OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

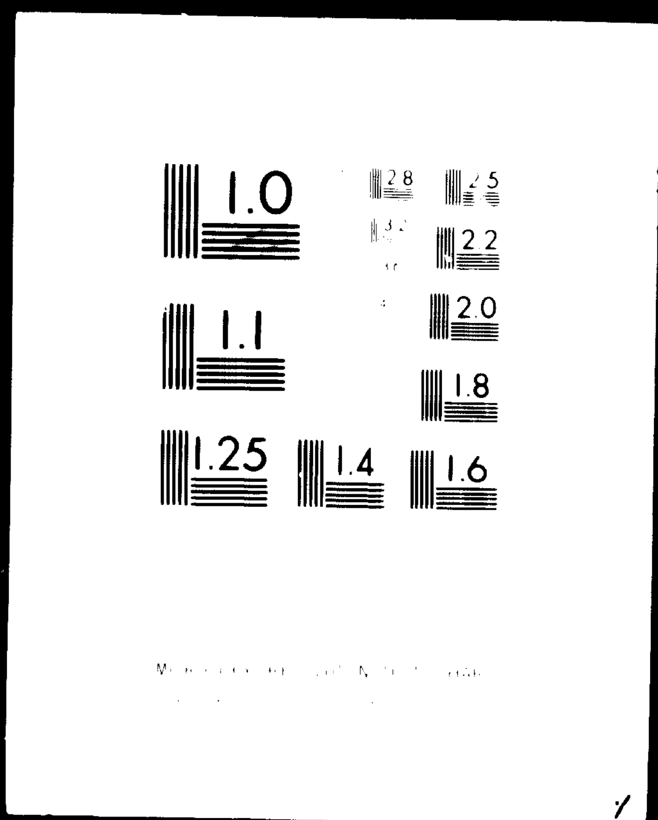
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

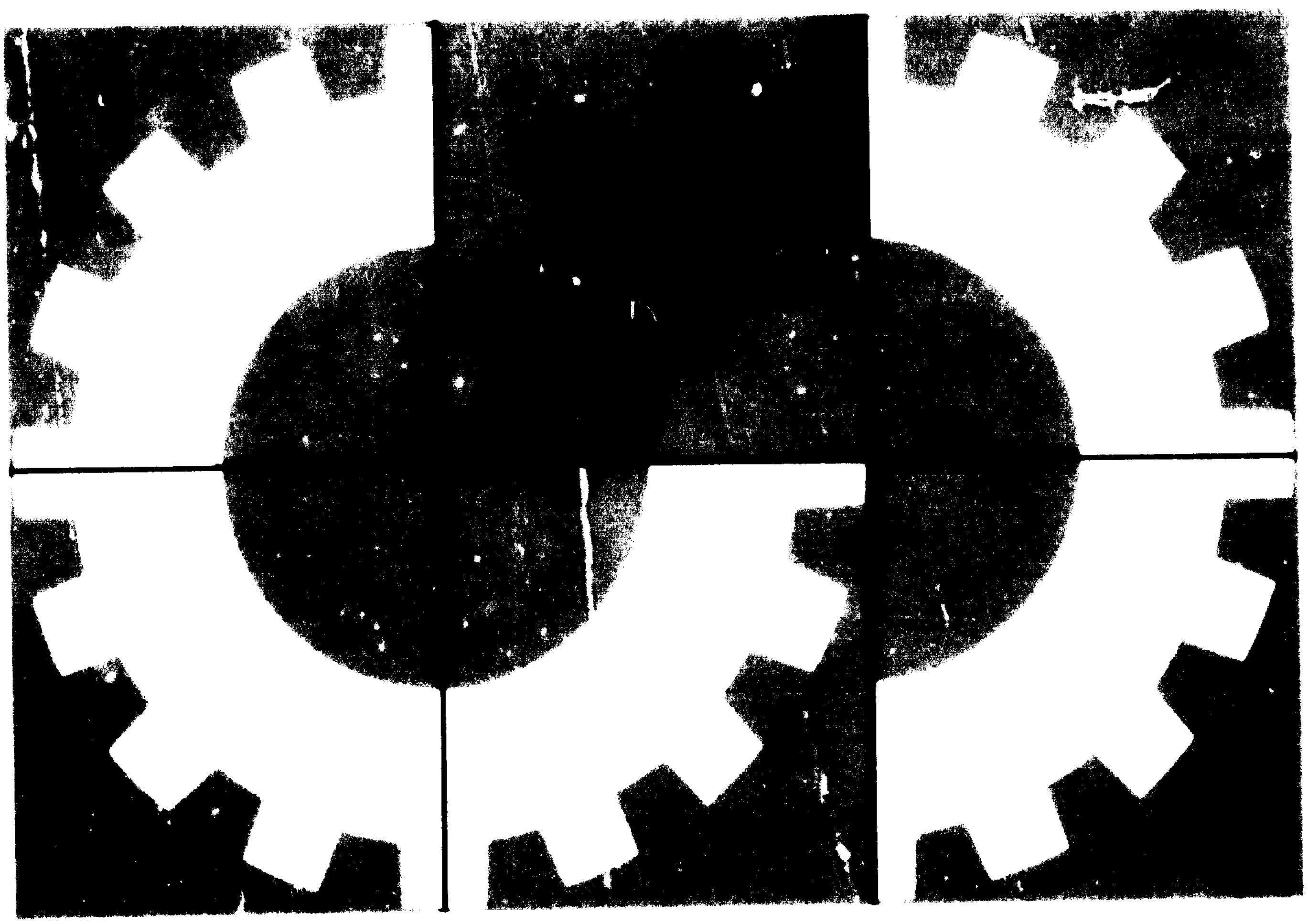
1 OF 1



24x
E

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

MACHINE TOOLS IN ASIA AND THE PACIFIC



UNITED NATIONS

MACHINE TOOLS IN ASIA AND THE PACIFIC

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

MACHINE TOOLS IN ASIA AND THE PACIFIC

UNITED NATIONS
New York, 1975

EXPLANATORY NOTES

A slash (/) between dates representing years indicates a crop year or financial year, e.g. 1971/72.

Reference to "tons" indicates metric tons, unless otherwise stated.

Reference to "dollars" ($) indicates United States dollars, unless otherwise stated.

The term "billion" is used to signify a thousand million.

The following forms are used in tables:

Three dots (. . .) indicate that data are not available or are not separately reported.

A dash ( ) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

ID/151
(ID/WG.187/25)

UNITED NATIONS PUBLICATION
Sales No.: E.75.II.B.4
Price: $U.S. 3.00 (or equivalent in other currencies)

Preface

At an Interregional Symposium on the Development of Metalworking Industries in Developing Countries held in Moscow in 1966 under the auspices of the United Nations, it was decided that a series of regional seminars would be held to examine the specific problems faced by the various regions in developing their metalworking industries. Special attention was given to the machine tool sector, which was recognized as being the key to the development of the metalworking industries. Accordingly, a series of regional seminars on the machine tool industry was planned by the United Nations Industrial Development Organization (UNIDO).

The first Seminar—on Machine Tools for Europe and the Middle East—was held in Bulgaria in 1971. This was followed by the Seminar on Machine Tools for Latin American Countries, held in Argentina and Brazil in 1972.

The third in the series, the Seminar on the Promotion and Development of the Machine Tool Industries in Countries of Asia and the Pacific, was held at Tbilisi, Georgia, USSR, from 5 to 13 October, and in Moscow, USSR, from 14 to 15 October, 1974.

The purpose of the Seminar was to analyse, through papers, films, discussions and factory visits, the technical and economic problems involved in the selection, production, utilization, maintenance and repair of machine tools and to provide an opportunity for the promotion of specific industrial projects related to machine tool industries in the countries of the Asia and Pacific region. Papers were presented by leading experts in their field, by UNIDO, and by other participants in the Seminar. The presentation of each paper was followed by detailed discussions on the application of the subject-matter in the countries of the region in general and in the countries represented at the Seminar in particular, consideration being given to the special conditions prevailing in those countries.

An insight into modern techniques and of experience gained in the creation and development of the industry in the USSR was gained through visits to the Kirov Machine Tool Building Plant at Tbilisi, where engine lathes, pipe-threading and cut-off machines are manufactured, to the Moscow Grinding Machine Tool Building Plant, and to the S. Ordjonikidze Plant for Production of Automatic Transfer Machine Tools, also in Moscow. Four films demonstrated the importance of replacing old machines with more modern types and provided information on modern technology.

General discussions among the participants brought suggestions for regional and international co-operation in the areas of financing, licensing, consulting; reconsideration of trade and investment policies; and provision of preferential duty arrangements for exports from developing countries. Such subjects as aid programmes, loans, and the preferability of establishing large enterprises in order to reduce production costs, were also examined, together with ideas for selecting the most suitable countries for the making of special types of machine tools. Training and the selection of the proper equipment needed to set up industries were also seen as areas requiring expert assistance. Early harmonization of plans was considered essential.

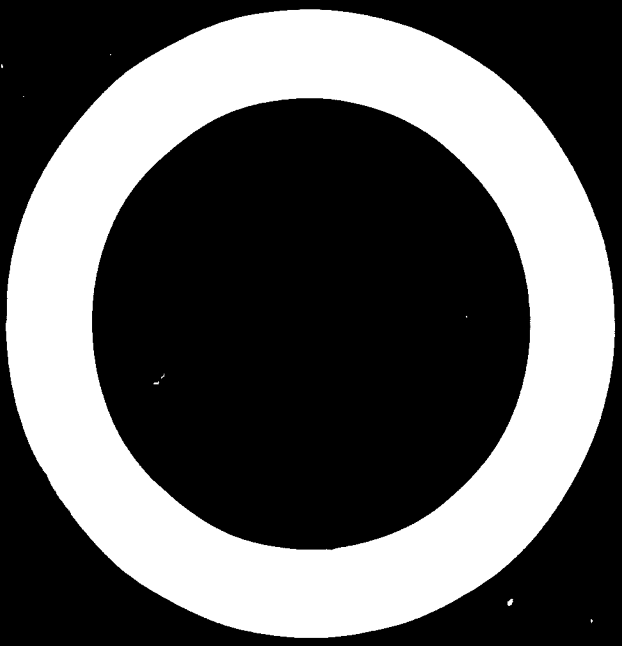
Part one of this publication is the report of the Tbilisi seminar. Part two is a monograph prepared by a UNIDO expert, Nikolai Krainov, on the problems of introducing numerically controlled (NC) machines into the developing countries, based on a paper presented to the NC Machine Tool Seminar organized by the Economic Commission for Europe (ECE) at Prague, Czechoslovakia, in November 1973.

CONTENTS

Part one

Report of a Seminar on the Promotion and Development of the Machine Tool Industries in Countries of Asia and the Pacific

held at
Tbilisi, Georgia, USSR,
5-13 October
and
Moscow, USSR,
14-15 October, 1974



I. ORGANIZATION OF THE SEMINAR

The Seminar was held under the auspices of UNIDO and the Government of the host country, the Union of Soviet Socialist Republics, in co-operation with the Economic and Social Commission for Asia and the Pacific (ESCAP).

It was attended by 58 representatives from 20 countries. They included representatives of UNIDO, ESCAP and the European Committee for the Co-operation of Machine Tool Industries (CECIMO).

T. N. Loladze (USSR) was elected Chairman; S. C. Banarjee (India) Vice Chairman; and R. Gabriel (United Kingdom of Great Britain and Northern Ireland) Rapporteur of the Seminar. A drafting committee consisting of T. N. Loladze, S. C. Banarjee, R. Gabriel, S. M. Lam and M. H. Siddique was appointed to prepare the report of the Seminar.

At the opening session, statements were presented by J. Cyranski and N. N. Krainov (UNIDO); O. E. Cherkesia, Deputy Prime Minister of the Georgian Soviet Socialist Republic; V. P. Naumov, State Committee of the USSR Council of Ministers on External Relations; and Y. S. Yakovlav, State Committee of the USSR Council of Ministers on Science and Technology.

J. Cyranski and N. N. Krainov both emphasized the importance of the machine tool industry to the developing countries and drew attention to the opportunities afforded by the Seminar itself for private bilateral discussions between representatives from both industrialized and developing countries. V. P. Naumov spoke of agreements between the USSR and the developing countries; 45 bilateral agreements already existed, including agreements with 20 countries of the ESCAP region, and more than 860 industrial projects were being initiated, out of which 420 had already been implemented and put into operation.

Investment promotion programme

Concurrently with the Seminar, an investment promotion programme was organized to provide an opportunity for the promotion of specific industrial projects related to machine tools in countries of the region.

Participants from a number of countries submitted projects they wished to promote and for which they would require industrial co-operation. UNIDO arranged, upon request, meetings among parties interested in discussing prospects for co-operation on these projects and on other matters of mutual interest.

Altogether, some 76 private discussions were held between representatives of the industrialized countries (and of those developing countries which already have a substantial machine tool industry) and representatives of the developing countries.

The talks covered a wide range of subjects, including the possibilities of:

(a) Establishing machine tool companies in developing countries, with 100 per cent foreign investment;

(b) Launching joint ventures with varying percentages of local investment;

(c) Drawing up new licence or know-how contracts, or expanding existing ones;

(d) Contracting for the purchase of machine tools built in the developing countries for export to world markets.

The participants felt that the direct cont^cts established and the business talks initiated during the promotional activities were very useful; those promising success would be actively followed up after the Seminar. In a number of cases, representatives of the industrialized countries announced plan. to visit certain developing countries for further discussions and to investigate collaboration possibilities.

II. FINDINGS OF THE SEMINAR

The importance of machine tools was fully recognized by all countries participating in the Seminar. The stage of development reached with regard to the production or utilization of machine tools varied considerably from country to country, however. In some developing countries of the Asia and Pacific region, a very high standard of quality and technology had been achieved, making the products competitive in world markets; in others the standard met only the requirements of the smaller local companies, which did not demand exacting standards of reliability and accuracy.

In the case of the first group of countries, there is good potential for co-operative manufacturing or sales ventures with machine tool companies in the industrialized countries. This co-operation may take the form of the joint manufacturing of machines designed in the industrialized country, or the joint marketing of machines designed and manufactured in the developing country. In order to develop this co-operation more rapidly, one European company is currently seeking to establish an industrial estate for machine tool manufacture in the region.

In the case of the second group of countries, considerable benefit could result from know-how or joint venture agreements under the terms of which most of the products would be sold in the developing country and the rest exported to neighbouring developing countries.

The importance of market research is not fully appreciated by the countries of the region. The dual problem of shortage of adequate statistics and lack of personnel trained in capital goods market research requires urgent attention.

Those countries which have not yet established machine tool industries should, before making any decisions to do so, arrange for a high-level team of financial, management and technical experts to study in depth their engineering industries. The team should also assess the desirability of establishing a machine tool industry, bearing in mind that a machine tool industry requires a supply of highly skilled workers and technicians who might be more beneficially employed in the servicing departments of other engineering operations.

There is a serious shortage of staff trained in the use of advanced technology such as numerical control (NC) in the region. This, however, could be remedied by the establishment of a regional NC demonstration centre.

It was noted that programmes of co-operation for the development and expansion of their machine tool industries already existed between some of the countries of the region. The Seminar offered an opportunity to further this desirable trend of self-help.

Expected demand for machine tools was examined in the light of experience reported and statistics prepared by ESCAP and UNIDO showing imports and exports of machine tools and machinery within the region, the growth of the engineering industry, population figures, national incomes, and annual rates of growth. For 10 countries–Laos, Indonesia, Khmer Republic, Malaysia, Philippines, Republic of Korea, Republic of Viet-Nam, Sri Lanka, Singapore, and Thailand–the projection was that machine tool demand would reach nearly $300 million by 1980, compared with about $150 million in 1970, both figures representing an average of 18.5 per cent of all machinery and equipment used.

Discussions of ways of meeting the demand revealed strong preference among participants from developing countries for manufacturing locally under licence, as compared with buying machine tools from other countries. This led to consideration of technical and investment co-operation programmes with organizations both within and outside the region.

III. SUGGESTIONS FOR FUTURE ACTION

On the basis of the papers presented at the Seminar and the subsequent discussions, a number of suggestions for future action in the Asia and Pacific region were formulated.

It was suggested that the developing countries of the region:

(a) Establish research and development institutes, and an information centre, to investigate and answer technological and economic questions related to the specific problems of the metalworking industries of the region. The institutes would begin as small pilot organizations and be gradually expanded. UNIDO and ESCAP would indicate where they might be most effectively located;

(b) Adapt existing machinery, equipment and production methods to local needs;

(c) Establish standards for metalworking engineering products manufactured in the region.

It was suggested that the developed countries:

(a) Provide technical assistance to the developing countries of the region in the selection, production, utilization, maintenance, repair and rebuilding of machine tools by supplying experts to train local engineers and technicians;

(b) Accept trainees from the region;

(c) Supply information relevant to the development and application of machine tools in the region;

(d) Co-operate with UNIDO in providing technical assistance in the field of machine tools;

(e) Initiate or expand training courses and on-the-job training for machine operators, technicians and engineers from the developing countries of the region;

(f) Establish refresher courses for senior engineers.

It was suggested that UNIDO:

(a) Provide technical assistance in the promotion of metalworking and particularly machine tool building in countries of the region;

(b) Make expert assistance available to the countries of the region for the carrying out of comprehensive machine tool surveys, financial reviews and market research, and for advising on marketing strategy and the selection, application, maintenance and repair of machine tools;

(c) Provide fellowships in various technologies, such as metal forming and cutting;

(d) Provide assistance in the establishment of machine tool training centres in the developing countries of the region;

(e) Advise the developing countries on the purchase of technology through licensing and other arrangements, and on types of contracts available and related fees.

IV. REQUESTS FOR TECHNICAL ASSISTANCE FROM UNIDO

In the course of the Seminar, attention was called to various needs for technical assistance from UNIDO, as indicated below.

Bangladesh

Technical assistance in the field of management urgently required for the Bangladesh Machine Tool Factory.

Technical assistance in jig, fixture, mould and die design and manufacture.

India

Technical assistance in setting up an NC centre for metalworking industries in Bangalore.

Fellowships in modern machine tool design.

Malaysia

Services of an expert who would undertake a financial and technical survey prior to the establishment of a machine tool industry.

Services of an expert in maintenance and repair of machine tools.

Pakistan

Services of an expert in heat treatment of specialized tool steels and high-speed steel; would be attached to the Pakistan Industrial Technical Advisory Centre.

Services of an expert in tool design to train staff of the Pakistan Industrial Technical Advisory Centre.

Fellowships in machine tool design for the staff of the design department of the Pakistan Engineering Company.

Expertise in machine tool design for the Pakistan Machine Tool Factory.

Philippines

Designs for low-cost drill press, tool and cutter grinder, and 135 mm centre-height lathe suitable for vocational training schools and similar establishments.

Fellowships in machine tool design especially related to low-cost machines.

Assistance in preparing machine tool statistics in accordance with international nomenclature.

Singapore

Technical assistance in the planning and development of a foundry industry.

Sri Lanka

Assistance in training engineers in the design of machine tools, jigs, fixtures and dies.

Assistance in the development of a machine tool manufacturing and rebuilding programme, and in training the engineers and technicians necessary for its implementation.

Assistance in setting up a toolroom and heat treatment centre, and fellowships for engineers and technicians.

Thailand

Services of an expert who would carry out a general survey of the existing stock of machine tools, its utilization and possible development, keeping in mind the stage of development of the country's metalworking industries.

Services of an expert in the technology of machine tool manufacture, including design, selection of materials, manufacturing processes and quality control.

V. REVIEW OF WORLD MACHINE TOOL PRODUCTION AND TRADE

There is a continuously growing demand everywhere for the metal-cutting and metal-forming machine tools that are indispensable to the production and repair of the various new machines being introduced into all branches of industry. Machine tools play a key role in the expansion of industrial production since nearly all products are manufactured by machines of some sort; the machine tool is not an end product, *per se,* but it is the means of manufacturing the end product.

It is therefore interesting to note that in the principal machine tool producing countries of the world, even in the largest producer, the Federal Republic of Germany, production is quite insignificant in relation to the engineering industry as a whole. It is also noteworthy that the large producers also tend to be the largest importers. This indicates the international nature of the industry and its potential for the developing world; a developing country that can produce a good-quality product of modern design has a real possibility of selling it on the world markets, including those of the industrialized countries.

World machine tool production in 1972 totalled some $8.4 billion. The estimated production for 1973 was $10.6 billion, an increase of 25 per cent (although some of this may have been due to the shrinking value of the dollar).

Production of metal-cutting machines expanded a little more than that of metal-forming machines. Metal-cutting machines accounted for 73.4 per cent of the total production in 1973, as against 71.3 per cent in 1972.

Table 1 shows production and trade figures for most of the world's machine tool manufacturing countries in 1972 and 1973.

In addition to the above, production of machine tools in Israel in 1974 was expected to reach $3.2 million, including $2.5 million of metal-cutting machines and $0.7 million of metalworking machines.

It was estimated that in 1973 the first four countries listed in table 1 would account for 64 per cent of world machine tool production and that each of the countries listed below Spain would produce less than 1 per cent of the total.

Imports of machine tools by the countries of the ESCAP region in 1972 are shown in table 2. It can be seen that the percentage of the region, in terms of world machine tool imports, was 24.3 per cent, but if the shares of Japan and the USSR are excluded the figure falls to a mere 5.6 per cent.

