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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
VIENNA

THE ESTABLISHMENT OF THE MACHINE TOOL DESIGN AND DEVELOPMENT CENTRE IN INDONESIA

Project No. DP/INS/88/030
Contract No. 91/119

FINAL REPORT

VOLUME I

Polytechna Ltd., Prague
The Czech Republic

Báňské projekty Ltd., Ostrava
The Czech Republic

FEBRUARY 1994

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LIST OF ABBREVIATIONS

Besides the common abbreviations, symbols and terms, the following have been used in this report:

MTDDC	The Machine Tool Design and Development Centre in Indonesia - Jakarta
ASIMPI	The Association of Machine Tools Producers of Indonesia
DOI	The Ministry of Industry of Indonesia
BAPPENAS	The Board of Planning of Indonesia
UI	The University of Indonesia - Jakarta
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CIM	Computer Integrated Manufacturing
NC	Numeric Control (of Machine Tools)
CNC	Computer Numeric Control (of Machine Tools)
QMS	Quality Management System
ISO	International Standard Organization
FA	Factory Automation
FMS	Flexible Manufacturing System
MC	Machining Center

REPORT

1. EXECUTIVE SUMMARY

The main features of the project implementation give a brief description of its course and achieved results:

1. The project idea was quite right.
2. The project references were worked out on a retrospective base but a forecasting view on the development of the Indonesian industry could not have been exactly defined.
3. It was in fact impossible to forecast a future world-wide economic recession in the 90s of this century.
4. The above-mentioned recession has had a bad influence on the machine tool manufacturing industry of the Indonesian Republic too.
5. All that caused a necessity to add the project objectives, as described in the first Progress Report of the first field mission.
6. In accordance with goals agreed by UNIDO authorities, wishes of the Board of Founders and requirements of Ministry of Industry of Indonesia contents and implementation of a training programme for the MTDDC staff were adopted.
7. For the above-mentioned reasons, supplementary aims were joined to the basic project objectives as follows:
    - methods of machine tool utilization
    - consultancy of quality management systems according to the ISO 9000 standard series
    - automotive industry services
    - feasibility study preparation and working out
    - educational programme (lectures, seminars, courses)

8. The absence of any executive foundation for the MTDDC processing was a big obstacle.
9. This fact led the MTDDC management to a continuous battle to survive its position. The first contracts concluded by industrial companies and institutions and the MTDDC National Director helped the MTDDC activity to spread and continue after the project dead line - October 1993.
10. All the Czech institutions taking part in the project implementation are ready to continue their co-operation with the MTDDC.
11. The subcontractor's experts helped in all MTDDC activities as follows:
    - to recognize the real Indonesian machinery industry situation
    - to make the partial transformation of the MTDDC objectives
    - to arrange such international contacts for future co-operation
    - to train the MTDDC staff according to the initial and additional aims of education
    - to create technical documentation for the first contacts with customers and activities on the contractual base
    - to provide technical lectures from the area of production planning, technological development, automation, and European and world-wide tendency of machine tools improvement for the technical staff of famous Indonesian machinery factories, and partially for students of the Technical Faculty of the University of Indonesia.
12. It can be declared that the MTDDC in Indonesia has been established in accordance with the UNDP/UNIDO project with the assistance of the Department of Industry of the Indonesian Republic and that this institution has all the conditions, and framework,

for the development of the services necessary for the Indonesian machinery industry. However, it would be both useful and significant to provide the MTDDC with a government grant for the first two or three years of independent activity.

2. PROJECT BACKGROUND AND HISTORY

2.1 History of the Project

The Project No. DP/INS/88/030 titled "The Establishment of a Machine Tool Design and Development Centre (M.T.D.D.C) was undertaken by UNIDO/UNDP and the Government of the Indonesian Republic to make necessary support for the developing local machine tool and metal working industries. The idea was first proposed in 1988.

At this time the metal working industry in Indonesia was based mainly on assembly operations in areas of higher product sophistication from workpieces and components imported from collaborating companies of advanced countries. A certain part of workpieces was manufactured by local producers who were the main users of machine tools. The machine tool industry in Indonesia was in its initial stage.

There were 16 companies which have been licensed by the Government of the Indonesia Republic as manufacturers of machine tools. A majority of these manufacturers was associated in the "Indonesian Machine Tool Industries Association - ASIMPI. The following 3 companies were so significant that they could become leading local machine tools manufacturers:
P.T. PINDAD in Bandung
P.T. PIMSF Jokro in Pulogadun
P.T. IMPI in Cilegon.

The remaining 13 licensed machine tool manufacturers used poor technologies and could not be a base for the development of local machine tool manufacturing. The types of machines assembled at that time were required more for training in technical schools than for maintenance and repairs. It was estimated that the Indonesian machine tool production was 50 per cent of the whole volume, and the rest consisted of imported parts, workpieces and components.

The import value of machine tools was about 60 mil USD per year in the second half of the eighties. The best example of the growth of machine tools manufacturing is the establishment of P.T. IMPI in 1983 collaborating with Mondiale Company of Belgium. It assembled comparatively simple lathes of "Celtic" type with centre height 185 mm and maximum length in centre distance 1500 mm. The main components: spindle, feedscrew, tailstock, headstock, etc. were imported from Belgium.

All the above mentioned factors proved a great need to establish a national design and development centre as a place of future independent designing of machine tools for consulting of metal cutting technology implementation and tools, jigs, fixtures and machine tools design.

These facts created a base for UNIDO Vienna headquarters and the Government of Indonesia to arrange an agreement to submit a tender for sub-contracting services for the implementation of the above-mentioned project. The Government Implementing Agency was the Ministry of Industry of the Indonesian Republic (DOI of IR).

2.2 Objectives

Expected outputs of the project according to the "Terms of reference for sub-contracting services" are as follows:

- Required activities of the operational Production Engineering Department of MTDDC

1. Consulting the metal cutting technology (selection of feeds and speeds for different types of cutting tools and materials related to the different metal cutting processes)
2. Establishment of a metal cutting technology data bank for all major metal cutting processes
3. Capability for production planning and controlling of machining processes and operations required in the metal working industry
4. Provision of extension services in production engineering technology to the industry
5. Provision of extension services in tool and jigs and fixtures design

- Required activities of the operational Machine Tool Design and Adaptation Department of MTDDC:

6. Capability for designing and adapting designs for conventional metal cutting machine tools (lathes, milling machines, drilling machines)
7. Supplying designs to local machine tool manufacturers
8. Testing procedures for machine tool manufacturers
9. Provision of extension services to the machine tool and metalworking industry

The project objectives described above were considered as initial tasks for field missions.

2.3 Executors of the Project

The project proposal worked out in response to UNIDO request No. P 90/75 was prepared by the following Czech institutions:

1. POLYTECHNA Technical Co-operation Agency
2. BANSKE PROJEKTY OSTRAVA, consulting and engineering centre
3. INPRO-BRANCH INSTITUTE, Prague, technical and educational centre
4. OSTROJ OPAVA, machinery works
5. ZPS ZLIN, machine tools producer
6. TOS KURIM, machine tools producer

During the project execution the above-mentioned institutions joined with other very important Czech companies to spread the capability of field team members and to utilize their experience of added areas of the MTDDC activities:

7. VUOSO, design institute of metal cutting technologies

8. CVUT Prague, the Technical University
9. INSPEKTA Prague, consulting centre for ISO 9 000 standard series implementation

The leading company of the project proposal preparation, training arrangement of the MTDDC staff and support of the MTDDC executive activities was POLYTECHNA Prague as a sub-contractor body.

3. PRESENT POSITION OF THE INDONESIAN MACHINERY INDUSTRY

3.1 General Description

The machinery industry sector in Indonesia has developed remarkably over the last ten years. From making simple machine parts the industry has progressed to building precise machines and equipment such as conventional machine tools (Celtic 14 lathe of IMPI Cilegon) to CNC machine tools (MC07-PF machining centre of PINDAD-FANUC Bandung). This growth has been conditioned by the inflow of capital investments from multi-national engineering companies. Access to this inflow of technology and expertise has created conditions conducive for the growth of the base of local machinery builders. With the acquisition of greater skills and technological experience, local machinery manufacturing companies are now able to fabricate more precise and complicated machines and equipment.

At the same time The Indonesian market is occupied by very skilled machinery producers from Japan, Taiwan, Singapore, South Korea, HongKong and other advanced countries on one side and on the other side it is flooded by a cheap machinery equipment from China and other developing countries. This has created very strong competitive pressure from those foreign producers upon local manufacturing companies. Regardless of the above-mentioned growth of capabilities the Indonesian machinery industry has lost a great part of its domestic machinery market. This can be considered a result of the world-wide recession of national economies of the majority of countries in the nineties too.

This general description can be elaborated upon with reference to the experience received during the visit of subcontractor's experts in several machinery companies in Indonesia. These visits to Indonesian factories were arranged to gain a general idea of the factories' performance, their effectiveness, and the level of production facilities used for operation. The state-owned and private companies visited by experts, were to represent typical samples of a higher technical level with medium or large size manufacturing from private and state sectors in Indonesia, all active in small and medium batch production. All factories visited represent a very good technical level and create not only new jobs for the Indonesian economy but influence positively all the factories in the surroundings of the region.

The basic problem of state-owned factories is that there is a low demand for their products. Factories were planned for higher annual production but their real production is only a small portion of their capacity. That means that the marketing activity to find better and available products for the transformation of production programmes is of greater significance. The position of private factories in that field is better now, but they need support by means of higher machine tool utilization and modern control system implementation, including quality management systems. Those factors make a sound base for economic growth.

3.2 Strategy of Development

The strategy of the Government of the Indonesian Republic in the development of the national economy in contemporary conditions is to support the growth of energy production, extraction of energetic resources, agricultural production and last but not least, the growth of the machinery industry through the implementation of highly advanced technology. But this approach is based on the assumption of optimum choice of machinery production sectors regarding the interest of national economy.

In accordance with this viewpoint the government interest is to increase and to develop local machinery industry in the field of manufacturing of workpieces, spare parts and components for trucks and personal cars. To this end, a special order was passed by the Ministry of Industry to raise the share of local industry in parts production.

The same can be said about the government interest to increase the export ability of the Indonesian machinery industry.

One of the ways to reach this objective is the wide application of QMS certification according to ISO 9000 standards in production companies. The procedure of certification needs a comparatively long period of company preparation for QMS implementation. This movement is supported by the significant order of the Ministry of Finance and the Ministry of Trade on the preparation of 50 famous state-owned production companies for QMS certification.

The most important step by the government since the first half of 1993 is the transformation of a rigid financial policy in Indonesia to a more free financing activity after a three year period of limitation of investment policy.

3.3 Machine Tool Producers

The Indonesian machine tool producers are associated in ASIMPI . The Indonesian Machine Tool Industries Association was founded in 1984 by 11 members. The aim of the association is to be a government partner in the identification of machine tool industry development policy and to support machine tool producers in their marketing, technological and manufacturing improvement.

Aims of the association:

- to be a government partner in the formulation of the machine tool industry development policy
- to collect information concerning the machine tool industry (Central Information Bank)
- to support the technological development of machine tool producers
- to analyze market conditions and define the strategy of machine tool manufacturing

A brief description of the main ASIMPI members:

- PT. INDUSTRI MESIN PERKAKAS INDONESIA (PERSERO)

Year of Establishment: 1983
Place: Cilegon
Status of Company: state-owned company
Amount of Employees: 60 persons
Business Line: Machine tools for metal/wood working and engineering services

- PT. PIMSF PULOGADUNG

Year of Establishment: 1973
Place: Jakarta, Pulogadung, Industrial Estate
Status of Company: Private Company (Tjokro Group)
Amount of Employees: 350 persons
Business Line: Machine tools, parts for vehicles, gear manufacturing

- P.T. PINDAD (Persero)

Year of Establishment: 1984
Place: Bandung
Status of Company: state-owned company
Amount of Employees: 5400 persons
Business Line: machine tools, Defence Industries

- P.T. TOOLS INDONESIA (TOOLSINDO) FIRST TRADE MACHINERY

Year of Establishment: 1985
Place: Jakarta
Status of Company: private company
Amount of employees: 85 persons
Business Line: marketing, sale, utilization of machine tools

etc.

In regard of the real situation on the machine tool market the MTDDC services will be offered to other Indonesian engineering companies. The 7th Progress Report includes a description of some companies of other branches.

4. PARTIAL TRANSFORMATION OF THE PROJECT OBJECTIVES

4.1 Additional Aims

The additional aims were defined by representatives of the MTDDC management. UNIDO/POLYTECHNA field team and UNIDO Vienna office, partially to transform the MTDDC activities in accordance with the actual situation of the Indonesian machinery industry. The additional aims are as follows:

- machine tools utilization
- operation management
    - production programme
    - capacity calculation
    - process design
    - production planning
    - inventory management
    - work force management
    - quality control management
- technology consultation
    - metal cutting conditions
    - available tools, jigs, fixtures
    - process charts
    - metal cutting technologies data base implementation
- evaluation of technology in automobile industry used for mechanical part manufacturing
- quality management systems consultancy
- arrangement of technical seminars and conferences
- educational training for machinery factory staff
- co-operation during Feasibility Study elaboration

4.2 Useful Additional Activities

4.2.1 Machine Tool Utilization
Data base (a choice from 7 suggestions)
User's guideline
Programmer's guideline
Metal cutting conditions
Total production costs calculation
Co-operation with VUOSO Prague

4.2.2 Quality System Services
Diagnostic analysis of customer's company
Training period (top management, management personnel, internal auditors)
Control system and technological standard assessment
Quality control documents elaboration
Experimental implementation
Preliminary audit
Preparation for certification
Co-operation with NOVOQS Singapore, INSPEKTA Prague

4.2.3 Automobile Industry Services
Methods of parts manufacturing evaluation
Local share of production of workpieces
Government RI Instruction
MTDDC tasks
SUCOFINDO Jakarta new division
Organizational structure
Future co-operation with LIAZ Jablonec

The 1st, 5th, 6th, 7th PROGRESS REPORTS give the explanation of the necessity of the above-described aim transformation.

5. PROJECT REAL IMPLEMENTATION

5.1 Project Subcontractor's Team

The subcontractor's team went through necessary changes in accordance with the development of the project implementation. The flexible changes regarding the partial transformation of the project objectives based on the agreement with the UNIDO office and National Project Director have been as follows:

- Initial team members set up from the Project Proposal: Messrs. Šebela, Ph.D., Ševčík, Ph.D., Houžva, M.Sc. Urban, M.Sc., Konečný, M.Sc.
- Added team members: Messrs. Tomek, PhD., Pujman, Ph.D. Bauer, M.Sc., Madle Ph.D., Wencl, M.Sc., Žemlička, M.Sc.

All the above-mentioned members of the team have set up the home base for the field mission preparation. The following part of this Chapter contains a brief explanation of the quality and proficiency of these experts.

In the training period other experts from the Czech companies and technical and educational institutions took part - a total of approximately 100 persons. Some other experts helped the MTDDC staff to arrange the follow-up training in Singapore.

Participants of field missions:

Mr. Šebela Zdeněk, Ph.D. - Team Leader - expert in the research of the modernization of the machinery industries including the implementation of advanced technologies and feasibility studies, skilled in operation management and production planning

Mr. Ševčík Arnošt, Ph.D. - expert in planning of research institute operation, information system utilization and hydraulic system development

Mr. Houžva Ladislav, M.Sc. - expert in machine tool designing and manufacture including jigs and fixtures

Mr. Tomek Pavel, Ph.D. - expert in research and development of metal cutting technologies and cutting tools, advanced technologies, flexible manufacturing systems

Mr. Pujman Jiří, Ph.D. - expert in the automation of machine tool drives and controllers, CNC control systems, programming of flexible manufacturing systems and robots

Mr. Bauer Jaroslav, M.Sc. - expert in standardization of testing of machine tools, measurement of machine tools and ISO 9000 implementation

Mr. Madle Luděk, Ph.D. - expert in metal forging, metal forming and metal welding technology data base and in CAD/CAM implementation

Mr. Wencl Karel, M.Sc. - expert in HW and SW of metal cutting technology data base responsible for its implementation

Mr. Žemlička Petr, M.Sc. - expert in consulting of quality system implementation as directed by ISO 9000 standard series.

The home support of field missions was provided by further experts as follows:
Mr. Urban Jiří, M.Sc. - expert in machine tool drives and servodrives and in automation

Mr. Konečný Bohumil , M.Sc. - expert in machine tool assembly, testing and set up

Mr. Imlauf Jiří, M.Sc. - expert in the preparation and provision of technical training planning and on-the job training preparation and providing.

The home support was also provided by the staff of participated institutions as follows:
- POLYTECHNA Prague Ltd
- BÁŇSKÉ PROJEKTY Ostrava Ltd
- INPRO Prague Ltd
- VÚOSO Prague Ltd
- ČVÚT Prague (Technical University)

etc.

The on-the job training was ensured through the assistance of many experts of machine tools producers as follows:
- KOVOSVIT Sezimovo Ústí Ltd.
- ŽĎAS Žďár and Sázavou Ltd.
- TOS Kuřim Ltd.
- ZPS Zlín Ltd.
- OSTROJ Opava Ltd.
- DIAGNOSTIKA Darkov-Karviná
- STROIMPORT Prague Ltd.
- TOS Čelákovice Ltd.

etc.

The MTDDC staff training in Singapore was assisted by experts form the following institutions:
- SISIR Singapore Ltd
- NOVO-QS Singapore Ltd
- OMRON Singapore Ltd
- The National University of Singapore

etc.

5.2 Project Field Missions

The objectives, members´ tasks, duration, and achievements of the field missions are described in detail in previous Progress Reports:

1st PROGRESS REPORT - 1st mission (08/1991 - 12/1991)

5th PROGRESS REPORT - 2nd mission (the first part, 10/1992 - 12/1992)

7th PROGRESS REPORT - 2nd mission (the second part, 04/1993)

(the third part, 05/1993 - 10/1993)

Because of this only a brief report of these field missions is made in this chapter.

The First Mission

Time Period: August 1991 - December 1991

Objectives:

- to investigate the actual situation of the Indonesian machinery industry and primarily in machine tool manufacturing
- in accordance with results of the above-mentioned analysis, to define the necessary goals of the MTDDC activities
- to assist in the MTDDC staff recruitment and to recommend available participants for technical training in Europe
- to prepare the basic version of the training programme

Participants:
Mr. Šebela, Ph.D. (4 m/m)
Mr. Ševčik, Ph.D. (2 m/m)
Mr. Houžva, M.Sc. (2 m/m)

The Second Mission, the 1st Part

Time Period: October 1992 - December 1992

Objectives:

- to participate in the preparation of training in Singapore
- to arrange on-the job training in the automation of engineering factories and metal cutting technologies - by OMRON Ltd Company - Singapore (free of charge)
- to continue the theoretical training received in the Czech Republic (data base for metal cutting technologies)
- to assist in the choice of a data base (process charts elaboration)

Participant: Mr. Šebela, Ph.D. (2 m/m)

The Second Mission, the 2nd Part

Time Period: April 1993

Objectives:

- to improve the possible co-operation in the sphere of the Quality Management System Services, between Inspekta Prague and the MTDDC Indonesia
- to investigate the main tendency of QMS implementation in the Indonesian industry
- to give the knowledge of QMS preparation and certification in the machinery industry
- to elaborate a programme of the last part of the second field mission in accordance with the current situation of the MTDDC

Participants:
Mr. Šebela, Ph.D. (1 m/m)
Mr. Žemlička, Ph.D. (1 m/m)

The Second Mission, the 3rd Part

Time Period:
The third part of the second mission was arranged in accordance with an agreement between UNIDO, DOI of IR, MTDDC and POLYTECHNA as the split missions as follows -
a) May 1993 - June 1993
b) July 1993 - August 1993
c) September 1993 - October 1993

Objectives:
a)

- to hand over lectures prepared by the Czech experts for the proposed seminars
- to work out general guidelines for the inspection of machine tools to verify all important characteristics
- to visit the chosen Indonesian factories to get the general idea of the industrial level in manufacturing
- to elaborate Field Report of the factories visited including the main suggestions for their modernization

b)

- to continue the elaboration of the instructions for inspection of machine tools for the verification of the properties of purchased machines and their durability during their utilization: quality of construction and adjustment of machines and their main components, function of machine, vibrations, noise, power utilization, safety of the machine
- to work out the recommendation of standards for manual control of machine tools for NC machine tools
- to recommend technological principles of forming and forging processes with some important basic technological rules
- to elaborate the questionnaire for quality control diagnostics and the directives for machine tools testing
- to take part in the training of new inspectors for the verification of manufactured parts in the automotive industry
- to take part in the preliminary assessment of some factories of the automotive industry

c)

- to provide customization of the data base of metal cutting technologies
- to implement the above mentioned data base in the conditions of the Indonesian machinery industry
- to hand over the whole program system including full documentation package (installation of diskettes, source listing, user's manual, programmers manual)
- to train the MTDDC staff in the data base implementation (process charts elaboration in accordance with metal cutting conditions)

- to take part in the postgraduate course preparation (organized by the MTDDC, the University of Indonesia, UNIDO POLYTCHNA team)
- to present lectures in accordance with a complete survey of technical information in the area of production planning in manufacturing industry (A) and in the field of machine tools automation and robotics (B)
- to publish proceedings of the above-mentioned topics (A-operation management, process design, production planning and scheduling, inventory management), (B-automation of manufacturing by using CNC, advanced technologies in machining, retrofitting of machine tools, Flexible Manufacturing Systems applications, CIM implementation)
- to define the future possibility of the co-operation between the MTDDC and collaborating institutions

Participants:
Mr Šebela, Ph.D. (4 m/m)
Mr Bauer, M.Sc. (4 m/m)
Mr Pujman, Ph.D. (1.5 m/m)
Mr Tomek, Ph.D. (1.5 m/m)
Mr Wencl, M.Sc. (2 m/m)
Mr Madle, Ph.D. (2 m/m)

The total duration of split field missions was 27 m/m.

The home support

The field missions and educational technical training of the MTDDC staff were supported by home activity of the team members. This home support has been provided from January 1992 to August 1993. The home support consisted of:

- working out of the technical training programme
- participation in both theoretical and on-the job training
- elaboration of the documentation of QMS (Quality Management System) presentation
- elaboration of the lectures for prepared seminars
- elaboration of the documentation of machine tool testing and measurement
- elaboration of the documentation of metal forging and forming processes
- preparation of the data base for metal cutting technologies
- elaboration of the proceedings of the postgraduate course - production planning
- elaboration of the proceedings of the postgraduate course - industrial automation and robotics

etc.

The team members who participated in the home support activities in accordance with necessary project preparation are the following:
Mr Šebela, Ph.D. - 8 m/m
Mr Ševčík, Ph.D. - 1 m/m
Mr Houžva, M.Sc. - 1 m/m
Mr Tomek, Ph.D. - 3 m/m
Mr Pujman, Ph.D. - 3 m/m
Mr Bauer, M.Sc. - 2 m/m
Mr Madle, Ph.D. - 1 m/m
Mr Wencl, M.Sc. - 2 m/m

Mr Žemlička, M.Sc. - 1 m/m
Mr Urban, M.Sc. - 2 m/m
Mr Konečný, M.Sc. - 2 m/m
Mr Imlauf, M.Sc. - 4 m/m

The total duration of the home support activities was 30 m /m.

5.3 Training of the MTDDC Staff

The main part of the training of the Indonesian engineers was arranged in the Czech Republic in accordance with agreed training stages as follows:
A - English language practice
B - Initial theoretical course
C - Labs and workshops practice
D - Basic theoretical and particular courses according to profession
E - On-the job training in factories, laboratories and enterprises
F - Final stage of training
G - Final project elaboration

Proposed principal subjects of lectures and on-the job training in the Czech Republic

I. Technology of manufacturing processes:

a) Machining - metal cutting processes
b) Abrasive processes
c) Forming performance prediction and control
d) Electro-physical processes including laser machining
e) Welding
f) Advanced processes of manufacturing
g) Engineering materials for metal cutting processes

II. Computer aided engineering

a) Advanced programming techniques
b) CAD principles
c) CAD/CAM and C/M
d) Computer aided measurement and inspection
e) Computer methods in the production planning

III. Machine tool design

a) Construction of machine tools principal nodes
b) Design and construction of the NC machine tool and machining centres
c) Construction of manipulators, tools magazines, technological pallets and other principal nodes of the machining centres and flexible production cells
d) Specific problems of the construction of grinding machines and gear generating machines
e) Selected problems of the precision of machine tools
f) Experimental methods of research of machine tool properties
g) Testing of machine prototypes

h) Theory of positioned and speed servosystems

IV. Tools, jigs, fixtures design

a) Materials of tools
b) Optimum cutting conditions
c) Tools quality inspection
d) Sharpening of tools
e) Jigs design
f) Fixtures design

V. Automation of machine tools and robots

a) Robots and machine tools automation
b) NC Machine drives and control systems
c) Machine performance
d) Attendance and maintenance of FMS

VI. Manufacturing systems

a) System elements and operation
b) Control and management systems
c) System simulation
d) World development of MC and FMS
e) Application of FMS in the advanced developing countries

VII. Marketing - evaluation

a) Sales and implementation of used and retrofitted machines
b) Marketing in the bids, sales and manufacture of engineering products
c) Network of shops and dealers
d) Methods of analysis of engineering production
e) Forecasting of production
f) Economic statistics
g) Licence policy and foreign trade
h) Methods of prognoses
i) Principles of management and financing
j) International commercial Laws
k) Principles and techniques of commerce

The first stage of the training was arranged by the following companies and institutions:
INPRO Prague (leading partner)
ČVÚT Prague
VÚOSO Prague
KOVOSVIT Sezimovo Ústí
ŽĎAS Žd'ár nad Sázavou
TOS Kuřim
ZPS Zlín
DIAGNOSTIC LABORATORY Darkov
BÁŇSKÉ PROJEKTY Ostrava

OSTROJ Opava
TOS Čelákovice, etc.
Planned subjects of lectures and on-the job training in Singapore:

I. Quality Management Systems

a) ISO 9000 standard series
b) Quality Systems manuals and documentation
c) Preparation process for QMS certification
d) Framework of the certification procedure
e) Training for provisional assessors
f) Training for lead assessors

II. Manufacturing Factory Automation

a) Strategy of total factory automation
b) Production management system
c) Control systems at machine station level
d) Sensing systems at equipment level
e) Programmable controllers for the factory automation and for the FMS
f) Computer integrated manufacturing - CIM

III. On-the job training in laboratories of the control equipment

The second stage of the training was arranged by the following institutions:
NOVO Quality Services, Singapore
OMRON Ltd, Singapore
National University of Singapore

The following participants of the above-described technical training in the Czech Republic and Singapore were recruited as trainees :
Mr. Ir. Henky Nugroho
Mr Ir. Rico Sihombing
Mr Ir. Bambang Prianto
Mr Ir. Arif Ahmadi
Mr Ir. Wardjito (partially)
Mr Ir. Bambang Yosef Dwiono
Mr Ir. Handono (partially)

The National Director of the MTDDC - Mr. Indra Putra Almanar, Ph.D., M.Sc. - has taken part in two study trips to the famous European institutions and companies in Great Britain, Austria and the Czech Republic.

The training topics have covered the entire area of the planned programmes.

A comprehensive explanation of the training implementation was described in the 2nd, 3rd and 6th PROGRESS REPORTS.

5.4 Fulfilment of Project Objectives

The project objectives were defined by the Project Document - No DP/INS/88/030/B/01/37. All planned outputs have been included into the MTDDC Work Plan. The outputs of the project objectives were discussed by MTDDC management and UNIDO/POLYTECHNA field team and common evaluation of their fulfilment (to December 1993) are as follows:

Output 1: Production Engineering

1.1 Software capability in metal cutting technology, such as for optimal selection of feeds and speeds for various types of cutting tools (high speed steels, carbides, ceramics) and different types of materials (such as grey cast iron, non-ferrous metal, bronze, brass, aluminium, all kinds of steels) and related to the different metal cutting process operations such as turning, milling, drilling, broaching, boring, grinding, etc. Capability for determining tool geometry requirements for above metal cutting processes
(fulfilment: 100 % - December 1993)

1.2 Establishment of a metal cutting technology data bank for all major metal cutting processes with the main parameters mentioned under 1.1 above, including cutting forces and heat development during the manufacturing process with and without cooling/cutting media etc.
(fulfilment: 100 % - December 1993)

1.3 Organizational arrangements for provision of extension services to the metal cutting industry for the proper selection of machine tools and their optimum utilization
(fulfilment: 100 % - December 1993)

1.4 Capability in design and manufacture of tools and tooling fixtures for metal cutting operations
(fulfilment. 80 % - December 1993)

1.5 Organizational arrangements for provision of extension services in tool design and tool application required for manufacture in the metal working industry
(fulfilment: 40 % - December 1993)

1.6 Trained staff for the above items
(fulfilment: 100 % - December 1993)

Output 2: An Operational Machine Tool Design and Adaptation Unit

2.1 Capability in design and adaptation of design for simple conventional metal cutting machine tools, such as lathes, milling and drilling machines
(fulfilment: 80 % - December 1993)

2.2 Introduction of designs to local machine tool manufacturers
(fulfilment: 60 % - December 1993)

2.3 Established design and testing procedures for machine tools manufacture
(fulfilment: 100 % - December 1993)

2.4 Provision of extension services to machine tool and metalworking industry
(fulfilment: 80 % - December 1993
2.5 Trained staff for the above items
(fulfilment: 100 % - December 1993)

The additional output aims were described in Chapter 4. The planned and unplanned achieved objectives together are to support the MTDDC ability to fulfil its required services for the Indonesian machinery industry.

6. THE ESTABLISHMENT AND DEVELOPMENT OF THE MTDDC

6.1 MTDDC Status

The Machine Tool Design and Development Centre in Indonesia - MTDDC - was established as a non-profit making and private institution at the beginning of August, 1991. The basic capital of MTDDC is 4.0 million Rupias which consists of equal contributions from eight founders.

The major right of every founder is to be nominated a member of the Board of Founders and other superior bodies as follows:

BOARD OF FOUNDERS
BOARD OF CONTROL
EXECUTIVE BOARD

The Department of Industry of the Indonesian Republic is responsible for guiding the development of the MTDDC through the period of the assistance by the UNDP/UNIDO project and then through the starting period of providing services to the Indonesian machinery industry.

The UNDP/UNIDO authorities are responsible for control and evaluation of the UNDP/UNIDO project implementation in accordance with agreed objectives.

According to its Status the MTDDC in Indonesia is a national promotion centre set up to develop the national machinery production including marketing services, and to be a national educational centre.

6.2 MTDDC Management

Mr. Indra Putra Almanar, Ph.D., M.Sc. was appointed the Head of the Executive Board and at the same time the National Project Director. The Board of Founders has the legislative power with a two thirds majority to make significant decisions. The Board of Control is obliged to check that the elaboration and implementation of the research and development programme is transformed into the comprehensive work plan.

6.3 MTDDC Personnel

The MTDDC staff consists of directly employed members and of fellow-workers submitted to external co-operation regarding activities provided. This flexible approach could help the problem of the shortage of sources of salaries and at the same time to manage sufficient consulting and design capacity.

The direct employed members for the full duty are:
- Mr Indra Putra Almanar, Ph.D., M.Sc.
- Mr Ir.Rico Sihombing
- Mr Ir. Dana S. Suroso M. Eng.

At the headquarters there are technical and subsidiary assistants. There is no certainty that the above-described situation remains the same because of very changeable conditions and continuing poor financial resources for salaries.

The group of external experts which consists of trained and skilled engineers is considered to be the technical and scientific power of the MTDDC for the future development of activities for the Indonesian machinery industry. From time to time they take part in working teams in accordance with existing contracts with clients or customers but they are permanently employed by other employers - mostly by the University of Indonesia. This group is divided into experts and assistants.

The external experts are as follows:
Mr. Ir. Henky Nugroho
Mr Ir. Bambang Prianto
Mr. Ir. Arif Ahmadi
Mr Ir. Wardjito
Mr Ir Bambang Yosef Dwiono
Mr Ir. Handono

The first four persons belong to the educational and/or pedagogical staff of the University of Indonesia and have good opportunities to give their high knowledge, received through the wide training during the UNDP/UNIDO project, to many students and participants of postgraduate courses.

This position is more advantageous because the utilization of their acquired knowledge of the engineering of the machine tools area and of the metal cutting technology development of the Indonesian machinery industry and the Indonesian engineering companies is increased by contacts with both postgraduate students and representatives of many companies.

The assistants of the external group are as follows:
Mr Reza Musa
Mr Misyal Abdullah
Mr Denny Andrew S.
and others.

The existence of a wider set of specialists to the MTDDC in Indonesia gives a guarantee of the increase and improvement of the MTDDC services.

6.4 MTDDC Organizational Structure

The MTDDC in Jakarta is a comparatively simple organizational body and its structure has often been adapted to the necessity of services required. At the end of 1993 it consisted of the organizational structure on the following diagrams.

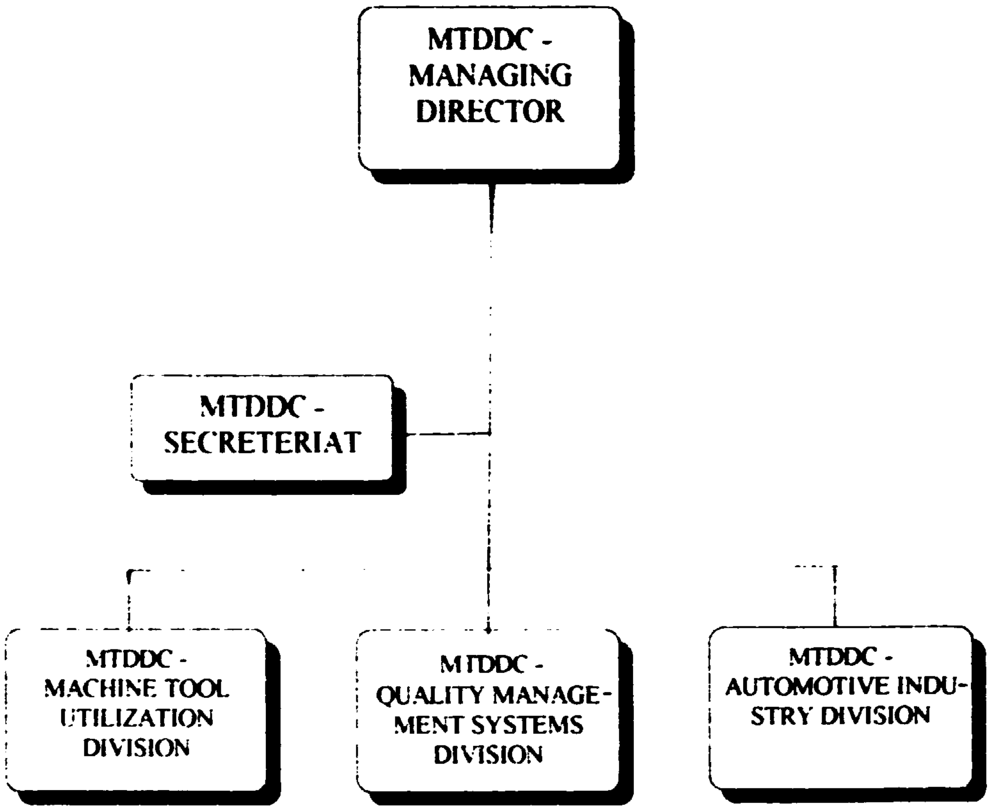
In accordance with the very close relationship between the MTDDC and SUCOFINDO Jakarta in the verification of the share of local industry in automobile parts manufacturing was worked out the organizational structure of the MTDDC automotive industry division shown on the next diagram.

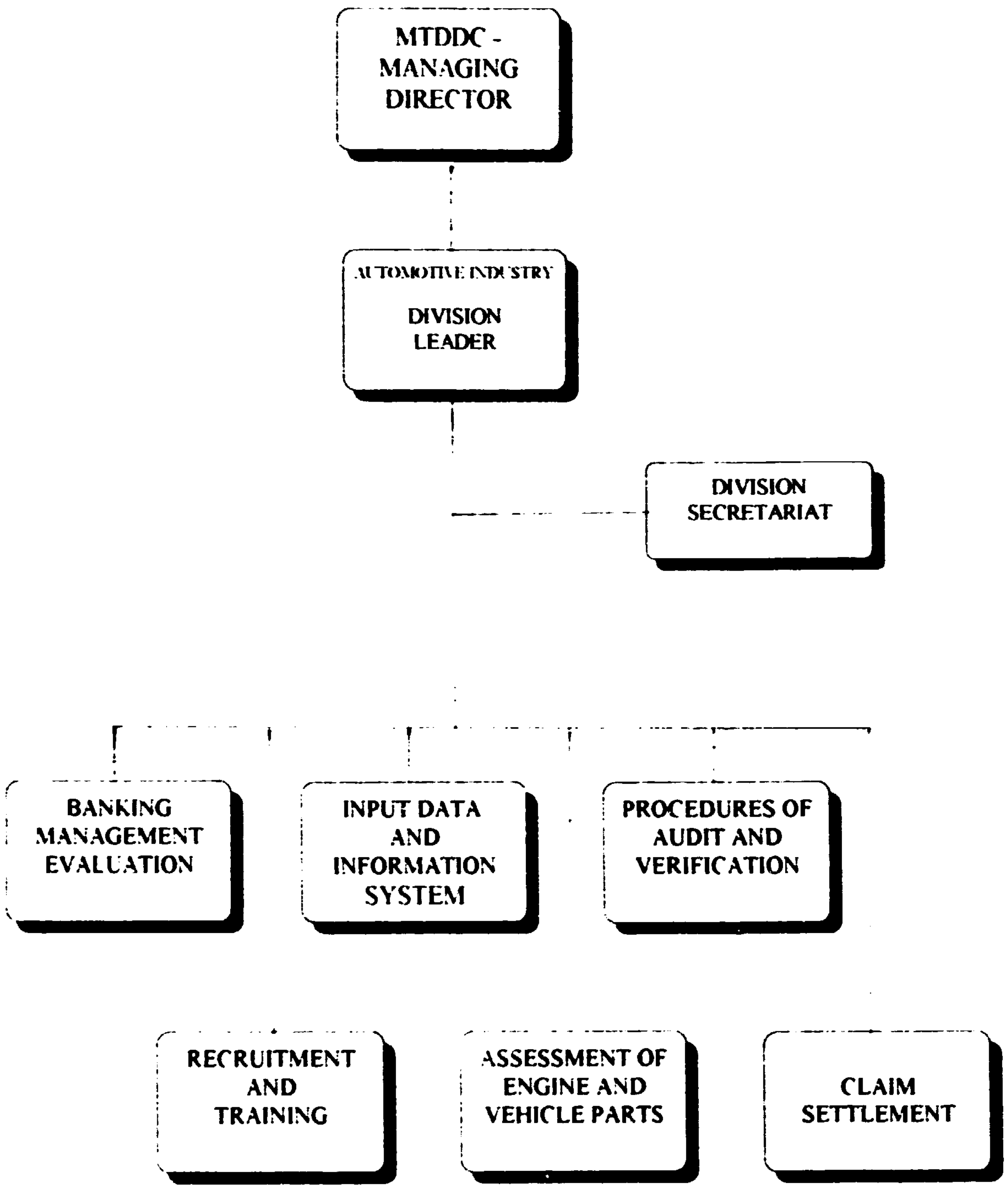
These structures are shown regardless of the actual people appointed for each function. The MTDDC organizational structure will be permanently developed in consideration of the development or services required by the Indonesian industry. For special tasks it could establish temporary working teams of experts.

6.5 MTDDC Offered Activities

After more than two years assistance of the MTDDC it is possible to define its ability to offer services for the Indonesian machinery industry as follows:

- consultations at the introduction and setting of conventional machine tools and the NC machines and machining centres
- consultations at design and implementation of production systems up to the level of flexible manufacturing systems
- consultations at the selection of tools and cutting conditions for hand-operated and NC and CNC controlled machines
- co-operation in the selection of working procedures by way of process charts elaboration (data base of mutual cutting technology)
- co-operation in the selection of production machines, tools, jigs, fixtures and accessories
- co-operation in the evaluation of production costs of forecasted workpieces manufacturing
- co-operation with manual and computer programming of NC and CNC machines
- working of expert studies of the machines installation and technology implementation for newly introduced or modernized production (lay-out design, production flows, traffic facilities etc.)
- training of operators of the CNC machines and machining centres for attendance and maintenance of the machines and adjustment of programmes
- co-operation in enhancing the precision and degree of automation of the manufacturing machines by retrofitting
- co-operation in designing and adjustment of the machines, tools, jigs and fixtures
- proposal of purchase of foreign machines, tools and technology, co-operation in evaluation of the competitor's quotations and participation in commercial and technical negotiations
- marketing studies for the evaluation of sales of newly introduced products such as machine tools, accessories and tools
- working the market through the advertisement of new products of local and foreign manufacturers


MTDDC - MANAGING DIRECTOR
MTDDC - SECRETERIAT
MTDDC - MACHINE TOOL UTILIZATION DIVISION
MTDDC - QUALITY MANAGE-MENT SYSTEMS DIVISION
MTDDC - AUTOMOTIVE INDU-STRY DIVISION


MTDDC - MANAGING DIRECTOR
AUTOMOTIVE INDUSTRY DIVISION LEADER
DIVISION SECRETARIAT
BANKING MANAGEMENT EVALUATION
INPUT DATA AND INFORMATION SYSTEM
PROCEDURES OF AUDIT AND VERIFICATION
RECRUITMENT AND TRAINING
ASSESSMENT OF ENGINE AND VEHICLE PARTS
CLAIM SETTLEMENT

- co-operation in the testing of machine tools (geometric accuracy, repeatability of positioning for manual control and for NC machines, noise, temperature, effects, rigidity, dynamic stability etc.
- co-operation in engineering plant preparation for the quality control system implementation according to ISO 9000 standard series
- co-operation with both production and non-production companies preparation for the MQS certification regarding the ISO 9000 standard series (education, training, diagnostic analysis, working out quality control documentation , providing preliminary audit etc.)
- co-operation in the verification of the local industry production share in the workpieces manufacturing (automotive industry of the Indonesian Republic in joint production with foreign automobile producers)
- co-operation in working out feasibility studies by means of input data preparation and elaboration of special tasks including economic assessment regarding local conditions
- organization of courses on new engineering production technologies and techniques for the staff of industrial research, production and investor's institutions and for students from the Indonesian universities
- organization of courses on operation management (production strategy according to conditions of national economy, process design, process planning, inventory workforce management, quality system management maintenance) for the staff of the Indonesian engineering companies and for students from the Indonesian universities
- publishing the MTDDC activities through active participation in scientific conferences and symposia and in local and international exhibitions.

This scope of possible MTDDC activities is based on the technical training of the MTDDC staff within the framework of UNDP/UNIDO project, on the skills of the MTDDC employees and external experts including top management, and last but not least on the experience of subcontractor's experts passed on during the field missions. The MTDDC workers will have to master and permanently maintain a great volume of knowledge and craft in the course of their activity with regard to various requirements of their clients.

6.6 MTDDC Space and Equipment

The rooms given to the MTDDC in 172 Kramat Raya Street in Jakarta as headquarters are not sufficient for increase of activities and corresponding work. Regarding the National Director's opinion it is necessary to arrange refurbishment of this space at the cost of approximately 25 000 USD. It is impossible to provide this from its own financial resources. Another issue of this situation would be to move to another space but it depends on the DOI's decision.

The co-operation between the MTDDC and SUCOFINDO has brought a second place of the MTDDC activity in ASPAC building at Rasuna Said Street in Jakarta .But these rooms can not be used by all the staff of the MTDDC.

During the period of 1992 - 1993 the MTDDC was supported by UNDP/UNIDO and DOI RI in obtaining the necessary equipment and accessories. At the beginning of the above-mentioned period they received two DAIHATSU cars for 4 and 6 passengers. Both cars are used by the MTDDC staff.

The MTDDC headquarters are also equipped with telephone, facsimile apparatus and air-conditioning.

Through UNDP/UNIDO project the MTDDC received two PC computers as follows:
PC AT-386, coprocessor, DOS5, oper. syst. WINDOWS, RAM 4 - 8 Mb, Hard disc 120 Mb, laser print.

The gradual obtaining of SW products for supporting the MTDDC services will be one of the main obligations of the MTDDC in the near future. The subcontractor's team handed over for the MTDDC utilization SW product The Data Base of Metal Cutting Technology to execute process charts (detailed explanation in 7th PROGRESS REPORT, chapter 1.3.1).

6.7 MTDDC Needs for Development

It could not be declared that all the needs for the running of the MTDDC are covered. In fact "The Machine Tool Design and Development Centre in Indonesia" needs great support for the initial period of the independent activity.

First of all they need certain funds to cover a part of running costs. The absence of this fund throws the MTDDC into the situation of fighting for survival at any price. On one side there are normal conditions of free market economy but on the other side the ambition of such an institution is higher than only to generate the financial resources for survival. The MTDDC's aim is to assist in the development of technology of the engineering industry of the Indonesian Republic regardless of the willingness of clients to pay money for these services.

Therefore the MTDDC's needs occupy its necessity to keep and to extend contacts with domestic and international institutions. These contacts will bring new information and new knowledge of technological development, new ideas and intentions. This tendency will be supported by all enterprises taking part in UNDP/UNIDO project which are ready to arrange co-operation between them and MTDDC after the dead line of the project. The above-mentioned co-operation could be transformed into paid subcontractors services.

7. EXPERIENCE

7.1 The Forecast of the Project Objectives

The forecast of evolution to a high degree of accuracy is one of the most difficult functions of consultants and authors of strategic decisions. Such a difficult task is in front of every project decision maker. No economists could have assumed such a world wide stage of decrease five years ago, first of all in the sphere of machinery production and investment ability. This trend has afflicted the machine tool production even in highly industrialized countries in the world. A risk of inaccurate forecasting can be partially eliminated by variable forecast with the same value of relevance for every variant. Even contradictory variants have to be taken into account. The project can be defined according to the most probable variant of evolution, on condition that the primary forecast is periodically analyzed and proportionally adapted referring to changing conditions. Only in this way we are able to avoid mistakes in definition and realization of projects.

7.2 The Flexible Approach to the Project Implementation

The project of the establishment and support of the activity of a new consulting and research centre has a long term character. Today's world of fast economic changes influences initial previously unchangeable project aims. The transformation of the project objectives earlier was supposed to be an unpleasent exception only. The analysis of the objectives necessary transformation has to be included into the project workplan directly. The acceleration of changes of sectors of the industry and the national economy of the country and the entire geographic region, is so strong that only the flexible approach to the transformation of the project aims brings the guarantee of the fulfilment of real, useful results of the project.

ANNEXES

DOCUMENTS OF THE MTDDC CO-OPERATION AND COLLABORATION

ANNEX 1 Memorandum of Understanding between the MTDDC Indonesia and Novo Quality Services Singapore

ANNEX 2 Memorandum of Understanding between the MTDDC Indonesia and the Department of Mechanical Engineering - Engineering Faculty - the University of Indonesia

ANNEX 3 Memorandum of Understanding between the MTDDC Indonesia and Báňské projekty Ostrava, the Czech Republic

ANNEX 4 Minutes of the Meeting Held by and between the MTDDC Indonesia and Inspekta Ltd Prague, the Czech Republic

ANNEX 5 Memorandum of Understanding between Inspekta Ltd Prague and the MTDDC Indonesia

NOVO QUALITY SERVICES

MEMORANDUM OF UNDERSTANDING

between
Machine Tool Design Development Center-Indonesia (MTDDC-Indonesia)
and
Novo Quality Services (NQS), Singapore

for collaboration in providing ISO 9000 consultancy/training to companies in Indonesia, associated with MTDDC - Indonesia

The parties hereby agree to collaborate on providing **ISO 9000** consultancy and training services to companies in Indonesia associated with **MTDDC-Indonesia** on the basis of the following understanding:

1. That **MTDDC-Indonesia** will provide NQS with its associated companies that need help in implementing **ISO 9000**.

2. That NQS will provide consulting and training services to the companies on behalf of **MTDDC-Indonesia**.

3. That NQS will charge an agreeable fee to **MTDDC-Indonesia** regarding services provided by NQS to the companies.

4. That NQS is free to provide **ISO 9000** consultancy/training services to other companies in Indonesia not associated with **MTDDC-Indonesia**.

5. That NQS will use the provisional assessor(s) provided by **MTDDC-Indonesia** in carrying out the services in the companies associated with **MTDDC-Indonesia** when necessary.

7. That NQS will give assistance to the provisional assessors provided by **MTDDC-Indonesia** in order to bring up their level of qualification from the provisional assessor to registered qualified assessor and lead assessor.

8. That **MTDDC-Indonesia** will provide NQS with an office space in **MTDDC-Indonesia's** office to support NQS activities on **ISO 9000** in the **MTDDC-Indonesia's** associated companies.

[illegible]

9. That this **Memorandum of Understanding** should be followed by a joint operation contract at the time **MTDDC-Indonesia** provides **NQS** with projects on consultancy and training of **ISO 9000** for the associated companies of **MTDDC-Indonesia**.

10. That this **Memorandum of Understanding** is valid for one year from the date of signing and may be renewed by mutual consent. It may be terminated by either party with 90 days written notice.

Signed in ...Singapore... on ...24 December... 1992.

Teo Nam Kuan
Managing Director
Novo Quality Services Pte Ltd (NQS)
Singapore

Ir.Indra Putra MSc.PhD
Director
Machine Tool Design and
Development Centre - Indonesia
(MTDDC-Indonesia)
Jakarta, Indonesia

MEMORANDUM OF UNDERSTANDING

between
The MACHINE TOOL DESIGN and DEVELOPMENT CENTER - INDONESIA
(MTDDC-Indonesia)
and
The DEPARTMENT OF MECHANICAL ENGINEERING, ENGINEERING FACULTY - UNIVERSITY OF INDONESIA
(Dept.of ME-EFUI)

for COLLABORATION IN THE DEVELOPMENT OF MACHINE TOOL TECHNOLOGY IN THE INDONESIAN MANUFACTURING INDUSTRIES

The parties hereby agree to collaborate in the development of machine tool technology in the Indonesian manufacturing industries on the basis of the following understanding :

1. MTDDC-Indonesia will provide the Dept. of ME-EFUI with internationally recognized experts concerning the projects of the development of machine tool technologies to be carried out with MTDDC-Indonesia.

2. Dept. of ME-EFUI will provide the MTDDC-Indonesia with engineers, laboratories, hardware and software facilities for the project.

3. MTDDC-Indonesia will provide the engineers of the Dept. of ME-EFUI involved in this collaboration with training, courses and any other opportunities available locally or abroad, to increase their knowledge and skill to a level accepted internationally.

4. Dept. of ME-EFUI will assign the engineers involved in the project, to support the activities of MTDDC-Indonesia.

5. MTDDC-Indonesia will give a full time assignment to the assigned engineers of the Dept.of ME-EFUI to develop and expand the machine tool technologies in the Manufacturing Technology Laboratory - EFUI.

6. Dept. of ME-EFUI will provide MTDDC-Indonesia with a working space in the Manufacturing Technology Laboratory - EFUI.

7. MTDDC-Indonesia will provide a working space and facilities for the engineers in the office of MTDDC-Indonesia.

This Memorandum of understanding is effective on the date of signing and will be valid for three years. Any changes will be accommodated by the agreement of the two parties, with at least 30 days notice in advance.

Signed in Jakarta on 5 January 1993

Dr.Ir.M.Idrus Alhamid
Head of Department
Dept. of Mechanical Engineering
Engineering Faculty
University of Indonesia

Ir.Indra Putra MSc.PhD.
National Project Director
Machine Tool Design and
Development Center - Indonesia
(MTDDC-Indonesia)

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ANNEX 3

Memorandum of Understanding

between

The Machine Tool Design and Development Centre
Indonesia
(MTDDC - Indonesia)

and

The Banske Projekty Ostrava- Czech Republic

(BPO)

for Collaboration in the production of Feasibility Studies (FS) for Indonesian Industries.

The parties hereby agree to collaborate in the production of Feasibility Studies for Indonesian Industries or companies associated with MTDDC-Indonesia on the basis of the following understanding:

1. That MTDDC-Indonesia will provide BPO with its associated companies that need help in production of FS
2. That BPO will provide appraising and any related activities for the production of FS to the companies on behalf of MTDDC-Indonesia.
3. That BPO will charge an agreeable fee to MTDDC-Indonesia regarding services provided by BPO to the Companies.
4. That BPO will use member of staff of MTDDC-Indonesia in carrying out the services in the companies associated with MTDDC-Indonesia.
5. That BPO will give assistance to the staff of MTDDC Indonesia in order to bring up their level of qualification in appraising and the production of feasibility study.

6. That MTDDC-Indonesia will provide BPO with an office space in MTDDC-Indonesia's office to support BPO activities in the MTDDC-Indonesia's associated companies.

7. That this Memorandum of Understanding should be followed by a joint operation contract at the time MTDDC-Indonesia provides BPO with projects on appraisal and production of FS for the associated companies of MTDDC-Indonesia.

8. That this Memorandum of Inderstanding is valid for one year from the date of signing and may be renewed by mutual corsert. It may be terminated by either party within 30 days written nctice.

Signed in Ostrava on 20 January 1992

Jiří Frantík MSc.
Managing Director
Bánské projekty Ostrava
Czech Republic

Ir.Indra Putra MSc.PhD
Director
Machine Tool Design and
Development Certre-Indonesia
(MTDDC-Indonesia)
Jakarta, Indonesia

Minutes of Meeting

ANNEX 4

Held by and between

MTDDC - Indonesia,
Represented by **Mr. Indra Putra**, Director,

and

Inspekta, a.s.,
Represented by **Mr. Jan Strnad**, General Director

in Inspekta's Prague office on January 19 and 25, 1993

Present:

- For **MTDDC - Indonesia (MTDDC)**:
  Mr. Indra Putra
  Mr. Zdeněk Šebela (Báňské projekty Ostrava)

- For **Inspekta, a.s. (IP)**:
  Mr. Jan Strnad
  Mr. Karel Zitko
  Mr. Jiří Žemlička

MTDDC on behalf of Sucofindo (the Indonesian government owned superintending company) informed IP that Sucofindo is seriously interested in co-operation in various fields of superintending, quality management, commercial consulting and trading.

The main target of interest is assistance by IP staff in establishing the Quality Assurance Services (ISO 9000) in Indonesia, i.e. assistance in the necessity of explanation of ISO 9000 purposes and targets, assistance in quality management services promotion, training of Sucofindo personnel, performing training for Indonesian manufacturers and preparation for official audits of an accredited certification body.

MTDDC recommended that IP take part in the UNIDO quality management activities in Indonesia using this opportunity to present itself there. IP is ready to delegate its representative to undertake this task for a period of two weeks under stipulated conditions.

IP found this opportunity to be interesting. The co-operation in the field of superintending activities (pre-shipment inspection of Czech and Indonesian goods in the mutual trade exchange as well as in third party activities, assistance to the technical acceptance procedure of imported goods according to the relevant national standards and prescriptions etc.) and in the field of commercial services (market research, feasibility studies, promotional activities for goods and services, trading etc.) can start practically immediately. It would be useful for this purpose, that MTDDC/Sucofindo specify the form of this co-operation in more detail.

Reported by Karel Zitko

MEMORANDUM OF UNDERSTANDING.
between
INSPEKTA PRAGUE a.s.
and
MTDDC-INDONESIA

Jakarta, 9 April 1993

The parties hereby agree to collaborate on providing technology, and quality services to Indonesian Industry on bases of the following understanding :

1. **OBJECTIVE**

To transfer the technology and experties available in Czech Republic to Indonesian Industry.

2. **SCOPE OF ACTIVITIES**

To participate in the development of the Indonesian Industry, especially in the areas which are still not being well developed. Thus, a confirmation on the scope of activities was based on the requirements of the Industry, and the immediate services that could be provided by both parties as followings :

1- machineries inspection
2- quality services (ISO-9000)
3- economic services,

These will be supported by the experts available in Czech Republic.

3. **RESPONSIBILITIES**

In the cooperation between both parties, the responsibilities will be internally divided as follows :

1- INSPEKTA will give technical support to MTDDC
2- MTDDC will provide INSPEKTA with projects in Indonesia
3- INSPEKTA will participate actively in the projects
4- MTDDC will provide office space in MTDDC office
5- MTDDC will provide INSPEKTA with legal matters required in conducting the business cooperation in Indonesia
6- INSPEKTA will actively participate in engineering, technology and quality trainings in Indonesia

4. **CONDITIONS UPON REALIZATION**

A formal contract shall be signed by both parties upon the execution of projects.

5. **RIGHTS**

Both parties can make any business relationship with any other parties as long as it is not in the domain of the agreed common projects.

6. **VALIDITY**

This Memorandum of Understanding is valid for one year from the date of signing and may be renewed by mutual consent. It may be terminated by either party with 90 days written notice.

Signed in Jakarta, on 9 April 1993

Petr ZEMLICKA MSc.
on behalf of
Jan STRNAD MSc.
General Director
INSPEKTA PRAGUE a.s
Prague, Czech Republic.

Ir.Indra P. Almanar MSc.PhD.
Director
Machine Tool Design & Development Centre - Indonesia
MTDDC-Indonesia
Jakarta, Indonesia

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
VIENNA

THE ESTABLISHMENT OF THE MACHINE TOOL DESIGN AND DEVELOPMENT CENTRE IN INDONESIA

Project No. DP/INS/88/030
Contract No. 91/119

FINAL REPORT

VOLUME II

Polytechna Ltd., Prague
The Czech Republic

Báňské projekty Ltd., Ostrava
The Czech Republic

FEBRUARY 1994

CONTENTS

VOLUME II

Technical Documents of the MTDDC and UNIDO/POLYTECHNA Field Team Co-operation

METAL CUTTING TECHNOLOGY DATABASE

Automatized system for multiprofessional operations composition

on IBM AT type personal computers

MANUAL

(User's guide)

VER 5.0 (C)
VUOSO Ltd.
Czech Republic
Prague 1993

CONTENTS

Appendix:

The complete documentation of product is included in this SW system as an example of process charts implementation. The documentation consists of following items:

assembly drawing

sketch of details

parts list of product

print of process charts

list of material

print of product calculation

1. INTRODUCTION.

The automatized software system for the composition of production procedures is operated as a dialogue system by means of a choice of orders from the display. The user is not obliged to know the computer system and the bases of programming.

This system is meant for the elaboration of multiprofessi - onal production procedures (process charts) and competent technological documentation in various types of enterprises with the conditions of the production of piece and medium production. The system would help you to introduce the group technology and classification of the details. The system facilitates and accelerates a work planning. At last but not at least the system can provide the documentation of the quality control system according to the standard 9000.

The system provides:

- automatized work of the system with a machine and material databases ("on line work")
- automatized work of the system with two vocabularies for text and tools of operations ("teach in")
- the changes and repairs of already finished process charts
- the determination of the weight and price of material
- the printing the technological documentation
- calculation of the total time of consumption and wages standards and total price of detail or product
- the perfect and safe archivation of technological documentation
- the automatized work of the system with parts list of products and with orders

The system contains dialogue programmers for the service ("off line work"):
- of material database
- of machine database
- of parts list
- of customers'orders

During the activity of the system every step of the user is automatically checked with the material and machine databases.

2. MIN. HARDWARE CONFIGURATION.

You can install the system on arbitrary kind of personal computer IBM type 286, 386, 486 with following requirements:

Numeric processor:	need not
Floppy Drive:	either 1.2 MB or 1.44MB
Display Type:	monochrome, colour (hercules, VGA, EGA etc.)
Base Memory Size:	640 KB min without resident portions
Hard disk	10 MB min. free
Parallel port:	1, LPT1 for printer of size 80 characters

3. SOFTWARE PACKAGE INSTALLATION.

The software package is saved on two floppy diskettes. They are named as " Automatized software system "
" TECHNO " " No. 1 " and " No. 2 "

on their labels. The floppy No. 1 contains installation program for customer setup by name: INSTALL

Install the software package on your computer in the following way:

- secure about 10 MB free memory on your hard disk
- setup hard disk on primary level where you want to install the software package (for exam. C: or D:)
- insert the floppy diskette No.1 to drive (A: or B:)
- enter message:

  A:\INSTALL   or   B:\INSTALL
- answer on dialogue-question by computer step by step:

```
PASSWORD (6 characters) ?     where
  Last but one character is LOG DISK DRIVE
  last character is          | LOG FLOPPY DRIVE
      _______________________|   |
     |                           |
 xxxxxx__________________________|
 ---- = password ( correct name is on label
        of install floppy No. 1 )
```

NAME of factory for sign on the papers (18 characters) ?
  enter name of factory which will be printed
  on page heading of technological documentation

NUMBER of the basic machine shop (4 digit) ?
  enter number of current machine shop or keep it free

PASSWORD for parts list, orders, databases(6 characters) ?
PASSWORD for time fixing (6 characters) ?
  enter the safety sign for requirement activities or keep
  it free (in this case the safety sign is six spaces).

Will you be using the numeric code
for classification of the details in archives ?

enter 1 if you need it (description of the numeric code see on page .17..)

else 0 if you don't need it.

After the correct installation the message: " The software system is installed on your computer " is displayed on the screen.

4. BASIC INFORMATION FOR USER.

> Start of the system is by input of the message: TECHNO
After it you see a MAIN MENU on screen. You see also the main activities which you can use immediately.

PROCESS CHART DIALOG

MENU

CORRECTION
NEW
CHART PRINTING
ARCHIVES
REMARKS ABOUT THE CHANGES
BULK PRINT
DATA BANK
PARTS LIST
ORDERS
E X I T

move bar: ↑↓ select: Enter exit: Esc F7 = Help
VER 5.0 (C) VUOSO Czech Republic, Prague 1993

> The manipulation of the system is very simple and comfort-table through the keys which are described in the bottom of each screen.

> Three kinds of screens are available:
1. for selection:
Using arrow keys move the highlight bar on necessary activity and press key 'Enter'
2. for entry data:
Enter require data through keyboard on competent line and press either 'Enter' for confirmation of it or 'Esc' for cancel of just entering data
3. for information in detail or for help:
Strike the function key 'F7'

> The system has the working area containing one process chart.
One process chart contains:
up to 10 kinds of materials
up to 40 operations
up to 35 lines of text for one operation

> After start or stop of the system the last current chart is in working area.

> The new description chart (also unfinished) or any correction chart has to be stored into archives.

> When starting the selection of ' NEW ' the working space is made free. (The last contain of working area is lost if not stored into the memory for archives).

> When storing the chart to the archives the data from working space are copied to the archives (The chart remains without changes in the working area). You can make the next correction of it and store it under new name to archives. This is idea of quick creation of similar process charts.

> By reading the chart from the archives the data are copied to the working area (The chart remains without changes in the archives). On the contrary you can read the typical process chart (as model or type) from archives and by small changes of it you compile a new process chart quickly. And this is idea of group technology of course.

5. PROCESS CHART

The process chart is compiled of some portions of instructions.On the page heading there is sign of factory, introduction data including data of material. Further the sequence of operations are described usually. Each operation of sequence data of machine or equipment and description of work and tools is included. The other data are situated in the bottom of the process chart. The example of printing of process chart you can see on next page 7.

6. USER'S MODULES OF SYSTEM.

The software system is compiled of a separate modules and start each of them is trough main menu. The manipulation with each module is described further.

MTDDC-INDONESIA	PROCESS CHART	Pages: 1 Page: 1

Parts list no.:125	Position: 1
Drawing no.: 5222	Version: 1
Drawing name: BAR	Basic shop: 321

1. Identif.material	Quality	SU	Dimension	SUprice	SUweight
1321113730900	11373.0	KG	425510	3	5.55
Name			SU number	Price-total-Weight	
STEEL BAR	30MM ?		0.35		1.94

Op.No.	Shop	W.place	W.place name	CL	BATHmin	MACHmin
1		5962	Saw 12	1	0.	0

Describe of operation: cut for length 40

Tools:

Op.No.	Shop	W.place	W.place name	CL	BATHmin	MACHmin
2		4126	S 35-18R			

Describe of operation:	Tools:
turning ϕ55 on the length 40	
drilling ϕ12 to the depth 16.5	drill ϕ12
cut off on the length of 36	

Op.No.	Shop	W.place	W.place name	CL	BATHmin	MACHmin
3		5514	BSs			

Describe of operation:	Tools:
grinding 35j6 on the length of 36	abrasiv wheel ϕ160

Op.No.	Shop	W.place	W.place name	CL	BATHmin	MACHmin
4		9311	MECH.W.			

