No. 16659

UNITED STATES OF AMERICA
and
DENMARK, FINLAND, NORWAY and SWEDEN

Agreement relating to atomic energy: research participation and technical exchange in loss of fluid test (LOFT) program (with appendices). Concluded on 15 September 1976

Authentic text: English.
Registered by the United States of America on 27 April 1978.

ÉTATS-UNIS D'AMÉRIQUE
et
DANEMARK, FINLANDE, NORVÈGE et SUÈDE

Accord relatif à l'énergie atomique : participation aux travaux de recherche et échange de renseignements techniques en matière de contrôle des pertes de fluide (projet LOFT) [avec appendices]. Conclu le 15 septembre 1976

Texte authentique : anglais.
Enregistré par les États-Unis d'Amérique le 27 avril 1978.

AGREEMENT[1] ON RESEARCH PARTICIPATION AND TECHNICAL EXCHANGE BETWEEN THE UNITED STATES NUCLEAR REGULATORY COMMISSION (USNRC) AND THE NORDIC GROUP (FORSOGSANLAEG RISO, DENMARK; VALTION TEKNILLINEN TUTKIMUSKESKUS, FINLAND; INSTITUTT FOR ATOMENERGI, NORWAY, AND AB ATOMENERGI, SWEDEN) IN THE USNRC LOFT RESEARCH PROGRAM AND THE NORDIC NORHAV PROJECT COVERING A FOUR-YEAR PERIOD

WHEREAS, the United States Nuclear Regulatory Commission (USNRC) and the Nordic Group

(*a*) Have a mutual interest in cooperation in the field of reactor safety research, and

(*b*) Have as a mutual objective improving and thus ensuring the safety of reactors on an international basis;

(*c*) Have as a mutual objective the achievement of full reciprocity in the exchange of technical information in the field of reactor safety research, and

(*d*) Recognize that they are participants in the cooperative programs on reactor safety research of the International Energy Agency (IEA), as defined in the Article IV of the Guiding Principles for Cooperation in the field of Energy Research and Development, agreed upon by the IEA Governing Board, and

(*e*) Have an interest in applying the rights of the participants with respect to intellectual property consistent with Article VI of the Guiding Principles for Cooperation in the Field of Energy Research and Development;

(*f*) Have expressed their intention to participate cooperatively in the USNRC-funded Loss of Fluid Test (LOFT) research program and in the Nordic Group-funded Norhav project. The LOFT program is performed at the Idaho National Engineering Laboratory, owned by the United States Government and operated under contractual arrangement for the U.S. Energy Research and Development Administration (USERDA). The Norhav project is performed in the Nordic countries under contractual arrangement between Nordic participants to the Nordic Group.

NOW, THEREFORE, the USNRC and the Nordic Group do hereby mutually agree as follows:

Article I. PROGRAM COOPERATION

1. The USNRC and the Nordic Group will join together, in accordance with the provisions of this agreement, for cooperative research in the USNRC Loss of Fluid Test (LOFT) program as described in the LOFT Program Description (LPD-1, October 1974) and in the Nordic Norhav project as described in Appendices A and B for this period of four years beginning upon execution of this agreement.

[1] Came into force on 20 October 1976, upon signature by all the Parties, in accordance with article VII. Signatures were affixed as follows:

State	*Date of signature*	*State*	*Date of signature*
United States of America	15 September 1976	Denmark	15 October 1976
Sweden	1 October 1976	Finland	20 October 1976
Norway	13 October 1976		

Article II. SCOPE OF AGREEMENT

A. *Scope of Responsibility—USNRC*

1. The USNRC agrees to provide the necessary personnel, materials equipment, and services in order that the LOFT research program may be carried out as described in the LOFT PROGRAM DESCRIPTION (LPD-1, October 1974), as amended, subject to the availability of funds. It is the USNRC's intention to include in the LOFT research program a series of Loss of Coolant Experiments (LOCE) with nuclear heating as soon as technically feasible following the nonnuclear LOCEs, subject to the availability of funds.

2. The USNRC agrees to permit the Nordic Group to assign up to three mutually agreed upon technical experts to the LOFT Program for participation in the conduct and analysis of program experiments.

