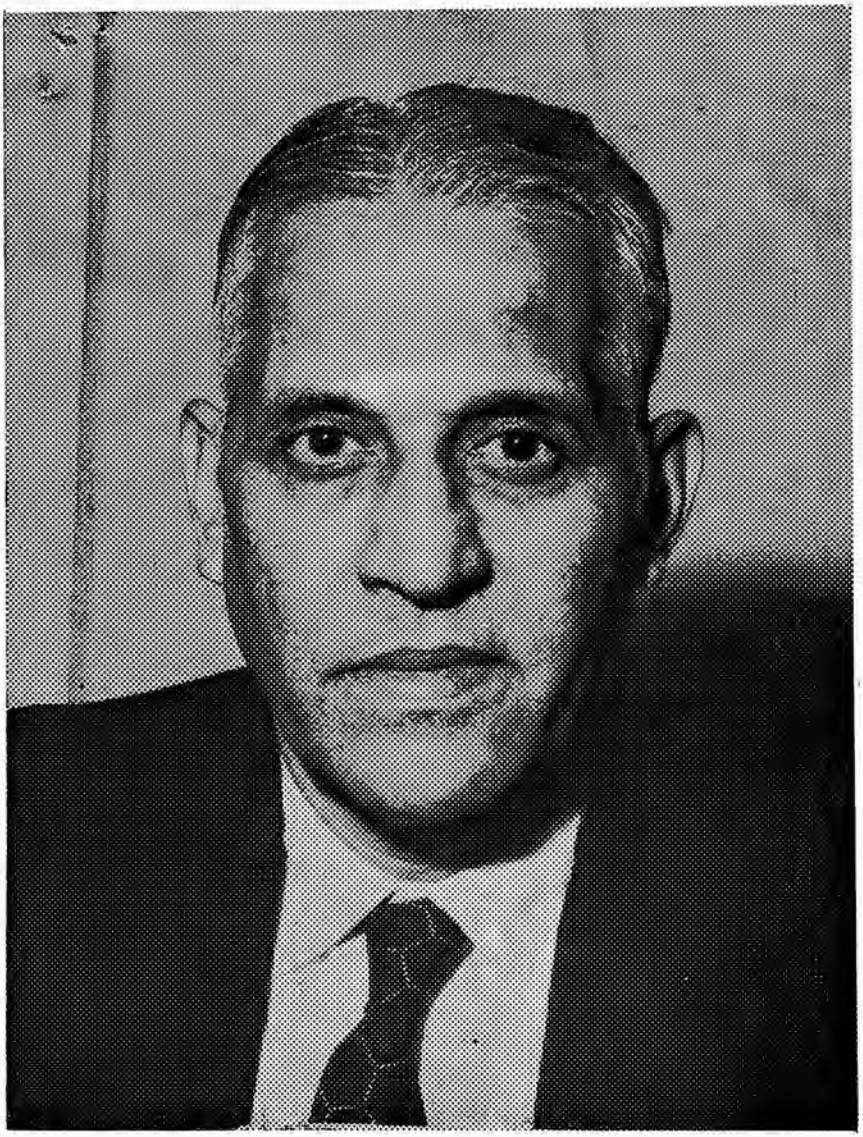

Brahm. Prakash.

BRAHM PRAKASH

(1912 – 1984)

Elected Fellow 1969

"The world today requires good men, honest men, accurate men, righteous men, patient men, self-restraining men, fair men, modest men, men who are aware of their vast ignorance compared with the vast amount that there is to be learnt in such a Universe as this; men who are accustomed to look at both sides of a question; who instead of making up their minds in haste like bigots and fanatics, wait like wise men for more facts and more thought about the facts"

—Charles Kingsley

IN post-independence India, Dr. Brahm Prakash, the eminent metallurgist and administrator, played a major role in formulating and implementing research and development activities of far-reaching consequence in the Department of Atomic Energy and Space. He was also vitally instrumental in establishing a firm base for self-reliance in many areas of advanced materials technology. In addition, his sphere of influence extended to several educational institutions, CSIR and Defence Laboratories. As a leader extraordinaire, Dr. Brahm Prakash influenced the people and activities around him by his total personality rather than by his mere professional gifts. The achievements of Dr. Brahm Prakash made an indelible impact on the character and growth of science and technology in India for well over three decades.

BIRTH, EARLY LIFE AND STUDENT DAYS

Brahm Prakash was born in Lahore (in pre-partition India) on August 21, 1912 as the third child of his parents, Shri Jodha Ram Sekhri and Shrimati Khem Kaur. His father Shri Sekhri was employed in the railway service and Brahm Prakash had his early upbringing in a traditional Hindu middle class family setting, along with his elder brother Roshan Lal and two sisters. Recalling childhood days, Roshan Lal remembers his younger brother as a boy of shy disposition, simple and straightforward in his ways.

