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FY15 Report on Lab Thermomechanical Testing

Fuel Cycle Research & Development

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Used Fuel Disposition Campaign
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APPENDIX E
FCT DOCUMENT COVER SHEET [1]

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This deliverable was prepared in accordance with Sandia National Laboratories *(Participant/National Laboratory Name)*

QA program which meets the requirements of

☐ DOE Order 414.1 ☐ NQA-1-2000 ☐ Other

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☐ Signed TR Report or,	☐ Signed PR Report or,
☐ Signed TR Concurrence Sheet or,	☐ Signed PR Concurrence Sheet or,
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Name and Signature of Reviewers

Steve Sobolik Steven R Sobolik

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SUMMARY

Sandia is participating in the third phase of a United States (US)-German Joint Project that compares constitutive models and simulation procedures on the basis of model calculations of the thermomechanical behavior and healing of rock salt (Salzer et al. 2015). The first goal of the project is to evaluate the ability of numerical modeling tools to correctly describe the relevant deformation phenomena in rock salt under various influences. Among the numerical modeling tools required to address this are constitutive models that are used in computer simulations for the description of the thermal, mechanical, and hydraulic behavior of the host rock under various influences and for the long-term prediction of this behavior. Achieving this goal will lead to increased confidence in the results of numerical simulations related to the secure disposal of radioactive wastes in rock salt. Results of the Joint Project may ultimately be used to make various assertions regarding stability analysis of an underground repository in salt during the operating phase as well as long-term integrity of the geological barrier in the post-operating phase

A primary evaluation of constitutive model capabilities comes by way of predicting large-scale field tests. The Joint Project partners decided to model Waste Isolation Pilot Plant (WIPP) Rooms B & D which are full-scale rooms having the same dimensions. Room D deformed under natural, ambient conditions while Room B was thermally driven by an array of waste-simulating heaters (Munson et al. 1988; 1990). Existing laboratory test data for WIPP salt were carefully scrutinized and the partners decided that additional testing would be needed to help evaluate advanced features of the constitutive models. The German partners performed over 140 laboratory tests on WIPP salt at no charge to the US Department of Energy (DOE).

The focus of this study was to complete a limited number of independent, adjunct laboratory tests in the United States to assist in validating the results being provided by the German facilities. We performed tests under a Quality Assurance procedure involving a reviewed and approved Test Plan. The testing protocol consisted of completing confined, triaxial, constant-strain-rate strength tests of intact WIPP "clean" salt at temperatures of 25°C and 100°C and multiple confining pressures. Assuming the adjunct tests substantially agree with the German test results, the overall database of test results will be considered more robust and confidence in the bases for assessing adequacy of heat-generating waste disposal systems will be enhanced. This adjunct testing program represents a subset of the extensive test matrix completed in Germany and will aid in reducing uncertainties that remain in the technical bases for a generic safety case for disposal of heat-generating waste in salt. These laboratory studies are consistent with the aims of international salt repository research programs.

ACKNOWLEDGMENTS

The authors acknowledge Michael Schuhen and Terry MacDonald of Sandia Carlsbad for retrieving large-diameter core as soon as possible after the WIPP shutdown. Till Popp from Institut für Gebirgsmechanik GmbH Leipzig (IfG) provided stress-strain plots for comparable test performed in Germany. This work was supported by the US DOE, Office of Nuclear Energy (NE), Fuel Cycle Research and Development (FCR&D) Program.

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ACRONYMS

DOE	Department of Energy
FCR&D	Fuel Cycle Research and Development
FCT	Fuel Cycle Technologies
FY	Fiscal Year
IfG	Institut für Gebirgsmechanik GmbH Leipzig
NE	Office of Nuclear Energy
PI	Principal Investigator
R&D	Research and Development
SDR	Sandia Delegated Representative
US	United States
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION

This is a preliminary report of laboratory thermomechanical testing, which investigates triaxial strength of WIPP clean salt. Analyses of the data and interpretation of comparisons with German data are envisioned within the framework of salt research and development efforts in fiscal year (FY) 16 and is expected to be reported in a Technical Letter Memorandum authored by RESPEC. This limited study completed independent, adjunct laboratory tests in the US to assist in validating the results being provided by the German facilities. The testing protocol consisted of completing confined triaxial, constant-strain-rate strength tests of intact WIPP clean salt at temperatures of 25°C and 100°C and multiple confining pressures. The stratigraphy at WIPP also includes salt which has been labeled “argillaceous.” The much larger test matrix conducted in Germany included both the so-called clean and argillaceous salt. When combined, the total database of laboratory results will be used to develop input parameters for models, to assess adequacy of existing models, and to predict material behavior. These laboratory studies are also consistent with the aims of international salt repository research programs.

