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DEPARTMENT OF TECHNICAL PHYSICS

OTANIEMI FINLAND

HELSINKI UNIVERSITY OF TECHNOLOGY

Otaniemi, Finland

Annual Report of the Reactor Laboratory in 1970

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1. Review of the Reactor Laboratory Activities in 1970

The activities of the Reactor Laboratory were affected by increasing activity in the nuclear field as a result of a decision to build a nuclear power plant, and also by the favourable economic situation. The importance of the Laboratory in training nuclear experts was accentuated.

Cooperation with industry increased considerably during the year. Tracer studies, neutron radiography and isotope production were important new forms of service.

The newsletter "The Reactor Laboratory informs", which is sent to 1000 key people in industry and research establishments, appeared 4 times.

1451 registerered visitors visited the Reactor Laboratory in 1970, 203 of them foreigners.

On 25.-27.8.70 the Laboratory arranged a Triga Users' Seminar, with 30 participants form 8 countries. The Laboratory also helped to organize the IAEA "2nd International Conference on Nuclear Data for Reactors".

The operation time of the reactor and energy generation remained at the level of the previous year. With one working shift these figures cannot be raised appreciably. Reactor utilization increased, however, due to the growing number of simultaneous experiments.

Irradiation activities increased greatly, especially with regard to samples for outside customers. As a result of the need for tracer study samples the total activity produced rose in one year by factor 3 to 26 Ci. Correspondingly the number of active samples delivered to industry or technical research establishments rose 400 % to 230 samples.

The research programme greatly benefited from the strong financial support given by the Ministry of Commerce and Industry to some larger investments. Thus it was possible, outside the normal budget, to buy components for the new cold neutron source, a television monitor system, a TV system for neutron radiography, β-current detectors, a noise measurement system and components for a new neutron diffractometer.

The Laboratory was financed mainly by the Ministry of Commerce and Industry through the Atomic Energy Commission. Funds were distributed as follows:

Ministry of Commerce and Industry/AEC: Scientists' salaries 610,000,-, technical staff 102,000,-, equipment and operational costs 275,000,-, travel costs 21,000,-.

Helsinki University of Technology: Salaries for the Operations Division and Radiation Protection Division 291,000,-, basic equipment 300,000,-, laboratory equipment 30,000,-. Service charges rose to 100,000,-. The total budget is thus ≃ 1.7 Mmk.

Expansion of the Laboratory's activities is increasingly restricted by lack of space. Unfortunately, no funds have as yet been allocated for starting the final planning of the new Isotope Laboratory.

The organization of the Reactor Laboratory changed on 1.6.1970 according to Fig.1.

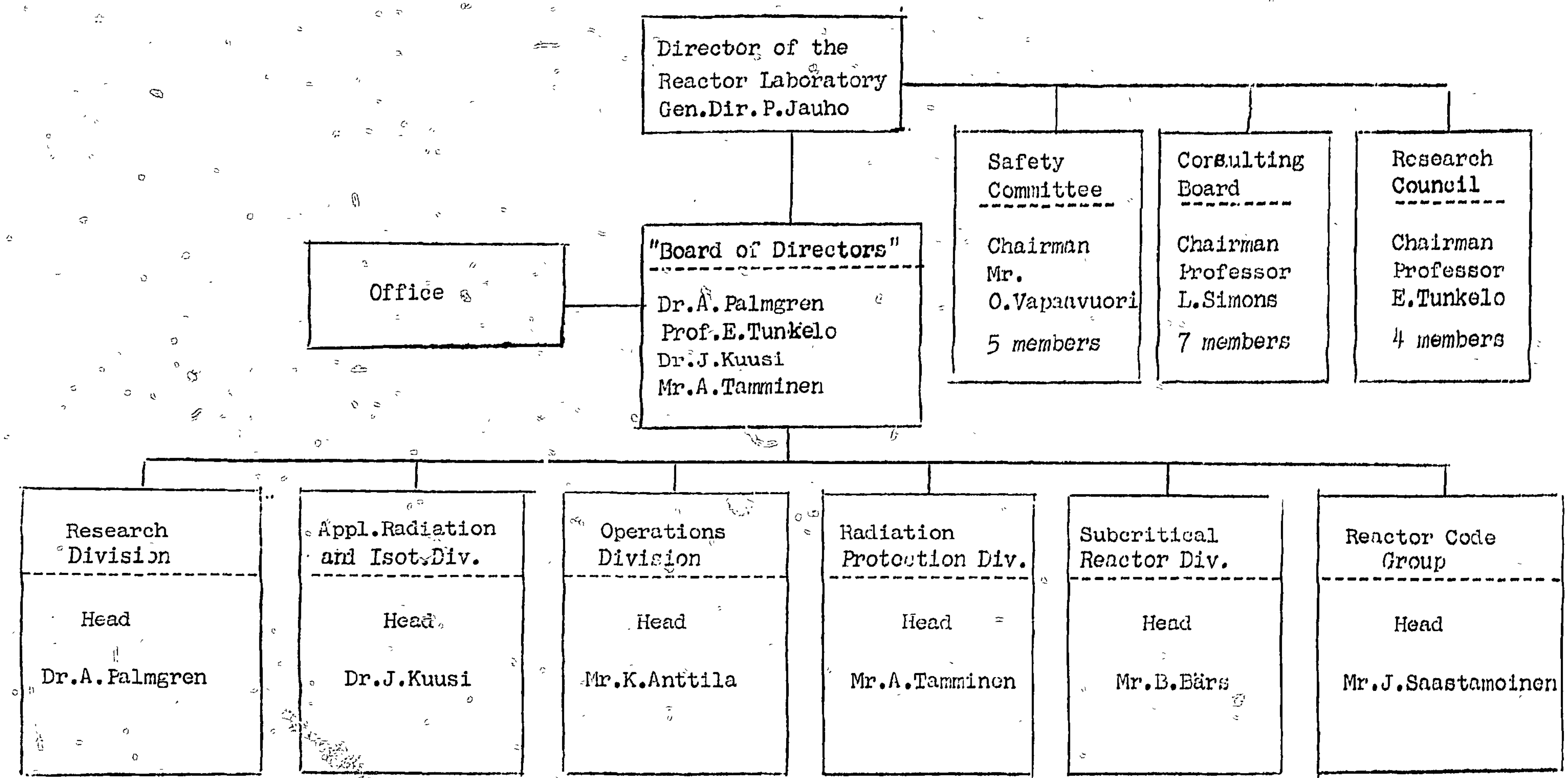
The Director of the Laboratory, Professor P.Jauho, was appointed Director General of the State Institute for Technical Research as of 1.6.1970, but he has still continued as Director of the Reactor Laboratory. Dr.A. Palmgren was appointed Deputy Director as of 23.3.1970.