At the Central Model School, Lahore, Brahm Prakash maintained a consistently excellent record. He was very fond of reading and was a keen sportsman too. His father exerted a special influence in cultivating in him a taste for English literature. Brahm Prakash stood first in Interscience at the Sanatana Dharma College, Lahore

and then qualified for his first degree in Chemistry at the Government College, Lahore. For a brief period, he worked as a demonstrator in the same college, doing his early research work in association with his teacher, Dr. H.B. Dunicliffe, who had made a deep impression on him and had also developed a special affection for him. It was during this period that Brahm Prakash attracted the attention of Dr. Shanti Swarup Bhatnagar (who was then Head of the Department of Chemistry at the University of Punjab in Lahore).

A close associate and friend of Brahm Prakash from Lahore days, Shri V.S. Bhatia (now an industrial consultant in Calcutta) recalls the early days : "Brahm Prakash and I used to be very close for many years during our days in Government College and the University Chemistry Laboratories, Lahore, when engaged in post-graduate research (1936-39). Brahm Prakash, when I knew him, was a clever and studious pupil, with a rather serious disposition. He did not have many close friends outside and had very few within the course. The reason was probably pre-occupation with studies but also a trait of having no patience for small talk and gossip, the conventional feature of student life. Even in those days, he was fond of weighing things too objectively and this attribute does not generally lead to popular response. Brahm Prakash's contemporaries were surprised in subsequent years how he became an accomplished metallurgist. He had no particular orientation for this line although he had a preferential interest in metal and mineral chemistry vis-a-vis organic chemicals. Brahm Prakash and I used to spend hours, arguing about authors (outside Chemistry), the latest books, cricket, tennis, etc. He was a competent tennis player himself. He always presented the image of a teacher in my mind and I remember, everyone who came in contact with him formed the same impression. We spent a few weeks together in a hostel in Simla in August/September 1939 when Great War II broke out. Brahm Prakash's habit of projecting different view points without emotion carried him the nick name 'Professor' among all residents. I am sure that, had fortune made him into a college professor, he would have liked nothing better, so long as there was an opportunity provided for private research at the end of one's teaching day. The complete absence of cant and ostentation in his mental make up would have suited the profession. Of course, his talent for application of new ideas and propositions would have fitted elsewhere also, as was subsequently observed wherever he worked professionally." Brahm Prakash had his early research training under Dr. Bhatnagar at the University Chemical Laboratories, imbibing from him the inspirations of the twin cultures of science and literature. He obtained his first doctoral degree in physical chemistry in 1942.

Marriage

During the World War II period, Dr. Prakash remained at Ajmer working in the Railway Metallurgical Laboratories. In 1945, he married Rajeshwari whom he

had met three years earlier as a neighbour residing next to his apartment in Ajmer. (Shrimati Rajeshwari was working as a principal in a local school at that time. Later she joined Dr. Prakash in USA to pursue her studies at Harvard University. After return to India and when Dr. Prakash was posted at Bombay, she resumed her interest in teaching, as principal at the Birla Public School and she has been a great influence on this institution todate). Shri and Shrimati Prakash made a charming combination : "he, shy, introspective and often silent and she, effervescent, bubbling with ideas for conversation, discussion and argument". Shrimati Prakash played an important role in the shaping of the professional career of Dr. Prakash. She had remoulded herself in the cast which enabled Dr. Prakash to pursue work with single minded devotion. She took care of the family problems in such a way that they did not interfere in his work. This remarkable spirit of adjustment, accommodation and even self-sacrifice shown by Shrimati Prakash definitely helped Dr. Prakash in realising his cherished goals and missions, as was evident in the subsequent years of his professional life. (Three children born to them—two daughters Suman and Manya and son Arun—are presently settled in the USA).

Doctorate at MIT

Dr. Prakash was one of the select group of students of distinct promise, who were deputed by the Indian Government for advanced academic training in USA at the end of World War II (1946). There is a short anecdote on the events leading to his shaping as a metallurgist. Dr. Prakash first went to the University of Columbia in USA for advanced research. At the University of Columbia, he was told that his proposed field of study was no longer pursued there. A disappointed Dr. Prakash was advised to meet a professor at MIT, if inclined to. The result of that meeting was a loss to the field of chemistry and a substantial gain to metallurgy. His stay at MIT provided him the opportunity of a liberal education in metallurgy under the influence of illustrious professors including John Chipman, Morris Cohen, A.M. Gaudin and Reinhardt Schumann (Jr). In November 1948, Dr. Prakash presented to the faculty of the MIT a thesis entitled "The Effects of Activators and Alizarin Dyes on the Soap Flotation of Quartz, Cassiterite and Fluorite" in partial fulfilment of the requirements for the degree of Doctor of Science in Metallurgy. He obtained his Sc. D, specialising in the field of mineral dressing. During his stay at MIT, Dr. Prakash had also developed a love for the subject of thermodynamics. On return to India after his doctoral qualifications in Metallurgy, Dr. Prakash was chosen by Dr. Homi Bhabha for the position of Metallurgist in the Atomic Energy Establishment.

