Incident Summary #II-1612461-2023 (#39700) (FINAL)

SUPPORTING INFORMATION	Incident Date		September 29, 2023
	Location		Vancouver
	Regulated industry sector		Elevating devices - Escalator or moving walkway
	Impact – Injury	Qty injuries	3
		Injury description	Three people were reported injured due to the escalator overspeed runaway and several more piled up at the bottom of the escalator during the runaways.
		Injury rating	Minor
	Impact – Damage	Damage description	Physical damage to the inside of the escalator gearbox.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		A 3-year-old, down-traveling escalator at a public transit SkyTrain station, suffered a mechanical failure that rendered the safety and braking systems ineffective and caused multiple uncontrolled descents of the loaded escalator steps at high-speed causing riders to fall and pile up at the bottom resulting in multiple injuries.
INVESTIGATION CONCLUSIONS	Site, system and components		The transit location has a bank of three escalators installed next to each other used for conveying passengers to and from the transit platform situated approximately 25m (82') underground. The escalators were originally installed at the transit station in 1984 and are the longest in Western Canada at 35m (115') long and 14.63m (48') high. The outer escalators are primarily dedicated to up or down traffic while the middle escalator is used alternating in both directions to accommodate higher traffic flows at different times of the day. The escalators typically operate 24 hours a day while only carrying passengers for 20 hours a day for the past 3 years. The transit station is the 5th busiest in the province and in 2022 had approximately 4.8 million boardings. The escalators can see up to 30,000 pedestrians per average weekday. The immediate location of the escalators does not have an accessible elevator or stairway and pedestrians must use alternate escalators or an elevator located at a separate area through the concourse to access or exit the transit platforms (Image 1). Staircases are only accessible to the public to be used as emergency exits and cannot be used as an alternative to the escalators (Image 16). In 2018 work began on the replacement of the original escalators at the station to a new modern direct drive technology. Work was completed and the escalators were put back into service in July 2020. The existing escalators were replaced with Kone EcoMod Transit units which use a direct drive system that connects the two electric drive motors, through a series of gears, directly to the step-drive main-shaft without the use of a drive chain. In systems that use a drive chain, a secondary separate chain or an auxiliary braking system are required that will apply a brake on the step-drive main-shaft in the event of a drive chain failure. Direct drive systems do not require auxiliary step-drive main-shaft braking systems. The escalators use a permanent magnet, variable torque brake assembly that is attached to one end of the VFD (variable frequency drive) main-drive electric motors (Image 4). The opposite ends of the motor shafts are connected through a series of gears, splines and shafts to the moving steps and handrails of the escalators. The

Incident Summary #II-1612461-2023 (#39700) (FINAL)

	brakes are magnetically applied and electrically released. When power is applied, it energizes an internal electromagnet in opposite polarity to the permanent magnet nullifying the magnetic attraction which allows a spring to release the brake assembly. Any disruption from the electrical safety circuit, including the emergency stop button, will disconnect power to the brake and it will be applied by the permanent magnet. A dynamic motor control system modulates the voltage to the electromagnet controlling brake torque to achieve the proper rate of deceleration dependant on weight load. The rate of deceleration is designed to avoid abrupt stops which can cause rider falls and injuries. Escalator systems are provided with many safety monitoring devices designed to automatically stop the escalator by cutting electrical power to the motor and applying the brake if a problem occurs. Effectiveness of the braking and safety systems is reliant on a positive mechanical connection between the braking system and the step-drive. When the drive units are first installed on site, the step-drive main-shaft alignment flanges must be loosened and moved to allow for installation of small oil wipers used to control oiling of the splined step-drive main-shaft during rotation. The alignment flanges then need to be repositioned to the appropriate gap and two set screws on each plate need to be retorqued to 40 newton-meters (Nm) (29.5 lbs/ft). Current escalator code prohibits the public from using a stopped escalator as a stairway and requires a stopped escalator to be properly barricaded. There are two reasons why the escalator should not be used as a stairway. 1. Escalator steps do not comply with the building code. The rise of the steps is generally too high and, depending on where the escalator is stopped, there are usually some steps which are not even. Both these situations can cause a tripping hazard. This is particularly hazardous when walking down the escalator. 2. If the reason for the stoppage of the escalator is unknown, using the escalators as a stairway may create a hazard. If the reason for the stoppage was due to a mechanical failure such as a brake failure or a main shaft or chain failure, the escalator could roll away when adding load from pedestrians using it as a staircase causing serious injury. When an escalator at the transit site has an unplanned emergency stop, physical barricades are brought out by employees to block the public from using them.
Failure scenario(s)	When the drive unit was commissioned three years prior to the incident, the set screws on the alignment flanges of the step-drive main-shaft were loosened to allow for the factory oil wiper installation. The alignment flanges were reset, and the set screws retightened. It is unknown if the screws were retorqued to the factory setting of 40NM (29.5 lbs/ft). During operation of the escalator, the alignment flange on the right side of the step-drive main-shaft on escalator #3 pushed out allowing the gearbox to shift approximately 1 cm misaligning the gearbox and step-drive main-shaft splines. The rotating alignment flange contacted the inside of the shaft cover which ground down the metal of the alignment flange and shaft cover and created fine metal dust and shavings (Image 5). Metal dust mixed with oil plugged the oiling port used to lubricate the step-drive main-shaft splines. The lack of lubrication and misaligned contact of

Incident Summary #II-1612461-2023 (#39700) (FINAL)

