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Love at first sight

Co-operation between the Netherlands and Norway on the peaceful use of atomic energy, 1950-1960

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Introduction

Late in 1938 the German chemists O. Hahn and F. Strassmann discovered the fission of the uranium nucleus. Soon thereafter the German physicist L. Meitner and her Austrian colleague O. Frisch showed that in this reaction a large amount of energy is released.[1] Aware of the possible consequences[2] the Dutch government purchased in the summer of 1939 ten tons of 'Yellowcake' (the trade name of partly refined uranium oxide) from Union Minière in Belgium.[3] This purchase became an important asset when after the Second World War the Dutch government faced the task of breathing new life into the pursuit of science. As regards nuclear science, it was soon realized that it would be impossible for the Netherlands to build a nuclear reactor on its own. To do so was not technically, and especially not financially, feasible for such a small country: 'We must learn to think on an entirely different scale from the Dutch scale, on a west European scale'.[4] Efforts to bring about joint working arrangements with the Americans in this sphere were severely hampered by the United States' policy of monopolisation and of keeping secret the information acquired in the field of nuclear energy.

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[1] R. Jungk, *Licht van duizend zonnen [translated from: Heller aus tausend Sonnen; also translated in: Brighter than a thousand suns]* (Amsterdam: Scheltens and Giltay, 1957), pp. 74-75.

[2] In the summer of 1939 the Dutch Prime Minister H. Colijn was informed of the latest developments on nuclear fission by the Duch Professor W.J. de Haas from the University of Leiden. The possible military consequences were also emphasized. Central Archives Ministry of Defence (hereafter CAMD), The Hague, Ministry of War, LITT P 34 25/10/45, W.J. de Haas to Prince Bernhard, Enclosure: 'Voorgeschiedenis van den aankoop van Uraanoxyde zouten', 3 Sept. 1945.

[3] H.M. Hirschfeld, *Herinneringen uit de bezettingstijd* (Amsterdam: Elsevier, 1960), p. 206; G. Dean, *Report on the atom* (New York: Knopf, 1953), p. 267; H.B.G. Casimir, *Het toeval van de werkelijkheid. Een halve eeuw natuurkunde [translated from: Haphazard Reality. Half a Century of Science]* (Amsterdam: Meulenhoff, 1983), p. 203; H. Ramaer, *De dans om het nucleaire kalf* (Rotterdam: Uitgeverij RAM, 1974), pp. 15-19; J.A. Goedkoop, 'Geel pigment en zwaar water', *Energiespectrum* 14(1990)1(January), pp. 14-20; CAMD, Chef Technische Staf KL 1946-1949, Box 1, File "Atoomenergie 1946", No. 60204-0-101 04/02/46, Meijnen to Sizoo, 4 Feb. 1946.

[4] Foundation for Fundamental Research on Matter (hereafter FOM by its Dutch acronym)), Utrecht, Minutes Governing Council FOM, 1946-51, Minutes of the meeting of the Governing Council FOM, 2 April 1949.

Eventually the Dutch search for a partner resulted in a working relationship with Norway started in 1951 with the Joint Establishment for Nuclear Energy Research (JENER), in which Great Britain would also come to play an important role. The Norwegians had experienced the same problems with American policy as the Dutch. They had also come to the conclusion that co-operation was necessary. The ability of the two countries to get along together so well in the nuclear field arose from their capacity to complement each other. By 1950 the Norwegians had already laid the foundations of a reactor at Kjeller near Oslo. Furthermore the essential heavy water,[5] used as a moderator in a nuclear reactor,[6] was produced in Rjukan. However, the Norwegians lacked one essential resource: uranium. Uranium ore was being mined near Evje in the Setesdal, but it was of poor quality and insufficient in quantity. The Netherlands by way of contrast possessed in their Yellowcake about seven tons of uranium and contributed it to the joint venture. Furthermore, the Netherlands was able to bring in considerable experience in nuclear research. A Dutch multinational, Philips in Eindhoven, had been active in nuclear research even before the Second World War.[7] In short, it was possible for the two small countries to enter into a joint working relationship based on reciprocity. This relationship would, however, have to compete against a policy being pursued by the United States that dominated the international atomic energy scene.

This study describes the co-operation between the Netherlands and Norway in the sphere of the peaceful use of nuclear energy: from the first,

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[5] Most of the hydrogen atoms in water only have a proton as nucleus. One in 5,500 also contain a neutron and are thus nucleii of the isotope hydrogen-2 or deuterium (D). By electrolysis, among other methods, they can be concentrated to produce in the end virtually pure D2O or heavy water.

[6] A moderator is a material which is used in nuclear reactors to slow down the neutrons released by uranium fission, thus increasing their chance to induce fission of another uranium nucleus and perpetuate the chain reaction. This is achieved by having the neutrons bump repeatedly into the atomic nucleii of the moderator. The neutrons thus slowed down are called thermal neutrons. A good moderator must have a low mass number and a low rate of neutron absorption. Examples are heavy water, graphite, beryllium and ordinary water, the latter however having significant neutron absorption.

[7] J.H. de Boer, *Van het een komt het ander, Afscheidscollege gehouden op 26 juni 1969* (Delft: Waltman, 1969), pp. 6-7; Philips Company Archives, Overzicht activiteiten Philips in de jaren dertig en veertig, undated, pp. 1-3; Dean, *Report on the atom*, p. 269; Harry S. Truman Library (hereafter HSTL), Independence, Missouri, Alphabetical File, Box 17, File: War report - Intelligence review, 13 feb. 1947, pp. 69-71.

'love at first sight', contact between H.A. Kramers and Gunnar Randers in 1950, via two JENER contracts to the liquidation of JENER in 1959.[8]

'Love at first sight'

In January 1950 the eminent Dutch physicist and driving force behind post-war Dutch research in nuclear physics, H.A. Kramers, visited Denmark, Norway and Sweden to follow up contacts that had been made on 10 November 1949 in Amsterdam on the inauguration of the first Dutch cyclotron.[9] The possibility of joint working arrangements with Denmark and Sweden came to nothing for various reasons. With Norway the outcome was completely different.

Kramers was received in Oslo by Gunnar Randers. Randers had gone all out to build a nuclear reactor in Norway and construction was now underway at Kjeller, just outside Oslo. As mentioned, the Norwegians still lacked the uranium. The Norwegians were forced to mine uranium from very poor ores near Evje. Not quite confident in their own mining, in 1948 they had knocked on the door of the British for supplies of uranium,[10] but had been informed that the British did not want to supply uranium metal because '... our own production programme is designed in such a way that we have very little spare capacity and must be cautious about accepting even a small additional amount of work'.[11] The British source was thus cut off.

The response from the French was to ask for the establishment of a formal co-operation. This was no surprise. Norway and France were

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[8] The co-operation between Norway, the Netherlands and Great Britain is also (partly) described in: J.A. Goedkoop, *Geschiedenis van de Noors-Nederlandse samenwerking op het gebied van de kernenergie* (The Hague: Reactor Centre Netherlands, Mededelingen No. 30, 1967); A. Forland, *Norsk Atomenergipolitikk, 1945-1951* (Bergen: Universitet i Bergen [Dissertation], 1985); A. Forland, 'Pa leiting etter uran. Institutt for atomenergi og internasjonalt samarbeit 1945-51', *Forsvarsstudier* 3(1987); A. Forland, 'Atomer for krig eller fred? Etableringa av Institutt for Atomenergi 1945-48', *Forsvarsstudier* 2(1988).

[9] For a report on Kramers' trip to Scandinavia, see: FOM, Minutes Governing Council FOM, 1946-51, Minutes of the meeting of the Governing Council FOM, 11 Feb. 1950, pp. 1-2.

[10] Public Record Office (hereafter PRO), London, AB6/360, Randers to Cockcroft, 31 March 1948; Cooperation with Norway, by Cockcroft, 3 Feb. 1948; Norwegian request for uranium metal, by Perrin, 17 March 1948.

[11] Ibid., Perrin to Randers, 30 Dec. 1948.

collaborating closely throughout the 1940's on the peaceful use of atomic energy. Doctorate students were sent to France to learn from French nuclear science. One of them, Einar Sealand, returned to Norway to become the director of the chemical department at Kjeller. Others worked for shorter stages in French laboratories. Odd Dahl, who would construct the first Kjeller reactor, likewise went to France to study the first French nuclear reactor. France assisted the Norwegians with their project because the French needed Norwegian heavy water for the construction of the first French piles. The Norwegians were very reluctant to enter into an agreement with the French.[12] The French option was eventually abandoned mainly for political reasons. The scientific leader of the French Commissariat à l'Énergie Atomique (CEA), Frédéric Joliot-Curie, was renowned for his left-wing sympathies and the Norwegians did not want to risk their good relations with the United States on this account.[13] The negotiations between the Norwegians and French had reached a stalemate when Kramers appeared on the stage.

The message from Kramers that the Netherlands possessed a substantial quantity of uranium oxide came to Randers 'like a lifebuoy'. Randers grasped the proposal of co-operation with both hands. The Norwegian central organisation for research, the Norges Teknisk Naturvitskaplege Forskingsrad (NTNF), received a generous donation for the reactor from the Norwegian Minister of Defence, Jens Chr. Hauge. Randers thought the Norwegians might have enough of their own uranium available within one to two years, but this estimate was seriously doubted by other physicists. Moreover, major problems were anticipated in purifying the uranium. In short, Kramers arrived in Norway at a strategically important moment. He recognised the Norwegians' eagerness to get hold of uranium and proposed that Dutch uranium oxide be used to fuel the Norwegian nuclear reactor. During the course of this meeting the broad outline of a joint working relationship was agreed upon.

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[12] A. Forland, *Norsk Atomenergipolitikk, 1945-1951*, pp. 127-146.

[13] The United States held the view that '... Prof. and Mme Joliot-Curie are active and ardent communists and are strongly anti-United States in their sympathies ... Their communist leanings are of long standing and have been fostered by close family associations with two extreme leftists, Profs. Paul Langevin and Jean Perrin, both now dead. This association formed the nucleus of a clique of communist physicists which, unfortunately, had been dominant in French scientific circles'. HSTL, Naval Aide Files, Alphabetical File, Box 19, War Department - Intelligence Review, June 1947, 26 June 1947, p. 57.

On 4, 5 and 6 March 1950 an 'international committee' of Norwegians and Dutch met in Leiden to discuss bilateral co-operation. C.J. Bakker, director of the Amsterdam cyclotron, and J.M.W. Milatz, treasurer of the Foundation for Fundamental Research on Matter (hereafter FOM by its Dutch acronym), the central organisation engaged in nuclear physics research in the Netherlands, took part in the discussions on the Dutch side, while Kramers had a more advisory role. Randers was present on the Norwegian side. The starting points that Kramers and Randers had discussed in January 1950 were worked out in more detail.[14]

The preamble to the agreement stressed the economies that could be achieved in the sphere of nuclear energy by small countries working together. Both countries wanted in this way to gain access to a nuclear reactor to carry out scientific research. It was hoped that the knowledge obtained would make possible a joint reactor producing significant power to be built at a later date. NTNF and FOM were to appoint a Joint Commission for co-operation whose task was to make the nuclear reactor in Kjeller ready for operation as quickly as possible and to set up and organise scientific and technical research. The committee was to be made up of six members and six deputy members appointed on a fifty-fifty basis. The duties of chairman would be alternately shared. The director on the other hand would be a Norwegian, to be appointed by the Joint Commmission. The normal running costs would be met by NTNF; FOM would contribute to these costs and provide technical equipment. FOM was also to supply no more than five tons of uranium raw material. Through the stipulation that the instruments and raw materials remained the property of those who had contributed them, the Netherlands kept possession of its uranium raw material. Thus the Netherlands retained the right of ownership which could be claimed should the need arise. Broad agreement was reached between the two delegations. Only one problem remained unresolved: The Dutch uranium oxide needed to be purified within the shortest time possible, because unpurified uranium could not be used in the Norwegian reactor.

