MICROBIOLOGICALLY INFLUENCED CORROSION IN THE NATURAL GAS INDUSTRY

ANNUAL REPORT
(January 1989 - December 1989)

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16. Abstract (Limit: 200 words)

This report presents the results of a continuing program funded and managed by the Gas Research Institute to investigate microbiologically influenced corrosion (MIC) in the natural gas industry.

The program consists of four phases. In Phase I, the objective was to develop methods of defining MIC and to test assumptions about MIC which were the basis for operating protocols developed by industry and the research community. Initial investigations demonstrated that MIC results from the activities of a microbial community rather than just sulfate reducing bacteria (SRB's). A metallurgical "fingerprint" for MIC was discovered in field samples and reproduced in the laboratory. Test kits and a field guide for identifying MIC were developed for use by gas industry personnel. The Phase II objective was to determine whether existing methods of controlling internal MIC were effective and how treatments could be improved. Protocols and sidestream test devices were developed to assess whether internal MIC was a problem and which mitigation strategies were effective. Phase III studies are examining external corrosion and investigating mechanisms in more detail. Models are being used to develop testable predictions about corrosion processes. Phase IV will focus on the development of new detection, prevention, and mitigation strategies.

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RESEARCH SUMMARY

Title	Microbiologically Influenced Corrosion in the Natural Gas Industry
Contractor	Radian Corporation GRI Contract Number: 5088-260-1747
Principal Investigator	D.H. Pope, D.R. Jackson, D.C. White, H.C. Aldrich, and D. R. Boone
Report Period	January 1989 - December 1989 Annual Report
Objective	Determine the nature of MIC in the natural gas industry and develop improved methods of detection and treatment.
Technical Perspective	Researchers estimate that corrosion costs all types of industry up to $126 billion annually. Of this, it is estimated that 10 to 30% results from microbiologically influenced corrosion (MIC). Often the cost of MIC is greater than these numbers reflect because most MIC consists of pitting which results in pipe or other equipment failure. Recognizing the seriousness of this problem in several other industries, the Gas Research Institute (GRI) initiated a research program to investigate MIC in the natural gas industry.
Results	The first phase of the program provided biological, chemical, and metallurgical "fingerprints" of MIC. Studies showed that MIC was associated with internal deposits, pitting corrosion, a type of corrosion which can result in through-wall failures of equipment. The work also demonstrated that MIC results from the activities of a microbial community rather than a single type of bacteria. Specific field test kits and a field guide for investigation of MIC were developed for use by gas industry personnel. The second phase focused on internal MIC. Results showed that many treatment protocols are ineffective. Field surveys showed that sometimes "hot spots" in systems can contribute to the contamination of downstream operating systems. Treatment strategies targeting these spots have been applied to some field sites and appear to work well.

The third phase is focusing on external MIC and the detailed mechanisms associated with MIC so that new detection and mitigation approaches can be developed.

Technical Approach

In Phase I, initial field investigations demonstrated that the microbial community associated with cases of MIC of gas pipelines was complex and dominated by organic acid-producing bacteria. Laboratory experiments were conducted to determine the extent of growth and acid production by MIC community members when growing on carbon steel coupons singly or in combination. The results clearly show that the slime formers, APB, and SRB grew much better and produced more organic acids when grown as a community. It was also determined that the metallurgical 'fingerprint' could be reproduced by either adding a microbial community, organic acids, or hydrochloric acid in laboratory experiments. A database was developed from these field site tests and laboratory experiments.

Phase II involved monitoring of gas facilities over a two-year period. Chemical, biological, and operational factors were studied to determine if significant relationships existed between these factors and MIC severity. Available test protocols and mitigation strategies were assessed and determined to not always be effective. In response, new protocols and sidestream test devices were developed. Targeted treatment strategies were applied at some field sites. These protocols will be published as Field Guides.

Studies in Phase III are focused on both laboratory and field investigations on the effects of MIC on coatings, cathodic protection, and metallurgy. Laboratory tests of mechanisms are underway to examine the effects of environmental gradients and conditions under a corrosion nodule. These studies will be useful in the development of new detection, prevention, and mitigation strategies.

Phase IV will focus on the development of methods for detection and mitigation. Mitigation approaches will be investigated which are more effective and do not require large chemical inputs.

