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VOLUME I

ESSEX CORPORATION

PREPARED FOR

NAVAL TRAINING EQUIPMENT CENTER

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ADVANCED CONCEPTS OF NAVAL ENGINEERING MAINTENANCE TRAINING

VOLUME I of II

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was concerned with the feasibility of applying various recent advances in instructional technology to maintenance training in the area of marine engineering. The study is divided into four principal sections: requirements analysis, media selection, training system description, and system development planning.

The requirements analysis identified all requirements which affect decisions concerning the use of instructional technology. Baseline job

Block 20. (Cont)

requirements were established for a representative course of maintenance instruction, the Hagan Automatic Boiler Control (ABC) course. These job requirements also included the tasks, skills, and knowledges for all relevant HAGAN ABC maintenance functions.

This analysis was also utilized in the establishment of course requirements including course phasing requirements and course content segmentation. Finally, training system requirements were developed which identified system capabilities required to meet course requirements.

The media selection technique which was developed for this study is a procedure for evaluating candidate media/method approaches in terms of relative effectiveness, usability, and dollar cost. The delphi method was used to rate alternate media on specific criteria, to establish the relative importance (weighting) of criteria for each training objective, and to integrate the ratings and importance weights.

The proposed engineering maintenance training system incorporates an audiovisual element and a programmable, modular simulator. A set of functional specifications and software requirements for the proposed system were developed.

SUMMARY

This study evaluated the feasibility of integrating recent advances in instructional technology to form an improved training system in the marine engineering maintenance training area. Results of the study included:

- A description of training objectives based on a selected segment of instruction and the training technologies necessary to achieve each objective
- A description of existing training equipment which could meet, or could be modified to meet, the training objectives
- Functional specifications of new training equipment, or modifications to existing equipment, which are necessary to provide the needed training
- Description of software and software modifications required to integrate the various hardware subsystems into an overall training system
- Assessment of the adequacy of existing training technology in accomplishing the training program
- Initial and lifetime cost, and training efficiency tradeoff projections, for all recommended solutions
- A preliminary plan for development and evaluation of the experimental training system

The study was divided into four major areas:

(1) <u>Requirements analysis (job, course, and system requirements)</u>.

The analysis of job requirements included the selection of an appropriate segment of instruction, description of its tasks, task sequences, and the skills and knowledges required to perform the tasks. The segment of instruction selected for study was the Automatic Boiler Control-Hagan course currently administered at the Development and Training Center (DATC), San Diego. Analysis of course requirements included the derivation of training objectives, course phases, training modules, and a preliminary course

outline which shows the sequence of presentation of course contents. System requirements were identified on the basis of the requirements and constraints imposed on the experimental maintenance training system by course requirements.

(2) Media selection. This effort entailed a survey of existing instructional technology and the selection of a cost-effective mix of training media. This was accomplished by application of a media selection method developed specifically for this purpose. The results of the trade-off analysis showed that, under the assumption that effectiveness and cost factors are of equal importance, the preferred system configuration is one which includes an audio visual device with intrinsic branching, and a programmable simulator based on interchangeable modular components. If media selection is not constrained by cost considerations, the most effective mix is a programmable video tape type of audio visual presentation with a closed-loop computer based simulator device.

(3) Training system description. This required identification of training modules for each phase of the training program, and the designation of training media appropriate to each module. The required characteristics of the selected mix of devices were then identified.

(4) System development plan. Specific requirements were identified for the development of an experimental program to support the advanced engineering maintenance training course selected for study. These are briefly outlined in terms of broad categories such as Preparation, Hardware Procurement, Syllabus Development, Course Software Development, Instructor Selection and Training, and Pilot Course Implementation.

PREFACE

This report describes the results of a study performed for the Naval Training Equipment Center by the Essex Corporation under Contract N61339-74-C-0151.

The objective of this effort was to assess the feasibility of integrating various recent advances in instructional technology into a new training system configuration designed to significantly expand maintenance training capability in the marine engineering area. This study addresses the optimal application of several pre-designated tools and techniques of instruction to a defined segment of instruction within the general area of marine engineering maintenance training. The instructional techniques which were considered were pre-designated in such a way as to insure that all major trends and recent advances in training technology were addressed.

The approach and specific analytic procedures used to achieve this objective are described and a new training system especially configured for test and evaluation of these concepts is proposed.

The effort described in this report constitutes the first phase of an on-going program of research whose objectives include: (a) feasibility analysis; (b) fabrication and test of a prototype training system; (c) cost and training effectiveness evaluation studies within the context of the Navy technical training community, and (d) follow-up fleet performance evaluations.

KNOX E. MILLER
Acquisition Director

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

The purpose of this study was to investigate the feasibility of integrating existing instructional technology into a new configuration designed to support the unique requirements of a selected marine engineering maintenance training program.

Any maintenance job requires the performance of many diverse maintenance tasks. The variety and complexity of such tasks presents a special problem in marine engineering maintenance, since the job incumbent must work effectively with many different types of equipments, including electrical, electronic, electro-mechanical, hydraulic, and pneumatic systems. An unusually broad range of maintenance skills is therefore required. This in turn means that training programs to support marine engineering maintenance must be similarly broad in scope.

The past two decades represent a period of rapid growth in instructional technology. Miniaturization and cost reduction of computers, coupled with fresh insights into the learning process, has stimulated the development of a wide variety of instructional techniques and applications. These include:

- Individualized instruction
- Audio-visual aids
- Computer assisted instruction
- Computer managed instruction
- Augmented feedback
- Programmed instruction

- Simulation
- Proceduralized job performance aids

Not all such techniques are equally appropriate for all training purposes. Some methods have particular value in imparting job-relevant knowledge and some methods are singularly appropriate for developing perceptual-motor skills. Some training devices attempt to deal with both of these areas with, perhaps, a reduced efficiency. It is questionable whether any single technique or training method is uniformly appropriate for all aspects of maintenance training, particularly when such training involves the scope of knowledge and skills represented by marine engineering maintenance.

The present study addressed the problem of how the diversity of available instructional technologies could be systematically examined in order to evaluate their cost-effectiveness in satisfying specific training requirements. This evaluation formed the basis for subsequent efforts in which selected training techniques were integrated into a recommended marine engineering maintenance training system.

2.0 STUDY METHOD

2.1 Study Objectives

The principal objective of this investigation was to assess the feasibility of developing an improved marine engineering maintenance training system based on the selective integration of advanced instructional technologies. A secondary objective was to select appropriate media components and to describe their necessary interfaces in a training system. Although the study was limited to a selected segment of instruction, the approach is applicable to a wide range of maintenance training programs.

2.2 Study Scope

Four major products were to be derived from the study:

(1) A description of training objectives based on a selected segment of instruction and the training technologies necessary to achieve each objective

(2) A description of existing training equipment which could meet, or be modified to meet, the training objectives

(3) Functional specifications of new training equipment, or modifications to existing equipment, which are necessary to provide the needed training

(4) Description of software and software modifications required to integrate the various hardware subsystems into an overall training system

In addition, a preliminary plan for the development and evaluation of the experimental training system was to be presented in outline form.

2.3 Study Approach

Four roughly sequential phases were involved in the study. These are depicted in the flow chart in Figure 1. A detailed description of

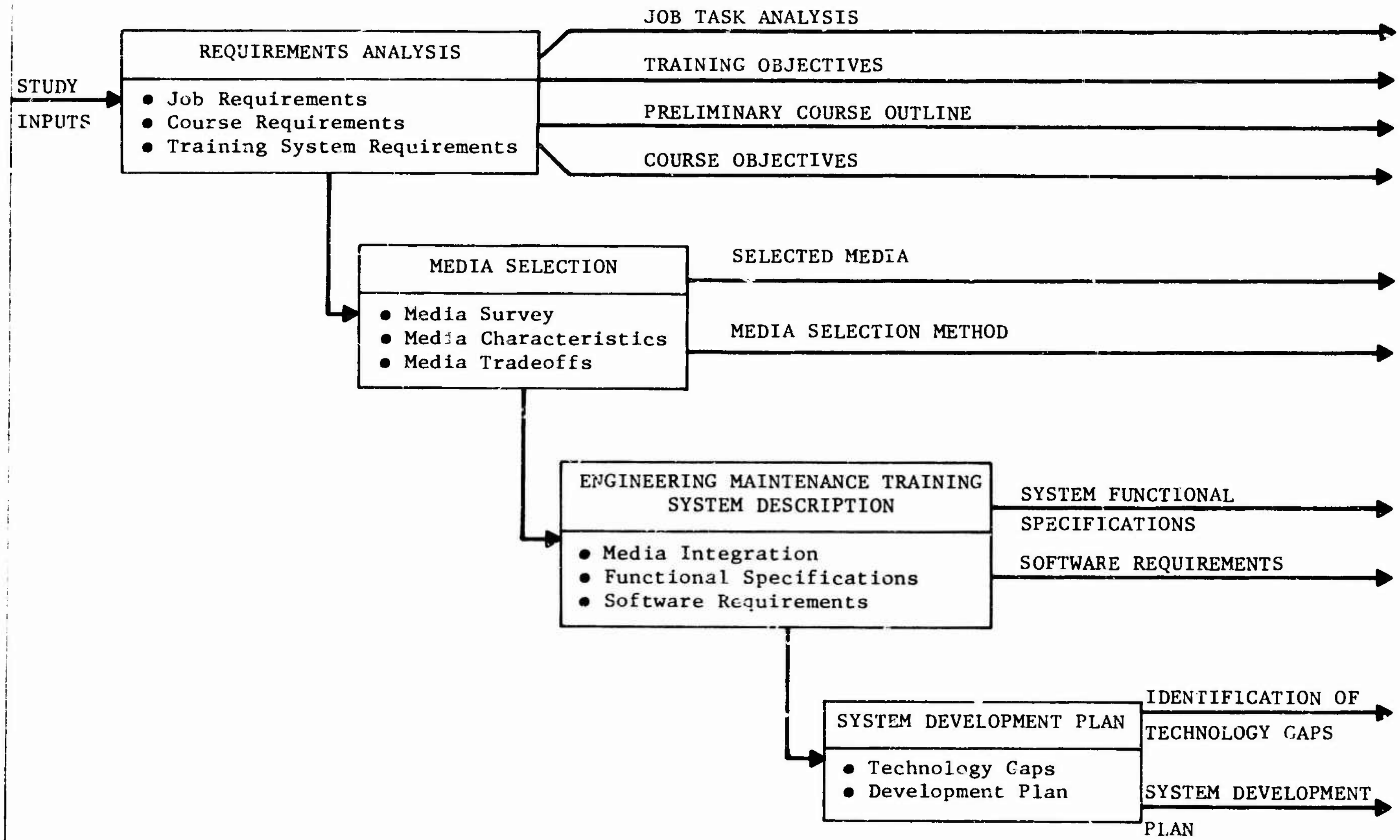

Figure 1. DEVELOPMENT OF ADVANCED ENGINEERING MAINTENANCE TRAINING SYSTEM

the work performed within each phase is presented in Figure 2. The study phases were:

(1) Requirements analysis. This involved analysis of job, course and training system requirements. This phase provided the basic data for subsequent analysis, including: (a) the comparative evaluation of alternative media; (b) integration of media into a conceptual training system; (c) derivation of functional specifications for that system; and (d) identification of training requirements which cannot be fully satisfied by current technology.

(2) Media selection. Alternative media were evaluated in terms of their ability to support the defined training objectives. One significant by-product of this activity was the development of an analytic tool which is expected to be useful in the selection of training media for other applications.

(3) Training system description. This was derived from the integration of the selected media with respect to all training objectives, and the formal specification of system hardware and software components.

(4) System development plan. This effort included preparation of the plan itself and identification of gaps in state-of-the-art instructional technology which might affect implementation of the plan.

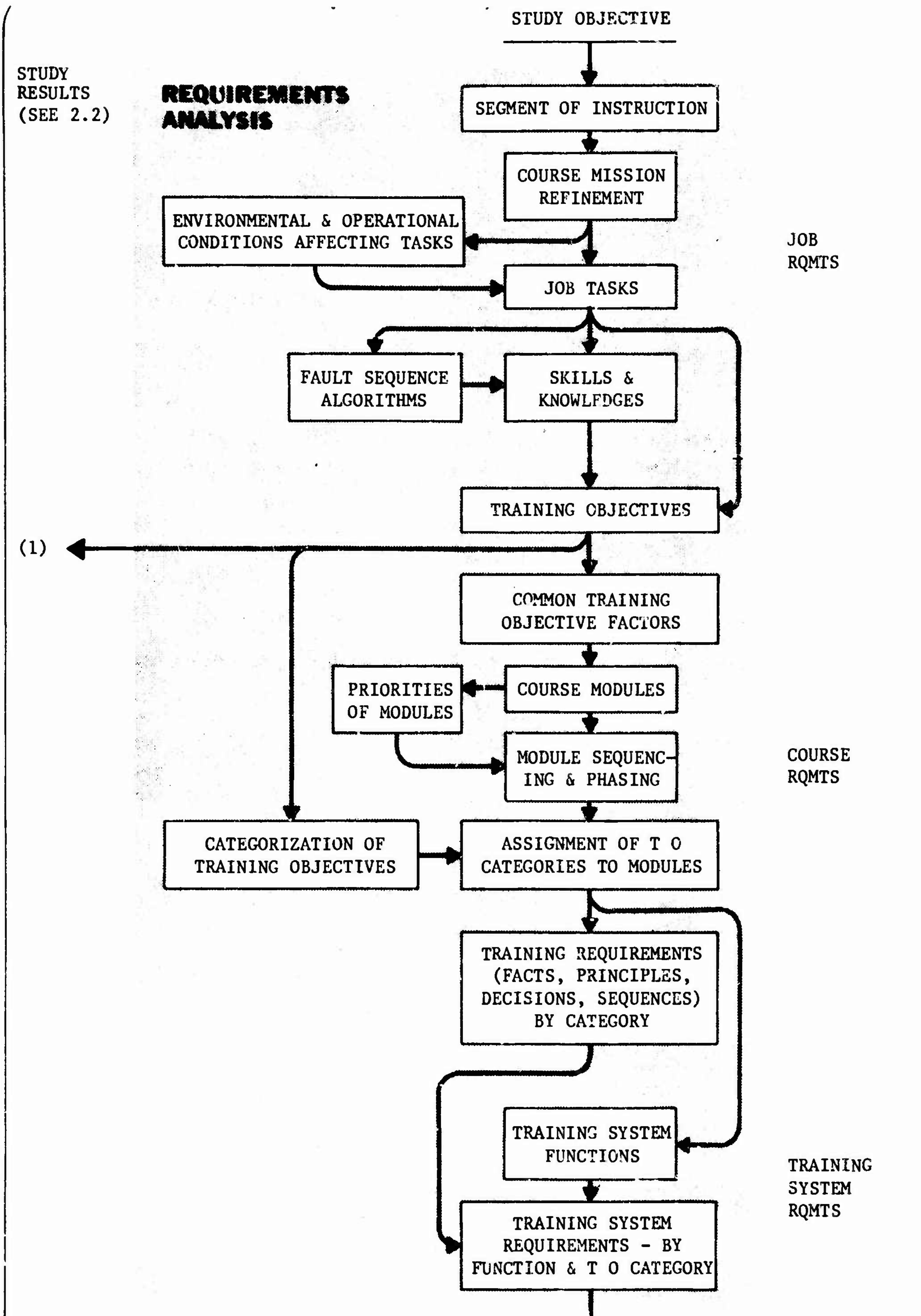

Figure 2. STUDY PHASES

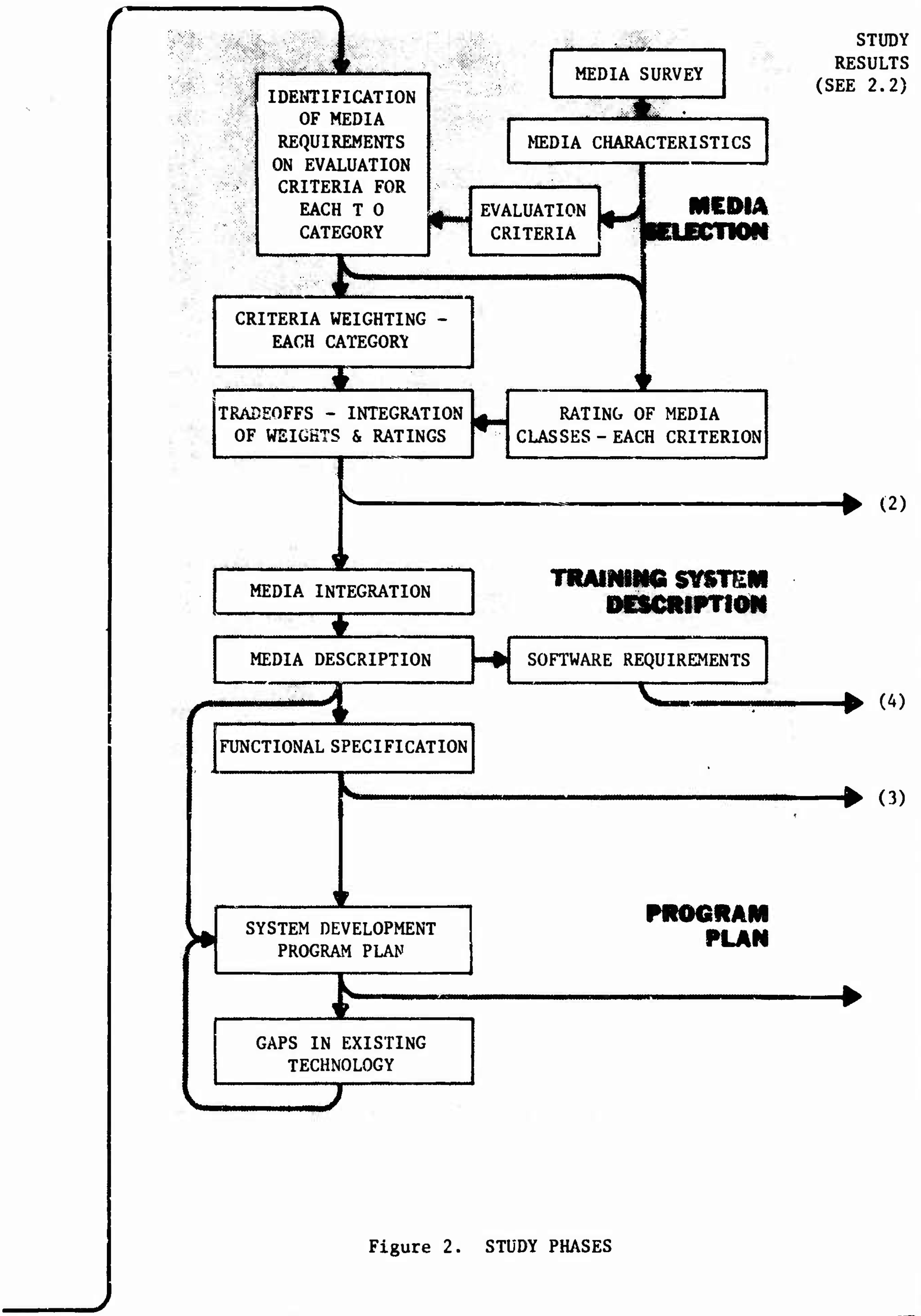

Figure 2. STUDY PHASES

3.0 REQUIREMENTS ANALYSIS

The principal elements of the requirements analysis were of three basic types: job requirements, course requirements, and system requirements (Figure 3).

