PROGRAMMED SAFETY THROUGH PROGRAMMED LEARNING

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PREFACE

The provision of a safe working environment for its employees is a problem which will confront American industry for the next half century. With the advent of very strict federal and state legislation relative to industrial safety, it has become imperative that industry develop new and improved techniques of providing for the health and safety of employees. Also, the current increase in the vigilance and militancy of the public with regard to the various practices of industry has made it socially unacceptable for a company to maintain conditions which may be hazardous to its workers.

Very little research has been conducted in the general area of employee training as it relates to the safe performance of industrial jobs. The purpose of this research is to determine the validity of using programmed learning techniques in the area of industrial safety education. Four separate and distinct training methods are compared on the basis of the quality part and accident performance of experimental subjects who underwent the training in question. A machine simulating a punch press was developed in order to determine the performance data indicated above. The results of the experimental simulation are analyzed quantitatively and subjectively so that lessons learned from the research can be applied, on a practical basis, to existing industrial jobs.

The author is particularly indebted to Dr. S. K. Adams for his persuasion and guidance in the development and preparation of this document. Also, special thanks is acknowledged to Professor Roy H. Norris, Wichita State University, for his valuable assistance in the design and construction of the electronic hardware used in the industrial simulator. Finally, indebtedness is acknowledged to the College of Engineering, Wichita State University, for the use of the facilities so necessary for the successful conclusion of this work.

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CHAPTER I

INTRODUCTION

A Statement of Purpose

It is the intent of this thesis to demonstrate the potential usefulness of programmed instruction in the area of industrial safety education. In order to validate this premise, an experimental, simulated job task was developed. This activity consisted of the dissemination of punch press operation instructions by:

(1) Classical oral means.

(2) Audiovisual techniques utilizing 35 mm slides in conjunction with a recorded aural presentation.

(3) A videotape program.

The punch press was specially instrumented to give direct digital readouts of the subject's quality and safety performance. The simulated punch press task was highly realistic because it retained the normal mode of its operation without the safety hazards which are normally associated with this type of device.

Safety Education - A Legitimate Need?

In the next decade, American industry will be faced with an immense problem of providing safer working environments for its personnel. The complexity of the problem is the result of four primary factors or situations. The first is the widespread proliferation of new and unique industrial processes. Many of these processes are extremely hazardous and some of them are potentially fatal. A major problem exists in providing proper education to the affected employee so that he may become familiar with the dangers inherent in a manufacturing process with which he has no previous experience. Many accidents occur when new processes are introduced into an industrial facility because the affected personnel are ignorant of the safety hazards associated with the technique.

The second factor deals with the transfer of technically obsolescent employees to new and different work assignments. As automation continues to reduce the number of conventional unskilled jobs, a logical conclusion is that many workers will be retrained and transferred to new areas where they can provide a positive benefit to the organization. This training must provide adequate safety instruction, especially if the new job environment is a significant departure from the previous one. Internal employee mobility, therefore, will demand modern efficient safety education methods and techniques.

The introduction of young, uneducated and unskilled men into the ranks of labor will create havoc with the safety performance of a particular industrial concern. This is due to the fact that the people recruited from the various "Poverty Programs" can be expected to be almost totally unaware of the hazards associated with an industrial environment. Individuals with ghetto and urban backgrounds do not generally have a mechanical frame of reference and they undoubtedly will not be able to recognize the hazards inherent in industrial situations. In this specific instance, the aspect of adequate safety education may become a dominant factor due to the lack of basic education in the disadvantaged worker. It becomes imperative, therefore, that new, more efficient safety education methods be developed in order to insure that this type of individual is thoroughly acquainted with the safety hazards related to his particular job assignment.

Finally, there is an extremely strong cultural trend currently existing in the United States which makes it socially and, in many cases, legally unacceptable for industry to injure employees, or even customers for that matter. It is an accelerated manisfestation of concern for human welfare which was initiated by the passage of the first effective workmen's compensation legislation in New York State in 1910. The rising tide of public concern and indignation against ecological pollution and unsafe products is a present day fact of life which must be met by effective action on the part of American industry. Industry simply cannot afford the social stigma associated with the production of unsafe, unreliable products or the maintenance of hazardous, unsafe working conditions or work practices. Industry must regulate its own standards or face the definite possibility of increased governmental control throughout a broad spectrum of its operations. In many instances, this latter type of activity results in legislation with which it is virtually impossible to be in compliance except by spending millions of dollars. Also, legislation passed under hasty conditions of critical public opinion does not effectively solve the problem intended. American industry must be cognizant of the social implications of its diverse activities because people are demanding accountability and responsibility from the individuals and organizations which supply their livelihood and standard of living.

Present Educational Methods - Deficiencies and Shortcomings

Without a doubt, the greatest shortcoming associated with mass safety education methodology is the failure of the individual employee to relate the safety message to himself in his specific job assignment. This is especially valid when safety education is general in its application. Educational efforts devoted to the preaching of safety, its value, its necessity, and its virtues usually fail to specify actual situations and procedures. Detailed instruction has been relegated to the foreman in charge of the employee in his particular work assignment. This concept is sound in theory, but in actual practice it is seldom effective. Harassed as he is by his production responsibility, the foreman usually has a minimal amount of time to devote to his safety training duties. The foreman may likely correct unsafe working practices if they occur under his direct observation but he seldom takes an active role in accident prevention. His actions usually take place "after the fact" rather than serving as a positive force for the elimination of accidents before they can take place.

Another important shortcoming related to mass safety education techniques involves the cost of lost production which occurs when the personnel of a production department have to be taken off the job in order that they be in attendance at a meeting to listen to safety instruction and lectures. For example, if 150 employees attended a one-hour session the cost of lost time would be $450, assuming an average wage rate of $3.00 per hour. Also, the time required to walk to and from the meeting would more than likely be, on the average, 10 minutes each way. This would result in an additional cost of 150 (.33)

(3.00) or $150. The total cost associated with the loss of productive time would be, therefore, $450 + 150 or $600. This is exclusive of the cost of preparing the program which can be extensive. Considering the fact that the attendees will retain only a fraction of the material presented, the return on the dollar investment is unacceptable.

Some organizations circumvent this idle production cost by conducting safety lectures during work-break periods or during off-shift hours. Procedures of this sort have questionable merit because the majority of employees are highly resentful of company intrusions on their personal time. It would seem to appear that lectures held during off-hours may generate and foster a hostility toward the safety program in general and, thereby, frustrate the very purpose of safety education and training. In many instances, a company may not be able to conduct off-hour safety lectures without violating Federal Wage-Hour statutes, thus incurring the cost associated with the payment of overtime wages. Regardless of the method utilized for the dissemination of mass safety information, it becomes an extremely costly task to assemble a large group of people for the purpose of attending a safety meeting.

Programmed Instruction - A Proposed Solution to the Training Dilemma

The preceding discussion should provide sufficient indication of the need for safety education to be on an individualized, personal basis. Russell DeReamer (4, p. 47) makes the following statement with regard to what he refers to as: "personalized safety training."

> Group or mass training has a place in the complete safety program. However accidents usually happen to people one at a time, so it would appear to be a natural step to carry the accident-prevention program to the individual employee one

> at a time, too. The advantages are many. Hazards vary on each job and because of individual differences might even vary for employees on the same job. These individual differences can be considered if the safety training is personalized. Personalized safety training permits consideration of the worker's rate of learning, his interests, his natural ability, and his physical limitations. Personalized safety training can be specific. Group training must be general. The key to successful job safety training is telling the employee what the hazards are and how to avoid them. The evidence indicates that industry can cut total injury rates in half by using this personalized safety-training approach. This is so because a large percentage of industrial accidents are due to poor work habits and a lack of knowledge or skill about the job. Mass training tells what the hazards are - personalized training tells what the hazards are and how to avoid them.

The application of programmed learning techniques would appear to provide the means of implementing individualized safety training. Little supervisory attention would be demanded in the utilization of this concept and the program would have the added advantage in that the worker would feel personally involved. He would realize that the company was interested in his welfare to the extent that safety education was being directed to him on a personal basis. Another advantage of programmed instruction is the fact that the student learns by doing. He associates a definite set of correct motor responses to a corresponding definite set of perceptual cues. He develops proper habits of perception and response. This is especially true in the case of a simulated job assignment such as the one developed in this thesis.

Specific Areas of Application

Programmed instruction could best be directed to three primary training situations. These are:

(1) New - hire training.

(2) Rehabilitation.

(3) Re-training of transferred employees.

In the case of a new hire, a teaching device could be utilized to indoctrinate the affected individual in the general safety philosophy and regulations of the company as a whole as well as acquaint him with the specific hazards related to his work assignment. Hopefully, this technique will reduce the accidents which are the result of a basic ignorance of safety on the part of the employee involved.

As far as rehabilitation is concerned, it certainly may be advantageous to require an individual to review his safety training after he is involved in a serious injury accident or an accident which could have resulted in a serious injury or considerable property damage. The timing of this rehabilitation training would be an important consideration because the employee would be more cognizant of the importance of safety when the memory of the accident is still vivid in his mind.

The re-training of transferred employees into their new job assignments is of extreme importance since automation, labor force adjustments, and seniority bumping have resulted in a great mobility of individual workers within a particular organization. In this instance, the safety indoctrination would consist only of a specific departmental hazard presentation because the transferred employee, theoretically, would be acquainted with the general safety philosophy of the company. This procedure would go a long way to insure that senior workers do not jeopardize their personal safety when they are introduced into a strange job environment.

The State of the Art

There is currently very little to be found in the literature concerning the application of programmed instruction to industrial safety education. Advanced Learning Systems (1) has published four programmed learning texts as a part of their SAFETY BOOSTER SERIES. These texts deal with:

(1) Ladder Safety.

(2) Slips and Falls - Tripping.

(3) Back Safety.

(4) Slips and Falls - Slipping.

Based upon their studies, the application of programmed learning has resulted in an accident reduction rate of as much as 89% (1).

The National Safety Council has also developed a series of programmed learning texts which are utilized in supervisory safety training. Called STEP (Self Teaching Education Program), the package consists of three program units (10). These discrete volumes are:

(1) Safety and Production.

(2) Recognizing Accident Causes.

(3) Influencing People To Work Safely.

It should be emphasized that this material is directed to supervisory personnel only. No effort has been made to develop course material for individual industrial employees.

Dr. Jerrold Glassman (5) examined, "The Effectiveness of a Teaching Machine Program as Compared With Traditional Instruction in the Learning of Correct Responses to Hazardous Driving Situations" during the course of his Ph.D. dissertation at New York University in 1965. This work, however, has little application and relevance to the problem of developing industrial safety programmed learning concepts.

The United States Air Force (13) has also developed a pamphlet related to the safety education of supervisory personnel. Again, this effort has been directed to supervisors rather than to the individual workers who are involved in accidents one at a time.

The United States Air Force also publishes two magazines related to flight and ground operation safety. One of these periodicals is entitled Aerospace Safety and it is devoted to aircrews, maintenance personnel, and support technicians. The other magazine is called Aerospace Maintenance Safety and its primary emphasis is in the area of ground support maintenance safety. Both periodicals discuss such diverse aspects as instrument reading and errors, weather conditions, runways, electrical hazards, proper use of maintenance equipment, refueling and other ground service, pre-flight checks, maintenance safety procedures, and fire hazards. The two magazines are available, at a modest fee, through the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402.

The above statements reflect the extreme lack of literature associated with the application of programmed learning to industrial safety education. There are probably numerous companies located throughout the country which utilize programmed learning concepts to disseminate basic safety information. The existence of such programs however, is not documented in the literature. Also, it is highly unlikely that industry uses programmed learning techniques in the area of safety education as extensively and to such a magnitude as will be suggested in this thesis.

The Future for Industrial Safety

The provision of safe working conditions in conjunction with the inculcation of safe work habits will be one of the major problems facing American industry in the foreseeable future. Governmental control will be more in evidence as time progresses. In fact, the aspect of increased Governmental regulation became readily apparent when the Walsh Healy Public Contracts Act was published in The Federal Register on May 20, 1969. This act, as initially stated:

> Requires that contracts entered into by any agency of the United States for the manufacture or furnishing of materials, supplies, articles, and equipment in any amount exceeding $10,000 must contain, among other provisions, a stipulation that no part of such contract will be performed nor will any of the materials, supplies, articles or equipment to be manufactured or furnished under said contract be manufactured or fabricated in any plants, factories, buildings, or surroundings or under working conditions which are unsanitary or hazardous or dangerous to the health and safety of employees engaged in the performance of said contract (11).

However, the Occupational Health and Safety Act of 1970, as passed by the 91st Congress on December 29, 1970, specifies that "the term 'employer' means a person engaged in a business affecting commerce who has employees, but does not include: the United States or any state or political subdivision of a state" (9). Therefore, the coverage is far more universal than that which was originally proposed in 1969.

This form of legislation will become increasingly familiar as new social pressures develop, so it certainly behooves industry to undertake positive steps to implement meaningful and effective safety programs. The penalties for non-compliance are real and quite severe. The next series of chapters of this thesis will attempt to deal with the aspect of employee safety education in a new unique way so that industry can equip its personnel with safe work habits and procedures while they are on the job.

CHAPTER II

EXPERIMENTAL METHOD OF ANALYSIS

Plan of Study

In order to prove the validity of the use of programmed instruction in the area of industrial safety education, a simulation technique was utilized. The procedure was confined entirely to a laboratory situation. A laboratory environment was selected in order that certain safety and quality performance criteria could be closely measured and controlled. It is very difficult to obtain data of this sort in an industrial situation because it usually means a costly disruption of the production process. Also, it is virtually impossible to isolate pertinent variables within an industrial environment due to the complex interactions which exist in this type of activity. The laboratory experiment, therefore, was designed to test some fundamental hypotheses concerning the effectiveness of programmed learning upon industrial safety and quality performance. Specifically, these hypotheses were:

(1) The stimulus control which is present in programmed learning techniques is superior to that of classical verbal training methods since in the latter case, the same instructions are never presented in exactly the same fashion. This fact should be reflected in better work and safety performance within the groups receiving this form of training.

(2) It is feasible to realistically simulate production activity without jeopardizing worker safety while, at the same time, making him cognizant of the fact that he could have suffered a serious injury.

(3) The rate of performance improvement (slope of the learning curve) should be significantly greater for the programmed learning methodology than for the classical means of instruction.

(4) The perception of movement associated with the videotape presentation provides more instruction relative to the performance of the task than is provided by the static picture related to the slide-aural presentation.

(5) The use of a startling feedback mechanism to inform the operator of his involvement in an accident will serve as an effective reinforcement for future accident avoidance.

The over-all conclusions derived from the experiment and the validation of the hypotheses advanced are discussed in Chapter VII.

The experiment consisted of a specially instrumented 5-ton punch press designed to automatically record operator safety performance as well as his quality part production. Three groups of unskilled persons not familiar with industrial processes underwent three distinct types of safety training on the proper use of this device. Group one received their safety instruction by the standard, classical means of verbal instruction in conjunction with a written safety pamphlet. The second group was given safety information by the means of 35 mm color slides which were synchronized with an aural narration. A sequential presentation method was utilized to disseminate the material and questions pertaining to the operation of the press were asked of the participants.

Group number three underwent their safety training by the means of a videotape communication media. In this instance, also, a sequential mode of presentation was utilized and the subjects were questioned during the instruction period with the correct response given during the course of the training. The reader is referred to Appendix C where a detailed account of the videotape script is presented. In all three cases, the learner was encouraged to ask questions when he was confronted with the actual job task.

A fourth group of subjects was utilized in the experiment in order to generate control data. This group received no formal training whatsoever. They were made aware of the elements of the simulated job task by the observation of two job cycles. No verbal job instructions were given to them with the exception of very brief detail. This group was not allowed to ask questions concerning any phase of the simulated job task. In other words, they were completely "on their own". This activity was undertaken to determine a basic skill level which could be used as a comparison against the work performances of the three training groups. It was a necessary element of the experiment because it served as a means of answering the inquiry, "Is the form of training in question (35 mm slides-aural, videotape, or verbal) better than no training at all?"

The Selection of Subjects

Experimental subjects were selected for participation in the various forms of training based upon the assumption that they represented a broad, diverse background of skills and experience which would make it unlikely that the results of the experiment would be biased. Twenty-five subjects were selected for each of the four experimental groups. A detailed demographic description of the experimental subjects is presented on page 56. Since no advance knowledge was available concerning the mean and standard deviation of the various performance parameters measured in the experiment, the number 25 was selected for convenience. It was also chosen because most statisticians agree that a number of this size reasonably assures a normal distribution (6).

Since it was assumed that the experimental subject's skills were to be random in nature and that a random sequence of subjects would be available for the experiment, subjects were assigned to their training media in an alternating manner. The alternating sequence chosen for the assignment was:

(1) Videotape.

(2) 35 mm slide-aural presentation.

(3) Verbal instruction.

This sequence was repeated until 25 subjects had been assigned to each training media. In order to determine the subjects who were to receive no training, a random selection process was used. Twenty-five random numbers between 0 and 99 were then assigned to the control experimental phase from the results of this random number selection. For example, if the random number six was selected from the random number table, subject number six was given no training. He, therefore, became a member of the control data group. Twenty-five subjects were placed within the experimental group by the random selection process. In all cases, the selected subjects were completely naive as far as the operation of the punch press was concerned. In fact, none of them had even seen a punch press before their participation in this experiment. A detailed subject assignment sheet is included in Appendix A of this thesis.

The Laboratory Experiment

This phase of the thesis was devoted to the simulation of an industrial task within an experimental laboratory environment. One of the prime requisites for the design of this experiment was that it be closely related to an actual production process in its mode of operation. In this respect, the experiment was valid because it retained the sights and sounds of a standard metal blanking operation which is quite common in industry. The simulated job task is, in actual practice, a very hazardous one since the operator must place his fingers in the working area of the press. Even so, its performance is well simulated. The laboratory task provides an experience which is very closely related to its industrial counterpart by presenting discriminative stimuli that actually occur on the job.

The training phase of the experiment consisted of the dissemination of training instructions for each of three specific media. The videotape presentation was given to the various subjects in a building located some distance away from the scene of the laboratory experiment. Each subject was required to view a 5.40 minute videotape presentation which gave salient information concerning the performance of the simulated job task. The training program consisted of an aural narration of the operations required in the work assignment in conjunction with a visual television presentation of the proper way to perform the task. A safety poster was used to open the television program and two very pertinent safety questions were posed and answered during the course of the presentation. The presentation consisted primarily of three job sequences:

(1) The job cycle in its entirety.

(2) The foot-trip press cycle operation.

(3) The proper alignment of parts so that good parts would be produced.

Upon completion of his training, the subject proceeded immediately to the simulated job task. All questions not answered by the television program were directed to an experimental observer who was present at the experimental laboratory.

The audiovisual training phase consisted of a 35 mm slide presentation in conjunction with a narrative description. Fourteen slides were utilized to inform the subject of the fundamental elements associated with the job task. Each slide was projected on a 24 inch by 18 inch optical screen for a duration of approximately 36 seconds. The entire program required 8.02 minutes for its complete presentation. As in the videotape case, a safety poster was presented along with two answered questions which were directly related to the safety of the subject as he performed the simulated job task. Upon completion of his training, the subject was led to the simulated work environment. As before, the training phase was conducted in a separate building from the one utilized for the laboratory experiment. Also, as in the case of the videotape training phase, all unanswered questions were to be directed to the experimental observer.

Classical verbal training was given to the experimental subjects by the experimental observer located in the actual simulated punch press area. Although each observer had a detailed script which described the elements of the simulated job, he was specifically told not to read this script verbatim. This latter instruction was given so that the training would be indicative of that actually received in industry. Each observer was told to include all elements of the job script in his presentation but to give the training in his own style while, at the same time, performing one job cycle as a demonstration for the subject. All questions regarding the performance of the task were directed to the appropriate observer.

Finally, the control group received no formal training as such. They were allowed to observe the performance of two job cycles so they could be made aware of the task. No questions were permitted but the function of the accident detection circuit was explained to them since they would certainly be aware of any accidents in which they may be involved in an actual job environment. Specific descriptions of the various training media and job instructions are presented in detail in Chapter IV.

Upon completion of the training phase of the experiment, each group of participants was required to simulate the production of a series of parts on the instrumented punch press which was previously mentioned. In order to help the reader fully understand the next series of statements, a sketch of the layout of the work station is presented in Figure 1. To accomplish this assignment, the operator picked up a

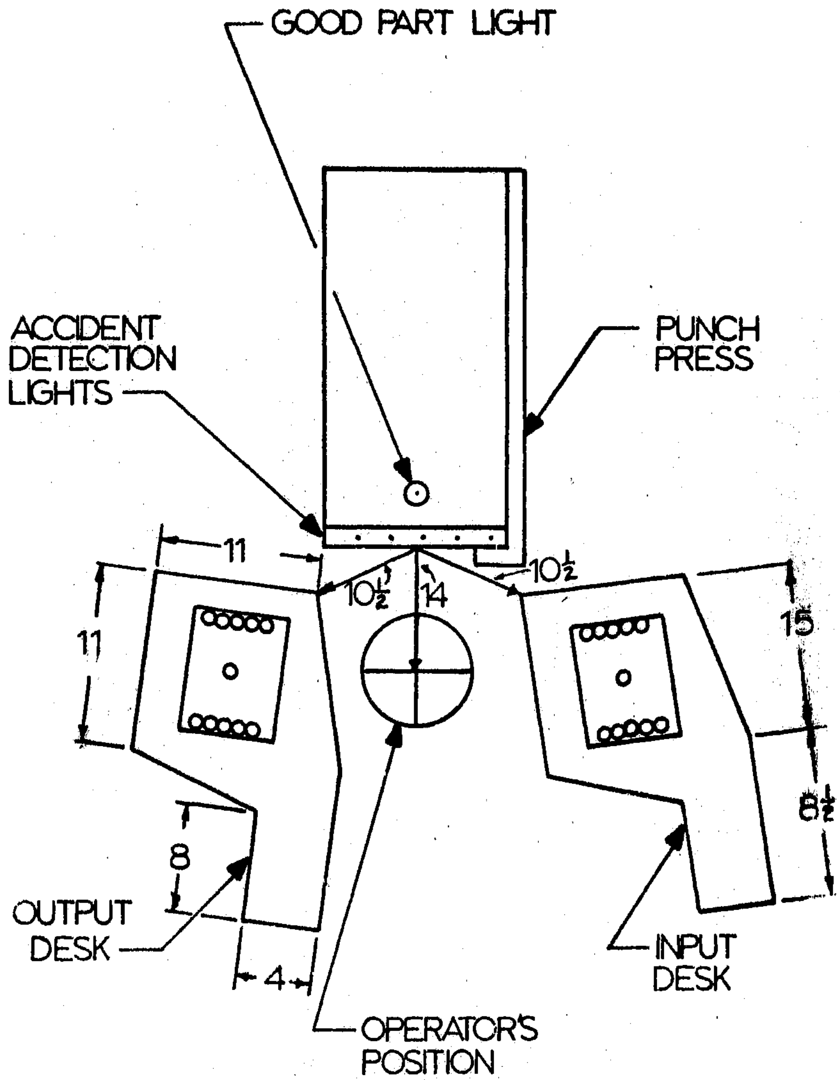
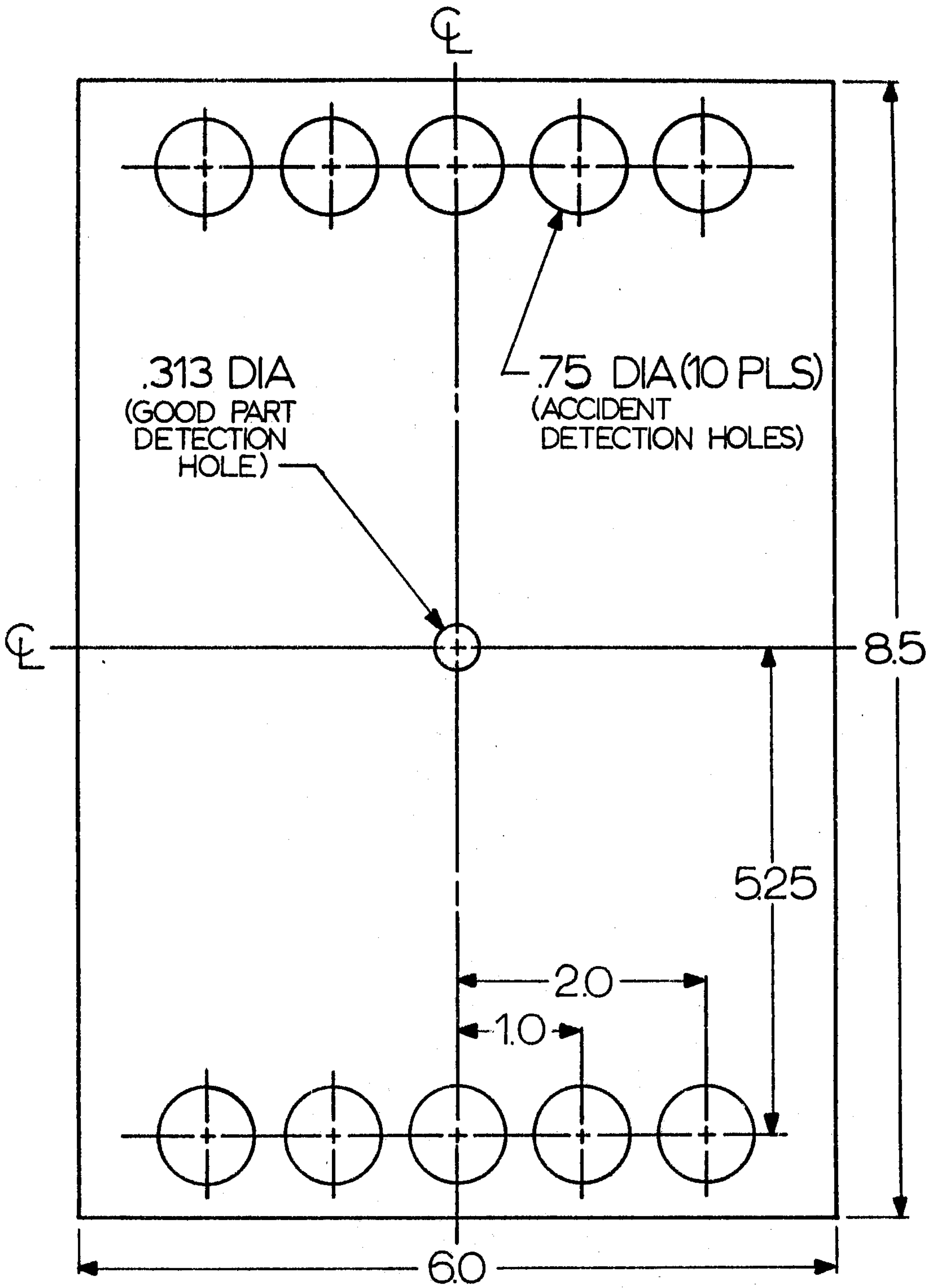


Figure 1. Experimental Work Station Layout

pre-drilled .040 inch aluminum blank (Figure 2), and placed it into the throat of the press against a back and a right-hand stop. After the part had been properly aligned, the press was cycled by actuating a foot trip lever. This cycling of the press simulated a blanking operation on the aluminum part. Upon completion of the press cycle, the operator removed the aluminum part, rotated it 180 degrees and re-inserted it into the press against the same two stops which were mentioned above. Again, the press was cycled and the part was removed and laid aside after the cycle was completed. A new part was then grasped and the process was repeated as before. In all, the simulated production of 100 aluminum parts was performed by the experimental subject. This means that 200 passes were made into the press since each part requires 2 separate press operations. The operator, therefore, had his hands close to the working area of the punch press 200 times during the course of his participation in the experiment. This created 200 possibilities for potential accidents if the job task had not been a simulated one.

