Indian Institute of Petroleum: Bringing technology to the market place

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Occupying a large corner of East Dehradun, the huge conglomerate of buildings in the picturesque surroundings is an unexpected welcome sight on a busy main road. This is India's ecologically designed premier R&D institution, the Indian Institute of Petroleum (IIP), is now a globally known organization with an annual budget of more than Rs 1,100 lakhs. Recently accredited with ISO-9001 standard by Det Norske Veritas, an international certification body based in The Netherlands and working jointly with several multinational giants, IIP has transferred its technologies to some 28 companies countrywide. The institute employs around 600 scientific and technical people who are working on some 100 projects each year.

IIP originated in 1959 in New Delhi when the Council of Scientific and Industrial Research through an act of Parliament established it as its constituent laboratory to provide techno-scientific services to the upcoming petroleum and petrochemicals industry of that era. The R&D activities initiated in science and technology with relevance to the petroleum refining and the petrochemicals industry resulted in the need for establishing a scientific and human resource base and, consequently, on 14 April 1964 the entire set-up was shifted to the present premises at Dehradun.

Initially the institute with technical assistance from French Institute of Petroleum, France, emphasized R&D in petrochemicals and petroleum refining; soon it was recognized as the centre *par excellence* to train personnel for oil and petrochemicals industry. For instance, it was one of the earliest institutes in assigning Bureau of Indian Standards in formulation of standards for petroleum products.

Technological forecasting for petroleum industry was another of its priorities. IIP's efforts in helping industries select the best foreign technologies and develop indigenous technologies have been well recognized. In its pursuit for excellence, the institute also sought financial help from UNIDO and UNDP to strengthen its various R&D facilities. Over time, the incipient R&D became pivotal in the development of technologies for petroleum refining, crude separation, efficient utilization of petroleum products in IC engines, speciality chemicals and alternative fuels. The institute, in this process, built a strong base for developing processes right from bench-scale operations to the pilot plant stage while always keeping excellent basic research in the forefront to achieve these objectives.

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Present status

Petroleum and its different products have a very dominant role not only in our society but also in the overall development process. It is a source of energy for domestic, industrial, agricultural and transport services and feed stock for fertilizer, chemical and other industries. The rapidly growing numbers of petroleum and petrochemicals industry in the country during the last three decades generate considerable employment at all levels, and IIP's work is, therefore, very relevant to the economic growth of the nation.

Since the last decade alone there has been a drastic change in the overall philosophy of the institute and an expansion in its activities, research facilities and scientific personnel. Today the institute's research, business and development activities are carried out through a network of areas, divisions, groups and multidisciplinary laboratories. Its modern laboratories are equipped to conduct research of a high order. The present management considers the institute as the corporate R&D centre of the entire petroleum industry with the aim to solve their short and long term challenges.

The major R&D programmes in the institute involve petroleum refining technology, including the development of separation, conversion and upgradation processes for crude oil supplied to the refinery together with synthesis of speciality and fine chemicals for treating and blending the refined crude. Other research addresses catalysis, petroleum products application, alternative fuels, renewable resources and biotechnology. The activities of business development and transfer of technology are well-organized by involving research planning and business development division at every stage of research.

Separation Processes Division

The separation processes division primarily evaluates crudes for lube base stock through solvent extraction and dewaxing. Solvent extraction technology development for light aromatics production and dearomatization is one of the thrust areas. Some of the successful processes that have gone into commercial scale include the sulpholane extraction process for the extraction of benzene/toluene and/or xylene from aromatic rich feed stocks. This technology has been transferred to BPCL, Mumbai, and CRL, Cochin. The process has also been modified for dearomatization of straight run naphtha for production of food grade hexane and special boiling point solvents (BPCL, Mumbai and MRL, Chennai). A more efficient extraction process based on a better solvent *N*-methyl pyrrolidone (NMP) has recently emerged for dearomatization, and a new plant based on this know-how has just gone into stream at BPCL and HPCL, Mumbai. Apart from conventional methods of separation, scientists also develop technologies based on liquid membrane and adsorptive separations. A liquid phase adsorption process involving activated carbon has been introduced to produce ultra pure petrochemical grade hexane (20 ppm Bz) from food grade hexane (10,000 ppm Bz). The beauty of this process is that the spent activated carbon can be regenerated by low pressure steam followed by vacuum drying and cooling with air.

