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IMPLEMENTING AGREEMENT

ON

"UNDER SODIUM DEFECT DETECTION USING ULTRASONIC GUIDED WAVES"

BY AND BETWEEN

THE INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH of the Department of Atomic Energy, Government of India located at Kalpakkam – Tamil Nadu – India, duly represented by Dr. Arun Kumar Bhaduri, Director, Indira Gandhi Centre for Atomic Research,

Hereinafter called as "**IGCAR**"

AND

THE COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, a French state-owned research entity with a scientific, technical or industrial activity duly organised under the laws of France and having its registered office located Bâtiment Le Ponant D - 25, rue Leblanc - Paris 15ème (France) - and declared at the Paris, Register of Commerce and Trade ("Registre du Commerce et des Sociétés de Paris") under the following registration number : R.C.S. PARIS B 775 685 019, duly represented by Mr. François Gauché acting as Director of the Nuclear Energy Division and duly authorised for the purpose hereof,

Hereinafter referred to as "**CEA**",

Hereinafter also referred to as individually as a "Party" or collectively as the "Parties"

WHEREAS the Government of the French Republic and the Government of the Republic of India signed on September 30, 2008 an Agreement on the Development of Peaceful Uses of Nuclear Energy (hereinafter "the Framework Agreement");

WHEREAS the Government of the French Republic and the Government of the Republic of India signed on December 6, 2010 an Agreement concerning intellectual property rights on the development of the peaceful uses of nuclear energy(hereinafter "the Intellectual Property Agreement");

WHEREAS CEA and IGCAR endorsed in November, 2005 a cooperation agreement in the field of Liquid Metal Fast Reactor Safety, which expired on November 2010;

WHEREAS CEA and DAE signed on December 6, 2010 an agreement in the field of nuclear science and technology for peaceful uses of nuclear energy with the aim to establish a general framework for their cooperation (hereinafter "Cooperation Agreement");

WHEREAS CEA and IGCAR have decided, pursuant to articles 4 and 5 of the Cooperation Agreement, to establish an Implementing Agreement to prepare the bilateral cooperation on a joint research project titled "Under sodium defect detection using ultrasonic guided waves";

Whereas the Parties consider that no nuclear incident can occur from the cooperation between the Parties subject to the Implementing Agreement within the meaning of the Civil Liability for Nuclear Damage Act, 2010 in force in India or the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29th July, 1960 as implemented by legislation in force in France, and that, as a consequence, the Implementing Agreement is not subject to nuclear civil liability.

Now therefore, in consideration of the foregoing and mutual covenants contained herein, the Parties agree as follows:

ARTICLE 1 - DEFINITIONS

For the purpose of this implementing agreement

(i) **"Implementing Agreement"** means the present agreement, its annexes and its prospective amendments.

(ii) "**Own Information and Technology**" means without limitation any know-how, data, studies, software, specifications or any information whether patented or not, in any and all medium belonging to one Party prior to the effective date of this Implementing Agreement or acquired or developed thereafter independently of this Joint Research Project of this Implementing Agreement,

(iii) "**Joint Results**" means any and all document and information whether in written form or not including but not limited to manuals, drawing, know-how, trade secrets, trademarks, copyrights, manufacturing process data, studies, software, designs, specifications, technical description and data whether patentable or not generated during the Joint Research Project.

ARTICLE 2 - OBJECTIVES OF THE IMPLEMENTING AGREEMENT

The objective of this Implementing Agreement is to define the terms and conditions under which the Parties shall co-operate on a balanced basis on the following Joint research Project

"UNDER SODIUM DEFECT DETECTION USING UTRASONIC GUIDED WAVES"

The Parties agree to cooperate pursuant to the terms of this Implementing Agreement according to the provisions of the Cooperation Agreement unless otherwise specified herein.

ARTICLE 3 – SCOPE OF THE COOPERATIVE ACTIVITY

According to the joint statement attached Appendix, this Implementing Agreement essentially deals with the goal of demonstrating the detection of crack like defects in components submerged in sodium inside the main vessel. Indeed, due to access constraints and difficulty in transducer manoeuvring, ultrasonic guided wave based techniques may be promising for long range defect detection in components by launching the wave at specific points within sodium using under sodium ultrasonic transducers.

