



**UNIVERSAL SILENCER**

*noise control and air filtration solutions*

## **Combined Cycle Systems For the Utility Industry**

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## INTRODUCTION:

Power plants can be defined by functional type (e.g. base load, peak load, or combined cycle). Each has advantages and disadvantages.

Base load power plants have the lowest operating cost and generate power most in any given year. There are several different types of base load power plants. The resources available typically determine the type of base load plant used to generate power. Coal and nuclear power plants are the primary types of base load power plants used in the Mid-West United States.

There are four types of base load power plants:

- High efficient combined cycle plants fueled by natural gas
- Nuclear Power Plants
- Conventional steam power plants fueled primarily by coal
- Hydropower plants

Peak load power plants are simple cycle gas turbines that have the highest operating cost but are the cheapest to build. They are operated infrequently and are used to meet peak electricity demands in period of high use and are primarily fueled with natural gas or oil.

The high efficient combined cycle power plant will be the focus of this project.

Gas turbines have increased in capacity over the last 25 to 45 years. Gas Turbines with rated outputs of 40 to over 350 MW that have increased specific power has led to the parallel development of highly efficient economical combined cycle power generation systems.

Each combine cycle (CCGT) power-generating system consists of a gas turbine, Heat Recovery Steam Generators (HRSGs), generators, controls, and a steam turbine. Combined cycle systems typically are an optimized system of high technology power generating equipment, software, and services that are integrated into the utilities ancillary equipment to create an economical and stable power generating facility.

Combined cycle systems encompass a large range of capabilities for both 50 and 60 Hz operation. Combined cycle systems are versatile allowing for many different configurations to satisfy the requirements of individual applications.

There are two major categories of combined cycle systems:

- 1 Oil or natural gas fired systems for power generation.
- 2 Combined cycle cogeneration systems and coal or oil fired integrated gasification combined cycle (IGGG) power generation systems.

There are many configurations for combined cycle systems. A significant portion of the systems contain an electrically controlled diverter damper, seal air fans, position indicators, and some type of control systems that integrates these components. It is the intent of this project to describe one such system that the author helped design, install, verify, and commission. The duration of the project, located in the Mid Atlantic region of the United States, was over 24 months in duration. The construction phase was in two parts. The first phase consisted of installation of three 100 MW rated turbines, ancillary equipment and commissioning of simple cycle operation while the HRSGs were being completed. This was completed in a relatively short period of approximately twelve months. The commissioning of the combined cycle systems is happening as this paper is being prepared (May 2002).

#### BASIC POWER PLANTS:

There are many types of power generating power plants. The basic features of the three most common types are described below. The steam plant, the simple cycle peaking units and the combined cycle power plants basic features are described below. After the basic features are described, much time will be spent on the combined cycle plant and the components that make up such a power generation facility.

#### Conventional Steam Power plants:

The conventional power plant that has been the basis for electric power generation for many years burns fuel to heat a boiler to produce steam. The steam is then used to turn a steam turbine that drives an electric generator. The steam is then condensed back to water (this requires the use of cooling water) and then is reheated. Conventional steam power plants can use a variety of fuels, basically anything that burns can be used. Typical fuels are coal, gas, oil, or biomass.

Features of conventional steam power plants are:

They are about 34% efficient in converting fuel to electricity.

Their heat rate is about 10,000 Btu (British Thermal Units) of fuel “heat” burned per kilowatt-hour (kWh).

Conventional steam power plants are slow to start or to change output while operating.

The low operating cost of steam power plants is a result of the inexpensive fuel used.

With coal costs of \$1.35/MMBtu, the fuel cost of producing electricity is about 1.35 cents/kWh<sup>New</sup>.

#### Simple Cycle Peaking Units:

Simple-cycle power generation plants are simply the basic gas turbine mounted in a noise reducing enclosure. Typically they are aeroderivative type gas turbines similar to jet aircraft engines. As a comparison, an engine of a Boeing 737 is equivalent to a 25 to 30 MW simple cycle power plant.

Simple cycle power plants typically use natural gas as fuel with kerosene or distillate oil as a back up. They are used to meet the highest (peak) electricity demands, for example very hot summer afternoons.

Basic features of a simple cycle power plant are listed below:

Simple cycle power plants have a heat rate of 9,900 to 12,000 Btu/kWh (28 to 35% efficient).

The start up time to full load is approximately 10- 20 minutes.

Low operation and maintenance (O & M) costs. This is because they have few moving parts or staff requirements and the moving parts move in a radial motion vs. the piston type motion of other internal combustion engines.

