4-1985

Identification of Technical Skills Required of Industrial Robot Maintenance Technicians in Manufacturing

David James Goetz
University of Northern Iowa

Identification of Technical Skills Required of Industrial Robot Maintenance Technicians in Manufacturing

Abstract

The primary purpose of this study was to identify those technical skills required of industrial robot maintenance technicians in manufacturing.

Specifically, the study:

1) obtained the work/training background of industrial robot maintenance technicians active in the field,

2) identified the technical skills required of industrial robot maintenance technicians, and

3) identified the desired technical skills of industrial robot maintenance technicians.

A secondary purpose of the study was to provide manufacturing engineers/supervisors with a baseline for detailing a training program for robot maintenance personnel.

April 12, 1985

Dr. Ervin Dennis
ITD Coordinator of Graduate Studies
University of Northern Iowa

Dear Dr. Dennis:

Attached is my research paper, "Identification of Technical Skills Required of Industrial Robot Maintenance Technicians in Manufacturing", and a Completion of Research Paper form signed by my advisor. These two items should complete the requirements for the Master of Arts Degree in Industrial Technology with a major in Industrial Supervision and Management.

Sincerely,

David J. Goetz

c: Patrick W. Miller, Advisor
Leslie C. Miller, Graduate Member
John T. Fecik, Department Head
Dean Roy Saigo
Dean John Downey
Registrar

Identification of Technical Skills Required of Industrial Robot Maintenance Technicians in Manufacturing

A Research Paper Presented
to the Graduate Faculty
Department of Industrial Technology
University of Northern Iowa

In Partial Fulfillment of the Requirements for
the Non-Thesis Master of Arts Degree

by
David James Goetz

April 1985

Approved by:

Dr. Patrick W. Miller, Advisor — Date: April 12, 1985

Dr. Leslie C. Miller III, Member — Date: April 12, 1985

IDENTIFICATION OF TECHNICAL SKILLS REQUIRED OF INDUSTRIAL ROBOT MAINTENANCE TECHNICIANS IN MANUFACTURING

A Research Paper

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

David James Goetz

University of Northern Iowa

April 1985

Acknowledgements

To my instructors and students whom I associated with at the University of Northern Iowa in making my Master of Arts in Technology a possible, challenging and tolerable achievement.

To Dr. Leslie Miller III, reader of my research paper and who provided unique and interesting classes in the history and future of industrial technology.

To my advisor and friend, Dr. Patrick W. Miller, who served very capably and whose inspiration, dedication and many conversations made my goal a reality. Many thanks for his special interest and help in polishing my research paper and enthusiasm in teaching the preciseness of research procedures in his classes.

To Jean Miller, for her aid in the laborious chore of typing my research paper to APA style.

Especially to my wife Maureen, daughter Rebecca and son Mitchell who supported me in my endeavor.

TABLE OF CONTENTS

Page

Acknowledgements..... ii

List of Tables..... v

Introduction..... 1

Statement of the Problem..... 4

Purposes of the Study..... 4

Significance of the Study..... 5

Assumptions 6

Limitations 6

Definition of Terms 7

Review of Literature..... 9

Introduction 9

Importance of Industrial Robot Maintenance 9

Technical Skills Required of Industrial Robot Maintenance Technicians..... 11

Methodology..... 13

Introduction 13

Subjects..... 13

Pilot Study 14

Questionnaire Development..... 14

Data Collection 15

Summary of Findings 17

Introduction..... 17

Findings..... 17

Work Related Background 17

Present job title..... 17

Time worked under job title..... 17

Originally trained for present job.... 17

Robot Background..... 18

Special schooling/training..... 18

Work time used for robot maintenance.. 18

Responsibility for robot maintenance.. 18

Assessment of Job Requirements..... 18

Necessary understanding for robot maintenance 18

Greater part of robot maintenance..... 21

Easiest part of robot maintenance..... 21

Difficult part of robot maintenance... 21

Important and desired technical skills associated with robot maintenance... 21

Comments/Additions..... 23

Discussion..... 24

References..... 26

Appendices

A. Letter to Industrial Relations Manager..... 29

B. Letter from Industrial Relations Manager... 31

C. Letter from Human Subjects Review Committee Graduate College University of Northern Iowa..... 33

D. Guidelines and Instruction for Maintenance Supervisors..... 35

E. Cover Letter and Questionnaire..... 37

LIST OF TABLES

Table Page

1. Robot Training..... 19
2. Robot Requirements 20
3. Important and Desired Technical Skills Associated with Robot Maintenance..... 22

Identification of Technical Skills Required of Industrial Robot Maintenance Technicians in Manufacturing

Introduction

Industrial robots in manufacturing have arrived. More than 25,000 of them are employed in the workday world; 14,000 are in Japan, 6,000 in the United States and the remainder in Europe (Robots Are Coming, 1983).

No longer a futuristic automaton animated by science fiction writers, robots have established themselves as a viable efficient solution to the problem of freeing humans from the drudgery of hazardous, fatiguing and demoralizing chores (Seman, 1979). Robots are being placed in factories of the future; highly automated factories that are interfaced with various computer systems to reduce human worker input. Managers, workers, politicians and economic planners see robots as the great savior to keep society from the ill fates of recession and economic decline (Goldwater, 1983). This adaptation of robotics to manufacturing is as close as mankind has yet come to getting its work done without "working."

