Troubleshooting Of High Exhaust Temperature Spread Issues In Gas Turbines

Asutosha Sahu

Deputy Manager- Maintenance Rotary

Hindustan Petroleum Corporation Limited

Visakh Refinery

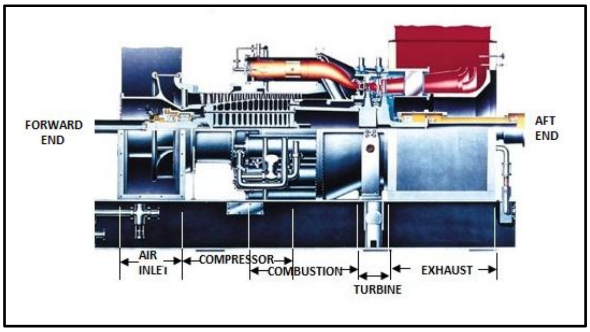
Abstract**—** *All major Oil & Gas Industries thruput is directly dependent on the reliability of continuous power supply, which are mostly met through internal power generation by using Gas Turbines Generators. Since Gas Turbine availability is very much essential for sustained and continuous running of Refinery, the activity of maintenance & troubleshooting cannot be ignored and the same to be done in a systematic manner. High exhaust temperature spread is one of the major concern in liquid fired Gas Turbines leading to low reliability of Gas Turbine & more down time. In this document some of the reasons for the high spread issues & troubleshooting are analysed and presented in detail. The information contained in this document is broadly applied in Refineries where Gas Turbines are installed for generation of power.*

Key words: Gas Turbine Generators, High exhaust temperature spread, swirl troubleshooting

I. Introduction

A Gas Turbine is a combustion engine that can convert chemical energy e.g. natural gas or other liquid fuels to mechanical energy. This mechanical energy then drives a Generator that produces electrical energy.

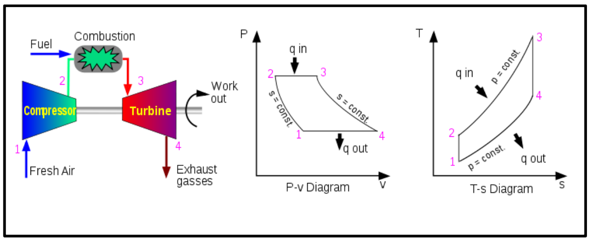
To generate electricity, the Gas Turbine heats a mixture of air and fuel at very high temperatures, causing the turbine blades to rotate. The rotating turbine drives a generator that converts the mechanical energy into electricity.



Gas Turbine main sections

Basic operation of a GTG:

Gas Turbine operates on Brayton thermodynamic Cycle:



Brayton Cycle

1. Adiabatic Compression: Inlet air compressed through compressor mounted on Gas Turbine drive shaft.
2. Constant pressure heat addition: Fuel atomises with air in fuel nozzle & burned at extremely high temperatures in combustion chamber generating hot flue gas.
3. Adiabatic expansion: Hot flue gas mixture moves through turbine blades

causing to rotate turbine drive shaft very quickly.

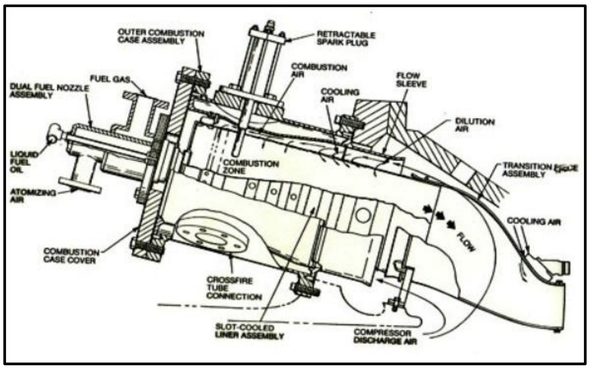
4. Constant pressure heat extraction: The high temperature exhaust flue gas from turbine utilized for heat recovery in steam generators.

The rotating turbine drive shaft powers the generator through reduction gearbox for electricity generation.

II. GAS TURBINE EXHAUST TEMPERATURE SPREAD BASICS:

An exhaust temperature spread refers to a high differential in temperature readings between the thermocouples placed radially around the exhaust of a gas turbine. It is the difference between maximum and minimum temperatures recorded by exhaust temperature thermocouples. If spread is allowed without correction, it will results in reduction of residual life of downstream components of the Gas Turbine. The worst exhaust temperature spreads occur when the hottest and coldest spot are nearer i.e. exhaust thermocouple readings are grouped very closely adjacent. Most exhaust temperature spreads are the result of combustion section problems that can lead to premature failure of turbine blade /bucket.

In other words, exhaust temperature spreads are indicative of combustion troubles that can lead to catastrophic failure of equipment.



Gas Turbine Combustion Chamber

Most heavy duty gas turbines employ multiple combustors, called 'can annular combustors' each of which produce high temperature gases that are funnelled to the first stage nozzles of the turbine section where they are expanded to produce torque. Ideally, each one of these combustors should be receiving equal amounts of fuel and air which should result in relatively uniform hot combustion gas temperatures from each of the combustors entering the first stage turbine nozzles.

