Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

RAIL TRANSPORTATION SAFETY INVESTIGATION REPORT R21V0144

LOCOMOTIVE ENGINE FIRE

Canadian Pacific Railway Company
Freight train 880-066
Mile 54.3, Cranbrook Subdivision
Elko, British Columbia
08 July 2021

Canada

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Summary

On 08 July 2021, Canadian Pacific Railway Company (CP) train 880-066 was travelling eastward on the Cranbrook Subdivision near Caithness, British Columbia, when its mid-train distributed power locomotive sustained a mechanical failure that resulted in flames emanating from the exhaust stack. Due to the remote position of the locomotive in the train consist, the situation went undetected until the condition was observed by the crew of an opposing CP train (V09-012) during a meet at the siding in Elko, British Columbia, about 5 miles east of Caithness.

It is likely that hot embers were emitted from the exhaust stack on the damaged locomotive, ignited vegetation, and caused a trackside fire near Caithness. The fire was reported by a member of the public, grew to 1.2 hectares, and was extinguished by the local volunteer fire department, with the help of BC Wildfire Service. The track in the area was not damaged.

There were no dangerous goods involved in this occurrence, and no one was injured.

1.0 FACTUAL INFORMATION

1.1 The occurrence

On 08 July 2021, eastbound Canadian Pacific Railway Company (Canadian Pacific or CP)[1] train 880-066 (the eastbound train) was travelling on the Cranbrook Subdivision, en route

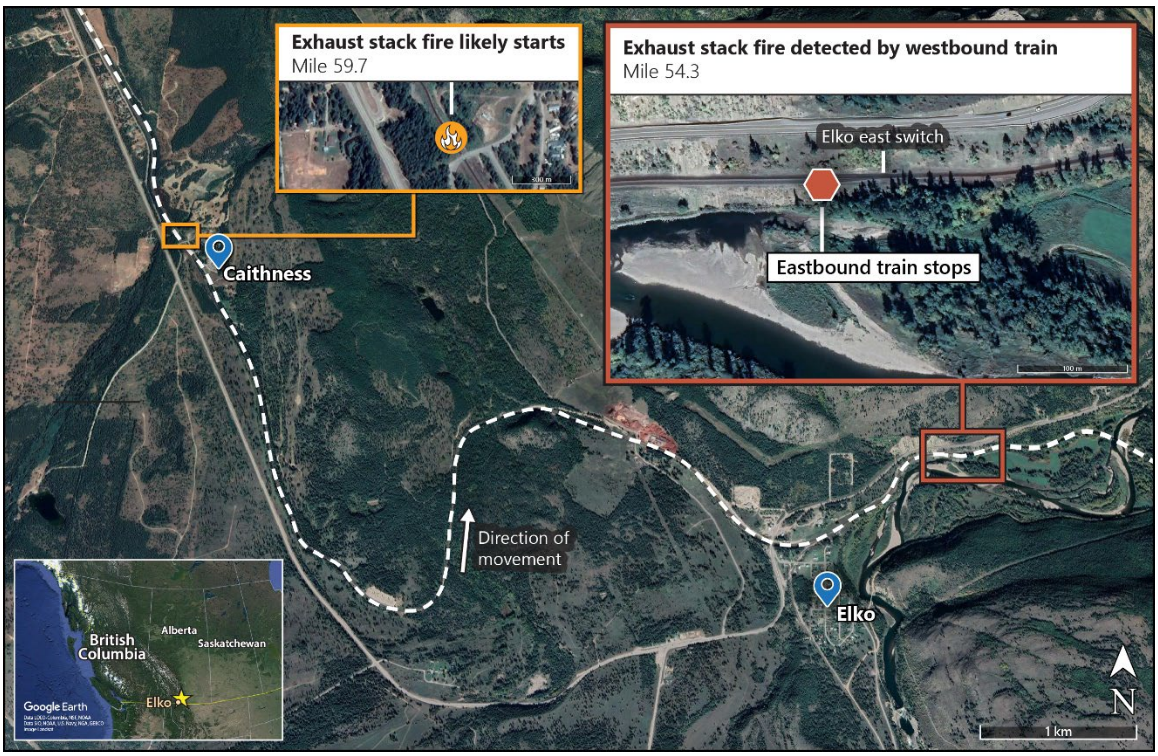
1 On 14 April 2023, Canadian Pacific Railway Company (CP) and Kansas City Southern (KCS) combined into a single railway company doing business as CPKC. As the occurrence took place before the transition date, the acronym CP will be used throughout the report.

to Sparwood (Mile 17.7),[2] from where it would travel to one of the several mines in the area to be loaded with coal for transport to Vancouver.

The eastbound train was powered by 3 distributed power (DP) locomotives:[3] 1 at the head end, 1 in a mid-train position, and 1 at the tail end. The mid-train and tail-end locomotives were remotely controlled by radio command from the lead locomotive. The train was handling 152 empty coal hopper cars. It weighed 3269 tons and measured 8289 feet.

At approximately 1500,[4] as the eastbound train was about a mile away from Elko, the rail traffic controller (RTC) radioed and asked the crew members if they had observed a fire in the vicinity of Caithness Road (Mile 59.2) (Figure 1). They responded that they had not.

Figure 1. Map showing the occurrence location, with inset maps showing the location where the exhaust stack fire likely started, and where it was detected by the westbound train crew; a third inset map, in the bottom left corner, shows the location of Elko in British Columbia (Source: Google Earth, with TSB annotations)



Shortly after, the eastbound train approached the east siding switch at Elko (Mile 53.56), where it would be meeting westbound CP train V09-012 (the westbound train). The eastbound locomotive engineer (LE) asked the westbound crew to look at his (eastbound)

2 All locations are in the province of British Columbia, unless otherwise indicated.

3 Distributed power (DP) systems provide synchronous or independent control of locomotives at up to 4 locations throughout a train. Train handling commands from the crew on the lead locomotive are transmitted by DP radio to each of the remote locomotives. When the remote locomotives receive the radio message, they respond by executing the train handling commands.

4 All times are Mountain Daylight Time.

train as the 2 trains passed each other, to check for a possible fire. The westbound crew agreed to perform the check.

The eastbound train came to a stop on the main track at the east switch at Elko. While the westbound train was operating through the siding, its crew performed the requested inspection and noticed that flames were coming out of the exhaust stack on the mid-train locomotive. The crew of the westbound train contacted the crew of the eastbound train to inform them of the situation.