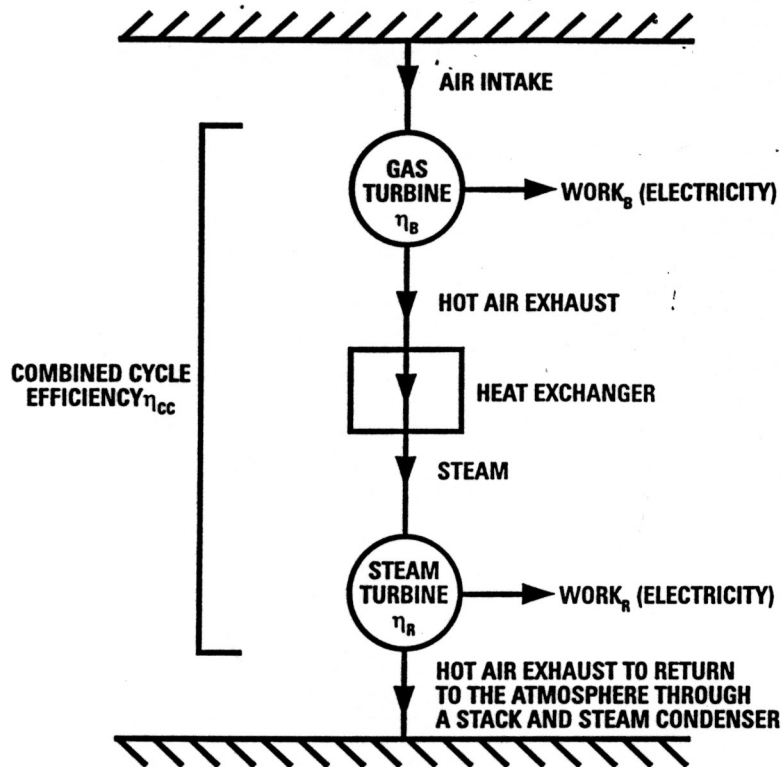
They are expensive to operate. The high fuel cost (relative to base load power plants) makes for expensive peak power.

Assuming natural gas costs of \$3.50 MMBtu, the fuel cost of producing electricity is 4 cents/kWh<sup>New</sup>.

Combined Cycle Power Plant:

A combined cycle gas turbine power plant is essentially an electrical power plant in which a gas turbine and a steam turbine are used in combination to achieve greater efficiency than would be possible independently. The gas turbine drives an electrical generator while the gas turbine exhaust is used to produce steam in a heat exchanger (called a Heat Recovery Steam Generator, HRSG) to supply a steam turbine whose output provides the means to generate more electricity. If the steam is used for heat (e.g. heating buildings) then the plant would be referred to as a cogeneration plant

Figure 1 is simple representation of a CCGT system. It demonstrates the fact that a CCGT system is two heat engines in series. The upper engine is the gas turbine. The gas turbine exhaust is the input to the lower engine (a steam turbine). The steam turbine exhausts heat via a steam condenser to the atmosphere.



**Figure 1: Schematic of Combined Cycle (CCGT) power plant. Overall efficiency ( $\eta_{CC}$ ) is a combination of the efficiency of the Brayton ( $\eta_B$ ) gas turbine cycle and the Rankine steam turbine cycle ( $\eta_R$ ). Total combined cycle efficiency is  $\eta_{CC} = \eta_B + \eta_R - (\eta_B * \eta_R)$  Chase.**

The combine cycle efficiency ( $\eta_{CC}$ ) can be derived by the equation 1 Langston.

$$\eta_{CC} = \eta_B + \eta_R - (\eta_B * \eta_R) \quad (1)$$

Equation (1) states that the sum of the individual efficiencies minus the product of the individual efficiencies equals the combine cycle efficiency. This simple equation gives significant insight to why combine cycle systems are successful.

For example, suppose the gas turbines efficiency  $\eta_B$  is 40% (a reasonable value for a toady's gas turbines) and that the steam turbine efficiency  $\eta_R$  is 30% (a reasonable value for Rankine Cycle steam turbine).

Utilizing equation (1) would lead to the following conclusion.

$$\begin{aligned} \eta_{CC} &= 0.4 + 0.3 - (0.4 * 0.3) \\ \eta_{CC} &= 0.58 \end{aligned}$$

$$\eta_{CC} = 58\%$$

The combined cycle efficiency of 58% is much greater than either the gas turbine or the steam turbines efficiencies separately. The 58% value is slightly misleading in that system losses were ignored. Efficiency values in the 60% range have been recorded for CCGT systems in the past few years<sup>Chase</sup>.

CCGT power plants may come in many different configurations. Some companies choose to treat the gas turbine exhaust bypass stack as a commodity, others choose to incorporate a diverter damper into the turbine exhaust gas path. The diverter damper allows for the rapid configuration of the power plant as a combined cycle or simple cycle system. The initial cost of the diverter damper is much higher than the cost of treating the gas turbine exhaust stack as a commodity however, the diverter damper allows for the gas turbines to be operated in simple cycle when HRSG or steam turbine repair or maintenance is required.

Some of the basic features of the combine cycle power plant are listed below:

Combined cycle plants use the hot exhaust gas from gas turbines to make steam, which drives a steam turbine which drives a generator to produce electricity.

Power output of the steam turbine is typically 1/3 of the total output of the total power output of the combine cycle power plant. It is this “extra” electricity produced from the same amount of turbine energy (without additional fuel consumption) that makes a combined cycle plant much more efficient than a simple cycle gas turbine peaking plant.

Overall efficiency of converting fuel to electricity is greater than a peaking plant 44 to 52% (Heat Rate of 6,600 to 7,700 BTU/kWh).

The steam portion of combined cycle plants takes approximately 1.5 to 3 hours to heat up. This is much slower than a true peaking plant that can be at load in about 10 – 20 minutes.

The combine cycle system cost is obviously a more expensive capital expenditure than a peaking plant (simple cycle plant).

However, a combine cycle plant has a high efficiency in converting fuel to electricity which makes it possible for relatively high price fuels like natural gas to be competitive for intermediate or base loads.

For natural gas costing \$3.50/MMBtu, the fuel costs of producing electricity is about 2.3 cents/kWh, which is less, expensive than some coal fired plants<sup>NEW</sup>.

Described below are the features of major components of a CCGT power generating plant that are required for safe efficient reliable combined-cycle systems.

