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# THE APPLICATION OF THE PRINCIPLES OF HUMAN ENGINEERING TO THE DESIGN OF A PUNCH PRESS

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## HUMAN ENGINEERING

Human engineering is a science devoted primarily to the service of man. It deals with the design of machines to fit the physical and mental capacities of man. It involves identifiable groups of mechanical engineers, electrical engineers, psychologists, anthropologists, and industrial engineers, working separately or together on common problems.

Ergonomics is another term used for human engineering.

The purpose of this report is to explore the field of human engineering, extract the principles from this science, applicable to a machine tool, and apply these principles to the design of a PUNCH PRESS.

To the knowledge of the author, no work has been done previously, even by prominent punch press manufacturers, pertaining to the design of a press from the human engineering viewpoint.

Hence, the "First Principles" approach has been followed throughout the body of the report.

## HISTORY AND BACKGROUND OF HUMAN ENGINEERING

Specialists in the field of human engineering apply available information about man-machine systems to the design of equipment. Human engineering is a fairly new field, one in which the assembled quantity of facts and tested principles has not yet reached that of the older sciences. Although psychologists and physiologists have systematically studied the human sensory system and the response characteristics for years, it was not until World War II that they were called in to cooperate actively with the design engineer in the development of equipment.

This union of interests resulted from the increased complexity of military equipments and inability of operators to utilize the equipment adequately in the job to be performed. Many human engineering organizations currently are made up of psychologists, physiologists, anthropometrists, mathematicians, engineers, and physicists, who work together in the solution of man-machine design problems. No one field of learning has a monopoly in human engineering.

In the past, consideration of human factors has been given a secondary role by most designers of equipment, largely because no systematically organized information on the subject was available to him. Today, a great volume of human engineering research has been done. An average engineer finds it difficult to interpret the results for practical application, because of the number and complexity of sciences involved.

Much of the information now available for human engineering purposes has been drawn from research performed in psychology, physiology, within a frame work usually different from that of the physical and engineering sciences. The translation of these data into one or more of the quantitative languages preferred by the equipment designer is often difficult and, in some cases, impossible.

## CONSIDERATIONS IN THE DESIGN OF EQUIPMENT

The successful design of equipment for human use requires consideration of the following basic human characteristics - sensory capacities, mobility and muscle strength, intellectual abilities, common skills and capacities for learning new skills, capacity for team or group effort, and body dimensions - and in addition, of the effects of working environments upon human performance.

### An Outline of Recommended Design Procedure

Preparation. Ascertain the job which the man-machine combination is to perform.

Determine the requirements and restrictions to which the design must conform.

Determine the conditions under which the man-machine combination must operate.

Determine the characteristics of the existing components which may be a part of the equipment which is to accomplish the job.

Selection. Block out alternative circuits, assemblies and combinations of components which will perform the required job.

Within each of the proposed designs, examine the appropriateness of the selected components and linkages in terms of -

Functional characteristics,

Compatability with design restrictions,

Reliability under expected operating conditions.

Select the most promising design and proceed with the establishment of detailed specifications.

Devise, when necessary, means for control of operating conditions arising as a result of the design selected.

Refine the design in terms of -

Economy of manufacture,

Efficiency of operation,

Ease of maintenance.

Check: Evaluate the total man-machine (system) design experimentally if possible. If it is not possible to check the total design, evaluate each separate sub-system, using as criteria the performance required by its role in the total design.

The last principle, in reality, has been used in the analysis of a punch press.

## INTRODUCTION TO THE PUNCH PRESS

Before the general principles of human engineering are applied to the design of a punch press, - BLISS C SERIES - SINGLE CRANK - INCLINABLE PRESS CONSOLIDATED No. 4 - it would be worthwhile to discuss in brief, some of its mechanical features.

### Modern Trends In Press Design

Many types of presses are constructed of welded steel frames, and others are one-piece high-test semisteel castings. In some instances, both of these designs are combined in one line of presses, while in others some of the parts are assembled with prestressed bolts and nuts.

### Types of Presses

Presses may be broadly divided into the following types:

(1) Gap- frame press.

(2) Foot press.

(3) Arbor press (mechanically or air-operated).

(4) Inclinable press.

(5) Enclosed press.

(6) Straight-side press.

(7) High speed press.

(8) Drawing press.

## SAFETY - THE PRIMARY CONSIDERATION IN A MACHINE TOOL DESIGN

Safety can be called one of the primary considerations in the design. Safe design goes beyond mechanical stresses and forces. It takes into account exposure of personnel to accident.

## Factor of Safety

A wide margin of safety should be maintained between the calculated tonnage required for any job and the tonnage capacity of the press. This is because certain metals have a tendency to work harden and because of the conditions inherent in most dies. Press failure or breakage is frequently the result of using dull dies.

### The Following Design Features Enhance Safety of Operator and Equipment

(1) Correct planning of dies.

(2) Selection of stock feed mechanism.

(3) Selection of ejection mechanism.

(4) Semi-automatic feeds:

  (a) Primary operations : Roll and hitch feed.

  (b) Secondary operations: Slide, push, or dial feed.

(5) Proper shielding.

Protection is an integral part of a well-designed machine. True safe design ensures that the operator or the casual visitor will not be hurt by being caught in shear, pinch points, reciprocating parts, or by flying missiles. This means removing or modifying hazards through controls built into the over-all design.

A 'hazard' is defined as any movement of materials, equipment or persons - or potential movement, that exposes persons to possible injury. Thus, the industrial engineers and designers have to give special considerations to see that their machines or products - for example, the punch press - meets safety obligations to the customer.

Shielding Devices. Feeds and dies must both be shielded to prevent the operator from reaching into the die area, or from being caught in the feeder. Shields of this type are interlocked with the clutch mechanism so as to allow press operation only when shields are in the complete protective position.

For manually fed primary operations it is usually possible and always preferable to design safety shields or guards as an integral part of the die. After the die is set, it becomes a completely self-guarded unit and no additional protection is required.

Guards. The commercially built guards are of the following types:

(1) Barrier guards.

(2) Interlocking gate guards.

(3) Sweep guards.

(4) Pull-out guards.

(5) Two-hand tripping devices.

(6) Trip guards.

(A more detailed explanation of the same can be found in "Accident Prevention Manual" - National Safety Council). A variety of empirical formulae are also used in designing the safe openings for guards.

The Fail-Safe Principle. This principle states that a safety device should always function in a correct manner, in order to keep the apparatus safe.

The Principle of Control. This principle requires that a machine be so designed that it can operate only in accordance with the wishes of the operator.

This principle can be well applied to the inadvertent starting of the punch press motor and the accidental operation of the push-button.

Inadvertent starting of a motor can occur when the power supply is restored after a failure, or the motor starts due to a vibration and not the starting torque of the motor. The first condition can be remedied by incorporating a 'no-volt' release, and the second by using a motor of the required torque characteristics.

The push-button should be recessed and provided with a guard ring so that it cannot be depressed by accident, unless the action is deliberate.

Inching. For a hazardous machine operation like that of a punch press, the machine should be stopped after every operation. In a punch press we can do so by providing an arrangement whereby the ram will descend only once during every depression of the foot-pedal.

Control Circuits. Positive thermal cut-out fuses of the correct capacity should be provided in the electrical circuit.

Limit Switches. These switches control the travel of a machine in the case of an emergency. A limit switch is incorporated in most of the punch presses. This consideration will again be taken up in the case study which follows.

## PRINCIPLES OF COMPATIBILITY IN THE OPERATION OF CONTROLS

Unlike the lathe and other machine tools, a PUNCH PRESS is a relatively simple machine tool. There is a bare minimum of knobs and levers mounted on it. As the design becomes more sophisticated, in the high production type of punch presses, there could be a maze of knobs and levers, unless the press is "numerically controlled."

Control movement to produce any increase in magnitude including switching "on" should be as follows:

(1) Rotary controls - movement clockwise.

(2) Controls associated with visual displays - movement should correspond to display movement.

(3) Linear controls - movement forward, upward, or to the right; and for overhead linear controls, movement to the right.

The principle of "Population Stereotype" is embodied here. Human beings have a natural tendency to operate the controls in a particular direction, and expect the display to be shown in a particular manner.

## Control - Display Relationships

(1) Display should inform the user:

(a) Which control to operate, also when, how much, in which direction, and at what speed to operate. A proportional linear relationship should exist in the speed.

(b) What equipment each control effects and ,

(c) What equipment each display describes.

(2) Operator's hand should not block display when using controls.

(3) Each control should preferably be directly below its display in order to avoid misidentification.

(4) Arrangements of rows of displays with columns of controls and vice-versa should be avoided.

# CONTROLS

## Identification

As mentioned earlier, the PUNCH PRESS at present does not have a variety of knobs and levers and switches mounted on it. However, anticipating some kind of innovation in the model, fine controls may be provided in a PUNCH PRESS of the near future.

The guiding principles which would be used in the identifiability of controls are:

(1) Primary and emergency controls should be easily identifiable both visually and non-visually. This would refer in particular to the "stop-start" switch, and the foot pedal for the release of the ram.

(2) Identification can be most effectively provided for by location, labelling, and shape coding. eg.The foot-pedal for the release of the ram should be to the right of the centre line of the machine, facing the operator. This would be the most natural position.

If a number of pedals are located close to each other, they should have different shapes. The main pedal should preferably have the shape of a shoe, the adjoining pedal can be square, etc.

For aiding the new operator, and for helping the experienced operator during periods of quick decisions, labelling of the controls would be an idea well worth consideration.

Grouping of Controls.

(1) The basic principle to be followed is that controls that are used together should be grouped together.

(2) When the controls are used in a relatively standard sequence, this sequence governs the placement of controls within a control group and the relative locations of the groups themselves.

(3) In general, for the controls manipulated with the same hand, the preferred sequence is from left to right, for a right handed person (population stereotype).

(4) The sequence in which the controls are operated should be:

  (a) Horizontally - left to right (preferred).

  (b) Vertically - top to bottom.

  (c) Where both horizontal rows and vertical columns are required, the layout should be arranged to read like the page of a book, in horizontal rows, left to right, proceeding from top row to bottom row.

(5) For gauged controls, the preferred sequence of operation is from front (smallest knob) to back (largest knob).