Dr A.Palmgren was Head of the Research Division. Working within the Division were: Associate Professor E.Tunkelo, Mr.P.Hiismäki, Mr.J.Junttila, Mr.J.Kajamaa, Mr.A.Lundán, Mr.H.Pöyry, Mr.A.Rastas (from 1.8.70 in the Reactor Code Group), Mr.H.Reijonen and Mr.J.Virtamo. Dr.W.-D.Seiffert worked as a visiting scientist. In the Applied Radiation and Isotopes Division were: Dr.J.Kuusi (Head), Mr.H.Aalto, Mr.J.Heinonen, Mr.E.Häsänen, Mr.R.Kuoppamäki, Mr.B.Palmén, Mr.R.Rosenberg and Mr.R.Uhlenius, and, employed by the Oy Medica Ab pharmaceutical factory, Mr.M.Saviranta and Miss M.Meinander. Mr.K.Anttila was Head of the Operations Division, to which Mr.M.Suniala, Mr.U.Sainio and Mr.O.Tiainen also belong. Mr.A.Tamminen was Head of the Radiation Protection Division and Mr.B.Bärs Head of the Subcritical Reactor Division. The other members were Mr.E.Markkanen, Mr.S.Salmenhaara and Mr.J.Vaurio.

Dr.J.Kajamaa, Dr.P.Hiismäki and Mr.A.Lundán left the Laboratory for responsible positions in industry or the civil service.

Mr.J.Saastamoinen was Head of the Reactor Code Group. The other members of the Group were: Mr.E.Kaloinen, Mr.P.Siltanen and Mr.J.Sillanpää. As of 1.1.1971 the Code Group has been separate from the Reactor Laboratory organization as independent unit financed by the Ministry of Commerce and Industry.

REACTOR LABORATORY June 1, 1970



2. Operational Report of FiR I in 1970

2.1. Operation of the Reactor

The FiR 1 reactor was used in 1970 for research, production of isotopes and training. Table I shows the operation hours for these various purposes in some selected years.

At the end of 1970 38 new fuel elements were flown to Finland. The 37 standard and one instrumented element each contain 12 weight-% uranium of the fuel alloy, and the isotopic enrichment of the uranium is 20 wt-% of U^{235}.

The distribution of the operation hours for various purposes at different power levels is shown in Table II.

Students at the Department of Technical Physics studied problems connected with research projects and reactor operation. Some students from other universities also performed a wide range of reactor experiments.

A reactor operator course was held for nine persons working at the reactor either as young scientists or students.

2.2. Maintenance of the Reactor

The reliability of the reactor instrumentation has increased in recent years and remained at an adequate level. As a result of successful maintenance there has been no major unplanned shut-down of the reactor.

At the annual inspection in 1970 the condition of the main instruments was checked and some maintenance and repair work was done. The lengths of all the non-instrumented fuel elements were measured and the elements were examined visually.

No significant increase in length or bowing was noted. The average growth of the elements in different rings of the core is recorded in Table III.

3. Accounting Report of FiR 1 in 1970

3.1. System of Records and Reports

The forms A and B show the changes in the FiR 1 loading.
The forms C and D show the situation in the reactor and stock.
Form E shows the total material balance report (20 % enriched uranium). There are 3 storage places (Column "Location" in the form D).

1) rack = two storage racks with 6 fuel element positions in each, located in the reactor tank, more than 2 metres below the water surface.
2) pit = vertical storage tubes (6 only) situated below the ground floor. The depth of the tubes is 3 metres, diameter 25 cm, and they can be filled with water.
3) safe = safety-deposit vault mdde of reinforced concrete situated in a corner on the ground floor. The dimensions of the safe area are: 125 x 180 x 340 cm.

The information for forms C and D was taken from cards individually prepared for every fuel element. These cards record the history of every element.

3.2. Accounting report

A: Charge of the reactor (Table IV)
B: Discharge of the reactor (Table V)
C: Material in the reactor (Table VI)
D: Material in storage (Table VII)
E: Material balance report (20% enriched uranium (Table VIII)

3.3. Use of the FiR 1 reactor fuel in 1970

Use of the fuel in 1970 is shown in Table IX. In 1970 there were 75 fuel elements in the reactor core.

4. Research Division

4.1. Cold Neutron Research

At the beginning of the year cold neutron work still aimed at studying the density anomaly of light water using inelastic neutron scattering. The study was completed by measuring the total cross section of water and heavy water.

In February measurements on methane at the triple point were started. This work was continued by studying the disturbing multiple scattering theoretically. In March the final measurements of the cross section of ZrH_2 were performed in the cold neutron beam.

Due to technical difficulties in the cooling system the cold neutron source was taken out of operation in April, by which time construction of a new source had already started. The new source will be based on the use of cold (30°K) and high pressure (20 atm) hydrogen gas. Study of the optimization of cold neutron sources was recommenced.

The tangential beam tube was meanwhile used for gamma ray studies.

4.2. Texture studies with the neutron diffractometer

At the beginning of the year the neutron diffractometer was still used for studies of cold drawn Al-wire, and some of the studies were made by students. During most of the year the ND equipment was used for texture studies of cold-rolled steel sheets made by Rautaruukki Oy.

The project was undertaken to study differences in mechanical properties and texture before and after recrystallization annealing due to different Al- and V-alloyings. The diffractometer measurements were mainly made to observe the amount of (111)-texture, which gives good deep-drawing properties. Some almost perfect (110)-pole figures were also measured to observe the texture components developing during cold-rolling and recrystallization annealing.

It was found that vanadium does not give the same good properties as aluminium when both materials receive exactly the same treatment.

The diffractometer was also used for some measurements concerning development of the equipment. The equipment will further be used for texture studies, probably aimed at steel sheets.

Work on developing the diffractometer was begun at the end of the year with the aim of making the equipment computer controlled.

4.3. Capture gamma ray studies

The application of (n, γ)-reaction for analytical use became possible with the development of the Ge(Li) detector. Using this method elements, for which activation analysis fails, such as hydrogen, boron, carbon and phosphorus, can also be analyzed.

The analytical potential was studied as a degree thesis using both external and internal targets. The analytical sensibilities obtained so far have not been significant.

Boron in iron was analyzed as an application. Boron contents of about 100 ppm could be detected. The determination of the U^{235}/U^{238}- ratio using the capture gamma technique was also investigated. This proved to be possible using capture gammas from U^{238} and gammas from short lived fission products of U^{235}. The accuracy is only about 15 %.

Capture gamma spectrums of Cu were measured in cooperation with the University of Oulu.

4.4. Neutron radiography

Neutron radiography techniques were developed further, and radiography was also done for industry. Both a beam constructed in the thermal column and the γ-free neutron beam were used for neutron radiography. Some additional measurements were made based on a degree thesis (Solidification of Sn-Cd Alloys), a report of which, "Neutron Radiography of Unidirectionally Solidifying Sn-Cd Alloys" (TKK-F-A-177) will be published in 1971 in Metallurgical Transactions. A lecture on neutron radiography was given at INSKO´s course on Non-destructive testing methods. An article of the same subject "Neutron radiography" appeared in Teknillinen Aikakauslehti (TA 8-9(70)).

