CAD/CAM - A CHALLENGE AND OPPORTUNITY FOR CANADIAN INDUSTRY

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Abstract

As a result of advances in computer technology, the cost of computation is decreasing approximately ten-fold per decade. In the manufacturing industries, this is fostering the development of widespread changes in design and manufacturing techniques, referred to as Computer Aided Design and Computer Aided Manufacturing, or CAD/CAM, at an unprecedented rate. This presents both a challenge and an opportunity for manufacturing companies and industrialized countries who wish to maintain or advance their relative positions as suppliers of manufactured goods of virtually all kinds.

CAD/CAM is defined as embracing the use of computers in the full sequence of manufacturing tasks, starting with the customer's order and proceeding to product design, manufacturing process planning, manufacturing, quality assurance, inventory, shipment and final delivery. A brief review of CAD/CAM development, emphasizing the role of governments, is given for Germany, Japan, U.S.A., United Kingdom, France and Italy.

A world view of CAD/CAM in the 1979-1980 time frame is given by means of an extensive list of selected literature references covering computer and graphics equipment; CAD analytical techniques; production, material and inventory control; data base design; numerical control; automated testing; industrial robots; computer languages; system design; project management and social implications plus applications in automotive, machinery, electronics, chemical and plastics, architecture, building design, automated warehousing and others. (381 references).

Introduction

Without making any attempt to be melodramatic it would appear that developments in computer aided design and computer aided manufacturing are taking place at a rate around the world that will strain the ability of companies and nations to maintain their positions in the world economy. This is both a challenge and an opportunity.

It is appropriate therefore in this light to examine some trends in Canada's performance in manufacturing industry productivity and some trends in world trade participation. It is appropriate also to examine some previous changes in technology and productivity, for example in agriculture and process computer control, and to see what effects or parallels, observable in those instances, may apply or provide guidance to what is happening today through the use of computers in design and manufacturing -- which some would describe as the CAD/CAM revolution. It is appropriate that we should have some definition, or at least an envelope of concepts, of what is meant by the term CAD/CAM. Last but not least it is useful to identify some of the issues involved, and responses that will be required, of Canadian industry, educational institutions and government in adapting to this new technological environment.

There is no doubt that CAD/CAM represents both a threat and a challenge to industry. It the nature of the response to this challenge that will determine whether it represents an opportunity which will be used widely and to best advantage.

A View of Canada's Present Position

In terms of long term growth and job creation, the manufacturing industries are one of the most important sectors of the total Canadian economy, yet manufacturing industry employment, as a percentage of the total labour force has been on a declining trend. Productivity will be especially important to the Canadian manufacturing industries in the 1980's if traditional markets are to be retained and new ones gained in the face of lowered tariff protection and increasing external competition.

In this context, the rapidly emerging use of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) technology is of special importance.

With the advent of CAD/CAM, it will become increasingly evident in the 1980's that the design of the factory is just as important as the design of the product. Developments will lead increasingly to the marriage of both Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) into highly integrated design and production systems.

Productivity will be especially important to Canadian manufacturers in the 1980's. During this decade, tariff protection will be lowered, competition from external sources will undoubtedly increase, and inflation will continue at a strong pace. At the same time a new world wide wave of industrial automation, based on a rapidly increasing use of computers in design and manufacturing, is occuring.

As a result of the latest round of trade negotiations, Canadian industry will face increasing competition from imported products. At the same time, however, our industry will have better access to foreign markets. However, to compete successfully in this new trading environment, Canadian industry will have to achieve levels of performance, in terms of productivity and technical excellence, equivalent or superior to industry in other countries, whereas Figures 1, 2 and 3 indicate Canada's current declining trend in export performance, manufacturing industry employment and productivity improvement in manufacturing relative to other nations.(1)

Previous Examples of Technological Change: Automation in Agriculture and the Process Industries

It is useful to remind ourselves that change is always with us, and that some very major adaptions have been made successfully, but not without effort, in the past.

One of the largest changes, which Canadians have responded to in the past 50 years, has been the change in farm labour and population as a percentage of total population. This has happened largely due to technology and the use of machinery. At one time nearly 100% of the population was directly involved in agriculture and food production. In 1941 it was over 30%. Today it is less than 5%. However we don't have 95% unemployment, because people now do other things, -- and most prefer it that way. In a mere 40 years this has produced a huge social and demographic change from a rural to an urban population society; from an agricultural to a non-agricultural economy.

A more recent example of technological change, bearing a closer relationship to computer technology, is available; namely the application of computers in control systems, which began about 1960, and which has since become widespread in the process industries such as pulp and paper, mineral production and petroleum refining.

This is a particularly useful example, because it bears many technical similarities to the current emerging use of computers in the discrete parts manufacturing industries which is generally referred to as CAD/CAM. Both the similarities and some differences are shown in tabular form in Fig. 4.(2) It will be to the advantage of many Canadian companies undertaking CAD/CAM developments and applications that much pioneering work has already been done, at considerable time and expense, in the process industry and capital intensive industry applications where it could be first afforded. Executive operating systems for handling real time, sensor based data, interrupts and distributed computing are a by-product or legacy that is available today from this earlier work, along with some of the lessons learned regarding system and project organization. Hopefully they will not be ignored or forgotten in too many instances.

Microelectronics and Economic Justification

It is useful to consider why this change in design and production technology is happening. As one might expect, there are a number of factors. Basically it is because it is economically justifiable, and technically possible. Without going into detail, a vast number of developments in microelectronics and computer technology have reduced the size of computers, increased their reliability, and above all reduced their cost to the point where a myriad of new applications are possible -- provided that one has the applications knowledge in hand to do it. A calculation costing $1,000 to perform in 1952 cost $10 in 1972 and will cost 10 cents in 1992.

While microelectronics and computer industry developments make the computation part of CAD/CAM systems possible, it is the applications knowledge, people, economic justification and availability of funds for development and investment that will determine the diffusion rate for adoption of this technology. Technological change does not take place overnight. While the concept of an invention may take place in an instant, the adoption of a new technology on a wide spread basis is a diffusion process that takes time -- time largely determined by the magnitude of the economic justification. The economic justification and know-how for CAD/CAM does not come as a packaged product from the microelectronics or computer industry. It resides in the manufacturing industries who are not only the users, but also the application developers. The mechanical engineering community has a large role to play in this. Reports from Germany, for example, indicate that CAD/CAM projects are organized with the mechanical engineering or manufacturing engineering personnel as leaders, and the electronics or computer oriented personnel in a secondary role.[3, 4] That could be a good formula for success, assuming that the mechanical or manufacturing engineering personnel are equal to the task, and particularly that they have the necessary orientation to think in terms of systems development. Trained or experienced personnel are already in short supply. There is a need for education and training in computer programming and applications analysis in virtually all industry sectors and disciplines. The situation today has been described succinctly with the remark "People who know how to program, don't know how to solve problems. People who know how to solve problems, don't know how to program".

What is CAD/CAM?

Besides being a useful abbreviation, it is useful as stated in the introduction, to have some sort of definition, or envelope of concepts, for what is meant by the term CAD/CAM. The term, with some slight variations, has come to very widely used in the past five or six years.

One may examine first the sequence of manufacturing industry tasks as shown in Fig. 5, starting with the customer and proceeding to product design, manufacturing process planning, manufacturing, quality assurance, inventory, shipment and final delivery. If one then identifies the ways in which computer systems are being used to assist in each of these design and manufacturing tasks, a series of application areas results, as shown in Table I, which can be regarded as a composite definition for the term "CAD/CAM". As indicated in Table I, the systems integration concept is important. There is a strong drive in this direction, particularly by larger companies who are the leaders in developing and applying the technology.

Another approach which can be useful, is to identify some of the technologies which are involved as elements in CAD/CAM, as shown in Table II. Education, understanding and development in these technologies, as applied to design and manufacturing, will determine the growth rate for CAD/CAM systems in numbers and in their technical capability.

Education and training is therefore of paramount importance. There are many facets to this. One point to be recognized is that if CAD/CAM was being developed and applied slowly on a world wide basis over a period of 30 to 40 years or more before use became prevalent, then it would be sufficient to focus the educational needs on the schools, colleges and universities who will train and educate the next generation of Canadians for their working life span. The role of these conventional education channels is important, but not sufficient under the circumstances. If the change to the widespread use of computer aided design and computer aided manufacturing takes place as quickly as would appear likely, then education and training of the existing work force is of equal or even greater importance. The mechanism preferred by industry for this is by means of in-plant training courses. The first requirement in this process, to multiply and fan-out capability, will be to assemble the best available source material and train the instructors who will then train their co-workers.

It may be important, especially in the long run, not to take too narrow a view of the training and education requirements related to CAD/CAM, especially if the secondary effects of its adoption are to be as broadly beneficial as possible. Education in the arts and cultural pursuits, in addition to education in technology, may become increasingly important if increased leisure is to be enjoyed, and as an alternative to the work ethic.

CAD/CAM Developments in Other Countries

A brief overview of CAD/CAM development in other countries, and the degree of involvement by governments, may provide a useful perspective.

Germany:

Government funding of approximately $179 million was provided for CAD, CAM and automatic process control from 1971-1979 as part of the $1,366 million Second and Third Data Processing Plans.(3)

CAD/CAM development is conducted through an extensive system of centres and institutes employing thousands of scientists and engineers with strong emphasis on the mechanical engineering aspects.

Japan:

CAD/CAM and robotics have high priority. Individual companies such as Mitsubishi and the automotive industry manufacturers have extensive working systems. The Methodology for Unmanned Manufacture (MUM) project, with $ 100 million government funding to develop an un-manned factory, has been modified to develop a Flexible Manufacturing System (FMS) as an intermediate step, incorporating machine tools and industrial robots.(5) Funding now reported is $60 million over 7 years.(6)

United States:

CAD/CAM activity is increasing rapidly as companies strive to meet the productivity challenge of Germany and Japan. The Society of Manufacturing Engineers is one organization playing a leading role, for example through their Autofact conferences and special interest groups.

Government projects, largely contracted out, include the $100 million United States Air Force, Integrated Computer Aided Manufacturing (ICAM) project for aerospace companies; the National Aeronautics and Space Administration CAD oriented Integrated Planning for Aerospace Design (IPAD) program; the United States Navy Computer Aided

Shipbuilding Design and Construction (CASDAC) program and others.(7, 8)

Following a bill enacted by Congress in October 1980, the Detroit Cooperative Generic Technology Center Inc. has been selected by the U.S. Department of Commerce to create and operate a research facility in the area of computer integrated manufacturing, supported by a grant of $1 million plus a $5 million grant for facilities and equipment.

United Kingdom:

Funding for CAD/CAM comes from three principal sources, the Science Research Council, Department of Education and Science and the Department of Industry. The National Engineering Laboratory near Glasgow undertakes development and provides advice in NC machine tool technology and tape preparation.

The Computer Aided Design Centre, a Department of Industry Research Establishment in Cambridge, as of 1980 has reached a staff of 150 and annual expenditure of $5 million.

A January 1980 report by a Cabinet Office Advisory Council for Computer Aided Design and

- Greater coordination and focus for CAD/CAM research and development.

- An expenditure of £1.5 - 2.0 million over the next three years in measures to increase awareness and disseminate CAD/CAM information, (in addition to the Microelectronics Awareness Program - MAP).

- A merger of the NEL at East Kilbride and the Computer Aided Design Centre (CADC) at Cambridge into a single institute, and a physical move to "one or more sites nearer the main manufacturing centres of the United Kingdom" in order to facilitate access by industrial companies.

France:

The French government are making a major effort under the Ministry of Industry to create awareness in general in industry of computer systems and to encourage small and medium sized firms to use CAD. A recent bulletin of the Institut National de Recherche en Informatique et en Automatique contains an extensive paper on CAD/CAM and reports on the CAM research and development activities of 19 other laboratories and institutes in France.(9)

Italy:

As of 1974, Italy ranked fourth in the world in production of numerically controlled machines (behind Japan, USA and West Germany), and second in NC machine tool installations (second and almost equal to West Germany). Italy does not appear to be a leader in CAD/CAM developments but the number of industrial robot installations reported is considerable.

The following figures for industrial robot installations (1979 estimates) may serve as a useful overall indicator of CAD/CAM technology diffusion and application.(10)

Japan	10,000
USA	3,000
West Germany	850
Sweden	600
Italy	500
Poland	360
France	200
Norway	200
Britain	185
Finland	130
USSR	25

The Canadian figure is estimated to be in the order of 100.

Another useful indicator of CAD/CAM activity may be provided by a count of the technical papers published on the technology. Of those selected in 1979-80 from the internationally recognized "Computer and Control Abstracts" for inclusion in the monthly newsletter, "CAD/CAM and Canada" the publications by country of origin are:

	%
USA	40
UK	23
Germany	14
Japan	6
France	3
Canada	3
USSR	2
Switzerland	1
Other	8
	100

In using these data, it should be recognized that some preference is exercised in the selection process to papers of most likely value or interest to Canadian readers.

It is clearly evident that development of CAD/CAM systems and equipment is widespread throughout all industrial sectors, and increasing rapidly. This is especially evident in the case of industrial robots, because they are relatively new, they are readily identifiable, and because they can be readily programmed to perform repetitive manipulation tasks previously difficult, prohibitively expensive or even impossible to perform in the practical sense, with any form of previously available mechanical apparatus.

As indicated above, the number of robots installed or produced by an industrial country is regarded by some as an indicator of the state of the art in manufacturing technology. It should be stressed that at best this is only an indicator. It could be as useful, as another indicator, to count CAD application programs, lines of code, or data bases; except that these are harder to define, identify and quantize. Another indicator is to count computers. During the early introduction of computers it was a common practice to maintain and publish survey data on numbers of computer installations of all types and sizes. For medium to large systems this census data is still partly maintained. For small computers it is becoming impossible. Such statistics can be useful, particularly when a new technology is at the frontier and the use of industrial robots is in this position today.

