2021 Award Nomination

Title of Innovation:
(Water Main Breaks and Corrosion)

Nominee(s)
Robert A. Leishear, PhD, P.E., PMP, NACE Senior Internal Corrosion Technologist, ASME Fellow

Category:

Modeling/Risk Assessment

Dates of Innovation Development:
(from [June, 2017] to [September, 2020])

Web site:

Summary **Description:**

Ground breaking technology in fluid transients, or water hammer, provides a definitive relationship between corrosion and water main breaks. For over a century, engineers believed that corrosion was the primary cause of water main failures, but new research disproves those opinions. Fluid transients cause 70% of the cracks in water mains, and most of the remaining failures are caused by fluid transients that crack pipes to accelerate corrosion. Presently, 250,000 water main breaks occur per year in the US at $13 billion per year, and an expected cost of $1.7 trillion over the next 35 years. This massive infrastructure problem affects every industrialized country, and nearly all of these water man breaks can be stopped.

A new theory was invented and published in a 2013 textbook to explain fatigue failures due to fluid transients ("Fluid Transients, Water Hammer, Dynamic Stresses, and Piping Design", R. A. Leishear, ASME Press). The crux of this theory is that hoop stresses are caused by fluid transients and that these hoop stresses are multiplied by a dynamic load factor (DLF) as high as 4. In short, a system operating at

70 psig can experience pressures of 250 to 350 psig when valves are suddenly closed in pipe systems, and DLFs can cause an effective pressure near 1000 to 1400 psig.

In 2017, this mathematically and experimentally proven theory was applied to water main breaks in a fire suppression system. Using DLFs on an operational water main system, 17 years of fatigue failures were stifled. By controlling fire hydrant and valve closure speeds, nearly all water main breaks were stopped. Previously, all of these failures were incorrectly attributed to corrosion, which is an important secondary failure cause. By controlling vale and hydrant closures and pump startups and shut downs, future water main breaks can be stopped.

Full Description:

1. What is the innovation?

Pumps, valves and fire hydrants need to be operated slower to prevent cracks, crevice corrosion, and general corrosion due to water hammer. Even so, some water main failures are caused by corrosion alone. A comprehensive, multi-year study of corrosion, water hammer and water main breaks proves that water hammer breaks pipes and causes most corrosion failures as well. By eliminating water hammer, water main breaks will be nearly eliminated. Simplified estimates to determine these closure speeds for valves, hydrants and pumps are available ("Water Hammer Breaks Water Mains", by R. A. Leishear, 2019, ASME Journal of Pressure Vessel Technology). Prior to this innovative discovery, water main breaks were completely misunderstood, and the understanding of corrosion mechanism and corrosion control were

entirely misguided. A clear understanding of fluid transients and hoop stresses now permits an appropriate understanding of water main cracks and corrosion.

A Large Water Main Break (www.nbcnews.com)