Mounting of Controls. Ideal mounting of controls is perpendicular to the line of sight but deviations of $30^{\circ}$ from the line of sight are acceptable.

Table 1. Recommended Separation Between Controls

| Control | Type of Use | Recommended Separation (Inches) | |
|---|---|---|---|
| | | Minimum | Desirable |
| Push Button | One finger, randomly. | 1/2 | 2 |
| | One finger sequentially | 1/4 | 1 |
| | Different fingers, randomly or sequentially. | 1/2 | 1/2 |
| Toggle Switch | One finger, randomly. | 3/4 | 2 |
| | One finger, sequentially. | 1/2 | 1 |
| | Different fingers, randomly or sequentially. | 5/8 | 3/4 |
| Cranks and Levers | One hand, randomly. | 2 | 4 |
| | Two hands, simultaneously. | 3 | 5 |
| Knobs | One hand, randomly | 1 | 2 |
| | Two hands, simutaneously | 3 | 5 |
| Pedals | One foot, randomly. | 4 | 6 |
| | One foot, sequentially. | 2 | 4 |

Location of Controls and Displays.

(1) High priority controls and displays should be placed in the optimum manual and visual areas; eg. a start-stop switch, foot pedal for ram, etc.

(2) Emergency controls and displays should be readily accessible. They need not be placed in the optimum areas unless the nature of the potential emergency is so critical as to require top priority placement. In the PUNCH PRESS, the main "on-off" switch should be given such a priority.

(3) Secondary controls and displays should be placed within the limits of the maximum manual and visual areas. If they are related to the higher priority controls, their placement should reflect this relationship.

(4) Set-up and calibration controls and displays that are used infrequently should be given lowest priority in assigning location.

(5) Controls which must be used most often should be placed somewhere between elbow and shoulder height. Locations forward and slightly below shoulder height are found most easily when "blind" reaching is required.

Maximum forces can be applied to levers gripped at shoulder level for the standing operator, and at elbow level for the seated operator.

These conditions are to ensure maximum physiological efficiency.

Spacing of Controls. The values of the spacing obtained from actual experiments only serve as a guide. Variations in these values can occur, depending on factors such as simultaneous or sequential use, size of control and range of movement, need for blind positioning, clothing and gloves, etc. (Refer to opposite page).

Table 2. Characteristics of Common Controls.

| | TYPE OF CONTROL | | | | | |
|---|---|---|---|---|---|---|
| | Discrete Adjustment | | | | Continuous Adjustment | |
| Characteristic | Hand Push Button | Foot Push Button | Toggle Switch | Rotary Selector Switch | Knob | Crank |
| Control Setting Time. | Very Quick | Quick | Very Quick | Medium to Quick | Slow | Slow |
| Recommended No. of Control Settings. | 2 | 2 | 2-3 | 3-24 | Unlimited | Unlimited |
| Space Required. | Small | Large | Small | Medium | Small to Medium | Medium to Large |
| Accidental Activation Possible. | Yes | Yes | Yes | Yes | Yes | Yes |
| Effectiveness of Coding. | Fair to Good | Poor | Fair | Good | Good | Fair |
| Ease of visually identifying setting. | Poor | Poor | Fair to Good | Fair to Good | Fair to Good | Poor |
| Ease of non-visually identifying Setting. | Poor | Poor | Good | Fair to Good | Poor to Good | Poor |
| Ease of check reading in array of of like controls. | Poor | Poor | Good | Good | Good | Poor |
| Ease of operating in array of Like Controls. | Good | Poor | Good | Poor | Poor | Poor |
| Effectiveness as Part of Combined Controls. | Good | Poor | Good | Fair | Good | Poor |

Some Design Recommendations For Selected Controls

Table 3.

| Control | Characteristic | Recommended Values Minimum | Maximum |
|---|---|---|---|
| HAND PUSH BUTTON | Diameter: | | |
| | Finger Tip Operation | 1/2 inch | |
| | Emergency operation - thumb or hand | 3/4 inch | |
| | Displacement. | 1/2 inch | 1½ inch |
| | Force: | | |
| | Fingertip Operation | 10 oz. | 40 oz. |
| | Little finger squeeze. | 5 oz. | 20 oz. |

General:

(1) Top should be concave, or provided with frictional resistance.

(2) Only two settings should be used.

(3) Positive indication of activation (eg. click, back light).

(4) Button should be labelled.

Table 4.

| Control | Characteristic | Recommended Values Minimum | Maximum |
|---|---|---|---|
| FOOT PUSH BUTTON OR FOOT PEDAL | Diameter | 1/2 inch | |
| | Displacement | | |
| | Normal operation. | 1/2 inch | |
| | Operator wearing | | |
| | Heavy Boots | 1 inch | |
| | Operated by ankle flexion | 2½ inches | |
| | Operated by Leg Movement | 4 inches | |
| | Force: | | |
| | Foot will not rest on control. | 4 lbs. | 20 lbs. |
| | Foot may rest on control | 10 lbs. | 20 lbs. |

General:

(1) Control should be designed for toe operation rather than heel operation.

(2) Where possible a pedal hinged at the heel should be used rather than a push button.

(3) Some status indication (eg. on-off indicator) should be provided.

## Force Limitations in The Operations of Controls

Although a PUNCH PRESS does not incorporate all the control devices like cranks, knobs, levers, pedals, etc., a treatment of the limiting forces is given below, for future designs

The human operator should not be expected to perform at a maximum capacity for any great length of time, so it is wise to leave a safety factor in force required.

A maximum force of 8 to 16 ounces is (required) recommended for small toggle switches.

A maximum torque of 2 inch pounds is suggested for rotating knobs.

A load of 2 to 5 pounds is suggested for smooth operation of small high-speed cranks.

Hand levers of the gear shift type should not require more than 30 pounds. of applied pressure.

Foot operated pedals requiring up to 20 inch pounds are adequate for operation of control adjustments. The pedal should be mounted, however, so that the fulcrum of the action is at the heel of the foot and spring tension should support the weight of the foot.

In the standing position the legs and feet are needed to maintain balance and to increase the operator's range of manual control capabilities. Thus, for the standing position, pedal controls should be avoided whenever possible except for occasional "in-between" operations.

In the case of the PUNCH PRESS, the foot pedal for the release of the ram is intermittent and hence, it satisfies the above given condition.

## DESIGN OF THE FOOT PEDAL FOR THE PUNCH PRESS

The foot-pedal used to operate the hammer stroke of the PUNCH PRESS, is the control second in order of importance to the main "on-off" control.

The designer keeps the following recommendations in mind:

(1) The pedal should return to its original position when the applied force is removed.

(2) Maximum pedal resistance should never exceed the maximum pressure exertable by the weakest operator. For leg operated pedals, in the standing position, this force should not exceed 150 lbs.

(3) For frequently but not continuously used leg-operated pedals, a force of about 50 lbs. is reasonable.

(4) Heavy foot-gear makes it difficult to gauge pedal travel, and excessive movements and force usually result. Under such conditions, pedal travel should be increased. The increase should be from ½" to 1½".

(5) Most pedals should be as wide, or almost as wide as the sole of the shoe, ie. at least 3½". What the maximum width is matters little as long as there is enough clearance between adjacent pedals.

(6) Pedals used intermittently or for short periods should be at least three inches long. Pedals used continuously or for long periods should be 11" to 12" long.

(7) Pedal shape is not very important; it can be square, rectangular, circular or oval, as long as it is flat and affords a large enough area of contact with the shoe.

(8) For pedals with which large forces must be exerted, ie 200 pounds or more, a pedal bar or recessed heel section, will prevent the foot from slipping off the pedal and will assist the operator in locating the

pedal by feel. (This is particularly advantageous in cold weather or with large,heavy boots.)

## VISUAL DISPLAYS

Most of the present day PUNCH PRESSES have little or no visual displays. Bearing in mind the rapid technological advances, the author of this report feels that modern "tape-controlled machines in the near future may have a maze of visual displays located on the body of the press or the immediate area. Hence, a discussion and functional evaluation of visual displays will not be out of place here.

Table 5.

| Function | Moving Pointer | Moving Scale | Counter |
|---|---|---|---|
| Qualitative Reading to Exact Value. | Fair | Fair | Good Minimum Time and Error in Obtaining Exact Numerical Values. |
| Qualitative and Check Reading to Approximate Value | Good Location of Pointer Easily Detected. Numbers and Scale Need not Be Read, Change in position Easily Detected. | Poor Difficult to Judge Direction and Magnitude of Deviation Without Reading Numbers and Scale. | Poor Numbers must Be Read. Position Changes not Easily Detected. |
| Setting Inserting Desired Values or Matching Other Indicators | Good Simple and Direct Relation of Pointer Motion to Motion of Setting Knob. Pointer Position Changes Aid Monitering. | Fair Somewhat Ambiguous Relation to Motion of Setting Knob. No Pointer Position Change to Aid Monitering. Not Readable During Rapid Setting. | Good Most Accurate Monitering of Numerical Setting. Relation to Motion of Setting Knob Less Direct Than for Moving Pointer. Not Readable During Rapid Setting. |

Table 5 (cont.)

Table 5 (cont.)

| Function | Moving Pointer | Moving Scale | Counter |
|---|---|---|---|
| Tracking<br>Continuous Adjustment to Maintain Desired Value | Good<br>Pointer Position readily Monitored and Controlled. Most Simple Relation to Manual Control Operation | Fair<br>No Pointer Position Changes to Aid Monitoring. Somewhat Ambiguous Relation to Control Motion Not Readable During Rapid Changes | Poor<br>No Gross Position Changes to Aid Monitoring. Ambiguous Relation to Control Motion. Not Readable During Rapid Changes. |
| Comments | Requires Greatest Exposed and Illuminated area on Panel. Scale Length Limited Unless Multiple Pointers or Non-Linear Scales are Used. | Offers Saving of Panel Space. Only Small Section of Scale Need Be Exposed and Illuminated. Long Scale Possible By Use of Tape | Most Economical of Space and Illuminated Area. Scale Length Limited Only By Number of Counter Drums. |

## An Ideally Designed Visual Display System

An ideally designed visual display system would satisfy the following requirements:

(1) It can be read quickly and easily in the manner desired (quantitative, qualitative or check reading.)