The goal of this study was to complete a subset of a test matrix on salt from the WIPP undertaken by German research groups. The work was performed by RESPEC in Rapid City, South Dakota.

2. PRELIMINARY RESULTS

A total of eight confined triaxial, constant-strain-rate strength tests were performed on intact WIPP clean salt specimens. Table 2-1 provides a summary of the stress and temperature conditions for the tests. These test conditions are a subset of tests performed at German laboratory facilities (Salzer et al. 2015).

Table 2-1. Summary of Triaxial Strength Test Conditions

Confining Pressure, σ_3 (MPa)	Strain Rate (1/s)	Temperature (°C)
0.2	$1x10^{-5}$	25.0
1.0	$1x10^{-5}$	25.0
3.0	$1x10^{-5}$	25.0
20.0	$1x10^{-5}$	25.0
0.2	$1x10^{-5}$	100.0
1.0	$1x10^{-5}$	100.0
3.0	$1x10^{-5}$	100.0
20.0	$1x10^{-5}$	100.0

Preliminary results are shown in Figures 2.1 through 2.4. Figures 2.1 and 2.2 plot differential stress versus axial strain for the tests run at 25.0°C and 100.0°C, respectively. Also shown on the plots is the test data obtained from tests under the same condition performed at the German laboratories. Axial strains agree well between the two different datasets. At higher confining pressures, the RESPEC tests do not reach the same maximum differential stress or peak axial strain limits as the German data. This is a limitation of the axial force capacity of the RESPEC test frame.

Figures 2.3 and 2.4 show volumetric strain versus axial strain for tests run at 25.0°C and 100.0°C, respectively. In some cases, jacket leaks occurred and volumetric measurements were truncated. As shown, the trends are similar at lower confining pressures, however, the RESPEC data show significantly more compaction of the specimens. The main purpose of the volumetric strain measurements is to determine the point at which dilation (volume expansion due to micro-fracturing) occurs. RESPEC also recorded acoustic velocities during the testing and these data will be analyzed to determine dilation limits and make comparisons of techniques.

