UNITED STATES
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MEMORANDUM FOR: William J. Dircks, Director
Office of Nuclear Material Safety
and Safeguards

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER # 50 CRITICALITY SAFETY GUIDANCE

INTRODUCTION

The report, Nuclear Safety Guide (issued in 1956 as a classified AEC report, LA-2063, and in 1957 as an unclassified report, TID-7016) and its Revision 1 (published in 1961), have been used extensively by the nuclear industry in design of fissile systems and by the NRC as technical basis for regulatory actions to avoid criticality accidents.

Since the issuance of the Guide and its Revision 1, many improvements have been made in nuclear criticality safety, additional experimental data have been developed and calculational methods have been improved. Consequently, the NRC funded a project at the Oak Ridge National Laboratory to assess this new information and incorporate the results in a 2nd revision of the report.

The results of this study, which have been published as NUREG/CR-0095, "Nuclear Safety Guide, TID-7016, Revision 2," are transmitted with this RIL. This revision provides a better interpolation, extension and understanding of available information, especially important in areas previously addressed by undefined but adequate safety margins. The nature of the report itself has also changed in that previous versions were intentionally conservative in their recommendations whereas Revision 2 does not have these safety margins included in the guidance.

This 2nd revision of the Nuclear Safety Guide report is not a replacement for the previous reports but is a supplement to them which, if used for criticality safety evaluations, must be done with adequate precautions. The format of Revision 2 offers the advantage that flexible and identifiable conservatisms can be added to the data presented in the Guide. It is the responsibility of those using the Guide to impose appropriate safety factors consistent with the possible normal and abnormal credible contingencies of the operations as revealed by their review. It is also the responsibility of the NRC staff to require appropriate safety factors from licensees to assure adequate safety margins.

In many cases, licensees will use analysis methods more sophisticated than those provided in the Safety Guide, such as Monte Carlo codes like KENO. However, the Guide is useful to those licensees who are unable to use the Monte Carlo codes.

DISCUSSION

The report, NUREG/CR-0095, cites seven supercritical accidents in chemical processing equipment in the United States, but none that have been associated with mechanical processing, storage or transportation. After the report was published, an eighth criticality occurred in chemical processing equipment at the Allied Chemical Corporation facilities at the Idaho National Engineering Laboratories. All eight occurred in aqueous solutions, five involved highly enriched uranium and three involved plutonium. The consequences have been two fatalities, nineteen significant over-pressures, no equipment damage, no loss of fissile material and no danger to the general public. None of the incidents are attributable to faulty criticality information, to an error in its interpretation or to the conservatisms applied. Rather, in each case, the cause was related to difficulties with equipment or to procedural inadequacies and violations or combinations of these.

The present Safety Guide report is an expansion and extension of American National Standards dealing with criticality safety and also includes these standards by reference, e.g., N16.1, "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," and N16.5, "America National Standard Guide for Nuclear Criticality Safety in the Storage of Fissile Materials."

Technical guidance on limits of criticality safety are presented in the Safety Guide for individual units (Chapters II and III) and for arrays of units (Chapter IV). Examples of application of the analysis methods developed in the Guide are presented for processing plants in Chapter V.

One of the advantages of the new NUREG/CR-0095 compared to older versions is that new data are utilized. Data used in previous reports are updated and expanded with experimental data and results from validated analysis methods. Thus, the methods presented in the current report for establishing criticality limits require less interpolation and extrapolation than in previous guides, therefore, resulting in less uncertainty in critical parameters. In addition, the new data sources have been used to develop criteria for new systems. Specifically in Chapter IV are presented data for determination of criticality indices for uranium and plutonium

systems as a function of chemical and isotopic form, density, hydrogen content, mass and unit cell size. The cells are assumed to be concrete reflected and the method is used to determine the number of units (units can be similar or different) that can be safely stored. A relationship is also presented between the criticality index and the transportation index required for shipping radioactive materials. This method is more generally applicable than methods in previous versions of the report.

A minor error was found in the calculation on page 96. Although the formulation of equations 4.5 and 4.6 are correct, the example given on page 96 should be 0.718m rather than 7.18m as indicated.

EVALUATION

The Nuclear Safety Guide report received wide peer review before it was published. Comments were solicited from all members of ANS Working Group 8.7 of which the author is chairman, and from many of the members of the ANS Subcommittee 8 on Fissionable Material Outside Reactors. These comments were considered in preparing the final version of the Guide. Two other projects sponsored by the NRC being performed in Mr. Thomas' organizational unit provide additional assurance that the most valid and current data, both experimental and analytical, were used in preparing the Safety Guide. These are (1) the SCALE code development which includes the Monte Carlo criticality code KENO, and (2) review of ongoing criticality experimental programs. These factors, as well as no finding of major technical errors by the NRC staff lead to the conclusion that the data presented in the Safety Guide are as accurate as is currently possible. However, because the current report does not include conservative factors as in previous guides, it may not be suitable for direct application to licensing of systems containing fissile materials. Nevertheless, the report should be useful to the NRC licensing staff as a supplement to previous versions rather than a replacement, and may be used by the staff to (a) obtain a better understanding of best-estimate critical parameters and (b) a quantification of minimal conservatism available with conservative analyses using criteria from previous versions.

Discussion of criticality accidents in the report leads to the conclusion that a current research project to evaluate administrative controls at operating installations with the purpose of developing an NRC Guide is an appropriate step for reducing the likelihood of future criticality accidents.

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Enclosure: NUREG/CR-0095