NATIONAL TRANSPORTATION SAFETY BOARD

OFFICE OF RAILROAD, PIPELINE &

HAZARDOUS MATERIAL INVESTIGATIONS

WASHINGTON, D. C. 20594

DCA-13-MR-002

BRIDGE DERAILMENT WITH HARZARDOUS MATERIALS RELEASE

On Conrail Penns Grove Secondary

Paulsboro, New Jersey

November 30, 2012

Proximity Sensor and Micro-Switch Study

Accident:

NTSB Accident Number:	DCA-13-MR-002
Date of Accident:	November 30, 2012
Time of Accident:	Bridge Derailment with Hazardous Materials Release
Type of Train :	Freight Train CA-11
Railroad Owner:	Conrail
Train Operator:	Conrail
Fatalities:	0
Injuries:	23
Location of Accident:	Paulsboro, New Jersey

Synopsis:

On November 30, 2012, about 6:59 a.m. eastern standard time, southbound Conrail freight train FC4230 consisting of two locomotives and 82 cars derailed seven cars, the 6th through the 12th, near milepost 13.7 on the Conrail Penn's Grove Secondary track in Paulsboro, New Jersey. The derailment occurred while the train traveled over the Paulsboro Movable Bridge.

Four tank cars that derailed on the bridge structure came to rest with portions of the cars in the Mantua Creek. Three of the tank cars contained vinyl chloride, and one contained ethanol. One of the tank cars carrying vinyl chloride breached during the derailment. Conrail reported that the breached tank car released approximately 20,000 gallons of vinyl chloride into the environment.

After the accident, 23 local residents were evaluated at nearby hospitals, including the conductor of the train. The initial damage estimates provided by Conrail are $225,000, which does not include environmental remediation. The weather at the time of the derailment was cloudy skies with a temperature of 34° F and calm winds.

Train movements are governed by the Northeast Operating Rules Advisory Committee (NORAC) operating rules and the Conrail timetable. The maximum authorized speed over the 160-foot bridge is 10 mph. The locomotive event recorder data showed that the train was traveling 7 mph when it derailed.

Parties to the investigation include: the Federal Railroad Administration, Conrail, Trinity Tank Car, the Brotherhood of Locomotive Engineers and Trainmen, and the United Transportation Union.

Items received for testing:

On 1/10/2013, the NTSB Vehicle Recorder Laboratory received the following devices:

Manufacturer/Model: Efector® IIM-200 inductive proximity sensor (Quant. 2)
Serial Number: n/a

Manufacturer/Model: Efector IGO-328 inductive proximity sensor (Quant. 4)
Serial Number: n/a

Manufacturer/Model: Honeywell LSYMC4NX-FP mechanical limit switch (Quant. 2)
Serial Number: n/a

Manufacturer/Model: Honeywell LSYAC3KP-FP mechanical limit switch (Quant. 2)
Serial Number: n/a

Description of Switches and Proximity Sensors Monitoring Bridge Operation:

The bridge control system monitors sensors and controls servos installed at various points on the bridge. The inputs from these sensors are processed by program logic running in the Modicon PLC. The sensors used to monitor bridge operation include:

- Mechanical limit switches indicating that the bridge is either fully open or fully closed. These switches interface with the bridge control system (BCS).
- Mechanical limit switches indicating that the rail span is in the lifted or seated position. These switches interface with the BCS.
- Inductive proximity sensors (submersible) indicating that the bridge is in the fully closed position. These sensors interface with the BCS.
- Inductive proximity sensors indicating that the four rail track links (two at each end of the movable span) are each fully extended. These sensors interface with the railroad signal system and the BCS.

Two of the IIM-200 inductive proximity sensors showed evidence of significant mechanical damage consistent with impact forces. The remaining two sensors appeared to be intact. Both of the IGO-328 inductive proximity sensors appeared to be mechanically undamaged. Several of the actuator arms on the mechanical limit switches showed signs of deformation and/or breakage consistent with mechanical impact forces. The switch housings for the mechanical limit switches all appeared to be undamaged.

Figure 1. Efector® model IGO-328 inductive proximity sensor interfaced to the bridge control system and used to verify bridge closure.

Figure 2. Efector® model IIM-200 inductive proximity sensor interfaced to the railroad signal system and used to verify rail slide-lock closure.

