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PROGRESS REPORT TO EANDC FROM DANISH AEC RESEARCH ESTABLISHMENT RISØ

H. Bjerrum Møller, Editor

OECD ENEA

APRIL 1965

EUROPEAN-AMERICAN NUCLEAR DATA COMMITTEE

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EANDC Secretariat
OECD European Nuclear Energy Agency
38, Boulevard Suchet, Paris 16e

PROGRESS REPORT TO EANDC

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DANISH AEC RESEARCH ESTABLISHMENT RISØ

FOR THE PERIOD UNTIL APRIL 1965

Content:

I SPECIAL BEAM FACILITIES

Continued work on angled Soller collimators

K. Abrahams, W. Ratynski, F. Stecher-Rasmussen and E. Warming.

A third version of the polarizing collimators has been constructed, and is now in use as a neutron polarizer for the (n, γ) experiment.

The collimator system is provided with 20 tapered channels, and the focus point determined by the tapering is 3,5 m away from the end window of the collimators. The channel walls consist of polished copper plates on which are deposited electrolytically a layer of cobalt, polished after depositing to form neutron mirror.

The layer of cobalt on each mirror is 12 μ thick, and x-ray analysis show that 90% of the cobalt is in the cubic phase and 10% in the hexagonal phase. It has been found that the ratio between cubic and hexagonal cobalt in the deposited layer is a function of the current density applied in the electrolytical process, and the composition of the electrolysis.

The mirrors are magnetized by means of an electromagnet. A cross section of the collimator system is shown on figures 1 and 2.

The overall polarization $\mathrm{P} = \dfrac{\int_0^\infty P(E)\phi(E)dE}{\int_0^\infty \phi(E)dE}$ of the neutrons energing from the collimator system has been found with a) Bragg-reflection from a Co-Fe single crystal and b) total reflection from a Co-Fe mirror. The measurement of $\overline{P}$ from a) and b) has been performed both with the shim method and the spin turning and field flipping method. Both methods gave $\overline{P}$ = 70 - 80% for the collimator system in the just closed configuration.

The value of $\overline{P}$ calculated from the simple theory of total reflection of neutrons from magnetized materials taking into account the geometrical corrections from the multiple reflection in the collimator system is $\overline{P}_{theoretical} = 98\%$.

The explanations of the discrepancy between $\overline{P}_{calculated}$ and $\overline{P}_{exp.}$

