

**COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN NO. 3.2.1.9
POTENTIALLY ADVERSE CONDITION: EVIDENCE OF IGNEOUS
ACTIVITY**

3.0 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA:

3.1 Acceptance Review:

In conducting the Acceptance Review for docketing, the staff will compare information in the License Application (LA) concerning the Potentially Adverse Condition (PAC) on evidence of igneous (i.e., volcanic/magmatic) activity during the Quaternary Period with the corresponding section of the FCRG and with the resolution status of staff objections to the LA submittal in the Open Item Tracking System (OITS). The staff will then determine whether this information meets the following Acceptance Criteria:

- (1) The information presented in the LA is clear, completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and properly referenced.
- (2) DOE has either resolved, at staff level, NRC objections to the LA submittal which apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions which precluded resolution of each objection.
- Described all attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful Compliance Review or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews:

Compliance determinations undertaken by NRC staff will consider whether Acceptance Criteria specified for each of the following Compliance Reviews have been met. Results of the compliance determinations should be documented by the staff in the Safety Evaluation Report (SER) to provide the basis for actual Evaluation Findings.

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(15)

The staff will determine whether the assessment of presence or absence of igneous activity has been accomplished in an acceptable manner, and whether description of the geology of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(c)(15). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE's analysis of the geology of the site as related to igneous activity and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(c)(15). For 10 CFR 60.21(c)(1)(ii)(B) the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses of the degree to which igneous activity has been characterized and found to be present. The staff will review and evaluate information provided by DOE in the LA to demonstrate either the absence of igneous activity or the extent to which its presence may have been underestimated or undetected, taking into account the degree of resolution achieved by the investigation. The staff will also determine whether the analyses and investigations have been accomplished in an acceptable manner and whether lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(c)(15). For 10 CFR 60.21(c)(1)(ii)(F) the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses and models used to predict future conditions and changes in the geologic setting as related to igneous activity. The staff will also determine whether the analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests, monitoring data, or natural analog studies for assisting review of 10 CFR 60.122(c)(15).

In accomplishing the Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) and 10 CFR 60.122(c)(15), the staff will need to determine whether the following Acceptance Criteria have been met:

- (1) Assumptions and analysis methods used by DOE to evaluate the information presented determine the absence or acceptably describe the presence of the PAC and encompass appropriate ranges of relevant parameters.
- (2) DOE can demonstrate that the extent of characterization is sufficient to define Quaternary igneous activity in the geologic setting and to assure that potential effects on critical pathways for radionuclide migration have been adequately described.
- (3) DOE can demonstrate that the scope of investigations has bounded the range of conceptual models supported by the available data.
- (4) DOE investigations at the site and in the geologic setting have been conducted in sufficient detail to assure that potential effects of igneous activity are well enough understood to be appropriately considered in performance assessment and design.
- (5) Results of DOE investigations are not in conflict with published results from various staff and CNWRA investigations or other independent studies, or the conflicts are adequately explained.

To make compliance determinations for these Acceptance Criteria, the staff must review the program of exploration, laboratory testing, and analysis implemented by DOE. This review will include, but may not be limited to, aspects discussed below under subsections 3.2.1.1, 3.2.1.2, and 3.2.1.3. These subsections present Acceptance Criteria for field exploration methods, laboratory testing programs, and computer modeling.

3.2.1.1 Field Exploration

The field exploration program should be sufficient to bound the characteristics of Quaternary igneous features and events in the geologic setting including number of events, size of event(s), location of the event(s) with respect to the repository, source and character (e.g., explosivity) of event(s), physical features of the crust/mantle that may be associated with the event(s), and area affected by the event(s).

Field Mapping - The staff will review and assess the results of DOE's field geologic mapping programs for defining the distribution and characteristics of igneous features including the relationship to structural and tectonic features to determine whether the following Acceptance Criteria have been met:

- (1) Areal extent of geologic mapping, in concert with other aspects of the field exploration program, is sufficient to define the Quaternary igneous activity in the geologic setting including its absence or the degree to which it is present, present but underestimated, or present but undetected.
- (2) Scale of mapping, including scales of aerial photographs used as base maps, is sufficient to provide the accuracy and precision required for locating and mapping the igneous features, including the effects of hydrothermal events.
- (3) Field verification of igneous features and characteristics which have been mapped demonstrates that they have been accurately located, described and reported by DOE.
- (4) Alternative interpretations of the data have been provided when appropriate.