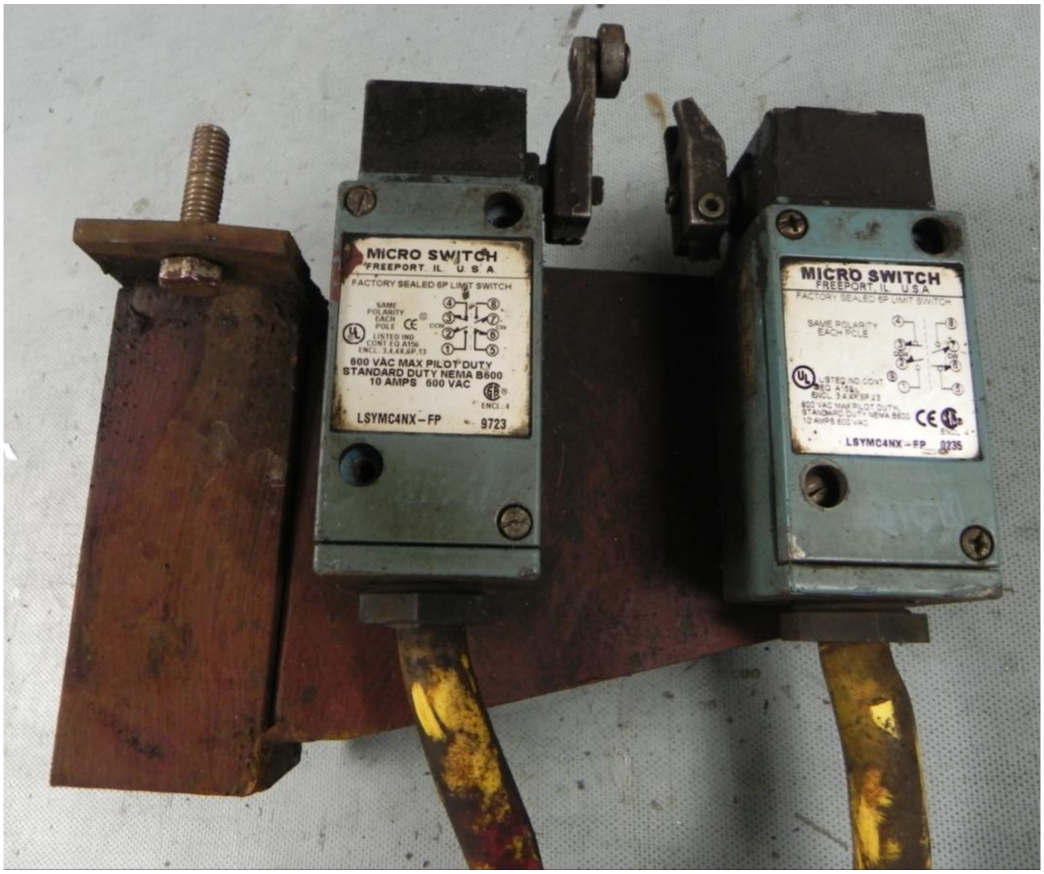

Figure 3. Honeywell mechanical limit switches (model LSYMC4NX-FP) interfaced to the bridge control system and used to sense bridge and span position.