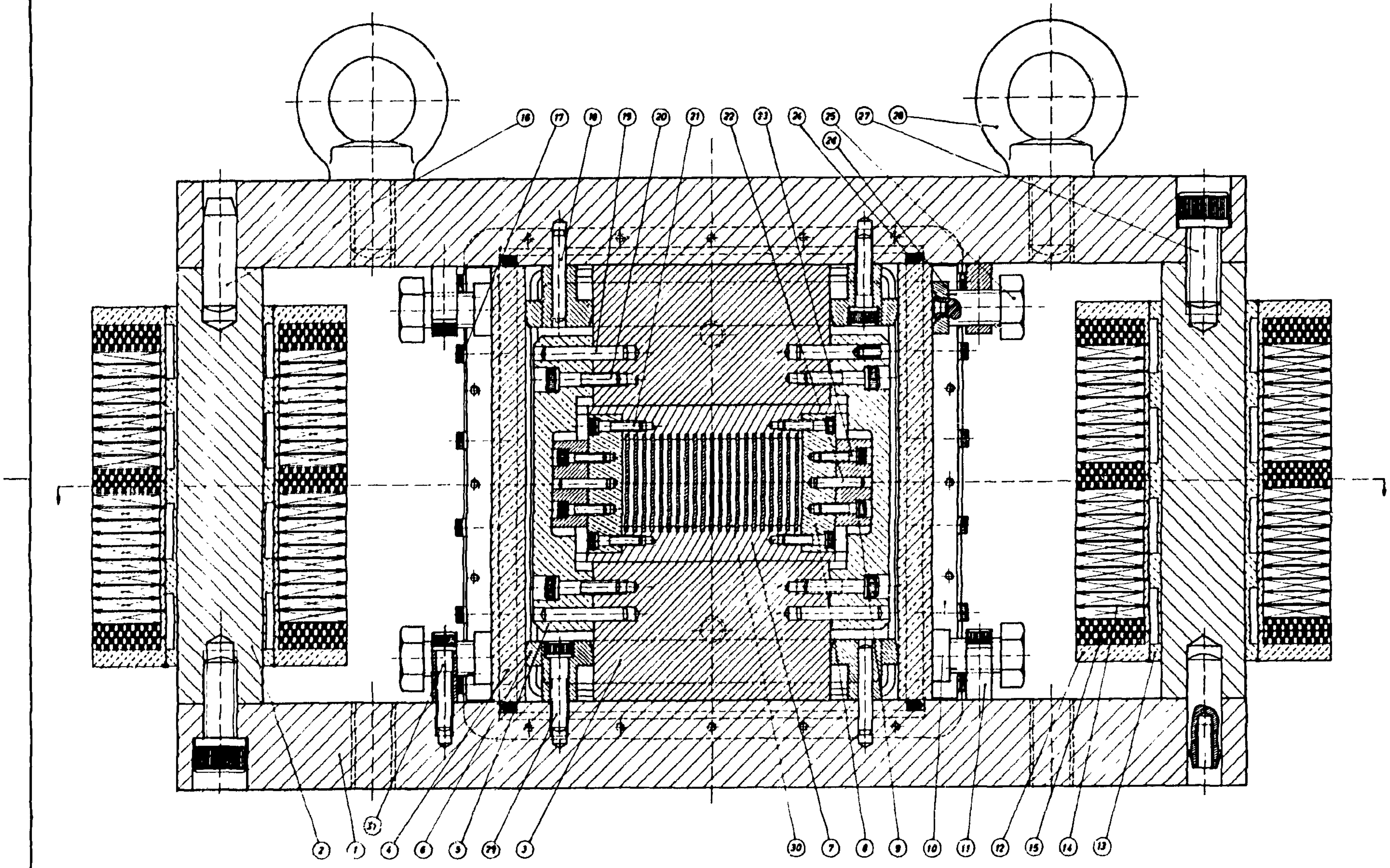
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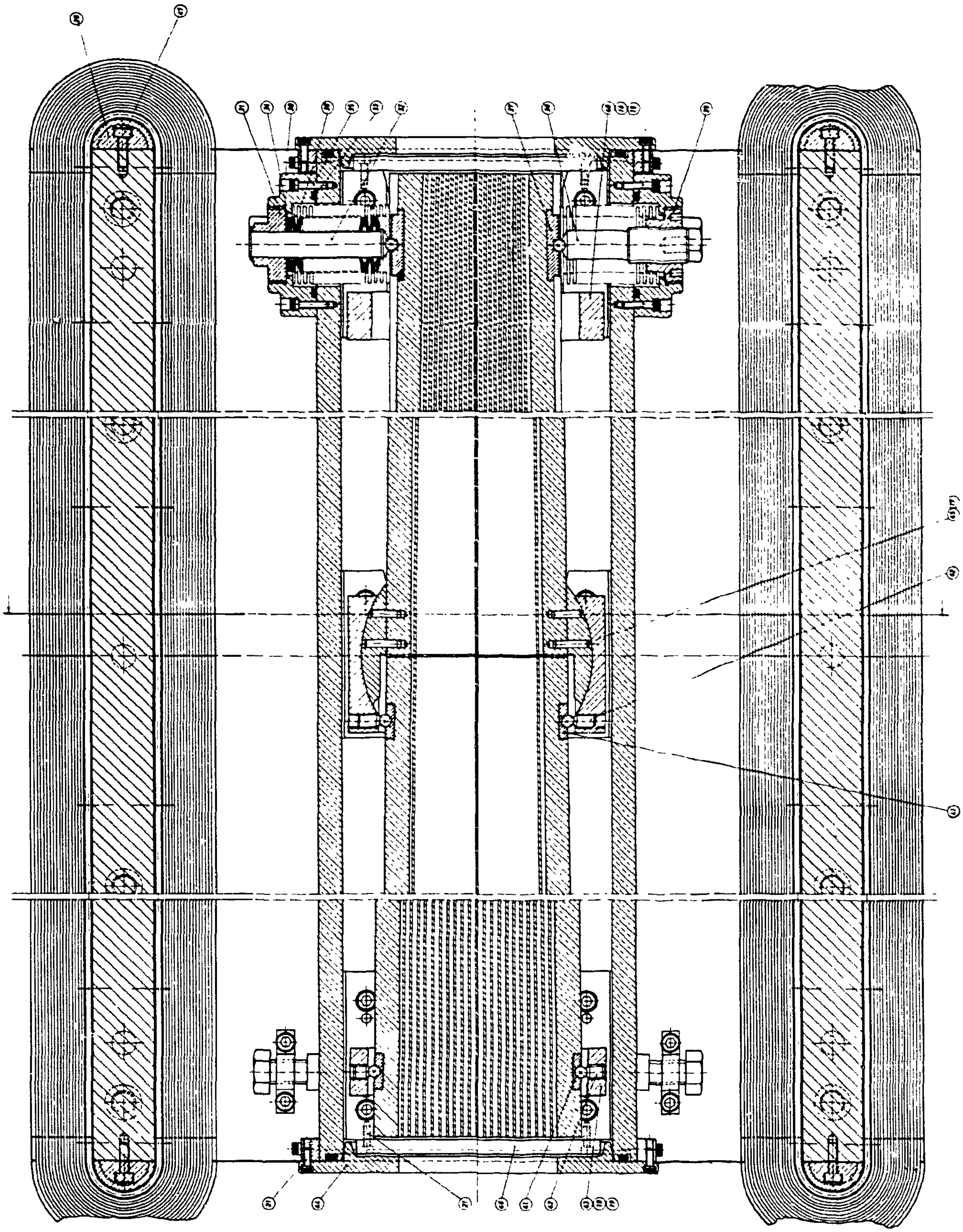
Fig. 1.

Fig. 2.



for the preceeding collimator systems (Fe-mirrors) given in the previous progress report may also be valid for this collimator system with the addition, that the admixture of hexagonal cobalt in the cubic cobalt may give deviation from magnetic saturation causing a lower value of $\overline{P}$.

