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D03612

Distr.
LIMITED

ID/WG.110/3
6 October 1971

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Workshop on Creation and Transfer
of Metallurgical Know-How

Jamshedpur, India, 6 - 10 December 1971

TECHNICAL CONSULTANCY SERVICES AND DEVELOPMENT OF METALLURGICAL KNOW-HOW FOR THE DESIGN AND OPERATION OF NON-FERROUS METALLURGICAL PLANTS IN DEVELOPING COUNTRIES AND REGIONS [1]

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id.71-7864

Synopsis

Short review of the peculiarities involved in the treatment of non-ferrous ores in comparison with other raw materials.

During the execution of a project for the beneficiation of ores and the smelting and refining of metals, several problems have to be solved which need the application of different kinds of know-how.

a) Process know-how : metallurgical and economic considerations

b) Project know-how : organization of plant design and construction

c) Management know-how : optimal operation of plant

The successive steps, including the consultancy services of a project, are outlined and it is demonstrated wherever know-how is applied. The possible ways for the development and transfer of know-how are critically summarized.

Introduction

1. The most important metal for a country in modern times is steel. Besides iron and steel, there is a large number of other metals which have lower production rates but are also of great importance in the technical and economic field. The value of these metals, to which belong copper, aluminium, zinc and lead, per unit of weight or volume is much higher than that of iron. The value of the world production of non-ferrous metals compared with that of iron production is of the same order. What makes it important and interesting for the developing countries is the fact that the raw materials for these metals, the ores, nowadays are found mainly in the developing countries, whereas they are consumed mainly in the industrial areas.

2. The dependence of the industrial countries on foreign raw materials is not older than 100 years. Formerly these countries treated their own ores and produced the metals for their own consumption. Mining, ore dressing and smelting are among the oldest industrial activities in the history of mankind. They were practised long before the different fields of exact science had been developed. This fact should not be neglected in the present discussion on the transfer of know-how. In spite of its long tradition metallurgy, especially extractive metallurgy, is a relatively young field of science. More than in any other industrial activities the metallurgical processes and operating methods are based on experience, and even sometimes on tradition. In other words: The proportion of know-how and skill in comparison with scientific knowledge is higher in non-ferrous metallurgy than in other fields.

3. This does not mean that the smelting and refining processes are not up-to-date and elaborate. On the contrary,

the steadily increasing need of metals led to a growing shortage of ores and decreasing metal content, and forced the European and Japanese metallurgists to develop more and more sophisticated methods and tricks to extract even the smallest traces of metals from the raw material. World-wide competition and the lack of financial help from governments simultaneously caused intense endeavours for improvement of operating technology in order to lower production costs and to raise quality.

Location of the Smelter

4. When the natural resources in Europe and other industrial countries were exhausted, these regions began to supply their smelters with ores from other continents. Big plants are now situated on the coasts, where ore concentrates from all parts of the world are treated; the metals being extracted and the sulphur of the sulphide ores converted to sulphuric acid, which is itself raw material for further chemical and fertilizer plants.

5. With respect to the high value of the metal content of the copper, zinc and lead ores, the smelters generally do not buy the ores and metals but extract these against a treatment charge. The owner of the ores pays a so-called returning charge to the smelter, and after extraction can dispose of the metal. If the metal needs refining, the owner can also pay a refining charge.

6. Due to the shortage of ores in industrial countries, the returning charges are low. The mining firms, which may also be government-owned companies in developing countries, send their ores preferably to that smelter which offers the lowest treatment charge.

7. In recent times there has been a growing tendency by the developing countries to treat their ores in their own country in order to save foreign currency. No doubt this tendency is justified, although the saving is limited to only the amount of the smelting and refining charges, which are not very high.

8. As the sea freights are low and the transport of ores sometimes gets special reduced rates, the difference between shipment of ores and metal bars is small. There are no major savings if the metals are produced far from the market. It has been proposed that the best solution would be if the developing countries which own the raw materials located their smelters not in their own country but in the industrial regions in close cooperation with the market, i.e. the consumers of the metals. This should be connected with financial support of the buyers or their governments.

