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FINAL REPORT

Contract No. 210-78-0111

STUDY OF METALCUTTING LATHE SAFETY

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Center for Disease Control
National Institute for Occupational Safety and Health
Division of Safety Research
Morgantown, West Virginia 26505

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Abstract (Limit: 200 words)
Safety techniques in the use of engine lathes and production turret lathes are discussed. Literature is searched to identify safety problems and to learn of existing or proposed methods for reducing the risk of injury. Hazards are analyzed to identify injury potential situations in actual machine shops. The major machine shop types evaluated are a job shop, a tool and experimental shop, a maintenance shop, and a manufacturing production shop. For injury data analysis, 538 workmen's compensation reports are used and injuries are categorized by accident type, similar characteristics within the type, and development of fault-free diagrams for groups of injuries. Countermeasures related to the events in the accident scenarios are developed to reduce workers risk of injuries. Engineering, training, and management policy countermeasures are described. OSHA and American National Standard Safety Requirements Standards are evaluated and recommendations are made for worker training, operation, proper tools, lathe design, and rules for standards implementation. The authors conclude that this study has been effective in identifying aspects of metal cutting lathes and operations that can cause injuries, and developing countermeasures to reduce workers' risk. The authors suggest future research for the development of lathe guards that provide fewer work flow restrictions, awareness devices to warn of chuck and holding device hazards, and improved chuck design.

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John Etherton

NIOSH Project Officer

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ABSTRACT

A 1975 report, Machine Guarding-Assessment of Need, concluded that NIOSH should conduct applied research to set forth safety recommendations in the operation and design of metalcutting lathes. The objectives of this study were:

a. To identify aspects of engine and turret lathes and associated operations that are likely to cause worker injuries, and

b. Develop countermeasures that will reduce worker's risk to these injuries.

The study involved performing four tasks. The first was to review domestic and foreign literature. Second, was to conduct a hazard analysis and human engineering evaluation of ten lathes in actual machine shops. Third, was to collect, analyze injury data and develop fault-tree diagrams that trace the accidents. Fourth, was to develop countermeasures and review existing and proposed safety standards.

The results of the study were safety recommendations that are applicable to a wide variety of machine shops.

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FIGURES (continued)

FIGURES (continued)

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TABLES (continued)

TABLES (continued)

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- International Association of Machinist and Aerospace Workers
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- National Machine Tool Builders Associataions
- Workmen's Compensation Agencies for states of California, Connecticut, Michigan, Ohio, Pennsylvania, Washington, and Wisconsin.

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SECTION 1

INTRODUCTION AND BACKGROUND

INTRODUCTION

The metalcutting lathe was selected for study as a result of recommendations made in Machine Guarding-Assessment of Need.* That study concluded that NIOSH should conduct applied research to set forth safety recommendations in the operation and design of lathes.

The study of metalcutting lathe safety is comprised of three phases. This report presents the result of Phases I and II, whose objectives were: (a) to identify aspects of metalcutting lathes and associated operations that are likely to cause worker injuries, and (b) to develop countermeasures that will reduce workers' risk to these injuries. The Phase III objective will be to develop an engineering guide that will enable engineering and safety personnel to implement the countermeasures.

The report consists of six sections plus references, bibliography and appendices. Section 1 includes the introduction and background information. Section 2 presents a discussion of the literature surveyed for the study. Section 3 describes the hazard analysis and human engineering evaluation methodologies and discusses the results. Section 4 describes the collection of injury data and the fault-tree analysis procedure used in the data anlysis. Section 4 also describes the development of countermeasures to minimize the workers' risk of injuries. Section 5 discusses the results of the evaluation of existing and proposed standards. Finally, Section 6 summarizes and presents a conclusion to the report.

BACKGROUND

The metalcutting lathes included in this study were manually operated engine lathes and production turret lathes. Engine lathes include four types. The light-power machine lathe is the first type. This type of lathe is designed for general light machining and for training purposes. Light-power machine lathes can be either bench models or floor models. The second type is the toolroom lathe. This lathe is more accurately constructed than the light-power machine lathe and may be equipped with special attachments and accessories. The primary function of this lathe

*The Bendix Corporation, Launch Support Division. June 1975. Machine Guarding-Assessment of Need. U.S. Dept. of Health, Education, and Welfare. Public Health Service. Center for Disease Control. National Institute for Occupational Safety and Health. Division of Laboratories and Criteria Development. Cincinnati, Ohio. p. 197.

is to perform precision machining in tool an die, and gauge work. The standard lathe is the third type. It is used for general, all purpose machine work. This lathe is built heavier and has more horsepower, a wider range of speeds and feeds, and in general has a greater capacity than either the light-power and toolroom lathes. The large swing and long bed lathes are the fourth type. Engine lathes of this type are designed for machining long shafts and large diameter work.

Production turret lathes include two types. The first is the ram type. This lathe can produce parts from bar stock up to 3" diameter or chuck work up to 20" diameter. On the ram type lathe, the end-working turret is mounted on a ram slide which moves longitudinally in a saddle clamped to the lathe bed during machine operations. The second is the saddle type. This lathe is basically a larger machine suited for heavy duty jobs. On the saddle type lathe, the end-working turret is mounted directly on the saddle which moves longitudinally on the lathe bed during machine operations.

There are approximately 493,500* metalcutting lathes of various types in the United States. Each year these metalcutting lathes are associated with injuries ranging from lacerations to fractures, amputations and death. During the performing of this study three lathe fatalities occurred within a period of five months. In the first fatality, a young man was killed when one end of a shaft he was polishing came loose from the tailstock and struck his chest. In the second fatality, another young man using a No-Go gauge caught his right hand between the pipe coupling mounted in the chuck and the gauge, and was pulled between the lathe bed and the coupling. In the third fatality, a woman at a vocational school caught her clothing in the workpiece and was pulled into the lathe.

Given the large population of metalcutting lathes in the U.S. and the fact serious injuries can occur on those lathes, there is potential for accidents and injuries with severe consequences.

SECTION 2

LITERATURE REVIEW

INTRODUCTION

The purposes of the literature review were to: (a) identify existing safety problems on lathes, and (b) learn of existing or proposed methods for reducing workers' risk of injuries on lathes.

This section deals with the literature search methods, the type and number of articles included and the discussion of the literature surveyed.

LITERATURE SEARCH METHODS

The literature search included both computer and manual searches of data banks containing articles in safety and health, engineering and psychology. There were two computer searches performed. One computer search was run on NIOSHTIC which is NIOSH's own computerized information system. The NIOSHTIC system includes over sixty other data bases, one of which is CIS from the Occupation Safety and Health Information Center located in Geneva, Switzerland. A second computer search was run on COMPENDEX which provides coverage of all engineering disciplines.

To supplement the findings from the computer searches, several manual searches were performed on data bases not included in the computer searches. One was on the Safety Sciences Abstracts Journal. The other was on a selected bibliography from the Ergonomics Information Analaysis Centre, University of Birmingham, England.

ARTICLES INCLUDED

There were a total of 33 foreign and domestic articles identified through computer and manual searches. Sixteen of the 33 articles identified were reviewed for the study. Nine of the reviewed articles were abstracted. The abstractions of these 9 articles are presented in Appendix A. The remainder of the articles identified could not be reviewed because they either could not be located or they were in a non-English language and resources were not available for their translation. It is important to note that of the 33 articles identified, only four domestic articles were included.

DISCUSSION OF ARTICLES

The articles reviewed were of two types. The first type included articles of a descriptive nature, dealing with such items as general lathe safety, safety devices, etc. These articles were useful in identifying known metalcutting lathe hazards and developing the countermeasures to reduce the workers' risk of lathe injuries. The articles will become important in developing the handbook which will provide detailed information concerning application of the countermeasures.

The second type of articles reviewed were of a research nature. These articles provided theoretical background information for the study.

Articles of Descriptive Nature

A brief set of engine lathe safety rules were compiled by the National Safety Council (Data Sheet 264, 1964). Another brief article described some specific devices for preventing lathe accidents on lathes (Preventing Accidents at Lathes, 1968). Two devices of interest were a spring loaded chuck key and protected lathe carrier (lathe dog). Balocco (1976) presented a list of ten sources of danger on the lathe and described ways of preventing injuries occurring at these sources. Balocco also described principles that should be followed when installing lathes in the workplace, hazards associated with transmission parts, preventing controls from being accidentally engaged, and devices for attaching the workpiece. The most complete description of the lathe safety principles, rules, guidelines, etc. was presented in a translated article from Poland (Dabrowski, 1973). Dabrowski described in detail a basis for machine tool arrangement, lifting devices in the working area, seats, lighting in the workplace, protective grounding, and guarding protections. Also in the same article was a section dealing specifically with work on lathes. One particular item of note was a unique two-handled wrench for securing jaws on large chucks. Seeger (1974) presented an interesting discussion on intergrated safety in metal working. Although much of the article did not deal with lathes, one particular statistic from a manufacturing plant indicated more than 40% of all lathe accidents in the plant resulted in injuries to the eyes caused by cuttings. The accident statistics were compiled over a two year period.

Articles of a Research Nature

Most of the articles that were of a research nature involved lathe design. Hartin and Derks (1975) discussed an ergonomically improved lathe that was based on analysis of specific ergonomic requirements. The key element of their design was a tilted lathe bed (15-20°) that accomodated the fifth percentile worker, as well as the taller or larger worker. Floyd and Ward (1967), although not specifically dealing with lathes, present findings that indicate poor posture at the workstation increases fatigue, may hinder productivity, and may lead to physical ailments, such as backaches and permanent posture distortions. Singleton (1964) presents information that indicates poor control configuration on lathes can lead to increased body movements, involve more awkward posture and increase the effort required to operate controls. Pratt and Corlett (1970) indicates that lathe designs need to be modified in the direction of reducing reaching and climbing during their operations. A rather interesting study was presented by Carr, Ashford and Easterby (1966). This study showed that by changing the configuration of a tabular chart specifying threads, fewer errors were made and less time was required to select threads from the chart.

One concern in metalcutting lathe operations was whether left-handed workers might have difficulty operating the lathe controls. Chapanis and Gropper (1968) and Sudden and Liwk (1959) indicated that in complex motor tasks, left-handed subjects had far less difficulty performing tasks designed for right-handed people than right-handed subjects did in performing tasks designed for left-handed people.

Two other articles provided information on job monotony, high noise levels, and low light levels associated with lathe operations. Branton (1970) reported in a study involving workers operating capstan lathes that deterioration of a worker's performance which may result in accidents was caused by monotony and underloading the worker's capacity, and not physical fatique and overloading the worker's capacity. The author also suggested that providing increased protection for the hands by the use of guards and protective devices would reduce, but not eliminate, accidents occurring at such places as the chuck and workpiece. This finding has implication in high production machine shops using turret lathes to produce 1000-1500 identical parts per jobs. In most situations of this type, the workers' only activity includes loading and unloading the chuck, and operating a few controls. Buzunov (1972) reported that the working environment for machine-tool operators and metal workers should be improved by reducing noise levels, improving lighting and by providing a sensible schedule of work and rest.

SECTION 3

HAZARD ANALYSIS AND HUMAN ENGINEERING EVALUATION

INTRODUCTION

The purpose of performing the hazard analysis was to identify, categorize and describe Injury Potential Situations (IPS) that occurred during the operation of metalcutting lathes in actual machine shops. The purpose of performing the human engineering evaluation was to determine: (a) if controls on the metalcutting lathes observed in these machine shops were difficult to operate, and (b) if there was a chance for workers to operate the controls incorrectly. The results from the hazard anlaysis and human engineering evaluation were utilized in the development of countermeasures for minimizing the workers' risks of injuries.

The first and second parts of Section 3 describe the methods for choosing the eight lathes recommended for the hazard analysis and human engineering evalaution and for selecting the machine shops in which to perform the analysis and evaluation. The next part details the hazard analysis methodology and defines the IPS. This part of the section describes the application of the hazard analysis methodology in the field. Following the analysis methodology are the results and discussion of the hazard analysis. The next part details the human engineering evaluation methodology. This is followed by a description of the application of the evaluation methodology in the machine shops. The last parts of this section present the results and discussion of the human engineering evaluation.

RECOMMENDED LATHES

A list of eight lathes were recommended for the hazard anlaysis and human engineering evaluation. The list included six lathes chosen from the four engine lathe categories (light-power machine, toolroom, standard, and large swing and long bed) and two lathes chosen from each of the turret lathe categories (ram and saddle type). The lathes were chosen from a list of 16 engine and turret lathes that were described in terms of distinguishing features. These features included such items as lathe size (e.g., swing, distance between centers), type of chuck (e.g., three and four jaws), accessories (e.g., steady rest, tracer attachment), type of feeds (e.g., manual, power) and age.

The approach used in choosing the metalcutting lathes from the list of 16 lathes was to choose one or more lathes from each of the categories:

1. that would likely involve a diverse or extreme set of jobs, e.g., difficult and routine setups, large and small work, precision and non-precision machining, few and many accessories required, and old and new equipment;

2. that would likely involve a variety of operators, e.g., male, female, apprentices, lathe operators and machinists;

3. that would likely represent the types found in the four major shops: job, tool/experimental, maintenance and manufacturing/production.

The eight recommended lathes* included: one light power machine lathe (bench model), one toolroom lathe (floor model), three standard lathes (floor models), one large swing and long bed lathe (floor model) and two floor-model turret lathes, one ram type, and one saddle type.

SELECTED MACHINE SHOPS

The primary considerations in the selection of the machine shops for conducting the hazard analyses were:

1. whether the machine shop had lathes with distinguishing features that came as close as possible to matching the features on the recommended lathe;

2. whether the machine shop represented one of the four major shop types: job, tool/experimental, maintenance, and manufacturing/production;

   a. Job Shop--a contracting shop that does a variety of machine work for other industries. Sometimes a job shop will also manufacture a small line of products.

   b. Tool/Experimental Shop--a shop that specializes in precision type work, usually tools and dies, or experimental machine work.

   c. Maintenance Shop--a shop that supports the maintenance efforts of a manufacturing plant.

   d. Manufacturing/Production Shop--a shop where products are manufactured or produced. The products can either be large or small scale in nature.

3. whether there was likely to be good cooperation on the part of the machine shop personnel.

The secondary considerations in the selection of the machine shops for conducting the hazard analyses were:

1. whether there was the likelihood that a mixture of jobs could be observed on the lathes. The term "jobs" is used to describe the activity or work performed to produce a part or parts from material (raw, or a secondary part such as a casting) to specifications set forth in accompanying engineering drawings or "sample piece" on a lathe by a worker.

2. whether there was the likelihood that a variety of workers could be observed operating the lathes. It was important that the workers observed in the study include: male, female, different skill levels

(apprentices, lathe operators, machinists), old and young, and left- and right-handed, and if possible, different body shapes and sizes of workers.

The method used in selecting the machine shops with the desired combinations of lathes, job, and workers was, first, to locate one of the machine shop types. Then, to determine if any of the recommended lathes were being used in the shop. Typically, a particular type of lathe is associated with a particular type of machine shop, e.g., a toolroom lathe is generally associated with a tool and die or experimental shops. After learning that a machine shop used one or several of the lathes on the recommended list, the lathe study was described to the machine shop personnel to determine if they would cooperate in the project.

The final aspect in selecting the machine shops was to ensure that a reasonable mixture of jobs were performed on the lathes and that a variety of the workers operated them. It was expected that finding an optimum mixture of jobs and variety of workers would be impossible. However, considering these factors ensured that a reasonable mixture of jobs and a variety of workers were observed on the lathes.

Descriptions and photographs*† of the actual lathes, jobs, workers, and machine shops observed are presented in Appendix C. There were a total of ten lathes included in the hazard analyses and human engineering evaluation. Two additional lathes were included to provide more analysis and evaluation data.

HAZARD ANALYSIS

Methodology

The key factor in the methodology used in the hazard analysis was the Injury Potential Situation (IPS). An IPS is a situation that occurs in a task in which there is reasonable potential for: (a) immediate worker injury resulting from the worker's actions (e.g., worker placed his hand close to the paths of revolving workpiece bolts while talking with a fellow worker), or (b) delayed worker injury resulting from some reoccurring activity (e.g., worker repeatedly bumped his knee on the lathe carriage). An occurrence of an IPS depends primarily on two elements being present at the appropriate time during the task-related situation. These are:

1. An <u>accident-associated event</u> that can cause or contribute to accidents and injuries, e.g., the worker's file slipped on a rotating workpiece; the worker's hand slipped on the file handle.

*No photographs of engine lathes (g) and (h) are included because of restrictions on taking photographs in the machine shop in which the lathes were located.

†Workpiece and setup shown on lathes do not match the descriptions of the job observed because the photography had to be scheduled at a later date.

2. A dynamic or static object capable of producing injury, e.g., rotating chuck or workpiece, sharp cutting tools etc.

A third element, poor workplace environment, can further increase the possibility of a IPS, e.g., high noise level or poor lighting can increase the chance a worker will not hear or see some important information cue and make a mistake and sustain injury.

The dynamics of an IPS involve two suppositions. One is that an accident-associated event occurs when a person is performing some task. The second is either simultaneously or sequentially there arises the potential for contact between the worker and an object capable of producing injury. This potential for injurious contact is the result of accident associated events occurring where there is the chance of bodily injury. For example: The worker forgot to tighten one of the chuck jaws securing the workpiece to the chuck (The workpiece could be thrown from the lathe striking the worker.); or the worker's hand was very close to the rotating chuck while he was facing in the opposite direction talking with a fellow worker (The worker could forget the location of his hand and accidentally move it into the rotating chuck.).

Identifying an IPS--

Identifying an IPS during the observation of lathe operations required:

1. Recognizing accident-associated events that occurred in the tasks performed by the worker when he was operating the lathe.

2. "Playing" of accident scenarios in the mind's eye for each accident-associated event recognized.

3. Identification of situations in the accident scenarios that could result in immediate or delayed worker injury.

The first step in identifying an IPS was to recognize accident-associated events that occurred in the tasks the worker was performing while operating the lathe. An accident-associated event is characterized by overt behavior that indicates some undesired activity has occurred that can cause or contribute to accidents, e.g., the worker forgot to wear his safety glasses; the worker quickly disengaged the clutch after he discovered the spindle speed was set at 1500 RPM instead of 15 RPM; the wrench slipped from the bolt head.

The next step in identifying an IPS involved the "playing" of accident scenarios. The "playing" of accident scenarios took place in the mind's eye of the observer when an accident-associated event was detected in the task being observed. Whenever an accident-associated event was detected, scenarios of potential accidents that could result were quickly conceived; that is, the situations that could result from accident-associated event were imagined. For example, if the observer sees a worker's hand slip while the worker is pushing a handle located just above a rotating workpiece, one scenario played would be that the worker could lose his balance and fall on the rotating workpiece. Another, which would be less severe, might be that the worker could place his hand on a sharp drill in the tailstock to prevent his fall.

The last step in identifying IPSs was to recognize the injury potential situations. Recognizing these situations involves making judgments based on clear evidence as to whether the accident scenarios could result in immediate or delayed injury. Where clear evidence was not available immediately, the observed situation was noted on the recording form for later evaluation.

A flow diagram showing the observation method is presented in Figure 3-1. The IPS identification process began with the observation of the worker's overt behavior during lathe operations and continued until all observations of the worker were completed. In addition to recording IPSs, an ongoing record of the lathe operations and worker's activity was made during the observations. Knowing the activity that occurred before and after an IPS helped in later evaluation of the IPS. Samples of actual completed hazard analysis recording forms are shown in Appendix D.

Using this observation method to identify IPSs in actual machine shops involved performing the following seven steps:

1. Observe the worker's overt behavior during lathe operations.

2. Recognize any accident-associated events that occur in the tasks the worker was performing.

3. "Play" scenarios for each of the accident-associated events recognized.

4. Recognize any situations that could result in potential injury situations.

5. Record the IPS on the hazard analysis forms.

6. Record the lathe operation the worker is performing when the IPS was recognized, e.g., turning, facing, filing, etc.

7. Describe the operation in terms of the worker's activities associated with the lathe operations, e.g., the worker placed the workpiece in the chuck with his right hand and tightened the chuck jaws with the chuck wrench in his left hand.

Applying the Hazard Analysis Methodology--

Applying the hazard analysis methodology during lathe operations in the actual machine shops selected required conducting pre-observational activities before the actual analysis. The first set of activities involved visiting the machine shops a week before performing the actual analysis. During the visit the analysis method was discussed with machine shop supervisory personnel to acquaint them with the specific

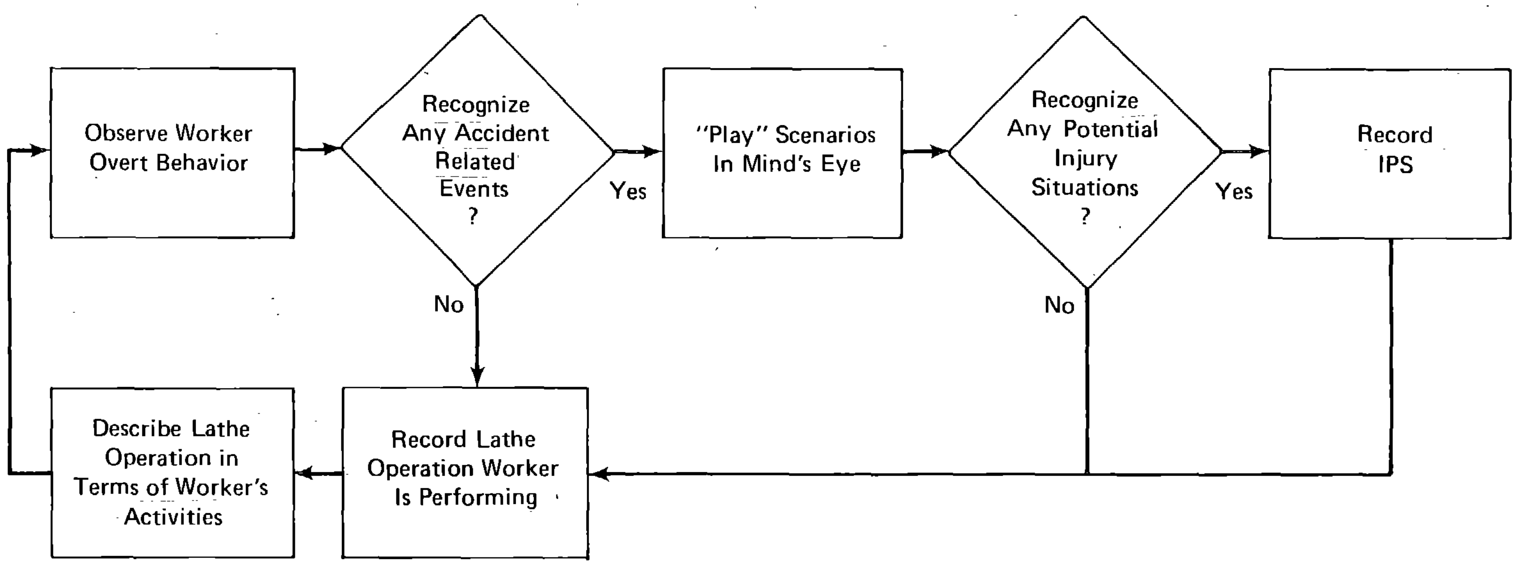

Figure 3-1. Flow Diagram of Observation Method for Identifying IPS During Lathe Operations

details of the study. Following the discussion, a list was made of the various jobs that would be scheduled (day and approximate time) on the lathes that would be involved in the hazard analysis. Before leaving the machine shops, discussions were held with the workers who would likely be operating the lathes to explain the analysis methodology. On the day of the actual hazard analysis the particular machine shop involved was first contacted to confirm that the job planned for the lathe chosen for the analysis was still scheduled. Upon arriving at the shop, a short discussion was held with the worker who was operating the lathe to be observed. It was important to encourage the worker to behave as naturally as possible. An observation position was then located in the machine shop that offered a clear view of the worker and the lathe, yet was as unobtrusive as possible.

The actual observations of the lathe operations were begun when the worker started a "new" job or when he was in the loading stage of an existing job. A new job was denoted when the worker began to set up the lathe in preparation to perform a job he had just been given by his supervisor. This was generally after the worker had a short discussion with his supervisor, or after the worker finished reviewing the engineering drawings that described the part to be produced.

The observations of the lathe operations continued until the last machining operation was completed and the finished part was unloaded from the lathe. The observations were only halted or stopped when: (a) the worker left the lathe area to perform such operations as grinding the cutting tool, obtaining tools from the tool crib, or (b) when quiting time came and the worker went home.

A follow-up interview occurred after the observation ended. These activities involved talking with the worker to clarify any information that was recorded on the hazard anlaysis forms. The follow-up presented an opportunity to ask the worker if he has ever has an accident or a near miss operating the present metalcutting lathe or on other lathes in his past experience. The worker was also asked whether he had ever seen a fellow worker have an accident or a near miss.

Pilot Study

The purpose of the pilot study was to evaluate the hazard analysis methodology so that changes could be made prior to going into the field to conduct the actual analyses. To verify that the observation method was capable of collecting the necessary data, a video camera was used to record the entire job being performed. This technique enabled a one-for-one comparison of the operations and worker's activity seen by the observer and those recorded by the video camera. The use of the video technique was limited to the pilot study, since a video camera was not permitted in most of the actual machine shops in the field.

The results of the pilot study indicated the observation method was capable of collecting the necessary data for the study in the machine shop environment. There were no major problems in using the hazard analysis methodology and recording the results. Only minor changes were made to the recording forms to provide more space for describing the worker's activity. The video recording of the lathe operations had limited usefulness because: (a) the camera could not be positioned to record all lathe operations, and (b) the variation in machine shop light levels could not be accommodated. Because of movable lamps used on the lathes to focus light on the workpiece, it was difficult to position and adjust the video camera so the variation in light levels would not affect the image being recorded by the camera.

Results

There were twenty IPSs identified from the observations of the ten lathes in the participating machine shops. These IPSs were grouped by the type of IPS observed.

Unsafe Devices. Unsafe devices refers to dangerous tools, fixtures, jigs or accessories that were used in performing some lathe related activity, such as removing cuttings from the lathe. These devices were solutions employed to solve specific problems encountered in operating the lathe. The devices also appeared to be made in the machine shops that were using them.

Unsafe Actions. Unsafe actions refers to dangerous working methods, habits, practices employed by the worker to perform some lathe related activity.

Limited Personal Protection. Limited personal protection refers to the worker not wearing all necessary safety equipment while operating the lathe.

Limited Personal Protection. Limited personal protection refers to the worker not wearing all necessary safety equipment while operating the lathe.

Unsafe Position/Posture. Unsafe position/posture refers to the potentially injurious body postions taken by the worker when operating the lathe. This category includes situations involving poor posture and situations where worker's continual contact with some part of the lathe could result in injury.

Applying Extreme Force. Extreme force refers to situations where the application of much force during some lathe related activity could lead to injury.

There were nine IPSs observed in the category of unsafe devices. In the category of unsafe procedures there were seven IPSs observed. Only one IPS was observed in each of the categories of limited personal protection and unsafe position/posture. The category of applying extreme force had three IPSs. The descriptions of the IPSs are presented in Tables 3-1 through 3-5. The lower case letters after the headings of engine and turret lathes in the tables indicate the specific lathes listed in Appendix C.

Table 3-1. Unsafe Devices

Engine Lathe (c)

1. Worker tripped on cuttings protruding from slotted wooden mat* used on the floor in front of the lathe. The worker could have fallen on the lathe or other material placed on the floor.

2. Worker lubricated rotating shaft collar with four protruding screws. Since the screws were not visible, the worker could have accidently caught the curved spout of the oil can on the screws. This action could have pulled has hand into the rotating shaft collar.

3. Worker rested his hand very close (approximately 2") to rotating centering cap with four protruding screws. The worker faced the opposite direction and talked with fellow worker while flexing his fingers. The worker's fingers could have accidentially contacted the rotating screws because of his inattention to the situation.

4. Worker reached over the centering cap to feel the finish on the workpiece. His arm was very close to the finish path of four protruding screws in the cap. The worker's arm could have accidentally contacted the rotating screws, since his focus of attention appeared to be on the finish of the workpiece.

5. Worker's hand was very close to the rotating path of four protruding screws in the shaft collar. The worker's hand could have accidentally contacted the rotating screws, since he intermittently looked away to visually check the cutting tool.

Engine Lathe (g)

6. Worker placed a combination of flat and wedge shaped wood between chuck face and end of large workpiece that he was centering in the chuck. Because the chuck jaws were not completely secure on the workpiece end, the wooden spacers could have slipped permitting the large workpiece to slide from the tailstock center to the floor. This could have possibly injured the worker.

Engine Lathe (h)

7. Worker used T-handled device to remove cuttings building up behind a point-of-operation guard. If the cuttings became wrapped around the workpiece, the device and the worker's hand could have been pulled into the workpiece. The rotating speed of the workpiece was such that it would be unlikely a person grasping this kind of device could react quickly enough to release his grip before his hand would be pulled into the rotating workpiece.

*Underlining indicates the unsafe devices.

Table 3-1. Unsafe Devices
(cont.)

Turret Lathe (j)

8. Worker used a rectangular file (without a handle) inserted in a drilled hole on the workpiece to catch the workpiece as it was cut from the rotating bar stock. Since the clearance between the file and hole was small, the file could have accidentally caught on the workpiece and rotated in the worker's hand. If the worker had a tight grip on the file, the worker's hand could have been injured.

Other

9. During the observation of Engine Lathe (c), a worker on another lathe was seen using a closed-loop-handle to remove cuttings wrapping around a workpiece. If cuttings had caught on the workpiece, the device and the hand could have been pulled into the rotating workpiece. The rotating speed of the workpiece was such that it would have been unlikely that a person grasping this kind of device could react quickly enough to release his grip before his hand would be pulled into the rotating workpiece.

Table 3-2. Unsafe Actions

Engine Lathe (a)

1. Worker stopped the chuck by releasing the tension on the flat drive belt between the spindle pulley and the rear drive pulley. Since the rear drive pulley was still powered, the drive belt could have accidentally engaged on the next larger step in the drive pulley and started the chuck rotating while the worker's hand was on the chuck. There also were no guards over the pulleys and drive belt.

Engine Lathe (f)

2. Worker loosened the chuck jaws without having a spacer between the chuck face and the end of workpiece. The workpiece fell from the tailstock center and onto the lathe bed, but did not injure the worker. However, the workpiece could have fallen from the lathe bed and struck the worker's legs or feet.

Engine Lathe (d)

3. Worker was cutting internal right-handed threads in the workpiece using an uncommon procedure. The common procedure is to cut threads with the cutting tool moving toward the chuck. Since the cutting setup appeared to involve a common thread cutting procedure, by habit the worker set the direction of the leadscrew to drive the cutting tool toward the chuck. After the worker engaged the leadscrew lever Turret Lathe (j) on the apron, he quickly realized his mistake and stopped the movement of the cutting tool. If the worker had not quickly recovered from his error, the thread cutting tool could have hit the chuck and possibly caused the workpiece to be thrown at the worker.

Turret Lathe (i)

4. Worker removed and installed workpiece in the chuck while the chuck was still rotating at a fairly high speed after the power was turned off. If the workpiece had caught when it was inserted into the chuck, the workpiece could have injured the worker's hand. The situation was made more hazardous because of the highly repetitive nature of the job. The worker appeared to perform lathe operations "automatically." Later in a conversation he said, "I usually think about other things once I get into the rhythm of the operations." He also said, "It could be dangerous, but nothing has happened so far."

5. Worker's hand slipped from the handle of a collapsed die as he pushed on the die handle and almost fell on the running lathe. After the incident, he wiped the cutting oil from the handle and made a more conscientious effort of securely grasping the handle.

Table 3-2. Unsafe Action
(cont.)

Engine Lathe (e)

6. Worker was filing a boss turned on the end of off-centered rectangular workpiece rotating between two centers. The worker did not always attend to the filing operation the worker was performing. Instead, the worker frequently looked away from the workpiece. If the file accidentally caught on the corner of the rectangular workpiece as it rotated, the worker's hands could have been injured by the file and the workpiece. The worker also held the file handle with the right hand and the tip of the file with the left (which is incorrect). The worker's left arm was over the rotating workpiece.

Other

7. During the observation of Engine Lathe (e) and (f) other workers in the same machine shop were seen filing incorrectly.

Table 3-3. Applying Extreme Force

Engine Lathe (c)

1. Worker appeared to use extreme force to loosen and tighten nuts securing tailstock to lathe bed. It appeared there was an opportunity for the worker to strain arm muscles in performing this activity.

Engine Lathe (g)

2. Worker used extreme force (handle on chuck wrench was bending) to tighten chuck jaws on workpiece. It appeared there was an opportunity for the worker to strain arm muscles in performing this activity.

Engine Lathe (h)

3. Worker used extreme force (handle on chuck wrench was bending) to tighten chuck jaws on workpiece. It appeared there was an opportunity for the worker to strain arm muscles in performing this activity.

Table 3-4. Limited Personal Protection

Engine Lathe (c)

1. Worker did not wear protective helmet when he was using overhead crane to load bar stock into lathe. The bar stock could have slipped in/from the rigging and struck the worker.

Table 3-5. Unsafe Position/Posture

Turret Lathe (c)

1. Worker had to maintain poor posture during lathe operation because an oil catch pan extended in front of the lathe. In addition, the worker's knees continuously contacted the pan causing soreness to the knees.

Discussion and Summary

Findings from the hazard analyses revealed a number of important problem areas associated with the metalcutting lathes that were observed. These problem areas involved a variety of machine shop situations in which there was potential for accidents and worker injuries. Although it was not possible to determine the probability of an accident and severity of injury, the findings indicate there was potential for accidents and injuries in some, if not all, of the IPSs identified.

The problem area that appeared to reflect the most potential for accidents and injuries involved the use of unsafe devices. The IPSs observed in this category revealed there was potential for accidents with severe consequences when the workers were using unsafe devices. The IPSs in Table 3-1 indicated this fact quite clearly. Both the shaft collar and centering collar used by the worker on engine lathe (c) (IPSs 2, 3, 4, 5) could have caused severe injury to the worker if he had made an error. Likewise, the workers using the devices with a T-handle and a closed-loop-handle (IPSs 7, 9) could have sustained severe injury if the cuttings they were attempting to remove caught on the rotating workpiece. The worker operating engine lathe (g) (IPS 6) could have been severely injured if the workpiece, weighing roughly 20,000 pounds, fell from the lathe and struck the worker's arms, legs or feet.

There are two important aspects associated with unsafe devices. One is that they are usually made in the machine shop at the time they're needed for performing a job. This means there is usually insufficient time to consider all safety aspects in making the devices. Moreover, persons responsible for fabricating the devices are most likely not those responsible for shop safety. In most situations, it is the workers who build the devices before they perform the jobs. In many cases, such devices are constructed from material that is readily available in the machine shop. For example, if 1/2" screws are required for a device and the screws are unavailable in the shop at the time needed, most likely longer screws would be substituted. Such decisions may not affect job safety in all situations, but in some they would; particularly if the screws are used on a device that rotates.

The other important aspect associated with unsafe devices is that they tend to remain in the machine shop and are used over and over again, even though they are sometimes viewed as only temporary solutions to immediate problems. When such dangerous devices remain in use, the original hazard is perpetuated until the devices are identified as causes of accidents, are destroyed, or wear out from use. It could not be determined exactly how long the unsafe devices observed in the hazard analysis had been in the machine shops. The workers who were asked could not recall when the devices were made.

Another significant problem area identified through the hazard analysis involved unsafe actions of the workers. The IPSs observed in the unsafe actions category revealed potential for accidents and injuries when the workers were performing unsafe actions. This fact is conveyed in Table 3-2. The unsafe action performed by the worker on engine lathe (f)

(IPS 2) could have resulted in the worker being struck by the workpiece if it had fallen from the lathe bed. Similarly, the worker operating engine lathe (d) (IPS 3) might have been struck by a flying workpiece if the cutting tool had contacted the rotating chuck or workpiece. In this IPS, the worker most likely did not remember that he was using an uncommon procedure to cut threads inside the workpiece. Habit told him to set the leadscrew direction control to drive the cutting tool towards the chuck. This was an obvious error on the worker's part, but a natural one, since most threadcutting operations involve chasing threads with the cutting tool moving toward the chuck.

Two unsafe actions performed by the worker on turret lathe (i) (IPS 4,5) further highlight the problem area of unsafe actions. Both of these IPSs illustrate the hazards of operating a lathe at a highly repetitive pace, almost without "conscious awareness" of the action being performed.

A third problem area involved the workers applying extreme force in performing some aspect of their job. Applying an extreme amount of force is common on lathes used to turn large and heavy workpieces. All three of the IPSs (IPSs 1, 2, 3) shown in Table 3-3 occurred on large lathes. One reason it is sometimes necessary for the worker to apply extreme force when chucking a large and heavy workpiece is because of the condition of the chuck. Many older chucks can be badly worn or can lack lubrication so that extreme force is required to overcome resistance.

HUMAN ENGINEERING EVALUATION

The human engineering evaluation of the eight engine and two turret lathes previously observed occurred after the hazard analysis. The evaluation also took place when the lathes were not in use. Five types of controls were evaluated.

Methodology

There were two aspects involved with performing the human engineering evaluation. One was selecting the controls that were to be evaluated. The other was evaluating these controls.

The method of selecting the controls for evaluation was based on identifying controls that are critical to safe lathe operation. Critical to safe operation refers to controls that, if operated incorrectly, will increase the potential of injury to the worker operating the lathe or standing nearby. For example, if an apprentice mistakenly sets the spindle speed to 1500 RPM instead of 15 with an irregular shaped workpiece in the chuck, the workpiece could be thrown from the lathe striking the worker.

Identifying controls that were critical to safe lathe operation on the eight engine and two turret lathes involved determining: (a) which controls are most frequently used, and (b) which controls, if operated incorrectly, could likely result in severe consequences. The identification of most frequently used controls and controls associated with severe consequences were both determined through interviews with the machine shop supervisors and workers, and from observations made during the hazard analysis.

Supervisors and the workers who operated the engine and turret lathes were interviewed and asked to indicate which controls from a list of 28 controls they felt: (a) were used most frequently, and (b) would likely result in severe consequences if operated incorrectly. The supervisors', and workers' answers, along with the information from observations made during the hazard analysis, determined the controls that were critical to the engine and turret lathes.

The controls selected for evaluation included 18 controls associated with the engine lathes and 12 controls associated with the turret lathes. Controls evaluated on the engine lathes were those located in the areas of the headstock, carriage and tailstock. Controls evaluated on the turret lathes were those located in the areas of the headstock, carriage and turret. The types of controls were levers, knobs, locks, crank/-wheels and push buttons/switches. Levers included such controls as headstock spindle engagement lever and carriage rapid traverse lever. Knobs included such controls as headstock spindle speed selectors. Locks included such controls as tailstock and tailstock spindle locks. Crank/wheels included the turret lathe turnstile. Push buttons/switches included the power on/off, forward/reverse/dog buttons, and forward/off/reverse switch.

The controls selected for evaluation on the engine lathe were:

1. Headstock spindle speed selectors
2. Headstock feed/thread selector
3. Apron feed/thread selector
4. Compound feed power engagement lever
5. Cross feed power engagement lever
6. Cross slide rapid traverse lever
7. Carriage feed power engagement lever
8. Carriage rapid traverse lever
9. Headstock on/off/jog power switch
10. Apron on/off/jog power switch
11. Headstock spindle forward/neutral/reverse selector
12. Apron spindle forward/neutral/reverse selector
13. Headstock spindle drive engagement lever
14. Apron spindle drive engagement lever
15. Tailstock locks (secures tailstock to bed)
16. Tailstock spindle lock
17. Headstock feed/thread reverse selector
18. Apron feed/thread reverse selector

The controls selected for evaluation on the turret lathe were:

1. Headstock spindle speed selectors
2. Apron feed selectors
3. Turret feed selectors

4. Cross slide power engagement lever
5. Carriage power engagement lever
6. Turret power engagement lever
7. Headstock spindle forward/neutral/reverse lever
8. Headstock on/off power switch
9. Collet chuck/bar stock feed lever
10. Air operated chuck activiation lever
11. Apron feed reverse lever
12. Turret turnstile

Not all controls listed under engine lathes and turret lathes existed on each of the eight engine and two turret lathes. Because the lathes were different types, the number of controls present on each lathe varied from lathe to lathe.

The method used to evaluate the controls on the engine and turret lathes involved establishing criteria and devising a procedure that could be used to apply the criteria. The criteria were based on factors associated with the operation of the controls by workers. These factors were visibility, identifiability, accessibility, and operability.

Visibility. Visibility refers to whether a worker could see the control from where he normally stood when operating the lathe.

Identifiability. Identifiability refers to whether a worker could discriminate between adjacent controls and the control he wanted to operate.

Accessibility. Accessibility refers to whether a worker could reach the control without reaching over, under or around, or without repositioning other controls.

Operability. Operability refers to whether a worker could move the control to the correct position based on the lathe operation or activity he wishes to perform.

The procedure devised for applying the criteria to the controls was a series of YES or NO checklist questions for each of the factors associated with the control operation. Each series of the checklist questions included rules/examples to reduce the possibility of applying the questions inconsistently. The checklist question that was used to evaluate the control for visibility was worded as follows:

"Is there a clear view of the control from where the worker normally stands during lathe operations?"

"Rule/example: If one must stoop to the floor or walk behind the lathe to see the control, the control is not visible from where the worker normally stands."

A complete list of the evaluation checklist questions are shown in Appendix E.

Applying the criteria checklist questions to the controls on the eight engine lathes and the two turret lathes involved five steps. The first step was to become familiar with the controls to learn their operating characteristics. Step two was to stand in the position the worker would normally stand in when operating the lathe control. This position varied depending on where the control is located on the lathe, e.g., if the worker is operating the headstock spindle speed selectors, he normally stands facing the headstock; if he is operating the cross feed power engagement lever, the worker normally stands in front of the carriage. The third step was to actually operate the control (power on, no work in chuck). The next step, after operating the control, was to ask the checklist questions. If any uncertainty arose in responding to the questions the control was operated again and then the question was answered. The final step was to record the YES or NO answer on the evaluation recording form. In places where a particular control listed on the form did not exist on a lathe then each question was marked N/A (non-applicable). A sample of one of the actual recording forms is shown in Appendix D.

Before the actual evaluation of the controls occurred, the procedure and form were tried on the lathe at the university machine shop that was utilized in the hazard analysis pilot study. The results of the trial evaluation indicated the procedure and form were capable of collecting the necessary data.

A follow-up interview with the worker who had been operating the lathe was held after the evaluation of the controls on the lathe in each of the machine shops. The interview was used to learn if the worker had ever experienced any difficulties operating the lathe controls that were evaluated, such as mistakenly operating the wrong control or not being able to determine which direction to move the control to obtain the desired results. The interview was also used to discuss the problems identified through the evaluation process.

Results

The results of the human engineering evaluation were tabulated to determine how well the controls met the evaluation criteria in each of the factors associated with the operation of the controls. Table 3-6 shows the percentages of all controls evaluated in all eight engine lathes meeting the evaluation checklist questions with a YES answer. Table 3-7 shows the percentages of all controls evaluated on the two turret lathes meeting each of the evaluation checklist questions. Also shown are the total numbers of controls evaluated on the eight engine lathes and on the two turret lathes. The percentages were not tabulated by individual controls because the numbers in each of the individual controls (apron feed selectors, turret feed selectors, etc.) would have been too small to provide meaningful results. Instead, controls were considered in total for engine lathes and for turret lathes.

Table 3-6. Percentages of All Controls Evaluated on All Eight Engine Lathes Meeting Each of the Evaluation Checklist Questions With a YES Answer

	Evaluation Criteria Questions											
	Visibility	Identifiability			Accessibility		Operability					
Checklist Question No.	1	1	2	3	1	2	1	2	3	4	5	6
Percentage*	98.9	78.2	71.3	88.5	82.8	97.7	100	100	98.9	96.6	93.1	27.6

*Percentages were based on evaluation of 87 controls.