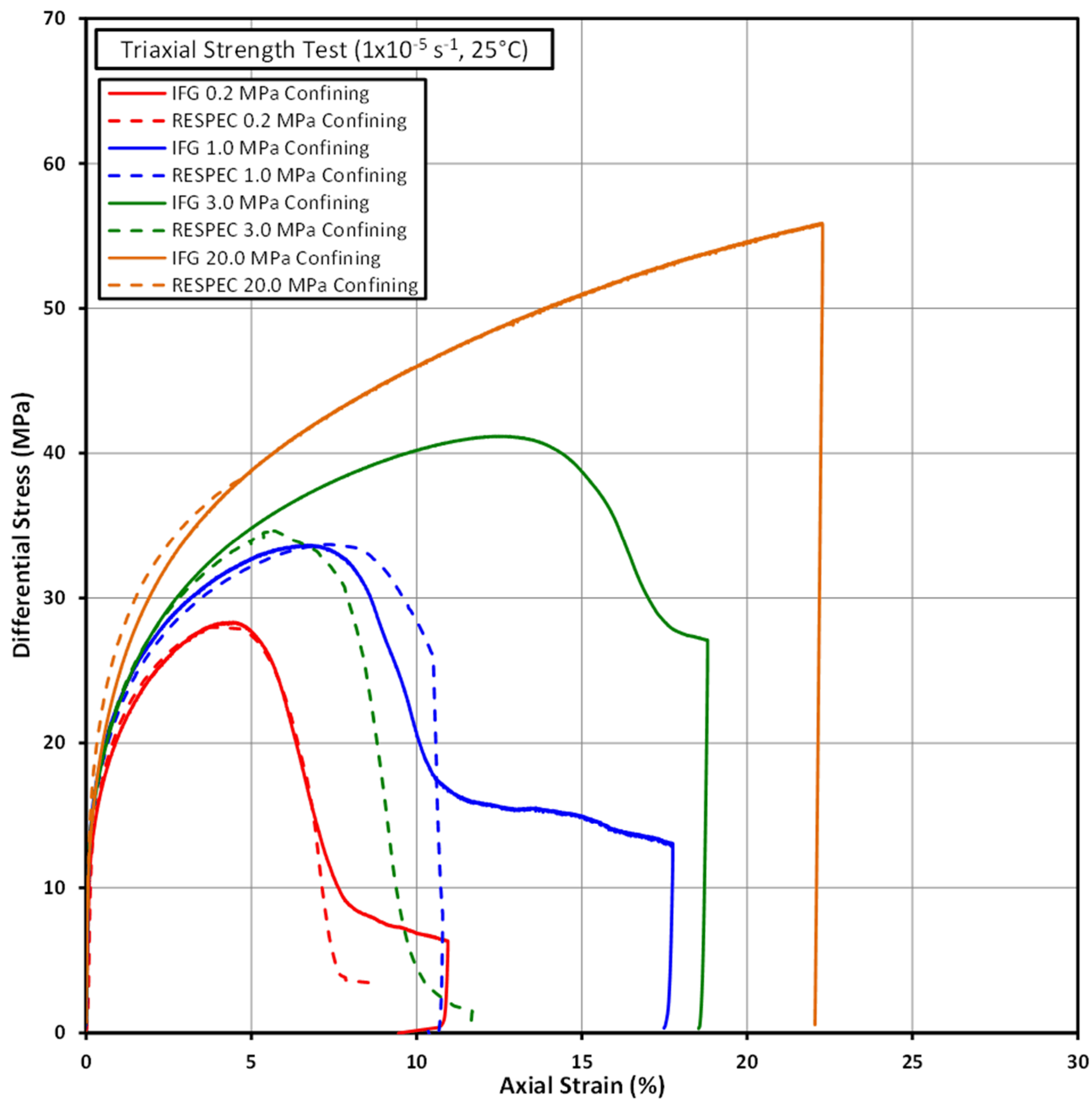

Figure 2.1. Differential Stress Versus Axial Strain for Triaxial Strength Tests at 25°C.