The polarized neutron beam is at the focus point about 3 cm broad and 5 cm high and the flux is $5 \cdot 10^6 n/cm^2 sec$ (measured with gold foils).

The flux distribution of the polarized neutrons is maximum at 10 meV and falls off more rapidly than a Maxwellian for energies above the most probable energy.

The Cadmium ratio in the beam is about 2000 and the gamma background 3 m R/h.

All the properties of the beam are given for just closed collimators, which has turned out to be the most favorable configuration of the system.

The surface finish and the flatness of the neutron mirrors applied in the described collimator can be still improved resulting in a better reflectivity of the mirrors, which would yield a higher intensity of the polarized neutron beam, but not affect the polarization.

II INVESTIGATIONS OF CAPTURE GAMMA RAYS USING POLARIZED NEUTRONS

1. Circular polarization of capture γ-rays from H, S, Ca, Ni, Cd and Pb. x)

K. Abrahams, W. Ratynski, F. Stecher-Rasmussen, E. Warming.

By measurement of the transmission through a magnetized alloy,

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x) To be published at the International Conference on the Study of Nuclear Structure with Neutrons, Antwerpen, July 1965. The measurements on Ca has been published at the International Congress of Nuclear Physics in Paris, July 1964, together with measurements of γ - γ angular correlations performed on the same element at Kjeller, Norway.

the circular polarization of γ radiation following capture of polarized thermal neutrons in H, S, Ca, Ni, Cd and Pb was determined.

As a source of polarized neutrons we used a system of 40 magnetized cobalt mirrors placed in a beamhole of the DR 3 reactor. The neutron density in our beam was 22 n/cm^3 and the polarization was 70 - 80%.

The circular polarization of the capture γ radiation gave information regarding the spins of excited states, the multipole mixture of the γ transitions between the excited states, and the mixture of spins involved in the compound state which is formed by s- capture of a neutron. The experiments confirmed earlier measurements and some new spin assignments could be made.

In this way we determined the response of our detector-system (two 3" x 3" NaI scintillation spectrometers) for the factor in the anisotropy of γ radiation after s- capture of polarized neutrons which explicitely depends on spins of states and on multipolarities of transitions. These responsfunctions will be used later to determine the factor in the anisotropy depending on parity impurities and on the nuclear structure.

2. Parity Nonconserving Internucleon Potentials studied by the (n, γ) Reaction. x)

K. Abrahams, W. Ratynski, F. Stecher-Rasmussen, E. Warming.

Because of parity impurities in the nuclear states involved in a γ transition, a small admixture of E_1 and M_1 radiation might occur. Consequently anistropy of γ radiation might be found after s- capture of polarized neutrons. The angular distribution of the capture γ radiation with respect to the polarization direction of the neutrons is given by $W(\Theta) = W(1 + A \cos\Theta)$. The parameter A is the product of three factors:

x) To be published at the International Conference on the Study of Nuclear Structure with Neutrons. Antwerpen, July 1965.

The first factor depends explicitely on the spins of the states involved in the transition, this factor we determined in an earlier experiment. The second factor is given by the relative hindrance of the parity conserving main transition, with respect to the parity non conserving fraction of the transition, due to nuclear structure effects. The third factor is the parity impurity F in the nuclear states.

Experiments were done with H, S and Cd as targets. Evidence for anistropy was found. For Cd we reproduced the results of earlier measurements.

III INVESTIGATIONS OF CAPTURE GAMMA RAYS USING NONPOLARIZED NEUTRONS

The following measurements have been performed by means of the bent crystal spectrometer at the DR 3 reactor at Risö. Details about this apparatus has been reported in [1], the method of measurement has been described in [2].

1. Level scheme of Ho 166 x)

O.W.B. Schult, R. Koch, U. Gruber, B.P.K. Maier, Labor f. Techn. Physik der TH München and Research Establishment Risö, Denmark.

360 neutron capture gamma lines have been observed in Ho 166. A level scheme was proposed including the rotational band of the ground-state K = 0^- [523↑ - 633↑] which comprises the following states: [energies in keV] 0 (I = 0); 54.239 (I = 2^-); 82.470 (I = 1^-); 171.074 (I = 3^-); 180.467 (I = 4^-); 329.775 (I = 5^-); 377.806 (I = 6^-) and 557.688 (I = 7^-). The

[1] U. Gruber, B.P.K. Maier und O.W.B. Schult, Kernetechnik 5, 17 (1963)

[2] O.W.B. Schult, U. Gruber, B.P.K. Maier und F.W. Stanck, Z. Physik 180, 298 (1964)

x) to be published

rotational band head of the configuration K = 3^+ [523↑ - 521↓] was suggested to lie at 190.901 keV, so the following members of the band are 260.661 (I = 4^+); 348.257 (I = 5^+); 453.772 (I = 6^+) and 577.210 (I = 7^+). Three levels at 371.984 (I = 4^+); 470.839 (I = 5^+) and 588.103 (I = 6^+) were assumed to be formed by the coupling [523↑ + 521↓]. One state at 425.9 keV (I = 1^+, K = 1^+) is due to the coupling of the K = $7/2^-$ [523] proton with the K = $5/2^-$ [523] neutron. Most of these levels discussed correspond well to the states found by (d,p)-studies.

