# ICL INQUIRY STATEMENT

## ROGER ANTONY KING

**Personal Information**

1. I have degrees in Chemical Engineering and Corrosion Science and Engineering and my doctorate related to soil corrosion with particular reference to the activity of sulphate-reducing bacteria. Over the past thirty years I have been hired by government departments and research centres, engineering contractors and operators to provide them with specialist advice on materials selection and corrosion management.

2. I am a member of the National Association of Corrosion Engineers and am a founder member of the UK Section of NACE, an ex-council member of the UK Institute of Corrosion Science and Technology and am a member of the Pipe Line Industries Guild.

3. I have written over eighty scientific papers, the majority of which are on subjects related to pipeline corrosion.

**Clarification and Expansion of Report [ICL/09163-09203]**

**The pipeline**

4. The LPG pipeline at the premises of Grovepark Mills, Maryhill, Glasgow, was fabricated using carbon steel pipes. Parts of this pipe were coated in a layer of zinc. Zinc provides cathodic protection but this is largely irrelevant in this case as it was a very thin layer of zinc and so would not have lasted long, perhaps a number of months. The zinc is essentially a red herring.

5. These pipes were interconnected by non-galvanised, malleable cast iron fittings, particularly at the elbows. The fundamental problem is the fact that the pipe was not protected by any means at all.

**Oxygen corrosion**

6. At ICL we are concerned largely with oxygen corrosion. Oxygen corrosion is the most common soil corrosion process. The more oxygen that reaches the metal the more rapid will be the corrosion. The presence of salts in the soil increases the extent of corrosion but it is the oxygen concentration which determines the rate of corrosion.

7. The failed bend would have been at particular risk in the soil compared to the main section of pipeline because it was less deeply buried in the soil

than the remainder of the pipeline. Oxygen diffusion would be higher at the location of the failed bend.

8. In addition to oxygen diffusion through the soil there would appear to be an additional oxygen diffusion path from the building to the failed bend. It is reported that there was a small hole in the wall where the pipe section entered the building. This would allow air to diffuse from the building into the soil around the bend.

**Additional pressure on the pipeline**

9. Sometime around 1972 the level of the yard, beneath which the pipeline was buried, was raised. This would impose an additional load onto the pipeline. The raising of the yard also covered the end section of the LPG pipeline where it entered the building. Soil corrosion would have initiated from this date. Prior to burial some atmospheric corrosion would have occurred.

10. The loading would be more severe than a straightforward soil overburden because construction debris, e.g. a concrete slab had been placed onto the pipeline. The additional overburden is reported to have distorted the final buried elbow by about 5°.

11. Heavy loading could have eventually led to mechanical failure of uncorroded material in the pipeline. This could occur because as the length of the flaw in the pipe increases, the load on the pipeline would be carried by

the smaller remaining section of uncorroded pipe, putting it under increased strain.

12. One further effect of additional strain is blow out of the adherent blanket. The build up of corrosion adheres to the surface of the pipe, creating plugs of corrosion. They are held in by a seal, and vapours seep out through this. However, when they are disturbed, e.g. by any large surge, they will pop out and so gas will be released faster than normal. Loading of the elbow made this a bit more of a problem in the case of ICL.

13. The increased burden caused by the raising of the yard and the concrete slab on the elbow of the pipe may have been of importance in the ICL case, as contributing factors. However, in general the biggest problem is corrosion. The unprotected pipes would have corroded despite raising the yard or adding the concrete slab. There is not any particular need to focus on the leading or any precise mechanism.

**Weather**

14. I was asked if the weather would have had any impact on the circumstances at ICL. There were reports of unusually heavy rain in the days prior to the incident. This may have meant that the ground surrounding the pipeline became very wet, so the gas that would have escaped from the rest of the pipe could not get out and so increased gas escaped from the failed bend into the void.

15. I was asked to comment on reports that 'the building shook'. Building settlement as a result of thunder and lightning seems remote. If the building was going to settle it would have settled a long time ago.

16. If the building did shake this would not have affected the pipework because the building was not pressing on the pipe: in the location where the pipe entered the building there was space between the pipe and the brickwork.

17. Occasionally lightning strikes on pipework, which may have caused damage, but this did not occur in this case.

18. I have been asked if the geology of the site has potential significance. There is nothing that leaps out at me. There could only be significance, for example, in relation to London clay which is potentially corrosive.

