BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DIRECT TESTIMONY OF WILLIAM W. ZAETZ
DOCKET NUMBER 010949-EI

DECEMBER 27, 2001

Respectfully submitted,

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DOCUMENT NUMBER-DATE
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BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

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DIRECT TESTIMONY AND EXHIBITS OF

WILLIAM M. ZAETZ

ON BEHALF OF THE CONSUMER ADVOCATE STAFF

DIRECT TESTIMONY OF
WILLIAM M. ZAETZ

INTRODUCTION

Q. PLEASE STATE YOUR NAME, POSITION AND BUSINESS ADDRESS.

A. My name is William M. Zaetz. I am a Senior Consultant with the economic consulting firm of Snavely King Majoros O'Connor & Lee, Inc. ("Snavely King"). My business address is 1220 L Street, N.W., Suite 410, Washington, D.C. 20005.

Q. WHAT IS YOUR PROFESSIONAL BACKGROUND?

A. Prior to joining Snavely King this year, I was a boilermaker for 33 years with Union Local No.193, headquartered in Baltimore, Maryland, rising eventually to the position of General Foreman. In the course of this career, I participated in or supervised the fabrication, installation, repair and dismantlement of boiler plant, fuel-handling equipment, and environmental abatement facilities in electric generating plants operated by both public utilities and private industrial and commercial enterprises. In the course of 180 separate projects, I participated in operations in most of the major power plants in Maryland, the District of Columbia, southern Delaware and the northern Virginia.

After leaving the Boilermakers' Union, I worked as a consultant and expert witness for the Department of Justice's Environmental Division in connection with their Power Plant Initiative. My duties consisted of analyzing and summarizing various "forced" and "scheduled" outage reports and providing the attorneys with contact lists from my association with the International Brotherhood of Boilermakers.

I joined Snavely King earlier this year. I have provided technical support and advice in connection with that firm's analyses of steam generation facilities and costs, principally in connection with depreciation proceedings.

Q. WHAT IS YOUR EDUCATIONAL BACKGROUND?

A. During my college years, I enrolled in the apprenticeship program of the International Brotherhood of Boilermakers and also served in the Naval Reserves as a boilermaker. In 1971, I received a Bachelor of Science degree in Business Management from the University of Baltimore.

Q. HAVE YOU ATTACHED A SUMMARY OF YOUR EXPERIENCE?

A. Yes. Appendix A is a brief summary of my qualifications and experience.

Q. FOR WHOM ARE YOU APPEARING IN THIS DOCKET?

A. I am appearing on behalf of the Florida Office of Public Counsel ("OPC")

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. First, I will explain the basic principles of the combined-cycle technology. Second, I will report on my December 14, 2001 tour of Plant Smith Unit 3. Third, I will describe my survey of the current disposition of retired electric generating units.

Q. ON WHAT INFORMATION IS YOUR TESTIMONY BASED?

A. My testimony regarding the principles of combined–cycle technology is based on my individual research, my observation of other combined cycle plants that are under construction, and my 33 years of practical experience with the stages and entities of the steam cycle. I have condensed and simplified the principles in Exhibit___(WMZ-1). My report of the plant tour of Smith Unit 3 is attached as Exhibit___(WMZ-2). (At the time this testimony was prepared, Gulf Power had not released the photographs that were taken during the tour. Exhibit___WMZ-2 will be filed separately when I receive those photos.)

Q. DO YOU HAVE ANY PERSONAL EXPERIENCE WITH COMBINED-CYCLE PLANTS?

A. These plants are relatively new to the scene and none have been constructed so far in the Mid-Atlantic region that was part of my jurisdiction while I was working in the field. I have, however, worked on several "waste heat boilers" over the years. Recapturing exhaust heat is not a new concept. Steel mills and refineries have used the waste heat concept for many years.

Q. HAVE YOU RECENTLY OBSERVED ANOTHER COMBINED CYCLE PRODUCTION PLANT UNDER CONSTRUCTION?

A. Yes. On my tour of seven plants in the Georgia Power System conducted on September 26, 27, and 28, 2001, I observed the construction of four combined-cycle units under construction at Plant Wansley. Exhibit___(WMZ-3) contains a photo that I took during that tour. You can see the similarity between those units and Plant Smith Unit 3.

Q. PLEASE SUMMARIZE THE RESULTS OF YOUR RESEARCH.

A. The combined-cycle technology combines the thermodynamic principles of the gas turbine cycle and the steam cycle. The heat contained in the exhaust gases expelled by the gas turbine is used to heat the water used in the steam cycle.

There has been an increase in the use of combined cycle power generation because of its advantages in the overall efficiency and the relatively low cost of construction compared with other known energy sources.

Over the years, improvements in the Brayton (gas turbine) Cycle and the Rankine (steam) Cycle has resulted in an efficiency of over 60% in combined-cycle cycle plants now under construction, and efficiency ratings in excess of 70% are expected before the end of this decade. Historically, the average efficiency of electricity generation has progressed from under 5% in 1900, to its high of around 33% in the mid-1980s. When the use of combined-cycle techniques became a reality for commercial operation, the efficiency rating has progressed approximately 10% per decade.

Q. HOW DO THESE FACTS RELATE TO THE FINAL RETIREMENT OF A COMBINED-CYCLE PLANT?

A. For a plant to be considered for retirement, it must be determined that the plant has become economically unfeasible to continue power generation. If all predictions are true about the increase in future power requirements to the grid, then the development of the most cost-effective method for delivering the needed power would be the only prudent answer. At the present time, the combined-cycle technology is the state-of-the-art in power generation. At each stage of the development of the entities used in this technology, improvements have been made to increase the life span of various parts.

Exhibit___(WMZ-4) is a *GE Power Systems* brochure in which the manufacturer elaborates on the various improvements to the state-of-the-art turbines that are being installed at Smith Unit 3.

Q. HAVE YOU COME TO A CONCLUSION BASED ON YOUR ANALYSIS?

A. The current average life span of existing electric generating plants over 50 MW is approximately 55 years (Snavely-King's National Study 2000-01). I have found nothing in my research, or on the plant tour that would lead me to conclude that Plant Smith Unit 3 would have a shorter life span than these existing plants.

RETIRED PLANT SURVEY

Q. PLEASE DESCRIBE YOUR SURVEY OF RETIRED PLANTS.

A. The Energy Information Agency of the Department of Energy maintains a database, which identifies the status of steam plants generating electricity in the nation. From this database, I was able to identify all generating units that had been retired since 1982. The FERC database also identified the units' owner as of the time they were retired. I telephoned those owners and found that in many cases, the ownership had changed. I then telephoned as many current owners as possible to inquire as to the present state of the retired unit, that is, whether it is still in place or whether it has been dismantled and, if so, what has become of the site.

Q. WHAT WERE THE RESULTS OF YOUR SURVEY?

A. Exhibit___(WMZ-5) provides a summary of the result of my survey. It lists all of the **146** steam generating units 50 MW and above that has been retired since 1982. I was able to contact **28** owners of 86 units in **40** separate locations. Only

15 units in **9** locations have actually been dismantled, and of these only **6** units in **4** locations have been returned to "Greenfield" status, meaning that there is not remaining evidence of the site having been used for electric generation.

This leaves **68** units in **26** locations that have not been dismantled. Most of these units are essentially untouched, although some are being retained to be cannibalized for their parts. **Four** units in **2** locations have been recommissioned and put back in service. **Four** more units, at Hawthorn in Missouri, owned by Kansas City P&L CO. are about to be returned to service. These units have been listed as retired since 1984.

Q. WHAT IS THE RELEVANCE OF THESE SURVEY RESULTS IN THE ISSUES IN THIS PROCEEDING?

A. GPC has incorporated a $5.6 million dismantling charge in its depreciation request. My survey indicates that utilities do not necessarily dismantle generating units when they are retired for a number of reasons. It is highly unlikely that any owner would dismantle a unit if any other units sharing the same building were still in operation. First of all, asbestos removal would <u>halt</u> the operation of the working units because it would represent a safety hazard for any personnel performing normal plant duties. Furthermore, it is probably uneconomical to dismantle a single unit within a plant while leaving other, operational units in place.

Q. WHAT DO YOU CONCLUDE?

A. I conclude that the dismantlement of all of GPC's existing units is an unlikely event.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

Experience

Snavely King Majoros O'Connor & Lee, Inc., Washington D.C.

Senior Consultant (2000 to present)

Mr. Zaetz provides technical expertise in all of the firm's projects involving the engineering, costing, operation, valuation, depreciation and dismantlement of electric and gas facilities. Mr. Zaetz has assisted in several electric and gas depreciation studies.

Independent Consultant (2000-2001)

Mr. Zaetz provided consultation to the U.S. Department of Justice in connection with several units to enforce the nitrogen oxide ("NOX") abatement regulations of the Environmental Protection Agency. Mr. Zaetz reviewed engineering plans and work orders to determine the nature and objectives of modifications to the generation plants subject to the suite. He prepared summaries of his findings in anticipation of possible testimony before Federal Courts.

Boiler Local 193
Severn, MD

General Foreman
Foreman (1973-2000)

Mr. Zaetz supervised the fabrication, installation, repair and dismantlement of boiler plant, synthetic natural gas, fuel handling equipment, and environmental abatement facilities in electric generating plants operated by both public utilities and private industrial and commercial enterprises. In the course of 180 separate projects, Mr. Zaetz supervised operations in most of the major power plants throughout the Maryland, Northern Virginia and Southern Delaware area.

Shop Steward

Mr. Zaetz represented over 100 boilermakers in labor arbitrations, safety disputes and the implementation of Federal worker protection provisions.

Legislative Education Action Committee

Mr. Zaetz participated as committeeman and Chairman of the Education Committee in the Union's efforts to facilitate and enhance the technical training of its members.

Education

University of Baltimore: B.S. in Business Management

Boilermaker Apprentice Program

William M. Zaetz

Testimony

Date	State	Docket	Utility
2001	Georgia 1/	14000-U	Georgia Power Company

Plant Tours

Date	State	Docket	Utility
2001	Kansas 2/ 3/ 4/	01-WSRE-436-RTS	Kansas Power & Light
2001	Kansas 2/ 3/ 4/	01-WSRE-436-RTS	Kansas Gas & Electric
2001	New Jersey 5/	GR0105029	Public Service Electric & Gas
2001	Georgia 1/	14000-U	Georgia Power Company
2001	Michigan 6/	U-12999	Consumers Energy
2001	Florida 7/	010949-EL	Gulf Power Company

Clients

1/ Georgia Public Service Commission
2/ Kansas Citizens' Utility Rate Board
3/ Kansas Industrial Group
4/ City of Witchita
5/ New Jersey Rate Advocate
6/ Michigan Attorney General
7/ Florida Office of Public Counsel

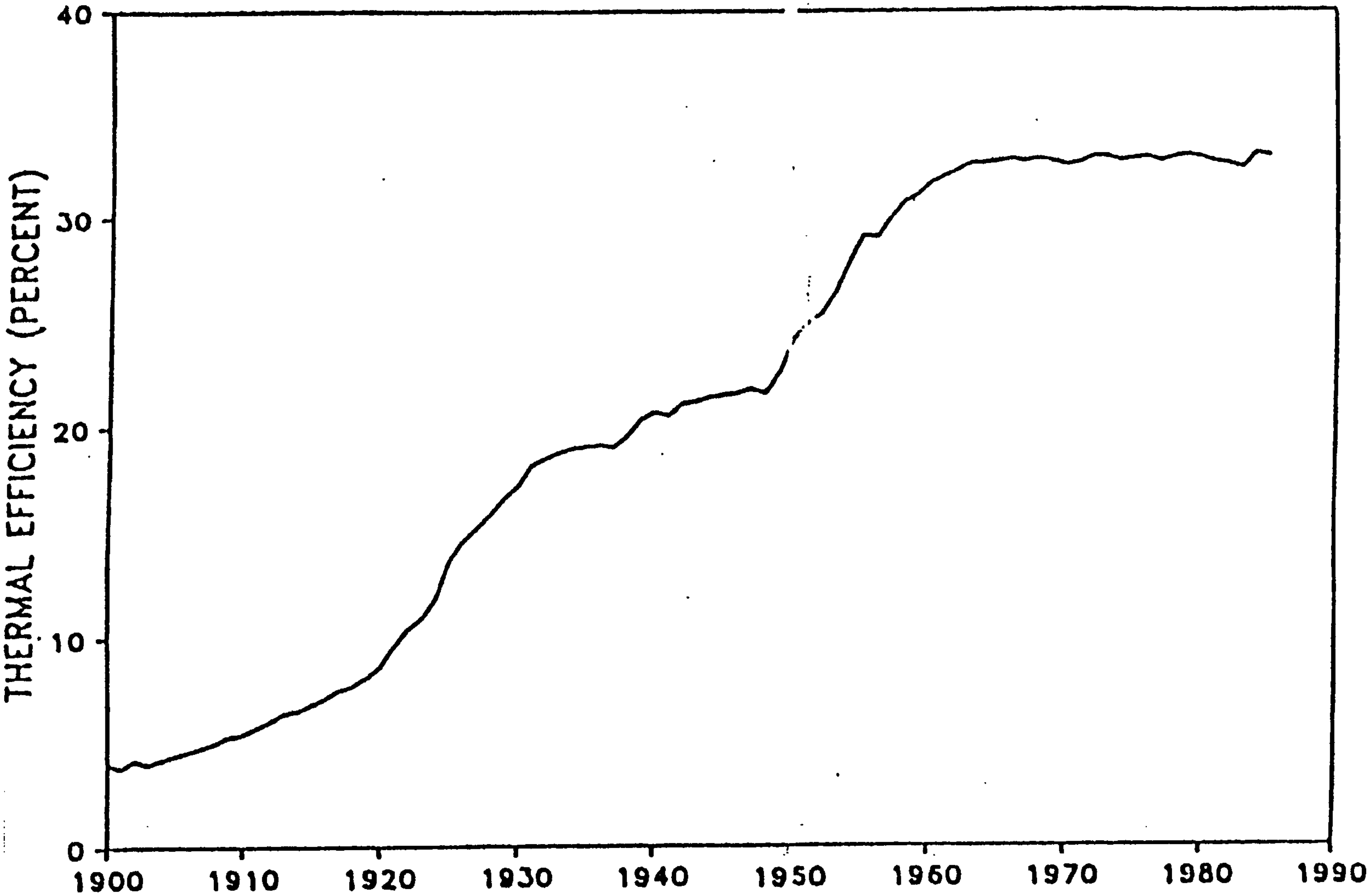
Exhibit___(WMZ-1)

