# Service Update

# SU2103 Shaw J1939 DEF Sensor Troubleshooting Guide

**Models Affected: Vision (BBCV), All American, and TX4 (T3FE, T3RE), with EPA/CARB certified on highway Cummins® Diesel Engine Features Built After 01/18/2016**

**Subject: The intent of Service Update SU2103 is to announce a "New Shaw Development® Technical Bulletin". The Technical Bulletin is intended to guide Shaw Development® customers in troubleshooting fault codes related to the DEF tank assembly on Cummins® engine equipment. This document is intended to be a "living document", and the details and processes within can/will change as system designs evolve, or other new information comes to light. Access to this Shaw Development® Technical Bulletin is also available on the Blue Bird Vantage website noted below.**

WARNING:
Always follow all Federal, State, Local and Shop safety standards and use proper safety equipment, and thoroughly read and understand all instructions before performing these procedures.
Park bus on level surface, apply parking brake, turn off ignition key, and chock wheels.

**Information:**
Shaw Development® manufactures and supplies the diesel exhaust fluid (DEF) tank assemblies installed on Blue Bird buses powered with Cummins® Diesel engines.
Technical Bulletin Document No: 0000297252 (attached) is intended to supplement existing Shaw Development® service documents that are currently available.
As noted this document is intended to be a "living document", therefore to ensure you always have the latest revision it is highly recommended that the document be downloaded from the Blue Bird Vantage website by clicking here. **https://vantage.blue-bird.com/Portal/supplier-documentation-P-and-S.aspx**

**Shaw Development® Bulletin Tools And Equipment:**

| Item Number | Part Number | Description | Quantity |
|---|---|---|---|
| 1 | BB# 10058812 | Shaw Scan Gauge diagnostic tool | 1 |
| 2 | Cummins® | Cummins ECM diagnostics application (Insite) | 1 |
| 3 | Cummins®/Industry Suppliers | RP1210 Communication Adapter (Inline/DPA5/Nexiq) | 1 |
| 4 | Cummins® | Refractometer calibrated for measuring DEF | 1 |
| 5 | Industry Suppliers | Digital Multimeter | 1 |
| 6 | Industry Suppliers | Temperature measurement device | 1 |
| 7 | Industry Suppliers | Infrared temperature measurement device | 1 |
| 8 | Cummins® QuickServe® | Cummins® field support portal for service information | 1 |

SHAW DEVELOPMENT
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25190 Bernwood Dr
Bonita Springs, FL 34135
239-405-6100
www.shawdev.com

# DIGITAL SENSOR FIELD TROUBLESHOOTING GUIDE

# DOCUMENT NO: 0000297252

Version: B Status:Approved

## VERSION HISTORY

| Version | Implemented By | Revision Date | Reason |
|---|---|---|---|
| A | Christian Braun | *1/31/2021* | Initial draft |
| B | Christian Braun | *2/16/2021* | Removed watermark |
| | | | |

## TABLE OF CONTENTS

# 1 INTRODUCTION

## 1.1 Purpose of Technical Bulletin

The Technical Bulletin is intended to guide Shaw Development customers in troubleshooting fault codes related to the DEF tank assembly on Cummins engine equipment.

This document is intended to be a "living document", and the details and processes within can/will change as system designs evolve, or other new information comes to light.

## 1.2 Applicable Part Numbers, Assemblies and/or Applications

Table 1

| | Source | Document No. | Title/Description |
|---|---|---|---|
| 1 | Shaw | DMCXX-XXXXXXXX | Gen4 headers with digital sensor |
| 2 | Shaw | DRCXXX-XXXXXXXX | Gen4 tank assemblies with digital sensor |
| 3 | Shaw | DM5XX-XXXXXXXX | Gen5 headers |
| 4 | Shaw | DR5XXX-XXXXXXXX | Gen5 tank assemblies |
| 5 | Shaw | DM6XX-XXXXXXXX | Gen6 headers |
| 6 | Shaw | DR6XX-XXXXXXXXXX | Gen6 tank assemblies |
| 7 | Shaw | DM7XX-XXXXXXXX | Gen7 headers |
| 8 | Shaw | DR7XX-XXXXXXXXXX | Gen7 tank assemblies |

## 1.3 Required Tools and Equipment

Table 2

| | Source | Equipment Name/PN | Description |
|---|---|---|---|
| 1 | Shaw | 960-0232-01-K | Shaw Scan Gauge diagnostic tool |
| 2 | Cummins | Insight | Cummins ECM diagnostics application |
| 3 | Cummins | Inline 6/7 | Cummins J1939 service tool |
| 4 | Cummins | DEF Refractometer | Refractometer calibrated for measuring DEF |
| 5 | Cummins | Quickserve Portal | Cummins field support portal |
| 6 | | Digital Multimeter | |
| 7 | | Thermocouple | Temperature measurement device |
| 8 | | IR Thermometer | Infrared temperature measurement device |

