# TIGER™ Diagnostic Report

***Diagnostic Analysis Report***
***for***
***GE LM6000***
***Gas Turbine 1***

Revision: 1.1

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# *Table of Contents*

# 1. INTRODUCTION

These are initial findings based on the analysis of results from TIGER diagnostic runs on data for the GE LM6000 unit 1 turbine.

Data for the period November 2002 to January 2003 was used.

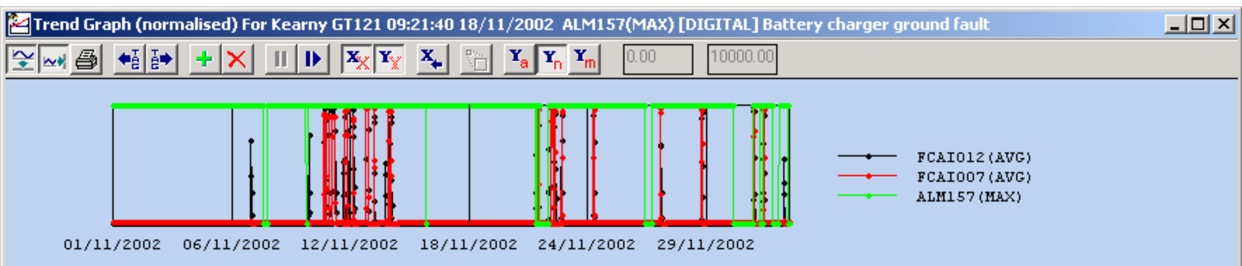
TIGER diagnostic messages are included where appropriate, in the original colour code format. Graphs and screen dumps are also included in some cases.

More analysis of some of the incidents reported is required, and there is also a requirement for maintenance action in some cases.

# 2. BATTERY CHARGER GROUND FAULT

This alarm (ALM157) is in force almost continuously throughout the data sample period. The occurrence of this alarm also does not appear to be affected by Turbine run state.

**Trend graph showing ALM157, turbine speed and power.**




| Tag Name | Min | Value | Max | Description | Turbine |
|---|---|---|---|---|---|
| FCAI012(AVG) | 0.000 | 0.000 | 9426.0... | [rpm] HP shaft speed corrected to sta... | |
| FCAI007(AVG) | -0.614 | 0.004 | 50.256 | [Mw] GEN load meter only | |
| ALM157(MAX) | 0.000 | 1.000 | 1.000 | [DIGITAL] Battery charger ground fault | |

**TIGER Diagnostic Messages**

16:48:54 27/11/2002 § Battery charger ground fault [ALM157}

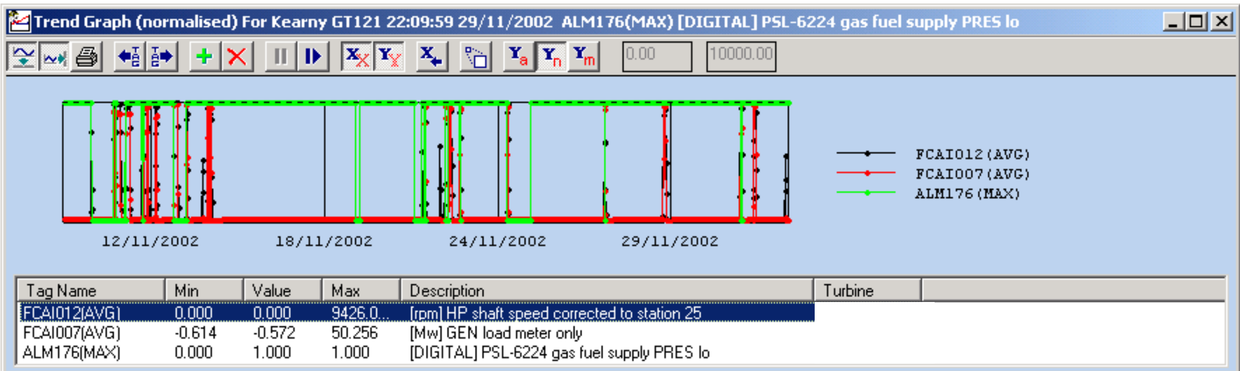
**Analysis**

This indicates a problem with the battery.

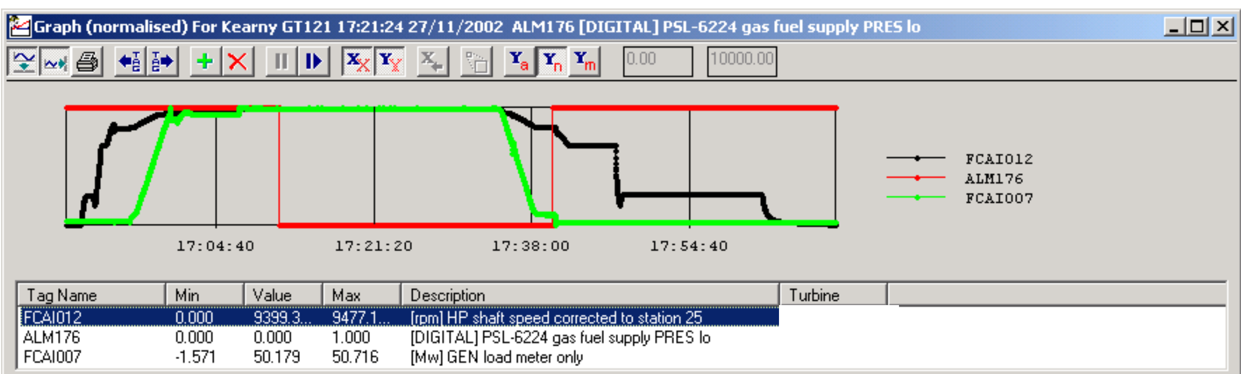
## 3. GAS FUEL SUPPLY PRESSURE LOW

This alarm (ALM176) is in force almost continuously throughout the data sample period.

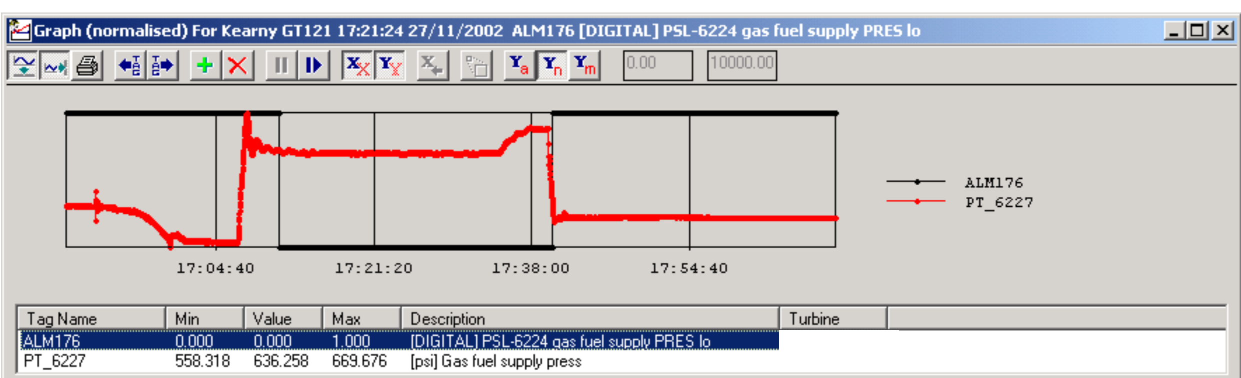
**Trend graph showing ALM176, turbine speed and power.**




**Graph showing ALM176 and turbine speed and power.**




**Graph showing ALM176 and gas fuel supply pressure.**



## TIGER Diagnostic Messages

**16:48:54 27/11/2002 § PSL-6224 gas fuel supply PRES lo [ALM176]**

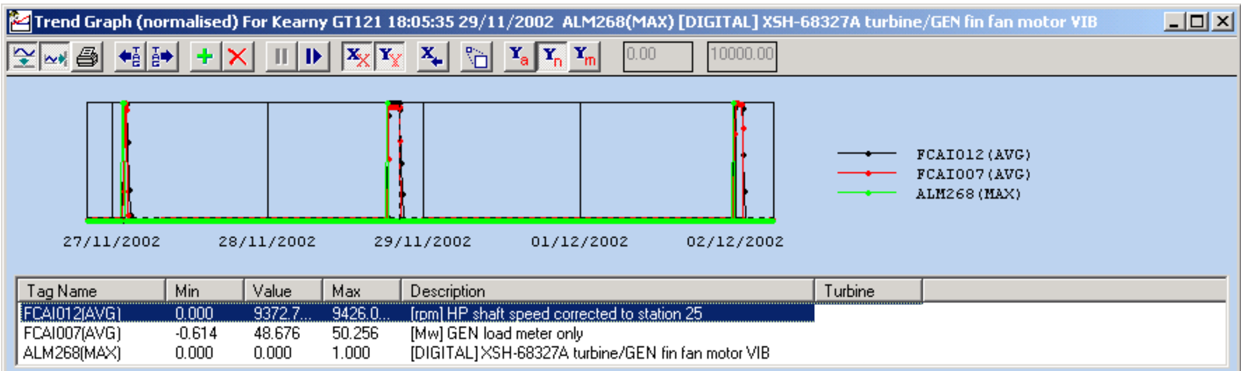
## Analysis

The occurrence of this alarm does appear to be affected by Turbine run state, with the alarm going off during some turbine run periods. This is indicated in the example data set shown above. In the data sample on the 27th this alarm occurs as the turbine is preparing to shutdown, and reducing power. There is a fall in gas fuel pressure which appears to cause the alarm. However, the alarm does not clear immediately at the start of the turbine run as gas pressure rises, which appears to be inconsistent. Also, from the data available it is not clear what caused the pressure to fall so rapidly during the shutdown.

