



ROTOR LIFE EXTENSION

How to keep your aging GE gas turbine running longer

A comprehensive guide to understanding rotor end-of-life issues and navigating the market for solutions that reduce your risk and provide the most return on your investment



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1. GE rotor life limits

Rotors are a critical part of a heavy-duty gas turbine. But they have a finite life. And failure to inspect increases the risk of defects, which can result in downtime, lack of availability, and even damage. All of which comes at a cost.

That's why GE issued a safety-critical technical information letter (TIL 1576) imposing limits on the operational life of its rotors.

TIL 1576 was first released in 2007 and subsequently revised in 2011. Although it has been around for a while, there remains a high degree of uncertainty for owners and operators.

But first, what factors affect rotor life?

Of all the components of a gas turbine, the rotor carries the largest burden. It experiences extreme temperature gradients from ambient up to combustion gases and down to exhaust.

Every start takes the rotor from a homogenous temperature to this extreme environment. All the energy produced and consumed flows through the rotor; the turbine section drives both the generator and axial compressor.

The environment your unit is in also contributes to the rotor's lifespan. For example, units based near the ocean may suffer corrosion from salt in the atmosphere. operating factors, such as starting time, heavy cycling, and unplanned shutdowns also decrease the life of the rotor and increase low cycle fatigue (LCF).

But the most pressing concern for many owners and operators is how rotor life is defined in TIL 1576.

In this guide, we'll look at:

1. the implications of TIL 1576;
2. what you need to do to comply;
3. how to arrive at an accurate evaluation of the remaining life of your rotor; and
4. your options for rotor life extension.



2. The owner's challenge

With the release of TIL 1576, the OEM placed restrictions on running its rotors beyond certain inspection intervals

As we'll see, however, there is a lack of clarity about what to do once those limits are reached.

What you need to know about TIL 1576

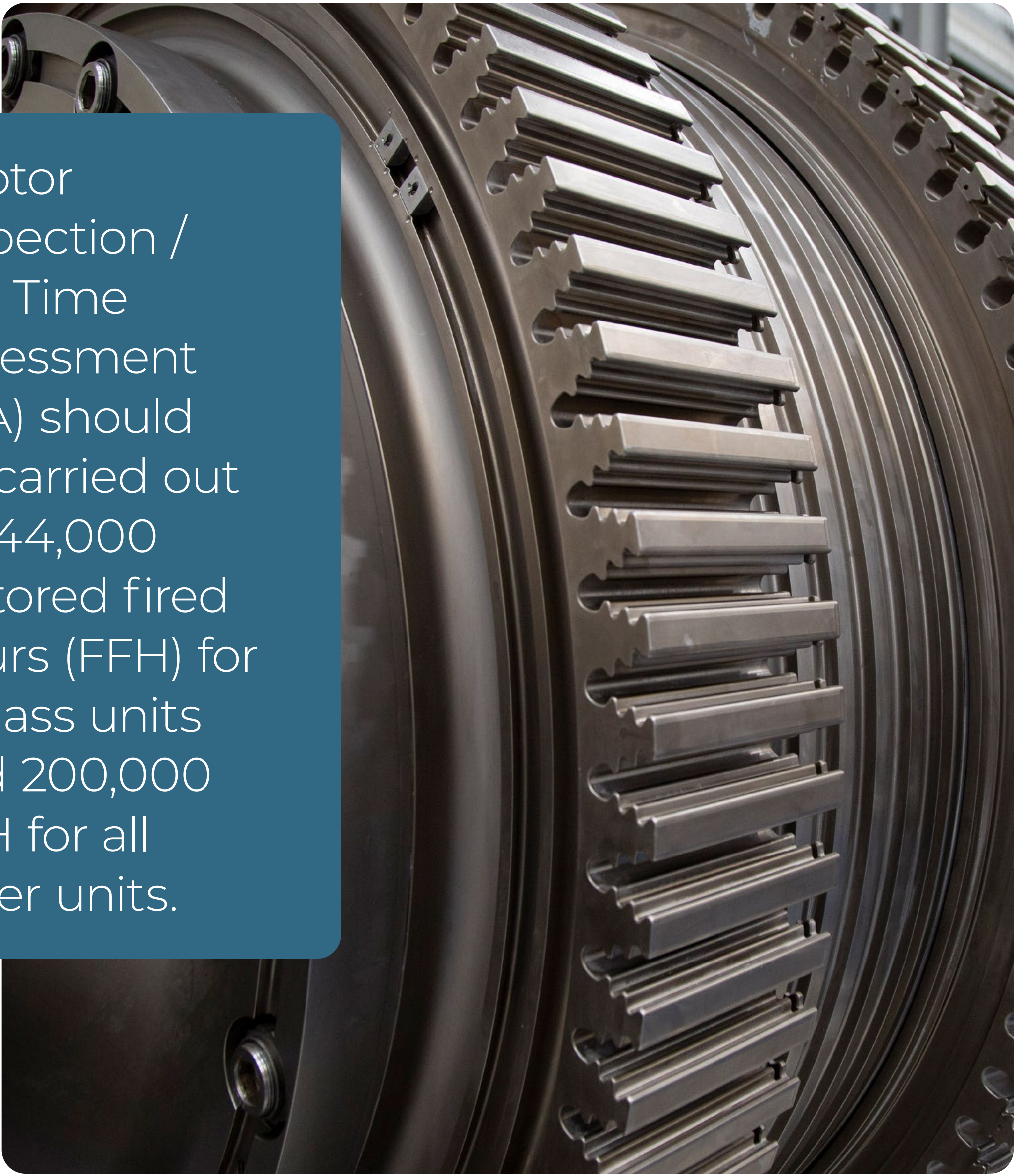
TIL 1576 applies to all heavy-duty GE gas turbines. It describes itself as safety-critical, and cites the risk of catastrophic failure leading to extensive damage to the turbine. It also warns of the potential for substantial damage to adjacent equipment and serious injury to nearby personnel.

