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Design Guidance and Evaluation Methodology for Fixed-Site Physical Protection Systems

Description, Implementation, and Testing of Design Guidance and Evaluation Methodology

Prepared by H.A. Bennett, M.T. Olascoaga

Sandia National Laboratories

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DESIGN GUIDANCE AND EVALUATION METHODOLOGY FOR FIXED-SITE PHYSICAL PROTECTION SYSTEMS

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ABSTRACT

Design guidance products and a system performance evaluation methodology have been developed to aid the Nuclear Regulatory Commission in the implementation of new regulations designed to upgrade the physical protection of nuclear fuel cycle facilities. The evaluation methodology, which incorporates the design guidance products, provides a means of arriving at an overall measure of performance for each capability required in the regulations. To arrive at this measure of performance, first the scores associated with responses to a series of equipment and procedure questionnaires are aggregated. The aggregation of scores then proceeds through successive levels of a hierarchical structure developed for each capability.

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Volume I: Description, Implementation, and Testing of Design Guidance and Evaluation Methodology

EXECUTIVE SUMMARY

On 28 November 1979, the Nuclear Regulatory Commission (NRC) published revisions to 10 CFR Parts 70 and 73. These revisions, known as the Safeguards Upgrade Rule, state that certain fuel cycle facility licensees "shall establish and maintain or make arrangements for a physical protection system which will have as its objective to provide high assurance that activities involving special nuclear material are not inimical to the common defense and security and do not constitute an unreasonable risk to the public health and safety" (10 CFR Part 73.20). The purpose of such a general performance requirement is to maximize design flexibility within the constraints of each of the following required performance capabilities found in paragraphs (b) through (f) of 10 CFR Part 73.45:

(b) Prevent unauthorized access of persons and materials into material access areas (MAAs) and vital areas (VAs);

(c) Permit only authorized activities and conditions within protected areas (PAs), MAAs, and VAs;

(d) Permit only authorized placement and movement of strategic special nuclear materials (SSNM) within MAAs;

(e) Permit removal of only authorized and confirmed amounts of SSNM from MAAs; and

(f) Provide for authorized access and assure detection of and response to unauthorized penetrations of the PA . . .

However, fundamental to the success of performance-oriented regulations is the ability to measure physical protection system (PPS) performance. Toward this end, Sandia Laboratories was requested by the NRC to assist in the development of the following design guidance products:

- Functional hierarchies to link each of the required performance capabilities with low-level system tasks which could be performed directly by components, e.g., equipment, procedures, and design features,
- Component selection matrices to aid in identifying potential components which could be selected to perform a particular task, and
- Questionnaires to comprehensively address the effectiveness of components in performing a particular task.

In addition, a system performance evaluation methodology was to be developed to provide a defensible and practical means of measuring PPS performance relative to the Upgrade Rule. The design guidance products are included in the design guidance compendium for fixed-site physical protection systems to be published by the NRC. To date, the evaluation methodology has not been included. In the authors' opinion, any evaluation method, quantitative or qualitative, which would be used by the NRC during the various stages of the regulatory process should also be available to the licensee during the design stage. This would permit the licensee to design and evaluate his preliminary design in an iterative manner until he was fairly certain of compliance with the regulations. An evaluation methodology should be provided to the licensee as part of a complete and concise guidance package to aid the licensee in designing his physical protection system.

In developing a functional hierarchy to analyze systems, all of the important system elements, the levels to which they belong, and the interactions between levels must be identified. Five hierarchies were developed. Each hierarchy had as its objective one of the primary performance capabilities (10 CFR 73.45 paragraphs (b) through (f)). The functional hierarchy was formed by successively decomposing the capability into its constituent functions and subfunctions until a level was reached where tasks could be achieved directly by components. Such tasks, when constrained in scope, are called performance characteristics. The hierarchy, so developed, provides both a means to measure the impact of component performance on system performance and a means to trace back through the structure to determine the specific contributions made toward system performance by each component.

Component selection matrices were developed by grouping performance characteristics which have a common generic task, e.g., intrusion sensing, in rows while placing components identified as having the potential of performing the same generic task in columns. Dots were placed at the intersections of rows and columns to indicate the potential of a component to accomplish a particular performance characteristic, e.g., an ultrasonic sensor system to sense building, room, or vault penetration. Nine such matrices were developed, one for each of the following categories:

- Intrusion Sensing
- Access Controls
- Delay
- Communication
- Alarm Reporting and Assessment
- Guard Force Response
- SNM Removal Controls
- Controls for Placement and Movement of SNM
- Controls for Activities and Conditions

Component performance is highly dependent upon many factors and contingencies. At best, component performance evaluation is a difficult task. However, experience gained through extensive hardware testing supported by the Department of Energy (DOE) at Sandia Laboratories has provided principles and guidelines for component utilization. While the employment of such guidelines will not guarantee satisfactory performance, it seems reasonable to assume that performance is a direct function of adherence to these guidelines. With this in mind, questionnaires which addressed factors deemed important to performance were developed, under joint NRC/DOE sponsorship, for 97 generic types of components. The responses to these questions were presented in a multiple-choice format in descending order of preference to reduce ambiquity and to facilitate the aggregation of these responses into a measure of component effectiveness. Similar questionnaires were developed to address important interactions between successive levels within the hierarchy.

A logical, comprehensive, and practical method was developed to evaluate physical protection system performance for each capability specified in the fixed-site Upgrade Rule. The evaluation methodology utilized probability theory to derive logical forms for component and system performance measures and employed multiattribute utility theory to aggregate the measures, many of which are assessed subjectively, into an overall performance measure for each performance capability.

The set of hierarchies developed from a functional decomposition of each performance capability provided the organizational structure for the evaluation to show clear traceability to the Upgrade Rule requirements. Starting at the component level, the evaluation methodology is used to synthesize performance measures or scores for each component based on responses to component effectiveness test questionnaires (ETQs). Once each component has received a score, scores for those components that address individual performance characteristics are aggregated to provide a single measure or score for the appropriate low-level system task. Continuing up the hierarchy, scores for low-level system tasks are combined into system subfunction scores, which are then aggregated into system function scores, and finally, into an overall score for each performance capability.

At each successive hierarchy level where an aggregation takes place, an appropriate aggregation rule must be selected. In many situations, the selection is a natural one; however, for situations in which it is not possible to simply select an aggregation rule independent of the specific elements in the system and/or of the site conditions involved, the aggregation is based on the responses to a system ETQ. Since system ETQs were not a program requirement, only a few have been developed at this time.

The evaluation methodology developed for this program provides a means of arriving at an overall measure of physical protection system performance relative to the Upgrade Rule requirements. This innovative methodology, unlike most current physical protection performance evaluation techniques, is structured to provide clear traceability to the regulations. It provides a logical, comprehensive view of the entire physical protection system at all levels, from components (including both equipment and procedures) through system subfunctions and functions up to performance capabilities. This methodology considers both equipment and procedures in the development of measures for component performance.

Within the scope of the project, a testing program was initiated to provide a preliminary check on the completeness, utility, and validity of the NRC design guidance compendium and the evaluation methodology. Allied-General Nuclear Services (AGNS), Barnwell, South Carolina, was contracted to develop and document a partial physical protection system that would provide "good" performance with respect to the requirements specified in 10 CFR 73.45 paragraph (b). The partial design consisted of an access control system and boundary penetration prevention system for an MAA. Although the test effort was insufficient to assess the total design guidance package, the results were encouraging. The following statement, taken from the report by AGNS, summarizes the results of the design guidance compendium testing: "Unequivocally, the design guidance compendium possesses invaluable attributes which facilitate and enhance the development of a physical protection system complying with the requirements of the physical protection Upgrade Rule (10 CFR 73)."

The evaluation methodology was partially tested by Sandia Laboratories in conjunction with Woodward-Clyde Consultants (WCC), San Francisco, California, using responses from component and system ETQs provided by AGNS for their partial PPS design. The results of the performance evaluation for the AGNS design show an overall score of 0.3 on a scale of 0 to 1. At this time, no acceptance criteria have been established by the NRC which would indicate the significance of a score of 0.3. The development of two physical protection system designs which by a consensus of experts were judged as "good" and "minimal" relative to the performance capability requirements would provide the NRC with some basis for establishing acceptance criteria. However, it should be emphasized that the aggregate score which results from application of the evaluation methodology to a physical protection system should not be used as an absolute measure of system performance. It is intended for use by an evaluator only as a guide to making a judgement regarding the adequacy of the physical protection system.

However, the results of the evaluation methodology testing did indicate the advantages of a hierarchical evaluation approach which permits tracing back through the structure to identify areas of concern to the licensee and/or NRC evaluators. This trace-back capability provides the licensee and the NRC with a valuable tool for discussion and resolution of discrepancies in perceived performance of the physical protection system. The methodology testing also demonstrated a need for more extensive testing, in particular, development of a "minimal" performance system to provide two data points for calibrating the methodology.

Recommendations which evolved from the development and implementation of the design guidance products and evaluation methodology are as follows:

1. Within the current project, the following points are suggested for further development:

   - Continue development of system effectiveness test questionnaires for systems in which performance is subject to functional and/or dynamic interaction between system elements.
   - Provide for comprehensive testing by both industry and NRC to determine the utility, completeness, and validity of the methodology.
   - Extend the methodology to evaluate the performance provided by the multiple layers of protection given an adversary gains access to the PA, MAA, etc.

2. As a matter of policy for future development of regulation guidance and evaluation methodology, it is recommended that early in the formation phase of new regulations potential contractors be retained, at least as consultants, to provide advice from an evaluation viewpoint.

1. INTRODUCTION

This report comprises two volumes which describe design guidance products and an evaluation methodology for fixed-site physical protection systems. The design guidance products and evaluation methodology were developed to aid the NRC and the licensee in the implementation of that part of the Safeguards Upgrade Rule which applies to fixed-site facilities (10 CFR Parts 73.45 and 73.46).

1.1 Background

The NRC is in the process of publishing and implementing revisions to 10 CFR Parts 70 and 73. These revisions, referred to as the Safeguards Upgrade Rule,[1] are designed to upgrade physical protection requirements at certain fuel cycle facilities and for specified quantities of SSNM in-transit. The regulations require the licensee to

> establish and maintain or make arrangements for a physical protection system which will have as its objective to provide high assurance that activities involving special nuclear material are not inimical to the common defense and security and do not constitute an unreasonable risk to the public health and safety. The physical protection system shall be designed to protect against the design basis threats of theft or diversion of strategic special nuclear material and radiological sabotage as stated in paragraph 73.1(a).

The goal of such general performance-oriented regulations is to maximize the licensee's design flexibility within the constraints of the performance capability requirements stated in the Upgrade Rule. The performance capabilities are design goals for the licensee to adapt to his individual site or transport conditions. A reference physical protection system (10 CFR Parts 73.26 and 73.46) is included to provide guidance regarding those measures which will generally be included in a physical protection system that achieves the performance capabilities.

The publication of system performance-oriented regulations to replace earlier regulations which prescribed component criteria is an innovative approach which shows considerable promise. However, fundamental to the success of this approach is the development of a feasible system of design, license review, and inspection with the aim of providing consistent interpretation of the regulations. This requires a practical and defensible method of evaluating physical protection performance relative to the performance capability requirements in the regulations. In the authors' opinion, any evaluation method which would be used by the NRC during the various stages of the regulatory process should also be available to the licensee during the design stage. This would permit the licensee to design and evaluate his preliminary design in an iterative manner until he was fairly certain of compliance with the regulations. An evaluation methodology should be provided to the licensee as part of a complete and concise guidance package to aid the licensee in designing his physical protection system.

1.2 Scope

Recognizing the need for completeness of regulatory guidance and consistency in evaluation, the NRC requested assistance from Sandia Laboratories in satisfying these needs for that part of the Safeguards Upgrade Rule which applies to fixed-site facilities (10 CFR Parts 73.20, 73.45, and 73.46). This effort involved development of the design guidance products described in this volume and an evaluation methodology which employs these products to measure physical protection system performance. Limited testing of the NRC guidance package, which includes these design guidance products, and of the evaluation methodology was implemented.

The following design guidance products were developed for this program and are included in the NRC Fixed-Site Physical Protection Upgrade Rule Guidance Compendium[2]:

1. An evaluation structure, composed of five functional hierarchies which correspond to each of the major performance capabilities (paragraphs (b) through (f) of 10 CFR Part 73.45), designed to provide a structured framework for licensee system design and NRC evaluation,
2. Component selection matrices to aid in identifying potential components (equipment, design features, and procedures) for performing low-level physical protection system tasks, and

3. Component effectiveness test questionnaires to comprehensively address the performance of individual components.

Although the development of system effectiveness test questionnaires was not included in the current scope of work, the need for questionnaires to treat the functional/dynamic interactions of various functions and subfunctions became apparent as the evaluation methodology evolved. Therefore, a limited number of system questionnaires were also developed.

The evaluation methodology developed for this program provides a means of arriving at an overall measure of physical protection system performance relative to the Upgrade Rule requirements. This methodology, unlike most current physical protection performance evaluation techniques, is structured to provide clear traceability to the regulations. This provides a logical, comprehensive view of the entire physical protection system at all levels, from components through system subfunctions and functions up to performance capabilities.

1.3 Program Support

Sandia Laboratories personnel currently involved in safeguards R&D for the DOE Office of Safeguards and Security contributed substantially to the development of component effectiveness test questionnaires. Support for the development of the evaluation methodology was provided by Woodward-Clyde Consultants (WCC), San Francisco, California, under contract to Sandia Laboratories.[3] WCC provided assistance in (1) developing portions of the methodology, (2) developing a computer program to automate the evaluation process, and (3) implementing the methodology using the test results as input. AGNS, also under contract to Sandia Laboratories,[4] provided test support. A partial physical protection system was designed using the NRC design guidance compendium,[2] input data to the evaluation methodology was provided based on the partial system, and a critique of the compendium, including the design guidance products, was provided. Portions of this report reflect the contributions of the organizations mentioned above.

1.4 Report Organization

A discussion of the development of each of the design guidance products is provided in Chapter 2. Chapter 3 contains a detailed description of the evaluation methodology. In Chapter 4, implementation of the evaluation methodology is discussed. Chapter 4 also includes a description of the computer program developed by WCC for implementation of the methodology application. An illustration of the computer implementation is also presented.

In Chapter 5, testing of the design guidance compendium and evaluation methodology is discussed. This chapter includes a description of the limited testing in which AGNS assisted Sandia Laboratories as well as a discussion of a comprehensive testing plan.

Two sets of recommendations are presented in Chapter 6. The first set of recommendations addresses improvements to the current design guidance and evaluation methodology. The second set consists of policy recommendations with regard to future methodology development.

2. DESIGN GUIDANCE PRODUCTS

This chapter describes three design guidance products requested by NRC: an evaluation structure, a set of component selection matrices, and a set of component effectiveness test questionnaires, which were developed primarily to aid the licensee in designing a physical protection system. The development of system effectiveness test questionnaires, although outside the current scope of work, is also discussed.

2.1 Introduction

In order to effectively implement the revised regulations for fixed-site facilities, NRC recognized the need to provide the licensee with comprehensive and concise guidance. As a result, a guidance package has been prepared by NRC to meet this need. This package, called the NRC Fixed-Site Physical Protection Upgrade Rule Guidance Compendium, contains two sets of guidelines. The first set of guidelines describes the type of information which should be included in the security plan and the recommended format to be used. The second set of guidelines is aimed at providing the licensee with a clear understanding of the scope of the regulations and NRC philosophy behind the regulations. This set of guidelines also provides the licensee with detailed guidance for selecting components for the physical protection system and for integrating these components into a system which satisfies the Upgrade Rule requirements. Included in this set of guidelines are three design guidance products: an evaluation structure, component selection matrices, and component effectiveness test questionnaires. Although not included in the design guidance products requested by the NRC, system ETQs were developed to address the effectiveness of multicomponent systems and the functional/dynamic interactions among various system functions and subfunctions.

2.2 Evaluation Structure

2.2.1 Overview -- When attempting to design a system or to evaluate the performance of a system as complex as a physical protection system, it becomes necessary to view the system in terms of its smaller, more manageable subsystems and their interrelationships. This decomposition then allows the problem to be treated as a hierarchy of subsystem design or evaluation decisions. In this particular case, the underlying problem is to design a physical protection system which will satisfy the performance capability requirements stated in the fixed-site Upgrade Rule. Thus, each performance capability (see paragraphs (b) through (f) of 10 CFR Part 73.45) may be considered an objective to be achieved by the licensee in designing his physical protection system. Each design objective is decomposed into those system functions which must be performed to achieve the particular objective. Each system function is decomposed into system subfunctions which are necessary to perform the corresponding function. This decomposition process continues until a simple task can be identified for which components can be selected to directly perform that task. This task defines the lowest level of the functional hierarchy and is referred to as a low-level system task. Figure 2-1 provides a schematic of the functional decomposition for one segment of a performance capability.

2.2.2 Structure Development -- As a result of the decomposition process described above, a functional hierarchy was developed for each of the following performance capabilities found in paragraphs (b) through (f) of 10 CFR Part 73.45:

(b) Prevent unauthorized access of persons and materials into material access areas (MAAs) and vital areas (VAs),
(c) Permit only authorized activities and conditions within protected areas (PAs), MAAs, and VAs,
(d) Permit only authorized placement and movement of strategic pecial nuclear materials (SSNM) within MAAs,
(e) Permit removal of only authorized and confirmed amounts of SSNM from MAAs, and
(f) Provide for authorized access and assure detection of and response to unauthorized penetrations of the PA . . .

The evaluation structure, which is composed of these five functional hierarchies (Figures 2-2 through 2-6), shows clear traceability to the provisions of the fixed-site Upgrade Rule. There are several areas in which the evaluation structure deviates from that of the regulations. In the regulations, response is included as one of the performance capabilities. In the evaluation structure, it is necessary to treat response as a system subfunction in the decomposition of each performance capability (paragraphs (b) through (f) of 10 CFR Part 73.45). This is necessary since the evaluation of performance

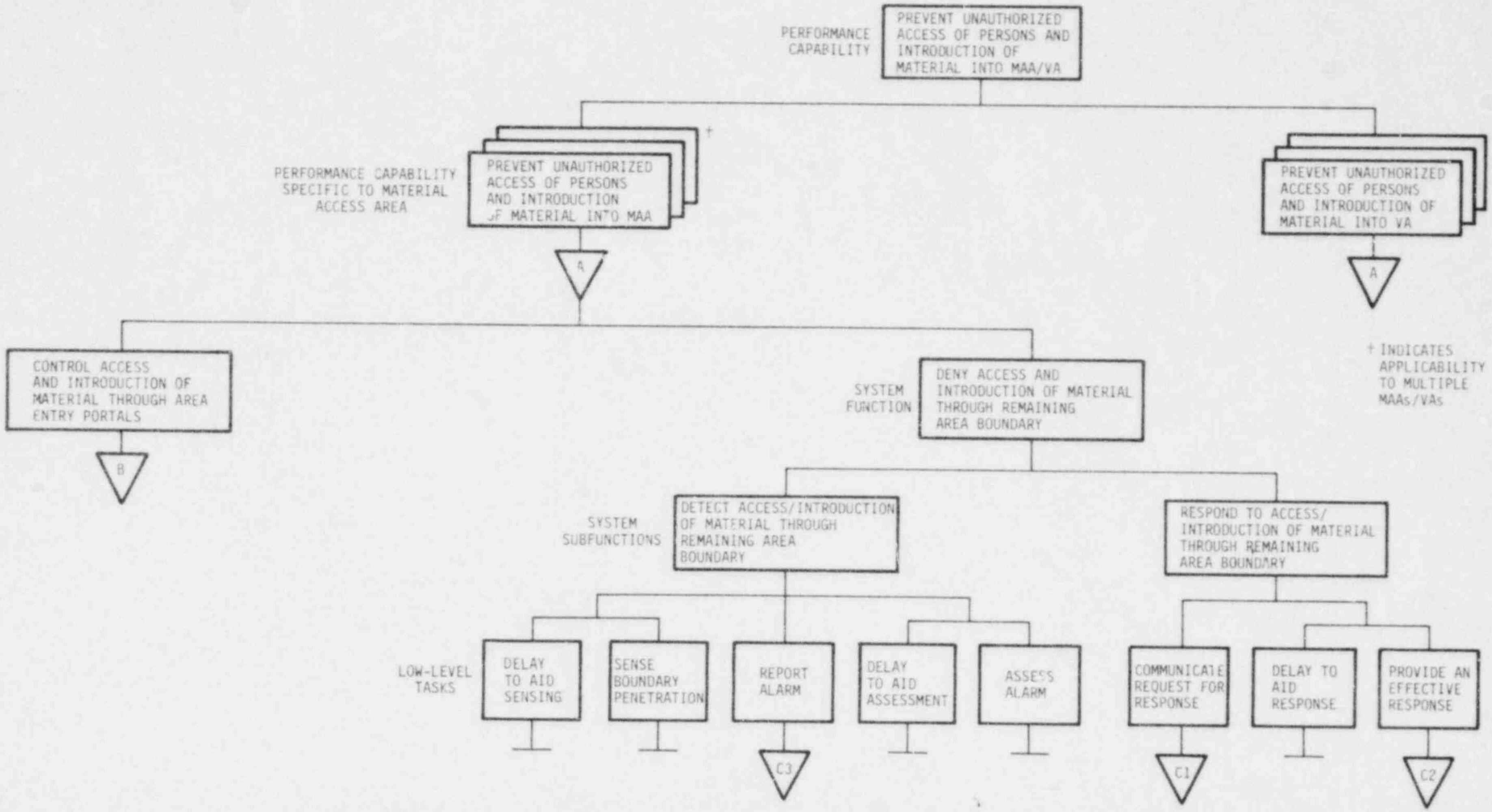


Figure 2-1. Schematic of a Partial Functional Decomposition of a Performance Capability

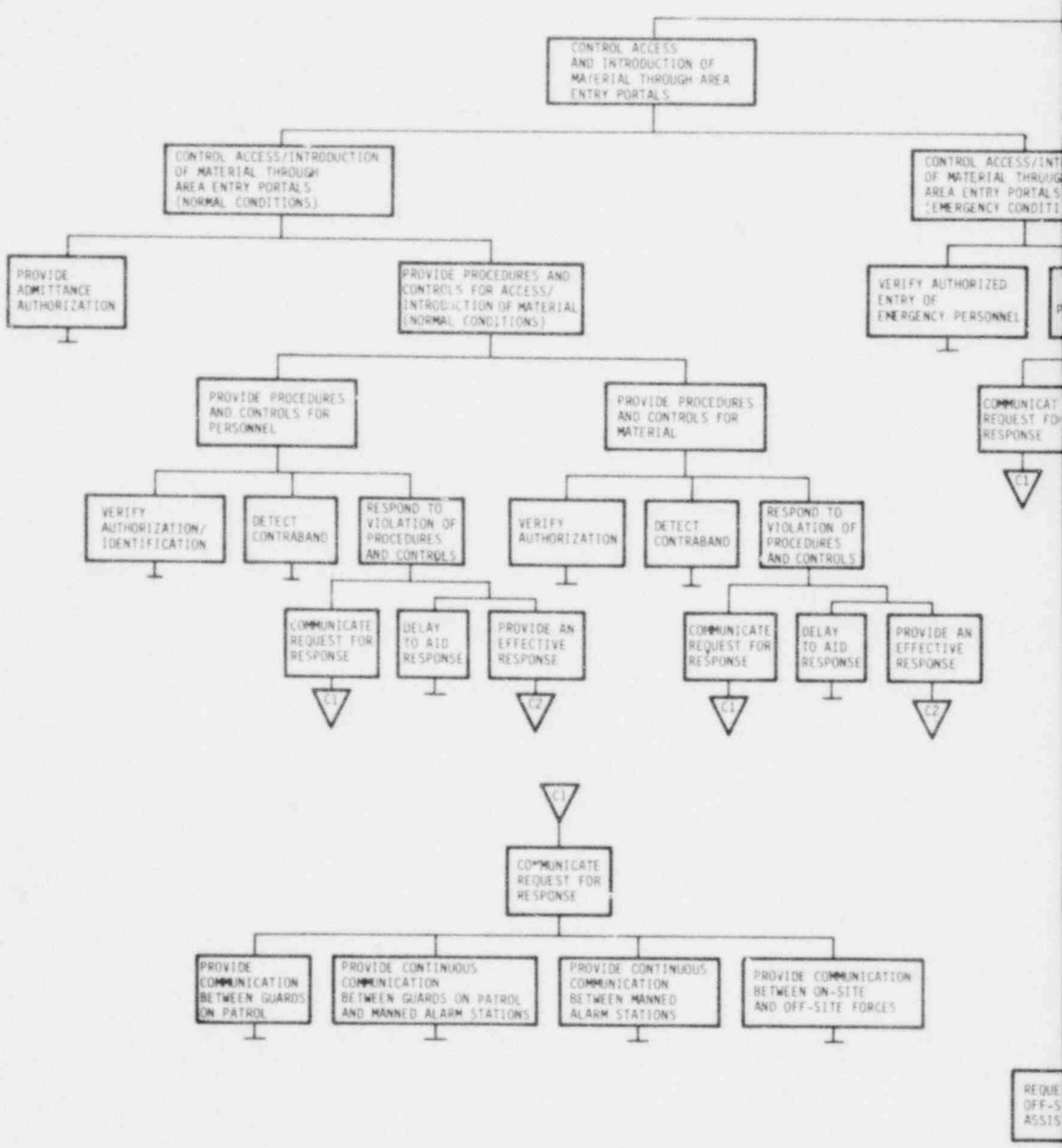
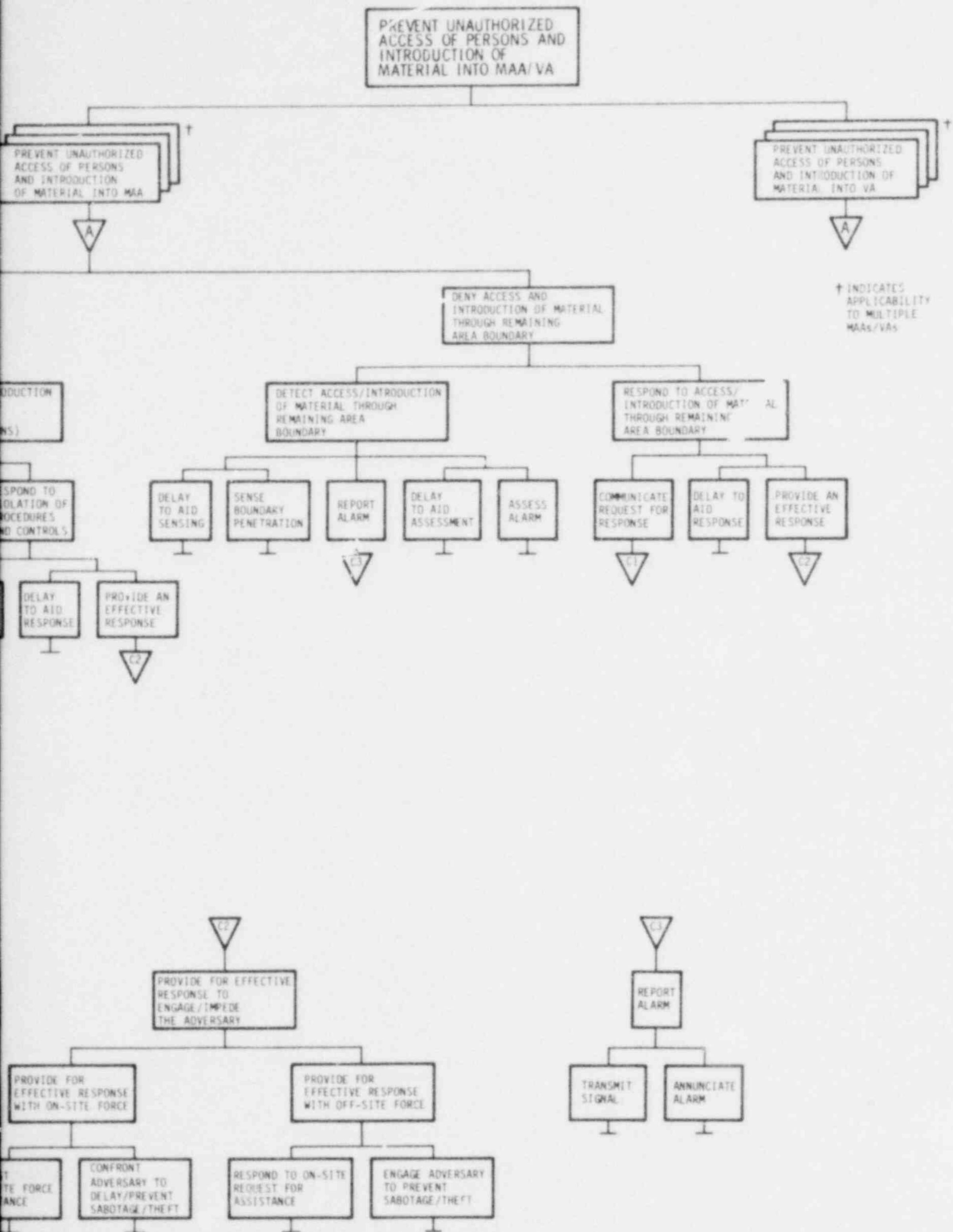


Figure 2-2. A Functional
10 CFR 73.45



Hierarchy for Proposed Rule
(b)

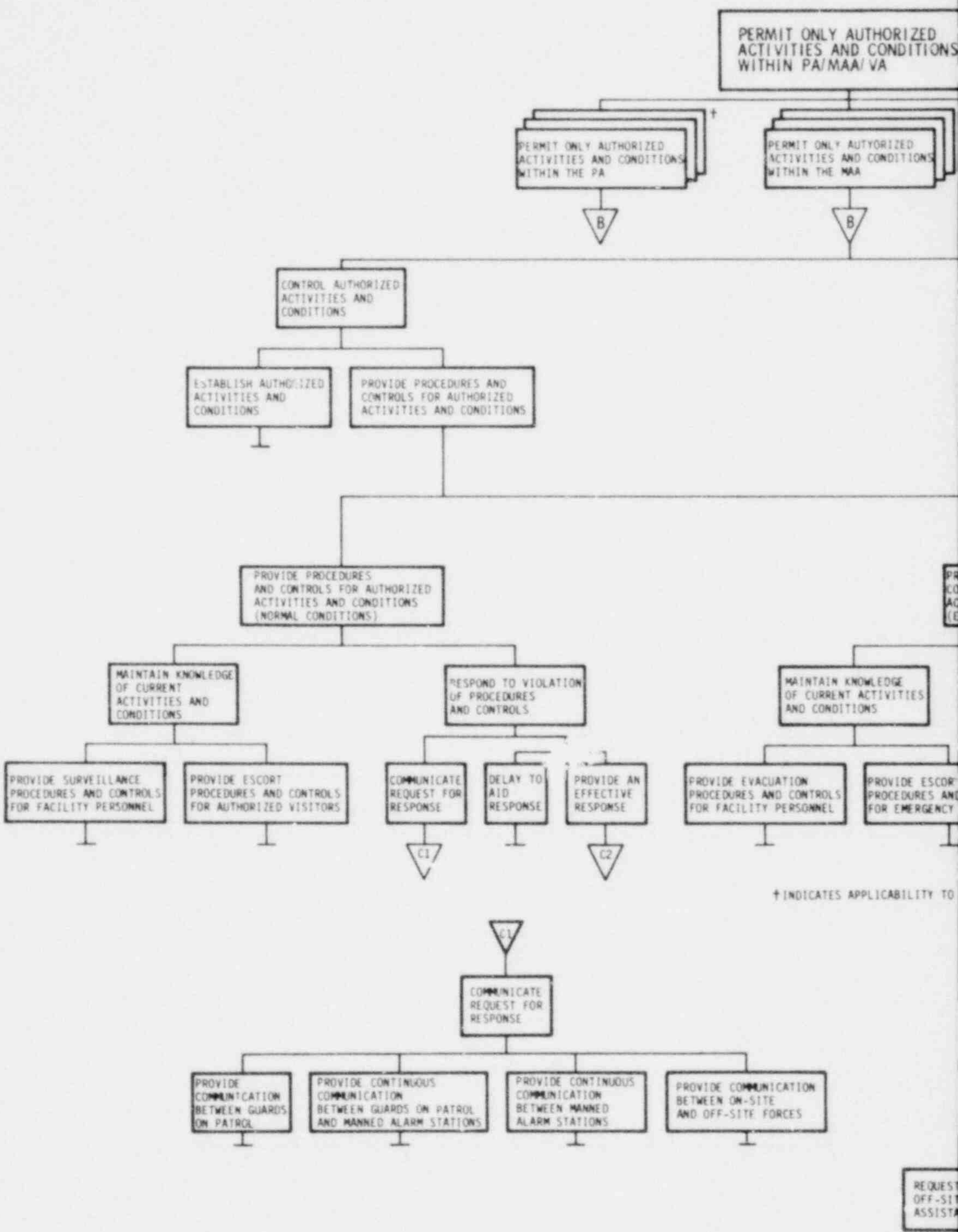
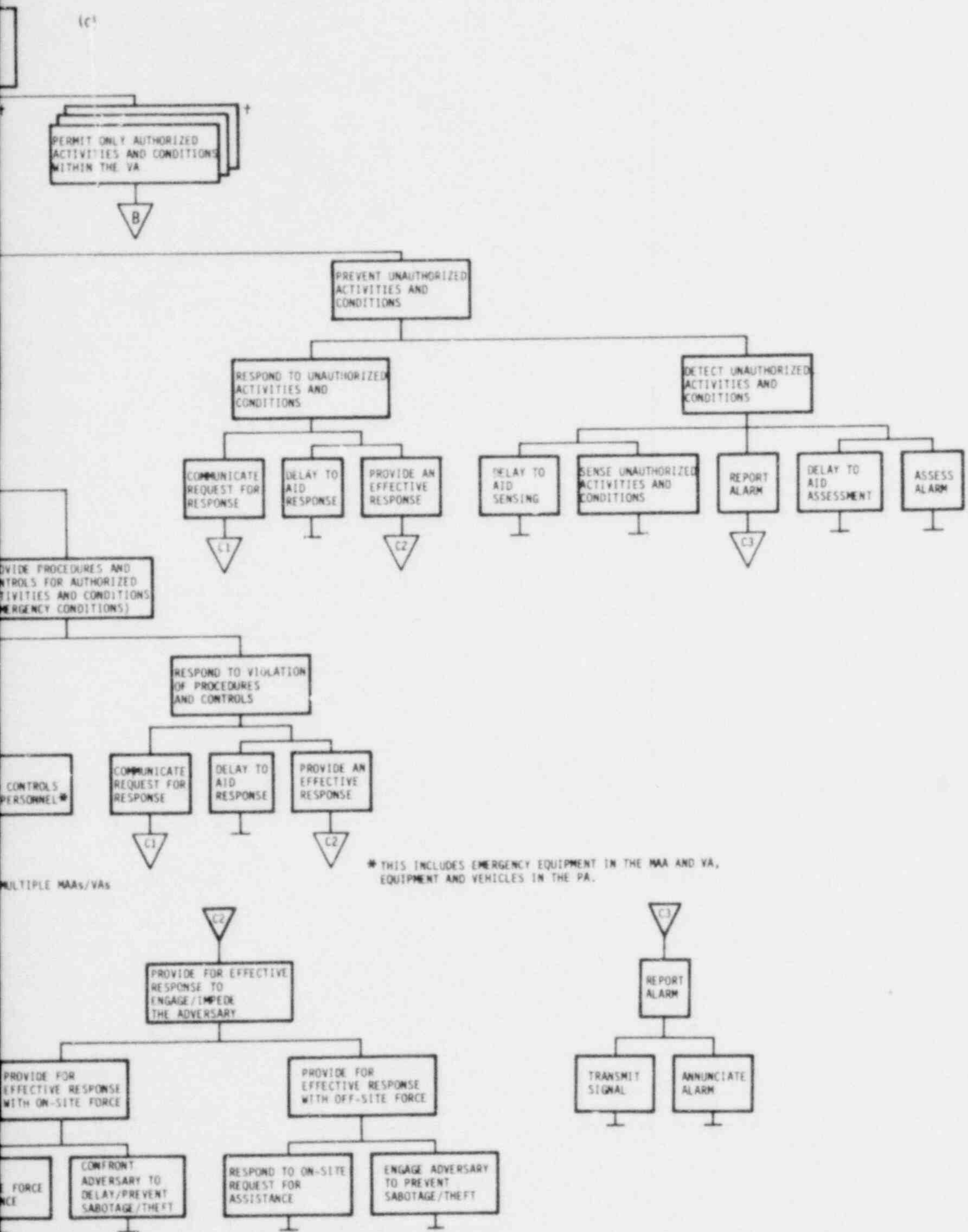


Figure 2-3. A Functional Hi
10 CFR 73.45(c)



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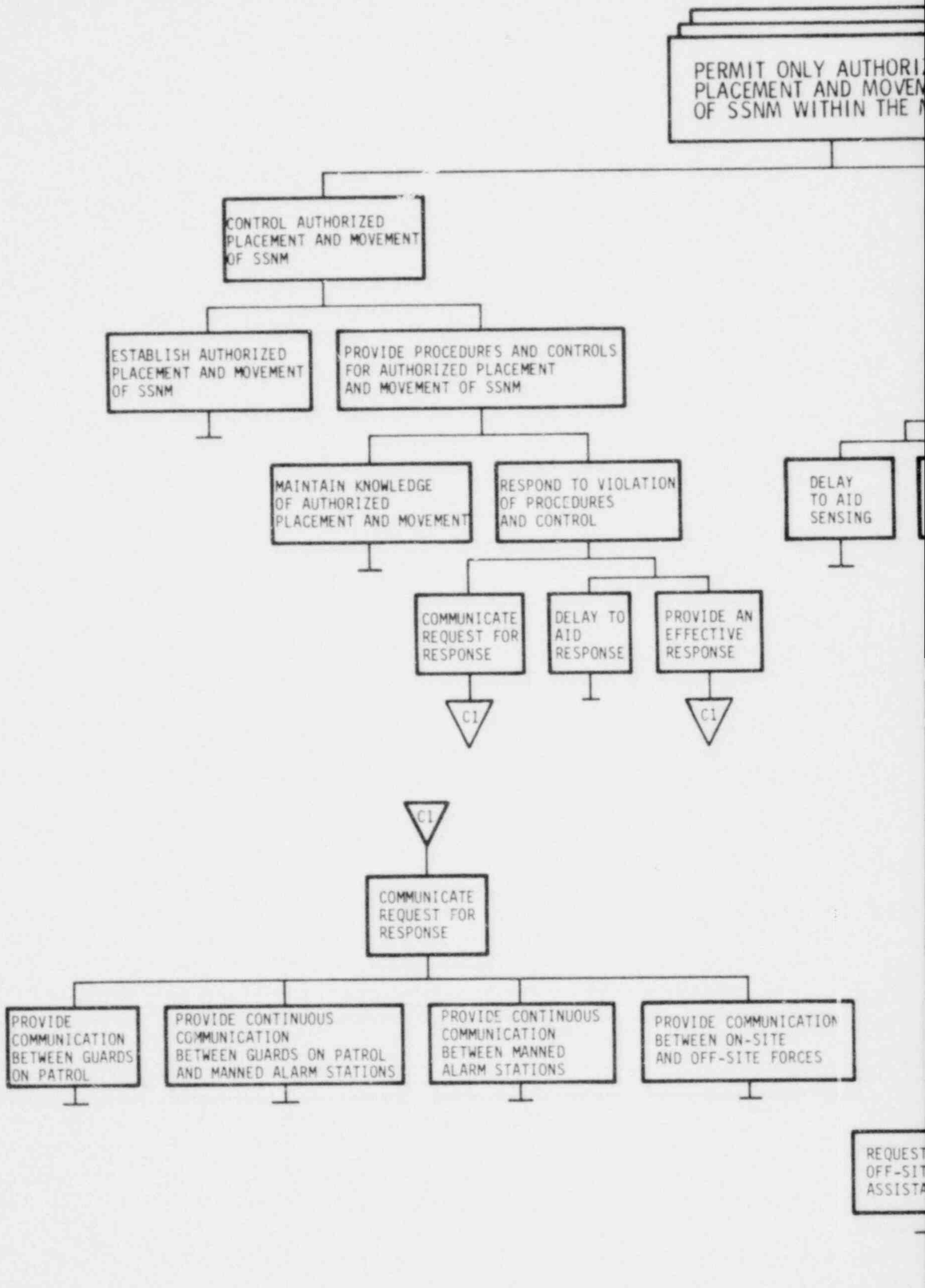
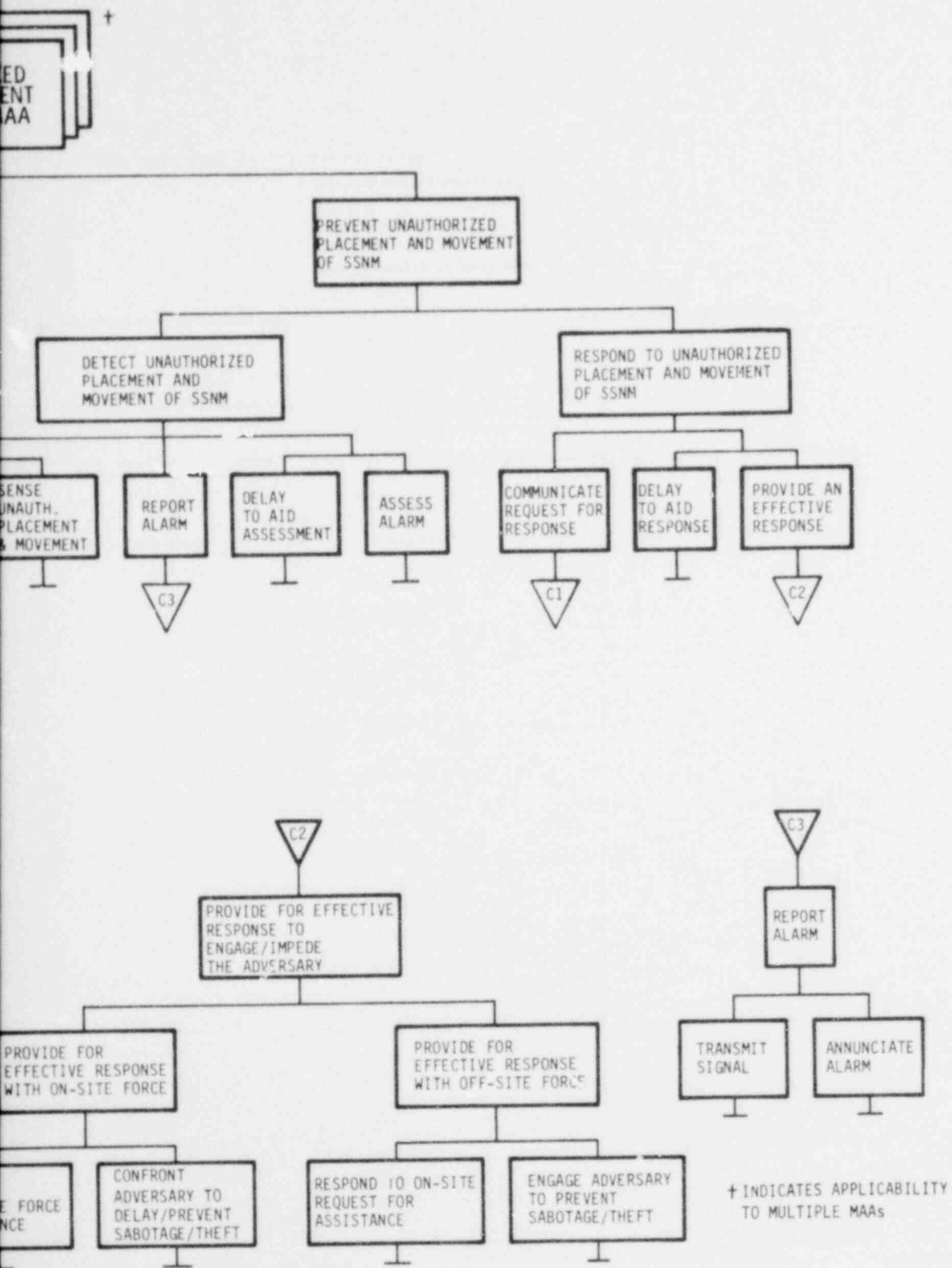


