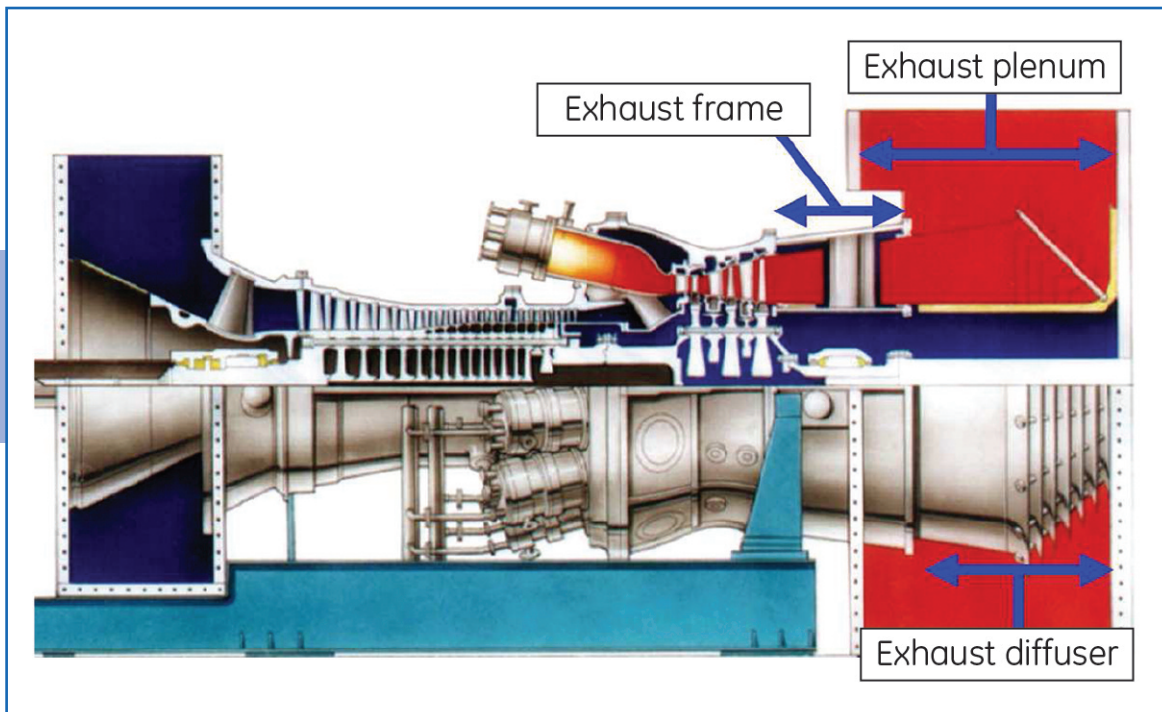


Exhaust System Upgrade Options for Heavy Duty Gas Turbines

GER-4610 (3/2012)



Timothy Ginter
Energy Services



Note: All values in this GER are approximate and subject to contractual terms.

©2012, General Electric Company. All rights reserved.

Contents:

Abstract	1
Configuration Overview	2
Site Inspections	5
Available Exhaust Upgrades	8
Frames, Aft Diffusers, Cooling, and Blowers	12
FS1U – Exhaust Frame Assembly Upgrades (51A-R, 52A-C, 61A/B)	13
FS1W – Exhaust Frame Assembly and Cooling Upgrades (71A-EA, 91B/E)	14
FS2D – Exhaust Frame Blower Upgrade (71E/EA, 91E)	21
FW3N – Exhaust Diffuser Upgrades (6FA, 7F-FA+, 9F/FA)	22
Plenums and Flex Seals	22
FD4H – Exhaust Plenum Upgrades (32A-K, 51A-R, 52A-C, 61A/B, 71A-EA, 91B/E, 6FA, 7F-FA+, 9F/FA)	23
FD4H – Exhaust Flex Seal Upgrades (61A/B, 71A-EA, 91B/E)	29
FD4H – Engineering Site Visits	29
Ductwork, Stacks, and Silencers	30
FD6G-K and FD4H – Exhaust Duct, Stack, and Silencer Upgrades (32A-K, 51A-R, 52A-C, 61A/B, 71A-EA, 91B/E, 6FA, 7F-FA+, 9F/FA)	30
Summary	32
References	33
List of Figures	34

Exhaust System Upgrade Options for Heavy Duty Gas Turbines

Abstract

Since their introduction in 1978, advances in materials, cooling, and design have allowed GE gas turbines to operate with increased firing temperatures and airflows. These advances have resulted in elevated exhaust temperatures and increased aero loading that affect the strength of exhaust systems during turbine startup, operation, and shut down. Also, a large quantity of peaker units with a high number of start/stop cycles are now operating, and they must deal with high transient thermal stresses and aero loading that come with turbine uprates. This generates raised fatigue stress that can significantly increase cracking in exhaust systems.

In today's deregulated market, owners/operators of gas turbines need to enhance the reliability of their assets. In many cases it can prove economically viable to modernize and upgrade their installed fleet of gas turbines. As power plant equipment ages and operation and maintenance (O&M) budgets become more constrained, the daily challenges of profitably operating a power plant can increase significantly. Upgraded exhaust systems can make good investments, with many having exhibited prompt payback for operators. Each owner of a GE heavy duty gas turbine should evaluate the economics of exhaust upgrades for their specific application.

This document discusses the Corrosion and Heat Resistant Original Equipment Manufacturer (CHROEM*) improved exhaust systems offered by GE. (See Figure 1.) The CHROEM exhaust system applies the latest GE technology to extend life and provide economic benefits through increased exhaust system reliability and maintainability. GE's CHROEM product line offers the application of advanced technologies that reflect the experience and expertise of dedicated service teams aimed at enhancing profitability, productivity, and availability. CHROEM components interface smoothly with downstream ductwork, and can be readily installed on older model turbines.

An electronic copy of this document currently is available gratis to GE customers at the web link: http://www.ge-energy.com/prod_serv/products/tech_docs/en/all_gers.htm

The engineers at GE that design CHROEM components are able to leverage their experience with GE's vast fleet and employ advanced design analytical tools that increase plant availability and reduce productivity losses due to underperforming or failing exhaust equipment. These efforts can provide the following reduced maintenance costs and improved performance.

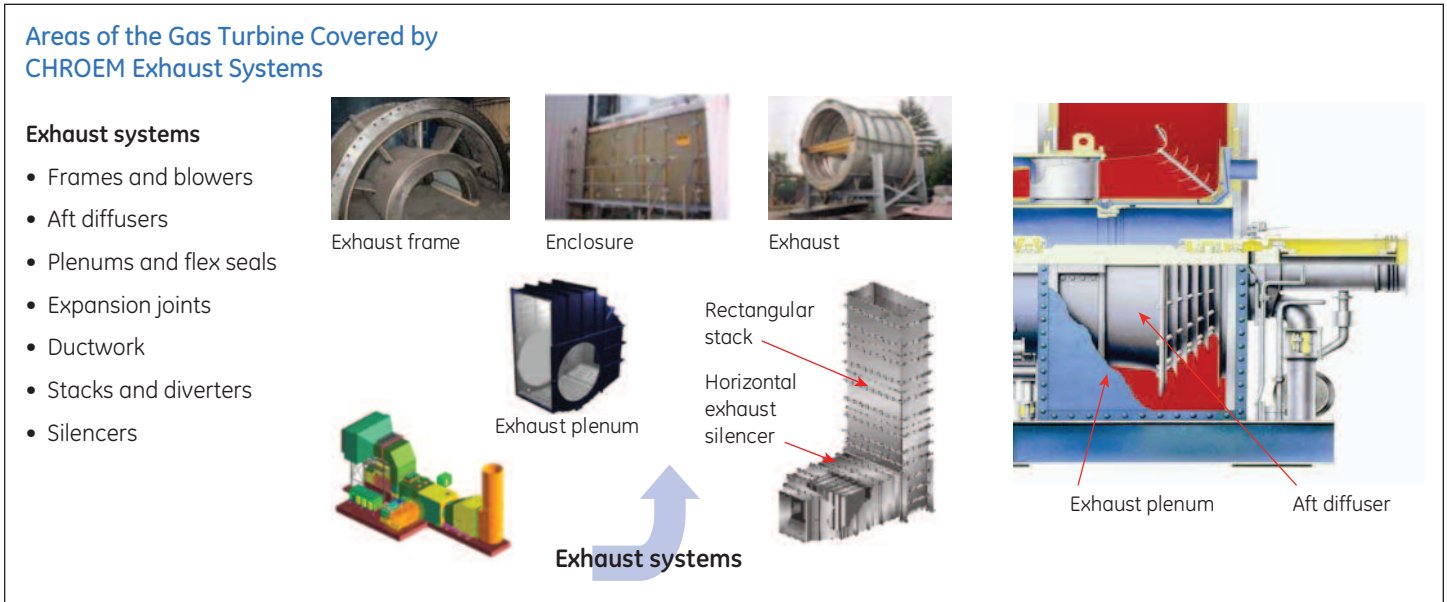


Figure 1. Corrosion and Heat Resistant Original Equipment Manufacturer (CHROEM) improved exhaust systems offered by GE.

Improved Thermal and Acoustic Performance

- Higher firing temperatures are allowed
- Design features improve availability
- Turbine and load compartment temperatures are reduced due to reduced hot gas path leakage from exhaust frame assembly
- External skin temperatures are reduced
- Compartment ventilation efficiencies are improved
- Operating personnel safety is enhanced
- Instrumentation reliability is restored to original levels
- The re-designed flex seal insulating collar has reduced radiation heat penetration
- Acoustic emission is reduced due to better insulation
- Aft wall flex seal offset is field adjustable, ensuring superior performance of the flex seal

Reduced Maintenance Costs

- Proactive inspections by the CHROEM team can help identify emerging thermal performance issues before they significantly erode plant profitability
- Provided gratis to customers, the Power Answer Center (PAC) at GE aids in system warranty and reduced component maintenance
- Lower aft and forward walls with a vertical split allow installation of plenum without removal of the rotor or exhaust frame diffuser
- Reduced cracking in the aft diffuser leads to reduced repairs
- The detachable forward wall cowl joint allows for upper-half casing removal without removing the cowl
- Flex seal gaskets are made of stainless steel, enabling longer intervals between repairs
- The aft wall mounting ring welding detail was re-designed to reduce mechanical stress and less cracking
- Utilization of special alloy double nut allows for removal of cowl, upper forward wall, and expansion joint during maintenance inspections—without the need for stud replacement
- Radiation tube immersion lengths are field adjustable

Configuration Overview

The MLI A042 and 1625 exhaust system is that portion of the turbine in which the exhaust gases are directed to an HRSG, or a bypass stack, or a simple cycle stack. *Figures 2 to 5* identify the general nomenclature as it applies to the fleets, including the 9E.

This GER document covers operation and maintenance recommendations for the following internally insulated components:

- MLI A042 (Exhaust Diffuser Duct) for 6FA, 7F, 7FA, 7FA+, 9F, and 9FA units (**F-Class**)
- MLI A042 (Exhaust Wing, Cowl, Expansion Joint) 6B, 7B, 7C, 7E, 7EA, 9B, and 9E units (**E-Class**)
- MLI 1625 (Exhaust Plenum) for 6B, 7B, 7C, 7E, 7EA, 9B, and 9E units (**E-Class**)
- MLI 1625 (Exhaust Plenum) for 51 and 52 units (**E-Class**)

This GER document also covers operation and maintenance recommendations for the following components:

- MLI 0706 (Exhaust Frame and Aft Diffuser) for 6FA, 7F, 7FA, 7FA+, 9F, and 9FA units (F-Class)
- MLI 0706 (Exhaust Frame and Aft Diffuser) 6B, 7B, 7C, 7E, 7EA, 9B, and 9E units (E-Class)

The **standard components** of the MLI A042 for **F-Class** include the forward flex seal expansion joint, the internally insulated conical diffuser duct, outlet aft expansion joint, and support steel bolted to the foundation. (See *Figure 3*.)

The **standard components** of the MLI A042 for **E-Class** (except 51 and 52) include wing, cowl, and the outlet expansion joint. The standard components of the MLI 1625 for **E-Class** include the base plenum and the forward and aft flex seal expansion joints. (See *Figure 4*.)

The **standard components** of the MLI 1625 for 51 and 52 frames in **E-Class** include the base plenum, side panel(s), and/or roof panel. (See *Figure 5*.)

The **standard components** of MLI 0706 for **E-Class** and **F-Class** include the exhaust frame with its forward diffuser and an aft radial diffuser that is bolted on the exhaust frame. The entire assembly is referred to as the Exhaust Frame Assembly.

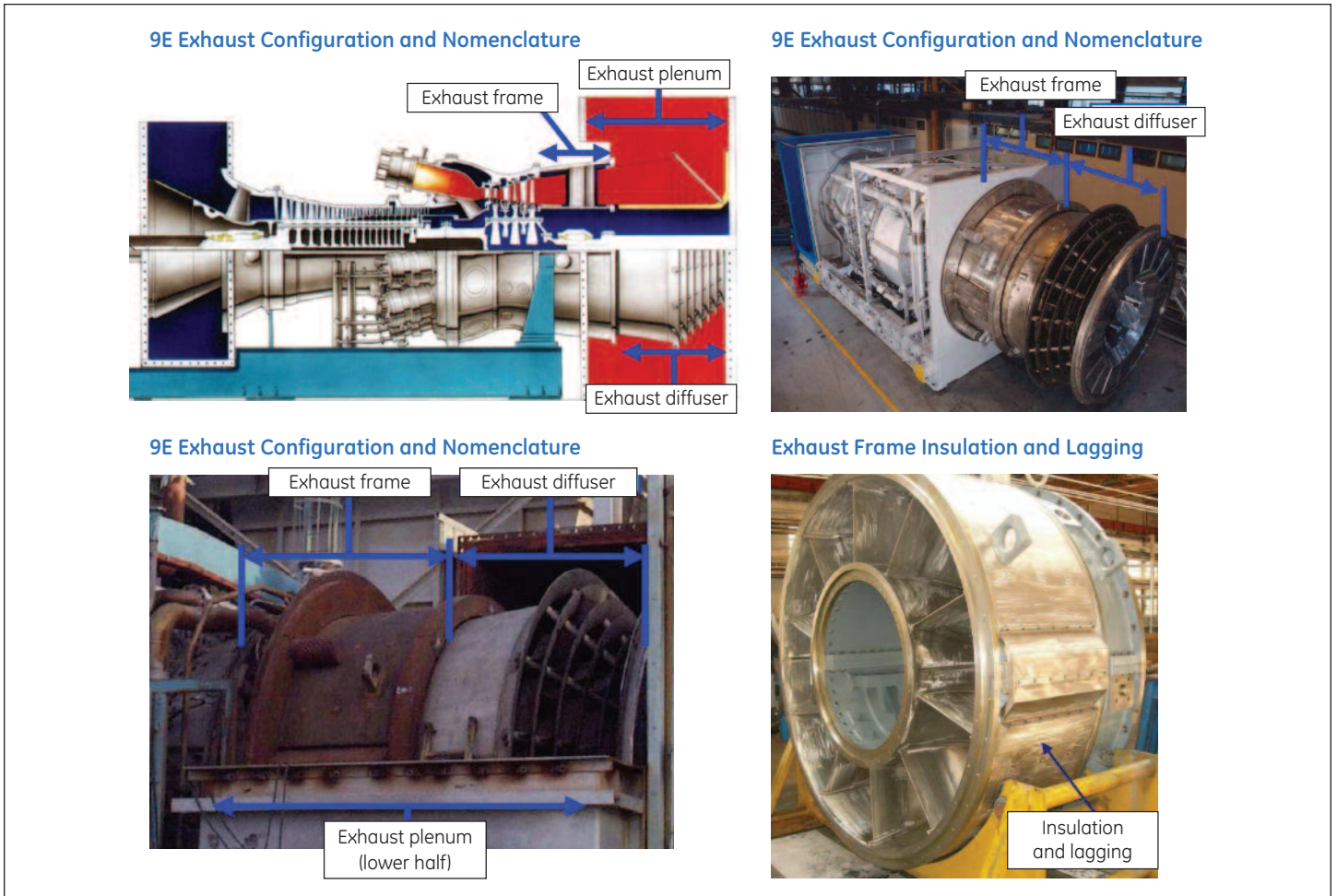


Figure 2. General nomenclature for exhaust components (Frame 9E shown only as an example).

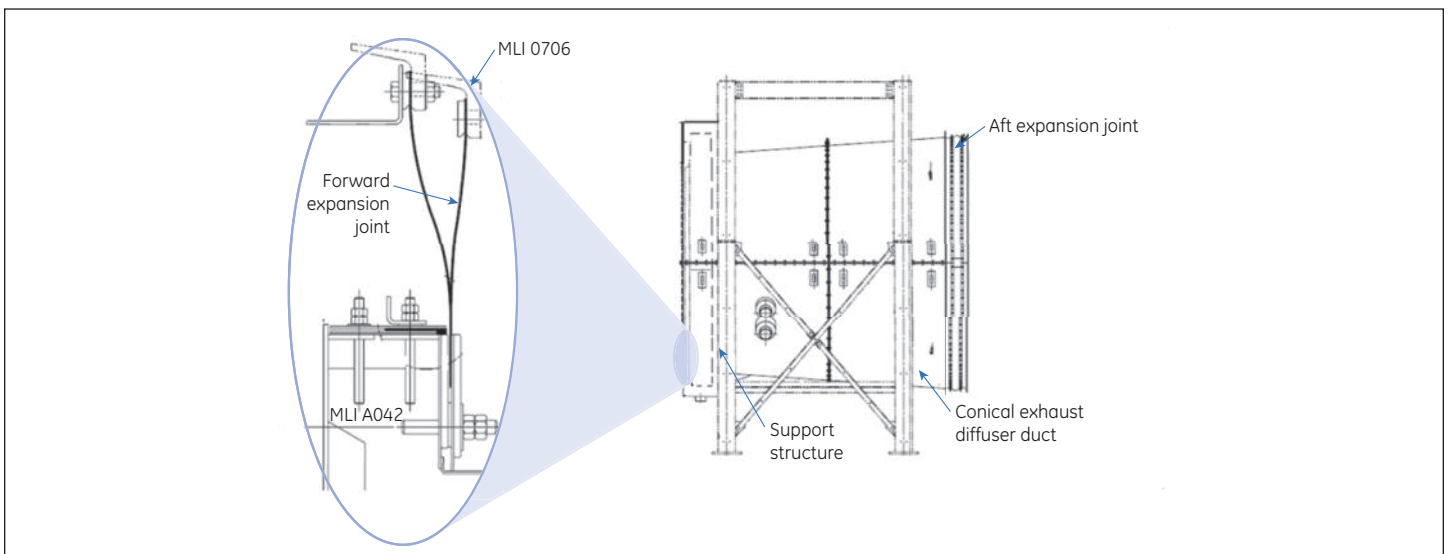


Figure 3. Typical F-Class MLI A042 arrangement.