14 PAGES

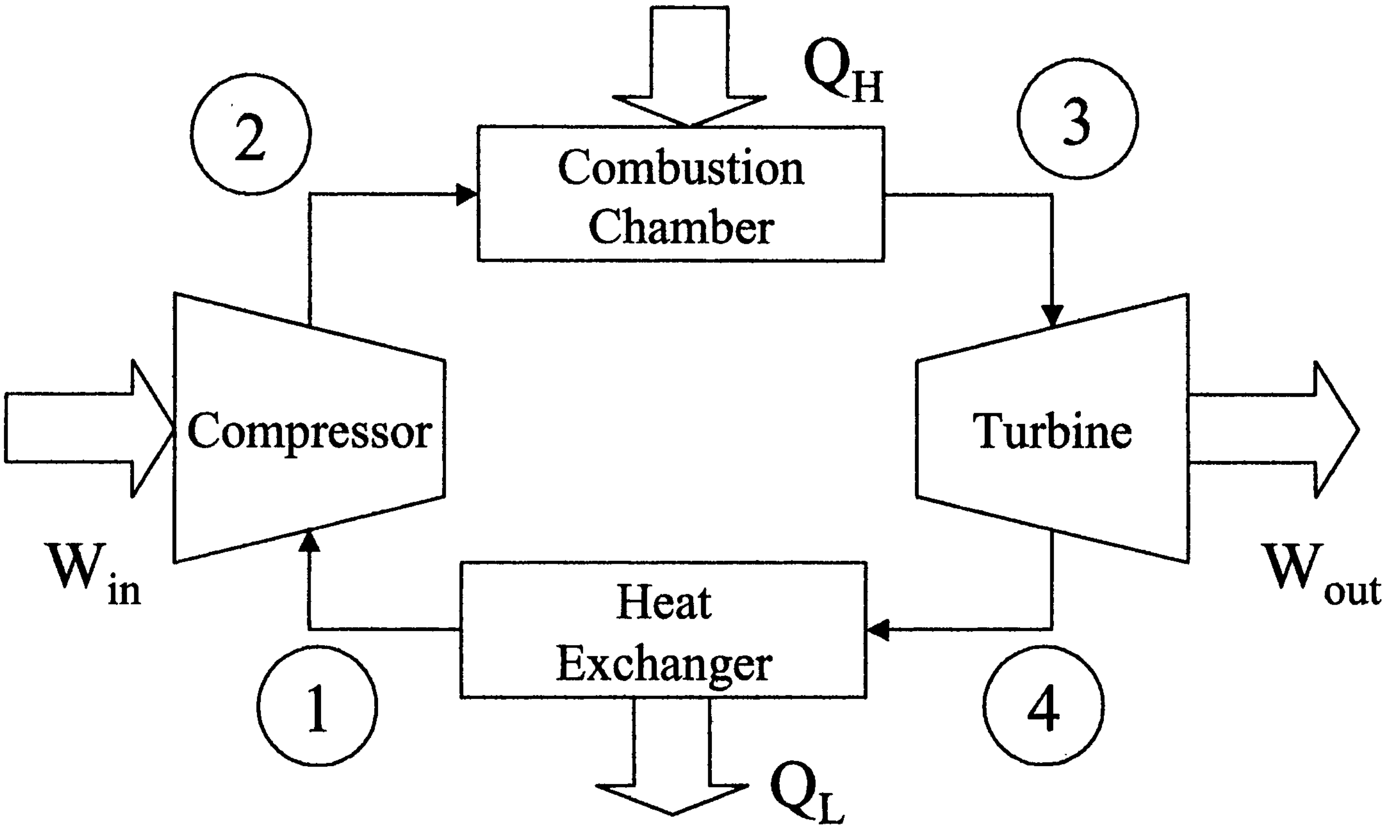
BASIC PRINCIPLES of
COMBINED-CYCLE
TECHNOLOGY

Historical trend in the average efficiency of electricity generation in central-station thermal power plants in the U.S.

(efficiency in percent, HHV basis)



Brayton Cycle (fluid = air)



$W_{in} = H_1 - H_2$

$W_{out} = H_3 - H_4$

$W_{net} = |W_{out}| - |W_{in}|$

$Q_H = H_3 - H_2$

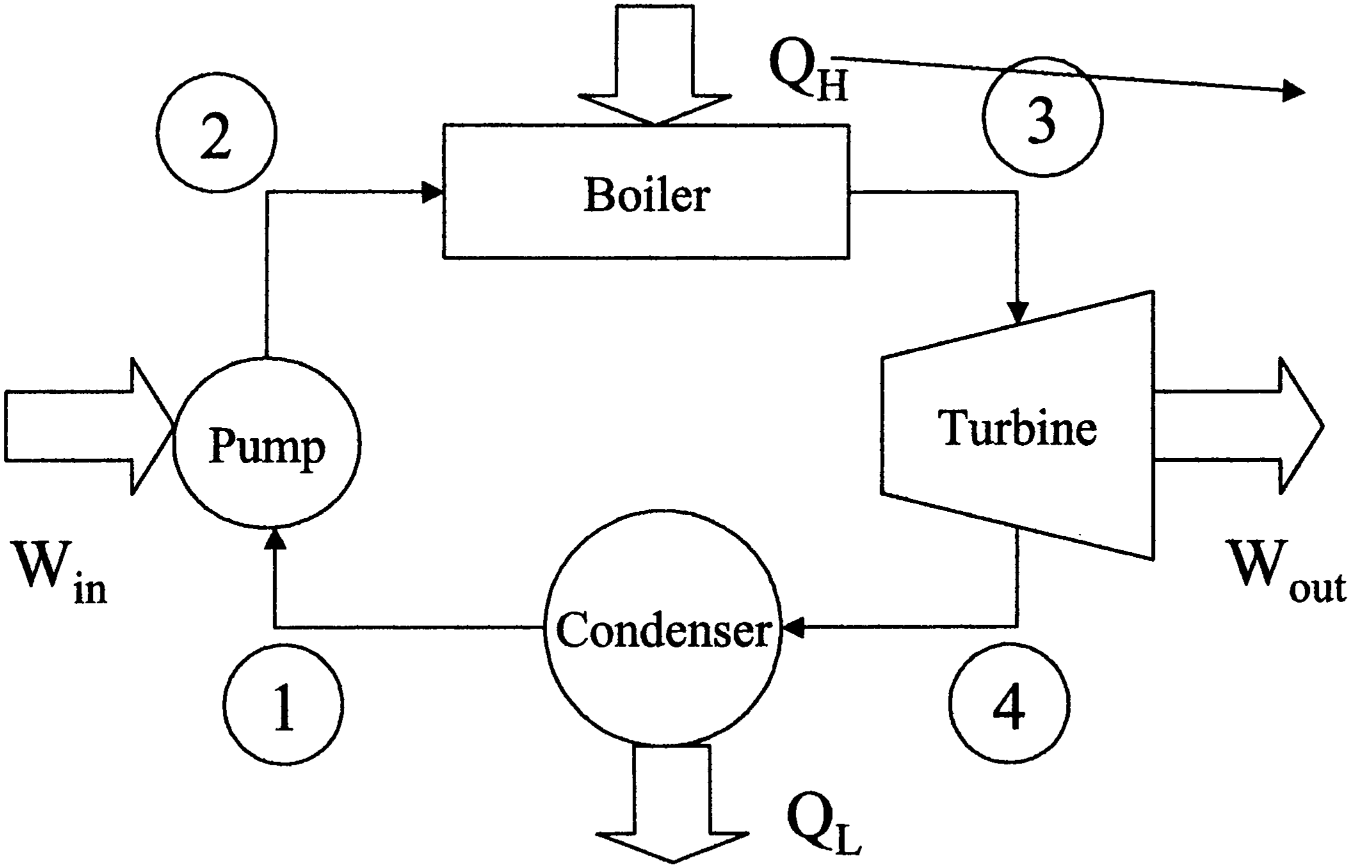
$Q_L = H_1 - H_4$

$\eta_I = W_{net}/Q_H$

$\eta_c = 1 - T_1/T_3 = 1 - T_l/T_h$

$\eta_{II} = \eta_I / \eta_c$

Rankine Cycle (closed cycle)



