Tail Pipe or Engine Fire

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1 Introduction

Fortunately, actual engine fires are a rare occurrence. A fire affecting an engine may be the result of different malfunctions and may have different origins. Thus, a fire affecting the engine should be dealt with according to the origin of this fire.

Two different types of fire may affect the engine and the procedures for fire fighting should be adapted according to each type of fire:

- The engine (or nacelle) fire
- The tail pipe fire

From the cockpit, it is not always obvious for flight crews to differentiate these two kinds of fire. This is particularly true in this unusual and stressing situation with the engine belching smoke and flames.

This is not specific to a given type of engine or even to a type of aircraft, but experience shows that flight crews may tend to discharge the fire extinguisher bottles in case of a reported tail pipe fire.

This article aims at describing the main differences between an engine fire, also called an external fire since it mainly affects the nacelle compartment, and a tail pipe fire, also called an internal fire since the fire is developing within the engine core.

This article also highlights the importance of always applying the relevant strategy for fire fighting depending on each type of fire.

This article is applicable to all Airbus aircraft, whatever the engines and with or without the ECAM system.

2 Engine (nacelle) Fire

2.1.The causes of an engine fire

The nacelle compartment may reach a very high temperature particularly in the HP compressor area or in the combustion chamber area.

Generally, an engine fire is the result of a flammable fluid coming in contact with very hot engine case surfaces.

The nacelle compartment is fitted with many fluid ducts or equipment that contain fuel, oil or hydraulic fluids which are flammable fluids.

Therefore, the source of fire will be due to a malfunction of an external component or a line fitted on the engine core in the nacelle compartment and which contains these flammable fluids.
These fluids have an auto ignition temperature of about:

- 230°C for the fuel
- 260°C for the oil
- 450°C for the hydraulic fluid (between 426°C for Hyjet IV or IV Plus and 507°C for Skydrol 500-B4)

In the event these fluids entering in contact with very hot engine case surface such as the compressor or the combustor, the fire will auto ignite.

The causes of an engine fire will be consequently the result of a malfunction that may be due to different events such as:

- The rupture of a pipe that contains fuel, oil or hydraulic fluid,
- A damage affecting the accessory gearbox. The accessory gearbox fitted on the engine typically contains fuel pumps, hydraulic pumps, oil pumps, starter, IDG,
- The rupture of a rotating part of the engine such as a fan blade or an uncontained compressor blade rupture, which when ejected may damage a pipe,
- The rupture of the combustion chamber leading to fuel leaks

In less frequent occurrences, an internal gaspath abnormality could lead to an engine case penetration resulting in an engine fire.

Consequently, the engine fire will be mainly the result of a fluid leak on the engine core itself. Such a fire will be external to the engine core and will mainly affect the nacelle compartment.

An engine fire may occur during any on-ground or in-flight phase whatever the power is high or low.

This type of fire should not develop inside the engine itself. This is the reason why an engine fire is also named a nacelle fire or an external fire.

2.2.Engine fire protection and detection system

In order to protect the engine and the aircraft against an engine fire (a nacelle fire), fire detectors are fitted in the nacelle compartment.
The detectors are located based on the most sensitive areas of the nacelle considering the temperature of each area but also the presence of flammable fluid and the ventilation of the nacelle. The location and the number of detectors vary with the engine type and model depending on the engine arrangement and the equipment fitted on the engine.

Whatever the engine type or model, the core element is always protected because of the compressor and the combustion chamber.

These parts of the engine can reach very high temperatures. Additionally, many fluid pipes are fitted all along the engine core and particularly fuel pipes at the level of the combustion chamber.

The pylon area is always fitted with fire detectors. This area is protected in order to detect any torch flame which could result from a rupture of the combustion chamber and which could affect the pylon structure integrity.

The detectors are always installed on the engine core in the nacelle compartment. They are not installed within the engine itself.

Each fire area is always well marked out and protected by fireproof partitions.
The purpose of these partitions is to contain the fire in a given area but also to maintain the agent concentration when the fire-extinguishing agent is discharged.