	the step-drive main-shaft created wear to the point of failure and allowed the shaft to rotate independently of the drive motor and braking system when loaded. At 14:57 a total of 11 riders boarded the escalator. This produced enough load to overcome the worn mechanical connection between the drive motor and the step-drive shaft. The steps slightly sped up independently of the handrail for approximately 14 seconds until enough riders exited at the bottom reducing the load and allowing the escalator to return to normal descending speed. No riders fell during this overspeed condition. At 15:00 a total of 14 riders boarded the escalator. The loaded escalator steps over sped again, this time in an uncontrolled descent at a high rate of speed for approximately 15 seconds causing riders to stumble and one rider to fall. The emergency stop button was pressed by a bystander which stopped the drive motors and activated the brakes. The escalator steps stopped when the riders unloaded. Pedestrians attempting to access the transit platform immediately accumulated at the top of the escalator. The only other access to the transit platform was a second set of escalators and a small elevator that was only accessible across a multi-level concourse at a separate transit entrance (Image 1). Qualified employees were unable to place physical barricades at the top of the escalator before some pedestrians began to use the escalator as a staircase to access the transit platform. There were no immediate warnings or barricades informing the public to not use the escalator after it had stopped. At 15:02:30. Riders began to walk down the stopped steps to access the lower transit platform. When 16 riders boarded the stopped escalator, the steps began to move again independently of the drive motors and braking system. The steps accelerated quickly for approximately 18 seconds while the handrail remained stopped causing riders to stumble, fall, and pile up at the bottom while 10 of them fell to the ground and 2 others jumped off the side over the handrails. The failed mechanical connection did not provide positive engagement between the motors and the step-drive main-shaft, which rendered the safety braking system ineffective and unable to hold the steps and protect the escalator riders during the uncontrolled descent “runaway” situation.
Facts and evidence	Transit website The transit station escalators: • Are the longest escalators in Metro Vancouver, at 115 feet (35m) long. • Each travel 12,744 kms/year – roughly the distance from Vancouver to Sydney, Australia or Mumbai, India. • Carry 10 million people/year – roughly the population of Sweden or Portugal. • Carry 30,000 people on an average weekday. • Each have 167 steps, half of which are visible at any one time. • Are original, from when line opened in 1986. The transit station: • Third busiest in the transit system. • 43,700 people travel through each weekday. • More than 14 million people use the station each year. • Four times as busy as when it opened. • Is the deepest station in the system, at approximately 25 meters.

Incident Summary #II-1612461-2023 (#39700) (FINAL)

Video Timeline

Review of the CCTV video footage from both the top and bottom of the escalator 5 minutes before the incident and a report from the transit company showed:

- 14:57:47 - Slight overspeed observed with escalator operating with 11 riders onboard lasting 14 seconds before returning to regular speed at 14.59:01. (No riders falling).
- 15:00:46 - Overspeed observed with 14 riders onboard with escalator operating lasting 15 seconds before escalator came to a stop after emergency stop actuated at 15:01:01. (One rider fell exiting the escalator with the others were able to exit escalator without falling).
- 15:02:30 - Stopped escalator began freewheeling, accelerating to a high rate of speed with 16 riders onboard lasting for 18 seconds before coming to a stop again at 15:02:50. (10 riders fell to the ground).
- 15:04:02 – Passengers placed a sandwich board at top of escalator to prevent more people from boarding the escalator.
- 15:08:41 – Employees placed a 'Do Not Enter' barricade at top of escalator.

Equipment disassembly and examination

Photographs of the escalator drive unit were taken during initial examination and disassembly after the incident by the manufacture's technicians while still installed in the escalator at the transit site. Examination of the photographs identified the following:

- A large quantity of metal shavings and dust were found inside the step-drive main-shaft right side end cap.
- The step-drive main-shaft right side alignment plate was found to have an excessive gap and grinding marks showing mechanical interference with the shaft end cap.

The main drive assembly was removed by the manufacturer's technicians and transferred to an independent testing facility for disassembly and examination. The following was observed during the examination:

- The roller bearing on the right side of the main step-drive main-shaft was discoloured suggesting evidence of high heat.
- A machined groove on the step-drive main-shaft showed markings from both right-side alignment plate set screws (Image 9 & Image 10) indicating the plate was forced out of alignment and into contact with the shaft end cap.
- The oil port supplying oil to the step-drive main-shaft splines was plugged with a metal dust/oil mixture (Image 14 & Image 15).
- The splines connecting the gearbox to the step-drive main-shaft were significantly damaged and worn and the splines on the shaft had a tapered wear profile with more wear on the right side of the splines (Image 11-13).
- The handrail gears, shaft and splines did not show any wear or indication of misalignment.

Code and Regulation

The current adopted Safety Code for Escalators in British Columbia is the ASME A17.1-2016/CSA B44-16. Code requirements for escalators include the following:

Incident Summary #II-1612461-2023 (#39700) (FINAL)

	• Stopped escalators shall not be used as a means of access or egress by non-authorized personnel and shall be properly barricaded to the general public to prevent such use. • Each escalator shall be provided with an electrically released and mechanically or magnetically applied brake. • The brake shall be applied automatically if the electrical power supply is interrupted and shall be capable of stopping and holding a down running escalator up to its maximum load capacity at an average rate not greater than 0.91 m/s² (3ft/s²). • When the escalator driving machine brake is separated from the step-drive main-shaft with a chain, the brake shall be provided on the main drive shaft or multiple and separate chains shall be used. The subsequent 2019 revision of the CSA B44 code (Not yet adopted in BC) included acceptance and requirements around escalator driving machine motor-controlled dynamic braking systems variable frequency control of the escalators motors. The latest 2022 revision of the CSA B44 code (Not yet adopted in BC) includes an additional requirement of auxiliary brakes on escalators that do not use dynamic braking systems and have a rise greater than 20 ft. The auxiliary brake is required to be installed on the main drive shaft only if the motor is separated from the main drive shaft by a chain. The escalator had a rise of greater than 20ft but, utilized a dynamic braking system and was direct drive which did not use a chain between the motors and main shaft. The escalator did not require a shaft mounted brake or an auxiliary brake and was compliant to the most current industry standards and met the applicable code requirements for braking. Documents • Maintenance log documents show that all regular scheduled maintenance detailed by the manufactures was completed on schedule by qualified technicians. • Equipment drawings supplied by the manufacturer show a required torque specification of 40NM (29.5 lbs/ft) for the main step shaft alignment flange set screws. • Manufacturer's maintenance documents identify the oil in the geared drive unit should be replaced every 25000 hours of operation. The escalator had not yet reached this replacement interval during its 3 years of operation.
Causes and contributing factors	The equipment failure was due to the disengagement between the gearbox and the step-drive main-shaft as a result of misalignment and oil starvation. These were caused by the alignment plate movement on the step-drive main-shaft and debris from the wear of the step-drive main-shaft creating metal dust and shavings that plugged the oil passages to the shaft splines. Contributing factors to the incident and related injuries includes: • No requirement or installation of an auxiliary shaft mounted braking system for the direct drive escalator that would have stopped and secured the escalator in place after the emergency stop was activated.

Incident Summary #II-1612461-2023 (#39700) (FINAL)

- No warnings or automatic barriers informing patrons the escalator was unsafe to use immediately after it was stopped when the emergency stop was engaged. This failed to prevent the final runaway incident and related injuries.