Figure 2 shows a photograph of the exhaust stack fire, taken by a resident at Elko while the train was coming to a stop on the main track. At this time, the locomotive throttle had been returned to idle, reducing the engine's RPM and the engine exhaust flow. It is likely that the flames coming from the exhaust stack were much higher when the train was in motion, as the locomotive throttle would have been in a higher position than idle.

After being told of the exhaust stack fire, the LE on the eastbound train asked the westbound crew to stop and activate the emergency fuel cut-off on the mid-train remote locomotive (CP 9779). However, the head end of the westbound train had already gone past this locomotive and the westbound crew, concerned that the fire might propagate to their own train, which was loaded with coal, elected to continue without stopping.

Figure 2. Exhaust stack fire on the mid-train remote locomotive (Source: Elko resident)

The LE of the eastbound train was able to shut down the diesel engine on the mid-train locomotive from his position on the lead locomotive using the on-board remote locomotive controls. He then contacted the RTC to provide an update, and indicated that the conductor would perform a walking inspection. The RTC, in turn, contacted the area supervisor, who was in Fort Steele at the time (43 miles away). The supervisor drove to the eastbound train's location to assess the situation.

The conductor inspected the mid-train locomotive, but there were no visible signs of fire. As a precautionary measure, he activated the emergency fuel cut-off on each side of the locomotive.

When the area supervisor arrived, he assessed that it was safe to bring the train to Sparwood. The train resumed its trip about 3.25 hours after having stopped at Elko.

At Sparwood, the mid-train locomotive was removed from the train and secured on the back track for follow-up mechanical inspection. The train then continued on to one of the coal mines in the area for loading, as planned.

There were no dangerous goods involved in this occurrence, and no one was injured.

1.1.1 Trackside fire

At about 1445, a member of the public heard a loud noise as the train was travelling past the Caithness Road public crossing (Mile 59.5). The person who heard the loud noise lived close to the railway right-of-way (ROW),[5] was familiar with the sounds associated with the passing of trains, and considered that this sound was unusual.

At about 1448, shortly after the eastbound train had passed over the crossing, another member of the public contacted local emergency services through 911 to report a trackside[6] fire on the north side of the ROW, west of the crossing.

The emergency services dispatched the local volunteer firefighters from the nearby community of Jaffray, then notified CP's Operations Centre. The local firefighters arrived at the scene about 12 minutes after receiving the call; at this time, the fire was about 0.5 hectare in size. BC Wildfire Service was also dispatched and brought in airborne support.

The fire grew to approximately 1.2 hectares in size and extended beyond the CP ROW, to the private property of a local farmer. The fire was extinguished about 3.5 hours later. The fence along the ROW was damaged, as well as some surplus ties; the damage to the local farmer's property was limited to vegetation (Figure 3).

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5 Railway-operated right-of-way (ROW) extends approximately 50 feet (15.25 m) from the centre of the outermost track on both sides.

6 Trackside refers to the property immediately adjacent to the railway ROW.

Figure 3. Damage from the trackside fire near Caithness (Source: TSB)

Follow-up inspection of the track and roadbed west of the Caithness Road public crossing revealed an accumulation of lubricating oil on the ballast on the south side of the track. The oil was first observed adjacent to the location of the trackside fire, about 1000 feet west of the crossing, and extended eastward through the crossing.

1.2 Crew information

The crew of the eastbound train was composed of an LE and a conductor. Both crew members met established rest and fitness requirements and were qualified for their respective positions.

1.3 Weather information

At the time of the occurrence, the temperature was 30 °C and the sky was clear.

According to the Province of British Columbia fire danger ratings, the fire danger in the Elko area was high on the day of the occurrence; the following day, it was extreme.[7]

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[7] The Province of British Columbia uses the Canadian Forest Fire Danger Rating System to rate the fire danger, i.e., the risk of a wildfire starting. There are 5 possible ratings, from very low to extreme. Different ratings are assigned to different geographic areas based on weather station data. Ratings are updated daily.

A high danger rating is defined as follows: "Forest fuels are very dry and the fire risk is serious. New fires may start easily, burn vigorously, and challenge fire suppression efforts. Extreme caution must be used in any forest activities. Open burning and industrial activities may be restricted."

An extreme danger rating is defined as follows: "Extremely dry forest fuels and the fire risk is very serious. New fires will start easily, spread rapidly, and challenge fire suppression efforts. General forest activities may

There were no restrictions applicable to railway operations on the basis of the provincial fire danger ratings in effect.

1.4 Recorded information

The tail-end remote locomotive was equipped with a forward-facing camera; however, it was not operative at the time of the occurrence.

The mid-train remote locomotive was equipped with an on-train monitoring recorder, which kept a log of all the errors generated by the computer on the locomotive, known as a fault log. Based on a review of the fault log, no mechanical failure of the locomotive was recorded by the system.

The investigation determined that the mid-train remote locomotive was in a high throttle position (6 to 8) when it travelled in the area of the Caithness Road public crossing.

1.5 Subdivision and track information

The Cranbrook Subdivision runs east to west between Crowsnest[8] (Mile 0.0) and Glenlily (Mile 156.8). Train movements are governed by the occupancy control system, as authorized by the *Canadian Rail Operating Rules* (CROR) and dispatched by an RTC located in Calgary, Alberta.

This is a Class 3 track under the *Rules Respecting Track Safety*, with a maximum permissible freight train speed on the subdivision of 40 mph.

In the area of the Caithness Road public crossing, the track has a 1% grade. For eastbound trains, the grade is ascending.

1.6 Turbocharged diesel engines

Locomotive CP 9779 is a General Electric AC4400CW locomotive manufactured in 2003. It is powered by a GE 7FDL 16-cylinder, 4-stroke turbocharged diesel engine capable of delivering up to 4400 horsepower.

The diesel engine drives a main alternator that generates 3-phase alternating current (AC) electrical power. The electrical power is passed through rectifiers and inverters before being supplied to the 6 AC traction motors that drive each axle on the locomotive.

The operation of a diesel engine requires a continuous delivery of the correct ratio of air and fuel, as well as circulation of coolant and lubricating oil. The 4 strokes, which relate to the movement of the piston in each cylinder, are as follows: intake, compression, combustion and exhaust.

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be restricted, including open burning, industrial activities and campfires." [Source: Government of British Columbia, "Fire Danger," at https://www2.gov.bc.ca/gov/content/safety/wildfire-status/wildfire-situation/fire-danger (last accessed on 02 August 2023)].

