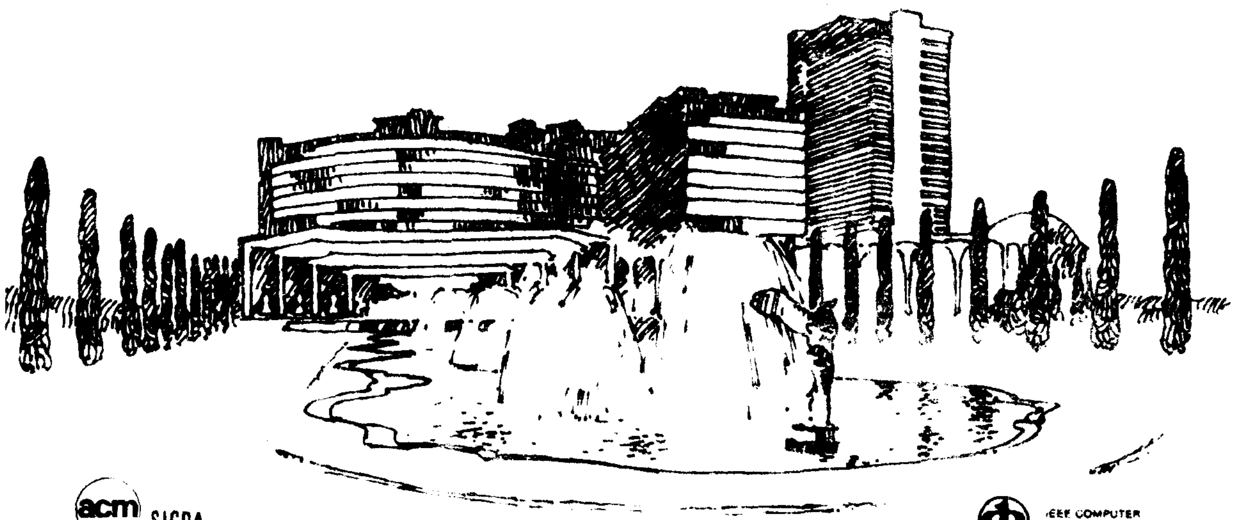
ISSN 0146-7123
IEEE Catalog No. 82CH1759-0
Library of Congress No. 76-150348
IEEE Computer Society Order No. 416
ACM Order No. 477820

ACM IEEE Nineteenth Design Automation Conference Proceedings

Caesars Palace *Las Vegas, Nevada*
June 14-16, 1982



acm SIGDA

IEEE COMPUTER SOCIETY-DATC

TABLE OF CONTENTS

Session 29: University Physical Design Automation
(E.S. Kuh, Chairman)

Session 30: Enhancement to Scan Design Techniques
(E. Ulrich, Chairman)

Session 31: CAD in Architecture (R.S. Frew, Chairman)

Session 32: Automatic Layout Verification
(C.R. McCaw, Chairman)

Session 33: Topics in Testing (M.C. Graf, Chairman)

Session 46: Recent Developments and Proposals

(A.C. Parker, Chairman)

Session 47: Process Characterization

(L. Steinberg, Chairman)

A SURVEY OF THE STATE-OF-THE-ART OF DESIGN AUTOMATION

AN INVITED PRESENTATION

MELVIN A. BREUER

University of Southern California
Department of Electrical Engineering
Los Angeles, California 90007

This paper is a brief overview to an invited talk presented at the 19th Annual Conference on Design Automation. The work presented is based upon an extensive study of the status of industrial and government design automation systems applied to digital systems, with primary emphasis on digital cards and LSI circuits. A detailed summary of our finds can be found in [1]. The study covered 18 companies and government laboratories, including three in Japan and three in Europe.

A few of the more basic findings derived from this study are summarized below.