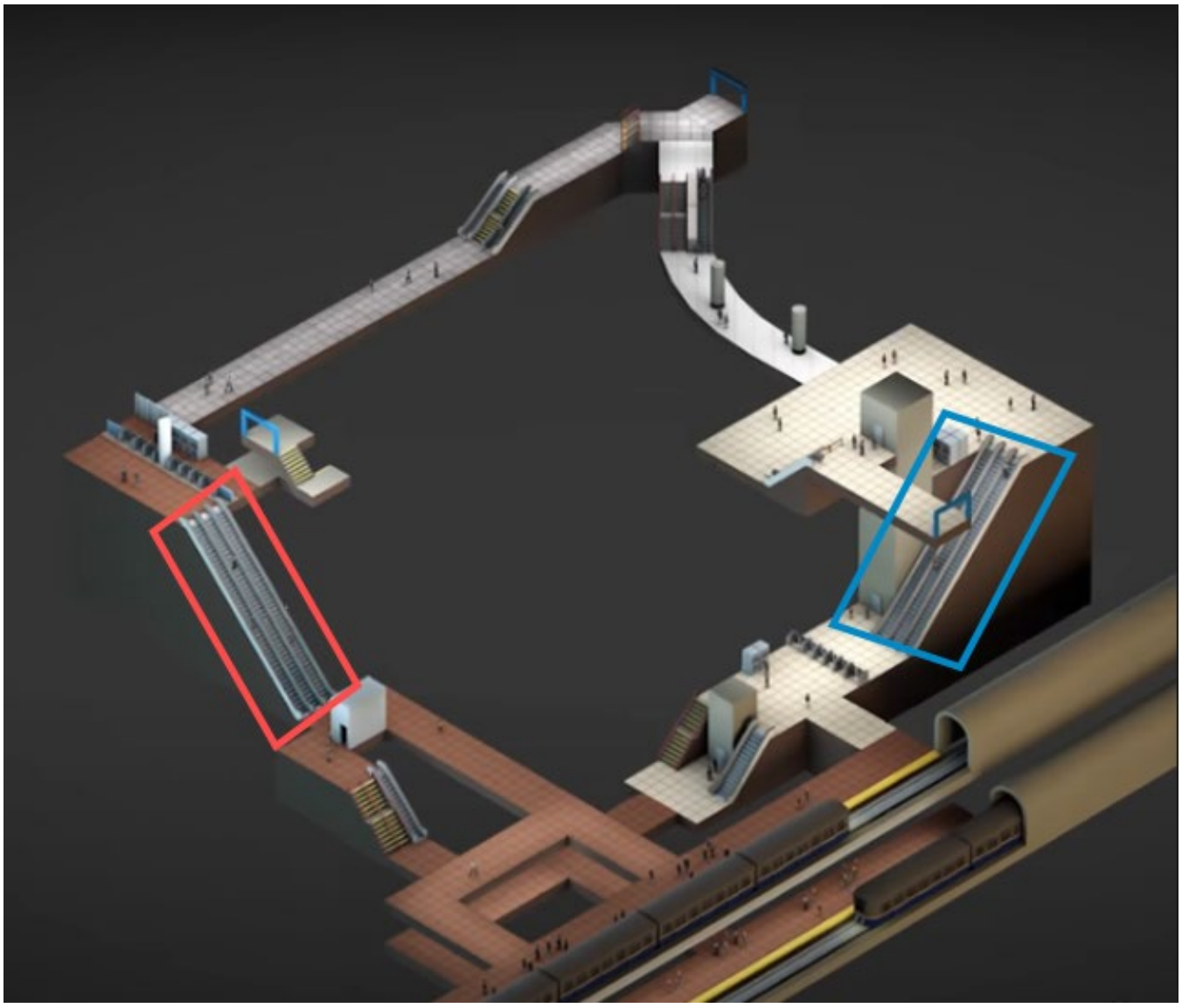

Image 1 – Escalator locations at transit station. [**RED**] Location of escalator involved in incident. [**BLUE**] location of alternative access to transit platform from above.
(Image source: https://www.translink.ca/news/2018/may/translink%20launches%20granville%20escalator%20replacement%20project)

Image 2 – Top of escalator #3. [**RED**] Emergency stop button.

