ICONE 9 - 818

The STRESA (Storage of Reactor Safety) Database
(Web page: http://asa2.jrc.it/stresa)

A. Annunziato, C. Addabbo, W. Brewka
Joint Research Centre, Ispra Site
Commission of the European Communities

Keywords: Databases, Experiences, Codes

Abstract

A considerable amount of resources has been devoted at the international level during the last few decades, to the generation of experimental databases in order to provide reference information for the understanding of reactor safety relevant phenomenologies and for the development and/or assessment of related computational methodologies. The extent to which these databases are preserved and can be accessed and retrieved is an issue of major concern. This paper provides an outline of the JRC databases preservation initiative and a description of the supporting web-based informatic platform STRESA.

Introduction

The Joint Research Centre (JRC) of the European Commission (EC) has been engaged in reactor safety research since the signing in 1957 of the Euratom treaty establishing the European Atomic Energy Community. Within the provisions of this treaty, large scale experimental and analytical research programmes have been carried out in collaboration with industrial and institutional research organisations from EC Member States to address reactor safety issues of general interest.

It is generally maintained that the experimental data acquired in scaled test facilities cannot be directly extrapolated to the safety analysis of the full size plant due to inherent scale-dependent distortions and simulation constraints. As such, reactor safety analysis has to rely mainly on computational evidence provided by validated computer codes. However, in order to verify that computer codes can provide realistic predictions of reactor system response during operational and accident conditions, a significant code validation effort against representative experimental data is required. Also, the code predictive capabilities have to be proven to be scale independent so that the full-size plant behavior can be predicted with an acceptable level of confidence.

In line with this generally accepted principle, the rationales underlying the JRC research initiatives were generally aimed at enhancing the level of understanding in the safety of existing reactors and, in perspective, of evolutionary or innovative reactor concepts, through the acquisition of representative experimental databases in scaled test facilities in order to provide reference information for the development and/or assessment of safety analysis codes.

Major research programmes carried out at JRC included amongst others, the LOBI experimental program established to investigate thermal-hydraulic safety issues relevant to Design Basis Accidents (DBA) and Transients in Pressurised Water Reactors (PWRs) [1] and the FARO/KROTOS experimental programmes [2] and [3] established to investigate melt coolant interaction phenomenologies of concern in the safety analysis of Severe Accident (SA) sequences. Both the LOBI and FARO/KROTOS experimental programmes have been complemented by extensive analytical studies which have included the development and application of the COMETA (Core Melt Thermal-Hyraulic Analysis) computer code [4] specifically dedicated to the computational analysis of melt quenching phenomenologies.

The management of the acquired knowledge through preservation and user-friendly access and retrieve of the experimental and analytical databases has been a major concern of JRC. In particular, it has been recognised that new working methods and rapid advancement of computer hardware and software technologies require continuous upgrading of storage methods which can otherwise render access to and retrieve of the data unpractical and in some cases impaired. Similarly, code documentation including code sources and input decks as well as relevant assessment cases need to be properly preserved.

Within this overall context, JRC has developed the STRESA (Storage of Reactor Safety Analysis Data) web-based informatic platform in order to provide a secure repository of the LOBI and FARO/KROTOS as well as COMETA databases exploiting modern computer information technologies for access and retrieve of the data [5].

JRC-STRESA Experimental and Analytical Programmes

This section provides a brief outline of the LOBI, FARO and KROTOS as well as COMETA databases which are included in the current configuration of STRESA.

The LOBI Experimental Programme

The LOBI experimental programme was conducted in the framework of the EC reactor safety research programme under contractual agreement with the former Bundesminister für Forschung und Technologie (BMFT) of Germany. The LOBI test facility was designed to represent a full-power, full-pressure 1:700 scale model of a 4-loop, 1300 MWe PWR of Siemens-KWU design, Figure 1. The essential features of a typical PWR primary and secondary cooling system together with all engineered emergency safety systems were properly configured to provide insofar possible and/or practical, integral system effect thermal-hydraulic response.

The LOBI test facility was commissioned in December 1979 and was operated until June 1982 in the MOD1 configuration for the investigation of large break LOCAs; it was then extensively modified into the MOD2 configuration which was operated from June 1984 to June 1991 for the characterisation of thermal-hydraulic phenomenologies relevant to small break LOCAs, Special Transients as well as operating procedures and accident management strategies.

