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Engineering Software is pleased to announce the introduction of ***Free Coursework Material***.

Engineering Software Coursework Material covers the following area:

- ***Energy Conversion Systems***

Introduction

Advanced energy conversion technologies will play a vital role in the future well-being of the U.S. As a reliable, affordable energy resource, coal and gas fuels will power economic growth, and help us achieve environmental goals at the same time.

The same dynamics that make clean advanced energy conversion technologies attractive in the U.S. will apply in many other regions of the world. Worldwide energy demand is expected to rise dramatically over the next two decades, particularly the demand for low-cost electricity in developing nations. Coal, which makes up 70 percent of the world's fossil energy reserves, is likely to be the primary fuel source for many nations.

Exporting advanced energy conversion technologies will help the U.S. improve our balance of trade and increase employment opportunities. It will also help other nations to achieve common goals: a cleaner environment, less dependence on oil and a better quality of life.

Advanced Energy Conversion Systems

In large part because of the focused teamwork among industry, Government, and academic resources, the U.S. now leads the world in coal and gas fired energy conversion research, development, and demonstration. Breakthroughs in both power generation and liquid fuel technologies will make the use of coal and gas progressively cleaner, more efficient, and more economical.

Breakdown

Six categories of advanced power generation systems hold the greatest promise for commercial use:

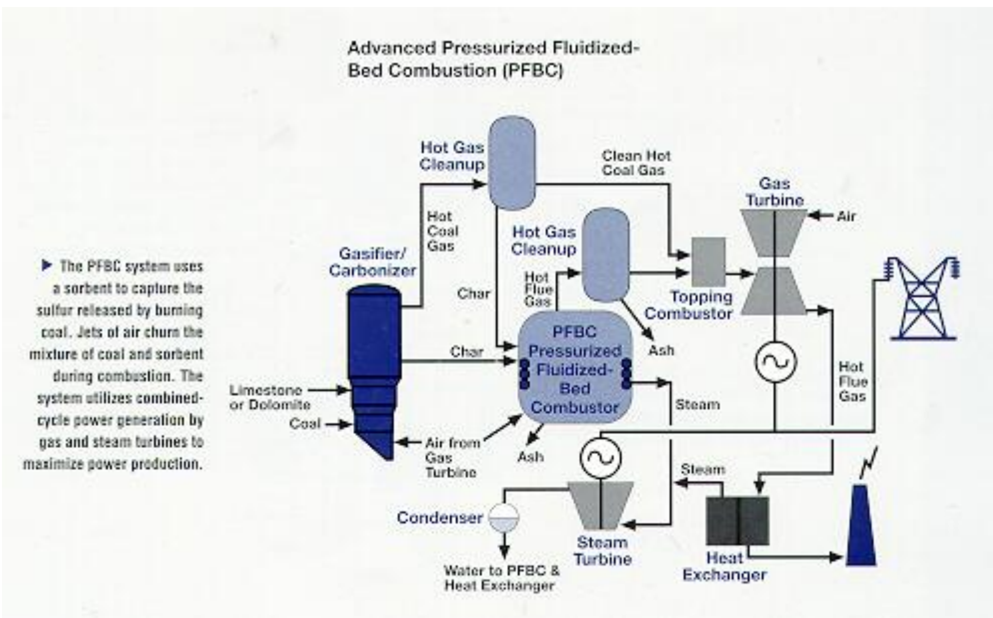
- Pressurized Fluidized-Bed Combustion
- Integrated Gasification Combined Cycle
- Indirectly Fired Cycle
- Fuel Cell
- Advanced Gas Turbine
- Magnetohydrodynamics

The first-generation version of most of these systems is either commercially available or under demonstration today.

