CIEMAT EXPERIENCE IN NUCLEAR SAFETY RESEARCH, EUROPEAN NUCLEAR FEATURES

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A review was done on the main activities performed and achievements managed by the Project of Nuclear Safety Research (Department of Nuclear Fission) of Ciemat in the last twenty years on the areas of: severe accident, advanced reactors and containment analysis.

It was emphasised Ciemat´s participation in national and international projects, mainly promoted by the Spanish Nuclear Sector, the CSN, the OECD, EPRI and the European Union. The experimental and analytical capabilities on reactor nuclear safety set up in Ciemat along this period of time were also described.

INTRODUCTION

The Safety Technology Programme was created in 1985, with severe accident research among its basic lines of work. Throughout these years, it has participated in national and international R&D projects, mainly those promoted by the Spanish Nuclear Sector (UNESA, DTN), within the Electro Technical Research Project (PIE-OCIDE), the CSN the OECD, EPRI and the EU, at the same time it has built up experimental facilities and implanted a system of computer codes for accident simulation and analysis.

This article offers a historical perspective of the most significant activities carried out by the Programme, along with its most outstanding results and achievements.

CORE DAMAGE ACCIDENTS AND SOURCE TERM

At the end of 1984, the CIEMAT, along with other Spanish organizations, participated in the following international severe accident research projects [1].

The Loft Project (1984-90)

Eight experiments were carried out in the Loft (Idaho, USA), six on LOCAs and two (FP1 and FP2) on fission products.

For Spanish participation, under the auspices of the OCIDE, an agreement was signed by the CSN, CIEMAT, ENUSA, UNESA, ENRESA and UPM. The CIEMAT contributed to the analysis of FP1 using the TRAC-PF1/Mod1 code (Fig. 1) and several models and codes on the production, transport and deposition of fission products in the core, piping and containment [2]. This participation meant a considerably strong effort by Spanish organizations and produced clear benefits for safety technology.

Phebus-CSD Project (1987-92)

The French project consisted of five experiments on: a) the cladding degradation and generation of hydrogen; b) the dissolution of UO_2 and formation of eutectics, and c) dissolution of structural materials and control rods.

Spanish participation was led by the CSN and co-financed by the OCIDE, in a consortium made up of CIEMAT, ENRESA, ENUSA and UNESA. The CIEMAT participated in the analyses, using the French I care code; other groups used the Scrap and Melcor codes.

LACE and ACE Projects (1987-93)

a) LACE – international

The purpose of LACE (Epri) was to study the behaviour of aerosols in the

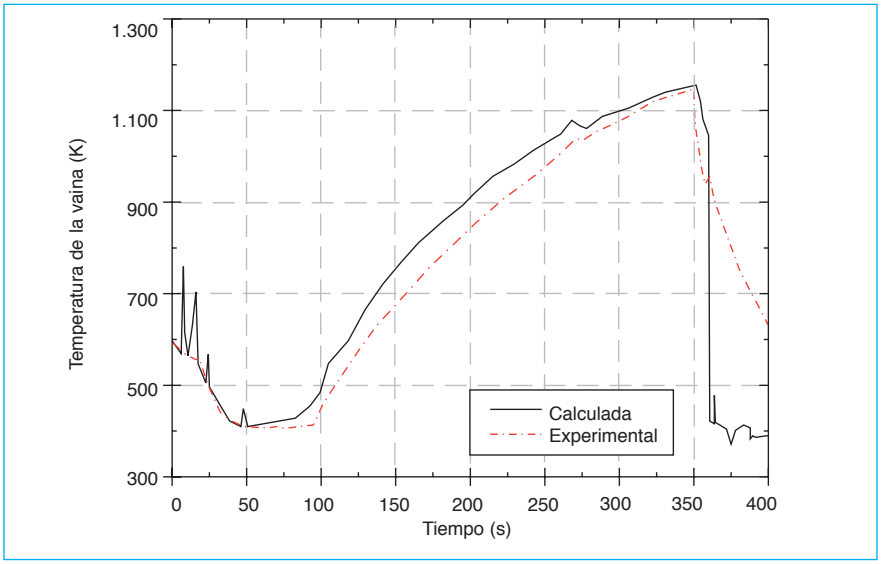

Figure 1: Cladding temperature of a Loft-FP 1 fuel rod.

Figure 2: PECA Facility.

containment and auxiliary buildings at nuclear plants in severe accident scenarios. The experiments were performed in a facility provided with an 850 m^3 vessel (Hanford, USA).