[14] FOM, Minutes Governing Council FOM, 1946-51, Minutes of the meeting of the Governing Council FOM, 25 March 1950, pp. 1-4.

Refining the uranium oxide

For a nuclear reactor to be maintained in a critical state [that is to say a state where it can sustain a chain reaction] with as little natural uranium as possible, all other neutron absorbing materials must be avoided. This is the reason one cannot use ordinary water as the moderator. Criticality is possible with graphite as moderator provided one has available at least ten tons of uranium; otherwise it is only possible with heavy water, which shows very little absorption. Norway could provide the heavy water, but then the Dutch uranium oxide needed to be purified to remove all undesirable components. Fortunately, oxygen scarcely absorbs neutrons so that the purification goal could be achieved with pure uranium oxide, rather than metallic uranium, something which neither the Netherlands nor Norway was anywhere near being able to manufacture at that time. Thus FOM was confronted with the question of where the unrefined raw material was to be converted into pure oxide for the reactor in Kjeller. There were two options: in the Netherlands or in France.[15]

The French option was the least desirable. The reason why was the same as the considerations of the Norwegians: American opposition and Joliot-Curie's 'communism'. Alongside political considerations, financial considerations also played a part. The factory of Vondelingenplaat Chemical Products PLC, near Rotterdam, had made an offer to refine the uranium for fifty thousand guilders,[16] thirty thousand guilders less than the price that the French were asking.[17] Finally, the members of the Dutch Joint Commission thought it better to keep everything in their own hands: '... then we gain essential experience which is invaluable. Moreover, there is always the risk, if it were done in France, that our hexa-oxide, a codename for 'Yellowcake', might be affected by an export ban'.

However, increasingly it became clear that even using pure uranium oxide would have drawbacks. Once the reactor would have been brought to a critical state, with a constant average number of neutrons circulating inside it, so that the neutron density, number of neutrons per cubic metre, and the neutron flux, the number of neutrons which would fly through an imaginary

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[15] Ibid., Minutes of the meeting of the Governing Council FOM, 25 May 1950, p. 8.

[16] FOM, Records Beekman, Netherlands Joint Commission delegation, Kernreactor-II, Factory of Vondelingenplaat Chemical Products PLC to Woltjer, 23 May 1950.

[17] Ibid., Minutes of the meeting of the Joint Commission-Netherlands, 8 June 1950, p. 6.

square metre per second, were both constant, the next question to consider would be the size of these numbers. To produce radioactive isotopes and to conduct physics experiments the neutron flux should be as high as possible. But this quantity is limited by the amount of heat which can be carried away per second from the reactor, the thermal capacity, usually expressed in kilowatts. Now for a reactor like that at Kjeller, with the uranium fuel compacted in rods, the thermal capacity would, apart from the size of the heat exchanger, the capacity of the circulation pump and the outside temperature, be determined by the temperature the fissionable material could sustain. Hence it would depend on both the diameter of the fuel rods and on their thermal conductance.

What Kramers had begun to fear now (Randers was rather more optimistic) was that even after the purified uranium oxide had been compacted as much as possible by compression, the rods would still be so thick and the heat conduction so poor that the reactor would only be able to produce approximately ten kilowatts. Kramers thought this amount inadequate and this is why he would much rather have metal uranium fuel rods. During a meeting at the British Foreign Office on 25 July 1950 he mentioned that the Netherlands wanted the reactor to produce one to two hundred kilowatts, which would not be possible with uranium oxide.[18] During this visit J.D. Cockcroft, the scientific leader of the British nuclear programme, had already indicated that the British were able to make the metal. The process was secret, so that it could not be produced under licence in the Netherlands. With this information in the backs of their minds the Dutch delegation of the Joint Commission decided, at its own meeting, to enquire into the possibility of obtaining uranium metal rods from Great Britain.[19]

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[18] Archives Ministry of Foreign Affairs (AMFA), The Hague, London Embassy, Secret Archive, 1955-64, Box 36, 813.33, Nederland-Noorwegen Atoomenergie, Gevers to Boon, 25 July 1950; and PRO, AB6/512, Records of Conversation by Roger Makins, 25 July 1950.

[19] FOM, Records Beekman, Netherlands Joint Commission delegation, Kernreactor-II, Minutes of the meeting of the Netherlands Joint Commission delegation, 2 Aug. 1950, p. 3.

Uranium metal rods from Great Britain for JENER

Kramers took it upon himself to implement the decision. On 4 August 1950 he asked Cockcroft to supply more technical details. Kramers proposed to come to Harwell, the British nuclear research centre, with Randers to discuss the matter further.[20] Cockcroft, however, demanded from Kramers that the Dutch Ministry of Foreign Affairs first '..make an enquiry from our Foreign Office as to whether they would be able to turn your uranium oxide into metal'. In short, both ministries had to give their authorisation.[21]

After the Norwegian-Dutch joint venture was approved in principle by the Dutch Council of Ministers on 27 December 1950,[22] Kramers played for high stakes by asking for more than was necessary: 'About three tons would suffice, but it might be useful to buy a good deal more, eventually all we can get, for the oxide available. Randers urges us strongly to buy all we can'.[23] It became apparent later that Randers really meant it when he offered to pay any costs in excess of what the Netherlands could afford: 'By non-payment Norway could give heavy water in exchange for the metal'.[24]

In reply to Kramers' earlier questions,[25] Cockcroft noted that the British '... should be able to deliver the uranium metal rods as soon as arrangements could be made to ship them provided that at the same time you could arrange to ship the oxide to us'.[26] An initial inspection of the metal rods led Cockcroft to conclude that they were perfectly suitable for the reactor in Kjeller. According to informal information given by the Americans three tons of uranium metal would be required for the reactor in

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[20] PRO, AB6/512, Kramers to Cockcroft, 4 Aug. 1950.

[21] Ibid. and AMFA, London Embassy, Secret Archive, 1955-64, Box 36, 813.33, Nederland-Noorwegen Atoomenergie, Cockcroft to Kramers, 11 Aug. 1950.

[22] Algemeen Rijksarchief (=General National Archive), Second Section (hereafter ARA-II), The Hague, 2.02.05, Archives Cabinet Council, Index no. 394, Meeting Cabinet Council, 27 Dec. 1950.

[23] PRO, AB6/512, Kramers to Cockcroft, 8 Jan. 1951.

[24] FOM, Records Beekman, Netherlands Joint Commission delegation, Kernreactor I,II,III, Blanco Map and Minutes Reactor Committee, 1950-52, Minutes of the discussions of the Netherlands Joint Commission delegation with Dr. G. Randers, 23 Feb. 1951, p. 3.

[25] PRO, AB6/512, Kramers to Cockcroft, 28 Nov. 1950.

[26] Ibid., Cockcroft to Kramers, 4 Dec. 1950.

Kjeller. After some uncertainty about what was the right amount,[27] the price per thousand kilos of metal was fixed at 7,540 English pounds including packing. The metal would be made available as soon as the Dutch 'Yellowcake' was ready for delivery.[28]

After initially asking for three and a half tons, Kramers soon reduced his request to no more than three tons of uranium metal: 'We now find, that the reactor tank will not even hold three tons'.[29] Of course Cockcroft could not have any objections to Kramers' request and agreed to supply three tons of uranium metal. Somewhat surprised he added: 'I presume that you have agreed on this with the Norwegians'.[30] Kramers was able to reassure him on this point.[31] Financial problems probably lay at the root of this remarkable step on Kramers' part. By exchanging less with the British the additional payment would be lower. Thus the Dutch gained more financial elbow room.

Once financing had been arranged on the Dutch side, the final phase of the deal between the Netherlands and Great Britain to exchange oxide and metal could be set in motion. The small countries were eager to proceed, for research at Kjeller could not proceed without the British uranium metal. But first the British wanted to analyse the uranium ore before the shipment left the Netherlands. Results of the analysis received on 8 May 1951 showed that the Dutch oxide '... obtained a figure of 65% metal approximately'. The British were prepared to exchange 103 (50 kilogram) containers of the Dutch ore for three metric tons of British uranium metal rods. Upon receipt of the Dutch uranium ore, the British material would be shipped straight to Norway.[32] The Dutch oxide was despatched to Britain on 25 May 1951[33] and after its arrival a message was sent to Randers on 12 June 1951 telling him that the metal was on its way to Norway.[34] On 22 June 1951 Randers

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[27] Ibid., Kramers to Cockcroft, 10 Jan. 1951 and Cockcroft to Kramers, 12 Jan. 1951.

[28] Ibid., Cockcroft to Kramers, 4 Jan. 1951.

[29] Ibid., Kramers to Cockcroft, 25 April 1951.

[30] Ibid., Cockcroft to Kramers, 27 April 1951.

[31] Ibid., Kramers to Cockcroft, 8 May 1951.

[32] Ibid., Stewart to Kramers, 8 May 1951.

[33] PRO, AB6/360, Randers to Cockcroft, 6 June 1951.

[34] PRO, AB6/512, Arnold to Randers, 12 June 1951.

informed Cockcroft that the material had arrived, in 137 boxes of which five or six were broken.[35]

JENER takes off

The problem of obtaining uranium in suitable form for the reactor at Kjeller had been resolved for the time being. Formal negotiations on Norwegian-Dutch co-operation could now take place. Following the earlier signing by Alf Ihlen, the director of NTNF, the Norwegian-Dutch contract was at last also signed by the Dutch in the meeting of the Dutch members of the Joint Commission on 15 March 1951.[36] On 12, 13 and 14 April 1951 a Dutch delegation from FOM visited Oslo to meet representatives of NTNF to discuss arrangements for their joint venture.[37]

The Joint Commission meeting of 12 April 1951 was mainly taken up with administrative matters.[38] Present on behalf of the Netherlands were members Kramers, Bakker and Milatz; observers W.J. Beekman (on behalf of FOM and moreover the Dutch secretary) and J.H. Bannier (secretary of the executive committee of the organisation for Pure Scientific Research (ZWO), through which FOM was financed). Present on behalf of Norway were members Svein Rosseland (University of Oslo), Odd Dahl (Christian Michelsens Institute) and Nicolai Stephansen (Norsk Hydro); observer Robert Major on behalf of NTNF. Gunnar Randers served as Norwegian Secretary. Alf Ihlen, who chaired the meeting provisionally until a chairman could be elected, emphasized the importance of Norwegian-Dutch co-operation in the field of nuclear physics; he saw the project as a first step towards West European integration in this field. Kramers was able to present the signed

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[35] Ibid. and AB6/360, Randers to Cockcroft, 22 June 1951.

[36] FOM, Records Beekman, Netherlands Joint Commission delegation, Kernreactor-I,II,III, Blanco map and Minutes Reactor Committee, 1950-52, Minutes of the sixth meeting of the Netherlands Joint Commission delegation, 15 March 1951, p. 5.

[37] Archives Ministry of Education and Science (hereafter AMES), Zoetermeer, Hoger Onderwijs en Wetenschappen (hereafter HOW), Index no. 141, Behandeling van aangelegenheden met betrekking tot de Stichting FOM, Note FOM regarding 'Samenwerking tussen Noorwegen en Nederland op het gebied van atoomenergie', undated; Bannier to Rutten, 18 April 1951.

