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Status Report on the Spent-Fuel Test-Climax,  
Nevada Test Site: A Test of Dry Storage of  
Spent Fuel in a Deep Granite Location

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STATUS REPORT ON THE SPENT FUEL TEST-CLIMAX, NEVADA TEST SITE:  
A TEST OF DRY STORAGE OF SPENT FUEL IN A DEEP GRANITE LOCATION\*

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ABSTRACT

The Spent Fuel Test-Climax (SFT-C) is located at a depth of 420 m in the Climax granite at the Nevada Test Site. The test array contains 11 canistered PWR fuel assemblies, plus associated electrical simulators and electrical heaters. There are nearly 900 channels of thermal, radiation, stress, displacement, and test control instrumentation. This paper is a general status report on the test, which started in May 1980.

INTRODUCTION

The Spent Fuel Test-Climax (SFT-C), a test of the retrievable dry geologic storage of spent fuel assemblies from an operating commercial power reactor, is located at the Nevada Test Site (NTS) of the U.S. Department of Energy. The SFT-C was authorized for construction in June 1978, and all of the fuel was in place by the end of May 1980. The test objectives, technical concepts and rationale, and a general description of the test were presented at the Waste Management 80 Conference.<sup>1</sup> A more detailed presentation of the technical concept is also available.<sup>2</sup>

FACILITY CONSTRUCTION AND GEOMETRY

Facility construction required excavation of about 6700 m<sup>3</sup> of the granitic intrusive. Nearly 1100 m of cored holes ranging in diameter from 38 mm to 152 mm were drilled in support of

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in situ properties and instrumentation tasks.<sup>3</sup> The SFT-C facility consists of a central canister storage drift 4.6 m x 6.1 m high x 64 m long, two parallel 3.4 m x 3.4 m heater drifts, and a tail drift (Fig. 1). The spent fuel canisters are lowered to the test level (420 m below surface) through a steel-lined 0.76 m diameter shaft. Each canister is stored in one of 17 lined emplacement holes 0.61 m in diameter.

This test uses thirteen encapsulated intact PWR spent fuel assemblies from the Florida Power and Light reactor at Turkey Point, Florida. Eleven of the thirteen assemblies are stored in the center drift of the SFT-C. The remaining two assemblies are stored at the E-MAD facility in southwestern NTS, and used for periodic exchanges with those in the test. Also deployed are six electrical simulators which, together with the spent fuel canisters, form a 17-position linear array.

In order to simulate the thermal field expected in a very large repository, electrical heaters are deployed in two drifts on either side of the central storage drift. These heaters together with the storage drift array provide an overall thermal field, within a 15-metre by 15-metre repository model cell, resembling that expected at the center of a very large repository (Fig. 2). The six electrical simulators provide the means for an additional experiment --- the direct comparison of the effect on the rock of heat alone versus heat plus radiation.

#### FUEL HANDLING OPERATIONS

The fuel-handling system designed and built for this test was not intended to be prototypical of that employed in a large repository. The intent was to provide an inexpensive yet safe and reliable fuel-handling system for the purposes of the test. Nevertheless, the handling system does demonstrate several aspects of interest to the general public: (1) that the handling of highly radioactive material is a fairly straightforward matter involving available technology, (2) that the emplacement and retrieval of spent fuel in a storage array is also relatively straightforward, and (3) that remote-control technology allows nuclear waste handling with minimal radiation exposure. During the initial emplacement period (April 18 to May 22, 1980), we operated at an emplacement rate of one assembly every two days. The underground system is capable of handling six cans per day --- a rate near that required for an operating repository. The fuel handling system is described in detail elsewhere.<sup>4,5</sup>

In order to demonstrate retrievability, there are a series of planned fuel exchanges. The first two were successfully completed in January and October 1981 and a third is currently planned for July 1982. Another result of these exchanges is that fuel will be available for post-test characterization prior to the termination of the entire test.

