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# The Solution Mining Research Institute — An Updated Overview

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ABSTRACT

The purpose of this paper is to present an updated overview of the Solution Mining Research Institute, commonly referred to as the SMRI. The predecessor of the Institute, the Brine Cavity Research Group, was formed to assist those engaged in the solution mining of salt (sodium chloride) with their common problems. The SMRI funds research in areas such as: dissolution and dissolution theory; drilling, completion and logging; subsidence; and rock mechanics. The paper will cover the following: history and development of the Institute; organization; purposes; summary of SMRI research; SMRI literature; and meetings.

The goal of the members of the predecessor of the SMRI was to make salt brine for the production of salt and/or chemicals. The process was later applied to the production of potash and soda ash. A significant development emerged with the utilization of the cavity (cavern) rather than the brine. Cavities are used for the storage of crude oil, gas, chemicals, compressed air and, possibly in the future, hazardous wastes.

The SMRI is international in scope, with members in North and South America, Europe and other countries around the world. The Institute provides a forum for those interested in solution mining by organizing technical meetings. The SMRI also acts as a Technology Center for the Industry, having some 700 pieces of literature which are in the public domain.

## INTRODUCTION

This paper is presented to update information about the Solution Mining Research Institute, commonly referred to as the SMRI. Except for the section on the SMRI research projects, the paper is descriptive rather than technical in nature. The topics that will be covered are as follows; definition; history and development of the SMRI; organization; purposes; summary of SMRI research; SMRI literature; and meetings.

## DEFINITION

The SMRI defines solution mining as the underground dissolution of water-soluble minerals using deep wells. This is not to be confused with leaching, which is the underground dissolution of water-insoluble minerals, usually with acidic solutions.

## ORGANIZATION

The Institute is supported primarily by membership dues. The current membership is forty-three. Classification of members is as follows:

*Regular members:*

Operating companies that do solution mining for brine production and/or utilization of cavities.

*Associate members:*

Class A: Service companies, Large consulting firms
Class B: Individual consultants

The business of the SMRI is conducted by an Executive Committee which is elected by the membership. Key posts such as the Technical Chairman and Program Chairman are by appointment. The only paid position is that of Executive Director who maintains an office and is the SMRI administrator.

## PURPOSES

– Identify and support research of interest and benefit to the Industry and members of the SMRI
– Act as the Technology Center for the industry
– Follow and disseminate information on enacted and proposed legislation affecting the Industry

## SUMMARY OF SMRI RESEARCH

The Institute has neither technical staff nor research facilities. It supports research projects approved by the membership. The SMRI welcomes proposals for research that cover areas of interest to the Institute. Such proposals will be carefully considered.

## GENERAL

The following are the areas of interest to the SMRI for which past, present and future research has been and will be considered.

(1) Dissolution
(a) Dissolution theory
(b) Dissolution simulation computer programs
(2) Brine wells — Drilling, logging, completion
(3) Subsidence and cratering
(4) Cavity (cavern) utilization
(5) Rock mechanics

Since the Sixth International Salt Symposium in 1983, SMRI-sponsored research is beginning to reflect more international participation. Canada was recently the site for the field work of a research project and a sizeable project is under way in France. Particularly in the light of Eastern European political changes, it is expected that new international members will contribute more ideas to enhance research and/or to lead to potential solutions for solving problems facing the solution mining industry.

## RECENTLY COMPLETED RESEARCH PROJECTS

### In-situ measurement of stress states in salt and associated sedimentary rock in relation to depth

This project involved development and testing of equipment capable of measuring *in-situ* stress, carrying out field measurements in the Goderich mine of Sifto Salt in Canada and interpreting the data. A significant contribution to the successful completion of the work was attention paid to drilling methods used by the mine personnel, such that the holes needed for *in-situ* measurement were of acceptable quality.

Due to perceived limitations of existing methods of measurement of material properties and stress in soft rock, salt in particular, the researcher developed specialized instrumentation designed to be used in-hole. The data obtained was processed by computer to characterize the stress states of rock formations for a given depth.

The Goderich mine operates in bedded salt of the Salina formation in Ontario, Canada. Actual testing of the equipment was performed in the underground workings at instrumented hole depths of about 305 and 550 m below ground. Test holes were drilled both horizontally and vertically at the test sites to provide a three-dimensional description of the stress states. Sifto Salt had previously adopted a new mining pattern which was designed to control stress and improve roof conditions, and in part, this SMRI project was utilized by Sifto to verify rock mechanical conditions. It is of interest to note that this research was able to benefit all involved. After a period of trial and error with drilling techniques and test equipment, the recorded data was judged to be reliable and the data interpretation phase began. The REM computer model, simulating stress states around the mine, showed that the data was collected from an adequate distance beyond effects of the mined area, such that the *in-situ* stress was actually measured. Researchers concluded that the maximum principal horizontal stress (also referred to as tectonic or excess lateral stress) is oriented in a northeast direction at the Goderich mine, which they claim is supported by the work of others. Stress states in the interbedded shales and dolomites were also characterized and found to be consistent with rock mechanics theory and the REM simulation model.

