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PERFORMANCE-BASED TRAINING

MASTER

A Systems Approach Used in the Gas Centrifuge Enrichment Plant

Presented by:

WILLIAM A. ROOKS JR.

1982 DESIGN ENGINEERING CONFERENCE

The American Society of Mechanical Engineers

Sponsored by: Management and Design Engineering Divisions

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PERFORMANCE-BASED TRAINING: A Systems Approach Used in the Gas Centrifuge Enrichment Plant for the Transfer of Technical Knowledge From Design Engineer to Production Operator

WILLIAM A. ROOKS JR.

ABSTRACT

A requirement exists for effective and efficient transfer of technical knowledge from the design engineering team to the production work force. Performance-Based Training (PBT) is a systematic approach to the design, development, and implementation of technical training. This approach has been successfully used by the U.S. Armed Forces, industry, and other organizations. The advantages of the PBT approach are: cost-effectiveness (lowest life-cycle training cost), learning effectiveness, reduced implementation time, and ease of administration. The PBT process comprises five distinctive and rigorous phases: Analysis of Job Performance, Design of Instructional Strategy, Development of Training Materials and Instructional Media, Validation of Materials and Media, and Implementation of the Instructional Program. Examples from the Gas Centrifuge Enrichment Plant (GCEP) are used to illustrate the application of PBT.

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SECTION I. INTRODUCTION

Introduction

Performance-Based Training (PBT) Criterion-Referenced Instruction (CRI) is a powerful and cost-effective methodology for the transfer of knowledge from design engineers to production operators (Figure 1). PBT refers to what an employee is expected by management to do on the job. CRI relates to how well that job is expected to be performed. Two major characteristics of this training methodology (PBT-CRI) are: training is based on actual job performance requirements, and learning is independent of time and is trainee-paced. This means that length of training is dependent upon the ability and the motivation of the individual trainee, as opposed to an administratively specified length of time for training requirements to be satisfied. Approximately two-thirds of the benefits derived from the PBT-CRI approach are attributed to training being directly related to job performance requirements and criterion tests for learning accountability. The remaining benefits are attributed to the instructional strategy and the trainee being in control of the learning environment.

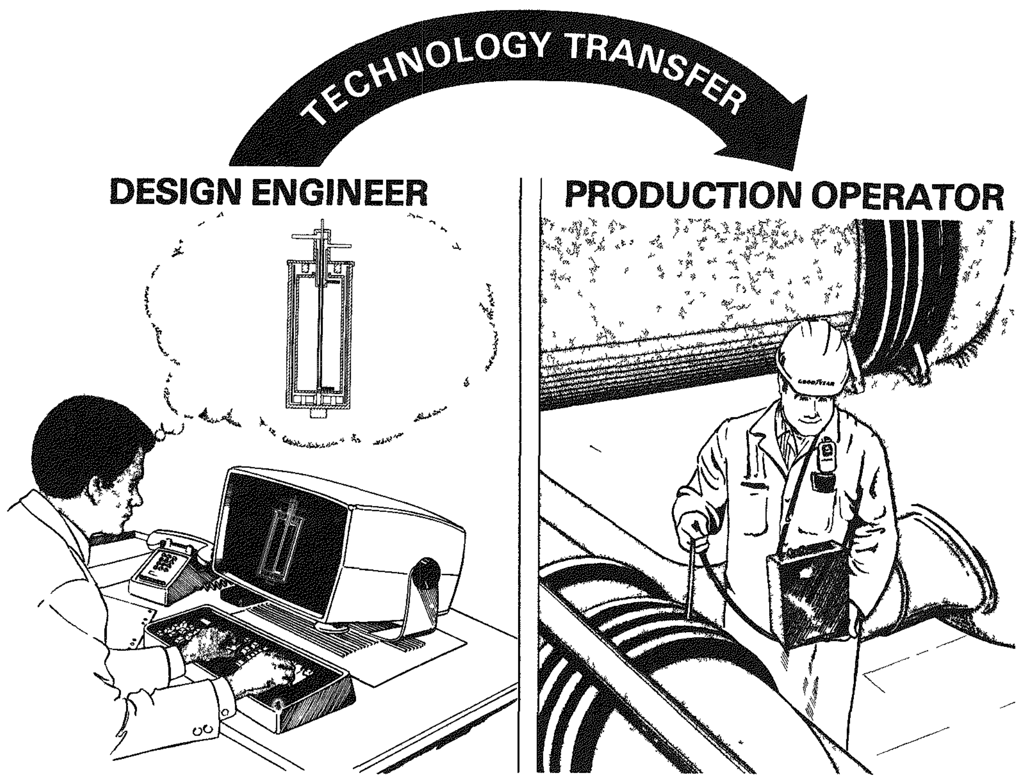

Figure 1. Performance-Based Training is an effective and efficient methodology for the transfer of technical knowledge from design engineer to production operator.

PBT and CRI are just another set of buzz words in the training rhetoric unless there is an understanding of their meaning and application. Other names by which this approach is known include: objective-based training, systematic instruction, mastery learning, trainee-paced instruction, and competency learning.

SYSTEMS APPROACH TO TRAINING

Five Phases

The systems approach to training is comprised of five phases. Figure 2 is a schematic representation of the approach to the analysis, design, development, validation, and implementation of instructional materials. The systems approach is familiar to engineers. It is characterized by an input, process, output, and control loop mechanism with feedback of corrective action as necessary. When the output has met all predetermined criterion, the desired product is the result.

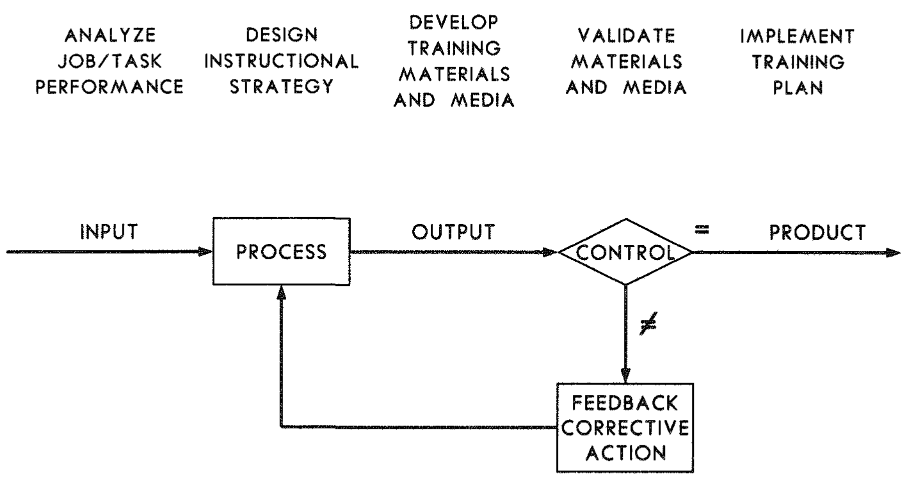

Figure 2. PBT is a systems approach with five phases.

Phase I of the systems approach to training involves an analysis of job and task performance requirements. This "front-end" analysis determines and specifies requirements essential to the performance of a particular job. These requirements are based on the engineering design of the equipment and nature of the man-machine interfaces.

Phase II involves the design of an instructional strategy that will ensure, with a high degree of probability, the transfer of technology from the design engineer to the production operator. Criterion testing is a part of the instructional strategy to ensure learning accountability and training effectiveness.

Phase III is the development process which is the actual production of printed training materials and audiovisual media such as 35-mm slides, videotape recordings, and transparencies.

Phase IV is the validation of the training materials and media. The three "Cs," Content of materials, Construct of materials, and Conduct of training are investigated. A pilot test with representative samples from the target population as a control group and experimental group is arranged, and the validity of the materials is determined.

Phase V is the implementation of the training management plan. This is the product of the systems approach to training. All pertinent elements of the instructional system are brought together at the right time, at the right place, and in the right sequence in order for effective and efficient training to take place.