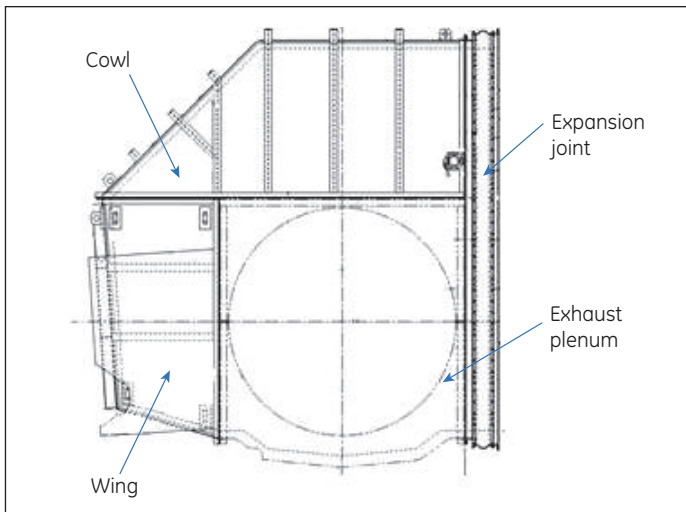


Figure 4. Typical E-Class MLI A042 and 1625 arrangement shown in right hand configuration.

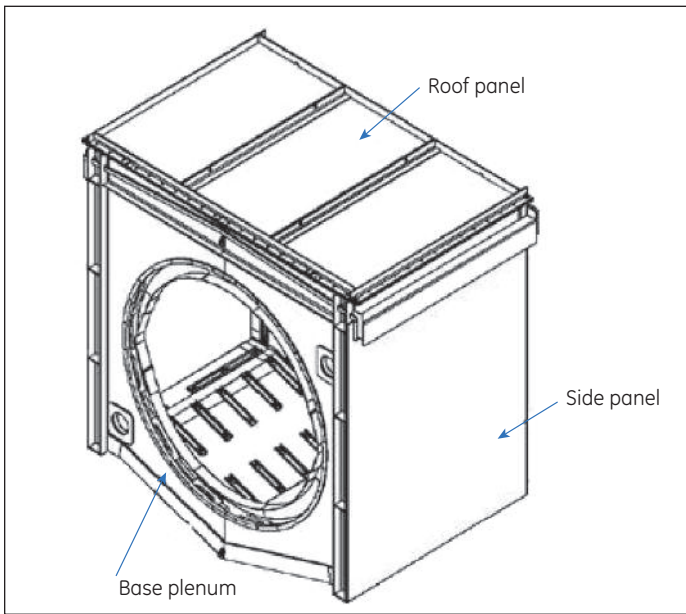


Figure 5. Typical 51 and 52 unit MLI 1625 arrangement.

F-Class Forward Expansion Joint (Flex Seal)

The forward expansion joint for F-Class turbines is composed of overlapping INCO 718 plates bolted to the turbine aft flange (MLI 0706) and clamped-in guide plates mounted on the MLI A042 inlet. The overlapping plates form a flexible gas seal. This is a “hot-to-hot” design that uses flex plates externally insulated (MLI A151) in the field with a layer of insulation, and a sheet metal weather shield that ties into the gas turbine external insulation package.

F-Class Aft Expansion Joint

The aft expansion joint for F-Class turbines is located at the end of the exhaust diffuser duct. This is a “cold-to-cold” design that uses a fabric belt that is fully insulated from the hot exhaust gases by field-installed liner plates.

F-Class Conical Exhaust Diffuser Duct (MLI A042)

The diffuser duct for F-Class turbines contains a drain system to accommodate off-line water wash and false starts with liquid fuel. The drain connects with MLI 0976. The compressor bleed lines MLI 0909 are connected to the diffuser duct and allow compressor bleed air to flow into the duct during startup and shutdown. The diffuser duct is internally insulated and is supported by four centerline mounts and positioned by two keys at bottom dead center. The diffuser duct gradually diffuses the exhaust flow for maximum pressure recovery of the exhaust flow, thereby enhancing the performance of the gas turbine. A floating liner system is applied over the internal insulation for free thermal expansion and internal insulation protection. Some older designs utilized a fabric expansion joint for the forward expansion joint. These should be reviewed as potential candidates for retrofit of the forward expansion joint to flex seals and a modified drain system. Some older externally insulated designs should be reviewed for replacement by the newer internally insulated design.

F-Class Support Structure

The support structure for F-Class turbines provides the mounting flanges at the diffuser duct horizontal centerline. The flanges are designed to allow axial and radial thermal growth. The support structure is bolted to the foundation through a standardized footprint. The support structure is painted or hot dipped galvanized per ASTM A123 or equivalent.

E-Class Wing and Cowl (except 51 and 52)

The wing and cowl for E-Class turbines complete the exhaust gas flow path from the exhaust plenum to the expansion joint that interfaces with the downstream exhaust system. The wing and cowl direct the exhaust gas to the right or left-hand side of the unit. Some units use two wings and redirect the exhaust gas straight up. The wing and cowl design incorporates static pressure probes, as well as a cooling-and-sealing air bleed port. The floating liner system is applied over the internal insulation for free thermal expansion and internal insulation protection.

E-Class Side Panel and Roof Panel for 51 and 52 Units

51 and 52 units in E-Class have side and roof panels to complete the exhaust gas flow path from the base plenum to the interfaces with the downstream exhaust system. The side and roof panels direct the exhaust gas to the right or left-hand side of the unit. Some units use two side panels and re-direct the exhaust gas straight up. The floating liner system is applied over the internal insulation for free thermal expansion and internal insulation protection.

E-Class Expansion Joint (except 51 and 52)

The exhaust expansion joint for E-Class turbines compensates for the thermal expansion of the exhaust ductwork system. It is located between the exhaust plenum/cowl and the downstream exhaust transition duct. It is a “cold-to-cold” design that requires field installed liner sheets. Some existing exhaust transition designs require a “hot” flange design at this interface.

E-Class Expansion Joint for 51 and 52 Units

The exhaust expansion joint for 51 and 52 units in E-Class compensates for the thermal expansion of the exhaust ductwork system. It is located between the exhaust plenum and the downstream exhaust transition duct. This is a “cold-to-cold” design that requires field installed liner sheets. Some existing exhaust transition designs require a “hot” flange design at this interface. This is needed in vertical configurations that contain an extended stack and support structure, or in a “side-out” configuration discussed later.

E-Class Base Plenum (except 51 and 52)

The exhaust plenum for E-Class turbines is the first component to receive the gas flow from the exhaust diffuser. It consists of a box-shape base plenum that is open at each side and at the top and welded to an extension of the turbine base. The base plenum is connected to the exhaust frame/exhaust diffuser assembly with flex-plate expansion joints in both front and rear. These flex seals utilize a radiant heat reduction system (RHRS) for thermal protection. Some configurations of the plenum include pipe penetrations for compressor bleed during startup and shutdown. Penetrations are provided on the aft wall for thermocouple radiation tubes (MLI 0531). Refer to the installation instructions for details regarding a specific installed unit. A floating liner system is applied over the internal insulation for free thermal expansion and internal insulation protection.

E-Class Base Plenum for 51 and 52 Units

51 and 52 units have a base plenum that receives gas flow from the exhaust diffuser. It consists of a box-shape base plenum that is open at each side and at the top and welded to an extension of the turbine base. The base plenum is connected to the exhaust frame/exhaust diffuser assembly with flex-plate expansion joints in both front and rear. These flex seals utilize a radiant heat reduction system (HRRS) for thermal protection. Pipe penetrations for compressor bleed during startup and shutdown are provided. Penetrations are provided on the aft wall for thermocouple radiation tubes, see MLI 0531. Refer to the installation instructions for details regarding a specific installed unit. A floating liner system is applied over the internal insulation for free thermal expansion and internal insulation protection.

E-Class and F-Class Exhaust Frame and Aft Diffuser

The exhaust frame and aft diffuser is the first assembly to receive the flow of exhaust gas exiting the unit. The gas flows axially through the exhaust frame and then diffuses radially for E-Class, but conically for F-Class.

Site Inspections

The scope for each operator is dependent on the needs at their particular site. Engineering visits to sites such as that illustrated in *Figure 6* are made by GE to determine which exhaust upgrades are to be designed, quoted, and offered to the customer. In some cases, an operator only needs a direct replacement of their existing exhaust components. But for the majority of operators, new upgrade designs for exhaust systems are quoted by GE Applications Engineering and delivered in a commercial offering customized for a specific site.

The GE recommendation for preventative maintenance of MLI A042/1625 hardware includes regular visual inspections (at least once a year) during planned plant and/or turbine outages using visual inspection guidelines for each component described in the following. While the unit is shut down, MLI A042/1625 components should always be inspected with permission by the owner with conformity to plant guidelines for confined space entry.

Note that repairs should be considered as only short-term fixes, and that GE should be contacted to determine what the cause of the problems are and what is the best long-term solution. Also note that partial load operation and over-firing have been observed

during site visits by GE to be associated with exhaust deterioration. Operators are encouraged to contact GE if they operate for extended periods at low load or over-firing so that GE can provide inspection assistance. In all cases, operators should plan to eventually install new exhaust components, and GE Application Engineering is available to provide assistance in planning to upgrade the exhaust system.

E-Class Flex Seal Expansion Joint, and F-Class Forward Expansion Joint

Recommended maintenance inspection of the F-Class forward expansion joint (flex seal) and B, C, E, 5N, and 5P flex-plate

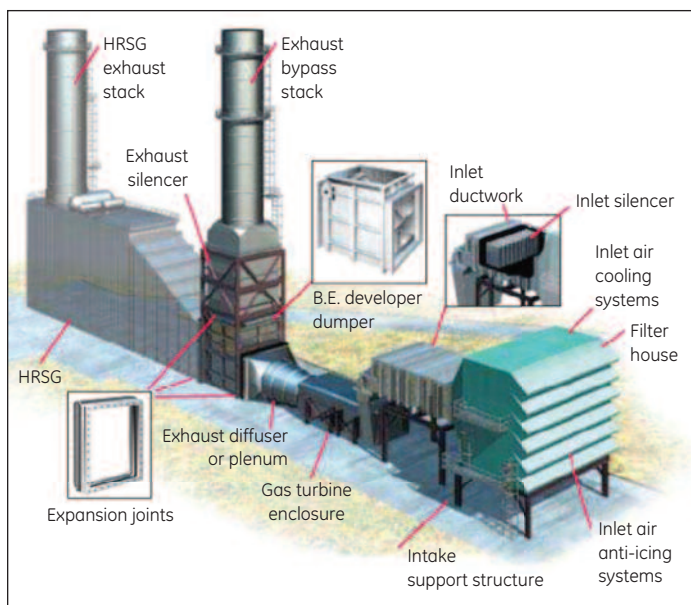


Figure 6. GE Engineers are available to visit sites and recommend exhaust upgrades.

expansion joints includes:

- Inspecting the metal backing bar, clamping bar and hardware on the flex plates for tightness
- Looking for cracks or wear on flex plates
- Looking for proper engagement of flex seals
- Performing thermal imagery to determine if unit should be modified with RRS

Flex plates must be replaced if wear or cracks are found on surfaces. The replacement must conform to GE's process or that of GE's qualified Manufacturing Associate. Contact the local GE Energy Services representatives for all concerns. For hardware tightness, refer to the torque instruction on GE drawings or drawings from GE's qualified Manufacturing Associate or contact the GE Energy Services local representative for assistance.

E-Class Expansion Joint, and F-Class Aft Expansion Joint

Recommended maintenance inspection of the expansion joint belt is as follows:

- Inspect the exterior belt for cuts, worn sections, burns or cracks
- Inspect the exterior belt for proper expansion
- Inspect the metal batten strips, clamping bars and hardware on the flanges for tightness

For hardware tightness, refer to the torque instruction on the GE drawing. Lacerations in the expansion joint belt will allow hot gas out of the diffuser duct, creating a safety concern, and must be replaced. For replacement parts, contact your local GE Energy Services dealer. Contact the local GE Energy Services representatives for all concerns.

E-Class Wing and Cowl, and E-Class Plenum, and F-Class Conical Exhaust Diffuser Duct

Recommended maintenance inspection of these internally insulated ducts is as follows:

- Inspect for loose scallop bar hardware (nuts and washers) and loose studs
- Inspect for the exposure of insulation material
- Look for missing or broken studs
- Look for missing or damaged liner sheets

- Look for missing batten hardware
- Look for cracks in shell
- Look for external burnt paint
- Perform thermal imagery of the exterior shell
- Inspect bleed pipe penetration
- Inspect gasket for wear, tears or corrosion

F-Class Support Structure

Recommended maintenance inspection of the support structure is as follows:

- Inspect for signs of corrosion on structure and hardware
- Inspect for loose hardware on structure

Grid Frequency Events Post Inspections

During operation of the gas turbine it may become necessary to over-fire the turbine—and thereby increase the exhaust gas temperature—to maintain grid frequency. This is called a grid frequency event. It is recommended after each grid frequency event that the exhaust duct should be inspected for possible damage from the increased exhaust gas temperature.

The minimum inspection points after the grid event are:

- Inspect the interior for broken, loose or missing studs, nuts, washers, and clamp bars. Broken studs are to be replaced. Loose hardware is to be tightened to the specifications on the A042/1625 installation drawings.
- Inspect the liner plates for distortions or cracks. Pay special attention to the areas where the studs penetrate through the plates. Damaged liner sheets are to be replaced.
- Inspect the flex seal at the connection to the E-Class Exhaust Diffuser or F-Class Exhaust Diffuser Duct for cracks or warped plates. Damaged flex seals are to be replaced.
- Inspect the exterior of the expansion joint for burns or tears.
- Inspect the exterior of the shell for damage to paint system.
- Inspect the bleed pipe penetrations for cracks using NDT (dye penetrant).

The inspection shall be recorded and the inspection record shall include, at a minimum:

- Date and time of the grid event
- Date and time of the inspection
- A detailed system map indicating each component checked

Extended Partial Load Operation Post Inspections

Units that have operated at partial load for extended time need to be inspected on a more frequent basis. This becomes more critical as the unit approaches loads under 70% of base and especially under 50% of base load.

Corrosion and Paint Repair

The exhaust system is typically painted with inorganic zinc in the shop. Support steel is typically painted or has Hot Dip Galvanization per ASTM A123. High temperature aluminum paint shall be applied for field painting of the exterior surfaces of the exhaust system after final installation. For information on the paint used for a specific unit, refer to the installation drawing for the duct to determine the particular paint product(s) used or contact the GE Energy Services local representative for assistance. The recommended process for repair of damaged and uncoated areas of Hot-Dip Galvanized shall follow ASTM A780/A780M.

The recommended process for paint repair is as follows:

- Consult the installation drawings for the manufacturer of the paint system applied
- Contact the paint manufacturer for information on the paint system applied
- Obtain the recommended amount of paint necessary and information for application from the paint manufacturer
- Power-tool or sand-blast clean the area that requires paint repair due to rust or other forms of paint damage
- Prepare the area to the metal surface profile recommended by the paint manufacturer for proper adhesion of the intended paint
- Apply the recommended thickness of the paint and abide to the manufacturers guidelines for curing time, temperature, dew point, etc.

Hardware Replacement

The recommended replacement hardware shall be the same as the original hardware. Refer to the material stamping on the hardware and/or the installation drawings for details. For further assistance, contact your local GE Energy Services representative.

Crack Repair, Weld Repairs, Missing/Broken Studs, and Other Damages

Broken/missing studs, a damaged gasket, missing batten angles, cracked liner sheets and/or a cracked duct shell, any cracks, or other damage should be reported to your local GE Energy Services representative for resolution. GE provides repair services, as well as diagnostic reports that are used to solve all issues of concern to operators. GE will make an assessment and present options with varying affordability and cycle schedules.

Available Exhaust Upgrades

This document covers advanced engineering CHROEM exhaust upgrades that have been successfully developed for designs from new unit production, or as specialized enhancements for operating

units. Advanced design technology is normally introduced for new unit production, and subsequently applied by an upgrade program to customer-operated gas turbines. Installing the latest technology CHROEM exhaust hardware for higher/highest firing temperatures in new and customer-operated units enables operators to reduce downtime and remain competitive. The Model List Items (MLI) available in CHROEM upgraded designs are listed in *Figure 7*.

CHROEM upgraded exhaust components are available as retrofits on Frames 32A-K, 51A-R, 52A-C, 61A/B, 71A-EA, 91B/E, 6FA, 7F, 7FA, 7FA+, 9F, and 9FA in simple cycle, cogeneration, and combined cycle plants. CHROEM components can be installed in all units, normally with minimal modifications. Furthermore, as the F-Class fleet continues to operate and age past about 10 years, their need for the components discussed herein will continue to increase. The technology offered in this GER applies to all Heavy Duty Gas Turbines, E and F-Class.

Whether the goal is to replace the entire exhaust system or just specific components, GE will look at the performance of the exhaust system as a whole, evaluating the interaction of all components. GE evaluates thermal performance

MLI	CHROEM Components Available
A042	Exhaust Diffuser Duct (F-Class)
A066	Exhaust Silencer Outline
A071	Exhaust Support Structure
A086	Exhaust Silencer
A042	Exhaust Arrangement, Transition Duct, Elbow, Acoustic Panels, Duct, Cowl, Wing, Expansion Joint (E-Class)
A094	
C053	
A096	Exhaust Stack
A097	Exhaust Expansion Joint (F-Class)
A102	Exhaust Enclosure
B019	Exhaust Air System
0471	Exhaust Flow Diagram
0706	Exhaust Frame Assembly
0531	Radiation Shields
0718	Exhaust Plenum Assembly, Flex Seals
1625	

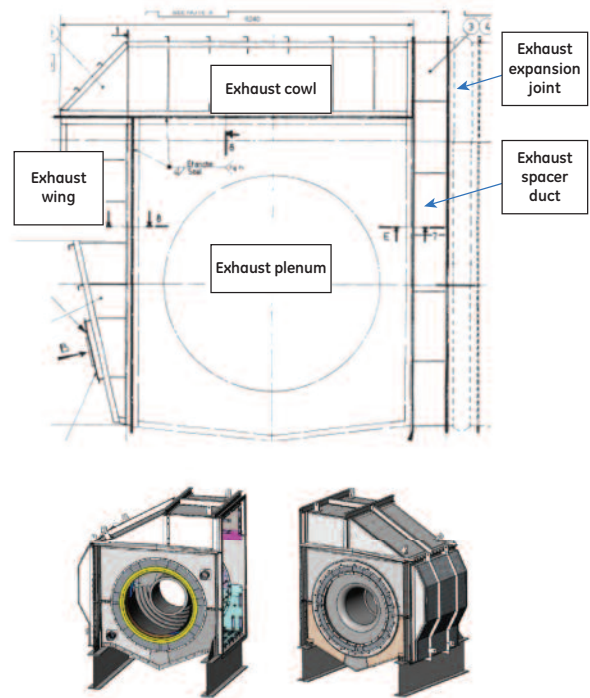


Figure 7. CHROEM upgraded designs offered for various Model List Items (MLI), including MLI 1625 as shown.

CHROEM Upgraded Design	E-Class									F-Class
	51, 52	61A	61B	71B	71C	71E	71EA	91B	91E	6FA, 7F-FA+, 9F/FA
FD4H – Exhaust Plenums and Ducting	X	X	X	X	X	X	X	X	X	X
FD6G, FD6H, FD6J, FD6K – Exhaust Silencing	X	X	X	X	X	X	X	X	X	X
FS1U – Exhaust Frame Assembly	X	X	X							
FS1W – Exhaust Frame Assembly				X	X	X	X	X	X	
FS2D – Exhaust Frame Blowers						X	X	X	X	
FW3N – Exhaust Diffuser Upgrade										X

Figure 8. Exhaust upgrade packages available in CHROEM technology.

as well as structural and mechanical stresses that can affect reliability. The latest design incorporates the requirements of latest building codes, ensuring the integrity of the exhaust system critical interfaces.

