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TRANSFER OF TECHNOLOGY IN THE CATALYST AND PETROCHEMICAL INDUSTRY[1/]

by

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INTRODUCTION

During the past thirty years there has been a spectacular increase in the transfer of technology and this has occurred principally with fertilizers, organic chemicals and petrochemicals. One very important reason for this is the effort needed to orginate and develop a process to the full scale. The situation is approaching the stage where the cost of research and development is so high that only the large state and private companies have the resources to undertake such work. Even the outcome of the research is not always successful and the company may in the end be forced to acquire technology under licence. Buying the technology perhaps represents a high cost in the short term but involves least risk as the product or process will normally be well established.

The importance of licensing is illustrated by the sums of money involved. In 1971 the United Kingdom earned £220m from the sale of know-how and at the same time spent about £175m in know-how acquisition. Germany and France, however, bought more know-how than they sold. Japan, of course, is the classical case, spending considerably more in buying know-how than it earns. In the 20 years from 1950 Japan spent $2 billion on licences to build up an industry with a capital value of over $80 billion. In 1972 the total cash spent on research and development in the USA was ten times that spent by Japan in the previous ten years which gives some indication of the cost effectiveness of licensing compared with the independent research and development. The implication is that the importation of technology itself gave rise to the Japanese economic miracle. Of course, this is not so. We know that the climate in Japan was ripe for the development, there was the infrastructure, the pool of skilled labour, the management expertise and the financial policies of the Government; the technology was the final link in the chain. Given the Japanese society the technology provided a cheap short cut to the present economic position.

The manufacture and sale of catalysts has also developed into a major industry during the past three decades, which of course is hardly surprising since a large number of the new processes invented involve catalytic steps. For ammonia producers the period has seen a change of feedstock from coal to natural gas and naphtha, a change which was permitted by the development of a whole new range of catalysts -

sulphur removal systems, nickel supported catalysts for reforming the heavier hydrocarbons, development of low temperature shift and methanation catalysts. This was due in part to a change which occurred in the industry. Individual ammonia manufacturers ceased to make their own catalysts and instead began to purchase from a few specialised manufacturers who emerged during the period. The change allowed large production units to be built, with the usual associated cost savings, and it also allowed investment to be made into the technical skills necessary for the investigation of existing catalysts and the development of new ones - skilled personnel to operate and maintain catalyst producing plants, quality control specialists and technical back-up of process engineers and chemists. The efforts led to new processes as well as cheaper and more stable catalysts. Harbermehl[1] showed that, during the period, the annual price of catalysts to produce ammonia synthesis gas fell dramatically from $2,340 per daily metric tons of ammonia in 1941 to $223 in 1968. In spite of the dramatic inflation of recent years our latest estimate for the cost of catalyst in a modern 1000 metric ton/day unit gives a figure of $235 per daily metric ton, an inflation in cost of less than 1% per annum from the 1968 figure of Mr. Habermehl. Probably most important from the ammonia manufacturers point of view is that it has allowed technical resources to be deployed away from the manufacture of catalysts - where the actual capital involved in a catalyst charge is no more than about 1% of the total investment in the ammonia plant - to the production of ammonia.

The Agricultural Division of ICI has a long-established interest in today's topic and I am very pleased to be invited here. My business interest within Agricultural Division is concerned with the sale of catalysts and technology developed in the Agricultural Division and it is from this standpoint I approach today's discussion. The views expressed, needless-to-say, are my own but tempered with experience gained from the Company's position as licensee, licensor, catalyst manufacturer and as one of the world's largest ammonia manufacturers.

I SOURCES OF TECHNOLOGY

The large manufacturing company with its team of skilled and experienced technologists is in a unique position to generate technology. It has the knowledge to develop new processes and improve the existing ones. Often the chemistry surrounding the process is well established and associated know-how is of more value than the basic invention. It is this knowledge gained from development work, from overcoming problems and from improvements carried out on the plant, in the laboratory and design department which is of great value and use to a licensee. These skills also contribute to technology transfer - not in the sense of development of processes but as a consulting service providing advice on specific process problems. Yet another well established practice arising from long experience with projects and production is the provision of technical assistance, project management, plant management and the supporting management services - much in the way Agricultural Division has done for its associated companies in India and Malaysia.

The old concept of the engineering company developing its own technology, though obviously still practised, is less significant as a source of technology. Continued development is related to adequate feedback from the commercial operation by the licensee and this is not always acceptable to the licensee because of the improvements and inventions he may have contributed to the process. There are still a few engineering companies, particularly in the USA, which maintain research and development activities. They are probably more active in the petroleum field but one or two are still doing research in the ammonia field.