(2) It can be read as accurately as demanded by the operator's needs, and preferably not more accurately.

(3) It should display only the necessary information

(4) It is free of features that produce ambiguity or invite gross reading errors.

(5) The information provided is in the most immediate form and does not require a mental translation into another unit.

(6) Changes in indication are easy to detect.

(7) The indicator is easily identifiable and distinguishable from other instruments.

(8) The information is current ie time delay is minimized.

(9) A failure in the indicator or in the system is clearly shown.

(10) The relationship between the indicator and its controls is unmistakable, in terms of:

(a) The proper control to use.

(b) The direction of movement of the control and;

(c) The rate and limits of movements of the control.

Note: Numerals, letters and scale markings should confirm to the recommendations made in the human engineering guides to equipment design.

## USE OF COLOR FOR EQUIPMENT

Principles of color scheme in painting equipment should, in general, follow utilitarian rather than aesthetic standards. The color scheme should consider both the physical and psychological factors.

It is unfortunate that a standard Color Code has not been developed. The British Color Code and the American Color Code for equipment differ. However, the following discussion will serve as a guide for all machine tools in general, and the PUNCH PRESS in particular.

Large expanses of fixed mechanical equipment body should be painted neutral eye-resting colors, such as gray, with the immediate working area a light buff for good seeing. Stand pipes, hose connection, fire-alarms, etc. should be painted red. Fresh-water hydrants should be yellow with red tops.

Mobile shop machinery, such as loaders and scooters, should be bright yellow, with the larger machines slightly darker and having black and yellow bumpers. Yellow has also been adopted for certain maintenance equipment.

Electric controls and outlet-box exteriors should be painted blue with the inside of the box door orange to indicate danger. High-voltage locations should be indicated by orange paint.

The indication for first-aid equipment has been standardized as a green cross on a white background.

Blue is another color for designating caution, generally limited to warning against starting or using equipment under repairs (signs for elevators, boilers, grinders, etc. that are under repair).

Purple is the basic color for designating radiation hazards. Yellow should be used with pruple for tags, labels, and signs for rooms and containers storing radio-active material or containers and areas contaminated with radio-activity.

## ILLUMINATION OF THE WORKPLACE AND SURROUNDINGS

It is a sincere belief of the author of this report that no discussion on color is complete without a reference to illumination.

Good illumination is necessary for most human operator tasks, in and around the workplace. The type of task that is to be illuminated, the speed and accuracy with which it must be performed, the length of time it is to be performed, and variations in the operating conditions must be known before a suitable lighting system can be designed.

The important factors that should be considered in the design of a lighting system in a factory or workshop, are as follows:

(1) Suitable brightness for the task at hand.

(2) Uniform lighting on the task at hand.

(3) Suitable brightness contrast between task and background.

(4) Lack of glare from either the light source or the work surface.

(5) Suitable quality and color of illuminants and surfaces.

Illumination in a work area can be provided by two means:

(1) Natural light and,

(2) Artificial light.

(1) Natural light: Daylight can be introduced into a room in a number of ways which assure adequate illumination and reduce glare. This is done with a proper combination of windows and north-light trusses.

(2) Arfificial light: As the name suggests, electrical lighting is used to illuminate the workplace, the machine-tool, and surroundings.

Direct lighting offers maximum utilization of light at the working plane with 90% to 100% of the light output directed towards the work area. Undesirable brightness ratio, shadows, and glare are the most prominent faults of direct lighting.

Indirect lighting offers general, even lighting without shadows or glare, by shielding the source so that between 90 and 100% of the light is directed towards the ceiling and upper walls, from which is reflected more or less evenly about the room.

Diffuse lighting is undirected light scattered evenly in all directions. It requires less wattage than either of the above systems but does cause some glare and shadows. Florescent units with baffles solve most of the glare problems of the diffusing enclosure.

Either direct or indirect lighting may be combined with diffuse lighting to provide modifications as needed.

The current trend, however, is to use a general florescent illumination for the workshop bay, and spot illumination in the required area by means of a lamp mounted on the body of the machine tool.

The recommended general illumination is between 50 and 100 foot-candles.

Fifty foot candles for average machine-shop work.

One hundred foot candles for fine machine-shop work.

## DESIGN OF THE WORKSPACE AND ARRANGEMENT OF EQUIPMENT

This area encompasses a broad field. Due consideration has to be given to the arrangement in the immediate vicinity of the machine tool, and also its relation regarding the optimum position in relation to the surrounding equipment.

When the most efficient workspace is to be designed around the machine tool, the principles of Time-Motion Economy come into the picture. The designer has to resolve conflicting demands based on both human and mechanical limitations and must reach the best compromise he can. Evaluations of workspace layouts differ, depending on the particular task. Some important factors which are considered are as follows:

(a) Accuracy.

(b) Speed.

(c) Comfort.

(d) Safety - operator and others.

(e) Reduction of unnecessary effort - for elimination of undue fatigue.

(f) Knowledge of results - the workspace ought to be so arranged that the worker can see and understand what he is doing.

Overall Workspace. One variable of great importance in this area is the human body itself.

Controls - foot-pedals, knobs, dials, levers, must be located so that operators of various builds and sizes can operate them. From the body measurements available - anthropometric data - the designer can find the size of the workspace in general, but in addition he must recognize that when the body is being used to perform a particular (task) act, these measurements are often inadequate; such factors as the flexibility of the joints, or the proportions of trunk to limit length play a big role, than just the measurements.

Workspace for Hand-Arm Movements. Most industrial and service jobs are manipulative, requiring the assembly of small parts or the response by some hand or arm movement to some kind of visual display. Because of this, the information regarding the area over which a man's hands and arms can readily function.

Here again, merely the lengths of the arms and hands are not the only factors that must be considered; we must also take into account the factors such as the trunk length, the flexibility of the joints, the direction of the movement and the amount of clothing.

Optimum Visual Areas. The optimum visual area is defined as the solid angle through which the operator can view displays by eye movement alone. In the case of a PUNCH PRESS, this should be the area in which the punch and die, and the important controls like the"stop-start" switch are located.

The maximum visual area is limited by the total amount of movement of both eyes and head which can occur without muscle strain.

The table below gives the optimum and maximum viewing angles, and the lateral and vertical dimensions on a panel or work area which corresponds to the optimum angles at a 28" viewing distance. Specifications of the visual area are in terms of deflections from the standard line of sight; ie the horizontal line normal to the lateral axis of the head.

Table 6. Dimensions of Visual Areas.

| UNITS | Direction of Movement | | |
|---|---|---|---|
| | Left or Right | UP | Down |
| Degrees: | | | |
| Optimum | 15 | 0 | 30 |
| Maximum | 95 | 75 | 85 |
| Inches: | | | |
| Optimum | 5.5 | 0 | 10 |

## Principles of Time-Motion Economy

Since the Principles of Time-Motion Economy have been mentioned in the foregoing discussions, it would be worthwhile to state them here in brief, within the framework which a machine tool like a punch press is designed.

The basic divisions are as follows:

(1) Use of human body. This deals with the motion of hands and feet.

(2) Arrangement and conditions of the workplace. A special emphasis is placed on the arrangement of tools and materials, comfortable standing and sitting postures of the operator, visual requirements of the workplace, and environmental conditions like illumination, venilation, and temperature.

(3) Design of Tools and Equipment. The control devices and tools are so designed that they are readily accessible to the operator, and offer the best possible mechanical advantage.

Equipment Arrangement. The arrangement of equipment and the people who must operate this equipment canmean the difference between achieving and not achieving the final objective, effectively. Proper arrangements of the components (man and machine) should be based upon the visual, auditory, and control links between them and an analysis of the task to be accomplished.

A qualitative method for the solution of this problem is "Link Analysis." It is a technique for arriving at the best arrangement, for a particular purpose of the men and machines in the system.

The various steps in the method are as follows:

(a) First, the general function of the system and the contribution of each unit are presented in the form of a process chart, activity analysis chart, or flow diagram. Such a chart or diagram shows how information flows between units and points out how the general sequence of operations falls into various stages. It shows all the men and machines in the system and gives a brief description of the function of each.

(b) The interrelations or links, between the units are determined and identified as visual, tactual, auditory, electrical, and mechanical; then the strength of each link is calculated. (strength is defined as the product of the frequency of occurence and the importance of a link during a typical operation. Importance is subjective, and hence the operator is consulted by the design engineer in this respect.)

(c) An analysis chart of the link values of the components of a system is prepared, and the relative importance and priority for placement of each component is determined.

(d) After the data on links and their strengths have been gathered, the units in the system are arranged graphically, in accordance with the link strengths, to arrive at a theoritical ideal solution.

(e) Then the plot is rearranged to shorten the links. The engineer first plots the unit with the highest link strength, around it are plotted the units with which it has the strongest links, connected by lines having numbers indicating the strength. After a good degree of manipulation, the figure appears in the modified form as shown.

Check. It should be noted that the highest ranking links are generally shortest and that there are few crossed link paths. The diagram represents the ideal layout of the workspace from the operator's viewpoint.