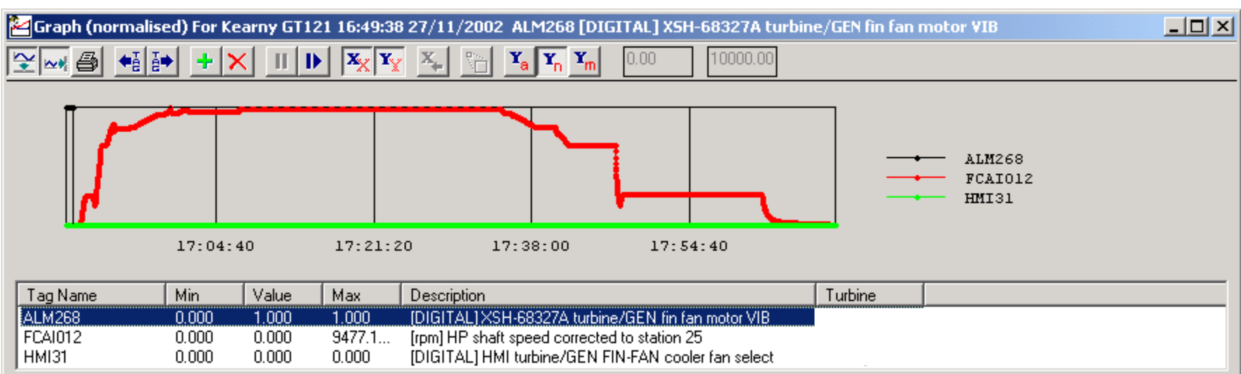
## 4. TURBINE FIN FAN MOTOR VIBRATION

This alarm (ALM268) comes on at the start of each turbine run, and then goes off.

**Trend graph showing ALM268, turbine speed and power.**




**Graph showing ALM268, fin fan cooler select and turbine speed.**




### TIGER Diagnostic Messages

16:48:54 27/11/2002 § XSH-68327A turbine/GEN fin fan motor VIB [ALM268]

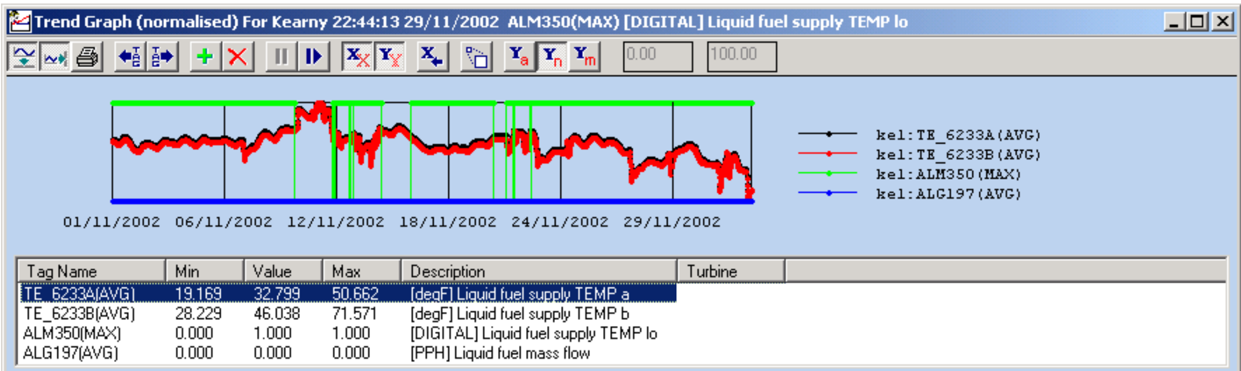
### Analysis

The occurrence of this alarm does appear to be affected by Turbine run state, with the alarm going on at the start of a turbine run, and then off. This is indicated in the example trend graph above. The fin fan select is permanently on. This may indicate a vibration problem with the fin fan, which disappears once the turbine starts.

## 5. LIQUID FUEL TEMPERATURE LOW

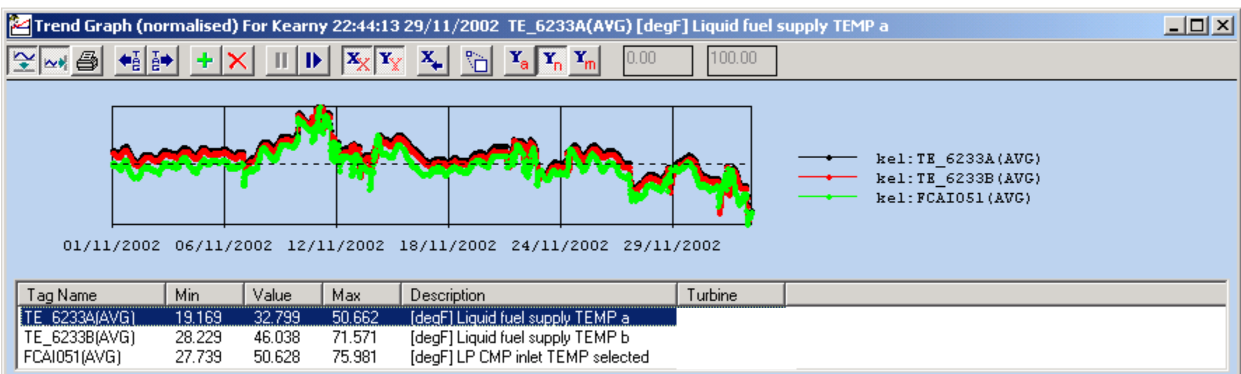
This alarm (ALM350) goes on and off depending on liquid fuel temperature.

**Trend graph showing ALM350, liquid fuel temperatures and liquid fuel flow.**




| Tag Name | Min | Value | Max | Description | Turbine |
|---|---|---|---|---|---|
| TE_6233A(AVG) | 19.169 | 32.799 | 50.662 | [degF] Liquid fuel supply TEMP a | |
| TE_6233B(AVG) | 28.229 | 46.038 | 71.571 | [degF] Liquid fuel supply TEMP b | |
| ALM350(MAX) | 0.000 | 1.000 | 1.000 | [DIGITAL] Liquid fuel supply TEMP lo | |
| ALG197(AVG) | 0.000 | 0.000 | 0.000 | [PPH] Liquid fuel mass flow | |

**Trend graph showing liquid fuel and compressor inlet (ambient) temperatures.**




| Tag Name | Min | Value | Max | Description | Turbine |
|---|---|---|---|---|---|
| TE_6233A(AVG) | 19.169 | 32.799 | 50.662 | [degF] Liquid fuel supply TEMP a | |
| TE_6233B(AVG) | 28.229 | 46.038 | 71.571 | [degF] Liquid fuel supply TEMP b | |
| FCAI051(AVG) | 27.739 | 50.628 | 75.981 | [degF] LP CMP inlet TEMP selected | |

### TIGER Diagnostic Messages

**16:48:54 27/11/2002 § Liquid fuel supply TEMP lo [ALM350]**

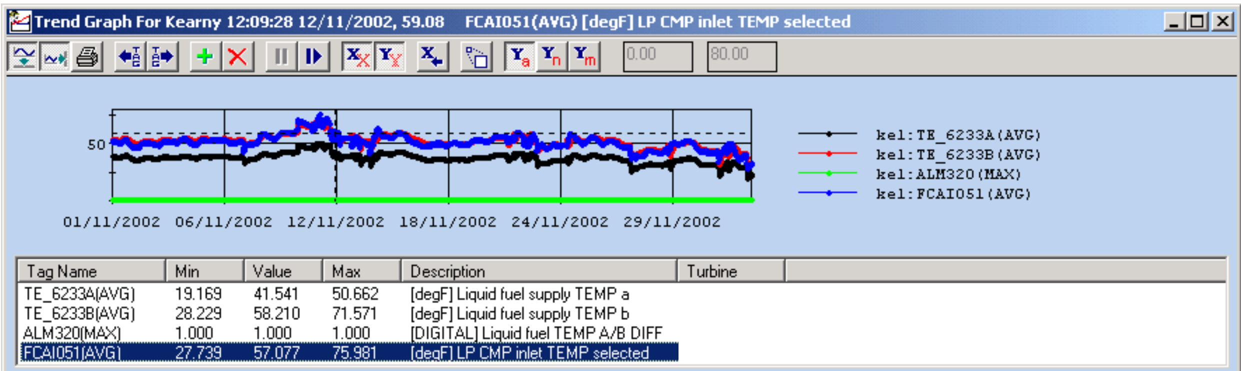
### Analysis

The occurrence of this alarm does not appear to be affected by Turbine run state, but by the ambient (or in this case LP compressor inlet) temperatures, with the alarm going on and off as ambient temperatures rise and fall. This is indicated in the example trend graphs above. Liquid fuel is not used during the sample data set shown above, as can be seen from the trend graph showing liquid fuel flow. It is possible that there may be problems firing on liquid fuel if the fuel temperature is too low. It is also possible that the thermocouples could be reading incorrectly (see next incident).

## 6. LIQUID FUEL TEMPERATURES A & B DIFFERENT

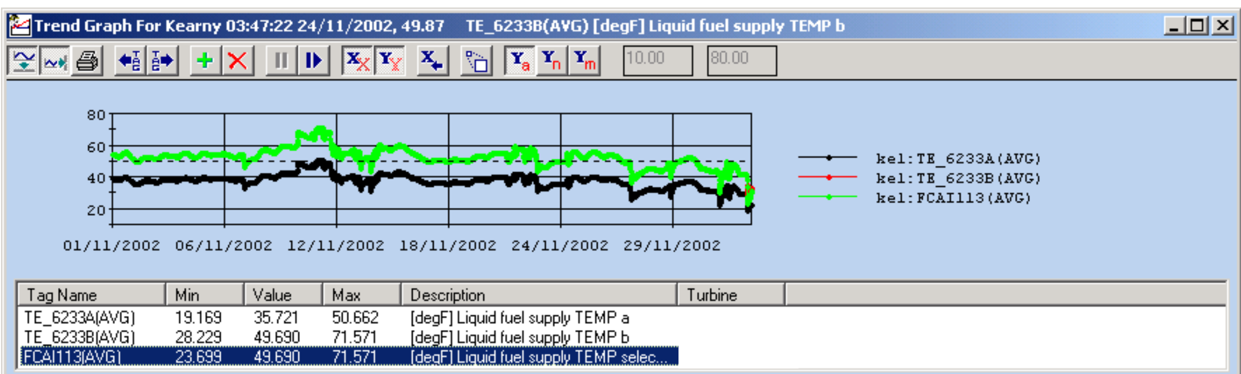
This alarm (ALM320) stays on throughout the sample data set.