## GAS TURBINE BASICS:

### History:

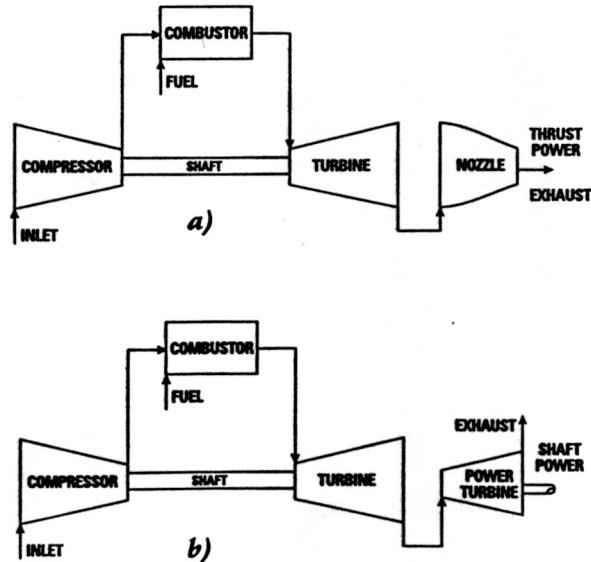
A turbine is any kind of spinning device that uses the action of a fluid to produce work. Air, wind, water, steam, and helium are typical fluids used by a turbine to produce work. Windmills and hydroelectric dams have used turbine action for decades to turn the core of an electrical generator to produce power for residential and industrial applications. Simpler turbines are much older with the first known appearance dating to the time of ancient Greece <sup>Langston</sup>.

Gas Turbines are relatively new in the history of energy conversion. The first practical gas turbine used to generate electricity ran at Neuchatel, Switzerland in 1939, and was developed by the Brown Boveri Company. The first gas turbine powered airplane flight also took place in 1939 in Germany, using the gas turbine developed by Hans P. von Ohain <sup>Langston</sup>.

The simultaneous development of the gas turbine for electric power generation field and the aviation field led to the gas turbine being known by several different names. The electric utility industry generally refers to the gas turbine as a gas turbine, combustion turbine, a turboshaft engine, and sometimes a gas turbine engine. The aviation industry generally to the gas turbine as a jet engine. Various other names will be used depending on the application or engine configuration such as jet turbine engine, turbojet, turbofan, fan-jet, and turboprop or propjet (when used to drive a propeller).

Many people assume that gas turbines use gas as its fuel. However, a gas turbine uses a compressor to suck in and compress gas (usually air), a combustor to add fuel to heat the compressed air, and a turbine to extract power from the hot air flow. Gas Turbines are internal combustion (IC) engines that implement a continuous combustion process. An intermittent combustion process characterizes IC engines used in automotive or diesel applications.

Figure 2 is the schematic of the two basic types of Gas Turbines. The schematic represented by (a) is the aircraft engine and the schematic (b) represents a land-based gas turbine typically used for power generation in the utility industry. The compressor, combustor, and turbine part of figure 2 is commonly called the gas generator <sup>Langston</sup>.



**Figure 2: Schematic for (a) an aircraft jet engine and (b) for a land based gas turbine** <sup>Langston</sup>.

#### Applications of Gas Turbines:

The aircraft gas turbine output is used to turn the compressor (which may have an associated fan or propeller). The hot air flow of the turbine is then accelerated through an exhaust nozzle into the atmosphere to provide thrust (propulsion power). Aircraft engines output can range from about 100 pounds of thrust to as high as 100,000 pounds of thrust and range in weight from 30 pounds to 20,000 pounds.

In non-aviation gas turbines, part of the turbine power is used to drive the compressor. The remainder, the ‘useful power’ is used as an output shaft power to turn an energy conversion device (figure 2b) such as an electrical generator or a ship’s propeller.

Land based gas turbines range in power output from 0.05MW (Megawatts) to greater than 550 MW. The lighter weight units derived from aircraft jet engines are known as basic aeroderivative type engines. Aeroderivative engines traditionally are utilized to drive compressors at natural gas pipelines pumping stations, power ships, and to provide peaking power for electric utility applications. Peaking power supplements a utility’s normal power output during high demand periods (summer demand on hot days). However, they are increasingly being used for base load electrical generation and combine cycle operation <sup>Langston</sup>. Larger heavier weight machines designed for land applications serving the utility industry are called industrial or frame engines.

The gas turbine machine has five principal advantages listed below:

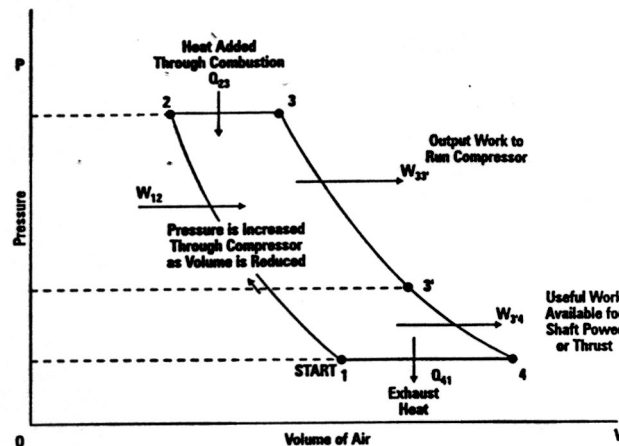


- 1 The gas turbine produces a large amount of useful power in a relatively small size and weight.
- 2 Maintenance cost is relatively low and its mechanical life is long when compared to a piston driven engine. All the gas turbine major components that move do so in rotation (no reciprocating motion as in a piston engine). However, repair costs are typically much higher for a gas turbine than for a reciprocating engine.
- 3 The start up time for a gas turbine to full load is measured in minutes vs. hours for a steam turbine plant.
- 4 Gas Turbines can operate utilizing a wide variety of fuels. Natural gas is typically used for land based machines while a lighter distillate is used for aircraft applications.
- 5 Atmospheric air is typically the working fluid for gas turbines and generally requires no coolant for basic power generation <sup>Langston</sup>.