Table 3-7. Percentages of All Controls Evaluated on the Two Turret Lathes Meeting Each of the Evaluation Checklist Questions With a YES Answer

	Evaluation Criteria Questions											
	Visibility	Identifiability			Accessibility		Operability					
Checklist Question No.	1	1	2	3	1	2	1	2	3	4	5	6
Percentage**	100	62	62	88	69	100	100	88	81	88	69	38

**Percentages were based on evaluation of 16 controls.

Discussion and Summary

The results from the human engineering evaluation revealed a number of interesting findings. The most significant surrounds the low scores (27.6% and 38%) on operability checklist question number six. These low scores indicate there were few position labels on, or adjacent to the controls on the eight engine lathes and two turret lathes. The significance of this finding is that varification of correct control positions by the workers before beginning lathe operations could have reduced the possibility of the workers detecting errors made in the setting positions of controls that might have led to accidents and injuries. Without labels marking control positions a worker planning to chase a right-hand thread, for example, may not detect that the spindle feed/thread selector was set for left-hand threads when he engaged the half-nut. The results of such an event could be that the threading tool hits the tailstock center, the workpiece comes loose, and then strikes the worker.*

This problem is further compounded by the fact that control operations on engine and turret lathes are generally not consistent from lathe to lathe, that is, a control might be pushed downward to engage the spindle drive on brand (A) while the spindle drive control on brand (B) might be lifted upward to perform the same function. Such inconsistencies mean that workers can not always rely on standard control positions (always up, down, in, out, etc.) when verifying the correctness of control positions. A check of lathes in the machine shops visited pointed to the inconsistencies in lathe control operations. For example, on one lathe the carriage feed was engaged by pushing downward on a lever; on another lathe the carriage feed was engaged by pulling upward on a lever. Both supervisors and workers in the shops visited expressed they have noticed inconsistencies in control operations between the lathes they have operated in their many years of experience as workers in machine shops. There were three other findings still of interest. First, the controls that were evaluated on both the engine and turret lathes as a whole were quite visible from where the worker normally stands during lathe operations. Visibility checklist question scores were 98.8% and 100%. Second, the controls appeared to be more difficult to identify by either sight or touch than by their location on the lathe. Identifiability scores for questions one and two dealing with discrimination by sight and touch ranged from 62 to 78% while checklist questions dealing with discrimination by position ranged from 88 to 88.5%. Third, access to the controls required some reaching over, under, or around as was indicated by the range of scores of 69% to 82.8% from accessibility checklist question one. However, there appeared to be few times that covers or other controls had to be moved for access to the desired control. Accessibility question two verified this with scores ranging from 97.7 to 100%.

*Normally right-handed threads are chased toward the headstock and left-handed threads are chased toward the tailstock.

SECTION 4

INJURY DATA ANALYSIS AND PROPOSED COUNTERMEASURES

INTRODUCTION

The purposes of performing the analysis of injury data involving metal-cutting lathe accidents were to:

1. Provide an overview of lathe injuries based on such factors as workers' activities at the time of the accidents, sources of injuries, nature of injuries, etc.

2. Categorize the injury data so that the fault-tree analysis technique could be applied to groups of injuries instead of single injuries.

3. Identify accident events that could have led to, or caused the injuries by applying the fault-tree analysis technique.

The purposes of developing countermeasures was to reduce the workers' risk to the injuries analyzed in the fault-tree analysis. The countermeasures were directed at reducing the occurrences of the accident events identified from the analysis through the application of engineering, management policy, and training solutions.

Section 4 first presents the method of data collection used in the analysis. Sources of injury data are identified and the criteria for selecting the specific sources on individual injury reports are described. Next, the method of data coding is presented. The material included under data coding describes the nature of the machine-shop job and the coding system that was used to code the injury data. Descriptions of the methods used to analyze the data follow. The descriptions explain the application of the cross-tabulation and fault-tree techniques. Next, the procedures used to develop and review the countermeasures are presented. The final portion of Section 4 presents and discusses the results of the injury data analysis and the development of the countermeasures.

INJURY DATA ANALYSIS AND COUNTERMEASURE DEVELOPMENT

Data Collection and Sources

The first objective of the data collection effort was to identify data sources that offered the most complete descriptions of metalcutting lathe injuries. The second was to obtain permission to use the data in the study. The third was to collect as many of these injury reports as possible given the time and resources available for the study. Data sources considered were company daily injury reports, Workmen's Compensation First Reports, and reports from insurance companies, unions, lathe manufacturers, and the National Safety Council. After reviewing all of these possible data sources, the Workmen's Compensation First Reports (WCFRs) were determined to provide the most detailed usable injury data available for the study.

The selection of states from which to collect the WCFRs was based on:

1. Whether the state was participating in the Bureau of Labor Statistics (BLS) Supplementary Data System (SDS).

2. Whether the state had industry that is likely to utilize metalcutting lathes. This was determined through the Standard Industrial Classification Manual.

3. Whether the states comprised a deverse geographic area within the United States.

One reason for restricting selection to states participating in the BLS SDS was that these states could identify metalcutting lathes under the 3250 code used in the SDS. Another reason was that states participating in the SDS were accustomed to working with outside research organizations. It was also learned that some states utilized additional coding and were capable of identifying types of metalcutting lathes. For example, Wisconsin could distinguish between engine and turret lathes.

There were over 800 injury reports received from the various states and other sources. Over 250 of these reports could not be utilized for a number of reasons. The most prominent reason was that many injury reports received did not involve metalcutting lathe injuries. The other reasons for rejecting the 250 plus injury reports were because of extensive amounts of missing information on the reports or because of poor accident descriptions that did not supply sufficient details to make the report useful.

The injury data included for anlaysis were primary WCFRs of injury obtained from Workmen's Compensation offices in the seven states which met the qualifying criteria. These seven states were:

1. California
2. Connecticut
3. Michigan
4. Ohio
5. Pennsylvania
6. Washington
7. Wisconsin

ASA contacted these offices and requested WCFRs of injury data involving metalcutting lathes.

Other injury data included were accident reports of injuries from NIOSH, OSHA, Pennsylvania Bureau of Occupational and Industrial Safety, and the Steelworkers of America union. The NIOSH, OSHA, and Pennsylvania Bureau of Occupational and Industrial Safety reports involved on-site investigation by those organizations and were more detailed than the WCFRs in their descriptions of the injuries.

Shown in Table 4-1 is a breakdown of the injury data by type, source, and number of injury reports.

Table 4-1. Data Sources

Type	Data Source	Number
Workmen's Compensation*	California	235
	Connecticut	43
	Michigan	34
	Ohio	103
	Pennsylvania	42
	Washington	8
	Wisconsin	68
Other	NIOSH	1
	OSHA	1
	PA. Bureau of Occupational & Industrial Safety	1
	United Steelworkers of America	2
	Total Injuries:	538

The injury data supplied on the First Reports were reasonably consistent, with the exception of some randomly missing information over all data parameters utilized in coding the injuries. In other words, not all reports contained entries in all data categories. The primary reasons for this missing data were: (1) The forms were not fully completed at the injury locations, and (2) data were accidentally removed during the blanking out of the confidential information at the Workmen's Compensation offices. Other injury data (identified as "Other" in Table 4-1), had no missing information in their data categories. Several of the "Other" injury reports included photographs.

Since the data were randomly missing from all the data categories and not consistently missing from any one specific category, the results of the injury analysis were not significantly affected. Missing injury data are represented on all tables showing showing numerical values.

Data Coding

The system utilized for coding the injury data incorporated 14 variables. Eight of these variables were used to code such general information as data source, worker characteristics, and lathe type. The other six variables were used to code accident information in terms of contributing

*Sample of Workmen's Compensation First Report shown in Appendix F.

events and resulting events, and the type of injury. Contributing events refer to events that caused or led to accidents, e.g., the hand tool (file) slipped when the worker was filing the workpiece. Resulting events refer to events that resulted from accidents, e.g., the worker's hand was injured on the chuck or holding devices. Injury information refers to the injury sustained, e.g., lacerations/cuts, fractures, etc.

Variables for Coding General Information--

Eight variables were used to code the general information from the injury report:

Injury Report Number. Injury report number was used to code the injury report number in data file.

Data Source. Data source was used to code the specific source of injury data.

Lathe Type. Lathe type was used to code the type of lathe (engine, turret or other) the worker was operating at the time of the accident.

Worker's Job Classification. Worker's job classification was used to code the worker's job or skill level as classed by occupation. The occupations were: apprentice/trainee, machine/lathe operator, machinist or other.

Worker's Age. Worker's age was used to code the age of the worker.

Worker's Sex. Worker's sex was used to code the sex of the worker.

Safeguarding Present. Safeguarding present was used to code whether safeguarding devices were present on the lathe at the time of the injury.

Good Injury Description or Unusual Injury. Good injury description or unusual injury was used to code whether the injury report has a good injury description and/or whether the injury involved an unusual type of accident.

Within each of these eight variables, there were values used to code specific information regarding some aspect of the variable. For example, in the Data Source variable there were nine values used to identify the sources of the injury data. Seven of the values (1 through 7) represente the states that supplied the First Reports; another value (8) represented other sources of data, and a ninth value (0) was used to indicate that the information identifying the data source could not be determined.

Variables for Coding Accident Information--

Six variables were used to code information from the injury reports that described events that contributed to, and resulted from, the accidents as well as the nature of the injuries.

Accident Type. Accident type was used to code nine different types of worker behaviors found to be associated with metalcutting lathe injuries.

The accident types were derived through discussions with personnel in job, tool/ experimental, maintenance and manufacturing/production machine shops and reviewing the injury data. Each accident type represents a particular worker behavior that is considered to be a factor contributing to, or causing the accident. For this reason, the term "accident type" can be viewed as causal factor when encountered in this report. The nine different accident types are:

1. Slipped Hand. Slipped hand refers to the worker's hand slipping on the tool/part/control lever, e.g., the worker's hand slipped from the tool and his hand struck the rotating workpiece in the lathe.

2. Slipped Tool. Slipped tool refers to the tool/part slipping on the lathe, accessory or workpiece while the tool/part is held in the worker's hand, e.g., the worker's wrench slipped from the bolt and his hand struck the rotating workpiece.

3. Unperceived Information. Unperceived information refers to not perceiving or recalling important information before acting, e.g., perception: worker did not perceive drive belt moving and placed his hand on moving belt and his finger was caught between pulley and belt; knowledge: worker did not remember jaws extended beyond outer diameter of chuck and jaws struck worker's hand when he had attempted to slow revolving chuck.

4. No Protection or Improper Use. No protection or improper use refers to not using protective equipment or using it improperly when performing hazardous lathe operation, e.g., worker did not use protective eyeglasses and a chip entered his eye; shield did not adequately cover point of operation machinery and chip entered worker's eye.

5. Misjudged Time/Space. Misjudged time/space refers to misjudging time or space required to access some lathe part, area or accessory with fingers, hand, etc., e.g., time: worker reached for dropped hand tool, but did not remove hand before off-centered rotating workpiece struck his hand; space: worker reached for dropped tool and his hand was caught on a rotating workpiece.

6. Misjudged Weight/Force. Misjudged weight/force refers to misjudging weight/force required to move object or device, e.g., weight: worker lifted workpiece beyond his capacity and sprained his back; force: worker applied force beyond his capacity and strained his arm muscle.

7. Improper Workpiece Securement. Improper workpiece securement refers to the workpiece not being properly secured in the chuck or holding devices, e.g., worker did not tighten chuck securely and workpiece was thrown from the lathe chuck, striking the worker.

8. Improper Procedure. Improper procedure referes to not using the correct procedure when performing a lathe operation or activity, e.g., worker did not stop workpiece rotating before removing cuttings and his hand was pulled into the workpiece.

9. Uncontrolled Limb Movement. Uncontrolled limb movement refers to the human response action from accidentally contacting a sharp or hot surface, e.g., worker's finger accidentally contacted a hot workpiece and reacted by moving his hand back against the sharp cutting tool.

These nine categories should not be interpreted as indicating the workers were solely responsible for their injuries. Injury reports used in this analysis primarily described the behavior of the workers, and thus, are biased. Information describing characteristics of the lathes was seldom indicated on the reports. Information describing machine shop conditions was almost never indicated. For these reasons, one must assume that the injuries reviewed could also have been the fault of improper lathe design, unsafe shop conditions and/or the lack of worker training.

The nine different accident types identified were defined in a manner that permits them to be identified from the description of the worker's behavior on the injury reports. To illustrate how these accident types were coded from the information supplied on the actual injury reports, four cases* are presented from the data. The cases presented illustrate coding of Accident Type 3--unperceived information--since these were the most difficult to code. Injury Report #975 describes the events associated with one reported injury:

> "After employee tightened chuck on the machine, he started the chuck moving without removing chuck key. As the chuck began to spin with the key still in it, the employee's finger was caught between the chuck key and start lever."

This description indicates the worker did not perceive important information cues (CHUCK KEY IN CHUCK) or recall important knowledge (PLACED CHUCK KEY IN CHUCK) before acting (STARTED THE CHUCK MOVING).

Injury Report #639 describes the events associated with a second reported injury:

> "While attempting to adjust belts on turret lathe, employee stopped machine, opened motor door and pulley enclosure and placed hand on belts to check belt tension. But motor was not completely stopped as yet and belts pulled hand into pulley."

This description also indicates the worker did not perceive important information cues (BELTS MOVING) or recall important knowledge (MOTOR DRIFTS AFTER POWER IS TURNED OFF) before acting (PLACED HAND ON BELTS).

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*Copies of the actual injury reports are shown in Appendix F.

Injury Report #651 describes the events associated with a third reported injury:

> "Stood at the back of the lathe discussing dimension of workpiece with operator. Right hand rested on top of lathe fram. Revolving bolt on headstock caught right shirt sleeve and pulled arm and body into lathe."

This description indicates the worker did not perceive important information cues (REVOLVING BOLT) before acting (PLACED HAND IN PATH OF REVOLVING BOLT).

Injury Report #951 describes the events associated with a fourth reported injury:

> "Frank was changing chucks in the lathe. He bumped his left knee on the handle of the apron on the lathe. He didn't think it was serious at the time. His knee swelled up in the evening of the 3rd. He reported to me on the 4th of February."

This description indicates the worker did not perceive important information cues (LOCATION OF THE HANDLE ON THE APRON) before acting (COMING IN PROXIMITY WITH THE LATHE APRON).

Lathe Operation/Worker's Activity. Lathe operation/worker's activity was used to code the lathe operations or worker's activity at the time of the accident. A lathe operation is the series of changes that must occur on the lathe, accessories or tools to produce the desired results in the workpiece. For example, if the desired result is that a 1" diameter piece of bar stock be reduced to 3/4", a turning operation would be used. The changes that must occur on the lathe to accomplish this results are: (a) The compound with the cutting tool must move toward the workpiece 1/8" (1/8" of the radius equals 1/4" reduction in the diameter), and (b) The carriage with the compound and cutting tool must move along the axis of the 1" bar stock removing the materials which reduces the bar stock to 3/4" diameter.

A worker's activity is the single unit of behavior that results when the worker performs one task step. In the turning operation example described above, the worker's task associated with carrying out the operation would involve: (a) turning the crank on the cross-feed wheel until the cutting was positioned to remove 1/8" material from the radius of the bar stock, (b) engaging the lever that provides the power to move the carrige along the axis of the 1" bar stock, and (c) disengages the lever when the carriage engagement when the cutting tool reaches the end of the bar stock. (In an actual shop situation there are more steps involved.) Each of these task steps results in a single unit of behavior or worker's activity.

Not all worker's activity is necessarily associated with lathe operations. Some worker's activity can be associated with an unexpected situation. If a bolt unexpectedly loosens on the lathe or accessory, the worker in order to tighten the bolt must: (a) pick up the wrench, (b) place the wrench on the bolt head and (c) apply a rotating force to the wrench with his hand.

The discussion to code the accident description by either lathe operation or worker's activity was made after reviewing the injury data. It was found that descriptions of the accidents in the injury reports did not always indicate what lathe operation the worker had been performing when the accident occurred. Often the accident description identified only some worker activity, e.g., the injury occurred when the worker was tightening a bolt. Providing the capability of coding either lathe operation or worker's activity presented a more complete picture of the accident described on the injury report. If lathe operations alone had been coded for data analysis, much important information would have been lost.

A list of lathe operations and workers' activities that were likely to occur was made based on visits made to job, tool/experimental, maintenance and manufacturing/production machine shops. The list included primary lathe operations, secondary lathe operations, and workers' activities. Examples of primary lathe operations are: turning, facing, threading, etc. Examples of secondary lathe operations are: setting up, loading/unloading, filing, deburring, polishing, etc. Examples of workers' activities are: reaching for, applying force, positioning/holding, etc.

Object of Worker's Activity. Object of worker's activity was used to code the object or item the lathe operation to which the worker's activity was directed, e.g., facing the workpiece, setting up the lathe, applying force to a control lever or reaching for the hand tool (words underlined indicate the object or item to which the lathe operation or worker's activity was directed).

Source of Injury. Source of injury was used to code the specific parts on the lathe, accessory, or workpiece that produced the worker's injury, e.g., cutting tool or holder, chuck or other holding devices, cuttings/chips, hand tools, and control handle or lever.

Nature of Injury. Nature of injury was used to code the type of injury sustained by the worker from the lathe, accessory, or workpiece, e.g., lacerations, bruises, and sprains.

Part of Body Injury. Part of the body injured was used to code the part of the worker's body that sustained the injury, e.g., fingers, arm, and head.

Data Analysis

The data analysis involved performing three tasks. The first, was to categorize the injury data by accident type. The second was to identify groups of injuries with similar acident characteristics within each acident type. the third was to develop fault-tree diagrams reflecting the groups of injuries. Accomplishing these tasks required performing four analyses:

1. A cross-tabulation of each accident type with the other eleven variables that were used in the coding system.

2. A cross-tabulation of each accident type with the two variables associated with contributing accident events.

3. A cross-tabulation of each accident type with the two variables associated with resulting accident events.

4. A fault-tree analysis on groups of injuries within each accident type.

A diagram illustrating the structure of the data that resulted from the application of these four analysis is shown in Figure 4-1.

Cross-Tabulation Analysis--

The first cross-tabulation analysis was used to determine the frequency with which injuries were distributed by each accident type over eleven variables used in coding the injury data. This analysis involved cross-tabulating each of the nine accident types with the other variables that were coded: (a) general information, such as data source, workers' characteristics, and lathe types, and (b) accident information. The variable used to code accident information were: (a) lathe operation/worker's activity, (b) object of lathe operation/worker's activity, (c) source of injury, (d) nature of injury, and (e) part of body injured. This cross-tabulation provided an overview of how the injuries were distributed by the accident type, by general information, and by accident information variables.

The nine accident types were considered meaningful if each individual accident type had a frequency of occurrence greater than five. Injuries falling into the category of "other" would not be used to classify injuries unless it included a group of similar injuries with an occurrence of greater than five. In such cases, a new accident type would be formed. The frequency of greater than five was selected because accident types occurring five times or fewer would result in many accident types that would not be meaningful.

Both the second and third cross-tabulation analyses were used to determine the various combinations of accident events that occurred in each of the accident types. Analysis number two cross-tabulated each accident type with the lathe operation/worker's activity variable and the object of lathe operation/worker's variable. This tabulation determined the contributing events associated with the accidents. Contributing events were the events that caused or led to the accidents described on the injury reports. The third analysis cross-tabulated each accident type with the source of injury and part of body injured variables. This tabulation determined the resulting events associated with the accidents.

A matrix showing the variables that were cross-tabulated with the nine different accident types is shown in Table 4-2.

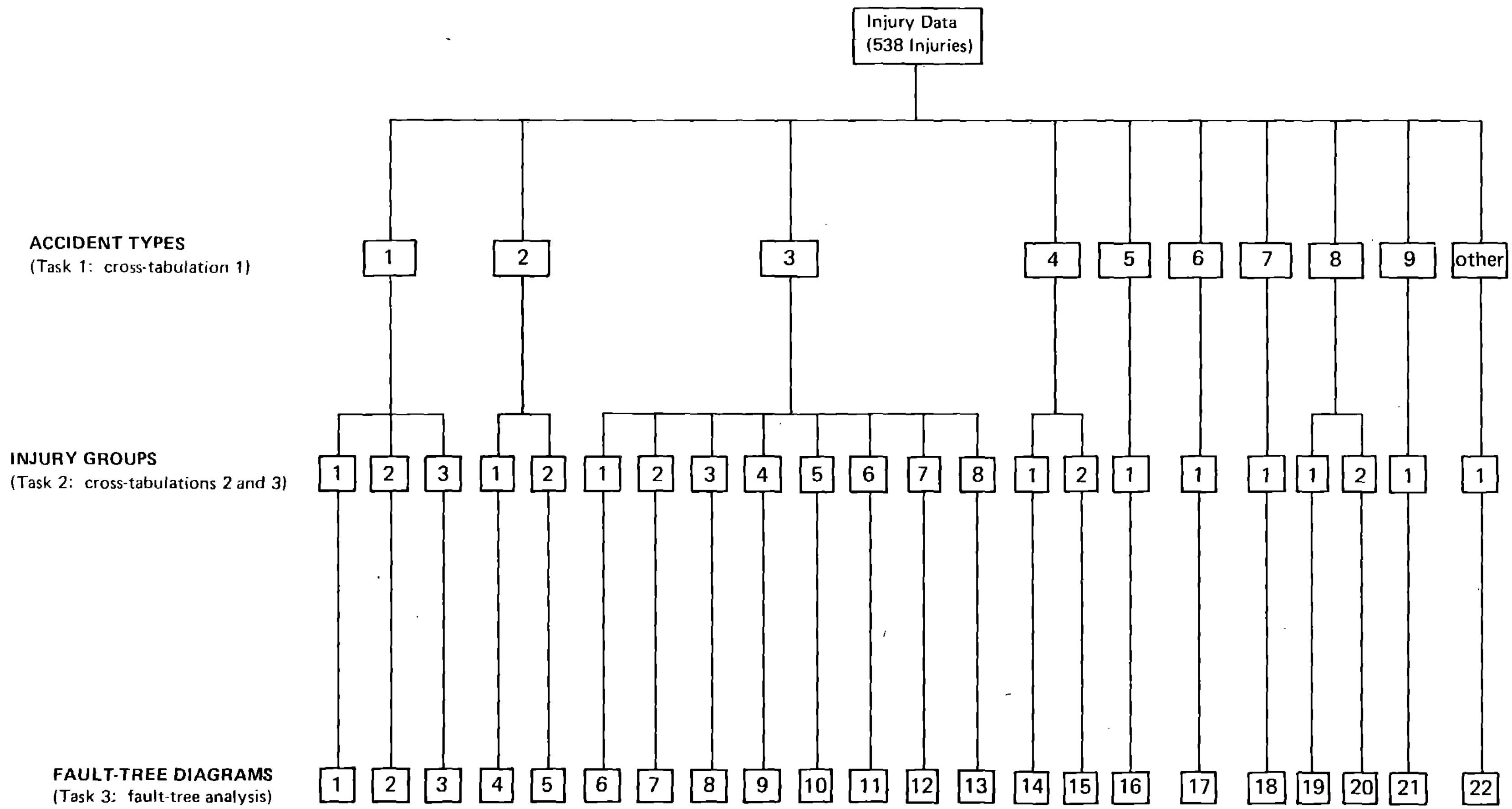

Figure 4-1. Data Structure Developed as a Result of the Application of the Four Analyses

Table 4-2. Matrix Showing the Variables That Were Cross-Tabulated With the Nine Different Accident Types in the Three Cross-Tabulation Analysis

	ACCIDENT TYPE VARIABLE								
OTHER VARIABLES	1	2	3	4	5	6	7	8	9
Data Source	1	1	1	1	1	1	1	1	1
Worker's Age	1	1	1	1	1	1	1	1	1
Worker's Sex	1	1	1	1	1	1	1	1	1
Worker's Job Classification	1	1	1	1	1	1	1	1	1
Lathe Type	1	1	1	1	1	1	1	1	1
Safeguarding Present	1	1	1	1	1	1	1	1	1
Lathe Operation/ Worker's Activity	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Object of Lathe Operation/ Worker's Activity	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Source of Injury	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3
Nature of Injury	1	1	1	1	1	1	1	1	1
Part of Body Injured	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3

Number in cell indicate the cross-tabulation that was performed.

1 = First cross-tabulation
2 = Second cross-tabluation
3 = Third cross-tabulation

The results of the cross-tabulation were primarily a reduction of the data. The cells in the first cross-tabulation indicated the frequency with which injuries were distributed by each accident type over the eleven variables used in coding the injury data. The results of this tabulation are presented in this section under results. Cells in the second cross-tabulation indicated the combinations of variables that formed the contributing events in each accident type. For example, the contributing events in Accident Type 2 were:

1. Applying force to: (a) tailstock or related accessories, or (b) wrench, chuck or attaching devices.

2. Polishing, filing or deburring the workpiece.

3. Setting up the: (a) chuck, attaching devices, or some other part of the lathe; or (b) workpiece.

4. Cleaning/clearing the cuttings.

5. Loading/unloading the workpiece.

6. Operating the lathe.*

These combinations of events were formed by pairing the word descriptors used to code the accident information in the variables of: (1) lathe operation/worker's activities, and (2) object of worker's activities. The pairs of word descriptors were selected according to the information provided in the cells of the second tabulation. For example, on the above list the word descriptors "Applying force" (combination number 1) were paired with: (a) "tailstock or related accessories," and (b) "wrench, chuck or other attaching devices" as a result of information in specific cells.

The cells in the third cross-tabulation indicated the combination of variables that formed the resulting events in each accident type. For example, resulting events in Accident Type 2 were:

1. The worker's fingers, hand, or wrist were injured in: (a) the cutting tool, or lathe bed center area; (b) the chuck or attaching devices; (c) the tailstock or related accessories; (d) polishing material; or (e) a hand tool.

2. Injury of the worker's back or upper abdomen on the workpiece or the area in the center of the lathe bed.

3. Injury of the worker's arm or shoulder on: (a) cutting tool; (b) tailstock or related accessories; or (c) workpiece.

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

These combinations of events were formed by pairing the word descriptors used to code the accident information in the variables of: (1) the source of injury, and (2) the part of the body injured. The pairs of word descriptors were selected according to the information provided in the cells of the third tabulation. For example, on the above list the word descriptors "Worker's fingers, hand, or wrist" (combination number 1) were paired with: (a) "cutting tool, or lathe bed center area," (b) "chuck or other attaching devices," (c) "tailstock or related accessories," (d) "polishing material," and (e) "hand tool" as a result of information in specific cells.

The combinations of accident events for all nine accident types are presented in Appendix G.

Fault-Tree Analysis--

The fault-tree analysis was applied to groups of injuries. A "group" was defined as a cluster of injuries from the same accident type that had similarities in: (a) contributing events, and (b) resulting events. For example, a group might include all injuries resulting from the worker's fingers, hand or wrist striking the chuck or other attaching devices, or the workpiece. A primary consideration in forming the groups was to include as many injuries as possible in each group. Injuries that were few in number and did not have contributing and resulting events similar to any of the groups were considered too different to be grouped and were not included in the fault-tree analysis.

The actual procedure used in grouping the injuries involved four steps. The first step was to select either contributing or resulting accident event combinations that had the highest frequency of injuries associated with them. For example, if the highest frequency of injuries involved resulting events in which the workers injured their fingers, hand or wrist on the: (a) chuck or attaching devices, or (b) workpiece, these combinations were selected. The second step was to form groups of injuries by identifying the injuries associated with the accident event combinations selected. The third step was to sub-divide these first groups according to a specific rule: if the first selection was made by using combinations from one kind of accident event (either contributing or resulting) then, a second selection was made by using another kind of accident event. In our example above, the first selection was made by using combinations of resulting events. Thus, following the rule, a second selection used combinations from the contributing events. Like the first selection of accident combinations, this second selection was also based on the highest frequency of injuries. For example, if the highest frequency of injuries involved contributing events in which the workers were applying force to the: (a) tailstock or related accessories, or (b) wrench, chuck or attaching devices, these combinations were selected. The fourth step was to form additional groups of injuries identifying the injuries associated with the second accident event combinations selected.

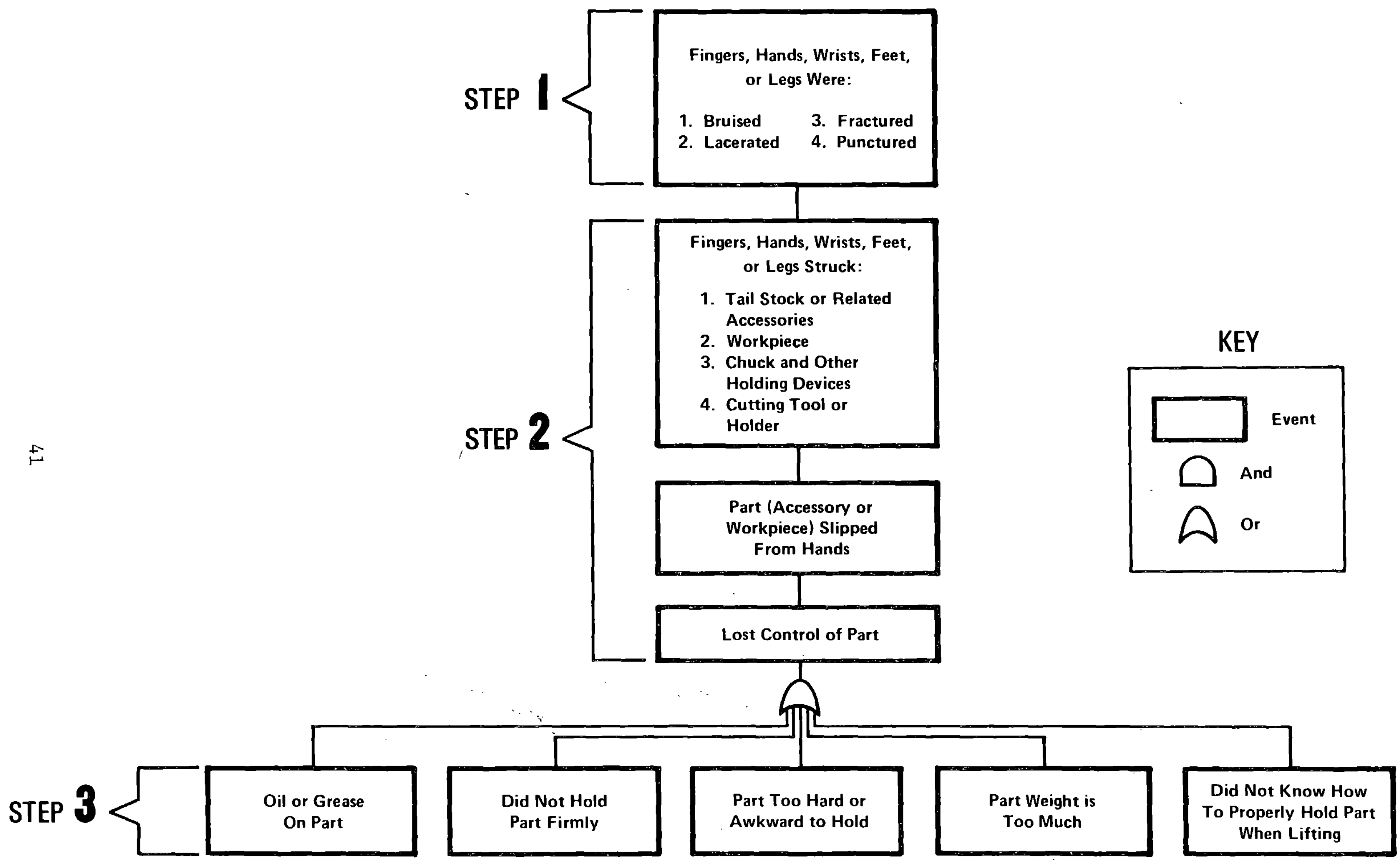

Figure 4-2. Steps Involved and the Results Obtained From Applying the Fault-Tree Analysis Process to the First Group of Injury Data in Accident Type 1 (Fault-tree Diagram 1)

This procedure was continued until all possible groups were formed in each of the nine accident types. The results of this procedure produced groups of injuries that had highly similar accident characteristics for use in the fault-tree analysis aspect of the study.

There were 22 groups of injuries formed by accident types that included 438 of the 538 injuries reviewed.

The 22 groups of injuries included injury reports representing all nine different types. Table 4-3 shows the number of injury groups in each accident type. Three injury reports that involved severe* injuries did not have accident characteristics similar to the injuries in the first 21 groups, but because they were severe and could be related to one another they were placed in a 22nd group termed "other."

Table 4-3. Number of Injury Groups Formed in Each of the Nine Different Accident Types

	ACCIDENT TYPES									
	1	2	3	4	5	6	7	8	9	Other
Number of Groups	3	2	8	2	1	1	1	2	1	1

The application of the fault-tree anlaysis to a group of injuries began by first reviewing all the injury reports in the group to get a "feel" for the nature of the accidents associated with the injuries. Next was the identification of the parts of the body that were injured and the types of injuries that resulted from the accidents. The body parts injured and injury type information provided the starting point from which to begin the fault-tree analysis.

The fault-tree analysis is a process that is used to identify the combination of events that could be lead to some undesirable event. In this application of the analysis procedure, the undesired event is the group of injuries described in terms of the parts of the body injured and the types of injuries sustained. From the undesirable event, the fault-tree analysis traces in a step-by-step manner the pathways that identify the combinations of events that could lead to the undesirable event. The results of this analysis process is a fault-tree diagram that shows the various combinations of events that could lead to the undesirable event. The diagram lists the undesirable event and all the other events connected by pathways and AND and OR gates that show the relationships between the events.

Application of the fault-tree analysis process to the groups of actual injury data followed the same procedure described above. Figure 4-2 indicates the steps involved and the results obtained from applying the

*Injuries that resulted in either death, amputation or fractures were termed severe.

process to the first groups of injuries in Accident Type 1 (Fault-Tree Diagram 1). The first step in applying the fault-tree analysis was to list the undesired event. This was when the worker's fingers, hands, wrist, feet or legs were either: (1) bruised, (2) lacerated, (3) fractured, or (4) punctured. Step two was to trace the series of events that produced the undesired event. These included the worker's loosing control of the part, the parts slipping from his hands and fingers, and his hands wrists, feet or legs striking the: (1) tailstock or related accessories, (2) workpiece, (3) chuck and other holding devices, or (4) cutting tool or holder. The third step was to trace the pathways or branches from the OR gate to the events that contributed to the undesired event. To perform this step, all the reports in the first group of injuries in Accident Type 1 were carefully read and interpreted to identify the possible events that could result in the worker loosing control of the part.

The result of applying the fault-tree analysis to this group of injury data was a fault-tree diagram that identified combinations of events that could have led to the injuries described on the reports. Each pathway or branch shows a combination of events. Figure 4-3 (Fault-Tree Diagram 1) highlights one such combination of events. This set of events constitutes one accident scenario that depicts the manner in which a portion of the injuries occurred in the first group of injuries in Accident Type 1.

All the groups of injury data were analyzed in this same manner and 22 fault-tree diagrams were developed.

Countermeasure Development

Countermeasures were developed to minimize the workers' risk of injuries that were represented in the 22 fault-tree diagrams. Countermeasures are the corrective measures that were developed with the purpose of reducing metalcutting lathe injuries. They are directed at preventing or reducing the possibility of occurrence of specific events that were believed to have caused or may have led to the accidents and injuries.

The types of countermeasures available to reduce the metalcutting lathe injuries represented on the fault-tree diagrams included improving lathe design and working environment, and training the worker. Improving lathe design involves "designing out" hazards before a lathe is built, or retrofitting existing machines with devices that reduce or eliminate hazards. Improving the working environment deals with providing the worker with a workplace to operate the lathe safely. Improving light levels, removing obstructions around the lathe, and reducing sound levels can often make the working environment safer. Worker training aims at instructing the worker in the correct and safe way to perform his job (correct and safe operating procedures for loading/unloading, filing, deburring, polishing, etc.) and making the worker more aware of safety

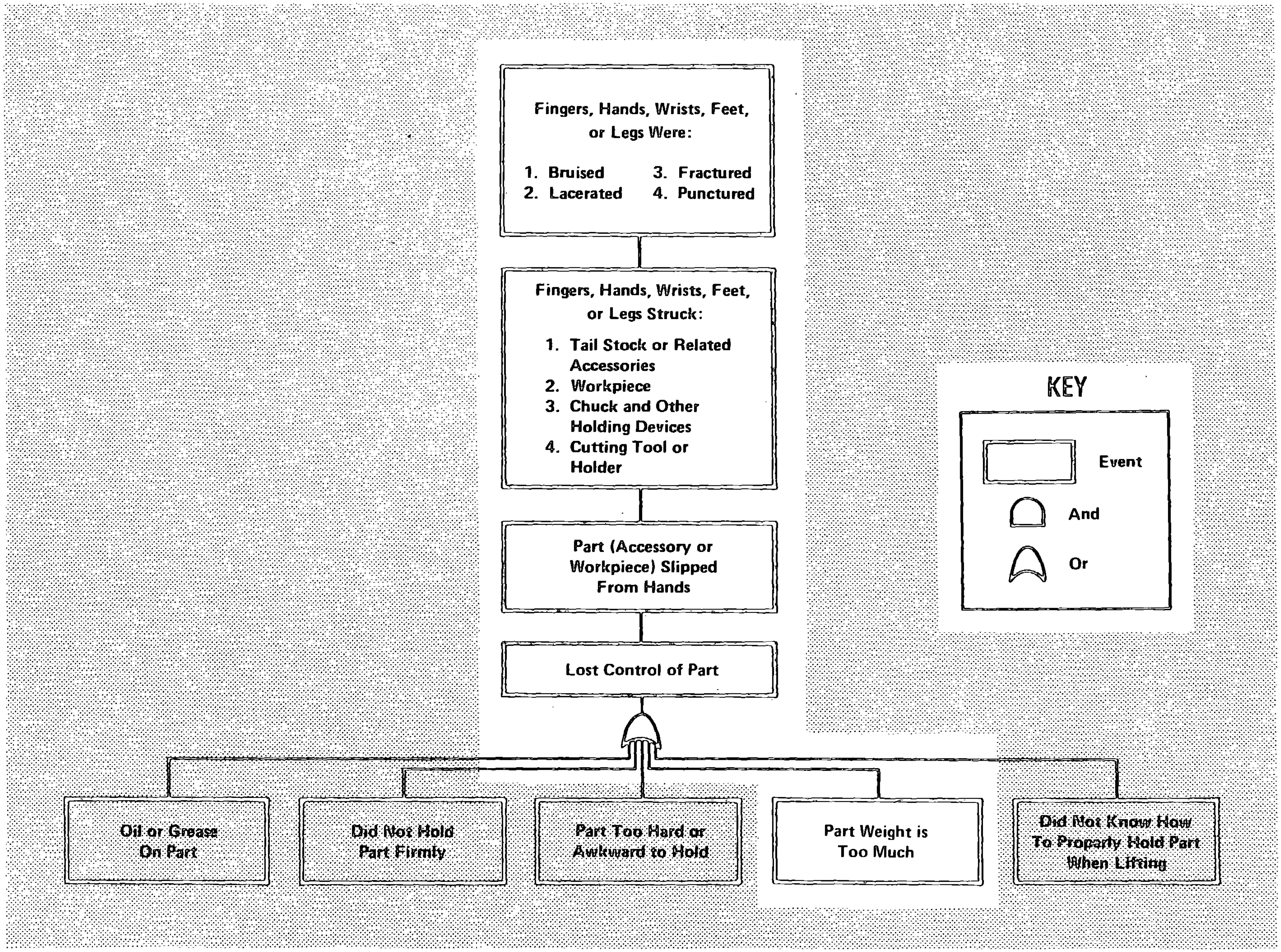

Figure 4-3. One accident Scenario That Depicts the Manner In Which A Portion of the Injuries Occurred in Fault-Tree Diagram 1 (First Group of Injuries in Accident Type 1).

concerns, such as the need for eye and ear protection, and hazards of wearing loose fitting clothing.

The procedure used to develop the countermeasures was to: (a) review each of the fault-tree diagrams, (b) generate countermeasures that were specifically directed at the events listed on the fault-tree diagrams, and (c) generate as many countermeasures as possible, for as many events as possible in each of the branches traced out in the diagrams.

Each of the 22 fault-tree diagrams was reviewed. Each combination of events or accident scenario was read in each of the diagrams to become familiar with the nature of the accidents associated with the injuries. Next, solutions were generated that had the potential of preventing events from occurring in the accident scenarios, and thus possibly preventing or reducing the likelihood of the accident scenario from materializing. Figure 4-4 shows the countermeasures that were applied to one event in Fault-Tree Diagram 1. These solutions were directed at preventing or reducing the liklihood the workers would attempt to move or lift parts that were beyond their capacity. The accident scenario depicts an accident in which the worker moved or lifted an accessory or workpiece that was beyond his capacity. In doing so, he lost control of the part, it slipped from his hands, some part of his body struck the lathe and an injury was sustained. By attempting to prevent the worker from moving or lifting a part beyond his capacity, the event has less chance of occurring and, thus, the accident scenario has less chance of materializing.

Once all countermeasures were developed, they along with the fault-tree diagrams were reviewed by Mr. O. D. Lascoe, consultant to the study. Mr. Lascoe, Professor Emeritus from Purdue University, has over 40 years experience in machine work. His primary concern during the review process was with the effect the countermeasures might have on productivity. Mr. Lascoe also provided review information concerning the ability of the proposed countermeasures to reduce injuries and the feasibility of implementating them.

The countermeasures were reviewed for a second time by members of the ANSI B11.6 committee and other persons concerned with metalcutting lathe safety. The purpose of this review was to identify countermeasures that needed to be clarified and to suggest a ways of implemenation. The review group consisted of individuals from:

1. Industries that utilize metalcutting lathes in their factories
2. A Labor union that represents machinists and lathe operators
3. Builders of metalcutting lathes
4. An insurance company
5. A university industrial engineering department
6. The National Machine Tool Builders' Association.

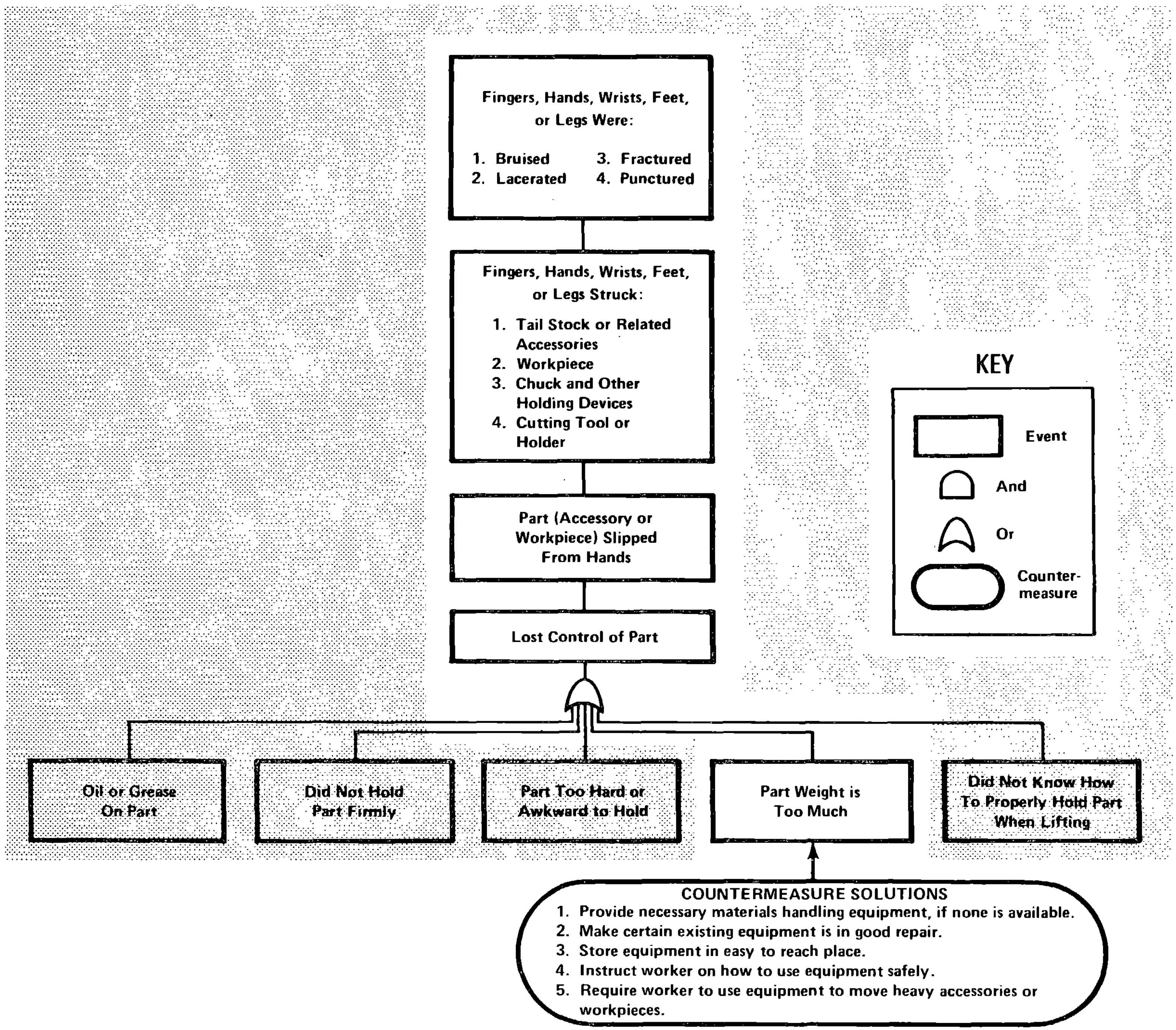

Figure 4-4. Application of Countermeasures To An Event In Fault-Tree Diagram 1 Accident Scenario

Results

The results of the data analysis include general findings and specific accident/countermeasure information. The general findings proivide an overview of the injuries surveyed through tables showing frequency of injuries by individual and multiple variables. Specific accident/countermeasure information provides information regarding individual accident types, fault-tree diagrams and proposed countermeasures.