3. In addition, the USNRC agrees to permit the Nordic Group to assign one technical expert as a consultant to the LOFT program review group which will periodically review the status of the present program and future program planning. Consultants to the LOFT program review group shall have the prerogative of attending and fully participating in review group meetings and transmitting views and comments on technical aspects of the program to program management.

4. The USNRC agrees to grant the Nordic Group and its assignees access, to the maximum extent authorized by the law of the United States, to all experimental data and results of analyses generated by the LOFT program during the period of this agreement.

5. The USNRC agrees to provide the Nordic Group access as necessary to operational computer codes developed to analyze experimental data generated by the LOFT program to the maximum extent permitted by the law of the United States, except for proprietary codes and data unless authorized by the owner.

6. The USNRC agrees to bear the total costs of transportation, living expenses and any other costs arising from its participation in the Norhav project under this agreement.

B. *Scope of Responsibility—Nordic Group*

1. The Nordic Group, as a contribution for the technical benefits received by participation in the USNRC LOFT research program and receipt of information under this agreement, agrees to provide research information, computer codes and analysis of experiments developed under the Norhav project, as described in Appendices A and B, subject to the availability of funds. The Nordic Group agrees to allocate, within the Norhav project, 6 man years annually for the period of the agreement to perform technical work designed for the USNRC programs as expressed in Appendix A.

2. The Nordic Group agrees to permit the USNRC to assign up to three mutually agreed upon technical experts to the Norhav project for participation in the code development and analysis of experiments.

3. In addition, the Nordic Group agrees to permit the USRNC to assign one technical expert as a consultant to the Norhav project review group which will periodically review the status of the present group program and advise on future program planning. Consultants to the Norhav program review group shall have the prerogative of attending and fully participating in review group meetings and transmitting views and comments on technical aspects of the program to program management.

4. The Nordic Group agrees to grant the USNRC access, to the maximum extent authorized by the laws of the Nordic countries, to all results obtained from the Norhav project's analyses of information and experimentation developed under and during the period of this agreement, including computer codes used in such analyses, except for proprietary codes and data unless authorized by the owner.

5. The Nordic Group agrees to bear the total costs of transportation, living expenses and any other costs arising from its participation under this agreement, and the transport and related costs for apparatuses and other equipment furnished by the Nordic Group.

Article III. PATENTS

A. With respect to any invention or discovery made or conceived during the period of, or in the course of or under, this agreement for Nordic Group participation in the USNRC LOFT research program, the USNRC on behalf of the United States Government, as recipient party, and the Nordic Group as assigning party, and for USNRC participation in the Norhav Project, the Nordic Group as recipient party and the USNRC as assigning party, hereby agree that:

1. If made or conceived by personnel of one party (the assigning party) or its contractors while assigned to the other party (recipient party) or its contractors:
   (*a*) The recipient party shall acquire all right, title, and interest in and to any such invention, discovery, patent application or patent in its own country and in third countries, subject to a non-exclusive, irrevocable, royalty-free license to the assigning party, with the right to grant sublicenses, under any such invention, discovery, patent application, or patent for use in the production or utilization of special nuclear material or atomic energy; and
   (*b*) The assigning party shall acquire all right, title, and interest in and to any such invention, discovery, patent application in its country, subject to a non-exclusive irrevocable, royalty-free license to the recipient party, with the right to grant sublicenses, under any such invention, discovery, patent application or patent, for use in the production or utilization of special nuclear material or atomic energy.
2. If made or conceived while in attendance at meetings or when employing information which has been communicated under this exchange arrangement by one party or its contractors to the other party or its contractors, the party making the invention shall acquire all right, title, and interest in and to any such invention, discovery, patent application or patent in all countries, subject to the grant to the other party of a royalty-free non-exclusive, irrevocable license, with the right to grant sublicenses, in and to any such invention, discovery, patent application, or patent, in all countries, for use in the production or utilization of special nuclear material of atomic energy.

B. Neither party shall discriminate against citizens of the country of the other party with respect to granting any license or sublicense under any invention pursuant to subparagraphs A(1) and A(2) above.