**Trend graph showing ALM320, LP compressor inlet temperature, liquid fuel temperatures A and B.**




| Tag Name | Min | Value | Max | Description | Turbine |
|---|---|---|---|---|---|
| TE_6233A(AVG) | 19.169 | 41.541 | 50.662 | [degF] Liquid fuel supply TEMP a | |
| TE_6233B(AVG) | 28.229 | 58.210 | 71.571 | [degF] Liquid fuel supply TEMP b | |
| ALM320(MAX) | 1.000 | 1.000 | 1.000 | [DIGITAL] Liquid fuel TEMP A/B DIFF | |
| FCAI051(AVG) | 27.739 | 57.077 | 75.981 | [degF] LP CMP inlet TEMP selected | |

**Trend graph showing liquid fuel temperatures A and B and selected liquid fuel temperature.**




| Tag Name | Min | Value | Max | Description | Turbine |
|---|---|---|---|---|---|
| TE_6233A(AVG) | 19.169 | 35.721 | 50.662 | [degF] Liquid fuel supply TEMP a | |
| TE_6233B(AVG) | 28.229 | 49.690 | 71.571 | [degF] Liquid fuel supply TEMP b | |
| FCAI113(AVG) | 23.699 | 49.690 | 71.571 | [degF] Liquid fuel supply TEMP selec... | |

### TIGER Diagnostic Messages

**16:48:54 27/11/2002 § Liquid fuel TEMP A/B DIFF [ALM320]**

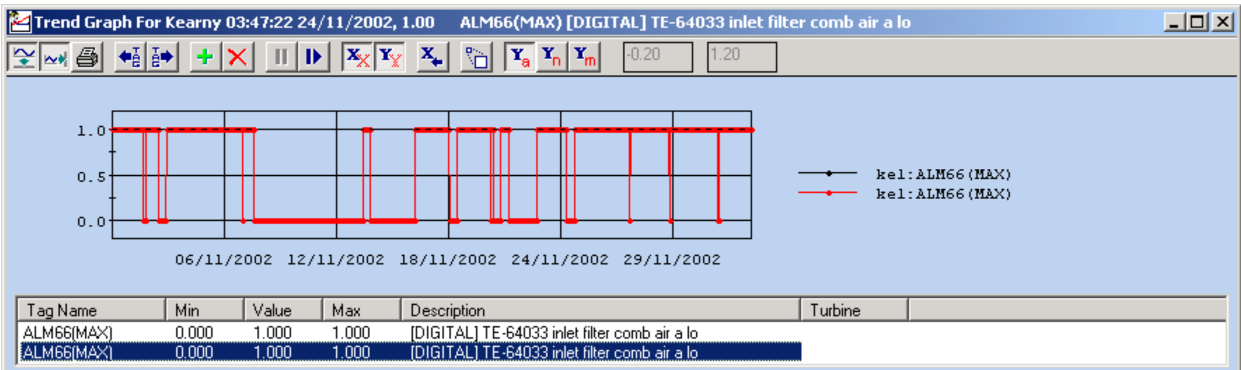
### Analysis

The occurrence of this alarm does not appear to be affected by Turbine run state, or by the ambient temperatures, as the alarm is permanently on. This is indicated in the example trend graphs above. There is a difference of about 17 Deg F between the two thermocouples, with the control system using the higher of the two. Thermocouple A is reading low, and there is also about 17 Deg F lower than the ambient temperatures. This probably indicates that this thermocouple is reading incorrectly, and low.

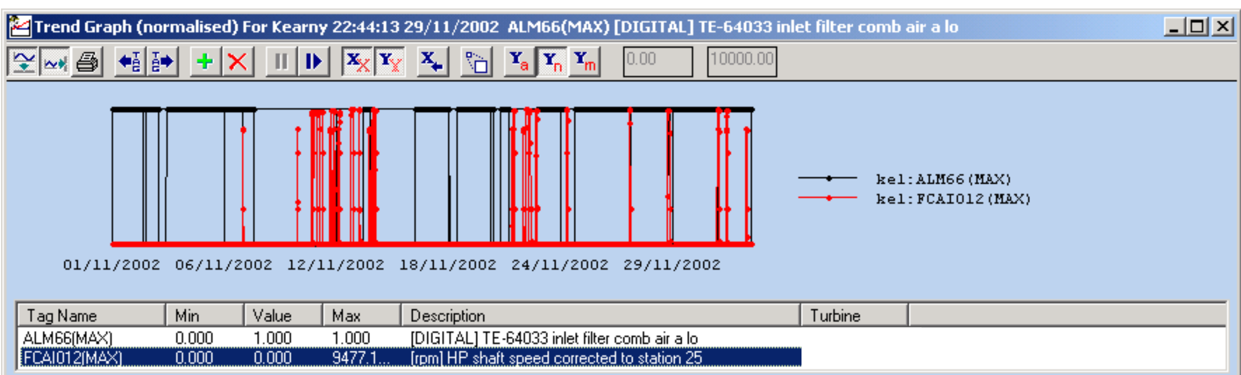
## 7. INLET FILTER COMB AIR A & B LOW

These two alarms (ALM66 & ALM68) go on and off throughout the sample data set, independently of turbine run state.

**Trend graph showing ALM66 and ALM68.**




**Trend graph showing ALM66 and turbine speed.**




**TIGER Diagnostic Messages**

16:48:54 27/11/2002 § TE-64033 inlet filter comb air a lo [ALM66]
16:48:54 27/11/2002 § TE-64032 inlet filter comb air b lo [ALM68]

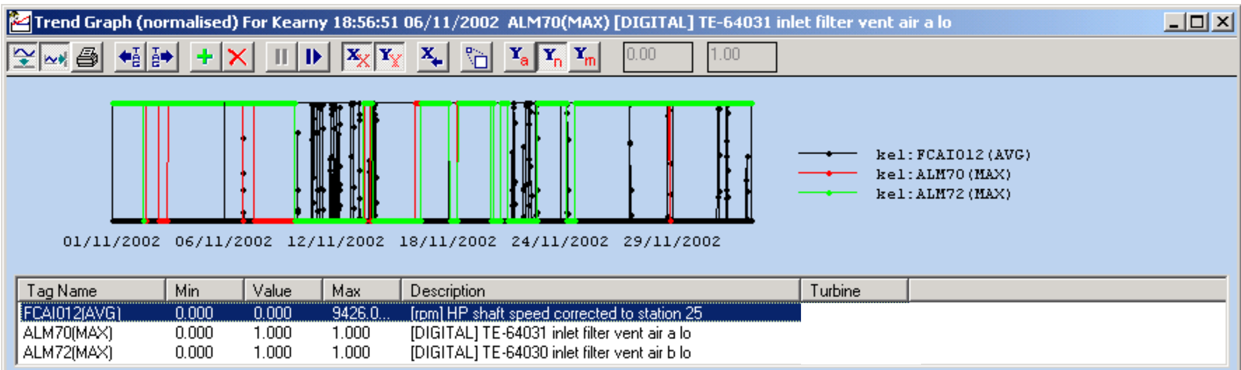
**Analysis**

The occurrence of these alarms does not appear to be affected by Turbine run state, but both alarms do occur simultaneously. This is indicated in the example trend graphs above. This probably indicates that there is a problem with this filter.

## 8. INLET FILTER VENT AIR A & B LOW

These two alarms (ALM70 & ALM72) go on and off throughout the sample data set, independently of turbine run state.

**Trend graph showing ALM70 and ALM72 and turbine run speed.**




### TIGER Diagnostic Messages

16:48:54 27/11/2002 § TE-64031 inlet filter vent air a lo [ALM70]
16:48:54 27/11/2002 § TE-64030 inlet filter vent air b lo [ALM72]

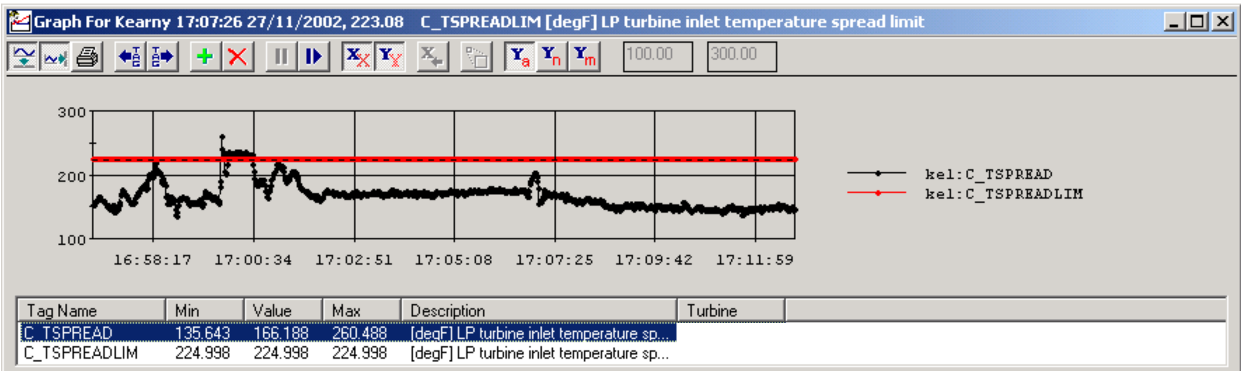
### Analysis

The occurrence of these alarms does not appear to be affected by Turbine run state, and each alarm has a different trigger pattern. This is indicated in the example trend graphs above. This probably indicates that there is a problem with the inlet vent filter, but may also mean that the A and B pressure sensors are out of calibration.

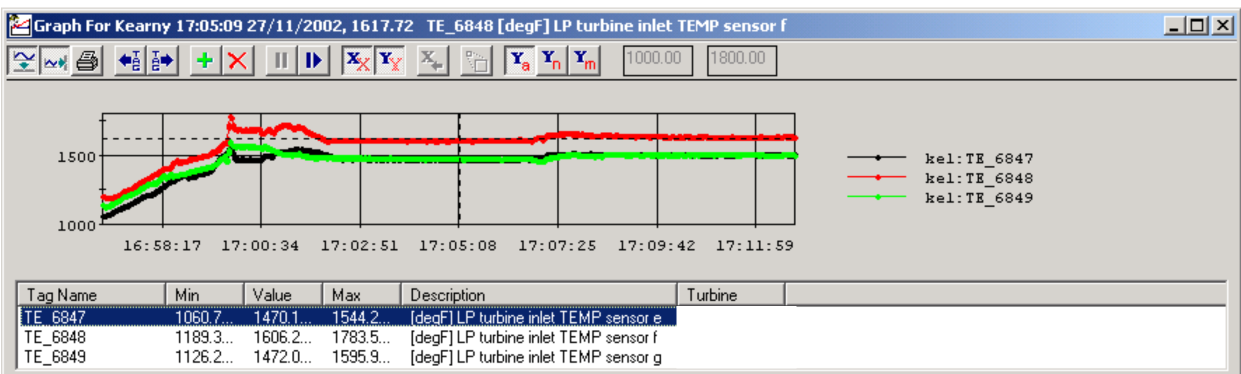
## 9. MAJOR LP TURBINE INLET TEMPERATURE PROBLEMS DETECTED

TIGER diagnostic rules detect major LP turbine inlet temperature problems during a run on the 27th November.