Period 1951-57 at Bangalore

As the organization of the Atomic Energy programme was still in the earliest stages of development, Dr. Prakash was posted at the Indian Institute of Science

Bangalore, where he served with distinction as Professor and Head of the Department of Metallurgy, at the same time being actively involved in the planning and organization of the Metallurgy Programme for Atomic Energy development. The period of 6 years (1951-57) that Prof. Dr. Prakash spent at the Institute was crucial for the development of the metallurgy department there. The department is greatly indebted to Prof. Prakash for the leadership and drive that he gave in establishing a sound tradition of learning and research in metallurgy. In a way, the stay at IISc. was also crucial to Prof. Prakash's own development. Prof. M.G.K. Menon in his recount of the period that Dr. Homi Bhabha spent at the Institute says : "I believe, this was the period when he found his mission in life; he became aware of the role he could play in the development of India." In a similar fashion, it can be said that in the congenial and contemplative environment of the Institute. Prof. Prakash was preparing himself for his later missions in life. In recognition of his professional eminence, Prof. Prakash was selected as one of the scientific secretaries for the First UN Conference on the "Peaceful Uses of Atomic Energy" held at Geneva in 1955. The paper presented by him at the conference on the work relating to the "Separation of Hafnium and Zirconium by Vapour Phase Dechlorination" was acclaimed as the first original pyro-chemical approach to the important problem of separating the two very similar elements.

Period 1957-72 at Bombay

In 1957, Dr. Prakash returned to his assignment in the Atomic Energy Establishment, Bombay, which centered around the development of nuclear fuels. As the Director of the Metallurgy Group, he gathered a team of metallurgists and created the necessary facilities and laboratories. That was truly the beginning of the emergence of Dr. Prakash as a major force in Indian science and technology-the unrelenting researcher, the consummate manager, meticulous planner and the venerable leader. The period 1957-72 saw the blossoming of a large number of vital programmes in Trombay. The stamp of the leadership of Dr. Prakash—with strong emphasis on systematic planning and detailed analysis, and care and insight into the assignment and coordination of all the ingredient functions—was very evident in the successful implementation of the programmes of nuclear metallurgy. As an index of the deep trust that was placed by Dr. Bhabha in Dr. Prakash, it may be mentioned that the Metallurgy Group under Dr. Prakash was the largest group in Trombay, encompassing not only metallurgy but also programmes in the various chemistry disciplines, reactor engineering and operation, isotope production and applications, and even the Engineering Services.

The tragic death of Dr. Homi Bhabha in 1966 was a set back to the Atomic Energy programme, when it was well poised for growth. It was also a great personal loss to Dr. Prakash. Dr. Vikram Sarabhai who succeeded Dr. Bhabha as Chairman,

Atomic Energy Commission, was quick to recognise the unique qualities and abilities of Dr. Prakash as a programme leader. Dr. Prakash was vested with additional responsibilities such as Chairmanship of the newly formed Uranium Corporation of India Ltd. (Jaduguda) and Project Directorship of the Nuclear Fuel Complex (Hyderabad). The premature and sudden demise of Dr. Sarabhai in the winter of 1971 came as a point of heart-searching for Dr. Prakash. While he was approaching the year of his retirement, his love and involvement in the Atomic Energy efforts on many fronts were still at their peak. He, however, decided to accept the offer of Directorship of the Vikram Sarabhai Space Centre (VSSC) Trivandrum.

Period 1972-79 at Trivandrum

"Old age hath yet its honour and toil.
Death closes all; but something ere the end,
Some work of noble note, may yet be done,
Not unbecoming men that strove with God."

—Lord Tennyson in Ulysses

The attention of Dr. Prakash at the ripe age of 60 turned to the Indian Space Research Organization (ISRO). There was a perceptible change in him, as he moved from the Atomic Energy scene to head the Space Centre at Trivandrum. The transformation in him was remarkable. The ascetic commitment to the profession witnessed earlier was now replaced by benevolent guidance to all. Dr. Prakash proved to be a tower of strength and inspiration to all the scientists and engineers at a crucial and formative phase of the Space Department, orphaned by the sudden demise of Dr. Sarabhai. To quote the words of Prof. M.G.K. Menon : "It was Dr. Brahm Prakash who brought success to VSSC, welding all the amorphous entities, out of which it was composed and nurturing it to make it the dynamic structure it is today." Unfortunately, the period of his service at Trivandrum was also the period when Dr. Prakash had to live away from his family in Bombay. The pressures of work took a toll on his health. He retired from active service soon after the first SLV-3 launch in 1979. He however continued his association with the programme as Member, Space Commission, enabling the Department of Space to benefit from his vast experience and wisdom.

Last Phase : 1979-84

Even retirement from active service did not give Dr. Prakash the much needed rest. By virtue of his vast experience and erudition and his reputation for objectivity and integrity, his esteemed counsel and active participation in decision-making were constantly sought by many organizations like the DST, CSIR, Defence Laboratories, Universities and Academies. Dr. Prakash was a regular and active member of the

Advisory Councils of NML, RRL (B) and NAL in the formulation of their R & D programmes. Till the last days, Dr. Prakash was actively associated with major responsibilities including the Chairmanship of Mishra Dhatu Nigam (Midhani).

