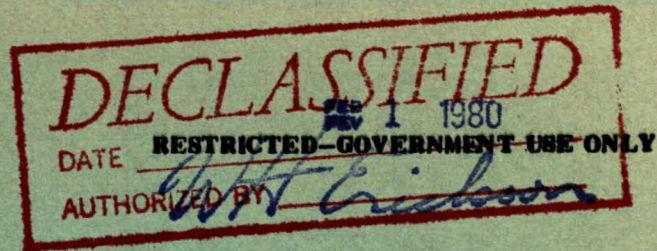


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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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MINES BRANCH INVESTIGATION REPORT IR 66-54

**CAUSE OF FAILURE IN KISKATINAW
RIVER PIPELINE**

by

K. WINTERTON

PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

This fracture probably resulted under abnormally high external stress due to changing conditions in the river bed. The crack originated near the longitudinal submerged-arc weld, though no defects were found in the weld at this location. Some cracking was associated with pits in the weld metal, and a mechanical gouge mark was found on the pipe surface, but these defects were not thought to have had more than a subsidiary effect.

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INTRODUCTION

A natural gas pipeline of API 5LX52 steel (26 in. diameter and 0.281 in. wall thickness) in the Alberta Mainline failed on December 12, 1965 at the Kiskatinaw River crossing, Peace River District, British Columbia, under normal service conditions with an internal pressure of approximately 260 psi.

Mr. Rutherford of the National Energy Board discussed the problem with the writer on May 26 and supplied a report on the failure by the Westcoast Transmission Co. Ltd. entitled "26 in. Kiskatinaw River Crossing Failure" dated May 18, 1966 and a metallurgical investigation report by Dr. A. Hanson of Hanson-Parr Engineering Ltd., dated May 6, 1966. In addition, the following items were made available:

- (a) Some numbered pieces cut from the broken line
- (b) Photographs illustrating the break, and indicating the position of the sample pieces mentioned above
- (c) Four specimens mounted for microscopical examination from Dr. Hanson's investigation.

VISUAL EXAMINATION

Visual examination of the fracture surfaces of the sample pieces and of the fracture surfaces visible in the photographs showed that the fracture was partly brittle but mostly ductile, the brittle part being in the general vicinity of the longitudinal submerged-arc weld.

It was not possible to establish with certainty the origin of the fracture. The fracture appearance of Sample No. 3 clearly indicated that the fracture was proceeding away from the weld. The fracture appearance of Sample No. 5 suggested that the fracture was proceeding away from the weld in the opposite direction. The crack may have originated in or

near the weld*.

Sample No. 8, a badly distorted piece, contained a subsidiary fracture of unusual appearance, contiguous with the main fracture and parallel to it. This subsidiary fracture, initiated at the inside surface, had penetrated only part way through the wall. The unusual appearance was imparted by a great many short parallel fissures alongside the fracture, suggesting a stress-corrosion or corrosion-fatigue phenomenon, but later found to be due to violent deformation.

MICROSCOPICAL EXAMINATION

A specimen was cut from Sample No. 8 across the subsidiary fracture. This was then mounted and prepared for microscopical examination by conventional means. The steel showed several inclusions, and some tearing could be seen to have occurred along these inclusions. Alongside the fracture, the short parallel fissures could be seen in section as shown in Figure 1. On the right-hand side, some tearing can be seen at right-angles to the fracture, parallel to the rolling direction. At higher magnification, in the unetched condition, it was noticed that these tears were associated with inclusions.

*Note: The evidence available to Dr. Hanson may well have justified a more positive conclusion in this respect.



Figure 1 - Fissures adjacent to subsidiary fracture in
Sample No. 8 (inside surface). Fracture on
right-hand side.
Etched nital

Mag. X50

At some locations, some of the fissures could be seen to have opened up, while others remained quite narrow. Figure 2 shows these two types in close proximity.

