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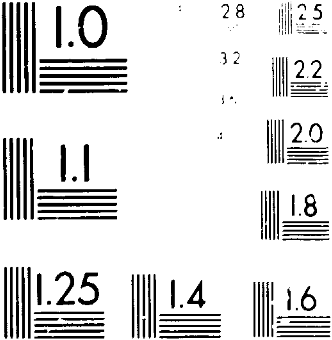

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Development and Transfer of Technology Series

No. 14

CASE-STUDIES IN THE ACQUISITION OF TECHNOLOGY (II)

UNITED NATIONS

ABSTRACT
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CASE-STUDIES IN THE ACQUISITION OF TECHNOLOGY (II)
ETUDES DE CAS D'ACQUISITION DE TECHNOLOGIE (II)
CASOS PRACTICOS DE ADQUISICION DE TECNOLOGIA (II)

ABSTRACT / SOMMAIRE / EXTRACTO

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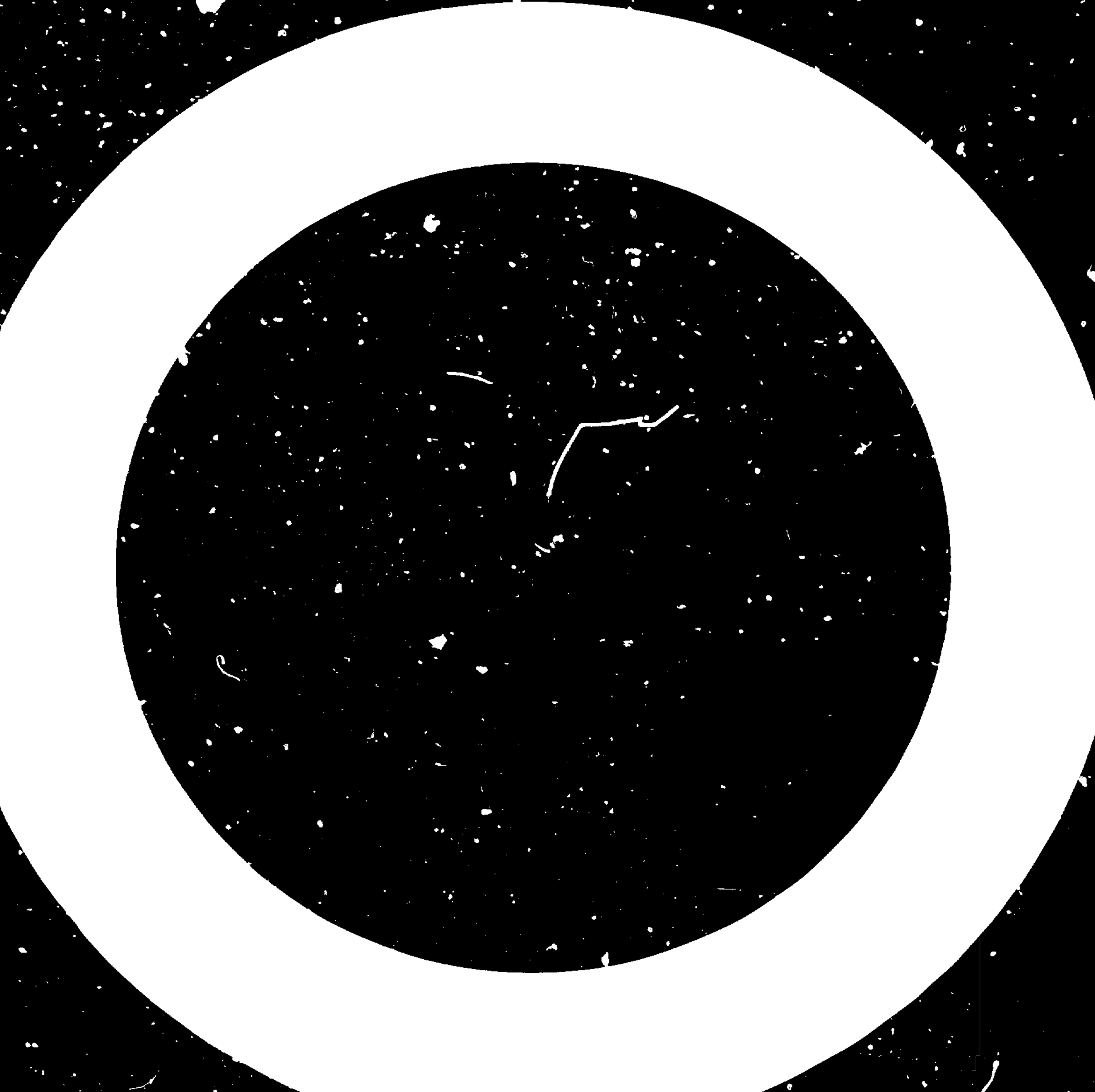


ABSTRACT

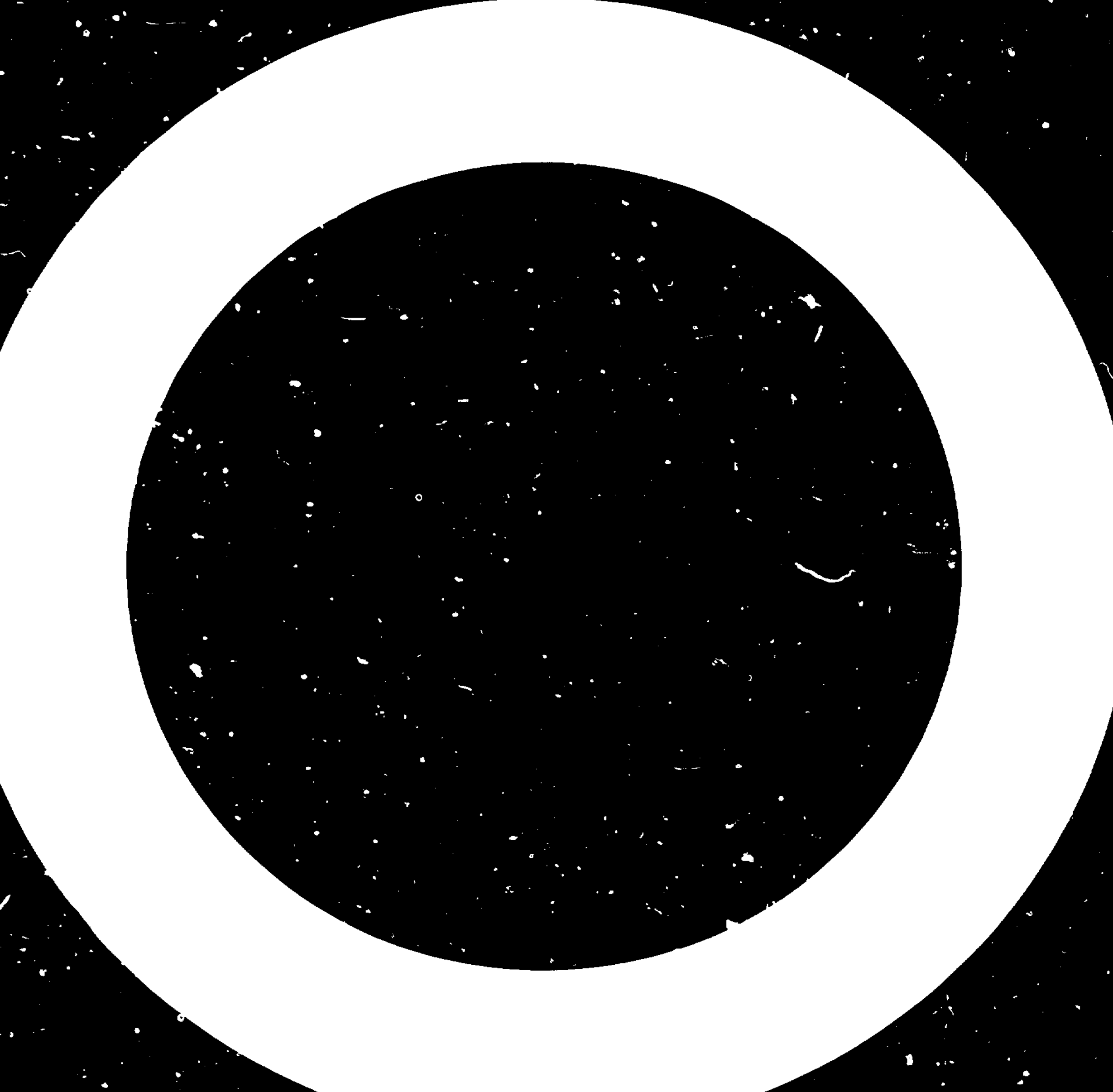
This volume focuses on the difficulties encountered by a developing country while acquiring technology for a product or process in which it has no prior experience, and especially while searching for a suitable technology and collaborator and negotiating an agreement. It contains three detailed case-studies of transfer and absorption of technology in India, and may be considered a companion to volume I in that it contains a chapter analysing not only these three case-studies but also the case-studies of two other Indian enterprises described in the earlier volume.

One of the three companies studied is Hindustan Machine Tools Ltd. (HMT), which is in the public sector. The initial collaboration agreement was arranged by the Government of India even before the plant existed. The experiences of HMT have been somewhat varied, since a complex technology is involved, but the company has successfully met its import-substitution objective and has diversified with considerable success into areas outside its principal industrial activity, which is the making of machine tools.

The other two companies are Jyoti Limited and Eicher Tractors India Limited, both of which are in the private sector. They differ from HMT in many ways. Both illustrate the importance of entrepreneurship in importing technology and assimilating it in spite of the hardships faced by enterprises in a developing country. Jyoti Limited is a good example of a company in a developing country that has entered into collaboration agreements with foreign companies on a highly selective basis and has completely assimilated the imported technology during the period of collaboration through indigenous research and development (R and D). The case-study on Eicher Tractors India Limited shows how a trading concern can transform itself into a manufacturing concern and, while doing so, find a good balance between traditional and modern manufacturing technology in the face of a shortage of capital and introduce a product obsolete in the country of origin but appropriate for the technology-starved rural environment of India.

The analysis of the five case-studies provides a comparison of their experiences in the acquisition of technology, the assimilation and adoption of foreign technology and the role of R and D. The conclusion is reached that the transfer of complex technology to a new environment creates problems that often defy theoretical solutions. Hence, the company acquiring the technology must either find a solution through trial and error, costly in terms of time and money, or obtain help from the experienced foreign collaborator, which means continued technical dependence on the collaborator. The acceptance tests in agreements should be so specified that they are carried out not at the collaborator's plant but in the new environment and possibly with local raw materials.

The major indices of technology assimilation by an industry in a developing country will be its success in import substitution, export performance and degree of horizontal and reverse transfer of technology. Constraints arise not only from technological problems, but also from the small volume of production usually encountered in developing countries. The ability to manufacture a complex product in an industry in a developing country, based on the design and manufacturing know-how supplied on a turnkey basis by a foreign collaborator, may help to achieve the objective of import substitution, but need not always signify that technology absorption has taken place and that the country is self-reliant in the technology concerned. The assimilation of technology is a multi-layered process; unless emphasis is placed on basic and applied R and D, the industry in the developing country will find itself peeling off the layers and discovering more areas in which dependence on the collaborator is necessary.



SOMMAIRE

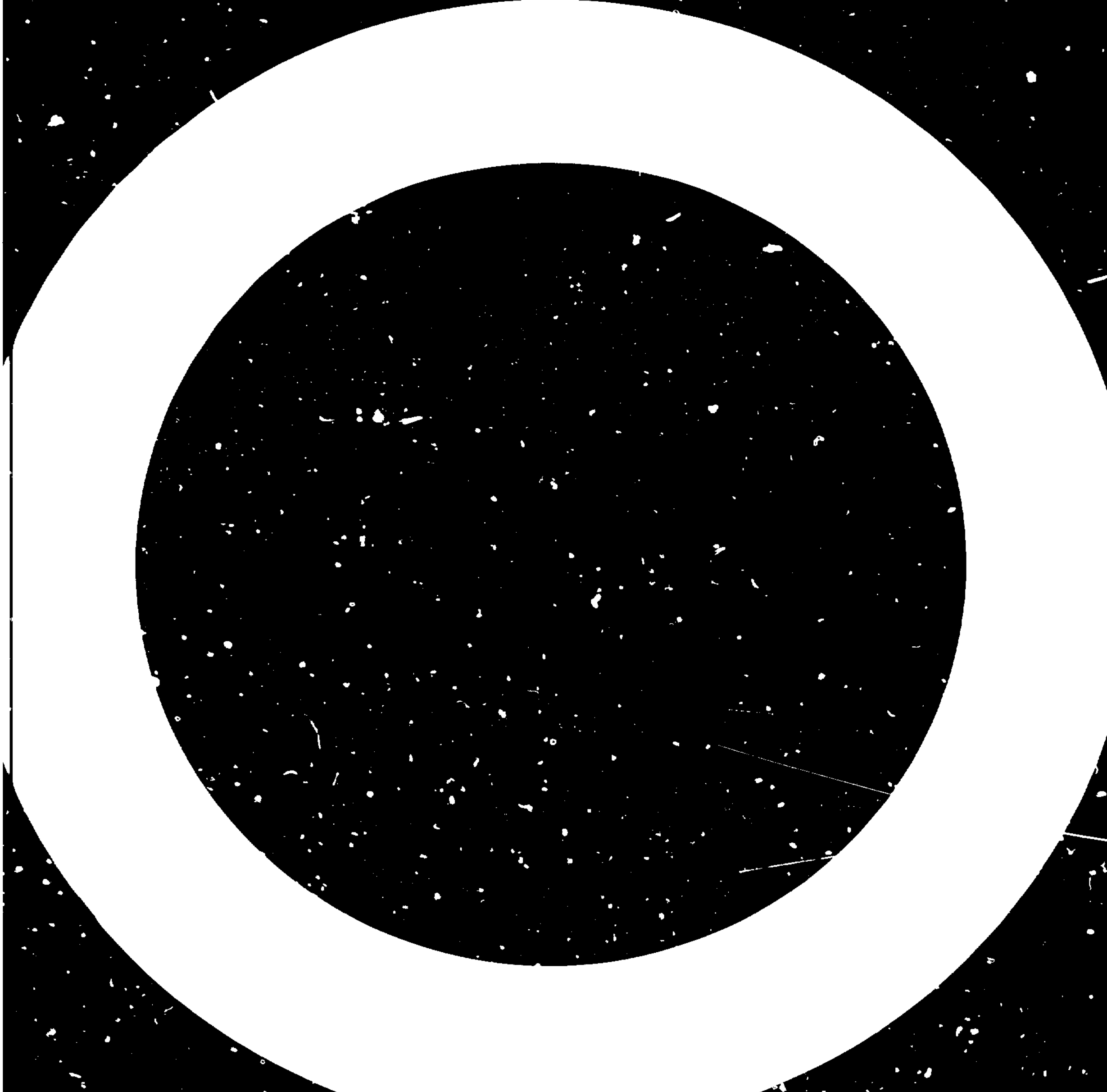
Ce volume traite des obstacles que doit surmonter un pays en développement pour acquérir la technologie correspondant à un produit ou procédé nouveaux pour lui, et, notamment, pour trouver une technologie et un collaborateur appropriés et négocier un accord. Il contient trois études de cas détaillées sur le transfert et l'absorption de techniques en Inde; comme un de ses chapitres porte, outre ces trois études de cas, sur deux autres entreprises indiennes déjà analysées dans le volume I, on peut estimer qu'il fait pendant à celui-ci.

Une des trois entreprises en question est la Hindustan Machine Tools Ltd. (HMT), qui relève du secteur public. Le premier accord de coopération a été conclu par le Gouvernement indien avant même la création de l'entreprise. Les résultats obtenus par la HMT ont été assez hétérogènes car elle devait mettre en œuvre une technologie complexe, mais elle a mené à bonne fin la tâche qui lui avait été fixée en matière de remplacement des importations et a su pénétrer avec beaucoup de succès dans des domaines autres que son principal secteur d'activité industrielle qui est la construction des machines-outils.

Les deux autres sociétés sont la Jyoti Limited et la Eicher Tractors India Limited, qui appartiennent l'une et l'autre au secteur privé et se distinguent à bien des égards de la HMT. Elles montrent bien le rôle de premier plan que peut jouer l'esprit d'entreprise lorsqu'il s'agit d'importer de la technologie et de l'assimiler en dépit des épreuves qui sont le lot des sociétés dans un pays en développement. La Jyoti Limited est un bon exemple d'une société d'un pays en développement qui, après avoir conclu des accords de coopération très sélectifs avec des entreprises étrangères, a entièrement assimilé la technologie importée durant la période de coopération grâce à des travaux autochtones de recherche-développement (R-D). L'étude de cas sur la Eicher Tractors India Limited montre comment une société commerciale peut se transformer en entreprise industrielle et, ce faisant, réussir à combiner correctement, malgré la pénurie de capital, les procédés traditionnels et les techniques de fabrication modernes, et à lancer un produit jugé démodé dans le pays d'origine mais à même de satisfaire la fringale de technologie des campagnes indiennes.

Ces cinq études de cas permettent de comparer l'expérience des entreprises concernées en ce qui concerne l'acquisition de la technologie, l'assimilation et l'adoption de techniques étrangères, et le rôle de la R-D. Cette analyse aboutit à la conclusion que le transfert d'une technologie complexe dans un nouvel environnement crée des problèmes que, dans bien des cas, les formules théoriques ne permettent pas de résoudre. C'est pourquoi l'entreprise qui acquiert la technologie doit ou bien trouver elle-même une solution par tâtonnements, ce qui demande beaucoup de temps et d'argent, ou bien obtenir le concours d'un collaborateur étranger expérimenté, et continuer par conséquent à dépendre de ce dernier. Il importe de spécifier dans les accords que les essais de réception seront exécutés non pas dans l'entreprise du collaborateur mais dans le nouvel environnement et, si possible, à l'aide de matières premières locales.

Les principaux indicateurs du degré d'assimilation d'une technologie par une industrie d'un pays en développement seront les résultats obtenus dans les domaines suivants : remplacement des importations, produit des exportations et instauration de transferts horizontaux et inverses de technologie. Les contraintes ne tiennent pas seulement à des problèmes d'ordre technologique mais également au fait que les pays en développement se contentent généralement d'un volume de production peu élevé. L'industrie d'un pays en développement, en prouvant qu'elle est capable de fabriquer un produit complexe basé sur les études et le savoir-faire industriels fournis par un collaborateur étranger dans le cadre d'un contrat clefs en main, peut faciliter le processus de remplacement des importations, mais cela ne signifie pas forcément que l'absorption de la technologie a progressé et que le pays est devenu autonome dans le secteur technologique concerné. L'assimilation de la technologie est un processus pluridimensionnel et, à moins que l'accent ne soit mis sur la R-D fondamentale et appliquée, l'industrie du pays en développement rencontrera toujours de nouveaux obstacles et découvrira de nouveaux domaines dans lesquels elle sera contrainte de faire appel au concours du collaborateur étranger.



EXTRACTO

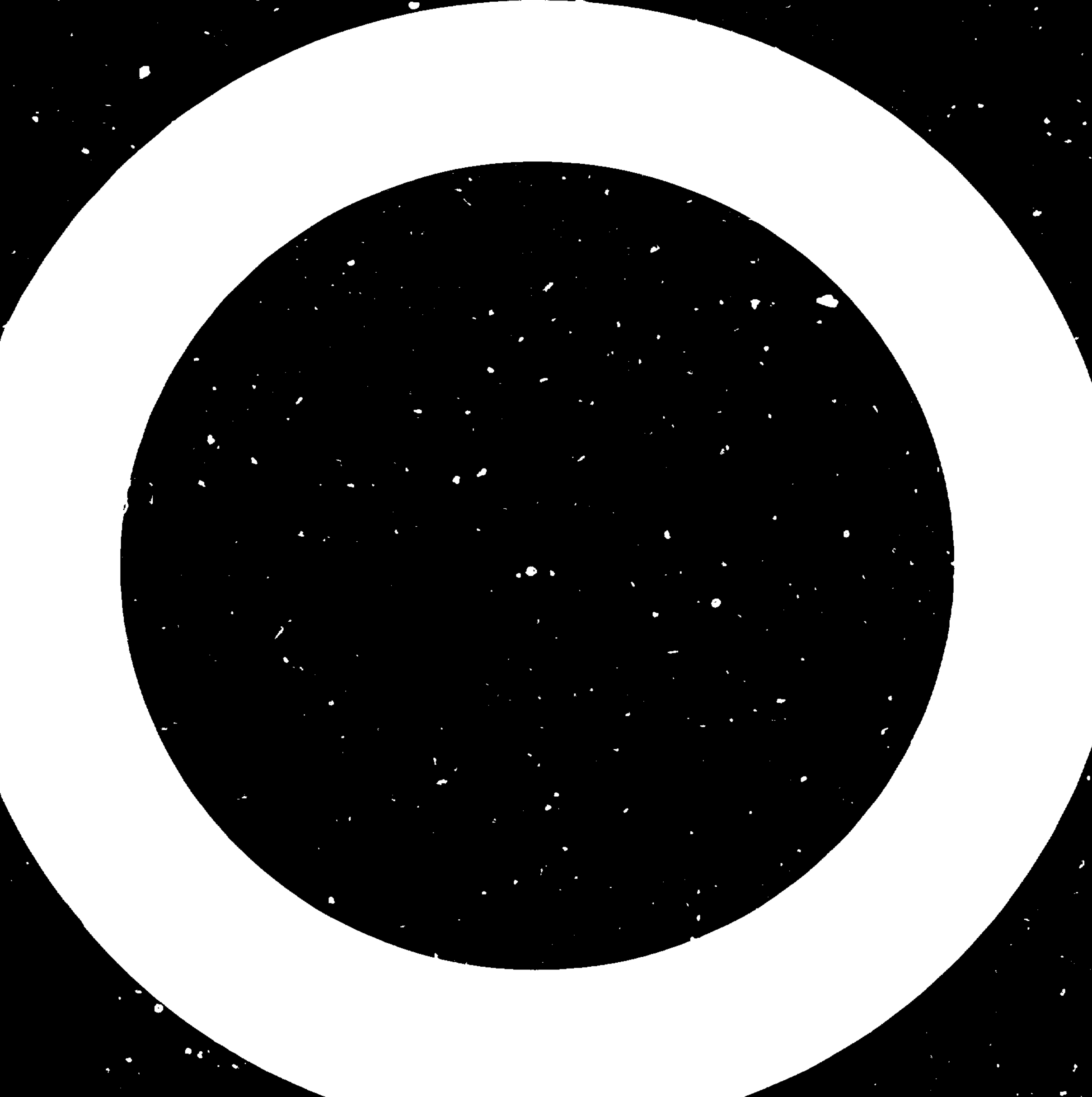
Este volumen se concentra en las dificultades que encuentran los países en desarrollo al adquirir tecnología para un producto o proceso con respecto al cual no tienen experiencia previa, y especialmente mientras buscan una tecnología y un colaborador adecuados y negocian un acuerdo. Contiene tres casos prácticos detallados sobre transferencia y absorción de tecnología en la India, y se puede considerar como un complemento del volumen 1 porque contiene un capítulo que analiza no solamente estos tres casos prácticos sino también los casos prácticos de otras dos empresas de la India que se exponen en aquél.

Una de las tres empresas que se estudian es Hindustan Machine Tools Ltd. (HMT), que pertenece al sector público. El Gobierno de la India concertó el acuerdo de colaboración inicial aún antes de que existiera la planta. Las experiencias de HMT han sido algo variadas, pues está en juego una tecnología compleja, pero la empresa ha logrado con éxito su objetivo de sustitución de las importaciones y se ha diversificado, también con éxito notable, en esferas ajenas a su principal actividad industrial, que es la fabricación de máquinas-herramientas.