To maintain perspective, however, we may remind ourselves that printing presses when first introduced probably raised fears similar to some concerns regarding robots today. The number of printing presses installed in the year 1500 was 73 in Italy, 51 in Germany, 39 in France, 24 in Spain, 15 in the Low Countries and 8 in Switzerland. Although the number in use today is vastly greater, the associated fears have long since disappeared. The situation for typewriters is somewhat similar.

Major suppliers of industrial robots and their customers have now achieved hundreds of highly productive, relatively trouble free industrial robot installations. Many applications now considered straight forward such as:

Spot welding of automobile bodies
Die casting
Investment Casting
Machine tool loading and unloading
Injection moulding of plastic parts
Forging
Spray painting

Provided that the application engineering is done carefully, the increased production, more consistent operation, improved operator safety, reduced scrap and savings in labour, will frequently pay for a $30 - 80,000 robot in 1 - 3 years, depending on the application.

It is important to give neither too much nor too little attention to the industrial robot "revolution" and its impact. Most robots today perform only a routine sequence of mechanical motions, often characterized by the "pick-and-place" nature of the function performed. Lacking any form of sensor input, if something goes wrong they will continue to perform dumbly until shut-off. This will change as sensor inputs are added, most notably force feed back signals from the hand or gripper, and vision capability using TV cameras and pattern recognition techniques. Market forecasts for numbers of robots to be produced and installed are highly dependent on the assumption of these developments, which will not necessarily take place without effort. Difficulties in achieving successful pattern recognition and other forms of robot "intelligence" may be greater than realized by some forecasts or popular reviews. Nevertheless we are in a world wide race for improvement of industrial productivity. Japan in particular, which already has 10,000 robot installations, has established a robot leasing program through the Japan Industrial Robot Association (JIRA), Ministry of International Trade and Industry (MITI) and 10 insurance companies.

A World View of CAD/CAM Technology

The abstracts on CAD/CAM technology selected from the world literature and reproduced monthly in the newsletter of the CAD/CAM Technology Advancement Council provide a vantage point from which it is possible to view the fundamental technology change which is taking place on a world scale, which is revolutionizing design engineering and manufacturing and which will penetrate every industrial sector.

The twenty abstracts reproduced by permission each month from the INSPEC publication "Computer and Control Abstracts" provide a good representation of the world literature. The following review and accompanying bibliography represent those selected in the June 1979 - December 1980 time frame, and have been organized in a subject sequence which could be used to prepare a reference text or series of chapter monographs for education and training on CAD/CAM systems and technology.

Introductory and review references[11-31] include two collected sets of reprints[11-12] available from the Department of Industry, Trade and Commerce, Ottawa. Published information on the economic justification of CAD/CAM is not widespread[32-34], partly due to the difficulty of documentation and commercial secrecy in detail but is known to exist elsewhere, for example in the papers of the SME Autofact conferences, Numerical Control Society and CAM-I.

Computer graphics, along with the use of industrial robots represents one of the fastest growing segments of CAD/CAM in commercial terms and capability, along with the use of microprocessors in terminals and production equipment[35-59]. Two rapidly emerging CAD analytical techniques are the use of geometric modeling for the generation of NC machine tool cutter paths[60], and finite element analysis[61-64], for stress, vibration and heat transfer analysis. Pattern router algorithms[65] may represent another useful CAD analytical technique with particular application to printed circuit board connection layout.

Production material and inventory control[67-74] has been a common manufacturing industry computer application for the past twenty years, but which may be considerably extended due to the information demands of integrated CAD/CAM systems, and the greater availability of shop floor and feedback data[75]. Similarly data base systems have received a long history of development, but are likely to receive new impetus due to their key and central nature in integrated CAD/CAM systems.[76-86]

Metal cutting machine tools, including direct numerical control (DNC) and computer numerical control (CNC), are the most widely used form of numerically controlled production equipment[87-108]. This is being extended however into many other forms of production equipment including arc welding, spot welding, resistance welding, sheet metal punching and shearing, grinding, polishing, injection moulding and packaging[109-129].

Automated testing and inspection for improved production and quality control form an important part of CAD/CAM systems if maximum benefits are to be obtained. Applications include mask testing for integrated circuits, line width testing on printed circuit boards, weld quality inspection, checking of dimensions, surface roughness, weighing and the on-line monitoring of other production equipment[130-147].

Industrial robots[148-177] along with turnkey CAD graphic systems represent one of the two most rapidly emerging CAD/CAM technologies. Their widespread use for parts handling, machine tool loading, spot welding, arc welding, die and investment casting, spray painting and even sheep sheering, as an experimental application, will change the nature of many factory and production systems.

The integrated CAD/CAM factory of the future must necessarily be designed as a distributed or hierarchical system. Hence developments in message handling, bus and data highway design, distributed and hierarchical systems[178-205] are an important yet complex aspect of system planning.

Computer programming languages are also an important consideration[206-209] and some special languages have emerged or are under development such as Grapple for CAD, ADA for real-time embedded systems, VAL for industrial robots in addition to the many languages for NC machine tool programming such as APT and ATLAS for automatic testing.

Project management[210-222] and systems design[223-252] bear special consideration. Education, training, the location and most efficient use of scarce people will be important to project managers. Proper design of flexible manufacturing systems will be important to the profitability of the firm, where used. The social implications of CAD/CAM are being recognized and discussed[253-262] as part of the adaptation process to this new technology.

Application papers are becoming more and more prevalent as the technology advances from concept to installation in a wide variety of industries including automotive[263-272], machinery and equipment manufacturing[273-284], the aerospace industry[7, 8, 14, 30, 285, 286].

The electrical and electronics industry is noted for many applications[287-310], because its personnel tend to be close to and familiar with CAD/CAM systems potential at an early date, and also because some industry products, such as the LSI chip in particular, would be impossible to design by any other method. Conversely food and beverage industry applications are not widespread as yet, although examples do exist[311]. Chemical and plastics industry applications are more widespread[312-318], particularly for injection moulding and the production of plastics parts.

CAD/CAM in the architecture, building and construction industry tends to focus on the CAD or design end[319-330]. Conversely as one would expect, automated warehousing and distribution systems[331-346] deal primarily with mechanical movement. It should be noted that automated warehousing techniques are being applied in integrated CAD/CAM systems to the movement of parts and work in progress between work stations, and not just to the storage and handling of finished goods. Reductions in work in progress inventory, interest carrying charges and shorter delivery time to the customer being the objective and economic justification. Miscellaneous applications[347-363] as in the textile, printing, glass and shipbuilding industries give evidence that every type of industrial activity is a potential user of the technology.

Major national programs and studies exist, such as those in Germany[3, 4, 364, 365], Japan[7, 8, 366-368], the USA[7, 8, 369-371], the United Kingdom [6, 372-376] and elsewhere[377-381].

Conclusion

- Productivity will be especially important to Canadian manufacturers in the 1980's. During this decade, tariff protection will be lowered, access to foreign markets will increase, but competition will also increase for both domestic and foreign markets.

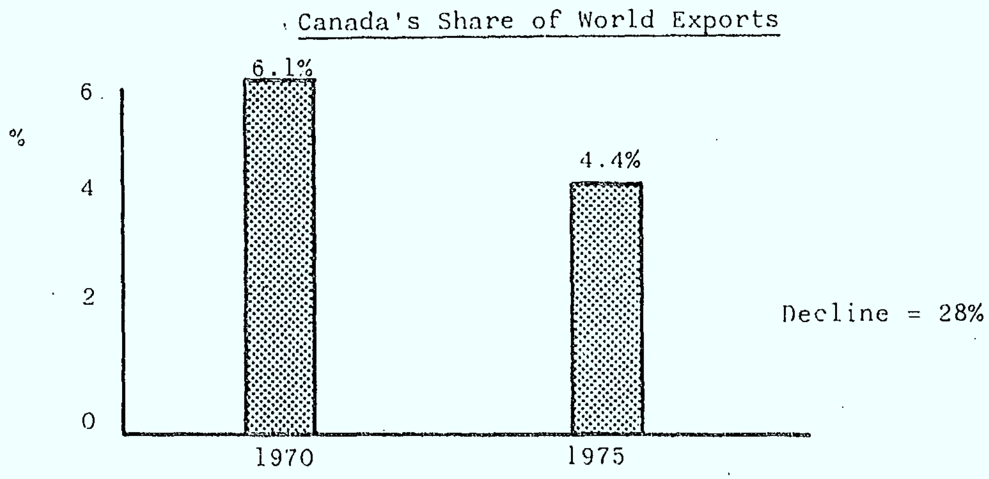
- At the same time, a new world wide wave of industrial automation is occuring in manufacturing, based on a rapidly increasing use of computers and industrial robots.

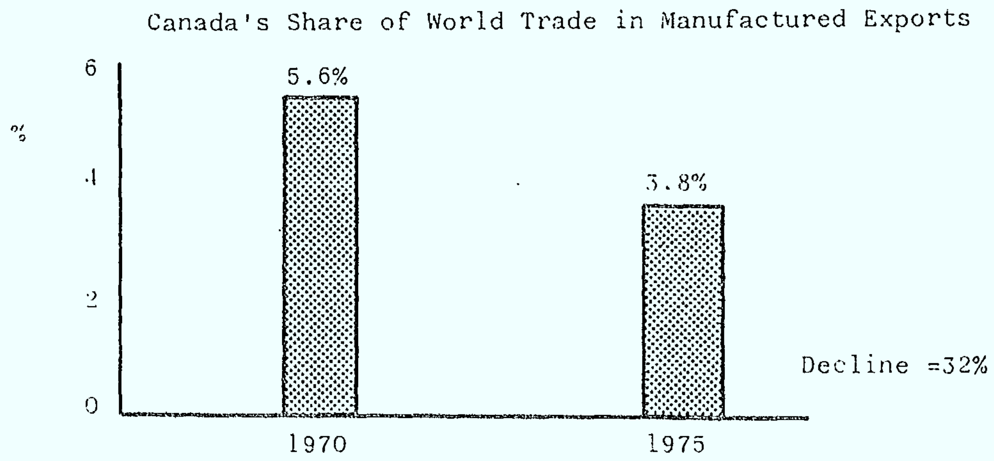
- As an indication of the rate and breadth of this technological change, approximately one thousand published articles on CAD/CAM are now appearing each year in the open literature.

- Within this wave of change, two of the most rapidly advancing fronts are the use of graphic systems for computer aided design and industrial robots for parts and tool handling, in addition to the more established use of numerically controlled machine tools and production machinery.

- It is the response to CAD/CAM, and not CAD/CAM itself, which will determine for companies and countries whether CAD/CAM represents a net challenge or opportunity to them.

FIG. 1 - TRENDS IN EXPORT PERFORMANCE

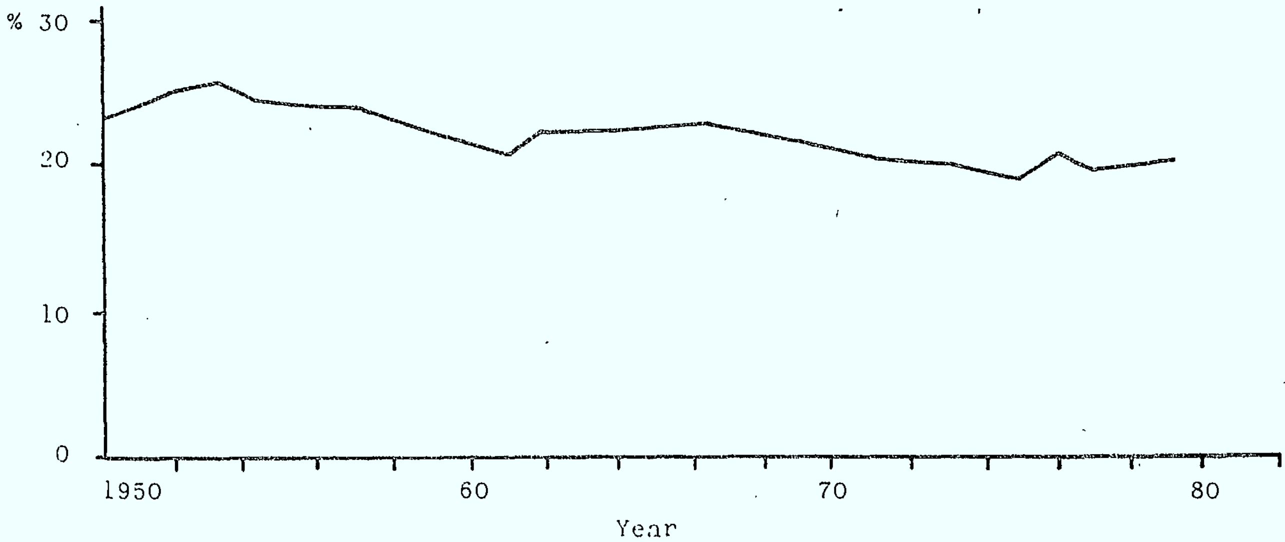




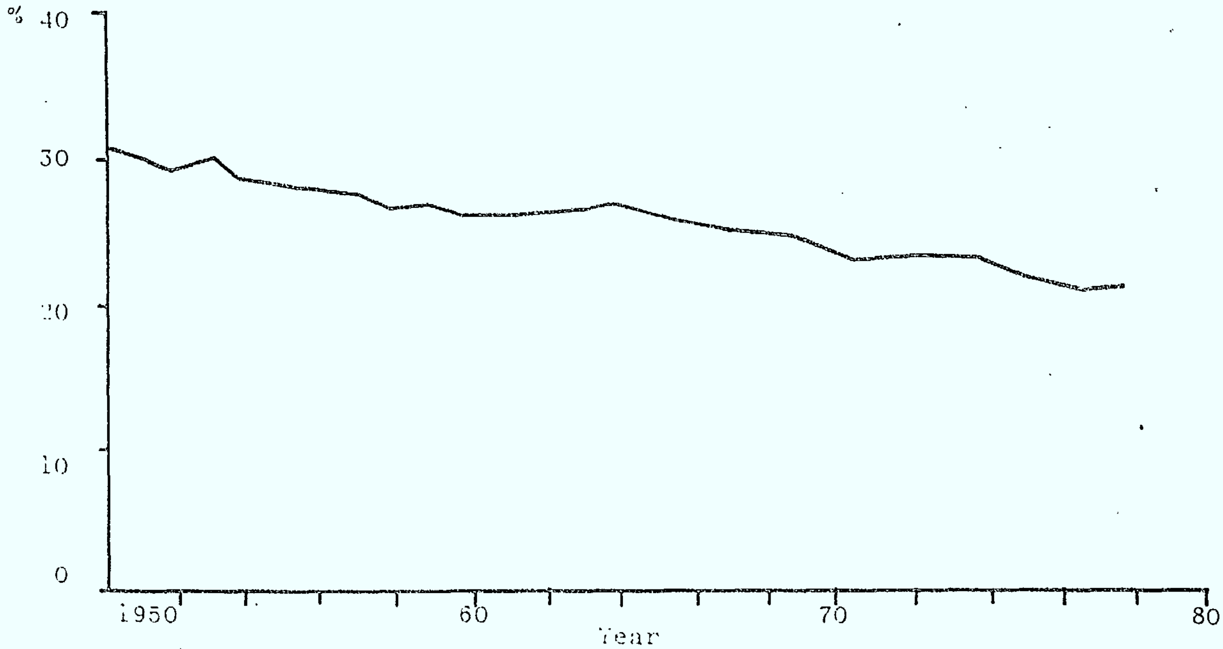
Source - Science Council of Canada "Forging the Links - A Technology Policy for Canada" 1979

