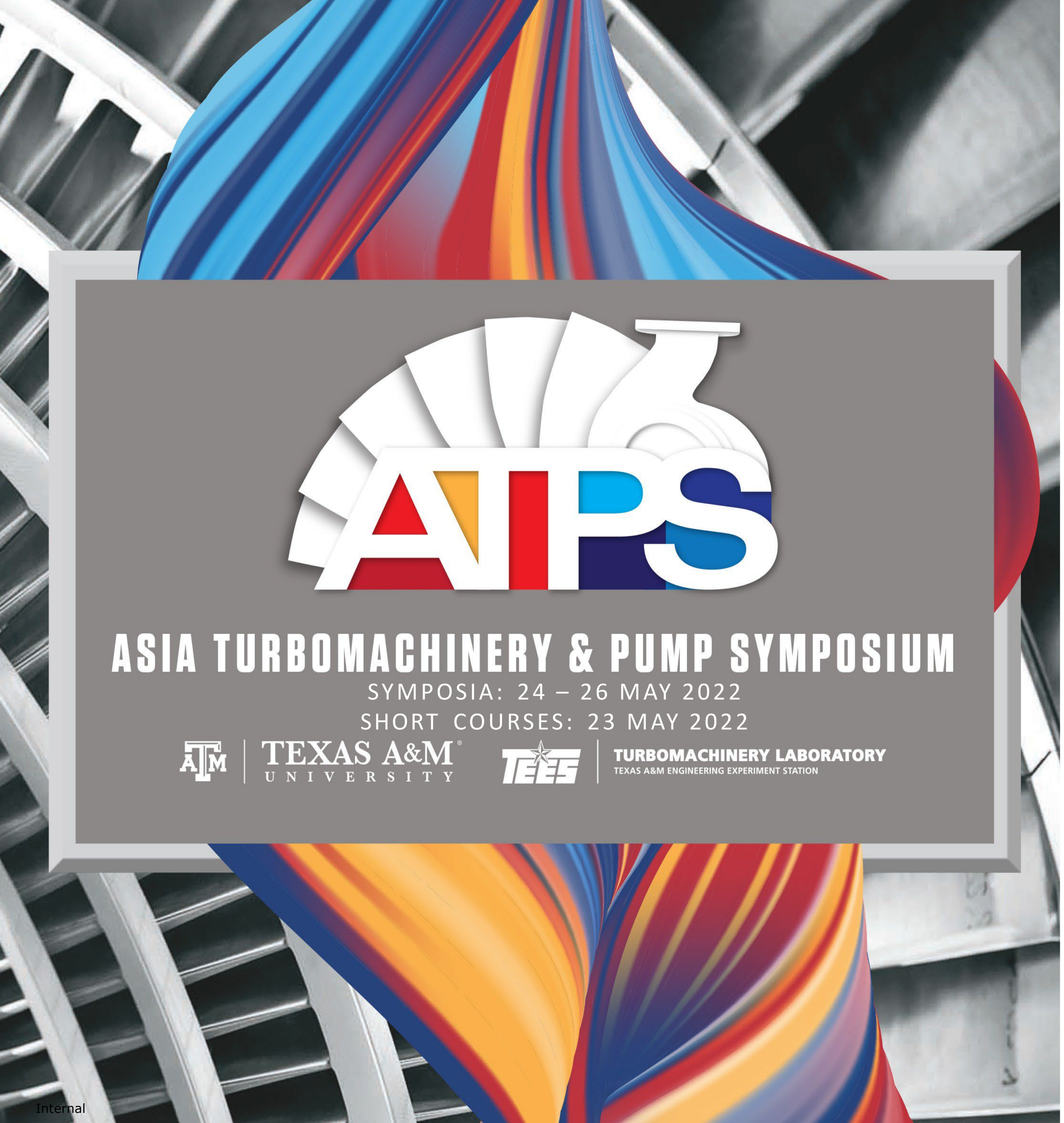

Implementation of Voted Flame Detectors to Prevent Spurious Fire Detection in Gas Turbines Enclosures.

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Abstract

Fire detection inside Gas Turbine enclosures is a safety critical component to prevent unwanted consequences should a fire occur within the enclosure.