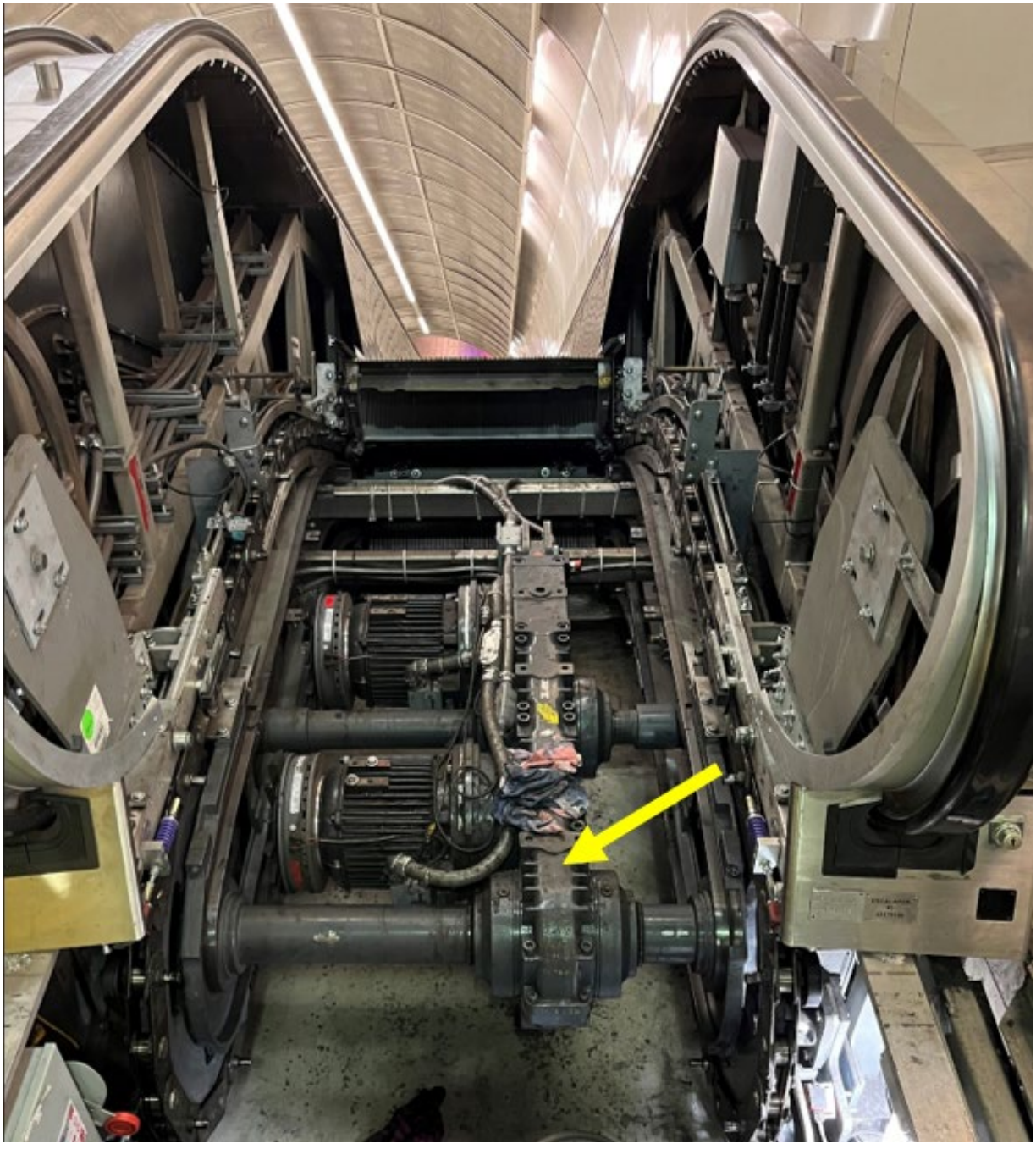

Image 3 – Escalator #3 drive system during disassembly. [**YELLOW**] Location of internal step-drive main-shaft spline failure.

Image 4 - Escalator #3 dual motor drive assembly installed at top of escalator.
[A] Permanent magnet braking systems.
[B] Electric drive motors.

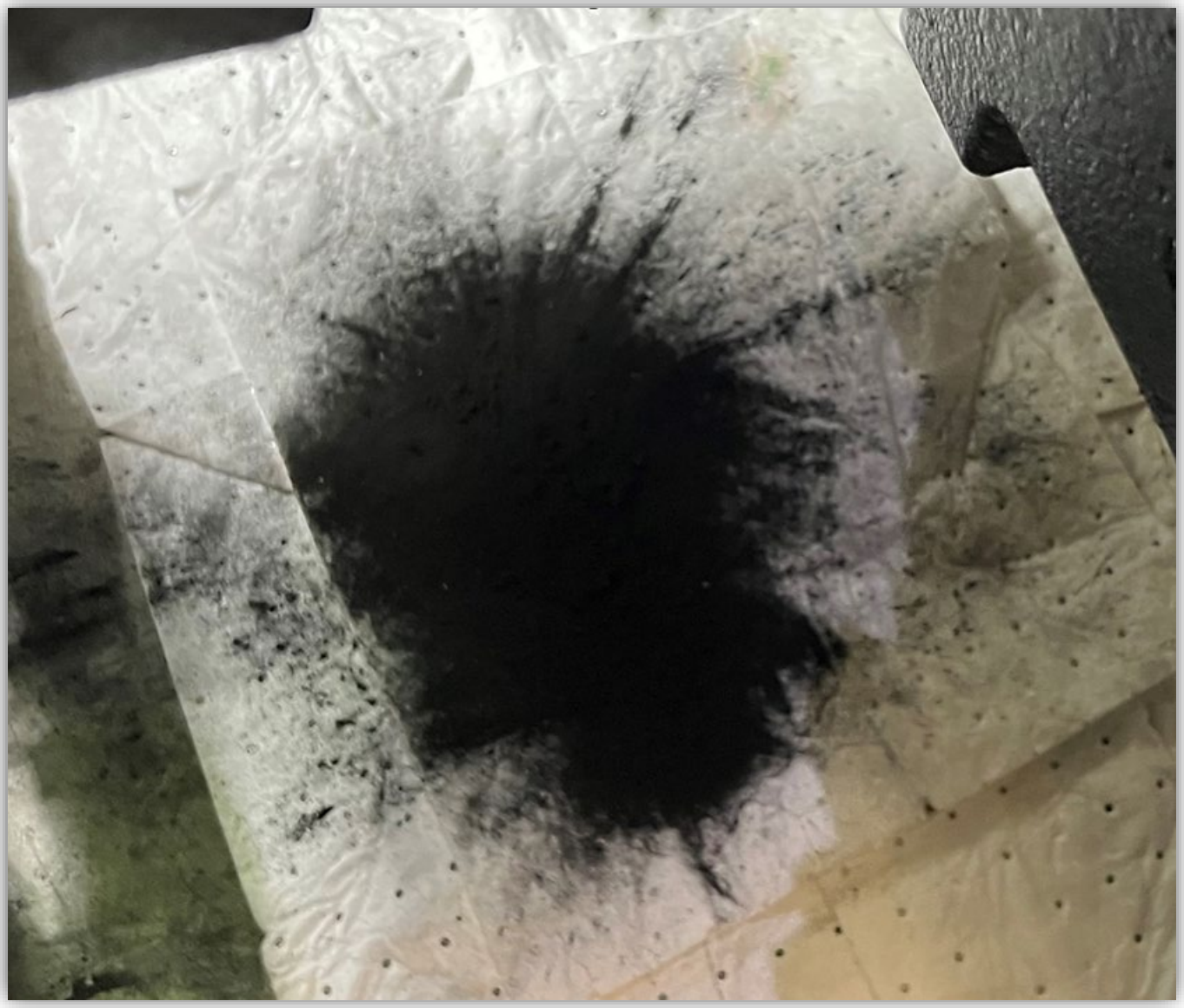

Image 5 - Metal shavings and debris from inside step-drive main-shaft end cap when it was removed.

