Technical University of Denmark

Accelerator Department. Annual progress report 1 January - 31 December 1974

Forskningscenter Risø, Roskilde

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Abstract

A description is given of work in the fields of radiation bacteriology research, chemical dosimetry and radiation chemistry, physical dosimetry and irradiation technology, as well as the operation of various irradiation facilities. Appendices include specifications of the irradiation facilities and a list of publications.

Abstract to

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CONTENTS

I. GENERAL INFORMATION

The objective of the Accelerator Department is to contribute to research, development, and the implementation of processes based on ionizing radiation; thus the following activities are carried out:

- Operation and maintenance of the irradiation facilities (three electron accelerators and three ^{60}Co-units).
- Customer irradiation services for laboratories within and outside Risø, for hospitals, and for industry.
- Irradiation technology studies, including the upgrading of present facilities, development of new irradiation equipment, and improvement of equipment and methods for customer irradiation services.
- Design and construction of equipment for radiation experiments.
- Radiation chemistry research in relation to chemical dosimetry and pulse radiolysis of aqueous solutions connected with fundamental problems in chemistry. This research is carried out in close collaboration with the Risø Chemistry Department and with research groups other countries.
- Radiation physics research in relation to systems used in dose calibration and dose distribution measurements, mainly through development of new methods such as holography and interferometry.
- Radiation bacteriological research mainly in relation to radiation sterilization problems and radiation resistant microorganisms, and also to increase basic knowledge of the radiation resistance mechanism.
- Production and supply (through the IAEA) of bacteriological standard preparations for control of irradiation sterilization plants.
- International collaboration on the subjects mentioned above, including IAEA research contracts and participation in international meetings and working groups. Bilateral collaboration arrangements are maintained with a number of scientific laboratories in Europe and in the United States.

II. EVENTS OF THE YEAR

K. Sehested was appointed head of the department as of May 7, 1974.

The "First Milestone" acceptance test for the new HRC Linear Accelerator took place, slightly behind schedule, in January 1974.

The "Second Milestone" acceptance test was concluded in August 1974 and the final "Third Milestone" is scheduled for March 1975.

A research contract was renewed with the International Atomic Energy Agency concerning investigations on the behaviour of the Fe^{++}/Cu^{++} chemical dosimeter under process conditions, including the influence of solute concentrations on the system.

A further research agreement with the IAEA was renewed concerning investigations on the microflora in the surroundings of reactors, irradiation plants, and other areas with a high level of irradiation over a long period of time.

Microbiological standard preparations for efficiency testing of medical radiation sterilization plants were prepared and issued according to the IAEA's Code of Practice, and two industrial plants were tested by the department in 1974.

A staff member studied holographic and interferometric methods at the U.S. National Bureau of Standards (1 October 1973 - 1 October 1974).

Staff members and/or consultant (Dr. Ebbe A. Christensen) participated in the following meetings, seminars or conferences:

- 5th International Congress of Radiation Research, Seattle, U.S.A. (14-2o July 1974).

- Fundamentals and Applications of Optical Information Processing and Holography, Boulder, U.S.A. (12-16 August 1974).

- Genetic Manipulations of Plant Material. Nato International Summer School, Liége, Belgium (3-18 August 1974).

- Radiation Sterilization of Industrial Products, Brussels, Belgium. Commission of the European Communities (18 February 1974).

- Technical Development and Prospect of Sterilization by Ionizing Radiation, Vienna, Austria. Johnson & Johnson, U.S.A. (1 April 1974).

- Revision of the IAEA Recommended Code of Practice for Radiation Sterilization of Medical Products, Vienna, Austria. IAEA (5 April 1974).

- Ecology of Microorganisms Introduced into Hospitals from Non-human Sources, Copenhagen. North-West European Microbiological Group (21-23 August 1974).

- Biologiske Risici i Forbindelse med Atomkraftanlæg, København. Medicinsk Selskab i København (1 oktober 1974).

- Nordisk Fællesmøde for Centralsteriliseringsklubberne, Gøteborg (23-25 oktober 1974).

- Possibilities of Ionizing Radiation Applications, Belgrade, Yugoslavia. Administration for Technical Cooperation of Socialistic Republic of Serbia (20-29 October 1974).

A student from Egypt studied dosimetry during an 8 month period. This visit was arranged by the DANIDA organisation.