Describe of operation:	Tools:
smooth the edges	flat file

Date: 23. 8.93 Prepared by: JOHN Approwed by: BENER

7. CORRECTION module

Correct the process chart step by step according to " correction menu ". You compile new process charts or you correct current charts either individually or according to parts list of product. The parts list is described in the paragraph 12 (Parts list service). You usually correct the introduction data of the process chart first at all.

```
PROCESS   CHART          DIALOG

  CORRECTION                          BASIC DATA
                                      PROCESSING SEQUENCE
                                      TEXT
                                      TEXT & TIME FIXING
                                      E X I T

move bar: ↑↓          select: Enter     exit: Esc            F7 = Help
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```

7.1 Correction of the BASIC DATA.

> The parts list number will be looked for in the total list of the parts list. If the required parts list would not be in the memory a message will be displayed.

> To print the total list of the parts list on screen press key '?' and you can immediately choose interactively the number using ARROW keys.
> The drawing number also will be looked for in the parts list.
> By pressing key 'F1' the parts list number and drawing number will not be checked-up. You can write in this case the arbitrary ones.
> If the parts list number and drawing number have been checked by the system you are not allowed to change these items. Enter other basic data.
> When you enter data of material only, according to the parts list, you must write the character '!' on the drawing's name line on the first position.
> Date line: For a new process chart a computer date is generated. For correction of the process chart current date is defaulted. In the both cases you can change it.

7.1.1 Material data correction.

> You can write arbitrary data or you may use key 'F1' and interactively find correct material and move it to the screen by pressing 'Enter'.
> Data of the material, which you want delete, you must mark on the line of the material number in the first position a a character '-'.
> Every material is checked through database of the material. Unknown material is marked on the line of material's name on the last position with character '?'
> When the line of the specific unit price or specific unit weight is empty, the system will ask for total price or total weight of the current material. Write other data in the correct form or you let unfilled them.

7.2 PROCESSING SEQUENCE correction.

PROCESS CHART DIALOG

FOR DRAWING No: 5222

PROCESS.SEQUENCE - correction

Op.No.	W.place	Shop.	Name	Remark
1	5962		Saw 12	frame saw
2	4126		S 35-18R	centre lathe
3	5514		BSs	int.cyl.grind.machine d.120
4	9311		MECH.W.	smoothing

F4=machine base F5=text a.time fixing correct. F6=text correction
Ctrl+Z=delete line Ctrl+U=new line ?=teach in F8=print on screen
Enter = select Esc = cancel Page Down,Up = shift pages F7 = help

> No.operation = is generated after finish of the correction

> Workplace No. = is workplace number, where second and third digits define the kind of device

> Workplace name = is name of the kind of device

> Note = is description of the workplace in the machine database

> You write up to 40 operation in the one process chart

> Page shift by keys 'Page Down' a 'Page Up'

> You needn't delete the free lines with the marked mask

> Data about the operations you can write manually or interactively by key 'F4'. You must write kind of the device to the column of the workplace No. starting from second

position (for example: 41 = centre lathe) before the key 'F4'is used. If you don't know workplace No.,write character '?' in the first position of that column. Then you interactively select the desirable kind of the workplace. Then using key 'Enter' write workplace No. to the current line immediately.

> You can change the sequence of operations by pressing the keys 'Ctrl + Z' and 'Ctrl + U'. By pressing the key 'Ctrl+Z' you delete current line. Shift the highlight bar to other line and press key 'Ctrl + U'. The deleted line will be written to the new position.

> For every operation when you move bar, you can write the text of the operation by pressing key 'F6' or text and time fixing by key 'F5'.

> You may print the current state of the process chart by pressing the key 'F8'.

7.3 Correction of the TEXTs for operations

> You can enter up to 35 lines of the text for one operation.

> Shift pages by pressing the keys 'Page Down'and 'Page Up'.

> Switch cursor from left to right window and back by pressing the key 'Tab'.

> Special characters: ~ = φ ` = ø ^ = ✓

> The free lines are also as text. The length of the text is defined by length of the window.

> You can change the lines of the text by pressing the keys 'Ctrl + Z' and 'Ctrl + U'. By pressing the key 'Ctrl + Z'you delete current line. Shift the highlight bar to other line and press key 'Ctrl + U'. The deleted line will be written on the new position.

> Exit of entry or correction is either by pressing the key 'Enter' to the next operation or by pressing the key 'Ctrl+PageUp' to previous operation (it is "listing in the text of operations").

> You may print the current state of the process chart by pressing the key 'F8'.

```
                        PROCESS   CHART          DIALOG

 TEXT - correction
 OP.No Work.No. Shop    Name                                  FOR DRAWING No:
    2   4126            S 35-18R                              5222

                 TEXT                                              TOOLS
turning ϕ55 on the length 40
drilling ϕ12 to the depth 16.5                              drill ϕ12
cut off on the length of 36

special characters:  ^ = √  ~ = °  ` = ϕ     F8=print on screen
Tab=text ↔ tools,  @  @=text search,  F9=delete - F10=input text to vocabular
Ctrl+Z=delete line,  Ctrl+U=new line,  Insert=switch,  Delete=delete characte
Move cursor: ↑↓<>   Select: Enter,(Ctrl+PageUp = ↑)   Esc = cancel   F7 = hel
```

"Teach in" vocabulary:

> You can use "teach in" vocabulary for easier writing text of the operation. One vocabulary is available for each window.

> The line of text will be written into vocabulary: Move cursor on the line and pressing the key 'F10'.

> For selection of the text from the vocabulary you can use three different ways, see bellow:

TURNING (example of the text)

- TURNING @

  The character '@' written over "space"

  - you will find all lines of the vocabulary

- TUR@ING

  The character '@' written over "character"

  - you will find the lines of the vocabulary, which contains the marked character (for example 'N')

- @URN@NG

  The two characters '@'..'@' written over the text

  - you will find the lines of the vocabulary, which contains string closed between that characters (for example 'TURN')

> The use of a vocabulary is following:
Write the character '@' if you need it (see table mentioned before). Move the cursor where you will write a chosen text from the vocabulary. Switch exchange or insert mode and press 'Enter'. After the choice of the necessary line you press 'Enter' and this line will be copied to the text on the position of the cursor.

> To delete the line of the text from the vocabulary:
Rewrite space with a character '@'. Move cursor to the first position of the free line and press the key 'Enter'.Move cursor to the line of the vocabulary which you can delete and press the key 'Enter'. The line of the text will be written on the screen and this line will be deleted from the vocabulary by pressing the key 'F9'.

7.4 Correction of the TIME FIXING for operations

```
                    PROCESS  CHART          DIALOG

TEXT a.TIME fixing-correction
 OP.No Work.No. Shop    Name                                   FOR DRAWING No:
   2   4126             S 35-18R                               5222

                 TEXT                                              TOOLS
turning ϕ55 on the length 40
drilling ϕ12 to the depth 16.5                                drill ϕ12
cut off on the length of 36




RATE      MACHIN min   BATCH min                Hours             Price(Rp.)
1             25          45                        1.16                1100
F2 = text ↑↓ RATE    ^ = √  ~ = °  ' = ϕ      F8=print on screen
Tab=text ↔ tools,  @  @=text search,  F9=delete - F10=input text to vocabular
Ctrl+Z=delete line,  Ctrl+U=new line,  Insert=switch,  Delete=delete characte
Move cursor: ↑↓<>   Select: Enter,(Ctrl+PageUp = ↑)   Esc = cancel   F7 = hel
```

> The programmed interlock is the password of payroll for access of entry or correction of the time fixing. Write 6 char. which have been defined by installation of the system

> 'F2' switch cursor from window of text to windows of time fixing and back

> 'Tab' move cursor between windows of time fixing

> Remember following:

- RATE = it is step of time fixing
  * number of steps, their signs and values(Rp./hour) are stored in file name TARIF
  * The changes of that data are possible always by computer editor

- 14 -

* max. number of steps: = 9
* wrong sign of rate is not allowed

- MACHIN min = time of machining (minutes)
- BATCH min = batch time (preparatory) (minutes)

> Data, you see bellow are calculated:

- Hours = total time per operation
  [(MACHIN + BATCH) / 60] (hour)
- Price(Rp.) = it is price per operation (Rp.)
  [Hours * value(Rp./hour)]

> The contain of file TARIF you see bellow:

```
 5          <-   number of rate   (MAX. 9 only)
1           <-   1.rate   (sign of rate)
2           <-   2.
3           <-   3.
4           <-   4.
5           <-   5.
     1000   1.rate            table of rate fixing
     2500   2.rate            Rp./hour
     5500   3.rate
    11000   4.rate
    16000   5.rate


   data       comment
|________| |_______________________________|
    |
    |____ The changes of those data values are possible
          always carefully by computer editor
```

---

8. NEW module.

This module contains all functions as module CORRECTION. The line of screens, where you enter data, are free in this case. You fill up these lines step by step.

9. CHART PRINTING module.

The process chart, which is stored in the working area, will be printed on screen or on printer immediately. The repeated print is available.

10. ARCHIVES module.

```
                 PROCESS   CHART              DIALOG

      ARCHIVES                         WRITING CHART
                                       READING CHART
                                       CANCEL OF CHART
                                       PRINT ARCHIVES-LIST
                                       E X I T

      DRAW.No: 5222          VER: 1

move bar: ↑↓            select: Enter     exit: Esc             F7 = help
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```

> The capacity of the archives is up to 20000 process charts

> The system automatically stores the process chart to the subdirectory of name A and W. You can execute the copy from one subdirectory to other after serious break-down of your computer.

> The archives make possible:

- Recording of the process chart from memory to the archives.
- Reading of the process chart from the archives to the memory for next corrections.
- Deleting the useless process chart from archives.
- Print the list of the archives on the screen or on the printer.

> The state of the process chart:

It is a code defining the current state of the process chart in the list of archives. The meaning of that is following:

"space"	is a full process chart
"#"	is a standard process chart, representing different types of charts inside the group technology.
"3"	basic data are complete only
"2"	the sequence of the operations are complete only
"1"	the texts of the operations are complete only

> The creation of the numeric code:

You can look for the process charts in the archives according to numeric code of the items. This is way,how you find the similar details according to the geometric and technological shape more precisely than by its name. If you don't know this numeric code, write character '?' on the first position. The system defines it interactively before the finished chart is stored in archives.

- The design code is 6-digits numeric code. It describes the detail according to the geometric shape. The meaning of that is following:
  * 1. = type (rotary, unrotary)
    (completely manufactured, drawing of the parts, weldment etc.)
  * 2,3,4. = the principal dimensions
  * 5,6. = function, basic name (pin, shaft, holder etc.)

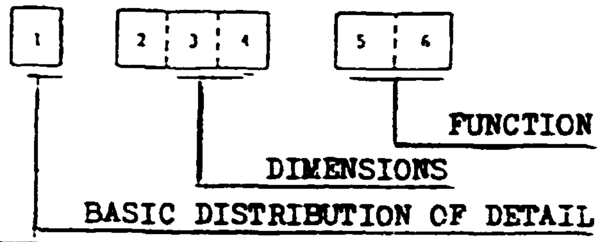
- The technologic code is 6-digits numeric code. It describes the detail according to the technologic processing. This code is useless for items, which are not completely manufactured. The meaning of that is following:
  * 1. = type of the material
    (heat treatment)
    (bar, cuttings, casting, pyrites etc.)

  rotary details:
  * 2. = shape and precision of the outside surface
  * 3. = shape and precision of the inside surface
  * 4. = The threads in rotary axis
  * 5. = the holes and flat elements not in rotary axis
  * 6. = toothing, splining etc.

  unrotary details:
  * 2. = flat surfaces
  * 3. = function holes (for precise bearing)
  * 4. = free holes (for screw etc.)
  * 5. = rotary surfaces
  * 6. = toothing, splining, grooves etc.

The graphic representation of these numeric codes is on next pages.

design code table



	1 2 3 4 5 6	DESIGN CODE rotary	DESIGN CODE un-rot.
1. char.	small portion of work	0	5
	complete manfactured	1	6
	parts list	3	8

max. dimensions	ROTARY items D_{max}	L/D	L_{max}	D max HOLE	UNROTARY items max HIGHT	max WIDTH	max LENGTH
	2 char.	3. char.	3. char.	4. char.	2. char	3. char	4. char
0	to 10	to 3	to 100	—	to 5	to 20	to 200
1	10-25		101-300	to 10	6-20	21-60	201-320
2	26-50		over 300	11-25	21-60	61-100	321-400
3	51-80	3 — 8	to 200	26-50	61-100	101-200	401-630
4	81-160		201-600	51-80	101-200	201-320	631-800
5	161-250		over 600	81-160	201-320	321-400	801-1000
6	251-400	over 8	to 200	161-250	321-400	401-630	1001-1250
7	401-630		201-500	251-400	401-630	631-800	1251-2000
8	631-1000		501-1500	401-630	631-800	801-1000	2001-3000
9	over 1000		over 1500	> 630	over 800	over 1000	over 3000

FUNCTION (5+6 char.)

retary item

1 PIN
2 SHAFT
3 SPEC.SHAFT
4 GEAR BAR
5 COVER
6 FLANGE
7 GEAR WHEEL

unrotary item

1 CUBE, PRISM
2 RAIL, SLIDEWAY
3 BOX
4 BLANK CUTT, SHEET
5 FLAME CUTT.
6 CASTING
7 WELDMENT

TECHNOLOGIC CODE — rotary items

1. sign: HEAT TREATING	1. sign: SEMI-PRODUCT	CODE	2. sign: OUTSIDE SURFASES — PRECISION	2. sign: OUTSIDE SURFASES — GEOMETRIC SHAPE	2. sign: OUTSIDE SURFASES — GEOMETRIC SHAPE (FUNCTIONAL CONE)	CODE	3. sign: INSIDE SURFASES (DEON CENTRE) — PRECISION	3. sign: INSIDE SURFASES — GEOMETRIC SHAPE	3. sign: INSIDE SURFASES — GEOMETRIC SHAPE (FUNCTIONAL CONE)	CODE	4. sign: THREADES (DEON CENTRE)	4. sign: THREADES	CODE	5. sign: EXTRA-AXIAL HOLES and FLATS	5. sign	5. sign	CODE	6. sign: GEARING, SPLINING KEY-SLOTS	6. sign	6. sign	CODE
WITHOUT HEAT TREATING UNINCREASED HARDNESS ANNEALING, BLACKING, STRAIGHTENING SOFT CHROME-PLATING E.T.C	BARS	1	CURRENT PRECISION UNITS >= 3.2 (IT 8) TURNING	FLAT	WITHOUT	1	CURRENT PRECISION UNITS >= 3.2 (IT 8) TURNING (REAMING)	FLAT	WITHOUT	1	EXTERNAL	CURRENT ≥ Ra 3.2	1	EXTRA-AXIAL HOLES + THREADES			1	GEARING EXT + INT		CURRENT ≥ 6c	1
	CUTTINGS	2		SINGLE-SIDE		2		SINGLE-SIDE		2		PRECISE ≤ Ra 1.6	2	FLATS	EXTERNAL	CURRENT IT 8 ≥ Ra 0.8	2			PRECISE ≤ 5c Ra 0.8 (GRINDING)	2
	CASTING	3		DOUBLE-SIDE	WITHOUT	3		DOUBLE-SIDE	WITHOUT	3	INTERNAL	CURRENT ≥ Ra 3.2	3			PRECISE IT 7 ≤ Ra 0.8	3	SPLINING	EXTERNAL	CURRENT	3
	FORGING	4				4				4		PRECISE ≤ Ra 1.6	4			INTERNAL ≥ Ra 1.6	4			PRECISE	4
	WELDMENT FLAME CUT. RUBBER PAPER OTHERS	5	SUPERIOR PRECISION UNITS <= 1.6 (IT 7) TURNING + GRINDING	FLAT	WITHOUT	5	SUPERIOR PRECISION UNITS <= 1.6 (IT 7) TURNING + GRINDING (REAMING)	FLAT	WITHOUT	5	EXTERNAL + INTERNAL	CURRENT ≥ Ra 3.2	5			INTERNAL + EXTERNAL ≥ Ra 1.6	5		INTERNAL	CURRENT IT 10 ≥ Ra 1.6	5
WITH HEAT TREATING INCREASED HARDNESS CARBURIZE, HARDENING, NITRIDING, N.TREATMENT, CHROME-PLATING E.T.C	BARS	6		SINGLE-SIDE		6		SINGLE-SIDE		6		PRECISE ≤ Ra 1.6	6	EXTRA-AXIAL HOLES + FLATS	EXTERNAL	CURRENT	6	EXTERNAL GEARING + SPLINING	EXTERNAL	CURRENT ≥ 6c Ra 1.6	6
	CUTTINGS	7		DOUBLE-SIDE	WITHOUT	7		DOUBLE-SIDE	WITHOUT	7	MOTIONS	EXTERNAL	7			PRECISE	7			PRECISE ≤ 5c Ra 0.8 (GRINDING)	7
	CASTING	8				8				8		INTERNAL	8		INTERNAL	CURRENT	8		INTERNAL	CURRENT	8
	FORGING	9	CAM			9	UNMACHINED HOLES			9	ROLLED		9			PRECISE	9			PRECISE	9
	WELDMENT FLAME CUT. RUBBER PAPER OTHERS	0	UNMACHINED SURFASES			0	WITHOUT HOLE			0	WITHOUT THREAD ON CEN.		0	WITHOUT			0	WITHOUT			0

TECHNOLOGIC CODE unrotary items

1. sign

HEAT TREATING	SEMI-PRODUCT	CODE
WITHOUT HEAT TREATING ANNEALING, BLACKING, STRAIGHTENING, S. CHROME	CUTTINGS	1
	CASTING GREY CAST IRON	2
	CASTING OTHERS	3
	FLAME CUTT. BLANK-CUTT. PLATE, SHEET	4
	OTHERS: FORGING WELDMENT PRESSING	5
WITH HEAT TREATING (INCREASED HARDNESS) CARBONITE, HARDENING, NITRIDING, H. FREQ., H. CHROME	CUTTINGS	6
	CASTING GREY CAST IRON (alloy)	7
	CASTING OTHERS	8
	FLAME CUTT. BLANK CUTT. PLATE, SHEET	9
	OTHERS: FORGING WELDMENT PRESSING	0

2. sign — PLANE SURFACES

UNIT	PRECISION	UNITS	CODE
CURRENT PRECISION ≥ Ra 3.2	WITHOUT BY-PASS	ONLY PLANE SURF. [A]	1
		OTHERS PLANE SURFACE + UNITS EXT.-INT. PROFILE [B]	2
		PLANE SURFACE + PLANE UNITS + SLOTS, BEVEL [C]	3
SUPERIOR PRECISION UNI 5 ≤ Ra 1.6	WITHOUT BY-PASS	[A]	4
		[B]	5
		[C]	6
	BY-PASS ON OTHERS UNITS	[A]	7
		[B]	8
		[C]	9
WITHOUT			0

3. sign — FUNCTIONAL HOLES

AXIS NUMBER	FACES NUMBER	UNITS	CODE
IN 1 AXIS	ONE		1
	TWO		2
	MORE		3
IN 2 AXIS	ONE		4
	TWO		5
	MORE		6
IN 3 + MORE AXIS	ONE		7
	TWO		8
	MORE		9
WITHOUT			0

4. sign — OTHERS HOLES

ACCURACY TO SIZE	SORT OF HOLES	CODE
CURRENT ≥ IT12	FREE > IT12	1
	CURRENT TO IT11	2
	COMBINATION 1 + 2	3
SUPERIOR ≤ IT9	FREE > IT12	4
	CURRENT IT6 – IT9	5
	COMBINATION 4 + 5	6
DRILLING PATTERN IN COMBINATION WITH	FREE + CURRENT 1 ÷ 3	7
	FREE + CURRENT 4 ÷ 6	8
	FREE + CURRENT 1 ÷ 6	9
WITHOUT		0

5. sign — ROTARY SURFACES

MAIN MOTION	SORT	UNITS	CODE
ROTARY WORKPIECE (TURNING)	EXTERNAL CYL. SURFACE + FACE [A]		1
	CYLINDER GUIDEWAY [B]		2
	INTERNAL CYL. SURFACE + FACE [C]		3
	COMBINATION 1 ÷ 3		4
ROTARY TOOLS (DRILL, BORING, MILL)	[A]		5
	[B]		6
	[C]		7
	COMBINATION 5 ÷ 7		8
	COMBINATION 1 ÷ 8		9
WITHOUT			0

6. sign — OTHERS UNITS

	SORT	CODE
GEARING (RACK)	ON PLANE SURFACE	1
	ON ROTARY SURFACE	2
	COMBINATION 1 + 2	3
LOCATING-LUBRICATING-TIGHTENING SLOTS	PLANE (CYLINDER)	4
	SPIRAL	5
	COMBINATION 3 ÷ 5	6
FURTHER SPECIAL UNITS (STRAIGHTENING, BENDING)	COMBINATION 1 ÷ 3 STRAIGHTENING	7
	COMBINATION 1 ÷ 3 BENDING	8
	COMBINATION 1 ÷ 6 + 7, 8 WELDMENT	9
WITHOUT		0

11. REMARKS ABOUT THE CHANGES module.

```
                 PROCESS  CHART          DIALOG

        REMARKS ABOUT THE CHANGES

                              for Draw.No5222             :

                        date:    06.09.93

 prepared by:..., executed by:.....   RAFAEL      RONY

                      change:     for information only




F1 = cancel of whole remark     Ctrl+Z = delete line      move cursor: ↑↓<>
Enter = end of remark              ESC = exit                     F7 = help
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```

Using this module you can describe in notes the changes of process chart during production of detail. The remark without text or name of author isn't accepted. Computer date is generated for a new remark. Current date is defaulted for correction of the remark. You can change it in both cases. Review of the remarks about the changes is available. Print of these remarks is through PRINTING module.

Entry of the remark about the changes is not so necessary. You can substitute it by the other way: Correct the process chart how you intend and store the chart to archives under other version.

12. PARTS LIST module.

PROCESS CHART DIALOG

PARTS LIST SERVICE

ENTRY
DELETE
REVIEW
HANDLING
E X I T

move bar: ↑↓ select: Enter exit: Esc F7 = Help
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The parts list is the list of all details and materials for production of product. This software system makes possible to compile the process charts just according to parts list. The parts list usually contains several subparts lists,which are build up as " tree structure ". You must compile main parts list of final product from " down to up ". The meaning of that is following:

> Enter parts lists of individual smaller partial details of final product first at all.

> These parts lists are stored in system on the same level.

> The bigger parts list are compiled step by step from already finished parts lists as " subparts list ".

> Any parts list can be stored to the next parts lists.
> Figure of compiling of parts list:

```
A3  A2  A1   A  B2  B1   B   C  D1   D   E
 |   |   |   |   |   |   !   |   |   |   |
 -----------------------------------------

     E
     |
     A--A1--A2--A3
     |       |
A2---C       B--B1---D
     |           |
     D--D1      B2
```

> This module serves for handling of parts list from memory to floppy and on the contrary as well.

Parts list number entry:
> For viewing the total list of the parts list on screen press '?' After this you can choose the parts list number interactively using ARROW keys.
> The parts list number is being looked for in the total list of the parts list. If the required parts list isn't in the memory, enter a new parts list. If it is there, it is viewed and you can correct current parts list.

Data entry of the first item of the parts list:
> Fill up the file name of the parts list. This file must not contain a character "space"
> Other data you can either enter arbitrary or keep it free

Rewriting of the record:
> See the current record of the parts list on the screen.You scan step by step, rewrite and cancel this record.
> For confirmation of the entry and crossing to the next page press "Page Down"

> Parts list positions are automatically renumbered after the correction is over.

Entry of subparts list:

> Enter all subparts list in the current parts list.

> If the required subparts list is not in the memory a message is displayed and you must enter it manually.

> The numbers of pieces of the subparts list are multiplied by number of pieces of current parts list.

> Remember following:
- Enter the line of number of pieces using integer
- Don't keep free drawing No. line
- When you enter the material contained in the parts list, you must write the character " ! " on the first position
- Other data you can enter arbitrary.

13. ORDERS module.

This module serves for entry of orders to the software system. Each order contains Order number, order name and number of pieces in order.

Order number entry:

> For viewing the list of the orders on screen press '?' After this you can choose the order number interactively using ARROW keys.

> The order number is being looked for in the list of orders If the required order number isn't in the memory, enter a new order. If it is there, current order is viewed.

> You can correct this order in both cases.

PROCESS CHART DIALOG

ORDERS

```
                                        enter:
Order No.       : -------------------- A123

Order NAME      : ---------(-1= exit)- BOLO

Parts list No. : ---------( ?= help)- B1

Parts list NAME: -------------------- ENGINE

Number of pieces in order: ---------- 5



delete line:  Ctrl+Z     Delete parts list:  F1
end:         Enter          cancel:        Esc                  F7 = help
VER 5.0  (C) VUOSO Czech Republic, Prague 1993
```

Data entry of the order:

> The order contains arbitrary number of final products

> Every final product of current order could be destined to different customers. In this case you can address it on the line of the "order name".

> The final product is defined with parts list number. Enter this number either manually or looking for it in total list of parts list interactively by pressing '?'

> You correct, change and cancel the data of order till any documentation about it is printed.

> You must review all valid data dealing with order and finish using character '-1'

14. DATA BANK module.

PROCESS CHART	DIALOG

DATABASES

MATERIAL

MACHINE & EQUIPMENT

E X I T

scanning or corection
of MATERIAL and MACHINE databases

move bar: ↑↓ select: Enter exit: Esc F7 = Help
VER 5.0 (C) VUOSO Czech Republic, Prague 1993

The system provides automatized work of the system with a machine and material databases (" on line work "). This module serves for fulfillment, correction and copying of databases in working mode " off line ".

Material database:

> The current record of this database contains:

- identification	13	characters
- quality	8	-"-
- dimension	9	-"-
- physical unit	2	-"-
- price for unit	10	-"-
- specific weight	9	-"-
- name	25	-"-

> Select the information of material either for whole database or according to required identification, quality, dimension and name of material respectively.

Machine database:

> The current record of this database contains:

- working place No.	6	characters
- sign of machine shop	4	-"-
- sign of working place	15	-"-
- remark	35	-"-
- additional notes	10 x 35 char.	

> Select the records of machine either for whole database or according to required working place No., working place name and machine shop respectively.

15. BULK PRINT module.

This module makes possible to print the whole technological documentation of one parts list. You can print either the entire process charts or list of material or calculation of product

Before printing:

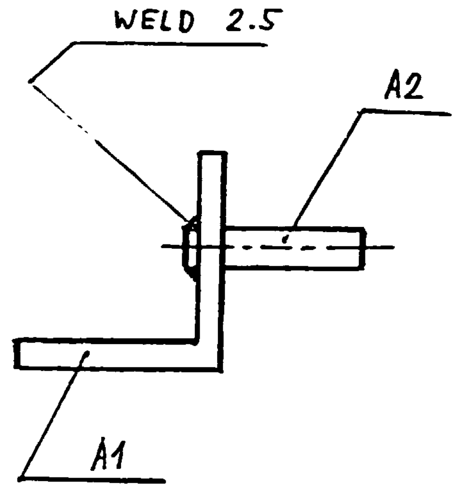
> Store all process chart of parts list in archives.

> Enter any order, which contains requirement parts list trough the " order module ".

PARTS LIST
(list of details)

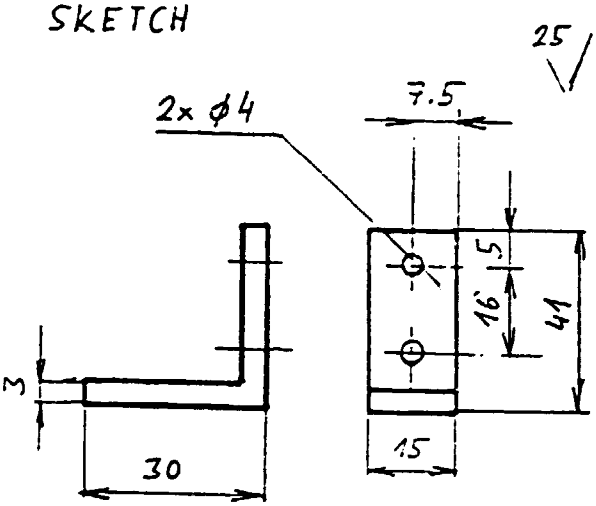
No.	Drawing No	Draw. name	No. of pieces
4	A4	! electrode (material only)	2
3	A3	! paint (red) (material only)	1
2	A2	PIN	2
1	A1	ANGLE PLATE	1
0	A	HOLDER	1

SKETCH:



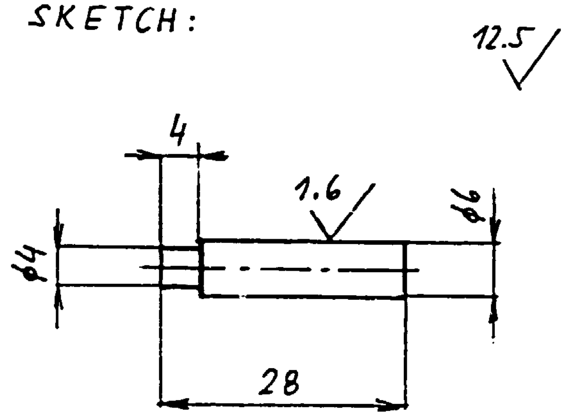
Drawing No.: A
Material: –
Drawing name: HOLDER
Product No. A
Product name: HOLDER

SKETCH



Drawing No.: A1
Material: sheet
Drawing name: ANGLE PLATE
Product No. A
Product name: HOLDER

SKETCH:



Drawing No. A2
Material: bar 8
Drawing name: PIN
Product No. A
Product name: HOLDER

Order No.: 1 Order name: BORNEO Order-pc: 5
Parts list No.:A P.list name:HOLDER Position: 0

Drawing no.: A No.of pieces: 1 Version: 1
Drawing name: HOLDER Basic shop:

1. Identif.material	Quality	SU	Dimension	SUprice	SUweight
Name			SU number	Price-total-Weight	
		?			0.00

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
1		9211	WELDING			

Describe of operation: Tools:
weld pin to plate twice

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
2		9311	MECH.W.			

Describe of operation: Tools:
file smoothly
colour twice red paint

te: 16.09.93 Prepared by: Approved by:

MTDDC-INDONESIA	PROCESS CHART	Pages: 3 Page: 2
Order No.: 1	Order name: BORNEO	Order-pc: 5
Parts list No.:A	P.list name:HOLDER	Position: 1
Drawing no.: A1	No.of pieces: 1	Version: 1
Drawing name: ANGLE PLATE		Basic shop:

1. Identif.material	Quality	SU	Dimension	SUprice	SUweight
1371613006300	11300.2	m2	425301	95000	2.85
Name			SU number	Price-total-Weight	
SHEET black 1000x2000x1			0.2	19000	0.57

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
1		8113	Hal			

Describe of operation: Tools:

shear by drawing chart 15x72

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
2		4613	DR05a			

Describe of operation: Tools:

drill ϕ4 twice dist. 16

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
3		9311	MECH.W.			

Describe of operation: Tools:

smooth the edges
bend size 30 to 90°

Date: 16.09.93 Prepared by: Approved by:

MTDDC-INDONESIA

PROCESS CHART

Pages: 3 Page: 3

Order No.: 1
Parts list No.:A

Order name: BORNEO
P.list name:HOLDER

Order-pc: 5
Position: 2

Drawing no.: A2
Drawing name: PIN

No.of pieces: 2

Version: 1
Basic shop:

1. Identif.material	Quality	SU	Dimension	SUprice	SUweight
1551115230800	11523.0	M	426510	4000	0.395
Name			SU number	Price-total-Weight	
ST.CIRC.DRAWN BAR 8H11			0.05	200	0.01

Op.No.	Shop	W.place	W.place name	Rate	BATHmin	MACHminute
1		4126	S 35-18R			

Describe of operation:
turning ϕ6 on the length 33
step ϕ4 length 4
cut off on length 28

Tools:

te: 16.09.93 Prepared by: Approved by:

MTDDC-INDONESIA	LIST OF MATERIAL	Pages: 1 Page: 1

Order No.: 1 Order name: BORNEO No.of pc: 5
Parts list No.:A Parts list name: HOLDER

Mater.ident.	Material name	Drawing No.	Dimension	SU	Weight	Price
		A			.60*	500*
1371613006300	SHEET black 100	A1	425301	m2	2.85	95000
1551115230800	ST.CIRC.DRAWN B	A2	426510	M	.20	2000
A321445	ELECTRODE	A4	D=3.5	PC	8.00	8000
C12380	PAINT (red)	A3		KG	3.15	15500
	T O T A L for 1 piece of product:				2.96	12100

= weight or price is approximate values only

te: 09.28.93 Prepared by: JAURA

Order No.: 1 Order name: BORNEO No.of pc: 5
Parts list No.:A Parts list name: HOLDER

Mater.ident.	Material name	Drawing No.	Dimension	SU	Weight	Price
		A			.60*	500
1371613006300	SHEET black 100	A1	425301	m2	2.85	95000
1551115230800	ST.CIRC.DRAWN B	A2	426510	M	.20	2000
A321445	ELECTRODE	A4	D=3.5	PC	8.00	8000
C12380	PAINT (red)	A3		KG	3.15	15500

Calculation for 1 piece of product:

Approximate gross weight: kg 3.

Price of material : Rp. 12100

Rate fixing(hours): .00 Piece rate: Rp.

A p p r o x i m a t e t o t a l p r i c e : Rp. 12100

ate: 09.28.93 Prepared by: JOUKA

Automatized system for multiprofessional operations composition

on IBM AT type personal computers

M A N U A L

(Programmer's guide)

VER 5.0 (C)
VUOSO Ltd.
Czech Republic
Prague 1993

CONTENTS

1. INTRODUCTION.

The software package is saved on two floppy diskettes. They are named as " Automatized software system "

" TECHNO No. 1 "

" TECHNO No. 2 "

on their labels. The customer setup is described in the user's guide book (page 2, paragraph 3. "software package installation ").

2. TREE STRUCTURE OF FLOPPY DISKETTES.

```
tree:               contains of directories:

No. 1:
A: (root)       --> installation program
|_____WFUNIV    --> 1. part of program modules


No. 2:
A: (root)       --> source programs, debugging tools
|                   source routines, text data
|
|_____WFUNIV    --> 2. part of program modules
       |            program data
       |__A     --> archives files
       |__K     --> parts list files
       |__M     --> working place
       |__W     --> security subdirectory of archives files
```

3. TREE STRUCTURE OF HARD DISK after the installation of system.

```
tree:                 contains of directories:
A:                --> source programs
|                     source routines, text data
|
|____WFUNIV       --> program modules
     |                program data
     |__A         --> archives files _____(it is equal)_______
     |__K         --> parts list files                        |
     |__M         --> working place                           |
     |__W         --> security subdirectory of archives files_|
```

4. TREE STRUCTURE AND LIST OF PROGRAMS MODULE.

```
tree:                                contains of modules:
TECHNO.EXE                       --> main module
|
|
|             _KATMATA.EXE_
EDIC0VA.EXE--|             |              |--> basic data
|            |_ARCH1VA.EXE |              |
|                          |              |
|             _EDIC2VA.EXE |              |
EDIC1VA.EXE--|             |              |--> sequence
|            |_EDIC3VA.EXE |_ correct._|       operations
|                          |  modules    |
EDIC2VA.EXE----TOBRAZA.EXE |              |--> text of
|                          |              |     operation
|                          |              |
EDIC3VA.EXE----TOBRAZA.EXE_|              |--> text & time
|                                               fixing
```

```
 tree: (continue)                      contains of modules:
 |
 T1ST1VA.EXE                      --> chart
 |                                    printing
 |              _KZNAKA.EXE__                  |--> design code
 ARCH1VA.EXE--|_TZSOUA.EXE   |- archiv-   |--> technological
 |             |_TZFREA.EXE__|  es         |     code
 |
 ZMENRIZA.EXE                     --> remarks about
 |                                    changes
 |
 |              _KATMATA.EXE_                 |--> material base
 KATBASVA.EXE-|_PLNMATA.EXE |                |-->    handling
 |             |_KATSTRA.EXE |- data          |--> machine  base
 |             |_PLNSTRA.EXE_|  bank          |-->    handling
 |
 |             _TISTMATA.EXE_                 |--> list of material
 TISKDOA.EXE-|_TISTKALA.EXE |- bulk           |--> calculation
 |            |_TISTPOSA.EXE_|  print          |--> process charts
 |
 KUSYA.EXE                        --> parts list
 |
 |
 ZAKAZKA.EXE                      --> orders

 Support programs name:                   contains of programs
 VYTEXA.EXE_______________
 VYTEXIA.EXE              |               special
 VYTEXFA.EXE              |-----------> printing
 VYTEXRA.EXE              |               on screen
 VYTEXTA.EXE______________|
```

- 3 -

Support routines name:

```
DEKLA.FOR    DICTE.FOR    DICTO.FOR__     common
DIZAO.FOR    DIZAP.FOR    FORMAT.FOR |-> fragments
MENCIS.FOR   MENEDO.FOR   MENTIS.FOR_|    of programs
SUBR1.OBJ    SUBR2.OBJ    SUBR3.OBJ ---> object modules
SUBR4.OBJ
MENU.CMN                            ---> common variables
SYSTEM.CMD                          ---> system interface
CIS.ASM _                                "assembler" routine
CIS.OBJ _|-------------------------> for screen control
```

5. DATA STRUCTURE.

file name:	contains:	type:	record structure: item:	size:	range:
CRF	special for date	S			
DATAT	working, texts of operation	I			
DATAW	working, process chart	S			
FISES	list of parts list	S	parts list No.	15	1-15
			file name	5	19-23
			parts list name	15	26-40
XXXXX	parts list in subdir. \K	S	position No.	3	1- 3
			number of pieces	3	5- 7
			drawing name	15	9-23
			drawing No.	15	25-39
			remark	15	41-55

file name:	contains:	type:	record structure: item:	size:	range:
KAZIMO.TXT	classification	S	change sign of machine carefully by computer editor in " over mode "		
LOGCIS	spec.information by installation	S			
MACHIN	machine base	S	work.place No.	6	1- 6
			machine shop	4	10-13
			sign of w.place	15	18-32
			remark	35	34-68
			addit. notes	10 x 35 char.	
MATER1	material base	S	identification	13	1-13
			quality	8	15-22
			dimension	9	24-32
			physical unit	2	34-35
			price for unit	6	37-42
			specific weight	9	44-52
			name	5	54-78
TEXTY.TXT	vocabularies	S	text of operation	55	
NARADI.TXT	"teach in"	S	tools	17	
TARIF	table of rate fixing	S	structure is described in file		
#*	text files	S	texts for function keys F7		

6. SOURCE PROGRAMS.

The source programs are written by Microsoft Fortran language except source file name CIS.ASM,which is written by Microsoft Assembler.
The all names of source programs are the same as the name of executive programs with extension *.FOR (see page 2 + 3 , paragraph 4.). The source programs are stored on floppy No. 2

7. CORRECTION, COMPILING and LINKAGE of programs modules.

If you need any correction of source programs at all, you must make the following:
- copy all files from floppy diskette No. 3 to the same subdirectories as on the floppy diskette on your hard disk
- copy files from floppy No. 2 under subdirectory MSF\LIB.
- write to the "Autoexec.bat" statements:

```
SET INCLUDE=C:\MSC\INC
SET BIN=C:\MSC\BIN
SET LIB=C:\MSC\LIB;C:\MSF\LIB
PATH=C:\MSF;C:\MSF\LIB;C:\MSC;C:\MSC\BIN;
```

- restart your computer.

In any case we recommend to make correction, compiling and linkage of source programs by "batch" file !.
The executable statement is following:

ETV3 EDICOVA for example
where
ETV3 is name of batch file
EDICOVA is name of source program

This competent statements are shown in next table:

ESV4 ARCH1VA	ESV3 TIST1VA
ESV4 EDICOVA	ES TISTMATA
ESV4 EDIC1VA	ES TISTKALA
ETV EDIC2VA	ES TISTPOSA
ESV2 EDIC3VA	ESV TOBRAZA
ESV4 KATBASVA	ETV3 TZFREA
ETV4 KATMATA	ETV3 TZSOUA
ETV4 KATSTRA	ETV22 VYTEXA
ESV4 KUSYA	ETV22 VYTEXIA
ESV4 KZNAKA	ETV22 VYTEXFA
ESV4 PLNMATA	ETV22 VYTEXRA
ETV4 PLNSTRA	ETV22 VYTEXTA
ETV3 TECHNO	ESV4 ZAKAZKA
ESV4 TISKDOA	ETV4 ZMENRIZA

After successfully linkage of source program you must make packing of executing program by statement:

PACK EDICOVA

where EDICOVA is name of that ex.program (for example)

You don't forget copying correction programs (source and executing) on competent place on floppy diskette.

8. LAST INFORMATION.

- Correct individual programs exceptionally only.
- Remember the whole software system is very complicated.
- The system is useless after any wrong correction of programs !!
- The user's guide book and this programmer's guide book are stored on floppy diskette No. 3 as "ascii" files.

The name of these files is following:

user's guide book	MANUAL1.GUI
its title page	MANUAL1.TIT
programmer's guide book	MANUAL2.GUI
its title page	MANUAL2.TIT

COST CALCULATION VERSION - INSTRUCTION FOR INSTALATION

On the request of the MTDIC the program modules operating over technological data base (process chart and cutting conditions) were equipped with the possibility of estimate of the overall production costs.

The input data of this costs calculation are keyed in with the help of one special menu-screen during the operator-computer dialogue. For usage of the system with this possibility,the new installation diskets must be prepared.These diskets will be prepared from the old ones and the help diskets "cost calculation".

When preparing the instalation diskets follow this procedure:

1. Make a copy from both instalation diskets with name "TECHNO" No.1 and 2.
2. Save the old installation diskets for instalation of the system without cost calculation.
3. From the disket "COST CALCULATION" copy subdirectory \FUNIV, the file TECHNO.EXE to the new disket TECHNO No.1.
4. From the disket "COST CALCULATION" copy subdirectory \FUNIV, the files [illegible],[illegible],KALKCA.EXE,MACHI1. to the new disket TECHNO No 2..
5. From the disket "COST CALCULATION" copy from the root directory the files [illegible],[illegible],KALKCA.FOR,to the new disket TECHNO No.2,together with file TECHNO.FOR.
6. On the new disket TECHNO No.2 copy the file TARIF from subdirectory \FUNIV into the root directory.

Now you have prepared the new instalation diskets.In the instalation of your new system follow the instalation procedure discribed in users manual.

-1-

Research institute — PART CALCULATION — Pages: 1 Page: 1

Parts list no.:
Drawing no.: 4 04 11 3245 [illegible]
Drawing name: TYC

Position: 1
Version: 1
Basic shop: 321

Identif.material	Quality	SU	Dimension	SUprice	SUweight	SUnumber
[illegible]	[illegible]	KC	4255 [illegible]	300	5.55	0.35

Name
[illegible] 50MM

Material: Weight: 1.94 Price (Rp.): 100

Op.No.	Shop	W.place	W.place name	M.hour	BATHmin	MACHminute
1		5902	PILA RAMOVA	100	0.	6

PRICE of operation (Rp.): 10

Op.No.	Shop	W.place	W.place name	M.hour	BATHmin	MACHminute
2		4115	SOUSTRUH	100	6.5	20

PRICE of operation (Rp.): 44

Op.No.	Shop	W.place	W.place name	M.hour	BATHmin	MACHminute
3		[illegible]	BUA 3F	100	4.0	30

PRICE of operation (Rp.): 56

Op.No.	Shop	W.place	W.place name	M.hour	BATHmin	MACHminute
4		[illegible]	ZAMECNIK	100	0.	5

PRICE of operation (Rp.): 8

TOTAL PRICE of operations (Rp.): 119

T O T A L P A R T P R I C E (Rp.): 219

Automatized system of the Calculation

of Cutting conditions

on IBM AT type personal computers

VER 1.0 (C)
VUOSO Ltd.
Czech Republic
Prague 1993

SOFTNORMA

The automatized system of the calculation of cutting conditions.

- This system is controlled by dialogue, by means of the choice of orders from the display. The user is not obliged to know the computer system or the knowledge of programming.

- The "Softnorma" system contains the software elaboration of the standard of cutting conditions for machining and replaces the conventional manual work of calculating the cutting conditions.

- This software system according to the choice of the user automatically calculates the cutting conditions either for maximum economy or maximum productivity or defined durability of the tool.

- The system contains many checking of the calculation.

- Results give are cutting conditions in an arbitrary number of turning and milling operations with the calculation of the machine time.

- The system co-operates with an open machine-tools database.

- The system brings higher productivity of the technological preparation of production.

HOW TO OPERATE THIS SYSTEM ?

This software system is stored on floppy diskette. They is named as " SOFTNORMA " on their label. The floppy diskette contains installation program for customer setup by name: INSTALL.

Install the software package on your computer in the following way:

- secure about 2 MB free memory on your hard disk
- setup hard disk on primary level where you want to install the software package (for exam. C: or D:)
- insert the floppy diskette to drive (A: or B:)
- enter message:
  A:|INSTALL or B:|INSTALL
- answer on dialogue-question by computer step by step.

After the correct installation the message: "The software system is installed on your computer " is displayed on the screen.
Start of the software system is by input of the statement: SOFTNORM

After it you see a " pull down menu " on screen. You see also the main activities which you can use immediately.

Restart of system you make following statements:

CD\ASOFT
CD SOFTA1
SOFTNORM

Remember following:

- The line " Number of pieces in ration " you fill according to the number of pieces in production batch.
- The line "Set class of material (CSN)" you fill oode according to the basic ration of material following:

code	kind of material	hardness kg/mm2
11 - 13	structural steel, carbon steel	49 - 123
14	blister steel	78 - 88
15 - 17	alloy, stainless, high quality	54 - 143
19	tool steel	45 - 103
42	cast steel	50 - 105

- This user's guide is stored on floppy diskette as " ascii " file. The name of this file is following:

user's guide	MANUAL3.GUI
its title page	MANUAL3.TIT

THE UNIVERSITY OF INDONESIA - MTTDC JAKARTA

SHORT COURSE PROCEEDING:

PRODUCTION PLANNING

MANUFACTURING AUTOMATION AND ROBOTICS

UNIVERSITY JAKARTA

MTDDC IN INDONESIA

SHORT COURSE

PROCEEDING

P R O D U C T I O N   P L A N N I N G

by

Zdeněk ŠEBELA, PhD and Pavel TOMEK, PhD

October 1993

JAKARTA

Content

I - INTRODUCTION TO OPERATIONS MANAGEMENT AND PRODUCTION PLANNING

Definition : OPERATIONS MANAGEMENT IS THE MANAGEMENT OF TRANS-FORMATION SYSTEM WHICH CONVERTS INPUTS INTO GOODS AND SERVICES.

Operations has responsibility for five major decisions area :

PROCESS
CAPACITY
INVENTORY
WORK FORCE
QUALITY

PROCESS

- Type of equipment and technology
- Process flows
- Layout of facilities

CAPACITY

- Providing :
  - Right amount of capacity
  - at the right place and
  - at the right time

(to solve size of the facility and proper number of people in operations)

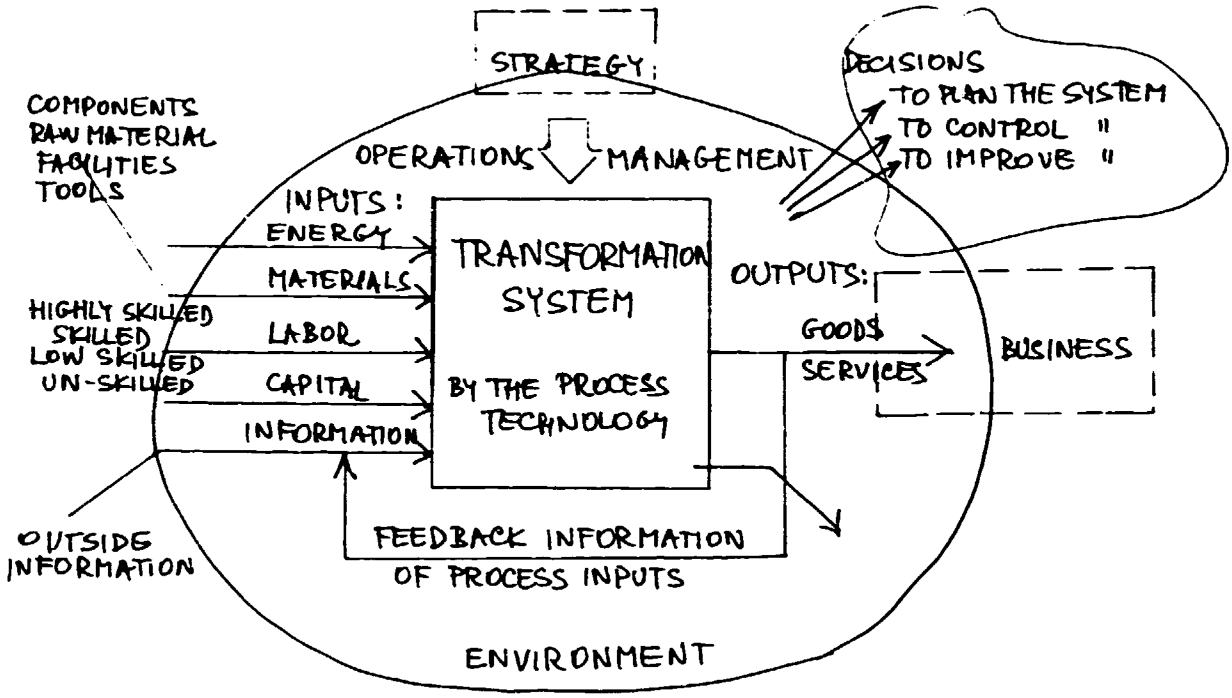
INVENTORY

- What to order
- How much to order
- When to order

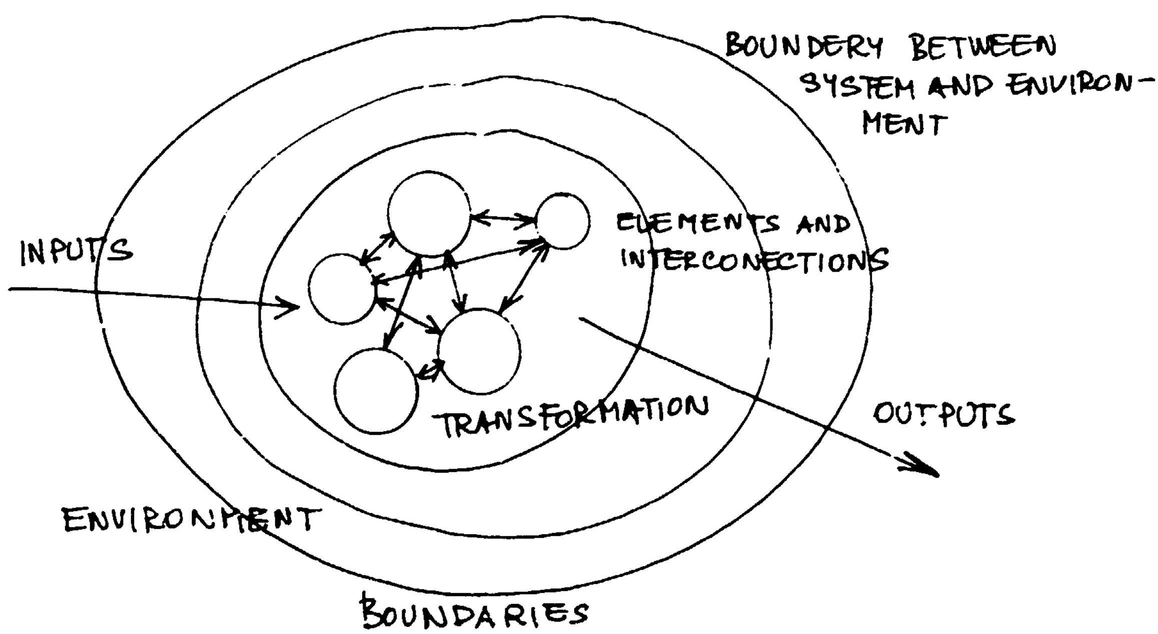
Inventory control system are used to manage :

MATERIAL FOR PURCHASING
RAW MATERIALS
FINISHED GOODS INVENTORIES
HOW MUCH TO SPEND
WHERE TO LOCATE MATERIALS
FLOW OF MATERIALS WITHIN THE FIRM

THE FACTORY AS A TRANSFORMATION SYSTEM



SYSTEMS THINKING



ADOPTED BY [3]

WORK FORCE

- Selection
- Hiring
- Firing
- Training
- Supervision
- Compensation

(Nothing is done without people - key tasks for operations today.)

QUALITY

- The quality is built into the product through all stages of operations
- Standards must be set
- Equipment must be designed
- People must be trained
- Goods and services must be inspected

DECISION FRAME WORK

Decision frame work is a frame-work which categorizes and defines decisions in operations.

MARKETING AND OPERATIONS

In goods-producing organizations MARKETING and OPERATIONS are organized as separate functiones (goods are produced and sold seperately).

The history of operations management includes 7 major contributions :

1 DIVISION OF LABOR

2 STANDARTIZATION OF PARTS

3 INDUSTRIAL REVOLUTION

4 SCIENTIFIC STUDY OF WORK

5 HUMAN RELATIONS

6 DECISION MODELS

7 COMPUTERS

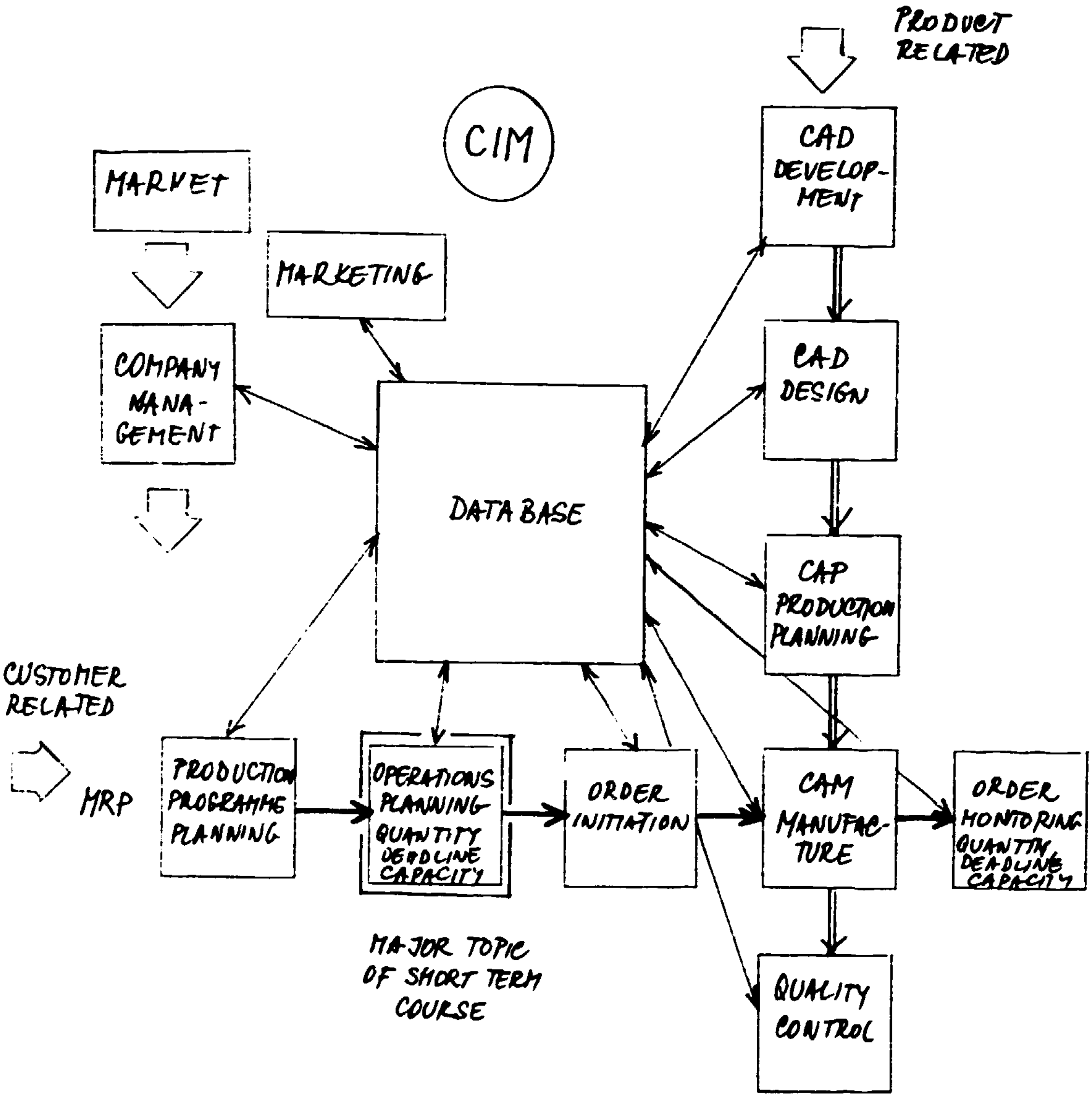
Marketing and finance are at the same time items of a functional area of business.

OPERATIONS STRATEGY

Operations strategy is a vision for the operation function integrated with business strategy.

Operations strategy consists of 4 components :

- MISSION
- OBJECTIVES
- DISTINCTIVE COMPETENCE
- POLICY



CIM - COMPUTER INTEGRATED MANUFACTURING

ADOPTED BY [9], [6]

II - PROCESS DESIGN

1 - PROCESS SELECTION

Process selection is often viewed as a layout problem. In the process design must be solved questions as follows :

FIRST QUESTION : the process is classified by type of production as a

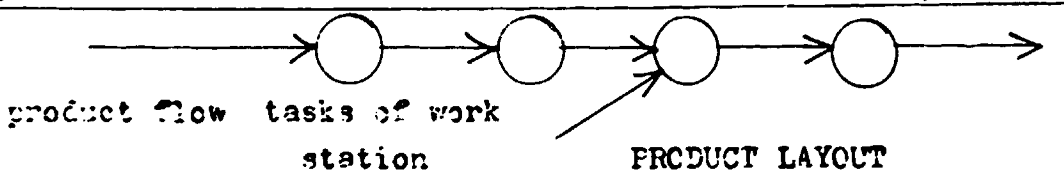
- LINE PROCESS
- INTERMITTENT PROCESS
- PROJECT

SECOND QUESTION : the process is classified by type of customer order

- MAKE-TO-STOCK
- MAKE-TO-ORDER

LINE FLOW is characterized by a linear sequence of operations used to make the product or operation service

EQUIPMENT AND LABOR ARE ORGANIZED INTO LINES OF WORK/STATIONS



Conditions : (1) product must be well standardized
(2) prescribed sequence

Exemple : assembly line

Line - flow operations : - MASS PRODUCTION (cars, trucks..)
- CONTINUOUS PRODUCTION (paper, beer..)

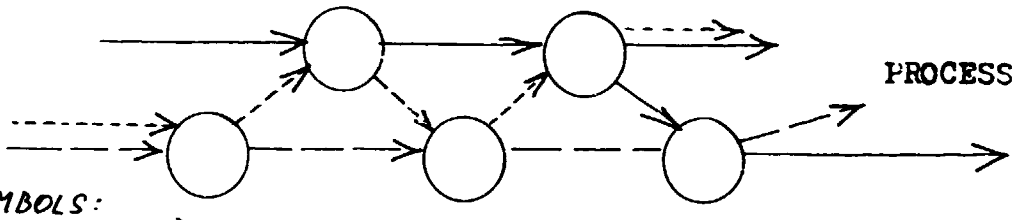
(3) highly efficient
(4) extremely inflexible

INTERMITTENT FLOW (JOB-SHOP) is characterized by production in batches at intermittent itervals

EQUIPMENT AND LABOR ARE ORGANIZED INTO WORK CETRES (BY SIMILAR TYPES), PRODUCTS FLOW ONLY TO THOSE WORK CENTRES THAT ARE RE - QUIRED GENERAL - PURPOSE EQUIPMENT

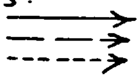
THROUGHPUT TIME for batches will increase

- much lower utilization of equipment
- much lower utilization of labor

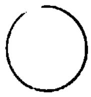


PROCESS LAYOUT

SYMBOLS:



product flows



tasks or work stations

$$TE = \frac{\text{total time(machine hours / labor hours) spend working} \cdot 100\%}{\text{total time in operations (including time of waiting)}}$$

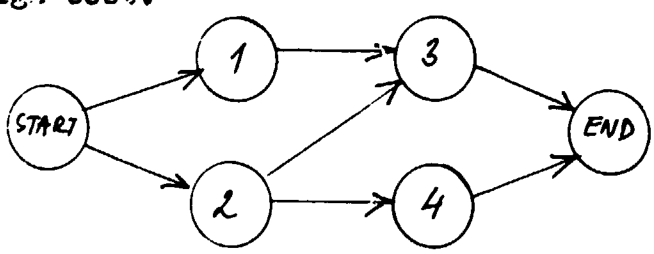
THROUGHPUT EFFICIENCY

TE -- lo - 20 % rarely 40 %

JOB SHOP is making products to customer order.

PROJECT FORM OF OPERATIONS - to produce a unique product(art, motion picture, a building) - each unit of these is produced as a single item.

There is no flow of product - but sequence of operations. Project has high cost.



PROJECT LAYOUT

Six factors appear to influence process selection from among the process :

(1) market conditions

ADOPTED BY [3]

(2) capital requirements
(3) labor
(4) management skills
(5) raw materials
(6) technology

2 - PROCESS - FLOW ANALYSIS

Macro level of process design - TYPE OF PROCESS SELECTED
- TYPE OF TECHNOLOGY USED

Micro level of process design - PROCESS-FLOW ANALYSIS
- FACILITIES LAYOUT

Facilities layout makes ifluence for
- SCHEDULING DECISION
- INVENTORY LEVEL
- TYPES OF JOB (DESIGNED)
- METHODS OF QUALITY CONTROL(USED)

FLOWCHART

Flowchart is tool for analysing by conventional way or by mathematical models. Flowchart gives analysis of following process elements :

(1) RAW MATERIALS
(2) PRODUCT DESIGN
(3) JOB DESIGN
(4) PROCESSING STEPS
(5) MANAGEMENT CONTROL INFORMATION
(6) EQUIPMENT AND TOOLS

Earlier - scientists broken the process to elements and studied each of them and seeking how to develop whole process through elements

Now - we are trying to minimize throughput time from beginning to the end (selling) by

SEEKING THE WASTE IN PROCESS

We consider like the waste any operation,which does not add any value during the production process

ONLY ACTUAL PROCESSING TIME OF THE MATERIAL BY MACHINE OR BY LABOR ADDS VALUE

Next documents describe the flow of material in great detail :

- ASSEMBLY DRAWINGS
- ASSEMBLY CHARTS
- ROUTING SHEETS (PROCESS CHARTS)
- FLOW - PROCESS CHARTS

Process charts (operation process sheets) give sequences of operations with all detail information for manufacturing.Data base of metal cutting technologies as a system for process charts elaboration has been handed over to MTDDC.Comprehensive explanation of above mentioned DATA BASE is published in that PROCEEDING.

Symbols used in a flow - process charts :

○ OPERATION (A TASK OR WORK ACTIVITY)

□ INSPECTION (OF THE PRODUCT FOR QUANTITY AND QUALITY)

⇨ TRANSPORTATION (A MOVEMENT OF MATERIAL FROM ONE POINT TO ANOTHER)

▽ STORAGE (AN INVENTORY OR STORAGE OF MATERIALS WAITING THE NEXT OPERATION)

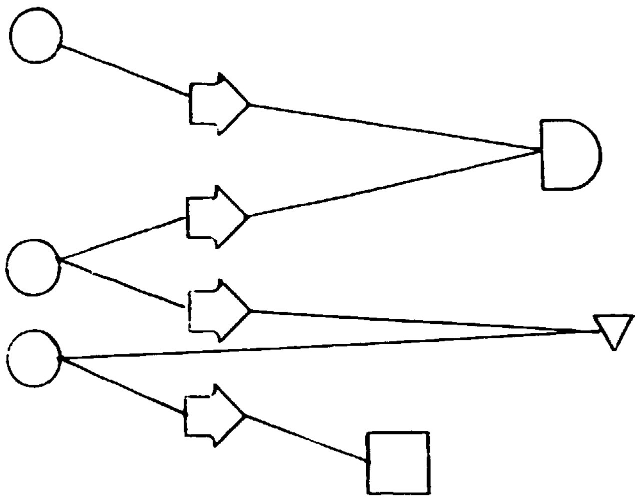
D DELAY (IN THE SEQUENCE OF OPERATION)

The key - questions for analysing :

(1) WHAT - what operations are really necessary
(2) WHO - is performing operation
(3) WHERE - is this operation conducted
(4) WHEN - is this operation performed

FLOW PROCESS CHART

TIME OPERATION TRANSPORTATION INSPECTION STORE DELAYS



order (printed)
to the dispatcher
prepared semi-product
to the operation
1-st opretion
to the store
2-nd operation
transportation
inspetction
.....

3 - INFORMATION FLOW ANALYSIS

1) information is the product of operations
   (clerical information of processing in offices)
2) information is used for management or control activities
   (order entry, purchasing documents etc.)

Often is necessary to realize it together - material and flow analysis.

SYMBOLS :

- origin of record
- significant step (new data is added to the existing record)
- nonproductive activity
- move of information
- inspection
- delay

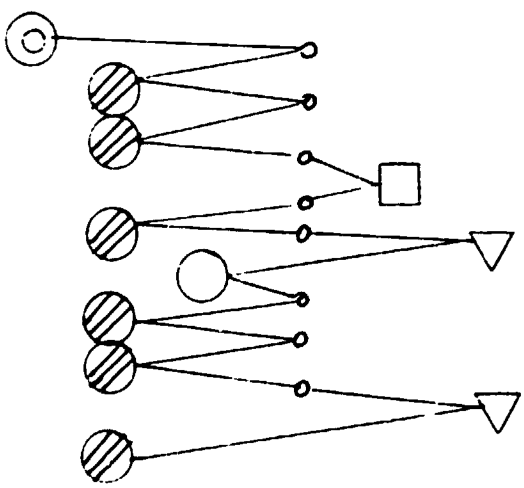
THE SAME QUESTIONS :

what who where when how

EXAMPLE :

" Development of a new product "

TIME ACTIVITIES REMARKS



Board of Directors
Marketing division
Market forecasting
Development and research
Design department
Operations department
Quality System Management
Inventory management
Waiting for final decision
Board of Directors

4 - MODELLING OF PROCESS FLOWS

Many types of models can be used :

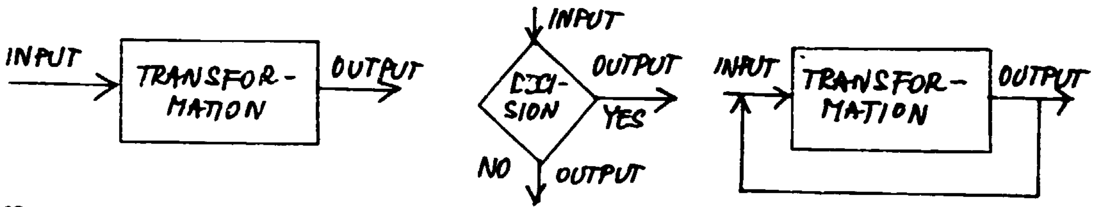
LINEAR PROGRAMMING
SIMULATION
QUEUING

General approach of modelling of process flows :

1 - st step : DRAW A FLOW - CHART OF THE PROCESS

(for example block - diagram flowchart)
THREE TYPES OF BLOCKS

PROCESSING BLOCK DECISION BLOCK FEEDBACK BLOCK



AN OPERATION PROCESS CANBE DESCRIBED AS A NETWORK OF THOSE TYPES OF BLOCKS

2 - nd step : TO ANALYSE TIME SEQUENCES

3 - rd step : TO ANALYSE QUANTITY OF REQUIREMENTS

4 - th step : TO ANALYSE PREPARED CAPACITY FOR PROCESSING

EXAMPLE : SIMULATION OF PROCESS FLOWS IN FMS

INITIAL CONDITIONS AND ASSUMTIONS

- ALL OPERATIONS ARE STARTED BY OPERATION 1 OF PART 1
- PART 1 BELONGS TO THE BATCH 1 WHICH NEEDS M PIECES OF PART 1
- PART 1 IS LOCATED INTO THE ONE CONTAINER
- VOLUME OF ONE CONTAINER - N PIECES OF PART 1
- THE SET UP TIME OF MACHINE 1 FOR PART 1 IS T_{SU}
- THE MASHINING TIME OF PART 1 ON MACHINE 1 IS T_M
- NUMBER OF MACHINES AVAILABLE FOR MANUFACTURING PART 1 - Z
- NUMBER OF ALL MACHINES IN WORKSHOP - S
- TOTAL TIME FOR TRANSPORTATION OF PART 1 - T_T ADOPTED BY [4]
- AVERAGE NUMBER OF OPERATIONS FOR PART 1 - N_O

5 - LAYOUT OF FACILITIES

FACILITIES STRATEGY:
1. How much capacity is needed ?
2. When is the capacity nedeed ?
3. WHERE should be the capacity located?

FACILITIES CAPACITY: Amount of capacity according to aims
1. Try not to run out (> capacity)
2. Build to average forecast (= capacity)
3. Maximize utilization (< capacity)

(Necessary to have place reserve.)

FACILITY LOCATION PROBLEMS:
1. Single facility location (Factory)
2. Location of multiple factories (Warehouses
3. Location of retail stores (Banks)
4. Location of emergency services (Police)

LAYOUT OF FACILITIES:
1. LAYOUT OF INTERMITTENT PROCESSES
2. LAYOUT OF LINE PROCESSES
3. LAYOUT OF PROJECTS

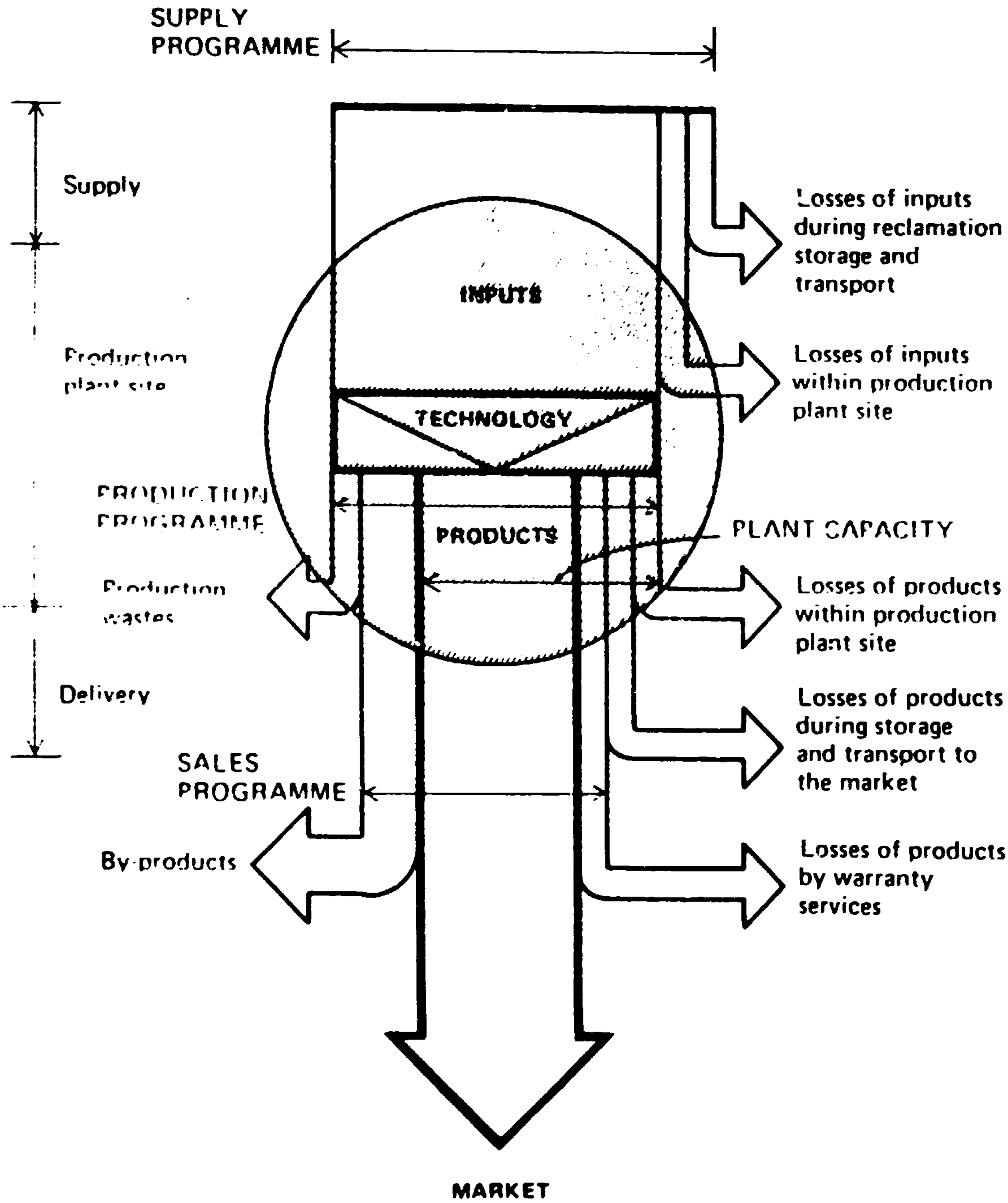
WIP - work-in-process - to be minimized
JIT - Just-in- time - inventory is minimized

LAYOUT OF INTERMITTENT PROCESS

is the next step after analysing and modelling of process flows

CHARECTERISTIC - different products flow through process along different paths
- it has to be created a process layout (similar equipment and similar worker skills are grouped)
- work pleces must be located according to quantitative criteria (A) or qualitative criteria (B)

Flow scheme of plant inputs and outputs



ADOPTED BY [10]

(A) quantitative criteria of layout decision (can be measured)

- materials handling costs
- travel time of customer
- distances etc.

(3) qualitative criteria of layout decision (is not possible to identify)

- safety rules
- noice
- information communication
- environment etc.

An example of " HEURISTIC DECISION RULES " is the solution of layout of spectrometric laboratory in VSZ KOSICE.

LAYOUT OF LINE PROCESSES

The sequence of processing activities in the line process is fixed by the product design (step by step along the line flow).

Example : Assembly - Line Balancing

MAIN FEATURES OF THIS LINE : THE CYCLE TIME

THE CYCLE TIME IS MAXIMUM TIME THAT ANY WORKER ON THE LINE CAN SPEND ON THE PRODUCT

1-ST TASK OF THE SOLUTION : GIVEN A CYCLE TIME, FIND THE MAXIMUM NUMBER OF WORK STATIONS OR WORKERS REQUIRED

$$C = \frac{N_{\text{WORKING HOURS}} \cdot 60}{\text{RATE OF PRODUCT (AMOUNT OF PIECES PER DAY)}}$$

$T = \sum t_i$ ... TOTAL WORK TIME IN A PRODUCT

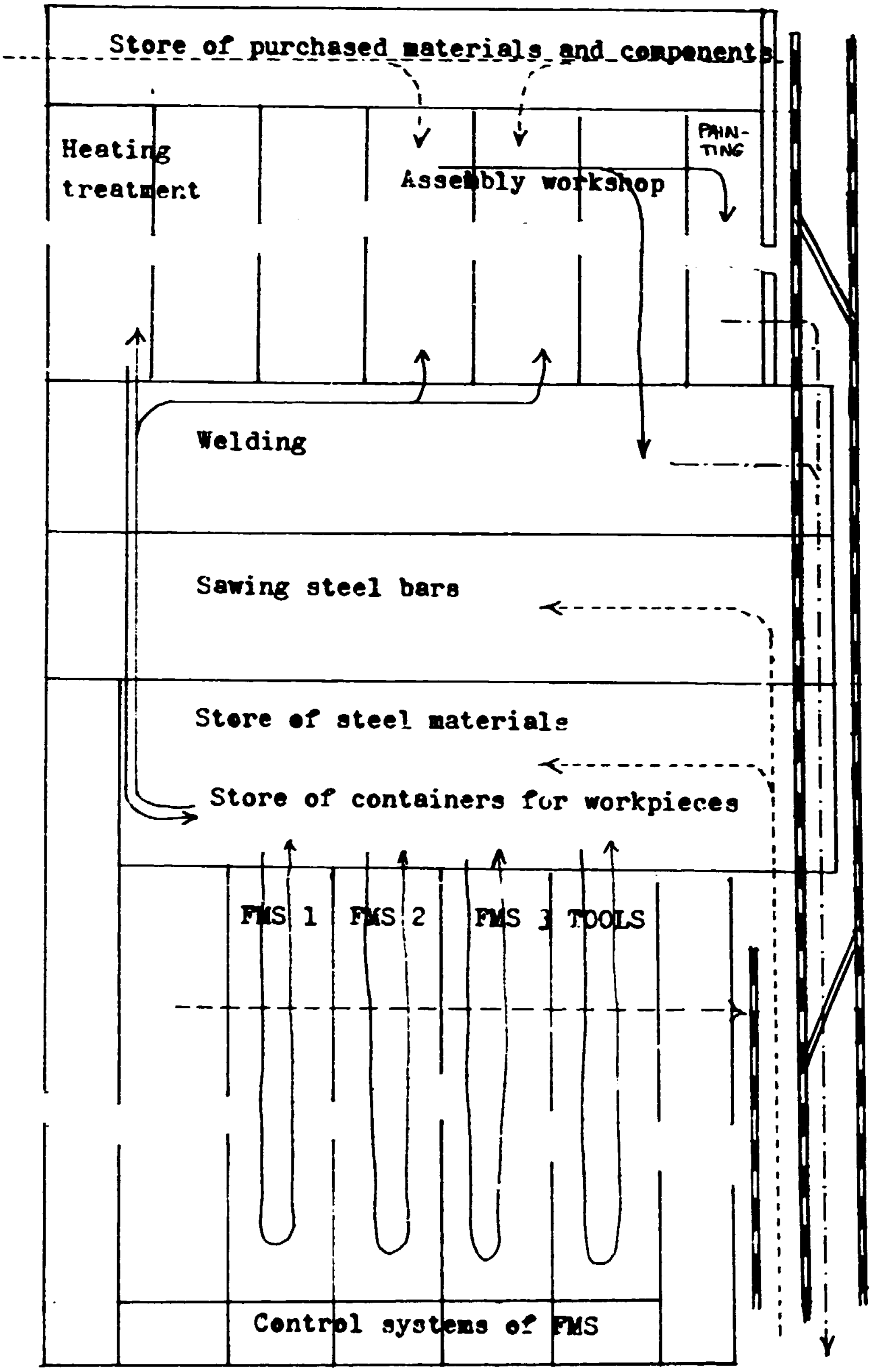
IF C IS KNOWN AND T IS KNOWN, WE CAN DERIVE A NUMBER OF STATIONS

$$N = \frac{T}{C}$$

2-nd TASK OF THE SOLUTION : TO MINIMIZE THE CYCLE TIME FOR A GIVEN NUMBER OF WORK STATIONS

(CLOSE RELATIONSHIP WITH ROBOTICS)

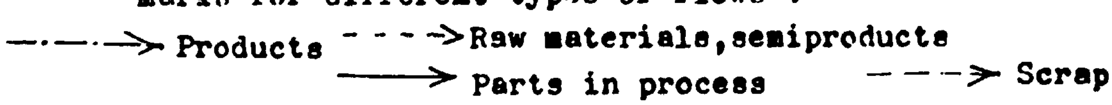
LAYOUT OF FACTORY
INTERMITTENT PROCESS



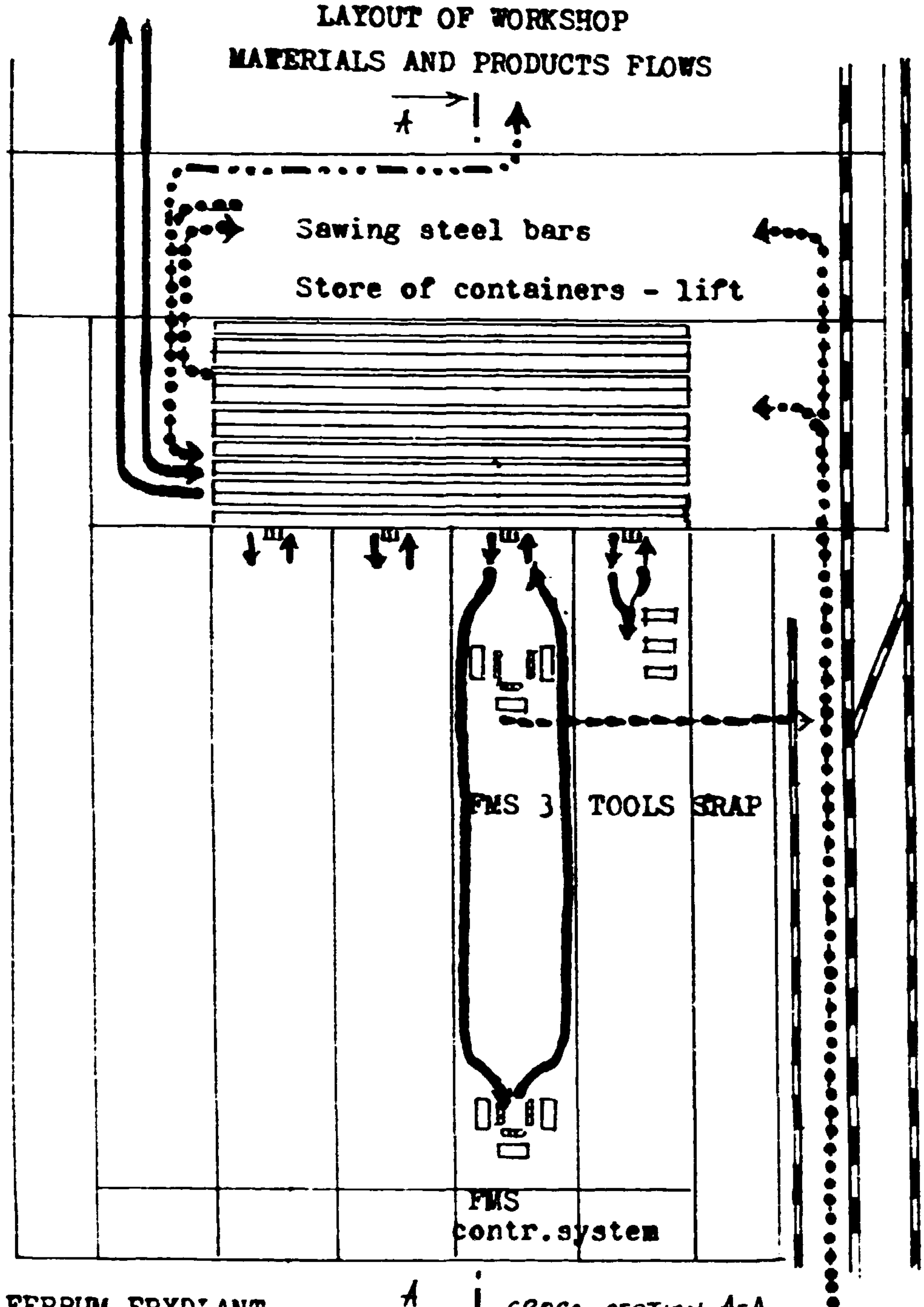
FERRUM FRYDLANT

ADOPTED BY [4]

Marks for different types of flows :



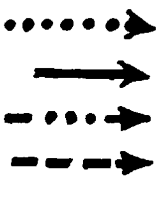
LAYOUT OF WORKSHOP
MATERIALS AND PRODUCTS FLOWS



FERRUM FRYDLANT

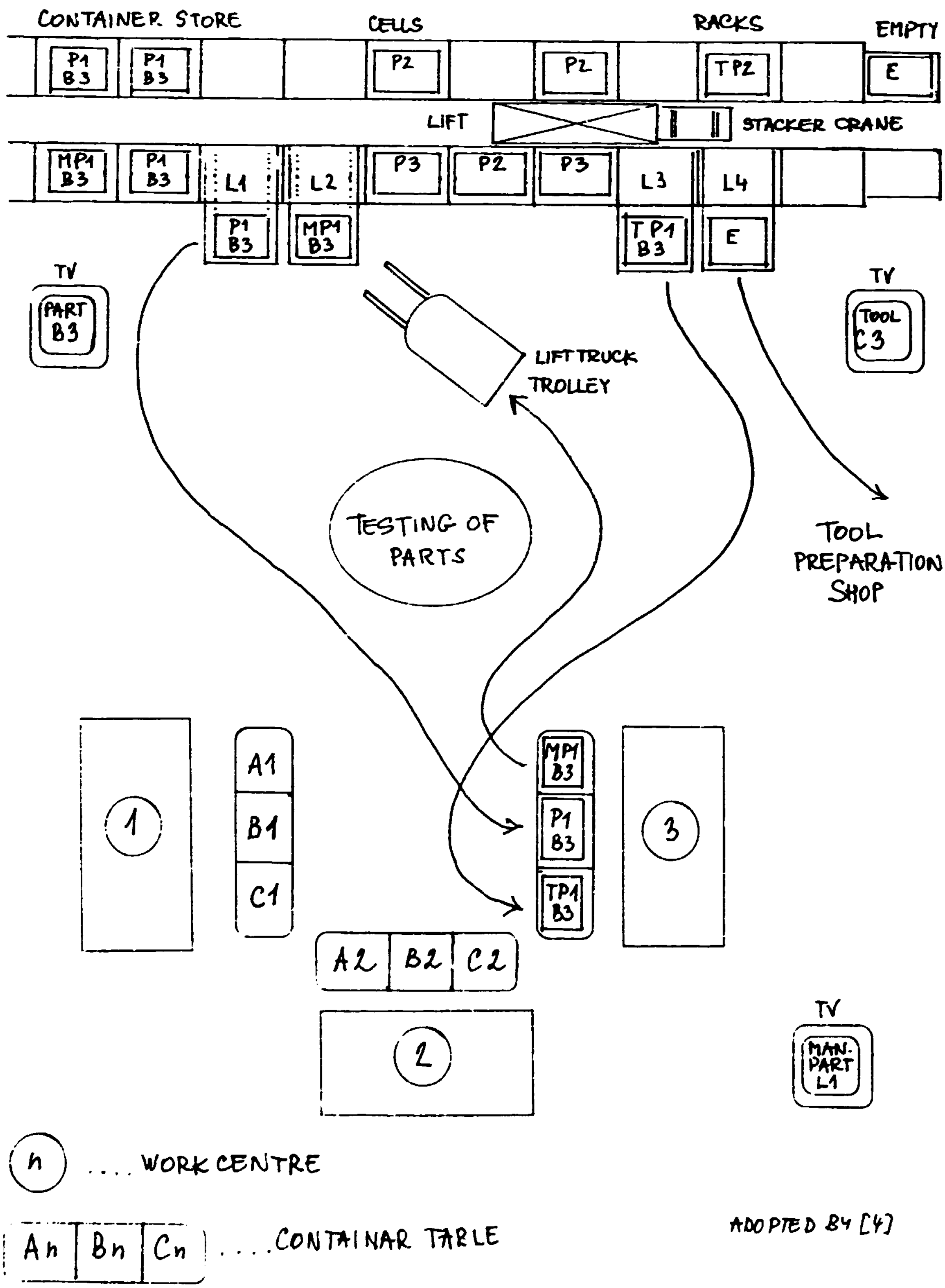
CROSS-SECTION A-A ON THE FOLLOWING FIGURE

ADOPTED BY [4]



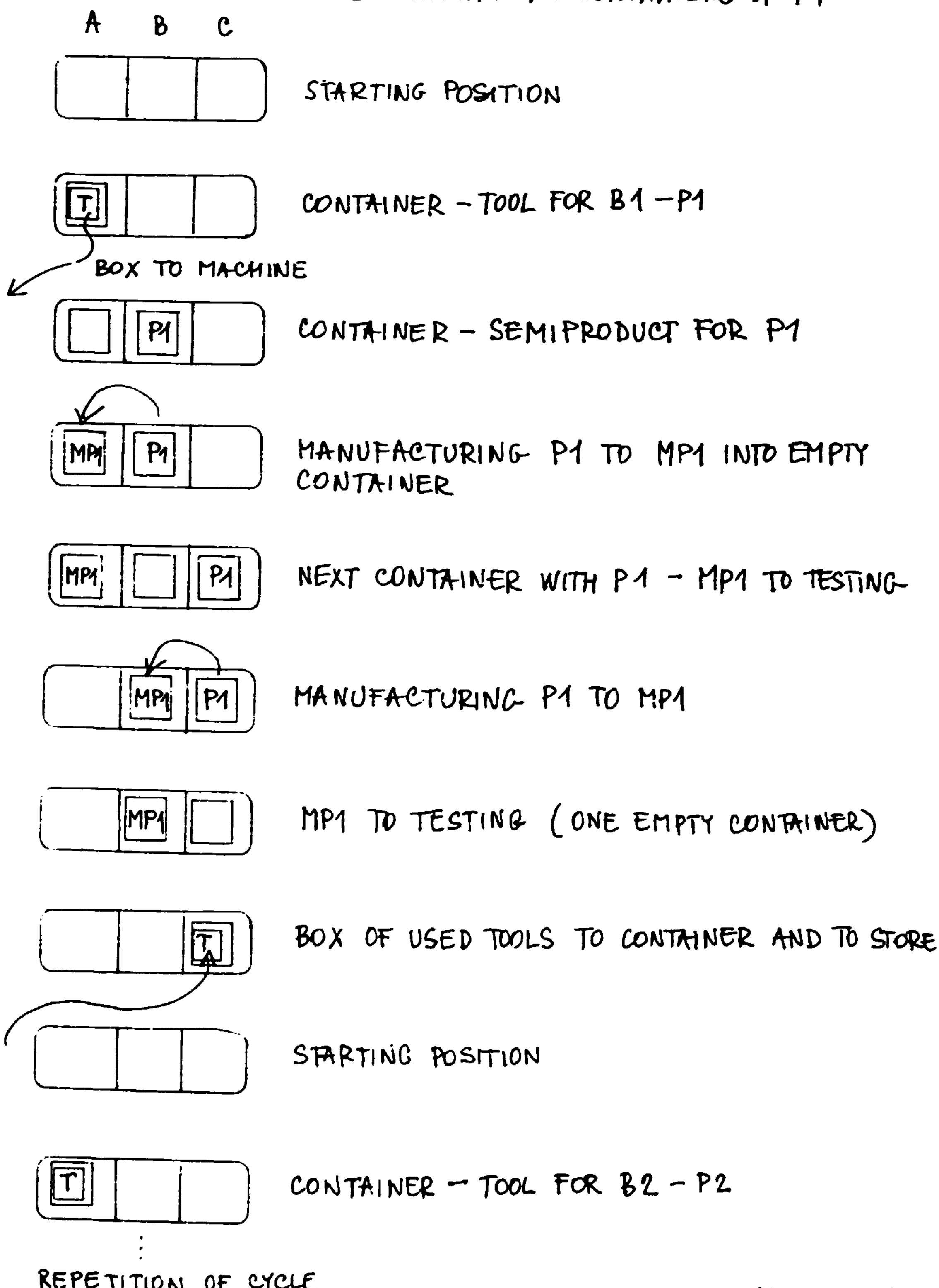
Raw materials
Parts in process flows
Manufactured par s to assembly
Srap

LAYOUT OF WORKCENTRE



SEQUENCE OF CONTAINERS FLOWS - FMS FERRUM

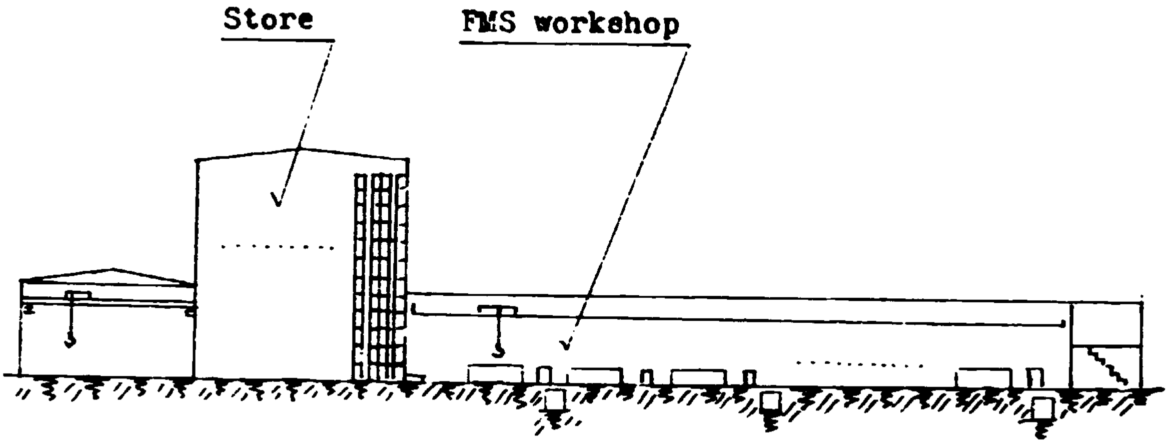
EXAMPLE – BATCH 1 ⇒ 2 CONTAINERS OF P1



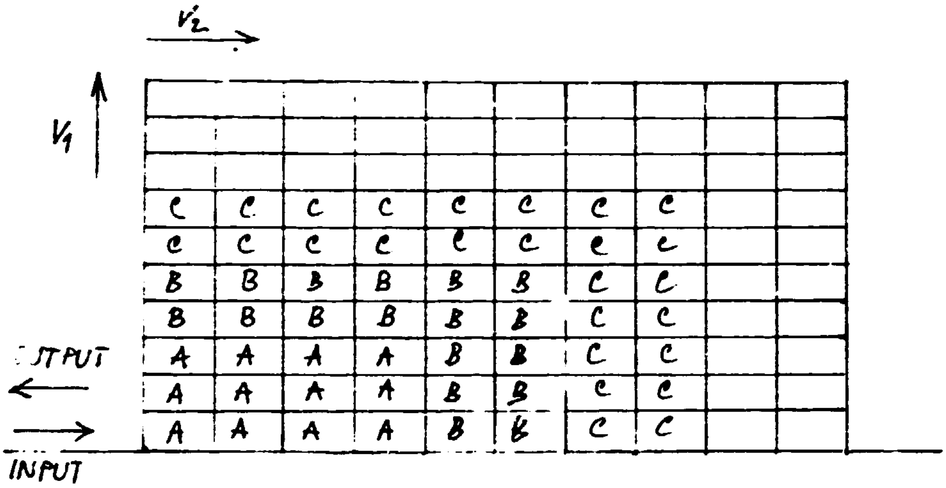
ADOPTED BY [4]

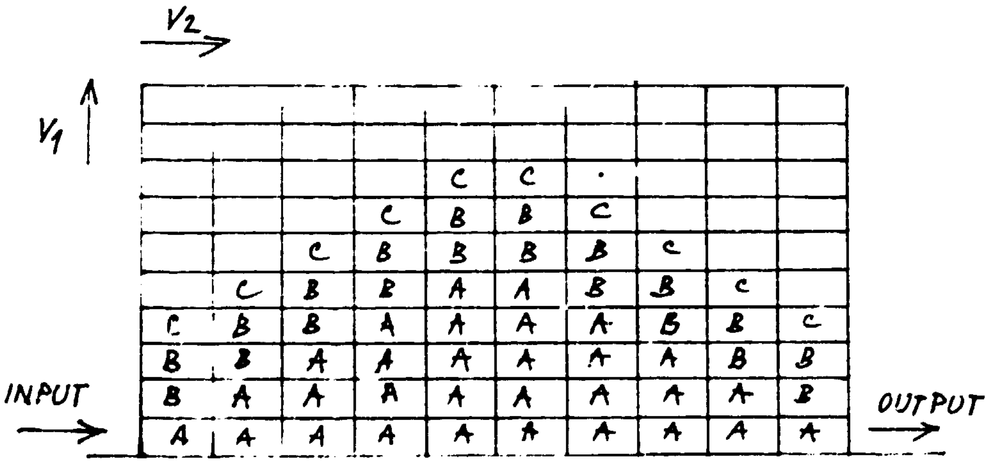
CROSS - SECTION OF WORKSHOP AND STORE

A - A



Process strategy of containers store





ADOPTED BY [4]

METHOD OF AVAILABLE LAYOUT DESIGN - PRINCIPALS OF ALGORITHM

(The example of spetrometic laboratory solution)

LIST OF ACTIVITIES:

A – SPECTROMETIC ANALYSIS (STEEL AND CAST IRON SAMPLES)
- A1 – VACUUM SPECTROMETRY
- A2 – X-RAY
- A3 – PLASMA
- A4 – CHEMICAL ANALYSIS

B – CONTROL SYSTEM (CONDUCTING OF TECHNOLOGY)

C – INFORMATION COMMUNICATION

D – SAMPLES TRANSPORTATION
- D1 – PIPE POST
- D2 – BY HAND

E – SAMPLES PREPARATION – HOT SAMPLES

F – " " – COLD SAMPLES – CRUSHING – LIQUID

G – STORE OF SAMPLES

H – WASTE, SRAB (USED SAMPLES)

I – STORE OF MATERIALS (SAMPLES PREPARATION)

J – STORE OF CHEMICAL MATERIALS

K – GAS STORE
- K1 – ARGON
- K2 – OXYGEN
- K3 – NITROGEN
- K4 – METHAN

L – HEATING - AIRCONDITIONING

M – VENTILATION

N – PRESS AIR

O – PAPER - DOCUMENTS STORE

P – COMPUTER STATION

Q – HW STORE

R – STAFF ROOM
- R1 – REST ROOM
- R2 – WASHING, LAVATORY

S – SECRETARY OFFICE

T – CHIEF ENGINEER OFFICE

U1 – MEETING ROOM –

U2 – GUESTS ROOM

V – MAINTENANCE STAFF

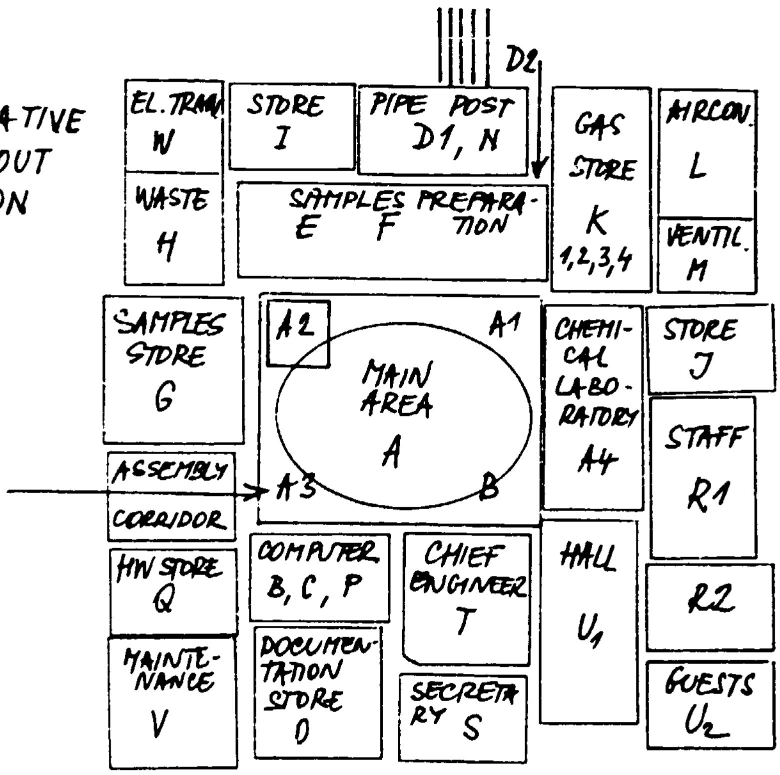
W – EL.TRANSFORMER

ADOPTED BY [7]

ESTIMATED VALUE OF CONNECTIONS

	A	B	C	D1	D2	E	F	G	H	I	....	U2	V	W
A		10	9	1	6	9	9	9	8	1		4	3	5
B	10		9											
C	10	10												
D1			5											
D2			5											
E														
F														
G														
H														
⋮											....			
U2														
V														
W														

ALTERNATIVE OF LAYOUT SOLUTION

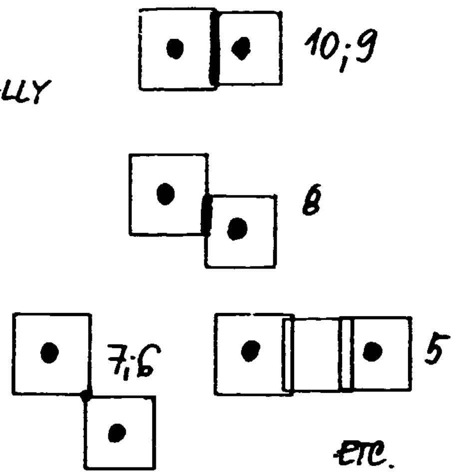


ADOPTED BY [7]

VALUE OF CONNECTIONS:

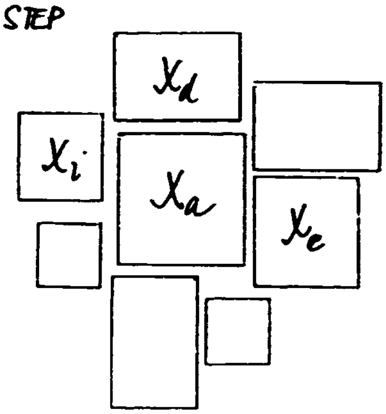
10	VERY STRONG, OFTEN, PERSONALLY
9	STRONG, VERY OFTEN
8	VERY OFTEN
7	OFTEN, BUT IMPORTANT
6	OFTEN
5	TIME TO TIME
4	RARELY
3	NOT PERSONALLY
2	ONLY OTHERS
1	ONLY FOR CHECKING
0	NO VISIT
-1	DANGEROUS
⋮	
-10	SURROUNDINGS

SHAPE OF CONNECTIONS:



LAYOUT DESIGN:

3rd STEP



4-th STEP

CHECKING SEQUENCES OF CONNECTIONS

POSSIBLE ALGORITHM:

CONNECTION 1-st STEP

$A \leftrightarrows B \Rightarrow X_{ab} = AB + BA$ (FROM TABLE OF INPUT DATA)

$A \leftrightarrows C \Rightarrow X_{ac} = AC + CA$

⋮

$X_a = \Sigma\, X_{ab} + X_{ac} + \dots\, X_{aw}$

2-nd STEP

SEQUENCE ACCORDING TO VALUE OF X_i

$\underline{\underline{X_a}}$, X_d, X_e, X_i ....

BASIC

ADOPTED BY [7]

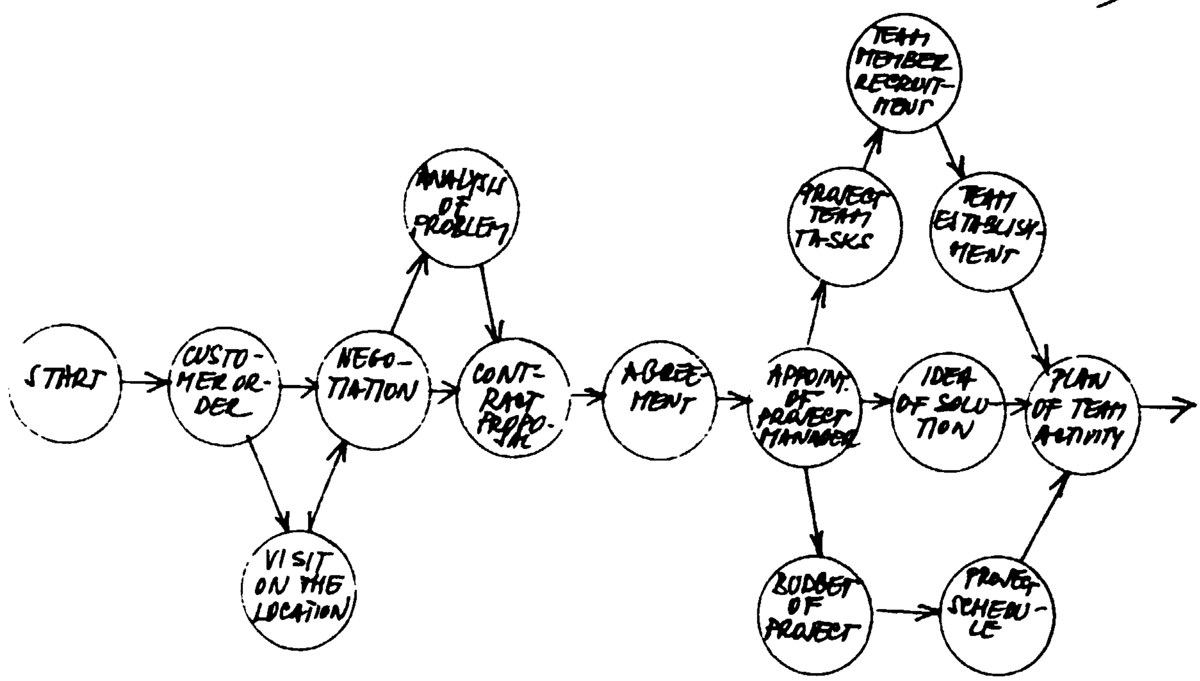
5 - LAYOUT OF PROJECTS

A project is a one - time activity which produces unique product.

CATEGORIES OF PROJECTS :

1. The construction of buildings,dams etc.
   (major factor - material handling costs)
2. Manufacturing in fixed positions
   (large items are manufactured - ships,space vehicles)
   (special factor - materials are located in concentric circles)
3. Multiple projects
   (research and development departmets,advertising agencies etc.)

EXAMPLE : THE STRUCTURE OF PROJECT PROCESS IN CONSULTANT COMPANY
(FIRST STAGE OF CONTACTS BETWEEN CUSTOMER AND COMPANY)



MAIN OBJECTIVE :
- CLEAR DEFINE THE PROJECT IDEA AND OBJECTIVES
- TO AGREE WITH CUSTOMER THE PROJECT CONCEPTION OF SOLUTION (CRITERIA OF QUALITY OF PROJECT)
- TO ELABORATE FORECAST OF PROJECT BUDGET
- TO DEFINE TASKS OF TEAM MEMBERS - RECRUITMENT
- TO CARRY OUT TIME SCHEDULE OF PROJECT
- TO START PROJECT ACTIVITY IN PROBLEM SOLUTION

⋮

ADOPTED BY [7]

III - CAPACITY PLANNING AND SCHEDULING

FACILITIES DECISIONS

Facilities decisions are often made at the level of top management and it can be integrated with corporate strategy. (Forecasting demand. Determining facility needs).

FACILITY LOCATION PROBLEMS

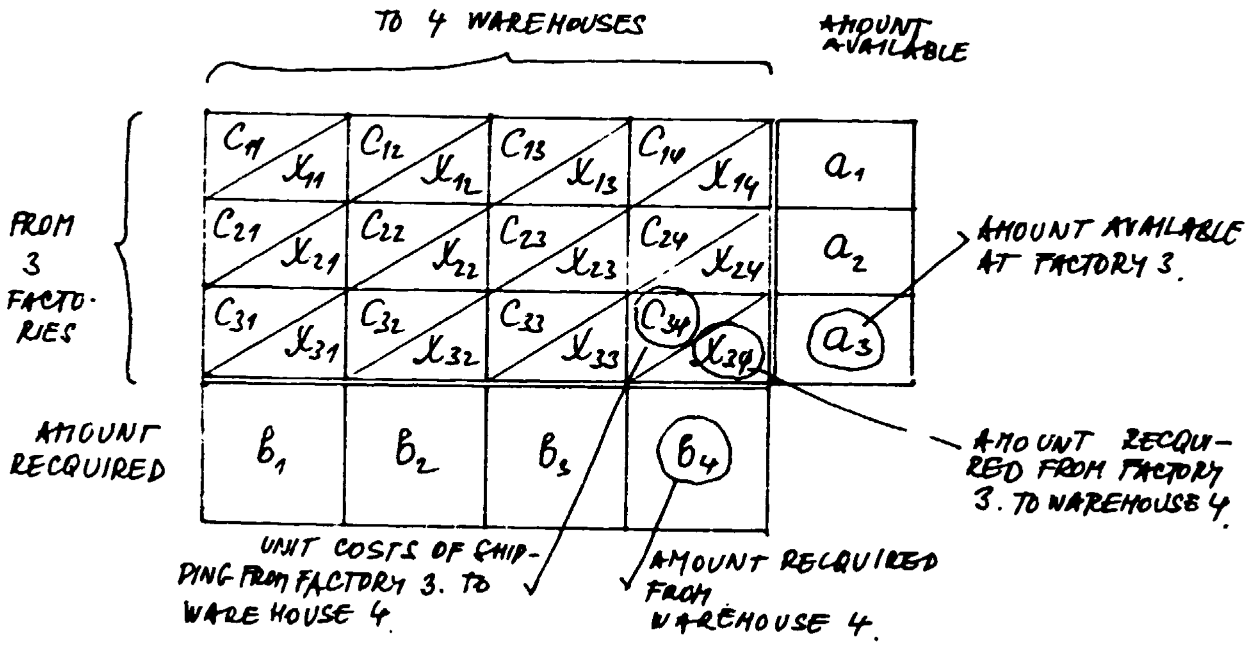
Location problems that involve the distribution of goods from one location to another. One of the available methods is

1 - TRANSPORTATION MODEL

Formulation :

We have shipment from one location to another (from factories to warehouses). This shipment needs to determine amount for shipping from factories to warehouses in accordance with amount required and amount produced in each factory.

TABLE OF ROUTES



MATRIX

ADOPTED BY [3]

WHERE

X_{ij} ... AMOUNT SHIPPED FROM FACTORY i TO WAREHOUSE j

C_{ij} ... UNIT COST OF SHIPPING FROM FACTORY i TO WAREHOUSE j

THE TOTAL TRANSPORTATION COST IS

$$C = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$$

m ... NUMBER OF FACTORIES

n ... NUMBER OF WAREHOUSES

WE ARE LOOKING FOR VALUE OF X_{ij} WHICH WILL MINIMIZE VALUE OF C AND FULFIL CONDITION b_{ij}

$$\sum_{i=1}^{m} X_{ij} = b_{ij}$$

THE TOTAL AMOUNT SHIPPED FROM EACH FACTORY i MUST EQUAL THE AMOUNT AVAILABLE AT THE FACTORY

$$X_{ij} \geq 0$$

THE TOTAL SHIPPED TO EACH WAREHOUSE j MUST EQUAL THE AMOUNT REQUIRED AT THE WAREHOUSE

$$\sum_{j=1}^{n} X_{ij} = a_i$$

ALL SHIPMENTS MUST BE NONNEGATIVE

EXAMPLE : INPUT DATA
1-ST

COSTS OF TRANSPORTATION

FACTORY \ WAREHOUSE	1	2	3	4	GOODS AVAILABLE
1	2	2	0	4	25
2	5	9	8	3	25
3	6	4	3	2	10
GOODS REQUIRED	20	15	20	5	Σ 60

THE TRANSPORTATION METHOD IS ITERATIVE METHOD :

RULES : (a) **NORTH WEST CORNER RULE**

HAVE TO START

INITIAL SOLUTION OF TRANSPORT PORTIONS

	(1)	(2)	(3)	(4)	
(1)	20	5			25
(2)		10	15		25
(3)			5	5	10
	20	15	20	5	

FINAL RESULT OF THE CALCULATION

	(1)	(2)	(3)	(4)
(1)	2 / 20	2 / 5	0	4
(2)	5	9 / 10	8 / 15	3
(3)	6	4	3 / 5	2 / 5

TOTAL COSTS : 40 + 10 + 90 + 120 + 15 + 10 = 285 UNITS

EXAMPLE
2-nd

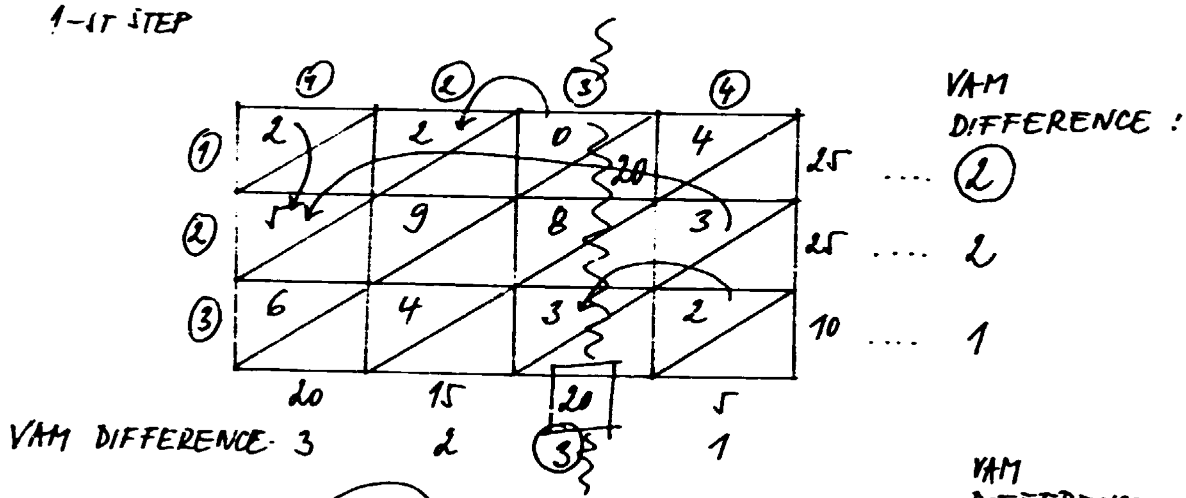
	(1)	(2)	(3)	(4)	(5)	
(1)	2 / 25	4 / 5	0	8	10	30
(2)	5	5 / 20	6 / 5	7	8	25
(3)	2	3	2 / 20	4	6	20
(4)	9	10	10 / 10	11 / 10	2 / 20	40
	25	25	35	10	20	Σ 115

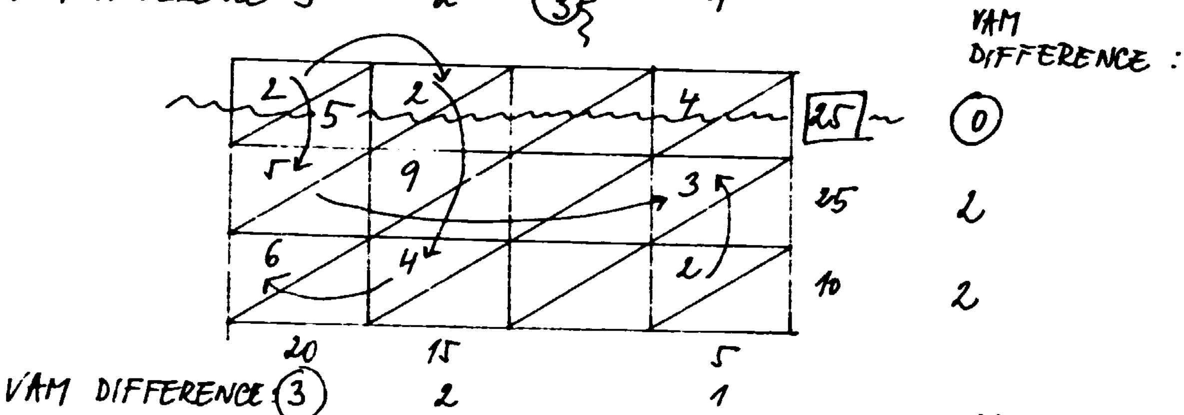
TOTAL COSTS : 50 + 20 + 100 + 30 + 40 + 100 + 110 + 40 = 490 UNITS

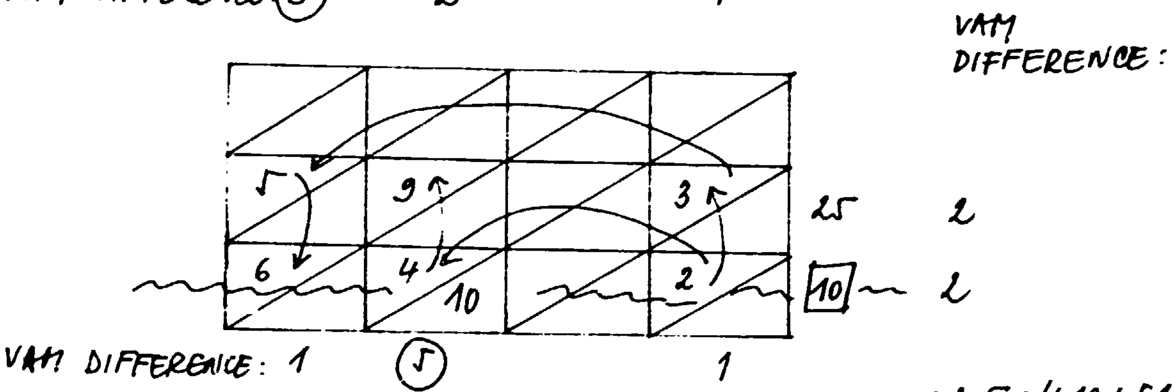
(b) VOGEL APPROXIMATION METHOD - VAM

COMPUTING THE DIFFERENCE BETWEEN THE LOWEST COST AND THE NEXT-LOWEST COST — WE ARE LOOKING FOR LARGEST DIFFERENCES (BY 1-ST EXAMPLE)

1-ST STEP





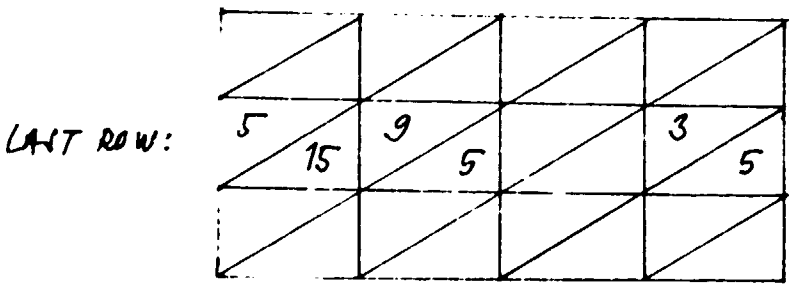


$20.0 + 2.5 + 4.10 + 5.15 + 9.5 + 3.5$

TOTAL COST:

185 AGAINST 285

SAVING ~40%



(c) EVALUATION AND IMPROVEMENT

SYSTEM DESCRIPTION :

1-ST RULE $U_i + V_j = C_{ij}$

WHERE IS

U_i .... EVALUATION NUMBER OF ROW i

V_j ... EVALUATION NUMBER OF COLOMN j

C_{ij} ... UNIT COST OF SHIPPING VIA CELL

2-nd RULE A CONDITION FOR OPTIMALITY OF SOLUTION IS – FOR EACH CELL

$$U_i + V_j \leq C_{ij}$$

(THE FIRST EXAMPLE IS USED BECAUSE OF COMPARISON OF RESULTS)

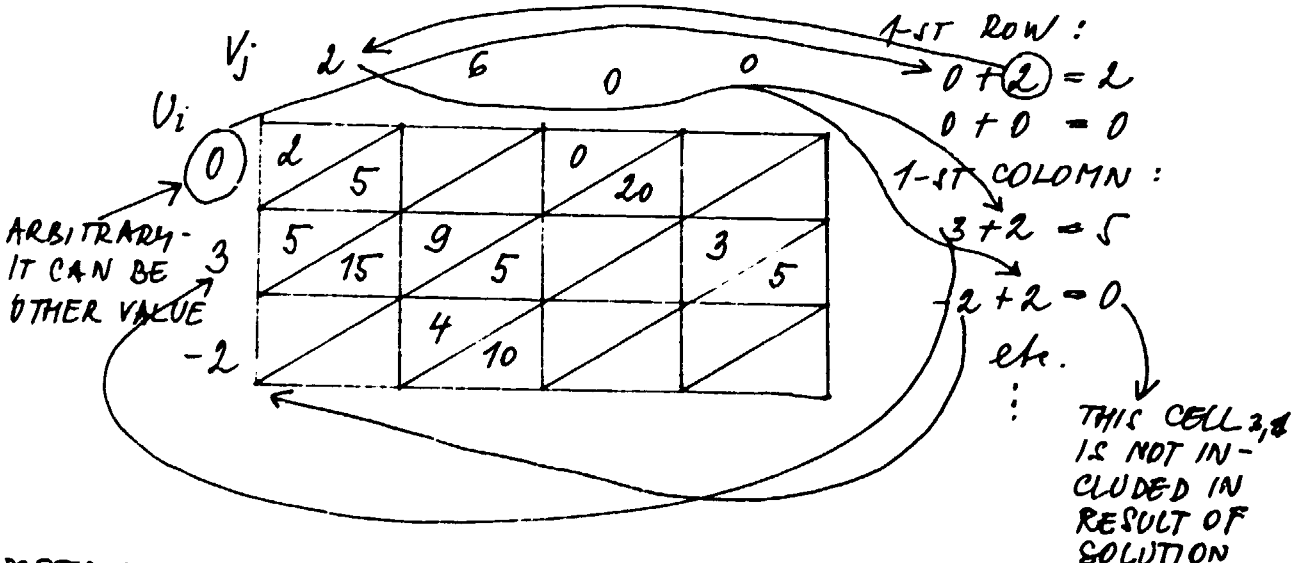
TESTING OF PREVIOUS RESULTS :

{ CELL $_{3,2}$ $-2 + 6 = 4$ ..RULE IS SATISFIED

BUT CELL $_{1,2}$ $0 + 6 = 6 > 2$ ...RULE IS NOT SATISFIED

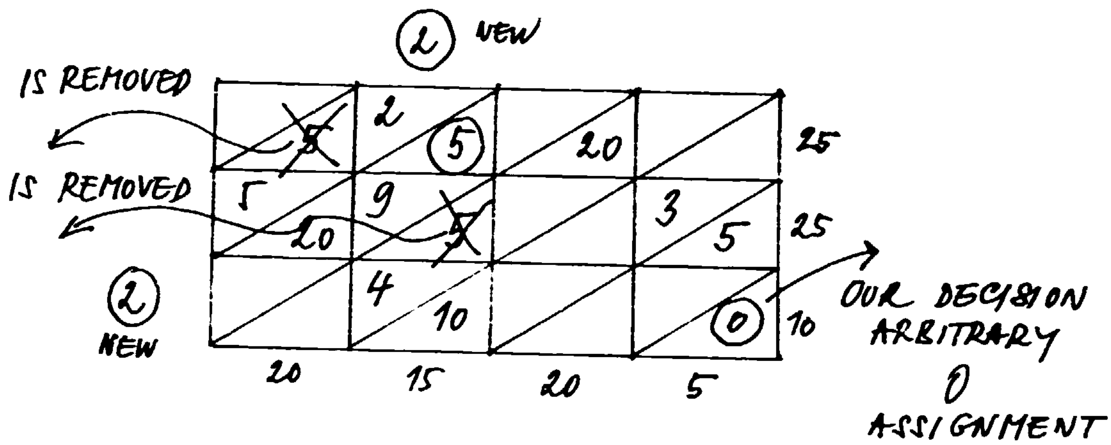
IT MEANS – PRESENT SOLUTION BY VAM IS NOT OPTIMAL

DETERMINATION OF EVALUATION NUMBER OF ROWS AND COLOMNS :



ADOPTED BY [3]

- WE SHALL TRY TO SOLVE OPTIMAL SOLUTION
- WE START THROUGH CELL 1,2 – WE HAVE 5 UNITS FOR DISPOSAL, BUT TO STAY SHIPMENT IN CELL 1,3 (WILL STAY 0)
- THAN WE REVISE NEW COLOMN NUMBER OF CELL 1,2 → WE CANCELLED 6 AND USE 2



FOR EACH CELL WE HAVE VALID THE RULE

$$U_i + V_j \leq C_{ij}$$

WE RECEIVED OPTIMAL TRANSPORTATION SOLUTION

TOTAL COSTS: $0 \cdot 20 + 2 \cdot 5 + 4 \cdot 10 + 5 \cdot 20 + 3 \cdot 5 = 165$ UNITS

ADOPTED BY [3]

2 - SCHEDULING OPERATIONS

Aggregate planning seeks to determine the resources needed (time frame about 1 year).

Scheduling allocates the resources made available to meet operations objectives (time frame of a few months, weeks, hours).

Scheduling objectives: high efficiency
low inventories
good customer service

by a schedule which maintains { high utilization of labor
of equipment
of space

Scheduling selection: classification by type of process
(A) line
(B) intermittent
(C) project

(A) LINE PROCESS:

- no for simple product
- only for multiple product - but process moves smoothly

(B) INTERMITTENT PROCESS:

- process moves not smoothly - many starts and stops
- irregular flow in due to the layout (machine group)

JOBS OR CUSTOMER'S WAIT IN LINE AS EACH UNIT IS TRANSFERRED FROM ONE WORK CENTRE TO THE NEXT

--> NETWORK OF QUEUES

--> HOW TO MANAGE THESE QUEUES

Scheduling problems for intermittent processes:

- input - output analysis
- loading
- sequencing
- dispatching

INPUT - OUTPUT CONTROL

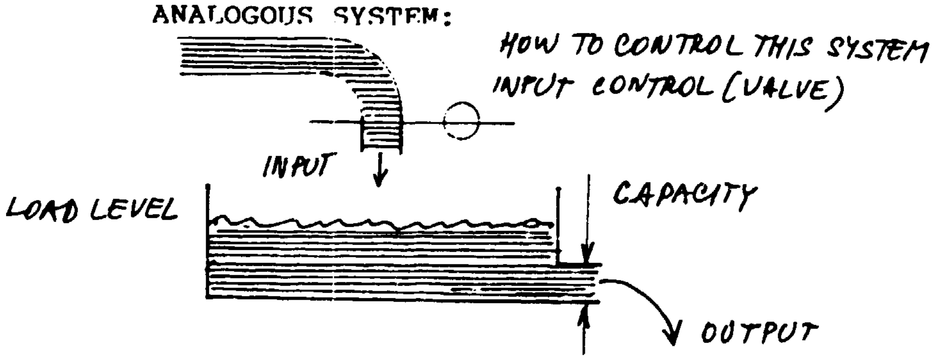
INPUT - the amount of work arriving at work centre per unit of time

LOAD - the level of work in process - WIP in the system

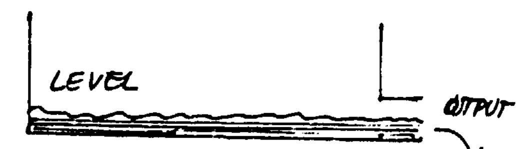
OUTPUT - the rate (amount) at which work is completed by a work centre

CAPACITY - the maximum output which can be produced

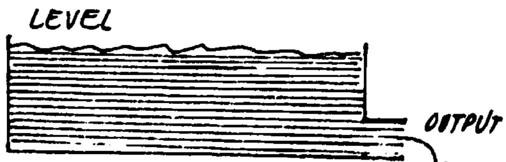
ANALOGOUS SYSTEM:



EXTREM. SITUATIONS



LOW MACHINE UTILIZATION
IDLE LABOR
HIGH UNIT PRODUCT COSTS



LONG WAITING TIME
CUSTOMER IS UNSATISFIED
BIG INVENTORY
HIGH UNIT PRODUCTION COSTS

ADOPTED BY [3]

EXPEDITING INDICATES A FAILURE BETWEEN OUTPUT AND INPUT
IDENTIFYING CRITICAL JOBS

ANALYSIS EXAMPLE:

INPUT	10 000 $	PER WEEK
INPUT	500 000 $	PER YEAR
OUTPUT	10 000 $	PER WEEK
WIP INVENTORY	200 000 $	

$$\text{LEAD THE FOR PRODUCT} = \frac{200\ 000}{10\ 000} = 20 \text{ WEEKS}$$

and in actual processing 1 - 2 weeks

3 - LOADING

(not detailed scheduling or sequencing)

Two types of loading:

- forward loading
- backward loading

The purpose of forward loading is to determine an approximate completion date of each job (and the capacity required in each time period).

The purpose of backward loading is to calculate the capacity required in each work centre for each time period. Due dates of jobs are always given for backward loading.

ALGORITHM OF JOB SEQUENCING --> m x n SCHEDULING PROBLEM

m .. NUMBER OF MACHINES (SOLVED ONLY FOR m $\leq$ 3 AND n ARBITRARY VALUE)

n .. NUMBER OF JOBS

a) SIMPLEST SW IS FOR m=1 n = arbitrary

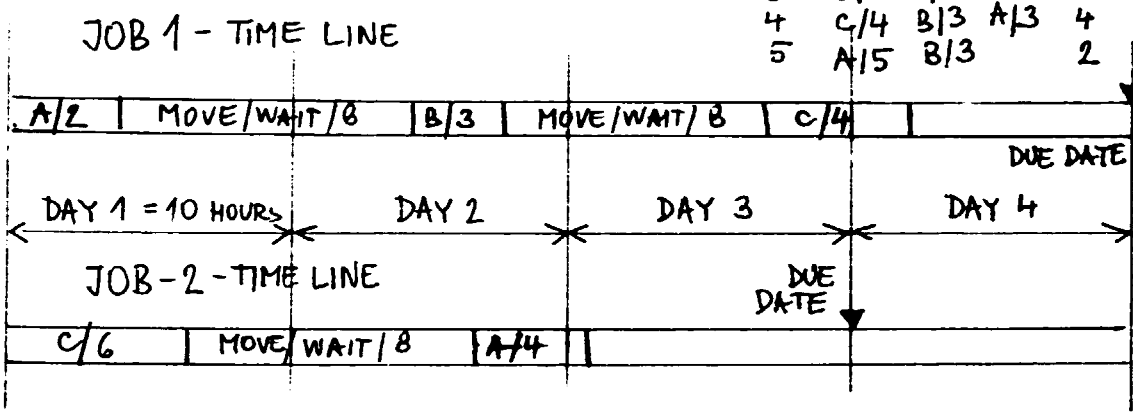
b) m=2 -> left - hand - right - hand - rule (S.M.Johnson - 1954)

LOADING

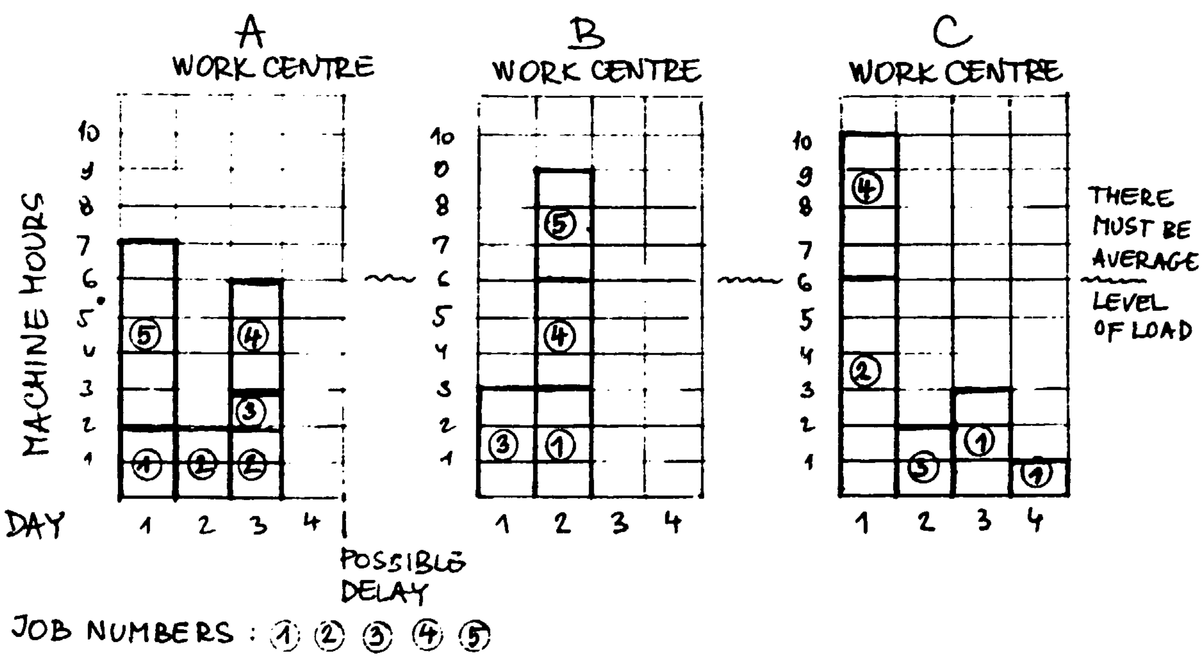
Loading is very rough procedure, in our case based on the assumption - waiting time 8 hours.

Example : WORK CENTRES A, B, C

JOB	MACHINE HOURS	DUE DATE	POSSIBLE DELAY (HOURS)
1	A/2 B/3 C/4	4	7
2	C/6 A/4	3	6
3	B/3 C/2 A/1	4	10
4	C/4 B/3 A/3	4	6
5	A/5 B/3	2	0



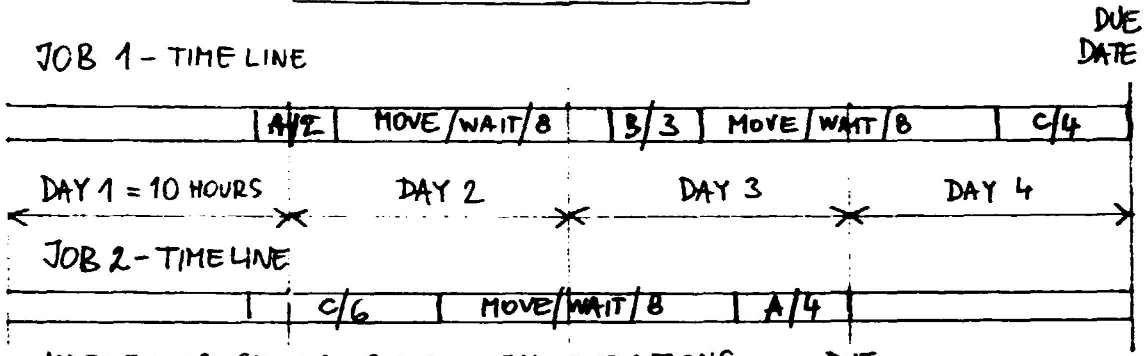
FORWARD LOAD CHARTS



FORWARD LOAD CHARTS FOR EACH WORK CENTRE. IT IS POSSIBLE TO MAKE BETTER BY INSPECTION AND HEURESTIC ANALYSIS. TO ADD ONE DAY - UP TO 5 - TO RECEIVE BETTER LOADING ON WORK CENTRES.

ADAPTED FROM [3]

BACKWARD LOADING



MARKETING SHOULD CHECK WITH OPERATIONS BEFORE MAKING DELIVERY PROMISES

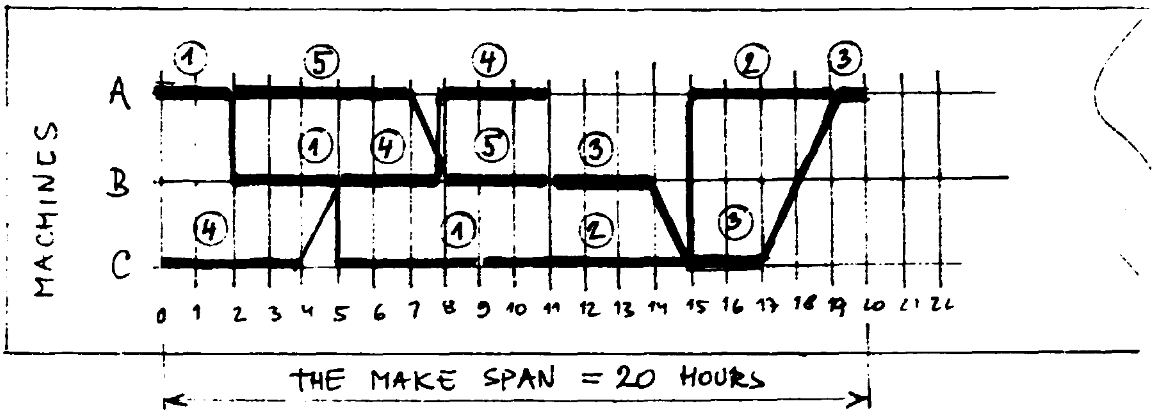
DUE DATE

4 - SEQUENCING - JOB

AN EXACT ORDER OF JOB PROCESSING

METHOD:

GANTT-CHART



43 HOURS OF PROCESSING

JOB ARE SEQUENCED		MACHINE IDLE (HOURS)		JOB IDLE (HOURS)		DELIVERY TIME (HOURS)
FIRST	①	Ⓐ	5	①	0	9
SECOND	④	Ⓑ	8	②	9	19
THIRD	⑤	Ⓒ	4	③	14	20
FOURTH	②		Σ 17	④	1	11
FIFTH	③			⑤	3	11

IDLE TIME ... $\frac{17}{60} \Rightarrow 28,3\ \%$

UTILIZATION ... $\frac{43}{60} \Rightarrow 71,7\ \%$

ADAPTED FROM [3]

5 - DISPATCHING RULES

Example: 100 - 150 shop orders/per day	available
1000 machines	to control by
2500 orders in process	dispatching
500 workers	process

A DISPATCH RULE SPECIFIES WHICH JOB SHOULD BE SELECTED FOR WORK NEXT FROM AMONG A QUEUE OF JOBS

SIX RULES:

MINPRT (1) minimum processing time
(shortest processing time - PRIORITY)
MINSOP (2) minimum slack time for operation
(due date minus processing time remaining)
(zero slack time - PRIORITY)
FCFS (3) first come, first served
MINSD (4) minimum planned start date
MINDD (5) minimum due date
(the job with the earliest due date - PRIORITY)
RANDOM (6) at random select - not in practice

Many systems for supporting dispatching control have been developed, each of them needs special explanation (CRP etc.).

6 - PLANNING AND SCHEDULING PROJECTS

Planning and control in projects:

A. PLANNING

Identity the project customer
Establish the end product or service
Set project objectives
Estimate total resources and time required
Decide on the form of project organization
Key personnel appointments (project manager)
Define major tasks required
Establish a budget

B. SCHEDULING

Develop a work structure
Estimate time required for each task
Sequence the tasks in the proper order
Develop a start/stop time for each order
Develop a detailed budget for each task

C. CONTROL

Monitor actual time, cost and performance
Compare planned to actual figures
Determine whether corrective action is noted

IV. INVENTORY MANAGEMENT

In the manufacturing company inventory and capacity must be managed together.In inventory management the primary focus will be on inventory,with capacity as a related variable.Inventory is one of the five major decision areas of operations.

INVENTORY DECISIONS : what to order
how much to order
when to order

Inventory control system are used to manage materials from purchasing through raw materials,work in proces and finished good inventories.This system manages the flow of materials within the company.

INDEPENDENT - DEMAND INVENTORIES - IDI
DEPENDENT - DEMAND INVENTORIES - DDI

IDI is independent of operations.Finished goods and spare parts are independent-demand inventories,as in automobile production.

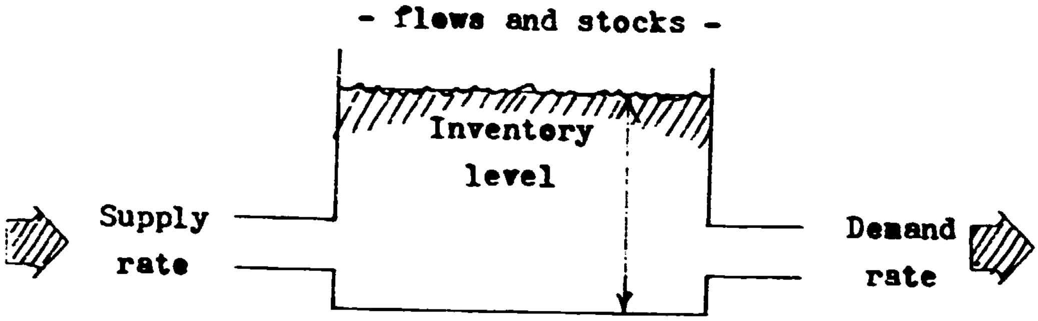
DDI is derived from the demand for another part or component.The work-in-process inventory and raw materials inventories have dependent demand.

1 - INDEPENDENT DEMAND INVENTORY

Finance is concerned to minimize funds allocated to inventory. Operations needs inventories to assure smooth and efficient production.
The finance function generally prefers to keep the level of inventories low,marketing prefers high level of inventories to support sales,operations prefers adequate inventories for efficient production.
INVENTORY MANAGEMENT MUST BALANCE THESE CONFLICTING OBJECTIVES.

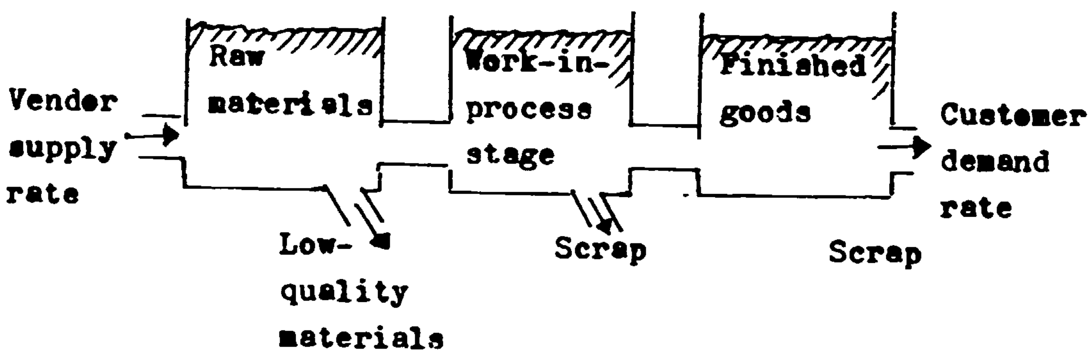
Inventory definition : AN INVENTORY IS A STOCK OF MATERIALS USED TO FACILITATE PRODUCTION OR TO SATISFY CUSTOMER DEMANDS! INVENTORIES INCLUDE - RAW MATERIALS,WORK IN PROCESS,FINISHED GOODS!

A water tank analogy for inventory :



- rate of flows out corresponds to demands -
- the water level (inventory)is a buffer between supply and demand

A water tank system analogy :



The tanks serve as buffers to absorb variations in flow rates within the system.

Purpose of inventories :

TO PROTECT AGAINST UNCERTAINTIES
TO ALLOW ECONOMIC PRODUCTION AND PURCHASE
TO COVER ANTICIPATED CHANGES IN DEMAND AND SUPPLY
TO PROVIDE FOR TRANSIT (DISTRIBUTION PIPELINE)

Decision problems :

WHICH ITEMS SHOULD BE CARRIED IN STOCK
HOW MUCH SHOULD BE ORDERED
WHEN SHOULD AN ORDER BE PLACED
WHAT TYPE OF INVENTORY CONTROL SYSTEM SHOULD BE USED

ADOPTED FROM [3] AND [2]

Inventory cost structure : - item cost
- ordering cost
- holding cost : - cost of capital
  - cost of storage
  - cost of loss
- stockout cost

INDEPENDENT DEMAND VERSUS DEPENDENT DEMAND :

Independent demand is influenced by market conditions outside the control of operatins.

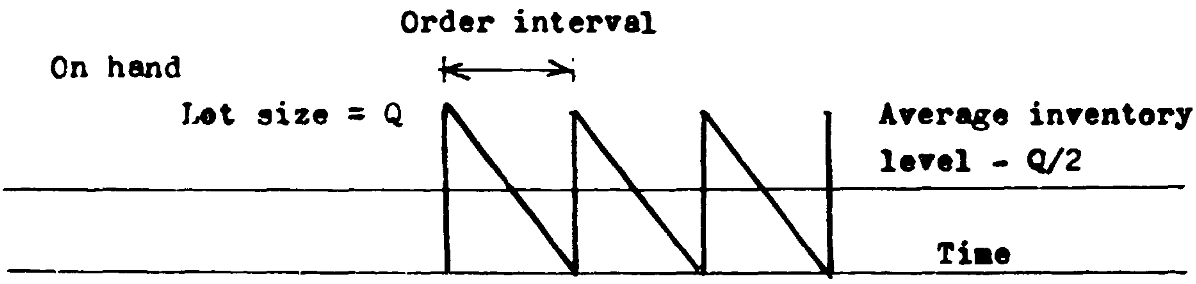
Dependent demand is related to the demand for another item and is not idepedently determinedby the market. (When products are built up from parts and assemblies, the demand for these components is dependent on the demand for the final product.)

IDI MANAGEMENT SYSTEMS :

EOQ MODEL - ECONOMIC ORDER QUANTITY
Q - SYSTEM - CONTINUOUS REVIEW SYSTEM
P - SYSTEM - PERIODIC REVIEW SYSTEM
ABC INVENTORY MANAGEMENT SYSTEM

EOQ MODEL

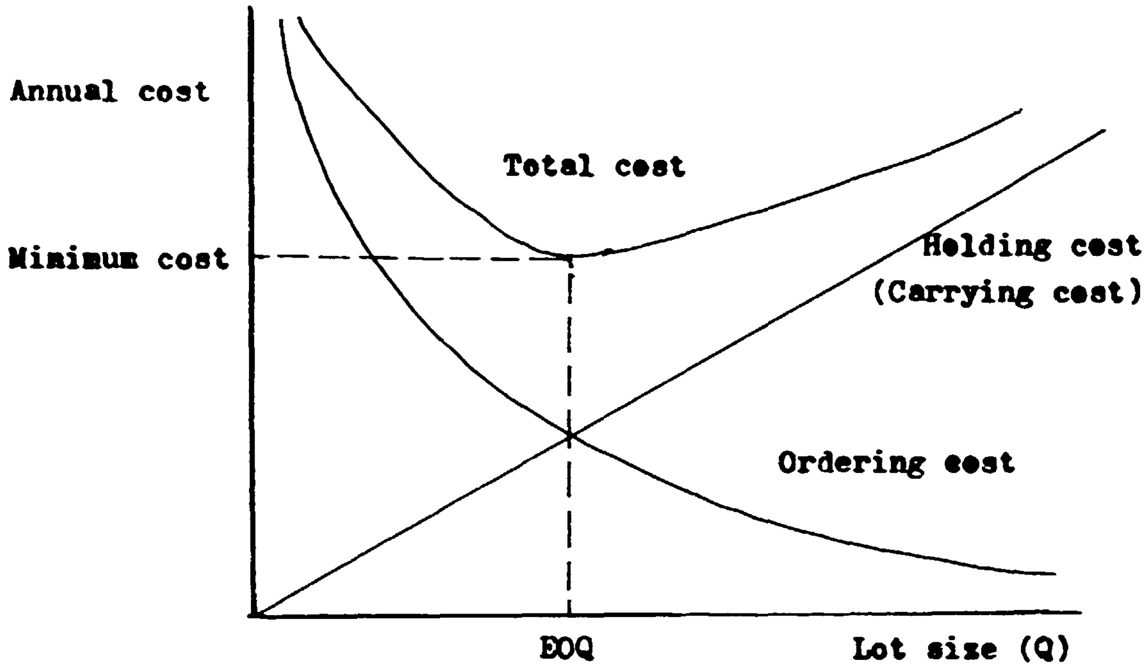
Main features : demand is constant and items are ordered in fixed lot sizes - relationship between ordering frequency and inventory level (reorders)



The value of lot size can be presented by a mathematical equation as follows : (Wilsons economic order quantity)

$$Q = \sqrt{\frac{2SD}{iC}}$$

Total cost of inventory :



Following symbols :

D ... demand rate (units per year)
S ... cost per order placed
C ... unit cost
i ... carrying (holding) rate
Q ... lot size (units)
TC ... total of ordering and carrying cost
EOQ ... economic order quantity

Q - SYSTEM

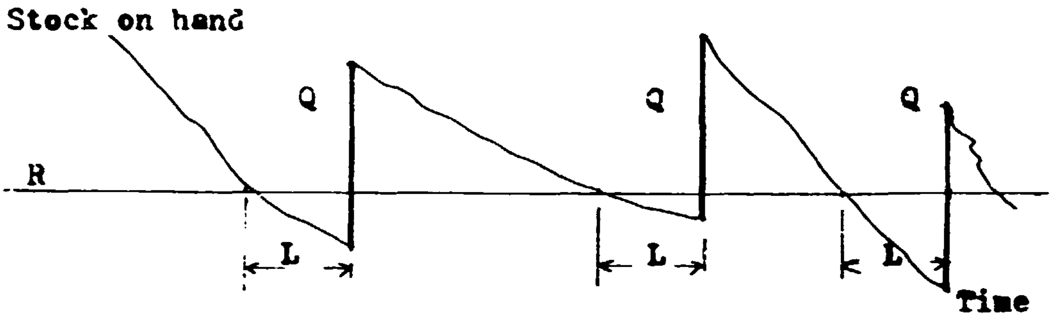
EOQ model is limited by the assumption of constant demand.

Main features of Q - system : the stock level is reviewed continuously, decisions to reorder stock are based on on the total on-hand plus on-order quantity (this amount is called stock position, when the stock position drops to a reorder point a fixed quantity is placed on order, the time between orders will vary depending on the random character of demand.

Q - system definition : CONTINUALLY REVIEW THE STOCK POSITION AND WHEN IT DROPS TO THE REORDER POINT R A FIXED QUANTITY Q IS ORDERED.

ADOPTED FROM [3]

A graph of the operation of the Q - system :



A continuous revview (Q) system,R - reordered point,Q - order quantity,L - lead time is time for resupply from vender.
The stock position dreps on a irregular basis until it reaches the order point R,where an order for Q units is placed.The order arrives later,after a lead time L,the cycle is then repeated.

The reorder point is defined as follows :

$$R - m + s \quad \text{(to protect against stockout)}$$

where R ... reorder point
m ... average demand over the lead time
s ... safety stock (or buffer stock)

SERVICE LEVEL is the pereentage of customer demand satisfied from inventory,different ways to express service level :

1 - it is the probability that all orders will be filled from stock during the replenishment lead time of one reorder cycle
2 - it is the percentage of demand filled from stock during a given period of time
3 - it is percentage of time the system has stock on hand

$$s - z\sigma$$

where z ... safety factor
σ ... standard deviation of demand over lead time

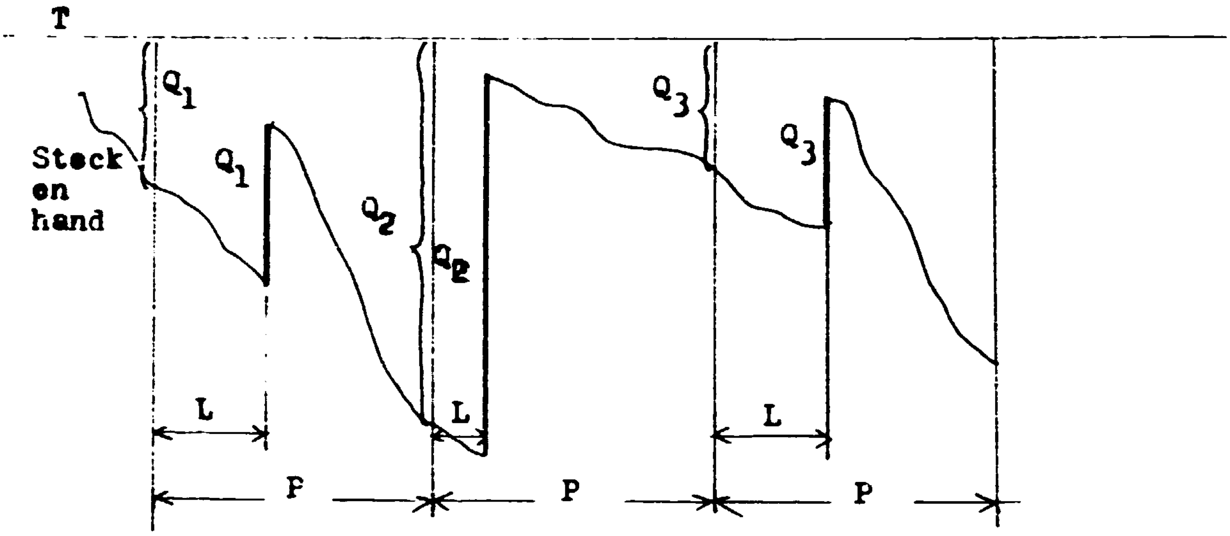
P - SYSTEM

The periodic review system is based on periodically review of the goods stock position (finished goods).

Main features : The P system is completely determined by the two parameters - P and T,P is the time between orders,T is target inventory level.

P - system definition : REVIEW THE STOCK POSITION AT FIXED PERIODIC INTERVALS P.AN AMOUNT EQUAL TO TARGET INVENTORY T MINUS THE STOCK POSITION IS ORDERED AFTER EACH REVIEW.

A periodic review system :



The target inventory level can be set by a specified service level.While the reviewed period is fixed,the amount ordered is not.The P system should be used for inexpensive items,or for items delivered at specified intervals.

ABC Inventory Management

In inventories,a few items sually account for most of the inventory value.The items are divided into three classes : A,B,C.

A -	contains about	20 %	of items	and 80 %	of the	finance value
B -	"	30 %	"	15 %	"	"
C -	"	50 %		5 %		"

Class A represents the most significant part of items and inventory can be controlled by closely monitoring the A items,Q - system.Looser control might be used for C items,P - system or manual.

ADOPTED FROM [2] AND [3]

DEPENDENT DEMAND INVENTORY

2 - MATERIAL REQUIREMENTS PLANNING - MRP

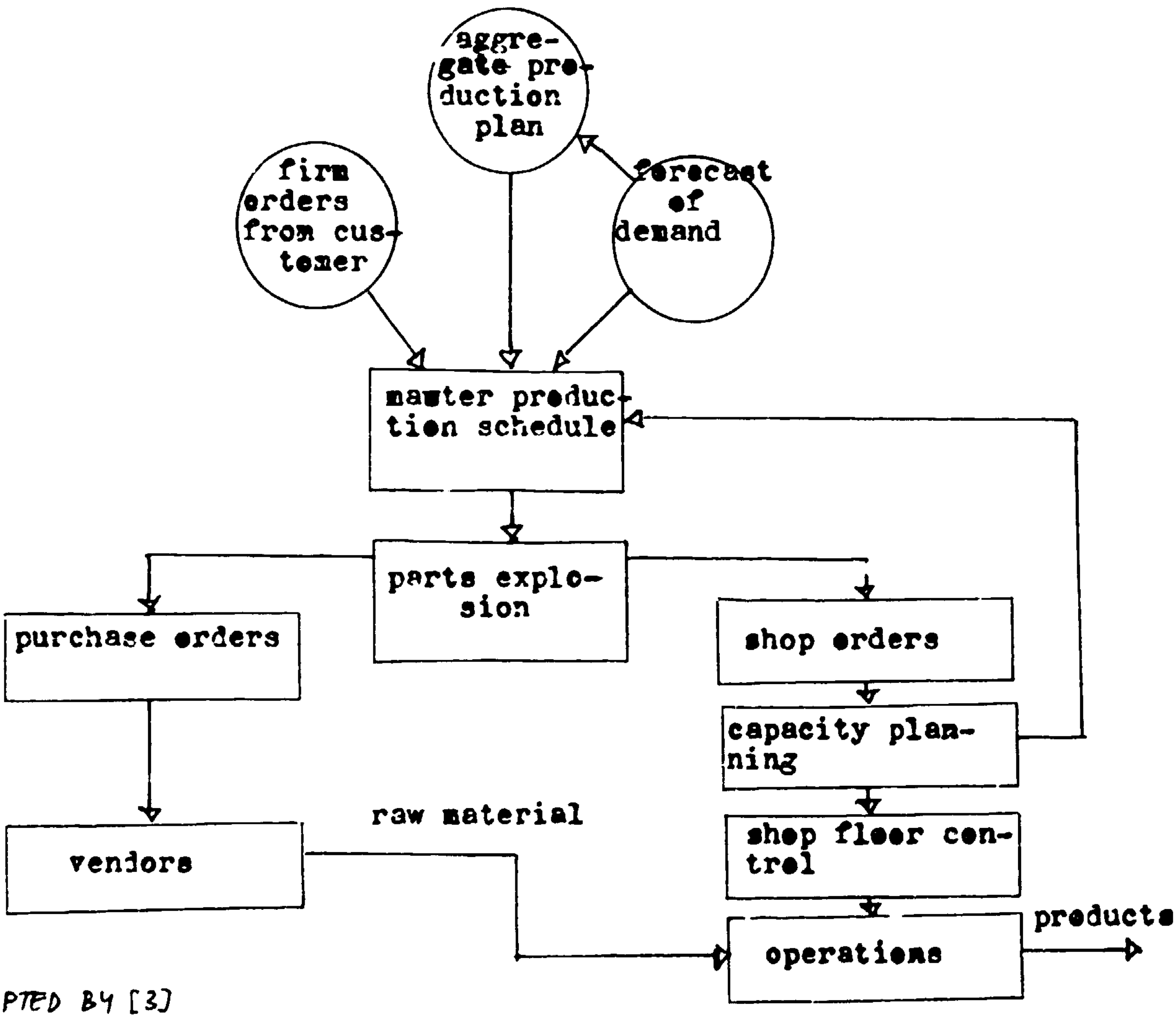
Definitions of MRP system - 3 types :

TYPE I. : AN INVENTORY CONTROL SYSTEM
(right quatities at right time to support the master schedule)

TYPE II.: A PRODUCTION AND INVENTORY SYSTEM
(to plan and control inventories and capacities in manufacturing companies)

TYPE III: A MANUFACTURING RESOURCE - PLANNING SYSTEM
(to plan and to control all manufacturing resources : inventory,capasity,cash,personnel,capital,equipment)

CLOSED-LOOP MRP SYSTEM



ADOPTED BY [3]

THREE PRINCIPAL INVENTORY FUNCTIONS :

	- order the right part
INVENTORY	- order the right quantity
	- order the right time
	- order with the right due date
PRIORITIES	- keep the due date valid
	- a complete lead
	- an accurate valid lead
CAPACITY	- an adequate time span for visibility of future load

BOM - bill of materials (parts list)

BOM is a structured list of all materials or parts needed to produce a particural finished product, assembly, subassembly, manufactured part or purchased part (BOM are 100 % accurate).

MATERIALS PLAN - PARTS EXPLOSION

Example

	Week						
	1	2	3	4	5	6	7
Shaft							
Gross requirements		-	-	-	-	50	50
On-hand/scheduled	10	-	-	-	-	-	-
Net requirements	-	-	-	20	30	30	20
