this project assume that the present power company will bear the expense of the planned modification of reducing the source serving the plant from 23 kv to 13.8 kv.

The estimate includes the necessary 15 kv switchgear required for receiving incoming power, on-site electrical generation, and feeding the necessary load center substation and existing switchgear. The new switchgear would supply power to two new 13.8 kv - 575 volt transformers which would in turn feed two existing 600 volt switchgear line-ups. In addition, the new switchgear would supply power to one new load center substation required for the WHRS auxiliaries. Fifteen (15) kw switchgear will be metal-clad construction with interrupting capacity, as required. Substations will consist of a metal enclosed load break primary switch, dry type, transformer and metal enclosed low voltage switchgear with suitable interrupting rating.

Motor controls are of the grouped motor control center construction with rigid free-standing NEMA 1A enclosures. Enclosures will consist of one or more vertical sections of modular dimensions permitting the addition of future sections. In general, AC motors will be NEMA Design "B" squirrel cage induction, with NEMA "T" frames, Class "B" insulation, 1.0 service factor, 575 volts, 3 phase, 60 hertz, and designed for severe duty service. Motors smaller than 200 horsepower will be totally enclosed fan cooled.

E. CONCEPTUAL DESIGN - Continued

In general, motors smaller than 200 horsepower will be rated 575 volts, 3 phase, 60 hertz.

New 15 kv cable will be single conductor, shielded with ethylene-propylene type insulation. New 600 volt power cable will be single conductor and/or multi-conductor with cross-linked thermosetting polyethylene insulation. Multi-conductor cable will have an outer PVC jacket.

Conduit will be rigid galvanized, with flexible conduit used as required for motors and other equipment to localize vibration. Flexible conduit will be "Sealtite", type UA with a PVC jacket. Conduit installed below grade or in concrete will normally be galvanized steel. In general, 15 kv cables will be single conductor installed in conduit. Six hundred (600) volt wiring will be single conductor cable installed in conduit and/or multi-conductor cable in cable tray. Cables will be installed without splices except as specifically designated on the drawings.

Where required, new electrical equipment room(s) will be provided to house electrical switchgear, motor control centers, power supplies, relay cabinets, etc. Fluoresecent lighting is included for electrical equipment rooms. Lights will be adequate for the tasks to be performed in each area and in accordance with IES recommendations.

Instrumentation will be miniature electronic utilizing an electric transmission system. Final control elements will be pneumatic. Panel board components will be miniature electronic. Controllers, recorders, indicators and alarms are to be mounted on an upright control panel located in a central control room. The electrical pushbuttons, pilot lights, alarm annunciator system, etc., will also be mounted on this panel.

E. CONCEPTUAL DESIGN - Continued

Control System Philosophy

1. Total waste heat from incinerators will be measured and ratioed to each boiler.

2. Proper temperature of waste heat to boilers will be maintained by modulating attemperating gas damper in conjunction with cooling air damper.

3. Temperature of super heated steam from each boiler will be recorded on a three (3) pen recorder.

4. Flow and pressure of generated steam to turbine will be recorded on two (2) pen recorder.

5. Level in hot well will control make-up condensate to boilers.

6. Waste heat and exhaust gas dampers will be operated by pushbuttons on control panel.

7. Generated steam to process will be reduced to proper pressure.

Pneumatic tubing to the final control elements will be bare copper supported on punched aluminum angles.

Waste heat boiler instrumentation and its installation is assumed to be purchased with equipment and not included in this estimate.

The piping systems will be designed to meet the requirements of the latest edition of the ASME Boiler and Pressure Vessel Code and the

E. CONCEPTUAL DESIGN - Continued

American National Standard Institute Code for Pressure Piping as well as any state and local codes that may be applicable to the work.

Piping materials were used in the estimates which are reasonable for the service.

F. ECONOMIC ANALYSIS

Case A - Incineration of 10 tons/hr. solid waste

1. Capital Investment = $4,523,000 (Total Escalated Project Cost)
2. No. 6 Fuel Oil Cost = $0.935/gallon
3. Electric Cost = $0.0736/kw hr.
4. Life expectancy of the equipment = 15 years
5. Estimated operating & maintenance = $120,300/year
6. 10% annual inflation rate applied to the costs of oil, electricity, labor & materials
7. No taxes

Recovered energy = 64.734×10^6 BTU/hr. = 62,300 pph steam

For UMM to generate 33,500 pph steam from 80% efficient boilers with 228°F feedwater the annual consumption of No. 6 oil would be:

$$\frac{(33{,}500)\ \frac{\text{lb-stm}}{\text{hr}}\ (1222-196)\ \frac{\text{BTU}}{\text{lb-stm}}\ (108)\ \frac{\text{hr}}{\text{wk}}\ (50)\ \frac{\text{wks}}{\text{yr}}}{(149{,}600)\ \frac{\text{BTU}}{\text{Gal-oil}}\ (.8)\ \text{effic.}} = 1{,}550{,}830\ \frac{\text{Gal-oil}}{\text{year}}$$

Annual Oil Savings = $1,450,026/year

62,300 pph - 33,500 pph (Process) = 28,800 pph (for Electricity)

$$\frac{28{,}800\ \frac{\text{lb-stm}}{\text{hr}}\ (.98)\ (.94)}{(20.02)\ (1.341)} = 988\ \text{kw}$$

Annual Electric Savings = $392,671

Operating Costs

(3 Operators) $(7.50\ \frac{\$}{\text{hr}})\ (1.4)\ (2{,}088\ \frac{\text{hr}}{\text{yr}})$ = $65,772

(1 Mechanic) $(7.25\ \frac{\$}{\text{hr}})\ (1.4)\ (2{,}088\ \frac{\text{hr}}{\text{yr}})$ = 21,193

$86,965

F. ECONOMIC ANALYSIS - Continued

Case A - Incineration of 10 tons/hr. solid waste - Continued

Maintenance Costs

Turbine-Generator = 2½% of capital cost

T-G = (0.025) ($280,000) = $ 7,000

WHRS = 1½% of capital cost

WHRS = (0.015) (1,747,600) 26,335

$33,335

Total Operating & Maintenance = $120,300

Case B - Incineration of 12.5 tons/hr. solid waste

1. Capital Investment = $4,523,000 (Total Escalated Project Cost)
2. No. 6 Fuel Oil Cost = $0.935/gallon
3. Electric Cost = $0.0736/kw hr.
4. Life expectancy of the equipment = 15 years
5. Estimated operating & maintenance = $120,300/year
6. 10% annual inflation rate applied to the costs of oil, electricity, labor & materials
7. No taxes

Recovered energy = 82.16 x 10^6 BTU/hr. = 81,000 pph steam

Annual No. 6 fuel oil consumption for process based on an annual average steam load of 33,500 pph steam = 1,550,830 gal-oil/year (See page F-1).

Annual Oil Savings = $1,450,026/year

81,000 pph - 33,500 pph (Process) = 47,500 pph (for Electricity)

F. ECONOMIC ANALYSIS - Continued

Case B - Incineration of 12.5 tons/hr. solid waste - Continued

$$\frac{(47{,}500)\ \frac{\text{lb-stm}}{\text{hr}}\ (.98)\ \text{Gear Effic.}\ (.94)\ \text{Gen. Effic.}}{(20.02)\ \frac{\text{lb-stm}}{\text{hp hr}}\ (1.341)\ \frac{\text{hp}}{\text{kw}}} = 1{,}630\ \text{kw}$$

Annual Electric Savings $647,827/year

Operating and Maintenance Costs = $120,300/year
(See Pages F-1 & 2)

ECONOMIC ANALYSIS
DISCOUNTED CASH FLOW RATE OF RETURN (VALUES GIVEN IN $)

YEAR	TOTAL INVESTMENT	TOTAL BENEFITS	TOTAL COSTS	OPERATING INCOME	TOTAL DEPRECIATN	TAXABLE INCOME	TAXES PAID	AFTER-TAX PROFIT	ANNUAL NET CASH FLOW	CUMMUL. NET CASH FLOW	CASH FLOW PRES WORTH
1	4523000	0	0	0	0	0	0	0	-4523000	-4523000	-3674165
2	0	2028966	132330	1894636	0	1894636	0	1894636	1894636	-2628363	1015598
3	0	2229663	145563	2084100	0	2084100	0	2084100	2084100	-544262	737189
4	0	2452629	160119	2292510	0	2292510	0	2292510	2292510	1748247	535101
5	0	2697892	176131	2521761	0	2521761	0	2521761	2521761	4270008	388412
6	0	2967681	193744	2773937	0	2773937	0	2773937	2773937	7043946	281935
7	0	3264450	213118	3051331	0	3051331	0	3051331	3051331	10095277	204647
8	0	3590895	234430	3356464	0	3356464	0	3356464	3356464	13451742	148546
9	0	3949984	257873	3692110	0	3692110	0	3692110	3692110	17143852	107825
10	0	4344982	283661	4061321	0	4061321	0	4061321	4061321	21205174	78266
11	0	4779481	312027	4467454	0	4467454	0	4467454	4467454	25672628	56811
12	0	5257429	343229	4914199	0	4914199	0	4914199	4914199	30586828	41237
13	0	5783172	377552	5405619	0	5405619	0	5405619	5405619	35992447	29932
14	0	6361489	415308	5946181	0	5946181	0	5946181	5946181	41938628	21727
15	0	6997638	456839	6540799	0	6540799	0	6540799	6540799	48479428	15771
16	0	7697402	502522	7194879	0	7194879	0	7194879	7194879	55674307	11447

RATE OF RETURN ON INVESTMENTS = 51.55 %

PAYBACK PERIOD ON INVESTMENTS = 2.24 YEARS

WASTE HEAT RECOVERY PROJECT
WITH COGENERATION - 10 TPH.
10% INFLATION RATE APPLIED TO
OIL, ELECT, LABOR & MATERIALS

ECONOMIC ANALYSIS
DISCOUNTED CASH FLOW RATE OF RETURN (VALUES GIVEN IN $)

YEAR	TOTAL INVESTMENT	TOTAL BENEFITS	TOTAL COSTS	OPERATING INCOME	TOTAL DEPRECIATN	TAXABLE INCOME	TAXES PAID	AFTER-TAX PROFIT	ANNUAL NET CASH FLOW	CUMMUL. NET CASH FLOW	CASH FLOW PRES WORTH
1	4523000	0	0	0	0	0	0	0	-4523000	-4523000	-3599774
2	0	2307638	132330	2175308	0	2175308	0	2175308	2175308	-2347691	1096647
3	0	2538402	145563	2392839	0	2392839	0	2392839	2392839	45147	764111
4	0	2792242	160119	2632123	0	2632123	0	2632123	2632123	2677270	532410
5	0	3071466	176131	2895335	0	2895335	0	2895335	2895335	5572605	370968
6	0	3378613	193744	3184868	0	3184868	0	3184868	3184868	8757474	258480
7	0	3716474	213118	3503355	0	3503355	0	3503355	3503355	12260830	180101
8	0	4088121	234430	3853691	0	3853691	0	3853691	3853691	16114521	125489
9	0	4496934	257873	4239060	0	4239060	0	4239060	4239060	20353581	87437
10	0	4946627	283661	4662966	0	4662966	0	4662966	4662966	25016548	60923
11	0	5441290	312027	5129262	0	5129262	0	5129262	5129262	30145811	42449
12	0	5985419	343229	5642189	0	5642189	0	5642189	5642189	35788000	29577
13	0	6583960	377552	6206408	0	6206408	0	6206408	6206408	41994408	20609
14	0	7242357	415308	6827048	0	6827048	0	6827048	6827048	48821457	14359
15	0	7966592	456839	7509753	0	7509753	0	7509753	7509753	56331210	10005
16	0	8763251	502522	8260728	0	8260728	0	8260728	8260728	64591939	6971

RATE OF RETURN ON INVESTMENTS = 57.88 %

PAYBACK PERIOD ON INVESTMENTS = 1.98 YEARS

WASTE HEAT RECOVERY PROJECT
WITH COGENERATION - 12 TPH.
10% INFLATION RATE APPLIED TO
OIL, ELECT, LABOR & MATERIALS

G. DERIVATION OF COSTS

Total escalated project costs for this WHRS conceptual design consists of the total of direct costs, indirect costs, and an allowance for escalation. Direct costs are composed of current direct costs and a contingency. Indirect costs include items listed below under "B" Indirect Costs. Escalation is explained under "C". Items not included in this estimate are listed under "D" of this section.

1. Direct Costs

a. General

On the Cost Summary sheet there are shown costs for the following: Equipment, Equipment Erection, Equipment Foundations and other Structural Costs, Buildings and Structures, Electrical Installation Costs, Instrumentation Installation Costs, Piping Costs, and Area Costs. All of the costs, except equipment costs, are normally incurred by a contractor or subcontractor and are described below under the heading "Contractor Costs (Labor and Material)". The total of all these items is the "Total Current Direct Costs".

b. Equipment

Equipment costs cover the costs of process equipment, motors, motor controls, switchgear, instruments, control panels, heating, ventilating, and air conditioning equipment, etc. that are normally purchased by the client through its Purchasing Department.

In general, current equipment costs are based on budget quotations from manufacturers or on prices received recently for similar equipment.

G. DERIVATION OF COSTS - Continued

1. Direct Costs - Continued

b. Equipment - Continued

Instrumentation equipment (hardware) costs were based on an itemized take-off from preliminary flow sheets. An allowance was provided for unlisted items. Instrument prices used were generally current list prices; in some cases, net prices were used.

c. Contractors Costs (Labor and Materials)

These costs were based on prevailing prices of materials and current construction wage rates of the various trades.

Equipment erection costs were made assuming a certain procedure of erection. In the establishment of these erection costs, consideration was given to the physical location of the equipment and also to the accessability and time required for erection equipment.

Major building and structural costs were based on material take-offs and the use of applicable unit prices. OSHA requirements have been recognized by applying a percentage factor to certain construction costs.

Electrical contractor costs for motor wiring were estimated by applying a composite cost of cable, conduit, fittings, and labor for each motor. The composite cost varies with the rating and characteristics of the motor. Lighting was priced by applying

G. DERIVATION OF COSTS - Continued

1. Direct Costs - Continued

c. Contractors Costs (Labor and Material) - Continued

an area unit cost that varies as a function of intensity. Instrument wiring is also included under Electrical Costs.

Instrumentation installation costs were based on estimated installation costs and estimated tubing installation costs.

Piping contractor costs were prepared by the use of preliminary flow sheets of major systems. A preliminary material take-off was made of major lines. Costs were obtained by the use of material price sheets, shop price sheets, and contractors' labor sheets with applicable labor rates being applied.

Area costs were based on unit price figures for paving, grading, change, etc.

d. Contingency

Contingency is an allowance given generally for unknown, underestimated, and omitted items. Generally, at least a 10% contingency is proposed. The amount applied is a function of the complexity of the project, scope definition, confidence in the vendor's budget quotes, time schedules, tie-ins to existing equipment, and other factors. The estimate included in the reqport has a contingency of 10%. The percentage used for contingency is applied to the Total Current Direct Costs.

2. Indirect Costs

The indirect costs are all those costs, except escalation, itemized in the Cost Summary sheets below "Total Current Direct Cost Plus

G. DERIVATION OF COSTS - Continued

2. Indirect Costs - Continued

Contingency". They were derived as follows:

a. Engineering

Engineering manhour estimates made by each Sirrine department involved in the project served as a basis for determination of total engineering costs. The engineering costs are current costs and have not been escalated. Its escalation is included under the "Escalation Allowance".

b. Construction Management

This cost includes the services of one man from the engineering consultant to act on the job site as a part-time resident engineer. The resident engineer would coordinate with the general contractor to clarify any questions regarding plans and specifications and to inspect overall quality of construction comprising materials, workmanship, and time schedule.

The estimated cost is based on one man at the site 10 days per month the final three months of construction. This includes six trips to the job site including all expenses.

c. Project Coordination and General Overhead

Project coordination and general overhead is included as 4.3% of the total current direct cost plus contingency. This includes expenses incurred by United Merchants and Manufacturers, Inc. over and above those included in the contractor's overhead such as the contract administration, legal cost, engineering coordination, the cost of security guards, contracts bonds,

G. DERIVATION OF COSTS - Continued

2. Indirect Costs - Continued

c. Owner's General Overhead - Continued

equipment checkout, temporary electrical power usage, temporary utilities, project construction, signs, etc.

d. Spare Parts

This cost was figured generally to be 2½% of equipment costs.

e. Sales Tax

Sales tax was figured as 4% of equipment costs.

3. Items Not Included

This estimate does not include the following:

a. Interest during construction

b. Cost of borrowing money

c. Engineering models (Not Required)

d. Material take-off (By Vendors)

4. Escalation Allowance

Both current equipment and construction costs have been escalated in accordance with the project Design and Construction Schedule with the beginning point of the escalation being March 1981, start of design being September 1981 and project completion being March 1983. Escalation is assumed to be 10% per year (compounded) for both equipment and construction costs.

H. ITEMIZED ESTIMATED COSTS

Direct Capital Costs

		Motor HP	Equipment	Equipment Erection	Equip. Fdns. & Other Struct. Costs
1.	Waste Heat Boiler No. 1	--	177,000	80,000	1,000
2.	Waste Heat Boiler No. 2	--	177,000	80,000	1,000
3.	Waste Heat Boiler No. 3	--	177,000	80,000	1,000
4.	Ductwork from Secondary Combustion Chamber to WHRS Boilers	--	53,500	D&E	w/struct.
	Expansion Joints	--	13,500	4,550	----
5.	Inlet Duct Damper No. 1	1/2	18,500	2,850	w/struct.
	Motor		incl.		
6.	Inlet Duct Damper No. 2	1/2	18,500	2,850	w/struct.
	Motor		incl.		
7.	Inlet Duct Damper No. 3	1/2	18,500	2,850	w/struct.
	Motor		incl.		
8.	Boiler Exhaust Gas Ductwork	--	39,500	D&E	w/struct.
	Expansion Joints		12,000	4,000	----
9.	Boiler Feedwater Economizer No. 1	--	19,600	3,200	1,700
10.	Boiler Feedwater Economizer No. 2	--	19,600	3,200	1,700
11.	Boiler Feedwater Economizer No. 3	--	19,600	3,200	1,700
12.	Boiler Feedwater Pump No. 1	125	28,500	1,500	800
	Motor		incl.		

H. ITEMIZED ESTIMATED COSTS - Continued

Direct Capital Costs - Continued

		Motor HP	Equipment	Equipment Erection	Equip. Fdns. & Other Struct. Costs
13.	Boiler Feedwater Pump No. 2	125	28,500	3,200	800
	Motor		incl.		
14.	Boiler Blowdown Tank	--	2,800	600	1,000
15.	Attemperating Gas Fan No. 1	150	17,500	3,500	1,200
	Motor		incl.		
16.	Attemperating Gas Fan No. 2	150	17,500	3,500	1,200
	Motor		incl.		
17.	Attemperating Gas Duct - No. 1 Incinerator	--	10,500	D&E	w/struct.
	Expansion Joint	--	2,800	1,200	----
18.	Attemperating Gas Duct - No. 2 Incinerator	--	10,500	D&E	w/struct.
	Expansion Joint	--	2,800	1,200	----
19.	Attemperating Gas Damper No. 1	1/2	3,600	700	w/struct.
	Motor		incl.		
20.	Attemperating Gas Damper No. s	1/2	3,600	700	w/struct.
	Motor		incl.		
21.	Ambient Air Damper No. 1	1/2	3,600	700	w/struct.
	Motor		incl.		
22.	Ambient Air Damper No. 2	1/2	3,600	700	w/struct.
23.	Draw Bridge Damper Incinerator No. 1	25	100,000	35,000	
	Motor	incl.			

H. ITEMIZED ESTIMATED COSTS - Continued

Direct Capital Costs - Continued

		Motor HP	Equipment	Equipment Erection	Equip. Fdns. & Other Struct. Costs
24.	Draw Bridge Damper	25	100,000	35,000	----
	Incinerator No. 2 Motor	incl.			
25.	Turbine-Generator 2,000 kw	--	280,000	55,000	2,200
26.	Atmosphere Condenser	--	50,000	6,500	1,500
27.	Instruments	--	51,000	w/Inst. Piping	----
28.	Instrument Panel	--	5,000	300	500
29.	Switchgear	--	142,000	14,200	----
30.	Motor Controls	--	32,850	2,950	300
31.	Battery & Substations	--	150,000	16,000	1,000
		603½	1,810,450	449,150	18,600

32. Building & Structures Costs

New Structure	$318,000
740 Foot Pipe Bridge	100,000
Total Building & Structures Costs	$418,000

33. Electrical Costs

Building Lighting	$ 2,000
Outside Lighting	1,000
Power Wiring	102,200
Instrument Wiring & Installation	15,000
High Voltage Feeder	130,000
Grounding	20,000
Demolition Existing Switchgear	50,000
Total Electrical Costs	$320,200

34. Instrumentation Costs

Installation of Instrumentation and Instrument Tubing	$ 18,000
Total Instrumentation Costs	$18,000

H. ITEMIZED ESTIMATED COSTS - Continued

Direct Capital Costs - Continued

35.	Piping Costs	
	Process Piping	$135,000
	Insulation	12,000
	Painting	3,000
	Total Piping Costs	$150,000
36.	Area Costs	
	Grading	
	Process Drains	$ 500
	Total Area Costs	500

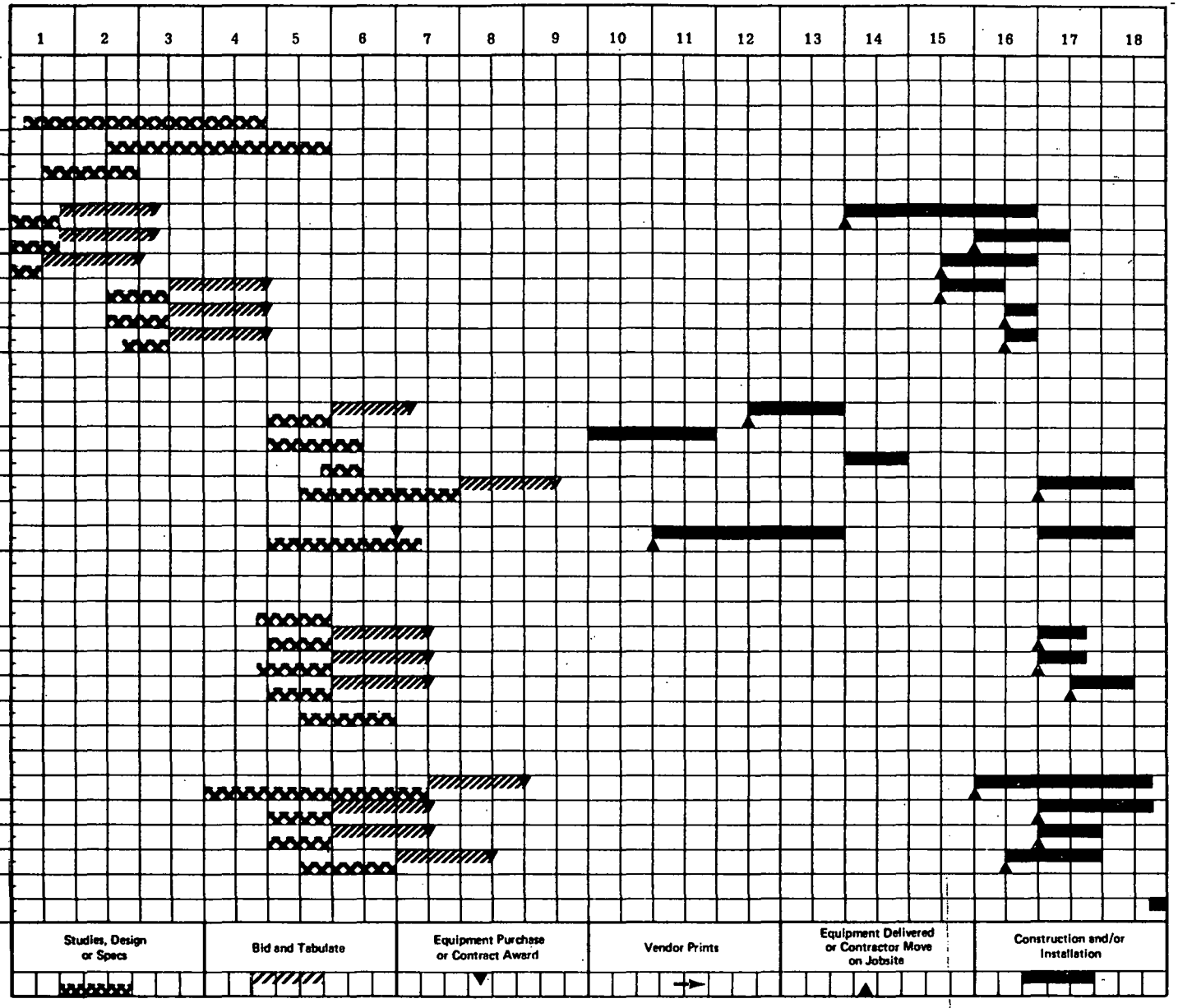
Preliminary

DESIGN & CONSTRUCTION SCHEDULE FOR ENERGY UTILIZATION - MUNICIPAL WASTE INCINERATOR, UNITED MERCHANTS & MANUFACTURERS, FALL RIVER, MASS.