The brazed joints of some welding apparatus were investigated as student work in cooperation with Oy Aga Ab. The results of this work will be published in "Hitsaustekniikka". Other student projects were investigations into the radiography of components used in reactor technology and the distribution of lubricant in rotating bearings.

Projects on the icing of carburettor and diffusion of water in contruction materials, especially in concrete, were embarked on. A vertical beam tube for neutron radiography was designed and an order placed for the components for a neutron TV-system.

4.5. Neutron guide tube development

Work continued on developing internally polished neutron guide tubes, based on a contract with Räty Oy. According to the latest time schedule the first long tubes (3 m) should be delivered during spring 1971.

4.6. Computer Project

A computer group including Mr. Junttila and Mr. Virtamo was established within the Research Division. In collaboration with the Reactor Laboratory the group procceded to investigate the need for and potential use of an on-line computer. A potential was found to exist both among the research and reactor operation facilities. The most important tasks to be excuted by the systems include controlling a neutron diffractometer, measurements and processing of pulse height and time-of-flight spectra, and concentrated monitoring of radiation levels and reactor operating parameters.

In order to find a suitable computer, the group placed inquiries with a few suppliers, After a preliminary selection, an official request for tender was sent to the representatives of four computers (EMR 6135, PDP-15, Strömberg 1000 and Supernova) on December 22nd. The tenders were opened on January 29th, and after assessment a proposal for the purchase was submitted to the Ministry of Commerce and Industry. If the proposal is approved, the computer will be installed at the beginning of 1972.

4.7. Other Research Division activities

Nuclear spectroscopy aimed at studying the decay of short lived fission product halogenides was completed. 83 sec ^{136}I was studied and a new 48 sec isomeric state found. Using the gas transfer facility a 5 sec isomeric state was found in ^{86}Br.

A research group from the University of Technology headed by Professor G.Graeffe continued its work using the Laboratory's nuclear spectroscopy equipment.

Semiconductor radiation damage studies were mainly made with microcircuits and CdSe thin film transistors. Radiation damage and the radiation resistance of these devices were studied. Further investigations of selenium were continued in order to obtain a better understanding of the radiation damage in selenium single crystals. The effects of high temperature irradiations were studied. New studies with amorphous semiconductors were started with Ovshisky-type chalcogenide thin films. Studies will be continued with amorphous semiconductors, partly in cooperation with the Electron Physics Laboratory of Helsinki University of Technology.

The rethermalization measurements at temperature discontinuity in water were completed in February 1970. The experimental situation was also treated theoretically. Three different scattering models were used. By comparing the experimental results with the theoretical calculations some conclusions were drawn of the goodness of scattering models.

Gammaradiography was performed for two industrial jobs.

Moisture determination with neutron techniques was tested at the Outokumpu Oy Kokkola works.

5. Applied Radiation and Isotopes Division

5.1. Radioisotope Applications

During the past year the main projects were research into and development of certain industrial quality and process control methods and instruments, development of methods and instruments for use in tracer measurements, industrial tracer studies and research and development connected with some special radiation and isotope applications.

The work on analytical instruments was connected with applications of radioisotope X-ray spectrometry and radioisotope neutron activation analysis. Determination of light elements (Al, Si, S) using X-ray flow counters and of heavy elements ($z > 50$) using K X-ray excitation were studied. The work on radioisotope neutron activation analysis consisted of effectivity studies of certain types of irradiation and counting geometries.

As an application of light element radioisotope X-ray analysis a laboratory instrument for the determination of the content and two-sidedness of the distribution of mineral filler in papers was developed as part of a degree thesis. A laboratory instrument for the determination of mineral coating weight on papers was also constructed and succesfully applied to a problem arising in the manufacture of coated paper. The determination of light elements (Al, Si, S) in metallurgical samples was also studied and a flow counter system was constructed for the feasibility studies. In the work on the determination of heavy ($z > 50$) elements using K X-ray excitation and semiconductor X-ray detectors in particular analysis of lead and lanthanides in various types of samples was studied.

During the past year tracer studies were responsible for the greatest expansion of the activities of the section. Work on the measuring methods and instruments and data processing methods continued and reached a level at which simple mixing and flow measurements can easily be made and even more complex studies carried out. During the year 9 separate studies were made, consisting of 83 radioactive tracer injections. Five of the studies were mixing, flow and process studies in the pulp and paper industry (Kajaani Oy, Savon Sellu Oy, Sunila Oy). The others comprised measurement of the total waste water flowrate from a pulp mill (United Paper Mills, Tervasaari Works), a process study in a chemical process firm (Rikkihappo Oy, Siilinjärvi Works), a process study in a metallurgic firm (Outokumpu Oy, Tornio Works) and a leakage study in a chemical process firm (Rikkihappo Oy, Siilinjärvi Works). Worth mentioning in the work on the measuring methods are the studies for activating relatively great amounts (≈ 10 kg) of process materials to be used as tracers, which give a real and statistically correct illustration of the process. Relatively short-lived activities were here preferred in some cases. This called for some special arrangements as regards irradiation and transportation but at the same time significantly reduced the radiation hazards inherent in the studies. During the year preparations began to be made for extensive waste water flow and water pollution studies.

Work on special radiation and isotope applications induced a study of the diffusion of Na-ion from bisulphite cooking liquor into wood chips using neutron activation analysis and the development of a special system for controlling the wear of the furnace lining.

5.2. Irradiation Service and Radioisotope Production

The irradiation service continued to work in cooperation with the Operations Division and the Radiation Protection Division. The results achieved can be seen from the Tables. Table X shows the distribution of irradiation services among the various clients and Table XI shows the distribution of radioisotopes. Radioisotopes produced as byproducts have been omitted from the Tables. The radioisotopes listed are almost entirely produced by the irradiation service. When it has been possible to use the reactor for radioisotope production, these irradiated targets have been included in the Tables. The development of the irradiation service from 1962 onward can be seen from Table XII. During the past year the amount of activity produced rose sharply. This is partly due to the fact that radioisotopes were for the first time exported to Sweden, and partly due to the significant increase in industrial research performed by the Radioisotope Applications group.

Commercial production of radioisotopes started on October 1st, 1970, when the first batch of ^{131}I for oral use was distributed to hospitals in the presence of press and television reporters. Marketing of the product by Oy Medica Ab was successful, and the product was favourably received.