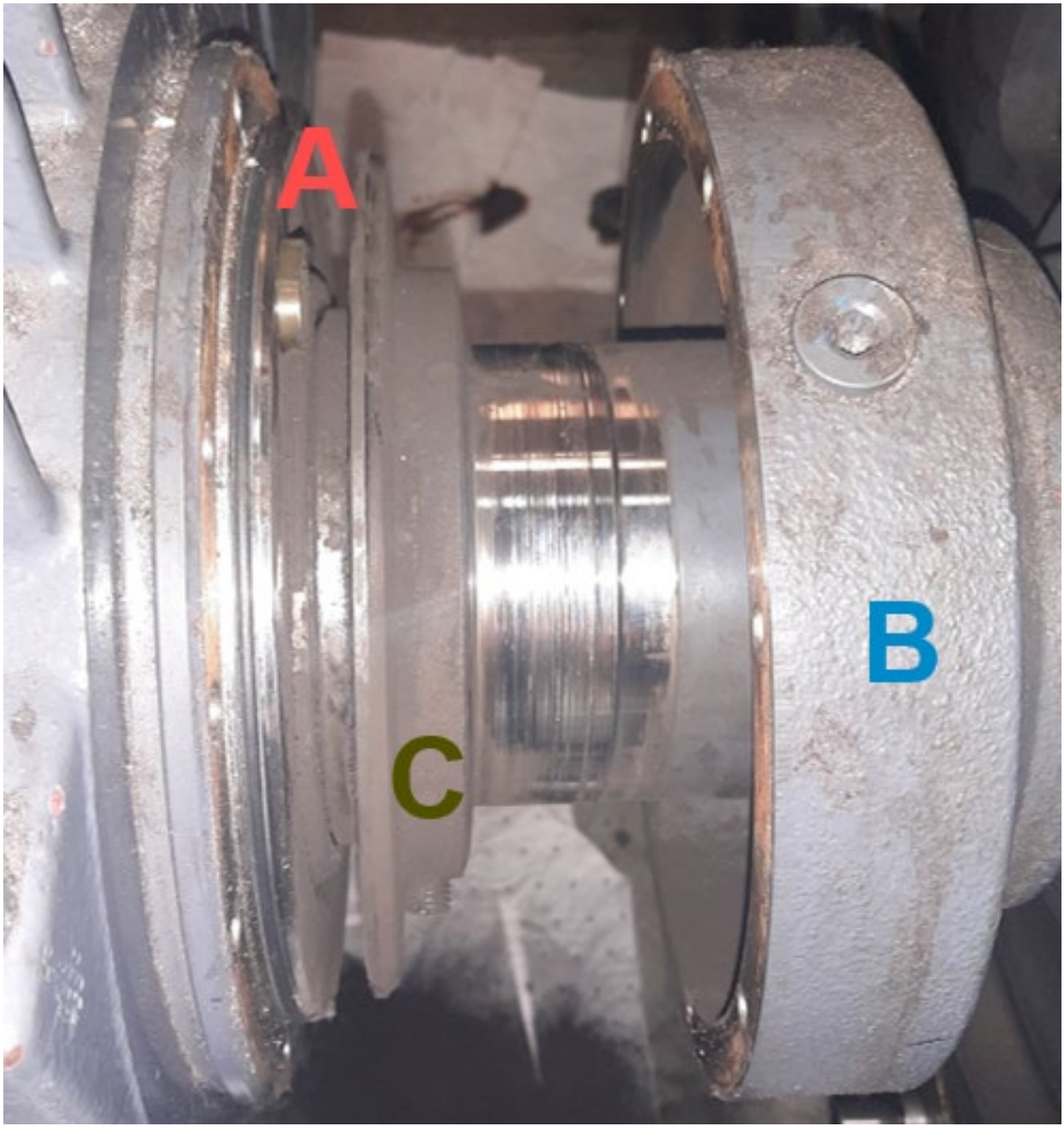

Image 6 - [A] Excessive alignment flange gap.
[B] Step-drive main-shaft end cap.
[C] Step-drive main-shaft alignment flange.

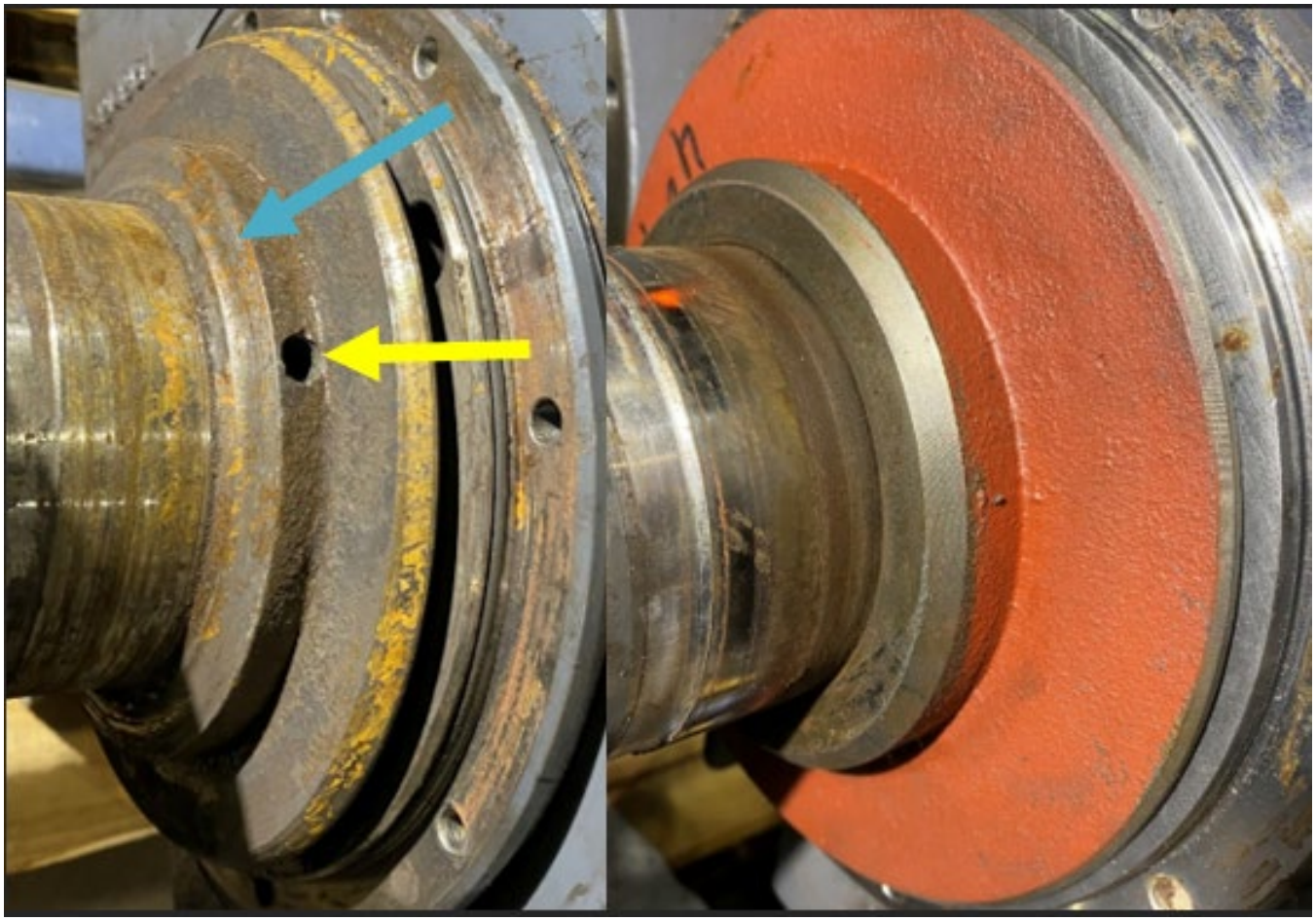

Image 7 – Step-drive main-shaft alignment flange showing one set-screw hole and ground down shoulder from interference with shaft end cap (Left). Undamaged shaft alignment flange from handrail shaft for comparison (Right).