In July 1983, Dr. Prakash had returned from Bhopal with the feeling that there was something seriously wrong with him. He was face to face with a formidable health problem in the form of lung cancer. Dr. Prakash knew that his end was nearing; but he accepted it with patience and composure. During this period of his ill-health, it was fortunate that there was Srimati Prakash taking complete care of him. Shrimati Prakash attended on her ailing husband almost single-handedly till the very end—with exemplary fortitude and courage. Finally, the inevitable end came when he passed away on the evening of January 3, 1984 in Bombay.

Personal Qualities

"Some persons do not impose themselves while they are in our midst; yet they leave a painful vacuum when they depart. We keenly feel their imperceptible presence". Dr. Brahm Prakash was one such person. The sublime qualities that made lasting impression on those who came in close contact with him were his gentleness, simplicity, humility and equanimity of temper. He had neither prejudice nor favouritism. If any, Dr. Prakash had one favourite approach, that is, looking at any issue with absolute objectivity, thoroughness and straight forwardness. As Dr. V.S. Arunachalam puts it in a metallurgical vein, "working with Dr. Brahm Prakash was like refining a metal or should one say, mettle refining". His achievements carried no touch of ostentation or self-consciousness. When a goal-oriented task was completed, there were no cheers or celebrations as he was shy of them. He moved on to another task, another pursuit, another mission with unflagging concentration.

The second chapter of the Bhagavad Gita describes the qualities of a स्थितप्रज्ञ (Sthita-Prajna), as an individual of steadfast mind and intellect, functioning in a state of constant enlightenment. Dr. Prakash was not a philosopher inclined to read the Gita. But he lived a life of virtues that the Gita preaches. Shrimati Prakash has written in fond remembrance of her late husband. In the words of Shrimati Prakash: "Calling my association with him a 'divine order' does not embarrass me now, having lived with him for forty years. In the midst of raising a family under constraints, doing a demanding job, he never looked for easy options, never succumbed to any impure impulses or less dignified ways, never entertained unkind thoughts or words. Every living moment of his life, he guarded his actions carefully in the light of his ultimate values—truthfulness, devotion to work and kind thoughts for all. This came spontaneously to him. He did not have to fight with himself to pour out such uniform goodness. That I was granted the boon of living

with a person whose sight or contact, word or presence brought out the best in others was a divine experience for me".

Professional Contributions

Contribution to Physical Chemistry :

During his stay at the University Laboratories in Lahore, Dr. Prakash worked with Prof. S.S. Bhatnagar and made significant contributions on fundamental problems in the field of physical chemistry. The problems for study centred around magnetic characteristics of transition metal compounds. Based on magnetic susceptibility measurements, Dr. Prakash elucidated the chemical structure and valence states of transition metal ions. He synthesised a variety of chromium compounds and derived the valence states of Cr ions in these compounds to resolve some of the controversies existing at that time. Dr. Prakash then extended the susceptibility measurements to the study of crystallographic phase transformations in systems such as MnS. Dr. Prakash realised the potential of magnetic susceptibility measurements for the study of Catalytic processes to demonstrate the formation of intermediate species and the reaction mechanisms of such processes. Dr. Prakash also investigated, during the course of his doctoral programme, the role of particle size in chemical reactions such as those of H_2S with the chromates of Pb and Ag.

Contributions to Metallurgical Education and Research :

The history of metallurgical education in India dates back to 1923, when the first Department of Metallurgy was established at Banaras Hindu University (BHU). The then prevailing emphasis on the teaching of metallurgy was mainly on industrial practice. The credit for formulating a detailed modern curriculum in metallurgy, with a balanced emphasis on the basic science and engineering aspects of chemical, physical and mechanical metallurgy belongs to Prof. Prakash. During his tenure at IISc., Bangalore, I had the opportunity to observe and admire his exhaustive efforts in introducing new courses and implementing teaching programmes in Metallurgical Thermodynamics, General Principles of Extractive Metallurgy and of Iron and Steel making and Physical Metallurgy of binary and ternary phase diagrams. Dr. M.A. Dayananda, Professor of Materials Engineering at Purdue University, USA and a former student of Prof. Prakash at Bangalore has written : "I fondly recall his extreme zeal in educating his students in the broad field of metallurgical thermodynamics and transmitting to them all the insights that he himself had developed during his stay at MIT. His personal commitment to metallurgical education in India was visionary and of the highest order. His method of teaching was a simple, direct and clear communication, characterised by personal charm, and innate intellectual honesty. The hard-to-understand concepts were made clearer and more relevant to

our education with his own personal insights of the subject matter and discussions of practical applications. Quietly at work in his office or laboratory, from early morning till late night every day, he taught us all, by personal example, the basic lesson of industry and hard work".

With keen interest and participation, Prof. Prakash guided research projects involving the application of thermodynamics to the process of metal extraction and refining : sulphatisation roasting of copper smelter slag, separation of zirconium and hafnium by vapour phase dechlorination, and separation of beryllium and aluminium by differential sulphatisation. He also took the initiative in establishing laboratory facilities for mineral dressing which were most useful in the early work of the Atomic Minerals Division. Cast in the true tradition of knowledge seekers and imparters, Prof. Prakash's own areas of specialisation included physical chemistry, mineral beneficiation (flotation technique) and extractive metallurgy and thermodynamics.