**Cathodic Protection**

19. Cathodic protection is very efficient particularly for small pipelines. It is a well established technique that is widely used to prevent corrosion of buried and submerged pipeline. Cathodic protection works by shifting the corrosion of the steel pipeline to another sacrificial material that is electrically connected to the steel. The steel and the sacrificial material form a battery similar to a

conventional primary battery. Normally for buried pipelines magnesium is used as the sacrificial metal.

20. The caveat to this is when a pipe is buried but at some point comes through the ground into the air, for example when it enters a building, it is exposed to corrosion. As this stage the pipe should be wrapped.

21. The duration of protection provided by cathodic protection depends on anodes but the standard is 25-30 years. The pipe will not corrode provided the gas internally is dry and cathodic protection is used externally. After this time cathodic protection can be replaced. The cost of the system is approximately £100 and there is no difficulty in replacing it. It makes good economic sense.

22. The ideal point to situate the anodes is for one to be buried by the tank and one at the entry to the building. It is a case of digging a hole, inserting the anode, connecting the anode lead to the pipe and filling in the hole. This avoids corrosion at the edges as it protects the whole length of the pipe.

23. It is an easy calculation to determine the number of anodes. Once the calculation is determined it can be published. For example, you could have one standard sized anode for every 100 metres of pipe. British Gas systems previously were protected in this way using standard anodes.

24. Cathodic protection can easily be retrofitted and it will work straight away. If it is applied to an old pipe one would need to provide more anodes. The effectiveness of the system depends on the condition of the pipe is in the first place. Prior to applying cathodic protection a pipe should undergo a proper pressure test at high pressure. Pressurise the pipe at a higher pressure than working pressure. If it is tested at 50% higher than working pressure that would pop out any corrosion plug. If the pipe is faulty replace it. If you then apply CP you would stop further corrosion. If you were being absolutely safe you would dig it up but this is not always practical.

25. The caveat to this is that is gives some short term protection, to avoid having to do something in a hurry. The user can be informed that this affords short term protection but that there are further measures to ensure the safety of the installation. If you can plan to do something over 6 months to a year you can get quotes in etc. This measure is more cost effective without putting on too much pressure on the owner of the pipe. For example if the pipe had been in service less than 10 years do a pressure test and add cathodic protection. If the pipe was over ten years one could be required to do x, y and z. If you do not know the age of a pipe in a high risk location e.g. near a school, look at the consequences and decide the procedure based on potential damage.

26. Can all risk from LPG pipes be eliminated? The only way to eliminate risk is to dig pipes up regularly. However, this is not a practical solution. Digging up pipes could be an option where it is a high risk area. For practical

reasons there should be a cascade of things to do, simplest & cheapest first. For example there was concern about the safety of gas tanks in Maryland approximately 20 years ago. Cathodic protection systems were required to be installed to stop further corrosion. There was a very successful uptake of this, almost overnight, because it was a cheap and easy option for protection.

27. Occasionally cathodic protection might not prevent leakage even if a pressure test has been passed. Where there is a badly corroded pipe the cathodic protection may take longer to come into effect (perhaps 4 weeks) by which time further corrosion may take place. However this is only in a very small percentage of cases. Cathodic protection would catch 99% of cases and provides a practical solution.

28. Wrapping of pipes is only done on new builds. You would not dig up pipes in order to wrap them because given the effort to dig up the pipes, it would be cost effective to replace the pipe, it would not be cost effective to wrap an old pipe.

29. A further weakness of wrapping as a form of protection is that many wraps have a limited life. It is also not easy to wrap a pipe well, and the wrapping can be damaged during installation. Cathodic protection is better because is eliminates these factors. It also prolongs the life of the pipe, compared to wrapping, because the pipe would only be protected for the life of the wrapping.

30. You could use cathodic protection and wrapping but anodes alone are better than wrapping alone. For large diameter pipes anodes would be expensive if the pipe was not coated/wrapped and it becomes more effective to wrap and use cathodic protection. However with small pipes wrapping can stop cathodic protection working, e.g. where the pipe is not cleaned before wrapping and soil is covered by intact wrapping.

