INDIAN NUCLEAR SOCIETY

INS News Letter

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Message from Chairman, Atomic Energy Commission

Department of Atomic Energy has been the originator, catalyst and promoter of the gamut of nuclear technologies and its applications in the country. Erstwhile luminaries of DAE established the Indian Nuclear Society (INS) as a forum representing the community of all stakeholders of the Indian nuclear sector - scientists, technologists, regulators, academicians, industrialists and entrepreneurs.

In recent times, a renewed thrust has been provided to the nuclear sector in India with capacity augmentations being undertaken in all aspects of nuclear applications.

INS will play an important role in facilitating these objectives, as it provides a vibrant platform and brings together a vast repertoire of knowledge, skills, expertise and enterprise not only from DAE but from industry and academia.

I am happy to note that INS is being restructured to resonate with the current activities and mandates of the nuclear sector. I am hopeful that this constructive change will be transformative for INS.

I compliment INS for launching a Newsletter to showcase and highlight the activities of INS and provide a holistic representation of the nuclear sector of the country. This shall serve not only as a repository of knowledge and information, but also be a source of inspiration to the nuclear community to put its best foot forward in the service of the society. It is heartening to note that DAE contributions in the fight against COVID-19 are also being highlighted in the inaugural issue.

I would urge INS to use this newsletter as a proactive vehicle for information dissemination, so that the seeds of our knowledge can be spread far and wide, leading to a substantive increase in uptake of our spin-off technologies towards societal applications.

Wishing INS the very best in all its future endeavours.

K. N. Vyas

Chairman, Atomic Energy Commission

Message from Dr Anil Kakodkar

Dear Shri Mehta,

Thank you for your mail. I am indeed very pleased that INS has decided to bring out a newsletter. As articulated by you, all of us, the members of INS, are looking forward to the realisation of our common objective, that is to 're-establish INS status to international level'. In this mission we are all with you as our President.

It is clear that the climate change crisis would have a far bigger impact than the Covid-19 pandemic that the world is presently grappling with. Without nuclear energy, it would be impossible to deal with the climate crisis in an affordable manner. There is an urgent need to take this message to people across the globe in a convincing and coordinated manner. Several eminent environmentalists who

were against nuclear energy to begin with, have turned pro-nuclear as a result of realisation about the indispensability of nuclear energy for protection of the earth. India, being one of the leaders in nuclear technology and being a country with the largest unmet energy needs, has a special responsibility in this regard both in the Indian as well as in the global context. There are some dimensions of this challenge like policy development, capacity building in industry, development and adoption of standards, professional motivation, leadership development, public awareness and many others where INS can and should play a major role. There are big voids in some of these activities currently.

Starting an INS Newsletter is of crucial importance in harmonising the nuclear community in the country and raising its stature to a level of a peer group that could guide the destiny of our nuclear programme. This would require INS becoming a credible think tank that can deal with some of the critical aspects mentioned above in a mature way and effectively communicate with all relevant stakeholders.

I am also very happy that Dr. Manchanda would be leading this activity. His experience and insights would be very useful in making the newsletter an effective vehicle for taking the mission INS forward.

My best wishes for the revitalised INS.

Warm regards,

Sincerely,

Anil Kakodkar

Chairman,
Rajiv Gandhi Science & Technology Commission
Former Chairman AEC

Imagination is more important than knowledge....

- Albert Einstein

Message from President Elect

At the outset let me thank the INS members for giving an opportunity to me and my colleagues of INS-EC to serve the prestigious organization. We are conscious of the legacy of INS and let me assure you that we will strive to attain the lost glory. EC will sincerely try to rise to the expectations of members and re-establish INS to international status with the support and cooperation from all members.

At this stage let me express my sincere wishes for your good health, active and healthy life under these challenging times of the worldwide COVID 19 Pandemic. We all will agree that the current SARS-Covid-19 pandemic is not only unprecedented and extremely ominous, this certainly is the biggest challenge encountered by the humanity in our living memory. The positive side is that in India there is a nearly unanimous support from practically all quarters to fight this situation. Let us earnestly wish that the crisis will be over and normalcy will return sooner than later. Praying for the safety and wellbeing of one and all of you

For the conduction of election in a very professional way we must thank all concerned. I particularly recall the contribution of late Shri Umesh Chandra and I pray for the departed soul
It is rather unfortunate that the INS-EC after election could not formally takeover due to lockdown imposed by the government. The present situation is rather unpredictable. However EC (elect) was keen to look ahead. One of our members, Dr Manchanda, proposed to resume the periodic publication of Newsletter which was widely welcomed. His association with the similar activity in AERWA has been helpful and INS members have responded very enthusiastically. We are glad that we are in a position to bring out our first issue on the TECHNOLOGY Day. I am sure that all INS members will find it of technical value and enjoyable. My personal thanks to all associated with this effort.
Our aim is to reach the members, keep them well informed with various aspects of Nuclear Science and Technology. In this respect we welcome support, contribution and suggestions from members. We would like to re-establish our contacts with the local units of INS.
I personally welcome you all in this joint endure to make INS a truly international body of professional nuclear scientists and technologists.
My warm regards and best wishes to all members.

S.K.Mehta

From Editor's Desk

Elections results of INS EC (2020-2022) were announced on 18th March, 2020. Many of the elected members had committed in their plans for future, that efforts will be made to resurrect the society from its present state of coma. It was frustrating for not being able to even initiate any activity in this direction due to prevailing circumstances. One possible way was to expedite development of interactive INS Website to connect with our members and keep them abreast with the subjects of their interest related to nuclear science and technology. However, I was told that any further developmental work on INS website (beyond elections) will involve fresh negotiations and new contract with the web designer by new EC of INS. As the new EC is yet to take over, this exercise may take at least few weeks whenever it starts. How the situation develops in the coming weeks, is any body's guess. Under the prevailing circumstances, it was prudent to think of only zero budget activity. Few INS / EC members encouraged by the President (elect) therefore decided to work in the present lock down period on News Letter by working from home.

