



Small, Untethered, Mobile Robots for Inspecting Gas Pipes

These robots would be powered by gas flows.

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Small, untethered mobile robots denoted gas-pipe explorers (GPEXs) have been proposed for inspecting the interiors of pipes used in the local distribution natural gas. The United States has network of gas-distribution pipes with a total length of approximately 10^9 m. These pipes are often made of iron and steel and some are more than 100 years old. As this network ages, there is a need to locate weaknesses that necessitate repair and/or preventive maintenance. The most common weaknesses are leaks and reductions in thickness, which are caused mostly by chemical reactions between the iron in the pipes and various substances in soil and groundwater.

At present, mobile robots called pigs are used to inspect and clean the interiors of gas-transmission pipelines. Some carry magnetic-flux-leakage (MFL) sensors for measuring average wall thicknesses, some capture images, and some measure sizes and physical conditions. The operating ranges of pigs are limited to fairly straight sections of wide transmission-type (as distinguished from distribution-type) pipes: pigs are too large to negotiate such obstacles as bends with radii comparable to or smaller than pipe diameters, intrusions of other pipes at branch connections, and reductions in diameter at valves and meters. The GPEXs would be smaller and would be able to negotiate sharp bends and other obstacles that typically occur in gas-distribution pipes.

Unlike a pig, a GPEX would be able to operate or even fail inside a pipe without stopping the gas flow. It would be capable

of operating for long times and traveling long distances without human intervention, so that expensive and disruptive urban excavation could be kept to a minimum; to make this possible, the GPEX would generate its own power from the flow of gas. It would communicate information, including low-rate data like those from an MFL sensor and high-rate image data that show corrosion, leaks, and buckles. Two-way radio communication, for both retrieval of inspection data and control of the GPEX, would take place at gigahertz carrier frequencies, with pipes serving as waveguides. The GPEX must transform its shape as needed to cope with changes in pipe dimensions, dents, pipe bends, and pipe intrusions.

A prototype GPEX that would be capable of operating inside either a 4-in. (10-cm) or a 6-in. (15-cm) pipe has been developed. At present, it is viewed as infeasible to package all the needed functions of the GPEX inside a single body that could negotiate right-angle turns in a 10-cm pipe. Therefore, the prototype GPEX is composed of a train of multiple units, much like a railroad train. Because the source of power would be the flow of natural gas in the pipe to be inspected, the first unit in the train would be a combination of a power generator and locomotive. The flow of gas [typically methane at a flow speed of 10 m/s, a pressure of 60 psi (≈ 0.4 MPa), and a temperature of 15 °C] could supply sufficient power to enable the robot to perform all its tasks, without a major loss of gas pressure.

The initial development effort is expected to focus on the power-genera-

tor/locomotive unit. The power generator would be a permanent-magnet motor back-driven by a miniature turbine driven by the flow of gas. In normal operation, power of at least 2 W would be required, and the pressure drop would have to be limited to no more than 0.3 psi (2 kPa). A further requirement is that in the event of worst-case failure of the generator or any other part of the GPEX, the pressure drop not exceed 0.6 psi (4 kPa).

The power-generator/locomotive unit is a pair of bodies connected by an extension actuator. Multiple bladders can be alternately inflated and deflated to exert forces on the pipe wall, and the extension actuator can increase or decrease the separation between the bodies to move the unit in "inchworm" fashion.

This work was done by Brian Wilcox of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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