It should also be emphasized that the task also presented 200 opportunities for mis-alignment of the aluminum blank which could result in the production of 100 defective parts. Therefore, the operator must be cognizant of the dual possibility of producing defective parts and suffering a simulated accident during his performance of the simulated job task. He was aware of his involvement in potential accidents because a loud klaxon sounded when this event occurred. He received immediate feedback of his error in this respect but he was unaware of his defective part production until the experiment had been terminated. This was directly related to an actual production environment since an employee receives immediate knowledge of his involvement in an accident



MATERIAL: .040 ALUMINUM

Figure 2. Part Configuration

but may only become aware of his quality part performance after a period of time.

As the experiment was structured, it was possible for a subject to suffer repeated accidents during the course of the simulated job activity. In this respect, the laboratory simulation was somewhat unrealistic since an employee would be removed from his job assignment upon the occurrence of an accident. The simulated job task allowed the operator to make a maximum of 200 mistakes which could have resulted in a disabling accident. From this standpoint, the experiment did possess an element of realism since an industrial employee can be involved in a repeated series of "near-misses" without suffering an injury accident. In this connotation, the term "potential accident" may have more meaning as far as the results of the experimental situation were concerned.

A specific form was designed for recording data in order to minimize data transcription errors and to ease the various tasks of the experimental observers. The form utilized discrete columns which were allocated for the recording of:

(1) The subject's name.

(2) The type of training he received.

(3) Total elapsed time to complete the experiment.

(4) Time until the occurrence of the first accident.

(5) The readings of the three digital counters for:

a. First ten parts.
b. Second ten parts.
.
.
.
.
j. Tenth ten parts.

The total elapsed time was obtained from a decimal hour stopwatch controlled by the observer. Time until the occurrence of the first accident was read from an electrically driven microchronometer which was specially instrumented to stop at the occurrence of the subject's first potential accident. This device was manually reset and started by the observer, however. In order to facilitate the reading of the counters after each ten parts, cardboard dummy parts were inserted into the input part stack after each ten parts. The observer, upon the observation of one of these dummy parts, recorded the counter readings in order that a time history of operator performance could be documented. The experimental subject was instructed to toss these dummy parts aside when he encountered them. Chapter IV contains an extensive treatment of the experimental procedures and forms which were developed to insure valid experimental data.

The simulated job task was designed to be performed in approximately eight minutes. Each experimental subject was instructed to work "quickly and accurately" under a nine-minute time limit. A positive motivational element was introduced into the experiment by informing each participant that a $20 cash prize would be awarded to the individual who recorded the best time, quality, and safety performance during the course of the experiment. This aspect was placed within the context of the experiment to insure that each subject would do his best in the performance of the simulated job task. An inducement of this sort is required because the subject was cognizant of the fact that he could not be hurt during the simulated job activity and he would not be penalized for sub-standard quality performance. The job task, while being very realistic, still did not possess the payoff elements which would be presented in an actual industrial environment.

The operator performed the simulated job assignment from the seated position by utilizing both his right and left hands. The job method had been standardized prior to the creation of the audio-visual training presentations and this fact was documented by the use of a "simo-chart". This documentation is included in Appendix B. In designing the work assignment, fundamental principles of human factors engineering were employed. The layout of the work station was developed with the idea that long reaches and awkward movements would be non-existent. A detailed layout of the work station is given in Figure 1, p. 18. Extreme care was exercised during the course of the experiment to insure that the layout of the job assignment remained constant. This latter activity was accomplished by locating input and output parts tables on indelible marks placed on the floor of the experimental room.

The experimental hardware, a punch press simulator, included photoelectric cells in conjunction with digital counters to give:

(1) <u>The total number of parts attempted or passes into the press if each part required more than one pass</u>. In reality, therefore, the parts attempted counter was incremented each time a micro-switch was actuated by the foot-trip lever. This means that the counter actually served as a digital readout of the number of press cycles. There is a one-to-one correspondence between press cycles and parts attempted when one cycle produces one part. Two press cycles were required to produce one part. This mode of operation was selected because it is

more indicative of actual industrial processes where multiple pass punch press activity is quite common.

(2) The number of acceptable quality parts produced or the number of good passes if multiple passes are involved. This counter was incremented by one each time the part was properly aligned within the punch press. Proper alignment was necessary to insure that a photoelectric circuit would remain undisturbed by the location of the part. Improper location of the aluminum blank broke the light beam associated with this circuit with the result that the counter remained at its initial value. In the case of multiple pass operations, the counter served to record the number of mistakes or the occurrence of improper alignments. When one press cycle produces one part, the counter records the production of an acceptable quality part.

(3) The number of potential accidents which occurred during the production cycle. In order to accomplish this task, the accident counter was directly connected to a photoelectric accident detection circuit which was located immediately adjacent to the front of the working area of the punch press. The counter was incremented when the operator's hand disturbed any of the five beams of light which comprised this accident detection circuit. It should be realized that this circuit was only energized after the foot trip lever had been depressed. The accident counter was only incremented during an actual

press cycle. There were, of course, other types of unsafe acts which could not be detected by this circuit. For example, the operator could have placed his hands into the working area of the press through either a right or left side access opening and escaped detection. The job training sequences, however, specifically stressed that the simulated parts were only to be inserted and removed from the front area of the press.

Again, it should be realized that the device functions as a simulator. There is no possible way that the participant can actually be injured during the simulated production cycle.

The laboratory experiment was designed to compress the time cycle which would have been required to observe the actual on-the-job safety performance of workers trained under each of the three independent methods. Also, it would have been extremely difficult to objectively measure the effectiveness of each technique under actual industrial conditions. The digital instrumentation, however, behaves in a completely impartial manner. It consistently records all of the pertinent data with no variation whatsoever. This is a decided benefit in the statistical analysis of the results since responses and errors are classified objectively, impartially, and automatically.

A Final Qualifying Statement

The experimental design was created from a very pragmatic viewpoint. The purpose of the research was to develop and validate a practical industrial technique, not to investigate theoretical models of human behavior. This being the case, the more sophisticated and advanced theories in engineering psychology were not taken into account. The laboratory study was conducted under rigidly controlled conditions with all pertinent variables not directly controlled or measured being held at nearly constant levels. A detailed description of the experimental procedures is presented in Chapter IV.

CHAPTER III

HARDWARE DESIGN AND DEVELOPMENT

Basic Philosophy of Design

In designing the hardware, four factors were of paramount importance. These were specifically:

(1) The device should simulate an actual piece of shop equipment.

(2) The simulated job task should be highly realistic.

(3) The production operation should be a relatively hazardous one under normal conditions.

(4) There should be no likelihood of accidental injury associated with the experimental task.

The device to be described in the next series of pages meets the above criteria in every respect and provides an excellent means of validating the effectiveness of programmed learning as applied to safety education.

The Punch Press

The primary device utilized in the simulated job task was a five ton capacity Di - Acro punch press, model number five. The press is a relatively small floor model with an over-all height of approximately five feet. The device is, however, quite dangerous in its mode of operation. First of all, it is a foot-actuated piece of equipment. This means that the operator has his hands free during the operation cycle of the press. This situation, therefore, allows the operator the opportunity of placing his hands within the working area of the press with the result that loss of limbs can <u>and</u> <u>do</u> occur. The second hazardous feature of the device is related to the fact that it is a mechanically actuated piece of equipment. The ram of the press descends when the crankshaft passes the point of top-dead-center. The descent cannot be stopped once it is initiated since the flywheel has enough inertia to cycle the press even after the power has been shut off. Also, the mechanical nature of the equipment results in a very short cycle time. This makes it virtually impossible for the operator to react quickly enough to avoid an accident if his fingers are in the vicinity of the working area of the press. The device is common in virtually all metal processing industries. This fact, plus the hazards associated with its operation, make it a prime candidate for experimentation. In fact, Blake (2) reports that punch presses caused 76.8, 64.1, and 71.3 percent of all injuries associated with the functions of forming, punching, and shearing in the states of Wisconsin, Pennsylvania, and New York, respectively. He further states that punch presses caused 48.5 and 67.7 percent of the serious injuries related to punching, forming, and shearing functions in the states of Wisconsin and New York, respectively. These statistics are certainly indicative of the hazards associated with punch press operations and of the need for training.

The Basic Mode of Operation

The best way to explain the functions of the experimental hardware is to examine a cycle of its operation. After this, a detailed description will be given in which each major component will be explained and its function analyzed.

The operation of the press can best be described by the following chronological sequence:

(1) From the shut-down condition, 115 volt power is turned on to energize the accident detection light sources and the relays associated with the three digital output counters.

(2) A toggle switch is then thrown to energize the accident detection circuits.

(3) The press simulator is now in the ready mode. No other procedures are required until the system is shut-down. In this case the steps listed in (1) and (2) are reversed.

(4) The operator then turns on the power to the punch press itself. This action brings the flywheel up to speed and insures proprer mechanical operation of the press.

(5) The operator picks up an aluminum blank and inserts it into the press. He aligns the part by placing it firmly against right-hand and back channel stops.

(6) He then actuates the foot-trip lever which mechanically activates a micro-switch within the electrical circuitry and cycles the press.

(7) The micro-switch activates the good parts, accidents, and parts attempted counters.

(8) If the part was properly aligned when the ram of the press made its downward descent, the good parts counter is incremented by one.

(9) If the operator's hands were in the throat area of the press during the operating cycle, the accident counter is incremented by one and a loud klaxon sounds to inform the operator of the occurrence of a potential accident.

(10) In all cases, the parts attempted counter is incremented by one when the foot-lever is depressed.

(11) After the press had cycled, the operator removes the aluminum blank, flips it end-for-end and repeats steps (6) through (10) as given above. He then lays the part aside and picks up another one to continue the job task.

These steps describe, in a general fashion, the fundamental operation of the hardware. The next sequence of paragraphs will explain the specific functions of the major hardware components (see Figure 3).

The Accident Detection Circuit

The accident detection circuit (see Figure 4) consists of five light sources and five photoelectric cells which are used to detect operator intrusion into the throat area of the punch press. The light sources are driven by 2.5 volts AC and are mounted on a steel channel frame which is approximately 10 inches square. This frame is securely fastened to a 10 inch by 1-1/4 inch by 2 inch aluminum block which contains five photoelectric cells mounted on 1-1/4 inch centers located 2-1/2 inches from the end of the block. This entire structure is mounted on the front lip of the press throat approximately 3-1/4 inches

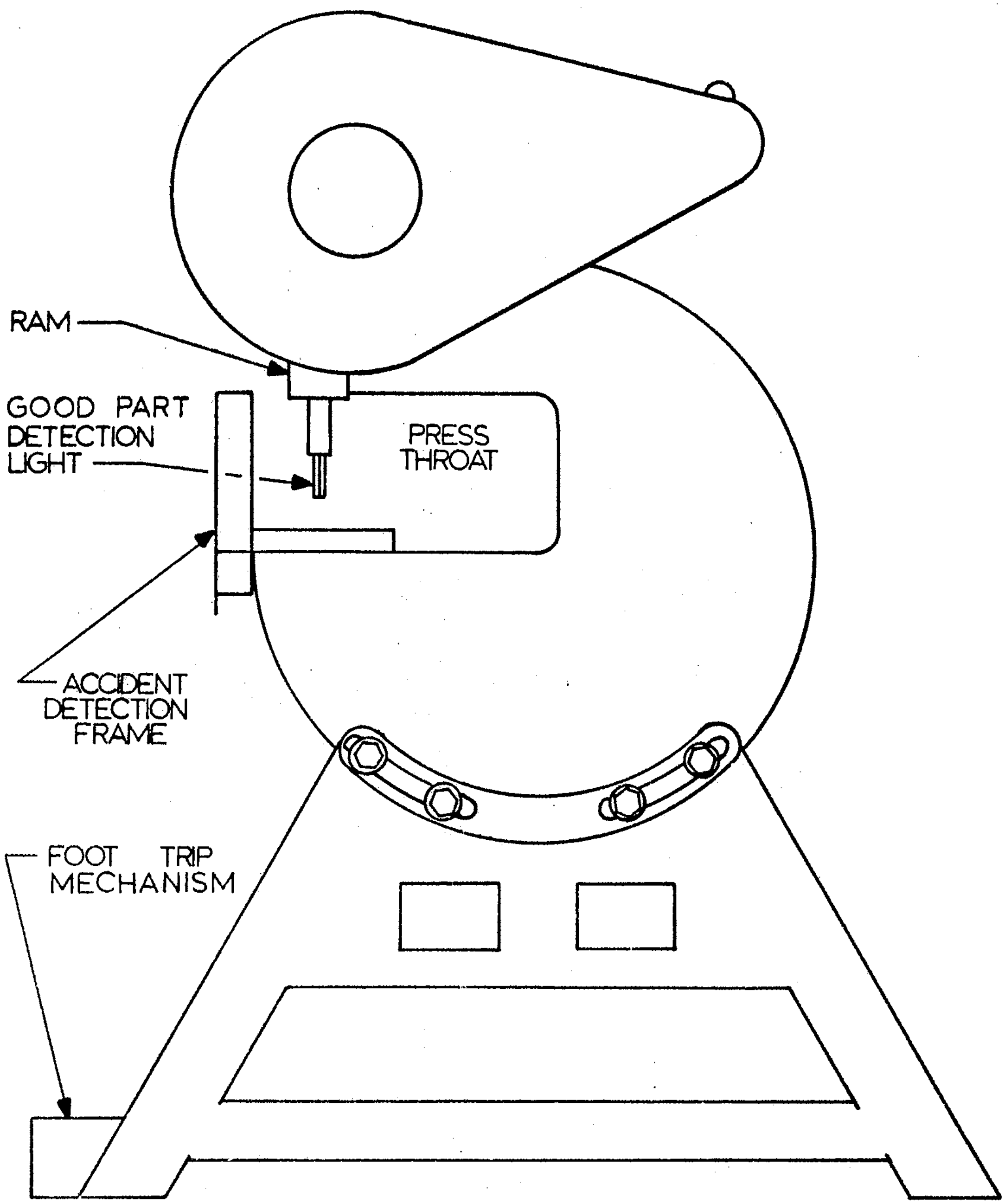


Figure 3. Punch Press Schematic Diagram

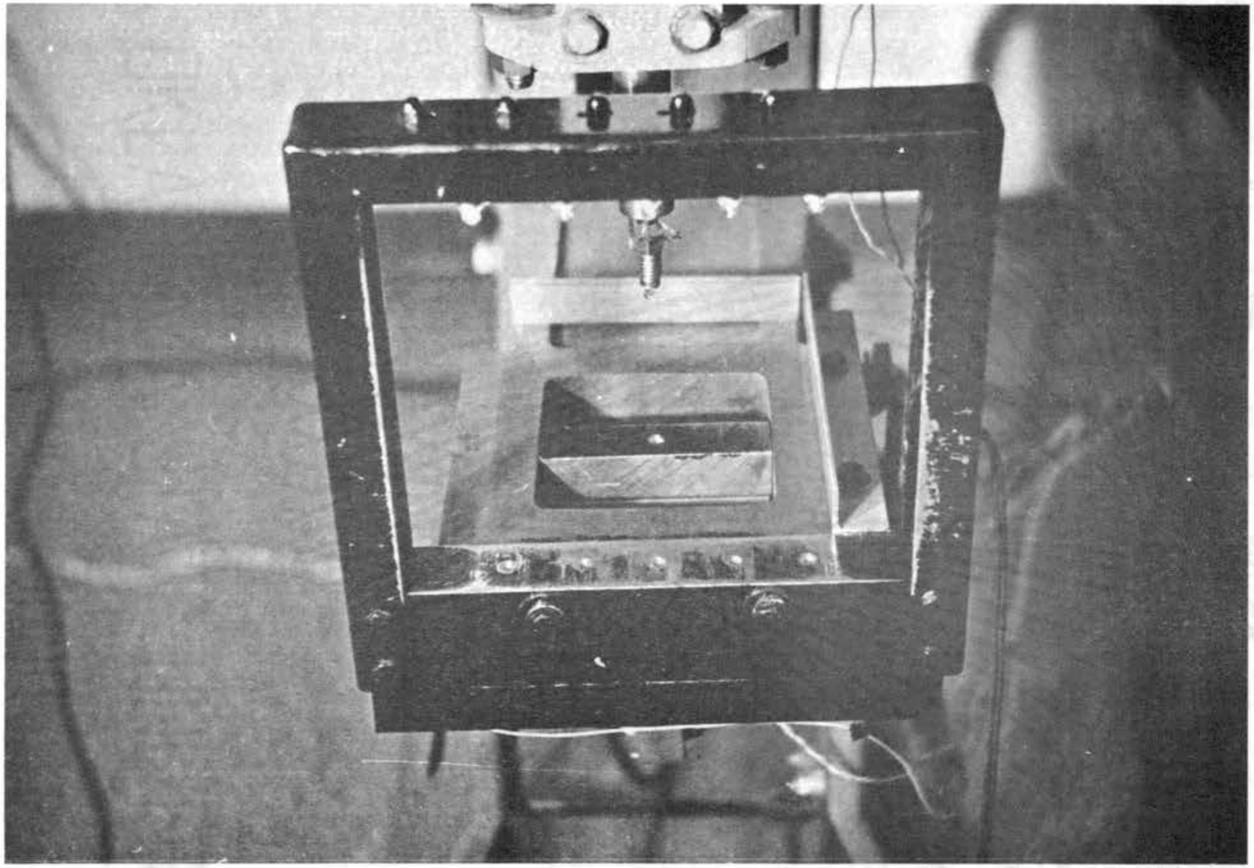


Figure 4. The Accident Detection Circuit

from the ram of the press. The lights are adjustable and can be refocused into the photoelectric cells as the need arises. Flat black paint has been applied to the structure to minimize ambient light effects. If the operator breaks any one of the five light beams after he has actuated the foot-trip lever, the accident counter is incremented by one and a klaxon sounds to inform him of his mistake. Five 3/4-inch diameter holes are drilled into each end of the aluminum blank (see Figure 2) to insure that the blank does not interfere with the accident detection light beams. A series of relays in the electronic accident detection circuit insures that no contradictory situations can occur. Logic circuitry protects the integrity of the accident detection function. In other words, there are no instances in which the accident detection circuit will be operative unless the punch press is in its normal operating mode.

The Good Part Detection Circuit

This element of the hardware is utilized to indicate the proper alignment of the aluminum blank within the throat of the press. It consists of a light source which is mounted on a 1-inch diameter steel rod which is clamped in the ram of the press. This light actually moves in the vertical plane as the ram of the press cycles up and down. Unlike the accident detection light sources, the good parts light remains off until the press is actuated by the foot-trip lever. This light source is focused into a photoelectric cell which is mounted in a 1-1/2 inch square aluminum block which is securely fastened at the exact center of the throat area of the punch press. As in the case of the accident detection structure, the photoelectric cell mounting block was given a coat of flat black paint to minimize the effect of reflected ambient light. A 5/16-inch hole is drilled in the exact center of the aluminum blank (see Figure 2) to allow the light to pass through to the photoelectric cell when the blank is properly aligned against the right-hand and rear aluminum channel stops. After the press has been actuated, the ram starts on its downward stroke with the light source energized. The light source reaches a point approximately 2 inches above the photoelectric cell when the crank shaft of the press attains bottom dead center. This 2-inch gap makes it virtually impossible for the operator to suffer an accident during the course of the simulated job task. The proper alignment of the aluminum blank insures that the photoelectric cell will be energized by the moving light source with the result that the good part counter will be incremented by one. A detailed description of the good part detection structure is given in Figure 5.

System Outputs

As mentioned before, the performance results of the simulated job task are recorded on three counters which are included within the logic circuits of the system. These counters (see Figure 6) are six-position digital devices with no provision for resetting. This latter feature makes it imperative to record the cumulative readings of the counters in order that the before-and-after task counter values may be obtained. The parts attempted counter is stepped by an increment of one every time the foot-trip lever is actuated. The accident counter is incremented when the operator breaks the photoelectric accident detection circuit. The good part counter is actuated when the aluminum blank is

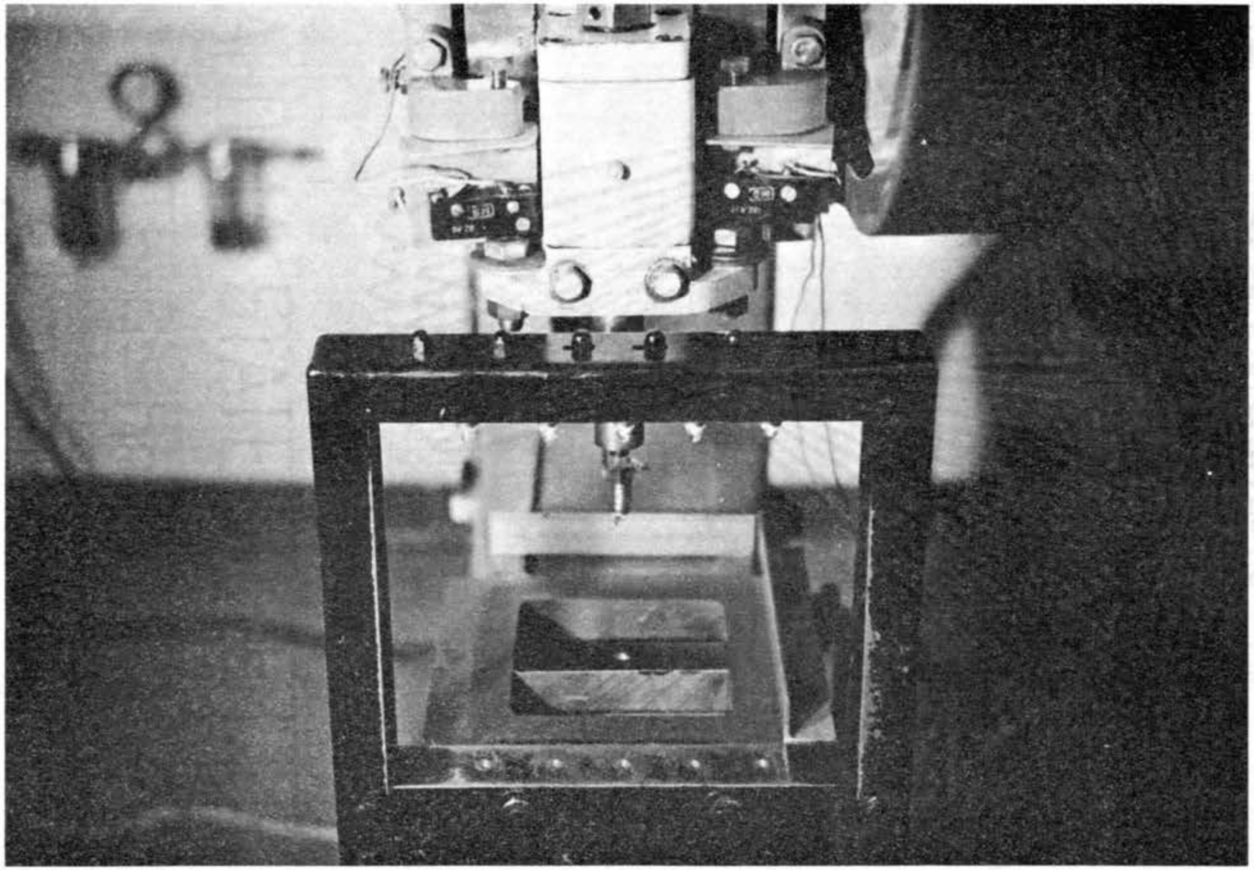


Figure 5. The Good Part Detection Mechanism

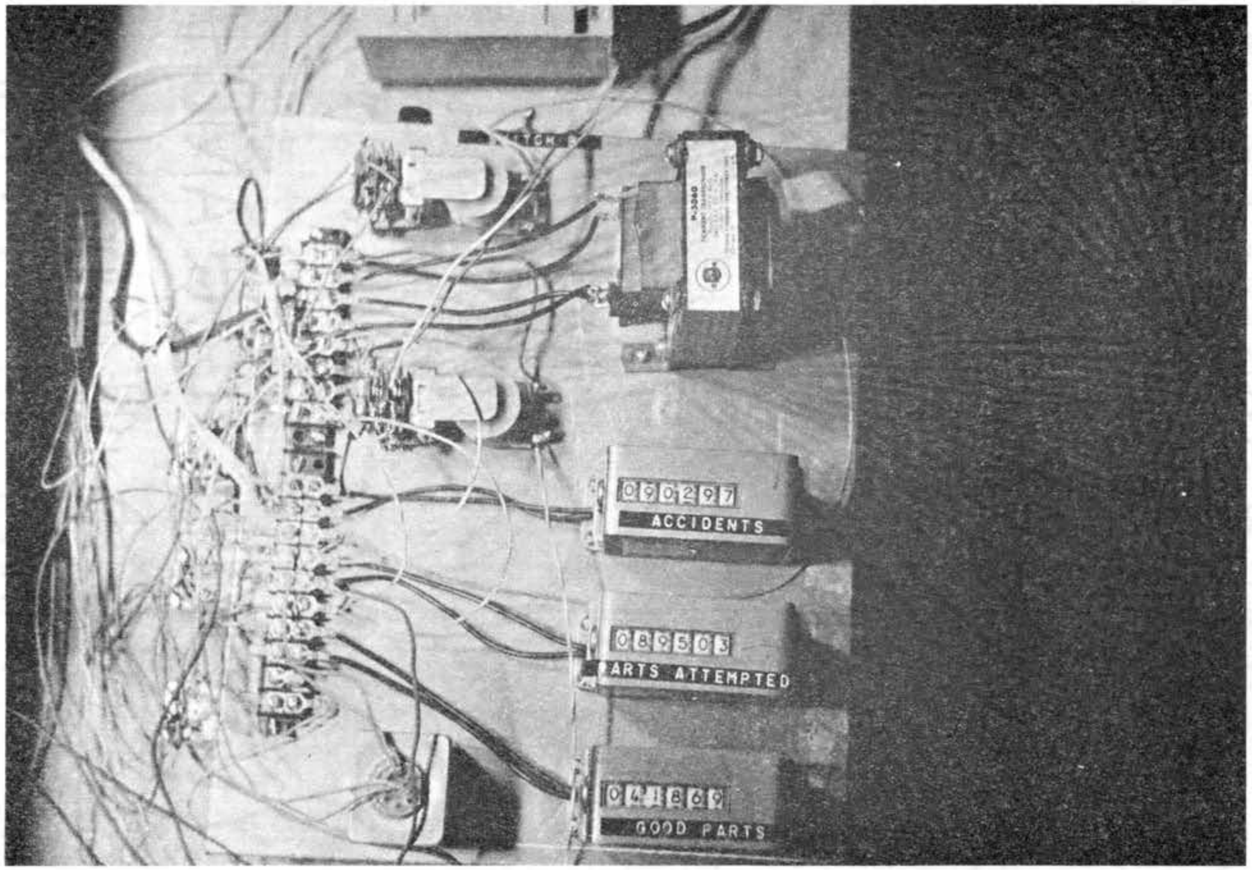


Figure 6. Digital Output Counters

properly aligned over the good part photoelectric detection circuit. The counters have proved to be extremely reliable in operation. No false alarms were detected during the performance of 2,000 test cycles.

Miscellaneous Comments

The hardware provides the means of presenting a highly realistic simulated job task within a laboratory environment. The operation of the piece of equipment is very closely related to its actual operation within an industrial setting. The digital output of the system gives an accurate and consistent performance record of the results of the simulated job task. It should be realized, however, that it is within the subjective judgment of the experimenter to place the light beams wherever he feels is dangerously close to the working area of the press. The advantage of automatic recording is consistency in the data rather than absolute validity. The experimenter must provide conditions and criteria that give meaning to the data. The aspect of consistency also simplifies the statistical analysis of the experimental data by a considerable amount.