Fuel input:
Coal
Nuclear …

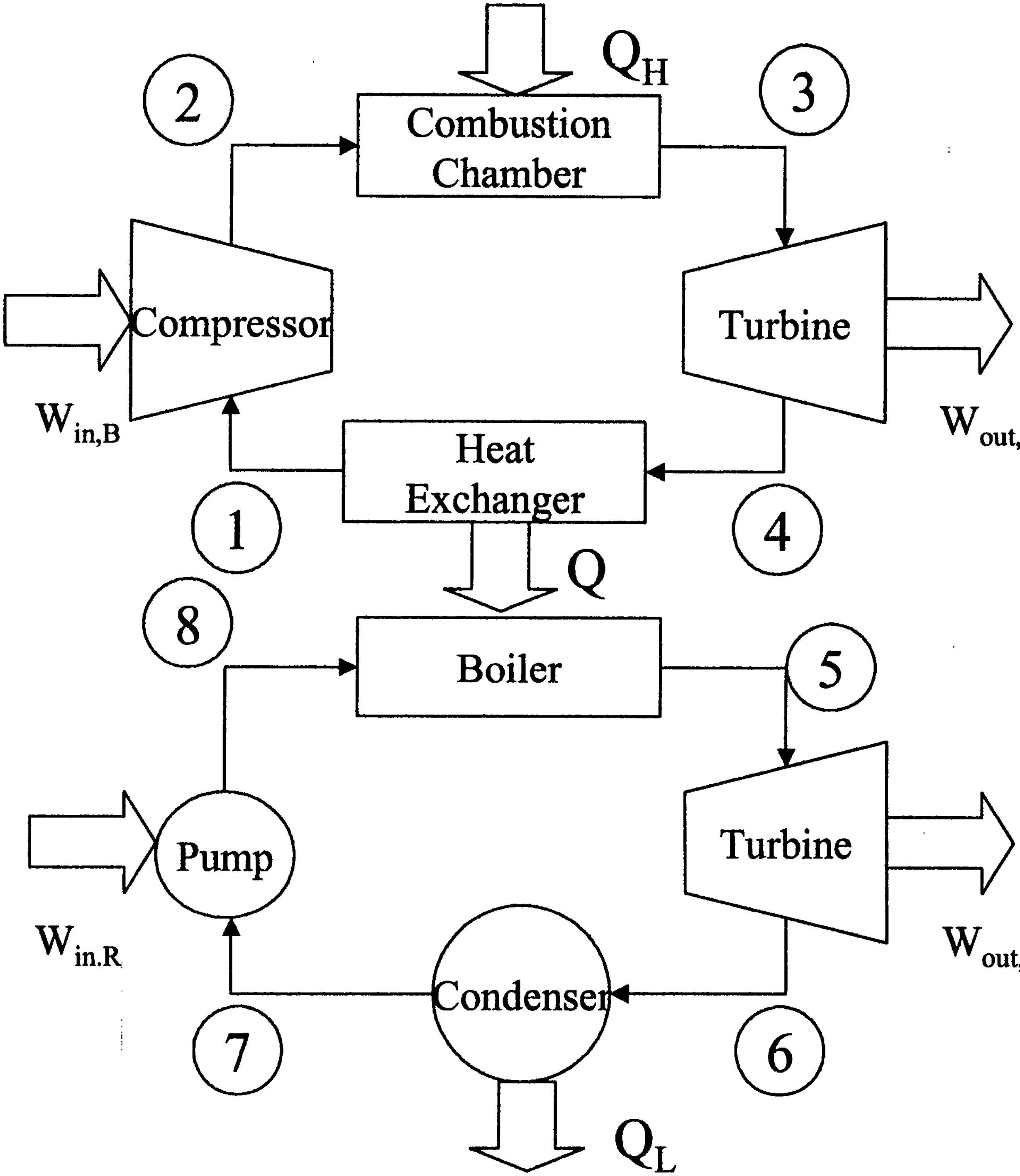
$$W_{net} = |W_{out}| - |W_{in}|$$

$$\eta_I = W_{net}/Q_H$$

$$\eta_c = 1 - T_1/T_3 = 1 - T_l/T_h$$

$$\eta_{II} = \eta_I / \eta_c$$

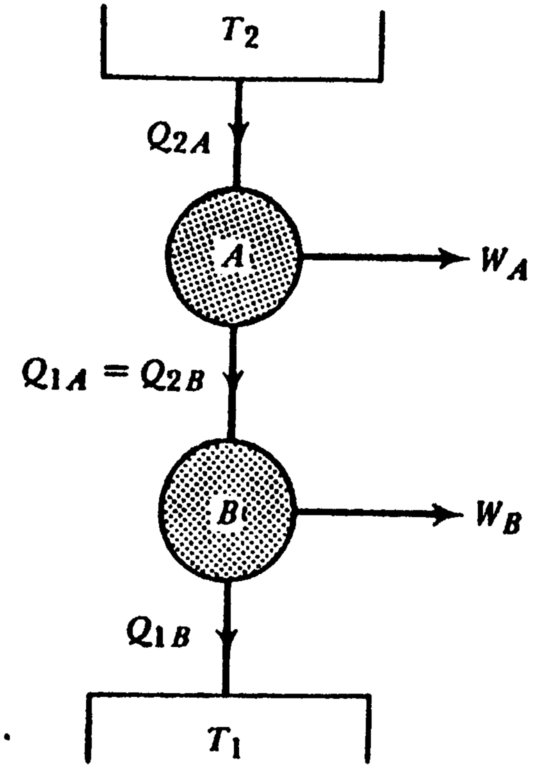
Combined Cycle



Instead of wasting the Q_L from the Brayton cycle, that heat is used boil the water in a Rankine cycle

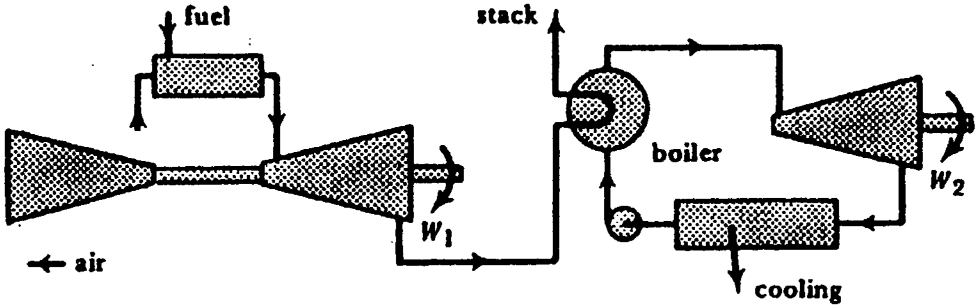
$$\eta_I = (W_{net,B} + W_{net,R}) / Q_H$$

Combined Cycle Heat Engine



$$\eta_A = \frac{W_A}{Q_{2A}}$$

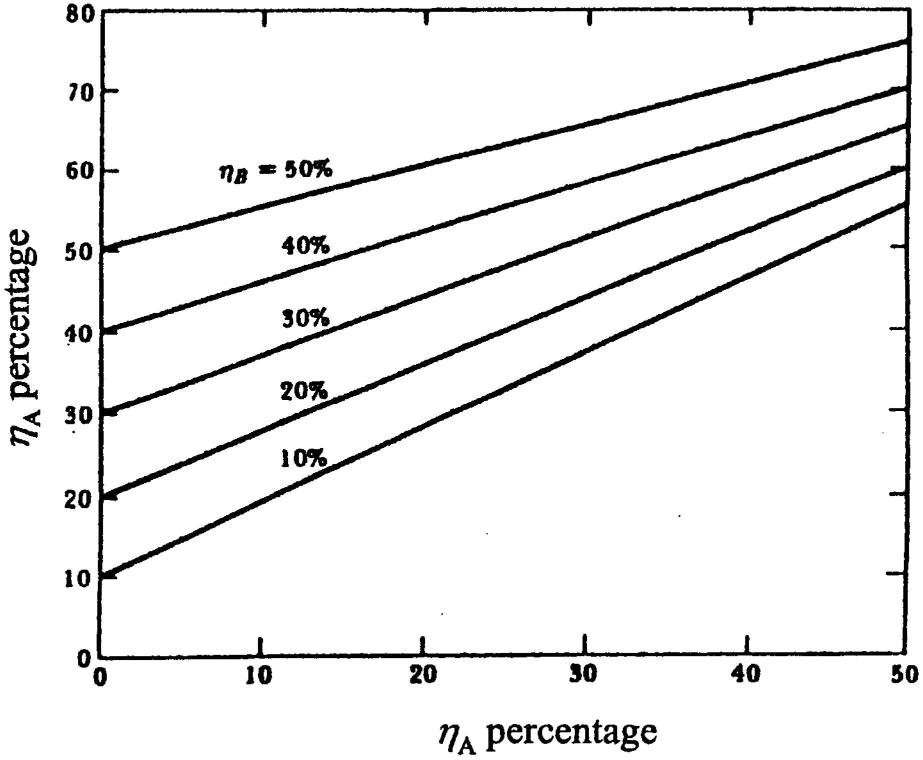
$$\eta_B = \frac{W_B}{Q_{2B}}$$



Gas-turbine cycle

Steam-turbine cycle

Overall efficiency for a combined cycle



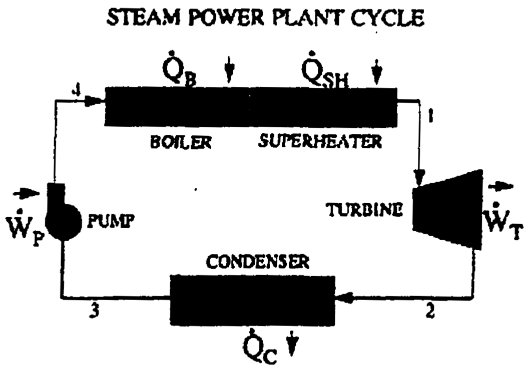
$\eta = W/Q_{2A} = (W_A + W_B)/Q_{2A}$

$W_A = \eta_A Q_{2A}$

$W_B = \eta_B Q_{2B} = \eta_B Q_{1A} = \eta_B(Q_{2A} - W_A) = \eta_B(1 - \eta_A)Q_{2A}$

$\eta = \eta_A + \eta_B(1 - \eta_A) = \eta_A + \eta_B - \eta_A\eta_B$

STEAM POWER CYCLE

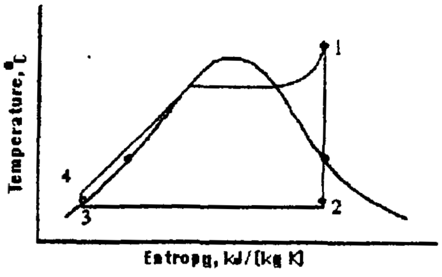

STEAM POWER PLANT CYCLE

Power plants generate electrical power by using fuels like coal, oil or natural gas. A simple power plant consists of a boiler, turbine, condenser and a pump. Fuel, burned in the boiler and superheater, heats the water to generate steam. The steam is then heated to a superheated state in the superheater. This steam is used to rotate the turbine which powers the generator. Electrical energy is generated when the generator windings rotate in a strong magnetic field. After the steam leaves the turbine it is cooled to its liquid state in the condenser. The liquid is pressurized by the pump prior to going back to the boiler A simple power plant is described by a Rankine Cycle.

RANKINE CYCLE

Saturated or superheated steam enters the turbine at state 1, where it expands isentropically to the exit pressure at state 2. The steam is then condensed at constant pressure and temperature to a saturated liquid, state 3. The heat removed from the steam in the condenser is typically transferred to the cooling water. The saturated liquid then flows through the pump which increases the pressure to the boiler pressure (state 4), where the water is first heated to the saturation temperature, boiled and typically superheated to state 1. Then the whole cycle is repeated.

Ts Diagram

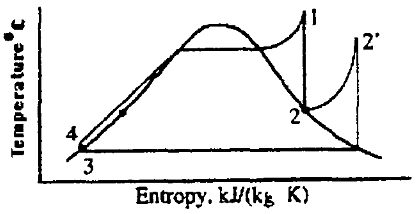


TYPICAL MODIFICATIONS

REHEAT

Ts Diagram

When steam leaves the turbine, it is typically wet. The presense of water causes erosion of the turbine blades. To prevent this, steam is extracted from high pressure turbine (state 2), and then it is reheated in the boiler (state 2') and sent back to the low pressure turbine.



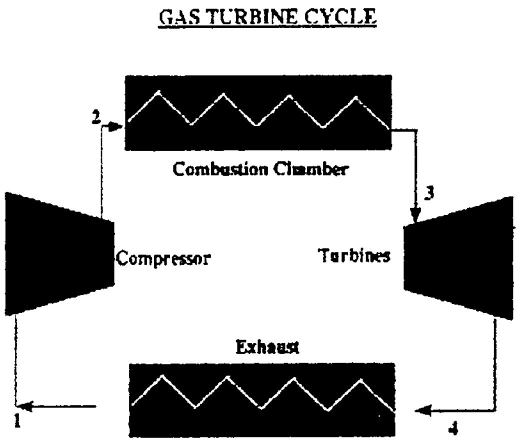
REGENERATION

Regeneration helps improve the Rankine cycle efficiency by preheating the feedwater into the boiler. Regeneration can be achieved by open feedwater heaters or closed feedwater heaters. In open feedwater heaters, a fraction of the steam exiting a high pressure turbine is mixed with the feedwater at the same pressure. In closed system, the steam bled from the turbine is not directly mixed with the feedwater, and therefore, the two streams can be at different pressures.

COMPONENTS • Boiler/Superheater • Condenser • Turbine • Pump	**THERMAL EFFICIENCY** $\text{Thermal Efficiency} = \frac{\text{Net power out}}{\text{Heat in}}$ $\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{(\lvert\dot{W}_T\rvert - \lvert\dot{W}_P\rvert)}{(\dot{Q}_B + \dot{Q}_{SH})}$ $\lvert\dot{W}_T\rvert = \dot{m}(h_1 - h_2)$ $\lvert\dot{W}_P\rvert = \dot{m}(h_4 - h_3)$ $(\dot{Q}_B + \dot{Q}_{SH}) = \dot{m}(h_1 - h_4)$ Power out of turbine : $\lvert\dot{W}_T\rvert$ Power into the pump : $\lvert\dot{W}_P\rvert$ Heat transfer rates to boiler/superheater : $(\dot{Q}_B + \dot{Q}_{SH})$
REFERENCES	**Engineering Thermodynamics** ***by*** **Jones, J. B., Dugan, R. E.,**

|Home| |Refrigeration Cycle| |Gas Turbine Cycle| | Jet Engines| |Internal Combustion Engine| |Compression Ignition Engine| |Turbine| |Compressor| |Combustion Chamber| |Pump| |Guestbook| |Credits|

GAS TURBINE CYCLE



The gas turbine is used in a wide range of applications. Common uses include power generation plants and military and commercial aircraft. In Jet Engine applications, the power output of the turbine is used to provide thrust for the aircraft.

In a simple gas turbine cycle, low pressure air is drawn into a compressor (state 1) where it is compressed to a higher pressure (state 2). Fuel is added to the compressed air and the mixture is burnt in a combustion chamber. The resulting hot products enter the turbine (state 3) and expand to state 4. Most of the work produced in the turbine is used to run the compressor and the rest is used to run auxiliary equipment and produce power.