Methodology Development

This training methodology is the result of the application of basic research from a number of disciplines. Learning theory and behavioral analysis have provided the concept of "spaced repetition with a difference" as a training model. Management science and cybernetics, as applied to human endeavors, have provided this methodology with predetermining objectives and a control loop feedback system. Educational and experimental psychology have supplied basic learning models derived from pedagogical procedures which have been translated into how adults learn, andragogical procedures. Communications theory has identified the potential of various instructional media to convey information for optimal retention and recall.

The PBT-CRI approach is more than theory; it is practical application. It has been fine tuned by U.S. military organizations, industry, and others for over 20 years into a well-developed tool for the systematic design, development, and implementation of training.

Travel Analogy

A travel analogy aids in understanding the systems approach. Reaching the destination is the desired performance (New York City). In addition to needing a method of getting there, a criterion is needed, a way of determining that New York City is reached. Since the Statue of Liberty and the Empire State Building are in New York and if Aunt Mary lives there, then when the criterion occur the desired result is reached.

In the training equivalent, if management knows what an employee is to do on the job (performance) and how well that job is to be done (criterion), then there is a high probability that the employee will be trained to do the job properly.

COMPARISON OF TRAINING METHODS

A comparison of PBT and more conventional, less rigorous, types of training will further delineate the systems approach. Six instructional parameters are used: (1) training requirements, (2) performance objectives and standards, (3) performance measures, (4) measurements of effectiveness, (5) learning ability differences, and (6) trainee progress rate.

Training Requirements

PBT has accurate, detailed, and well-defined requirements. This delineation is possible because it is performance-based. A detailed, front-end analysis of the task is performed, and the skills required to perform the task are prescribed. Unfortunately, in conventional approaches, training requirements often consist of general, vague, and fuzzy statements, or are nonexistent.

Performance Objectives and Standards

In the systems approach to training, performance objectives and standards of performance are the "name of the game." Training is based on job and task analysis. Under conventional approaches, objectives and standards are often not well-defined or are altogether absent.

Performance Measures

Performance is measured in terms of achievement of objectives in PBT-CRI. In some conventional training approaches, it is the number of training hours an employee has taken that qualifies the individual for a job. It is unwise to assume that after a predetermined number of hours an individual is trained. A more practical procedure is to have the individual's performance demonstrate that learning has been accomplished by satisfying criterion-referenced tests.

Measurements of Effectiveness

Measurements of effectiveness in PBT are built in. PBT is more specific, detailed, and objective because it is performance-oriented in its evaluation of skills. Evaluation in conventional training methods is either subjective or lacking. Such subjective measurements may be the instructor making a statement like, "Best class I ever had," or "Best group of trainees we ever turned out."

Learning Ability Differences

Individual learning abilities differ greatly. These differences are recognized and taken into account in the performance-based, criterion-referenced approach. Training is based on the individual's abilities, skills, learning capabilities, and motivation to learn. In conventional approaches, learning ability differences are not recognized.

Trainee Progress Rate

PBT permits the trainee to progress at his or her own pace. In conventional approaches, instruction often consists of group-paced, time-based training. The slower trainee, more often than not, does not keep pace with the group. Unfortunately, those that are quicker to learn are not motivated to perform up to their potential.

SECTION II. BENEFITS AND SUCCESSES

PERFORMANCE-BASED TRAINING BENEFITS

An obvious benefit of PBT is that training is directly related to job requirements. PBT is effective instruction because the trainee learns to perform the job properly.

Another benefit of PBT is that it is efficient. There are a minimum number of obstacles to learning because there is only one way to do the job, and it is taught in only one way. Learning progresses at the individual's own rate based on interest, motivation, ability, and desire to learn. This leads to an additional benefit in that all trainees have an equal opportunity to learn according to their abilities and motivations.

A major benefit to management is that PBT results in the lowest cost training possible because it represents the shortest training time a new hire needs to become an effective employee. Not only is the overall cost lower because PBT utilizes the shortest optimal training time, but it also represents additional operating cost savings since employees perform their jobs properly. PBT offers the lowest life-cycle cost of any training approach.

SUCCESS EXAMPLES

The following examples illustrate how a number of both large and small organizations have successfully applied PBT after initially using a more conventional approach. These examples are from the experiences of American Telephone and Telegraph Company, Xerox Corporation, American Red Cross, Scandanavian Airlines, and The Goodyear Tire & Rubber Company.

Installation and Service

The American Telephone and Telegraph story is one of the best documented examples of the benefits to be derived from converting to PBT. This example involves a training program for installation and service of long distance telephone equipment. An estimated training cost savings of $38 million over a 5-year period was realized between 1968 and 1973. Approximately 2,000 trainees per year participated in the program. There was an 80% reduction in the training implementation time. A previous administratively-determined 10-week training program was reduced to an average length of approximately 2 weeks per trainee (Shoemaker, 1972).

Maintenance Training

The Xerox Corporation story relates to a copier maintenance training course. Xerox indicated that significant benefits were derived from using a PBT program because course content was consistent from one training class to another. Course content materials were also more closely related to the specific copier maintenance job needs. Further, it was determined that trainees spent approximately twice as much time practicing important job skills. Xerox also found that PBT-CRI allowed for a much wider variability or difference in types of trainees entering the course. This ranged from training a new hire to cross-training the more experienced individual with 18 years or more service (Winkelbauer, 1979).

Retraining Course

The Scandanavian Airlines example relates to their stewardess retraining course. This is a course that all stewardesses are required to attend after having been off a particular job for a certain period of time. By changing to a performance-based training program, there was a 94% reduction in course training time. This conversion reduced a 2-day mandated training course time to one that was approximately a 1-hour training program, depending on the individual. The gain in instructional efficiency in this course resulted from the removal of the administrative requirement that all trainees spend the same amount of time in training (Mager, 1979).

First Aid Course

The American Red Cross first aid course is one of the most striking examples of the benefits to be gained from converting to a PBT methodology. Distributions of performance scores in Figure 3 (i.e., the percentage of correct answers for graduates of the two different training programs) show that the average percent of correct answers for

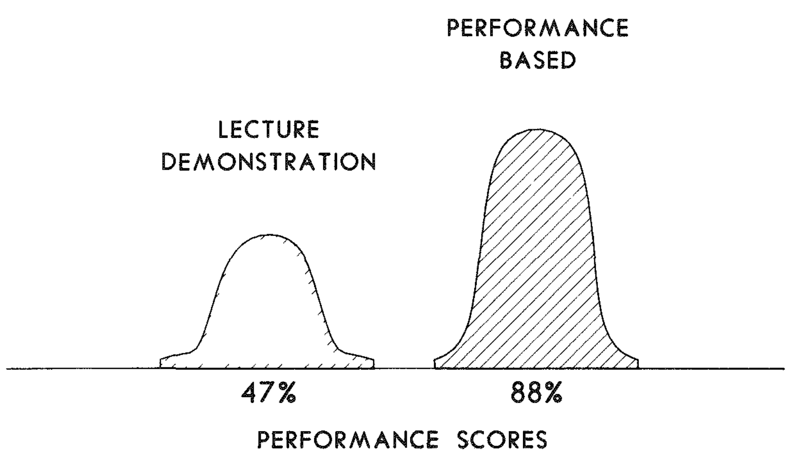

Figure 3. Distribution of performance scores show lowest performing individual in PBT outperformed highest performing individuals in lecture demonstration.

the lecture/demonstration course is 47%. The distribution for the course developed and presented using the performance-based, criterion-referenced approach shows that average performance scores were 88% correct answers. This 41 point difference in scores is striking in itself. An examination of the two distributions indicates that there is no overlap between the distributions. The lowest performing individual in the performance-based program outperformed the highest performing individuals in the lecture/demonstration session (Markle, 1967).

Apprentice Training

The Goodyear Tire & Rubber Company has successfully applied PBT and has been officially recognized by the U.S. federal government for its apprentice training program. Initially, apprentice training was a 4-year program. When it was converted to a performance-based format, the time was cut in half. Cost savings have been gained from reducing training time. Also, foremen indicate improved job performance from graduates of the PBT program.