The response time of the accident detection circuit is on the order of 30 milliseconds. This feature makes it virtually impossible for the operator to have his hands in the throat of the press and escape detection during the production cycle. The good part detection circuit is also extremely sensitive. A mis-alignment of plus or minus 1/16 of an inch will result in the non-incrementation of the good part counter. Since bad parts are the difference between parts attempted and good parts, the ultimate result of blank mis-alignment is the recording of a bad or defective part.

The dual recording of potential accidents and the production of good quality parts is an extremely important feature of the experimental hardware. Safety and quality are two inseparable elements of any production process. To emphasize one without emphasizing the other is to frustrate the very purpose of good production procedures and practices.

A 20-pound solenoid was installed in the throat area of the press to provide noise during the production cycle. It is actuated every time the foot-trip lever is depressed and creates the illusion of the ram actually striking the aluminum blank when in reality it is at a distance of two inches from doing so. This provides a discriminative stimulus which is actually present in a standard punch press operation. Also, the normal noise associated with the function of the press is still present since the punch press is being used in its standard mode of operation.

The feature of providing notification to the operator of the occurrence of an accident is also a very important aspect of the hardware. A loud klaxon sounds with every occurrence of an accident. The noise is very startling and makes the operator aware of the fact that he could have suffered a serious injury if the job task had not been a simulated one.

The design and development of the experimental hardware was one of the most significant efforts of this research. The author is not aware of literature which describes hardware designed to simulate industrial machinery. This appears to be a new approach to industrial training.

During the initial phase of hardware development, an experienced punch press operator was consulted as to the effectiveness of the simulator. He reported that the device simulated the operation of a real punch press in an industrial environment to a very high degree of realism. He was also instrumental in recommending changes in the hardware in order to improve the effectiveness of the simulation. Without exception, these modifications were incorporated into the design. A detailed circuit diagram outlining the electronic system is presented in Appendix B of this thesis.

CHAPTER IV

EXPERIMENTAL PROCEDURES AND TRAINING PROGRAM DEVELOPMENT

Experimental Procedures

In order to facilitate the training of experimental observers, three specific operating procedures were developed. Operating procedure one (see Appendix C) was referred to as the system initialization procedure. It was developed to acquaint the various experimental observers with the series of steps which were required to energize the electronic data recording system. Included within this procedure was a definite sequence of operations which had to be performed in a specific order to insure that the sensitive electrical circuits would not be damaged. The procedure also included a status check of the system so that the observer could ascertain the fact that the three counters were incrementing properly.

Operating procedure two was a detailed explanation of the steps required during the actual experimental simulated job task. Included within this document were instructions pertaining to:

(1) The location of the input and output part desks on the indelible marks on the floor.

(2) Placement of the aluminum blanks on the input desk within the area denoted upon the desk with the painted corners located at the upper right.

(3) The resetting of the accident timer and the elapsed time stopwatch to zero.

(4) Initiation of the job task by informing the experimental subject to "go".

(5) The recording of data after each ten (10) part sequence by observing the cardboard dummies inserted into the input stack.

(6) Procedures required to record counter values if the subject did not finish the task within the alloted nine minute time.

(7) Obtaining personal data from the subject and the type of training he received.

(8) Information to be given the subject upon his completion of the job assignment concerning the awarding of the $20 prize and the fact that potential subjects should not be informed of the nature of the experiment in order that its integrity may be preserved.

(9) The cycling of the press five times to insure its proper operation for the next experimental run.

The experimental observer was also responsible for informing the subject of the need for pressing the foot-trip lever firmly in order that the punch press would operate properly. He also had to tell the subject to insert the parts into the punch press with the painted corners at the upper right-hand position. An arrow was painted on the aluminum blank in order to facilitate this activity. This step was necessary to insure that proper alignment produced good parts since there were minute differences in the dimensions of the aluminum parts.

The observer also was required to inform the subject of the disposal of the cardboard dummies located in the input stack after each ten part sequence. Finally, the experimental observer answered any specific questions related to the job task which were not covered in the various training programs.

Procedure number three was concerned with the generation of control data. The observer was informed that no formal training was to be given to individuals who were selected for inclusion in the control group. This procedure specifically allowed the observer to acquaint the subject with the task by the performance of two (2) job cycles. No questions were to be answered by the observer but he was required to explain the function of the accident detection-klaxon system. Detailed copies of procedures two and three are presented in Appendix C of this thesis.

Experimental Data Forms

During the course of the experiment, four forms were extensively utilized. The first form was called a "subject assignment sheet". It was used by the training observer to assign each of the 100 subjects to the appropriate training media. This form was the means of implementing the subject selection process which was discussed in an earlier chapter of this thesis. The training observer was instructed to check off the subject number after the training had been given in order that the proper sequence could be maintained. Each training observer received a copy of this sheet and it was his responsibility to see that it was explicitly followed.

At this point in time, it may be well to distinguish the duties of the training and experimental observers. Training observers administered the two audiovisual presentations and then delivered the experimental subjects to the punch press laboratory area. The experimental observer then took over and ran the subject through the simulated job task according to the instructions given in operating procedure two. He was also responsible for the dissemination of job instructions to those subjects who were chosen to receive classical oral training. In addition, the experimental observer was required to process those individuals who received no training so that basic skill levels could be determined.

A volunteer form was also developed in order that experimental subjects could express their desire to participate in the training experiment. The form contained a very brief description of the experiment and the need for experimental subjects. The approximate time required to complete the experiment was noted along with the fact that a $20 award was to be given to the person with the best over-all performance. Space was allocated on the form for the potential subject to list:

(1) His or her name.

(2) Age.

(3) Sex.

(4) First, second, and third choice available participation times.

These forms were extensively utilized in the scheduling of subjects through the training and the job task phases of the experiment.

The primary form used in this research was referred to as Form A. It served as the major means of collecting experimental data. Specific columns were allocated for the recording of the various classes of job performance data. The form was designed in such a manner as to facilitate the experimental observer's task of recording time and counter values. A detailed instruction sheet was developed in order to acquaint the various experimental observers with the proper procedures required in filling out the form. The form was designed so that all pertinent information could be easily obtained with a minimum amount of clerical error.

Form B was developed to obtain initial and final good part and accident counter readings. In other words, Form B gave cumulative counter values so that a subject's over-all accident and good part performance could be determined. This form was a complementary one to Form A since Form A was utilized to obtain learning curve or time dependent data. Form A was used to record performance values for ten part increments while Form B was used to record gross values for the entire 100 parts. No provision was made on Form B for the recording of initial and final parts attempted values since the difference in all cases was the number of cycles or 200. Examples of all of the forms mentioned above are found in Appendix D. In order to preserve the privacy of the experimental subjects, the following coding format will be used throughout this thesis.

XX - YY - Z

where:

XX Denotes the training media

a. CL - Classical training

b. AV - Audiovisual training

c. NONE - No training

d. TV - Television training

YY Indicates the serial number of the subject

a. Ranges from 1 to 25

Z Denotes the sex of the subject

a. M - Male

b. F - Female

Audiovisual Program Development

The 35-mm slide-aural program was designed to present, in a sequential mode, a complete cycle of the simulated job task. In order to accomplish this feat, fourteen slides were utilized in conjunction with a recorded narrative explanation of the activity depicted within the slide. Each slide was projected on a 24" x 18" optical screen for approximately 36 seconds. The apparatus used for this mode of presentation was a Sears-Roebuck Number 9865 Automatic 500 Slide Projector in conjunction with a Sears-Roebuck Number 6233 Slide-Snyc Tape Recorder. This device utilized a tone recorded on a separate unused channel of the magnetic tape to automatically activate the slide projector. This feature insured a constant sychronization between the aural and visual segments of the presentation.

The slides utilized in the audiovisual training phase of the experiment were taken in the punch press area of an actual job cycle. This method was used to acquaint the subject with the job method and hardware associated with the simulated task that he was expected to perform. These slides presented a complete pictorial view of the major aspects of the job assignment. Specifically, the content of each slide was as follows:

(a) Slide 1 - This was a picture of a safety poster which read: "BE ALERT - ACCIDENTS OCCUR WHEN LEAST EXPECTED". Associated with the slide was a narrative explanation of the fact that punch presses are responsible for many accidents which result in severed limbs.

(b) Slide 2 - The aluminum blank which was utilized in the experiment was depicted in this slide. Informational data was given concerning the type of material and the approximate dimensions of the part. Also, it was made clear that 100 of the blanks were to be used in the experimental task.

(c) Slide 3 - The operation of grasping the part from the input stack was shown in this slide. Very little narration was required due to the simplicity of the task.

(d) Slide 4 - The fourth slide was related to the move which was required to bring the part to the immediate vicinity of the punch press. Again, very little narration was required for this slide.

(e) Slide 5 - The positioning element of the job assignment was shown in this slide. The aural explanation was concerned with the fact that the aluminum blank must be positioned flat on the working area of the press so that the simulated punching operation could take place.

(f) Slide 6 - This slide was a very important one in that it depicted the proper alignment of the part against the back and right-hand aluminum channel stops. The subject was told that incorrect alignment of the part would result in a bad part being produced since the photoelectric cell would not see the light from the light source mounted on the ram of the press.

(g) Slide 7 - The seventh slide was concerned with the proper operation of the foot-trip lever. The subject was impressed with the fact that the lever had to be pressed firmly in order for the punch press to function correctly. A question was posed to the trainee during the course of this slide. This question was concerned with the fact that the foot-trip mode of activation was a dangerous feature of this particular punch press. The question was answered by stating that foot activation was dangerous because it allowed the operator's hands to be free with the result that they could be placed in the dangerous working area of the press during the punch cycle. The operator was also informed that the placement of the hands under any one of the five accident detection lights would result in a horn sounding to inform him of his involvement in a potential accident.

(h) Slide 8 - This slide was intended to depict the proper removal of the part from the press. Again, a question was asked of the trainee. Specifically, he was asked why the mechanical nature of the press made it especially dangerous. The question was answered by stating the fact that the inertia of the flywheel is sufficient to allow the press to perform one cycle even after electrical power has been shut off.

(i) Slide 9 - The operation of flipping the part end-for-end was shown in this slide. The subject was informed that this was a necessary activity due to the fact that two passes were required to complete one part.

(j) Slide 10 - The tenth slide was merely a repetition of slide five in which the positioning element was described.

(k) Slide 11 - The proper alignment of the part within the press was again depicted in this particular slide. The subject was reminded of the fact that improper alignment would result in a defective part. He was also told to remove his hands from the working area of the press after the part was properly positioned.

(l) Slide 12 - The foot-trip operation was described along with the warning that the subject's hands should be clear of the press after the foot-trip lever was pressed. He was again informed of the fact that the horn would sound if any of the five light beams were disturbed during the operating cycle of the press.

(m) Slide 13 - This slide depicted the activity of grasping the part and removing it from the press after the ram had completed its final movement.

(n) Slide 14 - The final slide dealt with the element of laying the part aside on the left-hand output desk.

After all fourteen slides had been presented, the subject was informed that the series of operations described in the slides were to be repeated for each of the 100 aluminum blanks. He was told that a $20 cash prize would be awarded to the individual with the best over-all job performance. Also, the trainee was informed that he had a nine minute time limit to perform the job and that an observer would record data after each ten parts. The aural narration was terminated by telling the subject to work quickly and accurately and by wishing him "good luck". Upon completion of his training, the subject was led immediately to his simulated job task. A detailed script associated with each slide of the audio-visual presentation is included in Appendix C.

The Development of the Videotape Program

The videotape program essentially consisted of three separate segments. The first segment was an over-all wide-angle view of the entire simulated job task. It showed the primary elements of the work assignment, namely, the grasp, position, foot-trip, flip, re-position, foot-trip, removal, and lay-aside activities associated with the aluminum blanks. It was a continuous presentation of all of the necessary components of the job. The initial phase of this presentation was devoted to the dissemination of basic information. As in the case of the audio-visual presentation, a safety poster which read "BE ALERT - ACCIDENTS OCCUR WHEN LEAST EXPECTED" was the first item viewed by the trainee. Associated with the poster, was an aural explanation of the fact that the punch press is a dangerous piece of equipment which is responsible for many industrial accidents. The second informational data presented in the initial stage of the program was a picture of the aluminum blank to be used in the experiment with a description of its basic dimensions. The subject was also informed of the fact that 100 of the parts were to be utilized in the experiment.

An aural explanation was included with the visual presentation so that the subject could be made aware of the significant aspects of the work assignment that he was viewing. The script (see Appendix C) utilized for the aural narration was quite similar to the one used for the audiovisual program presented in the previous paragraphs. This approach was deliberately chosen so that the two training methods could be compared on the basis of the mode of presentation rather than on the content of the training program. The aural description was recorded on the videotape during the actual performance of the job task in order that the sounds associated with the job task could be heard by the subject. This element was not present in the audiovisual program since it was impossible to synchronize continuous sound with a discrete slide presentation. The Sony AV 3600 Videotape Recorder used in this research does have "audio-dub" capability which allows an aural narration to be made after the visual channel has been recorded. This feature was not utilized, however, since it would erase the background noise related to punch press activity. The noise aspect is a most important discriminative stimulus in the proper operation of any metal forming machine and it should be retained, if possible, in any training program. The first segment of the presentation depicted 35 job cycles and had a duration of 4.25 minutes.

The second discrete phase of the videotape program demonstrated the proper method of foot-tripping the press. This sequence lasted .08 of a minute and presented seven job cycles. It was included because the Sony VCL-20 zoom lens utilized in the taping did not have the necessary field of view to show the foot-trip operation in the general presentation of the job task. The proper actuation of the press was a very important aspect of the job task so it was imperative that the trainee be cognizant of its proper performance. The aural narration was terminated during this segment of the program. It should be emphasized that the narration was continuously presented throughout the first two segments of the videotape program in order that the subject could be made aware of specific aspects of the elements that he was viewing on the television screen.

Segment number three was a 35 second zoom shot of the proper procedure of part alignment within the press. Again, this sequence was included due to the fact that it was virtually impossible to include details of part alignment in the general presentation which was given in segment one. The first segment was essentially a wide angle shot of the entire job task and, as such, it did not present sufficient detail of the proper alignment procedure. Sequence three was added to correct this deficiency. No aural narration was given during this phase since the alignment element had been verbally described twice in the first segment of the program. Seven job cycles were shown to the subject in order to be certain that he understood the prime importance of proper part alignment.

The equipment utilized in the videotape presentation was manufactured by the Sony Corporation. This apparatus used one-half inch video tape and was the latest AV Series produced by Sony. Specifically, the equipment employed in the research was:

(1) AV-3600 Videocorder.

(2) AVC-3200 Video Camera.

(3) VCL-20 Zoom Lens, 20 mm-80 mm, f2.5.

(4) CVM-220UA Large Screen Monitor/TV Receiver (22" measured diagonally).

(5) V-30F Video Tape, 4 5/8" Reel, 380 feet - 10 minute duration.

The equipment proved to be quite reliable, no malfunctions were experienced during the course of the experiment. A greater element of realism could be introduced into the training program by using color videotape equipment. The cost of this apparatus, however, makes this approach somewhat unrealistic. Upon completion of the training assignment, the subject was led immediately to an adjacent building to perform the simulated job task.

Classical Training Development

The classical job instruction phase of the experiment consisted of a verbal presentation of the primary elements which comprised the simulated job task. A three page list of job instructions (see Appendix C) was prepared in order that the experimental observers could inform the experimental subjects of the specific, sequential steps which were required to correctly perform the job. The content of the instructions was virtually identical to that of the audiovisual and videotape presentations. As explained before, this approach was taken in order that the presentation media could be compared on the basis of constant instructional content. Each experimental observer was instructed to present the written job information in his own style and <u>not</u> to read it verbatim. He was cautioned to include all job elements in his presentation and to demonstrate the performance of the job by running one part as an example. As in the case of audiovisual and videotape training, the subject was encouraged to ask questions on any aspect of the job which was unclear to him. The observers were told to be courteous to the subjects and not to antagonize them in any way so that they would cooperate to the fullest extent to provide valid experimental data.

Control Program Development

The control training program merely consisted of showing the experimental subject two job cycles. The various experimental observers were not allowed to answer questions in order that the subject would remain in essentially an untrained state. The function of the accident detection system was explained to the subjects, however, since accident feedback data would be present in a real industrial environment. The data which resulted from this phase of the experiment was utilized to generate control job performance information which would be indicative of the native capability of the untrained operator. The subject was aware of the $20 cash prize for the best performance as well as the nine minute time limit. As far as specific elements of the job were concerned, he was completely naive.

General Comments

The audiovisual and videotape training programs were developed utilizing the sequential or linear mode of presentation. This approach was taken for four reasons:

(1) The nature of the simulated job task was such that a sequential explanation of the individual job elements was mandatory.

(2) The presentation equipment lent itself to the linear mode of instruction. It would have been virtually impossible to utilize the branching technique with the apparatus which was available.

(3) Numerous authorities state that the linear mode of instruction can be used for a wide range of aptitudes and skills. This is certainly indicative of the conditions which would be found in industry. In fact, A. J. Romiszowski (12) reports that 86.6% of the programmed learning applications in British industry utilize the linear mode of presentation.

(4) In the author's opinion the linear method of presentation was the best means of explaining the sequential relationships which exist among the various job elements of metal forming operations. This opinion was based on the author's experience in working with metal forming equipment as well as the establishing of numerous punch press time standards.

The various programs were developed from a very pragmatic approach. The pertinent information was selected from an analysis of the basic data required by an industrial employee to safely operate a small foot-trip punch press. No subtle psychological considerations were included in this analysis. The primary criteria used throughout the development of the training material was: "will the information be useful to the subject in the safe and correct performance of the simulated job task?" If the material met this objective it was included in the program. The result of this practical approach was, in the author's opinion, training programs which were very effective in disseminating necessary information related to the proper operation of a punch press. No "frills" or extraneous material was included in the programs to confuse or bewilder the subject. He was only given the information required to perform the job in a manner conducive to the preservation of his personal welfare.

CHAPTER V

EXPERIMENTAL RESULTS

A General Statement

The experimental research was initiated on June 1, 1971 and terminated on October 15, 1971. During this period of time, 83 male and 17 female subjects performed the experimental task. Approximately 95% of the experimental volunteers were obtained from the ranks of the undergraduate student body of Wichita State University. An earlier attempt to solicit volunteers from the members of the Neighborhood Youth Corps of the City of Wichita resulted in failure due to a lack of administrative coordination among the personnel involved.

The ages of the experimental subjects ranged from a low of 16 to a high of 50 with the average age being 23.9 years. The total time required to process the 100 experimental subjects through the simulated industrial task was 14.59 hours. The training time associated with the experiment was approximately 8.77 hours. The grand total time, therefore, to disseminate training instructions as well as to collect experimental data was 23.36 hours or 14.02 minutes per experimental subject.

In all cases, the subjects were completely naive as far as the operation of the punch press was concerned. Extreme care was exercised to insure that no experienced equipment operators were introduced into the experimental situation. Each subject was thoroughly quizzed to ascertain his experience in the general area of punch press operation.

The performance of the experimental subjects on the simulated job task was the direct result of their training and not related to any pre-conditioning derived from prior experience.

Accident Data

During the course of the experiment, 408 simulated accidents occurred. This total can be broken down in the following manner:

(1) Audiovisual Training - 103 Accidents.

(2) Classical Training - 54 Accidents.

(3) No Training - 144 Accidents.

(4) Television Training - 103 Accidents.

Of the 100 experimental subjects, 18 were involved in no accidents. In other words 18% of the volunteers had a perfect safety performance. As far as the extent of the accidents was concerned, one subject was involved in 21 accidents; another individual had 19 accidents while still another person was involved in 18 simulated industrial accidents. Figures 7 and 8 present a summarized breakdown of accident data as related to the type of training received. A detailed account of the experimental results associated with accidents is presented in Appendix D.

Detailed copies of the original data sheets are presented in Appendix D in order that a comprehensive record of the research may be documented.

Chapter VI is devoted to an extensive statistical analysis of the experimental data. However, at this point of time, Table I is included to present a brief indication of the statistical parameters associated with accident performance.

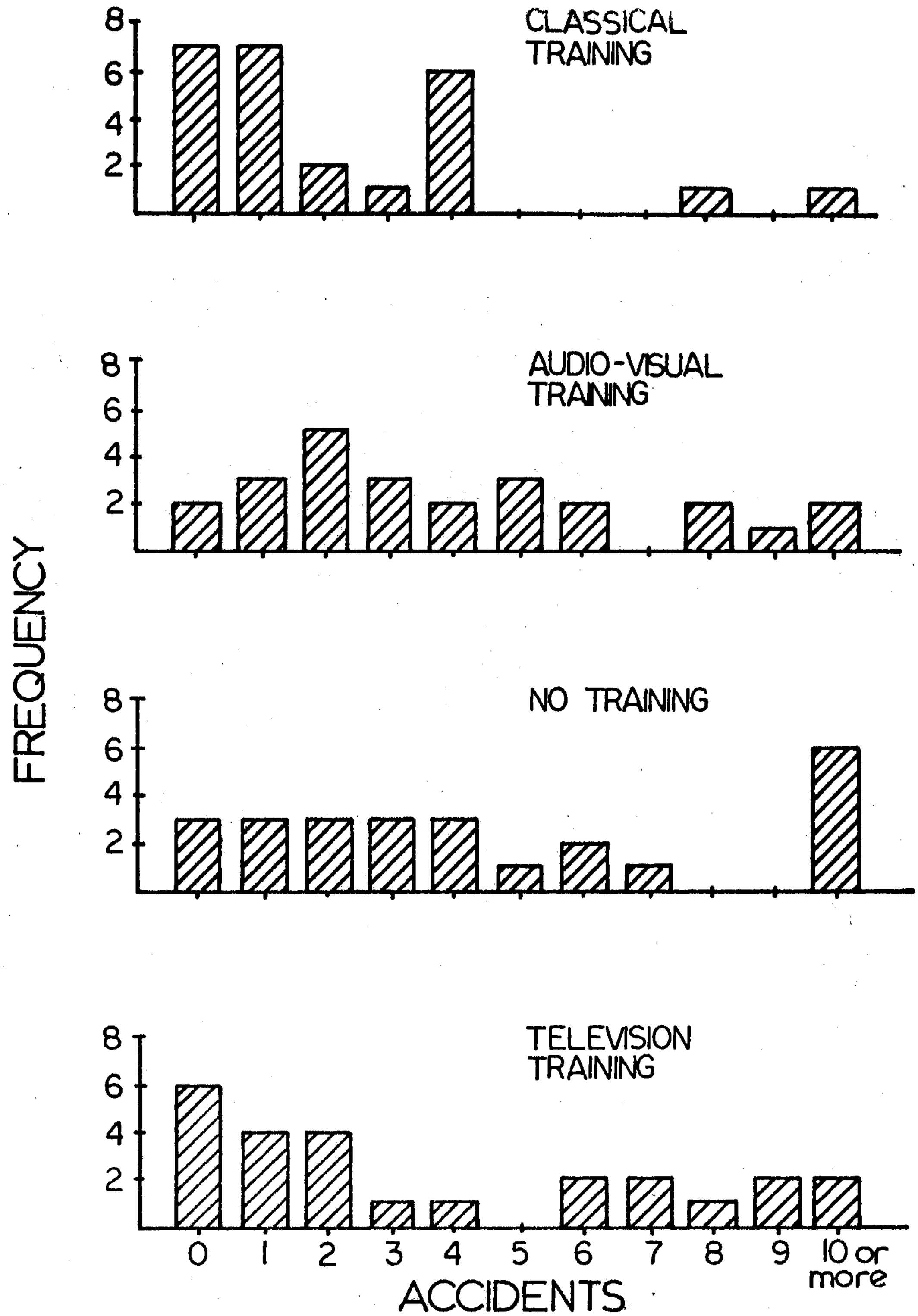


Figure 7. Accident Occurrence Data

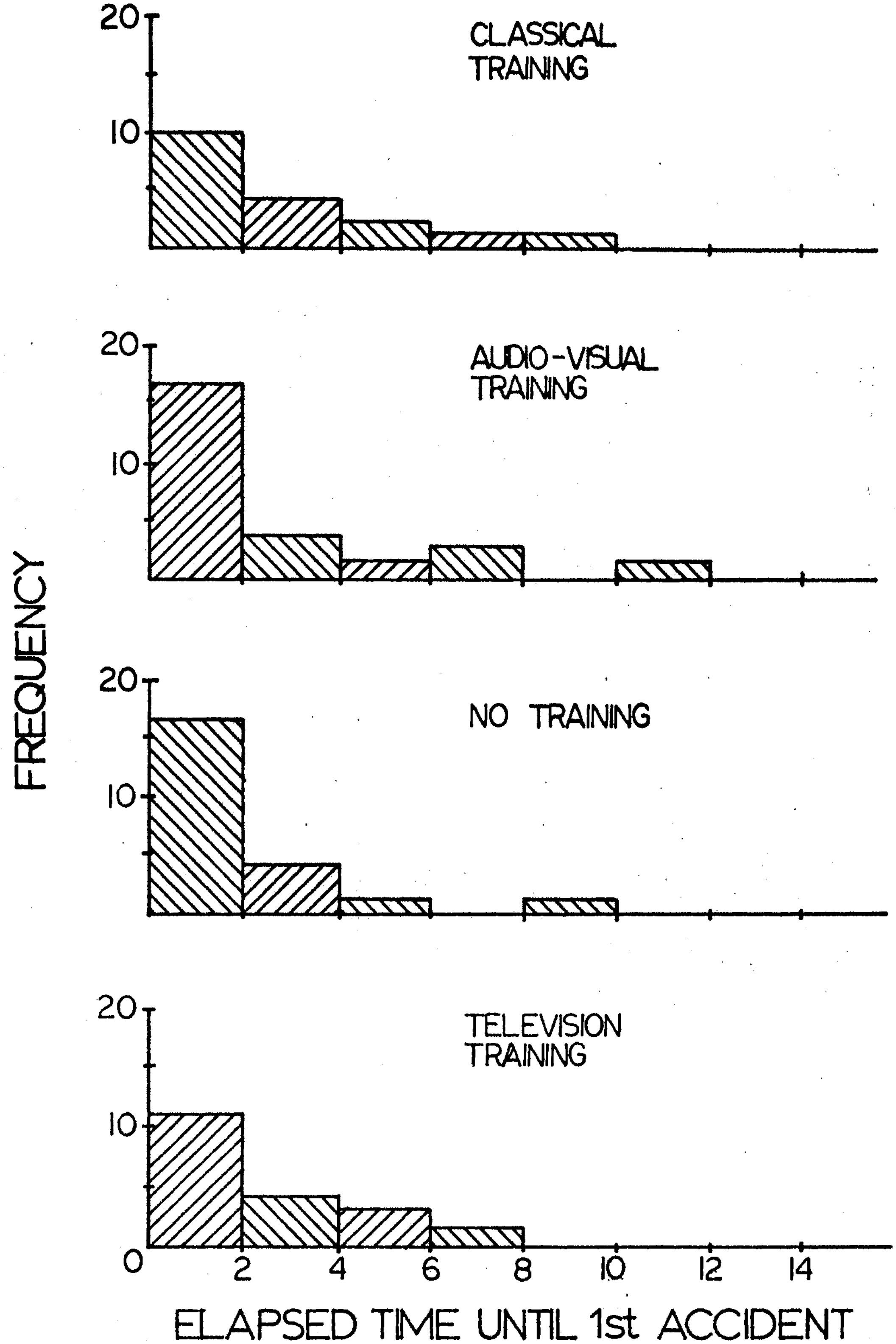


Figure 8. Elapsed Time Until First Accident Data

TABLE I

STATISTICAL PARAMETERS - ACCIDENT DATA

Training	Mean Number of Accidents	Standard Deviation (Accidents)	Mean Time to First Accident (Minutes)	Standard Deviation (Time to First Accident)
Audiovisual	4.12	3.13	2.41	2.79
Classical	2.32	2.84	2.39	2.67
None	5.76	5.94	1.61	2.12
Television	4.12	4.77	2.08	2.48

Good Part Results

As far as the quality part phase of the experiment was concerned, 40 of the experimental subjects, or 40% of the total population, recorded a perfect score. The relatively high percentage can be attributed to the fact that the punch press was equipped with positive alignment stops. These stops virtually eliminated the need for precision alignment of the simulated parts in order to produce an acceptable quality part. Figures 9 and 10 depict the quality part performance and the total elapsed time of each volunteer relative to the type of training he received. Again, a detailed record of these two phases of the experiment is given in Appendix D.