The inspection intervals are clearly spelled out. A rotor inspection/Life Time Assessment (LTA) should be carried out at 144,000 factored fired hours (FFH) for F-class units and 200,000 FFH for all other units.

But once your rotor reaches 5,000 factored fired starts (FFS), you must retire it. This means TIL 1576 has a significant impact on peaking units.

Performing an LTA requires you to completely disassemble and thoroughly inspect the compressor and turbine rotors to detect possible wheel-forging discontinuities or any other service-related damage.

Failure to perform an LTA as specified by the OEM exposes your gas turbine and your company to greater risk.



A rotor inspection / Life Time Assessment (LTA) should be carried out at 144,000 factored fired hours (FFH) for F-class units and 200,000 FFH for all other units.

3. The unanswered questions of TIL 1576

The revised version of TIL 1576 updated the language and expanded its reach to F-class turbines.

However, the life extension FFH specifics were removed and replaced with something much more vague.

The TIL now simply tells us that an engineering decision needs to be made to determine what life extension is available.

But is an extension still limited, as before, to 50,000 or 100,000 FFH?

Could it be less than that?

Or something more?

It's not clear. And many questions remain unanswered, such as:

What should be replaced?

What can be reused?

How long can a rotor run?

Can subsequent LTAs be performed for another 50,000 FFH? 100,000? 200,000?

Or does the rotor need to be scrapped?

The TIL identifies no clear path for extending the life of a rotor.

A particular difficulty for many owners and operators – and a situation you may find yourself in – is this: You know a life extension is necessary, but should you modify the existing unit rotor, buy a replacement used rotor, or consider purchasing a brand-new one?

Or you could find yourself in an equally uncertain situation. You know you want to run your rotor for longer than a one-time life extension, but not for as long as the life a brand-new rotor would give you. Can you justify the expense of a replacement rotor?



What if you ignore the TIL?

If your rotor reaches the inspection intervals of TIL 1576, you should expect an increased level of risk. But what are the consequences of gas turbine failure?

There are four potential outcomes:



Forced outage

Failure could result in a simple trip of the unit or vibration that leads to tripping. You can expect your unit to be unavailable for a short period but once you restart the rotor, you're up and running again. However, increased stops and starts can lead to faster degradation of the turbine's hot parts.



Operational restrictions

More serious consequences can include a loss of power or efficiency, increased operating costs, unavailability, and poor flexibility. You may need to augment power and you could potentially exceed your emissions compliance.



Contained failure

If the failure requires immediate major repairs but remains contained within the unit, you're looking at an unplanned outage and prolonged unavailability. Expect lost revenue, unpredictable lead times, and significant repair costs. The impact on the business is much higher, but you can resume operations once you've carried out the repairs.