Canvas of the topics under Nuclear World is very large. In this maiden issue, an attempt has been made to cover two areas of wide interest viz. New nuclear power reactors installed in different countries in 2019, LNT hypothesis to regulate the operation of nuclear power reactors. It is also proposed to add regular features on a) the bio sketch of Nobel Laureates who made innovative contributions to the nuclear world and b) reviews of books on nuclear science and technology released in recent times. News from the nuclear world from open platforms will also be covered briefly. It will be our particular endeavour to bring to you the major R&D developments within the Deptt of Atomic Energy. However, what is the most important for us is your feedback. May I urge on INS members to kindly forward your suggestions on INS NL to me on indiannuclearsociety@gmail.com

World is today witnessing a pandemic caused by COVID-19 , a novel Coronavirus (nCoV) strain that has not been previously identified in humans. About 4 million people are confirmed positive and about 300,000 have lost their lives. Vaccinologists, the world over are racing against time to discover a vaccine which can develop immunity against nCoV. It has changed the way people are advised to live. As one who has worked in a Plutonium laboratory for more than four decades and where the mantra used to be thorough washing and monitoring (de-contamination) of hands every time you step out of lab , I find that there are many similarities of COVID-19 virus with alpha emitting Pu (Pu-238, Pu-239, Pu-240). Like Corona virus, alpha particles emitted from Pu travel only very short distance in air and cannot penetrate human skin. However, both Pu and nCoV (as aerosols and as suspended particulate matter) can enter our lungs by inhalation and can be very dangerous. Unlike n-CoV (which binds to human cells with spikes protruding from its spherical surface), Pu is deposited mainly in lever and skeleton where it appears to be retained for many years. SOPs for Pu handling also include PPEs comprising respirator, gloves , caps , shoe covers etc . There had been frequent instances when we were required to decontaminate some part of the laboratory for hours together and could not come out for regular food and other necessities. It is recommended that a contaminated person should keep distance from others and should touch anything only after ensuring complete decontamination of hands. As a fraternity from nuclear establishment, it is our responsibility in the present scenario to spread the message of physical distancing from people and suspicious objects, disinfecting our surroundings, thorough washing of hands and following ultra hygienic habits in our daily life .

It is a great privilege to release the first issue of INS NL, in its new incarnation, on Technology Day. It is an historic day for the Scientists and Engineers of DAE. It is etched in their memory as a day of accomplishment and dedication to meet the new challenges to make India self reliant in Modern Science and Technology.

Vijay Manchanda

R&D Activities carried out at DAE Institutes to help in COVID-19 pandemic

Bhabha Atomic Research Centre (BARC) as well as associated institutes of Department of Atomic Energy with their multidisciplinary expertise have developed few technologies and are ready to provide assistance to the relevant govt. agencies in fighting the pandemic in following areas.

1) A detailed study, at laboratory scale as well as at plant scale (in collaboration with Tata Memorial Hospital, Mumbai) has been carried out to examine the reusability potential of PPEs following sterilisation by gamma irradiation. Three different types of PPEs (polypropylene and Polyethylene

based) have been irradiated at different gamma doses and their mechanical properties have been evaluated. It is estimated that, to achieve a sterility assurance level of 10^{-6}, a dose of 30 kGy is required. An additional study with surrogate virus has been initiated by BARC, TIFR and NCBS to evaluate more accurate D-10 dose level. This is expected to save both time and the embrittlement of the PPEs noticed at 30kGy dose can be contained. A large number of irradiation plants are available in the country, specifically near the cities like Mumbai, New Delhi, Bengaluru, where sterilisation using irradiation can be carried out. On 26th April **Ministry of Health and family welfare has approved the proposal and asked DAE to provide a detailed SOP.**

2) A new phytopharmaceutical (BRM) developed for cancer radiotherapy is being repurposed for treatment of COVID19. The safety, pharmacokinetics and pharmacodynamics of BRM has already been established in healthy human subjects. **A clinical trial protocol for testing BRM for treating COVID19 patients was submitted to ICMR and NOC has been obtained.**

3) A low cost equipment for decontamination of N95 mask using thermal treatment under calibrated moist conditions, a protocol listed by US-CDC, has been developed. Currently testing is under way at ACTREC.

4) Considerable progress has been made in developing masks, as per specifications of N99 with indigenous material . Development of the mask material using BARC technology has shown that the mask which has a product quality of N99 can be sterilised using dry heat equivalent to ironing.

5) A kit for detecting the SARS-CoV-2 virus through RT-PCR (reverse transcription polymerase chain reaction) has been prepared. **This kit was forwarded to Kasturba Hospital for Infectious Diseases (Mumbai) for initial evaluation and designed success has been obtained.** Soon, it will be sent to National Institute of Virology (NIV), Pune for validation. Alternative methods such as micro-patterned electrodes and modern molecular approaches such as CRISPR based detection of the virus are also being assessed.

Inputs from BARC
Editor

LNT Hypothesis and Public Suspicion of Nuclear Power

The National regulators have the responsibility of setting up radiation protection standards and prescribing safe limits of exposure of radiation to the occupational workers and to the public. In India these are well enunciated under the Radiation Protection Rules, RPR 2004 and Basic Safety Standards, BSS 1996, 2011 and 2014 codified by IAEA and adopted by AERB. The regulatory board has played their role well and the results are there for every one to see on the safety with which the nuclear power has evolved in India for the last half a century. But it is unfortunate that the public suspicion on nuclear power continues and the nuclear industry has from time to time faced this suspicion. The article tries to analyze the source of this mistrust of radiation amongst the public.

The International Commission on Radiological Protection is an independent International non-governmental organization which provides recommendations on setting safe limits of exposure of radiation and radiation safety standard norms the world over which is adopted by all national regulatory agencies in order to ensure occupational and public safety in the use of ionizing radiations. It has evolved over the years since 1928 and has been served by eminent scientists particularly from the biological sciences. From time to time ICRP revise and publish their recommendations in the light of evolving knowledge base. This base includes the pioneering services of another International organization known as United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR. This was set by the United Nations General Assembly in 1955. 21 countries are designated to provide scientists to serve as members of the committee which holds annual meetings and submits reports to the UN. This was initially formed to consolidate the vast amount of biological and epidemiological data on the Hiroshima and Nagasaki Bomb victims and their progenies. They have also done considerable work on the effect of radiation from a very few nuclear reactor accidents, notably from Chernobyl nuclear accident. The ICRP is guided by the findings of this committee in setting up safety standards in the light of scientific findings from all over the world. The consolidation of scientific findings is an ongoing process and continues to imbibe newer findings. India has also traditionally provided the knowledge base and expertise in the past. There have been notable names from India which were respected in these circles. Dr. A R Gopal Ayengar and Dr. A K Ganguly were

considered as gurus in this area by the international community. India has an important role to play since we are the custodians of vast amount of data being collated and analyzed over the last half a century on the effect of low level natural radiation on the population living in the naturally occurring HBRAs (High Background Radiation Areas) found in the West coast of India. Such areas also exist in a few places elsewhere in the world. Natural radiation exposures are naturally outside the control of regulatory bodies. However the HBRAs serve as a natural laboratory for the scientists to get valuable information on the effects of radiation on man and provide it to international bodies like ICRP and UNSCEAR to modify their recommendations. It may be noted this involves branches of microbiology and epidemiology and does not fall under the area of regulation. And hence it is important for our Government to be proactive in providing scientific feedback to these organizations on these findings.