## Adoption of the Final Plan for Equipment Arrangement

Discussion with other engineers will inevitably lead to changes in this preliminary design to allow for engineering requirements of space, piping, cables, storage, and locker space. Arrangement of small scale models on a floor is useful at this stage. Since there are often several good possible layouts, alternative layouts can be developed and compared for efficient visibility

SYMBOLS

Machines

Men

3 Link Line, with the number showing its strength.

Original

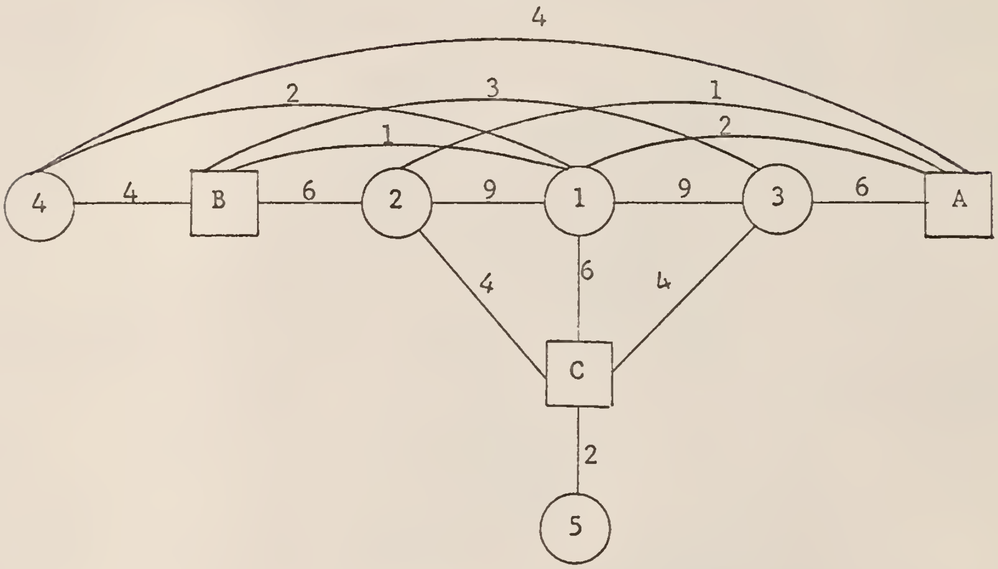
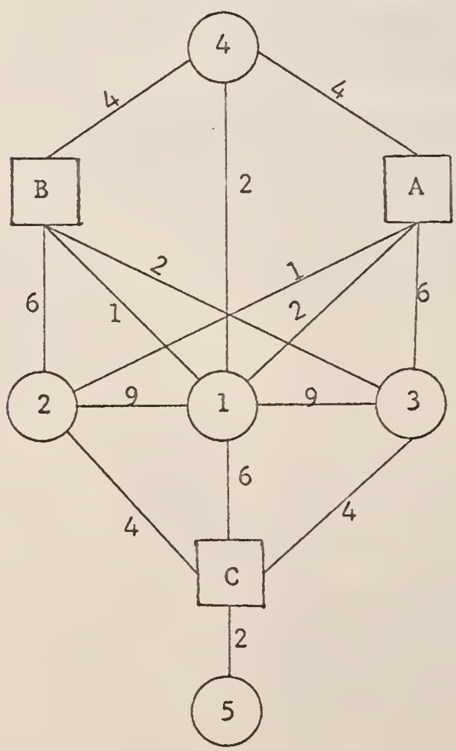



Fig. 1

Modified



walking, talking, crowding and accessibility. To evaluate the layouts, each is drawn to scale on a floor plan and the various links are indicated by lines drawn between the units. A general convention is to indicate the link strength by the thickness of the line.

Indices for visibility, walking, and talking are provided by measuring the distance over which the type of link is made and the frequency of its occurrence. For crowding and accessibility, an index is obtained by determining the amount of space provided for each individual, then weights are assigned to undesirable conditions.

After the best compromise is chosen, the selected layout is actually built and evaluated under simulated operating conditions. The final test of an efficient layout is, of course, the speed and accuracy of performance and the comfort of the men who operate it.

The environmental conditions for safety and efficiency are then reviewed. Proper ventilation, convenient storage and maintenance facilities, safety in the form of protective devices, and conveniences such as ash trays will provide for smoother operation and less physical and mental fatigue among operating personnel.

## EASE OF MAINTENANCE

Maintainability is the degree of facility with which an equipment or system is capable of being retained in, or restored to, serviceable operation. It is a function of parts accessibility, internal configuration, use and repair environment, and the time, tools, and training required to effect maintenance.

The broad objective behind the present emphasis on improved maintainability can be stated as follows:

(a) To increase the availability of equipment (or systems) for the performance of their intended function.

(b) To reduce the costs of operational support within the planned service life of an equipment. The above mentioned factors must be balanced at some reasonable level.

Reliability and Maintainability. When the major effort to improve reliability was first initiated, it was hoped by many that the improvement would be so substantial that the need for maintenance activity would be practically obviated. The growth in complexity, however, reduced this hope, and, although the search for further reliability improvement goes on, it is not very likely in the near future that maintenance activity will decrease.

Designing for Maintainability. Maintainability must be designed into a machine-tool (like a PUNCH PRESS, lathe etc.) in the early stages of its development, if costly maintenance or costly redesign is to be avoided.

Thus, a design schedule for maintainability should include the following steps:

(a) Planning for maintainability.

(b) Designing for maintainability.

(c) Testing and revising the design.

(a) The objectives to be accomplished are:

(1) Study operational equipment resembling the one to be designed. From past maintenance and history of the equipment, list the maintenance features that should have been designed into the equipment, but were not.

(2) Become familiar with entire system, like an integral machine shop, where the equipment will be installed. This will give an idea of the spaces and passages which the equipment will go through.

(3) Find out what the equipment and tools are already in use on related equipment and might be adapted to the one to be designed.

(4) Find out what kind of maintenance men are available to service the equipment.

(5) Investigate what supply facilities are available to provide spare parts for the equipment.

(b) The designer considers the following areas: prime equipment, installation, test equipment, maintenance manuals, and tools.

In the prime equipment the maintainability features are incorporated as follows:

(1) Modular of unit packaging, and "throw-away" units.

(2) Replacement modules that are interchangeable and independent.

(3) Ease of access to test points and the internal parts of the equipment.

(4) Self checking features.

Maintenance manuals should be ready to go with the equipment when it is released for use. Themanuals should list all the steps necessary to maintain the equipment.

Machine Tools and equipment should be so designed that they can be repaired and serviced with standard tools and with as few tools as possible. If special tools are required, however, design them early enough so that they can go out with theequipment.

(c) The design should be tested for maintainability under environmental conditions simulating those in the field.

In the tests:

(1) Use only those procedures, tools, test equipments, and manuals that will be available to the maintenance men.

(2) Use maintenance men, with the degree of skill, as would be available under actual job conditions.

(3) Include trouble shooting a variety of malfunctions.

All these tests are directed at finding ways to improve the prime equipment, test equipment, maintenance procedures and instructions, and tools for the maintenance man.

Maintenance Limitations. The following points should be kept in mind when thinking of maintenance:

(1) Physical limitations.

(2) Maintenance skills.

The first condition refers to the amount of force a human being can exert, the weights they can lift and carry, etc.

The level of maintenance skill possessed by the service personnel directly affects the design complexity of the equipment.

Maintenance Conditions. The conditions under which maintenance is performed frequently include the following:

(a) Extremes of lighting: Service personnel sometimes work in almost total darkness with only the illumination of a flashlight; at other times they work in bright sunlight.

(b) Lack of working space: This is one of the headaches of the maintenance crew. There usually is little room for technicians to work in - let alone spread out diagrams, instructions, and tools - because only a certain amount of space can be allotted to the performance of maintenance.

(c) Temperatures ranging from artic cold to tropic heat. Working in a position that might be only mildly uncomfortable in moderate temperatures can become almost intolerable in a few minutes of extreme heat or cold. Perspiration makes the technicians hands slippery so that objects tend to slip from his grasp; low temperatures make the fingers stiff so that it is extremely difficult to make fine movements or hold tools and equipment. In addition, weather changes often delay maintenance on equipment because the equipment is not protected from the weather.

(d) High psychological stress: Line maintenance is frequently performed under the stress of combat or a shortage of time.

Thus, the designer should detemine the working conditions under which equipment most likely will have to be maintained and design the equ'p-ment accordingly.

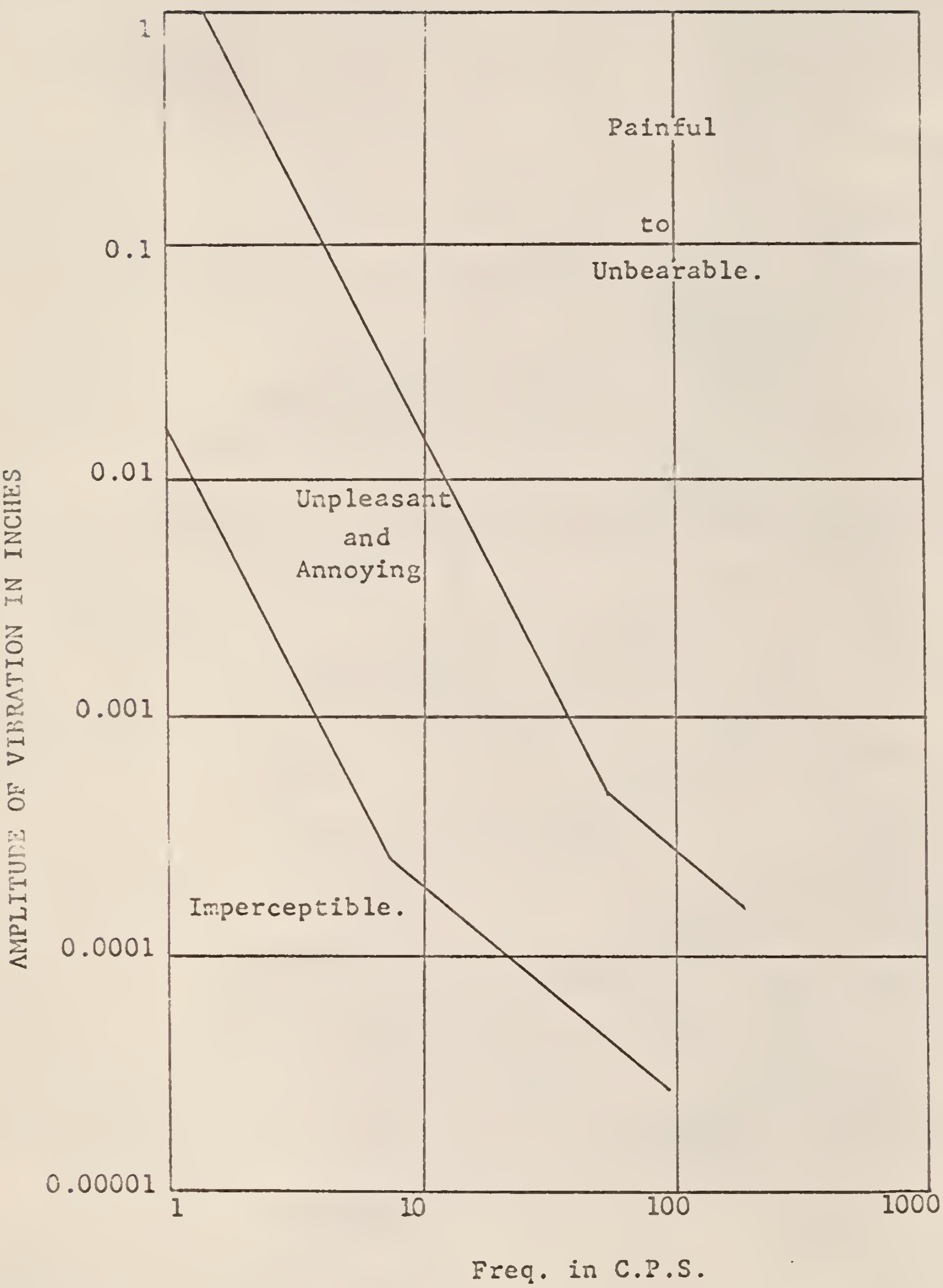
ENVIRONMENTAL CONSIDERATIONS

Speech Interference Level: (SIL). The speech interference level describes the effectiveness of noise in masking the speech. Normally an operator is not expected to talk, but a high degree of speech interference due to noise of machines may get "on the nerves." This may lead to fatigue, violence, and decrement of performance. SIL is measured in decibels. A typical value for a SIL of 75 db. for a distance of 2-3 feet minimal communication is possible and shouting is desired.