The standard design and implementation strategy remains by and large placing multiple detectors in a 1oo1 configuration which ensures sufficient coverage and focuses on specific areas within the Gas Turbine enclosure.

1oo1 configuration despite being safe comes at the expense of higher risks of unwanted spurious trips resulting in unwanted downtime.

This case study explores the course of action taken by end user to vote between flame detectors inside the gas turbine enclosure. This solution is supported by demonstrating sufficient area coverage of the flame detectors using 3D modelling software in order to arrive at a compromised balance between safety and availability.

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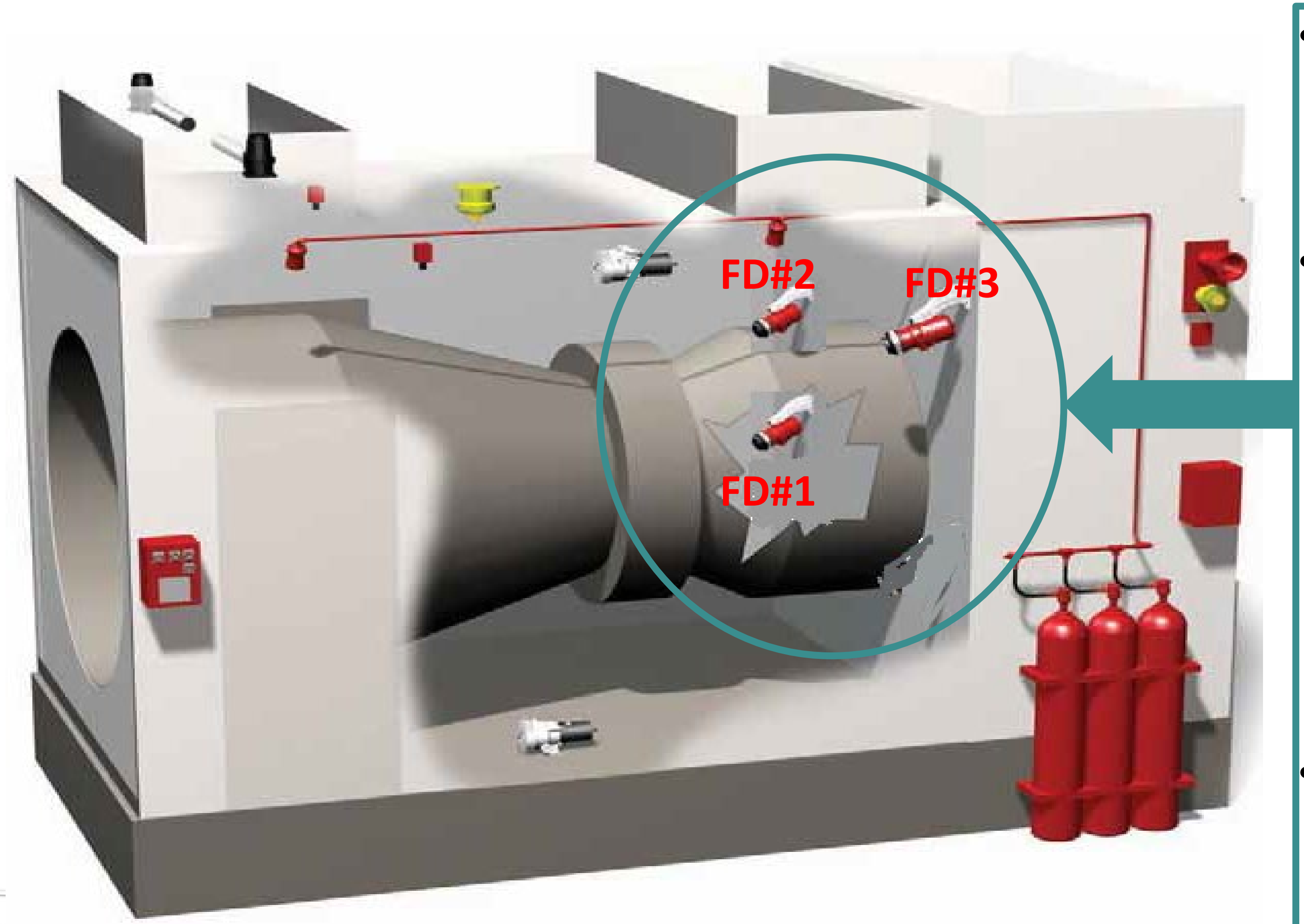
Part 1: Background