9. It seems that this proposal does not contribute directly to the purpose of this workshop, but one should not forget that the owners of a smelter in any case need the know-how regardless of whether the smelter is to be built in a remote area or on the Rhine, Seine or Thames.

10. Nevertheless it will be necessary to build more and more smelters in developing countries. In proportion to the improvement of the standard of living, the need for aluminium, copper, zinc and, of course, also for the remaining 35 other metals of importance, will increase. Figure 1 shows the consumption of 3 metals in highly industrialized countries in comparison to the consumption of the same metals in developing countries. The difference is astonishing. There is no doubt that in future the

need for metals will grow enormously in the developing countries.

11. In any case, wherever a smelter has to be constructed, it should fulfil several minimum demands from the technical and economic point of view. Some of these are:

a) low production costs
b) good metal recovery
c) suitable process
d) sufficient quality of the products

If a plant does not work economically, it needs subsidies which are paid by the population, thus lowering the standard of living. If the metal does not compete well because of poor quality, it will not be saleable. If the plant is located in the wrong place it will always be handicapped by high transportation costs. Another setback could be bad operations and/or poor management.

12. A great many questions and decisions arising during the time of planning a smelter, during its construction and during its operation can be solved better if sound know-how is applied at the right time. Before talking about this know-how and its transfer, a short review shall be given of some of the considerations, decisions, activities and experiences which are connected with the planning and construction of a metallurgical plant. First of all, some words about the metals' extraction in general:

Extraction of Metals

13. This is not the place to reveal all the different processes for the winning of metals. In non-ferrous metallurgy, differently from iron, there is a variety of possibilities and not only because there are so many metals.

Table 1

Per capita consumption of metals in kg (1970)

	Aluminium	Copper	Zinc
USA	17.0	9.0	5.1
Japan	8.7	7.8	6.1
Germany (W)	10.9	1[illegible].4	6.5
India	0.32	0.08	0.19
Mexico	0.75	1.12	0.99
Chile	0.52	2.17	0.72
Africa (North and Central)	0.07	0.04	0.04

Courtesy: Metallgesellschaft AG, 1971

For each metal there are various different processes available. If we take into consideration only copper, zinc, lead, aluminium, nickel, tin, cadmium and antimony, gold and silver, that means 10 metals, there might be about 60 - 100 multi-stage processes for their extraction in use today. If one further counts the possibilities of combining the different process steps in different ways to find out the most efficient treatment, one may arrive at several thousand process variations.

14. The raw materials of aluminium are oxides. Big deposits of nickel and smaller ones of copper ores are found in oxidic form too, but most of the ores of the above-mentioned metals are sulphides.

15. Figure 2 gives a scheme of their treatment. As the ores generally contain not more than 0.4 - 20 % of the metals which is too low for their direct extraction, they are upgraded in an ore dressing plant. This plant sends concentrates with 20 - 80 % metal content to the smelter. Here the sulphur is roasted and converted to sulphuric acid which can be sold.

16. In the smelter, the metals are separated further from iron and gangue, which are also contained in the concentrates. Other metals and impurities, like precious metals, selenium, tellurium, cadmium, germanium, metals of growing technological significance, but also arsenic and other deleterious elements remain in the raw metal.

17. It is now the task of the refinery, firstly to purify the metal so that it reaches the required quality, and secondly to convert the other constituents into products which can be treated separately until they are a saleable product or until they can be discarded without pollution of air and water.

18. Also the refining can be done according to several alternatives. These will be governed by the concentration and amount of impurities and by-products and the possibilities of their further treatment.

19. The existence of so many processes has technical, chemical and economic reasons. Nearly every ore has its special characteristics; there are hardly two ores of the same metal in the world which are chemically and physically identical. In most cases the composition of the minerals is different, so already the ore dressing has to be tailor-made. Concentration and proportion of the metals and impurities in the ore govern many alternatives in the recovery process. In addition, many problems have to be solved concerning the availability of water, kind of energy, manpower and fluxes, the prevailing economic conditions, cost of manpower versus energy and investment cost, transport and market, the state of industrialization and skill, and so on.