TABLE 1. WORLD MACHINE TOOL PRODUCTION AND TRADE
(Millions of US dollars)

	1973 (estimated)					1972 (revised)				
	Production			Trade		Production			Trade	
Country	Total	Cutting	Forming	Export	Import	Total	Cutting	Forming	Export	Import
Germany, Fed. Rep. of	2,118.7	1,416.3	702.4	1,346.3	213.8	1,790.6	1,178.6	612.0	1,020.5	218.2
USSR[a]	1,698.0[b]	1,260.0[b]	438.0[b]	142.0	478.0	1,390.1	1,029.2	360.9	116.1	390.1
United States	1,610.0	1,135.0	475.0	325.0	165.0	1,169.0	801.8	367.2	260.0	113.0
Japan	1,408.0	1,102.9	305.1	202.2	106.6	876.6	666.2	210.4	142.6	101.2
Italy	544.0	435.2	108.8	212.5	170.0	430.0	344.0	86.0	220.6	139.8
United Kingdom	504.0	340.8	163.2	210.5	153.8	424.4	282.9	141.5	196.2	119.4
France	475.8	344.2	131.6	178.9	263.2	408.0	306.0	102.0	129.1	237.7
German Dem. Rep.[a]	454.7	339.6	115.1	349.1	79.2	331.5	244.4	87.1	265.6	61.8
Switzerland	315.2	267.9	47.3	247.6	92.1	252.6	214.7	37.9	202.1	70.0
Poland[a]	270.7	252.5	18.2	90.5	232.2	234.2	217.9	16.3	87.4	158.0
Czechoslovakia	255.0[b]	208.0[b]	47.0[b]	140.0[b]	70.0[b]	250.0[d]	205.0[d]	45.0[d]	138.0[d]	68.0[d]
Spain	146.1	122.0	24.1	91.3	47.0	133.9	112.4	21.5	73.4	43.3
Sweden	99.8	69.7	30.1	76.7	73.9	82.5	57.7	24.8	56.6	65.1
Yugoslavia	86.0	68.0	18.0	18.0	66.0	69.6	55.0	14.6	15.0	65.0
China	70.0[b]	52.0[b]	18.0[b]	3.0[b]	80.0[b]	67.0[b]	50.0[b]	17.0[b]	3.0[b]	70.0[b]
Belgium	61.9	23.0	38.9	59.6	59.8	53.8	20.1	33.7	51.7	54.5
Hungary[a]	58.5	54.5	4.0	34.0	28.0	57.9	54.5	3.4	33.5	28.0
India	55.3[b]	48.3[b]	7.0[b]	3.5[b]	25.0[b]	55.3	48.3	7.0	3.5	25.0
Brazil	55.0	36.8	18.2	5.1	61.5	46.4	31.3	15.1	4.2	50.3
Austria	52.7	35.5	17.2	43.3	61.6	40.7	27.0	13.7	44.1	49.6
Canada	45.7	26.7	19.0	35.0	126.0	40.5	23.5	17.0	23.0	101.1
Australia	45.0[c]	21.5[c]	23.5[c]	6.7[c]	44.8[c]	33.0[c]	15.7[c]	17.3[c]	5.0[c]	52.4[c]

Argentina	40.0[b]	22.0[b]	18.0[b]	4.0[b]	20.0[b]	41.1[d]	22.9[d]	18.2[d]	4.5[d]	20.0[d]
Netherlands	28.7	18.5	10.2	35.2[e]	55.6[e]	26.5	17.1	9.4	26.9[e]	45.4[e]
Bulgaria[a]	27.3	25.0	2.3	17.5	35.0	26.4	24.1	2.3	17.0	35.0
Rumania[a]	20.0[b]	19.0[b]	1.0[b]	5.0[b]	30.0[b]	19.0[b]	18.0[b]	1.0[b]	4.9[b]	34.0[b]
Denmark	21.7	10.2	11.5	22.2	20.6	18.4	8.7	9.7	18.9	17.6
South Africa	10.0[b]	4.0[b]	6.0[b]	0.4[b]	32.0[b]	9.6[d]	3.7[d]	5.9[d]	0.4[d]	31.9[d]
Mexico	5.5	5.0[b]	0.5[b]	–	77.0	5.0	4.5[b]	0.5[b]	–	70.0
Portugal	4.5[b]	3.0[b]	1.5[b]	2.5[b]	15.0[b]	4.1[d]	2.6[d]	1.5[d]	2.2[d]	14.7[d]
Total	10,587.8	7,767.1	2,820.7	3,884.6	2,983.7	8,387.7	6,087.8	2,299.9	3,167.0	2,550.1

Source: American Machinist, 21 January 1974.

Note: Trade statistics are based on exports and imports of machine tools only, they do not include parts and attachments.

[a]Countries with controlled currencies. For the USSR and the German Democratic Republic, official conversion rates established by these Governments were used. For other countries, data were supplied in US dollars; the exchange rate used is not known but was probably the official commercial rate. Changes in relative values of currencies complicate the problem of making meaningful comparisons, and no one conversion method is entirely satisfactory. In the table above, the 1973 estimates are converted at the average rate for commercial transactions during 1973 and the 1972 values are converted at the average exchange rates for 1972. The 1972 values for some countries would be different if converted at 1973 rates, as follows:

Germany, Fed. Rep. of	2,142.0	1,409.8	732.2	1,220.7	260.7
USSR	1,561.6	1,156.2	405.5	130.4	438.2
Japan	992.6	754.3	238.2	161.4	114.6
Italy	425.0	340.0	85.0	218.0	138.2
United Kingdom	433.4	289.0	144.4	200.4	121.9
France	439.3	329.5	109.8	139.1	256.0
German Dem. Rep.	399.1	294.2	104.9	319.7	74.5

Switzerland	290.9	247.3	43.6	232.7	80.6
Spain	136.4	114.5	21.9	74.8	44.1
Sweden	92.2	64.5	27.8	63.3	72.7
Belgium	59.0	22.0	37.0	56.7	56.9
Austria	53.6	35.6	18.1	58.1	65.4
Australia	41.0	19.5	21.5	6.3	65.1
Netherlands	31.4	20.2	11.2	31.9	53.8
Denmark	20.5	9.7	10.8	21.0	19.6

[b]Rough estimate from fragmentary data

[c]Year ended June 30

[d]Unrevised

[e]Netherlands and South Africa. Netherlands import and export figures appear to include machines re-exported to other Common Market nations. The amount of these re-exports is not known. South Africa imports include machines re-exported to other nations. These values, not included in export values, amount to about $0.6 million per year

TABLE 2. IMPORTS OF MACHINE TOOLS BY THE COUNTRIES OF THE ESCAP REGION IN 1972

Country	*Millions of dollars, f.o.b.*	*Percentage of regional imports*	*Percentage of world imports*
USSR	463.9	64.8	15.8
Japan	85.6	12.0	2.9
China	48.3	6.8	1.6
India	37.6	5.3	1.3
Republic of Korea	18.3	2.6	0.6
Singapore	12.1	1.7	0.4
Philippines	6.3	0.8	0.2
Malaysia	5.9	0.8	0.2
Thailand	5.7	0.8	0.2
Indonesia	5.4	0.8	0.2
Hong Kong	3.8	0.5	0.1
Democratic People's Republic of Korea	3.3	0.5	0.1
Pakistan	3.0	0.4	0.1
Democratic Republic of Viet-Nam	1.6	0.2	0.05
Republic of Viet-Nam	0.9	0.1	0.04
Sri Lanka	0.5	0.08	0.02
Burma	0.4	0.06	0.01
Mongolia	0.2	0.03	0.007
Afghanistan	0.2	0.03	0.007
Other countries	12.3	1.7	0.472
Total, ESCAP region	715.4	100.0	24.306
Total world	2943.3		100.0

Source: Bulletin of Statistics on World Trade in Engineering Products, 1972 (United Nations publication, Sales No. 74.II.E.5)

VI. PREDICTED EXPANSION OF ENGINEERING INDUSTRY DEMAND IN COUNTRIES OF ASIA AND THE PACIFIC

The machine tool industry is unique in that it produces the machines that are fundamental to the production of all the modern equipment needed for the manufacturing, transportation and agricultural sectors. It occupies a central place in the interrelationship that exists between the various branches of production and is of paramount importance to the development of the engineering and electrical industries.

In developing the manufacturing sector of a national economy, technical progress and increased labour productivity can be accelerated by the use of advanced machinery and techniques. The rate of industrialization and technical progress achieved in the highly industrialized countries is partly explained by the way these countries have promoted their machine tool industries. Machine tool production also means active participation in world markets, because import and export movements form an essential technical and financial part of its evolution.

The import and export figures for total machinery (non-electric) for many of the countries of the region, in the years 1967-1971, are given in table 3.

Projection of demand

In 1972-1973, the Economic Commission for Asia and the Far East (ECAFE)—now ESCAP—undertook a survey of the potential for regional industrial co-operation. The survey, which covered 11 industries, found that the metalworking industry in 10 countries had possibilities for regional multinational co-operation.

In order to project demands for machine tools in the region, information was obtained on the growth prospects of the gross domestic product (GDP), the *per capita* income, population, the manufacturing sector, market, and apparent consumption of total machinery and equipment in each country.

Each of the components that make up a country's GDP (agriculture and fishing, mining, manufacturing, construction, electricity, gas, water, transport and communication, commerce and finance, housing, public administration, defence and other services) relies on the use of metal products.

Data from a large number of countries were analysed so as to arrive at a simple exponential relationship between *per capita* income and the apparent consumption of products from the engineering industries.

Figure I presents an index of apparent consumption. Figure II shows the relationship between population size and apparent consumption of all manufactured goods; it indicates that consumption of the products of the engineering and machine tool industries increases with *per capita* income at a relatively faster rate than does the consumption of all manufactured goods. Figure II also reveals that the *per capita* value added in these industries tends to be higher in countries with relatively larger populations and, in particular, in countries with relatively higher GDP *per capita*.

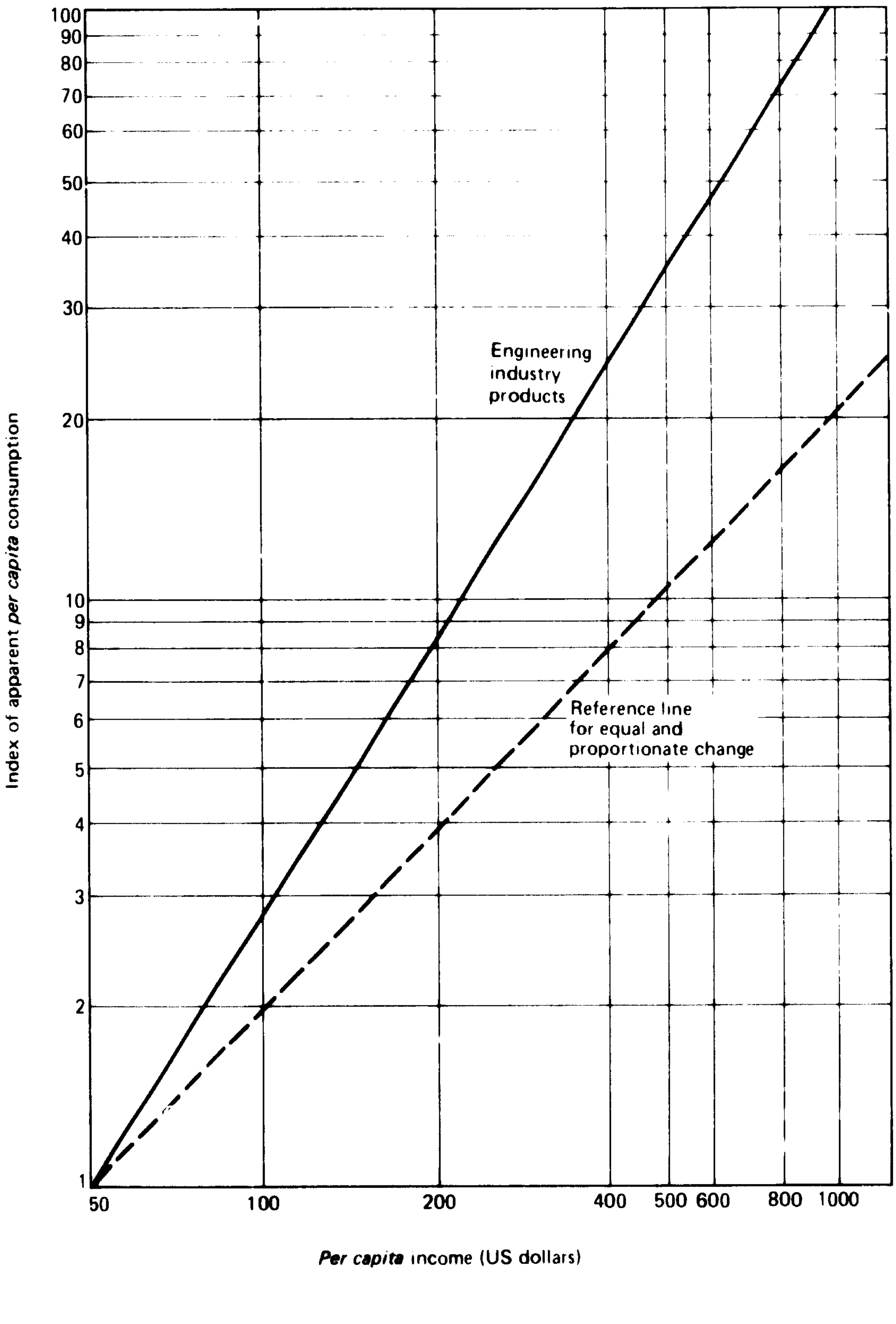
TABLE 3. IMPORTS AND EXPORTS OF TOTAL MACHINERY (NON-ELECTRIC) BY COUNTRIES OF THE REGION, 1967-1971

(Thousands of US dollars)

Country	Imports from rest of world					Exports to rest of world				
	1967	*1968*	*1969*	*1970*	*1971*	*1967*	*1968*	*1969*	*1970*	*1971*
Afghanistan	1,923	1,984	1,833							
Australia	627,502	681,058	717,951	856,314	866,990	50,926	51,209	61,522	114,575	147,111
Brunei	4,626	13,272								
Burma	26,267	34,273	34,879							
Sri Lanka	27,608	22,613	44,920			33	90			
China	139,162					14,775		33,634		
Fiji	5,057	6,505				3	240	290	312	515
Hong Kong	72,214	79,462				6,304	9,[illegible]10	10,040	38,191	38,862
India	469,545	499,990	402,388	339,009		9,546	15,518	28,219	36,991	
Indonesia	65,897	88,670	100,890	149,687		10,429	7,207	8,449		
Iran	273,646	301,645	377,004	386,792	463,291	53	79			
Japan	619,470	822,476	965,713	1,262,542	1,287,892	927,826	1,167,431	1,539,278	2,006,199	2,447,765
Khmer Republic	12,290	11,920	13,876			2	30			
Laos	1,800	2,916	4,003	6,493	4,522				1,718	
Malaysia		80,314	75,614	125,702						
New Zealand	132,464	110,547	131,207	174,[illegible]21	198,813	3,683	5,179	6,302	8,767	9,372
Pakistan	230,164	221,286	245,925	207,335	147,513	34,199	854	1,244	7,811	5,480
Philippines	238,846	245,894	267,717	242,567	258,975	91	162	255		
Republic of Korea	141,187	283,047	306,950	305,858	350,740	4,006	4,161	8,416	8,388	12,037
Republic of Viet-Nam	64,952	45,662	46,489							
Singapore	84,641	105,705	164,841	275,456	325,534	37,237		40,666	61,931	62,241
Thailand	167,223	180,634	189,327	220,148	214,369	103	137	286		
Total	3,406,484	3,839,873	4,091,527	4,552,344	4,118,639	1,099,216	1,261,807	1,738,601	2,284,883	2,723,383

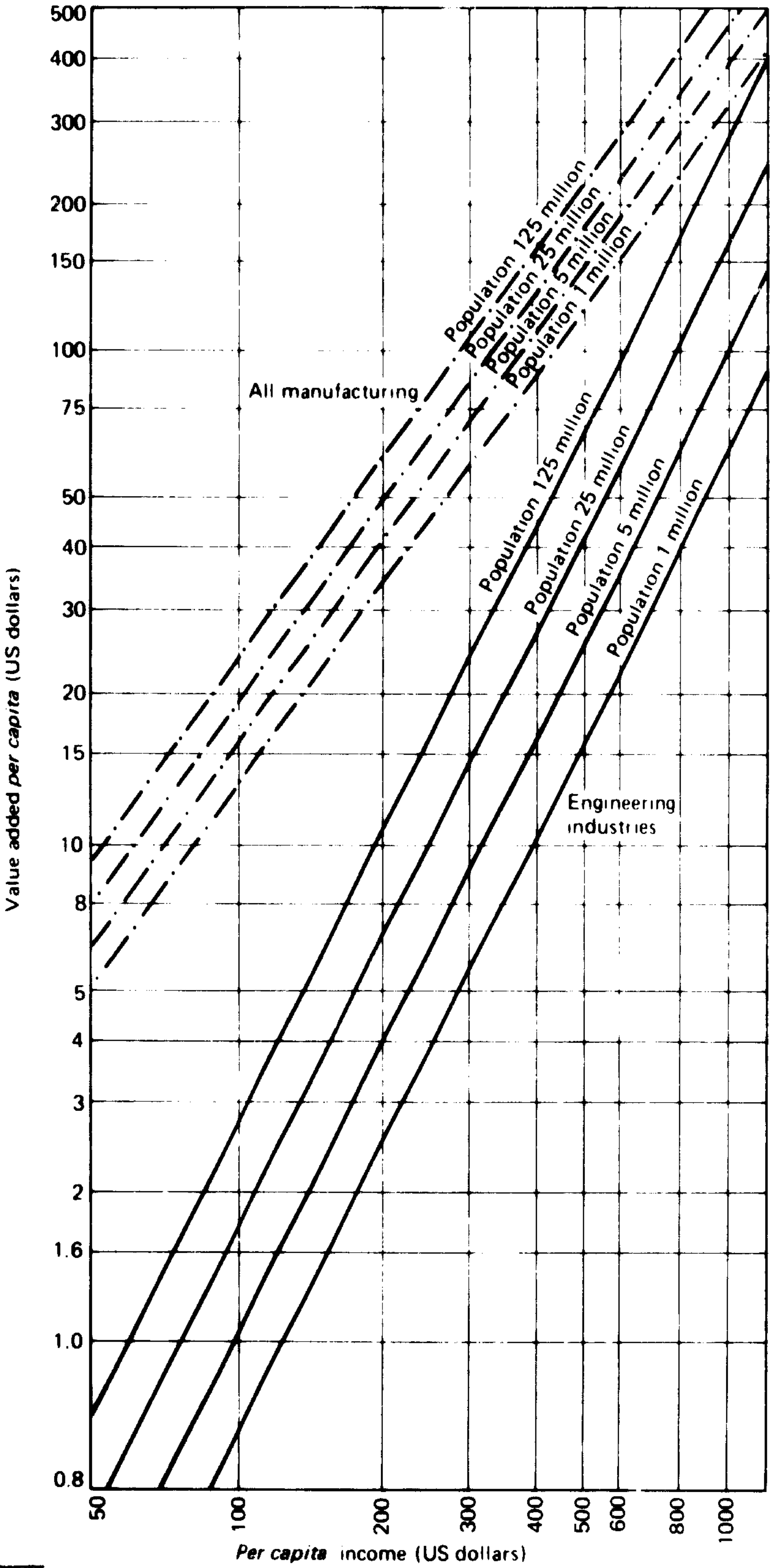
Source. "Review of machine tool industry in countries of the ECAFE region" (ID/WG.187/4), p. 15.

Figure I. Index of apparent *per capita* consumption of all engineering industry products as a function of *per capita* income



Source: Economic Commission for Asia and the Far East, *Asian Industrial Survey for Regional Co-operation*, vol. II, *Annex Reports 1-12* (1973), p. 370.

Figure II. Increase in engineering industry production compared with increase in all manufacturing as a function of *per capita* income



Source: Economic Commission for Asia and the Far East, *Asian Industrial Survey for Regional Co-operation*, Vol. II, *Annex Reports 1-12* (1973), p. 371.

Table 4 shows the population and GDP *per capita* figures for most countries of the region from 1969 to 1971.

TABLE 4. POPULATION AND GDP *PER CAPITA* FOR COUNTRIES OF THE REGION, 1969-1970

Country	*1969* Population (million)	*1969* GDP (US dollars)	*1970* Population (million)	*1970* GDP (US dollars)	*1971* Population (million)	*1971* GDP (US dollars)
Australia	12.26	2,709	12.51	2,914	12.76	3,379
British Solomon Islands	0.159	181	0.163	200	0.166	224
Fiji	0.51	358	0.52	424	0.53	506
Hong Kong	3.86	641	3.96	746	4.05	876
India	527.95	92	539.86	...	551.83	...
Indonesia	117.61	61	121.20	73	124.89	73
Iran	27.89	363	28.66	404	29.78	467
Japan	103.16	1,638	104.33	1,908	105.60	2,389
Malaysia (west)	9.019	339	9.245	347	9.488	371
Nepal	10.85	73	...	...	11.29	79
New Zealand	2.77	1,969	2.81	2,204	2.85	2,659
Pakistan (excludes Bangladesh)	52.28	189	53.51	194	54.77	203
Philippines	35.74	244	36.85	177	37.92	209
Republic of Korea	30.45	222	31.02	263	31.80	266
Republic of Viet-Nam	17.87	253	18.33	154	18.81	144
Singapore	2.040	312	2.070	941	2.110	1,113
Sri Lanka	12.25	161	12.51	173	12.76	175
Thailand	35.11	174	36.22	179	37.38	185

Sources: Based on data from *Monthly Bulletin of Statistics*, various issues and International Monetary Fund, *International Financial Statistic*, various issues.

Available market

The survey found that the regional market for products of the engineering industries could be described in two ways:

(a) Total apparent consumption which, in the absence of significant production in the region, was accepted to be the total of imports of the products being analysed;

(b) Total available market, an arbitrarily selected percentage of the total apparent consumption which it was believed a competitive regional producer could capture for each of the products.

In table 5, the indices from figure I, together with data drawn from other sources and using 1970 as the base year, have been combined in order to project, for 1975, 1980 and 1985, the total market in each of the countries surveyed. It will be seen that the total available market is forecast as growing from slightly more than $210 million in 1970 to more than $760 million in 1985 a 9 per cent average annual rate of growth.