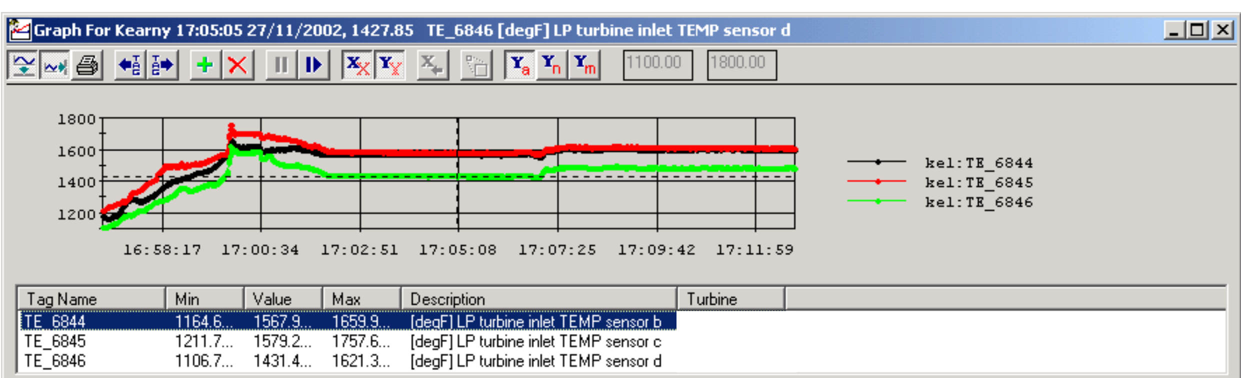
**Data graph showing LP turbine inlet temperature spread and spread limit.**



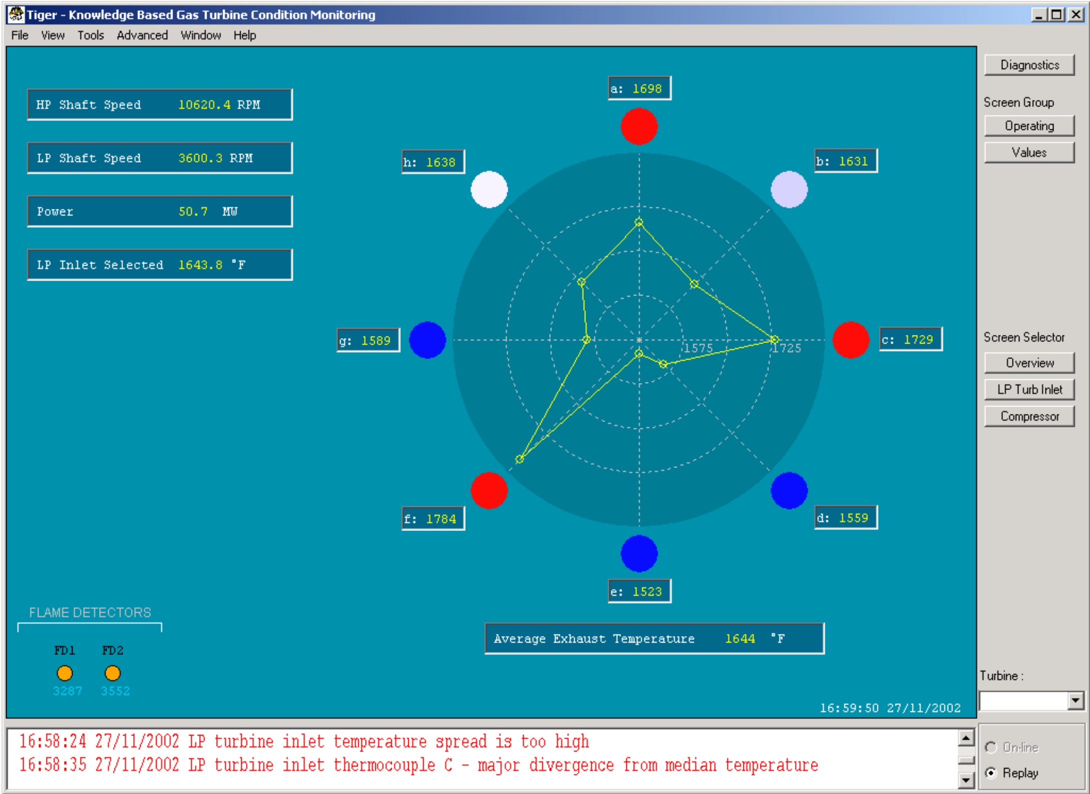

**Data graph showing LP turbine inlet temperatures E, F & G.**

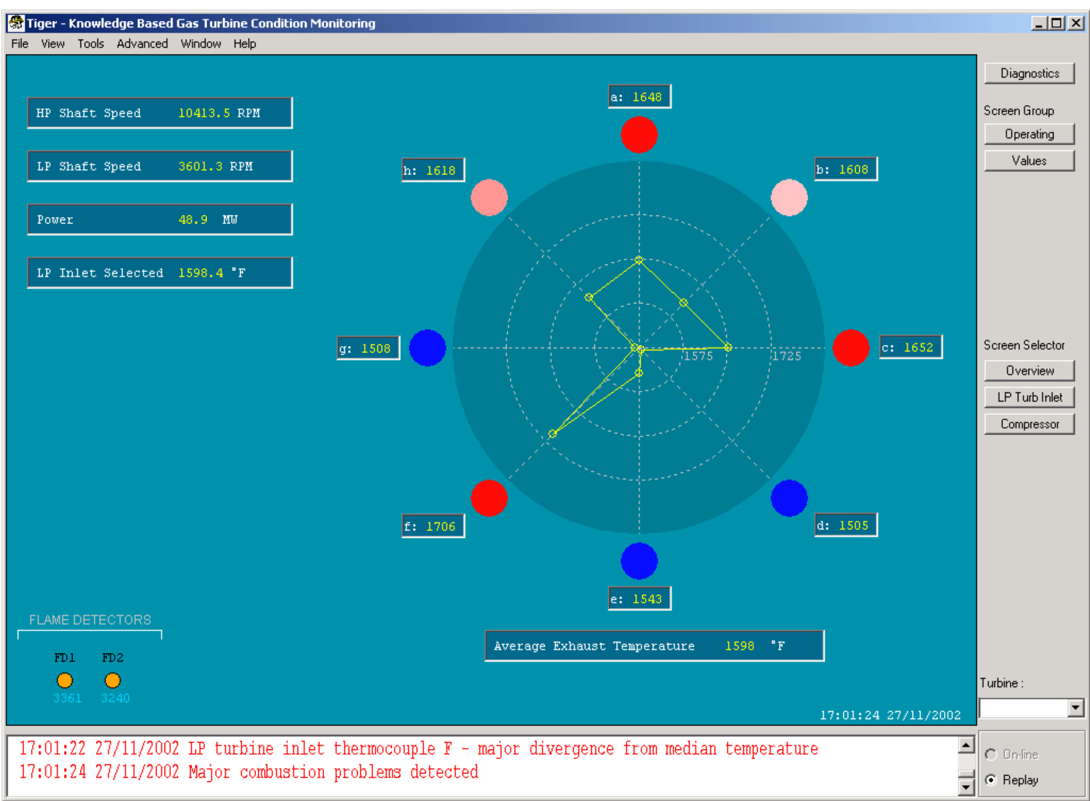



**Data graph showing LP turbine inlet temperatures B, C & D.**



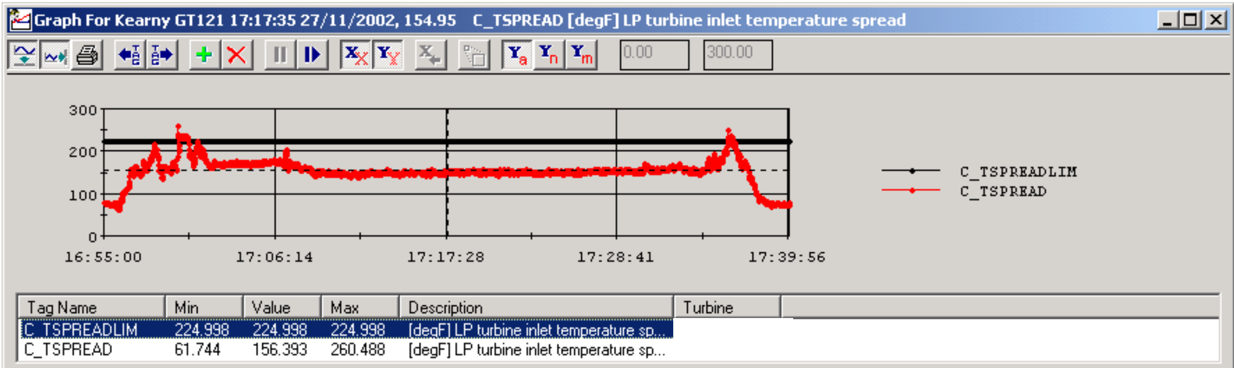
**LP turbine inlet temperature pattern screens on 27/11/2002 at 16:59:50 and at 17:01:24.**