In its final configuration, the LOBI database comprises 70 experiments covering a wide range of postulated accident conditions. It includes, among others, full-power and full-pressure large break LOCAs which represent a unique set of data at the European level. The LOBI small break LOCA Tets A2-81 was selected by OECD/NEA for the International Standard Problem 18 (ISP 18). It is generally recognised that the LOBI research programme has significantly contributed to the improvement of reactor safety analysis capabilities within the EU member countries promoting also international collaboration at the European level [6] and [7].

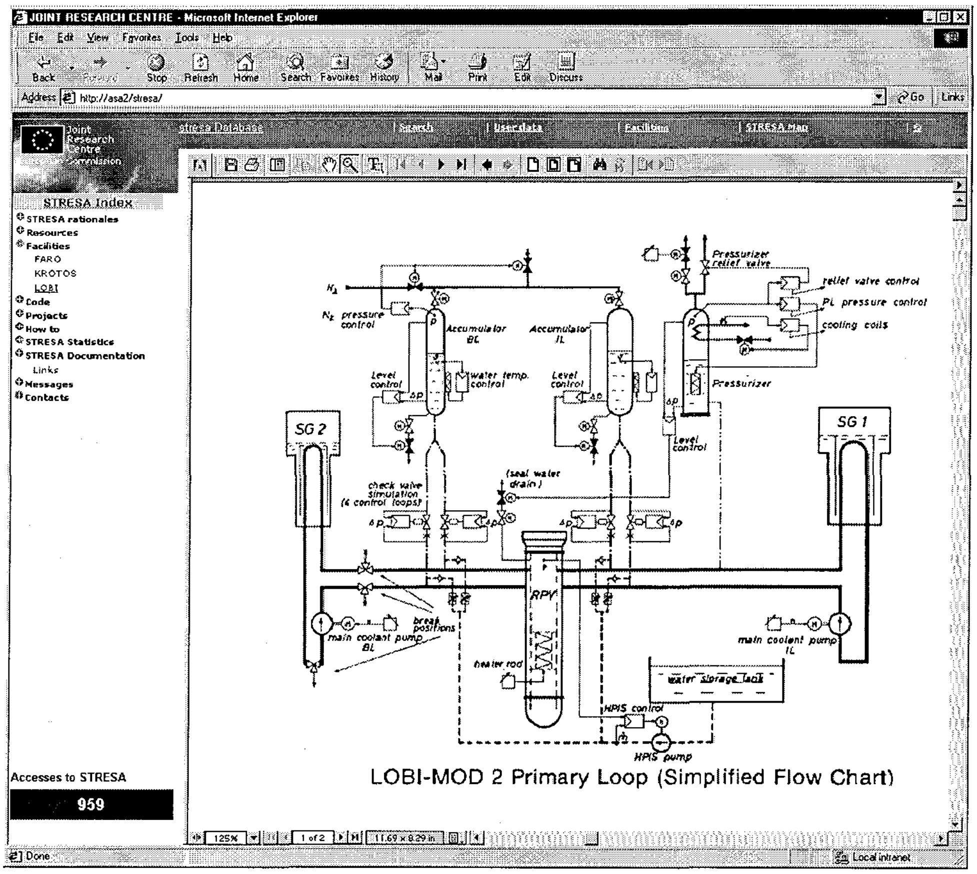

Fig. 1 – Flow chart of LOBI Test facility stored in the STRESA database

The FARO Experimental Programme

The FARO experimental programme represents an important contribution to the international effort devoted to the study of severe accidents in water cooled reactors. It has been executed from 1987 to 1999 in close collaboration with experts from European research organisations with financial contribution from the US Nuclear Regulatory Commission (US NRC).

The FARO test facility , Fig. 2, has been designed to investigate the interaction of large masses of corium (up to 200 kg) generated by induction heating with water under prototypical melt composition (i.e..; UO_2/ZrO_2, UO_2/ZrO_2 and Zr) and representative initial and boundary conditions such as system pressure (2 to 50 bars) water sub-cooling (up to 80 K) and water pool depth (up to 2m).

The specific objective of the FARO-LWR research programme was the investigation of the basic phenomenologies governing melt coolant interaction and quenching as well as melt spreading during the progression of severe accidents in water cooled reactors. The research programme addressed safety related phenomenologies relevant to both in-vessel and ex-vessel severe accident sequences covering a wide range of parametric variation to bound eventual conditions for an energetic interaction.