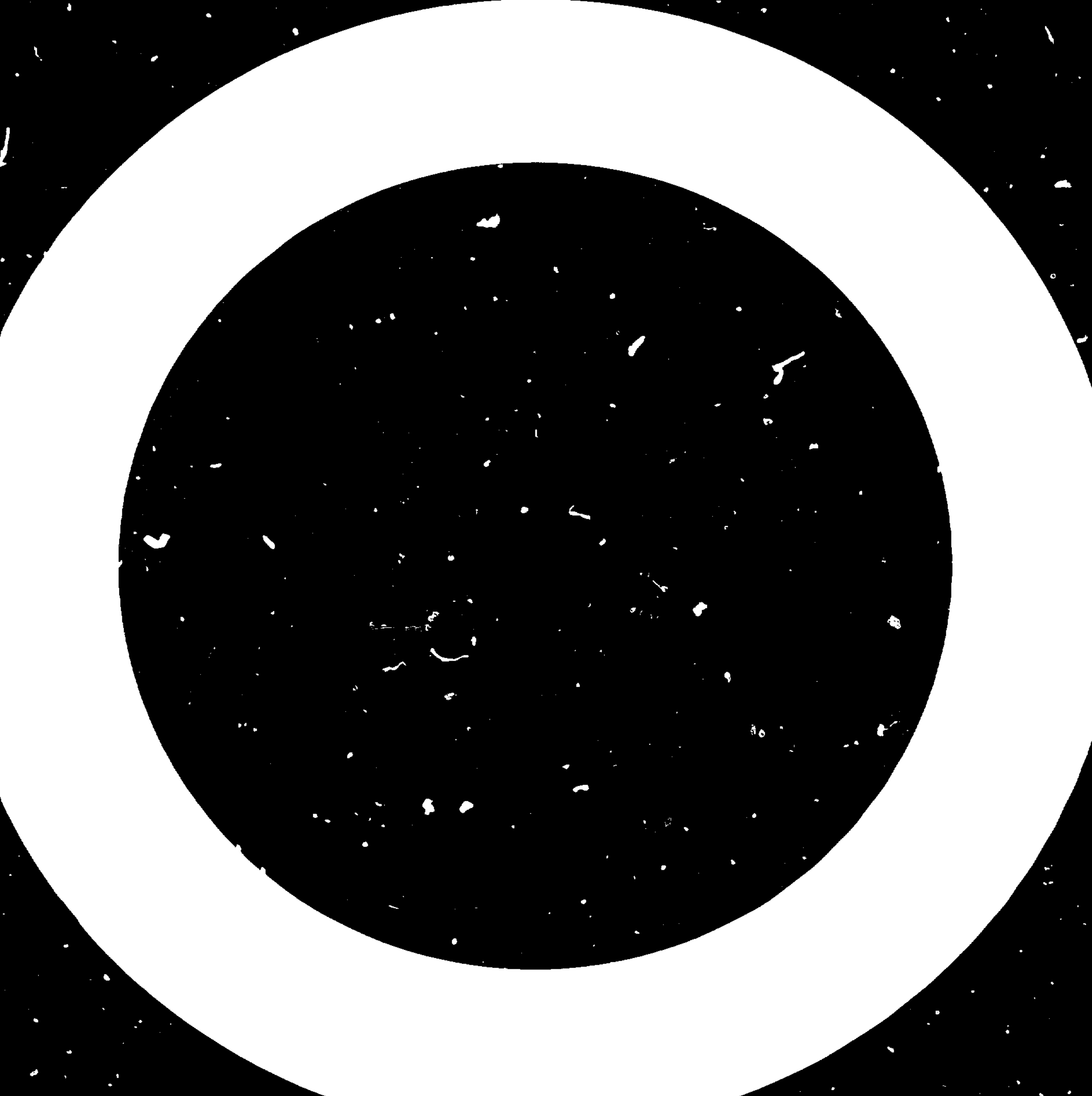
Las otras dos empresas son Jyoti Limited y Eicher Tractors India Limited, ambas en el sector privado. Se diferencian de la HMT por muchas razones. Ambas constituyen ejemplos de la importancia del empresariado en la importación de tecnología y su asimilación a pesar de las dificultades que enfrentan las empresas de los países en desarrollo. Jyoti Limited es un buen ejemplo de una empresa de un país en desarrollo que ha celebrado acuerdos de colaboración con empresas extranjeras sobre bases muy selectivas y ha asimilado completamente la tecnología importada durante el período de colaboración, a través de la investigación y el desarrollo locales. El caso práctico referente a Eicher Tractors India Limited demuestra cómo una empresa comercial puede transformarse en una empresa industrial y, al hacerlo, lograr un buen equilibrio entre la tecnología de fabricación tradicional y la moderna frente a la escasez de capital y, además, introducir un producto fuera de uso en el país de origen, pero apropiado para el medio ambiente rural de la India carente de tecnología.

El análisis de los cinco casos prácticos compara sus experiencias en la adquisición de tecnología, la asimilación y adopción de tecnología extranjera y el papel de la investigación y el desarrollo. Se llega a la conclusión de que la transferencia de una tecnología compleja a un nuevo ambiente plantea problemas que, con frecuencia, no admiten soluciones teóricas. En consecuencia, la empresa que adquiere la tecnología debe encontrar una solución mediante ensayos, que requieren mucho tiempo y dinero, o bien conseguir ayuda de un colaborador extranjero con experiencia, lo que entraña una dependencia técnica constante del mismo. En los acuerdos debe especificarse que los ensayos de aceptación no se llevarán a cabo en la planta del colaborador sino en el nuevo ambiente y, posiblemente, con materias primas locales.

Los principales indicios de asimilación de tecnología por parte de una industria de un país en desarrollo estarán dados por el éxito que se obtenga en la sustitución de las importaciones, la evolución de las exportaciones y el grado de transferencia horizontal e inversa de tecnología. No surgen sólo limitaciones debidas a problemas tecnológicos, sino también al reducido volumen de producción que, en general, se observa en los países en desarrollo. La capacidad de fabricar un producto complejo en una industria de un país en desarrollo, basado en el know-how de diseño y fabricación proporcionado llave en mano por el colaborador extranjero, tal vez facilite el logro del objetivo de la sustitución de las importaciones, pero no siempre significará que se haya realizado la absorción de la tecnología y que el país sea autosuficiente en la tecnología de que se trate. La asimilación de tecnología es un proceso de múltiples etapas; salvo que se haga hincapié en las actividades de investigación y desarrollo básicas y aplicadas, puede que la industria del país en desarrollo vaya pasando de una etapa a otra y descubriendo más aspectos en los que necesite depender del colaborador.



CASE-STUDIES IN THE ACQUISITION OF TECHNOLOGY (II)



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

Development and Transfer of Technology Series No. 14

CASE-STUDIES IN THE ACQUISITION OF TECHNOLOGY (II)

UNITED NATIONS
New York, 1984

Preface

Volume I of the *Case-Studies in the Acquisition of Technology*, published in May 1981, has found a large readership, and it is hoped that volume II will be of equal interest. This volume contains three more detailed cases of transfer and absorption of technology in India and is a companion to volume I in that it contains a chapter analysing not only the three case-studies of Indian enterprises presented here but the studies of two other Indian enterprises contained in volume I.

Naturally, the analysis and conclusions reached will apply first of all to India or countries with similar social conditions. However, all developing countries may derive a certain benefit from the experience gained by these Indian enterprises.

The UNIDO secretariat intends to prepare further volumes of case-studies.

EXPLANATORY NOTES

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

A slash between dates (e.g. 1970/71) indicates a crop year, financial year or academic year.

Use of a hyphen between dates (e.g. 1960-1965) indicates the full period involved, including the beginning and end years.

References to "tons" are to metric tons, unless otherwise specified.

The following forms have been used in tables:

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

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

A blank indicates that the item is not applicable.

Totals may not add precisely because of rounding.

In addition to the common abbreviations, the following have been used in this report:

Economic and technical

c.i.f.	cost, insurance, freight
CKD	completely knocked down
f.o.b.	free on board
NC	numerically controlled
R and D	research and development

Organizations

BHEL	Bharat Heavy Electricals Ltd.
CE	Combustion Engineering
FW	Fritz Werner
HMT	Hindustan Machine Tools Limited
HPF	Hindustan Photo Films Manufacturing Company Ltd.
ISI	Indian Standards Institution

CONTENTS

I. Development of HMT, a diversified manufacturing company

*S. K. Mukherjee**

The founding of HMT and first acquisition of technology

Before the Second World War, India depended on the industrialized countries of Europe and North America for imports of machine tools required for industrial production. The domestic machine tool industry was in its infancy. There were only a few Indian machine tool manufacturers, and the products were usually inferior and unstandardized. India's dependence on other countries for even simple machine tools was felt acutely during the Second World War, when the supply lines from Europe and North America were either completely cut off or became less and less dependable. The domestic machine tool industry at that time received considerable support from the Government, but once the war was over, this support did not last long. When imported machine tools were again available, the domestic machine tool industry could not continue to sell its products on the domestic market.

Soon after India became independent, the idea of setting up a modern machine tool industry in the public sector found support from the new Government.

A feasibility study for a machine tool plant was carried out, and machine tool manufacturers in several countries were approached for collaboration. Firm offers were received from Czechoslovak and Swiss firms. In 1949, the Government decided to enter into a joint venture with the Swiss firm Oerlikon Machine Tool Works, Buehrie and Company, Zurich. The main reason for selecting Oerlikon was that it had already set up some of the ordnance factories in India, and the Government was satisfied not only with its products, but also with its ability to train Indian engineers and workers in the difficult task of manufacturing machine tools.

*Indian Institute of Management, Ahmedabad, India.

The initial agreement with Oerlikon

The initial agreement with the Oerlikon Machine Tool Works was signed by the Government of India on 28 March 1949. Oerlikon agreed to provide technical assistance to the Government in setting up a factory to manufacture lathes, to provide the necessary know-how, to train the Indian personnel, and to manage the production of the factory for 20 years

Oerlikon selected the plant site at Jalahali near Bangalore and purchased 10 per cent equity shares in the proposed company. The Government agreed to assign 5 per cent of the share capital to Oerlikon in consideration of the transfer of the know-how to produce the lathes.

The project was delayed by four years, however, and Hindustan Machine Tools Ltd. (HMT) was formally registered only in February 1953.

In the same year, five engineers were sent to the Oerlikon plant in Zurich for comprehensive training. The engineers were given rigorous training on the shop floor, where they learned everything about machine tools, their maintenance, and how to dismantle and repair a machine.

When the new plant was set up, 84 Oerlikon engineers came to India. These engineers were responsible not only for setting up the factory, but also for all aspects of production. The trained Indian engineers initially performed only administrative functions. There was an initial difference of opinion between the Indian engineers and the Oerlikon group. While the Indian engineers wanted to diversify and produce more than one product, the Swiss advisers wanted to produce only a single product, the H-22 lathe, in batches of 400 per year, in the belief that the Indian workers and engineers had to be trained thoroughly in the manufacture of the basic precision lathe. Under their guidance a strong foundation was laid.

The production of H-22 lathes was inaugurated by the Prime Minister on 6 October 1955. At first the lathe was assembled from imported components, but the manufacture of these components started in Bangalore almost immediately. The first batch of five H-22 lathes produced entirely at HMT was released on 31 May 1956. However, there was not enough domestic demand to absorb the 400 H-22 lathes HMT was planning to produce, though the lathe was of a superior quality. As a result, there was wide criticism in the parliament, and the Government commissioned a British machine tool expert to inquire into the company's problems. His report, which predicted that HMT would be a "colossal financial failure" resulted in a change in management and a change in production policy.

One of the first things the new managing director did was to place operations in the hands of the Indian engineers, but he retained more than 60 Swiss engineers for a few years as advisers. He also decided on a diversification programme favoured by the Indian engineers. Since Oerlikon was still reluctant to let HMT take this new course, the management decided to buy out Oerlikon's shareholdings in HMT and negotiate a new agreement.

The revised agreement with Oerlikon

In July 1956, the new managing director went to Zurich and, with the approval of the Government, negotiated a new agreement to supersede that of 1949. It was agreed that Oerlikon would be repaid its share capital of Rs 3 million plus interest accrued subject to a maximum of five years at 5 per cent less taxes and a net sum of Rs 1.25 million in consideration of its forgoing the 5 per cent free shares.

Two other agreements between Oerlikon and HMT were subsequently signed. The first provided that Oerlikon would grant a licence for the manufacture of H-22 lathes to HMT for a period of 20 years dating from 1 October 1954. The other provided that Oerlikon would act as a technical consultant to HMT for seven years.

The H-22 licensing agreement granted HMT the right to manufacture an 8½" high-speed centre lathe, type H-22, including all standard and special accessories and any subsequent changes in the design. It also granted HMT the exclusive right to sell such machines in India, Burma, Ceylon and Pakistan for 20 years from 1 October 1954. Oerlikon promised to give all technical information, including secret processes, manufacturing secrets and know-how, and assistance concerning the manufacture, use and maintenance of all products covered by the agreement. It agreed to grant or transfer to HMT all licences and the right to use patents as required by HMT and all further improvements or modifications made from time to time. It would also supply all jigs, tools, fixtures, patterns, raw materials and equipment, finished and semi-finished components as needed for starting operations and for maintaining production at competitive prices in the future.

In consideration of the grant of the manufacture and sales right and other services specified, apart from the payment of Rs 1.25 million by the Government, HMT agreed to pay a royalty on actual sales at specified rates. HMT could not transfer the rights granted to it to a third party. Oerlikon also was prohibited from granting a licence for the manufacture of the same product to any other party in India, Burma, Ceylon and Pakistan during the term of the agreement.

The technical assistance agreement covered many areas, including granting of licences for manufacture and sales of other machines (on mutually agreed upon terms), assistance in negotiating and securing licences from third parties, provision of advice on technical questions and sending experts to HMT works at cost, provision of advanced training for Indian supervisory staff in Europe either at Oerlikon's works or elsewhere, and procurement of materials and inspection of goods purchased in Europe. For most of these services HMT was to pay the actual cost and overheads to Oerlikon and an additional payment of Rs 25,000 per year.

Once the original agreement between Oerlikon and the Government of India had been superseded by the new agreements, HMT was free to proceed with the diversification of its product range; and it then entered a dynamic stage of rapid growth. The first stage of diversification was completed within five years from the start of production, mainly based on new collaboration agreements.

Product diversification: the first phase

A working group appointed by the Ministry of Production recommended that HMT should diversify its output by manufacturing milling machines, grinders, drills and a wider variety of lathes. It also strongly suggested that the company should have its own foundry to produce high-quality castings needed for machine tool production. The Government accepted the recommendations of the working group, and accordingly HMT entered into a series of technical collaboration agreements with several other firms. It began diversifying by producing in addition to the H-22 lathe other general-purpose machines such as milling, drilling and grinding machine tools, then moved into other areas of sophisticated machine tools, such as gear shaping, gear cutting, special-purpose machines and other turning machines. Annex I lists the collaboration agreements HMT entered into.

General-purpose machine tools

A collaboration agreement was signed in January 1957 with Fritz Werner (FW) of Berlin (West) for the manufacture of two sizes of milling machines. A second collaboration agreement was signed in June 1958 with Hermann Kolb of Cologne, Federal Republic of Germany, for the manufacture of radial drills. A third collaboration agreement was signed with a French machine tool company (now known as H. Ernault-Somua) to manufacture a simpler type of lathe (LB lathe) in five sizes. HMT also signed a technical collaboration agreement with Officina Meccanica Olivetti of Italy in October 1959 for the manufacture of 16 types of cylindrical grinders.

In 1957/58, 89 milling machines were produced. In 1959, the radial drills and low-priced LB lathes were ready, and, in 1960/61, 30 cylindrical grinders were manufactured.

The collaboration agreement for the production of horizontal, vertical and universal-type milling machines in two sizes with Fritz Werner gave HMT the right to manufacture these machines of FW design in India and Ceylon under the HMT trade mark and involved lump-sum payments for the design and royalty payments at 3.5 per cent on the first 600 milling machines each of sizes 2 and 3. In the modified agreement signed on 4 March 1961, the royalty payment was deleted. Additional payments were also provided for patterns and pattern drawings. The collaboration agreement had a duration of seven years. Fritz Werner was expected to supply complete sets of reproducible drawings of machines and special equipment, jigs and fixtures, special tools and gauges and standards, a list of raw materials, an up-to-date operation schedule for the manufacture of component parts, details of assembly drawings, a complete set of standard sheets, and one set of patterns and pattern drawings for cast components.

The agreement also provided for training of up to 20 persons from HMT at the FW works in Berlin (West), not more than five at a time, and for sending up to five technicians to Bangalore. FW was to provide all licences for manufacturing the machines and further improvements during the period of the agreement, technical information and knowledge, and jigs and fixtures at cost. FW agreed to station one expert at Bangalore. Permission for one company's employees to visit the other's works was also agreed upon. HMT had the right to alter the FW design to suit the conditions and standards prevailing in the HMT works in consultation with FW, and FW agreed to provide technical assistance in making the alterations. FW also agreed to provide HMT with complete sets of ready-to-assemble parts for at least 50 machines of type 2 and 30 machines of type 3 at 67.5 per cent of cost f.o.b. ocean port.

The collaboration agreement with Hermann Kolb, for the exclusive right to manufacture 10 types of radial drills in India, Burma and Ceylon, also had a duration of seven years. It involved payment of a lump sum for the licence, but no royalties. HMT also had the right to adapt the design to Indian requirements. The agreement also provided for the training of HMT personnel at the collaborator's works (up to 10 persons, not more than five at a time).

Special-purpose machine tools and watches

Because of the growing need in India for special-purpose machine tools that HMT was not yet equipped to manufacture, in 1961, HMT entered into a technical collaboration agreement for the design and manufacture of such machine tools with Région nationale des usines Renault of France. The duration of the agreement was seven years.

The agreement with Renault involved no lump-sum payment or royalties, but there was a commitment to purchase a specified number of components and machines from Renault. Twenty HMT engineers went for training at the Renault works for periods of 6-12 months. Renault also sent experts to HMT, initially two and subsequently four, for a one-year period. These experts were in the fields of design, proposal making and marketing, assembly and servicing of special-purpose machines. The collaboration with Renault proved to be one of the most successful that HMT entered into. Since Renault was a government-owned company and HMT was also in the public sector, HMT had no problem in getting all the information it wanted.

HMT also entered into a technical collaboration agreement in 1961 with Limex, German Democratic Republic, covering the know-how and manufacture of any modern machine tools for which specific licensing agreements could be negotiated product by product.

HMT scored a major achievement in assimilating technology in 1960/61, when, in addition to producing machine tools under the licence of others, it added two turret lathes of its own design and two special-purpose machines designed in collaboration with Renault of France.

In 1960/61, HMT produced 1,261 machines and felt that the growing market for machine tools in India would support additional capacity, since its first unit at Bangalore was operating at full capacity. The construction of a second unit at Bangalore (HMT II), which started in April 1960, was completed in 14 months and doubled production capacity. This factory was also built entirely with HMT funds without foreign technical assistance.

The first major diversification in areas other than machine tools also came in 1961, when HMT set up a watch factory in Bangalore for which the Government entered into a collaboration agreement with the Citizen Watch Company of Japan in 1960. The earlier collaboration agreements for machine tools did not call for extensive training of Indian engineers and technicians owing to the excellent training imparted by the Oerlikon engineers and technicians both in their Zurich plant and at Bangalore. But as HMT was going to manufacture a precision product, for which it did not have any experience, over 100 Indian technicians were sent to Japan for 18 months of training. The first set of watches assembled from imported components was released in July 1961.

The agreement between the Government of India and Citizen Watch Company of Japan, the execution of which was assigned to HMT, was similar to a turnkey contract, with Citizen responsible for the layout of the factory; selection and supply of machinery and equipment; manufacture of jigs, tools and fixtures; training of Indian personnel; licensing; technical assistance; and management of production according to an agreed-upon schedule. The agreement had a duration of eight years and covered the manufacture of both men's and women's watches but did not cover assistance in the manufacture of shock absorbers, main springs, hair springs and jewels. The machinery and equipment supplied by Citizen were covered by a credit of 18 billion yen from the Government of Japan. Citizen agreed to supervise the erection, installation and initial operation of the machinery. The agreement involved paying a lump sum to Citizen for the supply of drawings, other information and technical assistance. Royalty payments to Citizen at the rate of 2 per cent based on the standard price of watches less the price of imported components was also agreed upon. Citizen agreed to provide the results of R and D, design improvements etc. The agreement gave HMT exclusive rights to manufacture in India and sell in India or elsewhere.

By 1961/62, HMT total sales reached Rs 74.5 million, and HMT earned a net profit of Rs 12.75 million (24 per cent return on its share capital of Rs 53.1 million) and paid a 10 per cent dividend to the Government. As the industrial growth rate in the country was high during the second and third five-year plans, demand for HMT machine tools was high accordingly. A third machine tool plant (HMT III), located at Pinjore, Haryana, was inaugurated in October 1963; its products were mainly milling and broaching machines. Later a separate division was added at Pinjore to produce tractors, for which HMT had been manufacturing various special-purpose machines. Encouraged by its rapid growth and the financial success, HMT set up two more machine tool plants. HMT IV was commissioned in July 1964 at Kalamassery, Kerala, to produce machine tools of the turning family.

A separate division to produce printing presses was also set up. HMT IV was located at Hyderabad to produce special-purpose machines, and trial production began in December 1965. A separate division to manufacture hydraulic and mechanical presses was added later following a collaboration agreement with Verson Allsteel Press Co., United States of America, and subsequently a new lamp and lamp machinery division was added.

Product diversification within the machine tool family continued with a collaboration agreement (1961) with Limex, German Democratic Republic, to produce surface grinders. An agreement was signed (1963) with Drummond Brothers Ltd., United Kingdom of Great Britain and Northern Ireland, to produce gear shapers and with Hans Liebherr, Federal Republic of Germany (1964), to produce gear hobbing machines.

The initial years of HMT, following the decision to diversify, were highly successful, for HMT was operating in a seller's market in a period of rapid industrial growth. But once a severe economic recession started in 1967, it was hard hit, especially because of the additional capacity created in HMT IV and V.

Product diversification: the second phase

During the first phase of diversification, HMT was mainly dependent on technical collaboration with established manufacturers of machine tools because its own design capability was not yet well established, in spite of a few machine tools of HMT design that were being produced. The HMT design staff were thus mainly occupied with adapting designs obtained through licences.

In 1967/68, HMT found itself in the red for the first time. The seller's market in machine tools had suddenly changed to a buyer's market in which the customers started making many demands on HMT to provide customized machine tools and special attachments. As a public-sector organization, HMT could not resort to a policy of retrenching on workers in spite of having few orders and idle capacity. HMT also did not want to become dependent on government finance and somehow managed to pay the workers from the revenue generated by the watch factory.

HMT decided to meet the challenge posed by the recession by moving into another stage of diversification, this time involving highly complex machine tools. Though the total market for machine tools in India shrank to Rs 388 million in 1969/70 from Rs 609.3 million in 1965/66, the country was still importing most of the high-priced machine tools it required, with imports valued at Rs 370 million per year. HMT decided to enter this market and was actively supported by the Defence Production Ministry, which placed an order for 275 electrically controlled milling machines for the small arms factory at Tiruchirapalli. These machines were to be specifically designed to meet the needs of the ordnance factory. HMT produced the milling machines within a year, wholly designed by HMT engineers. It took a much longer time, however, to eliminate certain problems with the machine.

During the second-phase diversification HMT followed a new strategy. It obtained licences and designs of new and complex machine tools from manufacturers in industrialized countries against bulk order of machinery for the ordnance factories, which would have been imported anyway.

Similarly, in 1967, in return for the bulk purchase of precision horizontal boring machines, needed by a company at Bangalore, HMT obtained a licence from Pegard, Belgium, without paying a lump sum or royalties. In 1969, the same strategy was adopted in signing a technical collaboration agreement with Ateliers GSP of France to obtain design and know-how for the manufacture of co-ordinate drills and jig borers.

HMT also carried out a major diversification at this time by taking up the manufacture of metal-forming machines, a departure from the metal-cutting machines that it was producing. As the automobile and other industries in India needed heavy-duty mechanical and hydraulic presses and press brakes, HMT started manufacturing both medium-heavy and heavy presses in HMT V, Hyderabad, based on a technical collaboration agreement signed with Verson Allsteel Press Co., United States, in 1969.

To modernize its technology for manufacturing special-purpose machines and transfer lines for which there was an earlier collaboration with Renault of France, HMT entered into a new collaboration agreement in 1976 with the Cross Company, United States. This collaboration also helped HMT export business.

Because of its earlier experience during the recession years, when the HMT machine tools business was seriously hurt but the company was saved from disaster by production of watches, HMT decided to enter new product areas where demand was expected to be more stable. It was also felt that the growth in machine tool business would not be fast enough to satisfy the corporate objectives of HMT. Accordingly, in 1972/73, a second unit to manufacture automatic watches was set up at Bangalore followed, in 1973/74, by a third unit at Srinagar to make hand-wound watches.

A market study indicated that there was a steady demand for printing machines of high quality, that were being imported. In view of the similarity in the manufacturing technology needed for producing printing machines and machine tools, HMT decided to enter this area. A collaboration agreement was signed in September 1969 with Societa Nebiolo, Italy, for the manufacture of printing presses, paper-cutting machines and off-set presses, and a new division was started at HMT IV, Kalamassery.

Similarly, again based on market studies, HMT decided to manufacture die casting and plastic injection moulding machines. A separate division was set up near HMT I and II, Bangalore, for this purpose; and, in May 1969, HMT concluded an agreement with Buhler Brothers Ltd., Uzwil, Switzerland.

HMT also did not hesitate to move away from its main area of business, i.e. manufacture of capital goods such as machine tools, to produce other products in areas where there was unmet demand, where HMT had some familiarity with production processes or where HMT felt that it could play a pioneering role. Based on its familiarity with the production process for agricultural tractors, gained through its production of special-purpose machine tools for the tractor industry, HMT decided to manufacture 12,000 tractors per year at its Pinjore plant. For this purpose, HMT entered into a collaboration agreement with MOTOKOV of Prague, Czechoslovakia, in January 1971.

HMT also began to manufacture lamps, lamp components and lamp-making machinery under a licensing agreement with United Incandescent Lamp and Electrical Company Ltd. (TUNGSRAM), Hungary, signed in April 1973. It set up a separate division, including a glass factory, near HMT V, Hyderabad, for the manufacture of lamp components and lamp chains.