Recent technological advances in computers/ electronics, changes in management philosophies, increased government safety restrictions and competitive pressures are all factors causing widespread robot use. Manufacturers,

such as General Motors, currently have only a few robots in use, but are projecting large robotic increases in the next decade (Heer, 1981). W.K. Weisel, Executive Director of the Robot Institute of America, estimates the industry's annual growth rate could reach sales of $1 billion by 1990 (Winter, 1984). Weisel further states that more robots were infused into production in 1983 and 1984 than in the previous 20 years combined; dating back to the development of the technology (U.S. Robotmakers, 1985). Even pessimists expect demand in the U.S. alone to quadruple or quintuple by 1990; to $1 billion, while the bulls insist $3 billion is sure to prove nearer the mark (Robots Are Coming, 1983).

While some robots exhibit anthropomorphic form--perhaps motivated by the proven success of the human body or the designer's limited imagination--other robots do not look like people (Sheridan, 1980). The new "smart" robots are appropriately defined as:

> ...nimble jacks-of-all trades. A typical computer controlled model can be fitted with a variety of "hands" (e.g., a mechanical "gripper" that enables it to pick up parts and pass them along, a spray head that converts it into a painter, or an arc that turns it into a welder). Such robots load and unload parts from furnaces, stamp presses and conveyers. They also quench red-hot parts, lubricate dies in stamping machines,

> drill holes, insert screws and grind parts. Some have arms with TV camera eyes that can even assemble parts (Bylinsky, 1979, p. 90).

Those jobs that the robots perform best are the ones that people usually avoid (i.e., repetitious, boring and unpleasant work). In many instances, they can work faster than a human, and do a better job. They can work around the clock, do not require periodic rest or lunch breaks, are more precise and more dependable than people and do not go on strike (Sheridan, 1980). In addition, robots do not require bonuses or overtime pay, coffee breaks, sick leave and do not complain about working holidays and weekends. Perhaps most significantly, robots perform steady reliable work under virtually any working condition regardless of the degree of danger and monotony (Schreffler, 1984).

As with any automated machine or equipment, robot applications are supported by maintenance technicians. It becomes the technicians responsibility to keep robots running. Ernst (1980) found the key to minimizing downtime (i.e., nonproductive worktime) was having a well-trained maintenance force provided with adequate tools and spare parts.

At the John Deere Component Works, the major goal of the maintenance program is to minimize cost and improve machine availability. What has changed, and will continue to change, is the company's approach to achieving these goals.

M.J. Wood, general supervisor from the John Deere Component Works, in "Hi Tech Production Will Require Hi Tech Maintenance," (Harvey, 1983) states:

> ...We have come to see that maintenance must come out of the steam tunnels and press pits and adapt a much more professional strategy or approach to accomplishing its objective (p. 44).

Until that time when robots can oil and repair themselves, people will be utilized to fulfill the need for industrial robot maintenance technicians. R.F. Thompson of Kaiser Aluminum states:

> ...If you don't gear up and train your people, you can't maintain the system. You can't fix it up with a hammer and nails. You have to turn to people (Senia, 1983, p. 74).

Statement of the Problem

What are the technical skills required of industrial robot maintenance technicians in manufacturing?

Purposes of the Study

The primary purpose of this study was to identify those technical skills required of industrial robot maintenance technicians in manufacturing.

Specifically, the study:

1) obtained the work/training background of industrial robot maintenance technicians active in the field,

2) identified the technical skills required of industrial robot maintenance technicians, and
3) identified the desired technical skills of industrial robot maintenance technicians.

A secondary purpose of the study was to provide manufacturing engineers/supervisors with a baseline for detailing a training program for robot maintenance personnel.

Significance of the Study

As stated in a number of corporation projections, the use of industrial robots will be a reality. Stark (1982) confirms that increased robot usage will occur at International Harvester, Ford Motor, and John Deere. A Delphi survey conducted by the Society of Manufacturing Engineers (SME) and the University of Michigan indicated that robot users and manufacturers will directly employ between 40,000 and 60,000 people with their supplier's employing another 80,000 (McElroy, 1982). Considering this involvement, it becomes obvious that the increased use of robotics in industry will require people with high maintenance expertise. Further, Groover & Zimmers (1980) state that maintenance will become significantly more important in the future automated factory than it is today.

In order to be economically feasible, it is essential that the automated equipment (robotics) be kept running as much as possible (Groover and Zimmers, 1980). As

manufacturers use more expensive, highly automated equipment, they cannot afford to keep the equipment idle. Thus, analysts expect a greater demand for skilled technicians to service all automated equipment (Goldwater, 1983).

Assumptions

1. Because there are some 300 different robot manufacturers worldwide offering robotic systems (U.S. Robotmakers, 1985), it is assumed that there are several power source (electrical, mechanical and pneumatic) commonalities that exist among robotic families.
2. Determining technical skills required of industrial robot maintenance technicians necessitates "hands on" experience.
3. The technical skills required of industrial robot maintenance technicians at the John Deere Component Works will not be unlike those of other industrial robot users.
4. The level of technical skills required of industrial robot maintenance technicians is constantly changing due to technological advances.

