CHAPTER 2

GAS TURBINE MAINTENANCE

This chapter will cover object damage, borescope inspection, troubleshooting, and maintenance of the LM2500 and the Allison 501-K series of GTEs. The majority of this chapter deals with the LM2500 GTE damage evaluation. The last part of this chapter is on proper preservation and corrosion control methods for maintaining all GTEs in peak operating status.

OBJECT DAMAGE

There are two basic types of object damage GS supervisors see. One of the most damaging gas turbine casualties, and one of the easiest to prevent, is foreign object damage (FOD). In this section we will discuss the hazards of FOD and some of the ways to prevent it. The other type of object damage that can cause failure of a GTE is domestic object damage (DOD).

HAZARDS

The effects of object damage and the hazards involved vary greatly with the size and location of the object ingested. Small dents and abrasions may cause little or no damage. However, if a large enough object is ingested by the engine, severe internal damage will result. Large, soft items (such as paper) can clog the FOD screen, causing a loss of power and elevated turbine inlet temperatures. The other type of damage that was mentioned is DOD. DOD occurs when an internal object from the engine breaks loose and causes impact damage to the engine.

PREVENTION

To prevent FOD to engines while working in and around intake and plenum areas, you and your personnel must observe the following safety precautions:

—When performing maintenance inside the intake areas, always follow all written guidelines found in the EOP. Remember to remove all loose objects from your person. You must also account for all tools and equipment used in the intake. After completing your work, inspect the intake for cleanliness, and reinventory the tools and equipment before securing the accesses.

—Periodically inspect all intakes for cleanliness, the state of preservation, and the condition of the FOD screens. Correct any abnormal conditions. The frequency of inspection will depend on the operating conditions, PMS requirements, and engineering department instructions. Remember, the PMS only provides minimum standards. PMS can always be exceeded if you or your superiors deem it necessary.

—When inspecting the intakes, be sure that the areas around the blow-in doors are kept clear of loose gear and debris that could be ingested if the blow-in doors are activated.

To prevent DOD damage, you and your personnel need to follow a strict regimen of cleaning and inspections (internal and external). This attention to detail, as described in the next two paragraphs, is absolutely necessary to avoid DOD damage.

—Make sure the engine is properly cleaned inside and out. Always following the standards in the PMS and the manufacturer’s technical manual. Cleanliness is an important factor in the fight against corrosion. Corrosion control (discussed later in this chapter) also can reduce the chances of component failures that can lead to DOD.

—Perform frequent external and internal GTE inspections to reduce the possibilities of DOD occurrences. GTE external inspections are very important. Locating loose, missing, or broken external components (VSV retaining nuts) during these inspections is a significant factor in preventing damage.

—Using borescope inspections aids in determining the extent and prevention of DOD. The most frequent damage is identified as potential component failures (blade stress cracks).

BORESCOPE INSPECTIONS

Borescope inspection requirements and procedures are found on the maintenance requirement card (MRC). These cards contain all the basic information necessary to conduct an inspection. Included on the MRCs are the serviceability limits and a list of conditions that require an inspection. Borescope inspections are usually performed semiannually or when the engine has been operated beyond the allowable limits listed on the MRC.
The following section discusses the borescope procedures used to inspect the LM2500 GTE. The inspection procedures and the knowledge gained from damage evaluation may also be applied to the borescope inspection of the Allison 501-K17 GTE.

**GENERAL INSPECTION PROCEDURES**

It is a good engineering practice to review the machinery history of an engine before you conduct an inspection. Various component improvement programs will eventually affect all engines in service. A rebuilt or modified engine may contain improved parts that differ from the original. An example of this is the first-stage compressor midspan damper that may have its original coating, an improved coating, or a carboloy shoe welded on at the midspan damper interface. If you review the machinery history, you will discover the status of those parts that have been changed or modified.

Assuming that the engine history is normal and FOD is not suspected, you should be aware of the following factors when conducting a borescope inspection:

- Know your equipment.
- Locate all inspection areas and ports.
• Establish internal reference points.
• Scan the inspection area thoroughly and in an orderly manner.
• Note any inconsistencies.
• Evaluate the inconsistencies.
• Report your conclusions.