3.1 Job Requirements

Job requirements are determined by the tasks to be performed in the fleet and by the skills and knowledges associated with those tasks. The two principal steps in deriving job requirements involved selecting a segment of instruction, and identifying the tasks, skills and knowledges associated with that segment.

The segment of instruction selected for this study was the steam plant Automatic Boiler Control (ABC) Hagan course currently conducted at Development and Training Center (DATC), San Diego. This course was selected because:

- The ABC Hagan course contains all the basic elements of advanced engineering maintenance training and is generalizable to electro and electro-mechanical troubleshooting and repair in such areas as:
  - diagnostic troubleshooting
  - fault isolation
  - component disassembly and repair
  - component reassembly and calibration
- The course involves a broad range of training materials from basic hand tools to sophisticated pneumatic control and calibration devices that would lend themselves to simulation and the application of advanced training technology
- This training is expected to remain in high demand. Requirements for combustion control training devices and ratings

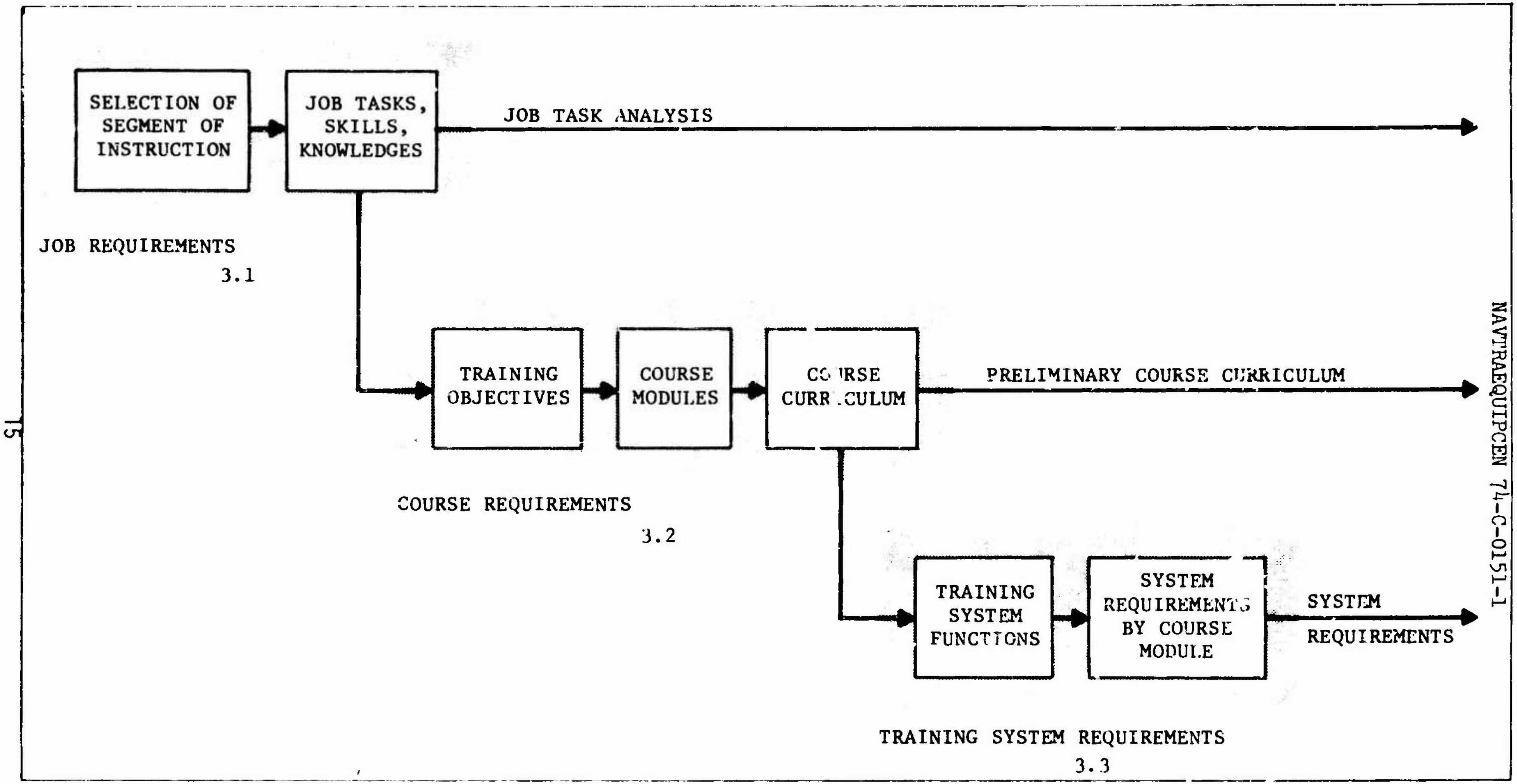

Figure 3. PROGRAM ELEMENTS OF THE REQUIREMENTS ANALYSIS PHASE

involved with the training can be projected far into the foreseeable future because of commitment of Naval marine engineering to high pressure steam plants.

- The course has a readily definable skill level for entry and does not require follow-on training in the Fleet.

- Continuous and almost immediate feedback can be provided, since there are a large number of ships with ABC equipment readily available in the San Diego area.

The criteria and procedures used in the selection process are fully described in Appendix B.

When the model course was selected, job experts were interviewed for the purpose of identifying tasks, operating conditions, procedural sequences, and special requirements. These personnel included those actively engaged aboard ship in performing ABC Hagan maintenance functions and also those who supervised the functions. In addition, course instructors and students, as well as recent graduates of the existing course, were surveyed. Based on data from these sources, the existing course mission was refined for the purpose of establishing the scope of the experimental course to be developed.

The mission statement for the course currently administered at DATC says that the course is designed to "... furnish specialized training in the operation, maintenance, repair and calibration of marine Automatic Boiler Controls, in order to provide well-qualified personnel for engineering duties necessary to the effective functioning of the Fleet." For the purpose of this study the above was supplemented with the statement that the primary purpose of the course is to train boiler technicians for assignment under NEC (Navy Enlisted Classification) 4512 (Hagan Maintenance Man). The refined mission also includes the statement that technicians will receive training in: (1) advanced maintenance concepts; (2) performance of the Hagan system and its components; (3) fault isolation; (4) component disassembly; (5) defect identification and repair; (6) reassembly; and (7) bench calibration using technical manual and bulletin specifications and appropriate test equipment. In addition, the fully trained technician must be able to conduct Automatic Boiler Control Hagar inspections for both hot and cold plant conditions and perform preventive maintenance for ABC Hagan systems.

The refined course mission establishes the scope of job elements to be analyzed. On the other hand, course mission statements do not provide job performance standards. These must be developed by means of task analysis.

The task analysis was based on all available sources of relevant information: technical manuals, preventive maintenance system documentation, Engineering Operation Sequence System (EOSS), existing course material, current maintenance bulletins, and experienced job experts. The Ship Specific Hagan Systems observed were DE 1052, DL, and CVA. The general duties of the Hagan maintenance man were derived from the course mission and were analyzed into functions (e.g., perform preventive maintenance), the functions were analyzed into tasks, and the tasks into task elements. No attempt was made to analyze all of the tasks of the maintenance man; e.g., disassembly and reassembly of ABC Hagan components already have extensive procedures documentation, and the skills required for those tasks are straightforward. Only those tasks that required complex and/or varied skills were analyzed. These included:

(1) The preventive maintenance functions

(2) Hot and cold plant inspection procedures

(3) Troubleshooting

The results of the task analyses for these functions are presented in Appendix A.

Once the task elements were catalogued, specific skill requirements were identified using the taxonomy of skills presented in Table 1. All of the task elements contain one or more of these skills.

TABLE 1. JOB SKILLS IDENTIFIED FOR ABC MAINTENANCE TASKS

1. Motor Skill - involves mechanism manipulation (tools and controls)

2. Perceptual Skill - involves assimilating information from displays or indications

3. Perceptual/Motor Skill - involves assimilating information from displays while manipulating controls

4. Memory Skill - capacity to recognize/recall set points, ranges, readings, etc.

5. Perceptual Memory Skill - capacity to evaluate acceptability of indications or readings in terms of known standards

6. Diagnostic Skill - capacity to infer the cause of malfunctions from all appropriate information sources

7. Text Retrieval Skill - ability to locate textual material using Table of Contents, Indexes, Tables, Schedules, Written Procedures, etc.
8. Kinesthetic Skill - ability to perform a function by feel without visual guidance

9. Organizational Skill - ability to organize work tools and unit components in an orderly manner, leading to more effective utilization, reduced lost work time, increased efficiency in following operation, maintenance and fault analysis procedures, i.e. "Good Engineering Practice"

The knowledge elements required to perform each task were then identified. These were either general information to be received (e.g., theory), or knowledges required as an element of a required skill. Examples include knowledge of:

(1) System or component operation

(2) System or component set points, ranges, limits, etc.

(3) Procedures, techniques, or sequences

(4) Hardware location

(5) Hardware nomenclature and identification

As job skills and knowledges were identified they were reviewed by job experts to the extent possible in view of the availability of ships and instructors.

An important by-product of this effort was the derivation of algorithms to diagram fault sequences. The algorithms, coupled with the task analysis, facilitated the identification of the significant decision, action and knowledge task elements, and enabled selection of appropriate task sequences based on binary (yes-no) decisions. Such algorithms also serve as job performance aids or as training aids: e.g., for student use or for job incumbents to provide a sequence of checks to be made in diagnosing system faults. It was beyond the scope of this program to provide fault analysis algorithms for the entire ABC Hagan course. However, an example of one such algorithm in a form suitable for use as a job training aid is shown in Appendix B.

3.2 ABC Hagan Maintenance Course Requirements

It became apparent early in the study that in order to make meaningful media selection decisions the course of instruction must be outlined at least in terms of sequencing of content. The initial steps in this process were to derive the training objectives from the job task analyses and to establish the scope of the course content based upon these derived training objectives. This was accomplished by analyzing the training objectives in terms of a number of common major component factors (facts, principles, sequences, information factors, decision factors, manipulation factors, and knowledge factors). The specific factors and their contents are listed in Tables C-2 through C-9 of Appendix C.

Based on these training objective factors, a list of required training course content topics was prepared (Table C-10, Appendix C). These topics define the content of the training material required in the course in order to satisfy the training objectives. The course content requirements were then reviewed and organized into four course phases, shown below:

Phase I: Conceptual Phase, devoted to describing the ABC system structure and function

Phase II: Maintenance Requirements, addressing the ABC maintenance strategies, responsibilities, and requirements

Phase III: Procedures and Decisions, concerned with system relationships, failure cues and effects, assembly techniques, and calibration criteria

Phase IV: Practice and Assessment, devoted to the acquisition of skills (diagnostic as well as manipulative) and the assessment of student achievement

Five course modules were identified for each of the above phases, based upon the course content requirements and the component factors of the training objectives. The allocation of training time to each module was then examined to determine the relative importance of the modules. The results of this exercise are presented in Table 2, and Table 3 indicates

TABLE 2. ALLOCATION OF TRAINING TIME TO MODULES

Phase I. Conceptual		
A.	Orientation to ABC system	2%
B.	System/subsystem structure	3%
C.	System/subsystem function	3%
D.	System/subsystem operation	5%
E.	Component structure, function, relationship	5%
	Phase Total	18%
Phase II. Maintenance Requirements		
A.	ABC maintenance philosophy	2%
B.	Preventive maintenance requirements	4%
C.	Calibration and repair requirements	4%
D.	Inspection requirements	2%
E.	Troubleshooting requirements	5%
	Phase Total	17%
Phase III. Procedures and Decisions		
A.	General safety	3%
B.	Preventive maintenance	4%
C.	Calibration and repair	8%
D.	Inspection	3%
E.	Troubleshooting	17%
	Phase Total	35%
Phase IV. Practice and Assessment		
A.	Safety	2%
B.	Preventive maintenance	4%
C.	Calibration and repair	7%
D.	Inspection	2%
E.	Troubleshooting	15%
	Phase Total	30%

the allocation of the categories of training objectives to the four course phases.

As a result of the course requirements analysis it was determined that training methods and media must be selected for three different course content areas:

(1) Acquisition of knowledge and information

(2) Acquisition of manipulative skills

(3) Development of diagnostic skills

3.3 Training System Requirements

The training system developed to support the course requirements identified in Section 3.2 must be capable of accomplishing the following functions:

- Convey factual information to the student
- Assist the student in the understanding of principles
- Support the student in practicing specific task sequences
- Provide for development of appropriate perceptual-motor skills
- Provide for development of the decision making skills required to maintain the system
- Provide the student with decision rules and an understanding of system relationships to support all maintenance activities, especially troubleshooting

The system must therefore possess the structural characteristics necessary to enable these functions:

(1) Knowledge and information transmission

TABLE 3. TRAINING OBJECTIVE CATEGORIES BY COURSE PHASE

COURSE PHASE	I. CONCEPTUAL	II. MAINTENANCE REQUIREMENTS	III. PROCEDURES & DECISIONS	IV. PRACTICE & ASSESSMENT
COURSE CONTENT AREA	KNOWLEDGE & INFORMATION		HANDS-ON FAMILIARIZATION & DIAGNOSTICS USING REPRESENTATIVE DISPLAYS	ACQUISITION OF PERCEPTUAL, PERCEPTUAL/MOTOR, MOTOR & DIAGNOSTIC SKILLS
TRAINING OBJECTIVE CATEGORIES	1. Using system diagrams, describe system, subsystem and component structure, location, operation, and function. 2. Describe and explain preventive maintenance and inspection requirements, decisions, procedures, techniques and criteria. 3. Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type. 4. Given representative component repair requirements, identify tools and techniques required for repair of each component type. 5. Using visual representations and mockups, describe procedures and techniques of fault isolation and component removal/replacement. 6. Using visual representations and displays, be able to correctly identify fault event cues and failure effects. 7. Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.		8. Using an operational system representation, describe procedures to detect and locate faults at the component level. 9. Using operational system representation, describe component removal/replacement, inspection and repair procedures. 10. Using an operational system representation, describe disassembly, test and calibration procedures.	11. Using an operational system representation, correctly complete system preventive maintenance and inspection procedures. 12. Using an operational system representation, correctly complete system calibration and component assembly, disassembly, and repair. 13. Using an operational system representation, correctly identify and locate failed components in different failure conditions.

(2) Diagnostic skill development

(3) Perceptual/motor skill development

The first item applies to all course modules within the Course Phases I and II (Table 2). Diagnostic skill development applies to Phase III modules in general, and the troubleshooting Procedures and Decisions module in particular. Perceptual/motor skill development applies to all modules within the Practice and Assessment Phase (Phase IV) of the course.

4.0 EVALUATION OF INSTRUCTIONAL MEDIA

One key problem in this study was the selection of instructional media to be integrated into the proposed training system. The term media is used here to mean the elements of a training system which provide for the acquisition of knowledge or skill. These elements usually include training equipment as well as other training support materials. As is evident from the definition of the term, two general types of instructional media can be distinguished: those which are primarily designed to facilitate the transmission of knowledge and information; and those which are primarily designed to support the acquisition of specific skills.

The selection process employed in this study is depicted in Figure 4. The process began with a survey of the state-of-the-art in instructional technology to establish the population of media options. Pertinent characteristics of the alternate devices and materials were determined and were used to compare the cost-effectiveness of different hardware/software options in meeting the different training objectives. The result of these analyses was a selected mix of instructional media. The details of this selection process are contained in Appendix D. The following is a brief description of the process.

4.1 Technology Survey

The survey began with a review of course requirements and identification of features which would be required of training equipment and materials in order to satisfy the course requirements. Representative training devices were surveyed to identify those which possessed, or were

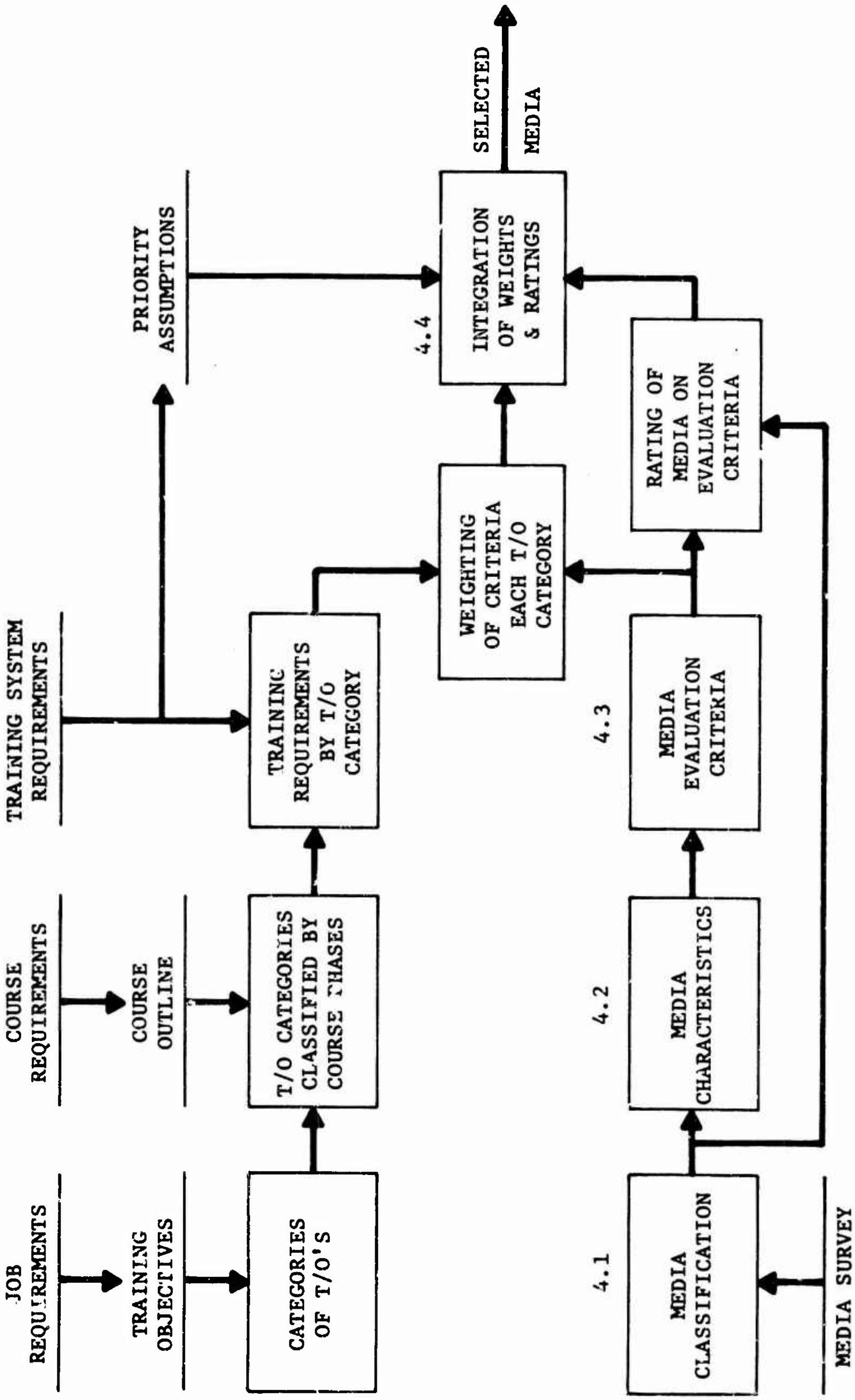

Figure 4. MEDIA SELECTION METHOD

capable of possessing, the required features. The media configurations discussed here are only examples of the possible hardware solutions available. Specific equipments are discussed in order to delineate the capabilities of representative classes of training hardware available in each of the media, and their appropriateness to course requirements.