## 1.4 Definitions/Acronyms

- CCV
  Coolant Control Valve
- DEF
  Diesel Exhaust Fluid
- ECM
  Engine Control Module
- FMI
  Failure Mode Indicator
- J1939
  SAE CAN Communication Protocol
- MFHU
  Multi-Function Head Unit
- MSU
  Multi-parametric Sensor Unit
- SAE
  Society of Automotive Engineers
- SPN
  Suspect Parameter Number

# 2 HEADER/SENSOR GENERATION IDENTIFICATION

Depending on the equipment vintage, there are multiple generations of DEF headers/sensors which could be encountered in the field. In order to assist personnel in troubleshooting, distinguishing features which can be used to identify which generation of Shaw products is being worked on are detailed below. Gen4 and Gen5 headers were produced with both the digital sensor, as well as analog sensors. Gen6 and Gen7 headers are only available with MSU sensors.

## 2.1 Gen4 Header With Analog Sensor

The Gen4 header with analog sensor is shown below. The contents of this document are typically not relevant to this product. From the exterior of the tank, this generation can be distinguished by a round, black sensor mounted into the DEF header, offset from center. Sensor part and serial numbers are present on the body of the sensor. Internally to the tank, a white plastic “focus tube” can be observed.

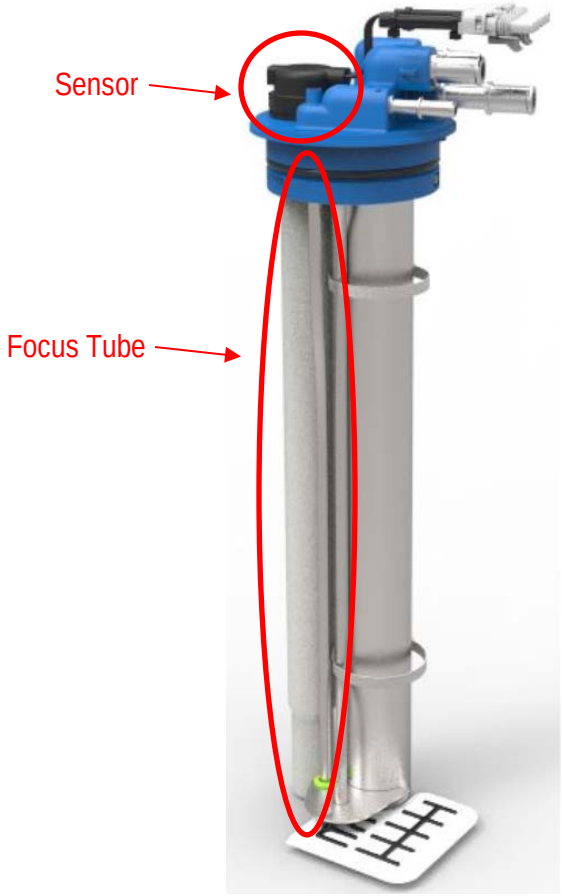


Figure 1: Gen4 Header with Analog Sensor

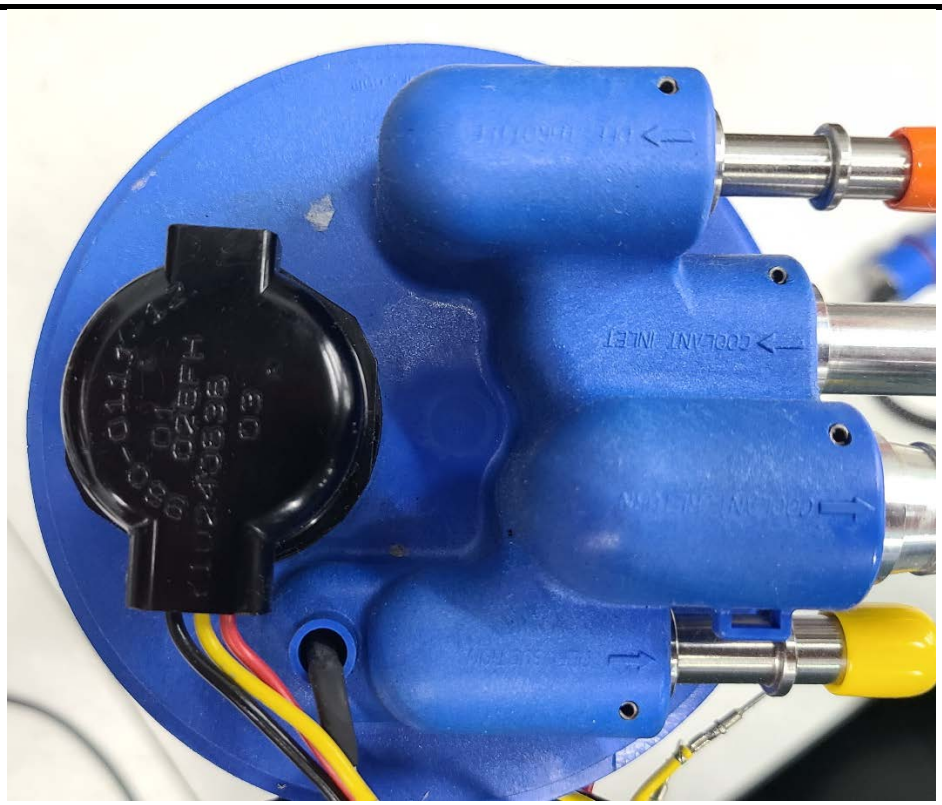


Figure 2: Gen4 Header with Analog Sensor Exterior Closeup

