Diagnosing fractured components—
Electron fractography

Just as fingerprint impressions are used for the positive identification of people, the impressions of fracture surfaces can be useful in the identification of the fracture mechanisms involved in the failure of a component. In this regard, an electron microscope capable of magnifications of up to 200,000 times is an invaluable tool to William Wiebe of the National Aeronautical Establishment of the National Research Council of Canada.

Here, the microscope is regularly used in the diagnostic procedures of failure analysis that are carried out in the Structures and Materials Laboratory. The instrument permits Mr. Wiebe to "interpret" the characteristics of the fracture surfaces of metal components so that the causes and circumstances of failure can be established with a high degree of certainty.

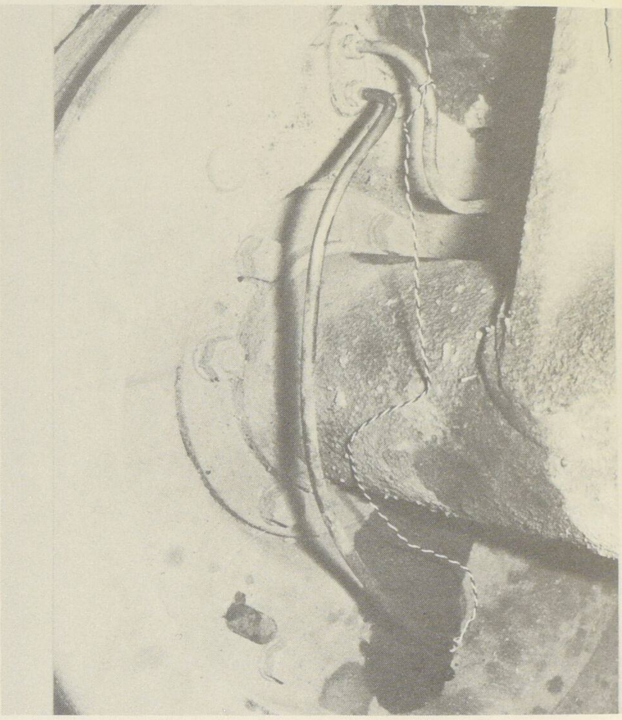
When used in the "diagnosis" of fractured components, electron fractography, as the process is called, is an example of the direct application of a sophisticated electronic device to the solution of engineering problems that arise from the premature failure of components in aircraft, motor vehicles and industrial equipment. Since such fractographic findings frequently point toward specific remedial action, fractography has demonstrated its potential for the saving of lives, and the prevention of extensive damage to vehicles and equipment.

Some of Mr. Wiebe's work has dealt with the estimation of the service life spans of particular metal components. These have resulted in recommendations for the scheduling of periodic examinations for early detection of cracks, before complete failure of the components occurs. The estimation of fatigue crack growth rates in aircraft wheels and wing spar components represents a particularly significant contribution of fractography to flight safety.

Mr. Wiebe's specialty, which he has developed at NRC over the last 12 years, makes vital use of the fact that each fracture surface has its own "fingerprint". In other words, the history of the fracture process is imprinted on the fracture surface, and with the aid of the electron microscope, it is frequently possible to recall this history in a visual sense. On the microscopic scale, there are essentially four types of fracture — ductile, cleavage, fatigue and intergranular — and each presents a different appearance on the surface of the fracture. More than one type of fracture mechanism may be involved in a single service component, and each can be recognized by examination at high magnification with the electron microscope. Sometimes, the fractures occur rapidly, under sudden and severe stress; sometimes they take months to occur under less severe but more frequent stresses.

Ductile fracture is created by an extensive 'slipping' along crystallographic planes, and is illustrated macroscopically by permanent deformation of the specimen. Ductile fracture takes place within the metal by the initiation and growth of microvoids, which usually start at sites of relatively brittle inclusions, or imperfections in the actual metal structure. Rupture of the specimen occurs when the voids join together because of internal necking, and the resulting fracture has a dimpled appearance at high magnification. Under conditions of shear strain and non-uniform plastic strain, elongated dimples are formed.

Cleavage cracks normally propagate by simultaneous advancement on a number of crystallographic planes. These cracks are joined by steps formed by secondary cleavage or ductile fracture. The steps run together in the direction of local crack propagation, producing the characteristic 'river patterns'.



Brake line tubing installed on a truck, with instrumentation for road test vibration measurements.

Conduite du circuit de freinage installé sur un camion équipé d'instruments pour mesurer les vibrations durant le roulement.

Fatigue fracture surfaces are frequently characterized by the appearance of striations (linear marks, ridges or furrows on the surface) oriented at right angles to the direction of the crack growth. It has been demonstrated that there is a one to one correspondence between the formation of a striation and the crack advance during the application of a single stress cycle. The spacing of the striations is proportional to the cyclic stress level.

Intergranular fracture occurs when the path of the crack follows the boundaries of the grains or 'crystals' of the metal. When this occurs, the microscopic aspects of the fracture surface resemble a 'rock candy' structure.

Many failed components from industry are being sent to Mr. Wiebe's laboratory in Ottawa. The components vary greatly, from a part of an industrial sewing machine to an aileron control tube from an aircraft, but the basic question is always the same: What caused the component to fail and how can further breakages be prevented?

Assisted by technical officer Ray Dainty, Mr. Wiebe begins the task of providing the answers for Canadian industry.

Using a two-stage method which does not damage the surface of the fracture, a replica of the failed component is fabricated. A visual inspection of the fracture surface usually pinpoints the area from which the fracture evolved. A strip of cellulose acetate softened with acetone to a sticky consistency is pressed firmly into the fracture area and left there for about an hour. The strip, which has been moulded to the same configurations as the fracture surface, is then removed.