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Recommendations Regarding the Instruction of Fluid Power in Utah

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RECOMMENDATIONS REGARDING THE INSTRUCTION OF

FLUID POWER IN UTAH

by

Ronald C. Baker

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of the requirements for the degree

of

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Ronald C. Baker

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ABSTRACT

Recommendations Regarding the Instruction of

Fluid Power in Utah

by

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Utah State University, 1971

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The fluid power systems equipment industry has shown a 117 percent growth from 1957 to 1968.

This impressive growth rate is critically affected by a shortage of competently trained workers.

The needs of selected Utah industries for trained personnel in fluid power were studied, and the results were projected from the sample to the state of Utah.

The skill levels most in demand were skilled, two-year technician, and semi-skilled.

Industries indicated that training to meet their needs could be conducted by on-the-job training, inplant schools, special schools, adult education programs, vocational high school programs, two-year vocational school programs, two-year university programs, and technical institute programs.

Based on the recommendations of Utah industries for training needed and using the Fluid Power Society curriculum as a substructure, recommendations for fluid power instruction in Utah were made.

(63 pages)

INTRODUCTION

The Problem

The fluid power systems equipment industry has shown an impressive 117 percent growth in the period from 1957 to 1968. Over 40 percent of the total gains were made during the four-year period from 1964 to 1968. This industry has consistently produced more vigorous gains than those of manufacturing as a whole.

The growth in use of fluid power systems, shown by a U. S. Department of Commerce survey, is expected to continue; but at present, the development of this emerging technology is critically affected by a shortage of competent technicians.

Dr. William D. Wolansky (1967, p. 94), from one of the leading schools in teacher preparation for fluid power education, stated:

> . . . the rapid and anticipated future growth in fluid power will undoubtedly continue to create jobs faster than we can train manpower--unless industrial education departments in secondary and post secondary schools provide programs and means where students can learn more quickly and effectively to enter this field on a productive basis.

A national survey on manpower needs in fluid power reported a serious shortage of skilled technicians as well as a lack of educational programs and teachers trained to oversee such programs.

In a Western Michigan University survey, educators said, "Prospects [of fluid power] are limited only by the lack of imagination curtailed by a lack of trained personnel." (Risher, 1965, p. 47)

Dr. Charles G. Risher (1965, p. 38), basing his comments on a round table discussion with industry and education, wrote:

> Automation and other applications of fluid power have created a growing demand for trained personnel capable of designing, servicing, maintaining, and operating fluid power systems. The result is a serious shortage of trained fluid power personnel.

Statement of the problem

The absence of fluid power instruction programs may have many causations which relate to a common problem. This problem is the absence of knowledge involving industrial needs in Utah for trained personnel in fluid power, such that decisions can be made pertaining to training programs.

Purpose of the study

The purpose of this study was to collect and analyze data relevant to the needs of Utah industry for workers trained in fluid power, identify employment opportunities for trained workers, and make recommendations regarding fluid power instruction.

More specifically, the objectives of the study were:

1. To determine the number of people in Utah industries which are directly involved with fluid power.

2. To determine the job opportunities in Utah industries for personnel trained in fluid power.

3. To determine the kinds and levels of fluid power skills required of employees in Utah industries.

4. To determine if educational programs should be established to train personnel in fluid power.

5. To examine existing Fluid Power Society education program course outlines to see if they meet the recommendations made for fluid power education in Utah.

6. To make recommendations regarding fluid power instruction.

Methods of procedure of the study

A questionnaire designed to provide data dealing with the preceding objectives was designed and data were gathered and recommendations made in the following manner.

1. Through the assistance of a fluid power component supplier and various telephone directories, a population of industries directly involved in fluid power was identified.

2. A letter containing a returnable postcard was sent to the various industries who completed and then returned the card.

3. From the completed cards, a sample of the total population was identified.

4. Industries in the sample were then contacted by personal interview and the data were collected.

5. The number of people in Utah industries which are directly involved with fluid power was calculated based on a percentage of national industrial involvement in fluid power.

6. Job opportunities for personnel trained in fluid power were determined by the needs of industries contacted and were projected to the total industry of Utah.

7. From the collected data, kinds and levels of skills required in fluid power by Utah industries were made.

8. From data on Utah's industrial need for skilled workers it was determined if education should train personnel in fluid power.

9. Through the areas of training needed by workers, identified by surveyed industries, it was determined if existing Fluid Power Society education program course outlines met the fluid power training needs of the state of Utah.

10. Using the Fluid Power Society's educational program as the substructure, recommendations were made regarding fluid power instruction in Utah.

Limitations of the study

This study was delimited to:

1. The author's identification of industries directly involved in fluid power.

2. The state of Utah.

3. The number of interviews conducted.

Definition of terms

Adult vocational education. "Vocational education for adults is chiefly of an upgrading and updating nature offered on a part-time basis, or of a retraining nature for persons displaced by automation or technical changes." (AVA Publications Committee, 1968, p. 3)

Engineer. One with a baccalaureate degree who applies scientific principles to the utilization of inorganic materials, properties of matter, sources of power, and physical forces for supplying that which will meet human needs.

Four-year university program. Organized study in a college or a professional school which is a branch or a part of a university.

Four-year technologist. A person with a baccalaureate degree in a field of technology who is narrowly specialized in an activity which requires the application of mathematical and scientific principles. He is more narrowly specialized than an engineer.

Graduate engineer. One who has earned a higher degree in the field of engineering that required additional study beyond the baccalaureate to obtain a Master of Science degree in Engineering or a Ph. D. in Engineering, or both.

Semi-skilled. A worker with a skill level which requires only a short period of instruction and practice. Instruction should include information directly related to the needed skills and the required technical facts.

Skilled. One competent to perform, with a high degree of expertness, the work in one or more specialized divisions of a given trade (AVA Publications Committee, 1968).

Technical institute. A school at the post high school level which offers technical education in one or more fields to prepare people for employment in positions which lie between the skilled workers and professional scientists or engineers (AVA Publications Committee, 1968).

Two-year technical school program. An educational program at the post secondary level which provides education for employment in an area which depends on knowledge and understanding of technical information, laws of science, and applied technology.

Two-year technician. A worker on a level between the skilled tradesman and the professional scientist or engineer. His technical knowledge permits him to assume some duties formerly assigned to the graduate engineer or scientist (AVA Publications Committee, 1968).