31. Pipe is bought in standard lengths and must be cut to size and the sections joined with metal to metal seal fittings. Once the pipe is made up someone has to wrap the pipe.

32. The cathodic protection system will require some monitoring, however this will not be onerous. After the first year in service the user should dig up and check the anodes. If the system is not working there would be no corrosion and it would be obvious at this stage. If the anodes are considerably corroded then the owner should seek advice. There might be cases where you have a small pipe but it is taking excess electricity from the anode because there is another source being protected, e.g reinforced metal wall. If the system is working properly, inspect again after 5 years.

33. I have been asked who should monitor the system. Competence in this case means understanding processes. If the gas supplier monitored the system there would be relatively few people to train. Conversely, if the onus is on the user to monitor the system many people would require training.

34. It is also possible to check the system by testing the potential of the pipes. This avoids the need to look at the anodes. This is an alternative method of testing and would require a competent person trained on this

35. Guidelines (LPGA COP) for new installations cover gas advises on this issue. They say wrapping as the primary form of protection.

**<u>Documents recovered from the rubble</u>**

36. Documents found in the rubble included pamphlets on corrosion provided to Companies by the UK Department of Industry (DoI). Three of these documents were directly related to corrosion of buried pipes, to the advantages of coating buried pipe and to prevention of corrosion by cathodic protection. Sally Hall headed the inquiry into corrosion in the UK. NPL sent these pamphlets out to the industry, free of charge, almost 30 years ago. The impetus for the review and issuing of pamphlets was that 4% GDP was wasted due to corrosion. It was an economic imperative rather than a safety imperative. This was successful with a high take up rate.

37. My group at Manchester were commissioned to make a series of these documents. The DoI guidance documents relate to all sized of pipework. In ICL there was a 1-1.5 inch pipeline however the pictures in the pamphlet gave the impression that cathodic protection related to a much larger pipe. The message may not have been taken up for this reason, although the same principles apply to both large and small pipes.

**Bilbao Incident**

38. I have presented expert opinion on the reason for failure of an LPG pipeline in Bilbao, Spain approximately 20 years ago. In this incident there was a corroded LPG pipe which allowed gas to leak into the foundations of a school, resulting in an explosion which killed 40-50 people. The pipe was protected by wrapping but not effectively because it was damaged during installation. The system was only 3 years old but there was accelerated corrosion because the LPG tank was also buried, to prevent the school children playing with it. This incident was a cause celebre in Spain however it does not seem to have percolated across to the UK and the rest of Europe.

39. If cathodic protection had been put in it would have stopped corrosion, although the anodes would corrode quickly because the tank was also buried. Additional anodes would be needed to allow for and protect the tank.

**Establishing the scale of LPG problem**

40. Studies I have been previously involved in include one for British Gas which particularly looked at offshore pipelines.

41. To give an idea of the scale of the potential LPG problem look to gas suppliers and identify the number of places they deliver to. Alternatively, approach a pipeline industries journal editor (e.g John Tiratsoo) who can

identify the institutions. Then determine when the tanks were installed. As a general rule the pipework will be as old as the tank. This survey will only give the number of installations, not the state of the pipes. However one problem with this is that many people will not know details of their LPG system. If they changed suppliers information can be easily lost. This makes estimation of the risks associated with the pipes difficult.

42. In terms of risks, do what companies do – risk is related to population density. Risk = probability x consequence. Probability = age of the pipe. If you do not know the age of the pipe, dig it up.

43. Information about LPG safety can be distributed via the technical press and the newspapers.

**Soil Type**

44. Soil can be mixed which makes it more corrosive. Different soil conditions in the UK could be considered. Rothamstead agricultural centre have undertaken surveys and produced soil and geology maps of the United Kingdom. Professor Colin Jones, Univ Newcastle working with the Construction Industry Research and Information Authority, based in London, considered underground services in contaminated soil. In the UK soil can be very mixed, especially in industrial sites. We have to assume the soil will be mixed and variable. We have to have a system that will overcome these problems.

45. It is possible to avoid underground LPG pipes however if they are above the surface of the ground there are other dangers, e.g. people damaging them or as in ICL where the pipes were above ground but in a damp environment. Therefore is cannot be said that underground pipes are bad per se. It is more important to focus on protection of the pipes.

I confirm that the contents of this statement are true

Witness Signature ________________________________

Dated ________________________________