### Dissolution simulation computer programs

For many years the SMRI has had a dissolution program known as SALGAS for controlling the development of a cavity. The original program is on tape. This program was recently adapted for personal computers. The new program is called SALSAS-PC and is available on a floppy disc for IBM or Macintosh personal computers.

### Hydrofrac gradient in gulf coast salt domes McIntosh and Rayburn

The project was started at the Rayburn's salt dome in northern Louisiana, where modified testing equipment was used to measure the hydrofrac gradient in a well. The well was drilled in 1978 and had been used for testing by Louisiana State University under contract to the U.S. Department of Energy. The research procedure consisted of packing off a test section of open hole in salt and applying increased pressure to the formation while recording pressure changes at the depth position. Tests were repeated at various depths ranging from 430 to 750 m. Pressure curves were then interpreted to arrive

at fracture initiation pressures for each given depth. The curves were plotted to display the measured hydrofrac gradient.

During the project's second phase, field work was performed at the McIntosh salt dome (made available to the SMRI by the Olin Corporation) in southern Alabama. Tests were successfully performed at four depths from 215 to 375 m in a well drilled in 1987. The same basic procedure was followed, with pressures recorded and interpreted for fracture initiation and propagation. Different mineralogy and petrofabric at several deeper individual test depths in the McIntosh salt possibly contributed to some variation from results achieved in cleaner salt.

The researchers suggested that a possible correlation exists between the rate of pressure increase and the maximum pressures achieved. The conclusion reached was that the two domes tested were capable of safely handling larger pressures than the regulations in effect at the time allowed.

### Long-term tightness evaluation with brine and gas in salt

This project was undertaken in 1988 for the purpose of investigating the long-term behavior of a liquid-filled brine well. The work was done in a well 1069 m deep in the Etrez bedded salt near Lyon, France. This extensive project included background research, lab testing, field testing and theoretical interpretation of the data. Lab testing included compression and creep testing and hydraulic testing of salt cores. Pressure, volume and temperature measurements versus time were made after instruments were installed in well EZ 58. The first of the field tests consisted of subjecting the well to a series of stepped pressure increases, with each step lasting about 30 days. A pressure gradient was then plotted versus injected volume. The short-term test was then performed by injecting at a constant, faster rate. A plot of the resulting pressure gradient versus time was compared with data from the long-term test. Results were judged similar enough to allow short-term well tests to verify maximum allowable cavern storage pressure. In order to analyze the hydraulic data, the effect of salt permeability and porosity was considered. Results indicated that, during tests, brine volume was lost due to measured salt permeability rather than by leakage due to loss of well tightness. The conclusion reached was that salt mico-permeability is a key parameter in analyzing well tightness under pressure.

This project was the first phase of a continuing SMRI research project. The second phase is discussed in the next section.

## RESEARCH IN PROGRESS

### Long-term tightness evaluation with brine and gas in salt

This is a continuation of the project discussed above. This endeavor has two purposes: determining the allowable pressure gradient for gas compared to liquid, and to investigate the capillary effects on salt permeability. Significance of this research applies to all salt cavern storage operations utilizing non-wetting fluid, i.e. liquid hydrocarbons, natural gas, compressed air, etc.

Procedures will be similar to those used in the first phase of this project, but with nitrogen gas to be injected as the pressurizing agent. Additional down-hole strings are planned for brine evacuation and to prevent crystallization during gas injection. Both surface and down-hole monitoring instrumentation will be used to control injection and record data. As in phase 1, both long and short-term test durations are planned, such that the results will be comparable. The project was scheduled to begin in the fall of 1991, with the final report expected about the spring of 1993. The Institute is funding only a portion of this project. A major contribution is being provided by the researcher, Gaz de France. Valuable input on salt permeability concepts was provided by other SMRI members, some of whom have related research under way.

### SALT-SUBSID — A PC-based subsidence model for design and evaluation of underground openings and casing strings in salt

This program is designed to evaluate subsidence above mines and caverns in either bedded or domal salt. Included is the capability of predicting maximum subsidence and rates above existing or planned openings, with the option of handling superimposed workings. The user will be able to develop and apply a predictive subsidence model to make predictions on subsidence rates at specified locations. Effects of predicted subsidence on casing strings may be shown as maximum stress and strain. Output may be displayed graphically as X–Y or contour plots, and can be in ASCII format. A user's manual will be written for the program after the final version is ready. The SMRI will retain exclusive rights to the program.

### SMART — A new computer dissolution model

The SMRI has had a continuing project to develop an improved mathematical model incorporated in a computer program to simulate salt dissolution in

three dimensions. Much of the work has been completed, but an impasse was reached in solving an algorithm. This has thus far prevented completion of the project. Recent developments indicate that this problem may be close to a solution. Hopefully, this will lead to the completion of the model.