Feasibility Study

20. Let us suppose, somewhere in the world there are raw materials in sufficient quantity to justify the project of an extraction plant for metals. Exhaustive studies will be made on the site for finding out the amount and type of ore, the best way to mine it, the appropriate means of concentration and the transport facilities to the smelter. Another group of studies will deal with the location of the smelter, the shortest and cheapest connections to the mine and to the market or to the refinery. The economics will be evaluated on the basis of cost factors ruling in different locations and general ideas of the process developed. All these considerations and calculations are

summarized in the Feasibility Study. This generally does not only serve for the evaluation of the project, but also for developing a basis for financing negotiations.

Test Work

21. If the ores are very similar to others which are already being treated somewhere and if the local and economic conditions are the same and no technological progress has taken place meanwhile, one might start with the outlining of the process details.

22. However, this is not a rule. Normally there are differences in behaviour of the ore and in local conditions. In these cases test work should first be done in the laboratory and then on a semi-industrial scale. Sometimes if the raw material turns out to be unconventional or if a new process has to be checked, a pilot plant on the site of the smelter may be necessary.

23. It must be borne in mind that a pilot plant can save much money; the process parameters will be developed, the number and dimensions of apparatus can be determined with much more accuracy in a pilot plant. Costly test work in the producing plant and losses in production can be reduced to a minimum by pilot plant operation.

24. On the other hand, a pilot plant needs a considerable capital expenditure in advance, i.e. money will be spent long before the produced metals pay the costs of operation and amortization. It has to be decided what is worse, to lose several years of production or to design a plant which later on may run into difficulties.

25. No doubt a pilot plant can cause a loss of some years before production can start. It is not possible to outline general rules indicating which way the decision should be made. Two examples might illustrate the problem:

26. The first case deals with an electrolytic zinc plant which was new in the country. There were no questions about the process as such although, of course, a lot of details had to be agreed upon between customer, consultant, engineering company and supplier of material. The ores came from a new mine, but the analysis showed no abnormalities. The aim was to find out the best operating conditions. There were no problems in designing and dimensioning of the equipment, like leaching vessels, types of filters and electrolytic cells for which tests were required.

27. Yet it was decided to build a pilot plant. The planning and design of the production plant commenced simultaneously with the building of the pilot plant. Parts of the test plant already contained commercial-type equipment; for example, the electrolytic cells. This enabled the use of easily accessible anodes and cathode sheets. Other parts were smaller prototypes, for example the tanks and thickeners. The pilot plant was already in full operation one year after the start of the whole project. The production plant was commissioned one year later. The pilot plant made it possible to check a lot of process details, such as operating conditions, temperatures of leaching, duration of settling, etc. Later on it turned out that a very important "by-product" of this plant was the possibility of training the operating personnel who went from the pilot plant directly into the big zinc electrolysis. This is a good example of the transfer and development of know-how.

28. A totally different situation arose in another case. There was a copper ore, atacamite, which could not be concentrated by conventional methods because it was a chlorine containing oxide. Every previous attempt to leach the ore had failed as the chlorine content caused corrosion and contamination of the product. It had seemed impossible for many decades to utilize huge resources of copper in Northern Chile.

29. It was then found out in the laboratory that the main disadvantage of the ore, the chlorine content, could turn out to be an ideal means for an elegant recovery of the pure metal. If one succeeds in precipitating the copper in the monovalent state as copper-1-chloride, which is insoluble in diluted sulphuric acid, no other impurity of the atacamite is precipitated and the chances are good that this copper will not need any further refining.

30. The laboratory tests turned out to be encouraging. A totally new process of copper extraction was developed, but for the time being this was based only on the paper and on laboratory tests. Several questions were left open on design, proper materials and composition of intermediary and end products.

31. In this case it was indispensable to build a pilot plant and spend sufficient time on this work in order to solve a lot of questions, such as leaching characteristics of the ore, acid consumption, settling conditions, efficiency of the precipitation, behaviour of acid-proof materials and of the furnace linings.

32. A period of 6 years elapsed from the expression of the first ideas, which at the beginning had seemed unbelievable,

to the commissioning of the plant. It turned out to be worthwhile having spent this time and trouble. In spite of so many pessimistic opinions of chemists and metallurgists, the process worked and the quality of the copper was excellent. The plant needed no further improvement worth mentioning. Fortunately, the whole venture was an economic and technical success.