At the end of 1969 the Reactor Laboratory Safety Committee stressed the importance of the efficiency and suitability of the filters used in the air conditioning system in the production unit. Together with the Radiation Protection Division measurements on the absorption of iodine in the filters were made and the results published in Report No TKK-F-C1. On the basis of the results suitable filter materials were chosen and small changes in the air conditioning system were made. Production was started on a full scale after publication of the reports "Safety Report of the Isotope Production Laboratory" (TKK-F-C3), "Safety Regulations" (TKK-F-C4) and "^{131}I Production Process Instructions" (TKK-F-C5), in Finnish, and after the Institute of Radiation Physics had inspected the laboratories. During production five destillations were performed with the iodine apparatus, and the iodine produced was dispatched for medical use. The production method can be considered routine, and the product meets the requirements laid down by the Pharmacopoea Nordica. On the development side a method for tagging hippuran with radioiodine was established but has so far not been tested on a large scale. The reason for this is the release of gaseous iodine during tagging procedures, which has made the construction of a special handling box necessary.

During 1970 there were 2 active participants from the Reactor Laboratory and 2 from the Medica pharmaceutical factory. At the very end of the year the Ministry of Commerce and Industry issued a grant to take on a chemist to do research into technetium. The necessity of this kind of research was obvious from discussions with medical persons and it is an important part of Nordic cooperation in the field of radioisotopes.Also during 1970 our staff took an active part in negotiations towards making this cooperation official.

The start of commercial isotope production and associated distribution and marketing, the development of new products and active participation in Nordic cooperation has from the start shown the lack of staff and facilities. Since activities will obviously expand rapidly, study of the possibility of building a new isotope laboratory and a timetable for this are of the utmost importance to national and economic planning. Without the new isotope laboratory this development, which has got off to such a promising start, would cease because of lack of space.

5.3. Activation analysis

During the past year the work of the activation analysis group consisted primarily of various activation analysis tasks arising in industry, research institutes and supervising officials.

Quantitatively the most prominent were mercury analysis of environmental samples for the Water Board. About 500 Hg-analyses were made. Also of importance was the analysis of blood and tissue samples sent in by several hospitals. One example is the determination of Ca, P, Mg and Na content in small (0.03 - 1.5 mg) cortical bone samples from patients with otosclerosis.

Great attention was also paid to the analysis of geological samples, the most important undertaking in this field being lanthanide analysis of Apollo 11 and Apollo 12 lunar samples.

For the lanthanide analysis a method was developed which makes it possible to analyze instrumentally 11 lanthanides out of the 14 existing in nature.

In trace experiments connected with different process studies the activation analysis group gave professional advice and analysed samples taken during the studies (spreading of water in the printing process, the effectiveness of pulp washing etc.).

The group's own research included analysis of trace elements in tumor tissues and lanthanide analysis in igneous rocks. These studies were made in cooperation with the second Clinic of Pathology, University of Helsinki, and with the Department of Geology, University of Helsinki.

In the course of 1970 about 900 different samples were analyzed. Including parallel analyses and considering that in some of the samples more than one element was analyzed the total number of analyses approached 2000.

Through the Reactor Laboratory lectures and demonstrations on activation analysis and its applications were arranged for several groups of students and visitors.

6. Radiation Protection Division

6.1. Medical Surveillance

The health of the Reactor Laboratory staff was supervised by the Institute for Occupational Health. Supervision included the following measures:

1. Complete blood study of the whole staff
2. Pre-employment medical examination of new employees.

Blood counts and examination did not reveal any changes indicating radiation effects.

6.2. Dose Control

Long-term dose control was effected by the Institute of Radiation Physics. Every worker has two fluoro glass dosemeters, one for gamma exposure and the other for gamma rays and thermal neutrons. The dosemeters are checked every three months, and the integrated dose equivalents for the staff are given in Table XIII. The Institute of Radiation Physics has also used some additional thermoluminiscent dosemeters for reference measurements.

Short-term control is based on pocket ionisation chambers, recorded weekly.

Whole body counting of the staff was made during the period 2.2. - 24.3.1970. The measurements were carried out by the Institute of Radiation Physics and no internal contamination was found, excluding fallout ^{137}Cs. In a separate measurement after the preparation period of the iodine production a light thyroid contamination was found (4 nCi, ^{131}I).

6.3. Surveying and Monitoring

The area monitoring system includes five γ-doserate channels with fixed alarm levels and continuous recording. A fixed filter air monitor and an open air G.M.-tune chamber are used for aerosol and noble gas monitoring in the reactor hall. Aerosol and pool water samples are analyzed every week with a γ-spectrometer.

The γ-background and ^{131}I-concentration in the air are repeatedly measured in the isotope production laboratory. ^{131}I-release and the efficiency of the iodine filter are measured using sampling method. The maximum permissible ^{131}I-release rate is 5 μCi/week. This figure was exceeded during the period 12.10.-12.11. because of a construction fault in the ventillation duct of one shielded box. The ^{131}I-release since the beginning of iodine production has been 100 μCi.

6.4. Research and Development

The health physics instrument development programme has included noble gas monitors and an air monitor for ^{131}I.

7. The Subcritical Reactor

In 1970 work at the subcritical reactor comprised

1. reactor noise or fluctiation studies and
2. experimental investigations on moderator systems with voids.

The reactor noise studies concentrated on

I) the development of mathematical models,
II) data collection methods and
III) noise measurement at the subcritical facility.

With power reactor applications in mind the influecee and use of gamma radiation in reactor noise measurements were investigated. The model developed reveals the influence of a large number of reactor and detector characteristics, including the influence of correlated and non-correlated gamma radiation and of various detector types. The measurements induced by the mathematical model were successful. The relaxation effects associated with the spontaneous fluctuation in the neutron population and in gamma emission of the subcritical facility could be observed by gamma counting techniques. Estimates for the main relaxation constant (Rossi-alpha) could be obtained from the detection of high energy photon radiation with scintillation detectors both inside and in the vicinity of the reactor system. The detectability of the correlated noise with gamma sensitive detectors, especially in out-of-core measurements, is of substantial interest, since it obviously opens up a wide range of practical applications. The investigations are being continued.

Systematic investigation of the data extraction methods was continued and displayed a number of alternate or modified techniques, some of which may be of practical interest. The application of information theory to noise problems proved a very powerful and useful approach.

Estimation theory was also applied to the theoretical investigation of the accuracy associated with parameter estimation on various data extraction methods.

Cylindrical moderator assemblies containing water and concentric void cylinders of various diameters were investigated using the pulsed neutron source method.

At the end of the year the number of fuel rods and the uranium content were unchanged, compared with the previous annual report, and comprised

189 rods of 10% enr.in U^{235}, length 1 metre
1 rod length 0.5 metre
1 opened experimental rod, enr.10 in U^{235}
original length 0.5 m
(See Table XIV)

As before, the subcritical facility was also used as an instructional tool.

8. Reactor Code Group

During the past year several reactor physics computer programmes, mainly concerning reactor statics, were developed. The need for spectrum and lattice codes is beginning to be met. Consequently the work of the group is moving more towards multi-dimensional power distribution, burnup and reactor kinetics calculations. Work was also started on reactor thermal hydraulic calculations.