Engineering companies too have an interest in making available any process they have in their portfolio; this includes licensed processes as well as the old type of process in which the originator's rights have long since lapsed.

II AGRICULTURAL DIVISION'S PHILOSOPHY

In Britain ICI is organised into nine manufacturing Divisions with each Division acting independently and pursuing its own sales and licensing policy. This may help to explain why different Divisions adopt a different approach to the way they license their technology.

The main interest of Agricultural Division is in the sale and manufacture of fertilizers. Ammonia the centre of the activity, was first made in 1923 for conversion into ammonium sulphate. Subsequently calcium ammonium nitrate and compound fertilizers were produced. At the beginning of the Haber-Bosch era there was very little interchange of technology between companies and secrets of ammonia production were difficult to obtain and then closely guarded and ICI had to develop its own technology. The most important information that the technologists had then was that ammonia could be produced with reasonable conversions over an iron catalyst. The teams of technologists and engineers established to solve the formidable problems associated with catalysts, high pressure technology, corrosion and engineering subsequently formed the basis of Agricultural Division's present engineering and research resources. The output of the first ammonia plant was about 30 tons per day which compares with today's output of 5,000 tons per day, a number which will be augmented shortly when a new 1100 ton per day plant comes on stream at our Billingham complex in the North of England.

Agricultural Division decided 15 years ago that it would license its technology. Furthermore only technology which had been proven on the companies own plants would be promoted. The list of technologies we license is shown in Table 1. The technologies are diverse but related to the ammonia technology through the preparation of synthesis gas, operation at pressure, and the manufacture of fertilizer down stream products or by-products. The licensing activity is grouped with a catalyst sales organisation since the two are so obviously related. Together they form a business area for the sale of technology, licensed catalysts and commodity catalysts. The catalysts are manufactured in England and in the USA.

The success of the approach is indicated by the record - over 350 plants use processes licensed by the Division. The technology includes the very latest developments - for example ICI's pressure steam reforming process for naphtha has been adopted in 176 town gas plants and 130 units for ammonia and chemical purposes. The ICI low temperature, low pressure methanol process has been adopted for 24 plants and accounts for 70-80% of all new methanol capacity since 1968 with plant sizes ranging from 50-1650 tons per day. The ammonia technology has been incorporated in 26 plants built since 1963. Developments by Agricultural Division's Engineering Department such as a new ammonia converter design using lozenge distributors has been adapted in 11 licensed plants. In addition ICI's fertilizer technology is being used in 15 of its own and licensed plants.

III TRANSFER OF LICENSED INFORMATION

Rarely are licenced plants the same size as the plant originally built by the licensor. With the ICI low pressure methanol process for example not one of the licensed plants has had the same capacity as the prototype built at Billingham. Thus it is completely impractical as a rule to transfer technology by the simple means of transferring specifications, schedules and drawings of the existing plant with the proven commercial record. Nor, with few exceptions, can the originator of the technology design the licensed plant. Although some large producers have their own engineering resource, and ICI is such a company, the engineering organisation is usually sized to be fully occupied at base load of demand within the organisation and there is very little surplus capacity for external work. It is of greatest importance that the transfer of the technology occurs in an organised manner to ensure a properly designed and constructed plant. The solution is for the licensed plant to be built by a chemical contractor.

The contractor can be chosen by the licensed operator or the process developer. The former practice occurs more especially in the USA and in Japan where close relationships, based on mutual confidence, exist between the operator and the favoured contractor. Such an arrangement is not always satisfactory to the process owner because he will be faced with the education and supervision of large numbers of different contractors. This could entail much extra work which a licensor, as a chemical producer, can not always undertake - such a practice also results in the dissemination of the original design information of course. A contractor on the other hand, who builds many plants is able to apply the results of experience obtained with earlier plants to improve the design of the later plants; this ongoing process is not possible if a different contractor is employed for each contract. The licensor also wishes to have the best possible demonstration for his process and is therefore reluctant to have no control over the choice of contractor. He may therefore select his own contractor or a small group of experienced international contractors to promote the process. The contractor then becomes associated with the licensor. If the licensor requires plants for his own organisation he will normally ask one of the selected contractors to build it. In the subsequent design and building of the plant the contractor is then made aware of all details of design which are subsequently incorporated in plants constructed for the external licensee.