Geophysical Testing - The staff will review and assess the results of geophysical tests (e.g., seismic reflection, seismic refraction, seismic tomography) conducted at and around Yucca Mountain by DOE for assessing characteristics and distribution of igneous features to determine whether the following Acceptance Criteria have been met by the geophysical testing methods:

- (1) Number and location of geophysical tests, in concert with other aspects of the field exploration program, are sufficient to define the Quaternary igneous activity in the geologic setting area including its absence or the degree to which it is present, present but underestimated, or present but undetected.
- (2) Detection capabilities of the testing methods have been evaluated and appropriately reported by DOE.
- (3) Resolution capabilities of the methods have been evaluated and appropriately reported by DOE.
- (4) Techniques for collection of field data have been shown to be appropriate, limitations of the techniques are understood and have been accounted for, and limitations and inherent uncertainties have been carried through the required analyses.
- (5) Capabilities and limitations of the data processing techniques have been evaluated and appropriately reported by DOE.

- (6) Independent processing of selected data performed by the NRC staff demonstrates that the reproducibility and sensitivity of the results to the various input parameters have been accurately described by DOE.
- (7) Alternative interpretations of the data have been provided when appropriate.

Drilling and Borehole Logging - The staff will review and assess DOE's program of drilling and borehole logging to determine whether the following Acceptance Criteria have been met:

- (1) The program of drilling used during site characterization, in concert with other aspects of the field exploration program, is sufficient to define the Quaternary igneous activity in the geologic setting including its absence or the degree to which it is present, present but underestimated, or present but undetected.
- (2) Field assessment of drilling techniques demonstrates that the techniques and their associated limitations have been accurately evaluated and reported by DOE.
- (3) Evaluation of the core logging program indicates an acceptably accurate portrayal of the conditions encountered by the drilling has been reported by DOE. The evaluation will place emphasis on amounts and areas of core loss, locations of fracturing and faulting, zones of alteration, locations of lithologic and stratigraphic contacts, and general lithologic descriptions. It will be based on standard industry practices for borehole logging.
- (4) Comparison of the results of geophysical logging with the core and accompanying descriptive core logs shows results which are consistent.
- (5) Alternative interpretations of the data have been provided when appropriate.

Other Exploration Programs - The staff will review and assess the results of all other exploration methods (e.g., trenching, natural analogs) used by DOE to determine whether the following Acceptance Criteria have been met:

- (1) Number and location of planned tests, in concert with the field exploration program, are sufficient to define the Quaternary igneous activity in the geologic setting including its absence or the degree to which it is present, present but underestimated, or present but undetected.
- (2) Detection capabilities of the methods have been evaluated and appropriately reported by DOE.
- (3) Resolution capabilities of the methods have been evaluated and appropriately reported by DOE.
- (4) Techniques for collection of field data have been shown to be appropriate, limitations of the techniques are understood and have been accounted for, and limitations and inherent uncertainties have been carried through the required analyses.
- (5) Capabilities and limitations of the data processing techniques have been evaluated and appropriately reported by DOE.

- (6) Independent processing of selected data shows the results can be reproduced and demonstrates that the sensitivity of the results to the various input parameters has been accurately described by DOE.
- (7) Alternative interpretations of the data have been provided when appropriate.

3.2.1.2 Laboratory Testing

The laboratory testing program should be sufficient to determine the ages of the Quaternary igneous event(s), their petrographic and petrologic make-up and their geochemistry.

The staff will review and assess procedures and results of the various laboratory testing programs used by DOE, including those from such tests as petrographic analyses, petrologic analyses, chemical analyses, and age determinations, to determine whether the following Acceptance Criteria have been met:

- (1) Approaches used in sampling various igneous/magmatic features are either standard or, if not standard, have been documented such that the sampling pattern can be repeated by those trained in the technique.
- (2) Procedures used in the analyses are either standard or, if not standard, have been documented such that the tests can be repeated by those trained in the technique.
- (3) Sufficient documentation exists to demonstrate that the procedures were properly followed.
- (4) Where standards have been used, they can be traced to a national or international standard.
- (5) Where calibration curves have been used, they are sufficiently documented to permit a thorough evaluation.
- (6) Results of all analyses have been documented by DOE.
- (7) If test results have been rejected, the basis for such rejection has been clearly established and reported by DOE. An assessment of whether rejection has unreasonably biased the results should also be made.
- (8) Uncertainties in the analysis have been appropriately reported.
- (9) Alternative interpretations of the data have been provided when appropriate.

3.2.1.3 Computer Modeling

The computer modeling of Quaternary volcanic/magmatic activity should be sufficient to assure an appropriate range of reasonable and realistic models has been considered.

