SANDIA NATIONAL LABORATORIES
CIVILIAN RADIOACTIVE WASTE MANAGEMENT
TECHNICAL PROCEDURE (TP)

TP-262

CONSTANT STRAIN RATE COMPRESSION EXPERIMENTS AT NEW ENGLAND RESEARCH, INC.

Revision 0

Effective Date: _Nov. 04, 2003__

__Original Signed by Peter J. Boyd____________ ___10/29/2003____
Author: Peter J. Boyd Date

___Original Signed by Ronald H. Price__________ ____11/03/2003___
Technical Reviewer: Ronald H. Price Date

___Original Signed by James F. Graff__________ ____11/04/2003___
Quality Assurance Reviewer: James F. Graff Date

(Reviewer signatures above document the review and resolution of comments.)

REVISION HISTORY

Revision	Description
0	Initial issue

1.0 Scope and Objective

This procedure applies to the performance of mechanical property experiments in compression at a constant axial strain rate. These experiments are performed in support of work of the Yucca Mountain Project, and will be performed at New England Research, Inc., White River Junction, Vermont.

2.0 Prerequisites

Before performing work under this technical procedure, personnel must be trained by the author or Principal Investigator (PI) and demonstrate their proficiency in performing the work in this procedure. The PI has the responsibility for generating a record of the personnel proficiency training, as well as the responsibility that work is performed and documented in accordance with this procedure.

The personnel performing the work are responsible for ensuring that a controlled copy of this procedure is available and used for performing this work.

3.0 Description of Activity

This TP details procedures for laboratory mechanical experiments on rock specimens. The experiments will be performed on right-circular cylinders of tuff with a nominal length to diameter ratio of 2:1. The laboratory mechanical experiments will be run in compression at a constant axial strain rate under specified temperature and pressure conditions.

For this experimental series, outputs from a variety of transducers (load, pressure, temperature, and strain) may be monitored. The output voltage from each device is conditioned, amplified, converted to digital format, and recorded as a function of time. The outputs from the devices are recorded with a PC-based data acquisition system (DAS). All devices (with the exception of strain gages, which are calibrated after the specimen is set up using a shunt resistor in parallel with one leg of the Wheatstone bridge) will be calibrated, in accordance to AP 12.1Q, *Control of Measuring and Test Equipment and Calibration Standards*.

For the constant strain rate experiments, the loading apparatus is operated in displacement feedback provided by the axial extensometer mounted on the test system. The displacement is controlled to within $\pm 10^{-3}$ mm when the system is in the displacement mode.

During each test the axial and radial deformations of the specimen are measured with appropriate gages (e.g., Linear Variable Differential Transformers [LVDTs] or strain gages).

One way to measure radial strain is with a radial displacement gage similar to the one developed by Holcomb and McNamee (1984). Their gage consists of an LVDT mounted in a ring, which is spring loaded against the surface of the specimen. The core of the LVDT is connected to the spring. As the specimen diameter changes, the spring deflects, changing the position of the core within the barrel of the LVDT in direct proportion to the radial displacement. Similarly, the axial LVDT components (typically two sets) are held securely in rings attached near the ends of the specimen, either directly on the specimen, or on the end caps. The axial LVDT components are aligned so as to sense the axial deformation experienced by the specimen.

When strain gages are used they are generally epoxied to an appropriate jacket on the specimen. Three gages are typically used, all located at the midheight of the specimen. Two of the gages are located in diametrically opposed positions, with their respective grids aligned so as to sense axial deformation. The third gage is aligned so as to sense radial deformation.

The outputs of the axial and lateral gages are fed into signal conditioners where the signals are demodulated and amplified. The output signals (volts) from the conditioners are fed into an A/D converter in a microcomputer and stored in digital format.

The force on the test column is measured with a load cell. The accuracy of the load cell is better than 2.0% of its full-scale output. The output of the load cell is amplified with a signal conditioner before it is presented to the A/D converter.

4.0 Operations

4.1 System Checks

Prior to any series of compression tests, when test results are suspect, or at other times specified by the PI, an evaluation of the operation of the entire test procedure will be performed. The evaluation consists of performing the experimental procedures (in Section 4.2.1) on a specimen material having known elastic properties (Young's modulus and Poisson's ratio). The test conditions will be as specified in the procedure, with the confining pressure at 5.0 MPa, no pore pressure, and ambient temperature. An acceptable check will result in a determination of the elastic properties to within ±5% of the published values. Otherwise, the overall procedure must be checked before tests on rock specimens can be performed, or continued. The proper operation of the test apparatus, measurement devices, and data acquisition system are verified by a successful check. The check shall be documented on the Test Data Report (TDR) in Appendix A, noting that the test is a system check.

