Controlled calcite deposition can renew corroded pipes, say Israeli researchers

Precipitation of calcium carbonate in pipeline systems, so often a water supply headache, could be usefully controlled as a remedial method for lining cast-iron pipes. Professor David Hasson of Technion — Israel Institute of Technology and M Karmon of the Mekorot Water Co of Israel revealed the results of their research to the 5th International Conference on Internal & External Protection of Pipes held in Innsbruck, Austria, last month.

The use of controlled calcite deposition as a remedial method for lining water pipes is now at the stage where it is ready to face the challenge of industrial application.

This was the claim made by Israeli researchers Hasson and Karmon in their paper to the Innsbruck pipe protection conference at the end of October, as a result of several year's work carried out in a pilot plant at the Wolfson Department of Chemical Engineering within the Technion - Israeli Institute of Technology in Haifa, Israel.

The use of calcium carbonate precipitation in this way, however, dates back much further to work done by R F McCauley in the US in 1960. He suggested that corroded water mains could be rehabilitated by controlled deposition of a tenacious calcite layer through recirculation of a highly supersaturated scale-forming water.

His work unfortunately never reached the point where crucial process elements were clarified, work which has now provided the focus for the new Israeli research, both theoretical and experimental.

According to Hasson and Karmon, the calcite lining process involves circulation at ambient temperatures of water dosed with cheap and harmless calcium carbonate forming salts to create and maintain supersaturation conditions with respect to $CaCO_3$.

Relining using this method has several advantages, say the researchers:

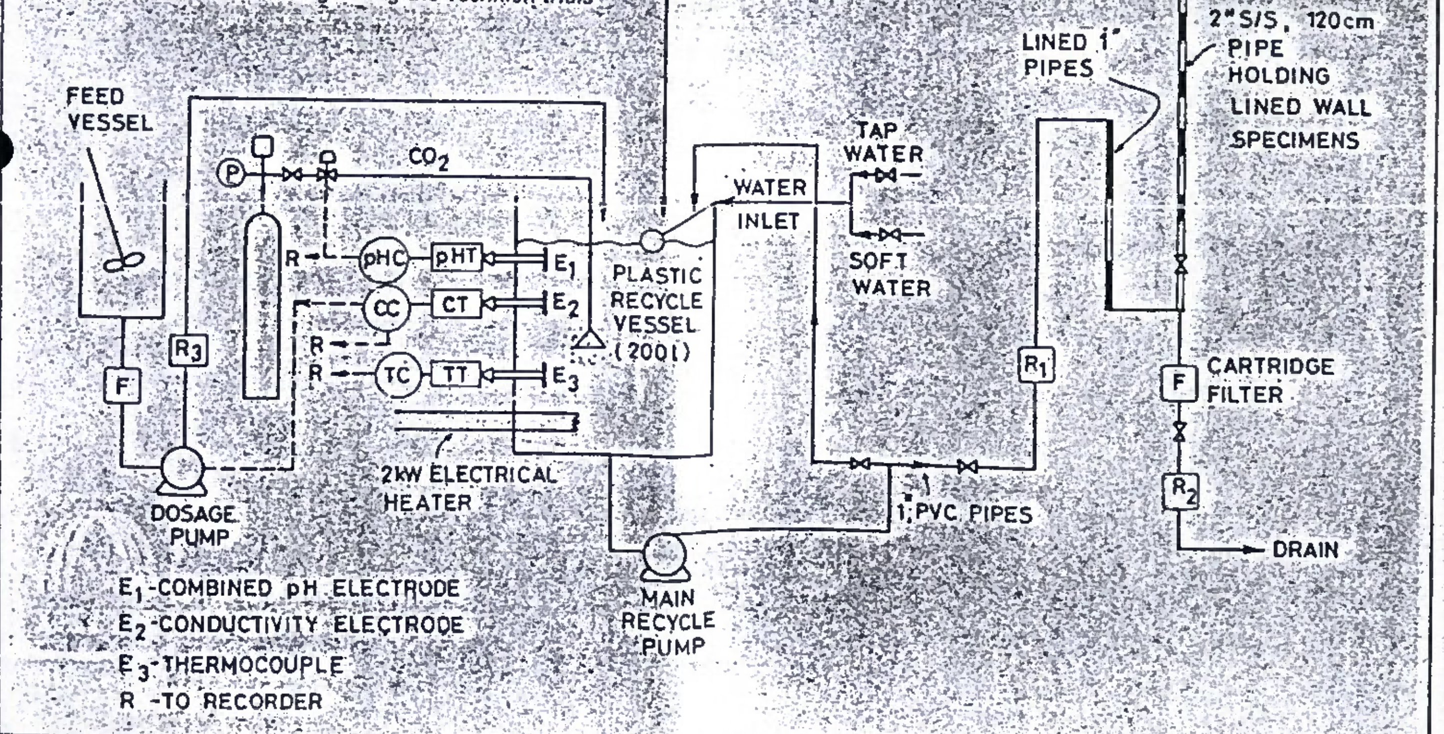
- Lengths of pipe up to 1km or even longer can be lined, whereas, for pipes of 300mm-dia or less, a conventional cement mortar lining can only be applied over a length of less than 150m;
- There is no need to deal with side connections since calcite does not adhere to surfaces exposed to stagnant water;
- Cement mortar lining becomes very expensive with small diameter pipes and impossible below 75mm — calcite lining has no small diameter limitation;
- Mortar linings also require time for curing the cement and for dissolving the lime until an acceptable pH level is obtained — calcite linings can be deposited during the night with the pipe in regular use during the day.