GE offers many exhaust design improvements for the installed fleet of GE’s heavy-duty turbines (all frame sizes and models). These upgrades are offered as individual upgrades, or can be applied in packages. Figure 8 lists the upgrades currently offered for exhaust systems. GE’s design philosophy on exhaust upgrades is to maximize interface commonality so that components can be installed in early and late models with minimal modifications. To supply equipment, GE adapts a set of fabrication drawings to customer units. At some sites, additional reinforcement may sometimes be needed to support the weight of added stack or silencer height.

Exhaust Frames, Aft Diffusers, Cooling, and Blowers

The exhaust frame assembly (see Figure 9, MLI 0706) directs high temperature exhaust gas from turbine outlet to the E-Class Exhaust plenum (MLI 1625) or the F-Class diffuser duct (MLI A042). It consists of the exhaust frame, a forward diffuser, and an aft diffuser turning vane sub-assembly (E-Class), or an externally insulated conical duct (F-Class). GE offers upgraded exhaust frame assemblies capable of handling increased exhaust temperatures and airflows.

Upgrading a unit to higher firing temperature will increase exhaust temperature; and the improved frame assemblies incorporate new design features allowing them to operate more reliably with less maintenance at the higher exhaust temperatures than the assemblies they replace. CHROEM components provide the needed capability for firing temperature upgrades, while also increasing reliability and decreasing maintenance.

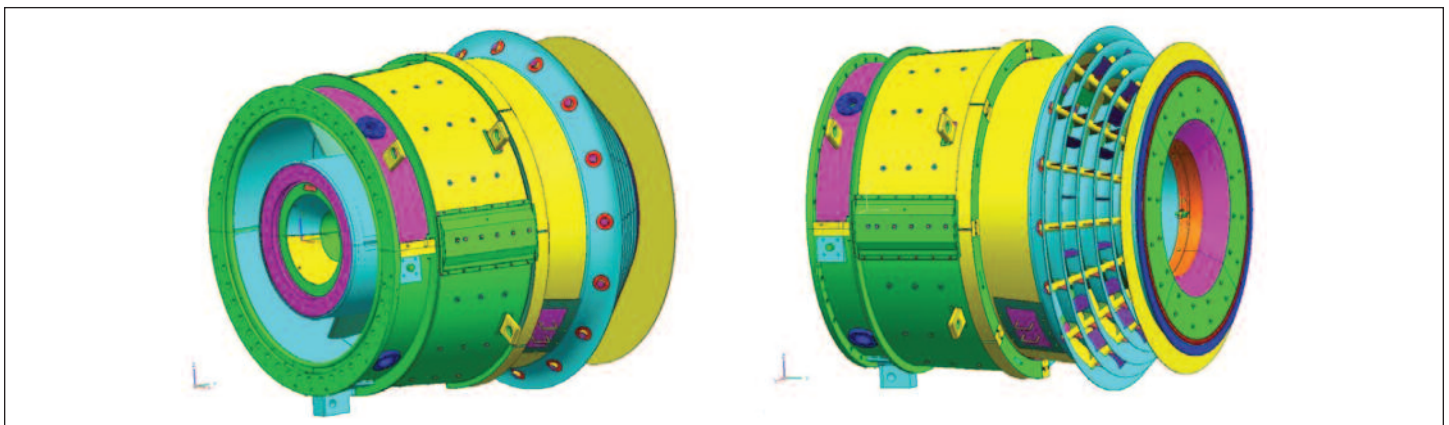


Figure 9. Illustration of CHROEM 7EA exhaust frame with aft diffuser.

The exhaust frame and aft diffuser assemblies can be modified for higher temperatures during site relocation, during hot gas path inspection, or during major inspection to bring the following benefits:

- Reduced cracking at higher firing temperatures
- Increased exhaust temperature limit
- Higher firing temperatures and therefore performance improvement at higher ambient temperatures.
- Enhanced exhaust frame cooling
- Reduced load tunnel over-temperature issues by reducing exhaust gas leakage
- Reduced stress, improved insulation and cooling, reduced cracking, and reduced maintenance

CHROEM exhaust frame assemblies installed by GE include an improved cooling air circuit, an increase of exhaust frame blower capacity, covers and upgraded gaskets for horizontal joints, new forward flex seals, stress relief scallops, turning vane enhancements, and floating diffuser airfoil configuration improvement. These modifications improve exhaust frame cooling, reduce repair costs, and address load tunnel over-temperature issues by reducing exhaust gas leakage. Higher horse power blowers are usually recommended, but are required when upgrading to the higher firing temperatures.

Exhaust Plenums and Flex Seals

GE's CHROEM exhaust plenums utilize an internal floating liner design, which lower thermally induced strains during unit operation, including startup and shutdown. CHROEM exhaust plenum and flex seal assembly components also provide other advanced features, such as:

- Drainable liner floor with optional jacking port
- Double-sealed wing door
- Cool shell and flange design
- Improved expansion joint design
- Improved flex seal design

To ensure that customers have access to high quality gas turbine exhaust plenums, GE offers CHROEM exhaust plenums with the latest technology designs available. (See *Figure 10*.)

GE supplies the latest improved design flex seals (forward and aft) that are made of thin steel sheets. (See *Figure 48*.) The forward flex seals fit into an external slot on the exhaust casing, and the aft flex seals fit on the aft end of the diffuser. These improved design flex seals prevent exhaust gases from escaping into the turbine (forward seal) and load (aft seal) compartments. It is recommended that, when convenient, older single-layer flex seals are changed to the latest and improved design.

Many new proprietary upgrades have been introduced for GE-designed exhaust plenums, such as the evolution from insulation pan design to the currently available floating liner design. (See *Figure 11*.) The new style plenum, wing, cowl, and expansion joint have an internally "floating" liner system, instead of the old style design insulation pans or panels. The new style now available provides better thermal protection of the outer shell. In addition, the vertical split line on the lower half of the plenum wall facilitates removal on pedestal mounted mechanical drive units without need to decouple or remove the exhaust frame. This saves significant time during plenum replacement and facilitates access to the load compressor pedestal bearing. Liner and insulation material inside the bolted flanges is used to reduce leaks from the connection points. This requires more work during the installation, but with the added insulation, the opportunity for leaks and thus cracks is reduced. Field reports of cracking in the previous design plenum walls are reported. It was found that the insulation contained gaps where the hot gas could get behind the insulation and directly impinge on the wall of the plenum. This overheating led to cracking of the wall. The insulation that was used (a wool based insulation)

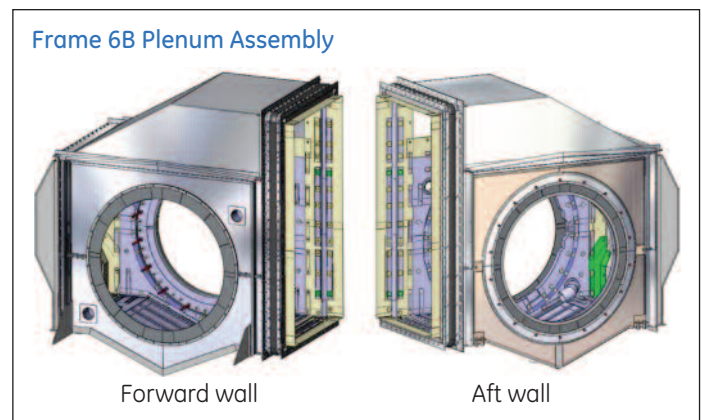


Figure 10. Example of CHROEM plenum assembly offered by GE.

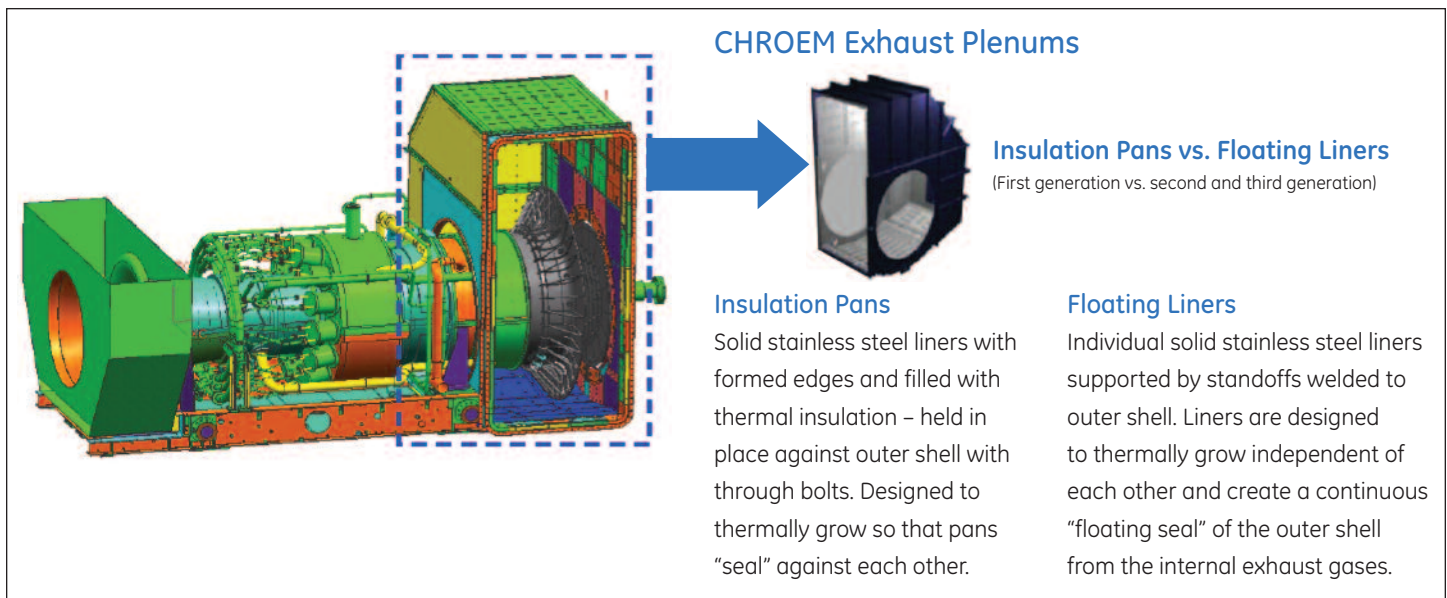


Figure 11. CHROEM floating liner plenum and exhaust frame with aft diffuser.

would break down from the heat and become less effective over time. The new insulation is packaged differently to withstand higher temperatures and to fill any gaps that might exist in walls.

In summary, the following points highlight the advances made in CHROEM exhaust plenums by GE:

- Front wall flex seal insulating collar
- Aft wall mounting ring welding detail is re-designed to reduce mechanical stress in the ring
- Acoustical insulation on aft wall acts to reduce noise
- All plenum connections are made with fiberglass gaskets and high strength bolts
- Flex seals are made of stainless steel alloy (E-Class) or Inconel (F-Class) to prevent deformation and leaks from developing in this joint
- New design has reduced stress, improved insulation and cooling, reduced cracking/maintenance
- The new floating liner state-of-the-art design allows thermal movement that lowers stress thereby resulting in reduced cracking and improved insulation retention
- Liner sheets sandwich the insulation against the outer shell to prevent falling and increase life
- Internal shingled design allows liquids to drain easily, resulting in reduced water build-up and prolonged insulation life

- Seal weld design with insulation reduces cracking of external skin
- Expansion joint is a cold flange design with downstream insulation that keep joints cooler and extend their service lives
- The plenum is split near its bottom for ease of field installation and maintenance access without removing the rotor

Ductwork, Stacks, and Silencers

The exhaust system ductwork is used to direct the exhaust of a gas turbine through a silencer section and exhaust stack to the atmosphere, or to an HRSG. This helps to contribute to atmospheric safety and to meeting emissions requirements.

The system is made up of long ductwork that is rectangular or circular in cross-section. (See *Figure 12.*) The exhaust stack can be round or rectangular and up to 200+ ft (61 m) in height. Many ductwork layout configurations are possible—straight up; left side and up; right side and up; left side aft and up; right side aft and up; left side forward and up; right side forward and up; and straight aft—all with varying duct lengths and stack heights.

New CHROEM exhaust ducts, stacks, and silencers offered to operators are intended to sit on foundation locations at the site. Also, they are intended to match the site-specific acoustic and pressure drop performance requirements. The site data is reviewed to determine if improvements are needed to fulfill these intentions. Every effort is made to utilize the existing foundation and meet

performance requirements at the site. However, foundation changes to accommodate an improved exhaust system may be required, and performance requirements may also drive the final designs. Quantification of any possible improvements is provided in the commercial proposal after the designs are finalized.

Frames, Aft Diffusers, Cooling, and Blowers

The E-Class and F-Class exhaust frames assembly consist of a frame, a forward diffuser, and an aft diffuser that is a turning vane sub-assembly for E-Class (see *Figure 13*), and axial for F-Class (see *Figure 14*). The exhaust frame assembly diffuses high temperature exhaust gas into the exhaust plenum. The exhaust frame assembly

penetrates the exhaust plenum, and is sealed by flex plate seals. The flex plate seals allow the exhaust frame assembly to expand and contract axially.

The gas path pressure levels vary depending on the arrangement of the exhaust system. For a combined cycle application, the gas path pressure is designated as high pressure due to additional backpressure of the HRSG and/or SCR. The configuration for a simple cycle application is designed generally as a low-pressure configuration.

When the gas turbine is updated to a higher firing temperature, or inlet bleed heat is added for DLN extended turndown, then the exhaust isothermal limit needs to be increased. To accommodate this increase, the exhaust frame configuration will need to be

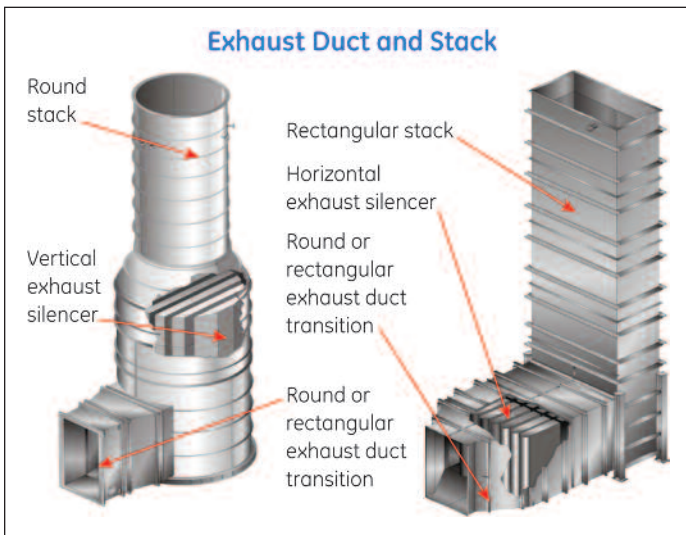


Figure 12. CHROEM exhaust duct and stack in circular and rectangular configurations.

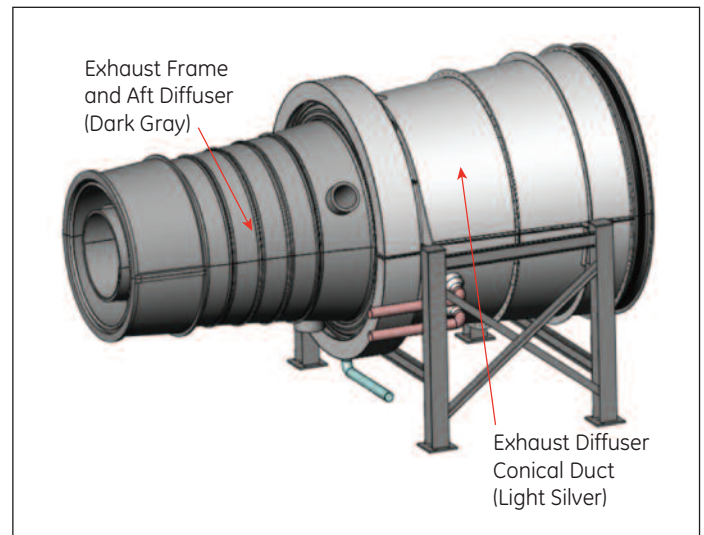


Figure 14. Illustration of F-Class exhaust frame, aft diffuser, and plenum.

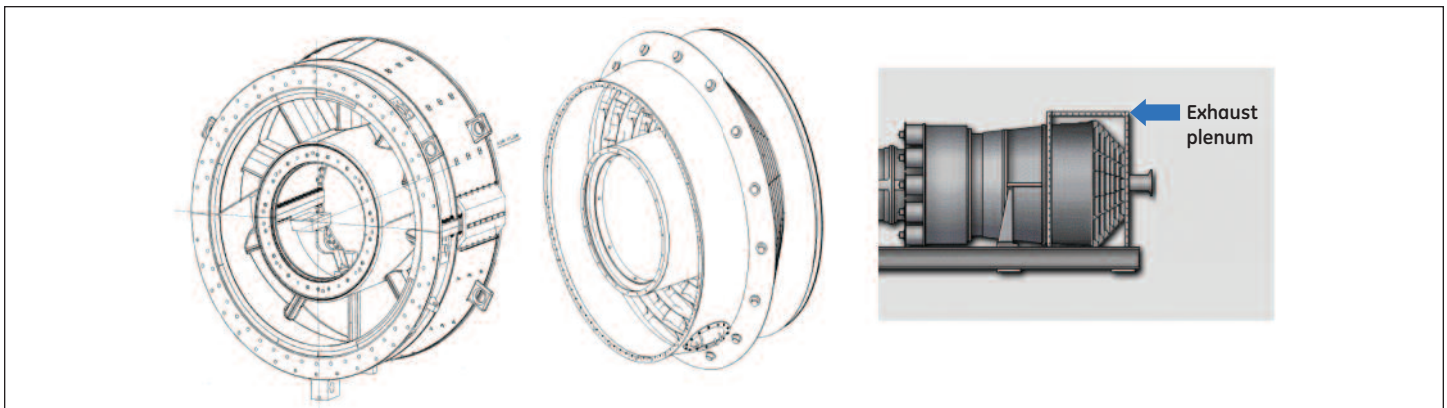


Figure 13. Illustration of E-Class exhaust frame, aft diffuser, and plenum.

reviewed and upgraded. The upgrades (see *Figure 15*) include among others: a change of cooling air circuit; an increase or addition of exhaust frame blower capacity; covers and upgraded gaskets for horizontal joints; new forward flex seals; stress relief scallops; and turning vane enhancements. These modifications improve exhaust frame cooling, reduce general repair costs, and address load tunnel over-temperature issues by reducing exhaust gas leakage.

Upgraded Exhaust Frame

- Reduced cracking in the exhaust frame in the area of the airfoil around the struts
- Reduced thermal cracking, especially where the airfoil attaches to the outer diffuser wall
- Improved airfoil leading edge design leading to reduced cracking
- Reduced potential for the frame forward seals becoming disengaged due to the new design; the pipe design used in this area has been improved as well
- The forward diffuser of the exhaust frame is fully insulated
- Improved sealing and new gasket design for the horizontal joint flanges that have very low or no leakage

Upgraded Aft Diffuser

- Improved sealing and new gasket design for the horizontal joint flanges
- New flex-seal design and turning vane enhancement

Figure 15. Benefits of exhaust frame upgraded assemblies.

As an example of the varying cooling configurations among frames, the 7EA exhaust frame assembly in *Figure 16* has a cooling annulus between the outer wall of the exhaust frame and outer diffuser wall that mates with the axial cooling holes in the turbine shell. The annulus has cooling air continuously flowing through it, which is supplied by external exhaust frame blowers. This air exits forward through the turbine shell, out into the turbine compartment, and finally to the atmosphere. Multiple orifices meter this flow. The remainder of the air flows aft through the exhaust casing and into the number three bearing support strut into the load tunnel area around the number-three bearing. After expending much of its energy in rotating the output shaft of the turbine, the exhaust gas is diverted by the aft diffuser turning vanes and flows into the exhaust plenum.