Two-year university program. Education in the application of scientific principles in research, design, development, production, distribution, and service in the applied sciences.

Two-year vocational school program. A program offering training in skilled or semi-skilled trades or occupations designed to train for initial employment and upgrade those who are employed.

Unskilled. A worker with little or no training in a trade or occupation. Often the required training can be given in an hour or two of instruction.

University post graduate program. Education offered for the purpose of conferring advanced degrees such as M.S. and Ph.D. in a specific area.

Vocational high school program. A program organized at the secondary level to provide job entry skills to classes which meet two or more hours a day.

Directly involved in fluid power. Any participation by a company in one or all of the following: sales, service, component assembly, inplant use, mobile use, and component manufacturing of fluid power related equipment.

Inplant training. Training for employees which relates directly to the products and/or services of the employing firm. The instruction is usually conducted in the firm's facilities to train, retrain, and update the job skills of workers.

Special school. Training conducted by an industrial or educational institution to train workers in specialized areas relating to particular skills or occupations. Training may range from a session of a few hours to an organized program.

REVIEW OF LITERATURE

Historically, man has used fluid power as a tool from the beginning of civilization to the present time. The blowgun, musical instruments, windmills, bellows, and sails are examples of early applications of pneumatics which are still being utilized today.

Many thousands of years ago hydraulics, another form of fluid power, was used in water works, irrigation systems, and crude waterwheels.

Ancient Chinese records state that wood valves were used to control the flow of water through bamboo pipes as early as 3,000 B. C.

> Control of fluids in confined spaces has been fairly well known since 3,000 B. C. when engineer-emperor YU devised a water system in China that was of such excellent design that one thousand years later an engineer named Li extended the system, and established rules of operation that are still followed. (Guentzler, 1968, p. 9)

The term "hydraulics" is a word of Greek origin and is derived from two words. "The first being 'hydor,' which indicates water and the second 'aulos,' indicating a pipe." (Kudity, 1964, p. 3)

Just prior to the Christian era, a mathematician, Archimedes, invented a water pump in the form of a hollow tube shaped into a screw. The Archimedes screw type pump is still being used in Europe for drainage systems. Near the time of Archimedes, Hero of Alexandria built a turbine to use the power from a moving liquid. But the water wheel, a primitive form of the turbine, probably dates back some five thousand years to Egypt and China.

The period of the Dark Ages seriously hindered any real developments of fluid power until the reawakening of the Renaissance period. With the awakening of the physical sciences, men's imaginations began to explore fields of thought dealing with the unknown.

About 1650, a French scientist Blaise Pascal was experimenting with fluid power as a means of power transmission. Pascal's experimentation started after he rammed the cork down in a jug completely full of wine and the bottom broke out. From this he went on to develop what we now call Pascal's Law which states, "If the pressure at any point in a fluid at rest is increased, the pressure is transmitted undiminished to all points in the fluid." (Fitch, 1966, pp. 15-16)

"A hundred years later Bernoulli developed his law concerning the conservation of energy in a flowing fluid." (Pease, 1967, p. 1)

"Bernoulli's principle tells us that the sums of the pressure and kinetic energy at various points in a system must be constant, if flow is constant." (Basal, 1967, p. 16)

In 1795 the first practical use of hydraulics was developed. "Joseph Bramah developed the original hydraulic press ... using water as a hydraulic medium, and using the principle of Pascal to achieve a huge mechanical advantage or force multiplication." (Basal, 1967, p. 1)

Applications of Pascal's Law and Bernoulli's Theorem were used in England between 1850 and 1900 in various types of hydraulic presses and motors.

> In fact, hydraulic power was so widely used to power cranes, winches, and extruding machines in England during this [industrial revolution] period that private utility companies in larger British cities built industrial, hydraulic-distribution systems similar to electrical transmission systems used today. Pipes carried the pressurized liquid to factories, where it was used to drive machinery. (Pearce, 1964, p. 21-2)

The emergence of electrical power in the late nineteenth century caused fluid power to be neglected, for industry concentrated on the refining of dectrical technology rather than on refining the applications of fluid power.

An important milestone in the applications of fluid power came in 1906, when a specially developed hydraulic system installed on the USS Virginia was used to replace electrical systems for elevating and controlling guns on battleships.

Until this time, water was primarily used as a hydraulic medium in systems; and although economical and available, it was very detrimental to the system, for it had a minimal lubricating ability. It was highly corrosive and formed ice at lower temperatures. Because of the drawbacks of water as a hydraulic fluid, oil now replaces water in most fluid power systems.

The somewhat slow progress in the application of fluid power came to an end with the beginning of World War II when an all-out effort was made to develop fluid power and utilize its advantages.

"In 1926, the United States developed what we call the direct hydraulic system--a type of packaged system with the pump, controls, and actuator in a self-contained unit on the machine or vehicle using it." (Pease, 1967, p. 1)

Since then the applications of fluid power have become virtually limitless and include systems on machine tools, all types of mobile equipment, production machines, and even in-space vehicles, just to name a few.

In a short period of about ten years, few professional-technical organizations can claim an eventful history parallel to that of the Fluid Power Society. Since 1960, the year of its founding, the Society has become the recognized authority on fluid power in the United States. This growth and recognition is attributed to the unselfish manner in which its members have provided their ideas, knowledge and training techniques to the Society in order to foster its growth and maintain its authoritative position in the field.

Fluidics, a new branch of fluid power, has emerged within the last decade.

> Fluidics is a part of fluid power technology that applies fluid mechanics principles to perform switching, sensing, logic and other control functions with no moving mechanical parts. Fluidics is primarily concerned with the control function for a fluid power system. (Henke and Martin, 1968, p. 40)

Until the introduction of fluidics, fluid power systems were controlled by electro-hydraulics, mechanical hydraulics, electricity, and electronics. Fluid power did the work, and the hybrid control systems supplied the commands.

> In January, 1960, the first published information concerning the use of no-moving-part fluid logic devices was made. Warren, Horton, and Bowles, then working with the Diamond Ordinance Fuse Laboratory, an agency of the United States Army, developed three air-operated devices which use no moving parts.

> . . . from this beginning, the technology of fluidics has grown to be an effective addition to the available control technologies. (Fox, 1969, pp. 1-2)

Fluidic systems offer significant advantages compared to the older devices including: no-moving-part reliability, economy of production, low-energy power consumption, sensitivity utilizing low-energy signals, and speed due to small size and the absence of moving parts. These new capabilities and environmental tolerances of fluid flow to radiation, heat vibration, and other conditions suggested to many individuals that this technology presented great promise in many applications.