GEOMETRIC ORIENTATION OF THE ENGINE

To communicate information about an engine inspection, you must establish a geometric frame of reference for the engine assembly. A language for describing the physical damage is also necessary. An example of this information is provided in figure 2-1, geometric orientation of the LM2500 GTE. Figure 2-2 shows an example of radial and axial cracking on a compressor blade; figure 2-3 shows an example of circumferential and axial cracking in the combustion section. Table 2-1, a foldout at the end of this chapter, provides a list of condition codes and definitions of terms that you need to know when inspecting the LM2500 GTE.

When the probe is in the inspection hole, it is not unusual for you to lose your sense of direction. On the Wolf borescope, the large plastic disk just beneath the eyepiece has an index mark that shows the direction the probe object window is facing. You can feel and see this mark. Another reference you can use to detect the direction the object window is facing is

Figure 2-3.—Examples of circumferential and axial cracking.
the light cable attachment. On the Wolf and Eder probes, the viewing window is 90 degrees clockwise from the light cable, as shown in figure 2-4. In the future, borescoping equipment may have changes incorporated that significantly improve the inspection equipment. Newer models may incorporate a swiveling light cable that allows the cable to hang down regardless of the viewing direction. You must read the manufacturer’s instruction manual before you can successfully use the equipment. Figure 2-5 is an example of how the engine and borescope geometry work together. It shows you how the borescope appears when looking forward and aft from the right side of the engine or from the left side of the engine.

**BORESCOPE PORTS**

Table 2-2 is a description of the ports and the areas that you can see from each borescope port. Figure 2-6 shows you the component materials and the temperatures at which the various components normally operate. The locations

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Figure 2-4.—Light cable azimuth for borescope probes.

Figure 2-5.—Geometric orientation of the borescope.
Table 2-2.—Area Visible From Borescope Inspection Ports

<table>
<thead>
<tr>
<th>PORT IDENTIFICATION</th>
<th>PART/AREA ACCESSIBLE FOR INSPECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Two Inlet Guide Vane Airfoils</td>
</tr>
<tr>
<td>28</td>
<td>Stages 1 and 2 Compressor Rotor Blades and two Stage 1 Stator Vane Airfoils</td>
</tr>
<tr>
<td>27</td>
<td>Stages 2 and 3 Compressor Rotor Blades and two Stage 2 Stator Vane Airfoils</td>
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<tr>
<td>26</td>
<td>Stages 3 and 4 Compressor Rotor Blades and two Stage 3 Stator Vane Airfoils</td>
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<tr>
<td>25</td>
<td>Stages 4 and 5 Compressor Rotor Blades and two Stage 4 Stator Vane Airfoils</td>
</tr>
<tr>
<td>24</td>
<td>Stages 5 and 6 Compressor Rotor Blades and two Stage 5 Stator Vane Airfoils</td>
</tr>
<tr>
<td>23</td>
<td>Stages 6 and 7 Compressor Rotor Blades and two Stage 6 Stator Vane Airfoils</td>
</tr>
<tr>
<td>22</td>
<td>Stages 7 and 8 Compressor Rotor Blades and two Stage 7 Stator Vane Airfoils</td>
</tr>
<tr>
<td>21</td>
<td>(Blocked)</td>
</tr>
<tr>
<td>20</td>
<td>Stages 9 and 10 Compressor Rotor Blades and two Stage 9 Stator Vane Airfoils</td>
</tr>
<tr>
<td>19</td>
<td>Stages 10 and 11 Compressor Rotor Blades and two Stage 10 Stator Vane Airfoils</td>
</tr>
<tr>
<td>18</td>
<td>Stages 11 and 12 Compressor Rotor Blades and two Stage 11 Stator Vane Airfoils</td>
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<tr>
<td>17</td>
<td>Stages 12 and 13 Compressor Rotor Blades and two Stage 12 Stator Vane Airfoils</td>
</tr>
<tr>
<td>16</td>
<td>Stages 13 and 14 Compressor Rotor Blades and two Stage 13 Stator Vane Airfoils</td>
</tr>
<tr>
<td>15</td>
<td>Stages 14 and 15 Compressor Rotor Blades and two Stage 14 Stator Vane Airfoils</td>
</tr>
<tr>
<td>14</td>
<td>Stages 15 and 16 Compressor Rotor Blades and two Stage 15 Stator Vane Airfoils</td>
</tr>
<tr>
<td>13</td>
<td>Combustor, Fuel Nozzles, and Stage 1 HP Turbine Nozzle</td>
</tr>
<tr>
<td>12</td>
<td>Stage 1 HP Turbine Rotor Blades and two Stage 1 HP Turbine Nozzle Airfoils</td>
</tr>
<tr>
<td>11</td>
<td>Stage 1 and 2 HP Turbine Rotor Blades and two Stage 2 HP Turbine Nozzle Airfoils</td>
</tr>
<tr>
<td>10</td>
<td>Stage 2 HP Turbine Rotor Blades, Stage 1 LP Turbine Blades and Vanes, Turbine Mid-Frame Liner, and T₅₄ Thermocouple Probes</td>
</tr>
</tbody>
</table>