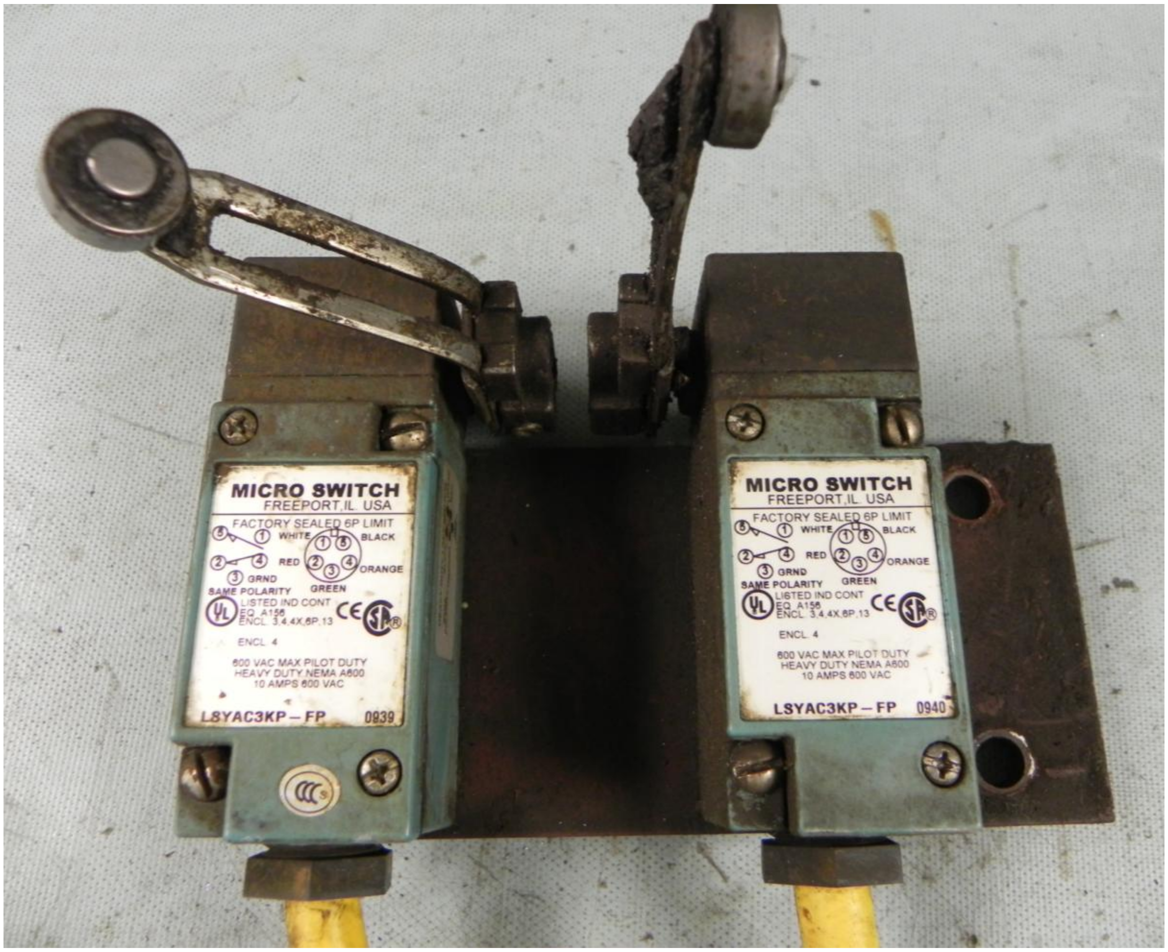

Figure 4. Honeywell mechanical limit switches (model LSYAC3KP-FP) interfaced to the bridge control system and used to sense bridge and span position.

<u>Post-Accident Sensor/Switch Testing:</u>

The IIM-200 inductive proximity sensors are 4-prong devices designed to be operated in several configurations. These devices were tested by applying 24 VDC to the L+ and L– inputs to the sensor while monitoring the Output pin using an oscilloscope referenced to L–. A large piece of railroad steel (a mount from another proximity sensor) was brought into proximity with the head of the sensor and the distance required to obtain a response on the output was noted. The two mechanically damaged sensors failed to switch at any distance. One of the sensors was found to be shorted out at the power supply inputs; the other failed to activate under any condition. The two mechanically intact proximity sensors operated repeatedly and activated at an average proximity to the sensor head of 14.0 mm and 12.5 mm, respectively. In each case, the voltage at the output pin with the switch in the open position was approximate 2.3 VDC, and the voltage at the output pin with the switch in the closed position was approximate 21.8 VDC. These parameters were all within the normal limits published for the IIM-200.

The IGO-328 inductive proximity sensors are 4-prong devices designed to be operated in several configurations. These devices were tested by applying 24 VDC in series with the proximity sensor using a 680 Ω load. The voltage across the load was monitored while a large piece of railroad steel (a mount from another proximity sensor) was brought into proximity with the head of the sensor and the distance required to obtain a response on the output was noted. One of these sensors was found to be unresponsive under any condition. The voltage across the load in this case was approximately 20 VDC. The other sensor activated repeatedly at an average distance of 5.1 mm. The voltage across the load in the closed position was found to be approximately 19.6 VDC. These parameters were all within the normal limits published for the IGO-328.

The Honeywell LSYMC4NX-FP heavy duty limit switch is a double-pole, double-throw (DPDT) side-mounted rotary switch with center-neutral. When the actuator arm is rotated clockwise, each 'pole' connection is electrically connected to its individual 'throw' connection on one 'side'. When the actuator arm is rotated counterclockwise, the same two 'pole' connections are electrically connected to two other 'throw' connections on the other 'side'. In this way two independent input signals (one on each pole connection) can be switched in concert to one of two output destinations – depending on which way the actuator arm is rotated. If the actuator arm is left in neutral, the input signal is not switched to either output. The pole and throw connections emanated from the switch housing on a 9-conductor color coded cable. No information was available correlating wire color to the published pole-throw pinout. The switch was tested using a standard ohmmeter by measuring the resistance between each cable-wire while activating the switch both clockwise (CW) and counterclockwise (CCW). The results are shown in Table 1. The portion of the table below the diagonal shows the results for CCW rotation (as viewed from the actuator side of the device). The portion of the table above the diagonal shows the results for CW rotation.[1] The results were identical for both switches.

Table 1. Results of testing for the Honeywell LSYMC4NX-FP heavy duty limit switches.

