COMBUSTION / COOLING SYSTEM

Combustion System

The M501/M701 combustion system consists of 16 and 20 can-annular combustors, respectively. The combustion system is dual-fuel (natural gas and no. 2 distillate oil), and the system is designed with provisions for steam or water injection for emissions control and power augmentation. A new premixed burn hybrid combustor is applied to meet the existing and new NOx emission limitations around the world. The hybrid combustor features a premix burner assembly and a diffusion zone which directs a portion of the compressor delivery air directly into the transition piece to enhance flame stability during starting and to maintain desired fuel/air ratio during loading. This unique design allows for full-closed or full-open operation.

Turbo-Cooling System

The cooling system for the turbine section consists of a rotor cooling circuit and four stationary cooling circuits. Rotor cooling air is provided by compressor discharge air extracted from the combustor shell. Direct compressor discharge air is used to cool stages 1 and 2, and compressor bleed air from HP, IP and LP stages provides cooling air to turbine blade ring cavities at stages 2, 3, and 4, respectively. This supply of bleed air also cools the stage 3, 4 vanes and ring segments and provides cooling air for the turbine interstage disc cavities.

GAS TURBINE CONTROL SYSTEM

Control System

Operation of the M501/M701 gas turbine and the combined cycle plant is supported by the Mitsubishi plant control system “DIASYS series”. DIASYS is the latest Mitsubishi Heavy Industries Gas Turbine and total plant control system that unifies State-of-the-Art Info-com technology, high reliability, economy, advanced automation, and easy maintenance.

Typical Gas Turbine Control system Configuration

DOOSAN GAS TURBINES

Gas Turbines have played a leading role in power generation with high performance, reliability, fuel flexibility, low emissions and compactness being a few of their main characteristics. Today’s Gas Turbines stand at an advanced Stage of the Art technology, providing highly continuous operation, covering both base load and peak load operating conditions.

DOOSAN is an approved manufacturer of the M501G, M501F, M701F and M701 heavy-duty Gas Turbine models under a Technology License Agreement with Mitsubishi Heavy Industries, Ltd. (MHI).

GAS TURBINE APPLICATION

DOOSAN GAS TURBINES

DOOSAN GAS TURBINES

GAS TURBINE COMPONENTS

1. Simple Cycle Performance

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Temp.</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
<td>613 600 614 542 592</td>
</tr>
<tr>
<td>Pressure ratio</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
</tr>
<tr>
<td>Turbine Efficiency</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
</tr>
</tbody>
</table>
| Combined Cycle Performance

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure ratio</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
<td>6.0 4.4 5.8 4.4 5.8</td>
</tr>
<tr>
<td>Turbine Efficiency</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
<td>37.0% 37.5% 37.7% 37.5% 37.7%</td>
</tr>
</tbody>
</table>

Model M501f
M501g
M501gaC
M701
M701f

GAS TURBINE COMPONENTS

1. Casings

All engine casings are horizontally split to facilitate maintenance with the rotor in place. Individual lower casings (blade rings) are used for each turbine stationary stage and can be readily replaced or serviced with the rotor in place. Similar blade rings have been added in the compressor seventh stage through last stage.

2. Rotor Assembly

Similar to previous 914/710i series designs, the single rotor is made up of compressor and turbine components. The M501/M701 rotor is a bolted construction supported by two tilting-pad bearings. The thrust bearing is also a tilting-pad design. The compressor rotor compressor is comprised of a number of elements that are splined and bolted together by 12 through-bolts.

3. Compressor

The compressor blade path is designed using a three-dimensional flow-field analysis computer program. Rotor blades are double circular arc designs in the first two stages. Stationary blades, fabricated into two 180 degree-dihedrals per stage for maximum efficiency, are made of the highly efficient iron-nickel cooling system.

4. Turbo

The M501/M701 turbine design maintains moderate aero-dynamic loadings in spite of the increased inlet temperature through the design of a 4-stage turbine. Improvements in aero-dynamic airfoil shapes have been made possible by utilization of a fully three-dimensional flow analysis computer program. The first and second stage casings of the turbine rotor are free-standing. The third and fourth stages have design shrouds.
### GAS TURBINE APPLICATION

