GAS TURBINE ASSOCIATION

26 Aug 2004

Air Docket
United States Environmental Protection Agency
Mail Code: 6102T
Room: B108
1200 Pennsylvania Ave. NW
Washington DC 20460

Attention: Docket ID No. OAR- 2002-0068 (Legacy Docket ID No. A-2002-04)

Re: *Comments on Prevention of Significant Deterioration (PSD) and Non-Attainment New Source Review (NSR): Equipment Replacement Provision of the Routine Maintenance, Repair and Replacement Exclusion; Reconsideration; Final Rule, 69 Fed. Reg. 40278 (July 1, 2004)*

Dear Sir or Madam:

EPA has requested input on reconsideration of three issues related to the Equipment Replacement Provision (ERP) promulgated on October 27, 2003. The ERP provision clarified when certain equipment replacements are excluded from the New Source Review (NSR) program, under the routine maintenance, repair and replacement (RMRR) exclusion provisions.

The three issues EPA has requested input on include:

1. The basis for determining that the ERP was allowed under the Clean Air Act
2. The basis for selecting the cost threshold (20 percent of the replacement cost of the process) that was used in the final rule to determine if a replacement was routine; and
3. A simplified procedure for incorporating a Federal Implementation Plan into state plans to accommodate changes to the New Source Review Rules

The Gas Turbine Association appreciates the opportunity to comment on the provisions. The Gas Turbine Association is an association of gas turbine equipment manufacturers whose role is to represent the gas turbine industry, and to provide relevant technical information needed for policy development. We believe that the basis for selecting the 20% cost threshold was proper and are concerned that lower thresholds would discourage important routine maintenance and replacement activities for a number of our sources across the country. Deferred or undone maintenance and replacement practices could negatively impact unit safety and also result in lower efficiency operation, thereby increasing emissions.

Turbines are owned by many commercial, industrial, and utility enterprises. These turbines are used for a variety of purposes such as power generation, gas pipeline compression, liquids pumping, and chemical process operations. They are manufactured in sizes that range from 1 MWe to power blocs larger than 250 MWe.

As highlighted in EPA's document: *Standards Support and Environmental Impact Statement Volume 1: Proposed Standards of Performance for Stationary Gas Turbines EPA-450/2-77-017, September 1977, Chapter 5,* Modification and Reconstruction, turbines require ongoing maintenance, repair and replacement. As stated in the above referenced document, EPA has concluded that these activities are "routine" and thus excluded from the NSPS modification and reconstruction provisions.

Some excerpts from this EPA document are below:

- 5.1.1 – ***Modifications*** – "paragraph (e) lists certain physical or operational changes which will not be considered as modifications, irrespective of any change in the emissions rate. These changes include: 1 – Routine maintenance, repair and replacement..."
- 5.1.2 – ***Reconstruction*** – "Section 60.15 states: If an owner or operator of an existing facility proposes to replace components, and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, he shall notify the Administrator of the proposed replacements. The notice must be postmarked 60 days (or as soon as practicable) before construction of the replacements is commenced..."
- 5.2.1 – ***Applicability to Gas Turbine Installations*** – General: "Most turbines are designed for 20,000 to 40,000 operating hours between overhauls.
- 5.2.2 – ***Modification*** – "The following physical or operational changes will not be considered as modifications to existing turbines: a. Changes determined to be routine maintenance, repair, or replacement in kind. This will include repair or replacement of stator blades, turbine nozzles, turbine buckets, fuel nozzles, combustion chambers, seals and shaft packings. .. The impact of the modification provision on existing gas turbines should be very slight."
- 5.2.3 – ***Reconstruction*** – "It is difficult to apply the definition of reconstruction to a gas turbine because substantial portions of a turbine may be replaced as a matter of **routine maintenance** during normal overhauls as described in 5.2.1. Since it is current practice to replace substantial portions of turbines, it would be difficult to discriminate between a major overhaul that was performed to avoid the purchase of a new turbine and one that was performed in accordance with a routine maintenance program. **Such routine maintenance should be exempted from the regulatory consequences of becoming a reconstructed turbine, subject to the "50 percent rule**", discussed in 5.1.2." (emphasis added)

It is clear that from the NSPS document cited above that major overhauls, or major disassembly inspections on turbines occur routinely and that EPA clearly considered them to be exempt from New Source Performance Standards under the routine maintenance, repair and replacement exclusion provisions. Further, EPA states that routine maintenance should also be exempt from EPA's reconstruction provisions.