Wire Color	**Orange**	**Green**	**Yellow**	**Blue**	**Black**	**White**	**Red**	**Pink**	**Brown**
Orange		–	–	–	–	–	*OPEN*	–	–
Green	–		–	–	–	–	–	–	–
Yellow	–	–		–	–	–	–	–	*CLOSED*
Blue	–	–	–		–	OPEN	–	–	–
Black	–	–	–	–		–	–	CLOSED	–
White	–	–	–	*CLOSED*	–		–	–	–
Red	CLOSED	–	–	–	–	–		–	–
Pink	–	–	–	–	*OPEN*	–	–		–
Brown	–	–	OPEN	–	–	–	–	–	

The dashed entries in the table represent wire pairs that are not electrically connected at any time, regardless of actuation lever position. The CLOSED entries indicate that an electrical connection is 'made' if the actuation lever is rotated counterclockwise (area below the red diagonal) or clockwise (area above the red diagonal), respectively. Similarly, the OPEN entries indicate that an electrical connection is 'un-made' if the actuation lever is rotated counterclockwise (area below the red diagonal) or clockwise (area above the red diagonal),

[1] Since current is free to flow in both directions through these devices, for any given actuation direction the area in the table above the diagonal would be a mirror image of the information found below the diagonal.

respectively. Entries in *italics* indicate the state of the connection when the actuation lever is in the default position.

The results in Table 1 indicate that the White-Blue wire pair leads to a switch that is normally closed (NC) unless the actuator is rotated CW, which opens the switch and severs the connection. And the Pink-Black wire pair leads to a switch that is normally open (NO) unless the actuator is rotated CW, which closes the switch and establishes a connection. Likewise, the Yellow-Brown wire pair leads to a switch that is normally closed (NC) unless the actuator is rotated CCW, which opens the switch and severs the connection. And the Orange-Red wires form a switch that is normally open (NO) unless the actuator is rotated CCW, which closes the switch and establishes a connection.

The Honeywell LSYAC3KP-FP heavy duty limit switch is a double-pole, double-throw (DPDT) side-mounted rotary switch with center-neutral. When the actuator arm is rotated clockwise, each 'pole' connection is electrically connected to its individual 'throw' connection on one 'side'. When the actuator arm is rotated counterclockwise, the same two 'pole' connections are electrically connected to two other 'throw' connections on the other 'side'. In this way two independent input signals (one on each pole connection) can be switched in concert to one of two output destinations – depending on which way the actuator arm is rotated. The pole and throw connections emanated from the switch housing on a 5-conductor color coded cable. The switch was tested using a standard ohmmeter by measuring the resistance between each cable-wire while activating the switch both clockwise (CW) and counterclockwise (CCW). The results are shown in Table 2. The portion of the table below the diagonal shows the results for CCW rotation (as viewed from the actuator side of the device). The portion of the table above the diagonal shows the results for CW rotation.[2] The results were identical for both switches.

Table 2. Results of testing for the Honeywell LSYAC3KP-FP heavy duty limit switches.

Wire Color	**Red**	**Orange**	**Green**	**White**	**Black**
Red		OPEN	–	–	–
Orange	OPEN		–	–	–
Green	–	–		–	–
White	–	–	–		CLOSED
Black	–	–	–	CLOSED	

The dashed entries in the table represent wire pairs that are not electrically connected at any time, regardless of actuation lever position. The CLOSED entries indicate that an electrical connection is 'made' if the actuation lever is rotated counterclockwise (area below the red diagonal) or clockwise (area above the red diagonal), respectively. Similarly, the OPEN entries indicate that an electrical connection is 'un-made' if the actuation lever is rotated counterclockwise (area below the red diagonal) or clockwise (area above the red diagonal), respectively. The state of each connected wire pair while in the neutral position was the opposite of its state in the activated position. Stated explicitly, the Red-Orange wire pair was electrically closed, and the Black-White wire pair was electrically open, when the activation lever was in the neutral position.

[2] Since current is free to flow in both directions through these devices, for any given actuation direction the area in the table above the diagonal would be a mirror image of the information found below the diagonal.

The results in Table 1 indicate that the Red-Orange wire pair leads to a switch that is normally closed (NC) unless the actuator is rotated either CW or CCW, thus opening the switch and severing the connection. And the White-Black wire pair leads to a switch that is normally open (NO) unless the actuator is rotated either CW or CCW, which closes the switch and establishes a connection.

Test Results:

In summary, the two undamaged IIM-200 inductive proximity sensors appeared to operate as designed and within published specifications. The two damaged IIM-200 inductive proximity sensors did not operate as designed.

One of the IGO-328 inductive proximity sensors appeared to operate as designed and within published specifications. The other IGO-328 inductive proximity sensor failed to operate as designed, and this behavior was consistent over multiple trials.

All four of the heavy duty limit switches appeared to operate as designed.

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