Problem solving in assimilating technology at HMT V, Hyderabad

Manufacture of metal-forming presses

A collaboration agreement was signed with Verson Allsteel Press Company, on 2 May 1969, for the manufacture of mechanical and hydraulic presses with capacities of up to 250 tons. The duration of the agreement was 10 years. HMT paid a lump sum for the purchase of designs, complete drawings and other necessary manufacturing documents and standard sheets, but had no royalties to pay on the quantity it produced. When the agreement was signed, it was decided that HMT would make only small presses (up to 250 tons capacity), but when HMT was ready to produce the presses, it found that several other Indian manufacturers were already making small presses and their prices were fairly low. HMT realized that it would face very tough competition in the market for small presses, so the management decided that HMT would have to manufacture heavy presses to survive. The production facilities that were being set up at HMT V, however, were limited, and the collaboration agreement with Verson was also limited to the manufacture of small presses.

So when design engineers were sent to the United States for training at Verson they were given to understand that they would also have to study the design of presses of higher capacity, since such technology was needed in India. HMT also considered buying engineering designs for one large press along with all supporting calculations so that HMT could design large presses.

Although no facilities for manufacturing heavy-press components from heavy-gauge steel plates were available at the Hyderabad plant, there was much spare capacity for such manufacture in other concerns in the public and private sectors. Accordingly, HMT decided to secure orders for heavy presses and have the various parts and components manufactured by other companies. HMT received an order for a large press from the Tata Engineering and Locomotive Company Limited (TELCO). But when it came to assembling components made at different manufacturing concerns, difficulties arose in assembling the press, since none of the manufacturers had been able to adhere to the quality standard required. HMT tried to ensure that the manufacturers would provide satisfactory products by asking them to provide certificates of quality before sending the completed parts, but still the method of having parts manufactured at different places did not work, since these concerns could not achieve the necessary accuracy. Although this method has worked well in some developed countries, it became apparent that it would not work in India. The HMT management then decided that HMT would have to build facilities for working with heavier plates and would manufacture the components itself.

During this period HMT was asked to manufacture a 2,000-ton press for Bharat Heavy Electricals Limited (BHEL) at Tiruchirapalli for bending boiler drum ends by hot pressing. Because of earlier difficulties in having the parts fabricated elsewhere and assembling the press later, HMT decided not to accept the order. However, the BHEL management offered to collaborate in manufacturing the parts needed, and together BHEL and HMT managed to build the press. The collaboration proved successful in this particular case, but it did not alter management's decision to manufacture large capacity, heavy-duty presses.

HMT did not have any experience even in designing metal-forming presses. Much of its earlier experience was in the manufacture of precision machine tools and wrist-watches. But as HMT by now understood the technology development process better and had gained confidence in its own abilities, a decision was taken to develop technology for designing and manufacturing metal-forming presses without help from its collaborator, Verson Allsteel Press. It was decided to recruit and train young engineering graduates. In fact, HMT could not have done otherwise, since the collaboration with Verson covered only the manufacture of small presses, and there was no assurance that Verson would agree to part with the technology for designing and manufacturing high-capacity presses. As a result, Verson was not informed that along with manufacturing the small presses for which it had purchased Verson design and manufacturing technology, HMT was embarking on a project to manufacture large-capacity presses for which there was no other manufacturer in India.

HMT had really set a gigantic task for itself, since the design of almost every press differs to some extent from all other designs, since it has to meet the requirements of each customer. Here was another reason for developing indigenous technology rather than extending the collaboration with Verson to cover large-capacity presses. Verson designs were such that the import content of a press would be very high, because for certain patented components Verson would not supply drawings. Since these components would have to be purchased from Verson, HMT decided to design and manufacture them itself. The result of this great effort to develop indigenous technology for large-capacity presses was that within five years HMT was manufacturing 3,000-ton presses.

On invitation from HMT, three of the top managers from Verson finally came to visit the Hyderabad plant. Hitherto the collaborator had shown little interest in monitoring HMT progress in producing metal-forming presses based on its design. The Verson managers were still under the impression that HMT was manufacturing only the Verson-designed small presses and were completely surprised to find HMT manufacturing large presses. They even asked how HMT obtained the design of the large presses and managed to manufacture them.

Another strategy that HMT followed was to some extent similar to the Japanese method of developing the design of a machine purchased from others by completely stripping down the machine and developing drawings and design calculations based on it. The same design could be adapted later to suit the indigenous conditions and enlarged in capacity, if necessary. HMT used this strategy to manufacture metal-forming machines that needed replacement in industries.

Most of the industrial plants in India had presses that were often 20-30 years old and needed to be replaced. Usually the enterprises wanted exactly the same kind of press without concerning themselves about recent improvements that had taken place in the technology. Thus HMT had to educate customers about the capability of HMT to manufacture modern metal-forming presses. Many industries were also not aware of the wide range of applications of metal-forming operations and the savings that they could obtain by converting manufacturing processes for some of their components from metal cutting to metal forming. As a result of HMT efforts, within a few years the demand for HMT metal-forming presses rose considerably. The customers also wanted presses of higher capacity.

Many of the presses that needed to be replaced were also special-purpose machines. Manufacturing them after buying the design from the collaborators would have been very expensive, since HMT would have had to buy different designs for different presses, and the quantity manufactured would have been too low to justify the cost. In such cases HMT used the strategy discussed above to develop designs. The customer was approached to let HMT strip down the small old press to be replaced and study the components. Based on the design calculations developed from the analysis of the old machine, a larger, modern machine could be designed. HMT also began to keep in closer touch with clients. When visiting HMT clients HMT design engineers gathered ideas about metal-forming machines or presses from the clients so that these ideas could be transformed into designs for the clients. As a result some half-baked ideas were transformed into workable designs.

The same method was used to design and manufacture roll-forging machines, a new technology widely used in manufacturing agricultural implements. HMT expected that it would receive many orders for roll-forging machines not only from companies in India but also from other countries in South-East Asia. Thus when a company wanted a replacement for its 80-ton roll-forging press, the whole machine was brought to Hyderabad and dismantled. Based on the study of this machine, the HMT designers developed a design for a 130-ton roll-forging press for this company. There was no manufacturer for this particular type of press in India, and, in fact, a United States version of the roll-forging press was being imported. After HMT developed this machine, no more licences to import these machines were issued.

These examples show that design technology often does not have to be developed from scratch but may start from a study of existing technology or a technology that may have become obsolete.

HMT has also taken up specific in-house R and D projects for the design of new products, including a high-speed press, roll reed device, guillotine and shearing machine and roll-forging machine. HMT is considering a proposal to set up a central institute of metal forming with government assistance to carry out R and D work on metal-forming processes for various new metals and alloys. In setting up this institute, HMT may collaborate with some foreign research institution. The metal-forming division in HMT has also carried out other projects such as manufacturing cold-extrusion machines for an Indian company and large gear boxes and haulage equipment for the Singerani coal mines. Both these projects have saved foreign exchange by making it unnecessary to import such machinery. HMT has also exported various designs of metal-forming presses, a test of its ability to assimilate technology, since in the export market competition is keen and it is necessary to keep abreast of new technological developments.

Manufacture of special-purpose machine tools

HMT first started manufacturing special-purpose machines at its Bangalore plant once it had signed a collaboration agreement with Renault in 1961. Following the establishment of HMT V at Hyderabad in 1965, the manufacture of special-purpose machines received a great impetus when large manufacturing facilities and a well-staffed design office were created.

HMT started manufacturing unit-built special-purpose machines initially with the basic design of electro-mechanically controlled, standardized unit heads provided by Renault and detailed design by HMT for performing multiple operations such as drilling, milling, boring, facing, turning and tapping. Both rotary indexing machines and linear transfer lines are being manufactured for parts of automobiles, locomotives and other engineering products. As these machines are designed for machining a particular product, they result in high productivity and stable quality at minimum cost.

Special-purpose machines are usually built using standard modules or unit heads, and other modules are built as required. They are meant for machining a particular component or product in a mass-production industry. In India there is not such a great demand for special-purpose machines as in Western countries, mainly because fewer automobiles and other such items are produced. The labour cost in India is also low compared with that in the industrialized countries, thus making highly mechanized or automated production uneconomical. Nevertheless, demand for special-purpose machines is increasing in India mainly because of the desire to have better quality control, which is also not entirely dependent on the worker's skill, as is often the case with general-purpose machines. HMT caters not only to mass-production industry, but also to the special requirements of other industries, and it has developed its own designs to meet the needs of the Indian market. It has also started to design and manufacture machines or products that require precision components and not necessarily machine tools.

HMT is also specializing in the area of semi-standard machines, which lie somewhere between general-purpose and special-purpose machines. Three machines initially developed in this area are the fine borer, facing and centring machine and multispindle adjustable drill. In 1977, it also succeeded in designing a floor-type drilling, boring and milling machine.

Introduction of special-purpose machines gave a fillip to the design base of HMT, since hitherto the design engineers had been mainly involved in conversion of standards and adaptation of designs obtained through a licence.

In 1962, Tata Engineering and Locomotive Company placed an order for six special-purpose machines for its automobile division. It was decided that two of these machines would be built by Renault in France and the rest by HMT. The design work was started at Bangalore for the parts except the standard equipment being designed under the direction of French experts from Renault. HMT design engineers learned quickly. They learned initially from Renault, then from visits to international machine tool exhibitions, from machines already in use with customers and often from catalogues and brochures. For example, the design of the multispindle automatic machine was inspired by a catalogue.

HMT also entered into some collaboration agreements for specific techniques for semi-standard machines, on the basis of running royalties. Usually some sales of machine tools or components were promised, and the collaborator had to provide all design documents in return. In 1971, HMT entered into a collaboration agreement with Fritz Werner for the manufacture of bed-type milling machines. A collaboration agreement with Pegard, entered into in 1966, for horizontal borers was renewed twice, in 1972 and 1978. Though HMT had absorbed Pegard technology and developed its own, it renewed the agreement because it wanted to manufacture larger machines and also to keep in contact with an advanced manufacturer. One of the machines manufactured at HMT was sold to Pegard.

After collaboration with Renault ended in 1968, HMT, having fully absorbed the Renault technology, continued to design special-purpose machines and develop indigenous technology. In 1976, to meet the exacting standards for modern special-purpose machines and transfer lines needed by the mass production industry in the country, HMT entered into a collaboration agreement with the Cross Company (CROSSCO), United States, with a view to entering the export market for special-purpose machines. With CROSSCO assistance, HMT succeeded in exporting special-purpose machines to Iran and other countries. The agreement with CROSSCO involved a down payment and royalties as well as an undertaking not to pursue Renault designs any more. A technical and a marketing expert from CROSSCO visited HMT. The agreement between CROSSCO and HMT was to be in force for seven years from the date of the first sale of commercial production by HMT. HMT already had a production capacity of special-purpose machines valued at Rs 60 million annually, which it planned to increase to Rs 100 million using the CROSSCO technology. HMT was given the exclusive right to use the CROSSCO technology in India and to sell the products in India. HMT was free to sublicense the technical know-how obtained under this agreement to another Indian party under terms of sublicensing to be discussed with CROSSCO and subject to the approval of the Government of India. The agreement provided for training of HMT personnel in CROSSCO plants in product design, production engineering, production processes, inspection practices and methods of quality control. CROSSCO also agreed to supply major assemblies and components required for the manufacture of the products at prices f.o.b. at CROSSCO plants according to an agreed schedule and not higher than the prices charged by CROSSCO to domestic consumers.

Although given the exclusive right to sell its products in India, HMT was restricted in the territories where CROSSCO had given exclusive rights to its licensees. HMT, CROSSCO and its licensees were to execute distribution agreements under which CROSSCO and its licensees would be given the exclusive right to sell the products manufactured by HMT in various territories outside India, and they were to be paid the amount specified for the sale of the products.

In consideration of the exclusive right to use CROSSCO technology, HMT agreed to pay a lump sum and an amount in the form of purchase credit towards export orders to be placed with HMT by CROSSCO. HMT also paid a fee for the services of the technical and marketing directors sent to assist in the manufacture and sales of the products for a total of 67 man-months. HMT also agreed to pay a royalty at the rate of 5 per cent of the net selling price of the products for a period of seven years from the date of the first commercial sale. HMT was permitted to convert the designs to metric measurements, but agreed not to make any modifications without prior written consultation with CROSSCO. HMT also agreed not to manufacture or sell any equipment that competed with products manufactured by CROSSCO without the prior written permission of CROSSCO. This clause meant that HMT had to discontinue manufacturing or selling products according to the Renault design after the existing orders, and orders for which quotations had been sent before executing the agreement, had been completed.

The CROSSCO collaboration agreement appears slightly more restrictive and it is more expensive than earlier agreements, since both lump-sum and royalty payments are involved. However, this superior technology has many advantages, and joining the CROSSCO name to HMT has helped in marketing special-purpose machines.

CROSSCO has a computerized production control system, and one person from HMT was sent to CROSSCO especially to be trained to use it. In this area Oerlikon originally introduced efficient procedures at HMT, for example, procedures regarding how to release a drawing and procedures for inspection. Based on these, company standards for procedures were set up. If a collaborator has good systems and procedures, they are adapted for use at the HMT plants.

Although the CROSSCO technology is modern and superior in many aspects to the technology HMT was using for special-purpose machines, it is about 10 per cent more costly, since some items have to be imported.

Technology absorption and adaptation in the company as a whole

In general, technology is absorbed in three stages.[1] In stage one, the foreign manufacturer provides the technology, which the local firm learns to use. In stage two the local firm learns to adapt the basic product design. In stage three the local firm carries out its own research and development.

In the case of HMT—specifically at HMT V, Hyderabad—the first two stages of the process started almost simultaneously. The HMT management realized that since a special-purpose machine was very much a custom-made product, the design know-how was as important to acquire as the new manufacturing technology. Besides, Indian conditions were completely different from those in the Western industrialized countries, since the production rates were lower, and the objective of labour saving might not be appropriate in India, where the labour cost was low. Thus, based on the core foreign technology, which provided the design know-how for the unit heads, various indexing and control devices, the design of a new class of machine tools, especially the semi-standard type, came out of the design office of HMT V. In the area of conventional special-purpose machine tools also, various machines were designed for the special requirements of the railway workshops, automobile plants and manufacturers of auto accessories.

In the area of presses and press brakes, HMT V was almost forced to start innovation and development of indigenous technology, as explained earlier in connection with the collaboration with Verson. The achievement of HMT in absorbing the Verson technology is noteworthy because no foreign experts either in designing or manufacturing were brought in from Verson. From the beginning the HMT engineers were on their own, led by the design engineers who went to Verson plants for training.

It was also HMT policy not to import machine parts and components, even at the beginning, unless it was unavoidable, as, for example, when certain components were patented by parties other than the collaborators and design know-how or drawings were not available. Generally indigenization has been very fast. For the first set of six special-purpose machine tools manufactured for the Tata Engineering and Locomotive Company only two were built by Renault and the rest were made at HMT.

The third stage of technology assimilation and adaptation, i.e. basic R and D, started later at HMT, mainly in the 1970s. Following the establishment of the Central Design and Development Office, the scope of R and D activity enlarged quite rapidly with the formation of unit-based R and D departments and R and D establishments serving the company as a whole. The establishment of an R and D metal-cutting centre also gave an impetus to specific R and D projects such as numerically controlled (NC) machine tools and

[1] For a fuller description of these stages, see *Case-Studies in the Acquisition of Technology (I)*, Development and Transfer of Technology Series No. 14 (ID/257).

spark-erosion machining. Similar centres for metal forming, horological institutes etc. are under development, and collaboration with other engineering and technological institutions is being pursued. Still, the total resources spent by HMT for R and D are less than 1 per cent of total sales. With the growth of R and D, foreign technology will be assimilated better and technology especially suitable for Indian conditions and those of other developing countries can be obtained as well as new technology that is not usually available through foreign collaboration.

Manufacturing technology

The manufacture of quality machine tools involves working to very close tolerances and precision technology, appropriate heat treatment of metals and alloys and proper finishing of the sliding surfaces, good inspection and quality control procedures, and knowledge of various control systems. It requires much greater precision than the manufacture of mass-produced consumer articles.

The basic training in the precision technology and the required systems of quality control was given by Oerlikon. The technology was transferred through the Oerlikon engineers and technicians that came to set up HMT and start production. The H-22 precision lathe was also specially designed for manufacture in India, and the design took the skills available in India and the shortage of expertise in the manufacture of machine tools into consideration. Oerlikon understood well the limitations of a developing country. Its tool room lathe was one of the best in the world in 1956, but it was designed in such a way that its manufacture did not require highly skilled workers. For example, special-purpose boring machines were developed to bore precision holes in the headstock. Thus, the skill required to manufacture the product was incorporated into the product design.

Oerlikon did not give high priority to making the product immediately, but to building the infrastructure. It established a training centre headed by a most experienced person from Switzerland, and training at all levels began. All production shops were set up with small modules, each headed by one Swiss engineer or technician with one or two Indians under him. Strict discipline was maintained. The Swiss experts set the example in methods of work. The Indian engineers and technicians thus learned the technology of machine building within three to four years at the Bangalore plant (HMT I).

Manufacturing technology consists not only of the technology for various processes and operations through which the raw material is transformed into finished parts and components and then assembled into a complete machine, but also includes various systems and procedures—industrial engineering, standards, material testing, methods-and-work study, inspection and quality control. Once HMT had mastered the basic manufacturing and assembly processes, it focused attention on systems and procedures. HMT maintained it was one of the first industries in India to start methods-and-work study. Quality control was taught by the Oerlikon experts on the shop floor so that quality consciousness was instilled in the workers.

Design technology and product development

Initially, the HMT management thought that it was not necessary to undertake its own product development. The technology coming from various countries had to be assimilated, and the first step in assimilation was to develop an HMT standard, based on the agreements with collaborating firms in France, Germany, Federal Republic of, and Switzerland. Such a standard was necessary to function effectively, since each collaborator followed its own national standards. The first collaborator, Oerlikon, gave no guidance in design, but subsequent collaborators provided training for HMT engineers in their design offices.

When an HMT design group was finally set up, it consisted of about five design engineers and one or two foreign experts. Additional engineers were recruited and trained. They were also sent abroad to machine tool exhibitions. A design and development standard was developed, and staff were trained in how things function and in subjects such as fits and tolerances and drafting standards. The products that were developed were considered good even by the standard at that time. Whatever was learned then was learned the hard way, with much experimentation. Later on the design and development department was extended, and today it is one of the company's main sources of strength. HMT now has a good infrastructure to assess a product. It also has a limited research facility, but a fully fledged R and D centre is to be set up.

Assimilation of technology through collaboration

Collaboration with a foreign company was the main vehicle for technology assimilation, adaptation and development at HMT, since the manufacture of precision machine tools was a reasonably new field of technology in India after it became independent. Only very few firms were manufacturing certain common machine tools of average quality. Since India had chosen industrialization as the path to economic development, emphasis on the manufacture of machine tools, needed for basic industry, was logical. Following the initial collaboration entered into by the Government of India with Oerlikon for a basic tool, HMT has entered into over 30 other foreign collaboration agreements (see annex I) of which most were for the design and manufacture of various tools, including special-purpose machines, and the others were for the manufacture of watches and watch components, presses, tractors, printing machinery and lamps and lamp-making machinery.

The terms of the collaboration agreements varied substantially from one to another. Some were almost turnkey contracts (specifically the ones with Oerlikon, Citizen Watch Co. and TUNGSRAM). Others were very loose, involving only the provision of drawings (e.g. Verson). Some of the agreements stipulated both down payment and royalties; some required only one down payment; and several others stipulated compensation from production. Almost every agreement provided for training of HMT engineers and technicians in the collaborator's works and visits of a few experts to the HMT plant to train local staff and help solve start-up problems.

Steps in assimilating technology

Usually when HMT undertakes to manufacture a new machine tool through foreign collaboration, the collaborator is asked to send the complete drawings of the parts and components, assembly drawings, layout and material specifications. Heads of planning (methods) and design teams for the particular machine tool are appointed. They study the drawings and determine the areas where clarification is needed. Then a group is selected for training at the collaborator's works for a period of three to six months depending on the product. A normal group consists of five engineers: a design engineer, a planning (methods) engineer, a manufacturing engineer, an assembly engineer and a servicing or inspection engineer.

After the group has returned to HMT, the drawings provided by the collaborator are converted to HMT standards, using the metric system wherever possible. At the same time process planning begins. During this period HMT usually tries to see that a design and a planning expert from the collaborator will visit HMT so that the conversion to HMT standards will de done under the supervision of the HMT trained engineer and the collaborator's design engineer.

The drawings are then released to the shop floor for the manufacture of the prototype. When all the components are ready for assembly, an expert from the collaborator's works is invited to assist the HMT group, especially if the machine is complicated. Once the prototype has been assembled and tested, the guidance of the collaborator is sought in dealing with any problems that may have arisen. This process often takes about two years, and only then can it be said that the technology has been acquired. During this period HMT usually tries to get completely knocked down (CKD) components or group assemblies from the collaborator. All external elements, such as covers and control panels, will be made at HMT. This two-year period can be divided into three phases. During the first phase, 80-90 per cent of the components are obtained from the collaborator, and the rest are made at HMT. During the next phase, group assemblies are obtained from the collaborator, and these are placed in the machine. During the third phase, all machined components are obtained in the CKD state except small and simple components, which are made or procured locally and then assembled. These phases also depend on the demand for the machine tool and the batch size, and they sometimes merge if the demand is low.

When project planning begins, the exact cost of production is not known. During the prototype stage, the cost of local production is added to the cost of imported parts to determine the price. Only after the prototype is made is the process layout available, and only then is the manufacturing cost known. The trainees coming back from the collaborator's works will know the capacity required in various sections for producing a particular machine tool. In certain sections HMT may not have adequate capacity. Then a decision is taken whether there is enough demand to justify purchasing a machine or whether production can be subcontracted. A separate detailed project report is prepared only if a different product group is started.

Benefits to HMT

While entering into one collaboration agreement after another to manufacture machine tools of various designs, HMT was gaining increasing experience in assimilating technology and adapting it to domestic requirements. It was also gaining confidence in its own ability to manufacture machine tools. Beginning with the general-purpose machines such as lathes, milling, drilling and grinding machines HMT went on to manufacture sophisticated machine tools, for which they obtained designs from foreign collaborators. To have reached this stage without collaboration with foreign companies would have been extremely difficult, if not impossible, and would have taken many years, during which the gap between HMT and the other modern machine tool manufacturers would have further widened.

Changes in the form of collaboration

Gradually the form of collaboration also changed. In 1967, barely 10 years after HMT began collaboration with Fritz Werner for milling machines, HMT entered into a special five-year collaboration agreement with Pegard, SA, Belgium, whereby the two companies were to be equal partners in developing, manufacturing and selling horizontal borers. The agreement provided for:

(a) Concurrent manufacture and selling by HMT and Pegard of horizontal borers of three families;

(b) Joint finalization of the design by HMT and Pegard engineers and further development of HMT horizontal borers of a new family, their concurrent manufacture and sale by HMT and Pegard;

(c) Manufacture at HMT of these machines to meet Indian demand.

The technical co-operation agreement provided for consultation to finalize technical documentation, communication of improvements made by either party, exchange of technicians, supply on demand of complete machines, assembled groups and components by either party, and joint development of a design for a new machine. Based on drawings prepared by HMT, Pegard was to manufacture two prototypes within 12 months, one of which would be sold to HMT. Based on prototype tests, Pegard was to release final manufacturing documentation within a further period of 12 months. The design would be modified on the basis of consultations.

A similar agreement was entered into with Oswald Forst, Federal Republic of Germany, also in 1967. It provided for the concurrent manufacture and sale by HMT and Forst of all types of broaching machines developed by Forst and all standard and special equipment that was developed during the 10-year period of the agreement. The goal was to enable HMT to manufacture these machines to meet the entire demand of the Indian market as soon as possible. The agreement provided that *(a)* HMT and Forst would formulate and finalize all technical documentation through consultations to achieve uniformity; *(b)* the technical documentation would be delivered to HMT only after the prototype machines had been thoroughly tested by Forst and released for serial production at its works; *(c)* technicians would be exchanged; and *(d)* further improvements carried out by one party would be made available to the other. HMT had the exclusive right to sell these machines in India, Burma and Celyon and also the right to sell in other countries mutually agreed upon.

Summary

Thus, within 10 years after entering into its first collaboration agreement after the plant was set up on a turnkey basis by Oerlikon under an agreement with the Government, HMT had not only assimilated the technology achieved through collaboration with various foreign companies, but it had also evolved its design and development capability to such an extent that other machine tool manufacturers were willing to join it in designing and developing machine tools on an equal basis.

HMT has now reached a level of sophistication where it is currently producing machine tools in almost all areas where domestic demand is high enough to justify economic production, and in most of the areas HMT technology is reasonably up to date consistent with needs of a developing country like India. In certain fields, such as NC machine tools, it is even in advance of market development in India. There is very little need for further collaboration with foreign companies in the machine tool area except to obtain new developments of systems in advanced countries such as the use of lasers for comparison, refrigeration in horizontal boring for better accuracy, tool wear compensation, in-process gauging and precision manufacturing. Future collaboration in the machine tool area would be mostly to obtain systems that would have wider applications and not for design of individual or groups of machines.