Dewaxing and deoiling are also research priorities; therefore, IIP has launched an intensive programme for optimizing novel solvent dewaxing and deoiling processes by lube distillation. In addition, a process is under development for treatment of heavy asphaltic base stocks using liquid propane for lube oil production. This process supplements distillation by carrying separation of high molecular weight compounds beyond the range of practical commercial distillation, permitting almost complete recovery of oil from asphaltic residue.

Lubes and bitumens play an important role in national economy as they are extensively used in automobile, transport and other industries. A process which IIP has developed in association with Engineers India Limited and Madras Refinery Limited extracts lube oil base stock using NMP as solvent. This technology has been commercially accepted, and a plant with a capacity of 350,000 MTPA is under construction at Haldia Refinery and Indian Oil Corporation Limited. A process for production of impregnating pitch used in graphite electrodes manufacture has also been developed and recently transferred to a private industry for its large-scale production.

Conversion Processes Division

Engineering various catalytic and thermal process packages is the main task before this division for different aspects namely the following: catalytic reforming (both semi-regenerative and continuous catalytic reforming); hydrotreating; hydrocracking; fluid catalytic cracking; and resid cracking. The institute's programme on visbreaking and delayed cocking is tailored to produce different grades of waxes, re-refining of used lubricating oil additives and speciality chemicals. Two of the success stories from this area include software for catalytic reformer optimization and a process package for naphtha hydrotreater using UCIL catalyst. While the first project developed jointly with EIL eventually led to the implementation of a simulation and optimization software for catalytic reforming at BPCL, Mumbai, the second led to wider applications in fertilizer and petroleum industry for hydrodesulphurization of naphtha and catalytic reforming to reduce sulphur in feed stock. Other commercially successful technologies are hydrodesulfurisation of straight run/blend of straight run cracked naphtha.

One more activity in this division is related to upgradation of diesel fuels. At present the technology available to achieve these specifications are the monopoly of several MNCs. Therefore, realizing the need to make the country self-reliant, the institute in collaboration with the Centre for High Technology is researching an indigenous catalyst and technology for hydrodesulphurization of diesel and vacuum gas oil (VGO) for meeting the future specifications. IIP is committed to develop technologies for fluid catalytic cracking (FCC) using modified zeolite and active silica-alumina matrix based catalysts. These technologies will help the worldwide petroleum industry which faces a growing demand for both gasoline and middle distillates.

Catalysis Division

The importance of catalysis for society and economy can hardly be overestimated. This is now a billion dollar business and it is estimated that one-sixth of the value of all manufactured goods in industrialized countries are contributed by catalysts. Understandably then, IIP's catalysis division is the nodal organ of the institute and almost all other groups are primarily dependent on it in one way or other. Its expertise in homogeneous, heterogeneous and zeolite based novel catalysts for refining and for producing bulk chemicals and petrochemicals has won many accolades. For conversion of heavier petroleum fractions to produce LPG, gasoline and middle distillates, a new generation FCC catalyst in collaboration with Indian Oil Corporation has been developed which is expected to be commercialized shortly. The group working on homogeneous catalysis produces various ammoniated cobalt pthalocyanin and its derivatives that can be used as sweetening catalysts. These special types of catalysts remove mercaptans (R-SH), a sulphur compound found in petroleum products which produces an obnoxious smell and creates corrosion in refinery units.

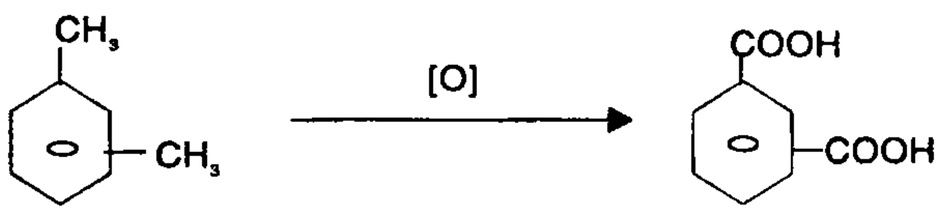
Box 1.