The turbine buckets rotate past each combustor at very high rates, 85 times per second for a 5100 RPM machine, 60 times per second for a 3600 RPM machine & 50 times per second for a 3000 RPM machine.

Hot combustion flue gases mixes very little with the gases from adjacent combustors before entering the Gas Turbine exhaust. It also don't travel axially straight through the turbine section, which is known as swirl. It's this fact that very little mixing occurs as the hot gases pass through the turbine section that allows the exhaust temperature thermocouples to be used to sense cold or hot spots in the gas turbine exhaust which are indicative of unequal fuel and or air flows into individual combustors.

III. FACTORS AFFECTING EXHAUST TEMPERATURE SPREADS:

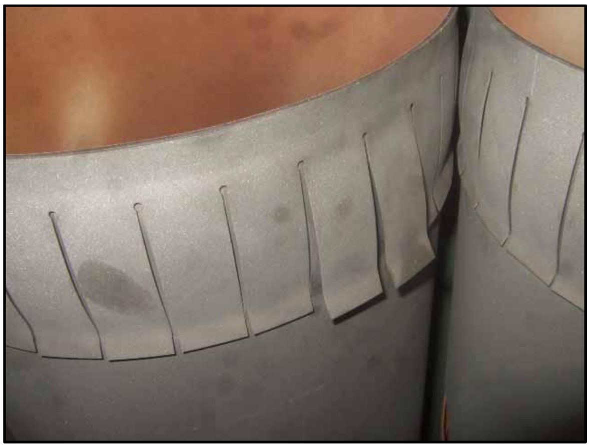
There are many reasons for exhaust temperature like instrumentation issues or mechanical issues but most of cases spreads are the result of mechanical issues.

1. Plugged fuel nozzle orifices, enlarged fuel nozzle orifices and fuel nozzle assembly problems (loose components due to improper uniform torqueing as per drawing, worn components etc.) are the most common causes of unequal fuel flow-rates. Fuel nozzle allowed range of flow variation between installed nozzles: Liquid fuel in 5% flow range, Atomising air in 20% flow range & fuel gas in 5% flow variation range.

Gas Turbine Fuel Nozzle (plugged)

Gas Turbine Fuel Nozzle (New)

2. On liquid fuel-fired machines, liquid fuel flow divider issues like internal erosion/improper torqueing can cause unequal fuel flow-rates causing high spread.
3. A leaking liquid fuel purge air check valves issues can cause unequal fuel flow-rates due to fuel bypass to fuel nozzle causing spread.
4. Fuel purge drain isolation valves passing will cause fuel bypass & high spread.
5. Failed/plugging liquid fuel check valves can also cause lack of atomisation / unequal fuel flow causing incomplete or unequal fuel combustion and high exhaust temperature spreads. Severe problems can even result in loss of flame in one or more combustors (combustors with or without flame detectors) which can cause very high exhaust temperature spreads/trips. Pop off pressure of all check valves should be in 10% variation range.
6. Low, high or uneven atomizing air flows can result in incomplete combustion and even loss of flame. Primary zone re-ignition or flashbacks in combustors can cause high exhaust temperature spreads.
7. Atomising air compressor insufficient output, moisture contamination & lube oil leak carry over can also cause very high exhaust temperature spreads. Atomising air compressor discharge pressure to compressor discharge pressure ratio should be greater than 1.34 for proper atomisation & avoid incomplete combustion. Atomising air temperature should be more than dew point temperature for avoiding moisture contamination. There should not be air seal leak from atomising air compressor.
8. Cracked or broken combustion liners or hula seal problems, damaged crossfire tubes can result in high exhaust temperature spreads.



Bend leaf on Spring/Hula seal of Combustion Liner

New Spring/Hula seal of Combustion Liner

Gas Turbine crossfire tube (New)

9. Cracked or broken transition pieces and leaking transition piece side seals/ hula seals seating area can result uneven flow & high exhaust temperature spreads.

Gas Turbine combustion liners

Wear in Transition piece Side Seal

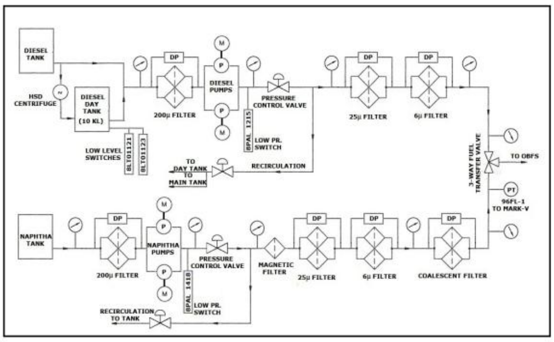
Damaged Crossfire Tube (material erosion/missing at OD)