Descriptions

Pressurized Fluidized-Bed Combustion

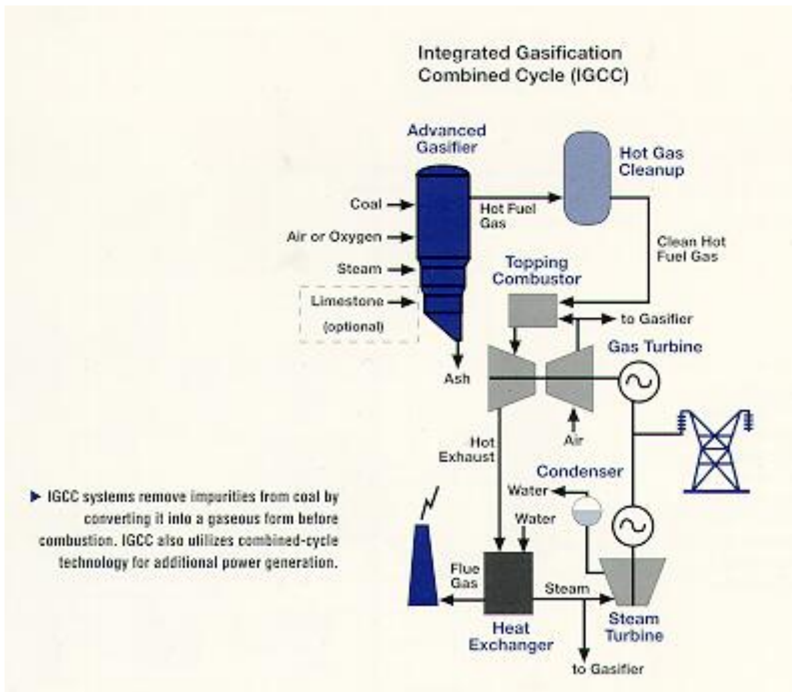
This coal fired combustion system reduces sulfur and nitrogen pollutants inside the boiler, eliminating the need for expensive add-on equipment. The hot, high-pressure gases produced by pressurized fluidized-bed combustors can power a "combined cycle" arrangement of gas and steam turbines. First-generation systems, with 40 to 42 percent efficiencies, are being commercially demonstrated. More advanced concepts are expected to boost efficiencies between 45 percent and 50 percent. These advanced systems will be capable of reducing sulfur dioxide by 95 percent and nitrogen oxides by 85 percent.



▶ The PFBC system uses a sorbent to capture the sulfur released by burning coal. Jets of air churn the mixture of coal and sorbent during combustion. The system utilizes combined-cycle power generation by gas and steam turbines to maximize power production.

