TOSHIBA

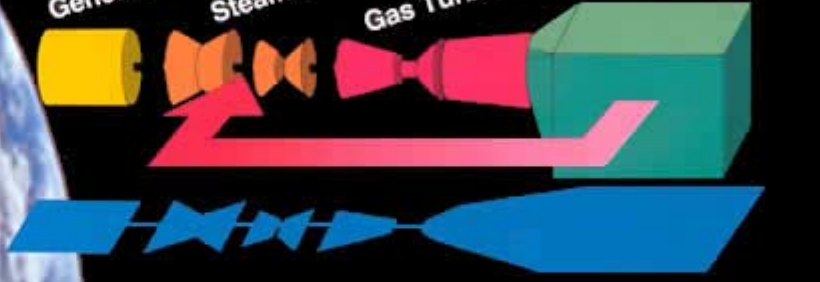
Combined-Cycle Power Plant

Marine snow

Like ocean snow flakes floating slowly to the seafloor for countless millennia, our precious energy resources have accumulated as a result of enormous geological pressures over eons.

The earth's precious energy resources have accumulated extremely slowly during the planet's long geological history.
We must use these precious resources as efficiently as possible.
Operating at more than 48% thermal efficiency, Toshiba's combined cycle power plants offer the best heat-recovery/power- generation systems available.

The energy is released
for the benefit of humanity...

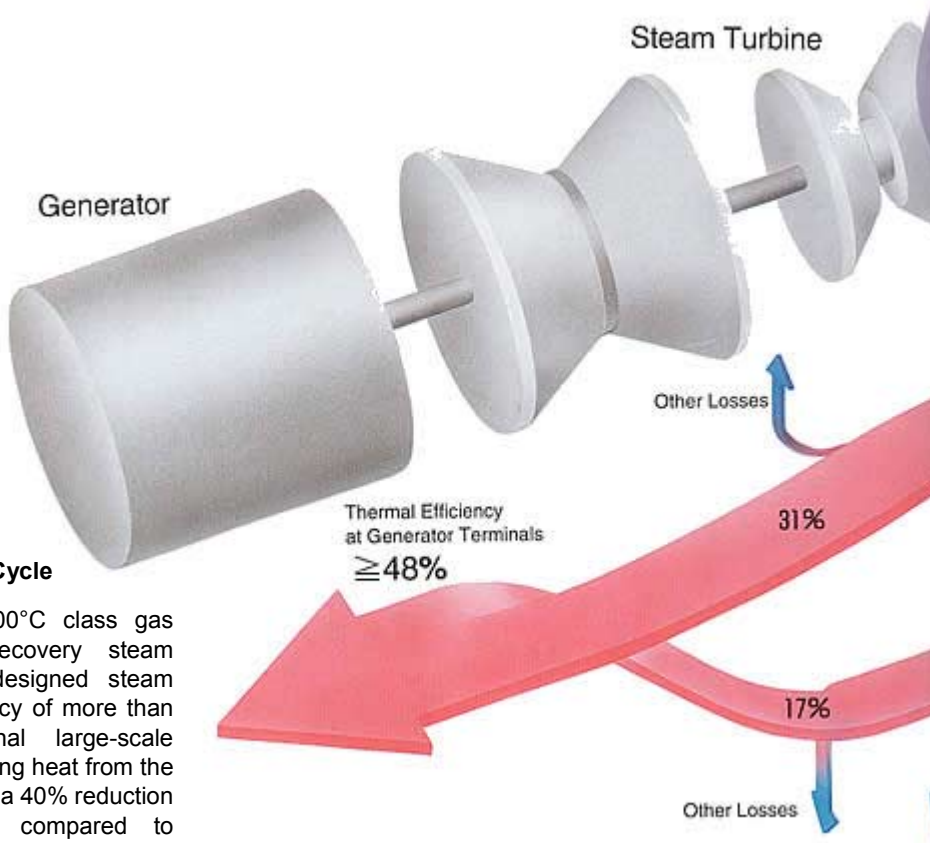


Combined-cycle power plant
A "combined-cycle power plant" recovers heat from the gas turbine's exhaust, uses the heat to generate steam in a heat-recovery steam generator, then the steam is used to generate electricity. This is one of several methods used by Toshiba to help its customers use existing energy resources more efficiently.

Higher efficiency and better operability

Heat Recovery Combined Cycle

If a power plant's output was our only consideration, our task as a manufacturer would be far simpler. However, because increased output, reduced fuel consumption, and environmental considerations are equally as important, we've developed our combined-cycle power plant technologies to meet these needs. The combined-cycle process operates at 48% thermal efficiency, generates larger output capacities, and consumes less fuel. Additional combined-cycle advantages are reduced NOx missions and improved unit operability.



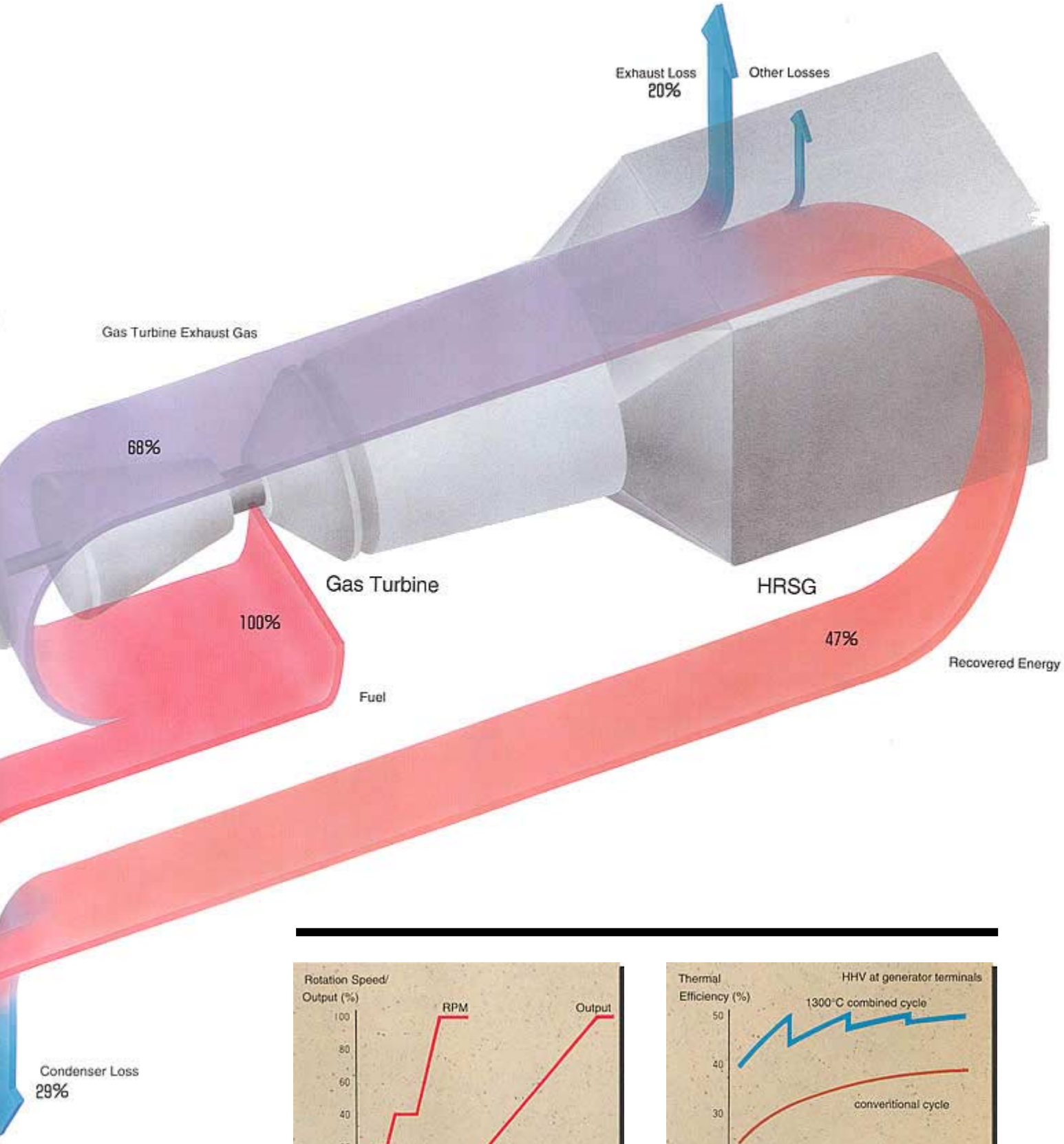
■Heat Recovery Combined Cycle

Toshiba's highly efficient 1300°C class gas turbine, large-scale heat recovery steam generator, and specifically designed steam turbine enable thermal efficiency of more than 48%, exceeding conventional large-scale thermal power plants. Recovering heat from the gas turbine's exhaust results in a 40% reduction of cooling water required, compared to conventional power plants.