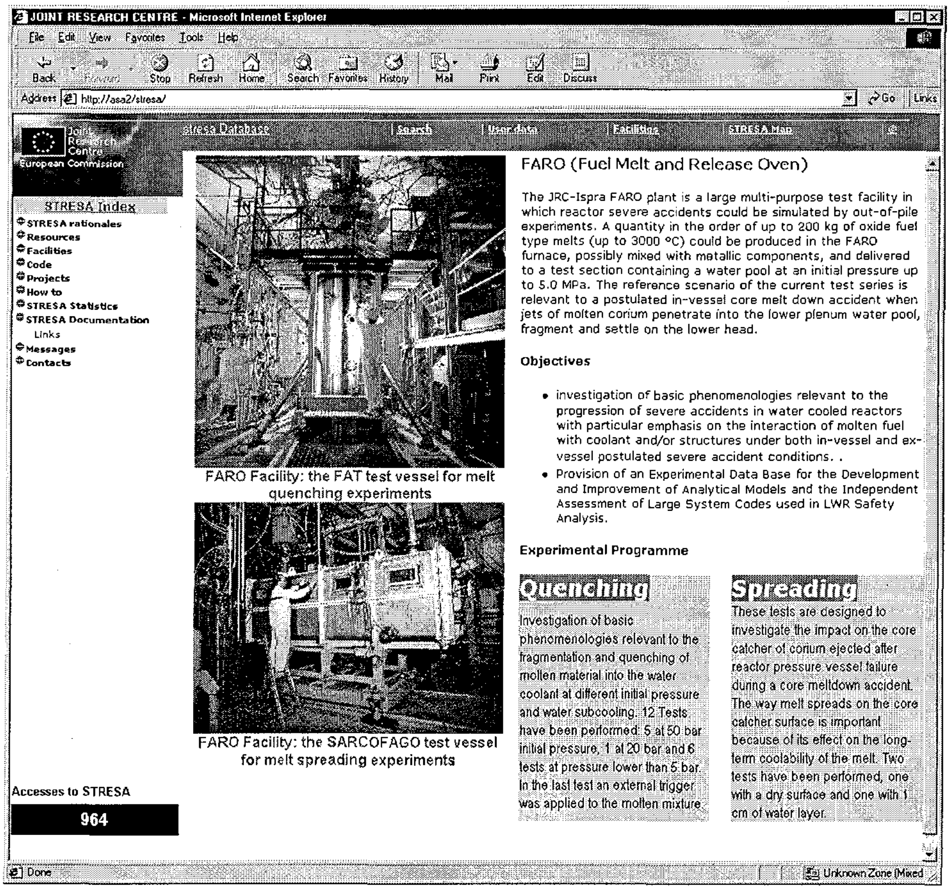

Fig. 2 – FARO Test facility description as appears in the STRESA web site

In its final configuration the FARO-LWR test matrix includes 14 tests of which 2 were specifically dedicated to melt spreading studies. FARO Test L-14 has been used as reference test for the OECD/CSNI International Standard Problem 39 (ISP-39) to benchmark the predictive capabilities of premixing codes.

The KROTOS Experimental Programme

The KROTOS experimental programme was basically dedicated to the investigation of melt coolant premixing and potential for energetic interaction or steam explosion which are of significant concern in the safety evaluation of water cooled reactors. As such, the KROTOS and the FARO experimental programmes are complementary.

The KROTOS test facility, is a relatively small scale experimental installation for the generation of prototypic reactor melts (UO_2/ZrO_2) or simulants (AL_2O_3) and for their spontaneous or triggered explosive interaction with water. The test facility consists of a radiation furnace housing a crucible containing the melt, the release tube and the test section enclosed in a pressure vessel designed for 2.5 MPa at 493 K. Melt masses up to 10 kg at a maximum temperature of 3300 K can be generated.

The KROTOS text matrix comprises 54 tests spanning a wide spectrum of melt composition and system parametric variations. It is planned to transfer and re-commission the KROTOS test facility in the laboratories of the Commissariat a l'Energie Atomique (CEA) in Cadarache, France.

The COMETA Analytical Programme

The COMETA (Core Melt Thermal-hydraulic Analysis) code is an integral system code coupling thermal-hydraulic and melt fragmentation modules for the simulation of melt coolant interaction and quenching. It has been developed at the JRC to provide a computational tool for FARO test design and specification, definition of operational procedures and test results analysis.