8 The east switch at Crowsnest is in Alberta. However, the yard tracks and the west switch are in British Columbia. The west switch is at Mile 0.0 of the Cranbrook Subdivision.

During the compression stroke, high-pressure fuel is injected and atomized at a precise interval to result in combustion, forcing the piston down and the crankshaft to rotate. The amount and timing of fuel delivery is electronically controlled by the engine governor unit as determined by various factors such as throttle position, associated load being demanded, and required engine speed. Low pressure fuel (90 psi) is pressurized to 18 000 psi by high-pressure fuel pumps. The engine governor unit controls a solenoid on the high-pressure fuel pump that delivers a precise amount of high-pressure fuel to the fuel injection nozzles.

The camshaft is used to control the opening and closing of intake and exhaust valves located at the top of the cylinder's combustion chamber; it has irregular-shaped lobes that are in constant contact with pushrods. When the camshaft rotates, the lobes move the pushrods up and down. The pushrods push on rocker arms which, in turn, pivot and push down on spring-loaded valves. When open, intake valves let compressed air into the cylinders, and exhaust valves allow exhaust to be expelled. The timing of the opening and closing of the valves is thereby controlled by the rotation of the camshaft.

Turbochargers use hot exhaust gases, expelled from the cylinder following combustion of the fuel/air mixture during each cycle, to drive a turbine that is connected by a shaft to a compressor. The compressor fan compresses the air being delivered to the cylinders. This increases the amount of oxygen being supplied, which makes the combustion process more efficient.

The lubricating system consists of a sump pan under the crankshaft and a lubricating oil pump. The oil is pumped through various passages in the engine block and other components to supply lubrication to friction surfaces throughout the engine. The oil lubricates, cools, and seals piston rings and cylinder walls, and it suspends microscopic particles from the combustion process to prevent them from causing wear.

Friction from the moving parts, as well as the combustion process, causes heat to build up in the engine. This heat is reduced by a liquid coolant that flows around the sides of the cylinder walls and liners. Engine heat captured by the coolant is then dissipated to the atmosphere through the radiators. The majority of North American freight locomotives use water as the coolant rather than an anti-freeze solution.

The diesel engine on locomotive CP 9779 is equipped with 16 power assemblies, with 8 power assemblies on each side in a "V" formation. The power assemblies include mechanical components that open and close the intake valves, regulating the addition of fuel and air delivered to each cylinder, and the exhaust valves, to expel exhaust gases from each cylinder during each combustion cycle.

Components inside each power assembly include the cylinder, cylinder head, jacket, liner, piston, connecting rod, fuel injector nozzle, pushrods, rocker arms, valves, and springs. The electronic high-pressure fuel pump and the high-pressure fuel line connecting to the fuel injection nozzle are visible on top of the power assembly cylinder head. Failure of key parts of the power assembly, such as a dropped valve or broken piston, require the replacement of the power assembly. Replacement of worn or failed parts in an individual power assembly can be made without a complete teardown of the diesel engine.

1.7 Locomotive CP 9779

1.7.1 Post-occurrence inspection

Following the occurrence, locomotive CP 9779, which was held in Sparwood, underwent a mechanical inspection by a TSB investigator and CP mechanical staff to determine the cause of the fire.

The inspection determined that the R8 power assembly (the 8th power assembly on the right side) failed. A rocker arm on this power assembly was found broken, and both the power assembly housing and the air intake manifold were damaged. An exhaust valve was found broken with its head badly damaged and the valve stems were bent on the remaining exhaust valve and both intake valves. The fuel injector tip was found broken off. In addition, valve seat recession[9] was noted on the failed valve.

Figure 4. Air intake manifold and R8 power assembly on locomotive CP 9779 (Source: TSB)

Figure 4 shows the relative position of the R8 power assembly and air intake manifold, Figure 5 shows various parts of the R8 power assembly, including the broken rocker arm, and Figure 6 shows the damage on the air intake manifold.

9 Valve seat recession occurs when a valve in an internal combustion engine gets embedded into the cylinder head.

Figure 5. Broken rocker arm in the R8 power assembly on locomotive CP 9779 (Source: TSB)

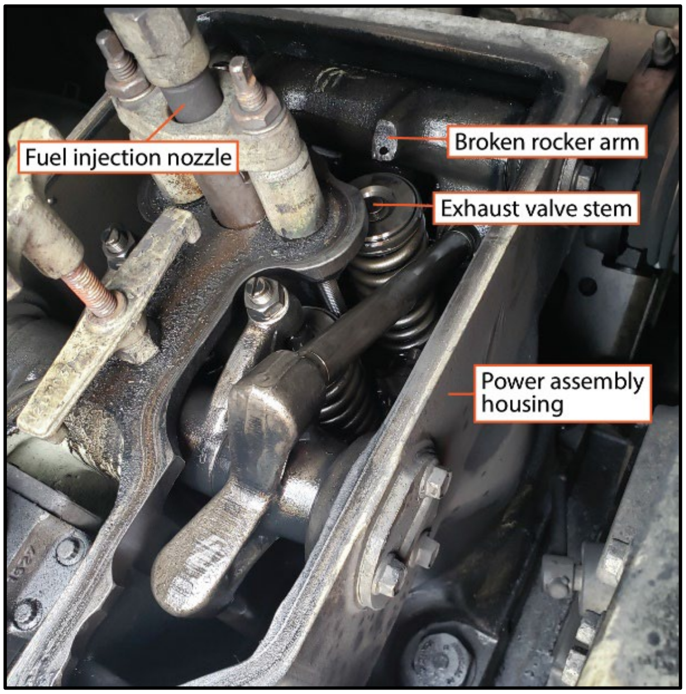

Figure 6. Bottom view of the air intake manifold on locomotive CP 9779, showing the damage and its location (Source: TSB)

The head of the exhaust valve broke off and dropped into the combustion chamber while the engine was in operation, breaking the tip off the fuel injector.

Lubricating oil from the damaged power assembly could no longer be contained within the power assembly and it accumulated within the engine compartment. The oil subsequently migrated down the side of the locomotive and onto the ballast.

The resulting loss of combustion air pressure due to the damaged air intake manifold caused all 8 cylinders on the right-hand side of the diesel engine to burn a rich mixture of fuel and air.[10] In addition, the broken fuel injector continued to deliver unatomized fuel to the cylinder. This allowed unburned fuel to enter the exhaust manifold, where it was ignited by the hot exhaust gases before exiting the exhaust stack.