Goodyear is convinced that there is neither a better or faster way nor a more cost-effective method than the PBT approach. Dr. J. Daniel Lyons, Corporate Director of Training for The Goodyear Tire & Rubber Company, has stated that "the documented evidence of the cost effectiveness of PBT methods is so overwhelming that Goodyear is committed to the use of these techniques."

The November 12, 1981, publication of The Wingfoot Clan (Figure 4) reports that the Bureau of Apprenticeship and Training for the U.S. Department of Labor has issued a certificate of registration representing official recognition by the federal government of Goodyear's performanced-based apprenticeship training program.

the WING FOOT CLAN

Akron Edition | The Goodyear Tire & Rubber Company

Thursday, November 12, 1981

For performance-based apprenticeships

Labor department lauds training program

Goodyear's Performance Based Training Apprenticeship Program earned strong recognition this week as the U.S. Department of Labor officially presented the company with a certificate of registration for the program

Daniel McCarthy, Ohio director of the Bureau of Apprenticeship and Training for the U.S Department of Labor, made the presentation.

"The new Goodyear program is based on accomplishments, not on a time schedule," McCarthy said "It certainly is a program that is more realistic in its approaches."

"Performance-based training is a realistic view of the apprenticeship program," said Clyde Boose, director, industrial relations. "It is designed to recognize individual abilities, skills and learning capabilities rather than rely on what we believe is an antiquated system"

The apprenticeship program covers jobs that traditionally have been involved with the skilled trades area, such as electrician, pipefitter and carpenter.

The certificate of registration represents official recognition by the federal government of Goodyear's program, Boose said.

"Goodyear's competency-based program is unique in the rubber industry," Boose said, "and represents one of the first programs of its type to be recognized by the Department of Labor in the entire country."

He said the program represents an effort by Goodyear to ensure an adequate supply of skilled craftspersons who are capable of maintaining the sophisticated systems and equip-

(See TRAINING page 3)

Training program gains recognition

(Continued from page 1)

ment with which Goodyear is involved.

"When compared with more traditional training programs that are based on time," Boose said, "the performance-based program is more specific, detailed, objective and, of course, performance-oriented in its evaluation of skills

"These differences provide improved job performance in less time and at a lower cost," he added.

Goodyear began its involvement in performance-based training in 1976 when it became apparent that company must seek a more efficient system of training in the skilled trade areas — in terms of both cost and quality

DANIEL McCarthy (left), Ohio director of the U.S. Department of Labor's Bureau of Apprenticeship and Training, reviews details of Goodyear's performance-based apprenticeship training program. McCarthy was in Akron to present a certificate of registration to Goodyear for the program. Dan Lyons (right), director of training, and Jay Miller, manager, labor relations, accepted the certificate.

Figure 4. Front-page article reproduced from The Goodyear Tire & Rubber Company's internal newspaper - Akron headquarters.

SECTION III. SYSTEMS APPROACH TO TRAINING

The systems approach to training consists of five sequential phases:

I. Analyze job and task performance.
II. Design instructional strategy.
III. Develop training materials and media.
IV. Validate materials and media.
V. Implement training management plan.

PHASE I - CONDUCT JOB AND TASK ANALYSIS

Conducting a job and task performance analysis is the first and most important step in the systems approach to training. Approximately two-thirds of the benefits derived from the systems approach come directly from this phase. This analysis ensures that all relevant and important materials have been included and that all irrelevant materials are excluded. The front-end analysis consists of a number of steps (Mager, 1976). If any part of the analysis is missing, then the benefits will be diminished.

Identify Equipment Within System

The first step is the identification of all major equipment and subunits in a hierarchial arrangement within each system. The equipment is limited to that which an operator will have access.

Define Human-Machine Interfaces

The next step identifies and defines the human performance requirements essential to the proper operation of the equipment. Two management tools are important elements of this step: task identification matrix and position description. Figure 5 is the task identification matrix. The left side, vertical axis, is a breakdown of major equipment items structured in a hierarchial arrangement. Across the top, horizontal axis, task descriptors are identified; i.e., what the operator does relative to the equipment. It is the intersection of these two axes that identifies the man-machine interfaces.

The other management tool is the position description. It describes what an operator is expected to do. A combination of steps forms a task. Tasks are organized to form a responsibility. Responsibilities are combined to form a position description. This "bottom-up" analysis provides solid data on which to make plant staffing and training design and development decisions. "Top-down" estimates are used initially, recognizing that they are only guesses.

TASK IDENTIFICATION MATRIX

MANAGEMENT CONTROL TOOL

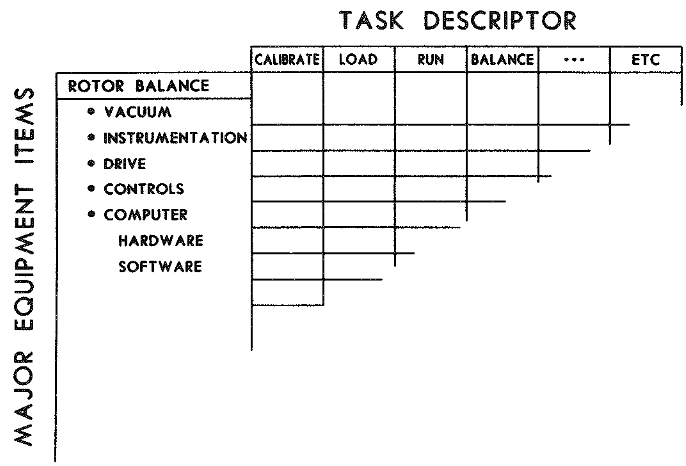

Figure 5. Task Identification Matrix depicts a hierarchial arrangement of major equipment items with task descriptors.

<u>Describe Task Performance</u>

To describe the nature of the man-machine interface, a description of each task is developed in terms of: frequency of performance; complexity (number of different physical activities and mental processes); importance relative to all tasks; and similarity to other tasks. A task and skills analysis data collection form is helpful in organizing data elements to conduct this analysis. The task action verb and object are identified from the task identification matrix, and performance times are determined. Safety hazards are specified. Starting and ending cues are identified, as well as the identification of each specific step in the proper sequence. Supervision and coordination requirements are given. Special tools and special skills are indicated. Performance conditions, safety procedures, test equipment, and special interactions between personnel are also detailed.

<u>Define Standards of Performance</u>

The next step is to define the standards of performance, the conditions that will be met when a job is properly performed. An example of standard of performance for a centrifuge assembler might be to assemble a centrifuge machine and then to test it using a given criterion standard. For example, the machine should run at a given speed with no leaks for a specified period of time. An example from the tire industry: an operator working a 6-hour shift is to build a minimum of 20 type "X" tires and no more than 1 of those tires is to be rejected.

Further, scrap material for that particular operator must weight less than 15 pounds. These are the standards of performance, referenced criterion, that management expects the operator to meet.

Identify Job Performance Measures

Job performance measures are the means by which it is determined whether or not the job performance standards have been obtained. In the tire industry example, the performance measures might include x-raying all tires to determine if a tire is defective. Other measures may include weighing the scrap material. An example of measuring job performance in GCEP might be to determine the ability of a centrifuge machine to maintain a specific vacuum within given tolerances at a predetermined speed and within a certain period of time in a test stand.

Specify Trainable Task

The last two steps in this phase relate to training analysis rather than task analysis. Some tasks, because of their critically important nature to the operation, must be supported by job aids. That is, some tasks are too critical to leave room for human error. For example, the law requires that the preflight checklist must be read by the copilot while the pilot actually performs the tasks. Thus it is believed that no amount of training would sufficiently prepare these operators, the pilots, to perform the task flawlessly 100% of the time without a job aid.

Trainable tasks have prerequisites. There are some tasks an individual would be expected to be able to perform prior to coming to a training session, either because they were tasks that were learned in a previous lesson or because they are generic in nature and trainees would be expected to have the skills and abilities prior to employment. Examples are reading and arithmetic comprehension at a specified level. Additional task selection criteria include learning difficulty, consequences of inadequate performance, frequency of task performance, and percent of job performance time.