TABLE 5. TOTAL AVAILABLE MACHINE TOOL MARKET IN SOME COUNTRIES OF THE REGION, PROJECTED TO 1985
(Thousands of US dollars)

Country	*1970*	*1975*	*1980*	*1985*
Indonesia	33,382	49,117	70,998	110,289
Khmer Republic	3,805	5,063	7,081	9,831
Laos	1,748	2,142	2,730	3,476
Malaysia	19,644	28,365	42,452	68,789
Philippines	32,917	47,992	68,277	98,225
Republic of Korea	32,107	62,284	104,419	168,151
Republic of Viet-Nam	16,870	22,374	28,861	40,152
Sri Lanka	9,351	12,553	17,901	28,252
Singapore	33,094	65,490	97,921	132,871
Thailand	26,737	41,287	62,456	100,394
Regional total	211,147	337,667	503,096	760,430

Source: Economic Commission for Asia and the Far East, *Asian Industrial Survey for Regional Co-operation*, vol. II, *Annex Reports 1-12* (1973), p. 377.

During the same period, the population of the region is expected to grow from about 280 million to more than 425 million. During this period also, a general increase of *per capita* income from $158 to $271, equal to a growth rate of nearly 4 per cent, can be anticipated.

From table 6 it can be seen that the machine tool sector occupies a share varying from 10 to 28 per cent of total machinery and equipment consumption, with an average for the whole group of 18.9 per cent.

Future plans

Many of the countries in the region have plans for the development and expansion of their metalworking industries. They should not lose sight of economies of scale, however, when setting up plants that are capital intensive and require large markets. The establishment of such plants may require assistance from other countries, particularly from other developing countries which already have machine tool industries. It is therefore important that co-ordination and harmonization of plans be attempted at a very early stage, particularly in respect of specialization in the production of types of machinery and equipment, if operations on an economic scale are to be achieved. This should be done before plant design and lay-out are final and funds committed for the purchase of capital equipment; after this stage it is too late to make changes. A practical way to achieve this objective would be to send a high-level team of commercial and technical experts to the countries concerned, to conduct consultations, gather technical data and make suggestions with regard to plant sizes, types of engineering products to be manufactured, and choice of location.

TABLE 6. EXPECTED DEMAND FOR MACHINE TOOLS IN SELECTED COUNTRIES OF THE REGION, PROJECTED TO 1980

Country	*1970*			*1975*			*1980*		
	Apparent consumption: total machinery and equipment	*Apparent consumption: machine tools*	*Share of machine tools in total consumption*	*Apparent consumption: total machinery and equipment*	*Apparent consumption: machine tools*	*Share of machine tools in total consumption*	*Apparent consumption: total machinery and equipment*	*Apparent consumption: machine tools*	*Share of machine tools in total consumption*
	(thousands of US dollars)		*(per cent)*	*(thousands of US dollars)*		*(per cent)*	*(thousands of US dollars)*		*(per cent)*
Indonesia	124,488	25,341	20.4	180,000	36,000	20.0	260,000	52,000	20.0
Khmer Republic	14,558	3,012	20.7	20,000	4,000	20.0	27,000	5,400	20.0
Republic of Korea	142,226	17,804	12,5	250,000	35,000	14.0	420,000	71,400	17.0
Laos	6,557	1,288	19.6	8,000	1,600	20.0	10,000	2,000	20.0
Malaysia	65,442	12,424	19.0	95,000	19,000	20.0	140,000	28,000	20.0
Philippines	123,937	34,857	28.1	180,000	45,000	25.0	250,000	55,000	22.0
Sri Lanka	34,914	6,882	19.7	50,000	10,000	20.0	65,000	13,000	20.0
Singapore	127,218	13,624	10.7	250,000	30,000	12.0	370,000	44,000	12.0
Thailand	100.236	28,065	28.0	155,000	40,300	26.0	230,000	57,500	25.0
Republic of Viet-Nam	41,991	4,252	10.08	55,000	6,600	12.0	70,000	9,800	14.0
Regional	781,567	147,553	18.9	1,243,000	210,400	18.9	2,452,000	292,900	17.0

Source: Economic Commission for Asia and the Far East, *Asian Industrial Survey for Regional Co-operation*, vol. II, *Annex Reports 1-12* (1973), pp. 356, 374, 375 and 789.

VII. SUMMARIES OF COUNTRY REPORTS

Bangladesh

Since 1972, most of the major manufacturing industries in Bangladesh have been nationalized and 29 engineering companies, ranging from shipbuilding to bicycle manufacturing, have come under the control of the government-owned Bangladesh Engineering and Shipbuilding Corporation.

There are two factories engaged in machine tool manufacture: the Tejgaon Engineering Company, which is a part of Rahim Metal Industries Corporation, and the Bangladesh Machine Tool Factory (BMTF), at Joyderpur, near Dacca.

Tejgaon manufactures 100-mm and 175-mm centre-height lathes; however, it manufactures only 36 units per year, and these are old-fashioned in design and of rather low quality. The factory is equipped with a number of machines which it made itself; all of them are copies of machines imported between 1900 and 1920, except for one hobbing machine, which is approximately 10 years old in design.

The BMTF employs 1,100 workers. It is currently engaged primarily in the manufacture of low-lift pumps for agricultural development programmes, but its production is very limited. Total investment in the factory to date amounts to some $10 million. About $5 million worth of new lathes, milling, grinding, drilling, shaping, slotting, hacksawing, jig-boring, measuring and gear-checking machines, mostly of Swiss origin, have been installed in the factory.

In 1973, BMTF assembled and sold 54 bench drilling machines, 5 pillar and radial drilling machines, 57 lathes and 2 woodworking machines.

In addition to local production, BMTF intends to import components for the assembling of machine tools. Lathe parts to the value of about $140,000 are due to be imported in 1974 and about twice that amount in 1975. Additional machine tools, to a total value of $840,000, have been ordered from Czechoslovakia. These include two planing machines of 6 and 8 metres machining length respectively; one horizontal boring machine; one vertical boring machine and one gear-shaping machine.

Utilization of the existing capacities is very low (sometimes less than 20 per cent) because of the lack of skilled labour, raw materials and components.

The estimated annual demand for machine tools is:

Lathes	424
Drilling machines	
Radial	11
Bench and column	194
Hacksaws	31

It is anticipated that by 1980 there will also be a yearly demand for 30 shaping machines and 30 power presses.

The Government Planning Commission, in a report issued in June 1973, proposed investments in BMTF during the period 1974-1978 of approximately $36 million, of which approximately one third would be foreign capital. The total capacity of the factory will eventually be 12,000 tons of castings, forgings and completed machines. A major foundry under construction at BMTF is scheduled for completion in 1974; plant will be installed in 1975. Until this foundry becomes operative, there will be no source of locally produced castings suitable for the machine tool plant. A second foundry and forge are also planned.

In order to improve the present situation in the metalworking industries–particularly with a view to training local labour in design and production, planning and control techniques, and management–the Government of Bangladesh is considering the establishment of a centre for technological research. This centre would be formed along the lines of the present Bangladesh Industrial Technical Advisory Centre (BITAC), which has a tool design department, a small foundry and a small but well equipped machine shop. BITAC runs courses for machine operators, supervisors and foremen, provides design services, and makes tools and jigs for local manufacturers.

India

The production of machine tools in India started towards the end of the period of British rule, but for a long time the range produced was very limited and very simple. In 1949, the volume of machine tools produced was only $40,000 and that of machine tools imported was $600,000. In that year, the Government secured assistance from a Swiss concern in establishing the country's first machine tool building plant, Hindustan Machine Tools Limited (HMT), which was completed, at Bangalore, in 1955. A second plant was constructed at Bangalore in 1961. These two plants manufacture lathes (including single-spindle automatics, capstan and turret), milling machines (horizontal, vertical and universal), boring and drilling machines, external cylindrical grinding machines, and special-purpose machines. In the financial year 1963/64, the volume of production was $3 million.

In order to meet the increasing domestic and foreign demand for machine tools, the Government, in 1961, decided to expand HMT's operations by establishing a third plant, at Pinjore. The Pinjore plant was completed in 1963 and manufactures milling, gear-cutting, and special-purpose machines. A fourth factory was constructed at Kalamassery in 1964 and is manufacturing universal turret and precision lathes. In 1965, a fifth factory, at Hyderabad, was completed for the manufacturing of special-purpose machines.

A census taken in 1968 recorded 382,000 machine tools in the country; 246,300 were metal-cutting, 86,400 metal-forming, and the remainder welding, die-casting and other machines. About 60 per cent of the machine tools are used in the large-scale sector of industry. Nearly two thirds of all machine tools in the country are of Indian manufacture, although many of the larger and more complex ones have been imported. Some 63.7 per cent of all machine tools are less than 10 years old while 16.1 per cent are more than 20 years old.

The Indian machine tool industry currently produces about 12,000 metal-cutting and metal-forming machine tools per year (table 7). Some 85 per cent of this output is produced by the 125 machine tool companies recognized by the Directorate General of Technical Development as comprising the machine tool industry. The remaining 15 per cent comes from the small-scale sector and comprises mainly small and simple machine tools. Of the 125 major companies, four are in the public sector and are controlled by the Government; the remaining 121 are in the private sector. The output of the four companies in the public sector represents more than 50 per cent of the total production.

TABLE 7. PRODUCTION OF SELECTED TOOLS IN THE ORGANIZED SECTOR OF THE INDIAN MACHINE TOOL INDUSTRY

(Units)

Tool	*1971*	*1972*	*1973*
Automatics	435	275	325
Boring machines	60	80	90
Gear-cutting machines	90	50	65
Grinding machines	1,780	1,055	1,625
Capstans and turrets	590	465	375
Lathes	3,465	2,890	3,255
Milling machines	780	630	775
Presses	890	625	525
Others	7,360	6,480	6,235
Total	15,450	12,550	13,270

The total number of persons employed by the machine tool industry in India is about 27,000, of which the four companies in the public sector employ 17,000 (including 12,000 employed by HMT).

During 1972/73, the volume of HMT's machine tool production was about $28 million; that for the country as a whole, including small tools and accessories, was $70 million. In the course of the Five-Year Plan which has just commenced, it is intended to increase production to $142 million with the public sector continuing to provide rather more than 50 per cent of the total.

The development of the machine tool industry over the last two decades has been based primarily on substantial imports of know-how and on collaboration with foreign firms.

Over the years, the Indian machine tool industry has, to a certain extent, built up its own design competence and manufacturing skill. The Government has established a Central Machine Tool Institute (CMTI) to conduct research, develop design, streamline testing procedures and provide general assistance to the entire machine tool industry. There is still a need to import technical know-how, however. Some 156 technical collaboration agreements involving 15 countries and covering almost all types of machine tools and accessories are currently in force; 98 involve metal-cutting and 16 involve metal-forming machine tools. Some 57 machine tool enterprises in the private sector are associated with 126 of these collaboration agreements, and the four public enterprises with the remaining 30.

The Government has requested the assistance of UNIDO in setting up a numerical control (NC) demonstration and training centre at CMTI to facilitate the introduction of NC machine tools and to teach the staff required to operate them. HMT has already entered into collaboration with a foreign firm for the joint development of certain types of NC machines for sale in India and abroad.

The Indian machine tool industry is currently endeavouring to increase its exports to both developing and developed countries. HMT plans to set up an export organization to export its own machine tools and those manufactured by other units in the country. The machine tool industry is also in a position to provide assistance to other developing countries desiring to set up factories for the manufacture of general-purpose machine tools. The assistance may cover, *inter alia*, the preparation of feasibility and project reports, the training of personnel, the setting up of factories, and the supply of capital equipment and technical know-how. HMT has already entered into technical collaboration with the Philippines in establishing a factory in that country.

Malaysia

The engineering industry in Malaysia is comparatively small, but appears to be growing rapidly (table 8). There are no metalworking machine tool companies in the country, but there are two woodworking machine companies, both making a fairly wide range of machines in small quantities and producing speed reducers and water pumps (which are becoming their principal products). The Government of Malaysia, with the co-operation of a French engineering concern, recently undertook a prefeasibility study on the establishment of an industry for the manufacture of both metal-cutting and woodworking machine tools. The study recommended the setting up of a fairly small plant, employing 150 persons, and making a wide range of both metal-cutting and woodworking machines, including lathes, bench and column drills, bench grinders, power saws, shaping machines, presses, and standard small woodworking machines.

TABLE 8. FORECAST OF MACHINE TOOL DEMAND IN MALAYSIA, 1970-1985

(Millions of US dollars)

Tool	*1970*	*1975*	*1980*	*1985*
Metalworking machine tools	4.35	7.3	13.2	22.7
Woodworking machine tools	6.43	7.8	13.8	24.0
Accessories and parts	1.84	4.7	8.6	14.7

There are over 150 foundries in Malaysia employing about 3,000 workers. The total tonnage of grey-iron castings produced is estimated to be 12,000-15,000 tons per year, depending on the demand. A small quantity of non-ferrous castings is also produced.

Most of the foundries and mechanical workshops are small-scale and use traditional skills and outdated equipment. Cost, quality, material and production control are non-existent, except in a few of them. Lay-out, material handling and maintenance are poor.

Malaysia needs assistance in the manufacture and maintenance of tools, dies, moulds, jigs and fixtures for the mechanical, electrical and plastics industries; local expertise is not sufficient. The light engineering and plastics industries, already set up or being set up under the present industrialization programmes, cover a wide range of products, such as bicycles, sewing machines, electric fans, builders' hardware, automobile components, wire and wire products, bolts and nuts. The plastics conversion industry alone numbers over 150 units and employs an estimated 2,800 workers. As few of the light engineering industries have tool-making facilities of their own, most moulds and tools are imported. The importation of tools, dies, moulds, jigs and fixtures is very costly, however, and delivery usually takes a long time. About $1.2 million are being spent yearly on importing moulds for the plastics industry alone. The lack of these tools is one of the reasons for the underutilization of the available capacity in the country. The few moulds and tools that are produced have a limited life and their quality is below international standards.

Another factor which inhibits the setting up of tool-making facilities is the lack of trained and skilled toolmakers. Many foreign entrepreneurs hesitate to invest in any industrial undertaking requiring the use of tools, dies, jigs, moulds and fixtures, unless tooling services are readily available in the country. For this reason, it is desirable that Malaysia establish modern toolrooms and train the necessary skilled labour as soon as possible.

Pakistan

A large number of the private and government-owned re-rolling mills, foundries, machine building, metal products and other engineering industries in Pakistan have been established without adequate planning as to capacity and demand. In 1971, a team of three UNIDO experts provided assistance and advice to the country on the co-ordination and efficient utilization of its steel, iron and engineering industries. It was noted that in many factories the installed capacity, 55-65 per cent, was being underutilized. The engineering industry in Pakistan is highly decentralized; it is estimated that there are altogether 1,700 production units (containing about 21,000 machine tools) of which 800 units employ less than 10 workers each. Eleven large plants provide employment for 45,000.

There are two public enterprises involved in the production of machine tools in the country, namely, the Pakistan Machine Tool Factory (PMTF), at Landhi near Karachi, which is part of the State Heavy Engineering and Machine Tool Corporation, and the Machine Tool Division of Pakistan Engineering Company (PECO) at Lahore, which is part of the State Light Engineering Corporation.

PMTF employs 3,500 persons and works on a double shift system. In addition to manufacturing combined gear and transfer boxes for jeeps and rear axles and brake drums for trucks, it manufactures milling machines and lathes under licence from Swiss and British concerns. In 1973, the plant produced 70 machines, but of these only 38 were sold.

The machine tool division of PECO manufactures centre lathes, small hand-operated turret lathes and shaping machines, and has the capacity to build 670 machines a year. At the present time, however, it is selling only 200-300 machines yearly. Many machines, some in partly finished condition, have been in stock for a considerable length of time.

The private sector, most of which is located at Lahore, also produces machine tools, but their quality requires improvement.

The total number of machine tool plants in the country, both publicly and privately owned, exceeds 70. PMTF and PECO each employ more than 1,000 workers; five plants employ between 100 and 500, while each of the remainder employs less than 100.

The total annual capacity of the industry is: centre lathes, 2,400; turret lathes, 100; milling machines, 250; drilling machines, 1,435; shapers and planers, 100; grinding machines, 10; power presses, 30; and hacksaw machines, 55. Production, however, has fallen far short of capacity, as shown below.

	Units manufactured			
	1970-1971	*1971-1972*	*1972-1973*	*1973-1974*
Lathes	278	118	205	137
Milling machines	11	8	50	70
Drilling machines	93	61	79	67

It is expected that in future all licensing agreements drawn up with foreign manufacturers will call for active collaboration, rather than the paying of royalties. The following terms are envisaged:

(a) The licensor will constantly improve and update the machine design and manufacturing techniques and keep the licensee abreast of such developments;

(b) The licensor will encourage and assist the licensee in exporting the finished machine tools.

The design and manufacture of machine tools in Pakistan are very limited at present, but the Pakistan Industrial Technical Advisory Centre (PITAC) is providing assistance to local industry in the form of training and advice, and, when requested, providing complete sets of tooling for particular products. The services of PITAC are intended primarily for the private sector of industry.

The Philippines

There are about 1,500 metalworking establishments dispersed throughout the Philippines. They manufacture various types of metal products, using some 260,000 to 300,000 machine tools. Most of these machine tools have been imported, since domestic production is minimal. They are mainly general-purpose tools (engine lathes, universal milling machines, drill presses, shapers, grinders, power presses), special types (automatic lathes and gear hobbers) being used only by a few of the larger firms.

Because of the importance of the local manufacture of machine tools, particularly lathes, shapers and drill presses, to the industrial development of the country, the Government has given this industry high priority for investment.

At the present time, local companies manufacture about 300 presses a year, including mechanical presses (5- to 80-ton capacity) and hydraulic presses. They do not produce metal-cutting machines. A machine tool manufacturing company, recently established, employs about 40 persons on jobbing work, making small castings and rebuilding textile looms. This company, which is registered with the Philippine Government for the manufacture of lathes and has a licensing agreement with a State-sponsored concern (HMT) in India, expects to produce 100 engine lathes (400 mm X 1,000 mm) in its first year of operation, increasing to 1,900 lathes a year by its tenth year. The company will use both imported and locally manufactured components. The necessary technical drawings, information and expertise will be provided by HMT, and the company's personnel will be trained in India.

Another local company, whose application for registration has been approved, will manufacture lathes and shapers. This company has entered into a joint venture with a machine tool concern in another Asian country, and will contribute 60 per cent of the equity. It expects to be producing 240 lathes and 96 shapers a year by its tenth year.

A third Philippine company, for the manufacture of drill presses of various capacities, expects to produce 96 units in its first year of operation (1974) and to be manufacturing 1,000 units by its fifth year.

A fourth company is entering into a joint venture with a foreign firm for the manufacture of lathes and vertical milling machines. It expects to be operational by the middle of 1975. Approximately 50 per cent of its production will be for export.

Table 9 shows the actual number of machine tools produced, imported and exported by the Philippines in 1970, with projections for 1975 and 1985.

TABLE 9. THE MACHINE TOOL INDUSTRY IN THE PHILIPPINES, PROJECTED TO 1985

(Units)

	Production			*Import*			*Export*		
Tool	*1970*	*1975*	*1985*	*1970*	*1975*	*1985*	*1970*	*1975*	*1985*
Milling	–	–	400	320	730	1,100		–	200
Drilling	–	800	1,000	2,000	2,300	3,900	–	20	50
Grinding	–	120	320	400	620	940	–	20	60
Lathes	–	250	3,000	3,200	3,800	5,800		20	120
Presses	150	230	500	480	730	1,100		10	60
Other machines	–	200	2,000	1,556	2,220	2,760		20	200
Total	150	1,600	7,220	7,956	10,400	15,600	–	90	690

At present there are about 150 foundries operating in the Philippines. Roughly 75 per cent of them are concentrated in the Greater Manila area. About 20 firms account for 75 per cent of the total foundry output.

Singapore

In 1961, the Government of Singapore launched an accelerated industrialization programme aimed at broadening the country's economic base and improving the living standards of the population.

Recognizing that good supporting industries were extremely vital to the development of modern, sophisticated manufacturing enterprises, the Government gave priority to their development and expansion. The growth of export-oriented industries has given great impetus to the modernization and progress of key supporting industries such as foundries, heat treatment and plating facilities, and precision tool and component manufacture.

In 1960, there were only 127 metalworking companies operating in Singapore. By 1974, the number had risen to 460, the number of workers had increased from 5,913 to 48,019, and the output had increased from \$33.6 million to \$516.7 million.

In the machine tool sector, three factories are already in production while a further nine are at various stages of completion. Altogether, these 12 machine tool facilities will involve an investment of over $2 million in equipment and buildings. The products manufactured will include surface and cylindrical grinders, radial and sensitive drills, milling machines, various types of lathes, cold-heading machines, saw-sharpening machines, and machine tool accessories.

As the machine tool facilities are either subsidiaries of reputable foreign manufacturers or joint ventures between local and foreign firms, the markets and the latest manufacturing processes and technical know-how are freely available to them.

Demand for machine tools has been increasing rapidly to meet the requirements of the expanding engineering industry. Imports which in 1960 amounted to $164,000 had increased to $13.3 million by 1970 and $30.5 million by 1973. Not all of these machines remained in the country, however; some were re-exported.

Sri Lanka

The metalworking industry of Sri Lanka has grown considerably in recent years, total volume of output rising from $29 million in 1965 to about $114 million in 1972. The industry is a blend of small, medium-sized and large enterprises, some of which have been operating for more than 50 years. It produces mainly rolled steel and cold-drawn-wire products, cast iron and steel castings, tea-processing machinery, and rubber- and paddy-processing equipment. Machine tools, dies, jigs and fixtures, agricultural implements, tractors and some other equipment are assembled, and in some cases manufactured successfully, but manufacturing technology, workshop organization and quality control are below modern industrial standards.