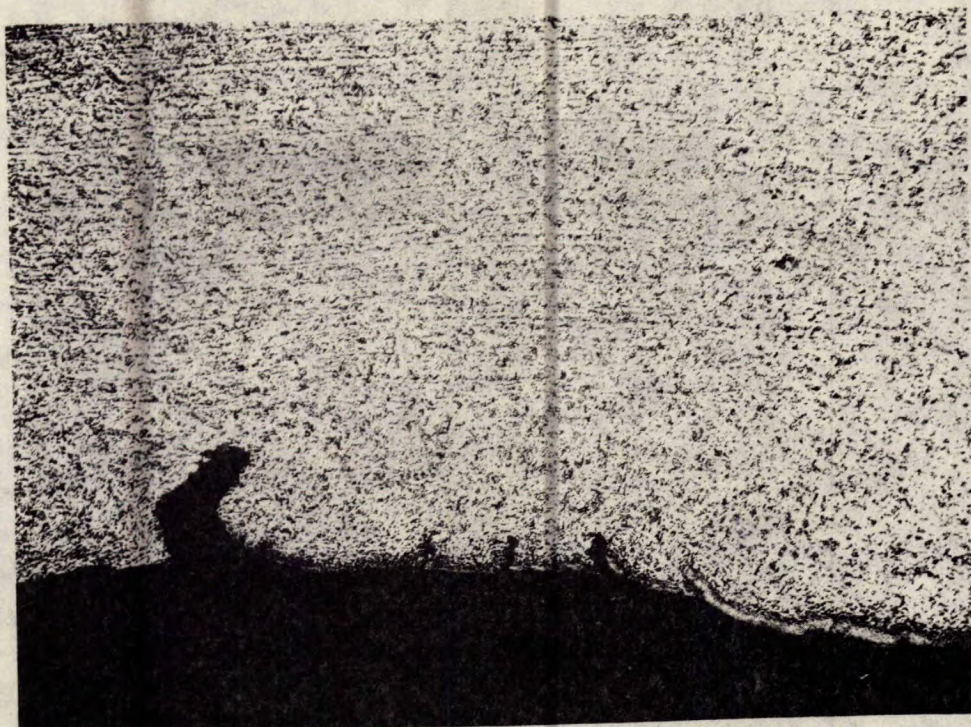


Figure 2 - Examples of opened and unopened fissures in
Sample No. 8 (inside surface).

Etched nital

Mag. X50

The fissures shown in Figure 1 are seen in the somewhat more general view in Figure 3. The slight banding indicated by the pearlite formation does not extend to the edges where the fissures occur. At the edges, the pearlite lamellae, though somewhat randomly oriented, tend to lie perpendicular to the plate surface. In addition, there is evidence of distortion in the pearlite formation around the fissures.

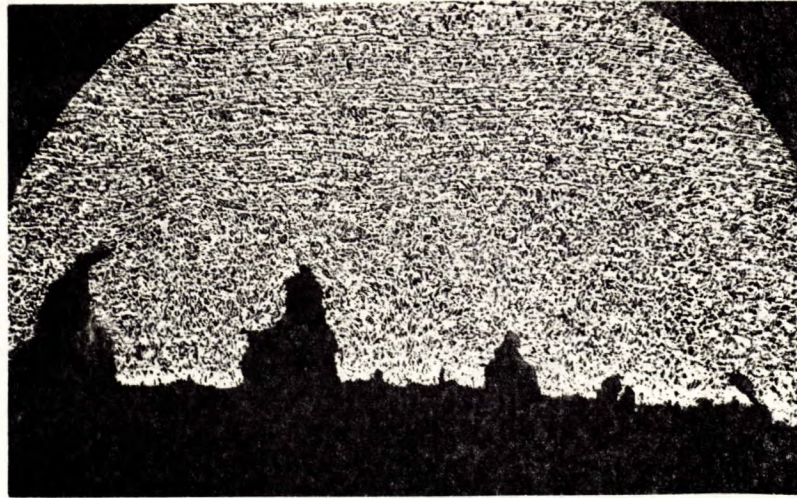


Figure 3 - Fissures and pearlite formation in Sample No. 8
(inside surface).
Etched nital

Mag. X36

On the same sample (No. 8), a mechanical gouge mark, which appeared to be superficial, was visible on the outer surface of the pipe wall, and for part of its length ran alongside the fracture, i. e. about $1\frac{1}{2}$ in. A specimen was cut for microscopical examination. The gouge mark showed its effect in a layer of highly compressed metal which had transformed to martensite. The sudden heating caused by friction raises the steel to a temperature above the critical point, and because the heating is so localized, the mass of metal has a quenching action, resulting in a transformation to martensite. Figure 4 illustrates the formation of the martensite layer. Some fine cracks can be seen in the latter.