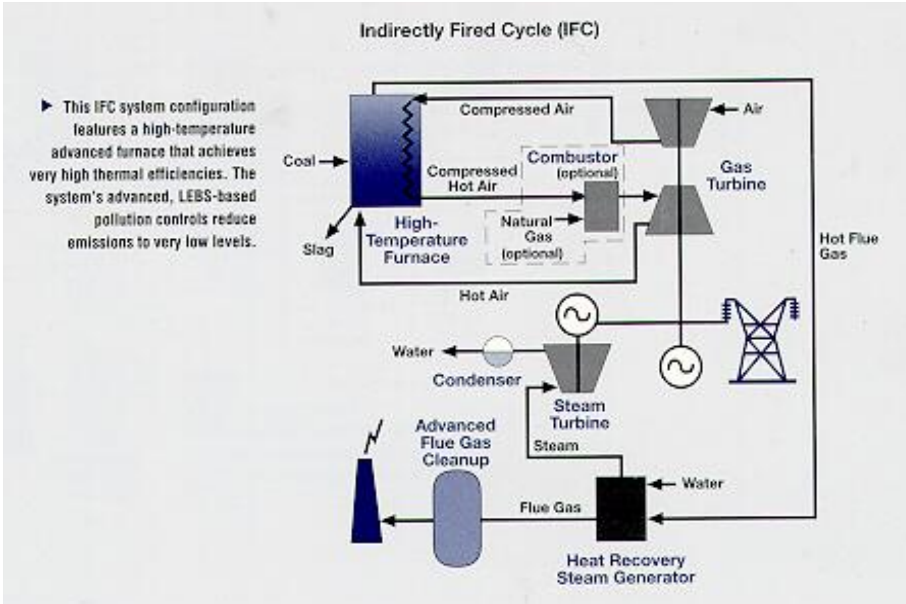
Integrated Gasification Combined Cycle

This power plant configuration relies on a coal gasifier rather than a boiler. Combustible gases produced by the gasifier can be cleaned to high purity levels (more than 99 percent sulfur removal) before being burned in a gas turbine. Exhaust heat can be used to drive a steam turbine. First-generation systems now being readied for construction can achieve efficiencies up to 42 percent. Second-generation systems could reach efficiencies of 45 percent by the end of this decade, and more advanced systems envisioned are expected to exceed 50 percent efficiency levels. Sulfur dioxide and nitrogen oxides emissions are less than one-tenth of the New Source Performance Standards.



Indirectly Fired Cycle

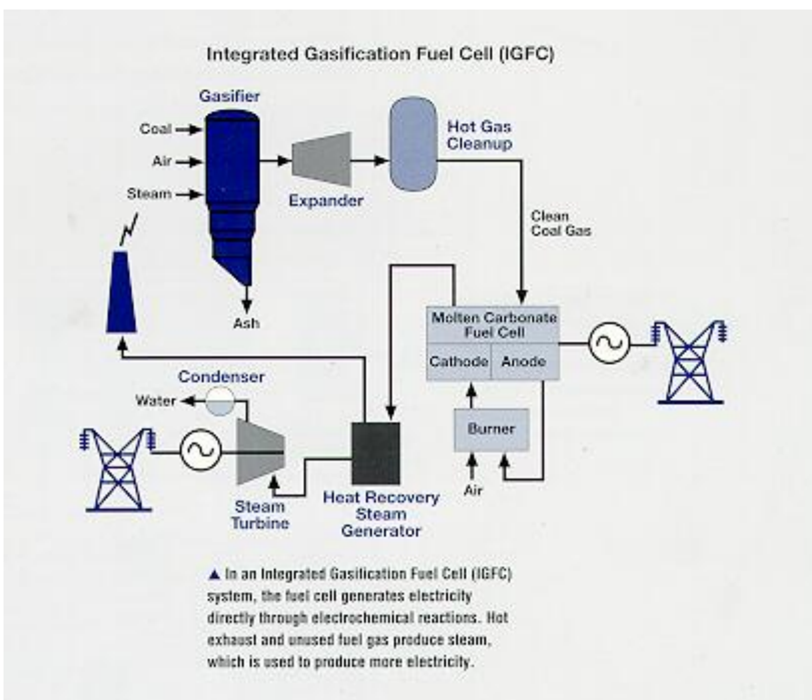
The combustion gases created by burning coal in this high performance power system are prevented from contacting a gas turbine. Instead, they transfer heat to an impurity free gas that powers the turbine. Currently, in the conceptual design phase, indirectly fired cycle systems could offer a coal-based technology with efficiencies approaching 50 percent, with sulfur dioxide, nitrogen oxides, and particulates reduced to one fourth of the New Source Performance Standards.



▶ This IFC system configuration features a high-temperature advanced furnace that achieves very high thermal efficiencies. The system's advanced, LEBS-based pollution controls reduce emissions to very low levels.

Fuel Cells

Fuel cells will enter the power generation market using natural gas and later may be adapted to coal-derived gas. Because fuel cells generate electricity electrochemically rather than by combustion, sulfur and nitrogen emissions are virtually nonexistent. Efficiencies can approach 60 percent for power-generating applications, and as high as 85 percent when the waste heat is used for cogeneration.