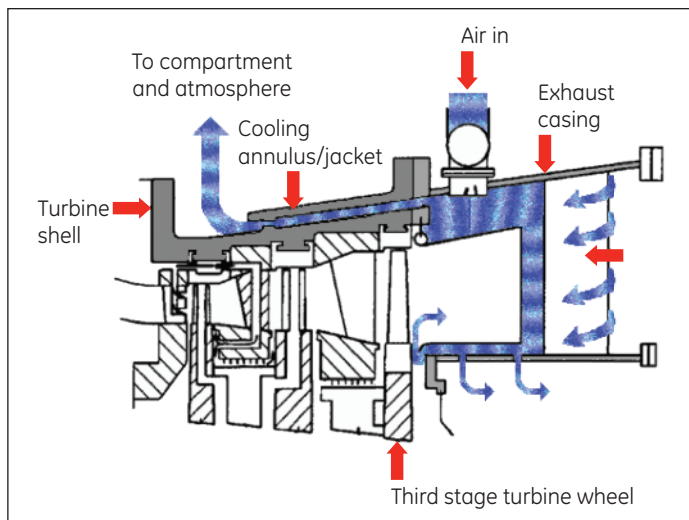


Figure 16. Exhaust frame cooling flow circuit in 7EA.

FS1U – Exhaust Frame Assembly Upgrades (51A-R, 52A-C, 61A/B)

There are three options for modification of the Frame 51A-R, 52A-C assembly as illustrated in *Figure 17*. The first and third options involve replacing the entire exhaust frame assembly.

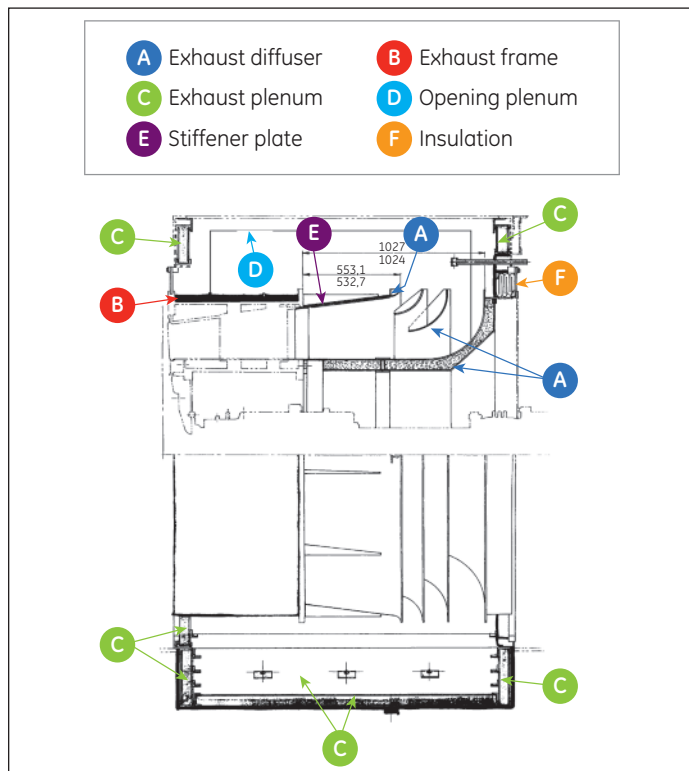


Figure 17. Frame 5 exhaust frame assembly illustration.

The second option is to re-skin the exhaust path surface areas with stainless steel. When the gas turbine is updated to a higher firing temperature, or inlet bleed heat is added for DLN extended turn-down, the exhaust isothermal limit may need to be increased. This alone can warrant upgrading the exhaust frame assembly.

The options available to Frame 5 also apply to the Frame 6, except that the 6B has a 304L stainless steel forward diffuser. Therefore, there is no option of COR-TEN® or stainless steel 409 for the 6B.

- The first option applies when firing temperature is increased. It uses new 304L stainless steel components and hardware to replace the entire exhaust frame, the existing exhaust diffusers, and related gas path skins and insulation packs. The new replacement will be the current production exhaust frame on the 51P/R that is already equipped with AISI 304L stainless steel hardware for all critical components. A complete assembly is supplied to ease field installation and shorten rebuild time.
- The second option supplies the aft diffuser and turning vanes as a pre-fabricated unit, and supplies the exhaust skin sheet metal for the forward diffuser and all new insulation packs as loose parts for field assembly with the customer's existing exhaust frame. This option will require above average amounts of engineering, drafting, field engineering and labor to support a conversion of this type. The material cost advantage of this option is offset by the labor-intensive nature of the field assembly of the exhaust frame, aft diffuser, and hot gas path skins. Field assembly of this second option will also require welders experienced with welding stainless steel. The recommended welding process is a flex cord type weld, which is a gas shielded weld process similar to MIG welding. Poor field weld quality will have a direct impact on lowering of durability and ease of final assembly.
- The third option is to replace the entire exhaust frame assembly with COR-TEN® material or stainless steel 409 when required due to excessive damage or wear at lower exhaust gas temperature. This option provides the latest design improvements but prohibits future increase in firing temperature. However, 304L stainless steel is an option when upgrading to higher firing temperature, or if better corrosion resistance and oxidation resistance are needed as well as improved weldability.

For 5/1 A~R/N/P, there have been many versions of the exhaust frame over the last 40 years of production. Therefore, for some units,

operators may be required to supply drawing numbers, hardcopy drawings, or any other detailed information that will help to identify the correct exhaust frame required for this modification.

FS1W – Exhaust Frame Assembly and Cooling Upgrades (71A-EA, 91B/E)

Cooling Upgrades

Cooling is provided by motor driven external blowers. The cooling air is introduced from the external blowers into the exhaust frame and is distributed to:

- Cool the turbine shell
- Cool the exhaust frame strut passages
- Cool the third aft wheelspace
- Purge the load tunnel

Configurations of exhaust frame and cooling air circuit arrangement vary, depending on unit year of manufacture and the plant application (simple or combined cycle). The latest design and materials are applicable to most of the older units. However, when the exhaust frame and its cooling system are upgraded, the cooling configuration should be studied and the cooling circuit orifices and/or plugs re-adjusted as needed for the new configuration. Generally speaking, the 9B has a similar configuration as the 7B, and the 9E has a similar configuration as the 7EA.

Modifications to the exhaust system may include a change of cooling air circuit in the frame and/or an increase in blower capacity. These modifications improve exhaust frame cooling, resulting in reduced cracking and repair costs. When the exhaust frame cooling air circuit is upgraded, the compartment ventilation system needs to be studied for any needed improvement or modification. The ventilation of load compartment and isolation wall to the generator needs to be reviewed. The objective is to not draw hot gas from the turbine compartment into the load compartment or generator cooling circuit.

The general design requirements for the exhaust frame cooling system are to provide positive pressure (greater than gas path pressure) and sufficient flow to overcome leakage, purge the cavities and maintain air temperature to prevent over-temperature of the exhaust frame, struts, third stage wheelspace and bearing housing area.

A typical 7EA and 9E configuration is illustrated in *Figure 18*. This configuration represents the latest design exhaust frame and cooling circuit. The configuration utilizes a “long” exhaust frame with 15° canted struts and a “short” aft diffuser without a horizontal joint. The exhaust frame forward diffuser has a simple conical surface to the outer barrel at the intersection of the struts.

The 7E cooling circuit uses two 25 HP blowers to force flow into the turbine case educator passages which exit into the exhaust frame through its forward flange. Some of this flow exits through a passage around the outer barrel of the exhaust frame and into a vent to the turbine compartment roof—and the other portion of the flow passes through the exhaust frame and then through the load tunnel, venting to the load compartment roof via another vent. Third aft wheelspace cooling flow is piped in from the #2 bearing vent.

The 7EA cooling flow comes from two 100 HP blowers. A portion of the flow exits forward through the educator holes while the balance passes through the exhaust frame. The balance of the flow exits into either the third aft wheelspace or the inner barrel into the load tunnel and then into the load compartment. The recommendation in many cases is to upgrade to two 100 HP blowers. This will eliminate the need for the #2 bearing air to be piped to the third aft wheelspace, as well as the need for the turbine compartment flow vent path to be fabricated on the outside of the new exhaust frame. This will require the modification of the turbine case to allow installation of orifice pins where the blower air is currently entering.

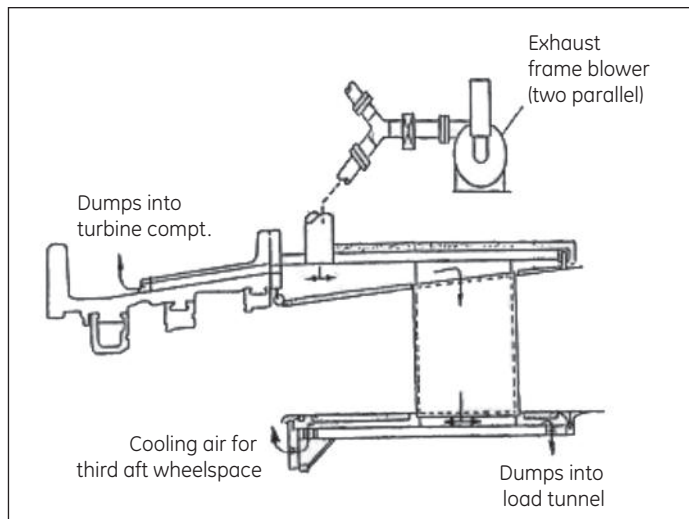


Figure 18. Typical configuration of 7EA and 9EA.

The gas path pressure levels vary depending on the arrangement of the exhaust system. For a combined cycle application, the gas path pressure

is designated as high pressure due to additional backpressure of HRSG and/or SCR. The configuration for a simple cycle application is designed generally as low-pressure configuration. When the exhaust frame and the exhaust frame cooling system are upgraded, the configuration should be studied, and the cooling circuit orifices and/or plugs re-adjusted as needed for the new configuration.

Cooling Configuration (7E) Upgrade

The 7E configuration uses external blowers for the exhaust frame cooling. However, the cooling circuit is different than that for the 7EA. With the 7E, cooling air is manifold and supplied to the turbine shell through 42 air nozzles as illustrated in *Figure 19*. As with the 7B and 9B configuration, the third aft wheelspace is cooled by vent air coming from the #2 bearing. The 7E has additional cooling of the outer exhaust frame wall and the cooling air is ducted from the forward part of the frame. The 7E and 7B configurations have a load tunnel end cover and vent piping to the load compartment roof. The 7EA and 9E do not have this end cover, and the load tunnel is an open space. Several early model 7E units have also been identified as having the modern design exhaust frame and cooling circuit. For the 7E blower modification, the third stage aft wheelspace cooling does not change; the cooling is still piped in from the #2 bearing vent. The cooling to the third stage aft wheelspace is usually changed when the complete exhaust frame is replaced.

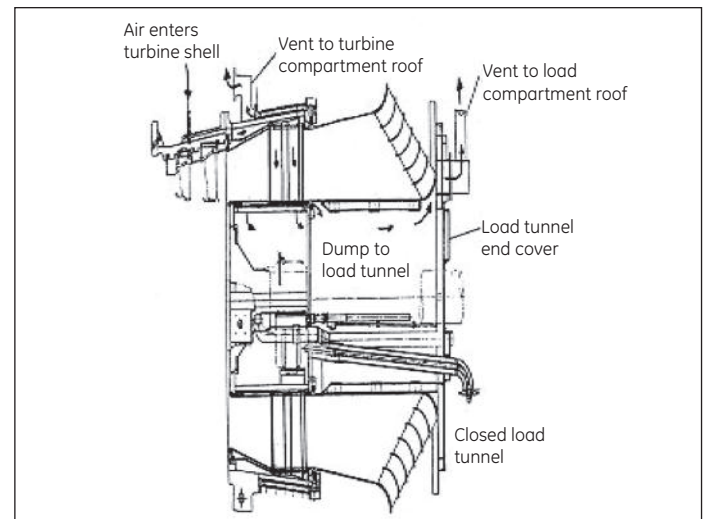


Figure 19. 7E exhaust frame cooling circuit.

Cooling (7B and 9B) Upgrade

The 7B has a different configuration of exhaust frame cooling circuit than the 7E, 7EA and 9E. As illustrated in *Figure 20*, the cooling air is supplied via an air extraction from the 11th stage compressor bleed into the turbine shell through 42 educators and flows through the exhaust frame. The source of this cooling air is not external blowers. The air cools the exhaust frame, exits into the load tunnel, and vents to atmosphere through a duct on the end cover. The third aft wheelspace is cooled by #2 bearing vent air routed through external piping.

To upgrade a 7B or 9B configuration to that seen in *Figure 21*, the following modifications are required:

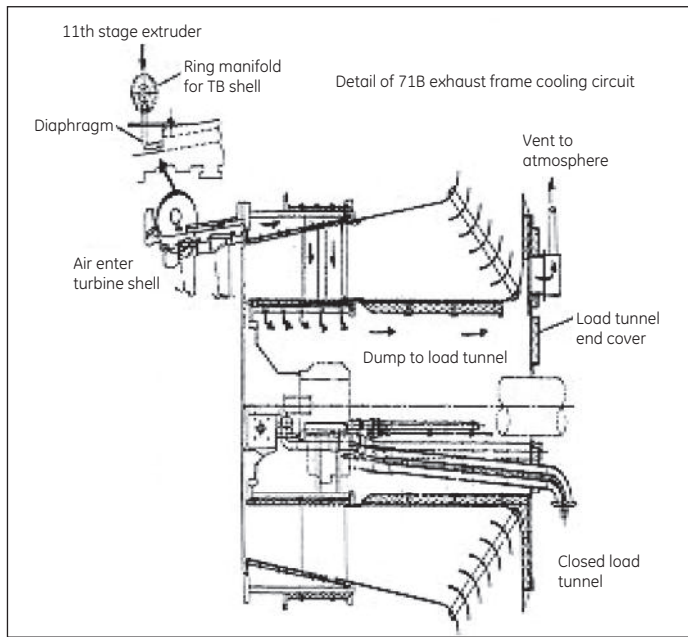


Figure 20. 7B exhaust frame cooling circuit.

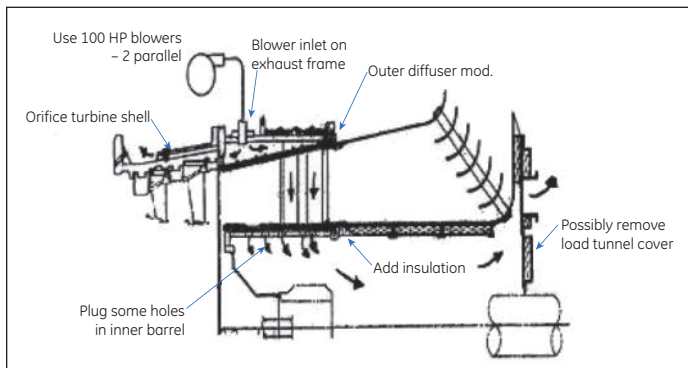


Figure 21. 7B modified exhaust frame and cooling circuit.

- The original 11th stage extraction piping is removed
- Two new external blowers and associated piping are installed
- New inlet ports are added on the exhaust frame, and cooling air is introduced to the exhaust frame
- Threaded studs are installed into the turbine shell cooling air path to adjust cooling air flowing out
- Several holes are plugged at the inner barrel to adjust air flow dumping in the load tunnel
- Local insulation is added on inner aft barrel
- Outer diffuser aft vertical flanges are replaced with new design flanges (aircraft flange in later text)
- The load tunnel end cover is removed, if necessary.

For the 7B configuration, there is also an option available to replace the exhaust frame with a modern design frame instead of modifying the existing exhaust frame. This frame is designed to be cooled with exhaust frame blowers. The entire exhaust frame, existing exhaust diffuser and related gas path skins and insulation packs are replaced with new parts. The new frame is equipped with AISI 304L stainless steel hardware for all critical components. A complete assembly is supplied to ease field installation and shorten rebuild time. Also, the replacement exhaust frame will be modified to match the 7B airflow and exit swirl with an axial style diffuser strut.

Exhaust Frame (7E) Upgrade

To upgrade to the 7E configuration as seen in *Figure 22*, the following modifications are needed:

- Blower capacity is upgraded up to 100 HP

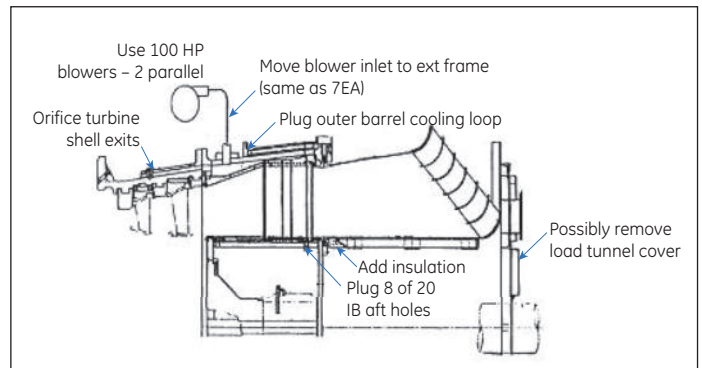


Figure 22. 7E modified exhaust frame and cooling circuit.

- New inlet ports are added on exhaust frame, and cooling air is introduced to the exhaust frame
- The outer barrel cooling loop is plugged
- Orifice pins are installed into the turbine shell cooling air path to adjust cooling air flowing out
- Several holes are plugged at the inner barrel to adjust air flow dumping in the load tunnel
- Local insulation is added on the inner aft barrel
- Load tunnel end cover is removed, if necessary

Modifications to Adjacent Hardware Needed for Cooling Upgrades

Implementation of the aforementioned recommendations will require modifications to the turbine case (to allow installation of orifice pins), the turbine compartment enclosure (to eliminate the roof vent), and the cooling and sealing air piping (to remove the third aft wheelspace air piping from the #2 bearing and to vent that air to the atmosphere).

Detailed flow analysis of the cooling air will be required. This will provide the necessary hole pattern on the exhaust frame inner barrel and may either allow or dictate additional changes to the aft end of the aft diffuser. This area is currently closed off with an insulated panel, and utilizes a vent to remove the load compartment air. It may be possible to either keep this arrangement in place, or to remove the panel and vent to allow use of a load tunnel blower.

Interfaces with the turbine case bolts, load compartment flex seals, and #3 bearing location will be maintained.

Assembly Upgrades

Exhaust Frame Assembly (7E) Replacement

The following highlights the recommendations of GE engineering for the replacement of the exhaust frame and aft diffuser assembly on a 7E. Based upon the desire of customers to replace these two major components, the following items are discussed:

1. The early 7E configuration (see *Figure 23*) consists of a “short” exhaust frame with 15° canted struts and a “long” aft diffuser with a horizontal joint. The horizontal joint is required to allow the removal of the upper half of the aft diffuser to allow removal of the rotor. The exhaust frame diffuser has a compound angle to allow a cylindrical surface at the intersection of the strut with the outer barrel.
2. The current production is the 7EA, whose configuration utilizes a “long” exhaust frame with 15° canted struts and a “short” aft diffuser without a horizontal joint. The exhaust frame forward diffuser has a simple conical surface to the outer barrel at the intersection of the struts.

The recommendation is to utilize the 7EA style assembly configuration. This will reduce the costs of manufacture since tooling will be similar to current production.