Figure 2-4. A Functional Hie
10 CFR 73.45(d)



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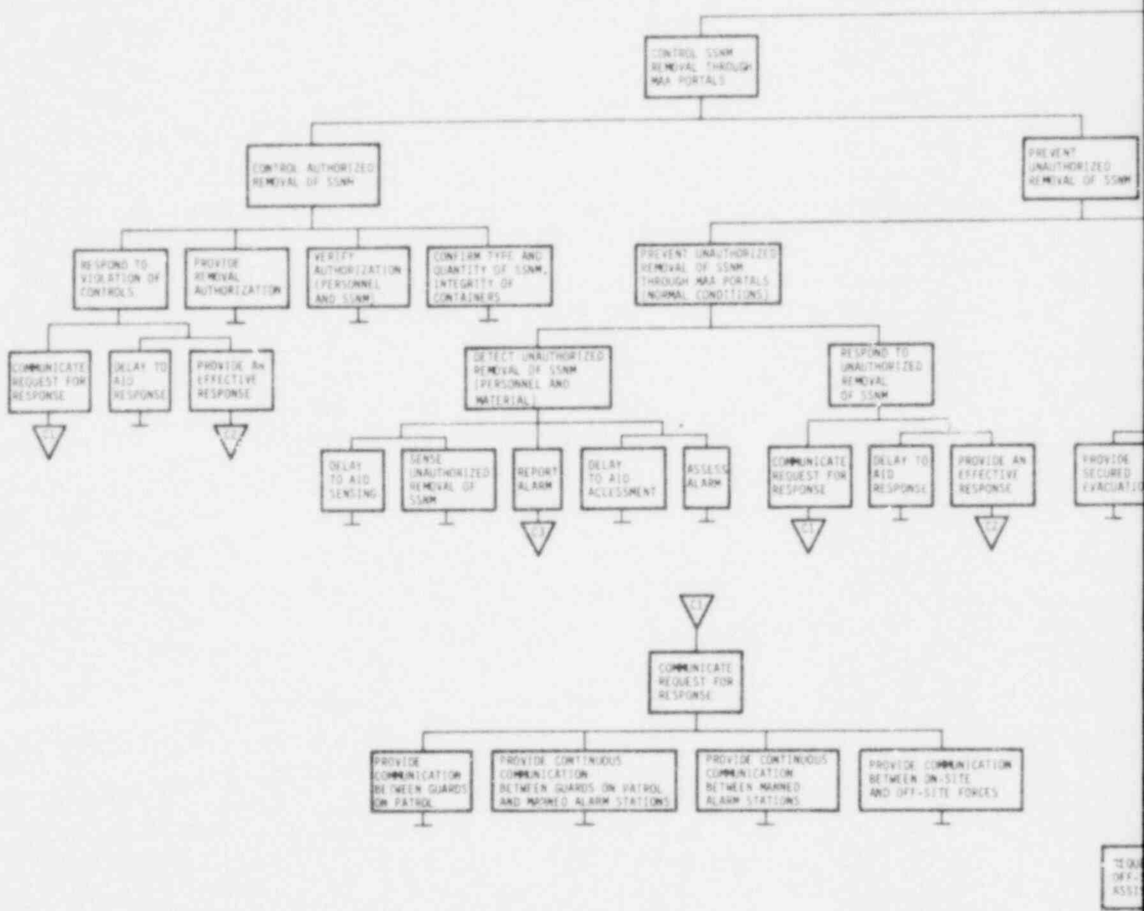
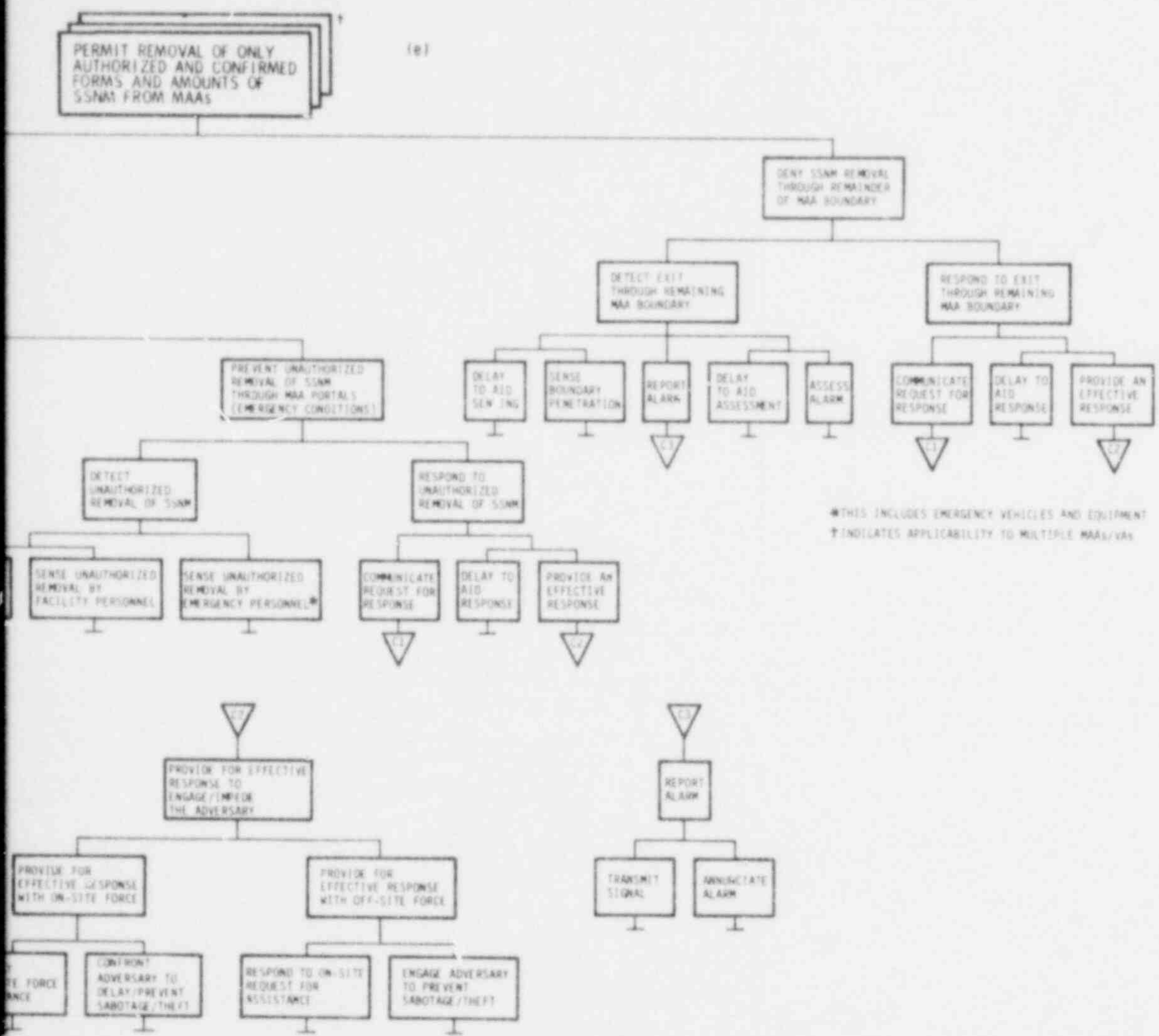


Figure 2-5. A Functional H
10 CFR 73.45(e



ierarchy for Proposed Rule

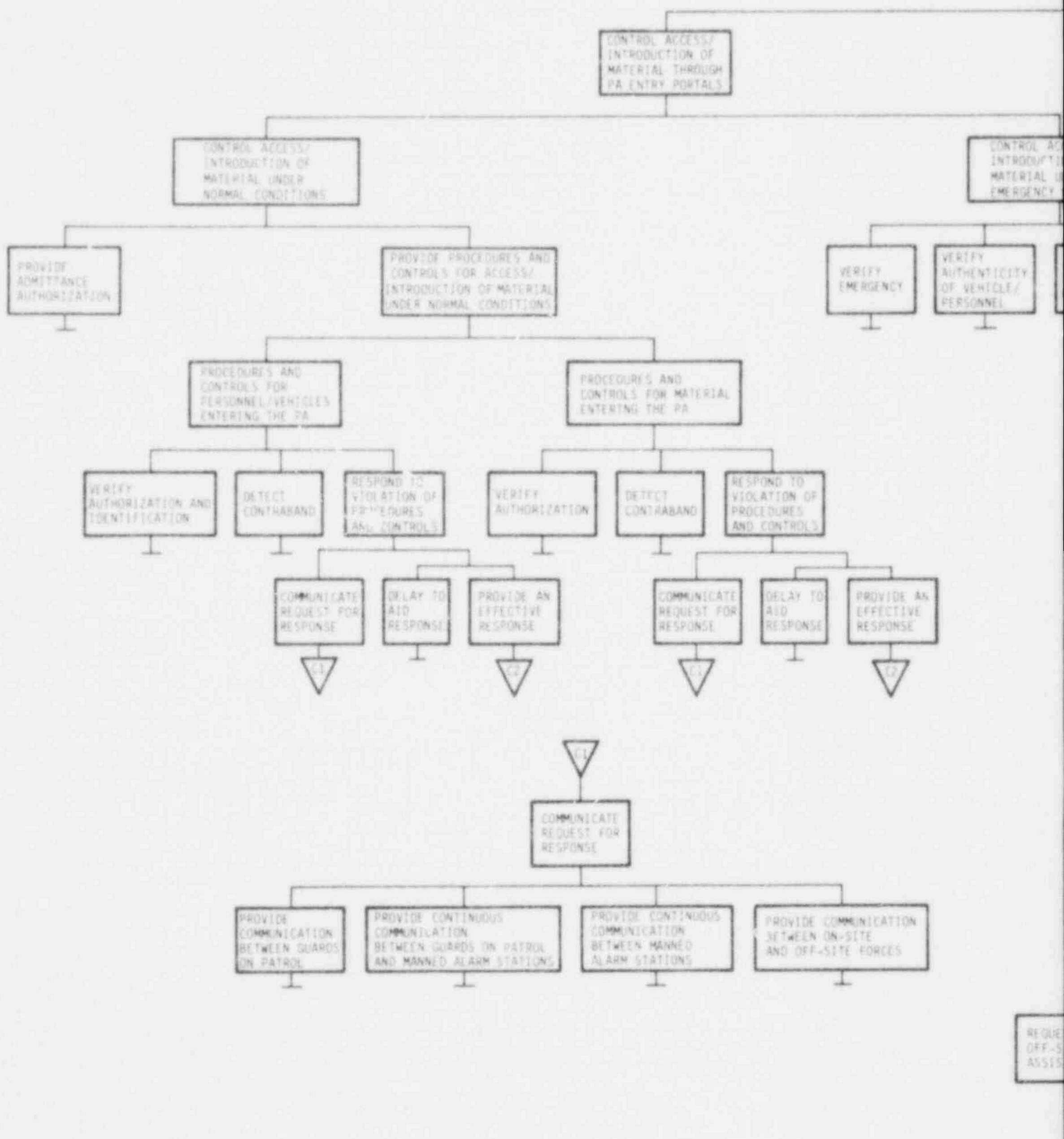
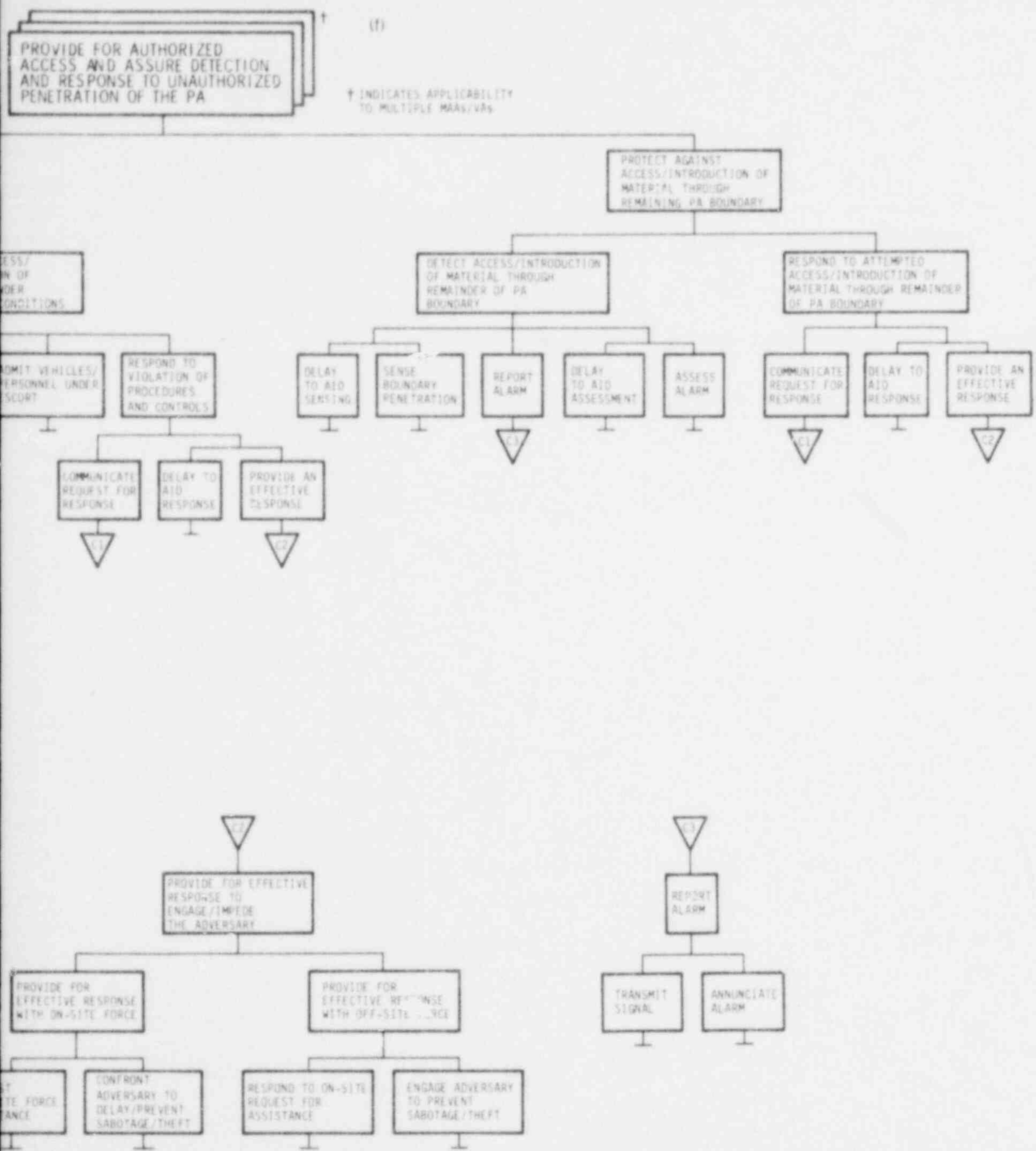


Figure 2-6. A Functional Hi
10 CFR 73.45(f)



erarchy for Proposed Rule

capability effectiveness is not complete without evaluating the performance of all the capability's functions and subfunctions.

Another difference between the evaluation structure and the regulations is in the treatment of adversary strategy (stealth, force, or deceit). In the regulations, adversary strategy is treated explicitly since it is the basis for decomposition of certain performance capabilities, while in the evaluation structure, it is treated implicitly. Because the evaluation structure is a functional decomposition of each performance capability, adversary strategy can be treated implicitly as it affects the system functions and subfunctions.

The structure also deviates from the regulations in that components, e.g., barriers, are not explicitly included because the evaluation structure is a functional decomposition, and components are viewed as means of performing the low-level system tasks.

In summary, although the evaluation structure shows clear traceability to the provisions of the Upgrade Rule, it differs somewhat from the structure of the regulations. This is primarily due to the functional decomposition approach taken. For the evaluation structure, a functional decomposition seems most advantageous. The regulations, on the other hand, require a structure which facilitates legal enforcement, so these differences are understandable.

2.2.3 <u>Functional Hierarchy Development Example</u> -- There is a noticeable similarity in the decomposition process used in developing each of the five functional hierarchies. Although there are differences in their overall objectives, in many cases the low-level system tasks identified in the various functional hierarchies are identical, e.g., "report alarm." Due to these similarities, only one functional hierarchy, which corresponds to performance capability (b), will be developed in this report for purposes of illustration.

To develop a functional hierarchy for a given performance capability, the functions and subfunctions which must be performed to achieve the objective stated in the performance capability must be identified. The objective in 10 CFR Part 73.45 paragraph (b) is

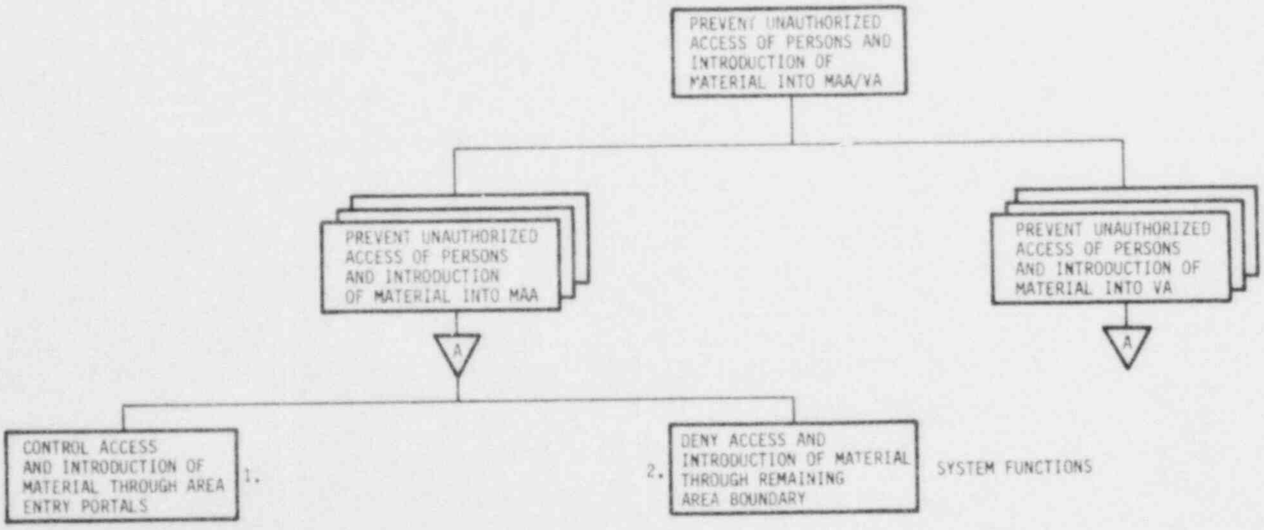
PREVENT UNAUTHORIZED ACCESS OF PERSONS AND INTRODUCTION OF MATERIAL INTO MATERIAL ACCESS AREAS AND VITAL AREAS*

The functional hierarchy shown in Figure 2-2 was developed by successively decomposing the above objective for an MAA into the functions and subfunctions necessary to achieve that objective. The functional decomposition of this objective for the VA is not expected to differ from that developed for the MAA, so the functional hierarchy for this performance capability will be developed only for the MAA. Note the applicability of this hierarchy to multiple MAAs and VAs.

The first step in the decomposition of the above objective is to identify those functions which are required to prevent unauthorized access and introduction of material into the MAA. To do this, it is necessary to ask how an adversary might gain access or introduce material into the MAA. There are two ways in which this can be accomplished: (1) through an entry portal or (2) through the remaining MAA boundary, e.g., wall, window, etc. Therefore, in order to prevent unauthorized access or introduction of material into the MAA, the following broadly defined system functions must be performed:

1. CONTROL ACCESS AND INTRODUCTION OF MATERIAL THROUGH THE AREA ENTRY PORTALS.
2. DENY ACCESS AND INTRODUCTION OF MATERIAL THROUGH THE REMAINING AREA BOUNDARY.

The corresponding fragment of Figure 2-2 is shown below.



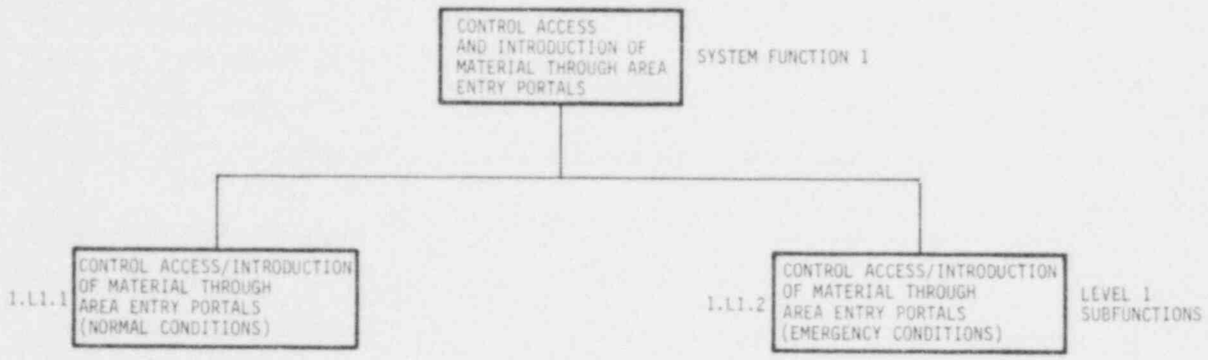
*The version of the Upgrade Rule for which the evaluation structure was developed did not include vehicles in the performance capability statement; however, the final version does include them.[1]

Each of these two system functions must be further decomposed into its respective constituent subfunctions. In order for system function 1 to be comprehensively performed, personnel access and the introduction of material must be controlled under both normal and emergency conditions. Thus, the following Level 1 (L1) subfunctions* must be performed:

1.L1.1 CONTROL ACCESS AND INTRODUCTION OF MATERIAL THROUGH THE AREA ENTRY PORTALS UNDER NORMAL CONDITIONS.

1.L1.2 CONTROL ACCESS AND INTRODUCTION OF MATERIAL THROUGH AREA ENTRY PORTALS UNDER EMERGENCY CONDITIONS.

This decomposition is shown below.



First, the system subfunctions for controlling personnel access and introduction of material under normal conditions will be considered. There are three ways in which an adversary might defeat the controls on access and introduction of material: (1) authorization for personnel or material admittance may actually be obtained by the adversary, (2) the adversary may attempt to gain admittance using false credentials or introduce contraband on his person or under the guise of authorized material, or (3) the adversary may attempt access or introduction of material by force. Therefore, in order to control personnel access and introduction of material under normal conditions, the following two Level 2 (L2) subfunctions are identified:

1.L2.1 PROVIDE ADMITTANCE AUTHORIZATION.

1.L2.2 PROVIDE PROCEDURES AND CONTROLS FOR ACCESS AND INTRODUCTION OF MATERIAL.

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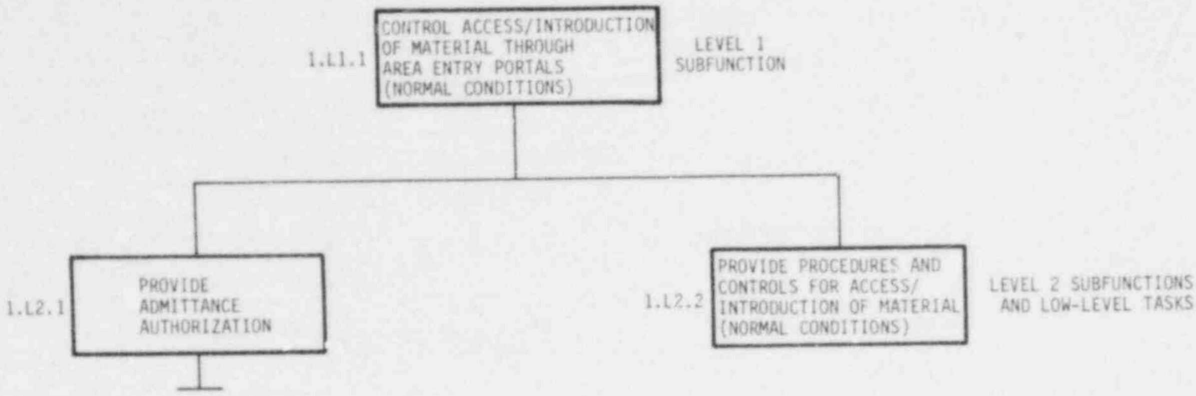
*Note that each box within the hierarchy will be labeled with a mnemonic such as 1.L1.2. The first digit refers to the function number, the alphanumeric L1 refers to subfunction Level 1, and the final digit indicates the number of the subfunction or low-level task in the level indicated.

The corresponding hierarchy segment appears below.



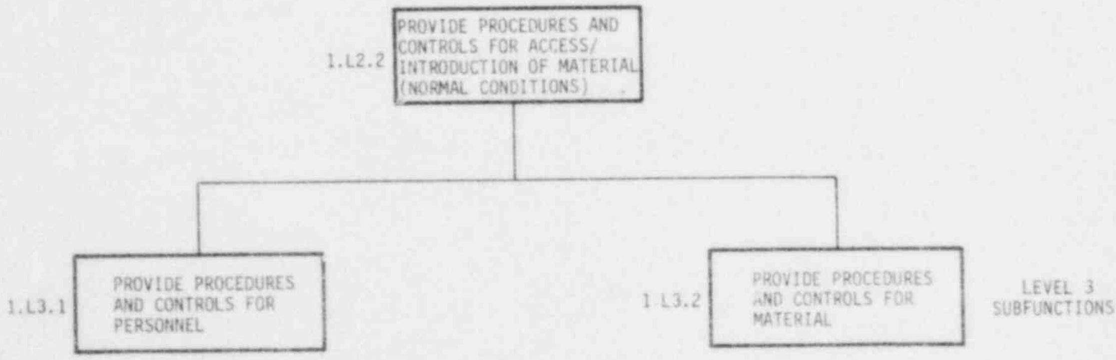
The symbol, ⊥, which appears under the Provide Admittance Authorization block identifies this as a low-level system task for which components to perform that task, i.e., provide admittance authorization, can be identified. In this particular case, the subfunction is actually a low-level task, and so no further decomposition of 1.L2.1 is necessary.

System subfunction 1.L2.2 can be further decomposed. In order to perform this subfunction, procedures and controls must be instituted for personnel entering the area and for any material they might be carrying. Procedures and controls must also be provided for any material deliveries to the area. Thus, the following Level 3 (L3) sub functions form the next level of the hierarchy:

1.L3.1 PROVIDE PROCEDURES AND CONTROLS FOR PERSONNEL.

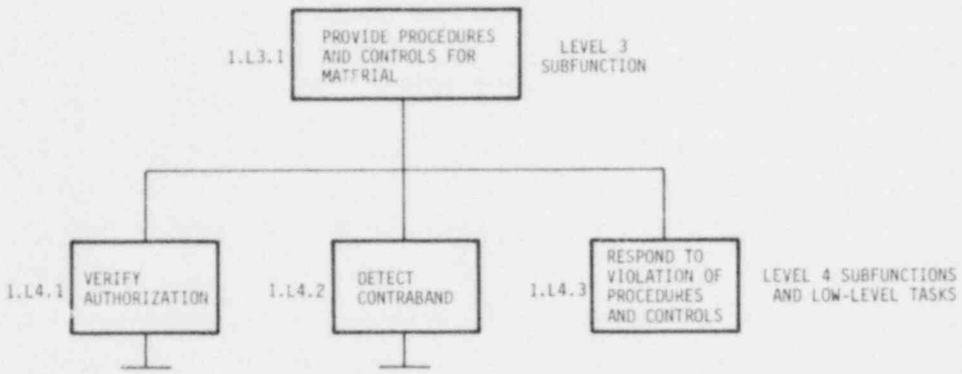
1.L3.2 PROVIDE PROCEDURES AND CONTROLS FOR MATERIAL.

This decomposition is shown below.



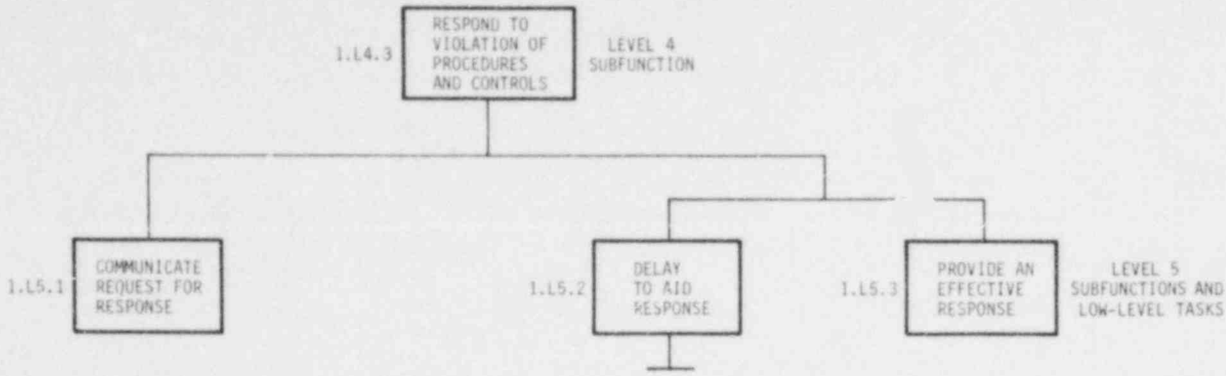
From Figure 2-2 of the complete hierarchy for performance capability (b), it can be seen that the decompositions for 1.L3.1 and 1.L3.2 are similar. Therefore, only the 1.L3.1 subfunction will be further decomposed.

In order to prevent an advers ιv from defeating these procedures, the physical protection system must first be able to detect any attempts to gain access to the area using false credentials, i.e., either authorization or identificat· . Also, any attempts by an adversary to introduce contraband into the area must be detected. Detection, however, is not sufficient. If such an attempt is detected or if forced entry is attempted, a response to violations of procedures and controls is necessary to render the attempt ineffective. Thus, the decomposition of L3.1 yields three Level 4 subfunctions, as shown below.

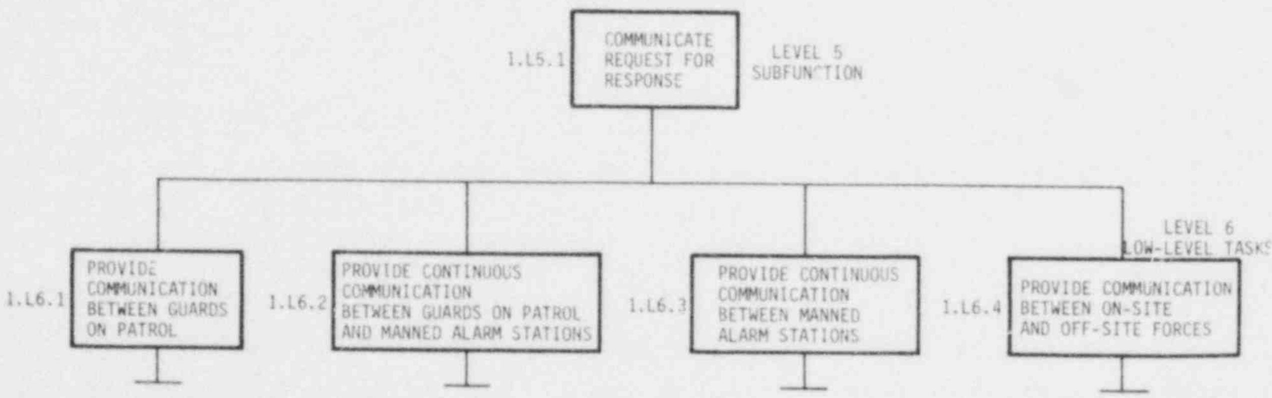


Note that 1.L4.1 and 1.L4.2 are low-level system tasks and need no further decomposition. There still remains one subfunction, 1.L4.3, which must be decomposed further.

To ensure a successful response, as required in subfunction 1.L4.3, there are several requirements. First, if access control personnel require assistance from security personnel, an effective means of communication must be available. Given a request for response force assistance, the physical protection system must provide a timely response. A timely response reflects a close interaction between the delay of adversary access provided by the system and the ability of the response force to arrive within that delay time. This interaction is shown in the following figure.

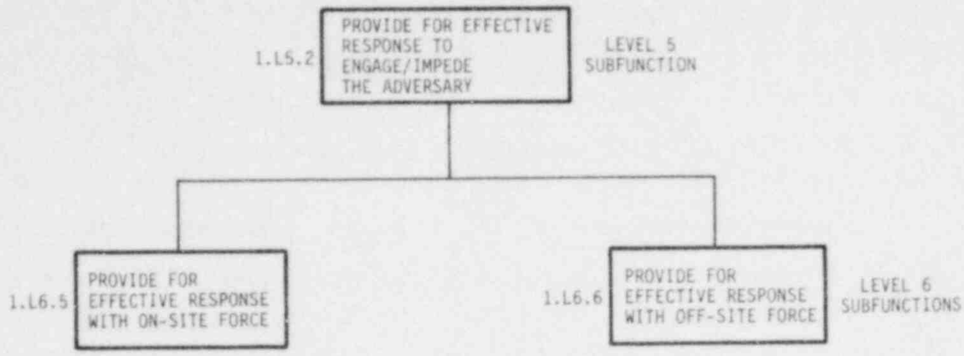


Subfunction 1.L5.2 is identified as a low-level system task. There are now two Level 5 subfunctions which require further decomposition. First, the communication subsystem (subfunction 1.L5.1) will be decomposed. In order to ensure effective communication, several different lines of communication must be available. Guards (response force personnel) on patrol must be able to communicate with each other should this level of assistance be required. These personnel also should be able to readily communicate with the manned alarm stations since this is where response decisions and commands will usually originate. There should also be continuous communication between the Central and Secondary Alarm Stations (CAS and SAS) for assistance of receipt of information and of response effort. Finally, if the threat is such that off-site response force assistance is required, there must be provisions for communication with local law enforcement officers. This decomposition is shown below.



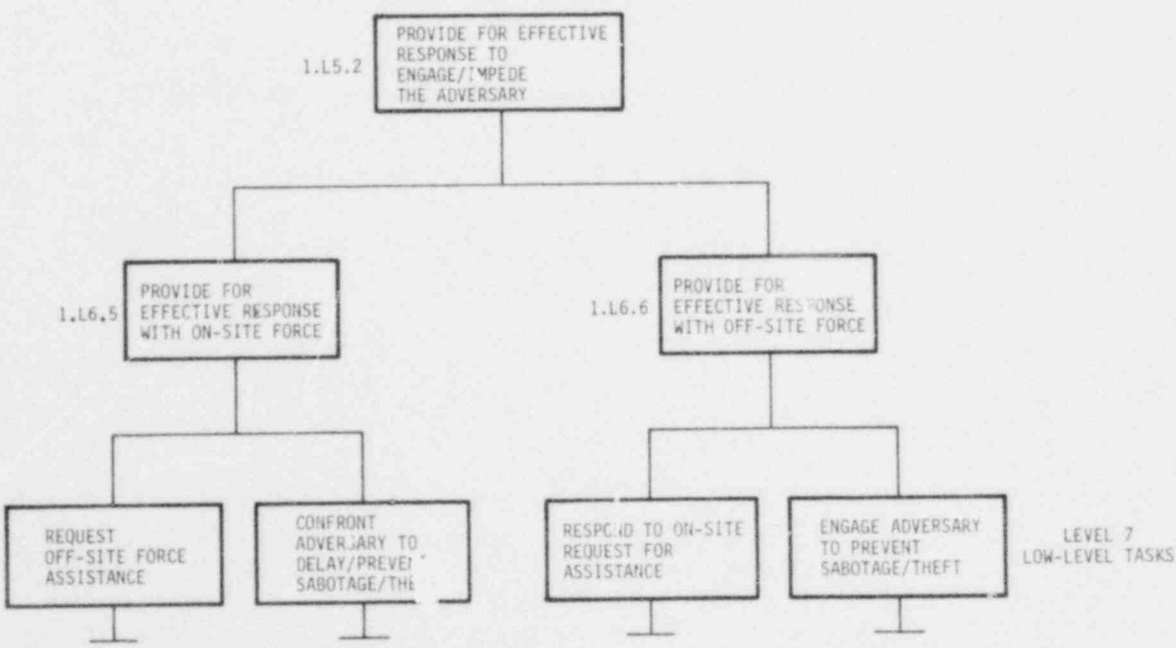
These are all low-level tasks, so further decomposition is unnecessary.

Subfunction 1.L5.3 must now be decomposed. To ensure that an effective response can be provided over a wide range of adversary threats, provisions must be made for both an effective on-site and off-site response. This decomposition is shown on the following page.



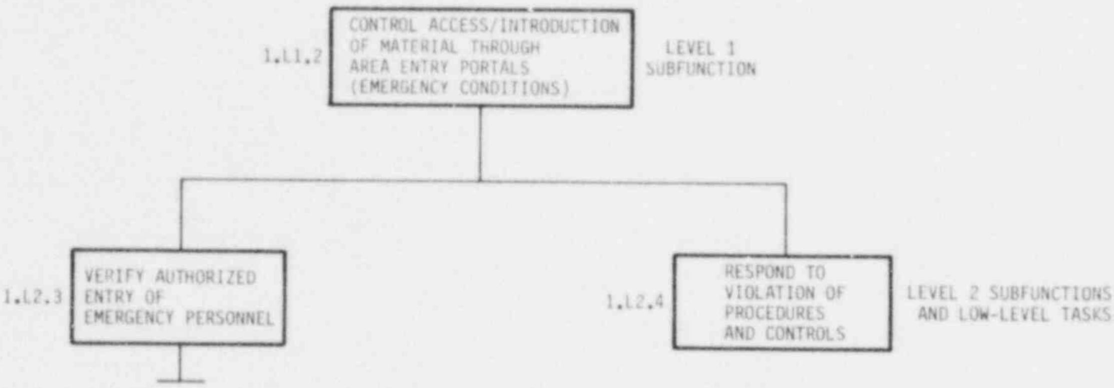
Each of these subfunctions can be decomposed one level further. For an effective response by the on-site force, first of all, adequate provisions for requesting off-site response force assistance must be available if such a request should become necessary. Second, the on-site response force must have the ability to successfully engage the adversary either to delay until off-site assistance can arrive or to actually defeat the adversary.

For an effective off-site response, adequate provisions must be available for responding to a facility's request for assistance. Upon arriving at the site, the off-site response force must be capable of defeating the adversary. This last decomposition level is shown below. Note that only low-level tasks remain and so further decomposition is not required.



This completes the hierarchy development for subfunction L1.1. A functional decomposition of subfunction L1.2 will now be presented.

The subfunctions necessary to control access and introduction of material under emergency conditions are somewhat similar to those required during normal conditions in that some means of detecting and responding to unauthorized attempts to gain access to the area and/or introduce contraband must be provided. Emergency conditions pose significant problems to the physical protection system since controls or personnel access and introduction of material will usually be minimal. In most cases, medical, fire, or other emergency personnel who are not usually authorized to access the MAA will require hasty admittance. Thus, controlling personnel access and introduction of material is limited to verifying with the security entry-control personnel that emergency personnel were authorized to enter the facility and providing an effective response if any violations occur. This decomposition is shown below.

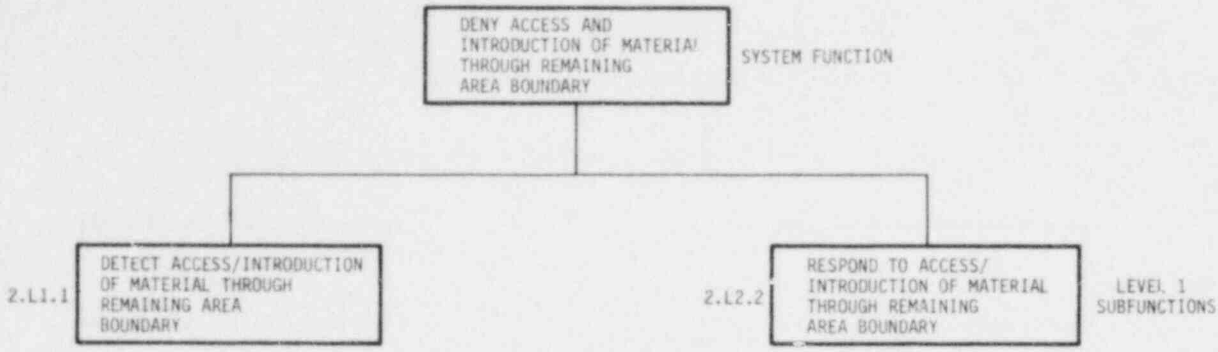


Note that 1.L2.3 is a low-level system task and, so, further decomposition is not required. The response subfunction 1.L2.4 will not be decomposed here since the subfunctions and low-level system tasks required to perform the response subfunction will be the same for normal and emergency conditions.

This completes a functional decomposition of the entire left side of Figure 2-2 for the system function CONTROL ACCESS AND INTRODUCTION OF MATERIAL THROUGH AREA ENTRY PORTALS.

System function 2, which appears on the right side of Figure 2-2, will now be decomposed.

There is a noticeable similarity between the subfunctions required to perform these system functions. Namely, the physical protection system must ensure detection of and response to the adversary threat. The resulting decomposition is shown below.



Again the decomposition of the response subfunction is expected to be the same as that for system function 1, so, it is not included here.