[38] FOM, Minutes Joint Commission, 1951-54, Minutes of the first meeting of the Joint Commission, 12 April 1951.

contract, which now carried, alongside Ihlen's signature the signatures of himself, H.R. Woltjer (from the Governing Council of FOM) and Milatz.

On 13 April, between the two meetings of the Joint Commission, the men visited Kjeller, where the laboratories and the construction of the nuclear reactor were almost completed. The reactor was to contain three tons of uranium and seven tons of heavy water as moderator. The heavy water was to be cooled by circulating it through a heat exchanger.

In the second meeting of the Joint Commission more substantive matters came up for discussion.[39] The Dutch had been impressed by the achievements of the Norwegians. The Norwegians, despite the uncertainty which had prevailed over the cooperative relationship for a long time, were proceeding in top gear: 'Many millions of crowns had been allocated before it had become completely certain that the 'material' [uranium raw material] would be available'. The Norwegians also expressed satisfaction about the achievement of the agreement with the Netherlands. Amazement was expressed at '... Dutch preparedness, abandoning all chauvinism, to allow all the work to be carried out in Norway'. The name for the joint project was agreed: Joint Establishment for Nuclear Energy Research (JENER). The work to be carried out at Kjeller was, in the first instance, to be concerned with production of radioactive isotopes, practical application of those isotopes, research on neutrons, research on metals and other materials using the reactor, and study of the possible application of nuclear energy for peaceful purposes. By inviting research workers from other countries the sponsors hoped to initiate a closer cooperation between the West European countries in the field of nuclear energy.

Svein Rosseland, Odd Dahl, the man who had designed the reactor, and Nicolai Stephanson were appointed as members of the Joint Commission on behalf of Norway. Kramers (chairman of FOM), Bakker (director of the Dutch cyclotron) and Milatz (treasurer of FOM) were appointed on behalf of the Netherlands. Rosseland was elected chairman, Kramers as deputy chairman, and Randers as director of the joint venture. The director's salary was to be paid on a fifty-fifty basis. The financial contribution from the Norwegians was budgeted at 885,000 Norwegian crowns for 1951-1952 and the Dutch contribution at 700,000.[40] By then the greater part of the Dutch contribution had already been spent on the conversion of the uranium. Finally, a press release was drawn up to officially publicise the Norwegian-

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[39] Ibid., Minutes of the second meeting of the Joint Commission, 14 April 1951.

[40] The exchange rate in 1951 was two Norwegian crowns for one Dutch Guilder.

Dutch joint venture. It was also decided to inform foreign governments through the official channels of the coming about of the Norwegian-Dutch agreement. For the Dutch this meant the governments of the United States and Great Britain. The Dutch ambassador in Oslo immediately consulted the Norwegian Ministry of Foreign Affairs, to produce a press statement in English which was made public on 15 April 1951.[41] The British[42] and the American governments[43] were informed on 16 April 1951.

By 30 July 1951 significant progress had been achieved: the reactor in Kjeller was ready with the uranium-metal rods, meanwhile clad with aluminium, in position. That day the heavy water was pumped up until the reactor went critical for the first time. After this succesful start it was given the name Joint Establishment Experimental Pile (JEEP).[44]

The dynamic start of JEEP presented JENER with some financial problems. When the budget for 1951-1952 had been drawn up it was still uncertain when JEEP would become operational and so no financial resources were reserved for it. An extra contribution of 100,000 Norwegian crowns from the Norwegian Ministry of Defence could have provided a solution, but the Dutch delegation objected to this because it thought that military involvement should be avoided as far as possible. The Netherlands was emphasizing the peaceful application of nuclear power. As a compromise it was agreed that the contribution from the Norwegian Ministry of Defence would be put into research on the propulsion of ships by nuclear power: 'Mr. Beekman would like to point out that it was not the research on

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[41] AMES, HOW, Index no. 141, Behandeling van aangelegenheden met betrekking tot de Stichting FOM, 1950-1973, Statement on Norwegian-Netherlands Cooperation on Nuclear Physics, 15 April 1951.

[42] AMFA, London Embassy, Secret Archive, 1955-64, Box 36, 813.33, Nederland-Noorwegen Atoomenergie and PRO, FO371/93213, Aide-Mémoire Ministry of Foreign Affairs to the Foreign Office, 16 April 1951.

[43] Washington National Records Center (hereafter WNRC), Suitland, Maryland, Record Group (hereafter RG) 59, Records of the Special Assistant to the Special Assistant to the Secretary of State for Atomic Energy Matters, 1944-52, LOT: 57D688, Box 51, Folder 21. Netherlands General, 1946-52 and National Archives (hereafter NA), Washington DC, RG 59, Decimal Files, 1950-54, Boxes 5980 and 5979, 956.7138/4-1651, Memorandum of Conversation with Ambassador Morgenstierne of Norway and Ambassador Van Roijen of the Netherlands by Perkins, with Attachments: 'Netherlands and Norwegian Aides-Mémoires', 16 April 1951.

[44] Netherlands Energy Research Foundation (hereafter by its Dutch acronym ECN), Petten, First Annual Report JENER, 1951-51, pp. 6-7.

ship propulsion by nuclear energy the Dutch delegation was opposed to but military work in general'. To which Milatz added: 'Ship propulsion is not a military subject'.[45]

The official opening of JEEP took place on 28 November 1951 in the presence of Norway's King Haakon and the Dutch Minister for Education and Science, F.J. Th. Rutten among others.[46] In spite of his poor health Kramers was also there. It would be his last contribution to the Norwegian-Dutch joint venture, which had to a large extent come about as a result of his early initiatives: He died 24 April 1952.

After a few teething problems JEEP was operated day and night five days a week from September 1952 onwards. Throughout the normal working day the scientific personnel conducted physics experiments; in addition, overnight isotope production took place. In the cold months in Norway, when the temperature outside was low, a capacity as high as 250 kilowatts was reached. However, when the outside temperature increased the reactor had to be turned down to prevent the moderating heavy water around the nuclear fuel rods from beginning to boil.[47]

JENER had taken off, but some uncertainty had developed concerning the legal connection between NTNF and JENER. The Dutch-Norwegian contract had been concluded between FOM and NTNF. However, on 1 January 1948 the Institutt for Atomenergi (IFA) had been set up to manage the Norwegian nuclear reactor. So a working party was set up at the beginning of 1952 to look into the legal aspects and the organisation of IFA. Based on a proposal in the Norwegian parliament (Storting) of 11 July 1953 a reorganisation was carried out in the second half of 1953, whereby IFA was granted the status of an independent foundation and acquired rights of ownership over the land, installations and materials of the Norwegian share in Kjeller. The purpose of IFA was defined as carrying out '... research, experiments and other activities with a view to the utilization of atomic

[45] FOM, Minutes Joint Commission, 1951-54, Minutes of the fifth meeting of the Joint Commission, 30 Nov. 1951, p. 11.

[46] FOM, Minutes Reactor Committee, 1950-52, Minutes of the ninth meeting of the Reactor Committee, 28 Aug. 1951, pp. 8-9; NA, RG 59, Decimal Files, 1950-54, Box 5985, 957.7138/12-1151, J.G. Mein (First Secretary of the US Embassy in Oslo) to State Department, 11 Dec. 1951.

[47] ECN, Second Annual Report JENER, 1952-53, p. 13.

energy'.[48] The agreement with FOM was duly adapted, so that from 1 January 1954 IFA in fact looked after Norwegian interests in JENER.

The 'Wessex Solution'

As early as November 1950 Randers had proposed to Cockcroft an exchange of Norwegian heavy water for British uranium metal rods with a view to acquiring more than three and a half tons of uranium metal. That Randers wanted more was already apparent before Kramers had ordered only three tons from Cockcroft, and his desire would become further evident in later discussions between Norway and Great Britain. While the joint Norwegian-Dutch negotiations with the British were going on, the Norwegians therefore conducted their own separate discussions, of which the Dutch had only very limited knowledge. Because the outcome of these negotiations was to have an effect on the course of the Dutch-Norwegian co-operation the next paragraphs shall first give a brief outline of the Anglo-Norwegian talks.

As early as 29 November 1951 a meeting had taken place in Oslo between representatives of Norsk Hydro and the British government. At this meeting the Norwegian government, represented through IFA which had in the meantime *de facto* replaced NTNF as regards nuclear energy, put certain substantial demands to the British. In exchange for the right to buy twenty to twenty-five tons of heavy water, the British government should agree to allow the Norwegians to buy up to ten tons of uranium metal and up to a hundred tons of graphite. Finally, the exchange of information and know-how should be stimulated.[49]

These were not trivial requests and presented the British with a problem. On the one hand Norsk Hydro wanted an answer as soon as possible, otherwise it would sell its heavy water to other prospective buyers. On the other hand, the British were obliged to consult the Americans and Canadians because of nuclear agreements that covered both the free exchange of knowledge and know-how and especially any deliveries of uranium metal. The British therefore could not give a definite answer quickly. They were also unhappy about the coupling of the sale of metal with the purchase of heavy water: 'This seems to us to be an odd way of

[48] Ibid., p. 40.

[49] PRO, FO371/99753 and AB6/1802, Memo by Randers, 17 Jan. 1952.

seeking our co-operation'.[50] J.V. Dunworth, who enjoyed a good relationship with Randers, was brought in to make clear to the Norwegians that this link would not be accepted.[51] While the negotiations between the British Ministry of Supply and Norsk Hydro on the contract to supply heavy water proceeded in the normal way,[52] the Foreign Office took steps to uncouple the contract with Norsk Hydro from the issues of the supply of uranium metal and the exchange of information and know-how. The Norwegians agreed, but added that '... the Norwegian government assumes that Her Majesty's Government will adopt a 'positive attitude' to cooperate with Norway in the field of atomic research, both as regards material equipment and exchange of experience'.[53]

A British delegation visited Norway in March 1952 to do the groundwork for the delivery of twenty-five tons of heavy water to Great Britain under the codename 'Wessex Solution'.[54] The talks were conducted in secret,[55] yet the British delegation brought a sample of twenty-five grams of heavy water from Norway for tests at Harwell. A contract was drafted, based on the results of these tests and sent to the Norwegians.[56] This draft was used as a basis for further negotiations between Norsk Hydro and the British delegation in Oslo between 10 and 19 May 1952.[57] Randers also took some part in the talks. Half of the clauses in the concept-contract were approved without amendment. Agreement was reached on who on the British

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[50] PRO, FO371/99753, Makins to Wright, March 1952; France to Harpham, 29 March 1952.

[51] Ibid., France to Harpham, 9 April 1952.

[52] PRO, AB6/1802, Wessex Solution: Goodway and Hart-Jones to Eriksen, 14 March 1952, pp. 3-6.

[53] PRO, FO371/99753, British Embassy in Oslo to Foreign Office, Telegram no. 99, 2 May 1952.

[54] PRO, AB6/1802, Wessex Solution: Note by Hart-Jones, 31 March 1952, E.7, pp. 15-16.

[55] Despite the fact that both parties agreed to try to keep the matter secret, at the beginning of April 1952 a report suddenly appeared in a Norwegian paper. Ibid., Wessex Solution: Hart-Jones to Eriksen, 7 May 1952, E.10, pp. 25-26.

[56] Ibid., Wessex Solution: Hart-Jones to Eriksen, 24 April 1952, E.8, pp. 16-20 and 2 May 1952, E.9, pp. 20-25.