The International Atomic Energy Agency, IAEA provides the guidelines for implementing these standards and brought out a document known as Basis Safety Standards BSS in 1996 and its revisions after feedback from the experts in the member states in formulating this document. This is adopted by AERB in ensuring safety in nuclear operations.

In India the Atomic Energy Regulatory Board is the national authority which has evolved over the years and derives its authority from the Atomic Energy Act. The act controls the safe use of radiation in the country. The radiation protection rules provide the legalistic frame work for the AERB. The recommendations of ICRP are adopted by AERB. This is the elaborate infra-structure in which the radiation protection science has evolved over the years.

What is LNT and what is ALARA?

The effect of radiation on living organism is biological but its manifestation is also epidemiological. The effects of radiation on human beings are two fold, carcinogenic and genetic. In technical terms these are known as stochastic effects since they are statistical in nature and results in probability of causing damage. The challenges in setting up safety standards for ICRP is this underlying probability. Another confusion at low levels of radiation occurs due to what are known as "confounding factors". Radiation is not the only carcinogenic agent but there are innumerable, often overwhelming other factors through various carcinogenic agents to which man is exposed. And for the minuscule effects of low levels of radiation, they form a large background and make it cofounding. Due to these it becomes difficult to discern clear cut health effects of low levels of radiation. But the primary effect of radiation due to its mutagenic nature is well known. The most benevolent and humane service of radiation to humanity in cancer therapy that saved millions of lives world over is also based on this principle. So traditionally biologists carried out experiments on living organisms on the effects of radiation at moderate and high levels where these effects can easily be quantified and tried to intuitively extrapolate the effects linearly to zero dose levels. Naturally if one linearly extrapolates without taking into consideration other hidden factors it will lead to a non zero risk even at fraction of the natural background radiation. This gives rise to a *wrong notion* that *any amount of radiation* is harmful and has given rise to the *Linear No threshold, LNT* theory and led to the philosophical concept *As Low as Reasonably Achievable concept in Radiation Protection, ALARA*. Historically this has become the corner stone of radiation protection philosophy.

Though the safe limits of exposure are prescribed by ICRP for occupational and public exposures, the ALARA became a regulatory requirement for optimization. Over and above this, they added further complex philosophy with ALARA, "social factors being taken into account" which leads it to further difficulties. This, in my opinion, gave a quibbling non quantifiable dimension to radiation protection standards. The responsibility to implement ALARA is delegated to the operators and to do the optimization exercise. Often the science (or lack of science) and deep philosophy behind these gets diluted at the stage of implementation. The ALARA has however helped the operators to reduce the radiation exposures in their operations but in the context of its originating principle LNT it can lead to misunderstanding. But many are of opinion that this noble objective is taken to the extreme when one tries to support it with the LNT principle. When we analyze this aspect it has no connotation to regulation. You will not find this mentioned in any regulatory bibles. But it got into it unnoticed when one refers to the ICRP documents and its interpretations. The idea of this article is to analyze the opinion in many scientific circles, the need to go away from these concepts which do not have any scientific basis.

The principal basis for the LNT is theoretical, and very simple. A single particle of radiation hitting a

single DNA molecule in a single cell nucleus of a human body can initiate a cancer. The probability of a cancer initiation is therefore proportional to the number of such hits, which is proportional to the flux of radiation, and thus related to the dose. Thus, the risk is linearly dependent on the dose; this is the LNT. To recap, the Linear No-Threshold Dose hypothesis led to a supposition that all radiation is deadly and there is no dose below which harmful effects will not occur. This is a drastic conclusion based on extrapolating the findings at cell level to a practical macro system. All over the world now many feel that, not only this is illogical but also an unscientific proposition.

Why a relook at the concepts is required:

The concepts of *"Linear No-Threshold Dose hypothesis" LNT*, and striving to overstress on ALARA have often been stumbling blocks in making nuclear energy acceptable to the public. To the common man the terminology smacks of helplessness on the part of nuclear operators in firmly putting it across *"what is safe and what is not".* The safe limits which are all there in the books are followed and that is to be stressed more than the safety philosophies. Often an insight into the science or lack of science behind this in the operational level becomes counterproductive. If this is not ensured, it is difficult to convince even unbiased people about the safety of nuclear power and impossible to convey it to the lay public swayed by the high pitched cry of the anti-nuclear lobby with various agenda.

Imagine, how disastrous it would be to tell someone everything is safe below the safe limits but *"be careful to keep it as low"*. Quibbling scientific exactitudes and philosophies will not sell in public! And can easily be exploited by interested people. Naturally anyone would like to know what is safe and what is not! As a result interested parties spread canard about thousands dying up to several hundred kilometers if an improbable nuclear accident happens. Yes, all they have to convince the lay public is to multiply the insignificant extrapolated risk factors given by the pundits and multiply with large number of population to project the number of "virtual deaths" from even a fraction of the variation in natural background radiation! This concept will give a fatality probability from any amount of radiation. Though it may be good cell biology but will not in any way help in projecting real health effects. Once such exaggerated reports are spread by the media then it is difficult to undo the harm however hard one may try.

Present thinking on the LNT hypothesis in the world.