The items of training hardware selected for investigation are identified in Table 4, grouped according to the type of media (knowledge/information or skill acquisition) with which they are most closely associated.

4.2 Media Characteristics

Major attributes of devices and materials were identified for later use in evaluating the media with respect to meeting the training objectives. These are listed in Table 5.

4.3 Development of Evaluation Method

The method developed to select media for specific portions of the course included the following steps:

(1) List evaluation attributes. These included all characteristics listed in Table 5, plus the cost factors of: initial hardware cost, initial software cost, and life cycle cost.

(2) Identify training requirements associated with training objectives. This step entailed identifying levels of capability required by each of the media characteristics in order to satisfy the training objectives.

TABLE 4. MEDIA SELECTED FOR STUDY

KNOWLEDGE/INFORMATION MEDIA	
Media Characteristics in Brief	Example
Audio/visual presentation, mini-computer, micro-fiche film, branching, no motion	Lincoln Labs
Plasma type display, maximum branching, large computer, modifications provide sound and pictorial	PLATO (Programmed Logic for Automatic Teaching Operations
Plasma type display, extensive branching, medium size computer, modifications provide pictorial	TICCIT (Time-shared, Interactive Computer Controlled Information Television
Audio/visual presentation, skip-branching, excellent pictorial, color, motion, utilizes three screens	Bell & Howell
Display screen, some branching capability, no motion, no sound	Auto-Tutor
Audio/visual presentation, color, excellent pictorial, motion, uses film cartridge, cumbersome branching capability	Norelco PIP (Programmed Individual Presentation)
Audio/visual presentation, good branching, color capability, motion uses video tape, excellent pictorial	Program Video Tape
Audio/visual presentation, no branching, color, no motion, excellent pictorial	Sound/Slide
Normal textbook material but programmed with liberal use of graphics and pictures	Programmed Textbook

TABLE 4. MEDIA SELECTED FOR STUDY (Cont)

SKILLS MEDIA	
Media Characteristics in Brief	Example
Real-world equipment, functionally identified to equipment used in the field	Actual Equipment
High fidelity representation with closed loop computer simulation	Automated Electronic Maintenance Trainer (Honeywell)
Part task trainers, part life-like equipment, integrated with small computer, efficiency increase due to interchangeable panels	EC-II
Part task trainers, part life-like equipment, activated by mechanical linkage or electrical power	Mock-ups

TABLE 5. MEDIA CHARACTERISTICS

KNOWLEDGE AND INFORMATION MEDIA	SKILLS MEDIA
• Visual Representation - pictorial - graphic - color - text • Motion Representation • Format Flexibility - capability of modifying information formats • Sound Representation • Branching • Scoring • Clarity - resolution	• Fidelity of Simulation - displays - system response - student response - system configuration • Range of Fault Capability • Safety
BOTH TYPES OF MEDIA	
• Prompting and cueing capability • Different levels of difficulty • Operability • Maintainability • Reliability • Transportability • Space requirements • Update capability • Extent of programming requirements • Special requirements • Generalizability • Applicability across training objectives • Support requirements • Instructor requirements	

(3) Assign weights to each evaluation characteristic for each training objective category. Each member of a team of five judges* independently reviewed the requirements associated with training objective categories and assigned an importance weight to each media characteristic for each category. The assigned weight indicated the judged degree of importance of the characteristic for a particular training objective category. The mean weightings of the five judges were calculated and used in subsequent computations.

(4) Assign ratings to each of the candidate hardware items for each characteristic. The same judges then independently rated each characteristic of each device in terms of its effectiveness in meeting the identified levels of capability required to satisfy the training objectives. The final ratings used were the mean values assigned by the five judges.

(5) Integration of weights and ratings. The media characteristics were then regrouped in terms of three criterion categories (Table 6), which were:

(a) Characteristics concerned with the effectiveness of training (18 items)

(b) Usability characteristics, or factors influencing efficient use of the medium (12 items)

(c) Cost (3 items)

Within each type of criteria the weights and ratings for individual criterion factors were multiplied and a mean score was obtained. The

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*The judges included three experimental psychologists with extensive experience in training and simulation work, a retired Master Chief Machinist Mate, and a graphic artist/illustrator.

TABLE 6. EVALUATION CRITERIA AND ASSOCIATED MEDIA CHARACTERISTICS

EFFECTIVENESS	

• Visual Representation
  - pictorial
  - graphic
  - color
  - text
• Motion Representation
• Clarity of Representation
• Format Flexibility
• Sound Representation
• Branching
	• Scoring
	• Prompting and Cueing Capability
	• Different Levels of Difficulty
	• Operability
	• Fidelity of Simulation
	  - display
	  - system response
	  - student response
	  - system configuration
	• Range of Fault Capability

USABILITY	
• Maintainability • Reliability • Safety • Transportability • Space Requirements • Update Capability	• Extent of Programming Requirements • Special requirements • Generalizability • Applicability Across Training Objectives • Support Requirements • Instructor Requirements
COST	
• Initial Software Cost • Initial Hardware Cost • Life Cycle Cost	

manner in which the mean scores for each of the three types of criteria were integrated depended on a set of assumptions. These assumptions were as follows:

Assumption 1. Effectiveness and cost criteria are of equal importance and are 3 times as important as usability criteria.

The formula used under this assumption to generate an overall score for each of the alternate hardware items for each training objective category was: three times the mean product of effectiveness ratings and criterion weights,

$$\left[\frac{\Sigma\ (E_R \cdot E_W)}{n_E}\right]$$

plus the mean product of usability ratings and criterion weights,

$$\left[\frac{\Sigma\ (U_R \cdot U_W)}{n_U}\right]$$

plus three times the mean product of cost ratings and criterion weights,

$$\left[\frac{\Sigma\ (C_R \cdot C_W)}{n_C}\right]$$

thus, the operations represented by the expression:

$$3\left[\frac{\Sigma\ (E_R \cdot E_W)}{n_E}\right] + \left[\frac{\Sigma\ (U_R \cdot U_W)}{n_U}\right] + 3\left[\frac{\Sigma\ (C_R \cdot C_W)}{n_C}\right]$$

can be more simply stated as: $3E + U + 3C$. This method assigns equal weight to effectiveness and cost, both of which were considered to be three times as important as usability. The factor of three was selected based on the judgement that it represented a reasonable magnitude of difference between types of criteria.

Assumption 2. Effectiveness criteria are of primary importance. In this case the formula is the same as under the previous assumption except that the cost criteria are not multiplied by 3. The integration of ratings for different types of criteria is then: 3E + U + C.

Assumption 3. Cost criteria are of primary importance. This assumption assigns cost criteria a weighting of 3 and gives effectiveness and usability a weighting of one, thus: E + U + 3C.

Assumption 4. Effectiveness criteria are the only factors to be considered In this case no consideration is given to cost useability, as: E + (0)U + (0)C.

Assumption 5. Cost criteria are the only factors to be considered. Under this assumption no consideration is given to effectiveness or usability, as: (0)E + (0)U + C.

4.4 Results of Tradeoff Analyses

It had been intended that tradeoffs be completed for ratings established for each of the 13 training objective categories (Tables D-10 through D-12 in Appendix D). Intercorrelations of device scores over different T/O categories were all above .9. Therefore, the mean ratings over the T/O categories were employed in the integrations of weights and ratings described below.

Assumption 1. Effectiveness and cost of equal importance. The mean scores of devices under this assumption are presented in Table 7. As indicated in this table the recommended knowledge/information device is the Norelco PIP and the selected skills acquisition device is the EC II.

Assumption 2. Effectiveness of primary importance. Table 8 presents the mean scores obtained under this assumption. When effectiveness is

TABLE 7. MEAN SCORES BY DEVICES UNDER ASSUMPTION 1, EFFECTIVENESS AND COST OF EQUAL IMPORTANCE

	EFFECTIVENESS	USABILITY	COST	TOTAL	RANK
KNOWL./INFO. DEVICES:					
NORELCO PIP	176	62	233	471	1
MODIFIED PIP	191	60	216	467	2
SOUND/SLIDE	148	62	225	435	3
PROGRAMMED TEXT	148	59	217	424	4
PROGRAMMED VIDEO TAPE	194	57	173	424	4
BELL & HOWELL	172	59	181	412	6
AUTO TUTOR	117	61	216	394	7
LINCOLN LABS	140	54	139	333	9
TICCIT	161	52	121	334	8
PLATO	148	53	69	270	10
SKILLS DEVICES:					
ACTUAL EQUIPMENT	188	34	176	398	4
AEMT	242	60	140	442	2
EC II	218	63	200	481	1
PART TASK TRAINER	121	58	234	413	3

TABLE 8. MEAN SCORES BY DEVICES UNDER ASSUMPTION 2, EFFECTIVENESS MOST IMPORTANT

	EFFECTIVENESS	USABILITY	COST	TOTAL	RANK
KNOWL./INFO. DEVICES:					
NORELCO PIP	176	62	78	316	2
MODIFIED PIP	191	60	72	323	1
SOUND/SLIDE	148	62	75	285	5
PROGRAMMED TEXT	148	59	72	279	6
PROGRAMMED VIDEO TAPE	194	57	58	302	3
BELL & HOWELL	172	59	60	291	4
AUTO TUTOR	117	61	72	250	8
LINCOLN LABS	140	54	46	240	9
TICCIT	161	52	40	253	7
PLATO	148	53	23	224	10
SKILLS DEVICES:					
ACTUAL EQUIPMENT	188	34	59	281	3
AEMT	242	60	47	349	1
EC II	218	63	67	348	2
PART TASK TRAINER	121	58	78	257	4

given priority the selected knowledge/information component is the upgraded programmable audio visual device (Modified PIP). Under this assumption the device selected for skills acquisition is the high fidelity closed-loop computer simulation device represented by the Automated Electronic Trainer (AEMT).

Assumption 3. Cost most important. As indicated in Table 9, the selected devices under this assumption are the PIP and the EC II.

Assumption 4. Effectiveness alone. When effectiveness is the sole consideration (based on the effectiveness column of Table 9 alone) the selected devices are the Programmed Video Tape of knowledge and information media, and the AEMT simulator.

Assumption 5. Cost alone. When cost alone is considered the selected knowledge and information device as seen in the cost column of Table 8 is the PIP with the part task trainer.

Summary.

The training system configuration appropriate for each assumption is as follows:

Assumption	Knowl./Info. Device Type	Skills Device Type
1. Effectiveness and cost equal	Norelco PIP	EC II
2. Effectiveness primary	Modified PIP	AEMT
3. Cost primary	Norelco PIP	EC II
4. Effectiveness alone	Programmed Video Tape	AEMT
5. Cost alone	Norelco PIP	Part Task Trainer

The mix of Norelco PIP and EC II was found to be optimal under two assumptions, that cost and effectiveness are of equal importance (assumption 1) and that cost is of primary importance (assumption 3). For this reason this mix of media was selected as the training system configuration.

TABLE 9. MEAN SCORES BY DEVICES UNDER ASSUMPTION 3, COST MOST IMPORTANT

	EFFECTIVENESS	USABILITY	COST	TOTAL	RANK
KNOWL./INFO. DEVICES:					
NORELCO PIP	59	62	233	354	1
MODIFIED PIP	64	60	216	340	2
SOUND/SLIDE	49	62	225	336	3
PROGRAMMED TEXT	49	59	217	325	4
PROGRAMMED VIDEO TAPE	65	57	173	295	7
BELL & HOWELL	57	59	181	297	6
AUTO TUTOR	39	61	216	316	5
LINCOLN LABS	47	54	139	240	8
TICCIT	54	52	121	227	9
PLATO	49	53	69	171	10
SKILLS DEVICES:					
ACTUAL EQUIPMENT	63	34	176	273	4
AEMT	81	60	140	281	3
EC II	73	63	200	336	1
PART TASK TRAINER	40	58	234	292	2

5.0 MAINTENANCE TRAINING SYSTEM DESCRIPTION

The major steps involved in the System Description Phase of the study are shown in Figure 5. Preliminary functional specifications are presented in this section for the first and lowest cost hardware option described in Section 4.0, i.e., the programmed audio-visual device and the modular programmable simulator.

5.1 Media Integration

The media required to support maintenance training on the ABC Hagan system consist of the following:

(1) Knowledge and information media

(2) Skills media directed specifically to:

(a) system operation and failure effects

(b) troubleshooting

(c) test and calibration

(d) assembly, disassembly and repair

These media were allocated to each of the course modules as indicated in Table 10. This table shows that all modules within Phase I (Conceptual) and Phase II (System Maintenance Requirements) require only knowledge and information media.

Modules assigned to Phase III (Procedures and Decisions) require both knowledge and information media and skills media, while those allocated to Phase IV (Practice and Assessment) require only skills media.

5.2 Media Descriptions

Descriptions of the media selected for this training system under the assumption that effectiveness and cost criteria are of equal importance are presented in the following sections. Details of the system functional

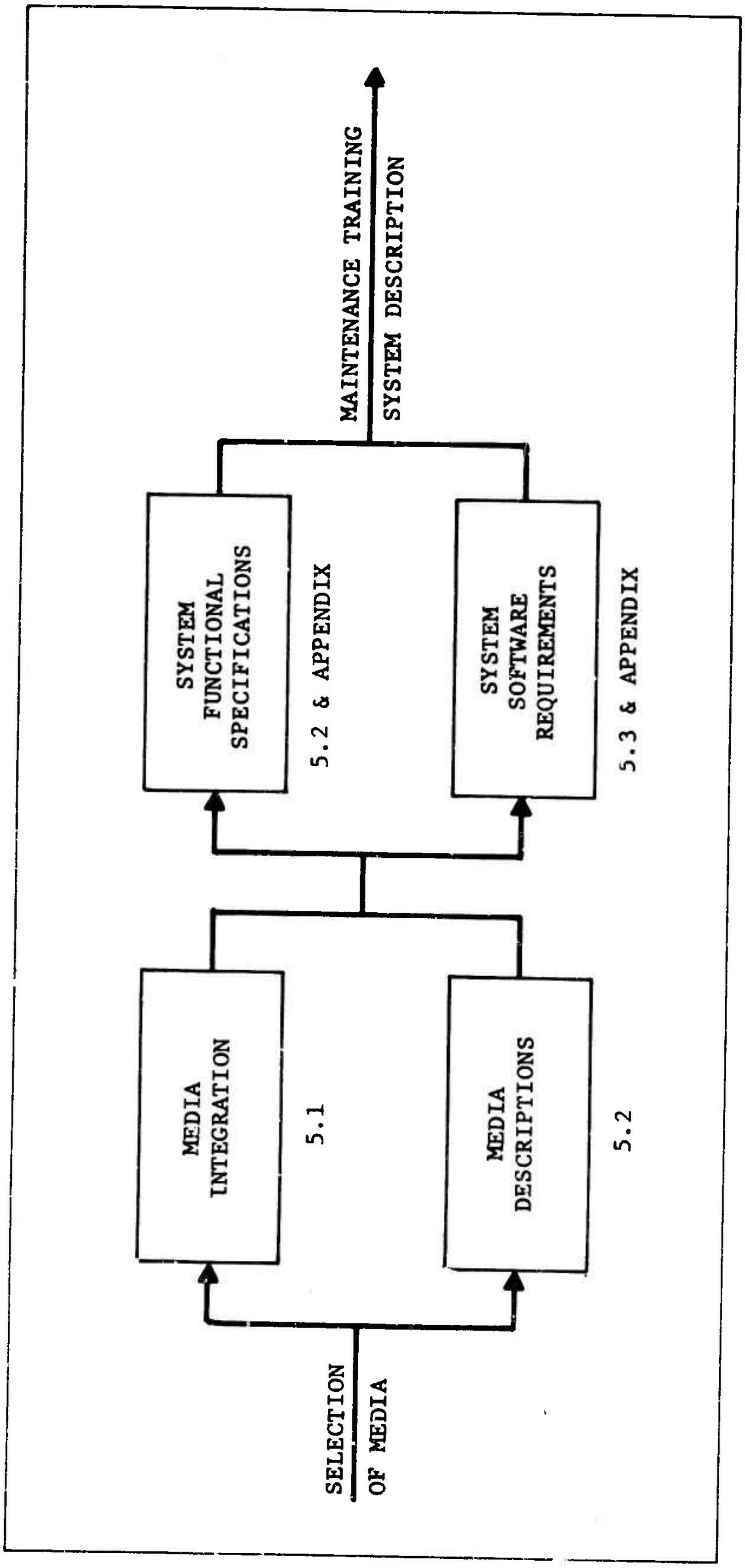


Figure 5. PROGRAM ELEMENTS OF THE SYSTEM DESCRIPTION PHASE

TABLE 10. ALLOCATION OF TRAINING MEDIA TO COURSE MODULES

COURSE PHASE AND MODULE	KNOWLEDGE/ INFORMATION MEDIA	SKILLS MEDIA			
		SYSTEM OPERATION & FAILURE EFFECTS	TROUBLE-SHOOTING	TEST AND CALIBRATION	ASSEMBLY, DISASSEMBLY AND REPAIR
Phase I. Conceptual					
A. Orientation to ABC system	X				
B. System/subsystem structure	X				
C. System/subsystem function	X				
D. System/subsystem operation	X				
E. Component structure, function, relationship	X				
Phase II. Maintenance Requirements					
A. ABC maintenance philosophy	X				
B. Preventive maintenance rqmts.	X				
C. Calibration & repair rqmts.	X				
D. Inspection rqmts.	X				
E. Troubleshooting rqmts.	X				
Phase III. Procedures & Decisions					
A. General safety	X				
B. Preventive maintenance	X	X			
C. Calibration & repair	X			X	X
D. Inspection	X	X			
E. Troubleshooting	X	X	X		
Phase IV. Practice & Assessment					
A. Safety		X	X	X	X
B. Preventive maintenance				X	X
C. Calibration & repair				X	X
D. Inspection					X
E. Troubleshooting			X		

specifications are contained in Appendix D.

