NUREG/CR-1329
SAND80-0399
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NUREG/CR--1329

TI86 002756

PHYSICAL PROTECTION OF NUCLEAR FACILITIES
QUARTERLY PROGRESS REPORT
October-December 1979

L. D. Chapman, Editor

Date Published: March 1980

Sandia Laboratories
Albuquerque, New Mexico 87185
operated by
Sandia Corporation
for the
U.S. Department of Energy

Prepared for
Division of Safeguards, Fuel Cycle and Environmental Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Under Memorandum of Understanding DOE 40-550-75
NRC FIN No. A1060

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SUMMARY

All of the activities during the past quarter were related to the facility characterization and evaluation methodology development efforts. The principal facility characterization activities included (1) the vital area analyses of operating reactor facilities, (2) support for studies of the Three Mile Island incident, and (3) the development of importance measures for rank ordering vital areas. Evaluation methodology work concentrated on continued development the Safeguards Automated Facility Evaluation (SAFE) methodology and contractor support related to the Safeguards Network Analysis Procedure (SNAP) application.

Vital area analyses, which are being performed jointly with Los Alamos Scientific Laboratory (LASL) for the Nuclear Regulatory Commission (NRC), were performed on a total of nine boiling water reactors (BWRs) and six pressurized water reactors (PWRs) during the past quarter. Also, computer codes for the calculation of importance measures for rank ordering vital areas was developed during this quarter. The theoretical nature and computational problems associated with importance measures was presented at the ORSA/TIMS Joint Meeting in Milwaukee, Wisconsin.

A user's manual for the SANDIA-ORIGEN computer code, which calculates detailed isotopic composition as a function of time in nuclear reactor fuel irradiation and radioactive decay problems, was published during the quarter. The SANDIA-ORIGEN computer code has been used to provide calculations of core inventory for Three Mile Island.

Work on the SAFE methodology centered on the preparation of documentation for the methodology and the modification to many of the computer codes currently used in or planned for SAFE. Volumes II and III

of the SAFE Users Manual are presently being written. The draft version of Volume II has been reviewed by NRC and a number of personnel at Sandia Laboratories. Several of the initial chapters of Volume III have been written, and the example facility to be used in Volume III has been defined and is ready for analysis.

Modifications have been made to the Brief Adversary Threat Loss Estimator (BATLE) model, the Adversary Path (ADPATH) routine, the Minimum Detection Probability and Time (MINDPT) code, and the Pathfinding Simulation (PATHS) code. The majority of this work provides improved user convenience in the application of SAFE. Work has also been done on developing an interface which will combine the Safeguards Engineering and Analysis Data-Base (SEAD) and SAFE.

FACILITY CHARACTERIZATION

In-House Activities

Vital Area Analyses

The vital area analyses of operating reactor facilities, which are being performed jointly with LASL for the NRC Office of Nuclear Material Safety and Safeguards, continued as the major activity during this quarter. Analyses of eight BWRs and three PWRs have been rerun or completed during this quarter. Additional changes have been received for three PWRs and one BWR.

Three Mile Island Support

During this quarter, additional SANDIA-ORIGEN computer-generated calculations of core inventory for Three Mile Island were performed to support ongoing studies related to the Three Mile Island incident. This information is being provided to the NRC Probabilistic Analysis Staff (PAS).

Documentation

A user's manual, SAND79-0299, has been published for the SANDIA-ORIGEN computer code. The code calculates detailed isotopic composition as a function of time in nuclear reactor fuel irradiation and radioactive decay problems. The manual describes the operation of the code, gives detailed descriptions of the input parameters and variables, the output, and the accompanying nuclear data file, and lists 21 sample problems developed to date. The code and data file are available on the Sandia Laboratories, Albuquerque, computer system. Copies of the manual have been sent to the Radiation Shielding Information Center at Oak Ridge National Laboratory and to the National Energy Software Center (NESC) at Argonne National Laboratory for general distribution.

Importance Measures for Vital Areas

The development of computer codes for the calculation of importance measures for rank ordering vital areas continued during this quarter. An interface between the Set Equation Transformation System (SETS) code and the importance measures code was tested. Due to the complexity of calculating values for importance measures in large problems, a modification to the computer code has been developed which allows the values to be approximated rather than calculated exactly.