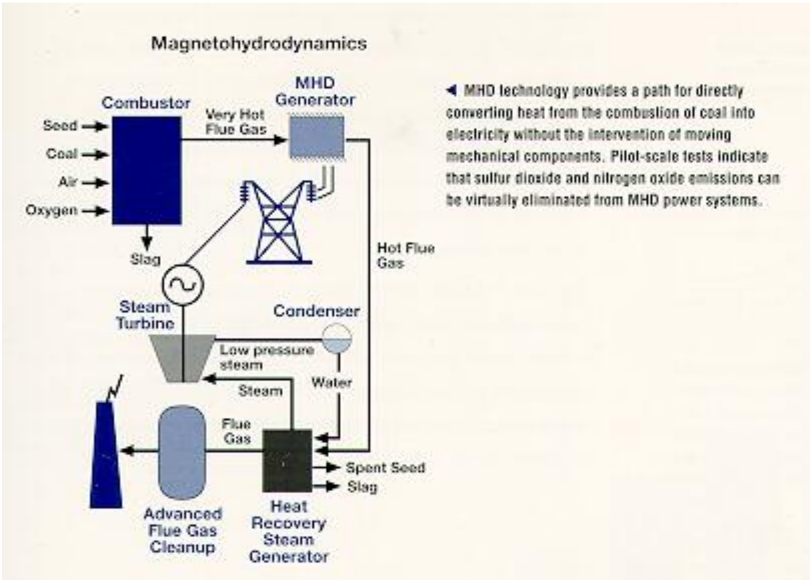
▲ In an Integrated Gasification Fuel Cell (IGFC) system, the fuel cell generates electricity directly through electrochemical reactions. Hot exhaust and unused fuel gas produce steam, which is used to produce more electricity.

Advanced Gas Turbine

Like fuel cells, advanced gas turbine systems are being developed initially for natural gas, with a future option to adapt to coal-derived gas. Advanced turbine systems being developed for the 21 st century will be capable of breaking through the temperature barrier that limits the efficiency of today's systems, while significantly reducing nitrogen oxides emissions.

Magnetohydrodynamics

This coal-based power option operates at ultra-high temperatures, producing a plasma which, when channeled through a magnetic field, can generate electrical current. Combined with a steam turbine-generator, magnetohydrodynamics systems are projected to be capable of efficiencies exceeding 50 percent with very low emissions.



Benefits

Advanced energy conversion technologies being developed by private industry and the U.S. Government will substantially increase the efficiency of coal and natural-gas fired power generation. Each step up in efficiency reduces the levels of fuel consumption and emissions per unit of power.

Basic Concepts

System: A system is an identifiable collection of matter whose behavior is the subject of study. For identification, the system is enclosed by a system boundary, which may be purely imaginary or may coincide with a real boundary. The term closed system is sometimes used to emphasize that there is no flow of matter across the system boundary. The type of thermodynamic analysis used is known as a system analysis or control mass analysis.

When motions are involved, the system definition must include a reference frame to which velocities and displacements are related. The most commonly used reference frame is the inertial reference frame in which a free particle moves at constant velocity.

Surroundings: Everything outside the boundary of the system is called the surroundings.

Isolated System: If changes in the surroundings produce no changes in the system the system is known as an isolated system. A system combining a system and its surroundings is an isolated system, often called the universe which is not a universe in the cosmological sense but only in the thermodynamic sense.

Property: A thermodynamic property is any measurable characteristic of a system whose value depends on the condition of the system.

Thermodynamic State: The state of a system is that condition of the system which is described fully by its observable properties. In identical states, the properties have the same values. Thus properties are functions of the state of the system and not of a process which the system might undergo.

State of Equilibrium: An isolated system which has no tendency to undergo a change of state even after a long time is in a state of equilibrium.

Process: When the state of the system changes it is said to undergo a process.

Extensive Properties: For a system divided into N sub-systems by real or imaginary boundaries, the value of an extensive property, X, for the whole system is the sum of the values of that property for all sub-systems. Mass and volume are extensive properties. Extensive properties have values regardless of whether the system is in equilibrium or not.

Intensive Properties: These properties are independent of the size of the system and only have meaning for systems in equilibrium states; pressure and temperature are intensive properties. A special type of intensive property is a specific property which is the ratio of an extensive property to the corresponding mass.

Homogeneous System: If the value of any intensive property is the same, the system is homogeneous.

Cyclic Process: When a system goes through some changes of state (or processes) and finally returns to its initial state, it has gone through a cycle or cyclic process.