Limitations

1. The population of this study included maintenance technicians from the John Deere Component Works involved in heavy manufacturing and robotic installations. The findings of this study should

not be generalized to other industrial robot users without caution.

2. Industrial robots at the John Deere Component Works factory are in varied operational stages. Hence, maintenance technicians may or may not have experienced a majority of the problems associated with robotic technology.
3. The research instrument used in this study did not measure if robot maintenance technicians were actually fulfilling the requirements of their job assignment.
4. Deere & Company corporate policy required that the research instrument (questionnaire) be completed during the technician's nonworking time on a strictly voluntary basis. Thus, the respondents may or may not have been candid in their responses.

Definition of Terms

Robotics is the field of science concerned with the construction, maintenance and behavior of robots for jobs ordinarily performed by people (Block, 1980).

Industrial robots are programmable, multifunctional manipulators designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The key words are "reprogrammable" and "multifunctional" because these qualities distinguish robots from other dedicated forms of

automation (Weisel, 1984).

Reprogrammable means capable of being instructed to operate in a specified manner and manipulate a mechanism to move and grasp objects (Glossary of Terms, 1982).

Multifunctional is the ability of the robot to perform a variety of different tasks simply by "calling up" the desired computer program and changing its work application (Robots in Manufacturing, 1984).

Downtime refers to the time when an industrial robot is not working (Engleberger, 1980).

Industrial robot maintenance technician refers to that individual assigned to service, repair and oversee the upkeep of industrial robots. The primary job responsibility of a robot maintenance technician is to restore the robot to a productive mode when a breakdown occurs (Harvey, 1983).

Review of Literature

Introduction

This review of literature presents two major sections: (1) importance of industrial robot maintenance and (2) technical skills required of industrial robot maintenance technicians.

Importance of Industrial Robot Maintenance

W.R. Tanner, Manager Automation Assembly, Ford Motor Company, stated:

> Although the reliability of industrial robots is quite satisfactory with 95 percent uptime or better, there must be planning for some form of backup system. This could take the form of having extra parts on hand, a parallel operation, or even a spare robot ready.
>
> Once installed, you will find that robots can produce scrap. They don't run forever as many suppose. Rather, things wear and change and need constant adjustments (Pond, 1976, p. 56).

Industrial robots are usually working in conjunction with other machinery. When the robot is down and there is no provision for backup or the capability for a "quick fix," the production machinery is also down. In some operations (e.g., die casting and metal stamping) the downtime is not

as sensitive but in other operations (e.g., glass manufacturing and other similar continuous manufacturing processes) downtime could be catastrophic (Engleberger, 1980). Vaccari (1982) states, "Low downtime is critical to us and to our customers, some of which are stocking only four or five days inventory. If our line stops, so does theirs."(p. 131). Thus, as more industrial robots are added to manufacturing, the "downtime" problem may be significant. Therefore, as computer controlled systems grow larger, more complex, more capital intensive, more centralized, and more tightly controlled, the costs of failure will be expensive (Sheridan, 1980). Experience has shown, however, that the reliability of today's industrial robot is very favorable. According to Ernst (1980) the average robot has only a one percent downtime as compared to about 11 percent for other heavy precision machinery. Typically, an industrial robot is expected to be up and running about 97 percent of the time (Industrial Robots Come of Age, 1984). Hence, the reliability of industrial robots usually surpasses that of other machinery and equipment. Just the same, robot maintenance is not approached lightly as exampled by several robot manufacturers that offer training at their facilities (Unimation Inc., Prab Engineering, Inc.). Manufacturing companies are moving to estabish and implement training centers for robot operators, programmers and maintenance techicians (Robotics Growth, 1983). Some robot manufacturers

suggest that to insure a successful installation, personnel should be trained before a robot is ever installed in the plant (Robotics..., 1982).

Ford Motor Company (Tanner, 1980) maintains it is both desirable and advantageous to develop in-house maintenance capabilities, rather than rely on a service contract with the robot manufacturer. The in-house capability will reduce reaction time whereas often it is the equipment supporting the robot that is at fault. Essentially, the technicians should be trained on all shifts with adequate parts and test equipment on hand.

Technical Skills Required of Industrial Robot Maintenance Technicians

The literature is mixed in regard to the type of work experiences a technician should have to maintain robotic equipment. Engleberger (1980) states that electricians should be the primary robot maintenance technicians. He asserts that since the mechanical and hydraulic systems are relatively straight forward, the major training should focus in the electrical/electronic area. Other authors state that the maintenance people should be fully responsible for the total robot (Tanner, 1980). This means doing the computer programming as well as keeping it operational. This maintenance of the total robot concept is supported by Ford Motor Company where technicians with proper training are capable of keeping robotic equipment operable (Pond, 1976).

R. Culp, The Austin Co. stated,

> The whole area of maintenance generally operates around emergency work orders. Maintenance will have to get out of that mode of operation and into more predictive and planned work, so that production will be less affected by downtime. Today, a lot of maintenance is just running from one fire to the next (Harvey, 1983, p. 44).

Maintenance personnel must have the technical background to respond as necessary or run diagnostics and let the computer tell them where the problem is. Nonetheless, trained and skilled maintenance technicians must be available to understand the computer readout and make the corrections.