FIG. 2 - MANUFACTURING INDUSTRIES EMPLOYMENT AND OUTPUT

Manufacturing Industries Employment as a Percentage of Total Employment in Canada

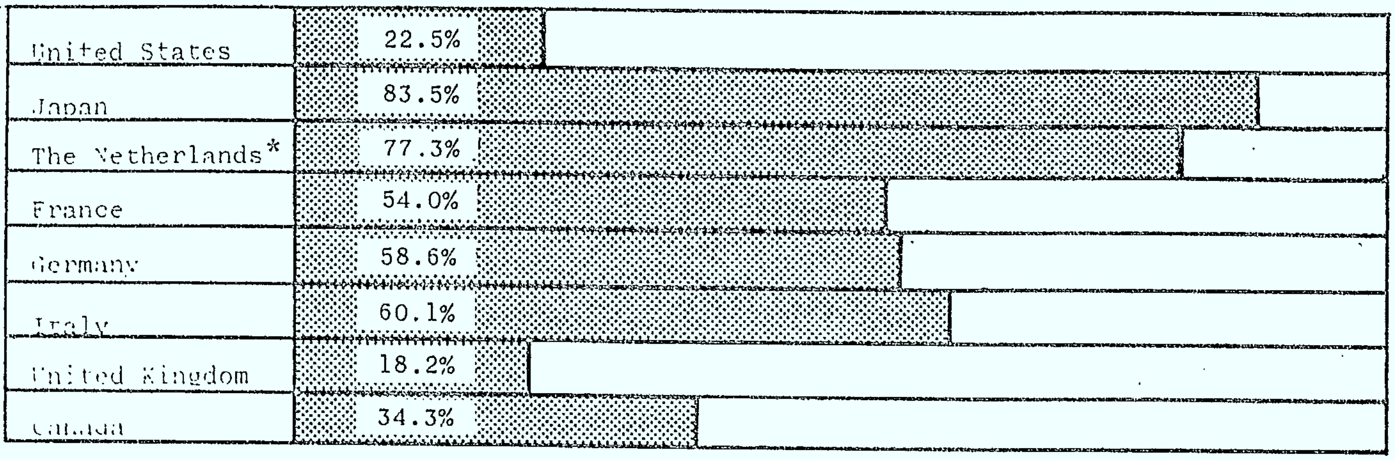


Manufacturing Gross Domestic Product (GDP) as a Percentage of Total GDP in Canada



Source: Statistics Canada

FIG. 3 - PRODUCTIVITY INCREASE IN MANUFACTURING 1968-1977



* 68-76

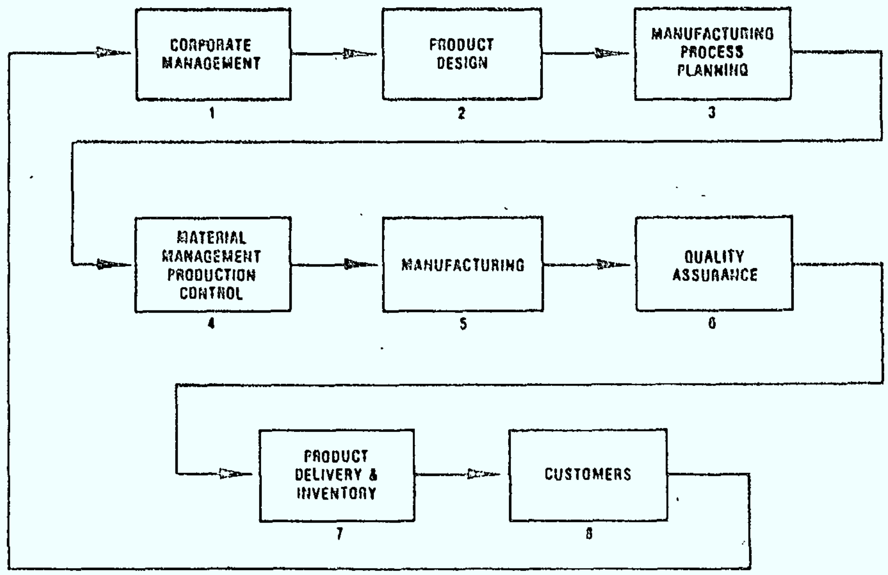
Source - U.S. Department of Labour May 1978

FIG. IV

SOME SIMILARITIES & DIFFERENCES BETWEEN CAD/CAM AND PROCESS CONTROL

Attribute	Process Control	CAD/CAM
Computer implemented	Yes	Yes
Real time sytem	Yes	Yes
Embedded System	Yes	Yes
Sensor based inputs	Main source for most information in system (Pressure, temperature flow etc, etc.).	Minor portion of information in system. Mostly events,timing,etc.
Input of human origin	Minor portion of information in system. (set points, etc.)	Major source of information.(Design configurations, production status, order status, information).
Expanding data base	No	Yes
Process control	Major purpose is feedback or feed forward control in classic sense. Major process units included within these loops, process gains & dynamics important.	Orientation is more towards the mere handling, timing, release etc. of large volumes of information.
Output interfaces	Set point stations, valves, etc.	Plotters, machine tools, wiring machines, flame cutters, robotic units, automatic test equipment.
Predominant user industries	Chemical, petroleum, steel, pulp and paper.	Discrete parts manufacturing, (transportation equipment, machinery, etc.)
Socio-economic impact	Modest	Much larger
Main period of pioneering	1960-1975	1975-1990

FIG. 5 - FLOW TASKS FOR MANUFACTURING



Source - Proceedings 1978 CAM-I International Spring Seminar

TABLE 1

SUMMARY OF CAD/CAM APPLICATION AREAS

Computer Aided Design	- Production design and analysis including graphic design, functional analysis, stress strain analysis, heat and material balances, simulation and modelling, data reduction and analysis and cost estimating of the proposed product or system to determine fitness of purpose and economically optimized production.
Customer Order Handling	- Record keeping, tracking and reporting on the status of individual customer orders, particularly when part of an integrated on-line system.
Production, Material & Inventory Control	- Scheduling and information handling pertaining to material requirements planning, inventory control, facilities planning and order scheduling, particularly when related to an integrated on-line system.
Automated Production	- Numerical and computer control of machine tools, lathes, milling, boring machines, pattern and fabric cutting, welding, brazing, plating, flow soldering, casting, flame cutting, spray painting and automated assembly (all of these exist and are under further development).
Automated Material Handling	- Integrated materials handling using computer operated conveyors, robotic units, etc.
Automated Testing	- Automated inspection of machined parts, testing of electronic components, circuits and products, automated material inspection and grading using sensor based computer systems, pattern recognition.
Automated Packaging	- Computer implemented coordination of material and information in packaging, bottling, labelling and weighing systems.
Automated Warehousing	- Computer implemented order picking and material handling for both work in progress inventory and finished goods inventory. Automated label reading, routing of packages, parcels, baggage in shipping, sorting and distribution centers.

Notes: - CAD/CAM technology will yield its greatest economic and productivity gains when all or most of the above application areas are married or joined together to form an integrated system. Hence there is a strong development trend in this direction.

TABLE II

TECHNOLOGIES INVOLVED IN CAD/CAM

- Computer Graphics
- Mechanical Design
- Electronics
- Simulation & modelling
- Engineering computation
- Numerical Analyses
- Data Base Design
- Interface Design
- Distributed Systems
- Programming Languages
- Communication Protocols
- Human Engineering
- Data Transmission
- Production Scheduling
- Material & Inventory Control
- Robotics
- Machine tool technology
- Numerical Control
- Sensors & instrumentation
- Feedback Control
- Pattern Recognition
- Socio-Economic Effects

REFERENCES AND BIBLIOGRAPHY

(1) "Strategy for Survival". CAD/CAM Technology Advancement Council report (Sept. 1980).

(2) "CAD/CAM and its Impact on the Manufacturing Industry". J. Scrimgeour. Proceedings, Canadian Conference on Automatic Control (May 23-25, 1979).

(3) "CAD/CAM and Process Control in the Federal Republic of Germany". J.H.C. Scrimgeour, J.R. Dickinson, J.E. Crozier, J.W.T. Battershill. A report for DITC Ottawa (1976).

(4) "Trip Report on Manufacturing Science and Production Technology in Great Britain and West Germany". E.H. Dudgeon, N. Burtnyk. National Research Council Ottawa (1980).

(5) "Unmanned machine shop project in Japan". H. Yoshikawa. Advances in Computer-Aided Manufacture (North-Holland Pub. Co.) (1977).

(6) "Computer Aided Design and Manufacture". Cabinet Office Advisory Council for Applied Research and Development. Her Majesty's Stationary Office. London, England (1980).

(7) "The Who and What of NC/CAM". K. Gettelman. Modern Machine Shop (Sept. 1979).

(8) "National Meeting to Review IPAD Status and Goals". R.E. Fulton. Astronautics and Aeronautics (July/Aug. 1980).

(9) "Bulletin de liaison de la recherche en informatique et en automatique" No.64 (1980). Institut National de Recherche en Informatique et en Automatique.

(10) "The Robot Revolution". Time Magazine (Dec. 8, 1980).

SECTION 1

AN INTRODUCTION OF CAD/CAM SYSTEMS

(11) "CAD/CAM and Canada"; a report of 15 published articles. Prepared in 1977 by the Dept. of Industry, Trade and Commerce, Ottawa K1A 0H5.

(12) "CAD/CAM and Canada" - A second reprint of approximately 25 published articles. To be available in 1981 from the Dept. of Industry, Trade and Commerce, Ottawa K1A 0H5.

(13) "Research and Design with Computer Graphics". Design Engineering (Feb. 1979).

(14) "Computer helps Canadair design the Challenger". Design Engineering (Feb. 1979).

(15) "How to get started in CAD/CAM". J. Scrimgeour. Canadian Machinery and Metal Working (March 1979).

(16) "Les répercussions de la technologie du microprocesseur et de l'ordinateur sur l'industrie manufacturière". J. Scrimgeour. Le Quebec Industriel (juillet 1979).

(17) "Help Needed for Canada's Secondary Manufacturing Industry. D.R. Strong. Engineering Journal (Aug. 1979).

(18) "Manufacturing Engineering Teaching and Research at McMaster University". J. Tlusty. Engineering Journal (Aug. 1979).

(19) "CAD/CAM - Bridging the Gap from Design to Production". J.K. Krouse. Machine Design (June 12, 1980).

(20) "CAD/CAM activities at NRC". K.A. Steele. Engineering Digest (Oct. 1980).

(21) "NC Turning Points Way to Larger Production Volumes". W.H. Maddock. Canadian Machinery and Metal Working (March 1978).

(22) "CAD/CAM merges mechanical engineering with computer technology". J. Scrimgeour, J. Nassr. Enj. J. (Canada), vol.62, no.3, p.3-7 (Aug. 1979).

(23) "Computers in manufacturing". J. Scrimgeour. Can. Datasyst. (Canada), vol.11, no.11, p.42-6 (Nov. 1979).

(24) "Solving the NC Puzzle". A.G. Harris. Tool & Prod. (USA), vol.45, no.7, p.94-5 (Oct. 1979).

(25) "The training of the future engineer [CAD in building construction planning]". J.H.A.E. Amkreutz. Polytech. Tijdschr. Bouwk. Wengen- & Waterbouw (Netherlands), vol.34, no.11, p.696-702 (Nov. 1979). In Dutch.

(26) "The future of numerical controls". M.M. Barash. Mech. Eng. (USA), vol.101, no.9, p.26-31 (Sept. 1979).

(27) "Industrial automation: ten years to save productivity". G. Cuntz. Autom. & Inf. Ind. (France), no.82, p.16-20 (Dec. 1979). In French.

(28) "CAD/CAM: small firms can think big". Mach. & Prod. Eng. (GB), vol.136, no.3514, p.37-9 (28 May 1980).