It will be possible to use new hardware that is very near the current production geometry as replacements, thereby avoiding design and tooling costs, and benefiting from the many design changes that have occurred since the original construction of the unit.

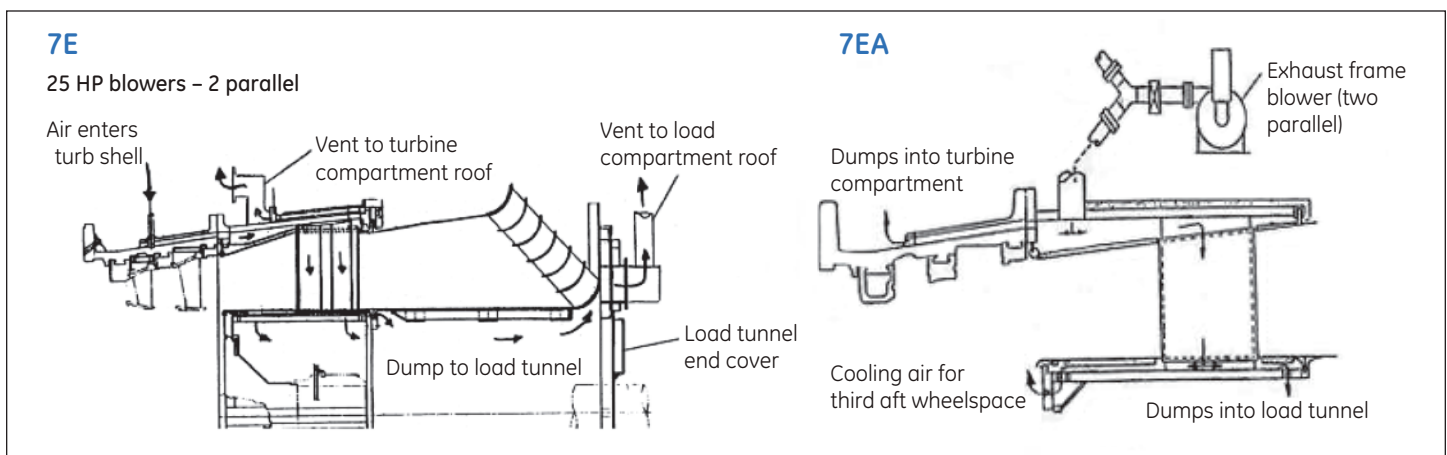


Figure 23. Comparison of cooling air flows in 7E versus 7EA exhaust frame assemblies.

1. The 7E unit exhaust frame will be replaced with a current production 7EA exhaust frame with minor modifications to the inner barrel cooling hole pattern. No special tooling will be required for its manufacture. See *Figure 23* for a comparison of 7E versus 7EA exhaust frame assemblies.
2. The 7E aft diffuser will be replaced with either a current production 7EA aft diffuser or a modified variant of the current production aft diffuser that incorporates the aft panel and vent. The modified option avoids the added time and expense of changing the load compartment ventilation and fire protection systems.
3. The blower system will be upgraded to the current pair of 100 HP motors feeding ports on the exhaust frame. This will keep changes to the exhaust frame at a minimum and eliminate the need for the cooling air manifold piping in the turbine compartment and the third aft wheelspace air piping.
4. Modifications to adjacent components are minor, mainly confined to the turbine case.

Aircraft Style Aft Vertical Flange (7B and 9B) Upgrade

The 7E and 7EA have the aircraft style vertical aft diffuser flanges, but the 7B has a high standing vertical aft flange. Because of the high thermal gradients that occur in this area, significant flange cracking can occur in high standing flanges. When upgrading to the blower configuration, upgrading to the aircraft style flange should be considered to provide an improved flange design with lower thermal gradients and lower stresses as a result of the welds being moved away from the thermal stress area.

Aft Diffuser Horizontal Joint (7B, 7E, and 9B) Upgrade

The 7EA has a 360 degree exhaust aft diffuser, but some older 7B/E units have a horizontal joint. Because of joint deflection, exhaust gas leakage has been observed at the horizontal joint resulting in higher temperatures in the load tunnel. To avoid exhaust gas leakage, a flange cover is added to cover the horizontal joint and bolting changes have been incorporated on 7B and E upgrades.

Ventilation Modification (7B, 7E, and 9B) Upgrade

When we upgrade or replace the exhaust frame of a 7B or 7E to the 7EA configuration as illustrated in *Figure 18*, it is necessary to upgrade the ventilation system, since additional heat is dissipated to turbine and load compartments.

Exhaust Frame Support Legs (7B, 7E) Upgrade

An option is available to upgrade the exhaust frame support legs of 7B/E machines with an improved water jacket design. It is noted that this change requires a change in turbine to generator alignment.

Forward Diffuser Horizontal Joints (7E, 7EA, and 9E) Upgrade

In addition, all configurations have horizontal joints at the forward diffuser. A ceramic fiber gasket typically has been used at this horizontal joint. Due to the loose nature of the joint (not a bolted joint), the ceramic fiber gasket has a tendency to be buffeted by the high velocity exhaust gas. As a result, cooling air leaks through the joint. A new Inconel® wire mesh gasket has been designed for the current product of 6B, 7EA, and 9E machines and is also applicable to early model 7E, 7EA and 9E units. This gasket offers a significant improvement in durability over the old ceramic fiber gasket.

Forward Flexible Seal Upgrade (7E, 7EA, and 9E) Upgrade

The existing flex seals are made of 304L stainless steel. These are changed to a Type 410 stainless steel which exhibits improved wear characteristics.

Aft Diffuser Stress Relief Mod (7E, 7EA, and 9E) Upgrade

Potential circumferential cracking on the inner drum of the aft diffuser assembly can be significantly reduced by scalloping the circumferential ribs on the load tunnel side of the aft diffuser, which reduces the thermal stresses in the drum wall area.

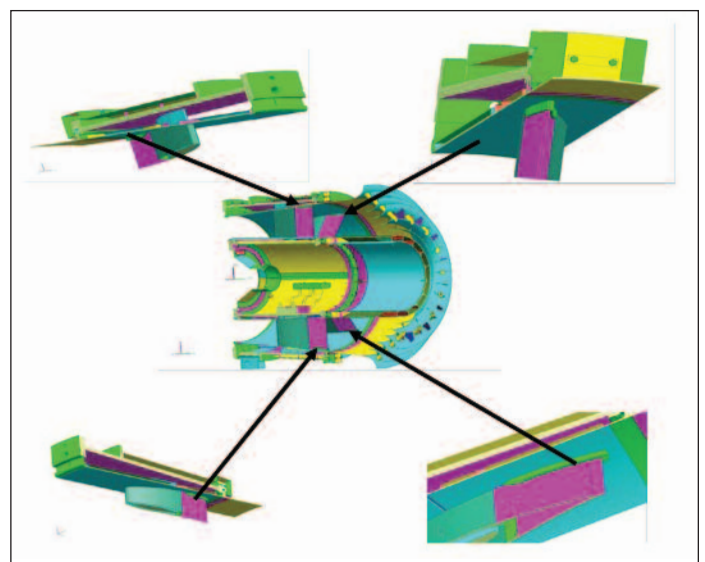


Figure 24. Improved design "floating tail" in 7EA advanced CHROEM exhaust frame.

Enhanced Turning Vanes (7E and 7EA) Upgrade

To stiffen the turning vane sub-assembly, some gusset plates are added between turning vane rows 3 and 4. This modification applies to 7E and early model 7EA models only, since they have the unique “flat plate” diffuser design when compared to the rest of the product range which use “pipes”.

Exhaust Frame Air Foil Floating Tail (7EA) Upgrade

The latest floating tail design reduces cracking. (See *Figure 24*.) This floating tail upgrade is installed on 9E exhaust frame designs, and intended for 7EA units.

Aft Diffuser Upgrades

6B Aft Diffuser Upgrades

Since the early 6B units were built, there have been upgrades designed for the aft diffuser. These improvements include the following:

- Vents in aft face
- New vane gussets
- Larger extension into plenum for better efficiency—as illustrated in *Figure 25*—requiring a larger mod to exhaust frame assembly to ensure fit to plenum at site, however some sites may require a new plenum assembly.
- New horizontal joint seal

Note that the PG6581B latest design with larger aft diffuser will not fit inside plenums on older 6B units, due to its increased dimensions relative to the older design plenum.

Improvements in the new exhaust frame assembly act to increase exhaust frame cooling, reduce general repair costs, and reduce

exhaust gas leakage to avoid load tunnel over-temperature. The improved aft diffuser installed on PG6581B units includes the following:

- Improved cooling air circuit
- Upgraded covers and gaskets for horizontal joints
- Upgraded forward flex seals
- Stress relief scallops
- Turning vane enhancements
- Improved aft diffuser supports
- Improved aft diffuser stress relief

71A-EA Aft Diffuser Upgrades

The advantages of the 7EA CHROEM aft diffuser illustrated in *Figure 26* are as follows:

- One important upgrade to the new aft diffuser design is the elimination of the structural ribs. The objective is to avoid the cracks that develop at the rib-to-barrel weld toe. These cracks, once they develop, propagate circumferentially around the inner barrel. Eliminating the ribs and the weld associated with them is critical to eliminating the cracks caused by the weld. GE is offering this significant upgrade to the customer for the 7EA aft diffuser. A modification is available for field units that scallop the circumferential ribs on the load tunnel side of the aft diffuser, which helps prevent circumferential cracking.
- In addition, cracking occurring in the turning vanes has been reduced in the upgraded diffuser. This is accomplished by adding pipe gussets that are welded between turning vane rows 1 & 2 and rows 3 & 4 to greatly increase their

PG6581 Exhaust Diffuser

- Improved performance from reduced loss of exhaust pressure
- Minimized design change
 - Same shaft line level and length
 - Same generator interface
 - Same exhaust casing and struts
- Two configurations available – lateral and vertical

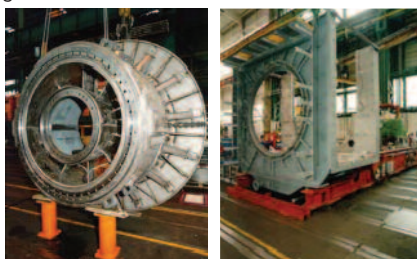


Figure 25. Advanced CHROEM PG6581B aft diffuser has increased dimensions.



Figure 26. CHROEM 7EA exhaust frame and aft diffuser in latest design configuration.

stiffness. Increased stiffness reduces strain and lowers stress in the turning vanes, and this directly leads to reduced cracking.

- In addition, cracking due to thermal mismatch is reduced in the advanced design. This is done by reducing the thickness of the retaining washers.
- The new design was changed from “flat plate” to “pipe” supports to eliminate potential cracking of the inner diffuser wall at the forward location of the strut where it is welded to the inner diffuser wall.

91B/E Aft Diffuser Upgrades

When a 9B/E unit is updated to a higher firing temperature, and/or the existing assembly has reached its service life, the exhaust frame assembly will need to be upgraded. (See *Figure 27*.) The upgrades and figures discussed for Frame 7 also apply to Frame 9E (but with the exception of the 9E aft diffuser supports). The 9B units were built by GE Manufacturing Associates and the designs vary slightly. As such, 9B configurations may require engineering on an individual basis, but the 9B configuration is similar to that of the 7B.

As part of the standard upgrade “Kit,” there is a modification, applicable to 9E units only, that replaces the square shaped plates (supports) on the outer wall of the aft diffuser with circular shaped plates. By eliminating the corners (replacing them with circular shapes), potential stress concentration areas are eliminated.

- Leakage at the flanges is reduced due to an improved flange design.

9E Advanced Exhaust Frame Assembly

- Improved exhaust frame has greatly reduced cracking
 - Reduced cracking in airfoil around the struts and where attaches to inner diffuser
 - Leading edge design of airfoil improved
- Improved exhaust aft diffuser has greatly reduced cracking
 - Scalloped circumferential ribs
 - Gusset plates added between turning vane rows
 - Eliminated structural ribs and associated welds
 - Added pipe struts between turning vanes
 - Reduced thickness of retaining washers

- Reduced potential for the frame forward seals to become disengaged is due to the new design. The pipe design used in this area has been improved as well.

- The forward diffuser of the exhaust frame is fully insulated.

Potential circumferential cracking on the inner drum of the aft diffuser assembly is significantly reduced by applying scallops on the circumferential ribs on the load tunnel side of the aft diffuser, which reduces thermal stresses in the drum wall area. To stiffen the turning vane sub-assembly, some gusset plates are added between certain turning vane rows.

One important upgrade made to the new aft diffuser design is the elimination of the structural ribs. The objective of this is to avoid the cracks that develop at the rib-to-barrel weld toe. These cracks, once they develop, propagate circumferentially around the inner barrel. Eliminating the ribs and the weld associated with them is critical to eliminating the cracks caused by the weld. See *Figure 28* for an illustration.

In addition, cracking occurring in the turning vanes has been reduced in the upgraded diffuser. This is accomplished by adding pipe struts that are welded between turning vane rows 1 & 2 and rows 3 & 4 to greatly increase their stiffness. Increased stiffness reduces strain and lowers stress in the turning vanes, and this directly leads to reduced cracking. Gussets between the pipe struts and turning vanes utilize an engineered profile to eliminate stress risers seen in older designs. See *Figure 29* for an illustration.

Cracking due to thermal mismatch is reduced in the advanced design. This is done by reducing the thickness of the retaining washers. Cracking at the diffuser walls has been eliminated by using a thinner pipe collar design welded to the diffuser walls. These upgrades act to lower stress, thereby reducing cracking. The amount of reduced cracking has proven to be very significant, as observed in units that operate the new design diffuser. GE is confident that customers will find cracking is significantly reduced in the new design diffuser as compared to older diffusers currently installed at sites. See *Figure 30* for an illustration.

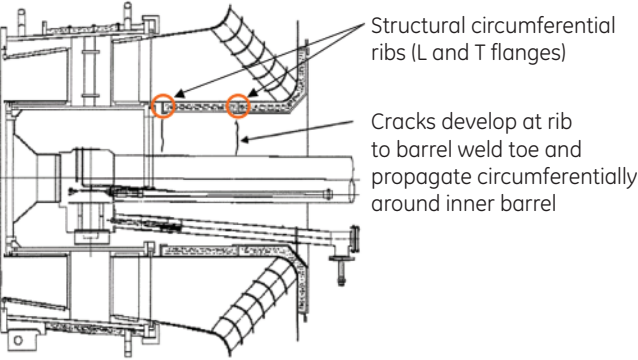
The latest design aft diffusers for the Frame 9B/E have larger dimensions compared to previous designs—and therefore will not fit inside older design plenums with smaller dimensions. General

Figure 27. CHROEM Frame 9E exhaust frame assembly.

Electric Applications Engineering should be contacted via a local Salesperson (or other GE personnel) whenever 6B or 9E aft diffusers or plenums are being replaced. GE will ensure that these replacements have correct dimensions.

FS2D – Exhaust Frame Blower Upgrade (71E/EA, 91E)

Cooling of the turbine exhaust casing and frame is accomplished by motor driven blowers. These fans are mounted externally to the turbine. The replacement kit will include 100 HP exhaust frame blowers, interconnection piping arrangement modifications, motor control center modifications and exhaust frame cooling circuit tuning.



Structural circumferential ribs (L and T flanges)

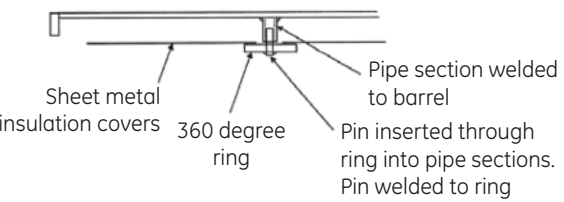
Cracks develop at rib to barrel weld toe and propagate circumferentially around inner barrel

New Inner Barrel Rib Proposal

Structural rib can be eliminated from inner barrel. However, some type of support structure is needed in inner barrel to:

- Support the insulation covers
- Provide mounting locations for instrumentation conduit, cooling and sealing air piping, and fire protection piping.

Proposal is to use a "floating" ring that eliminates any thermal constraint to inner barrel.



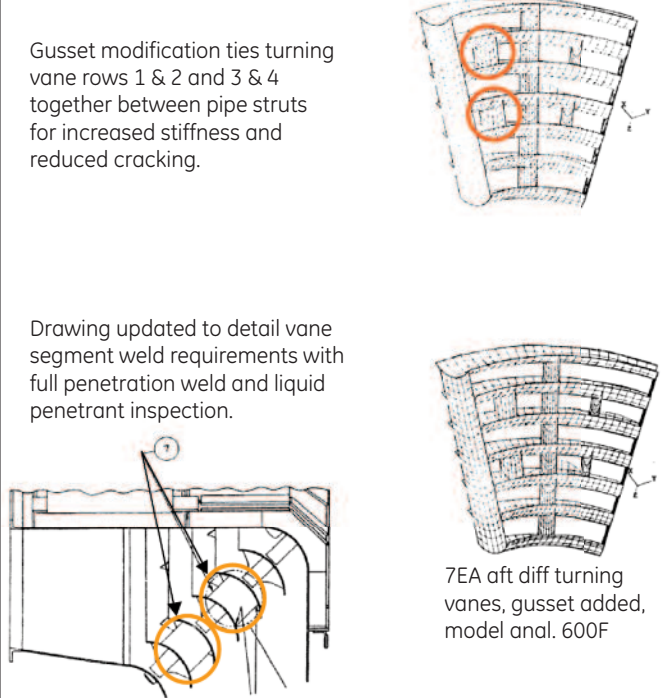
Sheet metal insulation covers 360 degree ring Pipe section welded to barrel

Pin inserted through ring into pipe sections. Pin welded to ring

Will use eight radial pins to "float" a 360-degree ring. Provides structure for mounting conduit and will support insulation sheet metal covers same as present design.

Figure 28. Elimination of structural ribs in CHROEM 9E diffuser avoids circumferential cracking in ribs.

The exhaust frame blowers help to reduce the temperature of the frame, which helps to reduce cracking, reduce general repair costs, and increase the service life of the exhaust frame. If one of the blowers should fail and the pressure drops, then a pressure switch will cause an alarm. Should both blowers fail, the gas turbine will shut down.

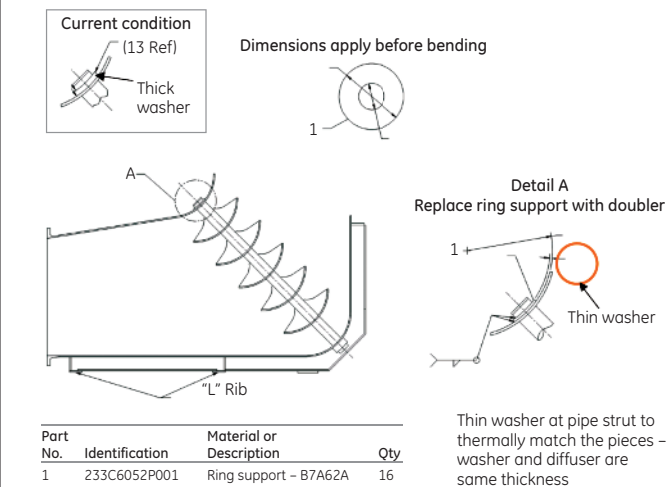


Gusset modification ties turning vane rows 1 & 2 and 3 & 4 together between pipe struts for increased stiffness and reduced cracking.

Drawing updated to detail vane segment weld requirements with full penetration weld and liquid penetrant inspection.