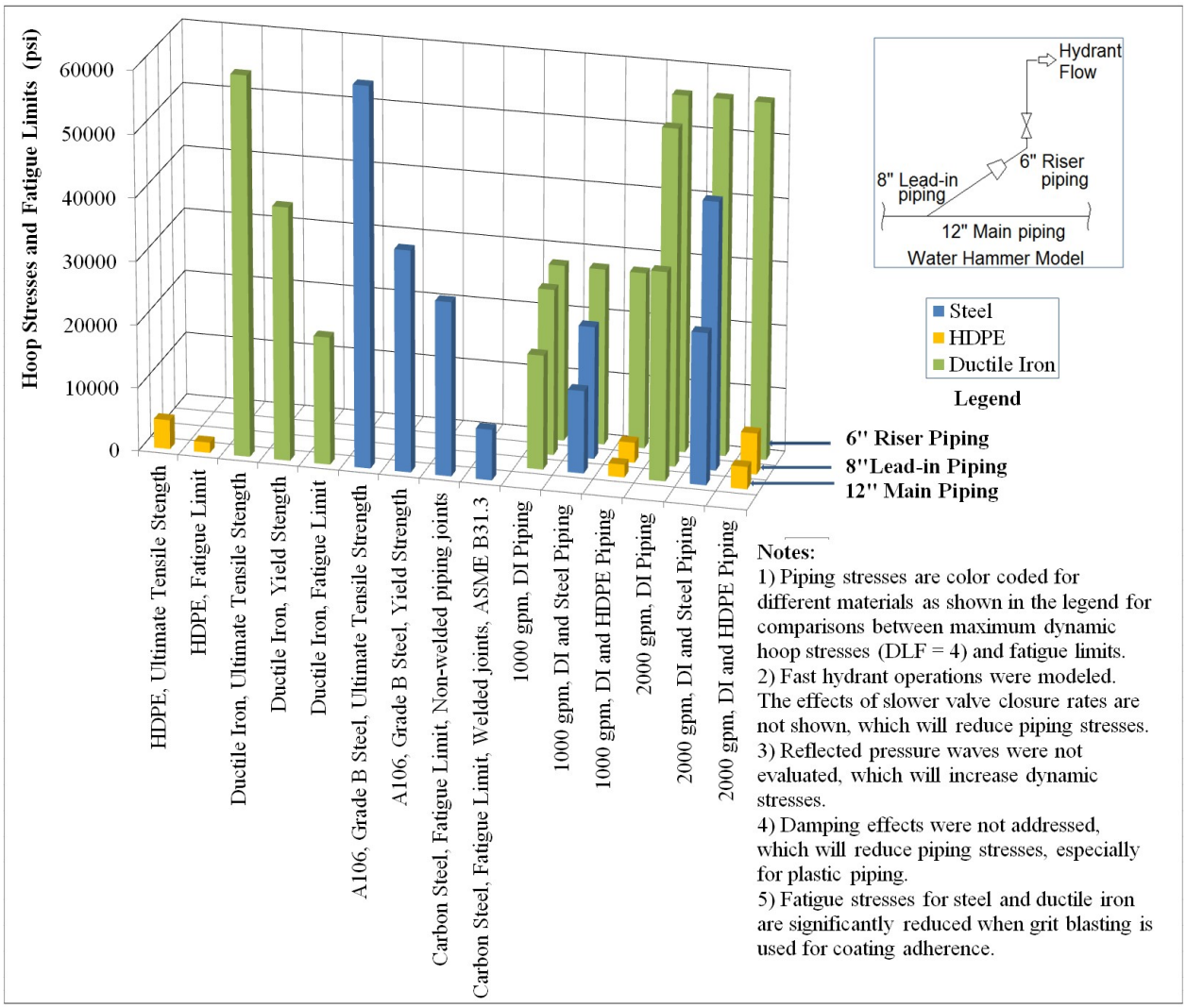
Road collapse due to scouring of soil by a water main break under a roadway (geotill.com)

2. How does the innovation work?

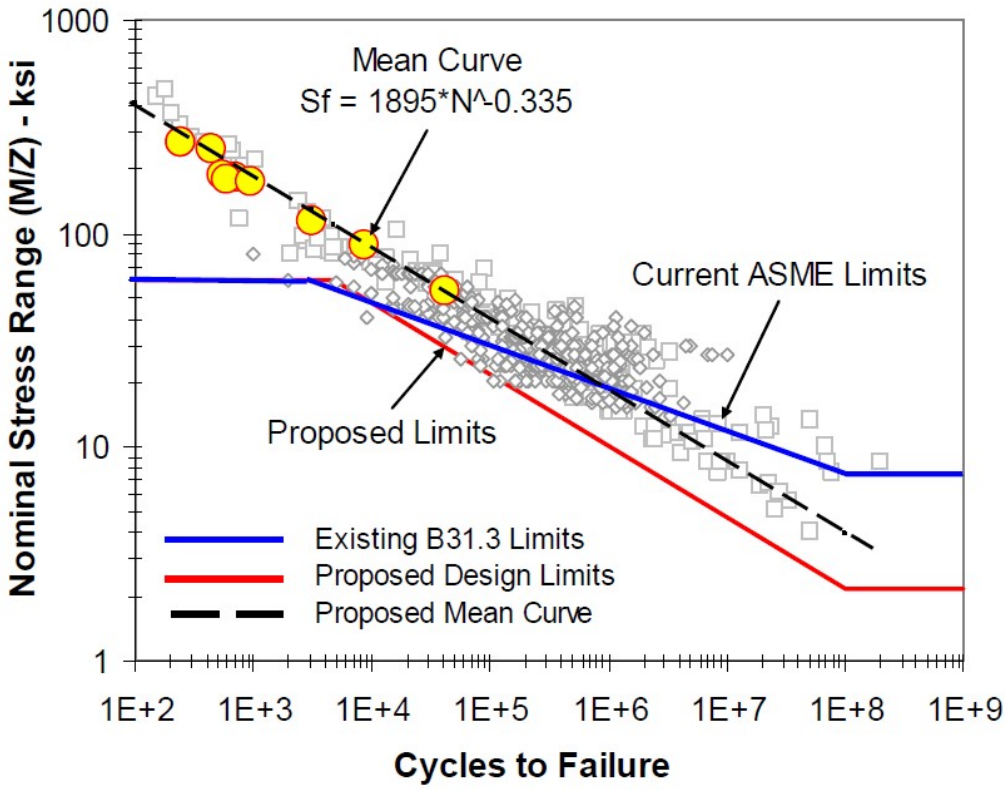
When water hammer pressures are magnified by DLFs, the hoop stresses in water mains approach the fatigue limits for all different piping materials. These high stresses result in low cycle fatigue cracks in piping for a limited number of cycles. Calculations were performed to compare limiting hoop stresses to tensile strengths and fatigue limits ("We Can Stop $1.7 Billion