Uncontained failure

This is the situation the TIL is really warning about. There's a risk of damage to property and serious injury to nearby personnel. The consequences are often dramatic and can include lengthy unavailability, extensive maintenance work, and expensive repairs and replacement costs. And if the OEM's recommendations weren't followed, this could open the door to litigation or loss of insurance.

4. How do you comply with TIL 1576?

When TIL 1576 was first issued, a large number of Frame 3 and Frame 5 units were already being operated beyond the hour limit and/or start limit.

The majority of Frame 7 and Frame 9 units are now starting to come of age. E-class units operating at the base load could reach 200,000 FFH after as little as 23 years' operation, while F-class units could reach 144,000 FFH after just 17 years. So if you're approaching those limits, what do you need to do?

Typical LTA inspection scope

There's now an industry-standard scope for an LTA inspection. This inspection can be carried out by the OEM and most experienced aftermarket facilities.

What's involved?

The rotor is removed from the unit and completely disassembled. That allows for a visual inspection of all surfaces and non-destructive testing of all critical areas of the turbine wheels, distance pieces, spacers, stub shafts, and compressor wheels. Other parts of the inspection include dimensional analysis and measuring material hardness.

LTA inspection outcomes

With a standard LTA inspection, there are two possible report outcomes: Either there were no findings or repairs are required.

1. If there are no findings

If there were no findings in the LTA inspection, the rotor should be reassembled with new through-bolts. But how long can you continue running your rotor?

Remember that the current TIL is vague.

But because the earlier version had specified some limits, it's generally accepted there can be a one-time life extension along the lines of what was described in the original TIL: 50,000 or 100,000 FFH, depending on the model.

2. If repairs are required

If repairs are required, owners originally had two options: new parts (or a brand-new rotor) from the OEM or used parts from the aftermarket.

OEM solution: From the OEM you could buy a completely new rotor and reset your risk. Or you could buy new parts to replace those found to have issues.

Aftermarket solution: The second option is to locate and purchase a used rotor – with a documented history if you're lucky.

You can either use that rotor in its entirety or disassemble it and reuse it for parts. But whichever approach you take, this solution can be risky for owners. You're having to put your trust in the previous owner's records: how they cycled the unit; how well they maintained and inspected it; how close it is to its end of life. To make things more complicated, what happens when you take parts from a used rotor and mix them with your existing rotor? How do you calculate the remaining rotor life? And how do you evaluate what's left if some parts have 100,000 FFH left but others only 50,000?

5. OEM + ISP: The best of both worlds

Traditionally, owners and operators have faced a tough choice: Do you buy an expensive new rotor/rotor parts from the OEM? Or do you take your chances and purchase an aftermarket rotor that might not fit your plant's operating timeline ... and probably isn't backed by a warranty?

But there's another way. A way that gives you the best of both worlds: long-term operation and savings on your capital expenditure.

EthosEnergy has created a range of unique solutions that go beyond aftermarket used parts. We offer low-risk, cost-effective, and flexible options that minimize downtime.

What makes our approach different?

EthosEnergy is a leading independent service provider of rotating equipment services and solutions to the power, oil & gas, and industrial markets. And there's a reason why we know exactly how to manufacture a brand-new rotor.

We're also an OEM.

EthosEnergy is the original equipment manufacturer of mature Westinghouse and Fiat gas turbines. We were formed as a joint venture to combine the rotating and stationary equipment capabilities of Wood plc (Wood Group GTS) and Siemens Energy (Turbocare) and we enjoy access to Siemens' materials database. In addition to our engineering capabilities, we can manufacture rotors and components in-house.

And now, we've leveraged our OEM know-how for legacy gas turbines. We've taken all that OEM heritage – our skills, knowledge, and design criteria – and completely analyzed and redesigned GE's rotors.