The detection subfunction in system function 2 shown on the right side of the hierarchy in Figure 2-2 does require a different set of subfunctions and low-level tasks from those previously identified for detection in system function 1. This is due mainly to the type of detection that is required at the entry-control portals. Either an attempt is made to gain access by force or by feigning authorized access. In either of these two cases, the detection subfunction is heavily dependent on entry-control personnel and procedures. On the other hand, detection of attempts to gain access or introduce material through the remaining MAA boundary, e.g., a window, will rely primarily on electromechanical components. There may also be a guard patrol which senses the intrusion; however, in both of these cases, sensing the intrusion is not sufficient to ensure detection.

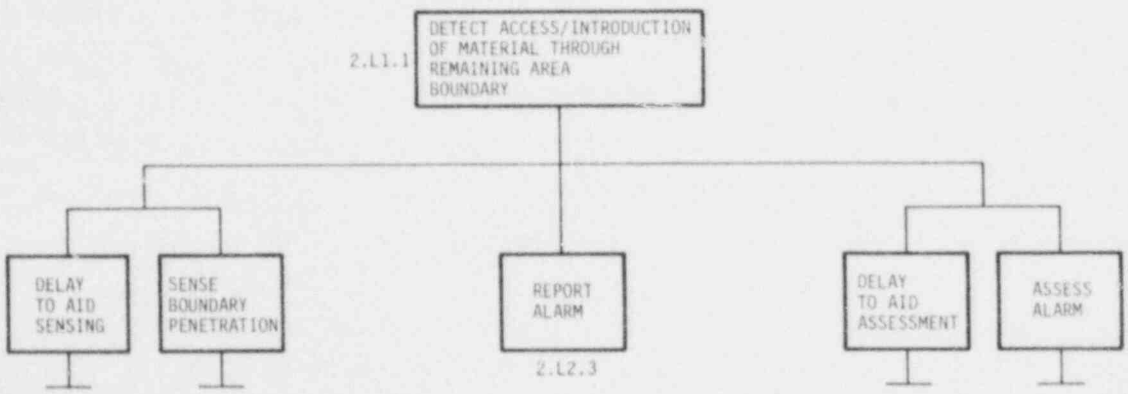
First, detection by some periodic means, e.g., a CCTV camera which scans an entire room a section at a time or a guard patrol which goes around a building once in an hour, will be considered. In this case, sensing of an intrusion will not occur unless there is sufficient delay to allow the sensor (equipment or personnel) to cover the point of intrusion during that time. For example, if it takes the adversary 10 minutes to pick a door lock and it takes the guard 30 minutes to patrol that building, then the adversary can begin the intrusion process once the guard has passed. By the time the guard returns to that point, the intrusion will be complete without signs of entry. This illustrates the time interaction between the sensing and delay tasks.

In the other case, in which sensing is not periodic, the delay task does not play a part in ensuring that the intrusion is sensed. Because the detection subsystem must be effective over a wide range of conditions, its decomposition reflects the case in which delay is necessary. Two interrelated tasks have been identified in this decomposition thus far:

2.L2.1 DELAY TO AID SENSING
2.L2.2 SENSE BOUNDARY PENETRATION

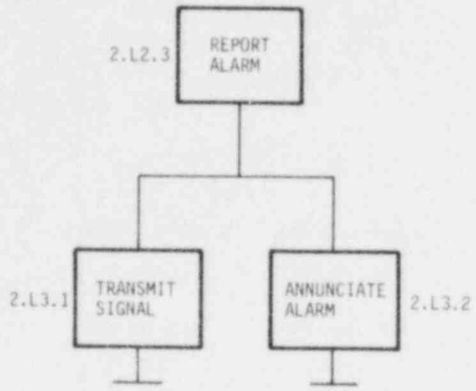
Sensing of an intrusion by either electromechanical or human means, however, is not sufficient to ensure detection. The alarm must be reported by either electronic means or by personnel who have sensed the intrusion. These factors alone still do not constitute detection. Because the incidence of false alarms is a possibility, assessment must also take place. Assessment is similar to sensing by periodic means in that sufficient delay must be provided to detain the adversary long enough to verify that a valid alarm has been received and to obtain sufficient information to initiate an appropriate response.

The resulting decomposition for the detection subfunction 2.L1.1 is shown below.



Note from the above that only one subfunction requires further decomposition, 2.L2.3. The other subfunctions have been defined in sufficient detail to permit identification of components for achieving the desired subfunction performance.

The final step in this decomposition requires the identification of low-level tasks which are necessary to ensure that an alarm is reported. In the case of a human sensor, this decomposition is not necessary. If a piece of equipment is the sensor, the signal from the sensor must be transmitted and the alarm must be annunciated at the alarm station in order for alarm reporting to occur. The low-level tasks resulting from this final decomposition are shown below.



This concludes the functional decomposition of the performance capability stated in 10 CFR Part 73.45 paragraph (b).

2.3 Component Selection Matrices

2.3.1 Overview -- To provide the licensee with feasible component options for performing low-level system tasks, nine component selection matrices were developed. These matrices, which are grouped by generic physical protection system tasks, are listed in Table 2-1 and included in Volume II of this report.

2.3.2 Matrix Development -- Development of a component selection matrix for a generic system task requires identification of performance characteristics associated with that subfunction. A performance characteristic is defined as a low-level system task, the performance of which is constrained to a particular location or in a specific application. For example, one low-level system task is "sense boundary penetration," and the corresponding performance characteristics include "sense boundary penetration at the MAA wall." Lists of components (equipment, design features, and procedures) suitable for achieving each performance characteristic were compiled for entry into a convenient matrix form.

For each generic system task, there is a component selection matrix with a column listing of corresponding performance characteristics. A row listing contains components which the NRC staff considers

Table 2-1

Component
Effectiveness Test
Questionnaires

1. Admittance Authorization Criteria and Schedules
2. Admittance Authorization/Verification
3. Air and Utility Inlet Barriers
4. Annunciation Systems--Computer-Assisted Annunciation, Individual Alarm Annunciation, Multiplex Alarm Annunciation
5. Area Zoning
6. Balanced Magnetic Switches
7. Breakwire Systems (Foil Strip and Grid Wire)
8. Buried Line Sensors--Seismic-Magnetic Cable, Geophone String, Piezoelectric Button String
9. Capacitance Alarms
10. CCTV Monitoring/Surveillance
11. CCTV Systems
12. Central and Secondary Alarm Stations
13. Closeout Inspection by a Third Party
14. Coded Credential Systems--Active Electronic, Electric Magnetic Coded, Magnetic-Stripe Coded, Metallic-Strip Coded, Optical Coded, Passive Electronic
15. Commercial Telephone System
16. Contingency Plan and Procedures
17. Controlled Security Lighting
18. Data Link via Radio Frequency
19. Direct-Line Telephone/Intercom
20. Direct Monitoring/Surveillance
21. Doors and Associated Hardware
22. Duress Alarms
23. Electric Field Fence (E-Field) Systems
24. Electret Cable and Tilt Switch Fence Sensors
25. Emergency Access/Egress
26. Emergency Battery System (EBS)
27. Emergency Evacuation Procedures
28. Emergency Exits
29. Emergency Generator Systems (EGS)
30. Equipment Checks/Maintenance
31. Escort
32. Explosives Detector--Hand-Held, Package Search
33. Explosives Detector--Hand-Held, Personnel Search
34. Explosives Detector--Hand-Held, Vehicle Search
35. Explosives Detector--Volume
36. Explosives Detector--Walkthrough
37. Fence Systems
38. Floors
39. Functional Zoning
40. Gates and Associated Hardware
41. Guard Force Personal Equipment
42. Guard Force Qualification
43. Guard Patrols/Intervention
44. Guard Post Assignment
45. Hard-Wire Video Systems
46. Infrared Beam Systems, Exterior
47. Interfaces Between Alarm Station and Sensors--Individual Hard-Wire Alarms, Multiplexed Hard-Wire Alarms, Hard-Wire Command Signals
48. Design Feature: Isolation Zones
49. K9 Package Search

Table 2-1 (Continued)

50. K9 Vehicle Search
51. Local Audible/Visible Alarms
52. Locks (Key Locks, Keyless Locks)
53. Manual Alarm Recording
54. Master (Fixed) Radio
55. Microwave Systems--Exterior
56. Mobile Radio
57. Motion Detectors--Infrared Systems, Interior; Microwave Systems, Interior; Ultrasonic and Sonic Systems
58. Multiman Rule
59. Night Vision Devices (Goggles, Scopes)
60. Package Search--Visual Inspection
61. Pat-Down Search
62. Personal Identification Numbers/Passwords
63. Photo Identification Badges
64. Physical Controls and Procedures for Keys, Locks, Combinations, and Cipher Systems
65. Portable Radios
66. Positive Personnel Identification--Fingerprint, Handwriting, Hand Geometry, Voice Print
67. Response Vehicles
68. Roof
69. Sally Ports, Pedestrian
70. Sally Ports, Vehicular
71. Shielding Detector--Volume
72. Shielding Detector--Walkthrough
73. SNM Containers
74. SNM Detectors--Hand-Held, Package Search
75. SNM Detectors--Hand-Held, Personnel Search
76. SNM Detectors--Volume
77. SNM Detectors--Walkthrough
78. SNM Holding/Storage Areas
79. SNM Identification/Authorization Procedures
80. SNM Liquid and Solid Waste Handling Procedures
81. SNM Scrap Removal Procedures
82. SNM Shipping and Receiving Procedures
83. Tamper-Indicating Circuitry
84. Tamper-Indicating Seals and Tamper Seal Inspections
85. Team Zoning
86. Uninterruptible Power Systems (UPS)
87. Vaults
88. Vehicle Search--Visual Inspection
89. Vibration Sensors
90. Walls
91. Weapons (Handguns, Shotguns, Semiautomatics)
92. Weapons Detector--Hand-Held, Package Search
93. Weapons Detector--Hand-Held, Personnel Search
94. Weapons Detector--Volume
95. Weapons Detector--Walkthrough
96. Windows and Associated Hardware
97. X-Ray Package/Container Search

feasible measures for performing the matrix task. The dots which are placed at the intersection of the rows and columns indicate potential components for achieving a particular performance characteristic. Figure 2-7 provides an illustration of these concepts. From this figure, the licensee could select from the following list of components to sense boundary penetration at the MAA wall:

1. Interior microwave systems,
2. Ultrasonic and sonic systems,
3. Interior infrared systems,
4. CCTV systems,
5. Breakwire systems,
6. Vibration sensors, or
7. Guard patrols.

Given this choice of components, the licensee may select one or several of these components to use in combination to sense boundary penetration at the MAA wall within the constraints imposed by his individual facility.

2.4 Component Effectiveness Test Questionnaires

2.4.1 Overview -- A set of effectiveness test questionnaires (ETQs) was developed for 97 generic components (equipment, design features, and procedures) which the NRC staff considers suitable for inclusion in a physical protection system. These components are listed in Table 2-1. The questionnaires provided in Volume II are designed to provide a method by which individual component performance can be measured in a consistent manner when applied by the licensee in the design phase and by the NRC in the licensing and inspection phases.

2.4.2 Effectiveness Test Questionnaire Development -- Component performance is highly dependent upon many factors and contingencies. However, experience gained through extensive hardware testing supported by DOE at Sandia Laboratories has provided principles and guidelines for proper component selection and utilization. While the employment of such guidelines does not guarantee satisfactory performance, it seems reasonable to assume that performance is a direct function of adherence to these guidelines. With this in mind, ETQs which address factors deemed important to performance were developed, under joint NRC/DOE sponsorship, for the 97 generic types of components listed in Table 2-1.

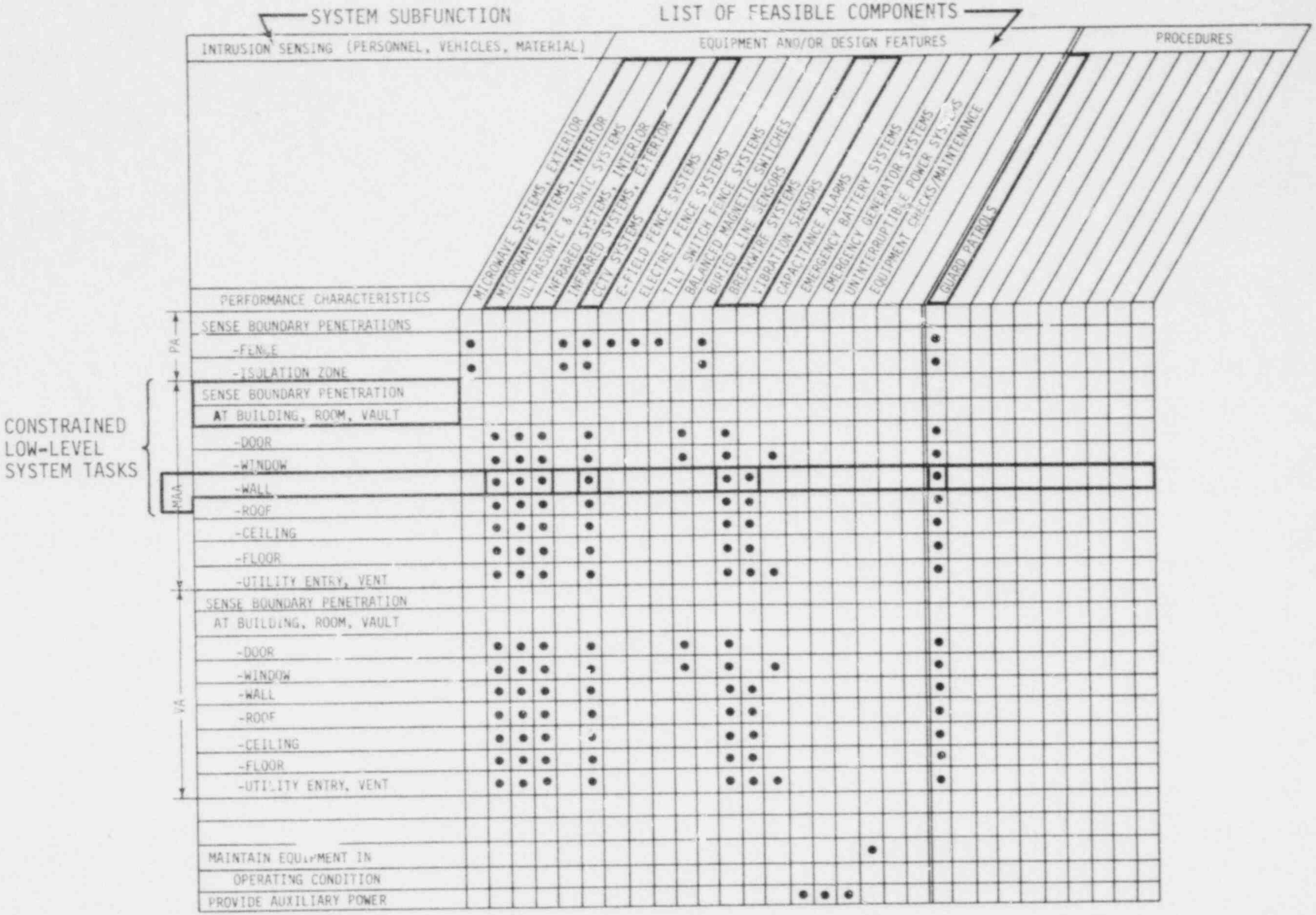


Figure 2-7. Component Selection Matrix for Intrusion Sensing

Another facet of this problem is the need for some means of measuring component performance. At best, component performance evaluation is a difficult task. In addition to the complexity involved, a certain degree of subjectivity further complicates evaluation of component performance. This subjectivity is due to several factors, including the inability to measure component performance during the design stage and also the inability to quantify certain performance measures. The ETQs which were developed facilitate the evaluation task by providing a framework for component performance evaluation within these constraints.

Questionnaire Content. Effectiveness test questionaires were developed for equipment, design features, and procedures. The questions in the equipment and design feature ETQs are based largely on experience gained from DOE's physical protection R&D program at Sandia Laboratories. The performance factors addressed in these questionnaires include the following:

1. Site conditions such as terrain features, structures in a sensing area, etc.
2. Environmental conditions which include natural conditions, e.g., wind, lighting, extreme cold, presence of wildlife, and manmade conditions, e.g., electromagnetic interference, ventilation, and heating equipment noise, etc.
3. Installation considerations such as mounting procedures for sensors on a fence, wiring techniques for capacitance alarms, etc.
4. Operation and maintenance considerations which include preventive maintenance schedules, criteria for setting sensor sensitivity levels, etc.
5. Reliability factors such as self-test capability, emergency power supply, availability of spare parts, etc.
6. Vulnerability aspects which treat the equipment's susceptibility to circumvention, tamper protection, etc.

The development of ETQs for procedures posed some difficulty in that very little analysis of physical protection procedures has been performed. Thus, there were no formal guidelines for procedures other than some rather general information in NRC regulatory guides. The

ETQs that were finally developed for procedures included the following type of information:

1. General performance conditions which include the more general factors pertaining to the implementation of the procedure, e.g., the means by which an emergency would be verified.
2. Site conditions such as questions pertaining to the size and function of the area in which monitoring will take place.
3. Training and proficiency levels which treat the instruction of personnel or animals performing a procedure, proficiency tests utilized and the frequency of testing and retraining in cases such as those in which dogs are used for explosives detection in vehicle searches.
4. Reliability factors such as length of duty assignments, operational testing to determine procedure effectiveness, double-checks on procedure performance, etc.
5. Vulnerability aspects which treat such factors as the procedure's susceptibility to circumvention, susceptibility to collusion, etc.

The ETQs, which consist of questions designed to address performance factors within the categories just listed, were developed to cover various adversary contingencies. The adversary strategy is treated implicitly in these questionnaires. For example, tamper protection is addressed to treat attempts by insiders or outsiders to surreptitiously disable the equipment. Another example is enclosure of a lock case and bolt mechanism to protect against forcible defeat of the lock.

Another feature of the component ETQs is the ability to treat the performance of a subcomponent within the ETQ of another component whose performance is affected by the performance of the subcomponent. For example, the following question is taken from a sensor questionnaire:

> If tamper protection will be employed, what will be the performance level of the tamper-indicating circuitry? (To aid performance estimation, refer to the questionnaire on tamper-indicating circuitry.)

In order to adequately describe the performance of the sensor, it is necessary to incorporate the performance of the subcomponent, in this case, the tamper-indicating circuitry. Other questionnaires for which subcomponent performance must be considered include those dealing with doors whose performance depends in part on the locks, CCTV monitoring and surveillance equipment whose performance incorporates that of controlled security lighting, and equipment whose performance is dependent on the performance of the emergency power source used in case of power failure.

Questionnaire Format. In developing these component questionnaires, consideration was given to several areas to ensure practicability. First, efforts were made to provide completeness in addressing all essential factors which affect performance. Attempts were also made to eliminate redundancy in the consideration of performance factors. In addition, efforts were made to minimize the number of questions in an ETQ.

To reduce ambiguity and to facilitate the aggregation of responses into a measure of component effectiveness, the question responses are presented in a multiple-choice format in descending order of preference. This response format attempts to minimize the subjectivity which is inherent in this type of evaluation where judgements by knowledgeable individuals play a major role. With this in mind, each specific response scale was designed to have the following properties:

- Comprehensiveness: The score on the scale should adequately reflect the component performance relative to the factor in question. The scale should be applicable in most situations and for most adversary actions.
- Operational: The scales should minimize ambiguity by providing (1) a sufficient number of possible responses to discriminate between most situations and (2) meaningful and concise scale point definitions that include examples for each point on the scale and should use specific quantitative units where possible.
- Linearity: Preferences over the scale responses were assumed to be linear to facilitate the aggregation of responses. If two responses are almost equally desirable, they are presented as alternatives having the same value on the scale.

In summary, the question response format which was adopted for the component ETQs should enhance the licensee's ability to select and effectively implement components to perform the physical protection system tasks identified at the lowest level of the functional hierarchies. In addition, this format will facilitate component performance evaluation.

2.5 System Effectiveness Test Questionnaires

The design guidance products requested by the NRC did not include system effectiveness test questionnaires. However, as the evaluation methodology discussed in Chapter 3 evolved, the need for additional ETQs to address the effectiveness of multiple component systems and the interactions among various system functions and subfunctions became apparent. Although the need for these ETQs was recognized as a result of the evaluation methodology development, they are equally necessary to provide comprehensive design guidance to licensees.

Certain system ETQs are needed to evaluate the effectiveness of combinations of components with respect to their ability to perform a given system task. These ETQs provide a means of selecting an approach for aggregating the individual component scores into an overall score for the multicomponent system's ability to perform the associated task. The selection of the aggregation approach is based on how effectively the individual components are combined. The effectiveness of the combination depends on various factors such as environmental conditions which could simultaneously affect the component's operational incompatibilities and mutual tamper protection.

Other system ETQs were required to address functional and dynamic interactions of various system functions and subfunctions. For example, to determine the effectiveness of the assessment subfunction, it is necessary to address the interaction between assessment and delay. The primary factor affecting this interaction is time. Therefore, the system ETQ must provide some means of correlating the delay and assessment times. A similar interaction occurs between delay and sensing when the latter performed periodically and between delay and response.

A limited number of system ETQs were developed under the current program. These questionnaires, which are included in Volume II of this report, treat the alarm assessment system, alarm reporting system, communication system, and penetration sensing system.

CHAPTER 3

EVALUATION METHODOLOGY

This chapter describes the development of a logical, comprehensive, and practical method of evaluating physical protection system performance for each of the capabilities specified in the fixed-site Upgrade Rule, 10 CFR Part 73.45

3.1 Overview

The evaluation methodology described in this chapter utilizes probability theory to derive logical forms of component and system performance measures and employs multiattribute utility theory to aggregate these measures, many of which are assessed subjectively, into a single overall performance score. The methodology is unified by a structure which provides clear traceability to the Upgrade Rule requirements. This evaluation structure consists of a set of hierarchies developed from a functional decomposition of each of the five performance capabilities specified in the Upgrade Rule.

Each functional hierarchy, shown in Figures 2-2 through 2-6, is headed by one of the performance capabilities, which is considered an objective. Each objective is partitioned into the system functions necessary for the operation of the system. This functional decomposition is continued until a task for a generic-type component can be identified. This task is the lowest level in the hierarchy and is called a low-level system task. A partial development of a functional hierarchy is illustrated in Figure 3-1. Since the same low-level task may be performed by different components at different locations, e.g., sense boundary penetration at fences, emergency exits, windows, etc., further constraints, called performance characteristics, may be imposed for component selection. At this point, an overall measure of performance, or score, based on an evaluator's responses to component ETQs is assigned to the component selected.

Once each component has received a score, the scores for those components that address individual performance characteristics must be

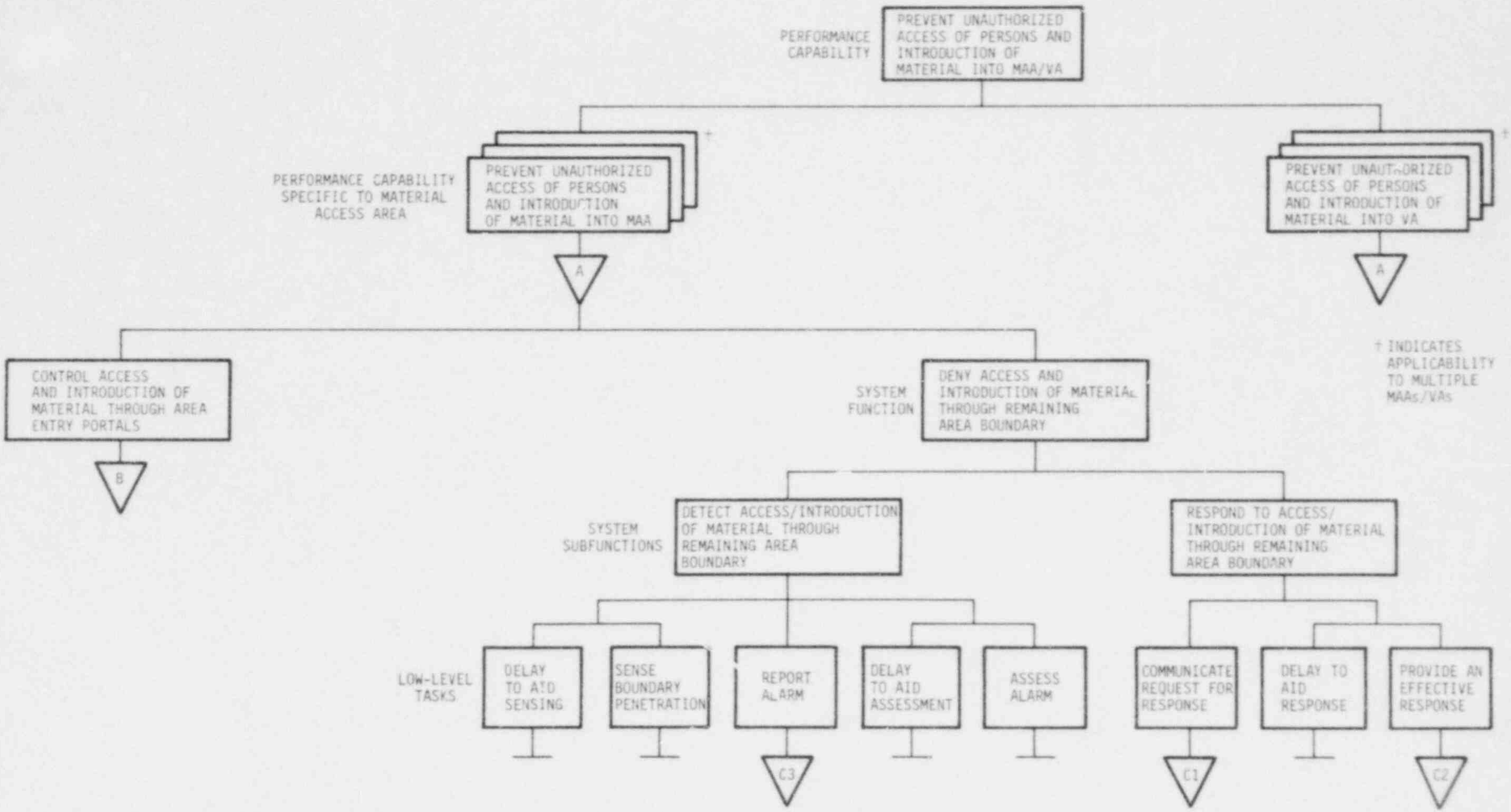


Figure 3-1. Partial Development of a Functional Hierarchy

aggregated to arrive at a single score for the appropriate low-level system task. In order to determine the scores for other levels of the hierarchy, the scores for low-level system tasks are combined into system subfunction scores, which are then aggregated into system function scores, and, finally, into an overall score for each performance capability. Therefore, five aggregations must be made using individual schemes that reflect the numerous questions, components, tasks, subfunctions, and functions.

3.2 Component Performance Evaluation

The objective of the component performance evaluation methodology is to synthesize responses to individual questions from an ETQ into a meaningful overall measure of expected performance. The initial method of evaluation developed was theoretically oriented and, while it established a logical foundation for the methodology, its implementation proved prohibitive within the current scope of the program. Subsequently, modifications to the methodology were developed to facilitate implementation. The evaluation methodology development is discussed in the following sections. The functions used in the evaluation method are derived in Appendix A.

3.2.1 Methodology -- The initial evaluation method provided a logical basis for structuring questionnaires, for scoring individual question responses, and for aggregating question scores into a measure of component performance. Application of the methodology to an ETQ consisted of the following four steps:

1. Structure the questionnaire for aggregation,
2. Assign a weight to each question,
3. Assign a value to each question response, and
4. Assign aggregation rules and compute an overall score based on question responses.

The following ETQ for the Hard-Wire Video System will be used to illustrate each of these four steps and to describe the results obtained by their application.

EFFECTIVENESS TEST

FUNCTION

The function of the hard-wire video will be to provide a means to transmit information from a remote video camera to the local video monitor.

CONDITIONS

Environmental Conditions

1. What means of lightning protection will be provided for the video cable?

2. If electromagnetic interference (EMI) sources are expected to be nearby, what will be done to minimize their effect on signal transmission?

3. Will all exterior connections be sealed from moisture?

4. Will messenger wires be used to support aerial cable runs?

Performance Conditions

Operation

5. Will impedance mismatching between video cable and equipment be minimized to avoid ghost images on monitors?

6. If excessive signal losses due to impedance matching transformers, isolation transformers, and/or long cable length cause unsatisfactory monitor pictures, will video equalizers and/or line amplifiers be utilized?

Maintenance

7. Will preventive maintenance be performed on a schedule supported by mean-time-between-failure (MTBF) data?

Reliability

8. If line amplifiers are used, what type of emergency power system (EPS) will be employed in the event that normal power is lost?

9. What will be the level of emergency power system (EPS) performance? (To aid performance estimation, refer to the questionnaire on the specific EPS.)

10. In the event of normal power failure (accidental or intentional), how much time will be required to restore video cable operation?

Vulnerabilities

11. Will the video transmission system be completely contained within the protected area?

12. If tamper protection will be employed, what will be the level of performance of the tamper-indicating circuitry associated with the video cable? (To aid performance estimation, refer to the questionnaire on tamper-indicating circuitry.)

ANSWERS

CONDITIONS

Environmental Conditions

1. a. 1. Equipment will be enclosed in a grounded metal enclosure (Faraday shield). Generally acceptable approximations are well-bonded all-metal structures or buildings, and concrete structures or buildings with all rebar and metal sheathing, including roof and floor, bonded, and
   2. All conductors penetrating the structure (plumbing, conduit, cable shields, etc.) will be bonded to an entry panel, which in turn will be bonded to the structure (Faraday-type) shield and a good ground, and
   3. At the entry panel, primary surge arresters, e.g., gas-filled spark gaps, will be connected between each cable conductor and ground, and
   4. If solid state electronic or other equipment sensitive to short-time over-voltage is to be protected, then secondary surge protection, e.g., silicon junction avalanche devices or metal oxide varistors, will be connected at the equipment between each cable conductor and ground. Sufficient circuit delays are necessary to permit the primary surge protection to function.

   b. All of the above except 1, plus properly installed and grounded lightning rods.

   c. Only 2. and 3. or, if sensitive equipment, only 2. and 4.

   d. Only 2.

2. a. Either EMI is not expected to be a problem, or shielded, balanced line transmission employing balanced line isolation transformers at each end of the line will be used.

   b. Shielded, unbalanced line with an isolation transformer at one end of the line will be used.

   c. Shielded, unbalanced line will be used.

3. a. Yes.

   b. No.

4. a. Yes, or messenger wire is not needed (e.g., cable will be installed in underground conduit).

   b. No.

Performance Conditions

Operation

5. a. Yes.

   b. No.

6. a. Yes, or signal losses will not be excessive.

   b. No.

Maintenance

7. a. Yes.
   b. No.

Reliability

8. a. Either power is not required for operation or uninterruptible power system.
   b. Emergency battery system.
   c. Emergency generator system.
   d. None (will be flagged for performance downgrade).

9. a. 0.8 to 1.0, or power will not be required for operation.
   b. 0.6 to 0.8.
   c. 0.4 to 0.6.
   d. Less than 0.4

10. a. Less than 5 seconds, or will not be required for operation.
    b. From 5 seconds to 1 minute.
    c. From 1 to 5 minutes.
    d. More than 5 minutes.

Vulnerabilities

11. a. Yes.
    b. No.

12. a. 0.8 to 1.0.
    b. 0.6 to 0.8.
    c. 0.4 to 0.6.
    d. Less than 0.4, or tamper protection will not be employed.

Step 1: Structure the Questionnaire. Each question in an ETQ addresses a factor which impacts component performance. The construction of a simple fault tree that relates each factor to component failure modes allows the question responses to be logically aggregated to arrive at an overall score for component performance. A possible fault tree for the Hard-Wire Video System ETQ is shown in Figure 3-2. The numbers shown in the boxes in this figure correspond to question numbers in the sample ETQ.

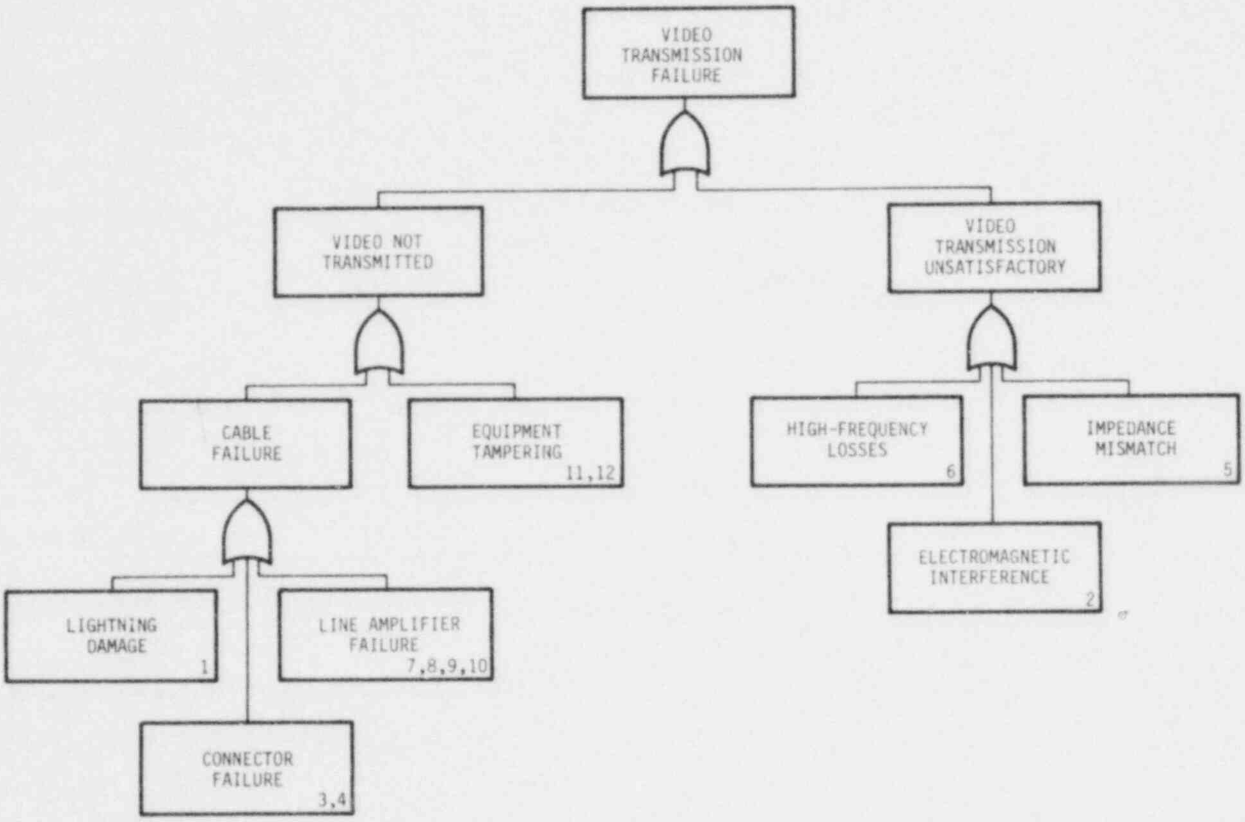


Figure 3-2. Hard-Wire Video System Fault Tree

Step 2: Assign Weights. Once the questions have been structured into groups, weights must be assigned to show the relative importance of the question within the group. Five possible weights are suggested:

1. High importance = 1.0
2. Medium importance = 0.5
3. Low importance = 0.25
4. Very low importance = 0.1
5. No importance = 0.0

For a set of questions which are relevant to an event in the fault tree, the weight assigned to each question can be viewed as a surrogate measure for the conditional probability of that event given the degraded conditions of component performance implied by the minimum response for that question. A question with an assigned low weight can have a negligible effect on overall performance, while a highly weighted question can have a dramatic effect. For example, a question that might be asked while assigning weights is "What possible degradation of component performance can occur as a result of a minimum (0) response to the question?" The weight assigned would depend upon which of the following is the appropriate answer:

1. A severe degradation in performance could occur, rendering the component incapable of performing its function. (Weight = 1.0)
2. A moderate degradation in performance could occur, resulting in the likelihood that the component would be ineffective. (Weight = 0.5)
3. Only a minor degradation in performance could occur, with the component still likely to function properly. (Weight = 0.25)
4. A very minor degradation in performance could occur, with only a minimal effect on component operation. (Weight = 0.1)
5. No degradation in performance could occur. (Weight = 0.0)

Questions which provide for branching of subjects, identify types of subcomponents used, or identify conditions under which the component must operate and which do not specifically pertain to performance should be assigned a zero weight.

The following provides the rationale used in arriving at the weighting for some of the questions in the example questionnaire:

Question 1. Question 1 was weighted 0.5. While response (d) implies little or no lightning protection, there are the additional conditions of lightning strokes and of damaging currents developing before video cable components (line amplifiers, matching transformers, etc.) could become inoperative. Such conditions provide a mitigating effect on the weight assigned.

Question 2. Question 2 was weighted 0.25. Electromagnetic interference (EMI) usually causes minor degradation in picture quality. The lines and bars caused by EMI are primarily an annoyance and do not opaque the screen. Response (d), while representative of a minimal effort to reduce EMI effects, indicates that some high-frequency attenuation occurs.

Question 8. Question 8 was weighted 0 since it only identifies the type of emergency power supply used.

Question 10. Question 10 was weighted 0 since the subject is included in the power supply questionnaire. When associated with CCTV surveillance and the assessment function, this question serves to emphasize the importance of outage time.

Question 12. Question 12 was weighted 1.0. Response (d) was interpreted to mean that undetected tampering could easily take place. Such a condition might be expected to encourage an adversary to take advantage of the situation and render the component ineffective.

Obviously, a set of responses to questions could be created which would result in any question being assigned a weight of 1.0. However, the minimum response to a question should represent an unsatisfactory threshhold; otherwise, the importance of the question might become inflated.

Step 3: Assign Response Values. After a weight (w_i) is assigned to each question (i), these weights are used to determine response values. Each question has a set of responses listed in descending order of preference. Where applicable, the first response should be of the following form: Either this factor is of no concern, or it is a particular design or procedure recommendation that is judged to provide the greatest likelihood of success with regard to the factor for all conditions considered. This form eliminates the possibility of penalizing a system for not incorporating the best recommendation when, in actuality, that particular factor, e.g., snow in Florida, is nonexistent at the facility being evaluated. The first response is assigned a value $x_i = 1$.

The last response listed for a question is judged to be unacceptable because either the success likelihood is considered too low for all conditions anticipated or the conditions for which success is likely are too limited. This last response is assigned a value $x_i = 0$.

For now, the question responses are assumed to fit linearly on a 0 to 1 scale, e.g., for three responses, $x_1 = 1$, $x_2 = 0.5$, and $x_3 = 0$. Responses can always be reevaluated individually if this method does not yield sufficiently accurate results. Each response (x_i) is then weighted by the importance of the question (w_i) to obtain a score (s_i) as follows:

$$s_i = 1 - w_i(1 - x_i) \qquad (3\text{-}1)$$

The sensitivity of this function is shown in Figure 3-3, which indicates that, regardless of weight, a maximum response results in a maximum question score. Responses other than the best response are increasingly penalized with increasing weight. The individual question parameters, along with the resultant question scores for the sample questionnaire, are shown in Table 3-1.

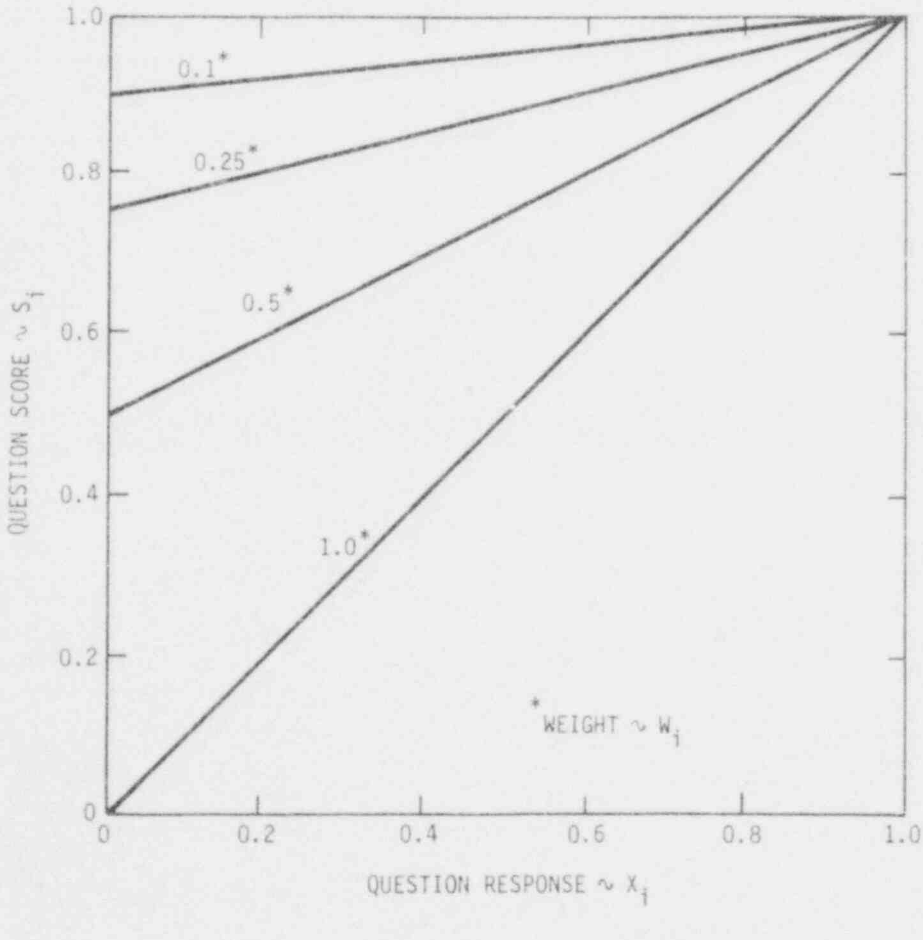


Figure 3-3. Sensitivity of Question Score as a Function of Question Response and Weight

Step 4: Assign Aggregation Rules. For an aggregation method to be acceptable in this application, it must treat each question score as if it were related to the probability of success or failure of some aspect of overall component performance under a given set of conditions. One approach is to construct a fault tree that relates question scores to an overall measure of component performance.