A survey of machine tools conducted by the Ceylon Steel Corporation (CSC) in 1970 showed the number of metal-cutting machine tools installed in Sri Lanka's workshops to be between 4,000 and 7,000 units. The number of metal-forming machine tools was considerably smaller, amounting to about 1,300 units. Much of the equipment was obsolete and required repair and rebuilding. In some plants, the machine tools were completely worn out although they were less than ten years old. This state of affairs was due primarily to lack of maintenance and to abuse by insufficiently trained operators.

The CSC handles all imports of machine tools in Sri Lanka. Machine tool imports (units) from India and the USSR in recent years were:

	1971	*1972*	*1973*
India	17	40	26
USSR	70	56	91

The demand for many of the more sophisticated types of machine tools in 1974 will go largely unsatisfied, owing to the scarcity of foreign exchange in the country. There is, however, a great demand for simple machine tools in Sri Lanka, and in this respect CSC has made a good start; it has already started to build pedestal grinders from drawings furnished by HMT (India). In addition, the Government is setting up a machine tool production shop, a toolroom, and machine tool rebuilding facilities. It is intended that these facilities will manufacture and assemble pedestal grinders; repair and rebuild used machine tools; manufacture lathe tools and milling cutters; and design machine tools, such as bench and pillar drilling machines, power hacksaws and small engine lathes that can be produced with the facilities available locally and with minimum investment.

Thailand

The engineering industry in Thailand consists mainly of small, privately owned units. There is little government-controlled industry, but a company whose project is approved by a national investment board receives considerable financial advantages, including tax concessions and duty-free importation of equipment.

Most of Thailand's machine tools are imported. Since 1965, imports of machine tools and accessories have been rising rapidly as shown below.

	Millions of US dollars
1965	2.7
1966	3.7
1968	5.0
1970	7.5
1971	8.7
1972	11.0
1973	13.1 (estimated)

The demand for lathes (all types) has also been increasing rapidly; in 1972, imports reached 4,240, compared with 1,784 in the previous year. The principle types of machines imported during 1970-1972 were:

	Units		
	1970	*1971*	*1972*
Lathes	1,555	1,784	4,240
Milling machines	107	127	99
Grinding machines	4,227	4,671	5,376
Drilling machines	3,566	5,447	2,342
Sawing machines	',971	2,164	3,472

The unit cost of the machines, in many instances, is very low.

In Thailand, there are about 10 small companies manufacturing rather crude machine tools. The largest of them produces yearly 120 small, simple, old-fashioned centre lathes, the prices of which range from $1,300 to $4,000, depending on size. Shapers are also produced by these companies.

A company near Bangkok, which planned to go into machine tool manufacturing some years ago but found it difficult to retain the skilled labour required, now imports used machine tools and reconditions them. It also runs a gear-cutting service for other companies. Another concern, a well established engineering company, has announced plans to manufacture lathes and accessories under licence from a company in the United States of America.

Foundry capacity for machine tool castings is available, as there are more than 200 small foundries with a total capacity of 20,000 tons a year. There are also four malleable iron foundries with an average daily capacity of about 200 tons each. One foundry has a licence from an American concern and is exporting castings to the machine tool industry in the United States.

With regard to training, a local technical institute has recently introduced a course in small engine lathe and shaping machine construction.

Annex I

TECHNICAL ASSISTANCE AND INFORMATION AVAILABLE FROM UNIDO IN RESPECT OF THE MACHINE TOOL INDUSTRY

The technical assistance provided by UNIDO to developing countries anxious to expand or establish metalworking and, particularly, machine tool industries, consists of *(a)* operational activities and *(b)* supporting activities.

Operational activities

Under this heading, UNIDO provides direct technical assistance in the selection, utilization, design, production, maintenance, and repair of machine tools and their accessories. The organization is particularly interested in encouraging the development of engineering design capabilities in the developing countries.

A number of case histories will serve to illustrate the nature of this assistance.

Philippines. UNIDO is assisting the Government of the Philippines to establish a metal industries research and development centre. The assistance began in 1971 and is scheduled to terminate in December 1977. Financial support is being provided by the United Nations Development Programme (UNDP). The total UNDP/UNIDO input amounts to almost $2.2 million.

The main objectives of the centre are to serve the varied and expanding needs of the metal industries with respect to extension services; applied research, introduction of adequate up-to-date technologies in such important engineering disciplines as tool and die design; manufacture and application; heat treatment; metal-casting and -forming, instrumentation; metrology; quality control and inspection; machine design; and mechanical maintenance and repair, including rebuilding.

Singapore. During a three-year period, which ended in 1972, a UNIDO expert formulated proposals on the establishment of a tool- and die-making and a hardware industry in Singapore. The expert was able to persuade foreign firms to set up these industries in the country. Following his advice, a company for the manufacture of carbon steel razor blades was established. The blades are now being sold in foreign countries. Under the expert's technical guidance also, a new factory for the manufacture of welded steel chains was completed and automatic production equipment installed.

Sri Lanka. The Ceylon Steel Corporation (CSC) is an enterprise set up by the Government of Sri Lanka to establish metalworking industries in the country.

In 1974, a UNIDO expert attached to the machine tool division of CSC at the request of the Government provided technical assistance in the production, testing and installation of pedestal grinders as well as in the production of spare parts and replacements. The expert demonstrated the correct regrinding of tools and the correct selection of feeds and speeds for effective operation. Training was provided on the production and proper utilization of machine tools and in the design of jigs and fixtures for the machine tool shops. To ensure a better selection of personnel for the machine tool division, the expert assisted in the preparation of 16 job descriptions for posts ranging from division manager to machine tool operator.

The Government has recently expressed interest in establishing a national research and development centre for metalworking industries. The centre will identify the product lines to be developed or adapted by industry. UNIDO has been asked to supply equipment and expertise and to arrange training programmes.

Malaysia. In 1972, at the request of the Government of Malaysia, a mission composed of experts from UNIDO and the International Labour Organisation (ILO) visited selected foundries, mechanical workshops and plastics factories, and studied the feasibility of establishing a metal industry development centre. The members of the mission, together with Malaysian Government authorities and the local UNDP representative, subsequently drafted guidelines for the establishment of the centre. The project has since been included in the country programme of Malaysia and approved by the Governing Council of UNDP. Total UNDP/UNIDO/ILO input will amount to some $1.4 million.

The project is expected to take five years and will be started at the end of 1974. The main purpose of the centre will be to provide advisory services to Malaysian foundries and mechanical workshops in the design, production and application of a variety of castings, dies, moulds, tools, jigs and fixtures. It will also provide repair and maintenance facilities and assist local manufacturers to establish their own toolrooms. The centre will also disseminate data and technical information on modern production techniques to the local manufacturing enterprises.

India. The Government of India has requested UNIDO to provide technical assistance in the field of NC machine tools to the Central Machine Tool Institute (CMTI) at Bangalore. The Institute has already established a department exclusively for the development of NC systems and is studying the nature of the components manufactured in various industries with a view to identifying parts that are suitable for production by NC. Point-to-point NC positioning systems and digital read-outs are being developed by the Institute. All circuits are fully transistorized and built as plug-in printed circuit boards, which facilitates maintenance and inspection.

A small number of NC machine tools have been installed in the country and more are likely to be installed in the coming years. However, the absence of suitable technical advisory services for the economical utilization of these machines is being keenly felt. The Government has therefore asked for technical assistance in establishing an NC centre which would be attached to CMTI. The project duration is six years (1974-1979) and is included in the country programme for India. The total UNIDO/UNDP input amounts to $1.5 million.

Pakistan. Three UNIDO experts recently visited a large number of private and government-owned re-rolling mills, foundries, machine tool building and metal products manufacturing industries in Pakistan, studied the causes of underutilization of the installed equipment, and made recommendations which have since been effectively implemented.

Indonesia. In another recent project, three UNIDO experts assisted the metalworking industries in Indonesia to introduce new pilot production systems using special operation cards designed to improve efficiency. The experts also studied the problems of underutilization of machine tools and related industrial equipment in Indonesian enterprises and recommended ways of improving the situation.

Supporting activities

UNIDO supporting activities in the metalworking sector are aimed at promoting its direct technical assistance to developing countries. The main types of supporting activities are: the organization of expert group meetings, workshops, international and regional seminars and symposia; and the preparation of economic, scientific and research surveys and reports.

The following meetings have been held by UNIDO on the problems of the metalworking industries in the developing countries: Expert Group Meeting on Design, Manufacture and Utilization of Dies and Jigs in Developing Countries, Vienna, 1968; Expert Group Meeting on the Development of Engineering Design Capabilities in Developing Countries, Vienna, 1970; Regional Seminar on Machine Tools in Developing Countries of Europe and the Middle East, Varna, Bulgaria, 1971; Regional Seminar on Machine Tools for the Countries of Latin America, Buenos Aires, Argentina, and São Paulo, Brazil, 1972.

Since 1967, the year in which UNIDO was created, the following publications and studies concerning the development of machine tools in the developing countries have been issued by UNIDO:

Report of the Interregional Symposium on Metalworking Industries in Developing Countries (United Nations publication, Sales No. 68.II.B.9)

Development of Metalworking Industries in Developing Countries (United Nations publication, Sales No. 69.II.B.2)

Design, Manufacture and Utilisation of Dies and Jigs in Developing Countries (United Nations publication, Sales No. 69.II.B.38)

The Selection and Acceptance Testing of Metal-Cutting Machine Tools (United Nations publication, Sales No. 71.II.B.3)

The Development of Engineering Design Capabilities in Developing Countries (United Nations publication, Sales No. 72.II.B.2)

Effective Use of Machine Tools and Related Aspects of Management in Developing Countries (United Nations publication, Sales No. 72.II.B.6)

Regional Seminar on Machine Tools in Developing Countries of Europe and the Middle East (United Nations publication, Sales No. 72.II.B.22)

Machine Tools in Latin America (United Nations publication, Sales No. 73.II.B.11)

The Machine Tool Industry (United Nations publication, Sales No. 74.II.B.3)

"Role of UNIDO in the promotion of machine tools in developing countries of Europe and the Middle East" (ID/WG.87/29/Corr.1)

"Machine tools in the countries of Latin America" (ID/WG.113/13/Corr.1)

"Problems of introduction of numerically controlled machine tools in developing countries" (UNIDO/ITD.190)

Annex II

PAPERS PREPARED FOR THE SEMINAR[a]

ID/WG.187/1	Some aspects of the development of machine tool industries of the ECAFE region Secretariat of UNIDO
ID/WG.187/2	Creation of a machine tool industry in a developing country; study of various phases M. Jeannerod
ID/WG.187/3	Country study report on the machine tool industry in the Philippines A. D. Viray and R. M. Consunji
ID/WG.187/4	Review of machine tool industry in countries of the ECAFE region Secretariat of ECAFE
ID/WG.187/5	Development of the machine tool industry in Georgia T. N. Loladze
ID/WG.187/6	Country study report: Machine tool industry in India S. C. Banarjee
ID/WG.187/7	Country study report on the machine tool industry in Bangladesh M. H. Siddique
ID/WG.187/8	Country study report on machine tools in Sri Lanka D. T. Abeysiri and J. A. D. W. Peries
ID/WG.187/10	The machine tool industry in Pakistan T. M. Khawaja
ID/WG.187/11	Prerequisites for machine tool production in a developing country P. Stöckmann
ID/WG.187/12	Country study report on the machine tool industry in Malaysia Koh Teck Seng
ID/WG.187/13	Promotion and development of machine tool industries in Thailand S. Changkasiri and V. Hutasingh
ID/WG.187/14	Source and use of funds in machine tool manufacturing companies L. Elliott
ID/WG.187/15	Country study report on the machine tool industry in Singapore Yeo Cheow Tong
ID/WG.187/16	A brief synopsis of activities in the industrial sector by the three members of the World Bank Group (IBRD, IDA, IFC) Secretariat of UNIDO
ID/WG.187/17	Technical and investment co-operation programmes with partners in other countries either within or outside the region for component or complete machine tool manufacture H. Göhren
ID/WG.187/19	Prerequisites for machine tool production in a developing country J. Halbert

[a] A limited number of copies are available from UNIDO upon request.

ID/WG.187/20	Technical assistance of the Soviet Union to the developing countries in organization of production of metal-cutting and metalworking machine tools and tools S. I. Eroshkin
ID/WG.187/21	A report on Bangladesh machine tool factory S. M. Rahman
ID/WG.187/22	Machine tool and tool industry of the Union of Soviet Socialist Republics V. Kudinov
ID/WG.187/23	HMT (Hindustan Machine Tools Limited): a case study in establishing a machine tool industry in a developing country R. Yogeshwar
ID/WG.187/24	Investment in machine tool manufacturing facilities: sources of finance and credit arrangements R. Gabriel

Annex III

LIST OF PARTICIPANTS

Country participants

Bangladesh

Rahman, S. M.	General Manager Bangladesh Machine Tool Factory Joyderpur, Dacca
Siddique, M. H.	Section Chief Bangladesh Planning Commission Dacca

Bulgaria

Penkov, D. T.	Manager NC Training and Demonstration Centre Machine Tool State Association P.O. Box 107 Sofia

France

Jeannerod, M.	Assistant to the General Manager H. Renault–Somua 168, rue de Javel 75015 Paris

German Democratic Republic

Meister, M.	VEB Werkzeugmaschinenkombinat "7. Oktober" Berlin Gehringstrasse 39 DDR-112 Berlin
Thürmer, R.	Director of Sales VEB Werkzeugmaschinenkombinat "Fritz Heckert" Strasse der Nationen 12 Karl-Marx-Stadt
Zimmermann, D.	Manager of Sales Promotion WMW Export-Import Chausseestr. 111/112 104 Berlin

Germany, Federal Republic of

Cöhren, H.	Director of R and D Werkzeugmaschinenfabrik Gildemeister and Company, AG Am Hauptbahnhof D-4800 Bielefeld
Stöckmann, P.	Director Pittler Maschinenfabrik AG Pittlerstrasse 6070 Langen bei Frankfurt/Main

Hungary	
Ando, K.	Chief of Marketing Group Technoimpex Dorottya-u. 6 1051 Budapest
Jacab, M.	Technical Director, R and D Section Technoimpex Dorottya-u. 6 1051 Budapest
Kapocsi, T.	Technical and Economic Adviser Technoimpex Dorottya-u. 6 1051 Budapest
India	
Banarjee, S. C.	Deputy Director General Directorate General of Technical Development Udyog Bhavan New Delhi
Mehrotra, J. N.	General Manager of Marketing Batliboi and Co. Pvt Ltd P.O. Box 190 A Forbes Fort, Bombay-400 001
Yogeshwar, R.	General Manager Foreign Operations Kindustan Machine Tools (HMT) Ltd Schrondweiler Luxembourg
Japan	
Murakami, M.	Manager Japan Machine Tool Trade Association Vienna Office Prinz Eugen Strasse 52/19 1040 Vienna Austria
Malaysia	
Koh, Teck-Seng	Engineer Federal Industrial Development Authority P.O. Box 618 Kuala Lumpur
Raja Zainai Abidin	Managing Director Jaya Raya Co. Ltd 101G Jalan Ampang Kuala Lumpur
Pakistan	
Ansari, S. A.	General Manager Pakistan Engineering Co. Ltd Lahore
Faruq, K. M.	General Manager of Planning State Heavy Engineering and Machine Tool Corporation 6th Floor, PIDC House Dr. Ziauddin Ahmed Road Karachi

Philippines	
Consunji, R. M.	President Machine Tool Manufacturing Co. of the Philippines Inc. 1120 Mendiola Ext. Otis, Paco Manila
Poland	
Mostowicz, W.	Marketing Adviser Metalexport Warsaw
Szepieniec, Z.	Technical Director "Ponar Union" Barbara 7 Warsaw
Wszelaki, S.	Commercial Adviser Metalexport Warsaw
Urbanski, L.	Engineer Metalexport Warsaw
Singapore	
Lam, S. L.	Director Singapore Nissan Motors (Pte) Ltd 8, Jalan Pesawat Jurong Town Singapore
Yeo, C. T.	Projects Officer Economic Development Board 2nd Floor, Fullerton Building Singapore
Sri Lanka	
Abeysiri, D. T.	Assistant General Manager Ceylon Steel Corporation Athurugiriya
Peries, J. A. D. W.	Chief Engineer/Maintenance Ceylon Steel Corporation Athurugiriya
Thailand	
Changkasiri, S.	Special Grade Engineer Department of Industrial Promotion Ministry of Industry Rama VI Road Bangkok
Hutasingh, V.	Chief of Planning Division Department of Industrial Promotion Ministry of Industry Bangkok
Suriya, S.	Manager of Marketing Department Sahaviviya Metal Industries Co. Ltd Soi Watchonglome Nang Linjee Road Bangkok

Union of Soviet Socialist Republics

Bokuchava, G. V.
Director
Institute of Metrology
Leninstr. 75
Tbilisi, Georgia, USSR

Didebulidze, V. A.
Department Chief
Committee of Ministry
Government House
Tbilisi, Georgia, USSR

Eroshkin, S. I.
Ministry of Machine Building of the USSR
Gorky Street 20
Moscow

Grukovietz, G.
Department Chief
Machine Tools Ministry
Moscow

Haindrava, A.
Head of Information Department
Committee of Ministry
Government House
Tbilisi, Georgia, USSR

Konsnetsov, G.
Department Chief
Ministry of Machine Tools
Moscow

Kudinov, V.
Ministry of Machine Building of the USSR
Gorky Street 20
Moscow

Leladze, N. S.
Deputy Chairman
Committee of Ministry
Government House
Tbilisi, Georgia, USSR

Loladze, T. N.
Vice-Rector of the Georgian Polytechnical Institute
Tbilisi, Georgia, USSR

Nikulin, Y.
Director
Stankoimport
Moscow

Sherbionok, D. I.
Ministry of Machine Building of the USSR
Gorky Street 20
Moscow

Smurov, S.
Department Chief
Machine Tool Ministry
Moscow

Yakovlev, Y. S.
Senior Expert
State Committee of the USSR Council of Ministers for Science and Technology
Moscow

United Kingdom

Elliott, L.
Partner
Peat, Marwick, Mitchell and Co.
Austral House
Basinghall Avenue
London EC2V 5EU

Halbert, J. S.
Managing Director
Associated British Machine Tool Makers, Ltd
20 Park Street
London W1

United States of America

Connor, J. A.	International Trade Director National Machine Tool Builders Association 7901 West Park Drive McLean Virginia 22101
Dillon, J.	Manufacturing Engineering Manager Ford Motor Company 3001 Millar Road Dearborn Michigan 48121

Yugoslavia

Krstevski, P. A.	Chief of Technical Services Metalski Zavod "Tito" Skopje
Vucic, A. A.	Engineer "Unis-Slaoko Rodić" Bugojno

Economic and Social Commission for Asia and the Pacific

Fedotov, A.	Economic Affairs Officer Division of Industry and Housing, ESCAP Sala Santitham Rajdamnern Avenue Bangkok

European Committee for Co-operation of Machine Tool Industries (CECIMO)

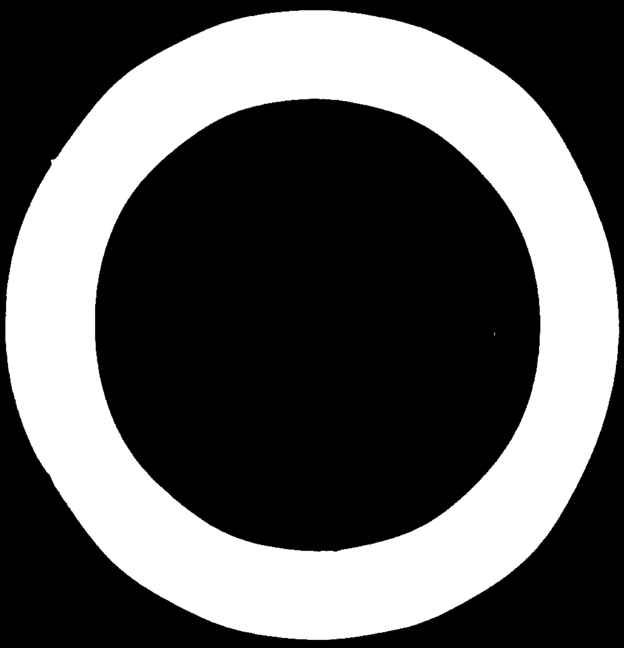
Gabriel, R.	Chairman Sub-Committee for Economic Expansion, CECIMO Briglea Engineering Ltd Ford George Guernsey

IBRD/UNIDO Co-operative Programme

Oettinger, W. H.	Principal Industrial Engineer IBRD/UNIDO Co-operative Programme UNIDO Lerchenfelderstrasse 1 A-1070 Vienna

Part two

Introducing numerically controlled machine tools into the developing countries



I. ADVANTAGES OF NUMERICAL CONTROL

Conventional machine tools

The poor quality of engineering products manufactured in the developing countries is the main factor preventing these countries from expanding their industrial production, import substitution and export promotion. Some developing countries have to buy the tools, dies, jigs and fixtures needed for production; others have to buy the steel needed to manufacture their own tools. Measuring instruments required for the production of replacement and spare parts are not always available and have to be imported. All these procurements require foreign currency, which is usually in short supply in the developing countries.

The proper operation of conventional machine tools is possible only when there are highly trained personnel available, personnel who are not only able to read, but who can understand and interpret complicated blueprints with tolerances expressed in fractions of millimetres. They must also be qualified to adjust, at any given moment, any deviation from the required tolerances in the operation of the machine tools serviced by them.

The success of the development of the engineering industry depends not only on the stock of machine tools but also on the way in which these are used. Some developing countries have sufficient stocks of equipment that are not being fully and properly utilized. This means unnecessary expenditure on buying, servicing, repair and maintenance.