■Standard Specification of Single-shaft Type Combined Cycle

Type		**109FA**	**107FA**
Gas turbine	Type	MS9001FA	MS7001FA
	Unit	1	
	Output (MW)	219	153
	Speed (rpm)	300	3600
	Inlet Temp. (°C)	1300	
Heat Recovery Steam Generator	Press Stages	3 Pressure Stages	
	Unit	1	
Steam Turbine	Unit	1	
	Output (MW)	123	85
Plant	Thermal efficiency (%)	48	48
	Output (MW)	342	238

*At ISO condition, on HHV base; at generator output terminals.



■**Start-up Characteristics (hot start)**

■**Partial Load Efficiency (1 unit/4 shafts)**

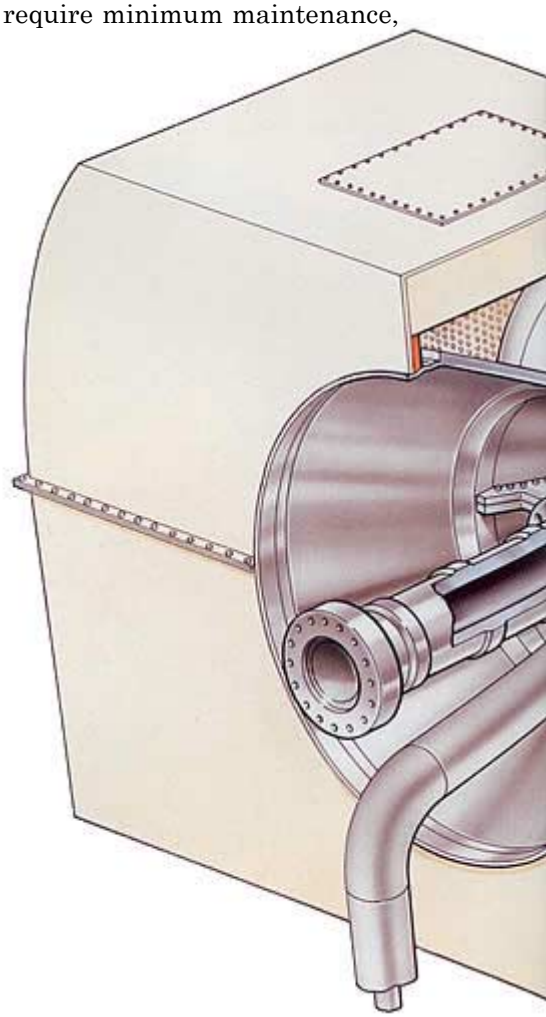
In a single-shaft type combined-cycle unit, each shaft can be stopped independently while still retaining the unit's superior start-up characteristics and high partial-load efficiency. This feature enhances power plant operability, and is also suitable for intermediate load operation. Such efficient flexibility also facilitates automatization of the plant's start-and-stop system.

GAS TURBINE

Major combined-cycle component having high output and high efficiency

1300°C Class Gas Turbine

The gas turbine is a major component in a combined cycle power plant. Toshiba adopted its 1300°C class, high-output and high-efficiency advanced gas turbine. Toshiba's time-tested gas turbines assure that our combined cycle plants are reliable, require minimum maintenance, and achieve low NOx-emission levels.

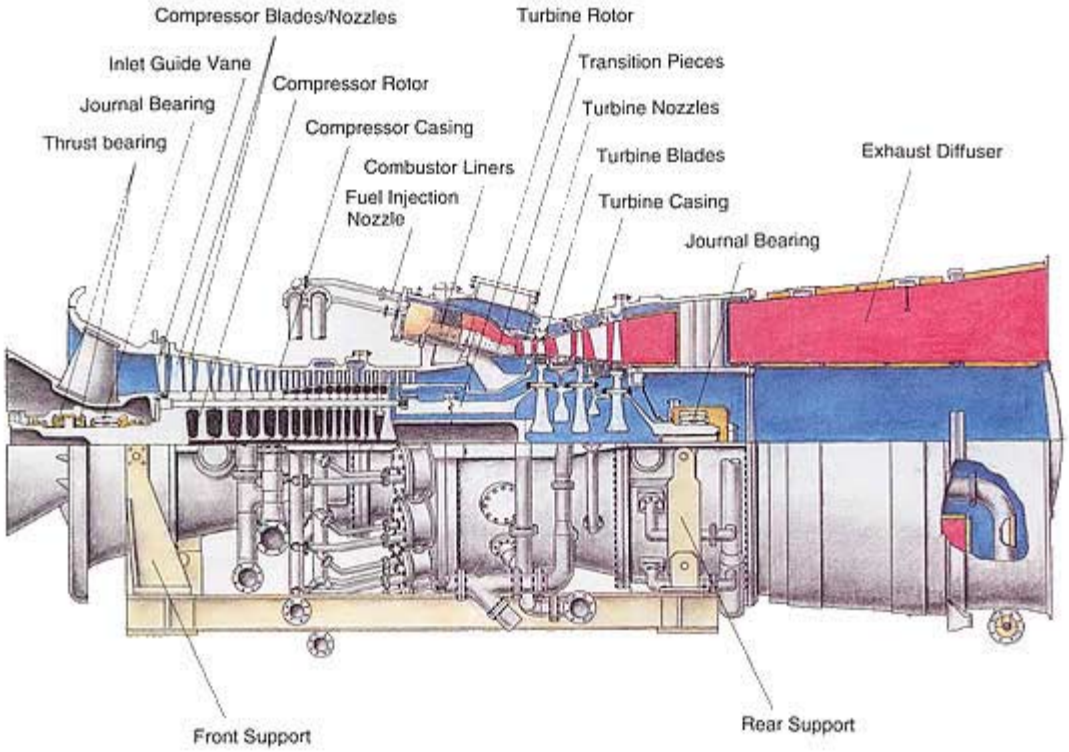


■Gas Turbine Performance

Type	M59001 FA	M57001 FA
Gas Turbine Output* (KW)	226500	159000
Gas Turbine Thermal Efficiency* (%)	35.7	35.9
Exhaust Gas Flow (kg/s)	613	427
Exhaust Gas Temperature (°C)	589	589
Rotation Speed (rpm)	3000	3600

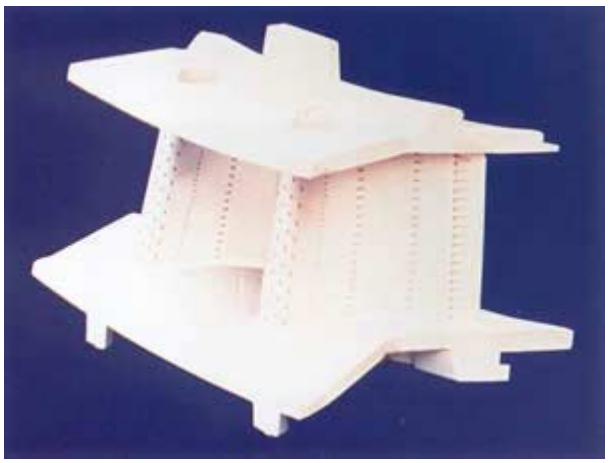
Ambient Conditions: 15°C, 1 atm 'LHV Base, at Generator
Terminal
Rated Load
Fuel: Liquefied Natural Gas