When a robot needs attention at the John Deere Component Works, the maintenance technician is dispatched to deal with it, just as with other automated machines. This sometimes requires various skills and ensuing work scheduling of more than one maintenance person.

It is apparent after examination of the current literature that skilled technicians do not have the background to handle all the sophisticated problems associated with robotics. If robotics equipment is increasing in the workplace, it is critical that training of technicians also increase to avoid robot downtime (Tuttle, 1981).

Methodology

Introduction

A review of related literature was completed to identify and define the technical skills required of industrial robot maintenance technicians in manufacturing. A questionnaire was developed and distributed to maintenance technicians at John Deere Component Works to assess required technical skills. Specifically, information concerning work history, previous training and perceptions of what was needed to adequately maintain robotic equipment was obtained and analyzed.

Approval to carry out this investigation was requested (Appendix A) of and provided by the John Deere Component Works Industrial Relations Manager (Appendix B) and the Human Subjects Review Committee from the Graduate College of the University of Northern Iowa (Appendix C).

Subjects

A meeting was arranged with the General Supervisor of Machine Maintenance to obtain the names of maintenance supervisors whose responsibilities included working with industrial robots. Next, an informative interview with each maintenance supervisor was completed to establish guidelines for the selection of subjects (Appendix D).

The population for the study included maintenance technicians that:

1) specifically or as a part of their duties were assigned to service, repair and oversee the upkeep of industrial robots, and
2) have been in the above capacity for more than two months in order to have some familiarization and exposure to the job requirement.

There was no consideration for the participants' sex, age, education or prior work background.

The total population consisted of 25 technicians at the John Deere Component Works, Waterloo, Iowa.

Pilot Study

A pilot study consisting of seven maintenance technicians was completed at the John Deere Component Works (Maintenance Areas A and B). These participants were used to examine the instrument and the procedures for collecting the data. It was found in the pilot study that a phone number of the investigator should be added to the maintenance supervisor's letter. Other minor stylistic revisions were made to improve the clarity and appearance of the questionnaire.

Questionnaire Development

In the formulation of the questionnaire, all areas requiring technical skills were considered. In order to aid in the analysis of the questionnaire, four generic categories with specific subquestions were established. These included:

1) work related background,

2) robot background (i.e., how robot training was obtained and current job responsibilities),

3) assessment of job requirements, and

4) comments and additional statements.

The questionnaire (Appendix E) included 12 questions and a comments section to satisfy the four categories. The content of the questions stemmed from literature readings and conversations with machine maintenance technicians and process engineers. All questions asked the technicians to respond to the listed choices or add their own.

Questions seven through 12 dealt directly with the purposes of the study and the others determined prior work background and current robot involvement per the designated categories.

Attached to the questionnaire was a cover letter (Appendix E) required by Deere & Company corporate policy. This policy clearly states: (a) that survey participation is "strictly voluntary," (b) the purpose for the survey be identified, (c) the participant know why (s)he was chosen, and (d) instructions for completing the questionnaire be provided.

Data Collection

The questionnaires were distributed to 25 maintenance supervisors at the John Deere Component Works. An interview with each supervisor explained the:

1) authorization letter from the manager, Industrial Relations Department,
2) scope of the study,
3) guidelines for choosing the participants,
4) limitations imposed by Deere & Company corporate policy on the study, and
5) procedures associated with responding to the questionnaire.

Each maintenance supervisor distributed the questionnaires to the participants within one work week. Completion of the questions required approximately seven to 10 minutes of the technician's non-working time (i.e., breaktime, lunchtime). When finished, the questionnaires were collected in no certain order and mailed back to the investigator.

Summary of Findings

Introduction

This section presents data in essay and tabulated form. Each question from the survey instrument was analyzed on an individual basis using frequency distributions and percentages when applicable. In addition, the technicians' comments/additions were summarized in essay form to provide miscellaneous feedback.

Findings

The findings of this study are classified under four major categories. In addition, each question is analyzed separately.

Work Related Background

Present job title. The findings indicated that robot maintenance technicians are either classified as electricians or mechanics. Specifically, 14 technicians (56%) were electricians and 11 (44%) were mechanics.

Time worked under job title. The amount of time technicians worked under their current job title ranged from one to 15 years. Five mechanics had more than 15 years whereas 17 mechanics each had six to 10 years work experience.

Originally trained for present job. All technicians except four, noted working under the job title that coincided with their training. This represented 84 percent of the total.

Robot Background

Special schooling/training.

Twenty-four (96%) of the technicians indicated that they had received company training. Of those that did have company training, 20 received it "on the job" and four at the vendor's factory; both in a range of one to 100 hours. The remaining technician received training at a previous job. The location and length of training is shown in Table 1.

Work time used for robot maintenance.

It was found that the maintenance of robots accounts for less than one-fourth of the worktime for 17 technicians and one-fourth to one-half for the other eight technician's time.

Responsibility for robot maintenance.

Nineteen of the technicians maintained they sometimes share responsibility for robot downtime while six stated they have little responsibility. One electrician and one mechanic were in the latter group.

Assessment of Job Requirements

In order to provide a ready comparison of data in this category, Table 2 presents the responses to questions seven through 10 in tabulated and rank order form.