J. E. SERRINE COMPANY

ARCHITECTS ENGINEERS PLANNERS

Job No. S-1881 Date: 3/81 By: ML



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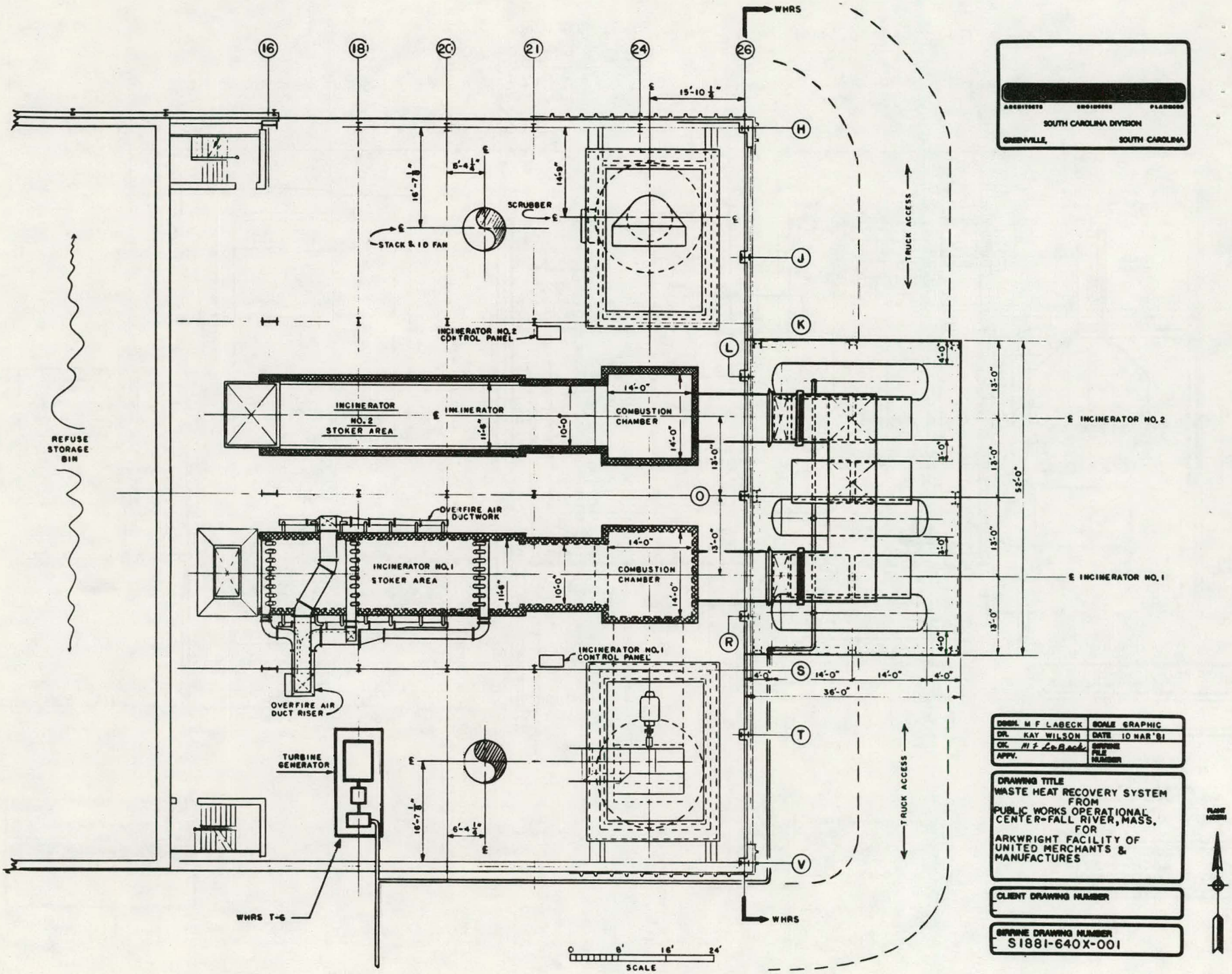
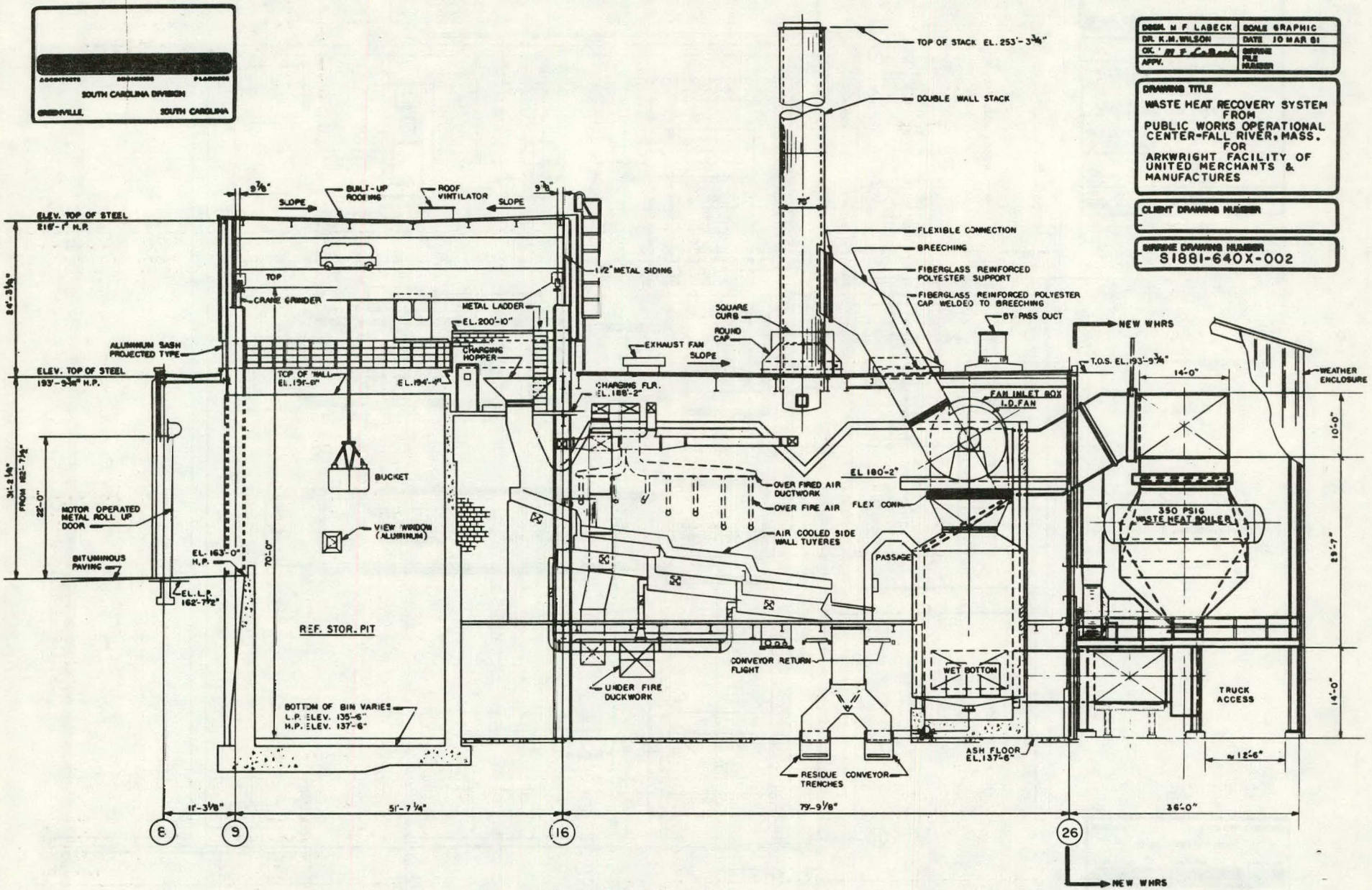
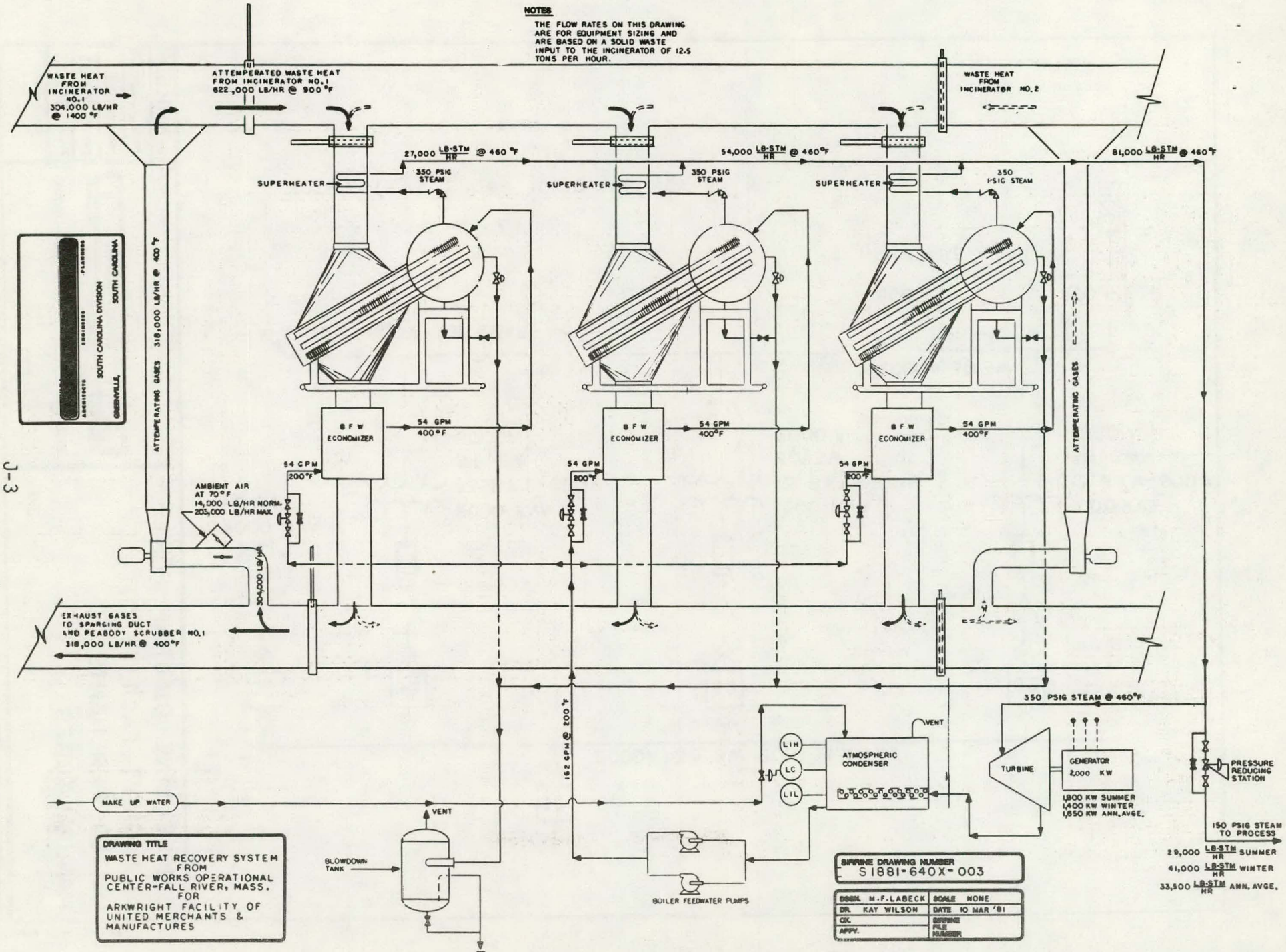

WHRS
16
18
20
21
24
26
H
J
K
L
O
R
S
T
V
15'-10 1/4"
16'-7 1/8"
6'-4 1/4"
14'-8"
SCRUBBER
STACK & ID FAN
INCINERATOR NO. 2 CONTROL PANEL
INCINERATOR NO. 2 STOKER AREA
INCINERATOR
COMBUSTION CHAMBER
14'-0"
11'-6"
10'-0"
13'-0"
4'-0"
52'-0"
℄ INCINERATOR NO. 2
℄ INCINERATOR NO. 1
REFUSE STORAGE BIN
OVERFIRE AIR DUCTWORK
INCINERATOR NO. 1 STOKER AREA
INCINERATOR NO. 1 CONTROL PANEL
OVERFIRE AIR DUCT RISER
36'-0"
TRUCK ACCESS
TURBINE GENERATOR
WHRS T-6
SCALE
0
8'
16'
24'
SOUTH CAROLINA DIVISION
GREENVILLE, SOUTH CAROLINA
DESIGN M F LABECK
SCALE GRAPHIC
DR. KAY WILSON
DATE 10 MAR '81
CK. M F LaBeck
APPV.
DRAWING TITLE
WASTE HEAT RECOVERY SYSTEM FROM PUBLIC WORKS OPERATIONAL CENTER-FALL RIVER, MASS. FOR ARKWRIGHT FACILITY OF UNITED MERCHANTS & MANUFACTURES
CLIENT DRAWING NUMBER
SIRRINE DRAWING NUMBER
S1881-640X-001
PLANT NORTH



SOUTH ELEVATION


NOTES
THE FLOW RATES ON THIS DRAWING ARE FOR EQUIPMENT SIZING AND ARE BASED ON A SOLID WASTE INPUT TO THE INCINERATOR OF 12.5 TONS PER HOUR.
WASTE HEAT FROM INCINERATOR NO.1 304,000 LB/HR @ 1400 °F
ATTEMPERATED WASTE HEAT FROM INCINERATOR NO.1 622,000 LB/HR @ 900 °F
WASTE HEAT FROM INCINERATOR NO.2
27,000 LB-STM/HR @ 460 °F
54,000 LB-STM/HR @ 460 °F
81,000 LB-STM/HR @ 460 °F
SUPERHEATER
350 PSIG STEAM
ATTEMPERATING GASES 318,000 LB/HR @ 400 °F
B F W ECONOMIZER
54 GPM 400 °F
54 GPM 200 °F
AMBIENT AIR AT 70 °F 14,000 LB/HR NORM. 203,000 LB/HR MAX.
304,000 LB/HR
EXHAUST GASES TO SPARGING DUCT AND PEABODY SCRUBBER NO.1 318,000 LB/HR @ 400 °F
162 GPM @ 200 °F
350 PSIG STEAM @ 460 °F
VENT
LIH
LC
LIL
ATMOSPHERIC CONDENSER
TURBINE
GENERATOR 2,000 KW
1,800 KW SUMMER
1,400 KW WINTER
1,650 KW ANN. AVGE.
PRESSURE REDUCING STATION
150 PSIG STEAM TO PROCESS
29,000 LB-STM/HR SUMMER
41,000 LB-STM/HR WINTER
33,500 LB-STM/HR ANN. AVGE.
MAKE UP WATER
BLOWDOWN TANK
BOILER FEEDWATER PUMPS
DRAWING TITLE
WASTE HEAT RECOVERY SYSTEM FROM PUBLIC WORKS OPERATIONAL CENTER-FALL RIVER, MASS. FOR ARKWRIGHT FACILITY OF UNITED MERCHANTS & MANUFACTURES
SIRRINE DRAWING NUMBER
S1881-640X-003
DSGN. M.F.LABECK
SCALE NONE
DR. KAY WILSON
DATE 10 MAR '81
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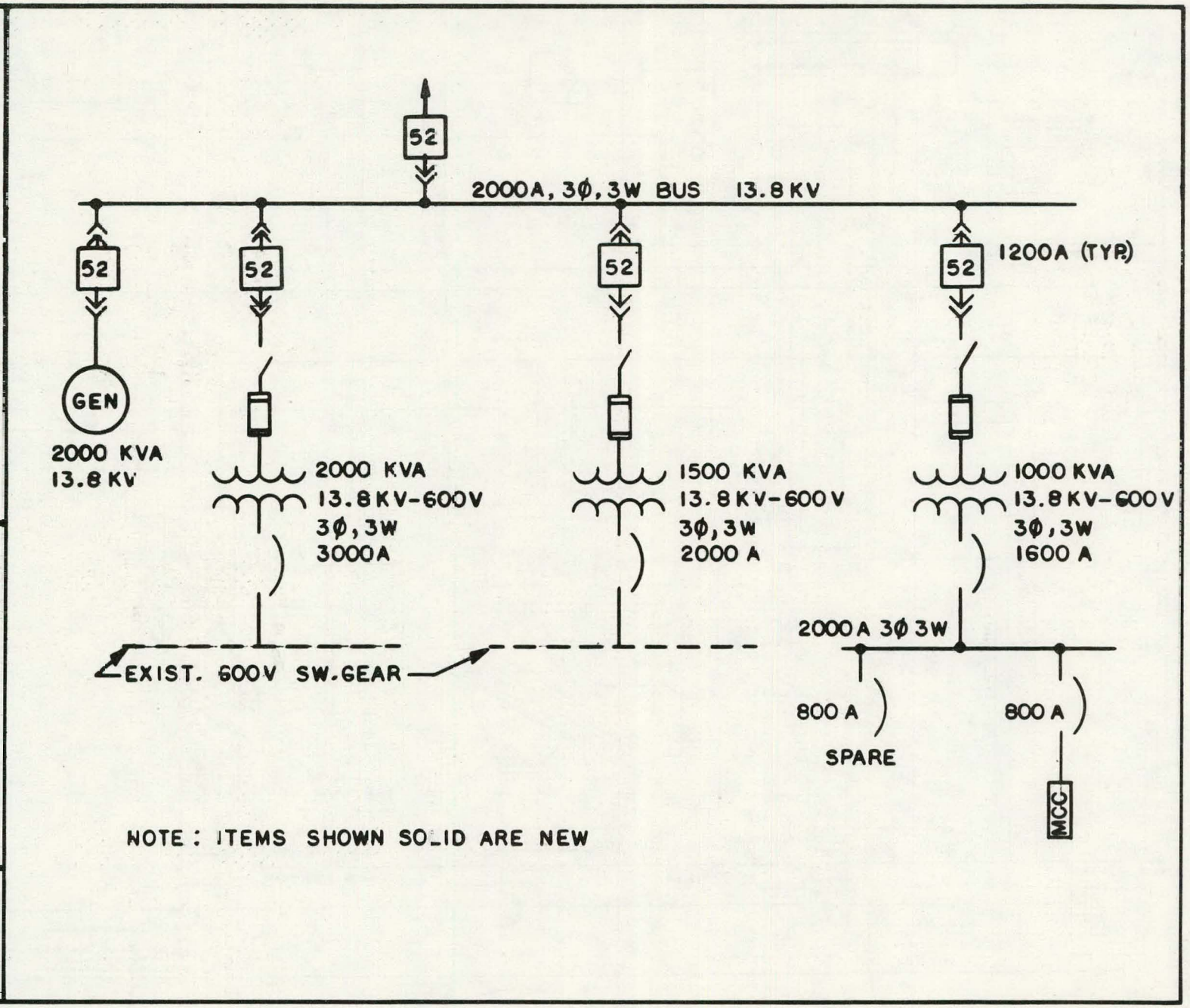
APPV.
SIRRINE FILE NUMBER
SOUTH CAROLINA DIVISION
SOUTH CAROLINA
GREENVILLE



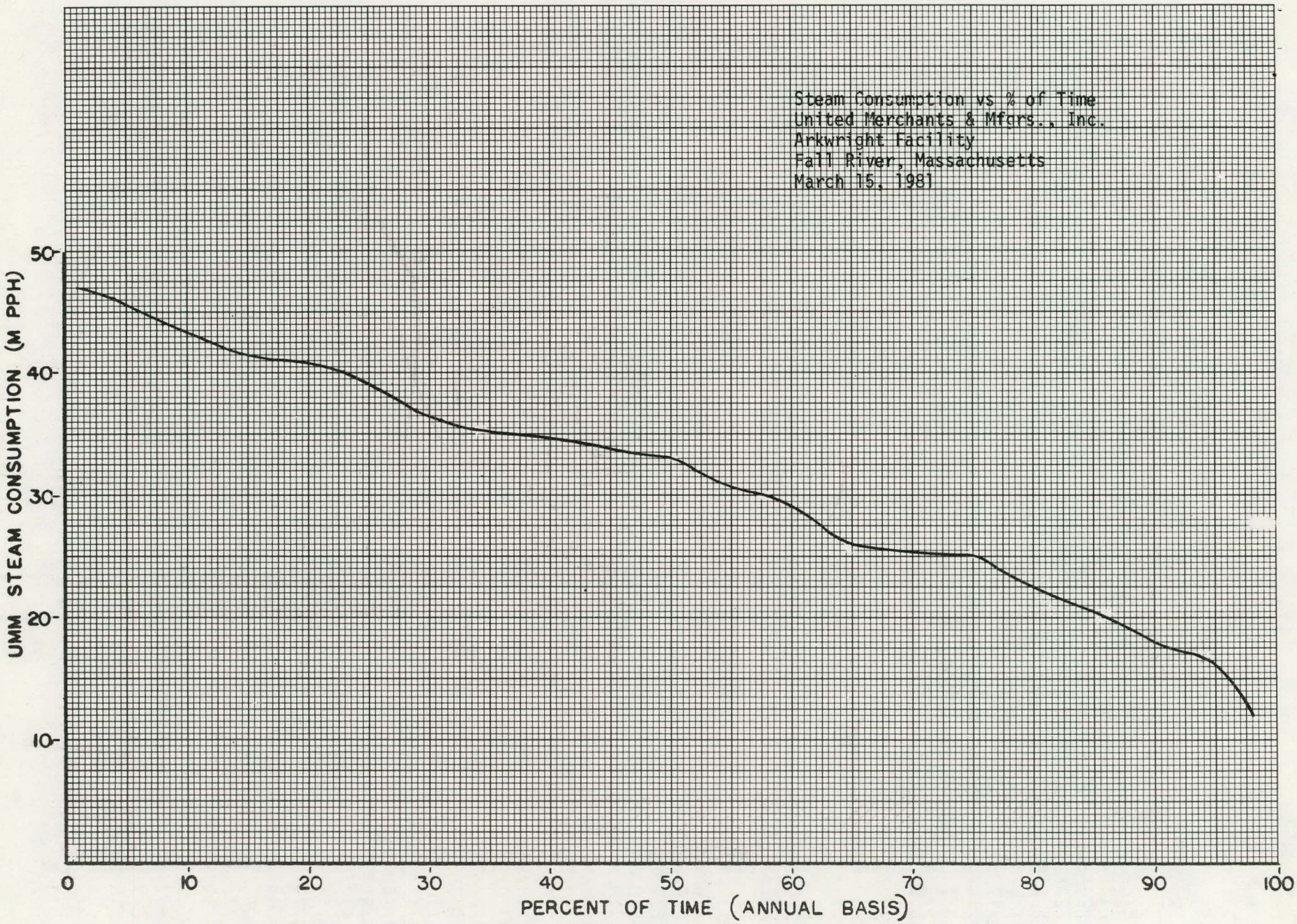
SINGLE LINE DIAGRAM FOR
ARKWRIGHT FACILITY OF
UNITED MERCHANTS &
MANUFACTURES

J-4

I. E. SERVICE COMPANY
CONSULTING ENGINEERS
SOUTH CAROLINA

K.WILSON
M.LABECK
NONE
3-26-81
S-1881

10 X 10 PER HALF INCH



APPENDIX K1

Week	Total Steam	Boiler Hours Of Operation	Plant Operating Hours	Average Plant Stm. Consumption/Hr.
1/6/80	2,160,700	244	120	18,005
1/13/80	5,136,200	400	120	42,802
1/20/80	4,953,900	376	120	41,282
1/27/80	5,367,800	335	120	44,732
2/3/80	5,491,700	408	120	45,764
2/10/80	4,884,900	420	120	40,708
2/17/80	5,234,700	370	120	43,623
2/24/80	2,957,900	292	120	24,649
3/2/80	5,359,400	295	120	44,662
3/9/80	4,948,300	289	120	41,236
3/16/80	5,086,600	291	120	42,388
3/23/80	4,529,200	290	120	37,743
3/30/80	4,102,100	261	120	34,184
4/6/80	4,216,100	252	120	35,134
4/13/80	4,220,700	267	120	35,172
4/20/80	4,200,700	288	120	35,006
4/27/80	3,295,500	236	120	27,462
5/5/80	4,055,400	247	120	33,795
5/11/80	4,096,100	219	120	34,134
5/18/80	3,820,000	247	120	31,833
5/25/80	3,657,700	225	120	30,481
6/1/80	2,498,700	162	120	20,822
6/8/80	3,926, 00	234	120	32,720
6/15/80	3,823,100	241	120	31,859
6/22/80	3,645,300	236	120	30,378
6/29/80	1,488,800	131	120	12,407
7/6/80	-0-	-0-	-0-	-0-
7/13/80	-0-	-0-	-0-	-0-
7/20/80	3,092,400	237	120	25,770
7/27/80	1,879,100	141	120	15,659
8/3/80	2,944,200	239	120	24,535
8/10/80	2,935,500	242	120	24,462
8/17/80	2,912,400	243	120	24,270
8/24/80	3,146,000	241	120	26,217
8/31/80	3,132,300	229	120	26,102
9/7/80	2,102,600	162	120	17,522
9/14/80	3,255,900	250	120	26,882
9/21/80	3,168,200	241	120	26,402
9/28/80	3,194,700	241	120	26,622
10/5/80	2,994,500	231	120	24,954
10/12/80	2,252,400	152	120	18,770
10/19/80	2,302,600	149	120	19,188
10/26/80	4,144,600	289	120	34,538
11/2/80	4,316,700	265	120	35,972
11/9/80	4,238,400	268	120	35,320
11/16/80	3,703,800	230	120	30,865
11/23/80	4,990,400	313	120	41,587
11/30/80	2,636,900	188	120	21,974
12/7/80	5,677,500	405	120	47,312

ENERGY
SYSTEMS
110 South Orange Avenue
Livingston, New Jersey 07039 U.S.A.

November 11, 1980
SO-163

CC: 13 Nov 1980
Mr. A. L. Hashe
Mr. Ben Knott
Mr. W. F. Thompson
M. LaBeck

Marvin LaBeck
J.E. Sirrine Company
P. O. Box 5456
Greenville, S.C. 29606

SUBJECT: FEASIBILITY STUDY, INCINERATOR WASTE HEAT RECOVERY, SIRRINE JOB NO. S-1881

Reference: 1) Letter dated 11/3/80, LaBeck to Hashe

Gentlemen:

We have reviewed the conceptual design received with reference 1) and have the following comments:

1. With the temperature range available (900-400°F), we would recommend a low pressure steam system for energy recovery rather than the Organic Rankine Cycle. A steam system using at the inlet, the same pressure and temperature (125 psig - 375 - 400°F) as the process steam you are currently generating, could produce 2250-2300KW net output by using a condensing turbine with 1.5 psia outlet pressure. This arrangement would:

   - Provide one simple low pressure steam system instead of two different system (one process steam one power vapor) each with its attendant problems.
   - Allow use of one large boiler or two smaller boilers in parallel.
   - Eliminate the need to control or balance the flow of flue gas to the two separate boilers.
   - Provide maximum utilization of available heat by diverting excess process steam requirements directly to power generation with simple rapid response controls.
   - Allow use of a single power turbine with only one set of controls. (Proven technology)
   - Eliminate any fire hazard in the flue gas stream.
   - Reduces feed pump power losses providing greater net power.

November 11, 1980
SO-163

Marvin LaBeck
Sirrine Company

2. The suggested use of toluene (an aromatic) as a working fluid in a superheater placed directly in the flue gas stream presents a safety and fire hazard problem which must be considered. With a known flue gas corrosion condition extra corrosion allowance and quality control on the construction would be a certain requirement and even with these precautions a fire monitoring and control system may be appropriate to protect the expensive equipment installed downstream of the superheater.

3. In the conceptual design shown, we feel that specific consideration for the mixing of the recycled flue gas with the primary hot gas is required to obtain a relatively constant temperature profile (plus or minus 50°F) to the boilers. The present configuration appears short or without mixing provisions.

4. A realistic pressure drop must be provided for the steam superheater (3-5 psi should be adequate).

5. If the process steam requirement would allow it, increasing the steam system pressure to 140-150 psig could be accomplished with little process change with an associated enhancement of a steam power generation system.

6. The use of heat pipe boilers appears to us as a good approach to providing a compact, simple, reliable heat recovery arrangement.

In summary, we feel that a single low pressure steam system can provide a simple, well proven, energy recovery system which will produce as much and probably more net power than any Organic Rankine System. The capital cost would probably be less and operating and maintenance costs of the single system would certaining be less.

We are pleased with your interest in us and would look forward to working with you on a more suitable application. I am enclosing our brochure and a paper which we delivered in Houston earlier this year. As described in this information, we prefer waste heat sources in the 200-450°F temperature range, which is where we feel the real potential for Organic Rankine Cycle Systems exists. Should you desire any additional information or have a potential application, please contact us.

Very truly yours,

AFI ENERGY SYSTEMS

Robert H. Sawyer
General Manager

RHS:jc
Attachment

cc: S. Ichikawa

ORGANIC RANKINE CYCLE SYSTEMS

FOR ENERGY RECOVERY FROM WASTE HEAT

ENERG

AFI

SYSTEMS

ENERGY

SYSTEMS

ENERGY CONSERVATION/COGENERATION

The AFI Organic Rankine Cycle System uses an organic working fluid to generate power from low temperature heat sources. Systems of 500 to 4,500 KW (or equivalent shaft power) using flurocarbon working fluids are currently offered for liquid or condensable waste heat applications. Potential investment paybacks can be as short as two years, depending upon energy rates and waste heat stream characteristics.

A complete package system

The AFI system is an assembly of compact modular units ready for use; particularly suitable for installation in existing plants. AFI is prepared to work with you to develop an estimate of cost and return on investment for your particular application. Engineering, procurement and installation services are provided to insure a complete operating system.

Commercial Availability

The AFI system incorporates a commercially proven turbo-generator in conjunction with other system components of standard "off the shelf" proven production designs.

System operating experience

Over ten years of experience presented in the table below backs the AFI *Organic Rankine* Cycle System. An example is the 3,800 KW unit which has been in operation in Japan since 1968. Deriving its energy from low temperature waste heat in a chemical process plant and using fluorcarbon refrigerant-11 as the working fluid, the unit has accumulated 75,000 hours of operation in 10 years time with an availability factor exceeding 98%.

U.S. Experience

A 560 KW Organic Rankine Cycle System is installed at Allied Chemical's Sulfuric Acid Plant at Claymont, Delaware. It will be available for inspection in mid 1979.

The AFI partnership

Responsibility for the sale, design and manufacture of Organic Rankine Cycle Systems is vested in AFI Energy Systems, a partnership formed by Foster Wheeler Energy Corporation and Ishikawajima — Harima Heavy Industries Co., Limited — Tokyo, Japan. The broad technical expertise and resources of these major corporations provide in-depth backup for AFI.

ORGANIC RANKINE CYCLE SYSTEMS PRODUCED BY IHI

		IHI Research Institute	Mitsubishi Gas Chemical Company	Iwataya Department Store Company	IHI Tokyo No. 3 Works	Allied Chemical Company Claymont, DE
Applications (Year of Manufacture)		200 RT turbo-refrigerator (1966)	2,000 RT turbo-refrigerator & generator (1968)	800 RT turbo-refrigerator (1969)	FTG-50 generator (1974)	650 KW generator (1977)
Heat Source	Fluid, flow rate (Lb/h)	saturated steam 4,400	Xylene Vapors 683,000	wet steam 11,900	saturated steam 12,800	Sulphuric Acid 927,700
	Temperature (°F) In/Out	316/167	223-307/ 156-307	266/131	304/167	240/183
	Heat duty (MM BTU/h)	4.8	105	12.7	13.5	19.4
Fluro-carbon turbine	Type	S.F. integral with compressor	D.F. separate reduction gear	S.F. integral with compressor	S.F. integral reduction gear	S.F. integral reduction gear
	Pwr Output (KW)/ Speed (rpm)	190/15,500	3,800/5,280	475/8,750	500/10,370	560/9,590
Vaporizer	Type	Fixed tube sheet shell and tube	U-tube kettle	U-tube kettle	Fixed tube sheet shell and tube	Fixed tube sheet shell and tube
Condenser	Type	Shell and tube	Evaporative condenser	Shell and tube	Fixed tube sheet shell and tube	Fixed tube sheet shell and tube
	Cooling Water Temp. (°F) In/Out	89.6/98.6	—	89.6/98.6	79/91.4	63/73

S.F. — Single Flow. D.F. — Double Flow.

ORGANIC RANKINE CYCLE SYSTEM

Application criteria

The AFI Organic Rankine Cycle System is offered for use on applications having the following characteristics:

Waste Heat Streams

Type	Inlet Temperature Range
Liquids	250 - 450°F
Condensable Vapors	200 - 350°F

The stream might include distillation tower overhead vapor streams, liquid or vapor product cooling streams, including those from reactor cooling coils.

System Output

- Mechanical power in the form of a direct drive to a compressor, pump, fan, etc.
- Electrical power from a driven generator.
- A combination of both electrical and mechanical power.