Consideration of Noise. The "critical exposure limit" and "damage risk criteria" defines noise levels resulting in minimum risk of permanent hearing impairment, considering a random type noise for the unprotected ear. With the onset of noise, the operator experiences physiological changes, fatigue, annoyance, and a reduction in his performance. Any attempt in the direction of reducing the noise level increases the overall efficiency of the operator.

A typical value for a "damage risk criteria" for a 10 second exposure is 135 decibels.

Prevention and Minimization of Noise. Excess noise can be greatly minimized by the use of accustic materials in walls, ceilings, and floors, by the proper placement of doors and windows, and by the isolation of the noise source.




SUBJECTIVE RESPONSE TO VIBRATION

Graph 1

Domed ceilings should be avoided in the planning stages, as they tend to focus all sounds about the head of an operator.

When the ventilation (exhaust) fans are required, they should be designed so that the top speed does not exceed 55 ft./ second and the air outlet velocity is not greater than 1500 ft./ minute. The fan casing should be truly rigid, or damped, and super-silent motors should be used.

Noisy machinery should be isolated or redesigned.

A simple means for controlling reverberation temporarily in areas such as shops is to use baffle boards of sound absorbing material. These boards can be suspended from the ceiling at different points without interfering with permanently installed equipment.

The noise levels in factories should not exceed 80 decibels.

Consideration of Vibration.

(1) The levels at which vibration is judged to become perceptible, annoying, and painful are indicated in fig. on the opposite page, a function of amplitude and frequency of vibration.

(2) One company has solved the problem of vibration by the use of absorbents and shock mounting.

A machine like a PUNCH PRESS would never emit a vibration which would be imperceptible. However, care should be taken to see that it does not give rise to painful or unbearable vibrations.

The degree to which an individual person is affected by vibration is quite dependent on physical, psychological and environmental factors. Symptons include loss of appetite, loss of interest, fatigue, annoyance, perspiring, salivation, nausea, headache and vomiting.

# A CASE STUDY - THE ACTUAL APPLICATION OF THE PRINCIPLES OF HUMAN ENGINEERING TO A BLISS PUNCH PRESS

## The Plan of Approach

The Job. The job which the man-machine combination has to perform is the following:

The punch press has to be operated after the die is set on the platform of the press. The basic operation is that of actuating the "start" switch, and then depressing the foot-pedal for the release of the ram.

Requirements and Restrictions. It was not possible to obtain the exact blue-prints from the company. Hence, the difficulties inherent in the mechanical manufacture of the press could not be ascertained.

However, the primary requirement in the punch press would be the criteria of 'safety.' This is more so because the press is in an educational institution (the Kansas State University, Engineering Shops, Industrial Engineering Department).

Conditions Under Which the System Operates. This takes into account the environmental conditions like illumination, heat, ventilation, color scheme of the machine, and surroundings.

Characteristics of the Existing Components. These are the parts of equipment that are used to accomplish the job. eg. Start-stop switch, foot-pedal, safety devices, etc.

The components are examined rigorously from the following viewpoints:

(1) Functional characteristics.

(2) Compatibility with design restrictions.

(3) Reliability under expected operating conditions.

(4) Efficiency of operation.

(5) Ease of maintenance.

Limitations. As mentioned earlier, it is not possible to check the total design. Hence, each separate sub-system has to be evaluated, using as criteria, the performance required by its role in the total design.

DATA SHEET

Specifications. Punch Press: Serial No. - H16431

Standard Stroke: 3 Inches 4085301

Strokes/ min: 115
(Non-geared). 1942

Consolidated No. 4. E.W. Bliss, Hastings, Mich.

Engg. Shops - No. 0194

Safety.

(1) Capacity of the press in tons: 30 Tons.

(2) Is it ever used beyond that capacity? No.

Remarks. Used only for instructional purposes where the jobs are quite small.

(3) What are the trip mechanisms and safety devices present?

None, except the start-stop switch.

Remarks. There should be a guard provided for the safety of the students and the instructional staff. (See Fig. 2).

(4) What type of Electric Motor is used?

AC 208 V. 3∮ 60~, 15.8 Amp. FL current, 5 HP - Continuous Induction Motor, fan-cooled, F.L. Speed - 860.

(5) Can the motor be protected against "inadvertent" starting?

Yes; a "no-volt release" and a "reset button" has been provided for the purpose.

(6) Is the start-stop switch easily accessible?

Yes; but by right-handed operators only.

(7) Is the push button mounted in such a fashion that it is protected

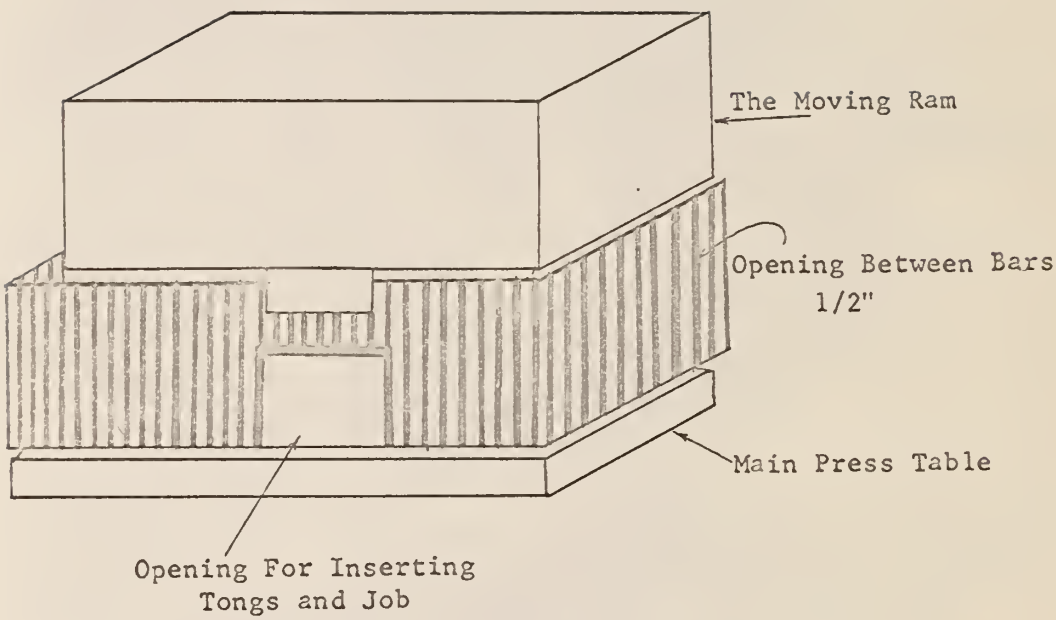



Fig. 2. A Recommended guard

from accidental operation?

Yes, there is a cylindrical projection within which the push button moves.

(8) Is the push-button provided with a concave surface or a serrated surface so that it may not slip under the finger?

Yes, there is a sufficient depression on the surface of the switch.

(9) Can the machine stop at every stroke?

Yes, but the foot-pedal should be released after every stroke.

(10) Are the fuses in the electric circuit, in good order, and the right capacities? Do they break the circuit?

Yes, the fuses break the circuit. They have been provided with an extra capacity of about 10% -15% than the full load current of the motor. (20 amp. capacity fuses).

(11) Does the moving mechanism of the press have a limit switch?

Yes. It is of the rotary type, driven from the crank-shaft. (See Fig.)

(12) Is a guard provided over the foot-pedal?

No.

Remarks. A box type guard should be provided over the foot pedal, to prevent accidental operation. (See Fig. 4).

Controls. The questions which can appropriately be asked are?

(1) What type of controls are provided? (a) Rotary. (b) Linear.

(2) If so, is the rotation clockwise or anti-clockwise? In the linear case, what is the direction of movement?

In the case of a punch press, no controls of these form exist, except the stop-start switch and the foot-pedal.

Displays. Are there any visual displays? If so, are the readings qualitative, quanitative, or check? In the case of the punch press there are no such displays.

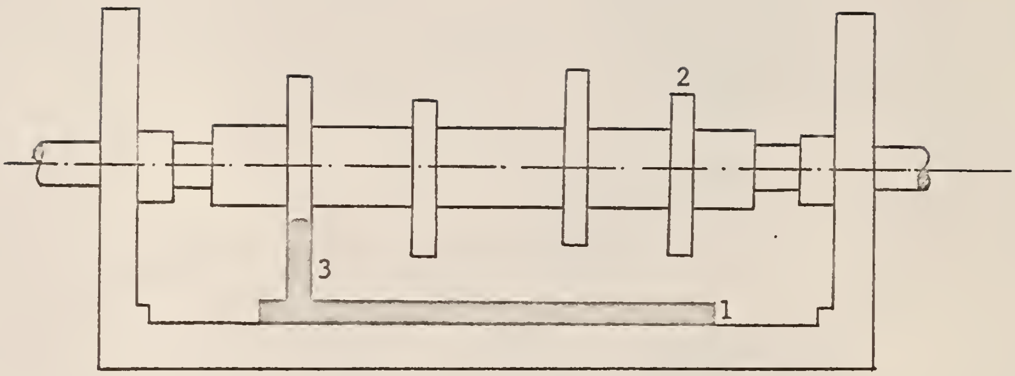



Fig. 3. A rotary limit switch showing the essential parts.