Dollars a Year in Water Main Breaks" by R. A. Leishear, May, 2020, NACE Materials Performance Magazine.

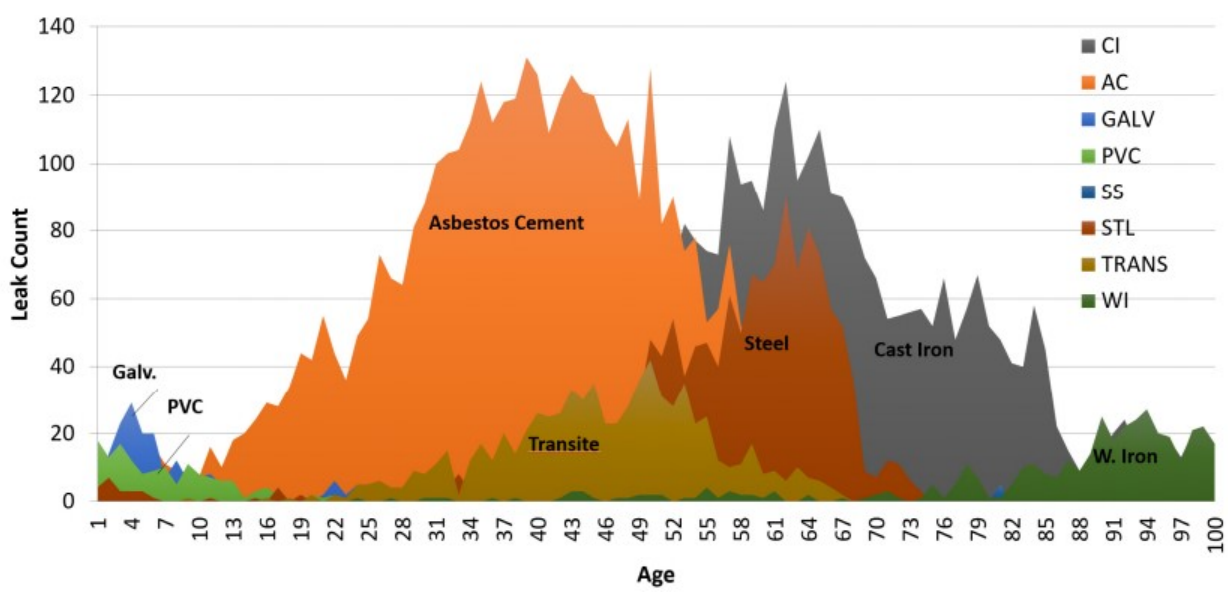
Water hammer cracks provide a readily available electrolyte source at crack sites as water leaks from the cracks. If the soil is non-corrosive, the cracks will grow in size due to repeated hammers. If the soil is corrosive, crevice corrosion will accelerate crack growth even faster. Such leaks also accelerate general corrosion on the pipe surface, and an available electrolyte may also induce galvanic corrosion between the soil and pipe surface. By reducing water hammers, stresses are reduced below the fatigue limit, and both cracks and resultant corrosion are eliminated.



