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.

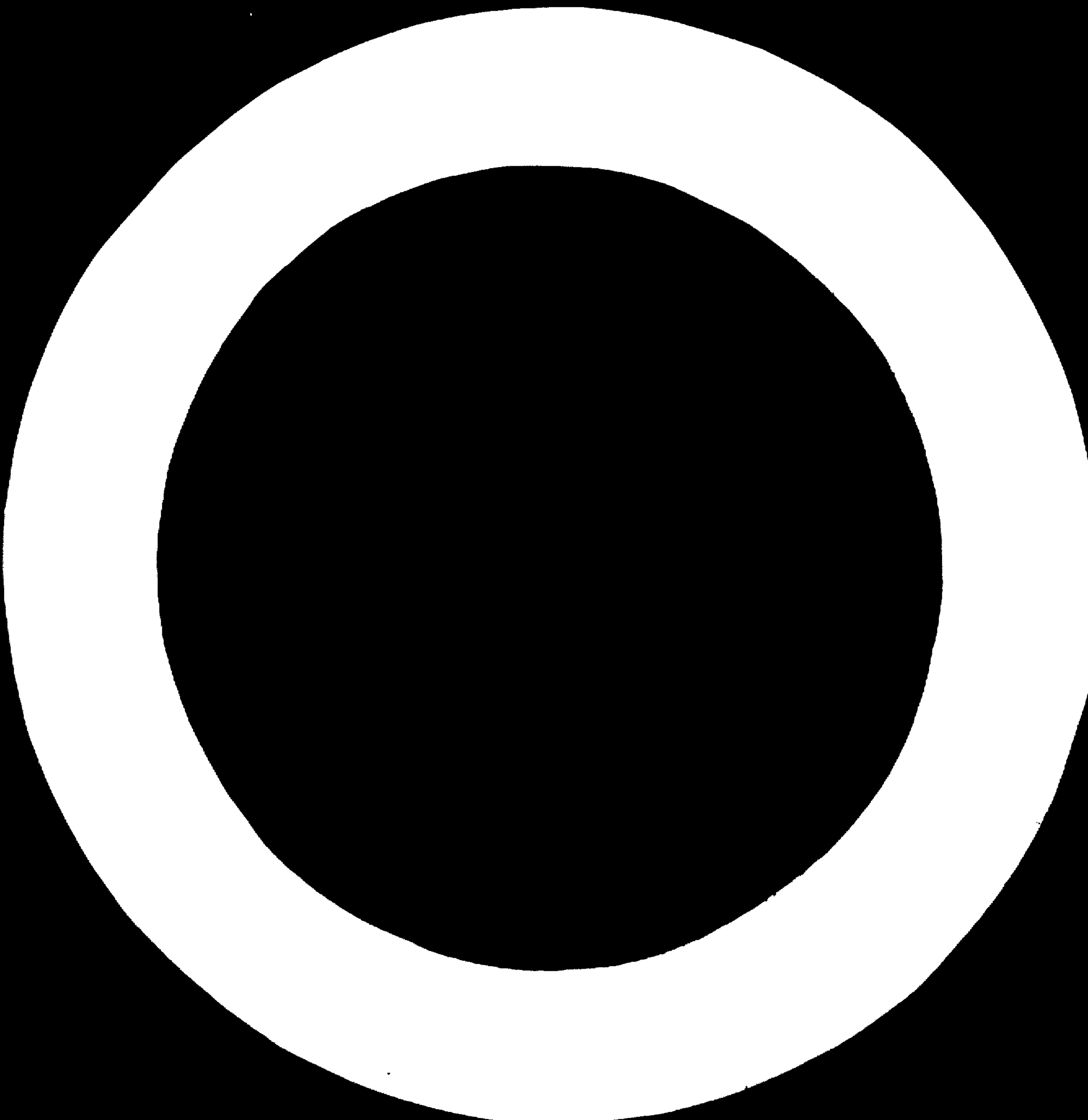
For more information about UNIDO, please visit us at www.unido.org

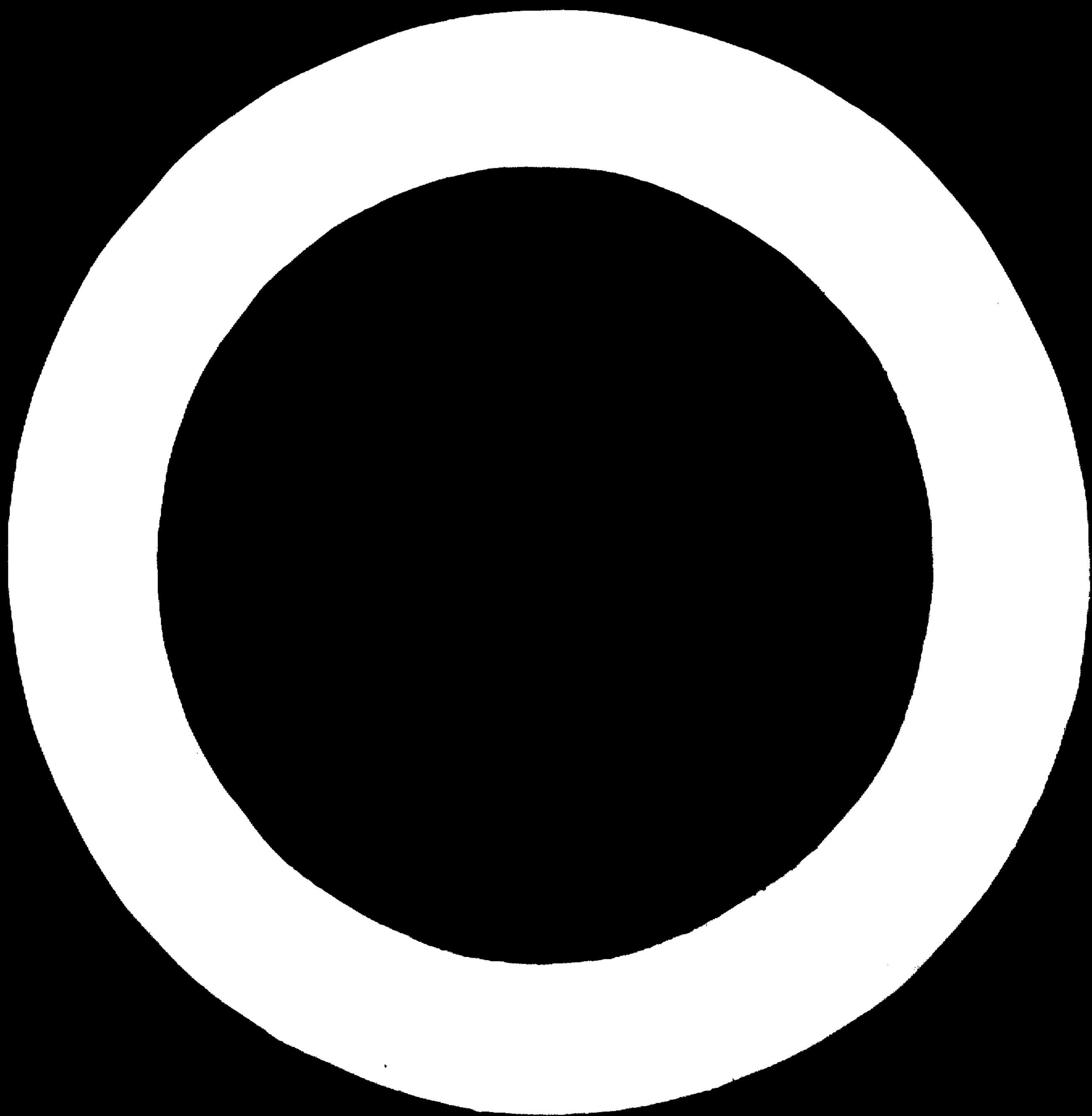
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

INDUSTRIALIZATION AND PRODUCTIVITY

BULLETIN 3

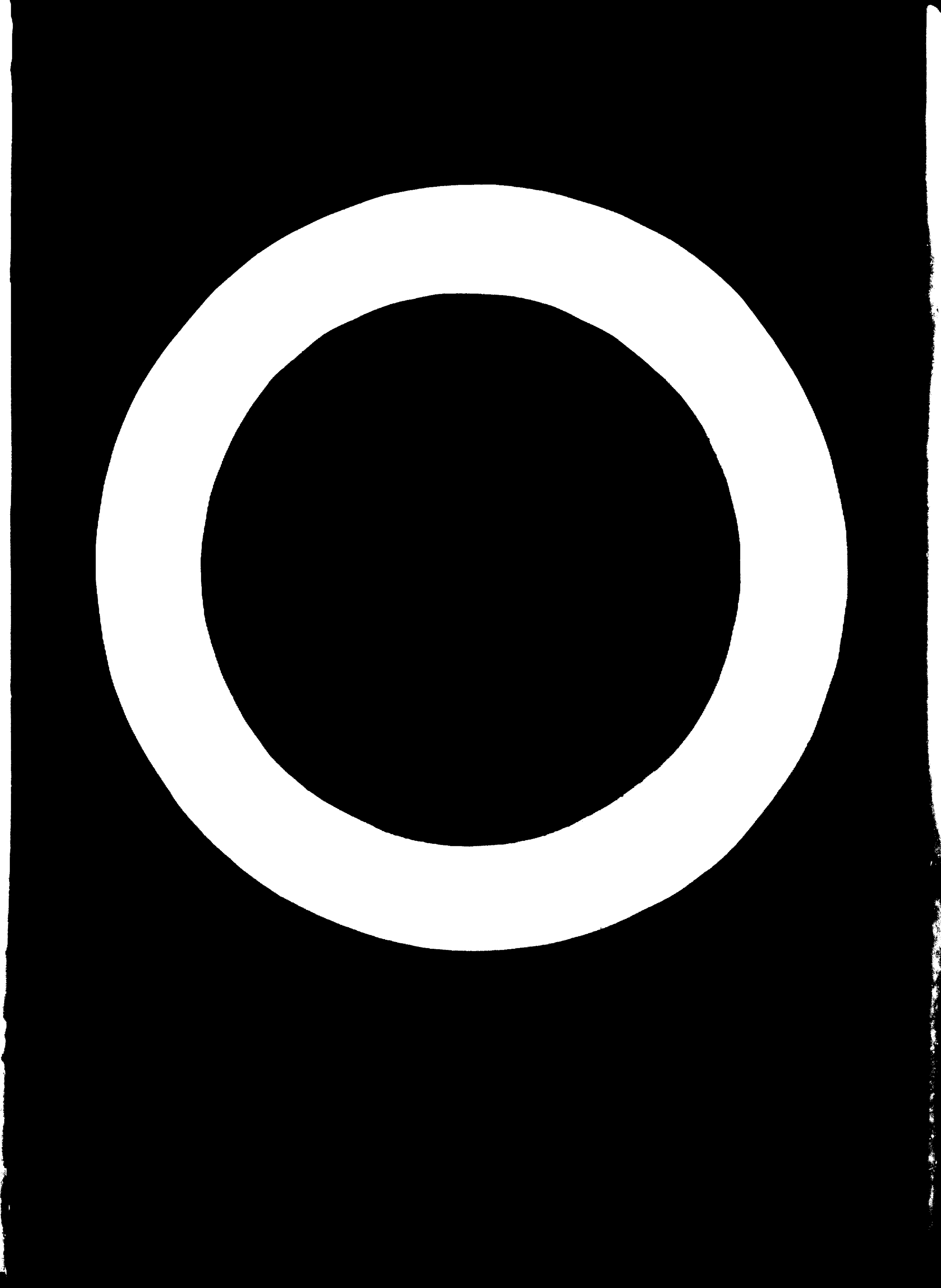
UNITED NATIONS NEW YORK





INDUSTRIALIZATION AND PRODUCTIVITY

3



In this issue

Cover illustration: Welding heavy plate sections of excavator with low hydrogen electrodes. An article in this issue discusses the use of welding in machine-building as a capital-saving technique

INDUSTRIALIZATION AND PRODUCTIVITY

BULLETIN 3

UNITED NATIONS

Department of Economic and Social Affairs

New York, March 1960

UNITED NATIONS PUBLICATION

Sales No.: 60. II.B. 1
Price: $U.S. 0.75; 5/- stg.; Sw. fr. 3.00
(or equivalent in other currencies)

Preface

THE FIRST FOUR articles in the issue are devoted to different aspects of the problem of most effective utilization of scarce capital resources in under-developed countries.

The first article, "Capital Intensity and Costs in Earth-moving Operations", prepared by the Industrial Development Branch of the United Nations Department of Economic and Social Affairs, follows up a previous study entitled "Capital Intensity in Heavy Engineering Construction", which was published in the first issue of this *Bulletin*. The article is based on material provided by Governments in response to inquiries conducted by the secretariat of the Economic Commission for Europe (ECE) and that of the Economic Commission for Asia and the Far East (ECAFE). It contains an analysis of the relationship between levels of capital intensity and costs in the various projects reported by Governments; methods of statistical measurement of the relevant magnitudes in comparable terms are developed for that purpose.

Following the first article is a note on the meeting of a working party on earth-moving operations in Asia and the Far East recently held in New Delhi under the sponsorship of the Secretariat at Headquarters and that of ECAFE, reference to which is made in the article. The working party dealt with various aspects of the technology of earth-moving using manual labour, mechanized equipment and combinations of both in the light of the conditions prevailing in that region.

The third article, "Choice of Industrial Technology: The Case of Wood-working", by Mr. G. K. Boon of the Netherlands Economic Institute, approaches another aspect of the same problem by analysing a simple industrial operation, the manufacture of wooden window frames and furniture. On the basis of this analysis, the author develops a method of appraisal of alternative production processes at different levels of mechanization, including the use of multi-purpose versus specialized machines. In spite of its specialized nature, the study was considered to present an interest of a wider scope as the proposed method is applicable also in appraising alternative techniques at different levels of mechanization in other industries.

The fourth article, "Use of Welding in Machine-Building", by Professor Evgeny P. Unksov, Director of the Central Scientific Research Institute of Technology and Machine-Building of Moscow, deals with a purely technological subject but is essentially concerned with the same basic issue—finding means of reducing capital requirements in industrial operations in newly industrializing countries. Professor Unksov's contribution is particularly significant in this respect since the capital-saving methods which are discussed in the article apply to a rather advanced stage of industrial development, namely, heavy machine-building. The development of a technologically mature machine-building industry, which is beginning to emerge in the more advanced among newly industrializing countries, makes heavy claims upon their capital resources because of the complex and expensive equipment which such industry requires. Such countries lack a sufficiently developed industrial infrastructure to produce the necessary heavy equipment by their own means and thus have to rely to a large extent upon costly imports. To substitute a technology based on welding for the costly and elaborate steel-shaping operations such as casting and forging, which are being used at the present time in heavy machine-building, represents a major capital-saving device. To quote from Professor Unksov's article, "the wide use of welding in machine-building has special significance under conditions prevailing in industrially under-developed countries, since it would enable them, in a comparatively short time and with relatively small capital investments, to establish new or convert existing machine-building installations according to modern technical standards".

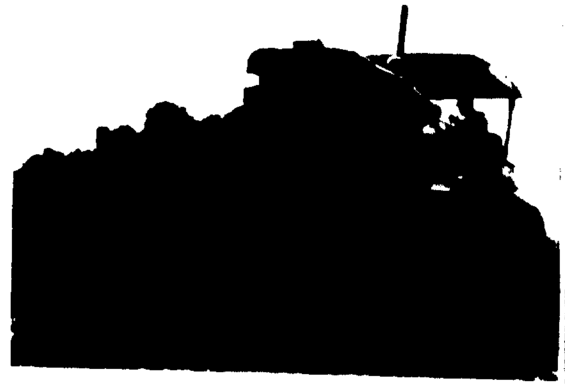
In addition, this issue contains an introductory study on financing of small-scale industries in under-developed countries prepared by the Industrial Development Branch, which examines a number of measures aiming at providing the small industrial enterprises in the less developed countries with adequate credit on favourable terms.

Another article, prepared by Mr. William R. Pabst, Jr., Chief Statistician of the United States Department of the Navy, deals with statistical methods of quality control in industry. It presents a particular interest for under-developed countries as it relates to methods of quality control which are fully applicable in small and medium-scale industrial enterprises.

A new international body—the Special Fund—has been recently established by the United Nations to provide financial assistance to under-developed countries for projects of a pre-investment nature. The last article in this issue discusses the role of the Special Fund in fostering industrial development.

Building a coffer dam at the Ottmarsheim section of the Grand Alsatian Canal in France

Capital Intensity and Costs in Earth-moving Operations



Prepared by the Industrial Development Branch

of the United Nations Department of Economic and Social Affairs

ORIGIN AND PURPOSE OF THE STUDY

THE PRESENT ARTICLE has been prepared as one of a series of studies of capital intensity in heavy engineering construction conducted by the United Nations Secretariat, under its work programme in the field of industrialization and productivity. Part of this programme consists of studies on problems which lie between the over-all assessment and allocation of resources and programming of targets, and the designing of industrial plant and production facilities. Such projects, which take the form of case studies in selected industries, aim particularly at developing a methodology for further research.

The choice of capital intensity as a topic in the projects carried out by the Secretariat is motivated by the importance, in the development of under-developed areas, of the problem prevailing in those areas of chronic imbalance between the two factors of production—labour and capital. The theoretical aspects of the problem of appropriate "factor-mix" in the development process have long engaged the interest of economists. Most of the recent research on this problem has, however, been based on what may be designated as the macro-economic or aggregative approach. As mentioned in previous studies by the Secretariat on the problem of capital intensity, it has become increasingly evident that further analytical work based on an economic and engineering analysis of individual industries, projects and processes is required.

One of the three studies on capital intensity published in the first issue of this *Bulletin* related to heavy engineering construction,[1] an industry selected because of its particular economic and technical characteristics. Engineering construction is an important activity in all under-developed countries, where it accounts for a substantial part of total physical investment; in many countries, economic development is associated in the first instance with a rise in construction activity. In most under-developed countries, this industry is undergoing a process of evolution which poses a number of economic and technological problems related to the question of capital intensity. Finally, it presents a high degree of flexibility in regard to technological alternatives of substitution of capital and labour, so that the choice of an appropriate level of mechanization is of practical importance.

In the study mentioned above, the analysis of the determinants of costs for mechanized earthwork operations was largely based on United States data. The findings derived therefrom were re-appraised in the light of conditions prevailing in under-developed areas, and a tentative conclusion was reached that in the latter areas the costs of mechanized earthwork are likely to be significantly higher than in industrial countries. The higher costs appeared to be due to such factors as the poor rate of performance of the equipment, both on the job and over its lifetime; inadequate maintenance, resulting in frequent breakdowns and costly repair; scarcity of skilled labour for operation and repairs, and inadequate general facilities, including the supply of spare parts. Lower labour costs arising from the generally low wage rates prevailing in those countries appeared only partially to offset higher costs on equipment account.

In the absence of actual cost data, these conclusions were based on a number of field observations of qualitative nature. Thus, experts assigned under the United Nations Technical Assistance Programme had reported in several instances various difficulties which they had experienced in connexion with construction projects, in particular as regards maintenance of heavy equipment, due to the lack of experience of operating and repair personnel and the shortage of imported spare parts. In some cases, lack of familiarity with equipment resulted in operating performance much below the norms achieved in more industrialized countries. In one instance, the capacity of equipment was found to exceed the needs of present or foreseeable future projects, which led to chronic under-utilization and poor performance. Similar observations were brought out in the report of the Con-

[1] United Nations, "Capital Intensity in Heavy Engineering Construction", *Bulletin on Industrialization and Productivity,* No. 1 (sales number: 58.II.B.2).

struction Plant and Machinery Committee, appointed by the Government of India in 1953 to examine certain aspects of this problem.[2]

A preliminary draft of the study under discussion was presented to a group of experts meeting in Geneva in November 1956 under the auspices of the United Nations Economic Commission for Europe (ECE) which was studying the effect of mechanization on the cost of construction of hydroelectric stations, on the basis of data submitted by Governments. Having analysed these data, the ECE expert group agreed that further data permitting a comparative analysis were needed in order to study this problem, and a questionnaire was drafted by the ECE secretariat in co-operation with the Secretariat at Headquarters for circulation to Governments in the region. The questionnaire was designed to elicit detailed economic and engineering data for recently completed earth-moving operations which would permit an analysis of cost in relation to the degree of mechanization.

Earth-moving includes a number of different operations whose combination depends upon the nature of the particular project. For example, construction of a canal involves excavation followed by transporting the removed earth and dumping it in some waste spot, or the use of the earth on the site to build up embankments for the canal. For this reason, the questionnaire contained a request to supply, wherever possible, a breakdown of costs of the work involved, by individual operations. In the analysis presented in the second part of this article, advantage has been taken of the fact that in some replies the various operations were separately reported.

In Asia and the Far East, considerable attention to the economic and engineering problems in earth-moving and in construction in general has been given by the Government of India which, in the early nineteen fifties, had convened two special committees to study these operations. A number of economic studies have also been prepared by consultants on individual investment projects of this type, planned or undertaken.[3] Reference may also be made to a study produced by a team of one engineer and two economists, containing, in addition to a review of the theoretical aspects of the problems, an analysis of two techniques of earth-moving, one involving mechanized excavation and transport, the other involving manual excavation and motorized transport.[4] The discussion of the practical possibilities of combining labour and capital concludes with a statement stressing the need for experimentation in the design of techniques and equipment with a view to meeting the particular requirements of under-developed countries. These conclusions substantially agree with those of the United Nations study on earth-moving cited earlier.

At the Second Regional Conference on Water Resources Development, held in Tokyo in 1954 under the sponsorship of the United Nations Economic Commission for Asia and the Far East (ECAFE), suggestions were made by participants for research on the technical aspects of earth-moving operations in this area. As a result, the ECAFE secretariat undertook a study of the particular problem of improving manual techniques of earth-moving in competition with machines.

The subject was further discussed at the Third Regional Conference on Water Resources Development held in Manila in 1957, to which papers were presented by ECAFE and the United Nations Secretariat. The discussion of these papers led to recommendations that further research and an increased exchange of information were required in this field. In accordance with these recommendations, the secretariats of ECAFE and of the United Nations Headquarters organized jointly a Working Party on Earth-moving Operations to meet in the ECAFE region. A detailed questionnaire was drawn up and circulated to Governments of the region in this connexion. The part of the questionnaire relating to costs and degree of mechanization in earth-moving was designed along the lines of the questionnaire circulated earlier in the ECE region; it was expected that the replies would make it possible, in particular, to test the hypotheses on the cost of mechanized earthwork operations in industrially less developed countries which had been made earlier. The working party was convened in New Delhi, India, from 7 to 14 September 1959.[5] A preliminary draft of the present study was submitted to it.

The analysis which follows is based mainly on the replies of certain countries to the questionnaires circulated in the two regions.[6]

As regards countries members of ECE, detailed and comparable data were received from Austria, Finland, France, Poland, Sweden and the Union of Soviet Socialist Republics. The replies from the Federal Republic of Germany, Turkey and the United States did not contain certain data—for instance, labour inputs or depreciation charges—required for the analysis undertaken in this study. The information on earth-moving operations received from Czechoslovakia was not comparable with that contained in the other replies.[7] The United States data referred to below originated from the United States Bureau of Public Roads which had carried out special cost surveys in this field.

As regards replies from countries of the ECAFE region, the material on costs of mechanized earth-moving operations was, in most cases, not sufficiently detailed and lacked comparability.

Considerable information on technical specifications and capacity of equipment was supplied by the Governments of Japan and the Philippines. The replies of Ceylon, the Republic of China, Hong Kong and Singapore

[2] Government of India, Ministry of Irrigation and Power, *Report of the Construction Plant and Machinery Committee* (New Delhi, 1954).

[3] One of these, entitled "Some Economic Aspects of the Bhakra Nangal Project", by Professor K. N. Raj, is to be published early in 1960 (Asia Publishing House, Bombay).

[4] "Capital Formation and Choice of Techniques in Under-developed Economies", by G. R. Deekshit, R. K. Patil and K. R. Datye, in *Indian Economic Journal*, July 1956.

[5] The final report of the working party is summarized elsewhere in this issue of the *Bulletin*.

[6] Information on the relevant projects is given in appendix I.

[7] Replies from the Governments of Belgium, Hungary, Italy and Romania were received too late for inclusion in the study.

provided either partial cost data or data on total costs with insufficient breakdown; data for such important items as wages or depreciation charges were lacking. In the case of Hong Kong, data on labour man-hours indicated rather extensive use of labour in combination with small pieces of equipment, and the unit costs appeared to be competitive with those obtained by use of other techniques in other countries; the incompleteness of the data, however, precluded further analysis. The replies from the Republic of China and Thailand provided data on direct costs, but not on indirect costs, particularly depreciation. In these instances, earthwork was part of very large and complex projects, and a full analysis of unit costs could not be undertaken. The reply from Burma contained detailed information on an operation involving a type of equipment different from that used in the projects of other countries. Thus, in the material originating from the ECAFE region, only that relating to India could be taken into consideration in the analysis. For that country, certain important data are taken from published and unpublished documentation relating to the year 1953 prepared by the Rates and Costs Committee of the Government of India, which was made available to the Secretariat.

The lack of adequate information in the ECAFE region may be explained by several factors, among which is the fact that mechanized earth-moving has only recently been undertaken on a large scale.[8] In countries where such projects have been carried out, much of the work was done by private contractors whose cost accounts are not generally made public. In other countries, the work was performed by government departments, but because of inadequate accounting practices it is difficult to ascertain actual expenditures for projects of this type. On the one hand, over-all budgets for specific projects often fail to provide detailed cost data for the various operations involved. On the other hand, these operations are frequently carried out by separate administrative units, each of which operates under its own budget; the latter would cover the expenditures involved in the participation of the unit, with its own staff, equipment and materials, in several projects, without spelling out the costs relating to any individual job. In these cases, it is impossible to ascertain not only itemized data relating to such cost elements as wages, depreciation, maintenance and repairs, but even total costs for individual projects.

As a by-product of the various investigations, the need for maintaining proper cost accounting records was made apparent, and a recommendation to that effect was made in the report of the working party.

[8] The Government of New Zealand stated in its reply that it was currently undertaking one of the largest earth-moving projects in the region; this, however, is in early stages of construction and detailed data are not yet available.

ANALYSIS OF COSTS

Measurement of capital intensity

THE ANALYSIS is divided into two parts. The first relates to excavation only, an operation which is common to all earthwork: data are presented for Austria, Finland, France, Sweden, the Soviet Union and the United States. The second relates to a combination of excavation, transport and compaction operations for which data are available for France, India, Poland and the Soviet Union.

As a first step, it is necessary to define a measure of capital intensity corresponding to the micro-economic level of analysis adopted in this study.

A measurement of the rate of mechanization which has been sometimes suggested in the literature[9] is the ratio of the power of equipment to output. In the present case, this measure would relate the horsepower (or kilowatt) capacity of the excavating equipment to the volume of earth moved. This, however, would present a number of drawbacks. First, this relationship would single out one of the factors in mechanization—horsepower capacity—which, from the point of view of capital input, is not necessarily the most important one. Secondly, it might often be misleading; in the case of hauling operations, for example, more installed horsepower would be required for haulage by trucks than by locomotive-drawn dump wagons on tracks for the same volume of output in ton-kilometres, and it is clear that there is no necessary relationship between installed power and level of capital intensity of the two techniques.

In the following analysis, it is proposed to use the ratio of capital input to labour input as a measure of capital intensity, both factors being taken here, conceptually, in terms of "flow" rather than "stock". Capital input is measured by the value of effective physical depreciation of equipment during the period of actual operation, as opposed to accounting depreciation charges which are calculated in a conventional and more or less arbitrary way.[10] Labour input is measured in hours of direct labour used on the job, including operating, maintenance, repair and ancillary personnel, but excluding supervisory and overhead staff.

This measure presents on the numerator side a problem of valuation for international comparability, since capital input figures in the replies of the different countries are expressed in local currencies. This difficulty, which is general in problems of this type, is, in this instance, alleviated by the fact that there exists an international market for capital goods used in earth moving, so that prices of equipment reflect the large measure of competition among the few producing countries. Moreover, as far as the first part of this study is concerned,

[9] Some of the definitions or measures proposed for capital intensity are mentioned in "Capital Intensity in Industry in Underdeveloped Countries", *Bulletin on Industrialization and Productivity,* No. 1, footnote 22, page 19.

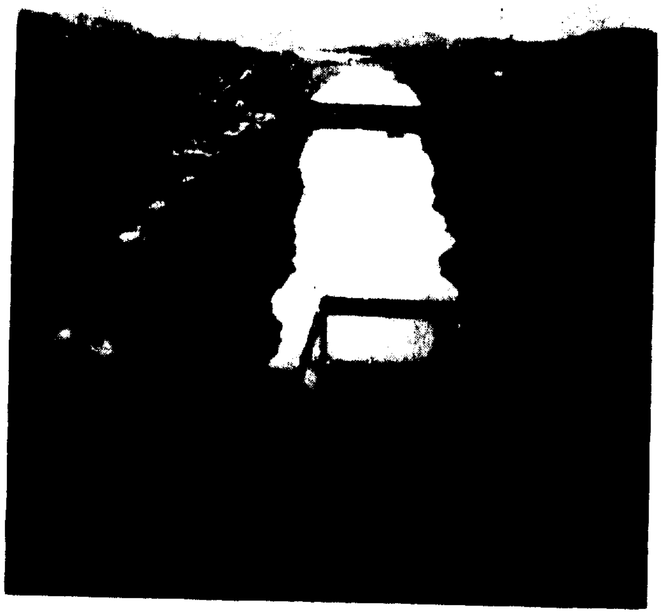
[10] For a discussion of this problem, *see* "Capital Intensity in Heavy Engineering Construction", op. cit. See also the discussion below of the relationship between maintenance and depreciation costs.

the problem was further simplified by the fact that practically all of the equipment used in the western European projects was of United States origin.

The problem of appropriate exchange rates for converting national currencies into a common monetary unit is more complex in the case of costs which, in addition to capital charges, comprise those for wages and materials, including locally produced supplies. It was necessary to make a certain number of assumptions concerning exchange rates, which are believed to provide a sufficient first approximation for the purposes of this study.[11] For the western European countries, a comparable set of data was obtained by converting the figures expressed in national currencies into a common monetary unit—the United States dollar—at current exchange rates. Some complications as regards an appropriate conversion exchange rate arose in the cases of Poland and the Soviet Union; these are discussed in detail in appendix II.