Table 3-1

Individual Question Parameters
for
Sample Effectiveness Test Questionnaires

EQUIPMENT: Hard-Wire Video System

	Question	Weight (w_i)	Response (x_i)	Score (s_i)
Group 1	1	0.5	0.67	0.84
	3	0.25	1.0	1.0
	4	0.5	1.0	1.0
	7	0.25	1.0	1.0
	8	0	0.67	1.0
	9	0.5	0.67	0.84
	10	0	0.67	1.0
	11	0.5	1.0	1.0
	12	1.0	0.67	0.67
Group 2	2	0.25	0.5	0.875
	5	0.25	1.0	1.0
	6	0.25	1.0	1.0

Utilizing concepts from fault tree logic, the component performance level associated with each group of questions is obtained by aggregating individual question scores (s_i) through whichever of the following rules is most appropriate: (1) AND, (2) SOFT AND, (3) AVERAGE, (4) SOFT OR, and (5) OR. A description of each of these rules follows:

AND. The AND rule is appropriate whenever all of the performance factors addressed by a group of questions are essential to component effectiveness under all conditions. That is, if any factor is unsatisfactory, component performance is unsatisfactory. For this case, the aggregation function is

$$S = \prod_{i=1}^{n} s_i \qquad (3\text{-}2)$$

where

S = the overall component event score
s_i = the individual question score
n = the number of questions in the group to be aggregated.

<u>SOFT AND</u>. The SOFT AND rule is appropriate whenever it is unlikely that all of the factors within the group will be simultaneously essential, but, due to the large set of possible conditions in which the component must function, there is uncertainty as to which subset of factors is essential at any given time. This case can be interpreted as the probability that all factors, within a subset chosen at random from all possible subsets, will be satisfactory. For this case, the aggregation function is

$$S = \frac{1}{2^n - 1}\left[\prod_{i=1}^{n} (s_i + 1) - 1\right] \qquad (3\text{-}3)$$

<u>AVERAGE</u>. The AVERAGE rule is appropriate whenever the component performance is dependent upon or dominated by a single factor within the group, but, due to the large set of possible conditions in which the component must function, there is uncertainty as to which factor is dominant. This case can be interpreted a the probability that any one factor, chosen at random from 11 possible factors within the group, will be satisfactory. For this case, the aggregation function is

$$S = \frac{1}{n}\sum_{i=1}^{n} s_i \qquad (3\text{-}4)$$

<u>OR</u>. The OR rule is appropriate whenever it is required that at least one factor within the group be satisfactory for satisfactory component performance under all conditions. For this case, the aggregation function is

$$S = 1 - \prod_{i=1}^{n} (1 - s_i) \qquad (3-5)$$

SOFT OR. The SOFT OR rule is appropriate whenever it is unlikely that all of the factors within the group will be relevant in a given situation, but, due to the large set of possible conditions in which the component must function, there is uncertainty as to which subset of factors is relevant at any given time. This case can be interpreted as the probability that at least one factor within a subset chosen at random from all possible subsets within the group will be satisfactory. For this case, the aggregation function is

$$S = \frac{2^n}{2^n - 1}\left[1 - \prod_{i=1}^{n} (1 - \tfrac{1}{2}s_i)\right] \qquad (3-6)$$

Figure 3-4 shows a comparison between these expressions as a function of question score for five questions, each having the same score. An indication of the resolution to changes in question responses is shown in Figure 3-5 for the sample ETQ. The AND rule appears too harsh in requiring that all factors addressed by the ETQ be treated as essential to performance under all conditions. On the other hand, component performance does not seem to be dominated by any single factor chosen at random, which eliminates the AVERAGE rule. The SOFT AND rule seems to be the most appropriate aggregation rule for the sample ETQ because it treats subsets of factors chosen at random as essential to performance.

3.3 Methodology Modifications

While the initial development provided a logical foundation for the component evaluation methodology, its implementation disclosed a very practical problem, namely, the prohibitive effort required to develop a fault tree for each of the 97 ETQs, to determine weights for each question, and to estimate a value for each question response. Therefore, it was necessary to devise a more practical approach to component evaluation that would still retain much of the original logic foundation. As a result of further investigations, the following modifications to the evaluation methodology were made:

1. The SOFT AND aggregation rule was applied to all component questionnaires,

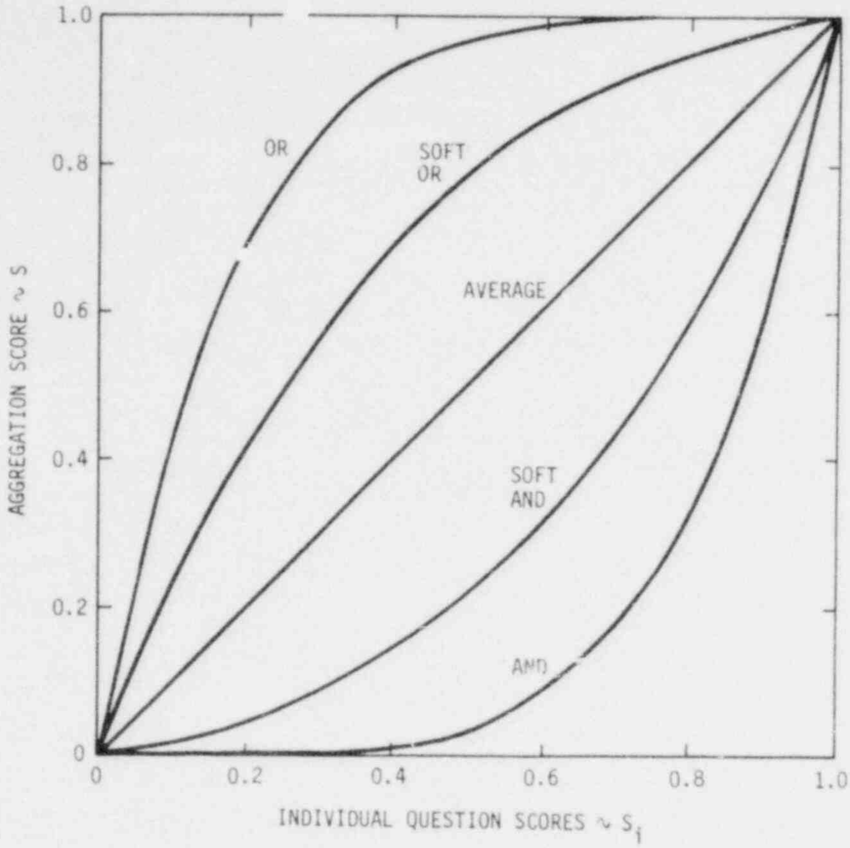


Figure 3-4. Comparison of Aggregation Rules for Five Questions of Equal Score

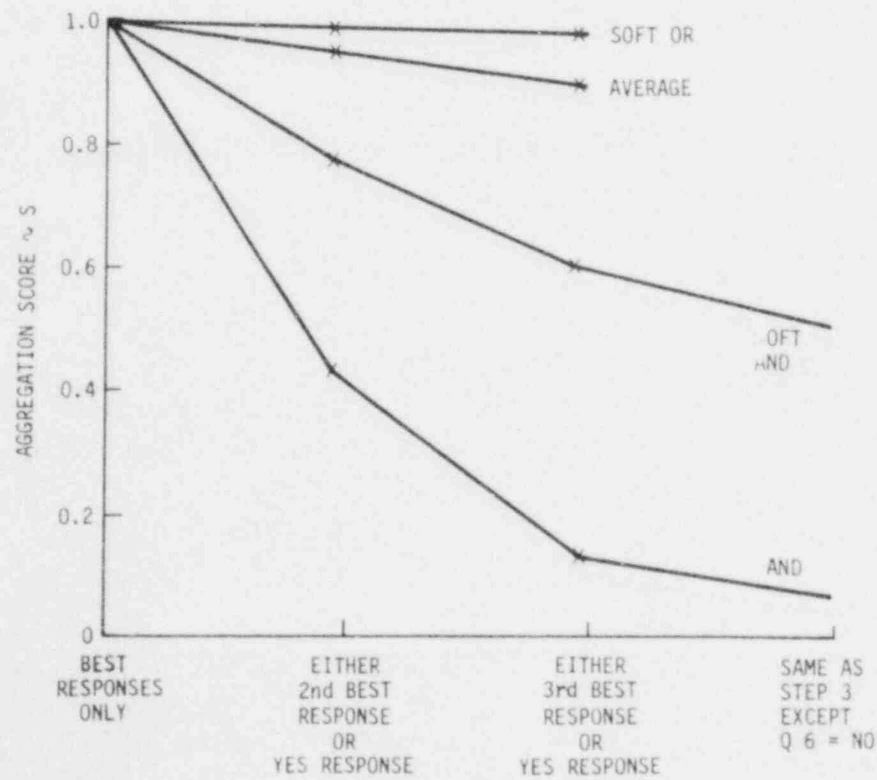


Figure 3-5. Resolution of Aggregation Rules to Question Responses in Sample Questionnaire

2. Each questionnaire was aggregated as a single group of questions,
3. All questions were weighted at 0.5, and
4. All trivial and nonperformance oriented questions were eliminated.

To provide a basis for simplification, sensitivities of results to aggregation structure and to question response were investigated using the Hard-Wire Video System ETQ.

3.3.1 <u>Aggregation Structure</u> -- If used exclusively to aggregate questionnaire responses, the AND rule provides a score which is independent of aggregation structure. This independence results from the fact that the AND rule is a simple product of individual scores.

Use of the SOFT AND rule is appropriate whenever it is unlikely that all of the factors treated in the questionnaire will be essential under all conditions, but, due to the large set of possible conditions in which the component must function, there is uncertainty as to which subset of factors is essential at any given time. Such a description makes the SOFT AND rule the leading candidate for aggregating most component ETQs.

In the application of the SOFT AND rule to various alternate structures for the Hard-Wire Video System ETQ, the most significant change in the aggregate score was caused by the change from an unstructured, single group of questions to a structure consisting of two basic groups of questions, such as that shown in Figure 3-2. The arrangement of the questions within the two-group structure seemed to be relatively unimportant. The effect of questionnaire structuring is shown in Figure 3-6. Comparison of the results from the two-group structure with those from a four-group structure indicated little or no difference. Therefore, it is evident that when the SOFT AND rule is utilized, the major concern is not the correctness of the aggregation structure but whether structuring is even necessary.

The other aggregation rules were not examined for sensitivity to questionnaire structure since no component was found whose performance was (1) dominated by any one factor chosen at random (AVERAGE rule), (2) dependent upon at least one factor addressed (OR rule), or (3) dependent on at least one factor within a subset chosen at random (SOFT OR rule).

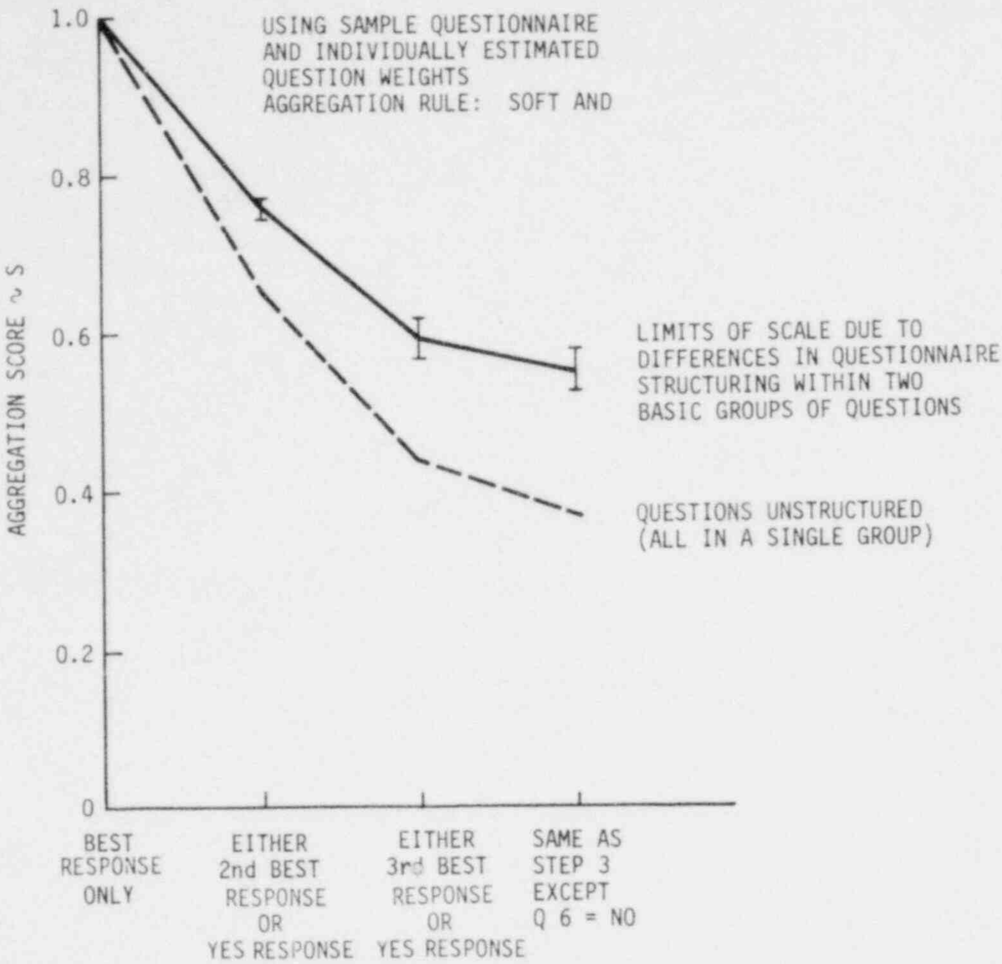


Figure 3-6. Effect of Questionnaire Structuring on Aggregation Scores

3.3.2 Question Response -- The sensitivity of the aggregate score (S) to the individual question response value (x_i) is obtained by finding the partial derivative of S with respect to x_i for each of the aggregation rules. The partial derivatives used to obtain the sensitivities are shown in Eqs. (3-7) through (3-11); these results were obtained at $x_i = 1$.

AND Rule

$$\frac{\partial S}{\partial x_i} = w_i S \qquad (3\text{-}7)$$

SOFT AND Rule

$$\frac{\partial S}{\partial x_i} \simeq \frac{w_i}{2} S \qquad (3\text{-}8)$$

AVERAGE Rule

$$\frac{\partial S}{\partial x_i} = \frac{w_i}{n} \tag{3-9}$$

where n = total number of question responses being aggregated

SOFT OR Rule

$$\frac{\partial S}{\partial x_i} \simeq \frac{w_i}{2^n} \tag{3-10}$$

OR Rule

$$\frac{\partial S}{\partial x_i} = 0 \tag{3-11}$$

if any $x_i = 1$

The partial derivatives shown in Eqs. (3-7) through (3-11) indicate the relative sensitivity of results between aggregation rules, shown earlier in Figure 3-5, and the importance of weights in the determination of the sensitivity of the aggregate score to individual question responses for a given aggregation rule. This second point presents somewhat of a problem in that the need for question weights was derived on a probability basis but the actual values must be provided on a subjective basis which is susceptible to personal bias and differing viewpoints.

In order to indicate the variability in estimating question weights, weight estimates for the Hard-Wire Video System ETQ were obtained from personnel experienced in this area. Aggregate scores based on these weight estimates were compared with scores derived from original estimates made by the authors (see Figure 3-7). The scores derived from estimates by experienced personnel were lower than the scores based on the authors' estimates. Although the lower scores resulted from a number of higher weight estimates, these estimates (with one exception) agreed within one increment (as defined on the weight scale described earlier) with the authors' original estimates. The differences in scores were within the range of scores obtained from differences in aggregation structure.

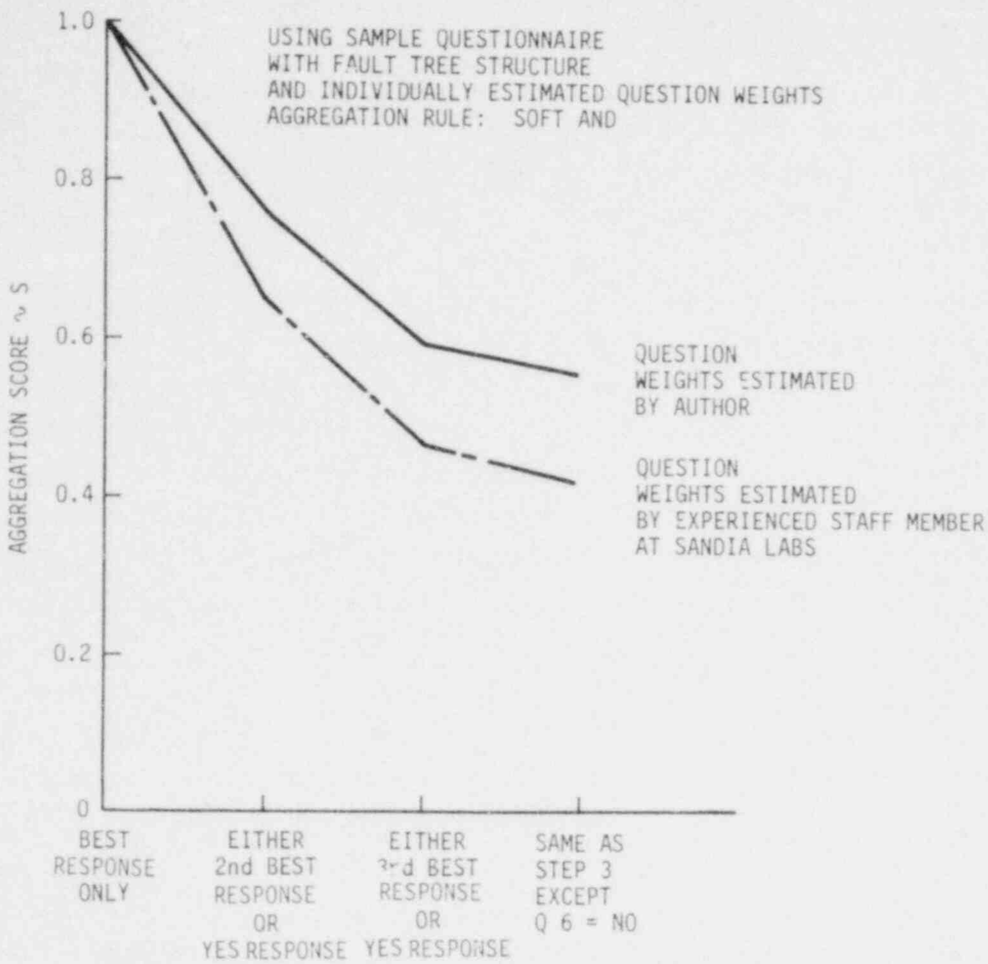


Figure 3-7. Effect of Different Estimates of Question Weights on Aggregation Scores

Due to subjectivity in weight estimates and possible variations in questionnaire structures, a feeling of uncertainty about the relationship between question responses and aggregate score is to be expected. Hopefully, a reasonable measure will lie somewhere within the ranges shown in Figures 3-6 and 3-7. Since this uncertainty exists, there seems to be little justification in implementing a complex methodology if a simpler one will provide satisfactory results. An enormous implementation effort could be eliminated if (1) each ETQ could be aggregated as a single group of questions and (2) all questions could be given an equal weight value (equal importance).

3.4 Methodology Simplification

If the evaluation problem is approached solely from the viewpoint of the question responses, without any measure associated with them, it seems likely that a component's performance could be acceptable if its

ETQ had mostly "best" and a few "second best" responses, or perhaps even a few "third best" responses. The question remains, how many minimum responses to questions would be acceptable? The answer to this question would depend on the nature of the questions in the questionnaire. To understand the impact of minimum responses to questions of different importance levels on the aggregate score, an ETQ was considered to be composed of many questions of each importance level (weight). The SOFT AND rule was selected as the aggregation rule with the set of response scores treated as a single group (unstructured). At a specific importance level, e.g., 0.10, an aggregate score was calculated for a group of questions. One of these questions was assigned a minimum response and the remaining questions were assigned "best" responses. These calculations were repeated while the number of questions that were assigned minimum responses was successively increased. This procedure was duplicated for importance levels of 0.10, 0.25, 0.50, and 1.0. The results of these calculations are shown in Figure 3-8 and indicate, for example, that if an ETQ receives one minimum response to a highly important question with best responses to all remaining questions, the aggregate score would be 0.5.

By equating aggregate scores from Figure 3-8 to those in either Figure 3-6 or 3-7, the number of minimum responses can be found that correspond to each category of question responses in Figures 3-6 and 3-7 (see Table 3-2).

Table 3-2

Conditions of Equivalent Aggregate Scores Between Figure 3-6 (Sample ETQ) and Figure 3-8

Sample ETQ Response Category	Number of Minimum Responses — Question Weights 1.0	0.5	0.25	0.1
2nd best or YES responses	<1	1	2-3	5-8
3rd best or YES responses	1	2-3	4-6	>9

If all the questions in the sample ETQ were considered to be of equal importance (assigned a single weight value) and the responses were aggregated as a single group using the SOFT AND rule, what weight value would be most acceptable? Assuming both response categories from the sample ETQ are satisfactory, it would be difficult to justify

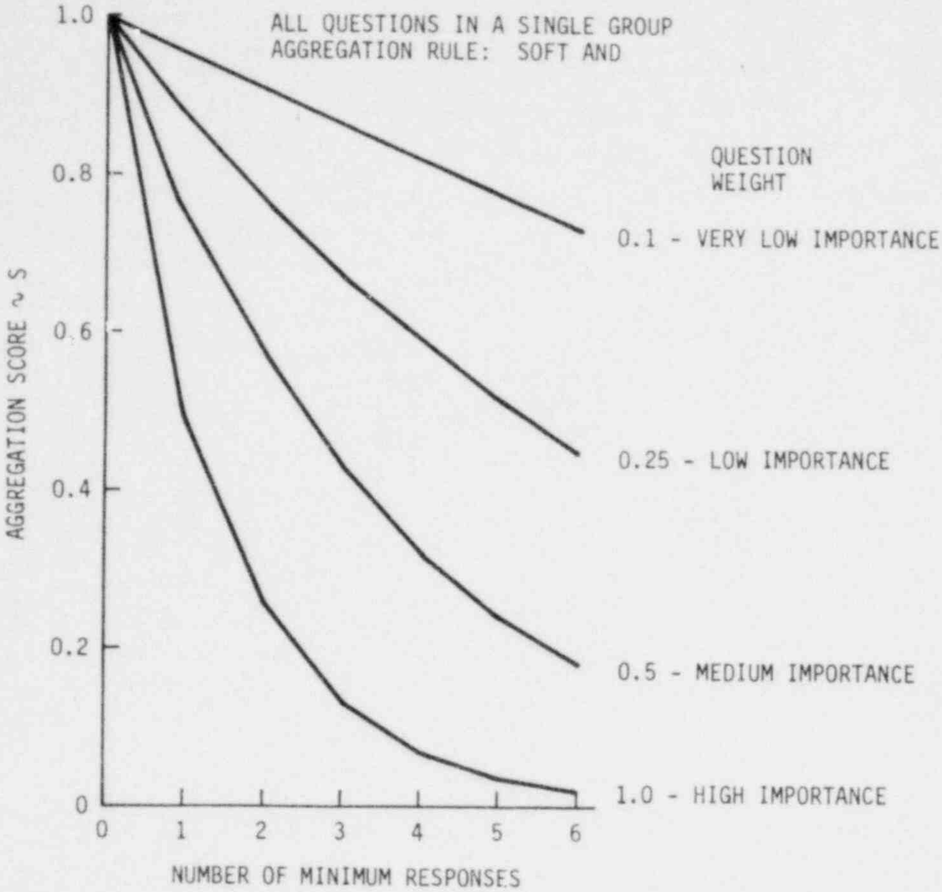


Figure 3-8. Effect of Question Weighting on Aggregate Score as a Function of Minimum Responses

the use of a weight of 0.1 if an equivalent score could result when more than half of the questions, taken at random, received minimum responses. Furthermore, component performance would probably be suspect if any four to six questions, taken at random, were given minimum responses. In this case, the weight value should be greater than 0.25.

At the other end of the scale, at a weight of 1.0, at most one question, taken at random, could be given a minimum response. Although questions of this nature could be singled out, it seems too harsh to weight all the questions in this manner. If experience indicates the existence of such critical questions, the methodology will allow for individual weighting of these questions. Now, with the weight value in the range, 0.25 < weight < 1.0, a value of 0.5 seems a reasonable choice.

Applying a fixed weight of 0.5 to all questions in the Hard-Wire Video System ETQ and aggregating the question scores as a single group, the dashed curve shown in Figure 3-9 was obtained. The results were disappointingly low until it was recalled that Questions 8 and 10 originally had a weight of 0 (see Table 3-1) and therefore did not affect component performance. Eliminating Questions 8 and 10 brought the questionnaire score well within the range of uncertainty of scores previously obtained with the more complex method and indicated by the solid curve in Figure 3-9.

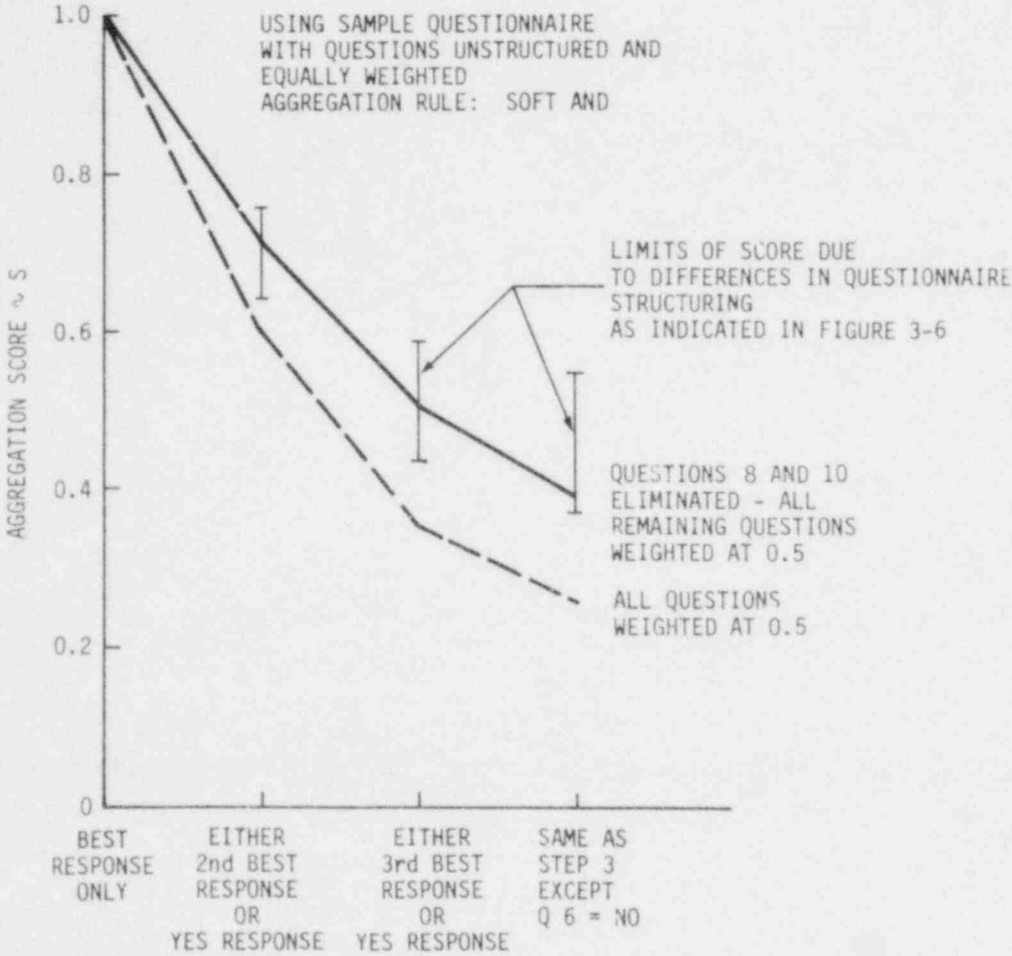


Figure 3-9. Comparison of Simplified Methodology Results with the Range of Results from Structured and Individually Weighted Questions

Since the size of the sample ETQ played a role in the simplifying process (number of minimum responses versus total number of questions), the same approach can be applied to most, if not all, of the remaining ETQs. The sample ETQ consists of 12 questions, while the average ETQ contains 13 questions. The maximum number of questions in any ETQ is 33; however, that particular ETQ has many questions which address conditions in both the central and secondary alarm stations.

As a result of the investigation described in the preceding section, the following modifications were made (subject to verification in test applications) to the component performance evaluation methodology:

1. The SOFT AND aggregation rule was applied to all component questionnaires,
2. Each questionnaire was aggregated as a single group of questions,
3. All questions were weighted at 0.5, and
4. All trivial and nonperformance oriented questions were eliminated.

3.5 Low-Level Task Evaluation

3.5.1 Methodology -- The objective of the low-level task evaluation methodology is to combine individual component measures of performance (scores) into a meaningful measure of task performance. "Sense boundary penetration" is a low-level task within the context of the partial hierarchy shown in Figure 3-10. The method consists of three steps: (1) identify performance characteristics, (2) assess the compatibility between components, and (3) assign aggregation rules. These steps are achieved with the aid of a system questionnaire. The Penetration Sensing System ETQ will be used to illustrate each of these three steps.

Step 1: Identify Performance Characteristics. A performance characteristic is a low-level task that is constrained to a specific location or application. In the case of sensing boundary penetration, the set of performance characteristics consist of all feasible access points on the boundary of the MAA. These access points specifically locate each sensor (or where one should be) and thereby identify whatever role it plays and any unique interfaces or problems, e.g., site conditions, environmental, etc., the component may have within the system. To avoid duplication, access points which have essentially the same sensor, conditions, etc., should be treated as one point, e.g., identical sensors at 50-foot intervals along a fence should be treated as a single access point.

The following questions taken from the Penetration Sensing System ETQ illustrate the identification of performance characteristics, both

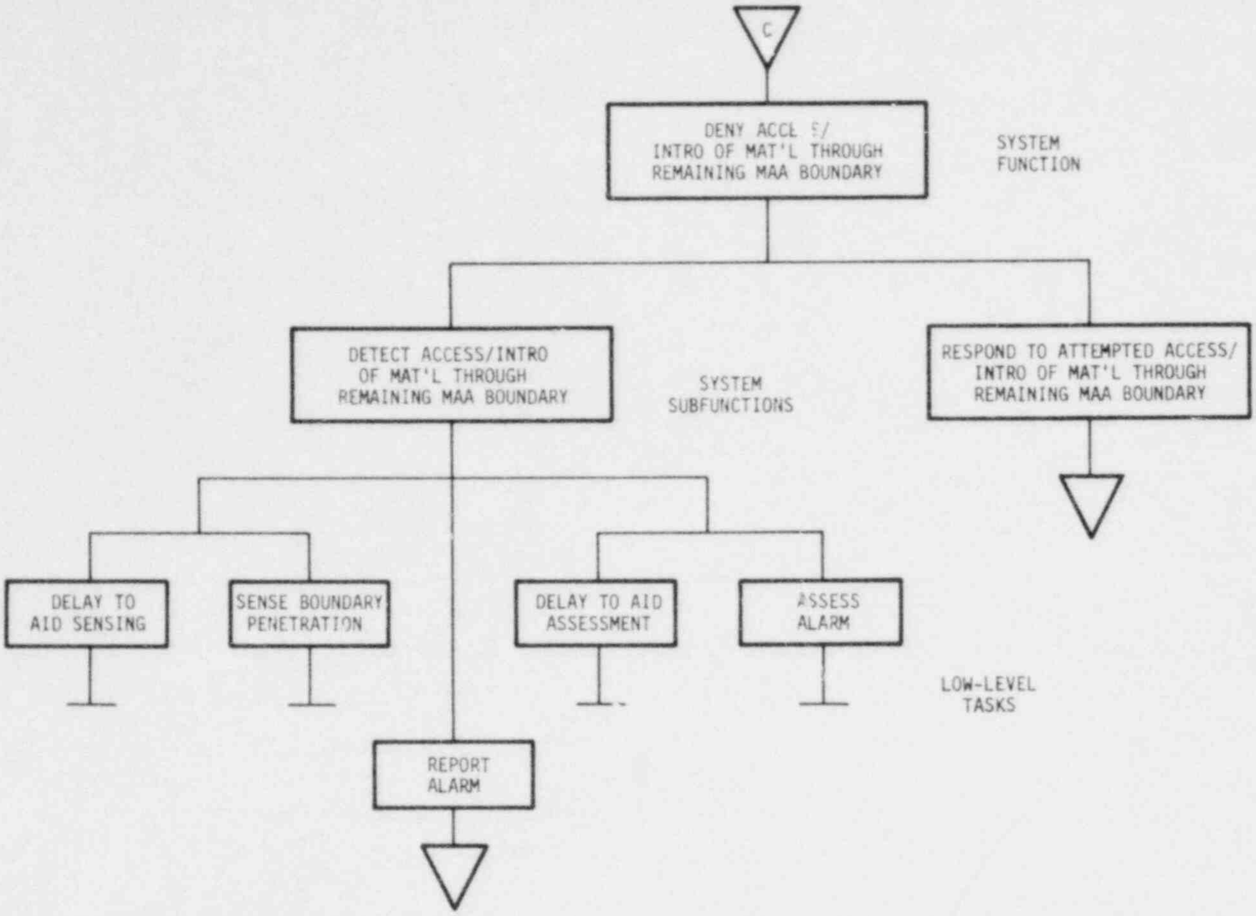


Figure 3-10. Partial Hierarchy for System Functions

as a frame of reference for the remaining questions and as a checklist to ensure complete sensor coverage:

1. If the boundary is defined exterior to a building, will the following access points (if applicable) for personnel and introduction of material be provided with sensor coverage:

   A. Inoperative entry gates or portals?
   B. Emergency exits?
   C. Utility entries?
   D. Fences?
   E. Other feasible access points?

2. If a building or part of a building forms the boundary, will the following access points (if applicable) for personnel and introduction of material be provided with sensor coverage:

   A. Inoperative entry doors or portals?
   B. Emergency exit doors?
   C. Windows?
   D. Building structures (walls, floor, roof, etc.)?
   E. Vents?
   F. Utility entries?
   G. Other feasible access points?

For each identified performance characteristic, the type(s) of component(s) selected to perform that task must be specified and individually assessed by means of an ETQ.

Steps 2 and 3: Assess Component Compatibility and Assign Aggregation Rule. Components may be used singly or in multiples to perform a given task. If a single component is used, the score from the ETQ for that component is the same as the performance measure (score) for that particular performance characteristic. However, if multiple components are employed, the total combined effectiveness must be assessed on the basis of how well the components were selected for harmonious operation, as well as diversity of functional method (to minimize commonality of environmental effects, failure modes, and vulnerability).

The assessment of compatibility between multiple components is achieved through a series of pertinent questions. These questions are weighted and the responses scored in a manner similar to that used for the component ETQs. The aggregation of these question scores is used to determine the aggregation rule used to combine individual component performance measures into an overall measure for the particular performance characteristic.

The sensing task will be used to illustrate the above procedures for assessing multiple component performance. Sensors which perform a direct or indirect monitoring role may be either electromechanical hardware or personnel. For multiple hardware components, the following questions, taken from the Penetration Sensing System ETQ, provide a means for estimating the degree of consideration and concern which must be given to sensor selection in order to provide in-depth performance over a wide range of contingencies.

Performance Conditions--Multiple Sensors

For each access point above where multiple sensor systems will be used,

3. Will each sensor type be selected to minimize the susceptibility of any two or more sensor types to the same local environmental (natural or manmade) source of nuisance alarms?

4. Will each sensor type be selected to minimize the likelihood that two or more sensor types will be affected by the simultaneous occurrence of environmental (natural or manmade) sources of nuisance alarms, e.g., wind and rain?

5. What provisions will be made to minimize the likelihood of responding to false or nuisance alarms?

6. Will collocated sensors be installed to provide mutual tamper protection for the sensors and processors?

7. Will collocated sensors be selected to provide coverage over a wide range of intrusion methods, (e.g., microwave to sense surface intrusion and buried cable to sense tunneling or crawling under the microwave beam or balanced magnetic switch to sense door opening and breakwire system to sense cutting through the door)?

8. Will collocated sensors be selected to minimize operational performance incompatibilities?

Performance Conditions--Sensors

For each access point above where either single or multiple sensors will be used,

9. What level of performance will be expected from each sensor? (To aid performance estimation refer to questionnaire on the particular sensor?

As in the case of a component ETQ, Questions 3 through 8 of the system ETQ are weighted at 0.5 and their responses are aggregated using the SOFT AND rule. This score then determines the particular rule for aggregating the individual sensor ETQ scores (submitted in response to Question 9) into an overall measure of sensing performance. A tentative rule selection scale (subject to verification in test applications) is shown below.

Score for Questions 3 through 8	Multiple Sensor Aggregation Rule
0.8 to 1.0	OR
0.6 to 0.8	SOFT OR
0.4 to 0.6	AVERAGE
0.2 to 0.4	SOFT AND
0 to 0.2	AND

The assumption behind the rule selection is that a high score from Questions 3 through 8 is indicative of synergistic performance; therefore, the highest scoring aggregation rule (OR) is appropriate. On the other hand, a low score is indicative of little or no thought being given to component interaction problems, leading to the usual degradation in performance. In this case, the lowest scoring aggregation rule (AND) is appropriate.

For personnel who perform either a direct or an indirect, i.e., CCTV, monitoring role, the time required by the adversary to penetrate or otherwise transit an area under observation must be compared with the time between observations. If an adversary can pass through an area in seconds and the guard makes his rounds once per hour (or any time significantly greater than the adversary's penetration time), the chances of the guard seeing the adversary are small. The following questions, taken from the Penetration Sensing System ETQ, provide a means to assess monitoring performance.

Performance Conditions--Direct or Indirect Monitoring

For each access point above where direct or indirect monitoring will be used (e.g., CCTV monitoring, inspection rounds, etc.),

10. Using data from the questionnaires pertaining to the barrier(s) and the type of monitoring that will be used, how will the time for adversary penetration or introduction of materials compare with time between monitoring observations?

11. What level of performance will be expected for the type of monitoring to be used? (To aid performance estimation, refer to questionnaire on the particular type of monitoring.)

12. What level of performance will be expected from the barrier(s) delaying penetration or introduction of materials? (To aid performance estimation, refer to questionnaire on the particular barrier.)

The responses from these three questions, each weighted at 1.0, are aggregated using the SOFT AND rule. If monitoring is the only sensor type employed, its score is then the measure of sensing performance. When used in combination with a hardware-type sensor, e.g., as a backup, the AVERAGE rule would be used to aggregate individual ETQ scores. This rule reflects the rationale that performance is dominated by only one sensor type at any given time. Similarly, the remaining low-level tasks are evaluated for each access point prior to system subfunction evaluation.

3.6 System Subfunction Evaluation

The object of the system subfunction evaluation methodology is to combine relevant low-level task performance measures (scores) into a meaningful measure of system subfunction performance. "Detect access/introduction of material through remaining MAA boundary" is a system subfunction within the context of the partial hierarchy shown in Figure 3-10. The method consists primarily of a determination of the role played by each low-level task within the system subfunction, and is used to select the most representative aggregation rule. The "detect access/introduction of material through remaining MAA boundary" subfunction will be used to illustrate the system subfunction evaluation process.

Detection is the culmination of sensing, alarm reporting, and assessment. Only after the assessment task confirms that a valid alarm has occurred can a detection of adversary action be declared. Of course, a valid alarm must be preceded by sensing of the action. This suggests that all three tasks are essential to the performance of the detection subfunction under all conditions. Therefore, the AND rule is appropriate for aggregating these low-level task scores into a measure of detection performance. This aggregation should be conducted so as to obtain a measure of detection performance at each identified access point. An alternate detection measure produced by first aggregating each low-level task over all access points and then aggregating the resultant three task measures fails to reflect the essential sequence of events for detection and to identify the location where detection is of concern.

3.7 System Function Evaluation

The objective of the system function evaluation methodology is to aggregate the appropriate system subfunction performance measures (scores) into a meaningful measure of overall system function performance. An example of a system function is the "deny access/introduction of materials through the remaining MAA boundary" function shown in Figure 3-10. The method for system function evaluation is essentially to determine the most appropriate aggregation rule. This process is similar to that given for system subfunction evaluation.

In order to deny access, it is essential that the system detect intrusions and respond appropriately under all conditions. Again, this condition indicates the AND rule as most appropriate to aggregate the system subfunction scores into a measure of performance for the access denial function.

In order to obtain a correct measure and to identify locations at which access denial may be deficient, the aggregation should first obtain a measure of access denial performance at each access point. Then, in order to obtain an overall performance measure for access denial at the remaining MAA boundary, the access denial scores at each access point should be aggregated using the SOFT AND rule. The SOFT AND rule implies that the adversary could be capable of simultaneously attacking some subset of the access points or have some information concerning their vulnerabilities. The AND rule is too harsh in that it reflects an ability to attack all points simultaneously or to know exactly which point is weakest. The AVERAGE rule seems a little too weak in that its results are indicative of an adversary who would attempt access at any point chosen at random.

Similarly, the system function "control access/introduction of material through area entry portals" is evaluated prior to performance capability evaluation.

3.8 Performance Capability Evaluation

The objective of the performance capability evaluation methodology is to combine the relevant system function performance measures (scores) into a meaningful measure of compliance with the performance capability in the Upgrade Rule. For example, consider the performance capability needed to "prevent unauthorized access of persons and introduction of material into the MAA/VA." The required evaluation method is essentially one of selecting the most appropriate aggregation rule.

To prevent unauthorized access into the area (MAA/VA), access through the portals must be controlled and access through the remaining area boundary must be denied. However, these two functions do not necessarily occur simultaneously (AND rule) nor do they necessarily occur only individually on a random basis (AVERAGE rule). Therefore, the SOFT AND rule seems most appropriate.

An additional aggregation must be made over all MAAs and VAs. Unless there is concern over access into more than one area at a time, the AVERAGE rule is suggested.

Since the Upgrade Rule specifies that the physical protection system must be designed to satisfy each of the performance capabilities, the evaluation is considered complete when each performance capability hierarchy has been aggregated. The coupling and interaction of functions between performance capabilities has not been considered for this report.

4. EVALUATION METHODOLOGY IMPLEMENTATION

4.1 Introduction

To implement the methodology described in Chapter 3, an evaluation computer program has been developed. This program is designed to automate the scoring of effectiveness test questionnaires and hierarchy elements and to provide maximum flexibility to the user for sensitivity analyses and for other revisions.

The program uses two basic types of input. The first type of input provides for the structure of the questionnaires and the hierarchies, and includes the number of questions (or inputs to a hierarchy element), weights, and the scoring rules to be used. These data are independent of any particular evaluation and can be developed and stored in the computer before an evaluation is performed. The second type of input consists of the evaluation responses to the questionnaires.