Although rarely discussed till recently, LNT does not take into account the organism's immune system, biological recovery time between doses or other relevant mechanisms that operate at low doses on an actual organism versus cells in a petri dish. Now comes the hint that the UNSCEAR has finally admitted that we can't use the LNT hypothesis to predict cancer from low doses of radiation. A recent study concluded what was suspected for decades – radiation doses less than about 0.1 Sv are no big deal. The LNT does not apply to low doses. But the question is no body want to bell the cat! On the other hand there are reports to show that such low level radiation in fact helps to increase the natural immune system and led to understand the beneficial use of low level radiation in what is known as hormesis. There are even reports to show that low level radiation can save lot of cancer deaths from other agents. The United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR submitted a report in 2012 that inter alia states that uncertainties at low doses are such that it "*does not recommend multiplying low doses by large numbers of individuals to estimate numbers of radiation-induced health effects within a population exposed to incremental doses at levels equivalent to or below natural background levels*." But the underlying concepts hidden in their books precisely lead to those extrapolations to be faced by nuclear operators.

Results of studies in the HBRA areas in West Coast of India

Detailed and long term studies of the genetic and carcinogenic effects in the population in the high background areas in the West Coast of our country have clearly shown that there had been no deleterious effects (carcinogenic or genetic) on the population staying there for generations which receive more than 50 times the dose limit for public of 1mSv per year. Microbiological and epidemiological studies do not show any increase in cancer or genetic effects in these population groups. These doses are also higher than most of the exposures of occupational workers in the nuclear industry and certainly orders of magnitude higher than the assessed public exposures around NPPs. The large volume of findings on long term intense research on the Hiroshima and Nagasaki bomb survivors and their progenies and even in the Chernobyl follow up cases also have led to the discovery that the genetic effects are highly

exaggerated and did not support the LNT hypothesis.

It is a good augury that in recent times opinion is building up around the globe, by American Nuclear Society and numerous organizations elsewhere on the need to go away from LNT hypothesis. In fact, we in India have a much higher responsibility in prevailing upon the international organizations to go away from LNT concept in view of the excellent epidemiological data from our high background areas.

Evolving view of International organisations against their LNT hypothesis.

The ICRP's view on the possibility of threshold dose for radiation-induced cancer, is given in ICRP Publication 103 (2007),[1] Para 178 entitled dose thresholds as: *"Possibility that there might be a threshold dose, below which there would be no radiation-related cancer risk, has been ignored. The LNT model is not universally accepted as biological truth, but rather, because we do not actually know what level of risk is associated with very-low-dose exposure, it is considered to be prudent judgement for public policy aimed at avoiding unnecessary risk from exposure.*"

Recently, the ICRP has taken the cognizance of the effect of repairs of such damaged/mutated cells by an existing DNA repair mechanism in the body, post-exposures. In addition to this, the emerging results with respect to adaptive responses, hermesis, and bystander effects add to the uncertainty of quantifying the risks at low level exposures by extrapolation of the well known risks at high level exposures. LNT concept is slowly being challenged!

The American nuclear society in its annual meeting in 2012 discussed in details the LNT issue. The ANS has taken an official stand on the issue: *"It is the position of the American Nuclear Society that there is insufficient scientific evidence to support the use of the Linear No Threshold Hypothesis (LNTH) in the projection of the health effects of low-level radiation."*

The French Academy of Sciences at the ANS meeting said *"The hypothesis of the risks of cancer induced by low doses and dose-rates is founded on the extrapolation of data of highly-exposed human groups, applying the risk as being constantly proportional to the received dose without being limited by a threshold, the linear no-threshold (LNT) assumption. This hypothesis conflicts with itself and has many scientific objections; and it is contradicted by experimental data and epidemiology."* Rockwell, President, American Nuclear Society testified on the need to rationalize radiation protection policy before the U.S. Advisory Committee on Nuclear Waste.

In conclusion, this is definitely time to have a re-look at the corner stone concepts in radiation protection philosophy. The exaggerated figures of deaths from the very few nuclear accidents are these "virtual deaths" that are projected as deaths by multiplying the probability using LNT theory and a large number of total population most of whom would not have been exposed to radiation after an accident. This gives rise to a finite number of virtual deaths. The cancer incidences also get submerged in the so called confounding factors due to various other carcinogenic agents to which people are exposed.

The INS has a responsibility to increase awareness about radiation effects and create a forum for the members to discuss the problem and to project the vast amount of microbiological and epidemiological data available in the country on the effects of low level of radiation in the country. And strengthen the hands of their counterparts elsewhere to bring about a change in the recommendations of the international organizations collectively.

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M. R. Iyer
Former Head, RSSD, BARC
& Ex Professional IAEA

The black holes of nature are the most perfect macroscopic objects there are in the universe: the only elements in their construction are our concepts of space and time....

- Subrahmanyan Chandrasekhar

Madam Curie: The Most Inspirational Woman in Science

If we ask any science student to name one lady nuclear scientist , the most probable answer is likely to be Madam Curie, originally known as Maria Salomea Skłodowska Curie. Not only a great scientist, Madam Curie is known for being simple, dedicated and unassuming radiochemist and happens to be the only female scientist to receive two Nobel prizes. Therefore it is befitting for the nuclear scientific community, to recapture the innovations of Madam Curie in this new form of INS E-NEWS LETTER.

Maria Salomea Skłodowska, was born on 7th November 1867, in Warsaw, Poland, which was part of the then Russian Empire, last among the five children to teacher parents Bronisława, and Władysław Skłodowski. Her father inculcated interest in science in his children, taught mathematics and physics, and he even built a small laboratory at home for his children. At the age of 15, Maria completed her secondary education in Poland, standing first in her class. Later she moved to Paris to pursue higher education (with the help of her sister, physicist, Bronisława) where she earned her higher degrees and conducted her subsequent scientific work.

Marie Curie with her daughters, Eve (left) and Irene (right)
Source:
https://commons.wikimedia.org/wiki/File:Eve,_Marie,_Irene_Curie_1908.jpg

In the University of Paris, Maria began her research career on the magnetic properties of various steels. There she met Pierre Curie, who was an instructor at *École supérieure de physique et de chimie industrielles de la ville de Paris* [ESPCI]). Their mutual passion for science brought them together and finally resulted in their marriage. Often people quote that Skłodowska is "Pierre's biggest discovery." After the discovery of X-rays by Roentgen (in 1895), and of Henri Becquerel's discovery (in 1896) of "Becquerel rays" or uranium rays, Marie Curie decided to look into uranium rays as a possible field of research using an electrometer, developed by Pierre Curie. She discovered that uranium rays caused the air around a sample to conduct electricity (ionization) and this activity depended on the quantity of uranium present. They hypothesized that the radiation was not the outcome of some molecular interaction but must be arising from the atom itself. Curies termed this activity as "Radioactivity" and attributed it to the atomic property. Curie used two uranium minerals, pitchblende and torbernite (chalcolite) and quoted in one of her papers: "The fact is very remarkable, and leads to the belief that these minerals may contain an element which is much more active than uranium." As the Curies did not have any laboratory of their own, these experiments were carried out in a converted shed next to ESPCI without any precautions as they were unaware of the deleterious effects of radiation exposure.

