CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 63-10

EXAMINATION OF EXHIBITS FROM THE SCENE OF A NATURAL GAS EXPLOSION AT 687 ALBERT STREET, OTTAWA, ONTARIO, JANUARY 10, 1963

by

R. F. KNIGHT

PHYSICAL METALLURGY DIVISION

FEBRUARY 4, 1963

Restricted – Government Use Only

Mines Branch Investigation Report IR 63-10

EXAMINATION OF EXHIBITS FROM THE SCENE OF A NATURAL GAS EXPLOSION AT 687 ALBERT STREET, OTTAWA, ONTARIO, JANUARY 10, 1963

by

R. F. Knight*

SUMMARY OF RESULTS

The material used for the hot air register was normal for such an application. The fracture orientation was consistent with the circumstance of the explosion.

The material and condition of the gas pipe were adequate for normal service. No imperfections could be found that would be responsible for the failure. An upward movement of the free end of the pipe had caused a crack at the bottom of the pipe to occur at an area which was constrained by a mass of concrete. This crack had been open for an undetermined period prior to the final fracture.

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

INTRODUCTION

Two exhibits from the site of the natural gas explosion, which occurred at 687 Albert Street, Ottawa, Ontario were supplied by the Ontario Office of the Fire Marshall, Ottawa, Ontario, to the Mines Branch, as well as a covering letter dated January 16, 1963 requesting an examination of these exhibits.

Exhibit No. 1 is a 34 inch length of a 4 inch diameter cast iron pipe that was part of the installation system of the Ottawa Gas Company. This is the south half of a broken length of pipe which was located beneath Albert Street at a point 36 feet to the south of the building in which the explosion occurred. The north length of pipe, containing the other half of the fracture, was rigidly imbedded in concrete. It was requested that an examination be made to assess the condition of the pipe, and to attempt to relate the characteristics of the fracture to the time of the explosion. A general view of Exhibit No. 1 is shown in Figure 1.

Figure 1. Exhibit No. 1 - As-Received.

This figure is shown for purpose of identification only. The fracture surface is obscured by material applied at the site to seal the break.

Exhibit No. 2 is a framework of a register and damper for the heating system of the building in question. It was requested that an examination of the fractures be made to assess their age, and to express an opinion whether or not the orientation of the breaks is consistent with an explosion occurring in the room beneath. Figure 2 is a view of Exhibit No. 2.

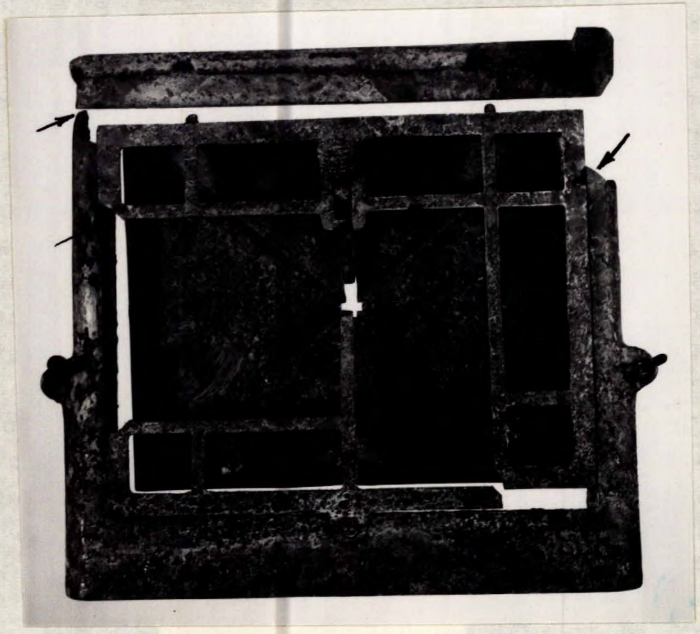


Figure 2. Exhibit No. 2 - As-Received.
The location of the fractures are indicated by arrows.