EthosEnergy is the original equipment manufacturer (OEM) of Mature Westinghouse and Fiat gas turbines

6. How we redesigned the rotors

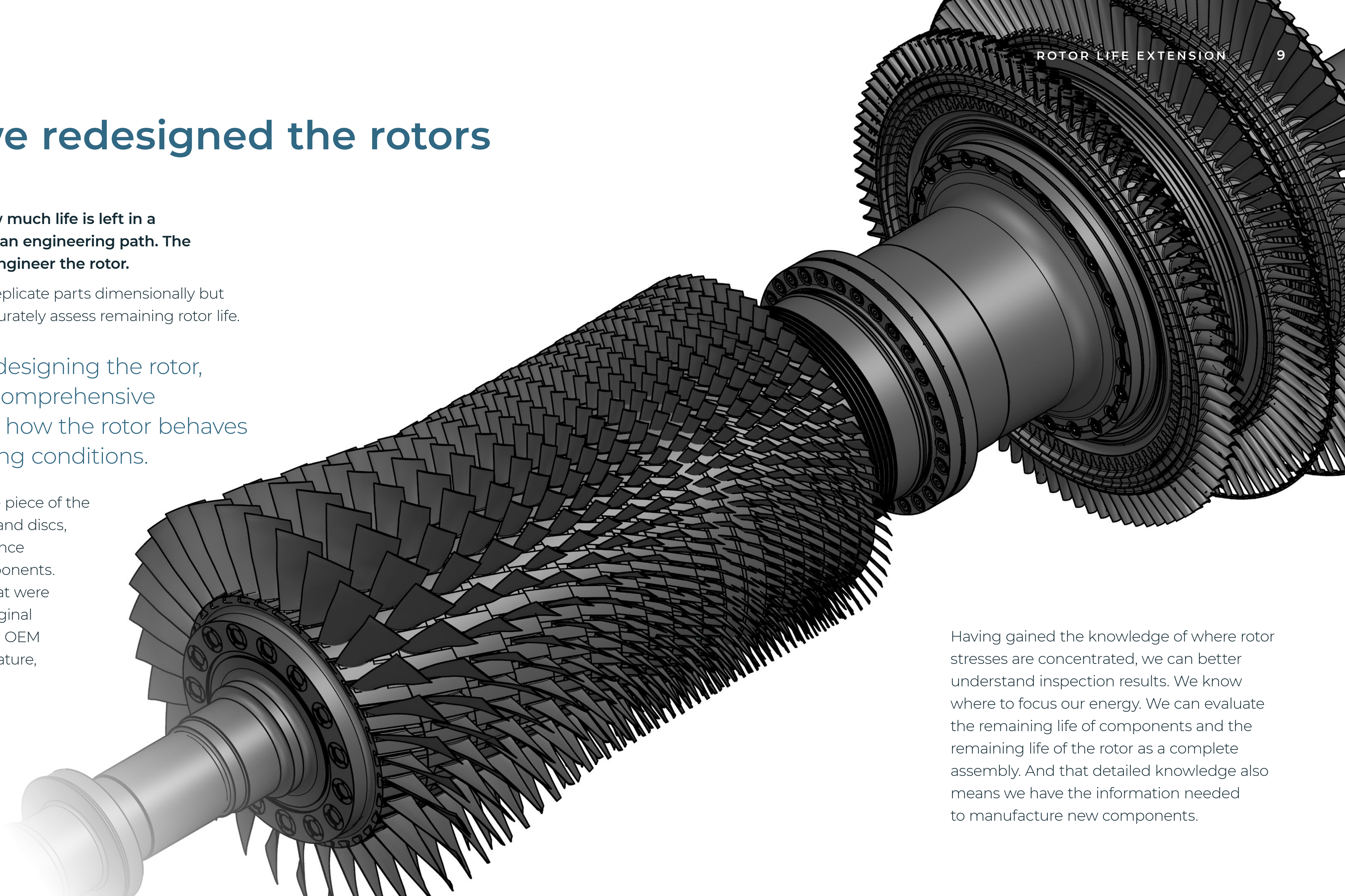
To properly evaluate how much life is left in a rotor, we needed to find an engineering path. The answer was to reverse-engineer the rotor.

Our goal was not just to replicate parts dimensionally but also gain the ability to accurately assess remaining rotor life.

By completely redesigning the rotor, we developed a comprehensive understanding of how the rotor behaves in various operating conditions.

We examined every single piece of the rotor. Not just the wheels and discs, but also the spacers, distance pieces, and all other components. We used modern tools that were not available when the original design was created by the OEM to evaluate stress, temperature, and operating conditions.

Having gained the knowledge of where rotor stresses are concentrated, we can better understand inspection results. We know where to focus our energy. We can evaluate the remaining life of components and the remaining life of the rotor as a complete assembly. And that detailed knowledge also means we have the information needed to manufacture new components.