1. Insulated finger mounting strip.

2. eccentric contact.

3. finger contact. (Only one shown).

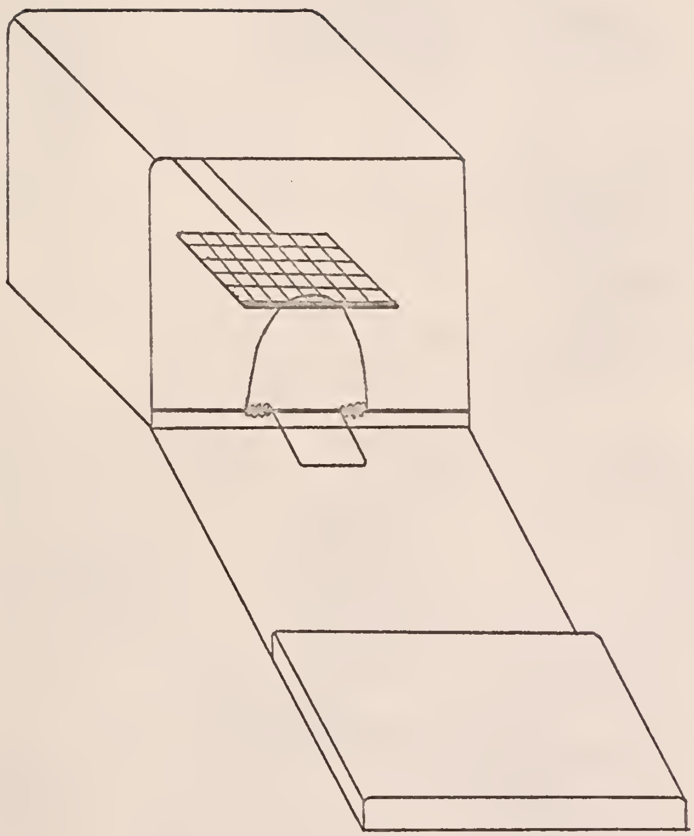


Fig. 4. A foot-pedal guard with a spring closing entry plate.

(Recommended).

Control Display Relationships.

(1) Which controls are to be operated?

Start-stop switch on the right hand side. Foot pedal for releasing the ram.

(2) How are the controls operated?

By depressing a switch with a finger. By depressing the foot-pedal with the right foot.

(3) How much is the movement of the controls?

Start-stop switch: 3/8 inch.

Remarks. The movement should be at least 1/2 inch.

(4) What is the speed of operation?

Almost instantaneous.

(5) Which equipment does each control affect?

The switch activates the motor which is coupled to a flywheel.

The foot-pedal releases the ram.

(6) Does the display describe an equipment?

Not applicable.

(7) Is each control below its display?

Not applicable.

(8) Does the operator's hand block the display or control, or operation area? No.

Control Idenfification.

(1) Are the primary and emergency controls easily identifiable both visually and non-visually? The start-stop switch is identifiable visually but not non-visually. This is because there are two switches. The foot-pedal is identifiable visually and non-visually, because there is only one foot-pedal and non-visually it can be identified with the feel of the foot.

(2) Are the locations correct?

Yes. Assuming a right handed operator.

(3) Is labelling necessary?

Yes. On the red, stop switch the word "stop" appears; and on the black, start switch, the word "start" appears.

(4) Is shape coding provided?

No, it is not necessary, because the number of controls are limited.

(5) Is grouping necessary?

Yes, in the simple sense, the "start-stop" switches are mounted adjoining each other.

(6) Is some standard sequence necessary?

Yes. "Start" switch, depression of the foot-pedal as need be, and the activation of the "stop" switch.

Mounting of Controls.

(1) Is the control panel or the area where the controls are mounted, perpendicular to the line of sight?

Not exactly.

(2) If not, how much is the deviation?

$20^{\circ}$ below the horizontal eye level. The foot-pedal is really $80^{\circ}$ below the horizontal eye level.

(3) Is it permissible?

Yes.

Location of Controls.

(1) Is the "start-stop" switch and the foot-pedal in an optimum manual and visual area?

The "start-stop" switch is in an optimum visual and manual area, but it is too close to the moving mechanism.

The foot-pedal is in an optimum operation area, but it is not in an optimum visual area. In reality, thepedal has to be operated without seeing it.

Remarks. Remove the "start-stop" switch to a location further away from the working area of the machine.

(2) Is the "start-stop" switch easily accessible?

Yes.

(3) Are there any secondary controls? If so, where are they placed?

Yes. The "reset" button for the motor is mounted on the left-hand side of the body of the machine.

(4) What about the set-up and calibration controls? Do they exist?

There are no calibration controls on this machine. The only set-up control which exists, is the tilting mechanism of the press. These two are T-headed bolts, sliding in slots; and a jack type of arrangement to support the weight of the press when the adjustment is being done.

(5) At what height are the controls located?

Between elbow and shoulder height.

(6) Can the emergency control be reached "blindly"?

In my opinion, NO.

Spacing Between Controls.

(1) What is the spacing between the push button switches, "start" and "stop"? 5/8 inch.

Remarks. The minimum separation recommended is 1/4 inch.

(2) What about the spacing of the other controls?

No spacing or separation of the foot-pedal is required, because it is a single unit. However, it does project 6 inches from the nearest obstruction. (The leg of the press).

Design Check of the Primary Controls.

"Start-Stop" push Button:

(1) What is the dameter?

15/16 inch. (Recommended - 1/2 inch).

(2) What is the displacement?

3/8 inch.

Remarks: Should be at least 1/2 inch.

(3) Can it be pressed with the palm?

No.

Remarks: The "stop" push button should be such that it can be operated by the palm in case of emergency.

(4) What is the force required to operate the push button?

2½ pounds

Remarks: The spring should be changed so that the force required does not exceed 1½ pounds.

(5) Is the top concave?

Yes.

(6) Does it have frictional resistance?

Very slight.

(7) Does it have a light at the back?

No.

(8) Does it click?

No. (Preferable to hear a click).

(9) Does the button glow in the dark?

No.

Remarks. In the event of a total power failure, it would be easier to spot the controls if they glow in the dark.

(10) Is the push button labelled?

Yes.

## Foot Pedal

(1) What force is necessary to operate the pedal?

70-80 lbs. (Measured value: 72 lbs. with a spring balance arrangement). (Maximum allowable - 150 lbs.).

(2) Where is the fulcrum?

36 inches from the line of the toe, produced.

(3) Does it return to the original position when the applied force is removed?

Yes, but there is a lateral swing.

Remarks: Corrective maintainence should be applied.

(4) What is the total pedal travel?

3/4 inch. (Recommended minimum - 1/2 inch).

(5) What is the width of the pedal?

3 inches. (Satisfactory).

(6) What is the shape and surface of the pedal?

Rectangular, with a corrugated surface for a better grip.

## Color

(1) What is the color of the machine?

(a) Body: dull green

(b) Other parts: Guard rims for the flywheel, orange.
Switch box and leads, blue
Name plate, orange
Moving parts, white.

(The recommended color for dangerous moving parts is orange.) Our college should repaint the machine according to standard specifications to set an example.

## Illumination

(1) What is the type of illumination provided?

Florescent lights: daylight type.

(2) Is it bright enough?

No; the illumination meter indicated it was not.

(3) Is glare emitting from anywhere?

No.

(4) Is there a local spot illumination in the working area of the machine?

No.

(5) Was the illumination measured?

Yes. It was only 35 foot candles on the working area of the press.

Remarks. Increase the number of florescent light so that the illumination is 50 ft. candles.

## Heating and Ventilation

(1) Is the ventilation in the workshop adequate?

Yes.

(2) Are the temperature and humidity comfortable in the shop?

Yes. The temperature is between $70^{\circ}$ and $80^{\circ}$ F.

## Workspace

(1) Is there sufficient room for the hand-arm movement?

Yes.

(2) How was this determined?

With the help of a full-scale dimensional human model.

(3) What is the height of the workplace from the ground?

36 inches.

(4) Can this work area be reached comfortably without stooping?

Yes.

(5) How was this determined?

With the help of the cardboard model.

(6) What is the visual area in the working zone?

(12" x 12") (Allowable).

## Environmental Considerations

Speech Interference Level. The actual noise emitted by the motor and by the ram during its downward stroke, were measured by means of a "Noise Level Meter." The noise was measured in decibels.

A series of readings were taken, and the following average values were obtained; (at distance of 2 feet).

| | |
|---|---|
| Motor working alone | 58 decibels. |
| Motor and the ram on its working stroke | 90 decibels. |

In the previous discussion, we gave a value of 75 db. as the SIL at 2 ft., when communication is possible only with shouting.

Consideration of Noise. As mentioned in the above paragraph, the maximum noise level at a distance of 2 feet was 90 db.

The human ear can bear a noise level of 135 db. continuously for 2.5 seconds without the risk of permanent hearing impairment.

The noise level of 90 db. is intermittent only during the working stroke of the ram. Thus, this noise level is not injurious to the human ear, but any steps taken towards decreasing this level of noise would tend to increase the operators efficiency.

In the present case, neither the workshop shed nor the roof can be redesigned from acoustics standpoint. At present the machine just rests on the floor, and is not provided with a foundation. Such a machine should be made to rest on a heavy wooden block, whereby the impact of the ram will also be absorbed, and noise and vibration could be minimized.

Another temporary method to prevent noise and reverberation would be to hang baffle boards from the roof, directly above the press parallel to the floor.

## Design of a Floor Which Would Minimize Noise and Vibration

Punch presses, power hammers, etc. and similar machines producing considerable vibrations should be installed on continuous bids extending from beam to beam, and by cushioning with springs, rubber blocks, wood blocks, and soft metal like lead under the machine beds.