EXAMINATION OF EXHIBIT NO. 2

Specimens were cut from the grille and frame of Exhibit No. 2 for microscopic examination. The microstructures of both sections were similar. Consequently, the microstructure of only the frame is illustrated and discussed.

Figures 3 and 4 show the microstructure in the as-polished and etched conditions, respectively. Figure 3 illustrates the type and distribution of graphite, and Figure 4 reveals the other phases present.

(X100-Unetched)

Figure 3. As-polished Sample from Exhibit No. 2.

Shows a random distribution of fine flake graphite, and clusters of undercooled graphite.

(X300-Etched in 2% Nital)

Figure 4. Microstructure of Exhibit No. 2.

The structure consists of a matrix of pearlite (grey), islands of ferrite (white) associated with the graphite (black), and a considerable quantity of phosphide eutectic (mottled intergranular phase). (Hardness-240 BHN)

The microstructure and hardness of this specimen is as would be expected for high-phosphorus, sand-cast, grey iron. The clusters of undercooled graphite are normal for such thin sections. The large quantity of phosphide eutectic indicates that phosphorus was purposely added, presumably to increase fluidity. By nature this material is extremely brittle, and would absorb little impact energy before breaking in the circumstance of an explosion in the room beneath.

The orientation of the fractures on Exhibit No. 2 appears to be consistent with the explosion. It is apparent that the damper was swung outward by the blast causing the fractures in the grille. The freed portion of the grille continued to swing outward, resulting in the fracture of the frame. All fracture surfaces were heavily rusted, but no gross defects or indications of pre-existing cracks were apparent. Hence, it is assumed that all fractures resulted from the explosion.

EXAMINATION OF EXHIBIT NO. 1

To facilitate the examination of the fracture surface of Exhibit No. 1, the pipe was cut approximately 5 inches below the fracture, as shown in Figure 5.

Figure 5. Fracture Surface of Exhibit No. 1

The fracture surface between the white marks, corresponding to the bottom of the pipe, showed considerable rust. The light fracture at the top was deformed due to the compressive forces. The remainder of the fracture was the grey colour characteristic of tensile fractures in grey iron.

Considerable quantities of rust were evident on the portion of the fracture corresponding to the bottom of the pipe. This indicated that a crack had been open for some time prior to the final rupture of the pipe. In removing the sealing compound that had been applied at the site, much of this rust was unavoidably removed as well. However, examination under a stereoscopic microscope revealed sufficient adhering traces of rust to indicate that the initial crack had extended between the white marks of Figure 5.

As requested, the fracture surface was not disturbed in any way, other than the vigorous cleaning required to remove the sealing compound. Drillings for chemical analysis and a section for metallographic examination were taken from a ring cut from the pipe 5 inches from the fracture.

The results of the chemical analysis were as follows:

Total carbon	-	3.51%
Combined carbon	-	0.08%
Manganese	-	0.64%
Silicon	-	2.21%
Sulphur	-	0.086%
Phosphorus	-	0.55%

This composition is quite normal for cast iron as produced at the time the pipe was laid, and for many modern grades. Normal carbon and silicon ranges for grey iron are 2.7 to 3.6% carbon and 1.00 to 2.75% silicon. The carbon equivalent (C.E. = % Total carbon + 1/3 (% silicon + % phosphorus) of this iron was 4.43%, which indicates a hypereutectic composition. This is borne out by the large quantity of graphite observed in the microscopical examination and by the presence of some "kish" graphite. The low quantity of combined carbon is consistent with the small amount of pearlite observed microscopically, and is indicative that the material has been given a full anneal to decompose the pearlite into ferrite and graphite.