5.2.1 Knowledge and Information Media

The hardware selected to support the knowledge and information media must provide both aural and visual presentations, including motion as well as still pictures.

The training method will be based on an individualized, self-paced, programmed instruction approach with limited branching capability.

5.2.2 Skills Media

The basic device used to support skill acquisition will consist of a general purpose programmable simulator designed to accept the hardware modules described below:

(1) System operation and failure effects. The interchangeable simulation model will include all necessary controls and displays of the ABC Hagan console and will incorporate a schematic of lines, valves, and components which, under stated operational or failure conditions, will dynamically depict fluid flow and will activate appropriate display values.

The device will include an integrated, programmed, self-paced instruction (PI) capability. Explanation of system operation and failure effects will be presented on the PI display, followed by test items to assess student understanding. The PI display will be comparable to that described in Section 5.2.1.

(2) Troubleshooting. One or more hardware modules will simulate the operation of a specified Hagan system. Individualized self-paced instruction similar to that described in Section 5.2.1 will permit the student

to progress through any number of fault isolation problems selected and sequenced by either the instructor or the student.

The troubleshooting media will authentically represent the operation of the system in a fail-free state for different operational conditions as well as under selected failure conditions.

(3) Test and calibration. The simulation model will consist of a replication of the ABC Hagan component test stand including all test board displays. Operations to be simulated include attachment to the test board of a component containing a specified fault, application of air, and interpretation of displayed data to isolate the fault within the component. Individualized, self-paced instruction similar to that described in Section 5.2.1 will be used.

(4) Assembly, disassembly and repair. The device will include actual components modified to incorporate built-in cueing for part identification and task sequencing, as well as components with malfunctions inserted by the instructor. An audio-visual capability similar to that described in Section 5.2.1 will be included and will be used in conjunction with the actual components to instruct students in procedures for assembly, disassembly and repair.

5.3 Software Requirements

The software requirements for the advanced maintenance training system involve media software, training course software, and training curriculum. (See Appendix F.)

6.0 SYSTEM DEVELOPMENT

This section presents the prototype marine engineering maintenance training system development plan and a description of advances in existing instructional technology required to complete the development.

6.1 Prototype System Development Plan

The major steps in the development of the system include the following:

(1) Course definition and syllabus development. In this initial step all supporting documentation will be assembled for actual course development. A detailed course outline will be generated to identify the course modules and the lessons to be included within each module. Lessons and modules will be phased and assembled in sequential order.

The course syllabus will indicate the relationships among learning objectives, course modules, and lessons. The syllabus will also describe: the supporting documentation for the course; the special resource requirements of the course; and the specific media-enabling hardware to be employed for each lesson.

(2) System hardware procurement. Refined hardware specifications will be generated and hardware vendors will be selected to produce system equipment designed to the specifications.

(3) System software development. System software encompasses three general areas: instructional materials, course administration software, and system support software. Instructional materials are comprised of the

actual course information content, in the form of lessons and modules. The instructional materials will be prepared in storyboard format including all text, pictures, and display states. The production of instructional materials from the storyboards will include such activities as:

- Preparation of text pages for printing - pagination and assembly
- Production of art work
- Production of negatives
- Printing of slide set masters
- Narration and editing of audio masters
- Synchronization of slide sets to audio tapes
- Production of instructor guides

The course administration software includes test booklets, answer sheets, templates, student progress charts, student data cards, and student/course records. System support software includes special software configurations required to support specific elements of the course. Examples are: graphic representations of system states and feeds; software control of system responses and display states based on student inputs; and software recording of student responses and analysis of response trends. A special case of system support software is the use of proceduralized job aids designed to serve as a cue to initiate learned response sequences.

(4) Integration of "hardware" and "software". As hardware is developed and software is produced, the special interfaces required to integrate the two will be developed. This activity will apply primarily to the presentation of material to be learned, to feedback information,

and to evaluation materials. The result of this integration will be the operational marine engineering maintenance training system with supporting documentation.

(5) Course and trainee evaluation procedures and measures. A significant portion of the effort expended in developing the course curriculum will entail development of evaluation rationales, methods and procedures. Evaluation must include assessment of trainees and assessment of the training course. A proposed feature of this course is that evaluation (of trainees and of the course) should proceed continuously. During actual training the lessons in each module should be designed to enable and enhance student self-evaluation on a continuing basis. Over and above the self-assessment, periodic evaluations of student progress will be required by the course administration elements. Finally, evaluation of course materials, methods and overall effectiveness will be required during individual student training and as a result of follow-up assessment after the student has terminated the course and has returned to the Fleet.

The technical issue in the evaluation area is the definition of criterion levels of performance. For most knowledge and skill areas this can be done with precise quantitative standards (e.g., time to read and comprehend, number of procedural errors, accuracy of part identification, etc.), if such standards are known and in use. If such standards of performance are not available, they must be approximated based on the job task requirements and opinions of personnel performing and supervising ABC Hagan maintenance activities.

(6) Instructor selection and training. Instructors for the pilot program will be selected and trained in student counseiling, content areas, student activity requirements, student testing, and data collection.

(7) Course implementation. A plan for implementing the course will be developed which will identify the relationship between the pilot course and the on-going course. It is projected that 30 training days will be required to implement the course, assess the data collection instruments and make necessary adjustments in student activity sequences. Since the ABC Hagan student throughput is small, approximately one year of continuous operation of the pilot program will be required to collect data on 75-100 trainees. Approximately 60 days after students complete the course, the at-sea data collection activity can begin.

6.2 Advanced Technology Development Requirements

Since the marine engineering maintenance training system described in this report was based on existing instructional technology, there is no extensive requirement for advanced technology development. One requirement for additional research and advanced technology involves the integration of troubleshooting procedures training and use of proceduralized job performance aids for troubleshooting. The technology in each of these two areas is well established. Computer assisted instruction (CAI) techniques for troubleshooting procedures training are being developed for the Air Force and the Navy. Techniques for job performance aids directed specifically to troubleshooting are also well established. What is needed is an effective synthesis of the diagnostic troubleshooting training and job performance aid. With such an integration of instruction and course material, the trainee will be provided with the necessary understanding of system operation and failure effects as well as a specially designed job aid to cue his response sequence based on diagnostic information.

APPENDIX A

DETAILED JOB REQUIREMENTS

APPENDIX A. DETAILED JOB REQUIREMENTS

A-1. Rationale for Selection of Segment of Instruction

The selection of a segment of instruction to serve as a demonstration vehicle for this study was the first major subtask accomplished.

The process involved four phases:

- Review of marine engineering maintenance training courses
- Identification of courses that met specified criteria
- Selection of three candidate segments of instruction
- Final selection of segment of instruction

The term "segment of instruction," as used in this study, may refer to any of the following:

- One complete course
- A part of a complete course
- More than one complete course
- Parts of different courses
- Any combination of the above

The selection of an appropriate segment of instruction was based upon a number of standards judged to be either essential or desirable for present study purposes. Thus, it was established that candidate segments of instruction must:

1. Involve marine engineering maintenance training
2. Address advanced level of instruction (versus "A" school courses)
3. Represent a stable program, i.e.,
   a. No plans for modification
   b. Expected to remain in existence for some time

4. Involve a rating that will be required into the foreseeable future

5. Be within framework of Navy's formal training programs

6. Embrace a broad range of training problems in order to facilitate generalization of the resulting data to related areas of Naval Maintenance Training

7. Have a definable entry and exit skill level

8. Require no immediate follow-on training prior to rejoining Fleet

9. Utilize a broad range of training materials and equipment

10. Have a mechanism for evaluating training effectiveness

11. Be based on 1200 PSI plant (versus 600 PSI plant)

12. Represent and support definite Fleet requirements

In addition, candidate segments of instruction <u>should</u>:

1. Be at least four weeks and no more than six weeks in duration

2. Be consistent with the NEOSC recommendations

3. Have the active cooperation and support of supervisory and instructor personnel with regard to the objectives of the present study

4. Involve aspects of training which are common to Machinist Mate, Boiler Technician, and related rates

A-2. Review of Marine Engineering Maintenance Training Courses

The content of all relevant courses was reviewed to assess the degree to which each conformed to the above standards. On this basis it was determined that relevant courses of instruction were being conducted at:

- Philadelphia, Pennsylvania
- Newport, Rhode Island
- Norfolk, Virginia
- San Diego, California

The Boiler Technician "B" school courses taught at Philadelphia are in the process of extensive revision. An attempt to assess the effectiveness of advanced technologies applied as a result of this study would suffer from the instability normally introduced by such a course revision program.

A number of Marine Engineering courses are being taught at Newport; however, for the most part they are operational in nature and are also undergoing revision. In addition, there is a strong possibility that the school will be moved from the Newport area.

While there are relevant courses being taught in Norfolk, they are not administered under the Navy's formal service school program but are under direct Fleet control. Also, as at Newport, most of these courses are operationally oriented rather than being based on maintenance training objectives.

A variety of courses oriented to marine engineering training and conducted within the Navy's formal service school program are available in the San Diego area. In addition, only a few of these courses are undergoing modification, and the location of the schools appears to be stable. Finally, since a large number of operational ships use the San Diego Naval Base, ready access to the Fleet is possible and would permit the validation of training objectives derived for certain individual courses.

On the basis of the above considerations it was decided to restrict the field of candidate courses to those available within the various training commands in the San Diego area.

A-3. Identification of Courses that Satisfy Established Standards

At the Development and Training Center (DATC) located at the 32nd Street Naval Station, discussions were held with LCDR Carl Bowelby, acting Officer in Charge, and Mr. Richard McCuecheon, Education and Training Specialist assigned to DATC. After a review of the Center's entire training program, the following marine engineering maintenance training courses were identified as possible candidates for the required segment of instruction:

- Boilerman 1200 PSI Maintenance
- Steam Generating Plant Inspection and Certification Program
- Boiler Water/Feed Water Testing
- Steam Plant Automatic Boiler Controls Hagan
- Steam Plant Automatic Combustion Controls GR
- Steam Plant Automatic Combustion Controls BM
- Woodward Governor 2301
- Woodward Governor EC-A
- Woodward Governor EG-M
- Electrician's Mate Maintenance

At the Service School Command, Naval Training Center, San Diego, discussions were held with CDR John R. Peterson, the Personnel Qualification Officer, and Mr. Russ Manley, the Education and Training Specialist assigned to the Engineering Department. As a result of these discussions it was decided to investigate the possible candidacy of the following courses:

- Air Conditioning and Refrigeration Class C
- Air Conditioning and Refrigeration

The Fleet Training Center located at the 32nd Street Naval Station was also visited. Discussions were held with LCDR Anthony Dollard, Director of Engineering System Training and his assistant, Chief Warrant Officer William Brigman. It was determined that the following course offered sufficient potential to warrant further investigation:

- P-250 Pump Repair Operation and Maintenance

None of the courses concerned with automatic propulsion or gas turbine systems were selected for investigation from any of the three training centers since none of these courses met the standards established for the selection of a segment of instruction. Specifically, of the two automatic propulsion courses available, one is still the responsibility of the contractor and the other addresses only minor aspects of maintenance training. Also, since the equipment is primarily based on solid state technology, the maintenance training is aimed at the IC Rate whose future is uncertain at this time.

With respect to gas turbine maintenance training, the GS rate recommended by the NEOSC board to operate and maintain gas turbine equipment has not yet been firmly established. In addition, these courses are still undergoing revision under the contractor's direction.

A-4. Selection of Three Candidate Segments of Instruction

Each of the above listed courses was reviewed in detail in order to narrow the selection to the three most appropriate candidates.

The P-250 Pump Repair Operation and Maintenance course which is conducted at the Fleet Training Center was judged to be too operationally oriented for the purposes of this study and the course was withdrawn from further consideration.

The courses, Air Conditioning and Refrigeration Class C, and Air Conditioning and Refrigeration, conducted at the Service School Command, were also withdrawn from consideration since they are both undergoing modification. The program of individualization currently being introduced to these courses creates an unstable training situation which would be difficult to deal with in the context of this study and in later evaluation efforts.

Thus, the issue narrowed to selecting the three most appropriate course segments or combination of segments from courses available at DATC. Applying the selection standards resulted in the selection of the following three candidate segments:

- Steam Generating Plant Inspection and Certification Program
- Steam Plant Automatic Boiler Controls Hagan
- Electrician's Mate Maintenance (parts of) and Woodward Governor 2301

Each of these is considered to be representative of maintenance training in general and of the marine engineering maintenance training program in particular. These segments share subject matter directly or indirectly with all the potential candidate courses at DATC with two exceptions (the Boiler Water/Feed Water Testing and the Boilerman 1200 PSI Maintenance courses). The Boiler Water/Feed Water Testing course addresses only a narrow portion of marine engineering maintenance training requirements, and the Boilerman 1200 PSI Maintenance course is too lengthy and too specialized to achieve the generalizability desired for this study.

A-5. Final Selection of Segment of Instruction

After a thorough analysis of each candidate, the five-week Steam Plant Automatic Boiler Controls (ABC) Hagan course was selected as the segment of instruction for the following major reasons:

- It contains all major elements of advanced maintenance training and is generalizable to electro and electro-mechanical troubleshooting and repair in such areas as:

  a. Diagnostic troubleshooting

  b. Fault isolation

  c. Component disassembly and repair

  d. Component reassembly and calibration

- It involves training materials ranging from basic hand tools to sophisticated pneumatic control and calibration devices that would lend themselves to simulation and the application of advanced training technology.

- It is expected to remain in high demand. Requirements for combustion control training devices, and ratings involved with the training, will be continuing because of commitment of Naval engineering to high pressure plants.

- It has a readily-definable skill level for entry.

- It does not require follow-on training prior to OJT in the Fleet.

- It can provide immediate and continuous feedback since many ships with ABC equipment are readily available in San Diego.

The Steam Generating Plant Inspection and Certification Program was judged to be a less appropriate selection than the ABC course because:

- The variety of training materials used in this course is smaller than that required for the ABC course.

- The course content is not as generalizable to other troubleshooting and repair maintenance activities.

- The course does not require as much "hands on" training as the ABC course. Such training is necessary to exercise fully the advances in training and simulation technology which this study is designed to address.

The same considerations apply with respect to the combination of parts of the Electrician's Mate Maintenance and the Woodward Governor 2301 course. In addition, it was also judged that:

- It would be difficult to combine the fragmented subject matter of these courses into a cohesive and integrated training system in such a way that training effectiveness could be meaningfully evaluated.

- The combination of courses offers even less opportunity for generalization than the SGPI course.

- One of the two courses (the Woodward Governor) addresses too small a population of the Navy's marine engineering maintenance force.

Therefore, the Steam Plant Automatic Boiler Controls Hagan course was judged to be the most appropriate segment of instruction currently available among the Navy's marine engineering maintenance training courses and provided the additional advantages of convenient geographical location and ready availability of shipboard equipments.

A-6. Fault Analysis Algorithms

An important by-product of this study was the derivation of algorithms to diagram fault isolation sequences. The algorithms, coupled with the task analyses, facilitated the identification of the significant decision, action and knowledge task elements, and enabled the selection of appropriate task sequences based on binary (yes-no) decisions.

It was beyond the scope of this study to provide fault analysis algorithms for the entire ABC Hagan course. Examples are, however, presented in Figures B-1 and B-2.

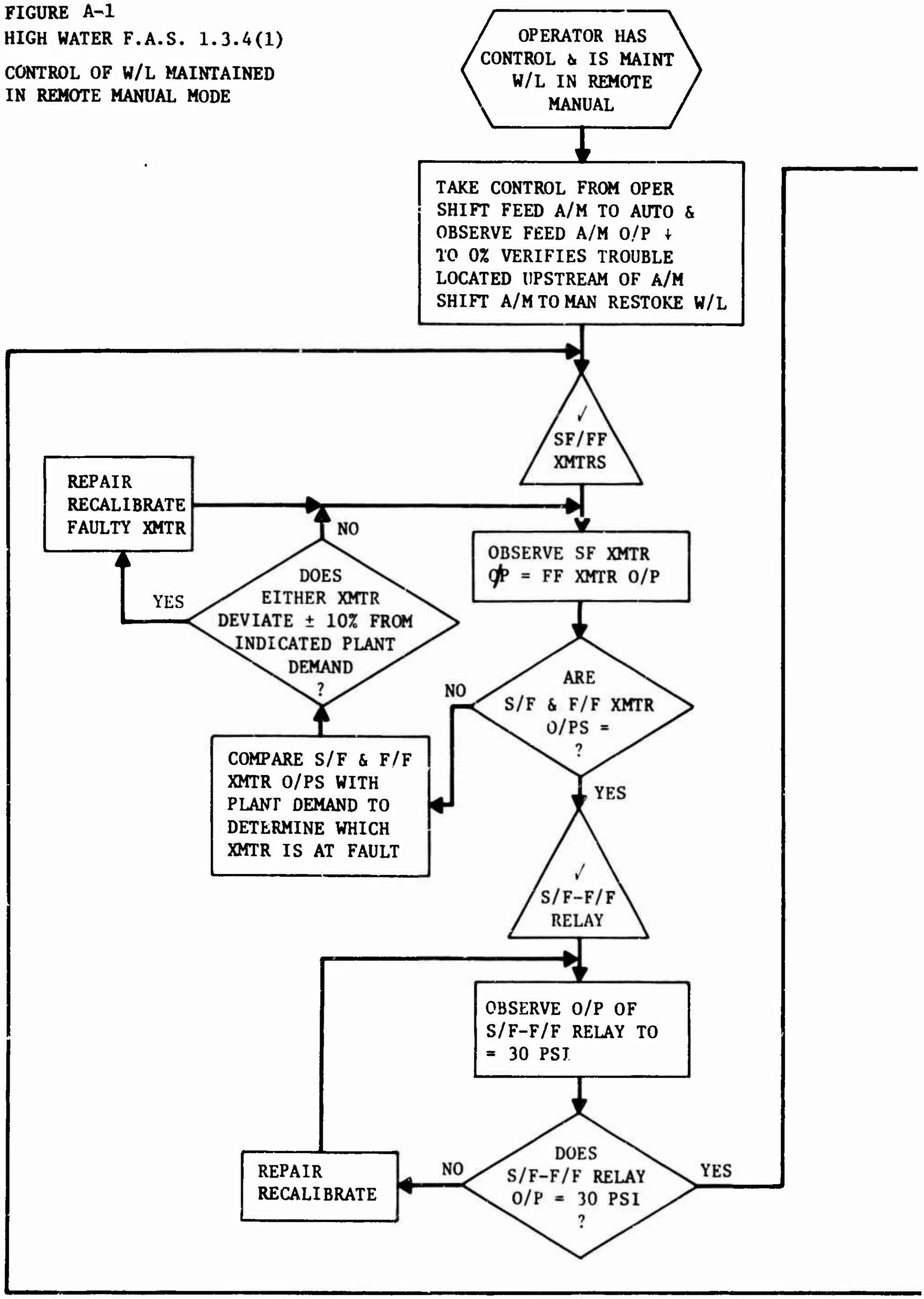
Figure B-1 represents the sequence of troubleshooting activities when water level (w/l) is controlled in the remote manual mode. Figure B-2 indicates the sequence when operating in the local manual mode. Table B-1 presents a glossary of abbreviations and symbols used in the algorithms.