## 2.2 Gen4 Header with Digital Sensor

The Gen4 header with digital sensor is shown below. From the exterior of the tank, this generation can be distinguished by a laser etched bent stainless steel plate offset from center in the header, which is marked with a 11-digit serial number, a part number of the format 'XXXX-XX' or 'XXXX-XXXX', and a revision code of the format 'XX_X XXXXXX'. Additionally, the wire harness on this generation comes out of the sensor at a 90° angle. Gen4 digital sensors went through two iterations of design. Internally to the tank, the earlier iteration did not include the aeration shroud (see Figure 3), while the later generation did (see Figure 4).

Figure 3: Gen4 Header with Digital Sensor (Without Shroud)

Figure 4: Gen4 Header with Digital Sensor (With Shroud)

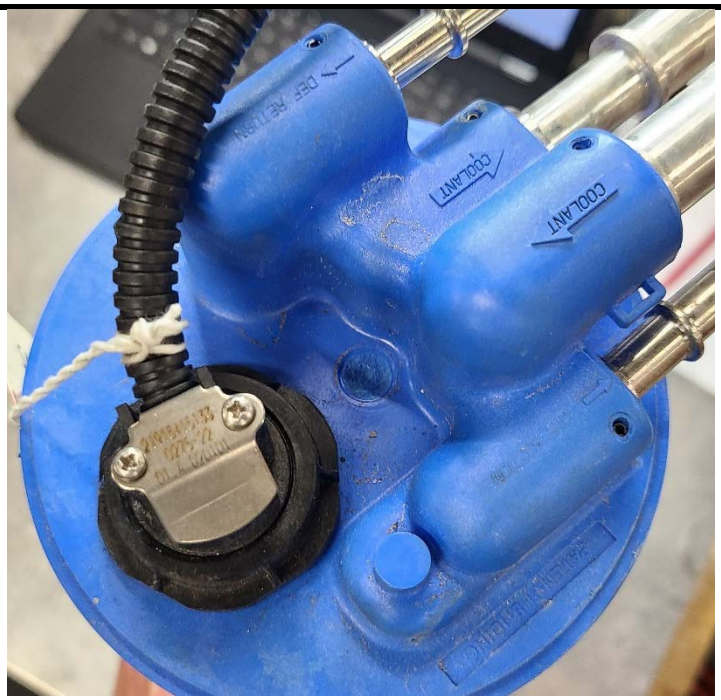


Figure 5: Gen4 Header with Digital Sensor Exterior Closeup

## 2.3 Gen5 Header with Analog Sensor

The Gen5 header with analog (reed switch) sensor is shown below. From the exterior of the tank, this generation can be distinguished by a laser etched stainless steel plate centered in the header, which is marked with a part number of the format 'XXXX-XX', and a 6-digit serial number below the part number. Additionally, the sensor harness is typically connected to the vehicle harness by a short jumper harness with a Deutsch DT06-4S on one end and OEM specific connectors on the other. Internally to the tank, a black magnetic float can be observed centered in the coolant coil.