To compute the score for a hierarchy, the program first examines the questionnaires. The questionnaire structure (number of questions, weights, lowest alphabetic response for each question, etc.) is read from one disc file, while the responses to the questionnaires are read off another disc. The computer program then automatically computes and saves the questionnaire score. After the questionnaires have been scored, the program can be switched into hierarchy mode. To score a hierarchy element (box), its name is entered into the computer program. If the scores for all the boxes subordinate to the box being evaluated have been computed, the program then scores the box using the appropriate rule. If not, the program attempts to score lower-level boxes, gradually working down in the hierarchy until it finds a box whose score can be computed. The program then works back up the hierarchy until the score for the original box can be computed. Low-level boxes (with component questionnaires) are scored in the same way except that the program assumes that all questionnaires have been scored.

The rest of this chapter describes in detail the structure and operation of the evaluation computer program. A program listing is provided in Appendix B.

4.2 Use of the Evaluation Program

This section describes how the evaluation computer program can be used to evaluate questionnaires and hierarchies. First the data base is described in detail, then the operation of the program, including the various options available and the flow of the program, is described. The use of the program is demonstrated with short sample runs.

4.2.1 Data Base -- The input to the program consists of four "files" (sets of data stored on cards or disc): These files consist of

1. Questionnaire structures,
2. Questionnaire responses,
3. Hierarchy structure, and
4. Hierarchy initial scores.

A description of the content and format of these files follows.

Questionnaire Structures. The questionnaire structures file contains information on the questionnaires to be evaluated. The data provided for each questionnaire include

1. Name,
2. Number of questions,
3. Number of question subgroupings (if any),
4. Weight of each question,
5. Lowest possible response for each question, and
6. Rules for aggregating the question subgroups (if any) and the overall questionnaire.

The specific layout of the questionnaire structure file is as follows:

Card 1: Card 1 contains the number of questionnaires in the file. Format 1I2.

Card 2: Card 2 contains the first card number for each questionnaire, i.e. the number of the card at which the questionnaire starts. Card 2 is repeated, as necessary, to specify the first record of all questionnaires in the file. Format 20I4.

Card 3: Questionnaire Title. Card 3 contains the questionnaire name (maximum of 4 characters), the number of questions (maximum of 40), and the number of subgroups (counting the overall questionnaire as 1). The initial implementation of the algorithm will not use subgroups, but the program has the ability to process them. Format 1A4,6X,1I2,8X,1I2.

Card 4: Worst Response. Card 4 contains the letter corresponding to the worst response for each question. (The best response is always assumed to be "A.") Format 40(1X,1A1).

Card 5: Group Information. Card 5 contains the group number. (The group number for the overall questionnaire is always 50). Additional groups are numbered 51,52 ..., etc. The number of questions (and subgroups) to be aggregated and the rule to be used are also given. The codes for the rules are as follows: HA = AND, SA = SOFT AND, AV = AVERAGE, SO = SOFT OR, OR = OR. Format 1I2,8X,1I2,8X,1A2.

Card 6: Group Inputs. Card 6 contains the questions (or subgroups) to be aggregated as part of the group. Format 40I2.

Card 7: Question Weights. Card 7 contains the weight (between 0 and 1) assigned to each question. Initially, the questions are equally weighted at 0.5, but the program can accept differential weights. Card 7 is repeated until a weight is specified for each question. A convenience option allows one weight for all questions to be set by specifying a 2. as the first weight and the equal weight for all as the second weight. Format 8F5.3.

Cards 5 and 6 are repeated for each group. Cards 3 through 7 are repeated for each questionnaire.

Questionnaire Responses. The questionnaire responses file contains the responses to the various questionnaires (the results of the evaluation). The format of this file is as follows:

Card 1: Card 1 contains the number of questionnaires evaluated. Format 1I2.

Card 2: Card 2 contains the first card number for each questionnaire. Format 20I4. The questionnaires must be in the same order as those for Card 2 in the questionnaire structures file. Card 2 is repeated as many times as necessary to identify the first record for each questionnaire.

Card 3: Card 3 contains the name of a questionnaire. Format 1A4.

Card 4: Card 4 contains the score for each question on the questionnaire. Format 40(1X,1A1).

Cards 3 and 4 are repeated for each questionnaire.

Hierarchy Structures. The hierarchy structures file contains structural data on the organization and scoring of hierarchies. The format of this file is as follows:

Card 1: Card 1 contains the number of complete hierarchies in the file. Format 1I2, maximum value = 5.

Card 2: Card 2 contains the first card number for each hierarchy. Format 5I4.

Card 3: Box Data Card. Card 3 includes the name of a box, the number of subelements to be aggregated, and the scoring rule to be used. If the elements to be aggregated are questionnaires instead of boxes, then 50 is added to the number of subelements. If a questionnaire is to be used to determine the scoring rule, the questionnaire name also appears on the card. The data are ordered as follows: box name, number of elements, rule, questionnaire name (if any). Format 1A6,4X,1I2,8X,1A2,8X,1A4.

Card 4: Input Box Data Card. Card 4 contains the name of an input subelement (box or questionnaire). Format 1A6.

Card 5: Card 5 is the last card for each hierarchy and has the word "NOMORE" in the first six columns.

Card 4 is repeated for each input subelement. Cards 3 and 4 are repeated for each hierarchy box having subelements. The only restriction on the ordering of the boxes is that a box name must not appear on a number 4 card after it has appeared on a number 3 card (i.e., the evaluation should not proceed from the top to the bottom of the hierarchy.

Hierarchy Initial Scores. The heirarchy initial scores file contains values for any initial scores to be set for hierarchy boxes. The file is structured as follows:

Card 1: Card 1 contains the number of hierarchies in Format 1I2.

Card 2: Card 2 is the initial card for each hierarchy in Format 5I4.

Card 3: Card 3 contains the names of the boxes to be set, followed by the initial score. If the score is set at -1, the initial score is free. (Otherwise scores must be between 0 and 1). There are no restrictions on the order of the boxes. If a box does not appear, its initial score is assumed to be -1. Format 5(1A6,4X, 1F5.3).

Card 3 is repeated until all set scores have been input.

4.2.2 Interactive Program Operation -- Questionnaires and hierarchy elements are evaluated using an interactive computer program. This program uses the data files described in the previous section as input and provides the user with a wide variety of evaluation and sensitivity analysis options. The following paragraphs describe the relationship of the program elements and data files and the options available to the user.

Input/Output Considerations. The evaluation program is designed to be used interactively at a time-sharing terminal. In addition, four disc storage files (described in the previous section) are needed. These files interface with the program as shown in Table 4-1.

Table 4-1

Data-Base Definitions

File	Unit	Type	Record Length (Characters)	Maximum Number of Records
Questionnaire Structures	1	Random access	80	200
Questionnaire Responses	2	Random access	80	200
Hierarchy Structure	3	Random access	80	200
Hierarchy Scores	4	Random access	80	50

Program Operation: General Features. When the evaluation program is called, it first initializes the major variables and then prompts the user with the following question:

SELECT 1-HIERARCHIES 2-QUESTIONNAIRES 3-STOP--

Typing "1" in response to this question initiates the hierarchy manipulation portion of the program. A list of options which allow the user to control the manipulation is then printed. These options are described later. Similarly, if the user responds with "2," a set of options relating to questionnaires is printed. Typing "3" stops the program. If the user is familiar with the program options described below, any valid option number can be typed and the program will branch directly to that option.

Program Operation: Questionnaire Manipulation. Selecting the questionnaire option causes the following table to be printed.

```
SELECT ONE:

21-Compute Scores              22-Print Scores
23-Set Scores                  24-Revise Weights
25-Revise Rules                26-Revise Responses
              29-No More Revisions

WHICH?
```

The user simply types in the number corresponding to the desired option, and the computer will initiate the option and ask additional questions to enable its completion. The options are described in more detail on the following pages.

Option 21--Compute Scores. Option 21 computes the score for a questionnaire. When this option is selected, the prompt "ENTER QUESTIONNAIRE NAME --" is given. If the name is valid, the questionnaire's information is retrieved from the questionnaire structure and response files and the score is printed and stored. If "ALL" is typed in response to the name prompt,* all the currently stored questionnaires are scored and printed as shown in Figure 4-1. The user is then asked to select another option.

Option 22--Print Scores. Option 22 prints the data associated with a questionnaire. A name is entered, as in Option 21, and the computer prints a table of information for the questionnaire. The information includes the scoring rule and score and a diagram of the questionnaire structure. The structure shows the subgroups (if any) used in scoring the questionna . the scoring rules used for the subgroups, and the individual questions included in each group along with their associated raw scores, weights, and adjusted scores.

Option 23--Set Scores. Option 23 allows the user to directly specify a score for a questionnaire. In response to a prompt, the user enters a questionnaire name. The prompt "SCORE =" is printed and the user may enter any value between 0 and 1.0. This score is saved until the score is recomputed or reset.

Option 24--Revise Weights. Option 24 allows the user to revise the weight assigned to a given question or questions. After the questionnaire name is entered, the prompt "NUMBER OF QUESTIONS TO BE REVISED =" is given. If the weight has been assigned using the brief form, the common weight assigned to all questions must be revised. For each question to be revised, the prompts "QUESTION NUMBER =" and "WEIGHT =" allow the new weight to be assigned to the appropriate question. After this option is completed, the score is recomputed and printed.

Option 25--Revise Rules. Option 25 allows the user to revise the scoring rule used to score a questionnaire or subgroup. After the questionnaire name is entered, the computer asks for the "GROUP NUMBER" to be changed. Group 50 corresponds to the overall questionnaire and 51, 52, etc., correspond to the subgroups (if any). Next, the revised

---

*Underline indicates user response.

```
SELECT 41-51 -- 21
ENTER QUESTIONAIRE NAME -- ALL
QUESTIONNAIRE 4    : THE SCORE = 0.755
QUESTIONNAIRE 6    : THE SCORE = 0.766
QUESTIONNAIRE 10   : THE SCORE = 0.670
QUESTIONNAIRE 47   : THE SCORE = 0.820
QUESTIONNAIRE 57   : THE SCORE = 0.579
QUESTIONNAIRE 1    : THE SCORE = 1.000
QUESTIONNAIRE 2    : THE SCORE = 0.917
QUESTIONNAIRE 3    : THE SCORE = 0.606
QUESTIONNAIRE 11   : THE SCORE = 0.820
QUESTIONNAIRE 14   : THE SCORE = 1.000
QUESTIONNAIRE 16   : THE SCORE = 1.000
QUESTIONNAIRE 21   : THE SCORE = 0.911
QUESTIONNAIRE 22   : THE SCORE = 0.237
QUESTIONNAIRE 25   : THE SCORE = 0.562
QUESTIONNAIRE 28   : THE SCORE = 0.516
QUESTIONNAIRE 32   : THE SCORE = 0.750
QUESTIONNAIRE 36   : THE SCORE = 0.875
QUESTIONNAIRE 38   : THE SCORE = 1.000
QUESTIONNAIRE 43   : THE SCORE = 1.000
QUESTIONNAIRE 51   : THE SCORE = 0.766
QUESTIONNAIRE 60   : THE SCORE = 0.516
QUESTIONNAIRE 63   : THE SCORE = 0.387
QUESTIONNAIRE 66   : THE SCORE = 1.000
QUESTIONNAIRE 68   : THE SCORE = 1.000
QUESTIONNAIRE 69   : THE SCORE = 0.548
QUESTIONNAIRE 74   : THE SCORE = 1.000
QUESTIONNAIRE 75   : THE SCORE = 1.000
QUESTIONNAIRE 83   : THE SCORE = 0.746
QUESTIONNAIRE 84   : THE SCORE = 0.637
QUESTIONNAIRE 87   : THE SCORE = 0.733
QUESTIONNAIRE 90   : THE SCORE = 0.667
QUESTIONNAIRE 95   : THE SCORE = 0.337
QUESTIONNAIRE 12   : THE SCORE = 0.338
QUESTIONNAIRE 33   : THE SCORE = 1.000
QUESTIONNAIRE ALAS: THE SCORE = 0.598
QUESTIONNAIRE PNSS: THE SCORE = 1.000
QUESTIONNAIRE 17   : THE SCORE = 1.000
QUESTIONNAIRE 18   : THE SCORE = 1.000
```

Figure 4-1. Scores of All Currently Stored Questionnaires rule is requested, using the following abbreviations, HA = AND, SA = SOFT AND, AV = AVERAGE, SO = SOFT OR, or OR = OR. The revised score is computed after the desired number of changes has been made.

Option 26--Revise Responses. Option 26 allows the user to revise the responses associated with particular questions. The procedure is similar to that for revising weights in that the questionnaire name and number of questions to be revised initializes a loop for entering revised responses. For each question, a prompt asks for the question number and then the user is prompted "ENTER REVISED RESPONSE (A to WORST) --". WORST is the letter of the alphabet corresponding to the worst answer on the question. The user enters the letter of the alphabet corresponding to the revised response. After all desired changes have been completed, the questionnaire score is recomputed and printed.

Option 29--No More Revisions. Option 29 simply returns the program to the original hierarchy/questionnaire/stop choice.

Options 21 through 26 and 29 represent all of the interactive routines related to questionnaires. Other changes, e.g., revisions to questionnaire structure, must be made using a text editor on the appropriate files.

Program Operation: Hierarchy Manipulation. When the hierarchy manipulation option of the program is first initiated, the computer requests "ENTER HIERARCHY NUMBER --". The user enters the number of the hierarchy to be manipulated in the current session. The computer then retrieves the data corresponding to that hierarchy from the disc files and computes the initial score for the top hierarchy element. Next, the following table is printed:

```
SELECT ONE:

     41-Compute Scores          42-Print Data
     43-Assign Scores           44-Revise Delay/Resp
     45-Revise Rules            46-Select New Hierarchy
     47-Print Box Names         48-File Hierarchy Data
     49-Change Box Name         50-Print Hierarchy
                   51-No More Revisions

WHICH?
```

To initiate one of the listed options, the user types in the corresponding number. In response, the computer asks additional questions, as necessary, to allow completion of the option. The hierarchy manipulation options are described in the following paragraphs.

Option 41--Compute Scores. Option 41 allows the user to compute the score for a hierarchy box. Of course, if the top box of the hierarchy is scored, the overall score will be computed. After the box name is requested and entered, the computer automatically searches as far down in the hierarchy as is necessary (up to a maximum of five levels) to identify boxes which can be scored, i.e., boxes for which scores are available for each lower level box or questionnaire. Then the computer works back up the hierarchy, scoring higher-level boxes until it is possible to compute the score for the requested box. This score is then printed. (Note: The scores for all higher-level boxes are reinitialized to -1 if a lower-level score has been changed.)

Option 42--Print Data. Option 42 allows the user to obtain a simplified diagram of the hierarchy structure beneath a specified box. Up to four levels of boxes are printed, as shown in Figure 4-2 (page 4-12). To interpret the mnemonics on the computer printout, refer to the corresponding numbers on the hierarchy shown in Figure 4-4 (page 4-14). The information for each box includes the box name, its score (-1 is shown if the score has not been computed), the scoring rule used, and scoring questionnaire (if any). The table is printed in outline style, with lower-level boxes indented beneath higher-level boxes.

Option 43--Assign Scores. Option 43 allows the user to assign a score to a specified box. The computer first prompts for the box name and then requests the score, which must be between 0.0 and 1.0. The scores for all higher-level boxes are reinitialized to show that a lower-level score has been changed.

Option 44--Revise Delay/Response. Option 44 is not used at the current time.

Option 45--Revise Scoring Rule. Option 45 allows the user to change the scoring rule associated with a box. The computer first requests the box name and then the rule. The rule is entered using the same abbreviations given for Questionnaire Manipulation Option 25, except that the abbreviation, Q = Scoring rule determined by questionnaire, is included in Option 45. If Q is entered, the computer will prompt for the questionnaire name.

Option 46--Select New Hierarchy. Option 46 reinitializes the program by allowing the user to reenter the data for the current hierarchy or for any other hierarchy which may be stored in Disc File 3. The only prompt is "ENTER HIERARCHY NUMBER".

Option 47--Print Box Names. Option 47 causes a list of the current box names to be printed.

Option 48--File Hierarchy Data. Option 48 saves all revisions and scores made for the hierarchy during the current session on Disc File 3. The original data are overwritten. This option is performed automatically at the termination of a session if Option 45 or 49 has been used.

Option 49--Change Box Name. Option 49 is used to change a box name. The computer first prompts for the original box name and then for a revised name. Names are allowed to be a maximum of six characters long.

Option 50--Print Hierarchy. Option 50 is similar to Option 42 except that the structure is printed in a simpler graphical form as shown in Figure 4-3 (page 4-13).* One to five hierarchy levels are printed starting with a box name entered with the computer prompt. Note: If time or conservation of paper is a consideration, it is best to use Option 42 for viewing hierarchy data.

Option 51--No More Revisions. Option 51 reverts the program back to the original questionnaire/hierarchy/stop choice.

---

*To interpret the mnemonics given in Figure 4-3, refer to Figure 4-4 (page 4-14).

```
SELECT 41-51 -- 42
ENTER BOX NAME -- CONACC (1)

HIERARCHY DATA FOR BOX CONACC

BOX:CONACC  RULE:SA  SCORE: 0.547   0:
 (2) BOX:NORMAL  RULE:HA  SCORE: 0.442   0:
        (3) BOX:ADAUTH  RULE:AV  SCORE: 0.917   0:
                  QUESTIONNAIRE: 2      SCORE: 0.917
        (4) BOX:PROCON  RULE:SA  SCORE: 0.482   0:
              (5) BOX:PERSON  RULE:SA  SCORE: 0.496   0:
          (6) --> BOX:MATERI  RULE:SA  SCORE: 0.635   0:
     BOX:EMERGE  RULE:     SCORE: 0.832   0:
SELECT 41-51 -- 42
ENTER BOX NAME -- PROCON

HIERARCHY DATA FOR BOX PROCON

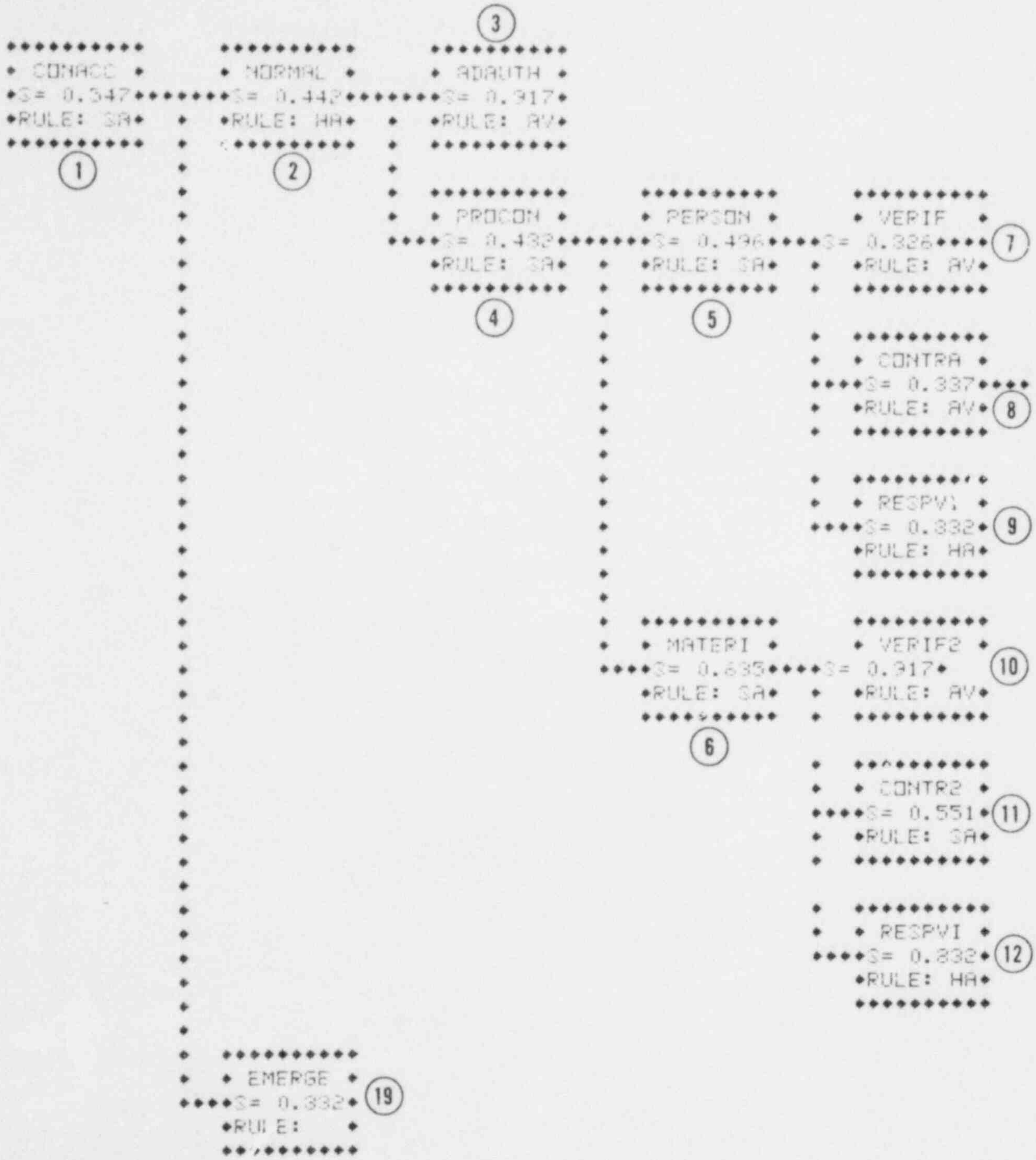
BOX:PROCON  RULE:SA  SCORE: 0.482   0:
 (5) BOX:PERSON  RULE:SA  SCORE: 0.496   0:
        (7) BOX:VERIF   RULE:AV  SCORE: 0.826   0:
                  QUESTIONNAIRE: 14     SCORE: 1.000
                  QUESTIONNAIRE: 63     SCORE: 0.387
                  QUESTIONNAIRE: 2      SCORE: 0.917
                  QUESTIONNAIRE: 66     SCORE: 1.000
        (8) BOX:CONTRA  RULE:AV  SCORE: 0.337   0:
                  QUESTIONNAIRE: 95     SCORE: 0.337
        (9) BOX:RESPVI  RULE:HA  SCORE: 0.832   0:
              (13) BOX:COMRSP  RULE:     SCORE: 1.000   0:
          (14) --> BOX:RESP    RULE:SA  SCORE: 0.832   0:
 (6) BOX:MATERI  RULE:SA  SCORE: 0.635   0:
        (10) BOX:VERIF2  RULE:AV  SCORE: 0.917   0:
                  QUESTIONNAIRE: 2      SCORE: 0.917
        (11) BOX:CONTR2  RULE:SA  SCORE: 0.551   0:
                  QUESTIONNAIRE: 32     SCORE: 0.750
                  QUESTIONNAIRE: 60     SCORE: 0.516
        (12) BOX:RESPVI  RULE:HA  SCORE: 0.832   0:
              (15) BOX:COMRSP  RULE:     SCORE: 1.000   0:
          (16) --> BOX:RESP    RULE:SA  SCORE: 0.832   0:
SELECT 41-51 -- 42
ENTER BOX NAME -- RESPVI

HIERARCHY DATA FOR BOX RESPVI

(12) BOX:RESPVI  RULE:HA  SCORE: 0.832   0:
 (15) BOX:COMRSP  RULE:     SCORE: 1.000   0:
 (16) BOX:RESP    RULE:SA  SCORE: 0.832   0:
        (17) BOX:DELRSP  RULE:     SCORE: 1.000   0:
   (18) --> BOX:EFFRSP  RULE:     SCORE: 0.706   0:
```

Figure 4-2. Hierarchy Structure in Outline Form

SELECT 41-51 -- 50
ENTER BOX NAME -- CONACC
HIERARCHY INFORMATION FOR BOX CONACC



SELECT 41-51 -- 3

Figure 4-3. Hierarchy Structure in Graphic Form

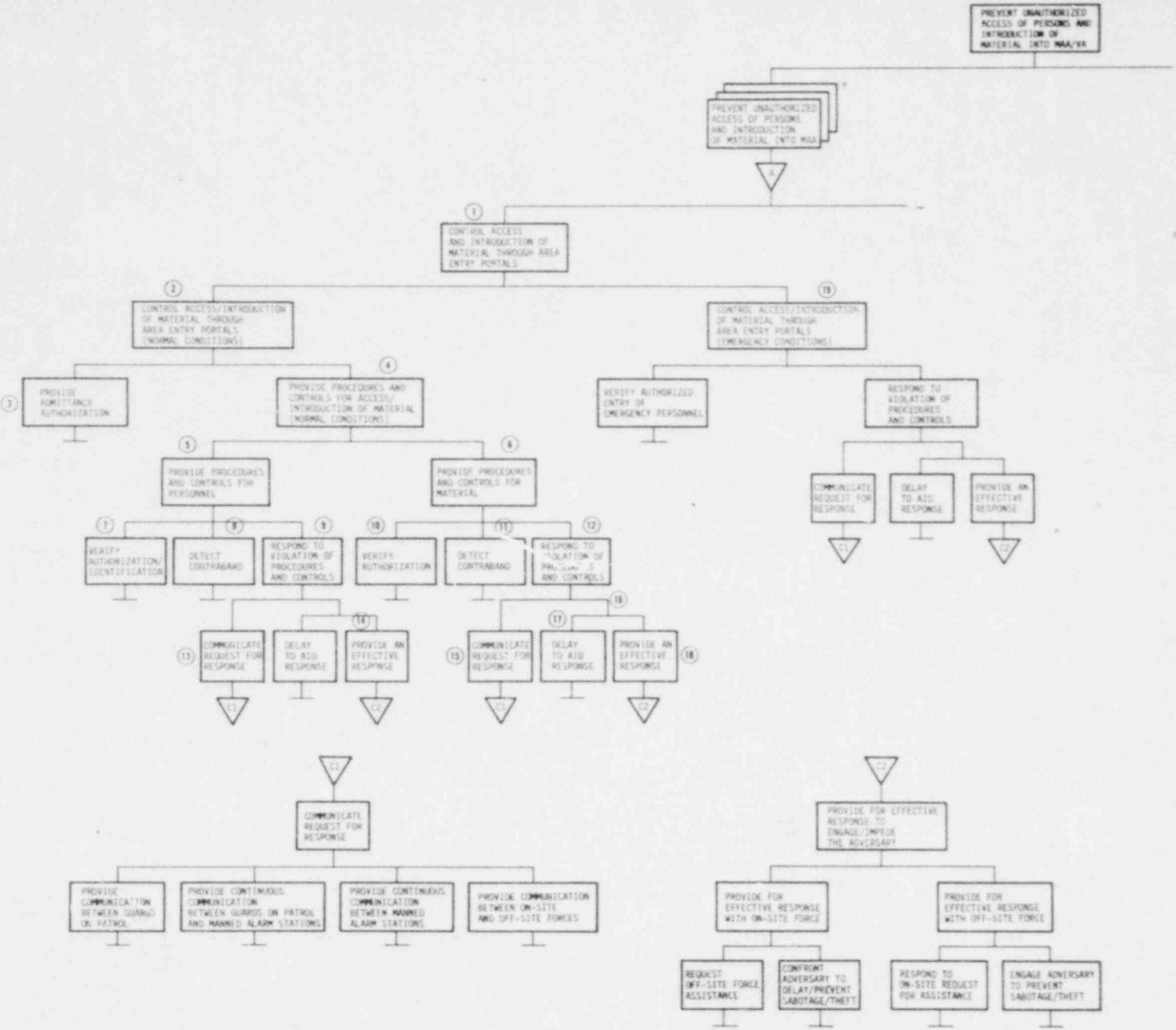


Figure 4-4. A Portion of the Functional Hierarchy for Proposed Rule Part 73.45(b)

5. TESTING PROGRAM

In this chapter, the program developed to test the NRC/Sandia design guidance compendium and the performance evaluation methodology is discussed. Attention is paid, in particular, to the limited testing of these products by Sandia and AGNS personnel.

5.1 Introduction

In order to determine the completeness, utility, and validity of the physical protection system design guidance compendium and the evaluation methodology, a testing program was required. A comprehensive test of these products would involve application of the material contained in the NRC Fixed-Site Physical Protection Upgrade Rule Guidance Compendium, including the Sandia design guidance products, and application of the evaluation methodology to the design of a complete physical protection system. The design of this system, preparation of the necessary documentation for license application, and completion of effectiveness test questionnaires (ETQs) would permit testing of the compendium and the evaluation methodology for all the performance capabilities in the Upgrade Rule. To provide a calibration of the evaluation methodology, at least two system designs are required, one which is considered a "good" performance system and one which is considered a "minimal" system, relative to the Upgrade Rule requirements.

Comprehensive testing of the design guidance compendium and the evaluation methodology was not feasible within the scope of the current program. Instead, limited testing of these products was performed by Sandia and AGNS personnel which provided for testing of the material in the compendium for only one of the performance capabilities. It also permitted partial testing of the evaluation methodology. This limited testing program is described in the following section.

5.2 Limited Testing Program

5.2.1 Overview -- AGNS, under contract to Sandia Laboratories, provided assistance in implementing and testing a portion of the design guidance compendium. Within the current program scope, the following tasks were undertaken by AGNS:

1. Based on the NRC Fixed-Site Physical Protection Upgrade Rule Guidance Compendium, a "good" partial physical protection system which complies with the requirements of the performance capability specified in 10 CFR 73.45 paragraph (b) was designed and documented, and
2. Responses to ETQs (component and system) appropriate to the partial system design were provided to serve as input to the evaluation methodology.

In addition, Sandia, with assistance from Woodward-Clyde Consultants, was able to partially test the performance evaluation methodology using the ETQ responses provided by AGNS in task (2) above. The results of the compendium testing tasks and the evaluation methodology testing are discussed in the following subsections.

5.2.2 Design of Partial Physical Protection System -- A partial physical protection system was designed in compliance with paragraph (b) of the Upgrade Rule. The performance capability is specified as follows:

> Prevent unauthorized access of persons and material into material access areas (MAAs) and vital areas (VAs).

The partial system includes an MAA which is totally enclosed within a VA. The MAA contains a single vault. A block diagram of this area is shown in Figure 5-1. The security plan for this partial system consists of two parts: the AGNS Sample Plan and Information Request Sheets (IRSs). The AGNS Sample Plan, a generic description of the physical protection system, contains information dealing with specific parts of the total physical protection system, including identification of components incorporated into the system and responses to specific regulatory requirements. The IRSs support the generic physical protection system description by providing specific, technically oriented information pertinent to the rationale used in selection and utilization of the components in the physical protection system. The exclusion of response from the partial system documentation should be noted. In the regulations and the compendium, response is considered a performance capability, while in the evaluation structure it is included as an integral part of each capability specified in paragraphs (b) through (f) of 10 CFR 73.45. Because AGNS completed task (1) for only capability (b) using the compendium format, response is not included in the compendium testing. The AGNS sample plan is contained in Appendix C, and three sample IRSs are provided in Appendix D.

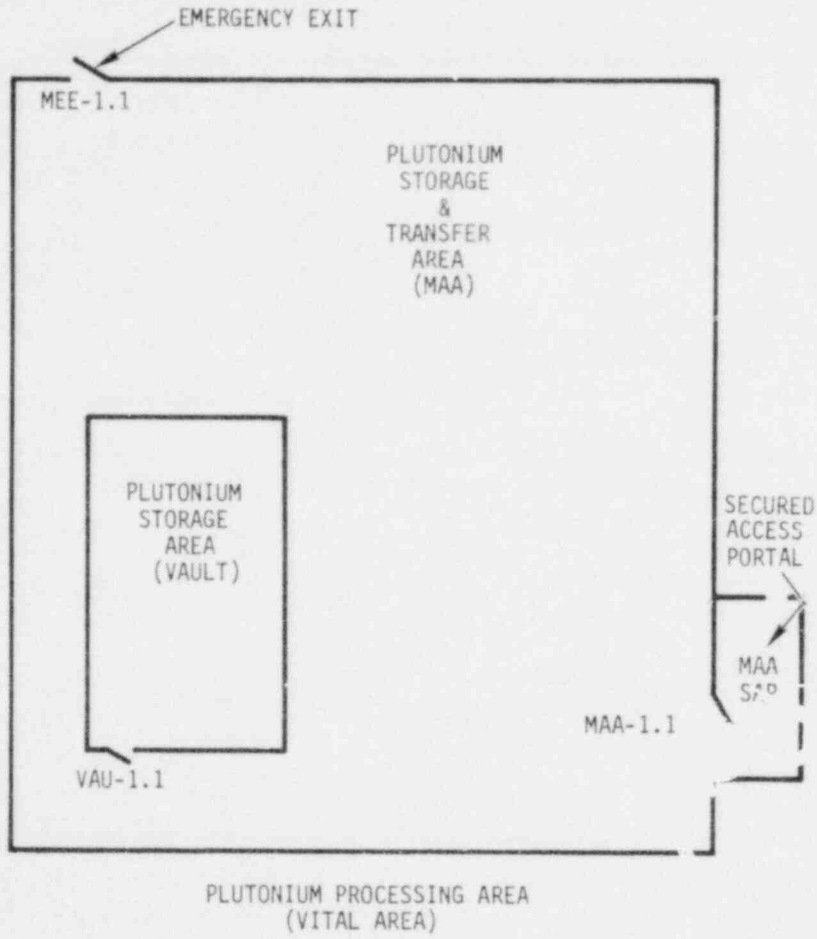


Figure 5-1. MAA and Vault Block Diagram

5.2.3 Completion of Effectiveness Test Questionnaires -- Responses were provided to ETQs associated with each component identified within the context of the generic description of the partial physical protection system. The components for which ETQs were completed are shown in Table 5-1. These ETQs are included in Volume II of this report (see corresponding questionnaire numbers). Note that there are only a limited number of questionnaires for components related to the response function. This is because consideration of this function was not within the scope of the partial design. The design guidance compendium (upon which this design is based) considers response a separate

Table 5-1

AGNS Partial Physical Security Plan Components

Questionnaire Number	Questionnaire Name
1.	Admittance Authorization Criteria and Schedules
2.	Admittance Authorization/Verification Procedures
3.	Air and Utility Inlet Barriers
4.	Annunciation Systems
	- Computer-Assisted Annunciation
	- Individual Alarm Annunciation
	- Multiplex Alarm Annunciation
6.	Balanced Magnetic Switches
10.	CCTV Monitoring/Surveillance
11.	CCTV Systems
12.	Central and Secondary Alarm Stations
14.	Coded Credential Systems
	- Active Electronic Badge Reader
	- Capacitance Coded Badge Reader
	- Electric Circuit Badge Reader
	- Magnetic Coded Badge Reader
	- Magnetic Stripe Badge Reader
	- Magnetic Strip Badge Reader
	- Optical Coded Badge Reader
	- Passive Electric Badge Reader
16.	Contingency Plan and Procedures
17.	Controlled Security Lighting
21.	Doors and Associated Hardware
22.	Duress Alarms
27.	Emergency Evacuation Procedures
28.	Emergency Exits
29.	Emergency Generator Systems
30.	Equipment Checks/Maintenance
31.	Escort
32.	Explosives Detector - Hand-Held, Package Search
33.	Explosives Detector - Hand-Held, Personnel Search
38.	Floors
43.	Guard Patrols/Intervention
47.	Interfaces Between Alarm Station and Sensors
	- Individual Hard-Wire Alarms
	- Multiplexed Hard-Wire Alarms
	- Hard-Wire Command Signals
51.	Local Audible/Visible Alarms
52.	Locks (Key Locks, Keyless Locks)
57.	Motion Detectors
	- Infrared Systems, Interior;
	- Microwave Systems, Interior;
	- Ultrasonic and Sonic Systems
60.	Package Search - Visual Inspection
63.	Photo Identification Badges
64.	Physical Controls and Procedures for Keys, Locks, Combinations, and Cipher Systems
66.	Positive Personnel Identification
	- Fingerprint
	- Handwriting
	- Hand Geometry
	- Voice Print
68.	Roof
69.	Sally Ports, Pedestrian
72.	Shielding Detector - Walkthrough
83.	Tamper-Indicating Circuitry
84.	Tamper-Indicating Seals and Tamper Seal Inspections
86.	Uninterruptible Power Systems (UPS)
87.	Vaults
90.	Walls
92.	Weapons Detector - Hand-Held, Package Search
95.	Weapons Detector - Walkthrough

performance capability, as specified in 10 CFR 73.45 paragraph (g). Therefore, many of the effectiveness scores for the response subfunction have been assumed in order to complete the aggregation. These responses were utilized by Sandia and WCC to partially test the evaluation methodology. This testing is discussed in the next subsection.

5.2.4 Testing of Evaluation Methodology -- The responses to the ETQs which were provided by AGNS for the partial physical protection system design served as input to the performance evaluation methodology described in Chapter 3. Using the computer program developed by WCC, the evaluation methodology was implemented (see Chapter 4) to arrive at a performance measure (score) for the AGNS system's ability to achieve the performance capability specified in 10 CFR 73.45 paragraph (b).

In this subsection, the results of the evaluation for performance capability (b) are shown in Figure 5-2, and a limited interpretation of these results is provided. In order to illustrate this discussion more clearly, the computer program output scores have been transferred to the functional hierarchy for performance capability (b).

The evaluation procedure begins with the aggregation of individual responses within a questionnaire to arrive at an overall component effectiveness score. These question scores are shown in Figure 5-3 (page 5-9). The questionnaire number underlined in this figure corresponds to that which appears on the Central and Secondary Alarm Stations questionnaire in Volume II.

At the next level, these individual component scores are aggregated to arrive at a performance measure for each performance characteristic corresponding to a low-level system task in the hierarchy. This process continues up through the various levels of the hierarchy until an overall score can be determined for the AGNS sample plan's ability to satisfy the requirements specified in 10 CFR 73.45 paragraph (b). The need for system ETQs to address the functional and dynamic interactions of various system functions and subfunctions has been discussed in preceding chapters. In this evaluation, where such questionnaires were available, the choice of aggregation rule, e.g., SOFT AND, reflects these interactions. However, where this is not the case, these operators were tentatively selected by the authors.