of the borescope inspection ports are shown in figure 2-7.

Compressor

Fifteen borescope inspection ports are in the compressor near the 3 o'clock split line. A port is located at every compressor stator stage. These vane ports start at the IGVs and work aft in the same direction as the airflow (except for stage 8, which is internally blocked). Stator stages 9 and 13 borescope ports require you to remove piping interferences.

Combustor and HP Turbine

Aft of the right-hand side compressor ports are six circumferentially positioned ports, just forward of the midflange of the compressor rear frame. From these ports you can inspect the combustor, the stage 1 HP turbine nozzle assembly, and a few fuel nozzles. Near the aft flange of the compressor rear frame on the right-hand side of the engine are two HP turbine stator ports that you can use for viewing the air-cooled turbine blades. The P₅₄ pressure probe harness adjacent to the after flange of the turbine midframe is located aft of the
Figure 2-6.—Turbine materials and operating conditions.

Stage land 2 turbine ports. Five pressure probes are located circumferentially around the turbine midframe at the inlet to the LP turbine. All five probes extend radially into the gas path and can be removed to inspect the LP turbine inlet and the HP turbine exhaust.

INDEXING AND ROTATING THE ENGINE

You can rotate the engine by using a socket wrench with an 18-inch long 3/4-inch drive extension. You attach the 3/4-inch drive extension after you remove the cover plate on the aft face, right-hand side of the accessory gearbox, next to the lube and scavenge pump (fig. 2-8). When you are inspecting through the forward-most borescope ports, there is not enough space for both you and the person turning the engine to work. This requires you to do the turning yourself or to have the turner rotate the engine from the other location on the accessory gearbox. You can find the alternate drive pad for manual engine turning on the forward face, left-hand side of the accessory gearbox, also shown in figure 2-8.
1. Exhaust Duct  11. Compressor Rear Frame Port
2. Outer Cone  12. Compressor Rear Frame Port
3. Turbine Rear Frame  13. Compressor Rear Frame Port
4. Turbine Case  14. Stage 15 port
5. Turbine Mid Frame  15. Stage 14 port
6. Compressor Rear Frame  16. Stage 13 port
7. Rear Compressor Casing  17. Stage 12 port
8. Front Compressor Casing  18. Stage 11 port
9. Compressor Front Frame  19. Stage 10 port
10. Turbine Mid Frame Ports  20. Stage 9 port

21. Stage 8 port  22. Stage 7 port
23. Stage 6 port  24. Stage 5 port
25. Stage 4 port  26. Stage 3 port
27. Stage 2 port  28. Stage 1 port
29. Stage 0 port  30. Transfer Gearbox
31. Drive Pad Cover Plate