Table II, presented on page 64, gives the basic statistical parameters related to the quality and elapsed time segments of the simulated industrial task.

If the mean number of proper alignments is divided by two, the result is the number of acceptable quality parts. For the various training media, these results were:

(1) Audiovisual Training - 98.26 Quality Parts.

(2) Classical Training - 98.46 Quality Parts.

(3) No Training - 98.04 Quality Parts.

(4) Television Training - 97.74 Quality Parts.

Again, it should be reiterated that the presence of the positive alignment stops accounted for the relatively high number of acceptable quality parts. This type of alignment device is quite prevalent in industry, however, so the results are quite indicative of a typical industrial environment.

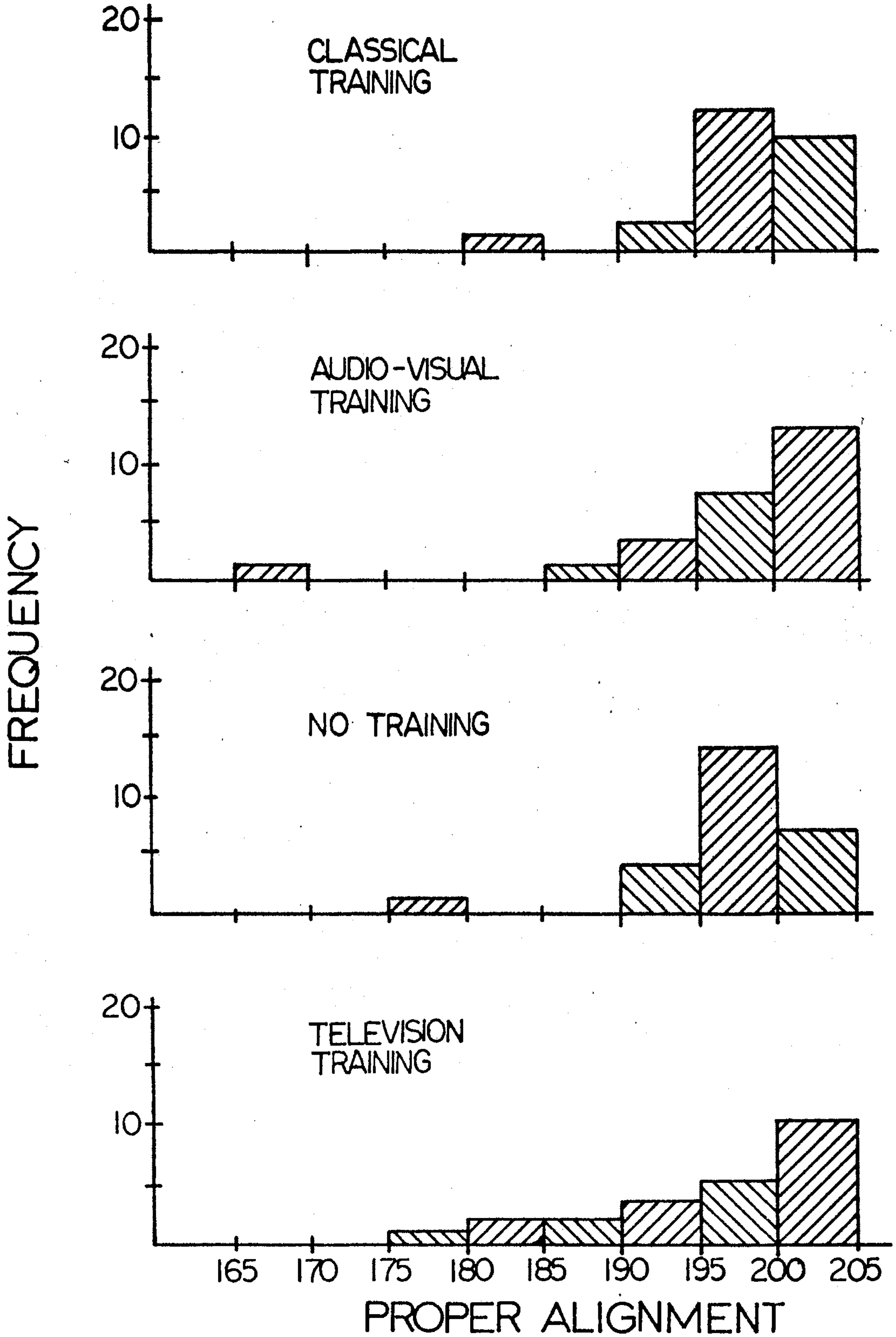


Figure 9. Proper Alignment Data

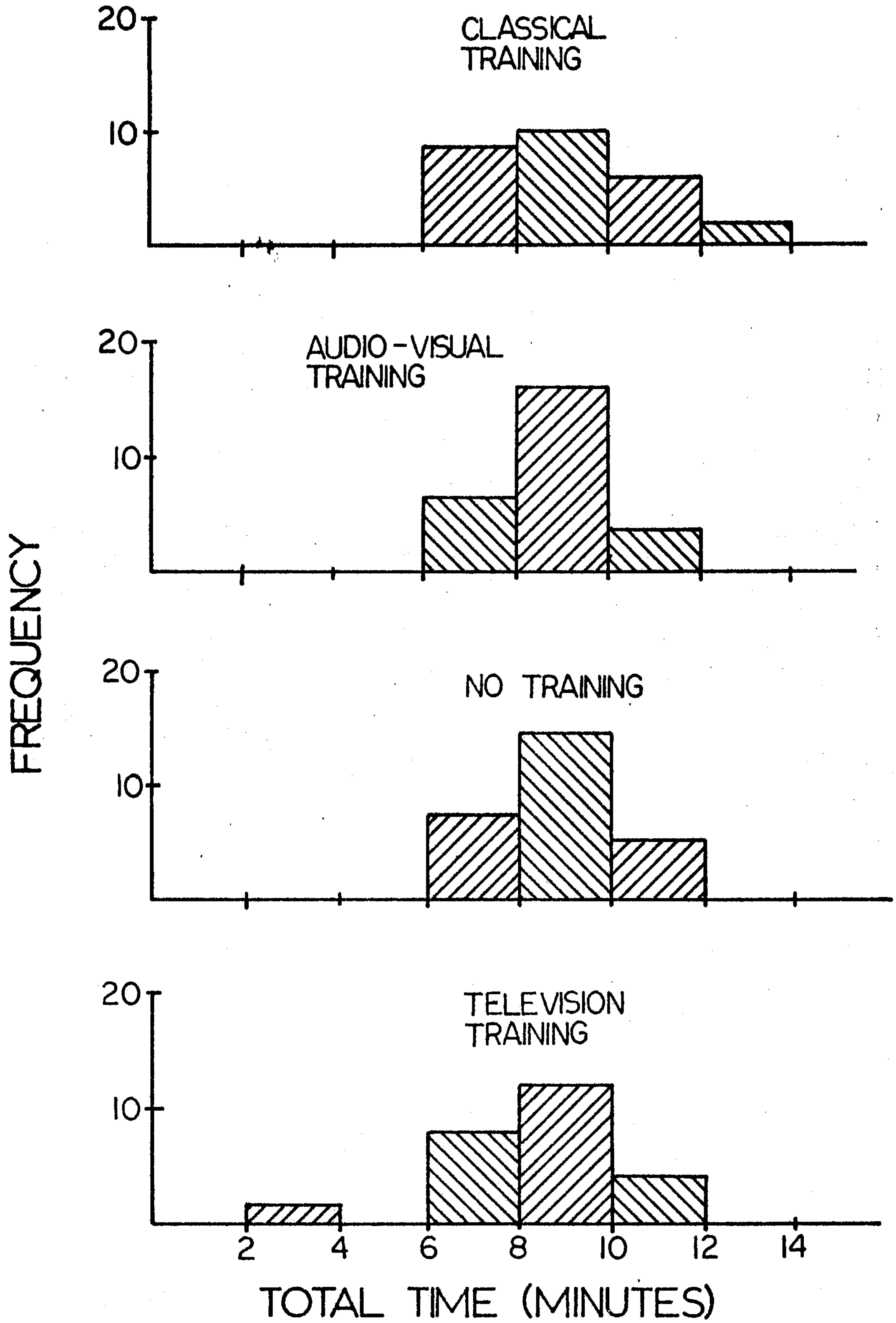


Figure 10. Total Elapsed Time Data

TABLE II

STATISTICAL PARAMETERS - PART ALIGNMENT DATA

Training	Mean Number of Proper Alignments	Standard Deviation (Alignments)	Mean Elapsed Time (Min.)	Standard Deviation (Elapsed Time)
Audiovisual	196.52	7.27	8.74	1.15
Classical	196.92	4.90	8.95	1.58
None	196.08	5.16	8.83	1.30
Television	195.48	7.06	8.49	1.59

Table II clearly indicates that the mean elapsed time was within the nine-minute time limit imposed on the subjects during the training phase of the experiment. It should be noted, however, that the subject was allowed as much time as he needed to perform the task. The nine-minute value was included in the instructions to indicate that time was an important factor in the performance of the simulated job task.

Of the 100 subjects who participated in the experiment, 13 compiled a perfect record of over-all performance. In other words, 13% of the total population achieved a perfect score in the simulated job task. Table III gives the data for these 13 individuals.

It is interesting to note that women comprised 17% of the total subject population but they represented 38.5% of those subjects who achieved a perfect performance score. This result tends to confirm the prevailing opinion that women make better operators on jobs of a monotonous and repetitive nature due to the fact that women have less inertia in their arms, and have more powerful eye muscles than men. No attempt was made to specifically assign female subjects to particular training groups. The volunteers were given their training assignments based upon the subject assignment criteria discussed in an earlier chapter of this thesis.

Experimental Difficulties

In order to obtain valid data for each of the 100 subjects, it was necessary to sample 120 persons. In other words, 20 experimental subjects were "wasted" due to equipment malfunctions. The first difficulty which appeared during the initial phase of the research was related to the parts attempted, good part, and accident detection circuits. These

TABLE III

PERFECT PERFORMANCE DATA

Rank	Name	Training	Proper Alignments	Accidents	Elapsed Time (Min.)
1	CL-3-M	Classical	200	0	7.31
2	CL-1-M	Classical	200	0	7.59
3	TV-13-F	Television	200	0	8.69
4	TV-4-M	Television	200	0	8.89
5	AV-8-M	Audiovisual	200	0	9.04
6	NONE-21-F	None	200	0	9.17
7	AV-2-M	Audiovisual	200	0	9.45
8	NONE-20-M	None	200	0	9.58
9	TV-12-F	Television	200	0	9.69
10	CL-22-F	Classical	200	0	10.23
11	TV-21-M	Television	200	0	10.33
12	NONE-16-F	None	200	0	10.79
13	CL-24-M	Classical	200	0	11.07

circuits were activated by a micro-switch which was attached to the foot-trip mechanical linkage. The problem concerned the fact that the adjustment of this switch was an extremely sensitive process. In many instances the accident, parts attempted, and good parts circuits would be energized without the punch press being activated. In other words, the parts attempted and good parts counters would be incremented even though the punch press had not experienced an operational cycle. Of course, this malfunction invalidated the readings of the counters and, therefore, introduced error into the experimental data. The problem was remedied by mounting the switch on the ram of the punch press. When the ram was stationary, the switch was in the open position and the various circuits were not energized. As soon as the ram started on its downward movement, the switch was closed and the circuit was in the ready mode of operation. This condition was maintained throughout the operating cycle until the ram again reached its uppermost stationary position. The introduction of this solution completely eliminated the problem.

The second difficulty experienced during the course of the experiment was related to heat dissipation problems in the transistors which comprised the logic circuits of the accident detection electronics. This situation was caused by the heat of summer (the experimental site was not adequately air-conditioned) as well as the extreme number of cycles which the circuit was subjected to during the course of the experiment. In order to illustrate this last point, it may be well to cite an example. Since each subject was required to make 200 passes into the punch press in order to complete the experiment, the logic circuitry was required to cycle 200 times per subject. During the course of a day, 25 subjects may have been processed so this meant that the transistors would have to cycle a total of 5,000 times. This activity, in conjunction with the high ambient temperature, produced the problem mentioned above. The difficulty was remedied by the installation of radiation heat sinks on the transistors and the introduction of forced air cooling. One particularly troublesome transistor was replaced by a high energy dissipation transistor combined with an extensive aluminum heat sink, this combination is commonly known as a "Darlington Pair". The problem was completely solved by the corrective action outlined above. The circuit was cycled many thousands of times without the recurrence of the problem. The forced air cooling was eventually removed with no apparent degradation of circuit performance.

Another problem which appeared early in the research concerned the duration of the accident klaxon warning sound. It was discovered that a slight intrusion of the hand into the photoelectric detection area would result in a very brief duration warning sound. The sound was of such a short nature that, in many cases, the subject was not aware that he had been involved in an accident. In order to eliminate this difficulty, a transistorized holding circuit was designed to give a constant three-second duration klaxon sound. This insured that the participant was fully aware of the fact when he had been involved in an accident.

A very perplexing problem which occurred toward the end of the experiment concerned the recording of "false alarms" by the accident detection circuit. This difficulty was extremely difficult to troubleshoot since it occurred on a random basis. In some instances, it would occur at repeated intervals while, in other cases, there was no way to induce the malfunction. After extensive analysis, it was discovered that metal particles were being abraided from the aluminum blank during the course of the experiment. These particles were in a very fine powdered form with the same texture and properties of powdered graphite. This metal became trapped in the accident detection photoelectric cavities with the result that the photoelectric cells were masked. In other words, the cells were unable to "see" the light sources and, therefore, a false accident was detected and recorded. The action was random because, in many instances, the shock impact associated the punch press scattered the powder. The solution was simple; the photoelectric cell cavities were cleaned with a vacuum cleaner after each group of ten subjects was processed. This procedure eliminated the problem, no "false alarms" were reported after its implementation.

Another difficulty which occurred during the course of the experiment was concerned with the solenoid which was installed to simulate the noise associated with metal forming operations. The return spring of the solenoid was mounted at an angle relative to the displacement direction of motion. This caused the solenoid to bind with the result that the inductance of the solenoid dropped, thus, increasing the current flow within the circuit. The high amperage produced a chronic problem of blown fuses. This situation was corrected by mounting the return spring in the same place as the displacement direction of the solenoid.

Finally, a potential problem was eliminated before it disrupted the experimental process. A particular accident detection relay was activated each time a part was placed in the press. It was feared that this relay might fail due to the high number of cycles which it was being subjected. Even though the accident detection circuit was not energized until the ram of the press descended, this specific relay was in operation during each press cycle. The potential problem was solved by attaching another microswitch to the ram of the press. As before, this switch was open until the ram was in motion. The switch closed upon the descent of the ram, thus, energizing the relay. It may well be that the relay would not have failed during the course of the experiment but the switch was added as a precautionary measure since the relay would have been extremely difficult to replace.

It should be emphasized at this point that the problems quoted above were quite minor considering the type of equipment involved. Almost all of the electronic elements were purchased as government surplus so it is remarkable that the system was as reliable as it was. The total cost of the hardware was less than $25.00. A purchased system of the type used in this research, if available, would have cost approximately $2,000.00. This figure would include roughly $1,000.00 for research and development effort. The cost effectiveness of the system, when viewed in this light, was, therefore, quite good. The physical size of the electronic devices could be considerably reduced by the introduction of integrated circuits but the money available for this research would not permit it.

CHAPTER VI

ANALYSIS OF RESULTS

Computational Procedure

In order to determine the statistical significance of the experimental results, an analysis of variance procedure was used. Specifically, an analysis of variance program for a one-way design developed by the Health Sciences Computing Facility at UCLA was utilized. This program, ANV10052, was modified for the Texas Technological University Computer Services on January 27, 1969 as well as Wichita State University on July 9, 1971. The program was run on the IBM 360/44 at the Digital Computation Center at Wichita State University. Execution time was in the order of just a few seconds depending upon the number of treatments.

An analysis of variance procedure was conducted on the following data which was generated during the experimental process:

(1) The occurrence of accidents.

(2) Number of proper part alignments.

(3) Elapsed time until the occurrence of the first accident.

(4) The total elapsed time required to perform the experiment.

In each case, the analysis of variance computions were made for all four of the training methods as a composite total. Also, analysis of variance treatments were conducted on the data based upon all combinations of pairs of training methods. This latter technique was used to determine which means did differ in cases when the null hypothesis was rejected. Tukey and Scheffe (3) have presented a method of determining which means differ in instances when the null hypothesis is rejected but it was felt that the sophistication of this technique was not warranted in this research. Also, the availability of the computer made it a relatively easy matter to conduct an analysis of variance analysis on each possible pair of training combinations. No attempt was made to determine cross relationships between the various forms of data. For example, there was no analysis made of the relationship between elapsed time until the first accident and the total number of accidents suffered. It was felt that even though there may be a significant difference between these values relative to the type of training received, it would be extremely difficult to explain this difference since there would not be a logical rationale for doing so. It was for this reason that a one-way classification analysis of variance model was used throughout the statistical analysis of the data.

The Statistical Analysis of Accidents

The following series of tables present the analysis of variance data relative to the occurrence of accidents.

TABLE IV

ANALYSIS OF VARIANCE TABLE - COMPOSITE OF ALL FOUR TRAINING METHODS - ACCIDENT DATA

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	148.08	3	49.36	2.60	
Within Groups	1821.28	96	18.97		2.70
TOTAL	1969.36	99			

Since $F_{.05;3,96} = 2.70$ (3) and $F = 2.60 < 2.70$, the null hypothesis cannot be rejected at the 5% level. The accident data in its raw form contained values which were obviously extreme in nature.

Using Chauvenet's Criterion for the rejection of the outliers (7) the following data were rejected:

(1) Classical training - one data point, CL-13-M - 12 accidents.

(2) No training - one data point, NONE-10-M - 21 accidents.

(3) Television training - one data point, TV-15-M - 19 accidents.

As a point of information, the Chauvenet Criterion rejects an observation in a sample of n items if the observation has a deviation from the mean greater than that corresponding to a 1/(n) probability. This probability is calculated on the assumption of a normal distribution, using an estimate of the variance on the basis of the sample considered. For $n = 25$, the probability $1/(2n) = 1/50 = .02$, which corresponds to a deviation of 2.33σ. In other words, values in excess of $\overline{X} \pm 2.33\sigma$ are rejected. It was felt that it was legitimate to reject outliers resulting from the experimental procedure because, in every case, the subject involved was not trying to avoid accidents. His primary concern was the rapid completion of the simulated task.

Table V presents the modified statistical parameters resulting from this procedure. Note that there is no change in the elapsed time until first accident values from those presented previously in Table I.

TABLE V

STATISTICAL PARAMETERS - REDUCED ACCIDENT DATA

Training	Mean Number of Accidents	Standard Deviation (Accidents)	Mean Time to First Accident (Minutes)	Standard Deviation (Time to First Accidents)
Audiovisual	4.12	3.13	2.41	2.79
Classical	1.92	2.04	2.39	2.67
None	5.12	5.13	1.61	2.12
Television	3.50	3.71	2.08	2.48

After the outliers were rejected, a new analysis of variance table was computed. The resulting values are shown in Table VI on the following page.

TABLE VI

ANALYSIS OF VARIANCE TABLE - COMPOSITE OF ALL FOUR TRAINING METHODS - REDUCED ACCIDENT DATA

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	130.34	3	43.45	3.23	
Within Groups	1251.10	93	13.45		2.71
TOTAL	1381.44	96			

Since $F_{.05;3,93} = 2.71$ (3) and $F = 3.23 > 2.71$, therefore the null hypothesis of identical populations is rejected at the 5% significance level.

The type of training received did influence the accident performance of the experimental subject. The next series of tables present the analysis of variance parameters for a paired comparison of all possible combinations of training methods.

TABLE VII

ANALYSIS OF VARIANCE TABLE - NO TRAINING - TELEVISION TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	31.69	1	31.69	1.58	
Within Groups	920.62	46	20.01		4.05
TOTAL	952.31	47			

TABLE VIII

ANALYSIS OF VARIANCE TABLE - NO TRAINING - CLASSICAL TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	123.52	1	123.52	8.11	
Within Groups	700.46	46	15.23		4.05
TOTAL	823.98	47			

TABLE IX

ANALYSIS OF VARIANCE TABLE - CLASSICAL TRAINING - TELEVISION TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	30.08	1	30.08	3.36	
Within Groups	411.83	46	8.95		4.05
TOTAL	411.91	47			

TABLE X

ANALYSIS OF VARIANCE TABLE - AUDIOVISUAL TRAINING - TELEVISION TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	4.71	1	4.71	0.40	
Within Groups	550.64	47	11.72		4.04
TOTAL	555.35	48			

TABLE XI

ANALYSIS OF VARIANCE TABLE - AUDIOVISUAL TRAINING - CLASSICAL TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	59.45	1	59.45	8.45	
Within Groups	330.47	47	7.03		4.04
TOTAL	389.92	48			

TABLE XII

ANALYSIS OF VARIANCE TABLE - AUDIOVISUAL TRAINING - NO TRAINING COMPARISON

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	12.37	1	12.37	0.69	
Within Groups	839.26	47	17.86		4.04
TOTAL	851.63	48			

The various tables presented above indicate that the following differences are significant at the 5% level:

(1) Classical Training from No Training.

(2) Classical Training from Audiovisual Training.

If the 10% level of significance were to be used as a criterion, the following differences are significant:

(1) Classical Training from No Training.

(2) Classical Training from Audiovisual Training.

(3) Classical Training from Television Training.

The reasons for these differences may be quite subtle. They will be discussed in detail in the next chapter.

The Statistical Analysis of Good Part Performance

The following table presents the analysis of variance results of the number of proper part alignments into the punch press. Remember that the number of good parts equals the number of proper alignments divided by two.

TABLE XIII

ANALYSIS OF VARIANCE TABLE - COMPOSITE OF ALL FOUR TRAINING METHODS - PROPER ALIGNMENT DATA

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	28.59	3	9.53	0.25	
Within Groups	3680.15	96	38.33		2.70
TOTAL	3708.74	99			

Since $F_{.05;3,96} = 2.70$ (3) and $F = 0.25 < 2.70$, the null hypothesis was accepted.

There is no significant difference among the means of the various training media as far as proper part alignment was concerned. No attempt was made to reject outliers since a series of rough calculations indicated no change in the results of the analysis. Again, the outcome of the calculations will be discussed, at some length, in the next chapter.

The Statistical Analysis of Elapsed Time Until First Accident Data

The table given below deals with the results obtained by applying analysis of variance techniques to the data related to the elapsed time until the occurrence of the first accident.

TABLE XIV

ANALYSIS OF VARIANCE TABLE - COMPOSITE OF ALL FOUR TRAINING METHODS - ELAPSED TIME UNTIL FIRST ACCIDENT DATA

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	8.99	3	3.00	0.47	
Within Groups	498.51	78	6.39		2.72
TOTAL	507.50	81			

$F_{.05;3,78} = 2.72$ (3) and $F = 0.47 < 2.72$, the hypothesis of identical populations was accepted.

As before, no outliers were rejected from the data since preliminary computations indicated that their effect would not change the outcome of analysis of variance results. A more extensive discussion of the results will be presented in the next chapter of this document.

The Statistical Analysis of Total Elapsed Time to Perform the Experiment

The following analysis of variance table depicts the results associated with the data relative to the total elapsed experimental time.

TABLE XV

ANALYSIS OF VARIANCE TABLE - COMPOSITE OF ALL FOUR TRAINING METHODS - ELAPSED TIME REQUIRED TO PERFORM THE EXPERIMENT

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	2.88	3	0.96	0.48	
Within Groups	192.55	96	2.01		2.70
TOTAL	195.43	99			

Since $F_{.05;3,96} = 2.70$ and $F = 0.48 < 2.70$, there was no basis for rejecting the null hypothesis.

The means resulting from the four training methods came from the same population. Outliers were not rejected since the hypothesis was still accepted after extreme data was discarded. Chapter VII of this work contains a fundamental analysis of the implications of the results presented above.

Learning Curve Analysis - Accident and Alignment Error Data

Figures 11 and 12 present the learning curve data associated with accident occurrence and improper part alignment, respectively. In order to understand the curves, it is necessary to recall the experimental procedure used to collect the data. During the course of the experiment, good part and accident counter readings were taken after the simulated production of each 10 parts in the 100-part sequence. This procedure resulted in 10 data points for each of the four training methods for both the quality and accident criteria of performance. In other words, 80 data points were generated by the data collection process. It is these points which are plotted in Figure 11 and Figure 12. The curves were plotted as shown in order to present a means of comparison of the learning trends relative to the various training methods. An attempt to plot one composite curve resulted in failure due to the cluttered nature of the resulting figure. The difference in the ordinate scales introduces a measure of confusion into the interpretation of the data, but it is felt that this disadvantage is more than compensated by the ability to compare the data in a composite format.