New Transition piece

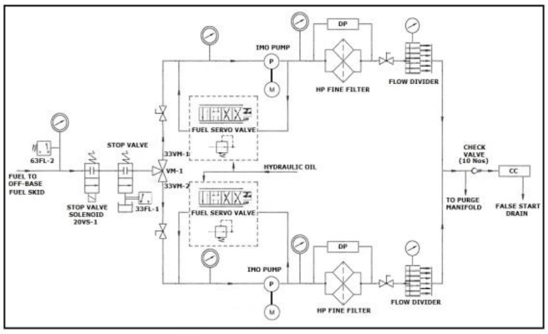
Gas Turbine transition piece assembly

Gas Turbine exhaust / thermocouples

10. Improper fuel filtration/ purification can cause poor firing & high temperature spread.



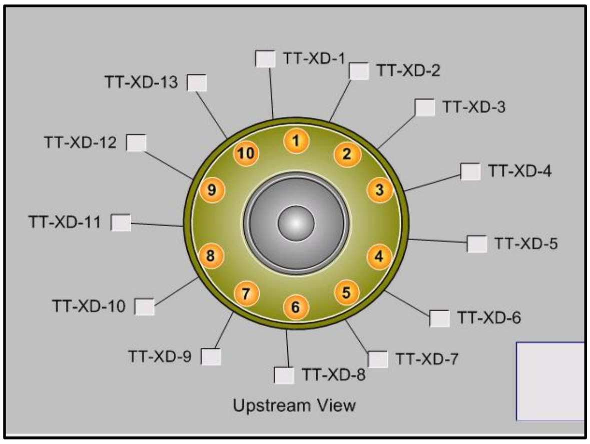
Gas Turbine fuel system Fig-1



Gas Turbine fuel system Fig-2

Misc. filtering system in fuel path like 200 micron/25 micron/6 micron/ 5 micron duplex filters in series for foreign materials filtration, magnetic filter for ferrous material filtration & coalescent filter for moisture content removal.

11. Some exhaust temperature spreads have been caused by insulation found to be blocking the air flow across the thermocouple.



Exhaust thermocouple distribution

12. Improper inserted/terminated exhaust thermocouples can cause high exhaust temperature spreads immediately after a maintenance outage.
13. Failed/failing or intermittent exhaust thermocouples can cause false exhaust temperature spreads and even trips.

One way to quickly eliminate instrumentation issues is to change load appreciably. If the highest and/or lowest exhaust thermocouple readings don't changes with load changes i.e. the position of the coldest / hottest exhaust thermocouple don't moves, then the cause may be attributed to failed or intermittent instrumentation. As was mentioned before, due to the swirl phenomenon a true exhaust temperature spread will appear to as load changes, if the problem is one or two failed or failing exhaust thermocouples the position of the hottest/coldest thermocouple will not change with load.

IV: TROUBLESHOOTING EXHAUST TEMPERATURE SPREADS

Machine data needed:

- Exhaust temperature thermocouple readings (TTX's) on more than one fuel.
- Load MW in different intervals.
- Fuel line pressure readings through pressure selector.

Clues to look for:

- Identify Hot spot or cold spot
- Does hot/ cold spot rotate with load then no issue with instruments
- Has the spread suddenly appeared or has been there always

4.1 *COLD SPOT*:

- Less fuel/ Excess air: Most likely problem is a blockage in the fuel passages due to debris/plugging in gas passages, Coked up in fuel nozzle liquid fuel passages & check valves, crossfire tubes damage/leak, transition piece / seal damage.
- Fuel bypassing the nozzle due to oil purge check valves are leaking
- Fuel purge drain valve passing
- Air leak in liner or Transition piece due to transition piece seal disengagement

4.2 *HOT SPOT*:

- Excess fuel / Less Air: Most likely problem is more fuel to one can due to fuel nozzle assembly (loose gas tip, eroded air cone, eroded fuel nozzle oil pilot) & Blocked / damaged liner holes, erosion in flow divider

4.3 COMPONENT PROBLEMS:

- Combustion System Components:
- ✓ Fuel Nozzles chocking
- ✓ Liners damage
- ✓ Transition piece damage including floating & side seals erosion
- Fuel System Components:
- ✓ Fuel check valves
- ✓ Purge check valves
- ✓ Flow divider

4.4 COMMENTS:

- Spread problems that occur during installation are usually not serious the same can be attended immediately.
- If spread suddenly occurs during operation, it could be serious.
- If during FSNL spread reaches more that could be due to one or more liner does not have flame. No need to worry, If possible, increase the load, the machine may crossfire after little loading or transfer to other fuel if available and transfer back
- Some unnatural causes of spreads due to human error in case gas flange tape not removed or one nozzle of a different design.

V. CONCLUSION:

If any unit running below allowable spread is acceptable to run. If a unit starts from the beginning at a perceived high spread and does not increase, there is no issue for concern.

If more than one unit are at a site, the spreads on the units will be different. Also, if one unit runs at low spread and the next at little higher, does not mean there is something wrong with the unit.

Time to get concerned:

a) If there is a sudden jump in spread

b) If spread continues to increase with time

REFERENCES:

[1] Active Swirl V2 by Nathan Spence
[2] Exhaust Spreads And Troubleshooting by Roointon Pavri, June 7, 2000
[3] Gas turbine manuals