General Findings --

All 9 accident types had a frequency of occurrence of greater than 5 in the injury data. The category of "other" had a frequency of 13. Four of the injuries in this category were the result of mechanical failures on the lathe or accessories. The remaining injuries in the "other" category were attributed to such causes as a worker tripping on nearby equipment or another worker accidentally engaging a control. The distribution of injuries in each of these nine accident types is shown in Table 4-4.

Tables 4-5 through 4-8 present frequency of injuries by accident type and: (a) lathe operations/workers' activities, (b) sources of injuries, (c) nature of injuries, and (d) parts of the body injured.

The frequency of injuries by worker's age, sex, job classification and by lathe type and safeguarding present are shown in Table 4-9. These data are not presented by individual accident types.

Table 4-4. Frequency of Injuries by Accident Type

Accident Type	Name	Frequency
1	Slipped Hand	55
2	Slipped Tool	41
3	Unperceived Information	149
4	No Protection or Improper Use	85
5	Misjudged Time/Space	13
6	Misjudged Weight/Force	67
7	Improper Workpiece Securement	21
8	Improper Procedure	71
9	Uncontrolled Limb Movement	10
Other		13
Missing		13
		538

Accident/Countermeasure Information--

Accident/countermeasure information is presented by individual accident types. The nine different accident types that were identified are included. Each accident type includes accident information that describes: (a) events that contributed to, or led to the particular type of accident, (b) events that resulted in the accident type, and (c) the type and the number of injuries attributed to the type of accident.

Table 4-5. Frequency of Injuries by Accident Type and Lathe Operation/Worker's Activity

	ACCIDENT TYPES									
	1	2	3	4	5	6	7	8	9	TOTALS
Primary Operations										
1. Turning	2	0	4	6	0	0	2	4	0	18
2. Facing	0	0	0	2	0	0	2	1	0	5
3. Boring	0	0	4	1	0	0	0	0	0	5
4. Threading	0	1	1	0	0	0	0	1	0	3
5. Grinding	0	0	0	4	0	0	0	0	0	4
Subtotals	2	1	9	13	0	0	4	6	0	35
Secondary Operations										
1. Setting-up	4	6	7	0	0	5	0	1	2	25
2. Loading/unloading	9	4	20	1	0	15	0	4	1	54
3. Measuring	0	0	2	0	0	0	0	1	0	3
4. Filing, deburring	4	17	10	1	0	0	0	5	0	37
5. Polishing	6	3	10	1	0	0	4	8	1	33
6. Cleaning/clearing	1	1	7	1	1	0	0	13	0	24
Subtotals	24	31	56	4	1	20	4	32	4	176
Workers' Activities										
1. Positioning/holding	1	0	6	0	0	3	1	0	0	11
2. Applying force	12	7	8	2	1	36	0	6	3	75
3. Removing/replacing	4	0	7	3	3	3	0	8	1	24
4. Reaching for	0	0	9	2	2	0	0	1	0	14
Subtotals	17	7	25	7	6	42	1	15	4	124
Operating lathe	12	2	58	61	6	5	12	18	2	176
Missing	0	0	1	0	0	0	0	0	0	1
Subtotals	12	2	59	61	6	5	12	18	2	177
TOTALS	55	41	149	85	13	67	21	71	10	512
"Other" Accident Types										13
Missing Accident Types										13
Total Injuries										538

Table 4-6. Frequency of Injuries by Accident Type and Source of Injury

Lathe Parts or Accessories	ACCIDENT TYPES 1	2	3	4	5	6	7	8	9	TOTALS
1. Control handle, lever or wheel	3	0	5	0	1	18	0	1	0	28
2. Power Switch	0	0	2	0	0	0	0	0	0	2
3. Cutting tool or holder	7	6	15	1	0	2	1	4	4	40
4. Chuck and other holding devices	22	17	50	0	4	21	0	6	2	122
5. Follower or steady rest	0	0	0	0	0	2	0	0	0	2
6. Tailstock or related accessories	2	3	4	0	0	3	0	0	0	12
7. Lathe steps	0	0	3	0	0	0	0	0	0	3
8. Chuck wrench	1	0	8	0	0	3	0	1	1	14
9. Coolant or dust	0	0	0	5	0	0	0	0	2	7
10. Cutter, tap, die drill or reamer	2	0	4	0	1	0	1	2	0	10
11. Cuttings/chips	1	0	17	74	0	0	0	30	0	122
12. Grinding wheel	0	0	1	0	0	0	0	0	0	1
13. Polishing material	0	1	0	0	0	0	0	2	0	3
14. Workpiece	10	9	18	2	4	10	18	12	0	83
15. Hand tool	2	1	4	0	1	0	0	5	0	13
16. Turret	0	0	0	0	1	2	0	0	0	3
17. Shield/guard	0	0	3	0	0	0	1	0	0	4
18. Belt, gear, pulley or lead screw	1	0	1	0	0	0	0	1	0	3
19. Taper or tracer attachment	0	0	0	0	0	1	0	0	0	1
20. General lathe	2	2	7	0	1	0	0	0	1	13
21. Other	0	0	0	1	0	1	0	0	0	2
22. Missing	2	2	7	2	0	4	0	7	0	24
TOTALS	55	41	149	85	13	67	21	71	10	512
"Other" Accident Types										13
Missing Accident Types										13
Total Injuries										538

Table 4-7. Frequency of Injuries by Accident Type and Nature of Injury

Injury Types		ACCIDENT TYPES 1	2	3	4	5	6	7	8	9	TOTALS
1.	Abrasion	0	1	1	1	1	0	0	2	0	6
2.	Amputation	1	0	3	0	0	0	0	2	0	6
3.	Bruise/contusion	16	11	26	0	3	5	5	9	1	76
4.	Burn	0	0	0	4	0	0	0	1	0	5
5.	Death	0	0	2	0	0	0	1	1	0	4
6.	Foreign body	0	0	0	67	0	0	0	2	0	69
7.	Fracture	4	6	17	0	2	0	1	9	2	41
8.	Laceration/cut	26	16	83	13	6	0	10	37	4	195
9.	Puncture	2	3	7	0	0	0	0	3	1	16
10.	Strain/sprain	1	2	1	0	0	62	1	2	0	69
11.	Other	0	1	0	0	0	0	0	0	0	1
12.	Missing	5	1	9	0	1	0	3	3	2	24
	TOTALS	55	41	149	85	13	67	21	71	10	512
										"Other" Accident Types	13
										Missing Accident Types	13
										Total Injuries	538

Table 4-8. Frequency of Injuries by Accident Type and Part of Body Injured

Body Parts		ACCIDENT TYPES 1	2	3	4	5	6	7	8	9	TOTALS
1.	Back	0	2	0	0	0	29	0	1	0	32
2.	Upper Abdomen	0	1	3	0	1	0	0	3	0	8
3.	Eyes	0	0	0	69	0	0	2	1	0	72
4.	Head, face or neck	1	0	5	2	0	3	3	2	0	16
5.	Right fingers, hand or wrist	23	22	67	7	5	9	5	29	5	172
6.	Left fingers, hand or wrist	15	6	42	4	4	5	4	19	2	101
7.	Feet or legs	3	0	2	0	0	1	1	1	0	8
8.	Lower abdomen	0	0	0	0	1	4	0	0	0	5
9.	Fingers, hands wrists	9	3	13	2	6	2	6	11	1	41
10.	Right arm or shoulder	4	6	7	0	1	5	6	1	2	26
11.	Left arm or shoulder	0	1	4	0	0	0	3	1	0	9
12.	Arms or shoulders	0	0	2	1	0	6	0	0	0	9
13.	Other	0	0	1	0	0	1	0	0	0	2
14.	Missing	0	0	3	0	1	2	3	2	0	11
	TOTALS	55	41	149	85	13	67	21	71	10	512
					"Other" Accident Types						13
					Missing Accident Types						13
					Total Injuries						538

Table 4-9. Frequency of Injuries by Worker's Age, Sex, Job Classifation and by Lathe Type and Safeguarding Present

Age:	10-25	26-35	36-45	46-55	56-65	66-75	Missing	Total
Frequency:	150	128	85	63	49	5	58	538

Sex:	Male	Female	Missing	Total
Frequency:	501	12	25	538

Job Classification:	Apprentice/ Trainee	Machine/ Lathe Operator	Machinist	Other	Missing	Total
Frequency:	35	192	216	48	47	538

Lathe Type:	Engine	Turret	Other	Missing	Total
Frequency:	95	109	14	320	538

Safeguarding Present:	Yes	NO	Unknown	Total
Frequency:	55	10	473	538

Information presented for each accident type also includes fault-tree diagrams and proposed countermeasures that were developed. The fault-tree diagrams trace the specific accident associated with the accident type. Referenced to each fault-tree diagram are the type and number of injuries represented by the diagram. The difference between number of injuries that were included in the accident type and the number of injuries represented by the fault-tree diagrams is also noted. Lathe operations and worker activities associated with the diagrams are indicated to provide a frame of reference when reviewing the fault-tree diagrams.

The proposed countermeasures that were developed in response to the accident events on the fault-tree diagrams keyed to each of the diagrams. The countermeasures include engineering, management policy and training solutions, and suggested methods of implementation.

The information regarding the nine accident types and the 22 fault-tree diagrams and corresponding proposed countermeasures is presented in Appendix G.

Discussion and Summary

The reliability of the injury data is based on several facts. F(rst, the injury data were collected from seven states that were determined through the Standard Industrial Classification Manual to have high numbers of industries utilizing metalcutting lathes, e.g., aerospace manufacturing in California and Washington; automobile manufacturing in Michigan, and home and industrial products in Ohio and Wisconsin. Four of these states were also selected as injury data sources in another NIOSH study* and were reported to have high numbers of industries utilizing metalcutting equipment, which included metalcutting lathes. The injury data collected included current data as well as data selected from the years 1976, 1977 and 1948.

Second, experts associated with machine shops having engine and turret lathes believed the accident scenarios reflected by the fault-tree diagrams presented a fairly reliable picture of metalcutting lathe accidents and injuries. One expert, Mr. O. D. Lascoe, stated that in his past 40 years of machine shop experience he has directly observed or indirectly learned of many of accidents and injuries reflected by the fault-tree diagrams. Other expe ts made similar statements. A supervisor from one of the large steel industry maintenance shops that

*Machine Guarding-Assessment of Need, DHEW Publication No. NIOSH 75-173 The Bendix Corporation, Launch Support Division. June 1975. Machine Guarding-Assessment of Need. U. S. Dept. of Health, Education, and Welfare. Public Health Service. Center for Disease Control. National Institute for Occupational Safety and Health. Division of Laboratories and Criteria Development. Cincinnati, Ohio participated in the study said he has personally seen or read injury reports describing most of the filing, deburring or polishing accident scenarios. Several older machinists working in one of the job shops said in their many years of machine shop experience they have witnessed or were told about many of the accident scenarios involving loading/ unloading operations.

Accident Types--

One important finding concerning accident types was Accident Type 3 involved the largest single block of injuries (27.7%). Figure 4-5 shows the percentages of injuries distributed over all accident types.

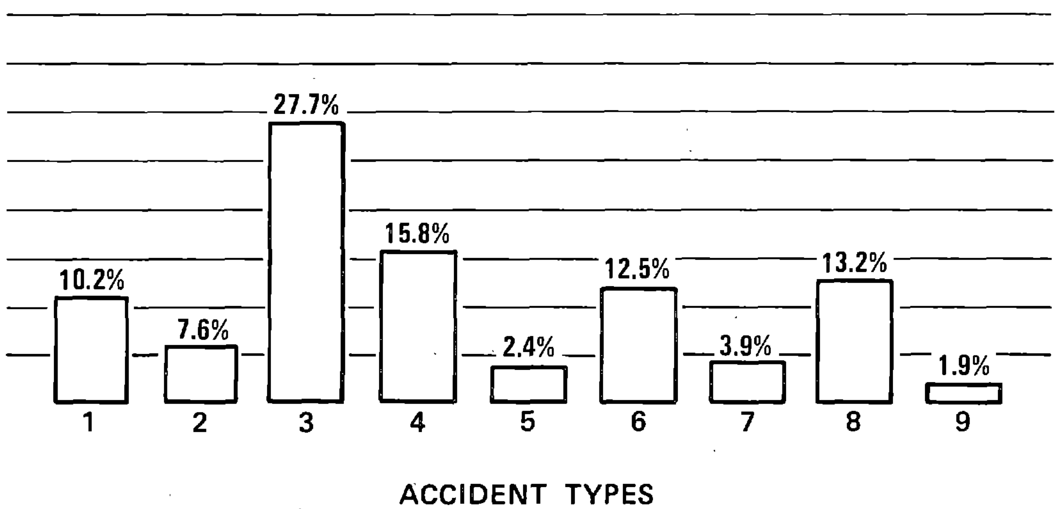

Figure 4-5. Percentages of Injuries Occurring in the Nine Different Accident Types

Most of Accident Type 3 injuries (67.2%) were the result of the worker contacting either the chuck or holding device, workpiece, cuttings/ chips, cutting tool or holder. Figure 4-6 shows the percentages of these sources of injuries.

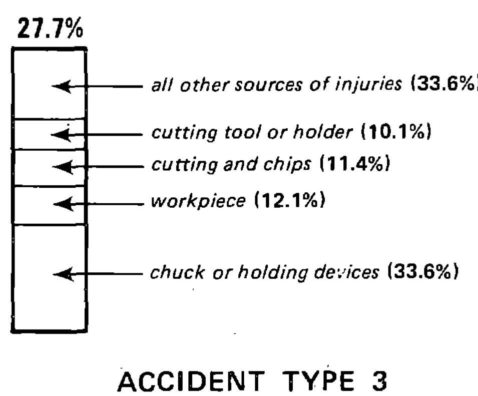

Figure 4-6. Percentages of Injuries Occuring by Source of Injury in Accident Type 3

The fact that the chuck or holding devices were the sources associated with 33.6% of the lathe injuries suggests that a number of these injuries might have been prevented if: (a) the worker could have been prevented from accidentally contacting the rotating chuck or attaching devices, or (b) the protrusions (chuckjaws, lathe dogs, etc.) on the chuck attaching devices could have been minimized.

Another important finding concerned Accident Types 1 and 2. The injuries in these two accident types involved either the worker's hand slipping on some hand tool or part, or a hand tool or part slipping on the lathe. When the injuries from these two accident types are combined they include 17.8% of the total injuries surveyed. Figure 4-7 shows that a reasonably high percentage of injuries from these two accident types (51%) occurred during filing, deburring and polishing operations, and when the worker was applying force with a hand tool. Several reasons for this finding could be: (a) The files, deburring or polishing tools, and the wrenches, nuts, bolts, etc. that were used on lathes may not have been properly designed, or engineered or maintained, and (b) The workers may have lacked the necessary training and motivation required to use the hand tools safely.

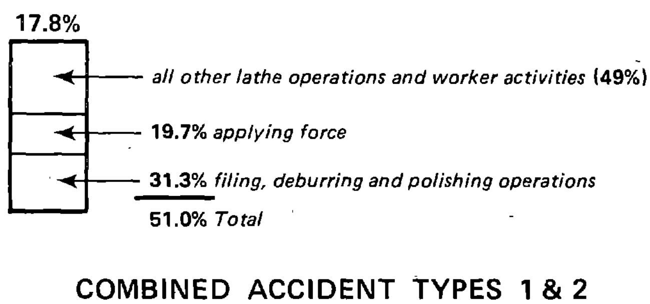

Figure 4-7. Percentages of Injuries Occurring by Lathe Operation/Workers' Activities When Accident Types 1 and 2 are Combined

Another important finding related to accident types was the fact that a high percentage (87.1%) of Accident Type 4 injuries were the result of cuttings/chips, most of which entered the workers' eyes. With such a high percentage of injuries resulting from cuttings/chips, a number of questions should be asked about why so many of these injuries occurred. Were the workers wearing eye protection? If they were wearing eye protection, did it fit properly? If the workers were not wearing eye protection, why weren't they doing so? It is not possible for this study to answer these questions because the injury reports did not provide the very detailed information necessary, but it is within the scope of the study to suggest these questions be addressed in future research.

Accident Type 8 findings revealed that most of the injuries (59.2%) were from the workpiece and cuttings/chips. Many of the injuries occurred when the workers were using an unsafe procedure to remove long stringers from the lathe while the workpiece was rotating.

Another finding revealed was that a very high percentage (92.5%) of the injuries included in Accident Type 6 resulted in strains or sprains to the worker.

When Accident Types 1, 2, 3, 4, 6 and 8 are considered together they account for 86.5% of the total injuries included in the injury data.

Lathe Operations and Workers' Activities--

The important finding concerning the kinds of lathe operations and workers' activities associated with the injuries was that the largest single group of injuries (32.7%) occurred during secondary lathe operations. Only a small percentage (6.5%) involved primary lathe operations. It should be noted here that on a portion of the injury reports descriptions, it was impossible to determine whether the injuries occurred during primary or secondary lathe operations. Because of this situation, some injuries were classified under specific workers' activities (23%), and some under operating lathe (32.7%). However, there is no reason to believe that these injuries would be distributed any differently from the proportions of injuries that presently exist between the secondary and primary lathe operations. Figure 4-8 graphically represents all those percentages.

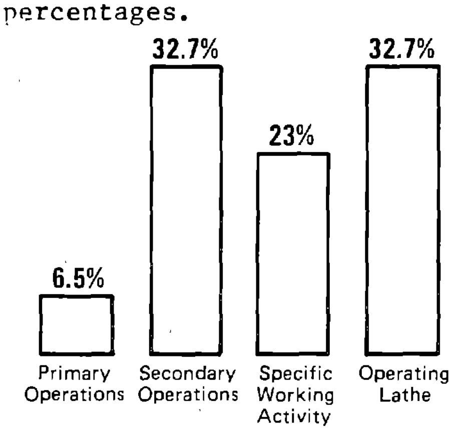

Figure 4-8. Percentages of Injuries Occurring by Lathe Lathe Operations/Workers' Activities

Source and Nature of Injuries, and Part of Body Injuried--
The sources of most metalcutting lathe injuries reported in the injury data were chuck or holding devices, cuttings/chips and the workpiece. These three sources accounted for 60.8% of the total injuries. Of this 60.8%, the chuck or holding devices accounts for 22.7%; cuttings/chips accounted for 22.7% and the workpiece accounts for 15.4%. A graph of these percentages is shown in Figure 4-9. The injuries that were classified under "All Other Sources" (39.2% of the total) were distributed fairly evenly over 17 other sources of injuries. The

highest percent of injuries for any of these 17 other sources was 7.4% for cutting tool or holder. The lowest percent of injuries for any of these other sources was .2% for taper or tracer attachment.

The greatest number of lathe injuries (90.6%) according to the injury data were not severe in nature. The highest number of these non-severe injuries (36.2%) involved lacerations/cuts, most of which occurred to

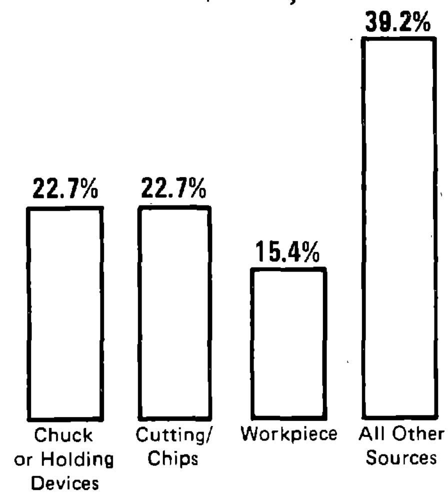

Figure 4-9. Percentages of Injuries Occurring by Sources of Injuries

the fingers, hands or wrists. The highest number of these non-severe injuries (36.2%) involved lacerations/cuts, most of which occurred to the fingers, hand or wrists. Severe injuries accounted for 9.4% of the total injuries. The highest number of severe injuries (7.6%) involved fractures. Amputations and deaths accounted for the remaining 1.8%. The number of severe injuries that were identified in the study shows that metalcutting lathes can be dangerous. This fact is important, since apprentices and trainees, and even some machinists, lathe operators and supervisors often believe that metalcutting lathes are seldom involved in accidents resulting in severe injuries.

The parts of the body that were most frequently injured (58.4%) were the fingers, hands or wrists. A suprisingly high number of injuries occurred to the eyes, most of which were the result of chips entering the eyes.

Accident Types, Fault-Tree Diagrams and Countermeasures--

The most important aspect about accident type, identification fault-tree analysis and countermeasure development was that the results were based on actual injury reports. Each accident type identified was supported by injuries. The fault-tree analysis process resulted in the development of diagrams corresponding to groups of related injury data from the accident types. Each event represented on the fault-tree diagrams was based on the interpretation of actual injury data involving metalcutting lathe accidents. Countermeasures applicable to one or more of the events in each of the accident scenarios were developed. Each countermeasure had the potential of preventing the occurrence of the events and thus, the possibility of preventing the accident sceanarios from materializing. Thus, based on the injury data analyzed and the logic of the methodology employed there is reason to assume that the workers' risk to the injuries traced on the fault-tree diagrams could have been significantly reduced if the countermeasures had been employed in those machine shops in which the injuries occurred.

A review of the percentages of injuries represented by the fault-tree diagrams presented in Figure 4-10, shows that some of the diagrams represent a greater proportion of the 438 injuries than others. This suggests that possible and practical countermeasures should be selected for implementation on the basis of their application to the greatest numbers of total injuries and total severe injuries as represented by the fault-tree diagrams.

The fault-tree diagrams were rank ordered seperately according to the highest number of total injuries and total severe injuries they represent. Diagram number 14 ranked first (with 69) in total injuries. Diagram 10 ranked first (with 10) in total severe injuries. Diagram 10 also ranked second in total injuries. Table 4-10 shows this information.

The actual determination of which countermeasures should be applied to reduce the risk of workers being injured depends upon the type of industries and machine shops. For example, it would be inappropriate to insist that all chuck wrenches be spring loaded to prevent the workers from forgetting to remove the wrenches before they start the chuck rotating. This countermeasure might be appropriate in some production shops using turret lathes, but not in maintenance shops that perform a variety of jobs on engine lathes. Often a worker must place the chuck wrench in the socket of the chuck while he/she uses two hands to position the workpiece, then quickly with the left hand reach up and turn the chuck wrench, while still holding the workpiece with the right hand. A spring loaded chuck wrench would cause the worker to have to pick-up the wrench with his/her left hand from a bench or some part of the lathe, insert the wrench in the chuck socket and then turn the wrench. This would be quite difficult to do while still holding the workpiece in the chuck with the right hand.

Specifying the countermeasures that should be used on engine and turret lathes in all of the various machine shops throughout the United States is beyond the scope of this report. The problem will be addressed in Phase III when an engineering guide is developed. This guide will provide a procedure for determining the appropriateness of countermeasures for the various industries and machine shops.

Most of the countermeasures that were developed to reduce the workers' risk of injuries resulted in management policy and training solutions because they imposed the fewest restrictions of the lathe/worker interactions. Both the engine and turret lathes are used to perform a wide variety of jobs, although this is generally less true of turret lathes. The amount of variety depends upon the type of industry and the

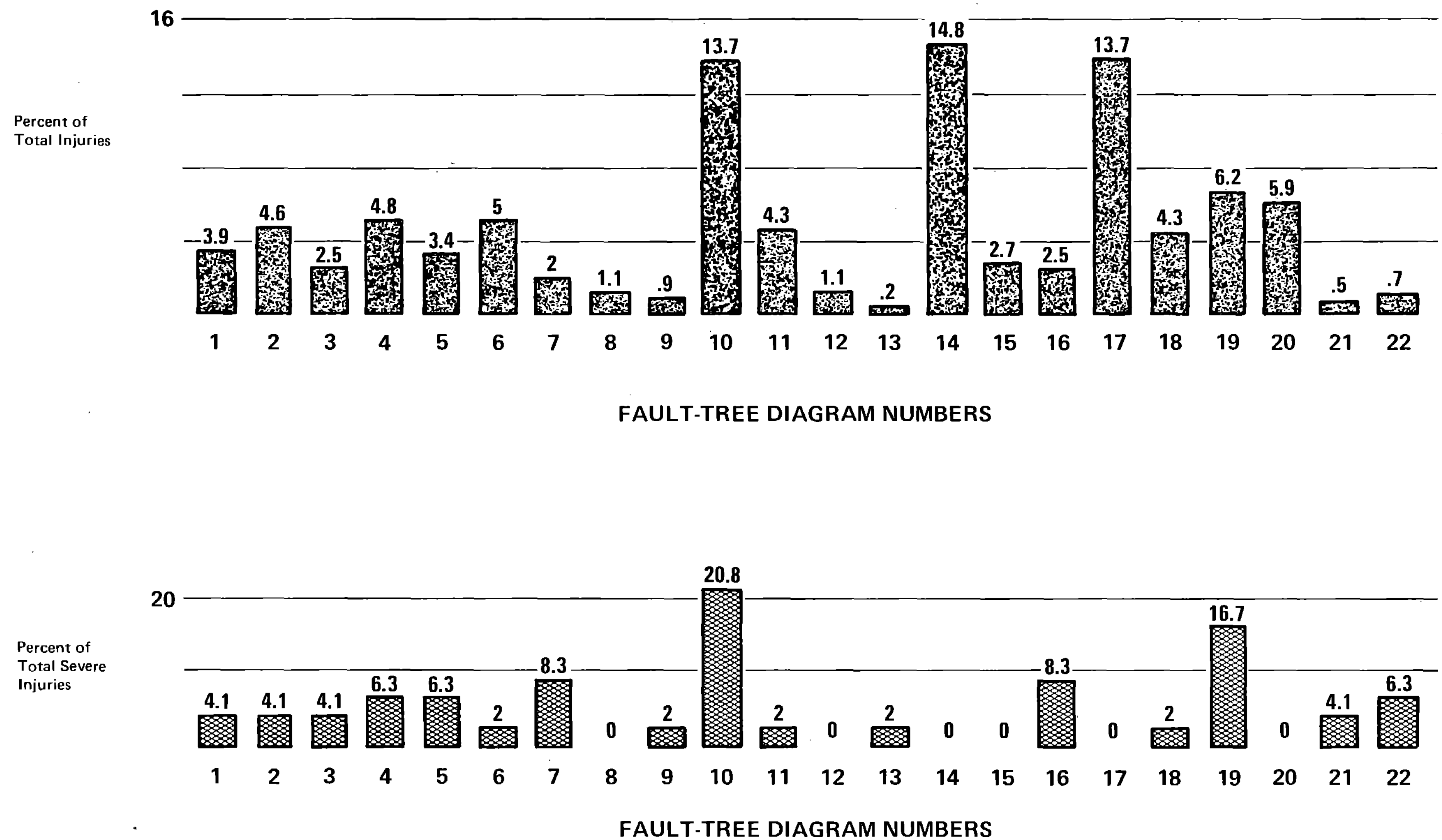

Figure 4-9. Percentages of Total Injuries and Total Severe Injuries Represented by Fault-Tree Diagrams

Table 4-10. Rank Orders of Fault-Tree Diagrams

ACCIDENT TYPES AND FAULT-TREE DIAGRAMS				RANK ORDERS	
Error Type	Diagram Number	Total Injuries Represented by Diagram	Total Severe Injuries Represented by Diagram	Total Injuries Rank Order	Total Severe Injuries Rank Order
1	1	17	2	9	5
1	2	20	2	7	5
1	3	11	2	12	5
2	4	21	3	6	4
2	5	15	3	10	4
3	6	22	1	5	6
3	7	9	4	13	3
3	8	5	0	14	7
3	9	4	1	15	6
3	10	60	10	2	1
3	11	19	1	8	6
3	12	5	0	14	7
3	13	1	1	18	6
4	14	69	0	1	7
4	15	12	0	11	7
5	16	11	4	12	3
6	17	60	0	2	7
7	18	19	1	8	6
8	19	27	8	3	2
8	20	26	0	4	7
9	21	2	2	17	5
Other	22	3	3	16	4

machine shop. For example, engine lathes in maintenance and some job shops are seldom used to perform jobs limited to one operation, such as turning. Instead, they are used to perform jobs that involve many operations. A job could involve turning, facing, boring, threading and polishing operations before the part is completed. Since engine lathes are manually operated, changes made in setup, tooling, etc. require much worker interaction with the lathe. The worker/lathe interaction or work flow becomes a practical consideration in developing countermeasures. The approach to countermeasures in this study was to develop solutions that would minimize the restrictions imposed upon normal work flow. This was seen as important, since creating undue interference would tend to encourage the workers to fail to use or to bypass safety devices or procedures. Such action would likely make the countermeasures ineffective.

The engineering countermeasures that are proposed primarily focus on future lathe control design. These include: (a) Placing controls that are frequently used in positions that are more accessible, (b) Designing controls so they cannot be easily mistaken for one another and cannot be accidentally activated, and (c) Making the controls operate consistently from lathe to lathe, e.g., making the clutch lever so that it is engaged by pushing downward on all lathes even though they are manufactured by different companies. The countermeasure proposed in (c) would appear to be the most difficult to institute, since it would require a considerable effort on the part of the machine tool builders.

Proposed management policy countermeasures were designed to encourage industry to provide the necessary equipment and tools for the workers so they can perform their jobs safely and to require the workers to follow good known safety practices. Many injuries surveyed appeared to occur when the workers were not following good safety practices, e.g., not wearing eye protection devices or wearing loose fitting clothing.

The training countermeasures that were proposed involved providing the workers with knowledge and skills related to secondary lathe operation, such as setup, filing, deburring and polishing. Although the fault-tree analysis indicated that a lack of knowledge and skills contributed to many worker injuries, the problem may not solely involve training. Lack of worker motiviation could also have contributed to some of these injuries. Sometimes a worker may have the necessary knowledge and skills to perform a lathe operation safely, but will "take a short cut." The results of this action will make it appear that the worker does not know how to safely perform the lathe operation. For example, the worker may make an unsafe lathe setup because the correct length bolts would require the worker to walk to the store room at the other end of the machine shop.

Risk taking is not the only behavioral problem associated with motivation. Habit can also cause the worker to perform lathe operations unsafely. For example, many right-handed workers through habit hold the file handle in their right hand and the lip of the file with their left hand, when filing on the lathe. This is an incorrect and unsafe procedure, since the left arm of the worker is usually positioned over the rotating chuck or holding devices.

In addition to the 22 countermeasures included in this report, three suggestions for future research are proposed. These are:

1. Develop engine and turret lathe guards that provide fewer restrictions on work flow than those currently on the market.

2. Develop awareness barriers or devices that can be used on engine and turret lathes to warn the workers of chuck and holding device hazards but do not restrict the work flow.

3. Develop a lathe chuck that incoporates a smooth surface on the face and circumference, but still permits the worker to attach the workpiece without difficulty.

4. Develop a safety checklist for the supervisor or worker to evaluate:

    a. Fixtures used in lathe operations that are made "in house."
    b. Lathe setups.

SECTION 5

STANDARDS EVALUATION AND RECOMMENDATIONS

INTRODUCTION

The purposes of the standards evaluation and recommendations aspect of the study were: (a) to determine what specific areas of the workplace were addressed by existing standards, (b) to determine if specific rules were provided to guide the implementation of the standards, and (c) to make recommendations concerning the development of new standards in view of the proposed countermeasures.

The standards that were included in the evaluation were the ANSI B11.6-1975 and the proposed OSHA 1910, 1977 standards. The ANSI B11.6 standard is the American National Standard Safety Requirements for the construction, care and use of lathes. The primary objective, as stated in this standard, "is to eliminate injuries to personnel associated with lathes by establishing requirements for construction, care and use of lathes." The ANSI standard also states, "to accomplish the objective, the committee approached the problem of safety from four directions:

1. Eliminating by design certain recognized construction hazards and establishing standard approaches to safety.

2. Eliminating, where possible, by design, procedure and process the necessity to expose the operator, or any part of the operator's body, to hazards related to the operation of lathes.

3. Establishing guidelines for general training and specific job-related instruction for eliminating unsafe practices and procedures for all personnel working in lathes.

4. Protecting personnel from exposure to hazards related to lathe operations."

The OSHA standard is the proposed Occupational Safety and Health Administration Part 1910-Machinery and Machine Guarding, Subpart O - Machinery and Machine Safeguarding. The purpose of Subpart O, "is to set forth mandatory performance criteria for protecting against those hazards which are associated with operation of machinery and which may cause traumatic injury or death and to provide methods for safeguarding against such hazards."

The remainder of Section 5 is divided into three parts, Methodology, Results, and Recommendations. Methodology deals with the procedure that was used to evaluate the existing standards. Results include the findings from applying the evaluation procedure in the methodology. The recommendations based on the results of the evaluation discuss the development of new standards in view of the proposed countermeasures.

METHODOLOGY

The methodology used to evaluate the existing standards involved reviewing the standards point by point and subjecting the standard to two questions. Question one was designed to determine what area of the workplace the standard addressed: the lathe and accessories, the worker, or the environment in which the lathe, accessories and the worker operated. This question was developed after a review of the injury data analysis findings and the proposed countermeasures indicated that although the primary source of injuries is the lathes and acccessories, contributing factors involved lack of worker training, lack of proper tools, etc. Question two was designed to determine if specific rules were provided to guide the implementation of the standards in the various type of machine shops in which engine and turret lathes are found. This question was developed from observations made during the hazard analysis and human engineering evaluation that indicated there was a variety of jobs, each having its own set of characteristics, being performed on the engine and turret lathes in the four different types of machine shops.

The two actual questions used in the standards evaluation were:

1. What area of the workplace does the standard address: lathe and accessories, worker, or environment?

    Lathe and accessories--includes the design, construction, reconstruction and modification of the lathe and accessories; also includes, guards, shields, warning devices, etc.

    Worker--includes training, personal safety devices, etc.
    Environment--includes workspace around the lathe, lighting, materials handling equipment, etc.

2. Does the standard include specific rules to guide the implementation of the standards under the various operating conditions found in the four different types of machine shops: job, tool/experimental, maintenance and manufacturing/production?

    Job shop--can involve either service manintenance or production machine work. Service maintenance work generally utilizes engine lathes and rarely involves making more than one or two parts per job. Production machine work generally untilizes turret lathes and most often includes production runs of parts greater than 150.

    Tool/experimental shop--almost always utilizes engine lathes and produces a very small number of parts per job. Specilizes in percision type work, usually tools and dies, or experimental work.

Maintenance shop--performs machine work similar to the service maintenance described under job shop. Maintenance shops often support the maintenance efforts of a manufacturing plant, almost always uses engine lathes.

Manufacturing/production shop--performing machine work related to the manufacturing of a product. Utilizes either engine or turret lathes or both to produce a wide variety of products.

The application of this methodology involved three steps. The first step required reading the standards to become familiar with them. The second step involved proceeding point by point through the standards, evaluating them by applying the two questions. The third step required recording the answers and describing their relationships to the standards. The methodology was applied to the ANSI B11.6-1979 standards first, and then to the OSHA 1910 standards.

Results and Discussion

The results from the evaluation of ANSI standards revealed that most of the standards address safety requirements affecting the lathe and the accessories. A portion of the standards addressed safety requirements affecting the workers, such as providing training, precautionary instructions, etc. Few of the standards addressed safety requirements affecting the environment, although there were some specific points addressing the necessity of having the proper chip removal tools and proper storage magazines for cutting tools.

The specific rules governing implementation of the standards that were included were generally in the form of guidelines. Few of these guidelines dealt specifically with implementing the standards under the different operating conditions in the various types of machine shops.

Section 4 of the ANSI standards, Construction, Reconstruction and Modification, described safety requirements affecting the lathe and accessories. Section 4 provided some specific guidelines for implementation of the standards. This was in part 4.2.1 dealing with hazards of personnel associated with power transmission components and in part 4.2.5 dealing with hazards to personnel associated with ladders, work platforms and walkways.

Section 5 of the standards, Safeguarding, also described requirements affecting the lathe and accessories with two exceptions. In part 5.3 of Section 5, work-holding device hazards included the requirement of precautionary instructions to warn workers of danger associated with work-holding devices. In part 5.8.2 the safety requirement associated with the working environment was described. This requirement states "Chips that are in the process of being generated, such as long stringy chips, shall not be handled by hand. Chips shall be removed by use of a tool, puller, brush, or shovel."

Section 5 provided some specific guidelines for implementation of the standard. The most complete were those dealing with chips or coolant hazards in part 5.8. Part 5.3 dealing with safety requirements for work-holding devices provided guidelines that recognized some of the job variation found among machines. Part 5.3 recognized the fact the workpiece sometimes extends beyond the periphery of the holding device and the worker should be protected from injury. Part 5.3 indicated that if the worker is not effectively protected by location then other means should be used: fixed or movable guard devices awareness barriers, or peripheral covers over areas exposed to the worker. Part 5.3.1 indicated that if the hazard cannot be eliminated by design or protection, precautionary instructions shall be given. The problem with these guidelines is they do not provide enough information (e.g., What is an acceptable protrusion length?) to help one make a decision as to whether precautionary instructions or guards, awareness barriers, etc. should be used.

Section 7 of the ANSI standard, Use, describes safety requirements affecting the worker, lathe and accessories and environment. This standard indicated in a general way training requirements for the worker, use and maintenance requirements pertaining to the lathe and accessories, and environment requirements important to safety, such as maintaining a clean workplace floor. Part E7.1.1, which presented some of the explanatory information of the standard states, "The employee should have a general understanding that proper feeds, speeds, and depth of cut depend upon the material being cut; whether the cut is continuous or intermittent; the tooling, rigidity of both the work-holding device and the workpiece and; the clamping force applied by the work-holding device to the workpiece." Missing from Part E7.1.1 was any reference to training that instructs the worker in the safe and proper method of filing, deburring and polishing on a lathe, or in general using hand tools. Findings from the analysis of the injury data indicated that 13% of the injuries included in the analysis involved filing, deburring and polishing operations.

Section 7 provides some specific guidelines for implementation of the standard, but most of the guidelines were directed at the lathe and accessories. Guidelines provided for implementing training and environment requirements were found to be limited in that they did not discuss the specific details. For example, Part 7.1.1.1, Mandatory Safety Instructions, stated that, "The chuck wrench shall be removed from the chuck immediately after using it." This part of the standard does not take into consideration setups that are often made in maintenance machine shops. This part of the standard might be appropriate in some machine shops, but not in others.

The application of the evaluation methodology to OSHA standards was more difficult. OSHA standards do not specifically deal with metalcutting lathes, but include them under cutting and shaping machinery. Thus, standards were much more difficult to evaluate.

The results from the evaluation of OSHA 1910 standards revealed that most of the standards addressed safety affecting the lathe and accessories.

There was only one paragraph that addressed requirements affecting the workers. Paragraph (b), Employee Training and Supervision, under 1910.213 of the general requirements, briefly described training requirements.

The specifications governing the implementation of the standards were included under 1910.216 of the rules for compliance. Appendix A of these rules included two drawings of lathes. Appendix B provided a list of the OSHA and appropriate ANSI standards. Both Appendix A and B provided few guidelines that dealt specifically with implementing the standards under the different operating conditions in the various types of machine shops.

RECOMMENDATIONS

The recommendations concerning the standards were based on the evaluations of existing and proposed standards, and a review of the proposed countermeasures. The first recommendation is that future metalcutting lathe standards should address all areas of the workplace: lathe and accessories, worker and accessories, worker and environment. The standard should include requirements for worker training in primary lathe operations (turning, facing, etc.) and most important secondary lathe operation (setup, loading/unloading, filing, deburring, polishing, etc.). Instructions on how to perform secondary lather operating is important, since findings from the injury data anlysis indicated 32.7% of the injuries occurred during secondary operations. The metalcutting lathe standards should also include requirements for providing the proper tools for the worker, such as materials handling equipment for heavy workpieces, wrenches, files, deburring tools, etc. The lathe standards should also include requirements for lathe design that are directed at providing labels on lathe control positions and where possible should re-quire industry-wide consistency in control operation, e.g., all clutch levers are pushed downward to engage the spindle drive.

The second recommendation is that standards should include rules that deal specifically with implementing the standards under the different operating conditions in the various types of machine shops. The rules should guide the selection of standards that apply to operating conditions found in the different machine shops. The rules should be responsive to the variety of jobs performed on engine and turret lathes by considering such variables as the kind of machining operations, the size and shape of the workpieces, and the quantity of parts to be produced.

SECTION 6

SUMMARY AND CONCLUSION

This study of metalcutting lathe safety, Phases I and II, has resulted in two important outcomes. First, the study showed the application of systematic methodologies for analyzing safety problems on engine and turret lathes. Necessary background information was supplied by the literature search. The hazard analysis identified injury potential situations that occurred on eight different engine and two turret lathes in four different types of machine shops. Potential safety problems were discovered through the human engineering evaluation. The injury data analysis provided 22 fault-tree diagrams that traced 438 actual injuries occurring on metalcutting lathes. Countermeasures developed generated solutions directed at preventing these injuries from occurring. And evaluation of existing and proposed standards resulted in recommendations concerning the development of new standards.

The second important outcome was the development of countermeasures that were founded on actual injury data and are directly applicable to reducing the risk of workers' injuries occurring on metalcutting lathes. These countermeasures can be utilized by the builders and users of engine and turret lathes.

The application of these methodologies was effective in providing the necessary results to meet the Phase I and II objectives of: (a) identifying aspects of metalcutting lathes and associated operations that are likely to cause worker injuries, and (b) developing countermeasures that will reduce workers' risk to these injuries.

During the performing of this study a number of problems were encountered. The most difficult problem to deal with concerns the collection of injury data. First, it was difficult to obtain injury data. Company injury reports and insurance data could not be obtained. Private corporations and insurance companies that were contacted would not release any injury reports. Workmen's Compensation First Reports of injury were obtained, but not from all states that were contacted.

Second, injury data frequently did not supply the level of detail desired. The quality of the accident description was sometimes limited and not complete in supplying details on how the injury occurred. Providing a a short structured accident recording form with the states' Workmen's Compensation First Reports might help this situation. A discussion of the problems encountered during data collection is presented in Appendix H.

Although there was excellent cooperation from the companies participating in the study, some other companies contacted during the search for machine shops indicated they did not want to participate because of the "cost" involved with the company's effort and plant restrictions. This attitude made the search for participating machine shops more difficult. Possibly there could be incentives to encourage participation in such studies.

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APPENDIX A

ABSTRACTED ARTICLES

Branton, P. A field study of repetitive manual work in relation to accidents at the work place. The International Journal of Production Research, 1970, Volume 8, No. 2, 93-101. Published by The Institution of Production Engineers, 10 Chesterfield Street, London, W.1, England.

ARTICLE SUMMARY

Purpose. To identify any relationships between the frequency of accident occurrence and time of day, fatigue, boredom, and gain of information in a light engineering factory or machine shop.

Methodology. Four-hundred-twenty-seven accident cases involving 141 subjects were selected from the records of 2000 accident cases involving 180 subjects collected by the British National Institute of Industrial Psychology research team. All the accidents occurred in the machine and assembly shops of a light engineering factory. The 427 accident cases selected for study met the following criteria:

1. They occurred at the actual work station and during normal working hours.

2. The nature and locus of injury, and times of occurrence were known.

3. The machine at which the accident happened and the job description were available.

The work day was divided into 15-minute segments and into four work periods. The author used several histograms to determine what if any relationship existed between frequency of accident occurrence and time of the work days or duration of the work periods.