IIP's metallic catalysts play a key role in bringing about self-reliance and indigenization in the field of refining and other industries. IIP has so far developed more than a dozen catalysts out of which several have been commercialized. The institute's success with state-of-the-art bimetallic Pt-Re reforming catalyst (semiregenerative) has already become something of a legend[1]. Produced commercially by the IPCL–CATAD plant at Mumbai, this catalyst has major applications in petroleum refining and petrochemicals industry for production of gasoline blending stock and aromatic rich concentrate of BTX, respectively. The maiden charge of this catalyst is in operation in the two reformer units at IPCL, Baroda and MRL, Chennai. The plants have been steadily running at more than 100% load for the last eight years.

Std. Surf. Sci. Catal., 1994, **88**, 359.

Box 2.

As an environmentally conscious organization, the Institute has developed an eco-friendly novel route for the single step oxidation of *m*-xylene to isophthalic acid. The process is found to be more economical with 99.9% conversion and 97.8% yield. Moreover, the catalyst is recyclable, and there is no use of bromine. The effect of reaction variables was studied and the catalyst system was found to be more efficient than the conventional one[2].



m-xylene isophthalic acid

US Patent No. 5 547905, 1996

Basic research forms an integral part of this division. Anticipating India's present and future technological needs, a group is engaged in development and structural elucidation of zeolite-based and amorphous type of catalysts for possible applications in petrochemical and other chemical industries.

Bulk intermediates, fine chemicals and additives

In the bulk intermediate area, emphasis is being given to cut short the multi-step organic reactions of economic importance. Accordingly, researchers have created an environment friendly novel route for producing adipic acid (nylon 66); the production envisages single-step oxidation of cyclohexane and is less corrosive and the technology has been developed in collaboration with Adarsh Chemicals and Fertilizers, Surat and the international ABB Lummus. Development of fine chemicals, multifunctional additives and antioxidants based on alkyl amines, alkyl phenols, phthalimide and their esters, alkyl salicylates and Mannich bases have been given prime attention. They mainly reduce oil's viscosity

Box 3.

Surfactants represent one of the most diverse classes of performance chemicals available, being derived from a broad spectrum of organic chemicals of varying ionic type, with each product exhibiting one or more surface-active properties. Similar compounds produced by microorganisms as secondary metabolites, known as biosurfactants have attracted worldwide attention because of their cost effectiveness and eco-friendly nature. Researchers at IIP have isolated several hydrocarbon degrading microbes and screened them for the production of biosurfactants[3]. The potential biosurfactant producing strains were identified as *Pseudomonas putida*, *Pseudomonas aeruginosa* and *Bacillus pumillis*. The growth parameters for all three strains were optimized, and cultured in a bench scale fermenter. The yield of biosurfactant was achieved up to 620 times of its critical micelle concentration. The emulsification activity of these biosurfactants for *n*-paraffin, toluene and crude oil was determined and found to be potential candidates for enhanced oil recovery applications.

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increase during use in service and thus prolong the life of lubricants to a considerable extent. Some of the antioxidants already developed are PTBP and BHT using resin type of catalysts. A few technologies for high temperature antioxidants, so far a world monopoly of only one or two multinationals, have recently been commercialized. In addition, synthesis of 'extreme-pressure-additives' (to reduce wear and friction), fuel additives and biodegradable lubricants from vegetable oils of Indian origin are other blossoming fields of research.

Biotechnology and renewable resources

The research in biotechnology seems to be incongruous in the scheme of things of a petroleum laboratory. Yet it is here that IIP has carved a niche by developing techniques for microbial dewaxing of heavier petroleum fractions and production of biosurfactants for microbial enhanced oil recovery.

The researchers in the renewable resource group explore the possible use of plants or any other eco-friendly material as fuel, lubricants, additives or antioxidants. For example, jojoba oil has been studied in detail. A process has been developed that obtains jojoba wax, long chain saturated and unsaturated fatty alcohols, fatty acids and their methyl esters. The ongoing project is directed towards synthetic biodegradable lubricants based on esters and polyglycols.