4.2 Constant Strain Rate Experiments on Rock Specimens

Specimens of tuff will be tested to failure at a constant strain rate under specified temperature and pressure conditions. The following section includes the step-by-step procedures for the mechanical property experiments.

4.2.1 Experiment Procedures

1. The specimen designated for testing will be prepared per TP-51, entitled "Preparing Cylindrical Samples, Including Measurement of Dimensional and Shape Tolerances." If drying and/or saturation are required, use SNL TP-65, entitled "Drying Geological Samples to Constant Weight" and/or SNL TP-64, entitled "Vacuum Saturation of Geologic Core to Constant Weight." All initial conditions, work activities and a list of all measurement devices (with relevant information) will be documented on the TDR.

2. Visually inspect the rock core. Any major surface irregularities/imperfections should be noted on the TDR, along with a sketch and/or photograph of the specimen.

3. When required, jacket the specimen in an appropriate material.

4. If strain gages are to be used, seat the jacket, and apply gages in appropriate locations.

5. Place the specimen on the base plug of the test apparatus, and swage the ends of the specimen to the end pieces.

6. Where LVDTs are to be used, place the gages in the appropriate set-up on the sample assembly. The axial gage(s) is (are) positioned in such a way to ensure that the line of the displacement measurement(s) is (are) parallel to the axis of the specimen. The radial displacement gage is positioned in such a way to ensure that the line of the displacement measurement: (1) passes through, and (2) is perpendicular to the axis of the specimen.

7. Attach the strain measurement devices to their appropriate feedthru electrical connectors.

8. Make the final mechanical adjustments on the LVDTs, if in use.

9. Position the sample assembly to ensure that all loading column components are coaxial.

10. For confined compression tests, load the sample assembly into the pressure vessel.

11. Where required, apply the defined confining and pore pressures.

12. Advance the loading platen and apply a differential stress of approximately 0.5 MPa on the specimen. This seats the specimen and all the elements in the loading column. This procedure is accomplished by manually operating the servo-controller in load feedback.

13. Change the servo-controller feedback to displacement control. Retract the loading platen until there is no force on the loading column and, if elevated temperatures are to be used, leaving space for the unloaded expansion of the sample assembly.

14. If the test is to be performed at elevated temperature, increase the temperature to the defined value at a rate of $\leq 2^{o}$C/min. Allow thermal equilibration for a minimum of two hours.

15. Advance the loading platen and apply a differential stress of approximately 0.5 MPa on the specimen. Back the platen off until the load is off, but the platen continues to just touch the specimen.

16. Initiate data acquisition. The amplified outputs from all transducers are monitored and recorded using a microprocessor based DAS. The conditioned output signals from the strain devices, pressure transducers, thermocouples and

the force cell are presented to an A/D converter, and the voltage data are stored on the data acquisition computer.

17. Adjust the setting on the displacement rate controller to the displacement rate that corresponds to the nominal strain rate to be used in testing.

18. After a final check of all the transducer values, load the specimen to failure (50% of yield stress for system checks).

19. Terminate data acquisition.

20. Unload the specimen until the loading piston is out of contact with the specimen.

21. If required, allow the specimen to cool to ambient conditions.

22. Where elevated pressures were applied, decrease them to ambient conditions.

23. Remove the specimen from the test apparatus and examine the manner in which the specimen failed. Record the observations on the TDR.

4.2.2 Data Processing

Reduce the data. Commercial software with a built-in linear fitting function can be used. The voltages recorded by the DAS will be converted to engineering units by employing simple mathematical formulae that incorporate the scale factors determined for the individual measurement devices during calibration. Ultimate strength, and the following elastic constants will be computed:

a) Young's modulus, E (GPa), where E= Δaxial stress/Δaxial strain and

b) Poisson's ratio, ν, where ν = Δradial strain/Δaxial strain.

The elastic constants will be computed from the uploading data collected between approximately 25 and 50% of the failure strength (10 and 50% of yield stress for system checks). Axial stress is computed by dividing the axial force by the initial cross-sectional area of the specimen. Stress will be reported in MPa. When using LVDTs, axial strain is obtained by dividing the axial displacement by the gage separation. The measured displacement is corrected for any endcap contribution, if the support rings for the axial LVDTs are attached to the endcaps. The average axial strain recorded by the two axial devices is used in the moduli calculations. Radial strain is computed by dividing the change in specimen diameter observed by the radial displacement gage by the initial specimen diameter. Where strain gages are used, their outputs are multiplied by their respective scale factors, as determined by their response to the shunt resistor. All strains will be reported as strain, percent strain, millistrain, or microstrain.