As HMT diversifies still further it may wish to enter into new collaboration agreements to cut down the cycle time needed for developing the design for a new product and planning for its manufacture. Thus, the absorption, adaptation and development of technology will continue at HMT.

Horizontal and reverse technology transfer

HMT has not been only at the receiving end in the process of technology transfer. Once HMT has absorbed a technology fully and mastered its design and manufacture, it has not hesitated to transfer that technology to other concerns in India and in other developing countries. HMT would like to keep for itself the manufacture of more complex and sophisticated machine tools and license other manufacturers to produce simpler machine tools according to HMT design. Having gone through the difficult process of assimilating advanced technology, HMT is now assisting machine tool manufacturers in other developing countries to absorb technology. In certain cases HMT is also supplying technology and products to industrialized countries. Such horizontal and reverse flow of technology is the true test of technology assimilation through collaboration with foreign companies.

HMT supplies technology through its Project Consultancy Division. This division assists in planning and setting up new industrial ventures or large expansion programmes in any of the engineering fields, specifically in metal processing, in India and in other developing countries. It carries out market surveys, prepares techno-economic feasibility studies and detailed project reports, and evaluates projects. It also identifies imported items and accessories that could be manufactured in India. In 1971/72, it prepared a detailed project report for the State Industries and Investment Corporation of Maharashtra for a plant to manufacture machine tool accessories.

HMT has been instrumental in promoting various machine tool manufacturing concerns in the State and co-operative sector based on its own designs. It executed a technical collaboration and sales agreement with the Quilon District Engineering Technician's Industrial (Workshop) Co-operative Society for the production of HMT-designed lathes. It signed an agreement with the Tamil Nadu Small Industries Corporation to establish a plant for the manufacture of pillar and gang drills and hack-saws and to provide the necessary know-how and technical assistance. HMT also assisted the Kerala Agro Machinery Corporation Limited by preparing process sheets, selecting and supplying machines and accessories, providing tooling and training workers. It is also assisting this firm in a project for manufacturing gears and shafts. In 1974, HMT joined the Gujarat Industrial Investment Corporation, Ahmedabad, in providing equity capital to form Gujarat State Machine Tools Corporation at Bhavnagar to manufacture centre lathes designed by HMT especially for this project. Similarly, HMT entered into a sublicensing agreement with the Bihar Agro-Industries Development Corporation, Patna, in 1975, for the production of tractors from CKD parts supplied by the HMT plant at Pinjore.

HMT carries out similar technology transfer projects in other developing countries in Asia and Africa. In 1972, HMT reached an understanding with Sigma Engineering of Manila, the HMT selling agents in the Philippines, and subsequently a new company, the Machine Tool Manufacturing Company of the Philippines (MTM), was set up to manufacture the LT-20 centre lathe, D-13 bench drill, D-20 pillar drill, HS-20 hack-saw, CSM-63 shaper and PG-25 pedestal grinder. Under the collaboration agreement, HMT was to provide technical know-how, train MTM personnel and give other assistance as required. MTM was to make a down payment of Rs 400,000 to HMT for technical documentation and pay a royalty of 3 per cent on the first 40 million of each type having a minimum of 51 per cent local content. HMT also agreed to supply machine tools worth Rs 3 million.

In 1972, HMT agreed to set up a small machine tool plant in Sri Lanka for the manufacture of pedestal grinders, bench and pillar drills, hack-saws and LT-20 centre lathes. The Project Consultancy Division prepared a feasibility report for a machine tool plant in Indonesia and conducted a market survey. A feasibility report was prepared for the Sikkim Government for a watch factory for the production of 100,000 wristwatches per year, the capacity ultimately to increase to 300,000 watches per year.

HMT prepared a feasibility report for the Industrial Survey and Promotion Council of Kenya and the Industrial Development Bank of Kenya on setting up a machine tool plant. It carried out a similar study for Nigeria under UNIDO sponsorship. HMT is also providing technical assistance in Algeria for the supply of machinery and equipment for setting up factories to manufacture water meters and gas regulators by the Société nationale de l'électricité et du gaz.

Research and development

From its inception in 1953 until 1959, HMT did not undertake real product development, and the product design office of the Bangalore factory was mainly engaged in converting various product designs acquired through licensing agreements, and in incorporating alterations or minor modifications in product design to suit immediate production requirements.

When the company decided to expand and diversify its product range, management realized the need to identify products to be produced in the various HMT units. A master plan incorporating short-term and long-term requirements for developing products depending on market needs was prepared, and graduates and post-graduates were recruited for training as machine tool designers.

Based on the recommendations of the projects department, 24 machine tools were identified for HMT manufacture, and out of the list 18 types were ultimately chosen.

The first product indigenously designed and developed, under the guidance of foreign experts, was the L22TP, a turret lathe based on up-to-date design concepts. It led to the development of a family of centre and production lathes. One small radial drill with infinitely variable speeds and feeds, the R34, was designed entirely by HMT designers, and a prototype was built. A heavy-duty radial drill was also designed entirely by

HMT personnel. A series of standard speed and feed drives for machine tools was designed in 1964. Annex IV lists products developed through R and D since HMT was established.

Once HMT had committed itself to developing a large number of machine tools, it began to build up its design manpower. It established 12-man teams consisting of 1 senior engineer, 2 design engineers, 3 junior engineers and 6 draftsmen to design a new machine tool of average complexity. By 1968, a standard force of 332 persons had been created.

Design and development departments were also subsequently set up in other HMT units, and a R and D metal-cutting centre was set up at Bangalore. In the design and development departments of HMT I and II, an advanced design cell was created, in 1967, to concentrate on the development of sophisticated products. It was finally restructured as the Central Design Development and Research Department, with the R and D metal-cutting centre and corporate R and D unit incorporated as subdivisions.

Functions of the unit design departments

The functions of the unit design departments are:

(a) To develop new products so as to remain competitive in the Indian and international markets;

(b) To develop existing products continuously to improve their performance and marketability;

(c) To determine how each product can be produced as economically as possible so as to be competitive in the domestic and international markets;

(d) To adapt products to the changing demands of technology and to develop new materials and standard parts;

(e) To build prototypes of new designs and conduct preliminary tests;

(f) To evaluate the quality of products manufactured;

(g) To engineer products to meet the special requirements of customers;

(h) To develop design staff;

(i) To prepare and maintain unit standards not covered by central standards;

(j) To maintain an effective technical information service;

(k) To maintain, store and distribute drawings, standard sheets etc. required for production.

Metal-cutting centre

The R and D metal-cutting centre is responsible for:

Product design (conceptual, layouts and detailed designs, if required)

System design

Research and testing

Technical information service

The centre is equipped with instrumentation valued at Rs 1.6 million, including sophisticated equipment for noise and vibration analysis, alignment testing, force and displacement measurements.

Corporate R and D unit

The corporate R and D unit is responsible for:

(a) Developing, in association with the marketing and the corporate planning divisions of the head office, technological forecasts for the company covering the next 5-10 years and carrying out annual reviews of these forecasts;

(b) Evolving, in association with the marketing and the corporate planning division of the head office, product development plans and priorities for the company for a period of up to five years, making annual reviews and preparing five-year plans for product development;

(c) Co-ordinating the product-development efforts delegated to the units and assisting unit executive directors in their product-development programmes, in staffing and in preparing R and D budgets;

(d) Establishing R and D centres for metal cutting, metal forming, and other areas, decided by management from time to time;

(e) Establishing liaison between HMT units, R and D centres, the Central Machine Tool Institute, Indian Standards Institution (ISI), universities, professional institutions and national laboratories;

(f) Evolving systems of evaluating products and testing and certifying prototypes developed at HMT.

Standardization activities of HMT

The need for evolving company standards was acutely felt while HMT was working with a series of foreign collaborators each using different standards. The standards department at HMT was set up in 1958 shortly after the formation of

ISI. The HMT standards department worked closely with ISI in formulating and adapting various standards for the manufacture of machine tools and other industrial products. For evolving company standards HMT drew on information from other national and international standards such as ISO (International Organization for Standardization), DIN (Federal Republic of Germany,) CSN (Czechoslovakia), GOST (Union of Soviet Socialist Republics), BS (United Kingdom) and ANSI (United States). At present HMT has about 2,300 company standards. The HMT standards department has also brought out the following manuals on standards for quick reference:

Electrical equipment of machine tools
Design calculations
Electrical units and elements
Antifriction bearings
Transmission and control elements
Fasteners and retainers
Design standards
Standards on drafting code
Manual for hydraulics and fittings (under preparation)
Applied ergonomic standards for machine tools

Computer-based production control system

The computer-based production control system was introduced in HMT V at Hyderabad on a trial basis in the spindles section in 1975, initially using an ICL-1901, a computer of Bharat Heavy Electricals. In early 1976, the computer system had to be changed to the EC-1030 Ryad computer of the Administrative Staff College of India, and the system was revised based on a study of the CROSSCO manufacturing information systems.

The computer-based control system has the following major objectives:

To prepare component progress schedule
To prepare machine loading schedule
To estimate excess capacity
To forecast critical items
To facilitate capacity planning

The output of the system consists of the following reports and statements:

(a) *Order, requirement and stock-position statement.* The statement facilitates proper planning and ordering of standard group components and rationalized items normally stocked. For these components, the statement indicates the quantity available in stock, the quantity that has already been ordered and the quantity required for machines. For special components that are released in batches, the statement indicates whether it covers the total requirement or not;

(b) *Materials requirement report.* This report helps the materials department to check their stock position against the quantity of materials required in manufacturing components and to take action to obtain materials not available in stores. The materials department has to update the material position and feed back the information for computer processing. If the material is available in stores the component will be scheduled without any constraints; otherwise the component will be scheduled from the promised date;

(c) *Critical component list.* This report lists the likely critical components (with respect to completion of components in time and not with respect to machining process) that may not be completed by the targeted date without proper follow-up;

(d) *Component progress schedule.* The report indicates how the manufacturing operations of a particular component are progressing in a particular period according to the component priority;

(e) *Machine loading schedule.* The report indicates the machine loading schedule;

(f) *Expected completion dates.* The report lists all the components by machine, and by group, that are likely to be completed in four weeks. It also indicates the components for which the operation progress has been delayed according to the planned "late start dates";

(g) *Balance capacity statement.* This statement indicates the probable capacity available on each machine on a daily basis for the first two weeks and on a weekly basis for the next two weeks.

A computerized material planning and control system was also introduced in HMT V on a trial basis for four months beginning January 1978. It initially covered standard parts and electrical parts and was extended later to cover tools, steels, foundry material and items in stock. The objective was to plan and control effectively the inventory of class A items, with a view to reducing the need to carry out an inventory and to minimize the possibility of running out of stock.

Growth in production, sales and exports

HMT output and sales grew steadily from the beginning of the company's operation, accelerating in the early 1960s, when additional plants were set up in quick succession. Some stagnation in output and sales set in during and immediately after the recession, but an even faster rate of growth followed in the 1970s. The profits, however, showed a rapid decline when the recession started, with the concern running at a loss for three years (1967/68-1969/70). HMT recovered completely only in 1974/75, when the profits were higher than the earlier peak in 1964/65 (see annex II).

The annual value of production of the various units of HMT, including the recently acquired Ajmer unit (HMT VI), is given in annex III. It shows that the machine tools division up to 1975/76, the last year for which figures are available, constituted the major share of total production in value, but other product groups were rapidly increasing their share, especially watches and horological machinery and tractors. The five-year corporate plan (1978/79-1982/83) of HMT shows that the share in production of machine tools, watches and tractors was, respectively (per cent): 38, 36 and 23 in 1977/78 and is expected to be 30, 41 and 22 in 1982/83 in the same order.

In 1976/77, the total HMT staff came to 20,944 employees, among whom were 1,041 engineers, 1,991 technicians, 3,095 supervisory staff and 700 managers.

HMT entered the export market as early as in 1961/62, when it exported machine tools to the Federal Republic of Germany and Switzerland, following the policy of exporting its machine tools first to industrialized countries, in the belief that if HMT machine tools were accepted there, they would be accepted more easily later in the developing countries. To enter the markets of developed countries successfully, HMT needed to exhibit its products, answer customer queries and build up after-sales service in those countries. HMT opened sales centres at Frankfurt and in New York in 1966 and at Melbourne and Sydney in 1968. Agents were also appointed to represent HMT in other developed countries in Europe and some developing countries in Asia. Through these export offices, HMT also conducted surveys to determine the specific requirements of different countries and the changes in design needed to make HMT machines acceptable in these countries.

Initially export sales were low, as HMT was competing with sophisticated machine tools manufacturers in markets that were always considered their territory. The profits from export sales were also low because the selling agents were also charging higher rates of commission. But gradually the export promotion efforts bore fruit, mainly because of the high quality of HMT machine tools; and engineers in industrialized countries could recognize a good product without being influenced by the name of the company and country of origin. In 1968/69, the value of exports jumped to almost Rs 10 million. Export orders for 519 machines were received as against export orders for 98 machines in 1967/68.

In 1971, HMT entered into a sales distribution agreement with the American Tool Works Company for the sale of machine tools in the western hemisphere, which helped exports to rise further. HMT also exported more watches against tough competition. In 1976/77, exports of machine tools accounted for 6.7 per cent of total sales, and their value crossed the Rs 60 million mark. According to the HMT corporate plan, exports would form 20 per cent of total production of the machine tool divisions by 1982/83.

HMT has exported machine tools to Australia, Czechoslovakia, Denmark, Germany, Federal Republic of, Malaysia, Netherlands, New Zealand, Philippines, Poland, Singapore, United Kingdom, United States and several African countries.

HMT involvement in rural industries centres

HMT, a centre of advanced machine tool technology, is also interested in rural industrialization and in assisting in transferring knowledge and technology to the rural population. This is being done through the rural industries centres, whose aim is to impart skills to villagers.

Summary of achievements and plans for the future

HMT was started as a public-sector undertaking by the Government with the objective of developing indigenous capability for the design and manufacture of precision machine tools. HMT has successfully met its import substitution objective. HMT has also diversified its production into other areas. Diversification began with the manufacture of watches when the Government assigned to HMT collaboration with the Citizen Watch Company, presumably because of HMT experience in manufacturing precision machine tools. But later on HMT on its own carried diversification into other areas, such as printing machines, agricultural tractors, die casting machines, lamps and lamp machinery and finally measuring instruments. This diversification away from machine tools was justified by the need to meet high rates of growth in output consistent with corporate objectives and to provide HMT shelter from slack periods in the machine tool market.

However, indiscriminate diversification into new product areas, especially in low-precision consumer goods, may be harmful to HMT, as it may shift the focus of the company from high precision and quality products to mass-production of consumer goods. Diversification into too many new product areas would increase the need for more and more collaboration agreements to reduce the time required for introducing new products, since it will always take longer to design and develop a new product internally.

HMT will not necessarily face this problem, but it is significant that Hindustan Machine Tools Ltd. changed its name to HMT Ltd., which suggests that the image of the company may have changed from that of a machine tool company to a more general manufacturing company. Top management has given some thought to the possibility of manufacturing cheap and rugged automobiles for use in rural areas and for the world market after producing tractors and diesel engines. However, the company's role as a prime machine tool manufacturer and areas of future diversification must be examined in terms of national requirements.

A five-year corporate plan for the period 1978/79 to 1982/83 lays down broad goals for the company, production and sales targets and the strategy to be followed. The machine tool industry's prospects are closely tied to those of the key user industries, the manufacturing and transport sectors. The Government's five-year plan 1978-1983 set growth rates of 6.28 per cent and 6.85 per cent, respectively, for these sectors. As the plan stresses increases in production more through better utilization of existing capacity than through creating new capacity, the major demand for machine tools can be expected to arise from the need to replace existing equipment that has become old or obsolete with modern equipment.

The corporate objective of 10 per cent annual growth in the value of output would require HMT to develop new products, since some of its present product areas will become saturated and some products will also be obsolete by the turn of the century. The strategy suggested in the corporate plan involves *(a)* diversification around existing products and technologies kept technologically up to date; and *(b)* product innovation and new product evaluation through technological forecasting.

Annex I

FOREIGN COLLABORATION AGREEMENTS

(not exhaustive)

Foreign collaborator	*Item of manufacture*	*Year entered into*	*Duration (years)*
Oerlikon Machine Tool Works, Buehrle and Company, Zurich, Switzerland	High-precision centre lathes	1949	20
Fritz Werner A.G., Marienfelde, Berlin (West)	Milling machines sizes M2 and M3 (mechanical type)	1957	6
Hermann Kolb, Cologne, Federal Republic of Germany	Radial drills (RM radial drills)	1958	7
H. Ernault Batignolles, 169 Rue D'Alesia, Paris, France	General-purpose centre lathes (LB lathes)	1959	7
Officina Meccanica Olivette, San Bernardo D'Ivrea, Turin, Italy	Cylindrical grinders (G type)	1959	7
Citizen Watch Co. Limited, Tokyo, Japan	Wrist-watches	1960	8
Limex GmbH, Taubenstraße 406, Berlin W8, German Democratic Republic	Machine tools of VEB-WMW design and hydraulic surface grinders SFW 250 × 1000 and 1500	1961	10
Regie nationale des usines Renault, Billancourt, Sienne, France	Special-purpose machines	1961	7
Drummond Brothers Limited, Ryedes Hill, Guildford, Surrey, United Kingdom of Great Britain and Northern Ireland	Maxicut 2A and 3A gear shapers	1963	7

Annex I (continued)

Foreign collaborator	Item of manufacture	Year entered into	Duration (years)
Manufacture De Machines Du Haut-Rhin S.A., Mulhouse-Bourtzwiller, France	Single-spindle automatics: types TR 16B, TR 22B, TR 25L, TR 32B, TR 42B, TR 60B, TR 65B	1964	7
Effehag Effekten-Handles und Lizenzverwertungs A.G., Nougasses Zug, Switzerland and Hans Liebherr, Maschinerfabrik Biberach a.d. Riss, Federal Republic of Germany	Gear hobbing machines, types/sizes L 300, L 400, L 630, L 900	1964	7
Gildemeister and Co. A. G., Bielefeld, Federal Republic of Germany	Multispindle bar and chucking automatics, types/sizes AVH 210, AS 32, AS 67, AS 48, AA48, AAH 150, ASH 160 and ASH 190	1966	8
H. Ernault-Somua S.A., 19 Rue D'Alesia, Paris, France	Copying lathes types/sizes S. Pilote Transpilotes—S 131 S 130 U. Pilote 760	1966	10
Jones and Lamson Division of Waterbury Farrel, Springfield, Vermont, United States of America	FAY automatic lathes, types/sizes 8" FAY, 12" FAY and 16" FAY	1966	5
Pegard S.A. Namur, Belgium	Horizontal borers of the families, Af, FA and U. HMT horizontal borers of the family Z41 (joint finalization of design and further development)	1967	5
Oswald Forst GmbH, Solingen, Federal Republic of Germany	Broaching machines, horizontal and vertical internal and external broaching machines	1967	10
Finmotii S. A., Zurich, Switzlerand	Berg clamping devices and power chucks	1968	5
Interfonda Limited, St. Gall, Switzerland	Cold chamber die casting machines and plastic injection moulding machines	1969	10
Verson Allsteel Press Co., Chicago, Illinois, United States of America	Presses	1969	10
Alteliers GSP, 92, Courbevoie, France	Drills and borers	1969	7
Societa Nebiolo, Turin, Italy	Printing machinery	1969	7
Buhler Brothers Ltd, Uzwil, Switzerland	Die casting and plastic injection moulding machines	1969	
MOTOKOV Foreign Trade Corporation, Trida, Dukelakych Hrdinu 17, Prague, Czechoslovakia	Zetor tractors 2011/2511, 4511, 5511	1971	8
Fritz Werner A.G., Marienfelde, Berlin (West)	Ram bed-type milling machines	1971	7
United Incandescent Lamp and Electrical Comp Limited (TUNGSRAM), Hungary	Lamp-making machinery, lamps and lamp components	1973	
The Cross Company, Fraser, Michigan, United States of America	Special-purpose machines	1976	7

Annex II

OUTPUT, SALES, PROFITS AND EXPORTS, SELECTED YEARS

(Millions of rupees)

Item	*1956/57*	*1957/58*	*1960/61*	*1964/65*	*1965/66*	*1967/68*	*1969/70*	*1970/71*	*1973/74*	*1974/75*	*1976/77*
Total value of output	5.0	15.5	32.5	122.3	131.8	110.9	164.2	203.7	394.2	601.3	949.7
Sales revenue	4.2	14.8	34.1	129.2	125.1	146.5	166.7	204.3	430.6	629.1	907.4
Profits or loss	0.4	2.2	7.4	37.9	15.6	−5.3	−5.4	3.1	−19.6	50.9	46.6
Total value of exports	—	—	—	0.2	1.9	1.2	8.8	10.8	25.2	25.8	60.5

Annex III

ANNUAL VALUE OF PRODUCTION OF HMT UNITS, SELECTED YEARS

(Millions of rupees)

Unit	*1968/69*	*1971/72*	*1975/76*
HMT I and II, Bangalore	50.9	107.0	180.2
HMT I and II Die-casting Division			13.3
WF I and II horological machinery, Bangalore	32.7	46.0	12.1
HMT III, Pinjore tractors	25.8	69.9	82.2
HMT IV, Kalamassery	17.9	18.9	66.2
HMT V, Hyderabad			
Machine tools	15.3	44.3	84.4
Presses			35.7
HMT VI, Ajmer			21.7

Annex IV

PRODUCTS DEVELOPED THROUGH HMT R AND D

1956-1959 In this period except for a longer bed version of the H22 lathe no other products were designed. The activity mainly involved conversion work for acquired designs, maintenance of design and shop liaison, minor modifications required by production technology.

1960-1963 L22 family of lathes: L22TP, L22UP, L22PP etc.
R34: small radial drill
L28: medium-duty lathe (prototype not built)
R78: heavy-duty radial drill
GT20: carbide-tipped tool grinder and lapper
VTM: vertical turning machine
Z14: short-piece turning machine, chucker
Z35: multispindle drill

1964-1967 E2: electrically controlled milling machine
FB: fine borer
L45: heavy-duty lathe
G9: small cylindrical grinder
M1TR: ram-type milling machine

1968-1971 Hydraulic chucker—minichucker
LT20: training centre lathe
FN2: milling machine size 2

1972-1975 C21: supercut lathe
AZ9: horizontal borer
A24NC: horizontal-bed MOGUL NC lathe
VMC/TMC: machining centres
DC60: die casting machine
FN3: milling machine

1976-1979 FC25: automatic front chucker
NM/NL: rationalized series of lathes

RW2: broaching machine	Under development	Horizontal machining centre
TUDM: travelling head universal drill		Auto tool changer
FN1: milling machine size 1		Multicut copying unit/ECONOP lathe
Single-purpose milling machine (unit construction)		Tool-room milling machine
G18: medium-duty cylindrical grinder		NC co-ordinate drill
Vikram: centre lathe		Flow-forming lathe
EDM: electro-discharge machine		Jig borer
Slant-bed NC lathe/copying lathe		

II. Jyoti Limited: an example of successful entrepreneurship

*K. Balakrishnan**

Early history of the company

For a small engineering section of a chemicals manufacturing company to transform itself into the leading engineering firm of Gujarat and one of the front-rank engineering industries in India, true of Jyoti Limited, Baroda, can be considered a signal achievement, credit for which should go in the first instance to N. B. Amin, its Managing Director and Chairman, the driving force behind this company.

After graduating in electrical engineering from the Massachusetts Institute of Technology, and receiving a Master of Science degree in electrical and mechanical engineering from Cornell University in the United States of America, he returned to India and joined Jyoti, which was then in its infancy. Later he became Jyoti's Managing Director and Chairman. Under his leadership, the company grew very rapidly, entering into several collaboration agreements with leading foreign companies and producing in quick succession a variety of pumps, electric motors, hydroelectric generating turbines and other related equipment.

In acquiring and assimilating foreign technology, company policy reflected the Chairman's personal philosophy, which was to pioneer in producing new products through collaboration if essential and through indigenous efforts alone whenever possible.

Jyoti had its beginnings, in 1935, as an engineering unit adjunct to Alembic Chemicals, Baroda, an enterprise started by the Amin family and run by N. B. Amin's elder brother. In addition to being a repair workshop for Alembic, this engineering unit began in a small way to manufacture engineering products, including paper-cutting machines, electrolyser frames and pumps. Encouraged by the initial success, the Amin family set up, in 1943, a separate manufacturing concern, Jyoti Limited. When N. B. Amin returned to India and took over the unit, it had a work-force of about 20 persons.

The gradual development of the company during its first 25 years and the subsequent spurt in its growth in the 1970s are reflected in the growth of sales (see figure I) and the corresponding rise in annual profits (see figure II).

Product development

Jyoti's product development over the years is illustrated by the flow chart in figure III. The flow chart is not exhaustive, but only indicative. There are more products and more key events to be presented. There are also alternative ways of presenting the "relatedness". However, the purpose of this chart is to indicate how Jyoti went about systematically acquiring technology for a set of related products over 30 years. Its methods of acquiring technology through a judicious mix of collaboration agreements and assimilating it through experimentation and its own R and D are discussed below.