[57] For a report of these negotiations see: Ibid., Wessex Solution: Heavy Water; Report on visit to Norway 10th-19th May, 1952 by V.H. Coleman, F.E. Pounder and C.W. Hart-Jones, undated, pp. 1-11.

side was to take care of inspection and analysis, how the containers were to be sealed, who was to clean the containers used to transport the heavy water, and to what level they could be filled. In short, immediate agreement was reached on the 'housekeeping' matters. Price, quality, secrecy, delivery date and payment period produced the usual discussions. Eventually it was agreed that the Norwegians would supply Britain with twenty-five tons of heavy water for 1,500 Norwegian crowns per kilogram and that the buyer would pay for the packing costs. It was further decided that the heavy water would preferably be delivered in batches of one thousand kilograms and that the first delivery would take place no sooner than 1 October 1952 and the last no later than 30 November 1955. If the deliveries of Norwegian heavy water were to exceed what Britain needed, the British might export the surplus, but only to Commonwealth or NATO countries and in each case the country to receive the heavy water had first to be approved by Norway. The agreement was treated as secret and was to be referred to as 'Wessex Solution' in all correspondence. Only with the approval of both governments might the agreement be made public.[58] The appendix specified that the hydrogen in the heavy water must consist of at least 99.7% deuterium. Also, Norsk Hydro was to supply the material with the minimum possible contamination by cadmium, boron and lithium.[59] After agreement had been reached on 14 May, the contract, dated 15 May, was signed on 16 May 1952 by V.H. Coleman and C.W. Hart-Jones for the United Kingdom Atomic Energy Authority (UKAEA) and Bjarne Eriksen and Stephansen for Norsk Hydro.

More British uranium for Norway

The contract between Norway and Great Britain for the delivery of heavy water was thus entered into without any coupling with an agreement for supply of British uranium metal wanted by Randers. True, there was a 'gentleman's agreement' whereby the British promised to do their best to supply Norway with uranium. But Randers foresaw problems with the Dutch if he had to let them know about the heavy water contract. The Norwegians

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[58] Ibid., Wessex Solution: Agreement between the Norsk Hydro-Elektrisk Kvaelstof-aktieselskab of Oslo in the Kingdom of Norway on the one part and Her Majesty's Ministry of Supply, 15 May 1952, E.13, pp. 32-37.

[59] Ibid., Wessex Solution: Appendix specified in Clause 2 of the agreement of the 15th May, 1952, E.13, pp. 37-38.

and Dutch had just concluded intensive negotiations on the exchange of (Dutch) uranium oxide for (British) uranium metal rods, which were vitally important for the progress of the joint Norwegian-Dutch project. Now, the Norwegians had agreed to supply Britain with twenty-five tons of heavy water without demanding any uranium in return. Randers therefore let Cockcroft know that '... as a result I am now personally responsible for having gambled with the future of our whole Dutch-Norwegian cooperative nuclear energy project - since exchange of D2O [heavy water] for U [uranium metal] is at present our only source of uranium for our ship-reactor plan. ... I do not personally consider it so much a gamble as a reasonable thing to do as a continuation of informal mutual help - where we so far have been at the receiving end. I shall, however, be criticized rather seriously for not being more businesslike - which does not concern me much - but I believe that the Dutch, with considerable right, may feel that the Norwegians have not looked properly after their common interests, if our work should be halted as a result of this act on our part'.[60]

Since Cockcroft had learned in the meantime of Norwegian and Dutch plans possibly to start a new project building a nuclear reactor with the French (a lot of French know-how went into the building of JEEP), he came to the view '... that we ought to make arrangements to supply these small quantities of uranium to the Norwegian-Dutch project. Otherwise we shall find them firmly coupled to the French project'. He was thinking in terms of a delivery of three tons of uranium metal for the current Norwegian-Dutch reactor project and seven tons for the future reactor, ten tons altogether. Given that the British did not have any stocks available, uranium from ore from the Belgian Congo could be a possibility,[61] but secret agreements made with the United States and Canada during the Second World War stood in the way of such a transaction.[62] Portuguese uranium seemed to offer a way out for the Norwegian-Dutch project: 'I would suggest

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[60] PRO, FO371/99753, Randers to Cockcroft, 25 May 1952.

[61] During the Second World War the control of the uranium deposits in Belgian Congo were transferred by the Belgian government to the United States and Great Britain. These secret negotiations are described in: J.E. Helmrech, *Gathering Rare Ores. The Diplomacy of Uranium Acquisition, 1939-1954* (Princeton, New Jersey: Princeton University Press, 1986).

[62] The Quebec Agreement of August 19, 1943; The Anglo-American Declaration of Trust, June 13, 1944; and the Roosevelt-Churchill Hyde Park Aide-Mémoire, September 19, 1944.

therefore that we obtain the concession of the U.S. to the supply of up to 10 tons of uranium metal derived from Portuguese ore, over the next 3 years'.[63] As far as price was concerned, Randers offered to exchange one ton of heavy water for three tons of uranium metal valued at twenty-five thousand English pounds per ton.[64] The Norwegians were required to make a formal request to the British government and did so on 9 September 1952.[65]

It was necessary to obtain permission from the United States. The British Ambassador in Washington, Sir Christopher Steel, was therefore instructed to discuss supplying Norway with three tons of uranium in the short term and seven tons in the longer term. In view of the short term planning for the supply of the three tons, the lack of sufficient stocks in Great Britain, and the difficulties in purifying Portuguese uranium, the British proposed that three tons of uranium from the Belgian Congo be delivered as a 'loan' to be replaced by uranium from Portuguese stocks as soon as it became available.[66] The American government's response, in this case from R. Gordon Arneson, was cautious. According to the British this was because of the fact that American thinking was dominated '... by the atmosphere of secrecy which surrounds the whole question of atomic energy in this country but it is also due to the fact that his mind, like that of most Americans, is not really attuned to think of uranium except in relation to the defence effort'. Arneson did, nevertheless, agree with the British that '... it was desirable that the Norwegians should obtain their uranium from us rather than from some other supplier'.[67] The door remained ajar.

In the second week of January 1953 Cockcroft, who had been authorised by the British government to inform the Belgians, visited Pierre Ryckmans, head of the Belgian Atomic Energy Commission and former governor-general of the Belgian Congo, in Brussels. The Americans were more or less bypassed. Because Steel had been unable to speak to Gordon E. Dean, the Chairman of the United States Atomic Energy Commission (USAEC), on account of the public holiday, he left a letter for him outlining

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[63] PRO, AB6/914, Note: 'Collaboration with Norway', by Cockcroft, 29 May 1952.

[64] PRO, FO371/99753, Randers to Cockcroft, 17 July 1952.

[65] Ibid., Aide-Mémoire from the Royal Norwegian Embassy to Her Majesty's Government, 9 Sept. 1952.

[66] 12 Ibid., Makins to Steel, 3 Nov. 1952.

[67] Ibid., Tomkins to Harpham, 7 Nov. 1952.

the British plans. Although the Americans had not been asked for their assent, Arneson let it be known that he was in agreement with the British plan and '... expressed the hope that the Belgians will be made aware of American interest in the Norwegian transaction', which caused the British to remark sarcastically that this '... like the original proposal for consultation on a joint Anglo/American basis, is a clumsy attempt to gain credit with the Belgians by showing them that they have their interests at heart'.[68]

During his visit to Brussels Cockcroft told Ryckmans about the Norwegian request for a total of ten tons of uranium metal, of which three tons was needed in the short term. The remaining seven tons could be discussed at a later stage. Although a small quantity of Portuguese uranium could be obtained, uranium from the Belgian Congo was preferred. Ryckmans was asked if he would cooperate with this arrangement and was told that the request had the support of the United States.[69] After consulting his minister, Ryckmans agreed. Everything had to be confirmed in writing later but a verbal agreement was reached.[70] Cockcroft was pleased to be able to report to Randers: 'I think we are pretty certain now to be able to supply you with the uranium metal which you require and I am asking Dr. Goodway to open up formal negotiations with you on this basis'.[71]

The next stage was to obtain the official approval of the United States of the deal. It might take some days, said Arneson. The Americans were expected to put forward the same conditions as they had done for the British delivery of (three tons of) uranium metal to the Netherlands, namely: no exchange of secret information on production processes and an express statement that the American government had approved the transaction.[72] This supposition proved to be correct; the Americans laid down precisely the same conditions, to which the British were also able to agree.[73] With these provisos, the Americans agreed to the delivery of three tons of uranium. The question of the remaining seven tons would have to be decided at a later

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[68] PRO, AB6/1104, Tomkins to Harpham, 8 Jan 1953.

[69] Ibid., Cockcroft to Ryckmans, 20 Jan. 1953.

[70] PRO, FO371/99753, Cabinet Office to B.J.S.M. Washington, CANAM 418, 22 Jan. 1953; PRO, AB6/1104 and AB6/914, Cockcroft to Goodway, 23 Jan. 1953.

[71] PRO, AB6/1104, Cockcroft to Randers, 20 Jan. 1953.

[72] Ibid., Tomkins to Harpham, 23 Jan. 1953.

[73] Ibid., France to Harpham, 18 Feb. 1953.

date.[74] On 24 February 1953 the Norwegian government could be informed that '... with the concurrence of the United States and Canadian Governments, they have now given permission for the delivery of this material'.[75]

After all the formal consents had been obtained, N.F. Goodway, on behalf of the British government, was able to get to work on converting the 'gentleman's agreement' into a contract to supply uranium to Norway. In his letter to Cockcroft of 17 July 1952 Randers had already proposed exchanging three tons of uranium for one ton of heavy water and Goodway took this up. In the meantime Britain had signed a contract with Norsk Hydro for a delivery of twenty-five tons of heavy water, which they now wanted to increase to thirty tons. Goodway therefore proposed drawing up a contract to settle both requests on mutual terms.[76] The three tons of uranium could be delivered within four weeks.[77]

The issue of the three tons of uranium to replace the stocks in Kjeller was now settled. The other seven tons still had to be dealt with. The British asked themselves what would be the best strategic course of action. They could tell the Norwegians straight away that they were able to deliver another seven tons or they could wait for a while until a better deal could be struck over the extra five tons of heavy water.[78] It was decided not to resort to horse dealing: 'As a general principle it is best to be quite straightforward and above board when dealing with the Norwegians'. By handling the matter as straightforwardly as possible the British expected that they '... would gain kudos by telling the Norwegians about the extra seven tons. This kudos would itself be a bargaining counter and would strengthen our case for asking for the extra five tons of heavy water and further supplies when required'.[79] It was better to keep pressure on Norsk Hydro itself via the diplomatic channels of the Foreign Office and the British

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[74] Ibid., Arneson to Tomkins, 30 Jan. 1953.

[75] Ibid., Aide-Mémoire from Her Majesty's Government to the Norwegian Chargé d'Affaires, 24 feb. 1953.

[76] Ibid., Goodway to Randers, 29 Jan. 1953.

[77] Ibid., Goodway to Randers, 30 March 1953.

[78] Ibid., Harpham to France, 7 March 1953; Wilson to France, 25 March 1953; Harpham to Wright, 13 April 1953.

[79] Ibid., Goodden to Harpham, 22 April 1953.

Embassy in Oslo.[80] Any coupling of the two matters was rejected out of hand.