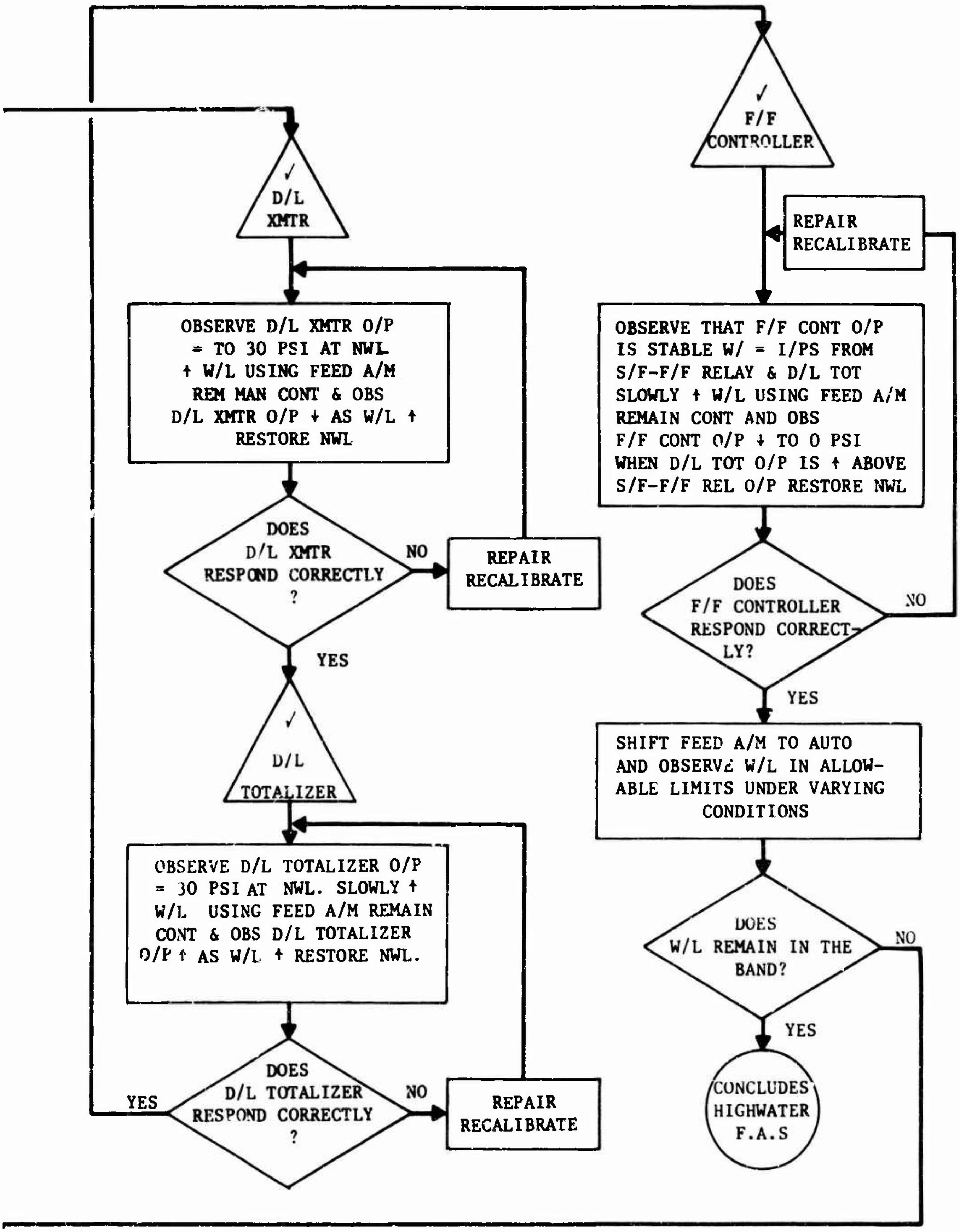
B-7. Examples of Failure Symptoms - Black and White Smoke

In the development of troubleshooting fault analysis sequences attention was given to the specific indications used by the maintenance technician to identify a failed component. The symptoms for the black smoke, white smoke, low water, high water, low steam pressure, and high steam pressure are presented in Tables B-2 through B-7.

FIGURE A-1
HIGH WATER F.A.S. 1.3.4(1)

CONTROL OF W/L MAINTAINED
IN REMOTE MANUAL MODE




✓ F/F CONTROLLER
REPAIR RECALIBRATE
✓ D/L XMTR
OBSERVE D/L XMTR O/P = TO 30 PSI AT NWL ↑ W/L USING FEED A/M REM MAN CONT & OBS D/L XMTR O/P ↓ AS W/L ↑ RESTORE NWL
OBSERVE THAT F/F CONT O/P IS STABLE W/ = I/PS FROM S/F-F/F RELAY & D/L TOT SLOWLY ↑ W/L USING FEED A/M REMAIN CONT AND OBS F/F CONT O/P ↓ TO 0 PSI WHEN D/L TOT O/P IS ↑ ABOVE S/F-F/F REL O/P RESTORE NWL
DOES D/L XMTR RESPOND CORRECTLY ?
NO
REPAIR RECALIBRATE
DOES F/F CONTROLLER RESPOND CORRECT-LY?
NO
YES
YES
✓ D/L TOTALIZER
SHIFT FEED A/M TO AUTO AND OBSERVE W/L IN ALLOW-ABLE LIMITS UNDER VARYING CONDITIONS
OBSERVE D/L TOTALIZER O/P = 30 PSI AT NWL. SLOWLY ↑ W/L USING FEED A/M REMAIN CONT & OBS D/L TOTALIZER O/P ↑ AS W/L ↑ RESTORE NWL.
DOES W/L REMAIN IN THE BAND?
NO
YES
DOES D/L TOTALIZER RESPOND CORRECTLY ?
YES
NO
REPAIR RECALIBRATE
CONCLUDES HIGHWATER F.A.S

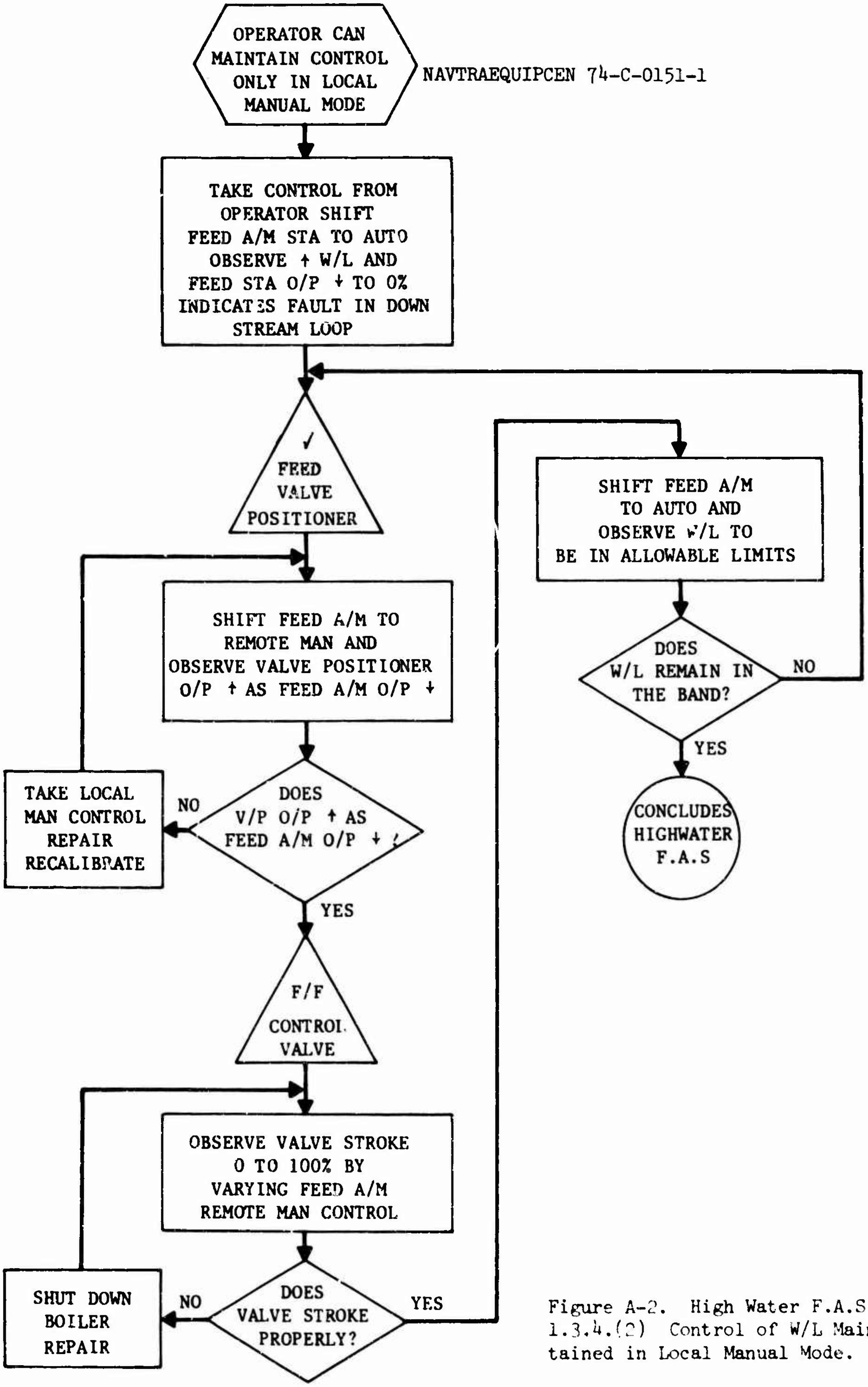


Figure A-2. High Water F.A.S. 1.3.4.(2) Control of W/L Maintained in Local Manual Mode.

TABLE A-1. ABBREVIATIONS AND SYMBOLS USED IN FIGURES A-1 AND A-2

A/M - Automatic/Manual

D/L - Drum Level

F/F - Feed Flow

FDB - Forced Draft Blower

I/P - Input

IAW - In Accordance with

NWL - Normal Water Level

O/P - Out Put

S/F - Steam Flow

STM - Steam

W/O - Without W/ With

XMTR - Transmitter

W/L - Water Level

FO - Fuel Oil

REM MAN. - Remote Manual

$=$ - Equal to

$\neq$ - Not Equal To

$\simeq$ - Approx. Equal

$\uparrow$ - Increase or Increasing

$\downarrow$ - Decrease or Decreasing

$\not\uparrow$ - Does Not Increase

$\not\downarrow$ - Does Not Decrease

$<$ - Less Than

$>$ - Greater Than

ΔP - Differential Pressure

✓ - Check

<u>SKILLS</u>

Per Mot - Perceptual Motor

MEM - Memory

MOT - Motor

Org. - Organization

TABLE A-2. FAILURE SYMPTOMS - BLACK SMOKE

Affected Unit	Symptoms
Signal Selector	FO Demand > Air Flow
Excess Air Adjuster	FO Demand = or < Air Flow
	Blower speeds not compatible with plant demand
	Excess air adjuster output ≠ air flow Xmtr output
Air Flow Xmtr	FO Demand = or < air flow
	Blower speeds not compatible with plant demand
	Excess air adjuster output = air flow Xmtr output
Steam Atom. System	FO demand = or < air flow
	Blow speeds compatible with plant demand
	Steam atom. pressure not at desired valve
Diff. Pressure Pilot Controller	Same as Steam Atom. System - and output of DPPC does not respond rapidly to FO pressure changes
Volume booster	Same as Steam Atom. System - and output of DPPC esponds rapidly to FO pressure changes
	Volume booster output ≠ DPPC output
Steam Atom. Control Volume	Same as Steam Atom. System - and output of DPPC resonds rapidly to FO pressure changes
	Volume booster output = DPPC output
	Control valve does not close with 3 psi signal - opens with 15 psi signal from volume booster
Characterizing Relay	FO Demand = or < air flow
	Blower speeds compatible with plant demand
	Steam atom. pressure at desired valve, or
	Steam atom. pressure not at desired valve, and control valve closes and opens in response to signal
	Characterizing relay output does not correspond to data table

TABLE A-2. FAILURE SYSPTOMS - BLACK SMOKE (Cont)

Affected Unit	Symptoms
FO Flow Control Valve	Characterizing relay output corresponds to data table
	FO pressure varies smoothly as FO output is varied

TABLE A-3. FAILURE SYMPTOMS - WHITE SMOKE

Affected Unit	Symptoms
Characterizing Relay	Relay output does not correspond to data table
FO Flow Control Value	Characterizing relay O/P does correspond to data table
	FO pressure does nto vary smoothly as FO O/P is varied
Compensating Relay	Characterizing Relay O/P does correspond to data table
	FO pressure varies smoothly as FO O/P is varied
	FO O/P does not equal the input in the auto mode
Downstream Air Loop	Characterizing relay O/P does correspond to data table
	FO pressure varies smoothly as FO O/P is varied
	FO O/P equals input in auto
	Blowers do not respond smoothly throughout the range to varied FDB A/M station output
Range Modifier	Range modifier output does not corresponde to FDB O/P (table data)
FDB Governor and Steam Emission Valve	Range modifier output does correspond to FDB O/P
	Defects identified by inspection
Upstream Air Loop	Characterizing relay O/P does correspond to data table
	FO pressure varies smoothly as FO O/P is varied
	FO O/P equals input in auto
	Blowers respond smoothly through range with varied FDB O/P
Air Flow Rate Relay	FDB Auto I/P does not decrease to 0 when excess air adjuster is increased over boiler demand
	Air flow rate relay O/P does not equal air flow controller input

TABLE A-3. FAILURE SYMPTOMS - WHITE SMOKE (Cont)

Affected Unit	
Air Flow Controller	FDB auto I/P does not decrease to 0 when excess air adjuster is increased over boiler demand
	Air flow rate relay O/P equals air flow controller input
	Stack still not clear
Excess Air Adjuster	FDB auto I/P does decrease to 0 when excess air adjuster is increased over boiler demand
	Stack still not clear
	Excess air adjuster O/P does not equal air flow Xmtr O/P
Air Flow Xmtr	FDB auto I/P does decrease to 0 when excess air adjuster is increased over boiler demand
	Stack still not clear
	Excess air adjuster O/P equals air flow Xmtr C/P

TABLE A-4. FAILURE SYMPTOMS - LOW WATER

Affected Unit	Symptoms
Feed valve	A/M output increases to 100%
	Valve position output decreases as A/M output increases
Valve Positioner	A/M output increases to 100%
	Valve position output does not decrease as A/M output increases
Feed Flow Transmitter	A/M output does not increase to 100%
	Steam flow transmitter output does not equal feed flow transmitter output
	Steam flow transmitter does not deviate from plant demand
	Feed flow transmitter does deviate from plant demand
Steam Flow Transmitter	A/M output does not increase to 100%
	Steam flow transmitter output does not equal feed blow transmitter output
	Steam flow transmitter deviates from plant demand
Drum Level Transmitter	A/M output does not increase to 100%
	Steam flow transmitter output equals feed flow transmitter output
	Drum level transmitter output not at 30 psi at normal water level and D/L output does not increase as water level decreases
Drum Level Totalizer	A/M output does not increase to 100%
	Steam flow transmitter output equals feed flow transmitter output

TABLE A-4. FAILURE SYMPTOMS - LOW WATER (Cont)

Affected Unit	Symptoms
Drum Level Totalizer, contd.	Drum level transmitter output at 30 psi at normal water level and D/L output increases as water level decreases
	Drum level totalizer output not at 30 psi at normal water level and output does not decrease as the water level decreases
Feed Flow Controller	A/M output does not increase to 100%
	Steam flow transmitter output equals feed flow transmitter output
	Drum level transmitter output at 30 psi at normal water level and D/L output increases as water level decreases
	Drum level totalizer output at 30 psi at normal water level and output decreases as water level decreases

TABLE A-5. FAILURE SYMPTOMS - HIGH WATER

Affected Unit	Symptoms
Feed Flow Tranmistter	A/M output decreases to 0%
	Steam flow transmitter output does not equal feed blow transmitter output
	Feed blow transmitter deviates for plant demand
Steam Flow Transmitter	A/M output decreases to 0%
	Steam flow transmitter output does not equal feed flow transmitter output
	Steam flow transmitter deviates for plant demand
Steam Flow - Feed Flow Relay	A/M output decreases to 0%
	Steam flow transmitter output equals feed flow transmitter output
	Steam flow - feed flow relay output does equal 30 psi
Drum Level Transmitter	A/M output decreases to 0%
	Steam flow transmitter output equals feed flow transmitter output
	Drum level transmitter output does not equal 30 psi at normal water level
	Output does not decrease as water level is increased
Drum Level Totalizer	A/M output decreases to 0%
	Steam flow transmitter output equals feed flow transmitter output
	Drum level transmitter output equals 30 psi at normal water level and decreases as water level is increased
	Drum level totalizer output does not equal 30 psi and does not increase as water level increases

TABLE A-5. FAILURE SYMPTOMS - HIGH WATER (Cont)

Affected Unit	Symptoms
Feed Flow Controller	A/M output decreases to 0%
	Steam flow transmitter output equals feed flow transmitter output
	Drum level transmitter output equals 30 psi at normal water level and decreases as water level is increased
	Drum level totalizer output equals 30 psi and increases as water level increases
	Feed blow controller output erratic - decreases to 0 psi when drum level totalizer output is increased above the level of the steam flow - feed flow relay output