In July 1898, Curies published a joint paper and announced the isolation of a new element which is named "polonium", in honour of Maria's native country Poland. On 26 December 1898, they announced a second new element, "radium", from the Latin word for "ray". Chemically Polonium is related to the element Bismuth , and Radium is related to Barium. Initially Curies had managed to obtain only traces of radium, but separating appreciable quantities of Radium, free from Barium, was a big challenge. Applying the method of differential crystallization in 1902, they were successful to separate 100 milligram of radium chloride after processing a ton of pitchblende. After this it took nearly eight years, to isolate pure radium metal.

Between 1898 and 1902, the Curies published, a total of 32 scientific papers, which included several fundamental aspects of radiation and also proposed that, when exposed to radium, tumor cells were destroyed faster than healthy cells, paving way for its potential use in cancer radiotherapy. Though they were aware of therapeutic usefulness of radium, they never patented their discoveries, and thus there was no attempt to use the discovery for the well-being of the society.

In December 1903, Pierre Curie, Marie Curie, and Henri Becquerel were jointly awarded the Nobel Prize in Physics, by the Royal Swedish Academy of Sciences in recognition of their researches on the radiation phenomena and radioactivity. Marie Curie became the first woman to be awarded a Nobel Prize. On 19 April 1906, Pierre Curie was killed in a road accident. Although Marie Curie was devastated by her husband's death, she continued her scientific research with same interest. She became the first woman professor at the University of Paris. In 1911, Royal Swedish Academy of Sciences, honored Marie Curie, with the individual Nobel Prize in Chemistry. This award was "in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium". She was the first person to win or share two Nobel Prizes.

Curie's second Nobel Prize enabled her to persuade the French government into establishing the Radium Institute (*Institut du Radium*), by the University of Paris and *Institut Pasteur*. One of the sections, the Curie laboratory, directed by Madam Curie, was dedicated to physics, chemistry and medicine research. Led by Curie, the Institute produced four more Nobel Prize winners, including her daughter Irène Joliot-Curie and her son-in-law, Frédéric Joliot-Curie. Eventually it became one of the world's top major radioactivity-research laboratories. In 1925, Radium Institute was also opened in Warsaw. In 1970, The *Institut du Radium* and the *Fondation Curie* merged and became *Institut Curie* dedicated for research, teaching and treating cancer.

During World War I, Curie helped in setting up field radiological centres and mobile radiography units near battlefield popularly known as *petites Curies* ("Little Curies") to be used for sterilizing infected tissue of over a million wounded soldiers. For this work she was assisted by her 17-year-old daughter Irène. Curie produced hollow radium needles, from her own one-gram supply of radium that she isolated, At the same time, she was also exposed to X-rays from unshielded equipment in field hospitals. In 1930 Curie was elected to the International Atomic Weights Committee, and in 1931, she was awarded the Cameron Prize for Therapeutics of the University of Edinburgh. After the war, she worked hard to raise money for her Radium Institute. But by 1920, due to unsafe handling of radioactive materials, she developed many health problems. On July 4, 1934, Curie died of aplastic anemia, caused by radiation exposure. Curie was buried next to her husband in Sceaux, a commune in southern Paris. Sixty years later, the remains of both were transferred to the Panthéon, Paris, alongside France's greatest citizens. Even after her death Madam Curie received many honours. In 1936, her name was included on the *Monument to the X-ray and Radium Martyrs of All Nations*, erected in Hamburg, Germany. In 1944, the 96th element of the modern periodic table of elements was named "Curium." In 2009, a survey conducted by *New Scientist*, voted her the "most inspirational woman in science". On the centenary year of her second Nobel prize, Poland and France declared 2011 as the Year of Marie Curie, and the United Nations declared this year as the International Year of Chemistry. Numerous locations around the world are named after her, which include a metro station in Paris, Polish nuclear research reactor Maria. In January 2020 a micro-satellite was named in honor of Marie Curie.

In Warsaw, several institutions, museums and public places bear her name. Maria Skłodowska-Curie Institute of Oncology and Maria Skłodowska-Curie Museum were established at Warsaw. In 2011, an allegorical mural was painted on the façade of her Warsaw birthplace. In 2011, a new Warsaw bridge over the Vistula River was named after her.

Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.

– Marie Curie

Madam Curie, even today remains as a symbol of hard work and commitment. Not only, her scientific research established new ideas in physics and chemistry, but also her life and legacy had equally profound effect in the societal sphere. Life was not always smooth for Madam Curie and she had her own share of struggles as well to succeed. To name a few, when she was just 10 years old, she lost her mother. In fact, she worked as a governess and tutor to save enough money to travel to Paris and enroll at the Sorbonne University. She could not study in the University of Warsaw, as Russian government prohibited enrollment of women in any of the universities. This never stopped her curiosity to gain knowledge and passion for science. In spite of having significant scientific contributions, she was never elected as a Fellow of the French Academy of Sciences and the original nomination letter to the Swedish Academy of Science for the Nobel Prize did not figure her name. It was upon the insistence of her husband Pierre Curie that she was included for the Nobel Prize in 1903.

Even after many setbacks in life, her passion for research and teaching was unprecedented. Curie is the first woman in France to obtain a PhD in Physics. After Pierre Curie"s death, instead of accepting a widow's pension, she immediately joined the Sorbonne University and became the first woman to teach there. Curie's interest in science was primarily of understanding basic phenomenon rather than its commercial usefulness. She often reiterated that her discovery of radium was the work "of pure science" rather than aiming at any "direct usefulness" . Thus, rather than complaining about the roadblocks, she continued to pursue her goal with determination. It was only her strong will, honesty and determination, that helped to overcome the barriers, in both her native and her adoptive country. In my opinion, she will continue to inspire many future generations and will remain, unmistakably a figure of convictions and role model for the scientific world.