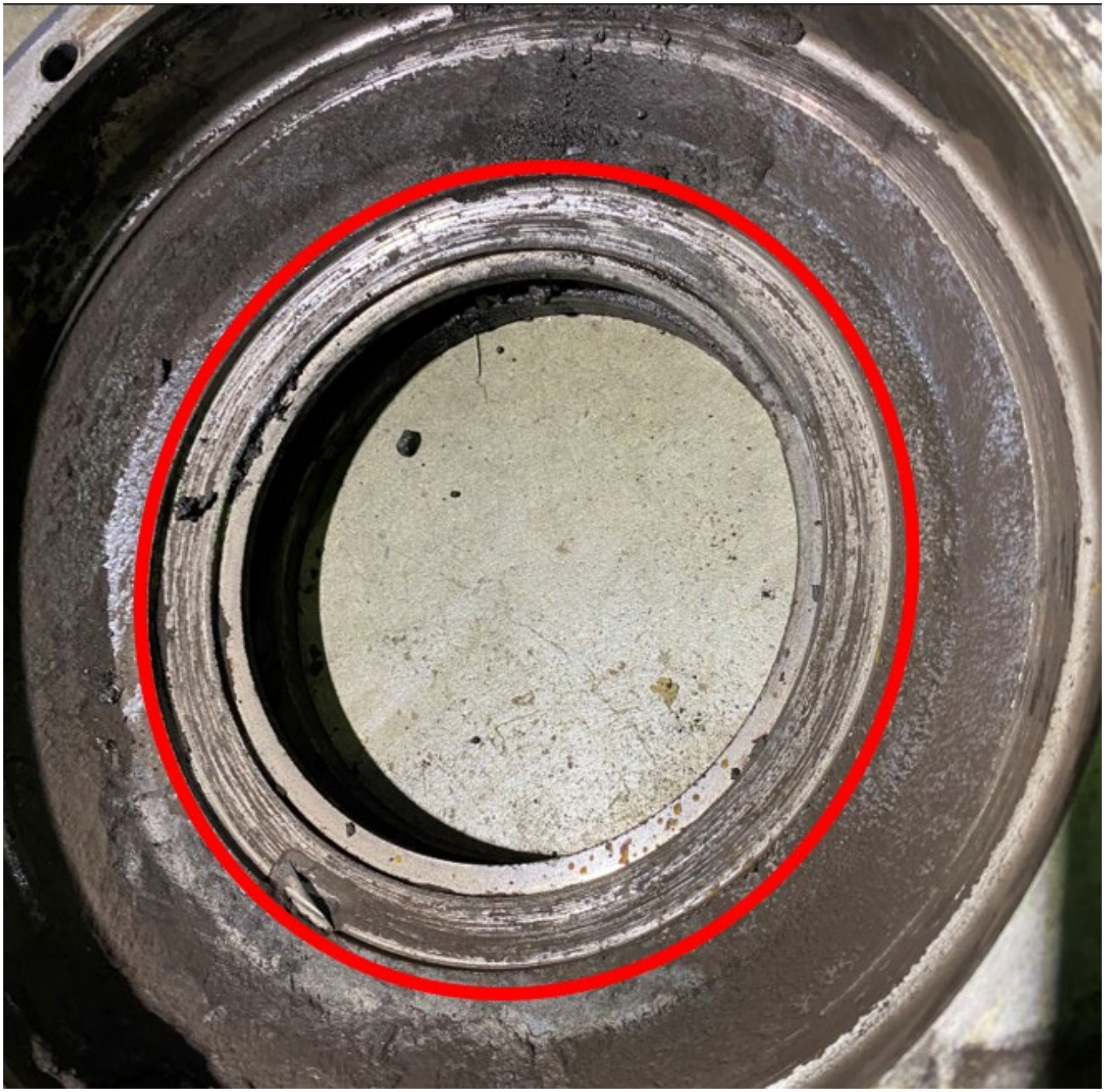

Image 8 - Red circle showing grooved mark on the inside of the end cap created by interference with the rotating step-drive main-shaft alignment flange.

Image 9 - Closeup of alignment flange set screw indentation mark on step-drive main-shaft.