The major steps of the cooperation project include:

- Simulation (Finite element using ABAQUS / Disperse / CIVA) for optimizing guided wave modes with minimal dispersion and damping in sodium, depending on geometry, sensors and defects to be detected,
- Specifications for selecting adapted acoustic transducers (and if needed manufacture of customized transducers),

- Specimen of suitable geometry with artificial defects to be designed (compatible with behaviours of available acoustic sensors),
- Experimental validation in water, at a scale to be determined (depending on transducer frequency),
- Experimental demonstration in sodium, at a scale to be determined.

This Joint research Project deals with four steps as further described in Appendix.

ARTICLE 4 – MILESTONES - DELIVERABLES

D1 and D2. CIVA and finite element simulations of propagation of guided waves in thick submerged structures (CEA will use CIVA and IGCAR will use ABAQUS and CIVA for specific cases)	T0 + 12 months
D3 and D4. Selection/development of acoustic transducers with optimized frequency and characteristics (bandwidth etc.) and simplified experimental tests	T0 + 24 months
D5 and D6. Under water tests at scale to be determined, with representative defects	T0 + 36 months
D7 and D8. Under sodium tests at scale to be determined, with representative defects	T0 + 48 months
D9 Common paper for publication	T0 + 54 months

**T0: date of entry into force of this Implementing Agreement*

ARTICLE 5 – NOMINATED CORRESPONDENTS:

IGCAR	CEA
Dr. G. Amarendra, Director, MMG Indira Gandhi Centre for Atomic Research Kalpakkam - 603102 (Tamil Nadu), India Tel: +91 44 27480107 Fax: +91 44 27480075 e-mail: dmmg@igcar.gov.in	Francois Baqué, Engineer C.E.A. Cadarache, F-13108 Saint Paul les Durance, France Tel: +33 4 42 25 38 30 Fax: +33 4 42 25 49 17 e-mail: francois.baque@cea.fr

The technical correspondents have to report the cooperation activities tothe Joint Research

Project to the Franco-Indian Joint Committee as stated in article 6 the Cooperation Agreement.

ARTICLE 6 –FINANCIAL PROVISIONS

Both Parties agree that all activities done under this Implementing Agreement are to be done on a self-financing basis.

CEA will bear the cost of internal travel, allowance and accommodation of one IGCAR scientific officer for up to one month in France (according to the description of activities defined in Appendix). IGCAR will bear the cost of internal travel, allowance and accommodation of one CEA scientific officer for up to one month in India.

Visits or meetings as indicated in appendix (step 3 & 4) will be organized according to provisions of article 8.1 of Cooperation Agreement.

ARTICLE 7 – CONFIDENTIALITY

7.1. "Confidential Information" means:

i. Own Information and Technology and/or any type of written information and in whatever form or medium that one Party discloses, whether directly or indirectly, to the other Party and relating to the Implementing Agreement.

ii. The Results arising from the Joint Research Project.

7.2. Each Party undertakes

i. to disclose only Confidential Information it has the right to dispose of, according to the following;

ii. to keep strictly confidential and not to disclose nor to communicate to any third party, by any means whatsoever, any Confidential Information received from the other Party, unless the communicating Party has explicitly notified to the receiving Party that such proprietary information was not subject to secrecy, and

iii. to use such Confidential Information solely for the purpose of the Implementing Agreement.

7.3. Each Party shall use at least the same degree of care in protecting Confidential Information against disclosure to any third party as it exercises in protecting its own Confidential Information.

7.4. Each Party undertakes to disseminate Confidential Information only to its employees on "a need to know" basis to use it within the scope of the performance of the Implementing Agreement, and the receiving Party shall take appropriate measures with such employees to ensure that the latter should be bound by equivalent confidentiality provisions as those stipulated herein.

Notwithstanding the above provisions, each of the Parties has the right to communicate Confidential Information received from the other Party to its government authorities and its national safety authorities subject to appropriate protection of the Confidential Information by the receiving government authorities.

7.5. However, the provisions of this article shall not apply to Confidential Information for which the receiving Party can prove in writing that:

- Such Confidential Information is or has become publicly known through no wrongful act on its part;
- Such Confidential Information is available to the public and already known, at the time of disclosure by the disclosing Party;
- Such Confidential Information was rightfully received by the receiving Party from a third party without breach of any confidentiality obligation;
- Such Confidential Information was independently developed or discovered by the receiving Party without use of any Information received under the Implementing Agreement;
- Such Confidential Information is disclosed pursuant to a judicial order, a lawful requirement of government agency; or by operation of law, but then only to the extent so ordered; in such case the receiving Party will make its best efforts to timely advise the disclosing Party prior to disclosure.