A paper which discusses the theoretical nature and computational problems of importance measures was presented at the ORSA/TIMS Joint Meeting in Milwaukee, Wisconsin. A number of individuals from both industry and academe expressed an interest in the contents of this paper. A draft report which describes research related to importance measure analysis, as well as summarizes the presentation at the ORSA/TIMS meeting, was prepared during this quarter and is currently being reviewed.

Contractual Support

Generic Sabotage Fault Tree Development

During this quarter, Science Applications, Inc. (SAI) continued to provide assistance in the expansion and revision of generic sabotage fault trees developed by Sandia Laboratories. The purpose of this revision is to improve the utility of the trees and reduce analyst time required for their application. Experience gained in vital area analyses performed over the past 2 years is being used to guide changes in the trees. The revised trees developed in this task will be logically equivalent to the ones currently in use, but will be structured to enhance ease of application. A preliminary version of SAI's input for the revised sabotage fault trees was delivered to Sandia in December.

EVALUATION METHODOLOGY

In-House Activities

Automation of System Evaluation

SAFE Documentation -- Volume II: "Method Description" of the SAFE Users Manual is still being revised. Changes to the document will be updated in order to reflect modifications to the SAFE pathfinding codes that permit the use of arbitrary starting nodes and the addition of the new version of the BATLE code. These changes have been prompted from recent SAFE applications and are primarily directed at user convenience. The current draft of Volume II has been reviewed by NRC staff members; several errors in the documentation were discovered during this review, and the general comments received from NRC have been very helpful.

Work also continued on Volume III: "Example Application" of the SAFE Users Manual. The initial chapters of Volume III have been written and efforts to modify and edit existing computer codes used in SAFE are nearly complete. The example facility to be used in Volume III has been defined and is ready for analysis. Also, the guard response times for the example application and the facility layout drawings and tables of input data for the facility have been generated.

SAFE Application -- Application of SAFE to an existing single-unit reactor was begun this quarter for the NRC. The facility has been digitized, and the digitization results have been reviewed and corrected. In addition, briefings were conducted to familiarize users with the SAFE methodology. Included were a briefing of Sandia Laboratories personnel by LASL representatives on the current vital area analyses for the single-unit reactor and a briefing of NRC personnel by Sandia representatives on the SAFE methodology.

Computer Code Modifications -- Further development and modifications have been made to existing and planned pathfinding codes for SAFE: the BATLE code, the MINDPT code, the ADPATH routine, and the PATHS code. In addition, work is continuing on the development of an interface between the SAFE methodology and SEAD.

ADPATH. The directed graph pathfinding routine, ADPATH, and a main program written to drive the routine have been loaded onto the NOS time-sharing system, preparatory to testing.

MINDPT. MINDPT has been modified to allow an arbitrary set of starting nodes to be used in the facility pathfinding routine. This capability facilitates the generation of guard response times and may allow some consideration of the insider problem.

PATHS. Modifications to the PATHS code were completed this quarter. The PATHS subroutines have been partially combined in order to consolidate input/output (IO) statements, and the IO statements have been modified to make them clearer and more usable. The use of non-ANSI statements has been eliminated, with the following exceptions:

1. The CDC program card, which is required for the Sandia system, remains in PATHS but is not recognized by ANSI, and
2. The interactive READ* statements remain.

BATLE. The new version of the BATLE code has been completed and integrated into the SAFE system. Through a series of interactive subprograms, the code builds a data file of battle events according to the user's desired scenario. The parameter set which determines attrition rates is substantially expanded and enables the user to build a fairly detailed scenario.