Develop Learning Objectives

The last step in the analysis phase is development of specific learning objectives. Learning objectives in PBT describe observable behaviors. These behaviors are the actions that the trainees are expected to exhibit as the task is being properly performed. A terminal objective is stated for each task selected for training. Each task is further analyzed to determine enabling learning objectives. Each of the subtasks has an objective written for it. As part of the analysis leading to the development of learning objectives, the instructional setting is considered.

If any part of the front-end analysis is missing, then the training will not be able to fully exhibit the benefits to be derived from this powerful PBT methodology. Further, learning will be incomplete, and both training and operating costs may be higher than necessary.

PHASE II - DESIGN INSTRUCTIONAL STRATEGY

In the second phase, the concern is with specifying the training program design. The design process includes: identifying the structure and sequence of tasks, specifying the appropriate learning strategy, and identifying an effective media delivery system (Harless, 1978).

Develop Criterion-Referenced Test

Test items are written immediately after the learning objectives are established and before the training materials are developed. This is to eliminate potential bias that may creep into the development process. Thus there is a greater probability that test items will truly reflect what is required in actual job performance. Both pretest and post-test items are developed.

There is no need for an individual who satisfactorily passes a pretest examination to go through the learning exercises since passing the pretest is indicative that the individual already knows how to perform that job task. Thus the tests are directly related to the measurement of the trainee's attainment of job performance objectives. For manual skills test, a can-do/cannot-do scheme is used.

Written tests for cognitive skills are used only for those items in PBT that cannot be directly observed from the trainee's behavior. Written tests include two types of questions. Certain questions are of a pass/fail nature. For example, a trainee must answer correctly all questions relating to safety or health hazards. If one of the go/no-go written questions is missed, then the individual has not passed the criterion test. For other written test items, an 80% or 90% correct score may be acceptable. Criterion test items are specified for both terminal and enabling learning objectives. Failure to pass a criterion test indicates that learning has not attained.

Describe Trainee Entry Behavior

The procedure in this step is to identify entry-level behaviors and characteristics. Both manual skills and knowledge items that the target population of trainees are expected to possess are identified. In other words, "What must a trainee be able to do as a prerequisite?"

Determine Task Sequence and Structure

Two types of tasks are recognized, dependent and independent. A dependent task must be performed in a certain logical, predetermined sequence. Independent tasks may be performed in any given desirable sequence. Both dependent and independent tasks are sequenced in a hierarchial arrangement to optimize learning efficiency. Task position in the hierarchial structure is a function of a number of parameters: when specific task skills will be applied on the job, availability of training time and facilities, estimated learning time, and the relationship of one task to another as defined in the position description.

Figure 6 is a generalized position description. Position "X" is comprised of a set of responsibilities, X-A, X-B, to X-N. Each responsibility, in turn, consists of a series of tasks. In this example, responsibility X-B has a sequence of tasks identified as X-B1, X-B2, to X-BN. Each task is comprised of a sequence of either subtasks or specific steps to be performed in a given order. Task X-B2 is shown to have a series of steps.

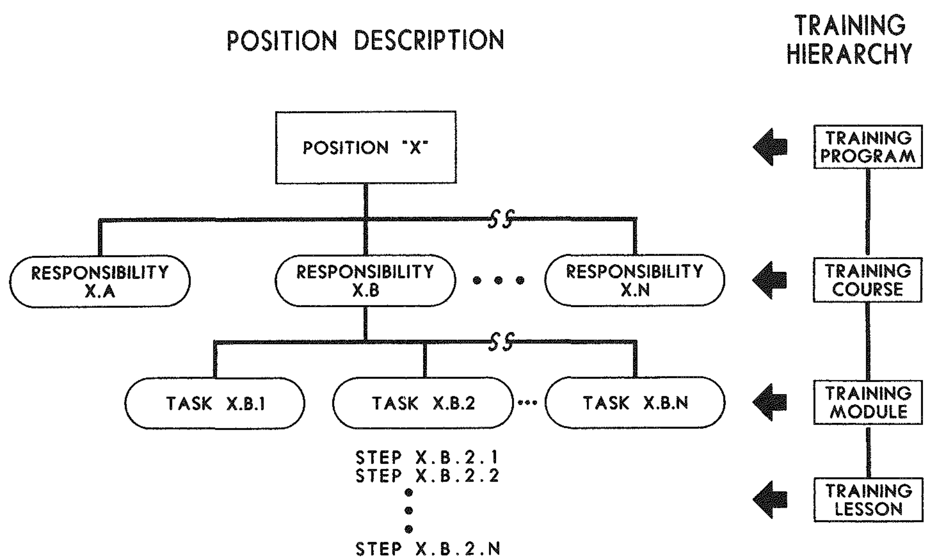

Figure 6. Position description diagram showing responsibilities, tasks, and steps and their relationship to the training activities hierarchy.

When the position description is combined with the training activities hierarchy, then the learning task sequence and structure can readily be seen as being directly related to the position description. A training lesson relates to the learning of a specific task. A training module is comprised of lessons for a number of tasks. In turn, a training course which relates to a specific responsibility is comprised of training modules. A trainee will be considered to have satisfactorily passed a training course, respective of a particular position responsibility, when all training modules within that course have been satisfactorily passed. An employee will be considered to be fully "job qualified" for a particular position when satisfactorily completing all training program requirements.

Specify Learning Strategy

A learning strategy is based on the development of an algorithm for spaced repetition with a difference. This relates to the structuring of different methods of instruction: lecture, demonstration, media, and a host of individual, small-group, and large-group discussion methods. Further, the specifying of a learning strategy is dependent upon the type of learning. Job performance objectives are classified by learning skill category such as cognitive, manual, and informational. Learning rate considerations, such as self-paced or group-paced factors, are determined. Effectiveness of group-participation activities is also analyzed.

Develop Training Design Algorithm

To convert job performance data into a training program, a training design algorithm is required. Four parameters: importance (I), complexity (C), frequency (F), and uniqueness (U) used for defining the training algorithm are scaled on a continuum of high, average, and low, 3, 2, and 1 respectively. The algorithm states that if a task is of high importance then it is rated a three. This means that the most rigorous algorithm is required. The reasons a task might be classified as high importance include human safety considerations, protection of expensive or unique equipment, or by the nature of the task to the total operation. Figure 7 is a logic diagram of the algorithm.

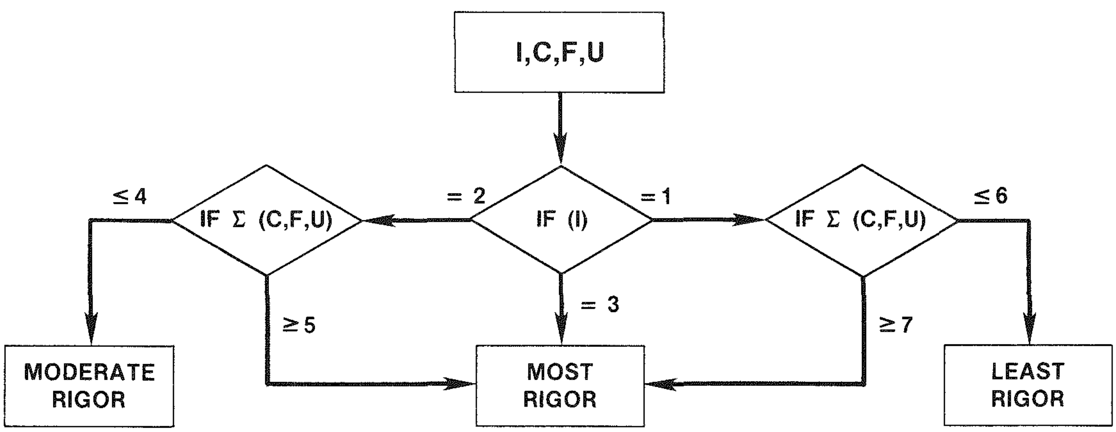

Figure 7. Training Design Algorithm.