Another factor to be taken into account in computing the measure of capital intensity is the difference in the rate of performance of equipment in various projects. In operations where this rate is below normal, the time spent by the equipment on the job is correspondingly higher and so, consequently, are the values of capital input as defined above.[12] To adjust for this, a coefficient of correction is applied to the rate of equipment performance; this coefficient, which relates the observed rate to a reliable norm based on past experience, also takes into account various physical factors, such as the terrain, and thereby also provides an adjustment for the lack of homogeneity of the "product" obtained in different types of earthwork.[13]

Account should finally be taken of the differences in the time periods in which the projects were carried out. Governments were requested to supply data for "recent" projects, and although the information generally relates to the period 1953-1958, some dispersion of time periods is indicated in the replies.[14] No adjustments for price changes with a view to bringing all costs to a common base were made. There are indications, however, that, excepting the case of Poland, only small adjustments would have been required.



TOP. *View of the tail-race canal of the Grundfors hydro-power station in Sweden*

BOTTOM. *Under-water excavation work at the tail-race canal of the Pälli hydroelectric station in northern Finland*

---

[11] A more detailed discussion of some of the conceptual and statistical problems involved in international comparisons of value data is contained in certain studies published by the Organisation for European Economic Co-operation; see *An International Comparison of National Products and the Purchasing Power of Currencies* (Paris, 1954) and *Comparative National Products and Price Levels* (Paris, 1958), both prepared by M. Gilbert and staff.

[12] Inefficient operation may, at the same time, involve more labour, so that both numerator and denominator are affected in the same direction; however, there is no reason to assume that they are affected in the same proportion. It is reasonable to assume, particularly in the case of under-developed countries, that inefficiencies in utilization are considerably greater in the case of labour than in the case of capital, because of the very low level of wages. In the absence of adjustments, this would tend to give consistently lower values to the measure of capital intensity.

[13] For example, in work involving rocky soil or under-water dredging.

[14] The data for France relate to a project begun in 1948 and completed in 1952. The French authorities themselves have revalued the data at March 1958 prices.

Excavation

Table 1 shows capital intensity and unit costs in excavation work for countries where relevant information was available.

In the case of Sweden, a very high figure of accounting depreciation is given in the reply; an analysis of the performance data shows it to be two to three times higher than the physical depreciation as defined above. On the other hand, the rate of performance is relatively low owing to the nature of the work, which involved an especially difficult operation of under-water excavation. The numerator of the ratio and the cost figures were adjusted accordingly. The French reply, which concerns a project involving both excavation and transport, indicates that the performance of the excavating equipment was affected by the inadequacy of transport equipment; this, too, was corrected by adjusting the ratio numerator and the cost figures. As regards the Finnish project, a breakdown of costs suggests that the accounting charges for depreciation were below the real rates. No specific data regarding the performance of equipment are given in the reply of the Soviet Union; performance has consequently been assumed to be comparable to that achieved in other projects.[15]

The capital intensity in the Austrian project—which is of small size—is shown in table 1 to be of the same order of magnitude as that of the other projects; however, a higher unit cost is obtained despite the fact that Austrian wage rates are significantly lower than those in the other countries. This probably reflects the diseconomies of scale arising from the small size of the project.[16]

The table also contains figures for the United States which were calculated on the basis of data for excavating operations in road construction analysed in a previous study by the Secretariat on capital intensity in engineering construction. The data concerning capital intensity and wages do not relate to one specific project, but to a sample of projects mainly in the medium-size range. The capital-labour input ratio thus obtained is only slightly higher than that in the other countries. The unit costs for excavation in road construction are average contractor's bid prices and have a broad nation-wide coverage.[17] They are higher than the costs in European projects. Large-scale projects in the United States, comparable to those described in the replies from European countries, would command somewhat lower costs, but these would still significantly exceed the average cost level obtaining in the European projects under discussion. As the estimates of equipment performance given in the replies of

TOP. *Construction of an airport in West Virginia, United States: loading trucks with power shovel*

BOTTOM. *View of the intake canal at Ottmarsheim, France. The navigation locks and the power plant head-race are visible in the background*

[15] Where data on levels of performance are available, these appear to be roughly comparable in projects with similar unit costs. Since costs in the Soviet project are of a comparable order of magnitude, the assumption made appears to be reasonable.

[16] If adjustment is made for the discrepancy between the Austrian and, say, the French wage rates which are representative of the average wage level, the Austrian unit cost would slightly exceed 40 cents, which would not be excessive as compared to the average unit costs for large-scale projects. For a discussion of the effect of size upon costs, *see* "Capital Intensity in Heavy Engineering Construction", op. cit., page 42.

[17] *Ibid.*, pages 40 and 41.

Completing work on the weekly pondage basin of a winter storage plant near Klagenfurt, Austria

some European countries indicate a level of efficiency comparable to that of the operations in the United States, the difference is attributable to the higher level of wages in the latter country, which, for this type of work, are two to three times higher than those in Europe.

In appraising the data shown in table 1, it should be borne in mind that the variations in factor inputs and costs which result mainly from differences in job conditions, such as the nature of the soil and topography, are extremely wide in earth-moving. As noted above, an attempt has been made to correct for these elements, but, because of the inadequacy of the available information, the corrections made are in the nature of approximations rather than precise adjustments. Under the circumstances, the range of variation of the values obtained for the capital-labour input ratio shown in the table does not appear excessive. From the methodological point of view, the definition of capital intensity developed in this study appears to be sufficiently meaningful and "operational" to justify further quantitative investigation. As to unit costs, these show only minor variations in those countries whose wage rates are comparable.

Combined operation of excavation, transport and compaction

Cost data on a combined operation of excavation, transport and compaction are available in the material provided by France, India, Poland and the Soviet Union. These data are shown in table 2.

In the case reported by the Soviet Union, the earth-moving operations were of a complex nature; the fill for the earth dam had to be obtained under water—a task which was especially difficult during the winter when the river froze. Excavation was accomplished in two stages; in the first, which was carried out during the ice-free months, huge draglines excavated the fill and deposited it along the river banks. In the second, the fill was loaded by shovel and dragline onto trucks for hauling to the dam site, where conventional methods were used for compaction. The second stage was conducted the year round by utilizing the "stock" of fill excavated during the earlier stage. The data provided in the reply made it possible to analyse each stage separately; by excluding the first stage, a set of operations comparable to that described in the Polish and French replies could be isolated.

The data for India are, as mentioned earlier, based on material from the records of the Rates and Costs Committee. The cost data are "recommended" norms based on prices prevailing in 1953. In calculating these rates, the committee reviewed current engineering practices in India and in other areas, notably the United States, and made certain assumptions concerning comparative equipment performance in order to arrive at a set of norms against which performance on projects under construction could be evaluated. In establishing these figures, the Rates and Costs Committee assumed that operating performance would be about 65 per cent of the ideal output estimated by equipment producers, primarily those of the United States.[18] The costs of overhead were not included in the calculations of the committee; they have been estimated, in table 2, at 25 per cent of total unit cost.

The Polish project is of special interest, as the data concerning it suggest that it was carried out by techniques much more labour-intensive than those applied in the other projects. One phase in the erection of a reservoir system described in the Polish reply was the construction of a catch-basin, involving excavation of 285,000 cubic metres of earth and transportation of this amount over an average distance of one kilometre. These data are directly comparable with those contained in the French reply. Both replies provided estimates of the total cost of excavating one cubic metre of earth and moving it a distance of one kilometre; the French reply also provided a breakdown of this total and, as was mentioned above, it was possible to derive an estimate of the cost of a similar operation in the Soviet Union from the material contained in that country's reply. As for the technique of operation, large draglines or shovels were used for excavation, and self-propelled dump trucks were used for transportation in both the French and Soviet projects; thereafter, bulldozers were used for compaction of the earth. In the construction of the catch-basin in the Polish project, small draglines and shovels were used for excavation, and transportation was carried out by means of a specially built narrow-gauge railway system with coal-

[18] The French data are based on equipment performance amounting to about 75 per cent of the "ideal" performance, which appears to correspond to average conditions of operation in the developed countries. In the earlier study of this problem, it was estimated that the level of performance in under-developed countries would be half of that found in the developed countries and the norms proposed by the Indian committee seem to be relatively high. This appears to be confirmed by information in the report of the committee, which indicates that, in most projects under examination, performance fell short of the proposed norm (Government of India, Ministry of Irrigation and Power, *Report of the Rates and Costs Committee* (New Delhi, 1956), chapter 16).

powered locomotives and small dump wagons.[10] More manual labour was involved in the Polish project than in the other works considered, at two stages of the operation: laying and maintaining the tracks; and unloading the dump wagons and spreading the earth on the site, prior to compaction by bulldozers.

It is difficult to assess the real significance of the differences in costs shown in table 2. In the earlier study of the Bureau of Economic Affairs on costs of mechanized earth-moving operations, an analysis was made of the various factors determining these costs in the more industrialized countries, and an attempt was made to transpose the findings to the conditions prevailing in under-developed areas. Thus, it was mentioned that, because of lack of familiarity with equipment and little experience with techniques of mechanized operations, productivity of labour could be generally expected to be lower than in the industrial countries. In addition, the efficiency of individual industrial processes in the latter countries is enhanced by the existence of external economies, such as availability of skilled labour, adequate repair and maintenance facilities and adequate supply of spare parts, which contribute to higher productivity and performance and better cost conditions. For these reasons, unit costs in mechanized operations in under-developed countries might be expected to be substantially higher than in the more advanced countries; this is true in spite of lower labour costs resulting from generally lower wage rates, even if the lower productivity of labour is taken into account.

The relevance of these considerations will be examined

[10] Some gasoline-powered dump trucks were used in other phases of the work, but the data do not permit direct comparison of the costs with those of the other transport method.

Table 1

CAPITAL INTENSITY AND UNIT COSTS IN EXCAVATION WORK

COUNTRY	CAPITAL INPUT[a] (*US dollars per thousand cubic metres*)	LABOUR INPUT (*man-hours per thousand cubic metres*)	CAPITAL-LABOUR INPUT RATIO (1) : (2)	COST PER CUBIC METRE OF EXCAVATION (*US dollars*)	WAGES (*US dollars per hour*)	YEAR
	(1)	(2)	(3)	(4)	(5)	(6)
Austria	88	111	0.8	0.34	0.40	1955
Finland	50	57	0.9	0.27	1.01	1957
France[b]						
A	60	51	1.2	0.22	0.71	1958
B	54	66	0.8	0.22	0.71	1958
Sweden[c]	58	50	1.2	0.28	1.03	1954-1957
Union of Soviet Socialist Republics	50	48	1.0	0.24	1.04	1956
United States of America	94	80	1.2	0.47	2.00	1953

Source: See text.

[a] Calculated as the physical depreciation charge of equipment per man-hour of direct labour; national currencies converted at official exchange rates as indicated in replies.

[b] The French reply contains data on two excavation operations involving different pieces of equipment; these are analysed under A and B.

[c] Labour inputs partially estimated since reply does not indicate direct labour other than operating and maintenance.

Table 2

CAPITAL INTENSITY AND UNIT COSTS FOR A COMBINED OPERATION OF EXCAVATION, TRANSPORT AND COMPACTION

COUNTRY	CAPITAL INPUT (*US dollars per thousand cubic metre-kilometres*)	LABOUR INPUT (*man-hours per thousand cubic metre-kilometres*)	CAPITAL-LABOUR INPUT RATIO (1) : (2)	COST PER CUBIC METRE-KILOMETRE (*US dollars*)	WAGES (*US dollars per hour*)	YEAR
	(1)	(2)	(3)	(4)	(5)	(6)
France	167	148	1.1	0.67	0.71	1958
India	190	600	0.3	0.60	0.13	1953
Poland[a] [b]	48	957	0.05	0.62	0.21	1952-1954
Union of Soviet Socialist Republics[a]	180	158	1.2	0.67	1.04	1956

Source: See text.

[a] For details on exchange rate used in calculation, *see* appendix II.

[b] Capital and labour inputs based on distribution of costs for entire project.

in the light of the data in table 3 which, for purposes of illustration, compares cost figures for projects in France and Poland. For the sake of simplification, only two cost elements are considered: depreciation and direct labour charges. Part A of the table shows the actual costs for the two countries; in part B, the labour cost figures are recalculated under the assumption of reversed wage rates (capital costs and labour productivity are assumed to be unchanged). The table shows that, with the French level of wages, the less mechanized technique used in Poland would lead to a very high unit cost of 117 United States cents as compared to an actual cost of 25 cents. On the other hand, a combination of the more mechanized techniques used in the French project with Polish wage rates would lead to lower costs, namely, 20 cents instead of 32 cents; the difference between the latter two figures is proportionately much smaller than that obtaining in the first instance. As labour productivity and equipment performance may be expected to be higher in Poland than in most under-developed countries, a less favourable comparative cost situation is likely to obtain in these countries in regard to mechanized operations.

As to India, it should be kept in mind that unit costs given for that country are based not on actual performance but on performance norms. For the combined operation described above, the Indian unit cost is equivalent to about 45 cents as compared, for example, to 67 cents for a similar operation in France. If adjustment is made for the fact that the Indian data do not include overhead and interest payments—which amounted to about 25 per cent of total cost in France—the adjusted unit cost would not differ much from that obtaining in France. The closeness of the cost figures for India and France may be largely explained by the fact that higher depreciation, repair and other costs obtaining in the former country are offset by lower wage costs. If, as in the case of Poland, average French wage rates are applied to the Indian cost calculations, assuming the same capital and labour inputs per unit of output, the Indian unit cost would rise to well above one dollar.

Finally, it should be noted that, even on the assumption of comparable operating efficiency of both equipment and labour, unit costs in highly mechanized operations in less developed countries would, in many cases, be low in appearance only. The cost data in table 3 are made up of wage and capital charges, the latter being depreciation charges on equipment; to simplify the calculations, interest charges have not been included. Omission of interest charges does not materially weaken the comparative value of the cost data among industrial countries, where essentially similar conditions prevail regarding endowment in capital resources as reflected in the rate of interest. However, when cost comparisons are made with under-developed countries, account should be taken of the higher cost of capital in these countries due to its scarcity; if an adjustment is made for this factor, the comparative cost selection would appear less favourable.[20]

An examination of the data in table 2 relating to capital intensity shows that, measured by the capital-labour input ratio, the degree of capital intensity of the Polish project is considerably lower than that of either the French or the Soviet works.[21] It can be seen in table 2 that the ratio is

[20] Such an adjustment should be made even for under-developed countries where the market rate of capital is relatively low because of such special circumstances as government credit policies or possibilities of borrowing under special conditions from international institutions, so that there is a discrepancy between the "market" and the "real" rate of interest. (*See* in this connexion the discussion of the problem of the so-called "accounting" or "shadow" prices of factors in an article by Professor Jan Tinbergen, "Choice of Technology in Industrial Planning", *Bulletin on Industrialization and Productivity*, No. 1.

[21] The comparison of the Polish and Soviet data with those of the western European countries poses a problem of conversion of data expressed in national currencies which was touched upon earlier. The methods of conversion used in these two cases are discussed in appendix II.

BELOW. *Construction camp for workers of the Bratsk hydro-power project on the Angara River in Siberia*

RIGHT. *Narrow-gauge locomotive and dumping cars used in building a reservoir system on the Vistula River, 100 km. above Krakow, Poland*

FAR RIGHT. *Construction of the Konar dam, Damodar Valley, India*

0.05 for the Polish project against 1.1 and 1.2 for the French and Soviet ones.[22] In the Polish case, the high input of manual labour was associated with a mechanized transport operation: labour was not used for transport proper as in conventional techniques of earth-moving of high labour intensity, but for building a rail track—a much more productive means than manual transport. (The use of small, narrow-gauge wagons also involved considerable use of labour for unloading and spreading the earth prior to compaction.) This roundabout labour-intensive technique of using unskilled labour to produce capital equipment of high productivity may be of interest to under-developed countries. Furthermore, rail transport equipment is rugged, relatively inexpensive and in many ways easier to maintain and operate than motor transport; and it may also be easily produced in the countries themselves, particularly in those which are in the more advanced stages of industrial development.[23] In all these respects, the method used in the Polish project meets many of the difficulties which were pointed out in the discussion of mechanized operations in under-developed areas in the earlier study on this subject.

The Indian data present a certain number of special

[22] Corroboration of the fact that the measure of capital intensity may vary widely with alternative techniques may be found in a recent Indian study on earth-moving. This study compared two techniques presenting only moderate differences in unit costs: the first involved completely mechanized excavation and transport; the second, manual excavation and motorized transport. The capital stock per unit of excavation required by the mechanized technique was about twice that required by the labour-intensive one; at the same time, the latter required an input of labour per unit of excavation fifteen times higher than the former. Thus, if one compares capital-labour ratios, as measured in these items, the ratio for the first technique is thirty times that of the second —an order of magnitude similar to that obtained above. *See* "Capital Formation and Choice of Techniques in Under-developed Economies", op. cit.

[23] A number of Governments, particularly Japan and Ceylon, have indicated in their replies that narrow-gauge rail track systems of transport of earth are currently in use in some of their projects. The characteristics of these systems are not given in detail, but it seems that the experience has been a favourable one.

Table 3

LABOUR AND CAPITAL UNIT COSTS[a] FOR A COMBINED OPERATION AT DIFFERENT LEVELS OF MECHANIZATION AND WAGE RATES

(United States cents per cubic metre kilometre)

ITEM	MORE MECHANIZED TECHNIQUES	LESS MECHANIZED TECHNIQUES
	France	Poland
A. *Actual costs*		
Labour	15	20
Capital (depreciation)	17	5
TOTAL	32	25
	Using Polish wage rates	Using French wage rates
B. *Costs with wage rates reversed*		
Labour	3	112
Capital (depreciation)	17	5
TOTAL	20	117

Source: See text.

[a] For a discussion of the method of computation of the data, *see* appendix II.

Table 4

INDIA: DISTRIBUTION OF COSTS FOR COMBINED OPERATION — EXCAVATION, TRANSPORT AND COMPACTION

(Per cubic metre-kilometre at 1953 prices and exchange rates)

ITEM	RUPEES	DOLLAR EQUIVALENT
Depreciation	0.89	0.19
Lubricants, fuel, etc.	0.47	0.10
Repair and spare parts	0.38	0.08
Labour:		
Operating	0.10	0.02
Repair	0.31	0.06
TOTAL	2.15	0.45

Source: Information supplied by the Rates and Costs Committee of the Ministry of Irrigation and Power, Government of India.

features. Labour input in man-hours shown in table 2 has been estimated by dividing wage costs by an assumed hourly wage rate (see table 4). For reasons discussed below, the labour costs have been separated into two components—operation and repair. An average wage rate of 0.5 rupee per hour has been taken for operating personnel; for repair workers, a rate of 0.75 rupee has been used.[24] On these bases, the labour input—for both operation and repair—has been estimated at 600 man-hours per thousand cubic metre-kilometres. The numerator—an unadjusted depreciation charge shown in table 2—is 190 dollars, a figure only slightly higher than that of 167 dollars in the French case. The unadjusted capital-labour input ratio is thus 0.3, or roughly 30 per cent of the modal coefficient found for the countries of the ECE region, of which the French case is representative.

The figure of 0.3 for the capital-labour input ratio in India calls for some comments, in view of the fact that, on the basis of the depreciation data contained in the Indian report, the earth-moving operation involves approximately the same level of mechanization as that in the French case; indeed, as mentioned above, the value of the capital input per unit of output is of the same order of magnitude as in France. The low value of the ratio results from a much greater labour input and, as can be seen in table 4, the latter arises primarily on account of repair and maintenance.[25] Labour input on repair account is about three times as high as that of operating labour, a situation almost exactly the reverse of that obtaining in France and in most developed countries. The sizable repair expenditure results, to a large extent, from the practice of producing on the site various spare parts which, in industrial countries, are readily available, and of engaging in extensive repair of parts which, in the latter countries, would normally be discarded and replaced. Certain aspects of this tendency deserve closer attention at this point.

Since most of the equipment and spare parts are imported, domestic production of the latter obviously represents a means of saving foreign exchange, an important consideration in India and most other under-developed countries. Even in countries which do not have foreign exchange difficulties, it may still be more advantageous to fabricate some parts on the site rather than undergo the expense of maintaining inventories of the numerous spare parts which are essential for operating construction equipment. In the advanced countries where use of such equipment is widespread, the overhead costs borne by spare parts dealers in carrying adequate inventories are justified by a large and continuing volume of operations; in under-developed countries, such overhead would be charged to individual projects and would lead to higher unit costs.

As repair is essentially a labour-intensive activity, reconditioning of parts as well as of large pieces of equipment may be more economical than buying new parts or new machinery.[26] In other words, increasing labour-intensive repair work is tantamount to saving capital by reducing the rate of consumption of physical capital and lengthening the life of existing equipment.[27] In the case of India, the authorities have specified a life span for calculating depreciation somewhat longer than that used in developed countries;[28] to compensate for this, higher repair expenditures are anticipated.

[24] According to the data of the Indian committee, skilled operating and repair labour was paid at the rate of 6 rupees per eight-hour day, while unskilled workers employed for various jobs on the site were paid from 1 to 2.5 rupees.

[25] The input in operating labour alone amounts to 200 man-hours per thousand cubic metre-kilometres in the Indian project as compared to a total—operation and repair—of 148 man-hours in the French one. The high value of the component for operating labour in India reflects a lower rate of performance of equipment and also the fact that, presumably because of very low wage levels, there is a tendency in India to use much more unskilled labour than in the more developed countries.

[26] While repair work in India is, as noted earlier, highly paid compared to unskilled operation, Indian repair wage rates are still considerably lower than their counterpart in developed countries.

[27] The depreciation charge per unit in India should thus be relatively low; as noted above, it is, in fact, higher than that in France. The difference may be due to the inclusion in the Indian costs of heavy expenses for transport of equipment and also to a lower rate of performance.

[28] United Nations, "Problems of Size of Plant in Industry in Under-developed Countries", *Bulletin on Industrialization and Productivity*, No. 2 (sales number: 59.II.B.1), pages 21 to 23. The significance of conserving capital through increased maintenance and repair was stressed in the earlier studies of the Secretariat. The question is now being studied in more detail by the Industrial Development Branch and the results of this investigation will be published in a subsequent issue of the *Bulletin*.

CONCLUDING REMARKS

THE OBJECTIVE OF this study was to correlate the degree of mechanization and costs in earth-moving operations on the basis of data from the field. This follows up a previous study in the same area, which was based primarily on United States experience.[29] The purpose of these studies is to develop a micro-economic approach to problems where aggregative analysis is inapplicable, such as choice of techniques in individual industrial operations.

A new measurement of the degree of mechanization or relative factor input was introduced for the purpose of the analysis, namely, the capital-labour input ratio. Both inputs are based on the concept of flow; in particular, capital input is measured by physical depreciation of equipment per unit of output. In measuring both capital-labour input ratio and unit costs, account was taken of factor performance, which, for physical capital, is represented by the rate of utilization of equipment—both between jobs and on the site—and, for labour, by its productivity. In the case of costs, account had to be taken

[29] "Capital Intensity in Heavy Engineering Construction", op. cit.

of the lack of homogeneity of the labour factor, that is, of the differences in skill required by operations involving different levels of mechanization. Moreover, certain statistical problems of valuation of data for international comparability had to be solved.

The statistical analysis indicated that, in the case of projects reported by industrial countries, the magnitude of both the capital-labour input ratio and the total unit cost which, under comparable factor costs and levels of mechanization is a measure of performance, varied within a reasonably narrow range; the significance of this has been discussed in the article.

The study suggests that the method may be of interest for appraising industrial projects in under-developed countries. Among the various factors to be considered in such appraisals are unit costs and—assuming that the industrial process involved is sufficiently flexible technologically to allow for factor substitution—a capital-labour input ratio which would make allowance for the general scarcity of capital in under-developed areas. The study provides an appraisal method based on quantitative measurements of the two magnitudes. The finding that these magnitudes are stable for the individual projects reported by the industrial countries—until now, such stability has been considered characteristic of aggregative measurements in the field of industry, such as capital-output ratios—provides useful standards of comparison or "bench-marks" for such appraisals; the results obtained may be indicative of similar conditions in other industrial operations.

The significance of the capital-labour input ratio as an effective measurement of the factor-mix in investment projects was particularly evidenced in the Polish case, where a mechanized transport operation achieved by means of labour-intensive investment—the posing of narrow-gauge tracks—was statistically reflected in a very low value of the ratio. The proposed measurements thus take into account the fact that capital is not a homogeneous factor. The attention of technical institutions and similar bodies is drawn to the usefulness of additional research into the possibilities of factor substitution in similar types of investment.

Construction of an airport in West Virginia: earth-moving operations

Appendix I

SUMMARY INFORMATION ON THE PROJECTS

THIS APPENDIX CONTAINS brief descriptions of the main features of the projects, the costs of which have been analysed above. This material is presented so that the reader may obtain a better understanding of the operations involved and of the influence of job conditions on the analysis of costs.

Austria

The project under review is the construction of a short run-off canal, 800 metres in length, ten kilometres west of Klagenfurt. The total of earth excavated amounted to 18,000 cubic metres; this spoil was deposited along the banks of the canal. The work was done in the month of November 1955, using a single shift.

Equipment on the site included three power shovels, each with bucket capacity of 0.6 cubic metre. Bulldozers were used to help prepare the site and to accomplish simple levelling for better operation of the excavators. The Austrian Government's reply indicates no special topographical problems or difficulties in the nature of the soil; this is described as stony sand with a slight admixture of clay.

Among the factors contributing to the high overhead costs noted in the text was the need for special equipment to move the construction machinery from the equipment park to the work site. Also, it was necessary to provide housing for the labour force; in view of the small numbers involved, it proved more economical to rent special caravan trucks for accommodation than to construct temporary huts. Special trucks for use as repair shops for the equipment were also rented.

Finland

The project involved a deepening of the tail-race canal at the foot of the Pälli hydroelectric station in northern Finland. The purpose was to raise the head[30] and thus increase the power potential. The canal is 2.8 kilometres in length and the depth of the excavation was approximately 2 metres. The total of earth excavated amounted to 658,300 cubic metres. The work was completed in the period February through August 1957, in a three-shift operation. The excavated masses were dumped on the sides of the canal.

Equipment on the site included a walking dragline with bucket capacity of 6 cubic metres. A bulldozer was used to level temporary roads and to prepare the site so as to facilitate operation of the dragline; the bulldozer was also used to level the excavated masses on the banks of the canal.

Excavation was accomplished under water, a type of operation for which the dragline is particularly well adapted. The reply indicates no unusual topographic problems, except that a small portion of the earth had to be moved twice because of the lack of dumping space at certain sections of the canal. The soil is described as easy to dig—sand mixed with clay.

Expenditures for housing some of the labour force and for transport of other staff from nearby communities are included in overhead charges, but, in view of the small size of the staff needed for the work, these are minimal. It was necessary to construct a small repair shop, the costs of which are included in overhead.

France

The reply relates to the construction of a portion of the Grand Alsatian Canal, the name given to the development of the Rhine between Basel and Strasbourg, for the dual purpose of hydroelectric power production and navigation. This particular section, at Ottmarsheim, consisted in an intake canal 11,830 metres in length, divided at its end into two branches, one containing locks for navigation, the other being the head-race for the power plant. The two branches converge below the plant. Over 19 million cubic metres of earth were moved for the entire project, which was carried out over the period 1948 to 1952.

The cost data relate to the construction of the intake canal, which required the shifting of about 13 million cubic metres of earth. In view of the nature of the soil and the requirements for embankments, earthwork was divided into three parts. The first (1.8 million cubic metres) involved simple stripping of the soil and dumping near the site; scrapers and small excavators were used for this work. The second (4.3 million cubic metres) involved excavation and transport of the earth for use as embankment; this was accomplished with large power shovels and dump trucks. The last part (6.8 million cubic metres) involved excavation of soil and dumping in the immediate area; this was done with draglines.

The analysis of costs covers the second and third parts of the work. The combined operation of excavation, transport and compaction, comprising the second part, was undertaken with electric power shovels of 3 cubic-metre bucket capacity, dump trucks of 10 cubic-metre capacity and bulldozers for compaction. The third part was undertaken using large draglines with bucket capacity of 7.6 cubic metres; bulldozers were used to assist in the preparation of the work-site to facilitate dragline operations.

There is no indication of any major difficulties arising from topographical features of the work-site or from the nature of the soil. Camps were erected for the large labour force involved in the entire project; this included considerable concrete work, installation of a power plant and provision of navigation locks. The camps were also used to house the workers engaged in subsequent projects in the area, which helped to reduce the costs charged to individual works. Elaborate repair shop facilities were provided, the costs of which are included in overhead.

[30] The tail-race is the channel conducting the water away from the dam; the head is the difference in elevation or drop of the water which provides the force to turn the power turbines.

India

As indicated in the article, the analysis is based on cost estimates prepared in 1953 by the Rates and Costs Committee of the Government of India. These are primarily performance norms used to evaluate the actual cost data recorded by projects undertaken in India at the time of the review by the committee. The data relate to excavation by a two and one-half cubic-yard excavator, transport by dump trucks and compaction by bulldozers.

Poland

The Polish project consisted of building a reservoir system on the Vistula River, 100 kilometres above Krakow. Total earthwork involved moving approximately 1.5 million cubic metres. The main works were an earth dam and a catch-basin; the earthwork for the latter, the costs of which are analysed above, amounted to 285,000 cubic metres. Excavation work on the project began in 1952 and was completed in 1954.

The equipment used on the entire project included eight excavators with bucket capacities ranging from 0.5 to one cubic metre, seven bulldozers and roller attachments for compaction, dump trucks and narrow-gauge railway locomotives and wagons. While both trucks and railway stock were used to transport earth in constructing the dam, only the railway was used for earthwork operations connected with digging the catch-basin.

Accommodation was provided on the site for about one-third of the labour force. The costs incurred in this connexion, and those of transporting workers from nearby communities, are included in overhead.

Other features of the project are given in the analysis above and in appendix II.

Sweden

The reply gives details on the costs of earth-moving operations in the construction of a tail-race canal at the Grundfors hydro-power station. Total excavation amounted to 2.5 million cubic metres. The whole length of the canal—3.55 kilometres—was dug particularly deep in order to add to the head at the dam and thus increase the power potential. Earthwork began in the middle of 1954 and was completed in the summer of 1957; operations were conducted on a three-shift basis.

The major portion of the work was done with a large walking dragline having a bucket capacity of 6 cubic metres; the analysis refers to the costs involved in the operation of this piece of equipment. In addition, as is normal in such cases, a bulldozer was used for simple clearing and levelling operations in order to facilitate the operation of the dragline. It was also necessary to use a smaller dragline for a small portion of the work, but the cost of operating this piece of equipment has not been taken into account. The excavated masses were deposited along the sides of the canal to provide embankments.