The new parameters provided for in BATLE include an expanded set of weapon types, posture, cover (while firing and/or while reloading), delaying tactics, and firing accuracy degradation (due to posture and/or light levels). In addition, one side can suppress another during any period of time throughout the battle at the user's discretion. This suppression capability can be used to model ambush scenarios. The input required for BATLE is outlined below:

A. Initial conditions
    1. Number of combatants on each side
    2. Eight characteristics of each individual combatant:
        a) Weapon type (1 to 5 below)
            1) handgun
            2) shotgun
            3) semiautomatic rifle
            4) fully automatic rifle
            5) submachine gun

b) Posture (1 to 3 below)

   1) standing

   2) crouching

   3) prone

c) Exposure while firing

   -- percent exposed area (0 to 100)

d) Exposure while reloading

   -- percent exposed area (0 to 100)

e) Delaying tactics

   -- percent time spent delaying (0 to 100)

f) Training

   -- number of months since last trained (0 or greater)

g) Firing degradation due to self-posture

   -- percent [0 (prone) to 100]

h) Firing degradation due to target illumination

   -- percent [0 (daylight) to 100]

3. Distance between opposing forces (1 to 500 meters)

4. Option to suppress firing by one side for a specified time (in seconds)

B. Next event

   1. Time of next event (in seconds)

   2. Choice of any or all event options (1 to 5 below):

      1) Changes to current combatants (eight characteristics)

      2) Arrival of reinforcements (includes eight characteristics for each new combatant)

      3) Option to change range of battle

      4) Option to suppress firing by one side (cannot overlap a previous suppression)

      5) Option to include current battle status in output

C. Repetition of next event sequence until battle scenario is complete.

Attrition rates (in casualties per second) are computed as a product of firing rate and casualty rate. Firing rates are measured in rounds per second for weapons types 1, 2, and 3 and in bursts per second for weapons types 4 and 5. Firing rates are calculated as a function of weapon type and range in meters (see Figure 1). Given a weapon type and posture, the casualty fraction is calculated as a function of target exposure and range in meters, as illustrated in Figure 2.