The second phase of the study involved four capstan cordings were made of machine sounds. The time between machine sounds was then measured to determine what speed variability existed for the time of performance during loading and cutting tasks. Recordings were taken on large and small capstan lathes and the operators' tasks were all self-paced.

For the third phase of the study, a woman capstan lathe operator, who had the highest number of reported accidents over the previous two years, was observed for one hour at a time during each of the four work periods. At the end of each five to determine when the highest frequency of unsuccessful hand movements occurred and what tasks generated the highest number of them.

Results. The frequency of accident occurrence was found to increase steadily throughout each work period.

Ninety and two-tenths percent (90.2%) of all the accidents were to the hands, almost equally divided between the right and left.

The time to perform loading tasks varied more than the time to perform cutting tasks.

The number of unsuccesful hand movements, monitored in the third phase of the study, was the highest during performance of the complex loading movements. During the periods of the highest occurrence of accidents, unsuccessful hand movements tended to increase.

Conclusions/Recommendations. The author concluded that deterioration of performance which may result in an accident is not caused by physical fatigue or overloading the operator's capacity, but that the deterioration is caused by monotony and underloading the operator's capacity. The author suggests that this deterioration can be reduced by providing a variety of dissimilar tasks for the operator or by providing the operator with finely graduated increases in complexity of the tasks he is to perform.

SAFETY ASPECTS

Places of Attachment. The author of this article suggests that providing increased protection for the operator's hands by the use of guards and protective devices would reduce, but not eliminate, accidents. This would apply especially to places of attachment such as chuck and tool holders where complex hand movements are required and where deterioration of performance due to monotony could precipitate an accident.

The author contends that monotony and underloading the operator capabilities tend to create a predisposition to accidental injury. Some possible solutions are shorter work periods and/or providing the operator with a greater variety of dissimilar tasks to perform. Another possible ingredient to a solution is to gradually increase the complexity of the tasks to avoid monotony.

Buzunov, V . H. A physiological assessment of occupational stress in machine tool operators and matal workers. Gig. Tr. Prof. Zabol., 1972, 16 (1): 19-22.

ARTICLE SUMMARY

Purpose. To physiologically assess the occupational stress in machine tool operators and metal worker.

Methodology. The subjects used for the study worked in the mechanical and instrument shops of an electrical instrument factory. The subjects ranged in age from 22 to 35 years. The subjects worked as metal lathe operators, milling machinists, polishers, and automatic turret lathe operators and setup men. The turret lathe operators were women and all the others were men.

The study was performed for three days a week during the first, fourth, and eighth hours of work of the first shift. A hygienic evaluation of noise and lighting was made and photochromometric studies of the work time were carried out while the condition of muscular activity for work, pulse rate, blood pressure, and higher nervous activity were studied.

Results. Noise in the high frequency spectrum was found to be in excess of acceptable levels in a number of industrial areas.

Illumination levels were found to be below acceptable levels in some industrial areas.

Muscle endurance was found to drop during the course of the shift in the majority of the occupational areas studied.

Higher nervous activity was found to decline in all occupational areas studied except for lathe and milling machine operators, which showed no change in higher nervous activity.

The pulse rate among the persons working in the instrument shop averaged 80-90 per minute and the average pulse rate among the persons working in the mechanical shop was 90-100 per minute. Maximum blood pressure among both groups was 110-115mm with a minimum of 70-75mm.

Conclusions/Recommendations. Occupational conditions for machine tool operators and metal workers should be improved by reducing noise, improving lighting, and by providing a sensible schedule of work and rest.

Noise could be reduced by installing removable casings and screens on lathes, and by the use of portable sound-absorbtion screens. Sound-deadening guide tubes could be used in automatic lathes and personal noise protection should be provided.

Industrial calisthenics should be performed for five to seven minutes at the beginning of the shift. Five minute breaks for rest should be provided every three hours during the first half of the shift and every two hours during the second half of the shift.

Carr, R., Ashford, F. C., & Easterby, R. S. Design of a lathe for international markets. Human Factors, August 1966, 327-337.

ARTICLE SUMMARY

Purpose. Based on a survey of international lathe requirements, a program was undertaken to develop a lathe for three main marketing areas that were considered important: Great Britain, North America, and Europe.

Methodology

Industrial Design Program. The industrial design program focused on selecting visual design characteristics that exhibited a recognizable company style suitable for the range of Mascot lathes.

Human Engineering Program. This program focused on the operator's task of programming the headstock gear train to cut threads and gears using data obtained from the tabular display on the lathe.

The approach to the problem first involved assessing the display on the Mascot 1600 lathe by three analytical steps: (1) systematically defining the number series based on the range of threads to be generated by the machine, (2) producing a block diagram showing the function of the gear box, and (3) providing a flow diagram showing the proposed gear train combination.

An experimental evaluation of two tabular displays (original and proposed) was performed utilizing eight experienced lathe operators as subjects. Each subject was asked to make 30 discrete control operations employing first the original design, then the proposed design. Twelve replications of each trial of 30 settings were run. Performance was measured in terms of mean time per trial to perform the 30 setting operations.

Results. Subjects improved their performance more rapidly on successive trials using the new display and after 12 trials or 360 settings. Performance was 20% better with the new design. Similar results were obtained by monitoring setting errors and the results were statistically significant for all eight subjects tested.

Conclusions/Recommendations. The design of the Mascot 1600 lathe represented a successful integrated engineering, human factors, and industrial design effort that extended to all Colochester lathes and their accessories.

SAFETY ASPECTS

Machines and Accessories

Control and Display Area. An important finding in the analytical assessment of the lathe was the discovery that the original tabular display presented the information in exactly the reverse order that was required by the operator. The operator was forced to first locate the threads per inch he wanted and then trace through the matrix to find the lever position letters used in setting the lead screw speed. A new tabular display was designed that presented the list of threads per inch with the associated letters for level positions displayed next to each thread per inch listing.

The safety implication for the research is that the operator is more likely to make a mistake in setting the lead screw from reading the original tabular display than from reading the proposed tabular display. The result of such a mistake is that the operator could engage the threading lever without knowing of his setting error. This situation would pose a safety hazard if the speed of the lead screw was higher than the operator expected. A lead screw turning at significantly higher speed than expected may not permit the operator to react fast enough to prevent the cutting tool from hitting a shoulder on the work or even the lathe chuck. Either situation could result in an accident or injury.

Chapanis, A, & Gropper, B. A. The effect of the operator's handedness on some directional stereotypes in control-display relationships. Human Factors, August 1968, 10,4,303-319.

ARTICLE SUMMARY

Purpose. To determine if the ways in which operators respond to directional relations differ depending on the hand they use and on their preferred handedness.

Methodology. The study used 64 male subjects, 32 right-handed and 32 left-handed, who were all students of John Hopkins University. Subject candidates had been tested to determine handedness and to screen out individuals wtih mixed handedness.

An experimental apparatus was used which consisted of a vertical panel with a simple linear scale which could be placed either horizontally or vertically. A smooth rotary knob was placed below the scale. The knob was used to move a hairline along the scale and the direction of the hairline movement in relation to the direction of knob rotation could be selected by the test administrator. The scale was divided into 100 divisions of equal spacing with major division lines at 10 division intervals and submajor division lines at 5 division intervals. All other points on the scale were shown by major division lines. Overlays were made which could calibrate the scale 0-50-100 going from left to right or bottom to top. Other overlays reversed the scale calibration to 100-50-0. A display was installed above the scale which glowed red when the apparatus was ready for use. When the subject touched the rotary knob, the red light was replaced by a two-digit number from 01 to 99. Using the rotary knob, the subject then adjusted the hairline on the scale to a number corresponding to the displayed number.

Each subject was required to make one setting to each of the 98 unnumbered scale markings, 01 through 49 and 51 through 99. Forty-nine (49) of these were made with the left hand and 49 with the right hand. The values were selected at random. Thirty-two (32) of the subjects were required to use their left hand first, and the other 32 subjects were required to use their right hand first, with right- and left-handedness equally divided between the two groups.

For each setting, the following aspects of the subjects' performance were recorded:

- Time to make setting
- Initial direction of control knob rotation

- The number of times the subject reversed the control knob in making his setting

- The value at which the hairline was set

Results. Out of the total of 6,272 setings, 74 times the hairline was set to an incorrect value. These errors were evenly divided between the handedness groups. Over half of these errors were $\pm$ 10. Fewer errors were made when using the horizontal scale than when using the vertical scale.

When subjects were tested first with their right hand and then with their left, the difference between times to make settings for each hand was trivial; but when subjects were tested first with their left hand and then with their right, the subjects made the settings significantly faster with their right hand. This was true for both left- and right-handed subjects.

The subjects made fewer errors in initial direction of rotation of the control knob with their preferred hand than with their non-preferred hand. Left-handed subjects made substantially fewer errors in initial direction of rotation with their non-preferred hand than did right-handed subjects with their non-preferred hand. Those tested second. Those subjects tested in the reverse order showed little change in performance.

Conclusions and Recommendations.

1. In tasks covered by this study, people (both right- and left-handed) generally do better with their right hands than with their left hands on a variety of control-display arrangements.

2. Population stereotypes for horizontal scales appear to be stronger than those for vertical scales.

3. Control-display arrangements that are best suited for right-handed operators are not necessarily best for left-handed ones.

4. Whether a change in particular arrangement will improve performance or not depends to a considerable extent on the performance measure in which one is interested. Time for responding, reversal movements, and errors in initial direction of movement appear to be largely independent of one another.

5. Left-handed subjects performed better with their non-preferred hand tand did right-handed subjects with thier non-preferred hand.

SAFETY ASPECTS

Control and Display Area. The results of this study seem to suggest that there is little need to design controls and displays to accommodate left-handed operators because left-handed people tend to adapt very well to using their right hands when they are required to use them and because, in at least some cases, left-handed operators perform better with their right hands than with their left hands. Designing controls in such a way as to make it easy to use either hand could conceivably create increased hazards for right-handed operators because they do not perform as well with their left hands as with their right. Designing controls to encourage the use of the right hand over the left would probably not hinder the left-handed operators significantly and would help them in some cases; and for right-handed operators, this would decrease the possibility of error because of their significantly better performance with their right hands as opposed to their poorer performance with their left hands.

The authors of this study state that the linear scale that would best aid operator accuracy is a horizontal scale with lower values at the left and higher values at the right. Subjects made more errors with horizontal scales with reversed calibration and with vertical scales that were calibrated in either manner.

Floyd, W. F., and Ward, J. Posture in industry. The International Journal of Production Research, 1967, 5, 3, 213-224. Published by The Institution of Production Engineers, 10 Chesterfield Street, London, W.1, England.

ARTICLE SUMMARY

Purpose. To emphasize the need to study the dimensional relationship between the operator and his machine so that the working posture can be improved.

Methodology

Study 1. This study involved female burlers and menders in the woolen textile industry. The women and girls employed inspected woven cloth for faults, mark the area according to the type of fault, and mend the faults. They worked at a table with a top that was adjustable in slope and illuminated from below. They sat on a wooden bench that was 24 inches high, with a seat depth of 10.5 inches. This combination provided inadequate space between the seat and undersurface of the table to accommodate the thighs. Then adjustable chairs were brought in that conformed to British Standards recommendations and a wooden platform was provided as a base for the chair to allow the women to rest their feet on the bottom support rail of the table.

Study 2. The subjects used for this study were women engaged in assemblying, soldering, packaging, and inspecting fuses at an electrical engineering firm who sat at their workplaces fro 80 tp 90 percent of their work day. The dimensions of their workspace are listed below:

Height of top of bench from floor:	32"
Height of chair seat from floor:	20 or 22"
Height of bench foot rail from floor:	6 to 10"
Height of chair rail from floor:	4.5 to 6.5"

A number of the subjects did not make use of the full depth of the seat for support, but sat forward so that their thighs sloped downward, permitting the operator to sit close to the bench. This meant that the backrest was seldom or never used. Others were better supported by the seat, but this prevented the feet from resting on any support other than the chair footrail. It frequently prevented use of the backrest.

Workplaces for nine women were modified to allow better working posture. The height of the workplace was reduced to 27 inches. The thickness of the working surface was reduced from, 3 inches to 2 inches. The bench footrail was removed and adjustable chairs were brought in that conformed to British Standards recommendations. The women were instructed on how to adjust the chairs and told to adjust them for maximum comfort. This allowed the women to work with their feet firmly planted on the floor while fully supported by the seat and enabled them to use the backrest.

Study 3. This study involved 11 men operating notching machines in a machine shop. In addition to using their hands on the work surface, the subjects operated a foot pedal at the base of the machine. Dimensions of the machines and operators are listed below.

Height of work surface:	32"
Height of foot pedal:	5.8 to 7"
Average operator stature:	67-9"
Average operator elbow height:	42.2"
Average operator knuckle height:	29.8"

The foot pedal was depressed once every 5 to 7 seconds, required about 40 pounds of pressure to operate, and was awkwardly situated for use.

One machine was modified so that the work surface was raised to 40 inches above the floor. The foot pedal was removed and replaced by a knob that was operated by the hand of the operator.

Results

Study 1. Use of the correctly dimensional chairs did provide better support for the operator but, due to the dimensions of the workplace, there was still inadequate space between the seat and the undersurface of the workspace for the thighs. The new chairs did permit more use of the backrest. One of the subjects stated that the new chairs eliminated her backache which she suffered when using the original bench and workplace.

Study 2. All nine subjects preferred the new workplace dimensions and said that they felt more comfortable. One subject stated that the backache from which she had suffered at the old bench and chair no longer bothered her.

Study 3. The modified machine dramatically improved posture and reduced flexing of the neck and shoulders. The modified machine also allowed a greater freedom of movement and stance because the operator did not have to stand in a fixed position in relation to a foot pedal. Two subjects still had a stooped posture when using the new machine, but this may have been due to a permanent distortion of posture caused by years of work at unmodified machines.

Conclusions and Recommendations. Modifying only part of the workplace may provide only limited improvement in posture. This is demonstrated by Study 1. Modifying the entire workplace, as shown in Studies 2 and 3, can provide optimum posture for the operator.

Poor posture at the workstation increases fatigue, may hinder productivity, and may lead to physical ailments such as backaches and permanent posture distortion. The workplace should be designed to allow optimum posture to prevent these consequences.

SAFETY ASPECTS

Operator Posture. If a machine is not designed to promote good operator posture, additional fatigue as well as physical ailments may result. Since fatigue is a major contributor to operator errors which may result in injury, good posture could help reduce the risk of injury to an operator. The posture of the operator will be determined to a large degree in the design and configuration of the machine. The incorporation of foot pedals into a machine design should probably be avoided. Controls and displays, as well as other areas where the operator may be required to be for prolonged periods of time, should be designed so that the operator does not have to remain in an uncomfortable position.

Harten, G. A., & Derks, P. M. A new ergonomically improved lathe. Applied Ergonomics, September 1975, 155-157.

ARTICLE SUMMARY

Purpose. Research studies have showed (a) there is a correlation between abnormal posture at work and disorders of the human motor system, and (b) lathe operator's posture includes more bent forward and twisted positions than occurring in other trades. As a result of these studies, the Philips Ergonomic Department set up a special working group to submit proposals for the construction of an ergonomically acceptable small lathe.

Methodology. The group drew up a number of requirements which an ergonomically acceptable lathe should have:

1. The working height of the lathe had to be appropriate to the height of the operator.

2. It had to be possible for the operator, if he wished, to perform in the seated position certain operations which lent themselves to that position.

3. The layout and pattern of movement of controls (handwheels, levers, etc.) had to be such that the necessary movements of the fingers, hand, arm, etc. took place around the centers of joints. These members must not be forced to take up extreme positions in the joints.

4. The operator had to be able to see the point of the tool without bending his trunk forward or turning it sideways.

5. The setup and lighting had to be such that the operator could also read position indicators easily in an optimum posture. The ergonomic ideal is that he should be able to see both the position indicators and the tip of the tool at the same time.

6. Apart from the above ergonomic requirements, the lathe had still to meet the technical and operational standards expected in a good lathe.

Results. The results of the design effort were: (a) a suitable height lathe for the five percentile operator, as well as the taller or larger operator, (b) unimpeded view of the tool by tilting the bed 15-20°,

(c) repositioning of controls, (d) placing the position indicators closer to the tool so they can be seen simultaneously for improved posture, and (e) providing changes that permit the operator to be seated more comfortably at the lathe.

A mockup of the new lathe was presented to a number of skilled and experienced lathe operators. The opinions and comments expressed were generally favorable.

Conclusions/Recommendations. The working group responsible for the new lathe was convinced that skilled workers in general will support the idea of an ergonomic lathe.

SAFETY ASPECTS

Machine and Accessories

Point of Operation. Most conventional engine lathes have been designed with the bed of the lathe remaining horizontally flat. This means that in order for the operator to obtain an unobstructed view of the cutting tool, he has to lean over the lathe bed. The result of leaning over the lathe bed has produced poor operator working posture. The new ergonomically improved lathe has improved this situation by tilting the bed 15-20° toward the operator to provide an unobstructed view of the cutting area.

The safety implication for this new design is that the 15-20° tilt of the bed provides the operator with a view of the cutting tool and work that is unobstructed by the toolpost, which in turn improves the working posture of the operator.

Pratt, F. M., & Corlett, E. N. The ergonomics of vertical turret lathe operation. Applied Ergonomics, December 1970, 302-309.

ARTICLE SUMMARY

Purpose. The study was conducted to determine whether the high level location of controls on vertical turret lathes constitute a limitation on the use of the machines.

Methodology

Study I. The first study involved samplind six operator's activities over a period of eight days. The activities involved the machining of large type moulds on lathes. The vertical turret lathes used in the study were not identical, but varied in control configuration.

The operators' activities occurring throughut the working day were classified in terms of effort. The classification included five groups ranging from group 1 involving lifting and carrying heavy loads and climbing up and down ladders beside the machine to group 5 involving sitting, watching, conversing, reading, writing, smoking, and drinking tea.

Study II. The second study was similar to the first study, but was expanded to inclue: (a) eight operators and eight vertical turret lathes, and (b) the operators' heart rates during the activity. In addition, the operators' ages and years of experience and the specific dimensions of the lathe were recorded.

Results. The results from Study I and the first part of Study II show the distribution of effort by percentage throughout the working day. These data reveal that most effort was distributed between groups 2 and 5. (Study I--group 2, x = 39.8%; group 5, x = 34.3%; Study II--group 2, x = 30.4%; group 5, x = 50.4%)

In the second part of Study II, results indicated that the average working heart rate is 99 beats/min over the working day and only about 20% of the day is spent with a heart rate in any of the higher effort classifications. In addition, 50% of the working day is spent in Class 5 activities.

Conclusions/Recommendtions. The authors suggest that although results from the second part of Study II appear to indicate that the job has no effect on limiting the operator's performance, the assumptions underlying such a conclusion should be reviewed. They feel that such variation in the operator's strength and work capacity with age and the different forces required to operate the machines preclude one making any firm conclusions about the results from the second part of Study II.

The authors did, however, draw some practical conclusions from Studies I and II. They feel that (a) improvements in cutting technology are unlikely to lead to improved output in four of the eight machines surveyed in Study II, (b) machine designs need to be modified in the direction of reducing reaching and climbing during their operation, and (c) short rest pauses should be included during activities requiring high effort.

SAFETY ASPECTS

Control and Display Area. An important finding from the studies was that a high percentage (Study I, $\bar{x}$ = 39.8%; Study II, $\bar{x}$ = 30.4%) of effort during the working day occurred in the group 2 effort level. Group 2 effort involves miscellaneous light movements: walking, transition between two places or activities, inspecting work (stepping up and bending over, often maintaining awkward positions), setting tool, tightening nuts, operating hand crane, and clearing swarf.

The safety implications for this research are that stepping up and bending over machines, and assuming and/or maintaining awkward positions during lathe operations (a) can cause or contribute to injuries such as operator's back, shoulder or wrist sprain, and (b) can result in the operator placing his hand, arm, or some other part of his body in a dangerous location such as near a rotating chuck or part, or cutting tool.

Singleton, W. T. A preliminary study of a capstan lathe. The International Journal of Production Research, 1964, Vol. 3, No. 3, 213-226. Published by The Institution of Production Engineers, 10 Chesterfield Street, London, W.1, England.

ARTICLE SUMMARY

Purpose. The purpose of the study was to introduce systematic ergonomics into the machine tool industry. The specific methods under consideration were: (a) systems analysis, (b) application of human factors standards, and (3) case studies.

A 4-1/2 inch capstan lathe was selected for study. A typical operation which made reasonable use of the machine's facility was also selected and films were taken of two operators--one highly skilled, and one only moderately skilled. The films were analyzed and a number of potentially useful control changes were identified. A block diagram and a link chart were prepared to check that no control deficiencies had been missed. The machine was modified and further films were taken. Modification of controls was made on the basis of frequency of use, and they were modified to make their use easier and faster.

The validation of the usefulness of the modifications was a simple comparison of the separate control changes. One of these comparisons was made with the old and redesigned star wheel.

A second experiment was carried out solely on the capstan operation. It measured the frequency of operation in two minutes. Six subjects were used in balanced groups of three, and each subject did three trials per day for 6 days. Each subject used both knobs and spikes.

Results. The star wheel comparison showed no significant difference between the times in the two cases, nor was there any significant difference in the average cycle time.

In the experiment on the capstan operation, the old control (spikes) resulted as the faster method. The mean cycles in two minutes for spikes was 65; for knobs, it was 62. There was a smaller learning effect for knobs than there was for spikes (11% to 22%).

Conclusions/Recommendations. This study can be regarded as an illustration of the problems involved in the ergonomic modifications of production machines. It's easy to show that something is wrong and it's easy to design changes that are probably improvements, but it's difficult to produce a numerical measure which will indicate the extent of the improvement.

The experiments have been of value as pilot studies. Further experiments are in progress on these lines

SAFETY ASPECTS

Control and Display Area. The results of the study indicated some of the original controls on the capstan lathe required more effort to operate, more movement and involved more awkward posture than the new controls.

The safety implications for this research are that controls requiring more body effort, movement, and awkward posture (a) can lead to situations that cause or contribute to injuries such as operator's back, shoulder or wrist sprain, or operator's hand or wrist bruises, (b) can delay an operator's response actions in emergency situations, and (c) can result in the operator placing his hand, arm or some other part of his body in a dangerous location such as near a rotating chuck or part, or cutting tool.

Suddon, F. H., & Link, J. D. 1959. Handedness, body orientation, and performance on a complex perceptual-motor task. Perceptual and Motor Skills, 9, 165-166.

ARTICLE SUMMARY

Purpose. To examine left- and right-handed performance on a complex motor task.

Methodology. The subjects were 15 right-handed and 15 left-handed randomly selected male university students. Each subject was required to perform for a five-minute period in the Toronto Complex Coordinator after a practice session. Measures were total number of matches, error-match ratio, and error persistance-total ratio.

Results. Left-handed subjects made more matches but not more errors.

Conclusions and Recommendations.

Since machines are designed mainly for right-handed people, left-handed people may have more skill, and/or experience less anxiety in performing complex motor tasks.

SAFETY ASPECTS

Operator Left-Handedness. The study suggests that left-handed subjects can operate controls designed for right-handed use with performance close or equal to right-handed subjects. Because of this fact, in some specific situations, it may not be necessary to design or redesign machine tools for left-handed operators.

APPENDIX B

LATHES RECOMMENDED FOR THE HAZARD ANALYSIS AND HUMAN ENGINEERING EVALUATION

ENGINE LATHES

LIGHT POWER MACHINE LATHE--Bench Model

Distinguishing features:

1. 5-15 years old
2. Precision
3. Bench mounted
4. 24-36" maximum between centers; 6-10" swing
5. Fitted with taper attachment
6. Power feeds (except compound)
7. Equipped with 3-jaw universal or 4-jaw independent chuck (threaded spindle nose)
8. Speed change by operator moving drive belts and/or back gears
9. Single-lever reversing motor switch

TOOLROOM LATHE--Floor Model

Distinguishing features:

1. Less than 5 years old
2. 4-6' bed; 10-12" swing
3. High precision
4. Cabinet mounted
5. Fitted with taper attachment
6. Single lever speed control
7. Power feeds (except compound)
8. Equipped with 3-jaw universal or 4-jaw independent chuck (threaded spindle nose)
9. Belt driven headstock
10. Single-tooth clutch arrangement on apron

STANDARD LATHES--Floor Models

Lathe #1

Distinguishing features:

1. Less than five years old
2. 5-7' bed; 15-16" swing
3. Fitted with taper attachment
4. Power feeds (except compound)
5. Equipped with 3-jaw universal or 4-jaw independent chuck (camlock spindle nose)
6. Single lever speed control
7. High precision

STANDARD LATHES--Floor Models

Lathe #2

Distingushing features:

1. 5-15 years old
2. Precision
3. 8-12' bed; 15-18" swing
4. Fitted with taper attachment
5. Power feeds (except compound)
6. Gear driven headstock
7. Multiple lever speed controls
8. Faceplates, fixtures or other devices used to secure work

Lathe #3

Distingushing features:

1. 15-20 years old
2. 6-7' bed; 15-16" swing
3. Precision
4. Power feeds (except compound)
5. Gear driven headstock
6. Multiple lever speed controls
7. Carbide and high speed cutting tools
8. Faceplates, fixtures or other devices used to secure work
9. Turret toolpost holder
10. Steady rest used

LARGE SWING AND LONGBED LATHE--Floor Model

Distingushing features:

1. 15-20 years old
2. 40-60' bed; 48-72" swing
3. Operator riding carriage or high platform used to enable operator to reach controls
4. Medium precision or precision
5. Power feeds
6. Gear driven headstock
7. Multiple lever speed controls
8. Uses faceplate, fixtures or other devices to secure work

TURRET LATHES

RAM TYPE--Manufacturing/Production

Distinguishing features:

1. 5-15 years old
2. Precision
3. 7-10' bed; 10-15" swing
4. Air operated chuck, or hand operated collet with bar feed
5. Coolant used
6. Collapsible die or tap used
7. Multiple lever speed controls

SADDLE TYPE--Manufacturing/Production

Distinguishing features:

1. 5-15 years old
2. Precision
3. 10-15' bed; 20-30" swing
4. Chuck with power wrench
5. Coolant used
6. Rapid traverse levers on carriage and turret

APPENDIX C

ENGINE AND TURRET LATHES INVOLVED IN THE HAZARD ANALYSIS AND HUMAN ENGINEERING EVALUATION

Engine Lathe (a)

Lathe Distinguishing Features

Size:	9" swing; 24" between centers
Accessories:	Fitted with 4-jaw chuck
Spindle Speed Change:	Move drive belts on pulleys to change speeds
Feeds:	All power, except compound
Toolholder:	Multiple
Year Manufactured:	Between 1950-1955
Other:	Mounted on bench, no guards over drive belts

Job Characteristics

Job:	Machine steel compression samples
Part Overall Dimensions:	1/4" dia., 1/2" long
Material:	Steel
Setup Arrangement:	Material secured in chuck
Machining Operations:	Turning, facing and cutoff
Guarding:	No point of operation and chuck guarding used during lathe operations
Other:	-

Worker Characteristics

Age and Sex:	45-50 years old, male
Position Title:	Machinist
Machine Shop Experience:	20 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	-

Machine Shop Characteristics

Nature of Shop Activity:	Build very precise experimental test equipment for metallurgical research
Location:	Large university in Pittsburgh, PA
Working Space:	More than adequate space in shop and around lathes
Shop Light Levels:	Good
Shop Noise Levels:	Very low
Other:	Only two machinists work in shop Occasionally there are graduate students who use shop equipment

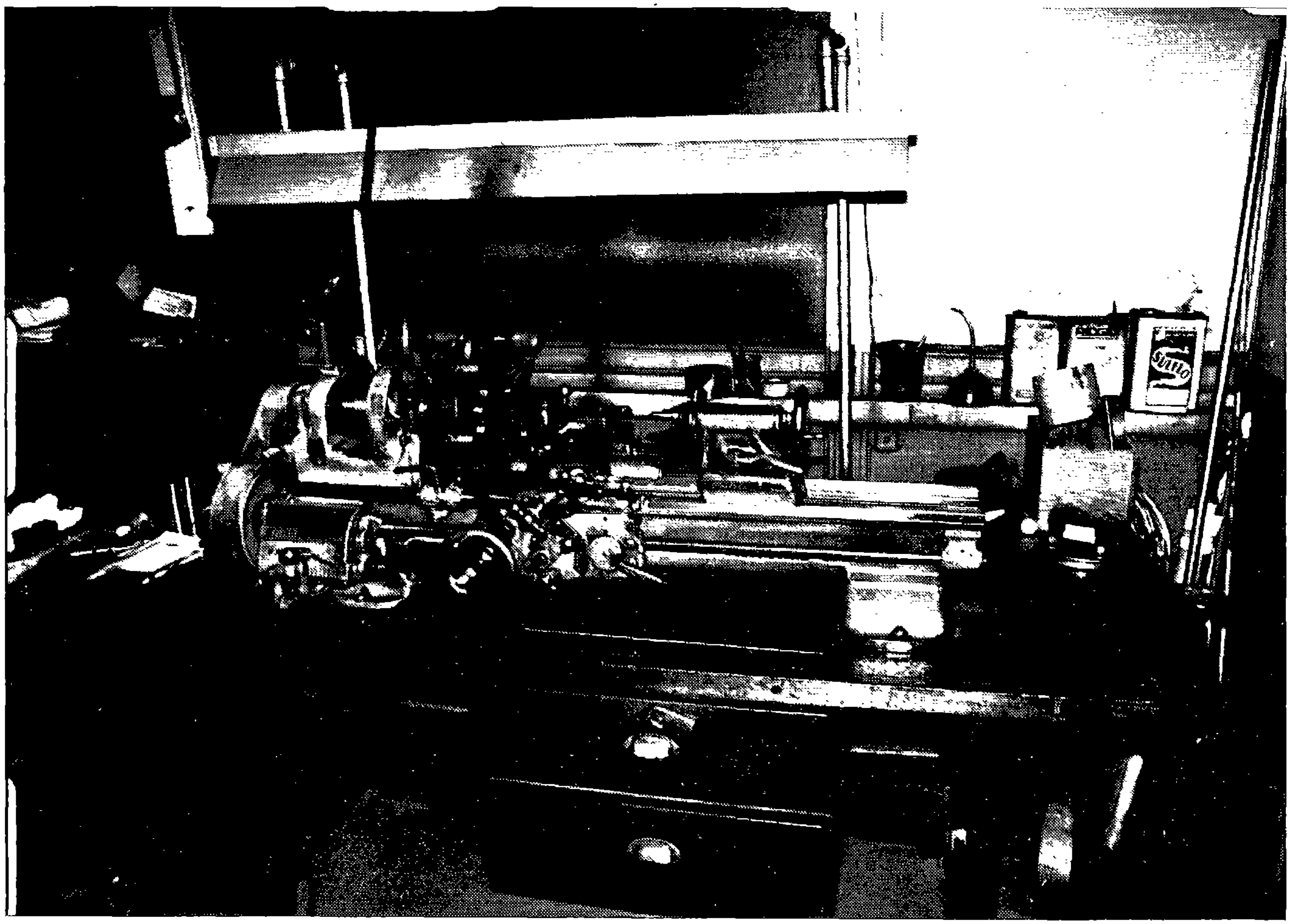


Figure C-1. Engine Lathe (a)

Engine Lathe (b)

Lathe Distinguishing Features

Size:	14-1/2" swing; 36" between centers
Accessories:	Fitted with 6-jaw chuck
Spindle Speed Change:	Move drive belts on pulleys to change speeds
Feeds:	All power, except compound
Toolholder:	Multiple
Year Manufactured:	1965
Other:	Single-tooth clutch arrangement on apron

Job Characteristics

Job:	Enlarge and finish hole in flat washers
Part Overall Dimensions:	3-3/8" OD: 2-1/16" ID; 3/4" thick
Material:	Brass
Setup Arrangement:	Washer secured in chuck
Machining Operations:	Boring and deburring
Guarding:	No point of operation and chuck guarding used during lathe operations
Other:	-

Worker Characteristics

Age and Sex:	50-55 years old, male
Position Title:	Machinist/Supervisor
Machine Shop Experience:	25 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	-

Machine Shop Characteristics

Nature of Shop Activity:	Build very precise experimental test equipment for metallurgical research
Location:	Large university in Pittsburgh, PA
Working Space:	More than adequate space in shop and around lathes
Shop Light Levels:	Good
Shop Noise Levels:	Very low
Other:	Only two machinists work in shop Occasionally there are graduate students who use shop equipment

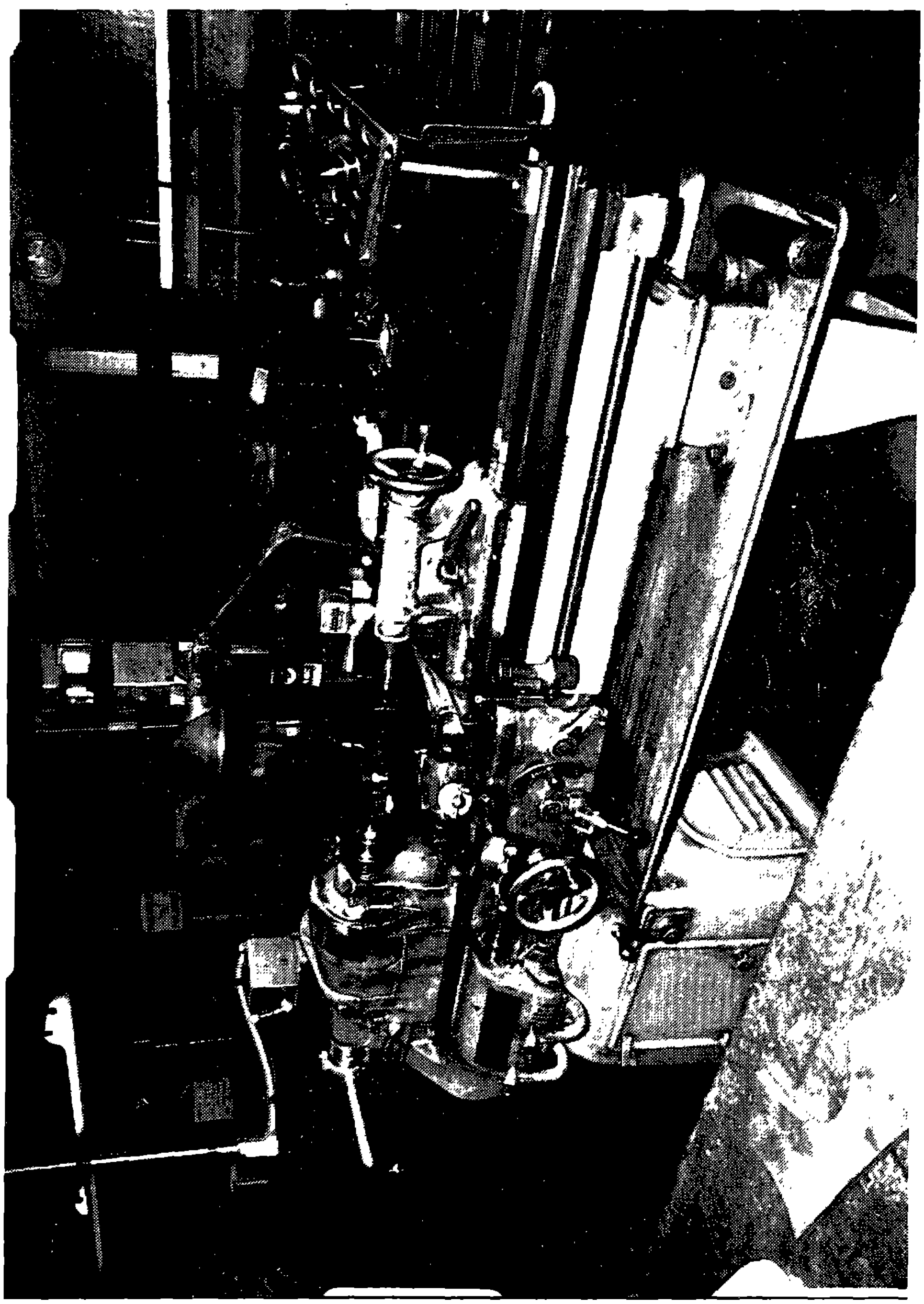


Figure C-2. Engine Lathe (b)

Engine Lathe (c)

Lathe Distinguishing Features

Size:	50" swing; 240" between centers
Accessories:	Fitted with 4-jaw chuck; steady rest
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	All power; 4-way rapid traverse
Toolholder:	Multiple
Year Manufactured:	1978 in Czechoslovakia
Other:	Coolant equipped.

Job Characteristics

Job:	Machine adjusting bolts for threading
Part Overall Dimensions:	3-3/4" dia; 13"-6" long
Material:	Steel
Setup Arrangement:	Material secured in chuck, tailstock and supported in center with steady rest
Machining Operations:	Turning
Guarding:	No point of operation and chuck guarding used during lathe operations; both point of operation and chuck guarding were removed and stored on floor in shop
Other:	Coolant used on job; job required the use of an overhead crane to position workpiece; machining one adjusting bolt generally required over 8 hours

Worker Characteristics

Age and Sex:	35-40 years old, male
Position Title:	Lathe Operator
Machine Shop Experience:	10 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations, except hard hat
Other:	Wore loose-fitting sweater over shirt with tails out of his trousers

Machine Shop Characteristics

Nature of Shop Activity:	Perform service maintenance machine work on a contract basis
Location:	Butler, PA
Working Space:	Space around the lathe was limited because of other machine tools, workbenches, and other material
Shop Light Levels:	Adequate in some areas; poor in others
Shop Noise Levels:	Moderate; occasionally high when other very large machines were operating
Other:	Most of the jobs performed in the shop involved machining very small quantities of parts

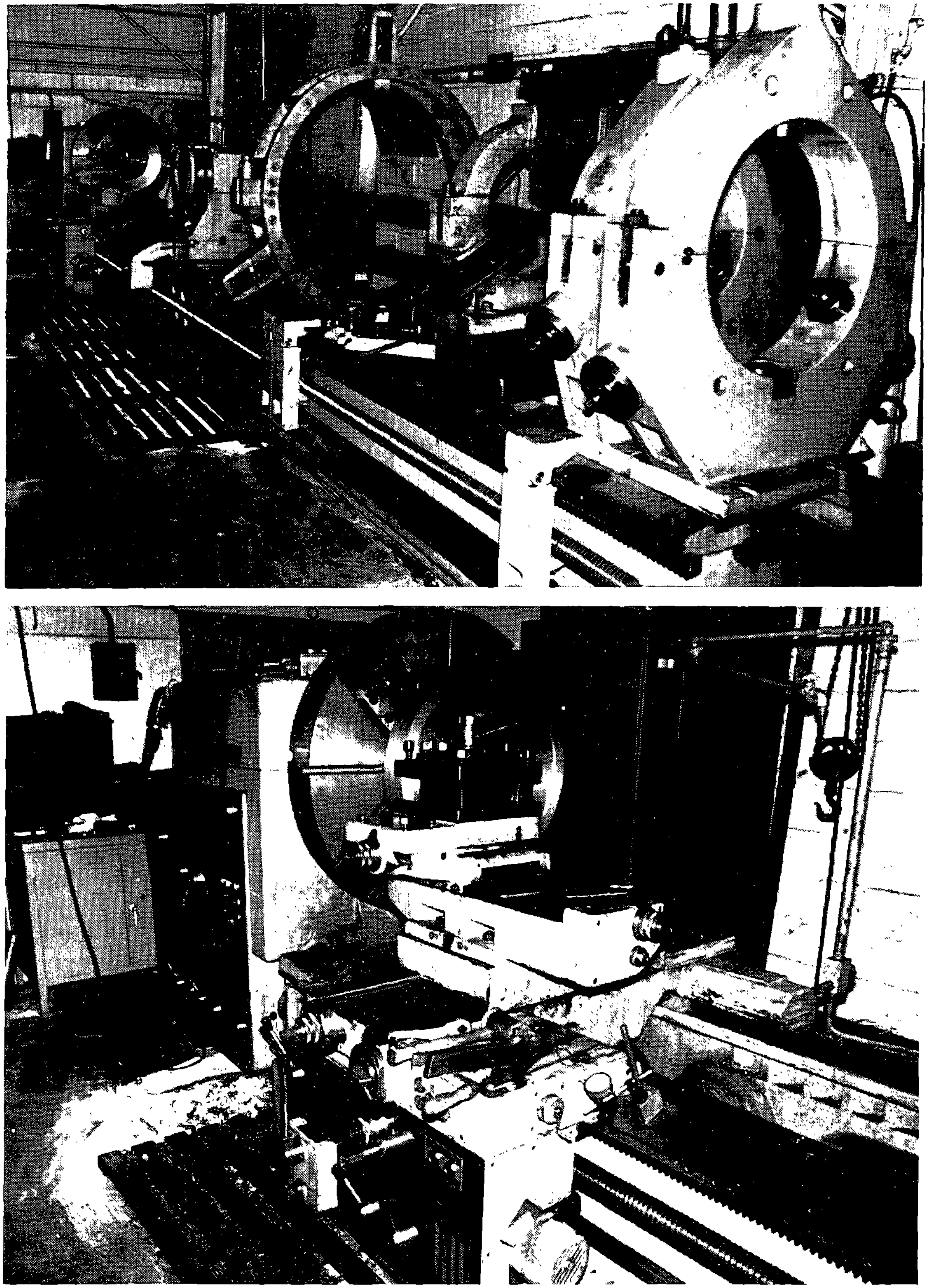


Figure C-3. Engine Lathe (c)

Engine Lathe (d)

Lathe Distinguishing Features

Size: 17" swing; 54" between centers

Accessories: Fitted with 4-jaw chuck; steady rest

Spindle Speed Change: Move speed selector handles to appropriate positions to change speeds

Feeds: All power, except compound

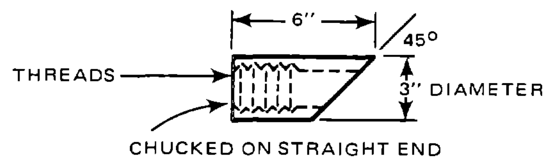
Toolholder: Boring bar with threading tool

Year Manufactured: 1966

Job Characteristics

Job: Cut internal threads on pipe coupling

Part Overall Dimensions:



Material: Steel

Setup Arrangement: Pipe coupling (straight end) secured in chuck; internal right-handed threads cut from straight end. Because the threads had to be cut from the straight end and the end with the 45° cut could not be secured in the chuck, a not-common thread-cutting procedure was used--chasing threads with the cutting tool moving toward the tailstock. The common thread-cutting procedure is to chase threads with the cutting tool moving toward the chuck.