Pioneering efforts: the 1940s and 1950s

The 1940s and 1950s were pioneering years for Jyoti, when it attempted to develop several products entirely through its own efforts. Some of the significant achievements during this period are briefly described below.

Pumps

As a repair workshop, Jyoti had been repairing the pumps used by Alembic. From repairers Jyoti soon moved on to become manufacturers. By 1943, when Jyoti started manufacturing centrifugal pumps, such pumps were being used extensively for lift irrigation within India. The large domestic market was, however, monopolized by a

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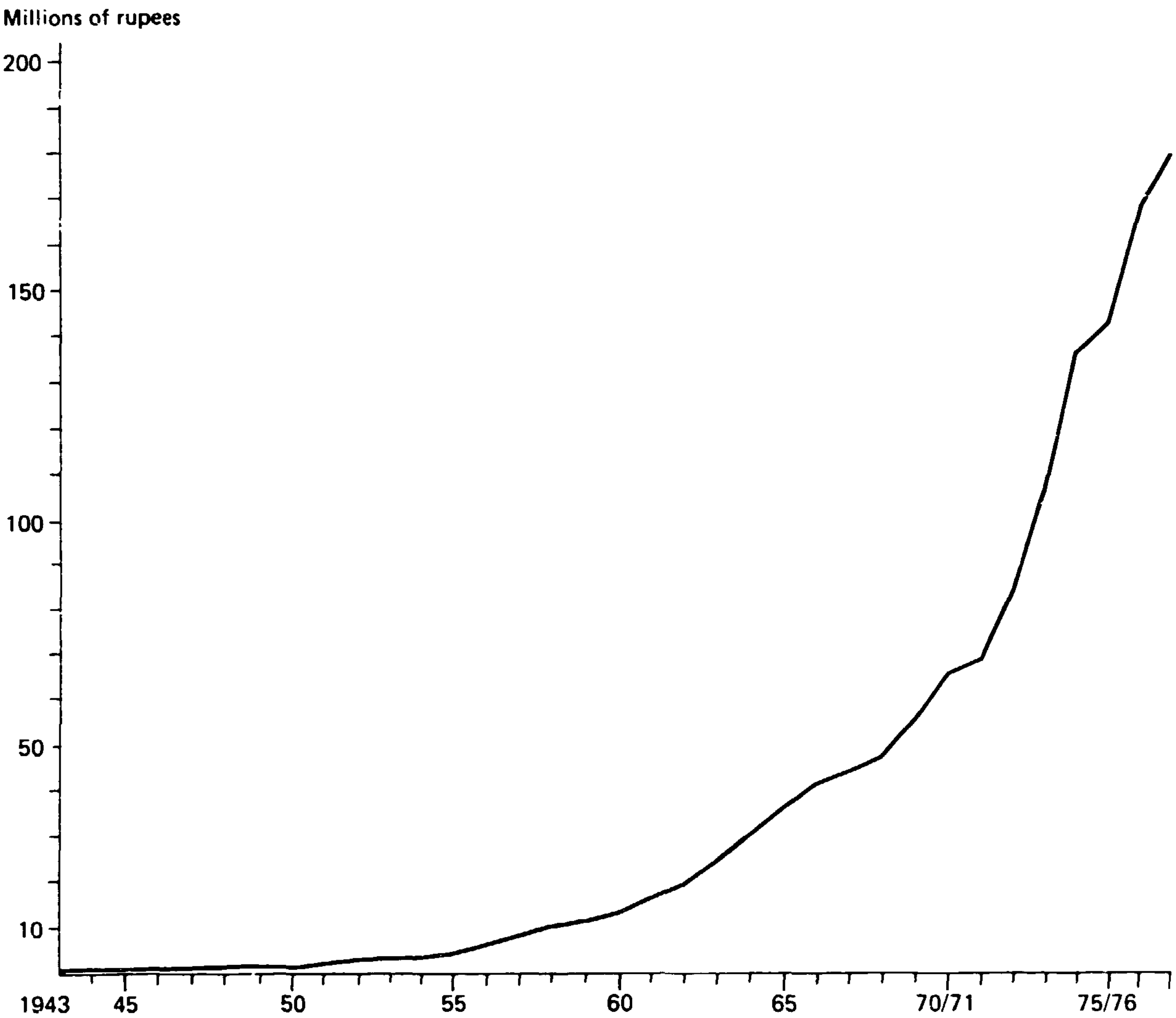

Figure I. Annual sales, 1943-1977/78

few British firms. Jyoti became one of the two Indian pioneers in this area.

Environmental conditions created the need for vertical turbine pumps. Facing drought conditions, the Government of Uttar Pradesh wanted to install tube wells all over the State, and many well-to-do farmers in Gujarat also wished to install tube wells. With this impetus, N. B. Amin, himself a designer, along with his chief engineer and second engineer developed vertical turbine pumps as early as 1947.

One of these engineers had been sent to the Federal Republic of Germany for training in pump technology under a Government of India scheme. He had rigorous training in several enterprises. He was subsequently sent to the United States for training. From both countries he brought back information on working methods, systems and some ideas.

Since municipal water supplies throughout the country were irregular, it was believed that potential demand for open well pumps would be considerable if they were compact and cheap and required little maintenance. Centrifugal pumps were the result, developed by the same team of engineers. Efforts to find new markets and new applications continued during this period.

Motors

Motors were needed to run the pumps. At first Jyoti bought motors from other manufacturers. However, N. B. Amin hired another young entrepreneur to develop motors and other rotating electrical machines and sent him to visit many manufacturers in Europe. After returning to India, he produced the first Jyoti-made motor, to

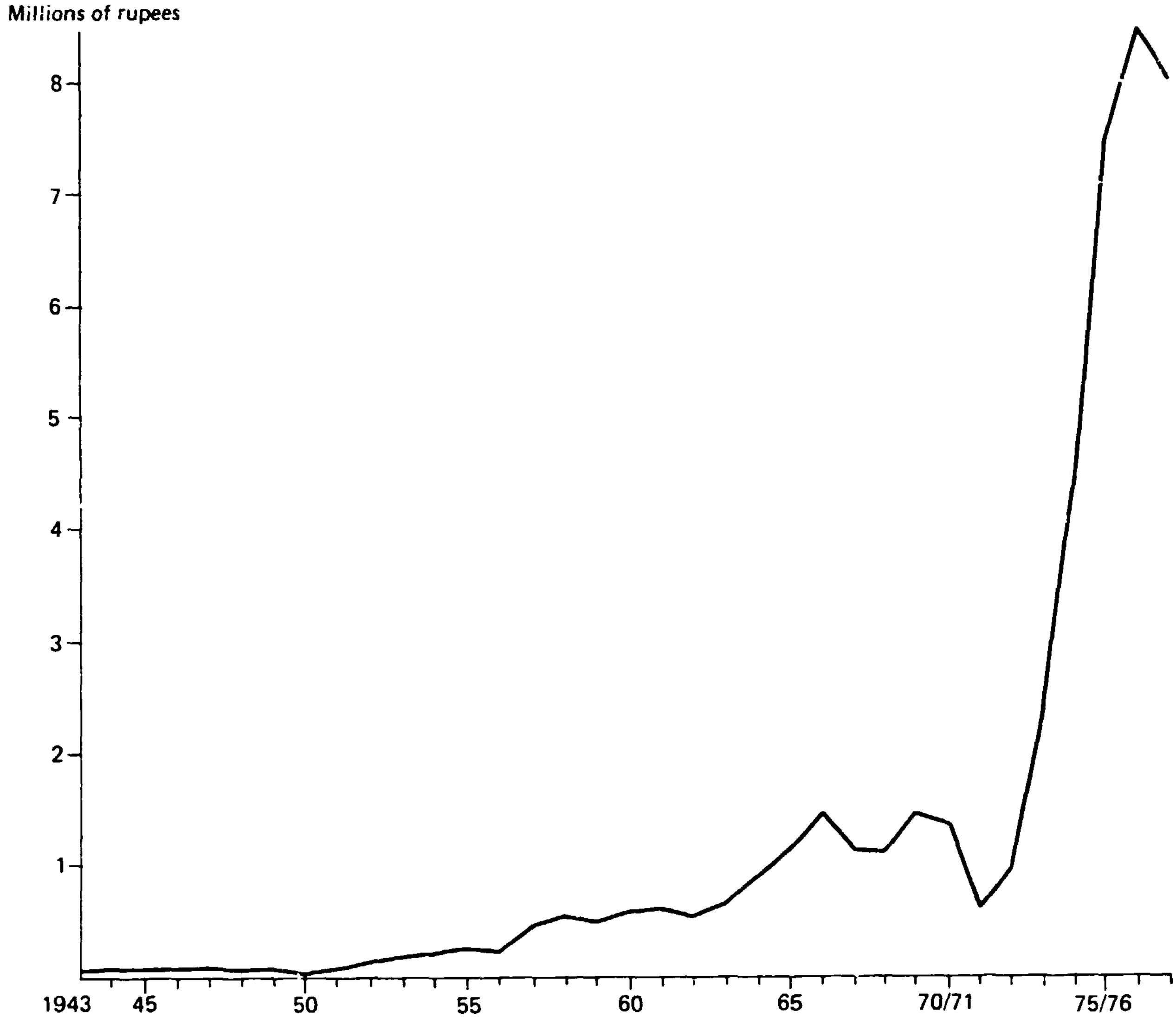

Figure II. Net profits after tax, 1943-1977/78

Alembic's order. It was an experiment, and it succeeded.

SLM Maneklal, a company that had shifted from importing motors to manufacturing them, chose Jyoti as machining subcontractor. The market for squirrel cage induction motors used in conjunction with pumps was expanding rapidly. Jyoti subsequently decided to manufacture these motors itself rather than continuing as a sub-contractor. Ninety per cent of the motors Jyoti produced in the early years were sold along with its pumps.

Since 1948, Jyoti has been successful in manufacturing, to its own design, newer and larger electric motors and generators. In 1954, Jyoti designed and manufactured India's then largest slip-ring electric motor (107 kW, 485 rev/min). It was followed by larger motors (210 kW, 485 rev/min) in 1957.

Jyoti also developed the first Indian-made prototype sugar centrifugal motor. Designed to provide drive t sugar centrifugals, this special-purpose motor, commercially known as the Jyoti Hans-Still centrifugal motor, was developed in collaboration with Hans-Still, Hamburg, Federal Republic of Germany. The collaboration agreement was entered into in 1961.

Switch gears

Once Jyoti was manufacturing motors, it needed starters. Once it started making centrifugal pumps, customers expected Hyoti to supply the

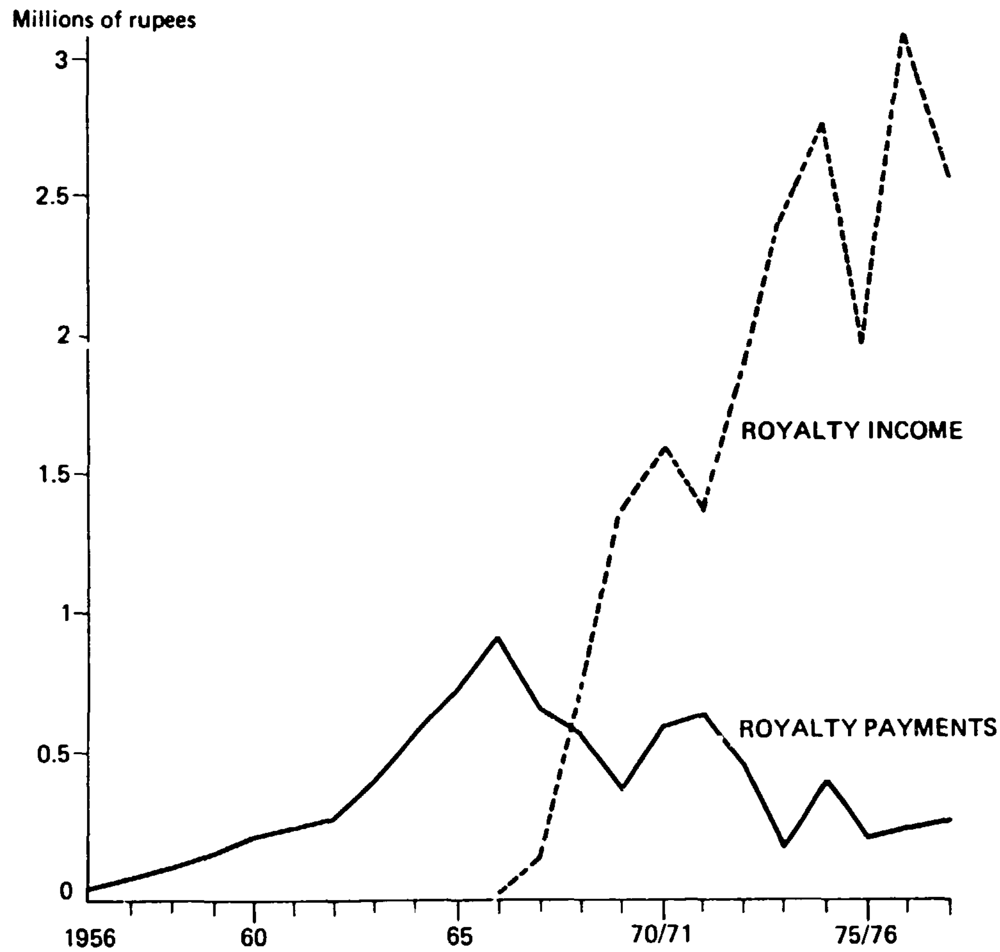

Figure III. Royalty payments and receipts, 1956-1977/78

required starters and other switch gears to go with them. From pumps to motors and from there to switch gears was a natural diversification arising from a combination of market forces and the desire to reach technical independence.

The move to switch gears was also the result of environmental changes. While the first five-year plan laid emphasis on food production and agriculture, the second five-year plan laid more emphasis on power projects and electrification, and thus the market for electrical installations was expanding. The switch gears needed for Jyoti's pumps and motors, it was felt, could find new markets with public agencies such as electricity boards. Around that time, Calor-Emag of the Federal Republic of Germany was also looking for collaborators in many countries, including India. It had been manufacturing switch gears for more than 40 years and had a good reputation all over the world. Jyoti was interested in collaboration but did not want a dominating partner. Since the Chairman of Calor-Emag and N. B. Amin knew each other, Calor-Emag agreed to sell the know-how to Jyoti for the manufacture of starters, cam switches, switchboards and control gears up to 33 kV.

Jyoti's engineers were given training in Calor-Emag's works in the Federal Republic of Germany. The engineers brought enough know-how back to India to manufacture the switch gears in Jyoti's works, to the exacting specifications of Calor-Emag. Two technical personnel from Calor-Emag also spent five years with Jyoti's team of engineers to absorb the technology. By 1957, the team succeeded in manufacturing 11 kV high-tension panels and minimum oil content circuit breakers up to 350 MVA.

Calor-Emag and Jyoti then set up a sales organization—Jyoti-Calor-Emag Ltd. Two purposes were served through this arrangement. In production and adaptation and assimilation of technology, Jyoti was free to experiment. However, for marketing on a wider scale, Calor-Emag's name and experience were an asset to Jyoti and brought financial returns to Calor-Emag.

Hydroelectric generating sets

In 1958, Jyoti faced growing competition in its existing product lines, and management began to think of new products that could be designed and developed with the experience and know-how it already possessed and that would make use of existing production facilities. After evaluating several products, hydraulic turbines and generators were selected for the following reasons:

(a) It was expected that in the near future there would be a large demand for small hydro-turbo generator sets in mountainous border areas, where electric power was badly needed;

(b) Management felt that the company should accept the challenge of producing some new and complicated machinery indigenously;

(c) It was hoped that the company would easily succeed in convincing the State Governments and electricity boards of the importance of power generation with small and medium-size hydraulic units;

(d) The successful experience of several European countries with such units encouraged the company to go ahead with their development, manufacture and marketing;

(e) Reserve funds of the company were getting larger and thus the company was in a position to take the financial risks entailed in the research and development of new products, a move the Chairman of the company favoured.

By the end of the 1950s Jyoti had established a name in all the three major product groups: pumps, motors, and switch gears. Diversification into generators also began. Jyoti entered the export market in 1959 with the export of a few pump sets to the Middle East.

The engineers

During the early years, Jyoti did not have a formal organizational set-up. Groups of engineers under the leadership of N. B. Amin worked on the three major product groups--pumps, motors and switch gears. All the four key engineers recruited during Jyoti's formative years set up their own businesses subsequently. N. B. Amin seems to have recognized their entrepreneurial talent, which was essential in the informal personal mode of technology acquisition Jyoti adopted in its formative years.

Growth and new developments: the 1960s and 1970s

As the trend in sales and profits indicates, the company witnessed a tremendous growth in the 1960s and 1970s, the result of a well-chosen mix of collaboration, research and development and introduction of new products.

Pumps

The manufacture of pumps was fairly well established by the beginning of the 1960s. Further product development was directed towards new applications, larger sizes and better performance.

In 1963/64, Jyoti succeeded in manufacturing for the first time special-performance chemical pumps and sand pumps to the design of two United States companies. In 1970, Jyoti once again made engineering news when it produced for Hindustan Shipyard India's largest indigenously developed 150-cm vertical propeller pumps with a discharge rate of 360,000 litres per minute. About the same time another big opportunity to prove its technological capabilities came Jyoti's way when it accepted the challenging assignment of making the first indigenous nuclear pumps—primary coolant pumps and moderator pumps—for the Rajasthan and Madras nuclear power plants.

Vertical pumps, dredger (slurry) pumps and horizontal split casing pumps were further developments. Jyoti is today in a position to accept orders for pumps up to 800,000 litres per minute capacity. All these product developments in pumps were achieved without any foreign technical collaboration.

Motors

Jyoti was the pioneer in developing indigenous technology, without any foreign assistance, for the manufacture of electrical equipment and the large high-voltage induction motors commonly used in power stations, pumping installations, fertilizer plants, and other similar projects. Today, many high-voltage motors manufactured by Jyoti are working satisfactorily in various projects all over India.

The manufacturing range of these induction motors covers voltages of 3.3 kv, 6.6 kV, and 11 kV, with outputs going up to 3,000 kW at speeds ranging from 315 rev/min to 3,000 rev/min. Both the squirrel-cage type and a slip-ring type of motor suitable for horizontal or vertical operations have been developed and installed.

Turbines and generators

Jyoti's decision to develop generating sets based on hydropower was explained earlier. It took the company some years, however, to acquire the technology, and, in 1964, Jyoti successfully manufactured the first turgo-impulse turbine of 37.5 kW (50 hp) in India in technical collaboration with Gilbert, Gilkes and Gordon Limited, United Kingdom.

In early 1966, Jyoti produced the first Indian-made 500 kW electric generator using completely indigenous technical know-how and skills. Towards the end of 1966, Jyoti produced and successfully tested India's first indigenous 1,200 kVA electric generator. This generator was part of a complete hydroelectric generating system manufactured by Jyoti for the West Bengal State Electricity Board. The system included a Pelton well turbine, a highly sensitive oil-pressure governor, and a protective device and supervisory panels. This project gave Jyoti an opportunity to develop 3.3 kV, 2,000 kW, 600 rev/min synchronous generators and eventually high-tension electric motors, of which Jyoti is now an important supplier.

Two water turbines were manufactured and installed by 1969, but both had problems with the governor. Technical collaboration was obtained from Gilbert, Gilkes and Gordon under the usual terms and conditions. However, Jyoti received only the drawings and not the design specifications. The choice of the material in some cases was wrong, and the buckets broke while in operation.

A few experienced engineers from other firms were then recruited. The new team of engineers redesigned the product, changed some materials and specifications, and after much experimentation and with substantial help from the Jyoti Research and Development Centre most of the problems were solved by 1971.

By 1974, Jyoti had succeeded in commissioning 52 water turbines of various capacities and ratings, all over the country. These turbines were also produced in three models—Francis type, Pelton type, and turgo-impulse type.

The present product range extends from the smallest kiosk-housed 3 kW package sets up to large units of 3,000 kW capacity.

Circuit-breakers

Until about 1957, the high-voltage circuit-breaker manufacturing industry was practically non-existent in India, and the country's requirements were met by imports. Thereafter, the Indian industry gradually came into being.

In 1957, Jyoti began its pioneering efforts in this field by manufacturing the first Indian-made circuit-breakers with voltages in the range of 11 kV-350 MVA in collaboration with Calor-Emag, Jyoti's partner in manufacturing switch gears.

Power programmes in India were expanding rapidly, and high-tension transmission lines having system voltages of 132 kV and 220 kV were becoming common. Calor-Emag produced only circuit-breakers rated at lower voltages. The Oerlikon Engineering Company, Switzerland, a well-known manufacturer of switch gears of higher capacity, had installed its equipment all over the world. Jyoti entered into a collaboration agreement with Oerlikon in 1966 for circuit-breakers of 132 kV and 220 kV rating.

On 14 April 1968, an eventful day for Jyoti, India's first minimum oil-content 132 kV circuit-breaker, manufactured by Jyoti in collaboration with Oerlikon, was tested in the presence of a distinguished gathering. At this occasion the first phase of Jyoti's high-rupture capacity laboratory was commissioned. The two events were interrelated, since the laboratory was essential to the development of circuit-breakers within Jyoti.

To develop a circuit-breaker successfully, however, several expensive laboratories and testing facilities are required at several stages. Some of these were not available in the country, and the Jyoti engineers had to rig up their own testing instruments and facilities.

Undeterred by all these impediments, Jyoti undertook, in 1969, to develop an indigenously designed 33 kV, 750 MVA outdoor low-oil-content circuit-breaker. Jyoti accomplished its goal in two years. Since testing facilities for high-voltage circuit-breakers in this rating were not available in India, Jyoti had its circuit-breaker tested by the Research Institute for Electrical Engineering at Prague, Czechoslovakia. A second prototype with some improvments was later also successfully tested in Czechoslovakia.

In 1978, Jyoti developed a 6.6 kV 500 MVA circuit-breaker and had it tested in the Netherlands. Further work is still going on in this area.

Collaboration with foreign companies

Jyoti entered into six major collaboration agreements. Two were with firms in the Federal Republic of Germany and one each with firms in France, Switzerland and the United Kingdom. The details of these agreements are summarized in table 1. Some of the significant points emerging from a close study of these agreements and Jyoti's efforts in assimilating the acquired technologies are given below.

Although Jyoti's association with Calor-Emag started in the mid-1950s, all the six major collaboration agreements listed here were entered into in the 1960s, after the company had acquired adequate technical capability to absorb and assimilate the acquired technologies.

In all cases the primary considerations for choosing the collaborator were the pre-eminent

TABLE 1. DETAILS OF TECHNICAL COLLABORATION AGREEMENTS

Particulars	*Gilbert Gilkes and Gordon Ltd., United Kingdom, for turbines, lubricating oil pumps, steam turbines and turbine governors*	*Hans Still Ltd., Federal Republic of Germany, for centrifuge motors*	*CDC, France, for relays*	*Oerlikon Co., Switzerland, for 321 kV/220 kV circuit-breakers*	*Calor-Emag, Federal Republic of Germany, for high-tension and low-tension circuit-breakers and switch boards*
Date of first collaboration agreement on record	5 August 1961	28 March 1961	21 November 1965	15 July 1966	15 May 1967
Duration	10 years initially, amended for 13 years	10 years	10 years	10 years	5 years
Equity participation	—	—	—	—	—
Lump-sum payment	—	DM 3 000 for each of the three types of machines to be manufactured	F 140 000	SwF 70 000 for 132 kV circuit-breakers	DM 3 000 for each non-automatic switch gear; DM 6 000 for each automatic switch gear
Royalty	5% of net selling price	5% of net selling price	5% of net selling price	5% of net selling price	5% of net selling price

name of the collaborator, its past experience in the field, and the availability of know-how for a fuller range of products. Considerations such as favourable terms, participation in the equity, the collaborator as a source of foreign exchange, the collaborator's ability to adapt its technology to Indian conditions, and continuing source for future technology development played an insignificant or no role in the choice. The company appeared to be confident of its ability to absorb the acquired technology fast by its own efforts and to develop the technology needed for the future.

The payment to the collaborators was fair. In all cases, in addition to a lump-sum payment, a 5 per cent royalty on sales was agreed upon. This was in line with the standard terms and conditions as approved by the Government of India in those days. The payment was for production know-how and drawings and specifications. It did not cover licences or patents, pre-investment services, machinery and plant construction, training and transfer of personnel, and periodic solving of unexpected problems.

It is thus clear that the company required only the minimum transfer of know-how. However, the collaborators did permit frequent visits of Jyoti's personnel to their manufacturing and research facilities. Reasonable royalty payments and good personal relationships between Jyoti's chairman and senior executives of some of the collaborators facilitated the transfer process. The fact that in many cases the collaborators were planning to develop new products in the same lines may also have facilitated the smooth transfer.

In all cases Jyoti had the right to choose the plant and equipment required for the manufacture of the products for which a collaboration agreement was entered into. It could acquire the equipment from anywhere, exclusively based on merits. The acquired know-how often needed some modifications, which were made by Jyoti's own Research and Development Centre. The company strongly believes that after initial collaboration to obtain a specific product or process, every company should carry on its own research and development and develop the next generation of products or equipment or process itself.

