Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

Detail Fracture Defects
The Canadian TSB Experience

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Canada

HEAVY HAUL SEMINAR • MAY 8 - 9, 2013

WRI 2013

Transportation Safety Board of Canada

Presentation at the
2013 Wheel Rail Interaction Conference

Heavy Haul Seminar

May 8 – 9, 2013

Outline for Today's Presentation

- About the TSB
- TSB vs NTSB
- Detail Fracture Wheel/Rail Investigations
- TSB Watchlist

Board Objectives

- To advance transportation safety by:
  - Conduct independent investigations and, if necessary, public inquiries
  - Make findings as to causes and contributing factors
  - Identify safety deficiencies
  - Make recommendations
  - Report publicly.

Unique Features of TSB's Enabling Legislation

- The TSB is independent from any other federal department or organization
- The TSB reports directly to Parliament
- The Board does not assign fault or determine civil or criminal liability

Unique Features of TSB's Enabling Legislation

- The Board shall not refrain from reporting fully because fault or liability my be inferred from findings.
- The Board's findings are not binding on parties to any legal, disciplinary or other proceedings

TSB vs NTSB

- The Chair and Board Members have no role in the fact finding portion of the investigation
- The TSB is not required to determine probable cause (although we sometimes do!)

TSB vs NTSB

- Limited use of observers.
- The IIC is the spokesperson of the investigation
- The TSB is the keeper of rail occurrence data

The TSB Rail & Pipeline Investigation Branch

- RPIB – approximately 25 staff
- 13 Regional Investigators in 8 offices
- 5 Head Office Investigators – specialists, standards and technical coordinators
- 1 pipeline investigator
- 3 regions – East, Central, West

TSB Watchlist

- As with the NTSB, the Board maintains a list of safety issues that pose the greatest risk to Canadians. In Rail, these include:
- On-board video and voice recorders
- Following signal indications
- Passenger trains colliding with vehicles.

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Detail Fracture Defects

The Canadian Experience

Main Track Derailments due to Fatigue Defects


Shell

Detail Fracture Defects

- A type of transverse defect
- Cannot be detected visually
- Usually only identified prior to failure by ultrasonic testing
- Unpredictable growth rate – may appear and fail between tests