On 29 April 1953 the Foreign Office sent an Aide-Mémoire to the Norwegian government informing it that, not only did the British agree to the delivery of three tons of uranium to replenish the stocks in Kjeller, but that consent had come in from the American and Canadian governments to the delivery of the additional seven tons of requested uranium metal.[81] The first three tons was shipped to Norway on the *Truro* on 25 May.[82]

Talks on the remaining seven tons of uranium metal did not take place until 1954. On 12 January of that year Goodway told Randers that '... the balance of 7 tons is now available and could be supplied to you under the authority which we received through the Ministry of Supply'. If Randers could agree to the same terms and conditions as applied to the earlier delivery of the three tons he should let the British know, after which delivery could take place.[83]

The discussions around the supply of the seven tons took a surprising turn in March 1954. The secretary of the Dutch Reactor Committee, Beekman, wrote in a letter to Cockcroft: 'We learned from Mr. Randers that he has - on the basis of an existing agreement - a claim on 7 tons of English uranium at the price of 25.0.0 English pounds per kg. Mr. Randers wrote us that he is willing to waive his rights in our favour. We should, now, like to know, if you think it will be possible to sell the 7 tons uranium to us'.[84] Cockcroft let Beekman know that there would be no objection to this, provided '... Dr. Randers lets me have a letter to this effect'. At the same time Milatz and J.H. de Boer, substitute member of the Joint Commission, were given permission to visit Harwell to talk about this and other matters. After that the Dutch took over from the Norwegians in the negotiations with the British. Why Randers took this remarkable step was not revealed in the archives.

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[80] Ibid., Wilson to France, 4 May 1953.

[81] Ibid., Peck to Goodden, 29 May 1953; Enclosure: 'Aide-Mémoire from Her Majesty's Government to the Councillor of the Norwegian Embassy', 28 May 1953.

[82] Ibid., Goodway to Randers, 14 May 1953.

[83] Ibid., Goodway to Randers, 12 Jan. 1954.

[84] Ibid., Beekman to Cockcroft, 16 March 1954.

BEPOP and SLURRYPOP

Within JENER plenty of discussions were taking place about plans for the future, but in the Netherlands itself ideas were also being explored. The experimental nuclear reactor in Kjeller (JEEP) had been working continuously with an output of around 250 kilowatts for quite some time. It was necessary to break new ground. Highest priority was given to building a nuclear reactor on Dutch soil.

Milatz and Dahl had already been doing informal calculations for the construction of a 10,000 kilowatt nuclear reactor.[85] Randers foresaw an important application for this in ship propulsion: 'Ship propulsion seems to be a necessary thing for us to take up. It is a sound idea to design a 10,000 kw reactor and put it into a ship'. From this standpoint he argued in favour of making nuclear-powered ships a priority. The Dutch delegation was more reticent about this, because '... the Americans have a large submarine hull under construction, a land-based reactor model for this has already been built, and two different types of submarine motors are under construction'.[86] Some degree of patience was therefore appropriate. In addition to these pragmatic considerations, the Netherlands and Norway also had different points of departure for the application of nuclear power. The Netherlands was dependent upon the dwindling production of the Limburg coal mines and the import of oil, and saw nuclear power primarily as the solution to its energy problem. The Norwegians had hydroelectric power and were more interested in using nuclear power in their large merchant fleet. This opposition between the use of nuclear power on land versus ship propulsion came to the surface regularly during subsequent Norwegian-Dutch co-operation.

Milatz and Dahl made the assumption that for either application the reactor would work using natural uranium with heavy water as moderator. Obtaining enough raw uranium and heavy water was not seen as a stumbling block. Norsk Hydro had already indicated its willingness to guarantee the sums involved for the purchase of three tons of uranium and 'from Sweden

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[85] FOM, Minutes Reactor Committee, 1950-52, Minutes of the twelfth meeting of the Reactor Committee, 13 May 1952, p. 5.

[86] FOM, Minutes Joint Commission, 1951-54, Minutes of the sixth meeting of the Joint Commission, 21 May 1952, p. 3.

and other sources more uranium is to be expected so the uranium will not be a problem'. No problems at all were anticipated with the acquisition of heavy water since '... Norsk Hydro has been extending its production of heavy water, a sufficient quantity will be available'.

A JENER working party on reactor development, consisting of the Dutchmen M. Bogaardt and J. Pelser, the Norwegian V.O. Eriksen and the Swiss W. Hälg, were considering the question of which type of heavy water reactor should be chosen for the next joint project. There were three possibilities from which a choice had to be made: a homogeneous reactor (that is one in which the uranium raw material and the moderator are combined in a single mixture) and reactors with fuel rods, clad either with aluminium or with beryllium oxide. Once the working party had chosen one of these options, Dahl would have to advise on whether the chosen reactor type could be built.[87]

The reactor design finally suggested would have a thick-walled steel vessel, filled with twelve tons of heavy water in which nine tons of uranium was suspended in the form of metal rods. The rods were to be surrounded by water jackets, through which heavy water would also flow to conduct the heat from the fission away to a heat exchanger where steam would be raised to produce electricity. Since the neutrons would be better slowed down the lower the temperature of the moderator, it was necessary to insulate thermally the heavy water jackets with beryllium oxide. In order to make plain that the aim was to produce useful energy and not to 'breed' plutonium, this design was initially designated BEPOP, for Beryllium Power-Only-Pile.

Meanwhile in the Netherlands J.J. Went, of the research centre of the joint Dutch electric utilities KEMA (NV tot Keuring van Electrotechnische Materialen te Arnhem), which had formal links with FOM in the field of nuclear reactors, had become convinced that the rods of uranium in a reactor of this kind would only have a short life so that they would have to be replaced many times. This led him to conceive of a similar reactor in which finely ground uranium oxide as a suspension, or to use the English word 'slurry', would be pumped through the water jackets and the heat exchanger, and also through an installation that would continuously remove the fission products. This plan, which was soon given the name SLURRYPOP (Slurry Power Only Pile), or SUSPOP, also suited the ambitions of KEMA to have their own reactor.

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[87] Ibid., Minutes of the seventh meeting of the Joint Commission, 8 Oct. 1952, p. 7.

Randers, however, had some doubts regarding the feasibility of SLURRYPOP and he expressed them in Dahl's presence at a meeting on 19 January 1953 in Utrecht in front of Bakker, Beekman, De Boer, Milatz and Went.[88] It was agreed that a joint decision would be made in Norway at a later date as to whether it would be possible to operate this reactor with natural uranium and, if not, what grade of uranium would need to be enriched in the fissionable isotope uranium-235.[89] This was the first time that the enrichment of uranium was mentioned!

In the Joint Commission of 15 and 16 April 1953 the foundation was formally laid for the second phase of the Norwegian-Dutch project: the nuclear power reactor. While the Dutch delegation laid the emphasis on SLURRYPOP, the Norwegian delegation preferred BEPOP: '... The BEPOP is a possible solution while for SLURRYPOP everything depends upon the slurry'. The plans for BEPOP had come about based on the recommendations of Dahl who had expressed a preference for it. As a compromise it was decided further to develop both ideas simultaneously, while 'It was assumed that the special problems for the SLURRYPOP would make this type a longer term project, while detailed planning could already be started on the BEPOP type'.[90] The intention behind both projects was to gain experience with a prototype with a view to the possible construction of power stations or ship propulsion machines. As far as the choice of location of a prototype reactor was concerned, the Joint Commission gave four alternatives: a site in the Netherlands; a disused merchant ship; a specially built lighter which could be warped in both the Netherlands and Norway; and last of all in Kjeller. The first option fitted in perfectly with the Dutch plans.

Once the formal basis had been laid, the question of raw materials arose. The most important raw materials for both BEPOP and SLURRYPOP were beryllium oxide, uranium raw material and heavy water. With respect to beryllium oxide the following was agreed: Randers would contact France and Great Britain and the mineral sources in Norway and Indonesia (Billiton)

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[88] FOM, Minutes Reactor Committee, 1953, Minutes of the seventeenth meeting of the Reactor Committee, 20 Feb. 1953, with Enclosure: 'Summary of the informal discussion on "Netherlands ideas about quasi-homogeneous reactors"', 19 Jan. 1953.

[89] Ibid., Enclosure: 'Notulen van Went's overzicht bij agendapunt 6.31 van de Reactor Commissie vergadering van 20 juli 1953'.

[90] FOM, Minutes Joint Commission, 1951-54, Minutes of the eighth meeting of the Joint Commission, 15-16 April 1953, pp. 6-8.

would be mapped. The search for available uranium raw material would take place both at home and abroad. At home the Norwegians would stimulate exploration work in Norway and the Dutch in Surinam. Abroad Beekman and Bakker would talk to the Belgians during their planned visit to Leuven in Belgium about the possibility of a delivery of uranium. The heavy water was mainly a budget issue. Norsk Hydro was fully prepared to sell the necessary quantity of heavy water. During talks with Stephansen and Randers, Milatz succeeded in obtaining a promise for the delivery of heavy water: four tons would be made available in the short term. A proviso was made that the delivery must be kept secret from Great Britain. It was agreed that FOM would write to the managing director of Norsk Hydro, Eriksen, referring to a conversation between Randers and Eriksen, and asking for a quotation. A delivery of four tons would be made to Kjeller, so that if news of the delivery were to leak out, it could be said that the four tons were the use of JENER.[91]

The choice of BEPOP

The Norwegian-Dutch joint project to build an experimental nuclear power reactor opened therefore on two fronts: the construction of a beryllium oxide heavy water reactor (BEPOP) and that of a slurry reactor (SUSPOP), for the latter an 'exponential experiment', that is to say a sub-critical reactor, would first be necessary. Co-operation with France was not ruled out. The gain to be had from this co-operation would consist of the gathering of as much information as possible for as little money as possible. In 1950 the French had already set aside one hundred million guilders for nuclear research and had declared themselves willing to finance thirty percent of the cost of founding a West European nuclear research centre. Talks in Paris with the French Commissariat à l'Énergie Atomique (CEA) on 12 and 13 June 1953 ended in a proposal to engage in limited co-operation on the construction of a nuclear power reactor in the Netherlands, in which the Norwegians would make their experience available and take care that the necessary twelve tons of heavy water would be supplied from Kjeller on time. France would provide the necessary expertise and facilities, such as supplying the beryllium oxide and metallurgical expertise and conducting the necessary

[91] Ibid., pp. 9-10; and Minutes Reactor Committee, 1953, Minutes of the nineteenth meeting of the Reactor Committee, 22 May 1953, pp. 9-10.

experiments.[92] The capital expenditure for the reactor fell of course upon the Netherlands. Although the new reactor was actually identical to BEPOP, it was given the name NUPOP (Natural Uranium Power-Only-Pile) to emphasise the use of natural uranium as fuel rather than refer to the insulation material. It was in no way the intention to put aside the SLURRY-POP plan, but - as had already been decided in the Joint Commission - to build NUPOP first since this was able to be realised in the short term and SLURRYPOP only in the longer term. For the Dutch NUPOP held another attraction: it was not only a prototype reactor in its own right, but would have a sufficiently large neutron flux to make it suitable for testing materials and therefore also for research into the stability of suspensions in a reactor. Finally, it would serve as a prototype of a ship's reactor. Against these advantages of NUPOP had to be set various disadvantages of SUSPOP. In the meantime, in addition to the heterogeneous model mentioned earlier (in which the nuclear fuel suspension would pass through channels separated from the moderator), a really homogeneous design had been conceived, in which both would pass through the reactor vessel as one mixture. This would get around certain construction problems but, on the other hand, such a reactor would certainly not be critical with natural uranium and so the Reactor Committee, the working group on the reactor within FOM, needed to face up to '... the question of whether enriched material would definitely have to be used which has not yet been answered, even in the U.S.A.'.[93]

During the conference on heavy water reactors held in Kjeller from 11 to 13 August 1953, to which nineteen countries sent representatives, Dahl presented 'his' design for the NUPOP reactor and the discussion which had taken place in the Netherlands on whether to begin with NUPOP or SLURRYPOP continued. In response to these discussions Milatz concluded that neither plan expressly ruled out the other, but '... the experimental energy reactor [Dahl's NUPOP] must be designed in such a way that it enables materials to be tested and developed (including the Slurry) at high temperatures and radiation intensities ('material testing reactor')'.[94]

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[92] FOM, Minutes Reactor Committee, 1953, Minutes of the twentieth meeting of the Reactor Committee, 19 June 1953, pp. 1-9.