OEM Manufacturing



Manufacturing new components

We've created and developed the processes necessary to manufacture new parts based on our redesign. The ability to machine forgings into wheels, spacers, etc., is well within the capabilities of our manufacturing and repair facilities.

Material selection for new parts is also critical. Fortunately, the body of knowledge on material properties (including life expectancy under defined conditions) has grown considerably since the original rotor designs were created. This information is based on real-world experience gained over decades and is closely guarded by OEMs.

As the OEM for the mature Westinghouse and Fiat gas turbines, we have access to that modern materials knowledge. This provides confidence in the life expectancy of newly manufactured parts.

Dimensional compatibility is also key to our designs. All our newly manufactured parts are fully interchangeable with OEM parts. So we can replace single components without having to change an entire rotor.



We go further than the industry-standard LTA

We're able to take information from an LTA and take it one step further. We let engineering define a scope of work for what needs to be done to extend the rotor's residual life.

We can then execute a custom solution that's founded on our OEM pedigree and tailored to your specific needs.

7. Our unique solutions: life extension

We've created a tiered approach to rotor life extension. This gives us maximum flexibility to meet your needs.

In total, we have five specific solutions. Two of these solutions make use of your existing rotor, with the other three replacing your rotor.

Extending the life of your existing rotor

1. Life Time Assessment (LTA)

We can perform a traditional LTA inspection and provide you with our findings in a report.

Based on the TIL, a report with no findings supports additional life. That generally allows for a one-time hours extension. But there's no warranty and risk ownership remains with the customer.

Remember that an LTA requires a full disassembly to diagnose the rotor, so this service is typically longer than a month, including transportation of the rotor to a capable shop. This doesn't include any time to repair if the report identifies issues with parts of the rotor.

SUMMARY	Unstack / restack of compressor and turbine rotor and perform Life Time Assessment Inspections of the rotor components per TIL-1576
EXPECTED ROTOR LIFE	Findings report and potential life extension
RISK OWNERSHIP	Customer
WARRANTY	N/A
OUTAGE TIME	●●●○○
COST	\$○○○○

2. Condition Based Life Extension (CBLE)

A step up is our CBLE rotor. Taking ownership of the risk, we translate the LTA results into a certified life extension.

We work closely with you to understand your operating profile and how long you want to run your rotor. An LTA is performed to identify areas of concern when compared to the required extension. We'll then generate a custom rotor solution based on the findings of the LTA.

By pinpointing the critical life-limiting areas, we can minimize our intervention. We extend the life of the rotor only as necessary, keeping your spend to a minimum.

SUMMARY	Engineering evaluation detailing the rotor condition, associated risks, and recommendations for components replacements
EXPECTED ROTOR LIFE	50K-200K Extension
RISK OWNERSHIP	EthosEnergy
WARRANTY	EcoLife™ Warranty
OUTAGE TIME	●●●●●
COST	\$●○○○

Our unique solutions: rotor replacement

Sometimes life extension is not a viable solution.

Perhaps the average time to perform the LTA and repairs is too long. Or your rotor has exceeded or is close to exceeding the start limit.

Cost-effective solutions for replacing your rotor

3. Certified Previously Operated (CPO)™

These are replacement rotors with a known pedigree. They have a remaining life of up to 150,000 FFH (or 128,000 FFH for Frame 7FA rotors). Where this solution differs from an aftermarket used rotor is we've already taken the time to inspect the rotor and carry out any necessary repairs. Plus, our engineers have assessed its remaining life and certified its use for that number of hours. So you go from TIL vagueness to CPO™ certainty.

SUMMARY	Rotor with known pedigree and recommended remaining life up to 150,000 FFH
EXPECTED ROTOR LIFE	50-150K Rotor
RISK OWNERSHIP	EthosEnergy
WARRANTY	EcoLife™ Warranty
OUTAGE TIME	●●○○○
COST	\$\$\$○○○

4. Phoenix Rotor®



The culmination of our complete redesigning, this is our flagship offering. With our manufacturing capability and understanding of the critical components, we've developed a hybrid rotor – using new and CPO™ components – that achieves the maximum possible life limit. You get the same life as a new rotor, but at a significant discount.