While the contribution of Prof. Prakash to metallurgical education and research at Bangalore is well known, it is perhaps not so well known that Prof. Prakash had a role in shaping the destiny of the Department at Varanasi as well. As a member of the Visiting Committee for the UGC, Prof. Prakash guided BHU through a decade until it blossomed into a Centre of Advanced Study. The Indian metallurgical community is greatly indebted to him for his outstanding contribution in the creation of the Centre at Bangalore and his sustenance of the Centre at Varanasi.

Prof. Prakash believed neither in the pursuit of scientific knowledge as an end in itself, nor in the industrial practice based on total empiricism. What he strongly believed in was the pursuit of innovative knowledge and its simultaneous translation into useful and sustained technology beneficial to mankind. Prof. Prakash was the President of the Indian Institute of Metals (IIM) in its Silver Jubilee Year (1972), when the important decision to form the three divisions of iron and steel, metal sciences and industrial metallurgy was taken. This gave a new dimension to the growth of IIM and thereby, to the image of metallurgical profession in the country.

Contribution to Atomic Energy Programmes – Special Materials Development :

Construction and operation of nuclear reactors require a variety of special materials for special functions. The list includes rare metals like uranium, thorium and plutonium (used in fuel compositions), zirconium (used for fuel cladding), and beryllium (for neutron reflection). The chemistry and metallurgy of these various metals are very unique and so different from those of the common metals. The flow sheets to be adopted for rare metal extraction have to reckon with the specific characteristics of the source material, reactivity of the metal being extracted and the ultimate nuclear grade purity required. Only by systematic application of the principles of physical chemistry and physical metallurgy, would it be possible to develop detailed

flow sheets for the individual metals for harnessing them for nuclear applications. Much of this development has taken place in the Western world since the days of World War II and the technologies are the preserve of the developed countries on account of the strategic nature of their end-uses. Development of an indigenous and truly self-reliant base for Rare Metals extraction and application became an important factor for the success of the Indian Nuclear Energy Programme. Through his academic training in physical chemistry and metallurgy—at a time that synchronised with epoch making developments in science and technology—Dr. Prakash was singularly qualified to lead such a programme.

An alloy of zirconium is extensively used as the cladding material for the uranium oxide ceramic fuel in water cooled power reactors. It is also used for the fabrication of structural components such as pressure tubes and calandria tubes. The zirconium alloy offers advantages of low neutron absorption cross-section, good strength and ductility at the operating temperatures and excellent corrosion resistance in high temperature water. The natural source material for zirconium is the mineral called zircon which invariably contains a small percentage of hafnium. Zirconium and hafnium are extremely close in their chemical properties. On the other hand, hafnium is a strong neutron absorber and hence removal of hafnium is a very important step in the nuclear metallurgy of zirconium. Pioneering investigations by Brahm Prakash and C.V. Sundaram, led to the development of two processes, namely, (a) selective vapour phase dechlorination of zirconium tetrachloride to form low-hafnium zirconium oxide and (b) selective reduction of zirconium tetrachloride with aluminium to form non-volatile zirconium tri- and di-chlorides. This was followed by pilot plant scale flow sheet development for the preparation of nuclear grade zirconium sponge from Indian zircon and then the establishment of full scale facilities for zirconium metal production.

Nuclear fuel development has been crucial for the Atomic Energy Programme. The fuel—which produces energy due to the fission reaction—may be in the form of a metal or alloy or a ceramic. For efficient utilisation of fissionable content and commensurate removal of heat generated in the fission process and for consistency and dependability of performance, it is essential that the fuel is charged in the form of regular sized 'elements', produced to a high degree of dimensional accuracy. Also, the fuel, which is chemically very reactive, ought not to be directly exposed to the coolant and needs to be clad in a thin, leak proof, corrosion resistant jacket, which serves as well to contain the radioactive fission products. In research reactors, uranium metal rods clad in aluminium have been used as fuel elements. And in water cooled power reactors, the fuel is charged in the form of sintered uranium-dioxide (UO_2) pellets jacketed in zircaloy tubes, assembled in bundles.