An information sheet by Harold L. Fox (1969), one of Utah's most noted authorities on fluidics, and President of Fluidics Production and Sales, Incorporated, of Salt Lake City, Utah, states:

> A Master's thesis, published in 1965 (Fluidics, edited by E. F. Humphrey and D. H. Taramoto), projects a sales potential for fluidics of about one-half to one billion dollars by 1975. It is probable that fluidics will emerge as an industry about one-fifth to one-fourth the size of the solid state electronics industry. This would mean an annual sales volume of two to two and a half billion dollars in 1981.

The growth potential and size of the fluid power industry can be illustrated by contrasting its size in 1945, with 1970. In 1945, the fluid power industry produced about one-third of a billion dollars worth of equipment and it is projected that in 1970, the volume will be $2 billion or more. This increase represents a 600 percent projected growth in a period of 25 years.

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> . . . the growth of the fluid power systems equipment industry increased from $486,144,000 in 1957 to $1,005,255,000 in 1968, a rise of 117 percent. The 1968 shipments were a vigorous 40 percent over the 1964 shipments of $753,508,000. The industry has consistently shown stronger gains than that of manufacturing as a whole. (U.S. Department of Commerce, 1969, p. 3)

The actual growth and the growth potential of the fluid power industry is paralleled by a growth in the shortage of trained personnel to work with fluid power components.

In a report based on data industrial representatives presented to the Industrial Arts General Session on Fluid Power at the 57th Annual Vocational Convention, A. J. MacDonald (1964, p. 22), Assistant Professor of Industrial Education at San Jose College in California, states, "The exceptional growth and multitude of technical advances in the fluid power industry have led to a serious shortage of persons trained to design, manufacture, service, maintain and operate fluid power systems."

A national survey conducted by the National Fluid Power Association in 1963 on the availability of trained manpower in fluid power disclosed that there were shortages of trained personnel in all categories.

> The highest incident of manpower shortages was reported for both engineers and engineering technicians or aids in design functions, followed closely by maintenance and installation functions for the same categories of employees. Operational functions showed the lowest incidence ranging from 43 percent for shortage among skilled workers to 50 percent among engineers. (MacDonald, 1964, p. 27)

Although the 1963 survey is some seven years old, it can serve to indicate that a shortage of skilled manpower existed at that date; and literature will indicate that the shortage has continued to the present time.

Dr. Charles G. Risher (1965, p. 47), Acting Head, Department of Industrial Education, Western Michigan University, stated in a special report from a "round table" on The Present Status and Needs of the Fluid Power Industry, The Implications for Fluid Power Education, that:

> Industrialists say that present shortage of technicians affect three groups of people: (1) manufacturers of basic machinery and equipment, (2) users of this equipment and (3) repairmen and technicians needed to service fluid power equipment. More personnel shortages exist among companies using fluid power than among the manufacturers. ... fluid power should be a major area subject in an engineering curriculum ... a greater need for circuit design and application engineers, as well as service and maintenance people ... secondary schools and post high schools must alter existing facilities, or create new facilities for fluid power instruction.

Participants from industry and from industrial education were at the round table.

In a report written for Hydraulics and Pneumatics magazine, Russ Henke (1968, p. 90), Executive Vice-President, Fluid Power Society, states:

> Fluid power is a 1 1/4 billion dollar a year technology. Reliable predictions show that by 1975, its annual sales volume will exceed that of the American machine tool industry. Yet, the growth of fluid power is plagued by a shortage of men trained and educated in fluid power.

Rapid growth in the fluid power industry and the numerous technological advances seem to have created a serious lag between education and the industry.

> Not only is education somewhat remiss in supplying a sufficient number of technical personnel to meet the demands of the industry, but education also seems to be failing to recognize the size and importance of fluid power in the industrial complex so that it can convey these concepts to both general industrial education students and industrial arts students. (MacDonald, 1964, p. 27)

The urgency for industrial education to become involved in fluid power education is becoming more critical with the expanding production and use of fluid power systems. Various segments of the educational community are beginning to assault the training void in industrial education which has been created due to the lack of fluid power training programs.

PRESENTATION OF DATA

Introduction

The data for this study were tabulated from the answers of industrial personnel to questions asked during a personal interview to determine the role of Utah public schools in the instruction of fluid power.

The total population of industries directly involved in fluid power used in this study was identified by two methods;

1. By contacting a fluid power component supplier who provided names of customers in the northern one-half of the state of Utah.

2. Through an extensive search of the telephone directories from all communities in the northern one-half of Utah, the author identified additional industries directly involved in fluid power.

Sample identification and returns

The letter of introduction and the returnable postcard (Appendix, pages 48 and 49) which were used to isolate a sample from the total identified population were mailed to 99 industries in the northern one-half of the state of Utah. In a period of five weeks, 33 postcards were returned, which was a 33 percent response (see Table 1).

Reasons for only a 33 percent response were not evident from the returned postcards. Based on empirical observation made by the author of a listing of non-responsive companies, it was theorized that companies did not respond for the following reasons;

1. Did not want to be involved in the study.
2. Fluid power education would not meet company needs.
3. The company involvement in fluid power was on a small scale.
4. The company was not involved in fluid power.

Table 1. Postcards returned from industries surveyed

	Number	Percent
Cards returned indicating no participation	7	7
Cards returned indicating participation	20	20
Cards returned not completed	6	6
Total cards returned	33	33
Cards not returned	66	66
Total cards sent	99	100

The postcard was designed to provide data such that a random stratified sample could be taken of the total identified population. As shown in Table 1, the total usable cards numbered only 20; therefore, a random stratified sample was not needed due to the small number of returns. Because the postcard was a means of identifying a population rather than collecting data, and because the data were to be gathered by interview, no follow-up mailing was made.

Since the success of this study was dependent on the identification of a sample of industries directly involved in fluid power, a question dealing with companies' involvement was included on the card. Some industries indicated that they were not directly involved in fluid power; but based on responses to other questions on the card, the author considered them as being directly involved. In the context of direct involvement in fluid power, a definition is stated--any participation by a company in one or all of the following: sales, service, component assembly, inplant use, mobile use, and component manufacturing of fluid power related equipment. Table 2 presents the data based on the actual responses of industries, not on the author's observations.