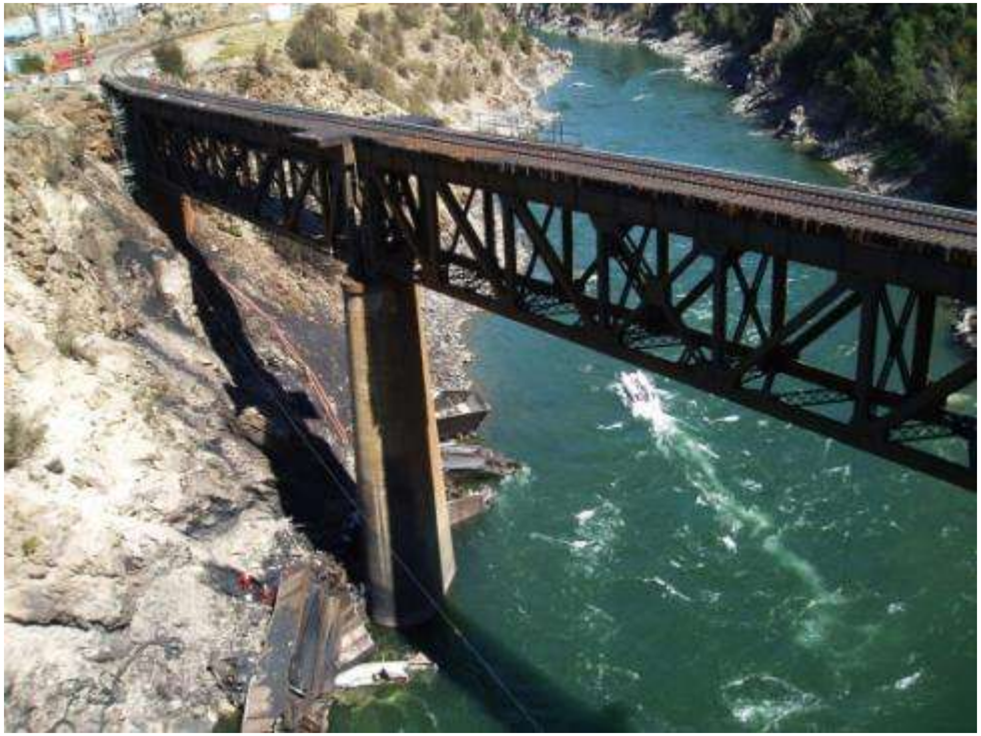
Detail Fracture Defects

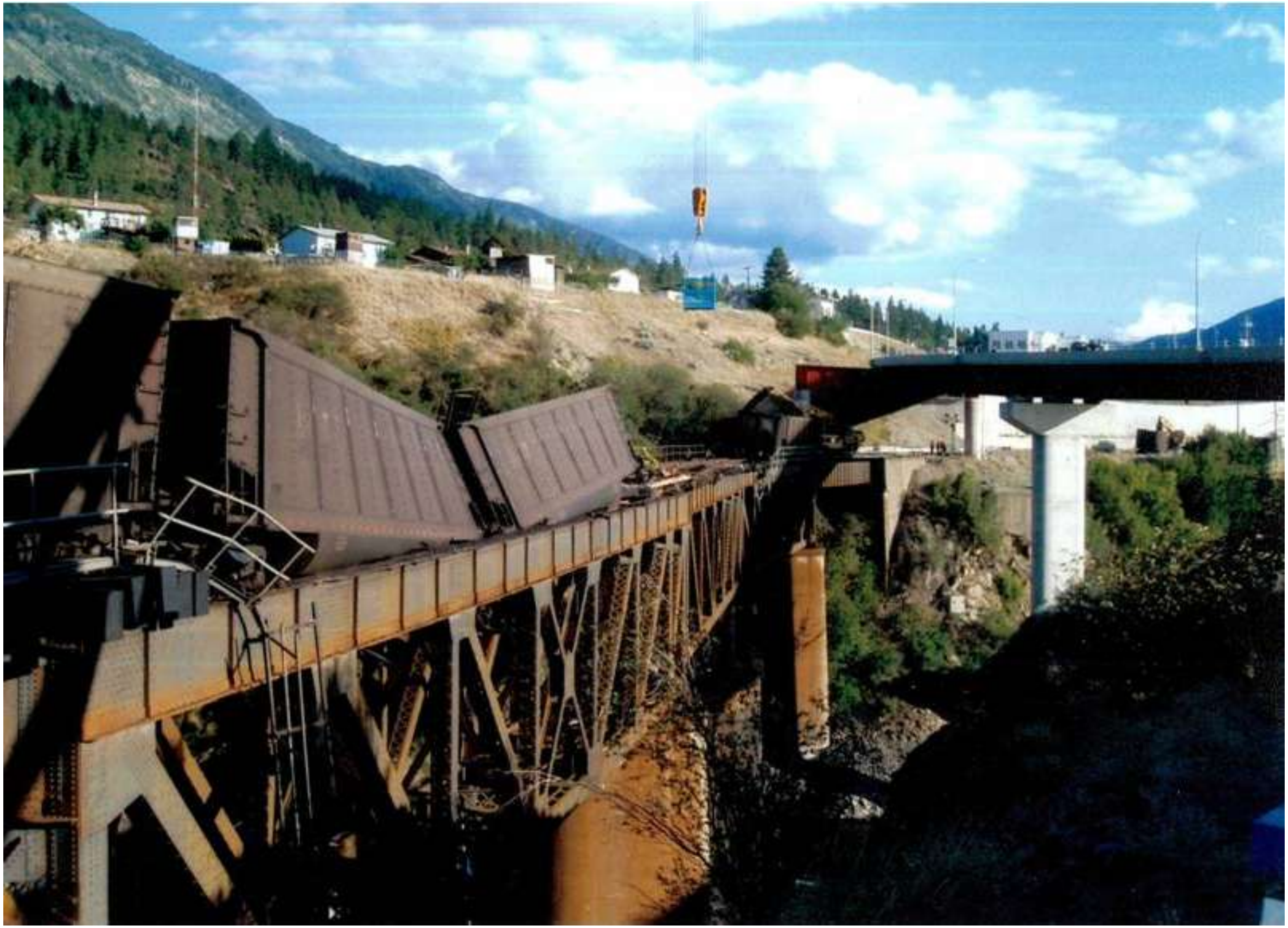
- Caused by rolling contact fatigue
- High traffic densities and loading
- Initiate at inclusion, surface cracks or internal longitudinal separation (shell)
- Can occur in any rail, but more likely to develop in older rails lacking mechanical properties, strength and quality of newer rails