SUMMARY	Hybrid Rotor with New and CPO components certified like new
EXPECTED ROTOR LIFE	200K / 144K Rotor E Class / F Class
RISK OWNERSHIP	EthosEnergy
WARRANTY	EcoLife™ Warranty
OUTAGE TIME	●○○○○
COST	\$\$\$\$○○

5. New rotor

At the top end of the scale, we have another solution. Having fully reverse-engineered GE's rotors, we're able to manufacture brand-new rotors with 200,000 FFH of design life (or 144,000 FFH for Frame 7A rotors).

SUMMARY	Completely new manufacture with 200,000 FFH of design life
EXPECTED ROTOR LIFE	200K / 144K Rotor E Class / F Class
RISK OWNERSHIP	EthosEnergy
WARRANTY	EcoLife™ Warranty
OUTAGE TIME	●○○○○
COST	\$\$\$\$\$

Our unique solutions

Exchange/fleet program

If you own multiple units reaching their hours limit, even more flexibility can be gained. All of our replacement rotors can be part of an exchange program or a fleet program. Planning rotor outages in a sequence can minimize expense. One example would be to start the program with a stock Phoenix Rotor™ and then use your removed rotor as the foundation for generating Phoenix Rotors™ for subsequent outages.

EcoLife™ warranty

Apart from the LTA, all our solutions come with our EcoLife™ warranty. Terms will vary based on each client's situation and the particular rotor in question.



8. Quick guide to planning for rotor end of life

Now that we have covered the TIL, the challenges associated, and our solutions, how do you decide what works best for your assets?

Know your own roadmap

A critical first step is to look at the big picture for your plant(s). With the energy transition taking center stage, make sure you have a clear understanding of the minimum amount of time that your plant(s) will need to operate using your existing combustion turbines. For example, if your company or the area you are in has set aggressive net-zero targets, you may be looking at a shorter window of operation and thus need fewer fired hours and starts to get you there.

Identify when your rotor will reach the limit

Once you have an idea of a target date that you'd like to reach, you'll need to determine how long your existing rotor will run. Identify the date when your rotor will reach 200,000/144,000 FFH or when it will reach 5,000 FFS.

Understand your outage timing

Work out whether you can afford to take on a longer-term outage to extend the life of your current rotor, or whether you need a replacement rotor to keep the outage to a minimum.

This will help you narrow down to one of two options:

1. Extend the life of your current rotor via an LTA or CBLE – if you can afford a lengthy outage.
2. Replace the rotor with a CPO™ rotor with a known pedigree, a Phoenix Rotor™, or a new rotor – and perhaps consider an exchange program.



Understand the market

There are a growing number of options in the market, so due diligence is vital to ensure that the vendor and replacement option you choose is aligned to your goals.

In general, you have three options for purchasing a rotor from the marketplace:

- via a broker;
- purchasing from an independent service provider (ISP) that manufactures/refurbishes rotors; or
- purchasing a new rotor from the OEM.

Before we get into the pros and cons of each option, however, there is a critical issue to consider.

Compatibility

With GE Frame B-, E-, and F-class rotors, there are technical details that need to be considered before swapping out your rotor.

It is essential to have a qualified engineering team evaluate and assess your system to ensure full compatibility as there may be nuances between the rotor you have been using and the replacement rotor. In some cases, engineering customizations will need to be made – again, this is something a qualified team should assess. And all of this should be backed by a thorough quality management system.

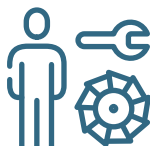
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Broker vs ISP vs OEM



Brokers

Traditional brokers are unlikely to be able to provide engineering support. Here, you are simply making a transaction to purchase the rotor (hopefully, after a proper inspection). You then have to engage another party to help with commissioning.



Independent service providers

There are a handful of ISPs in the market that offer rotor replacement and life extension, but there are some key factors to look for when reviewing ISPs. These include (but are not limited to):

- a robust engineering background;
- internal manufacturing capability; and
- technical depth

Without these, your risk is much higher.

Another critical item to consider during your evaluation is warranty. Find out how long any vendor stands behind their product/service. At EthosEnergy, all of our CPO™ and Phoenix Rotors™ are backed by our EcoLife™ warranty.