Calculations prove that water hammer causes fatigue failures



Fatigue data for carbon steel piping, showing the relationship between fatigue failures and hoop stresses



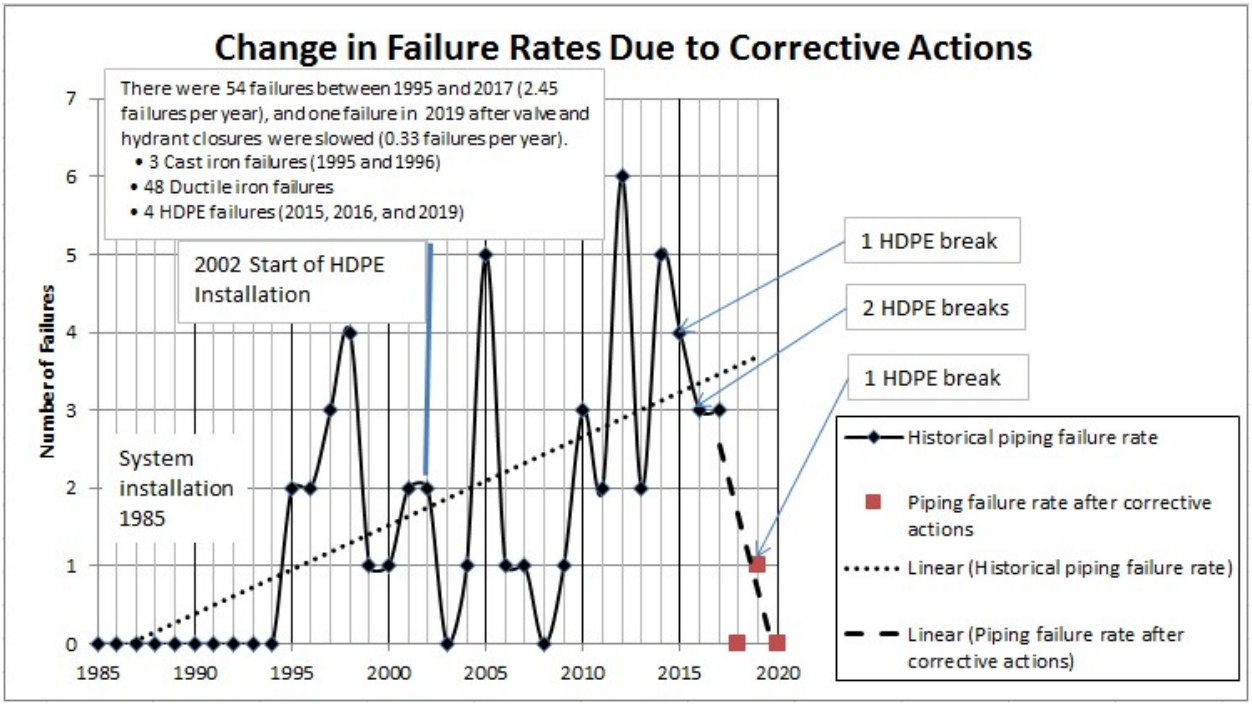
Data which demonstrates that all materials fail due to fatigue over time (Cantone, J., Keck, J., 2018**)**

