PLAINTIFF'S EXHIBIT

CAP-980

NO. Twenty Six
DATE November 19

AWWA RESEARCH FOUNDATION

Water Quality Research News

DISTRIBUTION SYSTEM

Main Breaks in a British Network

Ground forces and corrosion contribute to main breaks at the Severn-Trent Water Authority (STWA) in Great Britain. Many factors such as frost, drought, and soil can influence ground loading and movement, while corrosion depends on soil, water type, and pipe material. The highest burst rate befalls 30-year-old mains of spun-iron fabrication embedded in clay rather than sand and gravel.

Frequency and Cost. Over 8000 bursts occur annually in the STWA distribution system composed largely of iron pipe, equivalent to about one burst for every four kilometers (2.5 miles) of main. The direct cost of repairs exceeds one million British pounds ($2 million dollars) a year and the indirect cost of flooding and traffic disruption runs considerably more.

Types of Iron Pipe in System. Prior to 1940 the pipes were cast initially horizontally and subsequently vertically in molds with central cores. Then spun-iron pipes came into existence, cast by rotation at high speed without need of a central core, and possessing a generally thinner yet more uniform wall. Ductile iron pipes with still thinner and stronger walls entered the picture about 1970.

Iron mains typically fracture circumferentially and sometimes longitudinally in conjunction with corrosion. Corrosion alone can produce holes in the pipe wall. Failures can occur at joints, ferrules, and other fittings, as well as through accidental injury suffered during other construction, especially at new housing sites.

Winter Peaks. Detailed examination of the data from various parts of the STWA system discloses that cumulative data offer a valuable means of detecting trends in the burst rate.

CAPCO JEN 0021432

The burst data relate directly to frost, and particularly the earlier episodes. The first frigid wave provokes proportionately more bursts than the succeeding cold periods by purging the system of weak pipes in the primary onslaught. The added ground loading from frost accentuates circumferential fractures.

Correlation of the total annual bursts over the 1970-77 span versus the total Celsius degrees of frost in each year resulted in the following equation: Total Bursts Per Year = 2.5 x Total Celsius Degrees of Frost + 500. Thus, each degree of frost associated with 2.5 extra bursts, the figure rising to four at the beginning and decreasing through the winter.

Whilst frost in the STWA region normally reaches about six inches, only a minor increase in ground forces is necessary in order to alter the timing of a burst by a few months.

The magnitude of the winter peak can identify the geographic locations with the worst corrosion problems and the potential for additional failures. The temperature immediately above a concrete slab at ground level yields the best correlation.

Pipe Dimensions. Diameter, wall thickness, pipe length, and joint type also affect the likelihood and timing of failure. Circumferential failures involve smaller diameter mains more frequently, the approximate rates being:

Pipe Diameter in Millimeters	Burst Rate Per Kilometer Year
75	0.40
100	0.25
150	0.15
300	0.10

Thus, the overall-burst rate hinges on the lengths of each of the smaller diameters rather than on the total pipe length of the system.

Age of Pipe. The burst rate in the spun-iron locales approaches four times that of the pipes in the older areas of Nottingham. The ensuing table compares the burst rates among the pipe types during the period 1970-77. The pipe in areas one through four dates back to 1890 while 75% of the pipe in area five has been installed since 1920. The mains in area six have all been laid since 1952, and, with the exception of a few recent ductile-iron pipes, are of spun-iron manufacture.

Area	Average Burst Rate Per Kilometer Year
1	0.12
2	0.09
3	0.11
4	0.08
5	0.18
6	0.39

Tests performed by the Water Research Centre on selected STWA pipes confirm that the extent of deterioration cannot be assessed from age. Excavation of

CAPCO JEN 0021433

some spun-iron pipes authenticates stress corrosion as a cause of failure. The corrosion takes the form of a fissure propagated by stress that eventuates in a circumferential fracture, a flaw which accounts for well over half of the bursts.

Soil Characteristics. The enveloping earth determines the character of the ground forces and external corrosiveness, and the resultant pipe failure rate. Pipes entrenched in sands and gravels exhibit lower failure rates than those in certain clays which tend to be corrosive and subject to ground movement.

Summer Peaks. Excessively dry summer periods can also stimulate bursts originating from intensified ground forces. The British drought of 1976 induced cracks in the parched clay soil and consequent ground movement. However, such spells deviate from the norm of a fairly steady burst level.

This statistical evaluation excluded such important factors as water quality, water and soil temperature variations, internal water pressure, traffic loading, and accidental damage inflicted on the pipe prior to or in the course of installation.

Information Source: R. Newport, "Factors Influencing the Occurrence of Bursts in Iron Water Mains", *Aqua Scientific and Technical Review*, Number 3, Page 0274 (1981).

CAPCO JEN 0021434