7.6. The provisions of this article shall remain in force during the term of this Implementing Agreement, and for ten (10) years after the expiration or termination of the Implementing Agreement.

7.7 Any scientific publication, presentation or release paper relating to all or part of the Confidential Information, all or part of the work carried out under the Implementing Agreement shall be submitted to the prior approval of the other Party, as the case may be through the Joint Committee. The other Party shall examine it promptly and notify the submitting Party of (i) its consent to the content of the paper or (ii) its request to amend and/or remove certain parts of the paper or (iii) to delay the paper publication, presentation or release as long as necessary to ensure adequate industrial and intellectual protection, provided that such period shall not exceed eighteen (18) months from the date of the receipt of the paper by the notified Party.

Any failure of the notified Party to communicate its decision to the submitting Party within thirty (30) calendar days shall be deemed as its consent and a waiver of any objection to the contents thereof.

Unless otherwise agreed between the Parties, any scientific publication, presentation or release paper by the submitting Party shall clearly mention the collaboration with the other Party.

ARTICLE 8 – CLAIMS RESULTING FROM INFORMATION TRANSFERRED

8.1. While the information (including Confidential Information as defined in article 7.1) given by one Party to the other under this Implementing Agreement is accurate, in the opinion and to the best of the communicating Party's knowledge, the communicating Party does not warranty the pertinence of such information to any use which may be made by the receiving Party or by a third party. The use of such information by the receiving Party (including the communication to a third party) shall be entirely at the receiving Party's risk.

8.2. No claim shall be made against a Party for any direct or consequential damages to its property, its personnel or to third parties, which might result from the use of information given to the other Party.

ARTICLE 9 – INDUSTRIAL PROPERTY AND RIGHTS OF USE

9.1 Ownership

9.1.1 Ownership of Own Information and Technology

Each Party shall remain the exclusive owner of its Own Information and Technology. As such, each Party shall be free to transfer to a third party its Own Information and Technology.

9.1.2 Ownership of Results

9.1.2.1 General principles

The Parties shall ensure adequate and effective protection of the Joint Results.

The Parties shall inform each other of any Joint Result which is likely to be protected and shall engage in a timely manner on ensuring protection for the Joint Results.

To this end, the Parties undertake not to oppose the seeking, by a Party, of protection of Results in countries authorising such protection.

Each Party shall on the basis of its respective domestic legislation grant the other Party non-discriminatory treatment regarding the property, allocation and exploitation of Joint Results.

9.1.2.2 Co-ownership instrument

Before any exploitation for industrial and/or commercial purposes by one Party, the Parties shall draw up a co-ownership instrument determining the rights of use of the said Joint Results, according to the following principles:

- The co-ownership instrument shall take into account the respective material, human, financial and intellectual contributions to the acquisition of the Intellectual Property of each Party, the benefits of exclusive and non-exclusive licences in each territory or field of use, the conditions required by the respective national legislation of the Parties or other factors deemed appropriate.

- If the Parties cannot reach agreement on instrument of co-ownership within a maximum of six (6) months from the date of expiry of the Implementing Agreement, each Party may directly or indirectly exploit Joint Results throughout the world subject to remuneration for the other co-owner. Each Party should notify the other Party of its intention to invoke this clause before beginning exploitation with industrial and commercial purposes with prior notice of at least two (2) months.

9.2 Rights of use

9.2.1 Rights of use of Own Information and Technology

Each Party undertakes to grant to the other Party a non-exclusive licence without the right to sublicense on its Own Information and Technology within the scope of this Implementing Agreement for the Joint Research Project. This licence shall be granted royalty-free.

Each Party undertakes to grant to the other Party a non-exclusive licence without the right to sublicense on its Own Information and Technology if needed for industrial and/or commercial exploitation of its Joint Results. This licence shall be granted with fair and reasonable conditions as agreed by the Parties in a specific agreement.

9.2.2 Rights of use of Results

Each Party shall have the right of free use of the Joint Results for research and development purposes.