Reversible Process: A process is reversible if, after it has taken place, means can be found to restore the system and its surroundings to their-initial states with no residual effects in either of them. Full reversibility is not possible in a real process.

Quasi-Static Process: In such processes the system is infinitesimally close to at all times and all states through which the system passes can be described by thermodynamic coordinates referring to the system as a whole. A quasi-static process is an idealization which can be approached in practice with any degree of accuracy which may be desired.

Control Region: A control region, also known as control volume or open system, is any defined region in space under analysis. The extent of the control region is defined by the control surface.

Work and Heat: These phenomena are describable at the system boundary and exist only while the system (or control region) and the surroundings interact and thus both work and heat are called interactions. Since these interactions result in energy transfers across the boundary, work and heat may be regarded as energy in transit. Although they have this in common, there are also important distinctions between them. Work is an interaction between two systems such that the sole effect of the action of one system on the other can be shown to be equivalent to the raising or lowering of a weight. Heat results in an energy transfer between two systems in thermal contact by virtue of their temperature difference.

Thermal Energy Reservoir: A thermal energy reservoir is a body of constant volume in stable equilibrium with a very large heat capacity so that it may act as a heat source or heat sink without suffering a finite change in temperature. In practical thermodynamic analysis, any constant temperature body, such as a heated room or a refrigerated cold chamber, whose sole function is either to receive or to deliver thermal energy through heat interaction may be treated as a thermal energy reservoir within which all processes are assumed to be quasi-static.

Mechanical Energy Reservoir: This is a system capable of storing fully ordered mechanical energy as potential energy (raised weight in a gravitational field) or kinetic energy (spinning flywheel). A mechanical energy reservoir is an idealized system in which the energy is stored, received, and delivered in a reversible manner.

Heat Engine: A heat engine operates in a cyclic manner and exchanges thermal and mechanical energy with other systems.

Adiabatic Boundary: A system boundary or control surface which does not permit a heat interaction to take place is adiabatic.

Diathermal Boundary: A system boundary or control surface which permits a heat interaction to take place is diathermal.

Sign Convention: Heat transfer to the system is positive and heat transfer from the system is negative. Work done by a system is positive and work done on the system is negative.

State Postulate: The number of independently variable thermodynamic properties for a particular system is the number of relevant reversible work modes plus one. The reversible work modes, ie ways by which a system can transfer energy as work, depend on the properties of the substance comprising the system. For example if the substance is compressible and magnetic its work modes are associated with volume changes due to applied pressure and changes in magnetisation in a changing magnetic field. Three independently variable properties are required to define its state. Here the emphasis is not on magnetic effects, electric properties of substances, or with surface tension. Only the work mode due to compressibility will be considered; the state of such a simple compressible substance can be defined for a non-reacting system in terms of only two independently variable properties.

Equation of State: There are a number of equations of state relating the properties of simple compressible substances; the simplest is the ideal gas equation:

$$pv=RT$$

where R is the specific ideal-gas constant. When, for the range of properties under consideration, an ideal gas can be assumed to have constant specific heat capacities it is called a perfect gas. A real gas departs from ideal gas behavior, requiring a complex equation of state or tabular presentation of its properties.

Molar Properties: A mole of any give molecular species is the amount of subs which contains as many elementary entities as the reare atoms in 0.012 kg of carbon. This definition is cumbersome so, for practical purposes, the mass of one mole is to be given numerically in grammes by the relative molecular mass (molecular weight of the substance. For example, the mole of diatomic oxygen is approximately 32 using the kilomole (kmol), the molar mass is approximately 32 kg/kmol.

First Law

There is an extensive property, internal energy (U), such that a change in its value is for a system not in motion by the difference between the heating (Q) done to the system and the work (W) done by the system during any change of state.

$$Q - W = dU$$

Where:

$$dU = U_{Final} - U_{Initial}$$

This equation is known as the energy balance for a non-flow process or the non-flow.