2. Energies and character of the low-lying levels in Nb 94 x)

U. Gruber, R. Koch, B.P.K. Maier and O.W.B. Schult, Labor f. Techn. Physik, TH-Munchen and Research Establishment Risø, Denmark.

J.B. Ball and K.H. Bhatt, Oak Ridge National Laboratory, U.S.A. and R.K. Sheline, Institute for Theoretical Physics, Copenhagen, Denmark.

During the irradiation of Nb 93 by thermal neutrons 47 gamma lines from 54 to ∼ 1 MeV were measured. These transitions determine the following levels in Nb 94 (energy in keV, spin and parity in paranthesis): GS (6^+), ≈ 40.7 (3^+), 58.724 (4^+), 78.675 (7^+), 113.404 (5^+), 314.64 (5^+), ≈ 334 (2^+) and 640.5 (6^+). The 315 keV and 641 keV states probably correspond primarily to the J = 3/2 state of the three neutron configuration coupling to the $g_{9/2}$ proton configuration. The other size states result primarily from the coupling of the J = 5/2 state of the three neutron configuration and the $g_{9/2}$ proton configuration. Energies of the levels and transition probability ratios are consistent with this interpretation.

3. Neutron capture gamma rays observed during the irradiation of La 139, Er 170 and Ta 181 by thermal neutrons

x) To be published in Nuclear Physics

B.P.K. Maier, U. Gruber, R. Koch and O.W.B. Schult, Labor f. Techn. Physik, TH-München and Research Establishment Risö, Denmark.

About 60 low energy lines from the reaction La 139 (n, γ) La 140 were observed, whereas the spectrum of Er 171 revealed roughly 50 lines. Approximately 150 lines have been seen after neutron capture in Ta 181.

4. Gamma Radiation from capture of thermal neutrons in Tm 169 x)

B.P.K. Maier, U. Gruber, R. Koch and O.W.B. Schult, Labor f. Techn. Physik, TH-München and Research Establishment Risö, Denmark, and
T.v. Egidy, Th. Elze and E. Bieber, Labor f. Techn. Physik, TH-München
and H.T. Motz, Los Alamos Scientific Laboratory, U.S.A.
and R.K. Sheline and G. Struble, Florida State University, U.S.A.

177 gamma lines due to the reaction Tm 169 (n, γ) Tm 170 have been recorded. The multipolarity was measured for 40 transitions. A level scheme of Tm 170 including 13 states and 35 lines was proposed. Three levels with energies 0(I = 1), 38.713 (I = 2) and 114.543 (I = 3) were found to belong to the $K = 1^-$ groundstate rotational band. A state at 149.721 keV ($I = 0$, $K = 0^-$) was determined, whereas an even parity state I = 3, $K = 3^+$ was stipulated at 183.193 keV. Further levels at energies 204.452 keV, 219.713 keV, 270.555 keV, 349.727 keV, 411.45 keV, 604.08 keV, 661.91 keV keV and 719.21 keV were suggested. Most of these states are in excellent agreement with (d, p)-studies.

5. Gamma radiation from the reaction Hg 199(n, p) Hg 200

B.P.K. Maier, U. Gruber, R. Koch and O.W.B. Schult, Labor f. Techn. Physik, TH-München and Research Establishment Risö, Denmark. xx)

x) To be published.

xx) To be published in Zeitschrift für Physik.

103 gamma transitions in Hg 200 have been observed. 37 of them were fitted into a level scheme which comprises 17 states. The energy of the one-phonon vibrational state I = 2^+ has been determined to be 367.970 ± 0.020 keV, that of the two-phonon vibrational triplet 947.34 keV, 1029.37 keV and 1254.20 keV. Further levels have been found at energies of 1570.30 keV, 1571.7 keV, 1594.3 keV, 1631.5 keV, 1641.5 keV, 1718.5 keV, 1730.8 keV, 1775.7 keV, 1842.9 keV, 1882.9 keV, 2062.6 keV and 2082.9 keV.

6. Neutron capture gamma spectrum and level scheme of Er 167 x)

R.H. Koch, Labor f. Techn. Physik, TH-München and Research Establishment Risö, Denmark.

The (n, γ)-spectrum of Er 167 was investigated. The energies and intensities of 47 transitions were measured. 22 of them were fitted into a level scheme. The rotational bands of the K = $7/2^+$ [633], K = $1/2^-$ [521], and K = $5/2^-$ [512] states were found up to the spin values I = $11/2^+$, $9/2^-$ and $7/2^-$. Gammavibrational states of these Nilsson orbits were determined or proposed. The energy of the K = $5/2^-$ [523] state was suggested. The branding ratios were compared with theoretical predictions.

7. Neutron capture gamma rays and level scheme of Er 168 xx)

R.H. Koch, Labor f. Techn. Physik, TH-München and Research Establishment Risö, Denmark.

During the irradiation of a Er 167 sample by thermal neutrons 211 gamma lines were measured, using the bent crystal spectrometer. The following rotational bands of Er 168 were determined: The groundstate band up to the spin value I = 8, the gammavibrational band beginning at

x) Thesis, to be published in Zeitschrift f. Physik.

xx) Thesis, to be published in Zeitschrift f. Physik.