■Main Components



Type MS7001FA Gas Turbine

Hot Parts Cooled by Latest Technologies



■First Stage Turbine Nozzle

■First Stage Turbine Blade

■Transition Piece

Stable Combustion lowers NOx emissions

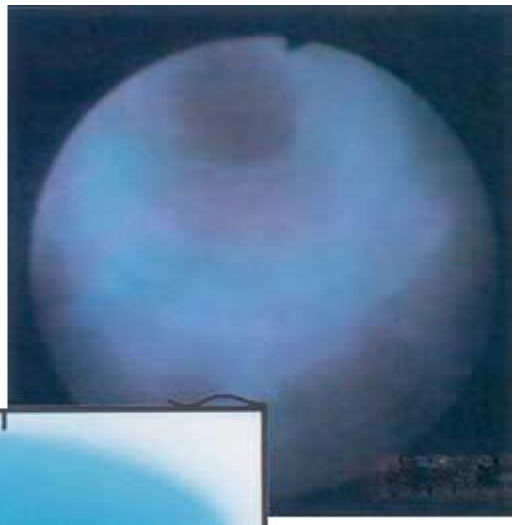
Dry Low-NOx Combustor

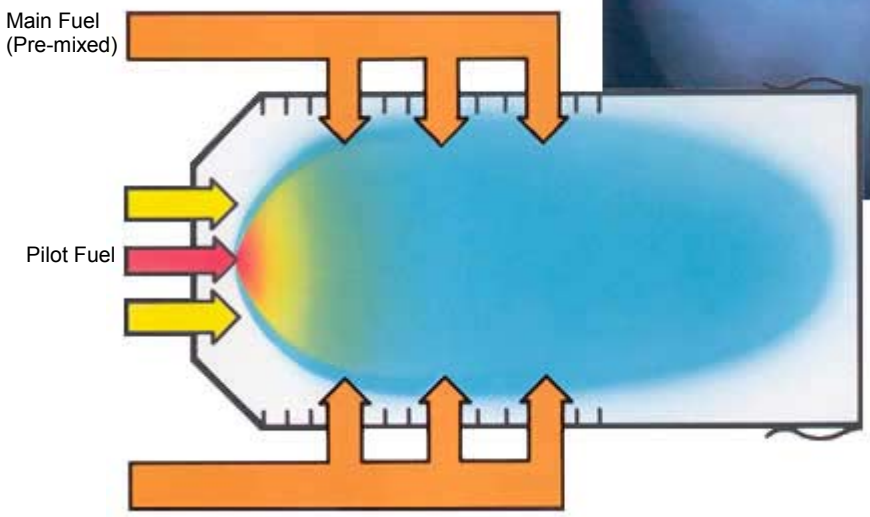
Although liquefied natural gas (LNG) is considered a clean-burning fuel, Toshiba has further decreased NOx emissions in high-temperature gas turbine combustion exhaust by developing a dry low-NOx combustor to restrict NOx generation at its source.

Use of a method to pre-mix combustion air and fuel evenly stabilizes combustion. As a result, NOx generation is reduced to one-tenth of that generated using conventional combustion methods.

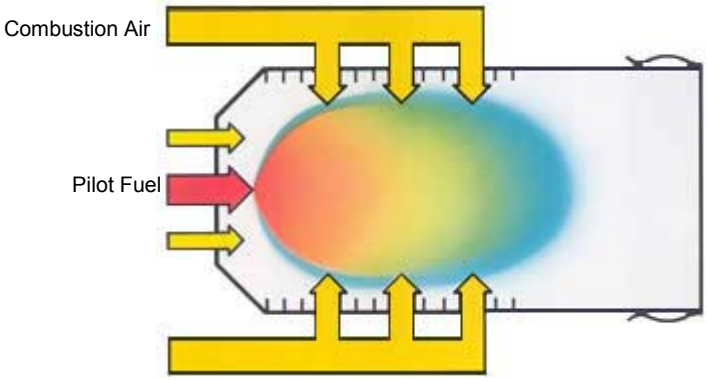
■Two-stage Pre-mix Combustion

This combustion method minimizes NOx emissions by improved flame stability, which in turn reduces the occurrence of local "hot spots" during the combustion process.



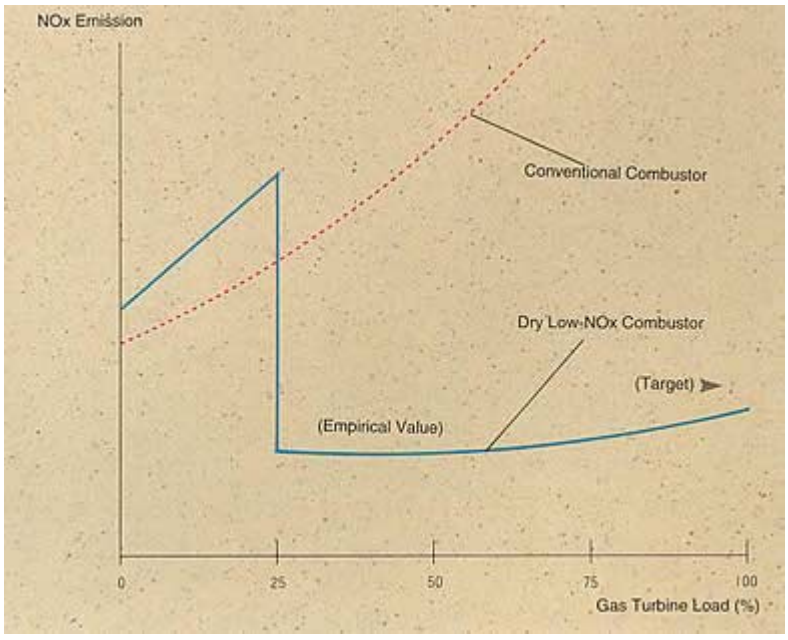


■Pilot Fuel-only Combustions (at low load)



■**Dry Low-NOx Combustor**

Fuel is impinged from pre-mix ducts installed on the outside surface of the combustor, which stabilizes the flame and reduces NOx emission. This combustor uses simplified, proven structure and fuel control process to assure high operation reliability.



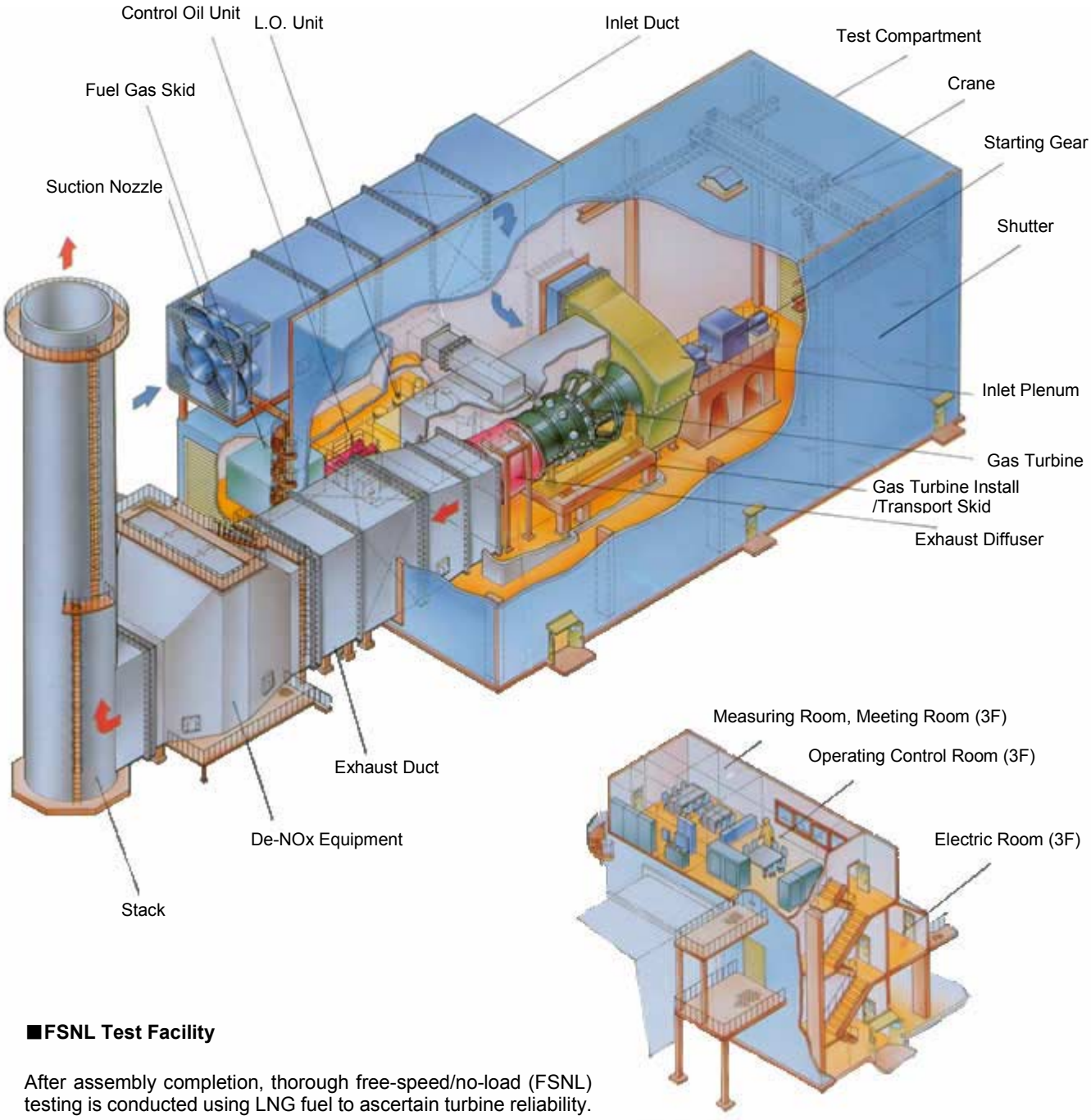
■**NOx Emission Characteristics**

Significantly lower NOx emission levels are realized used in a wide operation zone.