Low efficiency (high fuel usage) was a major disadvantage of gas turbines in the past when compared to other IC engines and steam turbine power plants. Continuous engineering development work over the past fifty years has pushed the thermal efficiency for 18% in 1939 to about 43 % today for simple cycle operation and 60 % for combined cycle operation <sup>Chase</sup>. These thermal efficiency values are significantly higher than for other prime providers of electrical power such as steam power plants.

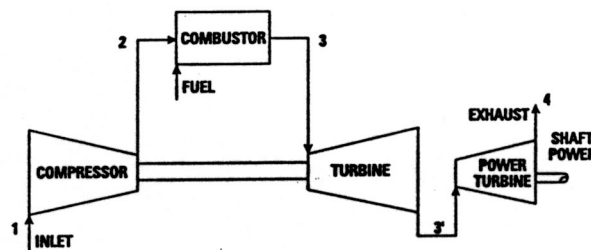
The Brayton Cycle:

Gas turbine cycles describe what happens to air as it passes into, through, and out of the gas turbine. The cycle describes the relationship between the volume (V) of air in the system and the pressure (P) the air is under. The Brayton cycle developed in 1876, shown in graphic form as Figure 3 is a pressure-volume diagram that represents the properties of a fixed amount of air passing through a gas turbine in operation. Figure 4 shows the same Brayton cycle point on an engine schematic.



**Figure 3: Brayton Cycle pressure-volume diagram for a unit mass of working fluid (e.g. air), showing work (W) and heat (Q) inputs and outputs** <sup>Langston</sup>.

Air is compressed from point 1 to point 2 increasing the gas pressure as the volume of the space containing the air is reduced. The air, at constant pressure, is heated from point 2 to point 3. This is accomplished by injecting fuel into the combustor and continuously igniting the fuel. Expanding air from point 3 to point 4 reduces the gas pressure and temperature and increases the volume of the gas. In the engine schematic of figure 4, this represents the flow through the turbine to point 3' and then flow from the power turbine to point 4 to turn a shaft. The useful work in figure 3 is indicated by the curve from point 3' to point 4. The useful work is the energy available to cause output shaft power for a land based gas turbine (used to turn a generator for the utility energy). Exhausting the gas turbine exhaust gas to atmosphere where the volume of air cools resulting in less volume completes the Brayton cycle. Heat from the exhaust gas is absorbed into the atmosphere <sup>Langston</sup>.



**Figure 4: Gas Turbine schematic showing relative points of the Brayton Cycle** <sup>Langston</sup>.

Performance Characteristics:

Specific power is the key performance characteristics of a gas turbine engine that influences combined-cycle performance. Specific power is the power produced by the gas turbine per unit of airflow (kW output per lb/sec of compressor airflow). High specific power provides the lowest simple-cycle cost while ensuring the highest combined-cycle operation efficiency.

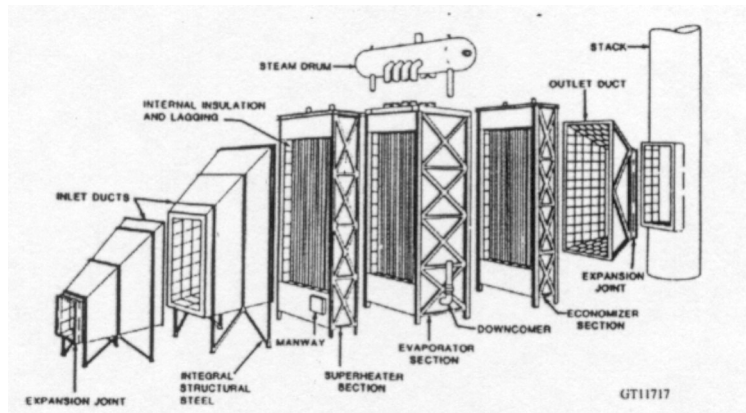
Combined-cycle thermal efficiency increases as gas turbine specific power increases. The gas turbine firing temperature is the primary determinant of specific power. Development of high temperature/high strength materials, corrosion resistant coatings, and improved cooling technology have led to increases in gas turbine firing temperatures. This increase in firing temperature is the primary development that has led to increases in CCGT thermal efficiencies. The improvements in combined-cycle thermal efficiencies and the commercial development of combined-cycle power plants have proceeded in parallel with advances in gas turbine technologies <sup>Chase</sup>.

Typical gas turbine exhaust gas temperatures of 1000-1100<sup>0</sup>F are well suited to efficient combine-cycle operation. The exhaust gas temperature enables the heat transfer from exhaust gas to steam cycle to occur with minimal temperature difference. This small difference ensures maximum in thermodynamic availability while operating with the highest steam cycle efficiency.

Gas turbine materials, coatings, and cooling systems enable reliable high firing temperatures. This achieves high gas turbine specific power and high efficiency of combined-cycle operation.

#### HEAT RECOVERY STEAM GENERATOR:

HRSGs are typically unfired and modular in design with finned-tube heat transfer surfaces and natural or forced-circulation evaporators. Figure 5 is an illustration of a Natural-circulation HRSG with modular construction.