### Permeability studies in relation to stress states and cavern design

This project deals with permeability in relation to stress state and cavern design. The project may eventually include development of a finite element computer program to calculate permeability of salt around solution caverns. A literature search was conducted to address mainly stress-dependent salt permeability and porosity. The theoretical research conducted to date suggests that four basic functions can be used to characterize permeable flow through salt. The four factors are: stress state vs. strain state, strain state vs. strength deterioration, strength deterioration vs. porosity, and porosity vs. permeability. SMRI members will decide whether to proceed with the next step of having a computer simulation program constructed to calculate permeability as a function of both cavern configuration and time.

## OTHER POSSIBLE RESEARCH SUBJECTS

(1) Geological investigations of both natural and man-made dissolution, with the goal of providing advance warning and improved understanding of sink-holes.

(2) Compilation of SMRI research information and references for access by personal computers.

(3) Well and/or cavern plugging and abandonment methods and materials, standard procedural guidelines and government regulations.

(4) Application of geophysical methods to cavern design and monitoring.

## LITERATURE

The Institute has on file literature in the following categories: (1) SMRI Research project reports; (2) SMRI meeting papers; (3) Outside reports and papers. This literature is in the public domain and is available on request from the SMRI.

## MEETINGS

The SMRI normally meets twice a year in the spring and the fall to conduct technical sessions and business of the Institute. Because of the large European membership a meeting is held in Europe every four years. Non-members are free to attend the meetings.

## CONTACT FOR SMRI

For general information on the SMRI, meetings, membership, literature and the SMRI computer programs, contact: Howard W. Fiedelman, Executive Director, Solution Mining Research Institute, 812 Muriel Street, Woodstock, IL 60098-3853, USA. Phone: (+1) 815-338-8579; Fax: (+1) 815-338-1228.

## Solution Mining Research Institute: Membership List

| Member company | Classification | Country |
|---|---|---|
| AKZO Zout Chemie Nederland | Regular | Netherlands |
| AKZO Salt[1] | Regular | U.S.A. |
| AGM | Associate (B) | U.S.A |
| ATOCHEM | Regular | France |
| Azufrera Panamericana | Associate (A) | Mexico |
| Billiton Refractories | Regular | Netherlands |
| Canadian Salt Company[2] | Regular | Canada |
| Cargill Salt | Regular | U.S.A |
| CHEMKOP | Associate (A) | Poland |
| Chuan Dong Salt Factory | Regular | China |
| Compagnie Industrielle et Minière | Regular | France |
| Compagnie des Salins du Midi et Salines de l'est | Regular | France |
| Dow Chemical Company | Regular | U.S.A. |
| Electric Power Research Institute | Associate (A) | U.S.A. |
| Fenix & Scisson[3] | Regular | U.S.A. |
| FMC Corporation | Regular | U.S.A. |
| Gaz de France | Regular | France |
| Golden Storage | Associate (A) | U.S.A. |
| GEOSTOCK | Regular | France |
| IFI Concession de Salines | Regular | Columbia |
| Imperial Chemical Industries (ICI) | Regular | England |
| Industria del Alcali | Regular | Mexico |
| Israel Electric Corporation | Associate (A) | Israel |
| Kavernen Bau-und-Betriebs (KBB) | Regular | Germany |
| MINIERA MONTECATINI | Regular | Italy |
| Morton International | Regular | U.S.A. |
| North American Salt Company | Regular | U.S.A. |
| North American Salt Company[4] | Regular | U.S.A. |
| North American Salt Company[5] | | |
| Sifto Canada | Regular | Canada |
| Olin Corporation | Regular | U.S,A. |
| PB-KBB | Regular | U.S.A, |
| Principia Mathematica | Associate (B) | U.S.A, |
| RE/SPEC | Associate (A) | U.S.A |
| Sales del Istmo | Regular | Mexico |
| Salgema Mineracao | Regular | Brazil |
| Serata Geomechanics | Associate(A) | U.S.A. |
| Shell Development | Associate (A) | U.S.A. |
| SOFREGAZ[6] | Regular | France |
| SOFREGAZ US[7] | Regular | U.S.A. |
| Solvay et Cie | Regular | Belgium |
| Sonar & Well Testing Services[8] | Regular | U.S.A. |
| Texas Brine Corporation | Regular | U.S.A. |
| Vereingte Schweizerische Rheinsalinen (United Swiss Salt) | Regular | Switzerland |

[1]U.S. Subsidiary of AKZO Zout Chemie; [2]Canadian Subsidiary of Morton International; [3]Subsidiary of PB-KBB; [4]Subsidiary of North American Salt (formerly Carey Salt); [5]Canadian Subsidiary of North American Salt (formerly Sifto Salt); [6]Subsidiary of Gaz de France; [7]U.S. Subsidiary of SOFREGAZ; [8]Subsidiary of Texas Brine