Importantly, since the NSR term "**modification**" came from the NSPS definition and since the NSR program, like the NSPS program, exempts "routine maintenance, repair and replacement" activities from NSR, *most agencies have appropriately considered major overhauls and other turbine maintenance to be "routine, maintenance, repair and replacement" for purposes of both NSPS and NSR*.

Indeed, if these operations were not exempt from NSPS and NSR, many critical industrial operations would be severely impacted, operating at reduced efficiency, while the operators stretch-out their maintenance intervals as long as possible. More likely, if normal gas turbine overhauls were not exempt from these provisions, neither turbines nor valuable cogeneration installations would have been installed in the first place, since the economic recovery period for such an installation is usually longer than 2 to 3 years. At any rate, overhaul maintenance activities are common, clearly required and have been recognized to be routine in the past.

Gas turbine manufacturers also recognize this, and typically specify a series of scheduled maintenance intervals. The shortest is usually being 8,000 hours. Manufacturers will specify the inspection and repair intervals based on a unique set of criteria that are appropriate for each type of engine. It is usually at the longest interval, somewhere between 30,000 and 50,000 hours where overhaul costs are the most significant. The expense for the maintenance overhaul will be influenced by the severity of the service, fuel type used, location, union vs. non-union personnel, and initial design features of the turbine (the use of high temperature alloys and ceramics which are costly, for example).

Premature failures, which are unpredictable, can also significantly shorten the inspection/overhaul interval. When this occurs, to minimize future downtime and expense, a complete overhaul is generally performed on the gas turbine, with inspections on equipment impacted by any of the potential turbine failure modes (such as the generator or the steam cycle).
In some cases a gas turbine will be used in a highly critical process application, where immediate redundancy is not available. A gas turbine failure in such an application can have severe consequences to the owner and potentially to the OEM. One solution is for the manufacturer (or the package supplier) to make available a temporary replacement unit from a lease pool for the owner to use while the original unit is repaired. Other manufacturers simply swap out the bad unit for functionally equivalent good unit allowing the bad unit to be fixed and ready for use when another unit fails... It should be noted that to minimize the expense of the maintenance and maximize the quality of repairs by providing well qualified personnel to inspect and maintain the turbines, most overhauls are done off-site at the manufacturer's recommended shop.

When considering the overhaul cost as a percentage of the initial investment costs, the figures can vary widely, because gas turbines are used in so many different applications. For a simple cycle gas turbine, the overhaul costs can exceed 20% of the initial investment. For a combined cycle power plant, those costs drop rapidly (as a percentage) because of the very large investment in auxiliary equipment that is not usually part of the regular gas turbine overhaul (the steam turbine, heat recovery steam generator, and power switchyard, for example). In such a case, the overhaul costs can drop to 10% or less of the initial investment.

In any case, overhaul maintenance operations have clearly been considered to be routine maintenance for turbines under NSPS and in most cases under NSR provisions. Yet, depending on the size of the unit and the complexity of the routine maintenance or replacement required, the repair/replacement costs as a percentage of the installed process unit cost is typically higher than the repair/replacement cost ratios for some other types of industrial equipment. Below, we provide some data on costs for turbine maintenance as a percent of total equipment costs.

Maintenance costs, as a percentage of the Equipment Replacement Value

Gas Turbine Overhaul and Maintenance

As noted in EPA's NSPS document cited above, gas turbine overhauls are routinely performed. Manufacturers specify the maintenance and overhaul schedules for each turbine model. To obtain data on overhaul cost, as a percentage of the equipment replacement value, the Gas Turbine Association requested Southwest Research Institutesummarize typical, industry-wide, overhaul costs as a percentage of the direct equipment replacement costs for units between 1 and 25 MW. GTA also requested that SwRI estimate the total installed equipment replacement value of the process unit, so we could compare these costs to EPA's 20% equipment replacement value exclusion. SwRI developed a set of budgetary installation factors from historical data which, when multiplied by the direct equipment cost, could be used to approximate the installed cost of the process unit, or the "equipment replacement value" of the process unit. These type of budgetary installation factors are commonly employed throughout industry for budgetary cost estimation purposes. In addition to the SwRI study, we requested readily available data from our members and from other industrial turbine users and compared the data to SwRI's analysis.