A position as bacteriologist, vacant for 7 months, has now been filled. A position as physicist/chemist is still vacant.

Risø's old mail van was transferred to the department to transport samples for irradiation to the Cobalt facility in the Agricultural Department. The rebuilding of the Conference Room was completed.

III. REPORT ON ACTIVITIES

III. 1. Operation and Maintenance of Irradiation Facilities[x)]

a. Electron Linear Accelerator (Varian)

In the past year the linac was used for radiation chemistry, mainly pulse radiolysis, radiation microbiology and irradiation services for customers inside and outside Risø, one day a week for sterilization of special items from hospitals.

The linac operated for 1750 hours. It was shut-down for two weeks due to preparation of some of the installations for the new HRC linac.

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x) Technical specifications of the facilities are listed in Appendix 2.

At the end of the year, five of the sixteen coils in the magnetic focusing element of the second accelerator waveguide shorted on three occasions. Water from a minor leak in one of the four integrated cooling tubes had destroyed the coil insulation. The faulty tube was disconnected. Should a few more coils malfunction, it may be impossible to operate the linac at a high repetition rate. A spare magnetic element is in stock, but to carry out a replacement would be very time-consuming, and is not advisable when the machine is due to be shut-down about February 1975.

No substantial spare parts were purchased in the past year except a new klystron (bought in March) to replace the spare klystron, which could not be repaired after malfunctioning, as mentioned in the last annual report.

b. HRC Electron Linear Accelerator

The construction of the new linac progresses well and in accordance with conditions in the contract for delivery.

The "First Milestone" acceptance test was completed in January 1974. The acceptance test included the High Voltage Injector System (power supply, electron gun, accelerator column and pulse sweeper).

The "Second Milestone" acceptance test was completed in August 1974, and included the Transmitter System containing the high voltage modulator and the high power microwave klystron amplifier.

The "Third Milestone", the accelerator waveguide and the complete accelerator system, is scheduled for March 1975. The delivery of the complete linac will take place shortly after, and it is thus expected to arrive at Risø in April 1975. The majority of spare parts and test instruments are on order and will be delivered together with the linac.

The design of the major parts of the beam-handling system is nearly completed. Two switching magnets for the individual beam ports in the accelerator room and target room and a triplet quadrupole are on order from Industrial Coils Inc., Boston. These components will be delivered together with the linac. The remainder of the components for the beam-handling system, including beam monitors, are designed by the Engineering Department and/or Accelerator Department. Several other components essential for the machine and the installation are or will be constructed by the Risø Workshop: a 90° bending magnet chamber, modification of the present scanner chamber, a beam shutter, beam collimator, beam slit, beam flight tube, supports and fixtures for the individual components such as injector, accelerator waveguide, the rectangular waveguide system, etc.

The x-ray shielding of the target room is designed in cooperation with the Engineering Department, the Health Physics Department and the Service Department. The purpose of establishing a target room is to have an irradiation facility for low level radiation (single pulse and up to 12.5 pulses per second), where the experimental apparatus (pulse radiolysis, etc.) can be permanently set up, in contrast to the time-consuming handling in the present situation where apparatus must be dismantled once or twice a week when running the accelerator at high radiation level. The ideal shielding of the target room proved to be too expensive, so a far cheaper alternative, including a local lead shield around the target, was worked out. This compromise fulfils the requirements with only a few drawbacks.

The exterior installations, water cooling, air cooling, air-conditioning, electrical power, hoists, beam conveyor, concrete shielding blocks, etc., will be ready for installation in the period prior to the installation of the linac.

c. Field Emission Accelerator (Febetron)

The field emission accelerator was used for aqueous and gaseous radiation chemistry research.

A visit at the beginning of the year by Field Emission Corporation's chief service engineer seems to have solved the problems with the faulty capacitor modules. He suggested that the problems were caused by excess humidity of the insulating gas. The insulating gas had not been checked for some time, and this may have resulted in too high humidity in the machine. The company now recommends a humidity lower than 3 ppm, rather than 12 ppm as stated in the accelerator manual.

The service engineer also gave advice on testing and cleaning the capacitor modules, and demonstrated a tesla coil check which could show pinholes in the module insulation. A high voltage check which could determine the pressure of internal defects in a module was demonstrated, and advice was given on how to repair defective modules. This procedure is only intended for use in case of emergency.