The turbine area is not fitted with a fire detection system.
This is because this part of the engine is not considered as a sensitive area and does not contain flammable fluid pipes or equipment.

Additionally, the turbines are usually made of highly resistant steel able to sustain extreme temperatures (for instance, combustion chamber exit temperature at HP turbine is between 1000 and 1200°C at max cruise).

2.3.Engine fire procedure

When an engine (a nacelle) fire is detected, the following indications are available to the flight crew:

- The fire warning is triggered. This includes the fire handle illumination, the ECAM activation, the Master Warning and fuel lever illumination accompanied by the continuous chime,
- A rise of nacelle temperature because the fire is affecting the nacelle compartment,
- An engine surge and/or engine performance abnormalities may be noticed if a critical component of the engine is affected.

Then, a fire warning indicates that a fire has been detected in a sensitive area of the engine with possible continuous feeding of fire due to hydraulic fluid, fuel or oil leak. Consequently, this warning requires immediate action from the crew.

3. Tail Pipe Fire

3.1. The causes of a tail pipe fire

Another type of fire that may affect the engine is the tail pipe fire. As presented in this part of the article, this kind of fire has different origins and different consequences compared to a nacelle fire.

Typically, a tail pipe fire occurs during ground engine start or shutdown and results from an excess of fuel in the combustion chamber or in the turbine area. Consequently, this is an event that may occur on ground only during engine start or shutdown sequence. In the engine, the combustion chamber is fitted upstream of the LP and HP turbines.

This excess of fuel in the combustion chamber or in the turbine area may be the result of:

- Engine control unit (MEC, EEC, PMC, FADEC depending on the model and type of engine) overfuelling, or
- Rotating stall with fuel continuing to be supplied to the engine, or
- Malfunction of the ignition system,
  Second engine start attempt with some residual fuel pooled in the turbine area due to the first unsuccessful engine start, or
- Oil leak in the tail pipe, or
- To a lesser extent, severe case of fuel in the oil or fuel nozzle cracking at a lower pressure than the design on a shutdown engine, allowing the fuel to enter a combustion chamber which is still hot.

This excess of fuel ignites in the combustion chamber with the engine not rotating or rotating below idle thrust and incapable of utilizing the energy released in production of thrust.

Contrary to the engine (nacelle) fire, which is an external fire, a tail pipe fire is an internal fire.
The source of the fire is within the engine core, i.e. within the combustion chamber or the turbine area. This fire will develop in the aft turbine race. Such a fire will mainly affect the turbine area which is not considered as a sensitive area since no flammable fluid pipe is present in this area. Additionally, as discussed in the previous chapter of this article, the turbines are made of highly resistant steel.

Consequently, such a fire is normally contained within the engine core and should not damage sensitive parts

3.2. Detection of a tail pipe fire

Such a fire is burning within the engine core, that is the combustion chamber and the turbine race It mainly affects the turbine area which is not a sensitive part of the engine with regards to the fire protection. Thus, the turbine area is not fitted with fire detectors.

Consequently, a tail pipe (an internal) fire will not be detected by the fire detectors fitted in the nacelle compartment (for external fire detection) and will not result in the triggering of the ENGINE FIRE warning.

Therefore, how to detect such a fire?

The main indication that a tail pipe fire occurs is a visual report.

Because this type of fire typically occurs at engine start or shutdown, the crew is mainly made aware of a tail pipe fire by a visual report from either ground crew, cabin crew or tower.

Since the EGT probe is located in the affected area (the turbine area), a rapid EGT rise can also be an indication that a tail pipe fire is developing.
This is one of the reasons why the EGT has to be monitored in accordance with the standard operating procedures during engine start or shutdown.
This should be particularly true in case of a second engine start attempt following an unsuccessful attempt where the risk of some residual fuel pooled in the combustion chamber or the turbine area should not be excluded.

3.3. Tail pipe fire procedure

As discussed previously, a tail pipe fire is mainly due to an excess of fuel or vapour in the combustion chamber or the turbine area during engine start or shutdown.

Because no warning is triggered, no ECAM (when fitted) procedure will be displayed.
The flight crew actions are also described in the QRH.