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

Internal

Fire Detection in Gas Turbine Enclosures



- Typical Set-up by Gas Turbine OEMs supported by F&G System Manufacturers

- Proper selection of suitable detector technology for Gas Turbine application:
  - ❑ Methane/Diesel Fuel
  - ❑ Operating Temperature
  - ❑ High Reliability with Self Diagnostics
  - ❑ High 'False Fire' Rejection

- OEM 3D Model document states 89.5% total enclosure area + 100% GG area coverage with ***1oo1 voting configuration.***

Part 2: The Problem

2013 – 2014: Spurious Incidents Chronology

Nov 2013
Trip due to FD2
Suspect due to broken PT rim cooling tubing

Jan 2014
Trip due to FD2
Faulty FD – Oi Fault

- Action Taken: Replaced FD2, sent to Factory

Feb 2014
Performed health check on FD1, 2 and 3 based on factory FD2 finding in Jan.

Action Taken:
- Recalibrated FD3
- Recalibrated but unable to recover FD2
- Repositioned FD1 to compensate FD2

April 2014
Periodic replacement:

- Replaced FD1 and FD2, recovered FD2

12 July 2014
Trip due to FD3
High IR background only on FD3

Action Taken:
- Replaced FD3

13 Aug 2014
Trip due to FD3
High IR background only on FD3

1. System event logs, post investigation discussion and testing confirm all events were spurious.
2. No visible fire was detected in the enclosure.

Impact

15MW Gas Turbine Driven Compressor in a Petrochemical Plant. Recycle Gas Compressor – essentially the heart of the plant – Each trip incident results in:

- Loss of circulation to key process units
- Reactor temperature cooling
- Unnecessary flaring

Economic Loss: Avg RM3M due to production loss, CO_2 cylinder replenishment, start-up delays per incident!

Sustainability Goals: Increased CO_2 + black smoke emission from additional ~126-130m3/hr flaring

Reputational Impact: Reliability of Plant Operations, Equipment, Sensors, Personnel, Vendor, OEM Capability

Part 3: The Proposed Solution

Corrective Action Taken

1. Increased routine maintenance to review alarm logs and analyze detector diagnostics.
2. Increased visual inspection inside enclosure via peephole.
3. Extraction of logs and clearing of alarm from system e.g., power cycling.
4. Contact machine OEM & F&G Vendor – investigation of data logs
5. Check detector batch for potential manufacturing faults.
6. Detector replacements.
7. Detailed review of detector configuration and installation practices.

Logs | Configuration | Status | Control

Event	Event ID	Date	Time	Description	Temperature	Voltage
1	252	17-Jul-2014	15:00:23	EE reset	+40C	24V
2	247	17-Jul-2014	14:57:25	Oi Cal	+37C	24V
3	254	17-Jul-2014	14:52:23	Powr Up	+26C	24V
4	249	12-Jul-2014	12:18:14	SYS reset	+55C	20V
5	255	12-Jul-2014	12:18:14	Powr Dn	+55C	20V
6	253	12-Jul-2014	05:26:25	Normal	+44C	20V
7	175	12-Jul-2014	05:26:25	CLR:Bin Disable	+44C	20V
8	176	12-Jul-2014	05:25:37	Bin Disable	+43C	20V
9	253	12-Jul-2014	05:21:57	Normal	+43C	20V
10	191	12-Jul-2014	05:21:57	CLR:Hi Background	+43C	20V
11	192	12-Jul-2014	05:21:34	Hi Background	+43C	20V
12	253	12-Jul-2014	05:20:25	Normal	+42C	20V
13	175	12-Jul-2014	05:20:25	CLR:Bin Disable	+42C	20V
14	199	12-Jul-2014	05:20:06	CLR:Fire	+42C	20V
15	202	12-Jul-2014	05:20:05	Fire E	+42C	20V
16	199	12-Jul-2014	05:20:03	CLR:Fire	+42C	20V
17	202	12-Jul-2014	05:19:58	Fire E	+42C	20V
18	199	12-Jul-2014	05:19:56	CLR:Fire	+42C	20V
19	202	12-Jul-2014	05:19:54	Fire E	+42C	20V
20	199	12-Jul-2014	05:19:49	CLR:Fire	+42C	20V
21	202	12-Jul-2014	05:19:47	Fire E	+42C	20V
22	176	12-Jul-2014	04:56:25	Bin Disable	+43C	20V
23	253	12-Jul-2014	04:51:13	Normal	+43C	20V
24	175	12-Jul-2014	04:51:13	CLR:Bin Disable	+43C	20V
25	199	12-Jul-2014	04:48:05	CLR:Fire	+43C	20V