Industries

Energy can be recovered from process streams in industries such as:
Petrochemicals / Chemicals / Pharmaceuticals / Paper / Petroleum and Refining / Steel / Smelting / Paint Manufacturing / and other manufacturing processes generating heat.

Or converted from natural energy such as solar and geothermal heat.

Organic Rankine Cycle Description

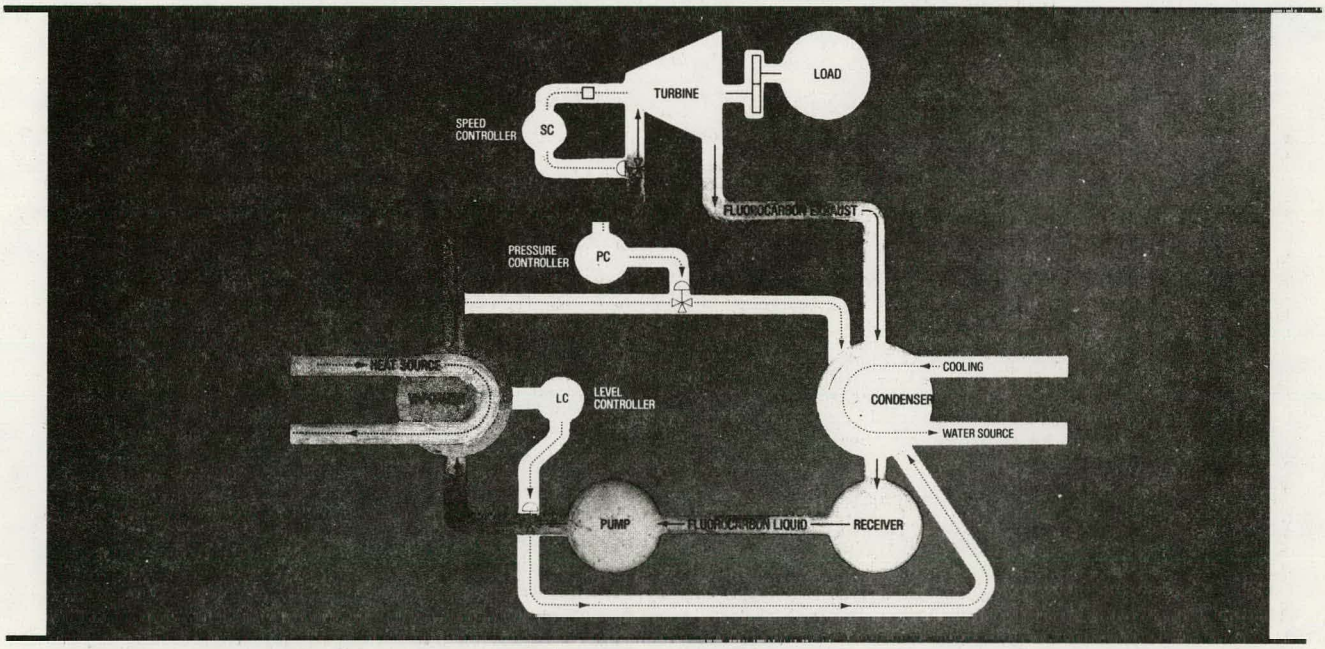
The AFI Organic Rankine System, utilizing a low boiling point working fluid, operates in the following manner:

Liquid fluorocarbon held in the receiver is pressurized by the pump and delivered to the vaporizer where it is heated and vaporized under constant pressure by the heat source. The dense fluorocarbon vapor produced, is led into the turbine where it expands adiabatically to drive the turbine and its connected load. The vapor from the turbine exhaust then flows to the condenser which condenses it to liquid form for recycling through the receiver and pump. The load driven by the turbine may be an electric generator, refrigerating equipment or other machinery.

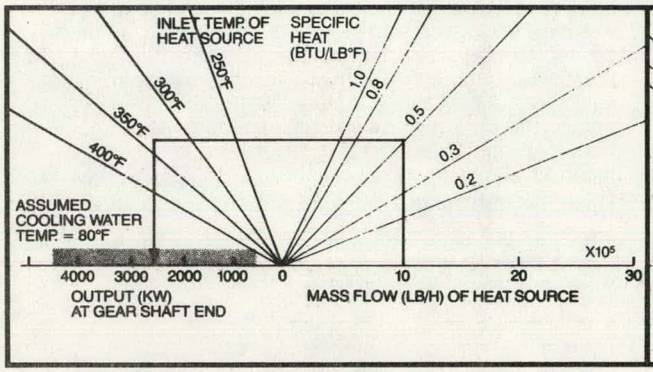
Three primary control circuits are utilized.

- A liquid bypass around the pump-receiver maintains a constant liquid level in the pool type vaporizer.
- A vapor bypass around the turbine allows operation of the heat source process with or without the turbine operating, as well as providing turbine inlet pressure protection and excess heat handling capacity.
- A speed control circuit to set and maintain turbine speed over the full power range.

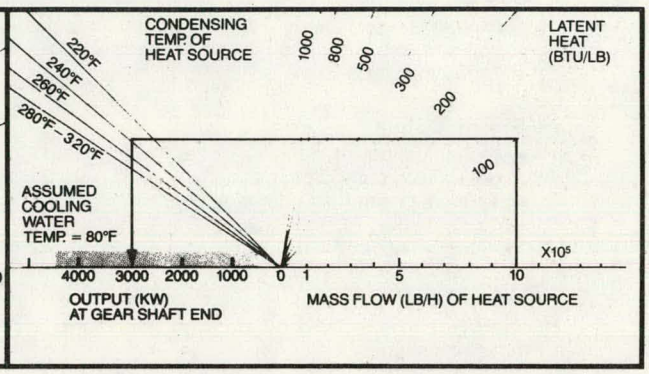
ORGANIC RANKINE CYCLE SYSTEM FLOW DIAGRAM



AFI ORGANIC RANKINE CYCLE OUTPUT



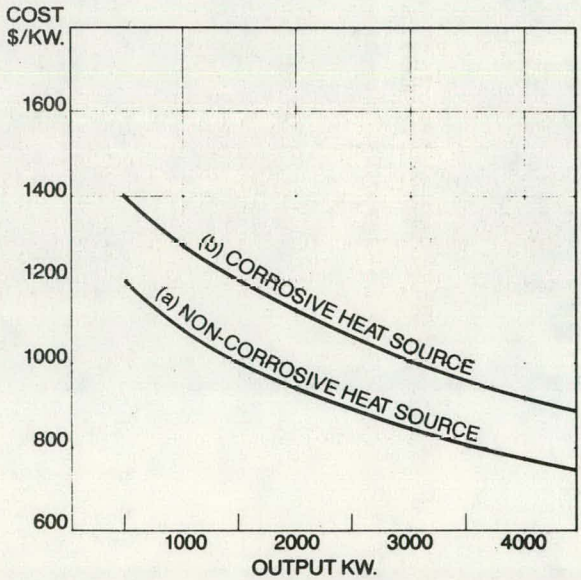
RECOVERED OUTPUT FROM LIQUID HEAT SOURCE



RECOVERED OUTPUT FROM CONDENSABLE HEAT SOURCE

Output estimation

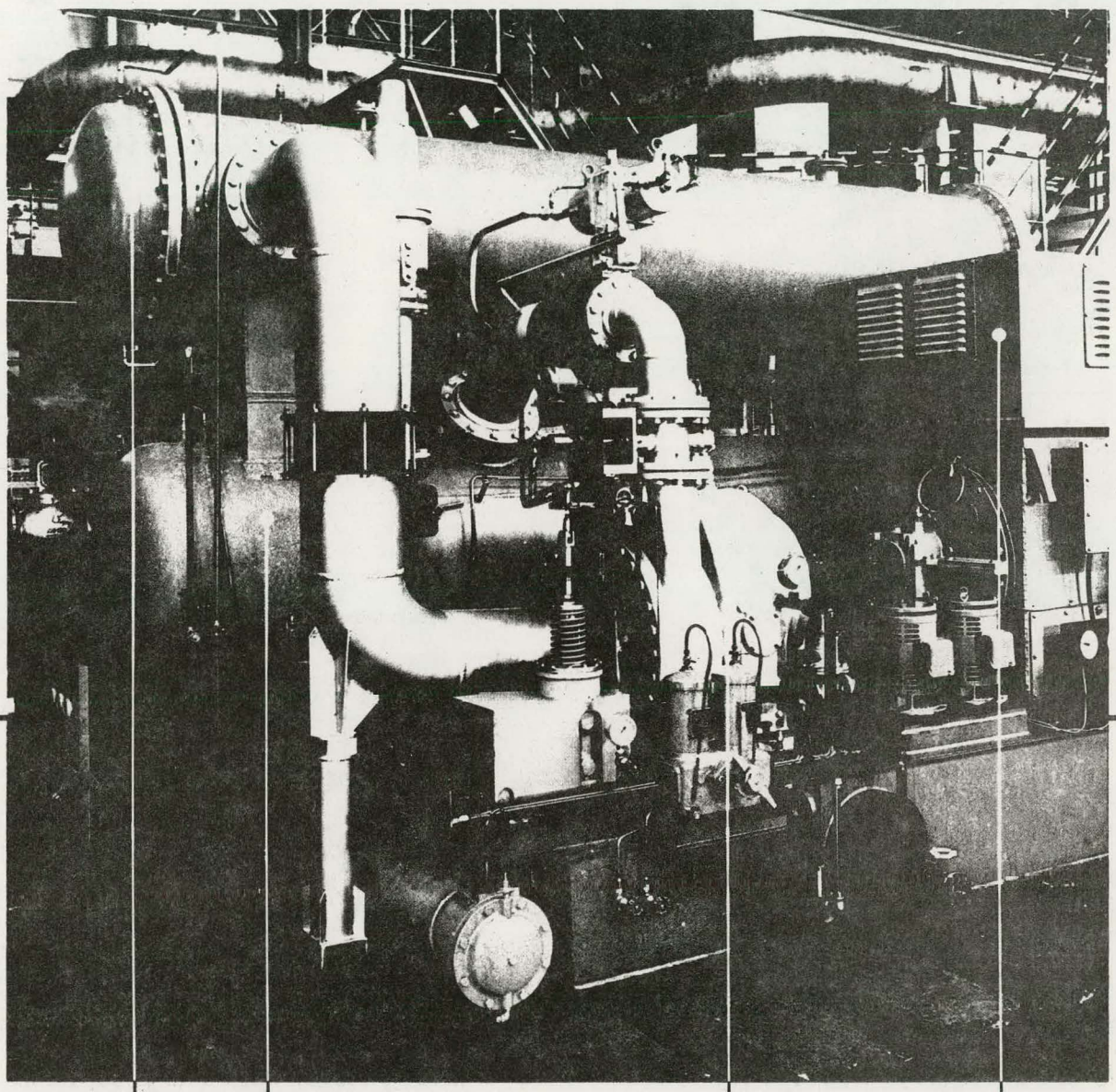
These nomographs provide a simple means for estimating Rankine Cycle System output. For example, with a liquid heat source flowing at 10 x 10^5 lb/hr with a specific heat of 0.5 and 340°F (171°C) inlet temperature, the gross output is 2,500 KW. Cooling water temperature has a significant effect on system output. The nomographs reflect an 80°F cooling water inlet temperature. Were this temperature decreased to 65°F, system output would increase from 2,500 KW to approximately 2,800 KW. Similar output estimates can be made for condensable vapors using the appropriate figures. A multiple unit system may be required to achieve an output exceeding 4500 KW. Again, it is emphasized that output may also be utilized directly as shaft power.



AFI Organic Rankine Cycle Equipment Size Vs. Complete Module Cost

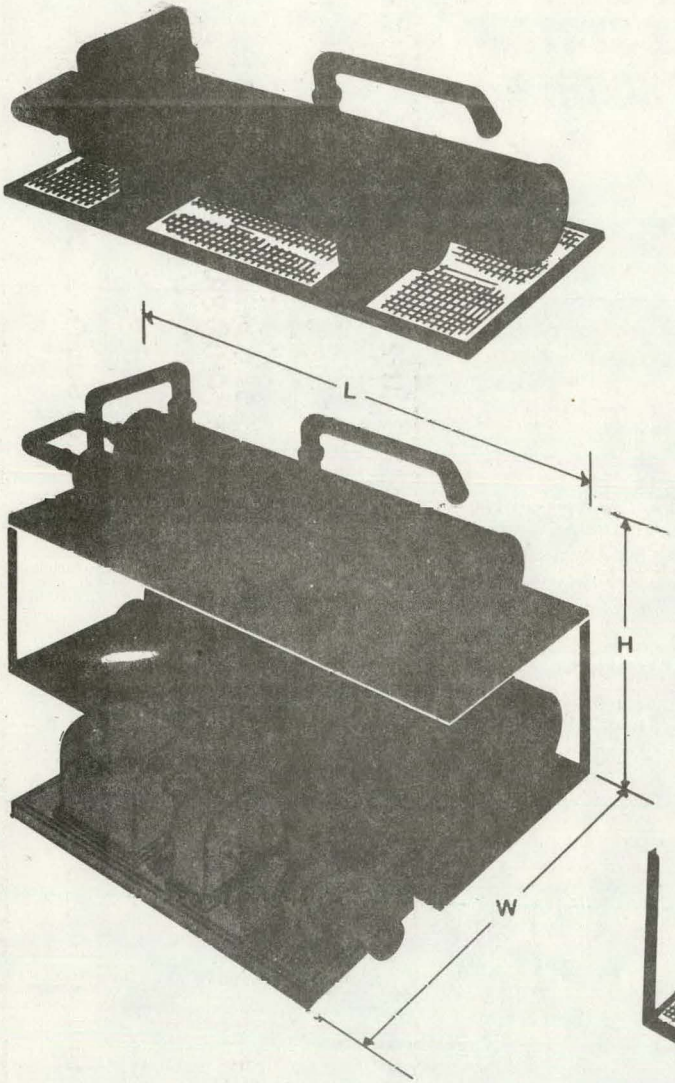
The cost of equipment can vary significantly with application. The two cost curves shown are (a) typical for applications where the heat source is noncorrosive and the heat exchangers are of carbon steel construction and (b) a typical corrosive heat source application using stainless steel heat exchanger construction. The economy of size is readily seen and multiple heat source streams should be considered when selecting a suitable system. Higher inlet temperature and heat transfer characteristics of the heat stream provide better equipment economics.

500 KW ORGANIC RANKINE CYCLE SYSTEM OPERATING ON L.P. STEAM HEAT SOURCE AT IHI TURBO-MACHINERY PLANT



CONDENSER VAPORIZER EXPANDER GENERATOR

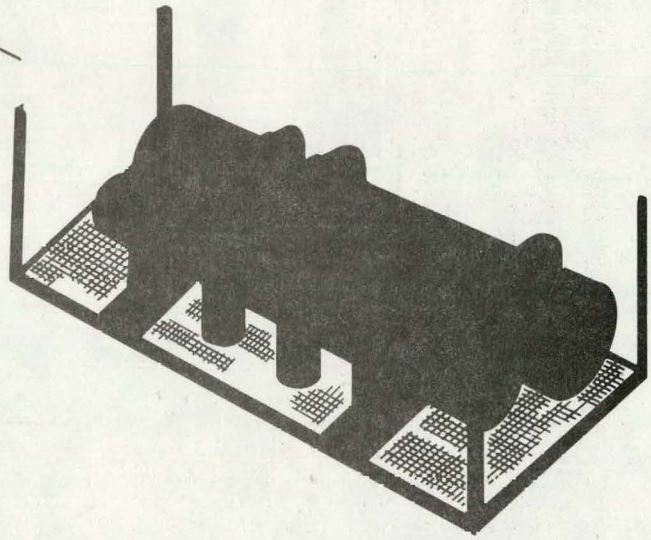
ORGANIC RANKINE CYCLE SYSTEMS



Space Requirements.

Systems normally require a clear area of 500 to 1,500 square feet adjoining the waste heat stream. Utilizing steam as the waste heat stream permits compact equipment which could reduce the required area by up to 50%.

Output (KW)	L	W	H
Up to 1000	30′	20′	25′
1000-2000	40′	25′	25′
2000-4000	40′	45′	30′

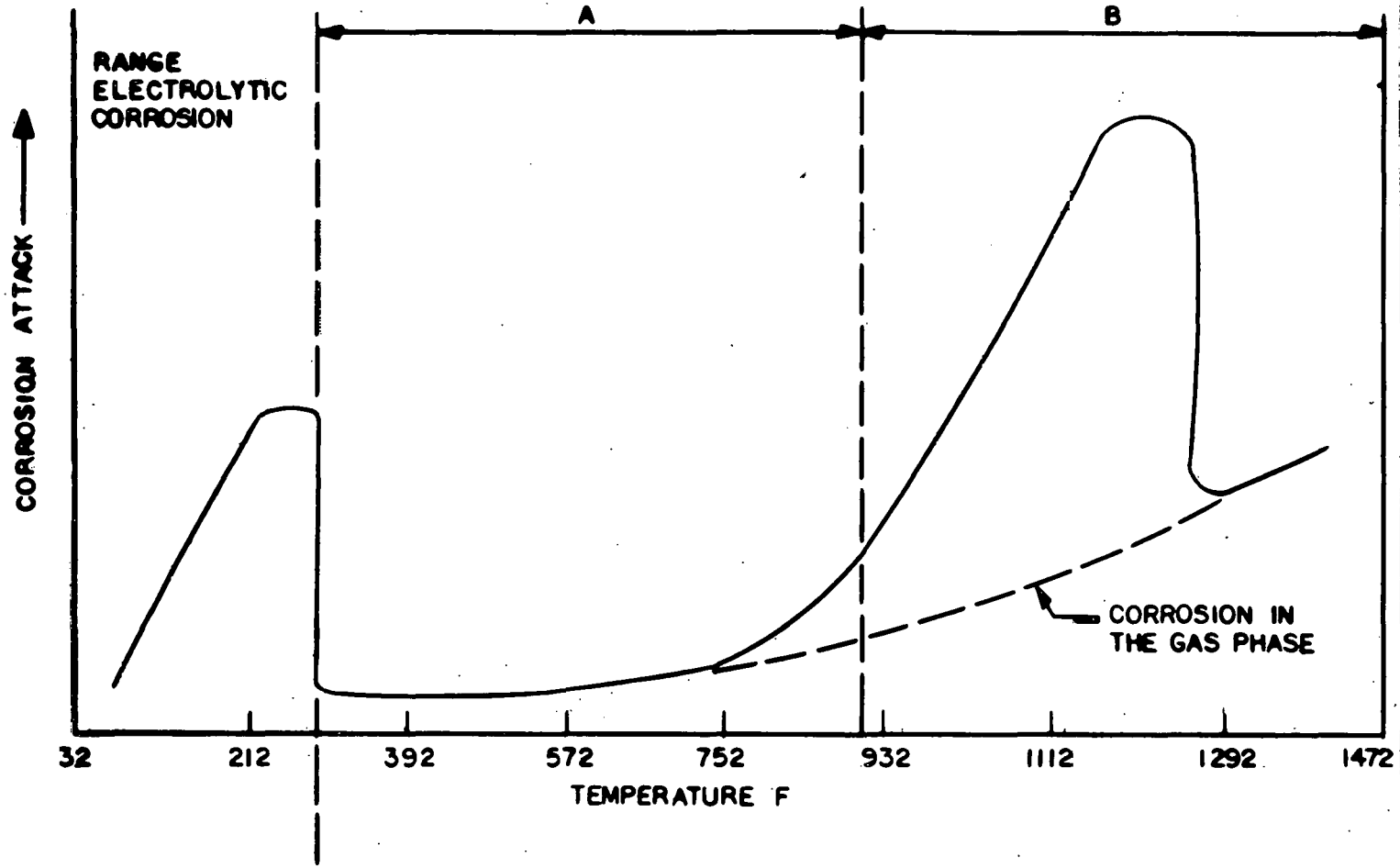


ENERGY AFI SYSTEMS

For an evaluation of an AFI Rankine Cycle System application to recover energy from waste heat in your facility, contact:

AFI Energy Systems
110 South Orange Avenue, Livingston, N.J. 07039
Telephone number - (201) 533-2091

SP 79-3



A = RANGE OF CORROSION DUE TO FERRIC CHLORIDE OR ALKALI FERRIC SULFATE FORMATION

B = RANGE OF CORROSION DUE TO FERRIC CHLORIDE OR ALKALI FERRIC SULFATE DECOMPOSITION

REF. COMBUSTION ENGINEERING BULLENTIN TIS-6504

CORROSION RATE VS. TEMPERATURE
SOLID WASTE FIRED BOILERS

K3 K3-1

U. S. SMELTING COMPANY

SOUTH CAROLINA

12-2-80

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Waste heat recovery with heat pipes

One of the most promising new developments in energy conservation technology is the heat pipe. Using a closed evaporation-condensation cycle capable of transferring heat at extremely high rates, heat pipes provide a highly efficient means of recovering waste heat from a wide range of processes and applications.

One of the pioneering heat pipe applications in Canada was installed in 1971 at the Brantford, Ontario plant of KeepRite Products Ltd. The company had just installed an automatic epoxy powder paint operation, where parts are given an electrostatic charge and a powdered epoxy paint is blown onto the surface, where it is evenly deposited. The parts are then heated in a bake oven to a temperature of approximately 400F.

With a 400F exhaust temperature from the oven, and daily usage of about sixteen hours, the oven seemed to be an excellent application for heat reclaim, and the decision was made to install a heat reclaim system based on new heat pipe technology.

Installation: The oven is fired by natural gas, with a total input of 2,000,000 Btu/hr. Maximum oven temperature is set to a limit of 450F. Exhaust is 2,100 scfm, but supply air is maintained at 1,100 scfm in order to keep the oven at a negative pressure.

A Q-Dot heat reclaim coil, five rows in depth, with eight fins per inch, and coil face dimensions of 24-in fin height and 48-in fin length was selected. It has an operating weight of 250 lb, and is installed on the roof of the bake oven along with exhaust and supply fans.

The original ducting within the bake oven remained undisturbed. In this way it was possible to proceed with the installation of the heat reclaim system without interrupting the production. Installation was simple, since the major work involved extending the exhaust duct to a point where the Q-Dot system could remove heat from the exhaust and transfer it to the supply air system.

Operation: The heat reclaim coil was selected for a maximum exhaust temperature of 470F. As a safety measure, a damper is installed in the exhaust duct to bypass the exhaust gas in the event that temperatures should exceed 450F. Note: Heat pipes can be provided to handle much higher temperatures than this, but the 450F limit was judged most suitable for this installation.

The coil is cleaned once a month by hand, spraying a solvent paint-removing compound over the fin and tube to remove any paint buildup. Access ports have been provided in the supply and return duct to allow inspection and cleaning of the coil surface.

Coil performance: Fin spacing of 8 fins. per inch was selected for the coil to provide long periods of operation between coil cleanings under the 18 hours a day operation experienced in this installation.

At a coil face velocity of 387 fpm, and with five rows of tubes in the direction of air flow, the recovery factor for the supply side of the coil was 0.65. This means that the temperature rise of the supply air is 65% of the difference in temperature between the entering exhaust and the entering supply air.

With exhaust air reaching the coil at 386F, and a .65 recovery factor, temperature of the supply air coming in at 39F ambient temperature would reach 226F.

In establishing the performance of heat reclaim devices, the effects of unequal exhaust and supply flows, and the resultant temperature drop and temperature rise, must be taken into consideration. The temperature-drop of the exhaust gas will be in direct proportion to the ratio of supply to exhaust volumes as standard cfm's.

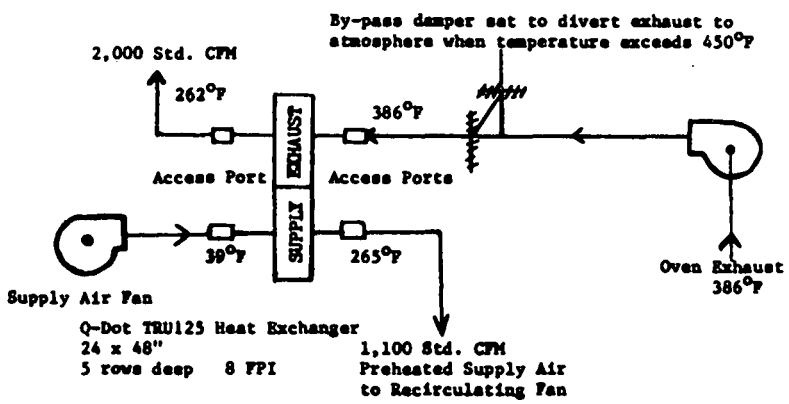
Since this installation uses a 226F temperature rise, but supply volume is only 1,100 scfm compared with 2,000 scfm exhaust, there will be a 124F temperature drop for the exhaust gas. Total amount of heat available for the conditions shown in Figure 1 is 755,000 Btu/hr., and heat being reclaimed is 272,000 Btu/hr. giving a heat recovery of 36% of the available heat in the exhaust.

If a negative system pressure was not necessary, the supply flow could be equal to the exhaust air flow. The exhaust temperature drop would then equal the supply air temperature rise, and the heat loss of the exhaust would equal the heat gain of the supply. In this case, the system would reclaim 53% of the heat available from the exhaust gas.

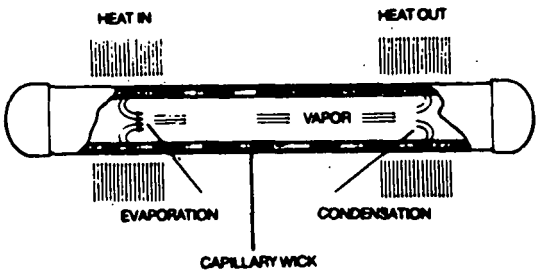
Justification: Calculations indicate that the heat reclaim system will return the original installation cost in just under two years. Because there are no moving parts in the heat pipe coil itself, maintenance costs are limited to periodic cleaning of the coil surface. With no parts to wear out or go out of adjustment, the coil life will equal or surpass that of the oven installation.

Heat pipes: Heart of the Q-Dot heat recovery system is a closed evaporation-condensation cycle Q-Pipe heat pipe capable of transferring heat at an extremely high rate.

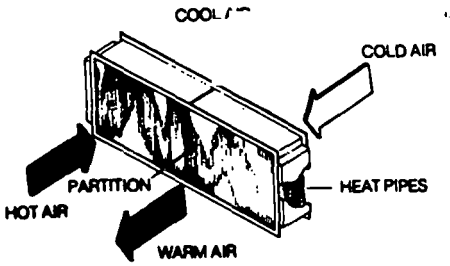
A refrigerant and a capillary wick



Heat pipes carry heat from the exhaust air system to the supply air system. Figures shown are for typical winter conditions, where the incoming air is warmed by 226°F. Heat recovery would be higher with balanced air flows.



Heat vaporizes refrigerant inside heat pipe tube. Vapor transfers heat to other end of the pipe, then returns.



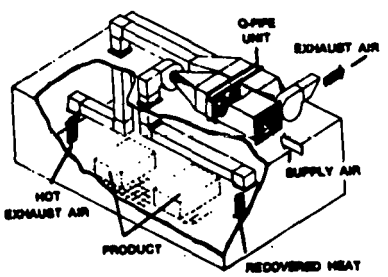
Rows of heat pipes use fins to increase heat transfer surface. Partition separates incoming and outgoing air.

are permanently sealed inside a metal tube setting up a liquid-to-vapor-to-liquid circulation loop. Heat, applied to either end of the pipe, causes the refrigerant to vaporize. The refrigerant vapor then travels to the other end of the pipe, where thermal energy is removed. When heat is removed, the vapor condenses into liquid again and the condensed liquid then flows back to the opposite end through the capillary wick to start a new cycle.

The Q-Dot thermal recovery unit is a counterflow heat exchanger. While it has the outward appearance of an ordinary plate fin heat exchanger coil, it actually contains many Q-Pipes. Each Q-Pipe extends across the total width of the unit, transferring heat from the warm exhaust air to the cooler supply air.

Cross-contamination of the two air streams is prevented by a sealed partition which divides the thermal recovery unit into two sections. Selection of the proper Q-Pipe and thermal recovery unit allows operation of the heat recovery coil at temperatures up to 900F.

Operating costs of the system are minimal, since no external power source is required, and there are no moving parts to wear. With its high heat transfer efficiency, the Q-Dot heat reclaim system offers significant economies and energy conservation potential by recovering heat from exhaust air and returning it to the process or space heating system.



Typical system uses compact heat exchange unit with ducts to provide reliable, efficient heat recovery.

Here's how cost savings were calculated . . .

A study of the economic feasibility of this application had been made using hourly data, summaries provided by the Climatology Division of the Department of Transport for the Toronto area. Temperatures had been averaged for a ten-year period thus allowing an accurate forecast of fuel savings. The study was based on an exhaust temperature of 400° F. and year-round operation of the system.