The accelerator was then operated with some 35 repaired modules, but the pulse-to-pulse reproducibility was good and self-fire events were rare. An overhaul in August showed no new defective modules, but most of the repaired modules had failed again. 25 new modules were installed, and the remaining "defective" modules will be replaced during the next overhaul. At the same time a monitor for measuring the humidity of the gas was installed and the operating voltage was lowered to 3o kV. The accelerator has performed well with practically no self-triggering in the last three months.

d. Low-Energy Electron Accelerator (ICT)

The low-energy electron accelerator was used for applied radiation chemistry studies (e.g. curing of surface coatings and polymer film modifications).

The operation of the accelerator was without troubles, but utilization was very low. It is intended to try to make use of the power supply for experiments with the cold cathode accelerator (see section III 5c).

e. 1o,ooo Ci ^{60}Co-Facility

The 1o,ooo Ci ^{60}Co-facility was used for radiation research and for customer services. It further serves as a reference source for microbiological efficiency testings according to the IAEA's recommendations for the radiation sterilization of medical products.

There was no major problems in operation except for the renewal of two thyratrons.

f. 5,ooo Ci ^{60}Co-Cell

The 5,ooo Ci ^{60}Co-cell is presently located in the Control Department of Statens Seruminstitut, Copenhagen, where it was used for bacteriological research.

The new sources (4,ooo Ci) were installed in the facility in March 1974 by the Service Department. The source was then recalibrated with the Fricke dosimeter.

g. 3,ooo Ci ^{60}Co-Cell

The 3,ooo Ci ^{60}Co-cell was used for research in radiation chemistry radiation bacteriology, and radiation biology including mutation breeding.

Operation of the cell was satisfactory, but the movable leadplug has become additionally scratched in the past year.

III. 2. Radiation Bacteriology Research

Bacteriological research concerns development and testing of radiation sterilization processes, and assistance to prospective users on specific projects. Research interests are concentrated on the mechanisms of radiation resistance, possibilities of unintentional accumulation of radiation resistant mutants and possible infectious radiation resistance.

a. Bacteriological Research Projects

A series of experiments on the radiation inactivation of bacteria at high temperatures were published (Appl. Microbiol. 27, 83o 1974). Vegetative bacteria like Streptococcus faecium, strain $A_2$1, and Micrococcus radiodurans, strain R_1, have much reduced radiation resistance at 8o°C, while spore formers like Bacillus subtilis var. niger and Bacillus sphaericus, strain C_IA, have almost unchanged radiation resistance at 8o°C, and have reduced, but often high radiation resistance at 1oo°C, depending on dose rates, preparation method, etc.

The "Investigations on the microflora in the surroundings of reactors, irradiation plants and other areas with a high level of irradiation over a long period of time" (IAEA Research Agreement No. 975-R3/CF), are now concentrated on anaerobic bacteria, because very little is known about the radiation resistance of anaerobes, except Clostridium botulinum. Progress was slow due to technical difficulties and lack of manpower.

About 1oo strains of radiation resistant Pseudomonas sp. from rice imported to Denmark were isolated. This group of bacteria has been termed Pseudomonas radiora by its discoverers Ito and Iizuka, Japan. According to Dr. Lautrop, Diagnostic Bacteriology Department, Statens Seruminstitut, it is an atypical Pseudomonas, gram variable instead of gram negative, with several unusual characteristics. The radiation resistance of these strains is at the same level as the resistance of the majority of endospores of bacteria. Pseudomonas radiora is, however, not spore-forming. The strains are easily isolated directly from nature without prior radiation. Pseudomonas radiora might be a useful partner for Pseudomonas aeroginosa in experiments on infectious radiation resistance.

Work was started on radiation resistant strains of Acinetobacter calcoaceticus (Bacterium anitratum) with the goal of investigating the genetics of radiation resistance.

b. Production and Supply of Microbiological Standard Preparations and Biological Indicators

The laboratory produces, supplies and assays standard preparations of Streptococcus faecium, strain $A_2$1, and Bacillus sphaericus, strain C_IA, according to the IAEA recommendations for radiation sterilization of medical products.

Two Danish radiation facilities were tested in 1974, and a test of biological efficiency at a third radiation plant is in progress. Biological standard preparations were exported on two occasions.

c. Customer Services for Hospitals, Research Laboratories and Industry

The following services are maintained on a routine basis:

- Sterilization services for Scandinavian hospitals, including general consultation, irradiation of test specimens, evaluation of materials and packagings, etc., in relation to the introduction of new hospital equipment.