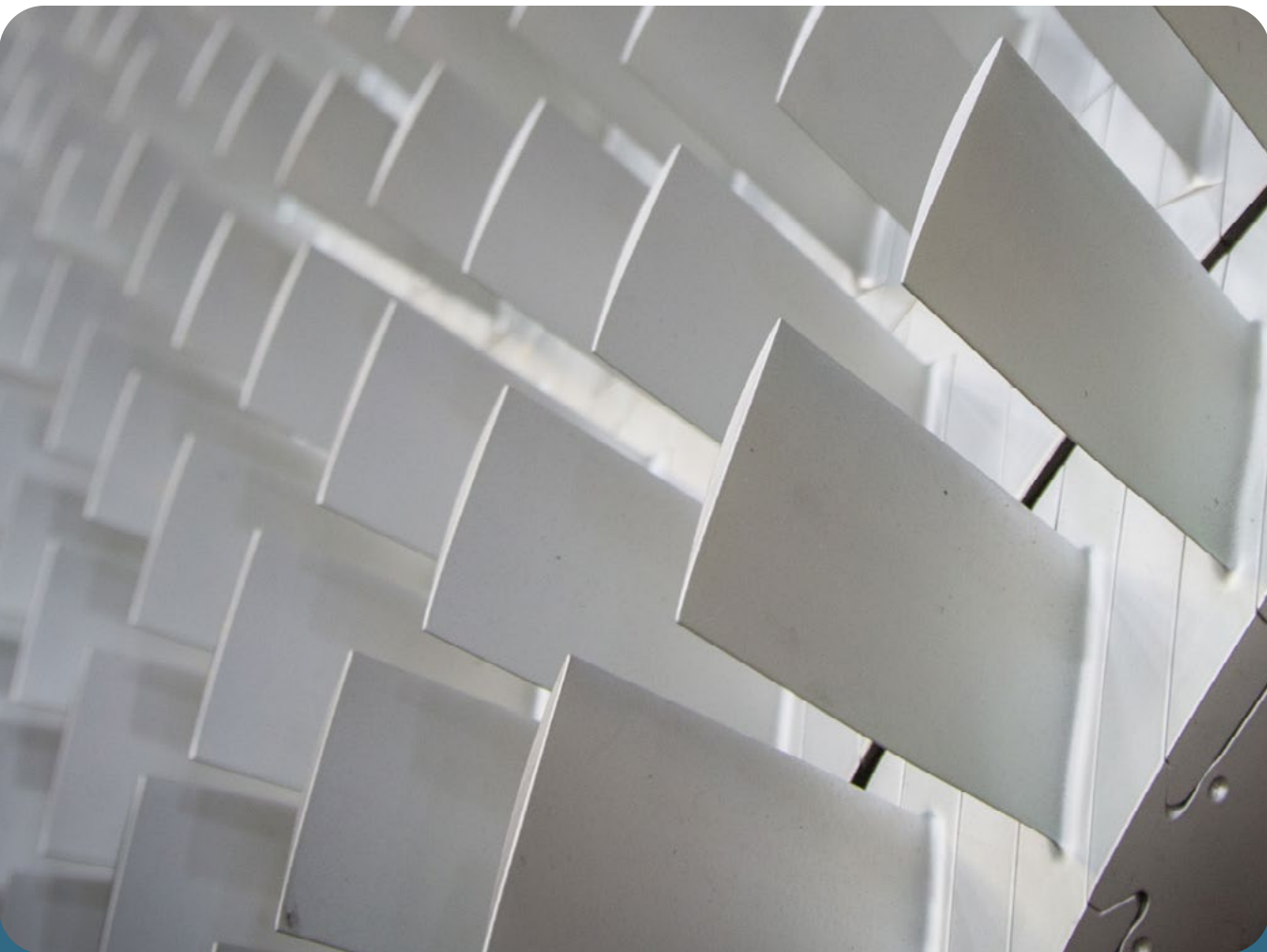


Original equipment manufacturer

The OEM will undoubtedly have the requisite engineering and manufacturing capability and can certainly replace your rotor, provide refurbishment options, and perform an LTA and more – all at a low risk to you. But this option comes with lengthy lead times and, very often, higher costs – the OEM tends to have a very long “wait list” for replacement rotors.

Remember, though, that EthosEnergy’s Phoenix Rotor™ is certified for the equivalent life of a new rotor, is backed by a warranty, and typically comes in at around 60% of the cost of a new rotor.