1.7.2 Maintenance history

At CP, locomotive engines undergo a complete overhaul at regular intervals, usually around 5 to 7 years. For the model of engine used in locomotive CP 9779, an overhaul is performed at every interval of 28 000 megawatt-hours. Engine overhauls require a change out of all main components, such as power assemblies. Some parts of the power assemblies, such as rocker arms and exhaust valves, may be replaced with requalified parts rather than new ones.

The maintenance of the CP 9779 locomotive is directed and performed by CP personnel, with technical support provided by Wabtec Corporation (Wabtec). Wabtec acts in an advisory capacity.

The last engine overhaul of CP 9779 was conducted by CP on 16 December 2017 at its facilities in St. Paul, Minnesota, United States. Since this last overhaul, 10 power assemblies were changed out (more than 60%), and 3 broken power assembly rocker arms were replaced.

Table 1 lists the engine repairs made to the locomotive in the last 2 years before the occurrence.

Table 1. Engine repairs made to locomotive CP 9779 in the 2 years before the occurrence (Source: Canadian Pacific)

Repair notification number	Date closed	Description provided in repair notification
1002129019	2021-04-19	Excessive smoke
1002129209	2021-04-19	Valve lash*
1002129276	2021-04-19	R3 power assembly changeout
1002129277	2021-04-19	Excessive smoke
1002129294	2021-04-19	R6 broken rocker arm
1002129295	2021-04-19	L6 power assembly changeout
1002101904	2021-02-07	Rocker arm on L6 power assembly replaced
1002097456	2021-02-07	Engine shut down – Hot engine
1001976159	2020-05-18	Engine not loading – Hot engine

10 A rich fuel/air mixture is a mixture in which there is proportionally more fuel than air. In a rich mixture, there is not sufficient air for complete combustion of the fuel.

1001967341	2020-04-20	L2 power assembly changeout
1001960689	2020-04-07	Engine not loading – Hot engine
1001929772	2020-01-17	All injectors changed out
1001906118	2019-11-09	R8 power assembly connecting rod replaced
1001906152	2019-11-09	L8 power assembly connecting rod removal
1001906154	2019-11-09	R4 power assembly changeout
1001905028	2019-11-09	Crankcase overpressure

*A valve lash refers to the “available clearance or gap between the rocker arm and the tip of the valve stem when the lifter for that valve is sitting on the base circle of the cam lobe.” (Source: MotorTrend magazine, “How to Set a Valve Lash” at https://www.motortrend.com/how-to/1707-how-to-set-valve-lash/#:~:text=Valve%20lash%20is%20the%20available,intended%20to%20be%20fully%20closed [last accessed on 04 June 2022]).
Note: The table does not include all 10 power assemblies changed out in the 3.5 years between the last engine overhaul and the date of the occurrence.

1.7.3 Regulatory inspections

CP locomotives are used on the railway's network in Canada and the United States (U.S.) and must be compliant with Transport Canada regulations, as well as regulations of the U.S. Federal Railroad Administration. Under these regulations, the following locomotive inspections are required:

- A pre-departure safety inspection – this inspection includes checking for any apparent safety hazard, verifying the operation of hand brakes, headlights, and ditch lights, and performing a visual inspection of trucks and running gear. In addition, an air brake test, which covers the operation of the safety control system, must be performed.[11]
- A qualified locomotive mechanical inspection (QLMI) once every 30 days – this is a visual inspection of the locomotive cab, the trucks, the safety appliances and the air brakes. It does not include an inspection of the diesel engine or the engine room.[12]
- A periodic general inspection at least once every 92 days – on locomotives equipped with advanced on-board electronic condition-monitoring controls that are microprocessor-based, as in this occurrence, this inspection must be conducted at least once every 184 days. The periodic general inspection includes all mechanical gauges used by the locomotive operator to aid in controlling and braking the train or locomotive, as well as all electrical devices, visible insulation, alerters, and remote control locomotive system components. In addition, all cable connections between locomotives and jumpers that are designed to carry 600 volts or more must be thoroughly cleaned, inspected and tested for continuity.[13]

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11 Transport Canada, *Railway Locomotive Inspection and Safety Rules*, Appendix I - Pre-Departure Inspection by a Locomotive Operator or Other Qualified Person, available at https://tc.canada.ca/en/rail-transportation/rules/railway-locomotive-inspection-safety-rules/appendix-i-ii-railway-locomotive-inspection-safety-rules (last accessed 08 August 2023).

12 United States Code of Federal Regulations (CFR), Title 49, Part 229.23 – Periodic inspection: general (December 2012).

13 Ibid.

- An annual inspection at intervals that do not exceed 368 days – this inspection covers the following:
  - load meters that indicate electric current being applied to the traction motors;
  - all devices that are used by the locomotive operator to aid in controlling and braking the train or locomotive and which provide an electronic indication of air pressure;
  - microprocessor-based event recorders; and
  - air brake system (calibration, maintenance and testing).[14]

The last QLMI was performed on CP 9779 on 08 July 2021, the day of the occurrence, at the locomotive repair shop in Golden; no defects were noted. The last periodic inspection was conducted on 08 February 2021; the locomotive passed the inspection. The last annual inspection was conducted on 31 July 2020; the locomotive passed the inspection.

1.8 System health monitoring

System health monitoring provides data on the status of a system, which allows operators to take action when the information provided indicates an abnormal condition.

DP systems, such as was used on the train in this occurrence, have limited health monitoring capabilities and can provide basic information on the status of remote locomotives.

For more advanced remote health monitoring, independent software solutions are also available.

1.8.1 Health monitoring on distributed power systems

DP systems enable an LE to monitor the following remote locomotive functions from the lead locomotive:

- throttle position and tractive effort generated
- dynamic brake operation through braking effort generated
- automatic brake operation through brake pipe pressure readings
- independent brake operation through locomotive brake cylinder pressure readings
- equalizing reservoir pressure
- main reservoir pressure
- airflow

These systems also provide the LE with an alarm notification for the DP remote locomotive in the form of a red square on the multi-function display. The various abnormal operating and fault condition alarms that can occur on a DP remote locomotive are streamlined and essentially grouped together by the on-board DP control system; they are then treated as a single "trainline fault" condition. The LE must attempt to diagnose the alarm situations from the available information.