Digging is described as particularly difficult on account of the nature of the soil; the dragline also operated under difficult conditions, which contributed to reducing the performance rate. These factors have been taken into account in the adjustments to the analysed figures. Some sections of the earth had to be blasted prior to excavation and pumps were used to drain other areas in this connexion. These costs have been excluded in order to obtain a set of operations comparable with those described in the other replies.

Overhead costs include a proportionate share of the expenditure on the construction camp for the labour force employed on the entire project. They also include the expenses incurred in erecting and operating a repair shop for the dragline and for fabricating certain parts.

Union of Soviet Socialist Republics

The reply gives details on some of the earthwork costs in the construction of an earth dam and other installations for the Irkutsk power station. The dam is 2,600 metres long and contains 3.3 million cubic metres of fill; total earthwork for the entire project, including excavation for the power plant and the coffer dam, was 6.7 million cubic metres. Earthwork began in 1950 and was completed at the end of 1956; the cost data given in the reply relate to operations during the year 1956. The installation is very large, the capacity of the hydro-station being 660,000 kilowatts.

The fill for the earth dam was taken from nearby borrow areas and was also obtained from the excavation for the channels and the power plant in the immediate vicinity of the dam site. The cost analysis given in the reply refers to operations at the borrow areas only.

Among the pieces of equipment used for the project were eighteen draglines and excavators with bucket capacity ranging from 1.4 to 10 cubic metres. Transport of earth was accomplished using ninety-five dump trucks, forty-five of these with a capacity of 14.3 cubic metres and fifty with a capacity of 4.7 cubic metres. Tractors and bulldozers of various sizes were used for simple levelling operations on the site and for compaction of the fill.

The main features of the earthwork have been noted in the text. Because the ground was frozen during winter months, excavation at the borrow areas was undertaken in two stages; during the ice-free months, the larger draglines were used to excavate earth and to dump the mass in a "reserve stock". The operations connected with moving this stock to the dam for fill were conducted throughout the year. The cost analysis in the text refers to the second stage only.

United States

The data are based on sample surveys conducted by the United States Bureau of Public Roads, the results of which were made available to the Secretariat. The costs refer to simple earth excavation by small shovels or graders in road construction.

Appendix II

COMPUTATION PROCEDURES

THIS APPENDIX PRESENTS in some detail the calculation procedures followed in estimating the unit costs and capital-labour input ratios for the French and Polish projects. Similar procedures were followed in respect of the data concerning the other projects discussed in the article. The appendix also contains a section on the conversion rates for cost and investment data expressed in Soviet and Polish currencies.

COMPUTATION OF UNIT COSTS AND CAPITAL-LABOUR INPUT RATIOS

FRANCE

Unit costs

Detailed data are given in the reply of the French Government on unit costs for the following operations: excavation by electric shovel per cubic metre of earth; transport by truck per cubic metre-kilometre; dumping of earth per cubic metre, including cost of maintenance of roads and work on spoil tip, constitution of embankments, and rough grading of the slopes. Table 1 presented two sets of data on excavation. The second set was taken up again in table 2, as part of the combined operation; the following discussion relates to this second set. The work was accomplished in 1948, but costs were recalculated in the reply at March 1958 prices; the conversion rate used was 420 francs to the dollar, the rate of exchange prevailing at that date. The data are summarized in table I.

All the data on the components of excavation unit cost were reduced by 20 per cent to adjust for the fact that job performance of the excavators was adversely affected by shortages of transport equipment.

As regards the depreciation item, both in excavation and the combined operation, two elements had to be taken into account in the adjustment. The cost of the equipment used in the French project includes additional charges in the form of customs duties and domestic taxes on machinery amounting to 30 to 35 per cent of their c.i.f. value; these charges are irrelevant for the purpose of this study. On the other hand, the rates of depreciation as given in the cost accounts appear to overstate the economic life of the equipment; thus, for excavation, the rate of depreciation used in the accounts corresponds to a life expectancy of about thirteen years, whereas normal expectancy is ten years. As the two elements involve adjustments in opposite directions which roughly cancel each other, the depreciation figures were used as given in the accounts, without adjustment.

Capital-labour input ratio

The capital-labour input ratio is obtained by dividing depreciation by man-hour of direct labour. Depreciation has been discussed above. The man-hours of direct labour are shown separately in the reply and cover those of operating, repair and maintenance, and other site personnel. Excavation of a thousand cubic metres requires sixty-six man-hours; the combined operation requires 148 man-hours per thousand cubic metre-kilometres.

The ratio for excavation is 22,700 : 66=344 francs, that is, 0.82 dollar, and for the combined operation—70,000: 148=473 francs, or 1.1 dollar per man-hour.

POLAND

Unit costs

The data for total unit cost were used as given in the reply without adjustment (table IV).

Depreciation of equipment in the operation under discussion—construction of a catch-basin—was calculated taking into account the following information. All equipment used on the project was rented from a central depot; the reply gives the fee charged for rental of the equipment used in the construction of the catch-basin without further breakdown. However, a breakdown of the total rental fee paid for equipment used on the entire project is available, including depreciation and wages for repair personnel. The percentage breakdown concerning the entire project has been applied to estimate the depreciation costs relating to construction of the catch-basin. The figures are shown in table II.

This yields a figure for depreciation of equipment used in constructing the catch-basin of 1,150 zlotys per thousand cubic metre-kilometres.

Table I

FRANCE: COMPONENTS OF UNIT COST

(Thousands of francs)

ITEM	UNADJUSTED		ADJUSTED	
	Excavation only (*per thousand cubic metres*)	Combined operation (*per thousand cubic metre-kilometres*)	Excavation only (*per thousand cubic metres*)	Combined operation (*per thousand cubic metre-kilometres*)
Wages	29.7	69.1	23.8	63.2
Depreciation	28.4	75.7	22.7	70.0
Other[a]	58.4	157.9	46.7	146.2
TOTAL	116.5	302.7	93.2	279.4

Source: Economic Commission for Europe.

[a] Including overhead, cost of materials and repair and interest charges.

Table II

POLAND: PERCENTAGE DISTRIBUTION OF RENTAL FEE FOR EQUIPMENT USED IN ENTIRE PROJECT

ITEM	PERCENTAGE
Wages	13.0
Depreciation	21.9
Spare parts	22.5
Other	42.6
TOTAL	100.0

Capital-labour input ratio

Depreciation has been discussed above. As regards man-hours, the reply gives data relating to all direct labour—including that of workers engaged in operating and maintaining the track and rolling-stock of the narrow-gauge railway system—except that for repairing and maintaining excavators and locomotives. To estimate hours worked by repair workers, their wage bill—13 per cent of the total rental fee—was divided, for lack of more detailed information by the hourly wage for workers on the project as a whole.[31] The total man-hours per thousand cubic metres thus obtained is 960. The capital-labour input ratio is equal to 1,150 zlotys divided by 960 man-hours, or 1.2 zlotys per man-hour.

CONVERSION OF DATA EXPRESSED IN SOVIET AND POLISH CURRENCIES

The difficulty in comparing cost data in the Soviet and Polish projects with those of the other projects analysed in this study has been briefly referred to earlier in the text. It was noted that the procedure of converting cost data expressed in national currencies into a standard currency unit—in this instance the United States dollar—using the official exchange rates, was not applicable in these two cases.

The method of conversion used for the Soviet and Polish data is presented in the following paragraphs.

[31] Since labour costs for repair are a small proportion of total labour costs, use of the average wage rate for this calculation does not affect the conclusions.

The unit costs for the Soviet and Polish projects were broken down into categories and a "real" parity between the currencies concerned and the dollar was estimated for each cost category. The calculations for the Soviet data are shown in table III and for the Polish data in table IV.

If the official rate of four roubles to the dollar is applied to the Soviet data, the prices of small and medium-sized pieces of equipment used in the project appear to be, in dollar equivalent, approximately equal to or only slightly higher than the prices of United States equipment of similar specifications. It was thus considered appropriate to apply the official rate to depreciation charges.

The official exchange rate was not, however, considered to be applicable to wage costs. A first approximation to parity is provided by the so-called "tourist" rate of ten roubles to the dollar, which has presumably been calculated on the basis of international price parity in respect of consumer goods. However, if it is borne in mind that some wage goods, in particular the basic subsistence items, and many services, for instance, housing, are preferentially priced, the "tourist" rate appears to be too high for the purpose and a rate of eight roubles—judged to be more realistic—has been adopted.[32]

With respect to fuel and lubricants, an analysis of the price data supplied by the Soviet authorities indicates that the rate of eight roubles to the dollar would also be appropriate. At this rate, the equivalent dollar prices are roughly comparable to United States prices for similar goods.[33]

The item "repair and maintenance" includes charges for shop overhead and spare parts. The rate of four

[32] It is true that, even at the tourist rate, the equivalent dollar prices of many consumer goods would appear to be considerably higher than those found in the United States or western European countries. For a full appreciation of this problem, the difference in consumption patterns among these countries should be taken into account—a task which lies beyond the scope of this article. Comparisons of this type underlie the previously mentioned studies on western Europe and the United States by the Organisation for European Economic Co-operation.

[33] This rate takes into account the importance of freight costs; these are relatively high in view of the remote location of the project.

Table III

CONVERSION OF SOVIET COST DATA

ITEM	EXCAVATION (*per cubic metre*) (Roubles)	COMBINED OPERATION (*per cubic metre-kilometre*) (Roubles)	EXCHANGE RATE[a]	EXCAVATION (*per cubic metre*) (United States cents)	COMBINED OPERATION (*per cubic metre-kilometre*) (United States cents)
Wages	0.40	1.32	8	5	16
Depreciation	0.20	0.75	4	5	19
Fuel and lubricants	0.22	0.47	8	3	6
Repair and maintenance	0.35	0.79	6	6	13
Overhead (25 per cent)	0.28	0.84		5	13
TOTAL	1.45	4.17		24	67

Source: Economic Commission for Europe.

[a] Roubles per United States dollar.

Table IV
CONVERSION OF POLISH COST DATA

ITEM	COMBINED OPERATION		
	Zlotys per cubic metre-kilometre	*Exchange rate*[a]	*United States cents per cubic metre-kilometre*
Wages	7.18	36	20
Depreciation	1.15	24	5
Fuel and lubricants	1.66	15	11
Repair and maintenance	3.41	30	11
Overhead (31 per cent)	4.16		15
TOTAL	17.56		62

Source: Economic Commission for Europe.
[a] Zlotys per United States dollar.

roubles to the dollar applied to equipment should be appropriate for the latter; for the former, the rate proposed above for the wage element of costs might apply, since labour accounts for a considerable proportion of such overhead. On balance, an average rate of six roubles to the dollar has been taken.

Finally, the item for overhead is taken, as given in the reply, at 25 per cent of the total of other costs.

The use of differential conversion rates is indicated in view of the fact that Soviet pricing is essentially a tool of planning of production and distribution of income. Thus, as indicated above, there is a relative under-valuation of capital goods vis-à-vis consumer goods (both taken in general terms). From the point of view of choice among techniques of production involving different levels of capital intensity, such under-valuation may result in a certain bias in favour of mechanized techniques.[34]

As regards the Polish data, the procedure which suggests itself in the first place is the use of the differential rates for cost components applied to the Soviet data, on the basis of the official rate of exchange of the rouble to the zloty, which is 1:1. However, the problem is more complex, as is shown in the following discussion.

With respect to the capital cost item, practically all the excavating equipment used in the Polish project was imported from the Soviet Union and Czechoslovakia, while transport equipment—rolling-stock--was of domestic origin. The zloty cost of the imported equipment is computed, in the Polish reply, at a rate of six zlotys to the rouble. While no indication is given of the method underlying this evaluation, it may be assumed that the Polish authorities have made an evaluation of the rouble-zloty parity for these capital goods. Taking this adjusted zloty-rouble rate and the 4:1 rouble-dollar rate applied above for small and medium-size Soviet produced equipment--which is similar to that used in the Polish project —a cross rate of 24 zlotys to the dollar is obtained for the conversion of capital charges. This rate was applied both to the imported and the domestically produced equipment.

For the wage cost item, a first indication of the parity rate is provided by the official "tourist" rate of 24 zlotys to the dollar. However, there are indications that this tends to overstate the purchasing power of the zloty for wage goods.[35] A rate of 36 zlotys to the dollar appears to be more appropriate for the purpose of conversion.[36]

For fuel, especially coal, which, in Poland, is subject to preferential pricing, a rate of 15 zlotys to the dollar was considered appropriate. As regards repairs, which include spare parts and repair shop overhead (largely indirect labour), the average of the rates for capital equipment and direct labour—30 zlotys to the dollar—was adopted.

Finally, the overhead charge was computed, as given in the reply, at 31 per cent of the total of all other costs.

[34] This question has been recently discussed in the Soviet literature. *See* "Obsuzhdenie voprosa o zakone stoimosti i tsenoobrazovanii v SSSR v Institute Ekonomiki Akademii nauk SSSR" (Discussion of the Question of Law of Value and Price Formation in the USSR in the Institute of Economics of the USSR Academy of Sciences); "Zakon stoimosti i problema tsenoobrazovanii v SSSR" (Law of Value and Problem of Price Formation in the USSR) by Y. Kronrod; "O deistvii zakona stoimosti i tsenoobrazovanii v narodnom khozyaistve SSSR" (Operation of Law of Value and of Price Formation in the National Economy of the USSR) by A. Bateburin, and "Problemy ekonomitcheskoy effectivnosti kapitalovlozheny v sotsialistitcheskoe khozyaistvo" (Problems of Economic Effectiveness of Capital Investments in a Socialist Economy) by T. Khatchaturov, all in *Voprosy Ekonomiki*, No. 2, February 1959 (Moscow).

[35] The rate of 50 zlotys to the dollar for consumer expenditures on goods and services is suggested in a recent study by M. Rakowski "Z problemów badán efektywnósci produkcji eksportowej" (Some Problems in the Investigation of Effectiveness of Export Production) in *Gospodarka Planowa*, February 1957 (Warsaw).

[36] The average hourly wage of 7.5 zlotys derived from data in the Polish reply is equivalent to approximately 21 United States cents, using the conversion rate of 36 zlotys to the dollar. The much higher wage rate in the Soviet project is explained by the preponderant use of skilled labour; unskilled labour appears to have been extensively used in the Polish project.

Working Party on Earth-moving Operations

A WORKING PARTY ON Earth-moving Operations was convened in New Delhi from 7 to 14 September 1959, under the joint sponsorship of the Economic Commission for Asia and the Far East (ECAFE) and the Bureau of Economic Affairs of the United Nations Secretariat.[1] The purpose of the meeting was to consider a number of problems relating to choice between manual and mechanized techniques or a combination of both, and to improvement of their efficiency.

Prior to the meeting, a questionnaire on costs of earthwork was circulated to Governments in the region, and working papers based on the replies received were submitted to the participants as background documentation.

The consensus reached in the discussions at the meeting was that, in a general way, mechanized operations ought to be combined with manual work in earth-moving projects in countries of the region. While the specific technical and economic conditions of individual projects should be taken into account, labour-intensive techniques appeared to be, in general, more effectively used when combined with mechanized transport.

The working party recognized that, even with the fullest degree of mechanization, there still was large scope for using manual labour in finishing and detailed work and that it would be useful to exchange information between countries on this aspect. It was suggested that mechanization should be first applied to replacing manual labour in the most exacting operations.

Attention was also drawn to the advantages of employing animal power (for example, bullock carts or animal driven wagons on tracks), simple implements or mechanical devices to assist in various phases of manual earthwork. This was considered to be particularly economical in small and medium-sized jobs. In many instances, the necessary implements for this purpose could be obtained or manufactured in the country. In this connexion the working party found that there was considerable variety in the types of implements used in the different countries of the region, and recommended that pilot projects be undertaken to select the types of implements appropriate to the diverse conditions and where the need was demonstrated—that simple and rugged types be developed. For example, the efficiency of animal-drawn transport used in conjunction with manual labour could be improved by using anti-friction bearings and improved tires.

The pilot studies should also include time studies of manual operations so as to provide guidance in planning and organizing the earthwork.

It was considered that the efficiency of manual labour could be improved by adequate compensation, wage incentive systems and provision of social welfare, including housing and recreational facilities. The hardships of irregular employment inherent in the construction industry might be eased by planning in advance the transfer of workers from one project to another.

Considerable attention was given by the working party to the possibilities of combining manual and mechanized

[1] The working party was attended by representatives from the following member and associate member countries of the Commission: Australia, Burma, Republic of China, France, India, Japan, Pakistan, Philippines, Union of Soviet Socialist Republics, United Kingdom, United States of America, Viet-Nam, Singapore and British Borneo. A representative of the International Labour Organisation took part in the meeting. Observers from the International Confederation of Free Trade Unions and the International Commission on Irrigation and Drainage also attended. The Government of India was host. The conference was followed by a five-day study tour of two river development projects currently under way in India so as to afford participants an opportunity to inspect works involving a large volume of earthmoving.

techniques, taking advantage in particular of the surplus of labour in the countries of the region. For instance, mechanized and manual labour methods could be used side by side in compaction work, and certain earth fill operations, particularly those involving low embankments, could be performed more advantageously by manual labour. Manual labour could also be employed in simple excavation jobs in combination with such transport as hand-pushed, animal-driven or locomotive-driven wagons on narrow-gauge tracks.

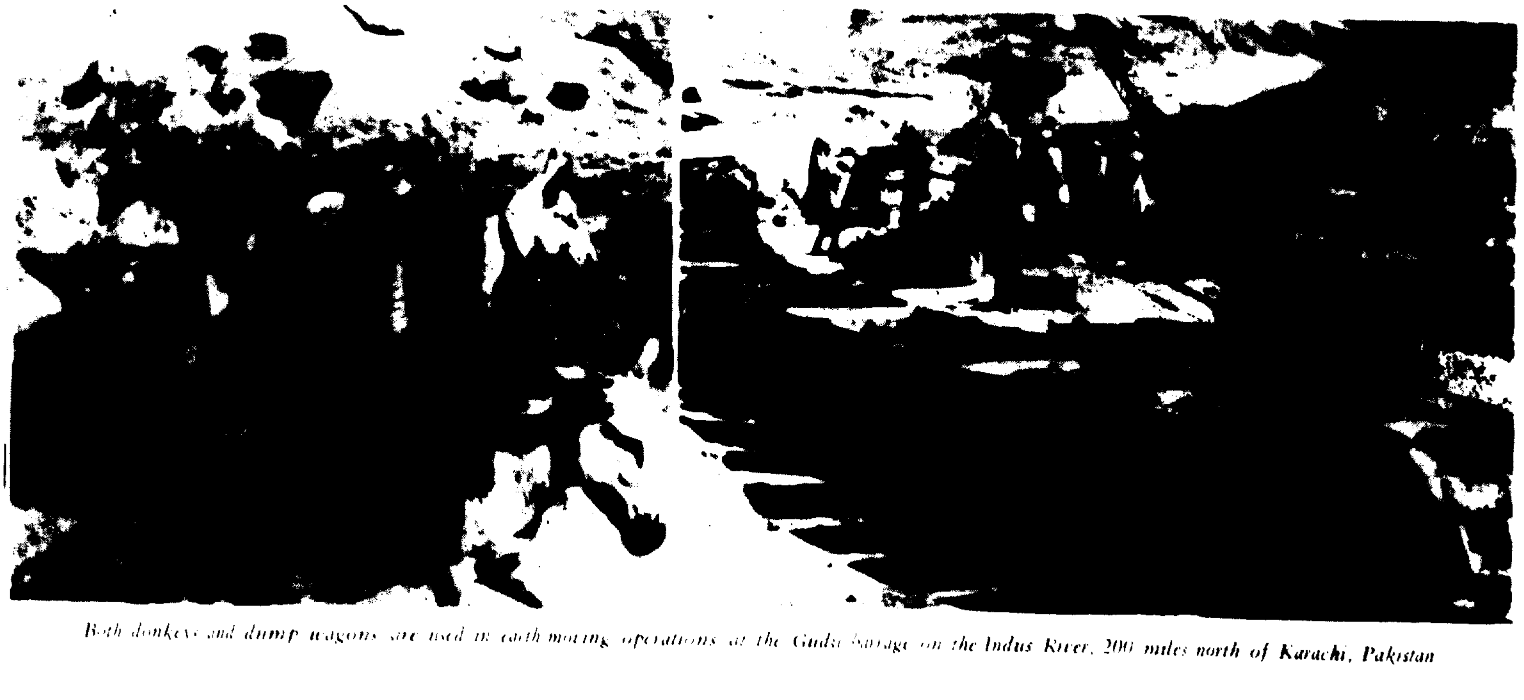
In mechanized operations, proper preventive maintenance procedures and adequate supplies of spare parts on the site were needed to improve efficiency of operation. In industrial countries, project managers have ready access to outside repair facilities and to adequate inventories of spare parts maintained by distributors. Such facilities are lacking in under-developed countries, and it was considered that provision for repair, including inventories of spare parts, was especially important to ensure efficient use of equipment.

The working party recognized the need for training operating and repair personnel and presented suggestions to this effect. It felt that—particularly in this area—wages of skilled workers were not commensurate with the responsibilities and tasks involved; it recommended that the economic and social status of skilled mechanical personnel be improved to impart a sense of responsibility which would contribute to better performance.

The question of selection of earth-moving equipment in the mechanized projects was discussed at some length. An excessive diversification of types of equipment on the job was to be avoided. In order to achieve efficiency and economy in operation, as few different makes as possible should be employed on any construction job. This was all the more important in the ECAFE region because of the difficulty of obtaining spare parts and the lack of adequate repair facilities mentioned above. This applies not only to earth-moving machinery proper, but also to components and ancillary equipment, such as engines and power control units. During the discussion it was brought out that the achievement of this objective was compatible with preserving a competitive market for equipment.

Before considering the purchase of new equipment, it was essential that machinery currently available in the country be fully used. Arrangements such as central pools for operating and renting out equipment would ensure maximum use of the existing stock; such organizations already existed in many countries. It was noted in this connexion that in those less developed countries where possibilities of re-use of equipment were limited, multi-purpose machines had distinct advantages.

The working party considered that it was important to improve budgeting and accounting procedures in order to obtain accurate cost records. It noted in this connexion that there is considerable variation in estimating depreciation allowances, and that the economic life of equipment, upon which the depreciation charge is based, is a variable depending in part upon the cost of repairs. Data relating to the impact of repair costs on life of equipment were cited for some projects, but these figures admittedly had to be appraised with caution; conclusions concerning the life of equipment in under-developed countries could not be made until additional data had been collected. The working party recommended in this connexion that research on cost analysis, taking into account the various factors mentioned above, be continued.



Both donkeys and dump wagons are used in earth-moving operations at the Gudu barrage on the Indus River, 200 miles north of Karachi, Pakistan

Choice of Industrial Technology: The Case of Wood-working

BY G. K. BOON

THE PURPOSE OF this article is not so much to explore the economics of alternative technologies in a specific industry—wood-working—which may or may not be of particular importance to under-developed countries, as to present a method of analysis which may be applied to other industries where a choice between technologies is possible. The method can be used to assess the costs of alternative techniques of production and thereby to select the most economical one in a given context of factor supplies, factor prices and levels and capacities of output.

Two specific problems will be envisaged: the first, which relates to alternative methods of producing window frames, deals with the choice of an appropriate degree of mechanization in processes of production with different prices of labour and capital and different levels of output; the second, which concerns production of furniture, compares the costs involved by the use, respectively, of single-purpose or multi-purpose machines with varying output levels. This requires a brief description of the alternative techniques of production; then, cost functions are derived and applied to the alternative techniques.[1]

[1] For full details, *see* "A Case Study of Wooden Window Frame Production", *Alternative Techniques of Production*, Progress Report No. 4, March 1959, and "Multi-Purpose versus Single-Purpose Woodworking Machinery", *Alternative Techniques of Production*, Progress Report No. 3, November 1958, by Ph. B. van Harreveld and G. K. Boon, published jointly by the Netherlands Economic Institute, Division of Balanced International Growth (Rotterdam), and the Research Institute for Management Science (Delft).

CHOICE AMONG ALTERNATIVE METHODS OF VARYING CAPITAL INTENSITY IN THE PRODUCTION OF WINDOW FRAMES

Collection of data

The investigation was conducted in a window frame factory in the Netherlands, which used highly mechanized processes of production. Each process was analysed with respect to equipment used, maintenance, energy consumption, setting time and time of operation. Information was then obtained on the various economic data bearing on costs—among others, prices of machinery, interest and wage rates and costs of energy.

A less mechanized method is not used in the Netherlands. The relevant information—technical and economic—was obtained from producers and importers of wood working machinery.

The product and the processes of production

The window frame under examination is composed of two long beams—stiles—each 1,500 millimetres in length,

MR. BOON *is a staff member of the Division of Balanced International Growth of the Netherlands Economic Institute, an organization which has carried out several research projects complementing studies undertaken by the United Nations Secretariat. Mr. Boon is particularly concerned with industrialization problems.*

Table 1

PRODUCTION OF WINDOW FRAMES: ALTERNATIVE MACHINE COMBINATIONS, PRODUCTION TIME AND ANNUAL PRODUCTION CAPACITY

PROCESS A

Source: See footnote *1*.

[a] Allowing 30 per cent for rest and relief periods.
[b] One unit consists of two stiles and two sills.
[c] Apparatus for automatic feeding.
[d] Apparatus for surfacing two sides simultaneously.

PROCESS B

and of two short beams—sills—each 790 millimetres in length. The stiles are surfaced and planed to a certain thickness; after being cut to size, they are grooved along the entire length, and holes are mortised at each end. The sills are also surfaced, planed to thickness and cut, and tenons are cut at each end.

There are two basic groups of operations, each of which can be carried out by alternative processes of production: (*a*) planing and moulding the piece of timber and (*b*) cutting it to length and cutting tenons. Each of the processes can be carried out by different combinations of machines which are summarized in table 1. Essentially, one can choose between using a special-purpose machine, which performs a group of operations in one sequence, or combining several single-purpose machines, each of which performs only one operation at a time, or combining a special-purpose machine with a certain number of single-purpose machines.

Table 1 also shows the production time and annual capacity of production of each machine and of each combination of machines.

Computation of costs

The formula used in computing the costs of producing a single window frame is simple. Total costs (C) equal the sum of fixed costs (F) and variable costs (V) multiplied by the number of units (u) produced, or $C = F + Vu$. Fixed costs are that part of total costs which, within a given range of output, do not vary with the volume of output—which means that as output increases, the fixed cost per unit decreases. Such costs are considered to include the following items: depreciation, interest on capital and cost of space, inclusive of light, heat and the like. Variable costs are those the sum of which varies directly as the volume of output changes, but which are approximately constant for each unit produced. They include wages, inclusive of social security charges, management costs directly associated with output, costs of setting the machinery and power costs. Output is measured at annual capacity; this is computed by dividing the total annual

Code number and class and name of machine		Cycle time[a] for one unit of production[b] (centiminutes)	Annual capacity (units)[b]
A I	SPECIAL-PURPOSE MACHINE		
	Four-sided planing and moulding machine	21	563,300
A II	SINGLE-PURPOSE MACHINES PLUS AUXILIARY MECHANICAL APPARATUS		
	Surface planer plus ETZ[c] plus WF[d]	60	200,000
	Thickness planer	27	444,400
	Vertical moulding machine plus ETZ[c]	39	307,700
	TOTAL, PROCESS A II	126	200,000
A III	SINGLE-PURPOSE MACHINES PLUS AUXILIARY MECHANICAL APPARATUS		
	Surface planer plus WF[d]	104	115,300
	Thickness planer	27	444,400
	Vertical moulding machine	82	146,300
	TOTAL, PROCESS A III	213	115,300
A IV	SINGLE-PURPOSE MACHINES WITHOUT AUXILIARY APPARATUS		
	Surface planer	153	78,400
	Thickness planer	27	444,400
	Vertical moulding machine	82	146,300
	TOTAL, PROCESS A IV	262	78,400
A V	COMBINATION OF SINGLE-PURPOSE AND SPECIAL-PURPOSE MACHINES		
	Combined planing and thicknessing machine	180	66,000
	Vertical moulding machine	82	146,300
	TOTAL, PROCESS A V	262	66,000
B I	SPECIAL-PURPOSE MACHINE		
	Double-ended tenoner	22	545,400
B II	SPECIAL-PURPOSE MACHINES		
	Combined circular saw and moulding machine	190	63,100
B III	SINGLE-PURPOSE MACHINE		
	Single-ended tenoner	187	64,100

TOP LEFT:
Feeding beams to four-sided planing machine

TOP RIGHT
Placing beams on transport chains of double-ended tenoner

RIGHT
Universal radial cutter

working time by the amount of time necessary to produce one unit defined as one frame, that is, two sills and two stiles.

The required calculations are made as follows: (*a*) depreciation is measured on a straight-line basis—that is, the cost of the machine (K) divided by its estimated life (N), which is fifteen years for machines and ten years for auxiliary apparatus; (*b*) the annual interest charge is estimated by multiplying the average of the annual depreciation values of the machine ($K/2$) by the assumed interest rate. For this analysis a rate of 4 per cent is assumed for a capital-rich country while a "shadow rate"[2] of 15 per cent is assumed for a capital-poor country. As a first approximation no allowance is made for interest on working capital. Costs of space are assumed to amount to 30 guilders[3] per square metre.

Among variable costs, wages are the most important. In the industry concerned, the wage rate in the labour-scarce economy of the Netherlands is 2 guilders per hour; in labour-surplus economies, shadow wages of 0.05 guilder per hour are assumed. Management costs are estimated at twice the level of wages. Energy costs per kilowatt-hour are estimated at 0.08 guilder per hour of operation, allowing for variations due to the differing horsepower of the machines. The costs of setting the special-purpose machines are estimated at 0.25 guilder per hour, and those of setting the other machines are assumed to be in proportion.[4]

[2] That is, a rate which, as a rule, is higher than the one prevailing on the market, but which reflects more accurately the actual capital endowment of the country. *See* United Nations, "Choice of Technology in Industrial Planning" by Jan Tinbergen, *Bulletin on Industrialization and Productivity*, No. 1 (sales number: 58.II.B.2), page 25.

[3] There are 3.8 guilders to the dollar; one guilder = $US 0.26.

[4] It is implicitly assumed that the selling price of the product is the same within the observed ranges of output, so that these do not influence profits. In applying this method of cost computation in other processes, industries or countries, these assumptions and calculations would have to be modified in the light of the costs and practices prevailing therein.