In 1957, when Dr. Prakash moved to Bombay, the construction of the Canada-India Research Reactor (CIRUS) was in progress at Trombay. The Uranium Metal

Plant and the Atomic Fuels Division were also under establishment around that time. Supplying half of the initial fuel charge for CIRUS had been accepted as the responsibility of the Indian side. This involved standardising and implementing the flow sheet for the fabrication of aluminium clad uranium metal fuel elements. An important aspect of this development was achieving a fine-grained structure in uranium metal to prevent its radiation-growth in reactor service. The commissioning of the fuel fabrication facility for the CIRUS reactor was achieved successfully by Dr. Prakash and his team in 1959. It was indeed a historic moment when the first fuel elements from India, that were flown to Canada for irradiation testing, performed even better than the Canadian fuel elements. Similarly, in the construction of the first atomic power station of the PHWR design at Kota in Rajasthan—built with Canadian Collaboration—it was decided that half of the first fuel charge for the first reactor would be provided by India. The development work for this was again undertaken at the Atomic Fuels Division, Trombay, for the production of some 2000 bundles of zircaloy clad UO_2 fuel. The microstructure of the sintered fuel pellets, the metallurgical quality of the fuel tubes, and the quality of all the welds in the various stages of the assembly had to be 100% inspected to conform to the stringent Canadian specifications. It redounds to the credit of the Metallurgy Programme under Dr. Prakash that this difficult target was also successfully accomplished through systematic efforts.

In the utilisation of uranium in research and power reactors, an important by-product is plutonium (Pu) formed by the transformation of U-238 to Pu-239. Like U-235, Pu-239 is a fissile material. A plant for the extraction of Pu from irradiated uranium had been established by the Chemical Engineering Group at Trombay by 1964. Establishment of highly sophisticated facilities for the fabrication of Pu fuels for research and power reactors was the responsibility of the Metallurgy Programme. Under the guidance of Dr. Prakash, the Radio-Metallurgy Laboratory facilities were commissioned in Trombay by 1971, with capabilities for the fabrication of Pu fuels over a range of fuel compositions—both metal and ceramic. The entire requirement of PuO_2 fuel for the Zero-Energy fast reactor, Purnima, was supplied from this facility. In 1965, a decision was taken to organise the production activities relating to uranium fuel elements and zirconium components for the entire power reactor programme, in the form of a Nuclear Fuel Complex (NFC) at Hyderabad. The efforts of detailed planning for the establishment of NFC were co-ordinated by Dr. Prakash in his capacity as the Project Director. The Complex represented the translation of indigenous technology from the developmental efforts at Trombay into large scale production levels, with the collaboration of scientists and engineers from the Chemistry, Chemical Engineering and Metallurgy Programmes. Apart from the plants for the production of pure zirconium metal, zirconium alloy components, and power reactor fuel elements, NFC also included a Special Materials Plant (for the production of high purity electronic grade elements like gallium, selenium and

tantalum) and a Titanium sponge pilot plant. In 1972, when Dr. Prakash retired from the Department of Atomic Energy, NFC had reached an advanced stage of completion, and production had already commenced in some of the units. (NFC has now completed more than 15 years of continuous operation, and is poised for expansion).

Contribution to Space Programmes :

Dr. Prakash took over as the first Director of the then newly formed organisation known as Vikram Sarabhai Space Centre (VSSC) at Trivandrum—which comprised the Thumba Equatorial Rocket Launching Station, Space Science and Technology Centre, Rocket Propellant Plant, Rocket Fabrication Facility and Propellant Fuel Complex. He brought to the Indian Space Research Organization (ISRO) his enormous experience with the organised sector of the R & D in the country (BARC being a prime example of the organised R & D). It was a challenging task for Dr. Prakash to integrate into a cohesive organic whole, a wide spectrum of technologies involving aeronautics, avionics, propulsion, materials fabrication and system engineering. In essence, the integration of men and materials in a focussed manner to achieve rapid progress in the development of rocket technology was his mission.

Two ISRO projects which benefited directly from the leadership of Dr. Prakash were : (a) Rohini Sounding Rockets (RSR) and (b) Satellite Launch Vehicle Development - SLV-3. "Sounding rockets of various diameters ranging upwards from 70mm were under development. Dr. Prakash sifted out the relevant from the irrelevant and set the RSR on a sound footing. Under his guidance and leadership, the RSR project achieved its dual objective of gaining basic knowledge about rocketry and of establishing the infrastructure for indigenous development of the sounding rocket technology. Over the years, this led to a respectable arsenal of sounding rockets such as RH125, RH200, RH300 and RH560, fulfilling a wide range of scientific tasks concerned with the study of the atmosphere and ionosphere". Dr. Prakash then reorganised the SLV-3 programme, synthesising the various compartmentalised developmental efforts into a cohesive and clearly directed activity. The main objective of this project was to design, develop, integrate and launch a four stage, all-solid propellant, guided rocket capable of injecting a 30-40 kg satellite into a low earth orbit. The first experimental flight of SLV-3 E^1 took place in 1979. But that was not a success. "SLV-3 E^1 failed on account of a malfunction in one of the control rockets in its second stage. But VSSC under Dr. Prakash, had by then learnt to build launch-vehicles. The next flawless flight of SLV-3 followed in one year. Dr. Prakash provided the necessary motivating force, which prevented VSSC from slipping into frustration and despondency after the first failure of SLV-3". Shri APJ Abdul Kalam has gratefully recalled later how on the night of the unsuccessful SLV-3 E^1 launch on August 19, 1979, he received a kindly tap on his shoulder and the reassuring words of Dr. Prakash 'Don't give up'.