The Parties shall facilitate the effective exploitation of the Joint Results. To this end, the Parties agree to conclude a co-ownership instrument before any industrial and/or commercial exploitation of Joint Results, as mentioned above in article 9.1.2.2.

ARTICLE 10 – LIABILITY

10.1. Personal damages to the staff of each Party:

Each Party on its own account, is fully liable for the damages to its own staff, e.g. for the insurance coverage of its own staff for workmen's compensation and professional diseases, in accordance with the appropriate local regulatory and legal requirements. Consequently, each Party proceeds to the appropriate formalities, and sustains if any, all the costs associated to the insurances underwritten in order to cover its own staff against the risks.

Each Party shall inform the other Party of any claim or damage that has occurred during or consequent to any work, by the staff of other Party, employed by it, in order to proceed to the various regulatory and legal requirements.

Notwithstanding the above provisions, each Party is liable in compliance with the applicable law to damages caused by its staff to the staff of the other Party in case such damages were caused by or contributed to by the gross negligence or wilful misconduct of that staff.

10.2. Damages to the other Party's properties

Each Party keeps on its own account, without any right of recoveries against the other Party, the damages caused to its own property by the staff of the other Party when the staff thereof put to its disposal, unless such damages were caused by or contributed to by the gross negligence or wilful misconduct of that staff.

10.3. Third party liability

In accordance with the appropriate local regulations, each Party remains liable for damages to third parties caused by its own staff, except if this staff is under the management and/or the control of the other Party, unless such damages were caused by or contributed to by the gross negligence or wilful misconduct of that staff.

ARTICLE 11 – DURATION

11.1 Subject to the entry into force of the Cooperation Agreement according to article 16.1 of the said Cooperation Agreement, this Implementing Agreement shall come into force upon signature by both Parties and shall remain valid for 54 (fifty four) months.

11.2 Three months before the date of termination, the Parties shall consult each other in order to decide whether this Implementing Agreement shall be extended or not.

11.3 Termination of this Implementing Agreement for any reason whatsoever shall be without prejudice to the rights which may have accrued under this Implementing Agreement to either Party up to the date of termination.

ARTICLE 12 - SETTLEMENT OF DISPUTES

The Parties agree that any dispute arising out of this Implementing Agreement will be settled amicably if possible with assistance of one or more independent experts.

All disputes which cannot be settled between the Parties will be finally settled under the Rules of conciliation and arbitration of the International Chamber of Commerce by one or more arbitrators appointed in accordance with the said Rules. Procedures of arbitration shall be conducted in English. The place of arbitration shall be in Geneva.

ARTICLE 13 - AMENDMENT

The Implementing Agreement may be amended by mutual consent in writing of the Parties.

ARTICLE 14 - LANGUAGE

This Agreement is drawn up and executed in English.

For the Indira Gandhi Centre for Atomic Research

Full Name: Dr. Arun Kumar Bhaduri

Title: Director, Indira Gandhi Centre for Atomic Research

Place and date: 11/7/2018

(Signature)

For the Commissariat à l'Energie Atomique:

Full Name: Mr François Gauché

Title : Director, Nuclear Energy Division,

Place and date: 25/06/2018

(Signature)

APPENDIX

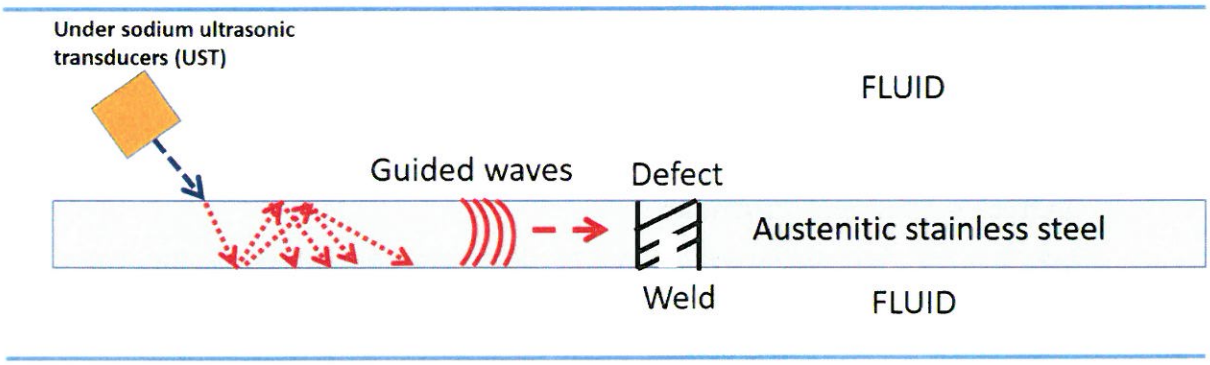
Under sodium defect detection using ultrasonic guided wave