(29) "Advanced monitoring techniques". E. Ford. Indian & East. Eng., vol.121, no.5, p.237-8 (May 1979).

(30) "The revolution is here to stay [CAD]. A. Biji. Comput. Aided Des. (GB), vol.12, no.3, p.107-14 (May 1980).

(31) "CAD/CAM - solving the Productivity Problem". Ed. K. Taraman.(book) Society of Manufacturing Engineers. Dearborn, Mich. 1980.

SECTION 2

ECONOMIC JUSTIFICATION OF CAD/CAM

(32) "The role of numerical control used for the manufacturing processing machining on main industries in Japan". M. Soeda, H. Yonaiyama, E. Yamaguchi. Information-Control Problems in Manufacturing Technology, Tokyo, Japan. 17-20 Oct. 1977 (Oxford, England; Pergamon 1978), p.345-55.

(33) "The economic winding of stators". J. Britschgi. Elektr, Masch (Germany), vol.58, no.7, p.183-92 (july 1979). In German.

(34) "Productivity drift in extended learning curves". D.R. Towill, U. Kaloo. Omega (GB), vol.6, no.4, p.295-304 (1978)

SECTION 3

COMPUTERS AND COMPUTER GRAPHICS

(35) "The microprocessor - more than only a technical revolution". R. Weiss. Schweiz. Tech. Z. (Switzerland), no.1, p.34-8 (11 Jan. 1979). In German.

(36) "Interactive graphics in new product quality assurance programs". J.A. Clements. Qual. Prog. (USA), vol.12, no.2, p.14-16 (Feb. 1979).

(37) "Interactive computer aided 3D engineering and art design". N. Marovac. Comput. & Graphics (GB), vol.4 no.2, p.87-93 (1979).

(38) "Computer graphics in Canada: growth exceeds forecasts". J. LaPrairie. Comput. Data (Canada), vol.4, no.7, p.24-5 (July 1979).

(39) "How voice data entry achieves a high standard or recognition". J. Saunders. Comput. Wkly. (GB) vol.25, no.631, p.14-15 (14 Dec. 1978).

(40) "A comparison of mainframe and micro-computer operating systems". J.M. Gross. Small syst. Software (GB), vol.3 no.4 p.2-10 (1978).

(41) "Things you wanted to known about micro's but were afraid to ask - hints on system design". M. Dennis. Pers. Comput. World (GB), vol.1 no.8, p.21-3 (Dec 1978).

(42) "Higher-performance HP 1000 computer systems". R.K. Juncker. Hewlett-Packard J. (USA), vol.29, no.14, p.2.-5 (Dec. 1978).

(43) "D-i-y keyboard training". J. Field. Data Processing (GB), vol.21, no.6, p.16-17 (June 1979).

(44) "How computer graphics benefit industrial robot technology". W.B. Heginbotham. Systems (S. Africa), vol.9, no.6, p.8, 10-12 (June 1979).

(45) "Data terminals - state of the art". Can. Controls & Instrum. (Canada), vol.19, no.6, p.36-7 (June 1980).

(46) "Recent advances in display technologies. J.F. Chang. Proc. S.I.D. (USA), vol.21, no.2, p.45-54 (1980).

(47) "Eyestrain" and Visual display units: A review T.F.M. Stewart. Display Technology and App l. vol.1, no.1, p.25-32, April 1979.

(48) "Integrated CAD for LSI". K. Loosemore. Computer-Aided Design of Digital Electronic Circuits and Systems, Brussels, Belgium, Nov. 1978 (Amsterdam, Netherlands: North-Holland 1979), p.237-44.

(49) "Models for 'computer-aided design' and 'computer-assisted design' systems". K. Mathur. PARC 79. International Conference on the Application of Computers in Architecture, Building Design and Urban Planning. Berlin, Germany, 7-10 May 1979 (Uxbridge, England: Online 1979), p.485-94).

(50) "Scanning digitizers: automating the input of drawings". C.M. Williams. Comput. Aided Des. (GB), vol.11, no.4, p.227-30 (July 1979).

(51) "Distributed processing terminal system for CAD/CAM". M. Nio, H. Kataoka, T. Ochi. Proceedings of COMPSAC the IEEE Computer Society's Third International Computer Software and Application Conference, Chicago, IL, USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.547-52.

(52) "Performance evaluation of a test distributed graphics system". J.R. Rao, W.F. Winters, L.D. Schmidt. Proceedings of COMPSAC the IEEE Computer Society's Third International Computer Software and Applications Conference, Chicago, IL, USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.512-18.

(53) "The programmable controller is finding its in-line niche". S.J. Bailey. Control Eng. (USA), vol.27, no.2, p.51-5 (Feb. 1980).

(54) "Present and future trends in logic analyzers". K. Barnes. Digital Des. (USA), vol.10, no.4, p.30, 32, 34 (April 1980).

(55) "Cordless light pen". R.L. Coburn, A.A. Friedrich, L.L. Johnson. IBM Tech. Disclosure Bull, (USA), vol.22, no.8B, p.3784-5 (Jan. 1980).

(56) "Computer graphics hard copy devices". G.H. Langeler. Ind. Res/Dev. (USA), vol.21, no.10, p.153-5 (Oct. 1979).

(57) "Interactive graphics and design automation for PC boards and hybrids". R.L. Myers. Electron Prod. (GB), vol.8, no.10, p.165, 168, 170, 172 (Oct. 1979).

(58) "CAD - a user's perspective. F.T. Dawson. Comput. Aided Des (GB), vol.12, no.3, p.127-32 (May 1980).

(59) "The CAD/CAM Handbook". Ed. C. Machover, R. Blauth. Computervision Corporation, Bedford, Mass. 1980.

SECTION 4

CAD ANALYTICAL TECHNIQUES

(60) "Geometric Models for CAD/CAM". J.K. Krouse. Machine Design, July 24, 1980.

(61) "Finite element analysis". H.H. Drews, F.J. Du Toit. Systems (S. Africa), vol.9, p.13 (Feb. 1979).

(62) "CAD makes press twice as stiff for high speeds". R. Hass. Metalwork. Prod. (GB), vol.122, no.12, p.102-3, 106 (Dec. 1978).

(63) "The UNCLE finite element system". J.A. Enderby. Engineering Software, Southampton, Eng., Sept. 1979 (London, England; Pentech 1979), p.28-42.

(64) "A generalized software system for nonlinear analysis". R.H. Dodds, Jr. Engineering Software, Southampton, Eng. Sept. 1979 (London, England; Pentech 1979), p.55-77.

(65) "Pattern router". J. Soukup, S. Fournier. Proceedings of the 1979 International Symposium on Circuits and Systems, Tokyo, Japan. 17-19 July 1979 (IEEE 1979 New York USA) p.486-9.

(66) "GRAPPLE: an application in heat transfer analysis". J.H.A.E. Amkreutz, D.J. Vanier. Comput. Aided Des. (GB), vol.12, no.3, p.133-7 (May 1980).

SECTION 5

PRODUCTION, MATERIAL AND INVENTORY CONTROL

(67) "Heuristic lot-sizing and sequencing rules in a multistage production-inventory system". J.R. Biggs. Decis. Sci. (USA), vol.10, no.1, p.96-115 (Jan. 1979).

(68) "Computerized job shop scheduling for smaller companies". S. Khatu. Tool & Prod. (USA), vol.44, no.11, p.100-1 (Feb. 1979).

(69) "Assembly line balancing and the application of computer techniques". N.A. Schofield. Comput. & Ind. Eng. (GB), vol.3, no.1, p.53-69 (1979).

(70) "Computer-aided design in the job shop". J.R. Frazier. Mod. Mach. Shop (USA), vol.52, no.4, p.96-101 (Sept. 1979).

(71) "Computerised production-control system". Tool & Prod. (USA), vol.45, no.6, p.98-100 (Sept. 1979).

(72) "Use of dynamic lot-sizing to avoid nervousness in material requirements planning systems". D.H. Kropp, R.C. Carlson, J.V. Jucker, Prod. & Inventory Manage (USA), vol.20, no.3, p.49-58 (1979).

(73) "MRP and the bottom line (material requirements planning)". L.S. Shealy. Prod. & Inventory Manage. (USA), vol.20, no.3, p.59-67 (1979).

(74) "Real-time inventory control: the pace quickens". Mater. Handl. Eng. (USA), vol.34, no.10, p.90-1 (Oct. 1979).

(75) "Bar code labels withstand harsh production operations". Electron, Packag. & Prod. (USA), vol.20, no.2, p.134 (Feb. 1980).

SECTION 6

DATA BASE DESIGN FOR CAD/CAM SYSTEMS

(76) "Database software". G. Baker. Data Processing (GB), vol.21, no.4, p.28-9 (April 1979).

(77) "TOTAL leads with more thatn 2000 installations". Which Comput. (GB), vol.3, no.2, p.44-5 (Feb. 1979).

(78) "The use of TOTAL at the Netherlands Energy Research Foundation ECN". H.M. Rietveld. In generalized data management systems and scientific information. Report of a specialist study, p.227-31. Report (unnumbered) OECD, OECD, Paris, France (1978), 346 pp.

(79) "Experience with TOTAL at SKF (UK), Ltd.". R.C.M. Dale. Database J. (GB), vol.9, no.2, p.8-14 (1979).

(80) "Integrating language and database for CAD applications". G.M.E. Lafue. Comput. Aided Des. (GB), vol.11, no.3, p.127-31 (May 1979).

(81) "PHIDAS - a database management system for CAD/CAM application software". W.E. Fischer. Comput. Aided Des. (GB), vol.11, no.3, p.146-50 (May 1979).

(82) "Descriptive databases in some design manufacturing environments". E.M. Hoskins. Comput. Aided Des.(GB), vol.11, no.3, p.151-7 (May 1979).

(83) "An overview of recent data base research". C. Mohan. Data Base (USA), vol.10, no.2, p.3-24 (Fall 1978).

(84) "Recommendations for database management system standards". Report NBS-SP-500-51. Nat. Bur. Stand., Washington, D.C., USA (Aug. 1979), 88 pp.

(85) "How not to turn your data base from a blessing into a burden". M. Seed. Can. Datayst. (Canada), vol.11, no.6, p. 28, 33 (June 1979).

(86) "The woes of DBMS". S.F. Hesprich. J. Syst. Manage. (USA), vol.30, no.10, p.27-31 (Oct. 1979).

SECTION 7

NUMERICALLY CONTROLLED MACHINE TOOLS (METAL CUTTING)

(87) "An adaptive CNC system of a milling machine tool". T. Watanabe, S. Iwai, Y. Nawata. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, Eng.: Pergammon 1978), p.195-205.

(88) "Control system of NC machine tool for high working accuracy". N. Nishiwaki, N. Hashiba, M. Masuko. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977, (Oxford, Eng.: Pergammon 1978), p.217-23.

(89) "Hardware and software developments for a DNC manufacturing cell". D.A. Milner, J.D. Brindley. Int. J. Prod. Res.(GB), vol.16, no.6, p.441-52 (Nov. 1978).

(90) "Numerical control (NC) of machine tools as a way out of manpower shortage". A. Fryatt. Microtecnic (Switzerland), no.4, p.5-7 (1978). In German.

(91) "Machining centers on the move". G.S. Vasilash. Manufacturing Engineering, Sept. 1980.

(92) "CNC boring plant for truck chassis". W. Mack. Werkstatt & Betr.(Germany), vol.112, no.3, p.146-7 (March 1979). In German.

(93) "NC machining centres and NC manufacturing lines in a flexible modular form". W. Lipp. Maschinenmarkt (Germany), vol.84, no.95, p.1939-42 (24 Nov. 1978). In German.

(94) Microprocessor revitalizes automatic drill press". P.W. Becker, J.G. Simes, P.L. Sutcliffe. 1978 MIDCON Technical Papers, Dallas, TX, USA, 12-14 Dec. 1978 (North Hollywood, CA, USA, Western Periodicals Co. 1978), p.10/2/1-5.

(95) "Low-cost CNC opens the door on profits". D. Potts. Mach. & Prod. Eng. (GB), vol.134, no.3464, p.30-1 (30 May 1979).

(96) "Computers add a new dimension to profiling". A. Astrop. Mach. & Prod. Eng. (GB), vol.134, no.3462, p.37-40 (16 May 1979).

(97) "Analogic part programming - automation for the small job shop". D.C. Gossard. ISA Trans. (USA), vol.17, no.3, p.81-8 (1978).

(98) "A linear-induction-motor slide drive". W.E. Barkman. 1978 Joint automatic control conference, Pt.1, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburg, PA., USA: ISA 1978), p.289-98

(99) "Adaptive control on machine tools". J.Casellas. Dyna (Spain), vol.54, no.5, p.117-23 (May 1979). In Spanish.

(100) "A microprocessor controlled twist drill grinder for automated drill production". M.A. Fugelso, S.M. Wu. Trans. ASME J. Eng. Ind. (USA), vol.101, no.2, p.205-10 (May 1979).

(101) "Computer-controlled production systems in manufacture of articles in sheet metal". W. Panknin. ZWF Z. Wirtsch. Fertigung (Germany), vol.74, no.6, p.319-25 (June 1979). In German.

(102) "In-process control of workpiece dimension in turning". M. Shiraishi. Ann. CIRP (GB), vol.28, no.1, p.333-7 (1979).

(103) "Automatic tool wear monitoring in NC turning". K. Uchara, F. Kiyosawa, H. Takeshita. Ann. CIRP (GB), vol.28, no.1, p.39-42 (1979).

(104) "Adaptive controls - set for the next step". H. Tipton. Metalwork. Prod. (GB), vol.123, no.11, p.132-3, 143 (Nov. 1979).