The most important programmes adapted during the past year were: HEX and TRIGON two-dimensional diffusion codes for a hexagonal or triangular lattice, FORM and GGC-4 spectrum codes, IRESINT resonance integral code, DTF-4 S_N-transport code, KYKER thermal neutron scattering kernel code and REPP thermal hydraulic design code. The programming of a revised and completed version of a THERMOS integral transport theory code, called THERMOS-OTA, continues.

The group performed calculations for the Loviisa Nuclear Power Station project and assisted in the work of the Nordic Working Group for Reactor Safety.

The group used about 35 hours of computer time on an IBM 360/50 for programme development at the Finnish State Computing Center. At the end of the year preparations for changing over to a UNIVAC 1108 computer were started.

The degree thesis of F.Wasastjerna entitled "Calculation methods for resonance absorption in nuclear reactors" (in Swedish) was written as a group project.

The group was supervised by an expert team nominated by the Finnish AEC. The group was administratively separated from the Reactor Laboratory as of the beginning of 1971.

9. The Safety Committee and the Consulting Board

The Safety Committee held 3 meetings in 1970. Mr.O.Vapaavuori was Chairman of Committee, the members being Professor K.A.Salimäki (with Mr.M.V.Bonsdorff as deputy), Mr.B.Regnell, Mr.J.Saastamoinen and Mr.A.Vuorinen, and as of 3.11.1970 Mr.J.Kajamaa and Mr.H.Väyrynen (deputy for Mr.Regnell). The Safety Committee issued directives concerning the safety report of the isotope production laboratory, the production of I-131 and several separate questions.

The Consulting Board held 2 meetings in 1970, giving statements on collaboration between the Reactor Laboratory, universities and industrial research centres. Professor L.Simons was Chairman of the Consulting Board, with members Mr.M.v.Bonsdorff, Professor P.Haapala, Professor V.Hovi, Dr.S.Hultin, Professor P.Jauho, Professor H.Miekk-oja, Professor J.Miettinen and Professor P.Taskinen.

10. Teaching and Training

Teaching and training of students has continued and in some respects expanded in the Reactor Laboratory. A course on reactor driving was taken by six students and three graduates working in the Reactor Laboratory.

During the year the following laboratory work was done as part of the University training programme:

Spring term: reactor technology (F dept.), 5 students

- Measurements of the prompt temperature coefficient of reactivity
- Investigation of the reactor cooling system
- Determination of the position dependence of the reactivity value of a perturbation
- Investigation of radiation damage

reactor technology (depts.of Mech. and El.eng.), 4 students

- Calibration of control rods
- Measurement of flux distribution by activation of a wire
- Measurement of the prompt temperature coeffifient of reactivity

Autumn term: reactor physics (F-dept.), 24 students

- Driving and regulation of the reactor
- Measurement of flux by a wire activation method
- Diffusion of neutrons

The following special work by the students of the Technical Physics department of the University was completed under the supervision of the Reactor Laboratory staff using Laboratory equipment:

- Absolute activity measurements with the aid of γ-γ coincidences (in Finnish)
- Investigation into radiation damage in amorphous switches (in Finnish)
- Construction of the direction for use of the analogy computer (in Finnish)
- Standardization of the flux measurements with Au-foils (in Finnish)
- Regulation of the cooling of a Bi-cryostat (in Finnish)

- Investigation into the statistical accuracy of estimates (in Finnish)
- Evaporation of the filaments on a glass dome (in Finnish)
- Investigation of silver solderings (in Finnish)
- Air flow ionization chamber (in Finnish)
- Use of air fractional distillation equipment in the determination of the concentration of noble gases (in Finnish)
- Rubber under tension in radiation (in Finnish)
- Damping of characteristic X-radiation in tissue (in Finnish)
- Investigation into the lubrication of bearings (in Finnish)
- Liquid crystals (in Finnish)
- Apparatus for copying microcards (in Finnish)
- Collection of multiparameter spectra (in Finnish)
- Apparatus for measuring the filling of liquid containers (in Finnish)
- Reformation of the neutron diffractometer (in Finnish)
- The biological applications of neutron radiography (in Finnish)
- The use of neutron radiography to detect hydrogen in metals (in Finnish)
- Scattering of neutrons from a hydrogen gas flame (in Finnish)
- The influence of pH on reactivity (in Finnish)
- The experimental value of Planck's constant (in Finnish)
- Positron annihilation (in Finnish)
- Angular distribution of positron annihilation in selene (in Finnish)
- Trapping of positrons by vacancies (in Finnish)
- Measurement of the transfer time of the pneumatic transfer system (in Finnish)
- Measurement of the reactor gamma radiation (in Finnish)
- Measurement of the fast flux of the reactor using transistors (in Finnish)
- Water sample under high pressure (in Finnish)
- Probability methods in noise analysis (in Finnish)
- Investigation into light collection in scintillation plastics (in Finnish)
- Photography of 2-phase flow (in Finnish)

The finished degree theses are mentioned together with the list of publications. Practice demonstrations were arranged for a group of students from the Åbo Akademi. Similar cooperation was offered to all professors of physics in Finnish universities.

For those students of the Department of Technical Physics who, in the course of practical work, come into contact with radiation-generating instruments or radioactive materials a course was arranged on fundamentals of the interaction of radiation with matter and radiation protection. The course comprised 14 hours of lectures, a calculation and a practice laboratory demonstration. It is necessary to pass the examination in radiation protection before beginning the exercises mentioned. Mr. O. Tiainen was responsible for the course syllabus.

An informative series of seminars was arranged among the research workers at the Laboratory, including lectures on all research sectors of the Laboratory.

11. International cooperation

The most important form of cooperation was the Triga Users' Seminar held in Otaniemi 25.-27.8.1970. There were 30 participants, from the following Triga laboratories: Atominsitut der Österreichischen Hochschulen, Vienna; Johannes Gutenberg Universität, Mainz; Deutsches Krebsforschungszentrum, Heidelberg; Gesellschaft für Strahlenforschung M.B.H., Munich; Gutehoffnungshütte AG, Sterkrade; Medizinische Hochschule, Hannover, Centro di Studi della Casaccia, Rome; Universita di Pavia, Pavia; Institut "Jozef Stefan", Ljubljana; International Atomic Energy Agency, Vienna; Gulf Energy & Environmental Systems, Zürich and San Diego, USA; Geological Survey, Denver, USA; Kansas State University, Manhattan, USA; Institute for Atomic Energy, Rikkyo University, Yokosuka, Japan; Institute de Pesquisas Radioativas, Belo Horizonte, Brazil. The programme consisted of 28 papers on: "Present and planned research programmes at the Triga reactors", "New developments in Triga reactor design", "In-core fuel management and attainable fuel burn-up in Triga" and "Experience in the operation and maintenance of Triga reactors". The seminar was rather succesful, and it was decided to aim at organizing a corresponding seminar intended mainly for European Triga laboratories in Pavia in 1972. During the seminar it was also agreed that a Newsletter be distributed. The Reactor Laboratory in Otaniemi is to be responsible for editing the newsletter during the first few years.