TABLE A-6. FAILURE SYMPTOMS - LOW STEAM PRESSURE
INITIAL SYMPTOM - DECREASING STEAM PRESSURE

Affected Unit	Symptoms
Boiler Master Station	Output does not increase as input increases
Inverting Relay	Boiler master output increases as input increases
	Relay output does not equal 60 psi less high signal selector otuput
Steam Pressure Controller	Boiler master output increases as input increases
	Relay output equals 60 psi less high signal selector output
	Controller output does not decrease to 0 as steam pressure drops below 1,275 psi
	Relay output does not equal air flow controller input
Air Flow Controller	Boiler master output increases as input increases
	Relay output equals 60 psi less high signal selector output
	Controller output decreases to 0 as steam pressure drops below 1275 psi
	Relay output equals air flow controller input
	Controller output does not equal 0 with air flow above demand
Air Flow Transmitter	Boiler master output increases as input increases
	Relay output equals 60 psi less high signal selector output
	Controller output decreases to 0 as steam pressure drops below 1275 psi
	Relay output equals air flow controller input
	Controller output equals 0 with air flow above boiler demand

TABLE A-6. FAILURE SYMPTOMS - LOW STEAM PRESSURE INITIAL SYMPTOM - DECREASING STEAM PRESSURE (CONT)

Affected Unit	Symptoms
Air Flow Transmitter, contd.	Blower response stable
Range Modifier	Boiler master output increases as input increases
	Relay output equals 60 psi less high signal selector output
	Controller output decreases to 0 as steam pressure drops belcw 1275 psi
	Relay output equals air flow controller input
	Controller output equals 0 with air flow above boiler demand
	Blower response erratic
Forced Draft Blower Governmor and Emission Valve	Boiler master output increases as input increases
	Relay output equals 60 psi less high signal selector output
	Controller output decreases to 0 as steam pressure drops below 1275 psi
	Relay output equals air flow controller input
	Controller output equals 0 with air flow above boiler demand
	Boiler response erratic
	Range modifier output corresponds to forced draft blower output

TABLE A-7. FAILURE SYMPTOMS - HIGH STEAM PRESSURE
INITIAL SYMPTOM - DRUM LEVEL STEAM PRESSURE NOT AT REQUIRED VALVE

Affected Unit	Symptoms
Boiler Master A/M Station	Boiler master output does not decrease to 0 as steam pressure increases above 1275 psi
	Boiler master output does not track input
Inverting Relay	Boiler master output does not decrease to 0 as steam pressure increases above 1275 psi
	Boiler master output tracks inout
	Inverting relay output does not decrease to 0 as high signal selector output increases
High Signal Selector	Boiler master output does not decrease to 0 as steam pressure increases above 1275 psi
	Boiler master output tracks input
	Relay output decreases to 0 as high signal selector output increases
	High signal selector output does not equal steam pressure controller output
Steam Pressure Controller	Boiler master output does not decrease to 0 as steam pressure increases above 1275 psi
	Boiler master output tracks input
	Relay output decreases to 0 as high signal selector output increases
	High signal selector output equals steam pressure controller output
	Steam pressure controller output does not increase to 60 psi as steam pressure increases above 1275 psi
Low Signal Selector	Boiler master output decreases to 0 as steam pressure increases above 1275 psi
	Steam pressure controller output increases to 60 as pressure increases above 1275 psi

TABLE A-7. FAILURE SYMPTOMS - HIGH STEAM PRESSURE INITIAL SYMPTOM - DRUM LEVEL STEAM PRESSURE NOT AT REQUIRED VALVE (Cont).

Affected Unit	Symptoms
Low Signal Selector, contd.	Fuel oil A/M output does not decrease to 0 as boiler output decreases to 0
Characterizing Relay	Boiler master output decreases to 0 as steam pressure increases above 1275 psi
	Fuel oil output decreases to 0 as boiler output decreases to 0
	Characterizing relay output does not decrease to minimum as fuel oil output decreases to 0
Fuel Oil Control Valve	Boiler master output decreases to 0 as steam pressure increases above 1275 psi
	Fuel oil output decreases to 0 as boiler output decreases to 0
	Characterizing relay output decreases to minimum as fuel oil output decreases to 0
	Fuel oil pressure decreases to minimum as fuel oil output decreases to 0

APPENDIX B. DETAILED COURSE REQUIREMENTS

The development of detailed course requirements proceeds systematically from the job task analyses. The succession of analytic and synthesizing steps is described and illustrated in the following appendix.

A review of the job task analyses resulted in the identification of seven training objectives (T/O) concerned with imparting knowledge and six training objectives concerned with skill acquisition (see Table C-1).

Each of these training objectives was analyzed within its job task analysis context to determine its specific training requirements in terms of major component factors. The major component factors for the knowledge T/O concern facts, principles, sequences and decisions. For the skill acquisition T/O the major factors concern knowledge/information, decisions and manipulations.

Tables C-2 through C-8 present the training requirements which were identified for each of the knowledge T/O categories. The reader will note a certain amount of redundancy among these several tables. For example, "sources of data," "time constraints," "failure effects," etc., appear on several T/O listings. Tables C-9 through C-14 present training requirements for the six familiarization and skill acquisition T/O categories dealing with troubleshooting, preventive maintenance, inspection, and component removal, assembly, disassembly, repair and calibration.

The training requirements shown in Tables C-2 through C-14 provided the basic data for identifying the course content requirements shown in Table C-15. The course content requirements and the aggregated training

TABLE B-1. TRAINING OBJECTIVES.

KNOWLEDGE:

1. Using system diagrams, describe system, subsystem, and component structure, location, operation, and function.

2. Demonstrate knowledge of preventive maintenance and inspection requirements, decisions, procedures, techniques and criteria.

3. Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type.

4. Given representative component repair requirements, identify tools and techniques required for repair of each component type.

5. Using visual representations and mockups, demonstrate knowledge of procedures and techniques of fault isolation and component removal/replacement.

6. Using visual representations and displays, be able to correctly identify fault event cues and failure effects.

7. Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.

SKILL:

8. Using an operational system representation, describe procedures to detect and locate faults at the component level.

9. Using operational system representation, describe component removal/replacement, inspection and repair components.

10. Using an operational system representation, describe disassembly, test and calibration procedures.

11. Using an operational system representation, correctly complete system preventive maintenance and inspection procedures.

12. Using an operational system representation, correctly complete system calibration and component assembly, disassembly, and repair.

13. Using an operational system representation, correctly identify and locate failed components in different failure conditions.

requirements then provided the basic data for the derivation of "course modules" and for their desired sequence of presentation in terms of the four course phases: I. Conceptual; II. Maintenance Requirements and Strategy; III. Learning and Familiarization; and IV. Practice and Assessment. These data are presented in Table C-16.

Thus, this analytic and synthesizing procedure proceeded from the detailed task/step job descriptive level of the JTA through a succession of data extraction and combining steps which resulted in a course outline for systematically imparting the required knowledge and skills. The analytic sequence is such that specific contents of the course modules can be reconstructed from data available in the previous analytic step. Similarly, the basic data supporting any analysis in the sequence are available from the antecedent analysis.

TABLE B-2. TRAINING REQUIREMENTS FOR T/O CATEGORY 1

<u>T/O CATEGORY 1</u>: Using system diagrams, describe system, subsystem, and component structure, location, operation, and function.

<u>FACTS</u>:

System structure, function, and modes of operation

Nomenclature

Subsystem structure and function

Subsystem components

Subsystem location

Component structure and structural interfaces

Component function and functional interfaces

Component modes of operation

Component location

<u>PRINCIPLES</u>:

Principles of system operation

Principles of subsystem operation

Principles of component operation

<u>SEQUENCES</u>:

Steam processing

Water processing

Air processing

TABLE B-3. TRAINING REQUIREMENTS FOR T/O CATEGORY 2

T/O CATEGORY 2: Demonstrate knowledge of preventive maintenance and inspection requirements, decisions, procedures, techniques and criteria.

FACTS:

Sources of PM-Inspection requirements and criteria
Time constraints
PM and Inspection schedules
Specific PM operations and techniques
Specific inspection operations and techniques
Precautions and warnings

PRINCIPLES:

Results of no PM or inspection
PM strategies
Inspection strategies

SEQUENCES:

Inspection procedures and techniques
- hot plant
- cold plant

PM procedures and techniques
- in port
- at sea

DECISIONS:

PM decisions (information, options, sources of data, and criteria)
- when to perform
- extent of PM
- when to remove/replace
- when to calibrate-test

Inspection decisions
- when to perform
- extent
- when to remove/replace
- when to calibrate-test

TABLE B-4. TRAINING REQUIREMENTS FOR T/O CATEGORY 3

T/O CATEGORY 3: Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type.

FACTS:

Sources of data

Time constraints

Specific calibration operations

Precautions and warnings

PRINCIPLES:

Calibration strategies

SEQUENCES:

Calibration procedures and techniques

- in place
- at test stand

DECISIONS:

Acceptability criteria and tolerances

Sources of criteria

Calibrate/test in place or at test stand

Repair/Replace decisions

TABLE B-5. TRAINING REQUIREMENTS FOR T/O CATEGORY 4

T/O CATEGORY 4: Given representative component repair requirements, identify tools and techniques required for repair of each component type.

FACTS:

Sources of data
Time constraints
Tool nomenclature
Special warnings
Specific repair operations
Special handling requirements
Part identification

PRINCIPLES:

Expansion of component operation principles

SEQUENCES:

Component assembly/disassembly
Component part inspection
Part removal-replacement
Tool utilization techniques

DECISIONS:

Repair location decision - in place or at work bench
Repair verification decision

TABLE B-6. TRAINING REQUIREMENTS FOR T/O CATEGORY 5

T/O CATEGORY 5: Using visual representations and mockups, demonstrate knowledge of procedures and techniques of fault isolation and component removal/replacement.

FACTS:

Verification criteria
Time constraints
Precautions and warnings
Sources of data (e.g., criteria, procedures, etc.)
Tool nomenclature
Component structural interfaces
Special handling requirements

PRINCIPLES:

Expansion of component operational principles and interfaces

SEQUENCES:

Procedures and techniques for:

- preparing the system/subsystem
- preparing the component
- actual removal/replacement
- transportation of component

DECISION:

Verification of preparation
Verification of replacement

TABLE B-7. TRAINING REQUIREMENTS FOR T/O CATEGORY 6

T/O CATEGORY 6: Using visual representations and displays, be able to correctly identify fault event cues and failure effects.

FACTS:

Specific cues and implications for system operation

Time constraints

Precautions and cautions

Typical failures producing cues

Failure effects - on system operation

Display and control locations

Display correct readings and tolerances

PRINCIPLES:

Expansion of system operation and function

Failure modes and effects

SEQUENCES:

DECISIONS:

Display out of tolerance

Fault detection verification

TABLE B-8. TRAINING REQUIREMENTS FOR T/O CATEGORY 7

T/O CATEGORY 7: Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.

FACTS:

Correct display readings and tolerances

Display locations

Time constraints

Precautions and warnings

Sources of data

Nomenclature

PRINCIPLES:

Troubleshooting strategies

SEQUENCES:

Check procedures for isolating to a subsystem

Check procedures for isolating to a component

DECISIONS:

Check decisions based on display readings, comparisons, responses, trends

Subsystem decision

Component decision

TABLE B-9. TRAINING REQUIREMENTS FOR T/O CATEGORY 8

T/O Category 8: Using an operational system representation, describe procedures to detect and locate faults at the component level.

KNOWLEDGE/INFORMATION FACTORS:

Identify controls and displays

Read displays

Integrate data from displays

Know sequences to isolate a fault to a subsystem or loop

Know sequences to isolate a fault to a component

Know correct values of displayed data

Know fault cues

Know locations of technical publications

Know how to use technical publications

Know safing procedures

DECISIONS:

Discriminate controls and displays

Discriminate system responses

Judge whether displayed data are correct

Judge that a failure has occurred

Identify the failed component

MANIPULATIONS:

Manipulate controls to adjust display readings

Manipulate controls to change system configuration

TABLE B-10. TRAINING REQUIREMENTS FOR T/O CATEGORY 9

<u>T/O CATEGORY 9</u>: Using an operational system representation, describe component removal/replacement, inspection and repair procedures.

<u>KNOWLEDGE/INFORMATION FACTORS</u>:

Know how to transport component

Know inspection routines

Know removal/replacement procedures

Know repair procedures

Know component isolation procedures

Identify tools

Identify component parts

<u>DECISIONS</u>:

Determine if component should be removed or repaired in place

Verify component is isolated

Verify component is repaired

<u>MANIPULATIONS</u>:

Manipulate controls to configure system for component removal

Manipulate tools to prepare for component removal

Assemble tools

Remove the component from the system

Remove/replace component parts

Replace the component

Set up component handling - transport device

TABLE B-11. TRAINING REQUIREMENTS FOR T/O CATEGORY 10

<u>T/O CATEGORY 10</u>: Using an operational system representation, describe disassembly, test and calibration procedures.

<u>KNOWLEDGE/INFORMATION FACTORS</u>:

Know assembly/disassembly procedures

Know test setup procedures

Know calibration procedures

Read displays

Compare displays and calibration tables

Identify tools

Know correct values of displayed data

<u>DECISIONS</u>:

Identify failed component part

Verify test

Verify calibration

<u>MANIPULATIONS</u>:

Set up test stand controls

Assemble tool set

Select tools

TABLE B-12. TRAINING REQUIREMENTS FOR T/O CATEGORY 11

T/O CATEGORY 11: Using an operational system representation, correctly complete system preventive maintenance and inspection procedures.

KNOWLEDGE/INFORMATION FACTORS:

Know PM procedures

Know location of PM cards

Know how to use cards

Know inspection procedures and routines - hot and cold plant

Identify displays

Read and integrate displays

Know component location, operation, configuration, nomenclature

DECISIONS:

Verify PM complete

Verify inspection complete

MANIPULATIONS:

Manipulate controls

Handle test sets

TABLE B-13. TRAINING REQUIREMENTS FOR T/O CATEGORY 12

T/O CATEGORY 12: Using an operational system representation, correctly complete system calibration and component assembly, disassembly and repair.

KNOWLEDGE/INFORMATION FACTORS:

Identify components

Identify component parts

Identify controls and displays

Integrate data from displays

Know calibration procedures

Know assembly/disassembly procedures

Know component removal/replacement procedures

Know component repair procedures

Know safing procedures

Know effects of repair operation

Know component handling and transport procedures

Know test stand setup procedures

DECISIONS:

Isolate fault to component part

Verify repair

Judge calibration data accuracy

MANIPULATIONS:

Handle-transport components

Select-handle tools

Manipulate controls

Prepare the system for component removal

TABLE B-14. TRAINING REQUIREMENTS FOR T/O CATEGORY 13

T/O CATEGORY 13: **Using an operational system representation, correctly identify and locate failed components in different failure conditions.**

KNOWLEDGE/INFORMATION FACTORS:

Identify controls-displays

Identify components

Know troubleshooting routines-procedures

Know failure cues

Know correct display readings

Know time criticality - each failure mode

Know location of publications and support data

Know how to use publications and support data

DECISIONS:

Determine next action based on displayed data

Isolate failure to a loop

Isolate failure to a component

Judge how and when to assume control

Judge time criticality

MANIPULATIONS:

Manipulate controls

TABLE B-15. COURSE CONTENT REQUIREMENTS

1. ABC maintenance philosophy, responsibilities and requirements

2. ABC system structure

    Major subsystems and components

        location
        identification
        structural relationships

3. ABC system functions

    Total system

    Major subsystems and components

        functions/operations
        failure signs/symptoms
        functional relationships

4. Component structure - physical configuration, parts, nomenclature

5. Component functions - operation of parts

6. Preventive maintenance procedures, sequences, schedules

7. Repair and calibration procedures and sequences

8. Inspection procedures and sequences

9. Troubleshooting procedures, sequences and decisions

10. Maintenance system components

    Technical publications

    Tools

    Calibration devices

    Test equipment

TABLE B-16. ABC HAGAN MAINTENANCE COURSE OUTLINE

	COURSE PHASES			
	I. CONCEPTUAL	II. ABC HAGAN MAINT. REQUIREMENTS & STRATEGY	III. LEARNING & FAMILIARIZATION: PROCEDURES & DECISIONS	IV. PRACTICE & ASSESSMENT
COURSE MODULES	Orientation to ABC Hagan & Overview	Maintenance Philosophy	Safety Procedures General	Safety Procedures Practice & Assessment
	System & Subsystem Structure	PM Requirements*	PM Procedures & Decisions	PM Practice & Assessment
	System & Subsystem Function	Calib./Repairs Requirements*	Calib./Repairs Procedures & Decisions	Calib./Repairs Practice & Assessment
	System & Subsystem Operation	Inspection Requirements*	Inspection Procedures & Decisions	Inspection Practice & Assessment
	Component Structure & Function	Troubleshooting Requirements*	Troubleshooting Procedures & Decisions	Troubleshooting Practice & Assessment
		*Requirements: Who? What? Where? When? Why?		

APPENDIX C. DEVICE EVALUATION PROCEDURE AND RESULTS

It is axiomatic that training devices differ in terms of their design characteristics, and that design characteristics are differentially important depending upon the training goals and the contents of particular training course segments. Therefore, any attempt to determine whether Device A is superior to Device B must accommodate these variables. The several design characteristics must be evaluated in terms of their individual effectiveness in meeting specified training goals, and the evaluation scheme must be equally appropriate for a diversity of design characteristics.

Since there is no single yardstick against which diverse design characteristics can be measured we elected to use the pooled ratings of five judges who evaluated each characteristic of each candidate device in terms of satisfying the training objectives of the selected course segment.

The evaluation method involved the specification of device characteristics (dimensions to be rated), the assignment of importance weights to these characteristics, and the assignment of ratings for each device in terms of the extent to which it possessed each characteristic. Mean ratings were multipled by the assigned weights and were averaged across the evaluation categories of effectiveness, usability and cost. These three category means were then weighted in terms of their judged relevance for this study to arrive at a single figure of merit.

The specific steps followed in this evaluation process were as follows:

(1) Categorize devices in terms of their appropriateness for imparting knowledge and information or in developing job skills. (see table 4)

(2) Identify the characteristics of the candidate media which are appropriate for imparting information and knowledge alone, for development of skills alone, or for both knowledge and information and skills (table D-1).

(3) Sort the design characteristics in terms of whether they concern training effectiveness or whether they influence the convenient usability or cost of the training device (see Table D-2).

The above exercise resulted in the identification of 13 "effectiveness" characteristics for the knowledge/information devices and 8 for the skills devices. Some overlap existed since three characteristics were common to both types of devices. Similarly, 12 "usability" characteristics were identified for the knowledge/information devices and for the skills devices.