(105) "The production possibilities of CNC-controlled cross-slides on boring mills". R.M. Miller. Werkstatt & Beir (Germany), vol.112, no.9, p.611-14 (Sept. 1979). In German.

(106) "CNC and copying put on a double act". G. Mason. Mach. & Prod. Eng. (GB), vol.135, no.3482, p.77-80 (10 Oct. 1979).

(107) "NC and CNC control applied to metal sawing". Eng. Dig. (GB), vol.40, no.11, p.25, 27 (Nov. 1979).

(108) "Process control in internal grinding". H.K. Tonshoff, G. Rohr, P.G. Althaus. Ann. CIRP (Switzerland), vol.29, no.1, p.207-11 (1980).

SECTION 8

NUMERICAL CONTROL OF OTHER MANUFACTURING EQUIPMENT

(109) "Tracking control for guiding electrodes along joints by pattern detection of welding groove". M. Kawahara, K. Taki. Trans. Soc. Instrum. & Control Eng. (Japan), vol.15, no.4, p.492-7 (Aug. 1979). In Japanese.

(110) "CNC-controls for shielded arc welding using microprocessors". P. Drews, J. Weissweiler. Maschinenmarkt (Germany), vol.84, no.73, p.1415-19 (12 Sept. 1978). In German.

(111) "Development of arc welding robot for shipbuilding (no. 1 report)". T. Nozaki, N. Mokudai, Y. Higo, S. Osaki, N. Inuiya, T. Nandate, M. Kishimoro, A. Saito. Mitsui Tech. Rev. (Japan), no.103, p.31-43 (1978). In Japanese.

(112) "Towards the automation of arc welding". P. Boughton, G. Rider, C.J. Smith. CEGB Res. (GB), no.9, p.33-40 (June 1979).

(113) "Computerized chain welding". A. Wust. Wire World Int. (Germany), vol.21, no.3, p.100-3 (May-June 1979).

(114) "Laser welding speeds relay production". Insul./Circuits (USA), vol.25, no.4, p.24-5 (April 1979).

(115) "How we moved up to NC plasma cutting". R.L. Thompson. Weld. Des. & Fabr. (USA), vol.52, no.6, p.67-75 (June 1979).

(116) "High speed laser system welds terminals of miniature relays under microcomputer control". Comput. Des. (USA), Vol.17, no.12, p.50 (Dec. 1978).

(117) "Computer programs for mounting-plate manufacture". R.C. Swanson. Western Electric Eng. (USA), vol.23, no.1, p.33-39 (Jan. 1979).

(118) "Mechanizing arc and resistance welding. Some insights into the art and its techniques". G. Green. Tool. & Prod. (USA), vol.45, no.7, p.80-S (Oct. 1979).

(119) "NC punch programming made easier". K. Peandro. Tool. & Prod. (USA), vol.45, no.7, p.69-70) (Oct. 1979).

(120) "Grinding and polishing with small tools under computer control". R.A. Jones. Opt. Eng. (USA), vol.18, no.4, p.390-3 (July-Aug. 1979).

(121) "A system for the automation of material handling in the garment industry". S. Ogawa, H. Ozaki, M. Morita, Y. Yonezawa. Mitsubishi Denki Giho (Japan), vol.53, no.10, p.763-7 (Oct. 1979). In Japanese.

(122) "Temperature control techniques for injection moulding machines". P.H.J. Ingham. Plast. & Rubber Int. (GB), vol.4, no.5, p.211-13, 215 (Sept.-Oct. 1979).

(123) "A microprocessor controlled butter packaging machine". D.R. Erickson. Industry Application Society IEEE-IAS Annual Meeting, Cleveland, OH. USA, 30 Sept.-4 Oct. 1979 (New York, USA: IEEE 1979), p.612-15.

(124) "Electronic distance measurement for industrial and scientific applications". D.E. Smith. Hewlett-Packard J. (USA), vol.31, no.6, p.3-11 (June 1980).

(125) "Sensors and transducers in the sphere of materials handling. Report IVF-resultat-79619". Inst. Verkstadsteknisk

Forskning (Gothenburg, Sweden) (Nov. 1979), 47 pp. In Swedish.

(126) "Torque motors - choosing the right motor for the job". Eng. Mater. & Des. (GB), vol.23, no.10, p.43-6 (Oct. 1979).

(127) "Matching stepping motor characteristics to the mechanical load". H.G. Stevens. Control & Instrum. (GB), vol.11, no.3, p.21, (March 1979).

(128) "ABC of stepping motors". L. Kozuchowski. Automation (GB), vol.14, no.3, p.7, 9, 11 (March 1979).

(129) "A device for automatic control of the welding of technological welds in pipes using several welding heads". A.I. Chvertko, E.F. Malchenko, N.N. Sakalo, V.S. Golinko, V.A. Timchenko. Autom. Weld. (GB), vol.31, no.7, p.35-8 (July 1978). Translation of Avtom. Svarka (USSR), no.7, p.56-9 (1978).

SECTION 9

AUTOMATED TESTING AND INSPECTION

(130) "Computer with eyes (for IC mask testing)". R. Pope. Ind. Res./Dev. (USA), vol.20, no.5, p.105-8 (May 1978).

(131) "Automatic recognition system for industrial quality assurance". C.C.K. Cheng. Proc. of the Soc. of Photo-Optical Instrum. Engrs., vol.155. Image understanding systems and industrial applications, San Diego, CA., USA, 30-31 Aug. 1978 (Bellingham, WA., USA: Soc. Photo-Optical Instrum. Engrs. 1978), p.78-82.

(132) "Computer spots for flaws in weld quality". Mach. & Prod. Eng. (GB), vol.134, no.3447, p.27-8 (31 Jan. 1979).

(133) "Computer spots for flaws in weld quality". J. Broomhead. Meas. & Insp. Technol. (GB), vol.1, no.3, p.34-5 (Sept. 1979).

(134) "Experiments in the automation of visual inspection". J.F. Jarvis. 1978 Joint automatic control conference, Pt.1, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburg, PA., USA: ISA 1978), p.307-13.

(135) "Replacing visual inspection with a scanned laser system". N.G. Altman. Proc. of the Soc. of Photo-Optical Instrum. Engrs., vol.170. Optics in quality assurance, II, Los Angeles, CA., USA, 22-23 Jan. 1979 (Bellingham, WA., USA: Soc. Photo-Optical Instrum. Engrs. 1979), p.85-90.

(136) "The mechanical programming of multi-coordinate measuring equipment". T. Pfeifer, H. Goluke. Qual. & Zuverlassigkeit (Germany), vol.24, no.5, p.124-8 (May 1979). In German.

(137) "Roughness measurement with a micro-computer". T.R. Thomas, M. Walker. Engineering Software, Southampton, England, Sept. 1979 (London, England: Pentech 1979), p.663-72.

(138) "Troubleshooting system for CNC machines". Autom. Mach. (USA), vol.40, no.9, p.20-2 (July 1979).

(139) "Production testing of loudspeakers using digital techniques". L.R. Fincham. J. Audio Eng. Soc. (USA), vol.27, no.12, p.970-4 (Dec. 1979).

(140) "Electronic weighing in industry, II. P.K. Basu. Stud. J. Inst. Electron. & Telecommun. Eng. (India), vol.20, no.1, p.12-17 (Jan. 1979).

(141) "Watchdog program for machinery: automatic vibration monitoring".

J.G. Lyons. Pulp & Pap. Can. (Canada), vol.80, no.1, p.69-73 (Jan. 1979).

(142) "The application of micro-processors in automotive test equipment". S.C. White. ISATA 79 Proc. Internat. Symp. on Automotive Technology and Automation, Pt.I, Graz, Austria, 10-14 Sept. 1979 (Croydon, England: Automotive Automation Ltd. 1979), p.231-47.

(143) "Fully automatic quality control in the production of automatic transmissions". P. Müller. ISATA 79 Proc. Internat. Symp. on Automotive Technology and Automation, Pt.II, Graz, Austria, 10-14 Sept. 1979 (Croydon, England: Automotive Automation Ltd. 1979), p.335-53.

(144) "The design of a microprocessor-based instrumentation and control system for a timber strength grading machine". C.H. McLaren. Design Engineering Conference, Birmingham, England, 22-26 Oct. 1979 (Farnham, England: Design Engng. Conf. 1979), 12 pp.

(145) "Roughness measurement with a microcomputer". T.R. Thomas, M. Walker. Meas. & Insp. Technol. (GB), vol.1, no.5, p.34-5 (Nov. 1979).

(146) "COOMS - computer orientated optical measurement systems". S. Freeman. Meas. & Insp. Technol. (GB), vol.1, no.5, p.25, 27 (Nov. 1979).

(147) "Joint 488-bus instruments and efficient software for fast, automatic tests". L. Smith. Electron. Des. (USA), vol.26, no.24, p.142-8 (22 Nov. 1978).

SECTION 10

INDUSTRIAL ROBOTS AND AUTOMATED MATERIAL HANDLING

(148) "Material handling in assembly production plants". M. Okada, T. Murao. Natl. Tech. Rep. (Japan), vol.24, no.6, p.1066-74 (Dec. 1978). In Japanese.

(149) "The industrial robots - the future of full automation of production". A. Kowalski. Pol. Mach. Ind. Offers (Poland), no.12, p.16-18 (1978).

(150) "Second generation robots have eye for industry". D.E. Hart. Data Manage. (USA), vol.17, no.6, p.13-14, 16-19 (June 1979).

(151) "Microprocessor controller rides freight stacker system". Instrum. & Control Syst. (USA), vol.52, no.1, p.82, 84 (Jan. 1979).

(152) "Mobile robots for industrial use". M.H.E. Larcombe. Ind. Robot. (GB), vol.6, no.2, p.70-6 (1979).

(153) "A robot system for better arc welding". J. Hollingum. Engineer (GB), vol.249, no.6438, p.28-9 (16 Aug. 1979).

(154) "Research issues for automatic assembly". J.L. Nevins, D.E. Whitney. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.15-24.

(155) "The dynamics of an industrial robot with two actuating mechanisms". M.I. Poteev, L.S. Poteeva, Yu.D. Zhabotinskii. Mach. & Tool. (GB), Vol.49, no.7, p.24-6 (1978). Translation of Stanki & Instrum. (USSR), vol.49, no.7, p.19-20 (1978).

(156) "Robot application simulation". W.B. Heginbotham, M. Dooner, K. Case. Ind. Robot. (GB), vol.6, no.2, p.76-80 (1979).

(157) "Acceptance tests for industrial robots". S.S. Anshin. Mach. & Tool. (GB), vol.49, no.7, p.11-13 (1978). Translation of Stanki & Instrum. (USSR), vol.49, no.7, p.8-10 (1978).

(158) "Voice command of a six-degree-of-freedom manipulator". J. Sachs, L. Leifer. Proc. of the 1979 Joint Automatic Control Conf., Denver, CO., USA, 17-21 June 1979 (New York, USA: American Inst. Chem. Engrs. 1979), p.783-9..

(159) "Air film system for handling semi-conductor wafers". J.A. Paivanas, J.K. Hassan. IBM J. Res. & Dev. (USA), vol.23, no.4, p.361-75 (July 1979).

(160) "Robot control systems and applications". R.R. Hohn. Proc. of the 1979 Joint Automatic Control Conf., Denver, CO., USA, 17-21 June 1979 (New York, USA: American Inst. Chem. Engrs. 1979), p.750-3.

(161) "Loading and unloading machine tools with industrial robots". G. Sautter. Maschinenmarkt (Germany), vol.85, no.65, p.1275-8 (14 Aug. 1979). In German.

(162) "Applications and future developments of sensor-guided robots". D. Haaf. Maschinenmarkt (Germany), vol.85, no.70, p.1365-9 (31 Aug. 1979). In German.

(163) "Industrial robots for fettling castings". M. Schweizer. Ind.-Anz. (Germany), vol.101, no.72, p.26-7 (7 Sept. 1979). In German.

(164) "Robots push carts through production fast". Weld. Des. & Fabr. (USA), vol.52, no.7, p.80-2 (July 1979).

(165) "Movement control techniques for a sheep shearing robot". J.P. Trevelyan. Australian Conf. on Computer Graphics and Spatial Analysis, Adelaide, Australia, 13-15 Aug. 1979 (Barton, Australia: Instn. Engrs. Australia 1979), p.82-6.

(166) "A structured approach to robot programming and teaching". K. Takase. Proc. of COMPSAC the IEEE Computer Society's Third Internat. Computer Software and Applications Conf., Chicago, IL., USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.452-7.

(167) "VAL: a versatile robot programming and control system". B. Shimano. Proc. of COMPSAC the IEEE Computer Society's Third Internat. Computer Software and Applications Conf., Chicago, IL., USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.878-83.

(168) "TEACH - a concurrent robot control language". C.F. Ruoff. Proc. of COMPSAC the IEEE computer Software and Applications Conf., Chicago, IL., USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.442-5.

(169) "Robotics at Renault". Tech. Mod. (France), vol.71, no.9-10, p.65-8 (Sept.-Oct. 1979). In French.

(170) "The Robot - the technique of the future". Rev. Polytech. (Switzerland), no.11, p.1279, 1281, 1283 (Nov. 1979). In French.

(171) "Material-handling robots for programmable automation". C.A. Rosen. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.147-52.

(172) "A system recovering method from tracking confusions in conveyor system". H. Takenouchi, S. Miyamoto, S. Seki, A. Shimizu, M. Sasaki, S. Ishikawa. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.159-64.

(173) "Survey of industrial robots". J. Koekebakker. Canadian machinery and metal working, Jan., 1980.

(174) "Computer techniques used in industrial robots". M.P. Skidmore. Ind. Robot (GB), vol.6, no.4, p.183-7 (Dec. 1979).