Table 2. Companies' involvement in fluid power

	Number	Percent
Yes	17	52
No	13	39
No Response	3	9
Total	33	100

Included in Table 3 are companies' responses to their involvement in the three applications of fluid power which are: hydraulics, pneumatics, and fluidics. Some of the firms indicated that they were involved in more than one application area of fluid power.

Table 3. Companies' responses to application areas in fluid power

	Number	Percent
Hydraulics	17	52
Pneumatics	15	45
Fluidics	5	15

Under any one or even all three application areas of fluid power (hydraulics, pneumatics, and fluidics), each company indicated its one or more specializations. For example, one firm was involved in the application areas of hydraulics and pneumatics and specialized in sales and service relating to those application areas. In reference to Table 4, therefore, this firm would be considered as being only in sales and service in fluid power, not in sales and service for hydraulics, and sales and service for pneumatics.

The data presented in Table 4 are the totals of the companies' specialties with no reference given to the application areas of fluid power.

Table 5 presents the companies' specializations with reference to the three applications of fluid power. For example, a firm may be working in the application areas of hydraulics and pneumatics with specializations in sales and service relating to those application areas. Therefore, this firm would be considered as being in sales and service for hydraulics and in sales and service for pneumatics. Most firms had one or more specializations in one or more application areas.

Table 4. Companies' responses to areas of specialization in fluid power

	Number	Percent
Sales	12	28
Service	10	24
Component assembly	7	16
Inplant use or mobile use	4	9
Manufacturing	6	14
Design and research	4	9
Total	43	100

Exemplified by Table 6 are company responses as to whether or not fluid power education would be of benefit to them. Only 14 of the companies indicated that fluid power education would be of benefit to them, while 14 of the companies indicated the fluid power education would not be of benefit to their firm. These results do not unequivocally support the value of fluid power education at this point in the study.

Table 5. Companies' responses to areas of specialization in the various applications of fluid power

	Hydrau-lics	Pneu-matics	Fluidics	Total Number	Percent
Sales	10	9	2	21	32
Service	8	7	1	16	24
Component assembly	5	4	2	11	16
Inplant use or mobile use	3	2	1	6	9
Manufacturing	3	3	3	9	14
Design and research	30	27	9	66	100

Table 6. Companies' responses to the necessity of fluid power education

	Number	Percent
Yes	14	41
No	14	41
No response	5	18
Total	33	100

The original proposal for this study stated that a random stratified sample would be taken from the population identified by means of a returnable postcard, but the total number of usable cards returned provided a population numbering only 20; therefore, a random stratified sample was not necessary. The population of 20 was considered to be an adequate number for a sample so the interviews were conducted on this basis.

Description of the instrument

Since this study is purely a descriptive one, an instrument was constructed within the parameter of descriptive research. A characteristic of the instrument was its design to be used as an interview form which was completed by the author during personal interviews. The instrument (Appendix, page 50) was highly structured to confine the interview discussion to predetermined limits and minimize any influence the author may have on the responses of the interviewee.

Sample size

From the identification of a population of industries in fluid power, a sample size of 20 was to be interviewed. This sample was composed of the total number of usable replies returned during the population identification. The writer was only able to contact 15 of the 20 industries for interviews.

Results of the study

Positions of persons interviewed are contained in the Appendix, page 53. Noteworthy is the fact that the persons responding to the postcard were different from those actually contacted during the interview. This may account for differences between the data from sample identification and the data from interviews.

Included in Table 7 are the firms' business activities in fluid power. Most firms were involved in more than one type of operation or service relating to fluid power.

Table 7. Firms' business activities in fluid power

Type	Number	Percent
Retailing	8	53
Service	8	53
Wholesaling	7	47
Component assembly	3	20
Component manufacturing	3	20
Research and development	3	20
Engineering	2	13
System installation	1	.06

Eight, or 53 percent, of the business firms interviewed indicated that they were involved in retailing and another eight, or 53 percent, also indicated they were involved in servicing of fluid power components as noted in Table 7. It can also be noted that seven, or 47 percent, were also involved in wholesale activities. System installation was checked by only one of the business firms contacted.

Table 8 presents the specializations of the firms in the three applications of fluid power: hydraulics, pneumatics, and fluidics. Most firms were working in one or more application areas of fluid power. Eleven of the 15 firms interviewed, or 73 percent of the total, were working in hydraulics. Pneumatics was second in firm specialization with 10 firms, or 66 percent.

Table 8. Firms' specializations in fluid power applications

Application	Number	Percent
Hydraulics	11	73
Pneumatics	10	66
Fluidics	5	33

The number of persons working with fluid power in various service or operation areas was indicated by interviewees. The 15 firms interviewed were working in one or more of the service or operation areas. These data are illustrated in Table 9.

Table 9. Number of persons working in various service or operation areas of fluid power

Service or operation	Number of workers	Percent
Testing	15	3
Component manufacturing	39	9
Research	32	6
Sales	33	7
Component assembly	37	8
Service	310	66
Total	466	100

The 15 firms employed a total of 466 workers in fluid power or an average of about 31 workers per firm. The largest number of employees (310, or 66 percent) were involved in servicing of fluid power systems. The second largest number of employees (39, or 9 percent) were involved in manufacturing of fluid power components. The third largest number of employees (37, or 8 percent) were involved in assembly of fluid power components.

During the interview the interviewees were asked to project the employment opportunities for trained personnel in fluid power with their firms. Only seven of the interviewees were able to project their future needs for trained personnel in number, but others did indicate a need for trained workers. The personnel needed by the 15 interviewees totaled 29 persons, or an average of 1.9 persons per firm contacted. It appeared that employers had difficulty in projecting their needs in such a rapidly expanding field. The difficulty of firms in projecting their employment needs seems to indicate a trend in the growth of the fluid power industry in Utah.

The following is a list of the interviewees' comments relating to their needs for trained personnel in fluid power.

"We will increase in size."

"My company has a need for a person in sales."

"We will employ more trained people in the future."

"One engineer will be employed in the near future."

"Probably we will need one or two trained people each year."

"Two or three trained personnel are needed now."

"Unable to project need for trained workers."

"We will hire two more employees within a year."

"Ten additional people will be needed in a year."

"We need two trained personnel in ninety days and will add six to ten more within the next year."

"Yes, we need personnel with fluid power training."

"We always need qualified personnel."

"We will employ workers as needed."

"My firm will have a need for trained people in time to come."