K. Indira Priyadarsini,
Former Head, Chemistry Division , BARC,
Raja Ramanna Fellow, DAE

NPPs that started Commercial Operation in 2019

Based on IAEA data base as on 31 December 2019, 450 nuclear power reactors are in operation worldwide, totalling 398.9 GW(e) in net installed capacity, an increase of 2.5 GW(e) since 2018. Nuclear power generated around 10% of the world's electricity in 2019 and remained the second largest source of low carbon electricity after hydro power.

In 2019, 30 countries generated nuclear power and 28 were considering, planning, or actively working to include it in their energy mix. Four of these countries, Bangladesh, Belarus, Turkey and United Arab Emirates, were building their first nuclear plants, with the plants in Belarus and the UAE nearing completion.

The IAEA's projections for global nuclear power capacity in the decades to come, depend in part on whether significant new capacity can offset potential reactor retirements.

New nuclear power reactors connected to the grid in 2019

1. SHIN-KORI-4, South Korea, APR-1400, Advanced Light Water Reactor
2. NOVOVORONEZH 2-2, Russia, VVER V-392M, Gen III+, PWR, 1114 MW(e)
3. TAISHAN-2, China, EPR, Gen III, PWR, 1660 MW(e)
4. YANGJIANG-6, China, Gen III, PWR, 1000 MW(e)
5. AK LOMONOSOV-2, Russia, Floating Nuclear power plant SMR, 32 MW(e)

SHIN-KORI-4, South Korea, APR-1400, Advanced Light Water Reactor

The APR-1400 is evolutionary advanced light water reactor designed by Korea Electric Power Company (KEPCO) that features improvements in operation, safety, maintenance and affordability based on accumulated experience as well as technological development. The key features with respect to previously standardised design are:

- Net Electric power: 1418 MW (40% increase)
- Design Life: 60 years (50% increase)
- Seismic Design Basis: 0.3 g (50% increase)
- Core Damage Frequency: less than 10^{-5}/yr (10x decrease)
- Core fuel assemblies: 241 (36% increase)

Several other changes are incorporated such as digital I/C and new systems in the Safety Injection System.

The core is designed for an 18-month operating cycle with a discharge burnup up to 60,000 MWD/MTU having a thermal margin of 10%. Up to 30% of the core can be loaded with Mixed Oxide fuel with minor modifications. The fuel is uranium dioxide with average enrichment of 2.6 w/o which is capable of producing an average volumetric power density of 100.9 W/cm^3.

APR-1400 has two coolant loops in the primary heat transport system. The loops are arranged symmetrically so the hot legs are diametrically opposed on the RPV's circumference. As the steam generators are elevated relative to the RPV, natural convection will circulate reactor coolant in the event of RCP malfunction. The pressurizer is equipped with a pilot-operated relief valve which not only protects against Reactor Coolant System over-pressure, it also allows manual depressurization in the case of a total loss of feedwater

NOVOVORONEZH 2-2, Russia, VVER V-392M, Gen III+, PWR, 1114 MW(e)

Unit 2 PWR, Model VVER V-392M was made critical on 22 March 2019, 30 days before the scheduled date as per Rosatom and connected to the grid on 1 May 2019. The Gen III+ reactor incorporates extra safety features to avoid disaster as suffered at Fukushima in 2011. The service life of the VVER is 60 years with extension of operation for 20 years.

The reactor has 20% increase in capacity on the previous VVER-1000 design. Safety improvements include a passive heat removal system that operates in the absence of electric power supply.

The lifespan of the main VVER equipment such as reactor and steam generator vessels has been "doubled from 30 to 60 years" and high-level automation and instrumentation has reduced operating personnel -requirements "by 30%- 40%," according to Rosatom.

TAISHAN-2, China, EPR, Gen III, PWR, 1660 MW(e)

The main design objectives of the Gen III EPR model are increased safety while providing enhanced economic competitiveness through improvements to previous PWR designs scaled up to 1650 MWe. The reactor can use 5% enriched uranium oxide fuel, reprocessed uranium fuel or 100% mixed uranium plutonium oxide fuel. The EPR is the evolutionary descendant of the Framatome N4 and Siemens Power Generation Division "Konvoi" reactors. The EPR is designed to use approximately 17% less uranium per unit of electricity generated than these older reactors.
The design had gone through a number of iterations. The 1994 conceptual design had a power output of 1450 MWe, the same as the Framatome N4, but using Siemens Konvoi derived instrumentation and including a new core catcher safety system.

The EPR design has several active and passive protection measures against accidents:

- Four independent emergency cooling systems, each providing the required cooling of the decay heat that continues for 1 to 3 years after the reactor's initial shutdown (i.e., 300% redundancy)
- Leak tight containment around the reactor
- An extra container and cooling area if a molten core manage to escape the reactor
- Two-layer concrete wall with total thickness 2.6 m, designed to withstand impact by aeroplanes and internal overpressure

The EPR has a design maximum core damage frequency of 6.1×10^{-7} per station per year. The EPR has a single steam turbine capable of using all the steam generated.

YANGJIANG-6, China, Gen III, PWR, 1000 MW(e)

The 1000 MWe Yangjiang 6, China general Nuclear (CGN) - designed ACPR1000 pressurised water reactor is the second plant to use third-generation nuclear technology. All the six operating reactors in the Yangjiang province produce a grand total of around 6100 MWe and is the largest nuclear power station in China. Yangjiang 6 becomes CGN's 23rd power reactor in commercial operation, with a combined capacity of 25.39 GWe.

The ACPR-1000 reactor is an advanced version of the CPR-1000 with complete domestic intellectual property rights and in line with post-Fukushima safety requirements.

The reactor comes with higher seismic standards than the older 1000 MWe reactor. It features a double containment and a reactor core catcher for

severe accident mitigation purposes. It also includes advanced features such as in-vessel retention and spray systems.