Planned order releases	-	-	30	30	30	20	-
Wheel							
Gross requirements	-	-	-	-	-	100	100
On-hand/scheduled	20	-	-	-	-	-	-
Net requirements	-	-	-	40	40	60	40
Planned order releases	-	-	60	60	60	40	-

etc --

3 - JUST - IN - TIME

Definition : JIT is method of inventory management eliminates anything which does not add value in production activities by providing the right part at the right place and the right time. JIT elinates all sources of waste. Objectives : Less inventory Lower costs Better quality

PHILOSOPHY OF JIT

JIT has been established by TOYOTA MOTOR COMPANY IN JAPAN - the mid of 1970 - Mr. TAICHI OHNO vicepresident of TOYOTA.
JIT has been expanded to USA at 1980.
JIT is available mostly for repetitive manufacturing (mass production of cars, trucks), for production of standardized parts in high volume, and in the certain extent for the job loz production too (nonrepetitive in nature).
(IBM's name of JIT - CONTINUOUS FLOW MANUFACTURING - CFM).

PRINCIPLES :
1. REDUCE INVENTORY AND OTHER WASTE
2. IMPROVE QUALITY TO ZERO DEFECTS
3. IMPROVE FLEXIBILITY BY REDUCING QUEUES AND LOT SIZES
4. REVISE THE PRODUCTION FLOW PROCESS
5. ISTABLISH SIMPLE VISIBLE CONTROL
6. DEVELOP A HABIT OF CONTINUOUS IMPROVEMENT

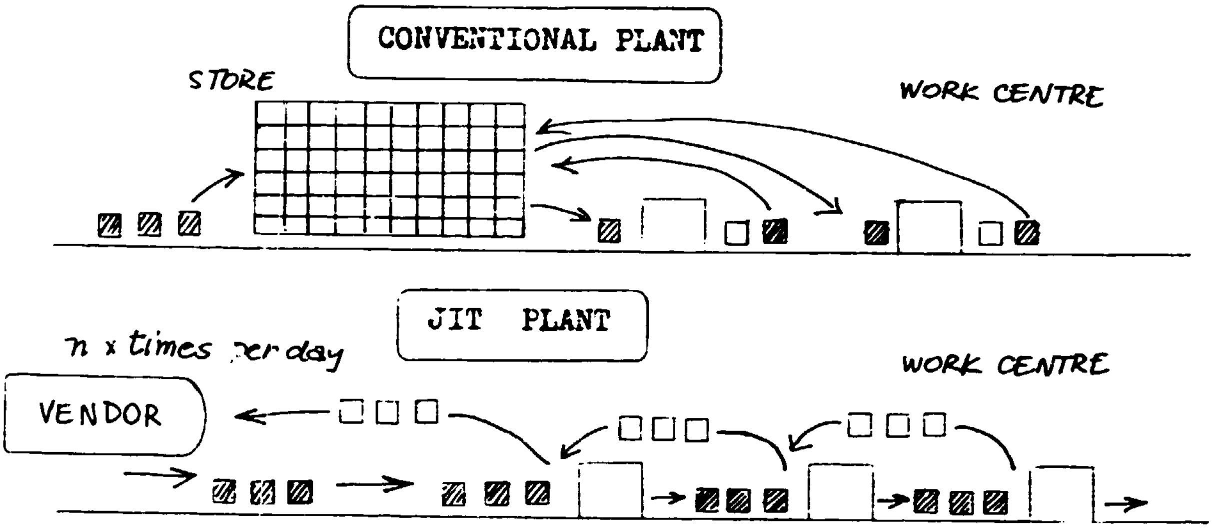
RESULTS :
- CYCLE TIME WAS REDUCED ON THE AVERAGE 50 %
- QUALITY WAS IMPROVE ON THE AVERAGE 30 %
- PRODUCTIVITY WAS IMPROVED ON THE AVERAGE 10 %
- INVENTORY WAS REDUCED ON THE AVERAGE 40 %

ELEMENTS OF JIT : - MASTER SCHEDULE or FINAL ASSEMBLY SCHEDULE for 1 to 3 months

- WITHIN CURRENT MONTH THE MASTER SCHEDULE IS LEVELED ON DAILY BASES (SMALL LOTS - STABLE MASTER SCHEDULE)
- WITHDRAVAL SYSTEM (KANBAN SYSTEM)

JIT uses a simple part withdraval system to pull parts from on work centre to the next. Parts are kept in small containers with limited number. When all containers are filled - machines are shut off - until the subsequent work centre provides another empty container.

Inventory is held on the shop floor and not in the storeroom between processes - inventory is KEPT LOW - only a few hours of supply.



vendor becomes as partner

next process descovered defects

IMPORTANT CONDITION : TO MAKE AVERAGED PLAN PER DAY
(of types 1 month in advance)

EXAMPLE :

product (A) (B) (C)

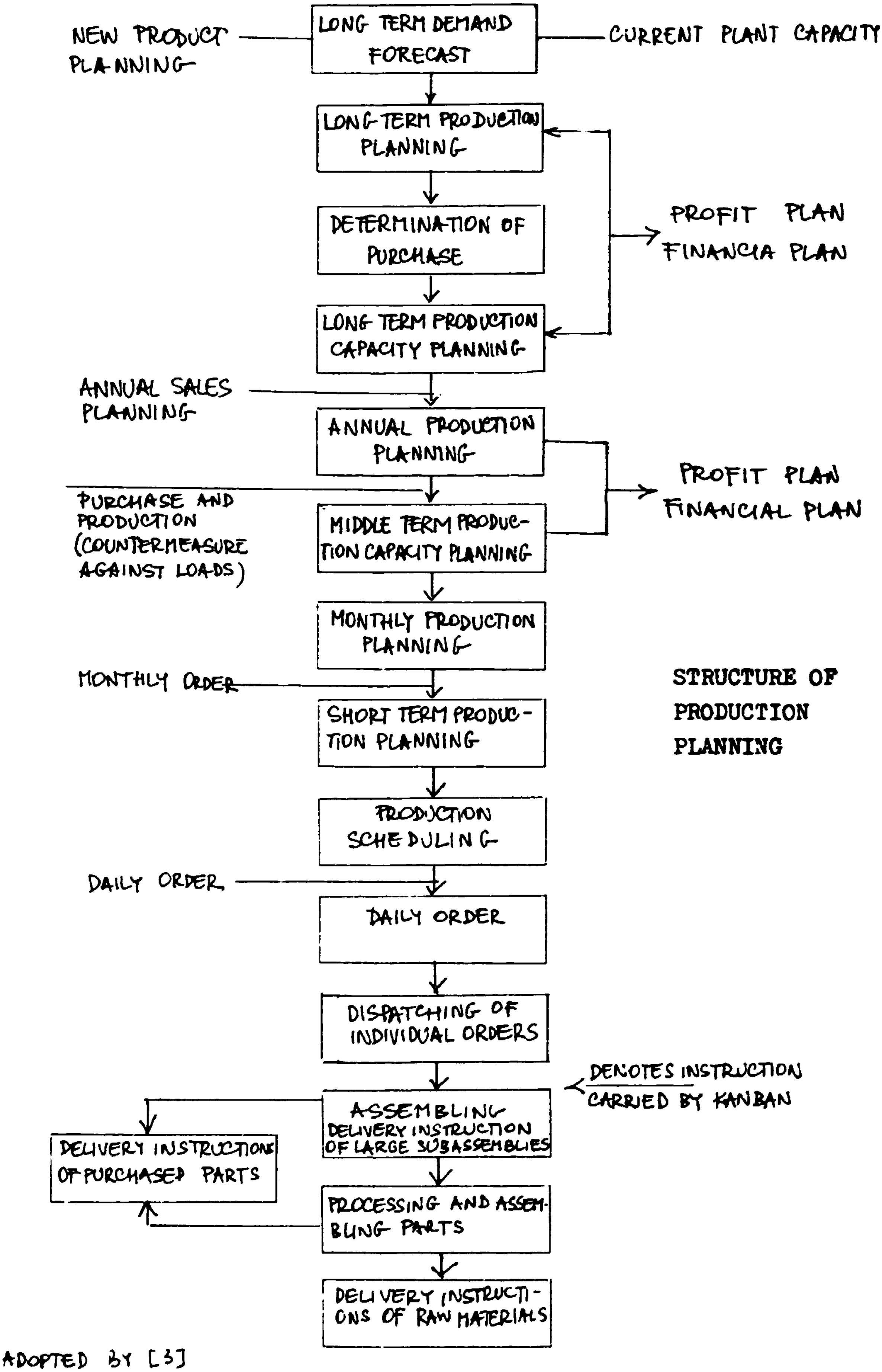
individual units will be mixed :

10 000 units of A
5 000 units of B
5 000 units of C

1/20 per day of each will be:

500 units of A
250 units of B
250 units of C

therefore sequence will be : AABC/AABC/AABC .....



STRUCTURE OF PRODUCTION PLANNING

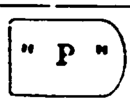
PRINCIPLES FOR DAILY PLAN MAKING :

- TO DETERMINE RIGHT QUANTITY
- DOES NOT ALLOW OVER PRODUCTION
- DAILY QUATA HAS BEEN SET
- UNIFORM LOAD ON ALL WORK CENTRES
- ENOUGH LEAD TIME
- DENOTES INSTRUCTIONS BY KANBAN CARDS

KANBAN SYSTEM

AIMS :
- TO AUTHORIZE PRODUCTION
- TO IDENTIFY PARTS
- TO START MANUFACTURING PROCESS
- TO KEEP PROCESS IN MOVING

PRODUCTION CARD



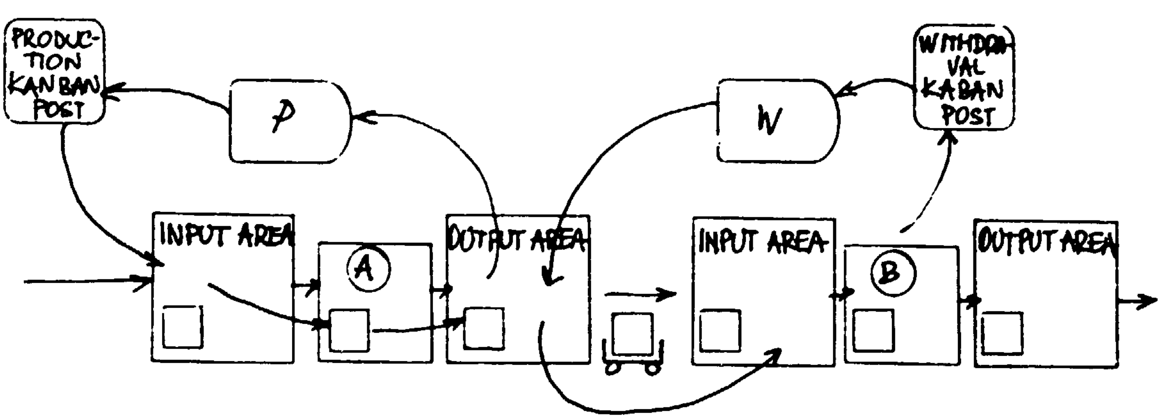
- PART NUMBER
- PART NAME
- PROCESS TYPE
- STORE LOCATION AT WHICH TO STORE
- CONTAINER CAPACITY

WITHDRAVAL CARD

- PART NUMBER
- PART NAME
- PRECEDING PROCESS
- SUBSEQUENT PROCESS
- CONTAINER CAPACITY
- CONTAINER TYPE
- ISSUE NUMBER

KANBAN CARDS :

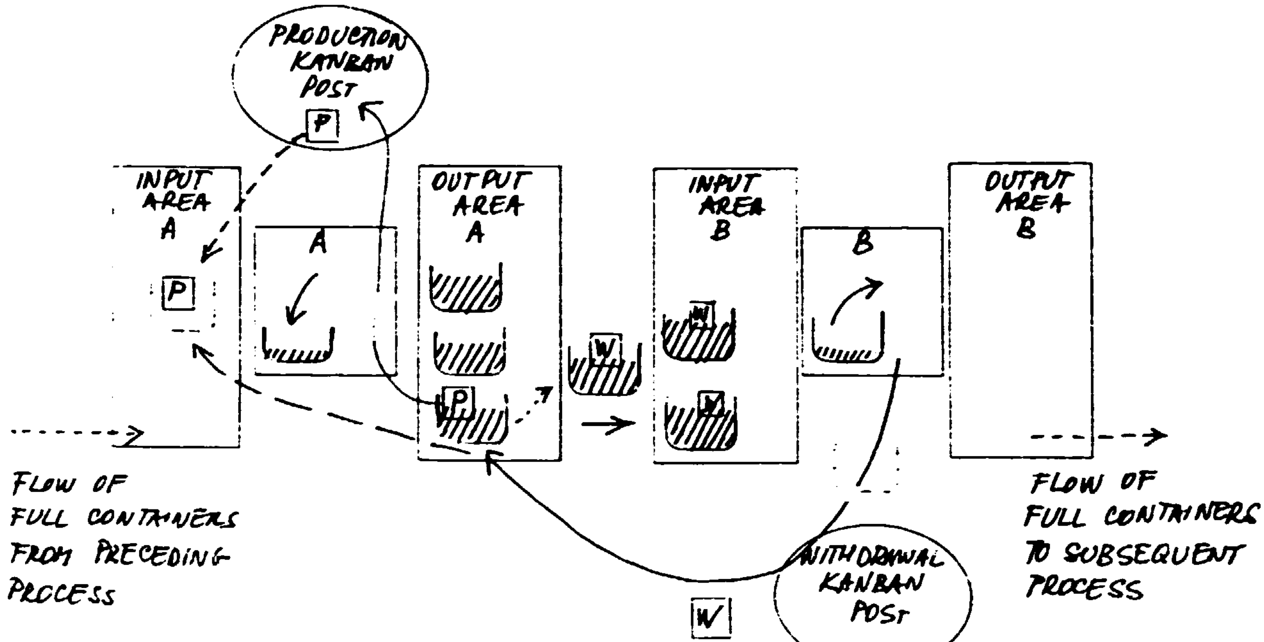
FLOWS OF „P' AND „W' KANBAN CARDS



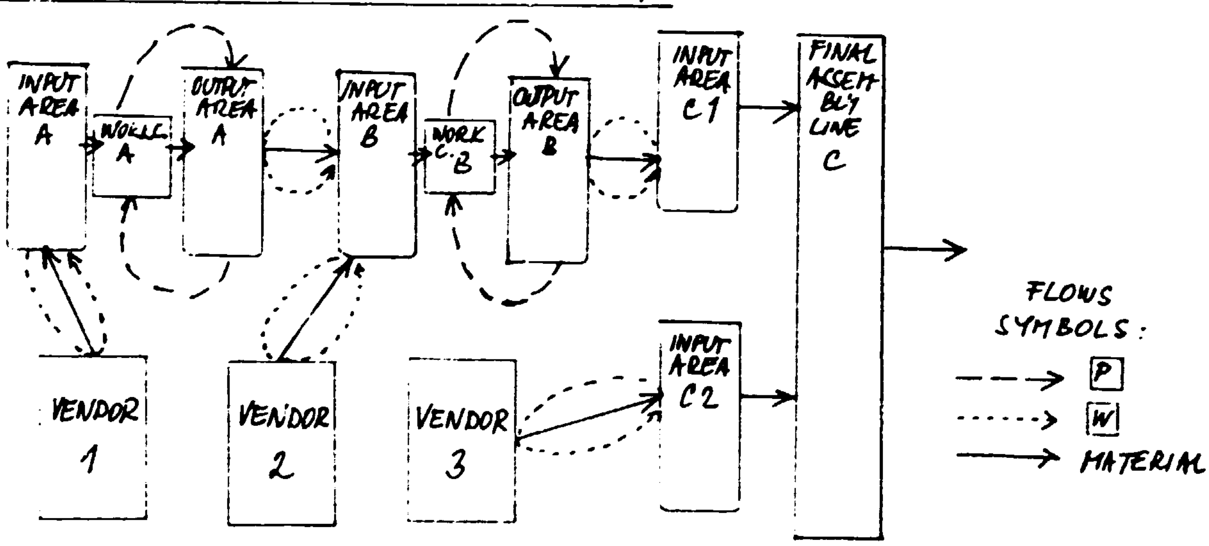
ADOPTED BY [2] AND [3] Principal JIT scheme

JUST - IN - TIME SCHEME IN DETAILED

ONLY THE FINAL ASSEMBLY LINE RECEIVES A SCHEDULE FROM THE DISPATCHING OFFICE (NEARLY THE SAME FROM DAY TO DAY).
ALL OTHER MACHINE OPERATORS AND VENDORS RECEIVE PRODUCTION ORDERS — KANBAN CARDS — FROM THE SUBSEQUENT WORK CENTRES (AS FROM USERS).
IF PRODUCTION SHOULD STOP IN THE USING WORK CENTRES, THE SUPPLYING WORK CENTRES WILL ALSO SOON STOP BECAUSE OF ABSENCE OF NEW RECEIVED KANBAN ORDERS FOR MORE MATERIAL. EXAMPLE : 8 CONTAINERS



EXAMPLE OF COMPLETE KANBAN SYSTEM :



ADOPTED BY [2] AND [3]

ADOPTED BY [8]

<u>JIT LEAD TIME</u> - entire time of an elementary cycle of JIT process

T - FILLED + WAIT + MOVED + USED + RETURNED + FILLED AGAIN

Where :

T ... Lead time

n ... total numbers of containers

D ... demand rate (number of parts/month)

C ... container size (number of parts)

Than is valid :

$$n = \frac{D.T}{C}$$

or

$$n.C = D.T$$ maximum inventory

WORK FORCE IN JIT PROCESS

JIT work is multifunctional.

<u>PRINCIPLES OF JIT WORK FORCE :</u>

- TO OPERATE SEVERAL MACHINES
- TO SHUT THE MACHINE
- TO MOVE ONTO ANOTHER JOB
- TO SET UP MACHINE
- TO DO ROUTINE MAINTENANCE
- TO INSPECT THE PART

} CROSS - TRAINED IN SEVERAL SKILLS

VENDORS

Vendors in JIT process are partners of production.Their obligations : PICK UP EMPTY CONTAINERS AND WITHDRAVAL KANBAN CARDS. THAN FILL CONTAINERS BY SEMIPRODUCTS OR COMPONENTS AND DELIVER JUST IN MANUFACTURING PROCESS OR ASSEMBLY PROCESS WITHOUT INSPECTION - DUE THE CONFIDENCE IN VENDORS QUALITY.

MRP - JIT COMPARISON

MRP	JIT
BATCH PRODUCTION	REPETITIVE PRODUCTION
NON REPETITIVE	(MASS PRODUCTION)

V - WORK FORCE MANAGEMENT

WORKERS ARE NOT APPENDIX OF MACHINES !

Worker's actual behaviour depended on rules established through contacts with other people within production process.

The fundamental principles of the human behaviour approach are as follows :

1. The amount of work rather depends on the social conditions surrounding the work
2. Non-economic rewards can motivate workers more than high wages (feelings of happenies and security - not to be unimploeee)
3. Better to give workers a wide variety of tasks (can stimulate productivity increasing)
4. Very important are established workers group,becsuse of high value of standards of behaviour and human relationship created by the group

INTERPERSONAL RELATIONS IN GROUP BEHAVIOUR :

Personal respect
Personel value
Pertinence to the group
Personal importance
Persona inadequacy and frustration
Individual involvement

PRINCIPLES OF WORK FORCE MANAGEMENT :

1. Match the worker and the job.People should be selected for for jobs on the basis of their idividual differences and preferences for work.Some people might be asked to accept too much responsibility while other are asked to accept to little.
2. Clearly define responsibilities of the worker.This would be done through written job description or statement of objectives which are kept up to date.

ADOPTED BY [1]

(3) Set standards of performance, for all jobs.

(4) Ensure communicatins and employee involvement. This is idea of the participative management.

(5) Provide training. Training should begin the first day on the job. Knowledge is rapidly changing and training must be continuous.

(6) Ensure good supervision. A superviser should be competent in both technology and management skills.

(7) Reward people for performance. Rewards for performance constitute the prime method of motivating people towseds goals.

NEW APPRCACHES TO MANAGING PEOPLE AND ORGANIZATIONS :

(1) A bias for action. Do it - fix it - try it.

(2) Close to the customer.

(3) Autonomy and entrepreneurship.

(4) Productivity through people.

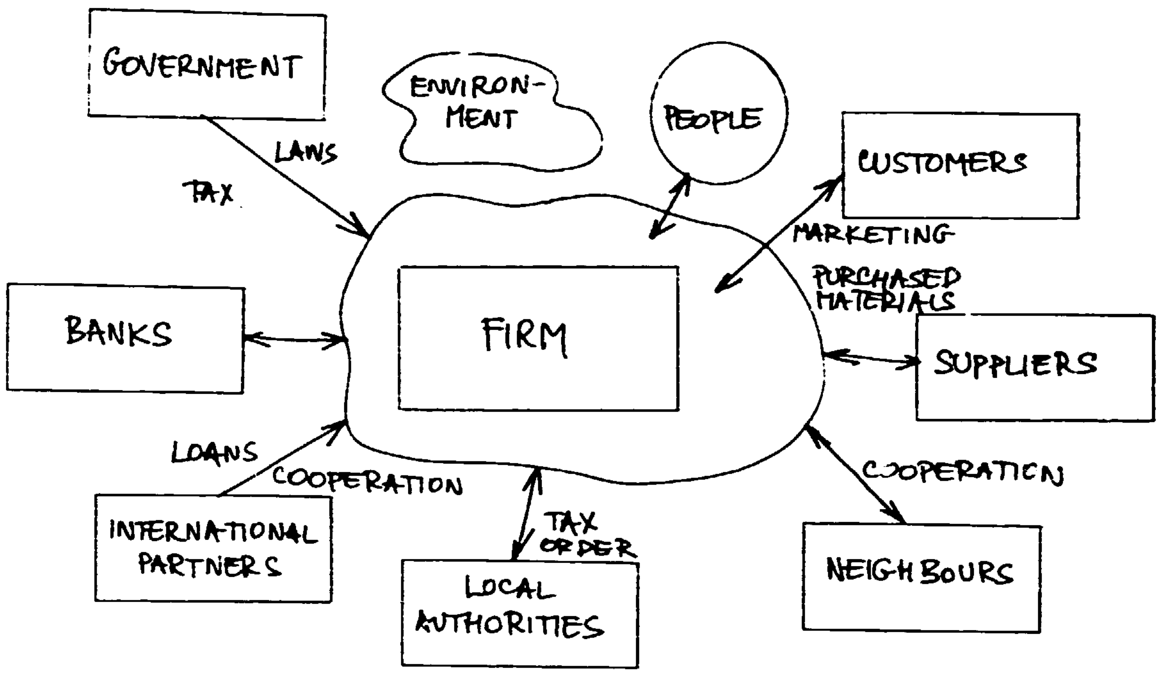
(5) Hands on value driven. The excellent companies have identified their basic values.

(6) Stick to the knitting.

(7) Simple form, lean staff.

(8) Simultaneous loose-tight properties.

FIRM ⇒ OPEN SYSTEM



ADOPTED BY [1] AND [3]

VI - QUALITY MANAGEMENT AND CONTROL

Definition : QUALITY HAS BEEN GENERALLY DEFINEDAS "FITNESS FOR USE.THE PRODUCT OR SERVICE MEETS THE CUSTOMER NEEDS - THE PRODUCT IS FIT FOR THE CUSTOMER'S USE.ONLY THE CUSTOMER CAN DETERMINE ABOVE MENTIONED FITNESS FOR USE.

DIMENSIONS OF QUALITY :

- Quality of design
- Quality of conformance
- The abilities
- Field service

The four different dimensions of quality are more devided in following scheme.
The process of quality planning and control requires a continuoue interaction between the customer,operations and other parts of the organization.Those interactions are creating the quality cycle.

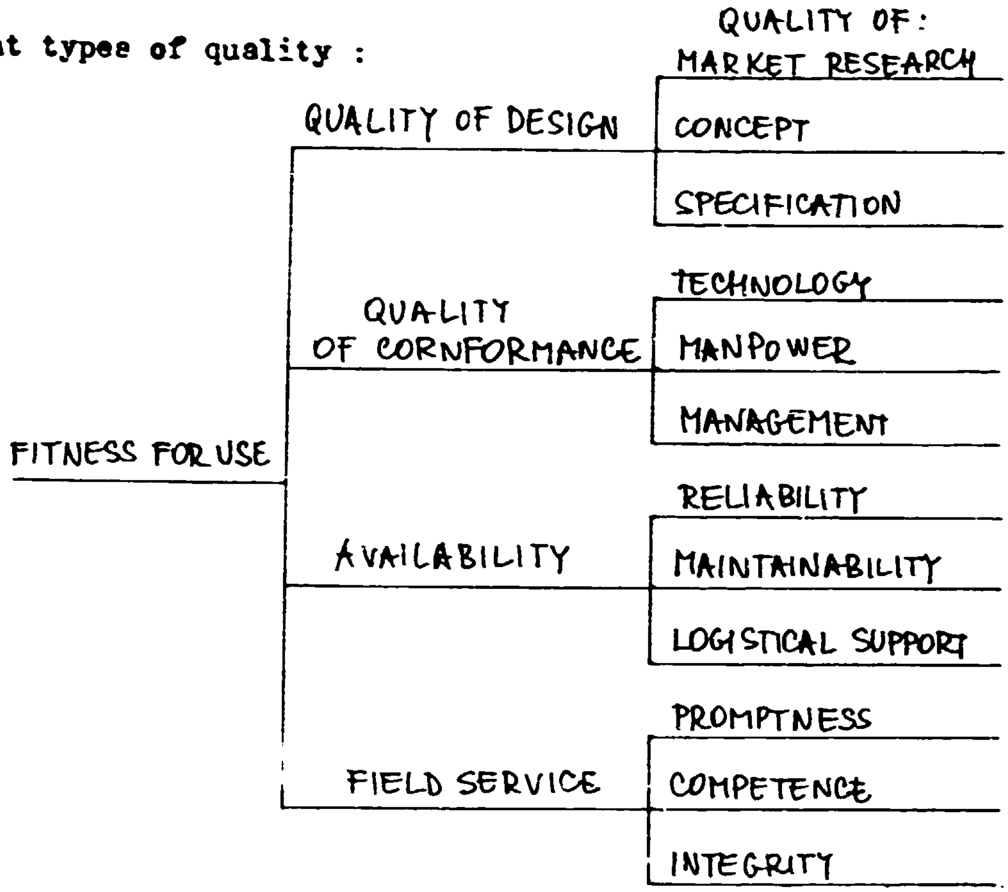
To implement planning and control of quality through the quality cycle requires the following sequence of steps :

1. DEFINE QUALITY ATTRIBUTES
2. DECIDE HOW TO MEASURE EACH ATTRIBUTE
3. SET QUALITY STANDARDS
4. ESTABLISH AN INSPECTION PROGRAMME
5. FIND AND CORRET CAUSES OF POOR QUALITY
6. CONTINUE TO MAKE IMPROVEMENTS

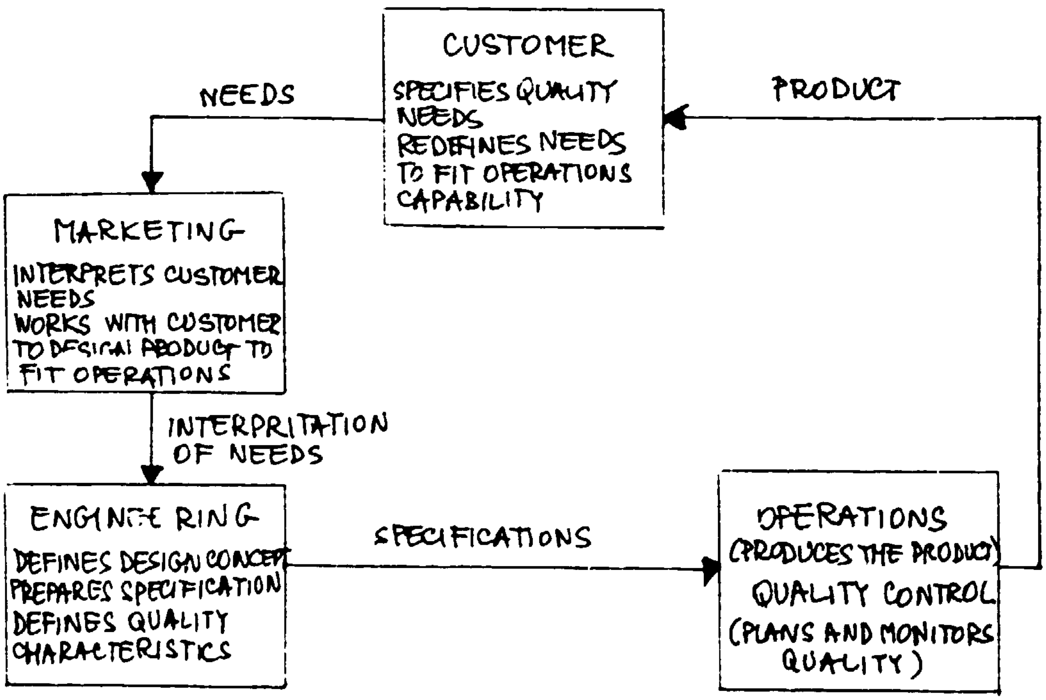
The best approach to the quality analysis,its improvement and implementation give ISO 9000 standard series.
The major ISO 9000 standard principles are describe on following figures.

ADOPTED BY [6],[8]

Different types of quality :



The quality cycle :



VII - PREDICTIVE DIAGNOSTIC

TECHNICAL PREDICTIVE DIAGNOSTIC OBJECTIVES:

- TO DISABLE FAULTS OF EQUIPMENT
- TO PRECEDE BREAKDOWNS OF MACHINES
- TO PRECEDE ECONOMIC LOSS
- TO SAVE PEOPLE IN WORKING PROCESS

RELEVANT BENEFITS OF PREDECTIVE DIAGNOSTIC SYSTEM IMPLEMENTATION:

- INCREASE IN THE TIME BETWEEN OVERHAULS (REDUCED MAINTENANCE COSTS)
- VIRTUAL ELIMINATION OF UNEXPECTED BREAKDOWNS
- ELIMINATION OF SECONDARY DEMAGE
- ELIMINATION OF COMPONENT WASTE
- REDUCTION OF SPARE PART STOCK
- REDUCTION OF REPAIR DURATION
- DECREASE POSSIBILITY OF DESTRUCTIVE BREAKDOWN

MACHINE CONDITION INDICATORS

- TEMPERATURE MEASUREMENT
- WEAR DEBRIS ANALYSIS
- ACOUSTIC EMISSION - NOISE
- MACHINES VIBRATION - MAIN AREA OF IMPLEMENTATION

THE MAIN REASONS OF MECHANICAL VIBRATING OF ROTATING PARTS OF MACHINES:

1. UNBALANCE
2. MISALIGNMENT
3. BENT SHAFT
4. MECHANICAL LOOSENESS
5. RESONANCE
6. CRITICAL REVOLUTIONS
7. OPERATIONAL UNSTABILITY
8. DAMAGED GEAR TEETH
9. BEARING FAULTS

PORTABLE DIAGNOSTIC SYSTEM | COMPUTED-BASED SYSTEM | PERMANENT MONITORING

VIII - INVESTMENT PROCESS

FEASIBILITY STUDY IN INVESTMENT PROJECT CYCLE

The meaning and objectives of an industrial investment project. The pre - investment, the investment and the operational phases.
The role of partners: investors, promotional agencies, commercial banks, suppliers of equipment, export credit insurance agencies and consulting firms.
Types of documents :
OPPORTUNITY STUDY (GENERAL O.S.,SPECIFIC PROJECT O.S.)
PRE - FEASIBILITY STUDY
SUPPORT (FUNCTIONAL) STUDY
CASE - STUDY
FEASIBILITY STUDY
APPRAISAL REPORT
REHABILITATION STUDIES (DIAGNOSTIC STAGE)
TENDER DOCUMENTATION
Basic aspects of pre - investments studies (strategic orientation, scope of the project, data for pre - investment studies, selection and verification of alternatives, total investment costs)

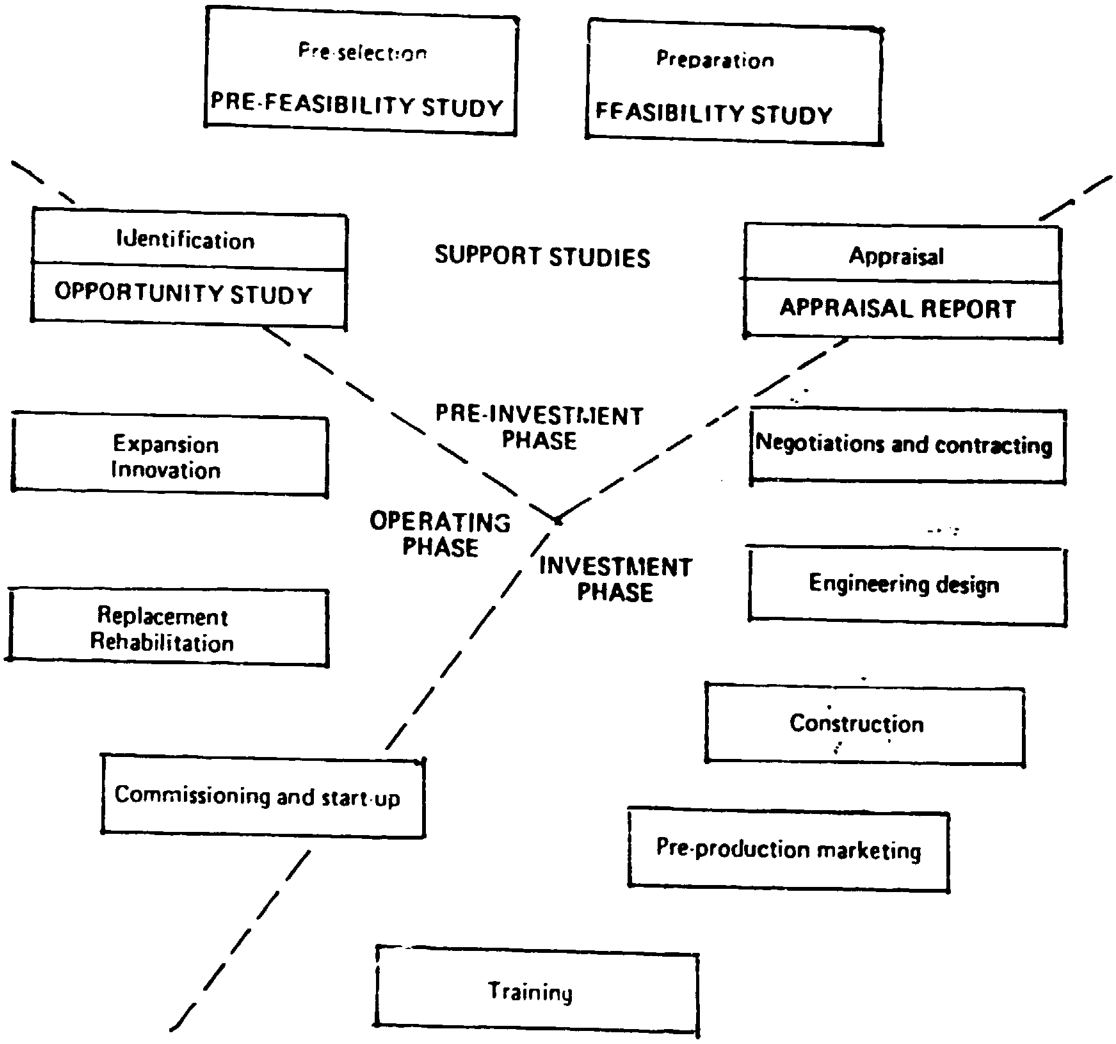
Feasibility study :- summary of project background,
- market analysis and marketing concept
- competition and market expasion strategy
- raw materials and suppliers
- location, site and environment
- production programme, plant capacity, technology
- organization and mangement
- mampower, training plan, recruitment
- implementation, budgeting
- financial analysis

GOVERNMENT INSTRUCTIONS FOR INVESTMENT PHASES ELABORATION

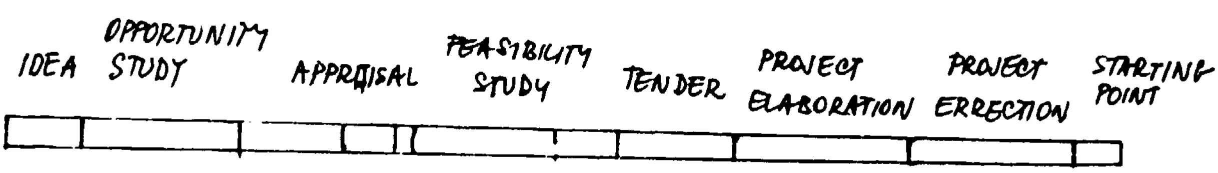
PROJECT TEAM ACTIVITIES :
- The role of team leader
- Main principles of team work
- Team members tasks and co - operation
- Methods of international projects co - ordination
- Charges of the team members work
- Timeschedul and implementation

EXAMPLES OF FEASIBILITY STUDY

TYPES OF STUDIES IN INVESTMENT PROJECT CYCLE



TIMING OF INVESTMENT CYCLE:



PRE-INVESTMENT, INVESTMENT AND OPERATING PHASES OF THE PROJECT CYCLE

ADOPTED FROM [10]

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[4] BPO : FEASIBILITY STUDY OF FERRUM FRYDLANT
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UNIVERSITY JAKARTA
MTDDC IN INDONESIA

SHORT COURSE
TEXT OF LECTURES

M A N U F A C T U R I N G A U T O M A T I O N A N D R O B O T I C S

Jiří FUJMAN, PhD and Pavel TOMEK, PhD

October 1993

JAKARTA

Content:

Jiří P u j m a n, Phd 1992

STRUCTURE OF CNC CONTROL SYSTEMS.

Summary: This paper deals with CNC control systems of Machine Tools. The basic terms of this problem are explained with the world progressive design tendencies. The level, reached in CSFR is characterized.

1. Development and production of CNC control systems in CSFR

Until the year 1990 the production of the automation means and mainly the control systems of the machine tools was secured by the two main producers - the electronic factories of the concern Tesla and Křižík (earlier ZPA). These factories had only very limited possibilities for the research and development. That was the reason, why design of the hardware and software of the NC and CNC control systems was concentrated mainly in the Research Institute of Machine Tools and Machining - VÚOSO Prague. The hardware development of the latest models was done by the firm VÚAP in accordance with the VÚOSO project.

The goal of this article is to make clear the software and hardware structure of these CNC systems. From this point of view is useful to repeat the basic terms of the NC control, which will be used later.

2. The basic terms of the Numerically Controlled Machine Tools

The NC machine is derived from the conventional production machine by the completing of all moving axes with drives and measuring systems, which are able to give the exact information about an actual position. The drive with the measuring system create a feedback circle - the servo-loop (fig.1). The commanded position generated by the NC control systems is brought in its input - the differential unit. This command is derived from a NC program - the geometrical and technological description of the working operations.

Not only the motion of the moving axes but also many others "miscellaneous" functions like clamping of the workpieces, cooling, lubricating, locking of the workspace etc. must be automated. They are controlled by the output commands for the electromagnetic relays and their action is checked from the state of the end switches on the inputs of the control system.

The first control systems occur in 1950 th. Their great development starts with the transition from discrete electronic elements to the integrated circuits; it means from second to the third electronic generation. In the fourth generation the computer appears in the kernel of the control system. The system is called CNC (Computerized Numerical Control). The using of the computer enables the higher variability and simplicity of the hardware and it brings the possibility to make the different models of the control system only by the software changes (fig.0). The minicomputers, which had been used in the first CNC systems are replaced by a structure of 16 or 32 bits microprocessors now. The performance of the systems is growing up. Also the user's comfort is rising up. The capacity of a memory for the technological data goes to 0,25 - 1 MByte. The handling of the system is more simple by using MENU techniqüe and more comfortable and convenient by using graphic.

A modern CNC system may be divided from the logical and often also from the physical point of view into three parts (fig.2):

NC - Numerical Control is the basic part of the system . Its main task is to shift over the NC program commands into the motion of the machine axes. It is fully realized by the CNC system manufacturers. The changes of its properties are possible only by setting of the parameters defined by a system producer - machine constants.

PLC (PMC, PC) - Programmable logical contro is the part which creates the interface between the control system and the machine. The control system manufacturer provides only the hardware and software means of this part. The machine electrodesigner must define the logical segments and conditions by creating working algorithm (a program of the PLC part). He does it in dependence on the actual connections of the inputs and outputs with contacts of the machine and utilizing of the means which gave him the producer of the control system (the program languages, libraries, subroutines etc.).

COM - Communication control is the system part responsible for the input, output and file managment of the technological data and often also for the communication with the operator panel and the control system peripheries. It is again realized by the system manufacturer but the unrepresentative demands of the user are solved as options. (DNC communication, the expansion of the memory capacity or the increase of the operator's comfort by using the graphic or NC programing facilities).

The NC - PLC - COM communication is rendered possible through the part of the system memory - the window. The window creates interface with the exactly defined meaning of all communications messages, state words, bytes and bits.

3. Typical hardware structure of the modern CNC systems

The kernel of the system is created by the Processor Unit serving to one or more logical areas NC, PLC and COM. The 16 bits processors Intel (8086, 80186, 80286) or 32 bits processors Intel or Motorolla are typically used. Their performance in a field of the mathematical calculations is often increased by the arithmetical co-processors, in a field of communications by the input/output co-processors. In this unit used to be realized also an EPROM memory for the system software with the capacity up to 0,5 MByte and the cash type DRAM work memory. Also several support circuits (interrupt, control of the bus) is often on the same unit. The communication with peripheries uses mainly serial

RS 232 - C interfaces in the modern CNC systems. Sometimes they form the special unit, but sometimes they are included in the processor unit.

The unit for the communication with the machine tool is called Input/Output Unit. The inputs used to be optically separated from the machine end switches, the outputs are rated at 0,2A 0,4A 1A or 2A, depending on the current necessary to control the machine relays and contacts.

The very important unit is the Memory for the Technological Data (NC programs). The typical solution uses CMOS RAM type memory with the battery back-up. Its capacity depends on the users specification and changes from 32 KBytes to 1 MByte.

The Operator Panel exists in two design variations. The older uses a design typical for the terminals of large computers. The panel has its own processor and the communication between it and the system has the form of characters or special messages. The modern variant is realized with the video RAM memory in the system and the communication is of the same type as the EGA or VEGA cards in PC computers. For connection of the panel keyboard is used the standard serial communication.

The most important unit is the unit for controlling servo-loops called the Differential Unit. The inputs of this unit are the actual position data. The outputs are commands for servodrives. The unit exist in analog (older) or digital (newer) version. Basically there are two variants - the active unit, with its own microprocessor or the passive unit, that uses the services of the central processor unit.

The global performance of the system depends on the interconnections of units (fig.3). The systems realized with all units on one central bus are limited by the bus through transmit, that decreases the ability of the parallel working processors. The solution with several buses is powerful but expensive.

The cheapest one processor systems, with one common processor for NC, PLC and COM parts, are not restricted by the performance of the central bus, but they are strongly limited by the necessity to divide the operating ability of the central processor between the tasks of the all three areas. Therefore they use the 32 bits microprocessors of the high performance and they have minimum units on the system bus.

The most common design of the middle price category use one processor for both NC and COM area. The other processor is used for PLC area. Very often is used the common bus (chapter 5.), the solution with two busses is not used so much, but it provides the higher performance.

The most expensive systems have for each of the NC, PLC and COM area the own processor unit. The communication between these areas is through special "more-gate memory" or through a memory on the system bus.

The latest tendencies in the design are to incorporate into the structure of the CNC system the IBM PC compatible computer. This computer can be used for NC programming, communication with the host computer, user comfort in the file managment area etc. The newest results in these fields can be incorporated into this type of the control systems only by the change of the computer software. The common connection of this IBM-PC computer with the control system is the way of connection of the data periphery. Sometimes there are the special gates between the computer bus and the CNC system bus. The most progressive design tendencies, to use the computer as a basic part of the CNC system and to complete it with servo-loop units (motion controllers) and PLC part, are still quite seldom.

4. Principles of the software design and its structure.

The design of the CNC software modules depends on the time demands of the simultaneously active tasks in the logically independent NC, PLC and COM area (fig.4).

The NC part, as the most important area responsible for the motion control, is kept in the time necessary for servo-loops control. For the common extend of the working speeds (10 m/min) and common curves of the generated trajectories is this NC time interval 5 - 20 ms.

An extension of the time period leads to the errors of generated trajectories; an abbreviation leads to the overload of the NC processor unit. The time interval for the closing a feed back of the servo-loops is 5 or 10 times shorter and it is often served by a processor of the differential unit. The NC area communicates with the machine through NC - PLC window; the interval for this communication is 50 - 100 msec.

The time interval of the PLC part is done by 1 cycle of the PLC program. This program derives from the machine inputs and NC-PLC window status the output signals and the status of PLC - NC window. It is suitable to design the PLC program in such form, that PLC cycle will not extend 100 - 200 msec. During this time period the high speed inputs can be served by the interrupt technique. This has only little influence on the NC - PLC communication.

The keeping of the COM area in time depends on the time demands of the communication channels, the admissible time of the keyboard reaction, and the time for the next NC program block transfer. There are no special problems, when this unit is equipped with an own processor.

The usual control of the synchronization of software tasks in the modern CNC system is on fig.5. The most of the tasks is subordinated to the Real time executive operating system. This system secures the interprogram communication, synchronization and their scheduling and running depending on the priorities . If any program task is interrupted by the task of the higher priority, the operating system makes possible to continue the execution of the interrupted task after all the programs with higher priority have been finished.

The task, which is superior over the operating system, is the transfer of the data last interpolation results to the differential unit of the servo-loops. This task has the form of the special interrupt service routine for the basic time interval. The operating system is master of the whole process control after finishing this routine. It chooses the task with the highest degree of the priority and makes it running. This is the interpolation; the task for calculation of the servo-loops motion increment for the next time interval.

It must be finished in the time shorter than the basic time interval of the system is. In the rest of the time interval the control system executes the tasks with lower priority (the communication through NC - PLC and PLC - NC window, the preparing the next program block, the communication with the operator, the position displaying, the edition or preparation of new NC programs, etc.)

The structure of a task is simple (fig.6) . After an initiation goes the task to the exchange - the mail box, where it waits for the messages from other tasks or from operating system. After receiving the message the task starts its activity, solves the message, sends messages to the other tasks and after finishing it, it goes again to wait for another messages to the exchange.

To create the CNC software is very complicated and in takes more then 50 man-years. It is suitable to use all modern information means like high programming languages, efficient operating systems, communication or graphic routines etc. But these means do not use always the CNC hardware by the most effective way. The capacity of this hardware is in comparison with a computer hardware very limited from the price reasons. So we must find the reasonable compromise between using modern programming technique with a shortening the software developing time and fulfilling the users demands without expansion of CNC hardware.

5. Basic data of the CNC NURIS systems

The last developed generation of the CNC control systems in Czechoslovakia is called NURIS- NS 730. The project of the system and the system software was made by VÚOSO, the hardware design by VÚAP and the production by Křižík.

The system is determined for middle degree of the machine tools intricacy. There are two variants - for milling and turning machines.

From the user point of view is the system very comfortable. The handling of the system is made simple by the MENU technique of operating , the system has more than 10 standard type of the display pictures, the programming language has three degree (ISO standard, programming language like Pascal with arithmetic, logic and control functions and the graphic dialogue for programing from the drawings), the simultaneous cutting and program preparation is possible.

The system has also a possibility for completing the high demands of automation (an adaptive control, an active control with touching probes and sensors, the systematic errors and temperature errors compensation etc.)

The hardware structure corresponds to the system with common bus and only one processor unit for the NC and PLC parts (fig.3, chapter 3). The Intel 16 bits processors and co-processors are used. The technological data memory is expandable to 256 KByte, the number of the machine inputs and outputs to 512. The display is monochromatic 12" with graphic possibilities (fig.7).

The software was developed in accordance with principles, described in chapter 4. It takes approximately 0,5 MByte of the system EPROM memory. It uses services of the standard Real time executive system RMX and the standard means for processor communication. In time critical sections the program language is Assembler, in tasks with lower priority mainly Pascal. The module structure enables the next development of the system.

The CNC NURIS (fig.8,9) could be marked like the middle class CNC control system with some luxury functions (like Fanuc 0, Sinumerik 810, Bosch CC 100).

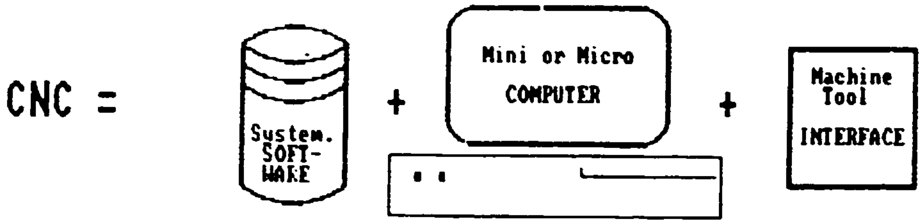
6. Situation on the Czechoslovak CNC market

The electronic production in all countries of the former Eastern European block (USSR, CSR, NDR ....) was characteristic by relatively high technical level of the design but a low production quality and reliability. Basically it was impossible to use imported electronic elements for the inlands manufacturing, the production technology was on a low standard.

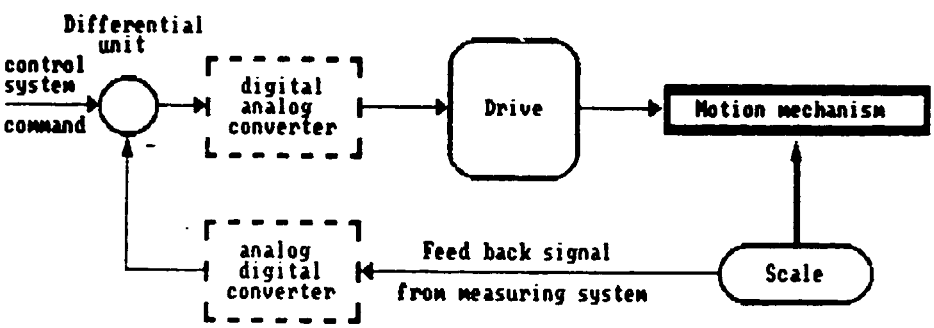
This facts were increased by the machine tool industry stagnation, caused partly by the world disarmament, partly by the privatization process in CSFR. It leads to the crisis of the Czechoslovak electronic industry.

These are the main reasons why the Czechoslovak CNC control systems are practically unsalable. Although the NURIS control systems are, after great hardware redesign and after imported some special integrated circuits, in a relatively very good quality, are these systems rather the evidence of the good standard of Czechoslovak research and design than the effective productive device.

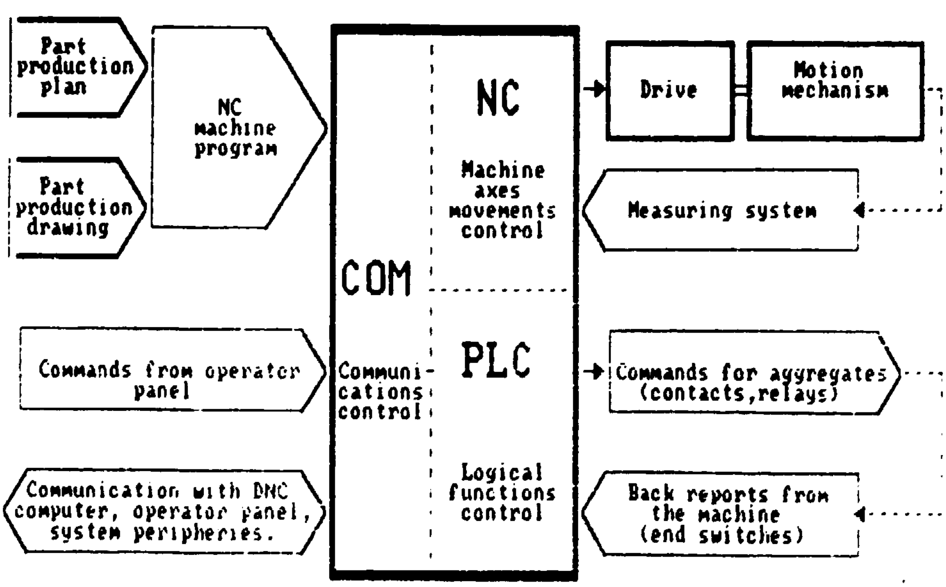
CNC - Control Systems of Machine Tools



CNC control system fig.0



Servo - loop fig.1



Basic areas of the CNC system fig.2

CNC – Control Systems of Machine Tools

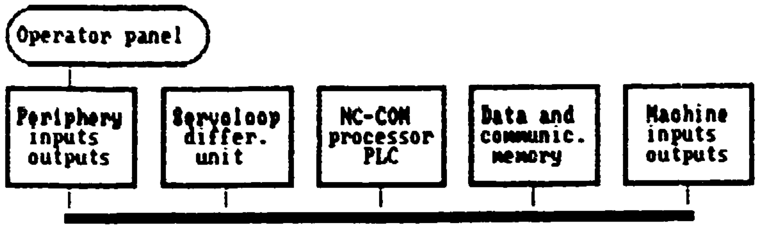


fig.3a

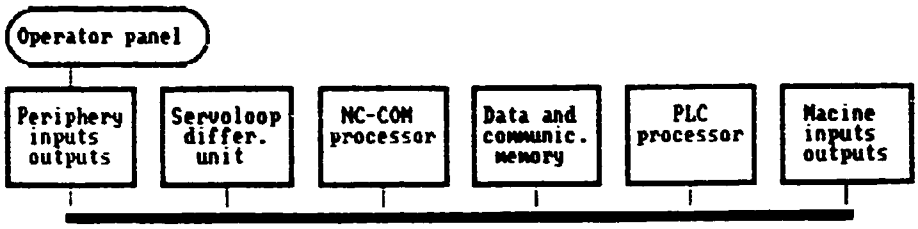


fig.3b

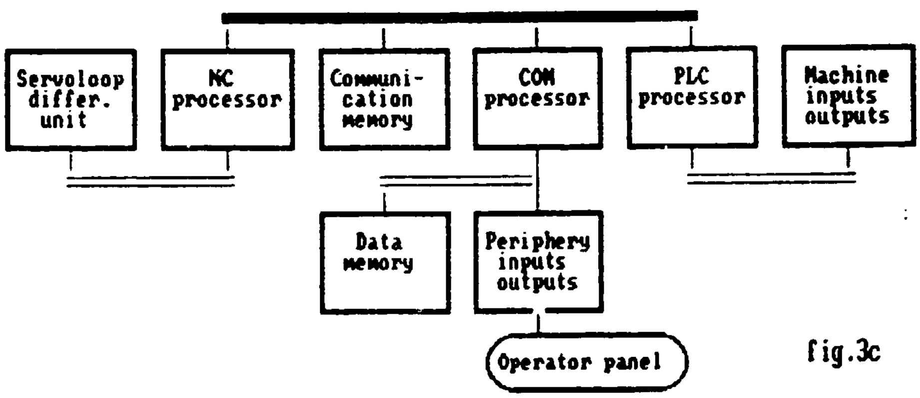


fig.3c

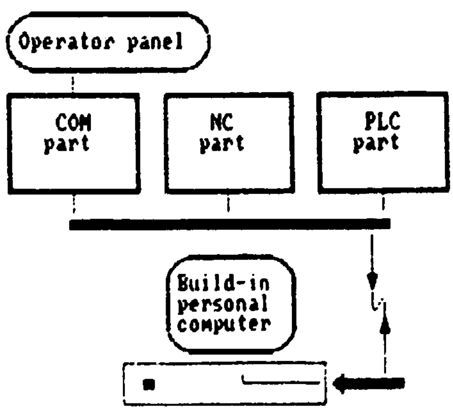
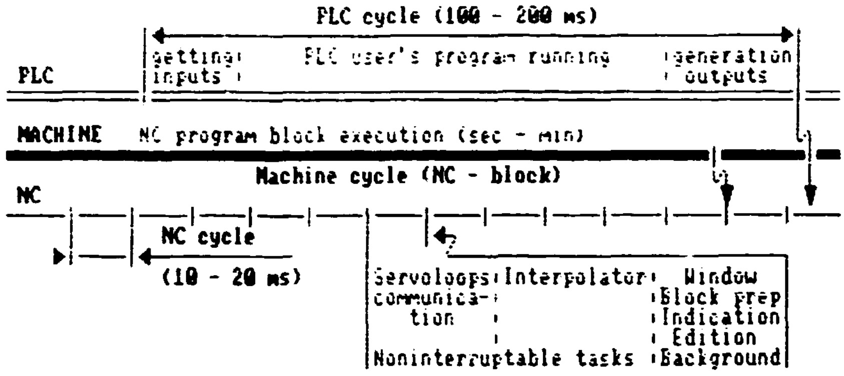


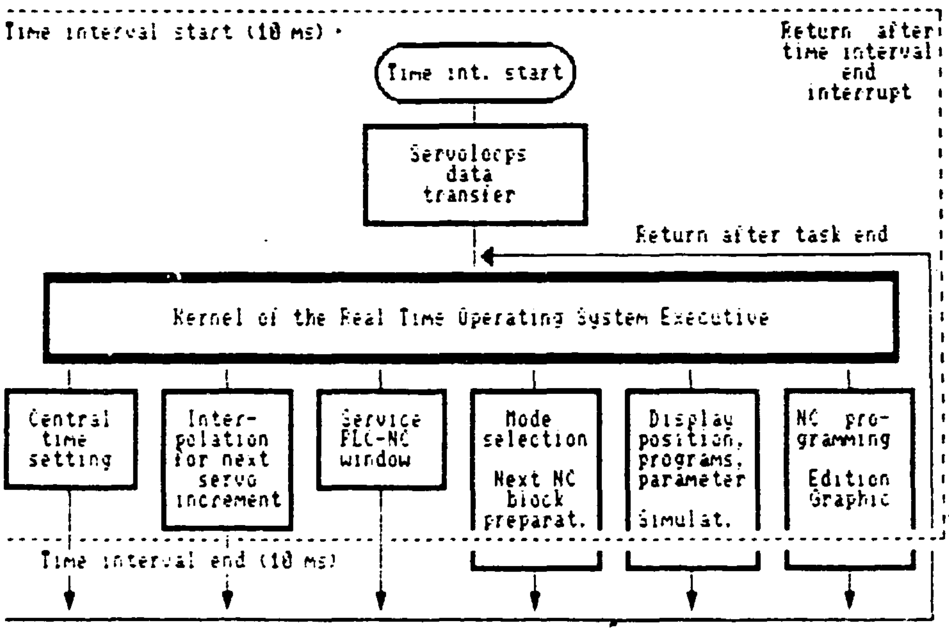
fig.3d

Typical CNC systems hardware structures fig.3

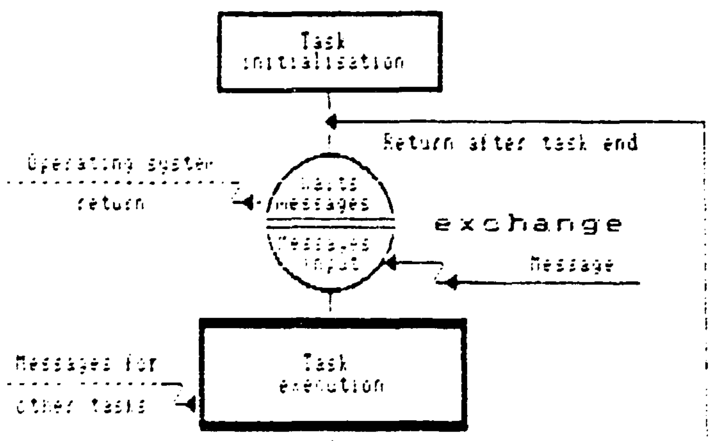
CNC – Control Systems of Machine Tools



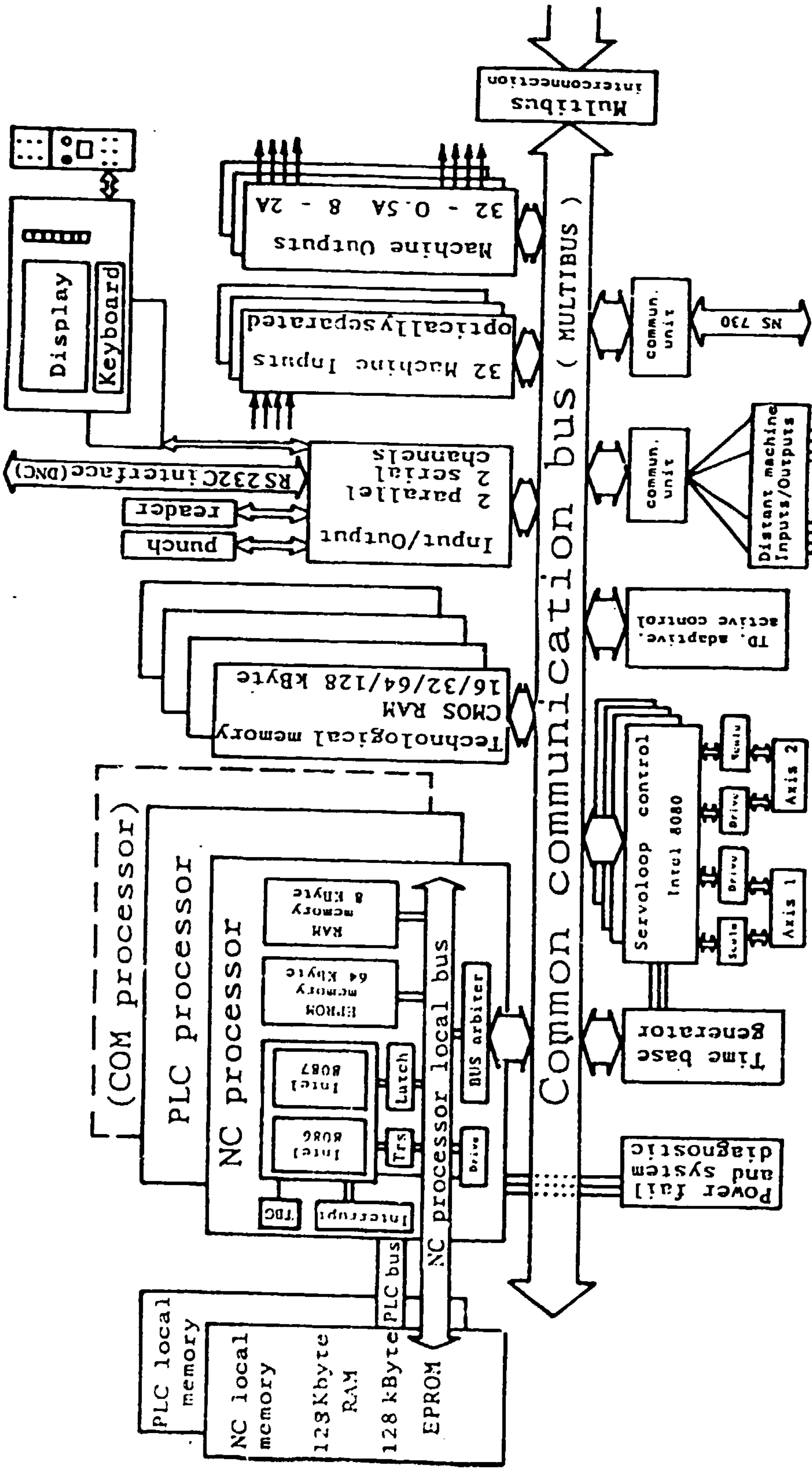
Time demands in the CNC systems fig.4



Typical software structure of the CNC systems fig.5

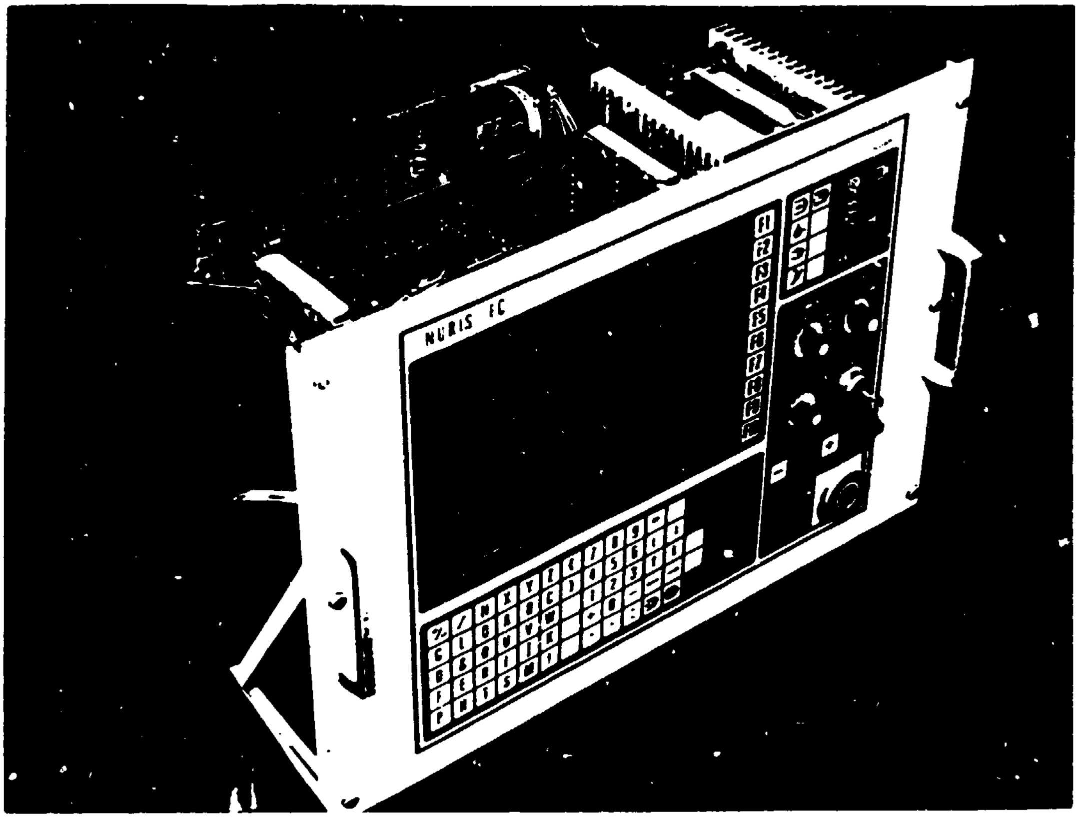


Structure of program task fig.6

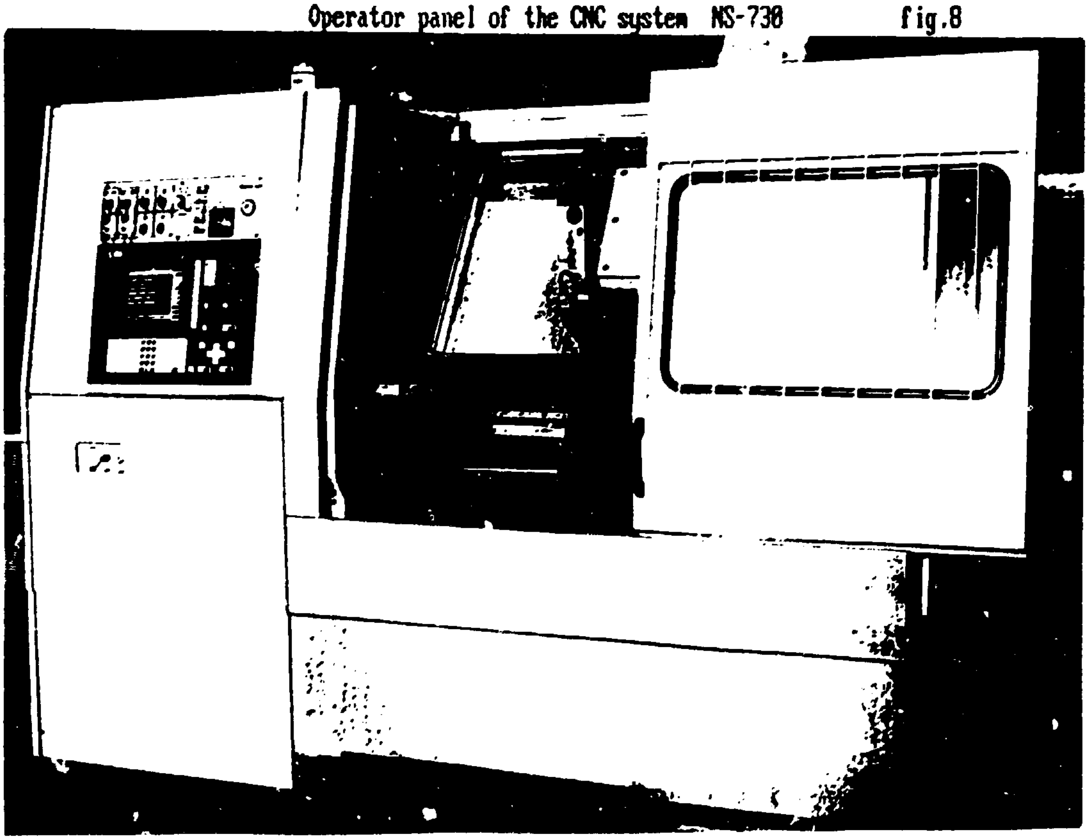


Hardware structure of the CNC system NS-730 fig.7

CNC - Control Systems of Machine Tools



Operator panel of the CNC system NS-730 fig.8



SPT 16 NC lathe with the CNC system NS-730 fig.9

Jiří P u j m a n, PhD 1993

RETROFITTING - THE WAY OF EFFECTIVE USAGE OF THE OLD MACHINES.

Summary: This paper deals with simple retrofitting method of the old machine tools by the modernization of their electronic equipment. The attention is given mainly to the completing of the conventional machines with the position measuring systems and readouts and to the exchange of the old fashion control systems of the old NC machines by the new one.

1. Introduction.

The Czech republic was and is highly industrialized country. It used to be among leading nations in word in production and utilization of machine tools. The long time orientation to the East European market led to stagnation in the technical level of the produced machines. Their mechanical quality was traditionally good but their electric and control equipment was not reliable enough and not very progressive from technical point of view. With this fact is connected the lack of the capital for great investments necessary to the modernization of our machine park by brand new machines. This modernization is necessary for increasing of the automation degree which is the most effective way to the pushing down of the production costs.

The one of the most reasonable way, how to solve this situation is modernization of the used machine tools called often "retrofitting". Under the term retrofitting of the machine is to be understand not only repair of the machines, but the completing of them with new mechanical and mainly electrical elements to get some more progressive properties, mainly from automation point of view. The conventional machine tools are often equipped with measuring systems and position readouts, the NC machines give the new quality by the replacing of the old control system with new and powerful one.

The retrofitting is not the special solution for the Czech republic with its nowadays economic troubles. It is the way how to modernize the production park of every company with limited financial means. It is very often used in many European countries as Austria, France, Dutch etc. In every from these countries are companies that are oriented on this activity and that are in this field very successful.

2.The degree of retrofitting.

There are basically three levels of retrofitting, used most often.

a/ The completing of the conventional machine tool with measuring system and readout of the position. This makes possible to higher the accuracy of the machining and to shorten its duration as the value on the readout is more accurate and much easy readable than the value which must be read from mechanical or optical position devices. This method is the simplest and cheapest one and though the most common.

b/ The replacing of the old control system of the used machine tool with the modern CNC system. The reliability of the machine is growing up and the machine often gets some new functions which increase the productivity and often the quality of the machining (simultaneous movment of several axes, parallel machining with the program preparation etc.). With this type of modernization is often connected the total rewiring of electric installation and the rebuilding of all electric boxes. That is the reason why this method is not very cheap, but in its result is very effective.

c/ The mechanical rebuilding of the conventional machines to the modern CNC machine and completing them with servo drives, measuring systems and CNC controllers. This method is relatively expensive and it is effective only for the machines in very good technical state. The rebuilding is often done with the help of subassemblies composed from gear boxes, drives and measuring systems which are connected to the slide (tables or supports) instead of manual handles.

3.The retrofitting steps.

It is necessary to check the whole machine before the start of retrofitting. As the first step, we must check all the functions of the machine and to repair those of them, which are for the next modernization important. Then it is necessary very thoroughly check the mechanical state of the machine tool. Mainly the accuracy of the machine (guideway straightness and parallelity, spindle rotation errcrs) and the state of the moving screws, gear boxes and drives are often the factors, which determine, if the modernization would be effective. Very important is also to consider the stiffness and rigidity of the whole machine, that can be only very seldom improved.

In the next step it is necessary to prepare the project of the whole modernization. One part of this project is the term plan for the sequence of activities, when the machine will be out of the operating state.

The technical preparation of the whole action is the next step. The new mechanical and electrical parts must be designed and produced, the standard parts must be bought. Only when everything is prepared, the machine will be taken from operating state.

The first step is mechanical repair of the wrong and unaccurate parts. Only then all new parts can be assembled. The last step of this assembly is to connect the measuring devices and check their function. Then all electric changes and rewiring must be done and the electric devices must be completed.

After it, all the function of the machines must be check from both mechanical and also automation point of view. If everything is working properly, the mechanical setup of measuring devices, electrical setup of the drives and control system and function setup of the electronic with machine constants must be done. At that moment we got practically the new machine, which can be father checked by the standard procedure (laser interferometr).

4.The means of retrofitting.

The main effect of retrofitting and its price effectiveness is in the fact, that the main part of the job is only the assembly of some standard parts and devices. The retrofitting company buy the indirect (mainly rotary encoders connected to the ball screws) or direct (linear optical scales) measuring systems, digital readout, electric drives and electronic control units from standard suppliers. The main job of this company is to fix this devices in proper way to the existing machine and to do the necessary electrical changes. Every company tries to develop small set of suitable fixing devices for this purpose.

For retrofitting are used mainly the standard linear scales. They can be relatively easily clamped to the machine and covered against the chips and cooling liquid. This paper is not meant as description of the detailed technical solution. In spite of it let me to describe shortly one type of measuring system, which was for this purpose developed by VUOSO Praha and which is proved to be very suitable from all points of view. The name is LIMAT.

5.LIMAT - linear measuring system.

LIMAT (fig.1) is fully covered linear measuring system of position with high accuracy, resolution and repeatibility and easy mounting on the machine due to self guided scale housing with IP 67 sealing. The output signals are fully compatible with incremental optical encoder standard. The device is highly reliable with long service life.

It is inductive cyclically absolute measuring device with pitch 2 mm. The fix part has couple of bifillar coils with exact pitch, the removable part (slider) has one bifillar coil for the exiting of the fix part. The slider is powered with AC sine and cosine input (resolver format). The output is amplified and transformed into standard incremental form in special electronic unit INDUKT, that also secures the piping of the measuring device.

LIMAT can be easily used on all devices to measure the position in the digital form. Small size, easy mounting, perfect sealing and repeatibility in 1 um are the main advantages of this device.

6. Conclusion.

Retrofitting is very effective way of encreasing of the automation degree on old machine tools. It can be done relatively easily by a small group of people (3-5) and it can bring very good results for both the user and the retrofitting company. Its main advantage is that uses mainly the existing elements and devices and it has relatively small claim on expensive machines or special technology. It can be recommended mainly in countries, where the capital for modernization of machinery is limited.

Jiří P u j m a n , PhD 1992

STATE OF THE FLEXIBLE MANUFACTURING SYSTEMS (FMS) CONTROL IN CSFR

Summary: This paper deals with Flexible Manufacturing Systems for machining. The structure of this systems is described, mainly from control point of view. The level, reached in CSFR is characterized.

1. The FMS as Means of Small-lot Production Automation.

The efforts pursuing the increase of small-lot production effectiveness have led from simple utilization of numerically controlled (NC) machine tools to their group application and finally to building of so called Integrated Productional Section (IPS) and Flexible Manufacturing Systems (FMS).

The FMS are characterized by an interconnection of NC machines by means of interoperation transport of workpieces, tools and other production aids. In this way their operation can be more easily planned , checked and consequently also managed and controlled either by a dispatcher or by a computer. Human participation in the FMS production process is limited practically only to the input and output places of the system.

The FMS systems represent a new quality of production automation. Their fully automatic function is guaranteed not only by ingenious machines, transportation systems and manipulators, but mainly by high adaptability of central control system, which continuously keeps operation of all subsystem under review. The control system's optimization programs striving for highest possible productivity of the system, make possible to pass the most advantageous commands, relating to the next operation, to all subsystem. Emphasis is laid on " high intelligence " of all controlled subsystems which prevents of overloading master system with information about such failures they are capable of coping with themselves.