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14 United States Code of Federal Regulations (CFR), Title 49, Part 229.27 – Annual tests (April 2012).

In contrast, an abnormal operating or fault condition occurring on the lead controlling locomotive triggers a descriptive alarm message about the specific fault condition, such as:

- wheel slip
- locked axle
- dynamic brake fault condition warning
- electronic air brake loss of communication
- end-of-train motion and loss of communication

Modern freight locomotives in operation are not equipped with remote sensing capability to monitor for common types of locomotive fires, such as exhaust stack fires, engine room fires, traction motor fires, and electrical compartment fires.

1.8.2 Third-party remote health monitoring systems

Many railways use third-party equipment integrated into their locomotives control and mechanical systems to transmit select data from the locomotive to a central data processing centre. Examples of this type of solution include PowerView Connect by Progress Rail and the Violet Edge platform by Wi-Tronix.

These systems, which are in widespread use in North America, enable a railway to remotely monitor how its trains are being operated and can provide valuable technical information about locomotive performance, including diesel engine performance. However, these systems have not been designed to record and transmit data specific to the presence of fires on locomotives operating in a remote position in a train consist.

CP 9779 was not equipped with a third-party health monitoring system.

1.8.3 Wayside inspection systems

North American railways use strategically located wayside inspection systems to monitor select safety-critical parameters as trains pass, such as the temperature of rail car wheels and bearings, and the presence of dragging equipment. In CP operations, hot wheel and bearing detectors on main track are typically spaced 20 to 25 miles, but not more than 40 miles, apart.

Wayside detectors are not equipped with cameras or heat sensors to detect common types of locomotive fires.

1.9 Regulatory requirements for train inspections

Rule 110 of the CROR, Inspecting Passing Trains and Transfers, sets the requirements for the inspection of passing trains or transfers by train crews of standing trains and other employees. It also provides guidance to crews on trains being inspected to be on the lookout for the results of passing inspections. Rule 110 states:

> (a) When duties and terrain permit, at least two crew members of a standing train or transfer and other employees at wayside must position themselves on the ground on both sides of the track to inspect the condition of equipment in

> passing trains and transfers. When performing a train or transfer inspection, the locomotive engineer will inspect the near side. When a group of wayside employees is present, at least two employees must perform the inspection. EXCEPTION: Crew members of passenger trains are exempted from the above requirements except when standing at meeting points in single track territory. However, every effort must be made to stop a train or transfer when a dangerous condition is noted.
>
> (b) Employees inspecting the condition of equipment in a passing freight train or transfer must, when possible, broadcast the results of the inspection.
>
> (c) Every effort must be made to stop a passing train or transfer if a dangerous condition is detected. Each crew member of a train or transfer must be alert at all times for a stop signal or communication given by an employee. The report to the train or transfer being inspected must state only the location of the dangerous condition and what was observed and not speculate as to the cause.
>
> (d) When a crew member is located at the rear of a train or transfer, a front crew member must, when practicable, notify the rear crew member of the location of employees in position to inspect their train or transfer.[15]

CROR Rule 111, Train and Transfer Inspection, establishes the requirements for the inspection of trains by the on-board operating crew. It states, in part:

> (c) All crew members on a moving train or transfer must make frequent inspections of both sides to ensure that it is in order.[16]

Fires on locomotives located in a remote position in a train consist are not usually within the line of sight of the train crew from their position in the cab of the lead locomotive. Mid-train DP locomotives are often thousands of feet from the lead locomotive and end-of-train DP locomotives can be a few miles behind the lead locomotive. Unless a train is being operated through flat, open terrain with long gentle curves, the mid or rear DP remote locomotives will remain out of sight of the train crew. Additionally, some locomotive fires may only be visible during running inspections at night.

1.10 Canadian Pacific instructions related to train operations during fire season

With respect to fire prevention during the fire season, CP's *General Operating Instructions* for Canadian operations state:

> **28.0 Fire Season and Prevention**
>
> **28.1** Locomotives that idle for extended periods, tend to discharge sparks from the exhaust stack.
>
> **28.2** Actions which will help reduce sparks:
>
> Where locomotives may have been idling for extended periods, it is beneficial to advance the throttle to notch 5 for at least ten (10) minutes before working the

[15] Transport Canada, *Canadian Rail Operating Rules* (24 April 2020), Rule 110: Inspecting Passing Trains and Transfers.

[16] Ibid., Rule 111: Train and Transfer Inspection.

locomotives under heavy load. Extra care is required near open top sulphur trains.
If spark emissions do occur, decrease throttle to reduce the distance that sparks may be thrown. This will also help reduce the size and heat content of the sparks.
Enroute, to minimize sparks; - if the locomotives have been "drifting" in IDLE or operated in low throttle positions for several miles, it is beneficial to advance the throttle slowly, one notch at a time. - use dynamic brake. It should be considered the primary choice of retardation, and - use contour braking/throttle modulation by allowing the natural resistance of grade, curvature and friction to slow the train.

> **28.3** Whenever possible, if a locomotive is suspected of starting fires, it must be shut down to prevent further damage to right of way or adjacent areas. Report accordingly on the Crew Information Form and notify Mechanical Facilities.
>
> **28.4** Train Crews should be particularly alert to detect any evidence of excessive spark emission from locomotives or the train.
>
> **28.5** When yard locomotives are moved on freight trains, they must be moved dead or isolated to their destination. They must not be restarted or operated by train crews enroute.[17]

1.11 *Railway Extreme Heat and Fire Risk Mitigation Rules*

To address the risks of fire in extreme heat conditions, the Railway Association of Canada proactively developed the *Railway Extreme Heat and Fire Risk Mitigation Rules*, which it filed on its own initiative with the Minister of Transport pursuant to subsection 20(1) of the *Railway Safety Act*. On 15 June 2022, Transport Canada enacted the new rules, with the following stated objectives:

> 2.1 These rules are intended to ensure that companies have:
>
> a. Mitigating measures to protect safe railway operations and the infrastructure during periods of extreme heat;
>
> b. Appropriate methods in place to detect and to prevent the starting of fires during periods of Extreme Fire Danger Levels; and
>
> c. Mitigating measures for fires that may be started on railway rights-of-way during periods of Extreme Fire Danger Levels.
>
> 2.2 Section 6 and Section 7 of these rules supplement the requirements of the *Prevention and Control of Fires on Line Works Regulations*.[18]

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17 Canadian Pacific, *General Operating Instructions (GOI) – Canada* (effective 14 October 2015 and revised 06 September 2018), Section 1: Locomotive and Train Operations – Train Handling, sub-section 28.0: Fire Season and Prevention, pp. 14–15.