Quality assurance for system reliability

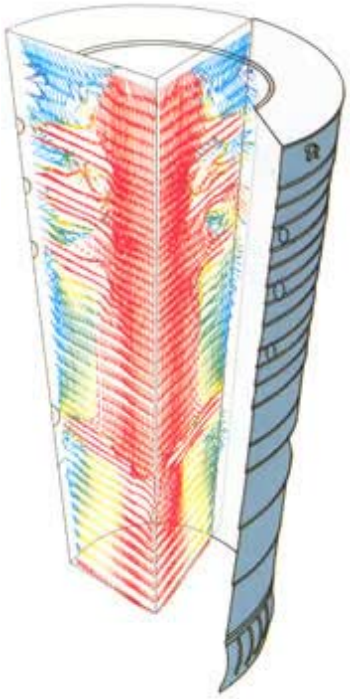
Test/Predictive diagnostics

Of course, the elimination of forced power-plant outages is the minimum goal of any manufacturer of power-generation systems. Toward this end, Toshiba conducts thorough f full-speed/no-load (FSNL) testing of each gas turbine to ascertain its reliability. Computer simulation models are applied using predictive-diagnostic and combustion-analysis technologies to pinpoint any potential flaws in gas-turbine units.



■FSNL Test Facility

After assembly completion, thorough free-speed/no-load (FSNL) testing is conducted using LNG fuel to ascertain turbine reliability.

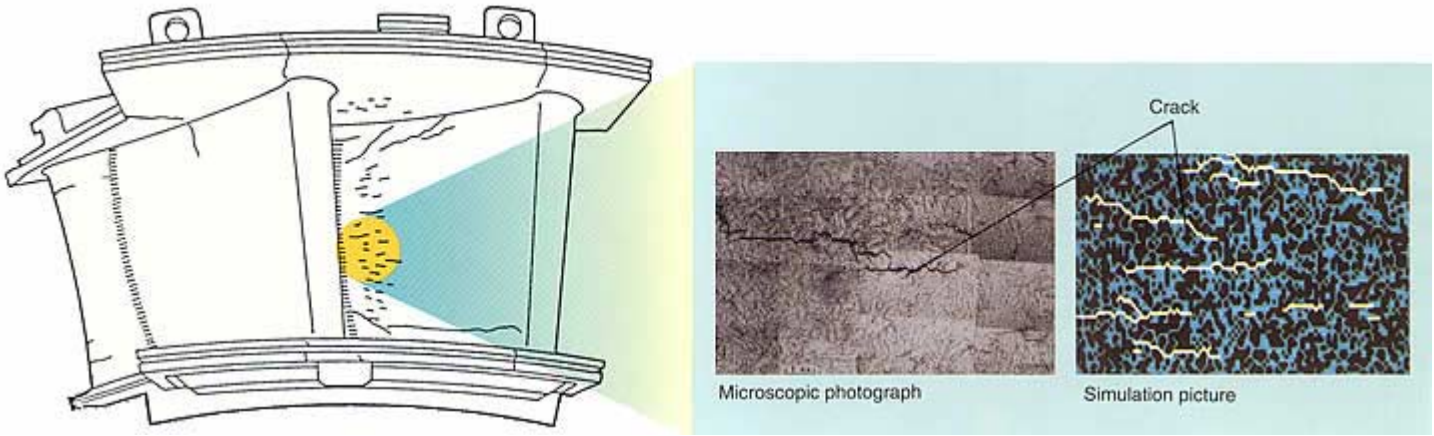


■**Viscous Fluid Analysis inside Combustor**

By simulating temperature and flame distribution inside the turbine's combustor, optimal fuel schedules can be prepared for each turbine.

■**Combustor Test Rig**

Toshiba uses an advanced test rig to determine reliable performance data for actual-pressure combustion, flame-transition and reliability testing.



■**Life Diagnosis Technologies**

The test rig's advanced technologies and computer-simulation models allow us to simulate component failures and their effects on the turbine's service life. We focus on the performance reliability of "hot parts" such as turbine blades, nozzles, and the combustor to eliminate failures before they occur.

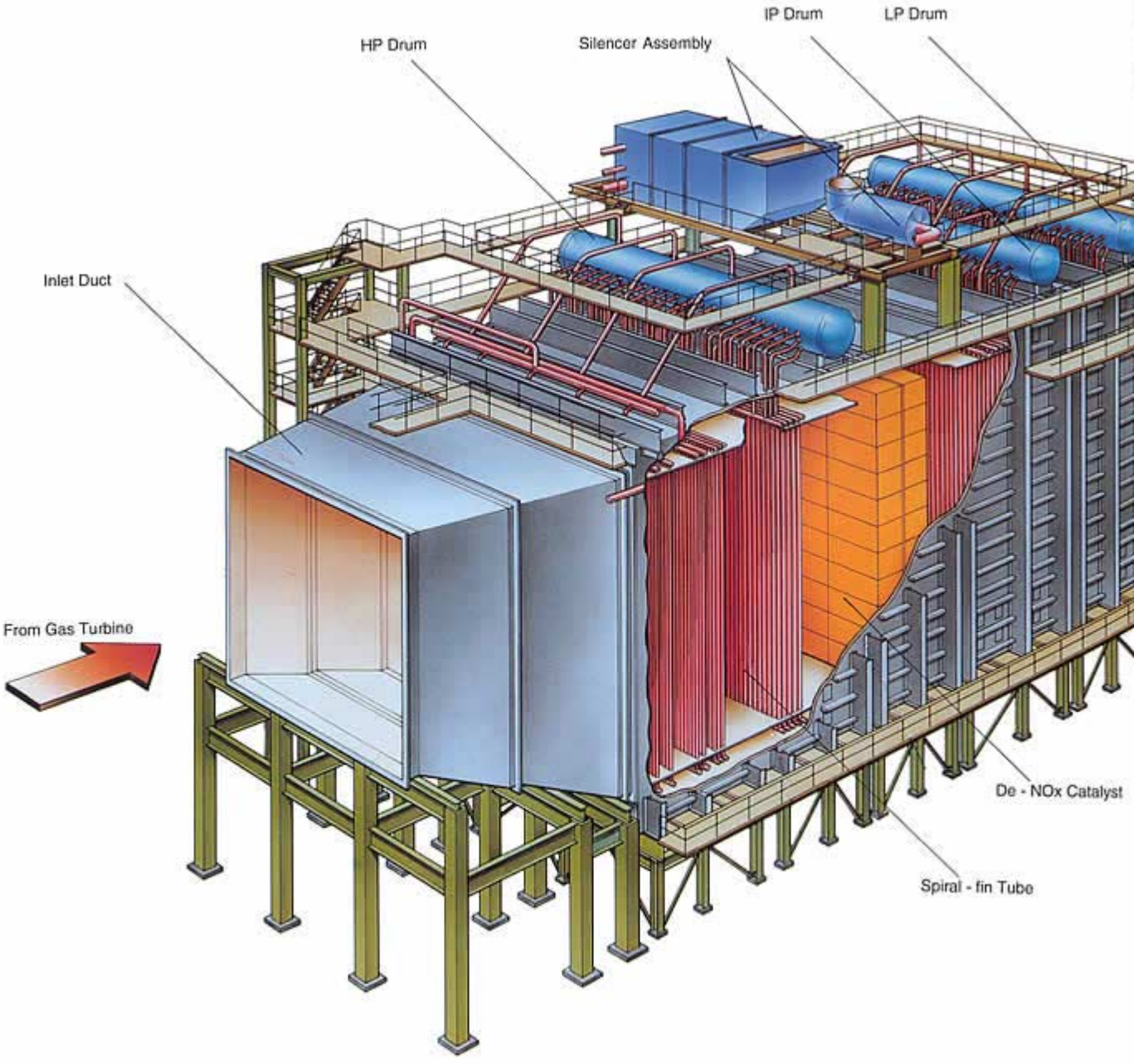
■**Gas Turbine Maintenance Technology**
Toshiba's state-of-the-art maintenance facilities have received full certification from General Electric Co.