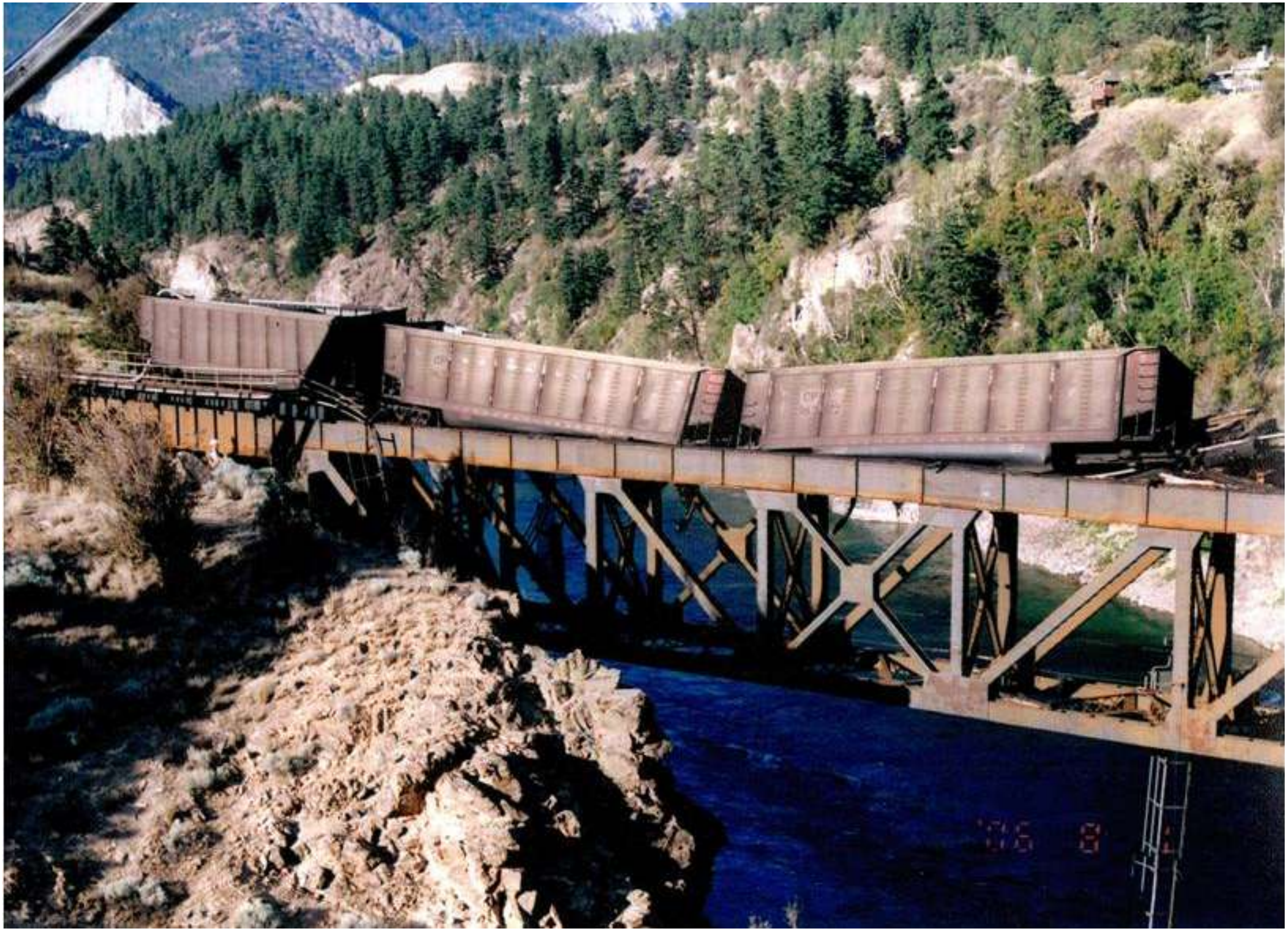
Advancing Transportation Safety

- Recommendations on fatigue, shell or head checking (eg NTSB 2006 New Brighton) very broad – difficult or impossible to implement
- The Department of Transport (TC) establish minimum standards for the quality and strength of maintenance rails. (R07-01)
- The Department of Transport establish standards requiring that rails approaching their fatigue limit be replaced. (R07-02)

- 20 loaded coal cars derailed while travelling across reversing 8°curves over the bridge
- 12 cars fell off the bridge, spilling about 1400 tons of coal into the river
- Extensive damage to the track and bridge

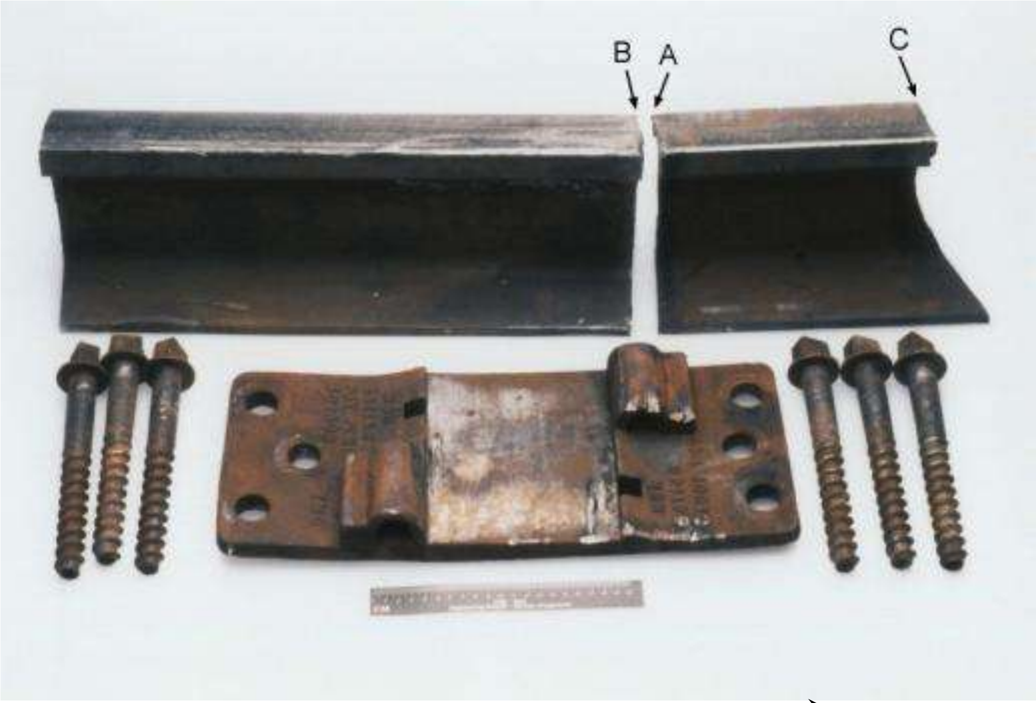






Recovered Rail Pieces and Fastenings

- Point of derailment was a broken rail on a tie plate
- Located 67 feet west of the east abutment (about 1 car length) on the north (high) rail and in the entry spiral of an 8-degree (about 218 m radius) left-hand curve



Direction of travel

- Fractures A and B matched
- More battering on fracture B
- Crack initiated from a shell at the lower gauge corner.
- Lip created by plastic metal flow caused by wheel/rail contact overstress.

Crack origin at a shell in the lower gauge corner

Beach marks in the fatigue crack region

Scuffing and tearing on gauge face

- Fine head checking, minor spalling, no visible evidence of shelling or corrugation.
- Rail showed 12 mm head wear and 6 mm flange wear.
- Rail did not exceed the specified limits for wear loss.

Fracture Face A

Beach marks in the fatigue crack region

Fracture Face B

- Fractures A and B matched
- More battering on fracture B
- Crack initiated from a shell at the lower gauge corner.
- Lip created by plastic metal flow caused by wheel/rail contact overstress.