The IAEA "2nd International Conference of Nuclear Data for Reactors" was held in Otaniemi 15.-19.6.1970 with 163 participants from 28 countries. The Reactor Laboratory took an active part in the organization. The Ministry of Commerce and Industry was responsible for the conference on the Finnish side. A large number of people visited the Reactor Laboratory during the conference.

Negotiations were continued with the Max von Laue-Paul Langevin Institute concerning cooperation over a project for building and using a dilution cryostat for polarized targets.

Discussions were started with the Dubna INAI concerning the possibility of starting a project aimed at determining Planck's constant with

~10 ppm. Based on a suggestion from Dr.R.Stedman, a rather promising method has been developed. A pulsed reactor is needed as the neutron source for an accurate time-of-flight experiment.

The laboratory staff went on several journeys abroad. Travelling accounted for ~ 1 % of the total budget.

The NAK-committee (Nordic Atomic Coordination Committee), actively promoted cooperation between the nuclear research centres in Sweden, Denmark, Norway and Finland. The Reactor Laboratory was represented at the meetings.

Attempts to coordinate isotope production in the Scandinavian countries continued.

The Code Group assisted in the work of the "Nordic Working Group for Reactor Safety".

Cooperation was started with groups in the German Democratic Republic and Poland working on texture studies with neutron diffraction. Dr.Kajamaa thus visited Poland for a working meeting and Dr. Bunge from the D.D.R. visited the Reactor Laboratory. A Polish texture scientist has been invited to work in Otaniemi in 1971.

Several other foreign scientists visited the Reactor Laboratory in 1970,e.g. Dr.R.L.Crowther and Dr.B.Alefeld.

The use of the FiR 1 reactor in 1962-1970

	1962[1)]	1965	1966	1967[3)]	1968	1969	1970
Total running hours	156	1440	1718	1344	1339	1441	1463
Testing/h	20	30	96	68	46	28	15
Training/h	98	61	46	55	75	89	55
Research/h[2)]	35	1387	1729	1411	2355	2485	2300
Isotope Production	112	1963	2740	1787	1627	2292	2337
Energy generated per year/MWh	11.5	130.3	159.7	168.0	319.2	333.1	338.3
Integrated energy/MWd	0.48	9.85	16.5	23.5	36.8	50.7	64.8
Number of power pulses	14	19	20	10	0	2	0

1) The operation of the reactor was started in the spring of 1962.

2) The running times for all the separate research projects and the separate irradiations are added.

3) In the summer of 1967 the reactor was shut down for more than a month because of the power raising project.

The use of FiR 1 reactor in 1970

	Running time (hours)	Testing	Training	Research	Isotope production
250 kW	1372	4	38	2240	2331
100 - 250 kW	13	3	3	7	2
1 - 100 kW	61	5	13	41	3
below 1 kW	17	3	1	12	1
	1463	15	55	2300	2337

Table III

The total average growth of the fuel elements in different rings (mm)

Ring	1968	1969	1970
B	0.20	0.16	0.19
C	0.38	0.47	0.53
D	0.86	0.79	0.80
E	0.79	0.79	0.79
F	1.30	1.28	1.19

In 1970 the largest individual change (2.34 ± 0.1) mm was noted in element No 2496 in position F5. The maximum permissible value has been increased to 5 mm in January 1968.

Table IV

Report No 8

FiR 1 Accounting Report A: Charge of the Reactor

Date 31.12.1970

Date of the foregoing Report 31.12.1969

No changes in 1970

Table V

Report No 8

FiR 1 Accounting Report B: Discharge of the Reactor

Date 31.12.1970

Date of the foregoing Report 31.12.1969

No discharges in 1970

Table VI

Report No 8 — FiR 1 Accounting Report C: Material in the Reactor

Date 31.12.1970

Date of the foregoing Report 31.12.1969

Date	Number of fuel elements	Total U content (kg)	U-235 content (g)	Plutonium content (g)	Remarks
31.12.1969-31.12.1970	75	13.717	2724		

Table VII

Report No 8 FiR 1 Accounting Report D: Material in Storage

Date 31.12.1970

Date of the foregoing Report 31.12.1969

Date	Location	Number of elements	Identification numbers	Wt (kg) uranium	Wt (g) U-235
31.12. 1969	safe	12	4174, 4603-TC, 5115 - 5124	2.302	456
	pit	1	2503	0.183	36
	rack	1	4166	0.192	38
31.12. 1970	safe	50	4174, 4603-TC, 5115 - 5124 6535 - 6571, 6575-TC	12.912	2583
	pit	1	2503	0.183	36
	rack	1	4166	0.192	38

MATERIAL BALANCE REPORT

ACCOUNTING REPORT No 8

Accounting area : Helsinki University of Technology,[1] Reactor Laboratory, Otaniemi

Accounting period : 1.1.1970 - 31.12.1970

Accounting unit : GRAMS for special fissionable material

KGS for source material

Type of material — 20 % enriched uranium	U (kg) Element	U-235 (g) Isotope
I. BEGINNING INVENTORY	16.395	3252
II. INCREASES IN INVENTORY		
1. Receipts		
a. Domestic receipt no.		
a. Domestic receipt no.		
a. Domestic receipt no.		
b. Import no. GGA invoice no. 23558	10.610	2127
b. Import No.		
b. Import no.		
2. Production		
3. Other increases		
III. DECREASES IN INVENTORY		
1. Shipments		
a. Domestic shipments no.		
a. Domestic shipments no.		
a. Domestic shipments no.		
b. Export no.		
b. Export no.		
b. Export no.		
2. Nuclear losses		
3. Non-nuclear losses		
4. Other decreases		
IV. ROUNDING ADJUSTMENT		
V. ENDING INVENTORY	27.005	5379

Date: 25.1.1971 Signature: [signature]

1) This new form of the English name of the University was accepted on April 28, 1970

Use of the FiR 1 Reactor Fuel during the year 1970

Period	Ring	No of elements	Burn-up coefficient	Identification No	kWh generated per element
1.1.- 31.12.	B	6	0.0198	4312-TC,4152,4154,4186, 4188,4205	6713
1.1. - 31.12.	C	11	0.0177	2548,2551,2544,2543, 2550,2499,2516,2513, 2502,2210,2552	5982
1.1. - 31.12.	D	15	0.0156	2515,2518,2517,2498, 2574,2070,2531,2537, 2529,2521,2555,2554, 2520,2508,2530	5284
1.1. - 31.12.	E	23	0.0119	2512,2523,2533,2497, 2575,2547,2494,2495, 2493,2540,2532,2538, 2546,2525,2534,2345-TC 2505,2539,2509,2519, 2504,2545,2549	4021
1.1. - 31.12.	F	20	0.0089	2514,2492,2535,2496, 2506,2527,2524,2510, 2344-TC,2541,2526,4173, 2501,2500,2536,2511, 2528,2507,2542,2522	3024