Figure 2-7.—Borescope inspection ports.
Detailed procedures are provided for indexing and rotating the engine on the MRC. Figures 2-9 and 2-10 show the accessory drive gear ratios and the locking lugs used for indexing the compressor rotor. Zero reference for the compressor and HP turbine stages is established by use of the locking lug blades. Establishing the zero reference ensures a complete inspection for each stage. It also provides you an immediate circumferential reference point for distress reporting for each stage. You should not concentrate on counting the blades. Instead, concentrate on the specific condition of each airfoil as it passes. The forward and aft drive pads have different drive ratios to the main rotor shaft. You may find it advantageous to use a torque multiplier to slow down and maintain better control over the main rotor speed. Depending on the manual drive setup, you will be able
to establish how many full arcs of the ratchet wrench are required to move the main rotor one full revolution. For example, when you are using the forward pad, a 344-degree revolution of the input drive equals 360 degrees on the main rotor.

**SERVICE LIMITS**

This section discusses the types of damage that you might find when conducting a routine inspection. This material will be limited to a discussion of the major engine areas. The parts nomenclature that is used in this section is found in figure 2-11, a foldout at the end of this chapter.

**Compressor Section**

You should inspect the compressor section for nicks and dents, cracks, spacer rubs, casing rubs, blade tip rubs, bent edges, missing pieces, and trailing edge erosion. Inspect the first-stage compressor midspan damper for leading edge dents and other types of
damage. Beginning with the third stage, if a slight tilting of the blade or raising of the blade platform is observed, suspect blade root failure. This condition requires suspended engine operation until the condition has been evaluated.

**COMPRESSOR DAMAGE.**—In the following paragraphs, redescribe some of the damage you may find during an engine inspection. You can find the condition codes used to describe engine damage in foldout table 2-1.

**Airfoil and Tip Cracks.**—Cracks in the compressor hardware are difficult to detect because they are tight and shallow in depth. You can miss these subtle defects because of deteriorated borescope optics or if you rotate the rotor too fast. You should record all crack information relative to the stage, area, magnitude, direction, and adjacent blade condition.

**Cracked Dovetail.**—A cracked dovetail of a blade may lead to blade loss. The location of the blade will determine the extent of engine damage. Before the actual catastrophic failure of the blade, the separated crack in the dovetail will be evident by a leaning blade platform. You can find this fault by using the borescope to inspect each blade platform. The leaning blade platform will be higher than the adjacent nonleaning blades. A “leaner” is a blade that has a crack on the aft...
side of the dovetail and is leaning in the forward direction (fig. 2-12). If a leaner is detected, it must be verified and the engine should be removed from service.

**Airfoil and Tip Tears.**—The most critical area of a torn blade is the area around the end of the tear and its location on the airfoil. You should inspect this area for cracks that lead from the tear and are susceptible to propagation. This condition could lead to the loss of the airfoil section that would create downstream impact damage. You should record all information such as stage, blade locations, area of the blade in which the defect was found, and the condition of the rest of the airfoil and adjacent airfoils. Section A of figure 2-11 shows the nomenclature of a blade.

**Leading and Trailing Edge Damage.**—Random impact damage can be caused throughout the compressor rotor stages by FOD and DOD. The leading and trailing edge of an airfoil is the area of the compressor blade extending from the edge into the airfoil. You must assess both sides or faces of the airfoil when determining the extent of a given defect. If you observe a defect, estimate the percentage of damaged chord length. Observe the defect and the condition of the airfoil area around the defect. If the observed damage is assessed to be “object damage,” the most difficult determination is the differentiation between cracks, scratches, and marks made by the passing objects. Cracks are usually tight in the airfoils, but the apex of the damage usually allows viewing into the airfoil thickness. This provides a direct inspection of the area around the crack. You may have to use all the probes at varying light levels to determine the extent of the damage.

**Tip Curl.**—Compressor rotor blade tip curl is a random and infrequent observation. Tip curl is usually the result of blade rub on the compressor case. Tip curl also can be the result of objects being thrown to the outer circumferential area of the flow path and then being impacted by the rotating blade tip (either leading or

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**Figure 2-12.**—Compressor blade leaners.