Second Law

Entropy Postulate

There is an extensive property of a system called entropy, S. The entropy of an isolated system can never decrease.

$$dS_{Isolated} \geq 0$$

where the equality sign corresponds to the ideal case of a reversible process.

Combined System

If the system under study is not an isolated system, it is necessary to consider all systems participating in the process so that the new, extended system can be regarded as an isolated system. By considering a combined system consisting of the system and the surroundings, can be written:

dS System + dS Surroundings > or = 0

Implications of the Second Law

The implications of the Second Law are manifold. The condition of the increase of entropy can be used to predict what processes, chemical reactions, transformations between various energy forms, or directions of heat transfer can and cannot occur. From the condition that a state of equilibrium of an isolated, two part system corresponds to a maximum of entropy of the system, it can be shown that the conditions of thermal, mechanical and chemical equilibrium correspond respectively to equality of temperature, pressure and chemical potential. In addition, the Second Law governs the limits to energy conversion between different energy forms, leading to concept of energy quality.

Microscopic View

From a consideration of the microscopic nature of matter through the statistical approach, entropy can be shown to be a measure of microscopic randomness and the resulting uncertainty about the microscopic state. Real processes tend to make the distribution of kinetic energy of molecules of the system more random, making a smaller proportion of this energy available for conversion to useful, organized work. Thus, it can be said that entropy is a measure of the 'unavailability' of internal energy.

Power Cycle Components/Processes

Most power and propulsion devices can be considered to comprise a number of simple processes. The most common are: expansion, compression, heat exchange, mixing, separation of constituents of mixtures, and chemical reactions including combustion of fuels.

Expansion

In power plants expansion generally occurs at temperatures above the environmental temperature. Except for throttling, the purpose of an expansion process is to deliver power at the expense of a reduction in the exergy of the stream of the working fluid. Most common expanders are rotodynamic and are usually treated as adiabatic. Expansion can occur as a single or a multi-stage expansion process.

Compression

In applications such as power plants, compressed air installations, gas pipelines a liquefaction plants compression usually starts at approximately environmental temperature. In refrigeration plants and heat pumps, compression processes start at temperatures lower than T_o, but usually end above it.

Heat Transfer

Heat transfer processes may be usefully divided into two groups.

Group 1: In this group of heat transfer processes the thermal component of exergy of one stream increases at the expense of a reduction in the thermal component of exergy of another stream. Thus in this case a heat exchanger transfers thermal exergy between two streams through conductive, convective or radiant heat transfer. Since there is a useful output expressible in terms of exergy, a rational efficiency can be formulated.

Group 2: This group of heat transfer processes is characterized by transfer of thermal energy to or from the environment. In some heat transfer processes such as those found in cooling towers and refrigerator condensers, the stream, at $T > T_o$, transfers heat to the environment. In heat pump evaporators, however, the stream is at a temperature lower than T_o, and heat transfer is from the environment. In either case the exergy of the stream decreases as a result of the heat transfer, and since the exergy of the environment can never increase, heat transfer processes in this group lead only to dissipation of exergy. As there is no output expressible in terms of exergy, there is no rational efficiency for a beat transfer process in this group. However, the magnitude of the irreversibility rate calculated for the process can be used to assess the process, particularly when it is compared with the value of intrinsic irreversibility calculated for the heat exchanger.

Forms of Irreversibility in Heat Transfer Processes

Loss of efficiency of heat exchangers is caused by different forms of irreversibility due to:

Heat transfer over a finite temperature difference
Pressure losses
Thermal interaction with the environment
Streamwise conduction in the walls of the heat exchanger

Mixing

Mixing occurs spontaneously when substances are put into physical contact with each other. The mixing process has two distinct aspects, the intermingling of the molecules of the substances and the exchange of energy between the streams involved in the process. Molecular aspects are irrelevant when the streams are of the same chemical composition while no energy will exchange if the streams are initially at the same pressure and temperature.