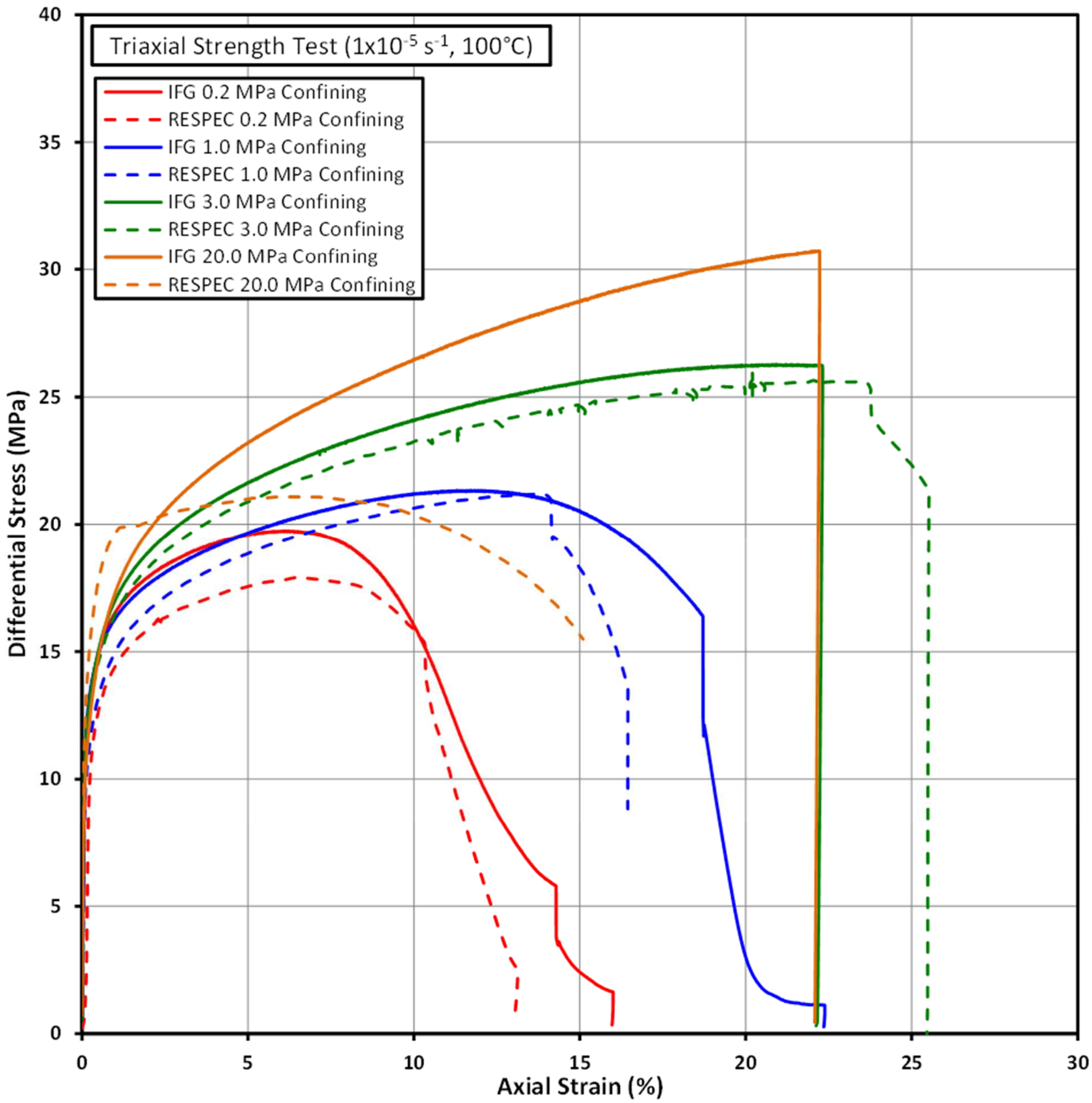

Figure 2.2. Differential Stress Versus Axial Strain for Triaxial Strength Tests at 100°C.