Machining Operations: Boring and thread-cutting

Guarding: No point of operation and chuck guarding used during lathe operations

Worker Characteristics

Age and Sex: 45-50 years old, male

Position Title: Lathe Operator

Machine Shop Experience: 20 years

Personal Protective Equipment: Wore all necessary protective equipment during lathe operations

Machine Shop Characteristics

Nature of Shop Activity: Perform service maintenance machine work on a contract basis

Location: Butler, PA

Working Space: Space around the lathe was limited because of other machine tools, workbenches, and other material

Shop Light Levels: Adequate in some areas; poor in others

Shop Noise Levels: Moderate; occasionally high when other very large machines were operating

Other: Most of the jobs performed in the shop involved machining very small quantities of parts

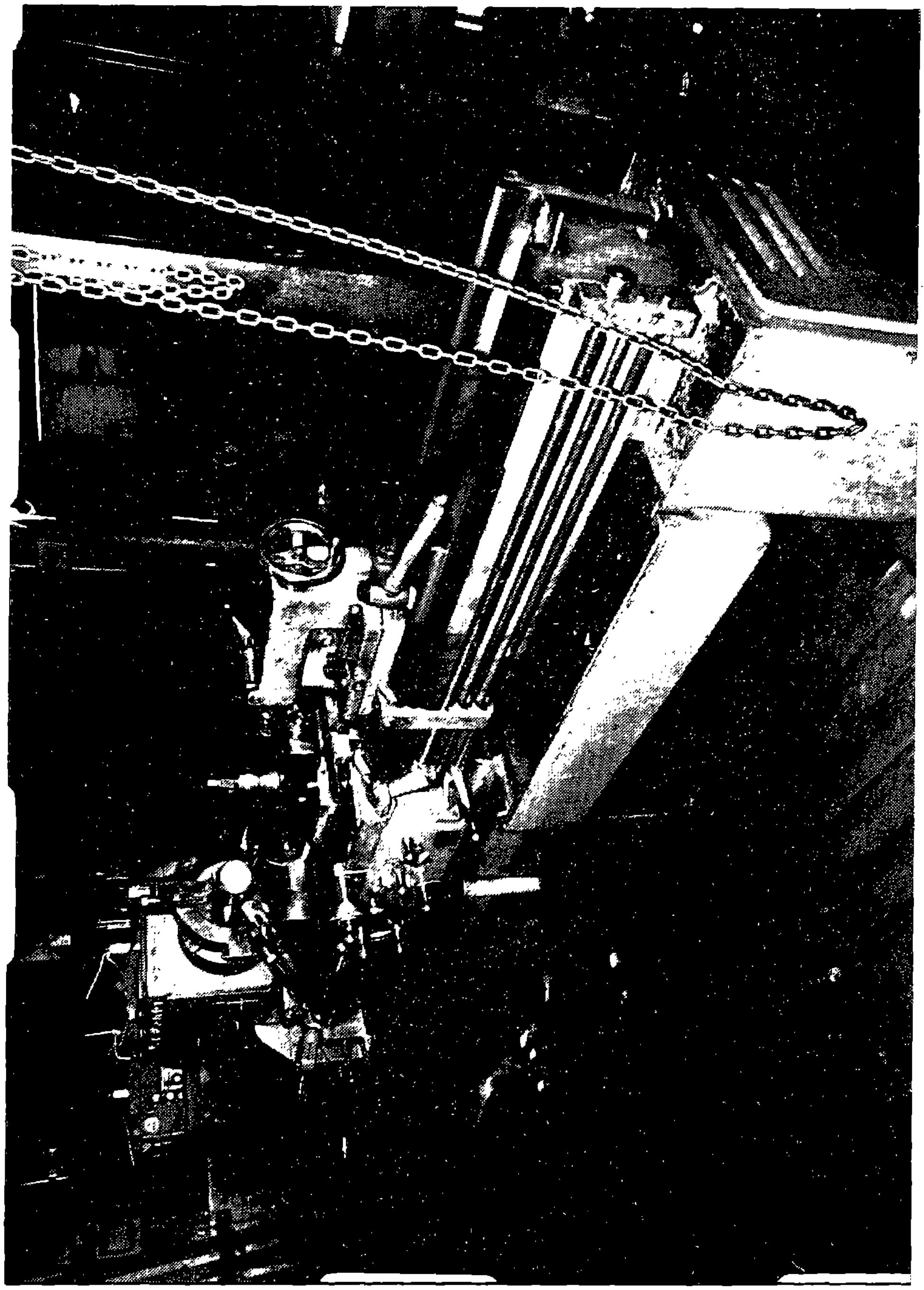


Figure C-4. Engine Lathe (d)

Engine Lathe (e)

Lathe Distinguishing Features

Size:	20" swing; 110" between centers
Accessories:	Fitted with faceplate
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	All power, except compound; 2-way rapid traverse
Toolholder:	Multiple
Year Manufactured:	1968
Other:	-

Job Characteristics

Job:	Finish machine pins
Part Overall Dimensions:	3" x 6"; 7-1/2" long
Material:	Steel
Setup Arrangement:	Pin secured between centers; used lathe dog to drive pin
Machining Operations:	Turning and facing
Guarding:	No point of operation and chuck guarding used during lathe operations
Other:	Pins had been rough machined

Worker Characteristics

Age and Sex:	18 years old, female
Position Title:	Apprentice
Machine Shop Experience:	5 months, 2 months on lathe
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	Wore a loose-fitting shirt

Machine Shop Characteristics

Nature of Shop Activity:	Provide maintenance support for large manufacturing plant
Location:	Butler, PA
Working Space:	Space around lathe and throughout shop was more than adequate; generally uncrowded
Shop Light Levels:	Above average
Shop Noise Levels:	Low to moderate
Other:	-

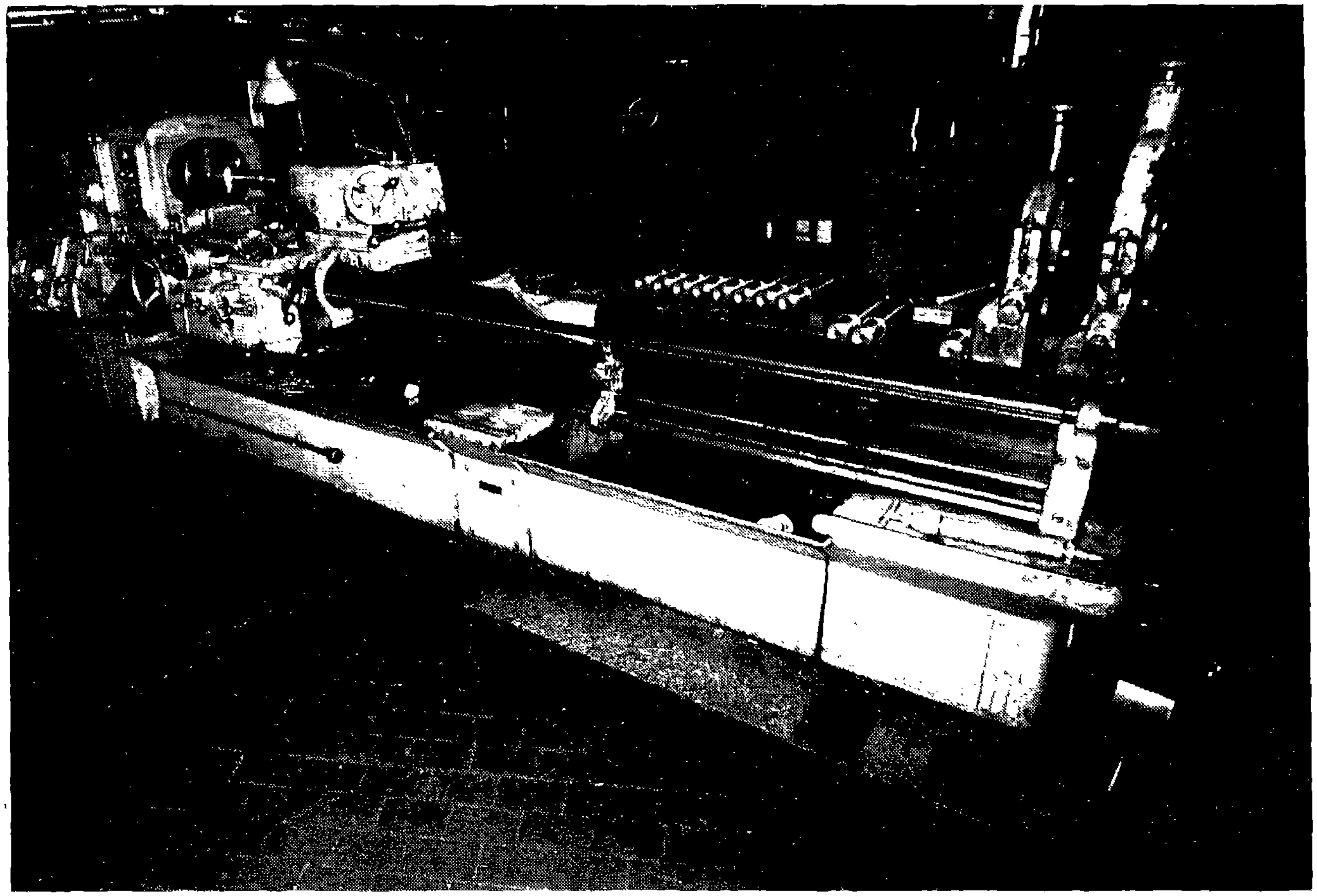


Figure C-5. Engine Lathe (e)

Engine Lathe (f)

Lathe Distinguishing Features

Size:	19" swing; 124" between centers
Accessories:	Fitted with 4-jaw chuck
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	All power, except compound; 2-way rapid traverse did not operate
Toolholder:	Multiple
Year Manufactured:	1955-1960
Other:	-

Job Characteristics

Job:	Rough machine ends of roll
Part Overall Dimensions:	8" dia.; 5'-6" long
Material:	Steel fabricated
Setup Arrangement:	Roll secured in chuck and tailstock
Machining Operations:	Turning and facing
Guarding:	No point of operation and chuck guarding used during lathe operations
Other:	-

Worker Characteristics

Age and Sex:	26-30 years old, female
Position Title:	Apprentice
Machine Shop Experience:	5-1/2 months
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	Left-handed

Machine Shop Characteristics

Nature of Shop Activity:	Provide maintenance support for large manufacturing plant
Location:	Butler, PA
Working Space:	Space around lathe and throughout shop was more than adequate; generally uncrowded
Shop Light Levels:	Above average
Shop Noise Levels:	Low to moderate
Other:	-

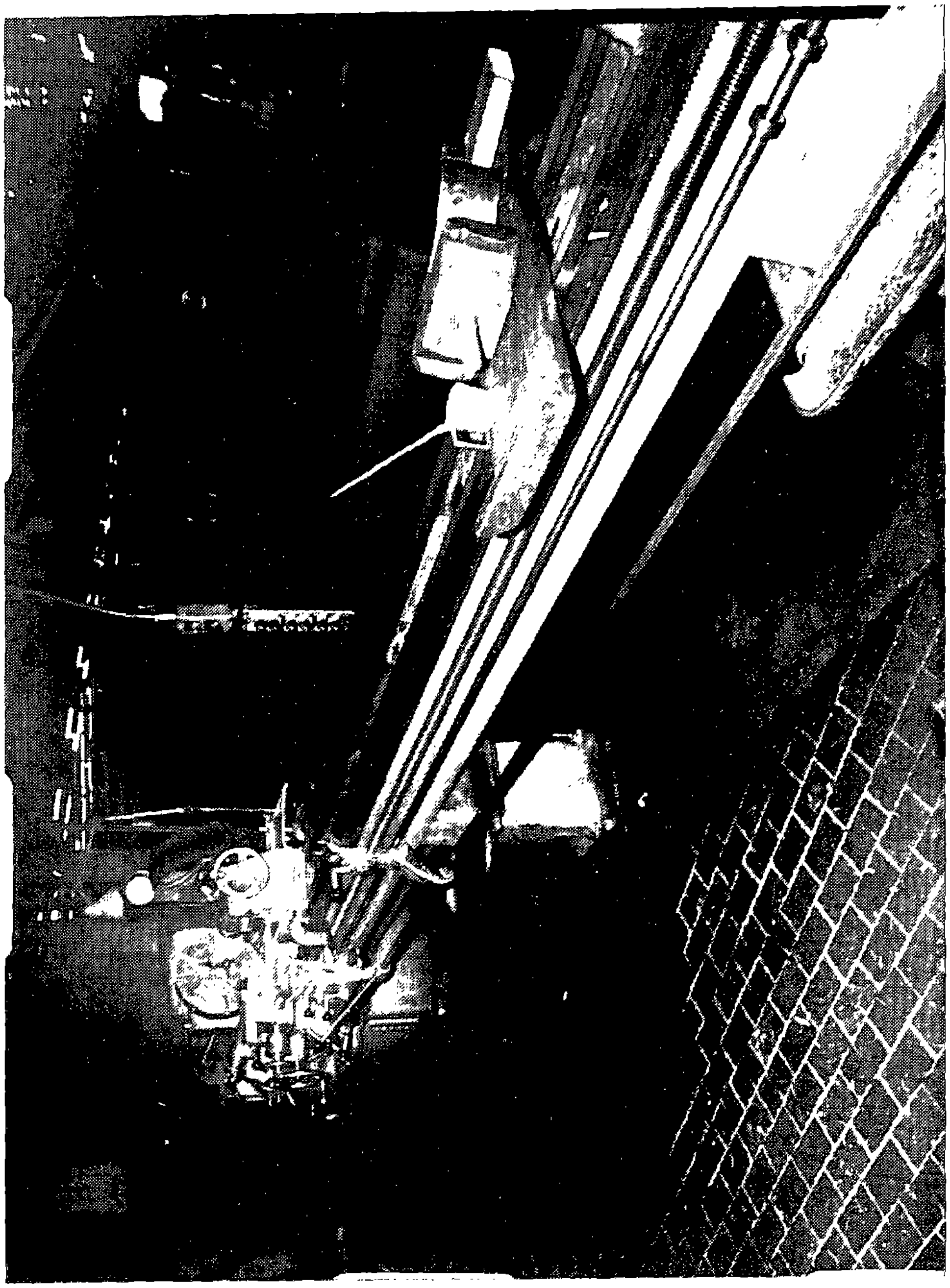


Figure C-6. Engine Lathe (f)

Engine Lathe (g)

Lathe Distinguishing Features

Size:	Approx. 50" swing; Approx. 300" between centers
Accessories:	Fitted with 4-jaw chuck
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	All power
Toolholder:	Multiple
Year Manufactured:	Approx. 1941
Other:	-

Job Characteristics

Job:	Rough machine rolls
Part Overall Dimensions:	21-1/2" dia.; 132-1/2" long
Material:	Forged steel, weighing approx. 20,000 lbs.
Setup Arrangement:	Roll secured in chuck and tailstock
Machining Operations:	Turning and facing
Guarding:	Point of operation guarding used, but no chuck guarding used during lathe operations
Other:	Job required the use of an overhead crane to position workpiece; machining one roll generally required 8 hours

Worker Characteristics

Age and Sex:	45-50 years old, male
Position Title:	Machinist
Machine Shop Experience:	25 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	Loose sleeves on shirt

Machine Shop Characteristics

Nature of Shop Activity:	Produce mill rolls
Location:	Pittsburgh, PA
Working Space:	Space around lathe was generally uncrowded, but there were areas in the shop that were crowded
Shop Light Levels:	Adequate in most areas
Shop Noise Levels:	Moderate; occasionally high when other very large machines were operating
Other:	-

Engine Lathe (h)

Lathe Distinguishing Features

Size:	Approx. 39" swing; Approx. 330" between centers
Accessories:	Fitted with 4-jaw chuck and tracer attachment
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	All power
Toolholder:	Multiple
Year Manufactured:	1959
Other:	-

Job Characteristics

Job:	Finish machine rolls
Part Overall Dimensions:	21-1/2" dia.; 132-1/2" long
Material:	Forged steel, weighing approx. 20,000 lbs.
Setup Arrangement:	Roll secured in chuck and tailstock
Machining Operations:	Turning and facing
Guarding:	Point of operation guarding used, but no guarding used during lathe operations
Other:	-

Worker Characteristics

Age and Sex:	45-50 years old, male
Position Title:	Machinist
Machine Shop Experience:	30 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	-

Machine Shop Characteristics

Nature of Shop Activity:	Produce mill rolls
Location:	Pittsburgh, PA
Working Space:	Space around lathe was generally uncrowded, but there were areas in the shop that were crowded
Shop Light Levels:	Adequate in most areas
Shop Noise Levels:	Moderate; occasionally high when other very large machines were operating
Other:	-

Turret Lathe (i)

<u>Lathe Distinguishing Features</u>

Size:	15-3/8" swing; 26-7/8" between spindle end and face of turret
Accessories:	Fitted with air-operated chuck
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	Power and hand-operated
Toolholder:	Ram type turret fitted with tools
Year Manufactured:	Between 1940-1945
Other:	No carriage used on lathe; coolant equipped

<u>Job Characteristics</u>

Job:	Machine threads on plugs (approx. 4000 plugs were being produced)
Part Overall Dimensions:	4-1/2" dia.; 2-1/4" long
Material:	Brass
Setup Arrangement:	Plugs secured in chuck
Machining Operations:	Turning and threading
Guarding:	A combination point of operation and chuck guarding used during lathe operations
Other:	Threading was done with a collapsible die

<u>Worker Characteristics</u>

Age and Sex:	18 years old, male
Position Title:	Operator trainee
Machine Shop Experience:	Approx. 6 months
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Other:	-

<u>Machine Shop Characteristics</u>

Nature of Shop Activity:	Perform production machine work on a contract basis; also manufactured a small line of products
Location:	Pittsburgh, PA
Working Space:	Space in the shop was very limited because of other machine tools, workbenches, and in general other material
Shop Light Levels:	Adequate in some areas, poor in others
Shop Noise Levels:	Moderate to loud, especially when some of the workers had their radios playing
Other:	Almost all the jobs performed in the shop involved machining large quantities of parts

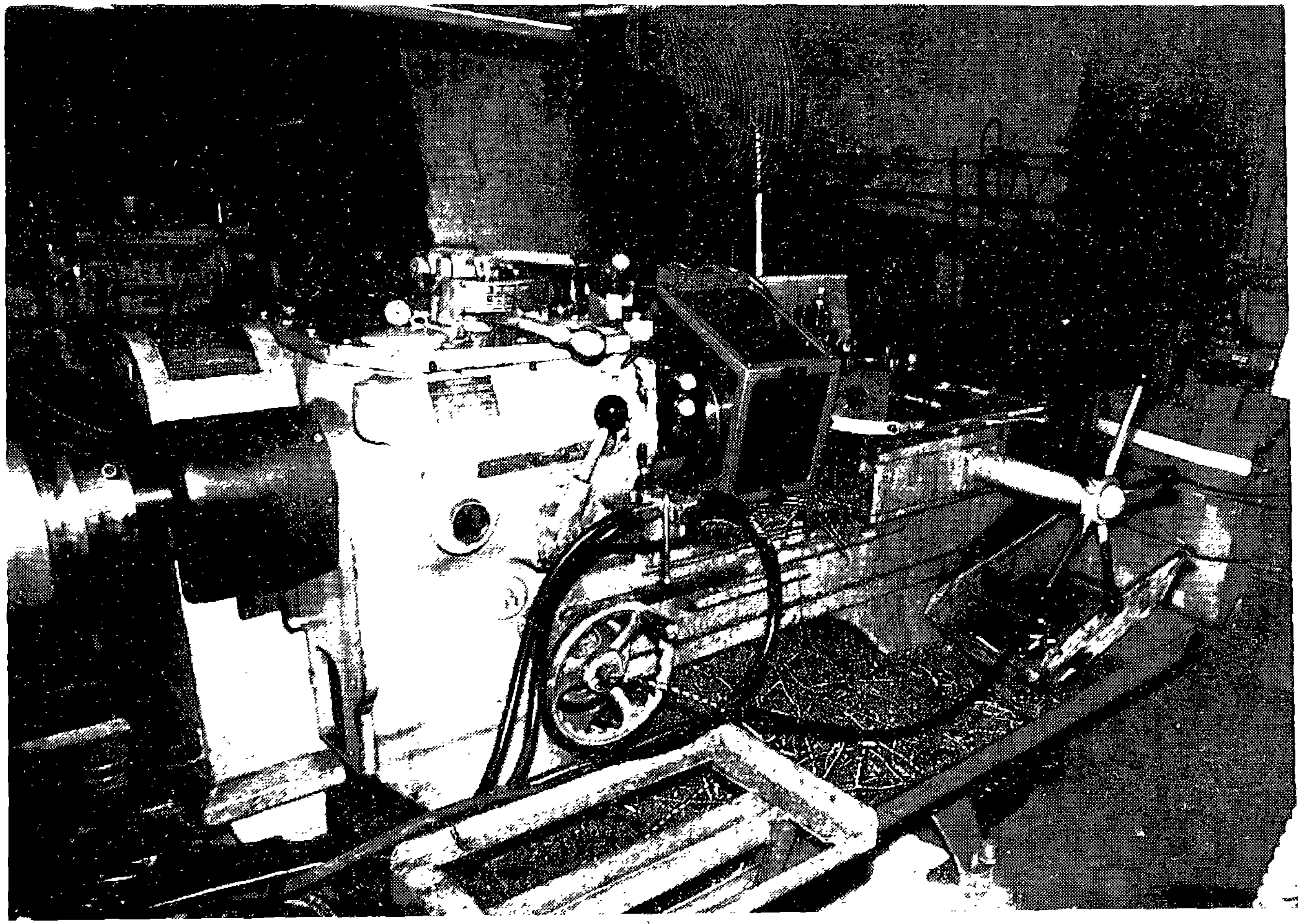


Figure C-7. Turret Lathe (i)

Turret Lathe (j)

Lathe Distinguishing Features	
Size:	20" swing; 36-1/2" between spindle end and face of turret
Accessories:	Fitted with hydraulic collet and bar feed
Spindle Speed Change:	Move speed selector handles to appropriate positions to change speeds
Feeds:	Power and hand-operated
Toolholder:	Ram type turret fitted with tools; multiple toolholder on cross-slide
Year Manufactured:	1960
Other:	Coolant equipped
Job Characteristics	
Job:	Machine spring housings (not all operations required to produce this part were observed because some operations were performed on another shift). 538 spring housings were being produced
Part Overall Dimensions:	1-7/8" dia.; 8-1/2" long
Material:	Steel
Setup Arrangement:	Material secured in collet
Machining Operations:	Drilling, taping, and cutoff
Guarding:	Guarding was used over collets, but not at point of operation
Other:	Threading was done with a tap
Worker Characteristics	
Age and Sex:	33 years old, male
Position Title:	Lathe operator
Machine Shop Experience:	15 years
Personal Protective Equipment:	Wore all necessary protective equipment during lathe operations
Machine Shop Characteristics	
Nature of Shop Activity:	Perform production machine work on a contract basis; also manufactured a small line of products
Location:	Pittsburgh, PA
Working Space:	Space in the shop was very limited because of other machine tools, workbenches, and in general other material
Shop Light Levels:	Adequate in some areas, poor in others
Shop Noise Levels:	Moderate to loud, especially when some of the workers had their radios playing
Other:	Almost all the jobs performed in the shop involved machining large quantities of parts

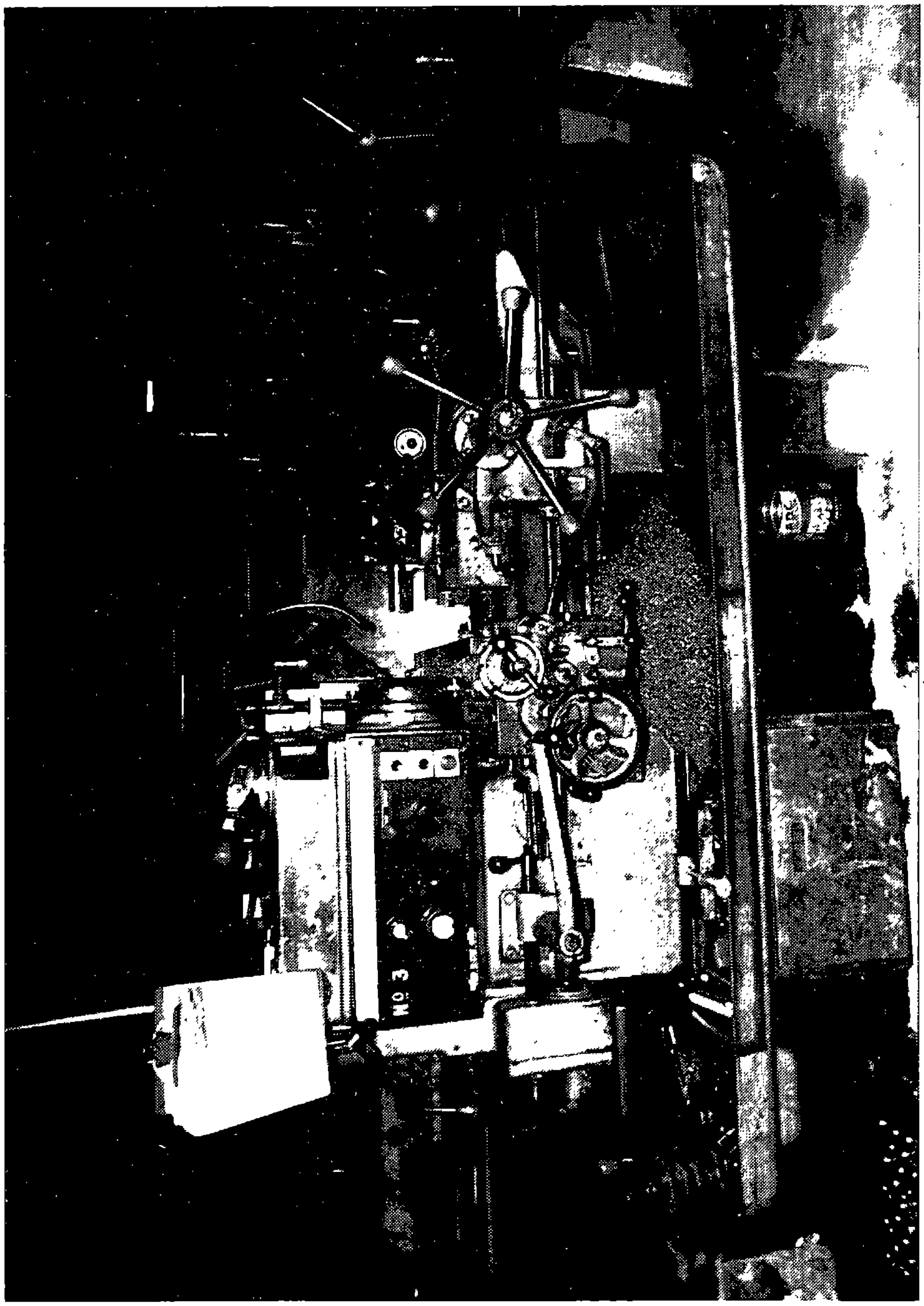


Figure C-8. Turret Lathe (j)

APPENDIX D

COMPLETED HAZARD ANALYSIS RECORDING FORM SAMPLES

Machine Shop Engine Lathe (c)

HAZARD ANALYSIS

Worker No. 1 Job Machine Adjusting Bolts Page 1

Lathe Operation	Worker's Activity Descriptions	Injury Potential Situations (IPSs)
1 Setup (approx. 10:00 a.m.)	-Opens chuck jaws—both hands used. -Moves Lever A on headstock. -Centers compound on carriage. -Loosens tailstock nuts.	Uses extreme force to loosen nuts--could strain arm muscle.
	-Brings bar stock over lathe with crane; opens steady rest.	Is not wearing hard hat--bar stock could slip in from rigging and strike worker.
	-Positions stock between chuck and tail-stock.	
	-Tightens jaws on stock while placing spacer between jaws and stock; then tightens jaws with both hands.	
	-Adjusts setscrews in shaft collar; places it over stock and moves it to steady rest. (Screws appear to be 1-1/2" to 2" long; collar will act as bearing surface for steady rest.)	

Machine Shop Engine Lathe (c)

HAZARD ANALYSIS

Worker No. 1 Job Machine Adjusting Bolts Page 2

Lathe Operation	Worker's Activity Descriptions	Injury Potential Situations (IPSs)
Setup (continued)	-Fits centering cap on tailstock end of stock (used for aligning bar stock with tailstock center); moves tailstock; secures tailstock.	Uses extreme force to tighten tailstock nuts--could strain arm muscle
	-Centers shaft collar in steady rest. -Centers bar stock in chuck--uses left hand to rotate chuck while watching dial indicator.	
	-Adjusts centering cap--uses dial indicator.	Trips on cuttings protruding from between slats of wooden floor mat--could have fallen.
	-Adjusts chuck to center stock. -Adjusts shaft collar in steady rest--places right leg inside of bed ways. -Locks tailstock spindle. -Sets cutting speed--does not refer to speed chart on lathe. -Starts up lathe. -Adjusts tool post toolholder.	
	-Oils shaft collar in steady rest with stock rotating--uses oil can with curved spout.	Oil can could catch on shaft collar set-screws (you can't see the screws--rotating too fast) and pull can and hand into rotating path of screws.
	-Sets levers on carriage apron.	

Machine Shop Engine Lathe (c)

HAZARD ANALYSIS

Worker No. 1 Job Machine Adjusting Bolts Page 3

Lathe Operation	Worker's Activity Descriptions	Injury Potential Situations (IPSs)
2 Turning	-Takes first cut; measures OD and takes another. -Makes mistake on movement of lever--pushed in, should have pulled out (error, but no potential for injury). -Sets lever on apron. Places right arm on tailstock.	Right hand is very close (approx. 2") to path of rotating screws on centering cap; faces opposite direction while talking with fellow worker; flexes fingers—fingers could contact screws. Reaches over centering cap to feel finish; arm is very close to rotating path of screws—arm could contact screws.
	-Increases depth of cut. -Moves carriage toward tailstock. -Adjusts cutting tool. -Takes cut--increases cutting feed. -Stops lathe--measures shaft. -Starts lathe--continues cut.	

Machine Shop Engine Lathe (c)

HAZARD ANALYSIS

Worker No. 1 Job Machine Adjusting Bolts Page 4

	Lathe Operation	Worker's Activity Descriptions	Injury Potential Situations (IPSs)
2	Turning (continued)	-Uses hand to check temperature of shaft collar while rotating--hand close to screws.	Hand is very close to rotating path of screws on shaft collar--could accidently contact screws since he is intermittently looking away to visual check cutting tool.
3	Shut Down (approx. 3:30 p.m.)	-Lathe is shut down and worker cleans lathe in preparation for quitting work at 4:00 p.m.	

OTHER

During the observation of this worker, another worker used a closed-loop-handle device to remove cuttings wrapping around a workpiece. If cuttings had caught, device and hand could have been pulled into the rotating workpiece.

APPENDIX E

EVALUATION CHECKLIST QUESTIONS;
COMPLETED HUMAN ENGINEERING EVALUATION FORM SAMPLE

EVALUATION CHECKLIST QUESTIONS

Visibility

1. Is there a clear view of the control from where the worker normally stands during lathe operations?

   Rule/Example: If one must stoop to the floor or walk behind the lathe to see a control, the control is not visible.

Identifiability

1. Are there sufficient differences (e.g., color, size, shape, etc.) between the control and surrounding controls for visual identification?

   Rule/Example: If one can not see a difference between the control selected for operation and surrounding controls, there is not sufficient differences for visual identification.

2. Are there sufficient differences (e.g., color, size, shape, etc.) between the control and surrounding controls for tactile identification?

   Rule/Example: If one can not feel a difference between the control selected for operation and surrounding controls, there is not sufficient differences for tactile identification.

3. Is there sufficient distance between the control selected for operation and surrounding controls for identification by location?

   Rule/Example: If one can not sense a difference in the position of one's hand when placed on the control selected and when placed on the surrounding controls, there is not sufficient differences for identification by location.

Accessibility

1. Can the control be reached without the worker bending over; stretching; reaching over or under, or around some part of the lathe; or taking an awkward position?

   Rule/Example: If one has to bend over; stretch (stand on toes); reach over or under, or around some part of the lathe; or take an awkward position, the control is not accessible.

2. Can the control be reached without removing or repositioning covers or other controls?

   Rule/Example: If one has to lift or remove covers, or reposition other controls, the control is not accessible.

Operability

1. Can the worker's hand fit around the control to provide the force and movement required to operate the control?

   Rule/Example: If one's fingers can not reach to the backside of the control handle (push buttons excluded), the control is not operable with respect to fit.

2. Would the control be comfortable if used for an extended period of time?

   Rule/Example: If there are sharp edges, points or abrasive finishes on the control handle, the control is not operable with respect to comfort.

3. Does the control have sufficient shape configuration to ensure the needed grip required for control operation?

   Rule/Example: If the control handle (push buttons excluded) does not have a shape that would prevent the hand from slipping off, the control is not operable with respect to grip.

4. Is there sufficient leverage to apply the required force when operating the controls?

   Rule/Example: If one has to exert an extreme amount of force (use two hands, use body weight), the control is not operable with respect to leverage.

5. Is there sufficient space to move the control with the worker's hand on it?

   Rule/Example: If in operating the control, one's hand is pinched, scraped, nicked, or bruised by other controls or other parts of the lathe, the control is not operable with respect to space.

6. Are there labels on, or adjacent to the control that identify control positions?

   Rule/Example: If there are no labels or markings on, or adjacent to the control indicating positions, the control is not operable with respect to identified control positions.

APPENDIX F

WORKMEN'S COMPENSATION FIRST REPORT SAMPLES

5

EMPLOYER'S FIRST REPORT OF INJURY OR DISEASE

FORM WC-12 (9-71)

STATE OF WISCONSIN
DEPARTMENT OF INDUSTRY, LABOR AND HUMAN RELATIONS
WORKMEN'S COMPENSATION DIVISION
P.O. BOX 2209, MADISON 53701

Send 1 copy of this report to Employers Insurance of Wausau (See address on fro... Retain 1 copy for OSHA filing)

STATISTICAL CODING BLOCK
0 2725 000666

Employer must make this report directly to the Department of Industry, Labor and Human Relations on the fourth day after employe leaves work if disability still continues. In death cases, report must be made within twenty-four hours. In case of permanent disability, or where disability beyond the three day waiting peri... is certain to result, make report at once.

1. Date of Report: 1-17-77 | Made Out By: [redacted] | Position of Person Making Out Report: Superv. Nurses | OSHA Case or File Number:

Employer

2. Employer's Name: [redacted] | Is Employer: ☐ Individual ☐ Partnership ☒ Corp. | Employer's Phone No. [redacted]
3. [redacted] (Street No.) (City or Town) [redacted] | Employer Location If Different From Mail Address:
4. [redacted] Transportation Etc.): Manufacture | (Specific Product): Machine Tools
5. Name of Your Insurance Company (If Self-Insurer by Commission Order, So State): EMPLOYERS MUTUAL LIAB. INS. CO. OF WISCONSIN, 6620 West Capitol Drive, Milwaukee, Wisconsin 53216 | Policy No:

Injured Employe

6. Name (First) [redacted] (Middle) (Last) | [redacted] | Sex: ☒ M ☐ F | Married: X Yes ☐ No
7. [redacted] | Occupation: Production Machinist - Engine La...
8. Age: 29 | Date of Birth: 5/10/47 | If Employe Under 18 Was Permit on File? Yes No | Worked for you how long? | Under Which Classification of Your Policy Were Wages Earned?
9. Is Injured an Officer, Partner, Proprietor or Manager? ☐ Yes ☒ No | If yes, State His Position:
10. Department (Enter Name of Department or Division in Which Injured is Regularly Employed Though He May Have Been Temporarily Working in Another Department at Time of Injury): Minor Machining

Accident/Illness Resulting From Exposure To Mechanical, Chemical or Physical Agency

11. Place of Accident or Exposure on Employer's Premises? Yes (X) No | Give Accident Location Below. If Location is Not Identifiable by Street & Number (e.g. Public Highway) Please Provide Place References Locating the Place of Injury as Accurately as Possible.
12. [redacted] | Accident Occured in (X): ☐ City ☐ Village ☐ Township
13. What Was Employe Doing When Injured? (Using What Tools & Equipment? Handling What Materials? Doing What With Them? Unsafe Acts?)
Employe was polishing a gear in a mandril using an emery cloth and a file. As he applied pressure on the emery cloth, the gear slipped in the mandril and the employe's left index finger struck the revolving chuck.
14. How Did The Accident Occur? (Events Which Resulted in the Injury or Occupational Disease—Tell What Happened and How it Happened—Give Full Details on all Factors Which Led or Contributed to the Accident, Objects or Substances Involved)
See above

Occupational Disease or Injury

15. Date of Injury (Mo.Da.Yr.): 1/13/77 | Hour of Day: 9:00 P. M. | Last Day Worked: 1/13/77 | Did Injury Occur in the Course of Injured's Regular Employment? Yes X No | Previous Physical Defects:
16. Nature and Extent of Injury (State Exactly the Part of Body Affected and the Nature of the Injury or Disease): Laceration dorsum left hand at head of 5th m.c. with adjacent abrasion
17. Name the Object or Substance Which Directly Injured the Employe. (For Example, The Machine or Thing He Struck Against or Which Struck Him; The Vapor or Poison Inhaled or Swallowed; The Chemical or Radiation Which Irritated His Skin; or in Cases of Strains, Hernias, etc., the Thing He Was Lifting, Pulling, Pushing, etc.): revolving chuck
18. Did Injury Occur Because of (Yes or No) → Intoxicated: no | Failure to Use Safety Devices: no | Failure to Obey Rules: no | If Employe Has Returned to Work Give Date → Mo. Day Yr. | If Employe Has Not Returned To Work, How Long Will He Be Away From Work? est. 7-10 days
19. Did Death Result? If yes, Give Name, Relationship, Age and Address of Dependents. ☐ Yes ☒ No
20. Name and Address of Treating Doctor: [redacted], Emergency Services [redacted] | Name and Address of Hospital if Injured Was Hospitalized: & Personal Physician (name not known)

Wage Information

CHECK IF MAXIMUM WAGE CONCEDED ☐ IF NOT, COMPLETE WAGE INFORMATION BELOW:

21. Wage Rate at Time of Injury $ 5.49	Per (X)	Hour X	Day	Week	Month	Other
21(a). Was Salary Continued During Lost Time?	Yes	No X	Hrs. Per Day	Hrs. Per Wk.	Days Per Wk.	In Addition To Cash Wages, Did Employee Receive: (Yes or No)
22. Injured Employe's Scheduled Work Week at Time of Injury			8	40	5	Board / Room / Tips / Laundry
23. Normal Full Time Employment for Injured's Kind of Work			8	40	5	
24. For the 52 Weeks Prior to the Date of Injury, Report the Number of Weeks Worked in the Same Kind of Work, and the Total Wage, Salary, Commission and Bonus or Premium Earned for Such Weeks.			No. of Weeks Worked: 10	Gross Amount (Excluding Bonus or Premium): 2164 24	Bonus or Premium:	If Piece Worker No. of Hours Worked:
25. Are Injured's Wages Carried on Your Regular Payroll Upon Which Your Policy Premium Is Based?	Yes X	No	If He is Employed as a Jobber or Contractor, Give Name			

26. Name of Witnesses

1303-4824 10-72

FIRST REPORT CASE NUMBER 975

EMPLOYER'S FIRST REPORT OF INJURY OR DISEASE
FORM WC-12 (9-71)

THE STATE OF WISCONSIN
Department of Industry, Labor and Human Relations
WORKMEN'S COMPENSATION DIVISION
Box 2209, Madison, Wisconsin 53701

STATISTICAL CODING BLOCK: 37280 | 069481 | 775

EMPLOYER

1. Date of Report: 7-13-78 — Made Out By: [redacted] — Position of Person Making Out Report: President
2. Employer's Name: [redacted] — Is Employer: Individual / Partnership / X Corporation — [redacted]
3. [redacted] Butler, WI. 53007 — Employer Location If Different From Mail Address
4. Manufacture, Trade, Transportation Etc.: Manufacture — (Specific Product) [redacted]
5. Name of Your Insurance Company (If Self-Insurer by Commission Order, So State): NORTHWESTERN NATIONAL INSURANCE CO. — 32147E

INJURED EMPLOYE

6. Name (First) (Middle) (Last): [redacted] — Social security No. [redacted] — Sex: Male X / Female
7. [redacted] West Allis, WI. 53214 — Occupation: General Machinist
8. Age: 65 6-17-1913 — If Employe Under 18 Was Permit on File? Yes / No — Worked for you how long? 4 months — Under Which Classification of Your Policy were Wages Earned?
9. Is Injured an Officer, Partner, Proprietor or Manager? Yes / No X — If Yes, State His Position
10. Department (Enter Name of Department or Division in Which Injured is Regularly Employed Though He May Have Been Temporarily Working in Another Department at Time of Injury): Machine Shop

ACCIDENT, ILLNESS RESULTING FROM EXPOSURE TO MECHANICAL, CHEMICAL OR PHYSICAL AGENCY

11. Place of Accident or Exposure on Employer's Premises? Yes X / No — Give Accident Location Below. If Location is Not Identifiable by Street & Number on a Public Highway Please Provide Place References Locating the Place of Injury as Accurately as Possible
12. [redacted] City or Town, State: Butler, WI. — Accident Occurred: City / Village ✓ / Township
13. [redacted] (Using What Tools & Equipment? Handling What Materials? Doing What With Them? Unsafe Acts?)
He was boring, reaming, and facing 3 1/2" Dia. round steel on a [redacted] 2L Turret Lathe.
14. How Did The Accident Occur? (Events Which Resulted in the Injury or Occupational Disease—Tell what Happened and How it Happened. Give Full Details on all Factors Which Led or Contributed to the Accident. Objects or Substances involved)
After employee tightened chuck on the machine, he started the chuck moving without removing chuck key. As chuck began to spin with the key still in it, the employees finger was caught between the chuck key and start lever.

OCCUPATIONAL INJURY OR DISEASE

15. Date of Injury (Mo., Day, Yr.): 7-10-78 — Hour of Day: 10:45 AM — Last Day Worked: 7-10-78 — Did Injury Occur in the Course of Injured's Regular Employment? Yes X / No — Previous Physical Defects: None
16. Nature and Extent of Injury (State Exactly the Part of Body Affected and the Nature of the Injury or Disease): Little finger on left hand was broken in two places
17. Name the Object or Substance Which Directly Injured the Employe (For Example, the Machine or Thing He Struck Against or Which Struck Him; The Vapor or Poison Inhaled or Swallowed; The Chemical or Radiation Which Irritated His Skin; or in Cases of Strains, Hernias, etc., the Thing He Was Lifting, Pulling, Pushing, etc.)
Chuck key and start lever of machine chuck.
18. Did Injury Occur Because of (Yes or No) → Intoxication: No — Failure to Use Safety Devices: NO — Failure to Obey Rules: NO — If Employe Has Returned to Work Give Date → Mo / Day / Yr — If Employe Has Not Returned To Work How Long Will He Be Away From Work? 1-2 weeks
19. Did Death Result? (If Yes, Give Name, Relationship, Age and Address of Dependents.) Yes / X No

20. Name and Address of Treating Practitioner: Milwaukee County General — Emergency — Name and Address of Hospital if Injured was Hospitalized

WAGE INFORMATION

CHECK IF MAXIMUM WAGE CONCEDED — IF NOT, COMPLETE WAGE INFORMATION BELOW

21. Wage Rate at Time of Injury $ 4.50 Per (X) Hr. X / Day / Week / Month / Other
22. Injured Employe's Scheduled Work Week at Time of Injury: Hrs. Per Day / Hrs. Per Wk. / Days Per Wk.: 20
23. Normal Full Time Employment for Injured's Kind of Work: [illegible]
24. For the 52 Weeks Prior to the Date of Injury, Report the Number of Weeks Worked in the Same Kind of Work, and the Total Wage, Salary, Commission and Bonus or Premium Earned for Such Weeks: No. of Weeks Worked: 16 — Gross Amount Excluding Bonus or Premium: 1,078.00 — Bonus or Premium: —
25. Are Injured's Wages Carried on Your Regular Payroll Upon Which Your Policy Premium is Based? Yes X / No — If He is Employed by a Jobber or Contractor Give Name: Employee Claims no lost time [illegible]
26. Name of Witnesses [redacted]

Employer must make [redacted] report directly to the Department [redacted] Industry, [redacted] on the fourth day after [illegible]

COMPLETED CODING FORM FOR
FIRST REPORT CASE NUMBER 975

CODING FORM

	Variables	Values
1.	First Report Case Number	975
2.	State	7
3.	Lathe Type	2
4.	Operator's Job Classification	3
5.	Operator's Age	65
6.	Operator's Sex	1
7.	Operator's Activity	14
8.	Object of Operator's Activity	29
9.	General Source of Injury	3
10.	Specific Source of Injury	17
11.	Nature of Injury	8
12.	Part of Body Injured	6
13.	Accident Type (causal factor)	3
14.	Safeguarding Present	—
15.	Good Injury Description or Unusual Injury	1

FIRST REPORT CASE NUMBER 639

Form C-1 6-72

INSTRUCTIONS: This application is to be used in injury cases where ONLY MEDICAL EXPENSES are involved. No compensation for lost time will be paid on this application. Mail completed application to: CLAIMS SECTION, Bureau of Workmen's Compensation, Ohio Departments Bldg., Columbus, Ohio 43215.