C. Each party waives any and all claims against the other party for compensation, royalty or award as regards any such inventions or discovery, patent application, or patent, and releases the other party with respect to any and all claims, including any claims under the provisions of the U.S. Atomic Energy Act of 1954, as amended, and applicable laws of the respective countries of the Nordic Group and

the Nordic Group assumes the obligation under the Nordic Group's laws insofar as the USNRC and its contractors are concerned.

Article IV. PROGRAM CHANGE OR TERMINATION

A. If the USNRC LOFT research program is substantially increased by mutual agreement the USNRC and the Nordic Group mutually agree to consider equitable adjustments in the Nordic Group's contribution.

B. If the LOFT research program is substantially reduced or eliminated, equitable work determined by the USNRC and the Nordic Group to be of equivalent programmatic interest will be substituted as may be mutually agreed.

C. Upon a decision by either USNRC or Nordic Group to withdraw from this agreement, the withdrawing party shall notify the other party of the intent to withdraw at least six months prior to the date of the withdrawal.

D. The Nordic Group is given the option to participate in the continuation of the LOFT program beyond the four year period of this agreement under mutually acceptable terms and conditions.

Article V. EXCHANGE OF SCIENTIFIC INFORMATION AND USE OF RESULTS OF PROGRAM

A. The USNRC and the Nordic Group agree that until approval is granted by the transmitting party for publication, the information, once transmitted, will be freely available to government authorities and organizations cooperating with the USNRC and the Nordic Group for their own use but not for publication. When required by administrative procedure in its own country, the USNRC and Nordic Group may on its own responsibility disseminate or otherwise make use of information received.

B. The USNRC and the Nordic Group agree that the application or use of any information exchanged or transferred among them shall be the responsibility of the party receiving the information, and the transmitting party does not warrant the suitability of the information for any particular use or application.

Article VI. DISPUTES

A. Any dispute between the USNRC and the Nordic Group concerning the application or interpretation of this agreement that is not settled through consultation shall be submitted to the jurisdiction of the United States federal courts. This Agreement shall be construed in accordance with the internal federal law applicable in the appropriate United States courts, to agreements to which the Government of the United States is a party.

Article VII. RELATIONS BETWEEN THE USNRC AND THE NORDIC GROUP REFERRED TO IN THIS AGREEMENT

The Nordic Group consists of four parties as listed below. This agreement shall become effective upon signature by appropriate representatives of the USNRC and the four parties which comprise the Nordic Group. The Nordic Group and the USNRC shall each appoint within 30 days after the signing of this agreement one coordinator to coordinate and implement the provisions of this agreement.

Article VIII. IEA GOVERNING BOARD

Upon signature by all parties to this agreement, the agreement will be presented to the Governing Board for information.

For the United States
Nuclear Regulatory Commission:

By: [*Illegible*]
Title: Executive Director for Operations
Date: September 15, 1976

For the Nordic Group:

Forsogsanlaeg Riso, Denmark,

By: [*Illegible*]
Title: Managing Director
Date: October 15, 1976

Valtion Teknillinen
Tutkimuskeskus, Finland,

By: [*Illegible*]
Title: General Manager, Research Division
Date: 1976-10-20

Institutt for Atomenergi, Norway,

By: [*Illegible*]
Title: Managing Director
Date: October 13, 1976

Aktiebolaget Atomenergi, Sweden,

By: [*Illegible*]
Title: President
Date: October 1, 1976

APPENDIX A

(SCOPE OF WORK)

Project Title: Assistance in LOCA Analysis Development.

Man-Years: 6 man-years per year, for the duration of NRC/Nordic Group agreement.

Scope:

1. General: To assist NRC/WRSR in the development of the Best Estimate computer codes, useful for analysis of experiments such as LOFT, PBF, and TLTA.

2. Near Term: To develop a BWR reflood module (or subcode) that could either perform as a self-standing code through specification of the initial and the boundary conditions—coming from either the Best Estimate codes presently being developed in U.S. under NRC/WRSR sponsorship, or from the test data; or be connnected with a simplified representation of the BWR system also developed by the Nordic Group. The BWR reflood description should be able to consider both the top sprays and the bottom reflood. The geometric representation is to include the whole BWR vessel and a core that features three (radial) heated regions and two bypass regions.