The staff will review and assess the results of DOE's computer modeling to determine whether the following Acceptance Criteria have been met:

- (1) Modeling incorporates reasonable and realistic bounds on the range of permissible parameters and input data.
- (2) Codes used have been shown to be mathematically correct and to adequately represent the phenomena.
- (3) Resultant output of the models and codes can be compared to results from other similar models and codes.
- (4) The range or bounds of the results have been correctly reported along with the results of sensitivity and uncertainty analyses.
- (5) Alternative models and interpretations have been provided when appropriate.

3.2.2 Detailed Safety Review Supported By Analysis for 10 CFR 60.122(c)(15) for Key Technical Uncertainty - Low Resolution of Exploration Techniques to Detect and Evaluate Igneous Features

In addition to the safety review of information provided by DOE as discussed in Section 3.2.1, the staff will perform a separate detailed safety review supported by analysis in relation to a Key Technical Uncertainty (KTU) concerned with low resolution of exploration techniques in detection and evaluation of igneous features. Because of this KTU, the review and analysis will be required for all exploration methods used by DOE to investigate igneous features and characteristics.

Special emphasis will be given during this review to consideration of potentially critical igneous features and characteristics, the presence of which is suggested by interpretation of data derived from several different techniques. The staff will need to consider limitations and uncertainties in the data base to assure that interpretations do not underestimate the presence of the PAC. In cases where igneous features have been suggested based on interpretation of data from a single technique, the staff must exercise professional judgment in determining whether a reasonable effort has been made to explore for the features and assess the degree to which the PAC is present, present but underestimated, or present but undetected. The staff must also consider whether it may be possible to define the features through expanded use of the technique or determine if alternate explanations of the data are reasonable through application of other techniques. Examples of potential igneous features derived from interpretation of results of a single investigative technique are shown in studies conducted by Evans and Smith (1992) and Brocher et al (1990). Subsurface data obtained in the Yucca Mountain area using seismic tomography alone have been interpreted by Evans and Smith (1992) to suggest potential zones of partial melt in the lower crust-upper mantle and controlling subsurface structures. Brocher and others (1990) have interpreted their high-amplitude reflection seismic data to suggest possible magma chambers in the crust near Yucca Mountain. However, both groups of researchers point out that alternative interpretations are possible for their respective data sets, reinforcing the importance of the concept of multiple working interpretations in analysis of geological data and hinting at the importance of using multiple methods, when feasible, to narrow the range of possible interpretations.

In addition, the staff will evaluate cases where expert judgment has been used to provide supplementary information in the absence of adequate data derived from a detailed exploration program. During this review, the staff will examine the bounds on the data supplied to and by the various experts and determine the sensitivity of the various models to these bounds. The models to be used in this evaluation are presently unspecified, but may include those developed from NRC research programs. Initial results

of NRC research conducted to evaluate the resolution capabilities of magnetic and seismic tomographic methods are expected to be available in May, 1994. This is an area needing further development. DOE's approach and results will be considered acceptable relative to this KTU if the following Acceptance Criteria have been met:

- (1) Interpretations drawn from the separate exploration techniques corroborate one another, or differences are adequately explained.
- (2) A logical range of reasonable and conservative alternative interpretations is presented when contradictions in interpretations do exist.
- (3) Uncertainties in the interpretations have been adequately documented and addressed by DOE.
- (4) Expert judgement is not used as a substitute for data where collection of data is reasonably achievable.

3.2.3 Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations for 10 CFR 60.122(c)(15) for Key Technical Uncertainty - Development and Use of Conceptual Tectonic Models as Related to Igneous Activity

Using all information gathered in the lower-level reviews, the staff will compare results of DOE's conceptual and numerical models with results from models independently developed by other agencies, the staff, and the CNWRA to determine whether models being used by DOE provide an adequate explanation of igneous phenomena in the vicinity of Yucca Mountain. The staff will also conduct independent investigations to compare results of the models developed to address igneous activity with those used to analyze structural deformation and earthquake activity in the Yucca Mountain region. The purpose of this comparison will be to determine whether the igneous activity models are compatible with those applied to describe other tectonic phenomena, such as structural deformation and earthquakes. Models addressing tectonic phenomena need further development which may be accomplished by NRC or CNWRA staff for use in this comparison. Finally, the staff will review the documentation, logic, assumptions, bounding conditions, and bounding assessments for the various models. The various DOE models will be considered acceptable relative to this KTU if the following Acceptance Criteria have been met:

- (1) DOE models are consistent with the field and laboratory data.
- (2) Assumptions incorporated into the models are clearly described by DOE.
- (3) Model descriptions clearly reflect the degree of resolution of the experimental and investigative techniques applied to acquire data for the modeling, including the degree of resolution of data related to what could be present but undetected due to limitations of the methods applied.
- (4) The models provide an adequate qualitative and quantitative explanation of features which are present or could be present but undetected.
- (5) DOE models and results are compatible with results of analyses using independent models such as those developed by NRC or CNWRA staff.