(175) "Robot arc welding developments". J. Weston, S.B. Jones, J.J. Hunter. Ind. Robot (GB), vol.6, no.4, p.187-9 (Dec. 1979).

(176) "Human combines with robot to increase welding versatility". J.G. Holmes, B.J. Resnick. Weld. & Met. Fabr. (GB), vol.48, no.1, p.13-14, 17-18, 20 (Jan.-Feb. 1980).

(177) "Industrial robots vol.I An industrial appreciation. vol.II A world wide literature survey". National Engineering Laboratory, East Kilbride, Glasgow, UK.

SECTION 11

DISTRIBUTED AND HIERARCHICAL COMPUTER SYSTEMS

(Interface, Bus & Data Highway Design)

(178) "Distribute your computer power for big productivity gains. Begin with task level micros". E. Zander. Prod. Eng. (USA), vol.25, no.8, p.43-7 (Aug. 1978).

(179) "Distributed systems for process control". P. Ficarro, R.E. Jones. Proc. of the 1979 Joint Automatic Control Conference, Denver, CO., USA, 17-21 June 1979 (New York, USA: American Inst. Chem. Engrs. 1979), p.644-8.

(180) "The IEC bus [interface system] - potentialities and limits to its application". G. Buren, W. Schutz. Regelungstech. Prax. (Germany), vol.20, no.12, p.341-7 (Dec. 1978). In German.

(181) "New environment for short-haul modems", G.B. Hick. Telecommunications (USA), vol.13, no.3, p.81-2 (March 1979).

(182) "IEEE Standard 488 (digital interface for programmable instrumentation): progress report". D.C. Loughry. Autotestcon '78. International Automatic Testing Conf., San Diego, CA., USA, 28-30 Nov. 1978 (New York, USA: IEEE 1978), p.169-71.

(183) "The IEEE-488 bus, a cost effective solution to system design". R. Zitzmann. 1978 WESCDN Technical Papers, Los Angeles, CA., USA, 12-14 Sept. 1978 (North Hollywood, CA., USA: Western Periodicals Co. 1978), p.35.4/1-3.

(184) "The implementation of an IEEE-488 interface with a large scale integrated interface circuit". D.A. Newton. Colloquium on Applying new Interface Devices, London, England, 17 Oct. 1979 (London, England: IEE 1979), p.3/1-2.

(185) "From the S-100 to CAMAC: the diversity of digital buses". M.J. McGowan. Control Eng. (USA), vol.26, no.4, p.31-4 (April 1979).

(186) "Standards committee activities: an update". D.B. Gustavson. Computer (USA), vol.12, no.7, p.61-4 (July 1979).

(187) "Summary of IEEE Computer Standards Committee activities". D.B. Gustavson. IEEE Trans. Nucl. Sci. (USA), vol.ns-26, no.4, p.4468-72 (Aug. 1979).

(188) "Computer system buses". A. Clements. Microprocess. & Microsyst. (GB), vol.3, no.9, p.413-20 (Nov. 1979).

(189) "An HP-IB extender for distributed instrument systems". D.H. Guest. Hewlett-Packard J. (USA), vol.30, no.8, p.26-32 (Aug. 1979).

(190) "On the bus or off the bus? [S-100 interface protocol]". Syst. Int. (GB), vol.7, no.11, p.33-4 (Nov. 1979).

(191) "Hierarchical control systems - a study". J.S. Gupta, R.S. Dahiya, D.P. Kothari. J. Inst. Eng. (India) Electron. & Telecommun. Eng. Div., vol.59, pt.ET 2-3, p.59-62 (Dec. 1978 - April 1979).

(192) "The once and future evolution of distributed control". J.G. Miller. Intech (USA), vol.26, no.9, p.52-4 (Sept. 1979).

(193) "Distributed control in discrete part manufacturing - an overview". K. Pluhar. Control Eng. (USA), vol.26, no.9, p.57-8 (Sept. 1979).

(194) "Hardware versus functions - a view of distributed and hierarchical industrial computer systems". T.J. Williams. J. Appl. Syst. Anal. (GB), vol.7, p.95-114 (April 1980).

(195) "A tutorial on protocols". L. Pouzin, H. Zimmermann. Proc. IEEE (USA), vol.66, no.11, p.1346-70 (Nov. 1978).

(196) "Why install a data entry system?". M. Aldrich. Syst. Int. (GB), vol.6, no.9, p.49 (Nov. 1978).

(197) "A survey of distributed data base management". M. Miller. Inf. & Manage. (Netherlands), vol.1, no.6, p.243-64 (Dec. 1978).

(198) "Distributed database technology: an assessment". W.T. Hardgrave. Inf. & Manage. (Netherlands), vol.1, no.4, p.157-67 (Aug. 1978).

(199) "Distributed process control architectures using microprocessors". A.C. Weaver. Proc. of the 3rd Rocky Mountain Symposium on Microcomputers: Systems, Software, Architecture, Pingree Park, CO., USA, 19-22 Aug. 1979 (New York, USA: IEEE 1980), p.36-47.

(200) "Architecture of distributed computer systems". G. Bochmann. Berlin, Germany: Springer-Verlag (1979), vii + 238pp.

(201) "Microprocessor-based direct numerical control systems". T.R. Crossley, D. McCartney. Ann. CIRP (GB), vol.28, no.1, p.273-6 (1979).

(202) "Advanced computer technology for better productivity; distributed control systems". J.F. Sutherland. Engineering Digest, May 1980.

(203) "Transaction Network, telephones, and terminals: overview". J.W. Fitzwilliam, R.L. Wagner. Bell Syst. Tech. J. (USA), vol.57, no.10, p.3325-9 (Dec. 1978).

(204) "Overriding power-line perturbations". A.J. Botte, J.H. Hubbard, P.R. Spivey. IBM Tech. Disclosure Bull. (USA), vol.21, no.4, p.1364 (Sept. 1978).

(205) "Performance problems in distributed systems". L. Svobodova. INFOR (Canada), vol.18, no.1, p.21-40 (Feb. 1980).

SECTION 12

COMPUTER PROGRAMMING LANGUAGES AND SOFTWARE DEVELOPMENT

(206) "Programmer's Workbench: new tools for software development". W.D. Roome. Bell Lab. Rec. (USA), vol.57, no.1, p.19-25 (Jan. 1979).

(207) "Microprocessor assembly language draft standard IEEE Task P694/D11". W.P. Fischer. Computer (USA), vol.12, no.12, p.96-109 (Dec. 1979).

(208) "Will Pascal be the next standard language?". B.W. Ravenel. Proc. of Spring Compcon 79, San Francisco, CA., USA, 26 Feb. - 1 March 1979 (New York, USA: IEEE 1979), p.144-6.

(209) "Application software - the problem child of the 80's". J. Kanngiesser. Online-ADL-Nachr. (Germany), no.12, p.1006, 1008-10 (Dec. 1979). In German.

SECTION 13

PROJECT MANAGEMENT

(210) "Managing application development". T.M. Ball. Data Processor (USA), vol.21, no.4, p.2-4 (Sept. 1978).

(211) "Getting off to the right start - good specifications and distributed processing make material handling systems work". M.W. Jones. Conf. Record of 1979 Thirty-First Annual Conf. of Electrical Engineering Problems in the Rubber and Plastics Industries, Akron, OH., USA, 9-10 April 1979 (New York, USA: IEEE 1979), p.1-7.

(212) "The documentation and checking of computer aided engineering computations". M.V. Jones. Comput. & Struct. (GB), vol.10, no.1-2, p.81-4 (April 1979).

(213) "The developing role of user groups in the United Kingdom and Europe". E.J. Howe. L'Insertion de l'Informatique un Facteur de Progres (The Insertion of Data Processing a Key to Success), Pt.II, Paris, France, 1978 (Paris, France: Convention Informatique 1978), p.5-8.

(214) "An association grouping industrial companies develops a common language". A. Stein. L'Insertion de l'Informatique un Facteur de Progres (The Insertion of Data Processing a Key to Success), Pt.II, Paris, France, 1978 (Paris, France: Convention Informatique 1978), p.13-14. In French.

(215) "How Stelco coordinates computer system developments". W.D. Boyle, K.R. Barnes. Can. Controls & Instrum. (Canada), vol.19, no.6, p.32-5 (June 1980).

(216) "A prescription for programming's least popular phase". J. Vaughn. Datamation (USA), vol.25, no.1, p.185-6 (Jan. 1979).

(217) "Seven basic principles of software engineering". B.W. Boehm. In book: Software engineering techniques, state of the art report, p.77-113. Maidenhead, England: Infotech Internat. (1977), vi + 612 pp.

(218) "Slashing software maintenance costs". J. Snyders. Comput. Decis. (USA), vol.11, no.7, p.44, 47-8, 50 (July 1979).

(219) "Training tomorrow's DP people". D.W. Croisdale. Post-secondary and Vocational Education in Data Processing, Amsterdam, Netherlands, 17-20 April 1979 (Amsterdam, Netherlands: North-Holland 1979), p.117-24.

(220) "Lack of skills and insight could keep CAM down". J.E. Crozier. Canadian

machinery and metalworking, March 1980.

(221) "A Survey to Identify the Attitudes and Awareness of Numerical Control Users to CAD/CAM Technology". J.E. Crozier. Report available from Technological Innovation Studies Program, Technology Branch (61), Dept. of Industry, Trade and Commerce, Ottawa, K1A OH5.

(222) "A Maintenance Overview of CAM Technology". R.W. Blandow. Manufacturing Engineering, July 1979.

SECTION 14

SYSTEMS DESIGN

(223) "Manufacturing systems architecture - an area of needed development and standardization report of the ARC manufacturing architecture overview group". M.E. Merchant. 197 Joint Automatic Control Conf., Pt.II, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburgh, PA., USA: ISA 1978), p.329-40.

(224) "Research in the CAD/CAM systems and related areas report of the ARC CAD/CAM systems group". E.E. Miller. 197 Joint Automatic Control Conf., Pt.II, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburgh, PA., USA: ISA 1978), p.341-6.

(225) "Needs of the personnel and hardware interface field report of computer and personnel interface systems group". T.B. Sheridan. 197 Joint Automatic Control Conf., Pt.II, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburgh, PA., USA: ISA 1978), p.347-53.

(226) "CAMSAM: a simulation analysis model for computer-aided manufacturing systems". J.A. Runner. Proc. of the 1978 Summer Computer Simulation Conf., Los Angeles, CA., USA, 24-26 July 1978 (Montvale, NJ., USA: AFIPS Press 1978), p.474-9.

(227) "The microcomputer invades the production line". R. Allan. IEEE Spectrum (USA), vol.16, no.1, p.53-7 (Jan. 1979).

(228) "Research in automated assembly and related areas report of the ARC programmable manufacturing systems group". D. Nitzan, D. Whitney. 1978 Joint Automatic Control Conf., Pt.IV, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburgh, PA., USA: ISA 1978), p.21-8.

(229) "GEMS: a generalized manufacturing simulator". D.T. Phillips, M. Handwerker. Proc. of the Twelfth Hawaii Internat. Conf. on System Sciences, Pt.I, Honolulu, HI., USA, 4-5 Jan. 1979 (North Hollywood, CA., USA: Western Periodicals Ltd. 1979), p.197-209.

(230) "Computer aids to the design of integrated manufacturing systems". P. Bernus, J. Hatvany. Comput. Ind. (Netherlands), vol.1, no.1, p.11-19 (July 1979).

(231) "GEMS: a generalized manufacturing simulator". D.T. Phillips, M. Handwerker, G.L. Hogg. Comput. & Ind. Eng. (GB), vol.3, no.3, p.225-33 (1979).

(232) "What's new in control standards". H.L. Mason. Control Eng. (USA), vol.26, no.9, p.77-80 (Sept. 1979).

(233) "Flexibly automated production plants". G. Vettin. VDI Z. (Germany), vol.121, no.3, p.83-95 (Feb. 1979). In German.

(234) "The provision of automatic tools for flexible manufacturing systems". P. Hopp. Ind.-Anz. (Germany), vol.101,

no.61, p.20-1 (1 Aug., 1979). In German.

(235) "Flexible assembly systems for different cores in electric machines and transformers". K. Feldmann, K.-G. Gunther, R.-P. Hartmann. Ann. CIRP (GB), vol.28, no.1, p.403-6 (1979). In German.

(236) "Flexible manufacturing systems in the United States". G.K. Hutchinson. Proc. of the 1979 Joint Automatic Control Conf., Denver, CO., USA, 17-21 June 1979 (New York, USA: American Inst. Chem. Engrs. 1979), p.743-9.

(237) "Material flow control in flexible production systems by use of process computers". R. Junemann, J. Kremser. Angew. Inf. (Germany), vol. 21, no.12, p.521-4 (Dec. 1979). In German.

(238) "Computer aided part manufacturing". O. Bjorke. Comput. Ind. (Netherlands), vol.1, no.1, p.3-9 (July 1979).

(239) "Flexible manufacturing systems, digital controls, and the automatic factory". S.J. Bailey, K. Pluhar. Control Eng. (USA), vol.26, no.9, p.59-64 (Sept. 1979).

(240) "Control of tooling in manufacture". U.W. Geitner. ZWF Z. Wirtsch. Fertigung (Germany), vol.74, no.4, p.166-9 (April 1979). In German.

(241) "No system looping!". V Shiff, R. Parr. Electron (GB), no.158, p.41 (12 Dec. 1978).

(242) "Avoid plant computer problems with proper power and ground wiring". R.I. Heider. InTech (USA), vol.27, no.4, p.34-8 (April 1980).

(243) "Design of computer control for manufacturing systems". Y. Koren. Trans. ASME. J. Eng. Ind. (USA), vol.101, no.3, p.326-32 (Aug. 1979).