The results of the performance evaluation for the partial physical protection system designed by AGNS show an overall score of 0.3 on a 0

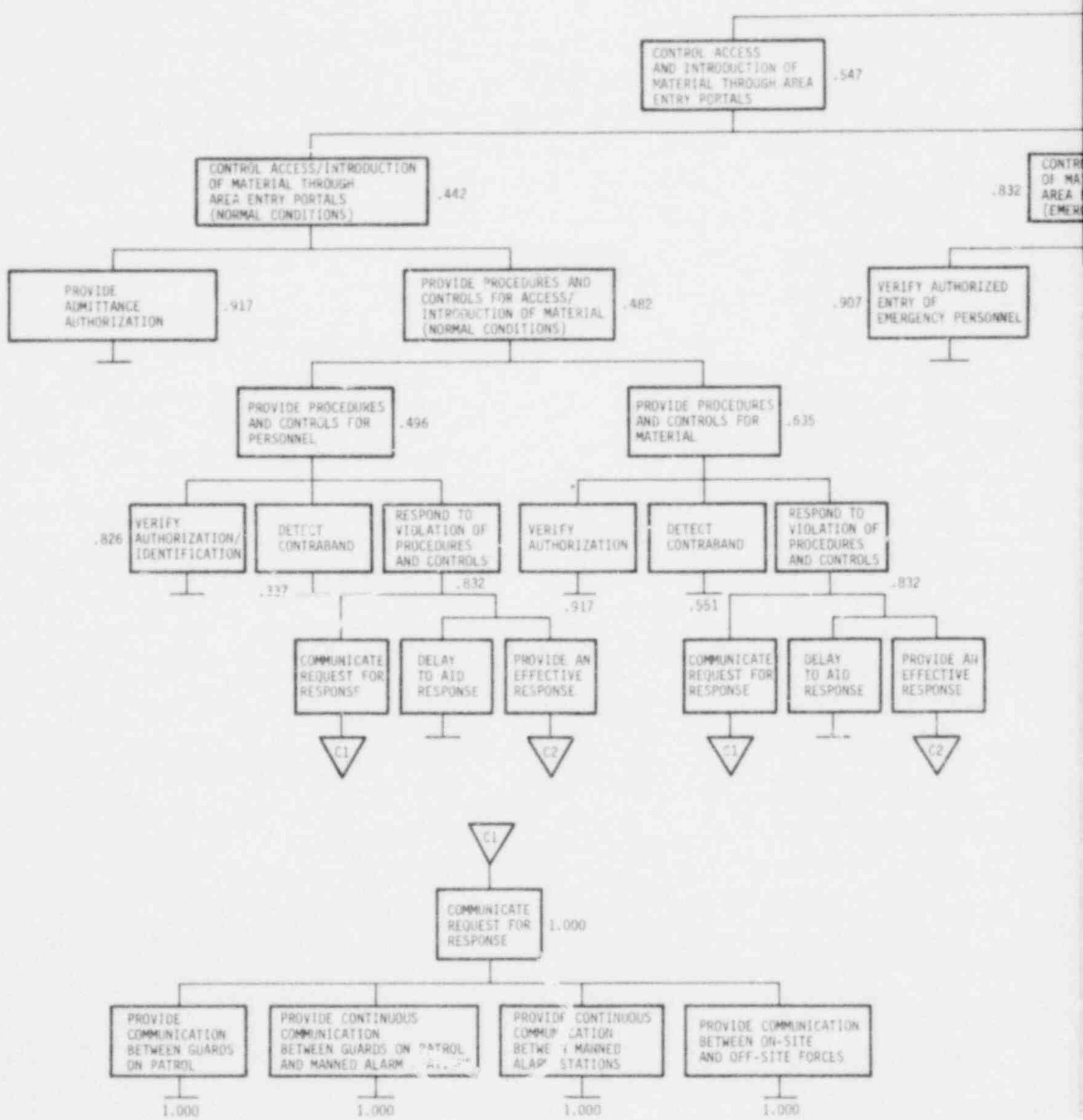
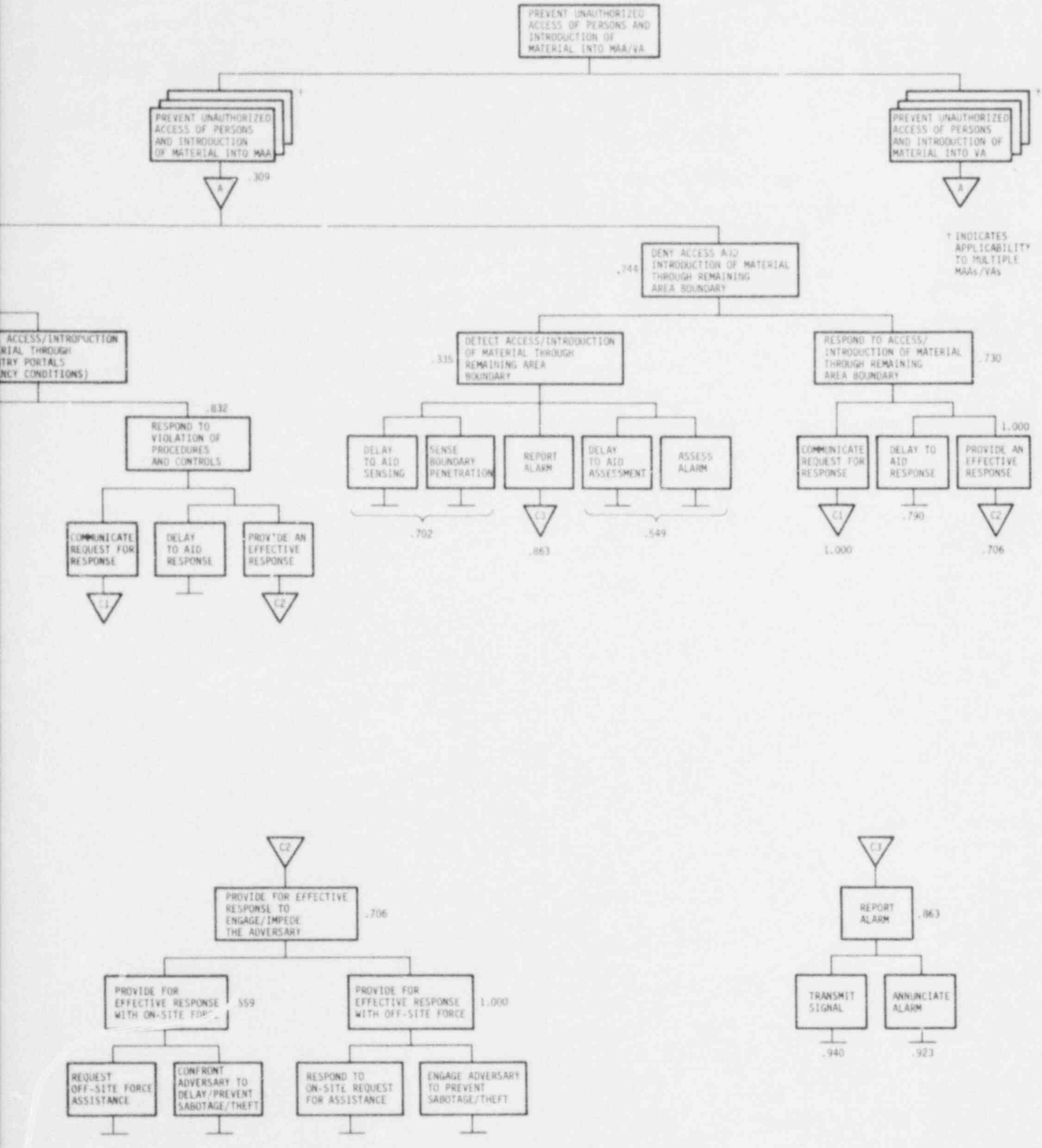

CONTROL ACCESS AND INTRODUCTION OF MATERIAL THROUGH AREA ENTRY PORTALS
.547
CONTROL ACCESS/INTRODUCTION OF MATERIAL THROUGH AREA ENTRY PORTALS (NORMAL CONDITIONS)
.442
.832
PROVIDE ADMITTANCE AUTHORIZATION
.917
PROVIDE PROCEDURES AND CONTROLS FOR ACCESS/INTRODUCTION OF MATERIAL (NORMAL CONDITIONS)
.482
.907
VERIFY AUTHORIZED ENTRY OF EMERGENCY PERSONNEL
PROVIDE PROCEDURES AND CONTROLS FOR PERSONNEL
.496
PROVIDE PROCEDURES AND CONTROLS FOR MATERIAL
.635
.826
VERIFY AUTHORIZATION/IDENTIFICATION
DETECT CONTRABAND
.337
RESPOND TO VIOLATION OF PROCEDURES AND CONTROLS
.832
VERIFY AUTHORIZATION
.917
DETECT CONTRABAND
.551
RESPOND TO VIOLATION OF PROCEDURES AND CONTROLS
.832
COMMUNICATE REQUEST FOR RESPONSE
DELAY TO AID RESPONSE
PROVIDE AN EFFECTIVE RESPONSE
C1
C2
COMMUNICATE REQUEST FOR RESPONSE
1.000
PROVIDE COMMUNICATION BETWEEN GUARDS ON PATROL
1.000
PROVIDE CONTINUOUS COMMUNICATION BETWEEN GUARDS ON PATROL AND MANNED ALARM
1.000
PROVIDE CONTINUOUS
1.000
PROVIDE COMMUNICATION BETWEEN ON-SITE AND OFF-SITE FORCES
1.000

Figure 5-2. P
P



rformance Scores for Functional Hierachy for
roposed Rule Part 73.45(b)

```
? 42
? ENTER BOX NAME --
? DENACC

  HIERARCHY DATA FOR BOX DENACC (DENY ACCESS)

 BOX:DENACC  RULE:HA  SCORE:  .244   0:
     BOX:DETACC  RULE:HA  SCORE:  .335   0:
          BOX:SENSE   RULE:SD  SCORE:  .702   0:
               BOX:MULTS   RULE:AV  SCORE:  .671   0:
               BOX:INDM1   RULE:SA  SCORE:  .575   0:
          BOX:REPALR  RULE:HA  SCORE:  .868   0:
               BOX:TSIG    RULE:SD  SCORE:  .940   0:
               BOX:ANALRM  RULE:SD  SCORE:  .923   0:
          BOX:ASSESS  RULE:AV  SCORE:  .549   0:
               BOX:MULTA   RULE:AV  SCORE:  .670   0:
               BOX:INDA1   RULE:SA  SCORE:  .640   0:
             * BOX:CASSAS  RULE:AV  SCORE:  .338   0:
     BOX:RESACC  RULE:HA  SCORE:  .730   0:
          BOX:COMFSP  RULE:SA  SCORE: 1.000   0:
               BOX:BETGDS  RULE:    SCORE: 1.000   0:::::
               BOX:GDSSTN  RULE:HA  SCORE: 1.000   0:
               BOX:BETSTN  RULE:    SCORE: 1.000   0:::::
               BOX:ONOFF   RULE:    SCORE: 1.000   0:::::
          BOX:RESP    RULE:SA  SCORE:  .730   0:
               BOX:DELRSP  RULE:SD  SCORE:  .790   0:
               BOX:EFFRSP  RULE:SA  SCORE:  .706   0:
               BOX:DRRSP   RULE:    SCORE: 1.000   0:::::
? SELECT 41-51 --
? 42
? ENTER BOX NAME --
? DETACC

  HIERARCHY DATA FOR BOX DETACC (DETECT ACCESS)

 BOX:DETACC  RULE:HA  SCORE:  .335   0:
     BOX:SENSE   RULE:SD  SCORE:  .702   0:
          BOX:MULTS   RULE:AV  SCORE:  .671   0:
                QUESTIONNAIRE: 6      SCORE:  .766
                QUESTIONNAIRE: 57     SCORE:  .579
                QUESTIONNAIRE: 10     SCORE:  .670
          BOX:INDM1   RULE:SA  SCORE:  .575   0:
               BOX:DDS     RULE:    SCORE:  .833   0:::::
               BOX:GP      RULE:AV  SCORE: 1.000   0:
               BOX:BARR    RULE:SA  SCORE:  .370   0:
     BOX:REPALR  RULE:HA  SCORE:  .868   0:
          BOX:TSIG    RULE:SD  SCORE:  .940   0:
                QUESTIONNAIRE: 47     SCORE:  .820
                QUESTIONNAIRE: 18     SCORE: 1.000
          BOX:ANALRM  RULE:SD  SCORE:  .923   0:
                QUESTIONNAIRE: 4      SCORE:  .755
                QUESTIONNAIRE: 51     SCORE:  .766
                QUESTIONNAIRE: 43     SCORE: 1.000
     BOX:ASSESS  RULE:AV  SCORE:  .549   0:
          BOX:MULTA   RULE:AV  SCORE:  .670   0:
                QUESTIONNAIRE: 10     SCORE:  .670
          BOX:INDA1   RULE:SA  SCORE:  .640   0:
               BOX:DDA     RULE:    SCORE: 1.000   0:::::
               BOX:GP      RULE:AV  SCORE: 1.000   0:
               BOX:BARR    RULE:SA  SCORE:  .370   0:
        * BOX:CASSAS  RULE:AV  SCORE:  .338   0:
                QUESTIONNAIRE: 12     SCORE:  .338
```

Figure 5-3. Segment of Computer Output

to 1 scale. At this time, no acceptance criteria have been established by the NRC which would indicate the significance of a score of 0.3. The development of two additional physical protection system designs which, by a consensus of experts, were judged as "good" and "minimal," relative to the performance capability requirements, would provide the NRC with some basis for establishing acceptance criteria. However, it should be emphasized that the aggregate score which results from application of the evaluation methodology to a physical protection system should not be used as an absolute measure of system performance. It is intended to be used by an evaluator only as a guide to making a judgement regarding the adequacy of a physical protection system.

In the present absence of acceptance criteria, no judgements are made here regarding the significance of a 0.3 score. Instead, the results of the evaluation are examined with the initial goal in mind, i.e., testing of the methodology to provide a critique. Given the scores for the various hierarchy elements (boxes) shown in Figure 5-1 (page 5-3), the evaluator would be expected to attempt, intuitively, to isolate the lowest score at each aggregation point in the hierarchy in order to permit identification of possible problem areas. As Figure 5-1 shows, the aggregate score (0.244) for the deny access function is lower than the score for the control access function (0.547). This presents a natural point from which to trace back through the evaluation process in an attempt to gain a better understanding of the reasons for this score. Continuing this process, it is found that the detect access subfunction has the lower score (0.335) of the two subfunction scores which contribute to the score for the deny access function. The 0.335 score for detect access is, in turn, the result of aggregating three scores, the lowest of which is 0.549 for assessment. At this point, the segment of computer output shown in Figure 5-3 (page 5-9) should be reviewed. The highlighted lines in this listing show a continuation of this trace-back process. The aggregate score for ETQ No. 12, Central and Secondary Alarm Stations, is 0.338. Examination of the questionnaire data for this ETQ (Figure 5-4) reveals that three questions have the lowest score, 0.5, in this ETQ. The first two questions, No. 12 and No. 13, refer to the existence of duress alarms and their ability to communicate between the CAS and SAS. The third question, No. 25, treats the ability to switch the status of an alarm from one station to another. Once these three questions have been pinpointed, the licensee and evaluator have a basis for discussing the ETQ scores. For example, the licensee may be able to show that his system

```
                    QUESTIONAIRE DATA FOR
                      QUESTIONAIRE 12
         OVERALL SCORE =      0.33838      RULE : SA


BOX: 50  RULE: SA
        Q= 1  RESP= 1.000 W= 0.500 S= 1.000
        Q= 2  RESP= 0.667 W= 0.500 S= 0.833
        Q= 3  RESP= 1.000 W= 0.500 S= 1.000
        Q= 4  RESP= 1.000 W= 0.500 S= 1.000
        Q= 5  RESP= 1.000 W= 0.500 S= 1.000
        Q= 6  RESP= 1.000 W= 0.500 S= 1.000
        Q= 7  RESP= 1.000 W= 0.500 S= 1.000
        Q= 8  RESP= 1.000 W= 0.500 S= 1.000
        Q= 9  RESP= 1.000 W= 0.500 S= 1.000
        Q=10  RESP= 1.000 W= 0.500 S= 1.000
        Q=11  RESP= 1.000 W= 0.500 S= 1.000
        Q=12  RESP= 0.0   W= 0.500 S= 0.500
        Q=13  RESP= 0.0   W= 0.500 S= 0.500
        Q=14  RESP= 0.500 W= 0.500 S= 0.750
        Q=15  RESP= 1.000 W= 0.500 S= 1.000
        Q=16  RESP= 1.000 W= 0.500 S= 1.000
        Q=17  RESP= 1.000 W= 0.500 S= 1.000
        Q=18  RESP= 1.000 W= 0.500 S= 1.000
        Q=19  RESP= 1.000 W= 0.500 S= 1.000
        Q=20  RESP= 1.000 W= 0.500 S= 1.000
        Q=21  RESP= 1.000 W= 0.500 S= 1.000
        Q=22  RESP= 1.000 W= 0.500 S= 1.000
        Q=23  RESP= 1.000 W= 0.500 S= 1.000
        Q=24  RESP= 1.000 W= 0.500 S= 1.000
        Q=25  RESP= 0.0   W= 0.500 S= 0.500
        Q=26  RESP= 1.000 W= 0.500 S= 1.000
        Q=27  RESP= 1.000 W= 0.500 S= 1.000
        Q=28  RESP= 1.000 W= 0.500 S= 1.000
        Q=29  RESP= 1.000 W= 0.500 S= 1.000
        Q=30  RESP= 1.000 W= 0.500 S= 1.000
        Q=31  RESP= 1.000 W= 0.500 S= 1.000
        Q=32  RESP= 1.000 W= 0.500 S= 1.000
        Q=33  RESP= 1.000 W= 0.500 S= 1.000
SELECT 21-29 -- 3
```

Figure 5-4. Data from Questionaire 12

has compensatory measures which are not reflected in the responses to the questions. This might result in a revised component score. On the other hand, the licensee may find the need to modify the system design to correct the deficiencies pointed out by the ETQ scores. This trace-back process would be repeated for the remaining system functions and subfunctions to isolate other problem areas.

In this subsection, only the individual hierarchy element scores were considered in tracing back through the evaluation process. Another consideration which might be investigated is the choice of aggregation rule at each level of the hierarchy. Tracing back through the evaluation process using the computer output and the functional hierarchy provides an invaluable tool for resolving discrepancies in the design and evaluation of a physical protection system. Discussions based on isolation of problem areas using this trace-back process should result in either revised component, subfunction, or function scores based on additional design information not reflected in the methodology or system design modifications to correct the deficiencies.

5.3 Test Results

5.3.1 Critique of Design Guidance Compendium -- Following the design and documentation of the "good" partial physical protection system and completion of the corresponding ETQs, AGNS provided a critique of the compendium. This critique was intended to illustrate both the strengths and the weaknesses of the compendium with respect to its utility to the licensee in designing a system which satisfies the Upgrade Rule regulations and in preparing the necessary documentation for license application. The following is a summary of the critique provided by AGNS:

1. The paramount attribute of the design guidance compendium is an inherent characteristic to continuously subject the licensee to an evaluation of the total physical protection system. As each new component or system is added to the total system, the licensee becomes initially exposed to both the beneficial and detrimental characteristics of the component. Subsequently, this exposure broadens and necessitates that the licensee evaluate both the impact of the component on the physical protection system and the impact of the physical protection system on the component. The principal benefit of this exercise is the continuous self-test capability afforded by the compendium which identifies component inadequacies and system incongruities.

2. A second attribute of the compendium is a responsiveness to the needs of the licensee to evaluate the effectiveness of the physical protection system in complying with the requirements of the physical protection Upgrade Rule. As components are added to the total system, the licensee evaluates the performance of the component. The licensee is, therefore, afforded the opportunity to compensate for minimal performance levels in one component by elevating the performance of other components which interact within the same physical protection subsystem. This attribute is extremely valuable to currently operating facilities which are, by design, restricted to certain types of security system designs.

3. The third major attribute of the compendium is the establishment of conformity in the licensing process. By responding to the information solicited in the compendium, the licensee is committed to the submission of security plans which are more cohesive and coordinated. These physical protection plans will contain, and be limited to, only the information necessary to perform a thorough evaluation of the physical protection systems' ability to achieve the performance capabilities. Additionally, the licensee is relieved of the responsibility of determining the type of information required since the design guidance compendium identifies the criteria from which the physical protection system and the associated security plan are evaluated.

4. The only notably deficient area in the compendium concerns consistency between the information requested by the IRS and the information evaluated by the associated ETQ. Generically, either information concerning a specific component or system is requested and then not evaluated, or information is evaluated but never requested. In addition, identical information for similar components or systems is not always requested or evaluated. However, the effects of this deficiency are minimal when compared to the positive attributes of the design guidance compendium.

In conclusion, the AGNS partial test shows that the benefits which can be derived from the implementation of the design guidance compendium are invaluable. The compendium is utilized most effectively if it is implemented during the design phase of the facility, e.g., concurrently with health and safety, operations, and maintenance design considerations. However, the reliability of all fixed-site facility physical protection systems is sufficiently enhanced if the compendium requirements are incorporated during system planning, construction, or operation. Thus, implementation of the NRC Fixed-Site Physical Protection Upgrade Rule Guidance Compendium seems warranted.

5.3.2 Critique of Evaluation Methodology -- The results of the evaluation methodology test show the need for more extensive testing and, in particular, for the development of a "minimal" performance system to permit calibration of the methodology. This would also provide the NRC with a basis for establishing acceptance criteria. The need for sensitivity analysis regarding question responses and aggregation rules is also indicated.

Finally, the trace-back capability provided in the evaluation methodology is an invaluable tool which can be used by licensees and NRC evaluators to discuss and resolve any discrepancies in the perceived performance of a physical protection system.

6. RECOMMENDATIONS FOR FURTHER DEVELOPMENT

Recommendations for further development of the design guidance and evaluation methodology fall into two categories. The first category consists of recommendations for improvements in the current methodology. The second category consists of policy recommendations with regard to future regulation guidance and evaluation development.

Within the current project, the following points are suggested for further development:

1. Continued development of system ETQs for systems in which performance is subject to functional and/or dynamic interaction between system elements.
2. Provision for comprehensive testing by both industry and the NRC to determine the utility, completeness, and validity of the design guidance products and evaluation methodology.
3. Extension of the methodology to evaluate the performance provided by multiple layers of protection, given an adversary gains access to the PA, MAA, etc.

Each of these recommendations is discussed in detail in the following paragraphs.

6.1 Continued System ETQ Development

The first recommendation, continued system ETQ development, is considered essential for situations in which it is not possible to simply select an aggregation rule, e.g., SOFT AND, independent of the specific components in the system and/or site conditions involved. Furthermore, it may not be desirable to allow rule selection to be performed by the licensee or evaluator under such circumstances. Rather, rule selection should be made on the basis of responses to a series of questions.

In addition, some systems require an interactive relationship between components for satisfactory performance to be achieved. In such cases, questions are required in order to probe the extent of the component relationships. Merely aggregating individual component ETQ scores will not provide a meaningful measure of performance. For example, a well-constructed, properly installed barrier which provides an adversary delay of 5 minutes, when evaluated as a component, could be given a high score. Similarly, a well-trained, well-equipped, highly motivated response team with a 10-minute response time could be rated highly as a component. However, only when the delay time is compared to the response time does it become apparent that the two components are incompatible as a system.

6.2 Comprehensive Design Guidance Product and Evaluation Methodology Testing

The second recommendation involves comprehensive testing of the design products and the evaluation methodology by both industry and NRC users to determine their utility, completeness, and validity in their various areas of application. These products and the evaluation methodology should be tested in their entirety by both industry and NRC users on a hypothetical, although realistically detailed, physical protection system. This expanded testing program will allow for a more in-depth application of each element, while providing an opportunity to incorporate the changes prescribed as a result of the testing program. Previously, a very limited testing effort was performed using only one MAA and one Upgrade Rule performance capability. A comprehensive testing of the design guidance products and evaluation methodology is required.

6.3 Extension of Evaluation Methodology

The third recommendation suggests that the evaluation methodology be extended to provide an estimate of protection in-depth performance. Such an extension could prove useful as a decision aid for NRC licensing personnel in the review of security plans whenever some uncertainty exists concerning a particular performance capability's acceptance. The reviewer could simply assume that the capability did not exist and obtain an evaluation of the remaining system's ability to achieve the general performance objective.

Finally, as a matter of policy for future development of regulatory guidance and evaluation, it is recommended that early in the formation phase of new regulations, potential contractors be retained, at least as consultants, to provide advice from an evaluation viewpoint.

For example, consider the difficulty encountered in developing functional hierarchies for the performance capabilities, as stated in the Upgrade Rule. A constraint in the form of the hierarchies was the existing form of the regulations which had been published for review prior to development of the methodology. This resulted in an evaluation structure which, although clearly traceable to the regulations, does not provide a one-to-one correspondence between the two. The concurrent development of regulations and a corresponding evaluation structure would facilitate development of future regulations, while providing a one-to-one correspondence between the evaluation structure and the regulations.

APPENDIX A

Derivation of Function Utilized in the Evaluation Methodology

Question Response Scores

Given a component whose performance is a composite of a number of factors, the probability that the component will fail to perform satisfactorily, given a failure or unsatisfactory condition in one of the factors, is

$$P(\overline{E} \mid \overline{F}_i) = \frac{P(\overline{E} \cap \overline{F}_i)}{P(\overline{F}_i)} \qquad \text{(A-1)}$$

where

$\overline{E}$ = the failure event for the component

$\overline{F}_i$ = the failure event of factor i

Rewriting Eq. (A-1) yields

$$P(\overline{E} \cap \overline{F}_i) = P(\overline{E} \mid \overline{F}_i) P(\overline{F}_i) \qquad \text{(A-2)}$$

From deMorgan's Law, the complement of

$$(\overline{E} \cap \overline{F}_i) = (E \cup F_i) \qquad \text{(A-3)}$$

and the complement of Eq. (A-2) is given by

$$P(E \cup F_i) = 1 - P(\overline{E} \mid \overline{F}_i) \left| 1 - P(F_i) \right| \qquad \text{(A-4)}$$

Now, given the following:

- a question (i) concerning the condition of a factor contributing to a component's performance,

- a set of responses to the question, each with a value, x_i, ranging from the best of conditions, $x_i = 1$, to the threshold of unacceptability $x_i = 0$,
- the response value, x_i, which in some way reflects a measure of $P(F_i)$, the probability of success for that performance factor, and
- a weight, w_i, assigned to the question that can serve as a surrogate measure for $P(\overline{E}|\overline{F}_i)$,

then the expression for the question score, S_i, should be analogous to Eq. (A-4) or

$$S_i = 1 - w_i(1 - x_i) \qquad \text{(A-5)}$$

Aggregation Rules

Extending the single question to a group of questions, each addressing a component performance factor, requires a means of aggregating the individual question scores into a meaningful measure of component performance.

Utilizing concepts from fault tree logic, the component performance level associated with each group of questions is obtained by aggregating individual question scores (s_i) through whichever of the following rules is most appropriate: (1) AND, (2) SOFT AND, (3) AVERAGE, (4) SOFT OR, and (5) OR. In order to indicate the basis for the functional form of the AND aggregation rule, the following derivation is offered:

Assuming for the moment that failure of any one of the factors (F_i) addressed by a group of questions can cause the component failure event (E) and that

$$\bigcup_{i=1}^{n} \overline{F}_i \supset \overline{E} \qquad \text{(A-6)}$$

Then

$$\overline{E} = \bigcup_{i=1}^{n} (\overline{E} \cap \overline{F}_i) \qquad \text{(A-7)}$$

or

$$p(\bar{E}) \leq \sum_{i=1}^{n} p(\bar{E}|\bar{F}_i)p(\bar{F}_i) \qquad \text{(A-8)}$$

However, to indicate a level of performance, the complement is a more appropriate measure; then from Eq. (A-7)

$$E = \bigcap_{i=1}^{n} (E \cup F_i) \qquad \text{(A-9)}$$

or

$$p(E) \geq \prod_{i=1}^{n} p(E \cup F_i) \qquad \text{(A-10)}$$

Drawing on the analogy between Eqs. (A-4) and (A-5), Eq. (A-10) becomes

$$S = \prod_{i=1}^{n} s_i \qquad \text{(A-11)}$$

where

S = the overall component event score
s_i = the individual question score
n = the number of questions in the group to be aggregated.

The AND rule is appropriate whenever all of the performance factors addressed by a group of questions are essential to component effectiveness under all conditions. That is, if any factor is unsatisfactory, component performance is unsatisfactory.

The following development,[5] employing what is called textured sets, is a flexible and rational approach to aggregation that bridges the gap between a full probabilistic analysis and fuzzy set theory:

A Textured Set S is a collection of elements {Z} (either finite or infinite) and a mapping $T:Z \in \smile \rightarrow [0,1]$ of the elements of S to the closed interval [0,1]. T(Z) will be called a Texture Function (or simply, texture) over S. This function is of course similar to the fuzzy set membership function introduced by Zadeh. S can have several associated textures ($T_i(Z)$ for i=1 to N). The Composite Texture over S will be defined by $CT(Z) = f(T_1(Z), T_2(Z), \ldots, T_N(Z))$. Fuzzy set theory would have $CT(Z) = \min T_i(Z)$ or $CT(Z) = \max T_i(Z)$ but there are alternatives.

Let $T = \{T_1(Z), T_2(Z), \ldots, T_n(Z)\}$ be a set of textures associated with a set S = {Z}. There are 2^N-1 non-empty groups (or subsets) of T. In particular there will be $\binom{N}{}$ ("N choose i") groups of i textures for i = 1 to N.

Let G_{ij} represent the j^{th} subset of T with i textures and let $T_{ijm}(Z)$ represent the m^{th} member of the G_{ij}. Thus if $G_{31} = \{T_1(Z), T_2(Z), T_5(Z)\}$ then $T_1 = T_{311}$, $T_2 = T_{312}$, $T_5 = T_{313}$.

Now, define the intersection of the j^{th} group of textures having i members as

$$P_{ij}(Z) = \prod_{m=1}^{i} T_{ijm}(Z) \qquad \text{(A-12)}$$

Note that if the $T_i(Z)$ represent the probability of "success" of a particular facet of the element Z and the factors are independent, then $P_{ij}(Z)$ is the probability that every one of the factors in the j^{th} group of i factors will succeed. Similarly, the union of a group of textures is defined as

$$Q_{ij}(Z) = 1 - \prod_{m=1}^{i} (1 - T_{ijm}(Z)) \qquad \text{(A-13)}$$

(For probabilities, $Q_{ij}(Z)$ is the probability that at least one of the $T_{ijm}(Z)$ will "succeed.")

Next define the <u>interaction function</u> V_{ij} as a weighting function over the 2^N-1 possible groups subject to the restriction that

$$\sum_{i=1}^{N} \sum_{j=1}^{\binom{N}{i}} V_{ij} = 1 \qquad \text{(A-14)}$$

Now, using the group intersections P_{ij} and the interaction functions V_{ij}, the <u>composite texture</u> of S is defined as

$$CT(Z,V) = \sum_{i=1}^{N} \sum_{j=1}^{\binom{N}{i}} V_{ij} P_{ij} \qquad \text{(A-15)}$$

This function is thus a weighted average of all the group intersections.

This discussion will be restricted to the case where V_{ij} depends only on the number of textures (i). Specifically, let

$$V_{ij} = \frac{V^i}{(1 - V)^N - 1} \qquad \text{(A-16)}$$

This is allowed by the definition, as can be seen by substituting into Eq. (A-14) as follows:

$$V_{ij} = \frac{V^i}{(1 - V)^N - 1} = \frac{1}{(1 + V)^N - 1} \sum_{i=1}^{N} V^i \binom{N}{i} \qquad \text{(A-17)}$$

$$= \frac{1}{(1 + V)^N - 1} \quad (1 + V)^N - 1 \ = 1 \qquad \text{(A-18)}$$

as required.

Using this interaction function in Eq. (A-15) gives

$$CT(Z,V) = \sum_{i=1}^{N} \sum_{j=1}^{\binom{N}{i}} \frac{V^i}{(1 + V)^N - 1} P_{ij}(Z) \qquad \text{(A-19)}$$

$$CT(Z,V) = \frac{1}{(1 + V)^N - 1} \sum_{i=1}^{N} V^i \sum_{j=1}^{\binom{N}{i}} P_{ij}(Z) \qquad \text{(A-20)}$$

This formula has different interpretations for various values of V. Results for some important values are summarized in Table A-1.

Examination of Table A-1 shows that when $V = +\infty$, all weight is concentrated on $P_{N1}(Z) = \prod_{j=1}^{N} T_j(Z)$. Thus, (CT(Z)) can be probabilistically interpreted as the probability that all of the facets will "succeed." As V gets smaller, weight is gradually shifted to P_{ij} with smaller i. At V=1, the weight is equally distributed among all the P_{ij}. This has a probabilistic interpretation when it is unclear how many of the $T_i(Z)$ must succeed for overall success. CT(Z) can be interpreted as the probability that all of the facets in a subset of T chosen at random will succeed. As V approaches 0, weight shifts to the N groups P_{1j} (which equal the $T_j(Z)$). CT(Z,0) might be interpreted as the probability that one of the facets (chosen at random) will not fail. Since $Q_{1j}(Z) = P_{1j}(Z)$, CT(Z) is also the probability that a randomly chosen facet will succeed. As V decreases, the weight is gradually spread to Q_{ij} with higher i. At $V = -1/2$ the weight is equally spread among all the Q_{ij}. Here CT(Z) is the probability that at least one facet in a randomly chosen subset of T will succeed. When V approaches -1, all weight is concentrated on $Q_{N1} = 1 - \prod_{i=1}^{N} (1 - T_i(Z))$. This is the formula for a fault tree OR gate, so T(Z) can be interpreted as the probability that at least one of the facets will succeed.

These five values of V (∞, 1, 0, -1/2, -1) relate to five different types of interactions ranging from a strong interaction between factors, when $V = \infty$ and all textures must have a high value for a high composite texture, to strong redundancy, when V = -1 and only one texture need have a high value for an overall high value. (This is why V_{ij} is defined as strength of interaction.) Borrowing some terminology from fault tree theory, the following definitions will be used:

$CT(Z,\infty)$ = AND operator

$CT(Z,1)$ = SOFT AND operator

$CT(Z,0)$ = AVERAGE

$CT(Z,-1/2)$ = SOFT OR

$CT(Z,-1)$ = OR

Table A-1

Interpretations of Interaction Function for Various Values of V

1. Basic Formula

$$CT(Z) = \frac{1}{(1+V)^N - 1} \sum_{i=1}^{N} V^i \sum_{j=1}^{\binom{N}{i}} P_{ij}(Z)$$

2. Computation Formulas

INTERACTION COEFFICIENT V	COMPOSITE TEXTURE CT(Z,V)	COMPUTATION FORMULA	COMMENTS
∞	$P_{Ni}(Z)$	$\prod_{i=1}^{N} T_i(Z)$	Strong interaction, analogous to fault tree AND gate.
1	$K \sum_{i=1}^{N} \sum_{j=1}^{\binom{N}{i}} P_{ij}(Z)$	$K\left[\prod_{i=1}^{N} (1 + T_i) - 1\right]$	Moderate interaction, "soft" AND.
0	$\frac{1}{N} \sum_{i=1}^{1} \sum_{j=1}^{\binom{N}{i}} Q_{ij}(Z)$	$\frac{1}{N} \sum_{i=1}^{N} T_i(Z)$	No interaction, average.
-1/2	$K \sum_{i=1}^{N} \sum_{j=1}^{\binom{N}{i}} Q_{ij}(Z)$	$2^N K \left[1 - \prod_{j=1}^{N} (1 - \frac{1}{2}T_i(Z))\right]$	Moderate redundancy, soft OR.
-1	$Q_{Ni}(Z)$	$1 - \prod_{i=1}^{N} (1 - T_i(Z))$	Strong redundancy, analogous to fault tree OR gate.