HEAT RECOVER STEAM GENERATOR

Recover to utmost gas turbine exhaust heat

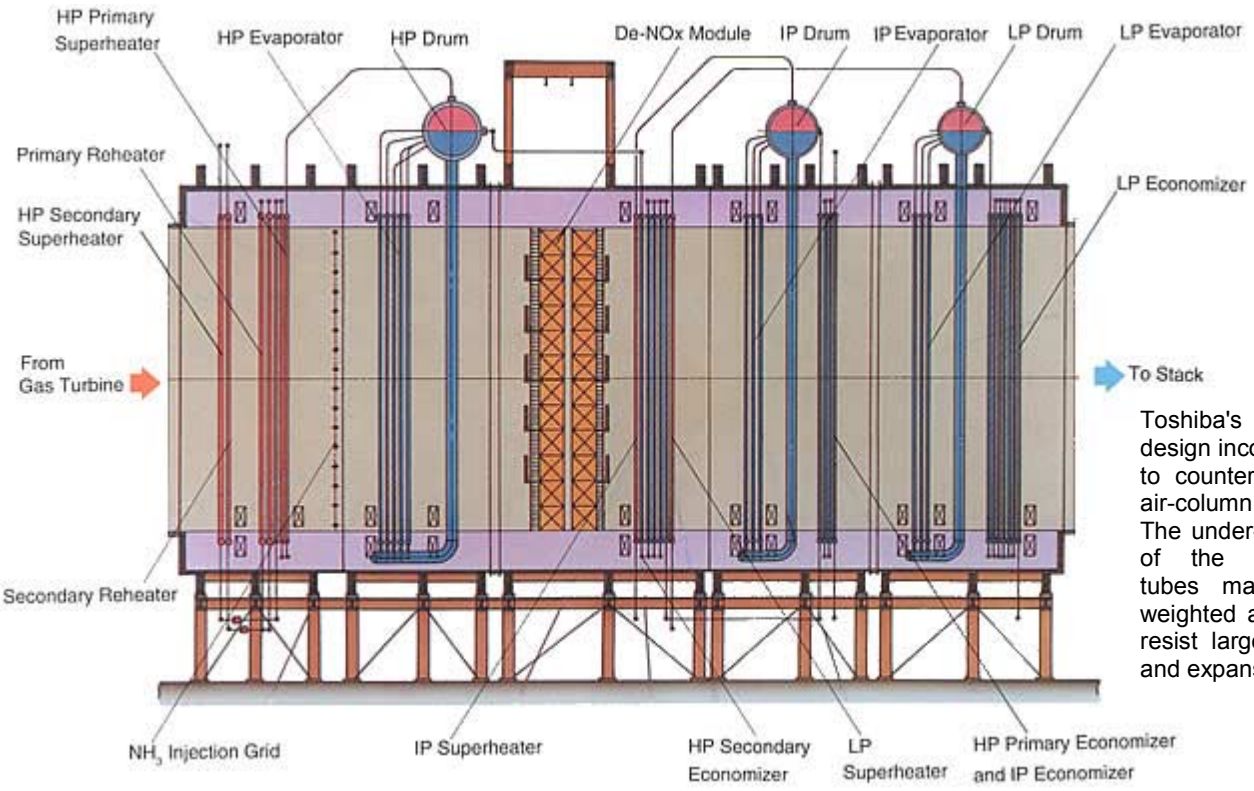
Large Scale Reheat Multi-Pressure Heat Recovery Steam Generator

Toshiba's combined cycle power plant uses a large-scale heat-recovery steam generator (HRSG) that captures heat from a gas turbine's exhaust to create steam. A multi-pressure steam cycle process has been adopted to enable the HRSGs to recover heat efficiently from today's gas turbines with their ever-higher operating temperatures. The result: 47% of fuel energy can be recovered as steam energy.

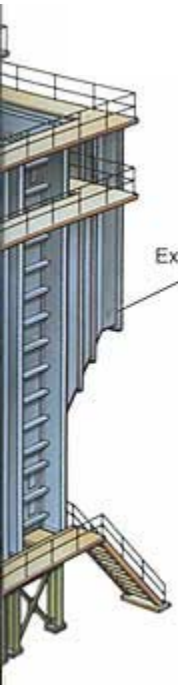


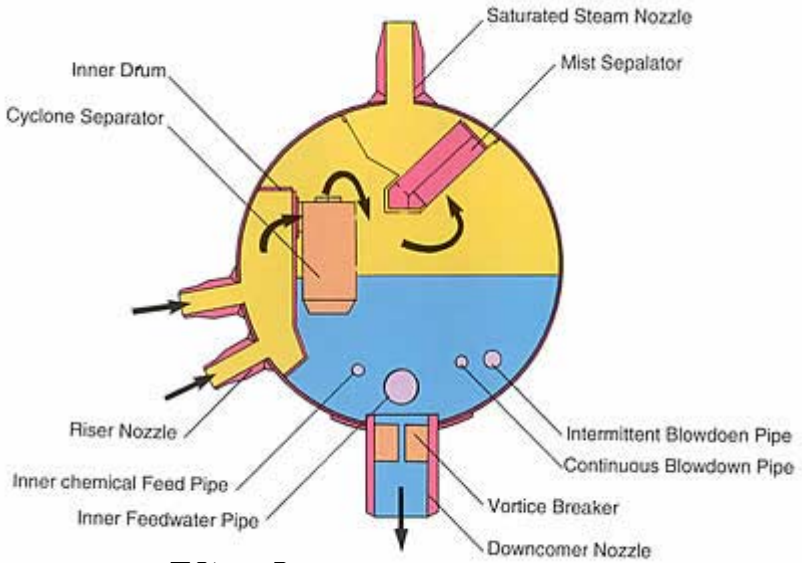
■Heat Recovery Steam Generator

Gas Turbine Type		MS9001FA	MS7001FA
Steam Cycle		Reheated 3 Pressure Cycle	
Steam Condition	HP	106 atg, 542°C, 261t/h	100 atg, 542°C, 176t/h
	IP	27 atg, 360°C, 48t/h	25 atg, 314°C, 35t/h
	LP	4 atg, 262°C, 32t/h	4 atg, 234°C, 25t/h
	Reheat	24 atg, 542°C, 298t/h	22 atg, 540°C, 204t/h



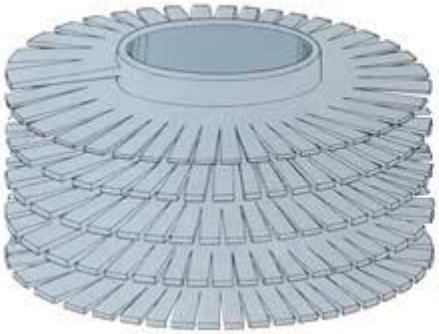
Toshiba's HRSG tube-array design incorporates features to counter fluid-elastic and air-column vibration.
The under-support structure of the heat-transmission tubes makes them light-weighted and therefore can resist larger thermal stress and expansion.



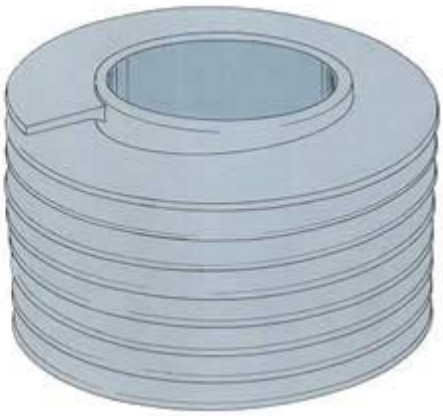


■ **Steam Drum**

Toshiba has decades of experience manufacturing HRSG systems that, owing to their module design, can be easily transported and installed.



■ **Serrated Fin Tube**



■ **Solid Fin Tube**

Toshiba's HRSG units use high-, intermediate-, and low-pressure turbines plus a reheat cycle to recover gas-turbine exhaust heat with maximum efficiency. Another efficiency boost results from use of heat-transfer tubes of high-fin configuration whose compactness reduces unit size and facilitates start and stop times.