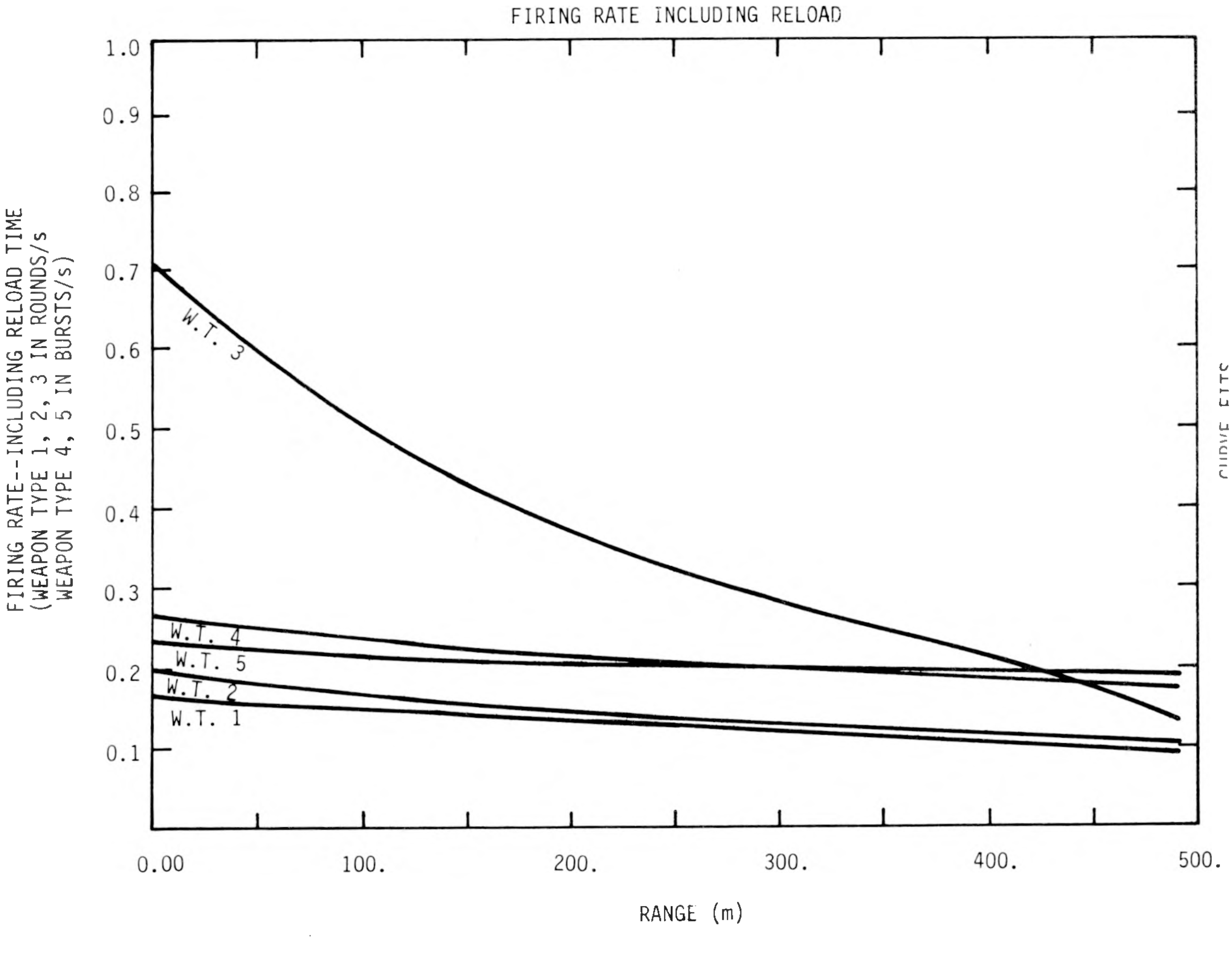

Figure 1. Firing Rate as a Function of Weapon Type and Range

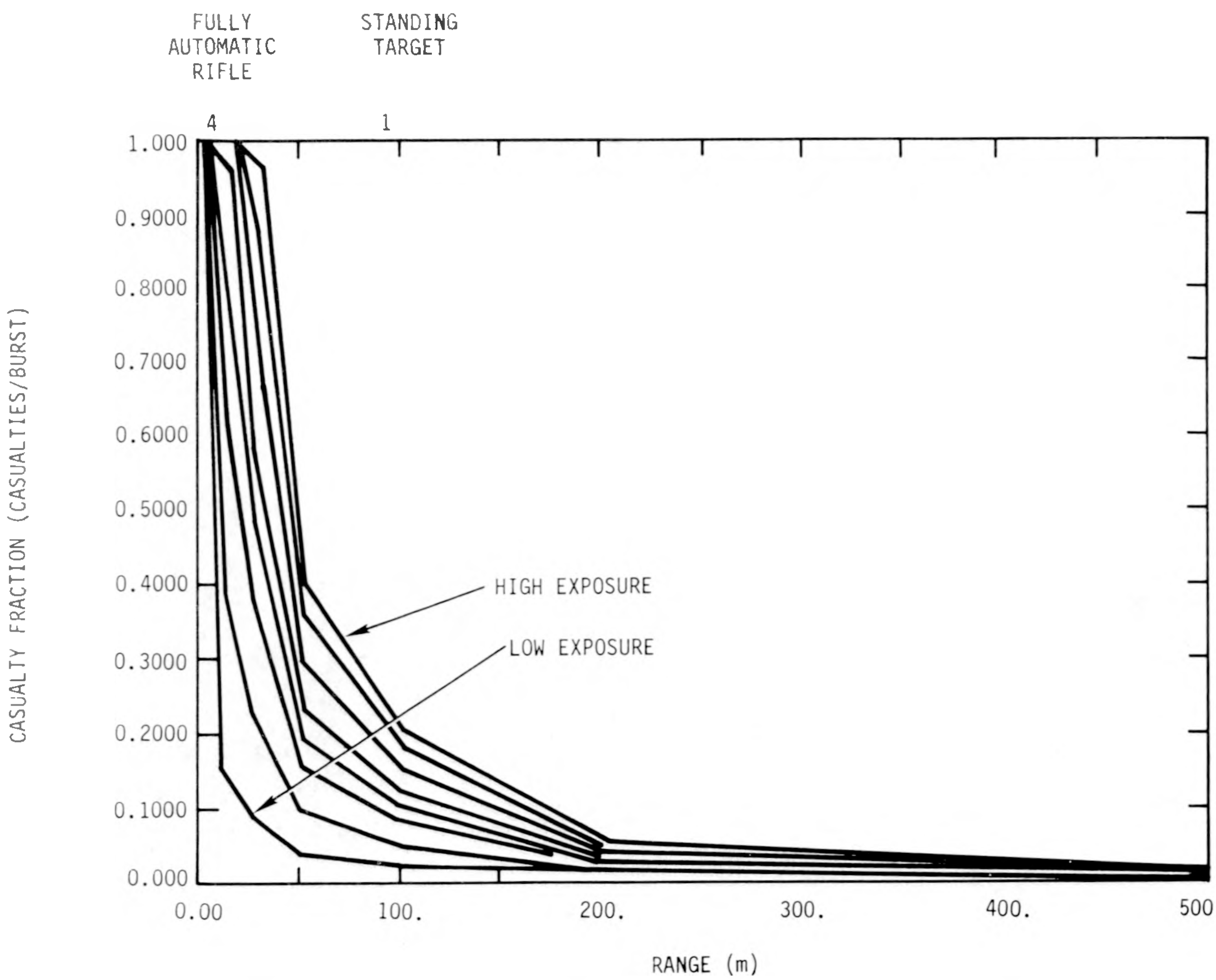

Figure 2. Casualty Fraction as a Function of Target Exposure and Range

BATLE generates new attrition rates for each event time to reflect the characteristics during that phase of the battle. Based on these attrition rates, the system is moved forward in time through all events to a steady state. A steady state status report is provided as output. Three output files are generated: (1) BATLE input and status reports, (2) guard delay time information, and (3) battle termination time information. The user selects whether to have some or all of these files printed.

The preprocessor has been interfaced with BATLE and SAFE in a manner that allows the user to simulate different battles for different paths. The user may either reuse the input scenario file with only slight changes, e.g., in range, exposures, weapon types, postures, firing suppression, etc., or an entirely new file may be constructed for use with different paths or groups of paths.

Documentation for a users guide to BATLE is currently being prepared and will include descriptions of (1) the input parameters (with an example case), (2) the method of computing attrition rates, and (3) the mathematical model used to determine the outcome of a battle based on attrition rates. Also included in this documentation will be the output of the example, a sensitivity analysis, and a program listing.

SAFE/SEAD Interface. Work was begun this quarter on an interface which will combine SEAD and SAFE. This interface will allow SAFE to perform an on-line access of data from SEAD. The program requests time delay and detection probability data from the user. At this point, an option can be installed which permits SEAD data to be accessed through SAFE or to be extracted from SAFE.

Contractual Support

SNAP Application Development

A meeting was held on 11 October 1979 in Washington, D.C., to discuss improvements to the SNAP model. Attendees at this meeting included representatives from Pritsker & Associates, Inc., Sandia Laboratories, and NRC. The present working model was presented and discussed in detail. Necessary adjustments to the model and areas which need further information were identified at the meeting through interaction between the attendees.