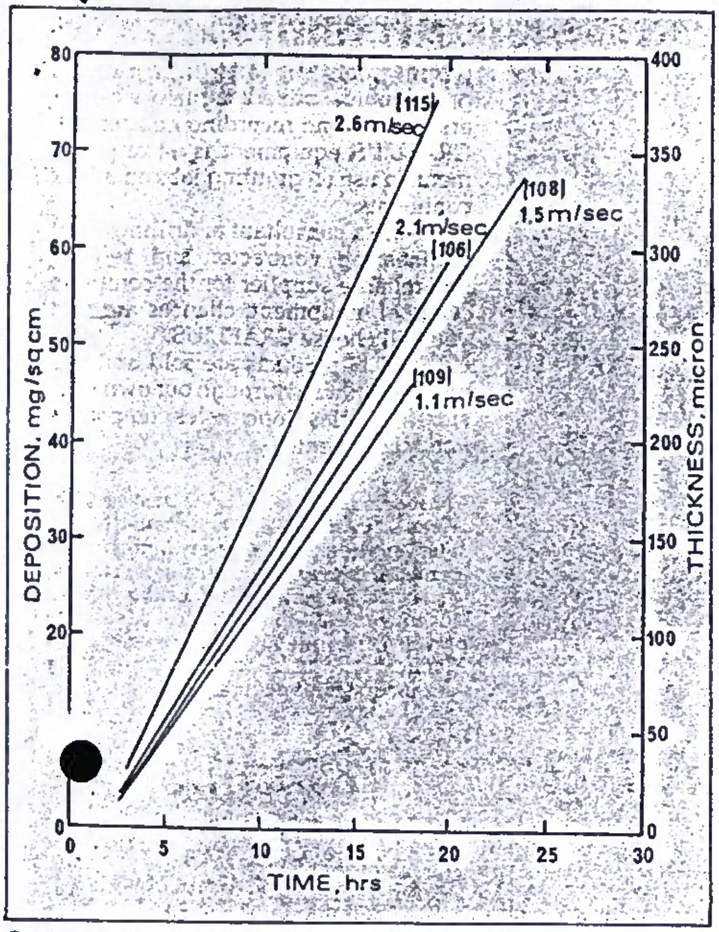
The only major drawback to calcite linings appears to be their vulnerability to aggressive water. Cement mortar linings can withstand attack by aggressive water for a long time. Cement is not immune to dissolution, but the thickness of the lining alleviates the problem. As long as leachable lime remains in the cement, any water penetrating the lining becomes alkaline and does not harm the cast iron.

The work done by Hasson and Karmon shows that calcite is leached by aggressive water at about the same rate as cement, but the sand in the mortar means that mortar dissolution rates were only 35%-45% of the values for calcite. The researchers conclude, "Calcite lining at its present development status is thus limited to non-aggressive water."