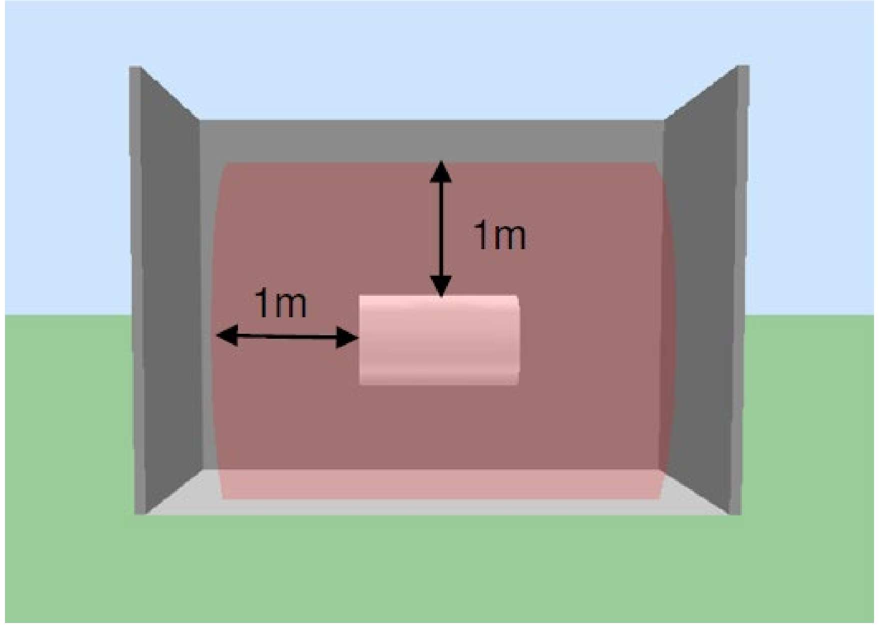
8. Changed detector sensitivity from default (Medium) to customized Gas Turbine application sensitivity parameters developed by Vendor

- Despite the corrective action – the fear of a trip is always present with ***1oo1 voting configuration***

Attempt to Vote with Existing Detectors

- Initiated attempt to carry out 3D F&G Mapping using PETRONAS fire and gas mapping software.
- Performed Internal Risk Assessment on Potential Fire Scenarios inside Gas Turbine Enclosure with all available documentation and discussion with Subject Matter Experts, OEM and F&G Vendors.
- Turbine OEM did not consent to the proposed changes to the original design philosophy.
- Obtained Turbine OEM Flame Detector and Location Coverage philosophy document for reference.
- 3D Mapping philosophy and results were presented to turbine OEM's F&G Vendor for assurance on adopted approach. F&G OEM agreed in principal without accountability for changes to original configuration. F&G OEM was at site with the end user during these activities.

Proposed 3D F&G Model Philosophy for GT Enclosure



Propagation Model for Grade A Equipment

- Equipment classified as grade A, highest flammability risk – model set-up to detect fire equivalent of 10kW in size (smallest)
- Fire model must ensure that flame detector detects a fire before propagation is 1m all around from equipment (smallest) – reference to Gas Generator
- Fire Alarm will be detected when any 1 detector detects a fire. The sum of all detector coverage of the enclosure shall be > 90 %.
- Fire Trip will be activated when 2 detectors detects a fire. Each pair of detectors coverage of the enclosure shall be >85%. (End User Standard)

- Enclosure dimensional drawings and site visit performed to ensure accurate modeling of existing Gas Turbine installation and Flame Detector placement and orientation.