Table 2

COSTS INVOLVED BY USE OF VARIOUS METHODS AT ALTERNATIVE INTEREST RATES, WAGES AND CAPACITIES

COMBINATION OF MACHINES	FIXED COSTS (*F*)	+	VARIABLE COSTS (*V*) (*guilders*)	× *u*[a]	LEAST-COST ANNUAL OUTPUT RANGE[b] (*units*)
Costs for interest rate of 4 per cent and wage rate of 2 guilders per hour					
A I	3,783	+	0.033	× *u*	13,522 to 563,000
A II	2,875	+	0.1	× *u*	12,566 to 13,522
A III	2,381	+	0.167	× *u*	
A IV	2,017	+	0.199	× *u*	
A V	1,631	+	0.199	× *u*	0 to 12,566
B I	5,340	+	0.034	× *u*	48,230 to 545,400
B III	710	+	0.13	× *u*	0 to 48,230
Costs for interest rate of 15 per cent and wage rate of 0.05 guilder per hour					
A I	5,708	+	0.005	× *u*	200,000 to 563,000
A II	3,514	+	0.0074	× *u*	115,300 to 200,000
A III	2,899	+	0.0088	× *u*	78,000 to 115,300
A IV	2,441	+	0.0089	× *u*	66,000 to 78,000
A V	2,075	+	0.0097	× *u*	0 to 66,000
B I	7,815	+	0.004	× *u*	452,800 to 545,400
B III (1)	875	+	0.006	× *u*	0 to 64,100
(2)					64,100 to 128,200
(3)					128,200 to 192,300
(4)					192,300 to 256,400
(5)					256,400 to 320,500
(6)					320,500 to 384,600
(7)					384,600 to 448,700
(8)					448,700 to 452,800

Source: See footnote *1*.
[a] *u*=number of units produced.
[b] The lower limit of the output range corresponding to a given combination of machines is identical with the higher limit of the output range corresponding to the next combination; these points of identical outputs are the break-even points.

Table 2 presents the relevant cost data. It shows, as expected, that the values of the two elements *F* and *V* vary with the methods of production, and with the assumed differences in wages and interest rates. Where the method of production involves a relatively low degree of mechanization and therefore requires more machines to produce a given output than another method, the fixed costs rise in proportion to the number of machines in use; in this instance, the variable costs per unit are higher than in the case of a more mechanized process.

Choice among alternative methods

The costs being determined, and unit prices being assumed not to vary with output, it becomes possible to choose among the methods. Here the key concept is the "break-even point"—that is, the output point at which the total costs involved by using any method are equal, so that the producer has no preference for any of them. If output were to change, he would prefer one over the others. The break-even point may be estimated arithmetically, or represented graphically as the point of intersection of the curves corresponding to alternative methods.

The arithmetical presentation of the data in table 2 shows that in a high-wage, low-interest economy, it is economic to use the most mechanized method for each process—A I and B I—once output expands beyond a very low level. In a country with low wages and high interest rates, another pattern of machine use becomes economic: (*a*) for carrying out process A—to adopt the less mechanized methods to the limit of the machine capacity before going on to the more mechanized ones which become economic as production expands, (*b*) in the case of process B—to use up to eight single-purpose machines before using the more capital-intensive special-purpose machine.[5] In the capital-poor, labour-abundant country, use of the most capital-intensive equipment becomes economic for each of the two processes, A and B, at outputs respectively fifteen and nine times higher than in the relatively capital-rich Netherlands. Demands for

[5] It is to be noted that one of the less capital-intensive methods for this process is uneconomic at either rate.

such high outputs may not necessarily exist in under-developed countries.

CHOICE BETWEEN SINGLE-PURPOSE AND MULTI-PURPOSE MACHINES IN THE PRODUCTION OF FURNITURE

The problem envisaged here is whether a combination of multi-purpose or of single-purpose wood-working machinery produces wooden furniture at lower cost, under the assumption of constant interest rates and wages, but with varying outputs. The method of analysis is the same as that given above.

The product and the process of production

In the factory considered, fifty men are employed to produce annually 8,000 tables and 4,000 chairs.[6] The machine utilization data indicate that the annual production, based on a 2,000-hour work-year, is too small to justify the use of separate machines for producing each item. Only three machines are in use for more than 2,000 hours. Separate production lines cannot be provided for each product and, accordingly, its components are processed in succession on the same machines. All other machines are thus not used to capacity, and it would be possible to save capital if the processes which they perform were carried out by a single machine which could be reset for different operations—that is, by a multi-purpose machine.

[6] This is defined as 4,000 sets of these products—one set equals two tables and one chair.

In this factory, two possibilities of substitution exist: process I—between (*a*) a combined planing and thicknessing machine and (*b*) separate surface and thickness planers; process II—between (*a*) a universal radial cutter (*see* illustration in table 1) and (*b*) a separate circular saw, moulding machine and boring machine.

Estimate of comparative costs

Costs will be estimated by applying the formula used earlier, $C = F + V.u$. It is assumed that the total working time—that is, the sum of set-up time, manual operations time, cutting time, plus the allowance for rest and relief periods—is approximately equal for operating both single-purpose and multi-purpose machines. It is also assumed that operator skills required for both methods are approximately equal so that wage costs are the same, wage rates being identical. Thus, variable costs are assumed to be roughly equal, and the differences in cost relate only to fixed costs. With respect to depreciation, it is assumed that the somewhat more complicated, and therefore possibly more vulnerable, multi-purpose machine has a shorter life—ten years, as compared with fifteen years for the single-purpose machine.[7] The cost of space is estimated at 30 guilders per square metre, and the interest rate at 4 per cent per year. The comparable fixed costs of combining several single-purpose machines or of using one multi-purpose machine, in each process admitting of substitution, are summarized in table 3A (pro-

[7] This conservative assumption would be revised in the case of machinery of very high quality.

Table 3A

FURNITURE PRODUCTION: FIXED COSTS IN GUILDERS PER YEAR FOR SINGLE-PURPOSE AND MULTI-PURPOSE MACHINERY

MACHINE	ANNUAL CAPACITY (*number of sets*)	PURCHASE PRICE	ANNUAL DEPRECIATION $\left(\frac{price}{life}\right)$	ANNUAL INTEREST AT 4 PER CENT $\left(\frac{price}{2} \times 0.04\right)$	ANNUAL SPACE COST: *Number of square metres*	ANNUAL SPACE COST: *Cost at 30 guilders per square metre*	ANNUAL TOTAL FIXED COSTS
PROCESS I							
Single-purpose (fifteen-year life)							
Moulding machine	2,400	3,000	200	60	20		860
Dimension saw bench	60,000	3,600	240	72	30		1,212
Circular saw	8,000	2,500	167	50	20		817
Single-ended tenoner	24,000	3,500	233	70	10		603
TOTAL		12,600	840	252	80	2,400	3,492
Multi-purpose (ten-year life)							
Universal radial cutter	1,600	4,300	430	86	25	750	1,266
PROCESS II							
Single-purpose (fifteen year life)							
Thickness planer	10,000	5,000	333	100	25		1,183
Surface planer	6,670	2,000	133	40	20		773
TOTAL		7,000	466	140	45	1,350	1,956
Multi-purpose (ten-year life)							
Combined planing and thicknessing machine	4,000	5,500	550	110	30	900	1,560

Source: See footnote *1*.

Table 3B

FURNITURE PRODUCTION: ALTERNATIVE COSTS FOR OUTPUT OF 4,000 SETS

REQUIRED NUMBER OF MACHINES	TOTAL ANNUAL FIXED COSTS (*guilders*)
PROCESS I	
Single-purpose—two moulding machines and one of each of the others	4,352
Multi-purpose—three radial cutters	3,798
PROCESS II	
Single-purpose—one thickness planer and one surface planer	1,956
Multi-purpose—one combined planing and thicknessing machine	1,560

Source: See footnote *1*.

cesses I and II). This shows that the annual fixed costs are invariably lower when multi-purpose machines are used.

By dividing the working time per set of output by the total working time per year (2,000 hours) for each machine, the capacity per machine per year is obtained. Then, by dividing the total planned output (8,000 tables and 4,000 chairs, or 4,000 sets) by capacity output per machine, the number of machines required, and thus the total fixed costs for that output, can be computed. When this is done, it may be seen that, while the capacity outputs of groups of single-purpose machines are much higher than those of the multi-purpose machines, in this particular factory with an annual capacity of only 4,000 sets, fixed costs for the multi-purpose machines are lower than those for the combined single-purpose machines (table 3B). However, with respect to the planing and surfacing operations, an output of 4,000 sets is near the break-even point; beyond that output, the two single-purpose machines have lower fixed costs. In the case of one multi-purpose universal radial cutter as compared with four single-purpose machines, the break-even point corresponds to an output of 4,800 sets. At 4,000 sets, the multi-purpose cutter is clearly economic—in fact, it pays to purchase three universal radial cutters, each with a capacity of 1,600 sets, ***before*** shifting to the single-purpose machines whose individual capacities are larger, but whose total capital cost is substantially higher.[8]

Generalization of the findings

To a certain extent the degree of mechanization is related to the time required by the machines under consideration to turn out comparable outputs; normally, the length of time required is inversely proportional to the degree of mechanization.

The degree of mechanization is also allied to the price relationship between the factors of production—capital and labour, to the planned quantity of output and to the degree of uniformity desired for the product. In general, the higher the degree of industrial development in a country, the larger the demand for its industrial products; consequently, the larger the planned output of standard products, the more justified the increase in the degree of mechanization of the equipment.

In industrial countries the use of specialized machinery is, as a rule, not justified when the production process is characterized by piece-work or small lot size; the more specialized the machine, the lower its production time per unit of output but the higher the time and skill involved for setting it. High setting costs are justified only if the lot size is large.

In under-developed countries, the market for industrial products, particularly those of standard types, is small and so, consequently, is the lot size of production. Non-specialized equipment—single-purpose or multi-purpose—is, as a rule, required.

In the second part of this analysis, interest rates and wages have not been varied to allow for differences in factor supply prices between countries.[9] With higher interest rates, such as prevail in capital-poor countries, the difference in the annual capital costs corresponding to the use of the alternative types of machines would be greater. At the same time, even if allowance is made for differences in skill, the absolute difference in wages corresponding to the use of the two techniques would not be great if the labour time involved were equal for both types of machine and if wages were low. The labour time involved by the use of a multi-purpose machine may, however, be higher. There may be a lack of workers of the requisite skill to operate multi-purpose machines and, in this case, the use of single-purpose machines would be preferable. Barring the latter contingency, higher interest rates would reinforce the advantage of the multi-purpose machine at low levels of output. Thus, in under-developed countries the use of multi-purpose machinery in the lower output ranges, which prevail in small establishments, appears to present definite economic advantages. In the case of goods produced for a small market, the use of multi-purpose machinery would permit lower-cost output than the use of single-purpose machinery. With multi-purpose equipment, the size of plant can be reduced,[10] and production of small quantities may prove economic.

[8] It is again assumed that prices do not vary with output. With an interest rate of 15 per cent—other factors being equal—the break-even point corresponds to an output of 6,400 sets. It then pays to purchase four universal radial cutters before shifting to the single-purpose machines.

[9] *See*, however, footnote *8*.

[10] *See* United Nations, "Problems of Size of Plant in Industry in Under-developed Countries", ***Bulletin on Industrialization and*** *Productivity*, No. 2 (sales number: 59.II.B.1), page 21.

It may also be mentioned that insurance costs of multi-purpose machines are usually lower than those of single-purpose ones. When equipment consists of the latter, some machines may be seldom used, although they have to be available so as to maintain flexibility in the utilization of production capacity. When multi-purpose machines are used, flexibility is achieved by utilizing more efficiently a smaller number of machines, and lower costs of production are obtained. Also, when more than one multi-purpose machine of the same type is installed, production will not be interrupted because of failure of one machine—only the capacity of production will be reduced; on the other hand, when the production line consists of a series of single-purpose machines, each performing an individual operation, failure of one machine breaks the cycle of production. Multi-purpose machines do not necessarily require more diversified operator skills than single-purpose ones; workers can be specialized by operations, as in the latter case, provided their work-time spent on other tasks remains productive.

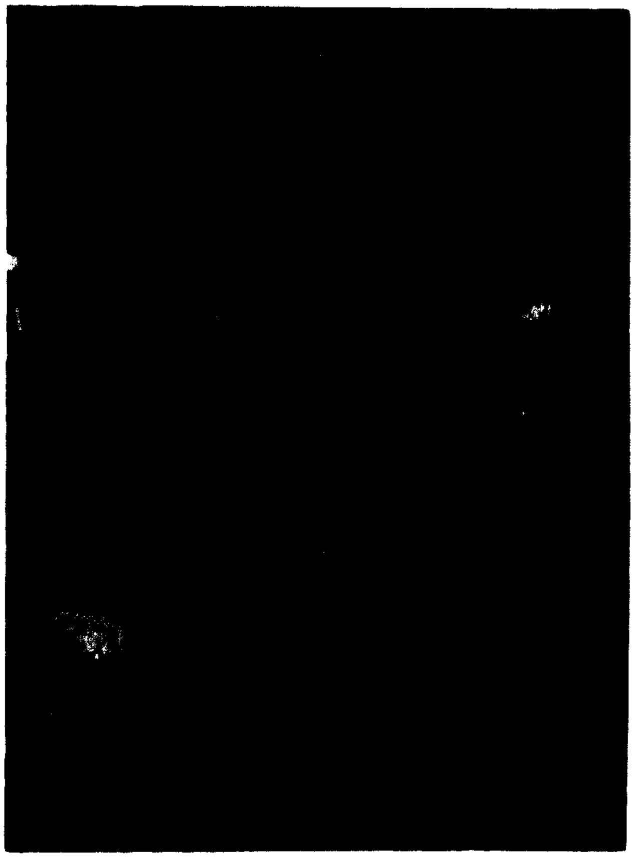
CONCLUSION

This study of costs of alternative processes in the wood-working industry under conditions of variable outputs and factor prices shows that at high interest rates and low wages, with relatively low output, a process of low capital intensity is likely to be economic, and that, under the same conditions, one multi-purpose machine is likely to be more economic than a combination of single-purpose machines.

If these conclusions were to prove to be true for industries other than wood-working, they would be of great significance to those under-developed countries which are characterized not only by a relatively high level of interest rates and a relatively low level of wages, but also by a restricted market for certain products and, consequently, by limited possibilities of rapidly expanding the production of such goods. By encouraging the development of industries in which less capital-intensive technologies may be used and by giving preference in those industries to the technologies in which alternatives are possible, these under-developed countries may be able to support a wider variety of industries than would otherwise be the case. As mentioned in an earlier article on this problem,[11] it is desirable, in order to confirm these findings, that economists and engineers, both in developed and under-developed countries, engage in further research along these lines to work out realistic cost functions for different industrial processes with proper assumptions and accurate measurements of all the variables involved. This will permit the selection of those technologies most suitable for countries where factor supplies, prices and outputs differ markedly from those prevailing in the developed economies.

[11] United Nations, "Choice of Technology in Industrial Planning", by Jan Tinbergen, *Bulletin on Industrialization and Productivity*, No. 1.

Sharpening saws in a wood-working shop in Ceylon



Co-operative carpentry workshop at Bandowoso, Indonesia

Use of Welding in Machine-building

BY EVGENY P. UNKSOV

ADVANCED WELDING TECHNIQUES are a major factor in the development of present-day machinery manufacture. Without the development of welding techniques, it would hardly have been possible to produce a whole range of items such as modern motor-car bodies, large high-pressure vessels, complex components of high-speed aircraft and many others.

Welding provides the manufacturer with an effective means of reducing weights and labour input and speeding up production processes in the manufacture of a very wide range of engineering products. It enables products to be fashioned in the most rational shapes, while ensuring the requisite strength and hardness, with minimum consumption of metal and the most effective use of materials; costly materials can be localized in welded composite units in such a way that their valuable properties are utilized to the full.

Extensive use of welding is of considerable importance in the establishment of new machine-building plants and the enlargement of existing ones where technological and material resources are limited, as in the industrially under-developed countries. Under such conditions, welding can and should be given wide application in the development of machine-building for transport and agriculture, of tool-making for industry, and so on.

PROFESSOR UNKSOV, *Director of the Central Scientific Research Institute of Technology and Machine-Building of Moscow, was a member of the Advisory Committee on the Work Programme on Industrialization which met at United Nations Headquarters in February 1959.*

Emphasis should also be placed on the economic importance of adopting the modern technique of hard-facing as a means of rebuilding worn components (steel mill rolls, wheel tires, and the like) and of increasing the durability and efficiency of new machinery and tools, such as crusher jaws or steam-pipe fittings.

Moreover, extensive use of hard-facing helps to reduce the consumption of costly steel alloys—for instance, in special cutting tools and water turbine blades—an important economic consideration in industrially under-developed countries.

Welding has a special part to play in the manufacture of large heavy engineering components. Much valuable experience has been acquired in recent years in this field in the Union of Soviet Socialist Republics. The replacement of massive castings and forgings by welded castings, welded forgings and composite sections (combinations of simple castings, forgings and sheet components) makes it possible to manufacture heavy pieces of virtually any shape or weight, without overloading the foundry or press-forge shops equipped with special-purpose casting and forging plant.

The successful solution of this problem was aided by the development and wide introduction by Soviet scientists, in collaboration with leading engineering plants, of such essentially novel and highly productive techniques and processes as electro-slag welding, developed at the E. O. Paton Electro-Welding Institute, and carbon dioxide shielded welding, developed at the Central Scientific Research Institute of Technology and Machine-Building.

Soviet experience in welding heavy components, as described below, may prove useful in industrially underdeveloped countries, since this method permits the manufacture of modern machinery with the minimum expenditure of time and resources and dispenses with the need for building large billet, foundry and forge shops.

WELDED COMPONENTS IN HEAVY ENGINEERING

The technical and economic effects of the use of massive welded components in power engineering have been manifold. The first large-scale replacement of massive castings by welded structures took place in boiler-making. Formerly, the drums of high-pressure boilers, with a capacity of 170 to 230 tons of steam per hour at a pressure of 110 atmospheres, were made from two forged halves with a nominal wall thickness of 90 to 100 millimetres, joined by a single annular butt-weld. For over ten years these drums have been made from welded plate. In practice, two techniques are employed, whereby the boiler drum is made from (*a*) separate rolled shell sections and drop-forged crowns, or (*b*) from drop-forged, trough-shaped sections welded together and to the crowns.

The change from forged to welded drums has taken some of the burden off heavy presses, reduced the weight of the drums by 15 to 20 per cent, since allowances could be drastically reduced, and lowered production costs.

A further radical technological improvement in the manufacture of boiler drums was the introduction of electro-slag welding, which considerably simplified the preparation of components for welding—eliminating the need for machined edges—speeded up the welding process itself and reduced its cost. As a result, the manufacture of a welded drum required 21 to 36 per cent less labour, 21 to 41 per cent less production time, 5 per cent of the flux, 40 per cent less power and 20 per cent less electrode wire, while output per unit of production area rose by more than 50 per cent.

It is worth mentioning that the successful application of electro-slag welding in boiler-making led to its extensive use in other branches of machine-building.

Welded castings, forgings and composite sections are now widely employed in all branches of the construction of power engineering equipment. The construction of the stators of high-capacity water turbines for the largest Soviet hydroelectric power stations is a typical example of effective application of welded castings in machine-building.

A welded water-turbine stator consists of an upper and lower ring, linked by supporting columns of varying cross-section (figure 1). For convenience of transportation and installation, the stator is divided circumferentially into segments which are subsequently bolted together. A stator segment is a very heavy, complex and bulky component which, when cast in one piece, requires moulds which must be manually constructed in large moulding pits. A further breakdown of the segment into ring-sections and columns results in a few simple castings which can be made in machine-produced moulds.

The change-over to combined welding and casting in stator construction has cut the length of the production process by more than half and led to a considerable improvement in the rate of utilization of the production area in mould-casting shops. In this instance, too, despite the complicated curved shape of the sections to be joined, the adoption of electro-slag welding had a very marked effect on production: labour input was reduced by more than 30 per cent and production time was further curtailed by almost 40 per cent.

Welded shafts for high-capacity water turbines have proved to possess great advantages and are now extensively used in turbine construction. Until recently, such turbine shafts were forged in one piece from ingots weighing up to 200 tons.

Two methods of construction of welded shafts have been developed: in one, the stem is forged from a hollow casting; in the other, the stem is made from two halves of shaped heavy plate welded together; in both cases cast flanges are welded onto the stem. The longitudinal and circular seams of the shaft, with a wall thickness of 150 to 200 millimetres, are welded by the electro slag method.

The use of welded construction in the manufacture of a shaft with a forged stem 1,500 millimetres in diameter for the Stalingrad Hydroelectric Power Station resulted in:

(*a*) Lower consumption of liquid steel per shaft (94 tons instead of 160 tons) and a higher metal utilization factor (40 per cent instead of 26 per cent);

(*b*) Considerably smaller allowances for machining (the gross cast weight of the shaft was reduced from 98 tons to 66 tons) with a consequent reduction in labour input (by more than half);

(*c*) A substantial reduction in the cost of the shaft (about 30 per cent).

Moreover, the forging time on the heavy forging press was reduced to a fraction of its former duration, while in the case of shafts with a welded stem the use of the press was dispensed with altogether. It should be mentioned that, in the production of shafts with a welded stem, there is no particular difficulty in obtaining the requisite degree of precision, either at the blank stage or after welding. Economically, the two methods of manufacturing welded shafts are virtually of equal value.

Large welded water-turbine shafts are superior to those forged in one piece, in so far as the mechanical properties of all the parts of the welded shaft meet all the technological requirements—especially in the case of the use of low-alloy steels, in particular 20GS steel, containing about 0.2 per cent carbon, 0.6 to 0.8 per cent silicon and 1.0 to 1.3 per cent manganese—whereas, even with modern heavy forging equipment, it is often not possible to apply sufficient forging power for the metal in the flanges of massive forgings to acquire the optimum characteristics of ductility and impact resistance.

In the Soviet Union, as in some other countries, research has lately concentrated on the development of a rational method of production by welding rotors for radial-axial turbines. Besides simplifying the casting process and taking some of the load off the large steel foundry units, the change to welded rotors permits economical combinations of alloy and structural steels whereby costly materials are used only where resistance to corrosion and erosion is really essential. The manufacture of welded rotors for large steam and gas turbines is one example of the very advantageous application of welding in power engineering.

Thus, the use of welded construction in the manufacture of rotors for the low-pressure cylinders of 150-megawatt turbines (figure 2) not only reduced the casting weight from 38 to 28 tons and the consumption of liquid steel by 40 per cent, but reduced considerably the load of the special-purpose forging equipment and raised the quality of the rotor's component elements to a level which is practically unattainable in a single-piece forging of 76 tons. By precision welding of the individual parts which had undergone high precision machining, rotors exceeding 1,600 millimetres in diameter can be produced with a play of no more than 0.5 millimetre.

Rotors of austenitic steels for powerful gas turbines with high operating temperatures are practically impossible to forge in one piece, owing to the difficulties involved in attaining heavy high-grade castings from heat-proof materials.

It is essential that the welded joints of rotors should have high resistance under conditions of high operating temperatures and stresses. The problem has been solved in the case of some austenitic and pearlite steels, for which special electrodes and appropriate welding and heat treatment methods have been developed.

It is common knowledge that welding is extensively used in constructing presses. The adoption of electro-slag welding in the construction of the frame and other components from heavy-rolled plates is particularly advantageous, as results have shown in the manufacture of upper frames for 4,000-ton and 6,300-ton crankshaft forging and stamping presses. The disposition of the welded seams in the frame of a 4,000-ton press is shown in figure 3. These frames were constructed from plates up to 150 millimetres thick and separate crosshead castings and horizontal pipe forgings. Most of the seams were produced by electro-slag welding. The change-over to welded construction eliminated the need for massive castings weighing 114 and 180 tons for the 4,000-ton and 6,300-ton presses respectively, resulted in a considerable saving in labour, speeded up the production process and reduced the cost and weight of the products (table 1).

Welding is a very useful means of extending the size of rolled plate. Here too, the best results are obtained with electro-slag welding, in which distortion is minimal and relatively easily controlled. Examples of plate welding are to be found in hydraulic press components and electric generator discs up to 4,800 millimetres in diameter.

In many instances where the machine-building industry lacks a sufficiently developed industrial supply basis, the use of welded castings might be profitably indicated, not only to replace massive one-piece cast special design items, but also items of medium weight (10 to 50 tons). Although this may not always result in appreciable savings, the use of welding is justified by the fact that it opens new possibilities for existing installations to produce necessary machinery with their own resources. A cast and welded bed plate for a rolling-mill stand is shown in figure 4.

The foregoing examples of welded castings, welded forgings and welded composite constructions show that the solution of complex and sometimes specialized production problems in machine-building is greatly simplified by the use of welding.

By means of the modern welding methods described below, it is possible to carry out quickly and reliably, with comparatively simple equipment, the most complicated operations encountered in the manufacture of basic machine sections.

SOME PROBLEMS IN WELDING LARGE STRUCTURAL PARTS

Since the present article is mainly concerned with welded structures in heavy machine-building, the production of which presents a number of special difficulties, the description of welding methods will be confined to those that have found wide application in the production of heavy, thick-walled parts.

At the present time, the most important method used in the production of thick-gauge weldments is undoubtedly the electro-slag method, which in Soviet practice has largely displaced the less efficient method of multiple-pass automatic flux-shielded welding, previously used for that purpose.

The various techniques of electro-slag welding developed by the E. O. Paton Institute, assisted by a number of plants, make it possible to execute not only straight

Figure 1

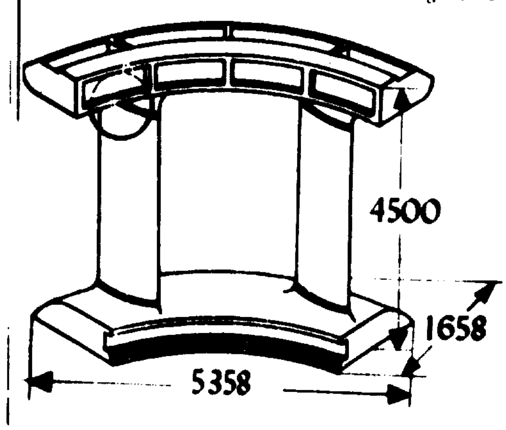
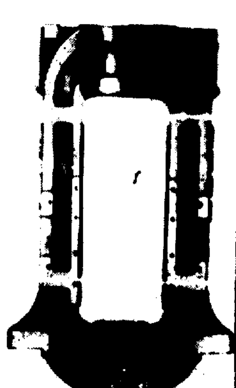


Figure 2

Figure 3

Figure 4



and circular welds but also curved, variable-section, double curvature, inclined and other welds.

Three types of electro-slag welding are now most widely used in industry: the wire electrode method, the plate electrode method and the fusible sheath method.

In the wire electrode method (figures 5A and 5B), the pieces to be welded (1 and 2) are arranged vertically with a clearance of 20 to 32 millimetres. The clearance is bounded on either side by copper slide blocks (3 and 4) which are kept thoroughly cooled by water running in through tube (5) and out through tube (6). In the space formed by the edges of the workpieces and the slide blocks an arc is first struck between the electrode (7) and the backing strip at the starting point of the joint. Granulated flux is poured into the blazing arc zone and as the flux melts it gradually forms a slag pool (8) over the pool of fused metal (9). At a given depth in the slag pool, the arc process changes into a slag process, in which the melting of the electrode wire and the fusing of the basic metal is processed by the heat given off by the electric current as it passes through the molten slag, which has a high resistivity. The temperature of the slag pool (1600° to 1800° C) is far higher than the melting point of the steel being welded. The weld wire is fed continuously into the welding zone by drive rolls (10) through a holder (11).

As the electrode and basic metal melt, the level of the metal and slag pools rises and the welding apparatus, complete with feed rolls, holder and slide blocks, is raised accordingly. In the lower portion of the metal pool, the cooling metal crystallizes and the welded joint is formed (12).

When steel up to 50 to 60 millimetres thick is being welded, the electrode need not move sideways. For steels of greater thickness (up to 150 millimetres), the electrode is made to move back and forth in order to ensure uniform heating and penetration over the entire width of the joint. For even thicker pieces, the number of electrodes is increased. With three electrodes it is possible to weld metal up to 450 millimetres thick. The source of current in electro-slag welding is a single-phase or three-phase transformer, preferably with constant-voltage characteristics.

When welding relatively short joints in thick metal, effective use can be made of plate electrodes. Plates 10 to 12 millimetres thick are slowly lowered into the welding zone as they melt. Otherwise, the process is essentially the same as the wire electrode method.

Table I

COMPARATIVE PRODUCTION FIGURES FOR WELDED AND CAST FRAMES OF MECHANICAL PRESSES

PRODUCTION FACTOR	PERCENTAGE REDUCTION OWING TO THE CHANGE FROM CAST TO WELDED FRAME	
	4,000-ton press	*6,300-ton press*
Labour	46	43
Duration of process	45	40
Cost	38	39
Weight	23.5	26

The advantages of welding with plate electrodes are the very simple construction of the welding apparatus — it is not necessary, as just mentioned, to have sideways moving electrodes or complicated holders—and the possibility of replacing the water-cooled slide blocks with stationary side stripping.

The length of the plates should be approximately three times the length of the joint being welded.

Particularly important technological possibilities are offered where very thick material is to be welded and where curved and variable-section joints are involved by the use of fusible sheaths (figure 6). Into the clearance between the workpieces (1 and 2), bounded by stationary side strips (3 and 4), is inserted a steel block (the fusible sheath) (5) shaped in conformity with the profile of the workpiece.

Fused into the centre, or down the sides, of the block is a steel tube (6) through which an electrode wire (7) passes into the welding zone. During the welding operation, the sheath is stationary but its lower end, submerged in the slag pool, gradually melts away. The sheath orients the electrode wire in the proper direction and thus ensures uniform penetration throughout the joint. When welding steel of considerable thickness, in some cases of up to 1,000 millimetres or more, several such fusible sheaths are used in parallel, each of them directing one or two electrode wires into the welding zone.