"We are expanding now and will hire people as needed."

"Within a year we expect to grow to five or six times our present size."

Data presenting the required skill levels of trained personnel in fluid power needed by the 15 firms surveyed are presented in Table 10. Most of the 15 firms employ a variety of skill levels of personnel, but the attainment of workers most in demand are the skilled level and the two-year technician level. Ten firms, or 66 percent, needed personnel trained to the skilled level, and 10 firms, or 66 percent, needed personnel trained to the two-year technician level.

Table 10. Skill levels of trained personnel in fluid power

Level	Number	Percent
Semi-skilled	5	34
Skilled	10	66
Two-year technician	10	66
Four-year technologist	3	20
Engineer	2	13
Graduate engineer	2	13

Table 11 illustrates the interviewees' responses denoting the type of training which would provide adequately trained workers to meet their firms' needs. Many firms employed several skill levels of workers in fluid power; therefore, interviewees provided information relating to a variety of skill levels and the various ways training could be accomplished. Responses indicate that training for the two skill levels most in demand could be conducted by a variety of institutions. The training for the skilled level could be provided by on-the-job training, inplant schools, special schools, adult education programs, vocational high school programs, two-year vocational school programs, and technical institutes. The training for the two-year technician level could be provided by two-year vocational school programs, two-year university programs and the technical institutes.

Table 12 presents how the 15 firms are getting trained personnel in fluid power. It is important to note that 89 percent of the firms contacted are getting trained personnel through on-the-job training, and 60 percent of the firms are getting trained personnel through inplant training. Most of the firms were obtaining trained personnel in a variety of ways and not relying on any single method.

The responses to plans to conduct inplant fluid power training programs are presented in Table 13. Twelve, or 80 percent, of the 15 firms contacted were either conducting inplant training programs or had made plans to conduct them.

Table 11. Responses indicating how the training of the various skill levels in fluid power could be conducted

Training	Semi-skilled	Skilled	2-year Technician	4-year Technologist	Engineer	Graduate engineer
General high school course	1					
On-the-job training	5	4				
Inplant schools	1	3				
Special schools	3	6				
Adult education programs	3	4				
Vocational high school program	1	2				
2-year vocational school program		6	7			
2-year technical school program						
2-year university program			4			
4-year university program				4	1	
Technical institute program		2	3	1		
University post graduate program						3

Table 12. How firms are presently getting trained personnel in fluid power

Training received	Number	Percent
On-the-job training	13	89
Inplant schools	9	60
Vocational schools	5	33
High schools	1	7
Special programs	6	40
Universities	4	26
Other	4	26

Table 13. Plans to conduct inplant fluid power training programs

Response	Number	Percent
Yes	12	80
No	1	7
Undecided	2	13
Total	15	100

The units of instruction which should be included in a fluid power program, as indicated by interviewees, are presented in Table 14. The instructional units specified most were: various common circuit types, basic principles of fluids and pumps. The units which were specified in the next order of importance were: tubing and piping, motors, and pressure control valves. Most firms suggested units of instruction which were indirectly related to fluid power instruction. The following is a list of the indirectly related units: welding, sheet metal, machining, drafting, reservoir design, trouble shooting, optics, fluidic circuits, salesmanship, electronics, and precision measuring.

Salary opportunities, a part of the total job opportunity picture, are presented in the Appendix, page 54. This data are the average of salaries that interviewees felt were approximate yearly starting salaries for personnel trained to skill levels in fluid power to meet their needs.

From the 1969-1970 Directory of Utah Manufacturers, prepared by the Utah Committee on Industrial and Employment Planning, the total number of manufacturing industries and the average number of personnel employed in manufacturing by industries in Utah was determined. The manufacturers in this publication were listed chronologically according to their four-digit standard industrial classification number which classified each firm as to their major manufacturing activity. Also listed was a size range based on the number of employees employed by each firm. Since the actual number of employees is confidential, a size range was given; for example, a size for one firm was listed as 400-499 employees and was considered for tabulating purposes to have 450 employees. Thus all firms listed were considered in the above manner to obtain a total of 65,787 workers involved in manufacturing with

Table 14. Recommended units of instruction needed for training workers in fluid power

Instructional units	Number of employers specifying instructional unit
Pumps	15
Basic principles of fluids	15
Various common circuit types	15
Pressure control valves	14
Motors	14
Tubing and piping	14
Symbols of fluid devices	13
Gages	13
Directional control valves	13
Cylinder sealing	12
Hydraulic filters	12
Linear actuators	12
Electricals	12
Indirectly related to fluid power	12
Flow control valves	11
Symbols for fluid power circuits	11
Fluid power standards	10
Accumulators	10
Compressors	9
Fluid conditioners	8
Fluidic devices	8
Hydrostatic transmissions	8
Fluid standards	7
Drafting standards for fluid power diagrams	4

1,246 firms. The previous totals were then used to project the findings of this study to the entire state of Utah.

The total number of people in Utah industries directly involved in fluid power was determined by using the national averages of fluid power involvement in manufacturing. These averages were taken from the following statement.

> ... 60% of all manufacturing plants in the United States utilize fluid power systems as part of equipment in the manufacturing of their products and about 53% of all industrial products produced in the United States have a fluid power system or component built into them. (MacDonald, 1964, p. 27)

The above statement was taken from an article on the proceedings of the 57th Annual Vocational Convention, where leading experts in the field of fluid power presented papers. These percentages were applied to the average number of workers in manufacturing as determined from the 1969-1970 Directory of Utah Manufacturers.

The following data were compiled based on the foregoing procedures. Sixty percent of 65,787, or 39,469 workers, were involved in fluid power through its use in manufacturing. Fifty-three percent of 65,787, or 34,867 workers, were involved in fluid power through its use in industrial products. Sixty percent of 1,246, or 747 firms in Utah, use fluid power in manufacturing. Fifty-three percent of 1,246, or 660 firms in Utah, manufacture products with fluid power systems or components built into them. It must be noted that many workers and firms were involved in fluid power both through manufacturing and a manufactured product so the totals cannot be categorized separately.

Only seven of the interviewees were able to project their future needs for trained personnel in actual numbers, but others did indicate a need for trained workers as presented on page 26. The personnel needed by interviewees totaled 29 persons or an average of 1.9 persons per firm contacted. To project the need to Utah industries involved in fluid power through its use in manufacturing, 747 firms need or will need 1,419 workers within the next five years. The 660 firms involved in fluid power through manufactured products with fluid power systems or components, need or will need 1,254 trained persons. It must be noted that many workers and firms were involved in fluid power both through manufacturing and a manufactured product so the totals could not be categorized separately.