The system where the licensor chooses the contractor is perhaps the only practical one when the process is to be licensed in large volume. The system need not be rigid since the contractor frequently has rights to sub-license - providing for example the basic design information and permitting the licensee to work more closely to the way he prefers. Where the demand for a process is small, arrangements are chosen to suit the circumstances. This is the method Agricultural Division has adapted for promoting the technologies outlined in Table 1, although with other technologies it has developed such as the Division's single cell protein process and its "Deep Shaft' effluent treatment

TABLE 1

LICENSED ICI PROCESSES

Name	Feedstock	Product	Special Features
Steam Reforming Process	Natural Gas, naphtha	Syn gas for ammonia, methanol, oxo alcohols, town gas and hydrogen.	Reforming in tubed furnaces
500 Process	Naphtha	Town Gas	Primary and secondary reforming of naphtha.
Ammonia Synthesis Process	Synthesis gas derived from natural gas, naphtha, heavy fuel oil, coke gas or coal.	Ammonia	Synthesis in a special design of converter.
Low Pressure Methanol	Synthesis gas derived from natural gas or naphtha, or coal.	Methanol	Synthesis in special converter. Distillation.
High Pressure Methanol.	Synthesis gas derived from natural gas, naphtha, acetylene 'tail' gas, coke oven gas.	Methanol	Synthesis. Distillation.
Formaldehyde	Methanol	Formaldehyde solutions.	Silver Catalyst Process.
Compound Fert. process	Ammonia, Nitric acid, Phosphoric acid, Sulphuric acid, Potash, Urea.	NPK Fertilizers of a wide range of formulations.	Granulation in drum or twin paddle mixers depending on product.
Ammonium Nitrate Process	Ammonia, nitric acid, magnesium carbonate.	Fertilizer grade ammonium nitrate.	Prilling. Uncoated product with desiccant.
Calcium ammonium nitrate process	Ammonium nitrate, calcium carbonate.	CAN	Granulation in paddle mixer.
Rigid-faced urethane laminate process.	Polyol, isocyanate and facing material eg paper, plywood, or metal.	Laminates with various facings for construction and insulation purposes.	Continuous foam lay-down.
Hemihydrate continuous Autoclave Process	By-product or natural gypsum.	Calcium sulphate hemihydrate	Liquid, continuous autoclave conversion in specially designed small size autoclave, centrifugal de-watering.
Nitric acid concentration Process.	Nitric acid and sulphuric acid.	Nitric acid up to 98% concentration.	Dehydration of nitric acid by sulphuric acid at reduced pressure in glass equipment.

process such an approach is not necessarily appropriate.

Where the system of linear licensing exists, the licensee must satisfy himself that the combination of process and contractor will lead to a successful plant. Any imbalance in the equation will affect the final result - the successful commissioning and operation of the plant itself. The licensee's main interest is to obtain an efficient and reliable plant at a cost he expects. Occasionally he obtains a plant he has asked for but not the one he wanted and this is related to specification, reliability and efficiency, etc of the plant.

There is the continuing debate in the chemical industry on the question of reliability and cost and these are topics to which we, being large manufacturers of ammonia and other tonnage products, attach great importance. The commercial success of a large single stream ammonia plant investment depends on high reliability being achieved in early life. In a recent paper, Mr. S.D. Lyon(2) a Deputy Chairman of ICI has discussed the effects of delay in achieving design capacity on the rate of return on the investment. The data are shown in Table 2.

Even a comparatively good commissioning performance in the first four years of 30%, 80%, 90% and 100% of design output respectively can result in less than half the DCF rate of return when compared with the best performance. In ICI the experience with large ammonia plants built 10 years ago was not very good. As pioneers in the technology we encountered most of the difficulties in the early years and forfeited production - some faults were due to the faulty equipment and others due to detailed design. The lessons learned have been incorporated in our engineering approach to the design of new plants - both ammonia plants and methanol plants.

Unfortunately competitive tendering and the award of the contract to the lowest bidder without any control over the quality of the plant offered, militates against reliability and creates considerable risk. When the contractor knows he must quote a low price he will

TABLE 2

Production Year	Achieved Performance As % Flowsheet	DCF Return (Typical) %
Year 1 onwards	100	26
1	60	16
2	80	
3	100	
4	100	
1	30	12
2	80	
3	90	
4	100	
1	30	7
2	70	
3	90	
4	100	

tend to cut corners and trim prices in order to achieve price reductions. On the other hand a client cannot allow the contractor free rein in respect of costs even on a net cost plus basis. The resolution of the dilemma is for the client to specify a duplicate of an existing successful plant or to specify the plant himself or employ a consultant to do so - either an experienced operating company or a reputable engineering firm which has experience in this sort of work. In some cases the licensor himself may be appointed as the consultant.