Algorithm rigor is a function of the number of different methods of instruction used and the length of each. The most rigorous algorithm uses more methods of instruction for longer periods of time than the moderate or least rigorous algorithm.

One alternate route to the determination of the most rigorous algorithm is if importance is rated average and at least one of the other three parameters (complexity, frequency, or uniqueness) is rated high. Complexity is based on task intellectual demands, physical requirements, and the number and diversity of task steps. Frequency is determined by the number of times a task is repeated. Uniqueness is based on comparing and contrasting similarities and differences among tasks.

Another route to the determination of the most rigorous algorithm is when the importance of a task is classified as low, and two or more of the other parameter ratings are high. On this decision branch, if the sum of the other parameter ratings is less than or equal to six, then the least rigorous algorithm is indicated. Similarly, when importance is rated as average and the sum of the other parameters is four or less, then a moderately rigorous algorithm is indicated.

Identify Media Delivery System

The next step in specifying the training program design is identification of an effective media delivery system. This involves a consideration of how the instruction is to be packaged and under what conditions it is to be presented. The media selection process considers: learning categories, training methods, media characteristics, training life cycle, cost of media implementation and development. Typical instructional media include: live presentation; printed material; audiovisuals such as 16-mm motion picture, 35-mm slide, overhead transparency, videotape, and cassette recording; and computer-based training.

Specify Instructional Implementation Plan

Specifying the instructional management plan includes recognizing all elements of the training process which need to be organized, directed, and controlled. The implementation management plan considers the bringing together of all the instructional elements in the proper sequence, at the right time, and in the right place. Elements of the training management plan include: trainees; physical training facilities including classrooms, learning laboratories, and actual work floor facilities; availability of training supplies and materials; trained instructors; instructional equipment; audiovisual equipment; and the developing and maintaining of appropriate training records.

PHASE III - DEVELOP TRAINING MATERIALS AND MEDIA

The third phase is concerned with implementation of the training design to produce instructional materials (Mager, 1977).

Review and Select Existing Materials

Existing training materials are located and reviewed. Appropriate materials are selected for inclusion in the program or for modification. It is often less costly to buy training materials than it is to develop and produce them.

Produce Printed Materials

The learning strategy identified during the design phase is implemented to produce a complete package of printed training materials. These materials include trainee lesson workbooks; instructor guidebooks and lesson plans; pretest, posttest, and answer sheets; audiovisual aids; and other training aids.

Develop Training Aids and Audiovisuals

The instructional design strategy for training aids and audiovisual media is implemented considering a number of factors. These include the instructional setting, difference between the cost of making or purchasing a training aid or visual, cost to use a particular media, and characteristics such as color motion, and resolution of detail.

Select and Train Instructors

The final step in the development of training resources is the selecting and training of instructors. Qualified individuals are selected and trained to be instructors if the training is instructor-dependent. The usual qualification for an individual to be an instructor in this type of training is that of being a subject-matter expert. This is an individual who knows the equipment, machinery, and the detailed nature of the technical task to be performed. In human relations and management training, conference leadership skills and an understanding of group dynamics are required of an instructor.

If the training is material-dependent, then a course manager or facilitator is selected and trained. This individual does not have to be a subject-matter expert. The facilitator is an administrator of training materials.

PHASE IV - VALIDATE MATERIALS AND MEDIA

Validation of the training program means to measure the effectiveness of the design and development process (Esseff, 1974). It is intended to answer the question, "Do the results of the design and development process correctly match the input objectives that were determined during the analysis phase?" If the results do not correctly match the objectives, then corrective action is required. If the results match the input conditions, then the result is the product (the training program).

Pilot Test

The first step in the validation phase is to pilot test the results. Representative individuals from the target population are randomly selected. These individuals are then divided into two groups for a split-group experiment (control and experimental groups). The training program is administered to the experimental group, and the results are determined.

Do Results Meet Objectives

If the trainees pass the criterion test satisfactorily, then the learning objectives are satisfied. The standard for satisfactory achievement of results might be the 90/90 criterion; that is, 90% of the trainees pass 90% of the written tests. However, all trainees may be required to pass 100% of the performance tests in order for these materials to be judged acceptable.

If the results fail to meet the stated objectives, then corrective action must be taken. Before corrective action can be taken in the design or development processes, the three "Cs" must be checked: Content, Construct, and Conduct. In the content area, the question to be answered is, "Do the training materials satisfy the job requirements?" To determine if the content of the training program is satisfactory, subject-matter experts are used, operating procedures are reviewed, and direct job observations are sometimes needed.

In checking the construct of the materials, the first question to be raised and answered is, "Was the instructional strategy correctly defined during the design phase," and secondly, "If it were correctly designed, was it properly carried out during the development activities?" If a deviation exists, is there sufficient justification documented for that deviation? Reading and math comprehension levels of the materials should also be checked. In checking the conduct of the training materials, the question to be asked is, "Were the training materials presented properly?" "Did the instructor follow the instructor's guide and present the materials in the proper manner and sequence?"

Take Corrective Action

Only when the root cause of a problem has been properly identified can corrective action effectively be taken. When the cause of the failure to validate has been determined, then repeating a portion of the previous phases is needed. After all corrective actions have been properly implemented and the training materials and media are validated, then the training process moves to implementing the training plan. The product of the design and development process comes to fruition, the training program.

PHASE V - IMPLEMENT TRAINING PLAN

In the last phase, all elements of the training process are brought together at the right time, right place, and in the proper sequence to deliver the product. To implement the training plan means to manage all aspects of the training implementation process. These include the organizing, directing, and controlling of the training process elements: trainees, instructors, facilities, materials, and records. In Phase V, the product is delivered. The proper number of job-qualified employees must be available when the operating divisions need them.

Conduct Planned Instruction

In this step, the instructor presents the materials in a classroom or other training facility. Training then progresses to the operating floor, shop, learning laboratory, or to a self-paced mode of learning.

Appraise Performance of Instructor

The basic question to be answered is, "Have the trainees learned?" In an attempt to answer this question, several other questions may need to be asked: "Did the instructor follow the lesson plans?" and "Did the trainer present the materials according to the instructor's guidebook?" It is sometimes difficult for training management to observe on a day-to-day basis what instructor is doing. Therefore, trainees are requested to complete performance appraisals of instructors at the end of each training lesson.

Maintain Training Data Records

Many types of training records are maintained. Perhaps the foremost is the updating of the trainee personnel files when courses have been successfully completed, and the individual is fully job-qualified. Training data records of performance appraisals of instructors are maintained. By maintaining data records of training materials and through a statistical analysis of the results of trainee test questions, the effectiveness of the instructional materials can be analyzed and assessed.

Monitor and Evaluate Effectiveness

Collecting data is the first step in categorizing and analyzing data to determine efficiency and effectiveness of the instructional strategy and for monitoring operating procedures as possible candidates for change. Not only must training materials be designed and developed properly, they must be kept current. They must keep pace with changes on the operating floor. A close liaison between the instructor and the operating foreman is a key source of data. A formal procedure change notification policy is required for large operations.

Modify, Revise, Improve

Instructional materials need to be revised to reflect job changes or improvements in instructional delivery systems or an instructional strategy that will be more cost-effective. In this step, some of the procedures used in Phase IV, "Validate Materials and Media," are replicated. As a result of continual evaluation or the longitudinal validation of training materials, portions of other phases may need to be repeated (Kirkpatrick, 1975).

Development Versus Conduct Time

PBT development time is significantly longer than conduct time. Ratios of development to implementation time can vary from 50 to 1, plus or minus 25, and it is not uncommon to have some ratios in the 100 to 1 range. The complexity of the man-machine interface and the required sophistication of the instructional strategy may increase the ratio. Thus a drawback to the systems approach is the disproportionate costs loaded into the front-end. However, significant cost advantages are gained from long and continued use of a training course. This should not be surprising to design engineers in that it is analogous to production efficiencies being obtained when the same product is manufactured for an extended period of time.