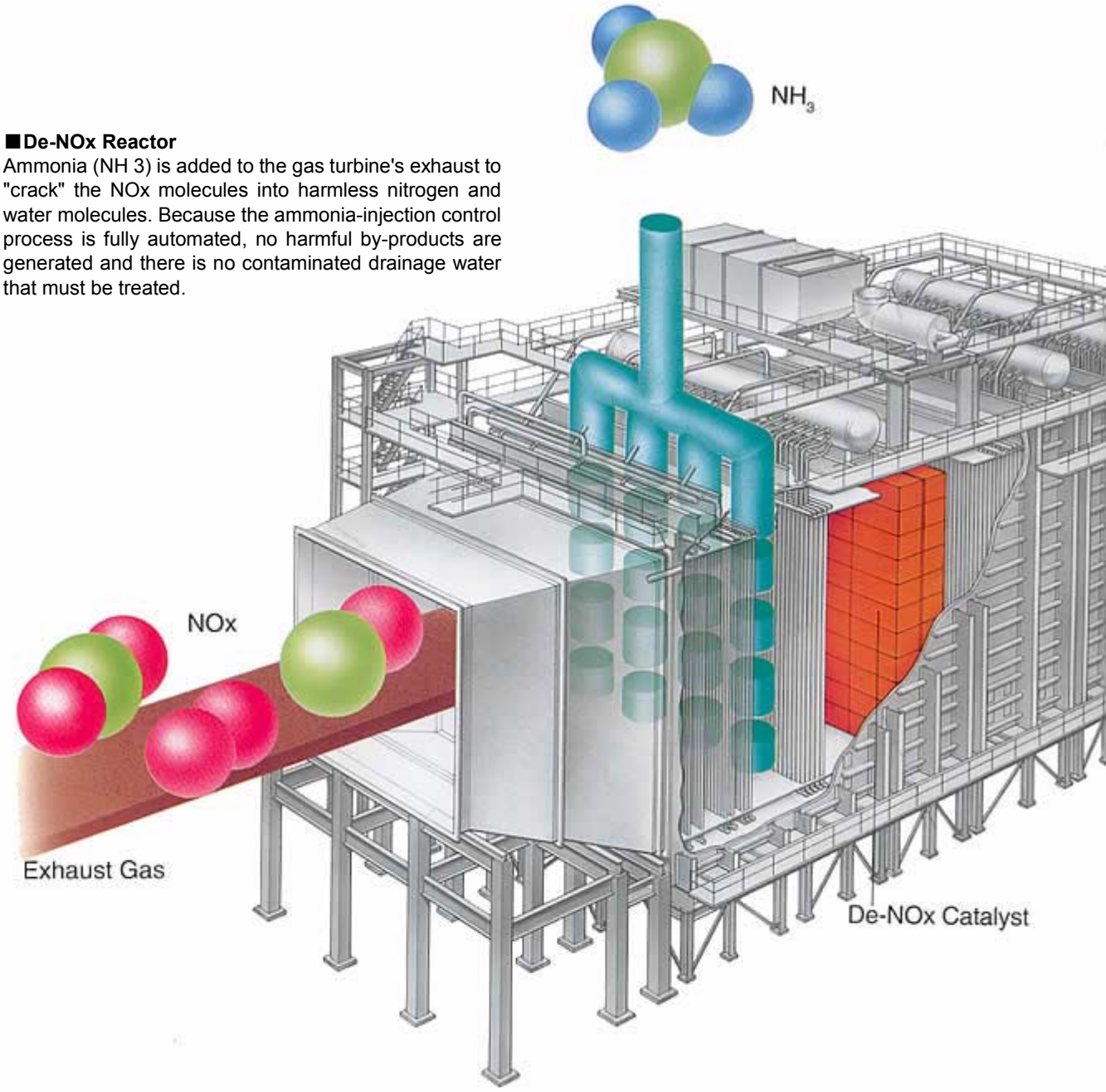
Cracks and Decrease NOx

Dry De-NOx Equipment

In addition to reduced NOx emissions that result from use of Toshiba's dry low-NOx combustor (DLNC), additional dry de-NOx equipment is installed with the combined-cycle plant's HRSG. This "cracking" equipment reduces NOx by separating its molecules into harmless nitrogen and water molecules.

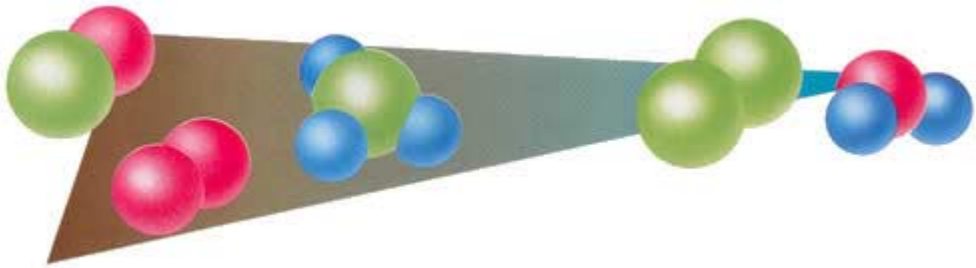
■De-NOx Reactor

Ammonia (NH 3) is added to the gas turbine's exhaust to "crack" the NOx molecules into harmless nitrogen and water molecules. Because the ammonia-injection control process is fully automated, no harmful by-products are generated and there is no contaminated drainage water that must be treated.