Out of 37 items for which Jyoti entered into collaboration with Calor-Emag, for only one did it need a second collaboration agreement. The production of this item started late, owing to meagre initial demand in the country; and the technology could not be assimilated before the first collaboration agreement expired.

After the collaboration with Oerlikon had begun, Oerlikon developed a new design for the 132 kV circuit-breakers. Jyoti decided to develop this improved version through its own research and development and consciously decided not to repeat collaboration.

Import substitution

Jyoti has actively pursued import substitution from its inception. Since most of the new products Jyoti began to manufacture had been imported previously, their entire production value can be taken as the import-substitution benefit to the country. Pumps, centrifuge motors, and turbines require no imported items for their manufacture. Import content for the 11 kV and 33 kV circuit-breakers is only about 2 per cent. Only for the 132 kV circuit-breakers is it significant—25 per cent. Even here, further indigenization efforts are going on. Only those items are imported for which capacity does not exist in the country, such as porcelain bushing, fibre-glass tubes, and high-pressure hydraulic components.

Research and development

Before Jyoti's Research and Development Centre was formally set up, developmental efforts were pursued as part of the regular manufacturing activity. In the early years, the emphasis was on applied work, on *(a)* reducing the costs by improving the designs and manufacturing processes; *(b)* promoting import substitution; and *(c)* improving the company's manufacturing capability to absorb the acquired or developed technology and know-how. With the increasing confidence arising from past success, the emphasis shifted to new product development and research into more advanced technology areas.

Accordingly, Jyoti started constructing a building having facilities for research and development in power electronics, fluidics, solar energy, relays and materials science, in addition to the existing product areas. By 1978/79, more than Rs 10 million had been invested in expanding research and development facilities. The annual operating costs also gradually increased from about Rs 2.4 million in 1974/75 to more than 9 million by 1978/79 (see table 2). Jyoti is the only private manufacturing company in India known to be spending almost 5 per cent of annual turnover on research and development.

Objectives

The primary objectives of the Research and Development Centre are as follows:

(a) To study basic phenomena and their effects and thereby to contribute to the product-oriented applied research work in the country;

(b) To undertake large, complex and sophisticated design and development assignments in electrical engineering, hydraulic power and electronics;

(c) To develop indigenous technical know-how, especially in respect of hydraulic, electrical and electronic products, and thus be free from continued technical dependence on developed countries;

(d) To initiate research in new areas of technology, such as solar energy and lasers;

(e) To develop and assess special materials for use in the products manufactured or planned for manufacture by the company;

(f) To stimulate commercially sound technical innovations;

(g) To promote research and development, scientific and technical work, including technical information, advisory, consulting and engineering services;

(h) To raise the level of industrial practice through more effective application of the knowledge and techniques of products and processes;

(i) To maintain contacts with scientific and technical institutions in India and abroad, to follow developments carried out elsewhere and to judge their relevance to the company.

TABLE 2. EXPENDITURE ON R AND D

Period or year	*Operating costs (Rs million)*	*Capital expenditure*			*Total expenditure (Rs million)*	*Ex-factory value of production exclusive of taxes (Rs million)*	*R and D operating costs as a percentage of production*
		Equipment (Rs million)	*Buildings and furniture (Rs million)*	*Total (Rs million)*			
1964-1974	—	2.73	1.06	3.79	—	—	—
1974/75	2.37	0.33	—	0.33	2.70	94.6	2.59
1975/76	4.00	0.33	1.75	2.08	6.08	110.2	3.63
1976/77	4.62	0.23	0.41	0.64	5.26	158.6[a]	2.91
1977/78	7.16	0.44	0.23	0.67	7.93	156.9[a]	4.56
1978/79 (projected)	9.05	3.17	1.75	4.92	139.7	190.0[a]	4.76

[a]Figures indicate total production, including the output of licensees.

The work of the centre embraces basic research (10 per cent), applied research (20 per cent) and development (70 per cent).

The annex gives details of the organization of the Research and Development Centre, collaboration with Indian institutes of technologies and other institutions, and some of the major projects it has successfully completed.

Manpower

The manpower of the R and D Centre as of 1978 is shown below. Current strength is even higher.

Engineers	
Ph.D.	12
M. Eng. or M. Tech.	71
B. Eng. or B. Tech.	100
Subtotal	183
Scientists	
Ph.D.	4
M.Sc.	6
B.Sc.	3
Subtotal	13
Other technical staff	71
Workers	
Skilled	40
Semi-skilled and unskilled	31
Administrative	22
Subtotal	93
TOTAL	360

The rate of growth in the manpower assigned to R and D has been higher than that in any other department, as shown in table 3.

Training

Jyoti has a comprehensive training and development programme for operators, supervisors, engineers and managers, since management recognized from the start the need to train workers. An apprenticeship school was started in 1958. Furthermore, engineers are given the opportunity to earn advanced degrees at various technical institutes. During their study period, they are paid 75 per cent of their salary in addition to the stipend given by the institutes.

Supervisors, technicians and managers are given opportunities for self-development individually and in groups, on-the-job and through formal in-company programmes. Company executives are encouraged to participate in programmes conducted by outside agencies such as the National Productivity Council, All-India Management Association, universities, and Indian institutes of management.

Both technical and non-technical staff are also given frequent opportunities to visit foreign countries, collaborators' units, international technical exhibitions etc. Thus, the head of the development group for switch gears spent two months in Europe, in 1967, visiting plants of collaborators in Czechoslovakia, France, Germany, Federal Republic of, Switzerland and the United Kingdom. In the United Kingdom, he also visited the Electrical Research Association, which has up-to-date testing facilities in the field of high-tension switch gears. Also in 1967, the superintendent of the pattern shop visited France, Germany, Federal Republic of, Switzerland, and the United Kingdom to study current trends in foundry practices, with particular reference to founding, pattern making and metal-mixing techniques. He also paid a visit to the Hanover International Fair in the Federal Republic of Germany.

Exports

Jyoti considers exports not only as a means of earning foreign exchange, but also as a way of testing the quality of its products by international standards, a sign of its success in assimilating technology.

In 1965, Jyoti made its first organized effort to penetrate international markets, though it had exported sporadically from as early as 1959.

TABLE 3. PERSONNEL STRENGTH BY DEPARTMENT, 1973/74-1977/78

Year	*General management*	*Manufacturing*	*Manufacturing services*	*Finance*	*Personnel*	*General administration*	*Marketing*	*R and D*	*Total*
1973/74	74 (10)	352 (1 284)	81 (178)	68 (37)	30 (28)	29 (90)	245 (33)	110 (34)	989 (1 694)
1974/75	76 (9)	364 (1 410)	88 (178)	74 (48)	33 (30)	30 (100)	318 (32)	119 (33)	1 102 (1 840)
1975/76	83 (7)	296 (1 362)	101 (176)	86 (46)	33 (30)	30 (106)	348 (34)	133 (41)	1 110 (1 802)
1976/77	89 (7)	379 (1 442)	105 (192)	89 (49)	42 (33)	32 (146)	319 (27)	148 (44)	1 203 (1 940)
1977/78	109 (9)	351 (1 557)	108 (193)	103 (58)	48 (36)	32 (153)	395 (26)	249 (73)	1 395 (2 105)

Note: Figures without parentheses refer to staff; those in parentheses refer to workers.

Within a few years, exports of its vertical turbine pumps and the motors to go with them had captured markets in several Arab countries and countries in South-East Asia. In the 1970s, exports expanded and became more diversified. By then, Jyoti had assimilated the switch-gear technology so that its products met international standards, and export orders were obtained. Lately, exported products include pumps and motors, switch gears, transformers, hydroelectric generating sets and relays.

Table 4 gives data on exports for the years 1972/73-1977/78. In the coming years, its marketing efforts will encompass the export of technology to the third world, turnkey assignments and integrated engineering systems.

Transfer of technology from Jyoti to others

In economic terms, Jyoti is as much a giver of technology as a receiver. A good indicator of the inflow and outflow of technology is the statement of royalty payments and receipts (see figure III). In the early years, Jyoti was predominantly a buyer of technology. However, by 1966, it had assimilated the technology to such a level as to *(a)* reduce the dependence on outside sources for technology, reflected in the downward trend in royalty payments; and *(b)* to sell the technology to others.

Since 1966, the growth in the royalty receipts through licensing by Jyoti to other Indian units has been phenomenal, as the graph indicates.

TABLE 4. GROWTH OF EXPORTS, 1972/73-1977/78

(Millions of rupees)

Year	*Hydraulics*	*Rotating electric machines*	*Switch gears*	*Relays*	*Others*	*Total*
1972/73	1.25	—	0.10	0.04	—	1.39
1973/74	0.45	—	1.24	0.05	0.14	1.89
1974/75	0.09	—	4.05	0.05	0.09	4.28
1975/76	5.81	—	1.61	0.03	0.18	7.63
1976/77	1.19	—	4.49	0.03	1.03	6.74
1977/78	1.23	1.85	2.82	0.19	1.83	7.92

Annex

RESEARCH AND DEVELOPMENT CENTRE

Main constituents

Development groups

- Hydraulic machines and systems
  - Pumps
  - Hydro-turbines
- Rotating electrical machines
- High-voltage transmission and distribution equipment
- Low-voltage distribution and control equipment and instrument transformers
- Power electronics and control
- Network protection equipment (relay and control panels)

Technological groups

- Energy systems group
  - Solar energy
  - Wind energy
  - Biogas
  - Waste-heat recovery
- Laser technology
- High-pressure hydraulics and pneumatic control systems
- Electronic instruments development

Common services and other facilities

- General administration
- Material science group
  - Metallurgy
  - Plastics and dielectrics
  - Ceramics
- Prototype shop
- Theory of elasticity and strength of materials group
- Instruments and instrumentation group (for calibration, maintenance repair and special measurements)
- Mathematics, statistics and computer group
- Technical information centre and library

Laboratories

High-rupture capacity laboratory
High-current testing and mechanical endurance laboratory (for high-voltage switch gear)
Impulse high-voltage laboratory
Switch gear laboratory
Power electronics and control laboratory
Heat transfer and rotating electrical machines laboratory
Hydraulic laboratory

Low-voltage switch gear mechanical and electrical endurance laboratory (for low-voltage switch gear)
Relay laboratory
Material science laboratory
  Metallurgical laboratory
  Plastics and dielectrics laboratory
  Ceramics laboratory
  Radiography laboratory
Solar energy laboratory
Photoelasticity laboratory
Instruments development, testing and calibration laboratory
High-pressure hydraulic laboratory
Laser laboratory

Collaboration with Indian institutes of technology and other institutes

For basic and fundamental research work, Jyoti also utilizes the services of various Indian institutes of technologies and other R and D laboratories.

Institutional membership and co-operation with other institutes

American Ceramic Society
American Foundry Society (AFS), United States of America
American Society of Mechanical Engineers (ASME), United States of America
British Hydraulic Research Association (BHRA), United Kingdom
International Conference on Large-Voltage Electric Systems (CIGRE), France
International Solar Energy Society, Australia
Electrical Research Association (ERA), United Kingdom
Laser Institute of America, United States of America
Central Board of Irrigation, New Delhi
Founder member of Electrical Research and Development Association (ERDA), Bombay
Indian Standards Institution, New Delhi
The Computer Society of India, Bombay

Some of the major R and D projects successfully completed

Development of:

Moderator pump for nuclear power stations
Micro hydropower sets for hilly and isolated areas and canal drop units for plains
Gravel pumps for handling ores, such as tin, and pumps for handling sand and heavy gravels
Condensate pumps for thermal power stations
Circulating water pumps for thermal power stations
Mechanical seals
Complete hydroelectric generator units comprising turbine, butterfly valves, generator, governor and control gear in ratings up to 1,500 kW
Computer-aided techniques for designing
Fluidic diverter valve and pressure regulator valve
Computer-aided design and optimization techniques for rotating electrical machines
3.3 kV, 6.6 kV and 11 kV induction motors up to 1,500 kW
Synchronous generators up to 3,000 kW
Insulation system for rotating electrical machines for use in nuclear power plants
Solid rotor centrifuge motors
Accelerated simulated outdoor weathering testing rig for estimating the outdoor life of materials
Laminated frame DC motors up to 37 kW for thyristor drives
Rotary frequency-converters
Tilting-pad journal bearings
Minimum oil circuit-breakers (33 kV, 750 MVA, 1,250)
Cast epoxy resin instrument transformers up to 33 kV
Epoxy resin instrument transformers using aluminium conductors
Technique for field plotting by electrolytic tank or semiconducting paper
Induction melting units up to 100 kW
Static converter drives up to 200 hp
Static inverters for AC variable frequency drives up to 200 kVA
Static excitation for generators up to 1,500 kW
Static automatic voltage regulators for generators up to 3,000 kW
Twelve-element solid state distance relay suitable for protection of transmission lines up to 220 kV
Static time delay relays
Dry-type, 33 kV current transformers for outdoor applications
Air-break contactor of 80 A rating

Studies:

Fluid flow in axial-flow and mixed-flow pumps
Guide-vane designs
Selective hardening process
Heat transfer in electrical machinery
Pressure development owing to high-current fault arcs
Contact bounce in low-voltage contactors
Arc-resisting properties of plastic moulding materials (box-test)
Partial discharge in epoxy resin castings

III. Eicher Tractors India Limited: an example of the importance of management

*K. Balakrishnan and S. Chowdhury**

History of the company

Eicher Tractors India Limited was started by M. M. Lall, the father of the present managing director, V. Lall. An active entrepreneur, he started trading activities in steel furniture and in plastics, which was a very new and lucrative field then, before turning his attention to tractors.

In 1948, he took up distribution of tractors manufactured by a Canadian company. Tractors at that time were an item of curiosity value, and a market for them still had to be developed. The distributorship in tractors proved to be profitable; and, in 1952, he decided to import tractors on his own. He then toured Europe fairly extensively looking for a tractor suitable for Indian conditions.

At that time Indian farmers were unfamiliar with mechanized agriculture and often subjected their tractors to abuse. There were almost no facilities for maintaining tractors. (Even now such facilities leave much to be desired.) A tractor was required that could be used for pulling trailers and other heavy loads, for ploughing and so on. Ease of maintenance was a necessity. The tractor manufactured by Gebrüder Eicher, Federal Republic of Germany, fulfilled these requirements. With a single-cylinder, air-cooled engine, without a radiator and with few moving parts, the Eicher tractor was easy to maintain. The tractor had been designed originally by an engineer in the Federal Republic of Germany who had started the business as a repair shop. The tractor company started as a small venture and had a production volume of 3,000 tractors per annum in the early 1950s. Because of its low production volume, its manufacturing technology was suited to the level of industrial development in India, where the markets were small then and are still small even now, compared with those in the developed countries.

In 1952, a few tractors were imported to test the market. The response seemed good, and from 1953 onwards M. M. Lall's company, Goodearth Private Limited, started importing about 100-200 of these tractors a year. A workshop was set up to carry out maintenance and repair, train farmers to use the tractor and train mechanics.

Import of complete tractors went on through 1956, after which the Government ended the liberal import of tractors through normal trade channels because of India's deteriorating balance-of-payments situation, and it had become necessary to save foreign exchange.

M. M. Lall then began to consider manufacturing tractors in India. In 1957/58, he went to the Federal Republic of Germany to explore possibilities of collaborating with Gebrüder Eicher in the manufacture of tractors to its design. At the same time, he applied to the Indian Government for an industrial licence to go ahead with the manufacture. At the beginning of 1959, the Government issued an industrial licence for the manufacture of 1,250 tractors per annum. In the same year, Goodearth Private Limited established Eicher Tractors India Limited. Construction of a plant at Faridabad began.

Foreign technical collaboration

A collaboration agreement with Gebrüder Eicher was signed in 1959. The product taken up for manufacture was a 26.5 hp air-cooled diesel tractor based on the foreign collaborator's design specifications, a design that was being phased out of the collaborator's own product line, since multicylinder and more sophisticated tractors were becoming increasingly popular in the Federal Republic of Germany.

The tractor selected did not have an automatic hydraulic system for implement control, whereas by the 1960s almost all tractors in the developed countries had incorporated this feature in their designs. Although an obsolete model, it was a sturdy machine that suited the low level of technical skills found in India.

The collaboration agreement provided that the collaborator would supply the Indian company

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with documentation for the manufacture and assembly of tractors according to the collaborator's design. It also provided that the collaborator would help in establishing production and assembly operations in India, would supply critical components until they could be manufactured locally, would supply drawings and documentation for all jigs, fixtures and special toolings, and would train the Indian company's engineers at its works, if required.

A royalty of 2 per cent was payable on the ex-works cost of components manufactured in India. Another 2 per cent was payable as a technical know-how fee. No lump-sum payment was required. The collaborator was given a share in the equity capital of the company, on the strength of which it was entitled to have two nominees on the Board of Directors.

The collaborator gave the documentation regarding the design; manufacturing and assembly drawings; manufacturing process sheets; and assembly manuals. The manufacturing technology for producing the tractors was simple, but the fledgling organization lacked the technical competence to adapt the collaborator's technology to the local environment. Only with the arrival of the new chief executive in the late 1960s, who helped to identify the technology that would meet the requirements of the market, did this become possible.

Eicher Tractors India received in fact very little help from the collaborator. In the first few years the collaborator sent two or three technicians to help the Indian company set up the assembly operations. Their methods were not the most appropriate for the Indian company's conditions, being more appropriate for mass production than for a volume of a few hundred tractors. Nevertheless, Eicher Tractors India was able eventually to overcome all the technical problems on its own because the technology of the product was simple.

The collaborator later ran into financial problems. In 1970, a Canadian company invested in it and finally bought it outright in 1974, but in 1973 the collaboration agreement with Eicher Tractors India had ended.

The collaboration with Gebrüder Eicher was not very satisfactory, since both parties were beset with problems. The Indian company faced production problems, import restrictions and so on. Lack of demand was the main problem of the collaborator.

Indigenization programme

Eicher Tractors India started production in September 1960. The manufacturing programme as approved by the licensing authority envisaged a phased increase in local content as follows (per cent): first year, 48.6; second year, 79.5; and third year, 100.

Implementation of this rapid indigenization programme was, however, fraught with numerous difficulties, and by 1966 a local content of only 37 per cent had been achieved. The Government's decision to end its liberal import policy had serious consequences for the company. The Government permitted the company to import CKD packs for only 150-200 tractors per year, and this situation continued for six years.

Neither the collaborator nor the Indian company had foreseen problems arising from the lack of foreign exchange. Gebrüder Eicher had specially produced 1,200 almost complete tractors for Eicher India, but they had to be kept in stock in the Federal Republic of Germany, since the Indian company did not have the licence to import them. The collaborator's financial position suffered as a consequence.

Furthermore, Eicher India lacked the proper infrastructure for meeting government requirements regarding indigenization, such as adequate engineering staff, tool-room facilities and purchasing and vendor-development staff. The low production volume, a result of the restrictions on imports, could not sustain the personnel strength required for the rapid indigenization programme.

After continuous representations to the Government, the company was granted an import licence for 1,200 CKD packs.

In a period of three to four years, losses kept on accumulating. If depreciation had been taken into account, the total accumulated losses in 1969/70 would have been double the paid-up capital.

Indigenization began with the manufacture of most of the simple sheet-metal components, the mudguards, bonnet, fuel tank etc. The engine coupled with the transmission was still imported from the collaborator, along with some of the complicated items such as mudguard tops, which required a sophisticated die. During this phase, which lasted until 1964, the fabrication shop and the tractor assembly shop were set up. In the second phase of indigenization, components fitted outside the engine and the transmission system were manufactured.

In 1966, the Government liberalized its import policy, and licences with a c.i.f. value of Rs 5.15 million for the import of essential raw materials and components were issued.

During 1967/68, machines worth Rs 1.67 million were installed to achieve indigenization of the tractors. The break-even point was calculated at 500 tractors per year, which became the target for manufacture in 1968/69.

In 1968, the Government granted another import licence valued at Rs 4.9 million for the import of special steels, tools and components.

In the third phase, the development of the engine was taken up, starting with the connecting rod, the crankshaft and then finally the engine housing. By 1970 the whole of the engine was being manufactured locally, and only the gear box was imported.

About this time some Indian companies started manufacturing automatic gears. By 1975, the company was successful in finding reliable sources for this item. A development department was especially created for concentrating on vendor development through which technical help was given to the gear manufacturers. Some of the suppliers' development expenses were also met by the company.

Policy regarding plant and equipment

Selection of plant and machinery was very much influenced by the poor financial position of the company in its first 12 years. The acute shortage of funds was a very important factor in influencing management to choose a technology having a low capital cost.

The company's share capital was extremely small. Prices of tractors were kept at an artificially low level, and the company was thus always extremely short of cash. It had constant difficulties in paying salaries, wages, government taxes or creditors. The company would not have survived had it not been for the enormous goodwill it had with its dealers. They financed the company's operations by giving security deposits; that is, a certain sum of money—about Rs 4,000 per tractor—was taken from a dealer for one year in advance of delivery of the tractor.

Technically, three choices of manufacturing technology were open to the company:

- Mass-production technology using special-purpose machines for all operations
- General-purpose machinery for all operations
- A combination of special-purpose and general-purpose machinery

The first choice was out of the question, since there were not enough funds to employ mass-production technology. Also, at production volumes of 100, 200 or even 300 tractors per year, the technology would not have been economically justifiable.

Exclusive use of general-purpose machinery was possible, but the skill level required in certain operations would be very high and the quality would fluctuate. So management considered the use of a composite technology, i.e. a combination of general- and special-purpose machinery to be a judicious solution.

To circumvent the financial problems, management decided to import second-hand machines from the collaborator. These machines had become obsolete for the collaborator, and the manufacture of the model taken up for manufacture by Eicher Tractors India had been discontinued. These machines were necessary for some of the critical operations, e.g. machining of the connecting rod and camshaft.

Owing to the financial constraints, the managing director wanted to purchase cheap machinery, but the machinery manufactured by Indian companies was considered too expensive. A team of engineers visited small-scale enterprises in the Punjab to observe the machines and equipment they used. After studying their practices thoroughly, the management of Eicher Tractors India decided to purchase very simple machines, called *addas*, that were being manufactured by small-scale industry in Ludhiana and Batala, two small towns in the Punjab. These machines are basically the skeleton cast-iron base of lathes, drills or milling machines fitted with very simple job and tool-carrying heads. These *addas* are general-purpose machines that can be tooled up for mass production of different items. The idea of the management was to design and manufacture proper jigs and fixtures by which the reliability of the operations could be increased. By this method, the operations could be "de-skilled" to a certain extent.

The layout of the shop was designed so that each component could be manufactured in a part of the shop, using a combination of these *addas*. Through a combination of process and product line layout for certain critical components the capacity of production could be increased with low capital expenditure in plant and machinery. The *addas*, including the special jigs and fixtures, cost between Rs 2,000 and Rs 4,000, whereas a machine from an established large machine tool manufacturer would have cost Rs 20,000-Rs 50,000.

A separate engineering team was created to convert simple general-purpose machinery to special-purpose machinery by designing proper jigs and fixtures and copying attachments, hydraulic systems etc. Also, many of the complicated machines were designed and manufactured in the company itself by a specially created cell. Machines such as the dynamic balancing machine for balancing the crankshaft and the flywheel and the fine boring machine for the cylinder head were designed and manufactured by the company's engineers.

The managing director's philosophy has been to economize on capital expenditure through such steps and at the same time to develop technical expertise through experiments. After he joined the company in its initial years he worked directly on the drawing boards, designing jigs, fixtures, special tools and special-purpose machinery.

This philosophy continues even now, although the company has long since turned the corner and is making handsome profits. The company is planning to make a pressurized paint booth that will cost approximately Rs 800,000. If purchased from established manufacturers it would cost twice as much.

The policy now is to purchase *addas* of better quality to obtain greater reliability. These *addas* have a life of 5-7 years.

However, in the R and D department, the policy is to have sophisticated machines. Total investment in this department is several times that in the production plant and in machinery. Of the total components, those manufactured in the company comprise 20 per cent.

Until recently the policy of management was to subcontract as many items as possible to reduce capital expenditure. Such a policy was appropriate while the production volume was low, at around 2,500-3,000 tractors per annum. With an increase in volume, the management now feels that the sensitivity of the manufacturing operations to supplier linkages has become critical, and therefore to ensure the supply of materials, management is creating a base in the company for manufacturing certain critical components. Such measures will also act to deter suppliers from raising their prices. Thus, the company set up an engine plant at Alwar to meet its needs in view of the increasing volume and also to serve other customers and set up a gear and transmission plant at Parwanoo.

A machine tool manufacturing unit now caters to the needs of the plants at Faridabad, Alwar and Parwanoo for machinery. This machine tool unit had its genesis in the early period of the Faridabad plant when a special cell was created to convert the general-purpose machinery into special-purpose machinery, to modify the machinery bought from the collaborator and to design and manufacture machinery for replacement purposes.

Research and development

Developmental activities were undertaken from the very beginning of the company, although initially they were very limited. A design cell was created for indigenizing the tractor components; converting the simple *addas* into special-purpose machines by designing suitable jigs, fixtures and other special toolings; and designing and manufacturing special-purpose machines required for machining critical components.