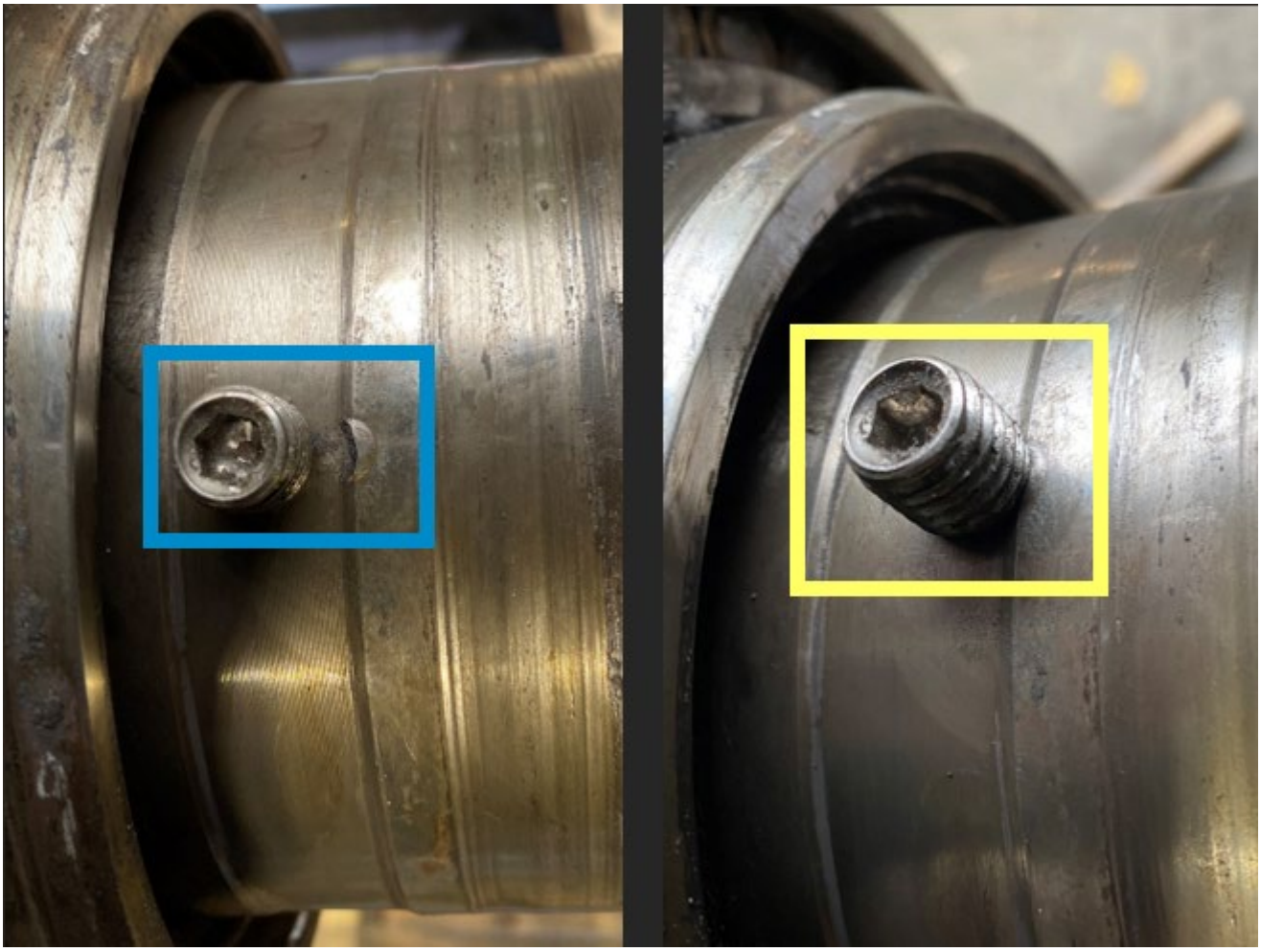

Image 10 - Blue box showing approximate start location of step-drive main-shaft alignment flange set screw. Yellow box showing set screw alignment with indentation mark on step-drive main-shaft machined shoulder.

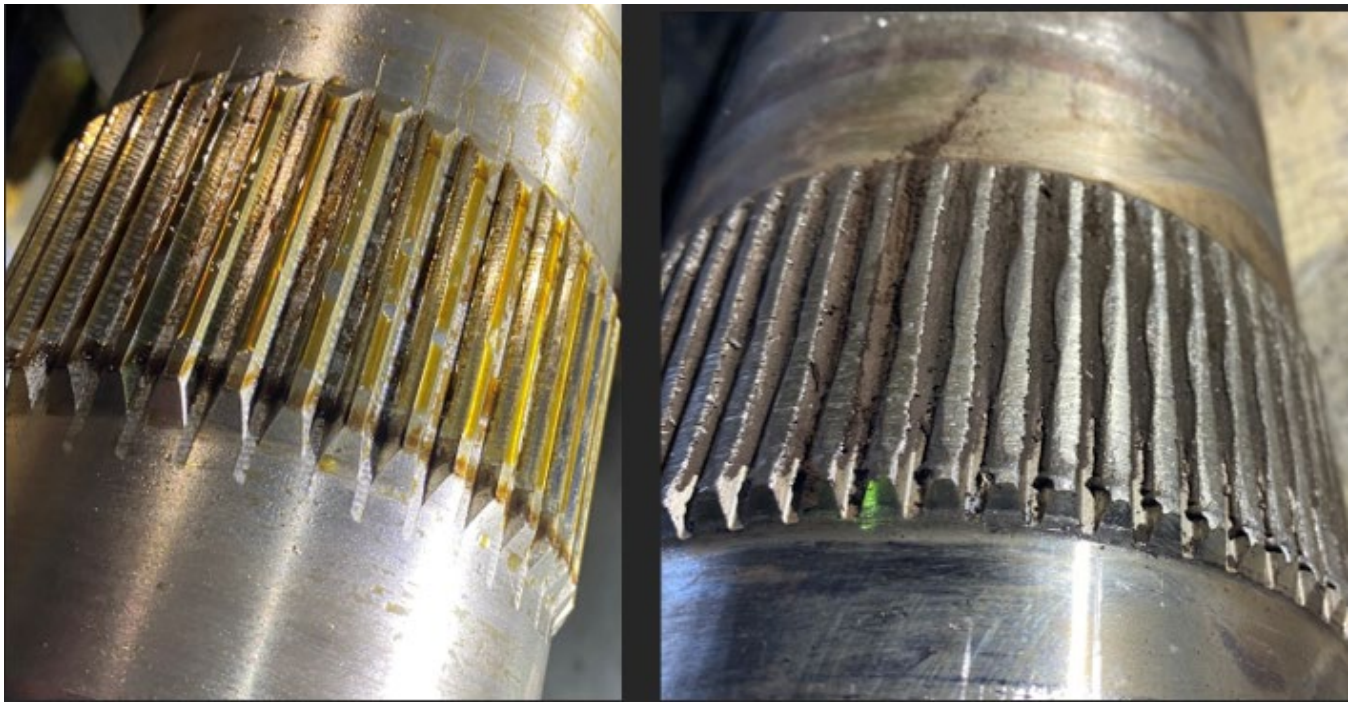

Image 11 - Undamaged handrail-shaft splines (Left) Damaged step-drive main-shaft splines (Right)

Image 12 – Step-drive main-shaft drive gear showing damaged internal splines.