FIG. 1. *Cast and welded segment of a water-turbine stator*

FIG. 2. *Welded rotor for the low-pressure cylinder of a 150-megawatt steam turbine*

FIG. 3. *Pattern of electro-slag welded joints in the frame of a 4,000-ton crankshaft forging press*

FIG. 4. *A cast and welded bed plate for a rolling-mill stand*

FIG. 5A and B. *Diagram of electro-slag welding with a wire electrode*

FIG. 6. *Diagram of electro-slag welding with a fusible sheath*

Figure 5A

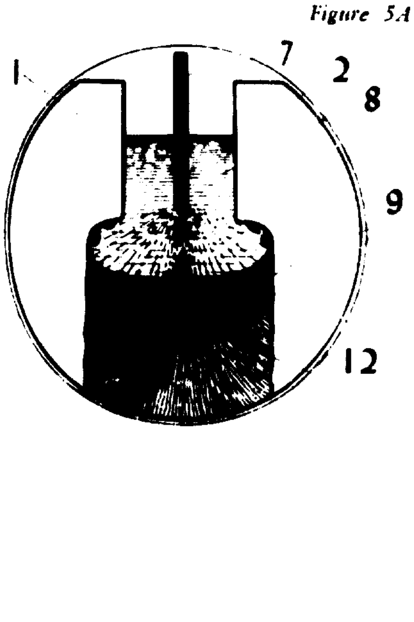


Figure 5B

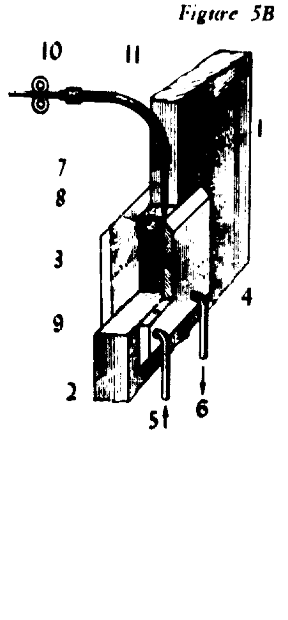


Figure 6

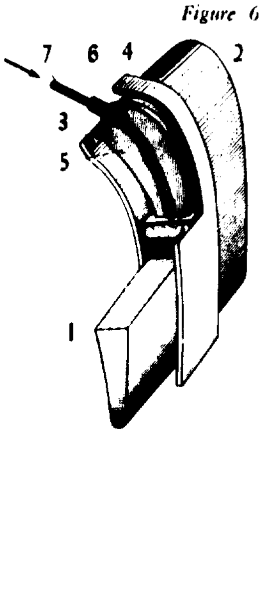


Figure 7

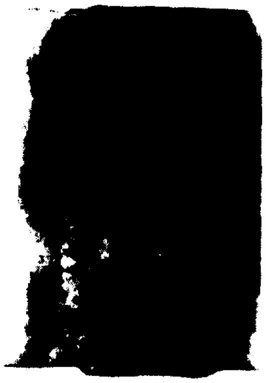


Figure 8

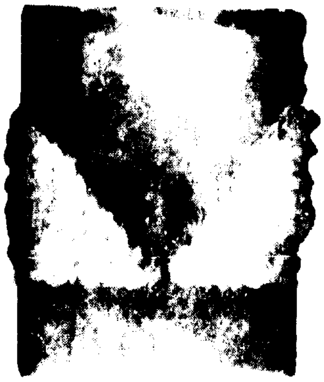


Figure 9

FIG. 7. *Macro-structure of a weld made by the electro-slag method.*

FIG. 8. *Macro-structure of a weld in steel 100 millimetres thick, made with carbon dioxide shielding*

FIG. 9. *Macro-structure of a weld in heat-resisting pearlite steel.*

The chief advantages of electro-slag welding are: the opportunity that it offers for welding thick steel in a single pass; the high efficiency of the process and excellent quality of the joint; the simple preparation of surfaces without special dressing operations; and the relatively low expenditure of power, electrode wire and flux.

Electro-slag welding of common carbon steels employs a weld wire with a somewhat higher manganese content—up to 1.5 per cent—and fused fluxes used in automatic welding (for example, FTs-7).

Various types of stationary and mobile electro-slag welders have been developed. In particular, the A-372r automatic welders are widely used for longitudinal and circular joints. They will work with either wire or plate electrodes.

In the welding of press frame components and other structural parts of complex shapes, successful use is being made of mobile automatic magnet-operated moving heads, which are moved along the vertical joint by alternative advancing magnets.

The electro-slag method produces high-quality welds. The typical macro-structure of one such non-heat-treated weld is shown in figure 7. Despite its coarse grain structure the weld metal in this condition is strong and ductile (table 2).

A considerable coarsening of grain occurs in the base metal along the line of fusion, which sometimes causes a lowering of impact resistance. Consequently, welds made by the electro-slag process are usually normalized and are as a rule as strong as the surrounding steel. Structural steels that do not require normalizing after electro-slag welding have been developed and are being put into use.

Studies of the endurance limit of welds executed by the electro-slag method in boiler steel up to 300 millimetres thick, in tests of large cross-section samples (round samples up to 200 millimetres in diameter and rectangular samples 200 millimetres square in cross-section), have shown that the fatigue strength of the as-welded joints, that is, joints that have not undergone heat treatment, with the weld reinforcement removed, approximates that of the base metal.

Aside from electro-slag welding, steel parts of considerable thickness and ordinary welded parts of small and medium-gauge metal can also be produced by automatic or semi-automatic welding with carbon dioxide shielding. This method is warranted in executing intricate profile welds, horizontal welds on vertical surfaces and inclined welds. In principle, the method can be used to weld joints in any position.

What essentially takes place in the carbon dioxide process is that the air is forced out of the welding zone by carbon dioxide, while the arc-fused metal is kept from oxidizing and the necessary weld quality is ensured by the use of wires with an increased deoxidizer content. Inexpensive deoxidizers normally used in steel—silicon and manganese—are applied.

Welding in a carbon dioxide atmosphere is considerably (two or three times) more efficient than manual welding, while at the same time it enables production costs to be appreciably reduced.

Table 2

MECHANICAL PROPERTIES OF ELECTRO-SLAG WELD METAL IN BOILER STEEL[a] USING A LOW-CARBON WIRE[b] AND FTs-7 FLUX

HEAT TREATMENT	TENSILE STRENGTH	YIELD POINT	RELATIVE ELONGATION	RELATIVE CONTRACTION	IMPACT RESISTANCE (*Kilogram-metres per square centimetre*)
	(*Kilogrammes per square millimetre*)		(*Per cent*)		
None	45.4	27.2	28.7	61.7	14.1
Normalized and tempered	43.0	25.0	32.3	63.3	14.6

[a] 0.18 per cent carbon; 0.29 per cent silicon; 0.8 per cent manganese.
[b] 0.09 per cent carbon; 0.04 per cent silicon; 0.90 per cent manganese.

It should be pointed out that gas-shielded welding is at present the only mechanized method of executing horizontal welds on very thick metal.

Horizontal welds in boiler steel up to zero millimetres thick, executed with silicon-manganese wire 1.6 to 2 millimetres in diameter and with current of 300 to 350 amperes, have full penetration (figure 8), high density and excellent mechanical characteristics (table 3).

The high purity of the deposited metal in terms of non-metallic occlusions is worth mentioning. The weld metal contains fewer occlusions in the carbon dioxide process than when flux shielding and electrodes with acid and rutile coating are used. The fact that the metal is well deoxidized and free from non-metallic occlusions is demonstrated hy its low limit of low-temperature brittleness. The weld metal still has a relatively high impact resistance at temperatures as low as −50 C, while the base metal becomes noticeably brittle even at −20 C (chart 1).

In cases where the production volume of heavy, thick-steel structural parts is limited, and insufficient use would be made of special equipment for electro-slag welding, welding in carbon dioxide is highly advisable, since this method employs inexpensive and universal equipment which can be used to perform practically any welding job, on thick or thin metal.

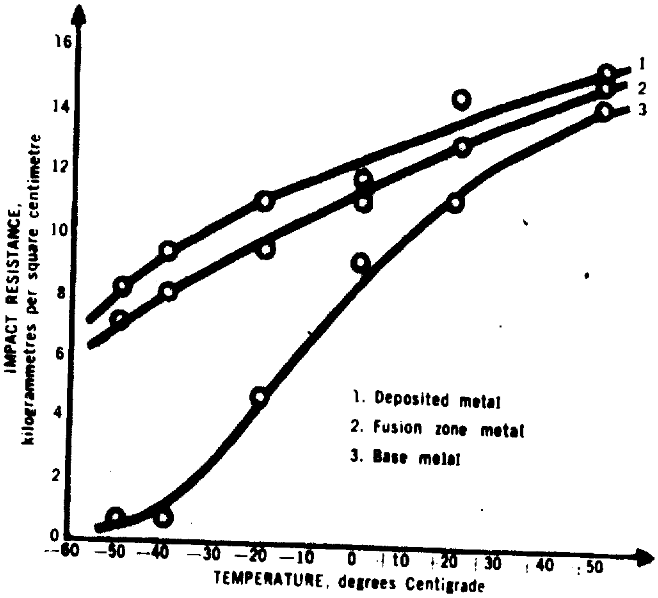
One possibility deserving notice is that of making relatively simple changes in automatic and semi-automatic flux-shield welding units so that they can also be used for carbon dioxide shielded welding. This reduces the number of the welding machines required, a matter of particular importance in equipping small undertakings which turn out a wide variety of welded objects.

Aside from the wide use of mechanized welding methods in the production of thick-steel structural parts, manual arc welding is still used in some cases, especially in production of precision weldments, where the concentrated heat inherent in the mechanized processes is undesirable, in welding certain high-alloy steels, and in other applications.

The present-day technical level of manual arc welding and the availability of high-quality electrodes make it possible to weld heavy parts made of practically any grade of steel (figure 9). For instance, when heat-resisting chromium-molybdenum-vanadium steel 20KhMF—used in power installations where it is subjected to temperatures up to 540 C—is welded with TsL-20 electrodes, the resultant weld has full plate strength both at normal temperature (table 4) and at the working temperature.

Chart 1

CHANGES IN THE IMPACT RESISTANCE OF THE WELD METAL, FUSION-ZONE METAL AND BASE METAL IN THE ±50°C TEMPERATURE RANGE, IN A WELD MADE WITH CARBON DIOXIDE SHIELDING



The long-term rupture strength found in a simulated 100,000-hour test at 540 C is not less than 10 kilogrammes per square millimetre for the 20KhMF steel and the metal deposited by the TsL-20 electrodes.

Modern methods of ultrasonic detection of flaws using portable and relatively inexpensive equipment have made it possible to control the quality of welds in steel of considerable thickness with a high degree of reliability. This is particularly important inasmuch as the older X-ray and gamma-ray testing processes quickly lose their sensitivity as the thickness of the steel increases. The existence of the new testing techniques has made it easier to generalize the use of welding in key structural parts.

* * *

Even the limited number of examples cited is sufficient to demonstrate the technical advantages and economic efficiency of different welding techniques in heavy ma-

Table 3

AVERAGE MECHANICAL PROPERTIES OF WELDS MADE WITH CARBON DIOXIDE SHIELDING IN STEEL 100 MILLIMETRES THICK,[a] AFTER TEMPERING AT 650°C

SAMPLE	TENSILE STRENGTH (Kilogrammes per square millimetre)	YIELD POINT (Kilogrammes per square millimetre)	RELATIVE ELONGATION (Per cent)	RELATIVE CONTRACTION (Per cent)	IMPACT RESISTANCE (Kilogrammetres per square centimetre)
Base metal	44.3	22.1	34.8	63.5	10.8
Weld metal	51.0	35.0	29.1	70.3	16.9
Fusion zone metal	48.6	25.7	22.0	57.4	11.5

[a] Composition of the steel: 0.25 per cent carbon; 0.53 per cent silicon; 0.73 per cent manganese.

Table 4

MECHANICAL PROPERTIES OF 20KhMF STEEL[a] AND THE WELD METAL AT NORMAL TEMPERATURE

SAMPLE	TENSILE STRENGTH	YIELD POINT	RELATIVE ELONGATION	RELATIVE CONTRACTION	IMPACT RESISTANCE (*Kilogram metres per square centimetre*)
	(*Kilogrammes per square millimetre*)		(*Per cent*)		
Base metal (not less than)	50	32	16	35	5.5
Weld metal (not less than)	55	45	14	45	7.0

[a] Composition of the steel: 0.20 per cent carbon; 0.28 per cent silicon, 0.5 per cent manganese; 1.1 per cent chromium; 0.6 per cent molybdenum; 0.25 per cent vanadium.

chine-building. The advantages of replacing riveted with welded structures are also well known. The wide use of welding in machine-building has special significance under conditions prevailing in industrially under-developed countries, since it would enable them, in a comparatively short time and with relatively small capital investments, to establish new or convert existing machine-building installations according to modern technical standards.

At the present time everything—technology, equipment, materials and testing methods—is available to solve virtually any production problem in welding engineering. The Soviet Union's extensive experience in that field could be used for that purpose.

Bibliography

(1) DAVYDENKO, I. D. "Automation of welding processes at the Taganrog boiler factory", *Svarochnoe proizvodstvo (Welding Production)*, No. 4, 1958.

(2) LYUBAVSKY, K. V. and YAROVINSKY, L. M., "Arc welding in machinery manufacture", *Svarochnoe proizvodstvo*, No. 11, 1957.

(3) The E. O. Paton Electro-Welding Institute of the USSR Academy of Sciences, *Handbook on Electro-slag Welding*, Mashgiz, 1956.

(4) KUDRYAVTSEV, I. V., NAUMCHENKOV, N. E. and SAVVINA, N. M., "The fatigue strength of welds in thick-section pieces, done by the electro-slag method", *Svarochnoe proizvodstvo*, No. 4, 1958.

(5) GELMAN, A. S., MELBARD, S. N., SINADSKY, S. E. and CHESHEV, P. I., "Electro-slag welding of hydraulic-turbine shafts with welded stems", *Svarochnoe proizvodstvo*, No. 9, 1958.

(6) NOVOZHILOV, N. M. and SUSLOV, V. N., *Welding with Fusible Electrodes in Carbon Dioxide*, Mashgiz, 1958.

(7) PATON, B. E., "Automatic flux-shielded welding", *Svarochnoe proizvodstvo*, No. 11, 1957.

(8) *Production Experience in Welding Engineering*, Collection No. 1, edited by I. D. Davydenko, Mashgiz, 1956.

(9) American Welding Society, "Electroslag Welding—A New Process for Heavy Fabrication", *Welding Journal* (New York), February 1960, pages 111 to 117.

Welding parts of a ship in a Japanese shipyard

Financing of Small-scale Industries in Under-developed Countries

Prepared by the Industrial Development Branch of the United Nations Department of Economic and Social Affairs

Among the many problems confronting small-scale industries in under-developed countries, few are as difficult to solve as those of financing. To the difficulties arising from limited capital resources and the well-known inadequate institutional set-up, which affect all enterprises in these countries, are added various obstacles due to the very smallness of their size. These are reviewed in the first part of this article in order to provide a background to the discussion of the solutions attempted in different countries presented in the second part.

Since, in this instance, size is the major factor, some definition of "small-scale industry" is called for. The term itself lacks precision and its definition varies from country to country—at times, from agency to agency in the same country—according to the amount or type of capital or assets of the industry, the number of its employees, the volume or value of its output, or any combination of these criteria. In practice, there is little need for a commonly agreed definition, as the choice or combination of criteria would vary with the end pursued; thus, a definition of small-scale industry for fiscal purposes—for example, to determine tax rates, exemptions or abatements—need not be identical with that establishing eligibility for membership in an organization, such as a co-operative association.

For the purposes of this article, small-scale industry will not include handicraft and cottage industries, whose problems are unlike those of small factory enterprises, since their operations are not entirely motivated by purely economic considerations. A small-scale manufacturing enterprise will be considered as one whose operations are guided by cost and return calculations, having some mechanization and some need for manufacturing equipment. On the other hand, its managerial functions are only slightly specialized and it is integrated in large degree with the local community. Such characteristics are typically found in enterprises with fewer than one hundred workers—a defining line which may conveniently serve the purposes of this study.

It is recognized that a number of industries are particularly well adapted to small-scale operation; in some activities, both small and large firms may be economic, but in certain other fields, small-scale operation may be uneconomic and inefficient. In many countries, Governments consider it desirable, for various reasons, to encourage the establishment and growth of small-scale industrial enterprises; these reasons may be economic, social or political. In the following discussion, the problem of financing will be examined regardless of whether the type of small-scale industry to be assisted is appropriate or economic for the given country or not, since the question of appropriateness raises a different set of problems, which are beyond the scope of the present study. It will be assumed that government policy provides for such assistance.

Sewing finished buttons to carton holders in a small button factory in Pakistan

FINANCING PROBLEMS OF SMALL INDUSTRY

There are important differences in the nature of the problem of financing small industry as between developed and under-developed countries. In countries with a well-established and developed industrial and financial structure, these problems are largely marginal from the point of view of the economy as a whole. In less developed countries with little or no industry, the problem of creating new industrial enterprises is fundamental. More often than not, these industries will be of small or medium size, which is one of the main reasons justifying government action on their behalf.

Another difference is that the risk involved for lending institutions in transactions with new enterprises is much higher in the less developed countries. Such elements as lack of trained enterpreneurship, absence of an industrial environment and of proper cost accounting procedures, inadequacy of the economic and social overhead, greater reluctance on the part of consumers to try new products and lack of proper marketing preparation make it difficult to foresee the success of any new industrial undertaking, particularly of a small one. In a developed country, this problem is less serious and its solution is facilitated by the existence of appropriate servicing institutions and the widespread use of such techniques as market research, credit rating and insurance.

There also exists in the developed countries a network of financing institutions of private, quasi-public or public nature, equipped to provide small business with credit under conditions and on terms which are, on the whole, not much different from those extended to the larger enterprises. Such institutional bank credit is seldom available to small business in the under-developed countries. When such credit is available, it is likely to be more onerous, beset with considerable difficulties and, in the case of government institutions, burdened with the cost of cumbersome and inefficient administrative machinery. Commercial banks, in particular, are little interested in the small borrower and, when making loans to small business, insist upon provision of physical assets as collateral, in the form of plant, equipment or stocks of readily salable merchandise, in addition to a guarantee by an individual whose financial responsibility is well known. It often happens that the small manufacturer owns neither his plant nor his equipment; if he starts a new firm, the salability of his product is unknown and he may have difficulty in finding a satisfactory guarantor. He may, from lack of experience or ignorance, fail to keep proper financial records.

Several surveys of small-scale industry were made in India covering the three largest cities.[1] These show that "own capital"—owner's equity plus funds invested by partners—is by far the most important source of capital, only a small proportion being financed by banking institutions. The share of own capital in the total ranges from a low of 50 per cent—in the largest group of firms covered by a survey of the engineering industry in Bombay—to a maximum of 95 per cent—in a group of small-scale engineering enterprises in Calcutta. The average share of own capital is, according to these surveys, from 75 to 80 per cent. The commercial banks finance, on the average, about 5 per cent of total liabilities, and from 5 to 20 per cent of funds borrowed by small enterprises. Comparable orders of magnitude were obtained in many surveys of smaller Indian cities. Even in the case of the larger firms within the small-scale group, the share of banking institutions in total borrowed funds is of far less importance than that of relatives or friends, middlemen, indigenous bankers and money-lenders. On the other hand, banks are usually willing to meet short-term requirements of older, well-established small firms.

[1] P. N. Dhar, *Small-scale Industries in Delhi* (New Delhi, 1957); Bureau of Industrial Statistics, *Problems of Small Engineering Industries* (Calcutta, 1953); D. T. Lakdawala and B. V. Mehta, "Small and Medium-scale Engineering Factories in Bombay City", *Journal of the University of Bombay*, January 1958; industrial and regional surveys by the National Development Commissioner for Small Industries (New Delhi) (mimeographed), from 1956 to 1958.

In 1958, the Reserve Bank of India made a sample survey of advances by commercial banks to small and medium-sized industrial and trading enterprises, which showed that such enterprises received about 30 per cent of the total credit—excluding personal credit—extended by scheduled banks, and 51 per cent of that extended by the non-scheduled banks.[2] While approximately 50 per cent of all bank credit to all borrowers, large and small, was extended for industrial purposes, small and medium-sized industrial enterprises received 18 per cent of the total credit from these two sources.[3] Such enterprises received 5 to 6 per cent of total bank credit for all purposes and about 12 per cent of that extended for industrial uses.

These findings corroborate the figures obtained in an earlier survey,[4] for the period 1950 to 1952, of finance, by sources of credit, received by incorporated industrial firms, both large and small. The rate of interest paid by the small firms was significantly higher than that paid by the larger enterprises. The survey showed that the small firms obtained 63 per cent of their credit from "trade" and "miscellaneous" sources, that is, from family, friends and money-lenders; the corresponding figure for the larger concerns was 24 per cent.

A few comparable figures may also be quoted for Japan. In that country a recent survey showed that the smallest enterprises—those with assets of less than 2 million yen, that is, $US 5,500—obtained a major proportion of their financing—46 per cent—in the form of book credit, principally from suppliers and purchasers. Larger enterprises—with assets of over 10 million yen—received only 16 per cent of their credit from this source.[5] This situation reflects, however, to a large extent, the particular structure of Japanese small-scale industry, the operation of which is closely integrated with that of large-scale industrial concerns.

Small-scale industrial enterprise in under-developed countries thus has to rely heavily—as far as credit is concerned—on the extremely onerous sources of supply provided by money-lenders and traders. The latter who, at the same time, supply the small industrial plants with raw materials or take over the finished products, may not necessarily charge a high rate of interest on the extended credit, but make their profit on their purchase and sale transactions with the enterprise. Because of their monopolistic position, they are able to exert effective pressure with respect to these transactions.

That existing sources of financing are grossly inadequate is indicated by the fact that shortage of working and fixed capital is an important cause of failure of small industrial and other undertakings in under-developed countries. It is, in all cases, a serious obstacle to their development and growth.[6]

[2] Scheduled banks, which number about ninety-five, are large banks which keep their reserves with the Reserve Bank; they extend more than 95 per cent of the total bank credit in India. The number of non-scheduled banks, which are small and exclusively local concerns, is over 300.

[3] "Commercial Bank Finance to Medium and Small-scale Business Units", *Bulletin of the Reserve Bank of India* (Bombay, 1959).

[4] "Financial Experience of Small Companies in India, 1950-1952", unpublished Ph.D. thesis by G. Balakrishnan, University of Poona, 1958.

[5] Statistics of the Ministry of Finance, quoted in *Asian Affairs*, vol. II, No. 2, June 1959 (Tokyo).

[6] For a discussion of this problem, *see* Government of India, Ministry of Commerce and Industry, *Small Industry in a North Indian Town*, by J. T. McCrory (New Dehli, 1956).

Small-scale industries in Indonesia:

Shoe-making

Making irons

Finishing umbrellas

MEASURES OF ASSISTANCE ADOPTED IN UNDER-DEVELOPED COUNTRIES

Measures aimed at meeting the problems of small-scale business have been developed in the advanced countries, among them the establishment of special agencies for financing and providing guarantees and various services. It has been seen that in the less developed countries these problems arise in a somewhat different context. The techniques which have been adopted are reviewed in the following paragraphs.

Improving the supply of funds

Many under-developed countries have set up special financial institutions to extend long-term and short-term credit to small and medium-sized enterprises; some of them cater specifically to the needs of industrial enterprises of this type.

In India, which has one of the most advanced programmes of assistance, small industry can avail itself of the services of an array of institutions, some of which are part of the central government machinery, others separate from it. The government-owned State Bank, the largest Indian institution with about 700 branches throughout the country, participates in this programme. It lends funds for working capital to small-scale enterprises, for which the security and collateral requirements are considerably relaxed. The State Bank has recently launched a trial programme of partially guaranteed credit to encourage privately owned commercial banks to increase their lending to small firms. Each of the branches of the State Bank also provides, in its area of operation, guidance to the applicant in his dealings with the various government institutions involved. This makes it possible for the needs of small businessmen to be taken care of by local bankers who are acquainted with them and with conditions in the area; this is a much more effective procedure than having the financing done by centrally located specialized financial institutions.

State finance corporations have been established in each Indian State to provide credit for the more important projects; these corporations do not, however, normally provide loans below a stated minimum amount, which varies from one State to another. Smaller loans are provided by the state industries departments. From the middle of the nineteen fifties through December 1958, the total amount of loans approved by all state finance corporations was 178 million rupees, of which 16 per cent—that is, 27.9 million rupees—were earmarked for small industries. During the same period, 127.3 million rupees were disbursed, of which 14 per cent, or 18.1 million rupees, were received by small industrial concerns. At the same time, the total amount disbursed by the industries departments of state governments was 26.5 million rupees.

The fact that small industry receives a modest share of business credit is explained by the following considerations: (*a*) applications for loans by small entrepreneurs were often incomplete or vaguely worded; (*b*) the financial records or accounts submitted were considered to be inadequate; (*c*) insufficient assets were offered by applicants for the required collateral; it appeared, in particular, that many would-be borrowers occupied rented premises on short-term leases, and that applicants were often unable to produce legal title to property offered as security; (*d*) reliable information could not be obtained on the business and credit standing of the prospective borrower, co-signer or guarantor, and (*e*) the soundness of the project for which financing was requested could not be assessed.

Special credit institutions have been established to foster industry in other under-developed countries, but small industry cannot as a rule, and for similar reasons, take full advantage of their services.

Thus, in Iran, large firms accounted for most of the loans from the Industrial Credit Bank, smaller firms being generally unable to meet its security requirements. In Burma, according to reports by United Nations technical assistance experts, loans to small industry have been too small; moreover, the repayment periods imposed by the lending agency were too short and the security requirements too high; procedures were inflexible and cumbersome and long delays occurred in processing loan applications. In Indonesia, several financial agencies established by the Government to assist small industry are prevented by their rules from extending loans to concerns which they have already assisted. As a result, a firm which has received an agency loan for purchasing its plant and equipment is precluded from obtaining the urgently needed further credit for replenishing its working capital. A scheme for hire-purchase of machinery administered by the government-owned Industrial Bank has faced considerable difficulties largely because one of the clauses in the hire-purchase contract required that the Bank participate in the management and share in the profits of the enterprise; most prospective borrowers were unwilling to take advantage of the plan under such conditions.

Credit schemes in the form of hire-purchase plans for mechanization of small industry were also introduced in Burma and India. In Burma, application of eligibility criteria resulted in a high percentage of rejections of requests for loans. The loans granted were to be matched by an equivalent amount of capital pledged by the borrowers for installation and operation of the machinery.[7]

In India, in the period 1956 to mid-1959, the National Small Industries Corporation approved 1,476 applications for hire-purchase of 5,259 pieces of machinery valued at 44.7 million rupees, of which 2,133 pieces valued at 17.7 million rupees were delivered by the middle of 1959. For the special-purpose machines which had to be imported, the Indian Government provided guarantees for letters of credit amounting to 3 million

[7] The programme has been in abeyance since 1958, pending the establishment of a Union Investment Corporation which is to take over its administration. *See* also a study of the Burmese hire-purchase plan, "Hire-purchase Loans for the Mechanization of Small Industry", by J. E. Stepanek, which appeared in United Nations, *Bulletin on Industrialization and Productivity*, No. 1 (sales number: 58.II.B.2).

rupees. This covered only a fraction of the applications; it was estimated that if all requests were satisfied, the annual foreign exchange requirements for such imports would be of the order of 10 to 15 million rupees.

In both countries, the hire-purchase scheme is associated with provision of specialized technical services aimed at ensuring proper utilization and maintenance of the equipment.

Reducing the cost of credit

The total cost of finance may be defined as the sum of the "pure" rate of interest plus compensation for the risk element and service charges. The pure rate reflects the relationship of supply of and demand for capital. The risk element has been touched upon in a preceding section, in which it was mentioned that the characteristics of small business, as regards both the calibre of entrepreneurship and the nature of small industry in under-developed countries, tend to make this element particularly important.

In many under-developed countries, the capital market may be considered as being subdivided, in fact, into two largely non-competing sub-markets: one an "organized" sector—mostly urban, government influenced and consisting of the banking system as lender and the larger firms as borrowers; the other an "unorganized" sector—consisting of indigenous bankers, money-lenders and traders, on the one hand, and small business borrowers on the other; this is mainly rural and is only marginally influenced by the credit policy of the government or the banking system.

The first market is, as a rule, highly competitive and the strong borrower is generally able to shop around for the lowest rate; relationships between lender and borrower are, as a rule, impersonal. The second market has monopolistic features, the prospective borrower having no access to sources of finance outside his locality, being thus restricted to dealing with a single local financier.

In the first market, interest rates may be relatively low, often owing to government intervention, and, in some cases, even lower than the level which would reflect the real conditions of supply and demand of capital prevailing in the country. In the second, interest rates are much higher and reflect not only the real conditions in the supply of and demand for capital, but also the high risk elements and service charges involved and the monopolistic position of the lender.[8] Interest rates in the various unorganized markets, even physically contiguous ones, may bear little relationship to each other; in any of them, the rate is determined by the urgency of the borrower's need and by what the traffic will bear. Nor do rates in the unorganized markets necessarily bear any definite relationship to those prevailing in the organized markets.

Data on losses incurred in financing small firms in under-developed areas would provide a means of measuring risk as a cost element; these are, however, not available. A high potential level of loss is suggested by the following discussion of conditions in the United States, based on limited survey samples:

"Within deposit size groups of banks and taking into account bank lending other than to small business, the banks that loaned heavily to small business experienced definitely higher loss rates than the other banks . . . Interest earning rates[9] on loans increase as the degree of lending to small borrowers increases [but the difference in loss experience among banks] accounts for only 10 per cent of the observed difference in interest earnings . . . The appreciably larger difference in . . . interest earnings . . . is believed to reflect, at least in part, the larger difference in average size of business loan and related difference in costs per dollar of loan between the two groups of banks which engaged extensively in financing business. [In the United States and possibly other developed countries] the banks may feel that businesses who cannot borrow under the prevailing conventional rates must be outside the zone of acceptable risks, or that not enough borrowers would be available to support a specialized type of financing, designed with unique protections to cope with the extra risk [and other related costs]."[10]

In under-developed countries, the high risk element is one of the contributing factors in discouraging commercial banks from entering the area of extending finance to small industry. On the other hand, it has the effect of raising the interest rate charged by money lenders to the maximum the borrower can bear.

As to the service cost element, administrative and other direct costs of lending and servicing are clearly higher on small loans than on large ones, because of diseconomies of scale. Here again, little quantitative information is available for under-developed countries and only fragmentary data exist in the developed ones. The following quotation refers to the United States:

". . . the relative cost of lending tends to be inversely related to the size of loan . . . since investigation and administration costs do not decline substantially as the size of loan declines, and the risk costs (potential losses) rise as loan size falls. Finally, since rejection rates tend to be higher for small concerns (because on the average, they represent poorer risks and, also, because most of them are new customers and need to be investigated thoroughly), the average cost per loan made (including the share of costs for loans rejected) is higher than for credit extended to larger firms.

[8] Thus, in India, interest rates charged by large commercial banks on unsecured advances—principally to large-scale industry—range from 4 to 8 per cent per annum. Those charged by small banks on similar unsecured advances—in all probability, mainly to small industry—range from 15 to 19 per cent. For short-term secured loans, the rates charged by the large commercial institutions in Bombay vary from 4.5 to 6.5 per cent. According to the Reserve Bank's information, rates charged by money-lenders in Bombay range up to 15 per cent; they are believed to reach 20 per cent or more in other areas.