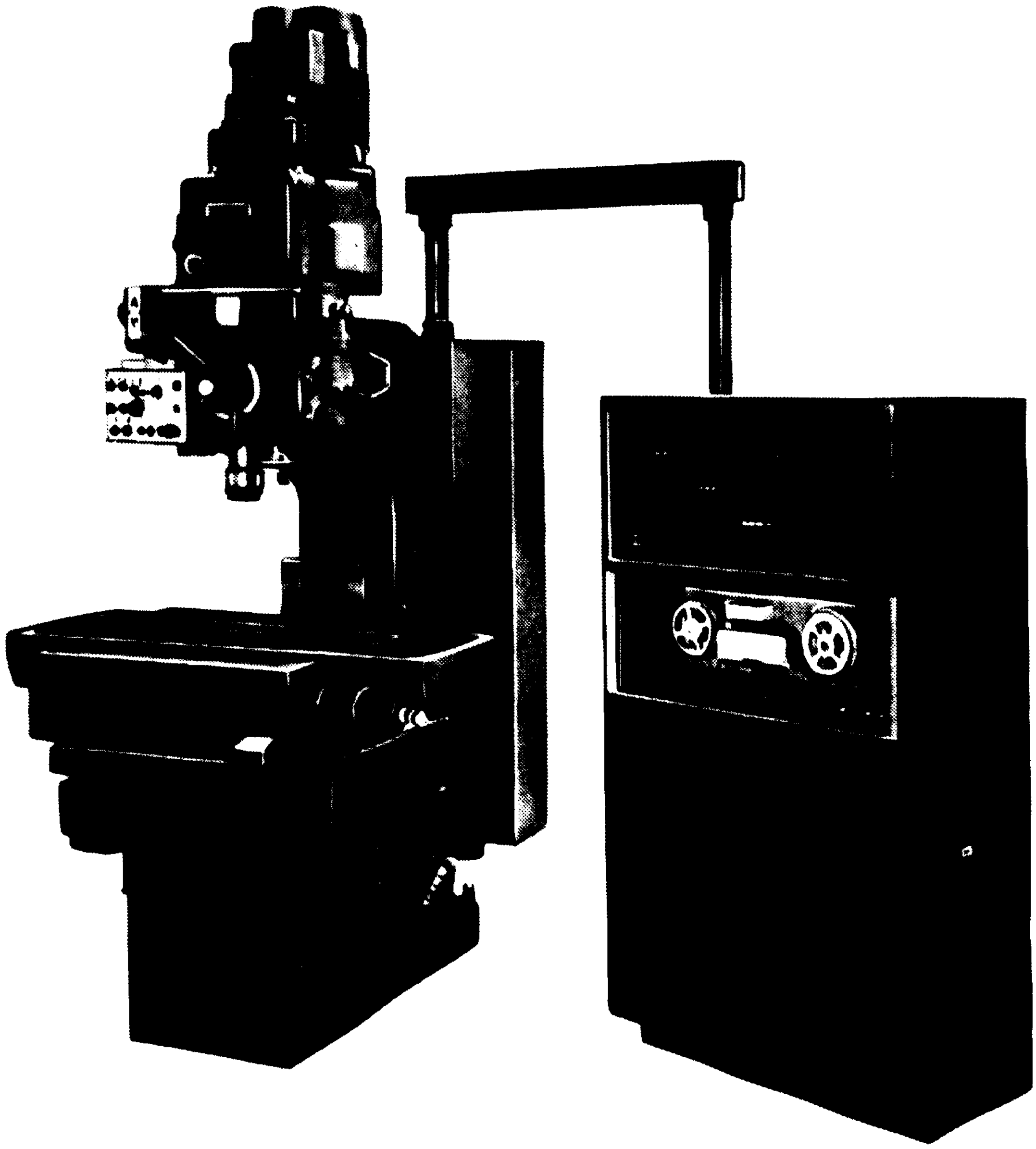
When an operator produces a part on a conventional machine, he must frequently refer to a drawing to find the dimensions of the part. Interruptions to adjust the hand wheels of the machine and to inspect the workpiece with gauges, calipers and micrometers are common. The machinist makes progressively smaller and slower cuts, measuring between each cut to avoid removing too much material; such a trial-and-error process is time-consuming and susceptible to error.

Most of these and other intractable difficulties confronting the developing countries could in large measure be resolved by the introduction of numerically controlled machine tools (figures III-IX).

Numerically controlled machine tools

Numerical control (NC) is a concept that provides for the automation of machining cycles on the basis of control information received in the form of numerical data. This type of control, which represents a particular type of sequence control, is concerned mainly with the travel of moving parts such as tool holders and workpiece holders. Numerical control is a very important improvement in the sequence control of machine tools because the travel of parts is no longer limited by steps that have to be adjusted with every change in the size of the workpiece, but by a feedback system to the NC unit itself, which counts the extent of the movements as they are performed and stops them as soon as the desired dimension is reached. When the tape carrying the control instructions has been set up, and the tools set to a

Figure III. Numerically controlled boring and drilling machine, using punched tape. These machines require only positioning (point-to-point) controls



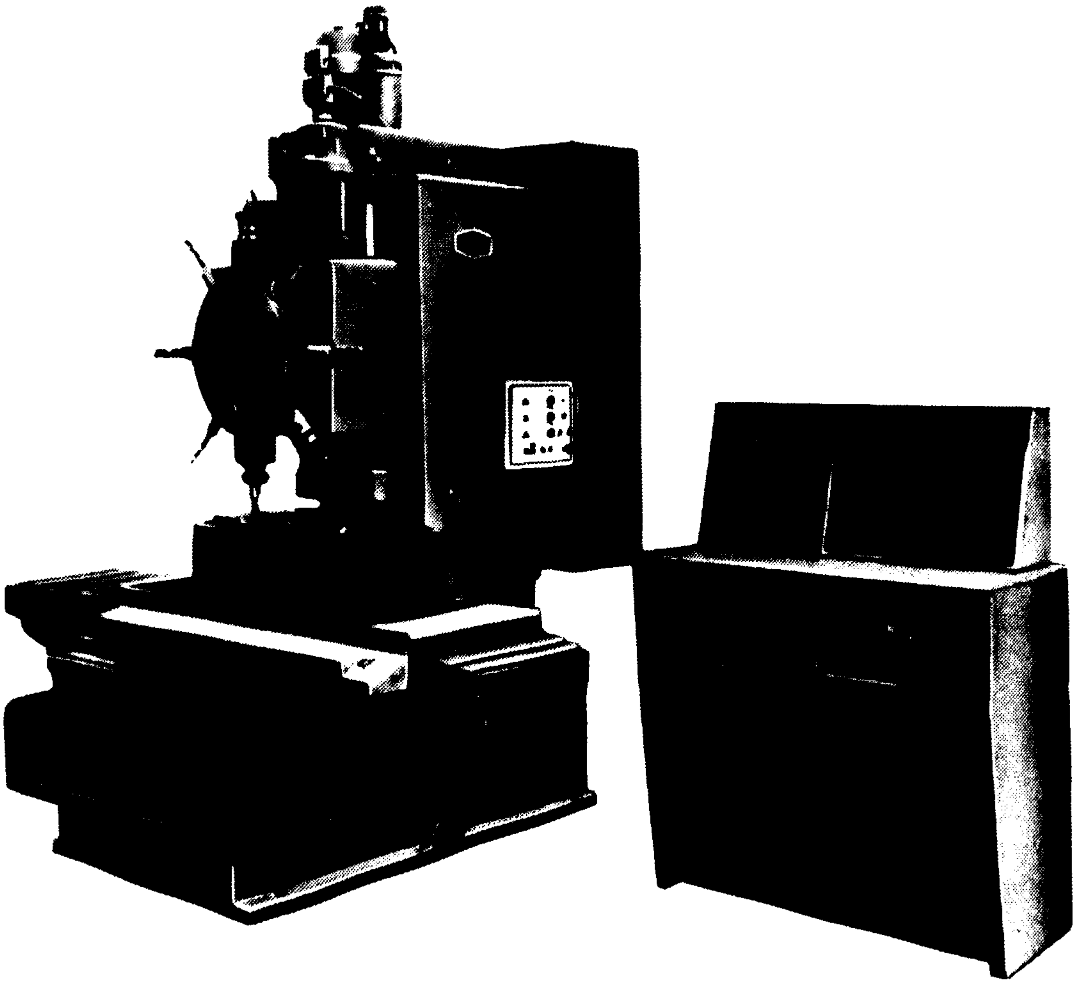
predetermined datum, no other adjustments of the machine motions have to be made at the beginning of the manufacturing process.

Numerical control increases the flexibility, versatility and performance of the machines to which it is applied. It reduces the time lost in passing parts from one machine to another, and time spent in loading, setting, inspecting and unloading the workpieces. It is important to note that NC automation is intended mainly for small- to medium-scale production. Also, NC can be used with or without a computer.

The main problem in using NC machine tools is maintenance. To ensure flawless performance, the machines should be kept in workshops with adequate air-conditioning and humidity control; experience has shown that NC machine tools installed in workshops with high temperature and humidity do not work properly.

There is no doubt that NC machine tools are much more expensive than conventional ones. These machines, however, seldom stand idle during an operation

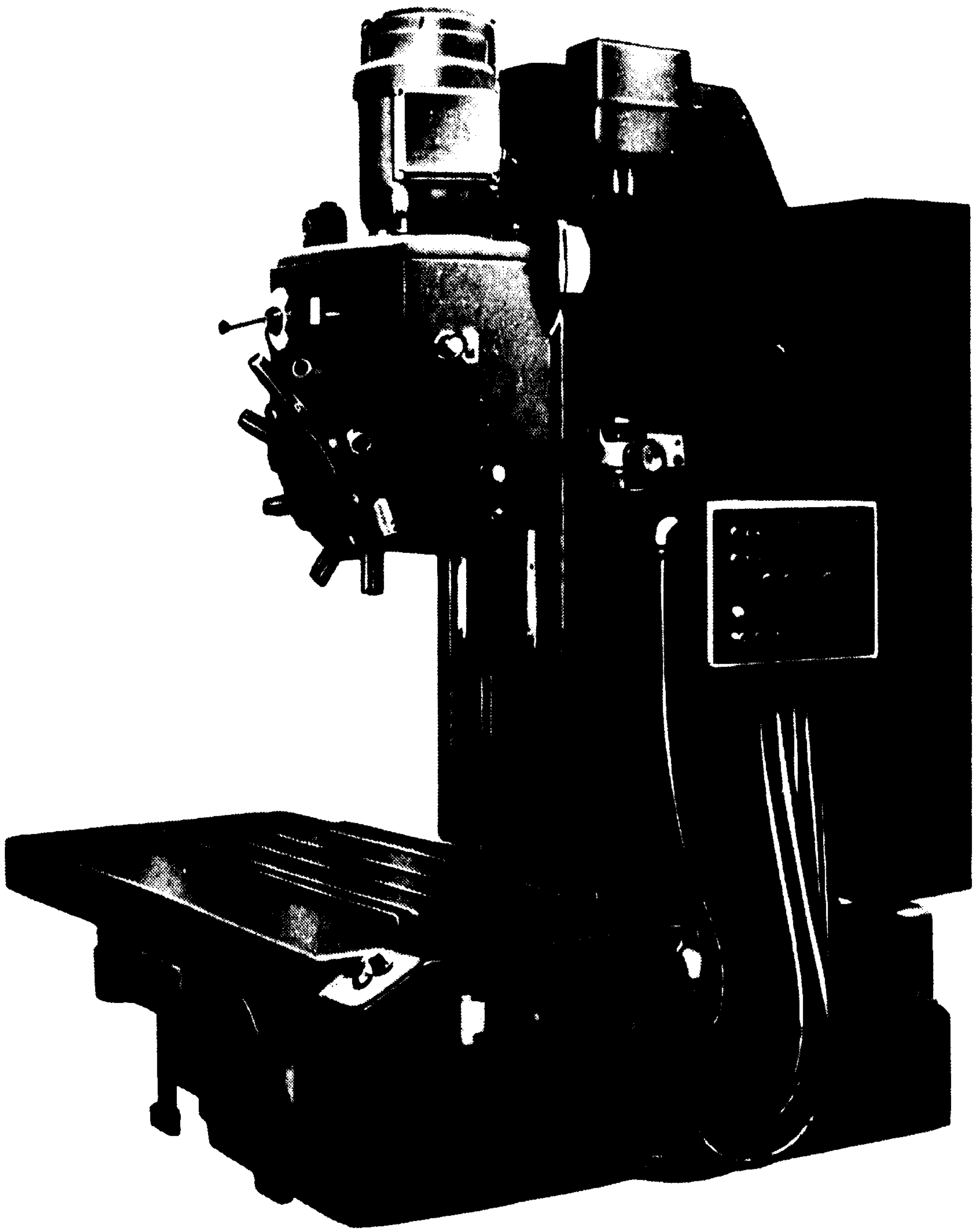
Figure IV. Eight-spindle turrethead milling-boring-drilling-tapping machine (three axes controlled table and spindle-head movements). This machine automatically drills, bores, reams, spot-faces, taps and positions the table in a sequence selected and controlled by a punched tape. After pressing the starter button, the sequence of operations for machining any number of holes of varying diameters and depths is completed without operator supervision. Relevant spindle speeds and feeds are selected automatically



and the proportion of the actual cutting time of the machine increases from a 10-30 per cent range for conventional tools to a 60-80 per cent range. Such high utilization of equipment is possible because accurate estimates of machining time can be adhered to on the production floor. Tight schedules are maintained since the pace of the machining sequence is not limited to the capability of an operator. Numerical control not only reduces labour costs per part, but makes 24-hour operation of tools feasible. And in developing countries, where skills and precision machine tools are scarce, it is vitally important to use the few assets available to the maximum capacity.

The introduction of NC usually has such an impact on an organization that it forces management to re-evaluate its methods of manufacturing and planning. The intelligent manufacturer re-examines most, if not all, of his manufacturing methods, from production planning to final inspection. Numerically controlled machines do exactly what they are commanded to do through their control systems and paper tape inputs. The conventional machine obliges the operator to make decisions that with NC are made in advance and put onto tape. Cost estimating for jobs to be run on NC equipment can be done on a much firmer footing than for jobs run on

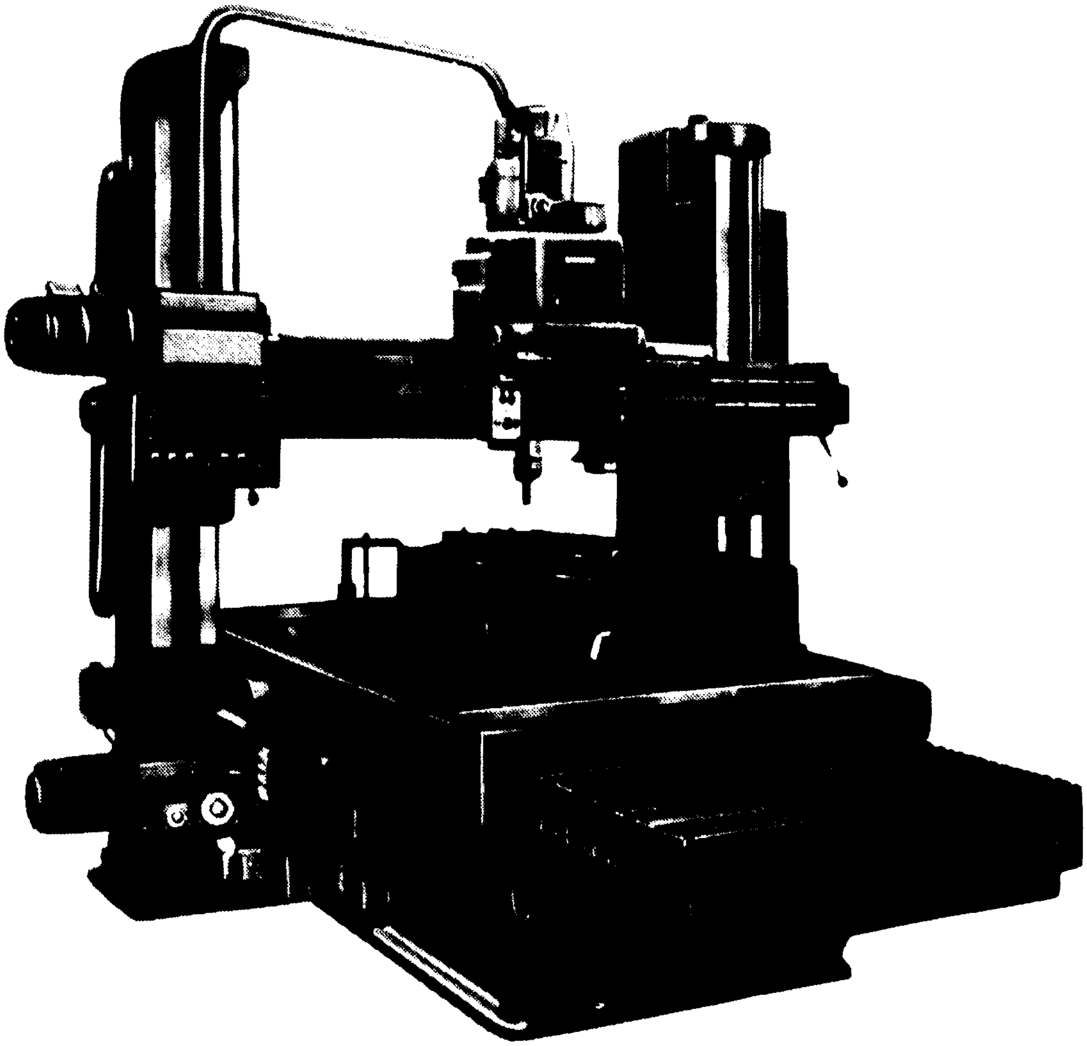
Figure V. Eight-spindle turrethead milling-boring-drilling-tapping machine with numerical control of the longitudinal and transverse displacements of the table and plain sequence control of the vertical displacement of the spindlehead by ajustable mechanical steps



conventional machines since control of the set-up and machining techniques is put into the hands of the engineering department rather than the shop.

Any company engaged in small- to medium-size batch production will eventually find that it is essential to accept NC manufacturing methods if it is to remain competitive. It is not the cost of labour that is the criterion for this judgement, but the high cost and the delays associated with the use of the complex jigs and fixtures that are otherwise required. As most developing countries are affected by a shortage of jig-, fixture- and tool-making capacity, NC can play a major part in their industrial development.

Figure VI. Numerically controlled boring and drilling machine (two axes and manual display of co-ordinates)



The NC machine most suitable for introduction in the metalworking industries of developing countries is the numerically controlled drill. This may be either a single-spindle machine or one with an indexing turret providing six or eight stations.

Horizontal boring machines are also particularly suited as they require far fewer complicated jigs and less special tooling than conventional boring machines. In addition, through the use of an indexing table, the four faces of a box-type component can be machined without resetting, including all milling, drilling and boring operations.

The NC lathe has fewer obvious advantages for the developing countries, except in cases of acute shortage of skilled labour. The digital read-out systems that can be fitted to the lathes can, however, be particularly useful as they make it much easier for the operator to quickly achieve high degrees of accuracy.

The main advantages of NC to the developing countries may be summarized as follows: reduced setting-up time; less need for complex jigs and fixtures; greater accuracy and repeatability; less need for inspection; greater operator safety and efficiency; less scrap; reduced lead time; minimal spare parts inventory; greater machine tool safety.