**Figure 5: Natural Circulation HRSG modular construction** Chase.

Combined-cycle power plants typically have many common features and several unique features that are site specific. A common arrangement is to have each gas turbine exhaust to a single HRSG. There are systems designed that two gas turbines would exhaust into a single HRSG. All HRSGs would exhaust into a common header that feeds the steam turbine. HRSG design features are:

Flexible tube support system to enable fast startup and load following capability.

Low gas side pressure drop for optimum gas turbine performance.

Large modular factory tested modules that can be shipped to provide reduce installation time and competitive construction cost Chase.

#### STEAM TURBINE:

Steam turbines for combined-cycle power plants generally are of two styles. Steam turbines with different exhaust annulus areas are available to permit optimization to meet specific condenser cooling conditions. Steam turbines with large annulus areas are more expensive, but provide increased capability and may be the most economical selection for applications with low steam turbine exhaust pressures. Steam turbines with small exhaust annulus area provide comparable or higher capability and low cost and are the more economical choice when steam turbine exhaust pressures are high.

Combined cycle steam turbines have features that include but are not limited to:

Modules assembled where they can be shipped and field assembled with a low profile installation, reducing installation time and cost.

Borescopic inspection access ports where the upper turbine casing does not have to be removed during inspection.

Main cold and hot reheat pipes as well as the main steam pipes connect to the lower half of the shell. This allows removal of the upper half shell for maintenance.

#### GENERATORS:

Air cooled generators are standard for small combined cycle systems utilizing gas turbines rated at approximately 100 MW and below. They may be open ventilated or completely enclosed water-to-air cooled. Hydrogen-cooled generators are standard for larger systems. Hydrogen cooled generators can be cooled by plant-cooling water or by ambient air with water-to air heat exchangers<sup>Chase</sup>.

#### CONTROLS:

Combined-cycle power plants typically have a distributed digital control (DCS) with redundant data transmission paths. Station operator controls provide an interactive color graphic displays of the overall combine-cycle system to enable the operator to operate the plant.

While the control systems for each installation may be tailored to the particular plant, they will all have the same principal objectives of simple operation, easy starting, automated operation and excellent load following capability. Each of the main components of the combine-cycle system will have individual control panels and interfaces that relay information to and from the plant operator through data ports to the operator console. Operator consoles generally have a detailed graphic display with a high level of detail that enables convenient and informative interaction with the plant as required.

Most control systems operate with a minimum of control loops. This in conjunction with well-established, automated operation of system components allows effective automation

of the complete power plant. This minimizes the number of control operators. Most systems operate with only one control operator and one roving operator.

Typical multi-shaft control systems are configured to enable automated startup and operation after remote manual starting of plant auxiliaries, remote manual operation of each major component, or operation of the gas turbine-generator units from local-control compartments. Maximum availability is ensured because the plant can be operated remotely with no additional control room operators. Equipment protection is typically provided within the control unit thereby ensuring that normal protection is maintained during all modes of operation, including local or remote manual operation.

Typical single shaft control systems are microprocessor-based controllers that coordinate the operation of each of the components in each integrated combined-cycle unit and communicate with the plant control. Because of the simple steam cycle, the tandem coupling of the gas and steam turbines to a single generator, and the elimination of the HRSG exhaust-gas, bypass system, the single-shaft control system is simple. Starting, operation, and shutdown of individual components are automatic. Single-shaft units typically controlled by a local control unit that is coupled to the central control operator's console by a data port. One control room operator and a one local operator can operate one or more single shaft combine cycle units<sup>Chase</sup>.

#### ANCILLARY EQUIPMENT:

The combined-cycle system can be equipped with several types of ancillary equipment. One such piece of ancillary equipment is a diverter damper. A diverter damper is a device that directs the gas turbine exhaust flow to either the HRSG for combine-cycle operation or to a bypass stack for simple cycle operation. The installation of a new combined cycle power plant is a major operation that is measured in months if not years. Typically, the utility will chose to complete the project in phases where phase 1 is to install the turbine(s) in simple cycle mode with the appropriate ancillary equipment (which may or may not include a diverter damper). This allows the utility to sell the power generated by the gas turbines much sooner than if the entire project had to be completed to sell power. Phase 2 usually entails bringing the HRSG(s) and the steam turbine online.

Some utilities choose to treat the gas turbine exhaust bypass stack as a commodity, others choose to incorporate a diverter damper into the turbine exhaust gas path. The diverter damper allows for the rapid configuration of the power plant as a combined cycle or simple cycle system. The initial cost of the diverter damper is much higher than the cost of treating the gas turbine exhaust stack as a commodity however, the diverter damper allows for the gas turbines to be operated in simple cycle when HRSG or steam turbine repair or maintenance is required.

Two basic types of diverter dampers are generally used for combine-cycle power plant operation. Electrical driven actuators are used for smaller gas turbines (upper limit of

approximately 110 MW). Larger gas turbines with the higher exhaust rates generally require hydraulic actuators to provide enough force to open and close the damper.

Diverter dampers require an electrical control system, control logic, safety switches, local and remote operation capability, limit switches, and a seal air system that is an integral part of the main control system. Such a system is described in more detail in the following pages. Photos of an actual site and the control diagram and wiring schematics are included for completeness.

#### PLANT OPERATION:

Gas turbines are constant volume mass flow dependent engines. Gas turbines exhaust flow and temperatures vary with ambient temperature and barometric pressure. As the ambient temperature decrease the gas turbine will experience a low heat-rate and increase in power output. Steam production and steam turbine output vary with the gas turbines exhaust gas flow and temperature supplied to the HRSG. The steam turbine should be sized so that their rated flow matches the steam production.