STATE OF OHIO
BUREAU OF WORKMEN'S COMPENSATION [redacted]

PART I. Application for Payment of Medical Benefits

1. Claimant's Name [redacted] (First) (Middle Initial) [redacted] (Last)
2. Home address [redacted] (Number) (Street) Tel. No. [redacted] (Area)
[redacted] (County) (City) (State) (Zip)
3. Social Security No. [redacted] Date Birth [redacted] Age 50 Male? ☑ Female? ☐ (Check correct reply)
4. Employer's Name: [redacted]

Accident location [redacted] (Address where accident occurred — number, street)
[redacted] 44044 (city, state) Was accident actually on employer's premises? yes (Yes or No)

5. Department Secondary (in which regularly employed), Occupation 2nd class machine operator (regular job title)
6. Date of Accident 3/31/78 A.M. (Month-Day-Year-A.M. or P.M.) Date reported to employer? 3/31/78
7. Describe accident: While attempting to adjust belts on [redacted] Turret Lathe employee stopped machine, opened motor and pulley enclosure and (Exactly what happened? How did it happen? Name objects or substances and explain how they were involved.) placed hand on belts to check belt tension. But motor was not completely stopped as yet and belts pulled hand into pulley.
8. Describe exact nature of injury and specific part (or parts) of body affected:
Broke tip of middle finger/left hand and lacerated ring and index finger same hand. (amputation of left little finger, laceration of right lower leg, back strain on lower right side, etc.)
9. Names and addresses of witnesses: None
10. If hospitalized, name of hospital: [redacted]
Address: [redacted] (Number) (Street) (City) (State) (Zip)
11. Name of attending physician: [redacted]
Address [redacted] (Number) (Street) (City) (State) (Zip)
12. Have you filed a previous application concerning this injury? no
If so, give claim number:
13. Last date worked 3/31/78 Date returned to work 4/10/78
Did you receive your wages during disability? no No. of Dependents 1
14. Have you filed other claims with the Bureau or Industrial Commission? no (Yes or No)
If so, give claim numbers and part of body injured: (Attach extra sheet if necessary)
15. Names of all employers for whom you worked during year prior to this injury:
[redacted]

I, the injured employee herein, certify that the information set forth above is true and ask that the medical expenses directly related to this claim be paid. I hereby authorize any doctor or hospital to furnish to the Bureau of Workmen's Compensation any medical information which they may have with reference to me.

Date: April 4, 1978 [redacted] (Signature of Claimant)

PART II. Employer's Report of Industrial Injury

1. Name of Employer [redacted] (Must be exactly as shown on certificate of coverage)
2. Office address [redacted] . Ohio 44044 (Number) (Street) (City) (Zone) (State)
3. Nature of business [redacted] (Farming, coal mining, etc.) Type of organization Corporation (Corp., Partnership, Individual)
4. The earnings of the injured employee for services rendered at time of injury are being reported on payroll reports of
Risk No. [redacted] Manual 3145

CRT - COY

By signing this report, I certify that I have authority to execute this Employer's Report and that the answers are true to the best of my knowledge and belief.

The Employer certifies that this is a valid claim for payment of medical expenses only and waives notice of claim and other approving its payment from the Administrator of the Bureau of Workmen's Compensation as provided in R. C. 4123.512-513.

0 K 16

[redacted] (Name of Employer must be exactly as shown on certificate of coverage)
[redacted] President (Signature and Title)

SPECIAL NOTICE TO EMPLOYER

If the validity of this claim is questioned by you, sign this application but cross out the last paragraph above and attach your reasons for denying the validity of the claim.

Case No. OSHA Log	
Do not write in this column	
Age	50
Sex & c.c.	4
Dependents	40
Location (Geo.)	478
Date Report Filed	4748
Date of Injury	033178
Report Lag	073
Occupation	690
Agency	0417
Agency Part	06
Type of Injury	0
Nature of Injury	60
Part of Body	3520
Complications	
Degree of Injury	7
Days Lost	0010
Coded by	
Manual No.	3145
Risk No.	[redacted]

JUN 19 1978

COMPLETED CODING FORM FOR
FIRST REPORT CASE NUMBER 639

CODING FORM

	Variables	Values
1.	First Report Case Number	639
2.	State	4
3.	Lathe Type	2
4.	Operator's Job Classification	2
5.	Operator's Age	50
6.	Operator's Sex	1
7.	Operator's Activity	13
8.	Object of Operator's Activity	1
9.	General Source of Injury	5
10.	Specific Source of Injury	37
11.	Nature of Injury	9
12.	Part of Body Injured	6
13.	Accident Type (causal factor)	3
14.	Safeguarding Present	1
15.	Good Injury Description or Unusual Injury	1

FIRST REPORT CASE NUMBER 651

Form C-1, Rev. 8, 1972

INSTRUCTIONS: This form to be used where the injury causes more than seven days of disability. Compensation and medical expenses are both paid on this application. The employee is to complete and sign Part I of this form and the employer is to complete and sign Part II. The completed application is to be mailed to CLAIMS SECTION, Bureau of Workmen's Compensation, Ohio Departments Bldg., Columbus, Ohio 43215. Only one copy of the application should be filed.

STATE OF OHIO — Claim No.
BUREAU OF WORKMEN'S COMPENSATION [redacted]
Application for Payment of Compensation and Medical Benefits

PART I

1. Claimant's Name [redacted] (First) [redacted] (Middle initial) [redacted]
2. Home address [redacted] (Number) (Street) Tel. No. [redacted] (Area)
[redacted] (County) (City) (State) (Zip Code)
3. Social Security No. [redacted] Date of Birth 3/26/58 Age 20 Male ☒ Female ☐ (Check)
4. Employer's Name: [redacted]
Accident location: [redacted] (Address where accident occurred — number, street, city, state)
Was accident actually on employer's premises? Yes (Yes or No)
5. Department Gear (In which regularly employed) Occupation Machinest (regular job title)
6. Date of Accident 4/28/78 9:30 AM (Month-Day-Year-A.M. or P.M.) Date reported to employer? Same
7. Describe accident: Stood at back of Lathe discussing (Describe in detail the events which resulted in the injury. Exactly what happened? How did it happen? Name objects or substances and explain how they were involved.) dimension of workpiece with operator. Right hand rested atop of Lathe frame. Revolving bolt on head stock caught right shirt sleeve and pulled arm & body into Lathe
8. Describe exact nature of injury and specific part (or parts) of body affected: Deep laceration of (Amputation of left little finger, laceration of right lower leg, back strain on lower right side, etc.) side from bottom of rib cage to underarm, lacerations to right arm. Partially collapsed lung.
9. Names and addresses of witnesses: [redacted]
10. If hospitalized, name of hospital: [redacted]
Address: [redacted] (Number) (Street) (City) (State) (Zip Code)
11. Name of attending physician [redacted]
12. Address [redacted] (Number) (Street) (City) (State) (Zip Code)
13. Have you filed a previous application concerning this injury? N/o
If so, give claim number:
14. Last date worked 4/28/78 Date returned to work 5/8/78
Did you receive your wages during disability? N/a No. of Dependents 2
15. Have you filed other claims with the Bureau or Ind. Comm.? No (Yes or No)
If so, give claim numbers and part of body injured: (Attach extra sheet if necessary)
16. Names of all employers for whom you worked during year prior to this injury: [redacted]

I hereby make application to The Bureau of Workmen's Compensation for the payment of money out of the State Insurance Fund for compensation for injuries sustained in the course of my employment, and which have not been purposely self-inflicted, and for money to pay for medical services, etc., which were necessary in the treatment of my said injuries. Notice of hearing is hereby waived.

I HEREBY AUTHORIZE The Bureau of Workmen's Compensation to pay any or all awards for medical, hospital and similar services directly to person or persons rendering such service.

By signing this application I expressly waive, on behalf of myself and of any person who shall have any interest in this claim, all provisions of law forbidding any physician or other person who has heretofore attended or examined me, or who may hereafter attend or examine me from disclosing any knowledge or information which they thereby acquired. I have read all the statements contained herein and know the same to be true and correct.

[redacted]

(If applicant signs by mark, two witnesses must sign here) (Signature of applicant (if unable to sign, mark must be made))

DATE 5/14/78

Do not write in this column	
Case No. OSHA Log	
Age	20
Sex & c. c.	04
Dependents	40
Location (Geo.)	090
Date Report Filed	5318
Date of Injury	042878
Report Lag	032
Occupation	544
Agency	0417
Agency Part	00
Type of Injury	0
Nature of Injury	60
Part of Body	2896
Complications	
Degree of Injury	7
Days Lost	0009
	JUL 31 1978
Coded by	/
Manual No.	5632
Risk No.	[redacted]

COMPLETED CODING FORM FOR
FIRST REPORT CASE NUMBER 651

CODING FORM

Variables	Values
1. First Report Case Number	651
2. State	4
3. Lathe Type	(crossed out)
4. Operator's Job Classification	3
5. Operator's Age	20
6. Operator's Sex	1
7. Operator's Activity	8
8. Object of Operator's Activity	31
9. General Source of Injury	3
10. Specific Source of Injury	8
11. Nature of Injury	9
12. Part of Body Injured	2
13. Accident Type (causal factor)	3
14. Safeguarding Present	(crossed out)
15. Good Injury Description or Unusual Injury	1

FIRST REPORT CASE NUMBER 951

EMPLOYER'S FIRST REPORT OF INJURY OR DISEASE
FORM WC-12 (9-71)

Department of Industry, Labor and Human Relations
WORKMEN'S COMPENSATION DIVISION
Box 2209, Madison, Wisconsin 53701

STATISTICAL CODING BLOCK: 08360 | 28355 | 19 -1

EMPLOYER

1. Date of Report: 2-4-77 | Made Out By: [redacted] | Position of Person Making Out Report: General Foreman | OSHA Case or File Number: #36

2. [redacted] | Is Employer: ☐ Individual ☐ Partnership ☐ Corporation | Employer's Phone No.

3. [redacted] (City or Town) Marshfield, WI 54449 | [redacted]

4. [redacted] (Manufacture, Trade, Transportation Etc.) [redacted] (Product): Manufacturer of Transformer Radiators & Concrete Products Equipment

5. Name of Your Insurance Company (If Self-Insurer by Commission Order, So State): FIDELITY & GUARANTY INSURANCE UNDERWRITERS, INC., 2525 NORTH MAYFAIR RD, MILWAUKEE, WIS. 53226 | Policy No.

INJURED EMPLOYE

6. Name (First) (Middle) [redacted] | [redacted] | Sex: Male Female | Married: Yes No

7. [redacted] Marshfield, Wis 54449 | Occupation: Lathe-mill Operator

8. Age: 62 | Date of Birth: 3/26/14 | [redacted] Was Permit on File? Yes No: x | Worked for you how long? 18 yrs. 7 mths. | Under Which Classification of Your Policy Were Wages Earned?

9. Is Injured an Officer, Partner, Proprietor or Manager? Yes No: X | If Yes, State His Position

10. Department (Enter Name of Department or Division in Which Injured is Regularly Employed Though He May Have Been Temporarily Working in Another Department at Time of Injury): Lathe department

ACCIDENT/ILLNESS RESULTING FROM EXPOSURE TO MECHANICAL, CHEMICAL OR PHYSICAL AGENCY

11. Place of Accident or Exposure on Employer's Premises? Yes: x No | Give Accident Location Below. If Location is Not Identifiable by Street & Number (e.g. Public Highway, Please Provide Place References Locating the Place of Injury as Accurately as Possible.

12. Place of Accident or Exposure (Street & No., City or Town, State): Town of Cameron - Marshfield, Wisconsin | Accident Occurred in: City Village Township ✓

13. What Was Employe Doing When Injured? (Using What Tools & Equipment? Handling What Materials? Doing What With Them? Unsafe Acts?)

Frank was changing chucks in the lathe. He bumped his left knee on the handle of the apron on the lathe. He didn't think it was serious at the time. His knee swelled up in the evening of the 3rd. He reported to me on the 4th of February.

14. How Did The Accident Occur? (Events Which Resulted in the Injury or Occupational Disease - Tell What Happened and How it Happened - Give Full Details on all Factors Which Led or Contributed to the Accident, Objects or Substances involved)

Bumped his left knee on the handle of the apoon on the lathe.

OCCUPATIONAL INJURY OR DISEASE

15. Date of Injury (Mo., Day, Yr.): 2-2-77 | Hour of Day: 11:50A.M | Last Day Worked: 2-11-77 | Did Injury Occur in the Course of Injured's Regular Employment? Yes: ✓ No | Previous Physical Defects

16. Nature and Extent of Injury (State Exactly the Part of Body Affected and the Nature of the Injury or Disease): Swellon left ~~knee~~

17. Name the Object or Substance Which Directly Injured the Employe. (For Example, The Machine or Thing He Struck Against or Which Struck Him, The Vapor or Poison Inhaled or Swallowed, The Chemical or Radiation Which Irritated His Skin; or in Cases of Strains, Hernias, etc., the Thing He Was Lifting, Pulling, Pushing, etc.)

Handle of the apron on the lathe

18. Did Injury Occur Because of (Yes or No) → Intoxicated: no | Failure to Use Safety Devices: no | Failure to Obey Rules: no | If Employe Has Returned to Work, Give Date → Mo. Day Yr. | If Employe Has Not Returned To Work, How Long Will He Be Away From Work? one week

19. Did Death Result? If Yes, Give Name, Relationship, Age and Address of Dependents. ☐ Yes XX No

20. Name and Address of Treating Practitioner: Marshfield Clinic - Marshfield, Wis. | Name and Address of Hospital if Injured Was Hospitalized

WAGE INFORMATION

CHECK IF MAXIMUM WAGE CONCEDED ☐ IF NOT, COMPLETE WAGE INFORMATION BELOW:

21. Wage Rate at Time of Injury $ 5.18 Per (X): Hr. X Day Week Month Other

22. Injured Employe's Scheduled Work Week at Time of Injury | Hrs. Per Day | Hrs. Per Wk. | Days Per Wk. | In Addition To Cash Wages, Did Employe Receive (Yes or No): Board Room Tips Laundry

23. Normal Full Time Employment for Injured's Kind of Work

24. For the 52 Weeks Prior to the Date of Injury, Report the Number of Weeks Worked in the Same Kind of Work, and the Total Wage, Salary, Commission and Bonus or Premium Earned for Such Weeks | No. of Weeks Worked | Gross Amount (Excluding Bonus or Premium) | Bonus or Premium | If Piece Worker No. of Hours Work

25. Are Injured's Wages Carried on Your Regular Payroll Upon Which Your Policy Premium is Based? Yes No | If He is Employed as a Jobber or Contractor, Give Name

26. Name of Witnesses

Employer must make this report directly to the Department of Industry, Labor and Human Relations on the fourth day after employe leaves wo if disability still continues. In death cases, report must be made within twenty-four hours. In case of permanent disability, or where disabili beyond the three day waiting period is certain to result, make a report at once.

COMPLETED CODING FORM FOR
FIRST REPORT CASE NUMBER 951

CODING FORM

Variables	Values
1. First Report Case Number	951
2. State	7
3. Lathe Type	—
4. Operator's Job Classification	2
5. Operator's Age	62
6. Operator's Sex	1
7. Operator's Activity	29
8. Object of Operator's Activity	4
9. Specific Source of Injury	2
10. Nature of Injury	3
11. Part of Body Injured	11
12. Accident Type (causal factor)	3
13. Safeguarding Present	—
14. Good Injury Description or Unusual Injury	1

APPENDIX G

ACCIDENT TYPES, FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES

ACCIDENT TYPE 1

Slipped Hand. The worker's hand slipped on the tool/part/control lever.

ACCIDENT TYPE 1 INFORMATION

Contributing Events. The events that caused or led to Type 1 accidents involved the worker's hand slipping from the tool/part when he was:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; or (c) the workpiece

2. Polishing, filing or deburring the workpiece

3. Loading/unloading the workpiece

4. Removing/replacing the chuck, wrench or other attaching devices

5. Setting up the: (a) chuck, other attaching devices, or some other part of the lathe; or (b) workpiece

6. Operating the lathe*

Resulting Events. The events that resulted from Type 1 accidents included injury of the worker's fingers, hand, or wrist on:

1. The cutting tool or holder

2. The chuck wrench, chuck or other attaching devices

3. The workpiece

4. The tailstock or associated accessories, or control handle, lever, knob or wheel

5. A cutter, tap, die, drill or reamer.

6. Cuttings/chips

7. Hand tool

---

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Other events that resulted from Type 1 accidents included:

1. Injury of the worker's arm or shoulder on the chuck or other attaching devices, or the workpiece.

2. Injury of the worker's foot or leg on the tailstock or associated accessories, chuck or other attaching devices, or the workpiece.

Injury Types. The types of injuries associated with Type 1 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	26
Bruises or Contusions	16
Fractures	4
Punctures	2
Amputations	1
Strains or Sprains	1
Missing	5
Total:	55

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
Three diagrams included; 48 injuries represented.

Diagram 1
Lathe operations and workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; or (c) the workpiece

2. Loading/unloading the workpiece

3. Removing/replacing the chuck, wrench or other attaching devices

4. Setting up the: (a) chuck, other attaching devices, or some other part of the lathe; or (b) workpiece

5. Operating the lathe

Types and Numbers of injuries represented:

Injury Types	Frequency
Bruises or Contusions	10
Lacerations	4
Fractures	2
Punctures	1
Total:	17

Diagram shown in Figure G-1; countermeasures shown in Table G-1.

Diagram 2
Lathe operations and workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; or (c) the workpiece

2. Polishing, filing or deburring the workpiece

3. Loading/unloading the workpiece

4. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	13
Bruises or Contusions	3
Fractures	1
Amputations	1
Missing	2
Total:	20

Diagram shown in Figure G-2; countermeasures shown in Table G-2.

Diagram 3
Lathe operations and workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; or (c) the workpiece

2. Loading/unloading the workpiece

3. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	5
Fractures	1
Bruises or Contusions	2
Punctures	1
Total:	11

Diagram shown in Figure G-3; countermeasures shown in Table G-3.

Table G-1. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #1

1. Require workers to remove, whenever practical, unneeded sharp cutting tools, drills, etc. when there is a chance of accidentally contacting them. Provide convenient holding magazine for storage of the tools, drills, etc.

2. Instruct workers in the proper procedures for grasping and lifting lathe accessories and the workpiece. Emphasize the use of materials handling equipment.

3. Provide workers with wiping cloths to clean accessories, workpiece, and hands before lifting accessories or workpiece.

4. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

5. Require workers to wear safety shoes.

Table G-2. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #2

1. Provide workers with wiping cloths to clean lathe control levers on lathes, and to wipe hands.

2. Instruct workers in the proper method of grasping and shifting lathe control levers.

3. Design handles on hand tools and lathe control levers so they provide a better hand grip.

4. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

Table G-3. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #3

1. Provide workers with wiping cloths to clean lathe control levers and to wipe hands.

2. Instruct workers in the proper method of grasping and shifting lathe control levers.

3. Design handles on hand tools and lathe control levers so they provide a better hand grip.

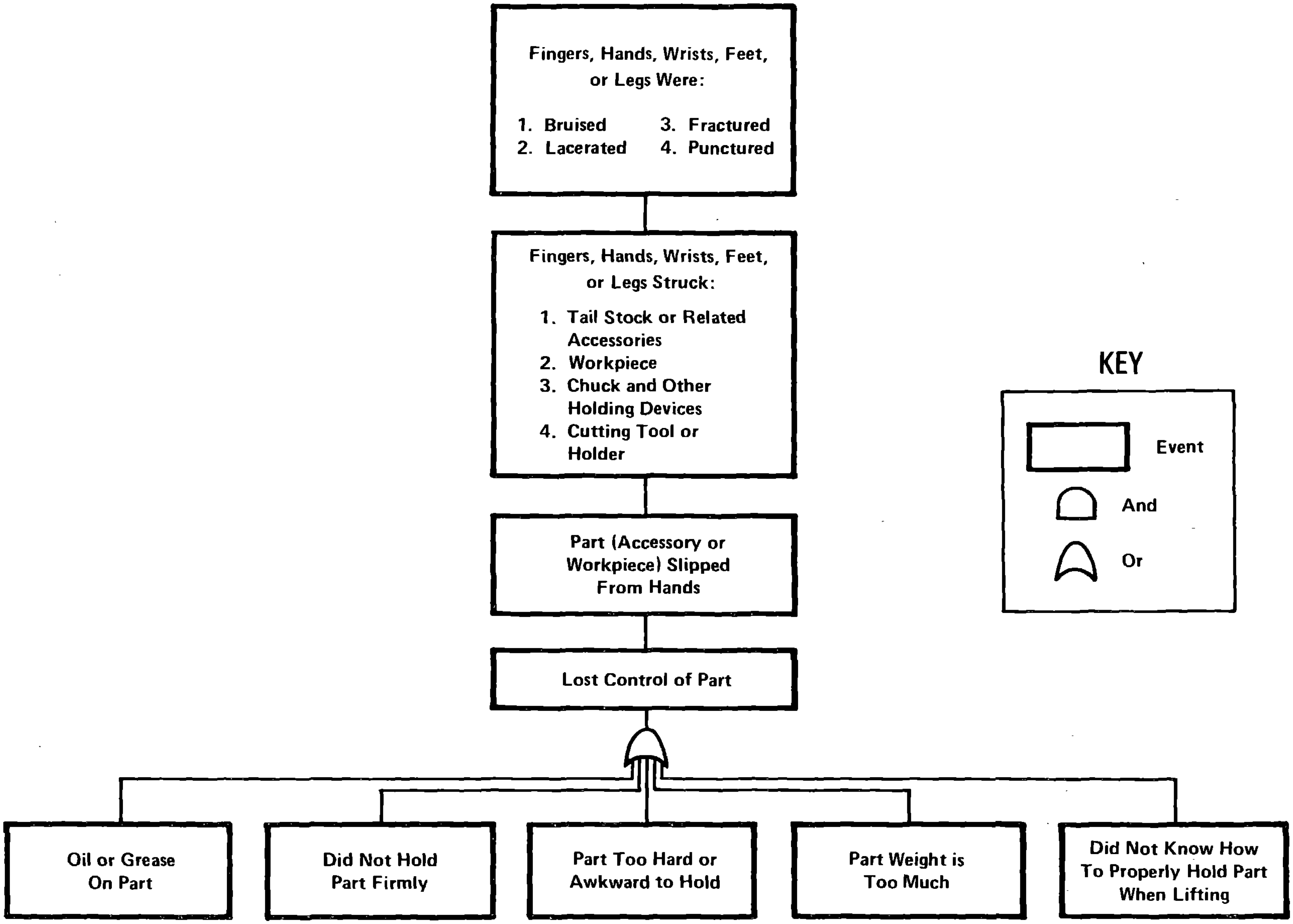


Figure G-1. Fault-Tree Diagram #1

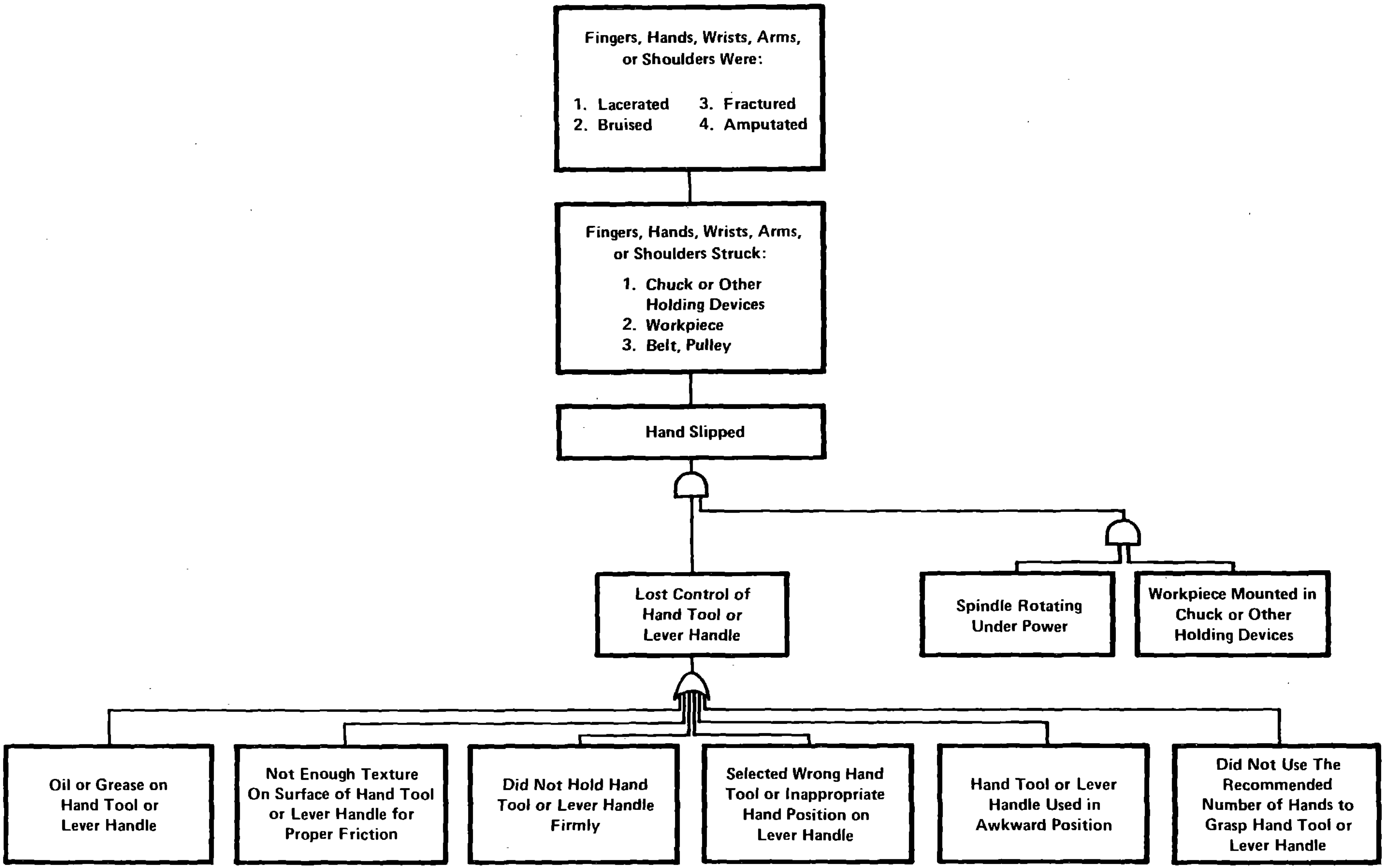


Figure G-2. Fault-Tree Diagram #2

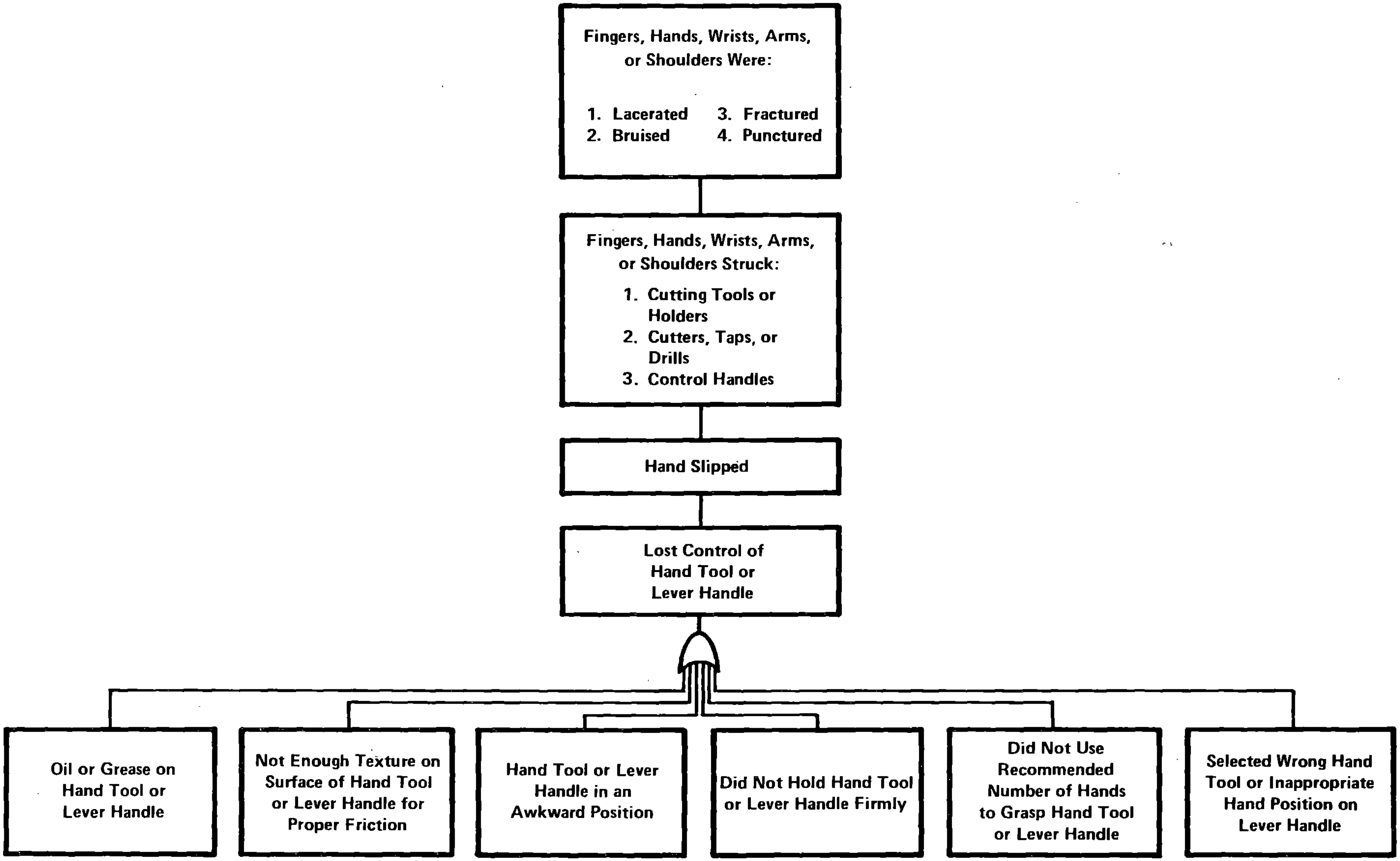


Figure G-3. Fault-Tree Diagram #3

ACCIDENT TYPE 2

Slipped Tool. The hand held tool or part slipped on the lathe or accessories.

ACCIDENT TYPE 2 INFORMATION

Contributing Events. The events that caused or led to Type 2 accidents involved the hand tool or part, which was held in the worker's hand, slipping when the worker was:

1. Applying force to: (a) tailstock or related accessories, or (b) wrench, chuck or other attaching devices

2. Polishing, filing or deburring the workpiece

3. Setting up the: (a) chuck, other attaching devices, or some other part of the lathe; or (b) workpiece

4. Cleaning/clearing the cuttings

5. Loading/unloading the workpiece

6. Operating the lathe*

Resulting Events. The events that resulted from Type 2 accidents included injury of the worker's fingers, hand, or wrist on:

1. The cutting tool, or lathe bed center area

2. The chuck or other attaching devices

3. The tailstock or related accessories

4. Polishing material

5. A hand tool

Other events that resulted from Type 2 accidents included:

1. Injury of the worker's back or upper abdomen on the workpiece or the area in the center of the lathe bed

2. Injury of the worker's arm or shoulder on: (a) cutting tool; (b) tailstock or related accessories; or (c) workpiece

---

* A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Injury Types. The types of injuries associated with Type 2 accidents are shown below.

Injury Types	Frequency
Lacerations	16
Bruises or Contusions	11
Fractures	6
Punctures	3
Strains or Sprains	2
Abrasions	1
Other	1
Missing	1
TOTAL	41

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
Two diagrams included; 36 injuries represented.

Diagram 4
Lathe operations/workers' activities included:

1. Filing, deburring and polishing the workpiece.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	11
Bruises and Contusions	3
Fractures	3
Abrasion	1
Puncture	1
Missing	2
TOTAL	21

Diagram shown in Figure G-4; countermeasures shown in Table G-4.

Diagram 5
Lathe operations/workers' activities included:

1. Applying force: (a) tailstock or related accessories, or (b) wrench, chuck or other attaching devices

2. Setting up the: (a) chuck, or other attaching devices, or some other part of the lathe; or (b) workpiece

Types and numbers of injuries represented:

Injury Types	Frequency
Bruises and Contusions	7
Lacerations	3
Fractures	3
Punctures	2
TOTAL:	15

Diagram shown in Figure G-5; countermeasures shown in Table G-5.

Table G-4. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #4

1. Replace defective files, deburring and polishing tools.

2. Provide workers with proper files, deburring and polishing tools that match the jobs they are required to perform.

3. Instruct workers on how to select the proper files, deburring and polishing tools for the job, and how to use them correctly.

4. Provide workers with the necessary setup equipment and instruct them on how to make setups that safely secure the workpiece for filing, deburring and polishing operations.

5. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

Table G-5. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #5

1. Replace worn bolts, nuts and other parts on the lathe and accessories (including chucks). Replace worn wrenches (including chuck wrenches) used on the lathe and accessories. Make certain movable parts on wrenches will not slip under pressure.

2. Provide workers with the correct size of wrenchs to perform the jobs they are required to do. Encourage workers to store wrenches in accessible locations. Where practical, remove obstructions interfering with tightening operations.

3. Instruct workers on the correct procedure for applying force when tightening or loosening bolts, nuts, chucks or other holding devices.

4. Install guards, awareness bariers or devices over chucks or other attaching devices whenever practical.

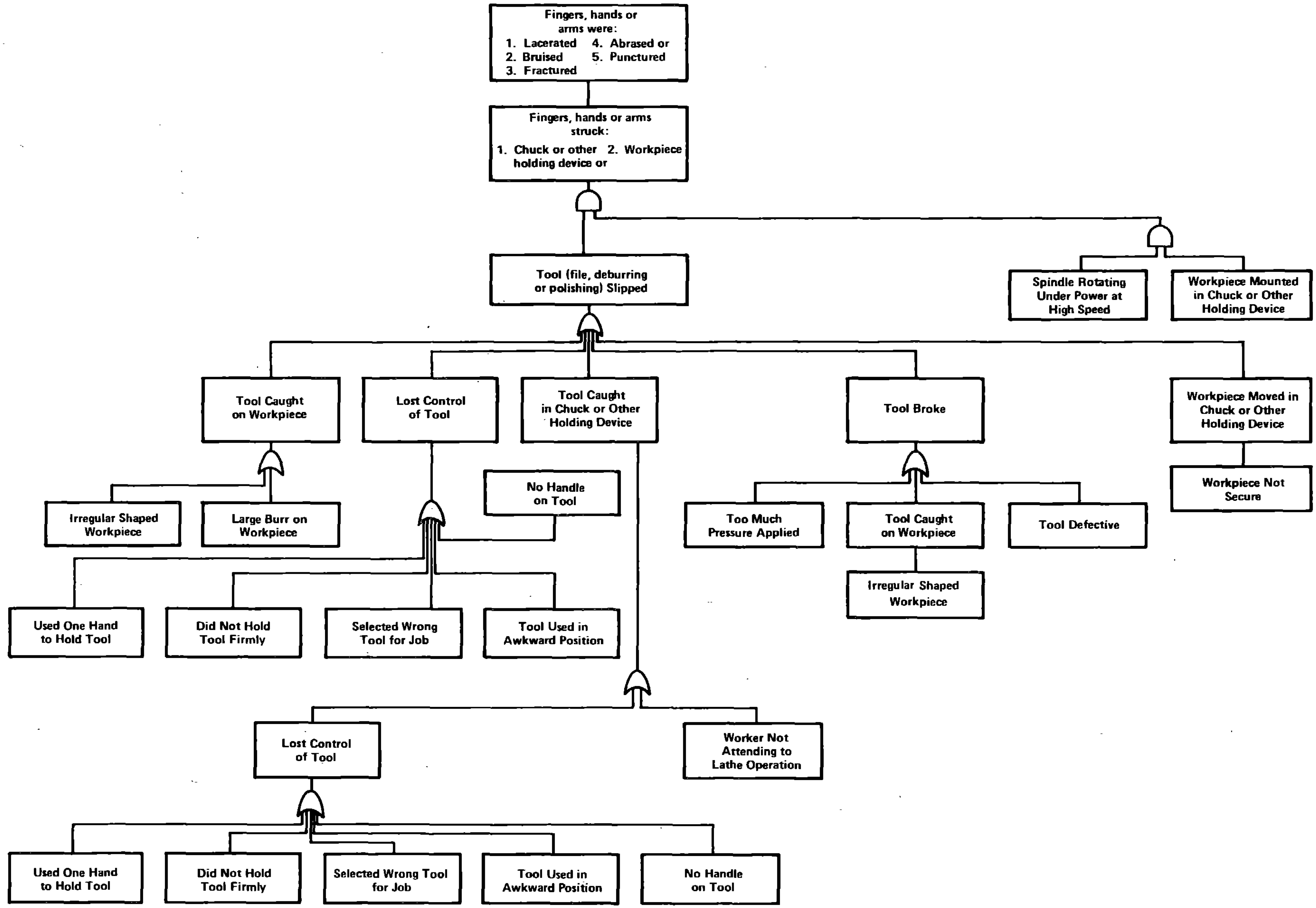


Figure G-4. Fault-Tree Diagram #4

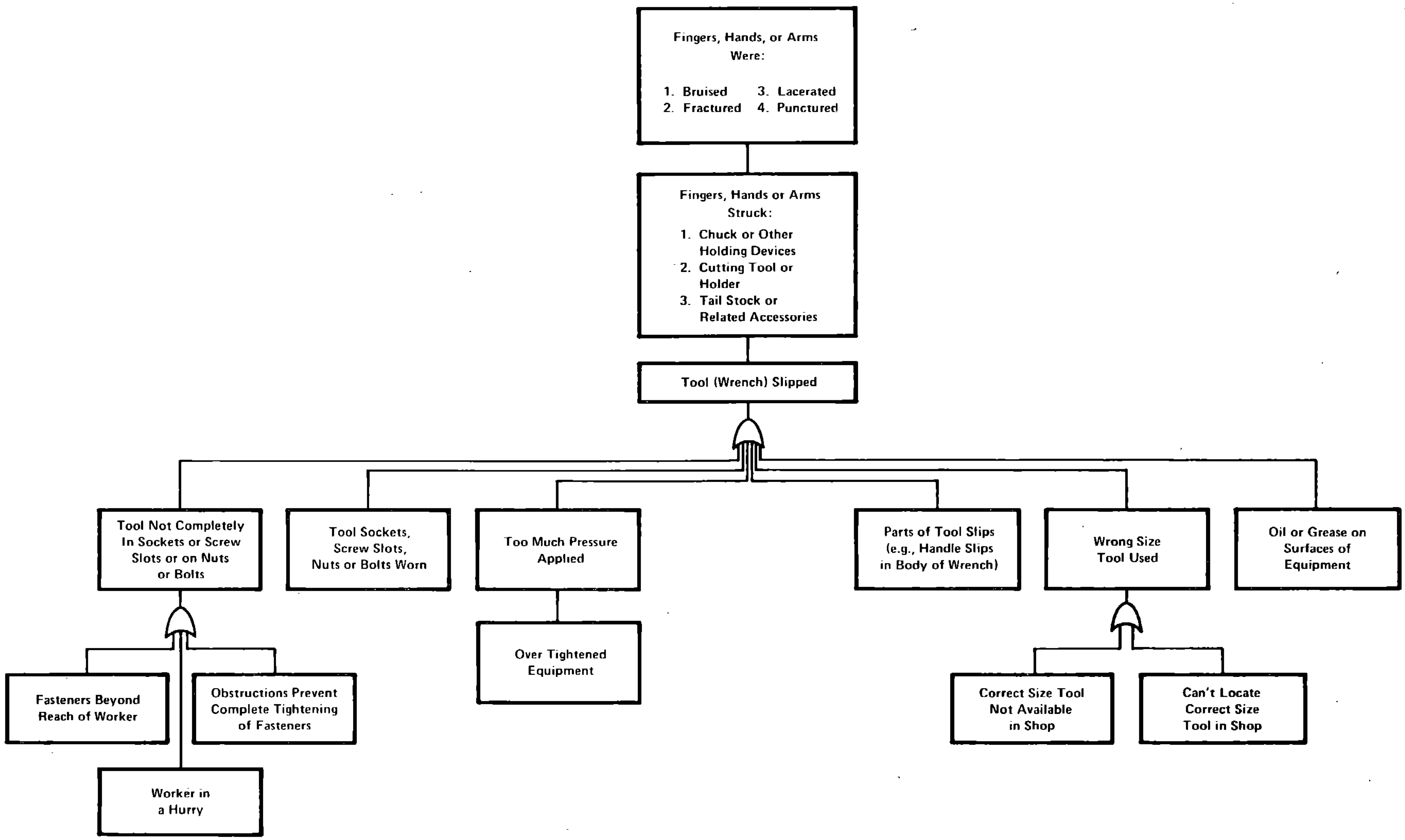


Figure G-5. Fault-Tree Diagram #5

ACCIDENT TYPE 3

Unperceived Information. Important information was not perceived before acting.

ACCIDENT TYPE 3 INFORMATION

Contributing Events. The events that caused or led to Type 3 accidents involved the worker not perceiving important information or not recalling important knowledge before acting when he was:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock and associated accessories; (c) control lever, handle or knob; (d) cuttings; (e) workpiece; or (f) small accessories or hand tools.

2. Polishing, filing or deburring the workpiece.

3. Measuring the workpiece.

4. Loading/unloading the workpiece.

5. Turning, boring or threading the workpiece.

6. Removing/replacing a control lever, handle or knob, or cuttings.

7. Setting up: (a) chuck or other attaching devices; (b) drill, cutter, reamer, tap or die; (c) workpiece; or (d) lathe.

8. Cleaning/clearing: (a) chuck or other attaching devices; (b) lathe; or (c) cuttings.

9. Reaching for: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; (c) power switch or clutch control; or (d) small accessories or hand tools.

10. Operating the lathe*.

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Resulting Events. The events that resulted from Type 3 accidents included injury of the worker's fingers, hand, or wrist on:

1. The wrench, chuck or other attaching devices
2. The cutting tool or holder
3. A control handle, lever, knob, power switch or carriage stop
4. The tailstock or associated accessories
5. A cutter, tap, die, drill, reamer or hand tool
6. Cuttings/chips
7. The workpiece
8. A shield/guard, belt, gear or pulley
9. The lathe bed center area or headstock area

Other events that resulted from Type 3 accidents included:

1. Injury of the worker's head, face or neck on: (a) cutting tool or holder; (b) cutter, tap, die, drill or reamer; (c) workpiece; or (d) lathe bed center area
2. Injury of the worker's feet or legs on the control handle, lever or knob
3. Injury of the worker's arm or shoulder on: (a) cutting tool or holder; (b) wrench, chuck or other attaching devices; (c) tailstock and associated accessories; (d) shield/guard; or (e) lathe bed center area
4. Injury of the worker's upper abdomen on chuck or attaching devices, or hand tool

Injury Types. The types of injuries associated with Type 3 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	83
Bruises or Contusions	26
Fractures	17
Punctures	7
Amputations	3
Deaths	2
Abrasion	1
Strains or Sprains	1
Missing	9
Total:	149

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
Eight diagrams included; 125 injuries represented.

Diagram 6
Lathe operations/workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock and associated accessories; (c) control lever, handle or knob; (d) cuttings; (e) workpiece; or (f) small accessories or hand tools.

2. Loading/unloading the workpiece.

3. Setting up: (a) chuck or other attaching devices; (b) drill, cutter, reamer, tap or die; (c) workpiece; or (d) lathe.

4. Reaching for: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; (c) power switch or clutch control; or (d) small accessories or hand tools.

Types and numbers of injuries included:

Injury Types	Frequency
Lacerations	15
Bruises or Contusions	5
Punctures	1
Amputations	1
Total:	22

Diagram shown in Figure G-6; countermeasures shown in Table G-6.

Diagram 7
Lathe operations/workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock and associated accessories; (c) control lever, handle or knob; (d) cuttings; (e) workpiece; or (f) small accessories or hand tools.

2. Loading/unloading the workpiece.

3. Reaching for: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; (c) power switch or clutch control; or (d) small accessories or hand tools.

4. Operating the lathe.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	4
Fractures	4
Missing	1
Total:	9

Diagram shown in Figure G-7; countermeasures shown in Table G-7.

Diagram 8
Lathe operations/workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock and associated accessories; (c) control lever, handle or knob; (d) cuttings; (e) workpiece; or (f) small accessories or hand tools.

2. Loading/unloading the workpiece.

3. Operating the lathe.

Type and number of injuries represented:

Injury Types	Frequency
Lacerations	5
Total:	5

Diagram shown in Figure G-8; countermeasures shown in Table G-8.