A summary of the data obtained is below. Further explanation of this data follows the summary.

Summary: Data for Overhauls as a Percentage of the Equipment Replacement Value

ERP Percentage For Overhauls	Comment
7 - 17%	SwRI estimate for various types of turbines (1 – 25 MW)
5.6 – 11.5%	Industrial turbine user.
6 - 14%	Industrial turbine OEM (1-24 MW)
9 – 20%	Frame turbine >100 MWe (OEM estimate)

The attached SwRI report indicates that the typical overhaul cost as a percentage of the total EPC plant cost for a 10 MW gas turbine combined cycle power plant is **11%** (see page 6 of report). However, as shown in Tables 1 and 2, the overhaul cost as a percentage of total ERP varies significantly with unit size. The highest typical overhaul cost, as a percentage of new equipment cost was for a 1 MW unit (ie. 33%). Utilizing the budgetary installation factor from page 5 for a simple cycle power plant, the highest typical overhaul cost as a percentage of total ERP is **17%**, for a 1 MW simple cycle plant (see page 6). The lowest typical overhaul cost, as a percentage of new package cost was for a 25 MW Two-Shaft Gas Turbine at a compressor station. For this service the overhaul cost is **7%**.

The SwRI data agree with data obtained from one turbine supplier who estimated overhaul costs as a percentage of the equipment replacement value to range from 6 to 14%. A second supplier estimated overhaul costs to range from 9% for a combined cycle system to over 20% for a simple cycle system. Note that for both the SwRI study and the turbine supplier data, the cost data is general and site and location specific factors have not been considered. Further note that the boundary of the process unit for both the SwRI data and the Turbine Supplier data presented is at the outlet of the power generation or cogeneration system. In contrast, in specific installations, the process piping between compressor stations may be considered to be part of the installation and for cogeneration systems, the steam piping to the plant supply header or ducting of exhaust hot air could be considered to be part of the process unit. With piping included, the equipment replacement value of the process unit could be larger for specific installations.

Steam Turbine Overhaul and Maintenance

To check the reasonableness of the SwRI assessment and the turbine supplier data, some additional data was obtained from industrial users. This data was also found to within the range of the data provided by SwRI and users in the industry, for both gas turbines and steam turbines (which are used in combined cycle applications). For example, a 32 MWe steam turbine experienced overhaul cost of $1.3 million (the estimated replacement cost was $32 million). Hence the repair/maintenance cost is 5.6% of the equipment replacement cost. In another instance a 49 MW unit with an estimated replacement value of $33 million incurred a maintenance overhaul cost of $3.2 million, or about 9.5% of the equipment replacement value. If the cost required to continue operation of the 49 MW turbine during the repair is considered, an additional $0.6 million must be added to the above maintenance costs for the lease pool service retainer and rental of the lease pool engine. This would increase the equipment maintenance and replacement cost to 11.5% of the replacement costs. (Note that the $33 million equipment replacement value for this 49 MW unit figure excludes $3 million for post combustion controls, but includes all other components of the cogeneration process.) Also, when a steam turbine overhaul is required, it is not uncommon to conduct maintenance on the gas turbine and generators connected to each primary driver. We did not obtain specific data from smaller size units but would expect that based on the data from SwRI and the turbine manufacturer, smaller size units would tend to have higher maintenance and replacement costs, as a percentage of the equipment replacement value.

Other equipment maintenance and replacement as a percentage of the Equipment Replacement Value

To assess the cost of other maintenance activities on turbines, we reviewed data previously submitted to EPA and solicited additional input from members. The data from the record includes comments from the *Interstate Natural Gas Association of America (INGAA) dated May 2, 2003. In Table III-A-4, INGAA provides several examples of ERP percentages in the Natural Gas Transport Sector*:

ERP Percentage	Comment
51%	Catastrophic failure of a industrial gas turbine in the Southeast
40%	Regrout of the engine foundation at a Compressor station in the Rocky Mountain Area
30%	Replacement of a regenerator on a turbine in the Southwest

In addition to the above data, EPA's regulatory analysis of the ERP rule in Appendix C (OAR-2002-0068-2210, pp 15-20) show a range of costs for a variety of maintenance activities for gas turbines and similar drivers.:

ERP Percentage	Type of maintenance/replacement project
0.4 - 23.3%	Automation Projects
20.5 - 22.7%	Crankshaft Replacement
3.3 - 4.5%	Exhaust System Projects
3.8 – 4.4%	Regenerator Repair and Replacement
6.6 – 30.1%	Regenerator Replacement
3.2 – 8.3%	Power Turbine Replacement
2.9 – 6.8%	Turbine Overhaul
3.3 – 42.9%	Engine Regrout
3.8 – 31.8%	Engine Foundation Repair
5.0 – 18.4%	Engine Foundation Replacement

From an owner/operators perspective, catastrophic damage is seldom encountered. However the maintenance and repair shops do encounter damaged units in sufficient frequency to have developed the experience base to repair or rebuild a substantially damaged gas turbine.

Summary

The compiled information shows a wide range of costs for turbine maintenance activities and demonstrates that many routine maintenance activities for these units are well above the 20% ERP exclusion. We continue to support EPA's bright line test which presumes that if the RMRR costs are below 20% of the Equipment Replacement value, maintenance and replacement activities can proceed.

We urge EPA not to consider decreasing the 20% ERP criteria. It is vital for the routine operation and maintenance of turbines that EPA provide certainty in the form of a reasonable bright line criteria for ERP, so that proper maintenance can be performed across the many industrial sectors that use turbines. If, however EPA chooses to change the 20% criteria, EPA should make clear, as they have for NSPS, that turbine overhauls and swap-outs with functionally equivalent units are exempt routine maintenance and do NOT constitute a modification under either NSR or NSPS provisions.

For projects above the 20% threshold, under the ERP provision promulgated, a case-by-case review is required. Self assessments using the current criteria are difficult and requiring industry to obtain an agency determination is too time consuming to allow for continued operation of many of these facilities. We therefore urge EPA to minimize the need for case-by-case assessments. We recommend that if EPA cannot increase the ERP exclusion percentage above 20%, that EPA clarify that activities such as crankshaft replacements, engine regrouts, and foundation repairs and replacements are routine maintenance for NSR purposes so that pipeline installations, power generation and combined heat and power facilities and other turbine installations may be constructed and operate with certainty.

If EPA otherwise chooses to determine that engine overhauls and other necessary turbine maintenance activities are not routine, they will be rendering a severe economic blow to an industry whose economic viability presumed that routine maintenance activities were excluded from both NSPS and NSR permitting. EPA would also be removing any incentive for continued operation and installation of environmentally beneficial cogeneration facilities. Again, the economic recovery period for many gas turbine installations is longer than the initial 2 to 3 year period before the first major overhaul is required.

Again, thank you for the opportunity to comment on the reconsideration.

GTA appreciates the opportunity to provide comments on this proposal. If you have any questions regarding these comments, please me at 407.736.5378.

Thank you for your consideration.

Respectfully,

Bruce Rising
Chair
Environmental Affairs Committee

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Mechanical and Materials Engineering Division
August 12, 2004

TO: Gas Turbine Association
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ATTN: Mr. Jeffrey S. Abboud, Executive Director
Mr. Bruce Rising, Manager Regulatory Affairs

FROM: Klaus Brun, Ph.D., Principal Engineer
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Gas Turbine Technology Center
Mechanical and Fluids Engineering Department

SUBJECT: Final Report
Commercial Review / Small and Medium Size Gas Turbines / Unit, Installation, and Maintenance Costs
SwRI Project No.: 18.18039.01.067

OBJECTIVE

The Gas Turbine Association (GTA) has engaged Southwest Research Institute® (SwRI®) to perform a study to determine costs associated with installing and maintaining small and medium size gas turbines. Specifically, SwRI collected data from the public domain and from interviews with manufacturers and end-users of gas turbines to analyze and report:

1. Typical 1 to 25 MW gas turbine package prices for power generation and mechanical drive applications.

2. Typical installed (EPC) costs of gas turbines in pipeline compression, liquids pumping, simple cycle power, combined cycle power, and combined heat and power (CHP) plants. These costs include: process system, ancillary, auxiliary, construction, engineering, start-up, and civil costs. EPC costs are inside the fence and do not include costs for land, any permits, right of ways, and construction financing.

3. Typical overhaul costs and typical overhaul intervals for gas turbine units from 1 to 25 MW. Overhaul costs as a function of gas turbine output (size) is also discussed.