Under the auspices of OCIDE, Spanish participation assembled the CSN, CIEMAT, Tecnatom, ENUSA, UNESA and the UPM. The CIEMAT collaborated in the analyses of two of the six experiments in the program (LA4 and LA6).

b) LACE-Spain

The PECA plant (Fig. 2), an intermediate-scale facility for studying aerosol retention in pool scrubbing accident sequences in LWR was built at the CIEMAT. The plant consists of a vessel (8 m^3) and auxiliary aerosol injection systems, instrumentation, data acquisition and control, and image analysis. Eleven tests were performed on decontamination factors [3].

c) ACE (1988-93) Project

The ACE project (Epri) for the study of the in-containment source term, was carried out in three phases: a) filtered containment venting systems, b) behaviour of iodine in the containment, and c) interaction of core melt with concrete (corium).

Under the sponsorship of the OCIDE, a consortium of the CSN, CIEMAT, Tecnatom, UNESA and the UPM was created. The CIEMAT contributed to the iodine chemistry study and interpretation of the experiments performed in the RTF facility (Canada).

Phebus-FP Project (1987-2007)

The French IRSN and the EU (JRC-Ispra) promoted the Phebus FP for the study of severe accidents and the source term. The project is composed of six experiments (FPT0,... FPT5), the first four of which have already been carried out. The CIEMAT has participated from the initial phase to the present. In the first stage (1987-88) it took part in the facility design and in bundle and circuit dimensioning verification, using the Icare, Scdap Trac, Trapmelt and Naua codes (2^{nd} FWP) [4]. Since the facility was erected, the CIEMAT has focused on the analysis of experiments in the Pheben project (4^{th} and 5^{th} FWP).

Source Term Project (1991-95)

The CIEMAT participated in the Project (3rd FWP), with a review of state of the art aerosol fission product pool scrubbing under severe accident conditions in PWR. Furthermore, it carried out an experimental programme simulating SGTR and Bypass (RHR) sequences and ten hydrodynamic tests in the PECA facility. The results obtained permitted an analytical expression of the decontamination factor as a function of submergence to be derived [5].

Storm Project (1991-2000)

The EU built a large-scale facility (Storm) in Ispra for the study of deposition and resuspension of aerosols, and their influence on the source term in certain severe accident sequences. Eleven experiments were performed. The CIEMAT participated in the analysis of the experiments and development of the codes.

ADVANCED REACTORS

The CIEMAT has collaborated on European and American prototypes, focusing on matters related to cooling systems and aerosol retention [6].

Spanish advanced and passive nuclear power plant programme (1991-96) UNESA and DTN led Spanish participation in advanced and passive reactors (AP-600, SBWR, EPR, EUR, etc.). A consortium of INITEC, EEAA, CIEMAT, ENUSA, ENSA and Tecnatom was created for it.

The CIEMAT mission was: a) along with the University of Valencia (UPV), develop a model for heat transfer by steam condensation for GE-SBWR containment insulation and passive condensers and b) performance of an experimental program on aerosol retention (CsI) right in the prototype suppression pool in the PECA facility. Decontamination factors were obtained under varied experimental and design conditions.

CIEMAT-Wisconsin-USA Collaboration (1997)

Participation in an experimental programme in passive reactor W-AP600, and development of heat transfer coefficient model associated with steam condensation on the horizontal and vertical flat walls typical of the system [7].

TEPSS Project (1996-98)

The Project (4th FWP), related to passive boiling water reactors, investigated the mixture and stratification in suppression pools, systems for passive heat removal from containment and aerosol deposition inside them. The experimentation was carried out in the PSI (Paul Scherrer Institute) LIN X-2, Panda and Aida facilities. The CIEMAT and the UPV contributed using the Trac-BF1 code for analysis of the Panda experiments (1/25-scale GE-SBWR), for different accident sequences, verifying the efficiency of the core and containment cooling systems [8].

BWRCA Project (1997-98)

The EU launched the EBWR-R&D-Cluster and the BWRCA project around the SWR prototype to study innovative passive safety systems, based on the experiments performed in the Jülich NOKO and the PSI Panda facilities. The CIEMAT was in charge of state of the art of the condensation phenomena within heat exchanger tubes with and without condensable gases.