Improvement of in-service inspection (ISI) is a major transverse issue to insure the safety of Sodium-cooled, Fast-neutron Reactors (SFR). ISI is strongly linked to safety analysis (the three defence lines: checking the state of material and equipment during the reactor's life span, detection of premature failures, and in-operation detection of significant failures), and economic reliability (implementation delays).

One of the major difficulties for SFR ISI deployment is the sodium environment [1].

Mandatory inspection of various structures and components inside the main vessel will be periodically performed with acoustic sensors, well adapted to sodium environment.

But, depending on the access for positioning of Non-Destructive Testing (NDT) equipment, it can happen that the sensor remains quite far from the area that requires inspection: instead of being in contact with it, or even quite close to it (some cms), acoustic waves are unlikely to allow an efficient control. It is why acoustic guided wave technique could be a solution to detect potential defects.



Principle chart of guided wave control

To check the feasibility of such defect detection, IGCAR and CEA propose to study the way the acoustic modes can propagate in a vessel wall, then impact a potential defect (flaw type) and come back to the emitter for NDT analysis. At the beginning, both companies will perform simulations, then specify adapted sensor. Water tests will be made by both companies on specific mock-ups, then demonstration sodium tests will be performed at IGCAR.

Four main goals have been identified:

- to detail the NDT scenario to be treated: structure to be controlled (geometry, material, potential defects...), available sensor performances, sensor access to structure to be controlled...

- to use modelling to predict the more efficient acoustic modes, in this NDT frame,

- to specify ultrasonic sensor design, able to produce these modes,

- to perform water then sodium tests, as qualification of this study.

II. OBJECTIVES OF THE COLLABORATION

The objective of the collaboration is to check the ability of defect detection with acoustic guided waves, for periodical inspection of immersed components and structures: evaluation of such technique will be done, depending on many parameters (geometry, access, material, sensors…) for finding efficient acoustic modes.

Indeed, due to access constraints and difficulty in transducer manoeuvring, ultrasonic guided wave based technique may be promising for long range defect detection in components by launching the wave at specific points within sodium using ultrasonic transducers.

IGCAR and CEA aims at controlling sodium immersed plate (or vessel) structures that are used as an acoustic waveguide; the challenge lies in the distance of acoustic paths in the structures and in the acoustic radiation in the surrounding fluid (sodium) which causes attenuation of the propagating waves.

On the basis of PFBR and ASTRID design, CEA and IGCAR will select different corresponding cases to be treated in components submerged in sodium in the main vessel, by considering different scenarios.

IGCAR and CEA aim at evaluating the effect of the following parameters on the defect detection efficiency: distance between transducer and defect, characteristics of the structure to be controlled, transducer behaviours, characteristics of defects to be detected.

III. SCOPE OF THE COOPERATION

This collaboration will be done in six main steps:

- **Step 1: CIVA and finite element simulations (ABAQUS) of propagation of guided waves in thick submerged structures**

First, IGCAR and CEA will define in detail the objectives of the work to be done (detection/sizing of defects with acoustic guided waves, acoustic properties to be simulated, parameters to be calculated and their ranges) and the cases to be treated, on the basis of criteria such as the actual conditions in SFRs main vessels: a table will be drawn, giving, geometry, material characteristics, transducer behaviours, access for acoustic transducer, surrounding medium (sodium or gas)… Defects to be detected will also be specified: shape (hole, flaw…), size (compared to structure thickness, length, and orientation), distance to transducer, presence of welds.

IGCAR and CEA will define the way to present simulation results, in order to be able to compare the results of the different cases.

Then, IGCAR and CEA will perform simulations with CIVA and ABAQUS.

Two reports (D1 & D2 see description Appendix) will be written summarizing the results obtained in simulation by both companies.

- **Step 2: Selection / development of ultrasonic transducers with optimized frequency and characteristics (bandwidth etc.)**

On the basis of former simulation results, adapted acoustic transducers will be specified for producing the right acoustic modes: they should be able to send acoustic waves in the right frequency range in order to produce the right acoustic modes.