18 Transport Canada, *Railway Extreme Heat and Fire Risk Mitigation Rules* (15 June 2022), Section 2.0: Objectives.

With respect to locomotive inspection requirements, the rules state:

> 6.1 Companies shall ensure the entire exhaust system of root blower locomotives is inspected and cleaned at intervals not to exceed 30 days. These inspections shall be conducted by a qualified person. A record of the inspection shall be retained for at least 90 days.
>
> 6.2 Companies shall ensure that locomotives equipped with turbocharged engines have had their entire exhaust system inspected and cleaned at intervals not to exceed:
>
> a. 92 days for turbocharged engines equipped with mechanical fuel injection
>
> b. 184 days for turbocharged engines equipped with electronic fuel injection
>
> These inspections shall be conducted by a qualified person. A record of the inspection shall be retained until the next required inspection has been completed.[19]

In addition, with respect to requirements for a fire risk mitigation plan for the prevention of fires on railway ROWs, the rules also state:

> 7.1 Each company must develop and adhere to an Extreme Weather Fire Risk Mitigation Plan (Fire Risk Mitigation Plan) that will be in effect during the fire season.
>
> 7.2 The Fire Risk Mitigation Plan must include, at a minimum, measures to:
>
> a. Monitor fire risk levels;
>
> b. Detect and report fires along the right-of-way including reporting by the public of fires on rights-of- way to railway companies;
>
> c. During periods of Extreme Fire Danger Levels, for each railway company that operates or maintains the line work, to manage vegetation, including the removal of combustible materials or debris from the right-of-way being generated through vegetation management activities;
>
> d. During periods of Extreme Fire Danger Levels, for each railway company that operates or maintains the line work, to mitigate fire hazards during line work maintenance activities; e.g., rail cutting, welding, rail grinding; and respond to fires resulting from such activities, if needed. Except in the case of emergencies or where required to maintain safe railway operations, mitigations may include restricting or stopping certain line work maintenance activities as appropriate;
>
> e. Assess conditions and implement appropriate mitigations during active fire events on or encroaching on the right-of-way to maintain safe railway operations, including adjustments to train operations; and
>
> f. Respond to detected or reported fires, which could include immediate action to suppress the fire, communication to and/or deployment of appropriate emergency response resources. Emergency response resources may include external parties such as first responders and/or fire services.
>
> 7.3 Companies must file their Fire Risk Mitigation Plan with Transport Canada within 30 days after the date on which these Rules come into force. Any subsequent

19 Ibid., Section 6.0: Locomotive inspection requirements.

> revisions to the plan must be filed with transport Canada before the revisions become effective.[20]

These rules were not in effect at the time of this occurrence.

1.12 Third-party reporting of locomotive fires

CP posts contact information for its Public Safety Communications Centre at all public crossings. In addition, the contact information is available on CP's website. The communication centre is open 24 hours a day to respond to emergencies. It can directly access the Operations Centre when immediate action to stop a train is required. Members of the public who observe locomotive fires, and other emergencies, can report the situation directly to the communications centre by way of the posted telephone number.

Alternatively, emergency calls from the public can be routed through local 911 services. Such services, in jurisdictions traversed by CP's railway tracks, have been provided with the coordinates to the communications centre.

In this occurrence, the trackside fire near the Caithness Road public crossing was reported by a concerned citizen through the local 911 service; the emergency service then relayed the information to CP.

1.13 Reporting of fires to the TSB

The *Transportation Safety Board Regulations*, pursuant to the *Canadian Transportation Accident Investigation and Safety Board Act*, list the types of railway occurrences that are required to be reported to the TSB. It states, in part:

> **Railway Occurrences**
>
> **Report to Board**
>
> 5 (1) The operator of the rolling stock, the operator of the track and any crew member that have direct knowledge of a railway occurrence must report the following railway occurrences to the Board:
>
> […]
>
> (b) the rolling stock or its contents
>
> […]
>
> (iii) cause or sustain a fire or explosion,
>
> […][21]

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[20] Ibid., Section 7.0: Requirements for a fire risk mitigation plan for the prevention of fires on railway rights-of-way.

[21] Transportation Safety Board of Canada, *Transportation Safety Board Regulations*, SOR/2014-37 (last amended on 23 November 2018), Part 1: Reports, Mandatory Reporting, Railway Occurrences, sub-part 5(1): Report to Board.

A review of fires reported to the TSB over the 10-year period prior to the occurrence identified 34 locomotive fires involving DP mid-train or tail-end remote locomotives, 3 of which are confirmed to have caused ROW fires. Between the date of the occurrence and the end of June 2023, there have been an additional 21 fires on DP mid-train or tail-end remote locomotives reported to the TSB.

2.0 ANALYSIS

The manner in which the train was operated and the condition of the track were not contributory to this occurrence. The analysis will focus on the locomotive engine failure, the resultant locomotive and trackside fires, and the absence of locomotive health monitoring capability to detect fires on distributed power (DP) locomotives in a remote position in a train consist (remotely located locomotives).

2.1 The occurrence

On 08 July 2021, Canadian Pacific Railway Company (CP) train 880-066 was travelling eastward on the Cranbrook Subdivision near Caithness when its mid-train DP locomotive sustained a mechanical failure that resulted in flames emanating from the exhaust stack. It is likely that hot embers were emitted from the exhaust stack on the damaged locomotive, ignited vegetation and caused a trackside fire near Caithness.

Due to the remote position of the locomotive in the train consist, the situation went undetected until the condition was observed by the crew of an opposing CP train (V09-012) during a meet at the siding in Elko, about 5 miles east of Caithness. They saw that flames were coming out of the exhaust stack on the eastbound train's mid-train locomotive.

2.2 Engine failure and fire on CP 9779

A follow-up mechanical inspection at Sparwood (Mile 17.7, Cranbrook Subdivision) determined that the R8 power assembly on the diesel engine of mid-train remote locomotive CP 9779 had suffered a catastrophic failure.