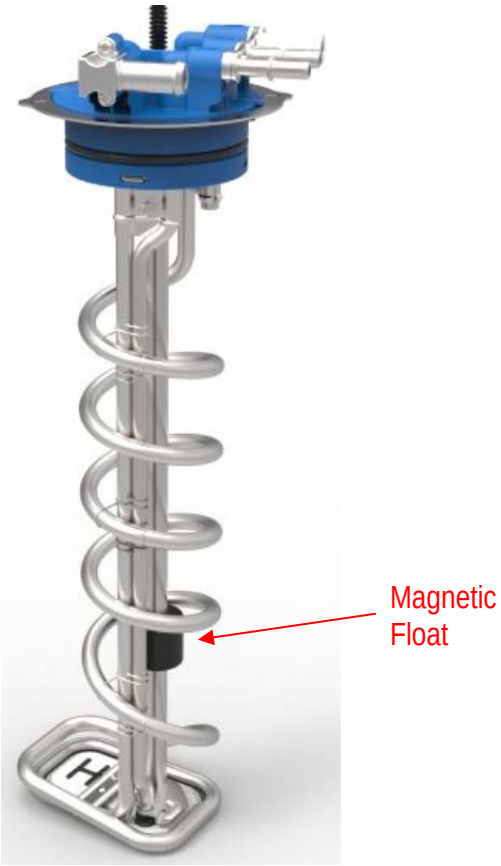


Figure 6: Gen5 Header with Analog Sensor


Figure 7: Gen5 Header with Analog Sensor Exterior Closeup

## 2.4 Gen5 Header with Digital Sensor

The Gen5 header with Digital sensor is shown below. From the exterior of the tank, this generation can be distinguished by a laser etched stainless steel plate centered in the header, which is marked with a 11-digit serial number, a part number of the format 'XXXX-XX' or 'XXXX-XXXX', and a revision code of the format 'XX_X XXXXXX'. Internally to the tank, the sensor is black and has a L-shape; and the bottom of the sensor is covered with a plastic shroud.

Figure 8: Gen5 Header with Digital Sensor


Figure 9: Gen5 Header with Digital Sensor Exterior Closeup

## 2.5 Gen6 and Gen7 Header (MSU Sensor)

The Gen6 and Gen7 headers are shown below. The headers are the same between Gen6 and Gen7. The MSU Sensor is also a digital sensor, and is backwards compatible to Gen5 Digital applications. Externally to the tank, these generations can be distinguished by a blank stainless steel plate centered in the header, and part markings on the backshell of the Deutsch DT04-4P connector. The part marking consists of a QR code, a 10-digit serial number, a part number of the format 'XXXX-XX' or 'XXXX-XXXX', a single digit revision code, and a 6-digit firmware revision code (see Figure 12). Gen6 sensors went through two iterations of mechanical design. Internally to the tank, the earlier iteration can be identified by a trapezoidal shaped inlet with a white felt window, the latter can be identified by an oblong shaped inlet with a white felt window.

Figure 10: Gen6 Header with Early Model MSU Sensor


Figure 11: Gen6 Header with Current Model MSU Sensor


Figure 12: Gen6 and Gen7 Connector Markings

# 3 FAULT CODES

## 3.1 Discussion

Which fault codes are triggered by a given condition can depend on the engine/ECM model. In some instances, different fault codes can occur for the same fault, depending if the equipment is an on-road or off-road application. Application specific details of the fault codes can be researched in the Cummins Quickserve portal, using the equipment Engine Serial Number.

## 3.2 DEF System Fault Code Details

Table 3: Cummins Fault Codes

| Fault Code | SPN | FMI | Cummins Verbiage | Cause | Section/Page |
|---|---|---|---|---|---|
| 4677 | 1761 | 9 | SAE J1939 Multiplexing PGN Timeout Error - Abnormal Update Rate. | ECM did not receive level message communication from sensor for 5 seconds | 4.3/19 |
| 4572 | 3031 | 9 | Aftertreatment Diesel Exhaust Fluid Tank Temperature - Abnormal Update Rate. | ECM did not receive level message communication from sensor for 5 seconds | 4.3/19 |
| 3868 | 3364 | 9 | Aftertreatment Diesel Exhaust Fluid Quality - Abnormal Update Rate. | ECM did not receive concentration message communication from sensor for 5 seconds | 4.3/19 |
| 1669 | 1761 | 3 | Aftertreatment Diesel Exhaust Fluid Tank Level Sensor Circuit - Voltage Above Normal or Shorted to High Source. | Sensor detects internal failure of level sensing circuit | 4.6/24 |
| 1686 | 3364 | 3 | Aftertreatment Diesel Exhaust Fluid Quality Sensor Circuit - Voltage above normal, or shorted to high source | Sensor detects internal failure of concentration sensing circuit | 4.6/24 |
| 1678 | 3031 | 3 | Aftertreatment Diesel Exhaust Fluid Tank Temperature Sensor - Voltage Above Normal or Shorted to High Source. | Sensor detects internal failure of temperature sensing circuit | 4.6/24 |
| 1677 | 3031 | 4 | Aftertreatment Diesel Exhaust Fluid Tank Temperature Sensor - Voltage Below Normal or Shorted to Low Source. | Sensor detects internal failure of temperature sensing circuit | 4.6/24 |