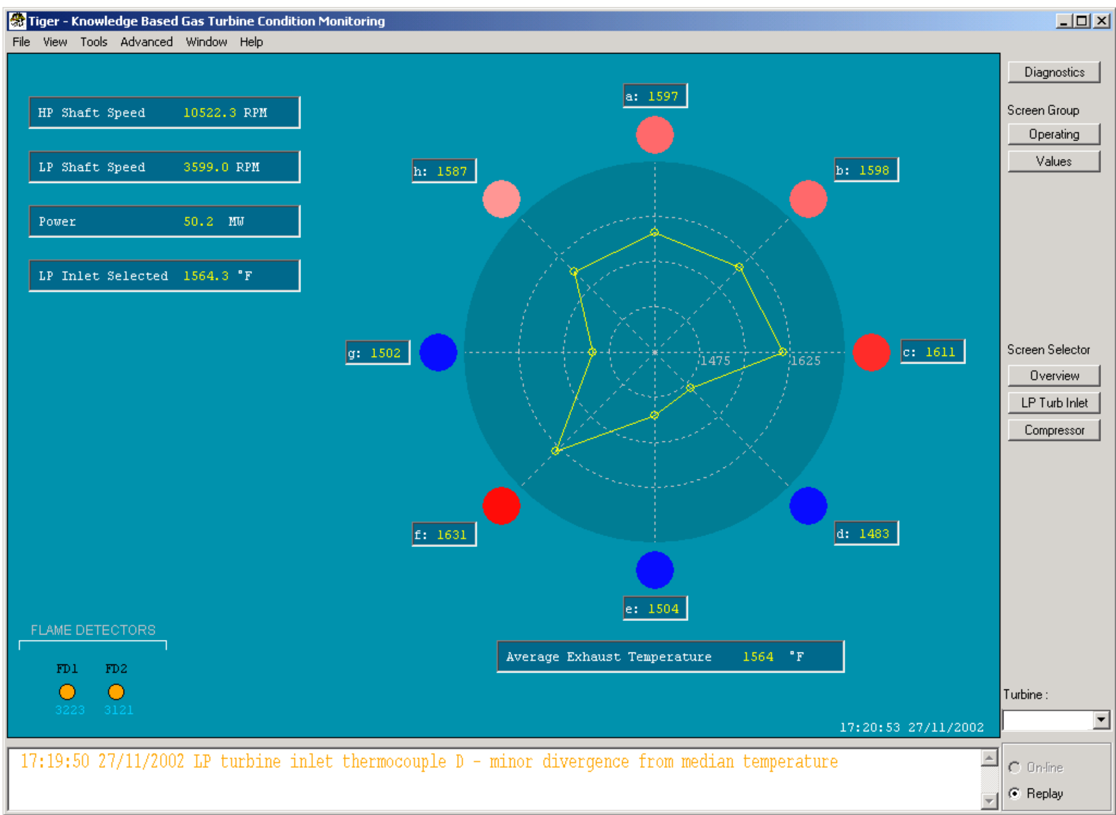
This graph shows how the spread varies over the course of the whole run.

**Data graph showing LP turbine inlet temperature spread and spread limit for whole run.**




This temperature pattern screen shows the same pattern in the middle of the run.

**LP turbine inlet temperature pattern screens on 27/11/2002 at 17:20:53.**

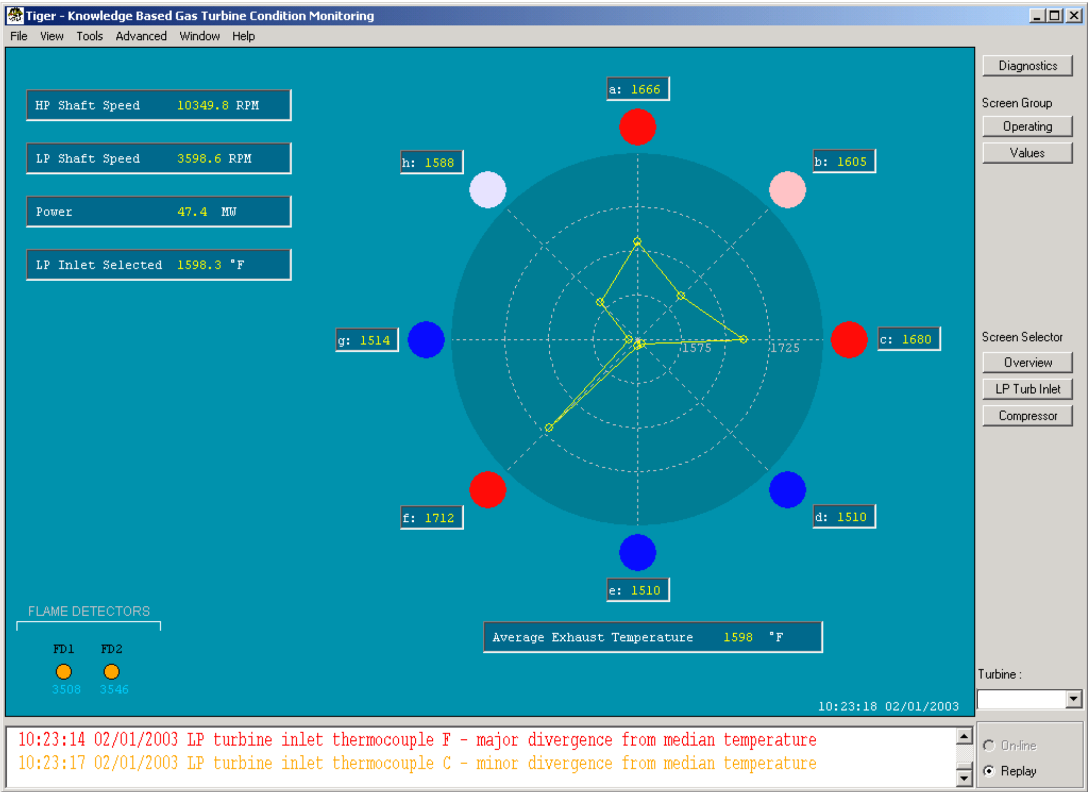


## TIGER Diagnostic Messages

16:56:54 27/11/2002 § LP turbine inlet thermocouple E - major divergence from median temperature
16:58:13 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
16:58:18 27/11/2002 § LP turbine inlet temperature spread is too high
16:58:24 27/11/2002 § LP turbine inlet temperature spread is too high
16:58:35 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
16:58:40 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
16:59:28 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature
16:59:50 27/11/2002 § LP turbine inlet temperature spread is too high
16:59:57 27/11/2002 § LP turbine inlet temperature spread is too high
16:59:58 27/11/2002 § LP turbine inlet thermocouple E - major divergence from median temperature
17:00:01 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
17:00:06 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
17:00:08 27/11/2002 § LP turbine inlet TEMP hi spread [ALM306] change from 0 to 1
17:00:09 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
17:00:13 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
17:00:15 27/11/2002 § LP turbine inlet thermocouple C - major divergence from median temperature
17:00:54 27/11/2002 § LP turbine inlet thermocouple F - major divergence from median temperature
17:01:03 27/11/2002 § LP turbine inlet temperature spread is too high
17:01:11 27/11/2002 » LP turbine inlet temperature - major divergence of thermocouples from median temperature
17:01:22 27/11/2002 » LP turbine inlet temperature - major divergence of thermocouples from median temperature
17:01:24 27/11/2002 § Major combustion problems detected
17:01:26 27/11/2002 § LP turbine inlet temperature spread is too high
17:01:28 27/11/2002 » LP turbine inlet temperature - major divergence of thermocouples from median temperature
17:01:28 27/11/2002 § LP turbine inlet temperature spread is too high
17:01:30 27/11/2002 § LP turbine inlet temperature spread is too high
17:01:56 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature
17:03:46 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature
17:03:49 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature
17:04:17 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature
17:04:43 27/11/2002 § LP turbine inlet thermocouple D - major divergence from median temperature

A similar pattern is occurring now, as is shown by this example from 2nd January 2003.

**LP turbine inlet temperature pattern screens – at 10:23:18 02/01/2003.**




**Analysis**

Examining the data from the 27th November, TIGER detects the uneven temperature pattern in the LP turbine inlet. This is probably an indication of combustion problems, although it may also be caused by thermocouple problems. An high spread alarm is also detected at 17:00:08.

A similar problem still exists, as is shown by the thermocouple pattern screen from 2nd January 2003. TIGER diagnostics detects this as on the 27th November.

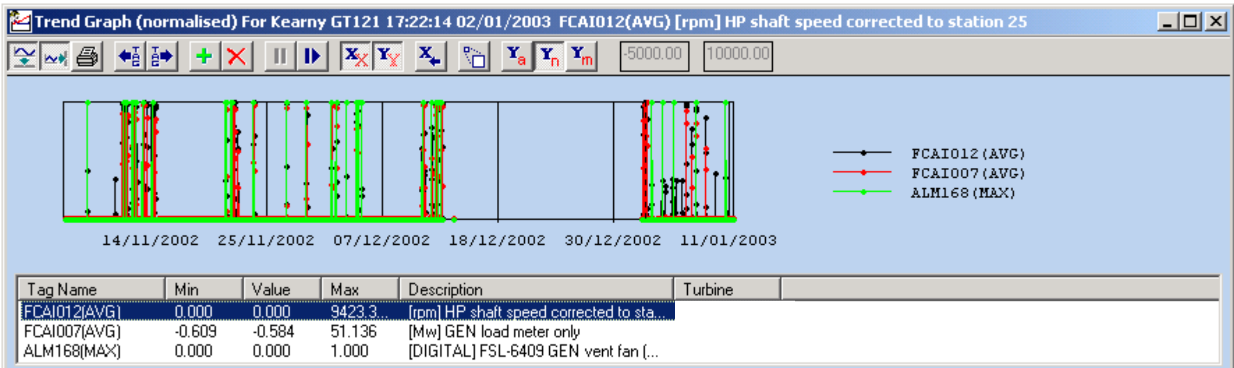
The graph of the whole run showing spread and spread limit, also indicates how the problem is worse just after start up and just before shutdown, although the lowest spread during the run is still at around 150 Deg F. The temperature pattern screen shown for the middle of the run also shows the same pattern, although not as severely.

There appears to be two hot spots (at thermocouples F and C) and two colder areas (at thermocouples E&D, and at thermocouple G). The pattern changes slightly as the turbine ramps up to full power, and worsens at around 17:01:22. This is when TIGER diagnostics indicate possible combustion problems, based on the cold area (at thermocouples E&D) as two adjacent thermocouples are reading lower than the others. The problem at thermocouple F may be due to a thermocouple problem, as it consistently reads higher than the others, throughout the data set.