(244) "Study of the prospects of production systems and processes". B. Colding, L.V. Colwell, D.N. Smith. Werkstatt & Betr. (Germany), vol.112, no.5, p.289-94 (May 1979). In German.

(245) "New methods of production from the point of view of work study". H.J. Warnecke, H.J. Bullinger. ZWF Z. Wirtsch. Fertigung (Germany), vol.74, no.6, p.282-90 (June 1979). In German.

(246) "Investigation of the computer aided classification of parts". J. Peklenik, J. Grum. Ann. CIRP (Switzerland), vol.29, no.1, p.319-23 (1980).

(247) "Automated wafer production [for LSI logic circuits]". Ning-Gau Wu. 1980 IEEE International Solid-State Circuits Conf. Digest of Technical Papers, Philadelphia, PA., USA, 13-15 Feb. 1980 (New York, USA: IEEE 1980), p.208-9.

(248) "Interactive graphical CAD/CAM in an engineering environment". W.S. Elliott. Proc. of the Internat. Conf. Interactive Techniques in Computer Aided Design, Bologna, Italy, 21-23 Sept. 1978 (New York, USA: IEEE 1978), p.452-8.

(249) "Scheduling policies for automatic warehousing systems: simulation results". L.B. Schwarz, S.C. Graves, W.H. Hausman. AIIE Trans. (USA), vol.10, no.3, p.260-70 (Sept. 1978).

(250) "The design and implementation of computer systems for small manufacturing companies." D.J. Rhodes. Comput. & People (USA), vol.29, no.5-6, p.16-19 (May-June 1980).

(251) "Model-driven vision for industrial automation". L. Lieberman. Advances in Digital Image Processing. Theory, Application, Implementation. Bad Neuenahr, Germany, 26-28 Sept. 1978

(New York, USA: Plenum 1979), p.235-46.

(252) "Flexible work handling and machine linking with gantry and pallet systems". F. Wiesner. Werkstatt &, Betr. (Germany), vol.113, no.3, p.159-65 (March 1980). In German.

SECTION 15

SOCIAL IMPLICATIONS OF CAD/CAM

(253) "Some social effects of computerisation". M.J.L. Cooley. In book: Man/-computer communication, state of the art report, p.53-70. Maidenhead, England: Infotech (1979), viii + 718 pp.

(254) "Robotics and society". J.F. Engelberger. Current Topics in Cybernetics and Systems (papers in summary form only received), Amsterdam, Netherlands, 21-25 Aug. 1978 (Berlin, Germany: Springer-Verlag 1978), p.23-7.

(255) "Automated office. The road to disaster?". P.H. Dorn. Datamation (USA), vol.24, no.12, p.154-6, 162 (15 Nov. 1978).

(256) "The changing life of engineers". J.F. Young, L.C. Harriott. Mech. Eng. (USA), vol.101, no.1, p.20-4 (Jan. 1979).

(257) "You can teach an old dog new tricks [computer based manufacture]". B. Kellock. Mach. & Prod. Eng. (GB), vol.134, no.3456, p.25-7 (4 April 1979).

(258) "Social implications of automation". P. Senker. Ind. Robot. (GB), vol.6, no.2, p.59-61 (1979).

(259) "Microelectronics and society". J. van Kasteren. Ingenieur (Netherlands), vol.91, no.51-52, p.891-4 (20 Dec. 1979). In Dutch.

(260) "Automation in the 1980s. Opportunity or threat?". P.G. Rogge. Output (Switzerland), vol.9, no.1, p.13-18 (15 Jan. 1980). In German.

(261) "How companies are preparing for change". EDP Anal. (USA), vol.18, no.2, p.1-13 (Feb. 1980).

(262) "The Introduction of CAD/CAM Systems and Their Employment Implications". S.G. Peitchinis. University of Calgary, 1980. Available from: Technological Innovation Studies Program, Technology Branch, Dept. of Industry, Trade and Commerce, Ottawa.

SECTION 16

CAD/CAM APPLICATIONS

a. Automotive Industry

(263) "'Current trends in on-line production control systems in the automotive industries'". R.W. Yeomans. Colloquium on Production Scheduling and Control Systems, London, England, 8 Nov. 1979 (London, England:IEE 1979), p.2/1-3.

(264) "Computer vision classification of automotive control arm bushings". W.A. Perkins. Proc. of COMPSAC the IEEE Computer Society's Third Internat. Computer Software and Applications Conf., Chicago, IL., USA, 6-8 Nov. 1979 (New York, USA: IEEE 1979), p.344-9.

(265) "Adding a human touch to auto assembly". A. Astrop. Mach. & Prod. Eng. (GB), vol.136, no.3517, p.51-3 (18 June 1980).

(266) "British Leyland banks on robots". A. Astrop. Mach. & Prod. Eng. (GB), vol.136, no.3516, p.39-40 (11 June 1980).

(267) "Assembly line control models in automotive industry". J. Hampl, P. Skvor. Information-Control problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.367-72.

(268) "Auto plants pick robots for some of toughest jobs". J. Koekebakker. Canadian machinery & metalworking, May 1980.

(269) "Truck factory under computer control". B. Prescott. New Electron. (GB), vol.12, no.24, p.80, 82-3 (Dec. 1979).

(270) "A showcase for material handling and control revisited". W. Mertle. Mater. Handl. Eng. (USA), vol.35, no.1, p.68-71 (Jan. 1980).

(271) "Progress in computer-aided production control and quality assurance". W. Neifer. ZWF Z. Wirtsch. Fertigung (Germany), vol.74, no.8, p.380-4 (Aug. 1979). In German.

(272) "How Volkswagen learned to love the robot [spot welding]". F. Weissgerber. Weld. & Met. Fabr. (GB), no.2, p.91-2, 94-5 (March 1980).

b. Machinery & Equipment Manufacturing

(273) "The possibilities and limitations of automated production methods". Ind.-Anz. (Germany), vol.100, no.73, p.38-44 (13 Sept. 1978). In German.

(274) "Semi-automatic camshaft inspection equipment". D. Smyth. Metrol. & Insp. (GB), vol.10, no.6, p.23-4 Nov. 1978).

(275) "Automatic designing and drafting system of elevators (MELDAC system)". C. Mitsuya. Rep. Stat. Appl. Res. UJSE (Japan), vol.24, no.2, p.18-27 (June 1977).

(276) "Computer-aided design, drawing and manufacturing system for dies and molds". T. Mori, M.Yasuda. Natl. Tech. Rep. (Japan), vol.24, no.5, p.1046-56 (Dec. 1978). In Japanese.

(277) "Computer-aided design of injection moulding tools". W. Eversheim, G. Bruninghaus. Ind.-Anz. (Germany), Vol.101, no.37, p.39-43 (9 May 1979). In German.

(278) "Some big fans for CNC lathes". G. Mason. Mach. & Prod. Eng. (GB), vol.134, no.3466, p.47-8 (13 June 1979).

(279) "Innovative assembly line uses computer controlled carriers". Ind. Eng. (USA), vol.11, no.5, p.44-5 (May 1979).

(280) "Computer-designed gearing". R.P. Wadlington, F. Hirschfeld. Mech. Eng. (USA), vol.101, no.6, p.32-3 (June 1979).

(281) "Gear-tooth generation with interactive graphics". P. Cooley. Comput. Aided Des. (GB), vol.11, no.6, p.353-7 (Nov. 1979).

(282) "Optimal die stock control at Firth Vickers foundry". R. Beatson. J. Oper. Res. Soc. (GB), vol.30, no.12, p.1077-84 (Dec. 1979).

(283) "Impeller machining proves CAD/CAM in production". L. Brown, J.C. Plucinsky. Canadian machinery & metal working, Oct. 1979.

(284) "Automatic control by microprocessor of a machine for fabricating spiral tubes". P. Sente, J. Janss. Electron. & Appl. Ind. (France), no.275, p.47-8 (1 Nov. 1979). In French.

c. Aerospace Industry

(285) "ICAM - foundation for next generation factories". D.E. Wisnosky. Ind. Eng.

(USA), vol.11, no.4, p.38-45 (April 1979).

(286) "Stretch forming comes of age". Tool. & Prod. (USA), vol.45, no.10, p.70-2 (Jan. 1980).

(see also references 7, 8, 14, 30)

d. Electrical & Electronics Industry

(287) "CAD system for VLSI". W. Wiemann. 16th design automation conference proc., San Diego, CA., USA, 25-27 June 1979 (New York, USA: IEEE 1979), p.550.

(288) "Can CAD meet the VLSI design problems of the 80s?". D. Gibson. 16th design automation conference proc., San Diego, CA., USA, 25-27 June 1979 (New York, USA: IEEE 1979), p. 543.

(289) "Computer-aided design for integrated circuits: trying to bridge the gap". H.J. De Man. IEEE J. Solid-State Circuits (USA), p.613-21 (June 1979). (Fourth European Solid State Circuits Conf., Amsterdam, Netherlands, 18-21 Sept. 1978).

(290) "Computer aided design. The problem of the 80s microprocessor design". B. Lattin. Computer-Aided Design of Digital Electronic Circuits and Systems, Brussels, Belgium, Nov. 1978 (Amsterdam, Netherlands: North-Holland 1979), p.169-71.

(291) "European community study on CAD of digital circuits and systems". A. De Mari. Proc. of the Internat. Conf. Interactive Techniques in Computer Aided Design, Bologna, Italy, 21-23 Sept. 1978 (New York, USA: IEEE 1978), p.411-21.

(292) "An experienced input system of hand-drawn logic circuit diagram for LSI CAD". M. Ishii, M. Yamamoto, M. Iwasaki, H. Shiraishi. 16th design automation conf. proc., San Diego, CA., USA, 25-27 June 1979 (New York, USA: IEEE 1979), p.114-20.

(293) "Computer-aided design of LSI circuit". C. Niessen. Philips Tech. Rev. (Netherlands), vol.37, no.11-12, p.278-90 (1977).

(294) "Business economic aspects on CAD/CAM-systems for electronic PCB, wiring and back plane". Report IVF-ResIVF-Resultat-7845, Inst. Verkstadsteknisk Forskning, Gothenburg, Sweden (Feb. 1979), 22 pp. In Swedish.

(295) "PC board layout techniques". D.R. Johnson. 16th design automation conf. proc., San Diego, CA., USA, 25-27 June 1979 (New York, USA: IEEE 1979), p.337-43.

(296) "PCB design and the computer". R. Larson. Circuits Manuf. (USA), vol.19, no.5, p.20, 22, 24-8 (May 1979).

(297) "Computer-aided design of printed wiring boards". M.H. Asghar, R.D. Wrigley. Western Electric Eng. (USA), vol.23, no.4, p.54-61 (Oct. 1979).

(298) "GAELIC - an integrated circuit design system". D.J. Lawrence. Engineering Software, Southampton, England, Sept. 1979 (London, England: Pentech 1979), p.550-6.

(299) "Applying computer aided design [to printed circuit boards]". C. Walter. Electron. Prod. (GB), vol.8, no.9, p.19, 21, 23 (Sept. 1979).

(300) "Improving automatic component insertion operations". I.Generating punched-paper-tape programs automatically". T.B. Long, Jr. Western Electric Eng. (USA), vol.23, no.1, p.24-8 (Jan. 1979).

(301) "Improving automatic component insertion operations. II.Minimizing sequencing machine set-up time". T.B. Long, Jr. Western Electric Eng. (USA), vol.23, no.1, p.29-32 (Jan. 1979).

(302) "Apparatus for testing, sorting and taping axially leaded devices". D.W. Hildner, W.N. Holmes, E.Y. Tang. Tech. Dig. (USA), no.53, p.9-10 (Jan. 1979).

(303) "Automation increased by capacitors makers". AEU (Japan), p.92, 94, 96 (April 1980).

(304) "Application of a process control computer for positioning of screens in colour picture tubes". A. Arth. Mess. & Pruef. (Germany), no.10, p.762-4, 790 (Oct. 1979). In German.

(305) "Testing of LSI-printed boards". B. Pohlmann, D. Giesbrecht. Mess. & Pruef. (Germany), no.3, p.117-20 (March 1979). In German.

(306) "Features of an automatic component - insertion layout". S.R. Ruppertsberg. Elektron. Anz. (Germany), vol.11, no.1, p.46-7 (Jan. 1979). In German.

(307) "Applications of pattern recognition to industrial inspection". T. Pavlidis. 197 Joint Automatic Control Conf., Pt.II, Philadelphia, PA., USA, 15-20 Oct. 1978 (Pittsburgh, PA., USA: ISA 1978), p.159-63.

(308) "Optimizing the Production of Electronic Designs". K. Blais, W. Clipsham, D. Pearson. Telesis, Dec. 1978.

(309) "Computer aided manufacturing in the Philips-Tessenderlo production plant". R.J. Goffin, G.J. Wegler. J. A (Belgium), vol.20, no.4, p.209-12 (Oct. 1979).

(310) "Electrostatic plotters in CAD of ICs". B. Boffin. Electron Ind. (GB), vol.6, no.5, p.65, 67 (May 1980).

e. Food and Beverage Industry

(311) "Automating a food canning line". R. Pleau. Instrum. & Control Syst. (USA), vol.51, no.7, p.39-44 (July 1978).

f. Chemical and Plastics Industry

(312) "Role of computers in production planning and control for plastics products manufacturing". A. Hammond, A.K. Kochhar. Plast. & Rubber Process. (GB), vol.3, no.2, p.52-6 (June 1978).

(313) "The microcomputer in plastics processing". E. Schwab, H. Kiel, G. Wiegand. Electrotechnik (Germany), vol.61, no.8, p.14, 16, 18 (27 April 1979). In German.

(314) "A case study of NC application in a medium sized Hong Kong factory". W.S. Lau, K.P. Pau. Hong Kong Eng., vol.6, no.10, p.39-43 (Oct. 1978).