Table 15 is a comparison of Fluid Power Society instructional unit offerings and units of instruction indicated as being necessary by interviewees for training skilled workers in fluid power to meet the needs of their firms. The Fluid Power Society education program contains all but four of the required instructional units (gages, fluidic devices, symbols of fluidic devices and hydrostatic transmissions) that were indicated as being necessary by interviewees.

During the interview, the interviewees did not respond to the units of instruction in the Fluid Power Society's hydraulic and pneumatic course (Appendix, page 55) but responded to the list of instructional units included in Table 15. Therefore, it can not be concluded that the unspecified instructional units presented in Table 16 are not necessary. The Fluid Power Society's hydraulic and pneumatic course is the first offering under a program specifically designed to prepare skilled workers and technicians for work in fluid power and to introduce engineers to fluid power technology. The five instructional units dealing with hydraulic and pneumatic power transmissions were written by John Pippenger, vice president of a large hydraulic development corporation and past president of both the National Fluid Power Association and the Fluid Power Society.

Table 15. Comparison of Fluid Power Society instructional unit offerings and units of recommended instruction for trained workers in fluid power to meet the needs of interviewees

Redommended instructional units	Fluid Power Society offerings
Fluid power standards	Yes
Fluid standards	Yes
Symbols for fluid power circuits	Yes
Directional control valves	Yes
Flow control valves	Yes
Compressors	Yes
Accumulators	Yes
Fluid conditioners	Yes
Gages	No
Drafting standards for fluid power diagrams	Yes
Electricals	Yes
Fluidic devices	No
Pressure control valves	Yes
Linear actuators	Yes
Pumps	Yes
Motors	Yes
Basic principles of fluids	Yes
Symbols of fluidic devices	No
Hydraulic filters	Yes
Hydrostatic transmissions	No
Tubing and piping	Yes
Cylinder sealing	Yes
Various common circuit types	Yes

Table 16. Fluid Power Society instructional unit offerings not responded to by interviewees

Units of Instruction
Choice of fluid for specific applications
Heat and energy in pump systems
Scavenger tanks--settling tanks
Suppression of shock waves
Reservoir maintenance requirements
Fluid temperature control
Automatic control of fluid temperature
Combination functions of flow control valve circuits
Priority circuits
Methods of actuation
Pressure drop - clearance flows - drain provisions
Accumulator circuits
Shock-wave absorption
Safety considerations
Servo systems
Mechanical linkage systems
Circuit design--new installations
Introduction of shock suppression devices adding heat
Modifications for easier maintenance
Adding capacity to existing systems
Maintenance and preventive maintenance of fluid power systems
Machine repair
Fluid problems
Marginal operation
Electrical failures
Care of systems using fire resistant fluids
Practical mathematics
Practical geometry and trigonometry
Electrical principles applied to fluid power equipment

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to collect and analyze data relevant to the needs of Utah industry for workers trained in fluid power, identify employment opportunities for trained workers, and make recommendations regarding fluid power instruction.

More specifically, the objectives of the study were:

1. To determine the number of people in Utah industries which are directly involved with fluid power.

2. To determine the job opportunities in Utah industries for personnel trained in fluid power.

3. To determine the kinds and levels of skills required in fluid power of employees in Utah industries.

4. To determine if educational programs should be established to train personnel in fluid power.

5. To examine existing Fluid Power Society education program course outlines to see if they meet the recommendations made for fluid power education in Utah.

6. To make recommendations regarding fluid power instruction.

A comprehensive review of current literature relating to fluid power education was conducted. This review provided data and criteria which were use to satisfy particular objectives and as a partial basis for recommendations made.

Historically, man has used fluid power as a tool from the beginning of civilization to the present time. Through the years, the applications of fluid power have become virtually limitless, and include systems on machine tools, all types of mobile equipment, production machines, and even in-space vehicles, just to name a few.

Fluidics, a new branch of fluid power, has emerged within the last decade. Fluidics is a part of fluid power technology primarily concerned with the control function for a fluid power system. It is estimated that the yearly sales potential of fluidics will be from one-half to one billion dollars by 1975 and increase to an annual sales volume of two to two and one-half billion dollars by 1981.

The growth potential and size of the fluid power industry can be illustrated by contrasting its size in 1945 with 1970. In 1945, the fluid power industry produced about one-third of a billion dollars worth of equipment, and it is projected that in 1970 the volume will be two billion dollars or more. This increase represents a 600 percent projected growth in a period of 25 years. The actual growth and the growth potential of the fluid power industry is accompanied by an increase in the shortage of trained personnel to work with fluid power components.

The urgency for industrial education to become involved in fluid power education is becoming more critical with the expanding production and use of fluid power systems.

A population of industries directly involved in fluid power was identified so a sample could be taken. The population was composed of 99 industries in the northern one-half of Utah. An introductory letter and a returnable postcard were sent to the industries. The postcard was designed to provide data such that a random stratified sample could be taken of the population.

The total usable returns numbered 20; therefore, a random stratified sample was not needed due to the small number of returns. Because the postcard was a means of identifying a population rather than collecting data; and because that data were to be gathered by interview, no follow-up mailing was made.

From the identification of a population of industries in fluid power, a sample size of 20 was to be interviewed. The interviews were conducted, but only 15 of the 20 industries selected were contacted for interviews.

An instrument was designed to provide additional data for satisfying the objectives. The data were gathered and recommendations and conclusions were made from the following procedure.

The approximate number of people in Utah employed in manufacturing was determined from the 1969-1970 Directory of Utah Manufacturers. Since the directory listed only a size range for each firm, an average of each range was taken to obtain a total of 65,787 workers involved in manufacturing with

1,246 firms. Using the previous totals and national averages of fluid power involvement in manufacturing (60% of all manufacturers utilize fluid power systems in manufacturing their products and 53% of all industrial products have a fluid power system or component built into them) the findings were projected to the entire state.

The following findings were compiled based on the foregoing procedures. Sixty percent of 65,787, or 39,469 workers, were involved in fluid power through its use in manufacturing. Fifty-three percent of 65,787, or 34,867 workers, were involved in fluid power through its use in industrial products. Sixty percent of 1,246, or 747 firms in Utah, use fluid power in manufacturing. Fifty-three percent of 1,246, or 660 firms in Utah, manufacture products with fluid power systems or components built into them. It must be noted that many workers and firms were involved in fluid power both through manufacturing and a manufactured product so the totals cannot be categorized separately.