#### PLANT ARRANGEMENT:

Combine-cycle equipment can be and should be adapted to installation requirements defined by varying climatic conditions, system configurations and owner/operator preferences. Combine-cycle equipment is suitable for outdoor installations, semi-outdoor installations, or fully enclosed installations.

#### INSTALLATION:

Short installation time and low installation costs of combined cycle systems are key features contributing to economical power generation. Factory packaging of major components and containerized shipment of small parts is a major factor in keeping installation cost down. Short installation time helps reduce the amount of interest payments during the construction phase.

The time from order to commercial operation for standard combine cycle systems typically range from 20 to 30 months excluding permits. The gas turbines typically produce 60 to 70 % to the power plants capacity. Typically the gas turbines can be installed in 12 to 18 months and be providing power while the steam system is being completed.

#### FUTURE LOAD EXPANSION:

Economics of power generation can be improved by installation generation capacity as the demand grows instead of having over capacity. Combine-cycle power plants allow generation to be increase as the load demand grows. Efficient, low cost plants are available in small modules of generating capacity.

Future capacity can be added quickly by modifying existing simple cycle gas turbine installations to combine-cycle operation when load demands require additional capacity. Site plans for the steam turbine and transmission line capability are the main considerations during the initial commitment for simple-cycle gas turbines.

#### AUTHOR'S EXPERIENCE:

The scope of a combine cycle power plant design and installation is such that there is typically one prime contractor and many sub contractors who are responsible for some sub system(s) of the power plant. Recently, I was the lead engineer and the program manager for Universal Silencer's scope of supply for a 550 MW combine cycle plant installation in the Middle Atlantic region of the United States.

The scope of Universal Silencer, for whom I am employed, was the diverter damper and its ancillary equipment. Ancillary equipment for the diverter damper includes seal air fans, the AC drive motors for the damper and seal air fans, and the electronic controls for the damper, seal air fans, emergency stops, position sensors, and the electrical interface to the plants distributed control system (DCS). The turbine bypass exhaust stacks, the acoustic silencer was also in Universal Silencers scope of supply.

The scope of supply for Universal Silencer was completed in the 1<sup>st</sup> stage of combine cycle plant installation where the plant was operated in simple cycle however I, along with two other engineers, returned to complete the installation once the HRSG and steam turbine was installed. The following pages described some of the finer points of such an installation and will focus on the diverter damper and the controls for such a system.

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## **Project Management Combined Cycle System in the Middle Atlantic Region Of The United States**

#### **Background:**

Universal Silencer received a purchase order from a Mid Atlantic power utility company in February 2000 for the design, fabrication, and installation of a diverter damper and an exhaust bypass stack for three 100 MW gas turbines used in a combine cycle power plant. Universal Silencer fabricated the by-pass stack silencers and plenum and contracted out the fabrication of the diverter damper and site installation services. Although the diverter damper fabrication was subcontracted Universal Silencer maintained design control and responsibility of all components within its scope including the electronic controls.



### **Combined Cycle Plant during installation**

The photo above is meant to demonstrate the size of the plants. The tall stacks on the left are the exhaust stacks for the steam generation portion of the combine cycle system. The shorter lighter colored stacks on the right are the exhaust bypass stacks for the three 100 MW gas turbines. The stacks in the background are for the existing combine cycle systems.

A second photo is included to indicate the time duration of these types of projects by the changing system. The author experienced such seasonal changes as witness by being in the foreground of the 2<sup>nd</sup> picture.





Same Combine Cycle system at different stage of installation

The photo above again demonstrates the size of these systems. A bypass stack for one of the three gas turbines can be seen in the background of the photo. The HRSG is located in the cream colored building. The diverter damper is located in the base unit of the stack and is also cream colored with vertical stiffeners. The turbine and the turbine enclosure are to the far right of the diverter damper and not in the photo.

#### Diverter Damper Description:

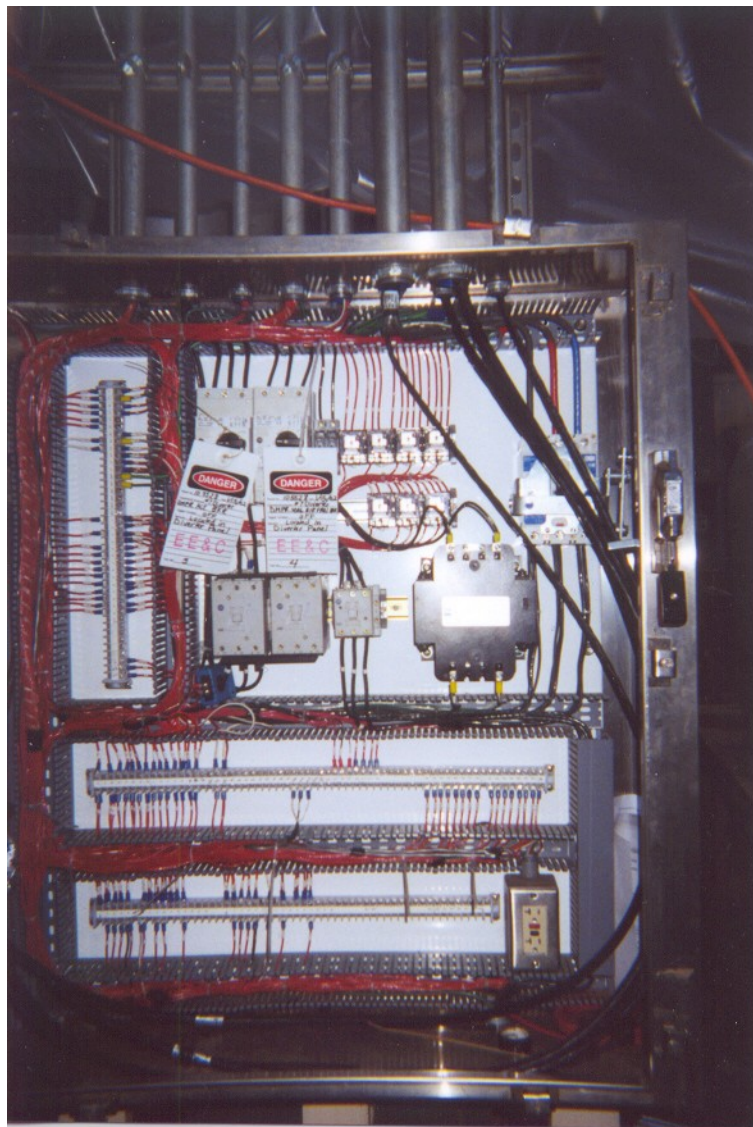
The purpose of the diverter damper is to direct the gas turbine exhaust flow to the atmosphere for simple cycle operation or to the HRSG for combine cycle plant operation. Seal air systems are used to seal the diverter tight against the appropriate mating surface. Electronic control of the diverter damper and seal air system must be integrated to prevent exhaust gas leakage from the sealing surface.