7EA aft diff turning vanes, gusset added, model anal. 600F

Figure 29. Cracking in CHROEM 9E aft diffuser is reduced by pipe gussets that increase stiffness of turning vanes.



Current condition (13 Ref)

Thick washer

Dimensions apply before bending

1

Detail A

Replace ring support with doubler

1

Thin washer

"L" Rib

Thin washer at pipe strut to thermally match the pieces - washer and diffuser are same thickness

Part No.	Identification	Material or Description	Qty
1	233C6052P001	Ring support - B7A62A	16

Figure 30. In CHROEM 9E aft diffuser, the washers securing turning vanes have reduced thickness to decrease thermal mismatch, lower stress, and avoid cracking.

The modern design exhaust frame is cooled through the use of two motor driven centrifugal blowers. An inlet screen and an inlet silencer are provided with each blower, and the discharge of each passes through a check valve before entering the exhaust frame through four inlet ports. The cooling air splits to flow through the turbine shell for cooling and to flow via the exhaust frame strut passages to purge the load tunnel and to cool the third aft wheel space.

An upgrade to exhaust frame blowers with a 100 HP rating may be required to obtain the elevated exhaust temperature capability needed to get the full benefit of a 2055°F (1124°C) firing temperature increase. Upgrade kits include 100 HP exhaust frame blowers, interconnection piping arrangement modifications, motor control center modifications, and exhaust frame cooling circuit tuning. Upgrading the exhaust frame blowers is applicable to units with the modern design exhaust frame that do not have 100 HP rated blowers. All 7EAs and 9Es have the modern design. Some early model 7E units also have the modern design exhaust frame and cooling circuit.

For 7B, 7E, and 9B units, see FS1W for the exhaust frame blower addition/upgrade and exhaust frame upgrade. These units either have an older cooling design that uses blowers for the exhaust frame cooling with the third aft wheelspace cooling air provided from the #2 bearing, or these units have educator style cooling using 11th stage compressor extraction air for the exhaust frame cooling, with the third aft wheelspace cooling air provided from the #2 bearing. Generally, the cooling circuit can be determined by looking at the cooling and sealing schematic.

When the exhaust frame cooling air circuit is upgraded, the compartment ventilation system needs to be studied. A gravity louver (suction inlet at lower position) is recommended in the case that a turbine compartment is changed from positive pressure to negative pressure. The ventilation of the load compartment and the isolation wall for the generator needs to be reviewed so that hot gas from the turbine compartment is not drawn into the load compartment or generator cooling circuit.

FW3N – Exhaust Aft Diffuser Upgrades MLI 0706 (6FA, 7F–FA+, 9F/FA)

This upgrade applies to all F-Class units in Frames 6FA, 7F, 7FA, 7FA+, 9F and 9FA that shipped before July 1997. Technical Information letter TIL-1230-2 forms the basis for this upgrade

package. The purpose of this TIL based upgrade is to avoid liquid leakage. The scope of supply includes the following:

- Weld leading edge of flow shield as shown in modification drawings
- Apply clips to trailing edge of flow shield
- Disassembly and re-assembly is to be done in accordance with GE service engineering procedures
- Review existing strut profile and other factors for potential component upgrades

In addition to FW3N, early manufactured Frame 9F/FA aft diffusers and exhaust diffuser ducts have further upgrade options available upon request made to Applications Engineering. This additional upgrade extends the service life of the aft diffuser and also the diffuser duct.

Plenums and Flex Seals

Operators can request a latest design exhaust plenum replacement assembly from the CHROEM team at GE. Exhaust plenums and systems have undergone continuous design improvements to produce a modern system of internally insulated ductwork that minimizes stresses from high thermal gradients. See *Figure 31* for an illustration of the plenum, with and without the exhaust frame assembly.

Improved insulation with increased insulation thickness on the floor and sidewalls are used in the CHROEM design. This reduces

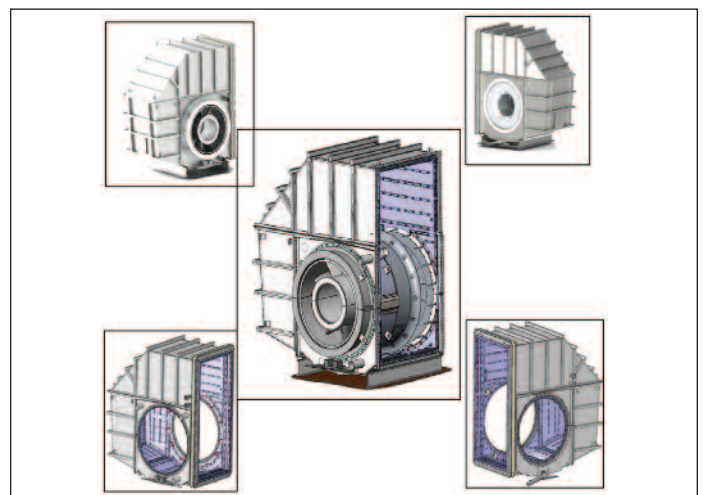


Figure 31. CHROEM exhaust plenum containing exhaust frame assembly (7EA shown as example).

the wall and floor temperature, and prevents the insulation from becoming dislodged or over-compressed. The densified insulation in the CHROEM design is packaged differently to withstand higher temperatures and to fill any gaps that might exist in walls. This insulation is capable up to very high temperatures to reduce thermal stress and fatigue cracking. Also, the previous design used a wool-based insulation that would break down from the heat and become less effective over time. The compressed insulation in the CHROEM design is packaged differently to withstand higher temperatures and to fill any gaps that might exist in walls. Also, the floor insulation of CHROEM design plenums is now improved and thickened to eliminate overheating of the concrete and cabling.

In the CHROEM design the joints are seal welded to minimize leaks from the connection points. This requires more work during the installation, but with the added insulation, the opportunity for leaks and cracking is greatly reduced. Flanges are field insulated to provide a cooler design with less distortion and therefore better sealing efficiency. *Figure 32* gives highlights of the important new design features.

Also, note that the cold flange to hot flange design expansion joint design is not optimum, and not preferred or advised. Cold flange to hot flange expansion joints are best re-designed and replaced to remove the cold-to-hot extreme transitions. However, outage time and financial resources may be substantial to accomplish this replacement, especially in those cases where physical space is limited and ductwork has to be re-configured.

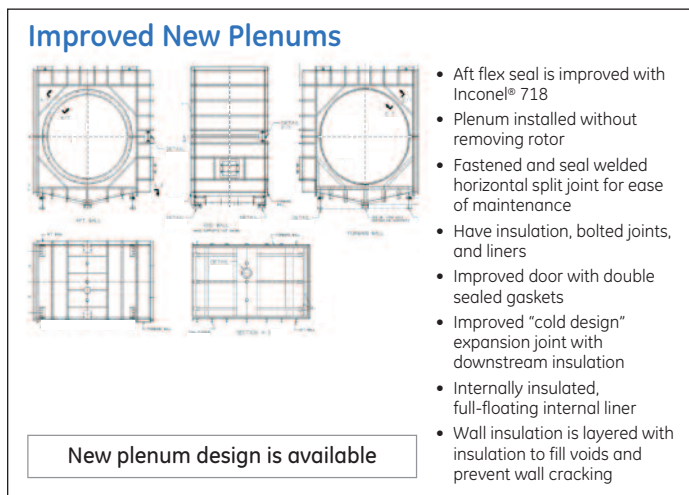


Figure 32. The CHROEM improved designs offered by GE.

The net benefit is reduced maintenance costs and greater reliability and availability.

GE supplies plenums of all frames in a left-hand side out or a right-hand side out, or a vertical configuration—depending on the configuration at site. As an example, *Figure 33* illustrates some of these for Frame 5.

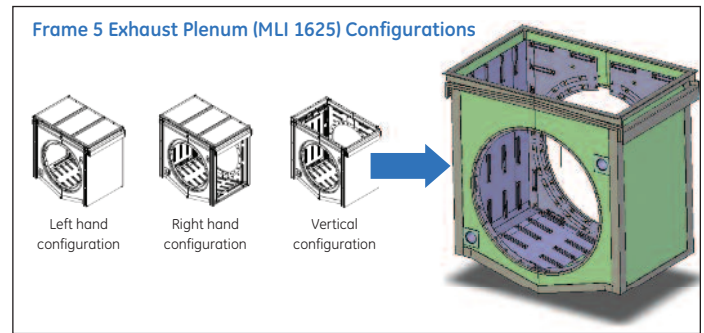


Figure 33. The CHROEM improved design is available in different configurations (Frame 51P shown as example).

FD4H – Exhaust Plenum Upgrades

(32A-K, 51A-R, 52A-C, 61A/B, 71A-EA, 91B/E, 6FA, 7F-FA+, 9F/FA)

CHROEM exhaust plenum assembly components are designed for installation with the turbine rotor and aft diffuser in place, saving both time and installation costs. The new CHROEM exhaust plenums are improved in the main areas of plenum design illustrated in *Figure 34*.

CHROEM plenum assemblies portrayed in *Figure 35* and *Figure 36* contain a combination of the following:

- Sidewalls, wing and cowl, insulation, flex seals, radiation tubes, optional jacking port, floating stainless steel liner, double sealed access door, improved insulation with increased thickness on floor and sidewalls, capability to field install insulation at all joints, and stainless steel interior skin. The insulating liner system reduces skin temperatures by 80% in some locations. Field liner that interfaces with the existing downstream duct liner. “Cold flange” design. Dual drain design. Improved compressor bleed pipe design.
- Expansion joint with field lagging to exhaust plenum. The expansion-joint is attached to the plenum with a cold-flange design and floating liner sheet that spans out over a recessed fabric expansion-joint and allows for thermal movement and

Frame	CHROEM Plenum Design Improvements
Frame 3	<ul style="list-style-type: none"> • Removable maintenance door • Drainable liner floor • Cool shell and flange design • Design to be installed with turbine rotor and aft diffuser In place • Acoustic treatment of exterior wall • Internal floating liner design
Frame 5	<ul style="list-style-type: none"> • Design to accommodate compressor bleed pipes through the flex seals or plenum wall • Drainable liner floor • Cool shell and flange design • Design to be installed with turbine rotor and aft diffuser In place • Acoustic treatment of exterior wall • Internal floating liner design
Frames 6 & 7	<ul style="list-style-type: none"> • Drainable liner with optional jacking port • Double sealed wing door • Cool shell and flange design • Design to be installed with turbine rotor and aft diffuser In place • Internal floating liner design
Frame 9	<ul style="list-style-type: none"> • Drainable liner floor • Double sealed wing door • Cool shell and flange design • Design to be installed with turbine rotor and aft diffuser In place • Internal floating liner design

Figure 34. Upgraded design features of CHROEM exhaust plenum.



Figure 35. Frame 7E plenum during installation.

expansion while maintaining a sound aerodynamic gas-path. The fabric expansion joint is layered with Teflon® gas-seals and insulation in a design that has been tested and proven on many exhaust systems. The downstream side of the expansion joint provides a flexible bolting-flange that can be mated with a variety of existing equipment. Improved maintenance access design that can be installed with turbine rotor and aft diffuser in place. The plenum contains a “split” for ease of field installation while minimizing downtime. There is no need to decouple or remove the exhaust frame. This way the lower section or floor section can be installed under the turbine without having to move the turbine. This saves significant time during plenum replacement and facilitates access to the load compressor pedestal bearing. Note that plenum sections must be lift-capable around the exhaust stack support structure.

- The flex seals are improved in the new design. The new flex seals are improved using 304L stainless steel (E-Class) or Inconel (F-Class). The older design was deforming and allowing leaks to develop in this joint.
- The exterior casing plates are a minimum of 1/4-inch thick ASTM A36 carbon steel, while the interior liner material is ASTM 240 Type 409 stainless steel.
- Gasket material inside bolted flanges is used to minimize leaks from the connection points. This requires more work during the installation, but with the added insulation, the opportunity for leaks and thus cracks is reduced.
- A topcoat (supplied and applied by customer) of high temperature paint, i.e., Product 4700 Carboline® Thermaline®,

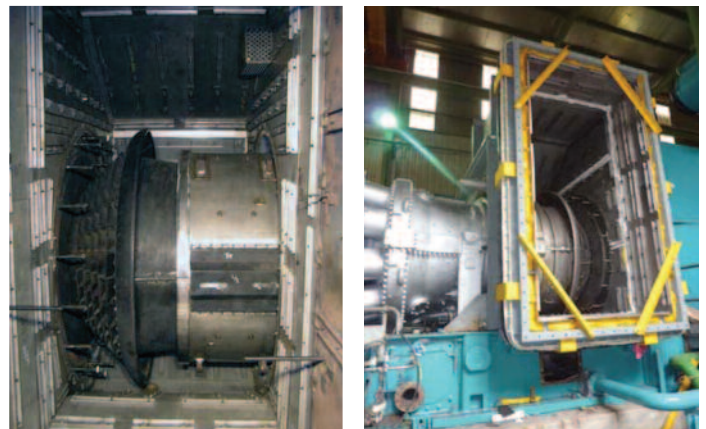


Figure 36. Installed 6B plenum and exhaust frame assembly.

is recommended following installation. The exterior of the carbon steel shell will have a zinc primer coating.

- Acoustic performance will be typically 85 dBA (near field) and 45 dBA (far field), but is not guaranteed
- Insulation in the duct walls is a newly specified calcia/magnesia silicate insulation, providing much better thermal protection of the outer shell than previous insulation.

Figure 37 illustrates the evolution of GE plenums from the first to the current generation (CHROEM). The latest designed plenums include: drainable liner floor with optional jacking port; double sealed wing door (E-Class); cool shell and cool flange; designed to be installed with the turbine rotor and aft diffuser in place (not removed); and an internal floating liner design.

The advancements achieved in the latest CHROEM design reduce thermal stress gradients, thereby leading to longer plenum life. External wall temperatures are greatly reduced (see Figure 38), leading to lowered temperature in adjoining compartments and increased reliability.

The expansion joint is attached to the plenum with a cold-flange design and floating liner sheet that spans out over a recessed fabric expansion joint and allows for thermal movement and expansion while maintaining a sound aerodynamic gas-path. The fabric expansion joint is layered with Teflon® gas-seals and insulation in a design that has been tested and proven on many exhaust systems. The downstream side of the expansion joint provides a flexible bolting flange that can be mated with a variety of existing equipment.

An internally insulated, floating-liner design is used throughout the plenum and ductwork system. This consists of liner sheets that are secured (but not laterally fastened) onto insulation that is compressed to optimum density between the liner plates and the plenum shell. Allowing the liner sheets to thermally move enables them to expand and contract throughout various stages of operation without encountering large thermal strain and stress that could buckle or distort them. The liner sheets are also installed in a “scaled” effect that allows liquids present within the exhaust plenum to exit the plenum through a supplied drain in its base. This draining motion greatly reduces the potential for saturation of the insulation, and greatly reduces any “slumping” effect that could lead to rotting insulation, or possible shell damage and hot-gas leakage.

The external gas-tight casing plate is maintained at temperatures only slightly above ambient, virtually eliminating thermal expansion problems. The internal liner is designed to “float” (See Figure 39) which eliminates stresses in the liner. The exterior casing plates are a minimum of 1/4-inch thick ASTM A36 carbon steel, while the interior liner material is ASTM 240 Type 409 stainless steel.

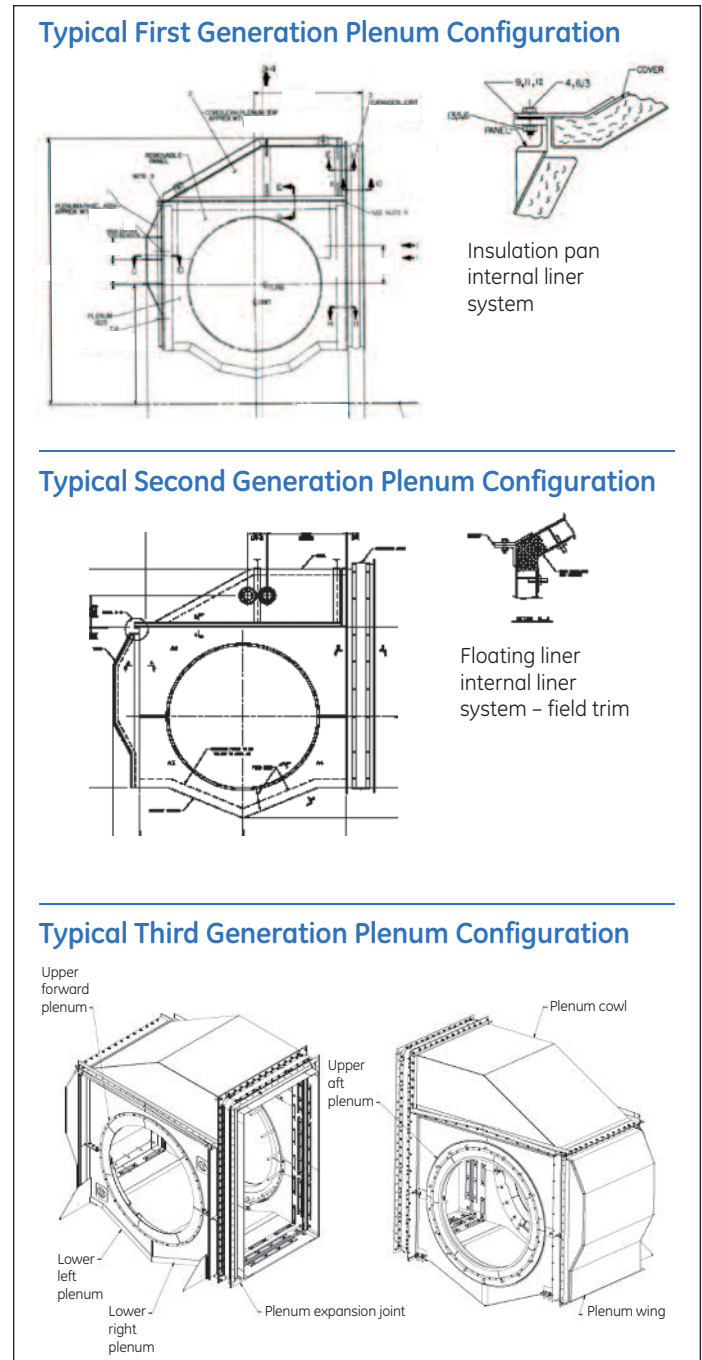


Figure 37. Evolution of 6B plenum from first to second to third (CHROEM) generation.