Dr. Prakash also provided the administrative umbrella to the Indian Scientific Satellite Project (ISSP) which was, to begin with, set up at Bangalore as a project of VSSC. Out of this project emerged the country's first satellite Aryabhata and today's ISRO Satellite Centre (ISAC). To quote the words of Prof. U.R. Rao, the present Chairman of ISRO and of the Space Commission, "Timely accomplishment of Aryabhata and the establishment of a strong base in spacecraft technology were greatly assisted by Dr. Brahm Prakash's philosophy of providing adequate flexibility and freedom to carry out the work".

Superalloys Project, Midhani

Mishra Dhatu Nigam (MIDHANI) was set up by the Government of India for the indigenous manufacture of superalloys and special metals for use in the strategic and critical industrial sectors. Dr. Prakash played a very important role in the setting up and managing of the Midhani plant. It was Dr. Prakash who persuaded the Government to set up the plant through a report named after him. He also played a crucial role in deciding on the product-mix for the superalloy project. As Chairman of the Midhani Board of Directors he steered the plant out of difficulties and guided it to become the important producer and supplier of superalloys and special metals in our country. Dr. Prakash's contribution to the choice of maraging steel for future space vehicles, also provided a unique opportunity for Midhani to make and fabricate this space age alloy of great importance.

Impact of Brahm Prakash on the National Scene

On the nuclear fuel development front poineered by Dr. Brahm Prakash, two decades of R and D work on zirconium process metallurgy and uranium fuel fabrication, carried out in the Department of Atomic Energy, had been effective in generating meaningful engineering data for designing production plants. This, coupled with the operating experience of NFC plants, has placed India among the very few countries (including USA, USSR, France and Japan) possessing integrated facilities for the production of reactor grade zirconium components and fabrication of nuclear fuel assemblies. The successful mastering of zirconium technology instilled self-confidence to venture into new vistas of materials technology such as those of titanium and beryllium. It has led to the setting up of a titanium sponge plant at DMRL, Hyderabad and of a pilot plant at Vashi near Bombay for the production of beryllium components. It should also be highlighted that the harnessing of the sophisticated technology of plutonium has been crucial for the self-reliant growth of the long term Indian Nuclear Programme-particularly for the development of fast breeder reactors. In the process, a strong and wellknit R and D base has been established at Trombay, devoted to all aspects of special materials development encompassing extraction and refining,

physical metallurgy of alloys, mechanical metallurgy, metal and ceramic forming processes, and analysis of service behaviour. This comprehensive programme is well tailored to meet the future growth needs.

"The large cost involved in any space programme, especially for a country like India, is a major factor in our space endeavours. Dr. Prakash was very much conscious of the consequences of establishing in-house facilities at the VSSC. As a doyen of metallurgists, he was fully aware of the dormant potentialities of the Indian metallurgical industries. He therefore made sure that all major hardware for our launch vehicles were produced by our own industries with direct participation from VSSC engineers". As a result, stupendous confidence was established within our industries—whether it be a public sector undertaking or a private industry. This enabled our industries to move forward hand in hand with our Space R & D departments, in reaching the forefront of sophisticated technologies and realising national objectives. In post-independence India, all crucial industrial sectors have been dependent on imports for their requirements of special metals and alloys. As these materials are of stragetic nature, their imports make the country vulnerable to external pressures. The need for indigenisation in the manufacture of superalloys and special metals and the achievement of self-reliance was one of the cherished visions that compelled Dr. Prakash to convince the Government to set up plants such as Midhani. Today, all the titanium for the Ti-6A1-4V alloy hemispheres required for gas bottles and tanks for ASLV and PSLV, are obtained from Midhani. Again we owe it to the vision of Dr. Prakash when we recognise the fact that India is the only developing country to use maraging steels in large dimensions for Launch Vehicle applications. Today, Midhani supplies large tonnage maraging steels and other special steels with high degree of cleanliness, high strength and good corrosion resistance for applications in space, atomic energy and defence.

Conclusion

We remember Dr. Brahm Prakash—the Karma Yogi par excellence—with gratitude, admiration and reverence. In the Indian renaissance of science and technology, here was a man who shunned all publicity and personal ambitions but rose to kindle the inherent capabilities of young scientists and engineers to high levels of achievements by his own example of patriotism and devotion to work. Such was his greatness that he simply walked away from the limelight.

Membership and Awards

Dr. Brahm Prakash was the President of the Indian Institute of Metals (IIM), elected Fellow of Indian National Science Academy (INSA), Fellow of the Indian Academy of Sciences, and a member of American Institute of Mining, Metallurgical and Petroleum Engineers (AIME).

The awards and honours conferred on Dr. Brahm Prakash include the award of Padma Shri in 1961, Bhatnagar Award in 1963, Padma Bhushan in 1968, VASVIK Award for Materials Science in 1976, Bhatnagar Memorial Medal of INSA in 1979 and the Bralco Medal of IIM in 1980.