Diagram 9
Lathe operations/workers' activities included:

1. Loading/unloading the workpiece.

2. Operating the lathe.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	1
Bruises or Contusions	1
Fractures	1
Missing	1
Total:	4

Diagram shown in Figure G-9; countermeasures shown in Table G-9.

Diagram 10
Lathe operations/workers' activities included:

1. Polishing, filing or deburring the workpiece.

2. Turning, boring or threading the workpiece.

3. Reaching for: (a) wrench, chuck or other attaching devices; (b) control lever, handle or knob; (c) power switch or clutch control; (d) small accessories or hand tools.

4. Operating the lathe.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	31
Bruises or Contusions	6
Fractures	7
Punctures	2
Amputations	2
Death	1
Missing	4
Total:	60

Diagram shown in Figure G-10; countermeasures shown in Table G-10

Diagram 11
Lathe operations/workers' activities included:

1. Turning, boring or threading the workpiece.

2. Reaching for: (a) wrench, chuck or other attaching devices; (b) control lever, handle or know; (c) power switch or clutch control; (d) small accessories or hand tools.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	17
Fractures	1
Missing	1
Total:	19

Diagram shown in Figure G-11; countermeasures shown in Table G-11

Diagram 12
Lathe operations/workers' activities included:

1. Filing, deburring, polishing.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	2
Bruises or Contusions	1
Punctures	2
Total:	5

Diagram shown in Figure G-12; countermeasures shown in Table G-12

Diagram 13
Lathe operations/workers' activities included:

1. Measuring the workpiece.

Types and numbers of injuries represented:

Injury Types	Frequency
Death	1
Total:	1

Diagram shown in Figure G-13; countermeasures shown in Table G-13

Table G-6. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #6

1. Instruct the workers on how to develop setup and loading and unloading procedures that do not require workers to place their hands or other body members in the path of potential: (a) moving lathe parts or accessories, or (b) falling workpieces or lathe accessories.

2. Design the hinging on chuck guards or splash shields so they will remain in a secure up position during setup and loading/unloading operations.

3. Direct workers to remove, whenever practical, unneeded sharp cutting tools, drills, etc. when there is a chance of accidentally contacting them. Provide a convenient holding magazine for storage of the tools, drills, etc.

Table G-7. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #7

1. Design future lathes (where practical, retrofit older lathes) with clutch levers, power switches and other frequently used controls so they:

   a. Are more visible from the worker normally stands.

   b. Are more conveniently located (reduce worker bending over) and more accessible.

   c. Cannot be mistaken for other controls. This includes providing labels that indicate control names and the directions of movement, and designing control handles so workers can identify controls by feel.

   d. Cannot be accidently activated.

   e. Operate consistently from lathe to lathe. For example, the clutch lever is always engaged by pushing downward on brands A, B, C, ... lathes.

2. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

Table G-8. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #8

1. Direct workers to wait until the spindle completely stops before placing their hands on or close to the revolving chuck or other attaching devices, or workpiece.

2. Install braking devices to prevent spindle drift if the lathe is not so equipped. Inspect and repair any braking devices that are not operating properly.

3. Install guards over chucks or other attaching devices whenever practical.

Table G-9. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #9

1. Provide the workers with a spring loaded chuck wrench or a spring loaded chuck, where applicable, to prevent the chuck wrench from being left in the chuck.

2. Apply brightly colored markings to increase chuck wrench visibility.

3. Direct the workers to visually check and to keep their hands away from the chuck, workpiece or accessory that will move when engaging the clutch or starting motor.

Table G-10. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #10

1. Prohibit workers from operating lathes when they are wearing long hair and loose fitting clothing that are not properly restrained.

2. Direct workers not to place their hands, arms, feet on the lathe when they are not actually interacting with lathe or lathe controls.

3. Install guards over chucks or other attaching devices whenever practical.

Table G-11. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #11

1. Provide the workers with the correct cutting tools made of the proper grade of material and have the proper tool geometry. Provide the workers with information regarding the proper depths of cuts, feeds and speeds for each job.

2. Instruct the workers on the importance of using the correct cutting tools made of the proper grade of material and have the proper tool geometry. Instruct the workers on the importance of using the proper depths of cuts, feeds and speeds.

3. Where practical, direct the workers to stop the spindle and remove continuous chips, should they accumulate on the workpiece or chuck.

4. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

Table G-12. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #12

1. Provide the workers with the proper file, deburring and polishing tools for the job, and instruct them on the proper use.

2. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

Table G-13. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #13

1. Direct the workers to switch the power off, and shift clutch to neutral or open gear position when taking measurements of the workpiece on the lathe. As an added precaution, provide measuring devices with an outboard handle that can slip from the workers' hands if the devices catch on rotating workpiece. Whenever practical, direct workers to remove workpiece from lathe before taking measurements.

2. Install mechanical stops that must be overridden to prevent the worker from accidently engaging the clutch.

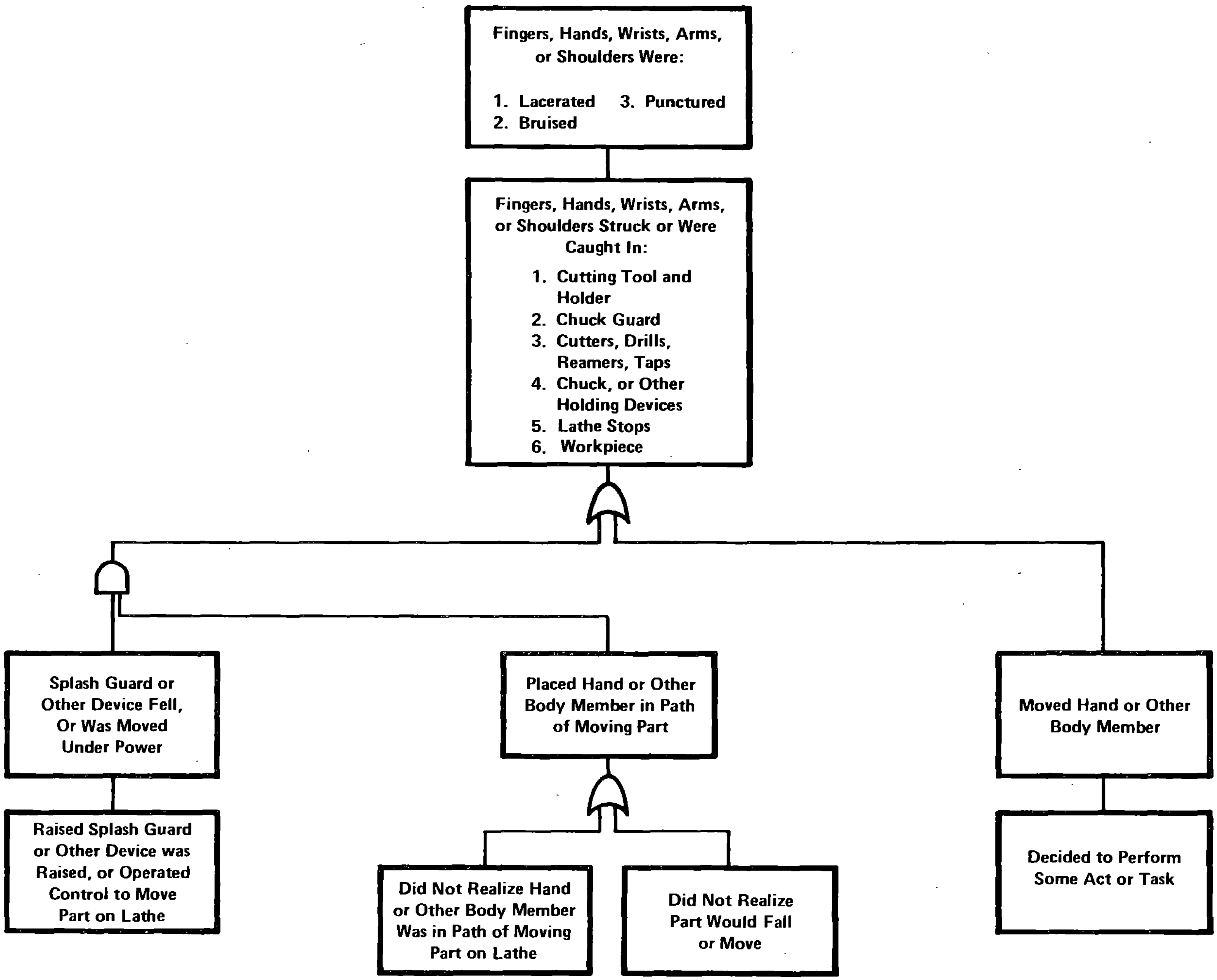


Figure G-6. Fault-Tree Diagram #6

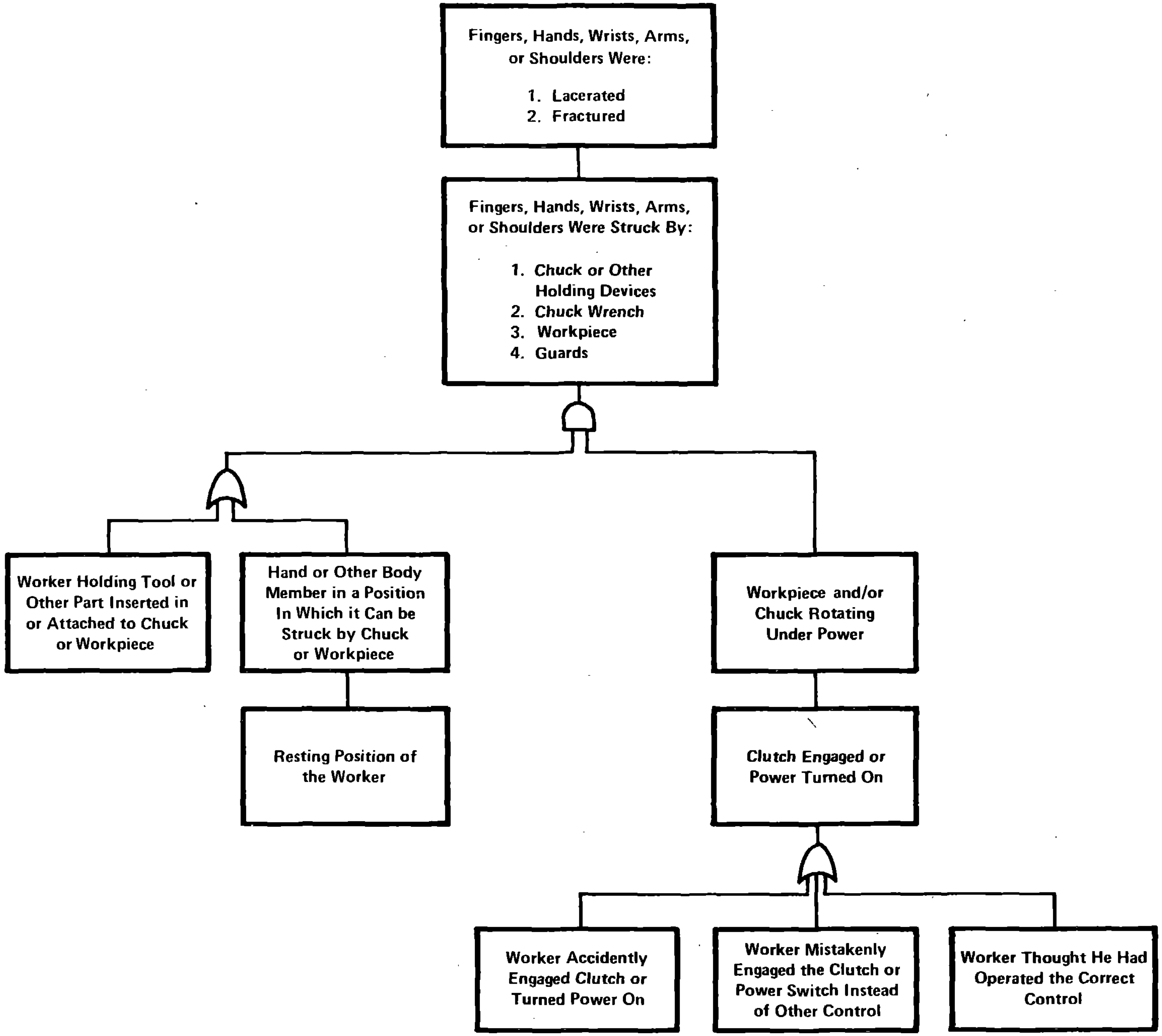


Figure G-7. Fault-Tree Diagram #7

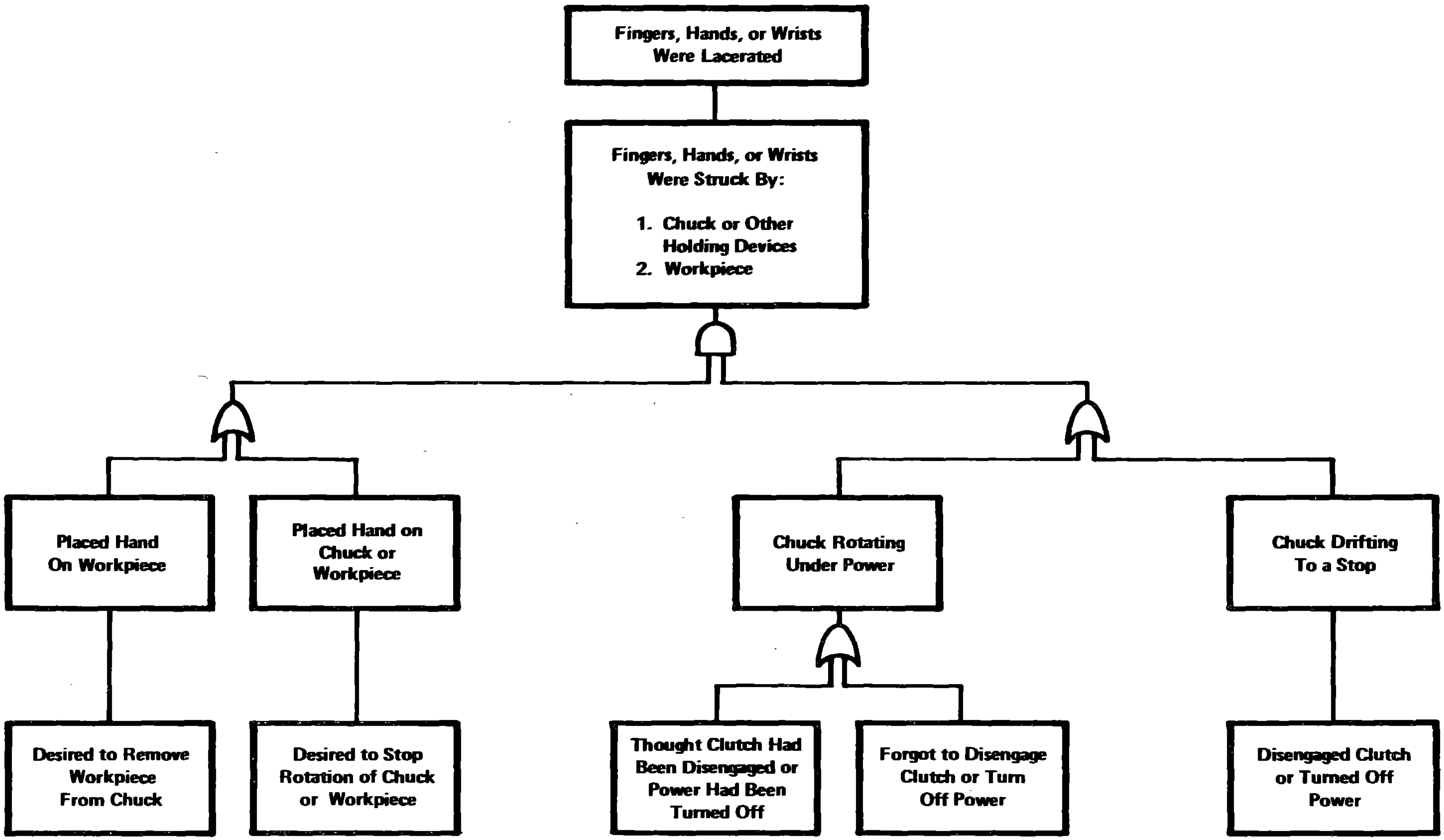


Figure G-8. Fault-Tree Diagram #8

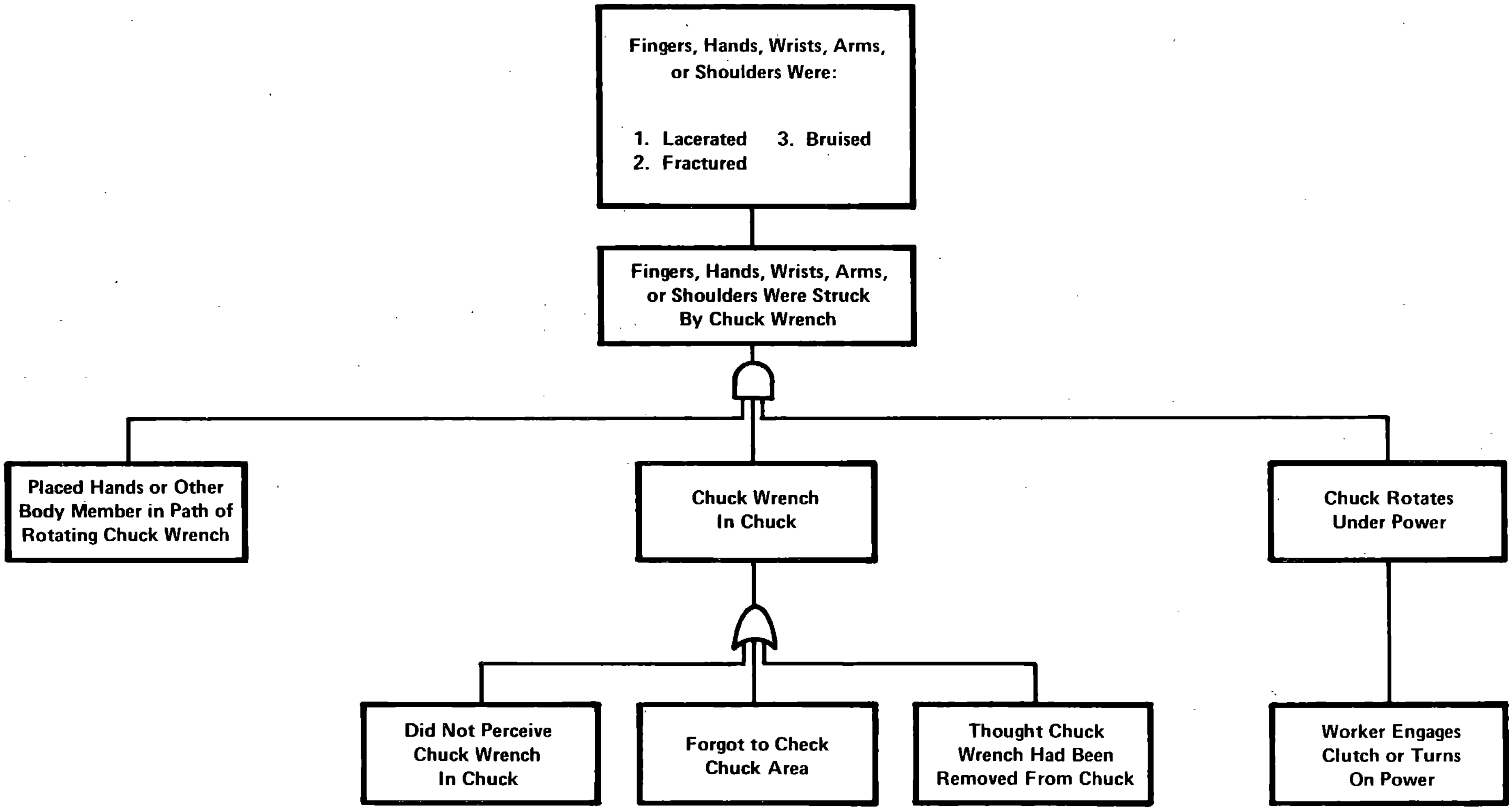


Figure G-9. Fault-Tree Diagram #9

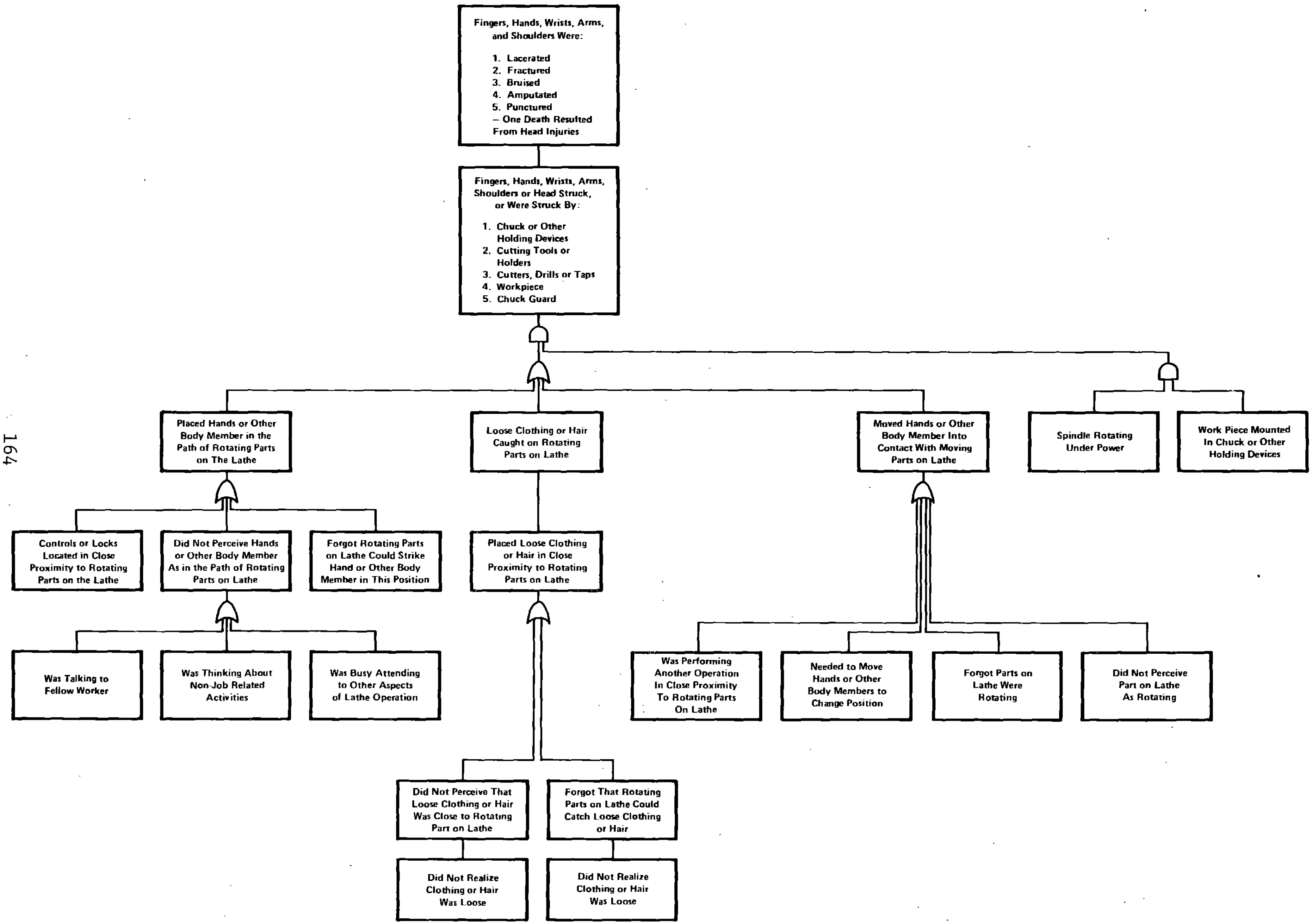


Figure G-10. Fault-Tree Diagram #10

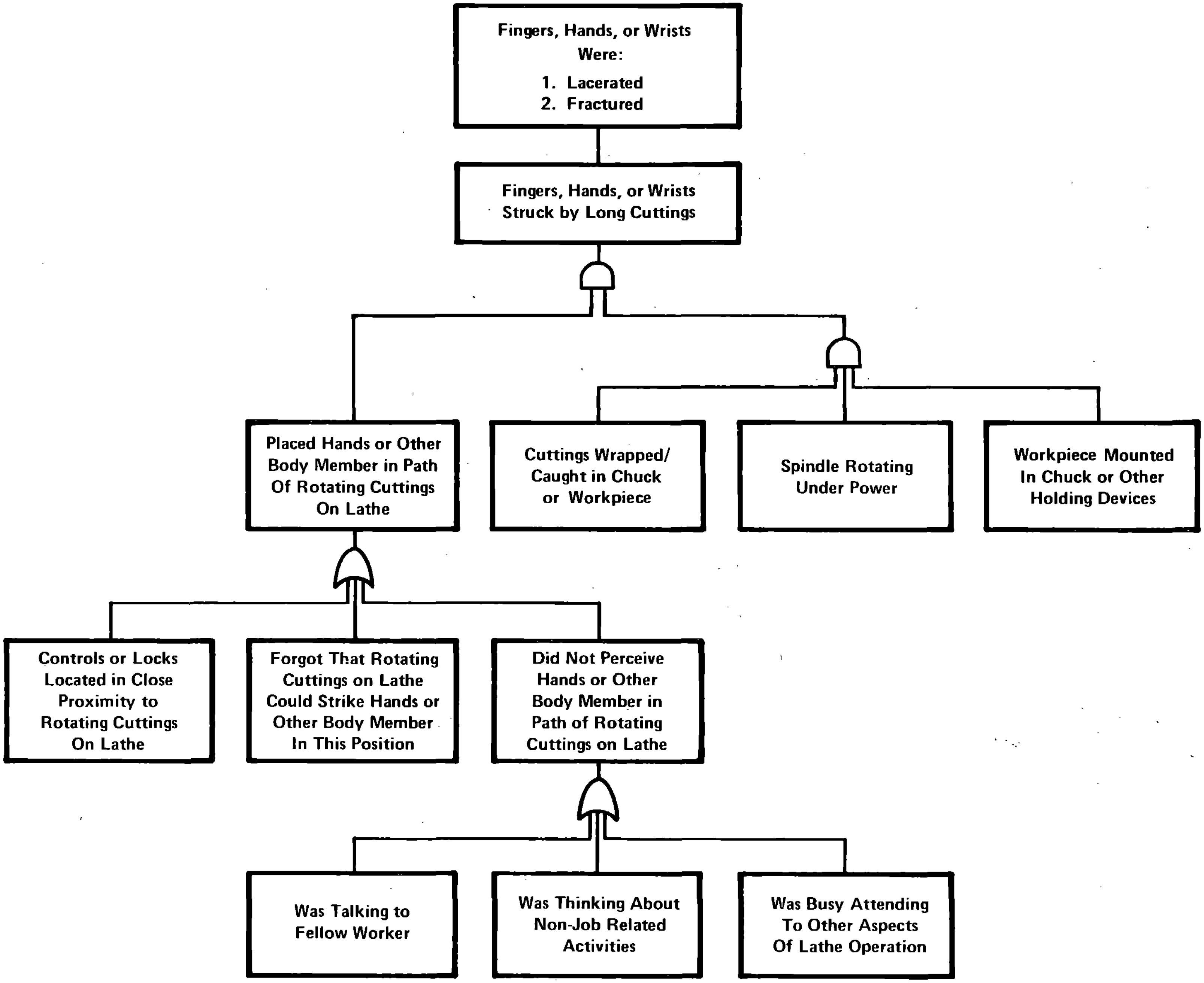


Figure G-11. Fault-Tree Diagram #11

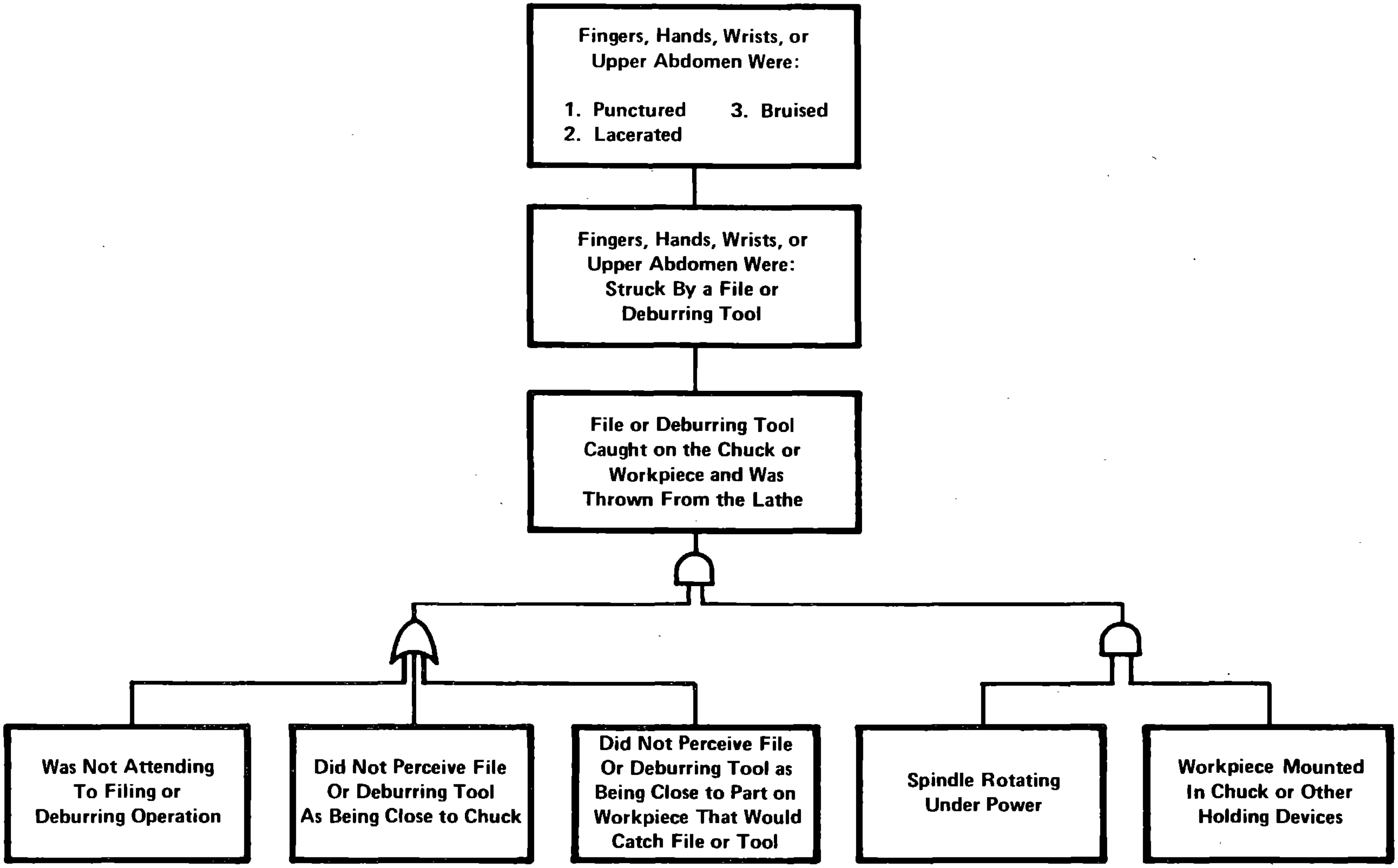


Figure G-12. Fault-Tree Diagram #12

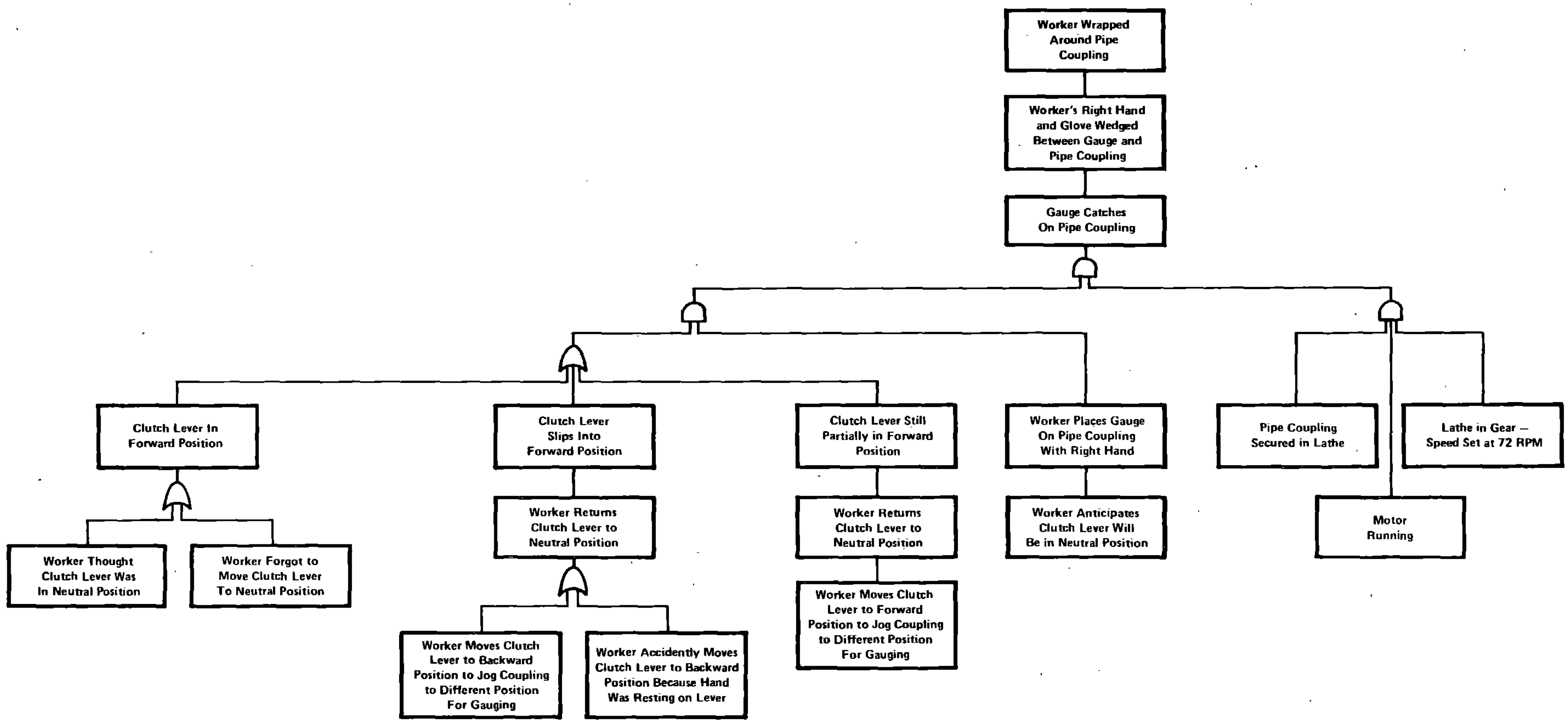


Figure G-13. Fault-Tree Diagram #13

ACCIDENT TYPE 4

No Protection or Improper Use. No protection was worn, or protective equipment was used improperly when performing hazardous lathe operations.

ACCIDENT TYPE 4 INFORMATION

Contributing Events. The events that caused or led to Type 4 accidents involved the worker not wearing protective equipment, or using the equipment improperly when he was:

1. Applying force to the control lever, handle or knob, or workpiece
2. Polishing, filing or deburring the workpiece
3. Loading/unloading the workpiece
4. Turning, facing, boring, or grinding the workpiece
5. Cleaning/clearing the chuck or other attaching devices
6. Reaching for the control lever, handle or knob.
7. Removing cuttings
8. Operating the lathe*

Resulting Events. The events that resulted from Type 4 accidents included injury of the worker's eyes, face, head or neck on:

1. Cuttings/chips
2. Coolant/dust

Other events that resulted from Type 4 accidents include:

1. Injury of the worker's fingers, hand or wrist on cuttings/chips, or cutting tool or holder
2. Injury of the worker's arm or shoulder on cuttings/chips

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Injury Types. The types of injuries associated with Type 4 accidents are shown in the table below.

Injury Types	Frequency
Foreign Bodies	67
Lacerations	13
Burns	4
Abrasion	1
Total:	85

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
Two Diagrams included; 80 injuries represented.

Diagram 14
Lathe operations/workers' activities inlcuded:

1. Polishing, filing or deburring the workpiece.

2. Turning, facing, boring or grinding the workpiece.

3. Operating the lathe.

Types and numbers of injuries represented:

Injury Types	Frequency
Foreign Bodies	67
Burns	1
Total:	68

Diagram shown in Figure G-14; countermeaures shown in Table G-14.

Diagram 15
Lathe operations/workers' activities included:

1. Polishing, filing or deburring the workpiece.

2. Turning, facing, boring or grinding the workpiece.

3. Reaching for the control lever, handle or knob.

4. Operating the lathe.

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	9
Burns	2
Abrasion	1
Total:	12

Diagram shown in Figure G-15; countermeaures shown in Table G-15.

Table G-14. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #14

1. Provide the workers with eye protection devices and require them to wear them. Instruct the workers on how to select the correct eye protection devices for the job, such as selecting full face shields for high speed machining. Instruct the workers on how to adjust the devices so they fit properly. Encourage the workers to keep the eye protection devices in an accessible location.

Table G-15. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #15

1. Where practical, provide protective shields that fit over compounds without making many adjustments. Instruct the workers on how to properly install the shields on the lathe.

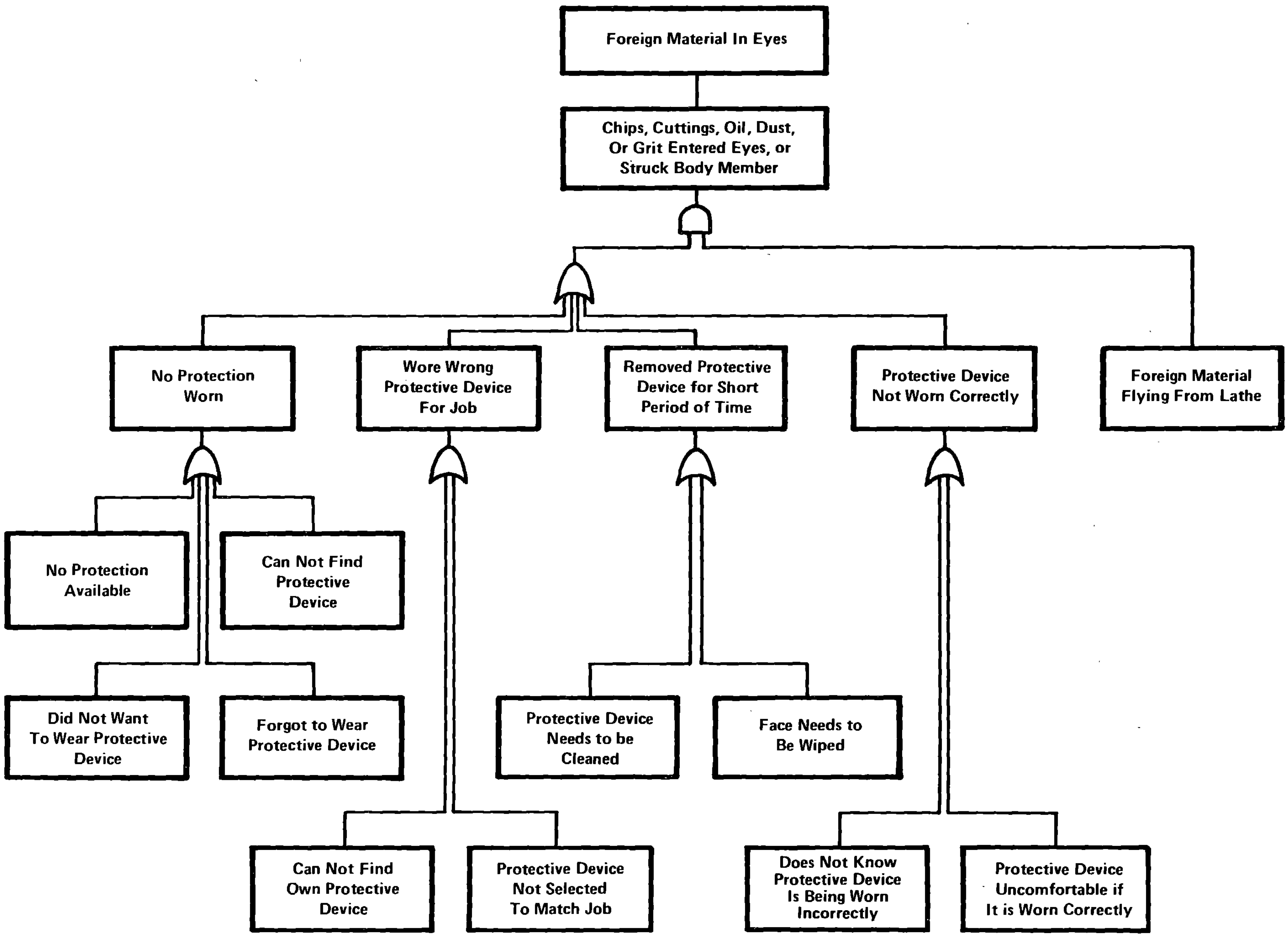


Figure G-14. Fault-Tree Diagram #14

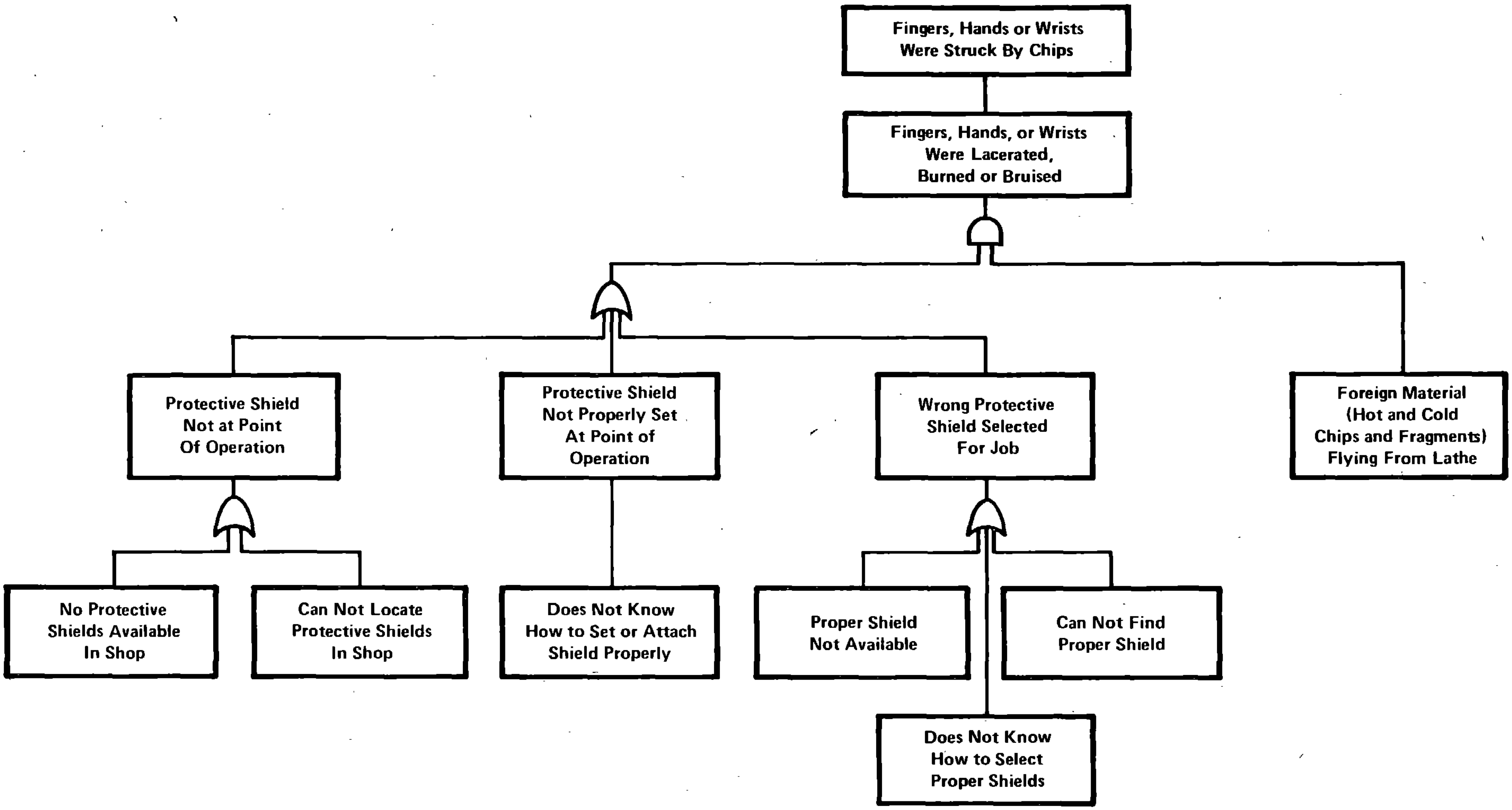


Figure G-15. Fault-Tree Diagram #15

ACCIDENT TYPE 5

Misjudged Time/Space. Misjudged the time/space required to access some lathe part, area or accessory with fingers, hands, etc.