821 keV up to I = 8, one two-particle state at 1094 keV with $K^{(\pi)} = 4^-$ and the corresponding rotational band up to I = 8. A $K^{(\pi)} = 3^-$ rotational band up to I = 7 was found to have the band head at 1541 keV. The intensity ratios of transitions from the gamma band to the groundstate band were used to determine the rotation-vibration interaction. The intensity ratios of transitions from the $K^{(\pi)} = 3^-$ to the $K^{(\pi)} = 4^-$ band were well explained assuming a Coriolis coupling between these bands.

8. Gamma rays from the reactions V 50 (n, γ) V 51, V 51 (n, γ) V 52, Y 89 (n, γ) Y 90 and Sc 45 (n, γ) Sc 46.

P. v. Assche, Mol, Belgium and
U. Gruber, R. H. Koch, B. P. K. Maier and O. W. B. Schult,
Labor f. Techn. Physik, TH-München and Research Establishment
Risö, Denmark.

Several gamma transitions were observed in V 51, which has not been investigated before. The level scheme in V 52, proposed by previous authors, was checked and the accuracy of the transition energies was improved in the average by a factor of 5 in respect to earlier works.

The (n, γ)-spectrum of Y 90 revealed roughly 10 lines, that of Sc 46 approximately 40.

IV STRUCTURE INVESTIGATIONS

1. Crystal structure investigations by a neutron diffraction time-of-flight spectrometer using powder samples

K. Mikke and B. Lebech.

The experimental method was described in the previous progress report. Since then we have mainly studied the effect on the resolution of sample size, chopper speed, entrance collimation and counter thickness. We have used samples of the Al and Si for calibration purposes, whereas samples as Pb_3O_4, PbO_2 and $PbTiO_3$ give an indication of the possibilities of the method.

Fig. 3 shows the resolution as a function of wavelength for various chopper speeds for a scattering angle 90^o. The resolution is defined as the halfwidth of a diffraction peak relative to the peak wavelength.

Also shown in Fig. 3 are the results obtained for Al by the Conventional Method [x)] and the results for Si obtained at the pulsed reactor in Dubna by the Time-of-Flight Method. The lower Dubna curve refers to 1% H_3BO_3 poisening of the moderators.

The resolution for the Time-of-Flight Method compares favourably with the Conventional Method. Caglioti et. al. [x)] however were able to obtain a resolution about 1% over the full range of observed aluminium reflections by using a triple axis spectrometer in the elastic arrangement, which is a much more elaborate system than the Time-of-Flight Spectrometer.

2. Crystal structure analysis of single crystals with the Time-of-Flight Spectrometer

K. Mikke and B. Lebech.

A slight modification of the Time-of-Flight Spectrometer gives a suitable arrangement for single crystal work. The method utilises the polychromatic beam. For a given scattering angle and properly adjusted orientation of the crystal the Bragg condition will be satisfied for a series of wavelengths corresponding to successive order of reflections. By using a wide range of scattering angles, several reflections from one zone can be studied simultaneously.

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x) G. Caglioti and D. Tocchetti: Nucl. Inst. Met. 32 (1965) 181 - 189.