Figure VII. Numerically controlled lathe with: straight cut or contour control; incremental programming; programmable rapid and work feed; manual override 0-100 per cent of programmed feed; two spindle speeds in ratio 1:2 programmable; longitudinal and cross motions driven by step motors via ball screws; cross slide shaped for multiple tool arrangement or automatically indexing toolpost

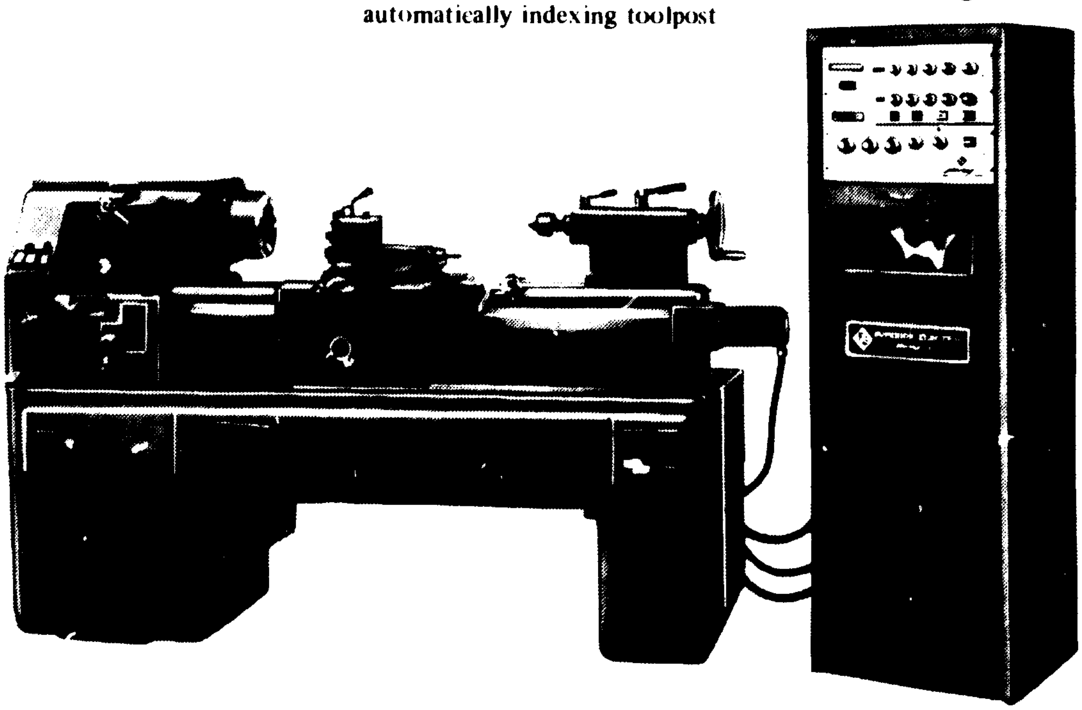


Figure VIII. Machining centre with tool changer

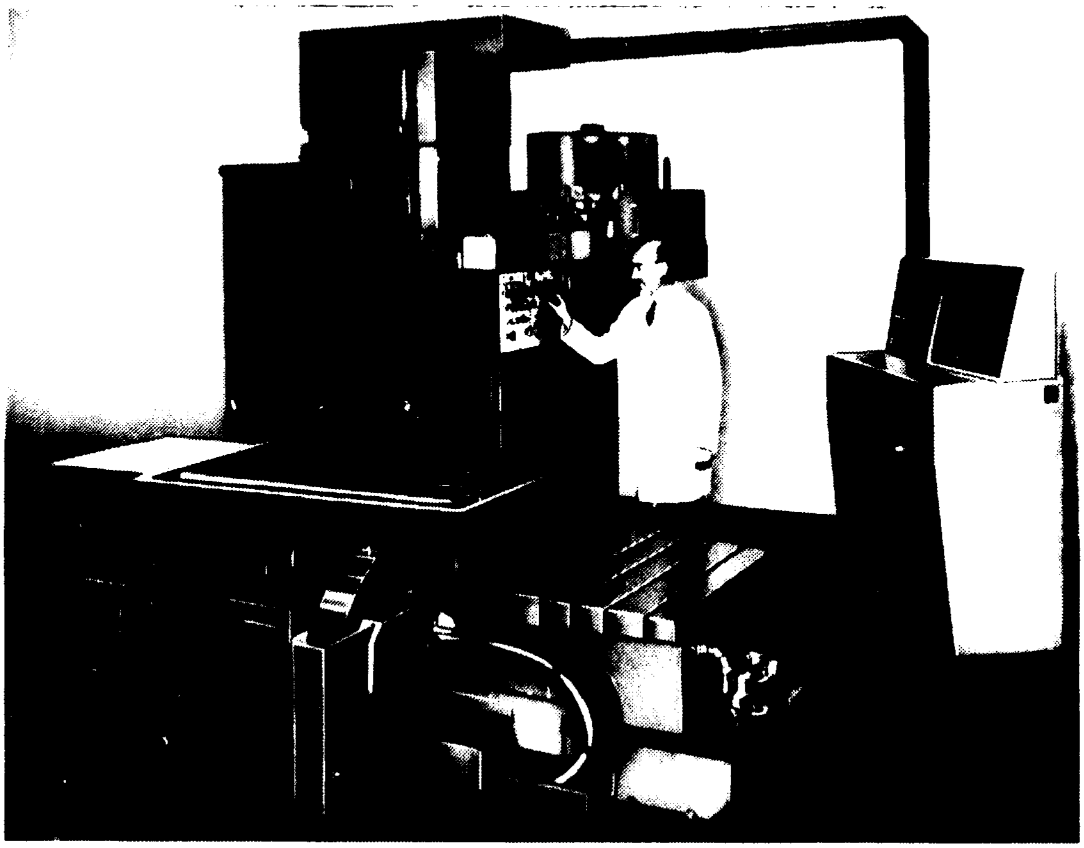
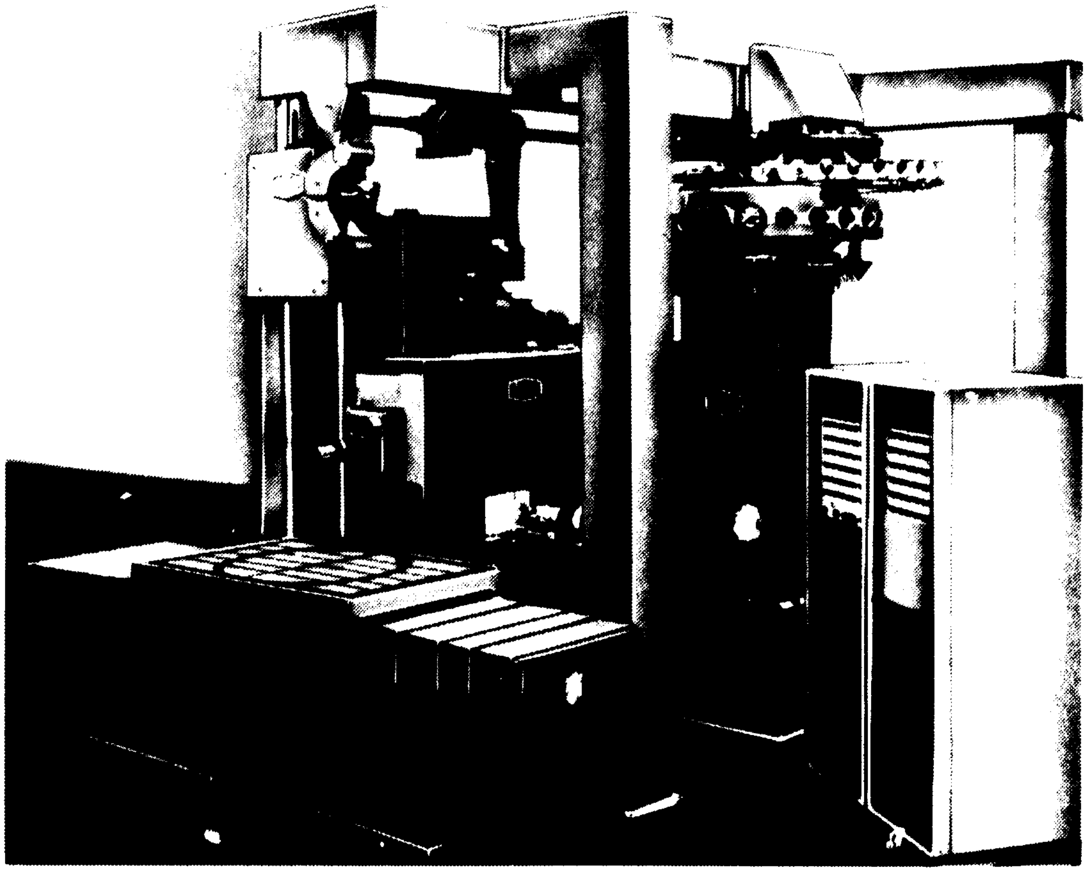


Figure IX. Another type of machining centre with tool changer



Reduced setting-up time

On standard machines, about 90 per cent of the time it takes to produce a finished item is waiting time time spent in handling workpieces, in changing from one machine to another, or in changing over from one process to another on the same machine. With NC, however, it is possible to make change-overs simply by changing the tape. Numerical control can, therefore, eliminate most of the waiting time and greatly increase both production and efficiency.

Less need for complex jigs and fixtures

Some NC machines have paid for themselves in the area of tooling costs alone. Tooling costs are reduced because less complicated fixturing is required. Complex drill jigs can be dispensed with since the accuracy generally associated with them is now built into the NC machines. This advantage contributes to easier set-ups for the machine operator. Only simplified holding fixtures are usually required with NC machines. Tool fixture design may be reduced by as much as 70 per cent, thereby reducing the workload on the drafting and tool departments. Numerical control does not require cams or stops that have to be adjusted with every change . the size of the workpiece; by electronic feedback, the control unit senses the extent of the movements as they are performed and stops them as soon as the desired amount of travel has been accomplished. Once the tape carrying the control instructions (program) has been prepared, no further adjustments of the machine travel are required.

Greater accuracy and repeatability

Numerical control will not make an inaccurate machine more accurate, but it will place the control of the accuracy in the hands of managers and part programmers rather than in the hands of machine operators. As machining operations increase in number and as set-ups decrease, compared to conventional machines, the word "accuracy" takes on additional meaning. The NC controller, using sophisticated feedback devices, is capable of positioning the slides of an NC machine to accuracies of +0.025 mm or less, over about 1 m of travel.

The inherent accuracy of the NC machine, coupled with its ability to repeat to the co-ordinates programmed on the tape, eliminates the need for constant inspection within a part lot. Each part in a lot can easily be within a tolerance of 0.025 mm or even 0.015 mm. With conventional machining methods, parts may vary according to the ability, the fatigue threshold, or the general attitude of the machine operator, or because of work shift changes. The NC concept is effective in producing any number of parts requiring only one reading of the tape for the production of each part. As this method is designed primarily for repeat work, it can be used for the manufacture of replacements and spare parts.

Less need for inspection

As the NC machine offers high accuracy, greater repeatability, and multiple machining functions with fewer set-ups, less detailed and costly inspection is needed. Field experience has shown that once the programmed NC tape has been tested, little further checking is necessary within the expected tool life. Fewer parts in each job lot need to be inspected; many parts require inspection of critical hole size and dowel hole positions only. The cost of inspecting parts machined using NC is generally from 50 to 75 per cent less than that of inspecting parts done with conventional machines.

Greater operator safety and efficiency

One of the advantages of NC is greater operator safety. As the NC system is operated from a remote station, the operator is exposed less frequently to moving machine elements or to the cutting tools. With the introduction of NC, the operator's efficiency increases. Since an NC machine requires less attention, he can perform other tasks while the machine is operating. In some cases, he may be in charge of two or more machines.

Less scrap

Experience shows that due to the consistently high accuracy of NC machines and the elimination of most of the human errors, scrap can be reduced to a minimum. Some companies have reduced the number of scrap parts produced on NC machines, as compared to conventional machines, by as much as from 50 to 60 per cent.

Reduced lead time

The lead time for the production, i.e. the set-up and tape preparation time for NC machines, is usually short. Sometimes jigs and fixtures are required, but these are usually standard items and readily obtainable from the toolroom. The tape may be filed for future production runs and requires very little storage space.

Minimal spare parts inventory

A large spare parts inventory is unnecessary. Additional quantities of spare parts may be produced simply by withdrawing from storage the tapes used for the original run.

Greater machine tool safety

Greater machine tool safety and utilization are other advantages of NC. The possibility of an operator error which could result in damage to the machine is reduced in proportion to the greatly lowered need for human intervention.

Numerical control requires less set-up time for tooling, and production time may go as high as 75-80 per cent up-time.

Manpower requirements

Four main types of specialist are needed for NC machine tool operation: programmers, machine operators, maintenance personnel, and managers.

Programmers, who prepare the control tapes, should have a background in production engineering. They should have the ability to read drawings and be acquainted with good machinery practices. The programmer must know the limits and capabilities of all the machine tools at his command. He must know the machine configuration, axes of motion and their respective limits, spindle speeds and associated horsepower and the table and spindle feed rates.

Most current NC operators were once operators of conventional machine tools. Their job has changed in that much of the control of machine tools is now in the hands of the part programmer. Many operators, once they have set up the machine, busy themselves with other jobs such as setting tools and inspecting parts while the machine is in tape-controlled cycles. They are sometimes called upon to monitor operations, especially when a tape is being run for the first time. Operators of numerically controlled machines should have backgrounds in mechanical engineering and control systems. Training on NC is usually provided by the machine builder at the time of installation.

Maintenance is the major problem in NC, as far as personnel is concerned. Maintenance personnel should have experience in electronics and be familiar with NC before the equipment is delivered.

Managers have an important role to play in co-ordinating production. It has been found that the most effective application of NC machine tools takes place in companies where the production management has a clear understanding of the advantages and limitations of the system and has introduced manufacturing procedures designed to exploit to the full the potential of the machines.

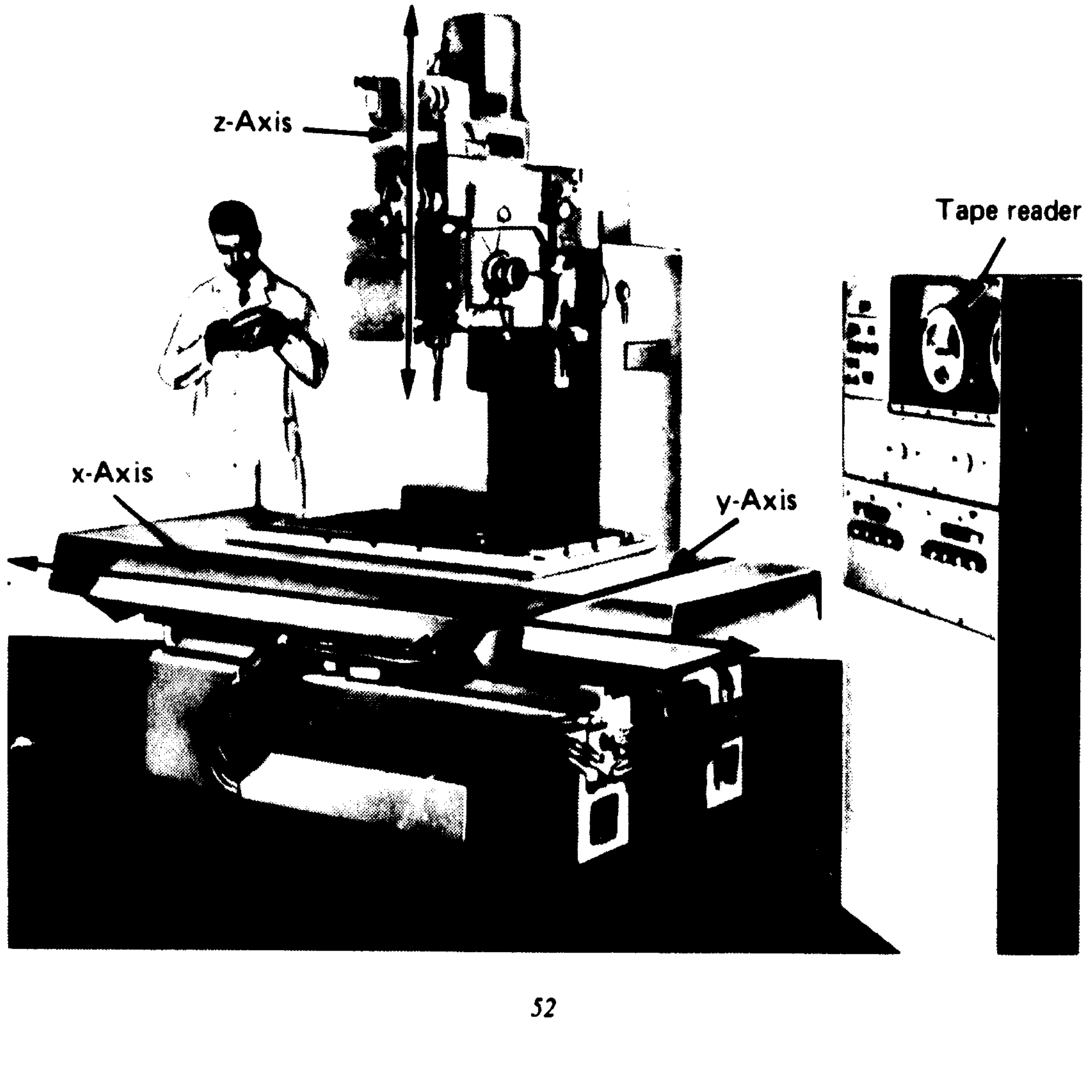
II. CO-ORDINATE AND CONTROL SYSTEMS

Co-ordinate systems

All machine tool movements can be considered as movements within a rectangular co-ordinate system and so directed or programmed. In other words, all machine tools can be adapted to NC and the co-ordinate axes in all cases will correspond to the major movements of each machine.

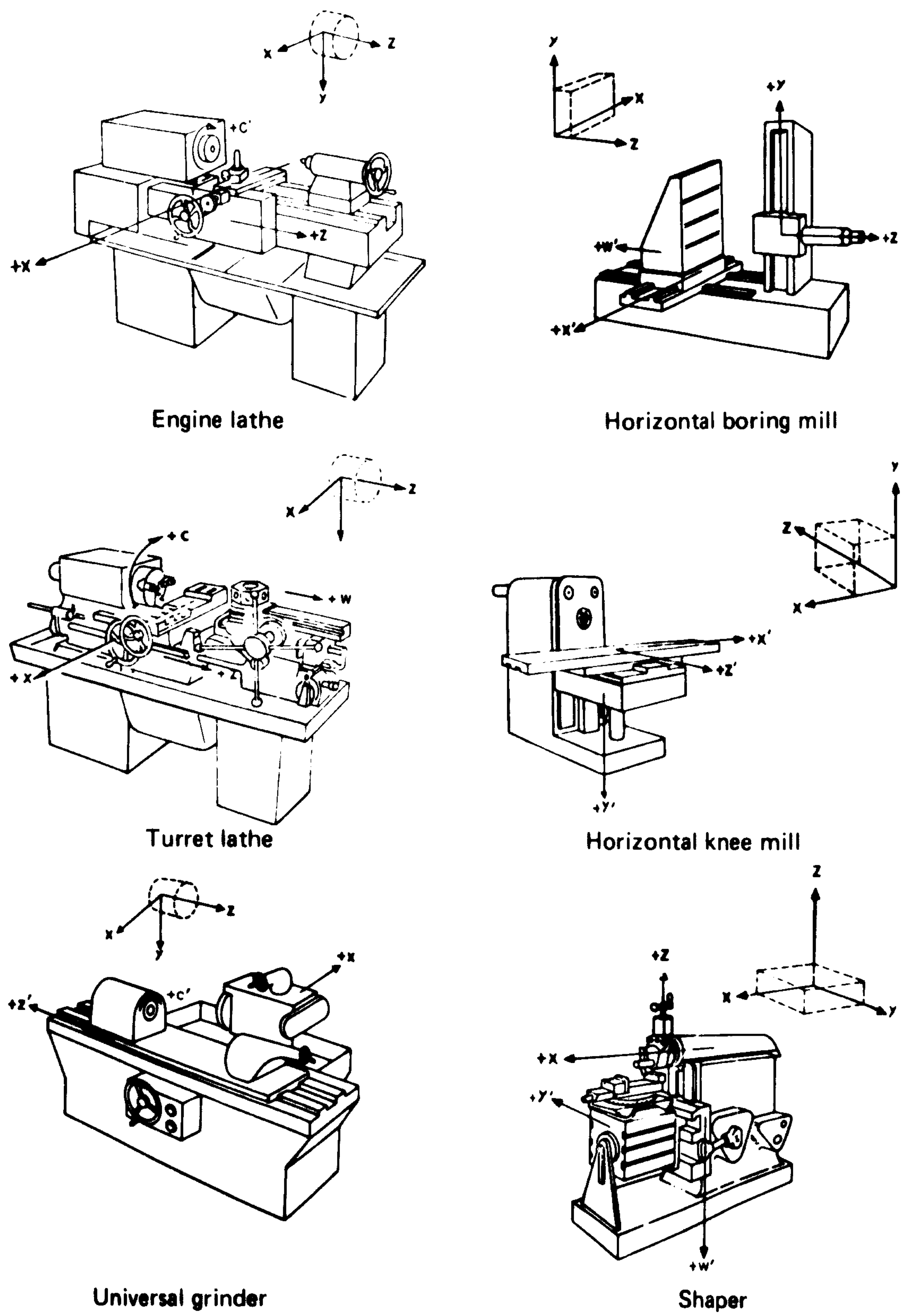
The designation of the axes of NC machine tools began with the drilling machine, where the customary co-ordinate system applies, i.e., that +x is the axis to the right in the horizontal plane, +y is the axis going north to the x-axis, and z is the axis vertical to the x-y plane. Although the principle is still used, it has been found necessary to adopt the co-ordinates to the requirements of programming for numerical control. The three perpendicular axes of the point-to-point NC drilling machine are shown in figure X.

Figure X. Point-to-point numerically controlled drilling machine



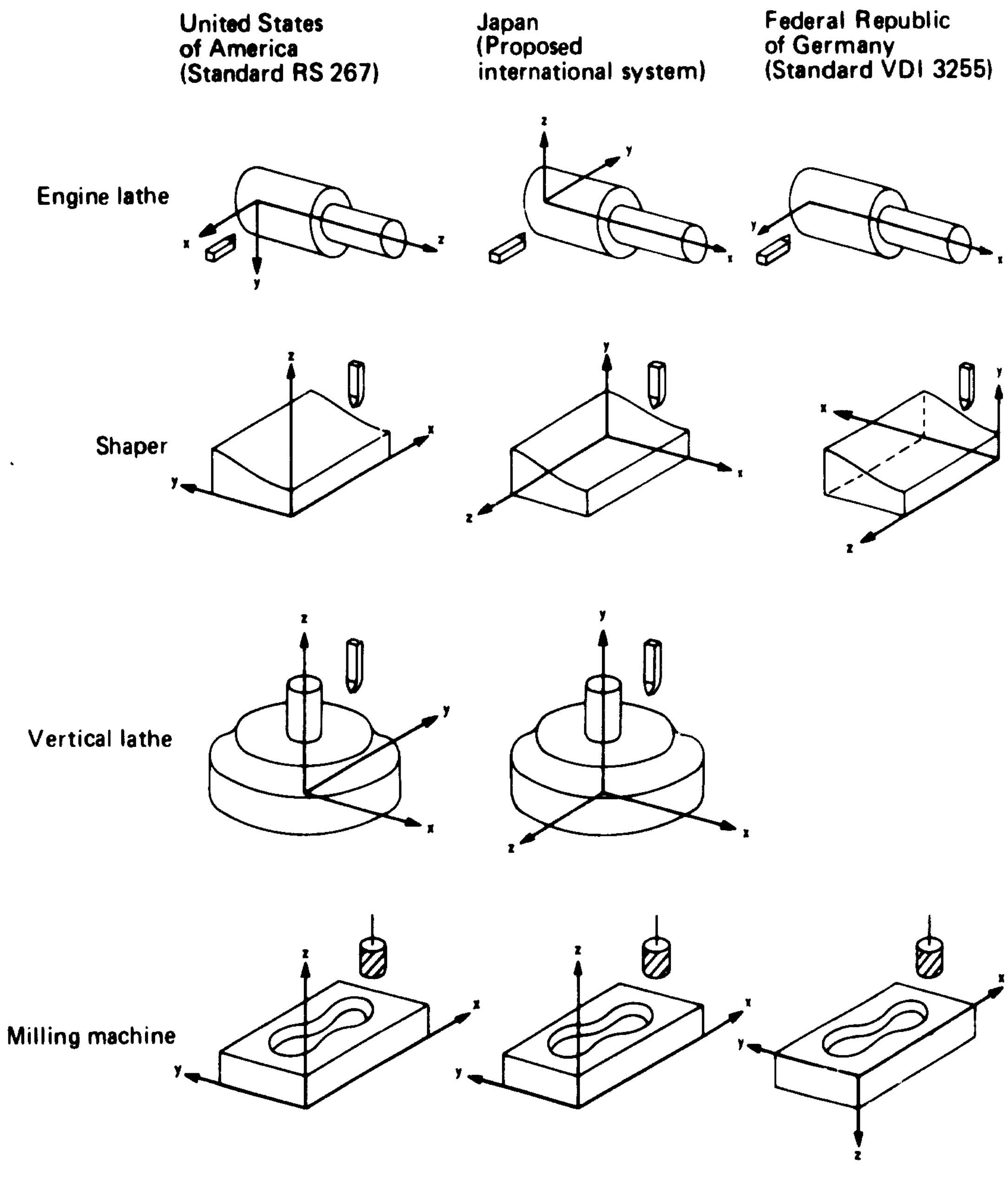
Numerical control can be simplified if the z-axis is taken either as the axis of rotation of the tool or as the axis of rotation of the workpiece. A sample of the designation of the axes for some types of NC machine tools is shown in figure XI.