Conga Project (Phase I) (1997-99)

This project (4th FWP) was concerned with the analysis of SWR passive boiling water reactor containment. Phase I was comprised of an experimental program on the effect of deposition of aerosols in presence of

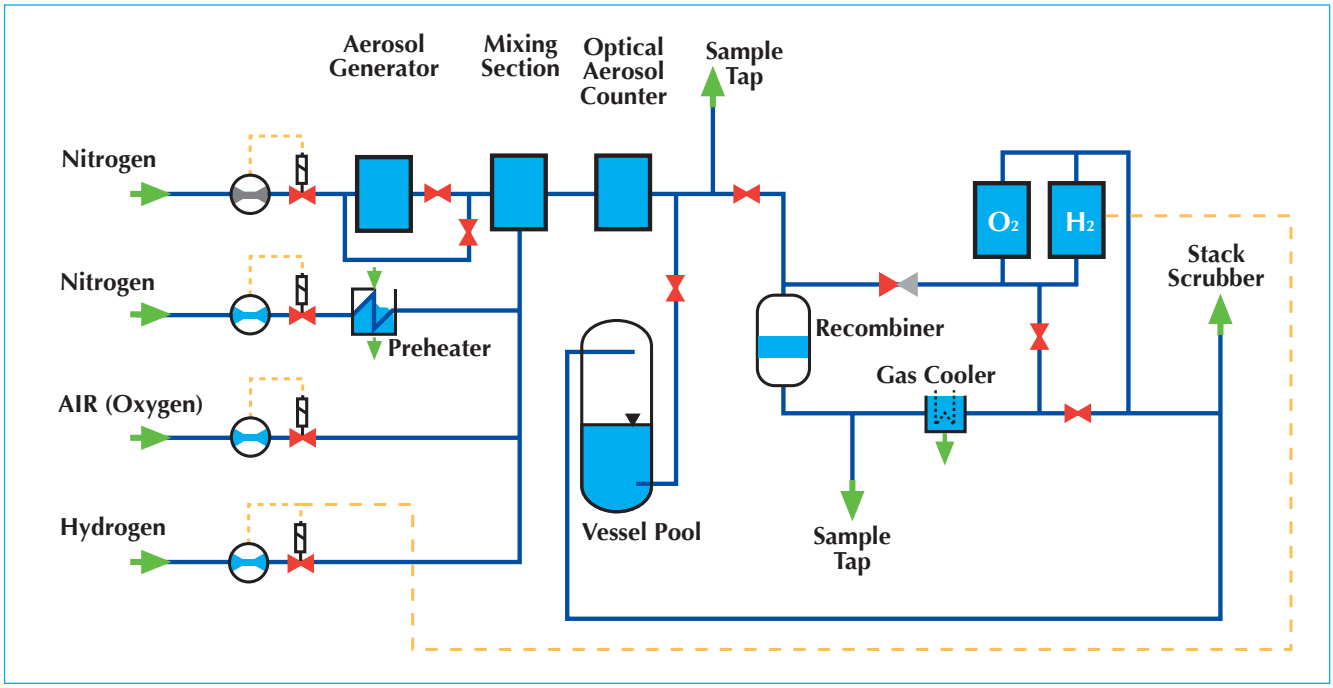

Figure 3: Flow diagram of the RECA Facility.

hydrogen on the inside of the containment heat exchangers and development of an analytical model. The experiments were carried out in the PSI Dragon and Cesane, Storm (JCR-Ispra) and CISE (ENEL) facilities. An analytical model to predict heat removal behaviour was developed and assessed by CIEMAT using the experimental data.

CONTAINMENT BEHAVIOUR

Conga Project (Part II) (1997-99)

In Phase II, the CIEMAT was in charge of carrying out two experimental series to study, a) the capacity of the pressure suppression pool as a system for aerosol retention, and b) the influence of the presence of aerosols on the efficiency of the hydrogen catalytic recombiner line [9].

The first, performed in the PECA, simulated a typical loss-of-coolant from a main steam line break accident, with venting to the suppression pool and depressurisation through the containment venting system provided with recombiners. Experimental results confirmed pool retention capacity.

The second was performed in the CIEMAT RECA facility (Fig. 3), which employs a catalytic recombiner and condenser supplied by Siemens. Seven experiments were performed, obtaining recombiner efficiencies demonstrating the low influence of aerosol presence within a catalytic recombiner line and the enormous capacity of the condenser to retain aerosols. In conclusion, the experiments showed the goodness of the containment venting system as a whole.