Great attention must be paid to an easy identification of all workpieces, tools and production aids in the system, so that the related information lost due to a control system defect could be automatically restored. In places where human intervention into information flow is necessary, a consistent checking of input information must be carried out.

2. The Design Aspects of the FMS

Every production system is composed of the three main parts:

a) the workplaces

b) the storeplaces

c) the transportation means

The connection of these parts can be realized by the fix way (fig.1a) (the transportation system goes through the work and store places) or by the flexible way. (fig.1b) (the transportation system goes along the work and store places). The first way creates the fix production lines (transfer lines), suitable for a mass production. The second way is suitable for flexible manufacturing systems, the means of small-lot production.

The FMS systems can , from the space point of view, form a line along the store places. Than a rail transportation system is convenient. (fig.2a) . The same is good for the systems with central storage (fig.2b) or with several production lines (fig.2c). The small FMS systems can be realized also in a circle form with the central transportation robot (fig.3) . The most flexible systems have workplaces freely situated in space. The transportation between them is rendered possible by inductive - led tracks or by NC portal cranes (fig.4).

The basic FMS subsystems are:

a) The production machine tools often called Technological

Modules (TM); they realize the machining process. The prerequisites of their operation are: a correctly adjusted workpiece, necessary tools and a corresponding machining program with tool and workpiece setting data.

b) Checking stations end measuring instruments. Their task is to perform independent checks and to transfer the obtained results to the computer which controls the production process. The conditions for their activity are the same as for the TM machine tools.

c) The manual work stations, where special operation, that is very difficult to mechanize, are done. Based on the DNC commands and the present workpiece does a man the demanded operation and after finishing it reports the results. The work aspects are again similar as for the TM.

d) The central transportation systems of tools, workpieces and production aids; these systems provide for transport between machines and store-rooms. The prerequisites of their functions is completion previous activities of the manipulators.

e) The workpiece and tools manipulators or robots; they transport workpieces and tools between the clamping points of the machine and central transportation systems. Their activity is conditioned by the commands obtained from the NC machine and central transportation systems on one hand and input of objects located at the points of manipulation on the other hand.

f) The storeplaces for workpieces, tools and working aids store these parts and secures their transfer from or to the transportation system under the command of the store control system.

g) Input and output workplaces. Based on commands given by the production process controlling computer and according to information reporting that the transport to these places has been completed, they identify workpieces, tools and production aids which either enter or leave the FMS.

3. **Characteristic Features of the Individual Control Levels FMS**

The FMS is composed of production machines, manipulation means for handling workpieces, tools production aids and chips, further by checking and measuring machines and control facilities intended for automated control of the given equipment. From the aspect of governing the FMS represents a complicated regulating system which controls a number of mutually coupled functions that are taking place simultaneously.The input data are specified by the production plan . The system operates according to this , due regard being laid to the instantaneous condition of all elements of the system. The aim pursed by the controlling activities is to attain the maximum possible productivity on the specified assortment.

The activity of the control system of the FMS can be divided into two groups (fig.5)

1) The OFF LINE operation, that means the activities, which can be prepared before the control process starts and which have loose feed backs often implemented by man. The main function of the OFF LINE actions is planning and preparing the production process control, the task of which is to secure, based on a long. term production program, the plan of activities for the next day, due regard being given to the results of the previous day. In addition, also such requirments as the supply of semi- products and necessary tools have to be taken in consideration.

The next important function is the technological preparation of the production. This means not only the automatic generation of the NC partprograms, but also the keeping and managment of the central technological data base.

2) The ON LINE operation , mainly the direct control of the production process, embracing the control of activities of all equipment employed in the FMS , with firm feed - backs.

The FMS operation is controlled by the production process control (DNC) computer. Its task is to specify the best operational conditions of all controlled subsystems and to issue commands and data concerning further activities.

The high number of subsystems specified in chapter 2 clearly indicates that it is impossible to control the functions of all the subsystems by the only one central control system. From this aspect the control structure in the FMS can be divided into three groups:

1) Production Process Control System (DNC -level):

In hierarchical order this is the uppermost control system in the FMS; it gives commands to the individual controlled subsystems, but does not control directly their operation. It also forms an information base of the whole system; it utilizes a control minicomputer capable of the real time control and is ready to cope with the work dealing with extensive amount of data sets.

2) Control system of central transportation, measuring and checking stations and technological modules (CNC-Level) . These subsystems handle the commands coming from the DNC system according to the momentary state of the controlled processes. They control namely the moving axes (servo -loops) of the machines depending on NC program - the geometrical and technological description of the working operations. These subsystems have a high-grade "intelligence" of their own and "liberty of making independent decision". In some cases they can even control directly the final control elements of the managed units, sometimes they generate commands for control systems of the lowest grade. They pass on all reports relating to the operation completion or failures to the DNC computer.

3) Systems of the final functional control (PLC - level)

These are control systems which, on the basic of commands given by superior-grade systems and input signals from machine end switches, directly control operation of final functional sets it means the relays or contact switches. Practically, they cannot make any decisions - they can only delay the performance of the next operation till the previous one has been completed. They use mainly programmable controllers. They pass the failure reports or information about the operation completion to the superior system.

4. Structure of the Control System Hardware and Software

The design of the control system hardware structure had gone through three stages.

The first FMS systems had been build around the high performance central DNC computer in star-like type. It enabled to connect CNC and PLC systems of different types and producers by the creating special hardware and software interfaces. The communication with OFF-LINE activities (CAD, CAM) was made by a man (fig.6).

The later FMS Systems were connected to the Local Network for CAD, CAM directly. The DNC computer was the member of this network. The solution of the interconnection CNC and PLC levels to the DNC was the same as in the former case, by special interfaces. The activities of the DNC computer could be divided between several smaller computers (IBM PC compatible), the DNC computer served only as "translator or communicator" (fig.7).

The most progressive FMS systems use the powerful Control Network for all - CNC, PLC, DNC communication and also for connection with CAD and CAM area. The control system producers must subordinate their systems to the demands of the network communication (fig.8). The whole DNC control area can have the bus type or rink type of the configuration.

To design one Control Network for the whole CIM area is not simple. It means to unify the software and hardware means of communications between computers and control systems producers. The great deal in this field had made the General Motor Company with the proposal of the MAP (Manufacturing Automation Protocol). This protocol has 7 levels like the ISO computer communication standard. The lower layers solve point-to-point

connection, the middle the reliable transport way and the upper the system translation of data and commands.
The MAP, although is very expensive, is very progressive communication system; the MAP enables to build FMS system without preliminary knowledge which control systems and from which producers will be used.

Software of the FMS system is always organized under the control of some Real time operating system. The individual tasks have determined priority an the operating system solves their scheduling, running stopping or interrupting. The modular conception is necessary for the later development of the system and realization of new user demands.

5. The state of the FMS systems in CSFR

There were strong tendencies for the FMS building in CSFR 10 years ago. After completing several Integrated Productional Section - the NC machine section with central transportation system, the relatively great government projects for FMS started. These projects were coordinated by VÚOSO - Research Institute of Machine Tools and Machining, where was also solved the control part of the whole system.
Three typical solutions as a "key " installation were realized. It were the large and small systems for non - rotating parts and the system for rotating parts.

These systems were basically in same form several times repeated. Because of the great stagnation in machinery and because of lack of money for such great projects, the research and developing works on FMS systems were interrupted several years ago. Against of it, it may be interesting to describe the results of the FMS 400, that was between the 5 best systems on the world in 1985.

6. FMS 400 for Non- rotating Parts in TOS Olomouc

The most progressive Czechoslovak FMS system was the FMS 400 for machining of nonrotating box type workpieces 400 mm in size, which was completed by the end 1984 in the TOS Olomouc machine tool factory (fig.9,10).

The production units of the system are composed of continuously controlled Technological Modules (TM). Under the term TM is to be understood an assembly consisting of an NC machine, workpiece and tool manipulators belonging to the given machine (fig.11). The bases of the TM in the FMS 400 are horizontal machining centers with a rotary table, three linear axes and a spindle controlled in a velocity and position loops. These machining centers are completed with workpiece manipulators having the form of shirt-over and rotary tables along which moves the technological pallet with clamped workpiece. Further, the machine is provided with tool manipulator and magazine that can accommodate up to 144 tool units.

The connection of the TM to the central transportation systems is shown in fig.12.

The central transportation for workpieces placed on technological pallets comprises a double-rack along which travels a stacker crane which transports the pallets between the TM and the double-rack. The double-rack forms a store of up to 250 pallets.

The central tool transportation system comprises a cart moving on a rail situated below the ceiling of the hall. This cart transports the tools between the TM manipulators and tool setting departments, where tools are input and output. The tool magazines of the tool setting departments together with the TM magazines comprise a common store of the FMS tools. Every tool has small identification punched card (fig.13) and every tool is stored in a special plastic cover cell (fig.14) . The inputs of workpieces are provided with lay-out machines which make possible easy and exact placing of the workpiece on the technological pallet.

Checking of workpieces is done on automatic measuring (inspection) machine. During the production the workpiece is washed and cleaned and thermal stabilization before measurment is carried out. Human participation is limited to the input and output areas and to the workplace, where the workpiece is reset for the next operation.

This system enables the fully automatic function of the all workplaces, stores, transportation and manipulation subsystems except the input and output places where a human activity is necessary.

The structure of the control system hardware (fig.15) corresponds to control structure characterized above (chapter 4,fig.6), which was designed 15 years ago. As may be seen in the diagram, the whole control network utilized the minicomputer control but for the NS 850 simple systems of transportation control, and the NS 920 programable controllers. The NS 750 systems and systems described as " LK TOOL hardware " represent interface between computers and the machines, their main function being the closed position loop control.

The minicomputers on the CNC and DNC levels are of the same type - ADT 4500. The type is compatible with HP 21-MX which is used for the CNC control of the measuring machines. The communication between the computers is rendered possible using the DS 4500 system, which is compatible with the HP DS-1000 distributed system network. The communication of the computers with the other control devices is done by special communication lines.

Also the structure of the control system software corresponds to the different levels of the control structure (PLC, CNC, DNC). It changes from the practically machine-coded programs of the PLC level, thought assemblers and special operating system of the CNC level to the high program languages and standard Real time multiprogramming operating system on the DNC level. For special activities such as the computer communication or the data base system the standard software blocks were also used.

The philosophy of the DNC control is based on the similar principles as the functions of Real time multiprogramming systems. For every workplace the queue of actions is defined. The definition of this queue is done with aid of optimization programs striving the highest possible productivity of the FMS. The finishing of any action in the FMS leads to the shift of the queue and the new optimization.

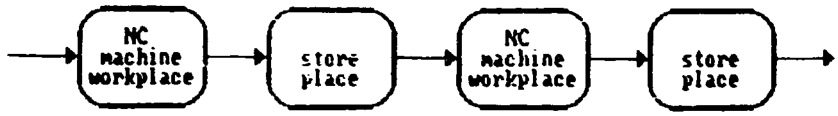
The base of the whole FMS structure is the CNC system NS 750 for a TM control (fig.16). It was a very efficient system with possibilities of controlling a group of TM and easy communication with DNC computer. Nevertheless its minicomputer base, the system was relatively long time produced for the CNC control of complicated machine tools.

7. Evaluation of the FMS Control Development and its Future

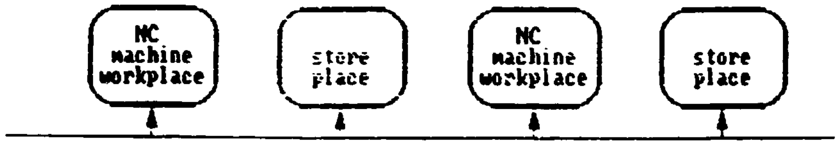
The present situation in Czechoslovak industry, the stagnation of the machinery and crises in the electronic, caused partly by the world disarmament, party by the privatization process in CSFR, do not stimulate the development of the new technique in CNC or FMS control. It was not possible to anticipate that introduction of the first FMS's would be highly profitable, since the costs of their production also included expenses incurred by the research and development of a number of new equipment. It is however an undeniable fact that the research, development and production of the FMS have brought about a considerable number of technical solutions, some of which being of unique significance. The FMS also contributed to the development of computation and control engineering in CSFR and promoted efforts aiming at achieving new forms and methods of production. In any case it may be claimed that from the point of view general results the development of FMS has signified an indubitable asset.

On the basses of the above mentioned facts we hope that also Czechoslovakia contributes to general CIM activities.

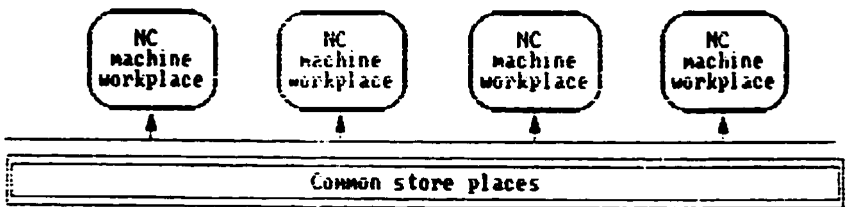
FMS - Flexible Manufacturing Systems



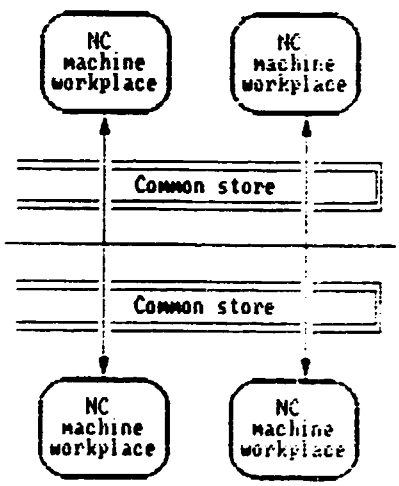
Fix production line fig.1a



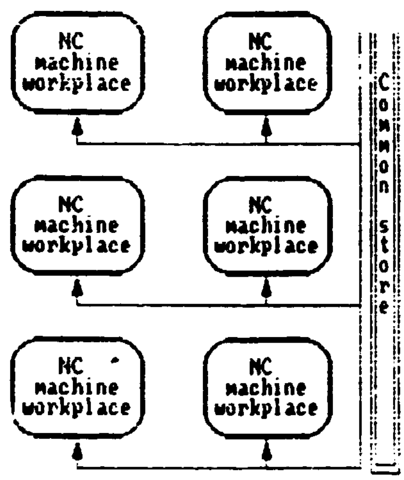
Flexible production line fig.1b



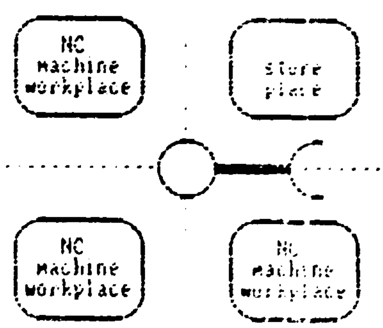
Linear FMS setting Transport along store fig.2a



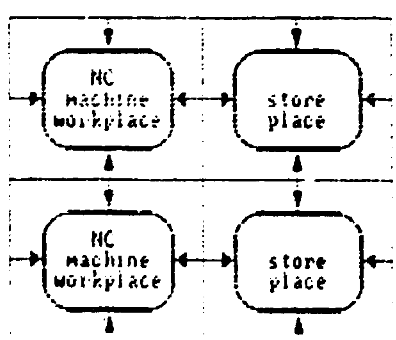
Transport through store fig.2b



Frontal store fig.2c

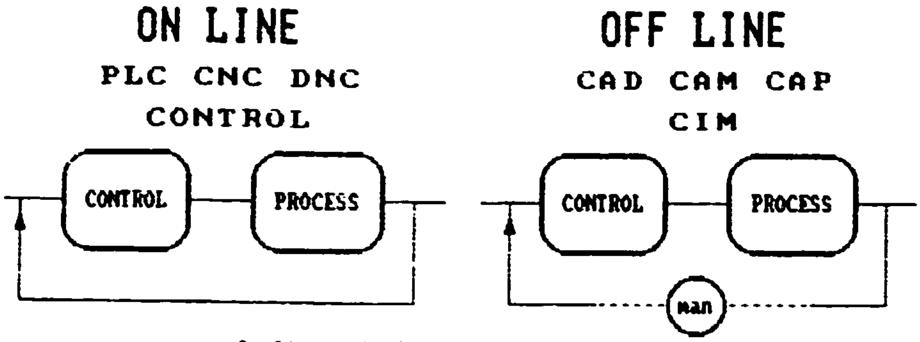


Circular FMS setting fig 3

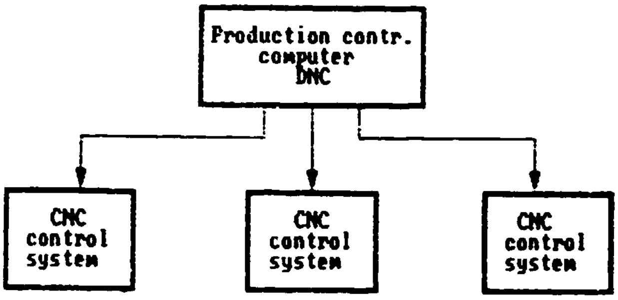


Space FMS setting fig.4

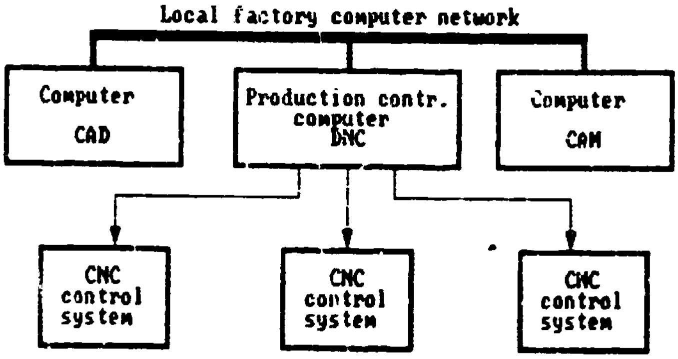
FMS - Flexible Manufacturing Systems



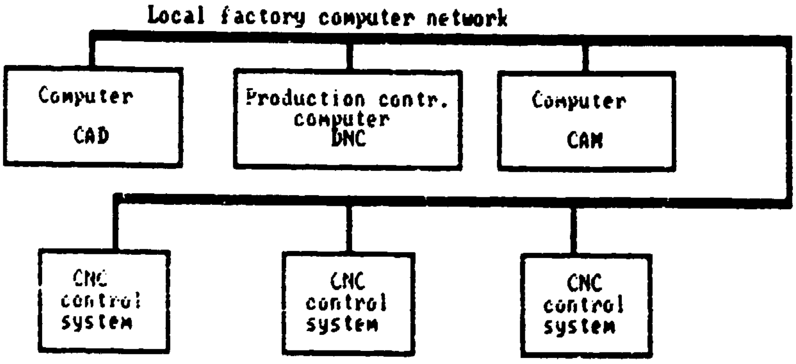
On line and off line FMS activities fig.5



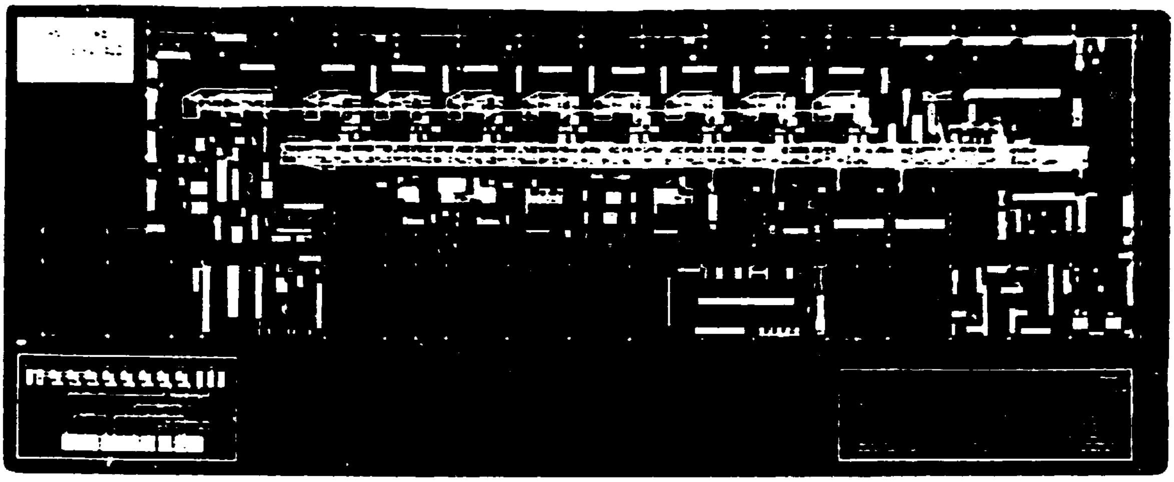
"Star-like" type DNC control network fig.6



"Star-like" DNC network in factory local net fig.7

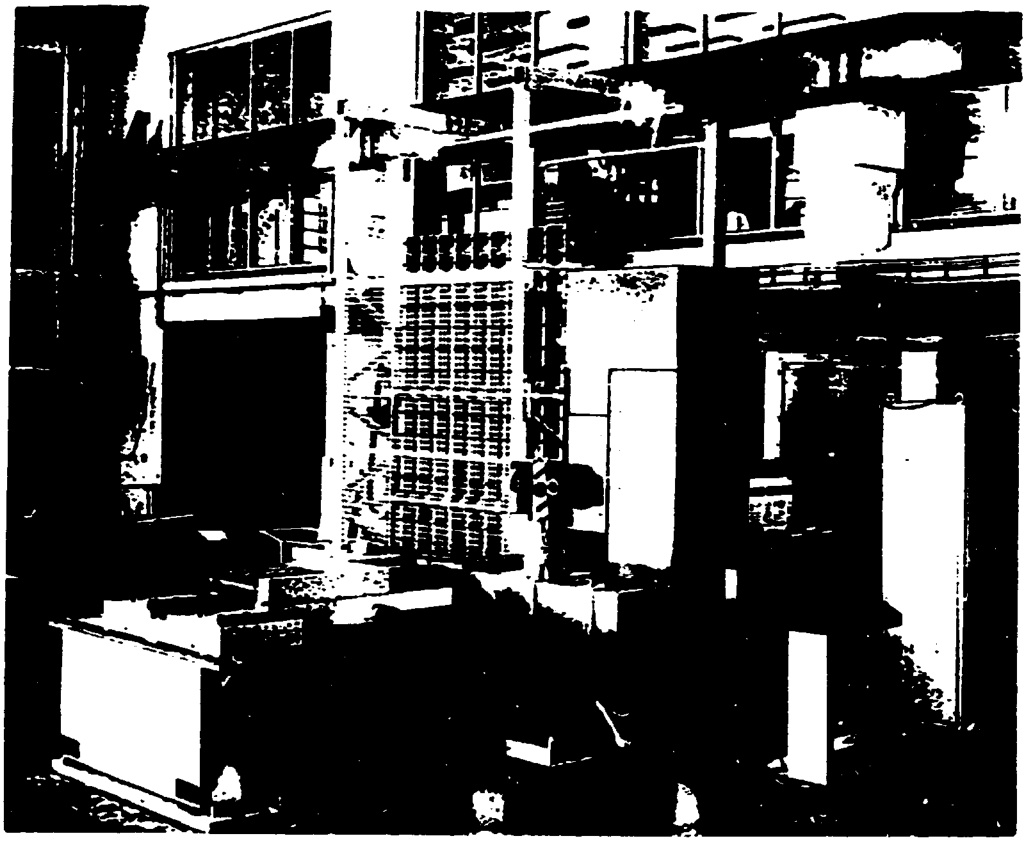


Common local factory network DNC - CIM fig.8

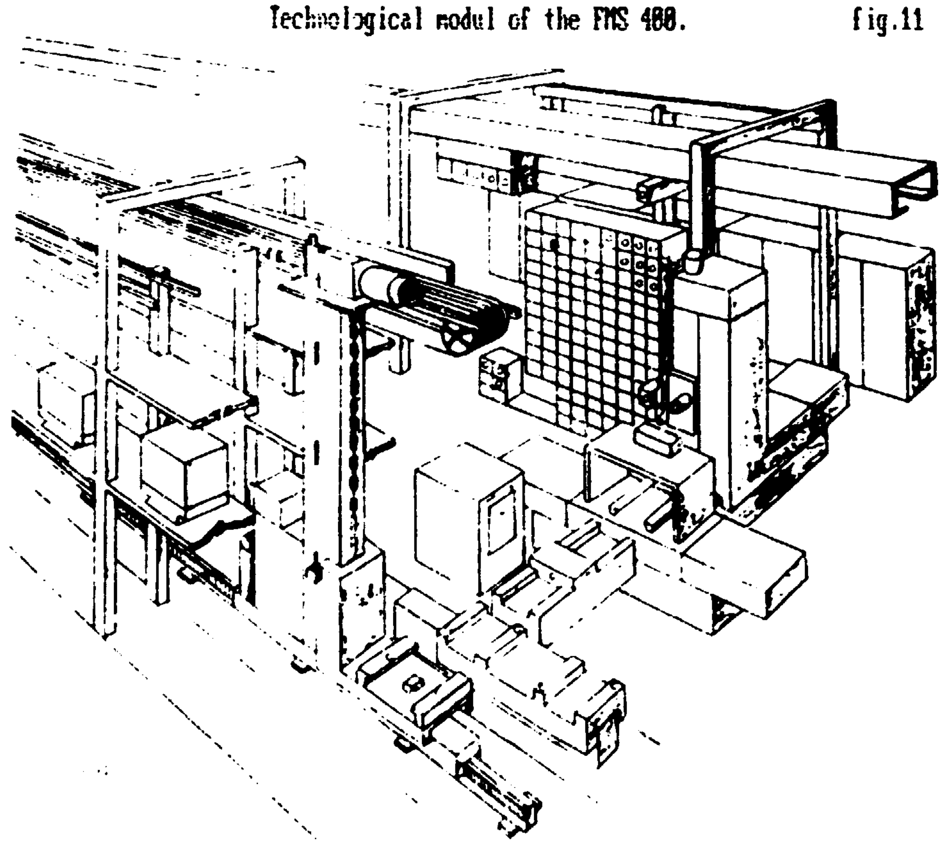


Model of the FMS 400. fig.9

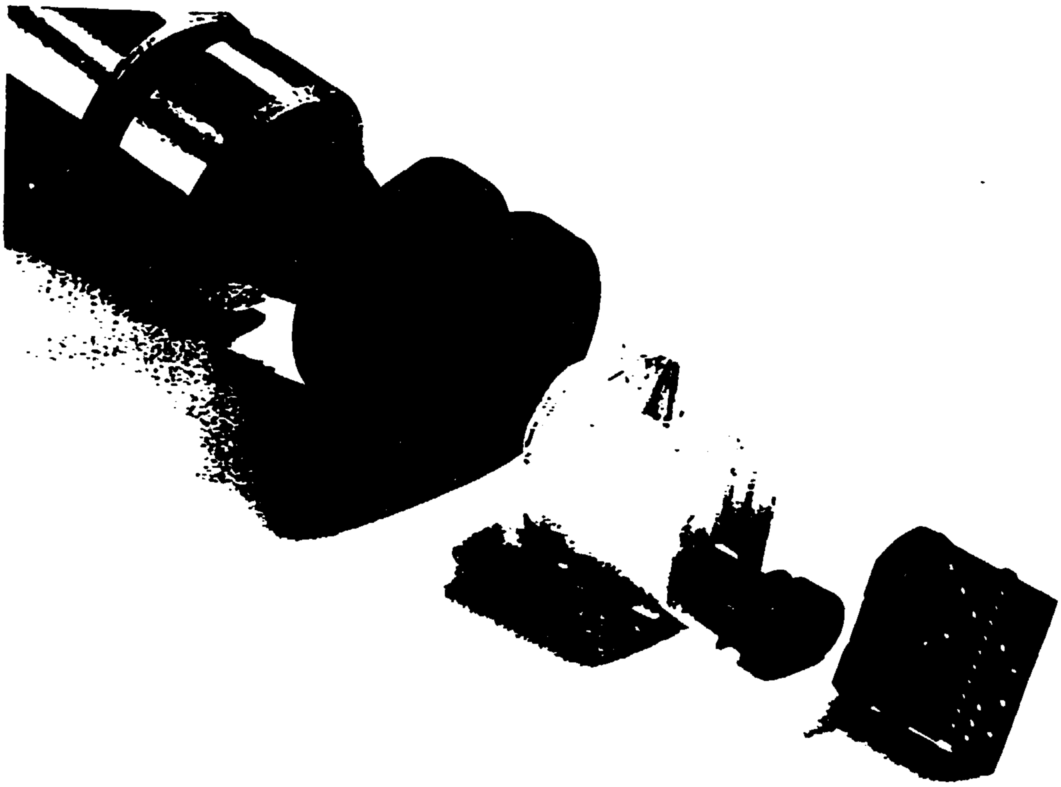
Global look on the FMS 400 fig.10



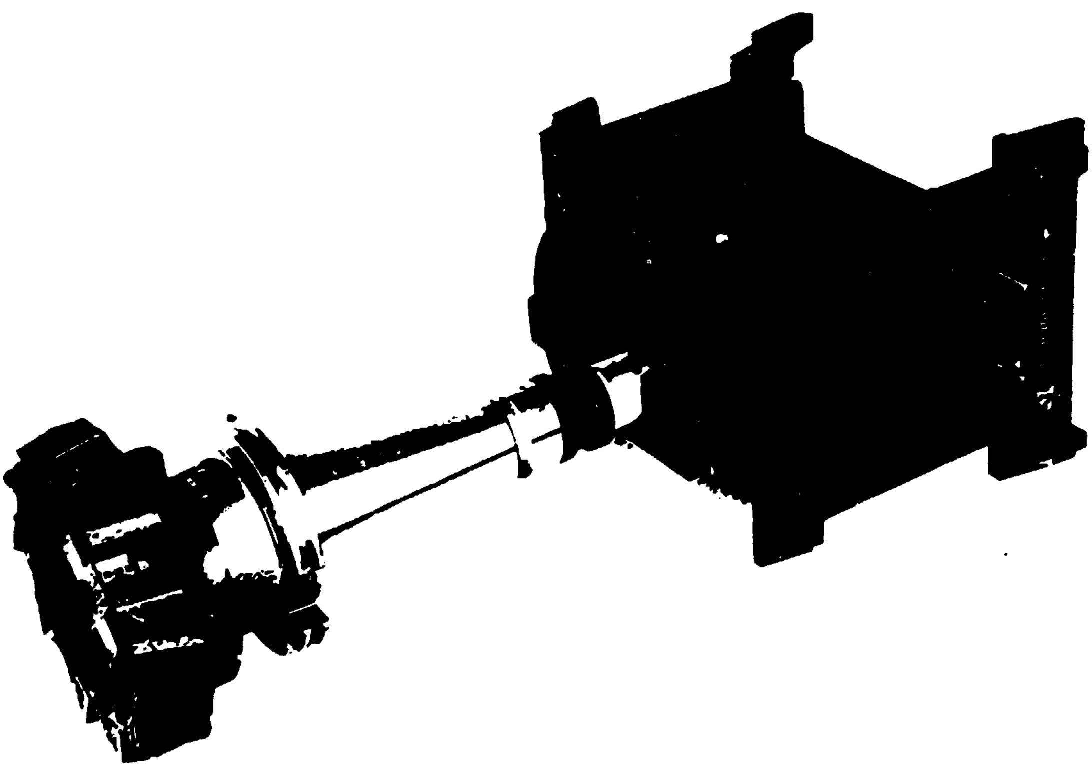
Technological modul of the FMS 400. fig.11



Schema of the technological modul build-into the FMS400 fig 12



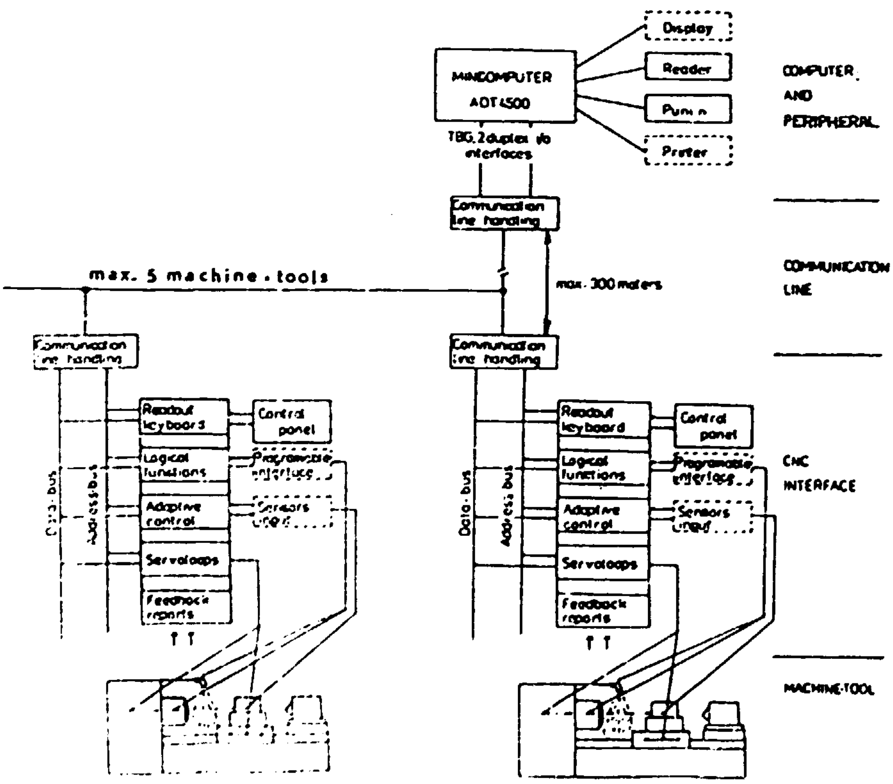
Coded cutting tools. fig.13



Tool transportation and storage plastic cell Fig.14

Controled subject	Technological cell				Tool's setting		Technological cell				Measuring machine		Lay-out machine		Manual workplaces			Transport	
	1	2	3	4	1	2	5	6	7	8	1	2	1	2	Input	Output	Reload	Tools	Workpieces
Logical funkcion control	NS 920	NS 920	NS 920	NS 920	NS 920	NS 920	NS 920	NS 920	NS 920	NS 920	LKTOOL	LKTOOL			NS 920		NS 920	:	
Technological process control	NS 750	NS 750	NS 750	NS 750	NS 750	NS 750	NS 750	NS 750	NS 750	NS 750	Hardware	Hardware	Hardware	Hardware				NS 850	NS 850
	Minicomputer ADT4500					Minicomputer ADT4500					HP 21 MX		HP 21 MX Minicomputer						
Production process control	Disc oriented system ADT 4500-RTE																		
Planning	Spare computer Disc oriented system ADT 4500 - RTE with Data base ability																		

Harduare structure of FMS400 fig.15



Harduare structure of NS 750 CNC system fig.16

Jiří P u j m a n , PhD 1992

THE FMS TRENDS FROM EMO EXHIBITIONS

Summary: This paper deals with basic trends and tendencies, which can be gained from analysis Flexible Manufacturing Systems and their modules, exhibited on 4 last international EMO shows. The main attention is given mainly to the point of view of the control strategy.

The subject of this paper is to explain the tendencies and trends, which we can anticipate, after the analysis of the EMO exhibitions, history of which is described in chapter 1. To do so, it is necessary to unify the common meaning of terms FMS, FMC, DNC, CNC, PLC, what is done in chapters 2 and 3. Chapters 4, 5, 6, 7 describe shortly the main features, observed in this field on EMO6, EMO7, EMO8 and EMO9. Chapter 8 tries to evaluate the collected information and to show the trends for reasonable design of FMS's and FMC's. Vith some imagination, this can be seen from the table, which is at the end of this paper. The numerical data have been gained from computer data service on EMO exhibitions. The most important exhibitors were visited and the serious facts, which are here presented, has been checked by the discussion with them. However the data could be a little distorted by the place of the exhibition (EMO in Hannover is bigger then the other two).

1. The EMO exhibitions as an indicator of the technical progress.

The EMO exhibitions has been for more then 17 years the largest European international shows with cutting tools, production machines (machine tools, forming machines, machines for new cutting technologies), robots, manipulators and their integrated application in Flexible Manufacturing Systems (FMS) and Flexible Manufacturing Cells (FMC). Very important is also the part of the exhibition, dedicated to the control technique (PLC, CNC, DNC) and software applications for CIM field.

These shows became during the years the prestige exhibition, where every producer tried to present the products, which were quite new, progressive and perspective for the future. They are not oriented exactly on the sale, like the most world known trade fairs (Metav-Dusseldorf, Germany, Componenta-Klagenfurt, Austria, MSV-Brno, Czechoslovakia ...), but on indicating tendencies of the technical progress. In this way they could be compared most closely to the Chicago Trade Fair, USA.

The EMO exhibitions are hold each second year in three European towns (Hannover, Milano, Paris). Several hundreds producers from all the word take part on them.

On EMO 5 th. were given the first serious signals, that the FMS could be built from the NC and CNC machines, robots, manipulators and suitable control technique, much more effectively, then the fixed production lines.

2. Basic characteristic of FMS and flexible cells.

The FMS are characterized by an interconnection of NC machines by means of interoperation transport of workpieces, tools and other production aids. In this way their operation can be more easily planned , checked and consequently also managed and controlled either by a dispatcher or by a computer. Human participation in the automatic FMS production process is limited practically only to the input and output places of the system.

The degree of automation in the system varies very much in FMS's of different producers. Also the structure of the systems changes. If we want to compare the exhibited systems, we must define some minimum configuration, which can be still considered FMS or FMC.

The minimal FMS or FMC is considered to be composed from at least two working technological modules (NC machines or machining centers, checking or measuring machines, washing or cleaning machines, manual working stations etc.), interconnected by the means of interoperation transport (robots, manipulators, rail or inductive guided vehicles etc.) with some storage possibilities (racks, shelf stands, storage tables, magazines etc.) and equipped with the control system, which synchronize their operation. The central transportation system secures at least the automatic transport of workpieces.

Real "flexible" FMS or FMC is to be considered the system with possibility to change production program without operator's interferences.

3. Characteristic Features of the Individual FMS Control Levels.

From the aspect of control the FMS represents a complicated regulating system which govern a number of mutually coupled functions that are taking place simultaneously. The activity of the FMS control system can be divided into two groups:

1) The OFF LINE operations, that means the activities, which can be prepared before the control process starts and which have loose feedbacks often implemented by a man. The main function of the OFF LINE actions is planning and preparing the production process control, preparation of all the technological data (NC programs) and also the keeping and managment of the central technological data base, often with connection to CIM field.

2) The ON LINE operations, mainly the direct control of the production process, embracing the control of activities of all equipment employed in the FMS , with firm feedbacks. This is secured in three different levels by:

1) Production Process Control System (DNC -level):

This is the uppermost control system in the FMS; it gives commands to the individual controlled subsystems, but does not control directly their operation. It also forms an information base of the whole system; it utilizes a control minicomputer capable of the real time control and is ready to cope with the work dealing with extensive amount of data sets.

2) Control system of technological modules, measuring and checking stations (CNC-Level):

These subsystems handle the commands coming from the DNC system according to the momentary state of the controlled processes. They control namely the moving axes (servo -loops) of the machines depending on NC program. They have a high-grade "intelligence" of their own and "liberty of making independent decision". In some cases they can even control directly the final control elements of the managed units, sometimes they generate commands for control systems of the lowest grade. They pass on all reports relating to the operation completion or failures to the DNC computer.

3) Systems of the final functional control (PLC - level):

These are control systems which, on the basic of the commands given by superior-grade systems and input signals from machine end switches, directly control operation of final functional sets it means the relays or contact switches of the electric devices. Practically, they cannot make any decisions - they can only delay the performance of the next operation till the previous one has been completed. They use mainly programmable controllers. They pass the failure reports or information about the operation completion to the superior system.

4. EMO 6 th. - 1985 Hannover (Germany).

That exhibition was the first one, having indicated the meaning of FMS for industry and economy. Nearly every machine tool producer tried to design the new machine as a module, which could be easily incorporated into FMS system (from mechanical point of view). The connection to the control systems was not solved by a satisfactory way. The exhibited systems were realized mainly by the special software firms which had bought all the necessary hardware equipment (machines, transportation systems, control systems and control computers) and created, after agreement with user, the special software block. This has the form "key installation", which very well satisfied the previously defined demands, but its future development was very complicated.

The system has been organized in the star-like form around the DNC computer. Computer of the high performance (Hewlett Packard, IBM, Digital) was connected with CNC systems of different producers. The communications line were not standardized yet. The advantage of this solution was the possibility to design very different communication interfaces on the computer side, with respect to the CNC solution. The communication lines has been usually serial, based on RS 232C or higher, but also parallel lines existed.

Nearly 40 exhibitors offered DNC solution. Between the best were probably firms Sharmann and Cincinati Milacron. More then 20 FMS system for box-type workpieces were exhibited, 10 turning FMS and 8 others. 75 machine tool builders offered the milling center like FMS module and 35 offered the turning center for the same purpose.

The transportation systems for milling FMS were based on rail or inductive guided vehicles; for turning cells mainly on the portal robot.

There were great innovations in CNC area. SIEMENS came with "channel structure", it was the ability to control simultaneously the action of several processes. The handling of CNC was made easier by using MENU technique, programming got the possibilities of the computer languages, operator panel was divided to system and machine parts. More then 100 producers exhibited the own CNC system.

PLC were more and more often integrated into CNC systems. Programming languages have changed from assemblers to the ladder diagram or STEP 5 language used by many west European producers. The number of exhibitors was around 80.

The EMO 6 th. was an evidence, that FMS revolution started.

5. EMO 7 th. - 1987 Milano (Italy).

EMO 7 th. proved the growing interest of the control system builders in the FMS area. They saw the promising entrance of FMS and FMC and realized, that they had not been prepared for that. They had used some hardware means for communication in the control network, but no standard for the meaning of messages in it. So they were very grateful for any activity in this área. They invited very enthusiastic the MAP communication protocol, previously developed by General Motors for unifying of the communication in company FMS systems, not regarding on type and producer DNC computer or CNC and PLC systems. They started to prepare their control systems for this protocol, simultaneously looking for cheaper solution. They also recognized the good business article in DNC software and started to create the common useful software modules and from them to configurate the DNC system. They needed to connect DNC and CIM computers, what could be easily done using standard computer network.

The whole system was again organized in the star-like form around the DNC computer, that used to be connected to the Local Area Network -LAN. The micro or personal computer was used very often. Its performance was not sometimes satisfactory for all DNC activities and the DNC functions were often split between more computers in LAN. The central computer served then more as special communication translator from LAN protocol into messages for CNC connected on serial lines RS 232C or higher. The advantage of this solution, it was the possibility to design very various CNC communication interfaces, lasts.

Some of the largest CNC producers offered simultaneously the possibility to connect the latest CNC into the LAN directly and to use the DNC - PC effectively for real DNC functions (Siemens, Mitsubishi - Traub). As the complete MAP solution was not been ready yet and it was very expensive, the cheaper protocols (LSV2, Mini MAP) or communication lines (RS 2.., Ethernet) were frequently used.

There were less special "key" solutions on the big computers (Comau, Mandelli, Renault Automation)

The number of firms offering the DNC system rapidly grew up to 120 exhibitors. Number of exhibited FMS for box-type workpieces increased to 30, number of turning FMS remained unchanged (10). 70 machine tool builders offered the milling center like FMS module, 60 offered the turning center for the same purpose and 50 produced other FMS modules.

The transportation systems for milling FMS were based mainly on rail and seldom on inductive guided vehicles; for turning cells mainly on the portal robot. The store was created mainly by fix store tables.

The 32 bits processors overruled the CNC area (Mitsubishi, Fanuc, Bosch). The user has got a chance to change the properties of the CNC by special subroutines (Fanuc - Custom macro, Siemens CL 800). The Tool managment system, Adaptive control, Active control and using of touching probes became standard on new CNC systems. Number of exhibitors decreased to 85.

PLC were mostly designed from the slice processors. The independent positioning units were typical solution for simultaneous processes in CNC systems without channel structure possibility. Between programming languages appeared also Pascal. The number of exhibitors was growing up to 100.

The EMO 7 th. changed FMS revolution in mechanical parts design into revolution in standards of communication in the control structures.

6. EMO 8 th. - 1989 Hannover (Germany).

The clear trends for building economically effective FMS and FMC could be observed at all machine tools builders. The starting investments into this field were very high and only small number of customers could afford it. The solution seemed to be the building these systems "STEP BY STEP". The customer bought at the beginning only the FMS module, which price was nearly the same as machining center. After this module had earned enough money, the next module was bought and connected to the transportation system and control system. The idea was to do so without wasting anything, what had been previously installed. The KTM company was one of the best in it. We could see the results of struggle for good communication standard in control system area. In spite of that the MAP was not totally standardized in all layers, many firms had necessary hardware and firmware packages prepared (Fanuc, Siemens, Mitsubishi, NUM). DNC software was very often offered by control system producers as set up from parametric modules.

The network solution became standard for new systems, old systems are connected by special intelligent DNC terminals, the star-like form was very seldom. The personal computers were typically used. Computer of the high performance (VAX, HP, IBM) were used only in small number "key installations" (Comau, Dorries Sharmann). As the complete MAP solution was still not ready, some more simple protocols overruled in Europe (LSV2, MiniMAP) and also some cheaper communication lines (Ethernet-SINEC H1, Bosch Plant Bus, DEC-NET) had been often used.

The number of firms offering the DNC system again grew up to 200 exhibitors. Number of exhibited FMS for box-type workpieces changed to 25, number of turning FMS increased to 15 and there were around 20 others FMS or FMC exhibited. 75 machine tool builders offered the milling center like FMS module. 45 offered the turning center for the same purpose.

The exhibited FMSs were much smaller then in previous years, composed mainly only from two working modules like FMC. That was the reason, why only the manipulator or robot was often used instead of the transportation system. The store was created mainly by fix store tables or simple magazines.

There was again a very strong new trend in the CNC area. The CNC producers connected personal computer into CNC structure by both way - like periphery or like the fix part on PC bus. The user got this way not only the large memory capacity for NC programs and technological data, but also the possibility to include some computer methods for NC programming or for control network communication (Philips 5000). The new tendency for open structure hardware and software seamed to become real (ECS, ELSAG). In spite of that the number of the exhibitors decreased to 80.

Selfstanding PLC systems have got some new luxury functions (operator panels with color graphic, keyboards) and they were more and more similar to computers than to simple controllers. Between programming languages appeared computer Basic. The number of exhibitors was nearly 120.

The "STEP BY STEP" tendency for FMS building was the main feature of EMO 8 th.

7. EMO 9 th. - 1991 Paris (France).

The great stagnation in machine tools industry caused partly by the peaceful tendencies in the word policy and disarmament, and partly by the crises of the market in past socialist countries could be seen on the whole exhibition. All producers tried to find very economical solutions, the new development practically stopped. In FMS and FMC building has won the trend of the Step by step solution. There was a great cooling in MAP network installations. The big CNC producers had the hardware and software ready in reasonable price level (Fanuc, Siemens, NUM), but the standard of the upper layers of protocol was not ready yet and so the cheaper solutions won (LVS 2, MiniMap). DNC software was usually composed from standard parametric modules designed by control system producers. Very interesting feature appeared in some simple DNC computers or computers closely cooperating with them. It is the trend to solve the problems of the technological (NC programs), organization (planning) and economical (accounting) preparation of production and production managment in very simplified form often without the central data base facilities.

The Step by step trend led to connection of earlier bought CNC to special intelligent DNC terminal, or again to the star-like form of network on serial RS 232C lines. The personal computers were typically used. Computers of the high performance (VAX, HP, IBM) were used again only in small number expensive "key installations" (Mandelli, Dorries Sharmann).

The total number of firms, offering DNC systems was not possible to find out exactly, probably again around 200. Number of exhibited FMS systems declined to 15 for box-type workpieces and 8 for turning and 15 others even though the number machine tool builders offering the FMS modules was nearly constant 85 milling centers, 50 turning centers and 40 others. Only few FMS or FMC with more then two working modules were exhibited. The transportation system in small FMC was typically manipulator or robot with some store tables around it.

In the CNC area was possible to see the growing up performance of the hardware (Fanuc RISC processors). The control system for standard machine tools was mostly from biggest producers (Fanuc, Siemens, Heidenhain, NUM, Mitsubishi), only untypical machines gave a chance to other producers mainly with promisable open structure hardware and software. There were some examples also based on industrial computer with motion controllers. The PC (computer) built in the core of the system was not so widely spread as it had been forseen after the last EMO. Number of exhibitors again decreased to 70.

Selfstanding PLC systems were more often designed as compact small units with possibility to be connected together and with optional degree of user comfort. The most spread programming languages were probably Ladder diagram, Step 5 and computer language (Pascal,Basic,C). The number of exhibitors was growing up to 150.

On the EMO 9 th. the ECONOMY became the main limitation for FMS building.

8. Conclusions - trends of FMS development.

After the great entrance in middle of 80th. there was a recognizable cooling down in FMS an FMC field after 1990. The attempts to build up fully automatic factories with large FMS systems are acceptable only for very rich companies, which solve the automation problems by themself or with help of some special software firms as "key installation" based on powerful computer network.

A common user looks for economic solutions of FMC from 2 to 5 workplaces, which could be easily build, used and govern.

From mechanical point of view are these FMC's composed from machining centers. Nearly each producer of machine tools produces the variation suitable for mechanical interconnecting to the transportation system - the FMS module.