Model Development -- In the previous quarter, both the facility model and four adversary scenarios were developed. All of these subnetworks were developed as completely as possible prior to the development of the guard operating procedures network. Several components of the guard network have now been developed, and debugging of the four adversary scenarios has been completed. Some minor problems occurred when these scenarios were run consecutively with the guard subnetwork, thus necessitating some minor modifications to the model. The scenario models are now essentially complete.

The main development effort during this quarter centered on the guard procedures subnetwork and the communication network segments necessary for the patrol portion of the code. Emphasis was placed on modeling the different alarm states. The alarm states which have been defined include missing guard alarms, unexpected loud-sound disturbance alarms, external sensor alarms, external alarms in the storage area, internal alarms in the process area, and engagement alarms. Each of these alarm types has been fully modeled, and the data input has been implemented and debugged.

A priority ranking of the alarm state responses has been developed in order to restrict the transitions between alarm states to a finite set. The ability to return to the normal operational state at the termination of an engagement was also incorporated into the model. Each of these states has been modeled, and the data input segment has been implemented.

Work was begun on the simultaneous execution of the adversary and guard subnetworks. During this procedure, minor modifications to the model design have been required but have been within the developmental bounds expected.

Documentation -- Documentation of the SNAP model is being prepared concurrently with the development of the model. This documentation includes two reports, one which deals with the specific site studies and one which deals with the SNAP modeling features incorporated in the model. One aim in preparing these reports is to illustrate the feasibility of developing SNAP models of actual nuclear facilities, as well as to illustrate the techniques used in building SNAP models which could aid future modeling efforts.

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