Rail Material

- Rail was 141-pound continuous welded head-hardened rail rolled in Oct 2001 and installed in July 2002
- The rail material met railroad specification requirements
- Brinell hardness (363 HB head surface, 352 HB head core)
    - Ultimate tensile strength was 1258 MPa (min 1172 MPa required)
    - Elongation was within the 6 to 12% range typical for rail materials

Rail Testing

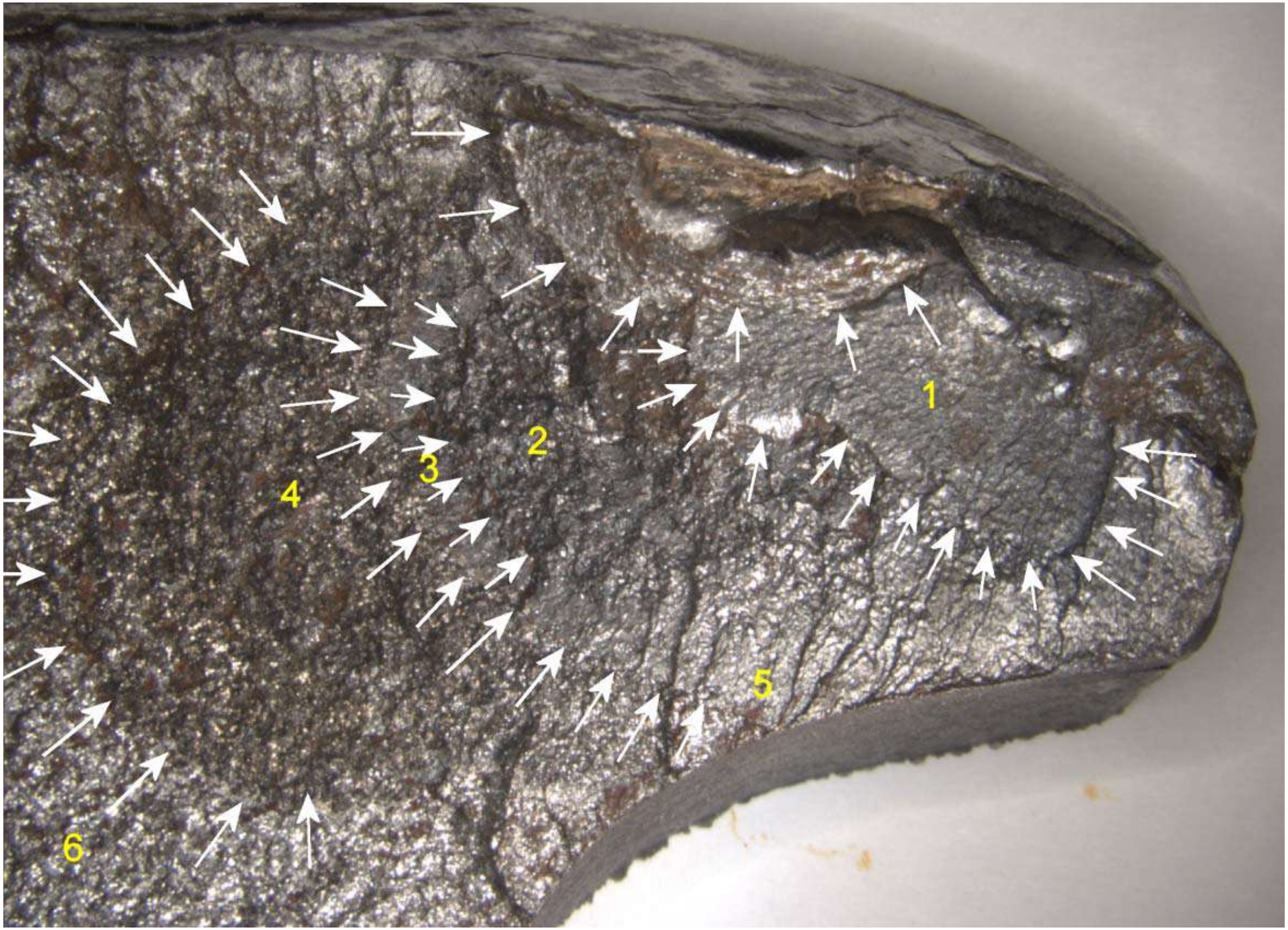
- Laboratory analysis concluded defects were present for some time
- Previous UT showed an indication near the location on the bridge where the rail broke
- Indication was attributed to a thermite weld upset/finish
- Action taken:
  - Testing frequency was further increased
  - Indications interpreted as weld must be confirmed visually
  - All suspect indications are hand-tested