At certain points in the development process, overlaps in phase activities may occur. However, there are several points where overlapping cannot happen. Pilot testing must wait until: the instructional technologists have completed the analysis and developed the learning strategy; the course developers and the media specialists have completed their tasks; and the instructors have been trained. Similarly, the conduct phase cannot begin until the training materials have been developed and tested. The necessity for this type of sequencing is mandated by the nature of the system approach, that is, taking a global look at the total learning process as opposed to suboptimal looks at only local, fragmented situations.

SECTION IV. GCEP APPLICATION OF PERFORMANCE-BASED TRAINING

Examples from the application of PBT on GCEP are used to illustrate the systems approach to technical training. First, a description of the plant, enrichment process, and start-up schedule are presented. The second part is a description of the centrifuge machine which is the core of GCEP. The last part contains training materials developed by design engineers for plant operating personnel. Examples of task and skills analysis, training design algorithm, and written and performance tests are given.

GAS CENTRIFUGE ENRICHMENT PLANT

The objective of GCEP is to produce enriched uranium using centrifuge technology. The plant is operated and managed for the Department of Energy (DOE) by Goodyear Atomic Corporation (GAT). GAT is a wholly-owned subsidiary of The Goodyear Tire & Rubber Company. This new centrifuge plant is being built at the site of an existing gaseous diffusion plant near Portsmouth, Ohio.

Centrifuge Uranium Enrichment Process

Figure 8 is a functional diagram of the centrifuge uranium enrichment process. The enrichment process starts at the Feed and Withdrawal (F/W) Building when a truck carrying 14-ton cylinders of uranium hexafluoride, UF_6, gas arrives. The cylinders are heated in an autoclave oven to vaporize the UF_6 which is piped to the Process Buildings (PB) and fed to the centrifuges. The product stream of UF_6 gas enriched in U-235 is piped from the centrifuges for final processing. The gas is condensed in cold traps and packaged in 2 1/2-ton cylinders. The tails of the process or the stream of depleted UF_6 gas is condensed into 14-ton cylinders and stored on plant site.

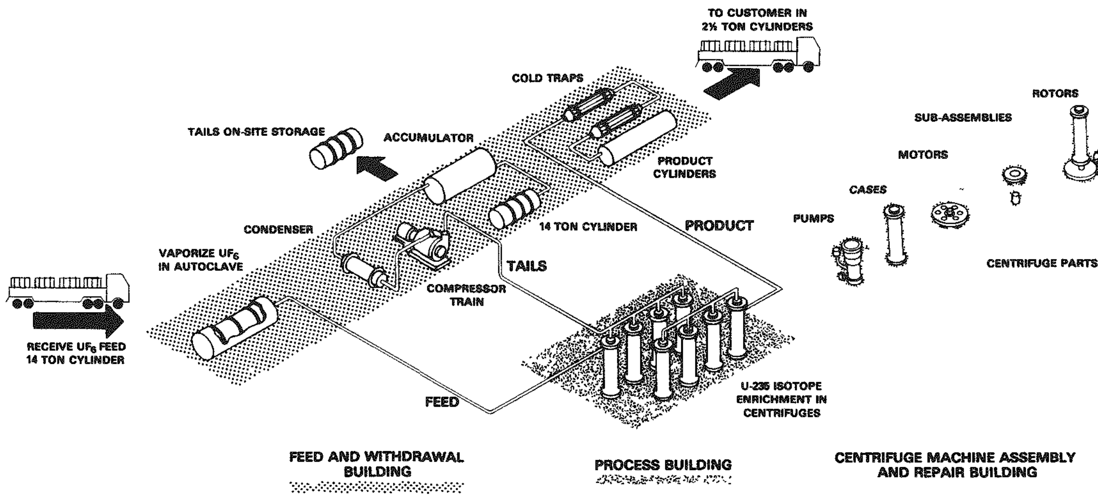

Figure 8. Functional diagram centrifuge uranium enrichment plant.

Centrifuge parts, such as rotors, pumps, cases, motors, and other subassemblies, are received and stored in the Centrifuge Machine Assembly and Repair Building. The facility will initially be used to assemble and test centrifuge machines to be sent to the PBs.

When the plant is in operation, failed centrifuge machines will be returned to this facility and the cause of failure will be diagnosed. Repairs will be made, rotors balanced, and centrifuge machines returned to operation (Burkley, 1979.)

Site Plan

Figure 9 is a block diagram of the GCEP site plan. The dominant structures are the eight PBs. At the bottom of the figure the F/W Building is identified. To the left of the PBs is the Centrifuge Machine Assembly and Repair Building. The centrifuge training facility is located in this building. This is one of two major training facilities. Located just above the Centrifuge Assembly and Repair Building is the Maintenance Building and the Central Training Facility. Additional facilities for operating the plant are the administration building and the warehouse.

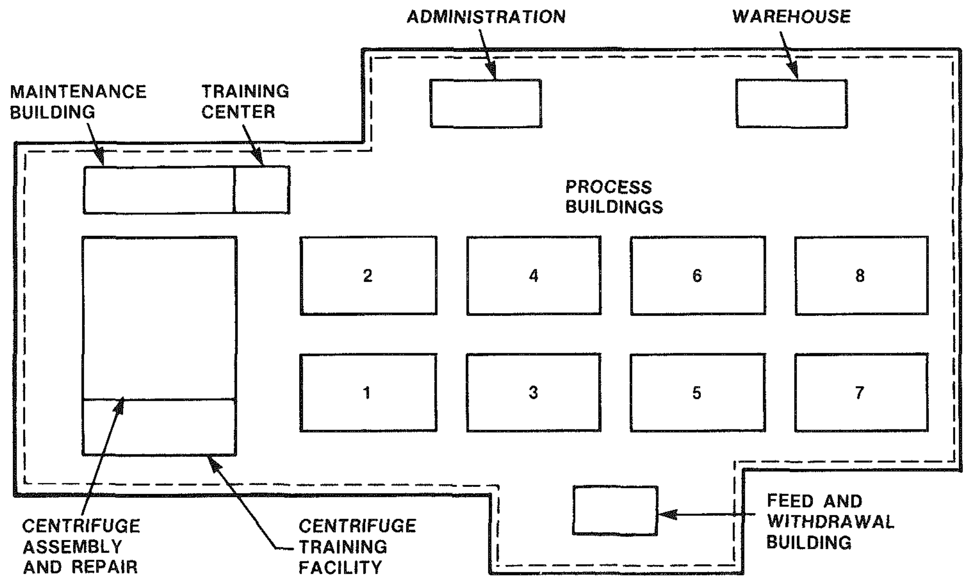

Figure 9. Centrifuge plant-site plan.

Plant Dimensions

Plant dimensions give an idea of the massiveness of this project. GCEP is one of the world's largest construction projects. The total enclosed area under roof is 90 acres, and each PB could hold 4 football fields.

The total amount of structural steel in the plant is 53,000 tons. The amount of earthwork required to prepare the site entailed moving 3.8 million cubic yards. Six hundred and twenty thousand cubic yards of concrete will be poured. Approximately 1,700 miles of piping will be used. This includes 300 miles of steel piping and 1,400 miles of aluminum piping. About 70,000 gallons of recirculating cooling water per minute will be required to keep the centrifuge machines and the environment at the appropriate temperatures. The estimated cost for the construction and start-up of GCEP is $6.5 billion using FY 1982 dollars. The project is on schedule and within budget.

This billion-dollar investment is cost-effective because of the electrical power consumption differences between the present gaseous diffusion technology and the new plant technology using centrifuge enrichment. The centrifuge plant will use approximately 5% of the electrical energy input necessary to produce the same amount of product as the gaseous diffusion plant. The centrifuge plant will use in the order of 135 megawatts of electrical power per year. A gaseous diffusion plant uses 2,400 megawatts.

Plant Milestones

Site construction began in 1977. The first centrifuge machine to be assembled, tested, and transported to the PB will occur in January 1984.