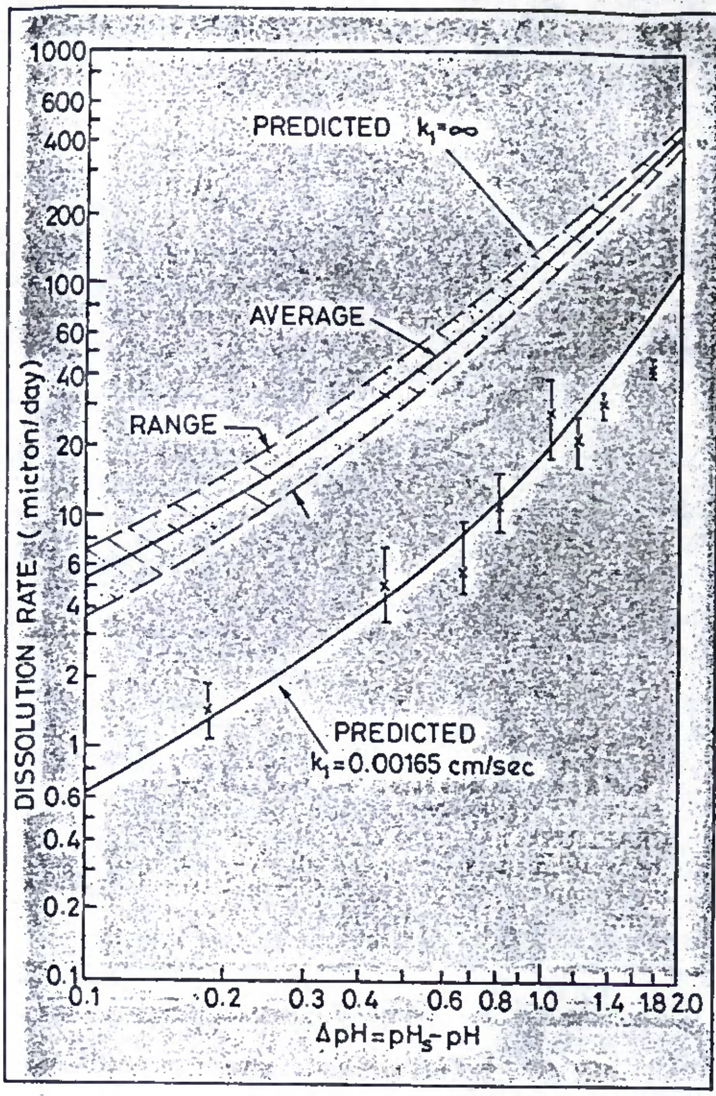
Nevertheless, they point out that no remedial method is perfect for all problems, and stress the usefulness of economic lining of small diameter pipes.

Flow system for testing durability and corrosion protection of the calcite lining during the Technion trials





Growth of deposit thickness at various flow velocities.



Effect of aggressive saturation index on the dissolution rate of calcite. The technique is currently limited to non-aggressive water.

"In Germany, for example, about 400,000 households receive their water supply through connecting lead pipes having diameters in the range of 12 to 32mm. No existing pipe lining technique is deemed suitable for dealing with such small bore pipes. The calcite process . . . offers an interesting remedial possibility [for th]e lead problem."

[The] Technion research programme began by identification of parameters that control the quality and rate of calcite deposit formation, with theoretical models developed to analyse and interpret experimental results. At the end of two years' work, the researchers had found that there were two key parameters for ensuring a tenacious lining: elimination of oxygen from water by sulphite dosage; and operation at a flow velocity above 1.5-1.7m/s.

The ability to design and control a calcite lining operation requires understanding of the kinetics of calcite layer growth and the rate of particle precipitation in the bulk of the lining solution.

A supersaturated feed solution with an initial calcium concentration of Ca^{+2} will partially relieve its supersaturation by both wall crystallisation of $CaCO_3$ and bulk precipitation of $CaCO_3$ particles. The first effect is the desired one, while the bulk precipitation needs to be suppressed.

Fortunately, the desired process of wall crystallisation follows a different quantitive relationship from the parasitic bulk precipitation process, making it possible to suppress bulk precipitation by inhibitors (Na_2SO_3 and Calgon) without greatly affecting the coating. The final outcome is an enhanced coating rate at a higher residual supersaturation level.

This research also demonstrated that increasing the feed velocity had a beneficial effect on the bulk density of the lining. At a flow velocity of around 2.6m/s, bulk density closely approaches the value for pure calcite (2,700kg/m^3), say the researchers. At lower velocities, greater quantities of the aragonite crystals are deposited which form weak powdery layers, of little use for lining.

Using these researched principles and empirical values to design a practical lining operation necessitates specification of the following parameters: pipe diameter; length of pipes to be lined at a time; permissible make-up water flow rate; chemical analysis of make-up water; lining solution velocity; desired coating rate; desired lining thickness; and the thickness difference tolerated over a specified length.

The practical limitation on length of pipe to be lined lies solely in the economics of laying the return pipe and taking measures to prevent it scaling. A secondary consideration is the drop in solution concentration along the pipe, which could result in the formation of a thickness profile in the flow direction. This can be rectified by reinforcing the lining solution at intermediate dosing points.

Giving an example of a 150mm-dia pipe to be lined in 1km sections, Hasson and Karmon estimate that, at a coating rate of 20µm/h, three intermediate dosage points could ensure a thickness profile uniform to within about 10%.

The experimenters also carried out corrosion and durability tests on the pipes they had lined. These suggested that the corrosion protection ability of calcite was more dependent on lining quality than lining thickness. They also decided that a lining thickness of about 500µm is a reasonable figure to adopt.

The 5th International Conference on Internal & External Protection of Pipes, at which the Hasson and Karmon paper was presented, was organised by BHRA Fluid Engineering, Cranfield, Bedford MK43 0AJ, England, who will be publishing the proceedings.