[9] Rates on loans measuring annual bank interest earnings.

[10] United States Congress, *Financing Small Business, Report to the Committees on Banking and Currency and Select Committees on Small Business, by Federal Reserve System* (Washington, D. C., 11 April 1958), pages 48, 88, 81 and 15.

Indeed the cost of screening acceptable risks among small and, in particular, new concerns, is high, as are the service costs. The analysis of Small Business Administration costs and revenues . . . suggests that, even without making provision for loss, loans below $20,000 do not yield a net return . . . The industrial loan experience of the Federal Reserve Bank of New York during the 1930's indicates that managerial assistance is an integral and perhaps indispensable part of a successful bank management of small-loan portfolios."[11]

Similar conditions are likely to prevail in under-developed countries, and to affect the cost of credit to an even greater extent than in the more advanced countries. Established commercial banks are poorly informed of the borrower's credit standing and would find it difficult, if not impossible, to secure such information; moreover, fewer loan applications by small businessmen are apt to be accepted, so that the overhead cost per loan granted tends to be larger. Investigation of the applicant's credit is hampered by the inadequacy of his financial records mentioned earlier, while evaluation of new projects for which loans are solicited is more difficult in view of the scarcity of personnel skilled in technical and marketing appraisal and the lack of experience in this field. Many financial institutions deliberately set minimum size limits on loans which they provide, especially when the interest rates they are permitted to charge are kept low by law, and are to be applied uniformly to all customers. Overhead costs per loan would obviously be reduced with an increase in the volume of lending. Thus, in a large institution specialized in financing small industry, it would be possible to set up an adequate technical staff to evaluate applications for loans; the cost of the operation would be spread over a large volume of lending. It would not be economical for an average bank processing only a few such loans to maintain a staff so qualified; the bank would be obliged either to hire *ad hoc* consultants or to entrust this function to personnel engaged in other occupations, and the cost would have to be absorbed by the customers directly concerned.

The measures discussed earlier, namely, the establishment of specialized financing institutions of public nature and provision of incentives and guarantees to private banks to furnish greater credit facilities to the smaller enterprises, are in themselves important steps in the direction of reducing the cost of credit. Such measures tend to weaken the monopolistic position of money-lenders and thus force down the rates of interest charged by them.

As a direct measure of intervention in the small-business credit market, which is usually combined with the establishment of financing institutions, rates on loans to small enterprises are set by Governments at levels comparable to those applying to large firms. Where special institutions are established to finance small industry, such rates may be as low as 6 to 8 per cent per annum, and, in some cases, 3 to 4 per cent. In Japan, where considerable assistance is given to small industry, interest rates are higher. In 1957, short-term loans extended by lending institutions were charged at 9.6 per cent and long-term loans at 11.5 per cent; rates on privately-secured loans were of the order of 12 per cent.[12]

In view of the risks involved and the high administrative and servicing costs of financing, measures to keep down interest rates for small-scale enterprises taken in isolation may be self-defeating. In order to cover their costs and return a profit to their stockholders, commercial banks may tend to curtail the number and amount of their loans to small enterprises, reducing by that much the flow of credit to small business. Thus, the resources of the special institutions established for that purpose will, in part, be used up in replacing private sources of finance.

For the lower rates to be realistic, the risk element in lending and the administrative and servicing costs should be reduced. This holds true even in cases where the lending is done by publicly sponsored institutions subsidized by Governments. Again, the most advanced form of an integrated approach to the problem is practised in India. The Small Industries Service Institutes established and operated by the Ministry of Commerce and financed by the central budget provide advice and information—often accompanied by demonstration—to small industrialists throughout the country, carry out market research and industry surveys, undertake technological research on raw materials, machinery, designs and other relevant matters, serve as technical agents for the National Small Industries Corporation to implement that agency's hire-purchase programme and provide financial, commercial and other research services. The industries departments of the state administrations also provide managerial services and technical advice to small manufacturers; those whose programmes include financing follow up the projects which they assist. In the absence of such organizations, all services of this type would devolve upon the lending institution itself.[13]

In spite of this progress, three major problems are still to be faced: technical assistance is not yet adequate; the activities of the service agencies are to be more closely co-ordinated both among themselves and with the special financing institutions; the services are to be extended to a large number of private banks which have not, so far, participated in the programme.

A solution along these lines deserves to be considered by the authorities of other under-developed countries.

[11] [illegible], *Small Business*, op. cit., pages 14 and 31.

[12] Japan Productivity Centre, *Small Business in Japan: Backbone of the Nation* (Tokyo, 1957), pages 11 to 13.

[13] In Japan, the solution of the problem of servicing and assisting small-scale business has taken a particular form because of the prevailing system of subcontracting arrangements between large and small industrial enterprises which is characteristic of that country. The parent company bears the cost of providing technical and managerial advice and other assistance, both to maintain adequate technical standards in the output of its subcontractors and to ensure efficient utilization of the equipment and funds which it has loaned to them. The large company also provides guarantees for loans which the small companies may request from financial agencies (*see* United Nations, "Interrelations Between Large and Small Industrial Enterprises in Japan", by Toyoroku Ando, *Bulletin on Industrialization and Productivity*, No. 2 (sales number: 59.II.B.1).

TOP LEFT
Drilling parts of plastic toys in a small Pakistani factory

TOP RIGHT
Using a hand-fly press in a steel workshop in Indonesia

Final assembly of toy tricycles in an Indonesian workshop

A technical agency could be set up to service a variety of public and private financial institutions by evaluating applications for loans and providing technical help to the borrowers. Such an agency would have sufficient demand for its services to be in a position to hire a competent staff, occupy it fully and enjoy the economies of scale of a large organization. It might establish regional offices and mobile units. It will be noted in this connexion that international machinery exists which could make an effective contribution in this field by assisting in financing the establishment of such an institution, and also in recruiting and training the necessary personnel.[14]

[14] Assistance for the establishment of such an institution may be provided under the terms of reference of the United Nations Special Fund. An article on the Special Fund is published elsewhere in this issue.

Reducing the risks of lending

The application of the measures discussed above, aimed at protecting and improving the operation of the lending institutions, also has a favourable effect on the position of the borrowers. When a small manufacturer receives adequate technical, financial and managerial advice, the over-all efficiency of his enterprise increases and the risk of insolvency or bankruptcy is thereby diminished. However, more direct measures of reducing the lending risks have been developed in a number of countries. In the United States, programmes of government guarantee of long-term and short-term loans to small enterprises were introduced during the depression of the nineteen thirties and expanded during the war and post-war years. Commercial banks were thereby encouraged to extend credit to small firms in larger volume and at longer terms than formerly.[15] Quite recently, a number of investment companies, which have been set up with government assistance to finance small business, have taken steps to provide joint underwriting of such financing, with a view both to increasing the size of loans and reducing the risks to individual lending companies.[16]

In Japan, a system of short-term credit guarantees by the Central Government to large and small financial institutions or associations has been in operation since 1937. In 1950, a law was passed extending guarantees to long-term credit.

In India, the Reserve Bank has recently outlined a test programme under which a stated proportion of the loans made by publicly-owned and private commercial banks to small industrial firms was guaranteed by the Bank.[17] A favourable response to this initiative on the part of the banks, which have a large volume of resources and a wide network of branches throughout the country, would represent a major advance in the field of financial assistance to small industry in India.

All the measures discussed above aim at reducing the risk of default on loans borne by the financial institution by spreading it between the institution and the government, or other lenders acting as a group, or both. These measures may be supplemented by other steps, in particular, by improving facilities for exchange of credit information and of debt collection procedures, which are generally inadequate. The main effort, however, should be directed towards inducing financial institutions to liberalize their lending policies to small-scale firms, by making such credit an economic proposition through an integrated policy as outlined above.

CONCLUDING REMARKS

It has been seen that the solution to the financial problems of small industry in under-developed countries lies essentially in expanding and improving credit facilities, providing technical and managerial assistance and reducing the cost of credit to borrowers. All these measures are interrelated.

The widening of the sources of finance could take place in the form of setting up specialized government institutions for financing and providing incentives to private banking to expand its own lending operations to small business. In doing this, the monopolistic position of money-lenders and traders would be correspondingly weakened and it could be expected that the excessive charges on credit from these sources would be reduced. It was also suggested that provision of technical and managerial service to small business, by improving the efficiency of operation, would thereby reduce the risk of lending; such measures would also provide for a better evaluation and servicing of loans. Various other measures were considered, such as reducing the risk on individual loans by government guarantees in co-operation with banking institutions, introducing methods of supervised credit and the like.

The solution of the problem involves an integrated approach, combining the various elements mentioned above. In view of the magnitude of the effort required, it is necessary that Governments provide guidance and assistance, which may take the form of direct participation in financing. International action can effectively supplement national efforts; this could take the form of assisting countries in the establishment of servicing institutions for small-scale industry, which would contribute to improving technical and managerial standards.[18]

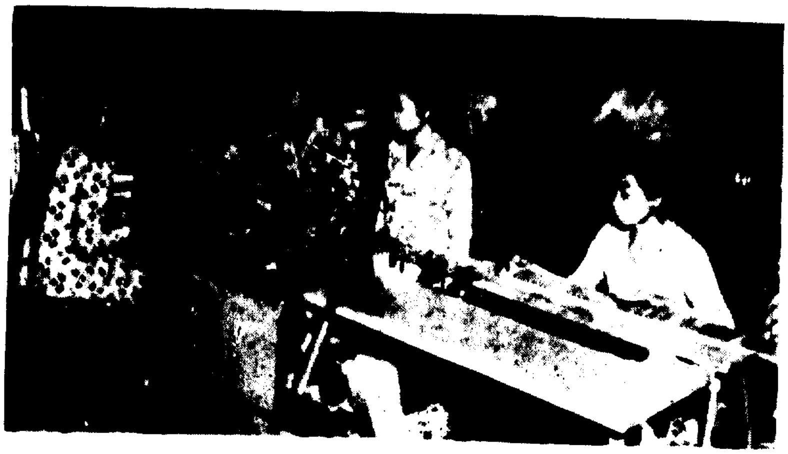
In preparing this article, it became apparent that much more information was required in respect of institutional structure, costs, risks and other aspects of financing small industry. Further research in this field by way of surveys, comparative analysis and interchange of information should be of considerable use to Governments and would contribute towards developing better methods of financing, appropriate to conditions prevailing in the less developed countries.

[15] For an evaluation of these programmes, *see* R. J. Saulnier, H. G. Salcrow and N. H. Jacoby, *Federal Lending and Loan Insurance* (Princeton University Press, 1958) and "Government Loan Programmes for Small Business" in *Financing Small Business*, op. cit., pages 253 to 281.

[16] *The New York Times*, 1 December 1959, page 55.

[17] *Economic Weekly*, vol. IX, No. 45 (Bombay), 7 November 1959, page 1,489.

[18] *See*, in this connexion, the recommendations in United Nations, *Management of Industrial Enterprises in Under-developed Countries* (sales number: 58.II.B.5) and also the annex on management service institutes.



Using modern machinery in a cigar factory at Jogjakarta, Indonesia

Use of Statistical Quality Control in the Industry of Under-developed Countries

BY WILLIAM R. PABST, JR.

STATISTICAL QUALITY CONTROL is a technique of industrial management which, so far, has been applied extensively only in developed countries. It aims at achieving better products and lower costs. Better products result from reduction of defective or substandard items and from improvement of standards, contingent upon considerations of consumer needs. Lower costs result from more effective use of raw materials and machinery and improved efficiency of labour, reduction of scrap and rework in plant processes, development of more effective maintenance procedures and a rational approach to standards and specifications in production.

Quality control is not exclusively concerned with improvement of quality or with control of manufacturing processes, but rather with the "economic control of quality of manufactured product"—as the original work in this field is entitled (1).[1] Economic control aims broadly at achieving on a plant-wide basis the objectives of management in obtaining more and better products of the kind consumers want. Economic control is also concerned with increasing industrial productivity through more effective utilization of labour and materials; from that standpoint, quality control is of nation-wide importance.

The techniques used in quality control are essentially statistical in nature. Data on the processes of production used in a plant are collected and analysed with a view to detecting and correcting inefficiencies and irregularities in production. Effective utilization of these techniques makes it possible to increase output appreciably without introducing basic changes in plant, equipment or manpower. The costs of employing the techniques are relatively modest and their application can serve small-scale establishments as economically as large industrial undertakings equipped for mass production.

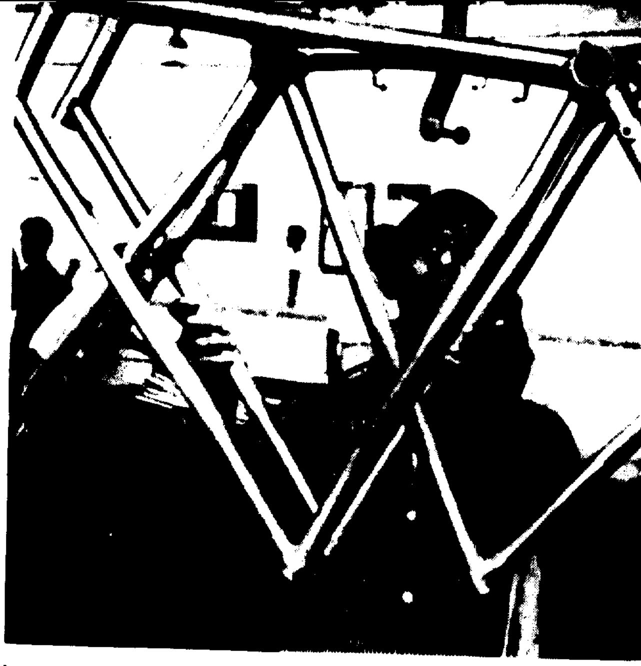
These considerations support the contention, despite historical evidence to the contrary, that the effectiveness of quality control techniques is in inverse relationship to the degree of industrial development—in other words, that the orderly use of these techniques should be most helpful to newly emerging industries. The purpose of this article is to support this view.

What quality control can do

Before examining the use of statistical quality control techniques, it may be appropriate to give a few instances of the types of problems which they may solve. The fol-

[1] Figures in parentheses refer to the References at the end of this article.

DR. PABST, *Chief Statistician of the Bureau of Ordnance, United States Department of the Navy, has advised the Government of India on quality control as an expert of the United Nations Technical Assistance Administration.*



Inspecting frames in a bicycle factory at Ansasol, India

lowing examples, based on the author's experience in India, relate to small-scale industries.

In a small plant employing about seventy-five workers engaged in making water pumps of various sizes, a relatively simple process of production was applied; the pump housings were cast and machined, the parts assembled and the final product tested. A quality control survey of this plant showed a relatively efficient batch processing of materials, a good layout for an efficient materials flow and, on the whole, a satisfactory product; yet examination of the scrap pile revealed that a significant number of castings were rejected. In all cases the reason was the same: air pockets were present in the castings that could not be discovered until the castings were machined. The defect was traced to the temperature control of the cupola used for melting the raw materials; the air intake in the cupola was not sufficient to produce the necessary temperature consistently, and blowholes were formed in the castings. Since the rejected castings were scrapped and remelted and since the manager had not been aware of the relative frequency of the defects, this loss was considered to be a necessary part of the system and was neglected. The quality control investigation attempted to measure and assess the volume of this scrap. Then metallurgical analysis, prompted by this quality information, uncovered the fact that the cupola had been improperly designed and that the air intake had been allowed to clog. Correction was made, the capacity of the cupola was trebled and, in order to keep output at the higher level thus achieved, continuous recording of "defectives" was set up at each stage of processing.

In another foundry, nine groups of workers were employed under contract in making standard railroad sleeper castings. These groups, consisting of about twenty men each, supplied the manpower for moving the sand and forming the castings, whereas the company supplied the moulds, the sand and even poured the metal for the castings. Examination of the payment records disclosed that one contract group had 93 per cent of its castings accepted over a long period of time, whereas several of the other groups had difficulty in getting as much as 60 per cent of their production accepted. Quality control revealed that the disparities were mainly due to differences in skills, and training, psychology and incentives were applied to bring the efficiency of the workers at the lower end of the scale up to the level of the leaders; as a result, the output of the entire plant was increased by more than 25 per cent. Quality control thus made use of previously unutilized data available in the plant to mobilize action for a plant-wide increase in productivity.

In a bicycle factory, a quality control investigation revealed that more than 25 per cent of the frames were rejected for roughness or blemishes and returned for cleaning and repainting. After investigation, rejection was traced to manipulating parts before sufficient drying time had elapsed—a trouble previously hidden by the methods of manufacture and handling.

In a pottery, high rates of rejection were experienced after firing. Sampling methods were applied for identifying the work of individual moulders and keeping score of the defects. Large differences in individual outputs were found, one moulder having a rejection rate more than three times that of the others. It was found that, in the interest of speed, he had been using an improper technique which had remained undetected owing to the separation of the final product from the work-place and to the time lag between production processes.

In these and other cases, quality control made it possible to trace the sources of defects or shortcomings—sometimes unknown to or neglected by management—by detecting inefficient or improper stages in processes of production, and thus to take corrective action.

Table 1

JOB HISTORY SHEET FOR FUSE BOX COVER

PERIOD	NUMBER CAST	NUMBER REJECTED	PERCENTAGE OF REJECTIONS	PERCENTAGE OF REJECTIONS DUE TO						
				PATTERN	TACKLE	MOULD	SAND	CORE	METAL	MISCELLANEOUS
July 19-30	83	62	74.7	24.1	18.1	19.2	9.6		1.2	2.5
August 1-5	35	17	48.5	—	2.8	43.0	—	—	2.7	—
September 9-13	18	7	39.0	—	—	27.9	11.1	—	—	—
September 16-23	16	6	37.5	—	6.2	25.1	6.2	—	—	—
September 24-30	26	6	23.0	11.5	7.6	—	—	—	3.9	—
October 1-7	60	14	23.3	—	18.3	1.6	1.6	—	—	1.8

Table 2

FOUNDRY PRODUCTS: NUMBER MADE, REJECTION RATE AND ACTION TAKEN DURING A TWO-WEEK PERIOD

PRODUCT	BEFORE ACTION *Number made*	BEFORE ACTION *Rejection rate (percentage)*	AFTER ACTION *Number made*	AFTER ACTION *Rejection rate (percentage)*	ACTION TAKEN
Pump shelter	77	83	135	7	Change of pattern
Four-inch impeller	22	70	44	19	Change in composition of sand
Pump body	34	30	21	0	Change of moulder
Starter cover	50	78	56	6.6	Use of good boxes and correct pins

USE OF STATISTICAL QUALITY CONTROL TECHNIQUES

EXCELLENT DESCRIPTIONS OF quality control techniques are contained in many articles and textbooks, some of which are listed at the end of this article (2)(3)(4). It is not proposed to give such technical information here, but rather to present some case studies showing how these techniques have been actually applied in factories in India. The case studies will be prefaced by brief references to the collection and presentation of data.

Historical record sheets

The first step in analysing a quality control problem is to prepare job history sheets summarizing the pertinent data over a period of time. Several examples of this form of presentation of the data will be found below.

In one foundry, the problem facing management was: is it possible to reduce the proportion of rejected castings to less than 10 per cent per day? Data collected from the routine production papers of the past revealed, "to the astonishment of everyone concerned [that] the average percentage rejection on number produced was 20 to 25 per cent for the previous month and [that] the rejection rates on some items were as high as 60 to 80 per cent" (5).

The causes of rejection were classified according to the following categories: pattern, tackle, moulding, sand, core, metal and miscellaneous. A daily foundry rejection analysis sheet was prepared to show the daily rejections by types of castings and by causes of rejection; the sheets for each part were then summarized to provide a historical record. An abbreviated version of the job history sheet concerning one of the products—a fuse box cover—is shown in table 1. This history sheet indicates a substantial decrease in the percentage of rejections over the period covered. In the early portion, before 23 September, most causes of rejection related to moulding, tackle and pattern, the defects due to the other causes being negligible. Application of corrective measures began on 24 September. The mould boxes were checked for wear, the old ones thrown out, usable ones painted and the pins stamped for identification. Defective boxes and pins that caused most of the tackle troubles were removed. The system of pattern issue was changed, patterns being inspected and checked prior to the production run and doubtful patterns removed for further correction. The work of the moulders improved immediately and, within a period of four months, the over-all rejection rate was reduced to between 11 and 12 per cent. The decline in the rate of rejection for other foundry products made in this plant, to which similar quality control techniques were applied, is shown in table 2.

In an automatic glass plant, bottles were produced on two sections of a machine. Inspection of the product led to rejection of defectives, but the causes of rejection and of the relative frequency of rejections as between the two sections of the machine were unknown until quality control was introduced. A sampling system, consisting of selecting bottles at fifteen-minute intervals over a series of days, yielded the information shown in table 3 (6).

Table 3 shows that section I was responsible for about twice the total number of defects as section II, the largest number consisting of neck cracks. Routine maintenance checks had not revealed that the neck-ring device on the machine was faulty. Corrective action resulted in a reduction in the number of defectives due to that cause on section I to the level obtaining on section II, and lowered the over-all rate of rejection from about 14 per cent to 9 per cent. The table also shows that the frequency of black spots in section II was twice that in section I; this difference verges on statistical significance, although the number of defects from this cause was so small in comparison to that from other causes as

Table 3

GLASS BOTTLES: NUMBER REJECTED, BY DEFECT

SECTION OF GLASS MACHINE	*Number of rejections due to* NECK CRACKS	LOADING MARKS	BLACK SPOTS	OTHER DEFECTS	TOTAL
I	151	39	8	45	243
II	17	32	18	52	119
TOTAL	168	71	26	97	362

to put in question the need for an investigation. However, examination of the reasons for this and other defects showed the possibility of reducing total defects to the one per cent level.

In these examples, quality control data have been used for diagnosis and correction. After correction, systematic statistical analysis by means of 'attribute" control charts—those based on percentage or number defective—is necessary to control further developments. Control charts for this purpose will be described below.

Frequency distributions

Frequency distributions or histograms describe variations in characteristics or events observed. Erratic scatters show the need for further investigation.

To give an example, frequency distributions were used in jute or cotton spinning factories to analyse the operation of the spinning frames. A spinning frame has one hundred spindles, each of which is engaged in spinning a sliver into yarn or thread. Perfect operation of the frame would be achieved if no thread breaks occurred between "doffs", that is, the time when spools of thread are nearly full and are replaced with empty spools. A measure of efficiency of operation of a frame is the number of thread breaks—usually called "ends down" or "end breaks". When a break occurs, the spinner must tie or twist the ends together and start the spool winding; frequent end breaks cause a loss in output from the frame. When one frame has an output lower than the others (there are usually fifty or more frames in a mill), it is not known whether the spinner works slowly or improperly, whether the frame or spindles are in need of repair or whether some other cause is involved. One method of determining this is to count the number of end breaks. The easiest way to do this is to place chalk tick-marks on the frame body itself, as each break occurs; at the end of a given period of time, usually a shift, the numbers of such marks are added and recorded. On one frame of one hundred spindles where such a count of ends down was made, the results were found to be as follows:

Spindle number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17, etc.
End breaks during shift	6	7	4	12	9	23	2	8	6	7	8	10	9	5	12	47	7, etc.

These data show a great variation in the number of ends down from one spindle to another in the course of a shift. The frequency distribution is shown in chart 1.

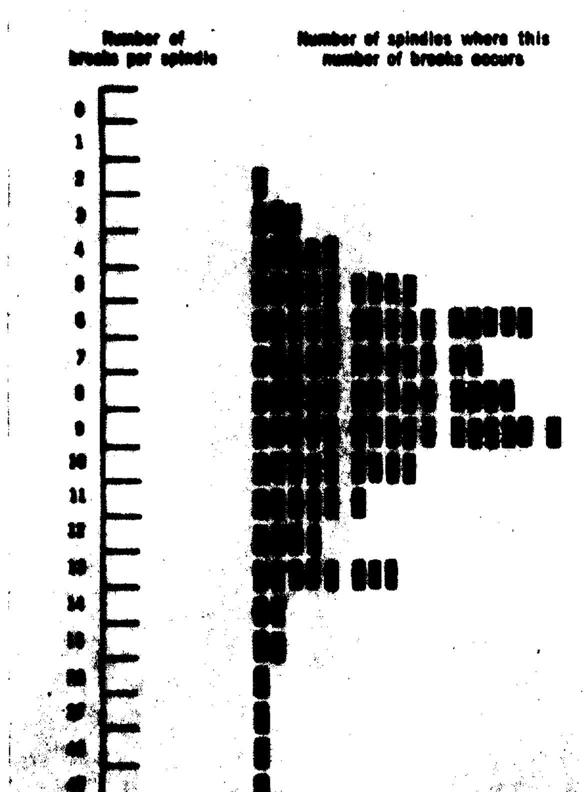
With the exception of the extremes, the pattern of distribution is very regular, varying from two to fifteen breaks per spindle per shift. Such a range of variation is normally expected in probability theory and, in fact, can be deduced from the average number of breaks per spindle per shift. Variation within this pattern is commonly said to be "by chance". In the case considered, more than fifteen breaks per spindle per shift is significantly different from the average—which is eight—and an investigation of the difference is called for. Each of the high-break spindles was therefore examined in detail. On most of them the fault was found to lie in worn rubber rollers, due to an erroneous maintenance practice of replacing the rollers at six-month intervals. Correction of the four defective spindles—8 per cent of the total—led to a 20 per cent increase in efficiency of the frame as a whole. In this example, the trouble within the frame was responsible for the low rate of production. Had the material been poor or had the entire frame been in need of repair, the distribution of breaks would have been regular, but with a higher average breakage than normal.

Frequency distributions are useful in other cases to indicate conformance to, or departure from, an expected pattern of distribution. Chart 2 shows a frequency distribution of the results of a lot-by-lot inspection of glass bottles. A sample of 150 items was examined from each lot; a lot was considered acceptable if not more than five defects were found. The lots are tallied in chart 2 on the basis of the number of defectives found (7).

The truncated or cut-off character of the distribution shows clearly that the inspectors almost never reject a lot at just the rejection number, in order, apparently, to avoid the trouble of re-inspecting the rejected lots. They reject only if the lot is evidently bad enough, and thus accept a quality of material lower than what is in fact desired. Under the circumstances, the inspectors were warned that proper procedures were to be followed and some of them had to be trained to improve their work.

Chart 1

SPINNING: FREQUENCY DISTRIBUTION OF SPINDLE BREAKS PER SHIFT

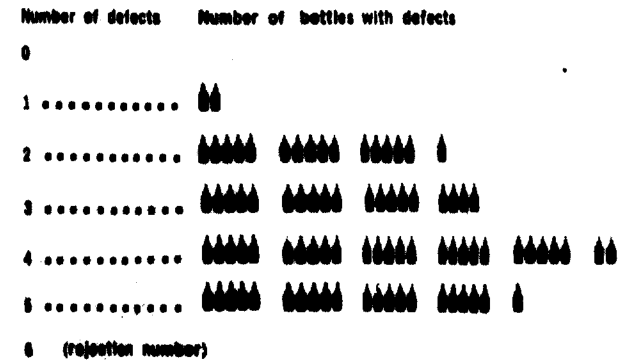


The quality control chart is a further development of the job history sheet and of the frequency distribution chart. It is used to determine whether a process is stable or is changing over time. The control chart establishes statistical limits within which periodic changes in the level of the process or in the process itself can be assessed. In this way the control chart not only records information historically but goes beyond simple historical and frequency distribution charts by providing an analytic tool with which to gauge the variability of the process.

It will simplify the presentation to revert to the frequency distribution of end breaks on a spinning frame during a shift. In that example the average number of breaks per shift was about eight; given this average, limits can be calculated beyond which the number of breaks would be excessively large or small. If all the spindles on the frame were about the same, the chances would be less than one per cent that a spindle would be observed with fewer than two breaks, and the chances would also be less than one per cent that individual spindles would have more than fifteen breaks during the shift. The fact that one spindle had forty-seven breaks was indicative of an "assignable" cause which required remedial attention. In addition to these limits, the control chart introduces the notion of time and thus has a predictive value. Were spindles chosen at random and observed for breaks during each successive shift, the number of breaks would be expected to fall within the predetermined limits unless some change occurred in the spindle in the course of time. If all subsequent breaks were within these limits and if the number of breaks were distributed regularly without tending to increase,

Chart 2

Glass bottles: Frequency distribution of defectives per sample



it could be concluded that the sample spindles were truly representative of all spindles in the process, and that the process was under control.

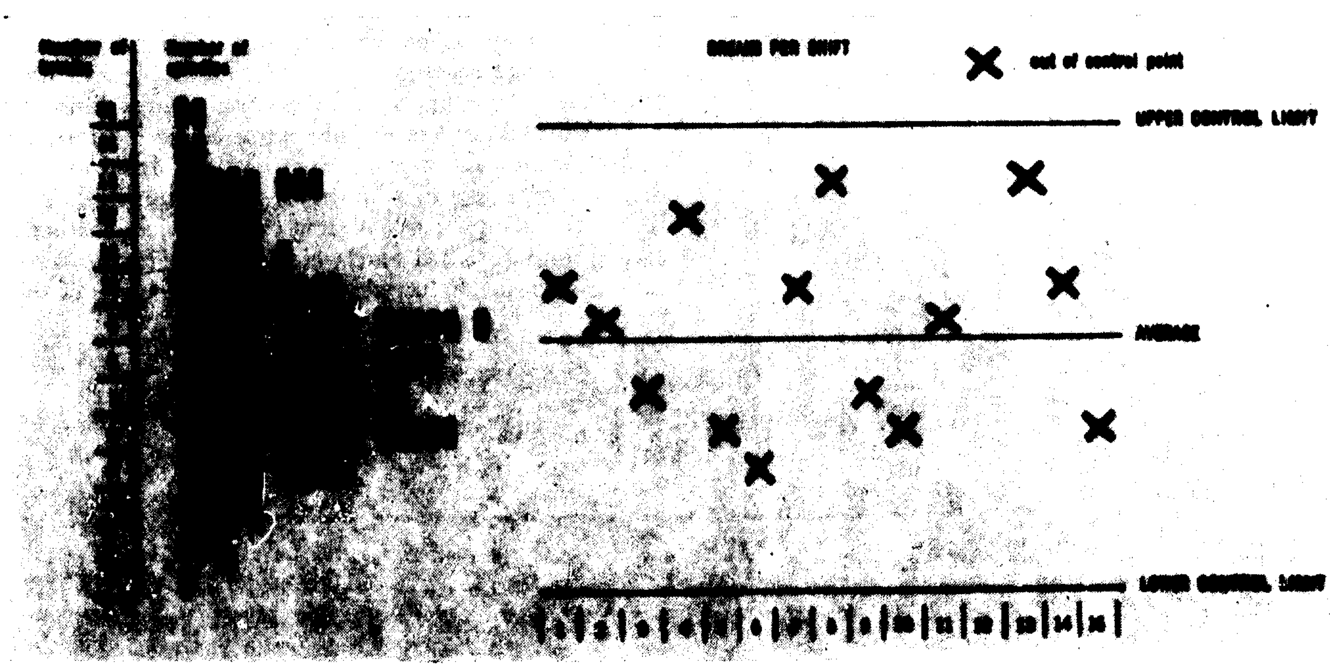
Graphically this is shown in chart 3.