The seal air system provides sealing air to the diverter damper whenever the damper is either the full open or full closed position thus preventing exhaust gas from escaping from the desired gas path. Radial type fans are used to provide the needed airflow and control valves are used to direct the airflow to the desired mating surface. The control of

the seal air system is such that the flow control valves automatically open or close as the diverter damper passes the 30 and 60° positions directing the seal air flow to the required sealing surface.

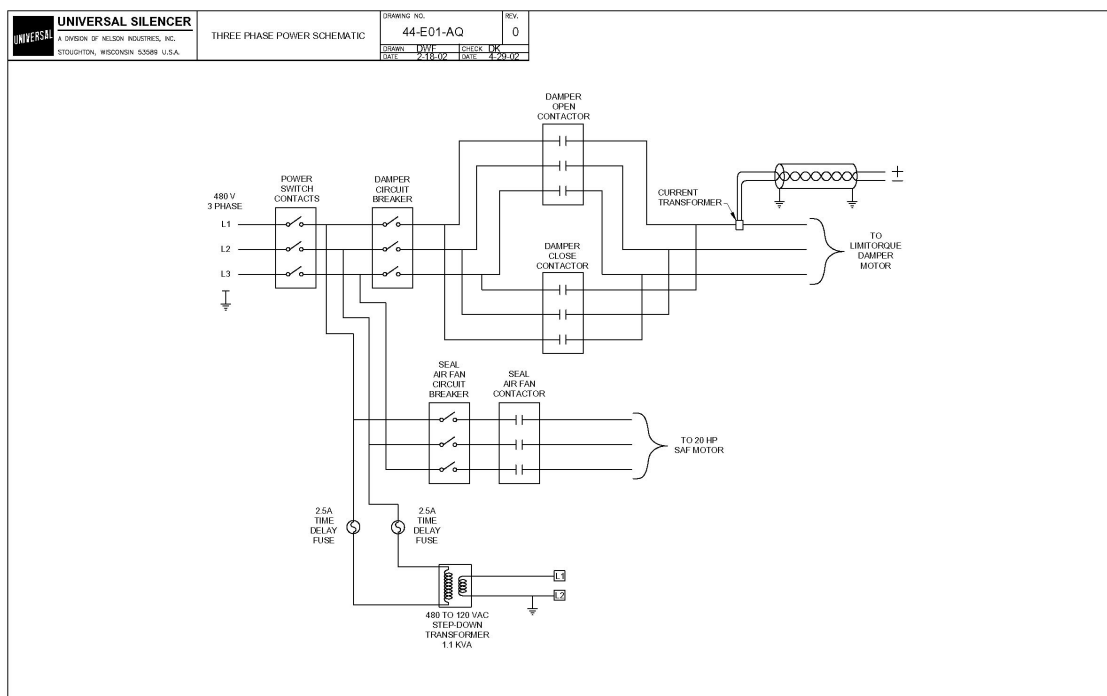
The control of the diverter damper, and the seal air system can be operated remotely from the power plants control room or manually from a local control panel. Included in the control panel are safety switches, power transformers, local control switches for the fan, actuator, and valves.

In the past the electronic control for this system was simply to fully open or close the damper. Recent developments in the industry have led to using the diverter damper as a throttling device to bring the HRSG (and thereby the steam turbine) up to speed quicker allowing the utility to achieve rated load quicker.



## Local Control Panel for the Diverter Damper and Seal Air System For a Combined cycle System

The above photo is of the local control panel for the diverter damper. Please take note of the safety tags as safety is always of major concern during any installation of this type. While the box may seem simple at first glance it is a major sub component to the entire power plant because the remote operation of the system is also routed through the control box.