Paint bake oven yearly heat reclaim tabulation

Average ambient supply air temperature	LVG. supply air temperature	No. of hours observed per yr. at avg. ambient temp.	*Btu's saved per year
93° F	293	17.0	4.03×10^6
85	290	276.6	67.30
73	286	877.6	22.30
63	283	1370.8	354.69
55	279	1344.6	358.29
45	276	1242.4	340.65
35	272	1622.6	468.70
25	269	1039.3	301.02
13	265	595.3	177.02
3	262	275.5	84.05
−5	258	60.8	19.02

*(1.08) (1,100 SCFM) (Temp. Rise) (Observed Hours) = Btu's Saved — $2{,}395.07 \times 10^6$ Btu Year

The yearly fuel dollar savings were then based on the following factors:

- — 5 day per week operation
- — 18 hour per day oven usage
- — 4 weeks shutdown for vacations, holidays, plant inventory, maintenance, etc.
- — 100% efficiency for gas burner
- — a natural gas rate for 1975 of $1.50 per million Btu.

The fuel savings in dollars for 1975 were calculated as

$$2{,}395.07 \text{ Btu/hr} \times \frac{(5)}{7} \times \frac{(18)}{24} \times \frac{(11)}{12} \times \frac{(1)}{1} \times (\$1.50) = \$1{,}764 \text{ per year}$$

(rate)

Similarly, at a predicted Natural Gas rate of $2.00 per million Btu for 1976, the fuel savings for 1976 will be $2,352.

PAY BACK

Upon completion of the installation, all charges and expenses were tabulated. The total cost of materials, labour and equipment for the installation was $4,069. Although the exhaust and supply air flows are minimal and their installed cost were correspondingly high on a dollar per cfm basis, the heat reclaim system will return the original installation cost in just under 2 years.

Because there are no moving parts in the heat pipe coil itself, maintenance costs are limited to periodic cleaning of the coil surface. With no parts to wear out or go out of adjustment the coil life will equal or surpass that of the oven installation.

Q-Pipe Waste Heat Recovery Boiler

Q-DOT

Q-dot KNOWS heat transfer. We are acknowledged world wide as the leader in heat pipe heat recovery. Q-dot understands today's and tomorrow's energy economics. When you provide more efficiency with less — less size, less weight, and less complexity — you've got a WINNER, the Q-Pipe Waste Heat Recovery Boiler.

Q-PIPE WASTE HEAT RECOVERY BOILER

The Q-Pipe Waste Heat Recovery Boiler (WHRB) is designed to convert waste heat from ovens, furnaces, turbines, incinerators, combustion equipment, etc., into valuable steam for use in your plant. The WHRB is comprised of a Q-Pipe Thermal Recovery Unit and a steam pressure vessel.

The Q-Pipe Thermal Recovery Unit is a heat exchanger consisting of numerous individual heat pipe heat exchangers, called Q-Pipes. The effectiveness of Q-dot's patented technology is evidenced by over 3000 Thermal Recovery Units currently in operation.

PERFORMANCE

The Q-Pipe Waste Heat Recovery Boiler produces 15 to 150 psig steam from 500 to 1200°F exhaust gases. The Q-Pipe WHRB is designed to maximize convective heat transfer, the most efficient heat transfer mechanism in this temperature range. With its large finned area, low pressure drop, and extremely efficient heat pipe energy transfer, the Q-Pipe WHRB is more efficient than waste heat recovery boilers intended for higher temperatures and dependent on radiant transfer.

The Q-Pipe Waste Heat Recovery Boiler delivers up to 80% recovery of available energy with less than 1.5" of exhaust static pressure drop.

The Q-Pipe WHRB is up to 50% lighter and smaller than conventional waste heat boilers delivering comparable performance.

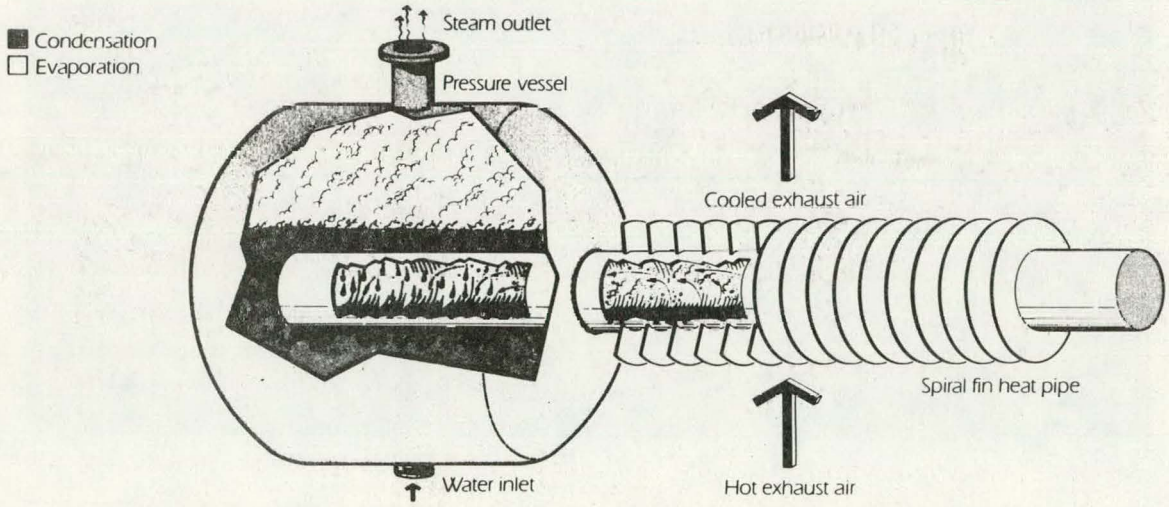
HOW IT WORKS

Each Q-Pipe is an individual, steel, spiral finned tube fabricated with a capillary wick structure, evacuated, filled with an operating fluid, and permanently sealed. Thermal energy applied to either end of the pipe vaporizes the fluid at that end. The vapor travels to the pipe's opposite end where thermal energy is removed, condensing the vapor into liquid and giving up the latent heat of condensation. The condensed liquid flows back to the hot end to be reevaporated, completing the cycle.

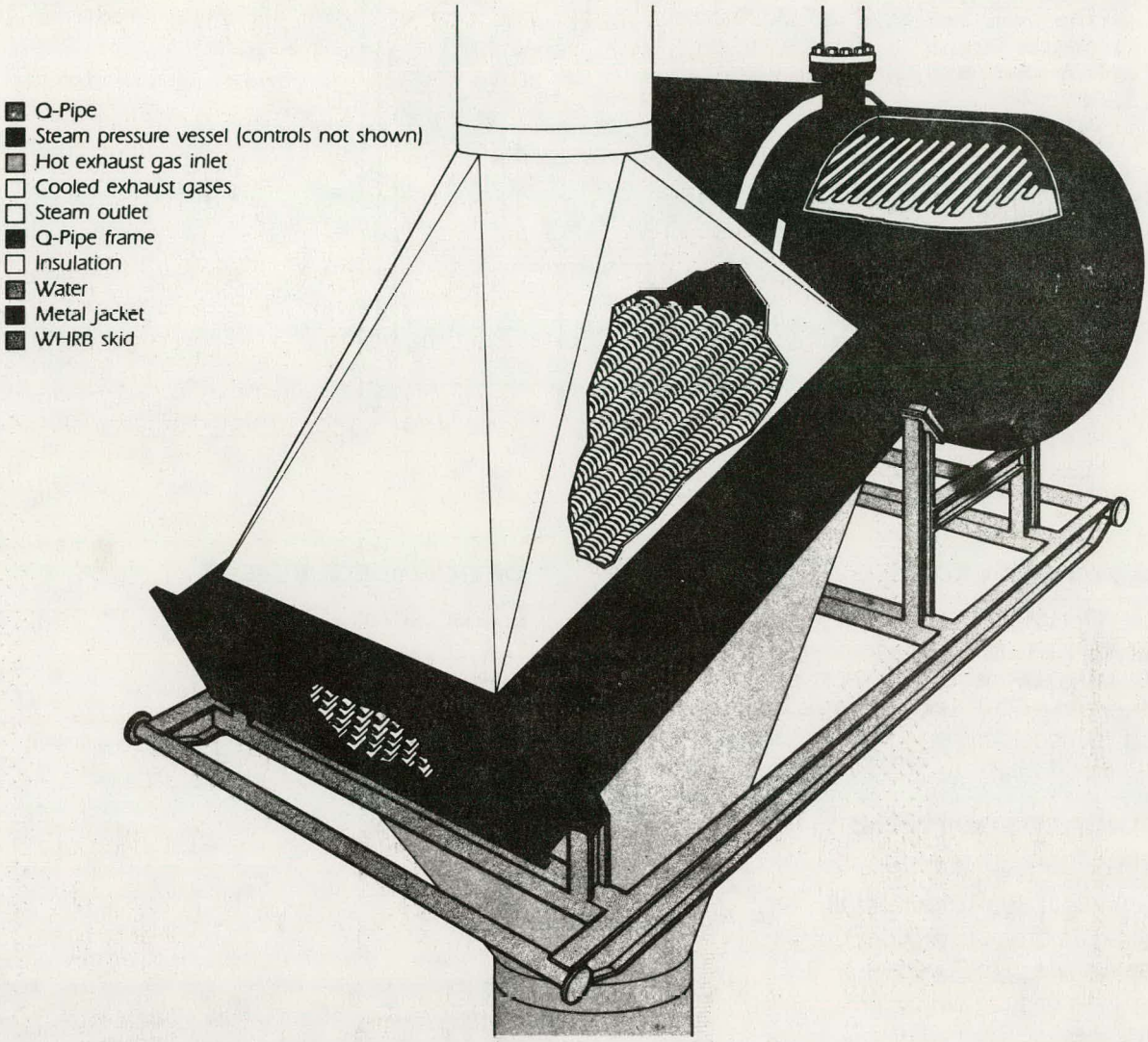
This closed loop condensation-evaporation cycle is continuous as long as there is a temperature difference to drive the process. In the Q-Pipe WHRB, this temperature difference is determined by the water entering the boiler and the exhaust gases passing through the thermal recovery unit.

DESIGNED TO FIT YOUR NEEDS

Q-Pipe Waste Heat Recovery Boilers are custom designed to provide the recovery you need. Standard configurations are sized to accommodate airflows from 4,000 SCFM to 22,000 SCFM. Special units can be fabricated to meet your airflow requirements.



THE WHRB



ADVANTAGES AND DESIGN FEATURES

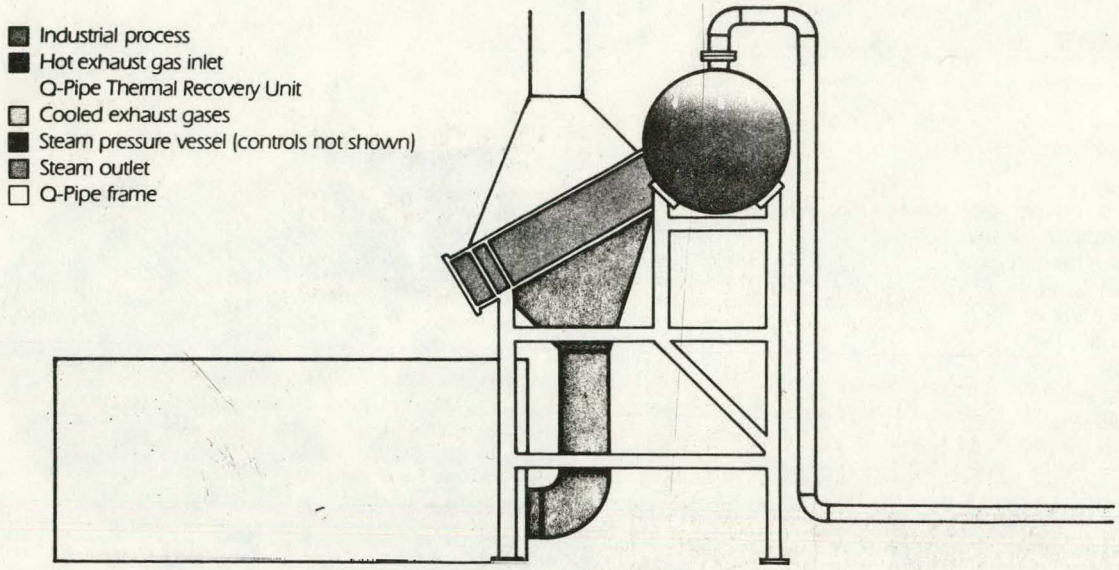
The Q-Pipe Thermal Recovery Unit is the only part of the Q-Pipe WHRB in the exhaust airstream. Because no water flows through it, the danger of water leaking into the duct or process is much less than for any other waste heat recovery boiler.

The Q-Pipes have no moving parts and require no mechanical maintenance. Each Q-Pipe is a self contained heat exchanger. They are assembled in a frame, but are not connected, so there are no tubing bends or joints to create problems. The Q-Pipes are individually replaceable.

To facilitate cleaning, the fin spacing of the Q-Pipes is variable between 2 and 6 fins per inch, depending on the degree of contamination of the exhaust air.

The Q-Pipes are attached to the ASME approved boiler in a manner allowing free expansion on the ends of the Q-Pipes. Removable plates in the boiler permit easy access for cleaning. All aspects of the Q-Pipe WHRB meet or exceed the ASME boiler construction code, and each boiler is hydrostatically tested.

To minimize heat loss, each boiler can be supplied fully insulated and covered with a heavy gauge enameled steel jacket. The Q-Pipe WHRB is delivered ready to install; complete with controls and mounted on its own skid.



COMPUTER ANALYSIS

Your Q-Dot WHRB Sales Representative is prepared to assist you with a free computer analysis of the energy savings and payback time for your Q-Pipe Waste Heat Recovery Boiler. The enclosed selection form details standard models and outlines basic sizing procedure for the Q-Pipe WHRB.

STANDARD EQUIPMENT

Feed Water Controller
Manual Reset Low Water Cut Off
Auxiliary Electronic Low Water Cut Off
Operating Pressure Controller
High Limit Pressure Switch
ASME Pressure Relief Valve
Gauge Glass With Tricocks
Dial Pressure Gauge
Drain and Blow Down Valve
Lifting Lugs
Steel Skid Mounting
ASME Stamping
National Board Registration
Removable Plates for Access to Boiler Interior

OPTIONAL EQUIPMENT

Condensate Return System
Dial Temperature Gauge
Alarm Bell With Silencing Switch
Automatic Blow Down With Timer
Heavy Density Fiber Glass Insulation
Baked Enamel Segmented Steel Jacket

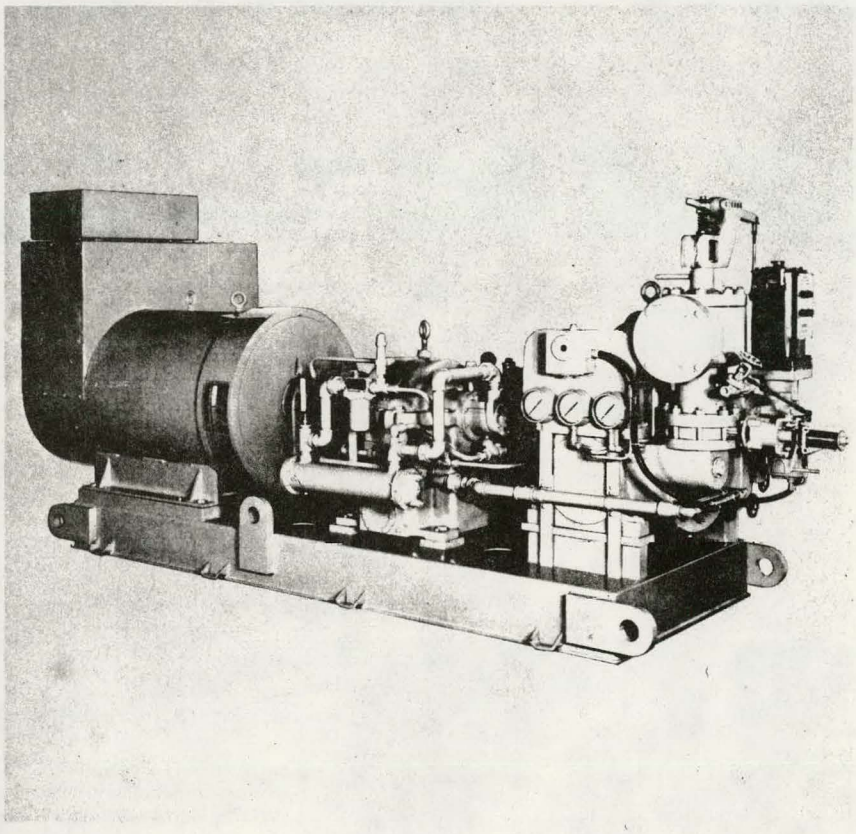
For information on Q-Dot's industrial air to air heat pipe thermal recovery units, write for brochure QIN.

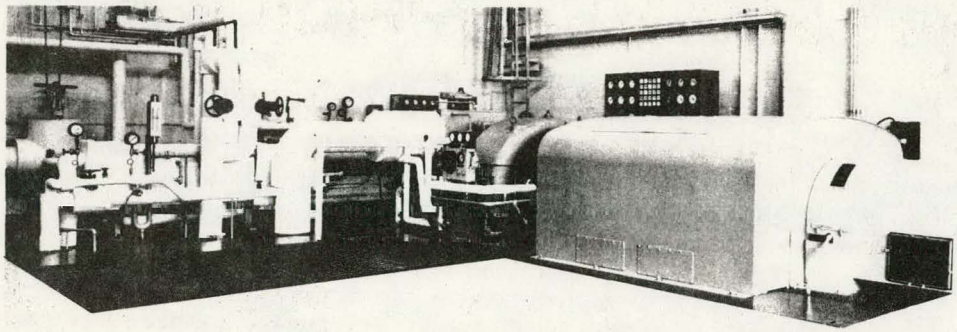
Patents Pending.

Q-DOT CORPORATION
726 REGAL ROW
DALLAS, TEXAS 75247
214/630-1224

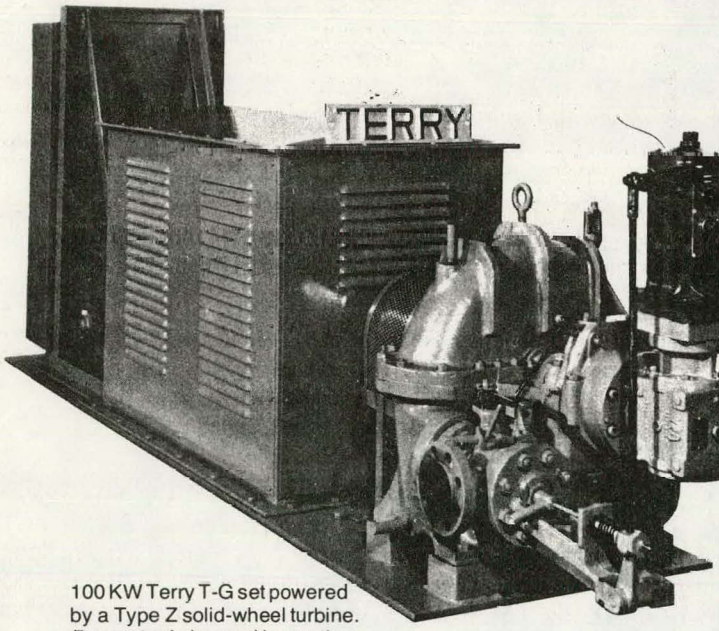
Bulletin WHRB-78-2

TERRY® TURBINE GENERATORS

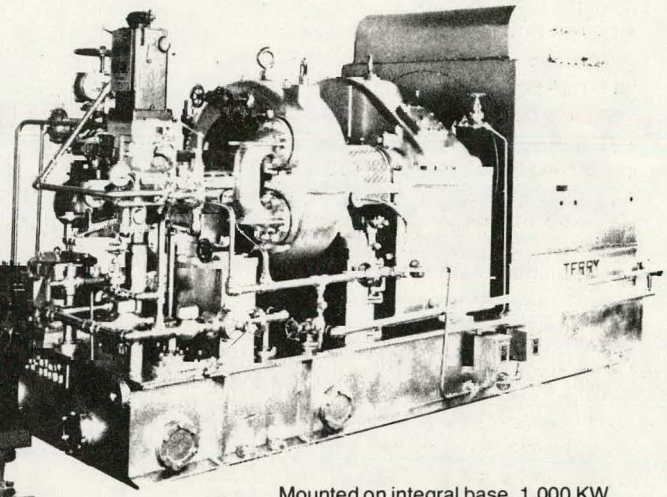




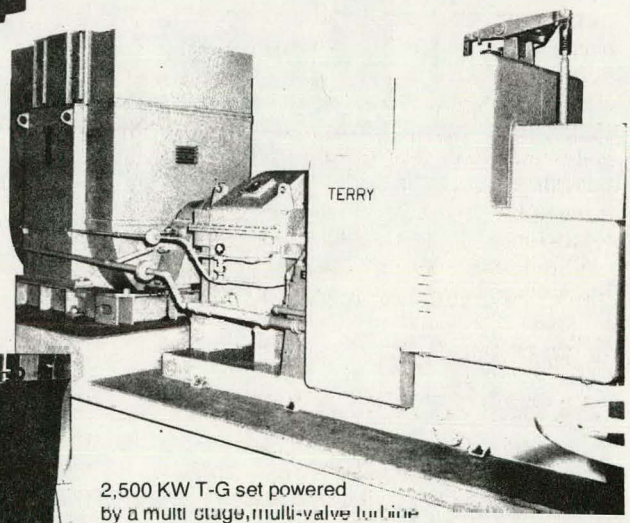
Multi-stage, multi-valve Terry turbine is directly connected to the generator of this 5,000 KW T-G set.



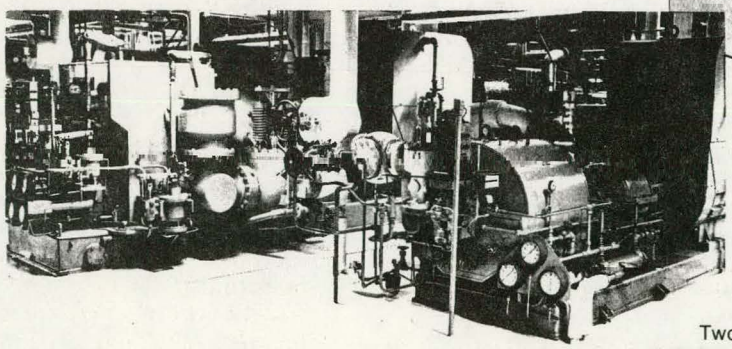
100 KW Terry T-G set powered by a Type Z solid-wheel turbine. Generator is housed in weather protected enclosure.



Mounted on integral base, 1,000 KW T-G set incorporates Terry solid-wheel turbine, Terry gear, and TEWAC generator.



2,500 KW T-G set powered by a multi stage, multi-valve turbine TEWAC generator is driven through Terry reduction gear.



Two 750 KW T-G sets incorporate Terry gears and TEWAC generators. Unit in the foreground is powered by multi-stage, single-valve turbine. Multi-stage, multi-valve turbine powers the other unit.

TERRY® T-G SETS...R G 3ED. EFFICIENT POWER PRODUCERS

Terry manufactures T-G sets with output capabilities ranging up to 15,000 KW. This brochure, however, focuses on units in the 50–1,500 KW range, because the economics of present-day energy management has brought about a changing role for smaller steam turbine generators. In the past, when electric power could be purchased for less than a penny per kilowatt hour, the use of T-G sets rated below 1,500 KW was usually confined to emergency and standby service.

While turbines are still ideally suited to the special requirements of backup duty, the search for ways to combat rising energy costs has resulted in increased use of smaller T-G sets for base load service. More and more energy managers are finding that steam generated for plant or process use is often not fully utilized. In some cases energy is being wasted when pressure reducing valves are used to bring steam pressures down to the levels required in the process. In other cases low pressure steam is being returned to the condenser or vented before all the useable heat energy has been extracted. Similarly available waste heat, which can be used to generate steam in a heat recovery boiler, is often not utilized.

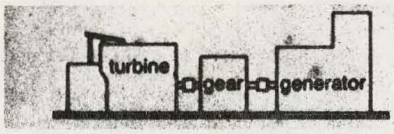
And wherever such waste is occurring, a Terry T-G set provides an excellent way to tighten the plant heat balance equation, conserve valuable energy. In most applications the steam to power the turbine is essentially free, yet the turbine can generate electric power that is worth as much as 5¢/kw-hr.

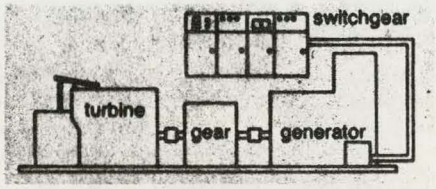
Terry's qualifications

Measured by experience in the turbine field, Terry's record is hard to beat. As a pioneer in the industry Terry started designing and manufacturing turbines in 1903. Since that time Terry has grown steadily and is now a leading supplier of steam turbines. Today there are hundreds of Terry T-G sets installed throughout the world in the petroleum, chemical processing, sugar, paper, marine, and food processing industries. Some units have been installed to meet emergency needs, many are supplying part of the basic plant electric power requirement.

Basic system configurations

Terry turbine generator sets are custom built systems, designed to meet the exact thermal and electrical requirements of each application. Basic components of the system are the turbine, reduction gear, and generator. These three components are normally factory assembled on an integral base, but can be supplied separately. System accessories include such items as couplings and coupling guards, trip and throttle valve, motor operated governor, pressure lubrication, and the full range of instrumentation needed to achieve proper interface with the existing electrical system. In addition Terry can supply the required switchgear and supervisory control equipment.





As the specific parameters are established for each application, system components are carefully selected to assure optimum efficiency, long equipment life, and the lowest possible first cost. For instance, in base load service the opportunities for long-term energy cost savings usually dictates the use of multi-stage turbines. Yet, for applications that call for cold, fast starts, a Terry single-stage, solid-wheel turbine is the best alternative.

The choice between direct connected and geared systems is also carefully evaluated from the standpoint of cost and overall system efficiency. Such factors as operating environment, electrical characteristics of the served load, and space limitations are thoroughly reviewed to match generator capabilities and application needs. In addition where there is a need to match new and existing switchgear or generators, Terry has the flexibility to put together the desired components.

Turbine selection

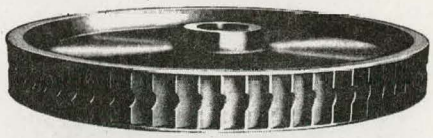
At Terry two basic types of turbines, single-stage or multi-stage machines, can be used to power T-G sets. Multi-stage machines usually consist of a Curtis stage followed by the proper number of Rateau stages, while single-stage machines may incorporate the unique Terry solid-wheel or a standard Curtis stage.

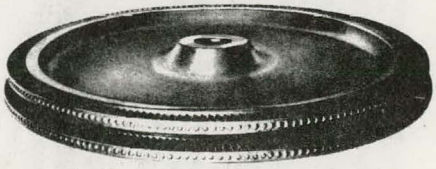
Single-stage turbines are normally non-condensing machines, used where low first cost is essential. In addition the inherent higher steam flow requirements of single-stage turbines makes them suitable for applications where the turbine serves as a pressure reducing device as well as providing shaft power to drive a generator.

Multi-stage turbines may be either condensing or non-condensing machines. First cost is, of course, higher than for single-stage machines, yet the efficiency of multi-stage turbines often result in fuel cost savings that are far greater than the difference in the initial cost.

Single-stage

When the application calls for single-stage turbines, the choice between a solid-wheel and a bladed-wheel machine is made on the basis of steam quality, the severity of the duty cycle, and the required KW output.





That is, where the required output is below 1,000 KW, available steam is wet or dirty, or where fast, cold starts are required, a Terry solid-wheel machine is hard to beat. The superiority of the solid-wheel design results from single piece construction, and the unique bucket configuration. Single piece construction means that there are no

separate parts to become loose or work out. And since the power producing action of the steam takes place at the backs of the buckets, wear does not materially affect performance.

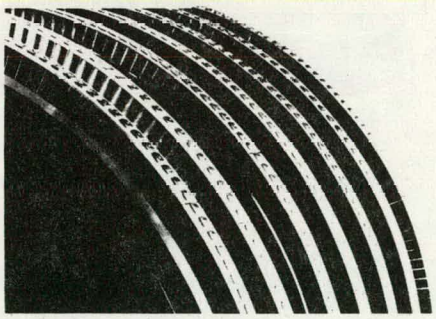
Terry solid-wheel turbines are available in output ratings up to 1,000 KW. Inlet pressures and temperatures can range to 1,500 PSIG, (105.4 KG/CM^2) and 1,000 FTT (538 C). Exhaust pressure upper limit is 400 PSIG (28.1 KG/CM^2).

Where steam quality is satisfactory and starting requirements are normal, bladed-wheel turbines can be used. Their higher efficiency and larger size provides greater power producing capability.

Terry single-stage, bladed-wheel turbines are capable of delivering from 1,500 to 2,000 KW with the specific rating depending on the pressure and temperature of available steam. These turbines are designed to operate at inlet temperatures and pressures up to 1,500 PSIG (105.4 KG/CM^2)—950 FTT (510 C) and exhaust pressures up to 400 PSIG (28.1 KG/CM^2).