The control chart thus provides both a summary of experience over time and a norm for assessing the necessity of corrective action and selecting its type. Similar charts are used to determine the percentage "defective", percentage "returned" or other such "attribute" data. The following example shows the percentage return of fans from final inspection to the assembly line; the production is of about 200 fans a day.

In the preliminary period covered by chart 4, the percentage of fans returned each day was very erratic, and reached a figure as high as 14 per cent. The causes of this high rate of rejection at final inspection were investigated and corrective action was taken, the effects

Chart 3

Spinning: Hypothetical control chart for the end breaks shown in chart 1



becoming apparent on the eighth day. Thereafter, only slight variations in the percentage of returns were found. The average percentage rejection (p curve) was determined on the basis of the results for the next ten days; the upper control limit (UCL curve) was computed and plotted on the chart. The chart showed that the returns for the sixteenth and eighteenth days were above the control limits; investigation was again undertaken, and an average daily rejection of less than one per cent, which was economical and satisfactory, was finally obtained. This sequence is typical of many situations in which almost immediate results have been obtained from the posting of a p chart; without this intervention, the lack of knowledge of the amount and of the erratic nature of returns would have allowed careless practice to continue undetected.

Certain types of control charts are commonly made when "variable" data (those arising from measurement of weights, dimensions, strengths and the like) are available. The procedure consists usually of selecting over a period of time samples of four or five units from a process. The average of the sample indicates the central tendency, and the range of the sample (largest minus smallest value in the sample) measures the variability of the process. This information can then be used to determine whether the process is stable and controlled. As regards the variability of the process, mathematical theory indicates, given an average of the ranges of twenty or more successive samples, how much variation among the individual ranges might be expected to occur by chance, just as in the case of the "ends down" in the frequency distribution discussed earlier. From the average range, it is possible to determine the upper range limit for each sample size; the lower limit is seldom higher than zero, except for large sample sizes.

Table 4

WEEKLY AVERAGE PERCENTAGE OF REJECTION (PER INSPECTOR) OF SEWING MACHINES BEFORE AND AFTER INTRODUCTION OF QUALITY CONTROL METHODS

REJECTION	BEFORE (*April*)	AFTER (*September*)
Maximum	32.4	8.6
Minimum	4.0	1.5
Average	15.0	5.0

The upper range limit is then drawn on the chart and a range of successive samples is plotted. If any of the individual sample ranges exceed this limit, there is good reason to believe that the process does not have a stable pattern of variability over the period considered, and that an "assignable" cause can be found.

Similarly, limits for the variability of the sample averages can be predicted from a stable pattern of process variation. The limits of variability for the averages are called the upper and lower control limits; they may be calculated from the general average—average of the averages—plus or minus an appropriate factor, times the average range. The important feature is that the limits for the sample averages are calculated from the ranges of the samples, and thus from the variation expected from within the samples. The control limits thus provide a test of whether the sample averages fluctuate more than would be expected on the basis of the "within process" variability alone. If the process average is shifting up or down or is otherwise changing, there will be more variation between the samples than within a sample, and some sample averages are likely to fall outside the control limits. If sample averages do fall outside the computed control limits, this suggests that assignable causes are affecting the process averages and that these causes can be found. A "controlled" state exists when the upper limit of the sample ranges falls below the upper range limit and the sample averages fall between the upper and the lower control limits.

An example of the use of control charts is given in chart 5 which shows the weight of "laps" from one of the four scutchers in a blowroom of a cotton mill. The lap is the 100-yard roll of raw cotton which has been carded and scutched and which is to be further processed as yarn. Undue variability in the thickness of the

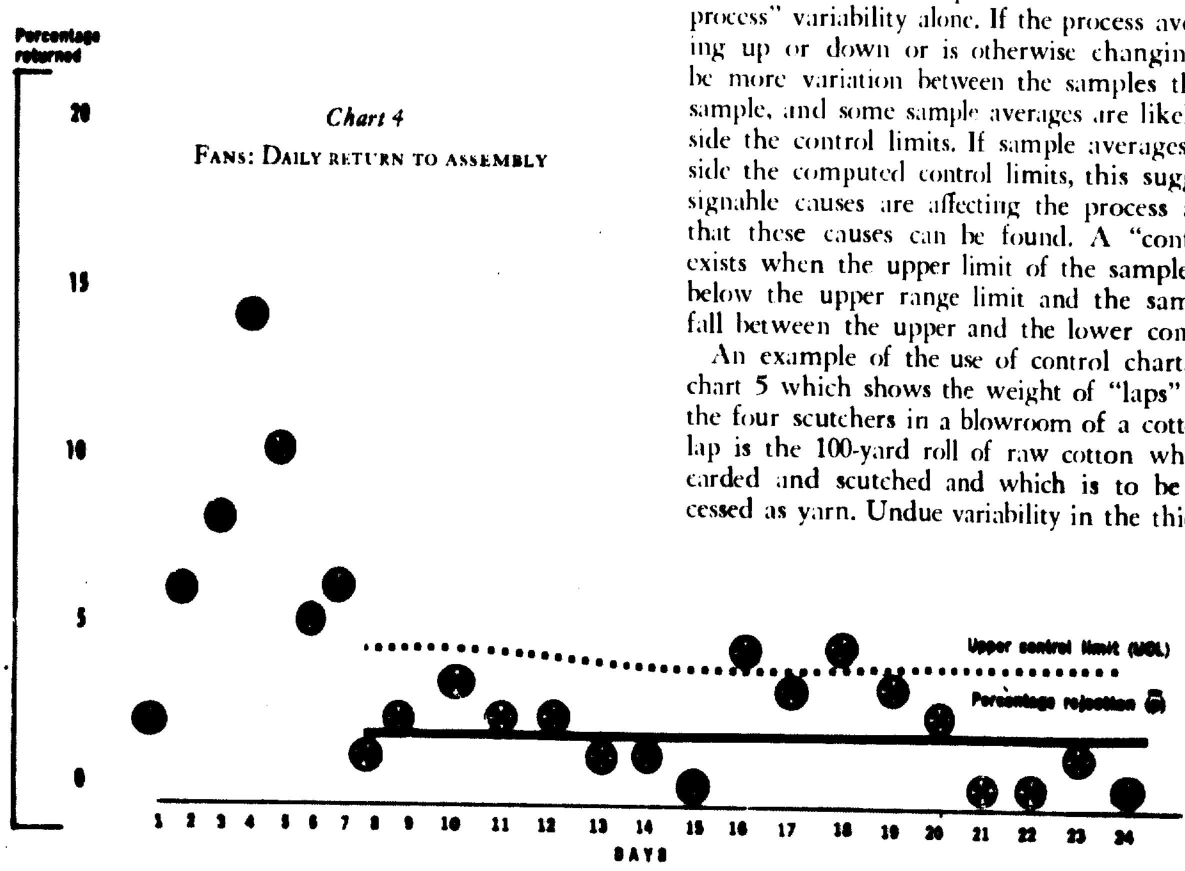


Chart 4

FANS: DAILY RETURN TO ASSEMBLY

cotton, and thus in the weight of the lap, causes undesirable variations in the thickness of the subsequent yarn. The desired weight of lap is 32 pounds 8 ounces and the desired tolerance allowance on the weight of lap is plus or minus 4 ounces.

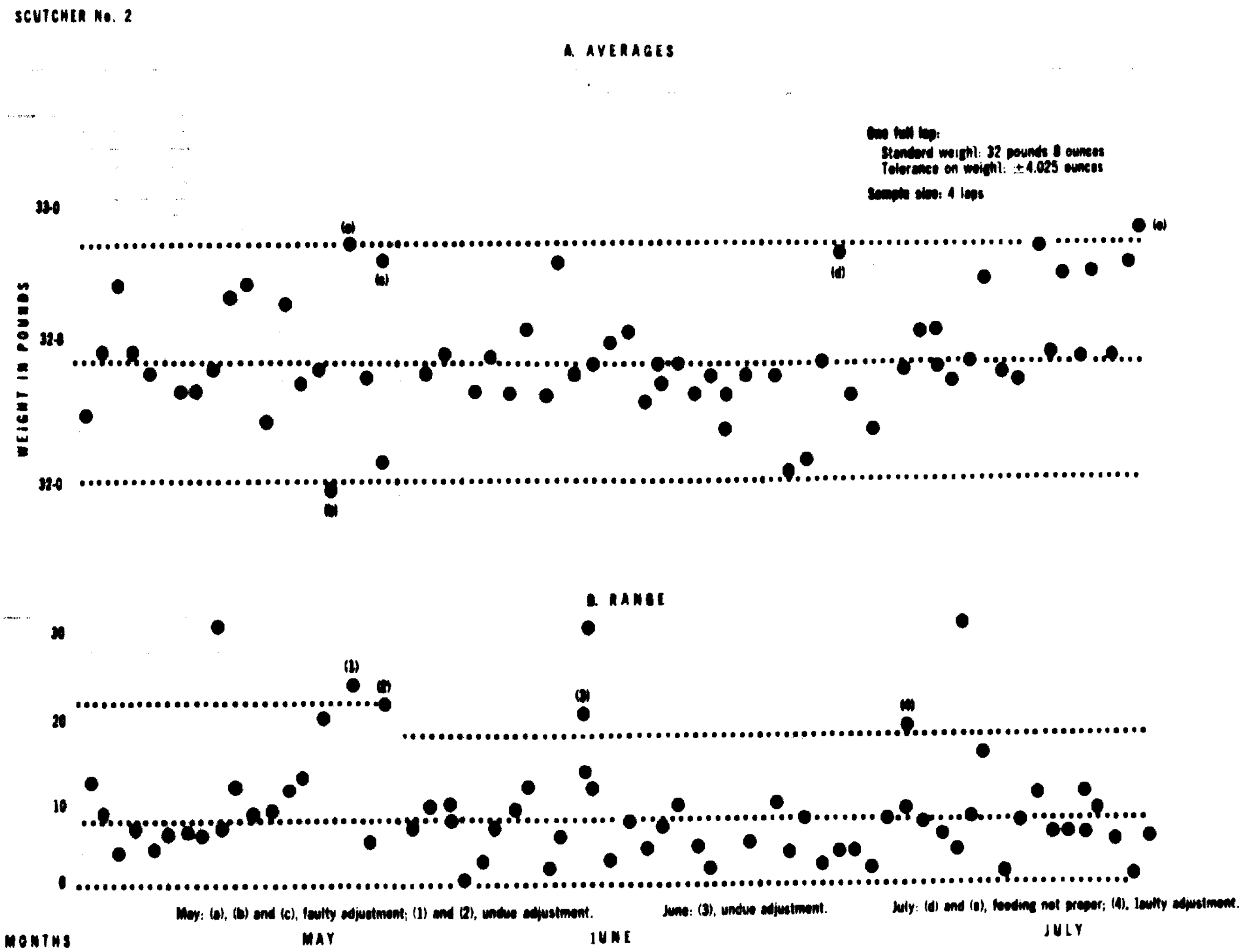
The control chart shown is derived from twenty-five samples of four laps each in three successive months, May, June and July (8). When the chart was begun in May, the variation in weights as shown in chart 5B was greater than that desired. The range points above the control limits indicated lack of control. Investigation of these revealed that unnecessary adjustments had been made. In addition, there were points outside the control limits, as may be seen in chart 5A, indicating that more than necessary variation was being introduced into the process. Investigation and attention helped to improve the process in June and July, although there was still one range point out of limits in each month and one average point out of control in July. The over-all variability of the process as measured by the average range did decrease during these months, but did not narrow down to the desired extent. Continued action was necessary to achieve satisfactory control. The chart, based on a very small proportion of total production, furnished management with knowledge of the process variability which contributed to the adoption of corrective measures.

Acceptance sampling—standardization of inspection

Acceptance sampling is a technique for evaluating the quality characteristics of purchased material; sampling is used in contrast to a complete inspection of the material. Standard sampling test procedures, which relate the size of the sample to the size of the lot and to the quality desired in the incoming material, are well determined. Given the size of lot and the level of inspection desired, the inspector can find from standard tables (9) the size of sample and the acceptance and rejection numbers. The theory of the acceptance and rejection numbers is similar to that which determines the control limits on a control chart. If the number of defectives observed in a sample is equal to or below the acceptance number, the lot of material is accepted; if not, the material is rejected for further screening or some other disposition.

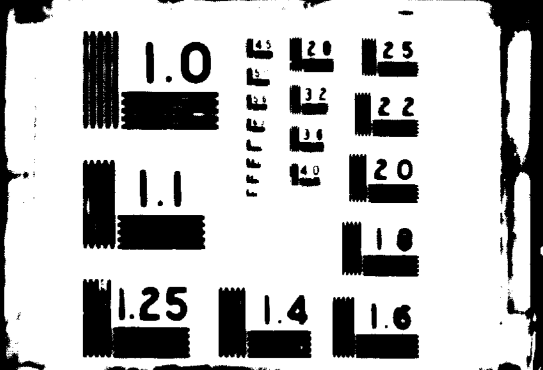
Chart 5

QUALITY CONTROL CHART FOR TWENTY-FIVE COTTON SAMPLES OF FOUR LAPS EACH OVER THE PERIOD MAY TO JULY



74. 10.10

05420



Although the theory of acceptance sampling is statistical, its effectiveness in practice depends to a large extent on the engineering preparation. Proper inspection standards must be pre-engineered so that they not only reflect adequately the quality characteristics desired but also reduce to a minimum any variation in judgement — or in gauging — between one inspector and another. One of the biggest gains that may be derived from acceptance sampling is the elimination of variation among the standards applied by inspectors working on the same material. Once the standards of acceptance have been analysed and laid down, they in turn provide a target towards which production activities can be aimed.

The following example of the use of acceptance sampling relates to the final inspection of completed sewing machines at the point of leaving the plant, or to inspection on arrival at the consuming clothing factory or distributor's premises.

Two principal devices were used to achieve uniformity in inspection. One of these was a standard inspection procedure to be followed by the entire group of inspectors—some twenty in all, many of whom had been working together for a decade. This procedure included a check-off list, on which the inspector could systematically indicate his findings and at the same time make sure that he had covered every requirement. The other device was the selection of standard machines with which machines having defects lending themselves to differences in judgement could be compared. The standard machines were selected in pairs, one of them just meeting the levels of acceptance, the other just failing them. The standard machines were replaced by the inspectors at weekly intervals, to guard against modification of their characteristics due to use. The results are partly illustrated in table 4.

Standardization of inspection directly helped to narrow down the spread between minimum and maximum percentages of rejections as between individual inspectors. The inspection data were reliable enough to be fed back into the process to secure dimensional control of the key components in the machine shop and in the assembly process. The difference between the April and September averages reflects the improvement in both processing and inspection procedures.

Design of experiments

So far, quality control data have been derived directly from given processes and have not allowed for possible inferences beyond the levels of process variables used.

Table 5A

CASTINGS: EXPERIMENT TO DETERMINE PROPER ANNEALING CONDITIONS

	TEST NUMBER							
FACTOR	1	2	3	4	5	6	7	8
Temperature	t	T	T	t	t	T	T	t
Annealing time	a	A	a	A	A	a	A	a
Sand	S	s	s	S	s	S	S	s

Table 5B

AVERAGE BEND OBSERVED IN TESTS FOR THREE MAIN EFFECTS (In degrees for standard specimens)

TEMPERATURE		ANNEALING TIME		SAND	
Low (t)	84.4	Low (a)	86.9	Refractory (s)	90.0
High (T)	93.1	High (A)	90.6	Hematite (S)	87.5

The "design of experiments" is a technique which permits such investigation and which leads to selection of optimum process levels.

The following example describes an experiment to determine the annealing conditions required for obtaining certain physical properties in castings. Three process factors were considered relevant, namely, soaking temperature, annealing time and type of packing sand. Two levels were considered for each factor—a high and low soaking temperature designated respectively "T" and "t", a high and low annealing time designated respectively "A" and "a", and two types of sand, refractory and hematite, designated respectively "S" and "s". An experimental procedure was established in which sixteen test pieces, eight from each of two experimental casts, were arranged so that each combination of the factors above would be tested. The arrangement, which was duplicated for the two experimental casts, is shown in table 5A (10).

After treatment the pieces were subjected to a bend test: the "average" values of bend corresponding to each main effect were obtained under the conditions shown in table 5B.

The figure 84.4 represents the average bend of the eight pieces treated at low temperature, whereas 93.1 is that of the eight treated at high temperature; similarly, the other two pairs of numbers are averages of eight test results relating to two sets of conditions—annealing time and type of sand, respectively. The figures in table 5B represent a three-way subdivision of the sixteen test results obtained in the two sets of experiments using the two experimental casts.

The figure 78.8 in table 5C represents the average bend of four pieces treated at a low level of temperature and a low level of annealing time; similarly, the other figures represent the average of four tests. Sand is not taken into consideration, as observation shows (see table 5D) that the difference between the two types does not affect significantly the bend characteristics. In table 5D, the interaction between sand and each of the other variables, as well as the triple interaction of temperature, time and sand are grouped together in the residual item.

A statistical analysis of variance based on the experimental data—the averages of these are shown in tables 5B and 5C—is given in table 5D.

The analysis of variance shown in table 5D is a statistical method of apportioning the total variation observed in the sixteen tests among its causal factors.

The sixteen tests provide for fifteen degrees of freedom. Of these, three correspond to the differences between the low and high levels of each factor; three others correspond to the two factor interactions—three of which are possible—and one to three factor interaction. In table 5D, only the temperature time interaction is dealt with separately; the other three—because of the very small values of the deviations involved—are grouped together under "residual". The remaining eight degrees of freedom are related to the duplication of each of the eight treatment tests using steels of two different experimental casts. They, in turn, are put together as chance variations or experimental "error". The second column of the table gives the sum of squares of the deviations of individual observations from average bend values, and the third column gives the mean square, that is, the sum of squares divided by the degrees of freedom, which measures the relevant variances. The square root of variance corresponding to "error" provides a measurement of the standard deviation of individual test results which—as is well known—indicates the test-to-test deviations from the mean that might be due to chance in the absence of causal factors.

The analysis of variance presented in table 5D indicates that the statistical variance related to the levels of temperature, as well as to the interaction between temperature and time, is significantly higher than the "error" or chance variance which is the yardstick against which individual variance is measured for statistical significance. It can be seen from the table that most of the variations in the test results are attributable to these two factors; hence, these are the strategically important factors that must be properly controlled in the production process.

The analysis indicates that better bend is obtained with the higher soaking temperature and the higher annealing time. There is, however, an "interaction" effect showing that time gives a desirable result at the lower temperature, but an adverse one at the higher temperature. The best combination tested appears to be, as shown in table 5C, high soaking temperature with low annealing time. Further experiments with respect to these properties could be undertaken to spell out more precisely the optimum conditions.

The results obtained made it possible to improve the quality of the foundry's product which had been low because the process used allowed for low soaking temperature and low annealing time. As regards sand, the difference between the two types did not affect significantly the physical properties of the castings, and selection could be made simply on the basis of relative cost.

Direct experimental methods of this kind can be applied to many processes with a view both to locating trouble spots and determining optimum operating conditions.

*

* *

The examples given above have explained and illustrated the usual quality control procedures—organization of quality data, use of frequency distribution techniques, control charts for attributes and variables, and design of experiments.

Table 5C

AVERAGE BEND OBSERVED IN TWO-WAY CLASSIFICATION OF TEMPERATURE AND TIME
(In degrees for standard specimens)

		TIME a	TIME A
TEMPERATURE	t	78.8	90.0
	T	95.0	91.2

These examples, which illustrate means employed, complement those given in the beginning of this article relating to results obtained. In nearly every plant in which quality controls are introduced, it would be possible to describe gains in productivity due to the employment of one or more of these techniques. In many cases, gains in productivity have been estimated to be as high as 40 per cent. One or more of the following results can usually be obtained:

(*a*) Different rates of output of different units in a plant and uneven rates of acceptance of their products can be equalized on the level reached by the most efficient unit;

(*b*) Waste, scrap and rework can be reduced and quality of product can be improved without increase in cost or changes in production processes;

(*c*) Judgement of quality can be standardized;

(*d*) Maintenance procedures can be made more effective;

(*e*) Raw materials, fuel and other supplies can be utilized more economically;

(*f*) Weights can be controlled and weight units standardized.

Table 5D

ANALYSIS OF VARIANCE IN BEND

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES OF DEVIATIONS	MEAN SQUARE (*variance*)	
Between temperatures	1	306.25	306.25*	
Between annealing times	1	56.25	56.25	
Between packing sands	1	24.00	24.00	
Interaction temperature-time	1	225.00	225.00*	
Residual	3	12.50	4.17	10.23
Error (chance variation)	8	100.00	12.50	
TOTAL	15	725.00		

* Effects significant at the one per cent level.

ONCE MANAGEMENT is convinced of the value of quality control, the question arises of how to introduce it. How should a quality control section be organized and staffed? Should some simple problems be tackled first so that the success achieved would stimulate more difficult endeavours? Should quality control charts be made for every machine and process? To all these questions, the answer is that any of these approaches might be appropriate under given circumstances, bearing in mind that there is no easy way to bring into any plant, whatever its size, what is essentially a revolutionary procedure. Psychological obstacles and technical limitations—fear of innovations, difficulties of communicating with those who may be affected by the changes and of having to train or retrain people—are to be reckoned with. A rather extended period of time is normally required before a new system is established and accepted. Quality control cannot be simply added to an enterprise; if it is to be effective, changes must be introduced in basic organization concepts and methods.

The problem of how to introduce a quality control system was probed by the author in a review of about one hundred plants in some thirty different industries in India. In nearly all cases the objective was to present to management a practical course of action divided into convenient steps, each of which could be implemented in one or two months. In all the industries considered, with the exception of jute and cotton manufacturing, the following five steps, which provide, in a sense, a check-off list of those areas in which the greatest gains can be achieved, were proposed as a normal order of procedure.

(1) Measure outgoing quality;
(2) Determine scrap and rework rates;
(3) Assess utilization of machinery and equipment;
(4) Evaluate incoming materials;
(5) Establish a quality control framework.

In the case of cotton and jute, step 3—study of utilization of machinery—appears to be the most effective first step because immediate gains in spinning and weaving efficiency can be quite easily won thereby.

STEP 1. *Measure outgoing quality*

In nearly all the companies surveyed, the first step in initiating quality control was the development of a means of measuring product quality in relation to the desired specification and to consumer needs and wishes. The reason for this is twofold. First, this provides management with information useful in comparing present quality both with that achieved in the past and that obtained in similar facilities; second, the final product reflects the influence of all the process factors in the plant. In making chairs, sewing machines, fans, soaps, jute and cotton textiles, shoes, and in nearly every other instance, the first question is whether the final product meets both the customer's and the firm's standards of quality and cost. Quality control investigation will show to what extent this is the case and will indicate which process factors must be dealt with to improve the product and reduce its costs.

Measuring outgoing quality is not a simple thing. First, standards of product must be developed or made explicit and methods for determining product quality must be evolved. A usual procedure is to make a classification of defects, grading the types of departure from specifications, or objectives, according to their importance. This must be properly engineered in order to reflect a correct evaluation of the material. The point at which final product quality can be determined must also be considered. For instance, in many industries, as in the manufacture of chairs and office equipment, the final coat of paint may hide objectionable details, so that, to express a final quality judgement, examination should be made before and after painting. "Acceptance sampling" methods are particularly appropriate for evaluating the outgoing product since accurate examination of a few items is more important than casual inspection of large numbers; routine inspection is normally inadequate for the accurate measurement of outgoing quality.

While it is important to measure outgoing quality, it is equally important to determine how good the measure is. What is needed is a measure of quality that is invariant as between inspectors and invariable over time, so as to minimize errors. Very often the error among the inspectors is greater than the variation of the material on which they are working. Like any gauging or measuring process, an inspection evaluation is not proper or useful until the error of measurement is small relative to the variability of the objects being measured. It is not unusual to find screening inspection less than 50 per cent efficient, as shown above in the cases of the glass and jute industries. Many techniques are available to resolve these differences, the direct experiment being foremost.

Foreman checking combers in cotton-spinning mill in Israel

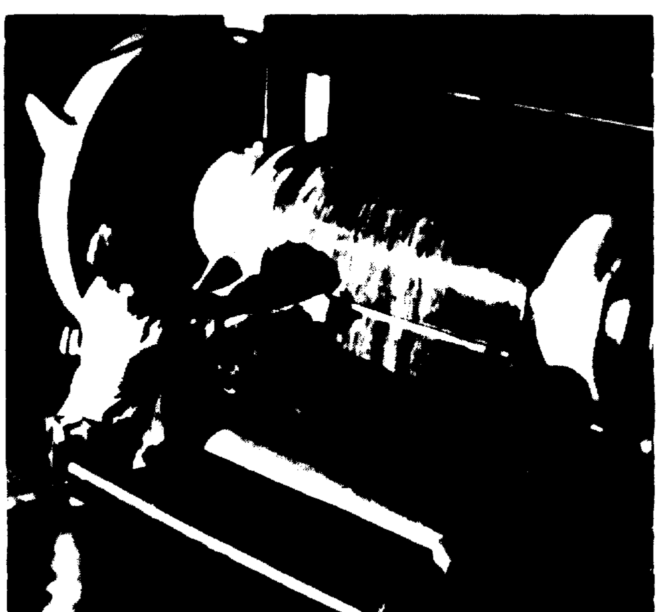
STEP 2. *Determine scrap and rework rates*

Whether or not product quality is satisfactory, the existence of scrap and rework justifies the introduction of quality control. The rate of scrap should be measured and classified by cause, as in the case of defective products at the stage of final product quality evaluation. Scrap is usually encountered at intermediate stages of the process, as a result of improper casting, improper machine setting and many other causes. It is usually possible to determine from technical sources the causes of all possible types of scrap. Grading can then be introduced to determine those phases in the process where stronger controls are needed. These phases may sometimes be revealed by use of control charts, frequency distributions and other devices. When causes cannot be easily determined, it may be necessary to resort to direct experiments as a preliminary step.

Some scrap is unavoidable, and its minimum amount may be determined by engineering methods or by comparison with similar operations either within the plant or in similar industries. The way scrap is disposed of sometimes hides its nature and its magnitude. In the case of "stuck" plates in a pottery plant, nothing can be done except to dispose of the material by dumping or destroying it, while moulds rejected before baking and glazing can be re-used as raw material. In soap plants, rough cakes rejected at the cutting stage go back into the vats as raw material. The volume of "return" or "rework" is seldom considered as important as that of material actually discarded, although it does involve costly labour, machine and plant time. A considerable volume of rework must be scrutinized with the same care as actual scrap in order to achieve the most efficient processing.

STEP 3. *Assess utilization of machinery and equipment*

Relatively simple quality control methods are available for measuring the rate of machine utilization. The method commonly used is known as the "ratio delay method" of sampling or "snap-check reading", and consists of noting or recording the number of machines or other equipment which are not in operation at the time the observer passes by. A given number of observations may be made per day at random time intervals, and a summary of these simple observations, as provided in a control chart, gives quite readily a measure of the percentage of machines in operation.



Checking the processing of polyvinyl sheets in a plastics factory at Split, Yugoslavia

This method can be used, for instance, to measure the rate of utilization of machine tools in a light machinery manufacturing plant or of typewriters in an office. It is used extensively in cotton and jute mills to provide a rapid measure of the efficiency of the spinning or weaving department by counting the number of "ends down", or the number of individual spindles on which the thread is broken, or the number of looms stopped.

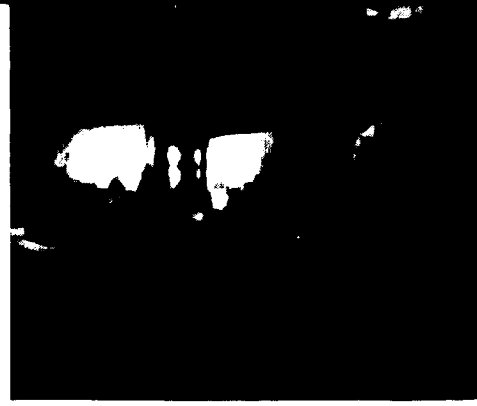
Such measurements of machinery utilization should be supplemented by information as to the causes of stoppage. These can be catalogued and the stopped machines can then be denoted by cause by a system of code numbers. In some textile mills snap-check studies have been used to compare the causes of stoppage between a certain number of the most productive looms and a corresponding number of the least productive ones. Differential studies of this kind provide the basis for remedial action to raise the level of output of the more inefficient machinery, whether by training machine operators, improving maintenance or repair procedures, providing better facilities for handling material, installing better lighting or adopting any of the numerous other measures which influence productivity.

STEP 4. *Evaluate incoming materials*

Quality control methods are useful for controlling the quality of incoming raw materials and purchased parts. Raw materials control may be relatively complex in some cases, such as that of jute manufacturing, where the level of spinning and weaving efficiency determines in large part the necessary raw materials mix. Consistent with colour and grade conditions, cheaper raw materials may be used provided that these can be spun without undue loss in processing efficiency. Control charts relating raw material costs to spinning or weaving efficiency may contribute towards achieving a controlled situation in which raw material and processing costs would be best combined by introducing certain changes in the raw materials used. It is sometimes possible to have a pilot line in which raw material mixes can be tried in actual practice, but, even if this is used, formal quality control methods would still provide a better basis for decision making. Control charts employing correlation theory are important in such instances.