- Experimental irradiation of medical products, pharmaceutical raw materials, fodders, and articles for industry and research laboratories.

The investment in manpower and machine hours in these services is small but the services appear to be much appreciated, particularly by hospitals.

III. 3. Chemical Dosimetry and Radiation Chemistry

Work within this area concerns:

- Performance of routine dosimetry in relation to irradiation experiments and customer irradiation services.

- Development and exploitation of chemical dosimetry systems.

- Radiation chemistry and pulse radiolysis research.

Research work concentrates on investigating the reaction mechanisms and kinetics of irradiated aqueous solutions with a view to obtaining a better understanding of the possibilities and limitations of the practical application of aqueous chemical dosimeters, and to contributing to radiation chemistry knowledge in general.

Radiation chemistry and pulse radiolysis research is carried out in collaboration with the Risø Chemistry Department; Hilbert Christensen, Studsvik, Sweden; Edwin Hart, Argonne, U.S.A.; Martin Fielden, Sutton, U.K.; N. Getoff, Vienna, Austria; and J. Sutherland, Brookhaven, U.S.A.

a. Routine Dosimetry Services

Routine dosimetry was carried out in connection with customer irradiation services and irradiation experiments. After reloading of the 5,000 Ci ^{60}Co-cell at Statens Seruminstitut a calibration of the facility was performed with the Fricke dosimeter.

b. Development of Chemical Dosimetry Systems

The research contract with the IAEA (No. 1173/R1/RB) was renewed. The contract covers investigation of the behaviour of the Fe^{++}/Cu^{++} chemical dosimeter including the influence of different solute concentrations and doses on the system.

The rate constants for the reactions $Fe^{++} + Cu^{+++}$, $Fe^{+++} + Cu^{+}$ and $Fe^{+++} + SO_4^{--}$ and the Cu^{+} spectrum in UV were determined by pulse radiolysis. A series of solute parameter experiments were performed. The Chemistry Department has synthetized a Cu^{+}-complex with cyclooctadien to be used in a competition study for the determination of the ratio of the rate constants for the reactions $Fe^{+++} + Cu^{+}$ and $O_2 + Cu^{+}$.

Part of the work was reported at the 5th International Radiation Research Conference, Seattle, July 1974. The work was reported in an IAEA Progress Report and a publication is being prepared.

The possibility of incorporating the Fe^{+++}/F^{-}-dosimeter in a gel was investigated by an Egyptian guest worker. In spite of using several types of gel, the results proved negative and no more work will be done on this project.

c. Radiation Chemistry

The study of the different methylated benzenes was extended and a paper concerning the H, OH and O^{-} reactions, the different methylated benzyl radicals and their behaviour in the water elimination reaction has been accepted for publication in J. Phys. Chem. The investigations concentrated on the new transient at longer wavelength assigned to the positive radical ion. A new transient in UV, with almost double the extinction belonging to the same radical ion, was discovered. The transient species are found for all compounds at slightly different wavelengths and with different formation and first order decaying rate constants. The precursor is the OH-adduct in acidic medium and the decay can be correlated to the build-up of the benzyl radicals.

An attempt to prove the existence of the positive species was made by investigating the same compounds in non-aqueous media, e.g. in hexan, 1.2 dichloroethane, carbontetrachloride, etc., where positive species are formed by charge transfer from the solvent ion. The same transients were found, slightly shifted in wavelength, but the literature does not agree on the assignments. Some measurements were performed with the aim to transfer the charge to anilin because the anilin positive ion has a known spectrum. Due to the fact that the rate constants involved are more or less similar, the extinctions only indicated that a charge transfer takes place.

One staff member spent a few days in Stockholm to carry out some preliminary experiments on the transient conductivity set-up at the Technical University. The experiments showed that some ionic species are involved in the reaction, but a final conclusion from the preliminary results is not possible at the moment.

To prove the theory of positive radical ion formation from OH-adducts in acid solutions, a new system was chosen in which the positive ions in organic solvents are well known and agreed upon. The biphenyl in aqueous solution was investigated, and in spite of its poor solubility in water the results proved as expected. The OH-adduct shifts by reaction with protons into the biphenyl positive ions with absorptions at 380 and 660 nm. A paper concerning this reaction was accepted by J. Phys. Chem.