Multi-stage

Today the rapidly rising cost of fuel makes driver efficiency more important than ever. Thus the efficiency gains possible from multi-stage turbines can pay big dividends, particularly when the turbine is applied in base load power generation service. In the 1,000 KW size range the efficiency gain possible with a multi-stage machine compared with a single-stage machine is about 11 percent. And measured in terms of fuel cost savings that's about enough to write-off the first cost of the turbine in just 12 months.



Terry manufactures a variety of multi-stage turbines. The Type GAF, one of these multi-stage machines, is well suited for powering T-G sets rated in the 500–3,000 KW range. Extremely compact, the length of a GAF is only about a foot longer than its single-stage counterpart. Width and height are about the same for both types.

Terry GAF turbines are impulse-type machines which are suitable for condensing or non-condensing service. Rotor designs incorporate materials and features that assure maximum thermodynamic efficiency, and long operating life. Wheels are made from forged steel discs with large hubs, which are shrunk on and keyed to the shaft. Assembled rotors are dynamically balanced. Other major turbine components such as bearings, governor valve, casings, diaphragms and glands are also designed and manufactured for minimum maintenance, maximum operating efficiency.

Type GAF turbines can meet the requirements of NEMA SM-23 and API 611/612 standards. Output capability of GAF machines ranges up to 3,000 KW. Inlet pressure and temperature limits are 700 PSIG (49.2 KG/CM^2) 950 FTT (510 C) and exhaust pressure condensing to 105 PSIG (7.4 KG/CM^2).

Generators

Every Terry T-G set incorporates a generator which is carefully selected to meet the critical performance requirements of the application . . . at a reasonable cost.

Generator efficiency is thoroughly evaluated. Transient performance is checked, to the extent possible, to make sure that the generator has the capability to handle plant starting loads, without excessive voltage dip.

Torsional compatibility studies are made when necessary to be sure that the turbine drive and the generator are matched. And the mechanical/electrical integrity of all generator components is critically evaluated to be certain that maintenance requirements will be minimal . . . operating life long and trouble free.

Where there is a need to match new and existing equipment, Terry can provide a generator manufactured by virtually any supplier.

SPECIFICATIONS:

The range of generator characteristics and capabilities available are tabulated below.

- **Size range**—up to 1,500 KW
- **Type**—synchronous or induction
- **Frequency**—50 or 60 Hz
- **Voltage**—standard voltages through 13,800 V
- **Power factor**—0.8
- **Excitation**—brushless or static
- **Insulation**—Class F, or as specified
- **Enclosures**—drip-proof, splash-proof, weather-protected, totally enclosed forced-ventilated, and totally enclosed water-to-air cooled
- **Temperature rise**—to NEMA standards
- **Bearings**—ball or sleeve
- **Lubrication**—ring or pressure, either self-contained or combined with turbine and gear

When required, a variety of control and instrumentation can be incorporated into a Terry T-G set. Available items include: Voltmeter, ammeter, frequency meter, voltmeter/ammeter selector switch, manual or electrically operated main circuit breakers of appropriate interrupting capacity, and synchronizing capability. Controls and instrumentation may be unit mounted or supplied in a free standing enclosure.

In total, the flexibility possible in terms of generator performance and design is virtually limitless. Yet, whatever the specific type or style of generator chosen, you can be sure that Terry engineers will carefully balance cost and performance considerations so that the system meets all your requirements.

Gears

First cost and operating cost considerations may dictate the use of a speed reducing gear in Terry T-G sets. From the standpoint of first cost, experience has shown that the premium paid for 3,600 rpm generators can exceed the cost of a gear many times over. From an operating cost point-of-view, running turbines in this size range at 3,600 rpm seldom permits achieving maximum efficiency. Each application is, of course, critically evaluated to make sure the use of a gear does in fact, result in the best overall cost/efficiency relationship.

And when a gear provides the best solution, a rugged precision built Terry gear is used. Experience-proven in thousands of applications, Terry gears are single-reduction, fully enclosed, double-helical, high-speed units, built to AGMA standards. Gears and pinions are machined from special alloy steel forgings and heat treated to achieve the proper combination of wear resistance and strength. The sleeve bearings are carefully matched to specific speed and load characteristics. All bearings and the gear mesh are pressure lubricated with filtered and cooled oil. Steel, flexible, gear-type couplings are normally used to connect the turbine, gear, and generator. Guards are designed to meet OSHA requirements.

SPECIFYING AND APPLYING TERRY T-G SETS

The process of selecting a T-G set should start with a determination of four basic application parameters. They are:

1. What is the amount, cost per 1,000 lbs., quality, pressure, and temperature of the available steam?
2. Can exhaust steam be utilized in the plant process or will it be directed to a condenser?
3. What type of duty cycle is required, base load, intermittent, or emergency service?
4. What is the character of the load to be served?

Available Steam—The need to carefully establish the character and amount of available steam is required so that a correct turbine selection can be made, and so that the Terry T-G set can be properly sized.

Steam quality (water content and chemical composition) often provides the basis for choosing between a bladed-wheel or solid-wheel machine. Steam pressure and temperature provides the basis for determining turbine type (single- or multi-stage), and for determining the kilowatt output that can be achieved. And a meaningful assessment of the economics of the application requires establishing the cost, expressed in dollars per 1,000 lbs. of generating steam at your plant location.

The information and chart below provides a method of roughly estimating how many kilowatts can be produced from a given amount of steam. Precise determination of output capability, of course, requires detailed calculations by the Terry engineering department.

Exhaust Steam Utilization—Another important factor on the thermal side of the equation is the need or desirability of using turbine exhaust steam to meet process or plant heating needs. Thus the steam pressure and steam flow requirement for the process must be established. If steam is not used in the plant process it is necessary to establish the vacuum level at which the steam is condensed.

Duty Cycle—Turbine selection is affected significantly by the type of service expected of the Terry T-G set. Base load and even intermittent service dictates the use of a turbine delivering maximum efficiency and the resultant minimum fuel cost. Fuel cost on the other hand is usually not as important in emergency service where the rapid, cold start capabilities of the turbine become the key selection factor.

Character of Load—A variety of factors control generator selection. The most important, however, is the make up of the served load. For instance, squirrel cage and synchronous motors draw several times full load current from the power supply under starting conditions. Conventional resistance load such as lighting equipment, on the other hand, does not create a significant starting current problem. Thus a detailed profile of the served load is needed to size the generator.

Other essential electrical system characteristics that must be established include; 1) Operating voltage. 2) Power factor. 3) Paralleling requirements . . . with another generator or the utility. 4) Permissible voltage dip, particularly as it relates to starting the largest motor or power consuming device. 5) Switchgear capability expressed in terms of manual or automatic operation and the specific MVA interrupt capacity of the breakers. 6) Desired generator connections, Wye or Delta.

In addition to carefully establishing electrical requirements it is necessary to define the environment in which the T-G set will operate. Without this information it is not possible to select a proper enclosure.

Estimating T-G performance

Determining the **approximate** operating efficiency of a T-G set is simple, readily accomplished by using the chart to the right.

The dotted line connecting the three elements of the chart demonstrates the sequence of the process. That is, starting at the upper left-hand corner inlet steam conditions and exhaust pressure for the application are established. Power range for either a single-stage or a multi-stage turbine is taken from the lower right-hand chart. Approximate efficiency can then be picked off the lower left-hand scale. In this example efficiency is 61%.

Steam Rate—Having established T-G efficiency, it is now possible to calculate steam rate. The first step requires establishing the amount of energy available for use in the turbine, then determining what portion of this heat will be converted to electric energy by the T-G. Remember whatever is not converted is **still** available for process use. Using Steam Tables or a Mollier Diagram the following calculations are required.

Available energy = isentropic heat drop = inlet enthalpy − exhaust enthalpy

Inlet enthalpy (at 650 PSIG, 750 F) = 1,377 BTU/lb

Exhaust enthalpy (isentropic drop to 4" Hg Abs) = 957 BTU/lb

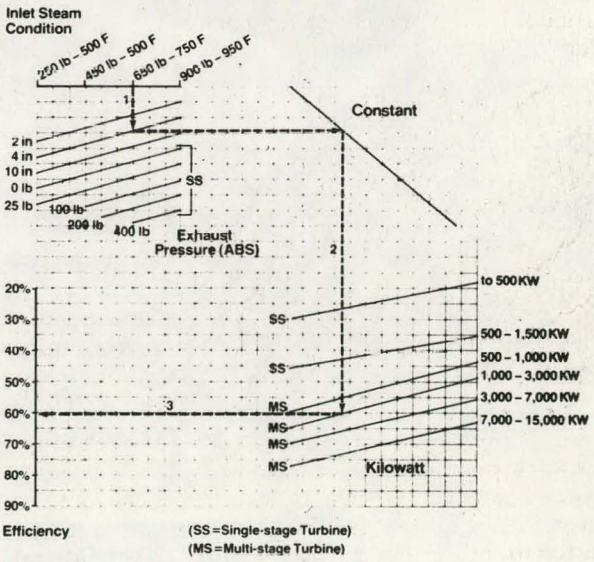
Available energy = 1,377 − 957 = 420 BTU/lb

Now the steam rate can be calculated.

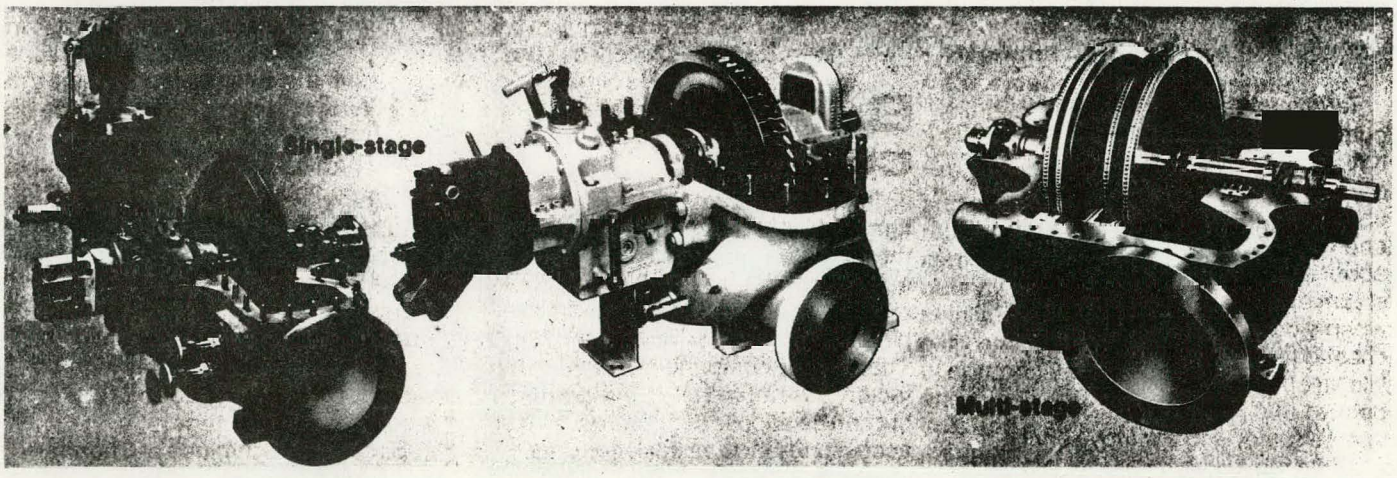
$$\text{Steam Rate} = \frac{3{,}413 \text{ BTU/KW-hr (a constant)}}{420 \text{ BTU/lb} \times .61 \text{ (T-G efficiency)}}$$

Steam Rate = 13.3 lb/KW-hr

Thus to determine the pounds per hour of steam required to operate the T-G, multiply the steam rate by generator kilowatts. Or divide the steam flow available by the steam rate to determine the number of kilowatts that can be generated.



T JRBINES



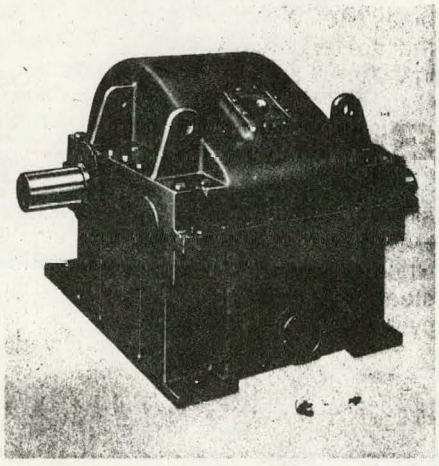
Terry single- and multi-stage turbines offer performance capabilities that are ideally suited to power generation service. Each of these turbines have established outstanding records in terms of efficiency, reliability, and ease of maintenance.

Terry single-stage, axial-flow machines are designed for high-volume, high-flow applications. These turbines meet the requirements of NEMA SM-23-1979 and can be easily modified to meet API-611 specifications.

Terry solid-wheel turbines are impulse, helical-flow machines that offer exceptional ruggedness and minimal maintenance requirements.

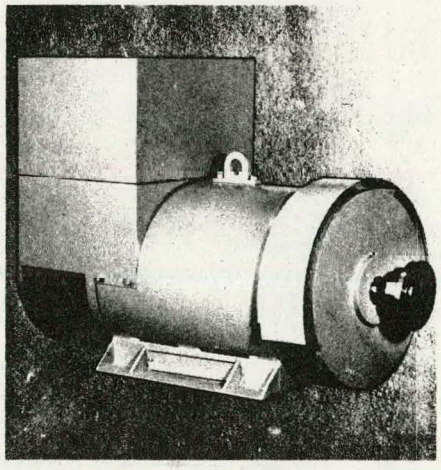
Type GAF turbines are extremely compact, multi-stage, axial-flow machines which are ideally suited for base load applications where maximum efficiency is imperative.

GEARS



Terry gears are high-speed, double-helical, parallel-shaft units designed to deliver efficiencies as high as 98%. Standard gears will readily accommodate the pitch line velocities encountered in turbine generator service.

GENERATORS



Every Terry T-G set incorporates the generator best suited for the application because Terry is not encumbered by the limitations of their own narrow product line. Generators from virtually any manufacturer can be supplied with the resultant benefits in terms of cost and performance.

Ready to Serve

Terry maintains a worldwide sales and service organization. Experienced engineers are always available to help with application problems. Factory-trained service engineers are available to supervise installation and provide operator training. And when parts, repairs, or overhaul are required the Terry PRO organization is ready to meet your needs throughout the world.

TERRY STEAM TURBINE COMPANY
P.O. Box 555 Windsor, Connecticut 06095 U.S.A.

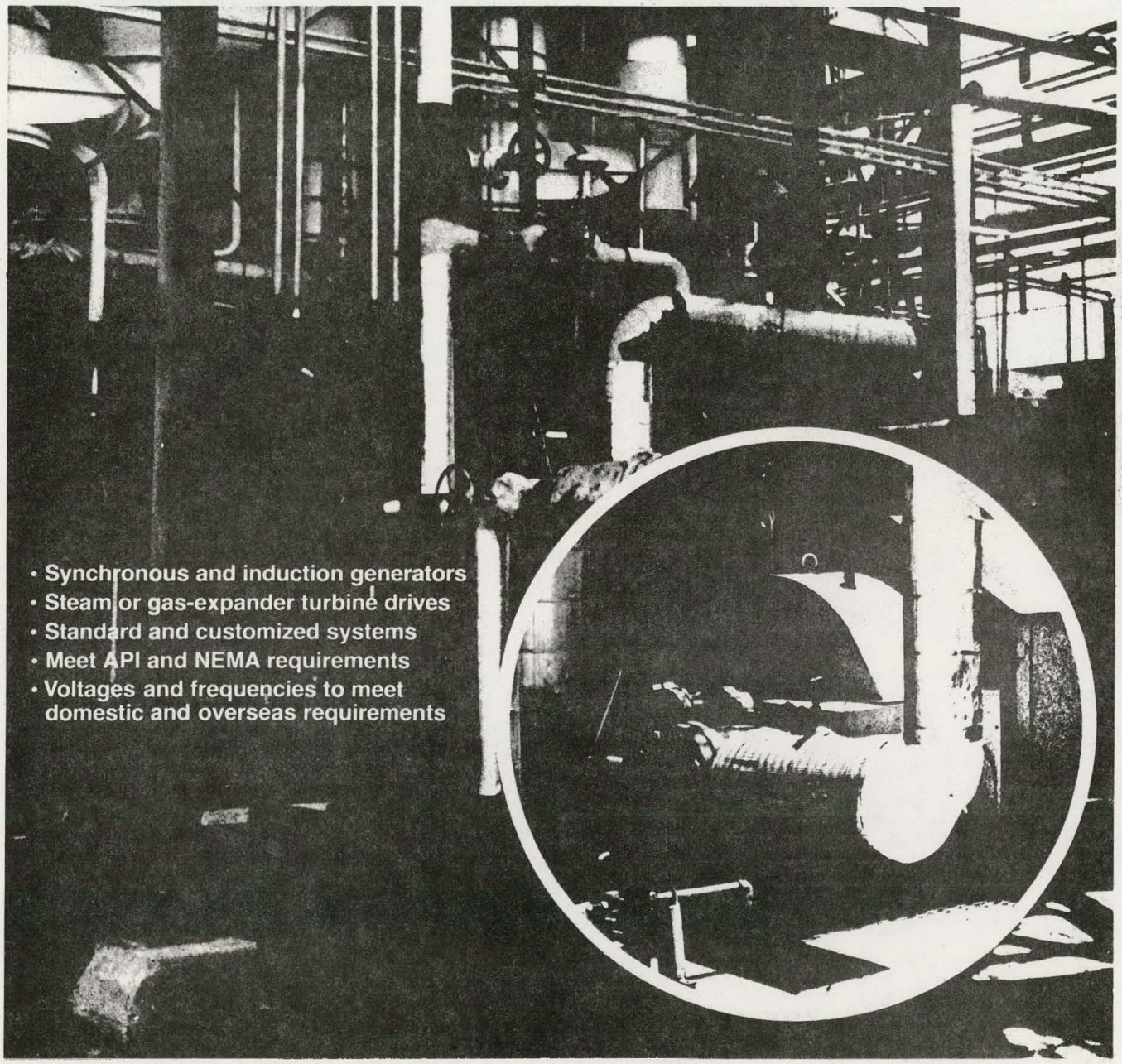
Bulletin No. S-246 2/80

COPPUS

TURBINE GENERATOR SETS

UP TO 2500 KW

Reliable continuous or standby Electric Power– Energy Saving Cogeneration



- Synchronous and induction generators
- Steam or gas-expander turbine drives
- Standard and customized systems
- Meet API and NEMA requirements
- Voltages and frequencies to meet domestic and overseas requirements

COPPUS TURBINE GENERATOR SETS —the reliable choice for continuous service— emergency power—cost-saving cogeneration.

Coppus is the leading manufacturer of single-stage steam turbines in the 1/2 to 4000 HP range. The company offers the most complete line of types and sizes, has the broadest application experience, and leads the industry in design advances.

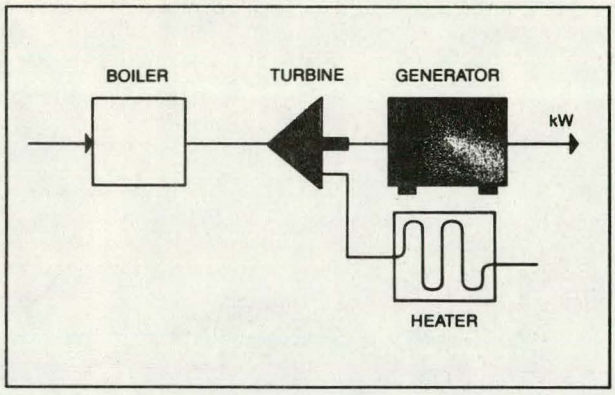
Today, thousands of Coppus Turbines and Turbine Generators are providing cost-saving independence from utility-supplied power, cogeneration to reduce purchased power, as well as an economical source of emergency power. In major refineries, petrochemical, manufacturing and processing plants, hospitals, commercial buildings and similar locations where power supply is critical, service-proven Coppus units assure the utmost in dependability. Their use is growing, particularly in areas where high electric rates underscore the substantial cost savings possible with turbine generator sets.

■ LOW INITIAL COST, ECONOMICAL OPERATION

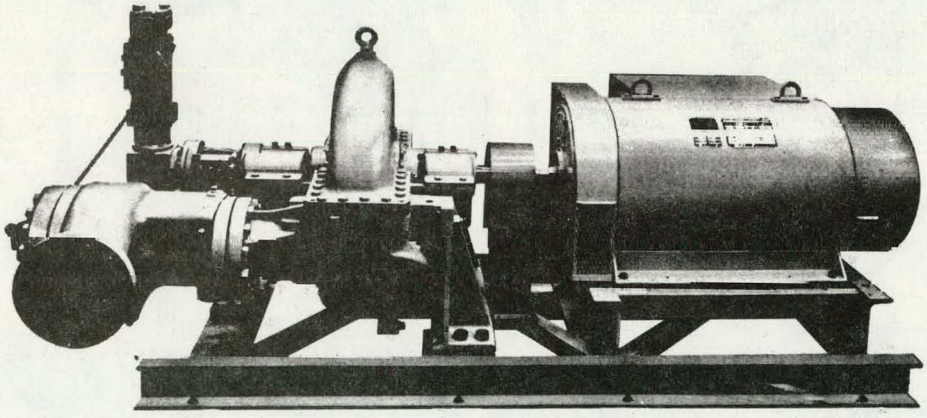
The straightforward design of Coppus Turbines provides a highly reliable, and uncomplicated prime mover for generators. Their initial cost in most cases is considerably less than diesels and other generator drives. Moreover, where high-pressure steam is available, operating efficiencies can provide tremendous additional savings over the years, particularly where low-pressure steam is used for heating or process work. That's because the operating cost of a back-pressure turbine depends solely on the amount of energy consumed while the steam is expanding through the turbine from high pressure to low pressure. Since the low-pressure steam retains most of its heat for other work, shaft horsepower is developed at a fraction of the operating cost of other prime movers.

■ LONG-LIVED DEPENDABILITY

Coppus Turbines and Turbine Generators Sets are capable of operating for years in continuous service with little or no downtime for preventive maintenance or replacement of parts. Since turbines run on steam, compressed air, or gas, their operation is independent of electric power for starting or driving generators, and they eliminate the problems associated with other types of drives—such as fuel tanks running dry, failure of auxiliary starting gear, or weak banks of batteries. In addition, turbine drives are safe in hazardous atmospheres, minimizing the risk of electric sparking and offering maximum protection against explosion.



Typical Turbine Generator Set/Process Steam System



■ The Basic Coppus Turbine Generator Set

The basic Coppus Turbine Generator Set consists of a Coppus single-stage turbine, directly connected through a flexible coupling or through a single-reduction gear box to a synchronous or induction generator, all mounted on a welded-steel base. The couplings between the turbine and generator are covered by a safety guard. Basic control packages are included for the various applications as specified.

COST SAVING APPLICATIONS

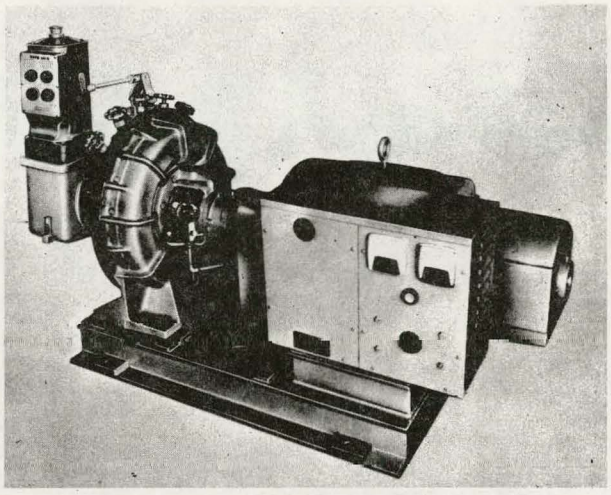
■ STANDBY/EMERGENCY POWER SUPPLY

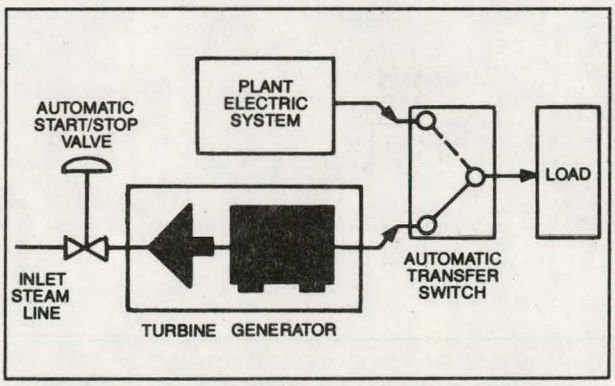
Coppus Turbine Generator Sets are ideal for providing emergency power for lights, utilities and essential equipment. In refineries and petrochemical plants, for example, a combination of mechanical turbine drive and a small generator providing power for electric instruments and essential services insures uninterrupted plant operation during electrical outages. Other applications include commercial buildings, schools and public facilities; and life-critical installations in hospitals where dependable electric power is an absolute necessity. In many cases, where turbine generators are required to start automatically after steam is admitted to the turbine, Coppus furnishes the entire automatic emergency power package including the automatic start-up valve, automatic transfer switch and any other accessories needed to meet individual specifications.

Coppus Turbine Generator Sets provide power within seconds of main power source failure.

Automatic or manually operated sets are available. In automatic start-up sets, loss of power signal opens automatic start-up valve and automatic transfer switch swings load from plant power system to turbine generator set.

In manually operated sets, the operator simply opens the block valve and closes the circuit breaker.





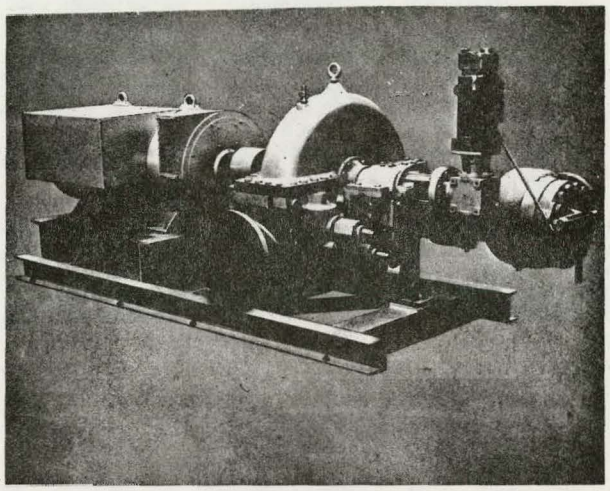
Automatic transfer switch shown in solid line when Turbine Generator Set is furnishing power. Dotted line shows switch position when Turbine Generator Set is on standby.

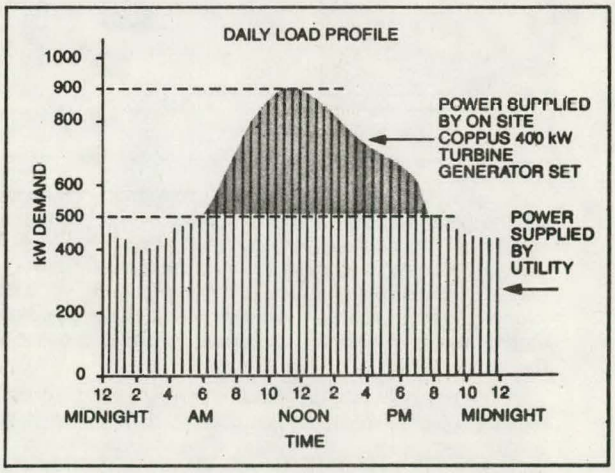
■ PEAK SHAVING

Very few plants have a constant electric power demand. Daily and seasonal swings are commonplace. In these situations, demand charges are usually imposed by the utility over a 12-month period based on the maximum peak demand.

Where steam-generating capacity is available, Coppus synchronous or induction turbine generator sets are selected to reduce this demand charge. Known as "peak shaving", this reduction can be achieved by switching fixed loads to the turbine generator on an isolated line by means of a transfer switch. Or, where variable loads cause peak demand, the turbine generator set can simply operate in parallel with the utility through a tie-breaker system.

Whether requirements call for manual control or completely automatic operation, Coppus offers a peak shaving system that will provide the simplest, most cost-effective solution.





Power supplied by Coppus 400 kW Generator Set, shown in blue shaded area, reduces demand charges from 900 kW to 500 kW.