Acknowledgements

In the course of preparing this memoir, I have corresponded with many colleagues and friends of Professor Brahm Prakash and I am grateful to all of them for the considerable material provided by them. Special mention should be made of the contributions of Smt. Brahm Prakash, Shri V.S. Bhatia, Dr. V.S. Arunachalam, Dr. S.C. Gupta, Prof. M.A. Dayananda, Prof. S. Ranganathan, Dr. K. Narayana Rao and Dr. P.V. Manoranjan Rao. I should also acknowledge the collaboration of Dr. B. Viswanathan in the compilation of this memoir.

C.V. Sundaram

Bibliography

1935. (With Dunicliffe H B) Action of hydrogen sulphide on insoluble chromates. *J. Ind. Chem. Soc.* **12**, 505.

1938. (With Hamid A *and* Bhatnagar S S) Magnetism and molecular constitution of some chromium compounds. *J. Chem. Soc. (London)*, p. 1428-34.

1939. (With Bhatnagar S S *and* Maheshwari J C) Magnetism and molecular constitution of some manganese compounds. *Proc. Ind. Acad. Sci.*, **10**, 150.

— (With Bhatnagar S S *and* Kapur P L) Magnetic study of the oxides of chromium and manganese. *Current Science*.

— (With Bhatnagar S S) The magnetic susceptibilities of metallic oxides, with special reference to those of chromium and manganese. *J. Chem. Soc. (London)*, pp. 1433-41.

— (With Bhatnagar S S *and* Singh J) Colour and magnetic properties of MnS. *J. Ind. Chem. Soc.* **16**, 313.

1940. (With Bhatnagar S S) Magnetism and Catalysis—Part I, Catalytic decomposition of potassium chlorate by manganese dioxide and ferric oxide. *J. Ind. Chem. Soc.*, **17**, 125.

— (With Bhatnagar S S) Magnetism and Catalysis—Part II, Catalysis of persulphate and iodide reaction by ferrous ions. *J. Ind. Chem. Soc.*, **17**, 133.

1941. (With Bhatnagar S S, Kapur PL *and* Bhatnagar A S) Magnetism and catalysis—Part IV, Catalysis of the reaction between amonium oxalate and mercuric chloride by ferric ions. *J. Ind. Chem. Soc.*, **18**, 371.

— (With Qayyam M A *and* Bhatnagar S S) Magnetic susceptibilities of metallic oxides and their molecular structures with reference to cobalt. *J. Ind. Chem. Soc.* **18**.

1945. (With Bhatnagar S S) Magnetic study of colorant ions in coloured glasses. *J. Sci. and Indus. Res.* **4**, (3), 151.

1950. Effects of $BaCl_2$ and other activators on soap flotation of quartz. *Trans. Amer. Inst. Min. and Met. Engr.* **187**, 591.

— Effects of activators and alizarin dyes on soap flotation of cassiterite and fluorite. *Trans. Amer. Inst. Min. and Met. Engr.* **187**, 601.

1953. (With SUNDARAM C V) Recovery of Cu from smelter slags. *J. Ind. Inst. Sci.* **35**, 17.

1954. Titanium and Zirconium—Paper presented at the Conference on "Development of Atomic Energy for peaceful purposes in India" (Delhi, Nov).

1956. (With SUNDARAM C V) Separation of hafnium from zirconium by vapour phase dechlorination. *Proc. Int. Conf. Peaceful uses of Atomic Energy. (Geneva)* **8**, p 554-57.

1957. Extraction of uranium and thorium and pyrometallurgical processing of reactor fuel and blanket material. *Ind. Mining Journal-Spl.* issue (September, Calcutta) p 165.

— Physical Chemistry of steel making slags, in Physical Chemistry of Steel Making, TISCO Journal.

— (With SUNDARAM C V) Present status of zirconium metallurgy. *Proc. Symp. on Rare Metals*, (IIM, December) 165.

1958. (With SUNDARAM C V) Separation of hafnium from zirconium by selective reduction of $ZrCl_4$ with Al. *Proc. Second Inter. Conf. on the peaceful uses of Atomic Energy* (Geneva) **4**, 271.

1959. Metallurgy of reactor metals. *Trans. Ind. Inst. Met.* **12**, 69-82.

1961. (With RAO N K) Fabrication of fuel elements at Trombay, India. *IAEA Symp. on Fuel element Fabrication (Vienna)* Vol. **1**, 391-402.

1962. (With KANTAN S K *and* RAO N K) "The Metallurgy of Throium Production"—monograph, *IAEA Series*, Vol. **22**, 56.

1966. Fabrication of nuclear fuels in India—Paper presented for the Bhatnagar Memorial Award in July (Published in *J. Sci. Indus. Res.* 1966).

1972. The Coming decades—The task before Indian Metallurgists—Presidential Address at the Annual Meeting of IIM (Published in Transactions IIM, Vol. 25, No. 1, 1972).

1978. "Space" in Proc. INSA symposium on "Science and its impact on Society—Indian Experience" (New Delhi, April).

1979. Metals and Materials Development for Atomic Energy and Space Programmes—Shanti Swarup Bhatnagar Medal Lecture, INSA.

1981. Uranium as a Source of energy—Prof. N P Gandhi Memorial Lecture, IIM Annual Meeting (Jaipur, November).