Air standard models provide useful quantitative results for gas turbine cycles. In these models the following assumptions hold true.

- The working substance is air and treated as an ideal gas throughout the cycle
- The combustion process is modeled as a constant pressure heat addition
- The exhaust is modeled as a constant pressure heat rejection process

In cold air standard (CAS) models, the specific heat of air is assumed constant at the lowest temperature in the cycle.

Brayton Cycle

The Brayton cycle depicts the air-standard model of a gas turbine power cycle.

The four steps of the cycle are:

- (1-2) Isentropic Compression
- (2-3) Reversible Constant Pressure Heat Addition
- (3-4) Isentropic Expansion
- (4-1) Reversible Constant Pressure Heat Rejection

THE GAS-TURBINE PRIMER

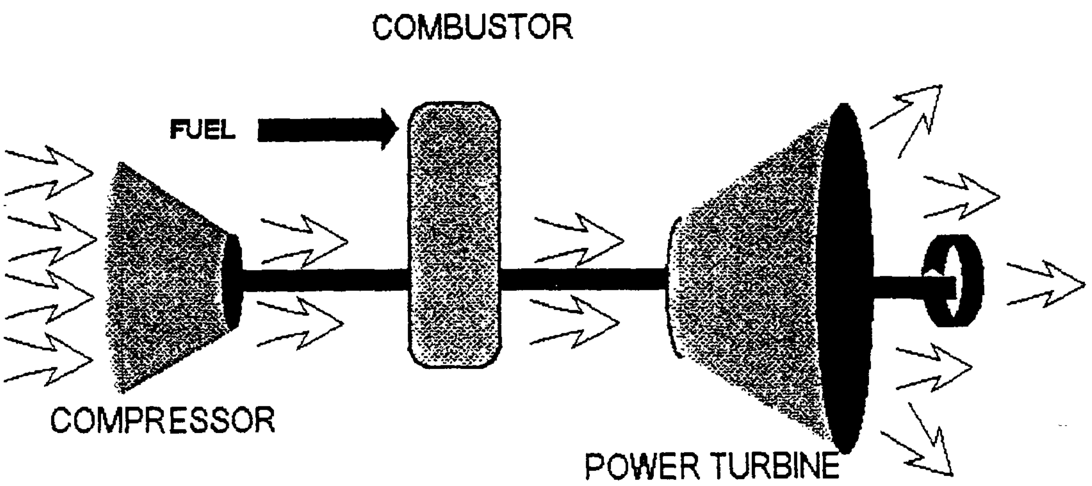
This section is provided as an educational service to people of all ages and professions who are interested in gas-turbine operation and theory. We feel it is in the best interest of the gas-turbine industry to educate the general population about this technology since it is a major power source used in the generation of electricity, and the power plant of choice for modern aircraft.

THEORY | HISTORY | GLOSSARY

GAS-TURBINE THEORY

A simple gas turbine is comprised of three main sections a compressor, a combustor, and a power turbine. The gas-turbine operates on the principle of the Brayton cycle, where compressed air is mixed with fuel, and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. In a 33% efficient gas-turbine approximately two / thirds of this work is spent compressing the air, the rest is available for other work ie.(mechanical drive, electrical generation)

SIMPLE GAS TURBINE

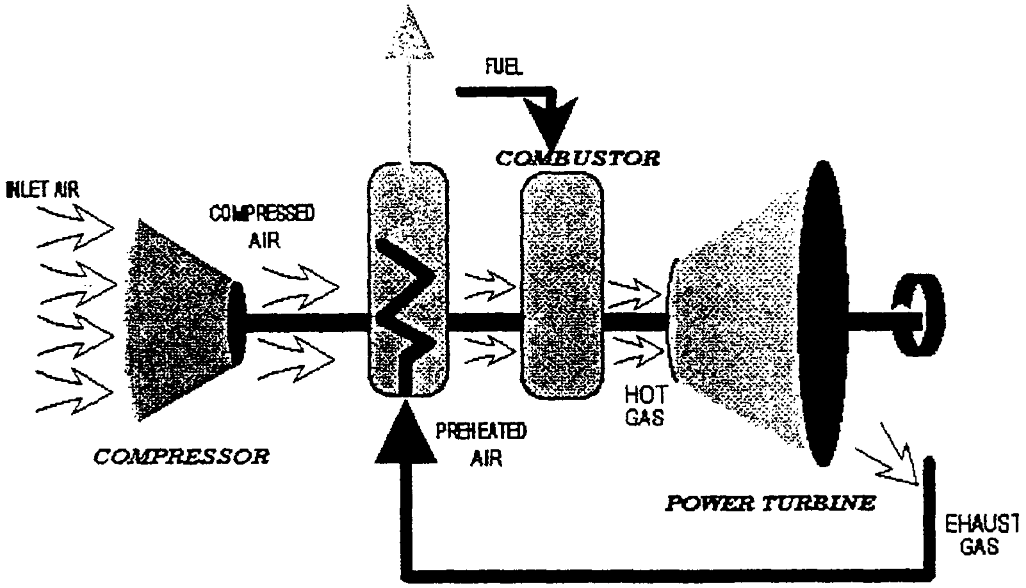


However there

are variations...

One variation of this basic cycle is the addition of a regenerator. A gas-turbine with a regenerator (heat exchanger) recaptures some of the energy in the exhaust gas, pre-heating the air entering the combustor. This cycle is typically used on low pressure ratio turbines.

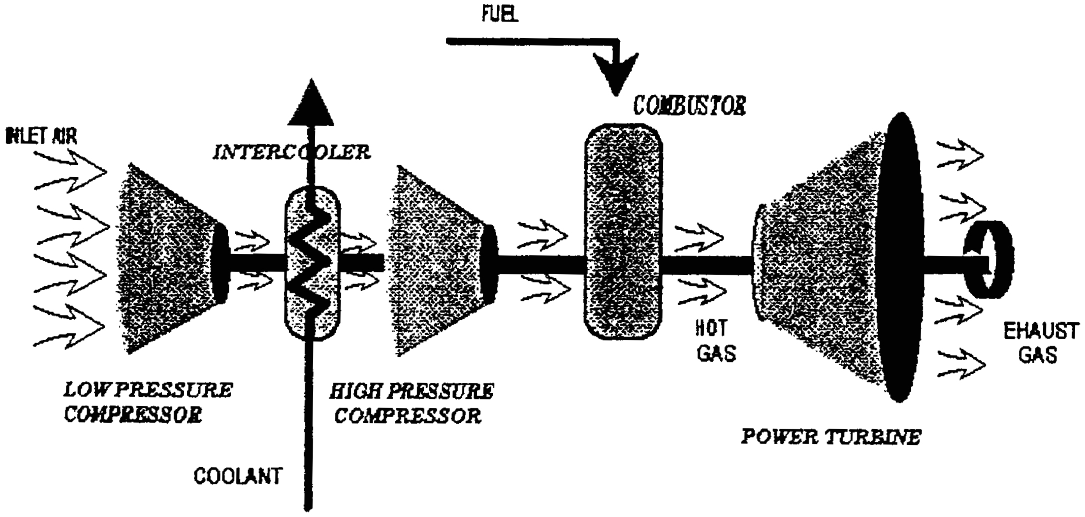
GAS-TURBINE WITH REGENERATION



Turbines using this cycle are: *Solar Centaur* / 3500 horsepower class up to the *General Electric Frame 5*

Gas-turbines with high pressure ratios can use an intercooler to cool the air between stages of compression, allowing you to burn more fuel and generate more power. Remember, the limiting factor on fuel input is the temperature of the hot gas created, because of the metallurgy of the first stage nozzle and turbine blades. With the advances in materials technology this physical limit is always climbing.<

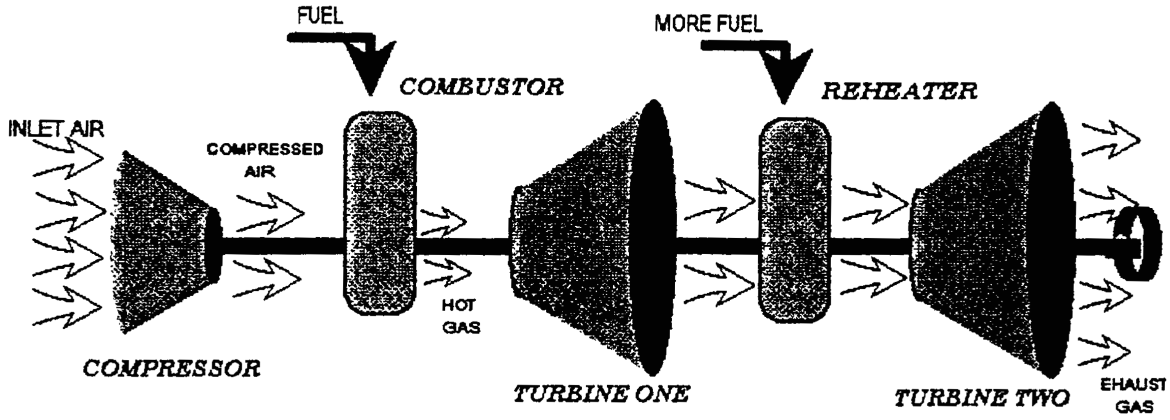
GAS-TURBINE WITH INTERCOOLING



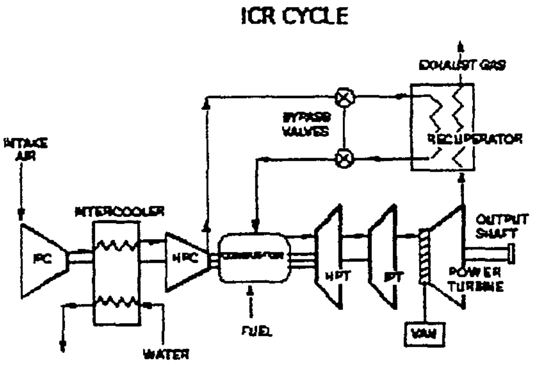
One turbine using this cycle is: *General Electric LM1600 / Marine version*

A gas-turbine employing reheat.

GAS-TURBINE WITH REHEATER



An Intercooled & Recuperated Turbine



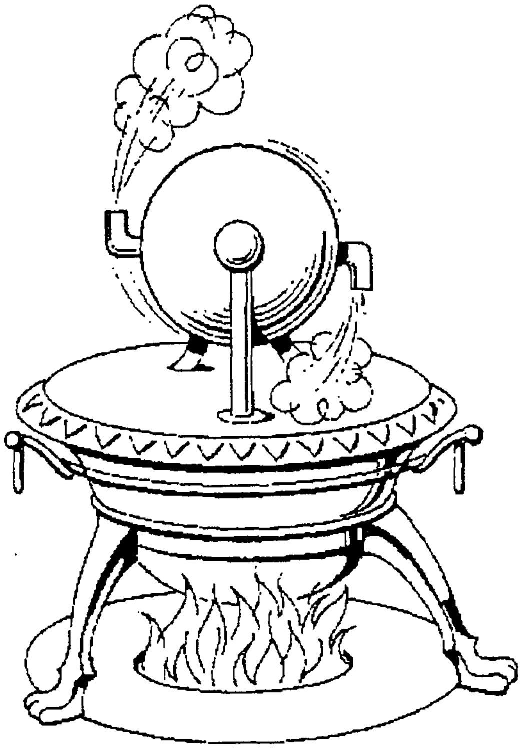
The WR-21 Project

GAS-TURBINE HISTORY

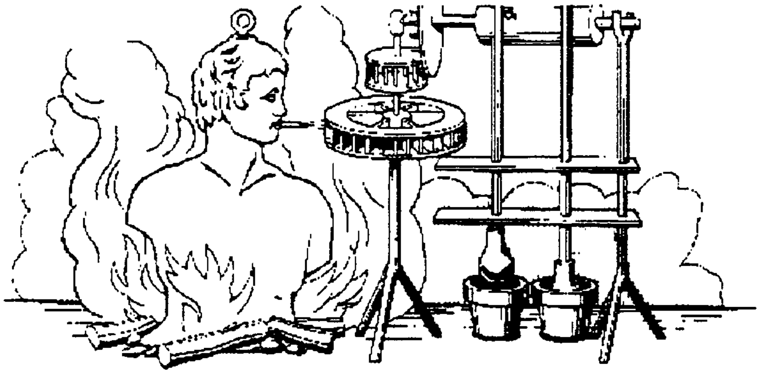
The history of the gas turbine begins with a quest for jet propulsion.