- Most DA systems consist of generic programs which communicate with one another via a common data base.
- Most DA system hardware consists primarily of large general-purpose CPUs with extensive use of commercial interactive graphics systems.
- About 50 percent of DA tools are developed by internal, corporate DA development groups.
- Logic design requires over 50 percent of the total design effort, yet few automated tools are used for this aspect of the design cycle.
- Architecture and RTL simulation is used extensively by designers of large mainframes, though the former activity is usually not considered part of design automation.
- Automated layout of PCBs and polycell and master-slice LSI chips is a well-developed, successful operation.
- Testing is one of the less-mature but most active areas of DA development.
- Little effort is being devoted to formal design verification; rather, designs are checked in an ad hoc fashion by simulation, by building prototypes, and by employing the "first built" machine.

Clearly industry and government laboratories have developed many effective DA tools to aid in the design of digital systems. Due in part to the lack of funds and in-house expertise, some companies make extensive use of vendor-supplied software. This leads to problems of system integration and hinders transmission of data from one process to another.

The use of several standard algorithms by most companies implies a lack of in-house research groups. This was confirmed by site visits to locations where almost all technical DA staff members were engaged in software development. Because of this situation, most companies are either not ready to deal with VLSI design problems or are very reluctant to discuss their present and planned efforts in VLSI. RTL design verification, layout, design for testability, and test generation must be strengthened if future DA systems are to take advantage of new technologies.

REFERENCE

[1] M.A. Breuer, A.D. Friedman & A. Iosupovicz, "A survey of the state of the art of design automation," *Computer*, October 1981, pp. 58-75.

0420-0098/82/0000/0001$00.75

ROBOTICS: THE NEW AUTOMATION TOOL

by Harold R. Marcotte

Honeywell Defense Systems Division
New Brighton, Minnesota

Abstract

Industrial robots have seen limited use by industries for over a decade but until the auto industry introduced robotics for spot welding applications in the late 60s the robot was not considered seriously. Now they are readily accepted throughout industry. The reasons for their current popularity are the rapidly increasing costs of labor and the seemingly declining productivity of todays workers. In addition, robots today are credited for additional product and quality improvements not seriously considered in the past. Benefits similar to those that have long been attributes associated with hard automation.

This paper looks at robotics from a users viewpoint and addresses some of the benefits and concerns attributable to their use. To this end, this paper will describe several applications that are currently used in production with results relative to production gains, side benefits and operator acceptance.

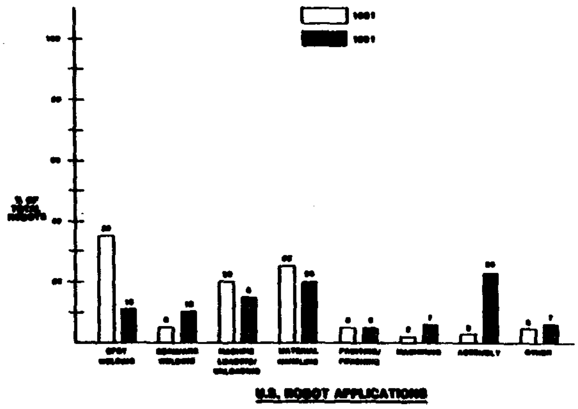


Figure 1

Introduction

It was in the automated assembly arena where robots were introduced in welding applications in the 1960s and early 1970s. This represented the total serious use of robotics. In fact, even today of all the robots used in the United States, nearly 40 percent are in the auto industry. Additionally, of all the robots in use less than five percent of these are used for assembling tasks. A recent study made jointly by the University of Michigan and the Society of Professional Engineers associated with the Robot Institute of America predicted that the trend is changing and the robots sold for assembly will increase to 25 percent of sales by 1990. (See Figure #1)

At Honeywell Defense Systems Division, high technology robots were first introduced to the assembly floor in 1981. To support and compliment the hard tooling concepts that had been in use since the 1960s. Their introduction coincides with current thinking of U.S. manufacturers that there is little question that the high technology robot is clearly contributing to improved productivity and quality and now must be considered as a viable automation tool. It is understood that the manufacturer of today who pursue robotic technology will be in a position to improve their competitive edge through the improved quality gained by consistent task performance and the reduction of manufacturing costs realized that improve productivity.