Only seven of the interviewees were able to project their future needs for trained personnel in actual numbers, but others did indicate a need for trained workers. The personnel needed by interviewees totaled 29 persons, or an average of 1.9 persons per firm contacted. To project the need to Utah industries involved in fluid power through its use in manufacturing, 747 firms need or will need 1,419 workers within the next five years. The 660 firms involved in fluid power through manufactured products with fluid power systems or components need or will need 1,254 trained persons. It must be noted that many workers and firms were involved in fluid power both through manufacturing and a manufactured product so the totals could not be categorized separately.

The two skill levels most frequently required of trained personnel were skilled and two-year technicians. Interviewees indicated that training for the skilled level could be provided by on-the-job training, inplant schools, special schools, adult education programs, vocational high school programs, two-year vocational school programs, and technical institutes. The training for the two-year technician level could be provided by two-year vocational school programs, two-year university programs, and technical institutes.

The Fluid Power Society hydraulic and pneumatic course contains all but four of the required instructional units (gages, fluidic devices, symbols of fluidic devices, and hydrostatic transmissions) that were indicated as being necessary by interviewees. Using the Fluid Power Society's educational program as the substructure, recommendations were made regarding fluid power instruction in Utah.

Conclusions

1. Inasmuch as training programs are needed to train workers, more research is needed to determine the availability of trained teachers to staff these programs.

2. Inasmuch as employment at the skilled level and two-year technician level is found in greatest numbers, it is concluded that programs established

under formal education for training workers to these levels would benefit Utah industries.

3. On the basis of the comments of interviewees, the trends indicated by national leaders, and the extensive use of fluid power equipment used in manufacturing in Utah, it is concluded that the demand for skilled workers exists now and will far exceed the supply in the future.

4. Inasmuch as a cross-section of industry indicated about one-half of the instructional units included in the Fluid Power Society's basic hydraulics and pneumatics program, it is concluded that the Fluid Power Society's program could be used as a basis for fluid power education in Utah.

5. Inasmuch as fluid power training programs are lacking, manufacturers are relying on inplant training programs to train workers; therefore, this trend indicates the need for emphasis in educational programs to train workers in fluid power.

6. Inasmuch as interviewees indicated that training could take place in adult education programs, vocational high school programs, two-year vocational school programs, two-year technical school programs, two-year university programs, and technical institute programs, it appears that interviewees feel a need for educational programs to train workers to entry-level skills and to supplement inplant training.

Recommendations

The following recommendations are made on the basis of this study:

1. That one of the industrial teacher education institutions in the state of Utah set up a program to train teachers in fluid power.

2. That training programs be established at appropriate institutions for training workers to the skilled level and the two-year technician level in fluid power.

3. That training programs be established to update and retrain workers now on the job and those workers unemployed or underemployed to help meet the existing and future demands for trained workers in fluid power.

4. That the Fluid Power Society's basic hydraulics and pneumatics program, with the addition of hydrostatic transmissions, fluidics, and symbols for fluidic devices be adopted as the substructure for fluid power education in Utah.

5. That the Utah State Board of Education prepare a state guide for fluid power instruction.

6. That research be done to determine the availability of trained teachers to conduct programs in fluid power.

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APPENDIX

UTAH STATE UNIVERSITY · LOGAN, UTAH 84321

COLLEGE OF ENGINEERING

DEPARTMENT OF
INDUSTRIAL AND
CHNICAL EDUCATION

A national survey on manpower needs in fluid power reported a serious shortage of skilled technicians as well as a lack of educational programs and teachers trained to oversee such programs.

We, at Utah State University, are conducting a study to determine the needs of Utah industries for workers trained in fluid power. This study will be used as a basis for making decisions which relate to our fluid power course offerings and it will also be available to other institutions in the state who have need of it.

For our study to have a real impact on fluid power education, your help is needed. We ask your assistance in providing us with information concerning your needs for workers trained in fluid power. This would involve about one half hour of your time for an interview. Arrangements will be made with you as to the most convenient time and date to schedule an interview.

Through this study we hope we can better meet your needs for trained workers through education.

Please fill out the enclosed postcard and return it to Utah State University.

Your efforts are greatly appreciated.

Sincerely,

Austin G. Loveless, Professor
Industrial and Technical
Education Department
Utah State University

Ronald C. Baker
Graduate Research Assistant
Industrial and Technical
Education Department
Utah State University

Enc.

Are you directly involved in fluid power? ☐ Yes ☐ No

If so, in what area? (Please mark at least one in each column)

☐ Hydraulics	☐ Sales
☐ Pneumatics	☐ Service
☐ Fluidics	☐ Component Assembly
☐ Other ________ (specify)	☐ Inplant Use or Mobile Use
	☐ Manufacturing
	☐ Other ________ (specify)

Would your company benefit from fluid power education? ☐ Yes ☐ No

Name and address of person to be contacted for interview should your company want to participate:

____

____
(Please Print)

INTERVIEW SHEET

FIRM ______________________________ DATE ____________________

ADDRESS ____________________________

____

1. Name of person interviewed ____

2. Position of person interviewed:

_____ Owner	_____ Plant Superintendent
_____ Owner-Manager	_____ Service Manager
_____ Hired Manager	_____ Plant Foreman
_____ Personnel Director	_____ Production Foreman
_____ Sales Manager	_____ Crew Chief
_____ Engineer	_____ Other ______________________

3. Basic type of firm:

_____ Job Shop	_____ Processing
_____ Mass Production	_____ Retailing
_____ Assembly	_____ Wholesaling
_____ Service	_____ Research
_____ Installation	_____ Construction
_____ Contracting	_____ Other ______________________

4. Areas of fluid power in which firm is involved:

   _____ Hydraulics
   _____ Pneumatics
   _____ Fluidics
   _____ Other ____________________

5. Number of employees involved in fluid power through:

_____ Sales	_____ Mobile Use
_____ Service	_____ Component Manufacturing
_____ Component Assembly	_____ Inplant Use
_____ Research	_____ Other ______________________