[93] Ibid., Minutes of the twenty-first meeting of the Reactor Committee, 24 June 1953, pp. 6-10.

[94] Ibid., Minutes of the twenty-second meeting of the Reactor Committee, 1 Sept. 1953, p. 13 and Minutes Joint Commission, 1951-54, Minutes of the ninth meeting of the Joint Commission, p. 2, with Enclosure: 'Press-release on heavy-water reactor conference', 17

Because of the position taken by the Norwegians, the Netherlands was more or less driven to choose NUPOP. Moreover Randers was less interested in a reactor for electricity production than for ship propulsion. Like Dahl he thought NUPOP most suitable for this. If the Dutch wanted to have a nuclear power reactor in their own country, they must opt for NUPOP now, if not Randers would do it himself; nine tons of (extra British) uranium metal and the necessary heavy water had already been reserved for this purpose. Randers was certainly prepared to support SUSPOP in the Netherlands, but only when it was founded on the construction of NUPOP. As well as Norwegian support for the construction of NUPOP in the Netherlands, contacts with France also played an important role. In short, the priority given to the construction of NUPOP over SLURRYPOP was determined by three factors. Firstly, the political aspect: if a start were to be made on the building of NUPOP in the Netherlands, FOM would be able to get hold of the necessary raw materials at short notice, heavy water from Norway and uranium metal from Norway and/or France. So it was a superb opportunity to guarantee the material position of the Dutch plans, including SLURRYPOP. Secondly, the direct contacts with France would bring in advantages: in the future it might be possible to obtain enriched material, and contact with French metallurgical experts could be rewarding. Thirdly, the scientific aspect: in Milatz's view NUPOP could serve as a materials testing reactor that could have great value in overcoming the technological problems associated with the construction of the SLURRYPOP. The Netherlands indicated that SLURRYPOP had by no means disappeared from sight but had rather been pushed into the background by tactical considerations.[95]

Detailed planning

The detailed planning for the construction of a nuclear power reactor in the Netherlands progressed less smoothly. The Reactor Committee, in this case Milatz and Beekman, had laid the foundations: a reactor in the Netherlands using heavy water from Norway and uranium from France, with work beginning initially on NUPOP and later on SLURRYPOP. The Governing

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Aug. 1953; ECN, Second Annual Report JENER, 1952-53, p. 39.

[95] FOM, Minutes Reactor Committee, 1953, Minutes of the twenty-third meeting of the Reactor Committee, 3 Nov. 1953, pp. 7-10.

Council of FOM, which had the final say over the Reactor Committee's plans, did not take decisions quickly. The members of the Governing Council had their hands full with the Kluyver Committee,[96] and with representatives of various ministries, industry and the business community. Support from the business community was of the utmost importance since the need for funds was urgent because the finances of FOM were insufficient for these new plans.

A decision was eventually taken in the meeting of the Governing Council of FOM on 31 December 1953. A 'Proposal to construct a 10,000 kw reactor centre in the Netherlands' was drafted and sent on 4 January to the Ministries of Education, the Arts and Science, Finance and Economic Affairs. The term reactor centre was now used not only to mean the construction of NUPOP, but also included the possibility of further research. Total investment was budgeted at 28 million guilders with running costs estimated at 1 million guilders per year. In view of the considerable amounts involved, expenses were to be shared between the state (50%), KEMA (25%) and a number of other industries (25%).[97]

It was not without good reason that the Reactor Committee had pushed for a speedy decision. It had become clear during the heavy water conference in Kjeller in August 1953, that a number of countries were venturing on heavy water reactors; demand for heavy water would be great. It was therefore decided during the meeting of the Joint Commission on 11 and 12 February 1954 - ahead of the debate in the Dutch parliament - to disclose the Dutch plans concerning NUPOP and SUSPOP to the Norwegians.[98] Not surprisingly, Randers urged the Dutch to make a choice between the two projects.[99]

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[96] The Dutch government had set up the Kluyver Committee to advise on the organisation of nuclear research. Initially it suggested creating a new foundation which would engage in nuclear reactor development. FOM would then confine itself to pure academic research. The Governing Council of FOM resisted this suggestion and managed to frustrate it - temporarily.

[97] FOM, Minutes Governing Council FOM, 1952-60, Minutes of the meeting of the Governing Council of FOM, 31 Dec. 1953, pp. 5-15.

[98] FOM, Minutes Reactor Committee, 1954-55, Minutes of the twenty-fifth meeting of the Reactor Committee, 28 Jan. 1954, p. 9.

[99] FFRM, Minutes Joint Commission, 1951-54, Minutes of the tenth meeting of the Joint Commission, 11-12 Feb. 1954, p. 3.

The Dutch delegation was able to clarify matters to their Norwegian colleagues at the meeting of the Joint Commission on 26 and 27 July 1954. In the meantime FOM had signed the so-called 'small contracts' with industrial firms, which gave more financial elbow room for both the current and the future reactor project. The financial position had been further strengthened by the adoption on 14 July 1954 by the Lower House of the 'Proposal to construct a 10,000 kw reactor centre in the Netherlands' with only the Dutch Communist Party voting against. The Norwegian-Dutch joint venture was enthusiastically supported. The contract with Norsk Hydro to supply fourteen tons of heavy water could now also be signed. Only the place where the nuclear reactor would be situated in the Netherlands had not yet been discussed. The Norwegian-Dutch agreements relating to the construction of a nuclear power reactor in the Netherlands now needed to be laid down in a contract as had been done when JENER was formed. IFA would contribute to the cost of research carried out in the Dutch reactor as FOM had with the Norwegian reactor in Kjeller. At the same time Randers - thinking in terms of symmetry - would be able to provide the Netherlands with uranium, in view of Norway's claim upon a delivery of ten tons of uranium from Great Britain and five tons from Sweden. The Norwegian government would have to agree to the delivery of uranium to the Netherlands. No Norwegian would be a member of the executive committee of the Dutch project, as there were no Dutchmen on the executive committee of IFA. The contract only covered the construction and inception of NUPOP.[100]

From 28 to 30 september, Milatz, Dahl and Randers held further talks in Kjeller on the draft agreement with IFA on the construction of a reactor in the Netherlands. The formal basis for these 'Planning Committee' discussions was the joint construction of NUPOP. The suggestion previously brought forward in the FOM Reactor Committee to build SUSPOP first was not discussed, since it had been decided in the meeting of the Reactor Committee of 2 September 1954 to say nothing about this before a policy had been reached in the Netherlands itself. The talks progressed with difficulty. An important cause was the Dutch delay in signing the contract between FOM and Norsk Hydro for the delivery of the sixteen tons of heavy water needed for NUPOP, which aroused doubts on the Norwegian side

[100] Ibid., Minutes of the eleventh meeting of the Joint Commission, 26-27 July 1954, pp. 2-4 and FOM, Minutes Reactor Committee, 1954-55, Minutes of the twenty-ninth meeting of the Reactor Committee, 17 July 1954, pp. 12-13.

about the real intentions of the Dutch. It was decided that the 'NUPOP Planning and Coordinating Committee (PCC)' - the new name for the Planning Committee - would develop a total package of plans and a cost-saving proposal for NUPOP. This package would be put before the Joint Commission before any further steps could be taken. From an earlier visit to the Netherlands Dahl had become convinced that the many scientists there would prefer a research reactor such as JEEP, without a steel pressure vessel but with a higher neutron flux, which could also be used for testing materials. He therefore stated that he was prepared to consider one of Milatz's ideas, TWINPOP, where a reactor of this type would be built next to NUPOP, so that the expensive heavy water would be available to be used in either.[101]

Choices needed thus to be made. There were a number of possibilities, and these were augmented by a spectacular turn in American policy, as heralded by President Eisenhower's 'Atoms for Peace' proposal. The end of the American policy of secrecy bode new perspectives for Dutch desires. It is not surprising therefore that the Dutch decided to go through everything systematically and carefully to reexamine all the possibilities. This reorientation was to lead, among other things, to the setting up of the Foundation Reactor Centre Netherlands (RCN) in July 1955. This organisation took over the work of FOM, just as IFA had done with NTNF in Norway. This meant that the Norwegian-Dutch project had to be adapted.[102]

The second Norwegian-Dutch agreement

A Norwegian proposal regarding the continuation of the Norwegian-Dutch project, which needed to be modified as a consequence of the setting up of the new Foundation RCN, contained a number of conditions which proved to be difficult to accept under the new circumstances in the Netherlands.

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[101] FOM, Minutes Reactor Committee, 1954-55, Minutes of the thirty-first meeting of the Reactor Committee, 7 Oct. 1954, pp. 8-9.

[102] AMFA, Code 8, 1955-64, Index no. 1110, Director-General for the Industrialisation and Energy Supply to Zijlstra, 30 June 1955; FOM, Minutes Reactor Committee, 1954-55, Minutes of the forty-first meeting of the Reactor Committee, 28 Sept. 1955, p. 1; PRO, FO371/125236, Copy of the deed of Foundation of the Netherlands Reactor Centre, 6 July 1955.

Under the former arrangements the Joint Commission, in which both parties had equal representation, had laid down the principal areas of research. This arrangement could now mean that while the Netherlands would be financing the Reactor Centre virtually alone, the Norwegians would have fifty percent representation. The Dutch objected. Nevertheless, on the occasion of the twelfth meeting of the Joint Commission on 25 and 26 January 1955, the Dutch delegation stated that it attached high value to continuing co-operation with the Norwegians. Since the Norwegians were starting from the same basic principle there seemed to be an adequate basis for an agreement. The starting point would be that both parties, that is RCN in the Netherlands and IFA in Norway, would be autonomous and would have to cover their own costs. The Joint Commission would have an advisory role and would have no decision-making power over the programmes of either organisation. The Norwegians were able to accept these basic principles.[103] At the meeting of the Joint Commission on 2 November 1955 two agreements were concluded between RCN and IFA. The first was a general agreement to work together as had been agreed in the Joint Commission in January 1955, except that an extra section was adopted enabling joint projects to be started which departed from these principles, for which a separate agreement would be necessary. This then was the basis for a second agreement, safeguarding the continued survival of JENER for three years until 30 June 1958.[104] The advantage of this new arrangement was that both countries had their hands free for projects which lay outside the scope of JENER. Before this time nuclear energy research in both countries had more or less fallen within the framework of the cooperative agreement or had been subordinate to it. Now the opportunities for each country to have its own nuclear projects were considerably enhanced.

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[103] FOM, Minutes Reactor Committee, 1954-55, Minutes of the thirty-sixth meeting of the Reactor Committee, 3 March 1955, pp. 8-9; AMFA, Code 8, 1955-64, Index no. 880, Kasa and Beekman to the members of the Joint Commission, 3 March 1955, with Enclosures: 'Draft Agreement IFA and FOM (FOM-1486)', 2 March 1955 and 'Draft Agreement on the Joint Establishment for Nuclear Energy Research (FOM-1501)', 2 March 1955.