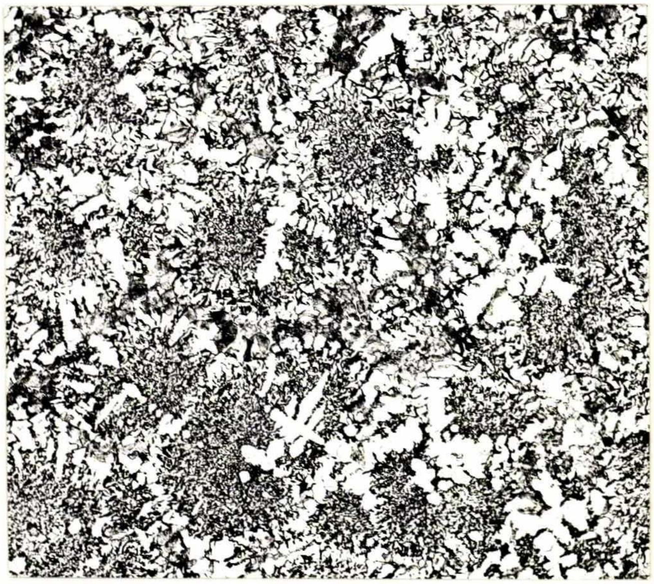
The phosphorus content is consistent with the amount of iron phosphide observed. This phosphide was not present in the eutectic form, as in the case of Exhibit No. 2, since the annealing treatment had agglomerated the particles of iron phosphide. The quantity present was normal for irons of this vintage although the trend today is towards lower phosphorus content. While phosphorus does not have a marked effect on the static strength of ordinary commercial irons except those of high strength it does lower impact strength appreciably, although not as drastically in the agglomerated state observed as in the eutectic form.

Microscopical examination of a section cut transverse to the pipe revealed two distinct microstructures, as shown in Figures 6 and 7. The presence of "kish" graphite is an indication that the material is a hypereutectic iron. "Undercooled" graphite is found when the solidification is sufficiently rapid. Areas of this type of graphite were found throughout, but were much more prevalent near the centre. Thus, it is likely that the cooling rate was very rapid, preventing the formation of most of the graphite near the surfaces until the subsequent annealing operation. Apparently this anneal was not complete in that all the pearlite had not decomposed. More pearlite was present in the centre than at the surfaces, indicating that this area was not at the required temperature for sufficient time. The difference in the microstructure accounts for the change in hardness from 141 BHN at the surface to 169 BHN at the centre.

(X100-Etched in 2% Nital)

Figure 6. Microstructure Near Pipe Surface.

This photomicrograph shows a ferritic matrix (white, a small amount of pearlite (grey), iron phosphide (small white islands) and "kish" and fine flake graphite (black). The hardness at the surface is 141 BHN.



(X100-Etched in 2% Nital)

Figure 7. Microstructure Near Centre of Section.

The matrix is mostly ferrite (white dendrites and background). More pearlite (grey) is seen than in Figure 6. Iron phosphide (small white islands) are also discernible. The graphite is in three shapes, "kish", fine flake, and "undercooled". The hardness at the centre is 169 BHN.

The examination revealed no defects in the material that would cause the failure assuming proper handling. Cast iron is brittle by nature and this particular material would probably have a low tensile strength (in the range 25,000 to 30,000 psi). Thus, a reasonable amount of care in handling is required. It has a distinct advantage over mild steel in that it exhibits markedly superior corrosion resistance. Satisfactory protective procedures for mild steel pipe have been perfected only in recent years.

CONCLUSIONS

1. Exhibit No. 2 is a pearlitic grey cast iron in the as-cast condition. The material is brittle by nature, but is a normal material for this application.

2. The orientation of the fractures in Exhibit No. 2 is consistent with the occurrence of an explosion in the room beneath the register.

3. Exhibit No. 1 is a grey cast iron in the annealed condition. Although the material used would have low strength and negligible ductility, it was certainly adequate for the service required, precluding accident.

4. A portion of the fracture surface, corresponding to the bottom of the pipe, was rust-coated, whereas the remainder of the fracture was fresh. This would indicate that a crack was present prior to the final fracture, allowing moisture to seep in and, of course, gas to escape. No estimate of the age of the initial crack could be made.

5. The fracture appearance is consistent with a movement of the free end of the pipe due to ground heaving causing the initial crack to occur where the pipe was constrained from movement by a mass of concrete.

RFK:vb