- (6) DOE models are compatible with those proposed for other tectonic phenomena such as structural deformation and earthquake activity.
- (7) DOE models either fit within the range of reasonable and acceptable alternative models or, if they are bounding models, clearly demonstrate that features which may be present and undetected have been taken into account.

3.2.4 Detailed Safety Review Supported by Independent Tests, Analysis, or Other Investigations for 10 CFR 60.122(c)(15) for Key Technical Uncertainty - Inability to Sample Igneous Features

Using all information gathered in the lower level reviews, the staff will assess how well the uncertainty related to inability to sample various igneous features has been considered in the DOE models and analyses. Independent analyses and investigations conducted by NRC Research or the CNWRA may be used in this assessment. This is an area needing further development. Consideration of this KTU will be deemed acceptable if, in the judgement of the staff, the uncertainty in interpretations of features which cannot be sampled directly has been appropriately incorporated by DOE into the modeling and its results.

3.3 Rationale For Review Procedures and Acceptance Criteria:

3.3.1 Rationale for Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(15)

The compliance determination Safety Review for evidence of igneous activity is based on standard scientific and industry practice. While many of the individual investigative techniques are used in mining and the oil industry, the combination of techniques and the reporting standards are more typical of those required in most investigations for other nuclear facilities. Qualifications and experience of the reviewers will be of critical importance to the review process. Success of the review will be strongly dependent on professional judgement of the reviewers, who must possess a thorough knowledge of geology of the site and its geologic setting. The Safety Review of 10 CFR 60.122(c)(15) will incorporate the requirements of 60.21(c)(1)(ii)(A), (B), and (F) as they relate to igneous activity through Acceptance Criteria based on the regulatory requirements of 10 CFR 60.122 and 10 CFR 60.21. The criteria emphasize assessment of methods for determining absence of igneous activity or describing what may be present or present but undetected or underestimated such that assumptions used in performance assessment and design regarding evidence of igneous activity since the start of the Quaternary Period will not lead to underestimation of potential effects of this condition.

3.3.2 Rationale for Detailed Safety Reviews of 10 CFR 60.122(c)(15)

Important output from review of this PAC will be a range of conceptual models for igneous processes and events which can be used to develop various mathematical models for application in performance assessment, including consideration of probability and consequences of potential volcanic or magmatic activity during the period of performance. Development of these models will be hampered by the poor resolution capabilities of many of the exploration techniques in a geologic setting such as Yucca Mountain, and by the fact that many of the causative features of igneous activity lie deep in the crust and sampling of these features is not possible. Therefore, characteristics of many igneous features can only be hypothesized. Although it is standard practice in both industry and research to use multiple exploration techniques and it is possible to eliminate certain models through use of multiple exploration techniques, there will remain an unknown residual uncertainty in the results and in the models used to explain the results. There are no basic standards by which to evaluate the models since the phenomena being

investigated are the subject of ongoing research efforts. Uncertainty in the features, potential models, and underlying processes is the subject of ongoing research.

While best estimates and ranges in estimates may provide the regulatory input for final performance assessment models, bounding analyses will be necessary to provide reasonable assurance that potential igneous activity during the period of performance will not adversely affect public health and safety. The research effort should help define many of these bounds, and final results of this phase of the review must rely on the professional judgement, experience, and qualifications of the review personnel. It is expected that model results will not be completely validated and verified. However, through site characterization, proper use of analogs, and careful application of professional judgement the results can be validated and verified to the degree necessary to provide bounding results and the confidence necessary to make a regulatory decision in regard to this PAC.

4.0 IMPLEMENTATION:

4.1 Review Responsibilities:

The review responsibilities for this review plan are as follows:

Lead:	HLWM/HLGE	Geology Section
Support:	HLWM/HLHP	Repository Performance Assessment Section
	HLWM/HLPD	Quality Assurance Section

4.2 Interfaces:

4.2.1 Input Information

Information derived from activities related to other review plans will provide input important for considering evidence of igneous activity during the Quaternary. A list of review plans for which this interface is anticipated to be particularly important is presented in the following table.