Resolution as function of wavelength

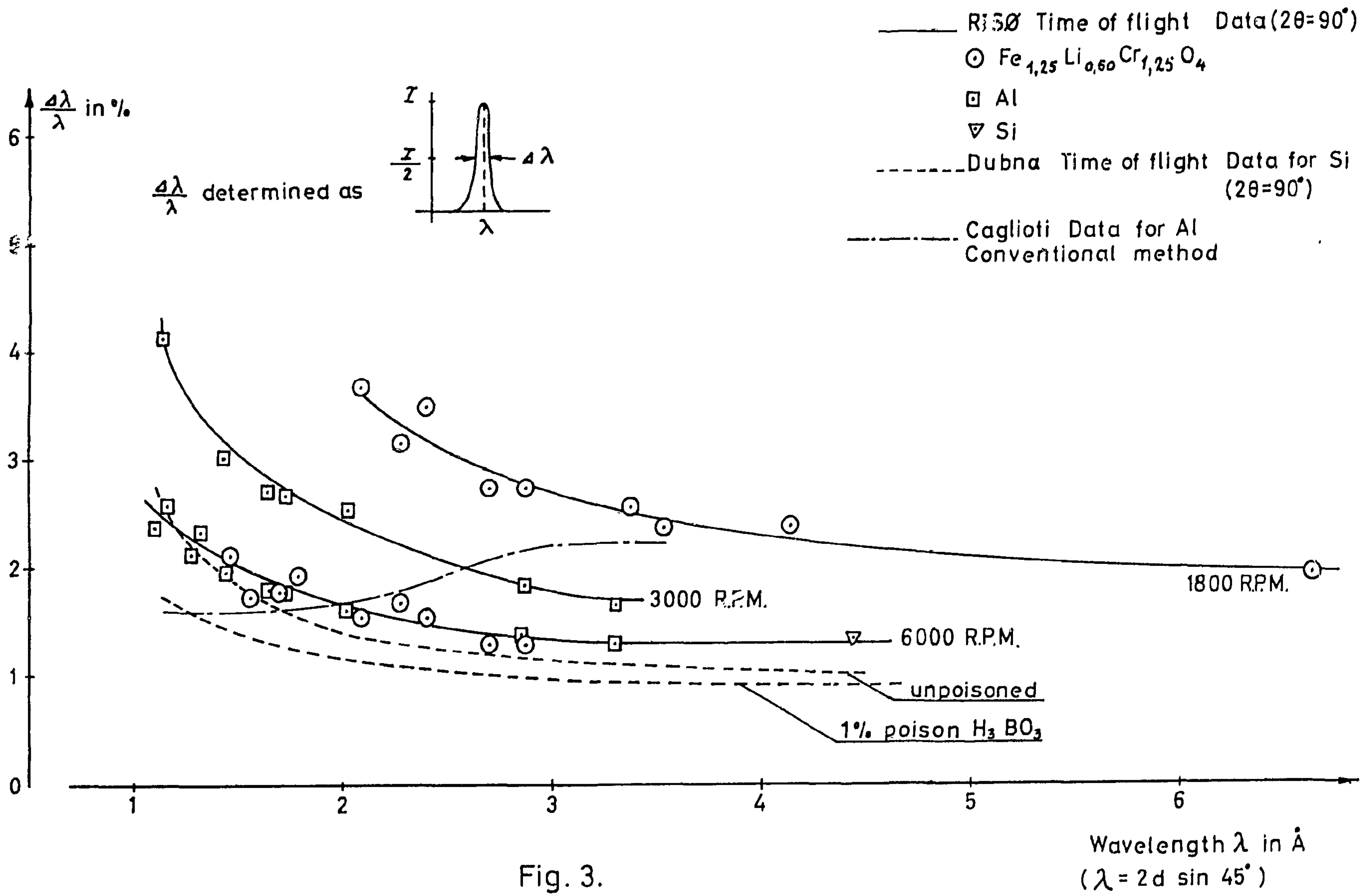

Fig. 3.

3. Inverted filter method combined with the Time-of-Flight Spectrometer

K. Mikke and B. Lebech.

A minor modification of the Time-of-Flight Spectrometer results in a simple facility for the measurements of double differential cross section for inelastic scattering of slow neutrons. The neutrons scattered at a fixed angle with an energy loss are selected by a detector shielded with beryllium [x)]. The method is particularly useful for studies of molecular dynamics of incoherently scattering solids.

4. Investigations of the magnetic structure of Cr-alloys

H. Bjerrum Møller and A. R. Mackintosh [xx)]

The period and amplitude of the spin wave in Cr and Cr-alloys has been studied by neutron diffraction using a crystal spectrometer.

It was found that the period as well as the magnetic moment of the spin wave in Cr-V alloys was decreasing with increasing amounts of V.

In Cr-Mn alloys the spin wave was found to be commensurate with the lattice and with a larger magnetic moment than found for pure Cr.

In thin Cr-Re alloys a coexistence of pure antiferromagnetic and sinusoidal spin state was found, while for thicker Cr-Re alloys such a coexistence only existed at low temperature, while the alloys at room temperature was found to be pure antiferromagnetic.

V CRITICAL NEUTRON SCATTERING

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x) B. N. Brockhouse et. al. IAEA Symp. Vienna (1960) 487.

xx) present address: Iowa State University, Ames, Iowa, U. S. A.

1. A neutron diffraction study of the order-disorder transformation in β-brass

O.W. Dietrich and J. Als-Nielsen.

Neutron scattering around a superlattice reflection in β-brass e.g. (100) reflection, yields information about the long range order parameter LRO and the short range order parameters, commonly described by a correlation function γ (R) for occupation of lattice sites.

LRO^2 is measured as the intensity of the superlattice Bragg-reflection, which only exists below the transformation temperature. The main interest is the temperature dependence of LRO. The old theory of Bethe[1] gives LRO $\sim (T_c-T)^{1/3}$ where T_c is the transformation temperature. Newer theories[2] find LRO $\sim (T_c-T)^{1/2}$. Preliminary experimental results of this investigation give a power in the temperature law slightly less than 1/3.

The short range order gives rise to critical neutron scattering around T_c. The range of short range order determines the width and the intensity of the critical diffraction peaks. Assuming the short range order parameters to follow the Ornstein-Zernike correlation function[3] $\gamma(R) \sim 1/r_1^{\,2} \exp(-\kappa_1 R)/R$, the critical phenomenon is described by the two temperature dependent parameters r_1 and κ_1. In that case the width at half maximum of the diffraction peak is 2 κ_1, and the critical intensity is proportional to $(r_1 \kappa_1)^{-2}$, making possible the determination of the temperature dependence of both r_1 and κ_1 and also of the absolute value of κ_1.

The experimental results yield excellent agreement between the shape of the measured critical diffraction peaks and the shape predicted by the Ornstein-Zernike correlation function.