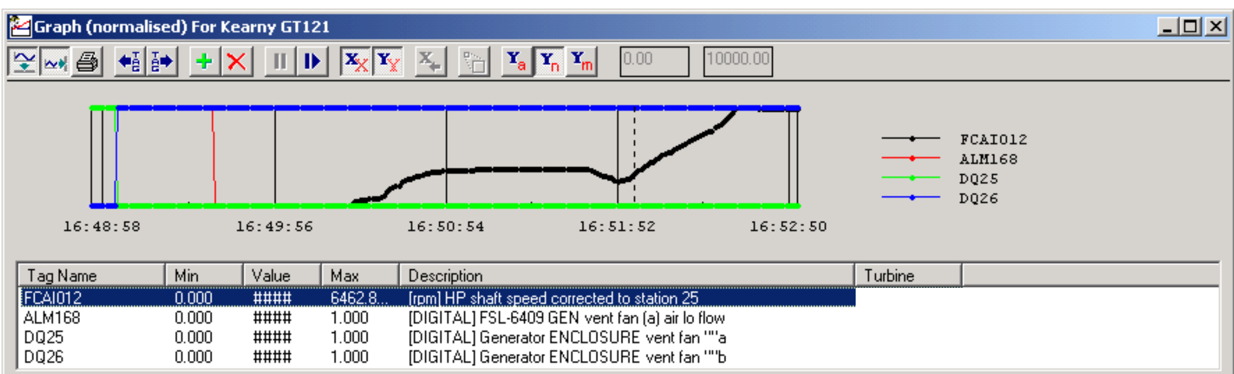
## 10. GENERATOR VENT FAN LOW AIR FLOW

This alarm (ALM168) comes on at the start of each turbine run, and then goes off.

**Trend graph showing ALM168, turbine speed and power.**




**Data graph showing ALM168, DQ25, DQ26 and turbine speed.**




### TIGER Diagnostic Messages

**16:49:03 27/11/2002 § FSL-6409 GEN vent fan [a] air lo flow [ALM168] change from 0 to 1**

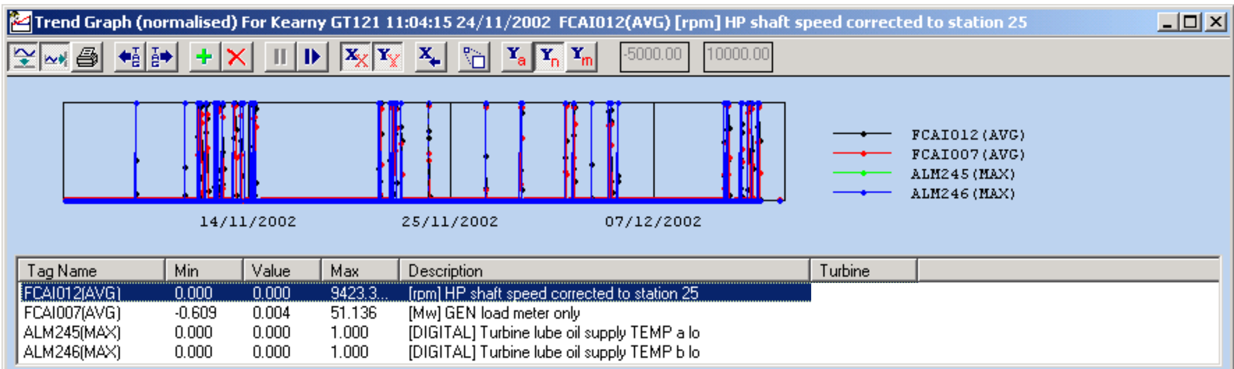
### Analysis

The occurrence of this alarm does appear to be affected by Turbine run state, and occurs nearly every time the turbine starts up. This is indicated in the example trend graph above. In the data sample on the above graph for 16:48 on the 27th November, the alarm is initiated as vent fan A turns off and vent fan B turns on. Fan B then stays on. It is possible that the alarm is a side effect of this, and may therefore be effectively a false alarm.

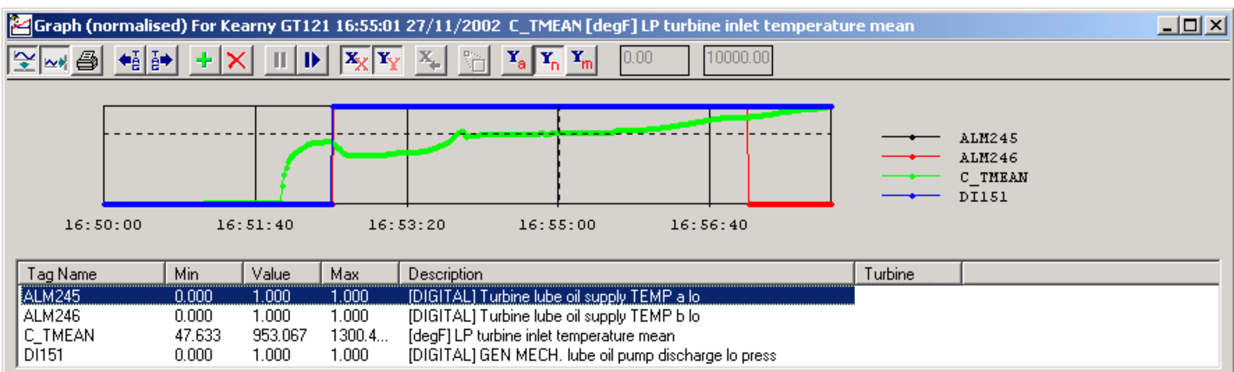
## 11. TURBINE LUBE OIL SUPPLY TEMPERATURES A&B LOW

These alarms (ALM245 and ALM246) come on during nearly every turbine run, and then go off.

**Trend graph showing ALM245 & ALM246, turbine speed and power.**




**Data graph showing ALM245 & ALM246, DI151 and LP turbine inlet temperature.**




### TIGER Diagnostic Messages

16:52:32 27/11/2002 § Turbine lube oil supply TEMP a lo [ALM245] change from 0 to 1
16:52:32 27/11/2002 § Turbine lube oil supply TEMP b lo [ALM246] change from 0 to 1

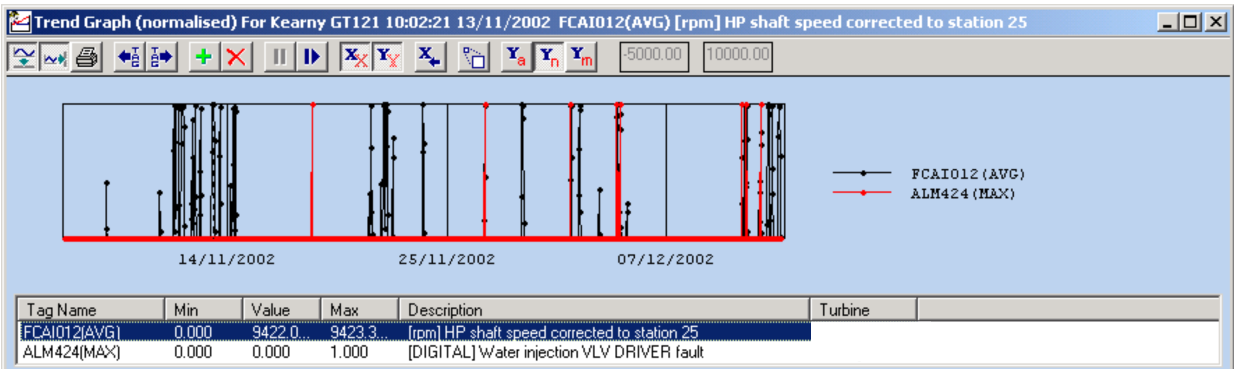
### Analysis

The occurrence of this alarm does appear to be affected by Turbine run state, and occurs nearly every time the turbine starts up. This is indicated in the example trend graph above. In the data sample on the above graph for 16:50 on the 27th November, the alarm is initiated just after the lube oil low pressure discharge pump starts up (DI151), and clears as the turbine runs up. This is probably due to the rising levels of the temperatures of the whole turbine, which will warm up as combustion temperatures rise, as indicated by the LP turbine inlet temperature. This will increase the lube oil temperatures. However, having a cold lube oil temperature on start up, could lead to increased wear on turbine components. Because both A and B sensors indicate an alarm simultaneously, this would tend to indicate that the low lube temperatures are real, and not due to thermocouple problems, and are probably caused by lower temperature oil flowing through the turbine lube system as the lube oil pump starts up.

## 12. WATER INJECTION VALVE DRIVER FAULT

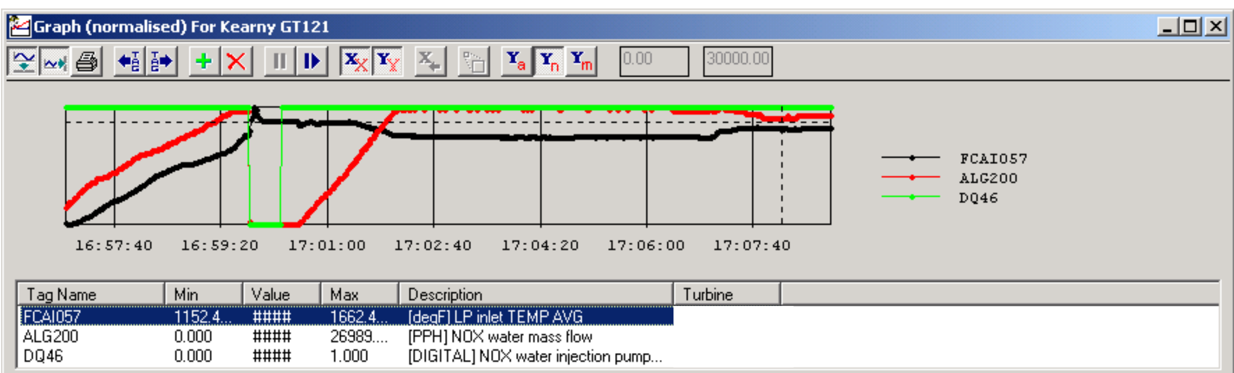
This alarm (ALM424) comes on occasionally, mostly during turbine running.