| Fault Code | SPN | FMI | Cummins Verbiage | Cause | Section/Page |
|---|---|---|---|---|---|
| 4233 | 3515 | 3 | Aftertreatment Diesel Exhaust Fluid Temperature Sensor - Voltage Above Normal or Shorted to High Source. | Sensor detects internal failure of temperature sensing circuit | 4.6/24 |
| 4234 | 3515 | 4 | Aftertreatment Diesel Exhaust Fluid Temperature Sensor - Voltage Below Normal or Shorted to Low Source. | Sensor detects internal failure of temperature sensing circuit | 4.6/24 |
| 4277 | 3364 | 10 | Aftertreatment Diesel Exhaust Fluid Quality - Abnormal Rate of Change. | Sensor is not getting a concentration reading, but does not detect a circuit failure. Sensor output 62.75% for concentration for some time. | 4.5/21 |
| 4769 | 1761 | 10 | Aftertreatment 1 Diesel Exhaust Fluid Tank Level Sensor - Abnormal Rate of Change. A valid diesel exhaust fluid tank level reading has NOT been received. | Sensor is not getting a level reading, but does not detect a circuit failure. Sensor output 100.4% for level for more than 2 hours. | 4.4/20 |
| 1673 | 1761 | 1 | Aftertreatment 1 Diesel Exhaust Fluid Tank Level - Data Valid But Below Normal Operating Range - Most Severe Level | Measured DEF tank level is very low. | |
| 1699 | 1761 | 2 | Aftertreatment 1 Diesel Exhaust Fluid Tank Level Sensor - Data Erratic, Intermittent, or Incorrect | | |
| 1679 | 3031 | 2 | Aftertreatment 1 Diesel Exhaust Fluid Tank Temperature - Data Erratic, Intermittent, or Incorrect | | |
| 3866 | 3364 | 1 | Aftertreatment Diesel Exhaust Fluid Quality - Data Valid But Below Normal Operating Range - Most Severe Level | The concentration of the DEF reported by the sensor is below normal range | |
| 3714 | 1569 | 31 | Engine Protection Torque Derate - Condition Exists | A fault code indicating the vehicle has gone into torque derate. The code can be triggered by many emissions related faults. | |
| 3712 | 5246 | 0 | Aftertreatment SCR Operator Inducement - Data Valid But Above Normal Operating Range - Most Severe Level | A secondary code triggered if other SCR related codes are active for some period of time | |

| Fault Code | SPN | FMI | Cummins Verbiage | Cause | Section/Page |
|---|---|---|---|---|---|
| 4863 | 1569 | 31 | Aftertreatment SCR Operator Inducement Active - Condition Exists | A secondary code triggered if other SCR related codes are active for some period of time | |

# 4 PROCEDURES

## 4.1 Read ECM Fault Codes

1. Turn keyswitch ON
2. Connect Cummins Inline diagnostic tool to J1939 connector on the equipment
3. Open the Cummins Insite application on your computer
4. Turn the equipment keyswitch to power on the equipment electronics (do not crank the engine)
5. In Cummins Insite, connect to the ECM
6. Open the “Fault Codes” page in Cummins Insite

## 4.2 Obtaining a Cummins Insite Job Image

1. Connect the Cummins Inline diagnostic tool to the J1939 connector on the equipment.
2. Open the Cummins Insite application on your computer
3. Turn the equipment keyswitch to power on the equipment electronics (do not crank the engine)
4. In Cummins Insite, connect to the ECM
5. When prompted, set up the work order details as instructed by your organization
6. Export the Work Order/ECM Image as follows
    i. Select the “Work Orders ECM Images ECM Templates” option on the left-hand side of the Insite application
    ii. Right click on the Work Order/ECM Image you just created
    iii. Select “Export Image(s) to External File
    iv. Complete the Save File dialog, and save the file to your preferred location