Only the order of the elements in the F-ring was slightly changed during the year 1970

Irradiations at FiR 1 in 1970

	Number of Irradiations	Number of Samples	Activity/mCi
Lunar Samples	7	43	25
Export	2	5	10600
Reactor Laboratory	780	3751	4478
Hospitals	114	229	3878
Radiation Protection Research Center	54	9	72
University of Helsinki	33	209	89
University of Jyväskylä	1	2	1
University of Turku	2	3	2
Åbo Akademi	4	9	211
The Finnish Pulp and Paper Research Institute	19	150	11
Industry	230	1628	6961
University of Technology	4	7	4
Total	1250	6045	26332

Produced radionuclides in 1970

Isotope	Samples	Irradiations	Activity/mCi
Lunar samples	43	7	25
Mixtures	1749	336	2715
^{18}F	92	92	1365
^{24}Na	481	88	2993
^{27}Mg	2	1	1
^{28}Al	244	176	30
^{32}P	23	2	1
^{35}S	13	11	2
^{38}Cl	114	22	719
^{41}Ar	15	15	2
^{42}K	8	8	11
^{51}Ti	4	4	1,
^{51}Cr	44	15	17
^{52}V	2	2	1
^{56}Mn	43	11	126
^{59}Fe	9	3	10
^{60}Co	34	9	53
^{64}Cu	130	57	1850
^{65}Ni	2	1	1
^{65}Zn	25	6	2
^{75}Se	63	24	148
^{76}As	2	2	1
^{82}Br	174	25	12119
^{86}Rb	5	9	2
^{99m}Tc	276	25	57
^{108}Ag	17	6	2
^{115}Cd	10	4	9
^{116m}In	37	2	2
^{124}Sb	2	2	3
^{128}I	31	23	13
^{131}I	86	15	2500
^{134}Cs	10	5	12

^{140}La	36	13	334
^{141}Ce	6	3	52
^{147}Nd	11	2	26
^{152}Eu	1	1	200
^{153}Sm	75	11	29
^{155}Eu	9	2	53
^{165}Dy	2	1	1
^{177}Lu	2	1	1
^{182}Ta	10	2	2
^{187}W	212	26	32
^{191}Os	2	2	3
^{194}Ir	18	5	408
^{197}Hg	1806	148	391
^{198}Au	53	21	5
^{210}Bi	7	1	1
^{233}Pa	5	3	1
Total	6045	1250	26332

Table XII

Radioisotope production at the FiR 1 in 1962-1970

	1962	1963	1964	1965	1966	1967	1968	1969	1970
Number of samples									
- total		221	434	1464	2631	3482	3179	4651	6045
- outside the Institute			219		541	798	527	758	2251
Number of irradiations									
- all	37	89	230	513	863	1404	805	1099	1250
- outside the Institute			133	190	203	219	257	204	463
- medical science			23	50	50	87	148	105	114
- scientific research			81	81	85	72	87	53	44
- industry and technical research			29	59	68	60	22	46	305
Activity of the samples/Ci									
- all	0,34		1,76		20,5	6,3	4,7	7,4	26,3
- outside the Institute			1,62	6,0	6,1	4,0	2,4	4,3	21,8

Integrated Dose Values of the Staff at FiR 1 in 1970

Name	Working time, months	Dose equivalent, upper limit, mrem
Aalto	10	230
Adamsson	12	170
Aittomäki	12	200
Anttila, K.	12	470
Anttila, M.	7	90
Aminoff	3	40
Biström	7	80
Bärs	12	220
Fahlenius	1	40
Graeffe	2	40
Hautakoski	12	180
Heinonen	9	140
Hiismäki	9	150
Häsänen	12	160
Ilmoniemi	3	40
Jaatinen	7	100
Jauho	12	160
Johansson	12	170
Junttila	7	90
Juurikkala	12	170
Kajamaa	9	120
Karilas	12	340
Kuoppamäki	12	380
Kuusi	12	520
Kuutschin	12	230
Kärpijoki	3	40
Leikkonen	7	110
Lemmetti	4	80
Lindegren	12	380

Lindfors	2	40
Lundán	11	160
Lääveri	12	160
Mankamo	12	190
Markkanen	9	130
Mattila	7	80
Meinander	2	80
Miettinen	3	40
Mokka	8	120
Mäkelä	8	120
Määttä	3	40
Ojanen	10	170
Ojaniemi	12	190
Palmén	12	240
Palmgren	12	180
Patrakka	3	40
Pellinen	4	40
Pietarinen	12	180
Puumala	8	120
Pöyry	12	160
Rajamäki	12	180
Rastas	9	160
Reijonen	12	180
Rosenberg	3	40
Ruoho	2	40
Rytsölä	5	80
Sainio	12	170
Salmenhaara	12	220
Saviranta	12	170
Savolainen	12	160
Schultz	7	120
Seiffert	12	170
Sirkiä	12	160
Suniala	12	200

Tamminen	12	240
Teräsvirta	7	80
Tiainen	12	210
Tiitta	12	200
Tunkelo	12	160
Uhlenius	12	180
Vaurio	12	160
Virtamo	4	40
Virtanen M.	12	190
Virtanen S.	9	120
Vänttinen	2	40

MATERIAL BALANCE REPORT

ACCOUNTING REPORT No 8

Accounting area : Helsinki University of Technology[1], Reactor Laboratory, Otaniemi

Accounting period : 1.1.1970 - 31.12.1970

Accounting unit : GRAMS for special fissionable material

KGS for source material

Type of material	10 % enriched uranium	U (kg) Element	U-235 (g) Isotope
I. BEGINNING INVENTORY		30.224	3022
II. INCREASES IN INVENTORY			
1. Receipts			
a. Domectic receipt no.			
a. Domectic receipt no.			
a. Domestic receipt no.			
b. Import no.			
b. Import No.			
b. Import no.			
2. Production			
3. Other increases			
III. DECREASES IN INVENTORY			
1. Shipments			
a. Domestic shipments no.			
a. Domestic shipments no.			
a. Domestic shipments no.			
b. Export no.			
b. Export no.			
b. Export no.			
2. Nuclear losses			
3. Non-nuclear losses			
4. Other decreases			
IV. ROUNDING ADJUSTMENT			
V. ENDING INVENTORY		30.224	3022

Date: 25.1.1971 Signature: [signature]

1) This new form of the English name of the University was accepted on April 28, 1970

Publications by members of the staff in 1970

Publications in scientific journals and at conferences

P.Jauho and P.Pirilä: Spin-lattice Relaxation of Nuclei Due to Conduction Electrons at Very Low Temperatures. Phys.Review 1, No 1, January 1970,21-24.