6. The employment opportunities for trained personnel in fluid power with your firm:

   Current: ____

   Projected: ____

7. Skill level of trained personnel in fluid power needed by your firm:

_____ Unskilled	_____ Four-Year Technologist
_____ Semi-skilled	_____ Engineer
_____ Skilled	_____ Graduate Engineer
_____ Two-Year Technician	_____ Other ______________________

8. How should the training for personnel in fluid power be conducted?

Unskilled Starting pay which you feel appripriate __________
_____ Limited Training
_____ No training needed
_____ Other ____________________

Semi-Skilled Starting pay which you feel appropriate __________
_____ General high school course
_____ On-the-job training
_____ Inplant schools
_____ Special schools
_____ Adult education programs
_____ Vocational high school course
_____ Other ____________________

Skilled Starting pay which you feel appropriate __________
_____ On-the-job training
_____ Vocational high school program
_____ Two-year vocational school program
_____ Technical institute
_____ Inplant schools
_____ Special schools
_____ Adult education programs
_____ Other ____________________

Two-year Technician Starting pay which you feel appropriate __________
_____ Two-year technical school program
_____ Two-year university school program
_____ Technical institute
_____ Other ____________________

Four-year Technologist Starting pay which you feel appripriate ________
_____ Four-year university program
_____ Technical institute
_____ Other ____________________

Engineer Starting pay which you feel appropriate ________

_____ Four-year university program
_____ Technical institute
_____ Other ________________

Graduate Engineer Starting pay which you feel appropriate ________

_____ University post graduate program
_____ Other ________________

Other Trained Persons Starting pay which you feel appropriate ________

_____ Other ________________

9. The areas which should be included in a fluid power program for training personnel to job entry skill levels are:

_____ Fluid power standards
_____ Fluid standards
_____ Symbols for fluid power circuits
_____ Directional control valves
_____ Flow control valves
_____ Compressors
_____ Accumulators
_____ Fluid conditioners
_____ Gages
_____ Drafting standards for fluid power diagrams
_____ Electricals
_____ Fluid devices
_____ Pressure control valves
_____ Linear actuators
_____ Pumps
_____ Motors
_____ Basic principles of fluids
_____ Symbols of fluid devices
_____ Hydraulic filters
_____ Hydrostatic transmissions
_____ Tubing and piping
_____ Cylinder sealing
_____ Various circuit types
_____ Other ________________

10. How are you presently getting your personnel trained in fluid power?

_____ On-the-job training
_____ Inplant schools
_____ Vocational schools
_____ High schools
_____ Universities
_____ Adult education programs
_____ Technical institutes
_____ Other ________________

11. Do you plan to conduct any inplant fluid power training programs?

_____ Yes
_____ No
_____ Undecided

12. Additional comments:

Table 17. Positions of persons interviewed

Position	Number	Percent
Production foreman	1	7
Engineer	3	20
Advanced systems manager	1	7
Service manager	2	13
Sales Manager	2	13
Project supervisor	1	7
General manager	1	7
Vice president	1	7
Shop instructor	1	7
Owner-manager	1	7
Secretary-treasurer	1	7

Table 18. Average starting salary for trained personnel in fluid power

Level	Average Salary
Semi-skilled	$5,185
Skilled	$6,278
Two-year technician	$6,696
Four-year technologist	$8,333
Engineer	$8,000
Graduate engineer	$8,500

HYDRAULIC AND PNEUMATIC POWER TRANSMISSION
(5 Instruction Units)

Unit 1: Introduction to Fluid Power; Basic Elements of Hydraulic Power Transmission Systems, Pressurization, Controls and Functions, Application of Pressurized Liquid, Gas or Air; Symbols and Drafting Practices, ASA-Y32.10 Fluid Power Symbols--Symbol Rules--Building Circuits with Symbols; Hydraulic Fluids, Fluid Characteristics, Choice of Fluid for Specific Applications; Glossary of Hydraulic and Pneumatic Terms.

Unit 2: Hydraulic Pumps and Motors, Purposes and Types of Motors and Pumps, Maintenance and Installation Practices for Pumps and Motors, Head and Energy in Pump Systems, Pump Characteristics; Fluid Power Cylinders and Rams.

Unit 3: Fluid Power, Types of Reservoirs, Scavenger Tanks --Settling Tanks, Overhead Reservoirs--Baffling of Flow, Sizing of Reservoirs; Fluid Power Plumbing, Purpose of Fluid Power Plumbing, Suppression of Shock Waves, Maintenance Requirements; Types of Conductors and Connectors; Filtration of Hydraulic Fluids; Fluid Temperature Control, Types of Heat Exchangers, Automatic Control of Fluid Temperature.

Unit 4: Pressure Control Valves, Purpose, Types of Pressure Control Valves, Methods of Actuation; Flow Control Valves, Purpose, Types of Flow Control Valves, Combination Functions Flow Control Valve Circuits, Priority Circuits; Directional Control Valves, Types of Directional Control Valves, Construction, Methods of Actuation, Pressure Drop--Clearance Flows--Drain Provisions, Pressure Accumulators, Purpose Types of Accumulators, Accumulator Circuits, Shock-Wave Absorption, Fluid Storage Accumulator, Safety Considerations.

Unit 5: Servo Systems, Mechanical Linkage Systems, Component Relief Valve Function, Typical Circuits; Circuit Design--New Installations, Introduction of Shock Suppression Devices, Adding Heat (Temperature Control) Transfer Equipment, Modifications for Easier Maintenance, Adding Capacity to existing Systems, Maintenance of Fluid Power Systems, Preventive Maintenance, Machine Repair, Fluid Problems, Marginal Operation, Electrical Failures, Care of Systems Using Fire Resistant Fluids.

VITA

Ronald Chester Baker

Candidate for the Degree of

Master of Science

Thesis: Recommendations Regarding the Instruction of Fluid Power in Utah

Major Field: Industrial Education

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Education: Attended elementary school in Fillmore, Utah; graduated from Millard High School in 1961; received the Bachelor of Science degree from Utah State University, with a major in Industrial Arts Education, in 1969; completed requirements for the Master of Science degree, specializing in industrial education and manufacturing engineering, at Utah State University in 1971.

Professional Experience: September, 1970 to present, instructor in industrial education, Northern Arizona University, Flagstaff, Arizona; vocational auto-mechanics instructor in Logan City School District, Logan, Utah, 1968-69; machinist and quality control inspector, Hesston Corporation of Utah, Logan, Utah, 1969-70; general auto-mechanic, Fillmore, Utah, 1962-65.