33. This fortune was due to the pilot plant. Also here, know-how and experience were developed from the beginning by the staff and workmen of the customer, the engineering people and suppliers. Everyone had to share the risk. The customer and his country, of course, was faced with the biggest portion of the risk; on the other hand, he could enjoy a good profit for the years to come.

Design and Construction of Producing Plant

34. Having dealt so much with processing, special attention must be drawn to the fact that the planning of the production plant and the execution of the building and construction as well as the commissioning, involve a totally different kind of know-how.

35. During the course of a project a detailed process flowsheet will be made, including all the returning materials. A balance of the input and output and circulating constituents is derived from the flowsheet; in many cases, heat balances are added.

36. The basic engineering has to be performed. During this stage the fundamental parameters and data for the number, capacity and type of the equipment, the requirements for transport facilities, general layout of the plant

and the final cost estimate are produced. Most of this work consists of calculations, tables and descriptions; the number of drawings is limited. The basic engineering also includes time and cost scheduling.

37. The next step in the realization of a project is the detailed engineering. Here, the final dimensions of the apparatus are settled, arrangement drawings and drawings of specially developed equipment are completed and the specifications are elaborated. Detailed engineering involves a large amount of labour in the engineering offices, where not only drawings, but also the specifications are compiled. These contain the design parameters of every piece of equipment and the delivery requirements. They are the basis of the enquiries and tenders.

38. The number of drawings for the zinc electrolysis plant mentioned above with the capacity of 100,000 t/y of zinc might well amount to 2,000 including gas cleaning and sulphuric acid plant. 1,200 orders for the zinc plant had to be placed, which means that about 6,000 offers had to be examined and compared. It was necessary to check 800 suppliers in order to ensure the scheduled delivery time and satisfactory quality of their deliveries.

39. Erection was executed by one main contractor, which was the engineering company entrusted with the whole work. 50 different companies had to be sub-contracted, because each of them supplied special equipment which needed specialized erection personnel. More than 150,000 shifts were spent for erection, including special construction on the site.

40. Other metallurgical plants are designed and constructed similarly to this example of a zinc plant. Some need more

engineering work than others. A considerable amount of know-how is involved in the organization of this work. In order to ensure the shortest delivery time, as many calculations, drawings and specifications as possible must be produced simultaneously, but most of them will be based on the results of preceding ones. To find out the optimum way of scheduling, the Critical Path Method (CPM) was developed. All the necessary activities, their minimum and maximum duration and their dependence on other activities, are drawn into a network. A computer prints out a schedule which expresses the times and dates when a drawing, a calculation or the placing of an order has to be started and finished. This schedule warns the management when a critical situation with respect to the time of delivery arises.

41. As a rule, the customer nominates a project committee for such a business. The engineering contractor which is entrusted with the work, appoints a project manager. He is the technical representative of the contractor.

42. The contractor in this sense shall be the company, or the group of companies, which supply:

the process engineering,
the basic and detailed engineering,
procurement services or delivery of the equipment itself,
and the site management.

This last-mentioned item will be carried out by a site manager.

43. The services of the contractor can also include the execution of all civil engineering work and the installation of the equipment. The civil engineering and erection con-

tractors have to execute their work under the direction of the project manager.

44. For managing a project, several systems are used in different companies and for different jobs. In one of the systems, the project manager represents the top of a pyramid. A number of different engineering groups carry out engineering work and business transactions in special fields. Each group is supervised by a group leader, who reports to the project manager. The project manager has full power to intervene directly into every activity in case it is necessary for the good progress of the project, and also has complete authority and responsibility for the project in the internal organization of the contractor.

45. In other systems for project administration, the project manager delegates the different tasks to established departments or groups in an existing organization. The groups carry out the work specified by the project manager. This system is called Matrix Project Management.+) The responsibility and the authority of the project manager is limited to the "what and when" of the different activities, whereas the different groups or departments are responsible for the "how" of the work to be carried out.