Subsequent mechanical examination of the locomotive found a broken rocker arm on the R8 power assembly. An exhaust valve was found broken with its head badly damaged and the stems on the remaining exhaust valve and both intake valves were bent. The fuel injector tip was found broken off. It was determined that an exhaust valve, which showed evidence of valve seat recession, had failed; its head dropped into the combustion chamber while the engine was in operation, breaking off the tip of the fuel injector. As evidenced by the bent valves stems on the remaining valves, the rocker arm failed either after or during its associated valve's impact with the broken exhaust valve head. The air intake manifold was also damaged. This resulted in a loss of pressure in the air supplied to the 8 cylinders on the right-hand side of the diesel engine and, consequently, the fuel–air mixture supplied to these cylinders contained more fuel than normal. In addition, the broken fuel injector continued to deliver unatomized fuel to the combustion chamber and hence out through the open exhaust valve port.

Unburned fuel was discharged through the exhaust ports to the exhaust manifold, where it was ignited by the hot engine exhaust gases before being expelled through the exhaust stack.

Finding as to causes and contributing factors

An exhaust valve on the R8 power assembly of mid-train remote locomotive CP 9779 failed, resulting in the head of the valve dropping into the combustion chamber, damaging a fuel injector and causing the rocker arm of the adjacent exhaust valve to fail while the engine was in operation. Subsequently, unburned fuel entered the exhaust manifold, where it was ignited by the hot engine exhaust gases before being expelled through the exhaust stack.

2.2.1 History of power assembly replacements on CP 9779

At CP, locomotive engines undergo a complete overhaul at regular intervals, usually around 5 to 7 years. For locomotive CP 9779, an overhaul is performed at every interval of 28 000 megawatt-hours. The last overhaul for CP 9779 was in late 2017. Maintenance records indicate that CP 9779 had 10 out of 16 power assemblies changed out since its last engine overhaul and that exhaust valve seat recession had been previously found when CP serviced this unit. The TSB does not collect data on locomotive power assembly failures.

Finding: Other

More than 60% of the power assemblies on locomotive CP 9779 were replaced in about 3.5 years, which corresponds to around half of the engine overhaul cycle.

2.3 Trackside fire near the Caithness Road public crossing

When the mid-train locomotive was travelling in the area of the Caithness Road public crossing, its engine was in high throttle position (6 to 8) as the train was ascending a 1% grade. At high throttle, gases exit the exhaust stack at an elevated rate and pressure. If there are hot embers in the exhaust stack, they are driven further into the air. When driven with sufficient force, airborne embers can be projected to the side of the track, depending on the presence of cross winds and the turbulence created by the moving train. In hot, dry weather conditions, when the risk of wildfire is high, as in this occurrence, the hot embers have the potential to ignite the surrounding vegetation and cause a fire.

Although there is no photographic evidence of embers in this occurrence, in the absence of another confirmed source of ignition, and given that the right-of-way (ROW) fire was reported shortly after the passage of the train, it is likely that the exhaust stack fire contained carbon-based materials that migrated to the ROW and started the fire.

Finding as to causes and contributing factors

Flames and embers exiting the mid-train locomotive’s exhaust stack likely resulted in the hot embers falling on the vegetation along the track west of the Caithness Road crossing. The danger of wildfire was high in the area, and the embers ignited the vegetation on the ROW, causing a fire which spread to adjacent land on the north side of the track.

The fire near Caithness Road public crossing was observed and reported to 911 in a timely manner. This enabled a rapid response by the local fire department. The BC Wildfire Service was also immediately notified, and responded with airborne support.

Finding: Other

Despite the fire's growth in high fire danger conditions, it was quickly brought under control and extinguished by the local fire department and the BC Wildfire Service.

2.4 Locomotive health monitoring

Locomotive CP 9779 was a DP remote locomotive operated in the mid-train position. On a train handling a large number of cars (the occurrence train was handling 152 cars), mid-train locomotives are not usually within the line of sight of the train crew from their position in the cab of the lead locomotive.

On DP systems, fault monitoring information for remote locomotives is displayed to the LE on the lead locomotive. It is represented as a single generic alert, with no information to help diagnose the cause of the fault. Fires on remote locomotives do not trigger the generic alert, unless they lead to a mechanical fault. Consequently, these fires can go unnoticed by the crew members.

Although DP systems provide limited fault monitoring information for locomotives operating in remote positions, more advanced health monitoring solutions exist, such as PowerView Connect by Progress Rail and the Violet Edge platform by Wi-Tronix. These systems, which are in widespread use in North America, enable a railway to remotely monitor how its trains are being operated and can provide valuable technical information about locomotive performance, including diesel engine performance. However, they have not been designed to record and transmit data specific to the presence of fires on remote locomotives.

Remotely located locomotives are not equipped with sensors to detect common types of locomotive fires, such as engine room fires, exhaust stack fires, traction motor fires, and electrical compartment fires.

Locomotives are not currently equipped with systems to alert crew members to locomotive fires. Therefore, the industry currently relies on inspections of passing trains by railway employees, and on reports made by the public to identify fires.

North American railways use strategically located wayside inspection systems to monitor selected safety-critical parameters as trains pass. These systems typically monitor for hot wheels/bearing, as well as dragging equipment.

In CP operations, hot wheel and bearing detectors on main track are typically spaced 20 to 25 miles, but not more than 40 miles, apart. Industry has not yet leveraged these installations to enable inspection for locomotive fires, either through camera-based visual inspection or sensor-based heat detection.

Finding as to risk

Until technologies are implemented to detect fires on remotely located locomotives, there is a risk that those fires will remain undetected using existing methods, which could lead to trackside fires or damage to the rolling stock.

2.5 Railway and regulatory requirements based on fire danger

The Province of British Columbia uses the Canadian Forest Fire Danger Rating System to rate fire danger, i.e., the risk of a wildfire starting. At the time of the occurrence, the fire danger was rated as high for the Elko area, where the train was travelling in this occurrence, and it transitioned to extreme the following day.

CP's *General Operating Instructions* provide guidance to train crews on best practices during fire season to avoid emitting sparks from a locomotive. These instructions require that locomotives be shut down when it becomes known that they are emitting sparks or embers. However, in the case of DP train operations, crews are often unaware of conditions affecting the remotely located locomotives until trackside employees or members of the public observe and report such conditions.

At the time of the occurrence, there were no regulatory restrictions on the operation of a train with remotely located locomotives based on fire danger rating, nor were there requirements specific to the continuous monitoring of these locomotives for fires.