In accordance with these procedures, the best method of arresting such a fire is:

In case of a reported tail pipe fire, the appropriate procedure is consequently to ventilate the engine in order to blow out the fire and any residual fuel or vapor.

Internal engine damage will normally not occur provided the engine is ventilated within minimum delay. A tail pipe fire should not become an external fire except if ignored and the fuel source was large enough or continual so that the fire became very intense. However, in this case, an external observer will warn that the fire is going on and appropriate actions will be taken.

Contrary to the engine (nacelle) fire, the engine fire extinguishing bottles do not have to be discharged in the event of a tail pipe fire.

The reason is because the fire is internal, it is developing within the engine (the combustion chamber and the turbine race).

<table>
<tr><th>A300/ A310</th><th>A318/A319/A320/A330/A340</th></tr>
<tr><td>Shutoff fuel supply (fuel HP valve off),</td><td rowspan="3">MAN START (if manual start performed)…OFF
ENG MASTER (affected)……..OFF

Note: do not press the ENG FIRE pushbutton, since this will cut off the FADEC power supply which will prevent the motoring sequence</td></tr>
<tr><td>Open the crossbleed valve (it has to be opened manually to prevent its closure when the fire handle is pulled),</td></tr>
<tr><td>Pull the fire handle to shutoff fuel LP valve on A300/A310 only</td></tr>
<tr><td colspan="2">Establish air bleed to supply the affected engine starter using either the opposite engine if still running, or APU bleed or Ground Power Unit if connected</td></tr>
<tr><td colspan="2">Crank the engine in order to:

inhibit the ignition circuit and dry motor the engine
reduce the internal temperature
blow out the fire and residual fuel or vapor</td></tr>
</table>

The fire extinguishing system is designed to extinguish a fire in the nacelle compartment where all fluid pipes and various equipment containing flammable fluids are fitted (IDG, accessory gearbox, hydraulic pumps, fuel pumps).

When used, the fire agent is sprayed onto the engine core without penetrating the engine itself.

Consequently, it will not extinguish a fire that is within the combustion chamber and the turbine area. Additionally, the turbine area does not receive extinguishing agent.
The fire extinguishing agent is made of halon gas, a very dry gas, and has no negative impact on the engine. If used, it will not damage the engine parts and will not lead to deposit any residue on the engine. However, since it is designed to extinguish an external fire within the nacelle, it will be of no benefit on an internal fire.
If used, it may even lead to a delay or a no go situation if the bottle that has been discharged cannot be changed or refilled.

In the very worst case where no bleed is available, a ground fire extinguisher can be used as a last resort to extinguish a tail pipe fire if there is no means to ventilate the engine.

The ground fire extinguishers should be used as a last resort since they usually contain dry chemical powder or chemical foam extinguishing agents. These agents are very corrosive agents and may cause serious corrosive damage to the engine.
In accordance with the maintenance practices, the engine must be removed from aircraft for disassembly inspection and cleaning after such an extinguishing agent has been used.

However, if there is no other way to arrest a tail pipe fire or even worse if the fire is developing, there is no doubt that ground fire extinguishers should be used to protect the aircraft.

4. Conclusion

In conclusion, this article highlights the need for a good understanding of the situation for a correct identification of the event that is occurring and for entering the appropriate procedure for fire fighting.

To summarize this article, the main differences between an engine fire and a tail pipe fire are briefly described hereafter:
An engine fire is an external fire. This is a ground or an in-flight event. It is due to a malfunction of an external component with possible continuous feeding of the fire. When occurs the ENGINE FIRE warning is triggered and nacelle temperature rises. The appropriate crew procedure is to shutoff the fuel supply, isolate the engine and, if necessary, discharge the fire extinguishing agent.

A tail pipe fire is an internal fire that is contained within the engine. This is a ground event normally at engine start or shutdown. It is due to an excess of fuel in the combustion chamber or in the turbine. It does not trigger any warning and is visually detected. It is accompanied with a rapid EGT rise. The appropriate crew procedure is to shutoff fuel and ignition and to dry motor the engine for ventilation. The ground fire extinguisher should be used as a last resort.

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