46. It needs a considerable amount of know-how to organize and delegate the work and the responsibilities. At the project manager's office all pertaining information required for the execution and all information elaborated in the different groups will come together. Therefore, the project manager is the technical partner of the customer.

+) D.I. Cleland
W.R. King
Systems analysis and project management
McGraw-Hill, New York, 1968
page 176

47. Before the plant is started, it is advisable to install a training programme for the future operators, like skilled workers, foremen, engineers and commercial people. In so many cases this point is neglected, also in the developing countries. The contractor can build and erect his plant, the project engineer will know every detail of the construction, but there is no other way: the operation and management must be in the hands of the customer's personnel.

48. Of course, the contractor will send a team of qualified engineers and foremen for the start-up, but as this is a costly operation the number of those specialists will be limited. They cannot stay on the site for too long a period, so the training methods of local people have to be discussed and planned thoroughly.

49. In some cases it might be advisable to make a management contract for the first few years of production with either the contractor or another know-how supplier. Then the operation of the plant will be managed by engineers who have done similar jobs before, so that troubles during the beginning of operation can be minimized and production losses kept as low as possible. Simultaneously, able local engineers can be trained so that they can take over the management position after a certain time. Such management contracts are especially advisable when complicated integrated plants are considered.

<u>The Procedure of a Project</u>

50. Summarizing the foregoing, one might list the most important steps of a project in the following way:

Preliminary investigations
raw materials, resources

First ideas about realization
duration, throughput, investment, location

Selection of processes
concentration, wet or pyrometallurgical recovery

Feasibility studies
metallurgy and economy, market, availability of energy, labour and utilities

Test work (if necessary)
pilot plant, revision of process details

Agreement on scope of work, conceptual engineering
limitations, handling of project

Basic engineering and cost estimate
flowsheet, material and heat balances, main equipment, general arrangement

Detailed engineering
final design, arrangement of equipment, off sites

Procurement
tenders, orders, expediting, controls

Site management
civil engineering, erection, test runs

Commissioning
start, operation, guarantee runs

Management
plant organization, commerce, optimizing

51. Sometimes, some steps are executed simultaneously. Sometimes too, one of the first steps can be omitted because the problems have already been solved. Anyway, in a project of an integral metallurgical plant, i.e. a plant performing several consecutive process steps which need different departments, involving the majority of the listed activities is practically inavoidable.

52. In every step a certain amount of know-how is applied and transferred. In ascending order the most important means of transfer might be mentioned:

Members of customer's staff
    they develop their own know-how by intense work with the object

Specialists in the pertaining country
    own specialized know-how from similar projects they have dealt with

University institutes and similar laboratories
    have general knowledge and may have made studies on the object

Consultants
    have wider knowledge and experience from the execution of process studies, comparisons of prices and methods

53. All these groups can do valuable work in the preparation of the project, i.e. until the selection of the process and the first rough price estimate. The following organizations could do this preliminary work as well, but also the next steps. They have in common a good stock of know-how from a variety of fields.

Technical departments of smelters

can use existing experience and drawings in a case where exactly the same process as that of the smelter is concerned. Helpful mainly for elaboration of operation costs

Engineering consultants

carry out feasibility studies, cost estimates, process suggestions

Engineering and construction companies

have specialized staffs of process engineers in all fields as well as project managers, purchasing and erection departments; can carry out tests, and often have good connections with other producing plants which facilitate training programmes for the future operators.

53. In many cases only limited amounts of money are spent, as the capital expenditure of a project grows step by step which means that preferably those institutions are contracted whose prices seem reasonable, i.e. the first groups in the above-mentioned list (52). This might be justified during the first contact with a new deposit or raw material. In order to avoid wrong investments, it should be taken into consideration as early as possible that a group which is known to own the highest concentration of know-how in the pertaining field should be engaged. This should put the project on to the optimum road with a minimum of risk.

The Different Kinds of Know-how

54. In the preceding passages the where and whereabouts of the application and need of know-how were outlined.

It might now be useful to define the different kinds of know-how. This should help to find a way for its development and transfer.