The work on benzene in alkaline solution and the behaviour of the phenyl radical was postponed because of lack of manpower. Some experiments, however, were made with benzene in very strong acid solutions to investigate positive ion formation. The preliminary results showed formation of the dimer positive ion with absorption above 900 nm.

Aromatic nitriles in aqueous solution were investigated (J. Holcman, funded by Dansk Flygtningehjælp (the Danish Refugee Organisation)) and the protonation reaction for benzonitrile electron adduct was determined and the absorption of the product, different from the H-adduct, was found. A paper has been accepted for publication in Trans. Faraday Soc.

The SO_2 in acid aqueous solution was further investigated on the background of recent conclusions, which did not fit our interpretation of the results. A paper on these discrepancies will be written when J. Sutherland visits the department in January.

Work on the pulse radiolysis of adrenaline (in collaboration with Professor N. Getoff) was continued during a 3-month visit by a graduate student (M. Gohn). Work concentrated on the determination of rate constants and of the main products from γ-radiolysis (in collaboration with the Risø Chemistry Department). Additional experiments on product determination (using GC-MS) are planned.

A series of experiments was performed for determining the oxygen consumption in aqueous solutions by irradiation. It was shown that an aqueous solution (O_2 in pure H_2O, phosphate buffer, H_2O + t-butanol, H_2O + bacteria) cannot be depleated of oxygen to lower concentrations than 10^{-7} M by irradiation, whereas solutions with an initial concentration of oxygen lower than

10^{-7} M do not change concentration through irradiation. This work is done in collaboration with Dr. E. Martin Fielden, Institute of Cancer Research, Royal Cancer Hospital, Sutton, U.K.

III. 4. Physical Dosimetry

The objective of physical dosimetry activities is to investigate physical problems related to radiation research and processing, in particular

- to provide standardization equipment for dose calibration of the irradiation facilities, e.g. by calorimetric, holographic and interferometric techniques.

- to develop and exploit new physical dosimeter systems for routine use in radiation research and processing.

Calorimeters based on conventional temperature sensors are available for calibration of the facilities in different irradiation geometries. A laser technique, measuring the changes in the refractive index of irradiated solutions, was introduced as a tool for dose and dose-distribution calibrations of electron beams.

The development program is mainly directed towards providing better experimental dose-distribution data to improve the monitoring techniques for straight beam experiments at the linear accelerator and the field emission accelerator.

Close collaboration is maintained with W.L. McLaughlin, National Bureau of Standards, U.S.A.

a. Optical Technique and Instrumentation for Dose Calibration

During the past year a staff member has studied holographic and interferometric techniques for determination of dose and dose distribution at the National Bureau of Standards, U.S.A.

Dose distributions from 3 MeV electrons from a Van de Graaff accelerator are measured by means of holography in

1) liquids of different density (from 0.7 to 2.5).

2) water layers thinner than the electron range and with materials of different density surrounded by water.

3) water with odd shaped objects immersed in the water.

A report is under preparation.

The work with the interferometric technique was concentrated upon increasing the sensitivity and decreasing the rise time, so that it might be possible not only to measure directly absorbed energy from an electron beam, but also the heat changes in time due to endo- and exothermic chemical reactions, introduced by the electrons. The following specifications were obtained with the interferometer built at the National Bureau of Standards: Sensitivity: 10^{-3} °C, rise time: 0.2 µsec, and measuring time range: from 1 µsec to 1 sec. These specifications should be sufficient to measure the released heat in a chain reaction, e.g. a polymerization reaction. This proved possible in a specific case, but the preliminary results showed a value much lower than theoretically expected. This may have been caused by the very high dose rate from a Febetron used to initiate the reaction such that the yield was lower than expected. This type of experiment will be continued.

During the stay a photon-counting densitometer was built in order to investigate the characteristics of such an instrument. It was shown that the sensitivity and accuracy might be better than a conventional instrument, but it would require extremely long measuring times. Two progress reports were prepared.

b. Film Dosimetry

PVC films and radiochromic dye films were used for dose and dosedistribution measurements of the scanned beam at the linear electron accelerator and at the low-energy electron accelerator. Work on preparing radiochromic dye film dosimeters resulted in an optimizing of the casting technique and chemical composition. The film is being calibrated. The work is carried out in collaboration with W.L. McLaughlin, NBS.