Finding as to risk

In areas susceptible to wildfires due to weather conditions, if there are no railway or regulatory restrictions on the operation of trains with remotely located locomotives, on which sources of ignition can go undetected for extended periods, there is an increased risk that these sources of ignition will migrate to and ignite surrounding terrain.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. An exhaust valve on the R8 power assembly of mid-train remote locomotive CP 9779 failed, resulting in the head of the valve dropping into the combustion chamber, damaging a fuel injector and causing the rocker arm of the adjacent exhaust valve to fail while the engine was in operation. Subsequently, unburned fuel entered the exhaust manifold, where it was ignited by the hot engine exhaust gases before being expelled through the exhaust stack.

2. Flames and embers exiting the mid-train locomotive's exhaust stack likely resulted in the hot embers falling on the vegetation along the track west of the Caithness Road crossing. The danger of wildfire was high in the area, and the embers ignited the vegetation on the right-of-way, causing a fire which spread to adjacent land on the north side of the track.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. Until technologies are implemented to detect fires on remotely located locomotives, there is a risk that those fires will remain undetected using existing methods, which could lead to trackside fires or damage to the rolling stock.

2. In areas susceptible to wildfires due to weather conditions, if there are no railway or regulatory restrictions on the operation of trains with remotely located locomotives, on which sources of ignition can go undetected for extended periods, there is an increased risk that these sources of ignition will migrate to and ignite surrounding terrain.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. More than 60% of the power assemblies on locomotive CP 9779 were replaced in about 3.5 years, which corresponds to around half of the engine overhaul cycle.

2. Despite the fire's growth in high fire danger conditions, it was quickly brought under control and extinguished by the local fire department and the BC Wildfire Service.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Canadian Pacific

To comply with Ministerial Order (MO) 21-06 issued on 11 July 2021, in which Transport Canada required railways to implement measures to increase their capacity to detect, monitor, and suppress fires, Canadian Pacific Railway Company (CP) implemented the following:

- A measure ensuring that no locomotive is operated through areas where the fire danger is rated as extreme, unless it has been inspected in the previous 15 days. This measure is to ensure that the locomotive's exhaust passages are clear of combustible material, including oil accumulation and carbonaceous deposits in excess of ⅛ inch in thickness.
- Extreme weather fire risk mitigation plans that address fire detection, monitoring, and response measures.
- Enhanced vegetation control measures along the right-of-way (ROW), including:
  - A guidance document for the management of forest fuel load that may develop as a direct result of vegetation management activities.
  - The removal of debris resulting from tree and vegetation work, or the disposition of the debris by mechanical mulching or chipping.
  - Guidelines for fuel management to contractors who perform vegetation management services on behalf of CP.

4.2 Safety concern

4.2.1 Monitoring for fires on locomotives operating in a remote position in a train consist

Modern freight locomotives are not equipped with real-time sensors to monitor, detect, and automatically communicate locomotive fires, such as exhaust stack fires, engine room fires, traction motor fires, or electrical compartment fires. Therefore, the industry currently relies on inspections of passing trains by railway employees, and on reports made by the public, to identify and report a fire condition, particularly when the fire occurs on an unmanned locomotive operating in a remote position in a train consist (remotely located locomotive). This creates a risk that an on-board fire will go undetected for an extended duration, potentially migrating to the ROW and beyond.

Many railways use third-party equipment integrated into their locomotives' control and mechanical systems to wirelessly transmit select data from the various locomotives operating on a train to a central data processing centre. These systems, which are in widespread use in North America, enable a railway to remotely monitor the operation of locomotives and can enable real-time monitoring of technical information (diagnostics, customizable alerts, etc.) about locomotive health, including diesel engine performance.

However, these systems have not been designed to detect the presence of locomotive fires and to alert train crews.

In addition, North American railways use strategically located wayside inspection systems to monitor select safety-critical parameters as trains pass by, such as the temperature of rail car wheels/bearings and the presence of dragging equipment. However, these wayside detectors are not equipped with cameras or heat sensors to detect fire on a passing train, and more specifically a fire on a remotely located locomotive.

While fires on remotely located locomotives are not uncommon, they do not often migrate to the railway ROW. A review of fires reported to the TSB over the 10-year period prior to the occurrence identified 34 locomotive fires involving DP mid-train or tail-end remote locomotives, 3 of which are confirmed to have caused ROW fires. Between the date of the occurrence and the end of June 2023, there have been an additional 21 fires on DP mid-train or tail-end remote locomotives reported to the TSB. According to the TSB Regulations, fires must be reported to the TSB if they are attributable to the operation of rolling stock, as determined by the railway; however, establishing a causal link to ROW fires can often be difficult. For this reason, the frequency and number of ROW fires caused by rolling stock, including fires caused by remote locomotives, could be higher than reported to the TSB. If such fire events were to spread to the ROW and beyond at a time of high or extreme fire danger, the consequences could be catastrophic to people, property, and the environment.

To address the risks of fire during times of extreme fire danger, the *Railway Extreme Heat and Fire Risk Mitigation Rules* have been developed by the railway industry and approved by the Minister of Transport. The new rules came into effect on 15 June 2022. Among other requirements, these rules are intended to ensure that railway companies have "[a]ppropriate methods in place to detect and to prevent the starting of fires during periods of Extreme Fire Danger Levels."[22] These rules also require that each railway company have a fire risk mitigation plan in effect during the fire season, and that such a plan include measures to "[d]etect and report fires along the right-of-way including reporting by the public of fires on rights-of-way to railway companies."[23]

The Board is encouraged by the initiative the rail industry has taken in developing the *Railway Extreme Heat and Fire Risk Mitigation Rules*, and it looks forward to improved management of the risks associated with railway operations during the fire season. However, there currently is insufficient data available for the TSB to assess the full impact of the new rules on reducing on-board fires and ROW fires.

Early detection of locomotive fires would allow for prompt intervention to prevent the spread of these fires to the ROW. Until technologies are implemented to detect fires on remotely located locomotives, there is a risk that those fires will remain undetected using

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22 Transport Canada, *Railway Extreme Heat and Fire Risk Mitigation Rules* (15 June 2022), Section 2.0: Objectives.

23 Ibid., Section 7.0: Requirements for a fire risk mitigation plan for the prevention of fires on railway rights-of-way.

existing methods, which could lead to trackside fires that extend beyond the ROW or damage to the rolling stock.

Therefore, the Board is concerned that steps have not been taken to leverage and expand the use of existing on-board locomotive systems to monitor remotely located locomotives for common types of fires while trains are in operation.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 02 August 2023. It was officially released on 24 August 2023.