Benefits of Robotics

Factors such as increased productivity improvements in quality and safety all must be considered as beneficial gains through robotics because in the final analysis these are the categories that when implemented establishes the manufacturer's competitive edge. Productivity improvements are phenomenal if a robot can be used for multiple shift operations, but even if single shift production is the norm, robots are effective. Robots are slow but because of their constant pace will normally out produce the efforts of man. The human pace tends to be erratic and on a highly repetitive task tends to deteriorate as the work day progresses. In most instances, the use of a robot will result in significantly increased productivity over man.

The consistent cycling of the robot tends to improve quality and reduce scrap on those jobs where timing is a factor. Die cast tending with robotics is a good example of this. A uniform time that the die remains open between machine cycles result in a stable die temperature that improves component quality.

Operating a robot on a task that is viewed as undesirable by workers because it is either highly repetitive or difficult to accomplish also has economic advantages. These jobs tend to lead to poor workmanship, job absenteeism or high turnover of labor. All of these factors increase the cost of doing business.

A robot is an excellent assembly tool for applications where safety is a concerning factor. Instances where workers must be in relative close proximity to combustive or explosive materials, temperature extremes, excessively high noise or where it is difficult to comply with safety regulations because of stringent guarding are examples of places where robots may be the best method to comply with safety requirements.

Examples of Robotic Applications at Honewell DSD

The first robot installation in Honeywell's Defense Systems Division was the introduction of three PRAB model 4200 Industrial robots used for tending die cast presses. This is not a highly sophisticated application for robotics but the paybacks on this installation are excellent. Not only were two operators replaced but additional gains were made in quality of product and reduced maintenance. The reduced maintenance is the result of two conditions: 1) reduced mold repair because core pins and mold cavities retained their integrity longer because of temperature consistency and 2) the present operator who now tends three die cast presses has gained a sense of responsibility for the upkeep of the molding equipment. In this role, the press operator applies considerably more care in clearing jams and general upkeep resulting in less tool breakage.

The first high technology robot installed was a PUMA 500. It was installed to perform a material handling function in conjunction with an existing assembly machine. (See Figure #2)

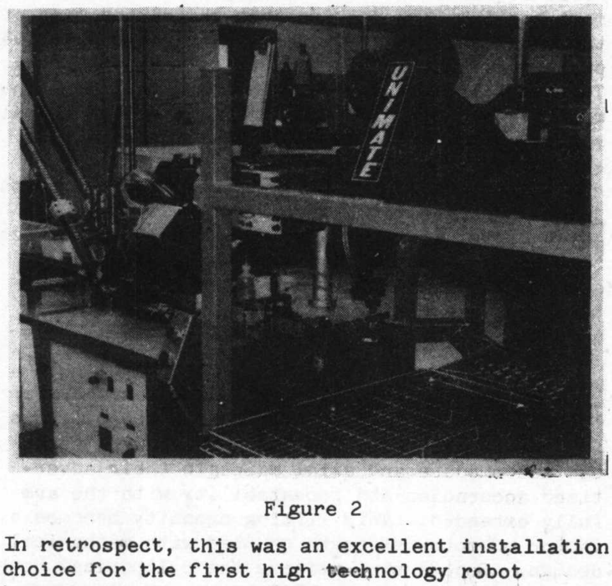


Figure 2

In retrospect, this was an excellent installation choice for the first high technology robot because it required a simplictic robot end effector, the software was easily performed and it established a demonstratable unit that assured management of benefits if this technology were pursued further. It is important to begin a new technology with a successfull application to convince management that this technological effort should continue.

The PUMA 500 project involved the installation of a robot to the exit track of existing machine that welded four gold plated leads to a dual cell reserved battery. The robot replaced the secondary operations of tinning these leads and placing the batteries in a degreasing tray. The robot picked up the end part of the eject track, double dipped the leads on both ends of the cell in a solder pot and placed the completed assembly in a wire degreasing basket in an established array. The welding machine cycle rate is seven seconds. The task required of the robot fit within this window so no degrading of the welding cycle was required. The robot has been in operation in a production environment for 10 months with only minimal down time attributable to the robot. The PUMA controller uses a computer based control language called VAL. This provides simplistic position sifting for placement of the components within the tray in the required positions.