Project Implications

This program on microbiologically influenced corrosion (MIC) has changed the thinking of much of the research community and industry on the role bacteria play in corrosion processes. It has also led to methods of detection and mitigation which are now widely used by the gas industry (and increasingly by other industries as well). This program is one of the few research efforts focused primarily on carbon steel rather than stainless steel or copper/aluminum alloys.

The current focus of the program is to finish documenting the results on internal mitigation developed in Phase II as useable field guides and videotapes. The Phase III activities are well underway and focus on external corrosion and a more detailed examination of how both microbial and 'classical' corrosion mechanisms are related with environmental factors. This should result in the development of better detection and mitigation approaches than those currently available.

The GRI MIC program will continue to include field and laboratory studies. It is recognized that field studies are essential to ensure that the results of laboratory studies are relevant and to facilitate the transfer of new methods to gas industry operating personnel which can be used in 'real-world' operating conditions. Laboratory studies are needed to interpret field data and develop new detection and mitigation approaches.

A crucial aspect of this program is the transfer of information and technology from the research team to the gas industry. This will be accomplished through refereed publications, field guides, videotapes, workshops, and the MIC Users Group which has guided this program. In fact, without the day to day participation in the program by gas industry corrosion control experts in the field (and laboratory) the progress which has been made in understanding and mitigating MIC in the gas industry would have been severely limited.

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1.0 EXECUTIVE SUMMARY

It is estimated that corrosion costs industry of all types up to $126 billion annually. Some corrosion experts have estimated that 10 to 30% of total corrosion results from microbiologically influenced corrosion (MIC). The actual cost of MIC is far greater than would be predicted by the percentage of corrosion attributed to MIC. This is because MIC leads most often to localized pitting which sometimes results in failures of the pipe or other equipment even though the total amount of corrosion is relatively minor. Recognizing that MIC had been documented as a serious problem in several other industries, the Gas Research Institute (GRI) in 1986 instituted a program to investigate MIC in the gas industry.

The objectives of Phase I of the program were to define which, if any, types of MIC occurred in the gas industry, determine how to best identify those types of MIC which occurred in the gas industry, and using these techniques, determine the characteristics of MIC in various aspects of gas production, processing, transmission and distribution. The results of this phase provided biological, chemical, and metallurgical "fingerprints" for MIC. Studies also showed that most MIC was of the pitting type, which is more likely to result in through-wall failures than are many other types of corrosion. This work also demonstrated that MIC resulted from the activities of microbial communities--not single types of microbes--as had been previously believed. Specific test kits and a field guide for investigation of MIC were developed for use by gas industry personnel. The work of the research team and the data generated by gas industry personnel demonstrated that MIC was an important mechanism of corrosion in the gas industry.

Phase II focused on internal MIC as it was agreed that this form of MIC might be easier to understand and control than external MIC. Accordingly, extensive monitoring of gas facilities (e.g., wells, separators, pipelines) was done over a two-year period. Chemical, biological, and operational factors were studied to determine if significant relationships existed between these factors and MIC severity. Available test protocols and mitigation strategies were assessed. The results showed that many test protocols in use fail to accurately assess the extent of MIC in the gas industry and the effectiveness of mitigation strategies. New protocols and test devices were developed. The survey also demonstrated that there were often "hot spots" in systems (e.g., some separators) which contributed greatly to the contamination of entire operating systems. Targeted treatment strategies were proposed for treating these components which would provide effective treatment at reduced cost and with reduced use of potentially hazardous chemicals. These have been applied to some field sites and appear to be working well. Additional field guides, for investigation of internal MIC and use of sidestream devices as well as protocols for testing of biocides, will be produced by the end of 1990. Additional test kits incorporating tests for chemical and biological factors will be produced.

The work in Phase III focuses on investigating the factors causing external MIC, testing the effectiveness of currently available mitigation measures (coatings and cathodic protection), developing on-line methods for monitoring MIC, and attaining a better understanding of the basic mechanisms whereby MIC occurs. Considerable evidence suggests that at least some types of coatings may be subject to biodegradation and possibly contribute to the occurrence of MIC. The influence of cathodic protection on MIC under various conditions will be investigated. Such techniques as alternating current (AC) impedance and electrochemical noise are showing promise as techniques for on-line monitoring. Current studies have demonstrated that metallurgical factors may influence the attachment of MIC bacteria and subsequent corrosion. Models have also been developed which make it possible to test predictions with regard to the MIC processes. (That is, the pH in a mature pit will be less than 4 and viable microbes will be largely absent from the interior of the pit.) Tests of these predictions are under way. These tests are important in the development of new detection, prevention, and mitigation strategies.