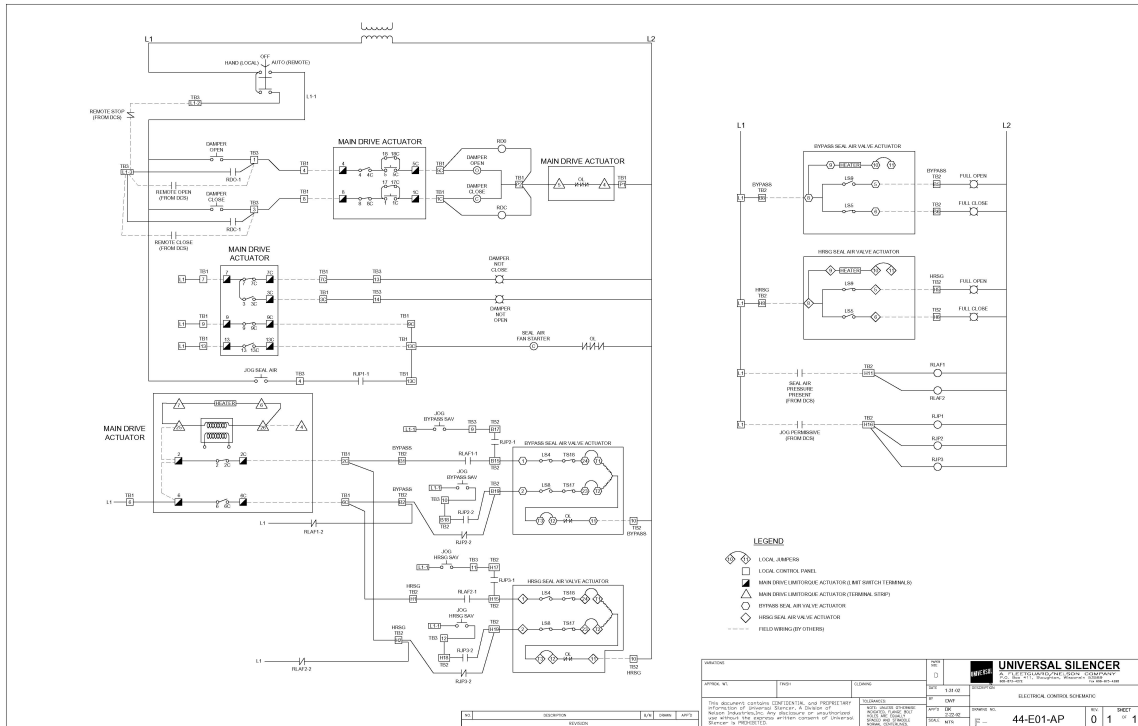
**Figure 7: Three-Phase Power for the Diverter Damper Control System.  
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Figure 7 is the three phase power schematic for the diverter damper control system. Three-phase 480 Vac power the control electronics. Power switch contacts prevent the system from operation when the control panel door is open.

480 Vac power is then fed to the damper open and damper close contacts to position the damper as appropriate for plant operation. 480 Vac power is supplied to the Limitorque three- phase motor to move the diverter damper into the desired position.

Operation of the seal air fan is automatically determined by the position of the diverter damper and is driven by a 20 HP motor which requires 480 Vac three-phase power. It was convenient to tap off the same power used for the diverter damper motor.

Separately, the 480 Vac three-phase power is routed to a 1.1KVA 480 Vac to 120 Vac step down transformer to supply 115 Vac line voltage to the damper and seal air systems.



**Figure 8: Electrical Control Schematic for the diverter damper. Printed with the permission of Universal Silencer and not to reproduced without written approval of Universal Silencer**

Figure 8 is the electrical control schematic for the diverter damper and illustrates the control mechanism for the diverter damper system and associated ancillary equipment. L1 from Figure 7 is the high side of the line voltage just as L2 from Figure 7 is the common side.

L1 is fed to the control circuits of Figure 8 through a master switch that selects between local, remote, or secures the system. Control of the diverter damper system is through the power plants control room when the master switch is in the remote position. Local operation of the diverter damper system is allowed with the master switch in the local position. The off position (with appropriate out tags in place) allow for maintenance and troubleshooting of the diverter damper system.

The dotted line control path in the upper left-hand corner of figure 8 illustrates remote control of the diverter damper from the DCS.

L1 refers to non-switched 115 Vac power routed directly from the step down transformer, while L1-1 refers to 115 Vac switched at the master switch.

L1-1 is then routed to the damper open and close switches to allow local control of the diverter damper. Additionally, L1-1 is routed to JOG seal-air switch, which controls the seal air fan starter, L1-1 is also routed to the JOG bypass seal air valve, and the JOG HRSG seal air valve switches that automatically control the corresponding valves routing the seal air to the appropriate damper sealing system.

Non switched 115 Vac (L1) is routed to the main diverter damper actuator heating circuit to prevent freezing of the circuits during winter months. L1 is also fed to the all indicator lights to provide the roving plant operator an indication of system status. Additionally L1 is feed to the heating circuits of the bypass and HRSG seal air valve actuators. The Limitorque actuators have position limiting circuits to prevent overdriving the diverter damper. These circuits also require non-switched L1 power for proper operation.

#### CONCLUSION:

Combine Cycle systems are efficient low cost systems that provides assurances of performance and operating objectives. Combine Cycle systems can be customized to the utility needs and preferences. They offer attractive economical reliable power generation. Operating flexibility of Combine Cycle power generating warrant their consideration for most power generation applications.

Besides they are fun to work on and offer the utility engineer a unique and challenging design opportunity.

A handwritten signature in black ink, appearing to read "Jim Causey", with a long, sweeping horizontal stroke extending to the right.

Jim Causey

References:

Langston, Lee S. University of Colorado, Opdyke, George Jr., Dykewood Enterprises, Introduction to Gas Turbines for Non Engineers

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