**NOTE.** 1. **ALL RATINGS ARE BASED ON ISO CONDITIONS.**

**NOTE.** 1. **PERFORMANCE ARE THE POWER RATINGS AT THE GENERATOR TERMINALS AND ARE BASED ON THE USE OF NATURAL GAS FUEL.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Net Plant Power (kW)</th>
<th>ISO Efficiency</th>
<th>Net plant Power (kW)</th>
<th>ISO Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M501F 1 on 1</td>
<td>285,100</td>
<td>57.1%</td>
<td>182,700</td>
<td>102,400</td>
</tr>
<tr>
<td>M701DA 1 on 1</td>
<td>212,500</td>
<td>51.4%</td>
<td>142,100</td>
<td>70,400</td>
</tr>
<tr>
<td>M701DA 2 on 1</td>
<td>426,600</td>
<td>51.6%</td>
<td>284,200</td>
<td>142,400</td>
</tr>
<tr>
<td>M701DA 3 on 1</td>
<td>645,000</td>
<td>51.8%</td>
<td>426,300</td>
<td>218,700</td>
</tr>
<tr>
<td>M501F 2 on 1</td>
<td>835,600</td>
<td>59.2%</td>
<td>547,600</td>
<td>288,000</td>
</tr>
<tr>
<td>M501GAC 1 on 1</td>
<td>404,000</td>
<td>59.2%</td>
<td>269,000</td>
<td>135,000</td>
</tr>
<tr>
<td>M501G 1 on 1</td>
<td>398,900</td>
<td>58.4%</td>
<td>264,400</td>
<td>134,500</td>
</tr>
<tr>
<td>M501GAC 2 on 1</td>
<td>810,700</td>
<td>59.4%</td>
<td>538,000</td>
<td>272,700</td>
</tr>
</tbody>
</table>

### DOOSAN GAS TURBINES

**M701 SERIES**

**M701F**
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...

**M501 SERIES**
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...

**MULTI-STAGE axial-flow AIR COMPRESSOR COMPONENTS**
- Individual first stage vanes removable with cylinder cover in place.
- Cooled by air cooler with cooling air filtered.
- Rotor assembly in place.
- Cylindrical hub and spoke design.
- Four-stage reaction type turbine features.
- Turbine includes four-stage reaction type turbine structure.
- Four-stage reaction type turbine components.
- Four-stage reaction type turbine features.
- Four-stage reaction type turbine includes.
- Four-stage reaction type turbine includes.
- Four-stage reaction type turbine includes.

**M501GAC**
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...

**M501G**
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...
- 4...4...4...4...4...

### GAS TURBINE COMPONENTS

**Casings**
- All engine casings are horizontally split to facilitate maintenance of the rotor in place. Individual inner casings blade rings are used for each turbine stationary stage and can be readily replaced or serviced with the rotor in place. Similar blade rings have been added in the compressor seventh stage through fifth stage.
- **Rotor Assembly**
- Similar to previous 501/701 series designs, the single rotor is made up of compressor and turbine components. The M501/M701 rotor is a bolted construction supported by two tilting pad bearings. The tilting bearing is also a tilting pad design. The compressor rotor consists of a number of components that are bolted together by 12 through bolts.
- **Compressor**
- The compressor blade path is designed using three-dimensional flow-field analysis computer programs. Rotor blades are double circular arc designs in the first four stages. Stationary blading, fabricated into two 180-degree diaphragms per stage by expansion, maintains the highly efficient inner-bald casing system.
- **Turbine**
- The M501/M701 turbine design maintains moderate aerodynamic loadings in spite of the increased inlet temperature through the design of a 4-stage turbine. Improvements in aero-dynamic airfoil shapes have been made possible by application of a multi three-dimensional flow analysis computer program. The first and second stage vanes on the turbine rotor are airfoil shaped. The third and fourth stages have designed shrouds.
Gas Turbine Application

**Simple Cycle Performance**

<table>
<thead>
<tr>
<th>Model</th>
<th>No. of Stage</th>
<th>Combined Cycle Performance</th>
<th>Simple Cycle Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>M501G</td>
<td>3</td>
<td>603</td>
<td>416</td>
</tr>
<tr>
<td>M501F</td>
<td>2</td>
<td>545</td>
<td>377</td>
</tr>
<tr>
<td>M501DA</td>
<td>1</td>
<td>212</td>
<td>627</td>
</tr>
<tr>
<td>M701F</td>
<td>1</td>
<td>273</td>
<td>613</td>
</tr>
<tr>
<td>M701DA</td>
<td>2</td>
<td>546</td>
<td>714</td>
</tr>
<tr>
<td>M701</td>
<td>1</td>
<td>185</td>
<td>267</td>
</tr>
</tbody>
</table>

**Gas Turbine Components**

- Casings
- Rotor Assembly
- Compressor
- Turbine

**DOOSAN Gas Turbines**

**Gas Turbine Components**

- All engine casings are horizontally split to facilitate maintenance with the rotor in place. Individual lower casings (blade rings) are used for each turbine stationary stage and can be readily replaced or serviced with the rotor in place. Similar blade rings have been added in the compressor seventh stage through first stage.

**Rotation System**

Similar to previous 501/701 series designs, the single rotor is made up of compressor and turbine components. The M501/M701 rotor is a bolted construction supported by two tilting-pad bearings. The thrust bearing is also a tilting pad design. The compressor rotor comprises a number of elements that are splashed and bolted together by 12 through bolts.

**Compressor**

The compressor blade path is designed using a three-dimensional flow-field analysis computer program. Rotor blades are double circular air designs in the first four stages. Stationary blades, fabricating into two 180 degrees-diaphragm per stage hyperbolic mainstream, maintains the highly efficient frame sheet cooling system.