55. Theoretical knowledge is accessible to those who search for it, in universities, technical documentations, associations and congresses. Practical experience is gained during the execution of projects, in the construction period and mainly during the operation of a plant. It is a means of development of know-how, but it needs time, years or generations and it involves errors and mistakes which can cause expensive trouble, unless it is done with the help of experienced and qualified people or organisations.

56. Know-how, in the sense of the present discussion, should be apart from science and new learning: it is the already existing treasure of knowledge, experience and skill which is in the brains and hands of a limited amount of people. In the scope of the present discussion, it is the group of those who know how to select and develop a process, build a plant and operate it. This group includes skilled workers and foremen, draftsmen, engineers in all fields, scientists, commercial people and managers. Those might be called the "donors".

57. To ensure better understanding, the different kinds of know-how shall be divided into 3 groups. These are:

A) <u>Process Know-how</u>

58. This is connected with all the metallurgical, economic and technical questions of the process. Some examples:

find out the best way of treatment with respect to the local conditions by connecting the available local information with existing knowledge and experience of the different processes which can be applied

exploring the best sites for ore dressing, smelting and refining, including requirements and resources of utilities

in case of unconventional raw materials, finding out suitable and cheap test methods for developing a new process or adjust existing methods to the demands of the materials

considering also the economic, political and sociological circumstances, including market studies, transportation costs

confirming the feasibility of the selected or tested process, calculating heat and material balances, flowsheets and possible alternatives

selection of equipment, including material of construction, design equipment, necessary spare parts and tools, everything not only under the aspect of technology but also of economy

supplying process descriptions, operating and maintenance programmes

B) Project Know-how

59. This especially includes the ability to manage a big project. Some examples of the scope of work:

organization of planning and scheduling of the different studies and activities

mode of sending out enquiries, tenders

comparing bids and placing orders

filing dates for official authorities

organizing the CPM

formulating responsibilities for the different activities

discussing conditions of finance and guarantees

co-ordinating and controlling all the stages of a project

time scheduling and quality control

C) Operating know-how

60. This contains, among others, the know-how for operating the plant. Some examples:

manual and mental skill to work with the tools and machines

to maintain and repair them

to operate, improve and co-ordinate the successive process stages to organize and control the labour in the plant in order to ensure effective and continuous production with high quality

trouble-shooting

creation and maintenance of a good psychological climate in the plant

steady efforts for improvements and research and development

to improve commercial activity for the purchase of cheap raw materials and spare parts and the sale of products on good terms

Development and Transfer of Know-how

61. The original sources of know-how in the industrial centres of the world are experience, tradition and learning. During decades, in some cases over generations, gradual expansion of skill, personal knowledge, speed of reaction, familiarity with sophisticated causalities, improved. Disappointment contributed in the same way to know-how as success.

62. Of course, all these items contribute also to the know-how of citizens of a developing country; but as they need so much time, the present efforts must be - so it seems - concentrated on the transfer of know-how.

63. There should not be any mental reserve against this transfer. Everybody of good will is interested in a high standard of living in all parts of the world. It is not only a demand of humanity, but also a personal and national interest of everyone and every nation.

64. Another thing is to be considered: the know-how is not concentrated in the industrial countries alone. The developing countries themselves own a lot of common sense, knowledge and know-how in many fields which might be of value to the industrial countries.

65. Why invent and develop ideas and experience which are already available elsewhere? Even if it is necessary to make some efforts, spend money or care, the acquirement of existing know-how will always be easier, cheaper and faster than the development of the same at one's own expense.

66. Of course, successful transfer of know-how is only possible if the recipient is prepared to accept it.

67. The recipient shall be critical, but this criticism should be limited to the degree of experience and knowledge already in his possession. Too much criticism without real background enlarges the time of reception and hinders the transfer.

68. As the possession of know-how is mainly connected with the individual being and not so much with organizations, the transfer of know-how demands personal contact between donor and recipient. As a matter of fact, this contact should extend over a certain time, the longer the better. In connection with metallurgical projects, different methods are practised. Some of them are:

> personal discussion between staff members and engineers from the companies in developing countries and the commercial and technical specialists of representations, consulting and engineering companies.