Combustion

Combustion processes are often accompanied by heat transfer as well as fluid friction and mixing so there is usually more than one form of irreversibility present. In principle it is impossible to evaluate in this case what part of the total irreversibility is due to any particular cause. The process of combustion can be examined, however, by assuming that it takes place under adiabatic conditions and that irreversibilities due to friction and mixing are negligible.

Exothermic and Endothermic Reactions

Exothermic reactions are accompanied by release of thermal energy. The chemical potential of the reactants in exothermic reactions is always greater than that of the products and this difference acts as a driving force so that an exothermic reaction, once started, will proceed on its own, although sometimes a catalyst may be required. Processes which take place by virtue of finite driving forces, may be called spontaneous or uncontrolled, and are inherently irreversible. The irreversibility of exothermic reactions may also be looked upon as being due to degradation of chemical energy, a relatively ordered form, to thermal energy which is of highly disordered form.

Endothermic reactions require an input of thermal energy from an external source. Consequently endothermic reactions are, in principle, controlled although in practical reactions there are irreversibilities due to lack of homogeneity of composition and to temperature gradients in the mass of the reactants and products.

Glossary

Acid Rain: Also called acid precipitation or acid deposition; precipitation containing nitric and sulfuric acids formed by NO, and SO, released into the atmosphere when fossil fuels are burned.

Demonstrated Reserves: Coal potentially mineable with existing technology, estimated at 475 billion tons in U.S.; current mining methods may not recover all these reserves.

Anthracite: Coal with a heating value of 15,000 Btu.

Bituminous Coal: Coal with a heating value of 10,500 to 15,500 Btu per pound and carbon content of 45% to 86%; located across the U.S.; see Coal rank.

Btu (British Thermal Unit): The amount of heat needed to raise the temperature of 1 pound of water by 1 F at or near 39.2 F.

Clean Coal Technologies: Advanced innovative systems designed to produce power from coal more efficiently and economically than conventional coal burning processes-while minimizing environmental impacts.

Coal Rank: An indication of the degree to which organic matter has been converted to coal. Rank is based on the fixed carbon, volatile matter, and heating value of a coal.

Coprocessing: The mixing and subsequent processing of coal and heavy, residual oil through a refining-like process to create a lighter, higher quality liquid.

Coal Gasification: The conversion of coal into a gaseous fuel.

Coal Beneficiation: Coal treatment, cleansing, or preparation to remove mineral or ash material.

Coke: A hard, dry substance of mostly carbon made from bituminous coal baked at very high temperatures in the absence of air, by a process called carbonization. Used chiefly as a fuel and reducing agent in smelting iron ore in a blast furnace, coke has a heating value of about 25 million Btu per ton.

Combined Cycle: Both gas combustion and steam turbines operating together.

Compressor: A pump or other type of machine using a turbine to compress a gas.

Cyclone Combustor: A device in which coal is burned in a separate chamber outside the furnace cavity and hot gases are then passed into the boiler. A vortex of air keeps ash out of the furnace, preventing fouling of boiler tubes.

Electrostatic Precipitator: A device that removes fly ash particles from combustion gases using an electrical charge.

Fines: Coal with a maximum particle size usually less than 1/16th inch and rarely above 1/8th inch.

Fluidized Bed Combustor: A device in which crushed coal mixed with limestone is suspended on jets of air while it bums. The powdery limestone absorbs sulfur as it is released. Low burning temperatures keep NO, from forming.

Fossil Fuel: Any fuel of an organic nature (carbon containing), such as coal, crude oil, natural gas or synthetic fuels.

Fuel Cell: A device in which an electrochemical reaction generates electricity by releasing the energy that bonds atoms together.

Gas Reburning: A technique in which coal is fired in a main heat-release zone in the lower part of a boiler and natural gas is burned in a cooler, oxygen deficient zone in the upper part of the boiler to control the formation of NO.

Gas Turbine: A device in which hot combustion gases expand to drive a generator and compressor.

Generator: A machine that converts mechanical energy into electrical energy.

Greenhouse Effect: The phenomenon that occurs when certain gases accumulate in the atmosphere allowing the sun's energy to penetrate to the earth but trapping heat radiated from the earth's surface.