It is most important that the contractual position is clear. There are three parties to the licensing operation and it is in the interest of the licensee that there should be no division of responsibility for the realisation of the project. The licensee's contract will most likely be with the contractor and the extent of supply, services, guarantees and liabilities defined. A separate licensing agreement, which the licensee may not necessarily see will exist between the licensor and the contractor and in it the responsibilities of each party is defined. If a plant fails to operate well, the licensee is faced not only with the problem of getting it to work but also with a consequential loss arising from there being less than the expected production. The licensee usually asks for a formal guarantee and indeed any reputable licensor is willing to give such a guarantee. Usually a licensor will commit a considerable portion of the fee to the correction of the plant and payment of penalties. However since the licensee stands to gain a much higher financial benefit than either the contractor or the licensor he must be prepared to accept more of the financial liability. The reputable licensor appreciates his obligations and is likely to exceed them in an effort to satisfy the licensee.

The objective of any process licensing operation is to provide an efficient reliable plant to the licensed operator. For the licensee interest is in the product, the contractors business is designing and building plants and he wishes to continue to do so, and the licensor wishes to continue to license the technology. If I were asked to summarise the essential ingredients to a successful licensing operation - a recipe not only for North Africa and the Middle Eastern countries but also for process operators who buy technology, and I would remind you that ICI is such a company, the main points I would highlight are :

1. Precise specification of what is required by the licensee and continued interest by him throughout the project.

2. Confidence and respect between all parties to the operation.

3. Full and unambiguous agreements.

IV CATALYST TECHNOLOGY

ICI is one of the few major ammonia and fertilizer manufacturers also involved in the production and sale of the range of catalysts for the ammonia process. Agricultural Division has been manufacturing and using catalysts since its first ammonia plant was built in 1923. It was necessary then to undertake manufacture since no commercial supplies were available. Catalyst research facilities, the forerunner of today's resource, were built up to study catalyst fundamentals and in particular catalysts relevant to the company's processes - particularly ammonia production. Something of the importance attached to this activity may be judged by the effort now devoted to it; in Agricultural Division alone more than 100 people are involved in catalyst work. It is believed that the extensive and effective research and technical sales and service which this makes possible is vital if we are to achieve outstanding catalyst quality - particularly if the cost of catalyst is so small in comparison with the value of lost production through catalyst failure.

The growth of ICI's Agricultural Division into a major international catalyst supplier is linked with the decision to license technology and accelerated in the early 1960's with the development in the Division of the ICI steam naphtha reforming process. The Division chose to license the process and to expand its own catalyst facilities to service the licensed plants with catalyst. At the same time a world-wide upsurge in the building of ammonia plants was beginning and many of these plants have used the ICI steam naphtha process. Many others were based on natural gas feedstocks but they also provided opportunities for catalysts developed in the Division's Research Department. The market opportunity was siezed and as evidence the production capacity at the Divisions factory in Clitheroe has had to be increased several-fold since 1966/67. In order to capitalise on the growth in ammonia production in North America a joint venture company, Katalco Corporation, was formed to produce catalysts in the USA. The technology comes from ICI and this joint venture is now one of the two biggest ammonia plant catalyst producers in North America. I have already mentioned the ICI steam naphtha reforming process and the low pressure methanol process. Other developments such as the "closed sandwich", a zinc oxide/cobalt molybdate/zinc oxide sulphur removal system, and highly efficient zinc oxide catalysts for removal of sulphur are also products of the Research and Development Department. The development of production techniques has also been an integral part in the development of successful catalysts but for obvious reasons cannot be discussed in this paper.

The established major markets for the catalysts for the past 20 years have been the United States, India, Japan and Western Europe. With the world energy scene changing dramatically, future manufacture of chemicals based on hydrocarbon feedstocks is likely to shift to countries with large reserves of these feedstocks. For this reason the Middle East and North Africa will assume increasing importance as also will Eastern Europe. The building and successful operation of large scale plants in the Middle East and North Africa will present many problems to licensor, contractor and licensee. The next twenty years for scientists in these countries will be particularly interesting and will provide all the challenge one could wish for.

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