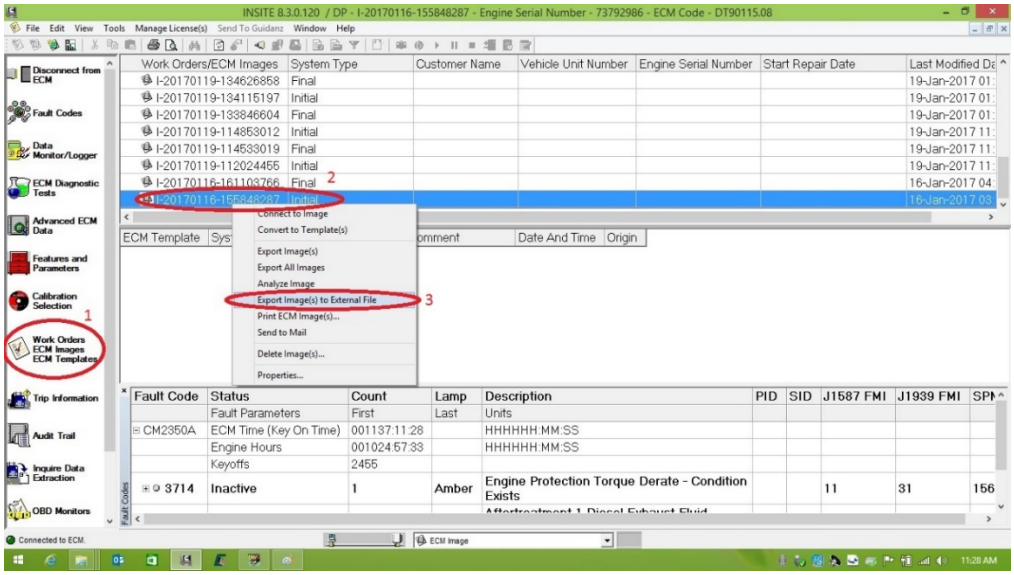


Figure 13: Cummins Insite Export Image

## 4.3 Abnormal Update Rate Fault Codes (3868, 4572, 4677)

### 4.3.1 Discussion

The Abnormal Update Rate codes are triggered when the ECM does not detect the 1Hz periodic messages transmitted by the DEF sensor for some period of time (typically 5 seconds). Depending on the ECM calibration, a subset of the three codes or all three have been observed to be present if this occurs. Information from Cummins Insite such as if the codes are active/inactive, how many counts of the codes are present, and whether Abnormal Update Rate codes for other Aftertreatment devices are present will factor into determining the root cause for these fault codes.

Occurrence of these codes due to a sensor failure has been associated with extended exposure to elevated DEF tank temperatures. If a fleetwide high failure rate, or reoccurring failures on a specific piece of equipment are observed, it is recommended to perform the DEF tank temperature evaluation in Section 4.7.

Note: The distinction between verbiage for these codes ("Abnormal Update Rate") and verbiage for other codes ("Abnormal Rate of Change"). These codes are caused by different phenomena and must be distinguished from each other.

### 4.3.2 Troubleshooting Procedure

1. Perform steps in Section 4.1
    i. If the codes are inactive, monitor vehicle for reoccurrence and proceed with troubleshooting when they go active
    ii. If "Abnormal Update Rate" codes are present for the DEF sensor and other aftertreatment devices, focus troubleshooting efforts on items that are common amongst them (power supply/grounds, harnesses, CAN resistors, etc)
    iii. If only "Abnormal Update Rate" codes for the DEF sensor are present, focus troubleshooting efforts directly on the DEF sensor
2. Check equipment battery voltage
    i. Turn keyswitch OFF
    ii. Measure voltage across the positive (+) and negative (-) battery terminals
    iii. If battery voltage is below 12V or 24V (depending on equipment power distribution system), follow Cummins service procedure for weak/damaged batteries
3. Check sensor supply voltage
    i. Turn keyswitch ON
    ii. Locate the sensor/ equipment harness connector interface
    iii. Using a multimeter, insert probes into connector pins 3 (GND) and 4 (Power) from the back of the equipment side of the connector and measure voltage
        a. If no voltage is present, check the fuse/breaker for the sensor circuit, check ground continuity between the sensor connector and chassis ground, and check all harness connections between the fuse/breaker and sensor connector
4. Check J1939 terminating resistors
    i. Turn keyswitch OFF

ii. Locate the sensor/ equipment harness connector interface
iii. Disconnect the sensor connector from the equipment harness
    a. Inspect connectors and pins for damage/engagement
iv. Using a multimeter, probe resistance across pins 1 (CANL) and 2 (CANH)
    a. If measured resistance is not approximately 60Ω, follow Cummins troubleshooting procedure for incorrect J1939 terminating resistance

5. Perform any additional troubleshooting steps listed in the Cummins Quickserve troubleshooting procedure for these fault codes

## 4.4 Level Sensor Abnormal Rate of Change (4769)

### 4.4.1 Discussion

In contrast to the fault codes in Section 4.3, this fault code indicates the sensor is still functional, however it has been unable to obtain a level measurement for some time (typically 2 hours). The root cause for this fault code can vary depending on which sensor generation is installed on the equipment. Some possible causes which are not related to a sensor failure are:

1. The DEF tank is empty, or extremely low
2. Crystallized DEF causing the sensor's float to stick
    i. Gen4 and Gen5 only. Typically only after equipment is removed from storage
3. The DEF tank is frozen and not thawing in the expected period of time

### 4.4.2 Troubleshooting Procedure

1. Perform steps in Section 4.1
    i. If the code is active, continue to Step 2
    ii. If the code is inactive, monitor the equipment for reoccurrence, and proceed with Step 2 when the code goes active
2. Confirm the tank is not frozen
    i. If the tank is frozen but has been running long enough that it can be reasonably expected to be thawed, troubleshoot the DEF header coolant loop per the procedure in Section 4.8.2.
3. Confirm there is fluid in the tank
    i. If the tank was very low/empty, fill the tank to 100%
    ii. If the tank is overfilled, remove fluid from the tank until the fluid level at the designed 100% fill level
4. If a Shaw Scan Gauge tool is available, connect the tool to the sensor and check sensor outputs L1, L2 and LF
    i. If the values are not L1: 1004, L2: 6426 and LF:31, perform the steps to clear the code as described in Cummins Quickserve
5. Perform any additional troubleshooting steps listed in the Cummins Quickserve troubleshooting procedure for this fault code