[104] FOM, Minutes Joint Commission, 1955-58, Minutes of the fourteenth meeting of the Joint Commission, 1-2 Nov. 1955; Archives Ministry of Economic Affairs (hereafter AMEA), The Hague, Archief Direktie Kernenergie (hereafter ADK), Index no. 307, Agreement on Joint Establishment for Nuclear Energy Research (JENER) and IFA and RCN, 2 Nov. 1955.

Even before the new JENER agreement came into being it had become clear to the Norwegians that NUPOP would not be built in the Netherlands. The 28 million guilders reserved for it would be used to buy an American reactor, following negotiations with the United States which had opened up new opportunities for the Dutch which they were eager to use. But also, after long negotiations, agreement was reached with Great Britain for the delivery of one kilo of uranium-235 before 1 August 1955. The price was 20,000 English pounds.[105] In Kjeller the NUPOP plan had been reconsidered and a modified reactor design produced in which the heavy water would boil, doing away with the problem of thermal insulation. This meant that a temperature of only 150 degrees Celsius could be achieved, but a paper factory in Halden proved to be interested in having this reactor built on its site as a heat source. An OEEC[106] project presently started around the Halden Boiling Water Reactor in which the Netherlands initially participated through EURATOM.[107] For many years Kjeller continued to be a place where new RCN staff went to gain experience with, among other things, the design of and experiments with the Halden reactor and the construction of an installation for reprocessing spent fuel rods from JEEP. Professor J.A. Goedkoop, who was connected with JENER from 1952 to 1959, called the period of the second JENER contract on the one hand the best and most fruitful years, but on the other hand the beginning of the end: 'Meanwhile it had become clear that in the long run, when the various reactor projects had got into their stride, JENER's role would have to diminish, and that therefore 1955 had only brought a stay of execution for a few more years'.[108]

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[105] AMFA, London Embassy, Secret Archive, 1955-64, Box 36, 813.33, Nederland-Verenigd Koninkrijk Atoomenergie, 1955-57, Went to Dunworth, 30 Dec. 1954; PRO, AB6/1488, Dunworth to Cockcroft, 28 Oct. 1954 and Punnett to Milatz, undated.

[106] The Organisation for European Economic Co-operation (OEEC) was initially created to organize the American Marshall Plan and became an impetus to further economic unification in Western Europe. The OEEC also worked on atomic energy.

[107] In the Treaty of Rome on 25 March 1957 the six countries of the European Coal and Steel Community (ECSC) established a European Atomic Energy Community, better known as EURATOM.

[108] Goedkoop, *Geschiedenis van de Noors-Nederlandse samenwerking op het gebied van de kernenergie*, p. 134.

The third agreement: the end of JENER

The second JENER agreement ran out on 30 June 1958. At the eighteenth meeting of the Joint Commission on 3 and 4 December 1957 a committee of four members, comprising W.A. de Haas, W. Reyseger, Hauge and Kasa, was given the task of revising the JENER contract. To give them sufficient time, it was proposed to extend the existing 1955 agreement for a one-year bridging period until 30 June 1959.[109] The Committee of Four met twice, in The Hague on 24 January 1958 and in Paris on 21 February, and drew up a draft agreement, which would replace both the general agreement of 2 November 1954 and that on JENER of the same date. The plan was to discuss this draft agreement at the meeting of the Joint Commission on 17 and 18 March 1958 and to round it off in no more than two subsequent committee meetings.[110] The basic principle was adopted that it was desirable to keep up the co-operation as far as possible and where ever possible to intensify it. On the other hand it was agreed that, in view of the rapid developments in the field of the peaceful application of nuclear power in both countries, it was not possible to keep JENER in its existing form, given that it was hardly possible for RCN, for example, to obtain adequate financing. Furthermore, IFA objected to doing all its national work within JENER. The draft contract therefore enabled both countries to do research under a jointly agreed programme, parts of which would be carried out as joint projects in both centres. Up to then it had been unclear where the territory of IFA stopped and that of JENER began.

Under the new agreement part of the work, and possibly also part of the work in the Netherlands, would be carried out jointly under the auspices of the Joint Netherlands-Norwegian Commission for Nuclear Energy Research, which was to be set up as the successor to the Joint Commission. At each national centre 'integrated groups', to which both of the contracting parties would contribute financial resources and expert staff, would carry out the work together. Outside these programmes both parties would be free to carry out their own national research. Both countries could therefore decide, on a case by case basis, which parts of their national programmes they

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[109] FOM, Minutes Joint Commission, 1955-58, Minutes of the eighteenth meeting of the Joint Commission, 3-4 Dec. 1957, p. 8.

[110] AMFA, Code 8, 1955-64, Index no. 882, De Haas, Reyseger, Hauge and Kasa to Joint Commission, 22 Feb. 1958, with Enclosure: 'Agreement between IFA and RCN', 22 Feb. 1958.

wanted to put into the joint projects; they were left free to tune their programmes to each other and to take up those elements which were attractive to the other party. In the execution of the joint projects full use could be made of the advantages which arose from working in one place with a single budget. This was a desire which had been cherished for a long time. In practice, though, the Joint Commission had in the past little influence upon the coordination of the programmes of the two organizations, but with these clearly defined joined projects it was more likely to be successful.

The draft agreement was discussed in the Joint Commission on 17 and 18 March 1958 and in the main approved. First, though, the two governments had to be brought into the decision-making process. Secondly, the committee had to incorporate some minor observations of the Joint Commission into the final draft which could be signed at the next meeting of the Joint Commission.[111] The Committee of Four therefore met one more time to prepare the text of the draft agreement, taking into account the observations of the Joint Commission, to be put before the executive committees of RCN and IFA. The new draft involved a few textual changes, the main points remained intact. Both executive committees approved the agreement.[112] The Joint Commission got to work on the Committee of Four's final proposal in its meeting on 7 August 1958 and agreed to the text as it stood. The only remaining difference of opinion concerned the Dutch uranium, to which we shall return in the next paragraph.[113] The agreement, signed on 27 January 1959, would come into force on 1 July 1959 and be valid for five years. Norwegian-Dutch co-operation was now operated through RCN and IFA, so there was no longer any place for JENER. It

[111] FOM, Minutes Joint Commission, 1955-58, Minutes of the nineteenth meeting of the Joint Commission, 17-18 March 1958, p. 9.

[112] AMFA, Code 8, 1955-64, Index no. 882 and FOM, Records Beekman, WAR, Reactor I (tot 1960), Overeenkomst IFA-RCN, Reyseger to the Joint Commission, as well as to Kramer and Riemens, No. 152, 17 July 1958; AMFA, Code 8, 1955-64, Index no. 880, Memorandum from Riemens to Luns, No. 1504, 14 Aug. 1958, with Enclosure: 'De Nederlands-Noorse samenwerking op atoomgebied', undated; AMFA, Oslo Embassy, 1955-64, 813.33, Box 35, Kernenergie. Samenwerking Nederland-Noorwegen, 1957-61, Note by Riemens: 'De Nederlands-Noorse samenwerking op atoomgebied', 23 Sept. 1958.

[113] FOM, Minutes Joint Commission, 1955-58, Minutes of the twentieth meeting of the Joint Commission, 7 Aug. 1958, p. 2.

meant that JENER ceased to exist on 30 June 1959.[114] In the eighth and final Annual Report (July 1958-June 1959) of JENER the disbandment of JENER was announced.[115]

Following the signing of the agreement further talks were held on the concrete details of the joint projects to be undertaken by RCN and IFA. It was proposed to begin with four projects at Kjeller and three at Petten, where RCN had begun construction of the American research reactor and associate facilities. These projects were given the numbers K-1 to 4 and P-1 to 3 respectively. Expenditure was budgeted at almost 400,000 Norwegian crowns to be divided on a fifty-fifty basis. The Dutch were not completely happy with these ideas. They proposed the expansion of the projects in Petten but had to give further consideration to the division of the costs. It was agreed that RCN should come up with counter-proposals to be discussed in the next Joint Commission meeting.[116] However, also the resulting new paper assumed that operating costs would be shared on a fifty-fifty basis, but increased the number of K-projects from four to six and of P-projects from three to five.[117]

The new agreement between RCN and IFA came into force on 1 July 1959. In the meantime agreements had been drawn up on the programmes and budgets of the (K and P) projects. The next step was the financial winding up of JENER where arrangements had to be made concerning the rights to the uranium and plutonium in JEEP.

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[114] AMFA, Code 8, 1955-64, Index no. 882, Gerbrandy to Baron van Aerssen Beijeren van Voshol, 3 March 1959, with Enclosure: 'Agreement between the Institutt for Atomenergi (IFA) and the Foundation Reactor Centrum Nederland (RCN)', 27 Jan. 1959; FOM, Records Beekman, WAR, JENER (tot 1960), Joint Commission-I, Folder: Belastingzalen, Minutes of the twenty-first meeting of the Joint Commission, 27-28 Jan. 1959, pp. 1-2.

[115] ECN, Eighth Annual Report, July 1958-June 1959 of the Netherlands-Norwegian Joint Establishment for Nuclear Energy Research, June 1959, pp. 6-7.

[116] FOM, Records Beekman, WAR, JENER (tot 1960), Joint Commission-I, Folder: Belastingzaken, Minutes of the twenty-first meeting of the Joint Commission, 27-28 Jan. 1959, pp. 3-4.

[117] Ibid., Minutes of the twenty-second meeting of the Joint Commission, 28 May 1959, pp. 3-4.

The disposal of Dutch uranium in JENER

In view of the fact that the Norwegian-Dutch co-operation on nuclear energy changed as a result of the new agreement between RCN and IFA, it was necessary to establish who owned what under the new arrangements. A thorny issue involved the five tons of uranium raw material supplied by the Netherlands in 1951, that had been put into JEEP in the form of (British) uranium metal. The agreement between FOM and NTNF of 1951 granted FOM the right 'to obtain uranium oxide from Norway', if it were to be produced there, up to the same quantity as FOM was supplying to JEEP. The contract between RCN and IFA of November 1955 had confirmed that 'three tons of uranium metal provided by FOM for the Kjeller reactor will remain Netherlands' property and RCN may, subject to six months' notice, request IFA to furnish RCN with an equivalent amount of uranium'.

The Norwegians noted that they had built JEEP, in which plutonium was produced, and that they had provided funds to reprocess the uranium and separate the plutonium. Given that the Netherlands had only contributed half toward this, the Norwegians standpoint was that the Netherlands was entitled to no more than half of the recovered uranium and plutonium. The amount of the latter involved a total of four hundred grams with a market value of fifty guilders per gram, amounting to 20,000 guilders. The possession of plutonium was more important than its market value, however, because it was very hard to get.