3D F&G Model Results

(i) Flame detection mapping with 3 flame detectors:

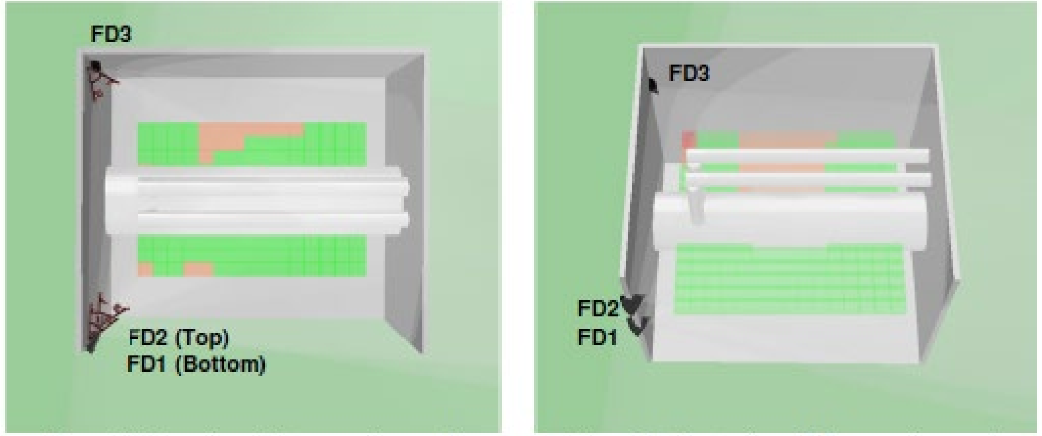


Figure 2A: Top view of the mapping result Figure 2B: Front view of the mapping result

Case	Alarm Coverage	Trip Coverage
Target	90%	85%
3 Detectors	96%	83%

(ii) Flame detection with 4 flame detectors:

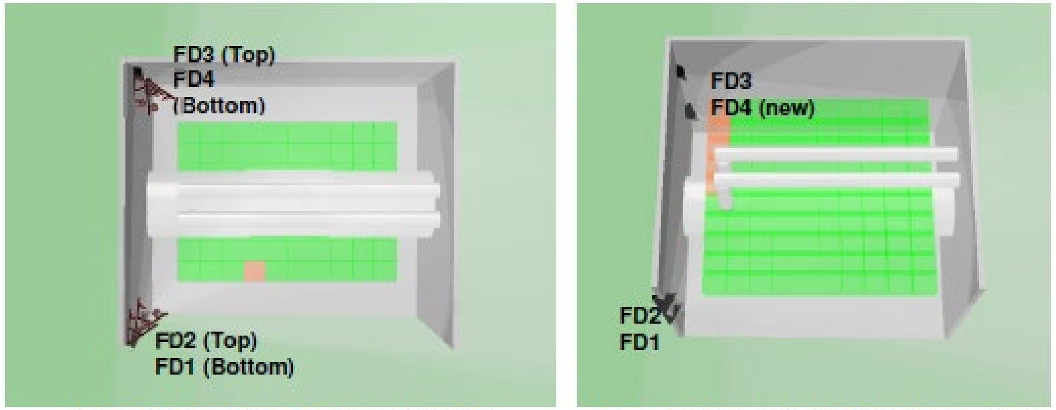


Figure 2A: Top view of the mapping result Figure 2B: Front view of the mapping result

Case	Alarm Coverage	Trip Coverage
Target	90%	85%
4 Detectors	98%	92%

- Model was performed with additional detector proposed inside enclosure.
- 4 Detector set-up exceeded OEMs Existing of Area of Coverage of 89.5% of the given protected space inside the enclosure + full coverage of the gas generator (including the underbelly), all hazardous areas, and ignition sources.