*The earliest example of jet propulsion can be traced as far back as **150 BC** to an Egyptian named **Hero**. Hero invented a toy that rotated on top of a boiling pot due to the reaction effect of hot air or steam exiting several nozzles arranged radially around a wheel. He called this invention an aeolipile.*

In **1232** the Chinese used rockets to frighten enemy soldiers.



*Around **1500** A.D. **Leonardo da Vinci** drew a sketch of a device that rotated due to the effect of hot gasses flowing up a chimney. The device was intended to be used to rotate meat being roasted. In **1629** another Italian named **Giovanni Branca** actually developed a device that used jets of steam to rotate a turbine that in turn was used to operate machinery. This was the first practical application of a steam turbine.*



***Ferdinand Verbiest** a Jesuit in China built a model carriage that used a steam jet for power in **1678**.*

*The first patent for a turbine engine was granted in **1791** to an Englishman named **John Barber**. It incorporated many of the same elements of a modern gas turbine but used a reciprocating compressor. There are many more early examples of turbine engines designed by various inventors, but none were considered to be true gas turbines because they incorporated steam at some point in the process.*

*In **1872** a man by the name of **Stolze** designed the first true gas turbine. His engine incorporated a multistage turbine section and a multi stage axial flow compressor. He tested working models in the early **1900's**.*

***Charles Curtis** the inventor of the Curtis steam engine filed the first patent application in the U.S. for a gas turbine engine. His patent was granted in **1914** but not without some controversy.*

*The General Electric company started their gas turbine division in **1903**. An engineer named **Stanford Moss** lead most of the projects. His most outstanding development was the General Electric turbosupercharger during world war 1. (Although credit for the concept is given to Rateau of France.) It used hot exhaust gasses from a reciprocating engine to drive a turbine wheel that in turn drove a centrifugal compressor used for supercharging. The evolutionary process of turbosupercharger design and construction made it possible to construct the first reliable gas turbine engines.*

Sir Frank Whittle of Great Britain patented a design for a jet aircraft engine in **1930**.He first proposed using the gas turbine engine for propulsion in 1928 while a student at the Royal Air Force College in Cranwell, England. In 1941 an engine designed by Whittle was the first successful turbojet airplane flown in Great Britain.

Concurrently with Whittle's development efforts, Hans von Ohain and Max Hahn, two students at Gottingen in Germany developed and patented their own engine design in **1936** these ideas were adapted by The Ernst Heinkel Aircraft company. *The German **Heinkel** aircraft company is credited with the first flight of a gas turbine powered jet propelled aircraft on **August 27th 1939**.The HE178 was the first jet airplane to fly.*

The Heinkel HeS-3b developed 1100 lbs. of thrust and flew over 400 mph, later came the ME262, a 500 mph fighter, more than 1600 of these were built by the end of WWII. These engines were more advaced than the British planes and had such features as blade cooling and a variable area exhaust nozzles.

*In **1941**Frank Whittle began flight tests of a turbojet engine of his own design in England. Eventually The General Electric company manufactured engines in the U.S. based on Whittle's design.*

To be continued ...... *information courtesy Ron Munson*

Home

Updated Dec 01, 2001

Since January 14th 1996... You are visitor 95449

Exhibit___(WMZ-2)

SITE VISIT TO

PLANT LANSING SMITH UNIT 3

12/14/01

Exhibit___(WMZ-3)

PLANT WANSLEY'S
COMBINED CYCLE UNITS

Here are two of the four combined-cycle units that are under construction. Each combined-cycle unit consists of two gas turbines that supply the heat for two Heat Recovery Steam Generators (HRSG), which in turn, power the steam turbine. These 400MW units are very similar to Unit 3 at Plant Smith..

Exhibit___(WMZ-4)

18 PAGES

MANUFACTURER'S CATALOG

for

COMBINED-CYCLE TURBINES

GER-4201

GE Power Systems

Structured Steam Turbines for the Combined-Cycle Market

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Structured Steam Turbines for the Combined-Cycle Market

Abstract

GE's variety of robust steam turbine products has proven to be a valuable choice in today's highly competitive, combined-cycle marketplace. A discussion of the GE steam turbine offering for 2-on-1, "F" technology, gas turbine, combined-cycle plants is the main focus of this paper, with emphasis placed on the structured D-11 product – the customer's choice for delivery cycle, performance, reliability, and availability.

Introduction

To date, GE has built over 40 steam turbines used in "F" technology, gas turbine, combined-cycle applications, totaling over 6000 MW in steam turbine-generator output. In a GE Steam And Gas (STAG) application, the steam turbine is matched with one or more gas turbines, utilizing the exhaust energy from the combustion turbine(s) to produce steam through a heat recovery steam generator (HRSG). A typical GE configuration uses a three-pressure HRSG for the plant, where steam is supplied from high-pressure (HP), intermediate-pressure (IP), and low-pressure (LP) drums to the corresponding section of the steam turbine.

In the past, GE's design philosophy dictated standardization of some of the major turbine components, but customization of the steam path for each application. In 1997, in response to customers' continual demands for shorter delivery cycles and higher efficiency, GE recognized the need to take a more proactive approach to meet the demands of a competitive and growing marketplace.

To be competitive in this market, GE needed a steam turbine product that was both efficient at baseload conditions and robust enough to be used in a variety of climates, configurations, and operating modes. While only a custom-designed unit could operate at peak efficiency in any given situation, the design and production of such a unit would result in a prohibitively high price and an excessively long delivery cycle. This was not an option for a domestic U.S. market that was beginning to add significant capacity for the first time in many years. Based on an analysis of market activity, GE focused its standardization effort on steam turbines for 207FA and 209FA combined-cycle plants. GE's product for these particular applications is the D-11 turbine, a design consisting of a combined, opposed-flow, HP/IP section with single-shell construction, and a two-flow LP section (*Figure 1*).

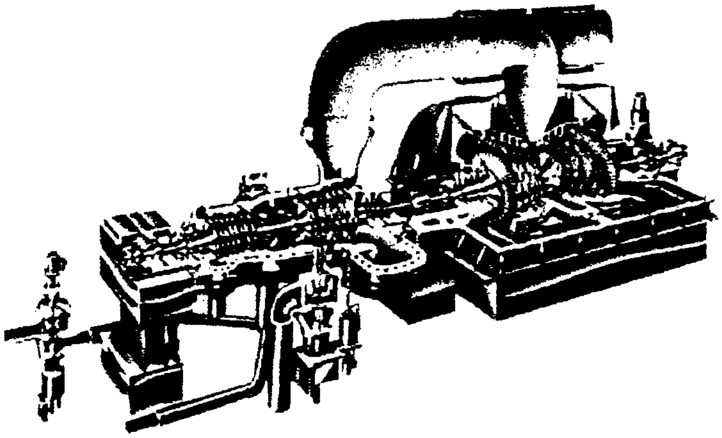

Figure 1. GE's D-11 steam turbine

The results of this design standardization yielded five basic D-11 structured configurations, which are listed in *Table 1*. For the 60-Hertz (Hz) market, three standard LP sections have been designed with last-stage bucket (LSB) lengths of 30 in. (76.2 cm), 33.5 in. (85.1 cm), and 40 in. (101.6 cm). For the 50 Hz market there are two standard LP sections, based on LSB lengths of 33.5 in. (85.1 cm) and 42 in. (106.7 cm).

STAG plant	**207FA**	**209FA**
Casings	**2**	**2**
HP Stages	**11**	**10**
IP Stages	**7**	**8**
LP Stages (per flow)	**5**	**5**
RPM	**3600**	**3000**
LSBs	**30 in.** **33.5 in.** **40 in.**	**33.5 in.** **42 in.**

Table 1. Structured D-11 configurations

Cycle Optimization

The starting point for designing the structured D-11 product is the highly efficient and reliable, three-pressure HRSG design, with nominal 1800 psia/1050°F (124 bar/566°C) throttle conditions and 1050°F reheat temperature. Given that the basic bottoming cycle parameters were already determined, efforts were centered on determining the optimum IP and LP admission pressures in terms of overall cycle and steam turbine efficiency.

IP Admission and Reheat Pressure

As shown in *Figure 2*, variation in hot reheat pressure does not have a significant effect on steam turbine generator output over the range considered. The reheat pressure will ultimately set the IP admission level since the IP admission is into the cold reheat line. The hot repeat pressure impacts the volume flow of the reheat system, and therefore, has a major influence on the design of both the HRSG and the steam turbine. Hot reheat pressure for the cycle is set by the flow passing area of the first IP turbine nozzle. For GE's structured D-11 product, the hot reheat pressure for the baseload condition was set at 333 psia (23 bar) for the 207FA configuration and 366 psia (25.2 bar) for the 209FA configuration. Since these results are very close to the combined cycle optimum level, GE's designs for the HRSG and steam turbine are both cost effective and mechanically conservative.

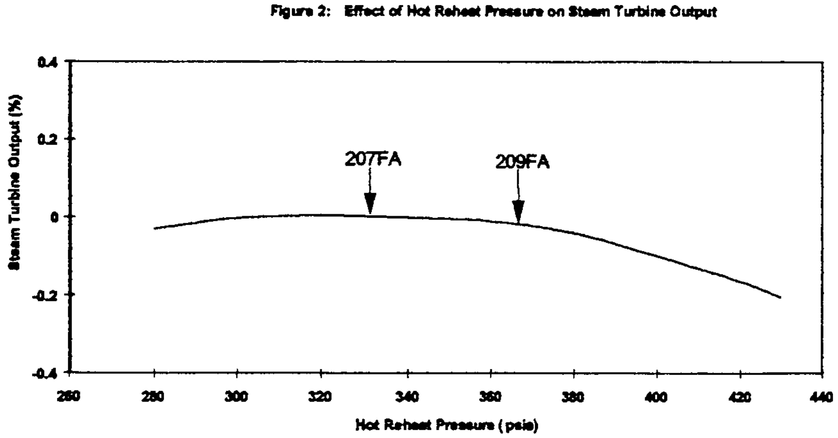

Figure 2. Effect of hot reheat on pressure steam turbine output

LP Admission Pressure

The second parameter that GE investigated for optimization was the LP admission pressure level, including the place within the steam turbine flow path to locate this admission. The effect of steam turbine output based on the variation of LP admission preassure is shown in *Figure 3.* This optimization considered steam turbine output effects, HRSG surface area effects and stack exit temperature, volume flow criteria, and location of admission interface with the steam turbine. As a result of the analysis of the parameters mentioned above, the low-pressure admission was located in the IP exhaust region of the steam turbine. Because the IP exhaust passes directly into the low-pressure turbine crossover pipe, the pressure in the crossover pipe is directly set by the HRSG LP drum pressure level.

As a result of extensive cycle and steam turbine efficiency optimizations as well as the careful selection and design of the IP and LP steam paths, GE was able to establish a common LP admission pressure and effective flow passing area (AeN). Because of this work on the standardization of the crossover pressure, it was now possible to design, for a given class of turbine (207FA or 209FA), a single IP section that was compatible with a variety of standardized low - pressure sections. The optimized LP Bowl pressures were set at 55 psia (3.8 bar) for the 207FA configuration and 66 psia (4.5 bar) for the 209FA machine.

Steam turbine condensing pressure has a large influence on steam turbine output and varies depending on the available condensing medium. Knowing the optimum required LP admission/LP crossover pressure made it possible for GE to match the fixed IP turbine with a newly designed series of standardized low-pressure turbine sections with different last-stage buckets and annulus areas for different condensing pressures. These LP modules can be interchanged without impact to the HP/IP turbine design.