Properly constructed floors from creosoted wooden blocks meet the requirements for a good, noiseless floor. The only objection is fire hazard. Heavy duty cork tile also offers insulation, resiliency, and quietness. Asphalt and roughened concrete also provides a good factory floor.

A typical moisture-resistant and vibration-proof floor would be constructed as follows:

Three inch creosoted square timbers embedded in a base made of 3" of tar concrete under 1½" of tarred sand. The subfloor is 3/4" salt treated pine with a layer of waterproof paper. The floor surface is 25/32 inch hard maple flooring.

Consideration of Vibration. In the earlier discussion it was seen that in order to get the subjective response to vibration, it was necessary to measure both, the frequency of vibration and the amplitude of vibration. Only then could we determine the "comfort zone" for the operator.

However, in the machine shop it was not possible to rig up a device for measuring the amplitude and frequency, and hence the experimental treatment of vibration is not given here.

<u>Equipment</u> <u>Arrangement</u>. The application of the 'Link Analysis' method. In the present set-up, there is only one operator, surrounded by four pieces of equipment:

(1) Punch press, used in minor forging operations.

(2) Steel table for resting the jobs.

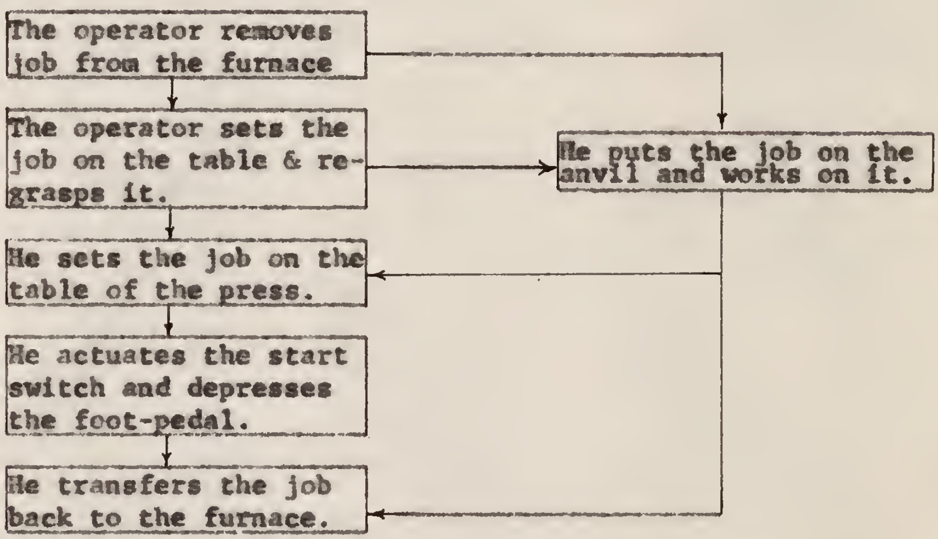
(3) The furnace for heating the job.

(4) The anvil and hammer for shaping the job.

Machine | Man | Link

The various steps in the method:

(a) Flow chart.




One or more operations in this sequence can take place. This typical cycle is shown from the time the job is removed from the furnace, to the time it is placed back into the furnace. (See instructions on the graph-sheet).

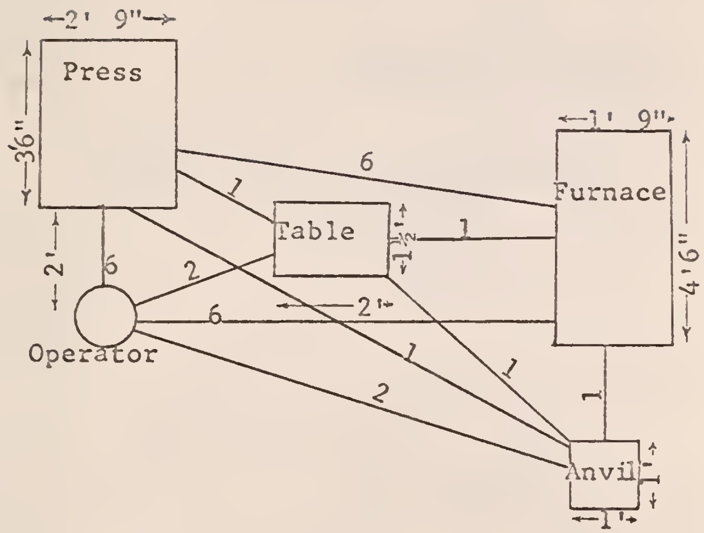
(b) The calculations for the link strength are shown on the graph sheet.

(c) The link diagram with the link-strengths are shown on the graph-sheet.

(d) In the new improved arrangement, the links are shortened, ie those having higher strengths are made shorter.

LINK DIAGRAM

(Original)




LINK DIAGRAM

(Improved)

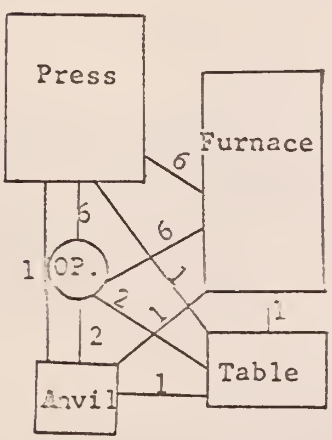



Fig. 5

All Links Are Mechanical in Nature.

| FROM | TO | IMPORTANCE | REL. FREQ. of OCCUR. | STRENGTH OF THE LINK |
|---|---|---|---|---|
| Press | Table | 1 | 1 | 1 |
| Press | Furnace | 2 | 3 | 6 |
| Press | Operator | 2 | 3 | 6 |
| Press | Anvil | 1 | 1 | 1 |
| Operator | Table | 1 | 2 | 2 |
| Operator | Furnace | 2 | 3 | 6 |
| Operator | Anvil | 1 | 2 | 2 |
| Furnace | Anvil | 1 | 1 | 1 |
| Furnace | Table | 1 | 1 | 1 |
| Anvil | Table | 1 | 1 | 1 |

The final improved arrangement is the best from the operator's viewpoint.

Maintenance

The ease of maintenance is to be evaluated by considering the following factors, given in the form of questions.

(1) Is the machine in a readily accessible area?

Yes.

(2) Are there dangerous obstructions around?

No, not in the working area of the press.

(3) Who would be available to service it?

College workshop personnel.

(4) Are spare parts readily available?

Yes. (Refer "Bliss Power Press Handbook").

(5) Are repair manuals available?

Yes.

(6) Are the necessary servicing tools available?

Yes.

(Since the machine is located in an enclosed shed, it is protected from the effects of inclemental weather.)

# DEMONSTRATION OF THE TECHNIQUE
# USING FULL SCALE
# HUMAN MODELS
# FOR
# DESIGNING A
# MACHINE TOOL
# (PUNCH PRESS)

## EXPLANATION OF PLATE I

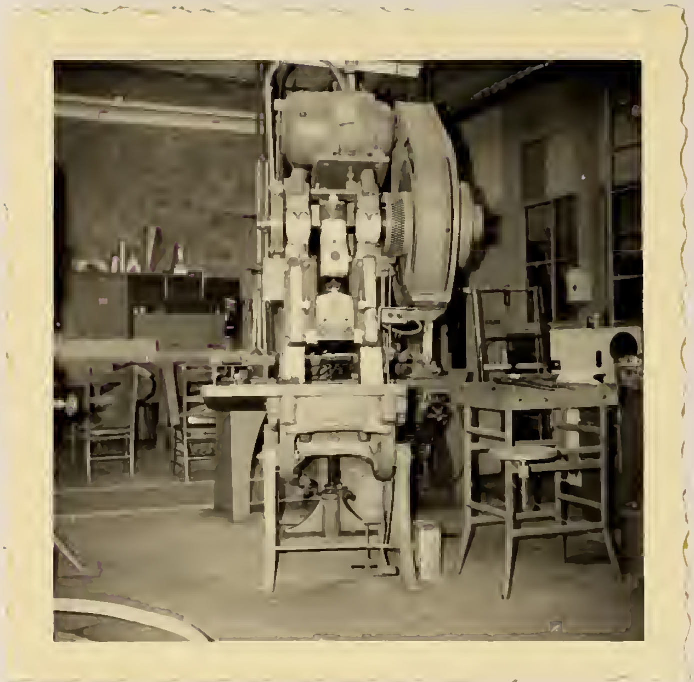
Upper Photograph

An elevation of the punch press under consideration.

Lower Photograph

An end view of the punch press under consideration.

PLATE I



## EXPLANATION OF PLATE II

Upper Photograph

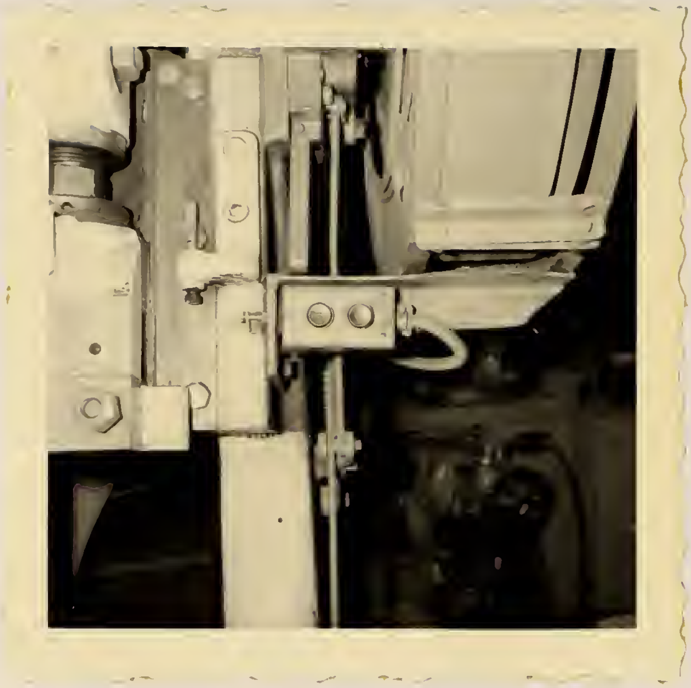
A close-up of the "start-stop" switch.