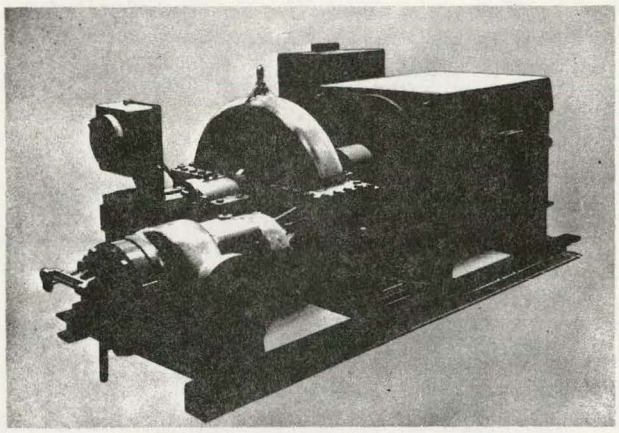
Cost Saving Applications continued on page 4

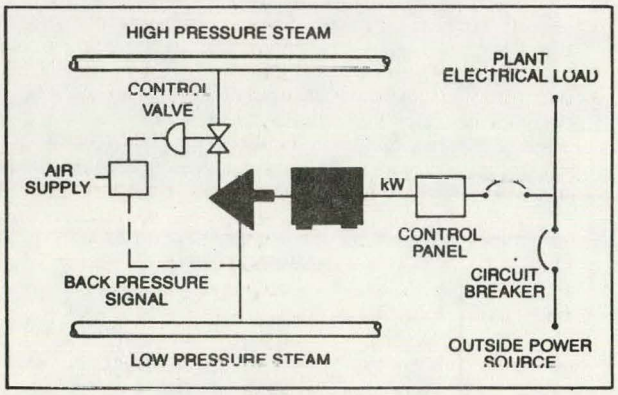
■ IN-PLANT COGENERATION OF ELECTRICAL POWER

Cogeneration is simply the production of electricity or mechanical energy in conjunction with the production of heat used in a process ("topping cycle") or from the waste heat produced by a process ("bottoming cycle").

In the topping cycle, steam is pressure-reduced through a turbine before being used for heating or process work. In the bottoming cycle, waste heat available as a by-product of a process is used to produce the steam that runs the turbine generator.

In either case, cogeneration can provide electricity at a fraction of the cost of purchased power.

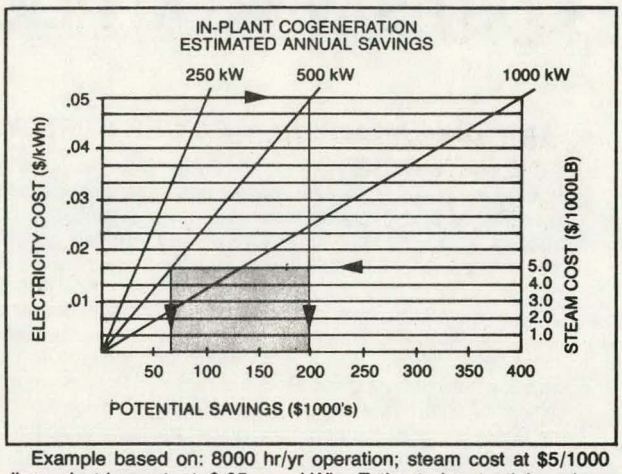




In this typical "topping cycle" cogeneration schematic, the turbine generator set operates in parallel with plant electrical system to reduce cost of purchased power. A simple back-pressure control maintains low-pressure steam flow to meet actual process demand. The turbine generator set produces kilowatts as a function of the demand for low-pressure steam and continuously optimizes the heat balance within the system.

In "bottoming cycle" applications, heat produced by prime movers, kilns and furnaces is recovered to generate steam in a waste heat boiler. This steam is used to operate a turbine generator set that produces kilowatts that can substantially reduce operating costs.

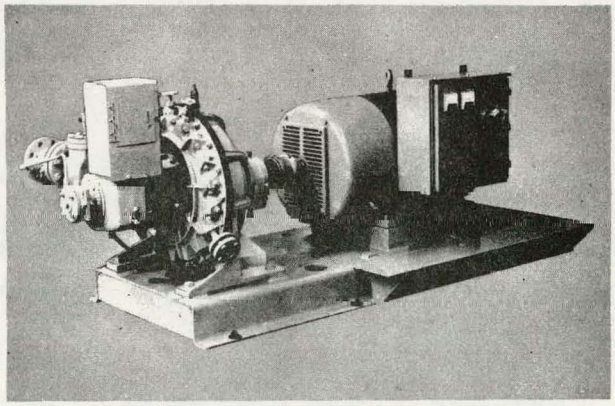
Cogneration savings can be estimated using the chart in the next column. Enter chart at your kW cost on left. Proceed right to your kW potential. Enter chart at your steam cost on right. Proceed left to kW potential. Annual saving is the difference between these two points as shown in the example.



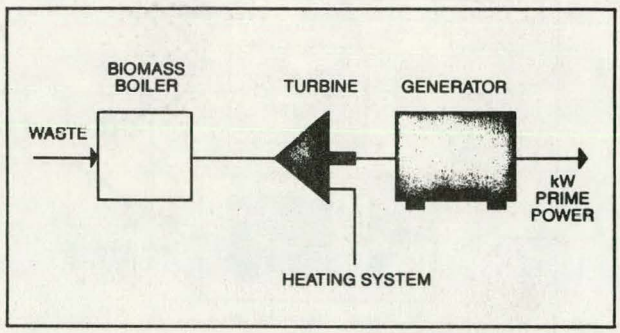
Example based on: 8000 hr/yr operation; steam cost at $5/1000 lbs.; electric cost at $.05 per kWh. Estimated potential savings $130,000 per year.

■ PRIME POWER SYSTEMS

In many installations, Coppus Turbine Generator Sets can provide for most or all of the power needs of users. Known as "prime power systems", these installations are typically found in plants where waste fuel or waste heat may be available in sufficient quantities, or in places where outside power sources are unreliable or not readily accessible.



Specially designed prime power Turbine Generator Set for outdoor installation includes totally enclosed fan-cooled generator, weather-proof panel for controls and circuit breaker, protective hood for NEMA D Isochronous governor.



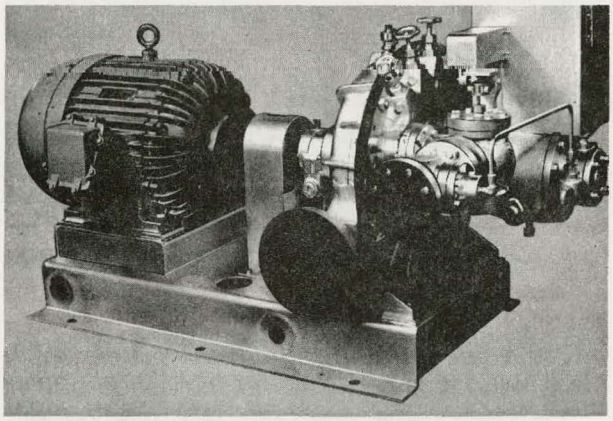
Waste fuel—bagasse, wood chips, peanut shells and other refuse—is used to fire boilers that produce steam to drive turbine generators. Such "free" fuel, combined with the economies of cogeneration, justifies installation of complete waste-burning systems that meet total plant power demand.

CUSTOM ENGINEERED TURBINE GENERATOR SETS FOR SPECIAL APPLICATIONS

■ GAS EXPANDER TURBINE GENERATOR SETS

In locations where high pressure or well head gas is available—such as oil production rigs, gas pipelines, gas platforms—Coppus Gas Expander Turbines have been used to drive generators that provide critical electric power for navigational lights, communication systems, computerized controls and other essential equipment.

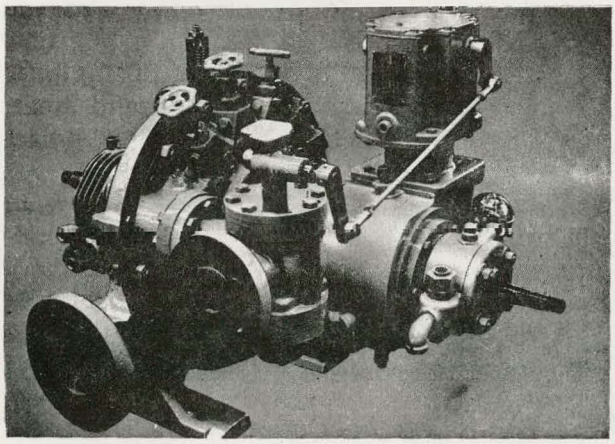
This application-proven technology is now being applied to Coppus Gas Expansion Turbine Generator Sets that provide "free" kilowatts wherever gas is being let down to a lower pressure.



Typical Coppus Gas Expander Turbine Generator Set.

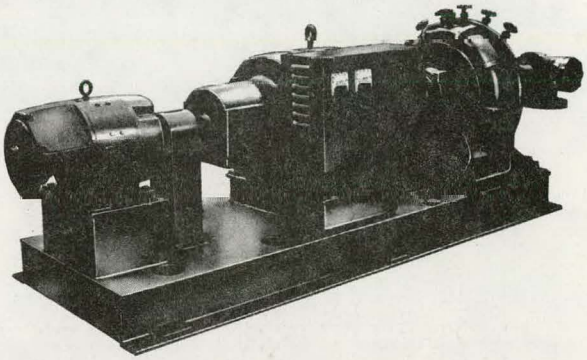
■ UNIQUE DUAL DRIVE TURBINE SERVES DUAL-PURPOSE APPLICATIONS

Coppus' total turbine generator capability is exemplified by its double-ended shaft turbine which can drive two machines simultaneously. For example, one turbine can protect both your forced draft fan and your boiler instruments from electric power failure by driving the fan from one end and a generator for instrument power from the other end.



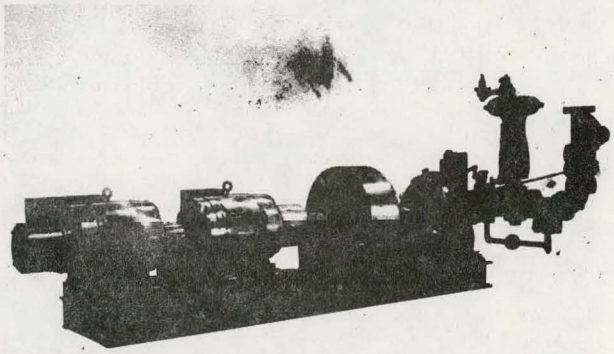
■ AC/DC TURBINE GENERATOR SETS

In applications where both AC and DC power is required in plant operations, Coppus can supply packaged units with both AC and DC generators driven by a single Coppus turbine to provide emergency standby power.

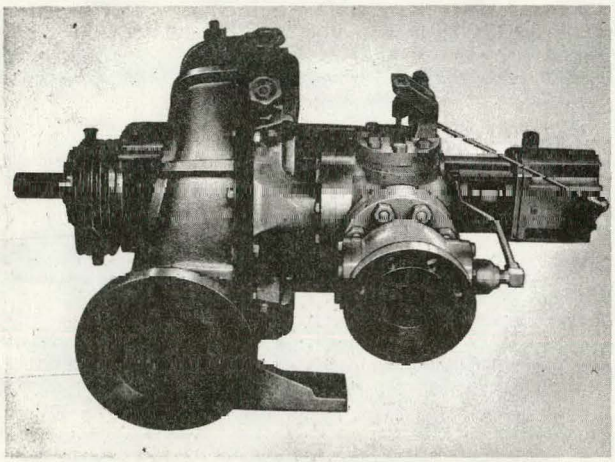


■ COPPUS "NO BREAK" TURBINE-MOTOR-GENERATOR SETS

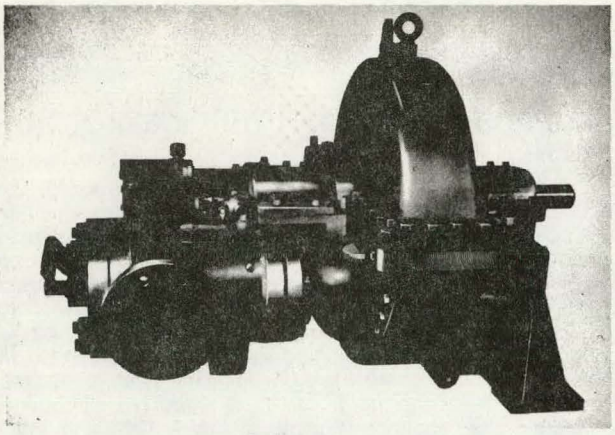
There are many situations where it is mandatory to have reliable, continuous electric power available even though there is no demand for exhaust steam. A process-control computer and critical instrumentation systems are good examples. Coppus "no break" turbine-motor-generator sets are ideal for such applications. Such sets normally include a turbine with isochronous governor, fly wheel, double-ended shaft synchronous motor and generator mounted on a single base plate. In normal operation generator is driven by the synchronous motor. In the event of power failure the fly wheel holds frequency output of the generator within acceptable limits during switch over to turbine drive. Isochronous governor on turbine holds the steady state frequency output of generator within 0.5% over the full load range.



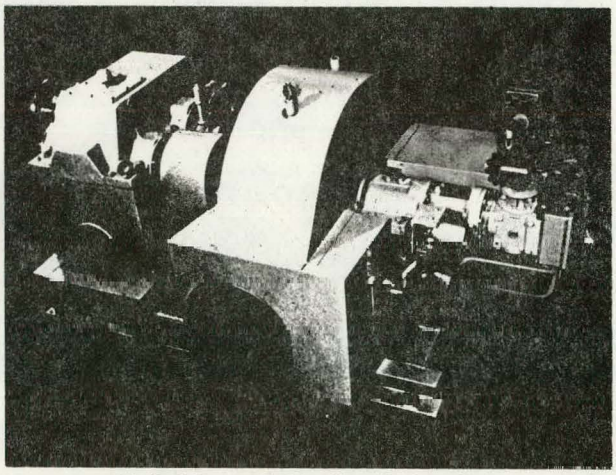
MAJOR COMPONENTS OF ENERGY COST SAVING



RL Turbine



RLH Turbine



Typical Coppus Turbine Gear Reducer Set

■ COPPUS RELIABILITY ENGINEERED TURBINE DRIVERS

Coppus offers the broadest range of energy-saving, single-stage turbines in the 1/2 to 4000 HP range. RL Turbines are available in 10 sizes from 1/2 to 1000 HP for generator sets delivering up to 650 kW. RLH Turbines are available in 3 sizes up to 4000 HP for generator sets delivering up to 2500 kW.

With this wide choice of turbine sizes and capacities, Coppus can select the most efficient, economical driver for synchronous, induction or DC generators required for specific applications.

Engineered throughout to provide the utmost reliability, Coppus Turbine Generator Sets offer all the inherent advantages of single-stage steam turbine drives—low initial cost, low operating costs, speed flexibility and low maintenance.

Typical Features

- Shaft driven oil relay governors.
- Horizontal and vertical split casings.
- Automatic start-up capability.
- Automatic shut-off capability.
- Independent excess speed safety trip.
- Hand speed changer.
- Heavy flanged safety brake rim on RL's.
- Long life, steel backed sleeve and anti-friction bearings.
- Removable carbon ring sealing glands.
- Unique In-tur-trol, integrated turbine speed control system on RLH's.
- Rugged support systems.
- Maximum capacity nozzles.
- Removable steam strainer.
- Rugged two row Curtis type wheel.
- Large diameter stiff shaft for low-stress, high-speed operation.

■ COPPUS TURBINE GEAR DRIVES

Turbines have a unique flexible speed capability—they are not limited to synchronous speeds. This feature offers the opportunity to select turbines with operating speeds that will optimize their efficiency. To capitalize on this high efficiency opportunity in generator set applications, Coppus turbine gear drives can be used to match the generator's operating speed with turbines operating at their most cost-efficient speed.

Construction features of Coppus Gear Sets assures the utmost in reliability. Rugged cast iron or fabricated steel housing. Horizontally split design provides easy access for inspection and preventive maintenance. Precision hobbed single or double helical gearing with precisely controlled tooth profile, spacing and runout for quiet, trouble-free operation. Options, depending on application, include splash or force feed lubrication; anti-friction or sleeve bearings.

COPPUS TURBINE GENERATOR SETS

■ SYNCHRONOUS, INDUCTION and DC GENERATORS

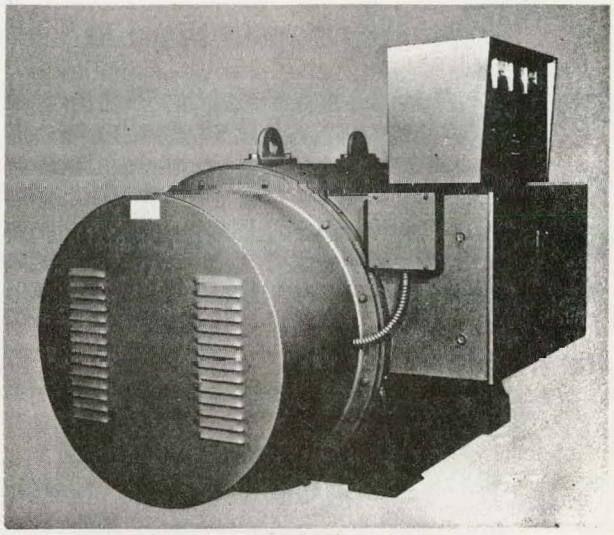
Synchronous Generators

Synchronous generators are used for standby power, independent operation, power factor improvement, peak shaving and cogeneration.

Coppus offers a broad range of synchronous turbine generator sets up to 2500 kW.

Typical Specifications

Voltage: Up to 6,600 volts.
Phase: Single- or three-phase.
Frequency: 50 or 60 Hz.
Insulation: Class F.
Enclosures: Open-drip-proof. Weatherproof. Totally enclosed and fan cooled. Explosion proof.
Voltage Regulation: Standard static regulators will keep voltage within ±1%.
Wave Form: Near sine wave perfection.
Phase Balance: Held within 1% with balanced loads.
Temperature Rise: 80°C above ambient for continuous operation and 105°C above ambient for standby applications.
Bearings: Anti-friction or sleeve bearings depending on application.
Excitation: Brushless, revolving exciter with static voltage regulator system.



Synchronous Generator

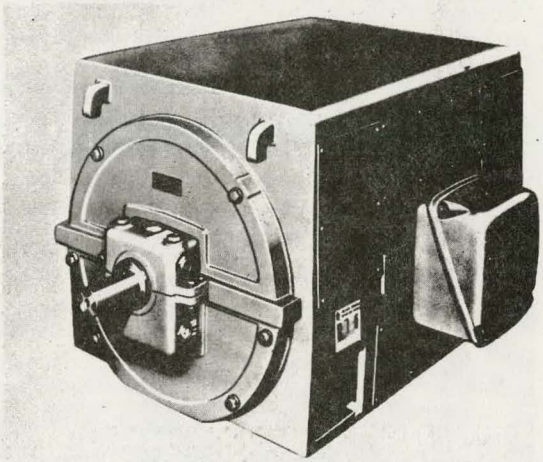
Induction Generators

Induction generators are simply induction motors driven above synchronous speed to produce kilowatts. They are ideally suited for cogeneration and peak shaving where standby power is not required. Excitation is obtained from a synchronous power system. Induction generators operate in conjunction with a relatively large synchronous power source.

Coppus Induction Turbine Generator Sets are available in a broad range up to 2500 kW. They can, without sophisticated control gear, recover energy from systems where process steam demand may fluctuate a great deal during the operating period.

Typical Specifications

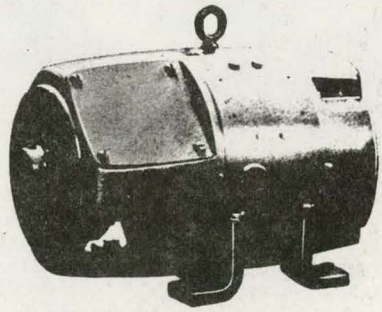
Voltage: Up to 6,600 volts.
Phase: Single- or three-phase.
Frequency: 50 or 60 Hz
Insulation: Class B.
Efficiency: 85% to 95%.
Enclosures: Open-drip-proof. Weatherproof. Totally enclosed and fan cooled. Explosion proof.
Excitation: The induction generator draws excitation from a synchronous power source. Voltage regulation, wave form and frequency match the characteristics of the synchronous source exactly without deviation.
Bearings: Anti-friction or sleeve bearing depending on application.



Induction Generator

DC Generators

Coppus DC Turbine Generator Sets can be supplied for applications involving battery charging, electroplating, cathode protection.



DC Generator

■ TURBINE SPEED CONTROL GOVERNORS

Generator frequency is directly proportional to turbine speed when the turbine generator set is operating independent of utility power. Therefore, the required frequency is maintained by controlling turbine speed with an oil relay governor driven from the turbine shaft.

When the turbine generator set is operating in parallel with a large synchronous power source, change in turbine speed setting by the governor produces a change in turbine load because the frequency of the turbine generator set is "locked" into the frequency of the supplied power system.

Three basic governors – NEMA A, NEMA D or Electric – are available to meet the requirements of any given application.

NEMA SPEED-GOVERNING SYSTEM CLASSIFICATION

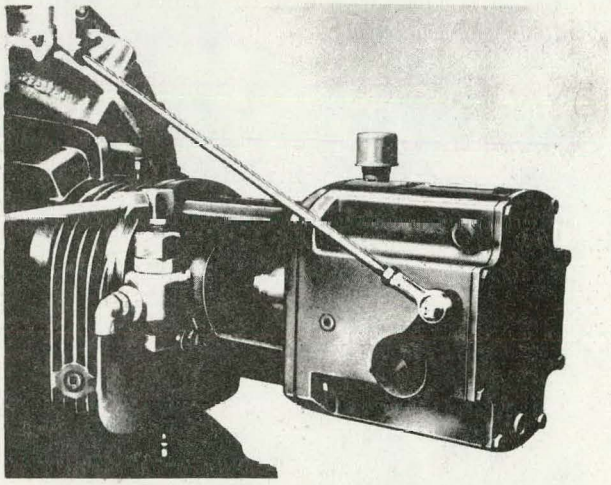
Class of Governing System	Per Cent of Rated Speed		
	Maximum Speed *Regulation, Per Cent	Maximum Speed **Variation, Per Cent ±	Maximum Speed †Rise, Per Cent
A	10	0.75	13
B	6	0.50	7
C	4	0.25	7
D	0.50	0.25	7

* The change in speed when load is changed gradually from full load to no load at steady steam conditions.

** Fluctuations in speed when operating under steady load and steam conditions.

† The momentary increase in speed when load is instantaneously dropped from full load to no load.

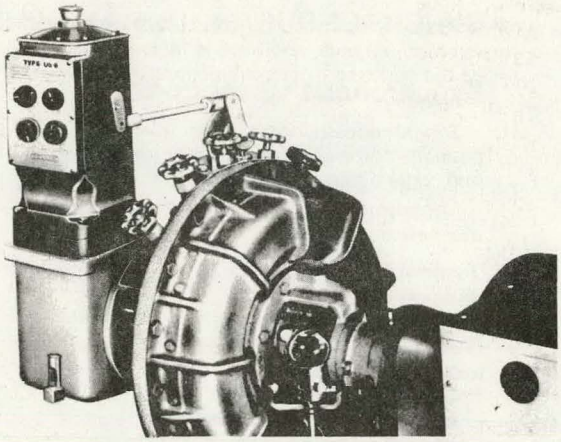
■ COPPUS RL GOVERNOR—NEMA A (WOODWARD TG 10)



The Coppus RL governor is a simple, reliable and powerful oil relay governor for non-frequency-sensitive applications. NEMA A performance is guaranteed. Governor will actually perform well into NEMA B range. Frequency variation caused by changes in turbine speed from full load to no load will normally not exceed ± 2 Hz in non-parallel operation. This governor is suitable for automatic start-up operation.

The Coppus RL oil relay governor has a manual speed setting screw for frequency control in non-parallel operation and for load control in parallel operation.

■ WOODWARD UG-8 or UG-40—NEMA D

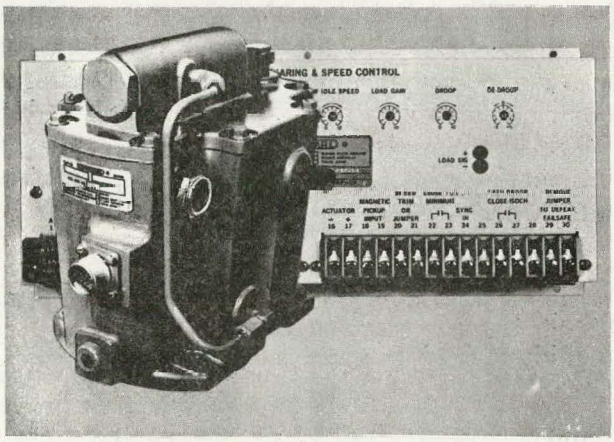


Woodward NEMA D governors are available for frequency sensitive applications and where parallel operation or load sharing is required between turbine generator sets. Both governors can be used for automatic start-up operation.

UG-8 and UG-40 governors have a manual speed setting dial for frequency control in non-parallel applications and load control in parallel applications. A remote manually operated motor control is available to synchronize the turbine generator in parallel applications. A manual droop-setting dial controls load sharing for two or more sets operating in parallel.

The UG-40 provides a higher operating force than the UG-8 and is used for speed control on turbines having larger valve sizes and higher inlet pressures.

■ ELECTRIC GOVERNORS



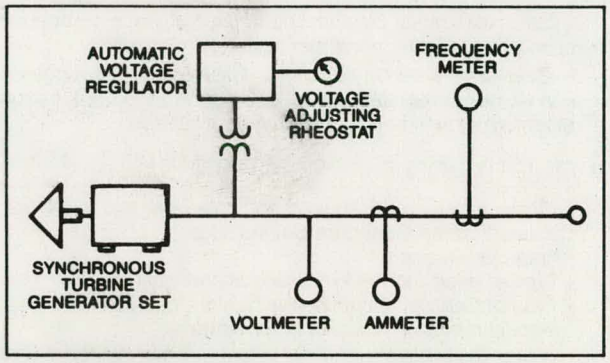
Basic electric governor systems consisting of a hydraulic actuator and an electronic control provide NEMA D isochronous operation. They offer distinct advantages due to the flexibility of the electronic control component which will accept add-on elements to meet a wide range of application requirements, such as:

- Parallel operation between two or more TG sets.
- Parallel operation with power grid.
- Fully automatic synchronization.
- Load sharing.
- Import/export control.

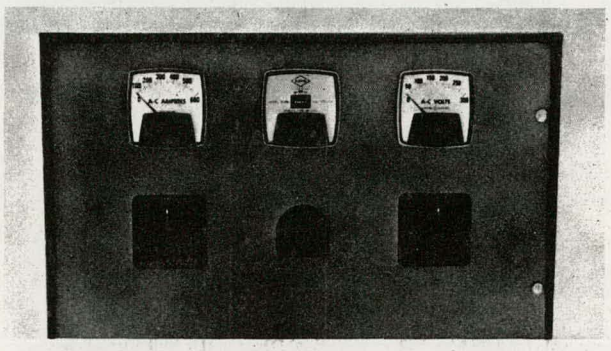
STANDARD CONTROL PANELS

Various standard control panels are furnished with Coppus Turbine Generator Sets. They are designed to meet the most commonly encountered application requirements, and each is factory pre-assembled and wired to provide the necessary control functions and instrumentation. Custom-engineered panels can also be furnished to meet special applications.

■ STANDARD CONTROL PANELS FOR AC SYNCHRONOUS GENERATOR SETS



Basic NEMA 1 Panel Includes:
- Automatic Voltage Regulator
- Voltage Adjusting Rheostat
- Voltmeter
- Ammeter
- Combination Selector Switch
- Frequency Meter
- Current and Potential Transformers



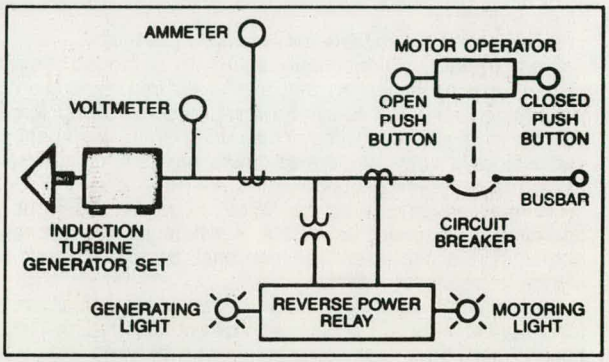
For Manual Non-parallel Operation Add:
- Manually Operated Circuit Breaker

For Automatic Standby Operation Add:
- Automatic Transfer Switch

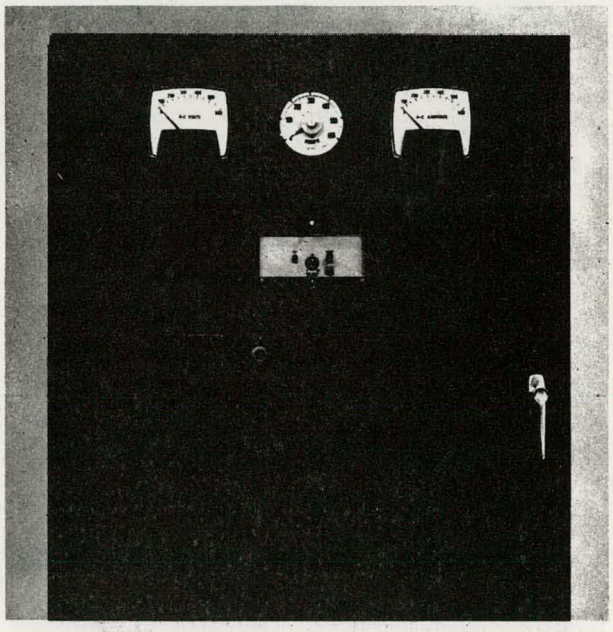
For Manual Parallel Operation Add:
- Shunt Trip Circuit Breaker
- Two Synchronizing Lights and Switch
- Reverse Power Relay—Lights and Reset
- Automatic Voltage Regulator with Reactive Droop Compensation

For Automatic Parallel Operation Add:
- Shunt Trip Circuit Breaker
- Synchroscope
- Reverse Power Relay—Lights and Reset
- Automatic Voltage Regulator with Reactive Droop Compensation
- Permissive Relay
- Electric Governor
- Synchronizing Relay with Speed Matching to Electric Governor

■ STANDARD CONTROL PANEL FOR INDUCTION GENERATOR SETS



Basic NEMA 1 Panel Includes:
- AC Ammeter
- AC Voltmeter
- Shunt Trip 3-Pole Circuit Breaker with Auxiliary Contact
- Reverse Power Relay
- Circuit Breaker Motor Operator with Open/Close Push Button
- Pilot Lights to Monitor Generating or Motoring Operation
- Current and Potential Transformers



Coppus will supply control panels that meet local or utility codes when customers advise Coppus of the specific requirements in their area.