Another robot project installed by Honeywell Defense Systems Division permitted a total automation for a bomblet production line. (See Figure #3)

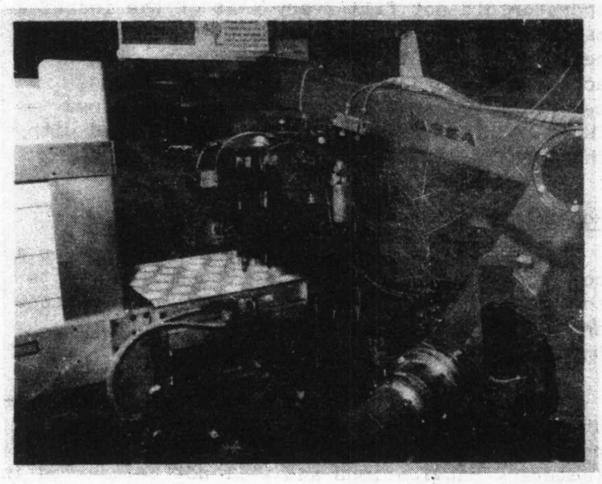


Figure 3

Three hard automation machines were previously interconnected to a power driven conveyor system. This system terminated at the final machine on the line because the bomblets could not be automatically placed in the final machine nest by normal pick and place units nor could the final product be removed and placed in the segregated tray. Initial plans for this installation considered the use of an operator to perform these tasks. As the hard automation equipment improved in efficiency over time it became apparent that the load/unload operator was the pacer on the line. Hard automation techniques could not be implemented because the cost of the infeed equipment was prohibitive and to place the bomblet in the segregated tray required a very complex X-Y motion to position the units in the prescribed array. To add to the complexity of the hard tooling was the extensive reach required to reach the existing trays.

An ASEA IRb-6 robot was chosen to perform both of these tasks. The ASEA was selected because of its weight lifting capacity of 6 kilograms or 13.2 pounds and a speed of 1.1 meters per second. Another reason for our selection of the ASEA was based on an engineering judgement of the mechanical strength and general construction of the robot. The cycle rate of this assembly system is 4.5 seconds and in that time the robot was required to pick up two parts from a conveyor, place them in a nest of an indexing machine, pick up two completed parts from the next two machine nests and place them in a prescribed array in a styrofoam tray. To accomplish this in 4.5 seconds required operating a robot at its top speed and eliminating the use of precision points wherever possible. These tasks could not be accomplished unless the robot chosen was fast and robust. At the time of this writing, this robot has been in production for four months. The 4.5 second cycle time of the automated assembly line was not changed with the addition of the robot. However, the total output per day has increased by 10 percent. Prior to installation of the robot, the operator did not fill every nest of the indexing machine and the machine was shut down for longer periods because the operator fatigue. Worker acceptance of this robot was not a concern because those that performed the load/unload function previously were very dissatisfied with the task.

Robot Comparisons

From the users viewpoint the following is a comparison only of those high technology robots that Honeywell Defense Systems have used. These are a PRAB Versatran, Cincinnati-Milacron T3, Unimate PUMA 500 and 600 and the ASEA IRb-6.

General categories such as velocity, repeatability, program storage, load capacity and physical size are all thoroughly covered in manufacturing publications and will not be covered in this paper. However, each robot has distinct characteristics that require consideration when robot selection is your task. Examples of these distinctions are as follows:

Controls. Each robot manufacturer uses a microcomputer for control but each uses different methodology relative to software. If the robot's use is experimental, the best supplier is Unimation. The Unimation controller and VAL language provides the user with the most comprehensive language and indifference to others the total capabilities of the controller are included in the original purhcase of the equipment. This includes the ability to count, shift locations by software instructions and the use of multiple subroutines based on flags or external signals etc. Of all control systems used by Honeywell to date, this one clearly provides the most options.