Necessary understanding for robot maintenance.

All 25 technicians responded that hydraulics was a necessary requirement to work on robotics. Seventeen technicians identified electrical and pneumatics, while six identified computers as needed areas to understand in order to maintain

Table 1

Robot Training

Did this company provide special schooling/training for your job assignment to the maintenance of robot?

If yes, where was training at?

Responses	Frequency	Percent
"on the job"	20	80.0
at the vendor's factory	4	16.0
other	1	4.0
Total	25	100.0

If yes, how long was training for?

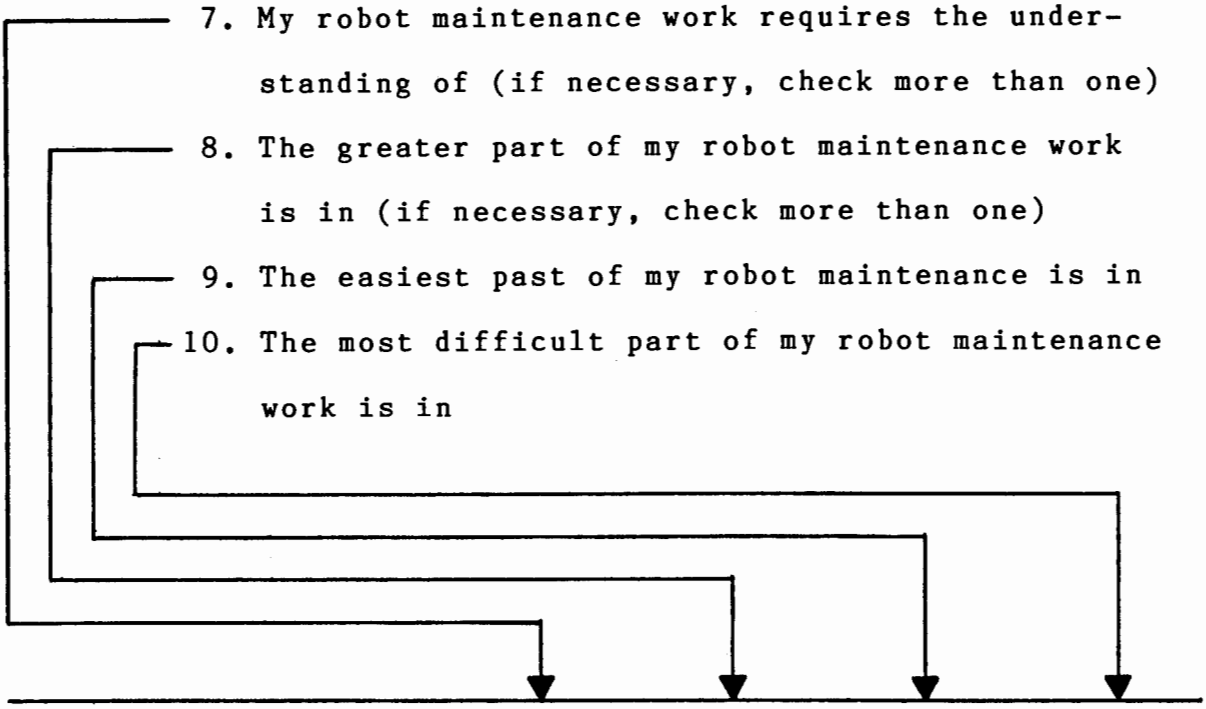
Responses	Frequency	Percent
1 - 24 hours	20	80.0
25 - 100 hours	5	20.0
more than 100 hours	-	-
Total	25	100.0

If no, how did you get training?

Responses	Frequency	Percent
obtained on own time	-	-
previous job	1	4.0
other	-	-
Total	1	100.0

Table 2

Robot Requirements



Responses				
Electrical	17*(2)**	14 (1)	12 (1)	4 (3)
Hydraulics	25 (1)	11 (2)	-	14 (1)
Pneumatics	17 (2)	4 (4)	-	4 (3)
Computers	6 (4)	8 (3)	4 (3)	4 (3)
Other,				
Mechanical	3 (5)	4 (4)	3 (4)	-
Inspection	-	4 (4)	-	-
No response	-	-	6 (2)	5 (2)

* = frequency
** = rank order

and repair robots. In addition, three technicians inserted mechanical as a necessary component of robot maintenance.

Greater part of robot maintenance. Technicians identified electrical, hydraulics, computers and pneumatics as requiring worktime attention associated with robotics.

Easiest part of robot maintenance. The easiest part of robot maintenance as reported by the respondents was in the electrical area.