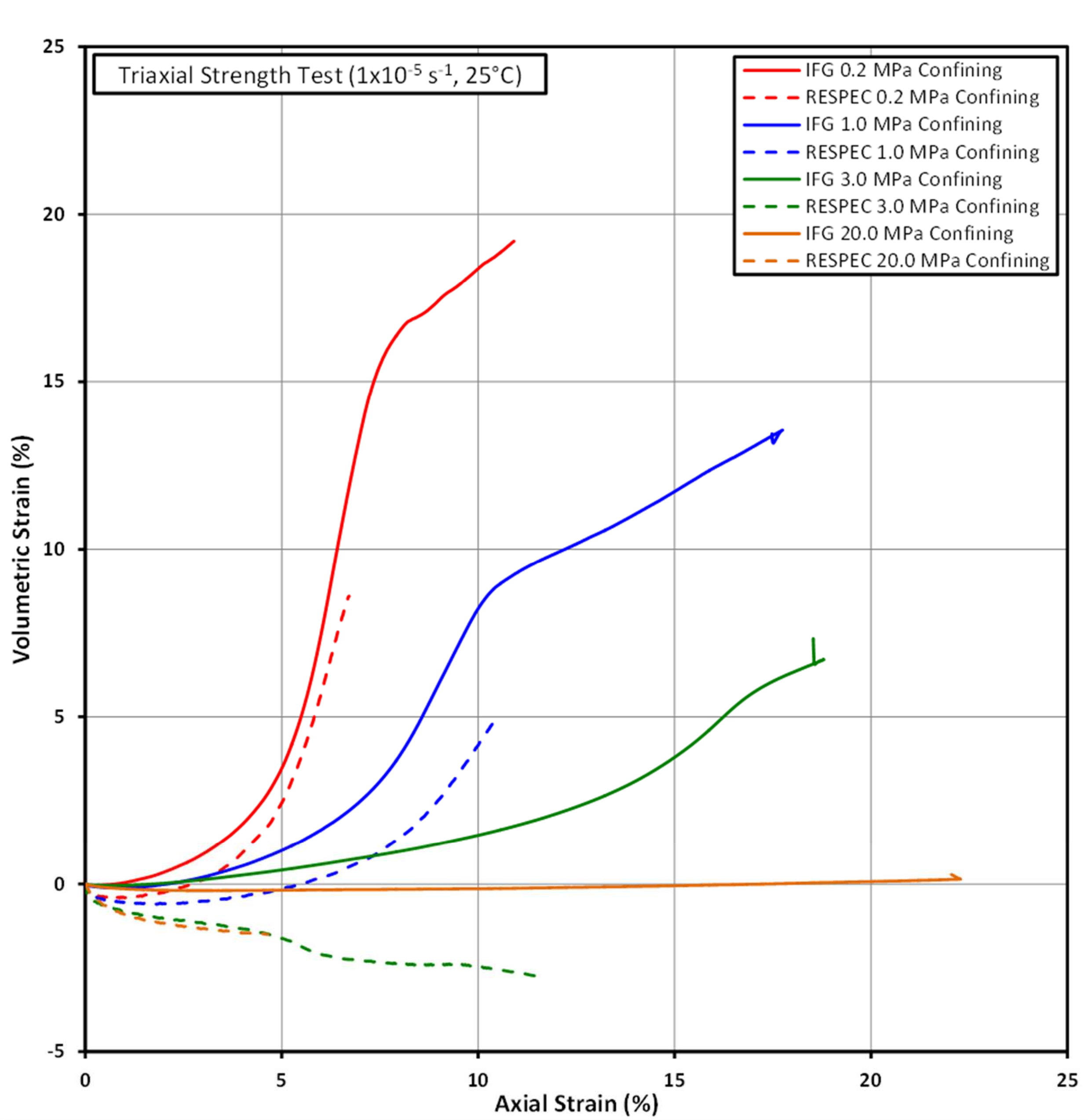

Figure 2.3. Volumetric Strain Versus Axial Strain for Triaxial Strength Tests at 25°C