Up to 1973, the whole organization was geared to increase production. Prices being controlled by the Government, the only other way of generating larger surpluses was to increase the volume. By 1970, the accumulated losses, after depreciation, amounted to Rs 3.52 million. However, by constantly increasing production, the deficit was wiped out by 1974.

During this period, i.e. from 1959 to 1974, the financial position of the company had been precarious, and therefore no major efforts at R and D had been made. There were no separate facilities for developmental work, and existing production facilities were used. Then, when an enlarged R and D department was envisaged, the company approached the Indian Overseas Bank for a loan.

In 1975/76, the company invested heavily in equipment and machinery for research and development for the first time and began to recruit personnel for the R and D department. By 1977, 90 persons were engaged in R and D work.

Figure I gives the organization structure of the department.

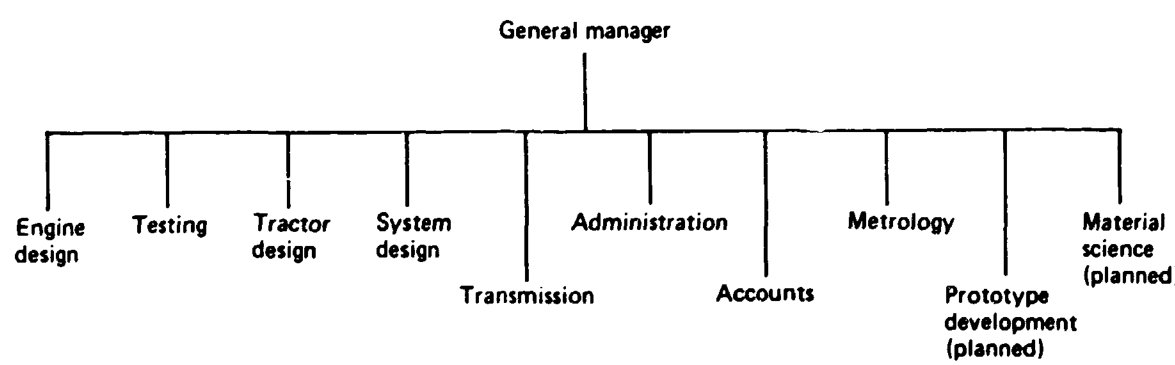

Figure I. Research and development

Two of the senior managers, including the chief of R and D, hold the Ph.D. degree in their fields of specialization. The company has a policy of recruiting holders of Master of Technology degrees with experience in research and development as section heads, and holders of either the Master or Bachelor of Technology degree as senior engineers or engineers below the section heads.

The present objective of the R and D department is to improve existing products, develop the 35 hp tractor, make improvements in the existing model in response to feedback from the field and reduce costs by making changes in design.

A value-analysis cell is to be created to determine how to provide the customer the value in the product at the least cost. Even now some attention is given to these aspects. Value analysis will help to reduce costs.

Systematic budgeting in the company is a very recent phenomenon. An annual budget is prepared by the R and D department. The capital expenditure on R and D is given below:

Year	Amount (million rupees)
1977/78	8.53
1976/77	1.08
1975/76	6.02
1974/75	9.06

Management and marketing

Company policies

In 1971, the market started showing signs of change. Demand for tractors was falling for various reasons, such as further reduction in the size of landholdings. To fight the strong competition, the company kept the price of its tractors below the authorized price.

In 1973, the company started manufacturing diesel generating sets, a stationary diesel engine and trailers (3-6 tons). No industrial licence was required for manufacturing and selling these new products.

In the same year some exploratory steps were taken to penetrate export markets, mainly for tractors. The company made efforts to develop markets in South America and in the Sudan. It also supplied its collaborator with samples of components for Eicher engines that met with the collaborator's full satisfaction.

In 1974/75, the financial position of the company became bright, with a net profit of Rs 3.6 million. The company started to diversify its tractor line, to improve the existing tractor by providing automatic depth control systems and to make other improvements.

In the early years of Eicher Tractors India the company lacked good management. In 1968, V. Lall, who had completed his engineering education in the Federal Republic of Germany and had been performing technical functions at another Goodearth unit, joined the company, although his position was not defined, and it was left to him to create his own role. For the first few years he worked in the various technical functions such as material procurement, vendor development, design of jigs and fixtures and special-purpose machinery, selection of plant and machinery, production planning and control. Later he was designated technical adviser in charge of all technical functions.

Changes in management

In the early 1970s the company was still small, and few people had an idea where it was heading. By 1975, it was producing 100 tractors per month but did not seem to be able to go beyond this figure. Something seemed to be wrong—there was by then no shortage of cash—so management consultants were called in to take a look at the company's operations. As a result of their findings, the company was reorganized in April 1975. Three general managers were appointed for finance, works and materials, respectively, with three officers at the middle management level and some at the junior levels. By September 1975, the production level had reached 150 tractors per month and jumped to 180 per month in December. It went up to 250 tractors per month without any input of machinery. By December 1978 production had reached 500 tractors per month.

The company's *Annual Report* for 1975/76 emphasized the importance of recruiting the right personnel and of training employees.

The rapid increase in production, however, brought its own problems. Not enough attention was paid to ensuring the necessary quality, particularly of the materials from the suppliers. Because of the failure of the suppliers to meet quality standards, production had to be suspended for two to three months to correct the situation, after which production then gradually increased.

Reorganization of marketing

The marketing organization underwent a radical change during this period. Figure II shows the earlier structure, where the sales function was separated from the service manager. As the production volume increased and the number of Eicher tractors in the field increased problems in the field also increased, but there was delay in the

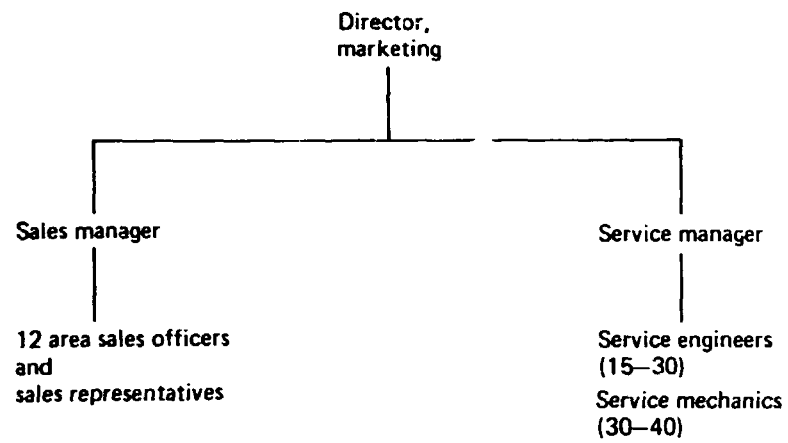

Figure II. Original marketing set-up

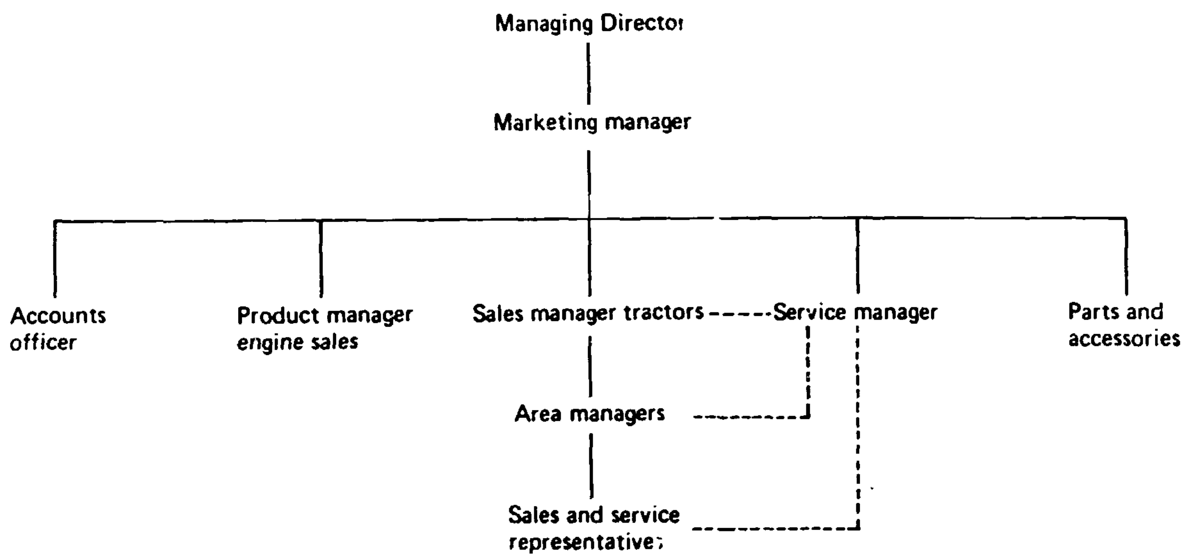

Figure III. Reorganized marketing set-up

feedback from the field. Because of the existing structure where sales and service were independent of each other, the two functions could not be integrated. With increasing competition, management realized that service was a very important means of competition, and the need for a marketing organization oriented to customer service was recognized.

In 1976, the marketing set-up underwent a radical change. Figure III shows the present structure of marketing.

In the reorganized marketing set-up, the former service representative was given the responsibility for sales as well as service in a particular territory. In addition to reporting to his immediate superior, the area manager, he now reports functionally to the sales manager. The dotted lines show the information flow and communication channels between sales and service. Thus, sales can be made only when the service function is well taken care of.

Systematic analysis of warranty claims was introduced. At present weekly warranty meetings are held between representatives of production, materials, quality control and service departments to deal with routine warranty and quality issues. For dealing with critical issues that may involve major investments to improve quality or major modifications in design of product, senior managers and other top officials meet regularly.

In view of the expanding operations the company decided to set up an engine plant at Alwar in Rajasthan to manufacture 7,500 engines per year. It was supposed to be a captive unit of the Faridabad tractor plant with the main technical services centralized at Faridabad. One of the senior officers from the Faridabad plant was sent to Alwar as the project manager in early 1976.

But it was soon found that the Faridabad works manager could not co-ordinate activities in Alwar properly. Communication channels did not seem to be effective, so the managing director decided that authority had to be given to those running the Alwar plant.

At this stage it was decided that with two plants, the old functional structure was no longer suitable. In November 1977, there was another reorganization, a shift from a functional to a divisional organization. A corporate office was created at New Delhi, to which the managing director, the secretary and general manager, finance, and other executives were moved from Faridabad.

One of the reasons for the shift was to give an opportunity to those in the plants to develop independence in decision-making. A divisional structure, it was felt, would help to develop managers.

Effect of government policy on acquisition of technology

Towards the end of the 1950s, the Government banned the import of tractors to force importers to venture into manufacturing. In issuing industrial licences, the Government favoured manufacturing programmes that envisaged collaboration agreements with foreign manufacturers whose products were already well known and in use in the country.

During the 1960s, owing to the growth in demand for tractors and the slow progress of the indigenous manufacturing programmes, the Government imported large numbers of tractors from the countries of Eastern Europe because the tractors could be paid for in soft currency and they were much cheaper than tractors manufactured in other countries. These policies of the Government affected a company's choice of collaborator.

The choice of the mode of collaboration was also influenced by government policy. In the 1950s and 1960s, the Government favoured minority foreign equity participation, as can be seen from the agreements entered into by the tractor industry during the period. The International Tractor Company of India (ITCI) and Eicher Tractors India signed financial-cum-technical collaboration agreements. Tractors and Farm Equipment Ltd. (TAFE) and Escorts Tractors Ltd. also entered into collaboration agreements that provided for foreign minority equity participation. Towards the end of the 1960s, however, the Government began to encourage selective foreign investment and collaboration. Hindustan Machine Tools (HMT) Ltd. and Kirloskar Tractors Ltd. (KTL), which entered the industry during the early 1970s, entered into pure technical collaboration agreements. The duration of the agreements during these periods differed. ITCI and Eicher's agreements were for more than 10 years, whereas those of HMT and KTL were for 5 years.

Assimilation of technology

Technology assimilation can be thought of as consisting of three parts—technology adaptation, technology development and technology utilization.

Technology adaptation

Eicher Tractors India's venture into manufacturing was a response to the import restrictions imposed by the Government. The tasks that it suddenly had to undertake were more than it could handle. The manufacturing programme of the company as approved by the Government envisaged a far too rapid indigenization, and for the first 10 years of its existence, production remained extremely low. Losses accumulated to almost double the share capital.

Since in this early period the company's tractors consisted mostly of imported components, production used to be held up because of perpetual supply problems. Further problems arose because of difficulties in getting import licences from the Government, which were necessary for making payments in a hard currency such as the Deutsche Mark.

The key task of management during this stage was to design an appropriate manufacturing system that matched the product-market strategy of the firm. It had also to build technical teams for performing this task.

At this stage management had to decide on:

- Manufacture or purchase of components
- Manufacturing processes to be used
- Type of plant and machinery to be purchased
- Type of buildings and other services facilities to be constructed
- Methods of recruiting and training technical personnel

Since there were virtually no funds for capital investment, existing machine tools were modified, and additional low-cost ones were bought and converted into single-purpose machines. Manufacturing processes were revised, and new tooling was manufactured. Several ancillary units were developed for the supply of components.

The organization during this stage was very informal. The technical leader was closely involved in performing the key tasks and co-ordinating the activities of the various teams.

Technology development

With a substantial improvement in its financial position by 1974/75, Eicher India's top management directed its attention to improving existing products and developing new ones. The R and D centre was set up with substantial investment in facilities. Specialists in engine design, farm machinery, transmissions, machine tools, electrical machines, metrology and materials sciences were recruited. These steps were taken to make possible the company's future expansion and diversification.

The key tasks of top management during this stage were: *(a)* building an organization geared to the tasks dictated by the firm's strategy; *(b)* developing management systems for co-ordination and control; and *(c)* defining policies in various functional areas consistent with the strategy.

The positive financial results also can be seen from the summarized balance sheets presented in table 1 and summarized income statements presented in table 2.

The Eicher case appears to be typical of a company in a developing country that has acquired and absorbed technology under difficult circumstances.

TABLE 1. SUMMARIZED BALANCE SHEETS, 1967-1977

(Millions of rupees)

Item	*1967*	*1968*	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*
Assets											
Fixed assets	0.78	1.62	2.08	2.66	2.38	2.30	2.19	2.32	2.69	10.56	15.47
Investments	0.001	0.002	0.003	0.001	0.001	0.001	0.002	0.003	0.004	0.004	0.004
Current assets, loans and advances	4.34	6.59	4.36	5.32	8.68	12.25	10.79	15.30	18.95	22.82	29.72
Accumulated losses[a]	1.49	2.41	3.17	3.52	3.27	2.84	2.18	—	—	—	—
Total	6.60	10.62	9.61	11.50	14.33	17.39	15.17	17.62	21.65	33.38	45.22
Liabilities											
Share capital	0.68	1.47	1.48	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
Reserves and surplus	0.21	0.21	0.21	0.21	0.14	0.12	0.14	1.08	4.97	7.42	9.45
Loans	3.07	4.98	3.24	3.62	4.40	7.93	6.14	5.86	5.60	9.73	8.29
Current liabilities and provisions	2.64	3.96	4.68	5.76	7.88	7.43	6.97	8.77	9.16	14.32	25.57
Total	6.60	10.62	9.61	11.50	14.33	17.39	15.17	17.62	21.65	33.38	45.22

[a]For bookkeeping purposes listed as an asset. In fact, the company was operating at a loss.

TABLE 2. SUMMARIZED INCOME STATEMENTS, 1967-1977

(Thousands of rupees)

	1967/68	*1968/69*	*1969/70*	*1970/71*	*1971/72*	*1972/73*	*1973/74*	*1974/75*	*1975/76*	*1976/77*
Income										
Sales	4 345	6 586	8 712	15 496	19 044	22 017	29 501	37 617	81 572	86 181
Miscellaneous income	13	27	90	65	79	292	205	276	170	84
Total revenue	4 358	6 613	8 802	15 561	19 123	22 309	29 706	37 893	81 742	86 265
Expenses										
Manufacturing and other expenses	4 171	6 530	8 260	14 160	17 548	20 154	25 030	32 575	72 505	79 484
Finance charges	592	572	536	703	925	1 133	879	1 108	1 166	1 286
Depreciation	337	381	573	483	427	355	381	540	800	1 122
Total expenses	5 100	7 483	9 369	15 346	18 900	21 642	26 290	34 223	74 471	81 892
Net profit (loss) before tax	(742)	(870)	(567)	215	223	667	3 416	3 670	7 271	4 373

Source: Reconstructed from the *Annual Reports.* There may be some errors in reconstructing the statements, since the format for classifying, grouping and reporting varied from year to year.

IV. Analysis of five case-studies on the acquisition and assimilation of foreign technology in India

*S. K. Mukherjee**

Acquisition of foreign technology

Developing countries usually depend on the industrialized countries for the supply of plant and machinery and technology needed for the manufacture of capital goods and infrastructure as well as many consumer goods, except perhaps some of the products manufactured in the industries already set up in the modern sector and those in the traditional sector. India, now a recognized leader in terms of technology development among the developing countries, became conscious after independence of the high degree of its technological dependence on the industrialized countries. To become self-reliant technologically, during the periods of the second and third five-year plans industries were set up mainly in the public sector for manufacturing basic materials (steel, cement and chemicals) and machinery, plant and equipment, machine tools and power and transport equipment. Since domestic technology was lacking in most of those areas, the technology was acquired through foreign collaboration with large transnational corporations and sometimes with Governments, often on a turnkey basis.

However, policy-makers apparently were not aware of the dynamic character of technology, which is always evolving, and the need for creating appropriate R and D infrastructure and management systems in the country and specifically in the industries being set up to assimilate and adapt the imported technology. They also failed to recognize that the ability to manufacture a product successfully, even complex capital equipment and machinery, does not remove technological dependence in the future unless not only the design and manufacturing know-how but also basic science and engineering principles are properly assimilated and the imported technology is suitably adapted through research and development to meet the situation in the country.

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The difficulties a developing country faces while acquiring technology for a product or process in which it has no prior experience, especially in searching for a suitable technology and collaborator and in negotiating an agreement, can be seen from the case-studies of Indian companies presented in this volume and in the preceding volume. Three of the five companies studied are in the public sector, and in each case the initial collaboration was decided upon by the Government even before the plant or the company to be engaged in manufacturing existed. In these three cases complex technology was involved—the design and manufacture of *(a)* steam-generating equipment for power plants; *(b)* machine tools; and *(c)* precision chemical technology for the manufacture of films and photo equipment. The experience of the three companies—Bharat Heavy Electricals (BHEL), Hindustan Machine Tools (HMT) and Hindustan Photo Films (HPF)—has been somewhat varied, partly owing to the nature of the product or process, but mostly owing to differing management systems and attitudes towards technology assimilation.

The other two companies studied, both in the private sector, differ from the three public-sector firms in many ways. They illustrate the importance of entrepreneurship in importing technology and assimilating it in spite of the hardships enterprises in a developing country face. Jyoti is a good example of a company in a developing country that entered into foreign collaboration on a highly selective basis and assimilated the imported technology completely during the period of collaboration through indigenous R and D. Eicher Tractors India shows how a trading concern can transform itself into a manufacturing concern and while doing so find a good balance between the traditional and modern manufacturing technology in the face of a shortage of capital and introduce a product obsolete in the country of origin but appropriate for the technology-starved rural environment of India.

Initial collaboration for a new product

Perhaps one of the most difficult phases of technology transfer is the first phase, when a developing country wants to set up a plant to manufacture a new product and is searching for a foreign collaborator who will supply designs and manufacturing technology and assist in setting up the plant. Often it is the Government that seeks foreign collaboration for setting up the first manufacturing units in a new area. The company that is to manufacture the product may be non-existent when the collaboration agreement is entered into. This was the case with BHEL, HMT and HPF.

The main problem that a developing country faces is that usually there is no centre of expertise in the country regarding the technology or the technology market for the product, and it is usually not clear which agency should carry on a world-wide search for the best and appropriate technology and then negotiate with the potential collaborators. Foreign consultants could be useful in this connection, but often the Government is not sure whether the consultants can be relied upon to keep the country's interests in mind. Negotiating an agreement is often carried on by government officials who, lacking the necessary expertise, are over-careful regarding financial terms while agreeing to other restrictions that are more costly. Sometimes the collaboration is decided on for political reasons, and a world-wide search for the best technology is not carried out.

The developing countries are in a poor bargaining position when negotiating agreements. Usually Governments enter into a turnkey type of contract, whereby the collaborator prepares a detailed project report; selects plant and equipment; provides machinery, product design, technical documentation and manufacturing technology; erects the plant; starts production; trains staff; and provides systems for material and quality control etc. Under the terms of such turnkey contracts not only is it difficult to reduce the company's dependence on the foreign collaborator, but the country also ends up importing hardware and software in which domestic capability exists. Often the collaborator even controls the management of the company during the initial years even if it has only a limited equity in the company. The collaborator takes decisions regarding product development, diversification, marketing, research and development, as well as day-to-day production according to its own interest. This situation occurred at HMT in the early years, and the initial collaboration agreement with the Government had to be renegotiated so that the company could take independent decisions regarding product diversification and its future development.

Because a developing country lacks knowledge of the technology market it often fails to make a world-wide search for technology. Consequently, the technology obtained may be either obsolete or inefficient, and the terms are unfavourable to the country. A knowledge of the technology market, the alternatives available and comparative advantages of each technology from the point of view of the developing countries is highly useful when searching for technology and negotiating with the collaborators. While government regulation can be used to control the terms of the agreement at least with regard to down payment and royalty fees, without a detailed knowledge of the technology, technology market and various alternatives available, it is impossible to ensure that the most suitable technology is being acquired.

Sometimes it is better for a company in a developing country deliberately not to seek the latest technology either to avoid its very high cost or to obtain technology that may be more appropriate for the skill level and working environment of the developing country, and Eicher Tractors India adopted such a policy. However, the operating costs and material costs may be higher than they would be if the most recent technology were used. When older and less efficient technology is obtained during the initial collaboration it is usually because the company lacks information on the latest technology or because the owners of such technology do not want to sell it to a company in a developing country that has had no experience in using the technology or in marketing the product.

Even when the Government is the agency responsible for searching for technology and negotiating with the collaborator, the situation is not much better as is clear from the case-study on BHEL. A few years after BHEL started to produce boilers, it became evident that the boiler technology obtained from Czechoslovakia through collaboration was not up to date. When BHEL realized that the Czechoslovak collaborators could not supply the latest technology for boiler design and manufacture, BHEL entered into a collaboration agreement with Combustion Engineering, United States of America, even before the period of the Czechoslovak collaboration agreement was over.

Similarly, the case-study on HPF shows the tremendous difficulties the company experienced in assimilating the foreign technology, technology that was, in fact, obsolete, and in getting production started. It also shows that the complexities of the technology were not really known to those who negotiated the collaboration agreement.

That Bauchet was not the best or even a suitable collaborator for setting up a plant manufacturing photographic goods in a developing country and in an environment different from that in the home country became evident from the difficulties it met in setting up a plant in India and getting production started. The case also shows that small units from developing countries in an industry dominated by a few giants from the developed countries have very little bargaining power.[1] They should try to get as much as they can by establishing good and long-lasting relationships with the collaborators and through their own efforts.

Experience with turnkey collaboration agreements

Many of the collaboration agreements entered into by firms in developing countries are turnkey contracts. The Government of India entered into this type of agreement when setting up the three public-sector industries studied, BHEL, HMT and HPF. The case-studies of these enterprises illustrate some of the problems that arise with this type of contract.

The poor experience of HPF with its turnkey contract with Bauchet can perhaps be attributed to the fact that Bauchet was not qualified to handle the responsibilities for all the products included in the agreement. Bauchet was not entirely familiar with the technology built into the design of the equipment it delivered. It furnished know-how for X-ray film it had never produced in its own plant, for example. The plant and machinery were subjected to a series of improvisations by the collaborator, and much of the equipment had to be repaired.

Some of the blame, however, should go to the management of HPF, which did not anticipate the difficulties faced and delays experienced over commissioning of plant and equipment and production start-up and was unprepared to deal with these problems. In spite of tremendous difficulties with quality control and very high rejection levels, appropriate management control systems were not developed until much later, and haphazard experimentation was encouraged in the absence of appropriate records.

HPF and the Government of India did not have much choice regarding the collaboration, since the better experienced and well-known firms were not interested in supplying technology to India. However, the case shows that firms in the developing countries should ensure the ability of the collaborating firm to handle all aspects of the turnkey contract to avoid a situation where the collaborator uses the project as a laboratory to learn the job, with scant regard for the delay and cost escalation experienced by the other party. Inserting appropriate penalty clauses into the contract and proper screening of the potential collaborators are steps that can be taken to prevent such an experience.

In the case of BHEL, while the technology supplied by the Czechoslovak collaborator was not the most up-to-date, the collaborator performed well as far as other aspects of the collaboration were concerned. Credit should also go to BHEL management, which followed a plan for technology transfer and assimilation and thereby made the work of the collaborator that much easier.

Nevertheless, because the agreement was of the turnkey type, BHEL was completely dependent on Czechoslovak expertise, and during the initial years the main job of the design personnel was to convert the various specifications for materials from Czechoslovak to Indian and British, Federal Republic of Germany or United States standards.