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P.Hautojärvi, A.Tamminen and P.Jauho: Trapping of Positrons by Dislocations in Aluminium. Phys.Review Letters 24, No.9, March 1970, 459-461,

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A.Lundán: On the Decay of Bromine Isotopes ^{86}Br and ^{87}Br. Z.Phys. 236 (1970) 403.

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H.Reijonen: Fiber Enforced Materials. Forum No.16, 1970. (in Swedish).

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No.	
TKK-F-A101	Trapping of Positrons by Dislocations in Aluminium. P.Hautojärvi, A.Tamminen and P.Jauho.
TKK-F-A102	Information Theoretical Aspects of Power Spectrum Measurements in Nuclear Reactors. B.Bärs.
TKK-F-A104	Radiation Resistance of CdSe This Film Transistors. O.Tiainen.
TKK-F-A105	A High Resolution Study of Bragg Cut-off in Aluminium. P.Hiismäki.
TKK-F-A106	Resonance Integral of Natural Zirconium. J.Saastamoinen.
TKK-F-A107	On the Influence and Use of Gamma Radiation in Reactor Noise Measurements. B.Bärs.
TKK-F-A108	On the Calculation of Moduli of Elasticity in Polycrystalline Cubic Wires. J.Kajamaa.
TKK-F-A111	Radiation Resistance of Microelectronic Systems. O.Tiainen and P.Jauho.
TKK-F-A112	Neutron Diffraction Analysis of a 78.5:21.5 at pct (60:40 wt pct) AlZn Alloy. J.Kajamaa.
TKK-F-A115	A Fast Method of Computing the Contribution from Interference Scattering to the Integral $J(\theta, a\beta)$.F.Wasastjerna.
TKK-F-A116	The Separation of Coherent and Incoherent Cross Sections in Inelastic Neutron Scattering Using Polarized Nuclear Targets. P.Jauho and P.Pirilä.
TKK-F-A118	Energy-Dependent Neutron Transport Theory in Adjacent Half Spaces. P.Jauho and M.Rajamäki.
TKK-F-A119	Noise Measurements in a Subcritical Facility Based on Photon Detection. B.Bärs and E.Markkanen.
TKK-F-A122	Neutron Radiography of Undirectionally Solifying Sn-Cd Alloys. H.Reijonen and J.Forstén.
TKK-F-A123	The Use of Nuclear Polarization in Neutron Scattering and Transmission Measurements. O.Tiainen, M.Anttila and E.Tunkelo.

TKK-F-A127	Scattering Cross Section at Subthermal Energies and Generalized Phonon Frequency Spectrum at Zirconium Hydride. J.Saastamoinen and A.Palmgren.
TKK-F-A129	The Decay of the ^{136}U Isomers to the Energy Levels of ^{136}Xe. A.Lundán.
TKK-F-A131	Positron Annihilation in Colour Centres of Alkali Halides. P.Hautojärvi and P.Jauho.
TKK-F-A133	The Biological Half-time of ^{137}Cs and ^{24}Na in Man. E.Häsänen and T.Rahola.
TKK-F-A134	Multiple Scattering in an Inel[illegible] Neutron Scattering Experiment with Liquid Methane. A.Tiitta and E.Tunkelo.
TKK-F-A136	Determination of the U^{238}/U^{235} Ratio with Activation Analysis. H.Aalto (in Finnish).
TKK-F-A137	On the Variety and Hierarchy of Data Extraction Methods in Nuclear Reactor Noise Analysis. B.Bärs.
TKK-F-A139	Iresint 2, a Fortran Program for Calculation of Resonance Integrals. F.Wasastjerna.
TKK-F-B1	The Effects of Radiation Damage on the Operation of Semiconductor Components. O.Tiainen (in Finnish).
TKK-F-C1	Efficiency of Effluent Air Filters in the Iodine Production Laboratory. R.Uhlenius, B.Palmén and M.Saviranta (in Finnish)
TKK-F-C2	Notes on the Use of the Subcritical Pile. B.Bärs. (in Swedish)
TKK-F-C3	Safety Report of the Isotope Production Laboratory. B.Palmén, M.Saviranta, A.Tamminen and R.Uhlenius. (in Finnish)
TKK-F-C4	Safety Regulations of the Isotope Production Laboratory. P.Palmén, M.Saviranta, A.Tamminen and R.Uhlenius. (in Finnish)
TKK-F-C5	^{131}I Production Process Instructions. R.Uhlenius, M.Saviranta and B.Palmén. (in Finnish)
TKK-F-C6	Positron Annihilation in Deformed Metals. P.Hautojärvi, A.Tamminen and P.Jauho.
TKK-F-C7	In-core Fuel Management and Attainable Fuel Burn-up in Triga. J.Saastamoinen, P.Siltanen and E.Kaloinen.

TKK-F-C8	^{41}Ar-concentration Measurements at the Finnish Triga Mark II. A.Tamminen.
TKK-F-C9	Experience in the Operation and Maintenance of the FiR 1 Reactor. K.Anttila.
TKK-F-C11	Determination of the Size Distribution of Droplets in an Oil Spray Using Diffraction. M.Seitola, A.Örn and E.Tunkelo. (in Finnish)
TKK-F-C12	Use of Nuclear Techniques in the Maesurement and Control of Environmental Pollution. J.Kuusi. (in Finnish)

Doctoral Theses

J.Arponen: Positron Annihilation and the Positron Electron Manybody System.

P.Hiismäki: Studies Initiated from Back-reflection of Neutrons from Single Crystals.

J.Kajamaa: On the Texture Strengthening of an Aluminium Strand.

J.Kuusi: On the Use of Radioisotope Methods of Analysis for Quality and Process Control in Industry.

J.Kurkijärvi: A Molecular Dynamics Investigation of the Coherent Scattering Function of Simple Fluids.

Licentiate Theses:

P.Hautojärvi: Positron Annihilation in Worked Metals (in Finnish)

O.Tiainen: The Effect of Radiation Damage on Semiconductor Devices. (In Finnish)

J.Vaurio: Stochastic Two Group Kinetic Theory of a Nuclear Reactor. (In Finnish)

First Degree Theses:

A.Fahlenius: Study of Characteristic X-Rays Generated by α - and p-Bombardements. (in Finnish)

B.Lindfors: Study of the Diffusion of Cooking Chemicals into Wood Chips Using Neutron Activation Analysis. (in Swedish)

T.Mankamo: Measurement of Momentum Correlation in Triple Quantum Annihilation of Positronium. (in Finnish)

H.Reijonen: Study of the Solidification of an Sn-Cd Alloy Using Neutron Radiography. (in Finnish)

S.Salo: Synthesis Methods in Solving Group Diffusion Equations. (in Finnish)

E.Schultz: On the Use of X-Ray Fluorescence Methods in Determination of Light Elements. (in Finnish)

A.Tiitta: Scattering of Neutrons on Methane at the Triple Point. (in Finnish)

F.Wasastjerna: Methods for Resonance Absorption Computations in Nuclear Reactors (in Swedish).