CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 61-150

REVISED FROM IR 61-86

AN INVESTIGATION INTO THE CAUSE OF FAILURE OF A SECTION OF A GAS TRANSMISSION PIPE LINE

by

C. M. WEBSTER & W. A. MORGAN

PHYSICAL METALLURGY DIVISION

COPY NO.

MARCH 13, 1962

Mines Branch Investigation Report IR 61-150

AN INVESTIGATION INTO THE CAUSE OF FAILURE OF A SECTION OF A GAS TRANSMISSION PIPE LINE

by

C. M. Webster* and W. A. Morgan**

SUMMARY OF RESULTS

Investigation of a failed section of a 30 in. diameter gas transmission pipe has been carried out to determine the cause of failure. Metallurgical examination showed that the failure originated at a hard spot.

---

* Technician, and ** Section Head, Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

On Friday, July 14, 1961 a visit was made, at the request of National Energy Board, to the location of a 30 in. gas transmission pipe line failure. The failure had occurred the previous night and extended over approximately a 4,690 foot length of the line. Examination of the fractured surfaces showed marked chevron patterns indicative of brittle failure. The origin of the break was found to be at a point 800 feet downstream from the northern end of the break. The fracture pattern showed typical sine wave form.

Subsequent to this visit, sections of pipe from the origin of fracture, at the extreme ends of the break, and from several random locations along the length of the fractured pipe, were shipped to the Mines Branch for examination.

THE ORIGIN OF FRACTURE

Macroscopic Examination

The fractured surface of the pipe at the point of origin is shown in Figure 1 and clearly shows two sets of chevron patterns pointing in opposite directions. No defects were visible to the naked eye on the inside or outside surface of the pipe.

Magnaflux Examination

Magnetic particle inspection was carried out on areas of pipe at and adjacent to the origin of failure. No positive indication of cracking or other defects was found.

Chemical Analysis

Drillings were taken at intervals around the pipe periphery and mixed so as to give a representative analysis of the pipe. Table 1 gives the results of this test.

TABLE 1

Mines Branch Chemical Analysis

C	Mn	Si	S	P	Cr	Mo
.29	1.12	.03	.028	.009	*<.01	*<.01

Ni	V	Cu	Co	Pb	Sn	Ti	N_2
*<.02	*<.01	*.02	*<.01	*<.01	*<.001	*<.001	.004

*Quantitative spectrographic analysis.

Mechanical Tests

From an area located approximately 45 degrees to the fracture, a section of pipe was removed for mechanical testing. From this section, radial, longitudinal and transverse tensile bars having a 2 in. gauge length and transverse sub-standard (5mm x 10mm) Charpy V-notch impact bars, were obtained. Results from the sub-standard (5mm x 10mm) Charpy impact bars have been doubled for this report.

Tensile and impact results are given in Table 2 and Table 3 respectively.

TABLE 2

Results of Longitudinal and Transverse Tensile Tests

Bar No.	UTS kpsi	Yield Strength kpsi	Elong. % in 2 in.	Direction
1	75.0	49.7	35.5	Longitudinal
2	75.0	49.1	37.0	"
3*	71.0	45.4	43.5	Transverse
4*	70.0	45.4	43.0	"

*Transverse tensile bars were straightened and stress-relieved before final machining.

Impact results given are an average of three tests at each of the following temperatures 0, 32, 82, 100 and 150°F.

Bars tested were sub-standard (5mm x 10mm) Charpy V-notch impact bars, notched 90 degrees to plate surface.

TABLE 3

Results of Charpy V-Notch Impact Tests and Hardness Tests

Temperature Tested °F	Energy Absorbed ft-lb	% Fibrous Fracture	15 ft-lb Transition Temp. °F	Rockwell 'B' Hardness
0	11	0	20	88
32	19	30		89.5
82	36	90		89
100	37	100		89
150	37	100		89.5

NOTE: Impact results given are double the actual values obtained.

Microscopic Examination

A transverse section was taken across the fractured surface at the origin of failure. In the unetched condition, the steel was not excessively dirty but did possess several large inclusions near the outside surface. Figure 2 shows two large inclusions near the outer surface, one starting at the fractured surface, the other starting further from the fracture and having a crack propagating from one end. Figure 3 shows the inclusions and cracks at higher magnification. Examination of the specimen in the etched condition shows tempered martensite at the outer surface, the structure gradually changing to a mixed structure of tempered martensite and transformation product, the amount of tempered martensite decreasing towards the inside surface (Figures 4 and 5). A hardness survey across the section (Figure 6) confirms this.