Figure XI. Designation of the axes of NC machine tools



The co-ordinate systems for NC machine tools used in various countries are different. For example, the standard used in the United States of America is based on a right-hand co-ordinate system and that used in the Federal Republic of Germany on a left-hand system. Figure XII compares these two systems with an international system proposed by Japan.

Figure XII. Comparison of the two standard co-ordinate systems for NC machine tools with an international system proposed by the Japanese electronics industry

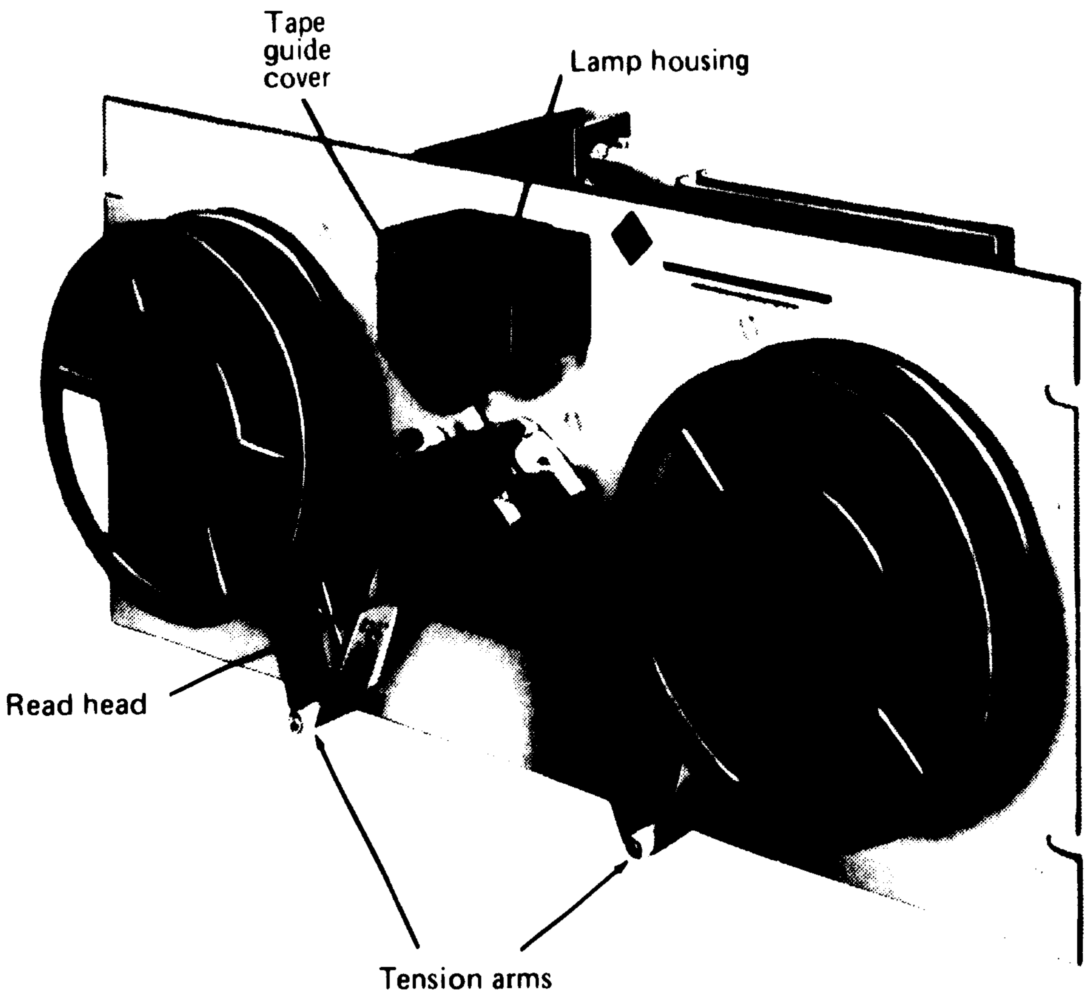


Looking at the workpiece for vertical milling machines in the direction of z-axes, it is realized that the x-axis turns the workpiece to the right in the American system and to the left in the German system. In the case of the vertical milling machine, Japan suggests adaptation of the method used in the United States, while in other cases new designations are submitted.

Control systems

Numerical control can be simply defined as the control of a machine from a series of numbers. The numbers are punched on tape and transferred to the control by an electronic interpreting device known as a tape "reader". The input codes are then converted to binary numbers consisting of only zeros and ones. Binary numbers are used because they can be represented by on and off signals in the electronic devices. The electronic signals are then circulated through the control registers and the data are processed according to the circuits wired into the control. The NC, using the information conveyed by the numbers, positions a cutter in relation to a part, or vice versa. Figure XIII shows a tape reader.

Figure XIII. Electronic tape reader gathers data from the tape and transfers it to the control unit without human intervention



Point-to-point systems

A positioning or point-to-point system is used to control machine tools such as drilling and jig-boring machines which perform single operations only at specified points on a workpiece. In drilling, for example, the drill spindle is positioned at a single specific point. The proper drill size, speed and feed are selected. The drill is advanced to cut a hole to the desired depth and is withdrawn when the operation is completed. Then it is positioned to cut at the next point.

The use of drilling machines with positioning controls on parts that require a defined path is highly impractical, if not impossible. In most drilling operations, however, a predefined point-to-point path is not required. The control is built to read first the x axis co-ordinate and to start moving towards the point in that axis. It then reads the y axis co-ordinate and moves towards that point.

Positioning control is also successfully used on boring and grinding machines. Boring machines can also move from hole to hole with accuracy and ease and grinding machines can switch from one diameter to another and position a table so that repeatability and accuracy are greatly increased.

In the initial stage, all efforts should be concentrated on acquiring this type of control. The point-to-point system is much simpler and considerably lower in cost than the continuous path system and can meet 80 per cent of the needs of the engineering industry. Furthermore, point-to-point control does not necessarily require the use of electronic computers for program preparation. For the simple machining operations carried out in most workshops (drilling, tapping, straight line or simple arc milling and plain turning), manual programming is quite sufficient as long as the number of instruction blocks carried by the punched tape does not become excessive.

The sequence of manufacturing of a part on a point-to-point NC machine tool, starting from the preparation of an engineering drawing, is shown in figure XIV.

Continuous path systems

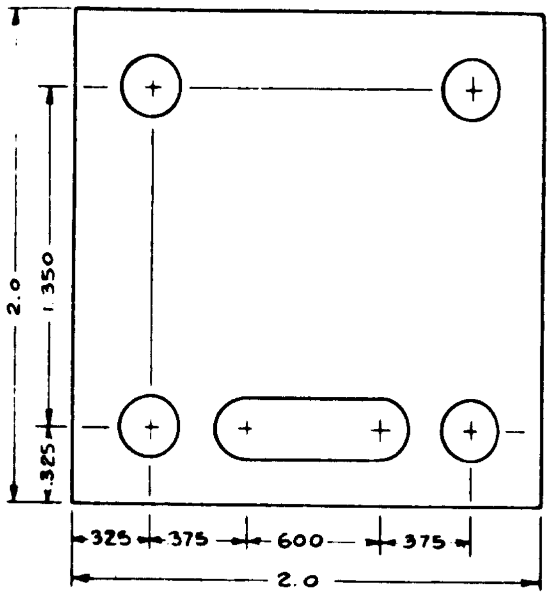
The continuous path control or contouring system is used to control machine tools such as lathes and milling machines, which remove metal continuously from the surface of a workpiece. The object of the system is to exercise continuous control over tools which require frequent changes in movement with respect to two or more machine axes simultaneously and which are in constant contact with the workpiece.

This control system is more costly and complex and requires a far greater input of detailed instructional information than a point-to-point system. The controls are able to move two, three and more axes—all co-ordinated in relation to both part geometry and cutter feed. The system is designed for the manufacture of complex parts of high accuracy, such as those required by the aerospace industry. The ratio of the movement of an axis in relation to all other axes must be calculated and the rate of movement of all axes defined so that the resultant move will end in the proper cutter feed. All of these calculations are done in the circuiting of a contouring control.

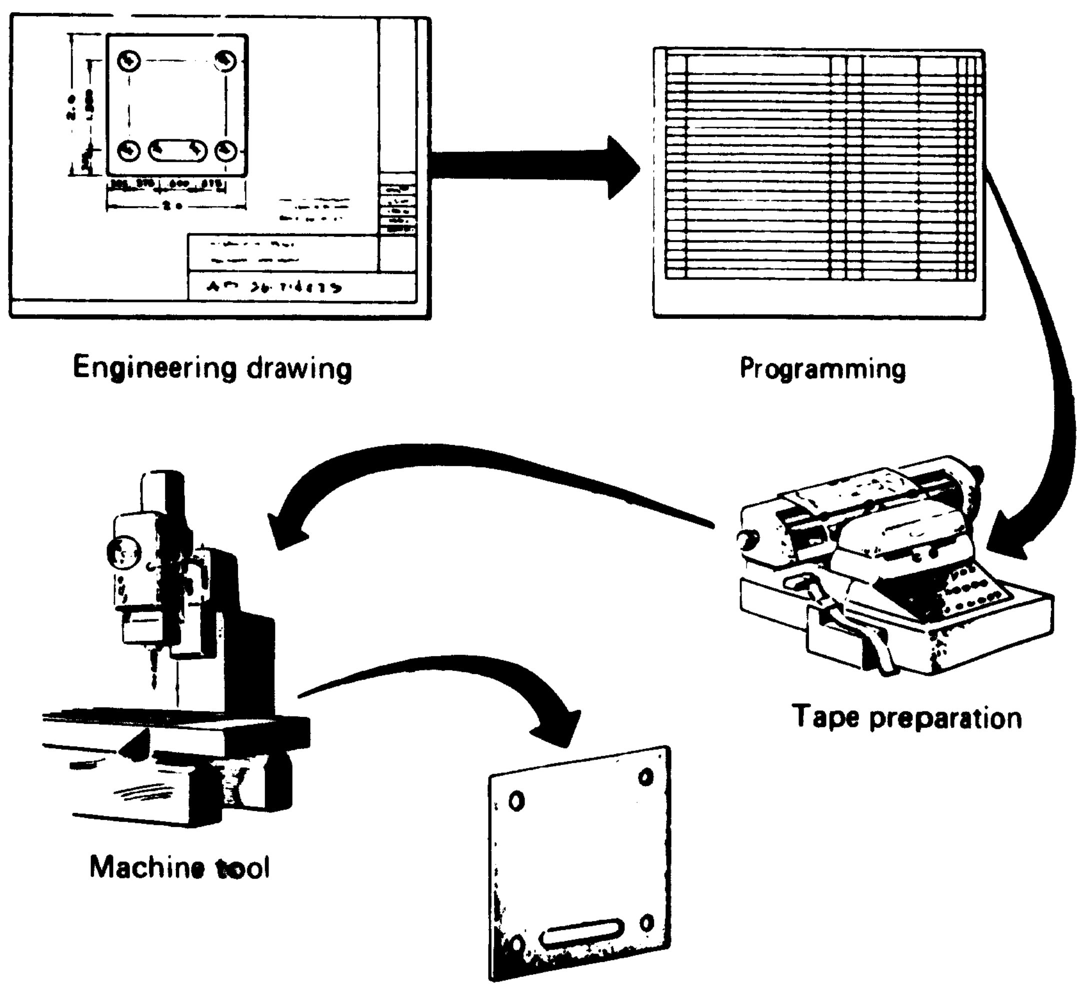
In spite of the fact that contouring control is more complicated than positioning control, the system has found very wide application in the machining of contoured parts on milling and turning machines. Parts that were previously made by tracer machines, or very laboriously by hand, are now quite easy to program and make on continuous control lathes. Capabilities such as tool-changing, circular interpolation and threading have been added to the controls, which allow parts to be manufactured in small or large lots. In addition, the application of continuous path control to turning-type machines allows operators with minimal training to produce parts that would have required years of training in the past.

Contouring controls have been used to advantage on many special-purpose machines, e.g., on machines that position flame cutters, punches and riveters. Applications in non-metalcutting industries include tape-controlled routers for the woodworking industry and pattern-cutting machines for the clothing and upholstery industries.

Figure XIV. The sequence of manufacturing of a part on a point-to-point NC machine tool



	x Axis	y Axis
1	.325	.325
2	1.675	.325
3	1.675	1.675
4	1.300	1.675
5	.700	1.675
6	.325	1.675



The essential differences between the point-to-point system and the continuous path system are shown in figure XV.

Figure XV. Differences between point-to-point and continuous path systems

	Point-to-point or positioning	Continuous path or contouring
Kinds of operations	drilling milling tapping boring counterboring reaming countersinking punching part-inserting metal-forming riveting spot welding	milling welding flame-cutting grinding sawing applying finishing materials
Relationship of tool to workpiece while machine table is moving	Tool is ordinarily not touching workpiece (except when milling) Tool is ordinarily not working (except when milling)	Tool is touching workpiece Tool is working
Machine table positioning speed rate	Usually high	Usually low
Adaptability to other system	Can be used for limited contouring	Can be used for point-to-point positioning
Reference point system	Incremental or absolute	Incremental
Machining unit	Small and less costly than contouring NC units	Large and more costly than positioning NC units

III. PROGRAMMING

Manual part programming

Programming is the sequential assembling of commands to be translated into a decodeable language that can be understood by the NC control unit. The individual who has the task of setting down a series of commands or instructions for an NC machine is known as a programmer. The manual part programmer should be a person with a shop background and a working knowledge of geometry and trigonometry. He is usually responsible for planning the job, writing the tape manuscript, putting the tape on the machine and optimizing the program.

The planning of an NC program should be considered at the design level. In many cases, if the programmer is consulted during the design of a part, savings can be obtained by the elimination of redesign and perhaps other operations, and by reduction of fixturing costs. Also, by indicating properly the required dimensions on the part drawing, errors can be reduced.

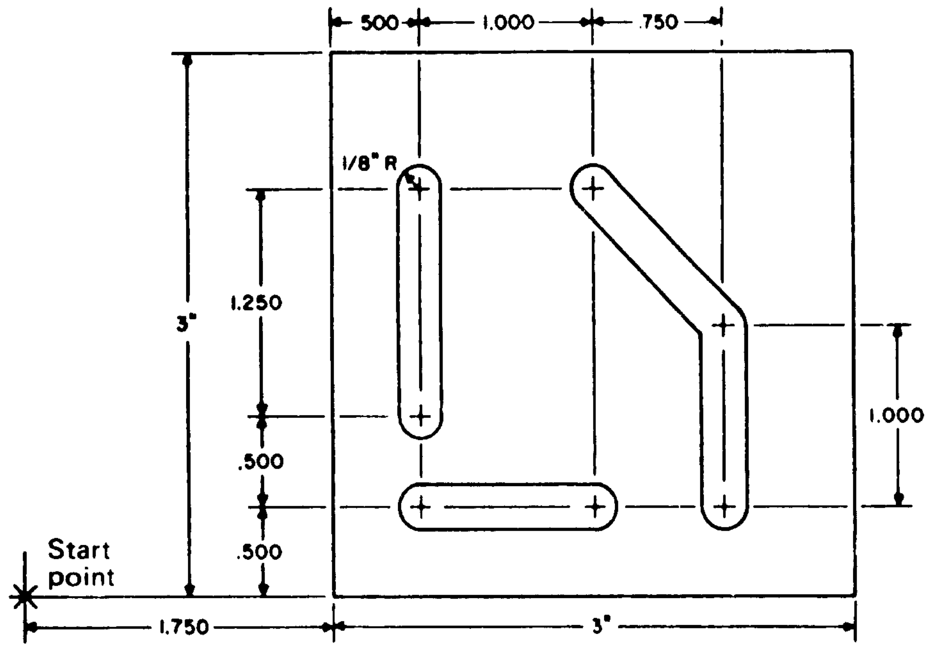
After receiving the part drawing from the engineering department, the programmer must decide whether the raw material should be a forging, a casting, or bar stock; for which NC machine the part should be programmed; and if conventional machine tools are needed for operations prior to NC. He should be informed about such determining factors as quantity of parts required; lot run sizes; comparison cost of material; lead time; production time and cost; and fixture cost.

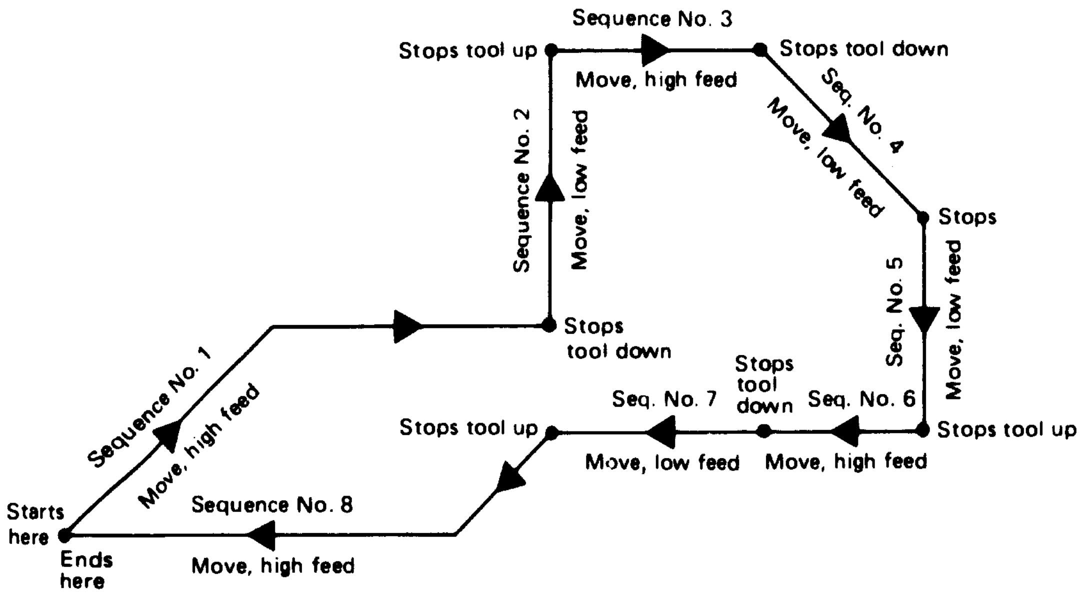
The programmer must know the limits and capabilities of all the machine tools at his command. He should determine which is the proper machine to use by analysing the machine load, burden cost and labour cost. Sometimes, due to heavy machine loads, he may elect to program a job for more than one machine.

After the type of material, particular machine tool and prior operations have been decided upon, the programmer specifies the design of the required holding fixture, if any is needed. His next step is to process the part by writing a step-by-step sequence of machining operations. In conjunction with this, he determines the perishable (cutting) tools and tool adaptors required for each step. Speeds and feeds are also calculated at this time. Depending on the complexity of the part, operational sketches may be helpful.

Figure XVI shows a plate with three individual slots to be milled and a graphic of the tool movement. It can be seen that in accordance with the program sequence 1 statement will cause the tool to move to the beginning of the first slot at high feed. Sequence 2 statement will cause the tool to lower into the work and mill the first slot. Sequence 3 statement raises the tool and moves it to the beginning of the next slot at high feed. Sequence 4 statement lowers the tool into the work and causes it to mill the 45 degree portion of the second slot. A slot such as this, which begins with a 45 degree angle followed by a section that is parallel with the axis, can be programmed in one block of information. (In figure XVI, a sample block that combines sequences 4 and 5 is shown below the program.) Programming this move in one block eliminates the tool dwell marks caused when the control pauses between

Figure XVI. Graphic of tool movement in milling operation





sequences 4 and 5. Slots consisting of a straight line followed by a 45-degree angle must be done with two blocks of information.

Sequence 6 statement raises the tool from the work and moves it at high feed to the beginning of the last slot, while sequence 7 statement lowers the tool into the work and mills the slot. Sequence 8 statement raises the tool, returns it to the starting point at high feed, and rewinds the tape.

Program writing is the process of listing the instructions on a program sheet. The completed list of written instructions is called the program manuscript. A sample of the program manuscript for the milling of the three slots discussed above is shown in figure XVII.