Structured D-11 Design Features

The optimized 207FA and 209FA thermal cycles have enabled the development of a standardized family of steam turbines. A cross-sectional drawing is shown in *Figure 4.*

Opposed Flow HP/IP Section

The structured D-11 steam turbine evolved from the opposed-flow, HP/IP turbine with a double-flow LP section, a design that has been

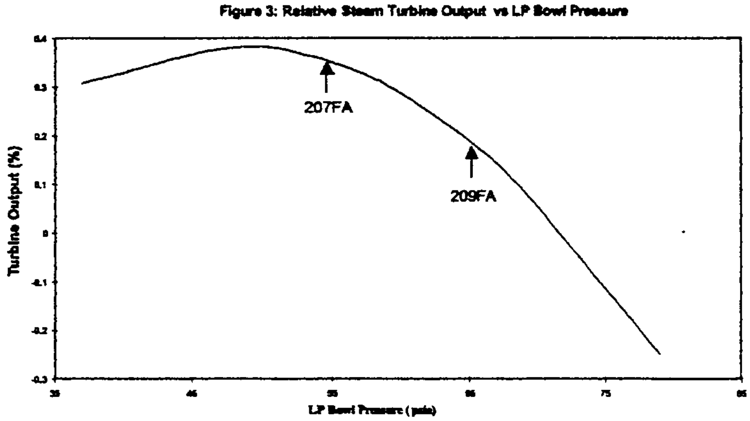

Figure 3. Relative steam turbine output vs. LP admission pressure

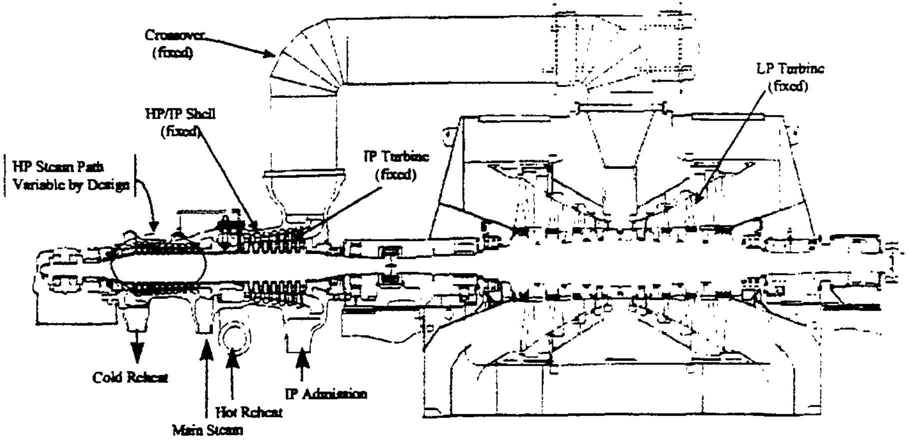

Figure 4. Cross-section of the structured D-11 turbine

applied in fossil and combined-cycle applications for many years. Main steam enters the turbine at the bottom of the high pressure shell via two separate stop and control valves. The flow of HP steam continues to the left in *Figure 4* and exits the section via the cold reheat line where it returns to the HRSG. The reheated, intermediate pressure steam enters the center of the casing via the hot reheat piping and flows through the IP section in the direction opposite that of the HP section. This design results in an even temperature gradient from the center of the casing to the ends, as the highest temperature steam in the system enters at the center of the shell and then gradually reduces its temperature as it flows outward toward the end packings and bearings.

The combined HP/IP section utilizes single shell construction that has been proven by successful operating experience at a maximum operating pressure of 1950 psia at an operating temperature of 1050°F. There are two HP/IP shell designs, one for 207FA, 60 Hz applications and one for 209FA, 50 Hz applications. Each shell design is standard, with the interstage diaphragm grooving and supports already designed into the shell (*Figure 5*). Variability in the steam path design is limited to the high pressure section, with the HP staging customized for each application.

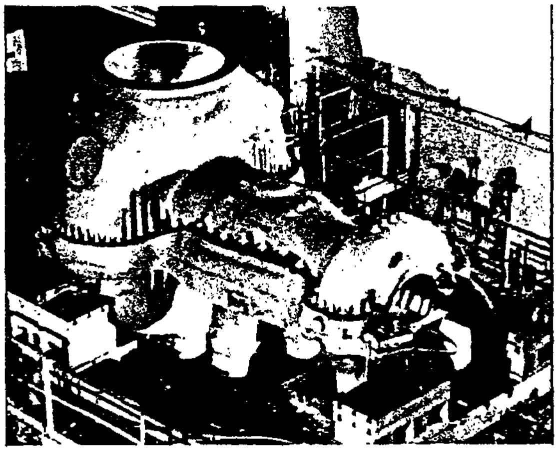

Figure 5. Machining of HP/IP casing

Steam Path Design

Staging within the HP and IP sections is based on low reaction design theory, which leads to the use of wheel-and-diaphragm construction (*Figure 6*). Rows of rotating blades, or buckets, are machined from blocks of 12Cr steel, utilizing a pinetree dovetail design, as shown in *Figure 7*. These buckets are assembled tangentially on a rotor wheel and locked into place by the use of several specially designed closure buckets and by bands or covers, which are fastened or "peened" over several buckets at a time. Stationary blades, or nozzles, are also machined from 12Cr steel and are assembled in the outer ring and inner web portions of the diaphragm (*Figure 8*). The diaphragm sections are then affixed in grooves in the upper and lower halves of the shell.

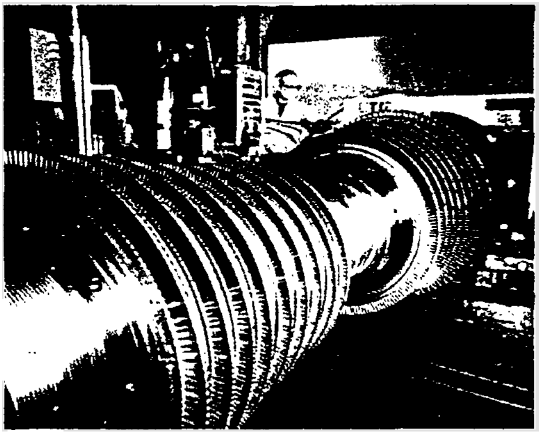

Figure 6. Assembled HP/IP rotor

The HP section was designed to accommodate up to 45% additional throttle mass flow based on the site-specific requirements for supplementary firing. Because of the fixed IP steam path and the variable range of reheater pressure drop, the cold reheat pressure varies within a certain range. Hence, this pressure variation requires some customization of HP staging for each application. Since two 7FA or 9FA gas turbines provide a predetermined amount of exhaust energy, and the HRSG surface areas are somewhat standardized by the constraints discussed earlier, it was possible to optimize HP turbine thermal performance, and to fix the number of high pressure stages at 11 for the 207FA turbine and 10 for the 209FA turbine. With the fixed staging of the IP section, it became possible to closely control the HP/IP rotor design in terms of forging size and bearing span. Rotor dynamic criteria have been thoroughly analyzed so that the relatively small steam path variations allowed in the high-pressure section do not require re-analysis of the design for each application.

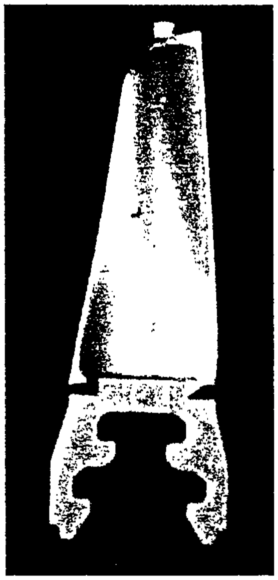

Figure 7. Tangential entry "Pinetree" dovetail bucket

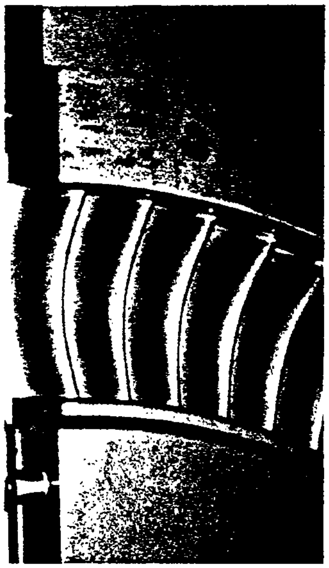

Figure 8. Diaphragm section

Low-Pressure Section

The low-pressure section designs are based on GE's established, highly reliable and efficient family of last stage buckets (LSBs), shown in *Figure 9.* These buckets are of the continuously

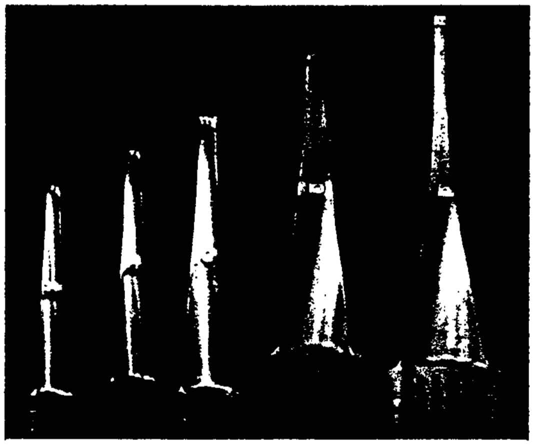

Figure 9. Last stage bucket family

coupled design, with attachments at both the vane tip and mid-vane to provide a high degree of rigidity, model suppression, and damping.

Through use of computer modeling of the LP section, GE found that this section could be optimized with a 5-stage design. In addition, maximization of the steam turbine output required redesigning the upstream LP stages, utilizing the most advanced, three-dimensional blade design technology. This redesign effort resulted in an integrated and interchangeable set of low-pressure turbines, specifically designed for combined-cycle applications.

In previous designs, provisions for feedwater heating extractions from the low-pressure turbine were included only if required by the specific application of any low-pressure section. Extraction provisions for feedwater heating are now included on all structured D-11 LP turbine sections.

Application Rules for the Structured D-11 Steam Turbine

The structured D-11 steam turbine is designed for an 1800 psia inlet pressure at nominal flow conditions. Like most combined-cycle steam turbines, normal operation is with valves wide open in boiler-following mode. Once the guarantee point inlet pressure is established, the corresponding HP turbine flow passing area (otherwise known as AeN) becomes fixed, at which point inlet pressure will vary directly with inlet flow. *Table 2* summarizes the key design parameters for the structured D-11 turbine. When supplementary firing is applied, the maximum inlet pressure for the fired case is allowed to float higher than the unfired case. This is permissible, given that the additional flow generated by supplementary firing causes a greater pressure drop across the inlet valves and piping, so that the same pressure will be seen at the high pressure bowl. If the intent is to apply a significant level of supplementary firing only during periods of peak energy demand, it is necessary to set the unfired inlet pressure at a much lower value. For instance, if up to 20% supplemental firing is anticipated on an intermittent basis, then the unfired pressure should be set at 1910 psia/ 1.2 = 1592 psia. (*See Figure 10.*)

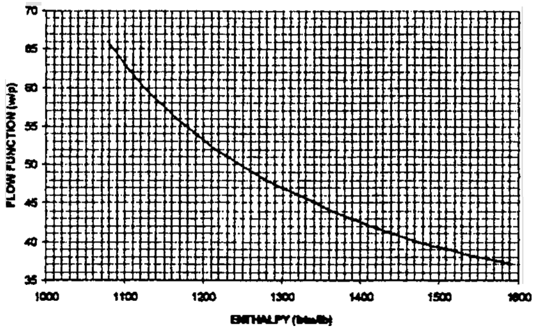

Figure 10. Flow function vs. enthalpy

Note that in *Table 2*, the inlet AeNs of both the IP turbine and LP turbine are already fixed because, unlike the HP turbine, the designs of both the IP and LP sections of the steam path are based on the optimizations mentioned in the "Cycle Optimization" section of this paper. These inlet AeNs remain fixed, regardless of the

STAG Configuration Machine Speed (RPM) Supplementary Duct Firing		207FA 3600 UNFIRED	207FA 3600 MAX FIRED	209FA 3000 UNFIRED	209FA 3000 MAX FIRED
Machine rating	MW	180	265	283	400
Throttle pressure limit	psia	1890	1910	1890	1910
Throttle temperature limit	F	1050		1050	
HP AeN	Sq-in	11.75	17.27	17.56	25.73
Cold reheat pressure at turbine flange, based on 12% reheat pressure drop	psia	379	509	416	548
Cold reheat pressure at turbine flange, based on 6% reheat pressure drop	psia	355	476	390	513
RHT pressure drop (Min.)	%	6		6	
RHT pressure drop (Nominal)	%	10		10	
RHT pressure drop (Max.)	%	12		12	
Hot reheat pressure	psia	333	448	366	482
Hot reheat temperature	F	1050		1050	
IP/Reheat bowl pressure (Nominal)	psia	330	443	362	477
IP/Reheat bowl AeN	Sq-in	74.38		101.78	
IP exhaust pressure (Nominal)	psia	56	71	69	87
LP admission pressure at valve	psia	58	73	71	89
LP bowl AeN	Sq-in	421		513	

Table 2 Thermal Application Data

amount of supplemental firing. Hence, for given mass flows, the pressures at the inlets of the IP and LP sections can be established. If the cycle is fired, then the additional flow will result in higher pressures at these points.

AeN, or the pressure that results from establishing the AeN, may be reasonably estimated from the equation:

$AeN = F/(w/p) \times P$; *or*

$P = F/AeN \times (w/p)$,

where:

F = *Flow in lb/hr*

AeN = *Flow passing area in sq. in.*

(w/p) = *Flow function, determined from the graph in Figure 10, once enthalpy is known*

P = *Initial pressure, in psia*

Close attention must be paid to the pressure vs. AeN equation to ensure that the turbine and HRSG are properly matched. *Table 2* shows AeNs for the IP and LP inlets, and the nominal pressures associated with each of these points if the thermal cycle is configured around these parameters.