Hardness Tests

A hardness survey was carried out to determine the extent of the hard area. Starting at the origin of failure, hardness readings were taken at 1 in. intervals in all directions. It was found that the hardness of a region of approximately 10 in. in diameter was above normal for this material. The hardness varied from Rockwell "B" 95-100 at the outer edge of the zone to a high of Rockwell "C" 44 at, and adjacent to the origin of failure The higher hardness (Rockwell "C" scale) zone was approximately 5 in. in diameter.

DISCUSSION

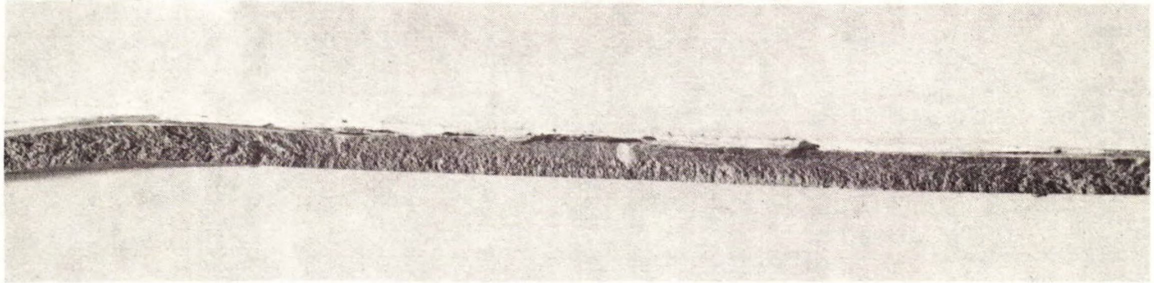
Macro examination of the failed area showed no mechanical damage or obvious defects which may have contributed to the pipe failure. Chemical analysis shows the material to be within the specified limits. Tension tests show the yield strength to be lower than that specified, both in the longitudinal and transverse direction. There is no evidence, however, that the low yield strength has contributed to the pipe failure. Impact results show a 15 ft-lb transition temperature of 20°F for the pipe material having a hardness of Rockwell "B" 89. The 15 ft-lb transition temperature for the hardened area is not known at this time. Micro examination revealed some large inclusions near the outer surface of the pipe, and quench cracks started at these locations. The failure of the pipe was due to quench cracks, which have propagated through the wall thickness to a critical size, and initiated brittle failure. The etched structure shows the material in the failed area to be in a quenched and tempered condition. Hardness surveys confirm this and indicate that an area of 10 in. in diameter has been affected.

CONCLUSION

1. The yield strength of the pipe is below that specified; however this has not contributed to the failure of the pipe.

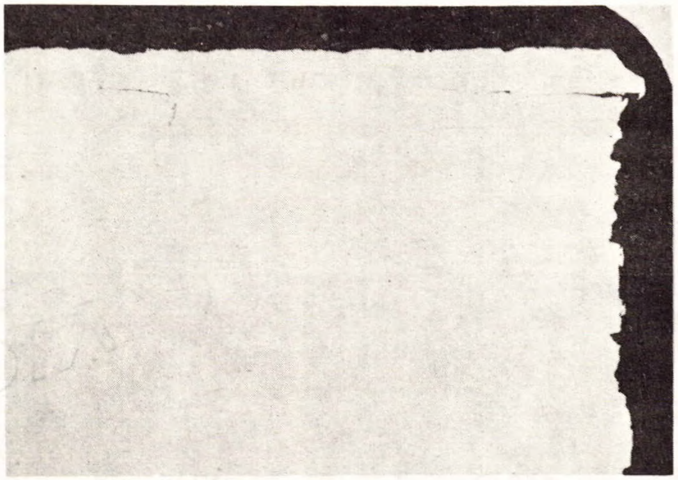
2. Failure of the pipe originated at a hard spot in the pipe.