Hot Gas Cleanup: Advanced techniques that remove sulfur oxide compounds and other impurities from high-temperature gases with minimal cooling.

Identified Resources: Coal identified from geologic evidence and engineering measurements, estimated at 1.7 trillion tons in the U.S.

In-Duct Sorbent Injection: A technique in which limestone is sprayed into ductwork between the boiler and smokestack to absorb sulfur pollutants.

In-Situ Gasification: The in-place gasification of coal deposits through partial combustion.

Integrated Gasification Combined Cycle: A power generating system in which coal is converted to a fuel gas which is burned to drive a gas turbine, generator and a steam turbine generator.

Lignite: Coal with a heating value of 4,000 to 8,300 Btu per pound, carbon content of 25% to 35%, and high moisture content; located primarily in the Gulf Coast and northern Great Plains; see Coal Rank.

Limestone Injection Multistage Burners: A system in which limestone is injected into a boiler above low-NO. burners to absorb sulfur pollutants.

Magnetohydrodynamics: A method of generating electricity in which coal is burned at extremely high temperatures to create a highly charged plasma which is channeled through an intense magnetic field to produce current.

Metallurgical Coal: Grades of coal with compositions suitable for making coke for reducing iron ore as a step in steel manufacturing; has particularly good agglomerating capabilities, high Btu and low ash content.

Methane: The chief constituent of natural gas; produced by decaying plant material or by coal gasification processes.

Mild Gasification: A modification of conventional coal gasification that produces gaseous, solid, and liquid products by heating coal in an oxygen-free reactor at atmospheric pressure and relatively low temperatures.

Mine-Mouth Power Plant: A steam-electric power plant built close to a coal mine.

Natural Gas: A naturally occurring mixture of hydrocarbons (principally methane) and small quantities of other gases found in porous geological formations, often in association with petroleum.

Proved Reserves: The estimated resources that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs or deposits under existing economic and operating conditions.

Recoverable Coal: Also called proved reserves; coal reserves that are likely to be mined and used, estimated at between 237 billion and 300 billion tons in the U.S.

Repowering: Replacing all or part of the outmoded power generating equipment in a power plant with advanced systems.

Retrofitting: Installing modern pollution control devices on older facilities without making major changes in plant design.

Run-of-Mine Coal: Coal as it comes directly from the mine, not treated or sized by a preparation plant.

Scrubber: Any of several forms of post-combustion devices that cause sulfur in gaseous emissions to react with other chemicals to form either a waste product or, in newer technologies, a reusable byproduct.

Selective Catalytic Reduction: An NO removal process in which ammonia is first mixed with flue gas and passed through a reaction chamber separate from the scrubber vessel; then in the presence of a catalyst, NO, and ammonia are converted to molecular nitrogen and water.

Short Ton A unit of weight equal to 2,000 pounds.

Slagging Combustor: A combustor in which temperatures are hot enough to melt the mineral impurities in coal and form a slag which is forced to outer walls and kept from fouling boiler tubes.

Sorbent: An alkaline substance that combines with sulfurous gases to create a solid substance that can be removed from coal flue gases.

Steam Coal: Coal used by a power plant or industrial steam boiler to produce electricity; generally lower in Btu content than met coal.

Subbituminous: Coal with a heating value of 8,300 to 11,500 Btu per pound and carbon content of 35% to 45%; located mainly in Montana, Wyoming, Utah, Colorado, New Mexico, Washington and Alaska; see Coal Rank.

Sulfur: An element present in varying quantities in coal; contributes to environmental degradation when coal is burned. The sulfur content in coal is low if 1% or less, medium if between 1% and 3%, and high if over 3%.

Total Resources: Coal deposits both known and undiscovered, estimated at 4 trillion tons in the U.S. and as much as 14 trillion tons worldwide.

Turbine: A device with rotating vanes for generating rotary mechanical power from the kinetic energy in a stream of fluid or gas.

Underground Gasification: See In-Situ Gasification.