(315) "Hydraulic injection moulding machines with full electronic microprocessor control". G. Dolker. Maschinenmarkt (Germany), vol.85, no.38, p.733-5 11 May 1979). In German.

(316) "Multi pressures control injection molding press". F.A. Rose. Hydraul. & Pneum. (USA), vol.33, no.7, p.93-6 (July 1980).

(317) "Production in molding". Plastics World, Sept. 1980.

(318) "An automatically adjusted, micro-computer controlled injection moulding machine". W. Bongardt, K.W. Plessmann, G. Menges.

Kunstst.-Berat. (Germany), vol.25, no.1-2, p.31-3 (Jan.-Feb. 1980). In German.

g. Architecture, Building Design, Construction and Civil Engineering

(319) "Teaching computer aided design in a school of architecture". B. Forwood. Comput. & Educ. (GB), vol.3, no.1, p.1-5 (1979).

(320) "Analysis in architectural design". A.H. Bridges. PARC 79, International Conference on the Application of Computers in Architecture, Building Design and Urban Planning, Berlin, Germany, 7-10 May 1979 (Uxbridge, England: Online 1979) p.175-85.

(321) "The incorporation of an ARK 2 computer aided design system into an architect's practice in England". P.G.Hughes. PARC 79. International Conference on the Application of Computers in Architecture, Building Design and Urban Planning, Berlin, Germany. 7-10 May 1979 (Uxbridge, England: Online 1979), p.145-52.

(322) "Dynamic 3-d modelling for architectural design". G.Rogers. PARC 79. International Conference on the Application of Computers on the Application of Computers in Architecture, Building Design and Urban Planning, Berlin, Germany. 7-10 May 1979 (Uxbridge, England: Online 1979), p.77-91.

(323) "Computer aided housing and site layout design: experience of research software in use in a production environment". A.Biji. PARC 79. International Conference on the Application of Computers in Architecture, Building Design and Urban Planning, Berlin, Germany, 7-10 May 1979 (Uxbridge, England: Online 1979), p.283-92.

(324) "Computer-aided design in industrial residential construction". A.Kociolek, A.Radwanski. PARC 79. International Conference on the Application of Computers in Architecture, Building Design and Urban Planning, Berlin, Germany, 7-10 May 1979 (Uxbridge, England: Online 1979), p.1-11.

(325) "Automatic design of structural steelwork." W.R.Laxon, D.H.Mountford, K.H.Malby, B.T.Shuttleworth. Comput. Aided Des. (GB), vol.12, no.1, p.35-42 (Jan 1980).

(326) "Computer Analysis of duct systems". B.Hutt. Heat. & Air Cond. J. (GB)' vol.49, no.573, p.12, 14, 16 (Oct. 1979).

(327) "Somel system: computer aids for the fabrication of structural steel." G.K.Raven. Comput. Aided Des. (GB), vol.11, no.6, p.342-7 (Nov. 1979).

(328) "Standardized structural steel detailing on an automated drafting system". A.Firkins, D.P.Hall. Australian Conference on Computer Graphics and Spatial Analysis, Adelaide, Australia, 13-15 Aug. 1979 (Barton, Australia: Instn. Engrs. Australia 1979), p.6-11.

(329) "Computer aided duct sizing". B.Hutt. Heat. & Air Cond. J. (GB), vol.49, p.10-12 (Aug. 1979).

(330) "Computer-aided structural design of buildings: state of a Canadian Industry". G.A. Hartley, D.J. Carson. Engineering Software, Southampton, England, Sept. 1979 (London, England: Pentech 1979), p.443-55.

h. Automated Warehousing & Distribution

(331) "New distribution system for ball and roller bearing products". H.Lorenz, J.Miebach, G.Drescher. Foerdern & Heben (Germany), vol.28, no.10, p.663-7 (Sept. 1978). In German.

(332) "Maytag's work-in-process storage system brings it all together". R.Betz. Mater. Handl. Eng. (USA), vol.33, no.7, p.38-43 (July 1978).

(333) "Order-picking controls mechanical warehousing". F.Gremm. Foerdern & Heben (Germany), vol.29, no.1, p.17-19 (Jan 1979). In German.

(334) "Almost an ultimate in dispatching a lift truck fleet (computerised truck dispatching)". J.C. Penney. Mod. Mater. Handl. (USA), vol.33, p.72-7 (Dec. 1978).

(335) "Order handling and stock control for the sale of spare parts with the help of the small computer Robotron 4200/4201". W.Franke. Neue Tech. Buero (Germany), vol.22, no.5, p.129-31 (Sept.-Oct. 1978).

(336) "Shipping system improves efficiency". Comput. Decis. (USA), vol.10, no.10, p.64 (Oct. 1978).

(337) "An exemplary design for management and automatic control of a pharmaceutical warehouse". J.-P.Bourbon. Autom. & Inf. Ind. (France), no.72, p.51-4 (Dec. 1978). In French.

(338) "Warehousing, automation, data processing, today, tomorrow". G.Coppel. Tech. Mod. (France), vol.70, no.11, p.21-5 (Nov. 1978). In French.

(339) "Process computers control high-bay warehouse". H.Pankert, U.Vaihinger. Foerdern & Heben (Germany), vol.29, no.3, p.186-7 (March 1979). In German.

(340) "Hong Kong ahead in computer use". G. Workman. Comput. & Oper. Res. (GB), vol.6, no.2, p.113-15 (1979).

(341) "Pharmaceutical manufacturer turns to AS/RS for total product control". R. Derven. Mater. Handl. Eng. (USA), vol.34, no.6, p.48-53 (June 1979).

(342) "Radio-controlled warehouse and conveying system supplies metal cutting manufacture". G.Handke, P.Beumer. Foerdern & Heben (Germany), vol.29, no.7, p.611-16 (July 1979). In German.

(343) "Computer-controlled order-picking store for spare parts". Foerdern & Heben (Germany), vol.30, no.2, p.123-5 (Feb. 1980). In German.

(344) "Automated factory production goods distribution center". H. Takei, N.Tanji. J.Tsuda, T.Tabuchi, K.Takahara, N.Oda, M.Itoh. Toshiba Rev. (Int. Ed.) (Japan), No.125, p.18-23 (Jan.Feb. 1980).

(345) "Destination control in a moving-pallet system". W.Rossner, W.Friedrich. Ind.-Anz. (Germany), vol.101, no.101, p.22-3 (19 Dec. 1979). In German.

(346) "Range of application of automatic classification and conveyor systems". K.Weiss. Ind.-Anz. (Germany), vol.101, no.101, p.24-5 (19 Dec. 1979). In German.

i. Other

(347) "Glass cutting in a small firm". O.B.G.Madsen. Math. Program. (Netherlands), vol.17, no.1, p.85-90 (July 1979).

(348) "Computers control and test processes in entire pharmaceutical tablet manufacturing facility". Comput. Des. (USA), vol.18, no.5, p.70, 74-8 (May 1979).

(349) "Quality control of textile color by minicomputer/microcomputer". A.D.Darby, Jr., J.N. Gowdy, M.L.Wolla. Proceedings of Southeastcon 1979, Roanoke, VA, USA, 1-4 April 1979 (New York, USA: IEEE 1979), p.329-32.

(350) "On-line color measurement system". T.K.Drake, J.L.Dorrity. Proceedings of Southeastcon 1979, Roanoke, VA, USA, 1-4 April 1979 (New York, USA: IEEE 1979), p.327-8.

(351) "Computer controls for automation of the dye house and drug room". R.L.Gaertner, A.C. Lineberger. IEEE 1979 Annual Textile Industry, Technical Conference, Charlotte, N.C. USA. 2-3 May 1979 (New York, USA: IEEE 1979), p.1-6.

(352) "A microprocessor based cut to length system as applied to a corrugator board machine cutoff". R.P.Veres. IEEE Conference Record of the 1979 Annual Pulp and Paper Industry Technical Conference, Pittsburg, PA, USA, 15-18 May 1979 (New York, USA: IEE 1979), p.98-105.

(353) "Fully computerized wide-flange beam mill and finishing line". N.Shimamura, H.Nishimura, K.Saito, A.Asanuma, A.Maeda. Iron & Steel Eng. (USA), vol.55, no.12, p.35-41 (Dec. 1978).

(354) "Computer-based product analysis preparation for distributed data processing". M.K.Bonner. Am. Lab. (USA), vol.11, no.2, p.33-8, 40-1 (Feb. 1979).

(355) "Process control: batch process automation." R.J.Thome, M.W.Cline, J.A. Grillo. CEP (Chem. Eng. Prog.) (USA), vol.75, no.5, p.54-60 (May 1979).

(356) "CAD/CAM in the Glass Industry". H.J.Kleiner. Design Engineering. Feb. 1980.

(357) "A Printing Press Order Sequencing Aid". A.W.Chan. National Research Council Computers Newsletter. Jan. 1978.

(358) "Computer Grading & Marker making Service Bureau established at Ontario Research Foundation". Canadian Apparel Manufacturer. Sept. 1979.

(359) "Painting by numbers-that's flexibility". D.Potts. Mach. & Prod. Eng. (GB), vol.135, no.3488, p.41-4 (21 Nov. 1979).

(360) "Management Information systems for shipyards in the 80's". B.B.Lindberg. Computer Applications in the Automation of Shipyard Operation and Ship Design, III, Glasgow, Scotland, 18-21 June 1979 (Amsterdam, Netherlands: North-Holland 1979), p.223-6.

(361) "DICON-computer design aids nuclear installations". G.T.Davis. Can. Electron. Eng. (Canada), vol.23, no.6, p.21-4 (June 1979).

(362) "CAD/CAM system for sheet metal structural parts-development and implementation". N.Kurochi, M. Shimozono, M.Okada, T.Watanabe, N.Okino. Bull. Jpn. Soc. Precis. Eng. (Japan), vol.13, no.3, p.111-16 (Sept. 1979).

(363) "Integrated computer aided design and ship production systems". H.Arnold, R.Brunner, J.Blackshaw. Computer Applications in the Automation of

Shipyard Operation and Ship Design, III, Glasgow, Scotland, 18-21 June 1979 (Amsterdam, Netherland North-Holland 1979), p.205-12.

SECTION 17

MAJOR AND NATIONAL PROGRAMS

a. Germany

(364) "Automation research in Germany and its role regarding national productivity". U.Rembold, I.Bey. Information-Control Problems in Manufacturing Technology, Tokyo, Japan. 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.297-304.

(365) "Major projects on control systems for discrete parts manufacturing in the Federal Republic of Germany". I.Bey. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.331-8.

b. Japan

(366) "Conceptual design of integrated production center". F.Honda, H. Takeyama. Information-Control Problems in Manufacturing Technology, Tokyo, Japan. 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.7-13.

(367) "Japanese throw light on hands-off factory (unmanned manufacturing). D.Potts. Mach. & Prod. Eng. (GB), vol.134, no.3445, p.22-3 (17 Jan. 1979).

(368) "Factory of the future is no place for man (remote computer control). A.Astrop. Mach. & Prod. Eng. (GB). Vol.135, no.3488, p.23-6 (21 Nov. 1979).

c. U.S.A.

(369) "Removing barriers to the application of automation in discrete part batch manufacturing". J.M.Evans. Information-Control Problems in Manufacturing Technology, Tokyo, Japan, 17-20 Oct. 1977 (Oxford, England: Pergamon 1978), p.293-6.

(370) "ICAM-foundation for next generation factories. D.E.Wisnosky. Ind. Eng. (USA), vol.11, no.4, p.38-45 (April 1979).

(371) "Need software? Ask Uncle Sam! NTIS - a valuable resource. M.S. Day. Data Manager. (U.S.A.) vol.17, no.4, p.40 - 42 (April 1979)

d. U.K.

(372) "The use of computers and analytical techniques for production planning and control in the British manufacturing industry." A.K. Kochhar Comput. & Ind. Eng. (GB), vol.2, no.4, p.163-79 (1978).

(373) "Education and training for CAD-an industrial viewpoint." E.A. Warman, F.J.Reader. Comput. & Graphics (GB), vol.4, no.1, p.1-4 (1979).

(374) "Mapping a future for industry (microprocessor application project). S.Hardcastle. Data Processing (GB), vol.21, no.3, p.23-4 (March 1979).

(375) "Britain must make ground in robot automation (electricity in industry." G.W.Bryce. Electr. Rev. (GB), vol.205, no.6, p.19-20 (17 Aug. 1979).

(376) "Overseas news: Success of numerical control." A.Fryatt. Rev. Polytech (Switzerland), no.4, p.347-9 (25 April 1978). In French.

e. Other

(377) "Survey of CAD applications in Italy." M.Bonatti. Proceeding of the International Conference Interactive Techniques in Computer Aided Design, Bologna, Italy, 21-23 Sept. 1978 (New York, USA: IEEE 1978). p.423-51.

(378) "Computer usage by small and medium sized European firms: an empirical study." L.D.Neidleman. Inf. & Manage (Netherlands), vol.2, no.2, p.67-77 (May 1979).

(379) "Status and prospects of robotics in the Soviet Union." E.I.Yurevich. Mach. & Tool. (GB), vol.49, no.8, p.3-5 (1978). Translation of: Stanki & Instrum. (USR), no.8, p.3-5 (1978).

(380) "Software training: a race with time." C.A.Zehnder. Bull. Assoc. Suisse Electr. (Switzerland), vol.71, no.11, p.574-6 (7 June 1980). In German.

(381) "A Study to Identify the Attitudes and Awareness of Numerical Control Users to CAD/CAM Technology." J.E.Crozier, Canadian Institute of Metalworking, McMaster University 1980. Available from, Technological Innovation Studies Program, Technology Branch, Dept. of Industry, Trade and Commerce, Ottawa.