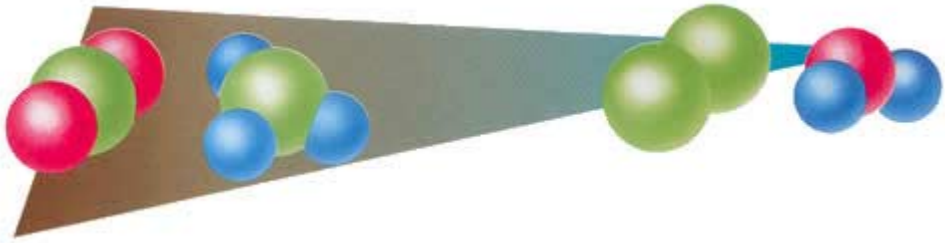


NOx-Cracking Reaction Process

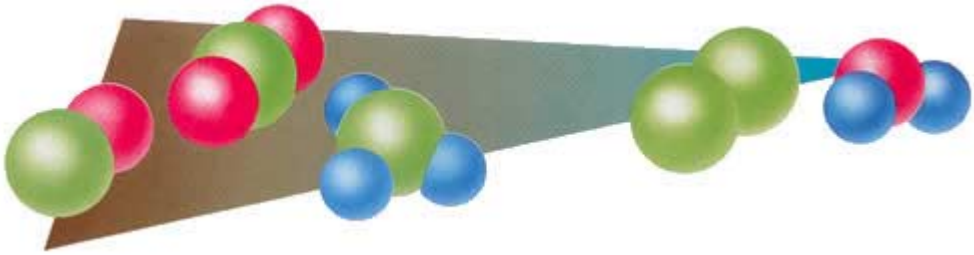
$4NO+O_2+4NH_3=>4N_2+6H_2O$

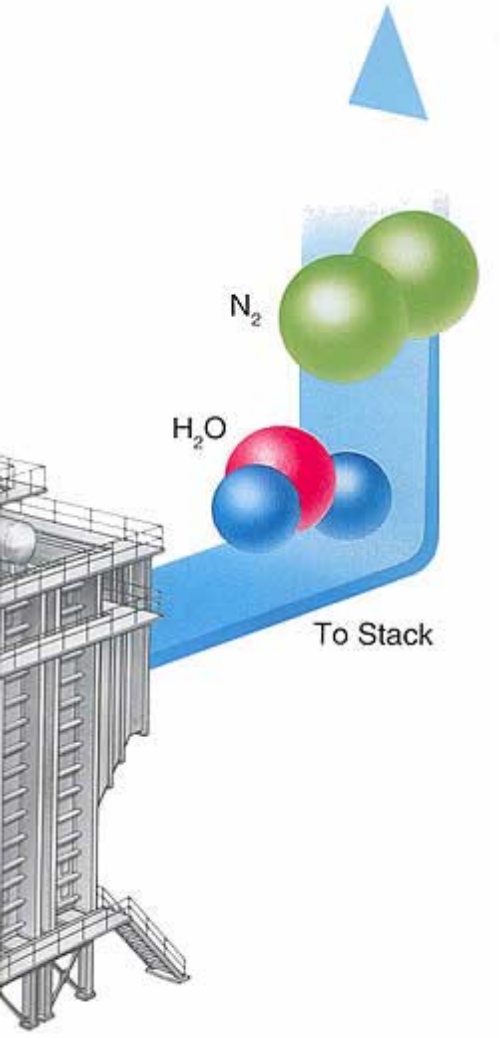


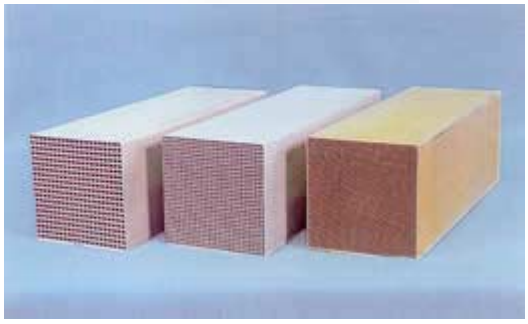
$6NO_2+8NH_3=>7N_2+12H_2O$



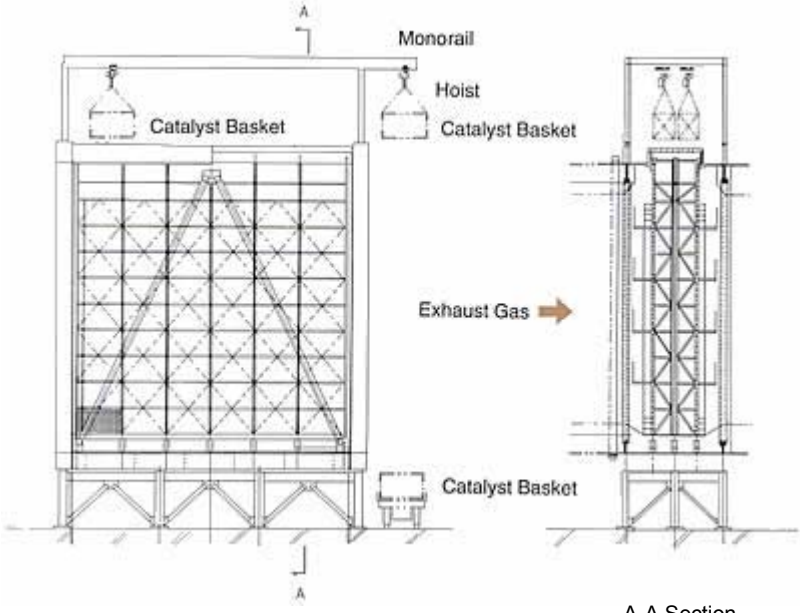
$NO+NO_2+2NH_3=>2N_2+3H_2O$







■ **Catalyst Module**



Front View

A-A Section

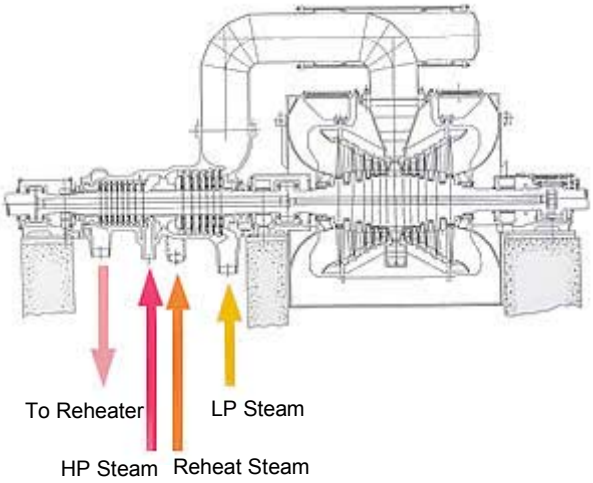
The de-NOx equipment's catalyst layer is comprised of compact, block-shape modules whose ease of installation and replace ability assure stable quality control.

STEAM TURBINE

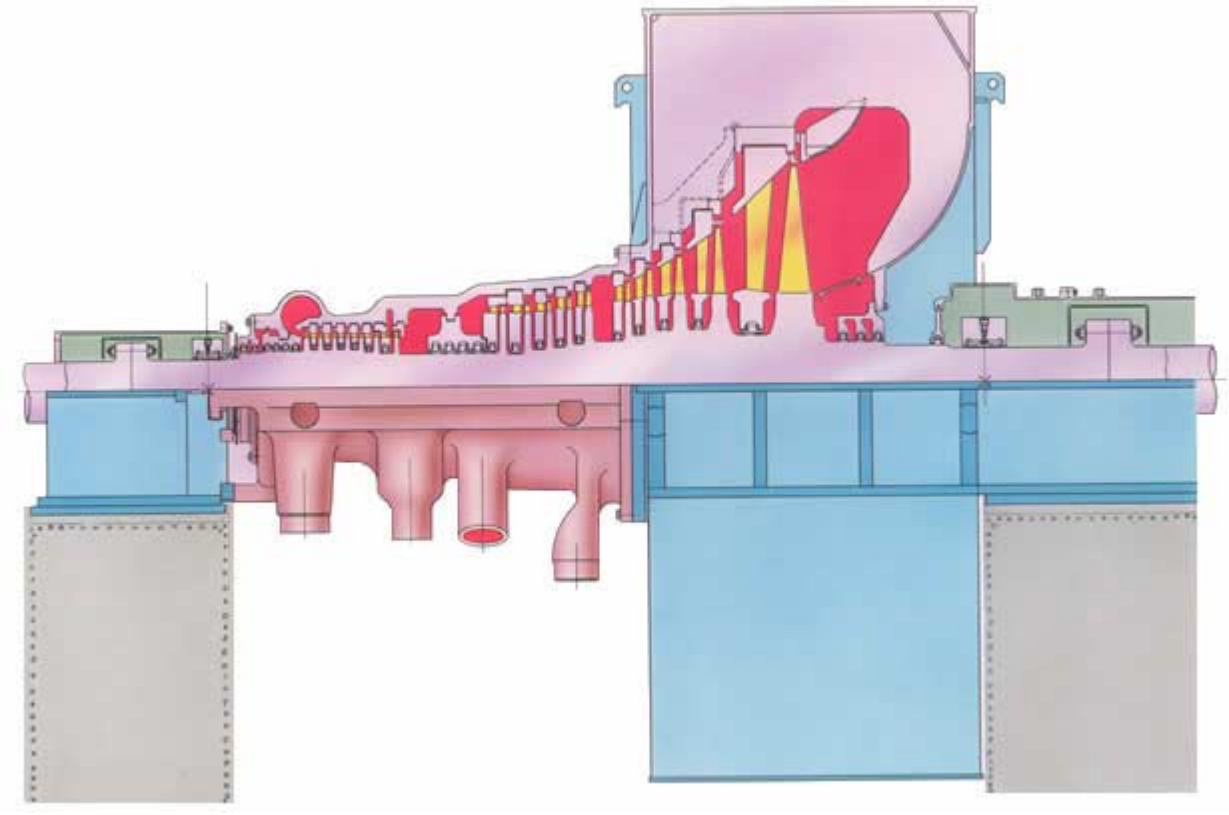
With improved efficiency and superior intermediate-load operability

Steam Turbine

The heat recovery steam generator transfers the gas turbine exhaust heat to its feed water and changes it into steam. The steam's energy is converted efficiently into rotating energy by Toshiba's steam turbine with enhanced efficiency and compact design. Numerous design features to reduce thermal stress enable a high tolerance of frequent quick starts/stops. Superior shaft design based on Toshiba's accumulated decades of experience reduces shaft vibration to a minimum. The unit's high thermal efficiency is achieved across a wide range of loads, and all steam supplies are fed from beneath the turbine to enhance maintenance access.