ACCIDENT TYPE 5 INFORMATION

Contributing Events. The of events that caused or led to Type 5 accidents involved the worker not correctly judging space or time requirements when he was:

1. Applying force to the workpiece

2. Reaching for the workpiece, cuttings, or small accessories or hand tools

3. Removing/replacing tool bit, tool holder, or tool post

4. Cleaning/clearing the cuttings

5. Operating the lathe*

Resulting Events. The events that resulted from Type 5 accidents included injury of the worker's fingers, hand, or wrist on:

1. A control handle, lever or knob

2. The chuck or other attaching devices

3. A cutter, tap, die, drill or reamer

4. The workpiece

5. The turret

Other events that resulted from Type 5 accident included:

1. Injury of the worker's arm or shoulder on the workpiece.

2. Injury of the worker's lower abdomen on a hand tool.

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Injury Types. The types of injuries associated with Type 5 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	6
Bruises or Contusions	3
Fractures	2
Abrasion	1
Missing	1
Total:	13

FAULT-TREE DIAGRAM AND PROPOSED COUNTERMEASURES
One diagram included; 11 injuries represented.

Diagram 16
Lathe operations/workers' activities included:

1. Applying force to the workpiece

2. Reaching for the workpiece, cuttings, or small accessories or hand tools

3. Cleaning/clearing the cuttings

4. Operating the lathe

Types and number of injuries represented:

Injury Types	Frequency
Lacerations	4
Bruises or Contusions	2
Fractures	4
Missing	1
Total:	11

Diagram shown in Figure G-16; countermeasures shown in Table G-16.

Table G-16. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #14

1. Direct the workers to stop the spindle and wait until it completely stops before placing their hands on or close to the revolving chuck or other attaching devices, or workpiece.

2. Install braking devices to prevent spindle drift if the lathe is not so equipped. Inspect and repair any braking devices that are not operating properly.

3. Direct the workers not to reach for tools/parts that have fallen in close proximity to the rotating chuck, other attaching devices or workpiece.

4. Provide the workers with the correct cutting tools that are made of the proper grade of material and have the proper tool geometry. Provide the workers with information regarding the proper depth of cuts, feeds and speeds for each job.

5. Instruct the workers on the importance of using the correct cutting tools made of the proper grade of material and have the proper tool geometry. Instruct the workers on how to determine the importance of using the proper depths of cuts, feeds and speeds.

6. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

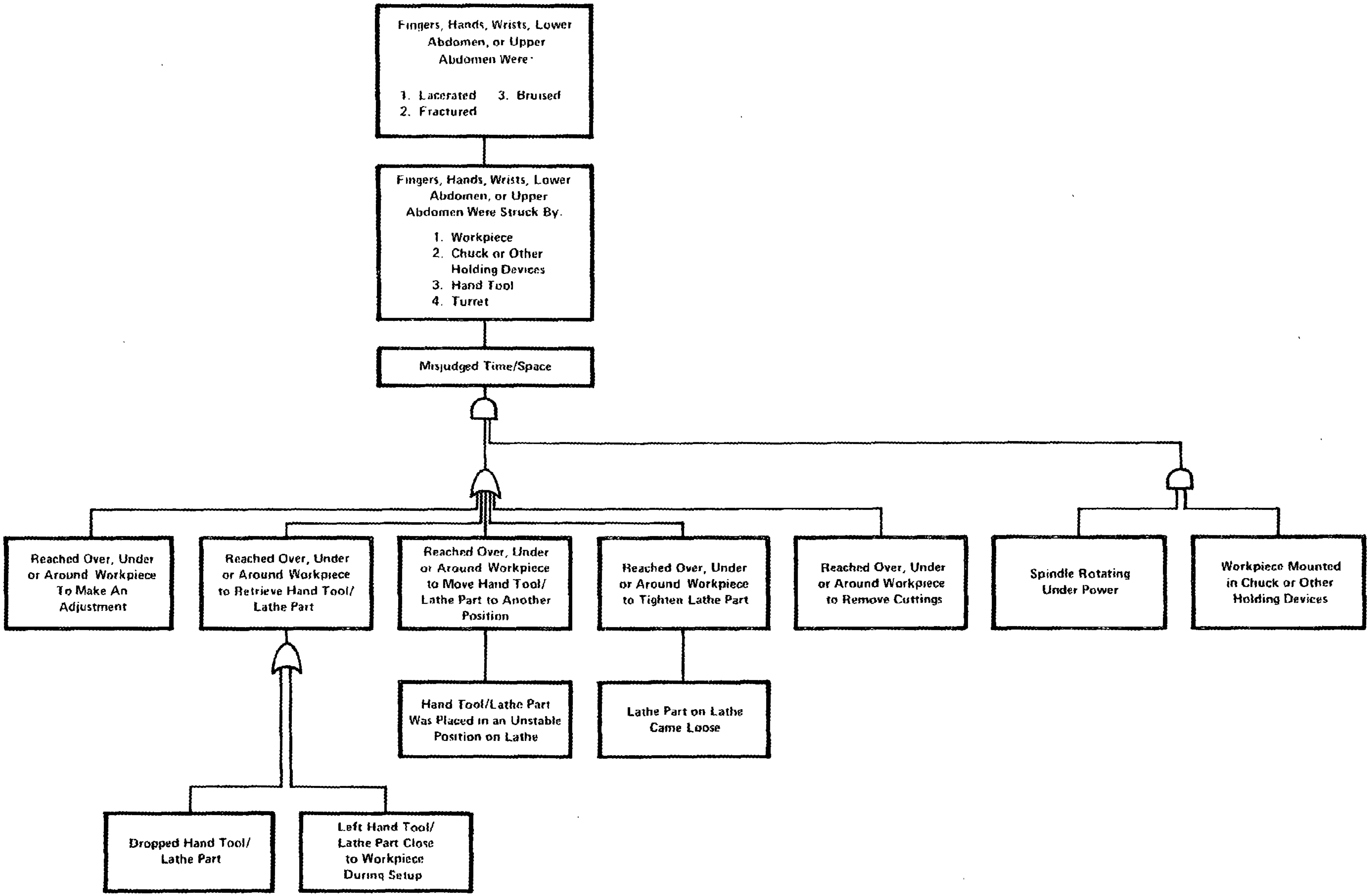


Figure G-16. Fault-Tree Diagram #16

ACCIDENT TYPE 6

Misjudged Weight/Force. Misjudged weight/force required to move object or device.

ACCIDENT TYPE 6 INFORMATION

Contributing Events. The events that caused or led to Type 6 accidents involved the worker not correctly judging weight/force requirements when he was:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock or associated accessories; (c) pulley, gear or sprocket; (d) control lever, handle or knob; (e) follower or steady rest, turret, compound, taper or tracer attachment; or (f) workpiece.

2. Loading/unloading the chuck or other attaching devices or workpiece.

3. Removing/replacing the wrench, chuck or other attaching devices or workpiece.

4. Setting up: (a) tailstock or associated accessories; (b) wrench, chuck or other attaching devices, or tool bit, tool holder or tool post.

5. Operating the lathe*

Resulting Events. The events that resulted from Type 6 accidents included injury of the worker's back on:

1. The control handle, lever or knob; headstock area

2. The wrench, chuck or other attaching devices

3. The taper or tracer attachment, or follower or steady rest

4. The workpiece

5. The tailstock or associated accessories

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Other events that result from Type 6 accidents included:

1. Injury of the worker's fingers, hand or wrist on: (a) control handle, lever or knob; (b) cutting tool or holder; (c) follower or steady rest; or (d) tail stock or associated accessories.

2. Injury of the worker's arm or shoulder on: (a) control handle, lever or knob; (b) cutting tool or holder; (c) chuck or other attaching devices; or (d) turret.

3. Injury of the worker's abdomen on: (a) control handle, lever or knob; (b) chuck or other attaching devices; or (c) turret.

4. Injury of the worker's foot or leg on the control handle, lever or knob.

5. Injury of the worker's head, face or neck on the chuck wrench.

Injury Types. The types of injuries associated with Type 6 accidents are shown in the table below.

Injury Types	Frequency
Strains or Sprains	62
Bruises or Contusions	5
Total:	67

FAULT-TREE DIAGRAM AND PROPOSED COUNTERMEASURES
One diagram included; 60 injuries represented.

Diagram 17
Lathe operations/workers' activities included:

1. Positioning/applying force to: (a) wrench, chuck or other attaching devices; (b) tailstock or associated accessories; (c) pulley, gear or sprocket; (d) control lever, handle or knob; (e) follower or steady rest, turret, compound, taper or tracer attachment; or (f) workpiece.

2. Loading/unloading the chuck or other attaching devices or workpiece.

3. Removing/replacing the wrench, chuck or other attaching devices or workpiece.

4. Setting up: (a) tailstock or associated accessories; (b) wrench, chuck or other attaching devices, or tool bit, tool holder or tool post.

5. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Strains or Sprains	60
Total:	60

Diagram shown in Figure G-17; countermeasures shown in G-17.

Table G-17. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #17

1. Inspect the lathe accessories and control levers to determine if they can be operated easily. Repair where needed.
2. Provide proper workpiece handling equipment in good repair and instruct the workers on how to use the equipment. Caution the workers not to over exert themselves.
3. Instruct the workers in the proper method of grasping and shifting lathe control levers.
4. Instruct the workers on how to select the correct wrench for the job. Instruct the workers on the correct procedure for applying force when tightening or loosening bolts, nuts, chucks or other attaching devices.
5. Install guards over chucks or other attaching devices whenever practical.

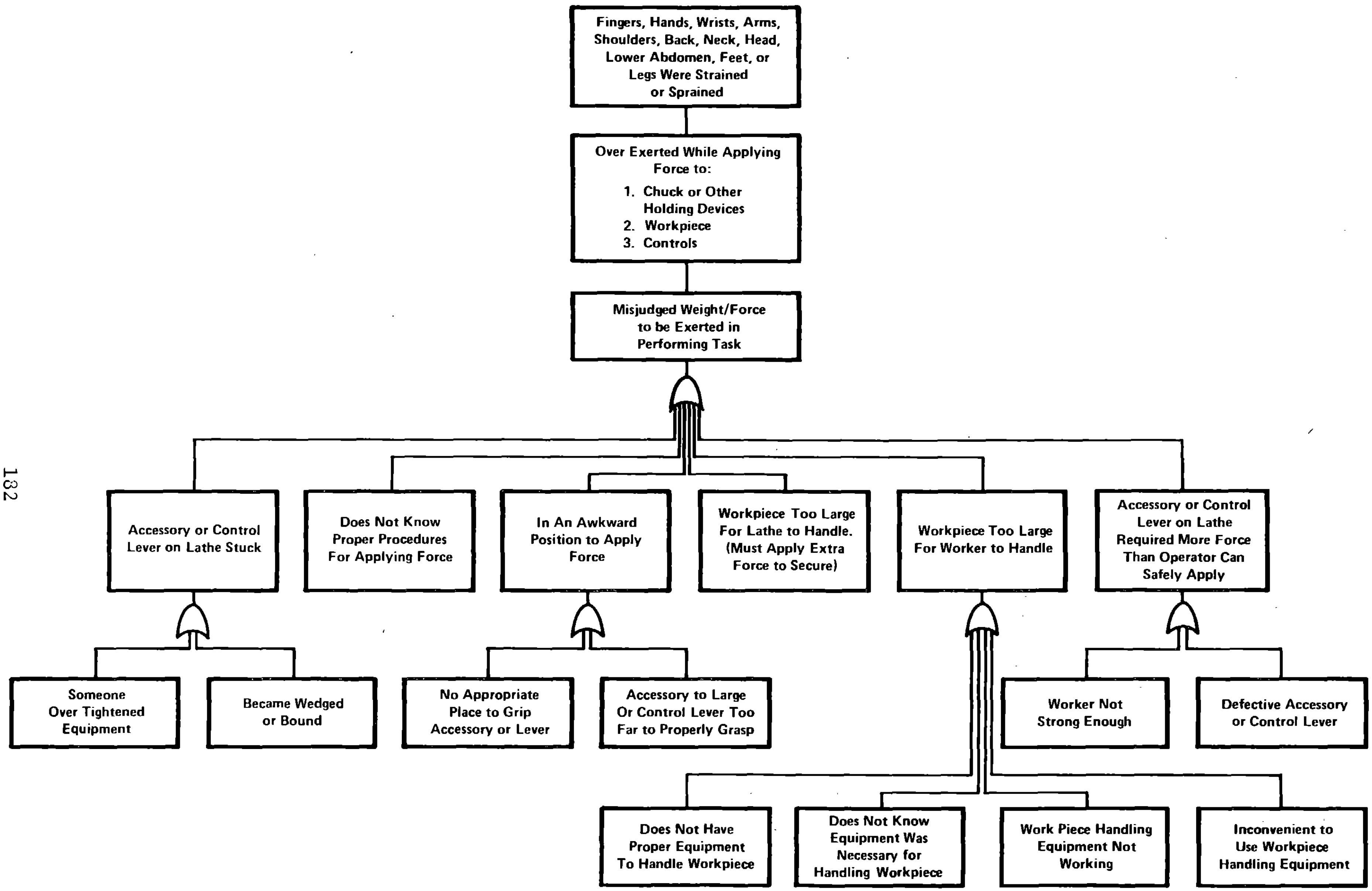


Figure G-17. Fault-Tree Diagram #17

ACCIDENT TYPE 7

Improper Workpiece Securement. Workpiece was not secured in the chuck or attaching device.

ACCIDENT TYPE 7 INFORMATION

Contributing Events. The events that caused or led to Type 7 accidents involved the worker not securing the workpiece before he began:

1. Positioning the tool bit, tool holder, or tool post

2. Polishing the workpiece

3. Turning or facing the workpiece

4. Operating the lathe*

Resulting Events. The events that resulted from Type 7 accidents included injury of the worker's fingers, hand or wrist on:

1. The cutting tool or holder

2. The workpiece

Other of events that resulted from Type 7 accidents include:

1. Injury of the worker's arm or shoulder on a cutter, tap, die, drill or reamer, or workpiece

2. Injury of the worker's eyes, head, face or neck on the workpiece

3. Injury of the worker's foot or leg on the workpiece

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Injury Types. The types of injuries associated with Type 7 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	10
Bruises or Contusions	5
Fracture	1
Death	1
Strains or Sprains	1
Missing	3
Total:	21

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
One diagram included; 19 injuries represented.

Diagram 18
Lathe operations/workers' activities included:

1. Polishing the workpiece

2. Turning or facing the workpiece

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	10
Bruises or Contusions	5
Death	1
Strains or Sprains	1
Missing	2
Total:	19

Diagram shown in Figure G-18; countermeasures shown in Table G-18

Table G-18. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #18

1. Inspect the chucks and attaching devices for undersized parts (e.g., bolts, nuts, screws, etc.) and for parts that have mechanical defects. Replace parts where required. Periodically check chuck jaw with force gauge.

2. Provide the workers with the necessary setup equipment and instruct them how to make setups that safely secure the workpiece for machining operations.

3. On future lathes, design locking devices (e.g., tailstock spindle lock) so lock and unlock positions are clearly visible from where the workers normally stand.

4. Provide the workers with the proper wrenches for tightening chucks and other attaching devices.

5. Instruct the workers on how to select the correct wrench for tightening chucks and other attaching devices. Instruct the workers on the correct procedures for applying force when tightening chucks and other attaching devices.

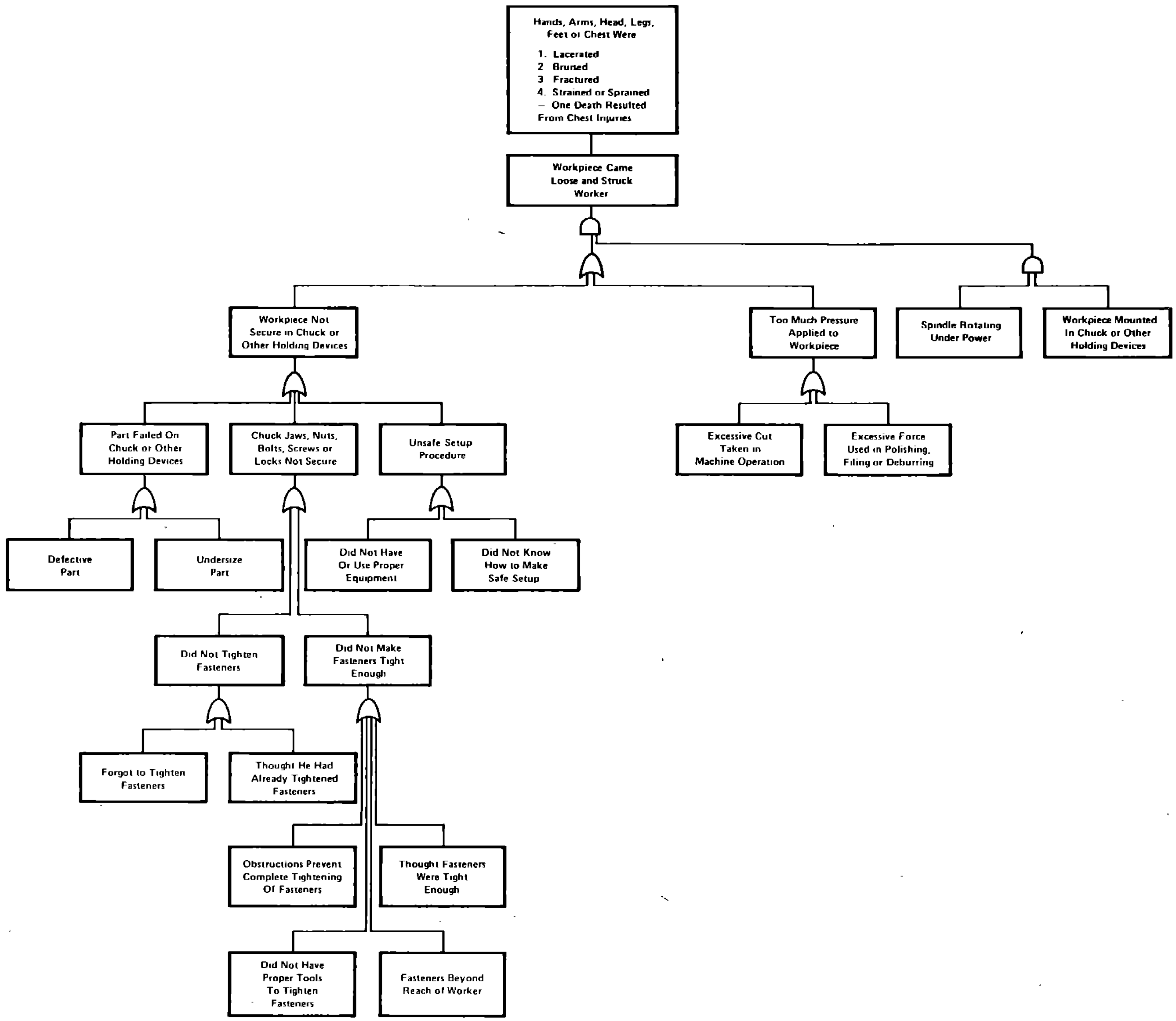


Figure G-18. Fault-Tree Diagram #18

ACCIDENT TYPE 8

Improper Procedure. Incorrect procedure was used when performing a lathe operation or activities.

ACCIDENT TYPE 8 INFORMATION

Contributing Events. The events that caused or led to Type 8 accidents involved the worker not using the proper tools or procedures when he was:

1. Applying force to: (a) wrench, chuck or other attaching devices; or (b) control lever, handle or knob, or cuttings
2. Polishing, filing or deburring the workpiece
3. Measuring the workpiece
4. Loading/unloading the workpiece
5. Turning, facing or threading the workpiece
6. Reaching for the workpiece
7. Removing/replacing: (a) wrench, chuck or other attaching devices; (b) tool bit, tool holder or tool post; or (c) cuttings
8. Setting up the lathe
9. Cleaning/clearing the cuttings, lathe, or pulley, gear or sprocket
10. Operating the lathe*

Resulting Events. The events that resulted from Type 8 accidents included injury of the worker's fingers, hand, or wrist on:

1. The cutting tool or holder
2. The wrench, chuck or other attaching devices
3. A cutter, tap, die, drill or reamer

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

4. Cuttings/chips

5. Polishing material

6. The workpiece

7. A hand tool

8. A belt, gear, pulley, or sprocket

Other events that resulted from Type 8 accidents included:

1. Injury of the worker's upper abdomen on: (a) control handle, lever or knob; (b) cutting tool or holder; or (c) workpiece

2. Injury of the worker's head, face or neck on the cutting tool or holder, or workpiece

3. Injury of the worker's back on the chuck or other attaching devices

4. Injury of the worker's foot or leg on cuttings/chips

5. Injury of the worker's arm or shoulder on cuttings/chips

Injury Types. The types of injuries associated with Type 8 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	37
Fractures	9
Bruises or Contusions	9
Punctures	3
Foreign Bodies	2
Strains or Sprains	2
Abrasions	2
Amputations	2
Death	1
Burns	1
Missing	3
Total:	71

FAULT-TREE DIAGRAMS AND PROPOSED COUNTERMEASURES
Two diagrams included; 52 injuries represented.

Diagram 19
Lathe operations/workers' activities included:

1. Polishing, filing or deburring the workpiece

2. Reaching for the workpiece

3. Cleaning/clearing the cuttings, lathe, or pulley, gear or sprocket

4. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	11
Fractures	4
Bruises or Contusions	3
Punctures	3
Abrasions	2
Amputations	2
Death	1
Total:	26

Diagram shown in Figure G-19; countermeasures shown in Table G-19.

Diagram 20
Lathe operations/workers' activities included:

1. Removing/replacing: (a) wrench, chuck or other attaching devices; (b) tool bit, tool holder or tool post; or (c) cuttings

2. Cleaning/clearing the cuttings, lathe, or pulley, gear or sprocket

3. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Lacerations	26
Total:	26

Diagram shown in Figure G-20; countermeasures shown in Table G-20.

Table G-19. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #19

1. Where practical, direct the workers to stop the spindle and remove discontinuous or continuous chips should they accumlate on the chuck or workpiece. When this is not possible, provide a safe tool for removing the chips.

2. Provide the workers with the correct cutting tools made of the proper grade of materials and have the proper tool geometry. Provide the workers with information regarding the proper depths of cuts, feeds and speeds for each job.

3. Instruct the workers on the importance of using the correct cutting tools made of the proper grade of material and have the proper tool geometry. Instruct the workers on the importance of using the proper depths of cuts, feeds and speeds.

4. Provide the workers with the proper files, deburring and polishing tools that match the jobs they are required to perform. If possible, provide handles for the tips of files to encourage workers to use two hands when using files.

5. Instruct the workers on how to select the proper files, deburring and polishing tools for the job, and how to use them correctly.

Table G-20. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #20

1. Where practical, direct the workers to stop the spindle and remove discontinuous or continuous chips should they accumulate on the chuck or workpiece. When this is not possible, provide a safe tool for removing the chips.

2. Provide the workers with the correct cutting tools made of the proper grade of materials and have the proper tool geometry. Provide the workers with information regarding the proper depths of cuts, feeds and speeds for each job.

3. Instruct the workers on the importance of using the correct cutting tools made of the proper grade of material and have the proper tool geometry. Instruct the workers on the importance of using the proper depths of cuts, feeds and speeds.

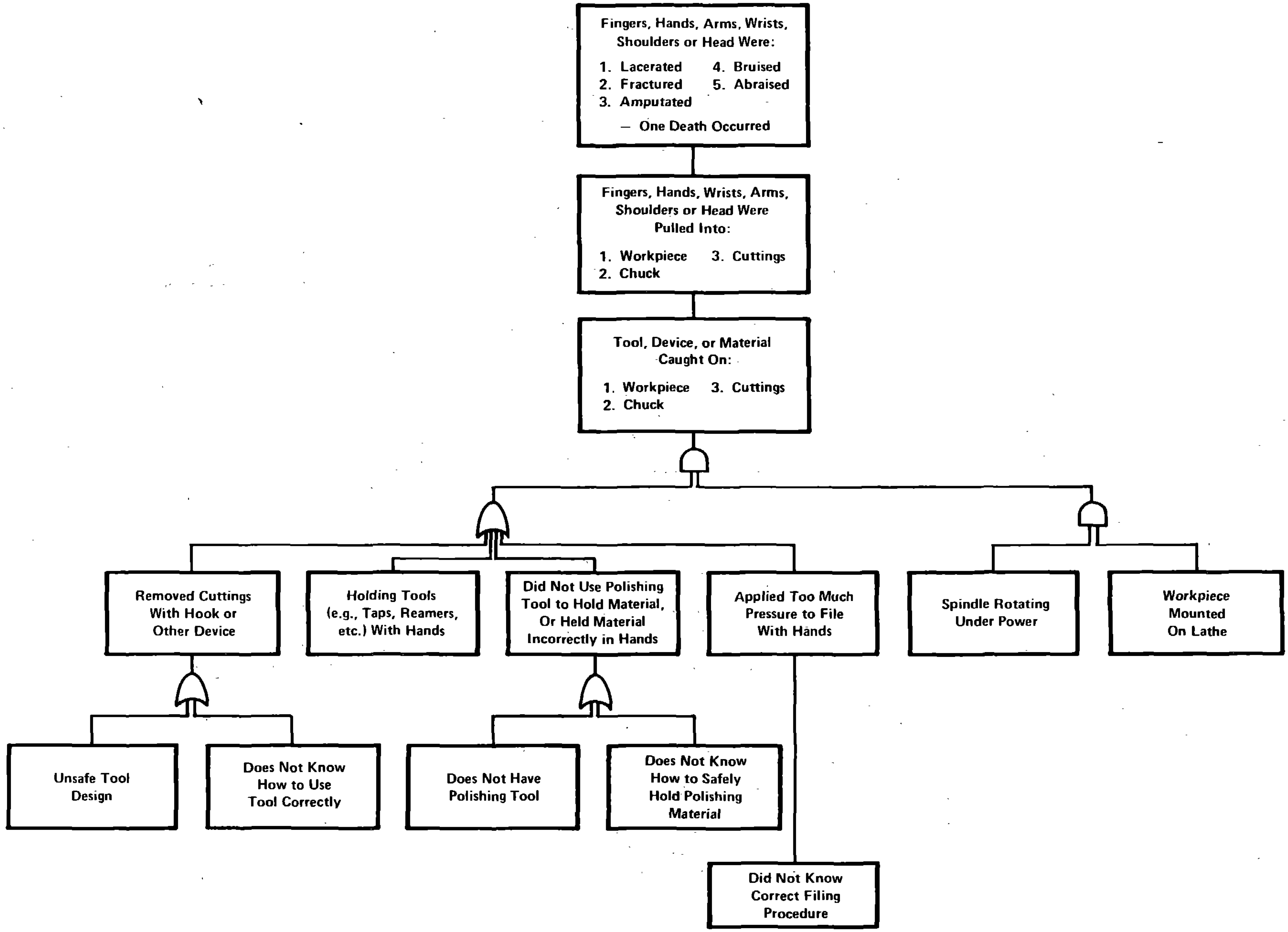


Figure G-19. Fault-Tree Diagram #19

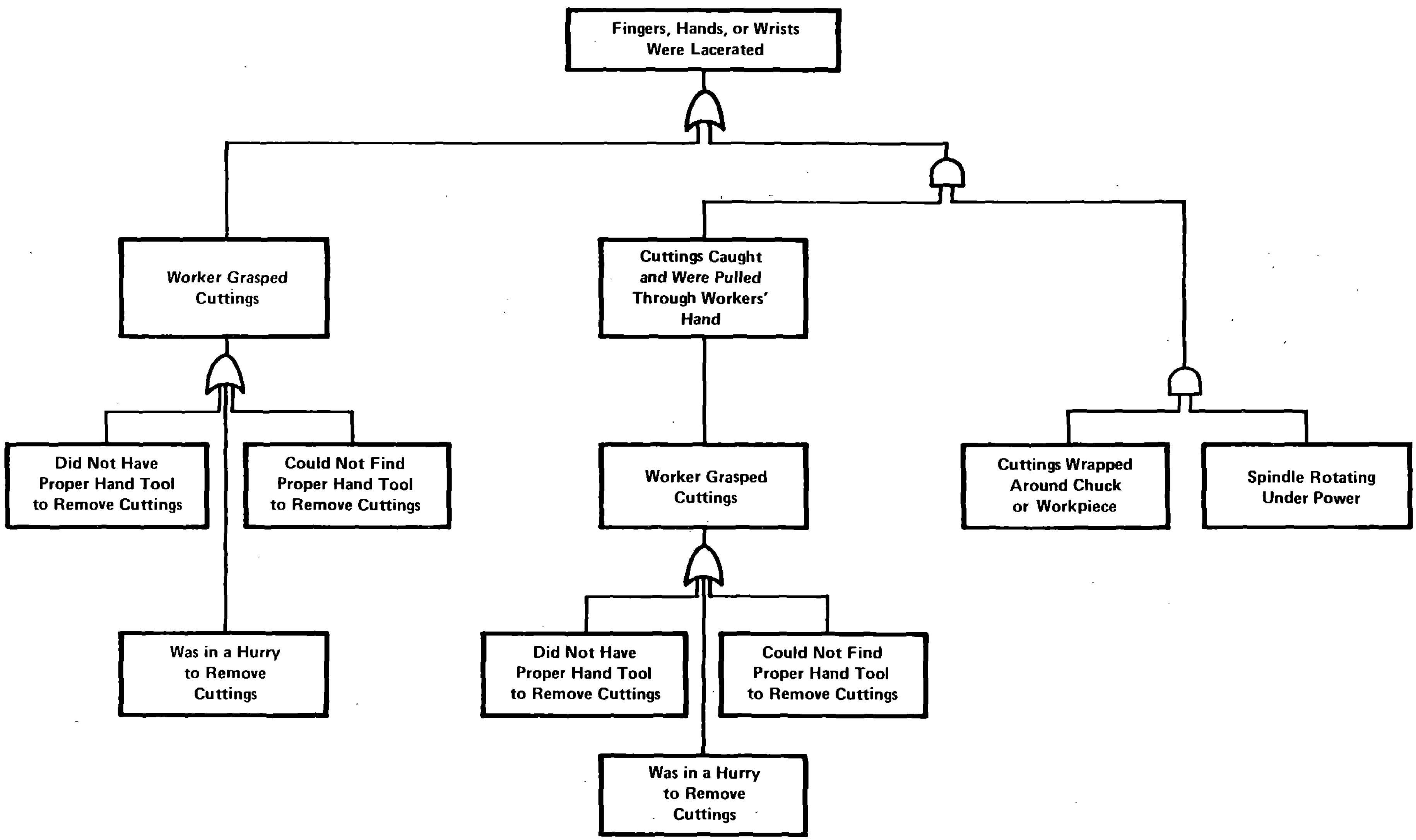


Figure G-20. Fault-Tree Diagram #20

ACCIDENT TYPE 9

Uncontrolled Limb Movements. Involuntary response action resulted from the worker accidently contacting a sharp or hot surface.

ACCIDENT TYPE 9 INFORMATION

Contributing Events. The events that caused or led to Type 9 accidents involved the worker not controlling movement of his hand, arm or other body limbs when he was:

1. Applying force to: (a) wrench, chuck or other attaching devices; (b) tool bit, tool holder, or tool post; or (c) small accessories or hand tools

2. Polishing the workpiece

3. Loading/unloading the workpiece

4. Removing/replacing a pulley, gear or sprocket

5. Setting up the chuck or other attaching devices, or workpiece

6. Operating the lathe*

Resulting Events. The events that resulted from Type 9 accidents included injury of the worker's fingers, hand, or wrist on:

1. The cutting tool or holder

2. The wrench, chuck or other attaching devices

3. A cutter, tap die, drill or reamer

Other events that resulted from Type 9 accidents included:

1. Injury of the worker's arm or shoulder on the cutting tool or holder

2. Injury of the worker's arm or shoulder in the area of the headstock

*A number of contributing events could not be classified by specific categories and were placed in the general category of "operating the lathe."

Injury Types. The types of injuries associated with Type 9 accidents are shown in the table below.

Injury Types	Frequency
Lacerations	4
Fractures	2
Bruises or Contusions	1
Punctures	1
Missing	2
Total:	10

FAULT-TREE DIAGRAM AND PROPOSED COUNTERMEASURES
One diagram included; two injuries represented.

Diagram 21
Lathe operations/workers' activities included:

1. Polishing the workpiece

2. Operating the lathe

Types and numbers of injuries represented:

Injury Types	Frequency
Fractures	2
Total:	2

Diagram shown in Figure G-21; countermeasures shown in Table G-21

Table G-21. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #21

1. Instruct the workers on how to apply force when attempting to release stuck accessories or lathe parts.

2. Direct the workers to stop spindle before applying force when attempting to release stuck accessories or parts on the lathe.

3. Install guards, awareness barriers or devices over chucks or other attaching devices whenever practical.

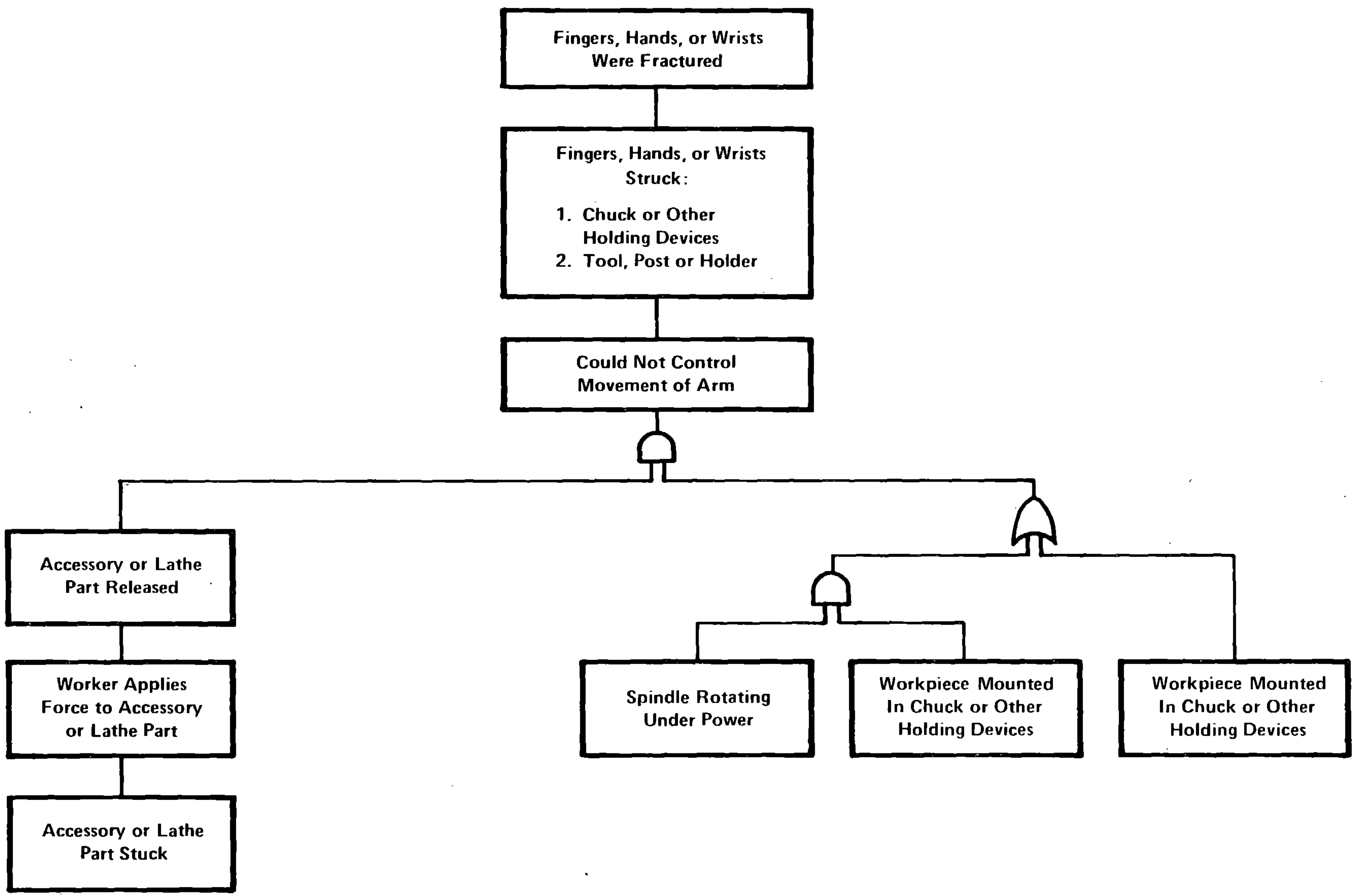


Figure G-21. Fault-Tree Diagram #21

ACCIDENT TYPE "OTHER"

FAULT-TREE DIAGRAM AND PROPOSED COUNTERMEASURES
One diagram included; three injuries represented.

Diagram 22
Lathe operations/workers' activities included:

1. Setting up the workpiece

2. Loading/unloading the workpiece

3. Applying force to wrench

Types and numbers of injuries represented:

Injury Types	Frequency
Amputations	2
Fractures	1
Total:	3

Diagram shown in Figure G-22; countermeasures shown in Table G-22

Table G-22. Proposed Countermeasures to Reduce Workers' Risk to the Injuries Represented in Fault-Tree Diagram #22

1. Where possible, install interlocks that switch power off when transmission guarding is removed.

2. Design future lathes (where practical, retrofit existing lathes) with clutch levers, power switches and other frequently used controls so they:

   a. Are more visible from where the worker normally stands.

   b. Are more conveniently located (reduce worker bending over) and more accessible.

   c. Can not be mistaken for other controls. This includes providing tables that indicate control names and directions of movement and designing control handles so workers can identify controls by feel.

   d. Cannot be accidently activated.

   e. Operate consistently from lathe to lathe. For example, the clutch lever is always engaged by pushing downward on brands A, B, C, ... lathes.

3. Inspect all clutch mechanisms to determine if they can accidently engage.

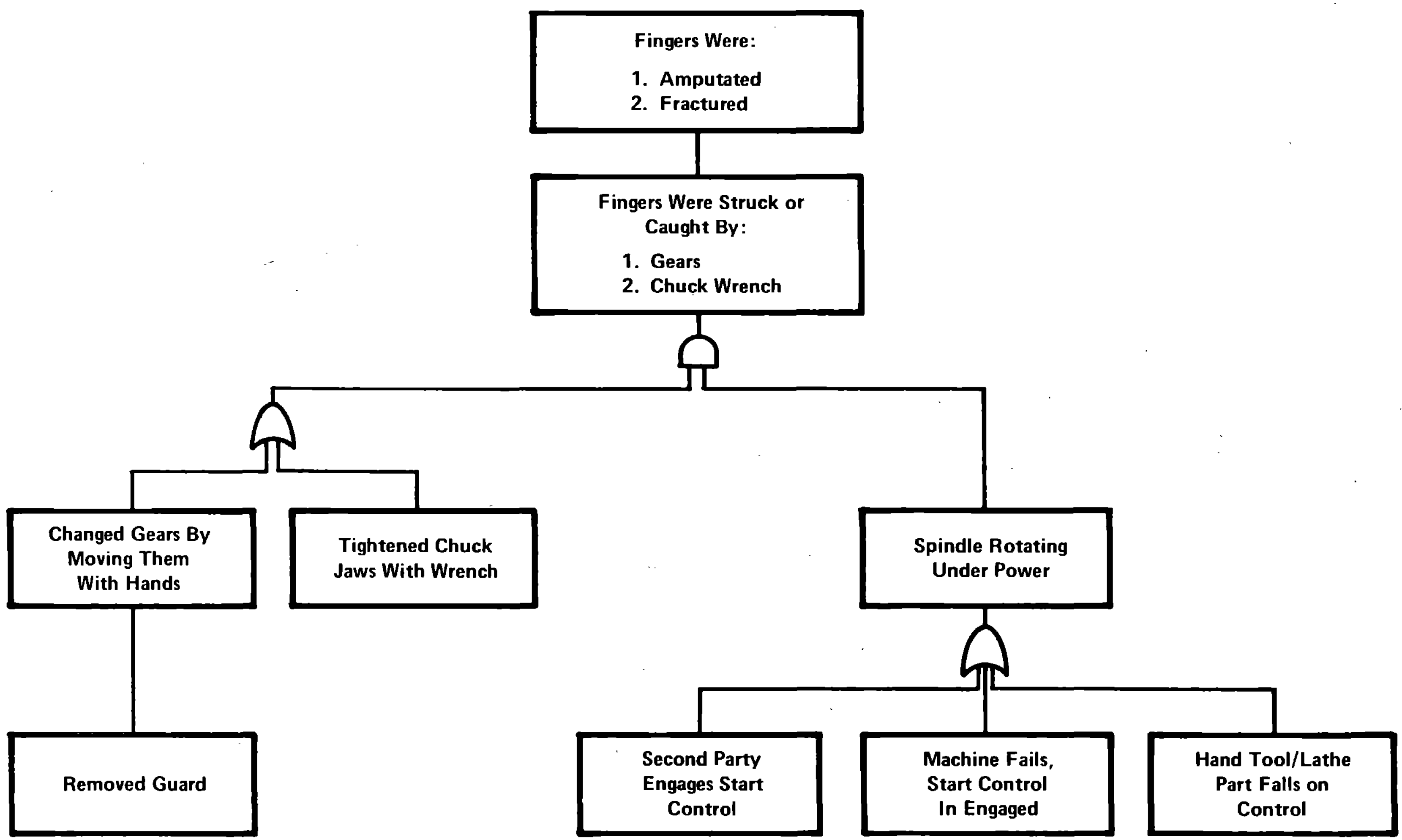


Figure G-22. Fault-Tree Diagram #22

APPENDIX H

PROBLEMS IN WORKMEN'S
COMPENSATION DATA COLLECTION

The two most common problems associated with the injury data involved the contents of the reports and the actual collection of the data. First, the injury reports usually described only the behavior of the worker that lead to the injuries (with the exception of two reports supplied by federal agencies). Seldom was information present describing the characteristics of the lathes, workpieces or accessories. There was almost never a description of the environmental conditions in the machine shops. Second, newly enacted state confidentiality laws restricted access to the Workmen's Compensation First Reports of injury. Obtaining copies of these reports required numerous telephone calls and letters to the directors and supervisors in state workmen's compensation offices. The arrangement that was mutually agreed upon was that the states would copy the reports, blank-out all personal information and then forward the reports to ASA for analysis. Two of the seven states (Wisconsin and Michigan) supplying data did not have confidentiality laws and were not required to blank-out personal information.

Each of the seven states participating in the study was requested to identify engine and turret lathe injuries. The states were instructed to include data from the years 1976, 1977 and, if possible, 1978. All seven states, with the exception of Wisconsin, identified, pulled and copied metalcutting lathe injury reports and forwarded them to ASA for analysis. Reports from Wisconsin were collected in Madison, Wisconsin by ASA personnel. One person spent three days in Wisconsin locating, pulling and copying the injury reports.

Wisconsin Workmen's Compensation First Reports proved to be the most useful source of injury data for the study. Wisconsin's records:

a) included a reasonably high number of metalcutting lathe injuries

b) provided the most complete accident description of all the workmen's compensation data

c) were coded at a level that permitted the identification of engine and turret lathes

d) were computerized for systematic access

California and Michigan supplied the greatest number of reports. However, California's injury reports occasionally had some of the non-personal information blanked-out. Pennsylania identified engine and turret lathe injuries as they were received at the Workmen's Compensation Office in Harrisburg, Pennsylvania during a three-month period. Pennsylvania's computer system was undergoing modifications and could be used to identify metalcutting lathe injuries from preceeding years.