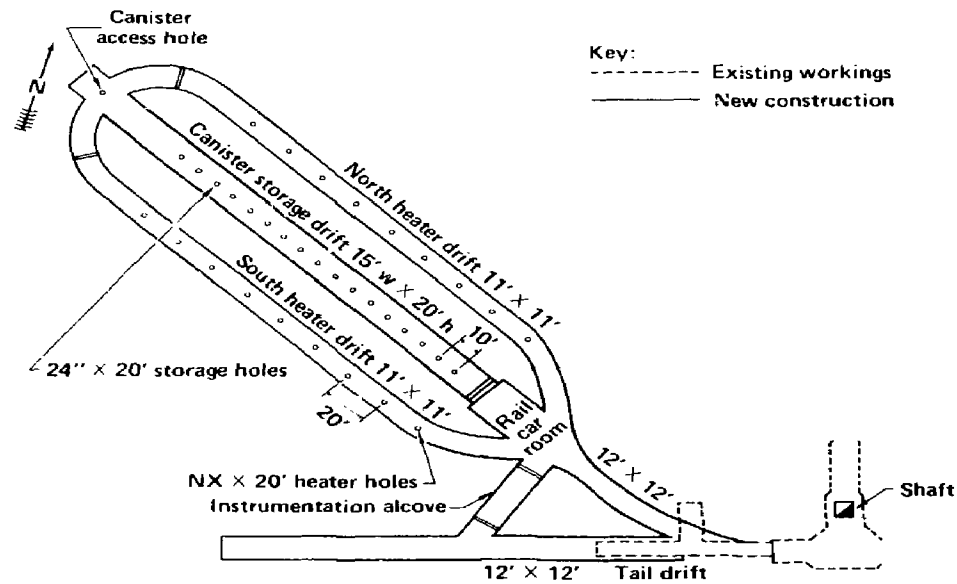


Fig. 1. Spent Fuel Test layout

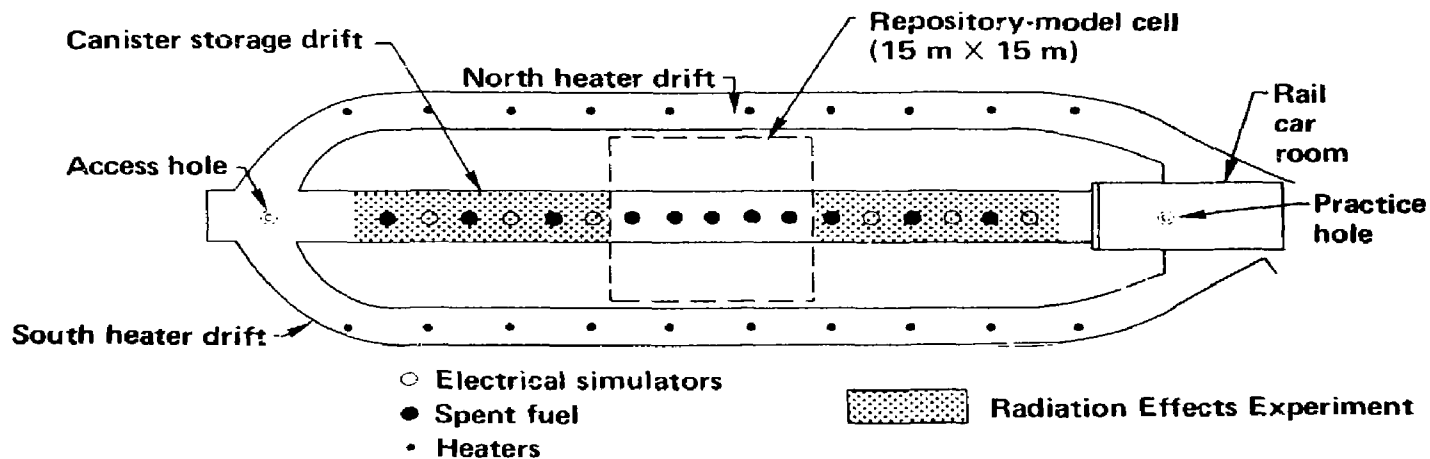


Fig. 2. Plan view of SFT-C showing repository-model cell and radiation effects experiment

## INSTRUMENTATION AND IN SITU MEASUREMENTS

Pretest investigations have provided properties for use in calculating the response of the SFT-C to excavation and thermal loads and have provided a better understanding of the test environment. A small-scale heater test provided thermal properties<sup>6</sup>. Hydrology studies bounded the location of the regional water table in the stock, some 160 m below the test level.<sup>7</sup> In-situ stress determinations,<sup>8</sup> a campaign of field properties measurements,<sup>9</sup> and extensive tunnel mapping<sup>10</sup> provided important boundary conditions and input properties for thermo-mechanical calculations.

The test is extensively instrumented.<sup>11,12</sup> Rock temperature, air temperature, flowrate and humidity, radiation, rock stress and rock displacement are all recorded remotely and automatically by a computer-based data acquisition system. This same system is used for test control and status monitoring.

Of the nearly 900 channels of data being recorded, nearly 600 are for thermal measurements. Rod and wire extensometers and 3-component fracture monitors account for another 170 channels. Eighteen vibrating-wire stressmeters are deployed to measure changes in stress. The remaining instruments monitor for the presence of ionizing radiation, radioactive gases, and the general status of test hardware.