Accident Experience Implications

In analyzing the accident experience data, the following facts appear to be relevant. First of all, it is apparent that learning did occur in each of the training cases. The curves are generally of the form expected in classical learning curve analysis. In the case of classical training, the curve has somewhat of a flat slope but it should be noted that the magnitude of the number of accidents is considerably

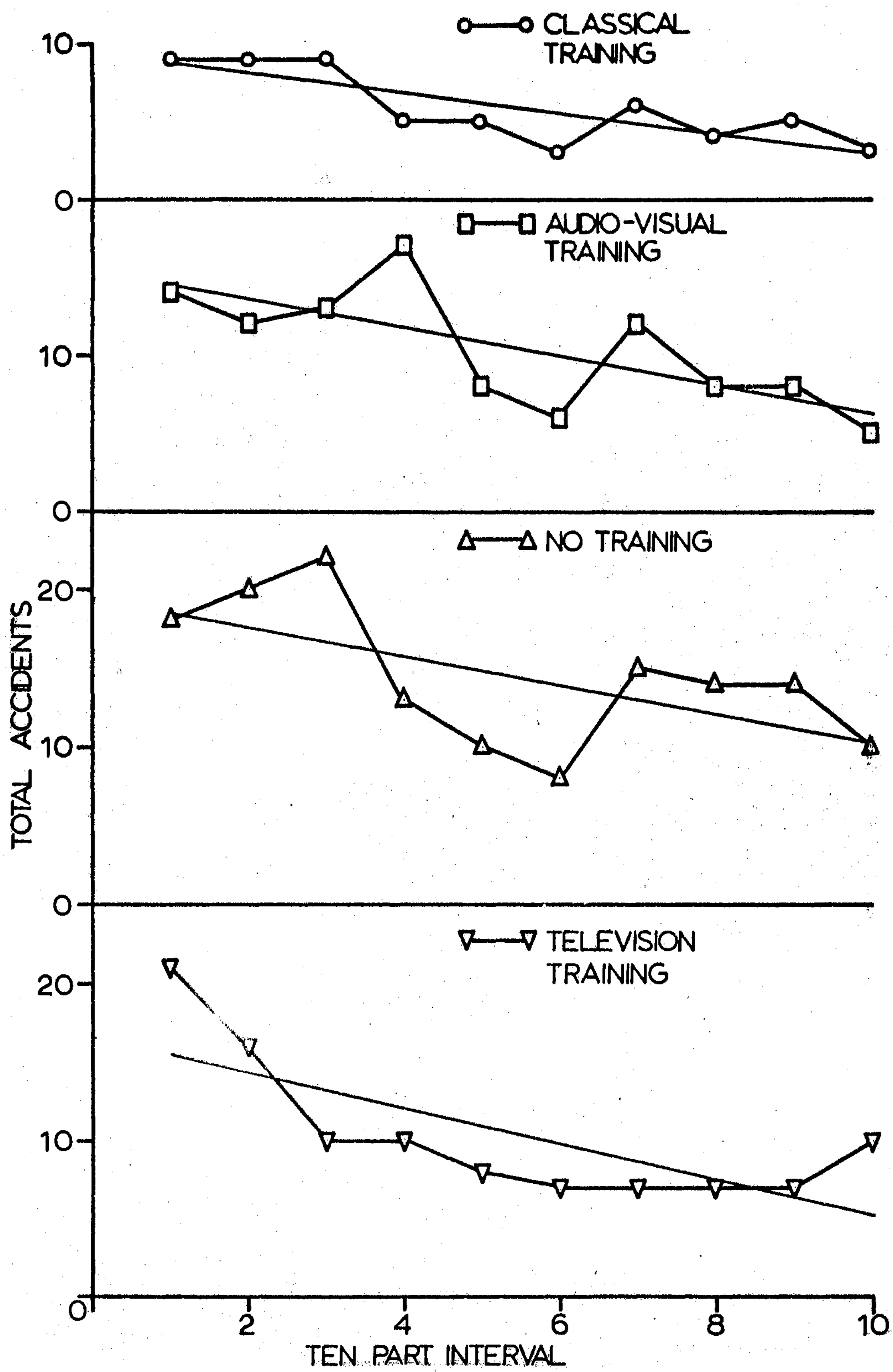


Figure 11. Accident Experience Data

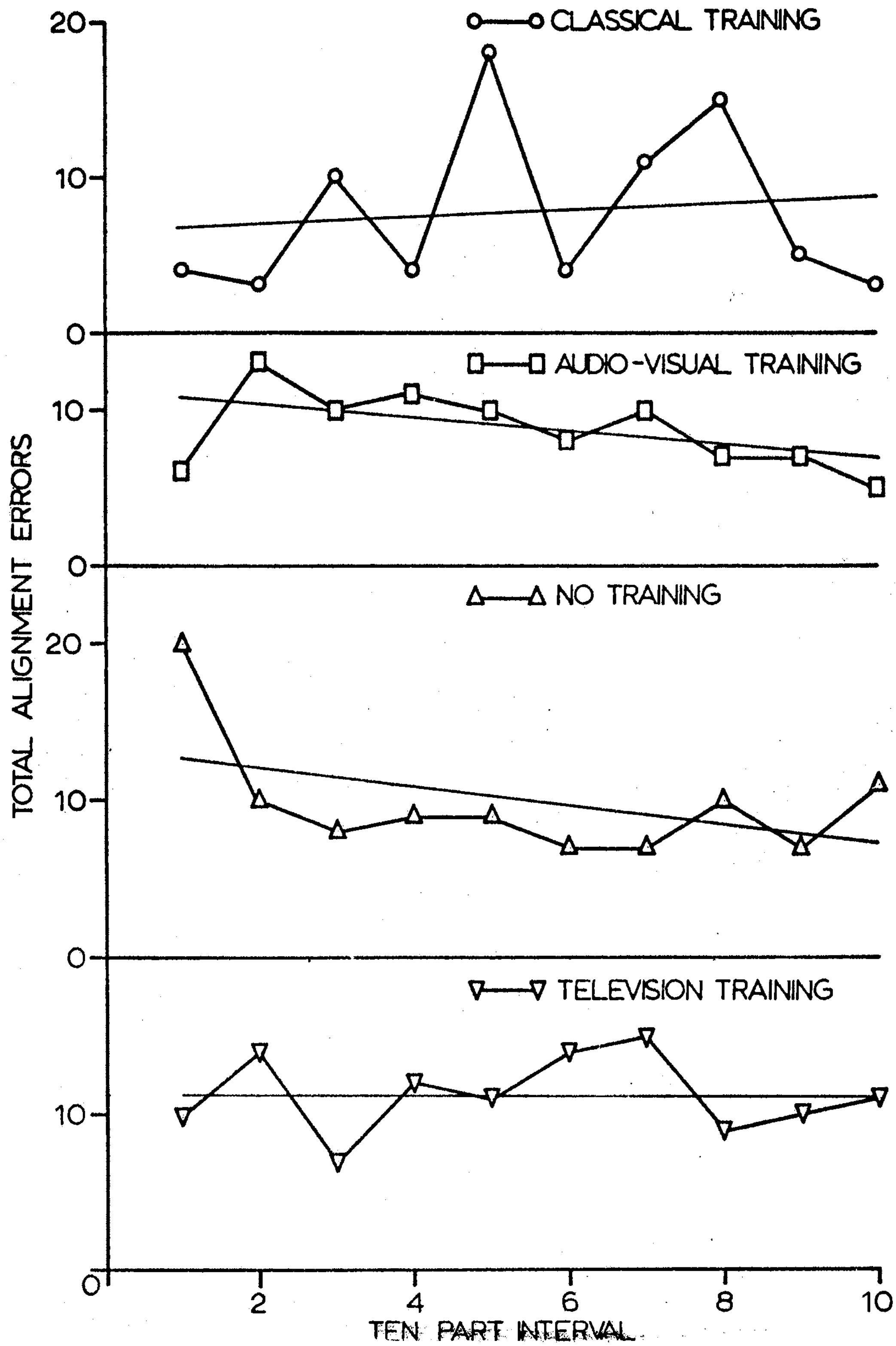


Figure 12. Part Alignment Experience Data

smaller than that of the other three training media. Audiovisual and no training produced an interesting phenomenon as indicated by the first three or four points on their respective curves. In this case, the accident rate actually increased until a maximum value was reached. Based upon the author's conjecture and judgment, this would tend to indicate that the job was somewhat misunderstood by the experimental subjects. Apparently, there was a need for the participants to become acquainted with the job which was not met by the instructional techniques. This is understandable in the case of no training, but it indicates that the audiovisual mode of instruction left something to be desired as far as an adequate explanation of the job task was concerned. In short, it would appear that a period of "pre-learning" was present in these two instances. After this period had elapsed, the curves follow the negative slope pattern which is a traditional indication of learning.

Television training produced a very steep curve initially with a level or near-level termination point. A disturbing factor of the results, however, was the high initial accident rate. In the author's opinion, the television training appeared to instill a high degree of confidence in the participants relative to the nature of the job requirements. This initial confidence apparently resulted in a high accident rate early in the experiment due to the element of carelessness. In other words, the experimental subjects felt confident enough of their knowledge of the job to "take chances" as far as the safety aspect was concerned. It is the subjective feeling of the author that the subjects who received the other forms of training tended to be somewhat cautious during the initial phase of the experiment with the result that their early accident performance was much better than that of the television group. In all fairness, it should be pointed out that one individual suffered six accidents on the initial ten-part segment of the experiment. This data was not discarded since it did represent the actual safety experience of an individual who received television training.

The experience curve data indicates an extremely important aspect relative to the accident occurrence associated with this particular simulated task. In the cases of classical, audiovisual, and no training, the curves generally follow a negative slope until the seventh block of ten parts was reached. Without exception, the accident rate increased to a local maximum at this point. Upon reaching this maximum the subsequent values decreased at a lower rate than had been experienced before the maximum had been reached. In short, the accident rate remained at a higher level after the local maximum had occurred than it was immediately prior to its occurrence. This behavior also manifested itself in the case of television training but it was displaced by a 30-part increment. The accident rate increased on the final ten-part phase rather than on the seventh ten-part segment which was common to the other training media. It is speculated that this degradation of accident performance indicates a threshold of accident sensitivity induced by the boredom and fatigue associated with the job. For the simulated job task, this point was approximately at the seventieth-part level. The highly repetitive nature of the job apparently resulted in a hazardous element being introduced at this point of time due to a lack of attention and interest on the part of the operator. The shift of this point in the case of television training is somewhat difficult to analyze but the following explanation based solely upon the author's subjective judgment may provide the answer. The simulated job task required both mental and physical effort to insure its proper performance. In the instance of television training, the mental effort may have been kept to a minimum due to the completeness of the training presentation. In other words, the subjects who received this form of training knew what they had to do to perform the task while the other groups had to exert mental effort during the course of the experiment in order to learn the requirements of the job. This extra mental effort resulted in an earlier accident sensitivity threshold due to extra fatigue which it induced. In simple terms, the boredom and fatigue associated with classical, audiovisual and no training was the sum of a physical and mental component while the television group only experienced a physical element of fatigue. Table XVI indicates the results of a least squares regression analysis of the accident experience data.

TABLE XVI

LEAST SQUARES ANALYSIS - ACCIDENT EXPERIENCE DATA

Training Method	Y Intercept	Slope	Coefficient of Correlation
Audiovisual	15.33	-0.09	0.72
Classical	9.33	-0.06	0.81
None	19.40	-0.09	0.61
Television	16.53	-0.11	0.74

Proper Alignment Experience Analysis

The curves related to alignment error experience indicate a result which is completely legitimate in light of the nature of the configuration of the simulated job task. The provision of positive alignment stops in the experimental apparatus precluded the occurrence of any extreme learning and the curves support this fact.

In all cases, the curves tend to fluctuate about a mean of ten alignment errors. The experimental subjects who received no training experienced the best rate of learning since their initial ten-part performance was quite poor. It apparently required a ten-part exposure in order to acquaint the experimental subjects with the function of the positive alignment stops because their performance was virtually a constant after the initial ten parts were processed. The classical training group experienced a wide variation in their part alignment performance, but again the mean number of alignment errors was approximately ten. There would seem to be no immediate explanation of this high degree of fluctuation other than the fact that the classical group may have been more concerned about their accident performance than their good part record. This is substantiated at least in theory, by their superior accident performance.

The audiovisual groups' performance was very consistent relative to proper part alignment. This was, in all likelihood, due to the fact that two slides of the training presentation were devoted to the proper positioning of the simulated part. These gave an excellent view of the proper positioning procedure with the result that the subject's performance was quite consistent in this area. The television group recorded a performance similar to the rest of the groups as far as the number of improper part alignments was concerned. They did exhibit a higher degree of variation than the audiovisual or "none" group but this may be explained, in part, by the fact that the television presentation did not give a good wide-angle picture of the stop arrangement due to the limitations of the television camera lens used in the taping procedure. A general statement could be made with a reasonable degree of validity that the provision of the alignment stops resulted in a constant positioning performance with variations occurring due to the element of chance. Table XVII presents data relative to the least squares analysis of proper part alignment experience data.

TABLE XVII

LEAST SQUARES ANALYSIS - PROPER PART ALIGNMENT EXPERIENCE DATA

Training Method	Y Intercept	Slope	Coefficient of Correlation
Audiovisual	11.07	-0.04	0.52
Classical	6.47	0.02	0.12
None	13.13	-0.06	0.48
Television	11.20	0.00	0.02

Sequential Analysis

In order to more thoroughly analyze the sequential accident implications of the experiment, the data was broken down into subgroups of five 20-part sequences. These sequences were analyzed on an inter-training and an intra-training basis in order to determine if significant differences did exist among the various training methods. The following tables summarize the results of this analysis.

TABLE XVIII

ACCIDENT COMPARISON OF 20-PART SEQUENCES - ALL FOUR TRAINING METHODS

Training	First 20 Parts	Second 20 Parts	Third 20 Parts	Fourth 20 Parts	Fifth 20 Parts
Audiovisual	26	30	14	20	13
Classical	18	14	8	10	8
None	38	35	18	29	24
Television	37	20	15	14	17
TOTAL	119	99	55	73	62

TABLE XIX

STATISTICAL PARAMETERS - INTRA-TRAINING ANALYSIS

Training	Part Sequence	Mean Number of Accidents	Standard Deviation
Audiovisual	First Twenty	1.04	1.21
	Second Twenty	1.20	1.47
	Third Twenty	0.56	0.77
	Fourth Twenty	0.80	0.91
	Fifth Twenty	0.52	0.82
Classical	First Twenty	0.72	0.98
	Second Twenty	0.56	0.92
	Third Twenty	0.32	0.63
	Fourth Twenty	0.40	0.71
	Fifth Twenty	0.32	0.63
None	First Twenty	1.52	1.53
	Second Twenty	1.40	2.18
	Third Twenty	0.92	0.98
	Fourth Twenty	1.16	1.60
	Fifth Twenty	0.96	1.27
Television	First Twenty	1.48	2.40
	Second Twenty	0.80	1.08
	Third Twenty	0.60	0.76
	Fourth Twenty	0.56	0.92
	Fifth Twenty	0.68	0.95

TABLE XX

ANALYSIS OF VARIANCE TABLE - INTRA-TRAINING ANALYSIS
AUDIOVISUAL TRAINING

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	8.77	4	2.19	1.92	
Within Groups	137.36	120	1.14		2.44
TOTAL	146.13	124			

Since $F_{.05;4,120} = 2.44$ (3) and $F = 1.92 < 2.44$, the null hypothesis cannot be rejected at the 5% level. There is no difference in the means of the 20-part sequences within audiovisual training.

TABLE XXI

ANALYSIS OF VARIANCE TABLE - INTRA-TRAINING ANALYSIS
CLASSICAL TRAINING

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	3.01	4	0.75	1.22	
Within Groups	74.08	120	0.62		2.44
TOTAL	77.09	124			

$F_{.05;4,120} = 2.44$ (3) and $F = 1.22 < 2.44$, therefore the null hypothesis of identical populations cannot be rejected based upon a 5% significance level.

TABLE XXII

ANALYSIS OF VARIANCE TABLE - INTRA-TRAINING ANALYSIS
NO TRAINING

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	10.51	4	2.63	1.07	
Within Groups	293.60	120	2.45		2.44
TOTAL	304.11	124			

Since $F_{.05;4,120} = 2.44$ (3) and $F = 1.07 < 2.44$, the null hypothesis cannot be rejected at the 5% level. The 20-part sequences are not significantly different as far as the occurrence of accidents is concerned.

TABLE XXIII

ANALYSIS OF VARIANCE TABLE - INTRA-TRAINING ANALYSIS
TELEVISION TRAINING

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	14.29	4	3.57	1.93	
Within Groups	221.84	120	1.85		2.44
TOTAL	236.13	124			

Since $F_{.05;4,120} = 2.44$ (3) and $F = 1.93 < 2.44$, the null hypothesis is not rejected at the 5% level. There is no difference in the 20-part sequences at the 5% level.

TABLE XXIV

ANALYSIS OF VARIANCE TABLE - INTER-TRAINING ANALYSIS
FIRST TWENTY PARTS

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	10.91	3	3.64	1.38	
Within Groups	252.48	96	2.63		2.70
TOTAL	263.39	99			

Since $F_{.05;3,96} = 2.70$ (3) and the computed $F = 1.38 < 2.70$, the null hypothesis is not rejected at the 5% significance level. There is no difference in the accident data relative to the method of training for the first 20-part sequence.

TABLE XXV

ANALYSIS OF VARIANCE TABLE - INTER-TRAINING ANALYSIS
SECOND TWENTY PARTS

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	10.83	3	3.61	1.62	
Within Groups	214.16	96	2.23		2.70
TOTAL	224.99	99			

The tabulated value of $F_{.05;3,96} = 2.70$ and $F = 1.62 < 2.70$, therefore the null hypothesis of identical populations cannot be rejected. The second 20-part sequences are not significantly different.

TABLE XXVI

ANALYSIS OF VARIANCE TABLE - INTER-TRAINING ANALYSIS
THIRD TWENTY PARTS

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	2.11	3	0.70	1.11	
Within Groups	60.64	96	0.63		2.70
TOTAL	62.75	99			

Since $F_{.05;3,96} = 2.70$ and $F = 1.11 < 2.70$, the null hypothesis cannot be rejected at the 5% level of significance. The various training methods do not produce significant accident differences for the third 20-part sequence.

TABLE XXVII

ANALYSIS OF VARIANCE TABLE - INTER-TRAINING ANALYSIS
FOURTH TWENTY PARTS

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	8.19	3	2.73	2.31	
Within Groups	113.52	96	1.18		2.76
TOTAL	121.71	99			

The critical value of $F_{.05;3,96} = 2.70$ and $F = 2.31 < 2.70$, therefore the null hypothesis cannot be rejected at the 5% level. However, $F_{.10;3,96} = 2.14$ and $F = 2.31 > 2.14$ so the hypothesis of identical populations can be rejected at the 10% level.

TABLE XXVIII

ANALYSIS OF VARIANCE TABLE - INTER-TRAINING ANALYSIS
FIFTH TWENTY PARTS

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Critical F (5% Level)
Between Groups	5.48	3	1.83	2.04	
Within Groups	86.08	96	0.90		2.70
TOTAL	91.56	99			

Since $F_{.05;3,96} = 2.70$ and $F = 2.04 < 2.70$, the null hypothesis cannot be rejected at the 5% significance level. The fifth or final 20-part sequence does not indicate significant differences among the various training methods as far as accident performance was concerned.

The results of the sequential analysis indicate that there are not statistical differences in the various training methods either on an inter- or an intra-training basis. The only exception to this conclusion occurred on the fourth 20-part sequence associated with the inter-training analysis. The null hypothesis of identical populations was rejected at the 10% level of significance for this particular analysis. This sequence of parts contained the seventieth-part interval which, as was indicated earlier, produced an increase in the occurrence of accidents. The results of the analysis of variance procedure would appear to show that the various training methods do produce different accident occurrence rates at approximately the seventieth-part level for the simulated industrial task. The implications of this heightened accident susceptibility point will be discussed in Chapter VII.

A Final Word

The analyses conducted within this chapter were not of a highly sophisticated nature. This was by design and not by chance. The procedures quoted throughout this thesis were designed from a pragmatic viewpoint to give an indication of the feasibility of creating, in a laboratory environment, a realistic industrial job simulator. To apply sophisticated statistical methods to the various parameters involved would imply a degree of accuracy to industrial applications which may not be indicative of the "real world" situation. This does not negate, however, some very important implications resulting from this research. In fact, the simple nature of the statistical analysis would appear to reinforce them in an industrial application.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Hypotheses Advanced and Conclusions Reached

In order to analyze the results of this research for the purpose of forming conclusions, it may be well to re-examine the hypotheses stated during the initial phases of this thesis.

Hypothesis Number One

Hypothesis number one stated that programmed learning techniques should be superior to classical training as far as accidents and quality parts performance are concerned.

Experimental Conclusions - First Hypothesis

The experimental data, unfortunately, does not support this hypothesis. There was no statistical significance in the quality part performance of the four experimental groups. This result can be readily explained, however, by the presence of the positive alignment stops which minimize the degree of alignment on the part of the operator. This type of alignment device is quite common in industry so the results of this phase of the experiment are indicative of what would be expected in a practical situation. Also, the simplicity of the task generated an over-all learning curve which was too flat to yield strong comparisons. A more difficult task would have provided better comparisons. <u>In this</u>

instance, therefore, the quality part production was independent of the training method utilized.

As far as the accident performance criterion was concerned, the classical training technique clearly emerged as the superior form of training. The reasons for this superiority are not readily apparent, but the following explanation may provide some insights into the matter. The audiovisual and television training was conducted outside the experimental laboratory. Classical instruction, however, was given in the immediate vicinity of the experimental setting. It would appear, therefore, that the immediacy of the experimental situation was the primary contributor to the superior accident performance of the classical training group. There is apparently no substitute for training given on the actual device to be used in the simulated job task. The audiovisual and television methods were artificial to the extent that they were not associated with the physical hardware utilized in the experiment. The advantage of being able to see and touch the piece of equipment which he will be operating in the near future provided a real and positive benefit to the experimental subject. From a practical point of view, however, it is somewhat idealistic to expect that industrial employees will receive adequate verbal instructions from their foreman or supervisor when they are confronted with a new or different job. In other words, classical training techniques may be used in a haphazard manner, if used at all, in an industrial environment. Also, it is possible that college students respond to classical training better than industrial workers would. The differences among the various training techniques may have been larger in industry. The classical mode of training proved to be the best in this study, despite the shortcomings cited.

The analysis of variance procedure indicated that there was not a significant difference in the means of the accident performance between the audiovisual and television mode of training. This analysis has its place but there is one practical point which must be raised to put these analytical results in their proper perspective. The group which received no training suffered 144 accidents, while the audiovisual and television groups each recorded 103 accidents. There is a difference, therefore, of 41 accidents between the two general groups. If this had not been a simulated job task, there would have been, theoretically, 41 more instances of human misery and suffering as a result of the occurrence of accidents. It is realized that this is not a completely valid argument because a single experimental subject could have been involved in more than one accident. It does underscore the fact, however, that statistical techniques alone do not measure the significance of accidents when the humanitarian aspect is considered. This being the case, the ranking of the accident effectiveness of each of the training methods based on the total number of accidents, was:

(1) Classical - 58

(2) Television - 103

(3) Audiovisual - 103

(4) None - 144

If outliers were rejected the ranking becomes:

(1) Classical - 46

(2) Television - 84

(3) Audiovisual - 103

(4) None - 123

If the data are examined under the assumption that the occurrence of an accident terminated the experiment, the following sequence is obtained:

(1) Classical - 18

(2) Television - 19

(3) None - 22

(4) Audiovisual - 23

On a part production basis, the following table presents the data relevant to the occurrence of the first accident.

TABLE XXIX

ACCIDENT OCCURRENCE - TERMINAL ASSUMPTION

Ten-Part Interval	Audiovisual Training	Classical Training	No Training	Television Training
First	8	7	11	11
Second	8	3	5	0
Third	1	3	2	1
Fourth	2	0	3	2
Fifth	1	1	0	1
Sixth	0	1	0	1
Seventh	0	1	0	1
Eighth	1	0	1	1
Ninth	0	2	0	0
Tenth	2	0	0	1
TOTAL	23	18	22	19

Figure 13 presents, in graphical form, the data of Table XXIX in order that the reader may determine the trend of accident occurrence. This figure does not depict a true learning analysis since an individual's performance is terminated with the occurrence of an accident. It does, however, indicate the degree of retention of the material presented by the various training sequences. This phenomenon has already been studied in the previous analysis of the elapsed time to the occurrence of the first accident so no detailed attempt will be made to analyze it here. The data does indicate that the greatest majority of accidents occurred on the first or second ten-part sequence. No matter which comparative technique is used one would have to conclude that classical job training, if properly performed, results in a superior accident performance on the job.

Hypothesis Number Two

Hypothesis number two stated that industrial job simulation is a feasible means of evaluating the occurrence of accidents.

Conclusions Reached - Second Hypothesis

Although there is no hard statistical evicence supporting this hypothesis, it can be stated on a subjective basis that this phase of the experiment was successful. If nothing else, the research indicated that certain individuals are not qualified to operate a punch press due to a basic lack of eye-hand coordination. The accidents experienced by these persons could have resulted in serious injury if the job task had been performed in an industrial environment. In virtually all cases, the occurrence of accidents had a very sobering effect on the

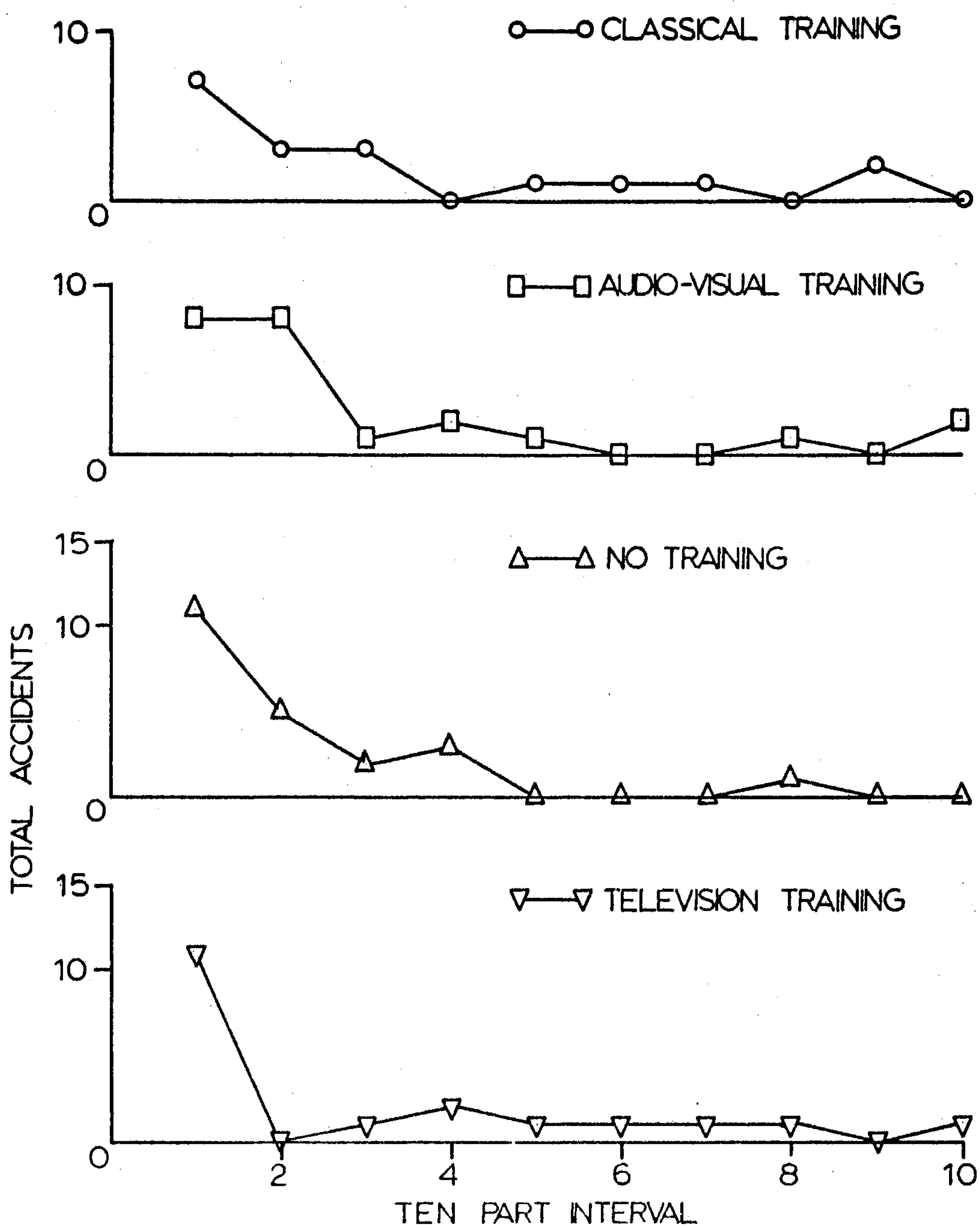


Figure 13. Accident Experience Data - Terminal Criteria

experimental subject involved so there was a positive motivation to avoid them. Even so, there were certain people who did not have the physical capability to perform the task and, at the same time, avoid accidents. It could be argued that these individuals knew, in fact, that the job was a simulated one with no possibility of physical injury so there was no strong motivation for them to work safely. If, indeed, this was the case, these persons would still be regarded as unfit to operate a punch press due to their lack of proper attitude relative to the hazards associated with the job. Based upon the results of this research, it can be stated that industrial jobs with their associated safety hazards can be realistically simulated in a laboratory environment. Furthermore, the occurrence of accidents, simulated though they were, had a strong psychological influence on the persons involved since they did realize the implication of accidents as projected into the non-simulated industrial environment.