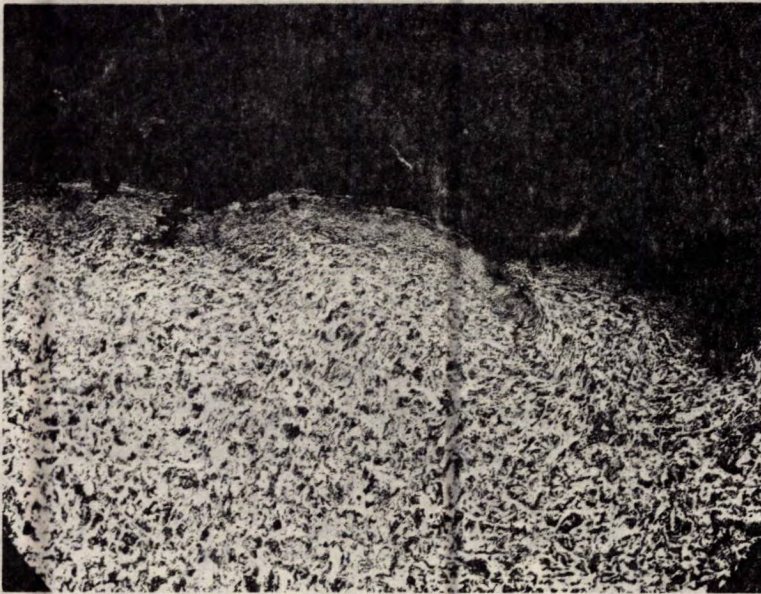


Figure 4 - Martensitic compressed layer caused by mechanical gouge (outside surface).

Etched nital

Mag. X100

A small unmarked sample containing part of the submerged-arc weld showed some pits on the outer surface. Microscopical examination showed that cracking had penetrated part way through the wall at these locations as shown in Figure 5. There were several small pits grouped together and located about $1\frac{1}{2}$ in. from the intersection of the weld with the fracture.



Figure 5 - Cracking from pits in weld metal (inside surface).

Etched nital

Mag. X50

A section for microscopical examination had been cut through the weld at the fracture, during the investigation by Dr. Hanson. In order to discover whether similar pits were present closer to the fracture, the micro-sample was broken from its bakelite mount. A few shallow pits were discovered on the inside surface, as shown in Figure 6, but no associated cracking was found.

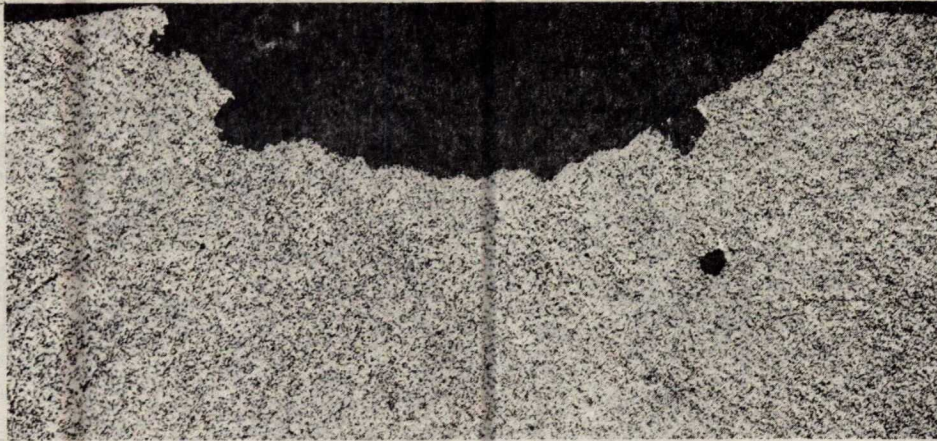


Figure 6 - Shallow pits in weld metal (outside surface)
close to fracture.