Performance testing of the dosimeters: PVC, Clear Perspex, Yellow Perspex, Red Perspex, Cellulosetriacetate, Blue Cellophane, and radiochromic dye films was completed and a report sent in for publication.

III. 5. Irradiation Technology

The objectives of the work are:

- to provide experimental equipment and irradiation technology know-how for research and pilot plant projects carried out at the irradiation sources.

- to engage in development projects of relevance to the industrial exploitation of ionizing radiation.

The first objective is part of our continued efforts to improve customer irradiation services. Some attempts in this direction have already been described in the previous sections. The second objective is based on the philosophy that the availability of cheaper and more reliable low-energy electron accelerators could be useful in radiation chemical processing. Some years ago a modest project was initiated in contact with Danish industry to exploit the possibility of constructing a small, simple accelerator unit based on a cold cathode.

a. Pulsed Deuterium Lamp Equipment

The lamp is usable in the UV range from 2oo-3oo nm, and will be used in connection with the pulse radiolysis equipment. The advantage of this lamp is the high stability compared to the Xenon lamp. The light area is very small, 1 mm^2, which gives a high light density.

The first lamp used was a standard Original Hanau type D 2ooF Deuterium lamp. By pulsing this lamp, i.e. increasing the current for a time period of loo ms, a magnification of seven times the light intensity was obtained. A further increase of current saturated the lamp. In order to increase the ionization cross-section of the gas in the lamp, a new construction with higher gas pressure is being developed by Original Hanau. It is expected that the light intensity can be increased by a factor of twenty with this new lamp.

The design and construction of the electronic equipment for pulsing is nearly finished.

b. Computer Equipment for Pulsed Radiolysis

The department acquired computer equipment removed from another experiment. The equipment will be used for on line analysis of pulsed radiolysis experiments and will substantially reduce the cost of polaroid films. It consists of:

PDP8-I minicomputer with 4 k memory,

32 k back up disc memory,

teletype control terminal,

fast paper tape reader and puncher,

a laboratory unit with display control and some analog input chanals,

a storage display unit,

some digital input and output chanals,

an analog output chanal.

A software display processor was written, which will make it possible to control the display unit by simple instructions (e.g. text or vector instructions). These instructions will be decoded and executed by the display processor. For the first few months there were many errors on the equipment, but after repair it has performed well.

A Biomation Model 8100 sampler unit which is needed for the new linac will be interfaced with the computer and also used for research.

Contact has been made with the group at Carnegie-Mellon University (Pittsburgh, Penn., U.S.A.) who have used similar (but larger) equipment in connection with pulse radiolysis for several years.

c. Development of a Cold-Cathode Accelerator

The testing of the electron gun was performed later than expected due to difficulties with the high voltage electrodes. The construction of a bigger and more suitable vacuum chamber was necessary. A test up to 125 kV, the upper limit of the power supply, was performed with good results. The current at this voltage is about 1 mA, but as the current-voltage characteristic is almost exponential, a potential of 200 kV is expected to give the rated current of 5 to 10 mA. However, a regulation up and down in current is possible. In order to increase the high voltage we intend to make use of the 400 kV, 50 mA transformer from the ICT accelerator.

Another version of the cold cathode was developed. This device employs a plasma which is generated within a low-voltage discharge, and the emerging electron beam, approx. 50 mm in diameter, is very broad compared to the 2mm beam from the previous gun. The beam current extracted from the discharge is controlled by means of a grid system in a manner very similar to that employed in a conventional vacuum triode. After extraction from the discharge plasma, the electron beam is accelerated in a plasma-free region to high energy. The accelerating region is at the same pressure as the plasma column, but the discharge is not struck because of small apparatus dimensions compared to the mean-free path of the molecules and the charged particles. This gun was tested up to 125 kV, but problems in the plasma region led to further investigations of the behaviour of the plasma through probe measurements.

In order to increase the voltage a new shielding against bremsstrahlung must be made. In spite of the low current, the x-ray radiation level is several tens of roentgen per hour.

A report on the cold-cathode work is under preparation.

The joint project with the Metallurgy Department on the development of a prototype electron beam welder, based on the hollow cathode principle, was not put into operation because the project does not seem profitable.