In addition to the effectiveness and usability rating scales, the devices were also rated in terms of three cost characteristics (initial hardware and software costs and life cycle costs).

The next exercise involved the determination of the weights to be assigned to each characteristic.

(1) Each of five judges independently assigned an importance weight to the characteristics which were identified as influencing training effectiveness. These weights were assigned on a 10-point scale for each training objective category with a rating of 10 indicating maximum effectiveness. For example, if a T/O category such as "troubleshooting procedures and

TABLE C-1. MEDIA CHARACTERISTICS

KNOWLEDGE AND INFORMATION MEDIA	SKILLS MEDIA
• Visual Representation - pictorial - graphic - color - text • Motion Representation • Format Flexibility - capability of modifying information formats • Sound Representation • Branching • Scoring • Clarity - resolution	• Fidelity of Simulation - displays - system response - student response - system configuration • Range of Fault Capability • Safety
BOTH TYPES OF MEDIA	
• Prompting and cueing capability • Different levels of difficulty • Operability • Maintainability • Reliability • Transportability • Space requirements • Update capability • Extent of programming requirements • Special requirements • Generalizability • Applicability across training objectives • Support requirements • Instructor requirements	

TABLE C-2. EVALUATION CRITERIA AND ASSOCIATED MEDIA CHARACTERISTICS

EFFECTIVENESS	
• Visual Representation - pictorial - graphic - color - text	• Scoring
• Motion Representation	• Prompting and Cueing Capability
• Clarity of Representation	• Different Levels of Difficulty
• Format Flexibility	• Operability
• Sound Representation	• Fidelity of Simulation - display - system response - student response - system configuration
• Branching	• Range of Fault Capability
USABILITY	
• Maintainability	• Extent of Programming Requirements
• Reliability	• Special requirements
• Safety	• Generalizability
• Transportability	• Applicability Across Training Objectives
• Space Requirements	• Support Requirements
• Update Capability	• Instructor Requirements
COST	
• Initial Software Cost	
• Initial Hardware Cost	
• Life Cycle Cost	

decisions" was judged as benefiting from a pictorial portrayal of a sequence of action then device characteristics such as "pictorial" and "motion capability" would be accorded high weights. This weighting exercise was conducted separately for: (a) devices using knowledge imparting media to meet the training objectives; and (b) devices using skill training media.

(2) Each of the judges then assigned an importance weight (1-10 scale) to each characteristic to indicate its judged importance in influencing the usability of the device and the cost features of the device whether for knowledge and information training or for skills training.

(3) The assigned weights were averaged for the five judges and rounded to the nearest whole number. The assignment of importance weights to each characteristic was therefore based on a review of the training requirements associated with each respective training objective category, and on judgments of the importance of the attribute inherent in each characteristic for that particular T/O category.

The characteristics to be rated and the weights (averaged over all T/O categories) which were developed for the several characteristics are presented in Table D-3 (for devices imparting knowledge and information) and in Table D-4 (for skill training devices).

Use of these scales was straightforward. Each of the five judges independently rated each candidate device on a 1-10 scale in terms of the extent to which it possessed each of the listed characteristics. Mean

TABLE C-3. KNOWLEDGE/INFORMATION TRAINING DEVICE WORKSHEET

		CHARACTERISTICS	WEIGHTS
EFFECTIVENESS	1	Pictorial/photographic	9
	2	Graphic/symbolic	7
	3	Color	7
	4	Motion/rates of motion	8
	5	Clarity/resolution	9
	6	Format flexibility	7
	7	Text	4
	8	Sound capability	7
	9	Branching capability/extent	8
	10	Scoring capability/trainee KOR	9
	11	Prompting/cues	8
	12	Different levels of difficulty	8
	13	Operability/ease of use	9
		SUB-TOTAL/MEAN	
USABILITY	1	Maintainability	8
	2	Reliability	9
	3	Transportability	4
	4	Space requirements	4
	5	Update capability	8
	6	Extent of programming requirements	8
	7	Special requirements	6
	8	Generalizability	9
	9	Applicability across T/O's	8
	10	Support requirements	7
	11	Instructor requirements	9
		SUB-TOTAL/MEAN	
COSTS		Initial software	9
		Initial hardware	8
		Life cycle	9
		SUB-TOTAL/MEAN	
		TOTAL OR WEIGHTED MEANS	

TABLE C-4. SKILLS TRAINING DEVICE WORKSHEET

CHARACTERISTICS			WEIGHTS
EFFECTIVENESS	1	Branching	8
	2	Scoring	9
	3	Prompting/Cues	8
	4	Different levels of difficulty	8
	5	Operability	9
	6	Fidelity of display	10
	7	Fidelity of system response	10
	8	Fidelity of student response	10
	9	Fidelity of system configuration	10
	10	Range of fault capability	9
		SUB-TOTAL/MEAN	
USABILITY	1	Maintainability	8
	2	Reliability	9
	3	Transportability	4
	4	Space Requirements	4
	5	Update capability	8
	6	Extent of programming requirements	8
	7	Special requirements	6
	8	Generalizability	9
	9	Applicability	8
	10	Support requirements	7
	11	Instructor requirements	9
		SUB-TOTAL/MEAN	
COSTS		Initial software	9
		Initial hardware	8
		Life cycle	9
		SUB-TOTAL/MEAN	
		TOTAL	

ratings were computed for each characteristic and were multiplied by the assigned weight for that characteristic. These products were averaged across the characteristics listed for the criterion categories of effectiveness, usability and cost. Thus, each candidate device received a "score" for these criterion measures.

The mean criterion "scores" for effectiveness, usability and cost were then examined and intercorrelations among these scores were found to be uniformly low and not statistically significant. The effectiveness and usability ratings correlated -.01, the effectiveness and cost ratings correlated -.11 and the usability and cost ratings correlated .39. These low intercorrelations would tend to suggest that the judges were not systematically biased and were indeed evaluating separate aspects of the devices. Therefore, the criterion ratings for effectiveness, usability and cost can be treated as evaluations of independent features of the equipments.

The problem now becomes one of determining how three independent aspects of equipments can be simultaneously considered, including whether the three evaluations should be combined into a single figure of merit. A number of assumptions were explored. The following hypothetical examples are provided to illustrate the nature of the problem.

First, let us illustrate a possible finding for three devices (identified as A, B or C). For simplicity, we shall use elemental mean "scores," and hypothesize the following three sets of uncorrelated evaluation aspects:

Device	Effect.	Use	Cost
A	1	3	2
B	2	1	3
C	3	2	1

If the "scores" on the evaluation aspects are simply summed, each device receives the same total score (6) yet their individual qualitative differences are apparent. Therefore, this result is intuitively unsatisfactory.

If we now assign weights to certain of the aspects we can alter the above result (break the tie). It was determined that a realistic scaling of the criteria would treat cost and effectiveness to be equally important and each to be three times as important as usability. We now multiply the effectiveness and cost scores by 3 and obtain:

Device	Effect.	Use	Cost	Sum
A	3	3	6	12
B	6	1	9	16
C	9	2	3	14

which gives edge to device B, and thus breaks the "tie." Clearly, however, the weights to be assigned to the three evaluation aspects are completely arbitrary in the general case and results can be manipulated simply by altering the importance weights.

Under the assumption of equal importance of effectiveness and cost, device scores were obtained for each of the 13 training objective categories listed in Table D-5. The results of these analyses in terms of mean ratings are presented in Tables D-6 through D-8 for effectiveness criteria. Table D-9 presents the ratings for usability and cost criteria. Tables D-10 through D-12 contain the overall integration of criterion scores. These scores contain the totals of the effectiveness, useability and cost ratings from tables 6 through 9.

As indicated in these tables the scores obtained by the device retained essentially the same ordering over all training objectives.

TABLE C-5. TRAINING OBJECTIVE CATEGORIES BY COURSE PHASE

COURSE PHASE	I. CONCEPTUAL	II. MAINTENANCE REQUIREMENTS	III. PROCEDURES & DECISIONS	IV. PRACTICE & ASSESSMENT
COURSE CONTENT AREA	KNOWLEDGE & INFORMATION		HANDS-ON FAMILIARIZATION & DIAGNOSTICS USING REPRESENTATIVE DISPLAYS	ACQUISITION OF PERCEPTUAL, PERCEPTUAL/MOTOR, MOTOR & DIAGNOSTIC SKILLS
TRAINING OBJECTIVE CATEGORIES	1. Using system diagrams, describe system, subsystem and component structure, location, operation, and function. 2. Describe and explain preventive maintenance and inspection requirements, decisions, procedures, techniques and criteria. 3. Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type. 4. Given representative component repair requirements, identify tools and techniques required for repair of each component type. 5. Using visual representations and mockups, describe procedures and techniques of fault isolation and component removal/replacement. 6. Using visual representations and displays, be able to correctly identify fault event cues and failure effects. 7. Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.		8. Using an operational system representation, describe procedures to detect and locate faults at the component level. 9. Using operational system representation, describe component removal/replacement, inspection and repair procedures. 10. Using an operational system representation, describe disassembly, test and calibration procedures.	11. Using an operational system representation, correctly complete system preventive maintenance and inspection procedures. 12. Using an operational system representation, correctly complete system calibration and component assembly, disassembly, and repair. 13. Using an operational system representation, correctly identify and locate failed components in different failure conditions.

TABLE C-6. RESULTS OF TRADEOFFS FOR EFFECTIVENESS CRITERIA KNOWLEDGE AND INFORMATION OBJECTIVES

KNOWLEDGE & INFORMATION TRAINING OBJECTIVE CATEGORIES		LINCOLN LABS	PLATO	TICCIT	BELL & HOWELL	AUTO TUTOR	PIP	PROGRAMMED VIDEO TAPE	SOUND SLIDE	TEXT	MODIFIED PIP
1. System - subsystem structure & function	Score Rank	141 9.	147 8.	159 5.	174 4.	117 10	179 3.	195 1.	150 6.	150 6.	192 2.
2. PM and inspection 3. Calibration rqmts. 4. Repair requirements 5. Component removal/ replacement	Score Rank	135 9.	141 7.	153 5.	168 4.	111 10.	171 3.	187 1.	144 6.	141 7.	184 2.
6. Fault event cues and effects	Score Rank	147 9.	156 6.	168 5.	183 4.	123 10.	187 3.	206 1.	156 6.	156 6.	202 2.
7. Troubleshooting procedures & decisions	Score Rank	144 9.	153 6.	162 5.	168 4.	117 10.	173 3.	191 1.	147 7.	147 7.	187 2.

TABLE C-7. RESULTS OF TRADEOFFS FOR EFFECTIVENESS CRITERIA FAMILIARIZATION TRAINING OBJECTIVE

FAMILIARIZATION TRAINING OBJECTIVE CATEGORIES		LINCOLN LABS	PLATO	TICCIT	BELL & HOWELL	AUTO TUTOR	PIP	PVT	SOUND/SLIDE	PROGRAMMED TVT	MODIFIED PIP	ACTUAL EQUIPMENT	AEMT	EC II	PART TASK TRAINING
8. Fault diagnosis	Score Rank	138 9.	150 6.	165 5.	174 4.	117 10.	180 3.	198 1.	147 7.	147 7.	195 2.	183 3.	234 1.	213 2.	117 4.
9. Inspect & repair	Score Rank	132 9.	138 8.	153 5.	159 4.	114 10.	162 3.	180 1.	144 6.	144 6.	177 2.	186 3.	237 1.	216 2.	120 4.
10. Test and calibration	Score Rank	141 9.	153 6.	168 5.	177 4.	120 10.	183 3.	201 1.	150 7.	150 7.	198 2.	192 3.	246 1.	222 2.	123 4.

TABLE C-8. RESULTS OF TRADEOFFS FOR EFFECTIVENESS CRITERIA SKILLS TRAINING OBJECTIVES

SKILLS TRAINING OBJECTIVE CATEGORIES		ACTUAL EQUIPMENT	AEMT	EC II	PART TASK TRAINER
11. PMS inspection 12. Test and calibration	Score Rank	183 3.	237 1.	213 2.	117 4.
13. Troubleshooting	Score Rank	195 3.	255 1.	228 2.	126 4.

TABLE 9. RESULTS OF TRADEOFFS - USABILITY AND COST CRITERION - ALL TRAINING OBJECTIVES

		LINCOLN LABS	PLATO	TICCIT	BELL & HOWELL	AUTO TUTOR	PIP	PVT	SOUND/SLIDE	PROGRAMMED TEXT	MODIFIED PIP	ACTUAL EQUIPMENT	AEMT	EC II	PART TASK TRAINER
Usability Criteria	Score	54	53	52	59	61	62	57	62	59	60	34	60	63	58
	Rank	11.	12.	13.	7.	4.	2.	10.	2.	7.	5.	14.	5.	1.	9.
Cost Criteria	Score	139	69	121	181	216	233	173	225	217	216	176	140	200	234
	Rank	12.	14.	13.	8.	5.	2.	10.	3.	4.	5.	9.	11.	7.	1.

TABLE C-10. DEVICE RANKINGS FOR KNOWLEDGE/INFORMATION TRAINING OBJECTIVES

(Includes effectiveness, usability, and cost)

KNOWLEDGE & INFORMATION TRAINING OBJECTIVE CATEGORIES		DEVICE TYPES: LINCOLN LABS	PLATO	TICCIT	BELL & HOWELL	AUTO TUTOR	NORELCO PIP	PROGRAMMED VIDEO TAPE	SOUND/SLIDE	PROGRAMMED TEXT	MODIFIED PIP
1. System & subsystem structure & function	Score	334	269	332	414	394	474	425	437	426	468
	Rank	8.	10.	9.	6.	7.	1.	5.	3.	4.	2.
2. PM and inspection; 3. Calibration rqmts.; 4. Repair rqmts.; 5. Component removal/replacement	Score	328	263	326	408	388	466	417	431	417	460
	Rank	8.	10.	9.	6.	7.	1.	4.	3.	4.	2.
6. Fault event cues & effects	Score	340	278	341	423	400	482	436	443	436	478
	Rank	9.	10.	8.	6.	7.	1.	4.	3.	4.	2.
7. Troubleshooting procedures & decisions	Score	337	275	335	408	394	468	421	434	423	463
	Rank	8.	10.	9.	6.	7.	1.	5.	3.	4.	2.
Mean Score		335	271	333	413	394	472	425	438	425	467
Mean Rank		8.	10.	9.	6.	7.	1.	4.	3.	4.	2.

TABLE C-11. DEVICE RANKINGS FOR FAMILIARIZATION TRAINING OBJECTIVES

(Includes effectiveness, useability, and cost)

FAMILIARIZATION TRAINING OBJECTIVES		LINCOLN LABS	PLATO	TICCIT	BELL & HOWELL	AUTO TUTOR	PIP	PVT	SOUND/SLIDE	PROGRAMMED TEXT	MODIFIED PIP	ACTUAL EQUIPMENT	AEMT	EC II	PART TASK TRAINER
8. Fault Diagnosis	Score	331	272	338	414	394	475	428	434	423	471	393	434	476	409
	Rank	9.	10.	8.	6.	7.	1.	4.	3.	5.	2.	4.	2.	1.	3.
9. Inspection & Repair	Score	325	260	326	399	391	457	410	431	420	453	396	437	479	412
	Rank	9.	10.	8.	6.	7.	1.	5.	3.	4.	2.	4.	2.	1.	3.
10. Test & Calibration	Score	334	275	341	417	397	478	431	437	426	474	402	446	485	415
	Rank	9.	10.	8.	6.	7.	1.	4.	3.	5.	2.	4.	2.	1.	3.
Mean Score		330	269	335	410	394	470	423	434	423	466	397	439	480	412
Mean Rank		9.	10.	8.	6.	7.	1.	4.	3.	4.	2.	4.	2.	1.	3.

TABLE C-12. DEVICE RANKINGS FOR SKILLS TRAINING OBJECTIVES

(Includes effectiveness, useability, and cost)

SKILLS TRAINING OBJECTIVE CATEGORIES		ACTUAL EQUIPMENT	AEMT	EC II	PART TASK TRAINER
11. PM and Inspection 12. Test and Calibration	Score Rank	393 4.	437 2.	476 1.	409 3.
13. Troubleshooting	Score Rank	405 4.	455 2.	491 1.	418 3.
Mean Score		399	446	483	413
Mean Rank		4.	2.	1.	3.

Uniformly high (greater than .96) intercorrelations were obtained among the ratings across different training objective categories. This suggests that the evaluation scheme was not sufficiently sensitive to permit discrimination among categories of training objectives. Therefore, mean ratings across categories of training objectives were used in subsequent analyses. The mean scores under the assumption of equal importance of effectiveness and cost are contained in Table D-13.

A second assumption considered is that effectiveness criteria are of primary importance. Under this assumption the effectiveness scores are multiplied by three while usability and cost are multiplied by unity. Thus:

Device	Effect.	Use	Cost	Sum
A	3	3	2	8
B	6	1	3	10
C	9	2	1	12

Under this assumption Device C is selected. The results of the tradeoffs using this approach are presented in Table D-14.

Another assumption would establish the cost criteria as of primary importance. The results for the example would be:

Device	Effect.	Use	Cost	Sum
A	1	3	6	10
B	2	1	9	12
C	3	2	3	8

Using this approach Device B is selected. The results of the tradeoffs using this assumption are presented in Table D-15. Under assumption 4, the values are the scores listed in the first column (effectiveness) of table D-15. For assumption 5 the scores are from the third column (labeled cost) of table D-14.