■ TYPICAL SPECIFICATIONS FOR TURBINE GENERATOR SETS

The Prime Mover

The prime mover shall be a horizontal shaft, single-stage impulse steam turbine with a one-piece axial flow Curtis wheel.

Turbine design shall include: oversized stiff shaft rotor assembly mounted between bearings, removable steam strainer, carbon rings removable without disturbing casing, independent emergency over-speed trip valve and shaft driven oil relay governor.

Turbine shall be suitable for automatic start-up.

Casing shall be horizontally split with a rugged, keyed, centerline support system that allows for free expansion of the casing about the centerline and transmits piping forces directly to foundation without disturbing shaft alignment or vertically split with over-speed brake rim protection and a rugged foot-mounted support.

Oil relay governor shall be NEMA D where isochronous operation is required; or, NEMA A where non-isochronous operation is acceptable. Selection shall be made based on allowable frequency variation.

Journal bearings shall be sleeve type with oil ring or forced feed lubrication or anti-friction with oil ring lubrication. Thrust bearing shall be a heavy duty anti-friction bearing.

The Generator for Synchronous Sets

Synchronous generators shall be of the two-bearing, brushless type with solid state exciter systems, automatic regulation within ±1% of rated voltage, response time from no load to full load of 0.3 to 0.5 seconds. Insulation shall be Class F.

Synchronous generator ratings shall be based on temperature rise of 80°C above ambient for continuous operation and 105°C above ambient for standby service.

Control panels for synchronous generators shall be generator mounted or free standing and shall contain, but not be limited to: voltage regulator, voltage adjusting rheostat, voltmeter, ammeter, voltmeter and ammeter phase selector switch and frequency meter. Appropriate NEMA panel enclosure shall be provided consistent with the area classification in which panel is to be installed.

When specified, the necessary components for manual non-parallel, automatic standby, manual parallel and automatic parallel operation shall be provided.

The Generator for Induction Sets

Induction generators shall be of rugged cast iron construction with dynamically balanced rotor mounted between anti-friction or sleeve-type bearings. Insulation shall be Class B.

Induction generator rating shall be based upon temperature rise of 80°C above ambient.

Control panels shall be free standing and shall contain, but not be limited to: ammeter, voltmeter, shunt trip circuit breaker, reverse power relay with pilot lights to monitor generating or motoring operation. Appropriate NEMA panel enclosure shall be provided consistent with the area classification in which panel is to be installed.

The Turbine/Generator Coupling and Base Plate

Turbine and generator shall be mounted on a one-piece, fabricated steel base plate with a gear-type, forged steel, flexible coupling between the two units. Coupling assembly shall be protected with an enclosed steel guard.

The Gear Drive

Gear drive shall be supplied when turbine is to operate at speeds higher than generator speed.

Gear drive shall be horizontal. Casing shall be rugged cast iron or fabricated steel. Gear bearings shall be anti-friction or sleeve type, with self contained lube system.

■ QUOTATION INFORMATION

Basic information required for selection and quotation of Coppus Turbine Generator Set includes:

- Area classification.
- Type of generator — synchronous, induction or DC
- Type of Service — continuous or standby, automatic or manual operation, parallel or non-parallel.
- kW (or available steam flow*), power factor, voltage, phase, and frequency.
- Total plant electrical load—required for induction generator applications only.
- Steam or gas conditions — inlet pressure, inlet temperature and exhaust pressure.

*Maximum kW will be based on steam flow available.

■ ACCESSORIES

A broad selection of readily available accessory equipment makes it easy to adapt Coppus Turbine Generator Sets to a variety of special installation and operating conditions.

■ ENGINEERING ASSISTANCE — WORLDWIDE

Turbine generator applications vary widely. In most cases, however, requirements can be met with standard Coppus Turbine Generator Sets — and your Coppus representative can give you sound, on-the-spot recommendations for a complete turbine generator system incorporating "off-the-shelf" components that meet your specific application needs.

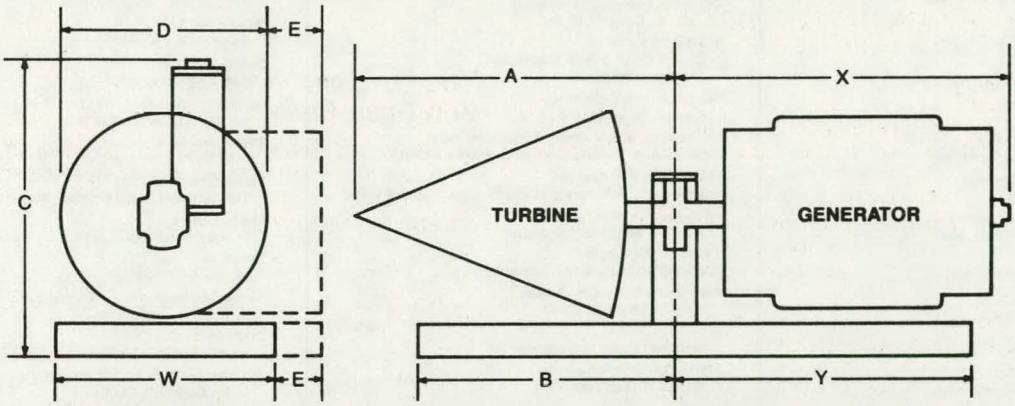
If your requirements are unique or unusual, Coppus offers engineering assistance that assures a turbine generator package or system that will meet your specifications precisely.

In addition, when you specify Coppus, our "Super Service Program" will help you keep maintenance costs and equipment downtime at a minimum. This comprehensive follow-up service includes . . . customized spare parts recommendations . . . parts interchangeability lists . . . maintenance training programs . . . fast, reliable parts replacement emergency service from factory inventories . . . and other valuable customer benefits designed to keep your equipment and processes in uninterrupted operation.

Coppus' engineering oriented Sales and Service Representatives are located in over 100 major cities worldwide.

OVERALL TURBINE GENERATOR SET DIMENSIONS

Dimensions are approximate and should not be used for construction purposes—inches in black, millimeters in blue.



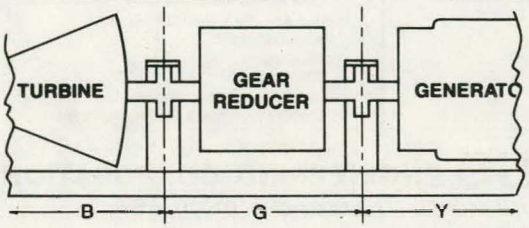
TURBINES

TURBINE SIZE	A	B	C	D	W
RL-12M	39.25 997	19.75 502	24.75 629	20.0 508	21.75 553
RL-12L	39.25 997	19.75 502	24.75 629	22.0 559	21.75 553
RL-16L	42.31 1075	23.0 584	28.63 727	32.0 813	25.25 641
RL-20L	42.31 1075	23.38 594	32.0 813	32.0 813	28.75 730
RL-22L	47.88 1216	30.0 762	34.5 876	44.0 1118	33.0 838
RL-23L	47.88 1216	30.0 762	34.5 876	44.0 1118	33.0 838
RL-23E	56.25 1429	30.5 775	33.5 851	44.0 1118	33.0 838
RLH-19	55.0 139	36.0 914	37.0 940	44.0 1118	33.0 838
RLH-24	65.0 1651	42.5 1080	43.0 1092	56.0 1422	41.0 1041
RLH-28	65.0 1651	42.5 1080	43.0 1092	56.0 1422	41.0 1041

NOTE: Turbine selection depends on steam conditions. Consult your Coppus Turbine representative.

GEAR REDUCERS FOR TURBINES

kW GENERATOR SIZE RANGE	G ADD TO DIMENSIONS "A" + "X" AND "B" + "Y"	E ADD TO TURBINE DIMENSIONS "D" AND "W"
200 to 400	26 660	7 178
400 to 600	29 737	8 203
600 to 800	32 813	9 229
800 to 1000	33 838	10 254
1000 to 1500	39 991	11 279
1500 to 1800	45 1143	14 356
1800 to 2500	50 1270	16 406



SYNCHRONOUS GENERATORS—480 V. 3 ph. 60 Hz

DIRECT DRIVE 2 POLE—3600 RPM			WITH GEAR REDUCER 4 POLE—1800 RPM		
kW	X	Y	kW	X	Y
10	33 838	27 686	250*	56 1422	44 1118
25	39 991	33 838	300*	57 1447	45 1143
50	43 1092	38 965	350*	63 1600	51 1295
100	45 1143	39 991	500*	66 1676	54 1372
225	56 1422	44 1118	750**	76 1930	64 1626
4 POLE—1800 RPM			1000**	79 2007	67 1702
20	36 914	30 762	1500**	90 2286	78 1981
30	37 940	31 787	1800**	103 2616	91 2311
50	43 1067	36 914	2500**	113 2870	101 2565
75	46 1168	40 1016	*Gear reducer is a turbine efficiency option **Gear reducer must be used with these generators		
150	53 1346	47 1194			

INDUCTION GENERATORS—DIRECT DRIVE

480 V—3 ph—60 Hz			2300/4160 V—3 ph—60 Hz		
kW	X	Y	kW	X	Y
30	25 635	19 483	350	48 1219	36 914
50	27 686	21 533	650	55 1397	43 1092
100	31 787	25 635	1000	68 1727	56 1422
250	40 1016	28 711	1650	84 2134	72 1829
450	48 1219	36 914	2000	93 2362	81 2057
650	55 1397	43 1092	2500	102 2591	90 2286

The dimensions in these tables are approximate and are intended to help you determine space requirements for a given turbine generator set.

After turbine and generator have been selected, combine the dimensions given in the tables for the turbine and appropriate generator; plus, those for the gear reducer when applicable.

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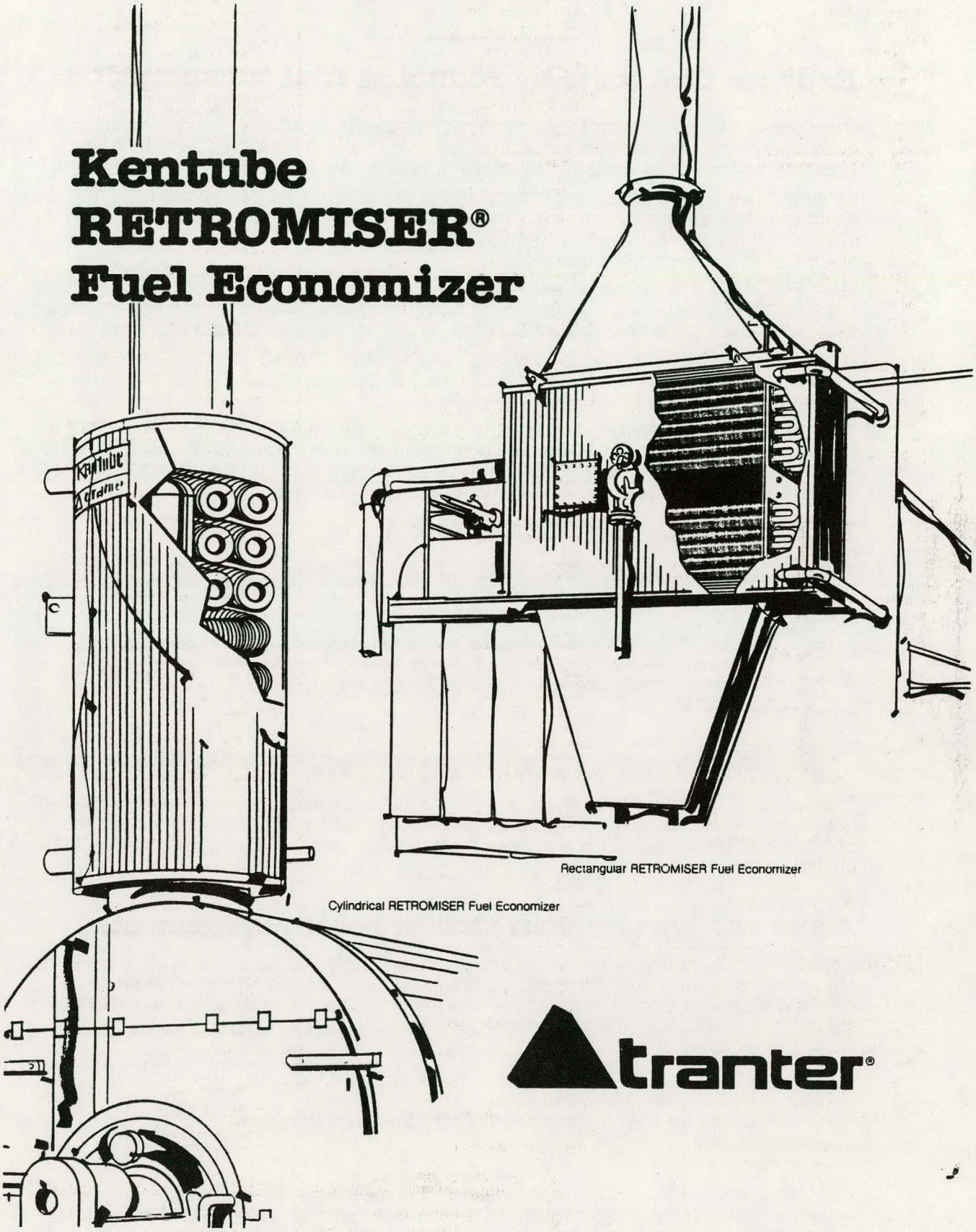
Kentube RETROMISER® Fuel Economizer



Rectangular RETROMISER Fuel Economizer

Cylindrical RETROMISER Fuel Economizer

tranter®

Kentube RETROMISER® Fuel Economizer

Reduces fuel costs by reducing fuel consumption

The Kentube Division of Tranter, inc. is the world's leading producer of finned tubing, fuel economizers, convection sections, and related heat recovery equipment for use in key industries where energy use and heat transfer are of prime concern.

Kentube has achieved unsurpassed capability in designing and supplying products that allow optimum use of available energy. A prime example of this capability is demonstrated by the pre-eminent position achieved by Kentube as the designer and producer of economizers for electric utility and industrial boilers.

The RETROMISER Fuel Economizer reduces fuel consumption by recovering heat from hot flue gases and transferring that heat to the boiler feedwater. In addition, the higher temperature feedwater entering the boiler allows the boiler to quickly respond to rapid load changes.

By reducing the fuel-firing rate for any given steam output, the NO_X emissions are reduced. In the process, by lowering the temperature of the flue gases going up the stack, thermal pollution is also reduced.

If finding a way to lower operating costs is a problem, RETROMISER is the key. If thermal pollution is a concern, or if fuel supplies need to be stretched, again RETROMISER meets the need. Not only does the RETROMISER provide answers to these problems, it guarantees the solutions will exactly meet your requirements and specifications.

Performance is guaranteed

All RETROMISER Fuel Economizers are custom-designed by modern computer techniques, thus enabling Kentube to examine multiple solutions to determine the optimum unit design for your specific needs. Each unit is *guaranteed* to meet individual performance specifications.

The Kentube Division of Tranter, inc. can make this guarantee because the RETROMISER Fuel Economizer incorporates the best possible engineering with performance-verified components and because it is a product manufactured under the industry's most rigid quality control and testing standards.

A size and type for your specific boiler requirements

Kentube manufactures retrofit fuel economizers in a range of sizes and types to meet the requirements of most watertube and firetube boilers. In fact, the Kentube cylindrical RETROMISER Fuel Economizer can be installed on boilers as small as 60 HP (2,000 lbs. of steam/hour). In addition, the cylindrical RETROMISER offers a number of other important advantages, including:

- Low installation cost — stack transitions not normally required
- Built-in maintenance-free sootblower
- Compact size for easy installation in confined boiler room areas
- Proven design
- Fast delivery

After determining your requirements, Kentube will recommend the specific economizer — whether cylindrical or rectangular — to meet your precise needs, based on such factors as your individual boiler characteristics, installation requirements, payback and other pertinent data.

RETROMISER® Fuel Economizer Design Characteristics

A hot structure design which consists of a heavy framework and fabricated tube supports. Wear caused by thermal expansion occurs only on the fin tips and not on a pressure part. *Most important, the unique design promotes the flow of hot gas across all internal parts to minimize corrosion.*

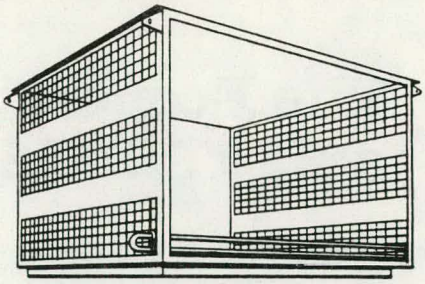
A finned tube heat exchanger providing the required amount of heating surface with the best possible heat transfer characteristics in the smallest practical space. Kentube's finned tubing has approximately 8 to 12 times the heat transfer capacity of bare tubing of the same diameter. Kentube's solid finned tubing is of the non-interrupted, spirally wound type which is continuously welded to the tube by high frequency resistance welding. *This provides the optimum in strength and heat transfer efficiency.*

A pressure vessel designed and constructed in accordance with the requirements of ASME Code Section I for power boilers. Each unit is hydrostatically tested, inspected, stamped and nameplated with the required ASME statutory information.

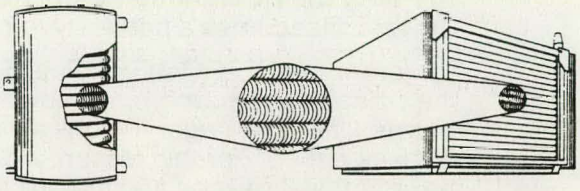
A feedwater line with low resistance to the flow of water. Inlet and outlet headers are of at least Schedule 40 carbon steel pipe with water connections being a minimum 300-lb. ASA raised-face, weld-neck flanges. *The standard, self-draining design of the RETROMISER Fuel Economizer allows outdoor installation where desired.*

A combustion flue having a gas-tight inner casing of carbon steel with at least 2" thick, mineral block insulation and a weather resistant outer casing of corrugated, galvanized carbon steel. *RETROMISER Fuel Economizers can be designed for gas-side pressure drops of ¾" water column or less so that existing fans can almost always be used without change.*

A heat accumulator with the ability to store heat by virtue of weight of metal and water contained in the unit. During low steam demand periods, temperature of metal and water will rise as much as 30°F above average. The excess heat will be delivered to the boiler as demand increases. This accumulator flywheel effect causes the RETROMISER to continuously and automatically take heat from the valleys of demand and put it into the peaks. *The heat accumulator effect allows the boiler to operate more steadily and more efficiently.*

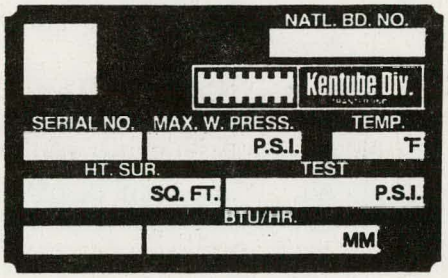


Latticework tube supports on rectangular RETROMISER unit

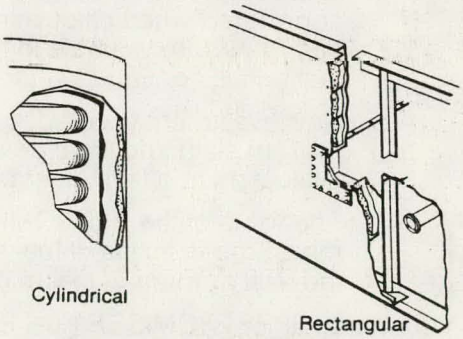


Cylindrical Rectangular

Kentube Finned Tubing

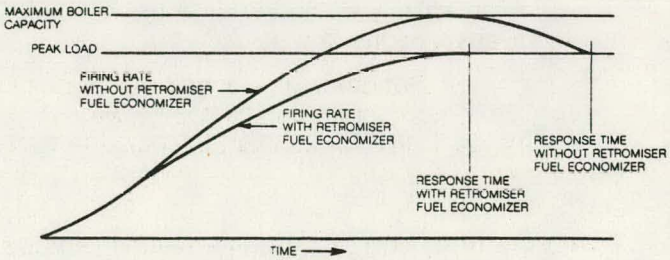


Built in accordance with ASME boiler and pressure vessel code



Cylindrical Rectangular

Cross section of RETROMISER wall



Heat Accumulator "Flywheel" Effect

K5-21

The Economic Advantages of a RETROMISER® Fuel Economizer

There are two basic economic reasons for installing a Kentube RETROMISER Fuel Economizer on your steam generating boiler:

IT SAVES MONEY – The fuel savings give an attractive return on investment.

IT SAVES FUEL – In view of dwindling energy supplies and curtailments, it becomes a necessity to conserve fuel.

The larger the RETROMISER Fuel Economizer, the greater the fuel savings. The sizing of any economizer, however, is subject to the law of diminishing returns. Thus, the larger the unit for a given application, the longer the payback period. For this reason, a balance must be sought between maximum fuel savings and the quickest return on investment.

This balance is obtained by the computer optimization program developed and used by Kentube to match the proper size RETROMISER Fuel Economizer to the specifications and requirements of each particular application.

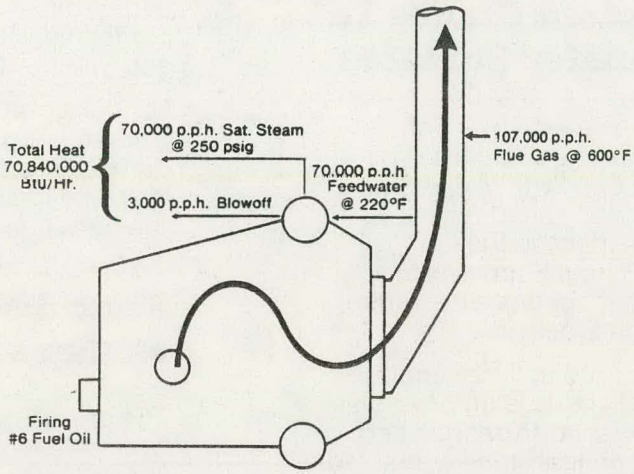
Once the dollar value of fuel to be saved by a RETROMISER has been determined, an investment evaluation should be made. There are several facts to consider in such an evaluation:

- A most important point to consider is that the RETROMISER Fuel Economizer will continue to earn dividends long after the unit has paid for itself.
- Capital costs will ordinarily be repaid within one to two years, but the savings achieved by the RETROMISER Fuel Economizer will continue to accrue as long as the unit is in operation. Future fuel prices should be considered when calculating long-term savings; it is likely your unit will become more valuable in terms of fuel savings as the years go by and fuel prices continue to increase.
- Any investment tax credits available from the federal government, as well as from state and local governments, should be included in your evaluation to offset your tax liability.
- The value of the RETROMISER Fuel Economizer need not always be measured in terms of fuel saved. The unit will also allow an increase in the total amount of steam generated without increasing fuel costs.

Kentube RETROMISER Fuel Economizers are operating today throughout the world in an ever-widening variety of industrial and institutional applications, saving each user thousands of dollars annually by putting potentially wasted energy back to work. *We'd like to put these economic advantages to work for you.*

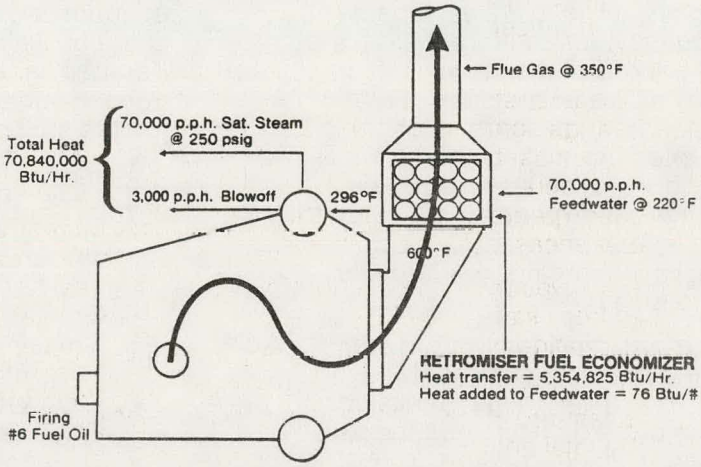
How The RETROMISER® Fuel Economizer Can Make The Difference

WITHOUT RETROMISER FUEL ECONOMIZER



Annual Fuel Cost based on 6,000 Hr./Yr. operation at 70% average load and fuel at 60¢/Gal. is $2,266,880

WITH RETROMISER FUEL ECONOMIZER



Fuel saved with Retromiser Fuel Economizer

$$\frac{5,354,825}{70,840,000} \times 100 = 7.5\%$$

REDUCTION IN ANNUAL FUEL COST based on 6,000 Hr./Yr. operation at 70% average load and fuel at 60¢/Gal. is $170,016

The illustration above depicts the operating characteristics of a typical steam generating boiler. By contrast, the illustration below shows the same boiler system using a RETROMISER. The resultant advantages are obvious. Less fuel is consumed, operating costs are reduced and the temperature of gases escaping into the atmosphere is significantly decreased. Payback of equipment, exclusive of installation costs, can be less than 3 months.

FUEL SAVINGS	Average Load = 70,000 p.p.h. Firing = #6 Fuel Oil at 60¢/Gal. Hours of Operation = 6,000 Hrs./Yr.	
	Before	**After**
Annual Fuel Bill	$2,266,880	$2,096,864
Annual Fuel Saved	—0—	$170,016
% Fuel Saved	—0—	7.5%
Approx. Installed Cost = $60,000	**Payback — Less than 5 months**	

Kentube Finned Tubing

The Efficient Choice In Heat Transfer Surfaces

While there are several types of extended surfaces available today, Kentube uses only high frequency, resistance welded finned tubing as the heat transfer surface in the RETROMISER Fuel Economizer. Kentube's finned tubing is the most efficient fin type available.

Kentube finned tubing's continuously welded, helically wound fin promotes excellent thermal performance and assures uniform fin-to-tube contact for maximum heat transfer. Its high frequency, resistance welding eliminates gaps in the heat flow which often occur when footed, spot-welded procedures are used.

By fusing a steel fin to a steel tube by high frequency, resistance welding, the resulting bond is of the same metallurgy as the fin and tube. Certain other attachment methods, such as brazing, often use nickel base alloys as the brazing material. This results in different thermal expansion rates due to dissimilar metals and imposes an interface, which impairs heat transfer from fin to tube.

Perhaps more importantly, both spot welded and brazed attachment methods have a very real potential for separation of the fin from the tube with soot build-up, acid corrosion, a significant reduction in heat transfer efficiency and the resulting increased maintenance.

Soot build-up also occurs on serrated finned tubing. The serrations, or periodic slits in the fins, readily accumulate soot and make cleaning extremely difficult. Soot build-up can entrap moisture which, when combined with sulfur oxides in the flue gas, will inevitably cause corrosion.