Figure XVII. Program manuscript

COMPANY NAME ______________________ ADDRESS ______________________

PREPARED BY / DATE	PART NAME	PART NO	OPER NO
CK'D BY / DATE			
SHEET OF	REMARKS: Tool Switch–Off; Feed Rate–6 ipm; Backlash–No. 1 or No. 2	Tools: 1/4" End Mill	
DEPT			
TAPE NO			

SEQ. NO.	TAB OR EOB	+ OR –	"x" INCREMENT	TAB OR EOB	+ OR –	"y" INCREMENT	TAB OR EOB	"m" FUNCT	EOB	INSTRUCTIONS
									EOB	
0	RWS								EOB	
1	TAB		2250	TAB		1000	TAB	55	EOB	
2	TAB			TAB		1250	TAB	52	EOB	
3	TAB		1000	TAB			TAB	535	EOB	
4*	TAB		750	TAB	–	750	TAB	52	EOB	
5*	TAB			TAB	–	1000			EOB	
6	TAB	–	750	TAB			TAB	535	EOB	
7	TAB	–	1000	TAB			TAB	52	EOB	
8	TAB	–	2250	TAB	–	500	TAB	02535	EOB	
*Sequence No. 4 and No. 5 can be combined as follows:										
4	TAB		750	TAB	–	1750	TAB	52	EOB	

The columns of the manuscript contain the basic language codes needed for NC commands.

RWS (Rewind stop) is the code symbol that is normally placed in the first block of information. When the tape is moving in reverse feed, the tape reader will stop on reading this code.

TAB is the code that separates information within a block. The x increment follows the first TAB, the y or z increment follows the second TAB and miscellaneous function codes follow the third TAB.

The **Plus** (+) code indicates travel in the plus direction. This sign may be omitted if desired. Absence of a sign indicates that travel is to be in the plus direction.

The **Minus** (–) code indicates that travel is in the minus direction.

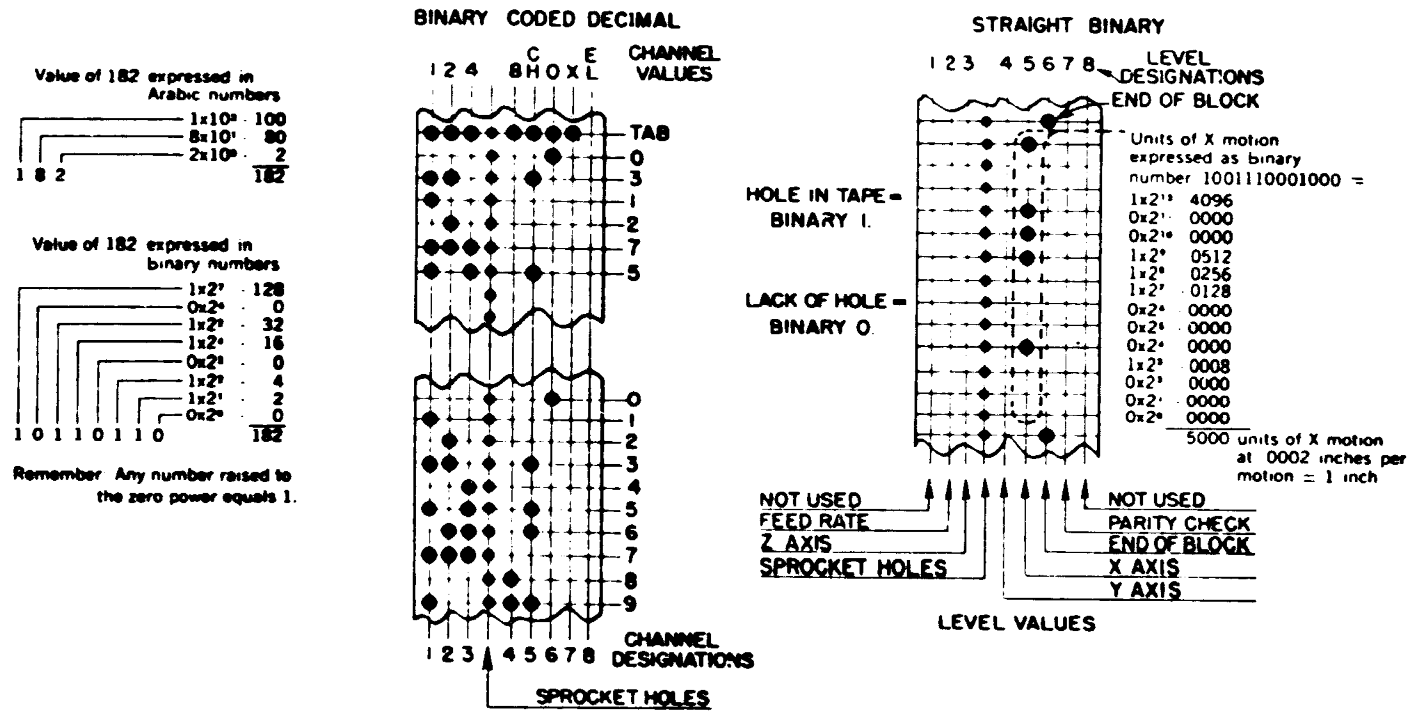
EOB (End of block) is the code that separates blocks of information on the tape. The EOB code stops the passage of tape through the reader, telling the system to act on the information received.

There are several additional codes which stop the system for the changing of tools and perform auxiliary functions such as controlling motor speeds, tool length and coolant.

Figure XVIII. Form of numerical representation

BINARY NUMBERS

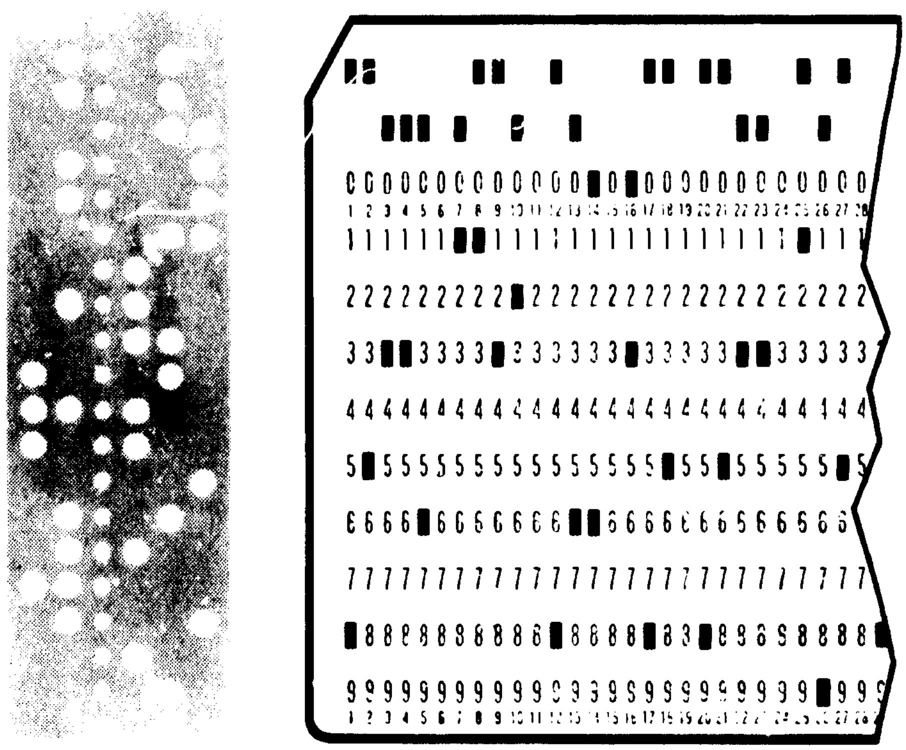
ARABIC	BINARY	POWERS OF 2
0	0	
1	1	2^0
2	10	2^1
3	11	
4	100	2^2
5	101	
6	110	
7	111	
8	1000	2^3
9	1001	
10	1010	
11	1011	
12	1100	
13	1101	
14	1110	
15	1111	
16	10000	2^4
17	10001	
18	10010	
19	10011	
20	10100	
21	10101	
22	10110	
23	10111	
24	11000	
25	11001	
26	11010	
27	11011	
28	11100	
29	11101	
30	11110	
31	11111	
32	100000	2^5
64	1000000	2^6
128	10000000	2^7



After the manuscript has been checked, a tape is prepared. For almost all point-to-point NC systems, the form of numerical representation shown in figure XVIII is used. The tape is prepared by a typist using a special typewriter that punches the proper holes in the tape.

The coded instructions may be recorded on a deck of cards, a magnetic tape, or a tape which may be made of paper, plastic, metallic foils, or any combination of these materials. Examples of these input media are shown in figure XIX. The perforated tape has become the most commonly used NC input medium. Indeed, it is so universally accepted and adapted that numerical control is quite synonymous with tape control.

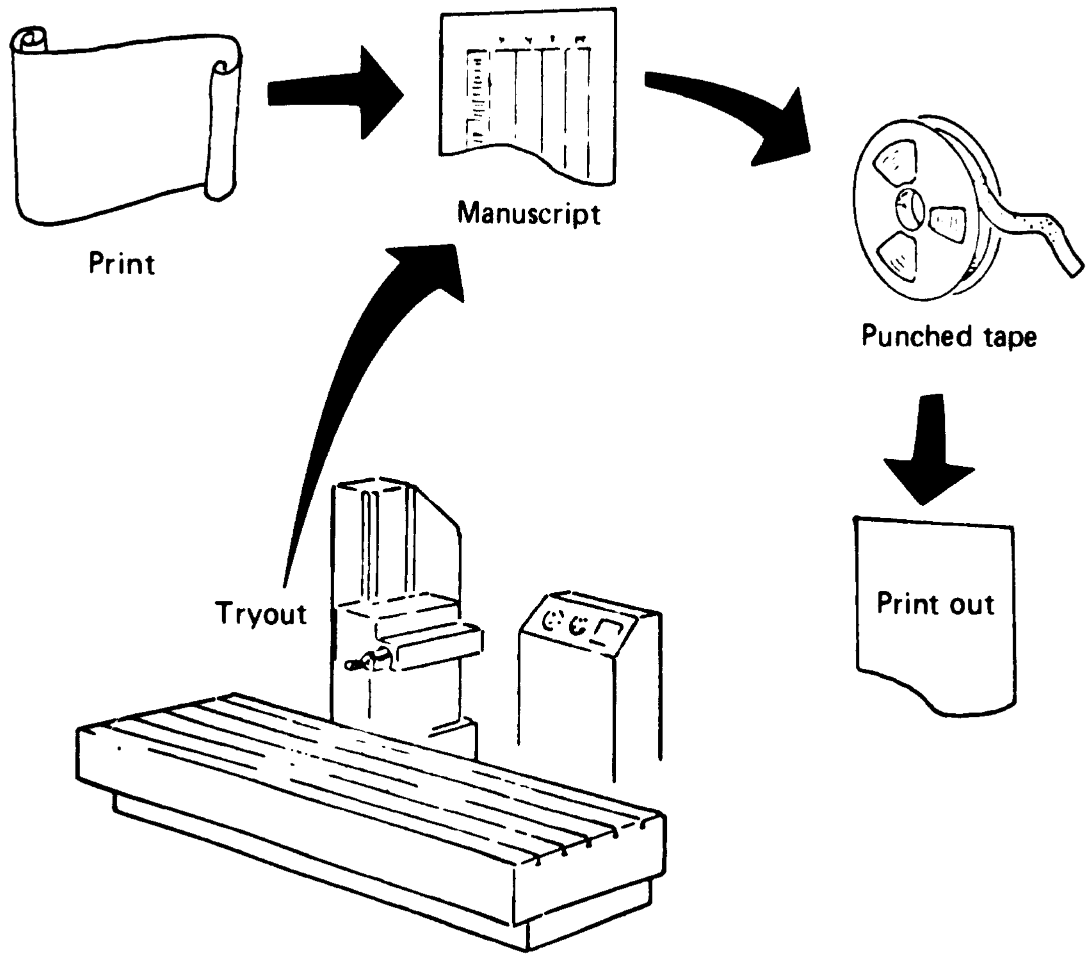
Figure XIX. NC input program media



Perforated tape   Punched cards   Magnetic tape

After the tape is prepared, it should be tried out on a machine tool. Trying out the tape on the machine tool and cutting the part is the only positive way of verifying the program. To do this, the programmer should prepare a "tape try-out package" consisting of the part drawing, operational sketch, sequence of operations, tool drawings, program manuscript, tape listing and the tape. This package should contain enough detailed information for any machine operator to set up and run the job without assistance once the tape is approved. During the try-out period, all program corrections should be made and approved. For final tape approval, the first part should be inspected to assure that all part dimensions and tolerances are met. A sample of manual tape preparation is shown in figure XX.

Figure XX. Manual tape preparation



The remaining responsibility of the programmer is optimization of the part program. Almost always, after the tape is approved and in production, some wasted motion can be eliminated. Many factors enter into the decision of whether or not to optimize. Three of the most important are: job lot size; repeat orders; and cost of optimizing.

Computer part programming

In contrast to the manual part programmer, who is responsible for the manual conversion of design and manufacturing information into a coded control tape that will produce the desired part on a given machine, the computer part programmer uses automated methods to reach the same end.

A design change to a manually programmed part often results in reprogramming of the remainder of the part program. However, a design change can be reflected in one small section of a computer part program and the NC processor will automatically recalculate the number of points remaining simply by submitting the part program for another computer run.

By far the greatest advantage of computer part programming is its highly increased efficiency and reliability. The elimination of the human calculating and clerical operations that lie between the initial writing of the manual part program and the output of an error-free control tape is alone enough to justify the transition from manual to computer part programming. Many American firms that introduced computer part programming reduced lead time by an average of 56 per cent.

The major advantages of computer-assisted programming are: shorter programming time; increased accuracy; better tool-path selection; and the possibility of establishing optimum machinability parameters.

The following sequence is observed in computer part programming:

(a) A part programmer secures the design specifications for a desired part;

(b) The programmer defines the part dimensions and the machining operations to be performed, using an English-like part programming language;

(c) The program is submitted to the computer to be run through an NC processor and post-processor;

(d) The computer output, consisting of the control tape needed to cut the desired part, is received.

The NC processor is a computer program that accepts part descriptions as inputs and makes the required calculations and data arrangements to generate the path the cutter must follow to produce the desired part.

The post-processor is a computer program that accepts the cutter location data generated by the NC processor as input; calculates feeds, speeds and other data needed by an NC system; and outputs data in an acceptable format for the machine/control combination specified.

Computer part programming languages are basically machine and control independent. The part programmer need not be as thoroughly familiar with each machine/control configuration as he need be when manually programming. Also, it is no longer necessary for him to remember specific codes or particular control tape formats. One of the major functions of the post processor is to make sure that the control tape, which is output by the post processor, is acceptable to the machine/control configuration for which the tape is intended. A sample of the computer tape preparation is shown in figure XXI.

In order to understand how the NC processor and post processor fit into the computer, it is necessary to look at the overall computer system. A computer system may be considered as having five subsystems:

(a) Memory of core storage. Used for the storage of data for the program being executed;

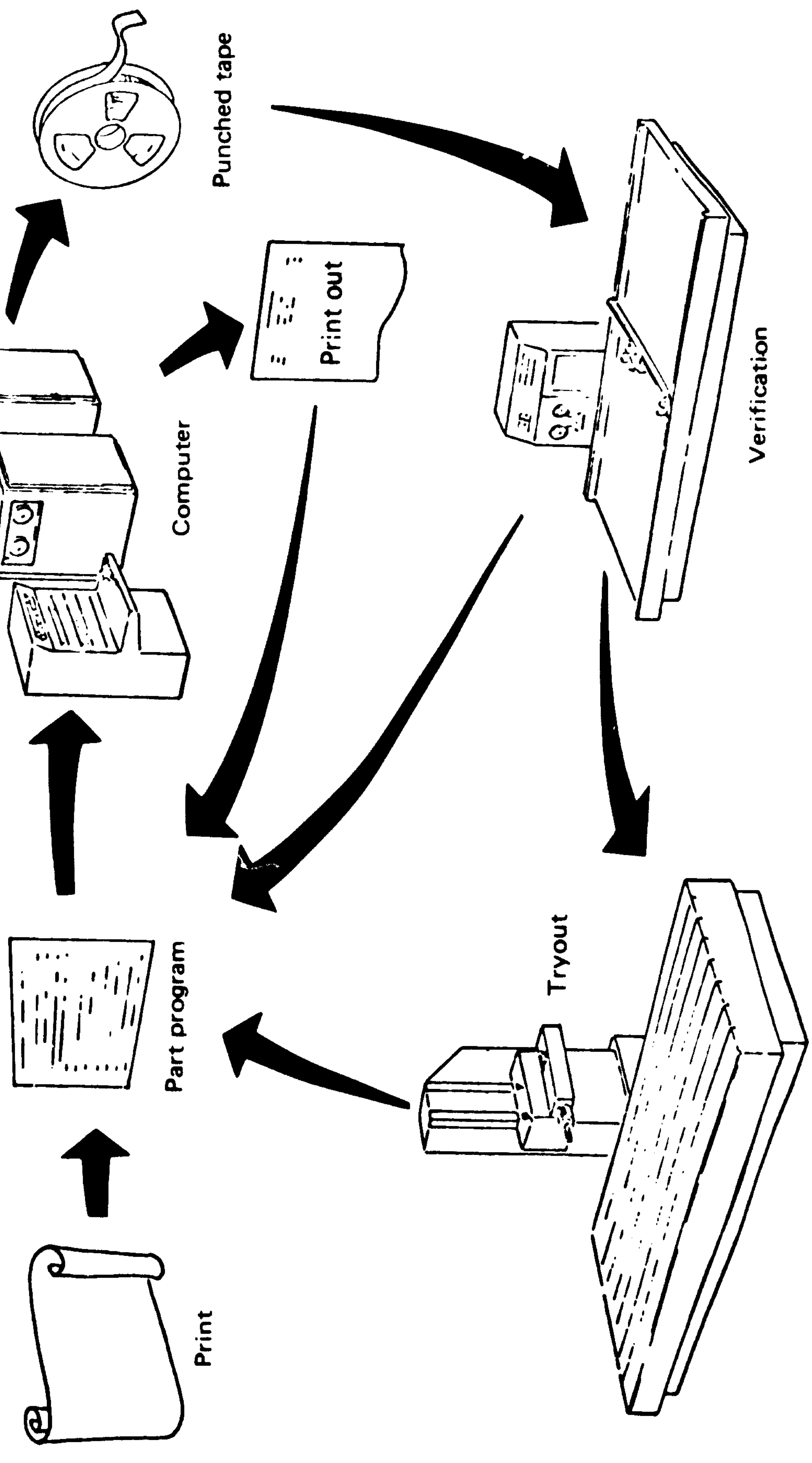
(b) Input. Used for absorbing information into memory, e.g. reading the part program from a card reader;

(c) Output. Used for extracting results of calculations from memory, e.g. writing the part programme results on the printer for checking by the computer part programmer;

(d) Arithmetic unit. Used for handling of arithmetical and simple logic operations, this device is the basis for the high speed of the computer;

(e) Central processing unit. Where actual data processing takes place and the flow of information throughout all five subsystems is controlled.

Figure XXI. Computer tape preparation



Most computer installations also have available some type of auxiliary storage such as magnetic dish or magnetic tape. This additional capacity is commonly used for storage of data for eventual use in memory.

Computer programs are executed within a central processing unit. The two programs with which a computer part programmer should be most familiar are the NC language processor and the post processor. The primary functions of the NC processor are to read the part program input, perform the operations specified by the programmer, and produce a file consisting of the cutter location data necessary to produce the desired part. The post processor then accepts the cutter location file as input, processes it, and outputs a correctly formated control tape that will be acceptable to the machine/control configuration specified in the computer part program. The post processor operates as a final step of the processor and is generally considered an integral part of the NC processor. In most cases, however, the NC processor is supplied by the computer manufacturer whereas the post processor is supplied by the NC manufacturer. Both the NC processor and the post processor are computer-dependent programs. This is unavoidable because of the differences in the internal design of the computer.

Computer programming languages

There are many types of computer programming languages in use today, such as APT, ADAPT, AUTOSPOT, and QUICKPOINT-8.

APT (Automatically programmed tools) is the most commonly used computer part programming language. It uses English-like words to represent directions, locations, speeds, surfaces etc., and to specify details regarding the operation to be performed. It is the oldest of the NC languages and has more post processors written for it and has been implemented on more computers than any other. It is, in addition, the most powerful and comprehensive NC language available, containing approximately 300 "words", such as POINT, FROM, PLANE, FEDERAT CIRCLE and PATS. APT is a universal language and may control simple positioning or complex shapes with up to five axes. Its main disadvantage is that a large computer, of which only a few expensive models are available, is needed. However, the average NC application does not require APT's high-level capability. In this case, a smaller NC processor, designed for a smaller computer, is satisfactory and more economical.

ADAPT (adaptation of APT) is a programming language for a smaller NC processor. The ADAPT language is able to define patterns and figures in the x-y plane, but is restricted in the z plane, which limits its solid geometry capabilities. However, it does offer three-axis point-to-point capability. This language is now used by approximately 16 per cent of all part programming installations.

AUTOSPOT (Automotive system for positioning tools), in use by about 20 per cent of all part programmers, is a three-axis point-to-point language with limited contouring capability. The AUTOSPOT processor, which requires about 32,000 core storage positions, was written originally for IBM 1620 computers—for programming pattern definition and manipulation, including straight-line milling requirements. AUTOSPOT is not as comprehensive as ADAPT.

QUICKPOINT-8 is a typical point-to-point language that is used on a small computer. It is designed to make two- or three-axis point-to-point tape preparation quick and easy.

كيفية الحصول على منشورات الامم المتحدة

يمكن الحصول على منشورات الامم المتحدة من المكتبات ودور التوزيع في جميع انحاء العالم . استعلم عنها من المكتبة التي تتعامل معها أو اكتب الى : الامم المتحدة ،قسم البيع في نيويورك او في جنيف .

如何购取联合国出版物

联合国出版物在全世界各地的书店和经售处均有发售。请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à : Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in Austria

Price: $U.S. 3.00
(or equivalent in other currencies)

United Nations publication

74-7693–September 1975–3,650

Sales No.: E.75.II.B.4

ID/151

B-902

82.09.27