The Nordic Group's RHC code could provide a suitable basis for this work. In its present form this code treats only the BWR top spray reflood without considering the countercurrent

flow limitation criteria. These will have to be introduced and the code extended into the bottom reflood regime, with the ability to track the time dependent location of the mixture level and of the quench front.

The treatment of heat transfer in the fuel rod (cladding, gap, fuel pellets) or in the simulated, electrically heated "fuel rod" ought to consider all the important phenomena.

The longer range mutually acceptable work scope is to be defined later.

Relationship to Other Federally Financed Projects:

The work encompassed by this project is applicable to analyses of various tests conducted in U.S. in the field of LWR safety, such as LOFT, Semiscale, TLTA, PBF, etc. It is also supplemental to NRC sponsored work on the development of LOCA codes such as RELAP, THOR, and TRAC.

Expected Results in FY-1977: Modeling of BWR top and bottom reflood.

APPENDIX B

NORHAV

(Revised programme for the Nordic contribution to the US-NRC LOFT project)

Within the Norhav agreement, a number of projects are underway in order to improve the understanding of "Loss of Coolant Accident Behavior" of a nuclear reactor system. Some projects are initiated with short time goals, others on a more long time basis.

I. *LOCA "Best Estimate" Computer Programme Development*

1) RHC and CORECOOL (a version of RHC) are core heat-up codes both for calculation of core heat-up transients and for evaluation of the performance of the spray cooling system.

The codes consist in the present version of two basic models, a fuel rod model and a model for the two-phase flow in the system. The two-phase flow model is based on the solution of the conservation equations for mass, momentum and energy. The two phases are treated separately and physical models and correlations are developed for the interchange of mass, momentum and energy. Thermodynamic equilibrium is not assumed. The coupling between the fuel rod model and the two-phase flow model consists of a number of physical models and correlations for the heat transfer including conduction, convection and thermal radiation. The heat transfer covers conduction in droplets and films, convection from superheated steam to droplets, convection from a surface to superheated steam and convection from a surface to a falling film. Sputtering heat transfer is calculated as a two-dimensional heat conduction problem. Thermal radiation between surfaces and channel with anisotropical reflection and radiation to the two-phase mixture in the bundle, steam and droplets, is taken into account. Determination of CCFL-phenomena will also be included in the codes.

The aim of the core heat-up work is to develop a model which is based on a physical approach, and not on gross-system dependent empirical correlations. This approach, besides giving a better understanding, makes the model more system independent. The development of a reflooding version of the programme is initiated recently.

2) NORA is a general purpose computer programme for the analysis of pressure-, temperature- and mass flow transients in a mixture of air, steam and water flowing through a system of pipes.

The following equations are applied: Continuity of mass for each component (i.e., three eqs.). Two energy equations, one for each phase. One momentum equation for the mixture plus slip correlations. The equation of state for air and superheated steam.

Table values are used to calculate properties of water and saturated steam. The flow equations describe one-dimensional flow.

The equations for continuity of mass and energy and the state equations for gas and steam are combined to give a set of differential equations for steam pressure, air pressure, water temperature and steam/air temperature. The exchange of mass and energy between the liquid and gas phases is governed by semi-empirical correlation. Critical flow due to pipe breaks, sudden expansion, etc., are treated assuming that the flow velocity at these locations cannot exceed the velocity of sound for infinite frequency, based on local flow condition.

The programme will include such features as water levels, walls simulating structure as well as heat exchangers, accumulators represented by pipes and specified by their initial water and gas contents, a pressurizer described by a pipe with heat input and spray, fuel with point kinetics and decay heat, electrical heaters, valves and pumps with their different characteristics.

The NORA program will be able to simulate a large variety of designs such as primary reactor systems, containments, and blowdown experiments.

3) The TINA is a transient subchannel code describing the conditions in the reactor core during blowdown. The hydraulic part of TINA treats sonic effects, slip between the two phases and non-equilibrium of the water phase. The program handles flow reversal and can accept any boundary condition which is physically conceivable. The hydraulics are coupled to a simple one-dimensional model for the transient temperature distribution in the fuel. The numerical solution procedure is implicit and allows large time steps.