Conclusion

- The train derailed when a pre-existing detail fracture defect grew to a critical size leading to the rail breaking under the train.
- The detail fracture defect grew from a shell at the lower gauge corner at a lip created by plastic metal flow caused by wheel/rail contact overstress.
- Neither the train operation, the condition of the rolling stock, fastenings nor the bridge timber under the rail break were considered contributory to the accident.

Conclusion

- The detail fracture defects grew quickly, consistent with heavy loading
- Shells and other defects can mask detail fractures (the UT signal reflects off the shell)
- Contributing factors to derailments:
    - Difficulty of detecting these types of defects using UT
    - Rapid unpredictable growth rate of the defects
    - Ineffective rail lubrication program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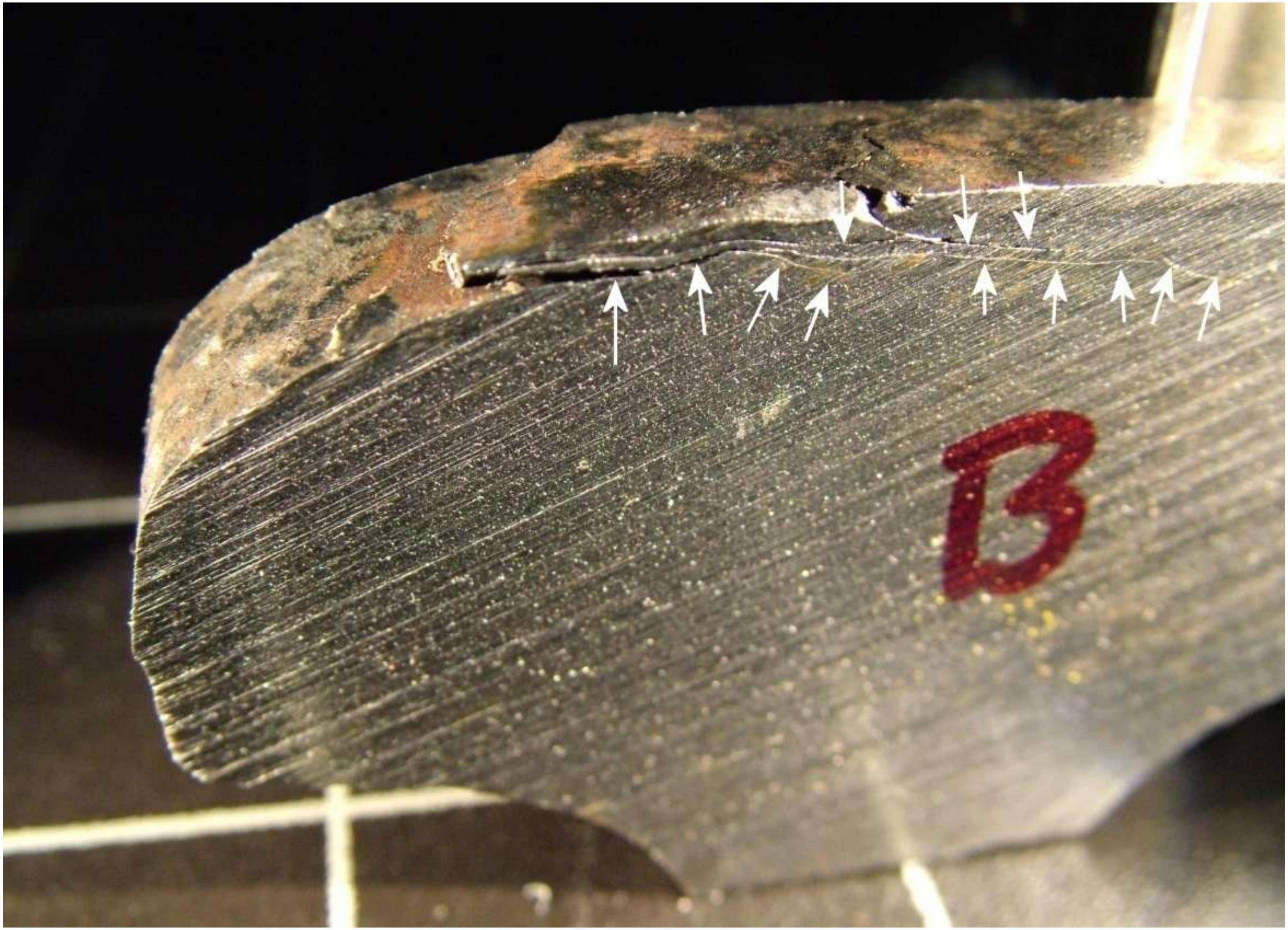