The Cincinnati-Milacron provides a rather complete control system as well but many control sequences must be purchased separately as options. These include options for repeating sequences, etc. Furthermore, each of these options fill up nonspecified program space and the more options purchased by the user leaves less program spaces available. In other words, if you do order optional control features, it is probably wise to order additional memory points as well. This controller includes a CRT. It displays the status of each program step. It can also display the position of each arm joint for reference.

The control provided with the ASEA robot is considerably simpler and quite compact. At first it seems to portray inadequate control but as the user works with the controller it is quite extensive in capabilities. However, programming is somewhat cumbersome. This unit does not include the CRT or copy facility or programming views so the operator must maintain his own written documentation for software debug.

The PRAB Versatran 600 microprocessor is the most simplistic of all units tested. It provides only the basic programming options. It is possible to skip a sequence with signal or call a subroutine but no other programming revisions are available other than the normal sequencing.

Work Windows. Each manufacturer of robots provides information relative to the units work range in their advertizing brochures. A word of caution, the user can be misled because in nearly every instance the task to be performed by the robot requires a restricted motion. For instance, most applications require that the center line of the robot hand start and end in the same relative position. That is either vertical or horizontal. The joint limitations on each robot restricts the motions with the end result being that the actual space limitation is somewhat less than their advertized work window. The robot suppliers rightly portray the reach extremes when the robot joints are lined in their optimum position. As noted above, it is rare that the user can utilize this optimum arm movements. This can be a serious problem if the user is not cognizant of this possible limitation and does not design accordingly.

Mechanical Construction. Each manufacturer lists the lifting capacity of their robot. This is the weight, including the hand, that a robot can accommodate and still maintain their advertized accuracies and repeatability with the arm fully extended. This lifting capacity becomes a factor of motor strength coupled with mechanical design. Robots that utilize the cylindrical configuration such as the PRAB high technology robot list higher weight capacity than those that utilize the jointed arm type robot. This is possible because linear motions using rack and gear drives can be designed with greater rigidity than the rotary joints used in the jointed arm robots. The cylindrical configured robots have the disadvantage of getting effective utilization of more than three servo joints. The yaw and roll motions that provide the robot with almost human abilities are usually pneumatic on this type of a robot. That is the reason more robot manufacturers are turning to the jointed arm motions.