The present version of TINA treats only two modes of heat transfer (non-boiling and boiling). The program will be extended to cover the post-burnout range, taking into account steam superheat, radiation heat transfer, etc. Also, reflooding calculations will be included. The fuel model will be extended to handle cladding failures. A simple reactor physics model will also be included.

The TINA code must in the present form be coupled to a general system code which, e.g., may be a loop code or the NORA code.

4) The future work will also include development of computer models for "small breaks" and "cladding failure."

II. *WREM-Development and Application*

1) The work in LOCA analysis development and verification which is based on the WREM-package will be included in the NORHAV-cooperation.

The work will be carried out in close cooperation between the responsible organizations. Regular semiannual WREM-development review meetings will be held with participation of NRC and NRC's contractors for exchange of results and discussion of development plans.

The work will be concentrated on the verification of WREM and its adaptation to reactor systems for interest to the Nordic countries with the aim of obtaining the knowledge necessary to use the WREM for licensing calculations.

Detailed working plans will be formulated after discussions with NRC, since the development plans of NRC must be considered in this context.

2) Participation in the standard problem exercises which allow meaningful comparison with WREM-calculations.

Comparison with LOFT-experiments. This work will be coordinated with the corresponding NRC-directed efforts.

III. *Experimental Investigations*

1) Spray-Cooling Experiments for BWR

Objective: Determination of heat transfer coefficients and the channel wetting time for conditions typical of ASEA-ATOM BWRs during top spray cooling.

Working plan: Experiments will be made with an electrically heated 64-rod bundle for different pressures (up to 25 bar), initial power, initial temperatures, spray flow and steam venting paths.

Convective heat transfer coefficients and the channel wetting time will be evaluated from the measured cladding and channel temperature responses.

Status: 17 experiments of 55 planned have been completed. Preliminary data for heat transfer coefficients indicate lower values than from BWR-FLECHT SS2N measurements.

2) CCFL-experiments

Objective: Determination of CCFL characteristics of the spray cooling loop with test assembly in position.

Working plan: Adiabatic experiments will be made with spray flows in the range 0.1 - 0.2 kg/s and upward steam flow from an external source of 0.02 - 0.10 kg/s. Experiments will be made in the pressure range 1-10 bar and with steam superheating up to 150°C.

The spray flow reaching the bottom of the test vessel will be measured together with the steam flows in and out and the water flow from the steam dryer at the top.

The data will be used to determine the fraction of the spray flow which penetrates into the test assembly.

Status: Test programme and experimental equipment will be finalized in February 1976. Testing and evaluation will be finished by March 1976.

3) Reflooding Experiments for BWR

Objectives:

— Determination of heat transfer coefficients and the channel wetting time for conditions typical of ASEA-ATOM BWRs during bottom flooding and combined top spray and bottom flooding.

— To determine the effective reflooding rate for bottom flooding/combined top spray and bottom flooding in a system simulating the ASEA-ATOM BWR for conditions typical of that reactor type.

Working plan: All the experiments will be made with an electrically heated 64-rod bundle for different pressures (up to 25 bar), initial power, initial temperatures, spray flow and steam venting paths.

After 20 experiments with a forced flooding rate the loop will be rebuilt to simulate the ASEA-ATOM reactor system. An additional 20 experiments will then be made with different ECC injection and with the flooding rate governed by the systems effects.

Convective heat transfer coefficients and the channel wetting time will be evaluated from the measured cladding and channel temperature responses. In the systems effects tests the effective flooding rate will be evaluated from inlet differential pressure measurements.

Status: Preliminary planning stage. Final planning and equipment installation will be finished by June 1976. Experiments with a forced flooding rate will start after July 1976.

IV. *Budget for the NORHAV Project for the Period 1976-1980 Including the Contribution to the Work Described in Appendix A*

Yearly Contribution to NORHAV[a] *man-year/year*	*Average Yearly Computer Cost* *K $/year*[c]	*Total Cost* *K $*[c]
20	500	7000[b]

[a] Excluding experimental work.
[b] Including experimental work.
[c] In 1976 cost level.