It is important to note that under all steady state operating conditions, both the main steam inlet and reheat steam inlet are designed to accommodate a maximum temperature of 1050°F.

It can be seen from *Table 2* that two sets of cold reheat pressure values are given. The first assumes a total of 6% pressure drop through the reheat section of the HRSG including cold and hot reheat piping, while the second assumes a total of 12% pressure drop. By using these pressure drops, the cold reheat values may be predicted knowing that the reheat turbine inlet AeN is set at 74.38 in^2 (479.87 cm^2) for the 60 Hz turbine and 101.78 in^2 (656.64 cm^2) for the 50 Hz turbine. This flow restriction controls the pressure in the reheat section of the HRSG and therefore, the pressure at the turbine high-pressure section exhaust.

Similarly, the LP bowl AeN is set at 421 in^2 (2716 cm^2) for the 60 Hz turbine and 513 in^2

(3310 cm^2) for the 50 Hz turbine. This parameter controls the pressure in the turbine crossover and therefore, the IP turbine exhaust, which is also the LP steam admission point. There is normally a total of about 2-psi pressure drop across the LP admission strainer, LP butterfly control valve and LP butterfly stop valve, admission pipe and turbine inlet flange. This is shown in *Table 2* as the pressure difference between IP nominal exhaust pressure and LP admission pressure.

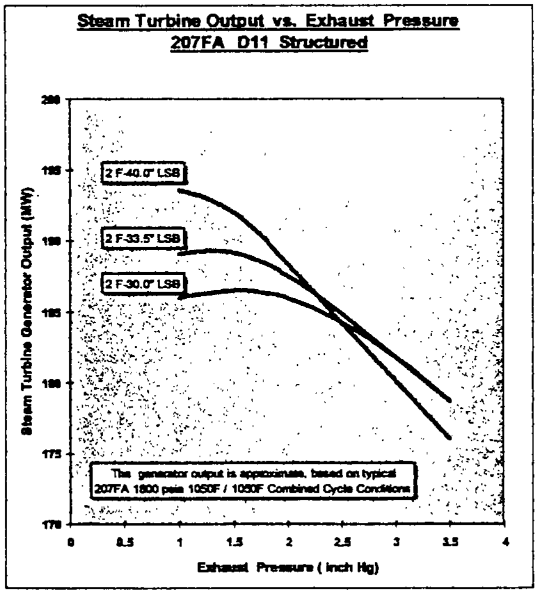

Figure 11a. Output vs. exhaust pressure – 60 Hz

LSB Selection

When configuring any steam turbine, it is very important to choose the proper annulus area for the anticipated exhaust flow and condenser pressure. *Figures 11a and 11b* show potential choices of last stage buckets for 60 Hz and 50 Hz applications, respectively. Given the design point of the turbine and the range of condensing pressures, the optimum LSB can be selected, and from there, the associated annulus area may be calculated. Economic factors come into play when selecting low-pressure turbine sections, but the use of *Figure 11* together with the LP turbine data shown in *Table 3* provides the proper selection for most applications, where LP exhaust loss is minimized for a particular condenser pressure.

Other Features

Structured D-11 steam turbines have additional flexibility because of the following thermal cycle variations that were taken into account as part of the conceptual design process:

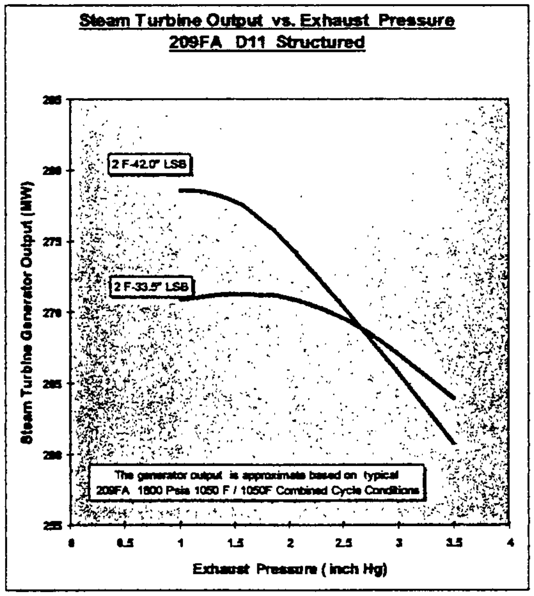

Figure 11b. Output vs. exhaust pressure – 50 Hz

1. Two-pressure reheat cycle (no LP admission). If fuel oil (containing sulfur) is the primary or secondary fuel, the thermal cycle will not support the third level of steam generation in the HRSG. A structured D-11 turbine applied to such a cycle should be configured without the LP admission port.
2. Process extraction from HP or IP exhaust piping, as shown schematically in *Figure 12*. The shell connections and

Note: All pressures are approximate

		207FA	207FA	207FA		209FA	209FA
LP LSB Length	inch	**40**	**33.5**	**30**		**42**	**33.5**
Back pressure range w/o firing	inch Hg	1.0 - 2.3	2.3 - 2.8	2.8 - 3.5		1.0 - 2.5	2.5 - 3.5
Back pressure range with firing	inch Hg	1.2 - 2.9	2.9 - 3.5	3.5 - 4.5		1.2 - 3.0	3.0 - 4.5
LP bowl pressure w/o firing	psia	55	55	55		66	66
LP bowl AeN	sq-in	421	421	421		513	513
LP extraction stage for DA	-	L-4	L-4	L-4		L-4	L-3
LP extraction size for DA	inch	2x14	2x14	2x14		2x16	2x16
LP extraction flow % of LP bowl	%	10	10	10		10	10

Table 3. LP turbine data for structured D-11 steam turbines

IP staging are designed to withstand the additional loads caused by process extraction flows.

3. Feedwater heating deaeration extraction from low-pressure turbine section. (Generally used for cycles where the gas turbine fuel has relatively high sulfur content)
4. Application of 1000°F/1000°F cycle temperatures in lieu of the standard 1050°F/1050°F, due to economic considerations, which allows the use of (less expensive) P22 main steam and hot reheat piping, rather than the more expensive P91 piping.
5. Application of two different GE generators at both 50 Hz and 60 Hz to accommodate the range of output, considering the steam turbine output difference between unfired and maximum supplementary fired cases.

Heat Balance Requirements

The information given above will allow a conceptual steam turbine design to be successfully incorporated into the thermodynamic design of the plant. It is necessary, however, to pay strict attention to the entire range of operating scenarios to which the plant will be subjected and to anticipate such occurrences in the design of the steam turbine, so that reliability and per-

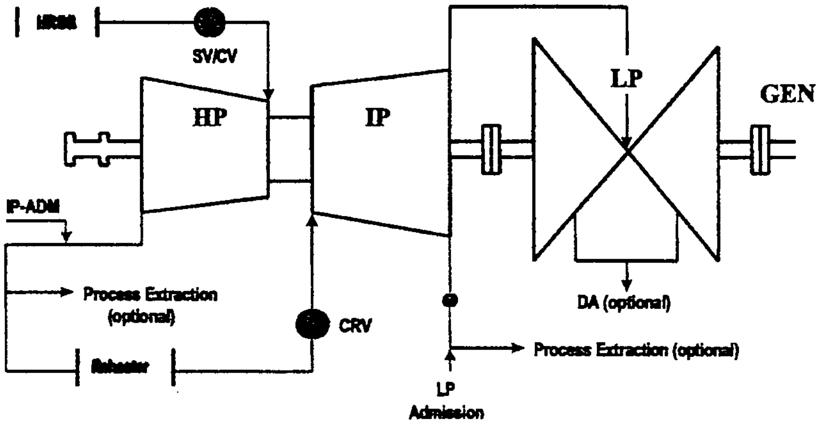

Figure 12. Schematic showing structured D-11 layout with possible extractions

formance targets are met. In addition to the guarantee point heat balance data, GE also requires the heat balance data at the maximum and minimum ambient conditions for which the plant will be designed. Simply put, cold air is denser than hot air, so that on a cold day the gas turbines will pass a greater mass flow and produce more power and exhaust energy. This in turn drives greater steam production from the HRSG, which results in greater flow to the HP turbine, and a corresponding higher throttle pressure. On a maximum ambient temperature day, the reverse scenario takes place, but the decreased steam production will result in potentially higher steam temperatures. Since the plant cannot operate safely at temperatures above 1050°F, excess heat must be handled by attemperation, or through features in the overall plant design. Therefore, at a minimum, the following three heat balances must be available:

1. Cold ambient day steam conditions.
2. Hot ambient day steam conditions.
3. Guarantee point steam conditions.

If these heat balances do not fully describe the operating envelope with respect to maximum throttle pressure and temperature, maximum and minimum IP and LP admission flows, and maximum and minimum process extraction flows, then additional heat balances will be required. This information is used to ensure that temperatures and pressures within the turbine steam path are accounted for in the design of the HP section, and evaluated against the pre-established design limits of the IP and LP sections.

Bypass System Information

Bypass system data is additional information necessary to successfully release any steam turbine for steam path design. Most modern combined-cycle power plants use the "Cascading" type of bypass system, for which the structured D-11 steam turbine may be configured as a standard option. Specific bypass system information required is:

1. Bypass configuration (i.e., cascading, or other configuration);
2. HP and LP bypass system capacities, expressed as a percentage of main steam flow; and
3. HRSG floor pressure (this parameter must be provided by the HRSG vendor).

This information enables the high pressure exhaust set point to be established, to enable bypass mode thermal modeling of the HP, IP, and LP turbines. This ensures that the low flow forward through the IP and LP turbines, and reverse flow through the HP turbine, do not cause overheating of any stages; a very important consideration in a machine already brought to 1050°F at the main steam and reheat steam inlets, and also continuing to rotate at rated speed. The floor pressure information is key to establishing:

1. Transfer point from reverse flow to forward flow in the HP section;
2. HP turbine exhaust temperature during the flow transfer operation; and
3. No excessive windage heating is occurring in the HP section during this low flow, high backpressure operating regime.

The bypass system flow information is then used to establish proper sizing for the HP reverse flow valving so that sufficient cooling steam will be available for all operating situations.

Advantages of Structured D-11 Steam Turbine

Delivery Cycle

Design standardization permits the structured D-11 steam turbine to be offered with 12 months ex-factory shipment from release date. Since the design of items which require long lead times will be essentially complete, GE will forecast reserve capacity and volume with experienced suppliers, resulting in shorter delivery cycles for rotor forgings, castings, and exhaust fabrications.

Customer Drawing Availability

Critical customer drawings will be available immediately after the customer gives GE notice to proceed. The product is specifically designed so that minor adjustments in the high pressure steam path to configure the turbine for the thermal cycle conditions of a particular application do not change the outline dimensions, component weights, sole plate layout or foundation loadings. This design consistency allows architect engineers and owners to get an early start on the turbine foundation design, overhead crane specification, auxiliary equipment placement, and design of piping and electrical systems.

Common Spare Parts

Spare parts inventory can be reduced from the levels required prior to standardization of the D-11's design. All possible variants of the structured D-11 steam turbine have common components throughout. Items such as valve stems, valve discs, journal bearings, thrust bearing, shaft end packing, interstage packing, spill strips, horizontal joint shell bolting, auxiliary system components and various gaskets will be common to all D-11 turbines.

Installation Time

Installation of the structured D-11 turbines has been simplified and will proceed more quickly than installation of non-structured turbines. When it is shipped from the factory, the HP/IP section of the turbine will be fully assembled with diaphragms and rotor installed and properly aligned, and with the horizontal joint shell bolts fully tightened. Delivering the HP/IP turbine pre-assembled saves about four weeks of field erection time.

Future Structured Applications

The structuring philosophy that was used to standardize the D-11 turbine is also being applied to other turbines being built by GE.

DX2

The DX2 is GE's new family of high-efficiency steam turbines, designed for both 207F and 209F applications. These new turbines feature separate casings for the HP and IP sections, while utilizing the LP sections that were developed in the structured D-11 design program.

A-10

The A-10 design consists of a single HP section and a combined IP/LP section and is used primarily in 107F and 109F multi-shaft applications. Although this design utilizes separate casings, it is compact, and has the additional feature of not requiring a crossover pipe.

DX4/GX1 Designs

GE is currently developing steam turbines for combined-cycle plants that are designed to operate with inlet conditions of 2400 psia (165 bar) and 1050°F (566°C). Although this increase in operating pressure requires use of more expensive balance of plant (BOP) components, the inherent benefit in overall cycle performance can outweigh the higher initial capital investment in certain operating environments.

As a result of the structuring process, GE's delivery cycle for these optimally designed steam turbines will be comparable to that of the structured D-11 line.