Given the technical nature of the matter De Boer, with his background in industrial chemistry, was asked to report on the extent to which the plutonium could be claimed by RCN. De Boer's view was that the Netherlands retained the right at all times to three tons of uranium metal. If the Netherlands was happy to take the reprocessed material instead, this would include plutonium. Norway could opt to supply three tons of new metal uranium, in which case the Netherlands would lose all rights to the plutonium. De Boer therefore suggested 'making the best of a bad job and making do with half of the Pu (which had been produced jointly by the Netherlands and Norway...)'. Since the uranium still was the property of the Dutch government this could not of course happen without that government's consent. Beekman, who had been involved in the whole history of the matter, that the Netherlands should claim three tons of virgin uranium raw material. The irradiated uranium would then become the property of the Norwegians. On the grounds that RCN and IFA had jointly funded the reprocessing and separation costs, RCN would be entitled to half of the

plutonium. There were three possible interpretations of the uranium section therefore. Firstly, that the Dutch could ask for three tons of uranium metal back whereby the irradiated uranium would become Norwegian property. Because RCN and IFA had jointly funded the cost of reprocessing and separation, RCN would also be entitled to half of the plutonium (Beekman's view). Secondly, there was the view that the Netherlands retained the right to three tons of unirradiated metallic uranium. Norway could always supply the Netherlands with this, but then the Netherlands would lose all rights over the plutonium. Given the importance of plutonium, the Netherlands should therefore be content to take half of it (De Boer's view). Thirdly, there was the Norwegian interpretation: the impoverished uranium in solution and the other byproducts after the extraction of plutonium, were the property of the Dutch. Half of the plutonium produced belonged to Norway because its production had been a joint effort. The Norwegians did not put a price on the other end products. The expense incurred for the waste problem would be met by the Norwegians (the Norwegian proposal). Although Beekman's standpoint was just and clear, Reyseger, the responsible director of RCN - with a view to future co-operation with IFA - advised the government not to take too tough a stance and to agree with the Norwegian proposal, even though it meant foregoing some Dutch rights.[118]

Section 11, subsection 3 of the 1955 JENER agreement stated that a separate agreement would be drawn up to settle matters relating to the uranium, heavy water, equipment and other possessions when JENER was disbanded. A draft agreement was drawn up by RCN which went along with the Norwegian proposal almost in full. The Dutch uranium, which was in the form of uranium metal in the nuclear fuel elements in Kjeller and which had been irradiated, was to be made available to the reprocessing plant to be run and financed jointly by RCN and IFA as a joint project. The transfer of the uranium from the JEEP heavy water reactor would take place gradually and would have to be completed by 1 July 1962. The *unirradiated* uranium rods in stock in Kjeller at that time (about 75 kilograms), would be used in the reactor in the period up to 1 July 1962 to replace those transferred for reprocessing. The uranium, for as long as and in as much as it remained in the reactor, could be used by IFA without any fee being paid to RCN. On

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[118] AMES, HOW, Folder: 54.2:5K, Splijtstofelementen; Diversen; Archives Ministry of General Affairs (hereafter AMGA), The Hague, Kabinet Minister-President (hereafter KMP), Dossier 62.093, Box 17, Samenwerking Nederland-Noorwegen, 1955-62; and AMEA, ADK, Index no. 313, Reyseger to Board RCN, No. 648, 23 Sept. 1959.

the other hand IFA must allow RCN and IFA to use the nuclear facilities of the reactor free of charge. The two organisations would each own half of the end products of reprocessing the uranium, thus including the plutonium. The remaining - slightly impoverished - uranium would stay the property of the Dutch state. IFA would be responsible for disposing of the radioactive waste resulting from reprocessing. For this arrangement to be accepted it was necessary for the Dutch government to give its consent to two matters. Firstly, the right, subject to six months notice, to an equal amount of uranium from IFA. Secondly, half of the plutonium and other nuclear products resulting from the reprocessing would have to be handed over to IFA. RCN employed two arguments to win over the Dutch government: a psychological argument and a business argument. The psychological one was that the Netherlands would thereby indicate to the Norwegians that they valued their continued good working relationship. The business argument was that the Netherlands would obtain half of the plutonium, considered to be of the utmost importance for Dutch research.[119]

Since the uranium raw material still belonged to the Ministry of Education, the Arts and Science, this ministry had to give the final consent for it to be relinquished. This permission followed on 21 November 1959 and the arrangements with the Norwegians could be finalized.[120]

The liquidation of JENER

The arrangements for the uranium were ratified at the meeting of the Joint Commission on 10 June 1960. The irradiated uranium still being used in JEEP would gradually be transferred to the reprocessing plant at Kjeller and afterwards RCN and IFA would each gain possession of half of the radioactive products, including the plutonium. This slightly impoverished uranium remained the property of the Netherlands and could be claimed back later. Of course the liquidation of JENER did not only involve the issue of the uranium. Arrangements also had to be made with respect to financial matters, since no agreement had as yet been reached on the financial RCN's rights to the assets left after the liquidation of JENER. This was because the

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[119] AMES, HOW, Folder: 54.2:5K, Splijtstofelementen; Diversen and AMEA, ADK, Index no. 313, Reyseger to Meylink, 9 Nov. 1959.

[120] AMES, HOW, Folder: 54.2:5K, Splijtstofelementen; Diversen and AMEA, ADK, Index no. 314, Piekaar to the Board of RCN, 21 Nov. 1959.

Norwegians could not agree to the sum of 834,000 Norwegian crowns that the Dutch were claiming. They were thinking in terms of 500,000 to 600,000 Norwegian crowns. Randers appealed to the Dutch not to push for a precise financial settlement that threatened to spoil relations between the two countries. To do so would be regrettable, since the liquidation did not mean the end of Norwegian-Dutch co-operation. Moreover, the Norwegians were to contribute a sum of 500,000 to 550,000 crowns to the construction of a library building in Petten. This neutralised the Dutch claim. With regard to an RCN loan to the company which had provided housing for its staff, it was agreed that IFA would pay this back in instalments. JENER's balance on 30 June 1959 stood at over 460,000 Norwegian crowns, made up of cash and stock. The Dutch delegation agreed that this sum be allocated for the waste disposal plant that IFA was to build next to the reprocessing plant. Agreement had been reached on the liquidation of JENER: this form of Norwegian-Dutch co-operation had thus ended but it was to be continued for a number of years through the joint projects of RCN and IFA.[121]

Conclusions

After the devastation of the Second World War the Netherlands and Norway were faced with the task of reconstructing their countries. Nuclear research was one of the issues that was subjected to close scrutiny in this context. The Netherlands quickly came to the conclusion that it would be impossible to build a nuclear reactor independently; to do so was not feasible either technically or financially. The Norwegians were of a different opinion at first. In 1945-1946 they set out to build a reactor independently and it took years before Randers was forced to change his mind because of the difficulties created by the lack of uranium. In view of this the hunt was on for collaborative links which would, moreover, strengthen the separate development of nuclear research in each country.

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[121] AMEA, ADK, Index no. 314, Minutes of the twenty-third meeting of the Joint Commission, 10 June 1960, pp. 6-10; Ibid., Agreement between RCN and IFA, 2 Dec. 1960; AMGA, KMP, Dossier 62.093, Box 32, Buitenlandse samenwerking RCN, Kramer to Board RCN, No. 773, 23 June 1960, with Enclosures: 'Korte samenvatting van de 23e Joint Commission vergadering op 10 juni 1960', undated and 'Punten waarover een liquidatieregeling met IFA zal worden getroffen', undated; AMFA, Code 8, 1955-64, Index no. 380, Memorandum from TMA to DGES, No. 1254, 16 June 1960.

The hunt for co-operative links was thwarted by American policy, which was characterised by secrecy and monopolisation in the field of the application of nuclear energy after the Second World War. The export of nuclear know-how or the strategic resources uranium and thorium was ruled out. The search was on then for another partner. Norway collaborated closely with the French throughout the late 1940's. But nuclear co-operation with this country was never formalized for political reasons, i.e. the American opposition and Joliot-Curie's 'communism'.

During Kramer's visit to Oslo in 1950, where he met Randers among others, the foundation for Norwegian-Dutch co-operation was laid. On a reciprocal basis the Netherlands was to contribute uranium raw material and the Norwegians heavy water and a reactor under construction in Kjeller. Great Britain functioned in a supportive role by being prepared to exchange the Dutch uranium oxide, which in its unpurified form could not be used in the reactor (JEEP), for rods of uranium metal. The start of operations at the Norwegian-Dutch reactor in Kjeller in July 1951 heralded the first phase of Norwegian-Dutch co-operation: JENER.

The mid-1950's saw an important change of direction in the nuclear policy of the United States, launched by President Eisenhower's 'Atoms for Peace' proposal. The end of the American policy of secrecy and exclusion brought new opportunities for other countries, included prospects for export of nuclear know-how, enriched uranium, and even complete reactors. Dutch nuclear physicists were at once interested in the new opportunities.

During the period of the first JENER contract (1951-1955), because of the international context, the joint project encompassed virtually everything that happened in the nuclear energy field in both countries. In the second contract period (1955-1959) further work outside the joint operations began. Two agreements were concluded between the Foundation RCN and IFA. The first was a general agreement to continue working together. Only an extra paragraph was inserted which allowed joint projects to be started; this departed from the principles of the agreement, for which a separate agreement would be necessary. This second agreement ensured the continued existence of JENER for a further three years until 30 June 1958. It was however the beginning of the end.

Negotiations were conducted with the Norwegians about the building of BEPOP (or NUPOP, a straightforward extrapolation of JEEP) or SUSPOP (a revolutionary design, with the uraniun fuel in suspension, favoured by the Dutch electric utilities). There was a world of difference concealed behind the two reactors. The Netherlands was dependent upon dwindling production from the Limburg coal mines and the import of oil, and saw nuclear power

primarily as a solution to its energy problems. The Norwegians had plenty hydroelectric power of their own and were more interested in using nuclear power in their large merchant fleet. Consequently while the Dutch preferred to build SUSPOP, the Norwegians preferred BEPOP (NUPOP), which could conceivably be installed in a ship. Although SUSPOP was considered more important in the long run, the Netherlands nevertheless opted for NUPOP. This decision was based on practical considerations. Only by going for NUPOP could the Netherlands get hold of the necessary raw materials. Furthermore the Netherlands did not want to place their successful relationship with the Norwegians in the balance. By co-operating with the Norwegians and using the heavy water reactor in Kjeller (JEEP), the Netherlands had leapt ahead in the field of nuclear research compared to other countries (apart from the United States, Great Britain and the Soviet Union). So NUPOP was, for the Dutch, first and foremost an intermediate step en route to SUSPOP, for which also the lack of enriched uranium formed a stumbling block.

The 'Atoms for Peace' speech by the American President Dwight D. Eisenhower in December 1953 heralded an important change in the American policy of secrecy and opened up the possibility of purchasing enriched uranium and so starting work on SUSPOP straight away.

In the end the Netherlands chose to purchase a research reactor based on American technology and JENER was more or less written off. Both agreements were extended for another year in 1958, but after that Norwegian-Dutch nuclear co-operation through JENER was really brought to an end. Co-operation between RCN and IFA continued though. Agreements were made to conduct joint projects, to be carried out by mixed Norwegian-Dutch teams, either in Petten or in Kjeller. They were given the names P(etten)-project 1 to 5 and K(jeller)-project 1 to 6. After the material assets and the finances had been wound up, a decade of Norwegian-Dutch joint operations through JENER had come to an end. It had been a very successful collaboration. By co-operating well and throwing chauvinism overboard, two small countries had managed to build a nuclear reactor and use it for research and the production of radioisotopes. Thus they were among the first West European countries to do so. That can be called an achievement.

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Foundation for Fundamental Research on Matter (FOM), Utrecht;
Harry S. Truman Library, Independence, Missouri;
National Archives, Washington DC;
Netherlands Energy Research Foundation (ECN), Petten;
Netherlands organisation for Scientific Research (NWO), The Hague;
Public Record Office, London;
Washington National Records Center, Suitland, Maryland