Nearly two years into the test, most instrumentation and the data acquisition system are functioning reliably. Two exceptions are the linear potentiometers associated with near-field rod extensometers and the vibrating-wire stressmeters. Extensive failures have occurred in these units, requiring replacement.<sup>13</sup> These failures have led to one of the most significant technical activities on the test: evaluation of instrument survivability in the test environment. The second generation of instruments is currently functioning normally.

## RESULTS OF CALCULATIONS AND FIELD MEASUREMENTS

The Spent Fuel Test-Climax (SFT-C) is the largest rock volume under test, using either electrical heaters or actual high level waste, in the world. The seventeen canisters are spaced 3m apart in a 50m long array and the volume of significantly heated rock is about  $10^4 \text{ m}^3$ . Thus, it provides a unique opportunity for the evaluation of thermal and thermo-mechanical models which will be used in a predictive sense for repository design, licensing, construction, and operation. Radiation transport codes may also be evaluated.

### Thermal

The thermal modeling for this test has been extensive,<sup>14,15</sup> and the agreement between measured and calculated thermal histories has been good.<sup>16</sup> Both in the near field

(Fig. 3) and in the intermediate field (Fig. 4), agreement between calculated and measured temperatures is within a few degrees.

The Spent Fuel Test-Climax has provided an opportunity to evaluate performance of repository-size openings under actual field conditions. Under these conditions, factors such as the ventilation system, the lighting system, and other sources of heat or transfer mechanisms must be considered. They must be properly evaluated in repository design and performance assessment.

Within the first year, thermal peaks within the fuel, on the canister surfaces, on the rock surface of the storage hole, and some 50 centimetres into the rock were attained (Fig. 3). Throughout much of the 15-metre by 15-metre repository model cell at the center of the SFT-C, maximum temperatures will have been attained by the end of the second year of the test (May 1982). Therefore, little additional significant thermal information is expected to be gained until fuel is withdrawn and high thermal gradients are caused by the cool-down period.

#### Thermomechanical

One early experiment in the SFT-C, the "mine-by", provided an opportunity to measure the displacement and stress changes resulting from the mining of the facility itself for later comparison with those caused by introduction of the heat-producing waste. Pre-test calculations indicated that these would be approximately the same magnitude. Agreement between calculated and measured response to excavation was poor.<sup>17</sup> Additional studies with 2-D jointed-rock models resulted in no better agreement.<sup>18</sup> Despite the disagreement between measurements and calculations of the response to excavation, it is significant that the mining of the facility itself has been shown to disturb the rock apparently as much as the introduction of the heat-producing wastes.

Calculations for the SFT-C were made using the ADINA and AFINAT codes<sup>19</sup> which, like most widely available thermomechanical models, assume continuum properties of the rock. For jointed rock like the Climax granite, it may be necessary to model both ubiquitous and discrete fractures. Many problems, such as the anomalous "mine-by" response, may require 3-D models with ubiquitous and discrete fracture models. Such models currently do not exist.