## 4.5 Quality Sensor Abnormal Rate of Change (4277)

### 4.5.1 Discussion

In contrast to the fault codes in Section 4.3, this fault code indicates the sensor is still functional, however it is has been unable to obtain a concentration measurement for some time. The root cause for this fault code can vary depending on which sensor generation is installed on the equipment. Some possible causes which are not related to a sensor failure are:

1. The DEF tank is empty or extremely low
2. The DEF tank was recently filled at a high GPM fill rate (Gen4 and Gen5 only)
3. Crystallized DEF causing the sensor shroud to seal, thereby now allowing DEF into the measurement chamber
    i. Gen4 and Gen5 only. Typically only after equipment is removed from storage
4. The DEF tank is frozen and not thawing in the expected period of time
5. The DEF tank temperature is excessively hot (>55°C)
    i. At elevated temperatures, the solubility of air in the DEF is reduced, and dissolved air can spontaneously come out of solution and form bubbles on measurement surfaces, thereby affecting performance.

### 4.5.2 Troubleshooting Procedure

1. Perform steps in Section 4.1
    i. If the code is active, continue to Step 2
    ii. If the code is inactive, monitor the equipment for reoccurrence, and proceed with Step 2 when the code goes active
2. Confirm the tank is not frozen
    i. If the tank is frozen but has been running long enough that it can be reasonably expected to be thawed, troubleshoot the DEF header coolant loop per the procedure in Section 4.8.2.
3. Confirm there is fluid in the tank
    i. If the tank was very low/empty, fill the tank to 100%
    ii. If the tank was recently filled, and was working correctly prior to filling, it could simply be air caught in the system. Perform the following:
        a. Impact the side of the tank with a rubber mallet. In some cases this has been proven to cause the sensor to vent the trapped air
        b. With the keyswitch OFF, unbolt the header from the tank, and raise it out of the fluid, allowing the sensor to drain. If the header is a Gen4 with a shroud, inspect the sensor “duck-bill” vent for interference with the “z-fin” (see Figure 14). If the header is a Gen4 with a shroud or Gen5, peel back the shroud (see Figure 15) and reseat it, and manipulate the “duck-bill” vent as shown in Figure 16 to ensure it is not sticking shut. Replace the header into the tank, turn the keyswitch ON and confirm the sensor is reading correctly (using either a Shaw Development Scan Gauge tool, or Cummins Insite).

4. Check the DEF tank temperature
    i. If the equipment was recently operating, using either Cummins Insite or a Shaw Development Scan Gauge tool (T1 and T2 values), record the DEF tank temperature measured by the sensor.
    ii. If the equipment has not recently been operated, perform the DEF Tank Temperature Evaluation per Section 4.7.
    iii. If tank temperatures greater than 55°C are observed during the above steps, perform the Coolant Loop Evaluation per Section 4.8 to determine if the elevated temperatures are caused by a defect on the equipment
5. Perform any additional troubleshooting steps listed in the Cummins Quickserve troubleshooting procedure for this fault code