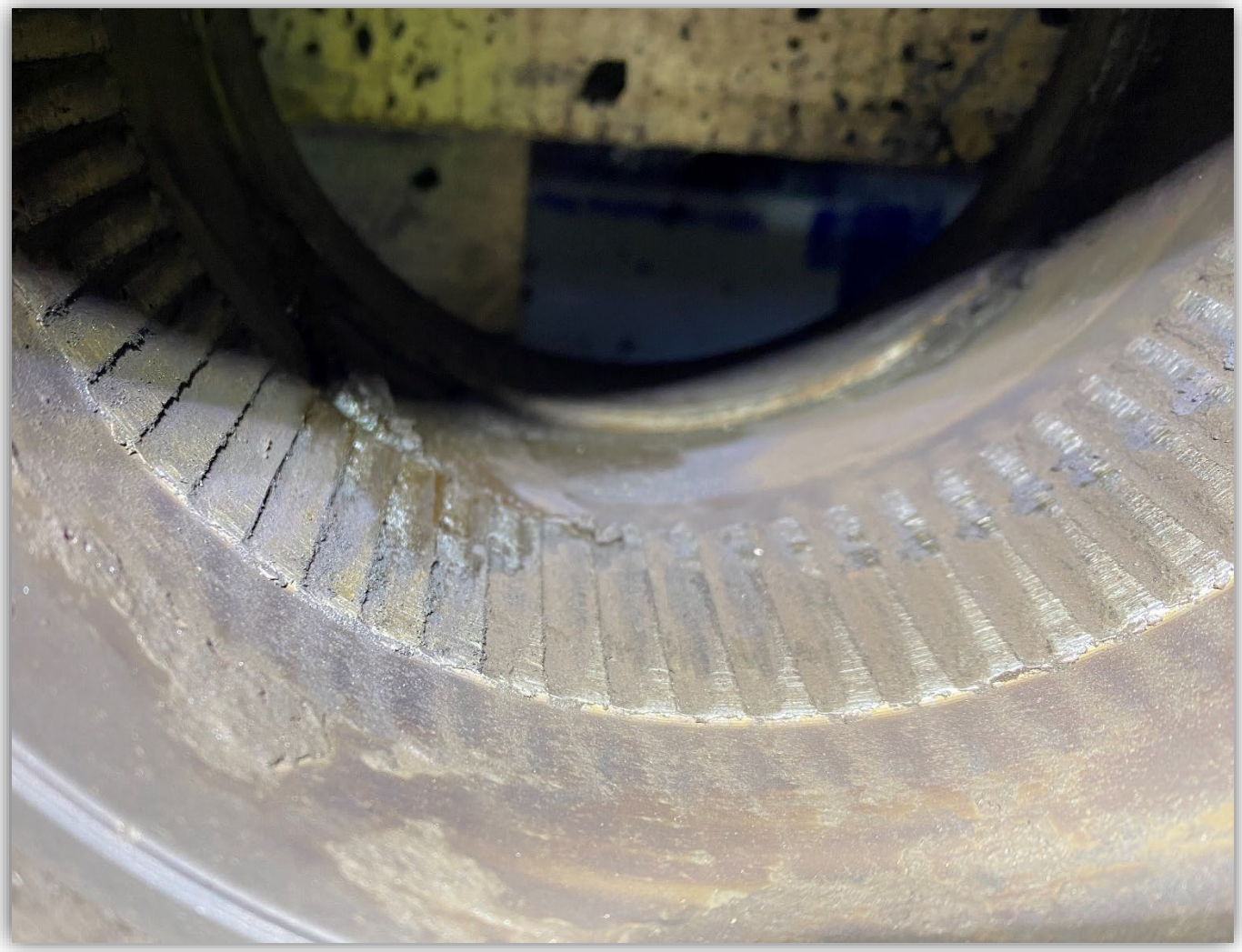

Image 13 - Closeup of damaged drive gear internal splines.

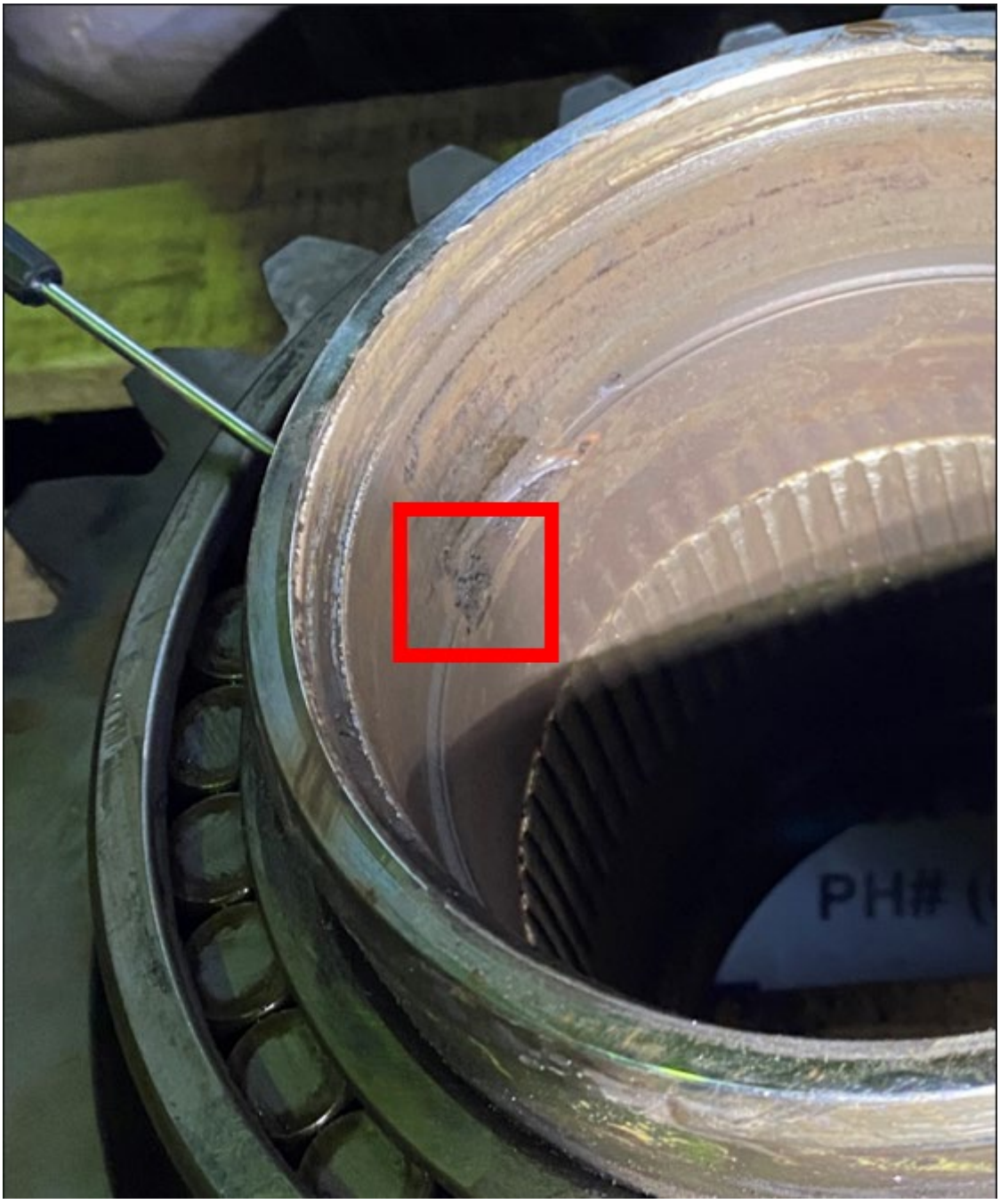

Image 14 – Step-drive main-shaft drive gear, red box showing location of plugged oil passage.

Image 15 - Oil passage unblocked with small screwdriver.

Image 16 - Staircases from transit platform for emergency exit use only.

Image 17 – Pileup of riders at the bottom of escalator #3 during the final runaway event after the escalator had been stopped with the emergency stop switch.