4. Typical repair/maintenance costs and intervals for gas turbines from 1 to 25 MW to assure safe and continuous operation.

5. Discussion on other cost differentiators such as DLE combustion, dual fuel combustion, and exhaust cleanup systems for gas turbines.

The data presented herein is based on information from manufacturers, end-users, and the public domain (publications, institute reports, advertising, and technical brochures). It is based on standard, commercially available (and prevalent) gas turbine units. None of the information included in this report is considered proprietary and none of it implies any commercial or technical commitments or guarantees.

DISCUSSION

New Unit and Overhaul Pricing

Generally, overhaul price as a percent of the gas turbine unit's first cost is seen to decrease with gas turbine size (as measured in output power); i.e., the smaller the gas turbine, the higher the relative cost of the overhaul. This is best illustrated in the following table that shows typical new unit prices and overhaul costs for standard new generator set and mechanical drive gas turbine packages:

Table 1. Power Generation (Single Shaft Gas Turbine and Generator Package Price)

Power* [MW]	New Unit [MM$]	Overhaul [MM$]	% Overhaul / New Cost
1	0.9	0.3	33%
3	1.6	0.5	31%
4	1.7	0.5	29%
5	1.9	0.6	32%
7	2.4	0.7	29%
9	3.4	1.0	29%
10	3.7	1.0	27%
14	4.6	1.2	28%
17	6.1	1.4	23%
18	7.5	1.5	20%
22	8.0	1.7	21%
25	9.2	1.8	20%

* *ISO shaft output power for mechanical drives and generator terminals output power for power generation applications.*

Table 2. Mechanical Drivers (Two-Shaft Gas Turbine without Driven Equipment Price)

Power* [MW]	New Unit [MM$]	Overhaul [MM$]	% Overhaul / New Cost
1	1.1	0.3	27%
3	2.2	0.5	23%
4	2.4	0.5	21%
5	2.6	0.6	23%
7	2.8	0.7	25%
9	3.7	1.0	27%
10	4.2	1.0	24%
14	5.0	1.2	24%
17	6.2	1.4	23%
18	7.6	1.5	20%
22	8.1	1.7	21%
25	9.3	1.8	19%

* *ISO shaft output power for mechanical drives and generator terminals output power for power generation applications.*

Thus, typical overhaul cost as a percentage of the original new gas turbine unit price range between 33% and 20% for small and midsize applications for power generation units and 27% and 19% for mechanical drive units. Multi-shaft gas turbine engines (mechanical drive applications) are mechanically more complex than single shaft engines and, consequently, have a higher new unit price. However, the overhaul price does not differ significantly between single shaft and multi-shaft gas turbines, as the power turbine is seldom repaired/refurbished in an early overhaul. Medium size aero-derivative gas turbines are mostly offered as two-shaft engines only (even for generator applications), and their new unit price does not vary significantly between mechanical drive and power generation applications.

One should note that the new unit price and overhaul cost of a gas turbine is a function of many technical and commercial factors that cannot all be included within this limited report. The above table represents typical domestic US pricing for overhaul by core engine exchange. Overhauls performed at the site are generally 10-20% lower in cost, but can also cause significantly more unit downtime (up to five weeks). Most small gas turbine and medium size aero-derivative gas turbine overhauls are performed by unit exchange, as most end-users cannot afford extended periods of unavailability.

Maintenance Intervals

The intervals between unit overhauls, also often referred to Time Between Overhaul (TBO), vary significantly between manufacturers and depend somewhat on the definition of an overhaul. Most end-users define an overhaul as a complete repair/refurbishment of the gas turbines hot-section flow path (gas generator turbine and power turbine) and the combustor internals (transition pieces, liners, cans, torches, etc.). Another generally accepted definition of an overhaul is that the unit is brought back to zero hours; i.e., it has the same life expectancy as a new unit. For these full overhauls, the TBO is typically between 24,000 and 30,000 operating hours depending on the particular manufacturer, the application, the quality of maintenance, and the duty cycle. However, several manufacturers employ Equivalent Operating Hours (EOH) rather than actual operating hours to calculate TBO. When using EOH, each start and stop counts as a fixed number of hours that are added to the actual operating hours to account for the higher wear and tear gas turbines experience during start-up and shutdown. Also, some manufacturers require combustor can (or liner) replacement prior to the full overhaul. These mandatory combustor maintenance intervals are usually referred to as a "Major Inspections" and are performed every 16,000 to 24,000 hours. Finally, all manufacturers require the end-user to perform regular package maintenance (lube oil, instrument calibration, seals, filters, etc.) and a routine combustor and turbine hot-section borescope inspection every 4000 to 8000 hours to identify potential premature life limiting material and dynamics problems.