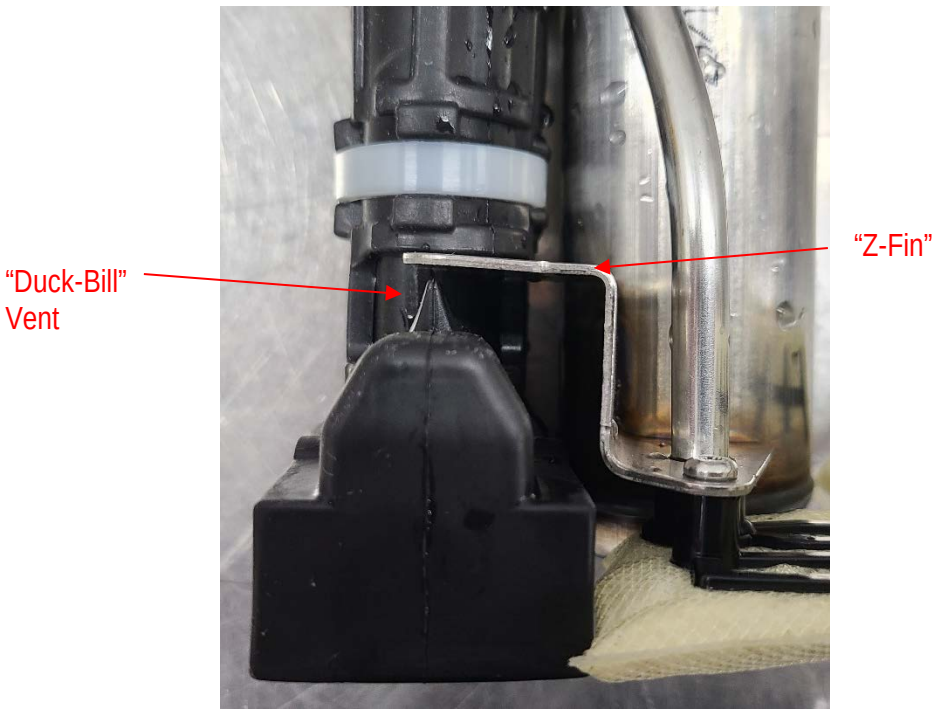


Figure 14: "Duck-Bill" Vent and "Z-Fin" Closeup


Figure 15: Shroud Manipulation Example

Figure 16: “Duck-Bill” Manipulation Example

## 4.6 Sensor Element Open/Short Circuit (FMI3 and FMI4 in Table 3)

### 4.6.1 Discussion

Sensor failures associated with these fault codes are directly detected by the sensor's internal diagnostic routines, and reported to the ECM; unlike most other fault codes in this document, which are set by diagnostic logic internal to the ECM.

### 4.6.2 Troubleshooting Procedure

1. Perform steps in Section 4.1
    i. If the code(s) is/are active, replace the sensor
    ii. If the code(s) is/are inactive, check the fault code count for the specific code
        a. If multiple counts of the code have occurred, and they were associated with an equipment derate, replace the sensor
        b. If a single count of the code is present, or multiple counts without associated equipment derate, monitor the equipment for reoccurrence. If possible, perform the steps in Section 4.2, and share the file with the equipment OEM and Shaw Development for troubleshooting support

## 4.7 DEF Tank Temperature Evaluation

### 4.7.1 Discussion

Some sensor failure modes have been associated with excessively high DEF tank temperatures. As such, it may be valuable to evaluate the temperature rise, and maximum temperature experienced by the DEF on a given application. Factors such as ambient air temperature, DEF tank fill level, and equipment load, amongst others can affect the temperature rate of change in the DEF, and must be considered.

Note: It is recommended to maintain nominal operating DEF temperatures below 55°C.

### 4.7.2 Procedure

1. Ensure the equipment is in a normal operating condition
    i. Perform required maintenance to alleviate any fault codes
2. Ensure the equipment has enough fuel to run, and the DEF tank is full
3. Set the equipment up to simulate normal operation
    i. If it is a power generation application, attach the equipment to a load bank set to 75% load
    ii. If it is an on/off-road application, ideally plan to perform the equipment's primary operation during testing. If this is not possible, as a last resort, place the equipment into high-idle
4. Record the ambient air temperature
5. Using either a thermocouple, IR thermometer, Cummins Insite, or the Shaw Scan Gauge tool, measure and record the DEF tank temperature
6. Crank the engine and begin operating the equipment under the given operating conditions
    i. Run the equipment for 4 hours, recording DEF temperature every 1 hour

## 4.8 DEF Tank Coolant Loop Evaluation

### 4.8.1 Discussion

In some applications where excessively high DEF tank temperatures have been identified, the cause has been found to be a defect in the coolant circuit on the equipment. If certain defects are present, they can allow hot coolant to enter the DEF header coolant loop when it shouldn't (ie the fluid is not frozen or near freezing), thereby causing the DEF to be heated. Examples of such defects include:

1. The CCV is stuck open/leaking due to debris in the coolant circuit or a failed solenoid
2. The CCV was installed backwards
3. The coolant source and return lines are swapped at the DEF MFHU
4. The coolant source and return lines are swapped at the engine

### 4.8.2 Procedure

1. Inspect the CCV installation for proper orientation
    i. Most CCVs have an arrow indicating fluid flow direction on their body. The arrow should be pointing toward the DEF tank.
2. Inspect the coolant hose routing to ensure it is plumbed per the OEM drawings
    i. The DEF header has indicators molded into it at the fittings denoting flow direction
3. Evaluate the functionality of the CCV solenoid
    i. Many applications test the CCV during startup. If you are working on one of these applications, turn the keyswitch ON while listening/feeling for the engagement of the CCV actuator.
    ii. If the above is not valid, the harness can be disconnected from the CCV, and equipment battery power can be applied directly to the CCV. The same engagement of the CCV actuator should be observed if the CCV is functioning correctly.
4. Ensure the equipment is in a normal operating condition, in an environment where the DEF temperature is above 5°C
    i. Perform required maintenance to alleviate any fault codes
5. Ensure the equipment has enough fuel to run, and the DEF tank is full
6. Crank the engine, and run the equipment until the engine/coolant is warm
7. Using an IR thermometer or thermocouple, check the coolant hose skin temperature at the following locations. A significant ΔT should be observed at the most upstream location, with the higher temperature on the coolant source side of the component.
    i. Either side of the CCV
        a. If no ΔT is observed, the CCV likely needs service/replacement
    ii. Either fitting of the DEF MFHU
        a. If a higher temperature is present at the coolant return fitting, coolant hoses are likely routed incorrectly