For box-type workpieces it used to be a milling center with 5 or 6 controlled axis (spindle, rotary table) and with a chain or plate magazine for 30 -160 tools, between them is often the touching probe.

For the rotary workpieces it is often used the turning center again with 5 or 6 simultaneously controlled axes (2 spindles, 2 turrets with 12-36 tools).

The milling and turning machines are not combined in one FMC.

The central transportation system for box type workpieces, transported on technological pallets have most often the form of the Rail Guided Vehicle. The inductive GV is more an exhibition solution. The connection to the machine is often done by manipulators, having the form of shift-over or rotary tables. The store has the form of racks or store tables.

The manipulation system for rotary workpieces is usually realized by interconnection of single or double portal robots of the individual turning centers. Store is on pallets for flanches or on drums for spindles.

The tool transportation between machines is for cheap solutions untypical.

From the control point of view is the system govern by the control network composed from DNC computer and CNC and PLC controllers. With exception of large projects, DNC computer is most often the powerful personal computer. More, then very promisable communication protocol MAP, are used some smaller firm protocols (DNC1,2 - Fanuc, LSV2 - Siemens, Heidenhain, MiniMap - Bosch). However all this producers enable to choose the protocol type, like an option for CNC. Probably the most common communication line today is the Ethernet, often connected to the factory network. The trend to build the FMS Step by step leads the DNC realizators to the solution to connect into the network also CNC controller without network ability, by using special intelligent interfaces between CNC systems and the DNC computer, or to return to the Star-like type of communication.

DNC software, running most often on the PC based computer (computers) is created from configuratable parametric modules by control system producers or software firms. It has usually an open structure form under the organization of the real time operating system. Its main function are to control and synchronize the function of the all FMC-FMS equipment automaticly or in dependence on dispatcher commands, to communicate with operators in input and output stations or stations for manual operations, to provide the dispatcher with status monitoring, material flow monitoring, diagnostic, to control NC programs and technological data managment, tool managment and newly also to help the manager of the workshop to plan, schedule and often also evaluate the cost of orders. Number of DNC software producers is growing up, which is the word trend in all clear software areas. That can be an evidence that hardware communication problems are already solved.

CNC systems has got in described time period several new features. The main is probably the channel structure for simultaneous controlling several processes. The next is user language which makes possible to change the basic system properties (Custom macro, CL 800). The special machines will probably use the advantageous of the CNC build as open structure system. The trends to integrate standard PC computer into CNC or to built CNC on industrial PC with motion controller have not convinced yet for the standard applications. The fact, that the number of CNC producers is decreasing is an evidence, that CNC is very complicated field with close connection between ingenious hardware and software, where only strong an experienced firms can succeed.

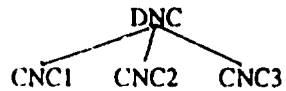
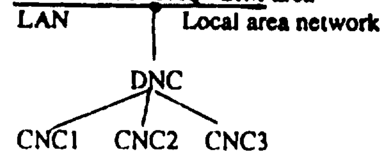
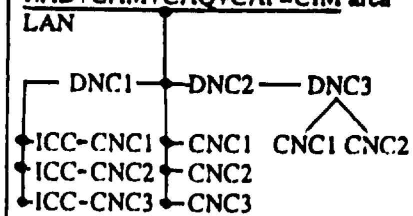
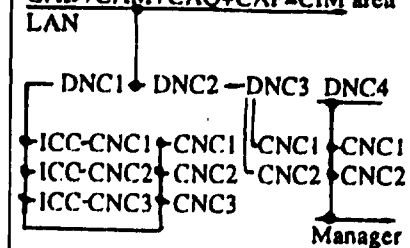
The main changes in PLC area are probably in user programming technique, which has changed to the most spread Ladder diagram and Step 5 languages. More universal computer languages have changed from assemblers to Pascal, Basic and C language. The powerful position units serve not only in independent PLC, but also in CNC systems for the control of manipulators. In selfstanding PLC can be seen the tendency for modular solution from small compact units with great optional possibilities.

The hardware performance of all the electronic solution has grown up enormously. But like in the machine area also in the control field, only these solutions are living, where the user gain is higher than the price of innovation.

All described EMO exhibitions proved very clearly that any technical revolution has no effect, if there is none economical profit from it. The most reasonable way, from today point of view, is to develop the modular FMS systems, easily expandable in both, their machinery part and their control area. The Step by step tendency is sure the best one.

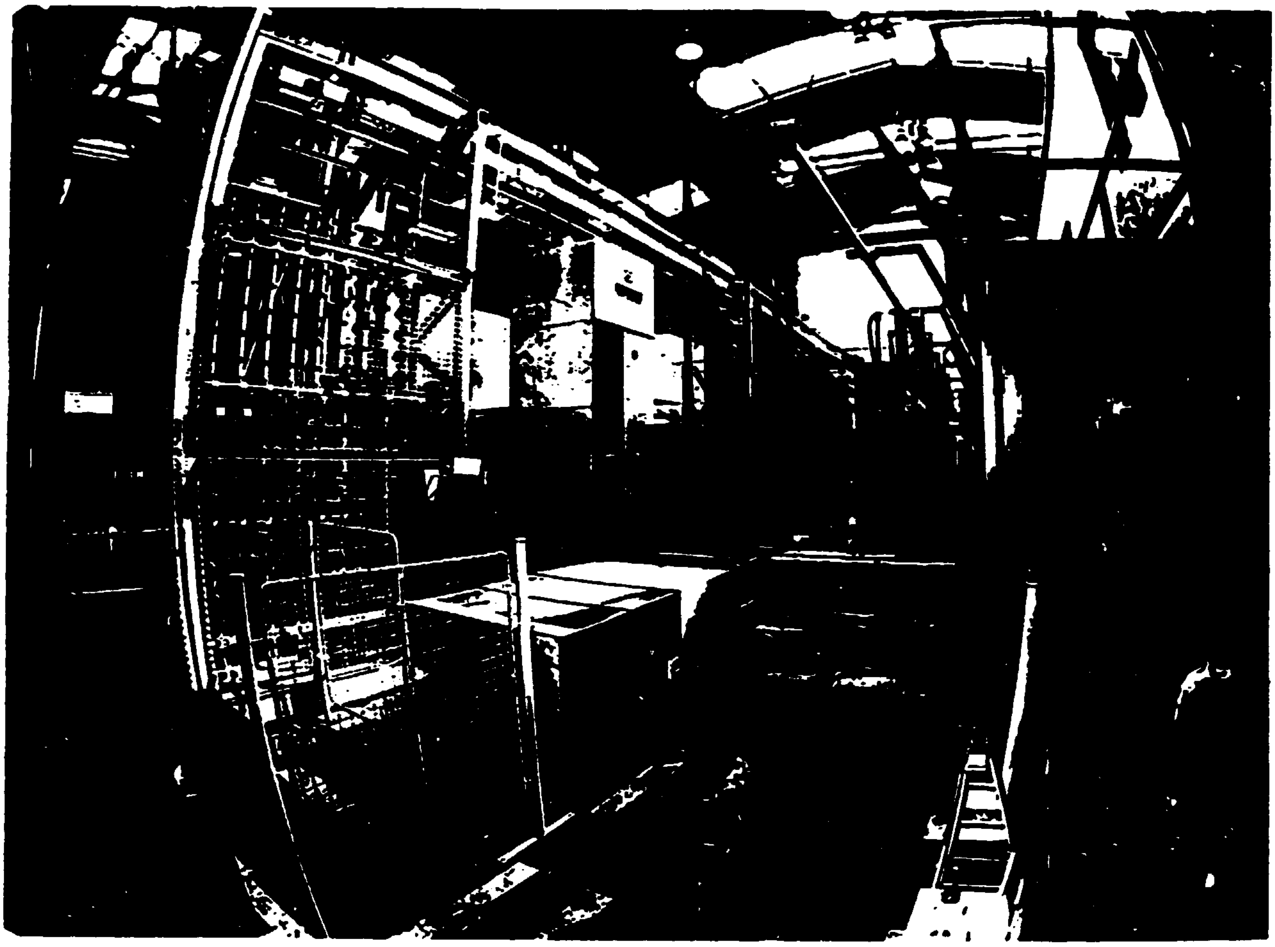
The survey of the FMS main features,
which could be seen on international EMO exhibitions of machine tools

The EMO exhibition term place	6. EMO 1985 Hannover (Germany)	7. EMO 1987 Milano (Italy)	8. EMO 1989 Hannover(Germany)	9. EMO 1991 Paris (France)
Main features of the exhibited FMS systems & FMS modules	The machine tools producers enter into FMS field. The new machines are designed as FMS module (connectable to FMS). Exhibited FMS are "The key installations" produced by a software firm or the realizator	The control system producers enter into FMS field. The CNC control systems gain the communication ability. The communications protocols originate (LSV2, MAP, MiniMAP). Stress on contents of messages	The tendency to build the FMS's "STEP by STEP" -it is expandable, without wasting parts, used before expansion The communication network is used in the control field	The stagnation of the machine tool industry The trend to build FMS cells- FMC instead of large FMS systems. The support for NC programs management and organization of the production in DNC
Number of exhibited Milling FMS systems/modules Turning FMS systems/modules Other FMS systems/modules	* really flexible system 20 (5*) / 75 10 (3*) / 35 8 ?	*really flexible system 30 (6*) / 70 10 (3*) / 60 ? 50	*really flexible system 25 (6*) / 75 15 (4*) / 45 20	*really flexible system 15 (7*) / 85 8 (3*) / 50 15 / 40
DNC The software system supplier	"Key" installation User, Software firm	Open installation (Partly) User, Software firm, Control system manufacturer	Open installation Control system manufacturer, User, (Software firm)	Open installation - user oriented Control system manufacturer, user, machine tool's producer, (Software firm)
DNC The way of realisation	One purpose software block	Fixed software modules	Parametric software modules	Parametric software modules
DNC Type of DNC computer	Large or Mini (IBM, PDP, HP)	Large or Mini/Micro (personal) PDP11, VAX, MicroVAX, IBM-PC	Personal or several personals (Mini/Micro) VAX, IBM-PC	Personal or several personals IBM-PC, (Mini or Work station DEC, HP)
DNC; software offer	40 exhibitors	120 exhibitors	200 exhibitors	?

DNC The typical structure	CAD + CAM = CIM area Data transferred by man  Star-like structure	CAD+CAM+CAQ=CIM area  LAN between computers Star to CNC controllers	CAD+CAM+CAQ+CAP=CIM area  LAN between computers and modem CNC Star or intelligent cell controller for old CNC	CAD+CAM+CAQ+CAP=CIM area  The same as on EMO8, but many self standing islands with Manager and NC programming support
Type of communications lines & protocols	Special , serial RS232C or higher RS...	serial RS..., or office Ethernet LSV2, MAP, MiniMAP	Ethernet, (serial RS..), MAP LSV2, MAP, MiniMAP	Ethernet, (serialRS...) (MAP) LSV2, (MAP), MiniMap
CNC News in the field Number of exhibitors	Channel structure, computer-oriented programming language wide NC-PLC window, operator MENU technique, separation of the operator system & machine panel 100	32 bits structure -Mitsubishi, Fanuc Custom macro-Fanuc, Basic-Bosch CL 800-Siemens. Tool Management system, AC, AK Touching measuring probes 85	IBM-PC compatible computer in the core of CNC- sometimes with a disk drive, like periphery or system part (Philips 5000) Motion controllers Open hardware &software structure 80	RISC processor in the CNC- Fanuc Open hardware & software structure for special systems Connection to theIBM-PC for NC program management and DNC production organisation support . 70
PLC News in the field Number of exhibitors	Integration into CNC systems programming : Assembler, STEP5, ladder diagram 80	Independent positioning units programming: like on EMO6+ Pascal 100	Luxury operator panel for self standing PLC systems (display with color graphic). Programming : like on EMO7+ Basic 120	The orientation for small & compact PLC units, but with great comfort in the user area programming : like on EMO8+C 150

FMS = EXECUTIVE part + CONTROL part

EXECUTIVE part of FMS is composed of :



Basic **FMS SUBSYSTEMS** are :

a) TECHNOLOGICAL MODULES (NC machine tools, washing and cleaning machines)

b) INSPECTION MACHINES (Measuring and checking machines and instruments)

c) MANUAL WORKSTATIONS (Places for manual operations, clamping, setting)

d) TRANSPORTATION SYSTEM (For workpieces, tools, production aids, chips)

e) MANIPULATORS and ROBOTS (For workpieces, tools, production aids, chips)

f) STORES (For workpieces, products, tools, production aids)

g) INPUT and OUTPUT (For workpieces, products, tools, production aids)

FMS Structure Fig.8

20913 (3 of 3)

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
VIENNA

THE ESTABLISHMENT OF THE MACHINE TOOL DESIGN AND DEVELOPMENT CENTRE IN INDONESIA

Project No. DP/INS/88/030
Contract No. 91/119

FINAL REPORT

VOLUME III

Polytechna Ltd., Prague
The Czech Republic

Báňské projekty Ltd., Ostrava
The Czech Republic

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VOLUME III

Technical Documents of the MTDDC and UNIDO/POLYTECHNA Field Team Co-operation

TESTING OF MACHINE TOOLS

STANDARDIZATION

G U I D E L I N E

for metrology organization and activities

1 Scope

The basic principles for metrology organization and activities in the measuring and manufacturing process are given in this document.

2 Terminology

The following terms are used for the purpose of this guideline :

Etalon (E) - measuring equipment in the laboratory or/and in the factory which serves to the realization and preservation of particular standard unit of measurement (unit of the length,angle, temperature, noise e.t.c.) and to the transition of this unit on the measuring equipment of lower accuracy (calibration of the measuring equipment of lower accuracy)
Note:Etalon may be used for the measurement (in this case it is working etalon WE) but only in the measuring laboratory or in the testing room, when the freqcy of use+
It may not be used for measurement in the manufacturing process.

Determinate measuring equipment (DME) - measuring equipment which was detrminated for periodical compulsury verification (calibration) in the national metrology institution.
Note: DME can be etalon (E) and the working etalon (WE) as well.

Working measuring equipment(WME)- measuring equipment used only for measuring purposes in the manufactoring process

+ can not cause the loss of its accuracy.

3 Calibration of the measuring equipment

3.1 Calibration of the determinate measuring equipment

This calibration shall be carried out in the national metrology institution according to the national regulations.

The first calibration shall be done before the measuring equipment is started to be used.

Every other calibration shall be provided if:

a) the validity of the last calibration is over (periodocal calibration). The period of calibration is determinated by the national metrology institution,

b) some changes have been done and if these changes might influence its accuracy

c) the measuring equipment has been damaged in the way, which could influence its accuracy

d) it is apparent, that the measuring equipment becomes incorrect

3.2 Calibration of working measuring equipment

Calibration of the working measuring equipment shall be carried out in the factory by means of the etalon (E) or working etalon (WE).

The first calibration shall be done before the measuring equipment is started to be used.

Every other calibration shall be done if:

a) the validity of the last calibration is over (periodical calibration). The period of calibration shall be determinated by the metrology department in the factory according to the type of measuring equipment and the frequency of its use (max.2 years).

b) some changes have been done on the measuring equipment and if these changes might influence its accuracy

c) the measuring equipment has been damaged in the way, which could influence its accuracy

+e) the marking of national laboratory has been damaged

d) it is apparent, that the measuring equipment becomes incorrect

The scheme of the calibration sequence (transmition of the standard unit from one measuring equipment to another one is shown on the fig. 1.

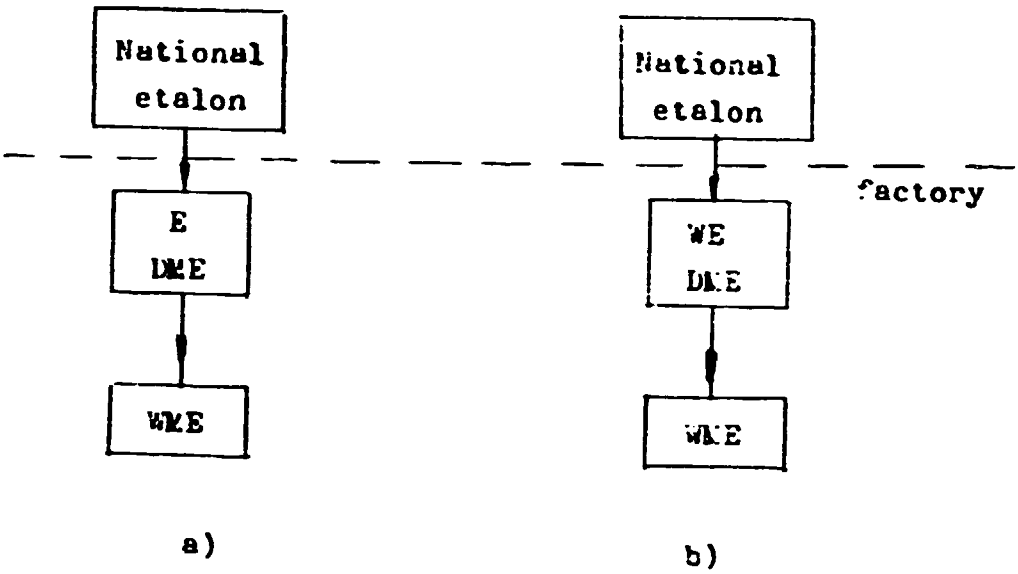

Fig.1.

3.3 Environment

The evironmental conditions for calibration shall be suitable for the particular measuring eguipment.

4. Documentation

The record shall exist for each measuring equipment used in the factory. Followingshall be stated in the record:

- name of the measuring equipment and its manufacturer
- technical specification
- manufacturing number
- evidence number
- date of purchasing
- place of the storage and place of the use of measuring equipment in the factory

- period of calibration
- dates and results of calibrations
- repairs of the measuring equipment, if any, date
- changes of the measuring equipment, if any, date
- name of person responsible for the storage and use of the measuring equipment

The documentation for E, WE, and WME should be separate

5 Storage, maintainance and handling

The storage, maintainance and handling of the measuring equipment shall be such, that the accuracy and fitness for use is preserved.
Training should be arranged for personnel handling the measuring equipment. The proper handling and storage shall be periodically verified.

6 Organization

The special metrology department responsible for all activities mentioned in this document shall be established in the factory. This department shall especially:
- arrange the calibration of measuring equipment in accordance with the given rules (see 3)
- maintain the documentation necessary (see 4)
- arrange the storage of measuring equipment, its maintainance and repairs, if necessary
- arrange the training for persnnel using the measuring equipment
- check - up the proper use of the measuring equipment periodically

The personnel using the measuring equipment is responsible for the proper use and storage (when not used) of it. In the case when the measuring equipment has been damaged or if it is apparent, that it becomes incorrect, the personnel shall announce this to the metrology department.

TESTING OF MACHINE TOOLS

General directives for inspection.

1 Scope

The tests in the range necessary for final inspection of machines from batch production to verify all important properties before the machines are sent to the userare specified in this document.These tests should be used for input inspection of purchased machines or for the verification of the durability of their properties during their use as well.

The following items are specified for each test:

- conditions of measurement (arrangement of the machine and its parts, arrangement of the testing equipment e.t.c.)
- environment conditions(if necessary)
- measuring methods and techniques
- evaluation methods of results
- presentation of results

All the tests are in the conformity with ISO standards existing or being in the last stage of development.

The directives have general form suitable for all the types of machine tools and on the base of them the specificetion for tests of particular type of machine may be easily provided.

Note: To have and to use such directives is one of the essential preconditions for quality control system certification of the factory manufacturing machine tools.

2 Terminology

The fooloving terms are used for the purpose of these directives.

Positioned part is the last part of the feed drive mechanism (slide, saddle, head stock, table, quill e.t.c.), the final position of which defines the dimension or the shape of the workpiece.

Positioning part is the first part of the manual feed drive, by means of which the final position of the positioned part is adjusted.

Target position of the positioned part is the theoretical final position of the positioned part defined e.g. by means of the position of positioning part, stop, dog or by means of coordinate programmed (numerical control system)

Actual position of the positioned part is the actual final position of the positioned part after its adjustment which does not change if no external actuation is there. The actual position can differs from the target position because of overrun, deformation of the feed drive parts e.t.c.

Stop is the equipment, which switch off the feed drive by actuating the control circuit (e.g. by means of proximity switch) after the target position of the positioned part is reached.

Dog is the equipment which stops the feed movement of positioned part because it forms the barrier to the next movement. The power for drive either remains (the positioned part is still pressed against the dog) or is switched off as the result of the power increasing.

Position control system is the system which provides the automatic positioning of the positioned parts to their final positions. The cutting process starts after the final positions are reached.

Rectangular path control system is the system of automatic path control either in one or in more coordinates subsequently (no simultanous movements even in two coordinates). The cutting process takes part during the movement.

Continuous path control system is the system of automatic path control either in the two or more coordinates simultanously. The cutting process takes part during the movement.

Numerical control system is the system either for the automatic positioning or for the automatic path control, where the information on both the target position and the path (shape, velocity) is given in the form of numerals.

Note: The designation for numerical control is NC (positioning or rectangular path control) or CNC (continuous numerical control).

Velocity constant of amplification of the feed drive (servo) is the ratio of the positioned part velocity "v" to the following error "y" (the difference between the instantaneous target position and the actual position during the movement by the velocity "v")

$$k_v = \frac{v}{y}$$

Cold condition of the machine is the condition, when the temperature of all parts of the machine corresponds to the temperature of environment.

3 General

3.1 Machine

The machine to be tested shall be completely finished and be able to perform all the functions according to its technical specification. Dismantling of certain components for the test purpose may only be carried out in the exceptional circumstances in accordance with the instructions of designer (or manufacturer. Measured properties must not be influenced.

3.2 Foundation

The machine shall be installed upon a suitable foundation and levelled in accordance with instructions of designer (manufacturer).

3.3 Adjustment

The machine shall be adjusted in accordance with the instuctions of designer (manufacturer).

3.4 Environment

The environment during the tests should correspond with the technical specification of the machine (e.g. temperature and its variation). In any way the varistin of environment temperature should not exceed 2°C during the accuracy test. There shall be no influence of direct thermal radiation or the flow of the air from outside.

3.5 Sequence of tests

The sequence of the tests in this document corresponds to the logic of its arrangement. It does not determine the actual sequence of the tests in no way.

3.5 Test protocol

The test protocol on the tests performed shall be worked out. In the protocol the following should be presented:

a) conditions of the test - thermal condition of the machine, temperature of the evironment and its varation during the test

- arrangement of the machine parts (e.g. position of the table e.t.c)

- loading of the machine
- cutting conditions
- sp-indle speed
- feed rate
- e.t.c.

b) the measuring equipment used and its arrangement on the machine (position, distances from some machine parts e.t.c.)

c) the results of the measurement (graphs, numerical values)

d) comparison of the results either with the demands on the machine (which are shown in the technical specification of the machine or in the particular standards)or with the results, which were found out during the prototype tests, during the final ispection test or during the last inspection tests of the machine during its use.

If any of the result does not correspond with the specification (permissible value), the repair of the machine should take place and the te-st or verification should be repeated.

4 Quality of construction

4.1 Machine

4.1.1 Scope

The quality of the construction and its correspondance with technical specification of the machine shall be verified. Especially the following should be checked up:

- lengths of machine parts strokes
- fitting of casting parts and covers (max. overlaping 2 mm only)
- quality of painting
- quality of the surfaces of nonpainting parts (no marks of paint, no scrapes, surface finish according to technical specification

4.1.2 Methods to be used

a) visual

b) measurement by means of suitable equipment (e.g. for lengths measurement)

4.1.3 Evaluation and expression of results

As the results ?? should be presented:

a) technical parameters found and the comparison of them with technical specification

b) List of shortcomings (if any)

4.2. Guideways

4.2.1 Scope

The quality of the guideways adjustment, their surfaces and their wipers should be verified.

a) Especially it should be verified:

- if the gudeways' surfaces are not demaged(no scrapes, no painting marks)
- if the guideways' wipers are not demaged and if their function is good

b) Especially it should be measured

- surface roughness
- hardness of the guideways
- backlash in the guideways

4.2.2 Methods to be used

a) visual

b)-the surface roughness should be measured by means of the portable equipment for surface roughness measurement at least in three different positions on each surface

-the hardness should be measured by means of portable equipment for hardness measurement on both ends of each surface

-the backlash should be measured on both sides of each positioned part by means of dial gauge. The force is applied on the measured end of the positioned part subsequently in both directions. The measuring is taken in the plane passing through both guideways of the positioned part. (see fig. 1).

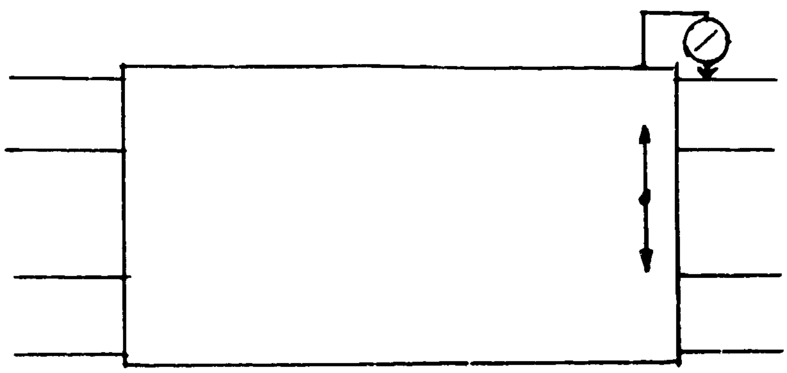

Fig. 1.

4.2.3 Evaluation of results

As the result it should be presented:

a) the list of shortcomings (if any)

b) - max.roughness found on each surface, the comparison with the technical specification (design demand)
- min. hardness found on each surface, the comparison with the technical specification
- backlash in guideways, comparison with technical specification

4.3 Drives

4.3.1 Scope

The quality of adjustment of all machine drives (spindle drive, feed drives) shall be verified. Especially it should be measured:

a) spindle speeds and feed rates (only in the case of drives with continuous velocity change)

b) fluency of the movement of feed drives

c)efficiency of drives

4.3.2 Methods to be used

a)The spindle speeds and feed rates should be measured either for each position of controller used for adjustment or at least for its ten positions in the whole range uniformly dislocated including both extreme positions.
The actual spindle speeds and feed rates should differ from the theoretical values no more than by 10%.
The measurement is taken by means of the equipment for speed measurement or by means of scale and stop-watch (in the case of feed rate)

b)The fluency should be measured for the minimum feed rate only by means of dial gauge. The movement of its hand is watched. No stick-slip motion should appear (the hand of the dial gauge should not stop).

c) The power of driving motor of each drive should be measured. The max. spindle speed or feed rate (or rapid travel) is used for this measurement. The power is measured on the input of of motor by means of watt measuring equipment. The power measured should be comparable with the power, which was found out on the prototype. If the motor is used for the rapid travel only, the power measured should correspond with the motor specification.

4.3.3 Evaluation and expression of results

As the result it should be presented:

a) The values of the actual spindle speeds and feed rates, the compari-son with tha theoretical values

b) The status of the motion (fluent motion or not)

c) The power measured, comparison with the power expected

4.4 Lubrication

4.4.1 Scope

The function and adjustment of all lubrication systems on the machine shall be verified. Especially it should be verified:

- if all lubricated points are lubricated in proper way (the qantity of lubricant should correspond with the purpose).
- if all the lubricating and filing points are marked properly.
- if there is no leakage of the lubricant out of the machine (on the floor)
- if there is no painting on the nipples

4.4.2 Methods to be used

The verification is to be done visally.

4.4.3 Evaluation and expression of results

As the result the list of shorcomings (if any) should be presented

4.5 Hydraulic equipment

4.5.1 Scope

The quality of the assembly and adjustment of the hydraulic system shall be verified. Especally it should be verified:

- if there is no leakage of the oil from the hydraulic system
- if the preasures in all circuits correspond with specification
- ifall parts of hydraulic control system are properly marked
- if all connection of flexible tubes afe properly marked

4.5.2 Methods to be used

The verification is to be done visually

4.5.3 Evaluation and expression of results

As the result the list of shortcomings (if any) should be presented

4.6 Cooling equipment

4.6.1 Scope

The quality of assembly and adjustment of the cooling equipment shall be veified. Especially it should be verified:

- if there is no leakage of the coolant outside the machine. The full quantity of the coolant shall be returned back to the tank without any problems.
- if it is possible to adjust the flow of the coolant to all points of cutting process.
- if it is possible to regulate the direcion and the quantity of coolant delivery to the cutting process.
- if the max quantity of coolant delivered to the cutting pro-process corresponds with the specification.

4.6.2 Methods to be used

a) visual

b) stop-watch and calibrated pot for coolant qantity measurement

4.6.3 Evaluation and expression of results

As the result it should be presented:

a) the list of shortcomings (if any).

b) the measured quantity of coolant, comparison with technical specification

4.7 Control actuators and displays

4.7.1 Scope

The efficient, healthy and safe interaction of the operator with the machine shall be verified. Especially it should be verified:

- the surface of the handles (no sharp edges)
- the forces on all the actuators (positioning parts), by means of which the positioned parts of the machine are moved. The forces should be comparable with the recommended

forces (with forces found on the prototype)
- labeling of control actuators (completeness, durability, visibility)
- labeling of the displays
- the visibility of the numerals of displays
- the quality of the graduation of scales

4.7.2 Methods to be used

a) visual

b) measurement of the force on the control actuators by means of suitable equipment for force measurement (e.g. spring-scale)

4.7.3 Evaluation and expression of results

As the result it should be presented

a) the list of shortcomings (if any)

b) the forces measured, comparison with the forces presumed

4.8 Spindle

4.8.1 Scope

The proper adjustment of spindle bearings shall be verified.

4.8.2 Methods to be used

a) clearance in the bearings (usually in the front bearing only)

Using special equipment the radial force is applied on the spindle in the plane of the bearing measured (for the horizontal spindle in vertical direction, for the vertical spindle in any direction) . The force changes from 0 to some max. value in one direction, subsequently in the opposite direction. The special equipment serves not only for force applying, but for the force measurement as well. The max. force must be at least twice more than the force necessary for the clearance elimination (for the horizontal spindle it is usually twice the weight of the spindle). In the same time the radial deflections between the spindle and the spindle head are measured by means of dial gauge (see fig. 2)

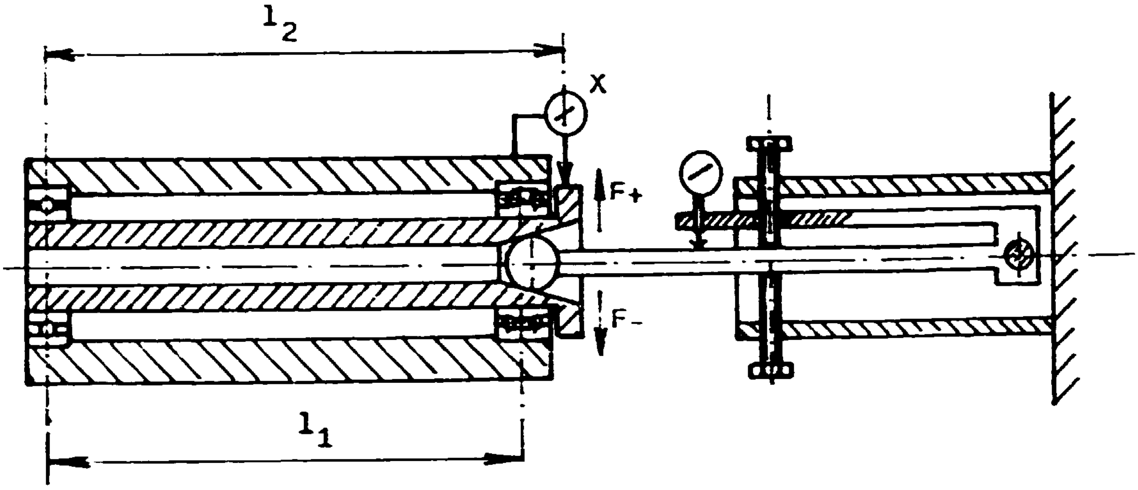

Fig.2.

Similer measurement should be performed in axial directi-on (axial clearance) - see fig.3.

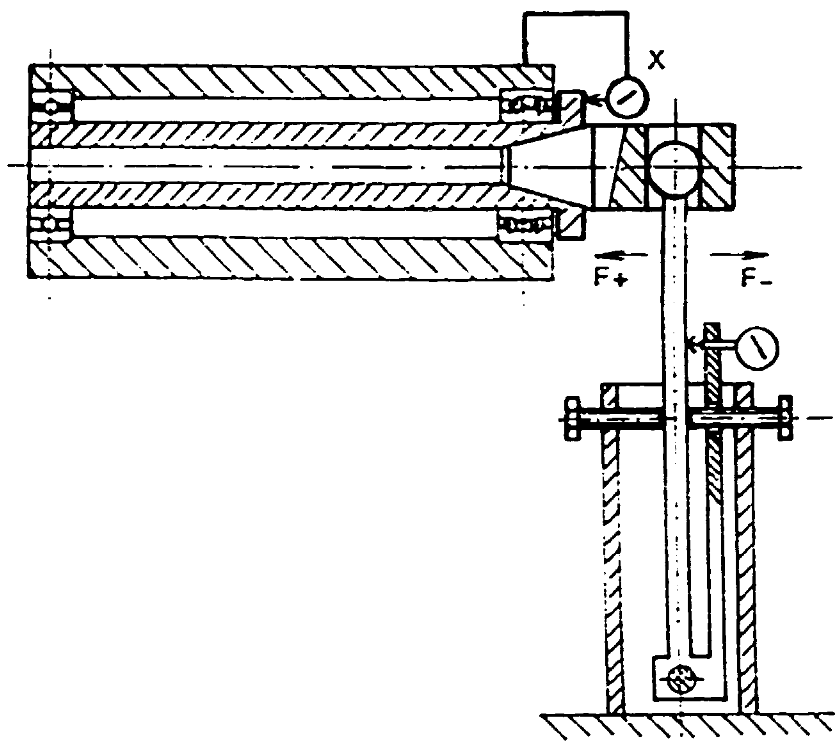

Fig.3.

b) Heating of the bearings

The spindle is running at max. speed and the temperature of the spindle head, near the bearings is measured on the surface

4.8.3 Evaluation and expression of results

a) The deflections measured are plotted versus the force applied on the graph. The clearance Δx in the measuring point is evaluated frm this graph (see fig.4).

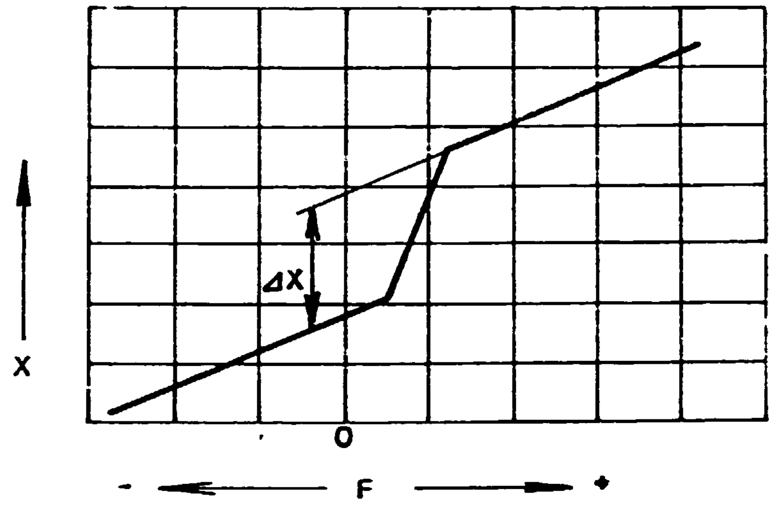

Fig.4.

The actual radial clearance in the spindle front bearing should be calculated using formula (1)

$$\text{clearance} = \Delta x \frac{l_1}{l_2} \qquad (1)$$

Both the radial clearance and the axial clearance should be presented as the result of this measurement

b) The max. temperature measured on the surface of the spindle head should be presented as the result of the heating measurement

Note: The temperature should not exceed the temperature of environment by more than 40° C for normal accuracy machines and by more than 25° C for precission machines.

4.9 Electrical equipment

The electrical equipment shall conform with IEC 204 Electrical ecipment fr industrial machines

5 Function

5.1 Scope

All the functions and their combinations in the whole range and in all machine modes shall be verified

5.2 Methods to be used

a) The manual control mode

The proper function of all control actuators and the responses of the machine shall be verified.

b) The automatic control mode

The testing program which contains all the functions of the machine, their changes and combinations possible according to the machine specification shall be used. The edition possibilities should also be verified.

c) Step by step mode

The same program as for the automatic control mode should be used.

5.3 Evaluation and expression of results

The list of shortcomings (if any) should be presented as the result

6 Accuracy

6.1 Geometric accuracy

6.1.1 Scope

The geometric accuracy tests according ISO acceptance conditions of machines - test code for particular type of machine shall be carried out.

6.1.2 Methods to be used

The test methods and test conditions shall be in the conformity with the general standard ISO 230-1: Acceptance code for machine tools - Part 1: Geometric accuracy of machines operated under no load or finishing conditions

6.1.3 Evaluation and presentation of results

The evaluation of results shall be in the conformity with ISO 230-1 mentioned above. The deviations measured must be within the tolerances prescribed by ISO acceptance code for particular type of machine.

6.2 Repeatibility of positioning of manual control machines

6.2.1 Scope

The repeatibility of positioning of positioned parts being set several times to the same target position by maens of positioning part shall be found out.

6.2.2 Methods to be used

The difference between the actual position and some selected position (usually the the first actual position) of positioned part is to be measured. The setting to the target position determinated by the defined position of positioning part should be repeated at least ten times. The measurement is taken near the cutting process point.

The test should be repeated in three positions of positioned part (1/5, 1/2 and 4/5 of the length of its stroke) for linear movement and in four angular positions (4×90^{0}) for rotational movement, everytime separately for both directions of the movement. Another machine parts should be in their middle positions.

The suitable measuring equipment for length measurement (e.g. dial gauge) or for angle measurement (autocclimator + reflector) should be used.

6.2.3 Evaluation and expression of results

The repeatibility of positioning "R" for each test (position of positioned part, direction of movement) shall be evaluated using formula (2)

$$R = 4 \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (\Delta x_i - \overline{\Delta x})^2} \qquad (2)$$

where n ... number of measurements

Δx_i.. difference of position for particular measurement i (i+n)

$\overline{\Delta x}$ .. average of diferences measured

$$\overline{\Delta x} = \frac{1}{n} \sum_{i=1}^{n} \Delta x_i \qquad (3)$$

The max. repeatibility of positioning "R_{max}" found on each positioned part should be presented as the resulting value.

It should be in the conformity with technical specification of the machine. Recomended permissible values of "R_{max}" for particular types of machines are shown in the Annex A.

6.3 Repeatibility of positioning of position control systems or rectangular path control systems using dogs or stops

6.3.1 Scope

The repeatibility of positioning of positioned parts being set several times to the same target position determinated by means of stop or dog shall be find out.

6.3.2 Methods to be used

The difference between the actual position and some selected position (usually the first actual position) of positioned part is to be measured. The setting to the target position determinated by the position of the stop (dog) should be repeated at least ten times. Finishing feed rate should be used for the setting. The measurement is taken near the cutting process point.

The test should be repeated in three positios of positioned part (1/5, 1/2 and 4/5 of the length of its stroke) for linear movement and in four angular positions ($4x90^{o}$) for rotational movement, everytime separately for both directions of the movement. Another machine parts should be in their middle positions.

The suitable measuring equipment for length measurement (e.g. dial gauge) or for angle measurement (autocollimator + reflector should be used.

6.3.3 Evaluation and expression of results

The evaluation and expression of results see 6.2.3.

6.4 Accuracy and repeatibility of positioning (for NC and CNC machines and for the machines with numerically indicated positions)

6.4.1 Scope

The accuracy and repeatibility of positioning in each coordinate axis shall be measured

6.4.2 Methods to be used

The measurement shell be carried out according to the ISO 230 - 2 Acceptance code for machine tools - Part 2: Determination of accuracy and repeatibility of positioning of numerically controled machine tools.

Note: The standard is in the revision stage.

The machine shall be in the cold conditions, when the measurements starts

The suitable equipment for length measurement (e.g. laserinterferometer) or for angle measurement (autocollimator + polygon) should be used. It should be placed on the machine in such a way, that the measurement is taken near the cutting process point.

6.4.3 Evaluation and expression of results

Evaluation and expression of results shall be in the conformwith the ISO 230 - 2 mentioned above. The results should correspond with the technical specification of machine. Recommended permissible values are shown in Annex B

6.5. Linear interpolation (for CNC machines only)

6.5.1 Scope

The accuracy of the resulting linear path that is produced by the simultaneous movements of two positioned parts in two linear axes shall be measured.

6.5.2 Methods to be used

The shape and the position of the resulting linear path should be measured by means of straightedge, which is clamped in the place of workpiece and by beans of pick -up (inductive probe) which is clamped in the place of the tool and touches the straightedge in the perpendicular direction(see fig.5).

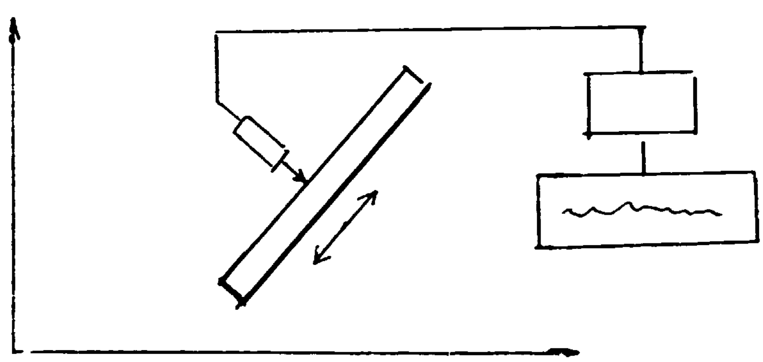

Fig.5.

The staightedge, the length of which is approximately 100mm, should be adjusted approximately in the direction of the resultant movement. The devations measured should be recorded versus the time. The measurement shall be take subsquently for both directions of movement (the same adjustment of measuring equipment, the direction of the movement of the recording medium is to be converted). The test should be carried out in all coordinates planes of the machine. The inclination of the linear path in relation to the coordinate axes should be 1:1. The velocity used for separate measurements should be v_{max} and 1/10 v_{max} (v_{max} is max. velocity of feed of the ma-mechine).

6.5.3 Evaluation and expression of results

The record of each test (coordinate plane, velocity) should be shown in the protocol (the example see fig. 6).

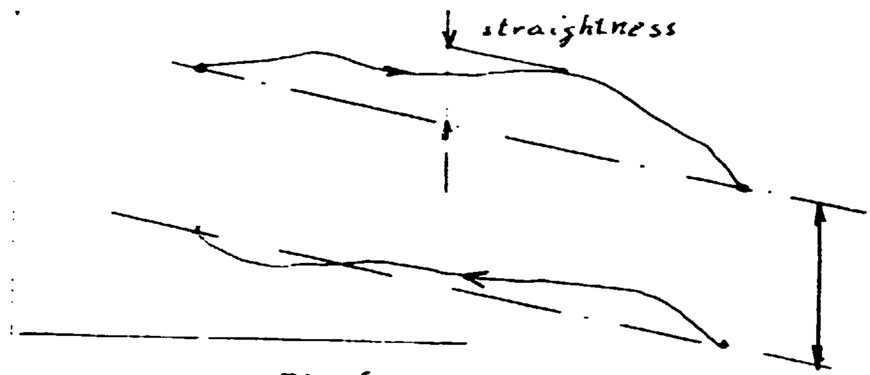

Fig.6.

The straightness of the movement (according to ISO 230-1) and the distance of the representative lines of both directi-on of movement should be evaluated on the record.
The difference between the distances of representative lines for the velocities v_{max} and 1/10 v_{max} shold be evaluated in each coordinate plane.

Note: The difference evaluated should be less or equal to 20 µm. If it is more, the adjustment of velocity con-stant of [illegible]ation of the drives in action is not correct (it should be the sme for all drives).

6.6 Circular interpolation

6.6.1 Scope

The accuracy of the resulting path that is produced by the simultaneous movements of two positioned parts in two linear axes shall be measured.

6.6.2 Methods to be used

The measurement shall be carried out according to the ISO 230 - 4 Acceptance code for machine tools - Part 4:

Circular tests for checking CNC machines.

Note: ISO 230 - 4 in the stage of CD (comittee draft)

Special equipment for the circuler measurement should be used (e.g. ball bar + PC with special software, two dimensional probe + XY recorder).

6.6.3 Evaluation and expression of results

The evaluation and expression of results shall be in the conformity with the ISO 230-4 mentioned above.

6.7 Practical tests

6.7.1 Scope