Hypothesis Number Three

The third hypothesis stated that programmed learning techniques should show a greater rate of learning than the classical form of instruction.

Experimental Conclusions - Third Hypothesis

An examination of the learning curves presented in Chapter VI indicates that generally this hypothesis was sustained by the experimental results. This was especially true in the case of the accident performance results of the television training group. The slope of this particular curve was much steeper than those for the audiovisual or classical training groups. The problem, however, was the fact that the television training experience curve started at a higher level of accident occurrence than did the curves associated with audiovisual and classical training. In other words, the television group exhibited a greater rate of improvement but they had the greatest opportunity for improvement due to their initial high rate of accident occurrence. The curves do indicate, however, that the improvement associated with television training was more consistent than the other two training media. Classical and audiovisual training techniques exhibited a greater degree of fluctuation in the rate of improvement than did the television method of instruction. As stated before in Chapter VI, the television experience curve did result in a displacement or shift in the increased rate of accidents which occurred during the latter half of the experimental task. The degraded performance occurred at the 70-part level for subjects receiving classical and audiovisual training while the phenomena did not occur until the 100-part level for individuals receiving television training. This fact has important implications for jobs of a long duration in which the degradation cycle may be repeated many times. The shift in the accident sensitivity point which was indicated in the television training experience curve may well result in a reduction of the total number of potential accidents in instances where the job cycle is both long and monotonous.

The improvement curve relative to audiovisual training was steeper than that associated with classical instruction but, again, it started at a higher level of accident occurrence. The audiovisual curve also exhibited a higher degree of fluctuation than that indicated by either the classical or the television training curves. In other words, the consistency of improvement was superior for the classical and television groups as compared to the individuals receiving audiovisual training. This was, more than likely, related to the lack of motion associated with audiovisual training due to the fact that training information was disseminated through the use of still pictures.

As far as part alignment experience data were concerned, the audiovisual and television techniques produced more consistent results than did the classical mode of instruction. The audiovisual experience curve exhibited the negative slope which is characteristic of learning behavior. The television training curve indicated a zero rate of learning while the classical data exhibited an erratic, highly fluctuating learning experience. This fluctuation can apparently be explained by the relative lack of consistency in the training instructions disseminated by classical means. Remember, that the same basic information was given to each participant receiving classical training but the instructions were never repeated in exactly the same manner. This procedure was utilized to duplicate the classical means of presenting job instructions which is prevalent in an industrial environment.

The third hypothesis, therefore, was generally verified by the experimental data. Higher rates of learning did occur in the instances which the experimental subjects received audiovisual and/or television training. This fact should be tempered, however, by the knowledge that the initial values of the accident experience curves of both the audiovisual and television techniques were higher than that of the curve associated with the classical means of instruction. In other words, there was a higher rate of improvement in these two cases because there was a greater possibility for improvement due to a poor initial accident performance.

The Fourth Hypothesis

Hypothesis number four advanced the theory that the television mode of instruction should be more effective than that presented by the audiovisual method due to the perception of motion associated with television.

Experimental Conclusion - Hypothesis Number Four

As far as the results of the statistical analysis were concerned, this hypothesis was rejected since no significant difference was discovered. If the raw data generated by each method is compared on a numerical basis alone, there were 103 accidents reported for each of the training techniques. If outliers were rejected the television training media produced 84 accidents while the audiovisual technique still resulted in the occurrence of 103 accidents. This difference, while not statistically significant, does indicate that the television training did produce more effective results related to accident prevention than the audiovisual technique. As far as the accident experience data was concerned, the television training produced a faster rate of learning than the audiovisual procedure although it did result in a higher initial accident rate. As mentioned before, the shift in the accident sensitivity point from 70 units to 100 units was a characteristic only demonstrated by the television mode of instruction.

On an absolute basis, audiovisual training was superior to television training in the area of proper part alignment by a count of 4913 to 4887. Again, the difference in the two methods was not significant from a statistical point of view. The experience curve data indicated a decided learning effect relative to the audiovisual training while the television form of instruction produced a zero rate of learning. As previously explained, this result was probably due to the fact that the still pictures utilized in the audiovisual presentation were more effective in describing the proper part alignment procedure. Based upon the accident data which resulted from the rejection of outliers, one would have to say that the hypothesis, on a subjective basis, was validated by the experimental results. The hypothesis when viewed in terms of quality part production, however, was not sustained by the results of the research.

The Last or Fifth Hypothesis

The fifth and final hypothesis essentially stated that the startling effect of the klaxon would serve as an effective means of reinforcement for future accident avoidance.

Conclusions Relative to the Fifth Hypothesis

An examination of the accident experience data will indicate that this hypothesis was substantiated by the experimental results. In all cases, the curves demonstrate the negative slope which is characteristic of learning behavior. The increased occurrence of accidents which developed during the latter half of the experimental sequence disrupted the continuity of the curves somewhat but the trend still indicated a learning situation after this local maximum was experienced. In other words, the boredom and fatigue associated with the simulated task manifested themselves to such a great extent during the latter half of the experimental job that the reinforcement effect of the klaxon was temporarily neglected. After this critical point was passed, the learning behavior continued in the same manner as before. It should be realized, however, that the only definitive way to determine the effect of the klaxon as a stimulus control medium would be to run a subject with and without the use of the klaxon. Under this condition, stimulus control should manifest itself in a wavering of the accident occurrence rate. No attempt was made to implement this technique during the experimental procedure because a preliminary study indicated that subjects repeatedly violated the danger zone when they were not made aware that they were doing so. The klaxon was utilized throughout the experiment to maintain the realism of the simulation since, in the real world, the subject would certainly be aware of his involvement in an accident. It can be concluded, therefore, that the presence of the klaxon did, indeed, serve as an effective reinforcement for the future avoidance of accidents.

Experimental Recommendations

In order to extend the results obtained from the initial research reported in this thesis, the following recommendations should be given serious consideration.

Recommendation Number One

First of all, the klaxon should be replaced as the accident reinforcement mechanism. This device did provide feedback to the experimental subject regarding his involvement in a simulated accident but it was relatively slow since the motor had to reach a certain speed before a sound was emitted. This being the case, the subject could have his hands in a safe position before the one- or two-second delay if the sound occurred. In other words, the hand was quicker than the feedback sound with the result that the subject could not relate the present position of his hands to the klaxon's telling him that he had been involved in an accident. It is recommended that this situation be corrected in future research by substituting an amplified buzzer or electric horn. In this case, the immediacy of the noise would insure that the participant would be aware, on virtually an instantaneous time scale, of his involvement in an accident. No confusion related to a time lag in the feedback mechanism would be present in this instance with the result that the reinforcement would be considerably strengthened.

Recommendation Number Two

A second recommendation concerns the use of asymmetrical parts in the simulated job task. The initial research reported in this thesis was designed to test the theory of industrial job simulation and, as such, it was purposely kept as simple as possible in order that a beginning could be realized. In future research, however, it is recommended that different simulated part configurations be utilized in developing a particular job task. Material handling requirements would be modified in this instance due to the fact that the rhythmic body motion patterns associated with symmetric part configurations would be disrupted. Also, the physical activity of grasping, positioning, and rotating simulated parts would be affected by the size and shape of the object in question.

This is an important aspect of the simulated job task since the majority of the accidents occurred during the insertion, positioning, rotational, and removal phases of the experiment. While it is certainly true that parts, whatever their configuration, must be made as needed, the development of job methods in conjunction with the design of jigs and fixtures would benefit from the knowledge of optimum human positioning sequences related to part configuration. This is an area which has been neglected as far as the development of practical criteria is concerned. It would be extremely interesting to observe accident occurrence rates as related to the geometric shape of the simulated part. Also, it is virtually certain that quality part production would be influenced by the positioning requirements imposed by various part configurations. The effect of part shape and size upon job performance would, almost certainly, be another area of research as extensive as that reported in this thesis.

The Third Recommendation

Another recommendation related to future research in the general area of job simulation concerns the utilization of relatively sophisticated data recording hardware. The research quoted in this document would have been much more significant if a time history of accident occurrence and good part production could have been recorded on a continuous multi-channel strip recorder. This was not economically feasible for this initial research reported but future study should incorporate this feature. The increased rate of accident occurrence which manifested itself during the latter part of the job task is an extremely interesting phenomenon and the recording of its occurrence on a time scale could provide additional information as to the point of heightened accident susceptibility of various simulated jobs. Also, the documentation of the time interval between accidents would be a meaningful parameter in the determination of critical points relative to the occurrence of accidents so that a prevention scheme may be developed. A complete time history of each experimental subject could provide a wealth of data to be used in the design of jobs both from a physiological and a psychological viewpoint. It should be realized, however, that this data could only be analyzed on an equivalent time basis. In other words, the subjects should serve as workers on a similar schedule for a constant time period over a series of months. This procedure would allow the accident and quality part data to be correlated with the time of day the experimental simulation occurred. In order for the results to be meaningful, the time of day must be known since the performance decrement could be significant over a normal industrial eight-hour day.

The Fourth Recommendation

Another recommendation which should be considered in conducting future research in this general area concerns the control of the time element of the simulated job. No attempt was made in the research to enforce the time restriction reported in the training instructions. Future research should incorporate a large clock, in full view of the experimental subject, which is set to "count down" the time remaining to perform the simulated task. It is felt that this added pressure to complete the task on time may have a significant effect on the occurrence of accidents as well as the production of quality parts. The presence of the clock will also allow the participant to pace himself with the result that the accident occurrence cycle may assume a different pattern or distribution. The time element is also a very real phase of the practical industrial environment since many organizations have piece rate incentive plans which are directly related to standard times.

Recommendation Number Five

The final recommendation which may prove beneficial in future research concerns the introduction, on a purposeful basis, of "noise" into the simulated job. This noise would manifest itself as a form of harassment of the subject during his performance of the job task. This harassment could take the form of:

(1) Intentional criticism of the subject,

(2) Frequent interruption on a scheduled or a random basis, and

(3) Praise of the work or performance of the subject.

The effect of these external stimuli upon the accident and quality part performance of the subject would be extremely interesting. It could well indicate that certain forms of interruption have a detrimental effect on the subject's concentration with the result that accidents are suffered or defective parts are produced. On the other hand, interruptions scheduled at the proper time may relieve mental boredom with the result that over-all performance is improved. Although operant behavior theory does provide an indication of what would occur in these situations, the author is unaware of any practical research oriented toward an actual industrial environment which has provided "hard" evidence on the effect of external stimuli on safety performance. In any event, the effect of this form of external stimuli should be investigated to determine if significant relationships do exist.

Practical Industrial Recommendations

As a result of the research reported in this thesis, two recommendations emerge relative to the practical application of job simulation techniques in an industrial environment.

The First Industrial Recommendation

The first recommendation deals with the utilization of industrial simulators in employee hiring and screening practices. The results of the research indicate that certain individuals either through a lack of the proper safety attitude or a deficiency in manual skills, are definitely not suited to be punch press operators. If this information could be discovered "before the fact" through industrial simulation the task of employee placement could be made on a more rational basis than is currently the common practice. It could be argued that a potential employee may not be motivated to work safely in a simulated environment since he knows that he cannot be physically injured. While this, indeed, is the case, the employee who exhibits this type of behavior indicates that he lacks the positive attitude which is fundamental to safe performance on the job. What is there to expect that this type of individual who cannot "get serious" in a simulated job environment will not carry this same attitude into the real work environment when he is confronted with it? This makes it imperative that this type of individual be placed, if he is placed at all, on jobs which are relatively free of hazards for his own safety as well as that of his fellow employees.

The results of this research also tend to indicate that there may be something basically wrong with the punch press from an engineering psychological viewpoint. The high incidence of accidents suggests that the design of the punch press may violate basic tenets of human factors engineering. The hand-foot coordination required to operate the device in its present configuration may well be in excess of the physical capability of the majority of the potential working population. The use of the punch press as a simulator could serve to indicate modifications in design which would make the device inherently safer to operate. The utilization of simulators in industry could bring about equipment modification which would benefit the production effort from both a safety and a quality standpoint. Simulation could very well result in the improvement of production equipment if the manufacturers of such equipment were appraised of the results of the simulation activity.

The cost of industrial simulators can be as high as the organization wants to make them. The simulator constructed for the purpose of this research was relatively inexpensive due to its simplicity of operation. As the sophistication of the simulator increases, the cost can be expected to increase accordingly, not necessarily at a linear rate. Throughout the development of the simulator, care must be exercised to insure that extra features are justified on a cost-effectiveness basis. The union also must be consulted in the development of industrial simulators particularly if employee placement is involved. This is especially important because numerous grievances can be expected to result from placement procedures which are developed from the application of industrial task simulation. Prior approval of the simulator and its procedures by union representatives will insure that these grievances can be kept to a minimum. It is strongly urged that industry give careful consideration to this concept since it is felt that the use of simulators for employee screening and placement is the most important implication of this entire research.

Industrial Recommendation Number Two

The second and final practical recommendation suggested by this research concerns the concept of accident sensitivity. The accident experience data would tend to indicate that there is a point in time during the job cycle in which the combination of mental boredom and physical fatigue results in a heightened susceptibility of accident involvement. In all likelihood, this point depends upon a combination of the many diverse factors which comprise a job. To isolate and identify these factors would not be economically feasible but it may be a sound economic investment to investigate key jobs in order to determine this accident sensitivity point. This investigation would involve an analysis of historical data as well as job simulation very similar to that described in this document. Once the critical accident sensitivity points, if they exist, have been identified, the industrial organization can take definitive action to minimize their occurrence and effects. For example, the industrial employee could be given alternate tasks at intervals to coincide with the heightened periods of accident susceptibility. Material handling operations can be introduced into the job to modify the pattern of fatigue and monotony which may result in the occurrence of an accident. The accident sensitivity points, if they are discovered, may be negated by the establishment of an additional allowance within the time standard for the express purpose of accident prevention. Historical data as well as simulation studies may indicate that a slight modification of the job in question would result in the complete disappearance of the accident sensitivity point. This concept, admittedly, is difficult to defend on an analytical basis but the research does indicate that it is present, nevertheless. It would behoove industry to conduct additional research in this area in order to validate the idea that there is a critical time during the job cycle in which the probability of the operator suffering an accident is increased by the mental and physical demands of the job assignment.

A Final Word

This research was conducted to attempt to prove the validity of some new concepts in the area of industrial safety education. The results of the study were not completely conclusive in proving the effectiveness of programmed learning as applied to safety education. Many beneficial and extremely interesting facts, however, did emerge from the simulated job task activity. In the author's opinion these concepts as well as the whole general theory of industrial simulation merit an extensive amount of additional research. If the outcomes of this research in conjunction with studies yet to be conducted result in the alleviation of only an infinitesimal amount of human suffering resulting from industrial accidents, the author can surmise that the long hours and hard work devoted to this research have not been spent in vain.

A SELECTED BIBLIOGRAPHY

(1) Advanced Learning Systems, Inc. *Safety Training Courses.* Advanced Learning Systems, Princeton, N. J. (1971).

(2) Blake, Roland P. *Industrial Safety.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1953, pp. 265-266.

(3) Bowker, Albert H., and Gerald J. Lieberman. *Engineering Statistics.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1959, pp. 295, 559-560.

(4) DeReamer, Russell. *Modern Safety Practices.* New York: John Wiley & Sons, Inc., 1958.

(5) Glassman, Jerrold. "The Effectiveness of a Teaching Machine Program as Compared With Traditional Instruction in the Learning of Correct Responses to Hazardous Driving Situations." (Unpub. Ph.D. dissertation, New York University, 1965.)

(6) Miller, Irwin, and John E. Freund. *Probability and Statistics for Engineers.* Englewood Cliffs, N. J.: Prentice-Hall, 1965, p. 134.

(7) Neville, Adam M., and John B. Kennedy. *Basic Statistical Methods for Engineers and Scientists.* Scranton, Pennsylvania: International Textbook Company, 1964, pp. 127-128.

(8) Niebel, Benjamin W. *Motion and Time Study.* Homewood, Illinois: Richard D. Irwin, Inc., 1972, pp. 184-185.

(9) Public Law 91-596, 91st Congress, S. 2193, December 29, 1970, 84 Stat. 1590, p. 2.

(10) Smith, L. C. *Report on the STEP Program.* Chicago, Illinois: National Safety Council, 1964.

(11) Title 41 - Public Contracts and Property Management, Chapter 50 - Public Contracts, Department of Labor, Part 50-204, Subpart A, published in the *Federal Register*, Vol. 34, No. 96, (May 20, 1969), pp. 7946-7949.

(12) Tobin, M. J., ed. Problems and Methods in Programmed Learning - The Proceedings of the 1967 APL/NCPL Birmingham Conference, Part 4, National Centre for Programmed Learning, School of Education, University of Birmingham, Birmingham, England (1967), p. 4.

(13) United States Air Force, Safety Supervisor's Guide, CONAC Pamphlet 127-1-1.

APPENDIX A

SUBJECT ASSIGNMENT SHEETS

SUBJECT ASSIGNMENT SHEET

The following is a list of the training assignments of the 100 experimental subjects. This list is to be followed explicitly in order that a representative sample for each type of training may be obtained. As each subject is assigned to his respective training media check off the subject number in question. This will insure that the proper sequence will be maintained. The explanation of the legend used for the type of training is as follows:

a. TV - Videotape

b. AV - Audiovisual

c. CL - Classical

d. NONE - None

Subject Number	Type of Training
1	TV
2	AV
3	CL
4	TV
5	AV
6	NONE
7	CL
8	TV
9	NONE
10	AV
11	NONE
12	CL
13	TV
14	AV
15	CL
16	TV
17	AV
18	NONE
19	CL
20	NONE
21	TV
22	NONE
23	AV
24	CL
25	TV
26	NONE
27	AV

Subject Number	Type of Training
28	NONE
29	NONE
30	CL
31	TV
32	NONE
33	AV
34	CL
35	TV
36	AV
37	NONE
38	CL
39	NONE
40	TV
41	AV
42	CL
43	TV
44	AV
45	NONE
46	CL
47	TV
48	AV
49	CL
50	NONE
51	TV
52	AV
53	CL
54	TV
55	AV
56	NONE
57	CL
58	TV
59	NONE
60	NONE
61	AV
62	CL
63	TV
64	AV
65	CL
66	NONE
67	TV
68	AV
69	CL
70	TV
71	AV
72	CL
73	TV
74	NONE
75	AV
76	NONE
77	CL
78	TV
79	AV
80	CL

Subject Number	Type of Training
81	TV
82	AV
83	NONE
84	CL
85	TV
86	AV
87	NONE
88	CL
89	NONE
90	NONE
91	TV
92	AV
93	CL
94	NONE
95	TV
96	AV
97	CL
98	TV
99	AV
100	CL

APPENDIX B

SIMO CHART AND ELECTRONIC CIRCUIT DATA

The five motion classes utilized in the simo chart given on the next page are as follows: (8)

1. Class one consists of finger motions which are made by the movement of the finger or fingers while the remainder of the arm remains at the fixed position.
2. Class two motions are composed of finger and wrist motions which occur while the forearm and upper arm are stationary.
3. The third class of motions are those which are composed of finger, wrist, and lower arm motions. This type of motion is called "forearm" movement and it comprises movements made by the arm below the elbow while the upper arm remains in the fixed position.
4. Class four motion consists of finger, wrist, lower arm, and upper arm motion. It is referred to as shoulder motion and it is used more frequently than any motion class.
5. The final or fifth class of motions include body movements which comprise ankle, knee, and thigh motions as well as those associated with the trunk of the body.

MICROMOTION DATA

PART NO. Simulated Blank DRAWING NO. 100-Simulation FILM NO. ______

OPERATION Punch Press Blanking OPERATOR Experimental Subject DATE 6-1-71

TIME SCALE	ELEM. TIME	LEFT-HAND DESCRIPTION	SYMBOL	MOTION CLASS 1 2 3 4 5	MOTION CLASS 5 4 3 2 1	SYMBOL	RIGHT-HAND DESCRIPTION	ELEM. TIME	TIME SCALE
		Idle	UD			RE	Reach for part		
		Idle	UD			G	Grasp input part		
		Idle	UD			M	Move part to press		
		Position part	P			P	Position part		
		Release part	RL			RL	Release part		
		Delay-Machine Time	UD			UD	Delay-Machine Time		
		Reach for part	RE			RE	Reach for part		
		Grasp part	G			G	Grasp part		
		Flip part	M			M	Flip part		
		Position part	P			P	Position part		
		Release part	RL			RL	Release part		
		Delay-Machine Time	UD			UD	Delay-Machine Time		
		Reach for part	RE			UD	Idle		
		Grasp part	G			UD	Idle		
		Move part to output	M			UD	Idle		
		Release part to desk	RL			UD	Idle		
				REPEAT	CYCLE				

Figure 14. Simo Chart

An Explanation of the Simulated Punch Press

Consider the functional block diagram of the simulated punch press as shown in Figure 15. This diagram is divided into three basic systems. The upper system is concerned with the accident detection circuit, the accident counter, and the time to the first accident clock. The heart of this circuit is the _and_ circuit which receives as its input a signal indicating that the press is activated, and a signal indicating that the danger zone has been violated. The output of the _and_ circuit is a logical one, if and only if both of the inputs are logical ones. If the output of the _and_ circuit is a logical one, indicating that someone has activated the press and violated the danger zone, the output of the _and_ circuit will be a 1. The output of the _and_ circuit is fed first to a holding circuit. The purpose of this holding circuit is to assure that the audio tone will be of standard length. Then, even though the operator manages to pull his fingers out of the danger zone very quickly, he would still be given the standard audio tone. The time to the first accident logic is so constructed that the experimenter starts the clock at the beginning of the experiment and after the first accident, the time to first accident logic will stop the clock. The output of the _and_ circuit is also fed to the accident driver circuit, which is basically a Darlington pair used to drive the accident counter.

The second portion of this block diagram is concerned with the parts attempted counter. This circuit receives as its input the press activated signal. The press activated signal acts as an input to the parts attempted driver. The parts attempted driver, again consisting of the Darlington pair, drives the parts attempted counter.

The third part of the circuit is concerned with the good parts counter. This circuit consists of an input logical _and_ circuit, which, if the press activated signal is a logical one and if the part is aligned properly and gives a logical one, the output of the _and_ circuit will be a logical one acting as an input to the good parts driver which again consists of the Darlington pair which drives the good parts counter.

Now consider the accident detector in detail. For example, consider the accident detector schematic Figure 16. Note that the positive 24 volts is fed through a switch which is normally open and which is activated by the press. This switch will be in the closed position when the press is activated and the plus 24 volts will appear at the collector of the Darlington driver pair, the MJ900. Note further the presence of the plus 12 volts which is fed through a photocell circuit into a 741 comparator. The photocells in the 741 are playing the part of the input _and_ circuit, they serve as one input of the output _and_ circuit. They determine whether or not the danger zone has been violated. In the quiescent condition, the photocells have a rather low resistence and will feed a predetermined value voltage into the 741. One may adjust the threshold of the comparator by adjusting the potentiometer that acts as an input to pin 5 on the 741. If one of the photocells is blocked, for example, by a finger or a hand, its resistance goes to a high value, the comparator senses this and the output of the comparator goes from -15 volts to +15 volts, thus, giving base drive to the MJ900. The MJ900, which receives its base drive from the comparator through the 1K resistor, goes into conduction, activating the accident relay K1. Accident relay K-1 also has a holding contact K1-1. These contacts are in the normally open position. However, when the accident realy K1 is activated, these contacts close allowing the +24 volts to by-pass the MJ900, thus assuring that the accident relay will stay activated until the press returns to its quiescent condition. Another contact of realy K1 is contact K1-4, again, normally an open contact. K1-4 applies 110 volts to the accident counter.

Another contact of relay K1 is associated with the horn circuit. K1-2, again a normally open contact, closes when K1 energizes and applies 110 volts to the horn circuit. Further note that relay K1 acts as a controller for the time delay circuits shown in the lower right hand corner of this schematic. When K1 energizes, contact K1-3 closes, applying a +24 volts to the end of K2 through the first transistor and energizing relay K-2. Transistor number one receives its base drive through the 33K resistor and the +24 volts. The purpose of the uni-junction transistor in this circuit is as follows: the uni-junction transistor will act as a time delay switch because the 100 micro farad capacitor's charging circuit is through the 10K resistor not the 1K resistor, to the 24 volt supply, through the base emitter junction of transistor number one. When the voltage on the 100 micro farad capacitor exceeds the gate drive on the uni-junction transistor, the uni-junction will fire, back bias transistor number one, therefore de-energizing relay K2, and after a predetermined time delay, the horn will quit sounding.

Now one considers the good part circuit, Figure 17. Note that this circuit receives the -24 volts through the normally open contacts of the press activated switch. When the press is activated, this acts as one of the logical ones to the <u>and</u> circuit, and applies -24 volts to the collector of the driver circuit. The other input of the and circuit is concerned with the photocells. The +12 volts is applied to the photocell to the input pin 4 of the 741 comparator. The +12 volts through the 100K resistor through the pin 5 is adjusted such that, in the quiescent condition, pin 10 of the comparator is at some minus voltage. When the photocell is blocked, its resistance goes high and the comparator changes states and pin 10 of the 741 goes high, in this case to almost 15 volts plus, which applies base drive to the driver transistor to the MJ1000 which energizes relay K4. Relay K4 has holding contacts K4-1, thus assuring that even though the accident is a momentary one, relay K4 will stay energized as long as the press is in the activated position. The press activated switch also applies +2.5 volts to the good parts lamps which will light and act as an input to the photocell if the part is properly aligned. Relay K4 also has contacts K4-2 which applies +110 volts to the good parts counter.

Now consider the time to the first accident circuit, Figure 18. The experimenter closes the momentary switch when the subject begins the particular run. This applies +115 volts to the momentary contact switch which energizes relay K6. Relay K6 has a holding circuit consisting of the normally closed contacts of relay K7, these contacts are realy K7-1, through the normally open contacts of relay K6, whose contacts are K6-2. When the momentary contact switch is pressed, relay K6 energizes and it remains energized through the holding circuits. Thus, when K6 is energized it applies +115 volts to the clock, energizing the clock. The clock will continue to run until relay K7 is energized which removes the holding circuit on relay K-6. Relay K7 recieves its +115 volts input from the horn. When the horn sounds indicating that there is an accident, relay K-7 will be energized opening the holding circuit by means of contact K7-1 and relay K6 will be energized. The parts attempted circuit is an extremely simple circuit. It consists of the parts attempted counter and the parts attempted relay K-5. When the press is activated the press activated switch closes, applying +110 volts to the parts attempted counter, simultaneously applying a -24 volts to relay K5. Relay K5 contains a holding circuit which holds K5 energized, keeping the good parts attempted circuit energized until the press returns to its quiescent condition.