Staff of the Accelerator Department

31 December 1974

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J. Fenger	
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Dr. E. Hart, Chemistry Division, Argonne National Laboratory, U.S.A.

Dr. W.L. McLaughlin, Applied Radiation Division, National Bureau of Standards, Washington, D.C., U.S.A.

Visiting Scientists

H. Christensen, AB Atomenergi, Studsvik, Sverige (11-14 February 1974).

E. Hart, Chemistry Division, Argonne National Laboratory, U.S.A. (21 March - 1o April 1974).

P. Aagaard, AB Atomenergi, Studsvik, Sverige (25 - 27 March 1974).

N.B. El-Assy, Egypt (1 April - 21 November 1974).

W.L. McLaughlin, National Bureau of Standards, Washington, D.C., U.S.A. (5 - 1o April and 5 - 17 July 1974).

Z.P. Zagorski, Institute of Nuclear Research, Warsaw, Poland (21 April - 2o May 1974).

J. Kroh, Institute of Applied Radiation Chemistry, Lodź, Poland (13 - 15 May 1974).

H.C. Sutton, Institute of Nuclear Sciences, D.S.I.R., New Zealand (2o - 21 June 1974).

P. Loaharanu, Atomic Energy for Peace, Bangkok, Thailand (24 - 25 June 1974).

M. Gohn, Institut für Radiumforschung und Kernphysik, Vienna, Austria (12 September - 6 December 1974).

J. Fodor, J. Kcrecsen, S. Czegledy, S. Hegyesi, L. Bodnar and T. Schmidt, Hungary (7 - 11 October 1974).

K. Brázdová, Medical Faculty, BRNO, Czechoslovakia (7 October 1974).

T. Akiha, Hirosaki University, Japan (3o October 1974).

Visiting Student

M. Draganić, Yugoslavia (25 July - 2o September 1974).

Irradiation Facilities at the Accelerator Department

Electron Accelerators

1. Linear Electron Accelerator, Varian Ass., Model V-7700

Specifications:

Electron energy	10 MeV
Average electron current	550 µA
Peak electron current	330 mA
Pulse length	0.2-7 µsec
Pulse repetition rates	single pulses and 1 to 300 pps
Scan width of bent beam	40 cm

The linear accelerator, which was installed in 1960, has over the years logged a little less than 50,000 hours of operation. Facilities are available for process irradiation and for a variety of research applications including pulse spectroscopy and X-ray experiments.

2. Field Emission Electron Accelerator, Febetron Model 705B

Specifications:

Electron energy	0.5-2.0 MeV
Peak electron current	4000 A
Pulse length (electron mode)	20 nsec

3. Low-Energy Electron Accelerator, High Voltage Eng. Corp., Model EPS 400-IND

Specifications:

Electron energy	400 keV
Electron current	50 mA
Scan width	120 cm

The accelerator, which was installed in 1970, is provided with conveyors to permit pilot-plant testing of dye-curing processes and polymer film modification processes.

^{60}Co-facilities

10,000 Ci ^{60}Co-facility (built at Risø 1957)

The facility is designed for very homogeneous irradiation of samples with a maximum length of 1,000 mm and diameters of maximum 180, 100, or 60 mm. The corresponding maximum dose rates (9,000 Ci, 1 January 1975) are 4.9×10^5 rads/h, 1.27×10^6 rads/h, and 3.1×10^6 rads/h respectively. A report describing the facility and its calibration (together with the 3,000 Ci ^{60}Co-cell) has been published as Risø-M-1651.

5,000 Ci ^{60}Co-cell (built at Risø 1971)

The facility, which is designed for laboratory use, is fitted with a 123 mm$^{\varnothing}$ x 150 mm irradiation chamber. The dose rate in the centre of the chamber (6,000 Ci, 1 January 1975) is 5.1×10^5 rads/h. The cell is located at the Control Department, Statens Seruminstitut, Copenhagen. The cell was reloaded to 6,700 Ci in March 1974.

3,000 Ci ^{60}Co-cell (built at Risø 1968)

The facility, which is designed for laboratory use, is fitted with a 120 mm$^{\varnothing}$ x 200 mm irradiation chamber. The dose rate in the centre of the chamber (2,900 Ci, 1 January 1975) is 2.8×10^5 rads/h. A report describing the cell and its calibration (together with the 10,000 Ci ^{60}Co-facility) has been published as Risø-M-1651.

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