Petroleum products applications

The major activities in this area include alternative fuels, fuel quality, vehicle emissions, engine design and development, and tribology. The facilities for the

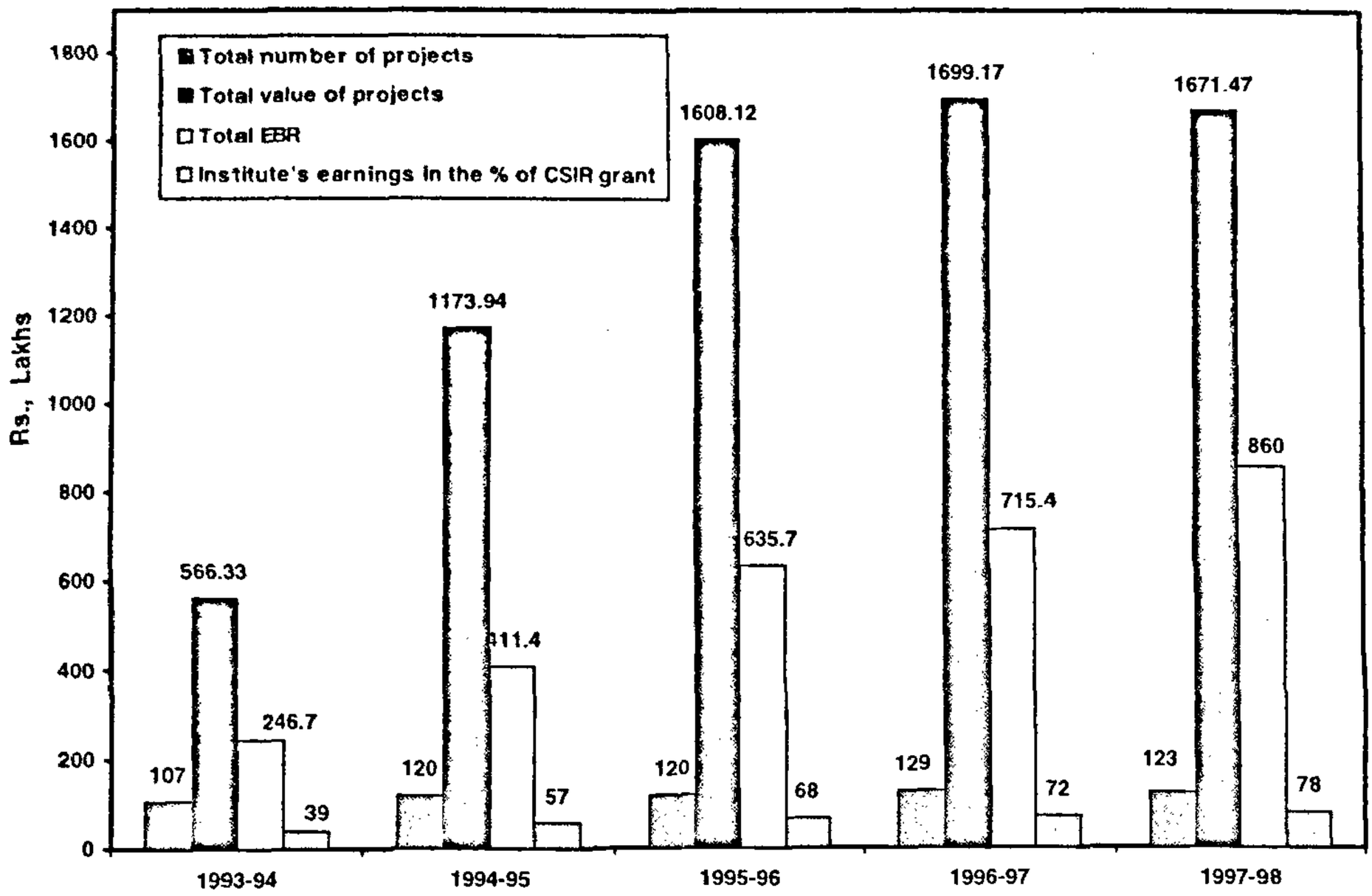

Figure 1. Year-wise chart showing the total number of projects, their values, total EBR* and the Institute's earnings in the percentage of CSIR grants. Clearly, specifically targeted, business-driven science and technology advances have led to a higher performance.

*Each laboratory under the umbrella of CSIR generates its own financial resources through interaction with user industries in the form of consultancy, license fee, royalties from technology transfer and collaborative sponsored research. These earnings are in addition to the regular CSIR budget and are termed as Extra Budgetary Resources (EBR). The more EBR generated, the greater is the success of the laboratory towards commercialization. Earnings in the % of CSIR grant means income (EBR) in % with respect to total grant provided by CSIR.

application of petroleum products in engines are the most comprehensive ones in the country; through these facilities IIP renders regular S&T support to the automobile and related industries. IIP has also extensively studied the use of alcohols as a substitute to gasoline and diesel fuels. Extensive field trials involving fleets of commercial transport vehicles have established the technical feasibility of methanol and ethanol as alternate fuels. The use of compressed natural gas (CNG) as an alternate fuel for both gasoline and diesel vehicles is an important ongoing project as well. For example, recently, a three-wheeler was successfully converted into CNG operated vehicle.