Etched nital

Mag. X50

TENSILE TESTING

Some small Hounsfield test-bars were cut from the relatively flat Sample No. 3. These had a finished diameter of 0.127 in. The tests were done in an Instron machine with a magnification of 2000 times. The results were as follows:

TABLE 1

Tensile Properties of Pipe (Sample No. 3)

Sample	Ultimate Tensile Strength, Kpsi	Yield Strength 0.2% Offset Kpsi	Elongation on 4D	Reduction in Area, %
1	90.2	69.4	28	48
2	88.2	68.4	34	50
3	89.2	67.6	33	50
4	88.1	68.4	33	50

IMPACT TESTING

Some half-size (5 mm x 10 mm section) Charpy-Vee impact bars were cut from the relatively flat Sample No. 3 from which the tensile specimens were taken. The notch in each specimen was perpendicular to the pipe surfaces. The specimens were tested in a Tinius Olsen machine (264 ft-lb capacity). The tests were done at 32°F. The exact temperature of the pipe at failure is not known, but there is a passage in the report by the Westcoast Transmission Co. Ltd. which reads: "If the area surrounding the break was under ice and water -----". It was thought that 32°F would represent a reasonable approximation. The results were as follows:

TABLE 2
Impact Properties of Pipe (Sample No. 3)

Specimen No.	Test Temperature	Impact Value (ft-lb)
1	32°F	20
2	32°F	15
3	32°F	20

The average impact value at 32°F is therefore 18 ft-lb for the half-size specimen. For a full-size specimen, the impact value could be estimated in the range 27-37 ft-lb, depending upon the conversion.

DISCUSSION

Based on the evidence of the fracture appearance, it is thought that the fracture started near the longitudinal submerged-arc weld, although no defects were found in the weld at this location. About $1\frac{1}{2}$ in. from the intersection of the fracture with the submerged-arc weld, some cracking was found emanating from pits on the inside surface (Figure 5). This may

have been due to slag traps near the weld surface from which cracks extended when the pipe was being distorted under high stresses at the time of failure. The shallow pits found in the weld metal on the outside surface close to the fracture (Figure 6) are probably corrosion pits. These pits may have occurred in the deformed metal subsequent to fracture before the pipe was retrieved from the river bed.

The unusual subsidiary fracture in Sample No. 8, thought at first to be due to some corrosion defect, appeared on closer examination to have been caused by violent deformation. A large number of small cleavage cracks had appeared along ferrite paths on the pipe surface, and these had opened up in varying degrees on bending, giving rise to a woody-textured fracture. This phenomenon was associated with the structure in the metal near the surface, with pearlite lamellae somewhat randomly oriented, but tending to lie perpendicular to the plate surface (Figure 3).

On the same sample (No. 8), which was badly twisted and deformed, a mechanical gouge mark, apparently somewhat superficial, ran for part of its length alongside the fracture, i. e. about $1\frac{1}{2}$ in. The gouge showed its effect on the structure by a layer of compressed metal which had transformed to martensite. Under slightly different circumstances, this could be a serious weakness in the pipe, but in the present instance the defect does not seem to have played a major role. It is not possible to exclude the possibility that a similar gouge mark was located near the weld at the failure origin, visible only on the other side of the fracture in the pipe which was not recovered.

The tensile properties of the pipe metal were satisfactory. The impact value at 32°F was not low, and showed that the transition temperature is probably below the test temperature. This result is consistent with the observation that the fracture is mostly ductile, showing a brittle appearance only at some locations.

It appears that Dr. Hanson's conclusion that "this failure was caused by abnormally high external loads on the pipe created by changing conditions in the river bed," provides the most probable explanation for the failure. Any tensile failure of this kind requires abnormally high external tension stress, since normal service stress can only provide tensile stress equivalent to half the hoop stress.