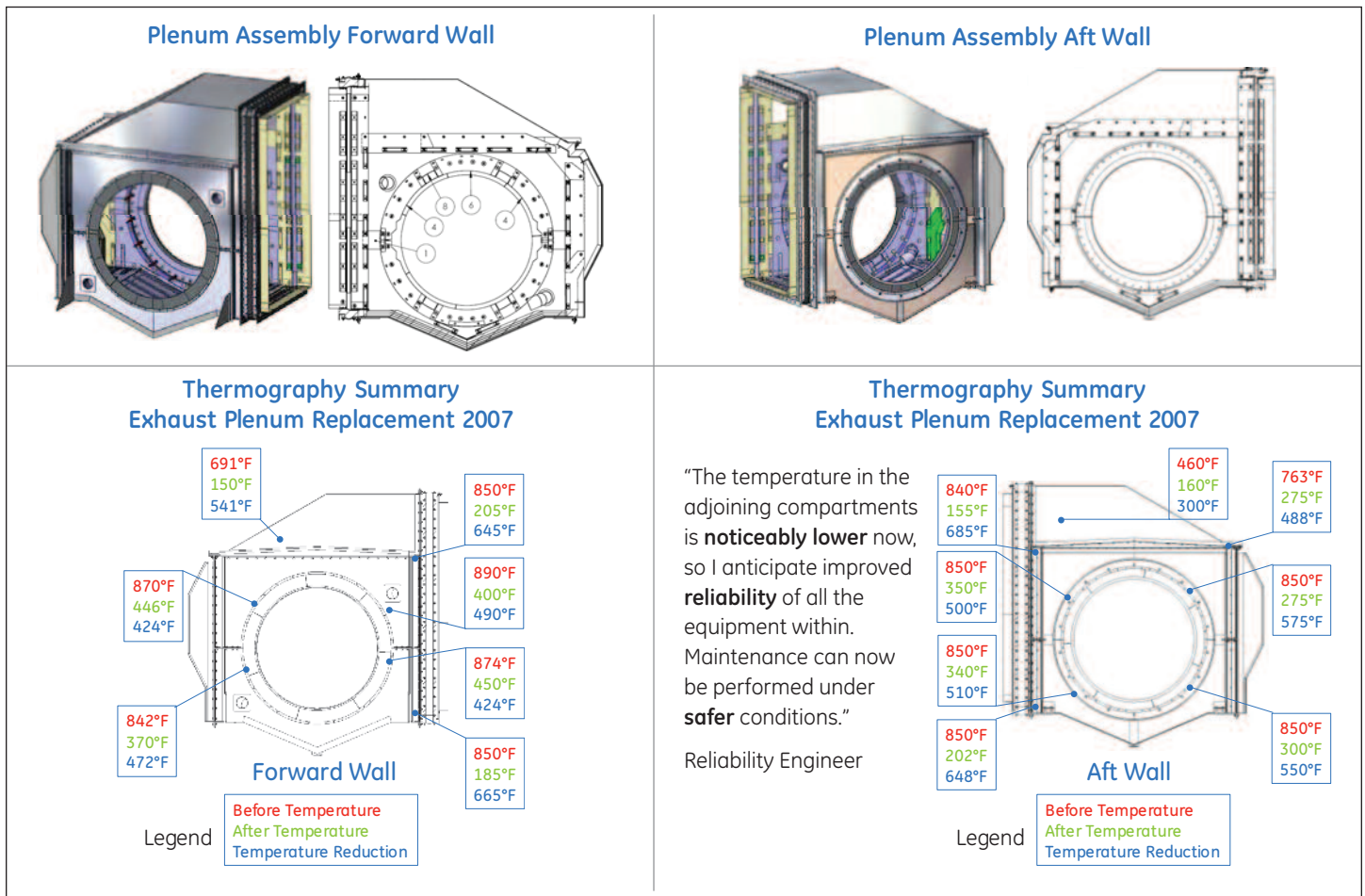


Figure 38. CHROEM design reduces plenum wall temperatures to reduce cracking (6B shown as example).

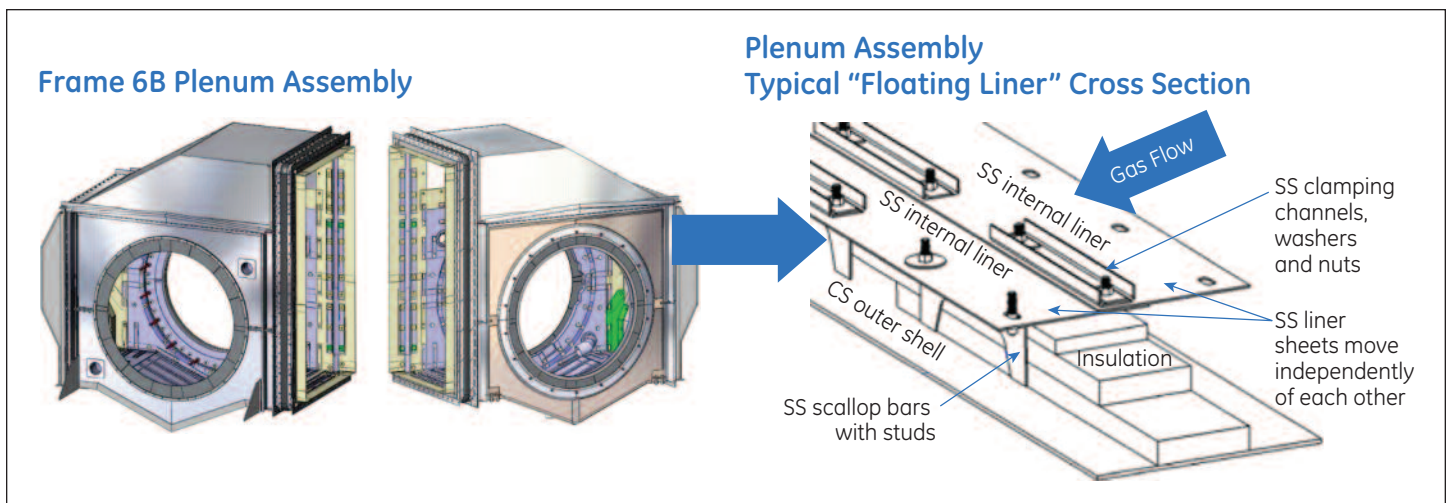


Figure 39. CHROEM designed plenums have a floating stainless steel internal liner (6B shown as example).

Exhaust systems can be re-designed to sit on foundation locations to match the current acoustic and pressure drop performance. Improvements in these areas can be reviewed accordingly to determine if improvements are possible. All efforts are to be made to utilize the existing foundation. However, foundation changes to accommodate a new exhaust system will be studied in detail, and any quantification of changes needed will be provided to customers when a replacement exhaust system is being offered.

Figures 40–43 illustrate the design details in the advanced CHROEM exhaust systems available.

E-Class plenums supplied by GE include: an improved drain to reduce moisture; a removable rain gutter for ease of maintenance; improved flex seals (forward and aft); and improved expansion joint. (See Figures 44–47 for illustrations of these improvements for the 6B as an example.)

Aft Wall Design Improvement in 6B

The failure of the bolting at the horizontal splice in the aft wall of the exhaust plenum was a result of a high differential temperature between the flex seal mounting bar and the bolting flange. The

Improved New Plenum

- Wall insulation is layered with insulation to fill voids to reduce leakage and thermal gradients
 - New design eliminates cracking of walls
 - Old design mineral wool insulation deteriorated and formed gaps allowing hot gas to overheat plenum walls, and cause cracking
 - New design plenum has ceramic insulation with higher temp capability
- Aft flex seal is improved
 - New design seals are Inconel 718 with new mounting that decrease cracking and has less leakage
 - Old design deformed and allowed leaks
- Bolted joints have insulation under liners
 - New design minimizes leaks from connections and has more insulation to avoid thermal gradients and reduce cracks
 - Seal welds made inside and outside of joints
 - Old designs used a hot-flange design which could leak

Reduced maintenance

Figure 40. The advanced CHROEM designs offered by GE reduce maintenance.

temperature difference led to a thermally induced strain at the bolt exceeding the bolt capacity. The factory-installed plenums do not experience bolt failures in the aft wall because:

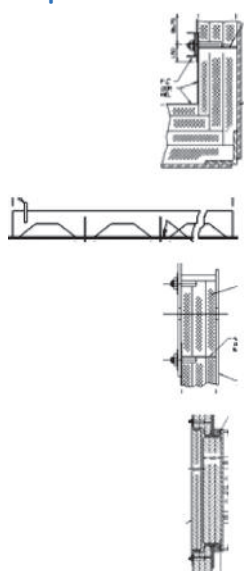
Improved New Plenum

- Internally insulated, full-floating internal liner
 - Liner sheets sandwich insulation against outer shell
 - Joints have liner over insulation
 - “Floating” liner design allows thermal movement with reduced stress
 - Greatly reduces cracking and improves insulation retention
 - Shingled design allows liquids to drain easily
 - Improved drainage reduces liquid build-up, prolongs insulation life
- Improved expansion joint
 - Expansion joint is “cold flange” design with downstream insulation
 - Similar to current offering on 7EA
 - Keeps joint cooler and extends operational life

Installed without removing rotor

Figure 41. The advanced CHROEM designs offered by GE are installed without removing rotor.

Improved New Plenum



- Corners are completely layered with insulation to reduce leakage and thermal gradients
- Internal supports are scalloped to reduce temperature of shell
- Insulation is layered into all areas of wall
- Access door has double insulation

Outer wall temp and cracking are reduced


Figure 42. The advanced CHROEM designs offered by GE have reduced cracking.

- There is no split in the material of the plenum aft wall (needed for field installation)
- The thermal gradients are dissipated more uniformly, and the high strains are not concentrated at a point in the wall

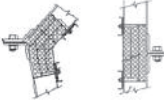
The new plenum design reduced the thermal gradients in the flex seal area by minimizing the direct conduction paths through the TC disk supports.

CHROEM Exhaust Plenums

Component Flange Connection



1st Generation



2nd and 3rd Generation

Pan design – “hot flanges”

- Exposed surfaces of the pan do not thermally grow consistent with the outer perimeter, thereby causing distortion along the perimeters of the pans. Gaps occur between pans, allowing hot exhaust gases to outer shell and causing distortion and cracking of the outer shell and bold distress flanges.

Floating liner design – “cold flanges”

- Utilizes field installed wrapped insulation pillows and liner plates. Creates a continuously “sealed” insulation thermal barrier, thereby creating a “cooler” interface. Liners are secured with double-nuts for ease of removal during maintenance.

Figure 43. The advanced CHROEM designs offered by GE have cold flanges for reduced cracking.

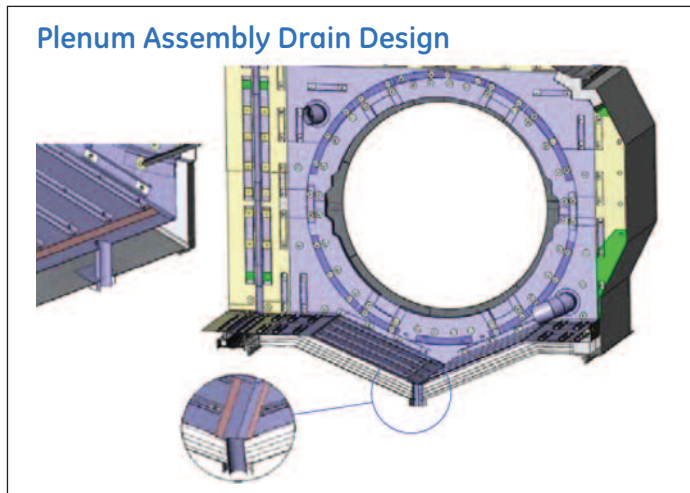


Figure 44. The advanced CHROEM designs offered by GE have an effective draining design.



Figure 45. The CHROEM designs offered by GE have a removable rain gutter for ease of maintenance.

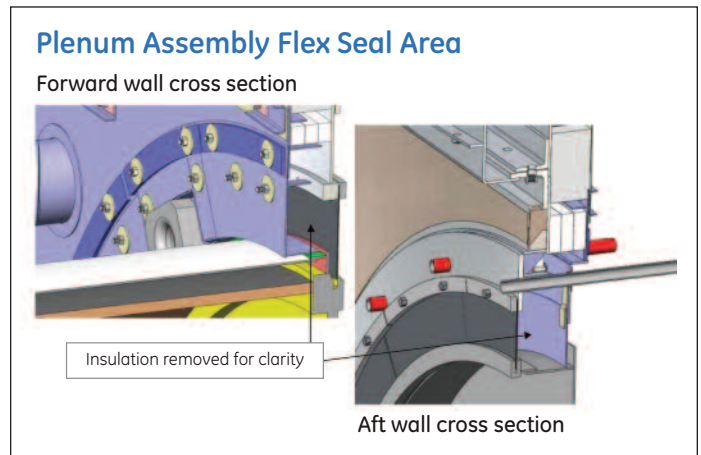


Figure 46. The advanced CHROEM designs offered by GE have improved flex seals.

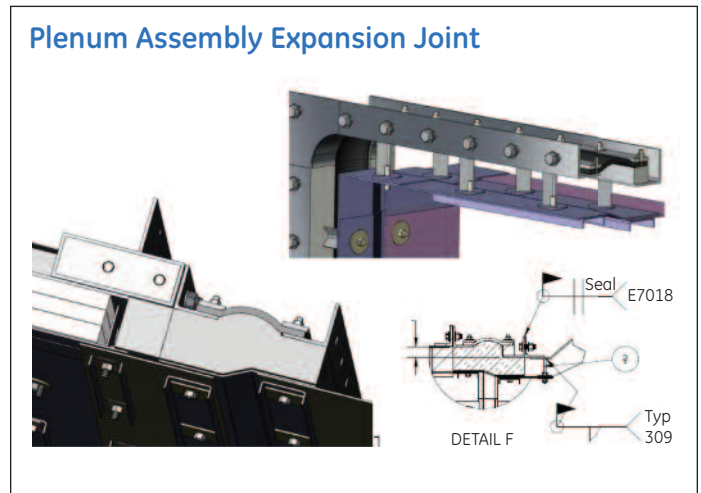


Figure 47. The advanced CHROEM designs offered by GE have an improved expansion joint.

Forward Wall Design Improvement in 6B

- High thermal gradients existed in the forward wall of the plenum due to lack of protection against direct hot gas and radiation exposure
- Failures of the horizontal bolting in the forward wall occurred for the same reasons described for the aft wall.
- Additional liners and insulation that extend and interface with the diffuser outer barrel reduce the flex seal mounting area exposure to the hot internal environment, and reduce the thermal gradients experienced on the forward plenum wall.

FD4H – Exhaust Flex Seal Upgrades (61A/B, 71A-EA, 91B/E)

The CHROEM program at GE has provided additional enhancements in the flex seal areas. (See *Figure 48*.) Customer surveys of the exhaust plenum identified problems that existed in the area of the forward and aft flex seals due to excessive surface temperatures. GE analyzed the design in the area of the flex seal mounting for both the forward and aft wall. The

evaluation concluded that the plenum configuration allowed for excessive heat transfer and high thermal stress in the structural portion of the plenum. Fractures were occurring due to the thermo-mechanical response of the equipment during transient and even steady state conditions. These areas have been improved by leveraging proven design technology from 7EA and 9E. Field experience has proven the effectiveness of this new design and has validated the integration of this design into the other frames and models.

If the current flex seals are leaking, then upgrading to the latest designs offered by GE is advisable. However, an older exhaust plenum may continue to distort after the new seals are installed, and there could be significant wear and cracking in the near future of newly installed flex seals. Therefore, it is recommended that the customer request and purchase a new exhaust plenum together with the latest and improved flex seal design. Otherwise, the flex seals may develop leaks in the near future due to ongoing distortion of the plenum. This is the best method to ensure the turbine and load compartments do not overheat.

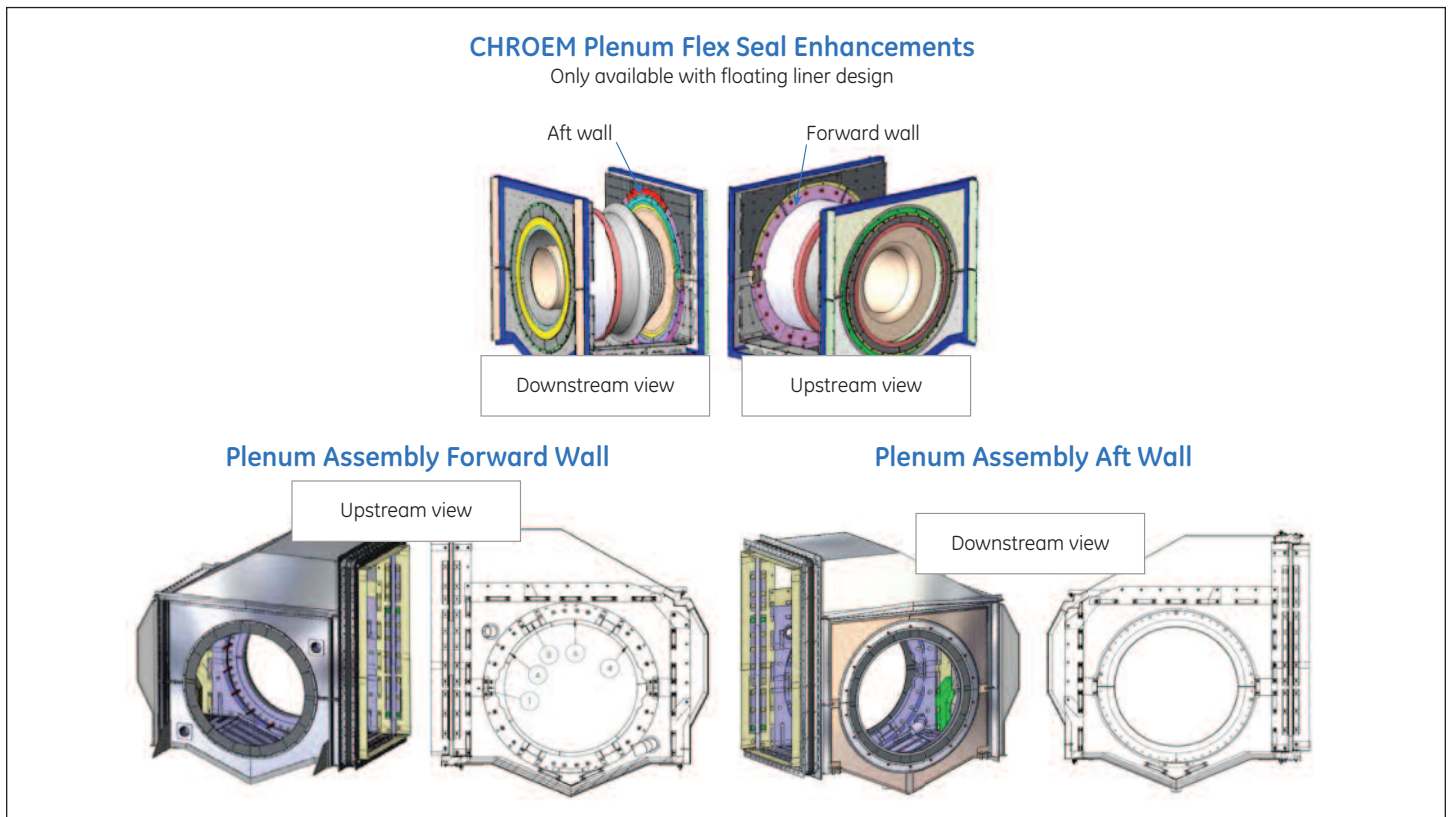


Figure 48. The CHROEM designs offered by GE have improved flex seals (6B shown as example).

FD4H – Engineering Site Visits

GE specialists in ducting and plenums are available to visit customer sites. Data will be gathered and an improved preliminary design prepared and proposed to the customer. Design consideration will be made to ensure that hot spots are cooled to reduce thermal strain, thereby increasing service life. The modification scope for each customer is dependent on the needs of their particular site as determined by the customer site visit and the preliminary design study. In some cases, customers only need a direct replacement of their existing plenum. In others, a completely new design is needed and applied.

Ductwork, Stacks, and Silencers

The exhaust system ductwork is used to direct the exhaust of a gas turbine through a silencer section and exhaust stack to the atmosphere or directly to HRSG. This helps to provide for atmospheric safety and contributes to meeting acoustic emissions requirements. It is made up of long ductwork sections rectangular or round in cross-section and up to 200 feet (61 m) in height. (See *Figure 49*.) Several ductwork layout configurations are possible (e.g., straight up; left side and up; right side and up; left side aft and up; right side aft and up; left side forward and up; right side forward and up; and straight aft)—all with varying duct lengths.