■**Double-Flow Exhaust Steam Turbine**



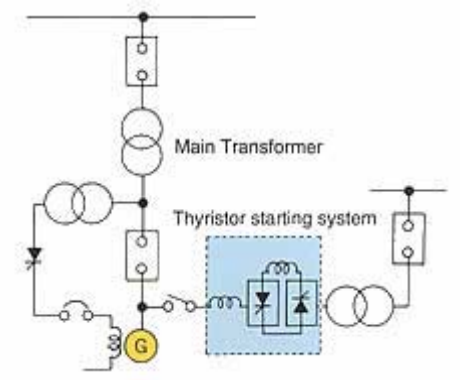
■**Single-Flow Exhaust Steam Turbine**

GENERATOR

Easy Start-up, Stable Operational Output

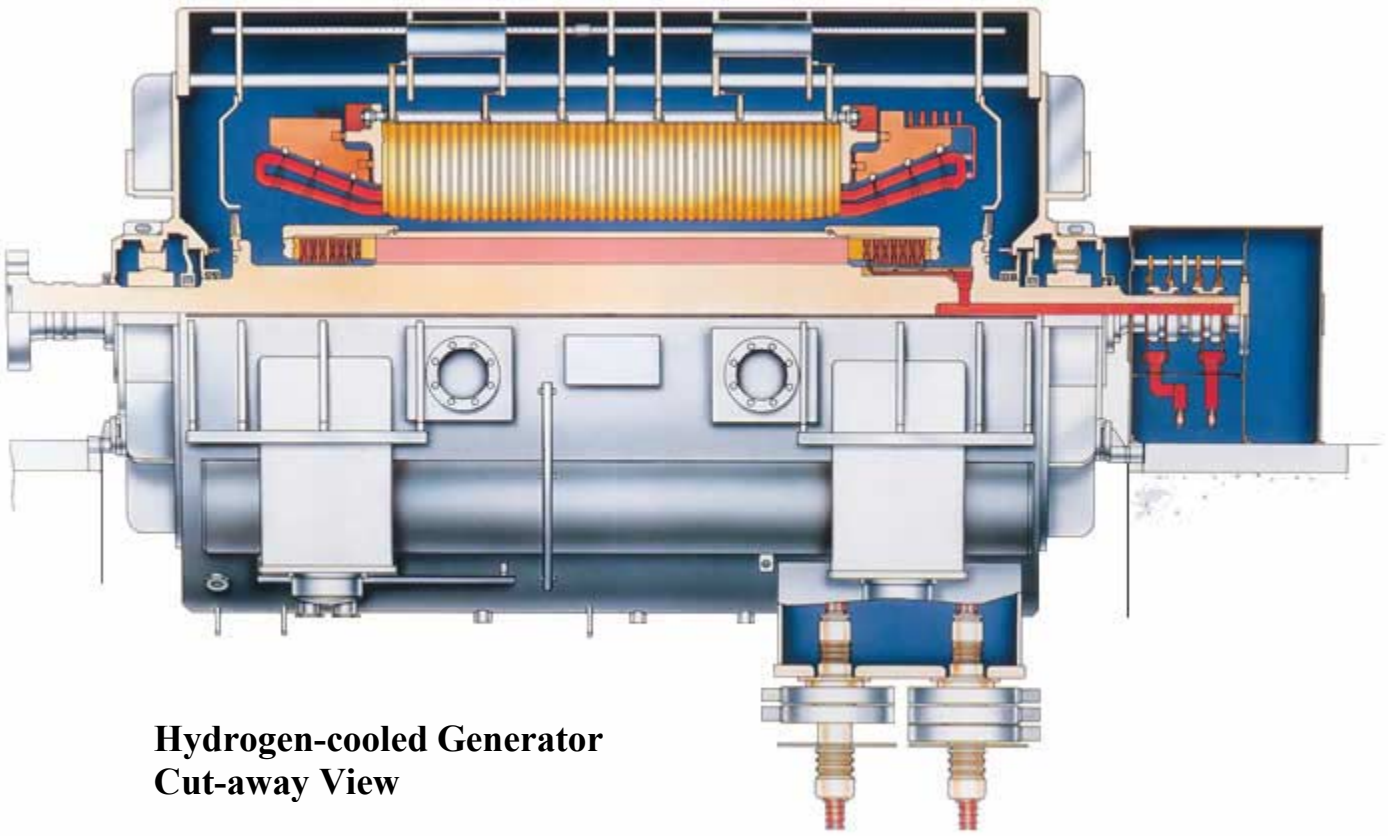
Generator

The generator used with Toshiba's combined-cycle power plant is a water- and hydrogen-cooled (for stator and rotor respectively) unit that efficiently converts rotational energy into electricity. Toshiba's long history as an integrated manufacturer of electronic devices and semiconductors enables it to apply leading-edge digital electronic techniques to the generator's control devices. Reliability of the AVR (Automatic-Voltage-Regulator) and the Thyristor starting system is improved significantly as production and maintenance costs are lowered by replacing customized printed circuit boards with standard memory circuits.



■ **Thyristor Starting Method**

■ **Digital ABR**



Hydrogen-cooled Generator
Cut-away View

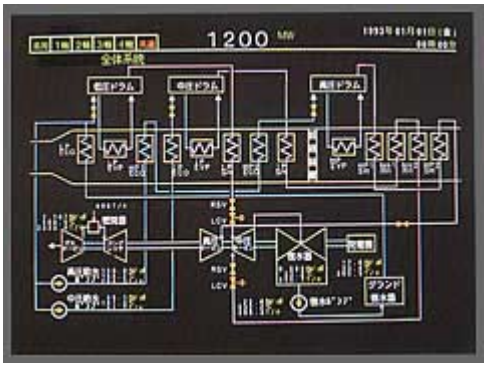
CONTROL

Maximum Control, Minimum Operators

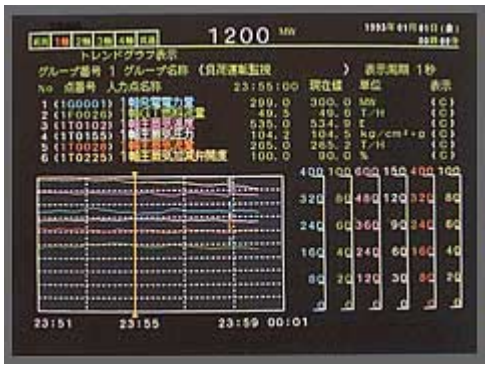
Digital Control System

The increased use of Toshiba's microprocessor-based digital control technologies enables centralized control over plant systems as diverse as the gas turbine, HRSG, steam turbine and the generator. The system uses high-resolution color display terminals and a user-friendly man machine interface that maximizes control while minimizing the number of operators required. Parallel sets of gas and steam turbines can be controlled as if they were a single set.

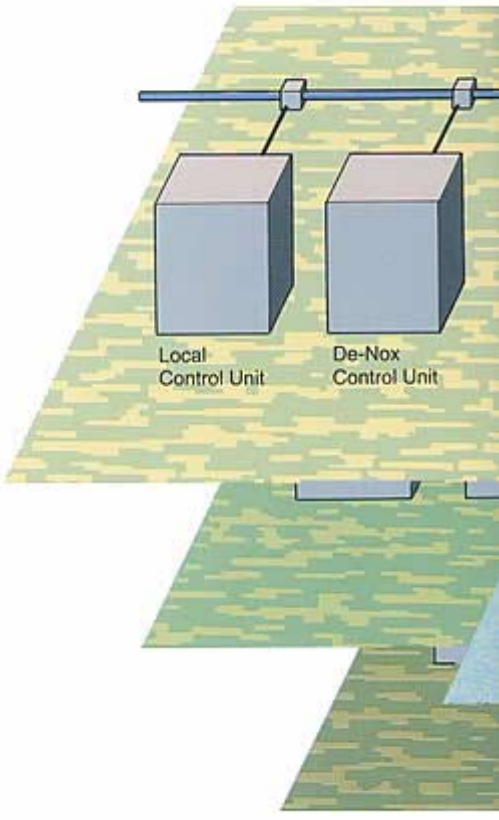
The plant's superior graphics- and text-based, high-resolution terminals assure real-time control over all plant operations for all loads.



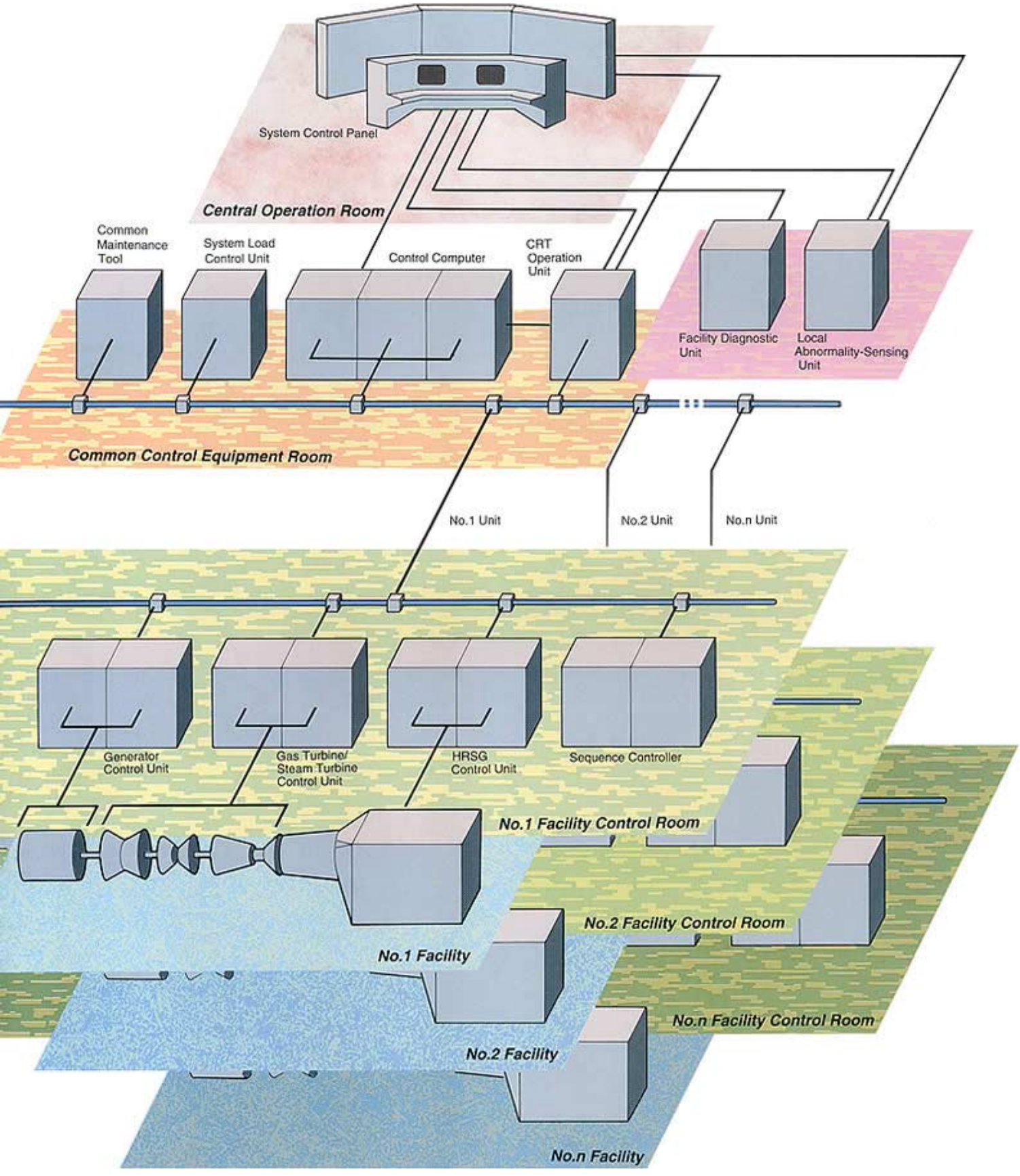
■CRT Graphic Display
(System flow schematic being displayed)



■CRT Graphic Display (Trend graph being displayed)



Combined-Cycle Power Plant Overall Digital-Control System Configuration



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