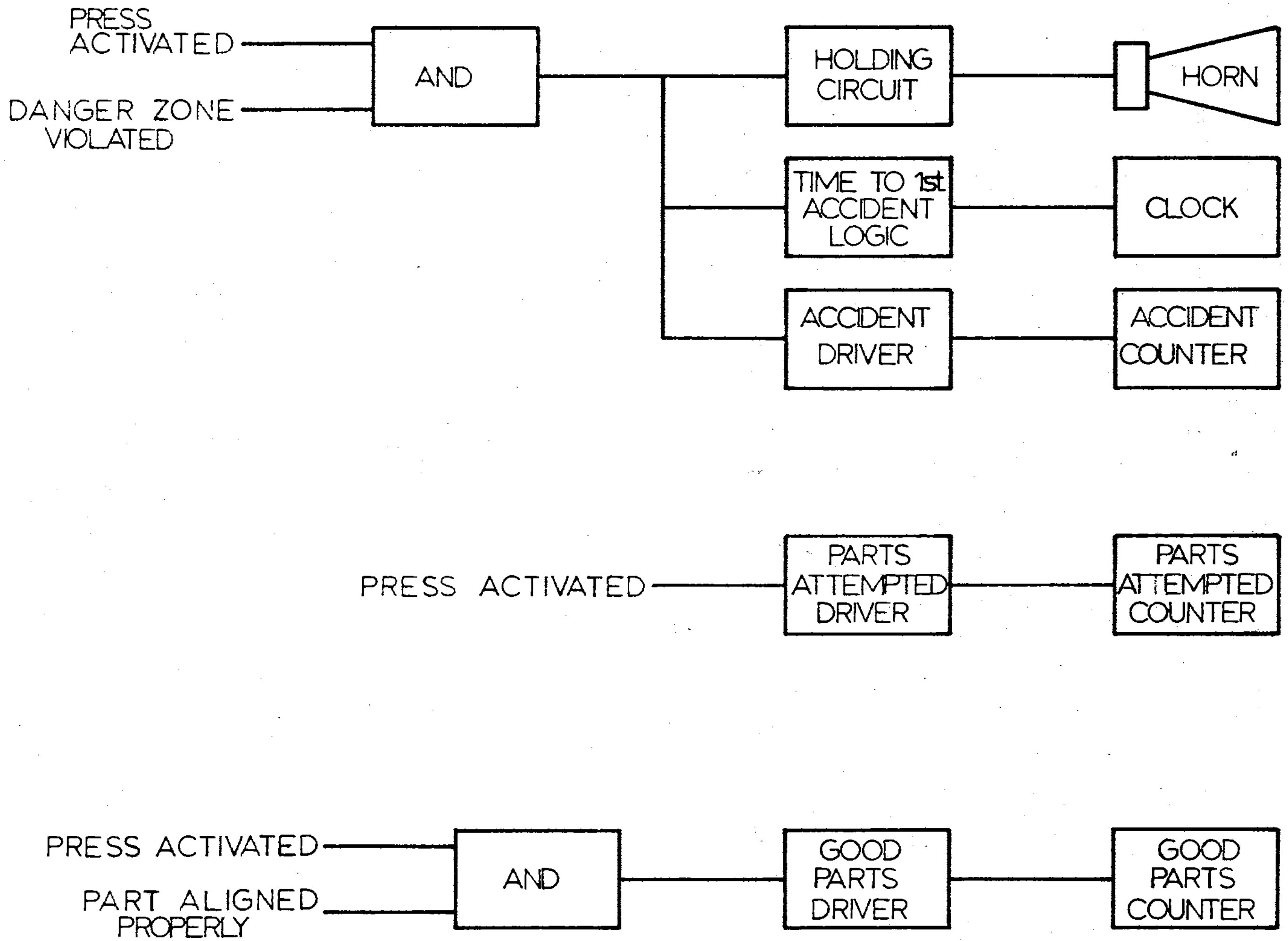


Figure 15. Functional Block Diagram of the Simulated Punch Press

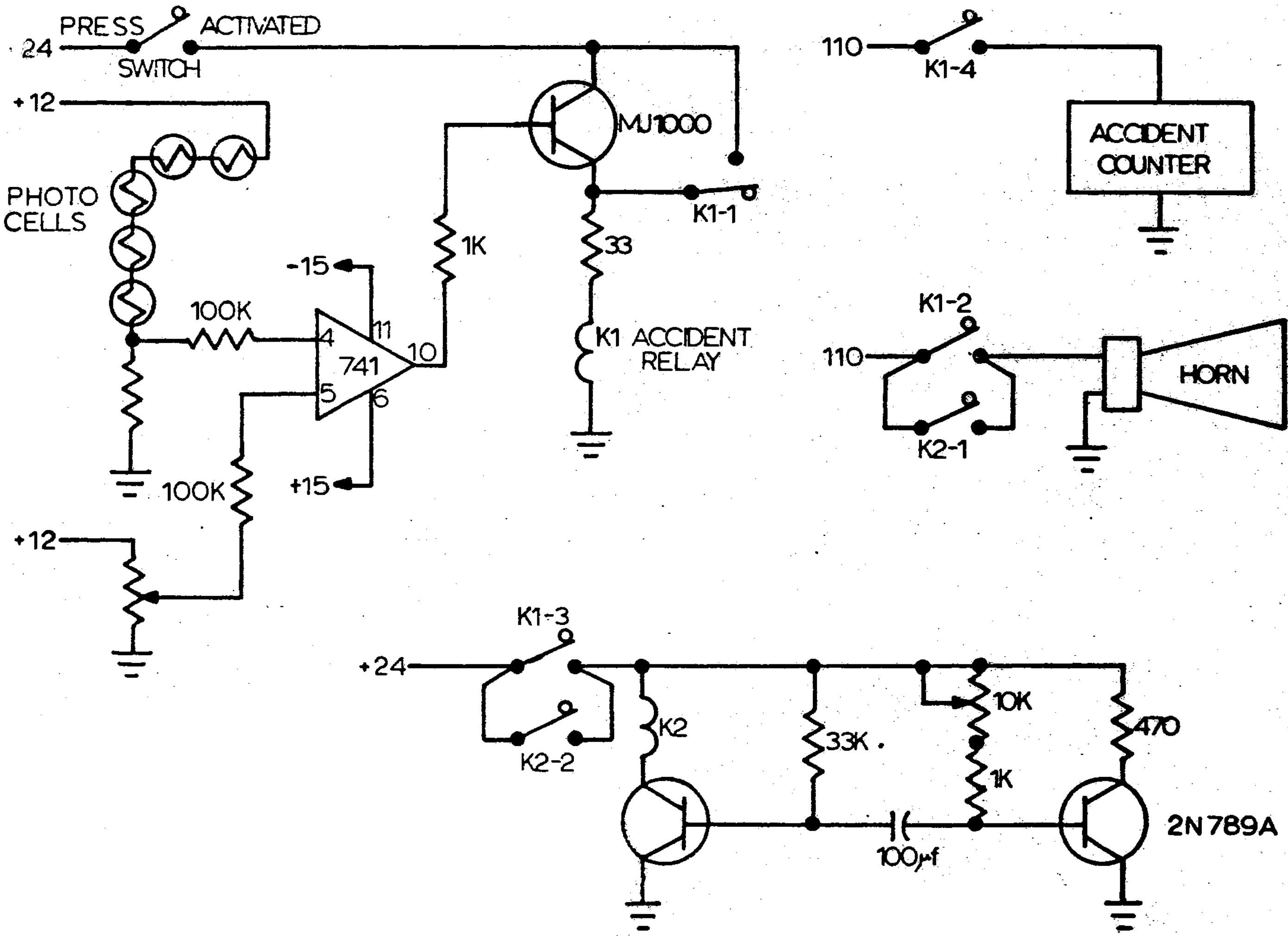


Figure 16. Accident Detector Schematic

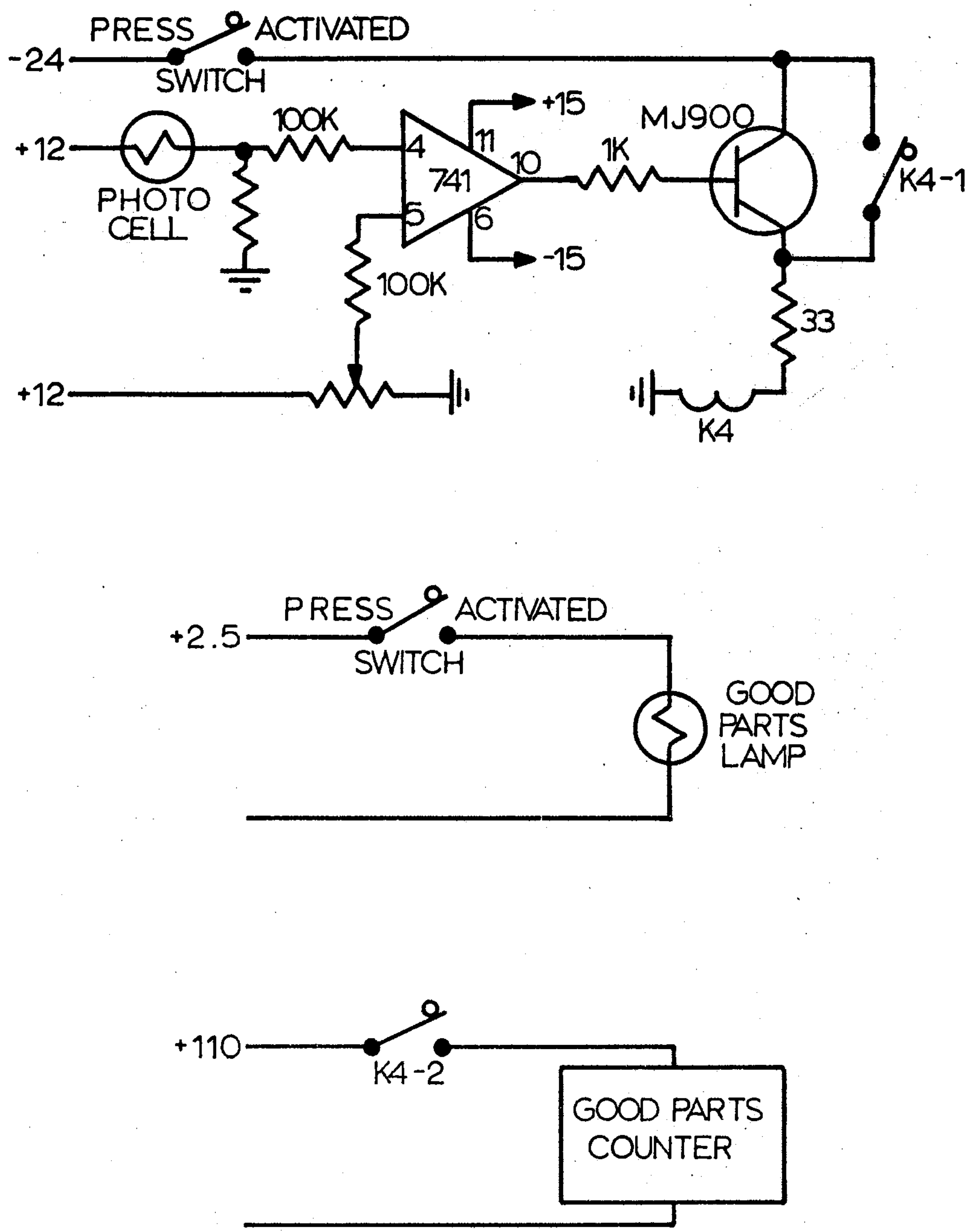


Figure 17. Good Parts Circuit

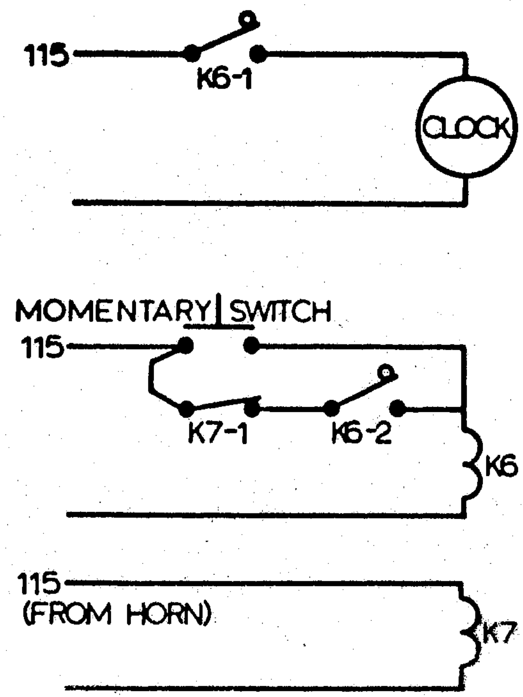


Figure 18. Time to First Accident Circuit

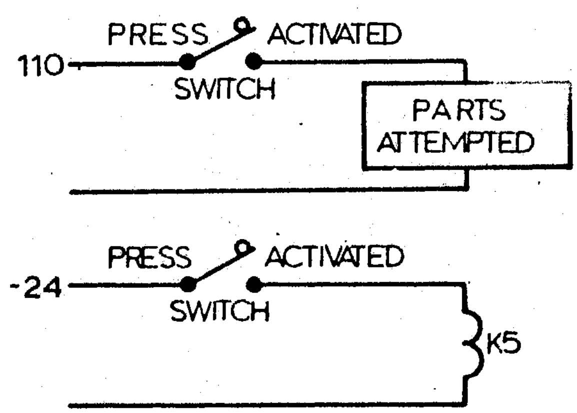


Figure 19. Parts Attempted Circuit

APPENDIX C

OPERATING PROCEDURES AND

TRAINING PROGRAM

SCRIPTS

Operating Procedure 1
System Initialization

The following series of steps are required to put the experimental apparatus into the ready mode of operation.

1. Plug in main power cords at the wall receptable if necessary.

2. Plug in the punch press power cord if necessary.

3. Throw switches A, B, C, and D in that order (this is important).

4. Observe the 5 accident detection light sources - if any of them are inoperative, check to see if they are screwed tightly into their sockets, if this does not correct the situation, replace the light with a new one.

5. Turn on the punch press by throwing the toggle switch located on the electric motor.

6. Cycle the press 10 times while causing the occurrence of 5 accidents. Observe the performance of the parts attempted, accident, and good parts counters to insure that they are incrementing properly. Also, observe the good part detection light to ascertain its proper operation. Always make certain that this light is tightly screwed in its socket since the vertical motion of the ram can loosen it.

7. Proceed to the various training runs.

8. To shut the system down, throw switches D, C, B, A in that order (this is important). The three power plugs can be left plugged in their respective wall receptacles.

Operating Procedure 2
Training Run

The sequence of procedures listed below must be followed during the experimental phase of the training research.

1. Make sure that the klaxon switch is turned <u>on</u>.

2. Locate the input and output desks on the tape marks on the floor. Locate the painted corners of the blanks so that they are at the upper right-hand corner.

3. Place the input part stack on the input desk according to the area denoted on the top of the desk. Record the initial counter values on Form A. Reset the accident clock if this is necessary.

4. Start the experiment by telling the subject to "go". When his hand makes contact with the first part on the input stack, press the accident clock switch and start a decimal hour stopwatch into operation.

5. At the end of each ten (10) parts, stop the subject momentarily and record the accident, parts attempted, and good parts totals of the appropriate columns of Form A. Pieces of cardboard will be utilized to separate the input stack into groups of ten (10).

6. When the subject releases the final part onto the output table, stop the decimal hour stopwatch, and record the following data on Form A.

   a. Total elapsed time from the stopwatch.

   b. Time until the first accident from the electric clock (reset the clock after the data has been recorded).

   c. Subject's name and the type of training he received.

   d. The final accident, parts attempted, and good parts totals must be recorded after the last ten (10) parts.

   e. If the subject does not complete the task in the alloted nine minutes, stop him at the nine-minute mark, record all counter values and then let him proceed until the task is finished. Note this fact on Form A and record cumulative accident and good parts totals on Form B.

7. Thank the subject for his participation and ask for his address so that the results of his performance and the outcome of the $20 prize winner can be mailed to him. Inform him that he should not discuss the experiment with friends who will also be serving as subjects since this will destroy the training aspect of the experiment.

8. After all data has been collected, cycle the press five (5) times to check its proper operation.

Note: The above procedures are presented under the assumption that the system has been initialized. If such is not the case, the initialization procedure as described in Operating Procedure 1 must be performed.

Operating Procedure 3
Base-line Run

This procedure is exactly the same as procedure 2 with the exception that the subject does not receive any formal training. The only training he receives is the observation of two (2) cycles of the job task. The sequence of steps to be followed in this observation segment is as follows:

1. Make sure that the klaxon switch is turned on.

2. Acquaint the subject with the task by running two (2) parts for him.

3. Explain to him the function of the accident detection lights and the klaxon.

4. Proceed with stpes 2 through 7 of Operating Procedure 2.

Slide Presentation Script

SLIDE 1

Even though this is a simulated job task, it pays to be careful because accidents happen when least expected. Over 600,000 hands, thumbs, fingers, arms, etc., are severed each year in United States industry. The punch press is a major contributor to these totals.

SLIDE 2

The part to be used in the job simulation is shown on this slide. It is made of aluminum and is 4/100 of an inch thick. It is approximately 8 1/2 inches long and 6 inches wide. One hundred of these blanks will be used in the experiment.

SLIDE 3

The first step in the job assignment is to grasp one part from the stack of parts on the right-hand desk with the right hand.

SLIDE 4

The part is then moved to the vicinity of the punch press to be ready for the next operation.

SLIDE 5

The aluminum blank now is positioned flat on the working area of the punch press in order that the punching operation may take place.

SLIDE 6

The part is positioned firmly against the back and right-hand L-shaped pieces of metal. These are called stops and they insure that the part will be properly aligned in the press. Failure to do so will result in a bad part being produced since the light will not shine through the hole in the center of the part. Remove your hands from the press after the part is properly positioned.

SLIDE 7

The press is operated by pressing the foot-trip lever on the floor. It must be emphasized that the lever <u>must</u>, <u>must</u> be pressed firmly as far as it will go and released for the punch press to operate properly. This is a dangerous feature of the press. Why? Well, because it allows the operator's hands to be in the dangerous working area of the press while it is functioning. The placement of the hands under the five lights after the lever has been tripped will result in a loud horn sounding to warn you that you could have suffered the loss of a hand or a finger if this had not been a laboratory experiment.

SLIDE 8

The part is then removed from the press. This punch press is especially dangerous because it is a mechanical device. Why is this so? Well, because the press, once it is tripped or actuated, is going to function even if power is shut-off. As long as the big flywheel is turning, there is no power on earth that will keep the ram of the press from descending if the foot-trip lever is pressed.

SLIDE 9

The part is then flipped end-for-end or rotated 180 degrees. This is necessary because this is a two pass job task. In other words, two passes into the press produce one part.

SLIDE 10

After flipping the part, it is repositioned into the press in exactly the same way as before.

SLIDE 11

As before, align the part against the right-hand and back stops. Make sure that the part is properly positioned so the light will shine through the hole in the center of the part and then remove your hands from the working area of the press.

SLIDE 12

Foot trip the press again by pressing the lever firmly to the floor and releasing it completely. Make sure that your hands are clear of the press or the horn will sound to inform you that you have been involved in an accident.

SLIDE 13

Grasp the part after the press has finished its movement and remove it from the press.

SLIDE 14

Lay the part aside on the desk to your left with your left hand.

These series of steps will be repeated for each of the 100 parts. A $20 cash prize will be awarded to the individual who performs the task in the shortest time and has the fewest accidents and the most good parts. You will have nine minutes to perform the job. An observer will interrupt you, momentarily after each 10 parts to record data. Work quickly and accurately. Good luck!

Videotape Script

Even though this is a simulated job task, it pays to be careful because accidents happen when least expected. Over 600,000 hands, thumbs, fingers, arms, etc., are severed each year in United States industry. The punch press is a major contributor to these totals.

The part to be used in the job simulation is shown here. It is made of aluminum and is 4/100 of an inch thick. It is approximately 8 1/2 inches long and 6 inches wide. One hundred of these blanks will be used in the experiment.

The first step in the job assignment is to grasp one part with the right hand from the stack of parts on the right-hand desk.

The part is then moved to the vicinity of the punch press to be ready for the next operation.

The aluminum blank then is positioned flat on the working area of the punch press in order that the punching operation may take place.

The part is positioned firmly against the back and right-hand L-shaped pieces of metal. These are called stops and they insure that the part will be properly aligned in the press. Failure to do so will result in a bad part being produced since the light will not shine through the hole in the center of the part. Remove your hands from the press after the part is properly positioned.

The press is operated by pressing the foot-trip lever on the floor. It must be emphasized that the lever _must_, _must_ be pressed firmly as far as it will go and released for the punch press to operate properly. This is a dangerous feature of the press. Why? Well, because it allows the operator's hand to be in the dangerous working area of the press while it is functioning. The placement of the hands under the 5 lights after the lever has been tripped will result in a loud horn sounding to warn you that you could have suffered the loss of a hand or a finger if this had not been a laboratory experiment.

The part is then removed from the press. This press is especially dangerous because it is a mechanical device. Why is this so? Well, because the press, once it is tripped or actuated, is going to function even if power is shut off. As long as the big flywheel is turning there is no power on earth that will keep the ram of the press from descending if the foot-trip lever is pressed.

The part is then flipped end for end or rotated 180 degrees. This is necessary because this is a two pass job task. In other words, two passes into the press produce one part.

After flipping the part, it is repositioned in the press in exactly the same way as before.

As before, align the part against the right-hand and back stops. Make sure that the part is properly positioned so the light will shine through the hole in the center of the part. Remove your hands from the working area of the press.

Foot trip the press again by pressing the lever firmly to the floor and releasing it completely. Make sure that your hands are clear of the press or the horn will sound to inform you that you have been involved in an accident.

Grasp the part after the press has finished its movement and remove it from the press.

Lay the part aside on the desk to your left with your left hand.

These series of steps will be repeated for each of the 100 parts. A $20 cash prize will be awarded to the individual who performs the task in the shortest time and has the fewest accidents and the most good parts. You will have nine minutes to perform the job. An observer will interrupt you momentarily after each 10 parts in order to record data. Work quickly and accurately. Good luck!

Job Instructions

Classical Presentation

All observers please note: These instructions are to be given verbally to the subjects who have been selected to receive classical job training. The instructions should not be read to the subjects because this is not indicative of the verbal methods utilized in industry. All elements included in the following instructions should, however, be presented to the subjects in order that they may become thoroughly acquainted with the job task. In other words, it is not necessary to repeat the job instructions verbatim, over and over again. Just make sure that each presentation contains all of the job aspects listed below.

Job Instructions

Even though this is a simulated work assignment, it pays to be careful because accidents occur when least expected. Over 600,000 hands, thumbs, fingers, arms, etc., are severed each year in United States industry. The punch press is a major contributor to these totals.

The part to be used in the simulated job task is made of aluminum and is 4/100 of an inch thick. It is roughly 8 1/2 inches long and 6 inches wide. One hundred of these blanks will be used during the course of the experiment. (Show the subject the experimental part as you explain the above information.)

Note: In the following series of instructions, the subject must be shown the various job operations at the time the job instructions are being quoted to him.

The first step in the job assignment is to grasp one of the aluminum parts with the right hand from the stack of parts on the right-hand desk. The part is then moved to the immediate vicinity of the punch press. It is then positioned flat on the working area of the press in order that the work assignment may be performed.

The aluminum blank is positioned firmly against the back and right-hand L-shaped pieces of metal. These are called stops and they insure that the part will be properly aligned in the punch press. Failure to do so will result in a bad part being produced since the light will not shine through the hole in the center of the part. Remove your hands from the press after the part is properly positioned.

The press is operated by pressing the foot-trip lever on the floor. It should be emphasized to the subject that the lever <u>must</u> be pressed firmly as far as it will go and released for the punch press to operate properly. Stress to the subject that the foot-trip lever is a dangerous aspect of the operation since it frees the operator's hand to be in the throat of the press. The placement of the hands under the 5 lights after the lever has been tripped will result in a loud horn sounding to warn the subject that he could have suffered the loss of a hand or finger if this had not been a laboratory experiment.

The part is then removed from the press. The subject should be impressed by the fact that a mechanical punch press is an especially dangerous device. They should be made to realize that the press is going to function even if power is shut off. As long as there is inertia in the flywheel, there is no power on earth that will stop the ram of the press from descending if the foot-trip lever is pressed.

The aluminum blank is then flipped end for end or rotated 180 degrees. This is a requirement because the job is a two-pass task. In other words, two passes into the press produce one finished part. After flipping the part, reposition it into the press in exactly the same manner as before.

As before, align the part against the right-hand and back stops. Be sure that the part is properly positioned so the light will shine through the hole in the center of the part. Remove your hands from the functional area of the press.

Foot trip the press again by pressing the lever firmly to the floor and releasing it completely. Make sure that your hands are clear of the press or the horn will sound to inform you that you have been involved in an accident.

Grasp the part after the press has finished its movement and remove it from the press. Lay it aside on the desk to your left with your left hand.

Inform the subjects that these series of steps will be repeated for each of the 100 parts. Tell him that a $20 cash prize will be awarded to the person who performs the task in the shortest time and has the fewest accidents and the most good parts. Make sure they are aware that they have nine minutes to complete the task. Inform the subjects that you will interrupt them momentarily after each 10 parts in order to record data. Tell them to work quickly and accurately and wish them "good luck".

APPENDIX D

EXPERIMENTAL RESULTS AND FORM A

RAW DATA SHEETS

TABLE XXX

ACCIDENT PERFORMANCE - AUDIOVISUAL TRAINING

Subject Name	Accidents	Elapsed Time Until First Accident (Minutes)
AV-1-F	2	3.960
AV-3-M	9	.376
AV-4-M	4	.935
AV-5-M	2	.818
AV-6-M	5	1.826
AV-7-M	5	2.772
AV-9-M	2	.625
AV-10-M	6	.865
AV-11-M	1	11.006
AV-12-M	10	1.580
AV-13-F	11	.141
AV-14-M	4	1.560
AV-15-F	8	.142
AV-16-M	1	7.446
AV-17-M	2	4.600
AV-18-M	3	1.500
AV-19-M	8	1.635
AV-20-M	5	.487
AV-21-M	3	.349
AV-22-M	3	2.225
AV-23-M	2	7.592
AV-24-M	6	1.220
AV-25-M	1	1.742
TOTAL	103	

Twenty-three of the 25 subjects receiving audiovisual training were involved in accidents. On a percentage basis, this amounted to 92% of the experimental population. Twenty-two men and three women participated in the audiovisual training phase of the experiment. The two individuals who had a perfect safety performance were both males.

TABLE XXXI

ACCIDENT PERFORMANCE - CLASSICAL TRAINING

Subject Name	Accidents	Elapsed Time Until First Accident (Minutes)
CL-4-M	1	2.960
CL-5-M	4	.093
CL-6-M	4	2.374
CL-7-M	2	3.896
CL-9-M	1	4.620
CL-10-M	8	.775
CL-11-M	4	1.750
CL-12-F	4	.149
CL-13-M	12	.380
CL-14-M	2	.043
CL-15-F	1	9.568
CL-16-M	4	.045
CL-17-M	3	.526
CL-18-M	1	1.185
CL-20-M	1	3.520
CL-21-M	1	4.337
CL-23-M	1	6.689
CL-25-M	4	.055
TOTAL	58	

Seven of the experimental subjects scored a perfect accident performance. Eighteen of the sample of 25 were involved in accidents representing 72% of the total population. On a sexual basis, 21 men and four women received classical training. Of the individuals who were involved in no accidents, five were men and two were women.

TABLE XXXII

ACCIDENT PERFORMANCE - NO TRAINING

Subject Name	Accidents	Elapsed Time Until First Accident (Minutes)
NONE-1-M	3	.030
NONE-2-M	6	1.894
NONE-3-M	11	.500
NONE-4-M	4	.143
NONE-5-M	18	1.100
NONE-6-M	2	.019
NONE-7-M	4	.951
NONE-8-M	3	1.630
NONE-9-M	3	3.075
NONE-10-M	21	.435
NONE-11-M	11	.304
NONE-12-M	4	4.827
NONE-13-M	5	.034
NONE-14-M	1	2.140
NONE-15-F	7	.550
NONE-17-M	1	.047
NONE-18-M	2	3.339
NONE-19-M	6	1.029
NONE-22-F	1	9.243
NONE-23-M	2	2.235
NONE-24-M	12	.293
NONE-25-M	17	1.558
TOTAL	144	

Twenty-two subjects were involved in accidents while three subjects had perfect accident records. On a percentage basis, 88% of the subjects in the experimental sample were involved in one or more simulated accidents. One man and two women achieved a zero accident performance. Twenty-one men and four women participated in the experiment.