B

Conclusion

- Transverse defect in 190′ plug of 1976 115lb relay rail
- initiated at a sub-surface crack and propagated downwards in the head
- Surface shelling and cracking prevented proper identification of internal rail defects on ultrasonic test done nine days prior to derailment
- Indications not checked by hand testing
- Grinding done on maintenance rail 14 months earlier before it was laid on the bridge

So what has been learned?

- Understanding wheel/rail interaction is essential
- Effect of wear and rolling contact fatigue on development of defects
- Rail maintenance strategies to reduce the stress state
- Rail performance and defect management

Rail Maintenance

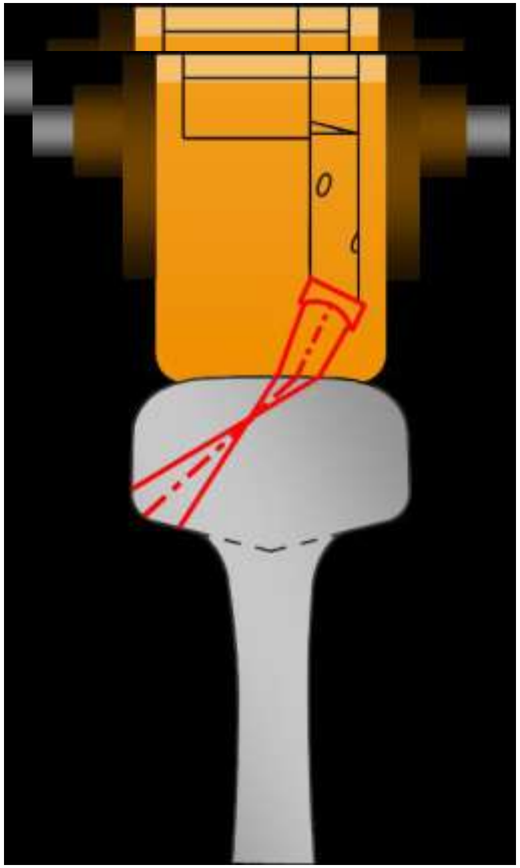
- Grinding:
  - Remove surface damage such as corrugations, head checking, shells due to fatigue under rolling contact conditions
  - Restore correct head profile, contact geometry and relieve contact stress
- Lubrication:
  - Wayside flange and top-of-rail lubricator system
  - Monitoring of lubrication effectiveness visually and by measurement of coefficient of friction at the wheel/rail interface