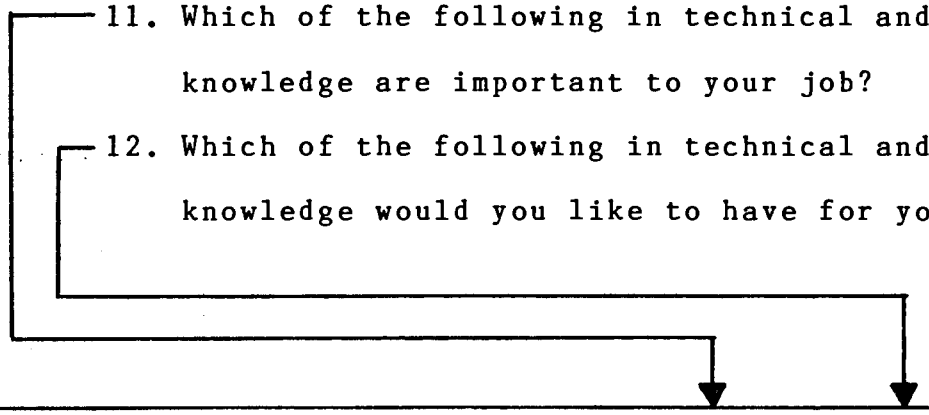
Difficult part of robot maintenance. Fourteen technicians--10 electricians and four mechanics--listed the work area of hydraulics to be most difficult. In addition, the work areas of electrical, pneumatics, and computers were identified by four technicians as a difficult part of robot maintenance.

Important and desired technical skills associated with robot maintenance. Basic, general machine shop exposure was most important to technical skill associated with robot maintenance. Such areas as machine background, blueprint reading, safety practices, shop experience and proper tool usage were listed in that order of consideration. There were equal responses of the technicians' desire to have an understanding in automation design and computer programming.

A composite of responses to the above questions are shown in Table 3.

Table 3

Important and Desired Technical Skills Associated with Robot Maintenance



Responses		
Machine Background	25*(1)**	-
Shop Experience	14 (4)	-
Blueprint Reading	25 (1)	4 (3)
Record Keeping	7 (8)	-
Safety Practices	17 (3)	-
Proper Tool Usage	14 (4)	-
Automation Design	11 (6)	14 (1)
Computer Programming	11 (6)	14 (1)
Other		
What Machine Does	3 (9)	-
Hydraulics	2 (11)	-
Pneumatics	3 (9)	-
Electrical	-	2 (4)
Computer Maintenance	-	-

* = frequency
** = rank order

Comments/Additions

Six technicians chose to express themselves in the comments/additions section. Three technicians stated that they learned robot hydraulics when helping the factory representative (i.e., the manufacturer that installed the robot) to make revisions. Another stated that there really has not been much time for troubleshooting because the two robots in the department are not yet fully operative. Lastly, there was a comment to the extent that production is so far behind and when a robot breakdown occurs, the technicians return to the old manual way of doing things to produce the component parts on schedule.

Discussion

The findings of this study indicated that the majority of practicing robot maintenance technicians have an electrical work background. These electricians as a group are doing the jobs they initially were trained in more than 15 years ago. Thus, it is apparent that robot technicians are likely to be well-established (i.e., work seniority) and experienced electricians. It should be noted that these findings parallel the findings by Engleberger (1980) when he suggested that electricians should be assigned to robot maintenance.

Almost all training for robot maintenance technicians is provided "on the job" within a relatively short time. Most technicians obtained their experience in less than three working days. This small amount of time is only a fragment of the instruction allocated other technical endeavors. Obviously, little emphasis has been placed on "in-depth" robot training.

A short training period for technicians working on robots at the John Deere Component Works may be appropriate since less than one-fourth of the available worktime is currently being used in this area of maintenance. Apparently, there is not an immediate need to become more involved at the John Deere Component Works until additional robots are operational and maintenance is a mainstream problem.

An understanding in the electrical, hydraulics and pneumatics fields is a must for the technicians. This study reports that all technicians checked hydraulics, and also stated it was the most difficult technical field. Evidently, industrial robot hydraulics are complex and cause problems for maintenance technicians.

The findings of this study also indicate that electrical work is the technician's easiest consideration in industrial robot maintenance. Electrical work was also the area that technicians spent the greatest amount of worktime. This may stem from the technicians becoming more involved in what they understand best or because robots have inherently weak electrical systems.

Examination of the findings revealed the typical industrial robot maintenance person should (a) have a machine shop background, (b) be proficient in print reading, (c) be cognizant of proper tool usage, automation design and computers, and (d) practice safety procedures.

The findings also indicate that robot technicians at the John Deere Component Works desire additional training in automation design and computers. Both these areas are integral areas of robot operation and should be part of training for prospective robot maintenance technicians.

References

Block, T. (1980, January). People are robots; robots as people. Design Engineering, 51 (1), 63-67.

Bylinsky, G. (1979, December 17). Those smart young robots on the production line. Fortune, 100 (12), 90-96.

Engleberger, J.F. (1980). Designing robots for industrial environments, Technical Paper, Unimation, Inc., Danbury, Connecticut, 1-7.

Ernst, B.D. (1980). Economic justification for industrial robots. Technical paper, Ford Motor Company, Dearborn, Michigan, 1-7.

Glossary of terms for robotics. (1982, March 19). Iron Age, 225 (9), 82-83.

Goldwater, L. (1983, April 13). Can hi-tech turn us around? Iron Age, 226 (11), 47-63.

Groover, P.E. & Zimmers, E.W. (1980, November). Energy constraints and computer power will greatly impact automated factories in the year 2000. Industrial Engineering, 12 (11), 39-43.

Harvey, R.E. (1983, December 14). Hi tech production will require hi tech maintenance. Iron Age, 226 (30), 44-50.