Phase IV is concerned with developing better methods for detection, mitigation and prevention of MIC. This will include attempts to develop metallurgies which might be MIC resistant, corrosion inhibitors which mask specific targets for MIC bacteria, and methods for in situ mitigation of external MIC (e.g., by altering the chemical environment surrounding the buried pipe).

Figure 1-1 shows the major milestones and deliverables for each phase of the project, including work for 1990 and beyond.

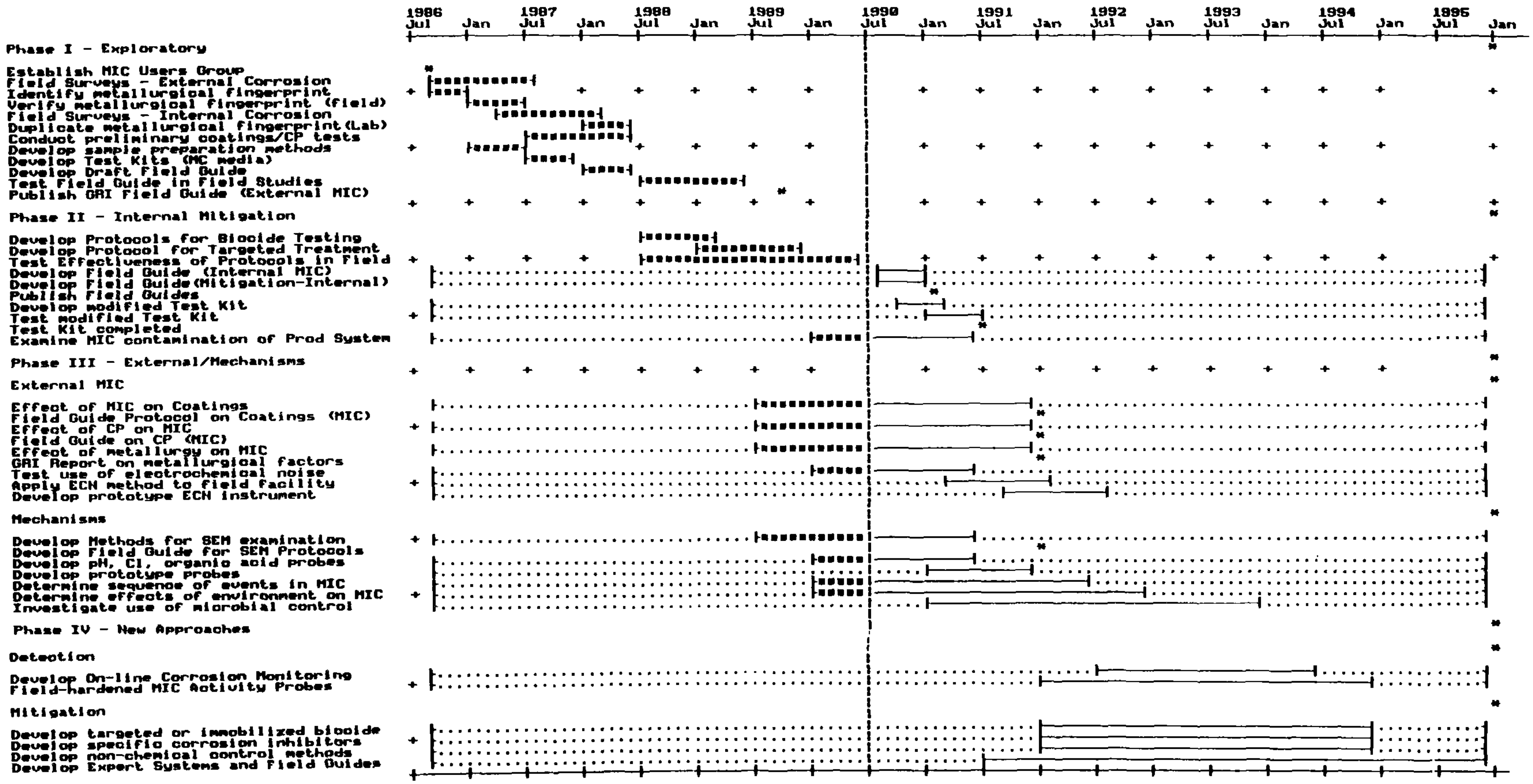

Figure 1-1. GRI MIC Program Plan - Major Milestones and Deliverables