In the past five years the institute has initiated programmes to work closely with some well known automobile industries for developing emission control strategy through catalytic convertors, soot traps, innovative engine technology and eco-friendly additives. The engine design and development group for example, is studying the intake system for two- and three-stroke engines. Performance evaluation and certification of engine oils is also an important activity.

Research into the basic science related to tribology is an integral part of IIP's work, including an effective hot rolling oil formulation also for steel which is in commercial production. IIP also is at the forefront of research in highly thermal efficient combustion appliances leading to fuel conservation. A low air pressure (LAP) industrial burner, kerosene wick stove, LPG stove and hurricane lantern developed by the institute are already released to entrepreneurs.

Industrial research

Competing in the world market place is the mainstay of today's petroleum industry and being successful in that market requires a serious commitment to research, product quality and high standards. IIP then ensures that industry has the standards to guarantee the quality. To prepare the Indian petroleum industry for challenges of process and product patenting under the new WTO-regime, the process and reaction engineering group of the institute has initiated an ambitious programme focused towards industrial research. Preparation of basic engineering packages for in-house developed technologies is an important activity, along with process development and replacement/substitution for imported technologies. The institute in this way is serving a range

of medium and large scale industries and the success lies partly in associating the end user from the time a project is conceived to the time when the technology is released to the user industry.

Industry too has worked very closely with IIP over the years. In addition to sponsoring various R&D projects, it uses IIP's expertise in engineering design for various process plants. IIP also promotes a new industry interaction programme in which industrial staff work as visiting researchers in the institute's laboratory, typically for two to three months. Not only do these programmes improve IIP–industry cooperation, but they help IIP identify technical trends and opportunities.

Analytical Sciences Division

The division of instrumentation and analytical sciences is not only the back-bone of the institute but also a bridge between IIP and academic and industrial organizations and thereby exploiting its knowledgebase commercially. The list of analytical instruments includes NIR-UV-Visible, FT-IR, NMR and mass spectrometers including GC-MS, HPLC, atomic absorption and emission spectrophotometers. Facilities of 300 MHz multinuclear solid state NMR spectrometer and computerized X-ray crystallography also exist. In addition to supporting the needs of other process development laboratories and pilot plants, this division is also reimbursed for the work for different industries, academic institutes and other government agencies.

IIP has a very strong infra-structure for the detailed evaluation of crude oils and a history of valuable services in this area to various oil companies. For instance, IIP has its own independent catalyst characterization laboratory for studying the nature of catalyst surface at various stages of its preparation and processing. The engine testing laboratory is equipped with most sophisticated instruments and screening of different lubricants, additives and speciality chemicals is important work in the institute. All the above activities under one umbrella provide an ideal environment for the institute to offer a complete package of industrial technologies and facilitation services.

Transnational collaboration and opportunities

After the restructuring of the Indian economy, the concept of commercialization is crossing international barriers and IIP has also realized the need for globalization. In fact for the last three years, the Institute has initiated programmes to collaborate closely with some multinational companies for innovative research and global marketing of its technologies. While a collaborative project with Bouskov Institute of Catalysis, Russia under the Indo-Russian integrated long term programme will involve innovative catalysts, the agreement with French Institute of Petroleum, France, will enhance the knowledge base in hydrotreating processes and catalytic reforming technology. IIP is also allied with US-based MNCs such as ABB Lummus, Stone & Webster Engineering Corporation, UOP and Mobil in the area of refining technology. A joint venture with United Technologies Inc, USA has also been finalized for setting up mini-refineries in southern India.

Future outlook

IIP has now emerged as a pioneering research institute. Not only recognized as a research centre specializing in knowledge and methodologies to support decision and policy making in hydrocarbon sector but over the years IIP has also emerged as a technology licenser. Optimistic about the future, the institute is ready for further challenges on the basis of its strong technological research base. Crowned with several national and international awards and membership of prestigious petroleum professionals, IIP strives to attract the country's best-known talents to continuously strengthen its R&D activity to meet the emerging challenges of the 21st century in petroleum refining and petrochemicals which are vital to our economic future.

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