In September 1985, the first major complement of machines will be fully operational on UF_6 gas. However, it will be more than 2 1/2 years later, June 1988, before the first complete PB will be operational. All eight PBs are scheduled to be completed by June 1994 (U.S. DOE, 1981).

CENTRIFUGE MACHINE

The basic component of GCEP is the centrifuge machine. The purpose of the centrifuge machine is to increase the concentration of the uranium isotope U-235, which in natural uranium is only 0.71% by weight. The other 99.29% of natural uranium consists of the uranium isotope U-238. Tens of thousands of these machines are required for all eight PBs to be operational.

Figure 10 is a diagram of a centrifuge machine. The assembly of a centrifuge machine begins with a cylindrically-shaped steel casing. A heat shield is placed inside the casing to ensure the proper flow of gas. Inside the heat shield is a vertical rotor that spins at high speeds to produce the centrifugal action. The column contains three UF_6 lines, one input feed line, and two output lines. The depleted UF_6 is in the tails line and the enriched UF_6 is in the product line. Attached to the column are scoops to withdraw the product enriched gas and the depleted UF_6. The product scoop is at the top and the depleted scoop is at the bottom. An upper suspension system is used to hold the rotor in a vertical position. The rotor is driven by an electromagnetic motor attached to the bottom of the casing. A lower suspension assembly is used to maintain an erect vertical position of the rotor.

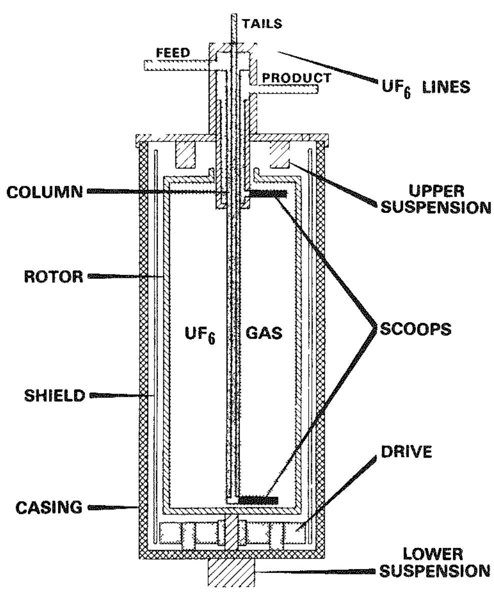

Figure 10. Centrifuge machine used for uranium enrichment.

Enrichment Process

The degree of enrichment in a centrifuge machine is dependent upon the mass difference of isotopes being separated, and the length and speed of the rotor. Gaseous UF_6 is fed into the rotor. It accelerates to approximately the same speed as the rotor. Centrifugal force causes the heavier U-238 molecules to move closer to the wall of the rotor, thus producing partial separation of the U-235 from the U-238 isotopes. Since the desired enrichment is not obtained in a single centrifuge, several machines are connected in series. The GCEP enrichment process increases the concentration of U-235 from 0.71% to about 3%, which is required for nuclear reactor power plants (Olander, 1978.)

TRAINING PROGRAM EXAMPLE

The GCEP training program example was developed by design engineers to train operating engineers who will ultimately train hourly workers to operate the plant. This program was developed and is being conducted at the Pilot Assembly and Balance Facility (PABF) in California. PABF is a major learning center for training individuals in assembly/disassembly, rotor balance, and testing of centrifuge machines. The training program consists of both a basic and advanced program. See Figure 11.

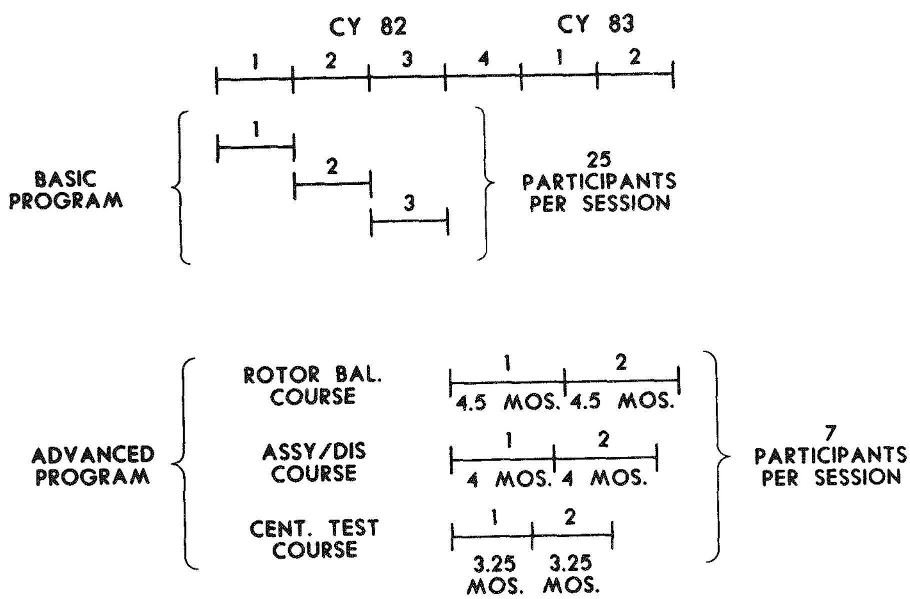

Figure 11. Basic and advanced program schedule for PABF.

Basic Program

There are three sessions of the basic program. Each session is 3-months long and can accommodate 25 participants; therefore, a maximum of 75 trainees will participate in the basic program. The learning objectives are to "perform operator tasks" and to develop "fault recognition" skills in: assembly and disassembly of centrifuge machines, testing machines, and in rotor balance. Centrifuge rotor balance is similar to balancing tires for an automobile. Weights are applied strategically for the tire to run smoothly. The same principle applies to centrifuge rotor balance. In the basic program, all participants receive the same training.

Advanced Program

In the advanced program, participants specialize in one of three courses: rotor balance, which lasts 4 1/2 months; assembly/disassembly, 4 months long; and centrifuge machine test, 3 1/4 months. Two sessions of each advanced course are given.

A maximum of 7 participants per session is possible; thus, there will be 14 participants per course for a total of 42 participants in the advanced program. These participants are selected from individuals who attended the basic program and whose performance and knowledge in the different areas are outstanding.

The three learning objectives for the advanced program are structured in a hierarchical arrangement, building on the basic program, and increasing in degree of difficulty. The lowest level objective of the advanced program is learning "fault diagnostic and isolation" skills. This builds directly on the basic course objectives of developing "fault recognition" skills. The second objective is recognizing "typical operating problems" and learning the "appropriate responses." The highest level learning objective for the advanced course and for the total program is understanding "design concepts and theory of centrifuge systems."

Tasks and Skills Analysis

A task and skills analysis data collection form was designed for the PABF training program. The form contains 29 data items which are used to provide a detailed description for each job task, including skills, step sequence, and other information.

Figure 12 is a flow chart of the subtasks in Task 302, Align Casing. Task 302 proceeds directly from Task 301. The centrifuge casing must be

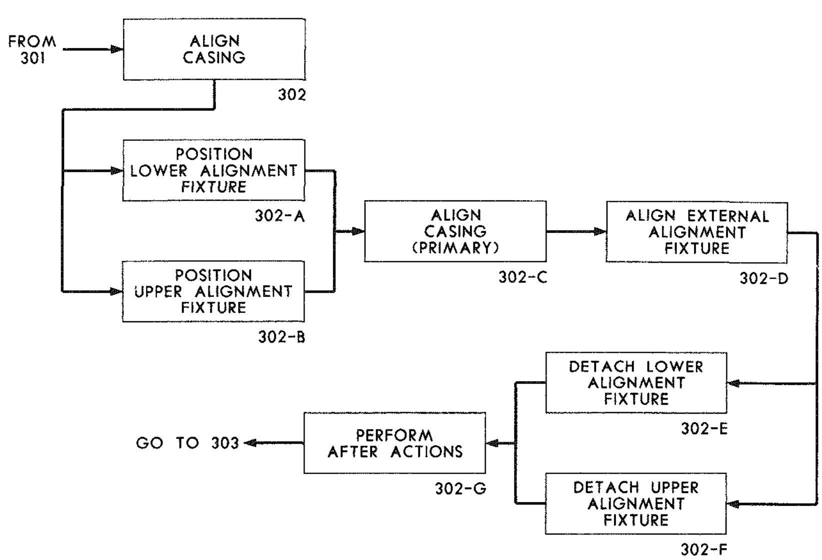

Figure 12. Task 302 showing a sequence of subtasks.

aligned vertically prior to the insertion of the shield, rotor, and column. Task 302 is comprised of a sequence of seven subtasks, A through G. Some of these can be performed in parallel (A and B) and (E and F). The others are performed sequentially.