4.2.3 Electronic Media and Hard Copy Handling

Data in digital format, and hard copy documents are handled so as to maintain their integrity, and protect information from damage, or destruction. All digital and hardcopy documentation of the testing will be retained at NER for a minimum of three years following the end of the testing sequence.

Data collected during the testing is stored directly on to the hard disk of the data acquisition computer in the laboratory. At least once each day, the data files are accessed, over the NER internal network, by the operator using the non-laboratory computer on which data processing will occur. The original, umodified content of the accessed raw file is also maintained on the data processing computer. The raw data will be manipulated in order to convert the voltage information to engineering units from which to determine the mechanical properties. System checks serve to verify proper input, transfer and manipulation of the data, so as to insure completeness and accuracy of the information, including changes thereto. The file generated by the data processing software program will include the unmodified raw data and the processed data, and it will also be retained on the hard disk of the operator's computer.

All computers are password protected, and behind a firewall. Access to the computers is limited to the employees qualified for YMP activities. Backups of non-laboratory computers are automatically performed nightly, with a redundant technique. All backups contain the actual date and time stamps of the original files, so no time stamp information is lost. The date and time that the backup was performed is also stored. Integrity verification is done by using checksums on source and backup files.

Multiple labeled, and redundant copies of all backups are kept offsite on removable hard disks in order to maintain retrievability. One copy, on disk, is rotated into onsite use on a weekly basis, while rotating another copy offsite. Additional integrity checks are performed when an offsite copy is rotated into redundant onsite service. In addition, the operator will backup all files on the data processing computer, weekly, by copying them to a compact disk that will be stored offsite along with the hard copy documents.

Hard copy documentation of the work will be maintained by ensuring that there is a copy of completed originals available offsite at all times. The operator will photocopy any completed documents. The copies will be stored offsite until the documents have been formally submitted to the YMP. All completed documents and copies will be stored in an environment suitable for their maintenance.

5.0 Saftey

There should be no safety hazards other than the normal hazards of the equipment. Operations will be in accordance with safety requirements of the facility where the work is being performed and those of the employer of person(s) performing the work.

6.0 Nonconformance, Deviations, and Corrective Actions

Any nonconformances or deviations must be reported to the PI as soon as possible. Deviations, deficiencies and corrective actions must be determined and documented in accordance with AP-16.1Q, *Condition Reporting and Resolution*.

7.0 QA Records

QA records, and any corrections or changes thereto, generated as a result of implementing this procedure will be prepared and submitted as inclusionary QA records (QA:QA) by the PI in accordance with AP-17.1Q, *Records Management*. These records include:

Proficiency training records (Section 2.0)

Test Data Reports (TDR) (Section 3.0)

Calibration records (if applicable)

8.0 References

Holcomb, D. J. and M. J. McNamee, 1984. *Displacement Gage for the Rock Mechanics Laboratory*. SAND 84-0651. Albuquerque, New Mexico: Sandia National Laboratories.

TP-51, *Preparing Cylindrical Samples, Including Measurement of Dimensional and Shape Tolerances*

TP-64, *Vacuum Saturation of Geologic Core to Constant Weight*

TP-65, *Drying Geological Samples to Constant Weight*

AP-12.1Q, *Control of Measuring and Test Equipment and Calibration Standards*

AP-16.1Q, *Condition Reporting and Resolution*

AP-17.1Q, *Records Management*

TEST DATA REPORT (TDR)

Appendix A

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Test Plan Number / Rev.:________________________________Specimen ID:__________________________

Moisture Condition:_______________Length: ____________Diameter:____________Weight:_____________

Dry Bulk Density:_________Saturated Bulk Density: _________Grain Density:_________Porosity: _________

Required Test Conditions (e.g., strain rate, pressures, temperatures):_________________________________

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Test Apparatus Used:_________________________________Latest System Check Date:_________________

Measurement Devices (Some categories not relevant to all devices) / Label unused channels “Inactive”:

Raw DAS Channel (Column)	Device/Model/Serial#	Latest Calibration Date	Gain Setting	Gage Factor	“Zero” Voltage	Shunt Voltage Difference	Scale Factor: Units/Volt	Notes

DAS raw voltage data file: ____

Processed data file:____

Operator(s): Name:________________________Sign/Date:____________________________________

Name:________________________Sign/Date: ____________________________________

Name:________________________Sign/Date: ____________________________________

Name:________________________Sign/Date: ____________________________________

Organization / Location of Testing:____

TEST DATA REPORT (TDR)

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Continuation Page

Specimen ID: ___________________________

Operator(s): Name:________________________Sign/Date:____________________________________

Name:________________________Sign/Date: ____________________________________

Name:________________________Sign/Date: ____________________________________

Name:________________________Sign/Date: ____________________________________