CMW:WAM/ls



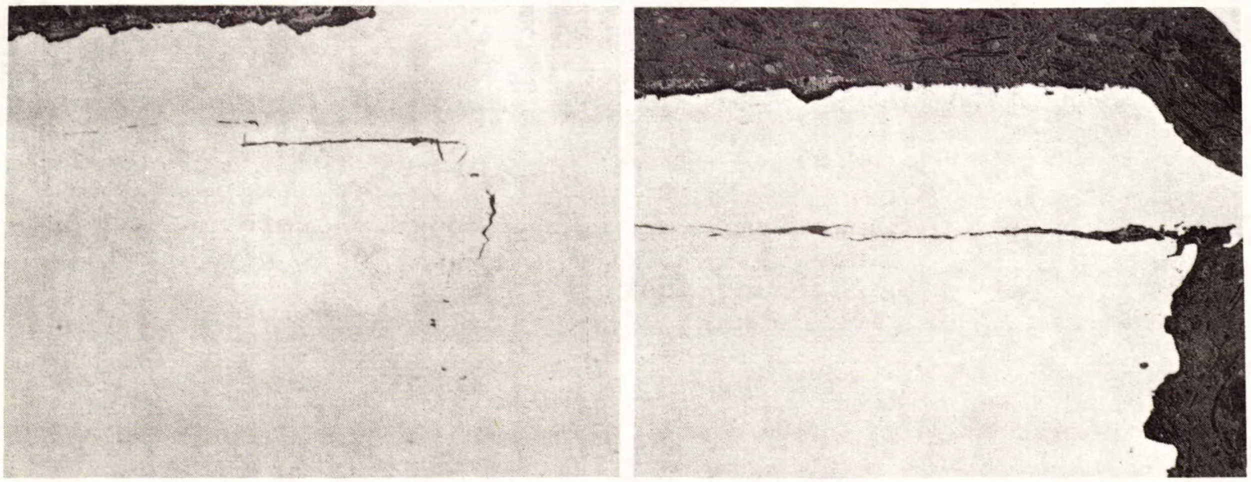
2/3 Actual Size

Figure 1. Chevron pattern pointing to origin of failure.



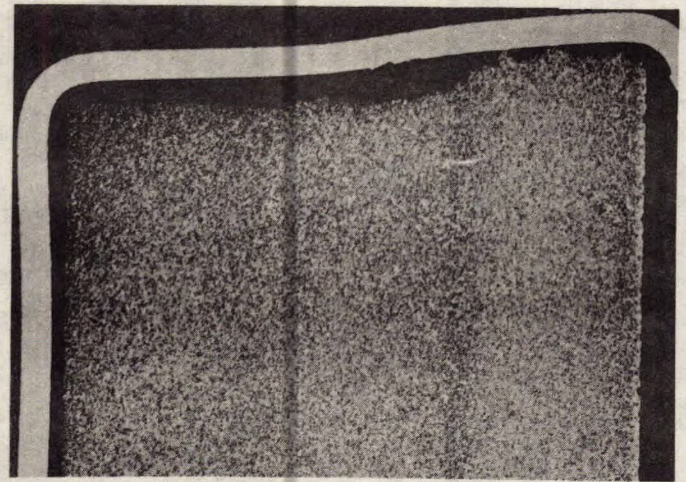
X30

Figure 2. Crack propagating from end of large inclusion.



(a) X100 (b) X100

Figure 3. (a) Cracks propagating from the end of an inclusion. (b) Large inclusions from which failure could have started.



X8

Figure 4. Darker etching structure at outside edge. (left side)

(a) X500

(b) X500

Figure 5. (a) Shows tempered martensite structure found near outside edge.

(b) Shows transformation product found near inside edge.

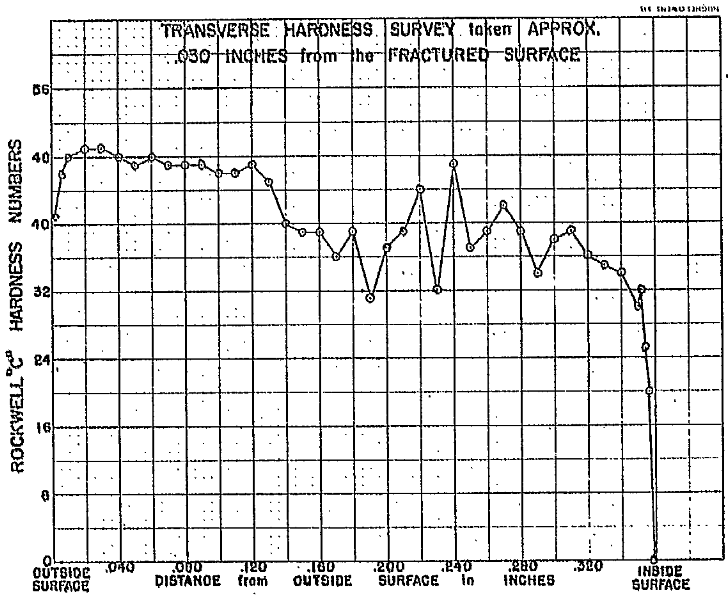


Figure 6. Hardness survey graph. Note the variations in hardness from the centre to the inside surface.