Installed Plant Costs

Gas turbines are installed within a plant that serves a specific function, such as: natural gas compression, liquid hydrocarbon pumping, simple cycle power generation, combined cycle power generation, combined heat and power, enhanced oil recovery, etc. Clearly, the total plant cost, which must include all process systems, gas turbines ancillaries/auxiliaries, site civil work, building construction, basic/detailed engineering, utility/pipeline interconnections, commissioning, startup, etc., strongly depends on a particular location, application, process, and regulatory environment. However, to determine rough "inside the fence" EPC plant costs, some relatively simple multipliers are usually employed for budgetary estimates. These budgetary estimates do not include costs for land, permitting, right of way, and construction financing costs. Based on historical data over the last ten years, the following multipliers were derived:

- Compressor Stations: 2.8
- Liquids Pumping Stations: 2.6
- Simple Cycle Power Plant: 2.0
- Combined Cycle Power Plant: 2.4
- Combined Heat and Power: 2.2

For example, to estimate the price of a pipeline compression plant with a single 10 MW unit, one should multiply the mechanical drive gas turbine price listed above (4.2 MM$) by 2.8 to determine the plant EPC cost (12.6 MM$). Similarly, for a 10 MW simple cycle power plant, one should take the single shaft gas turbine price (3.7 MM$) and multiply it by 2.0 to determine the EPC cost (7.4 MM$). Clearly, for multiple gas turbine units located within the same plant, the per-unit EPC cost adder is reduced by about 30% on each additional unit.

Because the total plant cost is much higher than the gas turbine unit purchase price, the overhaul cost as a percent of the total plant cost is significantly lower than overhaul cost as a percent of the gas turbine new unit purchase price. For example, the overhaul cost as a percent of the total EPC plant cost for a 10 MW gas turbine based combined cycle power plant is only 11% (i.e., \$1.0MM / \$3.7MM / 2.4 = 0.11).

Other Pricing Considerations

There are many factors that affect new equipment and overhaul pricing for gas turbines. Most of these factors are solely related to the technical features of a particular gas turbine and cannot easily be generalized. However, an important cost adder for gas turbines is the type of combustion system employed: (i) single or dual fuel system, and (ii) dry low NOx (DLN, also called DLE) or regular (diffusion flame) combustor.

The new unit purchase price and overhaul price for dual fuel units is typically 11% to 15% higher than the prices listed above for single fuel (natural gas) combustion gas turbines. Most modern gas turbines destined for the US domestic market utilize DLN combustion to meet stringent EPA and local air emission requirements. DLN combustion turbines are typically about 7% to 13% more expensive for both the new equipment purchase and overhaul price than regular combustor gas turbines. End-users have also reported that DLN units have higher service, repair, maintenance costs, reduced availability, and reduced operating range.

Some small gas turbine plants employ selective catalytic reaction (SCR) technologies for flue gas cleanup of NO_x / SO_x and continuous emissions monitoring systems (CEMS) or predictive emissions monitoring systems (PEMS) to measure exhaust air emissions. PEMS and CEMS systems typically cost less than 0.1MM per gas turbine unit. SCR systems vary widely in price depending on their cleanup efficiency and volumetric flow capacity but their price seldom exceeds \$0.5MM for small gas turbine units.

CONCLUSIONS

For small and medium size gas turbines (1 to 25 MW), the overhaul costs are the largest single contributor to the maintenance costs. Over a typical 30-year life of a gas turbine, the total overhaul costs will be about three to four times the cost of the gas turbine's new unit price. For this gas turbine size range, overhaul costs vary between 19% and 33% of the new equipment purchase price. Overhauls are typically performed every 24,000 to 30,000 operating hours (i.e., every 3-4 years). As the overhaul is a singular event that is often performed via unit exchange, it is difficult to spread the overhaul's costs evenly over multiple years as one can do with regular maintenance costs. Relating overhaul costs to gas turbine plant installed cost (EPC) is also difficult since plant costs vary widely depending on the application, process, location, permits, etc.