According to theory $(r_1 \kappa_1)^{-2} \sim \left[(T - T_c)/T\right]^{\gamma}$. The Elliot and Marshall theory[3] gives $\gamma = 1$ whereas the High Temperature Expansion Theory[4] gives $\gamma = 5/4$. The data obtained follow nicely a power law with

$\gamma = 1.11 \pm 0.1$. r_1 is experimentally found to vary linearly with temperature, the temperature coefficient being 3.6 ± 1.2 (referred to $T-T_c/T$). We want to point out that these results are only preliminary.

Further work on the critical scattering is carried out with special attention to the critical scattering below T_c.

References:

1) H.A. Bethe, Proc. Roy. Soc. (London) A 150, 552 (1935)

2) I. M. Essam and M.E. Fischer, J. Chem. Phys. 38, 802 (1963)

3) R.I. Elliot and W. Marshall, Rev. Mod. Phys. 30, 1, (1958)

4) C. Domb and M.F. Sykes, Proc. Roy. Soc. (London) A 240, 214 (1957)

2. Critical magnetic scattering of neutrons in chromium

H. Bjerrum Møller, K. Blinowski[x)], A. R. Mackintosh[xx)], T. Brun[xx)], and P. Nielsen[xxx)].

The critical magnetic scattering of neutrons in chromium for temperatures above the Neel point has been studied in order to determine the temperature dependence of the spin-correlation-range.

The results have been published on the International Conference on Magnetism, Nottingham 1964.

VI INELASTIC NEUTRON SCATTERING

H. Bjerrum Møller and A. R. Mackintosh[xx)].

x) present adress: Institute Badan, Jagrowych, Swierk k. Otwocka, Warsaw, Poland.

xx) present adress: Iowa State University, Ames, Iowa, U.S.A.

xxx) present adress: H.C. Ørsted Institute, University of Copenhagen.

The phonon spectrum of chromium has been studied by the inelastic scattering of thermal neutrons. A triple axis spectrometer situated at the DR 3 reactor was used for these experiments and the phonon dispersion curves were studied in symmetry directions, using the constant $\bar{q}$ method, with fixed energy of the scattered neutrons. The specimens were single crystals of pure chromium metal in the approximate form of a cylinder 4 cm long and 1 cm in diameter. They could be placed in a nitrogen cryostat or in an oven whose temperature could be varied over a range between room temperature and approximately $600^{o}K$. One of these crystals had earlier been used for studies of critical magnetic scattering in chromium (1).

Well defined neutron groups were observed for most of the q values studied. Their intensity was as great as three times the background intensity, which was principally due to incoherent scattering from the crystal. The room background counting rate was approximately 5 counts per minute.

The dispersion curves in symmetry directions are shown in Fig. 4. Because of poorly formed neutron groups, the phonon energies between P and H are rather uncertain at present. These dispersion curves bear a close resemblance to those of tungsten (2) and molybdenum (3) and can therefore also be fitted quite closely by a force constant scheme extending to third nearest neighbours. The phonon energies scale approximately as the inverse square root of the ionic masses, indicating similar force constants and manifesting the similarity in the electronic structures of the three metals. No anomalies of the type found in molybdenum (3) were observed.

When the crystals were heated from approximately $100^{o}K$ to $400^{o}K$, the neutron groups progressively broadened, but no change could be observed in the phonon energies. One of the crystals used in these experiments contained a small uniaxial strain, which produced a large magnetic anisotropy (1). This anisotropy was not reflected in the phonon spectrum, nor was any change observed in the energies of those phonons with wavelengths near to the magnetic periodicity of the crystal, when it was heated

Chromium.