**Trend graph showing ALM424 and turbine speed.**

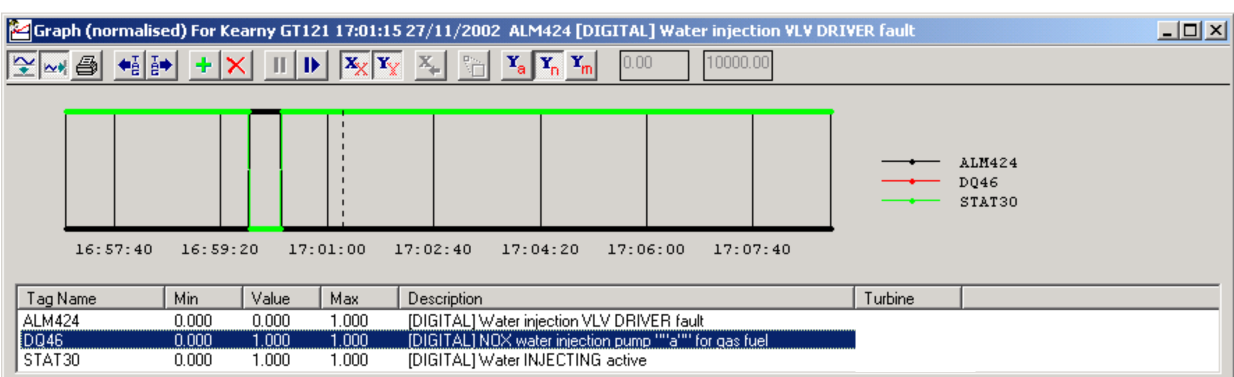



Example data on 27th November 2002.

**Data graph showing NOX injection pump status, water flow and LP turbine inlet temperature.**

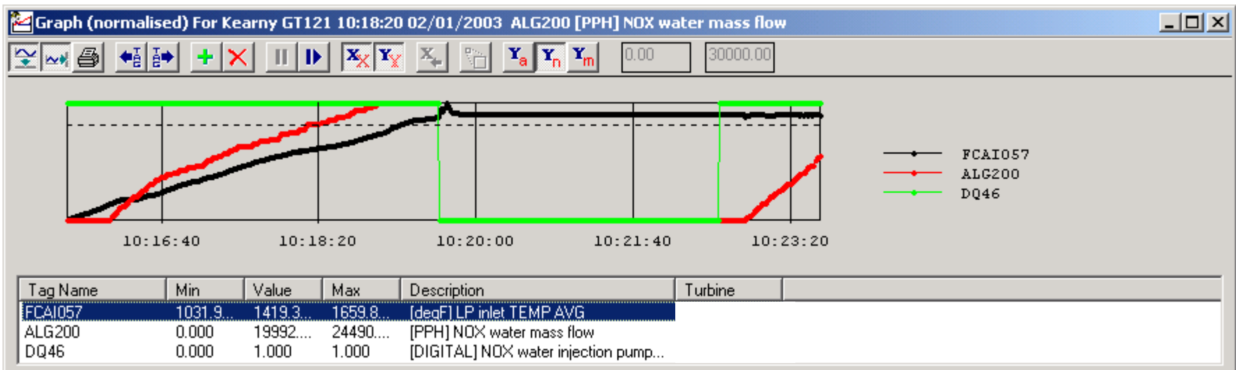



**Data graph showing NOX injection pump and water injection status and ALM424.**

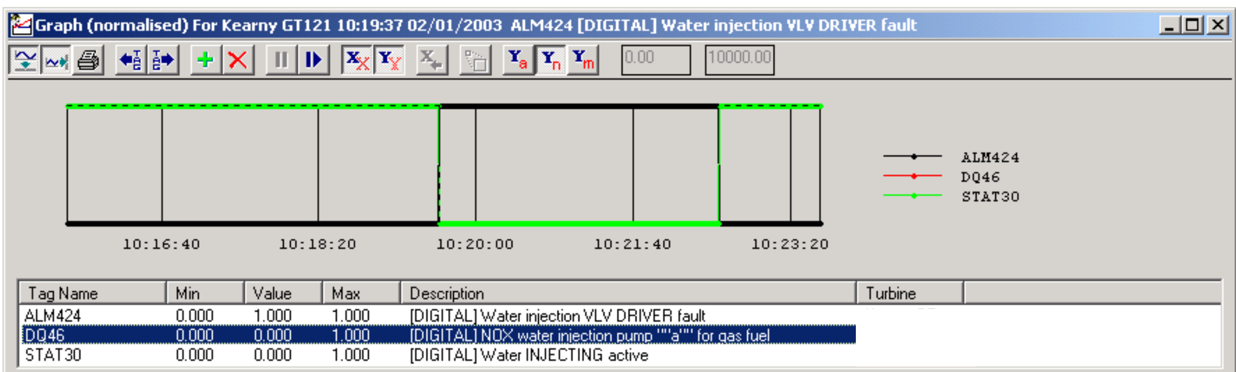


Example data on 2nd January 2003.

**Data graph showing NOX injection pump status, water flow and LP turbine inlet temperature.**




**Data graph showing NOX injection pump and water injection status and ALM424.**




**TIGER Diagnostic Messages**

**16:59:47 27/11/2002 § Water injection VLV DRIVER fault [ALM424] change from 0 to 1**

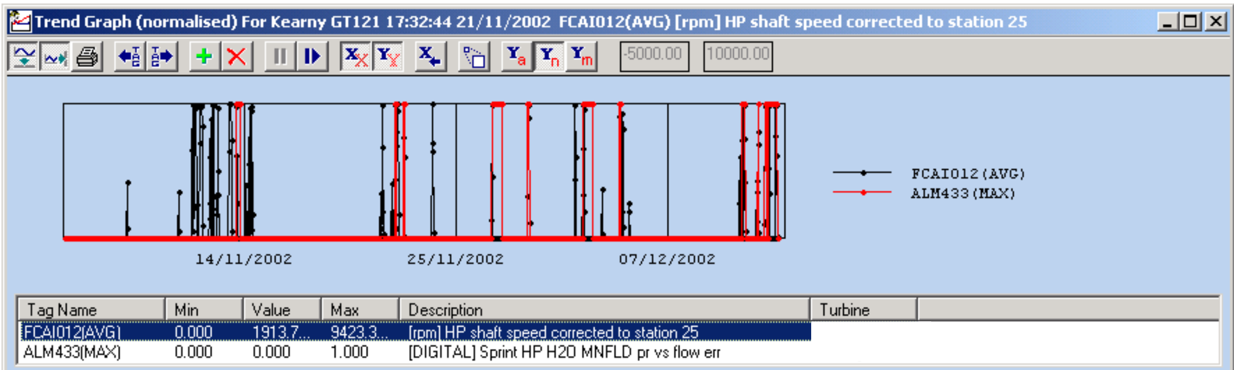
**Analysis**

The occurrence of this alarm does appear to be partially affected by Turbine run state, occurring a number of times during turbine running. This is indicated in the example trend graph above. In the data sample on the above graph for 16:57 on the 27th November, the alarm is initiated just during turbine run up, and is associated with a cut off of the NOX suppression water injection system. This also has an affect on the combustion temperatures. The NOX system comes back in after about 30 seconds. A similar sequence of events occurs on the 2nd January, although on this occasion the NOX water injection drops out for about 3 minutes. From the data available, it is not clear what caused the fault to occur, although the implication is that it is due to a valve driver problem.

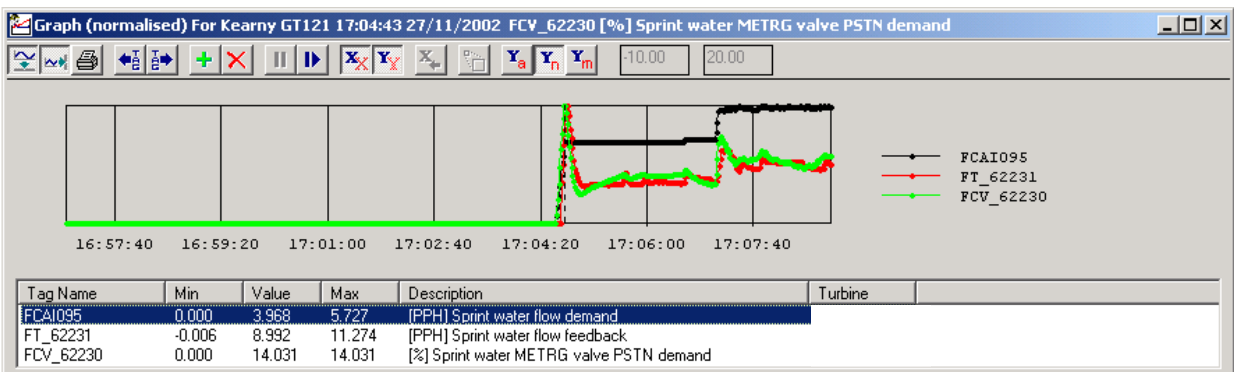
## 13. SPRINT HP WATER MANIFOLD PRESSURE VS FLOW ERROR

This alarm (ALM433) comes on occasionally, mostly during turbine running.

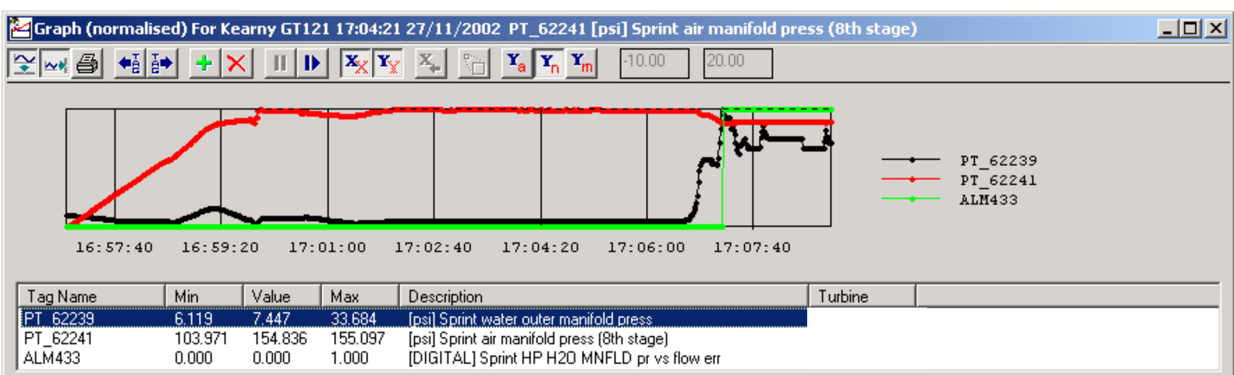
**Trend graph showing ALM433 and turbine speed.**