Heer, E. (1981, November). Robots and manipulators. Mechanical Engineering, 103 (11), 42-49.

Industrial robots come of age. (1984, February). Datamation, 30 (2), Special Report, V, X.

McElroy, J. (1982, September). Industrial Robot Growth. Automotive Industries, 43-45.

Pond, J. (1976, December 13). Putting it all together...with robots. Iron Age, 218 (24), 54-57.

Prab Engineering, Inc., 5944 East Kilgore, Kalamazoo, Michigan, 49033.

Robotics...coming on strong.(1982, February). Tooling & Production, 47 (11), 98-108.

Robotics growth spurs training programs. (1983, February). Production Engineering, 30 (2), 40-42.

Robots are coming. (1983, April 11). Barrons, 8,9,37.

Robots in manufacturing - the trend is systems. (1984, May 7). Modern Materials Handling, 39 (7), 56-59.

Schreffler, R. (1984, June 18). Japan's unmanned factory - The facts behind the mystery. Iron Age, 227 (12), 30-40.

Seman, N.G. (1979, January). Industrial robots--a preview. Foundry Management & Technology, 107 (1), 132.

Senia, A.M. (1983, November 25). Robots take the strain and pain out of the work at Kaiser. Iron Age, 226 (28),71-74.

Sheridan, T.B. (1980, October). Computer control and human alienation. Technology Review, 83 (10), 71-73.

Stark, J.A. (1982, January). Battling imports with robots. Truck & Off-Highway Industries, 38-39.

Tanner, W.R. (1980). A users guide to robot applications. Technical paper, Ford Motor Company, Dearborn, Michigan, 1-10.

Tuttle, H.C. (1981, September). How Westinghouse speeds its application of robotics. Production, 105-108.

Unimation, Inc., Shelter Rock Lane, Danbury, Connecticut, 16810.

U.S. robotmakers say '84 was a very good year, or was it? (1985, March). Tooling & Production, 50 (12), 26, 30.

Vaccari, J.A. (1982, January). Robots that point can create jobs. American Machinist, 126 (1), 131-134.

Weisel, W.K. (1984, October). A look at robotics - 1984 style. Textile Industries, 148 (10), 74.

Who's Who in Robotics. (1982, March 19). Iron Age, 225 (9), 79-80.

Winter, D. (1984, July). The robot growth curve is sagging. Ward's Auto World, 18 (7), 47-51.

Appendix A

Letter to Industrial Relations Manager

Cedar Falls, Iowa 50613
March 12, 1982

Mr. James L. Gable
Industrial Relations Manager
John Deere Components Works
Waterloo, Iowa 50704

Dear Mr. Gable,

As a student of graduate studies at the University of Northern Iowa, I desire to conduct a research survey of the John Deere Component Works maintenance personnel that work with industrial robots. It is my purpose to present my findings in a paper entitled, "The Identification of Technical and Skills Requirements for Maintenance Technicians of Industrial Robots in Manufacturing" as a partial fulfillment of the requirements for the degree of Masters of Arts in Industrial Technology.

I have attached a copy of the survey and a cover letter explaining its content for your inspection.

I fully understand that a survey of this nature must only be conducted on a voluntary basis and not during company time. Thus, it is my intention to distribute the survey during break time and buy each technician a coffee as an added encouragement to participate.

I hope this proposal will meet with your approval and would appreciate any advice or suggestions you might give me.

Sincerely,

David J. Goetz
Dept. 54S Ext. 5881

Enclosure

Appendix B

Letter from Industrial Relations Manager

JOHN DEERE COMPONENT WORKS

P. O. BOX 270, WATERLOO, IOWA 50704 U.S.A.

22 March 1982

Mr. David J. Goetz

Cedar Falls, Iowa 50613

Dear Mr. Goetz:

I have reviewed the survey that you propose to take here at the John Deere Component Works with maintenance personnel whose work is primarily concerned with the maintenance of industrial robots. We would be pleased to cooperate with you in the taking of this survey on the basis as proposed in your letter of 12 March 1982. I believe that you will find the employees involved in this type of work will be most cooperative and I am sure that you will find your efforts rewarding. Should you have any problems as you begin to implement your questionnaire, please feel free to contact this office for assistance.

Sincerely,

Jámes L. Gable
Manager, Industrial Relations

JLG/rdb

Appendix C

Letter from Human Subjects Review Committee

Graduate College

University of Northern Iowa

The Graduate College

UNIVERSITY OF NORTHERN IOWA • CEDAR FALLS, IOWA 50614 • 138 LATHAM HALL • OFFICE OF THE DEAN • 319-273-2748

April 2, 1982

David J. Goetz
Dept. of Industrial Technology
University of Northern Iowa

Dear Mr. Goetz:

Your project, Identification of technical and skills requirements, which you submitted for human subjects review on 3-12-82 has been determined to be exempt from further review under the guidelines stated in the UNI Human Subjects Handbook. You may commence participation of human research subjects in your project.

Your project need not be submitted for continuing review unless you alter it in a way that increases the risk to the participants. If you make any such changes in your project, you should notify the Graduate College Office.