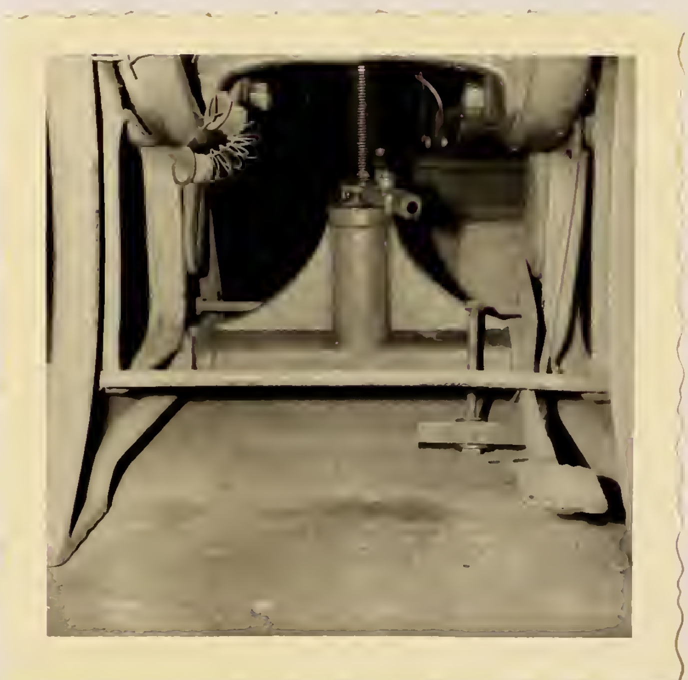
Lower Photograph

A close-up of the foot-pedal and lever mechanism.

(Note the absence of a foot-pedal guard).

PLATE II





## EXPLANATION OF PLATE III

Upper Photograph

The maximum upward reach with the outstretched arm, in a plane about at eye level.

(Standing position.)

Lower Photograph

The various members of the model being displayed. (Note the right foot resting on the foot-pedal).

PLATE III

EXPLANATION OF PLATE IV

Upper Photograph

The maximum arm reach to the table, with the body of the model in the "erect" position.

(Standing position).

Lower Photograph

The model demonstrating a "stoop."

(Standing position).

PLATE IV

## EXPLANATION OF PLATE V

Upper Photograph

The model operating the "stop-start" switch. (Note the position of the switch, between elbow and shoulder height.) (Standing position).

Lower Photograph

The human model ready to operate the foot pedal. (Standing position).

PLATE V

## EXPLANATION OF PLATE VI

### Upper Photograph

The maximum upward reach with the outstretched arm. (Sitting position).

### Lower Photograph

The maximum downward reach with the outstretched arm. (Sitting position).

PLATE VI

## EXPLANATION OF PLATE VII

Upper Photograph

The model actuating the "start-stop" switch. (Sitting position).

Lower Photograph

Demonstration of a stoop. (Sitting position). (Note: uncomfortable position on the non-adjustable stool, and the difficulty in operating the foot-pedal).

PLATE VII

## EXPLANATION OF PLATE VIII

Upper Photograph

A view of the moving parts of the press.

Lower Photograph

Author of the report, demonstrating the erect standing height of the model.

PLATE VIII

EXPLANATION OF PLATE IX

The author of the report with "Joe", the average American.

(All the pin-jointed limbs are displayed.)

PLATE IX

# THE FUTURE OF ERGONOMICS:
## A HUMAN GUIDE TO MACHINE DESIGN

Most modern machines are complex. Their functions have become more specialized and intricate; the jobs of the men who run them have also become specialized and intricate. As equipment designers think up more ingenious uses and techniques, they have been increasingly aware that, today, the least efficient element of a machine is often the man who operates it. The operator must be carefully selected and trained; the machine must make no more demands on the operator than he can effectively respond to.

Up to the present, man has been able to keep up with technological progress by education and training. But a stage has now been reached when the machine has dwarfed the man, for the characteristics of the individual - the human machine - have not changed in the memory of man and will not change for countless generations to come, while the man-made engine is capable of ever-increasing power, scope, and speed of operation. Thus, man's capabilities are considered a constant in contrast to the unending progression of the machine.

Look at it from a different viewpoint. Excessive operator fatigue cuts output, lowers morale, and boosts grievances. But what causes it? That's what Ergonomics or Human Engineering tries to find out. It studies man at work and strives to come up with designs better-suited to the operator.

One of the signs of a well-designed machine tool is its ease of operation. No matter how many pieces a tool can turn out, its design falls short if the operator is not happy running it.

Ergonomics is a science which deals with just such problems. It studies man at work and how he reacts in all kinds of man-machine systems. It considers the mental as well as the physical needs of the worker in relation to his job. A science which seeks to find ways to make an operator happy with the job has a tremendous future.

Fatigue Problems. Take fatigue for example. It's only common sense that an operator who tires easily will produce less. Not only that but his morale drops; minor irritations become major; grievances mount over working conditions; and quarrels develop about job rates. Sometimes neither the operator nor management care to do anything about it.

This is where Ergonomics comes into play. By carefully studying physical dimensions and other characteristics of human beings, standards can be set up governing limits of reach, vision, bending, standing, lifting, turning, etc. When these are taken into account, machine design can go a long way in cutting fatigue and improving operator comfort.

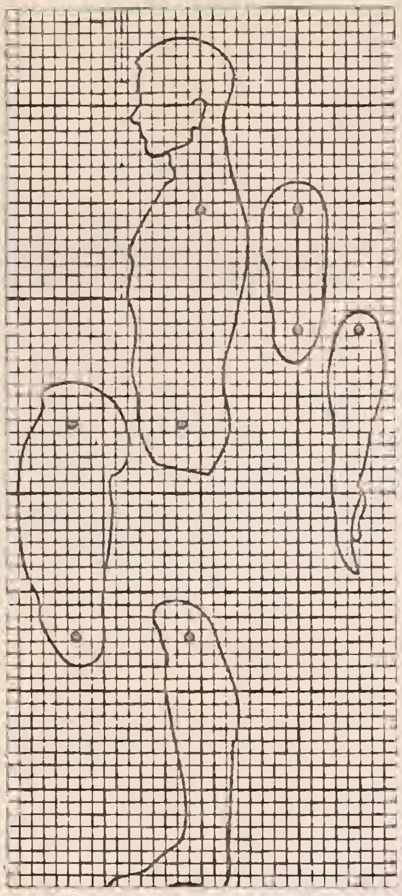
Human Factors. No designer overlooks the human factors in designing machine tools. In many cases, however, these considerations are based on the experience of designers, engineers, and maintenance men in industry - and the reactions of the equipment operators.

Improvements in the design of the machine tools are done by the following two techniques:

(1) In the first technique, lights are affixed to the operator's hands to trace his movements during the cycle. A photograph of the paths traced out by the light is taken on a single photographic plate. It is the technique known as "cyclegraph" or "chronocyclegraph" in motion and time study.

(2) The senond technique is that of link chart analysis. A link chart shows the number of moves, the number of body members employed in a cycle, and the frequency of their use. It also pictures back-tracking, repeated movements and waste movements.

In the improved design there are smoother actions, hand movements are short, effective and smooth. Unnecessary backtracking, repeated movements and waste



Unassembled: 1/16 Inch - 1 Inch

Assembled.

Fig. 6. Scale mock-up of a human being.

motions are cut down to the bare minimum. The standardization of the controls is, however, not changed.

Recent Trends. Anthropometric Data might come handy, but progressive designs done for Warner and Swasey in the Henry Dreyfuss Design Organization (for the turret lathe No. 3-A) employ human beings of various sizes and weights. Thus, subjective opinions are also taken. In one situation it might be best to take the upper limits of reach or height. In another case the lower limit may be the critical factor.

The machine-tools are designed so that they would be comfortable for 95% of all operators.

Three dimensional mannikins are sometimes used for elaborate designs. However, two-dimensional mock-ups also serve a useful purpose. The mock-up need not be elaborate, but it should be accurately scaled.

The author of this report has made a full scale mock-up of cardboard, with standard human dimensions. The photographs in the previous section show the scale mock-up, near the punch press, in the workshop of the Industrial Engineering Department of Kansas State University.

Special consideration is given to the height limits of the operators, grips of the manual controls, minimum movement of body during the operation, safety and maintenance considerations, and the mechanical and electrical transmission of power.

Closing Comment. Those who are responsible for the design of equipment or products which people use, or for the creation of working environments within which people work, have responsibilities which have a direct bearing upon work performance and human welfare.

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# THE APPLICATION OF THE PRINCIPLES OF HUMAN ENGINEERING TO THE DESIGN OF A PUNCH PRESS

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AN ABSTRACT OF A MASTER'S REPORT

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Manhattan, Kansas

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"HUMAN ENGINEERING" is a science which deals with the design of machines to fit the physical and mental capacities of man. This science has developed after World War II.

After a man-machine system has been designed, it should be evaluated experimentally if possible. If it is not possible to check the total design, each sub-system should be evaluated separately, using as criteria the performance required by its role in the total design. This principle has been used in this report. For the purpose of discussion, BLISS 'C' SERIES, INCLINABLE PRESS CONSOLIDATED No. 4 is chosen. Safety is the primary consideration in the design. This refers not only to the mechanical forces and stresses in the machine, but it also takes into account exposure of personnel to accident. Some of the safety devices are evaluated.

The Principles of Compatibility play an important part in the operation of controls. The concept of "Population Stereotype" is introduced here.

The characteristics of good controls is that they should be identified easily, grouped properly, mounted ideally, located and spaced in near optimal positions.

The foot-pedal which is one of the key controls is given a separate treatment.

An ideally designed visual display system should be quickly, easily, and accurately read, and only the necessary information should be displayed.

The suggested color for equipment and surroundings, and the effect of illumination of the workplace and surroundings is discussed in this small section.

The principles of Motion and Time Economy and other refined techniques like the Link Analysis are used to design and evaluate the immediate workspace, and the arrangement of equipment.

The ease of maintenance is a problem which has plagued designers from time immemorial. Reliability and Maintainability are also two factors which go hand in hand.

The environmental considerations like the Speech Interference Level, Noise and Vibration contribute to the overall operator efficiency.

No greater tribute can be paid to "human engineering" than the unique definition - "A SCIENCE WHICH SEEKS TO FIND WAYS TO MAKE AN OPERATOR HAPPY."

Truly, such a science has a tremendous future.