TABLE C-13. MEAN SCORES BY DEVICES UNDER ASSUMPTION 1, EFFECTIVENESS AND COST OF EQUAL IMPORTANCE

	EFFECTIVENESS	USABILITY	COST	TOTAL
KNOWL./INFO. DEVICES:				
NORELCO PIP	176	62	233	471
MODIFIED PIP	191	60	216	467
SOUND/SLIDE	148	62	225	435
PROGRAMMED TEXT	148	59	217	424
PROGRAMMED VIDEO TAPE	194	57	173	424
BELL & HOWELL	172	59	181	412
AUTO TUTOR	117	61	216	394
LINCOLN LABS	140	54	139	333
TICCIT	161	52	121	334
PLATO	148	53	69	270
SKILLS DEVICES:				
ACTUAL EQUIPMENT	188	34	176	398
AEMT	242	60	140	442
EC II	218	63	200	481
PART TASK TRAINER	121	58	234	413

TABLE C-14. MEAN SCORES BY DEVICES UNDER ASSUMPTION 2, EFFECTIVENESS MOST IMPORTANT

	EFFECTIVENESS	USABILITY	COST	TOTAL
KNOWL./INFO. DEVICES:				
NORELCO PIP	176	62	78	316
MODIFIED PIP	191	60	72	323
SOUND/SLIDE	148	62	75	285
PROGRAMMED TEXT	148	59	72	279
PROGRAMMED VIDEO TAPE	194	57	58	302
BELL & HOWELL	172	59	60	291
AUTO TUTOR	117	61	72	250
LINCOLN LABS	140	54	46	240
TICCIT	161	52	40	253
PLATO	148	53	23	224
SKILLS DEVICES:				
ACTUAL EQUIPMENT	188	34	59	281
AEMT	242	60	47	349
EC II	218	63	67	348
PART TASK TRAINER	121	58	78	257

TABLE C-15. MEAN SCORES BY DEVICES UNDER ASSUMPTION 3, COST MOST IMPORTANT

	EFFECTIVENESS	USABILITY	COST	TOTAL	RANK
KNOWL./INFO. DEVICES:					
NORELCO PIP	59	62	233	354	1
MODIFIED PIP	64	60	216	340	2
SOUND/SLIDE	49	62	225	336	3
PROGRAMMED TEXT	49	59	217	325	4
PROGRAMMED VIDEO TAPE	65	57	173	295	7
BELL & HOWELL	57	59	181	297	6
AUTO TUTOR	39	61	216	316	5
LINCOLN LABS	47	54	139	240	8
TICCIT	54	52	121	227	9
PLATO	49	53	69	171	10
SKILLS DEVICES:					
ACTUAL EQUIPMENT	63	34	176	273	4
AEMT	81	60	140	281	3
EC II	73	63	200	336	1
PART TASK TRAINER	40	58	234	292	2

APPENDIX D. FUNCTIONAL SPECIFICATIONS

D-1. Scope

System Philosophy.

One basic concept behind the Navy Advanced Maintenance Training System (NAMTS) is that the system provides training materials which are individualized and self-paced. The structure of the system will, therefore, be directed toward training methods and equipment characteristics which are appropriate for individualized, self-paced instruction. A second concept for the NAMTS is that the system will be applicable to a wide variety of maintenance training programs within the Navy. Thus, the training materials and methods incorporated in the system must be generalizable to an assortment of training problems, materials and objectives.

System Elements

The training equipment and methods to be provided in the system include those concerned with the following kinds of training:

(1) Knowledge/information

(2) Skills training - system operation and failure effects

(3) Skills training - troubleshooting

(4) Skills training - test and calibration

(5) Skills training - assembly, disassembly and repair

The following sections present functional specifications of Navy Advanced Maintenance Training System equipment and methods based on the above system philosophy and the analyses conducted during this study. The specifications are written for the system configuration selected under the assumption that effectiveness and cost factors are of equal importance.

D-2. Functional Specification: Equipment and Methods for Imparting Knowledge and Information

Scope

The training equipment and methods for imparting knowledge and information will apply to those segments of a maintenance training course which are concerned solely with presentation of information to be learned. The appropriate training objective categories include (see Table C-1):

(1) Using system diagrams, describe system, subsystem and component structure, location, operation, and function.

(2) Demonstrate knowledge of preventive maintenance and inspection requirements, decisions, procedures, techniques and criteria

(3) Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type.

(4) Given representative component repair requirements, identify tools and techniques required for repair of each component type.

(5) Using visual representations and mockups, demonstrate knowledge of procedures and techniques of fault isolation and component removal/replacement.

(6) Using visual representations and displays, be able to correctly identify fault event cues and failure effects.

(7) Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.

Description of Training Materials

The equipments required for the knowledge and information presentation segments of a maintenance training course will include provisions for visual and aural presentation with the visual medium encompassing motion and still pictures.

The training method associated with these equipments will be appropriate for individualized self-paced training. The basic method will use programmed instruction branching techniques to a limited but, what is believed to be, the most cost-effective degree. The method will comprise a programmed instruction approach wherein the trainee is presented information, is tested on his retention and understanding of the material, and is presented appropriate successive material depending on the "correctness" of his responses.

Description of Required Characteristics

The knowledge and information presentation devices are described in this section in terms of their required characteristics:

Characteristics	Requirements
Pictorial presentation	- required for orientation to the system and system components
Graphic representation	- required for description of spatial relationships, location of equipment, system physical composition, etc.
Color	- capability required for four-color process (red, yellow, blue and black)
Motion	- capability required for motion up to 24 frames/second
Clarity-resolution	- frame registration during motion will not cause displacement of successive images
	- single frame contrast and readability will be at a level comparable to slide presentations
Format flexibility	- capability required for still visual presentations and for variable motion

Characteristics	Requirements
Format flexibility, cont'd:	- visual cassette to be cued to the audio cassette, to permit variable speed visual presentation with accompanying audio and with no degradation in audio quality
	- to the extent possible, the system should provide the trainee with a choice of formats for the same information (text, text and graphic, text and sound, graphic and sound, etc.) thereby allowing the trainee to select a preferred format
Text	- required for most formats
Sound	- capability provided as an optional format
Branching	- capability of presenting material selected as a function of the trainee's response
Scoring	- recording capability required to obtain information on student performance
Prompting/cueing	- build into PI material as required
Levels of difficulty	- inherent in branching - at least three levels to be accommodated
	- capability for student interaction using four multiple choices
Operability	- simple operating procedures
	- quick and simple cassette changes
	- control functions designed for entry-level student aptitude and ability (e.g., reading, decision-making, etc.)
	- frame-skip without distracting the student
	- inaudible pulses to advance frames

Characteristics		Requirements
Space requirements	-	housed in a portable self-contained unit
Transportability/portability	-	capable of being carried by an individual student using one hand
Update capability	-	inherent in cassette approach
Programming requirements	-	PI programming
	-	scoring compilation
Special requirements	-	capability to accommodate different formats
Generalizability	-	applicable to knowledge/information segments of any training course
Applicability across T/O's	-	applicable to all knowledge/ information T/O's
Instructor requirements	-	tutorial for resolving trainee problems

D-3. Functional Specification: Skills Training - System Operation and Failure Effects

Scope

These training equipments will apply to course segments concerned with the student's acquiring an understanding of system operations and of effects of component failures. The applicable training objective categories include (from Table C-1):

(6) Using visual representations and displays, be able to correctly identify fault event cues and failure effects.

(8) Using an operational system representation, describe procedures to detect and locate faults at the component level.

(11) Using an operational system representation, correctly complete system calibration and component assembly, disassembly, and repair.

Description of Training Materials

The equipment will consist of a main-frame and interchangeable plug-in panels. The panels will be specific to the simulations required for specific skill training described under Sections E-3, E-4 and E-5. The main-frame will accommodate any set of these panels. The simulations to be provided will be designed for individualized self-paced use in that they will contain all instructions needed to proceed through course elements without the intervention, or even presence, of an instructor.

This simulation panel will display a large-size schematic of lines, valves, and other components which, under stated operational and/or failure conditions, will dynamically depict flow of fuel oil, steam and water, and the appropriate display values. The simulation will incorporate all controls and displays found on the ABC-Hagan console. As controls are activated, the effects of the action shall be displayed on the schematic and also on the appropriate displays.

Integrated with the simulation will be a programmed instruction capability. Explanation of system operation and failure effects will be accomplished by the PI capability, followed by a series of test items to assess level of student understanding. The PI display will be comparable to the knowledge and information presentation device described in D-2.

Requirements

Characteristics	Requirements
Pictorial	- no requirement
Graphic	- presentation of system loops and components depicting flow of fuel oil, steam and water, and effects of specific failures
Color	- differentiation of loops by color (four-color process)
Motion	- rate of change or flow of oil, steam and water
	- motion capability in PI accompaniment
Clarity	- comparable to color slide - high contrast
Format Flexibility	- fixed arrangement of system elements; different configurations of flow, effects, display readings
	- PI formats as described in D-2
Text	- identifying alpha-numerics
	- descriptive text accompanying the illustration of a failure and its effects
	- programmed instruction to teach failure effects and associated cues

Characteristics	Requirement
Sound	- not required
Branching	- student sequencing through the material, and level of difficulty, based directly on measured responses made by the student to problems posed by the program
Scoring	- measurement and recording of time to perform, time to respond, and number of procedural errors
Prompting and Cueing	- integrated into PI display or schematic
Different levels of Difficulty	- at least three levels, differing essentially in terms of level of specificity
Operability	- equipment to be operated by the student, which is separate from the simulated ABC equipment, must be designed in accordance with basic human engineering principles
	- time to learn how to use the equipment should be minimal
Fidelity of Display	- use of actual displays of the same location, size, type and scaling as ABC displays
Fidelity of System Response	- display changes synchronized with dynamic schematic changes
	- changes of both displays and schematic are essentially the same as changes in the real situation
Fidelity of Student Response	- the student shall not be required to perform any control function which is not normally in the sequence as part of the training sequence
Fidelity of System Configuration	- all displays and schematic states will reflect conditions as appropriate for the selected operation and failure
Range of Fault Capability	- capable of simulating the effects of any one of 25 different faults for each of 15 different failure events

Characteristics	Requirements
Maintainability	- system possessing a built-in check capability
Reliability	- not less than that associated with system used in the existing course
Update Capability	- changes in actual system design shall impact modules of the system rather than the entire system
Programming Requirements	- display change initiation based on selected failures, conditions and switch positions for up to 50 displays and 30 controls
	- instructional material presented to the student based on the student's response to test items
	- scoring requirements
Special Requirements	- instructional sequence for specific failures should be selectable by the student and by the course executive element
Instructor Requirements	- in-depth support of program - explanation, definition, etc.

D-4. Functional Specification: Skills Training - Troubleshooting

Scope

Troubleshooting training materials apply to course segments requiring acquisition of the diagnostic and perceptual-motor skills associated with system fault isolation. Troubleshooting refers to isolation of a fault to the component level, whereas the test and calibration training will involve isolation of a fault to a part within a component. The only limitation on faults to be simulated will be computer capacity.

The relevant training objective categories include:

(6) Using visual representations and displays, be able to correctly identify fault event cues and failure effects.

(7) Using fault analysis sequence diagrams, explain procedural steps in fault identification for selected failure events.

(8) Using an operational system representation, describe procedures to detect and locate faults at the component level.

(13) Using an operational system representation, correctly identify and locate failed components in different failure conditions.

Description of Training Materials

The troubleshooting training equipment will consist of interchangeable, plug-in panels. The panels and associated training materials will be designed for individualized self-paced instruction in that they will contain all information required for the student to progress through any number of selected fault isolation activities. Provisions will be made for enabling an instructor to sequence the faults to be presented or for the student to be able to select faults to be presented.

The troubleshooting training equipment will be designed to authentically represent the operation of the system in a fail-free state for different operational conditions and under selected failure conditions.

In addition to a high fidelity representation of the man-machine interface located at a station, the device will incorporate a programmed instruction capability with visual and sound presentation similar to that described in D-2, knowledge and information presentation.

Requirements

Characteristics	Requirements
Pictorial	- simulated optical view of stack condition - black smoke, white smoke, or clear
Graphic	- repeat of system schematic as part of PI accompaniment
Color	- only as in ABC console design
Motion	- displays
Clarity	- no requirement beyond fidelity of display
	- PI - same as color slide
Text	- PI accompaniment
Sound	- not required
Branching	- same as section D-3
Scoring	- same as section D-3
Prompting and Cueing	- same as section D-3
Different Levels of Difficulty	- only one level - that of the required sequences
Operability	- same as section D-3
Fidelity of Display	- replica of real-world system displays
Fidelity of System Response	- replica of responses in terms of lags, rates, etc.

Characteristics		Requirements
Fidelity of System Configuration	-	replica of actual system for specific conditions and failure modes
Range of Fault Capability	-	same as section D-3
Maintainability	-	same as section D-3
Update Capability	-	same as section D-3
Programming Requirements	-	same as section D-3
Special Requirements	-	same as section D-3
Instructor Requirements	-	same as section D-3

D-5. Functional Specification: Skills Training - Test and Calibration

Scope

Training equipments of this type will be employed in course segments concerned with the acquisition of test and calibration skills. Relevant training objective categories include:

(3) Using calibration procedure sheets, describe test techniques, decisions, and criteria for each component type.

(10) Using an operational system representation, describe disassembly, test and calibration procedures.

(12) Using an operational system representation, correctly complete system calibration and component assembly, disassembly, and repair.

Description of Training Materials

The equipment will consist of plug-in panels specific to this training category. The panels and associated training materials will be designed for individualized self-paced training in that they will contain all instructions needed to proceed through course elements without the continued need for an instructor.

The simulation model will consist of a replication of the AEC-Hagan component test stand. Operations to be simulated include attachment to the test board of a component containing a specified fault, configuration of the component, application of air, and interpretation of displayed data to isolate the fault within the component. The panel will include all replicas of the displays which are on the AEC-Hagan test board.

Characteristics		Requirements
Pictorial	-	no requirement
Graphic	-	in programmed instruction accompaniment
Color	-	for component diagrams
Motion	-	displays
	-	PI accompaniment - dynamic schematic
Clarity	-	PI - same as color slide
Text	-	PI accompaniment
Sound	-	not required
Branching	-	same as section D-3
Scoring	-	same as section D-3
Prompting and Cueing	-	not required
Different Levels of Difficulty	-	three levels - based on specificity
Operability	-	same as section D-3
Display Fidelity	-	replica displays of ABC - Hagan test stand
Fidelity of System Response	-	replica of real-world system responses to failures
Fidelity of Student Response	-	replica of real-world test and calibration sequences
Fidelity - System Configuration	-	replica of real-world system for conditions and failure modes
Range of Fault Capability	-	to be determined - presented on displays through logic in the simulation and instrumentation as required in component mockups

D-6. Functional Specification: Skills Training - Assembly, Disassembly and Repair

Scope

These equipments will be required in course segments devoted to skills acquisition in component assembly, disassembly and repair. The applicable training objective categories are:

(9) Using operational system representation, describe component removal/replacement, inspection and repair procedures.

(10) Using an operational system representation, describe disassembly, test and calibration procedures.

(12) Using an operational system representation, correctly complete system calibration and component assembly, disassembly and repair.

Description of Training Materials

The training equipment will include actual components incorporating built-in cueing for part identification and task sequencing, and actual equipment parts into which different failures can be introduced by the instructor. The equipment will also include an audio-visual (A/V) information presentation capability similar to that described in section E-2. The A/V capability will be used in conjunction with the actual components to instruct students in procedures for assembly, disassembly and repair of the components.

Requirements

Characteristics	Requirements
Pictorial	- in audio-visual, for presentation of procedures
Graphic	- in A/V
Color	- in A/V
	- color coding of parts within components

Characteristics		Requirements
Motion	-	A/V film for depicting procedures
Clarity	-	comparable to color slide
Text	-	A/V programmed instruction
Sound	-	capability provided for audio tape
Branching	-	PI branching as in section D-2
Scoring	-	same as section D-2
Prompting and Cueing	-	parts color coded and labelled
Different Levels of Difficulty	-	inherent in PI, as in section D-2
Operability	-	same as section D-2
Display Fidelity	-	actual hardware
Fidelity of System Response	-	no response necessary
Fideltiy of Student Response	-	actual hardware
Fidelity - System Configuration	-	actual
Range of Fault Capability	-	part failures inserted into components by instructors

APPENDIX E. SPECIFIC SOFTWARE REQUIREMENTS

The characteristics of training equipment and methods which can be considered to have associated software requirements include:

- Pictorial or graphic representation
- Text
- Sound
- Branching
- Scoring
- Prompting/cueing
- Alternate levels of difficulty
- Range of fault capability

The requirements for software in each of these characteristics for each of the three major segments of the course are discussed below:

Requirements for Knowledge/Information Presentation Segment (Phases I and II)

The device class selected for the initial two phases of the course is represented by the modified PIP equipment. The software requirements identified for this class in this training segment include:

- Representation - 8 mm type S film with capability for single frame presentation (slide mode) or motion of up to 24 frames/second (motion mode)
- Text - programmed texts will be required to accompany and supplement the information presented using the modified PIP class of training device
- Sound - audio tape, low noise level, cassette type; cued to film, with no degradation in sound quality at low film speeds
- Branching - in a programmed instruction format, skip-branching will be used to select the next visual for the trainee based on his responses to multiple choice items

- Scoring - recording of trainee responses to each question
  - computer program to compile, reduce and analyze patterns of response for one or a group of students, and for individual test items or groups of items
- Prompting/cueing - for these applications, considered to be inherent in the branching capability; no additional software requirements
- Alternate levels of difficulty - also inherent in the branching capability
- Range of fault capability - not applicable to this segment

Requirements for Familiarization Training Segment (Phase III)

Training equipment for this segment will include the modified PIP and the EC II classes. The software requirements are as follows:

- Representation - same as knowledge/information segment plus graphic depiction of system relationships with dynamic indications of state changes and fluid flows. The device for imparting knowledge/information will be driven by the EC II class of device such that the programmed instruction frames and supplementary dynamic representations presented by the modified PIP class will be selected and controlled by the logic of the EC II class. A special interface program will be required to enable this coordination.
- Text - programmed text to accompany and supplement the module lessons, for home study. Also within the category of text requirements are included the troubleshooting algorithms which will serve basically as job performance aids during the training and after completion of the course.
- Sound - audio tape as in knowledge/information segment.
- Branching - EC II class devices must have the capability of assessing a student response within a troubleshooting or calibration sequence, and informing the student of errors and implications of the errors.
  - modified PIP class devices will be capable of branching as described in the knowledge/information segment
- Scoring - the EC II class of devices will record trainee errors in performing specific sequences during all failure modes, and will also identify the failure modes being presented. These data will be analyzed for individual students or groups of students to identify for each failure mode the error rates, types of errors, frequency by type, and frequency of error.

- Prompting/cueing - the EC II class will provide prompting cues to the trainee on a demand basis (if requested by the trainee).

- Alternate levels of difficulty - inherent in branching

- Range of fault capability - software will be provided to ensure the greatest possible range of failure modes and symptoms. In addition, the software will be capable of being easily updated to add additional failure and symptoms. The selection of a specific failure condition will be possible in three different ways: instructor programming of the sequence of faults; random selection of failure modes by the computer; and trainee selection of failure modes for which he requires additional training.

Requirements for Skills Training Segment (Phase IV)

The requirements of this training segment are the same as for the familiarization training segment except that the EC II class will not provide the system representation but will, rather, be a high-fidelity simulation of the ABC Hagan console. Software requirements for this segment are the same as those identified for the prior segment.

Course Software Requirements

The software requirements for the course, other than those inherent in the individual training devices, include the following:

- Programmed instruction texts for each course module, as required

- Job programs - operational sequences and data to support the learning of complex sequences of activities

- Calibration tables and sheets

- Text answer sheets and templates

- Student progress charts

- Student data cards and records

- Instructor guides - containing (primarily) guidance concerning remedial training required on the basis of test results

- Remediation decision rules and criteria.