In the beginning these talks are more or less cursory, but parallel to the development of a project they may expand to a very intense exchange of know-how. The engineering offices try to delegate able and experienced people to assignments of this kind. If both parties succeed in achieving co-operation based on confidence and appreciation, this personal contact might lead to the best means of transfer.

69. The same also applies to other levels. During the construction of a plant and during commissioning, there are enough opportunities for personal contact.

70. In practice, it must be admitted that this method often works satisfactorily only in the first stages. For the practical construction and erection, the contractor sometimes sends men who either cannot speak the language of the country or who indeed do their work excellently but are not able or willing to teach others. The recipient on the other hand misses the opportunity because often he has not acquired sufficient personnel in due time. It can also be observed that during the construction and commissioning period engineers, future foremen and skilled labourers often have to change their position in the plant. As the transfer of know-how needs time, such reorganizations should be avoided. Another means of development and transfer can be seen in the training of the future personnel in similar plants. Such a training programme should be discussed early enough to have specialized engineers, foremen and operators ready when erection and commissioning starts. A programme should be fixed 2 years ahead for the engineers and 6 months for the foremen and the operators. The receiving organization needs to make preparations. If possible, the trainees should be entrusted with responsible work which is, of course within the scope of their ability.

71. If possible, this instruction should take place in plants in the country where the trainee was born. If there are no plants in this country, there should be the possibility to send people into the plants in the industrial countries. Of course, this will be limited to only a few people.

72. According to experience, this kind of assignment may have as many advantages as disadvantages. The trainee has the best chance to learn from the industrial experience of his new colleagues. However, sometimes the plants are old-fashioned or they work with partly different processes and the trainee may misunderstand things or gain a false impression of his qualifications which might cause trouble later on. The worst thing is that he may become discontented when he learns that the worker in an industrial country often gets more pay than he himself can hope to earn in his own country for quite some time. Dissatisfaction is a bad motor in the operation of a plant.

73. In any case, it is necessary to nominate a leader for each of the groups sent away for training. He has to watch the time schedule, control the living conditions of the trainees, supervise the progress of learning and act as a speaker between trainees and plant management. It is not strictly necessary that he is already trained, he might be a trainee himself, but he should be authorized by the management of the delegating company.

74. Nobody will be able to avoid foreign plants keeping the most able trainees if they express the wish to remain in the plant. This fact and the above-mentioned difficulties limit the delegation of people into other plants or foreign countries to a few special disciplines in plant operations which cannot be studied by other means. According to experience, the opposite way, that is the

contracting of personnel from other plants for a limited period, is more efficient and bears less risk.

75. The operators and foremen in industrial countries find it exciting to be sent into foreign countries in order to teach colleagues. They appreciate the honour this involves in the fact that their management had selected them and nobody else. They are personally interested in seeing that the trainees for whom they are specially responsible do the best work, and many long-lasting friendships have developed in this way.

76. Apart from the methods of know-how transfer directly related to a project, there are some other possibilities of a more general character. They shall be mentioned here because they also can convert into project orientated ones, though their original intention was different. Some of them are mentioned below.

77. Every year an increasing number of young men and women from developing countries enrol in the universities and technical schools of the industrial regions. The governments of the developing countries and the parents, who spend the foreign currency for the students' cost of living, hope that the returning graduated engineers and scientists will help to improve the standard of living of their country.

78. No doubt, those students work hard; as they are a selection of the most able and intelligent young people, it is not surprising that a good proportion of them get excellent marks in the examinations. They should be able to transfer the most modern knowledge and also know-how into their countries.

79. To a certain extent this is true. On the other hand, it must be said that a large number of engineers and scientists do not return after having finished their studies.

Those able and skilled men and women prefer to get a job in the industrial countries in spite of the often hard struggle for life.

80. If they are asked why they took this decision, they answer that their own country could not give them an adequate job.

81. Today in the industrial countries the young intelligent and able people who bring new ideas and who are well educated, are welcome members of society regardless of where they were born. Should it not be possible to offer them well remunerated positions in their own countries? During the years they were absent, they lost many personal and business connections to industry and public authorities which could be their future employers. This is a handicap which should be compensated by some means.