Practical tests on workpieces according to ISO acceptance code for particular type of the machine shall be carried out.

6.7.2 Methods to be used

The practical tests to ascertain the precision of a machine tool shall be the finishing operations for which the machine has been designed. The measuring methods for workpiece measurement should be in the conformity with ISO 230 - 1

6.7.3 Evaluation and expression of results

The evaluation and presentation of results should be according to the ISO acceptance code for particular type of machine. The deviations of the workpice dimesions and shapes measured must be within the tolerances prescribed.

7 Vibrations

7. Scope

The effective values of velocity of forced vibrations shall be measured.

7.2 Methods to be used

The velocity of vibrations is measured on the spindle head in the plane perpendicular to the spindle axis and passing through the front bearing, in two directions perpendicular one to another. All the spindle speed available are used subsequently. All the eqipment used on the machine is switched on. Both the small balanced workpiece and the small balanced tool are clamped in positions.

The special measurement equipment for vibration measurement is used

7.3 Evaluation and expression of results

The max. effective value of the velocity of vibration found should be presented. The value shall not exceed the specificated value. Recommended permissible values for particular types of machines are shown in Annex C

8 Noise

8.1 Scope

The A weighted equivalent sound pressure level at the work operator workstations shall be measured.

8.2 Methods to be used

The integrating Sound Level Meter complying with the requirements of IEC Publication 804, type 1 adjusted on A-weighting shall be used for measurement. The microphone of the Sound Level Meter should be placed in the measuring point in the direction towards the machine. The measuring points shall be as follows:

- operator seated: 0,8 m above the surface of the seat (above the centre point of the seat)
- operator standing: 1,5 m above the surface on which the operator stands(above the point, where he usually stands. This pointshould be chosen in the distance of 0,5 m from the circumference of the machine and 0,5 m from the front part of the pendent (if any)

If the operator takes more then one position to work the machine tool, the noise shall be measured at all the operator workstations (example see fig. 7)

The duration of the measurement should be sufficient with regard to the character of the noise, it means of its variation.

Conditions of the machine while measuring:

- idle running
- max. spindle speed
- max. working feed velocity
- all equipment necessary for for the normal work of the machine switched on

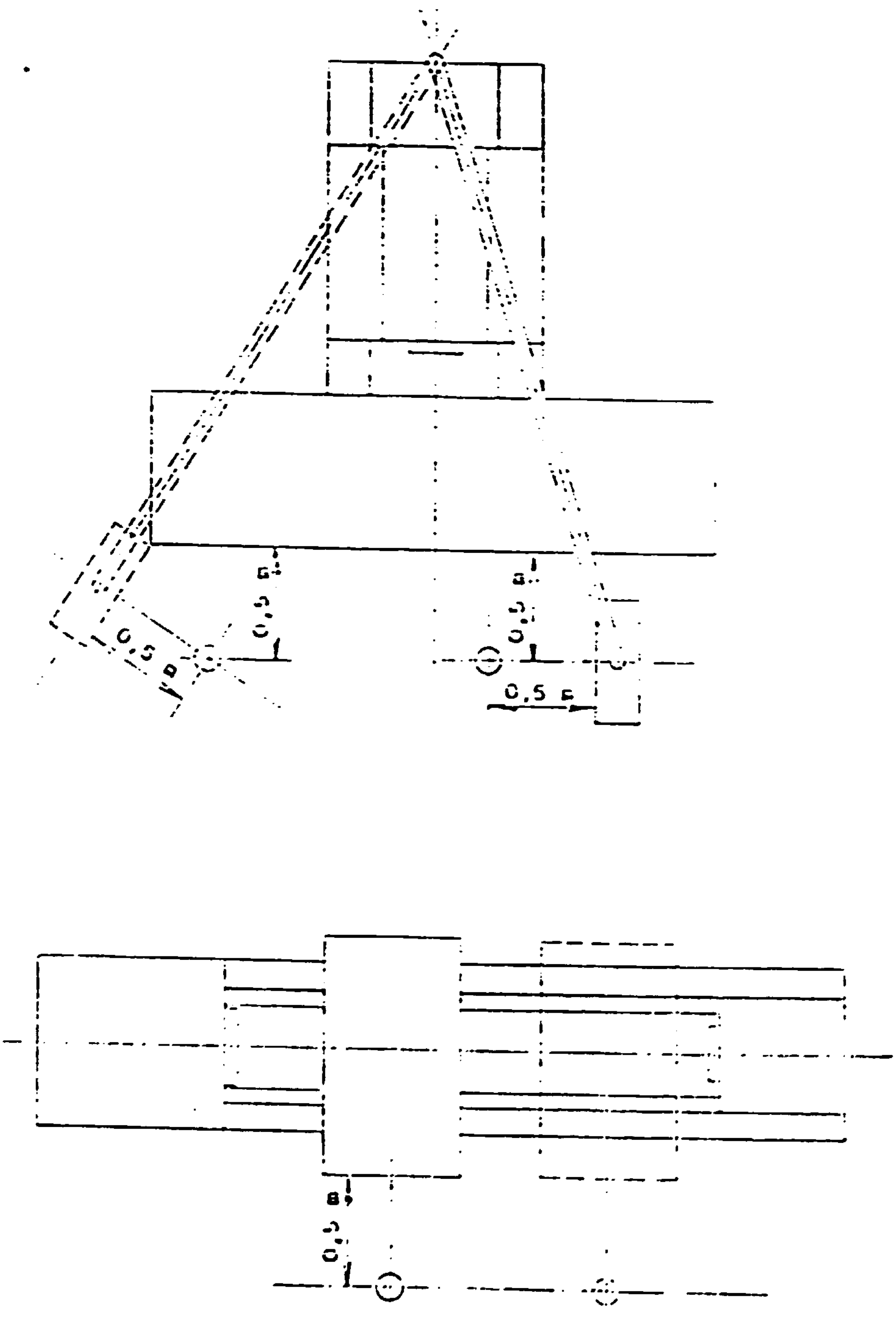

Fig. 7.

8.3 Evaluation and expression of results

The equivalent noise pressure levels L_{Aeq} at all operator workstations should be presented. The noise pressure levels should not exceed the specified value.

The recommended permissible values for particular types of machines are shown in the Annex D

Note: If the noise power level is required to be measured by the user, see ISO 230 - 5 Acceptance code for machine tools - Part 5: Noise. These standard is in the stage of DIS - draft intenational standard).

9 Power utilisation

9.1 Scope

The possibility of machine full power utilization shall be verified

9.2 Methods to be used

The workpiece of typical size and shape, manufactured from steel or from crucible steel (for some types of machine of big size) is clamped on the machine and the cutting process using rough-cut condition takes place. In the same time the input power of the spindle drive should be measured. The depth of cut is gradually increased till the max. power of the motor of the spindle drive is fully utilized.

Power of the motor = input power x efficiency of motor

No selfexcited vibrations or another shortcomings while cutting should appear.

Note: The recommended arrangement of the machine, recommended sizes and shapes of workpieces and recommended cutting conditions see Annex E

9.3 Evaluation and expression of results

It should be stated if full power of the spindle drive was possible to utilize or not.

10 Safety of the machine
10 Safety of the machine

10.1 Scope

The safety of the machine shall be verified

10.2 Methods to be used

It shall be verified, if:

- all the necessary safeguards are used on the machine
- all the safety functions are performed (e.g. interlocking of guards, switching off the feed at the end of the stroke)

10.3 Evaluation and expression of results

The list of shortcomings (if any) should be presented

Annex A - recommended limits for repeatibility of positioning for manual control and positionig control systems using stops or dogs

Annex B - recommended permissible values for positioning accuracy and repeatibility of numercally controled machine tools

Annex C - Recommended permissible values for vibration velocity

Annex D - Recommended permissible values for noise pressure level

Annex E - Recommended conditions for power utilization measurement

a) Recommended permissible values of R_{mu} for manual control (in µm or in arc sec)

Lathes

Max. diameter above the slide (mm)	Direction of movement		
	cross	longitudinal	
		slide	saddle
to 125	4	4	18
125 to 250	6	6	25
250 to 400	8	8	32
400 to 630	9	9	40
630 to 1000	10	10	50
more than 1000	12	12	62

Milling machines

Table width (mm)	Direction of movement		
	cross	longitudinal	vertical
to 250	10	10	10
250 to 400	12	12	12
400 to 630	15	15	15
more than 630	18	18	18

Horizontal boring machines

Table width (mm)	Direction of movement			
	cross	vertical	longitudinal	rotational
to 1000	13	13	18	4''
1000 to 1600	18	18	24	4''
more than 1000	24	24	35	4''

Cylindrical grinding machines

Max diameter of workpiece (mm)	Direction of movement	
	cross	longitudinal
to 250	1,5	-
250 to 500	2	-
more than 500	2,5	-

Grinding machines for internal grinding

Max diameter of the hole (mm)	Direction of movement	
	cross	longitudinal
to 80	1,5	15
more than 80	2	20

Surface grinding machines with horizontal spindle

Table width (mm)	Direction of movement	
	vertical	cross
to 320	1,5	6
320 to 500	2	8
more than 500	2,5	10

Surface grinding machine with vertical spindle

Table width (mm)	Direction of movement vertical
to 630	3
more than 630	4

b) Recommende permissible values of R_{max} for position control systems or for rectangular path control system using stop or dogs (in μm or in arc sec)

Lathes

Max diameter above the slide (max turning diameter (mm)	Direction of movement	
	cross	longitudinal
to 125	8	15
125 to 250	10	20
250 to 400	13	27
400 to 630	16	30
630 to 1000	18	30
more than 1000	20	35

Vertical lathes

Diameter of chucking plate (mm)	Direction of movement	
	cross	vertical
to 1000	18	24
1000 to 1600	24	30
1600 to 2500	30	35
2500 to 3200	30	35
more than 3200	35	40

Milling machines

Table width (mm)	Direction of movement		
	cross	longitudinal	vertical
to 250	12	12	12
250 to 400	16	16	16
400 to 630	20	20	20
630 to 1000	25	25	25
more than 1000	25	25	25

Horizontal borig machines

Table width (mm)	Direction of movement			
	cross	vertical	longitudinal	rotational
to 1000	13	13	18	6"
1000 to 1600	18	18	24	6"
more than 1600	24	24	30	6"

Drilling machines

Drilling diameter (mm)	Direction of movement vertical
to 25	40
25 to 50	50
more than 50	60

Gear hobbing and gear shaping machines

Max head diameter of the gear (mm)			Direction of movement radial
	to	160	12
160	to	320	16
320	to	600	20
more than		600	24

Cylindrical grinding machines

Max diameter of workpiece (mm)			Direction of movement cross
	to	250	1,5
250	to	500	2
more than		500	2,5

Internal grinding machines

Max. diameter of hole (mm)		Direction of movement cross
	to 80	1,5
more than	80	2

Surface grinding machines with horizontal spindle

Table width (mm)			Direction of movement	
			vertical	cross
	to	320	2	3
320	to	500	2,5	4
more than		500	3	5

Surface grinding machines with vertical spindle

Table width			Direction of movement vertical
	to	320	8
320	to	500	10
more than		500	13

Recommended permissible values of unidirectional repeatability R_{max} and accuracy of positioning A .

In the tables for particular types of macines following parameters are shown :
- max. permissible unidirectional repeatability R_{max}
- max. permissible reversal value B_{max}
- the grade of accuracy of cumulative error C_{max}. Max. permissible cumulative error is to be found on the table on the last page of this Annex according to the length of the movement measured.

The recommended permissible value of accuracy A should be calculated from the formula

$$A = 0,8\ (R_{max} + B_{max} + C_{max})$$

Lathes

Max. diameter above the slide (max turning diameter) (mm)	Direction of movement	Permissible values (μm)		
		C_{max}	R_{max}	B_{max}
to 125	cross longitudinal	VI IV	5 7	5 7
125 to 250	cross longitudinal	VI IV	7 9	7 9
250 to 400	cross longitudinal	VI IV	8 10	8 10
400 to 630	cross longitudinal	VI IV	9 12	9 12
630 to1000	cross longitudinal	VI IV	10 13	10 13
more then 1000	cross longitudinal	VI IV	12 15	12 15

Vertical lathes

Diameter of the chucking plate (mm)	Direction of movement	Permissible values (µm)		
		C_{max}	R_{max}	B_{max}
to 1000	cross vertical	V IV	10 13	10 13
1000 to 1600	cross vertical	V IV	13 18	13 18
1600 to 2500	cross vertical	V IV	18 25	18 25
2500 to 3200	cross vertical	V IV	22 25	22 25
more than 3200	cross vertical	V IV	26 30	42 50

Milling machines

Table width (mm)	Direction of movement	Permissible values (µm)		
		C_{max}	R_{max}	B_{max}
to 250	cross longitudinal vertical	V	5	5
250 to 400	cross longitudinal vertical	V	8	8
400 to 630	cross longitudinal vertical	V	10	10
630 to 1000	cross longitudinal vertical	V	13	13
more than 1000	cross longitudinal vertical	V	15	15

Horizontal boring machines and machining centres

Table width (mm)	Direction of movement	Permissible values (µm or ")		
		C_{max}	R_{max}	B_{max}
to 250	Perpendicular to the spindle axis	VI	4	4
	Parallel to the spindleaxis	V	6	6
	Rot. table	30"	8"	8"
250 to 400	Perpendicular	VI	6	6
	Parallel	V	8	8
	Rot. table	30"	8"	8"
400 to 630	Perpendicular	VI	8	8
	Parallel	V	10	10
	Rot. Table	30"	8"	8"
630 to 1000	Perpendicular	VI	10	10
	Parallel	V	13	13
	Rot. table	30"	8"	8"
1000 to 1600	Perpendicular	VI	13	13
	Parallel	V	15	15
	Rot.table	30"	8"	8"
More than 1000	Perpendicular	VI	15	15
	Parallel	V	18	18
	Rot. table	30"	8"	8"

Coordinate boring machines

Table width (mm)	Direction of movement	Permissible values (µm)		
		C_{max}	R_{max}	B_{max}
to 1000	Perpendicular to the spindle axis	VII	6	6
	Parallel to the spindle axis	V	11	11
more than 1000	Perpendicular	VII	8	8
	Parallel	V	15	15

Coordinate drilling machines

Drilling diameter (mm)	Direction of movement	Permissible values (μm)		
		C_{max}	R_{max}	B_{max}
to 25	longitudinal cross vertical	V V IV	15 15 20	15 15 20
25 to 50	longitudinal cross vertical	V V IV	18 18 25	18 18 25
more than 50	longitudinal cross vertical	V V IV	24 24 34	24 24 34

Gear hobbing and gear shaping machines

Max head diameter of the gear (mm)	Directin of movement	Permissible values (μm)		
		C_{max}	R_{max}	B_{max}
to 160	radial	V	10	10
160 to 320	radial	V	14	14
320 to 600	radial	V	18	18
more than 6000	radial	V	20	20

Cylindrical grinding machines

Max. diameter of workpiece (mm)	Direction of movement	Permissible values (μm)		
		C_{max}	R_{max}	B_{max}
to 250	cross longitudinal	VII VI	1,5 2,5	4 7
250 to 500	cross longitudinal	VII VI	2 3	5 8
more than 500	cross longitudinal	VII VI	2,5 4	6 10

Internal grinding machines

Max diameter of hole (mm)	Direction of movement	Permissible values (μm)		
		C_{max}	R_{max}	B_{max}
to 80	cross longitudinal	VII VI	1,5 2,5	4 6
more than 80	cross longitudinal	VII VI	2 3	5 8

Surface grinding machines with horizontal spindle

Table width (mm)	Direction of movement	Permissible values (µm)		
		C_{max}	R_{max}	B_{max}
to 320	vertical	VII	2	5
	cross	VI	3	8
	longitudinal	III	10	25
320 to 500	vertical	VII	2,5	6
	cross	VI	4	10
	longitudinal	III	12	30
more than 500	vertical	VII	3	8
	cross	VI	5	12
	longitudinal	III	14	40

Permissible values of C_{max} (µm)

Measured length		The grade of accuracy								
over	to	0	I	II	III	IV	V	VI	VII	VIII
	3	26	14	10	6	4	3	2	1,2	0,8
3	6	36	18	12	8	5	4	[illegible]	1,5	1
6	10	44	22	15	9	6	4	2,5	1,5	1
10	16	54	27	18	11	8	5	3	2	1,2
18	30	66	33	21	13	9	6	4	2,5	1,5
30	50	78	39	25	16	11	7	4	2,5	1,5
50	80	92	46	30	19	13	8	5	3	2
80	120	108	54	35	22	15	10	6	4	2,5
120	180	126	63	40	25	18	12	8	5	3,5
180	250	142	72	46	29	20	14	10	7	4,5
250	315	162	81	52	32	23	16	12	8	6
315	400	178	89	57	36	25	18	13	9	7
400	500	194	97	63	40	27	20	15	10	8
500	630	220	110	70	44	30	22	16	11	9
630	800	250	125	80	50	35	25	18	13	10
800	1000	280	140	90	56	40	29	21	15	11
1000	1250	330	165	105	66	45	34	24	18	13
1250	1600	390	195	125	78	54	40	29	21	15
1600	2000	460	230	150	92	65	48	35	25	18
2000	2500	550	[illegible]	175	110	77	57	[illegible]	[illegible]	22
2500	3150	[illegible]	330	210	135	93	69	[illegible]	[illegible]	26
3150	[illegible]	[illegible]	410	260	165	115	82	[illegible]	42	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	140	100	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	775	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10000	[illegible]	950	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	72

Annex C

Recommended permissible effective values (RMS) of the velocity and deviations of the forced vibrations.

Lathes

Max. diameter above the slide, max. turning diameter (mm)	RMS	
	mm.s^{-1}	µm
to 200	1,12	10
200 to 800	1.8	16
more than 800	2,8	25

Vertical lathes

Diameter of the chucking plate (mm)	RMS	
	mm.s^{-1}	µm
to 3000	1,8	16
more than 3000	2,8	25

Milling machines

Taper hole in the spindle	RMS	
	mm.s^{-1}	µm
to 50	1,12	10
more than 50	1,8	16

Boring machines and machining centres

Taper hole in the spindle	RMS	
	mm.s^{-1}	µm
to 50	1,12	10
more than 50	1,8	18

Gear hobbing machines

Max. head diameter of the gear	RMS	
	$mm.s^{-1}$	µm
to 500	0,71	6
more than 500	1,12	10

Drilling machines

Type and size	RMS	
	$mm.s^{-1}$	µm
Table type	4,5	40
Box type	2,8	20
Radial - drilling ø		
to 50	2,8	20
more than 50	4,5	40

Cylindrical grinding machines

Diameter of workpiece (mm)	RMS	
	$mm.s^{-1}$	µm
to 300	0,28	2
more than 300	0,45	3,5

Internal grinding machines

RMS	
$mm.s^{-1}$	µm
0,71	6

Annex D

Recommended permissible of equivalent noise pressure level L_{Aeq} on the operator workstation

Type of the machine	L_{Aeq} (dB)
Grinding machines	75
Drilling machines up to 1,6kW	75
Drilling machines more than 1,6 kW	78
All another machines	80

Recommended conditions for power utilation measurement

1 Lathes

a) workpiece in the chuck (see fig. 1).

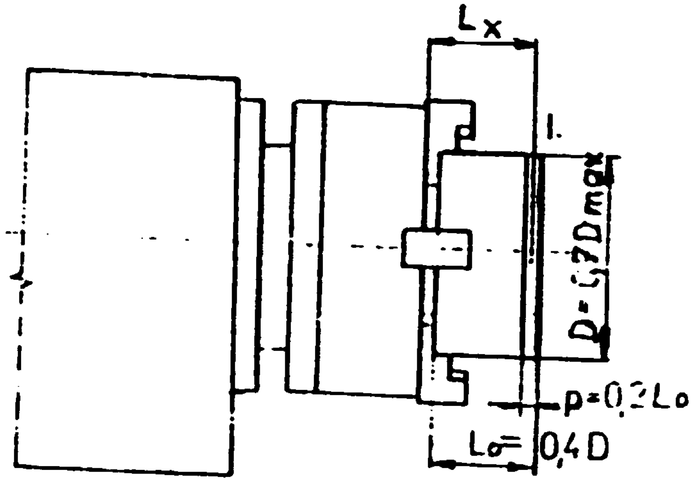

Fig. 1

Workpiece : diameter $D = 0{,}7\ D_{max}$ (max diameter above the slide, max. turning diameter)

length $L_o = 0{,}4\ D$

place of turning $p = 0{,}2\ L_o$

material - steel 600 $N.mm^{-2}$

Tool : with indexable insert from hard metal (K 05 - K 10)

$\varkappa = 95^o$

$r = 1{,}2 - 1{,}6$ mm

Cutting conditions : cutting speed $v = 170\ m.min^{-1}$

feed rate (see table 1)

Depth (h) or width (b) of cut is gradually increased till full power of the machine is utilized (see fig.2)

Table 1

D_{max}		Feed rate	
		Direction z	Direction x
	to 160	0,5	0,3
160	to 320	0,6	0,35
320	to 500	0,7	0,4

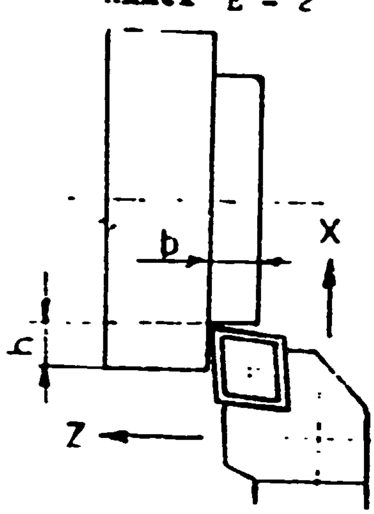

Fig.2

b) workpiece between centres (see fig.3)

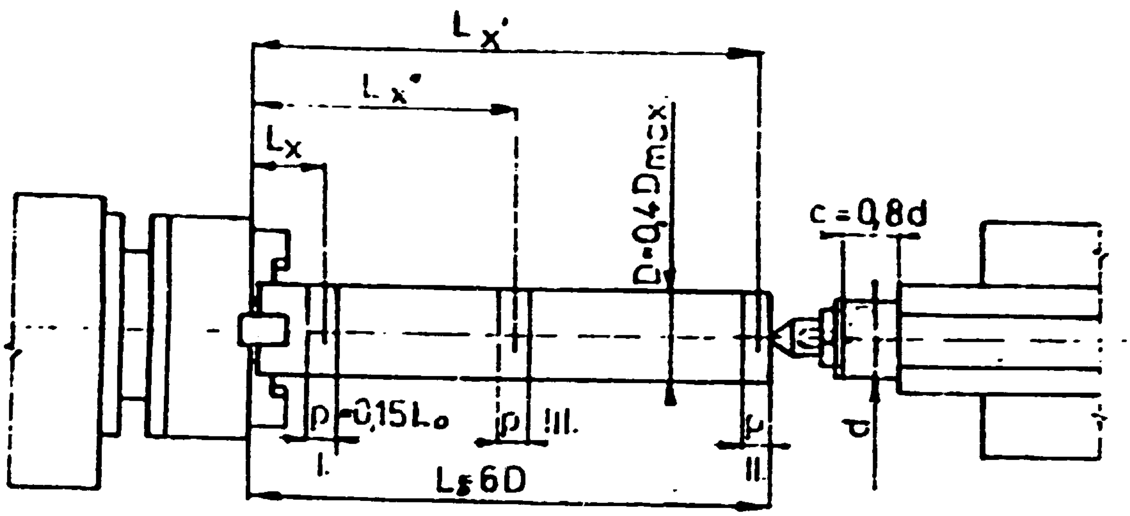

Fig.3

Workpiece : diameter $D = 0{,}4\ D_{max}$

length $L_o = 6D$

places of turning p_I , p_{II} , p_{III}

material - steel 600 $N.mm^{-2}$

Tool : the same as for workpiece in chuck

Cutting conditions : the same as for workpiece in chuck

2 Vertical lathes

a) machines with one saddle (see fig 4)

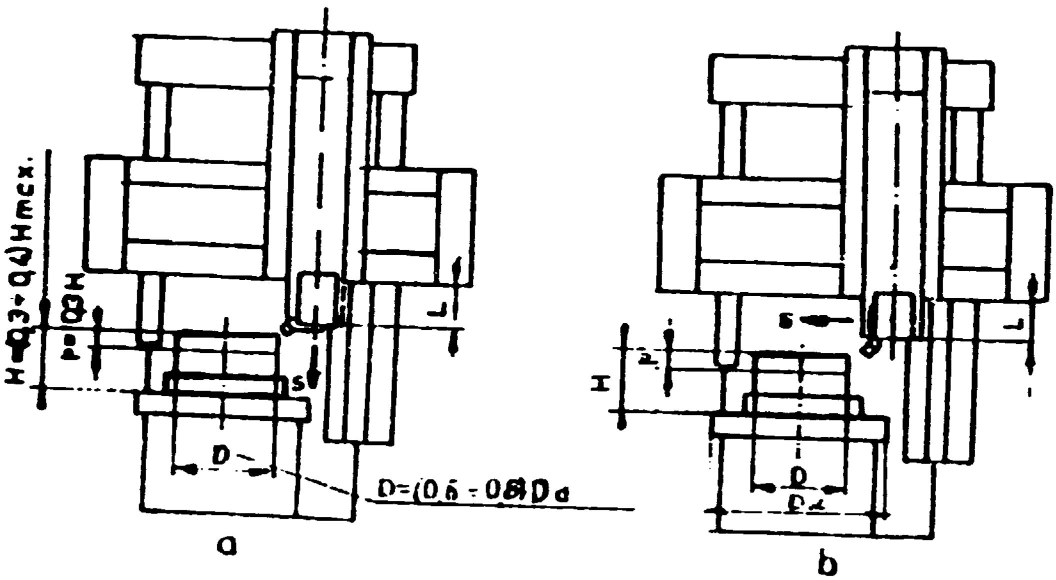

Fig. 4

Workpiece : diameter D (in the place of manufacturing)=
$(0,6 - 0,8)\ D_d$
where D_d is the diameter of chuck plate
high $H = (0,3 - 0,4)\ H_{max}$

material - crucible steel

Tool : with insertable insert from hard metal
= 45°
r = 1,6 mm

Cutting conditions :-cutting speed $v = 70\ m.min^{-1}$
-feed rate (per one rotation of table) =
1,2 - 1,4 mm for $D_d \leq 2000$ mm
1,4 - 2 mm for $D_d > 2000$ mm
- depth of cut is gradually increased
till full power is utilized
- places of turning - p

b) machines with two (or three) saddles (see fig. 5).

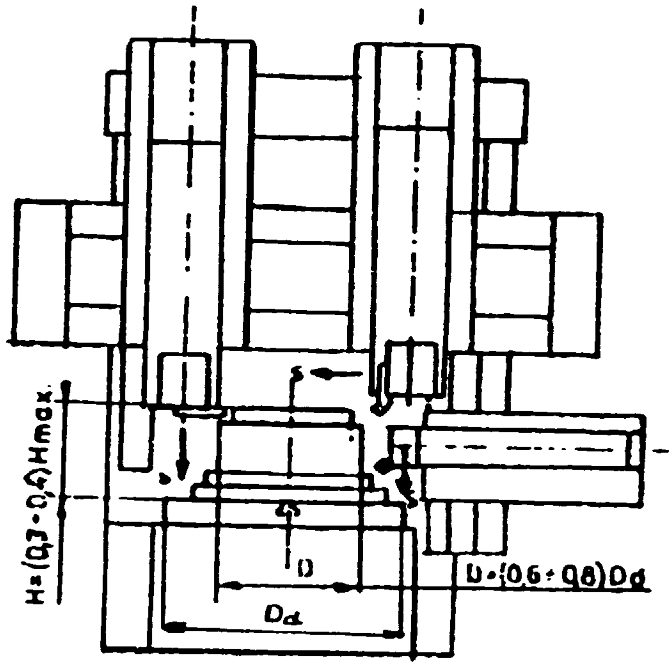

Fig. 5

Workpiece : the same as for one saddle machine
Tool : the same as for one saddle machine
Cutting conditions: the same as for one saddle machine.
All saddles are used for turning in the same time

6 Milling machines and machining centres with horizontal spindle and horizontal boring machines
(example see fig. 6).

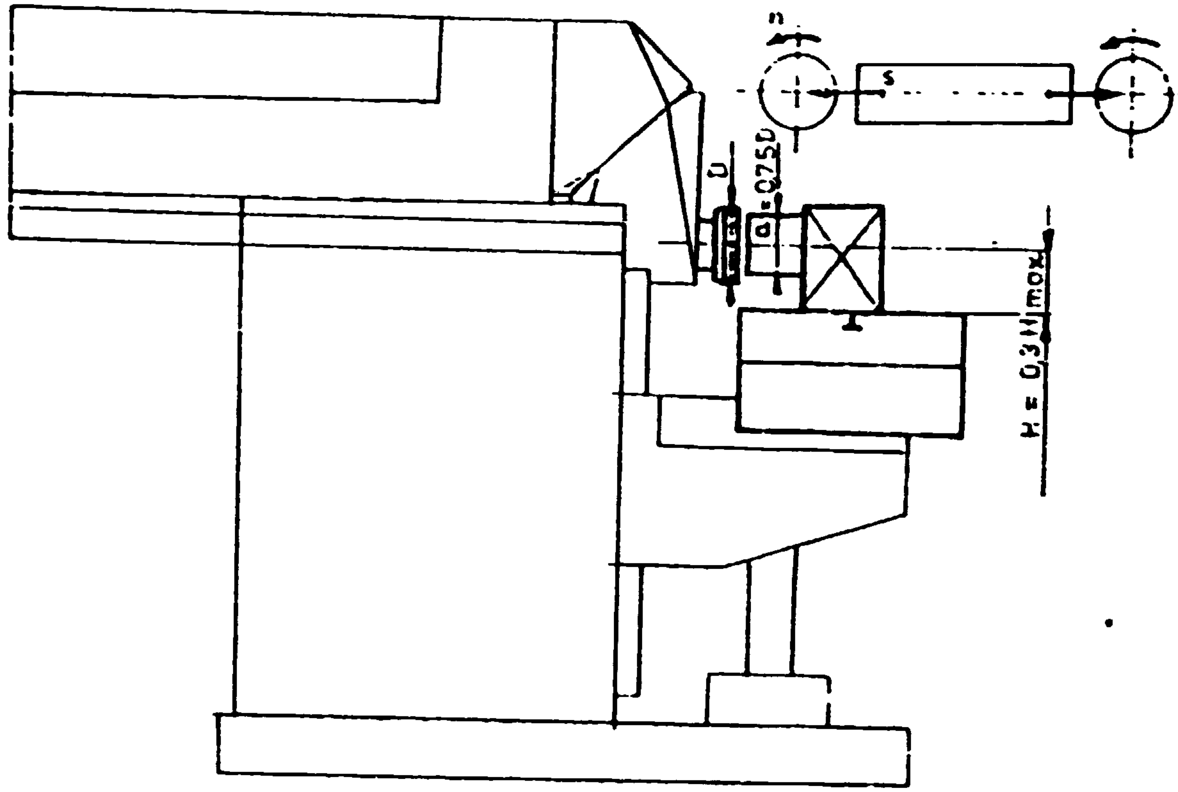

Fig.6.

Workpiece :-The bar a x a, a = 0,75 D
-material-steel 600 $N.mm^{-2}$
-clamping - rigid connection with table

Tool: face milling cutter with indexable inserts from hard metal, $\varkappa$ = 75°
diameter D = approximately 2d, where d is diameter of spindle

Cutting conditions:-cutting speed v = 130 $m.min^{-1}$
-feed rate 0,2 - 0,35 mm/tooth
-depth of cut is increased till full power is utilized

Clamping of the tool - by means of taper hole in the spindle or directly on the spindle by means of screws (large machines)

4 Milling machines and machining centres with vertcal spindle (example see fig. 7).

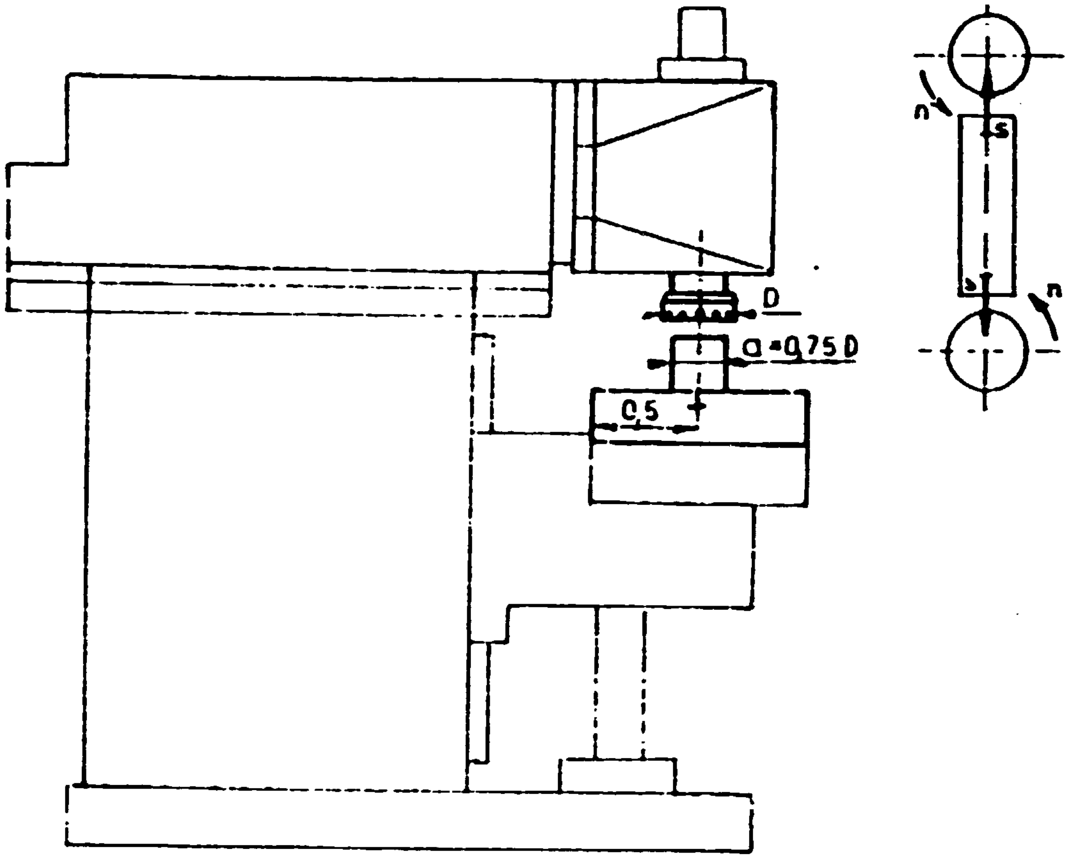

Fig. 7.

Workpiece
Tool
Cutting conditions
Clamping of the tool

} the same as for milling macines with horizontal spindle

5 Radial drilling machines (see fig 8).

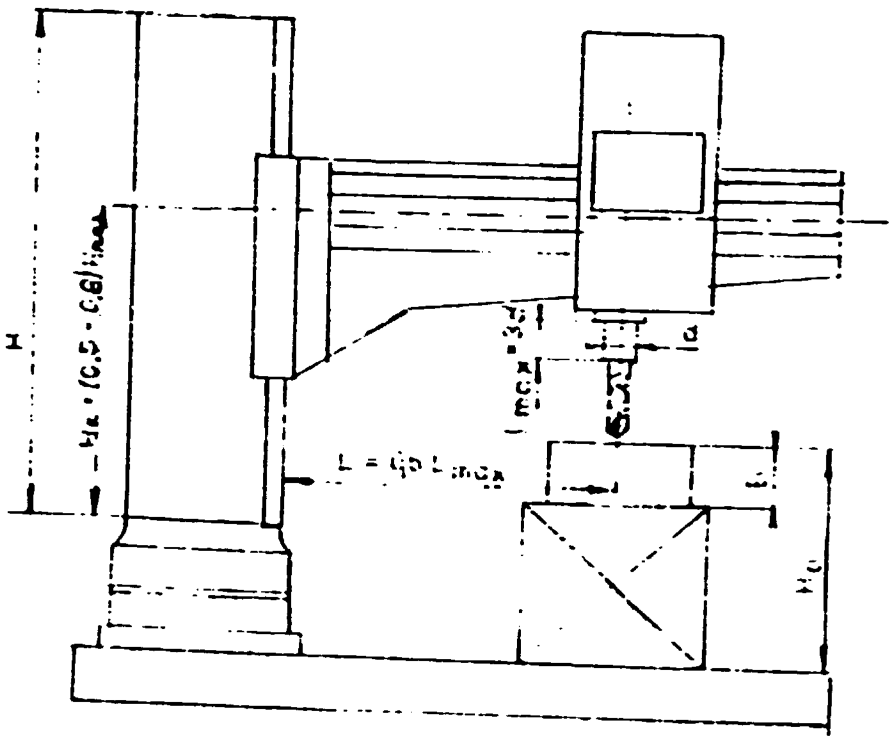

Fig. 8.

Workpiece: - steel 600 $N.mm^{-2}$
- rigid clamping to the base

Tool : - diameter D = max drilling diameter of the machine
- high speed steel

Cutting conditions:

Drilling diameter mm	Cutting speed $m.min^{-1}$	Feed rate max mm per one rotation
32	22	0,316
40	21	0,368
50	20	0,400
63	19	0,424
80	19	0,468

The feed rate is increased till either the max power is utilized or the max feed shown in the table is reached.

Arrangement of the machine -The high of the arm $H_R = (0,5 - 0,8) H_{max}$

where H_R is the max high of the arm
-The distance of the dill from the column $L = 0,6\ L_{max}$, where L_{max} is the max distance
-pushing out the quill $l_{max} = (0 - 3) d$ where d is the diameter of the dill.

6 Gear hobbing machines (see fig 9.)

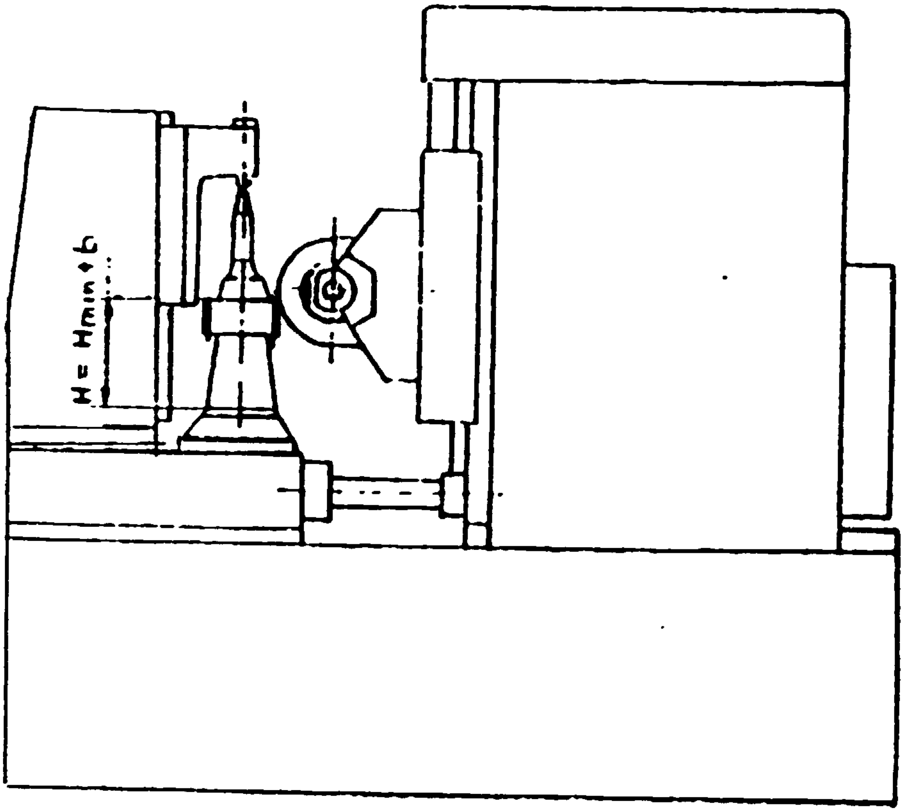

Fig. 9.

Workpiece: - diameter $d_a = (0,8 - 1)\ d_{max}$

where d_{max} is max head diameter according to the specification of the machine

- width $b = (0,2 - 0,4)\ d_a$
- material -steel 600 $N.mm^{-2}$ for $d_a \leq 320$
  crucible steel for $d_a > 320$
- clamping - see fig. 9

Tool:- Gear hobbing cutter - The teeth from hard metal

- head diameter $d_{ao} = (0,8 - 1)\, d_{ao\,max}$
  where $d_{ao\,max}$ is max head diameter standardized for machine under test
- module m - max possible for machine under test

Cutting conditions:

module m mm	cutting speed $m.min^{-1}$
4	80
7	70
10	60

- depth of cut - t = 2m
- The feed rate (per one rotation of the table) is gradually increased, till full power is utilized
- cooling - cooling oil
- the upper face of the gear is in the distance H above the table

$$H = H_{min} + b$$

where H_{min} is the min. distance of the axis of the tool from the surface of the table

FORGING AND FORMING

Introduction to Forming and Forging Processes

Metalworking consists of deformation processes in which a metal billet or blank is shaped by tools or dies. The design and control of such processes depend on an understanding of the characteristics of the workpiece material, the conditions at the tool/workpiece interface, the mechanics of plastic deformation (metal flow), the equipment used, and the finished-product requirements. These factors influence the selection of tool geometry and material as well as processing conditions (for example, workpiece and die temperatures and lubrication). Because of the complexity of many metalworking operations, models of various types, such as analytical, physical, or numerical models, are often relied upon to design such processes.

Historical Perspective

Metalworking is one of three major technologies used to fabricate metal products; the others are casting and powder metallurgy. However, metalworking is perhaps the oldest and most mature of the three. The earliest records of metalworking describe the simple hammering of gold and copper in various regions of the Middle East around 8000 B.C. The forming of these metals was crude because the art of refining by smelting was unknown and because the ability to work the material was limited by impurities that remained after the metal had been separated from the ore. With the advent of copper smelting around 4000 B.C., a useful method became available for purifying metals through chemical reactions in the liquid state. Later, in the Copper Age, it was found that the hammering of metal brought about desirable increases in strength (a phenomenon now known as strain herdening). The quest for strength spurred a search for alloys that were inherently strong and led to the utilization of alloys of copper and tin (the Bronze Age) and iron and carbon (the Iron Age). The Iron Age, which can be dated as beginning around 1200 B.C., followed the beginning of the Bronze Age by some 1300 years. The reason for the delay was the absence of methods for achieving the high temperatures needed to melt and to refine iron ore.

Most metalworking was done by hand until the !#th century. At the time, the tilt hammer was developed and used primarily for forging bars and plates. The machine used water power to raise a lever arm that had a hammering tool at one end; it was called a tilt hammer because the arm tiltedas the hammering tool was raised. After raising the hammer, the blacksmith let it fail under the force of gravity, thus generating the forging blow. This relatively simple device remained in service for some centuries.

The development of rolling mills followed that of forging eguipment. Leonardo da Vinci's notebook includes a sketch of a machine designed in 1480 for the rollling of lead for stained glass windows. In 1495, da Vinci is reported to have rolled flat sheet of precious metals on a hand-operated two-roll mill for coin-making purpose. In the following years, several designs for rolling mills were utilized in Germany, Italy, France, and England. However, the development of large mills capable of hot rolling ferrous materials took almost 200 years. This relatively slow progress was primarily due to the limited supply of iron. Early mills employed flat rolls for making sheet and plate, und until the middle of the 18th century, these mills were driven by water wheels.

During the Industrial Revolution at the end of the 18th century, processes were devised for making iron and steel in large quantities to satisfy the demand for metal products. A need arose for forging equipment with larger capacity. This need was answered with the invention of the high-speed steam hammer, in which the hammer is raised by steam power, and the hydraulic press, in which the force is supplied by hydraulic pressure. From such equipment came products ranging from firearms to locomotive parts. Similary, the steam engine spurred developments in rolling, and in the 19th century, a variety of steel products were rolled in significant quantities.

The past 100 years have seen the development of neww types of metalworking equipment and new materials with special properties and applications. The new types of equipment have included mechanical and screw presses and high-speed tandem rolling mills. The materials that have benefited from such developments in equipment range from the ubiquitous low-carbon steel used in automobiles and appliances to specialty aluminium-, titanium-, and nickel-base alloys. In the last 20 years, the formulation of sophisticated mathematical analyses of forming processes has led to higher-quality products and increased efficiency in the metalworking industry.

Classification of Metalworking Processes

In metalworking, an initially simple part - a billet or a blanked sheet, for example - is plastically deformed between tools (or dies) to obtain the desired final configuration. Metal-forming processes are usually classified according to two broad categories:

* Bulk, or massive, forming operations
* Sheet forming operations

In both types of process, the surfaces of the deforming metal and the tools are in contact, and friction between them may have a major influence on material flow. In bulk forming, the input material is in billet, rod, or slab form, and the surface-to-volume ratio in the formed part increases considerably under the action of largely compressive loading. In the sheet forming, on the other hand, a piece of sheet metal is plastically deformed by tensile loads into a three-dimensional shape, often without significant changes in sheet thickness or surface characteristics.

Process that fall under the category of bulk forming have the following distinguishing features (Ref 1):

* The deforming material, or workpiece, undergoes large plastic (permanent) deformation, resulting in an appreciable change in shape or cross section

* The portion of the workpiece undergoing plastic deformation is generally much larger than the portion undergoing elastic deformation: therefore, elastic recovery after deformation is negligible

Examples of generic bulk forming processes are extrusion, forging, rolling, and drawing. Specific bulk forming processes are listed in Table 1.

The characteristics of sheet metal forming processes are as follows (Ref 1):

* The workpiece is a sheet or a part fabricated from a sheet
* The deformation usually causes significant changes in the shape, but not the cross-sectional area, of the sheet
* In some cases, the magnitudes of the plastic and the elastic (recoverable) deformations are comparable; therefore, elastic recovery or springback may be significant

Examples of processes that fall under the category of sheet metal forming are deep drawing, stretching, bending, and rubber-pad forming. Other processes are listed in Table 2.

Types of Metalworking Equipment

The various forming processes discussed above are associated with a large variety of forming machines or equipment, including the following (Ref 1):

* Rolling mills for plate, strip, and shapes
* Machines for profile rolling from strip
* Ring-rolling machines
* Thread-rolling and surface-rolling machines
* Magnetic and explosive forming machines
* Draw benches for tube and rod; wire- and rod-drawing machines
* Machines for pressing-type operations (presses)

Among those listed abovve, pressing-type machines are the most widely used and are applied to both bulk and sheet forming processes. These machines can be classified into three types: load-restricted machines (hydraulic presses), stroke-restricted machines (crank and eccentric, or mechanical, presses), and energy-restricted machines (hammer and screw presses). The significant characteristics of pressing-type machines comprise all machine ddesign and performance data that are pertinent to the economical use of the machine. These characteristics include:

* Characteristics for load and energy:

  Available load, available energy, and efficiency factor (which equals the energy available for workpiece deformation/energy supplied to the machine)

* Time-related characteristics:

  Number of strokes per minute, contact time under pressure, and velocity under pressure

* Characteristics for accuracy:

  For example, deflection of the ram and frame, particularly under off-center loading, and press stiffness

Recent Developments in Metalworking

Over the last 20 years, metalworking practice has seeen advances with regard to the development of new processes nad new materials, the understanding and control of material response during forming, and the application of sophisticated process design tools. Some of these technological advances will be summarized in the following section in this article.

New Processes

A number of processes have recently been introduced or accepted. These include a variety of forging processes, such as radial, precision, rotary, metal powder, and isothermal forging, as well as sheet forming processes, such as superplastic forming. Laser cutting and abrasive waterjet cutting of sheet and plate materials are also finding increased use. Each of these processes is described in greater detail in subsequent articles in this Volume.

Radial forging is a technique that is most often used to manufacture axisymetrical parts, such as gun barrels. Radial forging machines (Fig. 1) use the radial hot- or cold-forging pronciple with three, four, or six hammers to produce solid or hollow round, square, rectangular, or profiled sections. The machines used for forging large gun barrels are of a horizontal type and can size the bore of the gun barrrel to the exact rifling that is machined on the mandrel. Products produced by radial forging often have improved machanical and metallurgical properties as compared to those produced by other, more conventional techniques.

Rotary, or orbital, forging is a two-die forging process that deforms only a small portion of the workpiece at a time in a continuous manner. As shoun in Fig. 2, the axis of the upper die is tilted at a slight angle with respect to the axis of the lower die, causing the forging force to be applied to only a small area of the workpiece. As one die rotates relative to the other, the contact area between die and workpiece (called the footprint) continually progresses through the workpiece until the final shape is obtained. The tilt angle between the two dies has a major effect on the size of the footprint and therfore on the amount of forging force applied to the workpiece. Rotary forging requires as little as one-tenth the force needed for convencional forging processes. The smaller forging forces result in lower die and machine deflections and therfore in the ability to make intricate parts to a high degree of accuracy.

Precision forging, also known as draftless forging, is relatively recent development that is distinguished from other types of forging principally by finished products with thinner and more detailed geometric features, virtual elimination of drafted surfaces and machining allowances, varying die parting line locations, and closer dimensional tolerances. These types of parts are most commonly manufactured from light matals, such as aluminium, and more recently from titanium for aerespace applications in which weight, strength, and intricate shaping are important considderations, along with price and delivery.

Precision forging achieves close tolerances and low drafts through the use of die inserts, improved accuracy in die sinking, and close control of process temperatures and pressures during forging. Modified die design are also frequently used. One such design is known as through die (Fig. 3), and it derives its name from the fact that the outer periphery of the forging cavity is machined completely through the die. An upper and lower punch enter and forge the part entirely within this ring. The top punch is then retracted by the press stroke, and the completed forging is ejected by raising the lower punch attached to a knockout mechanism below.

Powder forging is a process in which sintered preforms are hot forget to 100% of theoretical density. Powder forging is primarily used for ferrous parts and difficult-to-work superalloys that require high service integrity, and it is most suitable for symmetrical shapes containing large holes and parts that would otherwise reguire a large amount of machining.

Isothermal and hot-die forging are hot-forging processes in which the dies are at the same (isotermal forging) or nearly (hot-die forging) temperature as the workpiece. The processes are primarily used for costly materials, such as titanium and nickel-base alloys, which posses fine, stable two-phase microstructures at hot-working temperatures. Such microstructures often give rise to a property known as superplasticity. Superplasticity is characterized by good die-filling capacity in bulk forming processes and high tensile elongations in sheet forming applications.

The total (or partial) elimination of die chilling in isothermal (or hot-die) forging, in isothermal (or hot-die) forging, in addition to superplastic properties of the workpiece material, allows forging to closer tolerance than is possible with convential hot forging, in which the die temperature is typically only slightly above ambient. As a result, machining and material costs are reduced. Moreover, elimination of die chilling permits a reduction in the number of preforming and blocking dies necessary for forging a given part. In addition, because die chilling is not a problem, a slow ram speed machine, such as a hydraulic press, can be used. The lower strain rate imposed gives rise to a lower material flow stress and therefore a lower forging pressure. The net result is that larger parts can be forget in equipment of capacity smaller than that required for conventional forging. Figure 4 shows a number of Alloy 100 jet engine disks made using a varsion of isothermal forging known as "Gatorizing".

Superplastic forming is the sheet forming counterpart to isothermal forging. The isothermal, low strain rate conditions in superplastic forming result in low workpiece flow stress. Therefore, gas pressure, rather than a hard punch, is often used carry out a stretching-type operation; the ...y tooling requirements is a female die (Fig. 5). The very high ductilities characteristic of superplastically formed sheet alloys such as Ti-6Al-4V, Zn-22Al, and aluminium alloy 7475 enable the forming of parts of very complex shape. Although ..cle times for superplastic forming are relatively long (of the order of 10 min per part), economies of manufacture are realized primarily through reduced machining and assembly costs. The latter savings is a result of the fact that individual superplasticly formed parts are usually used as replacements for assemblies of many separate component parts.

Laser cutting is an increasingly popularmethod of cutting sheet materials accurately. Laser cutting typically makes use of a computer numerical control program that knows new cutting paths to be quickly generated. In addition to rapid cutting, laser cutting offers such advantages as precision cutting accuracy of 0.13 mm (or less), the ability to cut most materials including metals, ceramics, plastics, and ..ss), minimal head-induced distortion, and ..ry clean straight-sided cuts. The fact that cutting is done under computer control also provides ease of cutting copmplex shapes in sheet stock, high material utilization, excellent pattern reproducibility, and economical low-volume production. Laser cutting systems are generally used for cutting prototypes or small production runs from sheet stock. Hard tooling is usually more economical for high volumes. However, one high-volume application of lasers is the trimming of automobile parts. These parts are being made of thinner materials, and then dies capable of cutting to the requiredtolerances are so expensive that laser cutting is cost-competive even for the large lot sizes involved.

Abrasive waterjet cutting is a process developed in the late 1960s which relies on the impingement of a high-velocity, high-pressure, abrasive-laden waterjet onto the workpiece for the purpose of cutting. Among the advantages of the technique are high quality of the cut surface, almost total absence of heat genration within the workpiece (thus minimizing the development of a heat affected zone), and a relatively narrow kerf. Applications of abrasive waterjet cutting can be found in the machining of hard metals (for example, superalloys, high-strength steels, and titanium alloys) and a number of nonmetals (for example, concrete, ceramics, composites, and plastics). The only major limitation of the process is the inability to mill, turn, or drill blind holes or perfotm other operations that involve cutting or drilling to a partial depth.

New Materials Developments

An inreased understanding of materialbehavior during deformation has led to the improved design of metalworking processes. Two areas of particular significance in this regard are the emergence of thermalmechanical processing techniques and the development of metal workability/formability relationships.

Thermal-mechanical processing refers to the design and control of the individual metalworkingand heat treatment steps in a manufactoring process in order to enhance final properties. Originally used as a method of producing high-strength or high-toughness alloy steels, thermal-mechanical processing is now routinely used for alloy systems, especially those based on nickel.

Most thermal-mechanical processing treatments for steels rely on deformation that is imposed before, during, or after austenite transformation. The various types of treatments are summarized in Table 3. Thisclassification, based on the relative position of deformation and transformation in the treatment cycle, has other justification in that the tensile stress-strain curves and the rate of increase in yield strenght with increasing deformation (Fig.6) have been found to be broadly similar for a variety of steel subjected to a given class of treatment and have been found to differ for each of the classes.

In the thermal-mechanical processing of nickel-base superalloys, metalworking temperature is carefully controlled (especially during finish forming) to make use of the structure control effects of second phases. Above the optimal working temperature range, the struktur control phases go to into solution and lose their effect in controlling grain size and structure. Bellow this range, extensive fine precipitates are formed, and the alloy becomes too stiff to process. Proper thermal-mechanical processing leads to excellent combinations of tensile, fatigue, and creep properties.

Workability and formability are the terms that are commonly used to refer to the ease with whitch metal can be shaped during bulk and sheet forming operations, respectively. In the broadest sense, workability and formability indices provide quantitative estimates of the strength properties of a metal (and threfore the required working loads) and its resistance to failure. However, the latter characteristic (that is, ductility or failure resistance) is usually of primary concern. The techniques used to estimate this property vary, depending on the class of forming operation.