If you decide to seek federal funds for this project, it would be wise not to claim exemption from human subjects review on your application. Should the agency to which you submit the application decide that your project is not exempt from review, you might not be able to submit the project for review by the UNI Institutional Review Board within the federal agency's time limit (30 days after application). As a precaution against applicants' being caught in such a time bind, the Board will review any projects for which federal funds are sought. If you do seek federal funds for this project, please submit the project for human subjects review no later than the time you submit your funding application.

If you have any further questions about the Human Subjects Review System, please contact me. Best wishes for your project.

Sincerely,

Ruth Ratliff
Assistant to the Dean
for Faculty Services

RR:bjs

cc: Dr. John C. Downey
Dr. Norris M. Durham
Dr. John Fecik

Appendix D

Guidelines and Instruction for Maintenance Supervisors

UNIVERSITY OF NORTHERN IOWA · Cedar Falls, Iowa 50614

TO THE MAINTENANCE SUPERVISORS:

Your selection of the maintenance technicians (participants) for this survey shall consider the following guidelines:

1) maintenance technicians that specifically or as a part of their duties are assigned to service, repair and oversee the upkeep of industrial robots,

2) maintenance technicians that have been in the above capacity for more than two months in order to have some familiarization and exposure to the job requirements, and

3) maintenance technicians of all three shifts that qualify in steps 1 and 2.

Please use the money provided to buy each participant and yourself a coffee when the questionaires are handed out; if permissible at that time.

Please use the self-addressed interfactory envelope after completion.

THANK YOU VERY MUCH,

David J. Goetz
John Deere Component Works
Ext. 5881 Dept. 54S

Appendix E

Cover Letter and Questionnaire

UNIVERSITY OF NORTHERN IOWA · Cedar Falls, Iowa 50614

NOTE: YOUR PARTICIPATION IS STRICTLY VOLUNTARY AND THE RESPONSES WILL ONLY BE KNOWN TO ME

ATTENTION PLEASE:

Would you be so kind to give me a few minutes of your time?

As a requirement for my Research Projects class at the University of Northern Iowa, I have selected YOU to participate in a survey.

I am writing a paper entitled "The Identification of the Technical and Skills Requirements for Maintenance Technicians of Industrial Robots in Manufacturing."

You were so chosen because of your experience in maintaining robots.

INSTRUCTIONS FOR COMPLETING THE QUESTIONAIRE

Please indicate your answer with an "X" to each question or insert a reply when requested.

Additional comments will be appreciated if written in at the end of the survey.

THANK YOU VERY MUCH,

David J. Goetz

SURVEY QUESTIONS

1. What is your present job title?
   ( ) electrician
   ( ) mechanic
   ( ) pneumatic/hydraulics technician
   ( ) other, please list _____

2. How long have you worked under this job title?
   ( ) 1-5 years
   ( ) 6-10 years
   ( ) 11-15 years
   ( ) more than 15 years

3. Are you doing what you were originally trained to do?
   ( ) yes
   ( ) no

4. Did this company provide special schooling/training for your job assignment to maintenance of robots?
   ( ) yes
   ( ) no

   If yes, / If no,
   - Where was training at?
     ( ) "on the job"
     ( ) at the vendor's factory
     ( ) other, please list _____
   - How long was training for?
     ( ) 1-24 hours
     ( ) 25-100 hours
     ( ) more than 100 hours
   - How did you get training?
     ( ) obtained on own time
     ( ) previous job
     ( ) other, please list _____

5. Maintenance of robots requires
   ( ) the total of my work time.
   ( ) half of my work time.
   ( ) one-fourth to half of my work time.
   ( ) less than one-fourth of my work time.

6. Maintenance of robots requires that I
   ( ) am totally responsible for its downtime.
   ( ) sometimes share responsibility for its downtime.
   ( ) always share responsibility for its downtime.
   ( ) have little responsibility for its downtime.

7. My robot maintenance work requires the understanding of (if necessary, check more than one)
   ( ) electrical
   ( ) hydraulics
   ( ) pneumatics
   ( ) computers
   ( ) other, please list _____

8. The greater part of my robot maintenance work is in (if necessary, check more than one)
   ( ) electrical
   ( ) hydraulics
   ( ) pneumatics
   ( ) computers
   ( ) other, please list _____

9. The easiest part of my robot maintenance work is in
   ( ) electrical
   ( ) hydraulics
   ( ) pneumatics
   ( ) computers
   ( ) other, please list _____

10. The most difficult part of my robot maintenance work is in
   ( ) electrical
   ( ) hydraulics
   ( ) pneumatics
   ( ) computers
   ( ) other, please list _____

11. Which of the following in technical and skills knowledge are important to your job.
   ( ) machine background
   ( ) shop experience
   ( ) blueprint reading
   ( ) record keeping
   ( ) safety practices
   ( ) proper tool usage
   ( ) automation design
   ( ) computer programming
   ( ) other, please list _____
   ( ) other, please list _____

12. Which of the following in technical and skills knowledge would you like to have for your job.
    ( ) machine background
    ( ) shop experience
    ( ) blueprint reading
    ( ) record keeping
    ( ) safety practices
    ( ) proper tool usage
    ( ) automation design
    ( ) computer programming
    ( ) other, please list _____
    ( ) other, please lsit _____

COMMENTS:

THANK YOU VERY MUCH FOR YOUR TIME.