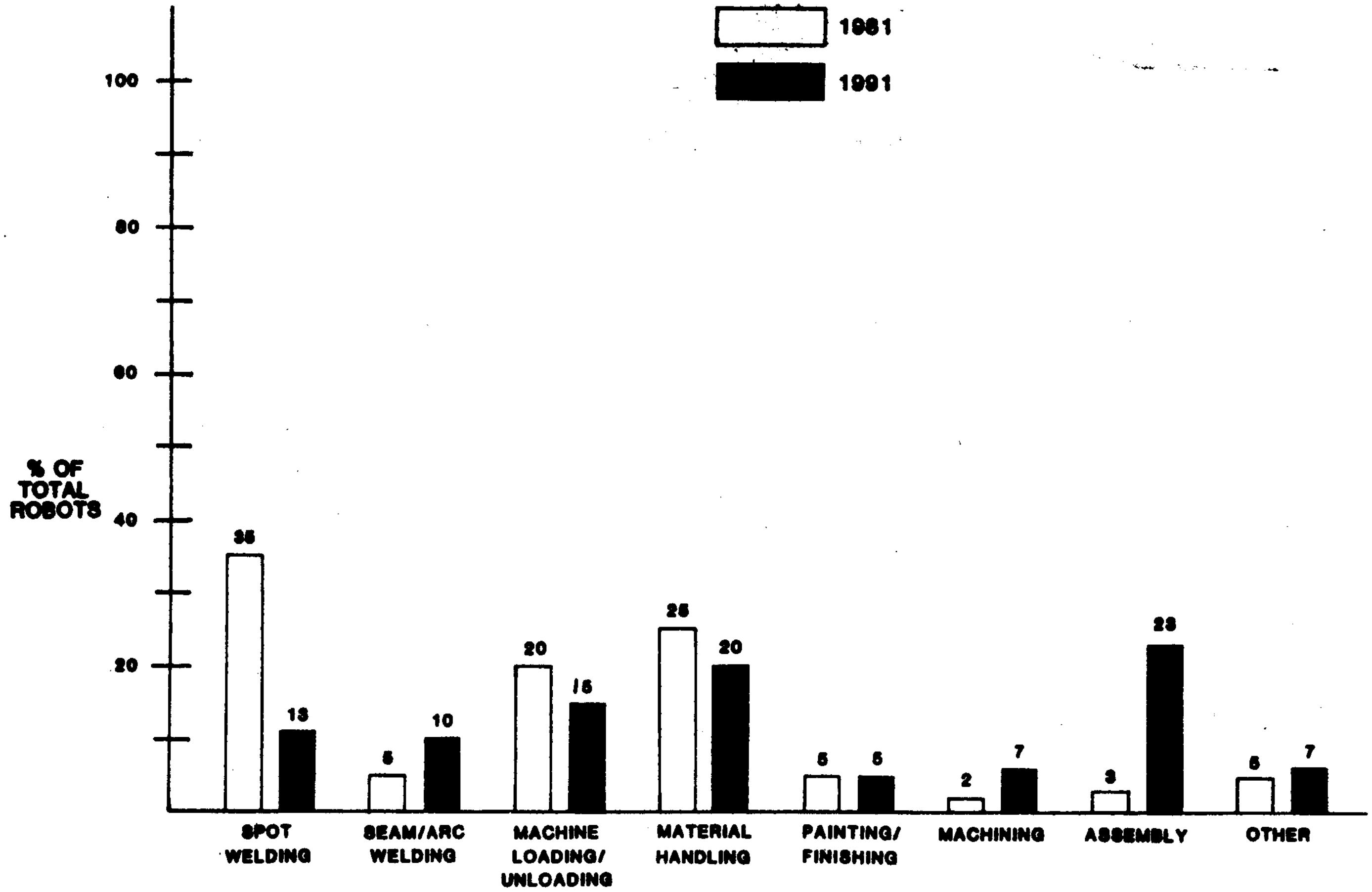
Hydraulic units use hydraulic rotary cylinders for elbow and wrist movements and these can provide the power to meet the lifting limits. The electrical servo units utilize two distinct systems. The PUMA direct drives each joint from a servo unit through couplings and drive shafts. Space limitations within the arm framework limit the servo and encoder size. Thus, the limit of five pounds on the model 500 and 600 robot. Many of the robots developed by overseas manufacture utilize belt crank motions on the servo joints so the servo drive and encoder units can be mounted on the base. Size constraints are thus lifted and consequently robots of this type typically have lifting capacities in excess of 20 pounds.

Future Plans at Honeywell in DSD

Robot manufacturers, academia and user research groups are earnestly pursuing artificial intelligence pursuits to increase the effectivity of robotics. It is felt that when the senses of sight and/or feeling become available the scope of robot applicability will be greatly enhanced.

Vision will permit the robot to pick up parts that have not been previously isolated or oriented. Tactile sensing will assist the robot react in real time to external forces such as true alignment of pins to holes or tightly palletizing units.

Honeywell Defense Systems is involved to some degree of both efforts. Current vision systems have a serious discrepancy that must be solved before "bin picking." Even partially oriented units can be realized. Efforts today by suppliers use centroid algorithms and perimeter dimensions to establish part recognition. The main obstacle with this concept is that these systems cannot distinguish overlapping or touching parts. For research this is not serious because it is easy to maintain separation by placement or by robot actuation used to accomplish this separation. However, when the goal is to put a robot system into production, cycle times must be met and time for separating parts by making indiscriminate motions by a robot is not a viable methodology. Honeywell Defense System effort today is to work with the equipment available and keep current with the market so that when break throughs are made our staff will be prepared to take advantage of this state-of-the-art technology.