In the case of HMT, the collaborator chosen by the Government was possibly one of the best that could be found anywhere for providing machine tool technology and assistance in setting up a precision machine tool plant and training Indian engineers and technicians. The product chosen for initial manufacture, the H-22 precision lathe, was especially designed by Oerlikon for HMT, keeping the skill level of the Indian workers in mind. The training provided by Oerlikon was also thorough, and it built up the confidence of the Indian engineers and technicians in their abilities. However, the main difficulty with this turnkey agreement was that Oerlikon had too much control in the running of the production and determining HMT policy. The plant was set up to manufacture 400 precision lathes annually for 25 years, though there was no market for so many of these lathes at that time in India. The Indian management of HMT wanted to diversify production by manufacturing other general-purpose machine tools, but Oerlikon did not agree. Only when the HMT management bought out Oerlikon's equity ownership did the management succeed in starting a diversification programme based on several other collaboration agreements.

In this case, perhaps the choice of the collaborator was correct, but the terms of the agreement were not appropriate and the choice of the single product taken up for production was too limited commercially. Some of this could have been foreseen, and the agency responsible for negotiating the collaboration with Oerlikon could have prepared a suitable project report. It also

[1]Contrary to the view expressed by Nathaniel H. Leff in "Technology transfer and U.S. foreign policy: the developing countries", *Orbis*, vol. 23, No. 1 (spring 1979), that a "third world country which wants to begin production . . . usually has available many alternative suppliers of advanced technology" the HPF case-study shows that an oligopolistic situation does exist in many specialized process and engineering industries.

appears that not much planning was undertaken in terms of the needs of the domestic market for machine tools. The subsequent experience of HMT showed that HMT could have proceeded much faster in assimilating the machine tool technology and producing a variety of general-purpose and special-purpose machine tools than Oerlikon assumed when the agreement was signed.

The collaboration agreements entered into by Jyoti and Eicher Tractors India were not of the turnkey type; they usually involved the supply of the design and documentation and the collaborator's help in establishing production and training.

Terms of collaboration

The collaboration agreement usually specifies clearly the terms of collaboration, including various clauses in the contract related to payment of royalties and amount of lump sum; restrictions related to the import of raw materials, components and machinery and export of output; and services such as provision of design and manufacturing know-how, trade marks and patents, training of staff and start-up of production. However, the actual services rendered by the collaborator and the restrictions imposed upon the recipient are based usually on the mutual trust and association that is formed between the two companies. Thus, instead of depending only on legal clauses, the company receiving the technology should try to establish good relations with the collaborator right from the beginning, and often even before entering into an agreement. The management of Jyoti took pains to see that informal contact between the chief executives of the collaborator and those of Jyoti was established long before entering into an agreement. The same policy was followed by one of the later chief executives of HPF, under whose direction the company changed from a losing concern to a profit-making one. HMT obtained much assistance from Du Pont through such an association for several years before a formal agreement was signed.

The terms of a foreign collaboration agreement are closely examined by the Government of India, and it has issued formal guidelines regarding the range of royalty payments that are permissible in specific industries and laid down other restrictions. The objective of such regulation is to reduce the direct and indirect costs arising from foreign collaboration not only to the recipient company, but to the country, and to ensure that companies will not enter into two or more collaboration agreements for the same technology or into agreements for technologies that are locally available. While such guidelines have been helpful to enterprises, insistence on reducing the direct costs of foreign collaboration through ceilings on royalty and lump-sum payments and various tax provisions may discourage top-ranking firms owning the most modern and efficient technology from entering into collaboration agreements. It may also contribute to increasing the indirect costs of such agreements through hidden mark-ups on the value of imported raw materials, components and machinery and other commonly used devices

As Jyoti's experience suggests, it is probably better to keep the collaborator contented by paying reasonably high royalties for a suitable technology, but ensuring that the period of such collaboration shall be short and the technology assimilated before the agreement expires so that there will be no need to extend it. Of the five collaboration agreements of Jyoti discussed in the case-study, all involved 5 per cent royalty payments; four also involved lump-sum payments. Four collaboration agreements were for 10-year periods and one for a 5-year period; only one agreement had to be extended from 10 to 13 years.

While the general terms of collaboration are easy to obtain, the detailed, quantitative terms are often not, since some companies are secretive about the terms of collaboration. As is to be expected, the terms change considerably from contract to contract, but often there are some underlying patterns that are similar for the same industry, including the restrictions imposed, showing the oligopolistic nature of the technology market, specifically in the West.

In the case of BHEL, the initial project agreement with Skodaexport provided for a lump-sum payment for supplying drawings and technical documentation and design standards for boilers and accessories. Separate payments were made for the detailed project report and for the plant and machinery purchased. The agreement also provided for training of Indian engineers and technicians in the collaborator's works and the visit of Czechoslovak experts to start up production at the plant at Tiruchi. There were possibly no specific restrictions regarding export of these boilers. Detailed terms of the agreement with Combustion Engineering (CE) are not available, but it provided for royalty payments and possibly restrictions on export of boilers to countries where CE had licences.

One of the salient features of some of the collaboration agreements entered into by HMT is that through compensation from production of machine tools HMT was able to obtain design and technology for certain machine tools without paying royalties or a lump sum.

The initial agreement with Oerlikon, in 1949, assigned 5 per cent of the share capital of HMT to Oerlikon in consideration of the licence and the know-how for the manufacture of lathes. Oerlikon also purchased Rs 3 million worth of equity share capital in HMT. When HMT renegotiated the agreement in 1956, Oerlikon was paid back its share capital plus interest and also paid Rs 1.25 million in consideration of its forgoing the 5 per cent free shares. HMT also agreed to pay a royalty on actual sales at specified rates. Export of the H-22 lathes was restricted by the agreement to Burma, Pakistan and Sri Lanka, and this restriction almost became a standard clause for all later machine tool collaboration agreements. The agreement with Oerlikon was for a 20-year period.

With the decision to diversify into other general-purpose machine tools, HMT entered into other collaboration agreements. Its agreement with Fritz Werner of Berlin (West) involved lump-sum payments and royalty payments at 3.5 per cent on the first 600 milling machines. The royalty payments were later deleted from the agreement. The agreement with Herman Kolb of the Federal Republic of Germany for a seven-year period also involved only lump-sum payments. The agreement between the Government of India and Citizen Watch Company of Japan that was transferred to HMT was a turnkey contract for eight years. The agreement stipulated a lump-sum payment for the supply of drawings, technical information and assistance as well as royalty payments set at 2 per cent of the value of watches less the cost of imported components.

The original agreement with Renault for special-purpose machine tools involved no lump-sum or royalty payments, but it contained a commitment on the part of HMT to purchase components and machines from Renault for a minimum amount. In 1976, HMT entered into a collaboration agreement with the Cross Company (CROSSCO), United States, for modern technology to produce special-purpose machine tools. This agreement was more restrictive and costly, since it involved both a down payment and royalties as well as an undertaking not to pursue the Renault design further. The seven-year agreement gave HMT the exclusive right to use CROSSCO technology in India only. HMT was, however, free to sublicense the know-how to another Indian party after discussion of terms with CROSSCO. It could also sell the products outside India after executing a distribution agreement with CROSSCO and its licensees and paying the necessary fees.

Except for specific agreements like the one with CROSSCO, the terms of collaboration agreements that HMT entered into improved with time. In March 1967, barely 10 years after its first collaboration agreement with Fritz Werner, HMT entered into a special co-operative collaboration agreement with Pegard S.A., Belgium, in which HMT and Pegard acted as equal partners and no payments were involved for any know-how. Similar agreements followed for other products.

In the case of HPF, the initial agreement the Government signed with Bauchet involved a down payment of $6.1 million and a royalty of 1.5 per cent of the net value of sales for the third, fourth and fifth years of the period of the agreement. An agreement signed in July 1977 with ORWO for licensing the manufacture of negative roll film involved only a licence fee of Rs 5.6 million. The 1976 agreement with Du Pont for technical information to produce and package processing chemicals for medical and industrial X-rays and graphic arts, however, involved a nominal payment of $2,000 and a 4 per cent royalty on net revenue for five years from the commencement of production.

In the case of Eicher Tractors India, the collaboration agreement for the supply of know-how for the manufacture and assembly of tractors and other services stipulated a royalty payment of 2 per cent of the ex-works cost of components manufactured in India under the agreement and an additional 2 per cent as a technical know-how fee. The collaboration agreement was for a period of 14 years.

Thus, it appears that a new industry in a developing country does not initially have much bargaining power in negotiating collaboration agreements, and the terms are governed by what the giants in a particular industry are ready to offer. Government regulations and ceilings on direct costs do not always help and often lead to a company's accepting obsolete and inferior technology. However, because of government regulations, HMT and other industries managed to include clauses in their agreements permitting transfer of technology to other Indian industries. The case of HMT shows that once a company becomes established and is known world-wide, much better terms can be obtained through shrewd bargaining. On the other hand, Jyoti's experience shows that it is better not to be too stingy regarding the financial terms and to keep on good terms with the collaborator so as to obtain the maximum benefit during the period of collaboration. There are usually restrictions on exports, but they can often be waived at a cost or through a marketing arrangement with the collaborator. The indirect costs are not obvious, and usually enterprises do not like to mention them. But, in general, the terms of collaboration accepted by the companies studied have not been unfair to these companies. That does not mean, however, that the technology obtained and the choice of collaborator have always been the best for the companies concerned.

Aspects of assimilation and adaptation of foreign technology

Role of management in assimilating technology

The transfer of technology through foreign collaboration makes the recipient industry or the country dependent on the collaborator. In fact, the greater the services rendered by the collaborator, the more dependent the recipient industry becomes, since it habitually turns to the collaborator for help in solving all problems. Assimilation of technology should increase the ability of the recipient firm to stand on its own once the period of the agreement is over. It should also develop the expertise to adapt the technology to the needs of the domestic situation. Thus, the degree of assimilation will depend very much on the recipient company's own efforts and the management systems it develops, including training and dissemination of the knowledge acquired from the collaborator and further research and development.

Jyoti provides an example of an enterprise devoted to innovation and development of indigenous technology. Jyoti was very selective in entering into foreign collaboration agreements and sought only specific technologies after it had devoted much effort to in-house R and D. Instead of going after the most modern or sophisticated technology, which would be costly to acquire, it acquired technology out of date in the collaborator's country but well-suited to the needs of India. It also created friendly ties to the collaborator through personal relationships between the chief executives and also through commercial arrangements such as joint distribution and sales.

Since products manufactured under foreign collaboration often embody subassemblies or components the collaborator directly purchases from other manufacturers and the technical know-how for them is not passed on, these components have to be developed through indigenous R and D to reduce the need for imports. Similarly, the materials specified in the collaborator's designs are not always readily available and have to be replaced by indigenous materials. Jyoti's experience shows that collaborators often refuse permission to change the specifications and that the firm acquiring technology can adapt these to suit its conditions only after it has gained enough technological competence to do so.

However, a new company being established in a developing country is usually not in a position to follow the example of Jyoti, an enterprise that has over the years developed indigenous technology through in-house R and D. For a new enterprise it is much more difficult to assimilate technology, and usually it becomes much more dependent on the foreign collaborator. It is the function of the management to see that the enterprise not only copes with the usual problems faced in setting up plant and equipment and starting production, but also creates a core of knowledge to enable it to begin to assimilate, adapt and develop technology. The three public-sector industries, BHEL, HMT and HPF, and the private-sector Eicher Tractors India faced such a situation, but their responses differed and so also the results.

Assimilation of manufacturing and design technology

In the initial stages it is natural to concentrate on assimilating the design and technical know-how supplied by the collaborator as it is and to produce the product according to the given specifications. The need to design and process technology to suit domestic conditions is usually realized much later. However, when the problems of adapting the process technology to the local environment, raw materials and equipments are faced right from the beginning, as in the case of a sensitive and complex industry such as the film industry, even the start-up of production becomes complex, as seen in the case of HPF. But in the Indian environment, where delays in the erection of plant and equipment and production start-up are quite normal, the success achieved by both BHEL and HMT is noteworthy. In both cases, not only the management of these enterprises in the initial years was effective, but the training received by the Indian technicians and engineers who went to the collaborators' plants was excellent, and the experts sent by the collaborators to assist in organizing the start-up of production and to train the Indian counterparts associated with each production process were highly competent.

In the case of HMT, however, the foreign experts controlled the production more than was necessary, and the Indian engineers and technicians who had received such excellent training felt frustrated, a situation that was remedied when HMT bought up Oerlikon's ownership in the company.

Import substitution and export performance

One indication that the technology acquired has been assimilated is the degree of import substitution and export sales achieved by the domestic industry on the basis of the imported technology. It is often not technically feasible, nor economically advisable at least initially, to produce all components of a product domestically, and these are usually imported from the collaborator or other suppliers. An enterprise can start by assembling the product from CKD parts obtained from the collaborator. As the technology is assimilated the proportion of the value of the components produced domestically increases; and if conditions are favourable, after several years all components will be produced domestically either by the recipient enterprise or by auxiliary enterprises.

Import substitution at BHEL, HMT and Jytoi has been quite satisfactory, and rapid progress has been made in manufacturing almost all components that it is economically advisable to manufacture domestically. At Eicher Tractors India there were delays initially in meeting its targets, but ultimately it achieved satisfactory import substitution. In the case of HPF, substitution of domestic material for imported raw materials created complex problems concerning quality, but after much experimentation HPF also succeeded in achieving satisfactory import substitution. In fact, HPF was successful not only in identifying domestic sources of photographic-grade chemicals but in assisting other industries to develop such materials.

Export performance should not be looked at only from the financial point of view of earning foreign exchange; the open competition in the export markets presents a challenge to the firm to continue updating its technology. Since the firm usually enjoys protection in the domestic market, there might otherwise be no pressing need to modernize the technology. BHEL entered into the export market quite early and has been successful in winning international contracts in competition with some of the well-known firms in developed countries.

HMT, too, entered the export market early, but for nine years exports grew only slowly. HMT first tried to export its machine tools to the developed countries, knowing that if its machine tools were accepted there they would be accepted also in the developing countries. It had to work hard, opening sales centres and service facilities in these countries, to get recognition, and competition was tough. Since 1971, the rise in exports has been rapid, and HMT has now successfully penetrated the world market in the developed and developing countries alike.

Horizontal and reverse technology transfer

Another indication that the technology acquired has been assimilated is the ability of a recipient company to act in turn as a supplier of technology to enterprises in other developing countries or even in developed countries (horizontal and reverse flow of technology).

Of the five industries studied at least two, Jyoti and HMT, are now acting as collaborators in setting up manufacturing plants in India and in other developing countries based on their own technology. In the early years Jyoti had been a buyer of technology while it was also developing its own technology. By 1966, it had assimilated the technology to such a degree that royalty payments began to decline and sales of technology to other industries began to rise. Since 1966, the growth in the royalty receipts through horizontal transfer of technology by Jyoti to other Indian firms has been very fast. Five major Indian units currently manufacture Jyoti's products under licence, and more proposals are under consideration.

HMT has transferred technology not only to Indian firms, but also to firms in other developing countries setting up machine tool plants. The HMT strategy is to keep for its own production the manufacture of more complex machine tools according to HMT design. Having gone through the difficult process of assimilating advanced technology in a developing country, HMT is now acting as the leader among the machine tool manufacturers in other developing countries. In certain cases, HMT is also supplying technology and products to developed countries.

Research and development

Research and development in product design, product performance, manufacturing and process technology and in basic sciences and engineering are needed not only to absorb foreign technology and know-how but to develop indigenous technology. To some extent inappropriate and inadequate R and D in Indian industry and research institutions have been the weak link in the process of assimilating, adapting and developing technology in India. Frances Stewart has compared the situation in India and Japan as follows:

> "The significance of the figure for import of technology also depends on what the country does with the technology import. Here the contrast between India and Japan is instructive. Whereas in India foreign technology imports often provide a substitute for local technology resources and rarely an impetus to it, in Japan imports of technology have been directly controlled so as to avoid competing with local technology, and the technology imports that are allowed have been used as the basis for further local innovation. The research and development expenditure on imported technology forms one-third of Japan's total research and development."[2]

[2] *Technology and Underdevelopment* (London, Macmillan, 1977).

Foreign technology imports have a restraining effect on the development of local technology unless they are chosen with care and adequately backed up by R and D with a view to developing indigenous technology suitable for the domestic environment. The technology planners in India did not understand this fact, at least in the beginning, when some erroneously thought that the ability to manufacture capital goods domestically based on foreign technology and design would create self-reliance in the country. Even now when the country has a sound technology and R and D base, some of the established industries often import technology on the plea of saving time and cost without realizing that repeatedly taking the easy path of importing increases the dependence on the foreign collaborators. Technology is dynamic and changes rapidly, and unless an enterprise takes a plunge at some point, cuts off technology import and on the basis of the technology already acquired starts R and D, it will remain dependent on a collaborator engaged in making improvements in technology and keeping it up to date.

Except for Jyoti, which is a rare example of an enterprise in a developing country with production mainly based on in-house development, all the other industries studied started serious R and D only at a late stage. It is not that these enterprises did not realize the importance of R and D, but in almost all cases, during the initial years they were so overwhelmed with problems of assimilating a new technology and starting production that R and D perhaps appeared to have a low priority, especially to managers who wanted the plant to build up production on schedule and remove various bottle-necks and teething problems arising from the use of new technology. They also perhaps felt some helplessness at the absence of an integrated R and D infrastructure in the country. There was no suitable group either in the universities, institutes of technologies or national laboratories that was ready to work on the actual problems of industry.

It was only when enterprises such as BHEL and HMT set up centres for R and D and also persuaded the technological institutions and government research laboratories to work on their problems that R and D really took root. The results are already encouraging.

It also takes time before a new company realizes the specific areas in which it should devote the resources available, which, for a company in a developing country, are quite limited in comparison with those that transnational corporations have at their disposal. After the boilers manufactured by BHEL were commissioned in the field and customer complaints started coming in, BHEL turned its attention to research, including field investigations of the boilers and their performance. BHEL also realized that it must move into new areas of R and D, testing the design parameters and underlying theoretical developments relating to its products as well as basic areas such as power cycles, heat transfer, materials, combustion of fuels and performance of complex systems. Since many of the problems in operating BHEL boilers were due to the poor quality of Indian coal, it was recognized that BHEL should engage in R and D to solve these problems.

BHEL expenditures on R and D are still moderate by world standards but should rise further.

HMT, initially heavily dependent on foreign collaborators for the design of machine tools, realized later the need for strong product development, and its design office was accordingly reinforced and a master plan prepared. Twenty-four machine tools were identified for development in 1963, and out of this list, 18 were ultimately produced. In 1968, a force of 332 persons was working in the design office, based on 12-man teams for machine tool development. Design and development departments were subsequently set up in all units, and a R and D metal cutting centre at Bangalore was established, which marked the beginning of more basic R and D work in machine tool technology at HMT.

The experience of HPF is unique in a sense. In a sensitive industry, a high quality of R and D is almost essential for survival. The few industrial giants in this field may spend up to 30 per cent of the value of their sales for R and D. As HPF is only about one hundredth or one fiftieth the size of these organizations, the limitation on resources puts a real constraint on R and D. The total amount spent on technology-related activities in HPF for 16 years was Rs 27.8 million, an average of Rs 1.7 million per year. This amount is insignificant in comparison with what others spend in this industry. Yet HPF has utilized its limited R and D facilities to achieve some results in product and process improvement, new product development and import substitution.

Eicher Tractors India realized the importance of R and D from the very beginning. Initially, the focus of all developmental activities was on solving manufacturing problems and increasing production and indigenization. Subsequently the company began to invest heavily in equipment and machinery for R and D and started recruiting highly qualified staff, a rare phenomenon for a small company. Eicher Tractors India is possibly the only enterprise in India that is profitably blending ideas used by small-scale industries in the Punjab with modern technology to create a truly indigenous technology that is low-cost and appropriate for India.

The important role played by R and D in the growth of Jyoti right from the beginning cannot be overemphasized. Its research and development centre was formally established in 1964, the first of its kind in the private engineering industry in India, but Jyoti had been engaged in the development of technical know-how since its inception in 1943. In the early stage the emphasis was mainly on improvement of design and manufacturing processes to reduce costs, import substitution and improving the company's ability to absorb the acquired technology. The emphasis shifted later to new product development and research into more advanced technology areas.

Jyoti has adopted the policy of developing indigenous technology as far as possible and entering into foreign collaboration agreements on a highly selective basis. Usually much work in the specific area is done in-house to identify the need for collaboration, to bargain from a position of strength with the potential collaborator and to assimilate technology during the period of the agreement, a policy that could well be followed by other Indian enterprises, both in the public and the private sectors.

Some conclusions and recommendations for developing countries acquiring technology

With very few exceptions, the developed countries, with an economic and technical environment very different from that in the developing countries, are the source of technology for the developing countries. Such technology is capital intensive and generally developed with the objective of minimizing labour, since the wage rates are higher in those countries in comparison with capital charges. New technology that requires a large volume of production and heavy capital expenditure may not be suitable for the developing countries, where labour is plentiful, wage rates are comparatively low and capital is scarce. Thus, the manufacturing technology and even the product design developed in the industrial countries cannot be transferred to the developing countries without modification. But that is what usually happens if the policy-makers in a developing country are not careful while searching for technology and negotiating with the collaborator. Either the collaborator or the acquiring agency must adapt the design and manufacturing technology to suit the environment in the country, and "off-the-shelf" technology should not be accepted.

Products manufactured under foreign collaboration often have subassemblies or components that the collaborator purchases direct from other manufacturers in its country. The manufacturers of such subassemblies are specialized in these items, and they do not divulge any technical know-how for designing and manufacturing them. During the agreement with the collaborator, some arrangement should be negotiated to obtain know-how related to such components. Otherwise, the know-how would have to be developed indigenously to stop an indefinite purchase of these items.

The material specifications in the collaborator's design reflect the ready availability of these materials in the collaborator's country; often other materials readily available in the recipient country should be substituted. Sometimes material specifications are too stringent and not required by the design. Collaborators often refuse permission to change the specifications, suggesting that the materials should be imported from the collaborator's country. Firms acquiring technology can adapt these materials to suit local conditions only after they have developed a certain degree of competence in technology.

Sometimes the product designs supplied by the collaborator are over-designed, expensive and also not suitable for the environment in the developing country; factors such as the existence of dust, moisture, heat and vermin have not been taken into account. In some cases the product may have to be redesigned to take these factors into consideration. Also, the product may have to be redesigned, as Jyoti discovered, so that the users are neither burdened with overmaintenance nor are overly dependent on specialized staff services that may not be readily available.

Seeking more than one collaborator for similar product lines has the advantage of generating more choices for those developing indigenous technology and creates less dependence on a single collaborator. However, this approach also creates problems in the initial stages, since having multiple designs necessitates multiple material specifications, which in turn creates additional problems in standardization and local vendor development. Nevertheless, collaboration should be attempted with different sources so that better terms can be obtained.

For the most effective transfer of advanced technology, a country's own technical personnel are better suited than foreign experts. Having acquired skills in modern technological operations in the country, they are better equipped to learn the skills required to adapt the new technology. Occasionally it may be necessary to engage costly foreign experts to undertake very specialized tasks related to the new technology, but the period of their service should be limited. They are often unable to adapt the technology to suit local conditions and raw materials.

Decisions concerning utilization of the end-products of technology are basically economic rather than purely technical. Much effort may be wasted if production turns out to be uneconomical or if the market for the output is small. Technical decisions are business decisions. The persons handling technology should know the market potentialities, the degree of risk involved, the extent to which the cost-benefit ratio is favourable, the degree of competition and other such factors.

For indigenous development of technology through R and D, the developing countries often lack the necessary infrastructure. In some cases, to evolve a design, many very costly destructive tests have to be performed. Unless the volume of production is high, a single manufacturer lacks the means to carry out such tests, and the required testing facilities are not available in developing countries. For example, Jyoti has to send circuit-breakers abroad for type-testing and development testing. This means both additional expenditure and costly delays owing to governmental red tape.

The transfer of complex process technology to a new environment creates difficult problems that often defy theoretical solutions. Hence, the firm acquiring the technology must either find a solution through trial and error, costly in terms of time and money, or obtain help from the experienced collaborator, which means continued technical dependence on the foreign collaborator. The acceptance tests in agreements should be so specified that they are carried out not at the collaborator's plant, but in the new environment and possibly with local raw materials.

The major indices of technology assimilation by an industry in a developing country will be its success in import substitution, export performance and degree of horizontal and reverse transfer of technology. Constraints arise not only from technological problems, but also from the poor economics of the small volume of production usually encountered in developing countries. The ability to manufacture a complex product in an industry in a developing country, based on the design and manufacturing know-how supplied on a turnkey basis by a foreign collaborator, may help in achieving the objective of import substitution, but need not always signify that much technology absorption has taken place and that the country is self-reliant in that product technology. Technology assimilation is a multilayered process; and unless basic and applied R and D is emphasized, the industry in the developing country will go through a process of peeling off the layers and finding more aspects for which dependence on the collaborator is necessary. Industry and the policy-makers in a developing country must reconcile this apparent paradox and make appropriate choices.[3]

[3]For other conclusions, see also *Case-Studies in the Acquisition of Technology* (I) (ID/257), p. 49.

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