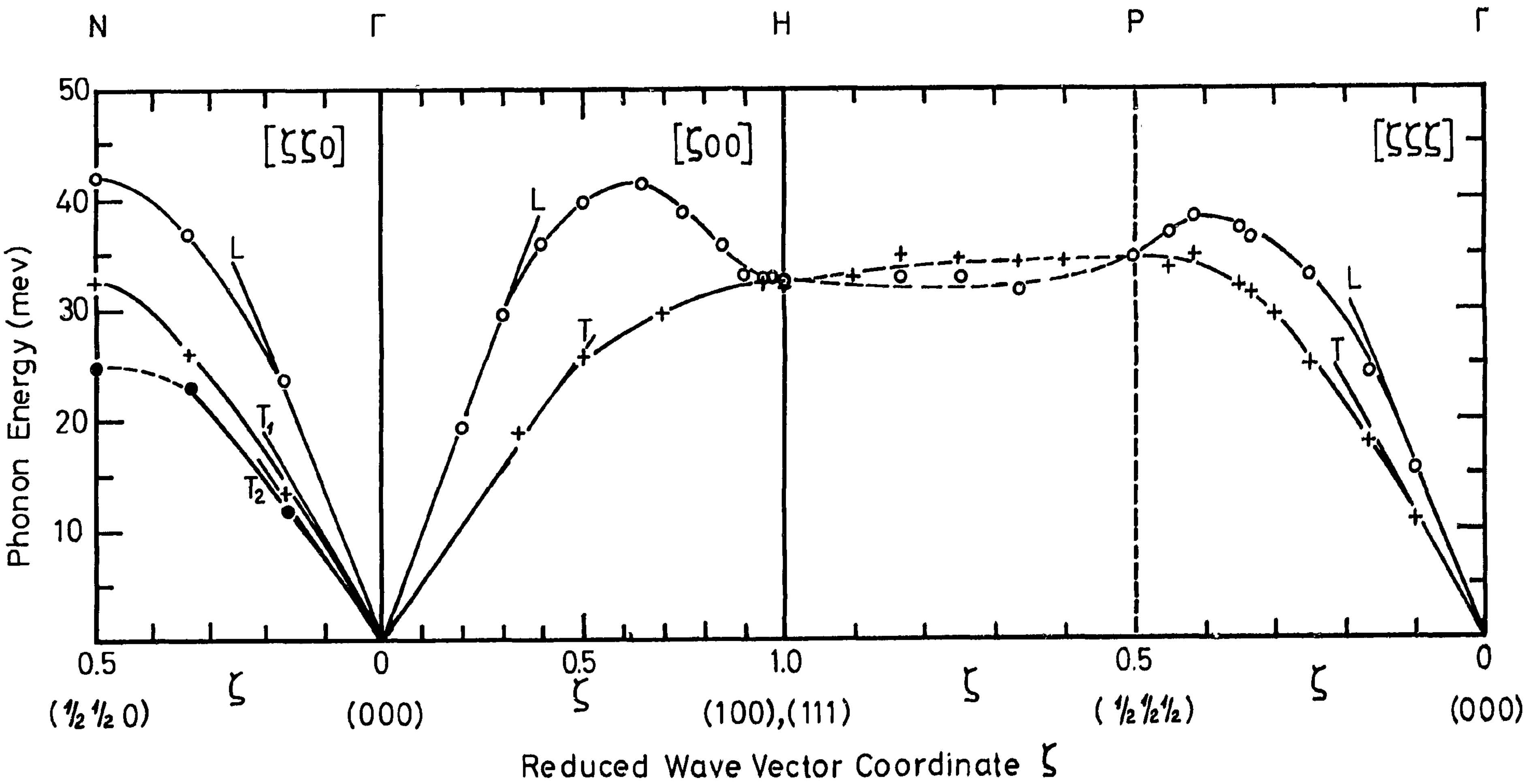

Fig. 4.

through the Neel temperature. The coupling between the magnetization waves and the lattice is therefore presumably small.

This work was presented on the IAEA Symposium on the Inelastic Scattering of Neutrons, Bombay 1964.

References:

1. H. Bjerrum Møller, K. Blinowski, A. R. Mackintosh and T. O. Brun, Solid State Communications 2, 109 (1964).
2. S. H. Chen and B. N. Brockhouse, Solid State Communications 2, 73 (1964).
3. A. D. B. Woods and S. H. Chen, Solid State Communications 2, 233 (1964).

VII THE NEUTRON β-DECAY HALF LIFE

C. J. Christensen, Arne Nielsen
and A. Bahnsen[x)], W. K. Brown[xx)], B. M. Rustad[xxx)].

This experiment has been described in previous progress reports. The main idea of the experiment is as follows. The β's from the decaying neutrons are detected by two plastic scintillation counters. The scintillators are placed in a homogeneous magnetic field, so that the two 5 x 10 x 93 cm scintillators and the field lines connecting the edges of the scintillators define a rectangular "box" of 5 x 10 x 20 cm size. When a neutron beam is passing this box parallel to the 10 cm side of the scintillator the part of the beam which is inside the box will be the effective source. The geometrical efficiency of the detectors for this source is 100%. By means of this detector system the energy spectrum of the neutron decay β's can be studied.

x) present adress: The University of Rochester, N.Y., U.S.A.
xx) present adress: Los Alamos Scientific Laboratory, New Mexico, U.S.A.
xxx) present adress: Brookhaven National Laboratory, Upton, N.Y., U.S.A.

Besides the decay rate it is necessary to know the neutron density in the source. This is measured by means of a He^3-proportional counter.

In the past year a new detector system has been finished. The principle was described in the last progress report. The system has a resolution of 20% for 976 keV conversion electrons from Bi^{207}. The length of the light guide is around 1 m.

The background in the electron detector has been improved so that we have now 5 decays pr. sec. 3 c/s room background, 0.5 c/s background from fast neutrons and reactor γ's coming from our own facility and 0.5 c/s capture γ's from our beam. This should be good enough for at least a 3% measurement.

The He^3 proportional counter is finished and a comparison with a gold foil irradiation gave less than 2% difference.

At present the decay spectrum is being studied and the detector arrangement with associated electronics is being studied in detail.

VIII PILE OSCILLATOR MEASUREMENTS

P. Skjerk Christensen.

The work with the Pile Oscillator at DR 1 has been concentrated on the following points:

i : Measurements of several compounds in the global oscillator.

ii : Measurements of various neutron sources.

iii: Measurements of transients introduced when a sample was shot through the core in a time of the order of 100 msec. These transients may give information of the cross sections (absorption and scattering) of the sample. If the sample is uranium one may be able to evaluate the burn-up of the sample. (These measurements were carried out on behalf of Brown-Boveri/Krupp, G.m.b.H., Jülich, Germany).

iv: In order to construct a pile oscillator utilizing the local effect, an annular ionization chamber was made. One item has been working satisfactorily in DR 1 during the whole period and improved versions have been produced.