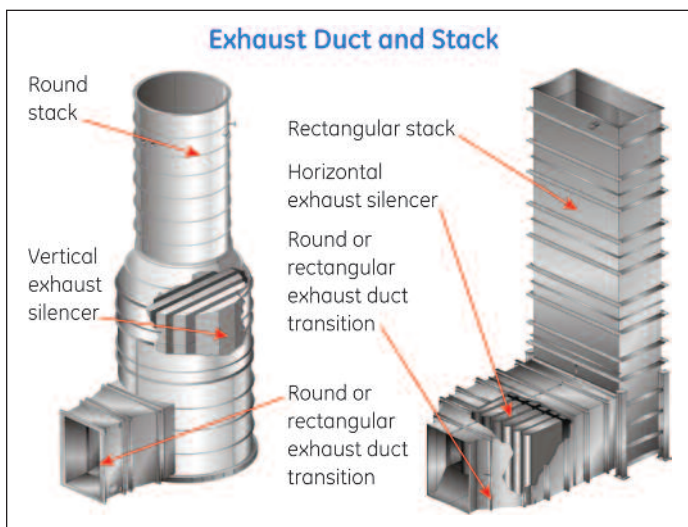


Figure 49. Advanced CHROEM duct and stack with silencers.

FD6G-K and FD4H – Exhaust Duct, Stack, and Silencer Upgrades (32A-K, 51A-R, 52A-C, 61A/B, 71A-EA, 91B/E, 6FA, 7F-FA+, 9F/FA)

The plenum and ductwork are typically internally insulated with the following sandwich construction:

- External carbon steel plate skin (minimum 1/4")
- Minimum 4.0" thick calcium/magnesium silicate insulation
- Internal stainless steel liner sheets
- Structural steel is welded to the duct exterior

Ductwork and stack sections bolted and are welded together in the field. (See *Figure 50*.) Ductwork is linked to the exhaust plenum with an expansion joint. The expansion joint compensates for misalignment and thermal growth of the ductwork. The compressed calcium/magnesium silicate insulation is capable up to very high temperatures, and internal liners are full floating. This reduces thermal stress and results in reduced cracking. The net benefit is reduced maintenance costs and greater reliability and availability.

An internally insulated, floating-liner design is used throughout the stack and ductwork system. This consists of liner sheets that are secured (but not fastened laterally) atop of insulation that is compressed to an optimum density between the liner plates and the outer shell. The fact that the liner sheets are not fastened enables them to expand and contract throughout various stages of operation without encountering large material stress/strains that would arise if the sheets could not float. The liner sheets are also installed with a "scaled" effect that allows any liquids present within the exhaust duct to exit the duct through a supplied drain. This draining motion greatly reduces the potential for saturation of the insulation and greatly reduces any "slumping" effect that could lead to rotting insulation or eventual shell damage and possible hot-gas leakage. Due to the above changes, GE exhaust duct and systems offer superior thermal-growth flexibility.

The ductwork contains a silencer section to muffle the gas turbine noise. (See *Figures 51 and 52*.) Silencer panels can have a radius bull nose on the leading edge of the panels and some have tapered tails on the trailing edge to help reduce pressure drop across the exhaust system. The customer must provide the location of any additional ports, and the customer is responsible for environmental permitting.

Acoustic requirements (i.e., for maximum 85 dB at 3 ft (0.9 m) and 65 dB at 400 ft (122 m)) can be yielded in theoretical calculations by GE for the unit theoretically operating with the new plenum, stack, and silencer. If theoretical calculations show that additional silencing is needed to achieve customer requirements, then additional stack height or more silencing would be options available. Sound pressure levels actually measured in dB are not guaranteed, however, supplied components will yield the customer goal in theoretical calculations. Operators have the option of purchasing additional silencing to result in the goal being met in theoretical calculations.

A simple cycle exhaust system simply carries the hot exhaust gases from the turbine through the ductwork and silencer section and releases them to the atmosphere through an exhaust stack where the heat energy is lost. A combined cycle exhaust system carries the hot exhaust gases from the turbine through the ductwork and silencer to a heat recovery steam generator (HRSG) where the heat energy is captured to make steam that powers a

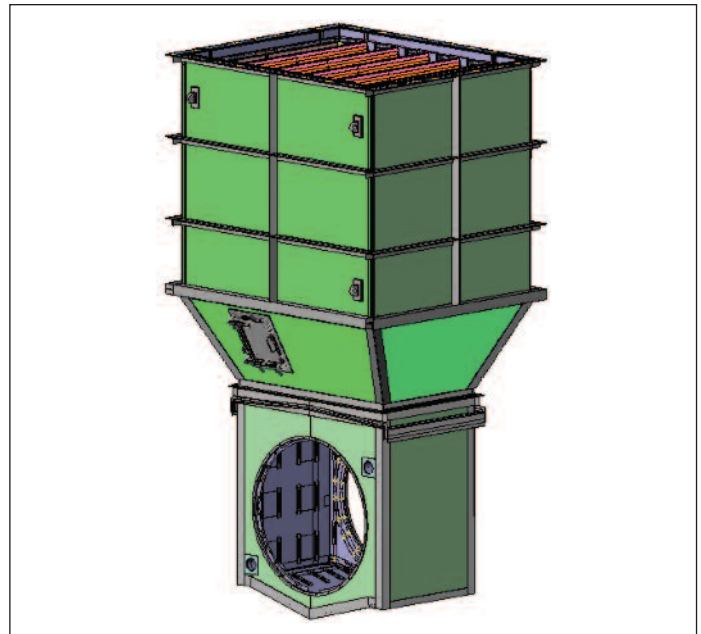


Figure 51. Frame 5 exhaust stack with silencers shown positioned above a vertical split plenum.

Exhaust Duct and Stack

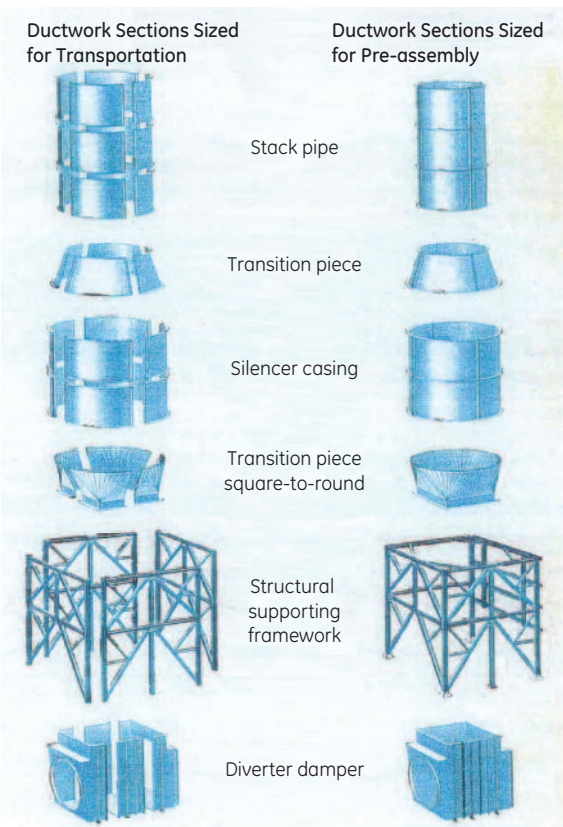
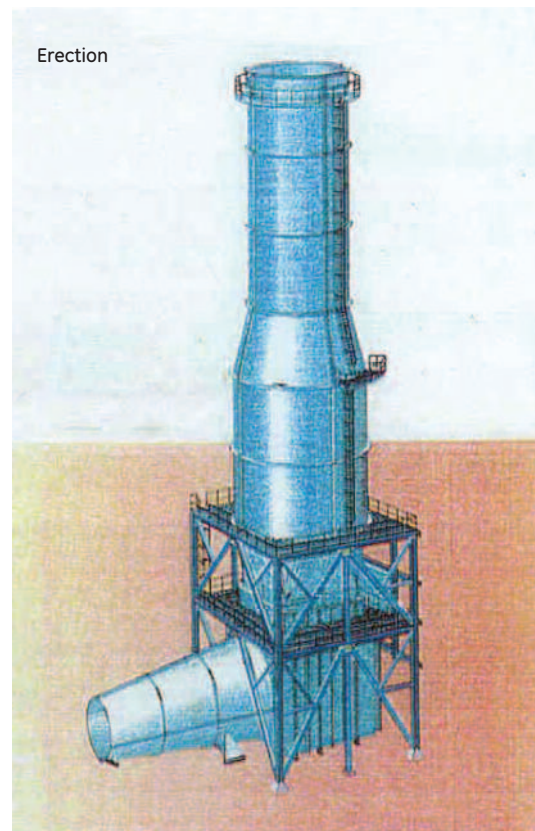


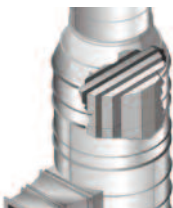
Figure 50. Overview of weldments in the duct and stack.



Exhaust Silencer

Exhaust silencer reduces exhaust noise by 20-30 dBA:

- The noise from a jet fly-by at 1000 ft (100-110 dBA)
- The sound of a car passing at 65 mph at 25 ft (70-80 dBA)



Silencer section up to 24 feet in diameter for 7FA 9B or 131 feet high for 7FA (or customer requirement)

Figure 52. GE offers silencers to all customers.

steam turbine. An option is available with a diverter box in the ductwork where the customer can divert the exhaust gases to the HRSG for combined cycle mode, or can choose to divert the gases to the atmosphere through a bypass stack in simple cycle mode.

Summary

GE offers CHROEM upgraded exhaust components or entire systems available for all GE heavy-duty turbines in the field. GE also offers installation that can be done during scheduled outages. GE is pleased and freely available to provide detailed technical proposals and quotes for owners of GE gas turbines, and to establish reliability improvements for those specific turbines at our customers' sites. CHROEM systems are available from GE for combined cycle (CC), cogen, or combined heat and power (CHP).

An example of GE's advanced exhaust system is shown in *Figure 53*, illustrating the improved aft diffuser and plenum available for increased performance on 6581B frame 6B units that have higher firing temperature than 6561B units.

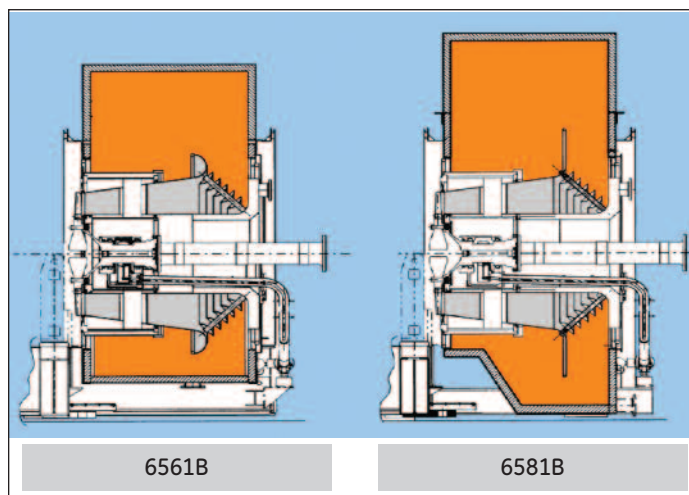


Figure 53. Higher firing temperature 6581B units have improved exhaust and increased performance as compared to 6561B units (combined cycle and cogeneration configuration shown as example). Similar advanced exhaust system (improved aft diffuser and plenum) is applied on PG9171E new units since 2003.

- GE Energy offers advanced CHROEM exhaust systems available to operators of GE Heavy-Duty Gas Turbines to improve their reliability under increased performance
- CHROEM exhaust components are available to increase maintenance intervals and reduce repair costs.

References

Electronic versions of a GER document are available gratis to GE customers at the following link: http://www.ge-energy.com/prod_serv/products/tech_docs/en/all_gers.htm

1. TIL-479C: Exhaust Diffuser Bolt and Nut Substitution
2. TIL-476C: Exhaust Temperature Spread Guidelines
3. TIL-519C: Exhaust Diffuser Inspection and Repair
4. TIL-440C: Exhaust Diffuser Doubler Plate
5. TIL-438C: Exhaust Material Replacement
6. TIL-509C: Starting Turbine Maximum Exhaust Pressure
7. TIL-482A: Exhaust Diffuser Turning Vanes
8. TIL-403C: Allowable Rejected Exhaust Thermocouples
9. TIL-354C: Exhaust Plenum Retainer Plates
10. TIL-550C: Exhaust Frame Blowers
11. TIL-543C: Exhaust Plenum Insulation Retainers
12. TIL-536C: Exhaust Diffuser Horizontal Flange
13. TIL-261: MS5000 Exhaust Plenum
14. TIL-142: Series 5000 Gas Turbines With Exhaust Plenums
15. TIL-1136-3: MS7001 Exhaust Plenum Anchor Bolt Modification
16. TIL 1555-R2: Pre-Discharge Alarm Required for MLI A102 Exhaust Enclosure
17. TIL 1560: Exhaust Spread Protection Calculation
18. TIL-1062-2: MS9001e Turbine Shell/Exhaust Flange Slippage
19. TIL 1617: MS9001E Turbine Shell to Exhaust Frame Flange Slippage
20. TIL 1230-2: Exhaust Diffuser Upgrade
21. TIL-1030-3A: Exhaust Temperature Allowable Spread
22. TIL 1267-2: Exhaust Frame Blower Aluminum Wheel Replacement
23. TIL 1358-2: 7EA Six-Segment Exhaust Temperature Control Curves
24. TIL 1415-3: MS6001B Lateral Exhaust Re-Alignment Procedure
25. TIL 1436-1A: Exhaust Silencer Panel Ceramic Fill Material Loss
26. TIL 1445-2: 3-Way Valve Exhaust Port Plugging Issues
27. TIL 1513-2: Upper Exhaust Hood End Wall Modification
28. TIL 1551-2: 6B Exhaust Plenum Modification on Units without Vertical Exhaust
29. GER-3569: Advanced Gas Turbine Materials and Coatings
30. GER-3620L: Heavy Duty Gas Turbine Operating and Maintenance Consideration
31. GER-3571: Performance and Reliability Improvements for Heavy-Duty Gas Turbine
32. GER-4196: Performance and Reliability Improvements for the MS5001 Gas Turbines
33. GER-4171: Performance and Reliability Improvements for the MS5002 Gas Turbines
34. GER-4217: Uprate Options for the MS6001 Heavy Duty Gas Turbine
35. GER-3808: Uprate Options for the MS7001 Heavy Duty Gas Turbine
36. GER-4217: Uprate Options for the MS9001 Heavy Duty Gas Turbine
37. GER-3571: Performance and Reliability Improvements for Heavy-Duty Gas Turbines

List of Figures

Figure 1. Corrosion and Heat Resistant Original Equipment Manufacturer (CHROEM) improved exhaust systems offered by GE

Figure 2. General nomenclature for exhaust components (Frame 9E shown only as an example).

Figure 3. Typical F-Class MLI A042 Arrangement

Figure 4. Typical E-Class MLI A042 and 1625 arrangement shown in right hand configuration

Figure 5. Typical 51 and 52 unit MLI 1625 Arrangement

Figure 6. GE Engineers are available to visit sites and recommend exhaust upgrades.

Figure 7. CHROEM upgraded designs offered for various Model List Items (MLI), including MLI 1625 as shown.

Figure 8. Exhaust upgrade packages available in CHROEM technology.

Figure 9. Illustration of CHROEM 7EA exhaust frame with aft diffuser

Figure 10. Example of CHROEM plenum assembly offered by GE.

Figure 11. CHROEM floating liner plenum and exhaust frame with aft diffuser

Figure 12. CHROEM exhaust duct and stack in circular and rectangular configurations

Figure 13. Illustration of exhaust frame, aft diffuser, and plenum

Figure 14. Illustration of F-Class exhaust frame, aft diffuser, and plenum.

Figure 15. Benefits of exhaust frame upgraded assemblies

Figure 16. Exhaust frame cooling flow circuit in 7EA

Figure 17. Frame 5 exhaust frame assembly illustration

Figure 18. Typical configuration of 7EA and 9EA

Figure 19. 7E exhaust frame cooling circuit

Figure 20. 7B exhaust frame cooling circuit

Figure 21. 7B modified exhaust frame and cooling circuit

Figure 22. 7E modified exhaust frame and cooling circuit

Figure 23. Comparison of cooling air flows in 7E versus 7EA exhaust frame assemblies

Figure 24. Improved design "floating tail" in 7EA advanced CHROEM exhaust frame

Figure 25. Advanced CHROEM PG6581B aft diffuser has increased dimensions

Figure 26. CHROEM 7EA exhaust frame and aft diffuser in latest design configuration

Figure 27. CHROEM frame 9E exhaust frame assembly

Figure 28. Elimination of structural ribs in CHROEM 9E diffuser avoids circumferential cracking in ribs

Figure 29. Cracking in CHROEM 9E aft diffuser is reduced by pipe gussets that increase stiffness of turning vanes

Figure 30. In CHROEM 9E aft diffuser, the washers securing turning vanes have reduced thickness to decrease thermal mismatch, lower stress, and avoid cracking

Figure 31. CHROEM exhaust plenum containing exhaust frame assembly and (7EA shown as example)

Figure 32. The CHROEM improved designs offered by GE

Figure 33. The CHROEM improved design is available in different configurations (Frame 51P shown as example)

Figure 34. Upgraded design features of CHROEM exhaust plenum.

Figure 35. Frame 7E plenum during installation.

Figure 36. Installed 6B plenum and exhaust frame assembly.

Figure 37. Evolution of 6B plenum from first to second to third (CHROEM) generation

Figure 38. CHROEM design reduces plenum wall temperatures to reduce cracking (6B shown as example)

Figure 39. CHROEM designed plenums have a floating stainless steel internal liner (6B shown as example).

Figure 40. The advanced CHROEM designs offered by GE reduce maintenance

Figure 41. The advanced CHROEM designs offered by GE are installed without removing rotor

Figure 42. The advanced CHROEM designs offered by GE have reduced cracking.

Figure 43. The advanced CHROEM designs offered by GE have cold flanges for reduced cracking

Figure 44. The advanced CHROEM designs offered by GE have an effective draining design

Figure 45. The CHROEM designs offered by GE have a removable rain gutter for ease of maintenance

Figure 46. The advanced CHROEM designs offered by GE have improved flex seals

Figure 47. The advanced CHROEM designs offered by GE have an improved expansion joint

Figure 48. The CHROEM designs offered by GE have improved flex seals (6B shown as example).

Figure 49. Advanced CHROEM duct and stack with silencers

Figure 50. Overview of weldments in the duct and stack

Figure 51. Frame 5 exhaust stack with silencers shown positioned above a vertical split plenum

Figure 52. GE offers silencers to all customers

Figure 53. Higher firing temperature 6581B units have improved exhaust and increased performance as compared to 6561B units (combined cycle and cogeneration configuration shown as example). Similar advanced exhaust system (improved aft diffuser and plenum) is applied on PG9171E new units since 2003.



* Denotes trademark of the General Electric Company.

COR-TEN® is a registered trademark of United States Steel.

INCONEL® is a registered trademark of the Special Metals Corporation.

Teflon® is a registered trademark of E. I. du Pont de Nemours and Company.

Carboline® and Thermaline® 4700 are registered trademarks of the Carboline Company.

©2012, General Electric Company. All rights reserved.

GER-4610 (4/2012)