AKADEMIK LOMONOSOV-2, Russia, Floating NPP, SMR, 32 MW(e)

Akademik Lomonosov is a pilot project and a 'working prototype' for a future fleet of floating nuclear power plants and on-shore installations based on Russian-made small modular reactors (SMRs). These units will be available for deployment to hard-to-reach areas of Russia's North and Far-East, as well as for export. The plant is equipped with two KLT-40C reactor systems, each with a capacity of 35 MW, similar to those used on icebreakers. Each reactor is enclosed in a steel hermetic containment vessel to withstand the pressure. The reactor is comprised of reactor, steam generators, reactor coolant pumps, heat exchangers, pressurisers, valves and pipelines used for various purposes. It is 144 metres long and 30 metres wide, and has a displacement of 21,000 tonnes.

These small nuclear reactors can operate non-stop without the need for refuelling for three to five years, thereby considerably reducing the cost of electricity generation. The plants are planned to undergo servicing and maintenance at the Baltic shipyard once every 12 years. It will be refuelled every three years.

The reactors have the potential to work particularly well in regions with extended coastlines, power supply shortages, and limited access to electrical grids and the plant can be delivered to any point along a coast and connected to existing electrical grids.

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Dr. A. Rama Rao,
Former Asso. Dir., RDDG, BARC

Status of PET imaging in India

Dr. M. G. R. Rajan, Ex-RRF, Ex-Head, RMC, BARC, Ex-Dy CE, BRIT

Positron emission tomography (PET) imaging, a revolutionary nuclear medicine diagnostic procedure, became available in India for the first time in October 2002, with the commissioning of the Medical Cyclotron Facility (MCF) and PET scanner at RMC, BARC, by the Prime Minister of India. The PET trace Medical Cyclotron capable of 16.5 MeV proton beam or 8 MeV deuteron beam at the MCF can produce short lived positron emitters viz., fluorine-18 ($T_{1/2}$=110 min), oxygen 15($T_{1/2}$=2 min), nitrogen-13($T_{1/2}$=10 min) and carbon-11($T_{1/2}$=20 min). Of these, fluorine-18, is the work-horse of PET-imaging, and is converted to [F-18]-2-fluoro-deoxyglucose ([F-18]FDG) and administered to patients for PET scans.

(*Please await our next issue of Newsletter for full text - Editor*)

News Snippets

Britain has 139 tons of plutonium (Burden or a Resource).

The United Kingdom's last plutonium reprocessing plant, B205, located in Sellafield in northern England, will shut down by the end of 2020, bringing an end to the era of plutonium separation in the country. The UK has a stockpile of almost 139 metric tons of separated plutonium which is highly toxic and poses a permanent risk of proliferation. It is enough material to build tens of thousands of nuclear weapons. The Nuclear Decommissioning Authority of UK is working on the consolidation of the stockpiles in Sellafield and developing the capability to retreat the packages to allow for long-term storage once the government makes a final decision on permanent disposal. The United Kingdom views the material as a resource and is pursuing options that involve burning the plutonium in reactors. Another alternative would be to treat it as waste and begin planning for its permanent immobilization and burial.
https://thebulletin.org/2020/04/britain-has-139-tons-of-plutonium-thats-a-real-problem/

IAEA to Ship Vital Testing Equipment to Countries in the Fight against COVID-19

The International Atomic Energy Agency (IAEA) is dispatching first batch of equipment to more than 40 countries to enable them to use a nuclear-derived technique to rapidly detect the coronavirus that causes COVID-19. Dozens of laboratories in Africa, Asia, Europe, Latin America and the Caribbean will receive diagnostic machines and kits, reagents and laboratory consumables to speed up national testing, which is crucial in containing the outbreak. These kits are for the technique known as real time reverse transcription–polymerase chain reaction (real time RT-PCR). This is the most sensitive technique for detecting viruses currently available. The nuclear-derived DNA amplification method originally used radioactive isotope markers to detect genetic material from a virus in a sample. Subsequent refining of the technique has led to the more common use today of fluorescent markers instead.
https://www.iaea.org/newscenter/pressreleases/iaea-to-ship-vital-testing-equipment-to-countries-in-the-fight-against-covid-19

IAEA releases its report on Occupational Radiation Protection in the Uranium Mining and Processing Industry

On the occasion of World Day for Safety and Health at Work, celebrated every year on 28th April, IAEA presented its Safety Reports Series no. 100 titled 'Occupational Radiation Protection in the Uranium Mining and Processing Industry'. The Report addresses suitable methods for control, monitoring and dose assessment for occupational exposure, and adequate radiation protection programmes. These must be designed and implemented for each of the three main methods of producing uranium — underground mining, open pit mining and in situ leaching (sometimes referred to as in situ recovery). The same approach shall be taken for each step of the life cycle of a uranium mining and processing: exploration, planning, construction and operation, decommissioning, handover and surveillance.
https://www.iaea.org/newscenter/news/world-day-of-safety-and-health-at-work-new-safety-report-on-occupational-radiation-protection-in-the-uranium-mining-and-processing-industry

IAEA supports discharge of Fukushima Daiichi treated water

An IAEA team of experts said in a review published on April 2 that the two options for the controlled disposal of treated water stored at the Fukushima Daiichi nuclear power plant are "technically feasible." A Japanese advisory subcommittee outlined the two options, vapor release and discharge to the sea, for the water that is being stored at the plant following the 2011 accident. The IAEA team said that water management, including the treated water disposal, was critical to the sustainability of the Daiichi plant decommissioning activities and a decision on the disposition path for the stored treated water, after further treatment as needed—should be made urgently, considering safety aspects and engaging all stakeholders. Contaminated water from Daiichi is treated through the ALPS process to remove radionuclides, other than tritium, and then stored at the site. The total tank storage capacity will amount to approximately 1.37 million cubic meters by the end of 2020, and all the tanks are expected to be full around the summer of 2022.
https://www.iaea.org/newscenter/pressreleases/iaea-reviews-management-of-water-stored-at-fukushima-daiichi-nuclear-power-station

IAEA Sees No Radiation Related Risk From Fires In Chernobyl Exclusion Zone

As per IAEA, the recent fires in the Exclusion Zone near the Chernobyl Nuclear Power Plant (NPP) in Ukraine have not led to any hazardous increase of radioactive particles in the air. Basing its assessment on data provided by Ukraine, the IAEA said the increase in levels of radiation measured in the country was very small and posed no risk to human health. In addition, these radiation levels fall significantly with increasing distance from the site of the fires as per the IAEA's Incident and Emergency Centre (IEC), which has been in close contact with Ukrainian authorities since the fires began in early April.
https://www.iaea.org/newscenter/pressreleases/iaea-sees-no-radiation-related-risk-from-fires-in-chornobyl-exclusion-zo

All reasonable men adapt themselves to the world. Only a few unreasonable ones persist in trying to adapt the world to themselves. All progress in the world depends on these unreasonable men and their innovative and often nonconformist actions.....