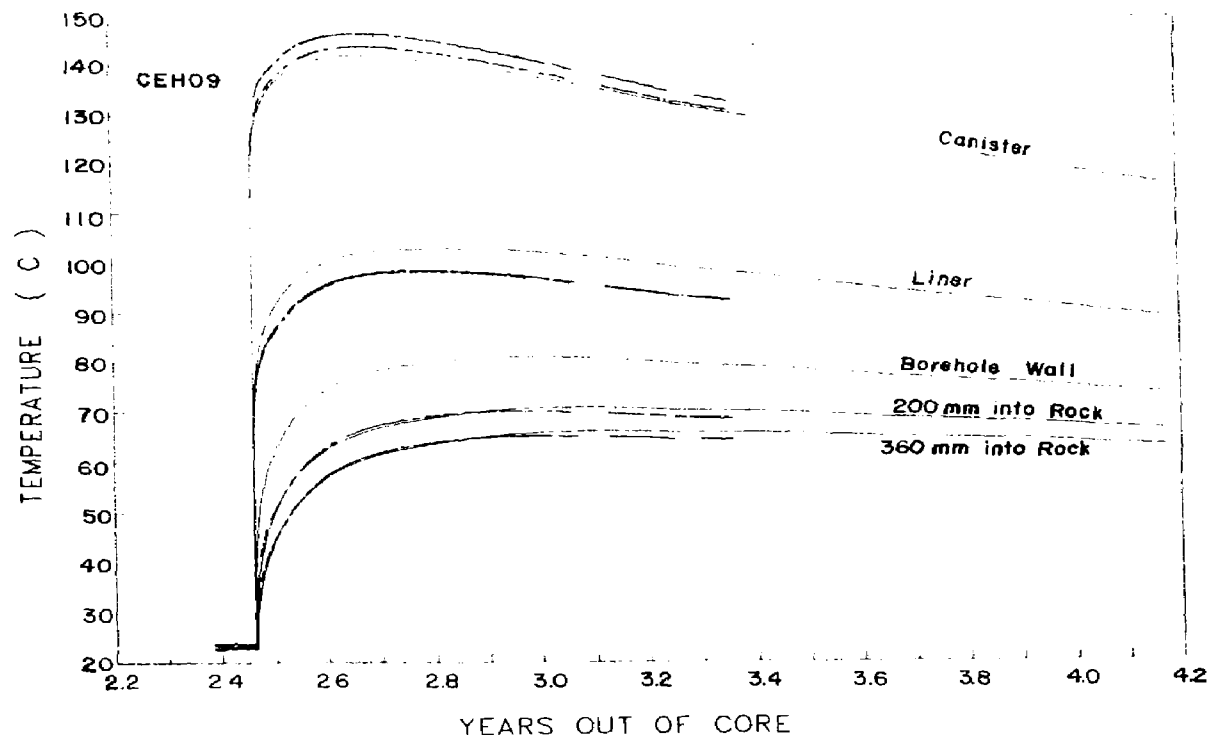


Fig. 3. Calculated and measured temperature histories near the Spent Fuel Assembly in CEH09



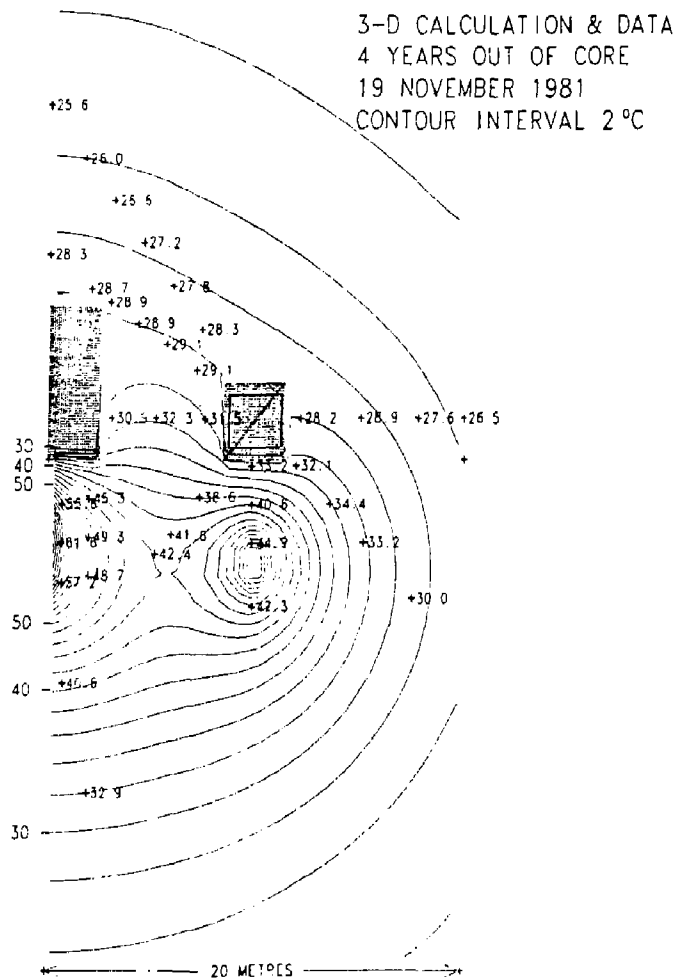


Fig. 4. Calculated thermal contours and measured temperatures at the SFT-C after 1.5 years of heating

Although analysis of displacement and change in stress data is currently incomplete, preliminary analyses indicate that thermally induced displacements and stresses are being calculated quite well. The continuum codes are apparently able to model the major phenomena involved. This is evidenced by the good agreement in calculated and measured curve shapes, including inflections and changes in slope of displacement histories.

#### Radiation Transport

Radiation transport calculations have been performed to determine the radiation dose to the granite surrounding the emplacement holes.<sup>20</sup> The results of these calculations and field measurements of gamma and neutron doses will be compared in later reports.

#### CONCLUSION

The Spent Fuel Test-Climax has provided experience working under repository conditions in crystalline rock. At present it is the only storage of high-level waste or spent-fuel in a deep geologic environment anywhere in the world. Thus there is a high level of public interest, evidenced by the fact that there have been 215 tours, through February 1982, involving 2461 people from U.S. and 23 foreign countries.

The technical goals will not be fully attained until the test has been terminated and decommissioned, but a great deal of information has already been gained during the test. Many of the activities associated with the construction and operation of a deep geologic repository in hard crystalline rock have already been demonstrated, and data relevant to repository design and performance is being collected. These data can be used to validate thermal and thermomechanical models which will be used in a predictive sense for repository design, licensing, construction, and operation.

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