**Data graph showing sprint water flow and valve position.**




**Data graph showing sprint manifold pressures and ALM433.**



**TIGER Diagnostic Messages**

**17:07:12 27/11/2002 § Sprint HP H2O MNFLD pr vs flow err [ALM433] change from 0 to 1**

**Analysis**

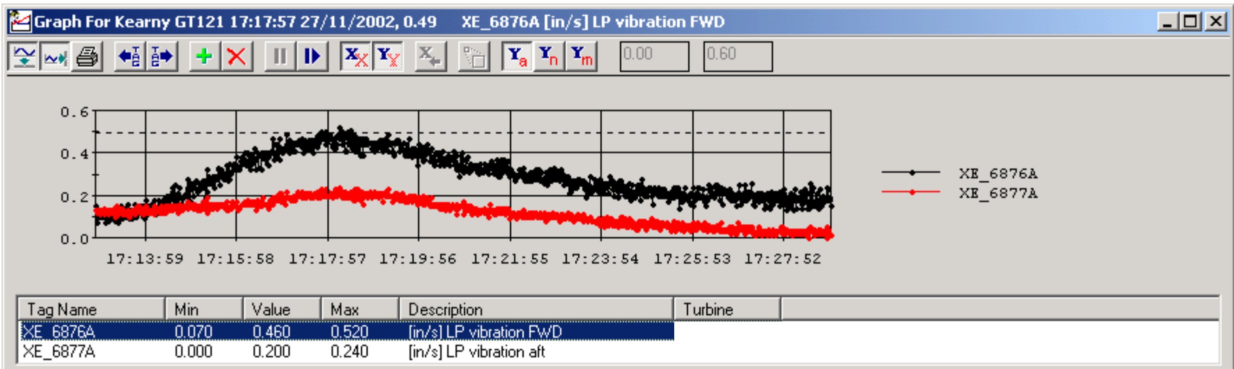
The occurrence of this alarm does appear to be partially affected by Turbine run state, occurring a number of times during turbine running. This is indicated in the example trend graph above. In the data sample on the 27th November, there appears to be a problem with controlling the sprint water flow and pressure when this alarm occurs. This may be due to problems with the sprint water flow valve.

## 14. HIGH VIBRATION ON FWD LP SHAFT

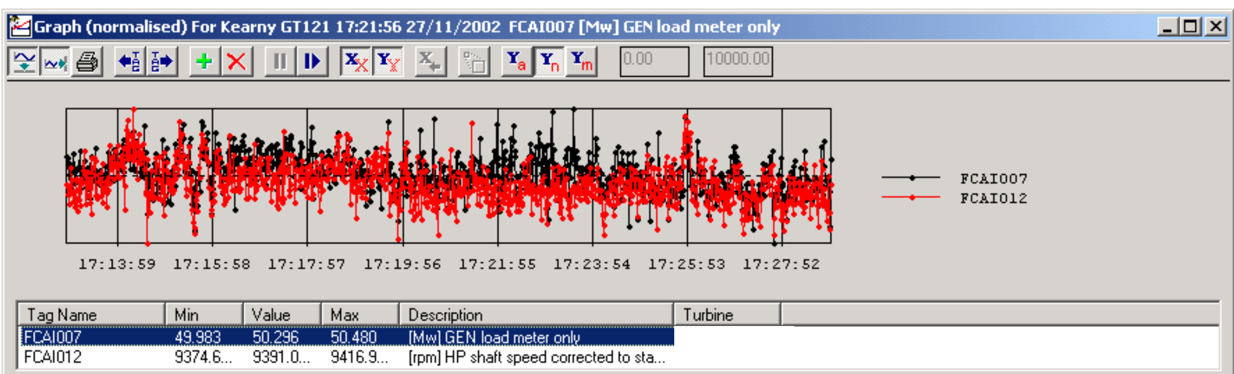
The vibration levels rise to 0.5 in/s during these two sequences. This is about 35 % of the alarm limit (1.4 in/s).

Data sequence from 27th November 2002.

**Data graph showing LP vibration forward and aft.**

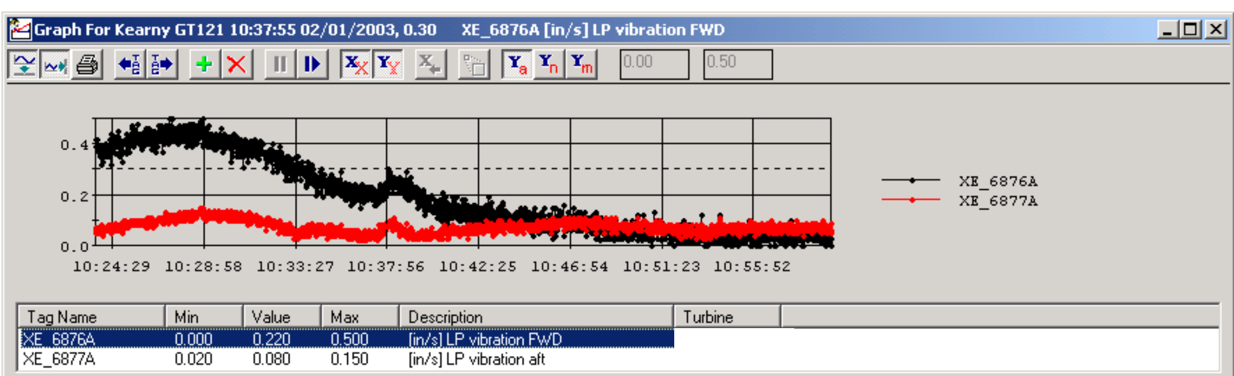



**Data graph showing turbine speed and power.**

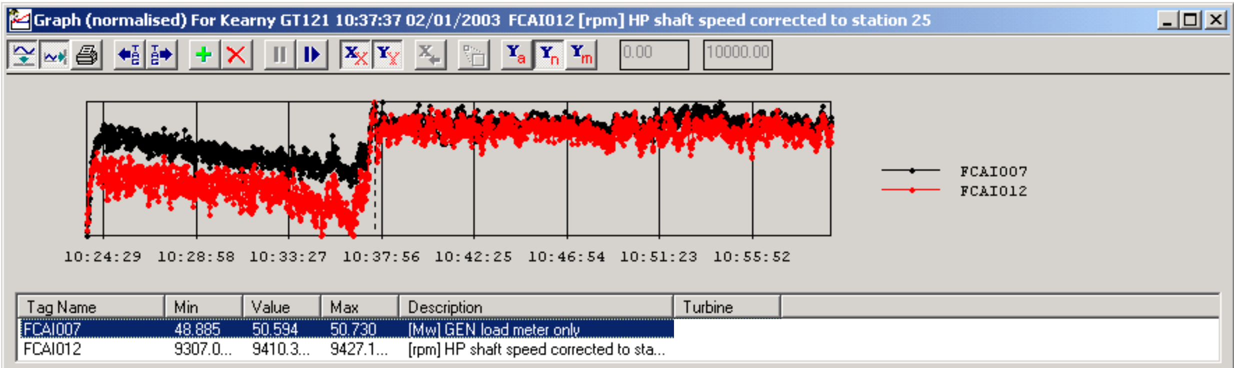



Data sequence from 2nd January 2003.

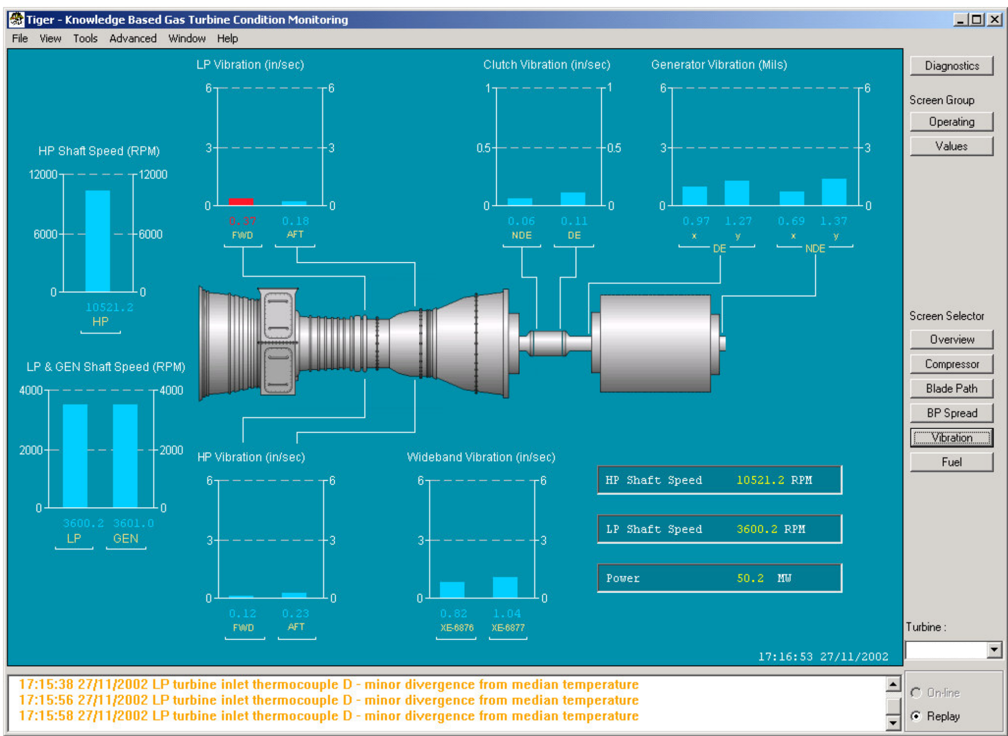
**Data graph showing LP vibration forward and aft.**



**Data graph showing turbine speed and power.**




**Turbine vibration screen showing diagnostic warning on LP FWD vibration.**




## TIGER Diagnostic Messages

17:16:51 27/11/2002 § LP vibration aft[XE_6877A] and LP vibration fwd[XE_6876A] differ for 1 seconds by 0.20
17:15:52 27/11/2002 § LP vibration FWD [XE_6876A] too high. Limit 0.30 in/s

## Analysis

As can be seen from the two data sets graphed above, the LP FWD vibration rises and then falls. This is still well within alarm limits, but it may indicate vibration problems developing. It is not clear why the vibration increases and then decreases, although this may be related to thermal expansion as the turbine warms up. TIGER diagnostics generates two warnings for this, one indicating a higher than normal level and one indicating a disparity with the vibration at the AFT end. Further tuning with more extensive data will confirm whether these warnings are set at too sensitive level, or do indicate incipient vibration problems developing.