**Turbine**

The M501/M701 turbine design maintains moderate pseudo-linear dynamics in spite of the increased inlet temperature through the design of a 6-stage turbine. Improvements in zero-dynamic airdiffuser shapes have been made possible by utilization of a fully three-dimensional flow analysis computer program. The first and second stage cover on the turbine rotor are free-standing. The third and fourth stages have design shrouds.
COMBUSTION / COOLING SYSTEM

1. Combustion System

The M501/M701 combustion system consists of 16 and 20 can-annular combustors, respectively. The combustion system is designed for both fired (natural gas and no. 2 distillate oil) and wet on wet firing for emissions control and power augmentation. A new pre-mixed burn hybrid combustor is applied to meet the existing and new NOx emission limitations around the world. The hybrid combustor features a single stage burner assembly, and a mixture valve which directs a portion of the compressed air directly into the transition plane to enhance flame stability during starting and to maintain desired fuel/air ratio during loading. This unique mixing system then is modulated to full closed at full load.

2. Turbine Cooling System

The cooling system for the turbine section consists of a rotor cooling circuit and four stationary cooling circuits. Rotor cooling air is provided by compressor discharge air extracted from the combustion chamber. Direct compressor discharge air is used to cool the stage 1 vanes. Compressor bleed air from HP, IP and LP stages provides cooling air to turbine blade ring cavities at stages 2, 3, and 4 respectively. This supply of bleed air also cools the stage 2, 3, and 4 vane and ring segments and provides cooling air for the turbine interstage disc cavities.

GAS TURBINE CONTROL SYSTEM

1. Control System

Operation of the M501/M701 gas turbine and the combined cycle plant is supported by the Mitsubishi plant control system “DIASYS series”. DIASYS netmation is the latest Mitsubishi Heavy Industries Gas Turbine and total plant control system that unites State-of-the-Art Info-com technology, MHI’s rich experience as a plant manufacturer, and control technology for maximum satisfaction of customer demands such as high reliability, economy, advanced automation, and easy maintenance.

2. Typical Gas Turbine Control system Configuration

- Site OPS (Operator Station): Human F/I for monitoring & operation
  - Graphic, Trend, Alarm
  - Control Plate
  - Control Logic Monitoring
- MpS (Multiple process Station): I/O processing to the field
  - Control逻辑 Execution
  - Short term data preservation
- browser OPS: Internet based CRT operation
  - Graphic, Trend, Alarm
  - Control Plate
  - Control Logic Monitoring
- eMS (Engine & Maintainance Station): Maintenance of whole system by DIASYS-IDOL++
  - System configuration
  - HML setting
  - Graphic creation
  - Object data base modification
  - Drawing management
- aCS (Accessory Station): Data store & management, and Web server, Gateway
  - Reports, Trip Log, Event Log, Operator Action Log, Flight Recorder


Gas Turbines have played a leading role in power generation with high performance, reliability, fuel flexibility, low emissions and compactness being a few of their main characteristics. Today’s Gas Turbines stand on an advanced Standard of the Art technology, providing highly continuous operation, covering both base load and peak load operating conditions.
COMBUSTION / COOLING SYSTEM

Combustion System

The M501/M701 combustion system consists of 16 and 20 can-annular combustors, respectively. The combustion system has dual fuel (natural gas and no. 2 distillate oil) capability. A preburner is applied to the existing and new NOx emission limitations around the world. The hybrid combustor features a low-range burner assembly and a high-stage section which directs a portion of the compressor delivery air directly into the transition piece to enhance flame stability during starting and to maintain desired fuel-air ratios during loading. This unique working system is then modulated to full-load at full load.

Gas Turbine Control System

Control System

Operation of the M501/M701 gas turbine and the combined cycle plant is supported by the Mitsubishi Plant Control System “DIASYS” series. DIASYS netmation is the latest Mitsubishi Heavy Industries Gas Turbine and total plant control system that unites State-of-the-Art Info-com technology, MHI’s rich experience as a plant manufacturer, and control technology for maximum satisfaction of customer demands such as high reliability, economy, advanced automation, and easy maintenance.

Typical Gas Turbine Control system Configuration

GAS TURBINE CONTROL SYSTEM

Control System

- Operation of the M501/M701 gas turbine and the combined cycle plant is supported by the Mitsubishi Plant Control System “DIASYS” series.
- DIASYS netmation is the latest Mitsubishi Heavy Industries Gas Turbine and total plant control system that unites State-of-the-Art Info-com technology, MHI’s rich experience as a plant manufacturer, and control technology for maximum satisfaction of customer demands such as high reliability, economy, advanced automation, and easy maintenance.

Turbo Cooling System

The cooling system for the turbine section consists of a rotor cooling circuit and four stationary cooling circuits. Rotor cooling air is provided by compressor discharge air extracted from the combustor shell. Direct compressor discharge air is used to cool the stage 1, 2, 3, and 4 stages, respectively. This supply of air also cools the stage 5, 6, and 7 stages. Compressor bleed air from HP stage provides cooling air to turbine blade cooling and stage 7, 8, and 9 stages, respectively. This supply of bleed air also cools the stage 5, 6, and 7 stages.