Some experimental tests will be performed in simplified conditions (with smaller scale plates, in air and in water, with available transducers) in order to confirm the selection of the proper transducers.

Two reports will be written by both companies (D3 & D4 see description Appendix), one that justifies simplified test conditions, and the other with the justification of transducer specifications (with simulation results).

If necessary, one company will use the transducer of the other company, for the specific need of this study. This transducer will be brought back to the providing company as soon as experiment will be finished.

As a back-up solution, if no available transducer can fit the requirement of this study, customized sensors could be designed and manufactured for operating at lower frequencies (as structure thickness is some cm large). No information will be exchanged on detailed transducer design. Only acoustic emitted beam will be characterized and exchanged between CEA and IGCAR.

- Step 3: Under water tests at a scale to be determined

After having selected the acoustic transducers, both IGCAR and CEA will perform in water tests with different mock-ups (plates, pipes, and welded structure) with artificial defects (such as machined slits) for demonstrating the ability of acoustic guided waves to detect these defects. Test conditions will be discussed for establishing common parameter ranges (and/or specific parameter values for specific mock-ups corresponding to PFBR and ASTRID cases).

Scale specimen will be determined, depending on guided wave behaviour, on sensor availability, on water tank characteristics, etc.

Two reports will be written by both companies (D5 & D6 see description Appendix), one for all test specifications, and the other for summarizing the results obtained in water with different specimen. These results will be compared to simulation ones.

Experimental data gained during the underwater tests will be exchanged between CEA and IGCAR (test conditions and recorded acoustic signals, in digitalized formats).

Visit will be organized so that one researcher of each institute will come and participate to the experimental tests carried out in the other institute during one week.

- Step 4: Under sodium at a scale to be determined

The last step of the collaboration will be to perform the sodium experiments at IGCAR, as a final demonstration of defect detection with acoustic guided waves. Scale specimen will be determined, depending on guided wave behaviour, on sensor availability, on sodium tank characteristics, etc.

Two reports will be written by both companies (D7 & D8 see description Appendix), one for all sodium test specifications, and the other for summarizing the results obtained in sodium for all test conditions. These results will be compared to simulation ones.

Experimental data gained during the under sodium tests will be exchanged between CEA and IGCAR (test conditions and recorded acoustic signals, in digitalized formats).

A visit will be organized so that two CEA researchers will come and participate to the experimental tests during one week at IGCAR and get back CEA transducer (if any), after experimental tests.

- Step 5: Common papers for publication

Complete analysis of simulation and experimental test results will be performed, before publishing common papers in order to conclude this action (D9 see description Appendix): two common papers could be issued, one with CEA as main author and the other with IGCAR as main author.

IV. LIST OF DELIVERABLES

All Deliverables will be common CEA and IGCAR documents

- Step 1: CIVA and finite element simulations (ABAQUS) of propagation of guided waves in thick submerged structures
  - D1: Technical note on objectives of simulation work, on cases to be simulated, on associated parameter choice and range.
  - D2: Simulation results of the different cases with parameter sensitivity study.
- Step 2: Selection / development of ultrasonic transducers with optimized frequency and characteristics (bandwidth etc.)
  - D3: Definition of simplified test conditions for first available transducer testing.
  - D4: Justification of transducer specifications (with experimental test and simulation results).
- Step 3 : experimental water tests
  - D5: Water test objectives, definition and conditions, for scales to be determined.
  - D6: Water test results. Analysis of water test results and comparison with simulation results.
- Step 4: Experimental sodium tests and comparison with simulation results.
  - D7: Sodium test objectives, definition and conditions, for scale to be determined.
  - D8: Sodium test results. Analysis of sodium test results and comparison with simulation results.
- Step 5: Two common papers for publication, one with CEA as main author and the other with IGCAR as main author.
  - D9: Common paper for publication in an International Journal or Conference

[1] Hindawi Publishing Corporation, Science and Technology of Nuclear Installations, Volume 2012, Article ID 718034, doi:10.1155/2012/718034, Research Article: Development of Tools, Instrumentation and Codes for Improving Periodic Examination and Repair of SFRs, F. Baqué F. Reverdy, JM. Augem, J. Sibilo.