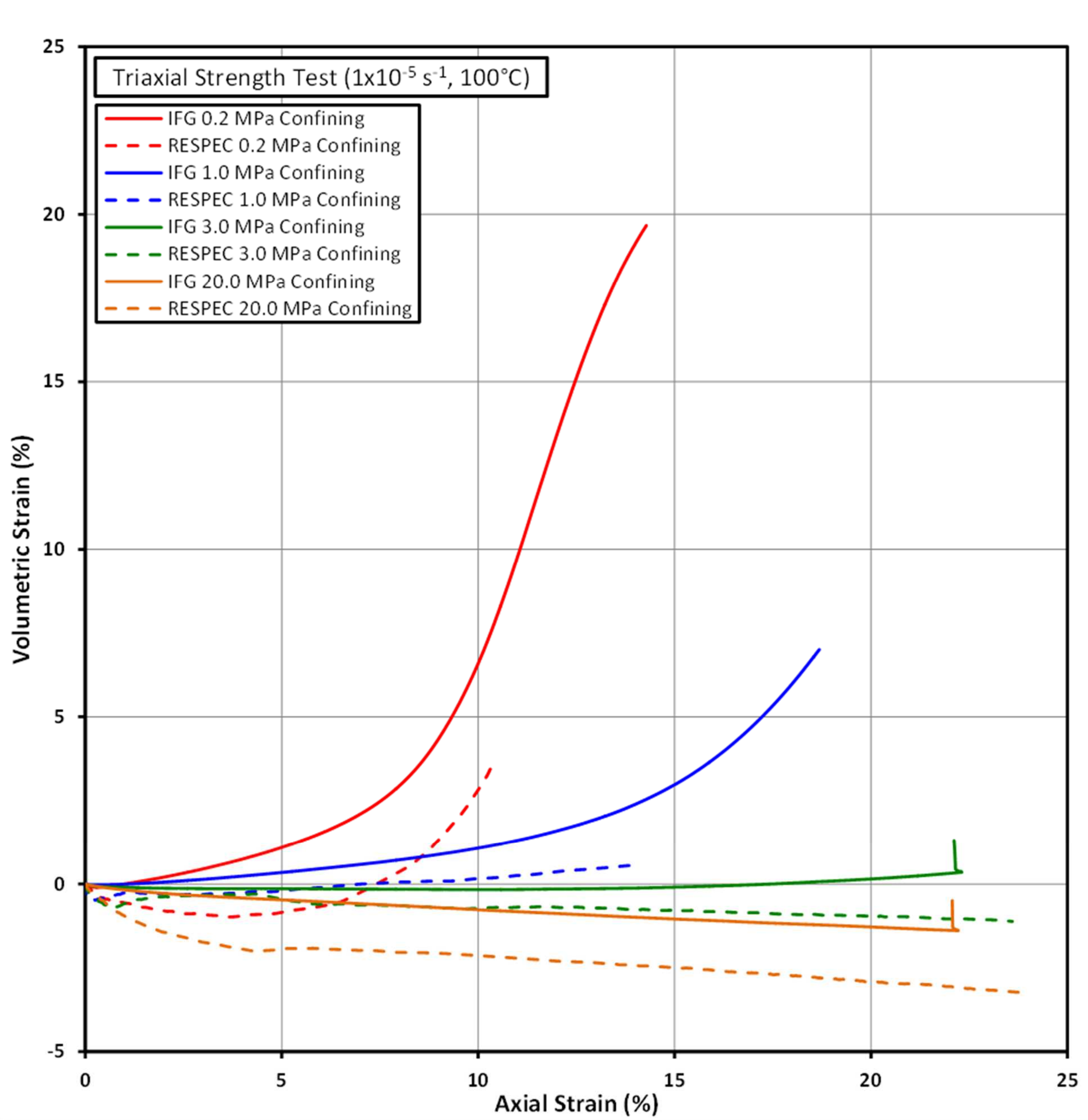

Figure 2.4. Volumetric Strain Versus Axial Strain for Triaxial Strength Tests at 100°C.

3. SCOPE OF WORK

This preliminary report has been compiled because a Level 3 Milestone [M3FT-15SN08180212] had been entered into FY15 DR Salt Research and Development (R&D) Milestone status. An analysis report on the technical results of these investigations was not funded in FY15 and was not part of the scope of work in the contract with RESPEC. The scope of work is detailed below.

Task 1. RESPEC will prepare a Test Plan that meets Quality Assurance requirements imposed by the Department of Energy as outlined in the Fuel Cycle Technologies (FCT) Quality Assurance Program Document dated December 20, 2012. The Contractor shall satisfy training requirements, write, review and approve a Test Plan within 30 calendar days after start of the contract. In the event Sandia does not retrieve WIPP core and provide it to the Contractor for test specimen preparation by the delivery date of the Test Plan, a day-to-day schedule slippage will be implemented.

RESPEC satisfied all of the training requirements and the final approved Test Plan was signed on October 6, 2014. RESPEC received 12-inch diameter WIPP salt core on December 15, 2014.

Task 2. RESPEC will conduct laboratory experiments. A preferred sub matrix from the complete list being undertaken by German laboratories includes four tests at a strain rate of $10^{-5}s^{-1}$ and temperature of 25°C and four tests at a strain rate of $10^{-5}s^{-1}$ and temperature of 100°C. Samples for testing will be provided by the Sandia Delegated Representative (SDR) with Quality Assurance chain of custody. RESPEC will prepare test specimens to final test dimensions and tolerances.

All testing was completed by RESPEC using the protocol described in this task.

Task 3. A RESPEC representative will attend a Joint Project meeting scheduled to be held in Albuquerque, NM, on May 28–29, 2014.

Two RESPEC representatives attended the meeting in Albuquerque, NM.

These newly derived test results will be discussed with the Germans at the 6th International US/German Workshop in Dresden, Germany held in September 2015.

More thorough analysis and interpretation of results will be forthcoming as a Technical Letter Memorandum if such a deliverable is identified and funded in FY16 Work Packages in PICS.

4. REFERENCES

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