In bulk forming, the most common types of failures are those known as free surface fracture (at cold-working temperatures) or triple-point cracking/cavitation (at hot-working temperatures). A vast array of mechanical tests and theoretical analyses have been developed for predicting failures of these ond other types during forging, extrusion, rolling, and other bulk forming operations. These tests and analyses are summarized in Ref. 7 and are discussed in the Section "Evaluation of Workability" in this Lecture. Other common test techniques used to gage bulk workability include the uniaxial upset, flanged or tapered compression, notched-bar upset, and wedge tests.

One of the most successful and useful design tools to come from bulk workability research is the workability diagram for free surface fracture during the cold working of wrought and powder metals. An example of a workability diagram of this type is shown in Fig. 7. The graph indicated the locus of free surface normal strains (one tensile and one compressive) that cause fracture. These diagrams are determined by mechanical tests such as those mentioned above. Formany metals, the fracture locus is a straight line of slope -1/2. Some metals have a bilinear failure locus. The workability diagrams are used during process design by plotting calculated or estimated surface strain paths that are to be imposed during forming on the fracture locus diagram (Fig. 7). If the final strains lie above the locus, part failure is likely, and changes are necessary in preform design, lubrication, and/or material. The fracture locus concept has been used to prevent free surface cracking in forging and to prevent edge cracking in rolling. With modifications, the fracture locus approach has also provided insight into such failure modes as center bursting in extrusion and forging and die-workpiece contact fractures in forging.

A related concept is the forming limit diagram used to quantify sheet metal formability. An example is shown in Fig. 8. As for the bulk workability fracture locus, the sheet metal forming limit diagram is the locus of normal surface strains that give rise to failure. The magnitudes of the failure strains are usually controlled by one of two processes: localized through-thickness thinning or fracture prior to localized thinning. In either case, the forming limit diagram is most easily determined by stretching experiments using a hemispherical punch. Strain path and failure strain (in terms of the so-called major and minor strain) are varied by changes in lubrication and test blank width. Experimentally determined forming limit diagrams are then compared to the strain that are to be developed during forming to determine the possibility for failure.

Process Simulation

The development of powerful computer-based simulation techniques, such as those based on the finite-element method, has provided a vital link between addvances in tooling and eguipment design, on the one hand, and an improved understanding of materials behavior on the other. Inputs to finite-element codes include the characteristics of the workpiece material (flow stress and thermal properties) and the tool/workpiece interface (friction and heat transfer properties), as well as workpiece and tooling geometries.Typical outputs include predictions of forming load; strain, strain rate, and temperature contour plots; and tooling deflections. This information can serve a number of design functions, such as selection of press capacity, determination of success or failure with regard to material workability or formability, and estimation of likely sources of tooling failure (abrasive wear, thermal fatique, and so on).

Process simulation techniques also provide a method for preform and die design through the ability to determine metal flow patterns without constructing tooling or conducting expensive in-plant trials. In addition, the output from process simulations can be helpful in selecting variables that are useful in process control (for example, ram speed or load monitoring) or finished-product quality control. The advent of these computer-based technologies will help in eliminating the hidden costs of trial-and-error desing and in increasing productivity in the metalworking industries.

Future Trends

The metalworking industry is likely to see changes in the major areas of materials,processes, and process design. Some of these changes will include the following.

Materials. Developments in materialsw ill greatly affect the metals that are formed. These will range from aluminium and titanium-base alloys to alloy steels and superalloys. New classes of aluminium alloys that will be processed include aluminum-lithium alloys, SiC whisker-reinforced aluminium metal-matrix composites, and high-temperature powder metallurgy alloys. More use will be made of β-titanium alloys, which combine good strength and toughness, and there will be increased use of thermal-mechanical processing for tiatanium alloys and superalloys. In the ferrous area, microalloyed steels, which permit elimination of final heat treatment by controlled cooling after hot working, are becoming increasingly popular for a variety of automotive applications.

Process. In the forming process area, metalworking methods that give rise to net or near-net shape will be increasingly used to conserve materials and to reduce machining costs. These process include precision forging, isothermal and hot-die forging, and suprplastic forming of sheet materials. There will also be increased use of automatic tool change systems as lot sizes and delivery times decrease.

Process design. With the development of user-friendly programs and decreasing cost of computer hardware, there will be significant growth in computer-aided techniques in tooling design and process control. In particular, there will be more interaction between parts users and parts vendors during the design stage. Process simulation will streamline the design process, and this will decrease delivery times as well as the overall cost of fabricated components.

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LECTURES

Pavel Tomek,PhD

DEVELOPMENT AND STRATEGY OF MACHINING TECHNOLOGIES

Summary:Involvment of electronics and introduction of new man made materials are followed by implementation of new machining methods.The overall reduction of number of mechanical parts used in machines and industrial equipment together with net shape processes means decline of metal cutting and metal forming in future.Nontraditional machining methods as laser,waterjet,EDM and ECM are shortly presented in the paper to ilustrate new production techniques which will be gaining on importance in conjunction with new material alternatives.

1.Introduction

Manufacturing is a process by which materials,labor,energy and equipment are combined to produce an output having a value greater than the sum of inputs.This broad definition of manufacturing applies equally well to an electronics plant,a steel mill,or machine shop.For our purposes we will concentrate our thoughts on Machining Technologies composed of Metalworking and Metalcutting,as the most significant element of Manufacturing. A variety of technical changes have occured over the past decades.These changes include:

-material alternatives
-manufacturing systems
-nontraditional,unconventional machining

These technology changes are important,but there has been significant changes in the products being manufactured.Electronic products have replaced a wide variety of mechanical products.Electronics have become significant portion of most products including cars,all sorts of machines and industrial equipment.Modernisation of consumer and industrial products has reduced the need for conventional,mechanical components.These changes have been significant and faster then expected.

2.Materials Alternatives

Material alternatives refer to the change from generally used,or commodity metals (primarily steel)to other new materials.Figure 1 shows that use of historical,commodity metals has been decreasing while the use of advanced materials has been increasing.Figure 2 contains similiar information as Figure 1,but adds insight on overall material usage.Overall usage is dropping although it is expected to start increase in mid 1990s.These predictions indicate that usage maight again reach the 1970 level after 2000.
The Figure 2 is based on dollar value.It should be noted that overall Gross Products of industrial countries in the world are and will be increasing,which means that material shipments as a percent of world Gross Products are and will decrease. Figure 1 forcasts that absolute usage of commodity metals will decrease by one half over 40 years period.As a percentage of world Gross Products this would indicate that usage will be less than one sixth of what it was in 1970.Even considering all materials from Figure 2,the result would be a reduction in total materials consumption as a percentage of Gross National Products of approximately one third.The combination of forcasts for material usage and growth of national GNPs is suspect and will greatly differ in developped and underdevelopped countries but the trends are meaningful:
-the absolute usage of commodity metals has and will continue to

decrease
-overall material usage as a percent of national GNP will continue to decrease -material usage is shifting from commodity metals to advanced materials

Figure 3 shows what is included as advanced materials.These predictions show market forecasts for USA and Japan.The USA and Japan are the worlds largest economies,so these forcasts effectively represent the world trends.
The point here is not to discuss the materials future.What is important is that advanced materials are not generally used in the same way as the traditional metals.New properties of these new materials require new machining methods and thus new machines are to be developped but generally cutting and forming are and will become less significant.

3.Manufacturing Systems

Manufacturing systems have changed over past decades even where the products are being made of comodity metals using traditional processing techniques.Figure 4 shows a simplistic view of manufacturing as a system.The idealized,historical machine shop would have only metal cutting and metal forming equipment.
Figure 5 shows extended view of manufacturing,where primary process is metal cutting or metal forming.
Preprocesses are those operations done in-house or by vendors which prepare the material for the primary process.Considered are processes related to the products being made,as forging,casting,powder metals and cleaning.
Secondary processes are those done on the products during the principal processes.Exampls are heat treating,welding and surface treating.This may be done at remote places by subcontractors or inside the plant.Whether done externaly or within the plant,secondary processes are accounting for even increasing portion of processing and production cycle time.

Finishing refers to those operations that may be completed after the machining is done. This may include assembly, painting, inspection and packaging.
Principal processes represent machining operations themselves. CNC control, machining centres, manufacturing cells and manufacturing systems are all aimed at improving these principal processes. Similiar developments on tool material, high speed machining, machinery and tool sensors are all directed at improving the primary processes. Locating of Principal Processes, Preprocesses, Secondary Processes and Finishing may be different. Subcontracting systems, where these processes are placed on different locations are widely used. On the other hand combined approach, where all of these processes are concentrated on the same site is used as well. The optimum approach would be to minimize the need for material handling and control directed to reaching the minimum production costs. One way to do this is to integrate preprocesses, secondary processes and finishing operations with principal processes.

4. <u>Net shape process</u>

Net shape processes for metals replace or reduce the need for machining. These processes have been known and used for metal. Forging and casting are used for centuries. The variety of net shape processes is very wide including powder metal, die casting, squeeze casting, isothermal forging, hot isostatic pressing etc.
For nonmetal products, net shape processes have even greater impact. Almost all plastic parts are made to final shape with limited finishing and occasionaly other machining operations. Similarly ceramic components are normally produced so that minimum machining is needed. Similarly when advanced composites are used, the procces normaly produces the net shape parts and again when required the machining is very difficult.
Net shape processes are playing ever more significant role. This

is occuring for metals for economic reasons.The result is that less machining is being used.

5.Nontraditional machining

Nontraditional processes may be mandatory for advanced materials where clasical machining methods are useless,but they are also having a major impact for traditional metals.Water jets,lasers,plasma arc and electrochemical can be used for cutting,replacing traditional machining methods.Net shape processing can produce parts requiring little or no machining.
Traditional processes have experienced incredible improvements through improved tool materials and coatings,computer controls,material handling,etc.As a result,even where conventional metal cutting and forming are used,it can be done much more effectively.A single modern machine may replace a variety of specialized equipment and will provide output that would have required several machines in earlier machine shop.

6.The consumer concept and production planning

The technical changes decribed above have been acceleretad by the consumer philosophy:The basic marketing strategy,which follows heavy competitions in all industrial branches,is based on positive respond to most client wishes as technical and time delivery are concerned.It has led to new ways of production,characterised by adoption of all possible means leading to quick and flexible respod to customers wishes:computer aided design,new machine design and flexible manufacturing.
Under these circumstances new mechanical concpets for multioperational machines or connection of different processes have been adopted.The idea of small batch production,integration

of processes and optimization of handling was generally accepted and enabled by using new computer control for real time management and process planning.
The influence of the new consumer oriented strategy has changed the primary processes of metal cutting and metal forming The classical bounderies between these two basic technologies from the point of applications are not so clear as they used to be.

7.Metal cutting versus metal forming

Machining using metal cutting stays as a major production method applied in the industry.Considering the worldwide production of machine tools in 1992 compared to previous years,only very small increas of metall forming machines in proportion to metalcutting may be seen.In this point the forcasts made in the previous dacade have not been entirely fulfilled.Table 1 ilustrates the ratio of cutting and forming machines in 1991 and 1992 (estimated):

	1991(%)		1992(%)	
	cutting	forming	cutting	forming
Japan	81	19	78	22
Germany	68	32	65	35
USA	69	31	72	28
Italy	67	33	64	36
China	77	23	76	24
Taiwan	70	30	70	30
Singapore	89	11	88	12
Czechoslovakia	75	25	75	25

Table 1 :World wide machine tool production,ratio between metal cutting and metal forming

The last two years have seen no changes in the distribution between cutting and forming.When we compare the current situation to 1985 we may see only a small increase in favour for metal forming,as ilustrated on Table 2.The most important is the increase of metal forming machines production in USA.

	1985(%)		1991(%)	
	cutting	forming	cutting	forming
Japan	81	19	81	19
Germany	70	30	68	32
USA	75	25	69	31
world wide production	78	22	71	29

Table 2:Recent changes in metal cutting and metal forming machines distribution.

It should be noted that 1992 statistics ilustrates the world crises in machine tool production.The decline of production world wide is substantial:it has dropped for 19% in metal cutting machines produced and for 20% in metal forming machines produced, compared to 1991.

The world crises of all sectors of industry which has been following the major political changes in the world,characterized by the fall of Soviet Union and recent heavy reduction of arms production has cooled down the rise of high sophiticated manufacturing technology.Plans for advanced computerised manufacturing systems or computer integrated manufacturing had to be postponed,cancelled or modified.More realistic and generally more economic solutions are currently used.In agreement with previously described changes,the general demand for machines and industrial equipment have been reduced and the existing

production capacities in Europe,USA and Japan are superfluous.Current demand for economical machines grows, only lower investment is accepted.High productivity and high quality production must be ensured.Reliable computer control is becomming a standard - but only necessary and economical parameters are demanded.Unmanned production is not pointed out just now
This is considered as temoprary situation but it gives signal that only economical solutions in development of new machining methods wil be accepted.

8.<u>The lasers place today</u>

Since industrial lasers,especially for metal cutting,have become common,they probably no longer belong in the "non traditional machining" category.There are companies that have hundreds of lasers in production and many companies that have tens of lasers manufacturing a broad range of products.Some laser users have tens of thousends of manufacturing hours on individual laser cutting machines.
Where early laser cutting machines were all of similiar design,there exist today a variety of machine designes available to potential users.These machines include the sheet grabber (it grabes the sheet and moves it)the moving table design (the part is held on the table and moved),the moving beam design and the hybrid machines.
The usefulness of laser cutting machines is shown in the diversity of jobs that they run.These machines produce items as diverse as short run automotive dies,french fryers etc.As more manufacturing companies implement Just in Time inventory management,it is expected that they will start using laser cutting to meet the need for minimum inventory and still give customers fast delivery.With laser cutting is no "hard tooling" - only software proamming is required.This makes changing of production easy.The need to maintain a large material inventory is diminished.

A newer solution is an imaging device integrated into laser cutter.Sheets are punched on a press and then brought over to the laser.A CCD camera locates a pair of holes on each sheet and rereferences the axes to correspond the press.Contour cutting is then performed to close tolerances by the laser.
As for industrial laser machining,the high power,solid state industrial laser are being used.Machine tool producers are graduallly adopting the idea of multiprofessional machines where laser machining is used together with metal cutting.Laser machining is still at its beginning and it finds aplications for machining of special metals,where other machining methods cannot be applied.

9.Water and abrasive jets

What makes traditional machining vulnerable to the influx of new non-traditional machining?New materials which are difficult to work using traditional machining methods is one factor.Another is the elimination of indirect costs such as tooling,NC programming,set-up time and scrap due to mistakes.
The most obvious application for a new or non-traditional machining or cutting method is that of solving cutting problem.The introduction of many new manmade materials led to many problems connected with their machining.
KEVLAR,broadly used now is a good example of enhanced cut quality, increased speed and elimination of process steps.Normal machining methods are useless for this material.
The abrasivejet,which combines an abrasive with the waterjet stream is capable of cutting most materials.
The diversity of materials that can be cut with abrasivejet is outstanding.All types of metals including titanium to 200 mm thick,manmade materials such as kevlar and graphite fibre components have been cut with the abrasivejet.
Reduction of processes steps is often a benefit of using abrasivejet.This is demonstrated with methods comparison of

producing a 100 mm diameter hole in 50 mm thick tool steel.Table 3 indicates a lower cost and reduced lead time compared to traditional machining and wire EDM.

step	traditional machining	abrasivejet	wire EDM
comments	standard equipment	31000 $ abrasivejet	125000$ EDM
material saving	none	slug	slug
cut hole	2 hours-60$	0.5 hour-9$	8 hours-23$
heat treat	1 to 3 day	not req'd	not req'd
finish grind	2 hours	2 hours	not req'd
total cost	210$	93$	168$
	2-4 days lead	2.5 hours lead	8 hours lead

Table 3:Comparison of methods

10.Electrochemical and electro discharge machining

Electro-discharge machining (EDM) and electrochemical machining (ECM) processes are presently being used in industries to meet challanges posed by machining,deburring and grinding of advanced materials.

EDM is a process of removing material in a closely controlled manner from an electrically conductive material immersed in a liquid dielectric with a series of non-stationary and transient electric sparks or discharges. The tools electrode (usually of softer material) generates its mirror image on the harder workpiece if an appropriate gap is continuously maintained.The erosion of work material is independent of mechanical properties of the workpiece.As the tool is made of softer material such as graphite or copper,close tolerances even for complex parts (such as precision components required in the production of integrated circuits in the electronic industry) can be achived.However slow machining rate,arcing and resulting surface damaging are main disadvatages of EDM process.

In ECM the passage of the direct current between two electrodes (anode-workpiece,cathode-tool)immersed in an electrolyte results in the dissolution of work material and evolution of gas at the catode.High machining rate and smooth,damage-free surface finishes are possible with ECM.The main disadvatages with ECM are poor geometric tolerances and difficoulties of appropriate tool design.

Recently,various versions of a process that combines the basic features of EDM and ECM have been proposed conceptually.This combined process is called Electrochemical arc machining (ECAM) or Electrochemical discharge machining (ECDM).

ECAM has a great potential for applications in long-hole drilling,smoothing of roughly machined surfaces,turning and wire cutting.

11.Conclusion

As it has been seen the new trends are heading to diversification of machining methods.Under the influence of market economy and political changes the general shape of industries is gradually being charged.Basically, with new man made materials and net shape processes in conjuction with reduction of mechanical components due to wide applications of electronics the machining processes are and will be loosing their priority in manufacturing.

New manufacturing methods used for new materials will be gaining on the importance. That is the outlook for next decades. In the current situation it should be pointed out that the crises of the world industries will influence the producers to accept the most economical solutions of newly developped methods and processes.The expected outcome of new high-tech methods may be slowed down in this connection.

Under these cirumstances the machining using traditional methods like cutting and forming will keep its importance for a long time.

For strategic decissions it is necessary to take in to conciderations all the above described outcomes.It is obvious that the classical boundaries for applying classical machining methods are changed.Production volumes are not the only criterion for choosing appropriate manufacturing method.More important influence gain flexibility and cost effectivness.Particular cases must be individually concidered to chose optimal way of production.It is probably no need to remark that in great majority of cases the conventional manufacturing ways are currently still the most economical ones.

The strategic decissions concerning the future should take in acount described trends which are stressing new materials and new nontraditional ways of machining.

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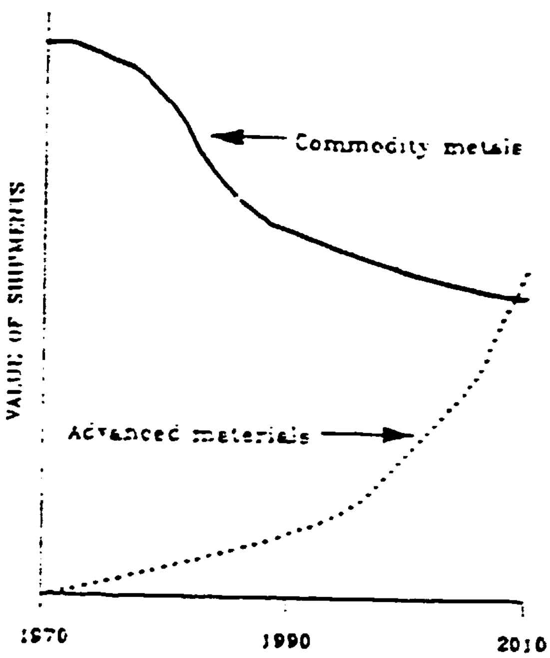

Figure 1. Material Changes

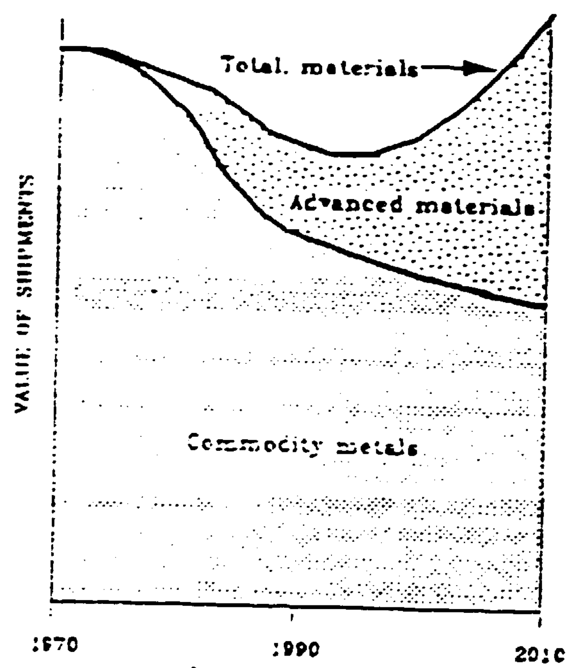

Figure 2. Overall Material Usage

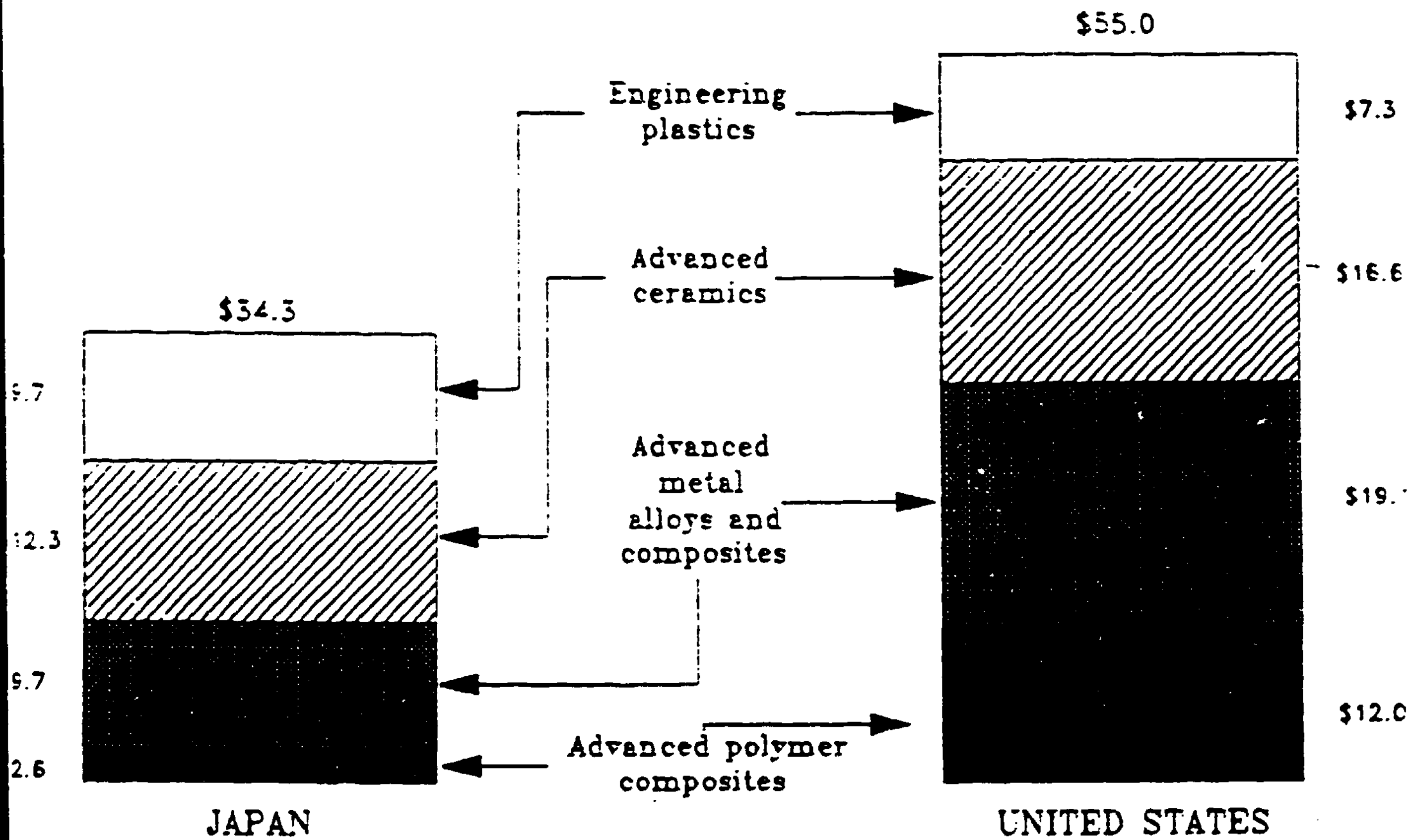

Figure 3. Advanced Materials: Forecast Markets in the United States and Japan in the Year 2000 (in billion dollars)

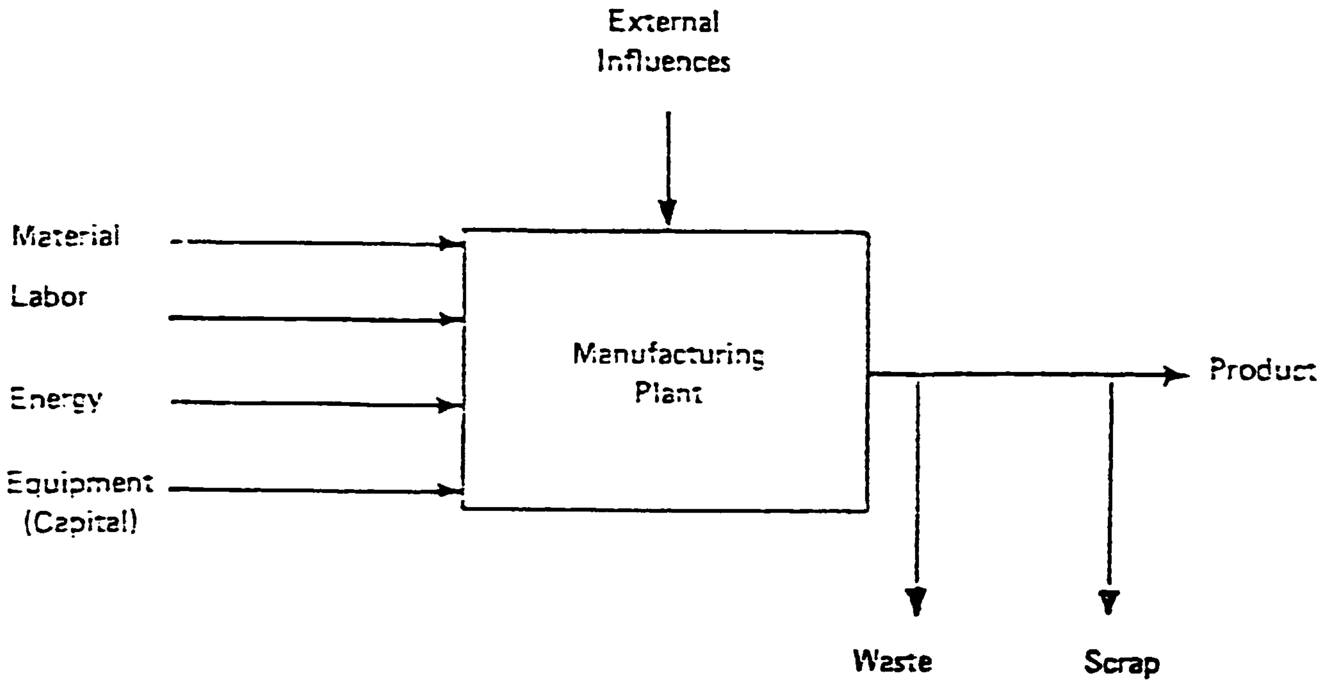

Figure 4. A Manufacturing System.

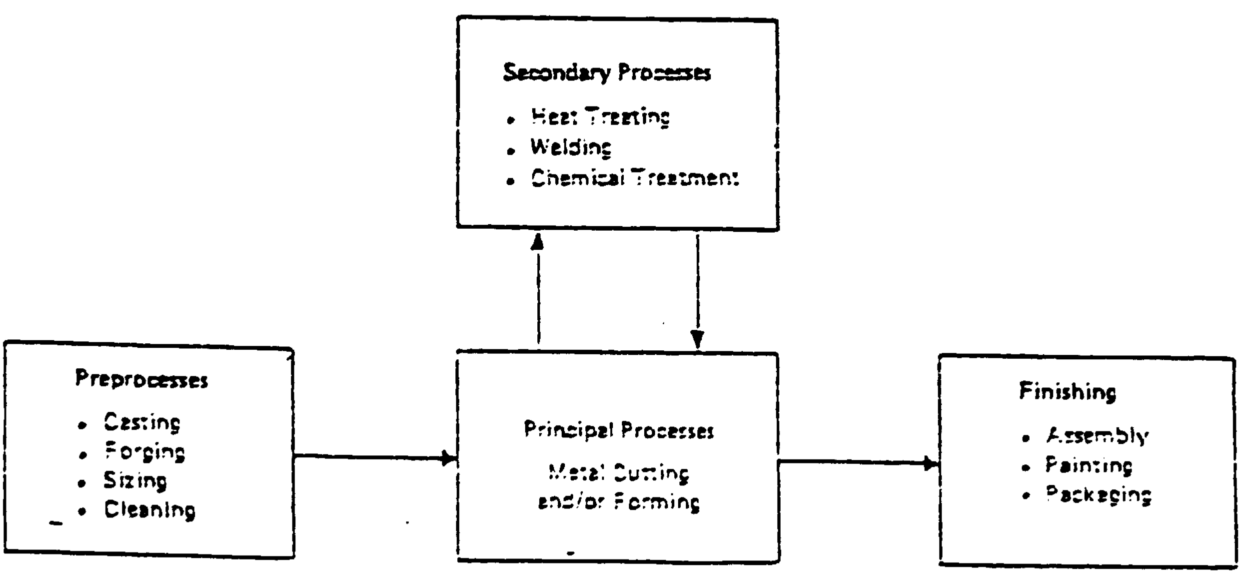

Figure 5. Extended View of Machining.

OTHER TECHNICAL DOCUMENTS

Jaroslav Bauer, M.Sc.

MACHINE TOOLS TESTING

(Lecture for inspectors)

Environmental conditions for tests

- shall correspond to the technical specifications of the machine under test
- for all the accuracy testts the temperature of environment should be 20°C,
  - for some machineswith the high accuracy the temperature shall be 20°C - air conditionong rooms
  - for another the temperature may differ from 20°C
  - in any case the changes of temperature of environment should not change more than ± 2° C during the measurement

Measuring equipment

- shall be suitable for the measurement from the point of view of - arrangement on the machine
  - accuracy
- shall be perodically calibrated (metrology organization and activities)

Tests

1 Function of the machine

All teh functions and their combinations in the whole range and in all machine modes shall be verified

- The manual control mode - function of all control actuators and the responses of the machine
- The automatic control mode - testing program which contains all the functions, their changes and possible combinations
- The step by step mode - the same programe as for the automatic control mode

2 Tecnical specification of the machine

The technical specification shall be verified.

Especially it should be verified - lengths of machine parts strokes (table e.t.c)

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- The step by step mode - the same programe as for the automatic control mode

2 Tecnical specification of the machine

The technical specification shall be verified.

Especially it should be verified - lengths of machine parts strokes (table e.t.c)

- velocities of spindle rotation (RPM)
- feed rate
- max. dimensions of workpiece

3 Important machine parts

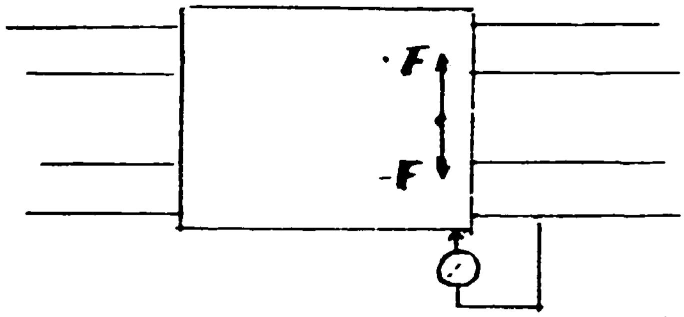
3.1 Guideways

The quality of guideways shall be verified. Especially it should be verified-

- if the surface of the guide ways is not damaged (no scrapes or another shortcomings)
- the wipers (or covers) of guideways are not damaged, and if their function is good.

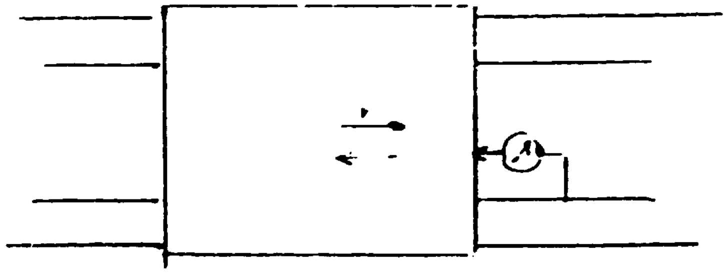
Note - from the quality of guideways it is possible to recognise the quality of the maintenance'

- the backlash in the guideways



3.2 Drives

The fluency of the movement of feed drive (positioned part) shall be verified, when the min. velocity (feed rate) is used



No stick slip motion should appear (the hand of the dial gauge should not stop)

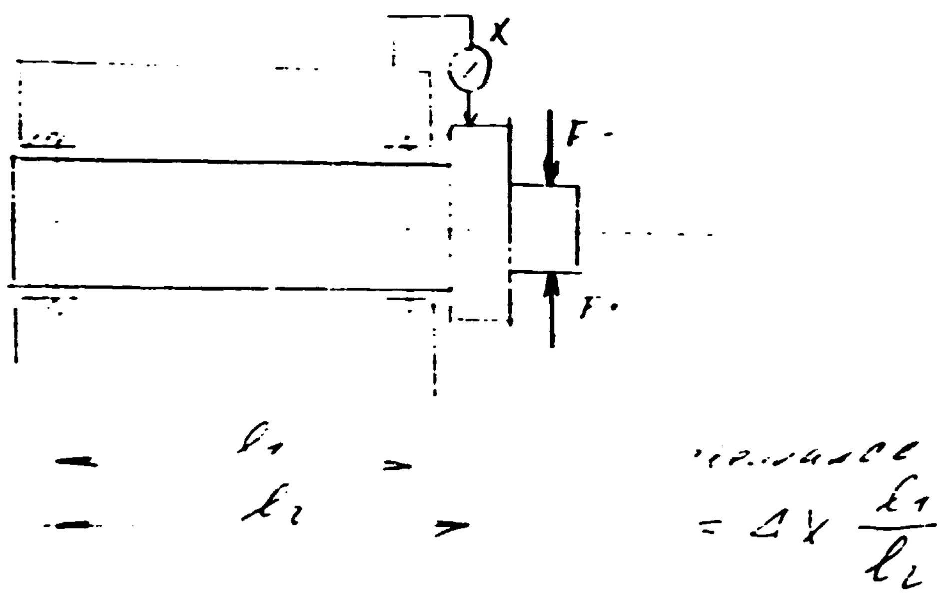
3.3 Cooling equipment

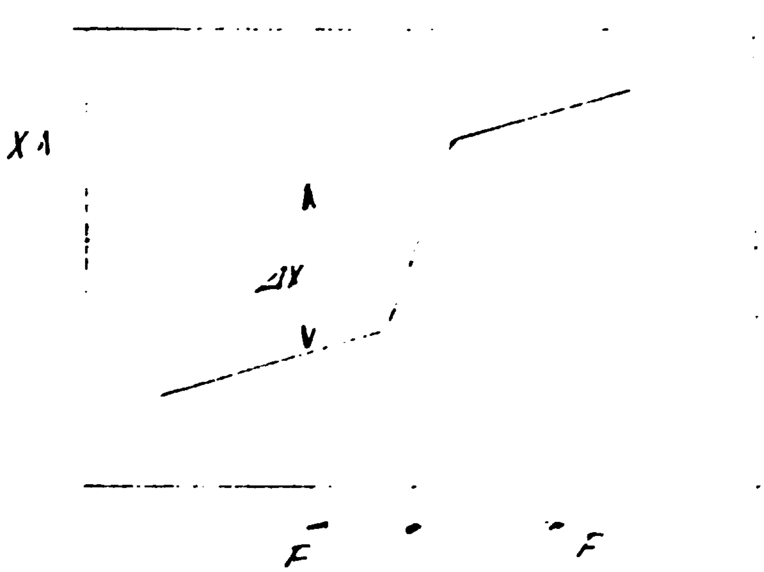
Especially it should be verified:

- if it is possible to adjust the flow of the coolant to all points of cutting process
- if it is possible to adjust the quantity of the coolant which flows to the point of cutting process

3.4 Spindle

The proper adjustment of the spindle bearings shall be verified. Especially the clearance in the front bearing should be measured.





4 Accuracy

Accuracy is one of the most important properties of the machine tools.

4.1 Geometric accuracy

Geometric accuracy - the accuracy of the shapes, relative positions and relative movements of the machine parts

It should be tested according to the national standards for particular types of machine tools. These standards should correspond to the ISO standard - acceptance conditions for particular type of the machine - permissible deviations.

The base for all the measurements is standard ISO 230-1 Acceptance code for machine tools, part 1 _ Geometric accuracy of machines operating under no load or finishing conditions

In this standard - conditions of measurement
- definitions related to the geometrical checks
- methods of measurement

Test conditions

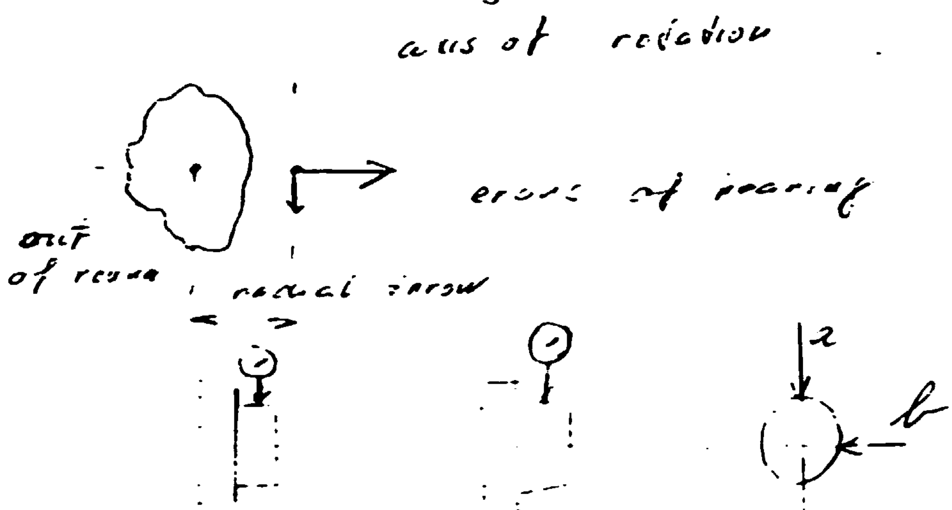
Instalation of the machine - foundation according to technical specification
- leveling of the machine according to the manufacturer instructions

Temperature of the machine - all the components (spindle) which are liable to warm up and consequently to change position or shape shall be brought to the correct temperature by running the machine idle in accordance with the condition of use and the instructions of manufacturer (user)
- another tests - cold conditions (temperature of environment)

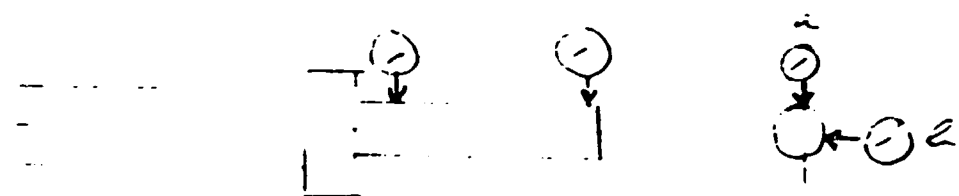
Definitions and measurement methods - most iportant

Run out - out of round - error relative to the circular form of the component

- radial throw of the axis of the part which does not coincide exactly with the axis of rotation
- the errors of bearings



Internal surface



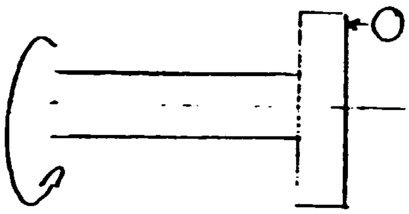
Periodic axial slip - extent of reciprocating motion along the axis of a rotating part

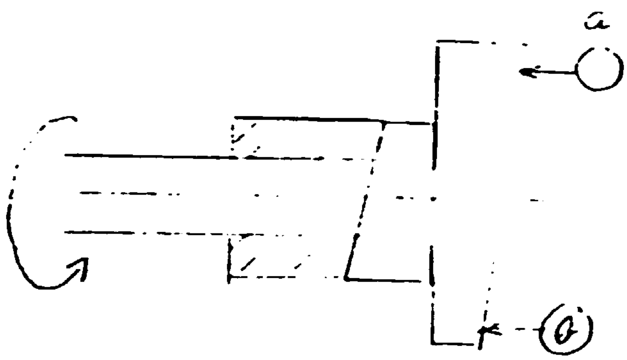
Camming - measuring on the axial surface
- is the resultant of various defect of the surface and axis of rotation

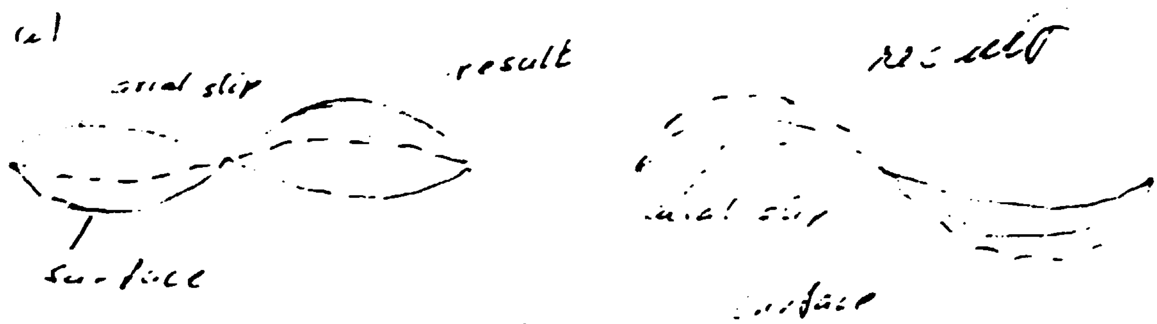
A) surface not flat

B) Surface and axis of rotation not perpendicular

C) Axial slip



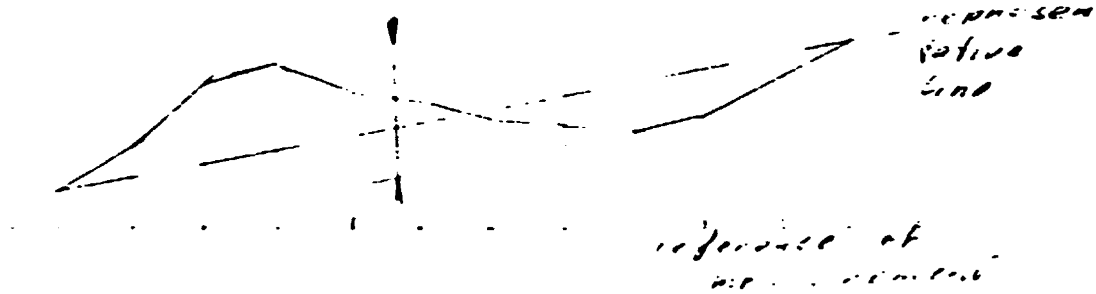


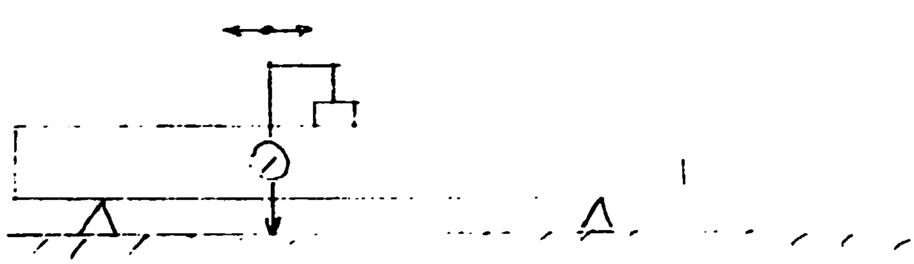


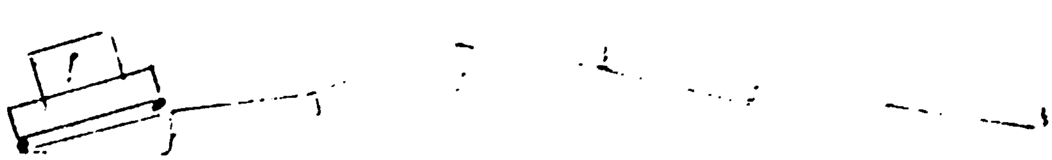
Straightness

A line located in a plane is deemed to be straight over a given length, whenall its points are contained between two straight lines parallel to the general direction of the line, whose distance apart is equal to the tolerance

The general direction of the line (representative line) shall be defined so as to minimize the staightness deviation. But it can be conventionally defined by two points chosen near the the ends of the line to be checked.



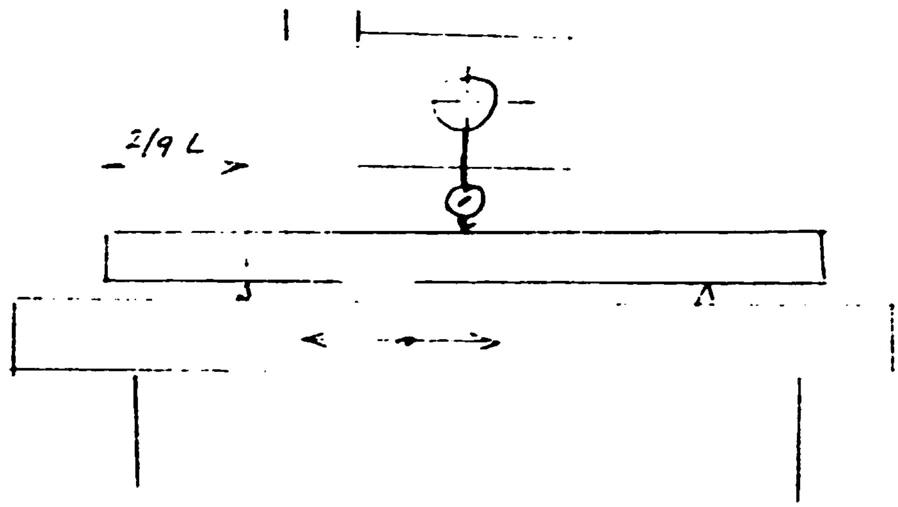


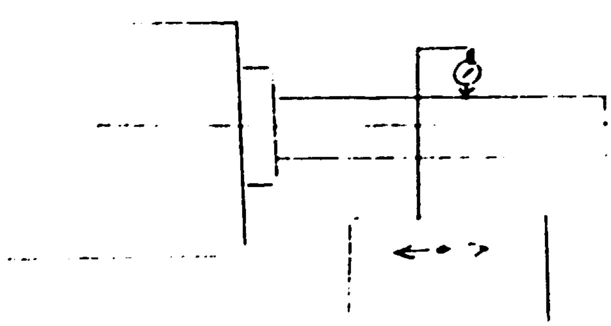


Straight line motion

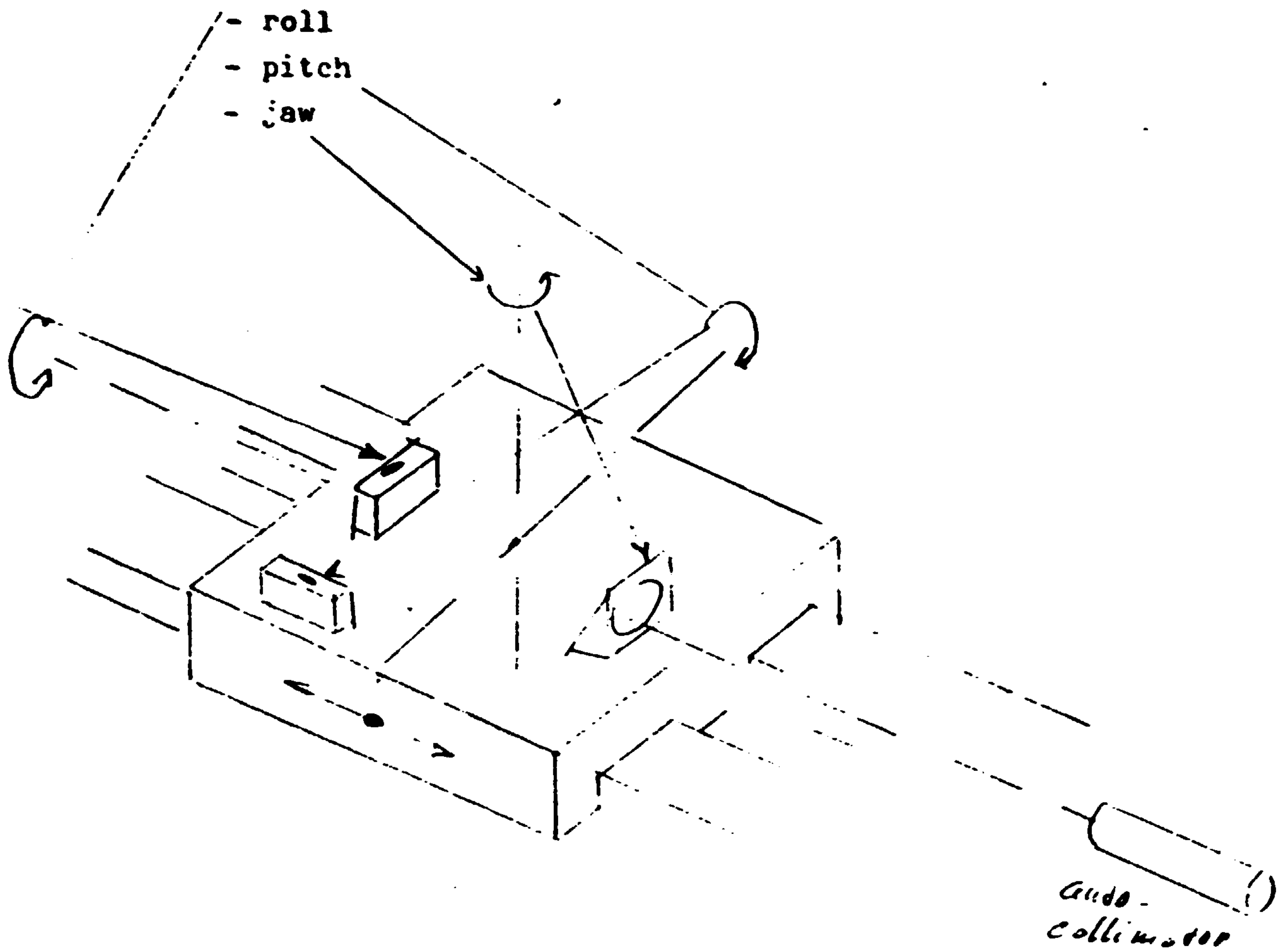
Linear deviation of straight line motion is defined by the straightness of the trajectory of the functional point or the representative point of the moving component - if the part carries the tool, the functional point is the position of the tool

When measured, the dial gauge shall be always placed in the position of the tool.



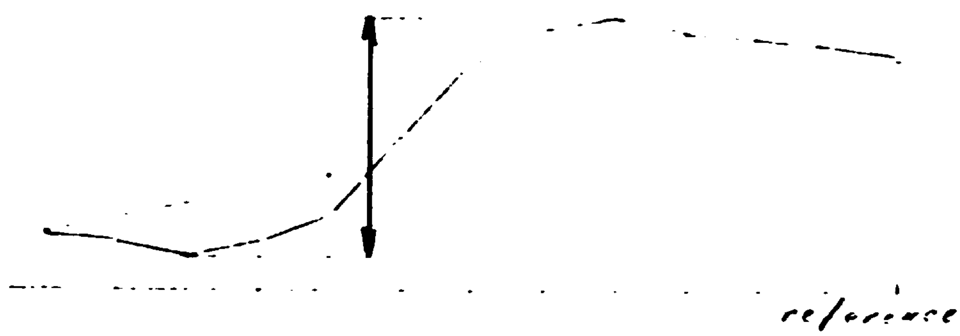


Angular deviations



Parallelism

A line is deemed to be parallel to the plane if, measuring the distance of this line from the representative line of intersection of the plane and the normal plane including the line at a number of points, the max. difference observed within a given range does not exceed the predeteminated value (tolerance)

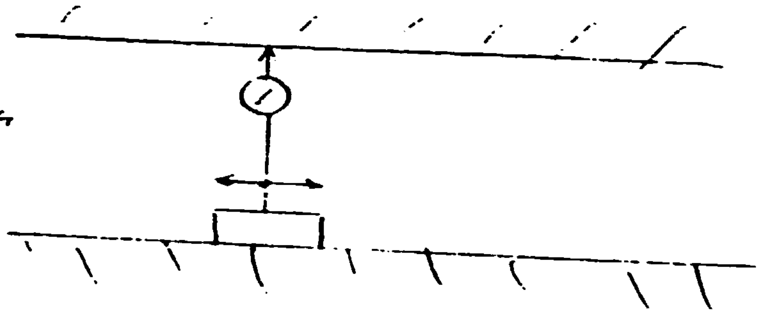


Parallelism of motion

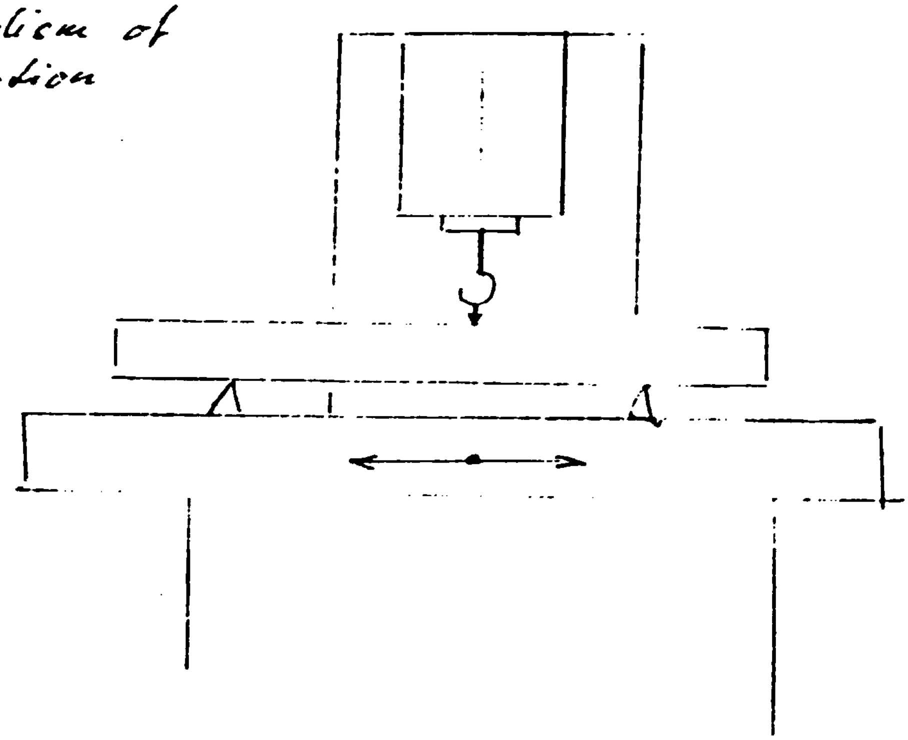
The term parallelism of motion referes to the position of the trajectory of the functional point of the moving part f the machine in relation to
- a plane
- a straight line (axis)
- a trajectory of a point of another moving part

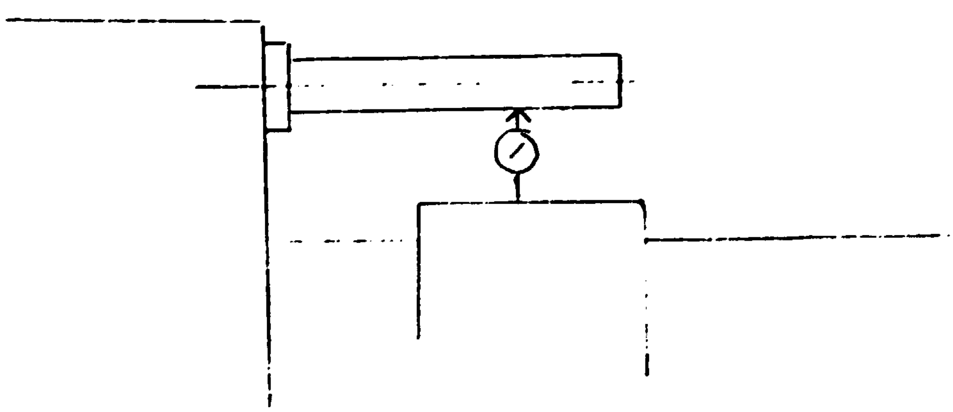
Important - parallelism includes straightness
- The unit of deviation is not the angle unit but the unit of length within a given range of distance (movement) on which was measured (mm over the length of...mm) (mm per .... mm)

Parallelism



Parallelism of motion

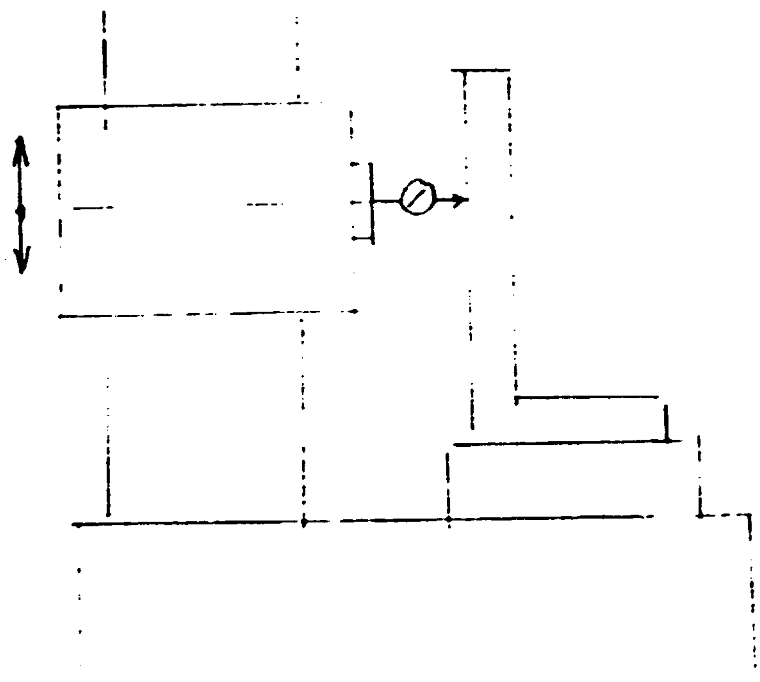




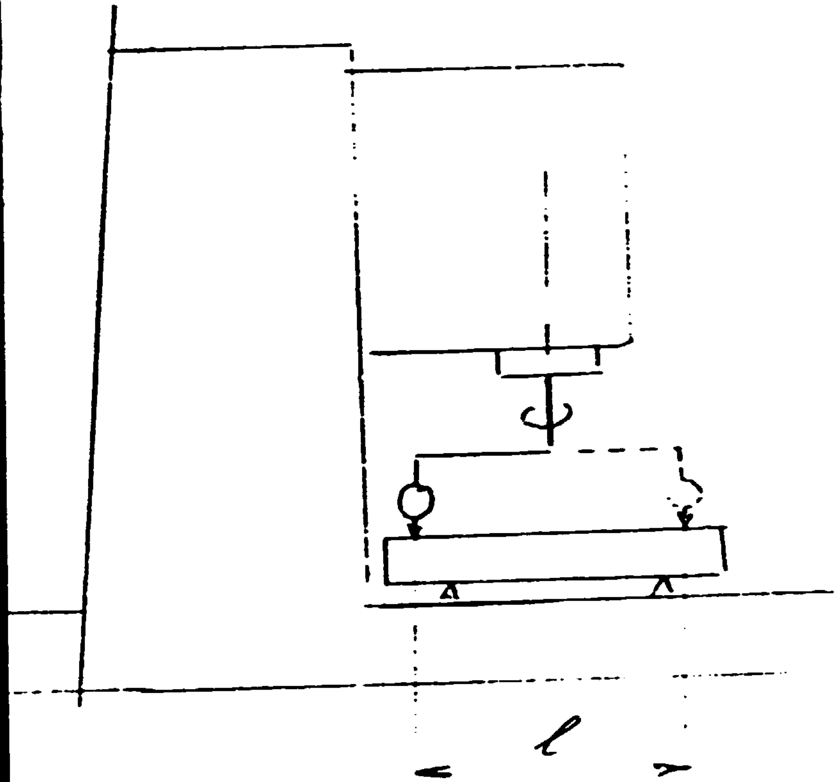
Squareness of straight lines and planes

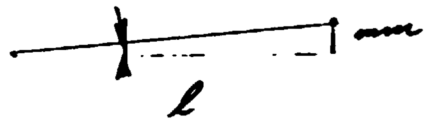
Two planes, two straight lines or a straight line and a plane are said to be perpendicular, when the deviation of parallelism in relation to the standard square does not exceed the predeterminated value

a) Squarness involves straightness
The unit of squarenes is not angle unit but the unit of length within a given range of distance (movement) measured - mm over the length of ...mm



b) squarness does not involve straightness





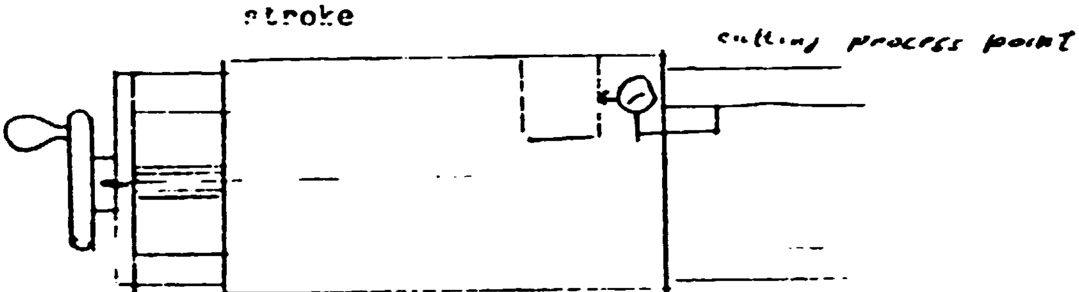
The unit of squarness is the angle unit mm/l

4.2 Repeatibility of positioning of manual controlled machine parts

The repeatibility of positioning of positioned machine parts beeing set several times (10 times) to the target position by means of positioning parts (hand wheels) shall be checked.

Note: The target position is the theoretical final position of the positioned part defined by means of control, in this case by means of positioning part (hand wheel)

Measuring - the difference between the actual position and some selected position (usually the first actual position) is measured - (Δx) n times in three positions of positioned part (1/5, 1/2 and 4/5 of the length of the stroke



Evaluation

Repeatibility of positioning

$$R = 4\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta x_i - \overline{\Delta x})^2}$$

where

n..... number of measurements (10)

Δx_i.... difference of position for particular measurement i (i=1 ÷ n)

$\overline{\Delta x}$ .... average of differences measured

$$\overline{\Delta x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The repeatibility found should be in the conformity with the technical specification of machine or with the recommended values - see Annex A - General directives for inspection

4.3 Repeatibility of positioning of positioned machine parts when the position control system with dogs or stops is used

The measurement and evaluation is the same as for manual control

4.4 <u>Accuracy and repeatibility of positioning of NC machines</u>

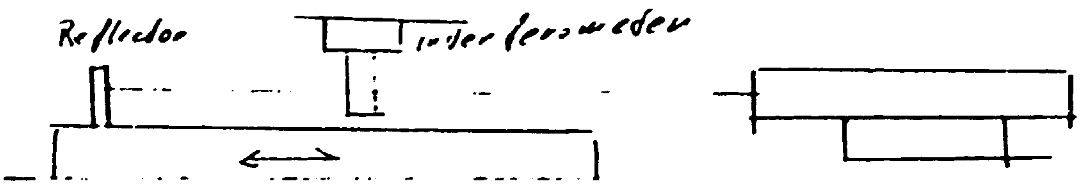
The measurement shall be carried out according to the ISO 230 - 2 Acceptance code for machine tools - Part 2: Determination of accuracy and repeatibility of positioning of numerically controled machine tools

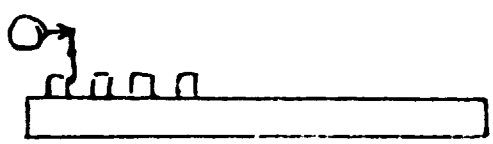
Note - the standard is under ravision - nearly finished.

According to the last draft

Conditions - at the begining of the measurement the machine is in the cold conditions (temperature corresponds to the temperature of environment

Measurement - Laserinterferometer
- optical scale
-step gauge





Linear movement - minimum 5 target position on the length of 2 m. The value of each target position can be freely chosen , the distance between two target positions should be

$P = (N - r)\ p$

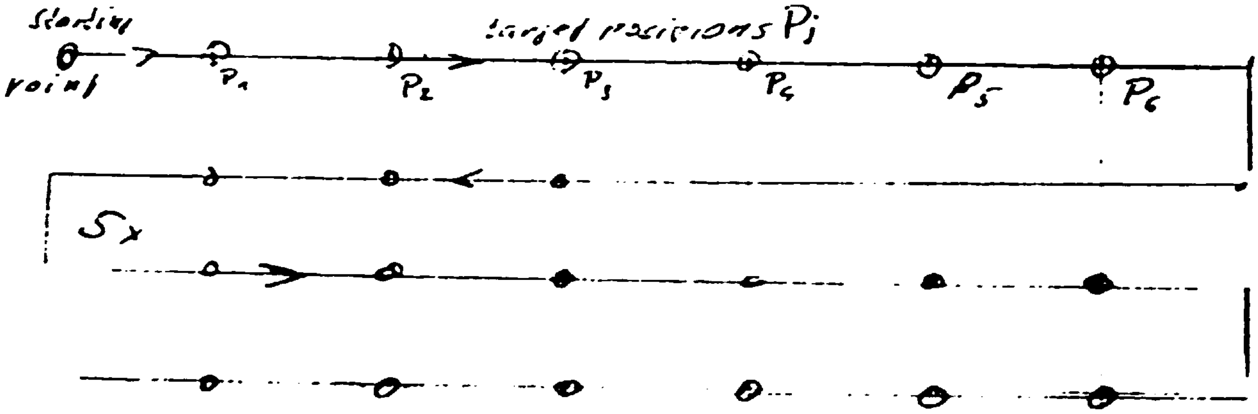
where N is an iteger

r is a random decimal fraction

p is the largest cyclic pich of the axis under test (e.g. one rotation of the measuring lead screw)

Rotary movement - minimum 8 positions inclluding 90°, 180°, 270° , 0° .

The measurement should be repeated 5 times in both direction of movement using "linear cycle"



The deviation of position is measured in each target position

P_j (j= 1 ÷ ... number of target positions)

$x_{ji} = P_{ji} - P_j$ P_{ji} actual position for i measurement in j target position

Evaluation

Then it is calculated:

The mean deviation of position in each target position for each direction separate

$$\bar{x}_j(+) = \frac{1}{5} \sum_{i=1}^{5} x_{ji}(+)$$

$$\bar{x}_j(-) = \frac{1}{5} \sum_{i=1}^{5} x_{ji}(-)$$

The reversal value for each target position

$$B_j = \bar{x}_j(+) - \bar{x}_j(-)$$

The estimator of the standard deviation for each target position, separately for both directions of movement

$$s_j(+) = \sqrt{\frac{1}{4} \sum_{i=1}^{5} (x_{ji}(+) - \bar{x}_j(+))^2}$$

$$s_j(-) = \sqrt{\frac{1}{4} \sum_{i=1}^{5} (x_{ji}(-) - \bar{x}_j(-))^2}$$

Unidirectional repeatability for each target position (separately for both directions)

$R_j(+) = 6s_j(+)$

$R_j(-) = 6s_j(-)$

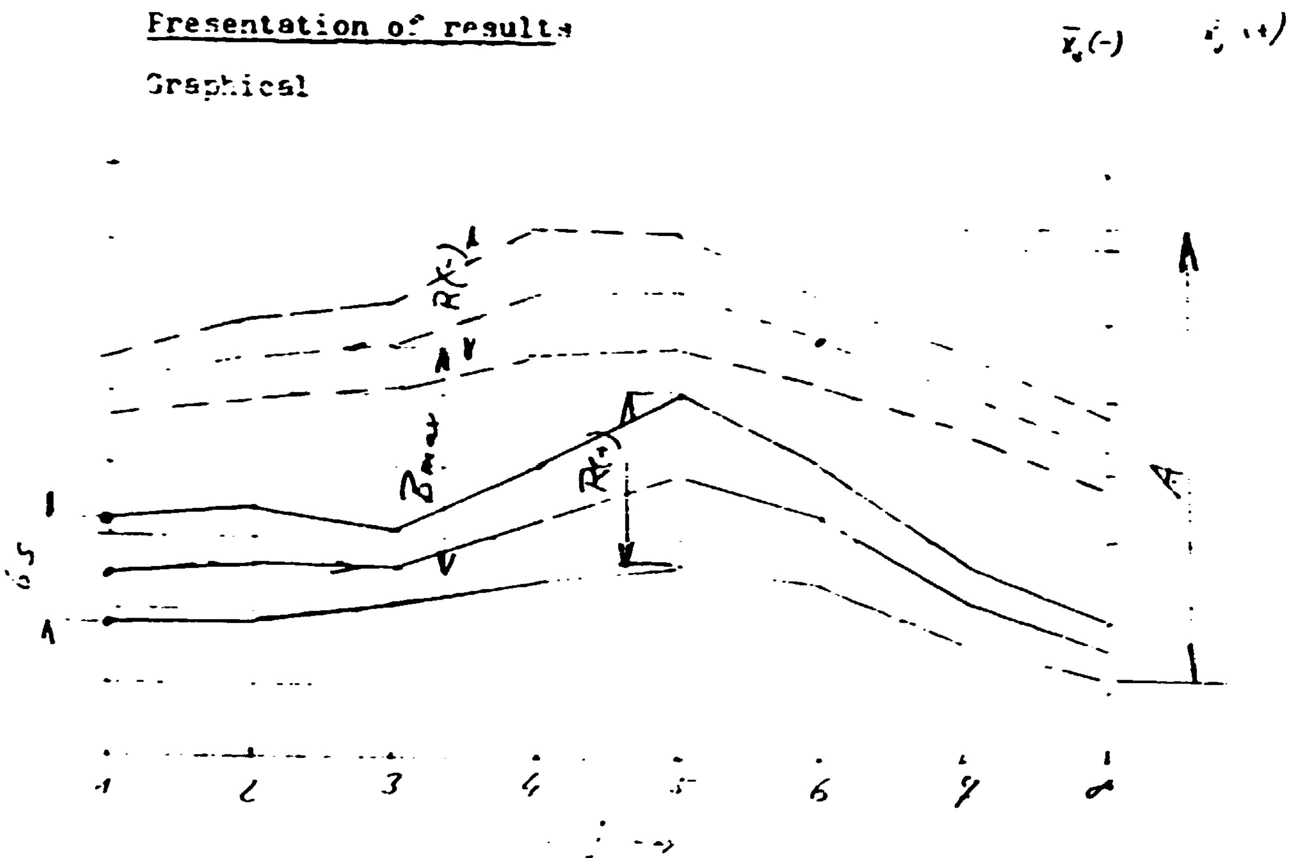
Maximum repeatability in both direction

$R(+)$ = max value of $R_i(+)$

$R(-)$ = max value of $R_i(-)$

<u>Presentation of results</u>

Graphical



Numerical

Unidirectional repeatability R (max value of R(+) and R(-))

Maximal reversal value B_{max} (max value of B_j)

Accuracy A - see fig

4.5 Linear interpolation

The accuracy of the resulting linear path that is produced by the simultaneous movements of two positioned parts in two linear axes (CNC control) shall be measured.

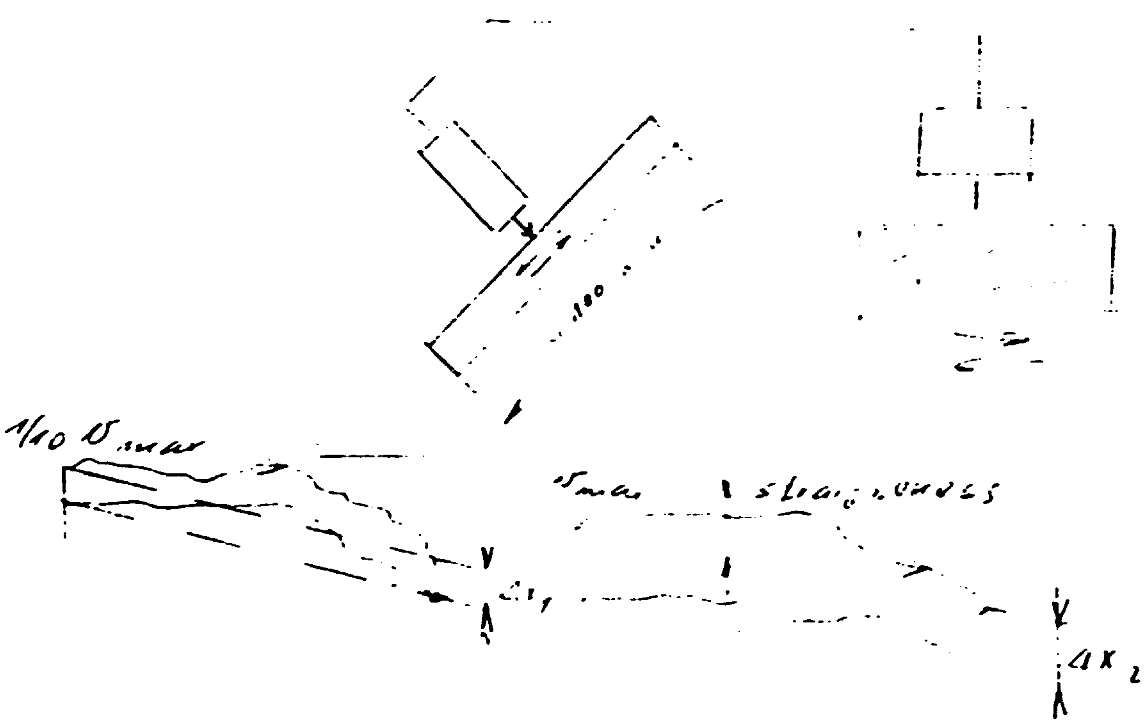
The inclination of the path to the axes - 45^0

The velocity of movement used - v_{max}

- $1/10\ v_{max}$

Measurement for both direction of movement without changing the arrangement of the measurement

The test should be carried out in all coordinate planes of the machine



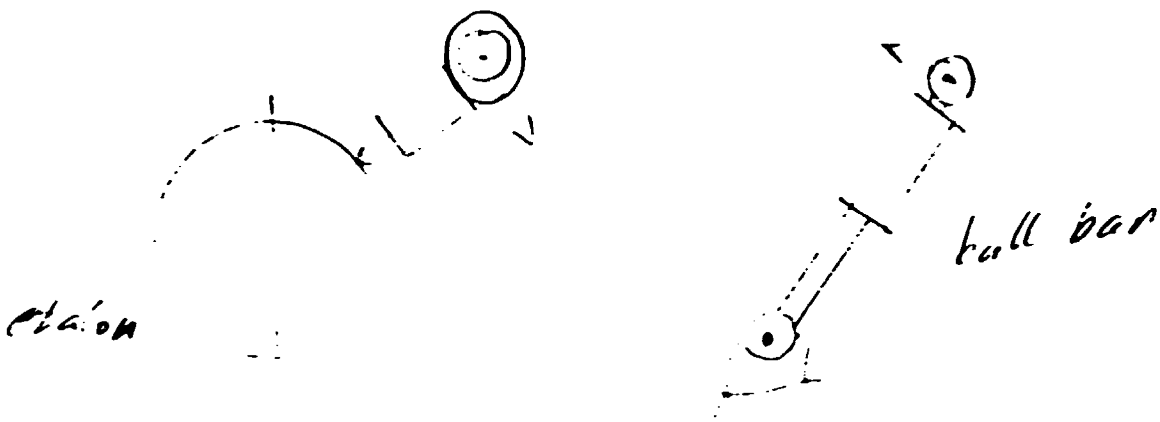
The difference of position of paths $\Delta x_2 - \Delta x_1$ should be max 20μm. If it is more, the velocity constant of amplification of the drives in action is not correct - it should be the same for all drives. (Foolowing error)

4.6 Circular interpolation

The accuracy of the circular path resulting that is produced by the simultaneous movements of two positioned parts in two axes shall be measured.

The measurement shall be carried out according to the ISO 230-4 Acceptance code for machine tools - Part 4: Circular tests for checking NC machines

Measurement



Evaluation

Circular deviation - The minimum radial separation of two concentric circles enveloping the actual path (minimum zone circles). It may be conventionally evaluated as the max. radial range around the least square circle

Circular hysterezis - max. radial difference between two actual paths, where one path is carried out by clockwise contouring and one by counter-clockwise

4.7 Practical tests

Practical tests on workpieces according to the ISO acceptance conditions for particular type of machine tools shall be carried out

5 Forced vibrations

The effective value of velocity and deviation of forced vibrations (caused by unbalanced machine rotating parts) shall be measured

Measurement - on the spindle head in the plane perpendicular to the spindle axis and pasing through front bearing in two directions perpendicular one to another

- all RPM available shall be used
- all equipment on the machine is switched on
- both the small balanced workpiece and the small balanced tool are clamped in positions