Whatever your situation, it’s important to do your research to find the best option for you and your plant(s). Understand what solutions are available and begin planning as far out as possible.



Lead time is critical

Supply chain issues, material shortages, and the number of B-, E-, and F-class rotors now reaching end of life mean that planning is critical.

At current demand, in some cases we are quoting lead times of 90 weeks or more at EthosEnergy for Phoenix Rotors™ and new rotors. So the sooner you

identify the need for a replacement rotor and lock in a replacement with a service provider, the lower your risk will be for extended downtime at the end-of-life point. It also means you will avoid having to go with a risky aftermarket solution that might not meet the operating profile of your plant.

Engage vendors

Once you know your roadmap, have researched and understood the current options available in the market, and figured out what’s most important to you, it’s time to engage with vendors. To really drill down into the details.

With growing lead times, the earlier you can start to do all of this, the better. A rough rule of thumb would be to start engaging vendors and getting bids once your rotor is within 36 to 24 months of reaching its FFH limit.

Here are some things to keep in mind when selecting a vendor:

- How much experience do they have with GE rotors?
- What is their past history with your site/ company? Do they have quality references?
- Is there commercial and financial flexibility? Do they allow for creativity with the offering and structure of the purchase and subsequent services?
- Where are the replacement rotor parts coming from? Is another third party involved?
- How is the life of the replacement rotors certified?
- How compatible is their offering with your system? Do they have the ability to provide a complete engineering evaluation, assessment, and customization as needed?

	BROKER	ISP	OEM	EE
Experience with GE rotors				
Compatibility				
Engineering breadth				
Parts Availability				
New Parts Mfg				
Warranty				
Commercial flexibility				



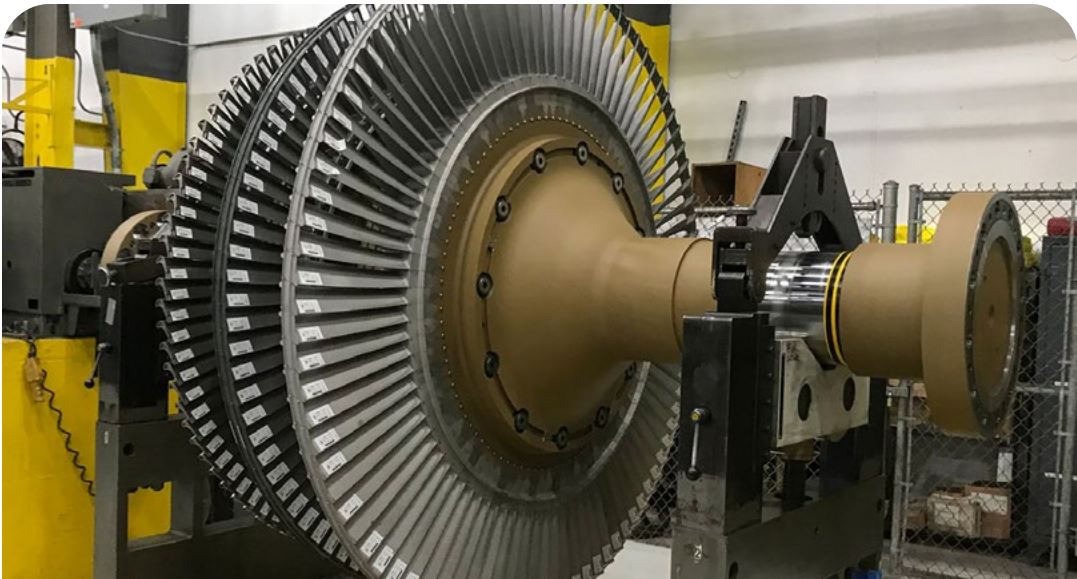
Ready to move forward?

We look forward to hearing from you

For more information on how to keep your rotor running smoothly or advice on what to do when you need to inspect it, email us at

enquiries@ethosenergy.com

Find out more about the support we offer in a world of changing expectations:



Regenerating a refinery cogen's Frame 7EA rotors

7EA Hybrid New/Used
Phoenix Rotor™ gives facility the best of both worlds

[Read the full case study](#)



First Frame 6B Phoenix Rotors™ still going strong

Global leader gives the go-ahead for our end-of-life rotor solutions

[Read the full case study](#)



One partner across critical assets

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by supporting you through the complexity
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