Subtask 302-C is Align Casing (primary). Figure 13 indicates that 302-C can only be started after 302-A and 302-B have been successfully finished. The nomenclature in the lower portion of each block, AO-B and AO-A, is for specifying locations. The B refers to the top and A to the bottom of the centrifuge.

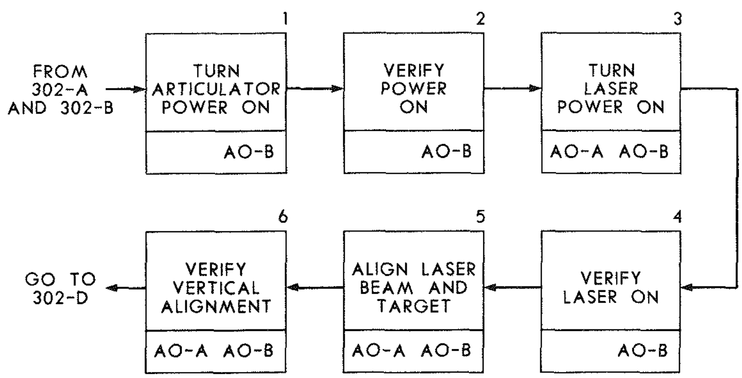

Figure 13. Subtask 302-C Align Casing, Primary.

Specific action words (turn, verify, align) and their objects (articulator, power, laser) are used. A significant amount of detail is required in this type of front-end analysis in order to have a successful PBT-CRI program.

PABF Training Algorithm

To convert task and skills analysis data into a training program and subsequently test for learning accountability, a training design algorithm is postulated. The algorithm used for PABF basic training is stated in terms of multiples of the task Actual Performance Time (APT).

Classroom activities include lectures and video presentations. Lecture is postulated to represent about 1.5 times the APT. That is, if the actual performance time of a task is 10 minutes, then the lecture portion of the classroom training would be designed to last 15 minutes. The second portion of the classroom training activity is the showing of videotapes, and 0.5 APT is used. This indicates that approximately 5 minutes of a 10-minute task would be devoted to videotape classroom activities. Hands-on training comprise three types of activities: demonstration, walk-through, and practice. Demonstration is 2.0 APT; walk-through, 1.5 APT; and practice, 1.5 APT. Testing both performance and written is 1.5 APT.

This algorithm represents a 20/60/20 activity arrangement. Twenty percent of the learning activities are in the classroom, sixty percent hands-on, and twenty percent testing.

Learning Accountability

In PBT, there is accountability for learning. If an individual already has mastered certain skills, there is no need to take the training. However, if an individual has not mastered certain skills, then training is repeated until mastery is accomplished. The instruments by which the accountability for learning is determined include written and performance tests.

Written tests are used only for those items which have no directly observable behavior, such as knowledge or safety items. In a performance test a trainee must perform all task steps in the given sequence with all the verifications and checkpoints accounted for. The task must be completed within the stated time. The instructor has a checklist of steps that must be performed and the sequence in which they are performed. Checkpoints are standards of performance and are also checked. Figures 14 and 15 are samples of written and performance tests.

TRAINEE TEST SHEET (WRITTEN)

LB 1.4.2 PREPARE LDA

1 TWO AREAS OF AN LDA WHICH MUST BE CLEANED ARE
A SURFACE TOUCHING LIFTING TOOL
B O-RING GROOVE
C FLANGES
D MOUNTING SCREW HOLES

2 THE CLEANING AGENT USED TO CLEAN AN LDA IS
A SOAP AND WATER
B CLEANING SOLVENT
C KRYTOX CLEANING AGENT
D DRY CLEANING CLOTH ONLY
E KEROSENE

3 AN EXAMPLE OF AN LDA DEFECT WOULD BE
A A BURR
B DISCOLORATION
C A DENT
D UNCLEAR LETTERING

4 KRYTOX GREASE IS APPLIED TO AN O-RING
A LIGHTLY TO THE ENTIRE SURFACE
B HEAVILY TO THE ENTIRE SURFACE
C LIGHTLY TO THE BOTTOM SURFACE ONLY
D HEAVILY TO THE BOTTOM SURFACE ONLY
E IN MODERATE AMOUNTS AS NEEDED

5 BURNING KRYTOX GREASE
A PRODUCES LARGE AMOUNTS OF VERY DENSE SMOKE
B PRODUCES A NON-TOXIC REPUGNANT ODOR
C PRODUCES A NON-TOXIC INVISIBLE GAS
D PRODUCES HALLUCINOGENIC FUMES
E PRODUCES A TOXIC GAS

Figure 14. Written test, Prepare Lower Drive Assembly.

PERFORMANCE TEST EVALUATION CHECKLIST

LB 1.4.3 INSTALL/REMOVE LDA

REMOVE	CHECK IF YES
1. STEP PERFORMED	
• READIES TOOLING FOR LDA REMOVAL	______
• REMOVES LDA FROM CASING	______
• MOVES LDA TO STORAGE LOCATION	______
• STORE TOOLING	______
• PERFORMS AFTER ACTIONS	______
2 CHECKPOINTS OK?	
• LIFTING TOOL AND LDA ENGAGES PROPERLY	______
3 STEP PERFORMED	
• CLEANS/VERIFIES LDA	______
• CONDITION	______
• INSTALLS O-RING	______
• PERFORMS AFTER ACTIONS	______
4 CHECKPOINTS OK?	
• USES LDA LIFTING TOOL CORRECTLY	______
• CLEANS AND INSPECTS LDA CORRECTLY	______
• APPLIES KRYTOX CORRECTLY	______
• INSTALLS O-RING CORRECTLY	______
• RESTORES LDA CORRECTLY	______

Figure 15. Performance test, Remove Lower Drive Assembly, evaluation checklist.

SECTION V. SUMMARY AND CONCLUSION

A number of organizations: American Telephone and Telegraph, Xerox, The Goodyear Tire & Rubber Company, and others have found that participants in Performance-Based Training (PBT) have outperformed those individuals participating in the more conventional, less rigorous types of training. Length of training time has been cut significantly with PBT, which provides for differences in individual learning abilities. PBT has resulted in training cost savings and training effectiveness superior to other methods.

The systems approach used in performance-based training is comprised of five rigorous phases. These phases include: analysis of job and task performance, design of instructional strategy, development of training materials and media, validation of materials and media, and implementation of training management plan.

The PBT methodology provides visibility into the true costs of developing and implementing training. However, some managers have difficulty in accepting these costs because they are far higher than their past experience permits them to anticipate. But it is the visibility that PBT provides which gives management the information needed to make effective decisions to plan and control training costs. Because PBT permits effective management control, it provides the lowest total life-cycle cost of training.

In conventional training approaches, learning deficiences are not readily apparent during training. Unfortunately, this lack of information as to the quality of training is conducive to fostering in management a false sense of training well-being. Poor quality instruction shows up later in the form of higher than necessary operating costs not directly attributable to any one factor.

The PBT budget is disproportionately front-end loaded with analysis and design costs. However, it is this factor that provides for the benefits of yielding the lowest possible total life-cycle training cost. But this visibility also provides some management with a rather attractive target for budget cutting.

The documented evidence of the cost-effectiveness of PBT methods is so overwhelming that Goodyear is committed to the use of these techniques.

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