A corrosion failure caused by water hammer

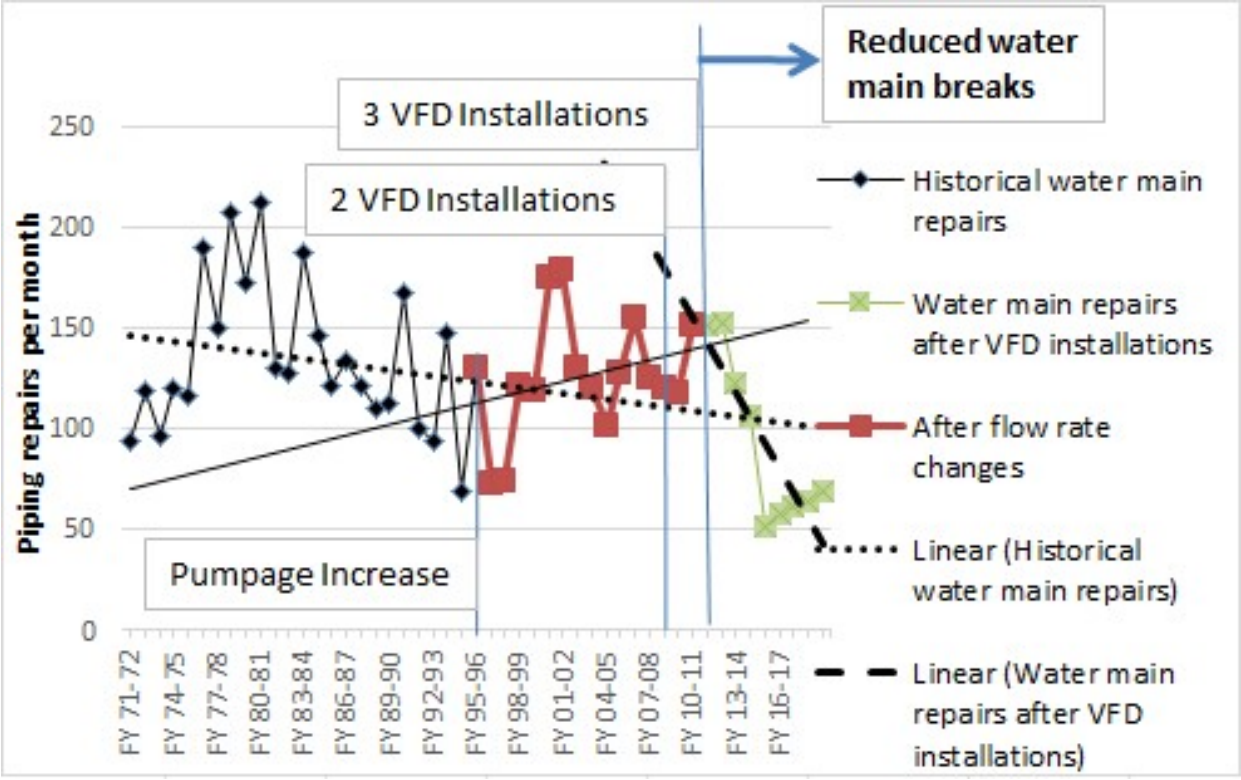
3. Describe the corrosion problem or technological gap that sparked the development of the innovation. How does the innovation improve upon existing methods/technologies to address this corrosion problem or provide a new solution to bridge the technology gap?
Applying dynamic load factors to water main breaks was a logical step after proving that water hammer cracks piping due to cyclic fatigue loading. This theory was used in 2002 to stop water main breaks in a cooling system for radioactive liquid waste processing at Savannah River Site in South Carolina. Although corrosion was falsely blamed as the piping failure cause for forty years, more than 200 years of piping failures came to an abrupt stop 18 years ago when sudden valve closures and sudden pump shutdowns were ended, as documented in the referenced ASME textbook. However, the intricacies of corrosion and water main breaks required further study. To do so, several water main systems were considered, and these systems showed that water main breaks were slowed down when water main breaks were partially eliminated.

This new technology presents a paradigm shift to the understanding of corrosion and its relationship to water main breaks with respect to the corrosion industry. This new understanding of the primary water hammer cause of water main breaks provides an opportunity to advance technology. Until this new theory was available, water main breaks were greatly misunderstood.

4. Has the innovation been tested in the laboratory or in the field? If so, please describe any tests or field demonstrations and the results that support the capability and feasibility of the innovation.
A 2017 study of a water main system used for fire protection afforded that opportunity. Seventeen years of water main breaks stopped, where corrosion was previously considered to be the problem. Other systems were studied as well ("Of Course We Can Stop $1.7 Billion Dollars a Year in Water Main Breaks" by R. A. Leishear, September, 2020, NACE Materials Performance Magazine).



Water main break reductions due to slow closing of fire hydrants and fire system valves used for building fire protection tests



Water main break reductions due to pump VFD installations

5. How can the innovation be incorporated into existing corrosion prevention and control activities and how does it benefit the industry/industries it serves (i.e., does it provide a cost and/or time savings; improve an inspection, testing, or data collection process; help to extend the service life of assets or corrosion-control systems, etc.)?

Service lives of water mains can be drastically increased. Damage can be arrested in many cases – unless corrosion is in process - when water mains have been damaged. There are more than a million miles of US water mains in danger of destruction due to water hammer combined with corrosion, in addition to water main damages in every industrialized country. Coupling this new theory with corrosion theory can lead to a much greater understanding of water main breaks to stop both water hammer and corrosion due to water hammer.

6. Is the innovation commercially available? If yes, how long has it been utilized? If not, what is the next step in making the innovation commercially available? What are the challenges, if any, that may affect further development or use of this innovation and how could they be overcome?

Several successful applications have been completed for water main systems using this new theory. The major challenge at this point in time is acceptance of this new theory, and the application of this theory to a major city to serve as an example for other cities to follow. Even so, any city or town can take preventive actions at any time to start cutting their major infrastructure costs, where every city and town experiences water main system damages to varying degrees.

7. Are there any patents related to this work? If yes, please provide the patent title, number, and inventor.

No patent applications have been submitted. The invention of a new theory is not patentable.