- **George Bernard Shaw**

IAEA Video on 'What Happens to a Nuclear Power Plant During a Pandemic Lockdown?'

Currently, all 442 nuclear power reactors worldwide are in operation. They continue to provide 10 percent of the world's electricity and around one-third of its low-carbon electricity. Nuclear power plants can continue operation because of their contingency plans, which include what to do during a global pandemic, such as COVID-19. If there is a concern that not enough staff are fit for duty, nuclear reactors could be pre-emptively shut down and maintained in a stable condition.
https://www.iaea.org/newscenter/multimedia/videos/what-happens-to-a-nuclear-power-plant-during-a-pandemic-lockdown

IAEA Marks World Book and Copyright Day with Three Most Popular Publications

The IAEA makes freely available thousands of online scientific and technical publications for researchers, scientists and students worldwide. To mark World Book and Copyright Day (April 23) this year, the Agency is celebrating the IAEA Library and the three most popular IAEA publications of 2019 viz. IAEA Safety Glossary: 2018 Edition, Regulations for the Safe Transport of Radioactive Material: 2018 Edition and Nuclear Power Reactors in the World, 2019 Edition

https://www.iaea.org/newscenter/news/iaea-marks-world-book-day-with-three-most-popular-publications

Conferences/Webinars/Symposia/ Workshops/ Courses/ Fellowships:

Helping Nuclear Medicine and Radiotherapy Departments Deal with Covid-19: IAEA Webinars Draw Thousands

Over 4000 people worldwide have attended webinars hosted by the IAEA on how nuclear medicine and radiotherapy departments can operate as safely as possible during the unfolding COVID-19 pandemic, with special emphasis on infection protection control. The webinars held so far included "COVID-19 Pandemic- Challenges for the Nuclear Medicine Departments", "COVID-19 Preparedness for Radiotherapy Departments" in both English and Spanish and "ESR Connect Special Reports- Radiology in the fight against COVID-19" in partnership with the European Society of Radiology and the International Society of Radiology.
https://www.iaea.org/newscenter/news/helping-nuclear-medicine-and-radiotherapy-departments-deal-with-covid-19-iaea-webinars-draw-thousands

First IAEA Workshop on Supporting and Managing Nuclear Security Upgrades

IAEA held its first Workshop on **Supporting and Managing Nuclear Security Upgrades during March 2 – 6, 2020** at its headquarters in Vienna, Austria. It focused on managing the implementation and oversight of physical protection upgrade projects for facilities with nuclear and other radioactive materials. The

training brought together regulators, operators and high-level policymakers from nine countries at various stages of implementing security upgrade projects with IAEA assistance.
https://www.iaea.org/newscenter/news/first-workshop-on-supporting-and-managing-nuclear-security-upgrades

Stuck in Self Isolation? Here are Hundreds of IAEA Online Courses for Free

Hundreds of courses are available via the Cyber Learning Platform for Network Education and Training (CLP4NET) launched in March 2016. More than 27 000 people have already joined online courses on nuclear safety and security, radiation protection, sustainable energy development, the use of nuclear applications and more. Accessible to anyone who registers, the trainings are developed for people studying, teaching or working in the field of nuclear science and technology. This includes, among others, regulators, plant operators, health professionals or crime scene specialists working with radiation technologies.These online courses help to fill gaps in knowledge and overcome barriers in career development.
https://elearning.iaea.org/m2/.
https://www.iaea.org/newscenter/news/stuck-in-self-isolation-here-are-hundreds-of-iaea-online-courses-for-free

IAEA International Conference on Molecular Imaging and Clinical PET–CT in November

IAEA International Conference on Molecular Imaging and Clinical PET–CT (IPET-2020), will be held in Vienna, Austria, from November 23 to 27, 2020. IPET-2020 will focus on theranostics which is a major topic in global health that allows to provide personalized care tailored to the specific needs of the patients. Participants will have the opportunity to attend in person, as well as virtually, to learn about advances in the field, the challenges faced by countries to address theranostic applications and future developments and trends.
https://www.iaea.org/newscenter/news/call-for-papers-international-conference-on-molecular-imaging-and-clinical-pet-ct-in-november

New IAEA Fellowship to Support Women in Starting Careers in Nuclear

The IAEA has launched a fellowship programme to provide an incentive for young women to consider a career in nuclear science and technology. Named after twice Nobel Prize winner, the Marie Skłodowska-Curie Fellowship Programme aims to increase the number of women studying in nuclear science and technology and non-proliferation studies through scholarships and work experience opportunities. The initiative, by IAEA Director General Rafael Mariano Grossi, was presented at an Agency event in Vienna to mark International Women's Day.
https://www.iaea.org/newscenter/news/new-iaea-fellowship-to-support-women-in-starting-careers-in-nuclear

25th World Energy Congress to be held in Russia in 2022

The 25th World Energy Congress of the World Energy Council (WEC) will take place in St Petersburg at the ExpoForum, Russian Federation on 24–27 October 2022. The triennial global flagship event of the WEC, the Congress represents all sectors of the energy system and adjacent industries with over 5,000 delegates. The 24th World Energy Congress was held at Abu Dhabi, UAE during September 9 – 12, 2019.
https://worldenergycongressrussia.org/en/

World Nuclear Association Symposium 2020
The World Nuclear Association Symposium 2020 will be held at London, UK during September 9 – 11, 2020.
https://www.wna-symposium.org/

Compiled by S. K. Malhotra

One machine can do the work of fifty ordinary men. No machine can do the work of one extraordinary man

- **Elbert Hubbard**

The scientist is not a person who gives the right answers, he is one who asks the right questions….

- **- Claude Levi-Strauss**

Know Your EC Members

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INS News Letter is Published by S. P. Dharne on behalf of Indian Nuclear Society, Project Square, Anushakti Nagar, Mumbai – 400094, E- mail: indiannuclearsociety@gmail.com. Tel: 91-22- 2559 8327 & 2599 1097, Fax: 91-22-2557 6261, Website: www.indiannuclearsociety.com