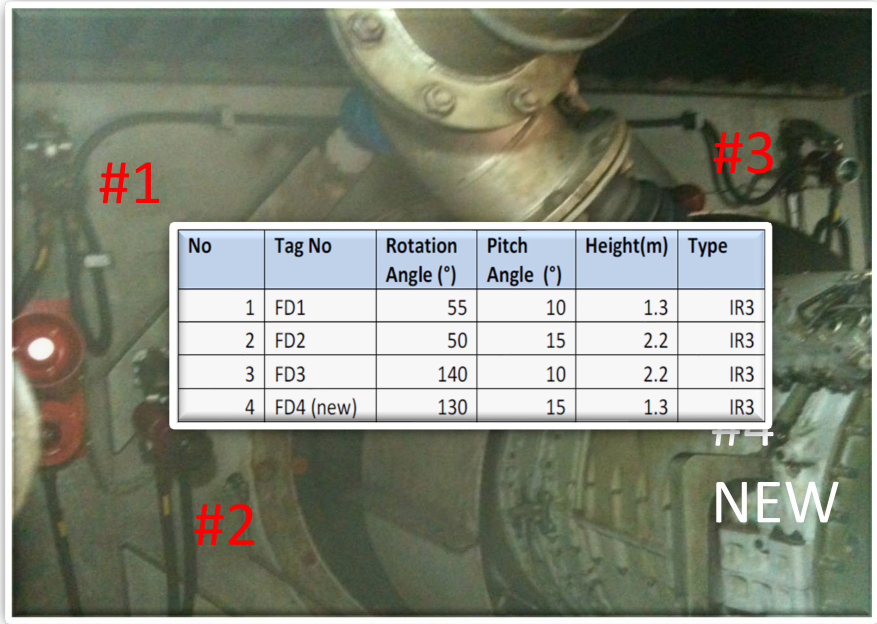
Logic Configuration

CONDITIONS	FD1	FD2	FD3	FD4	RESULT
FIRE>1 + HEALTHY	FIRE	HEALTHY	FIRE	HEALTHY	TRIP
FIRE>1 + FAULT	FIRE	FAULT	FIRE	HEALTHY	TRIP
FIRE=1 + FAULT>1	FIRE	FAULT	FAULT	HEALTHY	ALARM
FIRE=0 + FAULT>1	FAULT	FAULT	FAULT	FAULT	ALARM

- Non Critical Detector Faults do not degrade the detector's complete functionality, hence detector is still able to detect a fire.
- Faulty fires detected by Detector will be detected as FIRE and considered in the voting logic to trip.
- Faults are configured as alarm ONLY and not considered in the logic voting to trip the unit. As per original OEM configuration.
- System is locked and does not allow for any faulty detectors to be bypassed from the voting logic.
- All Detector Faults, Alarms and Trip are annunciated to the fire and gas controller display, turbine control panel and HMI.

Detector Testing & Implementation

- 2oo4 configuration was selected and implemented.
- Flame detector mounting was fabricated for the new location of the 4th flame detector inside the enclosure.
- Flame Detector simulation was performed in similar sized room to verify functionality.
- Logic modification was performed, and function tested accordingly.
- All flame detectors sensitivity were set to vendor approved custom setting for turbine enclosure application
- All activities were performed with the presence of Fire and Gas Detector Vendor at site for assurance.



No	Tag No	Rotation Angle (°)	Pitch Angle (°)	Height(m)	Type
1	FD1	55	10	1.3	IR3
2	FD2	50	15	2.2	IR3
3	FD3	140	10	2.2	IR3
4	FD4 (new)	130	15	1.3	IR3

Part 4: Lesson Learnt

Post Implementation Lessons

- 2oo4 Flame Detector Voting Implementation for this Gas Turbine Enclosure in 2015 was proven to be effective in preventing any nuisance trips till date.
- Flame detectors in a gas turbine enclosure can and should be voted in order to ensure robustness. The gas turbine is always vulnerable to spurious trips in a single device trip setup.
- Some types of detectors can register high IR background due to the natural heat intensity in a gas turbine enclosure. Care should be placed on Heat Insulation installation inside gas turbine enclosures.
- A higher enclosure coverage area is achievable with more detectors compared to original setup.
- Detector settings and delays must be properly implemented to ensure a genuine fire is picked up.

Part 5: The Message

Conclusions

Single trip device configuration or 1oo1 can always lead to spurious trips at any time regardless of the level of care given to the selection, installation and maintenance of the sensor.

Nevertheless, this is still the standard default set-up adopted by majority of Gas Turbine OEMs in the market today.

In order to have a more reliable and robust implementation, a voted set up with optimized detector placements should be considered by Gas Turbine OEMs as default for future implementation.

Minimizing spurious trips of Gas Turbines in operation leads to improved equipment efficiency, minimizes losses and improves overall sustainability goals.

Thank You

Q&A