82. To a certain extent it could possibly help when companies of the developing countries take an interest in those undergraduates who work in relevent fields. Of course, the students must be free to make up their own minds in respect to their future employers. It seems that Yugoslavian plants have had good experience with this method.

83. Certainly, there are countries which cannot offer enough adequate positions to their own graduates. In those cases it would be preferable if they send their students not to universities but to industrial training schools where technicians and craftsmen are being instructed. Those schools can supply practically-minded men who, in many cases, can be of more help to a developing country in building a new industry than scientists.

84. Last but not least, another method should be mentioned which, unfortunately, can only be applied to a small number of engineers and scientists who already have a degree. This is to work in industrial plants, scientific institutes or test plants of engineering companies. Here the young men will have the necessary close personal contact with the donors. They will be confronted directly with the problems and troubles of industrial processes.

85. There are still more methods for the transfer of know-how, but the foregoing examples may have shown the problems involved. There is a certain amount of progress in the development and transfer of know-how, but a critical examination would reveal that we are only in the process of beginning. It is worth-while thinking out sound improvements, which is the intention of this contribution.

86. If a developing country decides to go ahead with a project it has to be decided in the very beginning where the know-how will come from. Experienced engineering and construction companies can supply the know-how for every step of the project. They can carry through a project with the most efficient project know-how. The plant built by them can incorporate the best process know-how. The client receives a modern plant which would then have to be operated by his personnel.

87. If one did not ensure the transfer of know-how during the course of the execution of the project it would end in a disaster.

88. A client in a developing country should, therefore, build up his operating organization in the very beginning of the project. The manager, superintendents, metallurgists, maintenance engineers and the foremen should co-operate closely with the corresponding engineers of the engineering

contractor during the project execution. They should be present when major decisions are taken. They should know why a certain process was chosen, why the plant was arranged a certain way or why a specific piece of equipment was chosen. They should make the project their own project. They should be at the site to see their plant growing.

89. If this is supported by a good training programme every good project is bound to be a success.

90. This we think is the best way of know-how transfer for metallurgical plants.

Main steps for the development and the execution of a project

IDEA

↓

Exploration on ore body.
Investigation on possible processes.
Preliminary economic calculations.
Investigation on requirement and resources on raw materials and utilities.
→ **PRELIMINARY INVESTIGATIONS**

↓

Metallurgical calculations on various possible processes.
Economic calculations on various processes.
Comparison between processes.
Investigation on best disposal of by-products.
→ **SELECTION OF PROCESSES**

↓

Detailed metallurgical calculation on selected processes.
Requirements, resources and cost of labour, energy, fuels and other utilities.
Auxiliary plants and off sites.
Investment cost.
Operating cost.
Capital requirement.
Market for products and by-products.
Transportation cost for raw materials.
Transportation and distribution costs for products.
Economic calculation (cash flow, return on investment, profitability).
→ **FEASIBILITY STUDIES**

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Setting up of project execution procedere.
Definition of tasks.
Scheduling, budgeting.
Establishing of control systems.
Building up of project organisation.
Nomination of Project Manager.
Selection of main contractors and suppliers.
Preparation of financing.
→ **PROJECT ORGANISATION**

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Process engineering.
Development of plant lay out.
Design of process units, auxiliary plants and off sites.
Preparation of final cost estimate.

BASIC ENGINEERING

Detail design of process units auxiliary plants and off sites.
Design of special equipment.
Mechanical, electrical und civil design.
Development of instrumentation and control systems.
Consideration of special process requirements.
Selection of equipment.
Procurement of equipment and services.
Inspection of equipment.
Shipping of equipment.
Time and cost schedule control.
Contacts with public authorities.

DETAIL ENGINEERING

Construction of buildings.
Installation of equipment.
Testing of equipment.
Time and cost schedule control.

PLANT CONSTRUCTION

Final testing of plants and equipment.
Commissioning of plants.
Training of staff and operators.
Fullfillment of guaranties.
Setting up of control systems for plant operating (recoveries, quality of products).
Building up of operating organisation.

COMMISSIONING

Improvement of plant operations.
Optimizing of metallurgical and economic conditions.

COMMERCIAL OPERATION

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