NOTE: $K = 1/(2^N - 1)$

APPENDIX B

Computer Program Listing for Evaluation Algorithm

Briefly, the computer program that performs the physical protection system evaluation requires as input, the questionnaire and hierarchy formats and the evaluator's responses to the multiple choice questionnaires. The program computes the scores for all components, low-level tasks, and higher-level elements of the functional hierarchy for each performance capability in the Upgrade Rule. It provides for sensitivity analyses on questionnaire responses and hierarchy element interactions. The program is interactive and has hierarchy display features.

```
C QUEASI -- A PROGRAM FOR EVALUATION OF SAFEGUARDS QUESTIONNAIRES
C AND HIERARCHIES
      COMMON LOCQ(100),QSCORE(100),LOCR(100)
      COMMON SCOREH(40),RULEH(40),IDEX(40,10),QDEX(40),QNAME(100)
      DOUBLE PRECISION BNAME(40),BLANK,NOMO,HNAME(40),ANAME
      INTEGER LOCHS(5),ISET(40),FLAG(10),LOCH(5),IRESP(40),IBEST(40)
      REAL SCORE(40),WEIGHT(40),RULE(10),TEXTS(7)
      DATA TEXTS/2HHA,2HSA,2HAV,2HSO,2HOR,1HQ,2HDR/
      DATA IAA/1HA/,NOMO/6HNOMORE/BLANK/6H
      DEFINE FILE 1 (300,80,E,I9)
      DEFINE FILE 3 (200,80,E,I9)
      DEFINE FILE 2 (150,80,E,I9)
      DEFINE FILE 4 (50,80,E,I9)
      AAA=FLOAT(IAA)
      DO 399 I=1,40
  399 SCOREH(I)=-1.
      J=2
C READ QUESTIONNAIRE LOCATIONS AND NAMES
      READ(1'1,9464) NUMQ
      READ(1'J,9465)(LOCQ(I1),I1=1,NUMQ)
      READ(2'J,9465)(LOCR(I2),I2=1,NUMQ)
      DO 30 I=1,NUMQ
      J=LOCQ(I)
   30 READ(1'J,9272) QNAME(I)
      DO 10 I=1,100
   10 QSCORE(I)=-1.
      DO 20 I=1,10
   20 FLAG(I)=0
C SELECT INITIAL OPTION
 1000 WRITE(6,9100)
 9100 FORMAT(54H? SELECT 1- HIERARCHIES, 2- QUESTIONAIRES, 3- STOP -- )
      ICP=GETNUM(1.,3.,2.)
 1001 IF (IOP.EQ.3) STOP
      GOTO (4000,2000) ICP
C REVIEW OPTION SELECTION AND BRANCH TO PROPER OPTION
      ICPT=IOP
 1100 CONTINUE
      IF (IOPT.GE.1.AND.IOPT.LE.3) GOTO 1101
      IF(IOPT.GE.21.AND.IOPT.LE.26) GOTO 1102
      IF (IOPT.GE.41.AND.IOPT.LE.50) GOTO 1102
      GOTO (1000,230,1000,402) IOP
 1101 ICP=IOPT
      GOTO 1001
 1102 IOP=INT(FLOAT(IOPT)/10.)
      IF(IOP*10.EQ.ICPT) GOTO 1001
      IOPT=ICPT-IOP*10
      GOTO (1000,201,1000,404) ICP
      GOTO 1000
C PRINT MENU AND GET QUESTIONNAIRE OPTION
 2000 IF (FLAG(2).EQ.1) GOTO 210
  230 WRITE(6,9200)
      WRITE(6,9201)
      WRITE(6,9202)
      WRITE(6,9203)
      WRITE(6,9204)
```

```
      WRITE(6,9205)
 9200 FORMAT(/,14H  SELECT ONE: ,/)
 9201 FORMAT(51H  21- COMPUTE SCORES        22- PRINT SCORES          )
 9202 FORMAT(51H  23- SET SCORES            24- REVISE WEIGHTS        )
 9203 FORMAT(51H  25- REVISE RULES          26- REVISE RESPONSES      )
 9207 FORMAT(51H  27- REVISE NAMES          28- PRINT NAMES           )
 9204 FORMAT(51H            29- NO MORE REVISIONS                     )
 9205 FORMAT(/,9H? WHICH?  )
      GOTO 220
  210 WRITE(6,9206)
 9206 FORMAT(18H? SELECT 21-29 -- )
  220 IOPT=GETNUM(21.,29.,2.)
      IF (IOPT.LT.21.OR.IOPT.GT.29) GOTO 1100
      IOPT=IOPT-20
  201 FLAG(2)=1
C BRANCH TO PROPER OPTION
      GOTO (2001,2002,2003,2004,2005,2006,2007,2008,1000) IOPT

C -- OPTION 22 TO PRINT DATA FOR A QUESTIONNAIRE --
 2002 GOTO 222
  223 DO 221 I=1,NUMQ
      CALL PRINTQ(I,QNAME)
  221 CONTINUE
      GOTO 2000
  222 CALL GETQN(ID,QNAME,NUMQU)
      IF(ID.EQ.-1) GOTO 223
      CALL PRINTQ(ID,QNAME)
      GOTO 2000

C -- OPTION 21 TO COMPUTE A QUESTIONNAIRE SCORE --
 2001 GOTO 213
  214 DO 211 I=1,NUMQ
      WRITE(6,9301) QNAME(I)
 9301 FORMAT(16H? QUESTIONNAIRE ,1A4,1H:)
  211 CALL SCOREQ(I)
      GOTO 2000
  213 CALL GETQN(ID,QNAME,NUMQU)
      IF(ID.EQ.-1) GOTO 214
      CALL SCOREQ(ID)
      GOTO 2000

C -- OPTION 23 TO SET A QUESTIONNAIRE SCORE --
 2003 CALL GETQN(ID,QNAME,NUMQU)
      WRITE(6,9300)
 9300 FORMAT(30H? ENTER QUESTIONAIRE SCORE -- )
      QSCORE(ID)=GETNUM(0.,1.,1.)
      GOTO 2000

C -- OPTION 24 TO REVISE QUESTION WEIGHTS --
 2004 CALL GETQN(ID,QNAME,NUMQU)
      QSCORE(ID)=-1.
      WRITE(6,9240)
 9240 FORMAT(39H? NUMBER OF QUESTIONS TO BE REVISED -- )
      NUM=GETNUM(1.,FLOAT(NUMQU),0.)
      LOC=LOCQ(ID)
```

```
      READ(1'LOC,9500) R,NQQQ,NGRP
      LOC=LOC+2+2*NGRP
      READ(1'LOC,9243)(WEIGHT(K),K=1,8)
      IF(WEIGHT(1).LE.1) GOTO 241
      WRITE(6,9244)
 9244 FORMAT(47H? MUST REVISE ALL WEIGHTS. ENTER NEW WEIGHT -- )
      WEIGHT(2)=GETNUM(0.,1.,1.)
      WRITE(1'LOC,9243)(WEIGHT(K),K=1,8)
      GOTO 2000
  241 LOC=LOC+1
      IF(NUMQU.LE.8) GOTO 243
      READ(1'LOC,9243) (WEIGHT(K),K=9,NUMQU)
  243 DO 240 I=1,NUM
      WRITE(6,9241)
 9241 FORMAT(20H? QUESTION NUMBER = )
      NUMQ=GETNUM(1.,40.,0.)
      WRITE(6,9242)
 9242 FORMAT(11H? WEIGHT = )
      W=GETNUM(0.,1.,1.)
  240 WEIGHT(NUMQ)=W
 9243 FORMAT(8F5.3)
      LOC=LOCQ(ID)+2+NGRP*2
      WRITE(1'LOC,9243)(WEIGHT(K),K=1,NUMQU)
      CALL SCOREQ(ID)
      GOTO 2000

C -- OPTION 25 TO REVISE SCORING RULES --
 2005 CALL GETQN(ID,QNAME,NUMQU)
      QSCORE(ID)=-1.
      LOC=LOCQ(ID)
      READ(1'LOC,9500) R,NQQQ,NGRP
 9500 FORMAT(1A2,2(8X,1I2))
  251 WRITE(6,9502)
 9502 FORMAT(24H? ENTER GROUP NUMBER  -- )
      N=GETNUM(50.,FLOAT(NGRP)+49.,0.)
      WRITE(6,9503)
 9503 FORMAT(33H? ENTER RULE (HA,SA,AV,SO,OR) -- )
  254 READ(5,9504) R
 9504 FORMAT(1A2)
      DO 252 I=1,5
      IF(R.EQ.TEXTS(I)) GOTO 253
  252 CONTINUE
      WRITE(6,9505)
 9505 FORMAT(25H? BAD RULE, TRY AGAIN -- )
      GOTO 254
  253 L=LOC+2
      DO 255 I=1,NGRP
      READ(1'L,9506) IGRP,M,Z
 9506 FORMAT(2(1I2,8X),1A2)
      IF(IGRP.EQ.N) WRITE(1'L,9506) IGRP,M,R
  255 L=L+2
      CALL SCOREQ(ID)
      GOTO 2000

C -- OPTION 26 TO REVISE QUESTION RESPONSES --
```

```
 2006  CALL GETQN(ID,QNAME,NUMQU)
       QSCORE(ID)=-1.
       LOC=LOCR(ID)+1
       READ(2*LOC,9600) IRESP
 9600  FORMAT(40(1X,1A1))
       L=LOCQ(ID)+1
       READ(1*L,9600) IBEST
       WRITE(6,9240)
       N=GETNUM(0.,40.,0.)
       DO 260 I=1,N
       WRITE(6,9241)
       NUM=GETNUM(0.,40.,0.)
  261  WRITE(6,9603) IBEST(NUM)
 9603  FORMAT(16H? RESPONSE (A TO,1X,1A1,4H) = )
  260  READ(5,9260) IRESP(NUM)
 9260  FORMAT(1A1)
       X=1-(AAA-FLOAT(IRESP(NUM)))/(AAA-FLOAT(IBEST(NUM)))
       IF(X.LT.0..OR.X.GT.1.) GOTO 261
       WRITE(2*LOC,9600) IRESP
       CALL SCOREQ(ID)
       GOTO 2000

C -- OPTION 27 TO REVISE QUESTIONNAIRE NAMES
 2007  CALL GETQN(ID,QNAME,NUMQU)
       WRITE(6,9271)
 9271  FORMAT(15H? ENTER NAME -- )
       READ(5,9272) QNAME(ID)
 9272  FORMAT(1A4)
       GOTO 2000

C -- PRINT AND SELECT HIERARCHY MANIPULATION OPTIONS --
 2008  CALL PQNAME(QNAME,NUMQ)
       GOTO 2000

 4000  IF (FLAG(5).EQ.0) GOTO 4006
       IF(FLAG(4).EQ.1) GOTO 401
  402  WRITE(6,9400)
       WRITE(6,9401)
       WRITE(6,9402)
       WRITE(6,9403)
       WRITE(6,9404)
       WRITE(6,9405)
       WRITE(6,9407)
       WRITE(6,9205)
 9400  FORMAT(/,14H  SELECT ONE: ,/)
 9401  FORMAT(51H  41- COMPUTE SCORES       42- PRINT DATA           )
 9402  FORMAT(51H  43- ASSIGN SCORES        44- REVISE DELAY/RESP    )
 9403  FORMAT(51H  45- REVISE RULES         46- SELECT NEW HIERARCHY )
 9404  FORMAT(51H  47- PRINT BOX NAMES      48- FILE HIERARCHY DATA  )
 9405  FORMAT(51H  49- CHANGE BOX NAME      50- PRINT HIERARCHY      )
 9407  FORMAT(51H                 51- NO MORE REVISIONS              )
       GOTO 403
  401  WRITE(6,9406)
 9406  FORMAT(18H? SELECT 41-51 -- )
  403  IOPT=GETNUM(41.,47.,2.)
```

```
      IF(IOPT.LT.41.OR.IOPT.GT.51) GOTO 1100
      IOPT=IOPT-40
  404 FLAG(4)=1
C BRANCH TO PROPER HIERARCHY OPTION
      IF(FLAG(5).EQ.0) GOTO 4006
      GOTO(4001,4002,4003,4004,4005,4006,4007,4008,4009,4002,1000) IOPT

C -- OPTION 41 TO SCORE A HIERARCHY BOX --
 4001 CALL GETHN(ID,HNAME)
      CALL SCREH(ID)
      CALL SETH(ID,ISET)
      ISET(ID)=0
      GOTO 4000

C -- OPTION 42 TO PRINT HIERARCHY DATA --
 4002 CALL GETHN(ID,HNAME)
      IF(IOPT.EQ.2) CALL PRINTH(ID,HNAME)
      IF (IOPT.EQ.10) CALL HPR(ID,HNAME)
      GOTO 4000

C -- OPTION 43 TO ASSIGN HIERARCHY BOX SCORES --
 4003 CALL GETHN(ID,HNAME)
      WRITE(6,9430)
      CALL SETH(ID,ISET)
 9430 FORMAT(10H? SCORE = )
      SCOREH(ID)=GETNUM(-1.,1.,1.)
      IF(SCOREH(ID).LT.0) ISET(ID)=0
      IF(SCOREH(ID).GE.0) ISET(ID)=1
      GOTO 4000

C -- OPTION 44 TO REVISE DELAY/RESPONSE RULE. NOT CURRENTLY USED
 4004 CALL GETHN(ID,HNAME)
      IF(RULEH(ID).EQ.TEXTS(7)) GOTO 440
      WRITE(6,9440)
 9440 FORMAT(28H BOX DOES NOT USE DELAY/RESP)
      GOTO 4000
  440 CONTINUE
      GOTO 4000

C -- OPTION 45 TO REVISE SCORING RULES --
 4005 CALL GETHN(ID,HNAME)
      WRITE(6,9503)
  450 READ(5,9504) R
      DO 451 I=1,6
      IF (R.EQ.TEXTS(I)) GOTO 452
  451 CONTINUE
      WRITE(6,9505)
      GOTO 450
  452 RULEH(ID)=R
      SCOREH(ID)=-1.
      CALL SETH(ID,ISET)
      GOTO 4000

C -- OPTION 46 TO ENTER A NEW HIERARCHY INTO THE SYSTEM --
 4006 WRITE(6,9460)
```

```
      FLAG(5)=1
      READ(3'1,9464) NUMH
      READ(3'2,9465) (LOCH(I),I=1,NUMH)
 9464 FORMAT(1I2)
 9465 FORMAT(20I4)
      READ(4'1,9464) NUMH
      READ(4'2,9465)(LOCHS(I),I=1,NUMH)
 9460 FORMAT(28H? ENTER HIERARCHY NUMBER -- )
      HNUM=GETNUM(1.,FLOAT(NUMH),1.)
      DO 465 I=1,40
      ISET(I)=0
      DO 466 I1=1,10
  466 IDEX(I,I1)=0
      HNAME(I)=BLANK
  465 SCOREH(I)=-1.
      L=0
      LOC=LOCH(HNUM)
C BEGIN BY READING INFO FOR FIRST BOX
  460 READ(3'LOC,9461) ANAME,NUM,R,Q
 9461 FORMAT(1A6,4X,1I2,8X,1A2,8X,1A4)
      IF(ANAME.EQ.NOMO) GOTO 468
      CALL ATGET(ANAME,ID,HNAME)
      IF(ID.GT.0) GOTO 464
      L=L+1
      ID=L
      HNAME(ID)=ANAME
  464 IF(NUM.EQ.0) GOTO 463
      QDLEX(ID)=Q
      RULEH(ID)=R
  461 IDEX(ID,1)=NUM
      IF(NUM.EQ.0) GOTO 463
      IF(NUM.GT.50) GOTO 4601
      DO 462 J=1,NUM
      J1=J+1
      LOC=LOC+1
      READ(3'LOC,9462) ANAME
      CALL ATGET(ANAME,IE,HNAME)
      IF(IE.GT.0) GOTO 462
      L=L+1
      IE=L
      HNAME(L)=ANAME
  462 IDEX(ID,J1)=IE
 9462 FORMAT(1A6)
  463 LOC=LOC+1
      GOTO 460
 4601 NUM=NUM-50
      DO 4602 J=1,NUM
      J1=J+1
      LOC=LOC+1
      READ(3'LOC,9272) ANAM
 4602 IDEX(ID,J1)=NQ(ANAM)
      LOC=LOC+1
      GOTO 460
  468 CONTINUE
      J=LOCHS(HNUM)
```

```
      READ(4*J,9463)((BNAME(I1),SCORE(I1)),I1=1,L)
      J=J+L/5+1
      READ(4*J,9480) QSCORE
 9463 FORMAT(5(1A6,1F6.3))
      DO 469 K=1,L
      CALL ATGET(BNAME(K),ID,HNAME)
      IF (ID.EQ.0) GOTO 469
      SCOREH(ID)=SCORE(K)
  469 CONTINUE
      DO 459 I=1,40
  459 IF(IDEX(I,1).EQ.0) RULEH(I)=BLANK
      GOTO 4000

C -- OPTION 47 TO PRINT CURRENT BOX NAMES --
 4007 CALL PNAME(HNAME)
      GOTO 4000

C -- OPTION 48 TO FILE HIERARCHY DATA --
 4008 LOC=LOCH(HNUM)
      DO 480 I=1,L
      IF(HNAME(I).EQ.BLANK) GOTO 480
      WRITE(3*LOC,9461) HNAME(I),IDEX(I,1),RULEH(I),QDEX(I)
      I4=IDEX(I,1)
      IF(I4.EQ.0) GOTO 480
      LOC=LOC+1
      I1=MOD(IDEX(I,1),50)+1
      DO 481 I2=2,I1
      I3=IDEX(I,I2)
      IF(I4.LE.50) GOTO 483
      WRITE(3*LOC,9272) QNAME(I3)
      GOTO 481
  483 WRITE(3*LOC,9462) HNAME(I3)
  481 LOC=LOC+1
  480 CONTINUE
      WRITE(3*LOC,9462) NOMO
      J=LOCHS(HNUM)
      WRITE(4*J,9463)(HNAME(I3),SCOREH(I3),I3=1,L)
      J=J+L/5+1
      WRITE(4*J,9480) QSCORE
 9480 FORMAT(10F8.5)
      GOTO 4000

C -- OPTION 49 TO CHANGE NAME OF BOX --
 4009 CALL GETHN(ID,HNAME)
      WRITE(6,9271)
      READ(5,9462) HNAME(ID)
      GOTO 4000
      END
```

```
      SUBROUTINE GETHN(ID,HNAME)
C SUBROUTINE GETHN INTERACTIVELY REQUESTS A BOX NAME AND RETURNS ITS
C ID NUMBER.
      DOUBLE PRECISION ALL,HNAME(40),A
      DATA ALL/6HALL   /
      ID=1
   10 WRITE(6,9000)
 9000 FORMAT(20H? ENTER BOX NAME -- )
      READ(5,9001) A
 9001 FORMAT(1A6)
      IF(A.EQ.ALL) RETURN
      CALL ATGET(A,ID,HNAME)
      IF(ID.EQ.0) GOTO 20
      RETURN
   20 WRITE(6,9002)
 9002 FORMAT(11H? BAD NAME )
      CALL PNAME(HNAME)
      GOTO 10
      END

      SUBROUTINE ATGET(ANAME,ID,HNAME)
C SUBROUTINE ATGET CHECKS A BOX NAME AGAINST THOSE CURRENTLY IN
C THE SYSTEM AND RETURNS ITS ID NUMBER (0 IF NOT VALID).
      DOUBLE PRECISION ANAME,HNAME(40)
      DO 10 I=1,40
      IF (ANAME.EQ.HNAME(I)) GOTO 20
   10 CONTINUE
      ID=0
      RETURN
   20 ID=I
      RETURN
      END

      SUBROUTINE SCREH(ID)
C SUBROUTINE SCREH IS THE MASTER SUBROUTINE FOR SCORING BOXES
      COMMON L1(100),QSCORE(100),L2(100),SCOREH(40),RULEH(40)
      COMMON IDEX(40,10)
      CALL MULTEV(ID)
  102 WRITE(6,9000) SCOREH(ID)
 9000 FORMAT(13H THE SCORE IS,1F10.5)
      RETURN
      END

      SUBROUTINE BOX(ID)
C SUBROUTINE BOX SCORES BOXES WHICH HAVE QUESTIONNAIRES AS INPUT.
      COMMON L1(100),QSCORE(100),L2(100),SCOREH(40)
      COMMON RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40),RESP(100)
      NAT=IDEX(ID,1)-49
      DO 101 I=2,NAT
  101 INDEX(I)=IDEX(ID,I)
      INDEX(1)=NAT-1
      DO 102 I=1,100
  102 RESP(I)=QSCORE(I)
```

```
      RULE=RULEH(ID)
      CALL TXTURE(ID,RULE,INDEX,RESP,SCORE)
      SCOREH(ID)=SCORE
      RETURN
      END

      SUBROUTINE MULTEV(ID)
C SUBROUTINE MULTEV IS THE HIGHEST LEVEL OF THE
C NESTED BOX SCORING ROUTINE
      COMMON LL(300),SCOREH(40),RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40)
      NUMAT=IDEX(ID,1)
      IF(NUMAT.EQ.0) RETURN
      IF(NUMAT.GT.50) GOTO 40
      DO 10 I=1,NUMAT
      I1=I+1
      L=IDEX(ID,I1)
      IF(SCOREH(L).GE.0) GOTO 10
      CALL MULTE1(L)
   10 CONTINUE
      J1=NUMAT+1
      DO 30 J=1,J1
   30 INDEX(J)=IDEX(ID,J)
      CALL TXTURE(ID,RULEH(ID),INDEX,SCOREH,SCORE)
      SCOREH(ID)=SCORE
      RETURN
   40 CALL BOX(ID)
      RETURN
      END

      SUBROUTINE GETQN(ID,QNAME,NUMQ)
C SUBROUTINE GETQN INTERACTIVELY ACCEPTS A QUESTIONNAIRE NAME
C AND RETURNS ITS ID NUMBER
      COMMON LOCQ(100)
      DIMENSION QNAME(100)
   40 WRITE(6,9000)
 9000 FORMAT(29H? ENTER QUESTIONAIRE NAME -- )
      READ(5,9001) A
 9001 FORMAT(1A4)
      ID=NQ(A)
      IF(ID.EQ.0) GOTO 10
      IF(ID.LT.0) RETURN
      I=LOCQ(ID)
      READ(1*I,9002) NUMQ
 9002 FORMAT(10X,I12)
      RETURN
   10 CALL PQNAME(QNAME,NUMQ)
      GOTO 40
      RETURN
      END

      FUNCTION YESNO(Z)
C FUNCTION YESNO RETURNS THE ANSWER TO A YES-NO QUESTION
C 0 FOR NO, 1 FOR YES.
      DATA X/1HN/
```

```
      DATA Y/1HY/
      YESNO=0.
   20 READ(5,9000) A
 9000 FORMAT(1A1)
      IF(X.EQ.A) RETURN
      IF (Y.NE.A) GOTO 10
      YESNO=1.
      RETURN
   10 WRITE(6,9001)
 9001 FORMAT(20H? TYPE YES OR NO -- )
      GOTO 20
      END

      FUNCTION GETNUM(ALOW,AHIGH,TYPE)
C FUNCTION GETNUM RETURNS A NUMBER ENTERED INTERACTIVELY
C AFTER CHECKING FOR THE APPROPRIATE RANGE AND TYPE.
      REAL GETNUM
   10 READ (5,*,ERR=20) GETNUM
      IF (TYPE.EQ.0.AND.GETNUM.NE.AINT(GETNUM)) GOTO 50
      IF (GETNUM.GE.ALOW.AND.GETNUM.LE.AHIGH) RETURN
      IF (TYPE.EQ.2) GOTO 40
   30 WRITE(6,100) ALOW,AHIGH
  100 FORMAT(26H? ENTER A NUMBER BETWEEN  ,1G10.5,4HAND ,1G10.5,3H --)
      GOTO 10
   20 IF (TYPE.NE.2) GOTO 30
   40 CONTINUE
      RETURN
   50 WRITE(6,101) ALOW,AHIGH
  101 FORMAT(26H? ENTER AN INTEGER BETWEEN,G10.5,4HAND ,G10.5,3H-- )
      GOTO 10
      END

      SUBROUTINE TXTURE (NUM,RULE,INDEX,RESP,SCORE)
C SUBROUTINE TXTURE COMPUTES A SCORE USING A SPECIFIED
C SCORING RULE.
      COMMON LL(100),QSCORE(100),LL1(580),QDEX(40)
      DIMENSION INDEX(1),RESP(1),TEXTS(6)
      DATA TEXTS/'HA','SA','AV','SC','OR','G'/
      M=INDEX(1)
      N=M+1
      DO 5 I=1,6
      IF(RULE.EQ.TEXTS(I)) GOTO 6
    5 CONTINUE
      WRITE(6,900)
  900 FORMAT(38H  BAD RULE ENCOUNTERED COMPUTING SCORE   )
      RETURN
    6 GOTO (10,20,30,40,50,70) I
   10 SCORE=1.
      DO 11 I=2,N
   11 SCORE=SCORE*RESP(INDEX(I))
      RETURN
   20 SCORE=1.
      DO 21 I=2,N
   21 SCORE=SCORE*(RESP(INDEX(I))+1.)
      C=1./(2.**M-1.)
```

```
      SCORE=C*(SCORE-1.)
      RETURN

 30   SCORE=0.
      DO 31 I=2,N
 31   SCORE=SCORE+RESP(INDEX(I))
      SCORE=SCORE*(1./M)
      RETURN
 40   SCORE=1.
      DO 41 I=2,N
 41   SCORE=SCORE*(1.-.5*RESP(INDEX(I)))
      SCORE=(2.**M/(2.**M-1.))*(1.-SCORE)
 60   CONTINUE
      RETURN
 50   SCORE=1.
      DO 51 I=2,N
 51   SCORE=SCORE*(1.-RESP(INDEX(I)))
      SCORE=1.-SCORE
      RETURN
 70   Q=QDEX(NUM)
      ID=NQ(Q)
      A=GSCORE(ID)
      B=0.2
      DO 65 J=1,5
      IF(A.LT.B) GOTO 66
      B=B+0.2
 65   CONTINUE
 66   RULE=TEXTS(J)
      I=J
      GOTO 6
      END

      SUBROUTINE MULTE1(ID)
C SUBROUTINE MULTE1 IS THE SECOND LEVEL OF THE BOX SCORING
C SYSTEM. IT IS A CLONE OF MULTEV, AS ARE MULTE2, MULTE3, AND MULTE4.
      COMMON LL(300),SCOREH(40)RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40)
      NUMAT=IDEX(ID,1)
      IF(NUMAT.EQ.0) RETURN
      IF(NUMAT.GT.50) GOTO 40
      DO 10 I=1,NUMAT
      I1=I+1
      L=IDEX(ID,I1)
      IF(SCOREH(L).GE.0) GOTO 10
      CALL MULTE2(L)
 10   CONTINUE
      J1=NUMAT+1
      DO 30 J=1,J1
 30   INDEX(J)=IDEX(ID,J)
      CALL TXTURE(ID,RULEH(ID),INDEX,SCOREH,SCORE)
      SCOREH(ID)=SCORE
      RETURN
 40   CALL BOX(ID)
      RETURN
      END
```

```
      SUBROUTINE MULTE2(ID)
C SUBROUTINE MULTE2 IS THE THIRD LEVEL OF THE BOX SCORING SYSTEM
      COMMON LL(300),SCOREH(40)RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40)
      NUMAT=IDEX(ID,1)
      IF(NUMAT.EQ.0) RETURN
      IF(NUMAT.GT.50) GOTO 40
      DO 10 I=1,NUMAT
      I1=I+1
      L=IDEX(ID,I1)
      IF(SCOREH(L).GE.0) GOTO 10
      CALL MULTE3(L)
   10 CONTINUE
      J1=NUMAT+1
      DO 30 J=1,J1
   30 INDEX(J)=IDEX(ID,J)
      CALL TXTURE(ID,RULEH(ID),INDEX,SCOREH,SCORE)
      SCOREH(ID)=SCORE
      RETURN
   40 CALL BOX(ID)
      RETURN
      END

      SUBROUTINE MULTE3(ID)
C SUBROUTINE MULTE3 IS THE FOURTH LEVEL OF THE BOX SCORING SYSTEM.
      COMMON LL(300),SCOREH(40)RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40)
     NUMAT=IDEX(ID,1)
      IF(NUMAT.EQ.0) RETURN
      IF(NUMAT.GT.50) GOTO 40
      DO 10 I=1,NUMAT
      I1=I+1
      L=IDEX(ID,I1)
      IF(SCOREH(L).GE.0) GOTO 10
      CALL MULTE4(L)
   10 CONTINUE
      J1=NUMAT+1
      DO 30 J=1,J1
   30 INDEX(J)=IDEX(ID,J)
      CALL TXTURE(ID,RULEH(ID),INDEX,SCOREH,SCORE)
      SCOREH(ID)=SCORE
      RETURN
   40 CALL BOX(ID)
      RETURN
      END

      SUBROUTINE MULTE4(ID)
C SUBROUTINE MULTE4 IS THE FIFTH LEVEL OF THE BOX SCORING SYSTEM.
      COMMON LL(300),SCOREH(40)RULEH(40),IDEX(40,10)
      DIMENSION INDEX(40)
      NUMAT=IDEX(ID,1)
      IF(NUMAT.EQ.0) RETURN
      IF(NUMAT.GT.50) GOTO 40
      DO 10 I=1,NUMAT
```

```
      I1=I+1
      L=IDEX(ID,I1)
      IF(SCOREH(L).GE.0) GOTO 10
      CALL MULTE5(L)
   10 CONTINUE
      J1=NUMAT+1
      DO 30 J=1,J1
   30 INDEX(J)=IDEX(ID,J)
      CALL TXTURE(ID,RULEH(ID),INDEX,SCOREH,SCORE)
      SCOREH(ID)=SCORE
      RETURN
   40 CALL BOX(ID)
      RETURN
      END


      SUBROUTINE GETR(ILOC,RESP)
C SUBROUTINE GETR RETRIEVES THE RESPONSES FROM A SPECIFIED QUESTIONNAIRE
C LOCATION.
      INTEGER RESP(40)
      J=ILOC+1
      READ(2'J,9000) RESP
 9000 FORMAT(40(1X,1A1))
      RETURN
      END

      SUBROUTINE MULTE5(ID)
C SUBROUTINE MULTE5 SIMPLY PRINTS AN ERROR MESSAGE AND RETURNS.
      WRITE(6,900)
      WRITE(6,901)
  900 FORMAT(54H  YOU HAVE HIT THE LOWEST LEVEL IN THE SCORING ROUTINE)
  901 FORMAT(45H  PLEASE TRY SCORING LOWER LEVEL BOXES FIRST  )
      RETURN
      END
```

```
      SUBROUTINE PRINTH(ID,HNAME)
C SUBROUTINE PRINTH PRINTS A GRAPHICAL DESCRIPTION OF THE HIERARCHY
C BELOW A GIVEN BOX.
      COMMON LXX(100),QSCORE(100),LXXX(100),SCOREH(40),RULEH(40)
      COMMON IDEX(40,10),QDEX(40),QNAME(100)
      DOUBLE PRECISION HNAME(40)
      DATA Q/1HQ/
      WRITE(6,9000) HNAME(ID)
 9000 FORMAT(/,25H  HIERARCHY DATA FOR BOX ,1A6,/)
      I1=IDEX(ID,1)+1
      K1=MOD(I1,50)
      WRITE(6,9001) HNAME(ID),RULEH(ID),SCOREH(ID),QDEX(ID)
 9001 FORMAT(5H BOX:,1A6,7H  RULE:,1A2,8H  SCORE:,1F6.3,
     15H   Q:,1A4)
      IF (I1.EQ.1) RETURN
      DO 10 I2=2,K1
      WRITE(6,9002)
 9002 FORMAT(7H?      )
      I3=IDEX(ID,I2)
      IF(K1.EQ.I1) GOTO 15
      WRITE(6,9003) QNAME(I3),QSCORE(I3)
 9003 FORMAT(17H  QUESTIONNAIRE: ,1A4,8H  SCORE:,1F6.3)
      GOTO 10
   15 WRITE(6,9001) HNAME(I3),RULEH(I3),SCOREH(I3),QDEX(I3)
      I4=IDEX(I3,1)+1
      K2=MOD(I4,50)
      IF(I4.EQ.1) GOTO 10
      DO 40 I5=2,K2
      WRITE(6,9002)
      WRITE(6,9002)
      I8=IDEX(I3,I5)
      IF(K2.EQ.I4) GOTO 25
      WRITE(6,9003) QNAME(I8),QSCORE(I8)
      GOTO 40
   25 WRITE(6,9001) HNAME(I8),RULEH(I8),SCOREH(I8),QDEX(I8)
      I6=IDEX(I8,1)+1
      K3=MOD(I6,50)
      IF(I6.EQ.1) GOTO 45
      DO 30 I7=2,K3
      DO 11 J1=1,3
   11 WRITE(6,9002)
      J9=IDEX(I8,I7)
      IF(K3.EQ.I6) GOTO 35
      WRITE(6,9003) QNAME(J9),QSCORE(J9)
      GOTO 30
   35 WRITE(6,9001) HNAME(J9),RULEH(J9),SCOREH(J9),QDEX(J9)
   30 CONTINUE
   45 CONTINUE
   40 CONTINUE
   10 CONTINUE
      RETURN
      END

      SUBROUTINE SETH(ID,ISET)
C SUBROUTINE SETH IDENTIFIES WHAT BOX SCORES WILL BE CHANGED
```

```
C WHEN A LOW LOVEL BOX'S SCORE IS CHANGED AND REINITIALIZES THEM.
      COMMON LXX(300),SCOREH(40),RULEH(40),IDEX(40,10)
      DIMENSION ISET(40)
      IE=ID
      DO 20 I3=1,10
      ICK=0
      DO 40 I1=1,40
      I2=IDEX(I1,1)+1
      IF (I2.EQ.1.OR.I2.GE.50) GOTO 40
      DO 10 I4=2,I2
      I5=IDEX(I1,I4)
      IF(I5.NE.IE) GOTO 10
      SCOREH(I1)=-1.
      IE=I1
      GOTO 20
   10 CONTINUE
   40 CONTINUE
      IF (ICK.EQ.0) GOTO 50
   20 CONTINUE
   50 RETURN
      END

      FUNCTION NQ(ANAME)
C FUNCTION NQ RETURNS THE NUMBER OF THE PASSED QUESTIONNAIRE NAME.
      COMMON LL(820),QNAME(100)
      DATA ALL/4HALL /
      DO 10 I=1,100
      IF (ANAME.EQ.QNAME(I)) GOTO 20
   10 CONTINUE
      IF(ANAME.NE.ALL) GOTO 30
      NQ=-1
      RETURN
   30 WRITE(6,9003)
 9003 FORMAT(10H  BAD NAME)
      NQ=0
      RETURN
   20 NQ=I
      RETURN
      END
```

```
      SUBROUTINE SCOREQ(ID)
C SUBROUTINE SCOREQ SCORES QUESTIONNAIRES.
      COMMON LOCQ(100),QSCORE(100),LOCR(100)
      DIMENSION IRESP(40),RESP(40),RULE(10),IWRST(40),WEIGHT(40)
      DIMENSION SCORE(40),SCO(40),INDEX(40)
      INTEGER QDEX(10,40)
      DATA IBEST/1HA/
      BEST=FLOAT(IBEST)
      CALL GETQ(LOCQ(ID),RULE,IWRST,WEIGHT,NUMQ,NUMGP,QDEX)
      CALL GETR(LOCR(ID),IRESP)
      DO 10 I=1,NUMQ
      IF (IWRST(I).EQ.IBEST) GOTO 10
      RESP(I)=(BEST-FLOAT(IRESP(I)))/(BEST-FLOAT(IWRST(I)))
      RESP(I)=1.-WEIGHT(I)*RESP(I)
   10 CONTINUE
      DO 150 I=1,10
  150 SCORE(I)=-1.
      DO 140 I1=1,10
      FLAG=0.
      DO 100 I=1,NUMGP
      J1=QDEX(I,1)+1
      DO 110 J2=2,J1
      J3=QDEX(I,J2)
      IF(J3.GE.100) GOTO 115
      IF(SCORE(J3).LT.0) GOTO 120
  115 CONTINUE
  110 CONTINUE
      DO 130 J4=2,J1
      J5=QDEX(I,J4)
      IF(J5.LT.100) GOTO 160
      J5=J5-100
      SCO(J4)=RESP(J5)
      GOTO 170
  160 SCO(J4)=SCORE(J5)
  170 INDEX(J4)=J4
  130 CONTINUE
      FLAG=1.
      INDEX(1)=QDEX(I,1)
      CALL TXTURE(I,RULE(I),INDEX,SCO,SCORE(I))
      IF(I.EQ.1) GOTO 145
  120 CONTINUE
  100 CONTINUE
      IF(FLAG.EQ.0) GOTO 145
      IF(SCORE(1).GE.0) GOTO 145
  140 CONTINUE
  145 QSCORE(ID)=SCORE(1)
      WRITE(6,9000) QSCORE(ID)
 9000 FORMAT(13H  THE SCORE =,1F6.3)
      RETURN
      END

      SUBROUTINE GETQ(LOC,RULE,IWRST,WEIGHT,NUMQU,NUMGP,QDEX)
C SUBROUTINE GETQ READS THE STRUCTURE OF A QUESTIONNAIRE OFF DISC FILE 1
```

```
      INTEGER QDEX(10,40),ISAVE(40),IWRST(40)
      DIMENSION RULE(10),WEIGHT(40)
      J=LOC
      READ(1'J,9000) X,NUMQU,NUMGP
 9000 FORMAT(1A4,6X,1I2,8X,1I2)
      J=J+1
      READ(1'J,9002) IWRST
 9002 FORMAT(40(1X,1A1))
 9001 FORMAT(8F5.3)
      DO 50 I2=1,NUMGP
      J=J+1
      READ(1'J,9003) NAME,NUM,R
 9003 FORMAT(2(1I2,8X),1A2)
      NAME=NAME-49
      QDEX(NAME,1)=NUM
      RULE(NAME)=R
      J=J+1
      READ(1'J,9004) (ISAVE(J2),J2=1,NUM)
      DO 50 I=1,NUM
      I1=I+1
      IF(ISAVE(I).LT.50) QDEX(NAME,I1)=ISAVE(I)+100
      IF(ISAVE(I).GE.50) QDEX(NAME,I1)=ISAVE(I)-49
   50 CONTINUE
      J=J+1
      READ (1'J,9001)(WEIGHT(I2),I2=1,8)
      IF(WEIGHT(1).GT.1) GOTO 70
      IF(NUMQU.LE.8) RETURN
      J1=J+1
      READ(1'J1,9001)(WEIGHT(I2),I2=9,NUMQU)
      RETURN
   70 DO 100 J2=1,NUMQU
  100 WEIGHT(J2)=WEIGHT(2)
 9004 FORMAT(40I2)
      RETURN
      END


      SUBROUTINE PRINTQ(ID,QNAME)
C SUBROUTINE PRINTQ PRINTS THE STRUCTURE FOR A QUESTIONNAIRE.
      COMMON LOCQ(100),QSCORE(100),LOCR(100)
      INTEGER QDEX(10,40)
      DIMENSION RULE(10),RESP(40),QNAME(100),IWRST(40),WEIGHT(40)
      DIMENSION IRESP(40),X(40),Y(40)
      DATA IBEST/1HA/
      CALL GETQ(LOCQ(ID),RULE,IWRST,WEIGHT,NUMQU,NUMGP,QDEX)
      BEST=FLOAT(IBEST)
      CALL GETR(LOCR(ID),IRESP)
      WRITE(6,8999)
      WRITE(6,9000) QNAME(ID)
 8999 FORMAT (//,20X,22H QUESTIONAIRE DATA FOR)
 9000 FORMAT(23X,13HQUESTIONAIRE ,1A4)
      WRITE(6,9002) QSCORE(ID),RULE(1)
 9002 FORMAT(8X,16HOVERALL SCORE = ,1F10.5,5X,7HRULE : ,1A4,//)
      DO 5 I=1,40
      IF (IWRST(I).NE.IBEST) GOTO 4
```

```
      X(I)=0.
      GOTO 6
    4 X(I)=1-(BEST-FLOAT(IRESP(I)))/(BEST-FLOAT(IWRST(I)))
    6 Y(I)=1.-WEIGHT(I)*(1-X(I))
    5 CONTINUE
      I=1
      J1=50
      WRITE(6,9004) J1,RULE(1)
 9004 FORMAT(7H  BOX: ,1I2,8H  RULE: ,1A2)
      I1=QDEX(I,1)+1
      IF(I1.EQ.1) GOTO 10
      DO 20 I2=2,I1
      WRITE(6,9005)
 9005 FORMAT(7H?      )
      I3=QDEX(I,I2)
      IF(I3.GE.100) GOTO 30
      J1=I3+49
      WRITE(6,9004) J1,RULE(I3)
      I4=QDEX(I3,1)+1
      IF(I4.EQ.1) GOTO 20
      DO 40 I5=2,I4
      WRITE(6,9005)
      WRITE(6,9005)
      I8=QDEX(I3,I5)
      IF(I8.GE.100) GOTO 50
      J1=I8+49
      WRITE(6,9004) J1,RULE(I8)
      I6=QDEX(I8,1)+1
      IF(I6.EQ.1) GOTO 45
      DO 60 I7=2,I6
      DO 11 J2=1,3
   11 WRITE(6,9005)
      J9=QDEX(I8,I7)
      IF(J9.GE.100) GOTO 70
      J1=J9+49
      WRITE(6,9004) J1,RULE(J9)
      GOTO 60
   70 J1=J9-100
      WRITE(6,9006) J1,X(J1),WEIGHT(J1),Y(J1)
 9006 FORMAT(4H  Q=,1I2,7H  RESP=,1F6.3,3H W=,1F6.3,3H S=,1F6.3)
   60 CONTINUE
      GOTO 45
   50 J1=I8-100
      WRITE(6,9006) J1,X(J1),WEIGHT(J1),Y(J1)
   45 CONTINUE
   40 CONTINUE
      GOTO 20
   30 J1=I3-100
      WRITE(6,9006) J1,X(J1),WEIGHT(J1),Y(J1)
   20 CONTINUE
   10 RETURN
      END
```

```
      SUBROUTINE HPR(ID,HNAME)
C SUBROUTINE HPR PRINTS A PICTURE OF A PORTION OF THE HIERARCHY.
      COMMON LXX(300),SCOREH(40),RULEH(40),IDEX(40,10)
      DIMENSION DOT(20,5),IPR(20,5)
      DOUBLE PRECISION HNAME(40)
      DATA STAR/4H****/BLANK/4H
      DO 1 I=1,20
      DO 1 J=1,5
      IPR(I,J)=0
    1 DOT(I,J)=BLANK
      LEV=1
      I1=IDEX(ID,1)+1
      IPR(LEV,1)=ID
      IF (I1.EQ.1.OR.I1.GT.50) GOTO 5
    6 DO 10 I2=2,I1
      I3=IDEX(ID,I2)
      IPR(LEV,2)=I3
      I4=IDEX(I3,1)+1
      IF(I4.EQ.1.OR.I4.GT.50) GOTO 15
   16 DO 20 I5=2,I4
      I6=IDEX(I3,I5)
      IPR(LEV,3)=I6
      I7=IDEX(I6,1)+1
      IF(I7.EQ.1.OR.I7.GT.50) GOTO 25
   26 DO 30 I8=2,I7
      I9=IDEX(I6,I8)
      IPR(LEV,4)=I9
      I10=IDEX(I9,1)+1
      IF(I10.EQ.1.OR.I10.GT.50) GOTO 501
      DO 500 I11=2,I10
      IPR(LEV,5)=IDEX(I9,I11)
  500 LEV=LEV+1
      GOTO 30
  501 LEV=LEV+1
   30 CONTINUE
      GOTO 20
   25 LEV=LEV+1
   20 CONTINUE
      GOTO 10
   15 LEV=LEV+1
   10 CONTINUE
    5 CONTINUE
      DO 60 I=1,19
      DO 60 J=1,4
      I1=IPR(I,J)
      IF(I1.EQ.0) GOTO 60
      I2=IDEX(I1,1)+1
      IF (I2.LE.2.OR.I2.GT.50) GOTO 60
      I5=I+1
      DO 61 I3=I5,19
      J1=J+1
      DOT(I3,J)=STAR
      IF(IPR(I3,J1).EQ.IDEX(I1,I2)) GOTO 62
   61 CONTINUE
   62 CONTINUE
```

```
   60 CONTINUE
      WRITE(6,9000) HNAME(ID)
 9000 FORMAT(32H  HIERARCHY INFORMATION FOR BOX ,1A6,//)
 9001 FORMAT(11H?**********)
 9002 FORMAT(3H?* ,1A6,2H *)
 9003 FORMAT(4H?*S=,1F6.3,1H*)
 9004 FORMAT(6H?*RULE: ,1A2,1H*)
 9005 FORMAT(3H?**)
 9006 FORMAT(1H?1A1)
 9007 FORMAT(3H?  )
 9008 FORMAT(2H? )
 9009 FORMAT(11H?          )
 9011 FORMAT(3H?  ,1A1,2H  )
 9012 FORMAT(/,2H?  )
      I=LEV-1
      WRITE(6,9006)
      DO 40 LEV=1,I
      LE=LEV+1
      MAX=1
      DO 101 III=1,5
  101 IF(IPR(LEV,III).NE.0.OR.DOT(LEV,III).EQ.STAR) MAX=III
      DO 41 I1=1,MAX
      IF(IPR(LEV,I1).NE.0) GOTO 39
      WRITE(6,9009)
      GOTO 41
   39 WRITE(6,9001)
   41 WRITE(6,9011) DOT(LEV,I1)
      WRITE(6,9012)
      DO 42 I2=1,MAX
      I3=IPR(LEV,I2)
      IF(I3.EQ.0) GOTO 43
      WRITE(6,9002) HNAME(I3)
      GOTO 38
   43 WRITE(6,9009)
   38 WRITE(6,9011) DOT(LEV,I2)
   44 CONTINUE
   42 CONTINUE
      WRITE(6,9012)
      DO 66 I1=1,4
      IF(DOT(2,I1).EQ.STAR) DOT(1,I1)=STAR
   66 IF(DOT(1,I1).EQ.STAR.AND.MAX.LT.I1) MAX=I1
      DO 45 I2=1,MAX
      I3=IPR(LEV,I2)
      IF(I3.EQ.0) GOTO 47
      IF(I2.GT.1) WRITE(6,9005)
      WRITE(6,9003) SCOREH(I3)
      IF(I2.EQ.4) GOTO 45
      I4=I2+1
      IF(IPR(LEV,I4).GT.0) GOTO 46
      WRITE(6,9007)
      GOTO 65
   46 WRITE(6,9005)
      WRITE(6,9006) STAR
      GOTO 45
   47 WRITE(6,9009)
```