Input Information	Review Plan No.
Geologic System Description	3.1.1
Tectonic and Structural Models:	
(a) Regional	3.1.1.x.x
(b) Local	3.1.1.x.x
Stress Field:	
(a) Regional	3.1.1.x.x
(b) Local	3.1.1.x.x
Nature and Rates of Quaternary Igneous Activity	3.1.1.x.x, 3.2.1.1

Input Information	Review Plan No.
Nature and Rates of pre-Quaternary Igneous Activity	3.1.1.x.x
Historical Seismicity	3.2.1.6
Exploration Results: (a) Borings (b) Geophysics (c) Mapping (d) Geodetics	3.1.1.x.x 3.1.1.x.x, 3.1.2.6 3.1.1.x.x 3.1.1.x.x
Structures: (a) Regional (b) Local	3.1.1.x.x 3.1.1.x.x
Geologic History	3.1.1.x.x, 3.1.1.x.x
Laboratory Results: (a) Geochemistry (b) Age determinations (c) Mineralogy	3.1.1, 3.1.3 3.1.1, 3.1.3 3.1.1, 3.1.3
Correlation of Seismicity with Tectonic and Structural Features	3.2.1.7

4.2.2 Output information

Output from activities associated with this review plan will provide specific information important for use in review plan 6.1 as the following table indicates.

Output Information	Review Plan No.
Models of Quaternary Volcanic Activity	6.1
Nature and Rates of Quaternary Igneous Activity (from this plan and Review Plan No. 3.2.1.1)	6.1

5.0 EXAMPLE EVALUATION FINDINGS:

The staff should consider the Example Evaluation Findings presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual Evaluation Findings resulting from the Acceptance Review for docketing and the Compliance Reviews. The actual Evaluation Findings resulting from the Compliance Reviews, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review:

The NRC staff finds the information presented by DOE on the PAC concerned with evidence of igneous activity during the Quaternary Period is (is not) acceptable for docketing and compliance review.

5.2 Findings for Compliance Reviews:

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(15)

The NRC staff finds the conclusions presented by DOE on the PAC related to evidence of igneous activity during the Quaternary are (are not) acceptable and there is (is not) reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(c)(15) will be met. The staff is developing supporting Example Evaluation Findings for each regulatory requirement for inclusion in subsequent revisions of this review plan.

6.0 REFERENCES:

Brocher, T.M., P.E. Hart, and S.F. Carle, "Feasibility Study of the Seismic Reflection Method in Amargosa Desert, Nye County, Nevada," USGS-OFR-89-133, United States Geological Survey, 1990

Evans, J.B., and M. Smith III, "Teleseismic Tomography of the Yucca Mountain Region: Volcanism and Tectonism," in Proceedings of the Third Annual Conference, High Level Radioactive Waste Management, Las Vegas, Nevada, 1992

Nuclear Regulatory Commission, "Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, Disposal of High-Level Radioactive Waste in Geologic Repositories," Office of Nuclear Regulatory Research, NUREG-80804, December 1983.

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository" (FCRG), Office of Nuclear Regulatory Research.

Nuclear Regulatory Commission, "License Application Review Plan for the Review of a License Application for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste, Yucca Mountain, Nevada" (LARP), Office of Nuclear Material Safety and Safeguards.

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CENTER FOR NUCLEAR WASTE
REGULATORY ANALYSES

011745 JAN 26 8

NOTE TO: Larry McKague, Geologic Setting
Program Element Manager
Center for Nuclear Waste Regulatory Analyses

SUBJECT CODE 703.6
PROJECT NO. 20-5702-422

FROM: Keith I. McConnell, NRC-GS Program Element Manager
Geology and Engineering Branch
Division of High-Level Waste Management

SUBJECT: TRANSMITTAL OF PRELIMINARY NRC STAFF APPROVAL OF THE COMPLIANCE
DETERMINATION METHOD FOR REVIEW PLAN 3.2.1.9: POTENTIALLY ADVERSE
CONDITION: EVIDENCE OF IGNEOUS ACTIVITY

The purpose of this note is to transmit the subject compliance determination method that has received preliminary approval by the NRC staff. Final approval of the CDM is subject to our review and resolution of any comments or changes made by the Center for Nuclear Waste Regulatory Analyses. This is the first CDM developed for a potentially adverse condition, as such, it may require revision as other PAC CDMs are developed and the process and knowledge base matures.

Enclosure: As stated

cc: BJYoungblood/HLWM
JLinehan/HLWM
JTrapp/HLWM
DLoosley/PMDA
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MARK-UP VERSION SHOWING
CHANGES PREPARED BY
G. STREWALT.

11 March 94
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OFFICE:	HLGE <i>JK</i>	HLGE <i>JK</i>	HLGE	HLGE <i>JK</i>
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DATE:	01/14/94	01/14/94	01/14/94	01/14/94

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