TABLE XXXIII

ACCIDENT PERFORMANCE - TELEVISION TRAINING

Subject Name	Accidents	Elapsed Time Until First Accident (Minutes)
TV-1-M	6	.281
TV-2-M	8	.030
TV-3-M	9	.142
TV-5-M	1	7.630
TV-6-M	7	.526
TV-7-F	2	3.540
TV-8-M	2	.033
TV-9-M	6	.036
TV-10-F	7	.890
TV-11-F	9	.252
TV-15-M	19	.162
TV-16-M	13	.415
TV-17-M	1	5.750
TV-18-M	2	3.140
TV-19-M	4	.046
TV-20-M	1	2.770
TV-23-F	3	5.277
TV-24-M	2	2.710
TV-25-M	1	5.979
TOTAL	103	

Six volunteers realized a perfect score as far as accidents were concerned. Nineteen subjects were involved in accidents, or 76% of the total of 25 subjects. Nineteen male subjects and six female subjects volunteered for the experiment. Four men and two women achieved a perfect score relative to the occurrence of accidents.

TABLE XXXIV

GOOD PART AND ELAPSED TIME PERFORMANCE - AUDIOVISUAL TRAINING

Subject Name	Number of Proper Alignments	Elapsed Time (Minutes)
AV-1-F	200	8.11
AV-2-M	200	9.45
AV-3-M	200	9.14
AV-4-M	200	8.00
AV-5-M	197	7.75
AV-6-M	200	8.78
AV-7-M	200	7.99
AV-8-M	200	9.04
AV-9-M	199	8.98
AV-10-M	200	7.95
AV-11-M	195	11.32
AV-12-M	194	9.25
AV-13-F	188	8.99
AV-14-M	196	7.94
AV-15-F	195	7.33
AV-16-M	200	8.14
AV-17-M	199	11.76
AV-18-M	193	8.89
AV-19-M	194	8.30
AV-20-M	165	8.40
AV-21-M	198	6.64
AV-22-M	200	10.24
AV-23-M	200	9.79
AV-24-M	200	8.03
AV-25-M	200	8.30

As can be noted from the table, 13 of the experimental subjects performed perfectly on this phase of the experiment. Perfect performance is equivalent to 200 proper alignments since each of the 100 simulated parts had to be inserted twice into the punch press.

TABLE XXXV

GOOD PART AND ELAPSED TIME PERFORMANCE - CLASSICAL TRAINING

Subject Name	Number of Proper Alignments	Elapsed Time (Minutes)
CL-1-M	200	7.59
CL-2-F	199	8.71
CL-3-M	200	7.31
CL-4-M	200	7.06
CL-5-M	200	9.77
CL-6-M	197	9.97
CL-7-M	199	8.74
CL-8-M	199	9.50
CL-9-M	197	7.18
CL-10-M	192	8.45
CL-11-M	182	10.37
CL-12-F	196	9.33
CL-13-M	183	6.36
CL-14-M	199	11.44
CL-15-F	200	11.74
CL-16-M	198	7.91
CL-17-M	196	9.17
CL-18-M	192	8.65
CL-19-M	197	7.58
CL-20-M	200	12.08
CL-21-M	199	8.24
CL-22-F	200	10.23
CL-23-M	200	7.70
CL-24-M	200	11.07
CL-25-M	198	7.53

Nine experimental volunteers achieved a perfect score as far as the quality part criterion was concerned.

TABLE XXXVI

GOOD PART AND ELAPSED TIME PERFORMANCE - NO TRAINING

Subject Name	Number of Proper Alignments	Elapsed Time (Minutes)
NONE-1-M	199	11.19
NONE-2-M	198	8.32
NONE-3-M	196	6.77
NONE-4-M	198	8.08
NONE-5-M	196	9.58
NONE-6-M	196	9.26
NONE-7-M	194	10.71
NONE-8-M	176	7.60
NONE-9-M	190	9.36
NONE-10-M	195	7.66
NONE-11-M	192	7.52
NONE-12-M	190	8.20
NONE-13-M	199	9.32
NONE-14-M	200	9.19
NONE-15-F	195	8.76
NONE-16-F	200	10.79
NONE-17-M	198	7.23
NONE-18-M	199	8.15
NONE-19-M	195	7.76
NONE-20-M	200	9.58
NONE-21-F	200	9.17
NONE-22-F	200	11.89
NONE-23-M	197	7.73
NONE-24-M	199	8.02
NONE-25-M	200	9.00

For this particular case of training, six subjects achieved the 200 proper alignments which was equivalent to perfect quality performance.

TABLE XXXVII

GOOD PART AND ELAPSED TIME PERFORMANCE - TELEVISION TRAINING

Subject Name	Number of Proper Alignments	Elapsed Time (Minutes)
TV-1-M	176	8.54
TV-2-M	186	7.23
TV-3-M	200	7.86
TV-4-M	200	8.89
TV-5-M	200	8.67
TV-6-M	200	8.17
TV-7-F	200	9.04
TV-8-M	198	6.51
TV-9-M	183	9.57
TV-10-F	200	8.97
TV-11-F	200	10.20
TV-12-F	200	9.69
TV-13-F	200	8.69
TV-14-M	199	8.90
TV-15-M	185	3.57
TV-16-M	183	9.56
TV-17-M	194	7.58
TV-18-M	194	7.90
TV-19-M	193	6.62
TV-20-M	198	7.82
TV-21-M	200	10.33
TV-22-M	199	11.70
TV-23-F	199	8.75
TV-24-M	200	7.29
TV-25-M	200	10.11

Twelve subjects recorded a perfect performance relative to the quality part phase of the simulated job task.

Instructions for Filling Out Form A

The following series of statements describe the proper procedure to be utilized in recording data on Form A.

1. SUBJECT'S NAME - record the name of the subject.

    a. Also record in parentheses the subject's age.

    b. When it is not apparent from the name, record the subject's sex in front of the name in the left-hand margin (M-Male, F-Female).

2. TYPE OF TRA. - record the type of training the subject received.

    a. TV - Videotape

    b. AV - Audiovisual

    c. CL - Classical

    d. NONE - None

3. TOTL. ELPS. TIME - record the total elapsed time required to complete the entire job task - will be given in hours from the decimal hour stopwatch reading.

4. TIME UNTIL FIRST ACC. - the elapsed time until the occurrence of the first accident is recorded here - will be expressed in minutes from the electric microchronometer.

5. In the next series of columns the cumulative counter readings for each 10 parts will be recorded - the last three digits of the counters need only be recorded.

    a. AC - Accident counter reading

    b. PA - Parts attempted counter value

    c. GP - Good parts counter reading

FORM A

SUBJECTS NAME	TYPE OF TRA	TOTL ELPS TIME	TIME UNTIL FIRST ACC	FIRST TEN PARTS			SECOND TEN PARTS			THIRD TEN PARTS			FOURTH TEN PARTS			FIFTH TEN PARTS			SIXTH TEN PARTS			SEVENTH TEN PARTS			EIGHTH TEN PARTS			NINTH TEN PARTS			TENTH TEN PARTS		
				AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP
AV-1-F	AV	8.106	3.960	0	20	20	0	20	20	0	20	20	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
AV-2-M	AV	9.45	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
AV-3-M	AV	9.138	.376	2	20	20	0	20	20	2	20	20	2	20	20	0	20	20	1	20	20	1	20	20	1	20	20	0	20	20	0	20	20
AV-4-M	AV	8.004	.935	0	20	20	1	20	20	1	20	20	1	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20
AV-5-M	AV	7.746	.818	0	20	19	1	20	20	1	20	20	0	20	20	0	20	19	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20
AV-6-M	AV	8.784	1.826	0	20	20	1	20	20	0	20	20	1	20	20	0	20	20	2	20	20	1	20	20	0	20	20	0	20	20	0	20	20
AV-7-M	AV	7.992	2.772	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	1	20	20	3	20	20	0	20	20
AV-8-M	AV	9.036	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
AV-9-M	AV	8.976	.625	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	19	0	20	20	0	20	20	0	20	20
AV-10-M	AV	7.95	.865	1	20	20	2	20	20	0	20	20	0	20	20	1	20	20	0	20	20	1	20	20	0	20	20	0	20	20	1	20	20
AV-11-M	AV	11.316	11.006	0	20	20	0	20	20	0	20	19	0	20	20	0	20	18	0	20	20	0	20	19	0	20	20	0	20	20	1	20	19
AV-12-M	AV	9.246	1.590	1	20	20	2	20	19	2	20	20	2	20	20	0	20	19	0	20	19	1	20	18	0	20	20	0	20	19	2	20	20
AV-13-F	AV	8.988	.141	5	20	19	0	20	18	4	20	20	1	20	19	0	20	20	0	20	18	0	20	18	0	20	19	1	20	18	0	20	19
AV-14-M	AV	7.944	1.560	0	20	20	1	20	19	1	20	19	1	20	19	0	20	20	0	20	20	0	20	20	0	20	20	1	20	19	0	20	20
AV-15-F	AV	7.332	.142	2	20	20	0	20	19	0	20	19	0	20	20	0	20	20	2	20	19	2	20	20	1	20	20	1	20	19	0	20	19
AV-16-M	AV	8.142	7.446	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20
AV-17-M	AV	11.758	4.600	0	20	20	0	20	20	0	20	20	0	20	19	2	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
AV-18-M	AV	8.892	1.500	0	20	18	1	20	18	0	20	20	0	20	19	1	20	19	0	20	20	0	20	20	1	20	19	0	20	20	0	20	20
AV-19-M	AV	8.304	1.635	0	20	20	1	20	20	0	20	19	2	20	20	1	20	19	1	20	20	0	20	19	1	20	18	2	20	19	0	20	20
AV-20-M	AV	8.40	.487	1	20	18	0	20	15	0	20	14	3	20	13	0	20	16	0	20	16	1	20	18	0	20	17	0	20	19	0	20	19
AV-21-M	AV	6.642	.349	1	20	20	0	20	19	0	20	20	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19
AV-22-M	AV	10.242	2.225	0	20	20	0	20	20	2	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20
AV-23-M	AV	9.792	7.592	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	2	20	20	0	20	20	0	20	20
AV-24-M	AV	9.034	1.220	0	20	20	1	20	20	0	20	20	1	20	20	1	20	20	0	20	20	2	20	20	1	20	20	0	20	20	0	20	20
AV-25-M	AV	8.298	1.742	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
Total				14	500	494	12	500	487	13	500	490	17	500	489	8	500	490	6	500	492	12	500	490	8	500	493	8	500	493	5	500	495

FORM B

SUBJECT'S NAME	ACCIDENT COUNTER			GOOD PARTS COUNTER			TYPE OF TRA
	BEGIN	FINAL	DIFF	BEGIN	FINAL	DIFF	
AV-1-F	171	173	2	820	020	200	AV
AV-2-M	196	196	0	848	048	200	AV
AV-3-M	197	206	9	053	253	200	AV
AV-4-M	207	211	4	453	653	200	AV
AV-5-M	217	219	2	469	666	197	AV
AV-6-M	221	226	5	868	068	200	AV
AV-7-M	230	235	5	481	681	200	AV
AV-8-M	150	150	0	976	176	200	AV
AV-9-M	152	154	2	382	581	199	AV
AV-10-M	271	277	6	807	007	200	AV
AV-11-M	321	322	1	452	647	195	AV
AV-12-M	350	360	10	400	594	194	AV
AV-13-F	392	403	11	385	573	188	AV
AV-14-M	421	425	4	961	157	196	AV
AV-15-F	451	459	8	945	140	195	AV
AV-16-M	174	175	1	221	421	200	AV
AV-17-M	467	469	2	547	746	199	AV
AV-18-M	471	474	3	750	943	193	AV
AV-19-M	497	505	8	346	540	194	AV
AV-20-M	862	867	5	951	116	165	AV
AV-21-M	092	095	3	739	937	198	AV
AV-22-M	113	116	3	153	353	200	AV
AV-23-M	122	124	2	767	967	200	AV
AV-24-M	264	270	6	108	308	200	AV
AV-25-M	287	288	1	512	712	200	AV
Total			103			4913	
22 Men							
3 Women							

FORM A

SUBJECTS NAME	TYPE OF TRA	TOTL ELPS TIME	TIME UNTIL FIRST ACC	FIRST TEN PARTS			SECOND TEN PARTS			THIRD TEN PARTS			FOURTH TEN PARTS			FIFTH TEN PARTS			SIXTH TEN PARTS			SEVENTH TEN PARTS			EIGHTH TEN PARTS			NINTH TEN PARTS			TENTH TEN PARTS		
				AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP
CL-1-M	CL	7.59	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-2-F	CL	8.712	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19
CL-3-M	CL	7.314	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-4-M	CL	7.062	2.960	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-5-M	CL	9.768	.093	1	20	20	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20
CL-6-M	CL	9.972	2.374	0	20	20	0	20	20	2	20	19	0	20	20	1	20	18	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20
CL-7-M	CL	8.736	3.896	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	1	20	19	0	20	20	0	20	20	0	20	20
CL-8-M	CL	9.498	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-9-M	CL	7.176	4.620	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	1	20	19	0	20	19	0	20	20	0	20	20
CL-10-M	CL	8.454	.775	1	20	20	1	20	20	2	20	19	1	20	19	1	20	19	0	20	20	0	20	17	1	20	19	1	20	19	0	20	20
CL-11-M	CL	10.368	1.750	0	20	18	3	20	20	0	20	17	1	20	20	0	20	16	0	20	19	0	20	17	0	20	15	0	20	20	0	20	20
CL-12-F	CL	9.33	.149	1	20	19	0	20	19	0	20	18	1	20	20	2	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-13-M	CL	6.36	.380	0	20	20	2	20	19	2	20	19	1	20	18	0	20	16	2	20	19	3	20	19	0	20	17	0	20	18	2	20	18
CL-14-M	CL	11.436	.043	2	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-15-F	CL	11.742	9.568	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20
CL-16-M	CL	7.914	.045	1	20	19	1	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	1	20	19	0	20	20	0	20	20
CL-17-M	CL	9.168	.526	2	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	18	1	20	19	0	20	20
CL-18-M	CL	8.646	1.185	0	20	20	1	20	19	0	20	19	0	20	19	0	20	18	0	20	20	0	20	19	0	20	19	0	20	19	0	20	20
CL-19-M	CL	7.579	None	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	19	0	20	20	0	20	19	0	20	20	0	20	20
CL-20-M	CL	12.084	3.520	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-21-M	CL	8.238	4.337	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	19	0	20	20	0	20	20	0	20	20	0	20	20
CL-22-F	CL	10.23	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-23-M	CL	7.704	6.689	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20
CL-24-M	CL	11.070	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
CL-25-M	CL	7.530	.055	1	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	1	20	19	0	20	20	1	20	20	1	20	20
Total				9	500	496	9	500	497	9	500	490	5	500	496	5	500	482	3	500	496	6	500	488	4	500	485	5	500	495	3	500	497

FORM B

SUBJECT'S NAME	ACCIDENT COUNTER			GOOD PARTS COUNTER			TYPE OF TRA
	BEGIN	FINAL	DIFF	BEGIN	FINAL	DIFF	
CL-1-M	157	157	0	596	796	200	CL
CL-2-F	158	158	0	797	996	199	CL
CL-3-M	168	168	0	417	617	200	CL
CL-4-M	179	180	1	840	040	200	CL
CL-5-M	180	184	4	046	246	200	CL
CL-6-M	184	188	4	248	445	197	CL
CL-7-M	214	216	2	068	267	199	CL
CL-8-M	229	229	0	280	479	199	CL
CL-9-M	293	294	1	047	.244	197	CL
CL-10-M	326	334	8	831	023	192	CL
CL-11-M	381	385	4	809	991	192	CL
CL-12-F	386	390	4	189	385	196	CL
CL-13-M	409	421	12	778	961	183	CL
CL-14-M	121	123	2	790	989	199	CL
CL-15-F	176	177	1	424	624	200	CL
CL-16-M	460	464	4	150	348	198	CL
CL-17-M	493	496	3	146	342	196	CL
CL-18-M	507	508	1	742	934	192	CL
CL-19-M	095	095	0	939	136	197	CL
CL-20-M	110	111	1	550	750	200	CL
CL-21-M	112	113	1	954	153	199	CL
CL-22-F	121	121	0	566	766	200	CL
CL-23-M	136	137	1	170	370	200	CL
CL-24-M	246	246	0	297	497	200	CL
CL-25-M	241	245	4	091	289	198	CL
Total			58			4923	
21 Men							
4 Women							

FORM A

SUBJECTS NAME	TYPE OF TRA	TOTL ELPS TIME	TIME UNTIL FIRST ACC	FIRST TEN PARTS			SECOND TEN PARTS			THIRD TEN PARTS			FOURTH TEN PARTS			FIFTH TEN PARTS			SIXTH TEN PARTS			SEVENTH TEN PARTS			EIGHTH TEN PARTS			NINTH TEN PARTS			TENTH TEN PARTS		
				AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP
None-1-M	None	11.19	.030	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	1	20	20	0	20	20
None-2-M	None	9.316	1.894	0	20	20	1	20	19	0	20	20	0	20	20	1	20	20	1	20	19	2	20	20	0	20	20	1	20	20	0	20	20
None-3-M	None	6.774	.500	2	20	20	2	20	18	2	20	20	0	20	20	0	20	20	0	20	20	2	20	19	1	20	19	1	20	20	1	20	20
None-4-M	None	8.092	.143	1	20	20	1	20	20	0	20	20	0	20	20	2	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19
None-5-M	None	9.576	1.100	0	20	20	2	20	19	5	20	19	4	20	20	2	20	19	0	20	20	1	20	20	3	20	19	1	20	20	0	20	20
None-6-M	None	9.264	.019	2	20	20	0	20	19	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	18	0	20	20
None-7-M	None	10.71	.951	1	20	19	0	20	19	2	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	1	20	18	0	20	19
None-8-M	None	7.602	1.630	0	20	11	1	20	19	0	20	19	0	20	19	0	20	15	0	20	19	0	20	18	1	20	19	1	20	19	0	20	18
None-9-M	None	9.360	3.075	0	20	20	0	20	20	0	20	17	1	20	17	1	20	20	0	20	20	0	20	19	0	20	19	1	20	19	0	20	19
None-10-M	None	7.662	.435	2	20	17	2	20	20	5	20	20	2	20	20	0	20	20	3	20	19	4	20	20	1	20	19	1	20	20	1	20	20
None-11-M	None	7.524	.304	3	20	19	1	20	19	0	20	19	3	20	18	1	20	20	0	20	19	1	20	20	1	20	19	1	20	20	0	20	19
None-12-M	None	8.196	4.927	0	20	19	0	20	19	0	20	19	1	20	20	0	20	18	0	20	18	0	20	20	2	20	19	1	20	20	0	20	18
None-13-M	None	9.324	.034	2	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	19	1	20	20	0	20	20	0	20	20	1	20	20
None-14-M	None	9.192	2.140	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
None-15-F	None	8.76	.560	2	20	15	1	20	20	2	20	20	0	20	20	1	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20
None-16-F	None	10.794	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
None-17-M	None	7.23	.047	1	20	20	0	20	20	0	20	19	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
None-18-M	None	8.154	3.339	0	20	20	0	20	20	0	20	20	1	20	20	1	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20
None-19-M	None	7.764	1.029	0	20	20	2	20	19	1	20	20	0	20	19	0	20	20	1	20	20	0	20	19	0	20	18	0	20	20	2	20	20
None-20-M	None	9.576	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
None-21-F	None	9.174	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
None-22-F	None	11.992	9.243	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20
None-23-M	None	7.728	2.235	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	1	20	18
None-24-M	None	8.022	.293	1	20	20	4	20	20	1	20	20	1	20	20	0	20	20	1	20	20	0	20	20	2	20	20	1	20	20	1	20	19
None-25-M	None	9.00	1.558	0	20	20	2	20	20	1	20	20	0	20	20	1	20	20	2	20	20	3	20	20	2	20	20	3	20	20	3	20	20
Total				18	500	480	20	500	490	22	500	492	13	500	491	10	500	491	9	500	493	15	500	493	14	500	490	14	500	493	10	500	499

FORM B

SUBJECT'S NAME	ACCIDENT COUNTER			GOOD PARTS COUNTER			TYPE OF TRA
	BEGIN	FINAL	DIFF	BEGIN	FINAL	DIFF	
None-1-M	101	104	3	147	346	199	None
None-2-M	104	110	6	350	549	198	None
None-3-M	124	135	11	971	167	196	None
None-4-M	137	141	4	377	575	198	None
None-5-M	475	493	18	948	144	196	None
None-6-M	505	507	2	544	740	196	None
None-7-M	508	512	4	938	132	194	None
None-8-M	323	326	3	652	828	176	None
None-9-M	347	350	3	210	.400	190	None
None-10-M	360	381	21	601	796	195	None
None-11-M	425	436	11	161	353	192	None
None-12-M	437	441	4	359	549	190	None
None-13-M	446	451	5	746	945	199	None
None-14-M	151	152	1	182	382	200	None
None-15-F	159	166	7	997	202	195	None
None-16-F	167	167	0	207	407	200	None
None-17-M	169	170	1	622	820	198	None
None-18-M	188	190	2	450	649	199	None
None-19-M	190	196	6	653	848	195	None
None-20-M	211	211	0	657	857	200	None
None-21-F	212	212	0	863	063	200	None
None-22-F	227	228	1	073	273	200	None
None-23-M	236	238	2	689	886	197	None
None-24-M	252	264	12	909	108	199	None
None-25-M	270	287	17	312	512	200	None
Total			144			4902	
21 Men 4 Women							

FORM A

SUBJECTS NAME	TYPE OF TRA	TOTL ELPS TIME	TIME UNTIL FIRST ACC	FIRST TEN PARTS			SECOND TEN PARTS			THIRD TEN PARTS			FOURTH TEN PARTS			FIFTH TEN PARTS			SIXTH TEN PARTS			SEVENTH TEN PARTS			EIGHTH TEN PARTS			NINTH TEN PARTS			TENTH TEN PARTS		
				AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP	AC	PA	GP
TV-1-M	TV	8.544	.281	1	20	19	1	20	18	1	20	18	1	20	17	1	20	17	0	20	17	0	20	17	0	20	17	0	20	18	1	20	19
TV-2-M	TV	7.23	.030	4	20	18	2	20	19	0	20	20	1	20	18	0	20	17	1	20	18	0	20	18	0	20	19	0	20	20	0	20	19
TV-3-M	TV	7.86	.142	1	20	20	0	20	20	1	20	20	1	20	20	0	20	20	2	20	20	2	20	20	0	20	20	1	20	20	1	20	20
TV-4-M	TV	8.886	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-5-M	TV	8.67	7.630	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20
TV-6-M	TV	8.166	.526	1	20	20	1	20	20	1	20	20	1	20	20	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	1	20	20
TV-7-F	TV	9.036	3.540	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20
TV-8-M	TV	6.51	.033	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	19	0	20	20	0	20	20	1	20	20
TV-9-M	TV	9.57	.036	1	20	17	1	20	19	0	20	18	0	20	18	1	20	19	0	20	20	2	20	19	1	20	19	0	20	17	0	20	17
TV-10-F	TV	8.974	.890	1	20	20	3	20	20	1	20	20	1	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-11-F	TV	10.20	.252	1	20	20	2	20	20	2	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	2	20	20	1	20	20
TV-12-F	TV	9.69	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-13-F	TV	8.688	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-14-M	TV	8.888	None	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-15-M	TV	3.574	.162	6	20	19	3	20	19	2	20	19	2	20	17	1	20	19	1	20	19	0	20	18	1	20	19	1	20	18	2	20	18
TV-16-M	TV	9.564	.415	3	20	20	3	20	15	1	20	20	1	20	20	1	20	20	1	20	17	1	20	17	0	20	18	1	20	17	1	20	19
TV-17-M	TV	7.584	5.750	0	20	19	0	20	19	0	20	19	0	20	20	0	20	19	0	20	20	0	20	19	1	20	20	0	20	20	0	20	19
TV-18-M	TV	7.902	3.140	0	20	20	0	20	18	0	20	19	0	20	20	1	20	19	0	20	20	1	20	18	0	20	20	0	20	20	0	20	20
TV-19-M	TV	6.618	.046	1	20	18	0	20	20	0	20	20	0	20	19	1	20	19	0	20	18	0	20	20	1	20	20	1	20	20	0	20	19
TV-20-M	TV	7.924	2.770	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	19	0	20	20	0	20	19	0	20	20	0	20	20
TV-21-M	TV	10.326	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20
TV-22-M	TV	11.704	None	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20
TV-23-F	TV	8.754	5.277	0	20	20	0	20	19	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	2	20	20	0	20	20	0	20	20
TV-24-M	TV	7.290	2.710	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20
TV-25-M	TV	10.110	5.979	0	20	20	0	20	20	0	20	20	0	20	20	0	20	20	1	20	20	0	20	20	0	20	20	0	20	20	0	20	20
Total				21	500	490	16	500	486	10	500	493	10	500	488	8	500	489	7	500	486	7	500	485	7	500	491	7	500	490	10	500	489

FORM B

SUBJECT'S NAME	ACCIDENT COUNTER			GOOD PARTS COUNTER			TYPE OF TRA
	BEGIN	FINAL	DIFF	BEGIN	FINAL	DIFF	
TV-1-M	867	873	6	116	292	176	TV
TV-2-M	873	881	8	289	475	186	TV
TV-3-M	083	092	9	539	739	200	TV
TV-4-M	111	111	0	750	950	200	TV
TV-5-M	117	118	1	355	555	200	TV
TV-6-M	141	148	7	575	775	200	TV
TV-7-F	148	150	2	776	976	200	TV
TV-8-M	465	467	2	349	547	198	TV
TV-9-M	856	862	6	768	951	183	TV
TV-10-F	106	113	7	380	580	200	TV
TV-11-F	123	132	9	989	189	200	TV
TV-12-F	173	173	0	020	220	200	TV
TV-13-F	178	178	0	630	830	200	TV
TV-14-M	270	270	0	607	806	199	TV
TV-15-M	294	313	19	244	429	185	TV
TV-16-M	334	347	13	023	206	183	TV
TV-17-M	385	386	1	991	185	194	TV
TV-18-M	406	408	2	578	772	194	TV
TV-19-M	442	446	4	549	742	193	TV
TV-20-M	206	207	1	255	453	198	TV
TV-21-M	216	216	0	267	467	200	TV
TV-22-M	220	220	0	667	866	199	TV
TV-23-F	238	241	3	886	085	199	TV
TV-24-M	248	250	2	502	702	200	TV
TV-25-M	251	252	1	703	903	200	TV
Total			103			4987	
19 Men							
6 Women							

VITA

John Howell Leslie, Jr.

Candidate for the Degree of

Doctor of Philosophy

Thesis: PROGRAMMED SAFETY THROUGH PROGRAMMED LEARNING

Major Field: Engineering

Biographical:

Personal Data: Born in Wichita, Kansas, July 28, 1938, the son of John Howell and Pauline Elizabeth Leslie.

Education: Attended grade school in Wichita, Kansas; graduated from St. Mary's Interparochial High School, Wichita, Kansas in 1956; received the Bachelor of Science degree from Wichita State University, with a major in Industrial Engineering, in January, 1961; received the Master of Science degree from Wichita State University, with a major in Mechanical Engineering, in June, 1964; completed requirements for the Doctor of Philosophy degree, with a major in Industrial Engineering and Management, in May, 1972.

Professional Experience: Upon graduation from college in 1961, entered the Manufacturing Training Program of the General Electric Company; after a three-month's tenure in this position, accepted a job with the Boeing Company as a numerical control computer programmer and analyst; joined the faculty of Wichita State University in September, 1962, with an appointment in the Industrial Engineering Department; from 1964 to the present time, serving as the Chairman of the Industrial Engineering Department with the responsibility of developing academic and administrative policies.