Conclusion

The structured D-11 steam turbine is a highly efficient, highly reliable, cost-effective steam turbine, configured specifically for 207FA or 209FA combined-cycles. Within the base design, there is allowance for significant variation on the basic three-pressure level reheat condensing cycle, while maintaining a 12-month ex-factory shipping commitment. The concept of product structuring has proven to be valuable on the D-11 turbine, and will be equally beneficial on future GE steam turbines.

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List of Figures

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Alabama								
Alabama Power Co.								
Gorgas	5	69	ST	BIT	1944	1989	55	in place
Arizona								
Tucson Electric Pwr. Co.								
De Moss Petrie	4	57.5	ST	Nat Gas	1954	1991	37	dismantled
California								
Pacific G&E Co.								
Potrero	1	50	ST	FO6	1931	1983	52	in place
	2	50	ST	FO6	1931	1983	52	in place
Contra Costa	1	118.8	ST	Nat Gas	1951	1994	43	in place
	2	103.5	ST	Nat Gas	1951	1994	43	in place
	3	103.5	ST	Nat Gas	1951	1994	43	in place
	4	112.5	ST	Nat Gas	1953	1994	41	in place
	5	112.5	ST	Nat Gas	1953	1994	41	in place
Kern	1	66	ST	Nat Gas	1948	1994	46	in place
	2	99.5	ST	FO6	1949	1994	45	in place
Moss Landing	1	107.6	ST	Nat Gas	1950	1994	44	in place
	2	111	ST	Nat Gas	1950	1994	44	in place
	3	107.6	ST	Nat Gas	1951	1994	43	in place
	4	112.5	ST	Nat Gas	1952	1994	42	in place
	5	112.5	ST	Nat Gas	1952	1994	42	in place
Southern Cal. Edison								
Long Beach	11	106	ST	FO6	1930	1983	53	Ret. In place
San Onofre	**1	456	NP	Uranium	1967	1992	25	perm. Mothb
City of Los Angeles								
Harbor Gen. Station	1	65	ST	Nat Gas	1943	1988	45	dismantled
	2	65	ST	Nat Gas	1947	1988	41	dismantled
	3	86.4	ST	Nat Gas	1949	1991	42	in place
	4	86.3	ST	Nat Gas	1948	1997	49	in place

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Connecticut								
Conn. Light & Power Co.								
Middletown	1	69	ST	FO6	1954	1991	37	sold to NRG energy
Florida								
Florida P&L Co.								
Palatka	2	75	ST	FO6	1956	1983	27	Greenfield
Riviera	2	75	ST	Nat Gas	1953	1991	38	removed parts; generator intact
JEA								
Southside Generating	3	50	ST	FO6	1955	1998	43	
Georgia								
Georgia Power Co.								
Atkinson	ST1	60	ST	FO2	1930	1993	63	
		60	ST	FO2	1930	1993	63	Still in place
		60	ST	FO2	1930	1993	63	
Illinois								
Central Ill. Light Co.								
R S Wallace	6	85.9	ST	BIT	1952	1985	33	Greenfield
	7	113.6	ST	BIT	1958	1985	27	Greenfield
Indiana								
Indiana Michigan Pwr. Co								
Breed	1	495.6	ST	BIT	1960	1994	34	
		495.6	ST	BIT	1960	1994	34	removed parts
		495.6	ST	BIT	1960	1994	34	
Iowa								
Iowa Public Service Co.								
Maynard Station	7	54.4	ST	BIT	1958	1988	30	

STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Kentucky								
Louisville G&E Co.								
Paddy's Run	5	74.7	ST	BIT	1950	1983	33	in place
Cane Run	1	92	ST	BIT	1954	1985	31	in place
	2	90	ST	BIT	1955	1985	30	in place
	3	147.1	ST	Nat Gas	1958	1995	94	in place
Louisiana								
Louisiana Pwr.& Light Co.								
Ninemile Point	4	783	ST	Nat Gas	1971	1992	21	
CLECKO Corporation								
Coughlin	5	65.3	ST	Nat Gas	1958	1998	40	
Maryland								
Baltimore Gas & Electric Co.								
Riverside	1	60	ST	FO6	1942	1991	49	in place
	2	60	ST	FO6	1944	1993	49	in place
	3	60	ST	FO6	1948	1993	45	in place
	5	81.3	ST	FO6	1953	1993	40	in place
Westport	3	60	ST	FO6	1941	1993	52	in place
	4	69	ST	FO6	1950	1993	43	in place
Massachusetts								
Western Mass. Elec. Co.								
West Springfield	2	50	ST	FO6	1952	1991	39	sold to NRG energy
Michigan								
Consumers Power								
Morrow, BE	3	50	ST	NG	1941	1982	41	in place
	4	66	ST	NG	1949	1982	33	in place
B C Cobb	1	66	ST	BIT	1948	1990	42	back on line
	2	66	ST	BIT	1948	1990	42	back on line
	3	66	ST	BIT	1950	1990	40	back on line
Detroit Edison Co.								

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Conner's Creek	13	60	ST	FO2	1937	1983	46	
	14	60	ST	FO2	1936	1983	47	
Delray	11	50	ST	FO6	1929	1983	54	
	12	50	ST	FO6	1929	1983	54	
	13	50	ST	FO6	1933	1983	50	
	16	75	ST	FO6	1942	1983	41	
	14	75	ST	FO6	1938	1987	49	
	15	75	ST	FO6	1940	1987	47	
Enrico Fermi	1	158	ST	FO2	1966	1983	17	
Minnesota								
Northern States Pwr. Co.								
Riverside	6	75	ST	Nat Gas	1949	1987	38	
Missouri								
Kansas City P&L Co.								
Hawthorn	1	69	ST	BIT	1951	1984	33	in place
(these units are about to go back on line)	2	69	ST	BIT	1951	1984	33	in place
	3	112.5	ST	BIT	1953	1984	31	in place
	4	142.8	ST	BIT	1955	1984	29	in place
Montana								
Montana Power Co.								
Frank Bird	1	69	ST	Nat Gas	1951	1997	46	
Nebraska								
Omaha Public Power Corp.								
Jones Street	12	49	ST	FO2	1951	1988	37	in place
New Jersey								
Jersey Central Pwr.&Lt. Co.								
Gilbert	3	69	ST	FO6	1949	1996	47	in place
Werner	4	60	ST	FO6	1953	1996	43	in place
Public Service Elec. & Gas								
Burlington	5	125	ST	FO6	1940	1984	44	
	6	125	ST	FO6	1943	1984	41	
	7	205	ST	FO6	1955	1997	42	

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Essex	1	117	ST	FO6	1974	1984	10	
Linden	4	93.5	ST	FO6	1972	1996	24	
Sewaren	5	389	ST	FO6	1962	1991	29	
Atlantic City Electric Co.								
Deepwater	5	53	ST	FO6	1930	1991	61	
New York								
Consolidated Edison Co. NY Inc.								
East River	5	156.3	ST	FO6	1951	1996	45	
Hudson Avenue	8	160	ST	FO6	1932	1986	54	
	7	160	ST	FO6	1931	1987	56	
	10	60	ST	FO6	1951	1997	46	
Waterside	4	50	ST	Nat Gas	1937	1990	53	
	14	60	ST	Nat Gas	1948	1992	44	
	15	75	ST	Nat Gas	1949	1992	43	
	7	81.3	ST	Nat Gas	1941	1992	51	
	5	66.3	ST	Nat Gas	1938	1995	57	
74th Street	10	69	ST	FO6	1956	1992	36	
	9	75	ST	FO6	1959	1992	33	
59th Street	13	57.5	ST	FO6	1952	1990	38	
Astoria	ST1	200	ST	Nat Gas	1953	1993	40	
	2	200	ST	Nat Gas	1954	1993	39	
Niagra Mohawk Pwr. Co.								
Oswego	ST1	92	ST	FO6	1940	1995	55	sold to NRGi
	2	92	ST	FO6	1941	1995	54	6 units
	3	92	ST	Nat Gas	1948	1995	47	portions wer
	4	100	ST	FO6	1951	1995	44	dismantled
Rochester Gas & Electric								
Rochester 3	12	81.6	ST	BIT	1959	1999	40	
Ohio								
Cincinnati G&E Co.								
Miami Fort	3	65	ST	FO2	1938	1982	44	in place

STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
	4	65	ST	FO2	1942	1982	40	in place
Cleveland Elec Illum Co.								
Ashtabula	B1	50	ST	FO6	1930	1983	53	in place
	B2	50	ST	FO6	1930	1983	53	in place
	B3	50	ST	FO6	1931	1983	52	in place
	B4	50	ST	FO6	1938	1983	45	in place
Avon Lake	5	50	ST	FO6	1943	1983	40	in place
	8	233	ST	BIT	1959	1987	28	in place
	6	86	ST	BIT	1949	1997	48	in place
	7	86	ST	BIT	1949	1997	48	in place
Lake Shore	14	60	ST	FO6	1941	1992	51	in place
	15	60	ST	FO6	1942	1992	50	in place
	16	69	ST	FO6	1951	1992	41	in place
	17	69	ST	FO6	1951	1992	41	in place
Columbus Southern Power Company								
Poston	3	69	ST	BIT	1952	1987	35	dismantled
	4	75	ST	BIT	1953	1987	34	dismantled
Dayton Pwr.&Light Co.								
Frank M Tait	4	147.1	ST	BIT	1958	1987	29	greenfield
	5	147.1	ST	BIT	1959	1987	28	greenfield
Toledo Edison Co.								
Acme	5	72	ST	BIT	1941	1992	51	in place
	6	112.5	ST	BIT	1949	1992	43	in place
Oklahoma								
Public Service Co.of Okl.								
Tulsa	3	95	ST	Nat Gas	1958	1997	39	recommish. back in servi
Pennsylvania								
Philadelphia Elec. Co.								
Richmond	12	165	ST	Coal	1935	1983	48	in place

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
	9	189.7	ST	FO6	1950	1985	35	in place
Southwark	1	172.5	ST	FO6	1947	1985	38	in place
	2	172.5	ST	FO6	1948	1985	37	in place
Pennsylvania Elec. Co.								
Front Street	5	50	ST	BIT	1952	1991	39	in place
PP&I Inc.								
Holtwood	17	75	ST	ANT	1954	1999	45	
Rhode Island								
New England Power Co.								
South Street	12	62.5	ST	Nat Gas	1955	1992	37	
Texas								
Gulf States Utility Co.								
Neches	7	114	ST	Nat Gas	1956	1983	27	
Southwestern Pub. Ser. Co.								
Denver City	4	50	ST	Nat Gas	1955	1984	29	
Moore County	3	49	ST	Nat Gas	1954	1984	30	
Houston Lighting&Pwr. Co.								
Greens Bayou	3	112.5	ST	Nat Gas	1953	1985	32	
	4	112.5	ST	Nat Gas	1953	1985	32	
	1	75	ST	Nat Gas	1949	1986	37	
	2	75	ST	Nat Gas	1949	1986	37	
Hiram Clark	ST3	75	ST	Nat Gas	1950	1985	35	
	ST4	75	ST	Nat Gas	1951	1985	34	
Webster	1	112.5	ST	Nat Gas	1954	1985	31	
	2	112.5	ST	Nat Gas	1954	1985	31	
T H Wharton	1	75	ST	Nat Gas	1958	1986	28	
Texas Utilities Elec. Co.								
Dallas	3	78.8	ST	Nat Gas	1954	1998	45	
	9	75	ST	Nat Gas	1951	1998	47	
Trinidad	5	69	ST	Nat Gas	1949	1994	45	
Pennsylvania								
Philadelphia Elec. Co.								

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STATUS of RETIRED ELECTRIC GENERATING UNITS (50MW or GREATER)

State Company Plant	Unit #	Nameplate Rating MW	Unit Type	Primary Energy Source	In Service Date	Year Retired	Age	Status
Richmond	12	165	ST	Coal	1935	1983	48	
Wisconsin								
Wisconsin Elec. Pwr. Co.								
Lakeside	9	60	ST	Nat Gas	1928	1983	55	
	11	60	ST	Nat Gas	1930	1983	53	
Wheaton	1	54	ST	FO2	1973	1983	10	
North Oak Creek	3	130	ST	BIT	1955	1988	33	
	4	130	ST	BIT	1957	1988	31	
	1	120	ST	BIT	1953	1989	36	
	2	120	ST	BIT	1954	1989	35	
Port Washington	5	80	ST	BIT	1950	1991	41	

CERTIFICATE OF SERVICE
DOCKET NO. 010949-EI

I HEREBY CERTIFY that a true and correct copy of the foregoing Direct Testimony of William M. Zaetz has been furnished by hand-delivery (*) or U.S. Mail to the following parties on this 27th day of December, 2001.

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