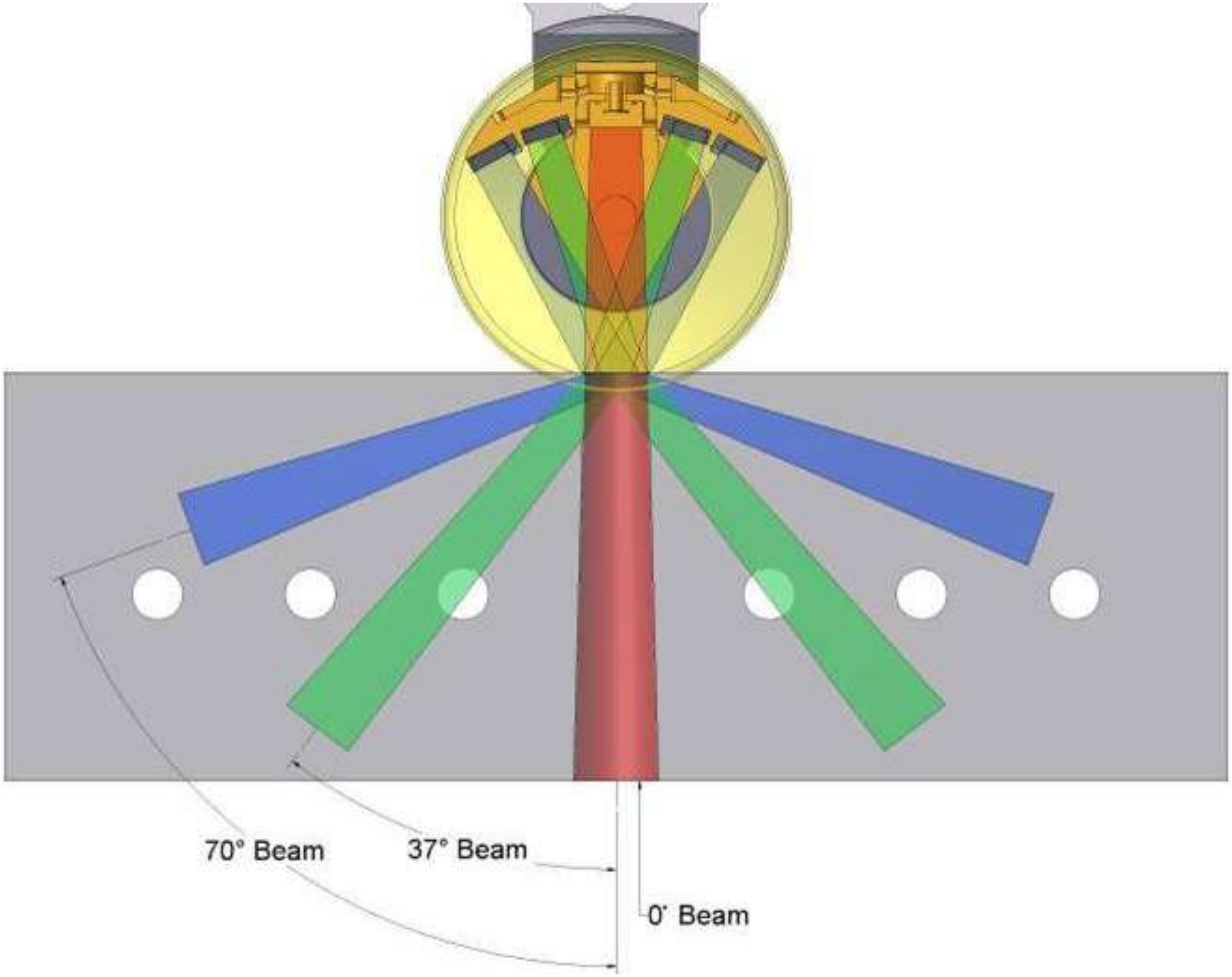
Ultrasonic NDT Rail Testing

- Primary risk-control method used to detect internal rail defects and manage fatigue
- Reliable, cost-effective, efficient and productive way to test rails in track
- Rail head contact system that relies on a smooth rail surface
- Operator training, experience, expertise and interpretation skills

Ultrasonic NDT Rail Testing

- Transport Canada requires ultrasonic testing for internal defects based on class of track
- Annually for Class 4 thru 6, in tracks where the annual tonnage is 25 mgt or more and in Class 3 track over which passenger trains operate
- Railways typically exceed this requirement




70° Beam
37° Beam
0' Beam

Phased Array Ultrasound

- Ultrasound and integrated rail profiling
- Laser profiling system resolves rail shape, and ultrasonic beams “steered” to correct for rail wear adjusting probes to target the proper reflection surface on any cross-section
- Beam sweeping can confirm defect information automatically from the truck without stopping for a hand test – higher inspection speeds
- Non-contact means not dependent on clean rail surface for testing integrity

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