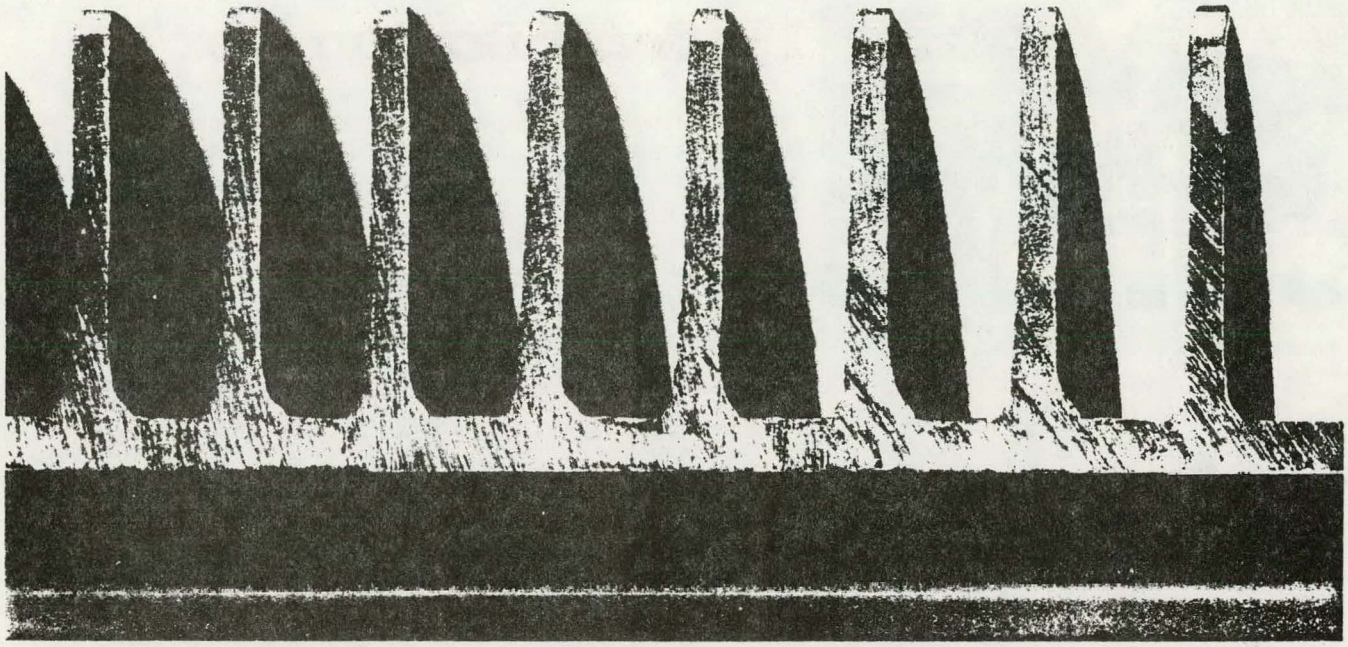
For these reasons, Kentube uses only smooth, solid finned tubing in the RETROMISER Fuel Economizer to resist the fouling action of soot in the flue gas stream.

Kentube Finned Tubing vs. Bare Tubing

The choice of Kentube finned tubing over bare tubing is clear-cut. Kentube finned tubing has approximately 8 to 12 times more heating surface than a bare tube of the same diameter. Therefore, a Kentube RETROMISER Fuel Economizer requires less tubing for a given capacity than a bare tube economizer. The following is a summary of the outstanding advantages of Kentube finned tubing as a heat transfer surface when compared to bare surface tubing:

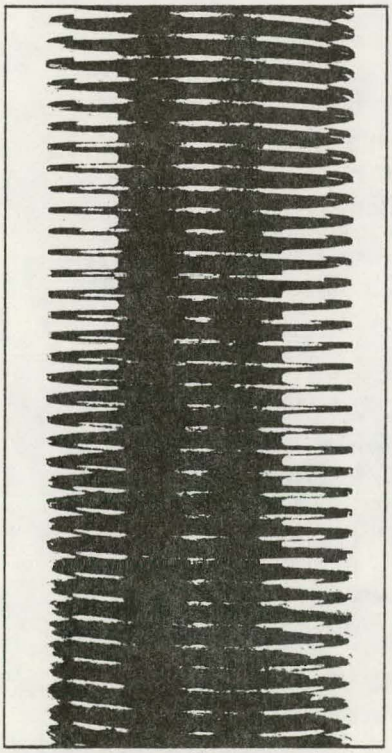
1. Lower pressure drop on liquid side
2. Lower pressure drop on gas side
3. Less space required for equivalent amounts of heat transfer surface area
4. Greater resistance to fouling
5. Greater resistance to loss of performance
6. Less weight for equivalent amounts of heat transfer surface
7. Lower cost for equivalent amounts of heat transfer surface
8. Long life

It is easy to see. Engineered precisely to match each application's particular requirements in tube diameter, fin size and pitch, Kentube finned tubing is the best heat transfer surface available for fuel economizer applications.

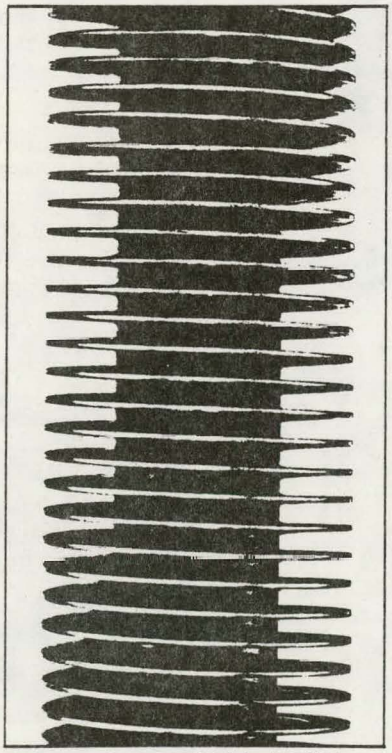


Helically wound, continuous high frequency, resistance welded steel finned tubing utilized as the heat transfer surface in RETROMISER Fuel Economizers assures uniform fin-to-tube contact for maximum heat transfer

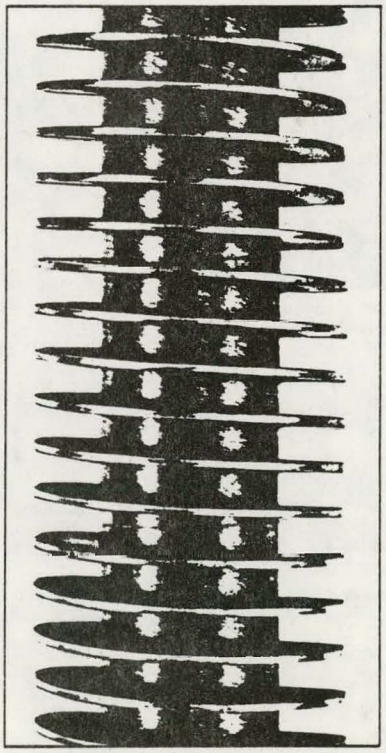
Examples of Typical Finned Tubing



48 fins per ft. × .075" thick, .875" high — 2" O.D. tube, for use with #2 fuel oil, or combination of #2 fuel oil and natural gas

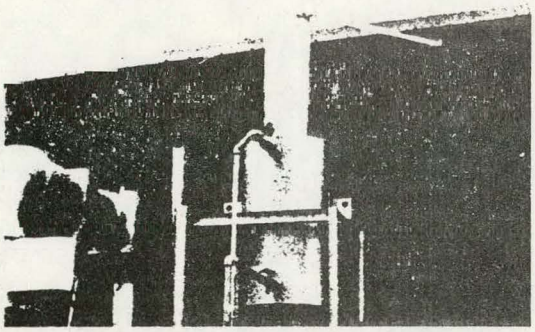


36 fins per ft. × .075" thick, .875" high — 2" O.D. tube, for use with heavy fuel oil

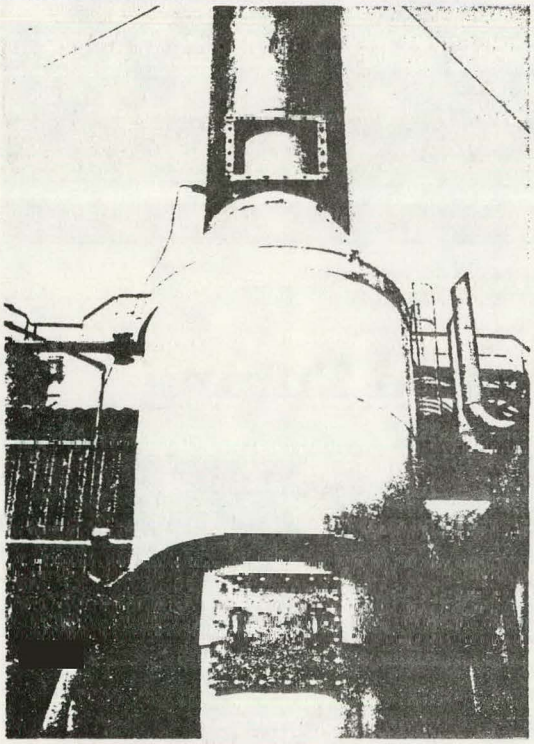


24 fins per ft. × .105" thick, .750" high — 2" O.D. tube, for use with solid fuels, including coal and wood

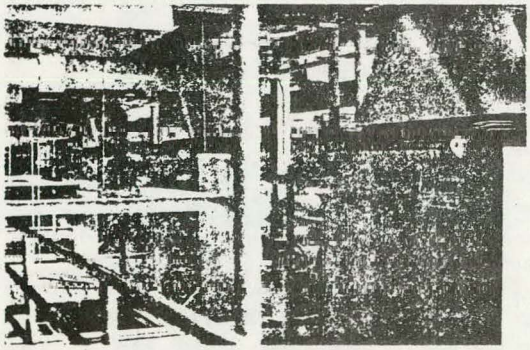
Typical RETROMISER Installations



Cylindrical RETROMISER installed at a rubber products manufacturing company where it achieves fuel savings of 5.6%



Cylindrical RETROMISER at a chemical processing plant providing annual fuel savings of 7.6%



Multi-unit RETROMISER installation on boilers firing natural gas at institutional complex provides annual savings of 7.2%

Cleaning the RETROMISER® Fuel Economizer

Kentube has given careful consideration to the cleaning mechanics of the RETROMISER Fuel Economizer. Fin configuration and tube arrangement are critical in this process.

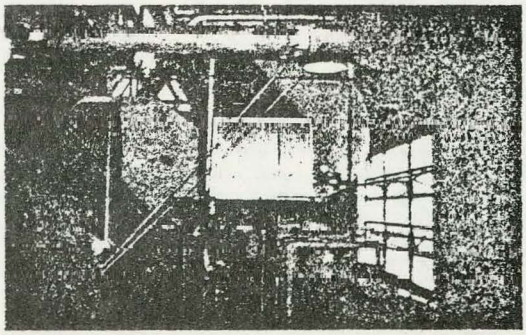
The principal concern is the proper selection of fin height, pitch and thickness. For example, thick, widely spaced, short fins are ordinarily used for dirty fuel applications such as coal or wood. More closely spaced fins are normally specified for use with fuels such as natural gas, oil, or a combination of the two.

Proper selection of the fin configuration, based on the dirtiest fuel being fired, is the first step in assuring maximum heat transfer efficiency.

By designing each unit with a square tube pitch arrangement, sootblowers can be located in a position transverse to the tubes to permit lane blowing. (See diagrams on facing page.) The nozzles are aligned with the tube lanes so the sootblower can be located near the tube bank without concern for erosion caused by steam impingement on the tubes.

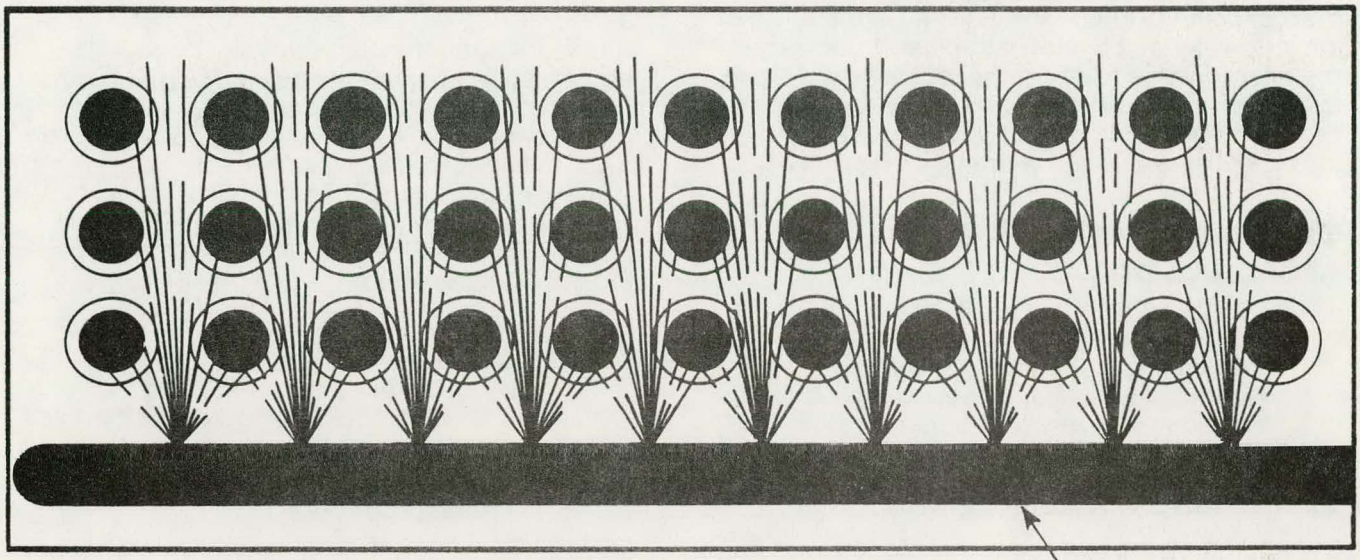
Lane blowing and proper fin spacing, coupled with a square-tube pitch arrangement which allows the steam or air to reach every tube in the bundle, results in the most effective means of maintaining clean tube surfaces.

Periodic inspection of the tubes will help to determine the required frequency of sootblowing. As a general rule, sootblowing should occur often enough to maintain high operating efficiency which can be monitored by the exit water temperature.



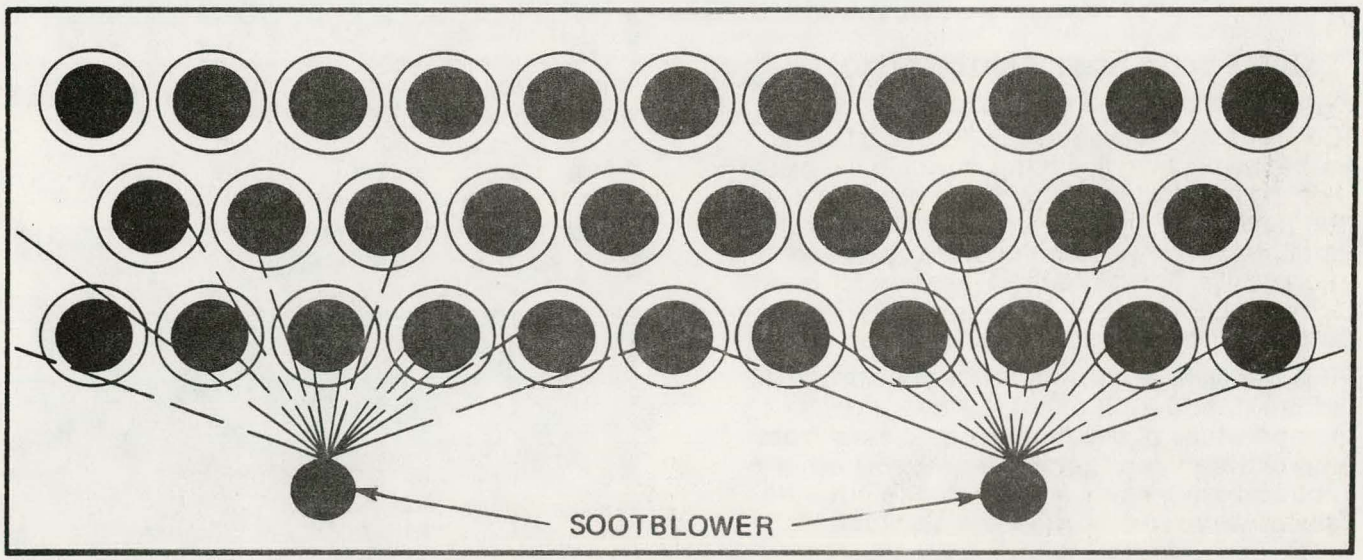
RETROMISER installation at pharmaceutical company, retrofitted on a boiler firing natural gas and #2 fuel oil, achieves annual savings of 5.79%

Method of RETROMISER® Fuel Economizer Sootblowing



LANE BLOWING — The Proper Method

Square tube pitch allows lane blowing. Nozzles are aligned with tube lanes so the element can be located next to tube bank, thus allowing the steam to reach and clean each tube in the economizer. The method illustrated above for rectangular RETROMISER Fuel Economizers is also utilized in cylindrical RETROMISER models.



MASS BLOWING — Not Accepted Method

Triangular tube pitch requires mass blowing. No attempt can be made to direct blowing medium down each tube lane. This method is significantly less effective than the cleaning obtained with square pitch lane blowing for a given blowing radius. Blower nozzles for mass blowing are wide angle producing lower velocities and, accordingly less penetration into the tube bundle.

The RETROMISER® Fuel Economizer Feedwater Preheat System*

When analyzing requirements for installation of an economizer, there are two important criteria that must be considered: (1) the sulfur content of the fuel being burned; and (2) the temperature of the feedwater at the inlet of the fuel economizer or heat recovery device. If the temperature of the inlet feedwater is not maintained at proper levels, certain by-products of the fuel being burned have the potential to cause low temperature corrosion.

The Corrosive By-Products of Combustion

If sulfur is present in the fuel, it will combine with oxygen to form sulfur dioxide (SO_2) and sulfur trioxide (SO_3). It is presence of these sulfur oxides in the flue gas that represents the largest potential cause of corrosion. Sulfur dioxide, for example, will dissolve in any free moisture that may be present in the flue gas to form sulfurous acid (H_2SO_3) — a powerful corrosive.

Depending on the sulfur content of the fuel, the amount of excess air in combustion and the flame temperature, approximately one to two percent of the sulfur dioxide is further oxidized into sulfur trioxide. When combined with superheated water vapor, sulfur trioxide forms sulfuric acid vapor (H_2SO_4).

Inlet Feedwater Temperature vs. Corrosion Potential

Condensation of acid vapors from the flue gas is the result of the flue gas contacting the metal heating surfaces in the heat recovery unit. The temperature of the flue gas in contact with these surfaces will be virtually the same as the temperature of the metal. The metal temperatures, in turn, will be within a few degrees of the feedwater temperature flowing through the tubing.

It is the temperature of the metal surfaces of the finned tubing, not the average temperature of the flue gas as it exits from the economizer, that determines whether or not corrosive acids will condense out of the gas as it passes through the economizer.

Based on this, Kentube has established minimum recommended feedwater temperatures for feedwater entering the RETROMISER Fuel Economizer.

When sulfur dioxide (SO_2) gases pass through the economizer, the minimum feedwater temperatures indicated will maintain the heating surfaces well above the water dew point and eliminate the possibility of sulfurous acid (H_2SO_3) corrosion.

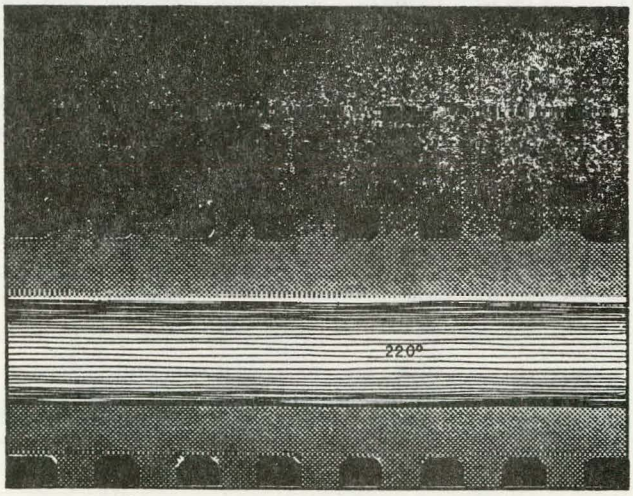
As far as sulfur trioxide (SO_3) gases and sulfuric acid (H_2SO_4) formation is concerned, research studies indicate that relatively little condensation takes place at the acid dew point. In fact, maximum condensation does not occur until temperatures are approximately 80-100°F below the acid dew point. Additionally, less than 2% of the sulfur dioxide in the flue gas is converted to sulfur trioxide. Therefore, only minimal amounts of sulfuric acid will condense on the heating surfaces at temperatures between the recommended feedwater temperature level and the acid dew point.

Proof by Experience

The concept of acid corrosion on boiler economizers being determined by the adequacy of the feedwater temperature is not new to the boiler industry. As long ago as 1951, a major boiler manufacturer made the following comments:

"Corrosion is due, not so much to the temperature of the combustion gas, as it is to the temperature of the water passing through the tubes which produce the condensation of sulfur dioxide and thus corrosion.

"This contention is confirmed by the fact that external economizer tube corrosion is being experienced with installation where the economizer is placed ahead of an air heater and where the economizer exit gas temperature is over 500°F, but where, at the same time, the temperature of the feedwater entering the economizer is in the neighborhood of 200°F."



The temperature of the tube wall in contact with the flue gas is more nearly that of the feedwater than the bulk flue gas. This is due to the greater resistance to heat transfer on the gas side (gas film) than the water side (water film). It is this tube wall temperature, and therefore the feedwater inlet temperature, that will determine if cold-end corrosion will occur.

*Patent No. 4,173,949

Corrosion Control

It is important to maintain the correct feedwater temperature to ensure maximum heat transfer and minimum corrosion. This can be achieved with the Kentube Feedwater Preheat System.

The Kentube Feedwater Preheat System provides the flexibility to accommodate a variety of fuels, both high sulfur and low sulfur, always maintaining the correct feedwater temperature level for trouble-free, efficient heat transfer.

As you increase the feedwater temperature into the economizer, you are realizing a greater margin of safety against cold-end corrosion. As you decrease the feedwater temperature into the economizer, which would be allowable with lower sulfur fuels, you are realizing greater heat transfer by a larger gas/water temperature differential (LMTD), which is the driving force behind heat transfer.

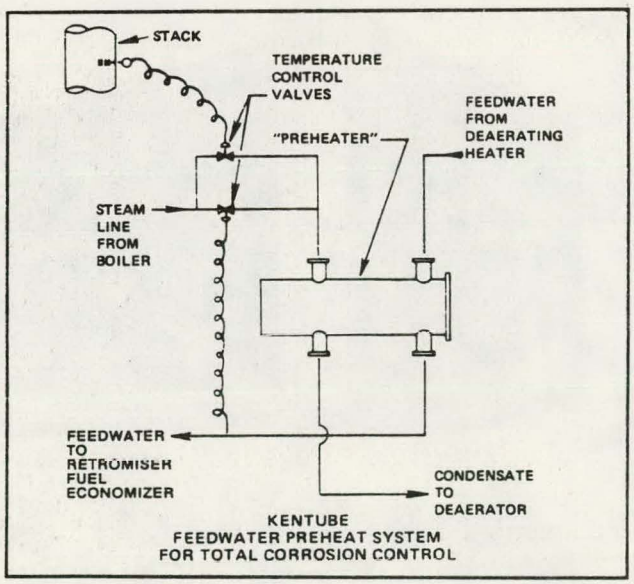
The preheating medium is steam – the flow of which is regulated by a temperature control valve. This valve is controlled by the temperature in the feedwater line downstream from the preheater (see Figure 1). When the control valve is set for the desired feedwater temperature, that temperature will be maintained at all rates of flow (see Figure 2).

Proper feedwater temperature is the solution to the problem of cold-end corrosion. The same concept of feedwater preheat can help solve the problem of stack corrosion. If the steam demands are such that you have occasion to operate at very low firing rates for extended periods of time, this could result in low flue gas temperatures from the economizer. Although the economizer itself is protected by adequate feedwater temperature, the stack may be susceptible to acid corrosion.

A second temperature regulating valve, controlled by the economizer flue gas exit temperature, can be incorporated into the system (see Figure 1). When steam demand is very low, this second controller will override the feedwater temperature regulator increasing the feedwater temperature. By reducing the gas/water temperature differential, the exit flue gas temperature is maintained at the level set on this second temperature controller. *This is total corrosion control.* The system requires no utilities to operate, eliminating the need for conduit or pneumatic tubing.

The patented Kentube Feedwater Preheat System, incorporated into an economizer package, not only maximizes efficiency and performance, but minimizes risk.

For a detailed discussion of the causes of corrosion, refer to Bulletin KFPS-1, "Kentube Feedwater Preheat Systems for Controlling Corrosion on Boiler Economizers."



KENTUBE FEEDWATER PREHEAT SYSTEM FOR TOTAL CORROSION CONTROL

Fig. 1

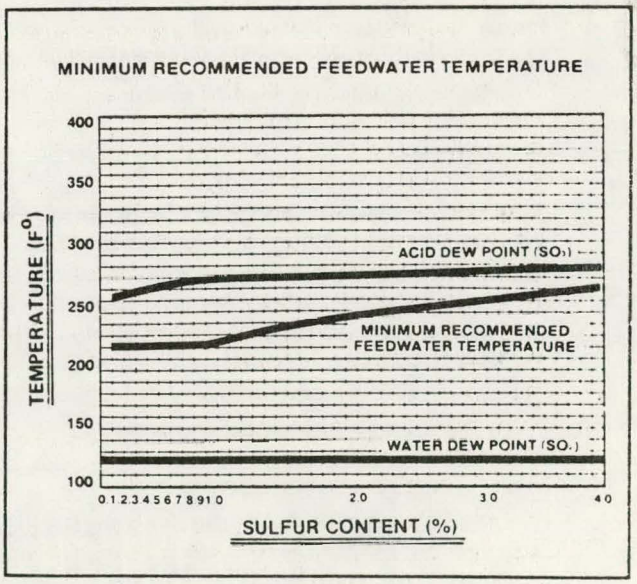
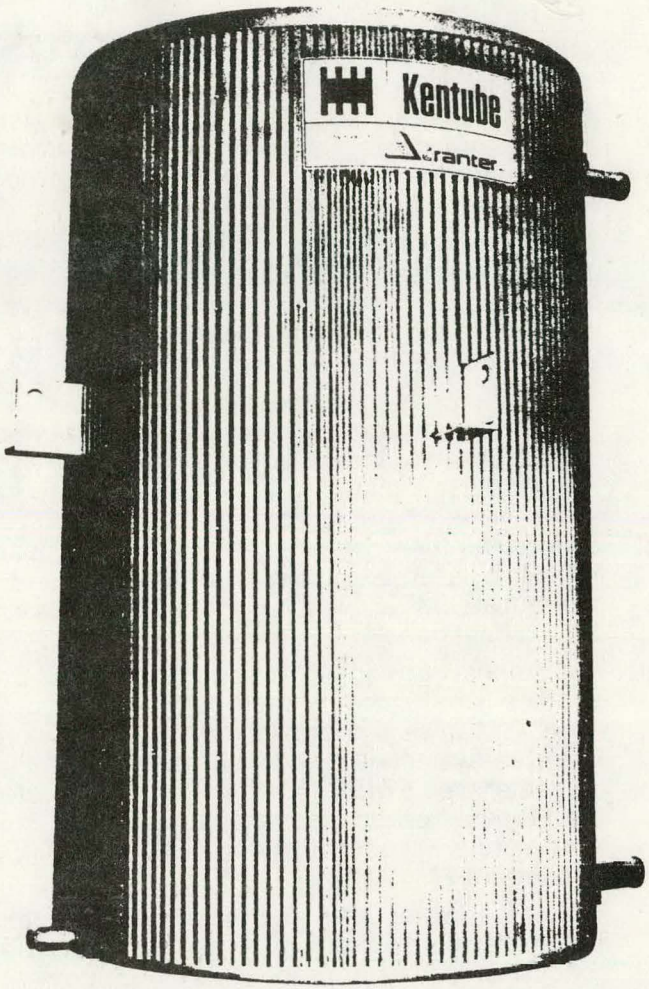


Fig. 2

Kentube RETROMISER Fuel Economizer Accessories



Cylindrical

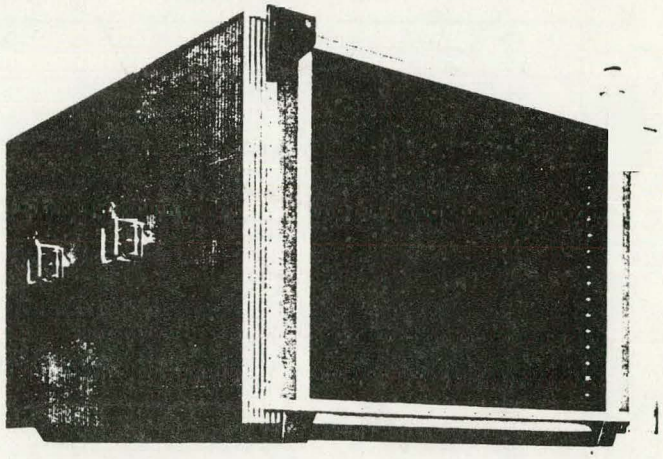
All cylindrical RETROMISER Fuel Economizers are equipped with built-in sootblowers. In addition, the following accessory components are available from Kentube for use with the cylindrical RETROMISER Fuel Economizer:

1. Structural support kit, a framework of structural steel containing all the necessary structural steel elements for the supporting framework.
2. Feedwater control kit, includes a column-mounted, proportioning-type feedwater pump controller; a motorized feedwater regulating valve; and a back-pressure regulator to ensure a continuous feedwater flow to the Cylindrical RETROMISER Fuel Economizer.
3. Thermometer connections, installed on the feedwater headers.
4. Safety valve connection, installed on the feedwater header.

Rectangular

Kentube auxiliary components available for use with the rectangular RETROMISER Fuel Economizer include:

1. Wall box and distal bearing for sootblower, installed by Kentube.
2. Manually operated, rotary sootblower, shipped separately with unit.
3. Access manway in casing, approximately 16" square, carbon steel construction, installed by Kentube.
4. Thermometer connections, installed on the feedwater headers.
5. Safety valve connection, installed on the feedwater header.



For further information, contact:

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