STEP 5. *Establish a quality control framework*

The last and probably the most important objective of a quality control survey in a plant is the setting up of an organization for solving quality control problems. Such



LEFT. *Final inspection of television sets in a Japanese factory*

TOP RIGHT. *Testing electric bulbs in a Pakistani factory*

BOTTOM RIGHT. *Inspecting roll of cloth in Israeli cotton mill*

an organization may vary from a sizable group in a large plant to a few people working possibly part-time in a small establishment; regardless of its size, it must enjoy direct management support and interest. In a small concern, the best way of introducing quality control is to train its management. In the author's experience, nearly all managers who attended training courses were able to initiate effective programmes in their own enterprises. The manager's subordinates collected the necessary information and the manager himself scrutinized and interpreted it. Success achieved in solving one problem led to the tackling of another and, little by little, relatively effective quality control measures were introduced throughout the plant. A manager of a shoe factory who was satisfied with the quality of his production undertook, after the completion of his training, a final product evaluation which revealed, to his astonishment, that, in spite of thorough inspection of partly finished and final products, more than 10 per cent of the latter failed to meet specifications. This led him to take the necessary steps in the tanning process and in the cutting procedures to attain a controlled process within specifications. Where quality control functions are entrusted to a team not immediately connected with management, it should enjoy an independent status and should not be under the direct supervision of those whose efforts it is trying to evaluate. When quality control is entrusted to an operating division of a company, it is usually not able to deal effectively with major quality problems and is reduced to a routine application of techniques. The same situation sometimes occurs when, for instance, quality control is introduced by the owners of a plant without first winning the confidence and support of the managerial personnel. To be successful, a programme of quality control should win a minimum degree of co-operation from both supervisory staff and labour. It is their operations that are to be examined and improved. This may have major effects upon their jobs and earnings and, to avoid suspicion and opposition, what is being done should be explained by management and accepted by those concerned.

NATIONAL PROMOTION OF QUALITY CONTROL

QUALITY CONTROL HAS grown and developed in different patterns in the many countries where it is now utilized. In the United States, it grew from the war-time interest in increasing national production. War-time courses of the ten-day variety were given under the auspices of the War Production Board and were enthusiastically received. Groups of students formed local quality control organizations; in Buffalo, such a group began publishing a journal. These groups were banded together in 1946 into a national organization, the American Society for Quality Control, which has grown in this twelve-year period to well over 10,000 members and is now one of the largest professional societies in the United States.

The society has over a hundred local chapters, each of which holds a monthly meeting. The society also holds a general annual meeting and annual national meetings for each of its six divisions, as well as regional meetings. It publishes a technical journal entitled *Industrial Quality Control*.

Knowledge of quality control expands continuously and new developments are disseminated throughout the industrial field by publications of the society. College and university courses in quality control and research in universities and private laboratories have had an important influence. Recently, United States government specifications required contractors to develop satisfactory quality control systems with a view to decreasing government inspection. Consumers' organizations have added pressure for improvement of consumer product quality.

In Japan, the Japanese Union of Scientists and Engineers, founded in 1949, has been largely responsible for the growth and development of quality control work. For a time its approach to quality control was limited to technical and mathematical research. With the help of W. Edwards Deming, the quality control movement, since 1950, has received an impetus which has had a profound effect on the development of the Japanese post-war economy. The emphasis that Japan has placed on the quality of goods for export and on export quality evaluation procedures has strengthened the role of quality control in Japanese industry.

The union is supported by private membership with little or no subsidy from the Japanese Government. It holds many lectures and training programmes, works closely with universities in establishing courses and research work in the field of quality control and statistics and publishes several journals, including ***Statistical Quality Control, Operations Research as a Management Science*** and ***Reports of Statistical Application Research.***

In India, work in quality control has been recognized for some time. The Indian Society for Quality Control was established in 1948, following a visit by Dr. Walter Shewhart, but has not grown in membership much beyond its original size and its influence appears to be limited to Calcutta. This society publishes a bulletin. Another small society, the Quality Control Association, has been established in Bangalore. A United Nations team of experts headed by Professor Ellis Ott visited India in 1952 under the auspices of the Indian Statistical Institute and gave training courses in the four principal cities. As a result, full-time statistical quality control units were established by the Indian Statistical Institute. These units, now six in number, are financed by government subsidy and by membership fees of member companies, in return for which consulting services are provided on a regular basis. These units have recently grown in size and stature and contribute significantly to the industrial development of the country. In addition, a National Productivity Council has been established as a government-sponsored organization engaged in promoting the development and use of productivity techniques, including quality control. Although much has been done to foster quality control in India, there is great opportunity for further increasing the use of these techniques.

This review suggests several generalizations concerning the development of quality control in under-developed countries. First, there is need for assistance from a central body to start the movement, as was the case of the War Production Board in the United States and the Indian Statistical Institute in India. Second, the role of training courses, particularly of on-the-job training of plant personnel, is of great importance; however, while training courses are necessary, they are not sufficient to spread the movement. Third, technical assistance by foreign experts is in many cases indispensable. Fourth, the development of a national society of people working together in the field of quality control is highly desirable and should receive encouragement. Fifth, promotion of quality control should be integrated with broader national policies aimed at fostering higher quality in domestic production, such as the policies of government purchase specifications in the United States, of control of export quality in Japan, and the productivity drive in India.

As has already been stated, quality control developed most rapidly when associated with steps to utilize a country's resources with maximum efficiency, in periods of scarcity or national emergency. For under-developed countries, which by definition are short of equipment, raw materials and skills, the need to use resources more efficiently is a matter of great urgency, as acute, in fact, as that prevailing during the war-time and post-war years in the United States or in Japan; as in these countries, quality control can make a significant contribution to this effort.

References

(1) Shewhart, W. A., *Economic Control of Quality of Manufactured Product*, D. Van Nostrand Co., Inc. (New York, 1941).

(2) Deming, W. Edwards, "Statistical techniques in industry as a national resource", *I. S. Q. C. Bulletin*, vol. 1-1, Indian Society for Quality Control (Calcutta, India), October 1953, pages 29 to 37.

(3) Burr, Irving W., *Engineering Statistics and Quality Control*, McGraw-Hill Book Co., Inc. (New York, 1953).

(4) Duncan, Acheson J., *Quality Control and Industrial Statistics*, revised edition, Richard D. Irwin, Inc. (Homewood, Illinois, 1959).

(5) Kulkarni, K. N., Rao, A. L. A. and Varadachari, K. V., "Statistical quality control in Jyoti foundry", presented at the Conference on Statistical Quality Control, Calcutta, December 1958.

(6) Ramamurthy, K. G., "SQC in automatic glass industry", presented at the Conference on Statistical Quality Control, Calcutta, December 1958.

(7) Rao, W. R., "Outgoing quality in glass industry", presented at the Conference on Statistical Quality Control, Calcutta, December 1958.

(8) De, M. K., "Quality control in the blowroom of a cotton spinning mill," presented at the Conference on Statistical Quality Control, Calcutta, December 1958.

(9) United States Military Standard 105A Sampling Procedures and Tables for Inspection by Attributes.

(10) Prasad, C. R. and Munshi, Madhab, "Experiments on chemical composition and annealing conditions", presented at the Conference on Statistical Quality Control, Calcutta, December 1958.

A New Impetus to Industrial Development: The United Nations Special Fund

In October 1958 *a new form of international assistance came into being with the establishment of the United Nations Special Fund. The function of this new body, as stated in General Assembly resolution 1240 (XIII), was to facilitate "capital investment . . . by creating conditions which would make such investments either feasible or more effective".*

By this decision to create a new piece of international machinery designed to promote economic development, the United Nations was seeking primarily to enlarge the scope of the existing programmes of technical assistance and of the existing international lending agencies so as to include, for the first time, the financing of projects of a pre-investment nature. Such projects, which would extend over a wide field of activities basic to economic development, would cover all stages of work preceding the actual investment of capital in productive facilities. The purpose of this article is to show some of the ways in which the Special Fund may exercise its mandate to foster investment in one of the major fields of development, that of industry. Discussion of this subject will be prefaced by a brief outline of the Fund's purposes and functions.

PURPOSES AND FUNCTIONS

The Special Fund is not a lending institution. Its assistance is normally given on a grant basis. It may be described as a "new look" in technical assistance.

The "new" quality of the Special Fund is, briefly, the flexibility with which it can utilize its resources. Unlike the United Nations Expanded Programme of Technical Assistance which, in order to take account of the wide variety of needs for technical assistance, has had to spread its resources over a large number of projects and allocate its funds on a year-to-year basis, the Special Fund is specifically designed to give concentrated and sustained assistance to a limited number of selected projects involving relatively heavy budgetary commitments and extending usually over a period of several years. It is thus able to provide technical assistance "in depth".

Further, while the Expanded Programme distributes its resources geographically under the procedure of country programming, the Special Fund develops its programmes on a project basis. The Fund does not make any *a priori* allocation of funds as between countries or between basic fields of assistance, although it will, over a period of years, give consideration to achieving a balanced geographical distribution of its aid among the beneficiary countries. Projects are usually national in scope; however, projects requested by a group of countries or even by an entire region are eligible for assistance.

Projects appropriate for Special Fund financing should have prospects of early and tangible results in advancing the economic and social development of the country or countries concerned; those which would facilitate new capital investments would be particularly suitable. For that reason, the Fund would assist research already at an advanced stage and near the point of commercial use, but not basic research—for instance, in physics, chemistry or economics. Requests for surveys of resources should be specific and based on reliable preliminary information; prompt action should follow the conclusion of the study. Appropriate and effective machinery should be available in the requesting country to give effect to the recommendations; in some cases, the setting up of a special organization to take the necessary action should be contemplated by Governments at the earliest stages of the project. Governments should also be prepared, at the time of submitting their requests, to take the legislative measures which might be required to give effect to the recommendations, subject, of course, when necessary, to parliamentary approval.

Participation in the Special Fund is open to Members of the United Nations, its specialized agencies and the International Atomic Energy Agency. The participating Governments make voluntary contributions to the Fund, normally on an annual basis, but are expected, whenever possible, to give pledges for a number of years ahead.

The administration of the Special Fund is under the general authority of the Economic and Social Council and the General Assembly of the United Nations. General policy guidance of the Fund's operations is provided by a Governing Council of eighteen members, nine representing economically advanced countries, and nine less developed countries. The Council usually meets twice a year and has final authority regarding the projects and programmes recommended by the Fund's Managing Director.

The Special Fund does not itself execute the projects that it finances. This is entrusted to the organization of the United Nations family within whose competence the project falls. This organization enters into a formal agreement with the Special Fund to act as executing agency for the project. When no appropriate international agency exists for the particular project, the Managing Director is authorized to contract the services of some outside organization. In each case arrangements for the execution of the project are subject to prior approval of the requesting Government.

The scope of the Special Fund's assistance covers, broadly, the following basic fields: resources, including manpower; industry, including handicrafts and cottage industries; agriculture; transport and communications; building and housing; health; education; statistics, and public administration.

Projects qualifying for assistance can take various forms or combinations of forms, such as surveys, research and training, demonstrations—including pilot projects—and establishment of centres and institutes. Implementation may involve provision of regular staff and *ad hoc* experts, equipment, supplies and services, demonstration facilities and other appropriate means. The grant may also cover fellowships in so far as they are an integral part of a project financed by the Fund.

Normally, the Special Fund will not finance projects requiring less than $250,000. There is no statutory upper limit to the size of projects, but the Fund has, evidently, to be guided by the total amount of resources available to it. The Fund will not finance the local currency costs of a project, nor will it contribute towards the cost of building or construction. The requesting Government would be expected to provide all locally available services, such as those of technicians, and supplies, office equipment, and the like.

ASSISTANCE IN THE FIELD OF INDUSTRY

The Special Fund uses its resources to facilitate capital investment through six principal types of action: resource surveys, pre-investment studies, research institutes, small-scale industry advisory services, training institutions and pilot plants and demonstration units.

Surveys of resources

The Fund contributes towards the cost of surveying all types of resources—mineral, water, land, forest, other industrial raw materials and manpower—needed for economic development, subject, however, to three limitations: (*a*) as mentioned above, the Special Fund contributes only to surveys likely to be followed by immediate action; (*b*) its minimum contribution being $250,000 and Governments being expected to pay at least one-third and preferably one-half of the cost of a survey, the Fund would generally consider only projects whose total cost is expected to be in excess of $375,000; (c) smaller projects should be referred by Governments to the Expanded Programme of Technical Assistance.

Surveys of resources would usually be preceded by some kind of review of the work already done. Such a "survey of surveys" would bear on material prepared under instructions of government authorities, international agencies or private interests. Information would be summarized and assessed and areas for further investigation mapped out. An important task also would be to ascertain the outcome of recommendations made in earlier reports. If recommendations have failed to lead to further action, an investigation would obviously be called for. Clearly, before embarking on the effort and expense of another survey, both the requesting country and the Special Fund will want to be satisfied that such action is justified.

The existing information being assessed, the next step is to formulate the scope of the survey work to be done and define the terms of reference of the survey mission. This work might be done by one or several experts to be recruited by the responsible agency of the United Nations family or, in some cases, an outside consulting firm might be contracted to do it.

Pre-investment surveys, or "feasibility" reports

Resource surveys may lead to recommendations for the establishment of industrial undertakings but, as a rule, such recommendations will not explore in detail the commercial feasibility of the proposed projects. Special investigations are required for that purpose. In such cases, the intervention of the Special Fund is subject to the same financial limitations as in the case of surveys. In particular, for most factories of the size generally established in under-developed countries, the cost of a feasibility report would be well under the figure cited earlier, and requests for less expensive feasibility studies would be best referred to the Expanded Programme of Technical Assistance. This means that only in the case of projects involving very large investments—amounting to several million dollars—could the financing of the feasibility study be considered by the Special Fund.

A feasibility report would consist of a technical, economic and marketing evaluation of any or all of the following aspects: a detailed technical and economic analysis of the project, including an evaluation of the marketing aspects; recommendations on a site with particular reference to water supply, power, transport and other utilities; approximate cost of the project at a selected site (if no site has been selected, a theoretical layout could be suggested); estimate of optimum production capacity; analysis of the raw materials available (for example, in the case of a cement plant, an analysis of the quality of the clay and limestone); guidance on the amount of financing required, in both local currency and foreign exchange, for plant, equipment and working capital.

The final stage—seeking funds for the emerging project from national or international, public or private sources—is outside the scope of activities of the Special Fund. However, to be fully effective, the feasibility report might properly contain a draft "prospectus", as it were, of the project. The preparation of such a prospectus—in effect, a suitably presented summary of the information included in the report—might also be financed by the Special Fund.

A feasibility report involving expert collection of information and evaluation of the various aspects of a project is a costly operation. It would be undertaken only when the findings of the resource survey are sufficiently encouraging as far as the possible commercial exploitation of the resource is concerned. In certain cases, the Special Fund might finance a joint report covering both resource survey and feasibility study.

Research institutes

The Special Fund will contribute towards the cost of technological institutes or laboratories for industrial research. The tasks of such institutes are to analyse and test industrial raw materials, processes and products, and provide engineering, economic and managerial assistance to increase production, improve quality and operating efficiency, reduce costs, and so on. Institutes might also undertake market research, study problems of manpower and industrial organization and provide training.

Technological institutes may sometimes be organized on a regional basis to take advantage of economies of scale; in this way costly equipment and staff may be better utilized. This is particularly the case when the scientific and engineering problems to be studied are common to several neighbouring countries. However, a regional organization may create certain complex organizational problems and, unless the element of economies of scale is a primary consideration, a national organization is to be preferred.[1] In any event, the Fund would not contribute towards setting up new institutes if the work they are to do can be done more cheaply and effectively in existing institutes in neighbouring countries.

The contribution of the Special Fund to the establishment or expansion of institutes will normally be limited to a period of five years, and will be expected to taper off in the latter part of this period, so that the Government will gradually take over the financial responsibility for operating the institute. In its request, the Government concerned should, therefore, make provision for assuming increasing financial responsibility. Should foreign experts still be required upon termination of the Special Fund grant, payment of their salaries would be taken over by the Government. The Special Fund is willing to assist nationals of a country to take over the responsibilities of the foreign experts by providing a number of fellowships for study abroad. The number of fellowships and the subjects of study should be strictly related to the work of the institute.

---

[1] *See* United Nations, "Establishment of Technological Research Institutes in Under-developed Countries", *Bulletin on Industrialization and Productivity*, No. 2 (sales number: 59.II.B.1).

Small-scale industry advisory services

In many countries, indigenous handicrafts or small scale industries need assistance to improve techniques, select equipment, study raw materials or survey markets. Advice in such matters may be provided by special agencies with mobile units and field personnel.

The success of such agencies is generally contingent upon the availability of funds to lend to small entrepreneurs for purchasing new equipment or executing projects as the result of advice tendered to them. The Special Fund will consider making a grant to cover all or part of the foreign exchange costs of establishing such agencies only if it rests assured that investment funds are available for translating into practice the agency's recommendations.

Training institutions

In the field of education, the Special Fund operates at two levels—vocational training and higher technological training at the university level. It does not contribute towards establishing or operating technical institutes to impart basic artisan skills, nor does it contribute directly to training artisans. It confines its assistance to higher vocational training, especially that of instructors for technical schools, foremen and other supervisory personnel. Assistance is also given for training in certain advanced skills, such as aircraft maintenance.

At the university level, the Special Fund contributes to the cost of faculties of engineering and architecture. It also gives assistance to post-graduate training in administration and managerial techniques, and to courses in development planning.

Pilot plants and demonstration units

The Special Fund is not a source of investment capital and does not normally supply finances for manufacturing concerns. Its participation in pilot plants is justified only where the plant is needed as a stage between laboratory research and full-scale commercial production; such a plant is usually of less than commercial size.

The Fund will consider assistance to pilot factories whose object is to test new uses for local materials, develop new production processes not previously tested commercially in any country, or manufacture new products not previously made elsewhere. It will not give financial assistance to a pilot plant unless one of these three elements is involved. In particular, it will not participate in a new pilot factory whose object is merely to manufacture a product not previously made in the country concerned, or to test a process not previously used there, provide training to staff unfamiliar with the process, test the reaction of the public to the product or encourage the public to use the product.

Before supporting a pilot factory, the Fund will require evidence that there has been adequate investigation of raw materials, technical skills, factory design, production flows and other elements requisite to successful industrial production. The Fund will also need assurance that the management will be competent and experienced.

CONTRIBUTION OF THE ORGANIZATIONS OF THE UNITED NATIONS FAMILY TO THE OPERATIONS OF THE SPECIAL FUND

The Special Fund works in close co-operation with the secretariats of the United Nations, the specialized agencies and the International Agency for Atomic Energy. When serving as executing agencies for the Special Fund, these organs follow up the projects assigned to them from inception to completion. The Department of Economic and Social Affairs of the United Nations Secretariat will generally serve as executing agency for most projects in the field of industry.

In some cases, national authorities may be assisted by United Nations personnel in formulating requests for Special Fund assistance; this is most likely to happen when an expert assigned to a country under the regular or expanded technical assistance programme finds himself confronted with a problem of such a type and scope as to justify request for Special Fund co-operation. The expert's participation in the drafting of the request might, in such a case, be of great value. It must, however, be clearly understood that the Special Fund is an autonomous agency within the United Nations. Commitments cannot be made on its behalf by the specialized agencies, or by any of the departments of the United Nations. Correspondence on Special Fund matters should be addressed directly to the Special Fund, or to its agents in the field—the resident representatives of the Technical Assistance Board, who have also been appointed as representatives of the Managing Director of the Special Fund. Government requests for assistance should be presented to the Resident Representative concerned.

Evaluation of project requests

Appraisal of requests involves research into the background of the proposed project. In the case of industrial projects for which the Department of Economic and Social Affairs is executing agency, the Fund avails itself of the experience of the various divisions or branches of the Department dealing with economic development, including industrial development, water resources and energy, transport, and housing and planning. The co-operation of the appropriate division of the Department may be secured for checking and assessing the material made available by the "survey of surveys", and for formulating the terms of reference of the mission to be financed by the Special Fund. Proposals for the establishment of technological institutes, the erection of pilot plants and other relevant projects would also be submitted to the Department for its views.

When necessary, the Special Fund may arrange for one or several consultants to visit the country for a short time to scrutinize the application or carry out preparatory work, in consultation with the Government. The recommendations of these consultants, however, are not binding on the Special Fund. Where the preparatory work cannot be completed within six months, Governments are referred to the United Nations Expanded Programme of Technical Assistance, under which longer-term expert help can be provided.

Burmese trainees checking calibration of a fuel pump in the Rangoon Diesel Training Centre

Execution of projects

The duties of United Nations organizations serving as executing agencies consist of preparing a plan of operations for the project, which includes scheduling the work, making financial and administrative arrangements for it, and ensuring that it proceeds smoothly. The Executing Agency makes arrangements for engaging and briefing experts, purchasing equipment, supervising progress by reviewing reports and, if necessary, by visiting the mission, and maintaining financial accounting. It keeps the Managing Director of the Special Fund periodically informed of the progress of the project; upon completion of the project, it assesses the results.

*

* *

The Special Fund can spur the economic development of under-developed countries and, in particular, their industrialization. The value of its contribution will largely depend upon the amount of resources at its disposal and the quality of the projects it will be called upon to assist. The latter condition is, undoubtedly, fundamental. Outlays which are relatively modest in comparison with certain government expenditures can, when applied to well-chosen "catalytic" projects, set in motion a process of development. The task of sustaining and expanding this process is the responsibility of the Governments concerned.

Group of Japanese experts participating in the United Nations Mekong development scheme

The cover illustration is by courtesy of the Harnischfeger Corporation, Welding Equipment Division, Milwaukee, Wisconsin; the photograph on page 6, by courtesy of Electricité de France, Paris; the photographs on pages 7, 11 (top), 17 and 60 are by courtesy of Standard Oil Company (New Jersey); the photograph on page 10 (top) is by courtesy of the Swedish State Power Board, Stockholm; that on page 10 (bottom), by courtesy of Imatran Power Ltd., Helsinki; that on page 11 (bottom), by courtesy of Electricité de France (by H. Baranger, Paris); that on page 12, by courtesy of Österreichische Draukraftwerke, AG., Klagenfurt; that on page 14, by courtesy of the Embassy of the Union of Soviet Socialist Republics, Washington, D.C.; that on page 15 (left), by courtesy of the Ministry of Mining and Power, Warsaw; the picture of the circular saw, left, second row from bottom of page 26, is by courtesy of the H. K. Porter Company, Inc., Disston Division, Philadelphia, Pennsylvania; the remaining photographs on page 26 and those on page 27 are by courtesy of the Netherlands Economic Institute, Rotterdam; those on pages 31 (right), 41, 45 (top right and bottom) and 46, by courtesy of the Indonesian Information Office, New York; the photograph on page 32 is by courtesy of the American Welding Society, New York; figures 1 through 9 on pages 34, 35 and 36 are by courtesy of the Central Scientific Research Institute of Technology and Machine Building, Moscow; the photographs on pages 38 and 58 (left) are by courtesy of the Consulate General of Japan, New York; those on pages 39, 40, 45 (top left) and 58 (top right), by courtesy of the Consulate General of Pakistan, New York; the photograph on page 47 is by courtesy of the Information Service of India.

SALES AGENTS FOR UNITED NATIONS PUBLICATIONS

ARGENTINA
Editorial Sudamericana, S.A., Alsina 500, Buenos Aires.

AUSTRALIA
Melbourne University Press, 369 71 Lonsdale Street, Melbourne C. 1.

AUSTRIA
Gerold & Co., Graben 31, Wien, 1.
B. Wüllerstorff, Markus Sittikusstrasse 10, Salzburg.

BELGIUM
Agence et Messageries de la Presse, S.A., 14-22, rue du Persil, Bruxelles.

BOLIVIA
Librería Selecciones, Casilla 972, La Paz.

BRAZIL
Livraria Agir, Rua Mexico 98-B, Caixa Postal 3291, Rio de Janeiro.

BURMA
Curator, Govt. Book Depot, Rangoon.

CAMBODIA
Entreprise khmère de librairie, Phnom-Penh.

CANADA
The Queen's Printer, Ottawa, Ontario.

CEYLON
Lake House Bookshop, Assoc. Newspapers of Ceylon, P.O. Box 244, Colombo.

CHILE
Editorial del Pacífico, Ahumada 57, Santiago.
Librería Ivens, Casilla 205, Santiago.

CHINA
The World Book Co., Ltd., 99 Chung King Road, 1st Section, Taipeh, Taiwan.
The Commercial Press, Ltd., 211 Honan Rd., Shanghai.

COLOMBIA
Librería Buchholz, Bogotá.
Librería América, Medellín.
Librería Nacional, Ltda., Barranquilla.

COSTA RICA
Imprenta y Librería Trejos, Apartado 1313, San José.

CUBA
La Casa Belga, O'Reilly 455, La Habana.

CZECHOSLOVAKIA
Československý Spisovatel, Národní Třída 9, Praha 1.

DENMARK
Einar Munksgaard, Ltd., Nørregade 6, København K.

DOMINICAN REPUBLIC
Librería Dominicana, Mercedes 49, Ciudad Trujillo.

ECUADOR
Librería Científica, Guayaquil and Quito.

EL SALVADOR
Manuel Navas y Cía., 1a. Avenida sur 37, San Salvador.

ETHIOPIA
International Press Agency, P.O. Box 120, Addis Ababa.

FINLAND
Akateeminen Kirjakauppa, 2 Keskuskatu, Helsinki.

FRANCE
Éditions A. Pédone, 13, rue Soufflot, Paris (Ve).

GERMANY
R. Eisenschmidt, Schwanthaler Strasse 59, Frankfurt/Main.
Elwert & Meurer, Hauptstrasse 101, Berlin-Schöneberg.
Alexander Horn, Spiegelgasse 9, Wiesbaden.
W. E. Saarbach, Gertrudenstrasse 30, Köln (1).

GHANA
University Bookshop, University College of Ghana, P.O. Box Legon

GREECE
Kauffmann Bookshop, 28 Stadion Street, Athènes.

GUATEMALA
Sociedad Económico-Financiera, 6a Av. 14-33, Guatemala City.

HAITI
Librairie "A la Caravelle", Port-au-Prince

HONDURAS
Librería Panamericana, Tegucigalpa

HONG KONG
The Swindon Book Co., 25 Nathan Road, Kowloon.

ICELAND
Bokaverzlun Sigfusar Eymundssonar H. F., Austurstraeti 18, Reykjavik

INDIA
Orient Longmans, Calcutta, Bombay, Madras, New Delhi and Hyderabad
Oxford Book & Stationery Co., New Delhi and Calcutta.
P. Varadachary & Co., Madras.

INDONESIA
Pembangunan, Ltd., Gunung Sahari 84, Djakarta.

IRAN
"Guity", 482 Ferdowsi Avenue, Teheran.

IRAQ
Mackenzie's Bookshop, Baghdad

IRELAND
Stationery Office, Dublin.

ISRAEL
Blumstein's Bookstores, 35 Allenby Rd. and 48 Nachlat Benjamin St., Tel Aviv.

ITALY
Libreria Commissionaria Sansoni, Via Gino Capponi 26, Firenze, and Via D. A. Azuni 15/A, Roma.

JAPAN
Maruzen Company, Ltd., 6 Tori-Nichome, Nihonbashi, Tokyo.

JORDAN
Joseph I. Bahous & Co., Dar-ul-Kutub, Box 66, Amman.

KOREA
Eul-Yoo Publishing Co., Ltd., 5, 2-KA, Chongno, Seoul.

LEBANON
Khayat's College Book Cooperative, 92-94, rue Bliss, Beirut.

LIBERIA
J. Momolu Kamara, Monrovia.

LUXEMBOURG
Librairie J. Schummer, Luxembourg.

MEXICO
Editorial Hermes, S.A., Ignacio Mariscal 41, México, D.F.

MOROCCO
Bureau d'études et de participations industrielles, 8, rue Michaux-Bellaire, Rabat.

NETHERLANDS
N.V. Martinus Nijhoff, Lange Voorhout 9, 's-Gravenhage.

NEW ZEALAND
United Nations Association of New Zealand, C.P.O., 1011, Wellington

NORWAY
Johan Grundt Tanum Forlag, Kr. Augustsgt. 7A, Oslo.

PAKISTAN
The Pakistan Co-operative Book Society, Dacca, East Pakistan.
Publishers United, Ltd., Lahore
Thomas & Thomas, Karachi, 3.

PANAMA
José Menéndez, Apartado 2052, Av. 8A, sur 21-58, Panama

PARAGUAY
Agencia de Librerías de Salvador Nizza, Calle Pte. Franco No. 39-43, Asunción.

PERU
Librería Internacional del Peru, S.A., Lima.

PHILIPPINES
Alemar's Book Store, 769 Rizal Avenue, Manila.

PORTUGAL
Livraria Rodrigues, 186 Rua Aurea, Lisboa.

SINGAPORE
The City Book Store, Ltd., Collyer Quay

SPAIN
Librería Bosch, 11 Ronda Universidad, Barcelona.
Librería Mundi-Prensa, Castello 37, Madrid.

SWEDEN
C. E. Fritze's Kungl. Hovbokhandel A-B, Fredsgatan 2, Stockholm.

SWITZERLAND
Librairie Payot, S.A., Lausanne, Genève.
Hans Raunhardt, Kirchgasse 17, Zürich 1.

THAILAND
Pramuan Mit, Ltd., 55 Chakrawat Road, Wat Tuk, Bangkok

TURKEY
Librairie Hachette, 469 Istiklal Caddesi, Beyoglu, Istanbul.

UNION OF SOUTH AFRICA
Van Schaik's Bookstore (Pty.), Ltd., Box 724, Pretoria.

UNION OF SOVIET SOCIALIST REPUBLICS
Mezhdunarodnaya Knyiga, Smolenskaya Ploshchad, Moskva

UNITED ARAB REPUBLIC
Librairie "La Renaissance d'Egypte", 9 Sh. Adly Pasha, Cairo

UNITED KINGDOM
H. M. Stationery Office, P.O. Box 569, London, S.E. 1.

UNITED STATES OF AMERICA
International Documents Service, Columbia University Press, 2960 Broadway, New York 27, N. Y.

URUGUAY
Representación de Editoriales, Prof. H. D'Elía, Plaza Cagancha 1342, 1° piso, Montevideo.

VENEZUELA
Librería del Este, Av. Miranda, No. 52, Edf. Galipán, Caracas.

VIET-NAM
Librairie-Papeterie Xuân Thu, 185, rue Tu-Do, B.P. 283, Saigon

YUGOSLAVIA
Cankarjeva Založba, Ljubljana, Slovenia.
Državno Preduzeće, Jugoslovenska Knjiga, Terazije 27/11, Beograd.
Prosvjeta, 5, Trg Bratstva i Jedinstva, Zagreb.

[60B1]

Orders and inquiries from countries where sales agents have not yet been appointed may be sent to: Sales and Circulation Section, United Nations, New York, U.S.A.; or Sales Section, United Nations, Palais des Nations, Geneva, Switzerland.

Printed in U.S.A. **Price: $U.S. 0.75; 5/- stg.; Sw.fr. 3.00 (or equivalent in other currencies)** **00024-April 1960-4,300**

74. 10. 10