U.S. ROBOT APPLICATIONS

Figure 4

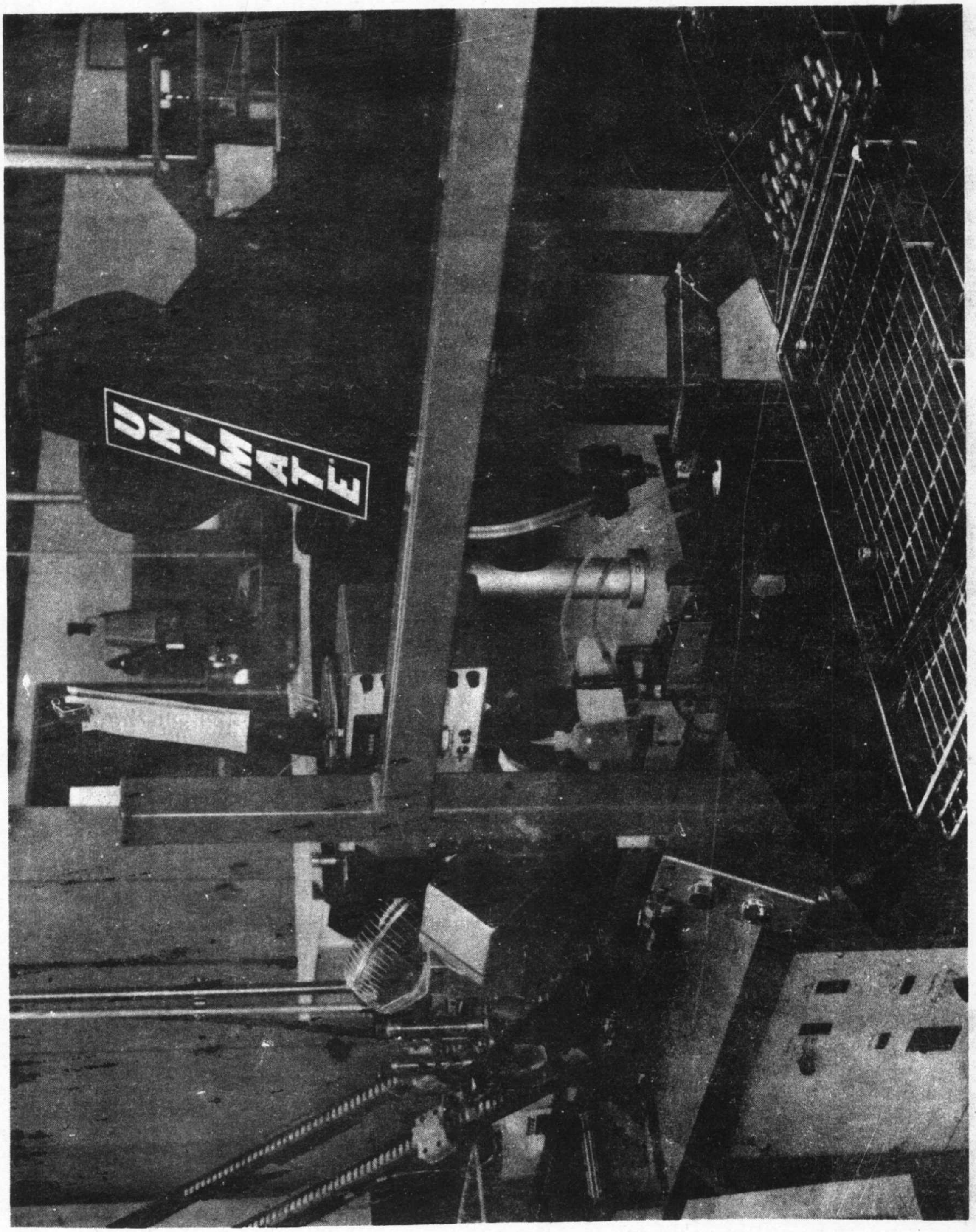


Figure 5