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      WRITE(6,9007)                                                     QUE01110
      IF(I2.GT.1) WRITE(6,9007)                                         QUE01120
   65 WRITE(6,9006) COT(LEV,I2)                                         QUE01130
   45 CONTINUE                                                          QUE01140
      WRITE(6,9012)                                                     QUE01150
      DO 49 I2=1,MAX                                                    QUE01160
      I3=IPR(LEV,I2)                                                    QUE01170
      IF(I3.EQ.0) GOTO 50                                               QUE01180
      WRITE(6,9004) RULEH(I3)                                           QUE01190
      GOTO 51                                                           QUE01200
   50 WRITE(6,9009)                                                     QUE01210
   51 WRITE(6,9011) COT(LE,I2)                                          QUE01220
   49 CONTINUE                                                          QUE01230
      WRITE(6,9012)                                                     QUE01240
      DO 52 I1=1,MAX                                                    QUE01250
      IF(IPR(LEV,I1).NE.0) GOTO 53                                      QUE01260
      WRITE(6,9009)                                                     QUE01270
      GOTO 55                                                           QUE01280
   53 WRITE(6,9001)                                                     QUE01290
   55 WRITE(6,9011) COT(LE,I1)                                          QUE01300
   52 CONTINUE                                                          QUE01310
      WRITE(6,9012)                                                     QUE01320
      DO 54 I1=1,4                                                      QUE01330
      WRITE(6,9009)                                                     QUE01340
   54 WRITE(6,9011) COT(LE,I1)                                          QUE01350
      WRITE(6,9012)                                                     QUE01360
   40 CONTINUE                                                          QUE01370
      RETURN                                                            QUE01380
      END                                                               QUE01390
                                                                        QUE01400
      SUBROUTINE PNAME(HNAME)                                           QUE01410
C SUBROUTINE PNAME PRINTS THE NAME OF THE CURRENT HIERARCHY BOXES.      QUE01420
      DOUBLE PRECISION HNAME(40)                                        QUE01430
       WRITE(6,9470)                                                    QUE01440
 9470 FORMAT(38H  THE CURRENT HIERARCHY INCLUDES BOXES ,/)              QUE01450
      DO 470 I=1,5                                                      QUE01460
      I1=8*(I-1)+1                                                      QUE01470
      I2=I1+7                                                           QUE01480
  470 WRITE(6,9471)(HNAME(I3),I3=I1,I2)                                 QUE01490
 9471 FORMAT(8(1X,1A6,1X))                                              QUE01500
      RETURN                                                            QUE01510
      END                                                               QUE01520
                                                                        QUE01530
      SUBROUTINE PQNAME(QNAME,NUMQ)                                     QUE01540
C SUBROUTINE PQNAME PRINTS THE NAMES OF THE CURRENT QUESTIONNAIRES.     QUE01550
      DIMENSION QNAME(100)                                              QUE01560
      WRITE(6,9000)                                                     QUE01570
 9000 FORMAT(33H  THE CURRENT QUESTIONNAIRES ARE: ,/)                   QUE01580
   10 WRITE(6,9001)(QNAME(I2),I2=1,NUMQ)                                QUE01590
 9001 FORMAT(2X,10(1A4,2X))                                             QUE01600
      RETURN                                                            QUE01610
      END                                                               QUE01620
```

APPENDIX C

AGNS Sample Plan*

18.0 PREVENT UNAUTHORIZED ACCESS OF PERSONS, MATERIALS, AND VEHICLES

This section describes the components, systems, and procedures utilized to ensure attempts by personnel to gain unauthorized access and/or to introduce unauthorized materials are detected, assessed, and communicated. All attempts, either by stealth, force, or deceit, result in a timely response initiated to deter, delay, or deny the unauthorized access or penetration. These entry controls satisfy the performance capability requirements of 10 CFR 73.45(b).

18.1 Portal Entry Control

Figure 18-1 identifies the MAA, the vault, and the associated portals. One entry/exit point, designated MAA-1.1 (Reference 21-1), penetrates the east wall and one emergency exit, designated MEE-1.1 (Reference 28-1), penetrates the north wall of the MAA. One entry/exit point, designated VAU-1.1 (Reference 21-1), penetrates the south wall of the vault (Reference 86-1).

18.1.1 Entry Authorization Procedures

Entry authorization verification procedures (Reference 2-1) limit controlled access area admittance to only those personnel authorized to perform specifically assigned tasks and at only those times when the performance of these activities is authorized. Authorization Schedules (Reference 1-1), derived from Shift and Production Schedules, determine what activities are authorized and when, and by whom, these activities are conducted. Entry authorization verification procedures progressively become more restrictive as the sensitivity of the controlled area increases.

18.1.1.1 Entry Authorization

Entry authorization consists of a computerized criteria screening process. This process compares area access criteria, contained in the Area Authorization File (AAF), against personnel access qualifications, contained in the Personnel Authorization File (PAF). Area access criteria include administrative and security requirements, the category of activities requested (Work Designation Codes, Table 18-1), and the periods these activities are authorized (Production Schedule). Personnel access qualifications include the category of activities an individual is authorized to perform (Work Designation Codes), the periods

*The text for this appendix was supplied by AGNS from the Sandia "Upgrade Rule" Contract report (see Reference 6). For information on the references cited in this appendix, refer to that document.

the individual is authorized to perform these activities (Shift Schedule), and the administrative and security requirements possessed by the individual.

18.1.1.2 Personnel Entry Authorization

Personnel entry authorization is automatically initiated and verified each time an individual requests admittance to a controlled access area.

18.1.1.3 Maintenance and Distribution of Entry Authorization

Personnel e try authorization is maintained current by continuously updating the ersonnel Authorization File (PAF) and the Area Authorization File (AAF). No two individuals are capable of programming the PAF with sufficient data to authorize an individual admittance to a controlled access area. Similarly, personnel authorized to program the AAF with area access criteria do not have access to the PAF.

Personnel entry authorization information is displayed on computer communication terminals located in manned entry control points and at the Central Alarm Station (CAS) and the Secondary Alarm Station (SAS).

The CAS and the SAS have the capability of displaying a list of all personnel currently occupying a controlled access area and a record of all entry and exit events which have occurred within the last 24 hours.

18.1.2 Entry Procedures and Controls

The incorporation of security officers and entry control systems and procedures serves to maximize the capability of detecting unauthorized persons, contraband, and unauthorized vehicles attempting to enter a controlled access area. These measures are applied during both routine (Table 18-2) and nonroutine conditions.

18.1.2.1 Routine Conditions

Table 18-3 identifies generic criteria which govern access functions during routine working and nonworking conditions, excluding nonroutine conditions which are identified in Section 18.1.2.2.

18.1.2.1.1 Procedures and Controls for Personnel Entry

Personnel entry controls and procedures are designed and operated in a manner which verifies admittance authorization and positive personnel identification prior to authorizing admittance into the MAA Secured Access Portal (SAP) (Reference 68-1) and the MAA, respectively. These controls ensure that access to MAAs shall include at least two individuals. All admittance search functions are conducted within the MAA SAP which is isolated from both the MAA and the PA. This admittance concept maximizes the integrity of the MAA until access authorization and personnel identification are verified and provides containment of personnel until all admittance search functions have been satisfactorily completed. It also facilitates containment of personnel by security officers should suspicious activities be observed within the MAA SAP.

Vault entries require additional authorization, but do not require additional search or identification measures.

18.1.2.1.1.a Secured Access Portal Operations

MAA SAP and MAA Entry

The following steps are performed by the individual desiring access unless otherwise specified:

- Step 1 - Note the condition of the red light located next to the MAA SAP proximity reader. If the light is "off," pass the Coded Credential Badge (Reference 14-1) in front of the proximity reader. If the red light is "on," indicating admittance functions are in progress, wait until the light is de-energized.

  Passing the Coded Credential Badge in front of the proximity reader signals the control processor to initiate a search of the PAF and the AAF to determine if MAA SAP access is authorized. Authorization de-energizes an electronic door strike opening one of two MAA SAP door locks and keys the Voice Verification System (VVS) (Reference 65-1). The second door lock is normally open. This door lock, operated by the security officer inside the MAA SAP, prevents MAA SAP entry while admittance operations are in progress.

- Step 2 - Enter the MAA SAP and close the entrance door.

  This action enrolls the individual on the Personnel Inventory System as being within the MAA.

- Step 3 - The security officer, after ensuring the MAA SAP entrance door is closed and that only one person entered the MAA SAP (two, if one requires an escort), actuates the second MAA SAP entrance door lock.

  This action prevents MAA SAP entry while admittance functions are in progress and energizes the red light next to the proximity reader.

- Step 4 - Inside the MAA SAP, establish positive personnel identification by responding to the requests of the VVS minicomputer.

- Step 5 - The security officer, after positive personnel identification has been verified, performs a sequence of contraband search functions on the individual requesting admittance.

- Step 6 - The security officer, having completed the contraband search, inputs the control processor indicating successful completion of the contraband search and requests the CAS or the SAS to actuate the MAA-1.1 door lock.

- Step 7 - The CAS or the SAS, verifying only one person passes through MAA-1.1 by CCTV (Reference 11-1), de-energizes an electronic door strike opening one of two MAA-1.1 door locks.

- Step 8 - While the door strike is de-energized, pass the Coded Credential Badge in front of the MAA proximity reader. The control processor, after verifying positive personnel identification, successful completion of the contraband search, and MAA access authorization, de-energizes the second of two door locks permitting MAA admittance.

- Step 9 - The security officer, after the individual has entered the MAA, closes MAA-1.1.

- Step 10 - The security officer de-engerizes the second MAA SAP door lock allowing MAA SAP admittance and de-energizing the red light.

Vault Entry

The following steps are performed by the individual desiring access unless otherwise specified:

- Step 1 - Pass the Coded Credential Badge (Reference 14-1) in front of the vault proximity reader.

  This action signals the control processor to initiate a search of the PAF and the AAF to determine if vault access is authorized, and alerts the CAS, the SAS, and the security officer at the MAA SAP that a vault entry has been requested. Authorization de-energizes an electronic door strike opening one of two VAU-1.1 door locks.

- Step 2 - The CAS or the SAS, verifying that only one person passes through VAU-1.1 by CCTV (Reference 11-1), de-energizes an electronic door strike opening the second of two door locks permitting vault entry.

- Step 3 - Enter the vault and close VAU-1.1.

  This action enrolls the individual on the Personnel Inventory System as being within the vault and removes the individual from the MAA inventory listing.

- Step 4 - The CAS and the SAS ensure VAU-1.1 is closed.

  This step is accomplished by observing that the alarm, generated by the balanced magnetic switch (Reference 6-1) monitoring VAU-1.1, de-energizes.

18.1.2.1.1.b I.D. Verification and Authorization

Entry authorization utilizes a Coded Credential Badge system (Reference 14-1). When an individual requests access to a controlled access area, the credential system's control processor automatically scans the PAF and the AAF and verifies that the individual to whom the Coded Credential Badge was issued is authorized entry. The employee's name, employee number, and Work Designation Codes (Tables 18-1 and 18-7) are also displayed on the MAA SAP computer communications terminal.

Positive personnel identification utilizes a Voice Verification System (VVS) (Reference 65-1). When an individual enters the MAA SAP, the VVS minicomputer requests the individual to repeat a randomly selected sequence of fo prerecorded words. Positive personnel identification is verified b an acceptable response from the individual requesting admittance.

18.1.2.1.1.c Personnel Escort

Reference 31-1 describes the procedures and policies for escorting visitors within a MAA and a vault.

18.1.2.1.1.d Contraband Detection

The purpose of contraband detection is to identify the introduction of unauthorized materials into a MAA or vault. These detectors possess a moderate to high degree of sensitivity and medium throughput. Because the vault is located within the MAA, a search for contraband is only required for access to the MAA.

Metal Detection (Table 18-4)

Metal detectors are capable of detecting weapons and hand tools and the presence of metal utilized for shielding SNM. Because higher frequency range metal detectors possess the highest sensitivity to small amounts of metal, an active metal detection system was selected. Both walk-through (Reference 72-1 and 95-1) and hand-held (Reference 92-1) metal detectors are used.

Explosive Detection (Table 18-5)

Specificity is a critical factor when selecting an explosives detector. The SAP is manned by security officers trained to differentiate between different types of explosives initiating an alarm. Resultantly, hand-held explosive detectors, with moderate to low specificity and moderate to high sensitivity, are employed (Reference 33-1).

Nulcear Material Detection (Table 18-6)

Because it is possible to defeat a SNM detector by shielding the material, the above referenced metal detectors (Reference 72-1 and 92-1) are utilized in conjunction with the SNM monitor. Hand-held monitors were selected because of their greater sensitivity for detecting nuclear material than doorway type monitors (Reference 74-1).

As an entry control component, the SNM detector functions to prevent the introduction of substitute nuclear materials. As an exit control component, the SNM detector functions to prevent the unauthorized removal of SNM.

18.1.2.1.1.e Response to Suspected Unauthorized Personnel

MAA

Requesting admittance to a MAA's SAP with a Coded Credential Badge which has been issued to an individual not possessing MAA admittance authorization automatically alerts the CAS, the SAS, and the security officer inside the MAA SAP of the attempted entry. The response is in accordance with Chapter 23 of this plan.

During admittance operations, should positive identification of an individual be questioned, contraband detected, or the activities of the individual warrant suspicion, the security officer does not indicate his concern to the individual. Instead, the security officer continues and prolongs the admittance operation until response personnel arrive at the MAA SAP. The security officer reports this situation to the CAS and the SAS in accordance with Chapter 23 of this plan.

Vault

Requesting admittance to the vault with a Coded Credential Badge which has been issued to an individual not possessing vault admittance authorization automatically alerts the CAS, the SAS, and the security officer inside the MAA SAP of the attempted entry. The response is in accordance with Chapter 23 of this plan.

18.1.2.1.2 Procedures and Controls for Introduced Materials

SNM entering or exiting the MAA and the vault is always confined to the various piping systems appropriate to the type of transfer operation. Resultantly, only maintenance- and operations-related materials, subject to periods when such activities are authorized, are authorized admittance to the MAA or the vault. Additionally, a predetermined inventory of frequently required tools, emergency first aid equipment, and materials which are required, but could also be utilized for sabotage, are maintained within the MAA to minimize the introduction of materials through the MAA SAP.

Materials are always searched after the individual requesting admittance has successfully completed all admittance search functions.

18.1.2.1.2.a Verification and Material Identification

Individuals desiring to introduce materia into a MAA or vault are required to submit a Security Work Order (.)) (Reference 98-1) to the Security Supervisor prior to MAA SAP entry. The SWO specifically identifies each component to be introduced. The Security Supervisor authorizes the material by checking the Production Schedule, assigns the SWO an identification number, files the original, and gives the individual a copy. The SWO is then entered into the computer communications central storage file. When the materials are presented for introduction, the security officer retrieves the inventory listing by inputting the computer communications terminal with the SWO identification number. The security officer then checks the inventory listing against the materials being introduced to ensure only authorized materials are admitted.

18.1.2.1.2.b Material Inspection and Monitoring

Materials are searched for contraband utilizing those measures identified in Tables 18-4 through 18-6. All boxes, parcels, and packages are opened and inspected for concealed, unauthorized materials while within the MAA SAP. Instrumentation and other similar components are checked to verify that tamper seals are authentic and that they have not been violated (Reference 83-1).

18.1.2.1.2.c Response to Unauthorized Materials

In the event material is presented for admittance to the MAA, or the vault which is not listed on the SWO's inventory listing, or if contraband is detected, the security officer does not indicate his concern to the individual. Instead, the security officer continues and prolongs the admittance operation until response personnel arrive at the SAP. The security officer reports the situation to the CAS or the SAS in accordance with Chapter 23 of this plan.

18.1.2.1.3 Procedures and Controls for Vehicle Entry

Facility configuration makes vehicle entry to the MAA or the vault impossible under all credible conditions.

18.1.2.2 Nonroutine Conditions

Nonroutine conditions are comprised of one or more categories of postulated incidents or various nonroutine production and/or environmental conditions. Postulated incidents are identified in the Site Emergency Plan. During the initial stages of a nonroutine condition, the exact status within the controlled area may not be known. However, to cope with the nonroutine condition in a manner which satisfies both the physical protection and emergency planning performance objectives, a mutually beneficial blending of both planning concepts is required. Table 18-7 identifies nonroutine conditions and associated Work Designation Codes.

18.1.2.2.1 Verification of Nonroutine Conditions

The authenticity of a nonroutine condition is verified in accordance with the Contingency Plan and Procedures (Reference 16-1). Verification of the condition is communicated to all Security personnel in accordance with Chapter 23 of this plan.

18.1.2.2.2 Nonroutine Entry Authorization

The need for nonroutine admittance to a controlled area cannot be anticipated during the preparation of a Production Schedule. Consequently, the AAF is updated continuously and as necessitated by the occurrence of such activities.

Emergency Conditions

Individuals assigned to the various emergency response teams have Emergency Work Designation Codes (Table 18-7) added to their personal access qualifications. When an emergency occurs and its authenticity verified, the AAF is immediately updated with the Emergency Work Designation Codes of required emergency response teams so as to authorize appropriate response personnel access to the controlled area. Programming the AAF with Emergency Work Designation Codes also cancels all routine work access authorization for the affected area until the emergency condition terminates.

Production and Environmental Conditions

When these nonroutine conditions occur and their authenticity verified, the AAF is updated with Production or Environmental Work Designation Codes to authorize access to those individuals required to mitigate or correct the situation. Normally, access would be authorized to operations personnel for production perturbations and extended to maintenance personnel for environmental problems. Programming the AAF with Production or Environmental Work Designation Codes does not automatically cancel routine work access authorization. However, routine work cancellation may be an appropriate response alternative until the nonroutine condition terminates.

18.1.2.2.3 Procedures and Controls for Personnel Entry

Entry procedures and controls specified in 18.1.2.1.1 are applied to all personnel desiring access to the MAA or the vault, except personnel possessing an A1 (fire) and A2 (personnel injury) Emergency Work Designation Code (Table 18-7).

18.1.2.2.3.a Secured Access Portal Operations

Personnel Injury

A2 designated personnel responding to a personnel injury individually request admittance to the MAA SAP by passing their Coded Credential Badge (Reference 14-1) in front of the proximity reader. The A2 Emergency Work Designation Code permits MAA SAP entry, as specified in 18.1.2.1.1.a. The security officer ensures only one individual enters the MAA SAP at a time, but does not enforce the one-man occupancy rule during admittance functions or conduct the contraband search. Positive personnel identification is established in accordance with 18.1.2.1.1.b. Entry to the vault is as specified in 18.1.2.1.1.a of this plan.

Fire

The nature of a fire, coupled with the potential malfunction of entry control components and the necessity for a personnel evacuation, places an extreme burden on personnel entry controls and MAA SAP operations. Whenever possible, the MAA SAP is utilized to assemble personnel responding to an A1 emergency. Should the fire make MAA SAP occupancy impossible or degrade the performance capabilities of entry control components or procedures, the Vital Area (VA) SAP is utilized as a focal point for consolidating fire response activities.

A1 designated personnel responding to the fire individually request admittance to the MAA SAP by passing their Coded Credential Badge (Reference 14-1) in front of the proximity reader. The A1 Emergency Work Designation Code permits MAA SAP entry, as specified in 18.1.2.1.1.a. The security officer ensures only one individual enters the SAP at a time, but does not enforce the one-man occupancy rule during admittance functions or conduct the contraband search. Positive personnel identification is established in accordance with 18.1.2.1.1.b. Entry controls for MAA-1.1 and VAU-1.1 are designed to accommodate firemen entering the area of a fire. When the Fire Brigade is ready to enter the MAA or the vault, only the first person to enter the controlled area passes his/her Coded Credential Badge (Reference 14-1) in front of the proximity reader as the CAS or the SAS de-energizes the electronic door strike. Access to the MAA, through MAA-1.1, or the vault, through VAU-1.1, is now unencumbered for the remainder of the Fire Brigade entering the controlled area. Each new assault by the Fire Brigade gains access to the controlled area in the same manner. In the event entry controls for MAA-1.1 or VAU-1.1 fail, all door locks fail open providing unencumbered access to the controlled area for personnel inside the MAA SAP (MAA for access to the vault).

18.1.2.2.3.b I.D. Verification and Authorization

Entry authorization is verified as specified in 18.1.2.1.1.b for personnel and 18.1.2.1.2.a for material.

Positive personnel identification is verified as specified in 18.1.2.1.1.b.

18.1.2.2.3.c Personnel Escorts

Reference 31-1 describes the procedures and controls for escorting visitors within the MAA and the vault.

18.1.2.2.3.d Contraband Detection

All personnel and materials, except as specified in 18.1.2.2.3.a, are subject to the contraband detecting measures specified in 18.1.2.1.1.d and 18.1.2.1.2.b of this plan.

18.1.2.2.3.e Response to Suspected Unauthorized Personnel

The response to suspected unauthorized personnel is in accordance with 18.1.2.1.1.e and 18.1.2.1.2.c of this plan.

18.1.3 Bypass of Admittance Procedures and Controls

This subsection describes those measures employed to deter, delay, or deny attempts by an adversary, utilizing stealth or force, to bypass admittance procedures and controls. Routine and nonroutine admittance measures, identified in 18.1.2.1 and 18.1.2.2, respectively, provide a minimal degree of protection and assurance that attempts to violate entry controls are detected, assessed, and communicated. The following additional measures provide entry control points with the performance capability requirements specified in 10 CFR 73.45 (b).

18.1.3.1 Isolation Capabilities

The MAA SAP is confined within the Vital Area (VA) and is isolated from the MAA by the entry/exit point designated MAA-1.1 and from the Protected Area (PA) by the VA physical barrier (Figure 18-1). The structure is totally enclosed, permitting the passage of personnel and materials through only the MAA SAP and MAA entrance doors. Reference 68-1 describes the MAA SAP in detail.

Personnel desiring access to the MAA are individually admitted to the MAA SAP and contained until the entire admittance operation is satisfactorily completed.

18.1.3.2 Surveillance Capability

During open portal conditions, the MAA SAP is continuously monitored from the CAS and the SAS by CCTV (Reference 11-1). A Microwave Detection System (Reference 57-1) provides continuous surveillance during closed portal operations. In the event a microwave detector annunciates, the MAA SAP is automatically monitored by CCTV from the CAS and the SAS for the purpose of verifying and assessing the alarm.

18.1. .3 Doors

All doors providing access to the MAA SAP are interlocked to permit only one entry/exit door to be open at a time. Balanced Magnetic Switches (Reference 6-1) alert the CAS and the SAS of each entry and exit event. The security officer inside the MAA SAP also possesses the capability of locking each entry/exit point door while admittance or exiting functions are conducted. This capability ensures the security officer of a one-on-one confrontation with a potential adversary during routine conditions.

Doors, MAA-1.1, MEE-1.1, and VAU-1.1 are bullet resistant and afford a penetration resistance equivalent, as a minimum, to the weakest component of the physical barrier (References 21-1 and 28-1).

18.1.3.4 Entry Control Personnel

Security officers performing entry control functions do not carry a weapon and are monitored by a duress sensor (Reference 22-1) which annunciates in the CAS and the SAS. Only one security officer is present in the MAA SAP at a time performing entry control functions. The second member of the entry control team monitors the MAA SAP remotely by CCTV (Reference 11-1) and can both detect and respond to a bypass attempt.

18.1.3.5 Penetration Resistance

Because the MAA SAP is totally within the confines of the VA (Figure 18-1), it does not possess the physical attributes of the MAA physical barriers. However, the MAA SAP is constructed of materials presenting sufficient penetration resistance to allow the security officer time to ensure MAA-1.1 is closed, should an individual b passing through MAA-1.1 when the bypass attempt is initiated. Refe ce 68-1 describes the construction of the MAA SAP.

18.1.3.6 Response to a Bypass Attempt

The MAA SAP security officer always attempts to delay and contain the adversary until response personnel arrive at the MAA SAP. The reporting of and the response to an attempt to bypass admittance procedures and controls at an exit/entry control point is in accordance with Chapter 23 of this plan.

18.2 Entry Through Remainder of the MAA/Vault Boundary

This subsection describes those measures employed to deter, delay, or deny attempts by an adversary to penetrate the physical barriers of the MAA or the vault. Physical barriers include walls, floors, ceilings, ventilation ducts (Reference 3-1), and emergency exits (Reference 28-1). Reference 38-1 describes the floor, ceiling, and walls. These protective functions provide assurance that such attempts, utilizing stealth or force, are detected, assessed, and communicated and satisfy the performance capability requirements of 10 CFR 73.45(b).

18.2.1 Detect Boundary Penetration Attempts

The physical barriers of both the MAA and the vault are monitored by components capable of sensing and alerting the CAS and the SAS of an attempted or actual penetration and facilitating assessment of such an occurrence. Table 18-8 identifies each of these components by function and specifies, when appropriate, whether the associated detection capability is primary (P), redundant (R), or diverse (D).

18.2.2 Deter Boundary Penetration Attempts

The physical barriers of the MAA and the vault are fabricated from materials and erected in a manner which provides assurance that penetration attempts by an adversary are deterred. The incorporation of frequent Security Force patrols, warning signs indicating boundary surveillance, adequate lighting, audible alarms, and unobstructed vision provides the perimeter of the physical barriers with an additional deterrence to penetration attempts. Table 18-9 identifies the various measures utilized to provide the MAA and the vault with positive deterrent capabilities.

18.2.3 Response to Penetration Attempts

Security personnel respond to an actual or attempted penetration of a physical barrier in accordance with Chapter 23 of this plan. During the response phase of an actual or suspected penetration attempt, admittance to and all activities within the MAA and the vault are terminated. Normal operations are resumed only after the response force has established control of the penetration attempt or a surveillance component malfunction has been verified.

TABLE 18-1

WORK DESIGNATION CODES IDENTIFYING CATEGORIES OF ACTIVITIES INDIVIDUALS MAY BE AUTHORIZED TO PERFORM WITHIN A MAA OR VAULT

Work Designation Codes	Categories of Work
A. AGNS Employees	
LP	Licensee Personnel
LP-1	Operations
LP-2	Maintenance
LP-3	Security
LP-4	Escort
LP-5	Management
LP-6	Administration
LP-7	Janitorial
LP-8	Health Physics
LP-9	Safety
LP-10	QA/QC
LP-11	Nuclear Technology
B. Visitors	
SLP	State and Local Personnel
SLP-1	LLEA
SLP-2	Fire
SLP-3	Governmental
FO	Federal Officials
FO-1	NRC Inspectors
FO-2	Other NRC Personnel
FO-3	IAEA
FO-4	Other Governmental
V-1	All Others

TABLE 18-2

SCHEDULE FOR IDENTIFYING ROUTINE WORKING AND NONWORKING TIME PERIODS

WORKING PERIODS	SCHEDULE DESIGNATION	
0001 - 0800	Swing Shift	(SS)
0745 - 0815	Shift Change One	(SC-1)
0801 - 1600	Day Shift	(DS)
1545 - 1615	Shift Change Two	(SC-2)
1601 - 2400	Night Shift	(NS)
2345 - 0015	Shift Change Three	(SC-3)

NONWORKING PERIODS	SCHEDULE DESIGNATION	
0001 - 0800	Nonworking Period 1	(NWP-1)
0801 - 1600	Nonworking Period 2	(NWP-2)
1601 - 2400	Nonworking Period 3	(NWP-3)

TABLE 18-3

GENERIC CRITERIA GOVERNING ACCESS AUTHORIZATION DURING ROUTINE WORKING AND NONWORKING PERIODS

	Working Periods	Working Periods Shift Changes	Nonworking Periods
1. Vaults will be locked.		+	+
2. General maintenance may be performed (excluding access authorization components).	+		
3. Access authorization components may be repaired, adjusted, calibrated or replaced.			+
4. Entry/exit portals will be locked.		+	+
5. Materials may be allowed entry.	+		+*
6. SNM receipt and transfer operations may be performed.	+		
7. Maintenance may not be performed.		+	
8. Access control personnel may not be changed.		+	
9. Emergency exits will be locked to prevent external entrance.	+	+	+
10. No individual may be authorized entry unless escorted by Security Personnel.			+

*Only for access authorization components

TABLE 18-4

METAL DETECTION

OBJECT TO BE SEARCHED	LOCATION			
	Material Access Area Portal Designation MAA-1.1		Vault Portal Designation VAU-1.1	
	Method	Ref	Method	Ref
1. Personnel	Walk Thru	95-1 72-1	N/A	
2. Unsealed Materials				
Clothing	Hand Held	92-1	N/A	
Tools/Metallic Parts	Visual		N/A	
Instrumentation	Sealed*	83-1	N/A	
Cleaning Materials	Hand Held	92-1	N/A	
Boxes/Parcels/Packages	Hand Held	92-1	N/A	
3. Sealed Packages**				

*Tamper indicating seals.

**All sealed packages, except packages sealed with authorized tamper indication seals, are opened prior to entry into the MAA.

TABLE 18-5

EXPLOSIVE DETECTION

OBJECT TO BE SEARCHED	LOCATION: Material Access Area Portal Designation MAA-1.1		Vault Portal Designation VAU-1.1	
	Method	Ref	Method	Ref
1. Personnel	Hand Held	33-1	N/A	
2. Unsealed Materials				
Clothing	Hand Held	32-1	N/A	
Tools/Metallic Parts	Hand Held	32-1	N/A	
Instrumentation	Hand Held	32-1	N/A	
Cleaning Materials	Hand Held	32-1	N/A	
Boxes/Parcels/Packages	Hand Held	32-1	N/A	
3. Sealed Packages*	N/A			

*All sealed packages are opened prior to entry into the MAA.

TABLE 18-6

NUCLEAR MATERIAL DETECTION

OBJECT TO BE SEARCHED	LOCATION: Material Access Area Portal Designation MAA-1.1		Vault Portal Designation VAU-1.1	
	Method	Ref	Method	Ref
1. Personnel	Hand Held	74-1	N/A	
2. Unsealed Materials				
Clothing	Hand Held	74-1	N/A	
Tools/Metallic Parts	Hand Held	74-1	N/A	
Instrumentation	Hand Held	74-1	N/A	
Cleaning Materials	Hand Held	74-1	N/A	
Boxes/Parcels/Packages	Hand Held	74-1	N/A	
3. Sealed Packages*				

*All sealed packages are opened prior to entry into the MAA.

TABLE 18-7

WORK DESIGNATION CODES IDENTIFYING NONROUTINE RESPONSE ACTIVITIES INDIVIDUALS MAY BE AUTHORIZED TO PERFORM WITHIN A MAA OR VAULT

Work Designation Codes	Response Activities
	A. Emergencies
A1	Fire
A2	Personnel Injury
A3	Explosion
A4	Radiological
A5	Chemical
A6	Bomb Threat
A7	Material Loss
	etc.
	B. Production
B1	Equipment Failure
B2	Equipment Malfunction
B3	Leaks
B4	Stoppages and Blocking
	etc.
	C. Environmental
C1	Lighting
C2	Heating
C3	Air Conditioning
C4	Plumbing
	etc.

TABLE 18-8

COMPONENTS UTILIZED FOR SENSING, TRANSMITTING, AND ASSESSING PHYSICAL BARRIER PENETRATION ATTEMPTS

SENSING

Area	Type	Reference
MAA	(P) Microwave Systems	57-1
	(D) Video Motion Systems	11-1
Vault	(P) Microwave Systems	57-1
	(D) Video Motion Systems	11-1

TRANSMITTING

Systems	Type	Reference
Microwave	(P) Individual Hardwire	47-1
	(D) Multiplex Hardwire	47-2
Video Motion	(P) Individual Hardwire Video	47-3

ASSESSING

Area	Type	Reference
MAA	(P) CCTV Surveillance	10-1
	(D) Patrols	43-1
Vault	(P) CCTV Surveillance	10-1
	(D) Patrols	43-1

TABLE 18-9

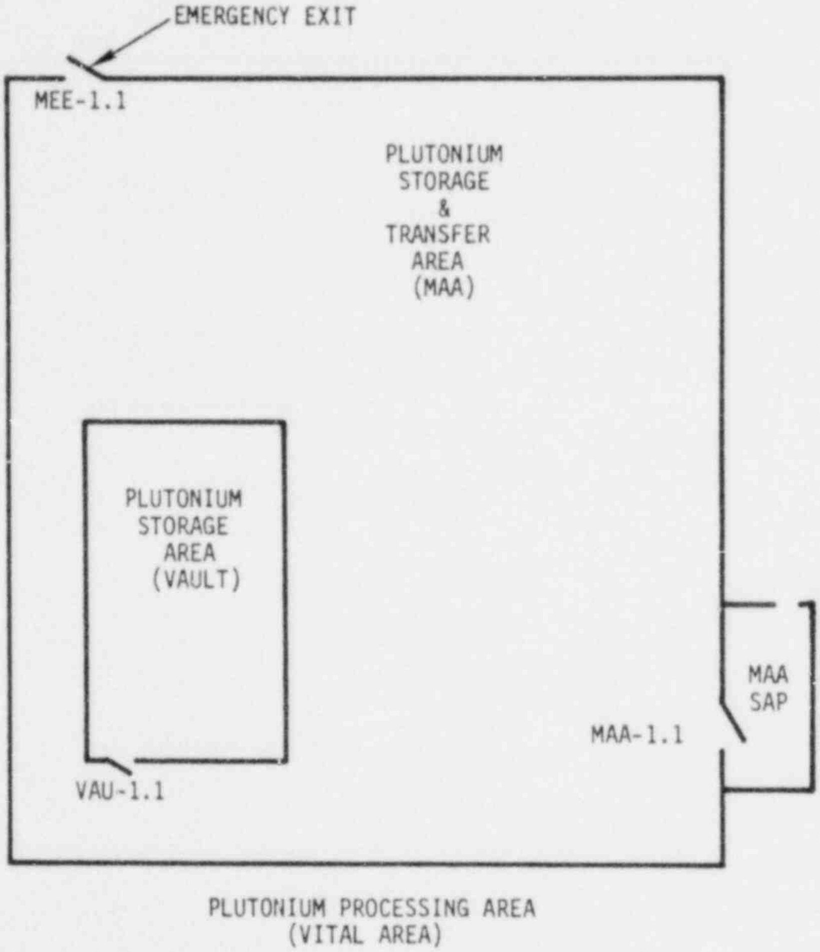
MEASURES UTILIZED TO DETER ADVERSARY PENETRATION ATTEMPTS

Area	Type of Measure	Reference
MAA	Barriers (Walls)	38-1
	Patrols	43-1
	Signs	*
	Lighting	17-1
	Alarms (Microwave)	51-1
	(Video Motion)	11-1
Vault	Barriers (Walls)	38-1
	Signs	*
	Lighting	17-1
	Alarms (Microwave)	51-1
	(Video Motion)	11-1

*No Information Request Sheet identified

FIGURE 18-1

MAA AND VAULT BLOCK DIAGRAM



APPENDIX D

Sample Information Request Sheets*

ADMITTANCE AUTHORIZATION CRITERIA AND SCHEDULES

I. FUNCTION

Admittance authorization criteria and schedules are developed for the purpose of determining WHAT activities are authorized, WHO is authorized to perform these activities, and WHEN these activities are authorized to be performed.

II. SYSTEM DESCRIPTION

Admittance authorization criteria and schedules are incorporated into a computerized admittance criteria screening process. This screening process, initiated by the Access Control System (Reference 14-1), integrates data stored in two authorization files: the Personnel Authorization File (PAF) and the Area Authorization File (AAF). The PAF contains the admittance authorization criteria possessed by each employee and preprocessed visitor. The AAF contains the admittance authorization criteria requirements for admittance into each controlled access area within the Industrial Security Area (ISA).

The integration of data contained in the PAF and the AAF results in admittance authorization verification (Reference 2-1).

III. PERFORMANCE CRITERIA

A. Performance Conditions for Personnel

1. Personnel Authorization File (PAF)

a. Personal Authorization Criteria

The following record of admittance authorization criteria is maintained in the PAF for all employees and preprocessed visitors:

(1) Qualification Criteria

(a) Employee or visitor

(b) Basic radiation safety training (YES or NO)

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*These sample information sheets were provided by AGNS from the Sandia "Upgrade Rule" Contract report (see Reference 6). For information on references cited in this appendix, refer to that document.

(c) Advanced radiation safety training (YES or NO)

(d) Security clearance (AGNS, DOE Q or L, NRC Q or L)

(e) Work Designation Codes (Table 18-1)

(f) Emergency Work Designation Codes (Table 18-7).

(2) Work Period Criteria

Work period criteria identifies those shifts for which the individual is authorized to be on-site (Table 18-2). Work period criteria is determined by the Shift Schedule which is derived from a detailed analysis of the facility's operational and support requirements.

b. Entering Personal Authorization Criteria

To prevent collusion by individuals authorized to enter personal admittance authorization criteria into the PAF, no two individuals are capable of programming the PAF with sufficient information to authorize an individual admittance into a controlled access area. The following indicates responsibilities for entering personal authorization criteria into the PAF:

(1) Employee/Visitor - Personnel Manager

(2) Basic Radiation Safety Training - Training Manager

(3) Advanced Radiation Safety Training - Health Physics Supervisor

(4) Security Clearance - Security Manager

(5) Work Designation Codes - Personnel Manager

(6) Emergency Work Designation Codes - Site Emergency Director

(7) Work Period Criteria - Physical Security Supervisor.

2. Area Authorization File (AAF)

a. Area Authorization Criteria

The following record of admittance authorization criteria requirements is maintained for all controlled access areas within the ISA:

(1) Baseline Criteria

(a) Employee or Visitor

(b) Completed Basic Radiation Safety Training

(c) Completed Advanced Radiation Safety Training

(d) Security Clearance.

(2) Variable Authorization Criteria

Variable authorization criteria determines what activities are authorized and on which shifts these activities are authorized to be performed. Variable authorization criteria is determined by the Production Schedule which is derived from a detailed analysis of the controlled access area's operational and support requirements.

(a) Work Designation Codes (Table 18-1) - Identifies those activities which are authorized.

(b) Work Period Criteria (Table 18-2) - Identifies those periods when the activities are authorized to be performed.

b. Entering Area Authorization Criteria

To prevent collusion by individuals authorized to enter area authorization criteria requirements into the AAF, no two individuals are capable of programming the AAF with sufficient information to allow an individual access to a controlled access area. The following indicates responsibilities for ente area authorization criteria requirements into AAF:

(1) Employee/Visitor - Physical Security Supervisor

(2) Completed Basic and/or Advanced Radiation Safety Training - Safety and Environmental Control Department Manager

(3) Security Clearance - Security Manager

(4) Work Designation Codes - Plant Manager

(5) Work Period Criteria - Production Superintendent

(6) Emergency Work Designation Codes - Security Shift Supervisor.

NOTE: Emergency Work Designation Codes are only entered into the AAF upon verification of the authenticity of the emergency in accordance with the Contingency Plan and Procedures (Reference 16-1).

B. Performance Conditions for Vehicles

Vehicles are not authorized inside the MAA.

C. Performance Conditions for Materials

Authorization criteria for materials is based upon detailed analysis of the controlled access area's operational and support requirements. A predetermined inventory of frequently required tools, emergency first aid equipment, and materials which are required, but could also be utilized for sabotage, are maintained within the MAA to minimize the introduction of materials through an MAA SAP.

Admittance authorization criteria for materials is in accordance with the Security Work Order (Reference 98-1).

IV. PREPARATION OF SCHEDULES

A. Shift Schedule

The Shift Schedule, prepared on a monthly basis, is a composite of all departmental shift schedules; e.g., operations, security, maintenance, etc. The Physical Security Supervisor is responsible for the preparation of the Shift Schedule. The Security Manager approves the Shift Schedule.

Shift Schedules may be updated by each Security Shift Supervisor, on a daily basis, depending upon operational and support requirements. Any changes to the Shift Schedule are automatically recorded by the control processor. This record, maintained for three years, identifies who made the change and who was affected by the change. Changes to the Shift Schedule are brought to the attention of the Security Manager on the next regularly scheduled working day.

B. Production Schedule

The Production Schedule, prepared on a weekly basis, is a composite of all departmental production schedules. The Production Superintendent is responsible for the preparation of the Production Schedule. The Plant Manager approves the production Schedule.

The Production Schedule, for routine conditions, may be updated by the Facility Shift Supervisor. During nonroutine conditions (Table 18-7), the Production Schedule may only be updated by the Security Shift Supervisor after verification of the condition in accordance with the Contingency Plan and Procedures (Reference 16-1). Any changes to the Production Schedule are automatically recorded by the control processor. This record, maintained for three years, identifies who made the change. Routine and nonroutine production or environmental changes to the Production Schedule are brought to the attention of the Plant Manager on the next regularly scheduled working day. Emergency (Table 18-7) changes to the Production Schedule are brought to the attention of the Plant Manager in accordance with the Facility Site Emergency Plan.

V. MAINTENANCE OF THE PAF AND THE AAF

The baseline criteria of the AAF and the qualification criteria of the PAF are maintained current by continuous updating by those personnel responsible for entering the data. The variable authorization criteria of the AAF and the work period criteria of the PAF are updated in accordance with IV.A and IV.B, above.

VI. AUDITING

The control processor automatically records any changes to the PAF and the AAF. At least once each month, the QA/QC Department reviews the record of changes to ensure these changes were valid and properly supported by authentic documentation. Documentation includes training records, health physics records, personnel records, and approved shift and production schedules.

VII. VULNERABILITY

Defeating the admittance authorization criteria and schedules requires collusion by at least three individuals. Additionally, these individuals must be extremely knowledgeable about the computer screening process and the data stored in both the PAF and the AAF.

CODED CREDENTIAL SYSTEMS

I. FUNCTION

The coded credential system is utilized to verify admittance authorization to controlled access areas.

II. SYSTEM DESCRIPTION

The Schlage, Model 414, Access Control System employs a standard credit card size passive-electronic-coded credential badge and a proximity reader. The credential badge contains a laminated, electronically tuned circuit which responds to three specific RF frequencies in the range of 4 to 30 MHz. The Schlage Access Control System has a maximum capacity of 1,500 credential badges and can control up to eight (custom systems can accommodate more) proximity readers located a maximum distance of 305 meters from the system's control processor.

III. PERFORMANCE CRITERIA

A. Performance Conditions

1. Operation

a. Issuing

An individual desiring access to the Industrial Security Area enters a personnel portal located at the Main Gate and is issued a coded credential badge. Within the personnel portal, the individual positions the coded credential badge on the Schlage proximity reader and enters his employee number on the control processor's communications terminal. This action inputs the Voice Verification System (VVS) (Reference 65-1) which requests the individual to repeat a randomly selected sequence of four prerecorded words. A satisfactory response inputs the VVS to signal the control processor to identify the coded credential badge identification number with the employee identification number for all subsequent admittance requests.

b. Obtaining Access to Controlled Areas

To obtain access to a controlled access area, the person positions the coded credential badge within 10 centimeters of the proximity reader located next to the entrance door. The credential's identification number is read and transferred to the control processor which, after associating the credential's identification number with the individual's employee number, scans the PAF and the AAF to determine if access is authorized. Access authorization inputs the control processor to initiate admittance operations to the area for which admittance has been requested.

c. Badge Retention

All personnel exiting the Industrial Security Area return their coded credential badges to the Main Gate security officer. Credential badge identification numbers are removed from the control processor's memory a the end of each shift.

2. Protective Features

a. Anti-Pass-Back

Once a coded credential badge is utilized to gain access to an area, the control processor only allows the coded credential badge to be used to exit the area or to enter the next elevated security area within the controlled access area. Any attempt to use the coded credential badge in another manner, such as to request admittance to the same controlled access area, is rejected by the control processor.

b. Lost or Stolen Badges

Each coded credential badge contains a unique identification number. In the event a credential badge is lost or stolen, the control processor is programmed to reject any future use of the badge for controlled area admittance.

3. System Interfaces

a. Positive Personnel Identification

Admittance to a MAA requires positive personnel identification. When a coded credential badge is utilized to gain admittance to a MAA's SAP, the control processor automatically inputs the VVS with the employee number of the individual. Once inside the MAA SAP, the VVS requests the individual to repeat a randomly selected sequence of four prerecorded words. A satisfactory response inputs the VVS to signal the control processor that positive personnel identification has been established.

b. Personnel Inventory System

Each entry and exit operation using a coded credential badge inputs the control processor to upgrade the occupancy listing for each controlled access area within the Industrial Security Area. Security officers have the capability of displaying a listing of all personnel occupying a specific controlled access area and to track personnel throughout the facility and determine their present location.

4. Accountability

The Security Department is responsible for ordering, receiving, auditing, conducting inventories, issuing, decoding, and destroying all credential badges.

IV. SYSTEM VULNERABILITY

a. The passive-electronic-coded credential badge system ranks as one of the two most difficult of all coded credential systems to duplicate or decode. Additionally, badges are randomly issued each time an individual enters the industrial Security Area. This procedure eliminates the threat of duplication because one never knows which coded credential badge he will be issued.

b. The Schlage Access Control System does not possess the capability to detect equipment tampering. However, the proximity readers may be installed inside a wall, thus eliminating exposed parts. Additionally, the coded credential badge does not contain access authorization information, it is only the instrument by which the control processor identifies the individual requesting admittance. All access information is contained in the PAF and the AAF.

EXPLOSIVE DETECTOR HAND-HELD, PACKAGE SEARCH

I. FUNCTION

Packages are searched for the purpose of detecting incendiary and explosive devices being introduced into the MAA.

II. SYSTEM DESCRIPTION

The Ion Track Instruments, Model 70, explosives detector is employed. This unit continuously draws an air sample onto an elastomeric membrane. An argon, carrier gas flows behind the membrane and mixes with the vapors which selectively permeate the membrane. The vapor-argon mixture is then split into two parallel streams. One stream passes through an unobstructed column to an electron capture detector. The other stream passes through a parallel column packed with a substance which selectively retards the flow of the vapor. The amount of retardation depends on the constituents of the vapor. This second column also terminates with an electron capture detector. When the unobstructed column detects the presence of a vapor mixture, the system is programmed to examine the response of the explosive detector's packed column for a fixed period of time. If a detector response from the packed column occurs within this time period, an alarm is sounded. The unit possesses moderate to low specificity and moderate to high sensitivity.

III. PERFORMANCE CRITERIA

A. Site Conditions

All packages are searched inside the MAA SAP (Reference 88-1).

B. Environmental Conditions

1. NO smoking is permitted inside the MAA SAP.

2. Prior to placing the MAA SAP in "open portal" conditions, the MAA SAP is searched for sources of contaminating air or objects which may generate false explosives detector alarms. When possible, such sources are minimized or removed from the area.

C. Performance Conditions

1. Search Procedure

All packages, except those sealed with approved tamper seals (Reference 83-1), are opened and thoroughly inspected using the explosives detector to aid the visual inspection (Reference 88-1). Packages are searched for explosive vapors at each seam and opening. Additionally, the package is compressed slightly with the detector positioned at the most prominent opening to assure sampling of internal vapors. The search procedure requires one to two minutes to complete. Security officers, based on the expected throughput of packages, are not rushed to complete their inspection of packages entering the MAA SAP.

2. Calibration

Explosives detectors are calibrated to detect 200 grams or less of dynamite, TNT, or similar nitrogen compounds with a 90% confidence rate and a false alarm rate not exceeding 1%. Calibration is performed by Technical Security Officers 30 minutes prior to the day shift (DS) (See Table 18-2).

3. Operational Checks

The explosives detector is operationally checked once per hour, utilizing the manufacturer's Nitrogen Test Sample, to ensure proper operation. Security officers performing the operational test exercise care to prevent self-contamination or contamination of the area.

4. Training

Security Officers receive classroom and on-the-job training prior to being authorized to conduct package searches for explosive materials. This training, utilizing written procedures when applicable, includes instructions for properly operating the equipment, proper search techniques, and proper response procedures.

IV. MAINTENANCE AND TESTING

A. Maintenance

All maintenance is performed by Technical Security Officers.

1. Corrective Maintenance

Corrective maintenance is performed on an as-needed basis. Normally, spare explosives detectors are maintained so as to not impede admittance operations while maintenance is being performed.

2. Preventative Maintenance

Preventative maintenance is performed in accordance with the manufacturer's instruction manual.

a. Batteries

The ITI, Model 70, explosives detector utilizes two 13-volt, sealed nickel cadmium batteries and two 6-volt, lead acid batteries. Batteries are inspected on a monthly basis.

b. Membrane

Explosives detector membranes require replacement every two to four weeks.

B. Testing

All tests are performed by Physical Security Officers.

1. Operational tests are conducted hourly (See III.C.3).

2. Weekly tests, utilizing explosive test samples, are conducted to motivate security officers to perform thorough package searches.

V. DETECTION AND ASSESSMENT

A. Detection

The ITI, Model 70, explosives detector alarms within three to five seconds of the admission of a detectable concentration of nitrogen vapor. The time to clear the detector, after saturation, varies from five seconds to one-and-a-half minutes, depending upon the type of vapors detected.

B. Assessment

When an alarm occurs, the security officer reports the alarm to the CAS and the SAS. The security officer then attempts to locate the object causing the alarm.

If an explosive device, or potential device, is located, the security officer notifies the CAS and the SAS in accordance with Chapter 23 of this plan. If the object causing the alarm cannot be located, the package is removed from the MAA SAP and inspected independently by another security officer and explosives detector. If the alarm is determined to be false, the package is readmitted to the MAA SAP.

The individual desiring access to the MAA is not admitted until the package has been cleared.

VI. VULNERABILITY

The level of detection varies with the type of explosive. In general, electron capture detectors function very well for detecting dynamite, but do not perform well when used to detect other types of explosives. Additionally, countermeasures are available to reduce the amount of vapor available for detection.

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Design guidance products and a system performance evaluation methodology have been developed to aid the Nuclear Regulatory Commission in the implementation of new regulations designed to upgrade the physical protection of nuclear fuel cycle facilities. The evaluation methodology which incorporates the design guidance products, provides a means of arriving at an overall measure of performance for each capability required in the regulations. To arrive at this measure of performance, first the scores associated with responses to a series of equipment and procedure questionnaires are aggregated. The aggregation of scores then proceeds through successive levels of a hierarchical structure developed for each capability.

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