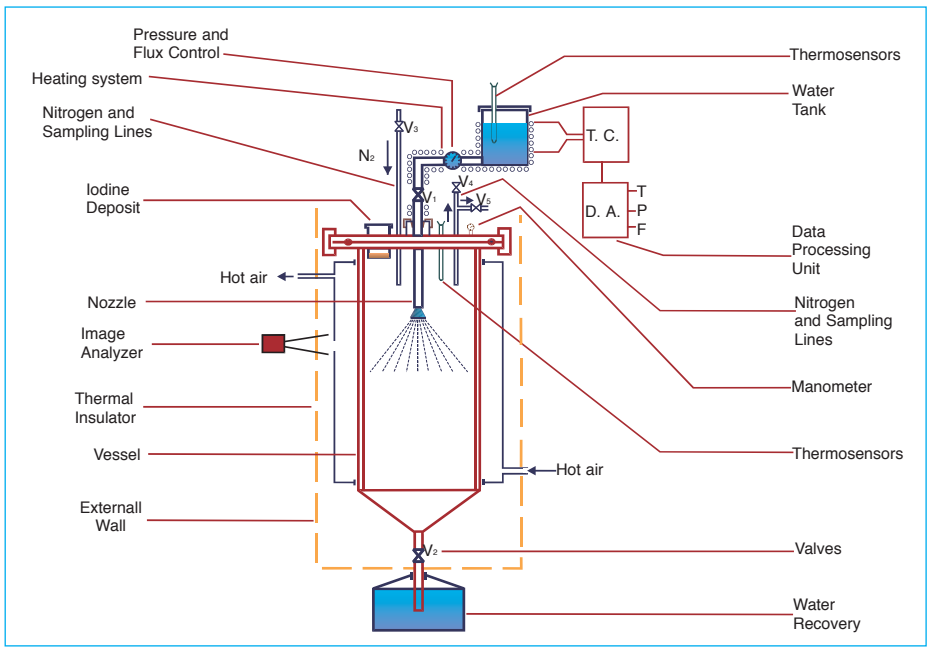

Figura 4: Simplified scheme of the GIRS facility.

Dabasco Project (1997-99)

The creation of databases for the development of models and correlations in the field of containment thermal hydraulics was the purpose of the Dabasco Project (4th FWP). The CIEMAT contributed with the GIRS facility to the study of sprays as a system for eliminating molecular iodine present in the containment atmosphere in severe accidents (Figure 4).

The GIRS facility consists of a glass vessel (50 x 50 cm x 1.3 m), in which

iodine (I_2) vapour and steam are injected through a nitrogen line. The concentration of I_2 in gas phase and in the tank at the bottom of the vessel was measured. 18 tests were performed which enabled the evolution over time of iodine as a function of temperature, the pH and the size of droplets to be found [10].

Iodine Chemistry and Pheben Projects (1996-1998)

Both EU-4th FWP projects were support for the Phebus FP Project. The first dealt with the reaction of iodine with silver in the control rods and its importance to the source term. The CIEMAT reviewed the bibliography on iodine-silver interaction and participated in the development of a kinetic model and its implementation in the Iode code. The Pheben project (4th and 5th FWP) is an analytic support for Phebus FP. The CIEMAT participates in the thermo hydraulic analysis of aerosols and iodine in the containment, using the Contain and Iode codes.

AASC Project (1997-2004)

The CSN and the CIEMAT maintain collaboration for the of severe containment accidents analysis (SCAA). In its first phase, it consisted of: a) performing experiments (PECA) on pool scrubbing sequences; b) reporting on the state of the art of hydrogen combustion in light water reactors, international experiments and computing tools, and c) evaluation of possible areas of uncertainty in the MAAP code with regard to aerosols, pool scrubbing, iodine and hydrogen combustion.

At the present time, work essentially focuses on the SGTR (5th FWP) and ARTIS (PSI, CSN), projects, in which CIEMAT contributes with twelve experiments in the PECA, simulating aerosol retention in the secondary steam generator in absence of water and evaluating possible mitigating action. Furthermore, current research on safety phenomenology, and in particular, on severe accidents, is being done in the European SARNET network.

International Standard Problems (ISP) (1994-98)

The international exercises in code comparison organized by the OCDE CSNI are a very efficient way to validate computing tools employed in nuclear safety for qualified experiments. The CIEMAT has participated in three such exercises for containment (ISP-34, ISP 37 and P-40.

RESULTS AND FINAL CONSIDERATIONS

The results obtained can be summarized as: assimilation of knowledge; implantation and use of computer codes and qualification of users; development of models; erection of facilities and experimentation; creation of databases; specific studies, judgements, etc.

Furthermore, creation of consortia for participating in national and international projects played a decisive role for safety research in CIEMAT, and has favoured the diffusion of results and strengthened relationships with industry, utilities, regulatory authorities, research centres, universities and other research organizations, with undeniable multiplier effects. This action has been projected through presentations to national (60) and international (50) congresses, publications in national (5) and international (25) journals; EUR (7), CIEMAT (7), and progress reports (100); participation in national (5) and international (9) experts committees, etc.

Finally, it may be concluded that the knowledge acquired along this stage, both on a worldwide scale and in our own country, has been essential and has contributed to a deepening knowledge of the phenomena and, thereby, the safety of plants in operation and to their regulation, at the same time that they have created the scientific basis for future development. In addition, it must be pointed out that a large part of the knowledge and technologies acquired have great potential for conventional applications.

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