COMETA is composed of a two-phase flow field described by '6 + n' equations (mass, momentum and energy conservation for the each phase and 'n' mass conservation equation for 'n' non-condensable gases) and a corium melt field with three phases: the jet, the droplets and the debris. The two-phase flow and the corium melt fields are described, respectively, in Lagrangian and Eulerian coordinates.

The melt field is described by the jet, the droplets and the debris components. The melt is released in the form of a coherent jet which is conical shaped. The basic model for jet fragmentation and erosion included in COMETA is based on the Jet Break-up Length criterion (L/D is evaluated at each position at each time step providing the local erosion rate).

COMETA includes a model for hydrogen generation from metallic components based on validated correlation and also an empirical model for hydrogen generation from oxidic components based on the experimental evidence acquired in the FARO experiments. Heat transfer from the fused debris-bed to the coolant is accounted for by the energy conservation equation.

COMETA has been extensively applied to FARO as well as KROTOS test design and pre- and post-test prediction calculations, Fig. 3. Scoping calculations have also been performed for relevant full size reactor plants.

STRESA Informatic Structure

In order to fulfill the object of preservation of experimental databases and the maintenance of supporting information/documentation a new database has been developed at JRC with the following specific requirements:

- the database had to be accessed via Internet
- Access to data is to be controlled
- Access authorization to specific documents is performed locally, by responsible of data, not by an overall institution
- If needed, the data can be stored in various servers computers across the network

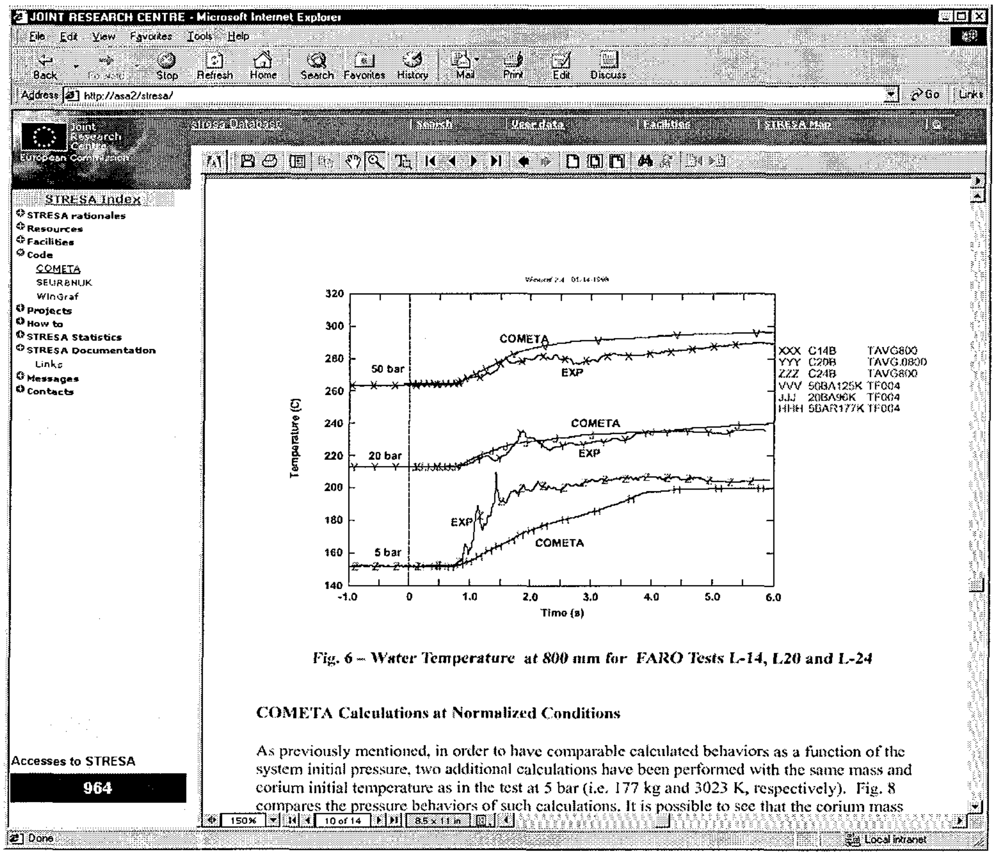

Fig. 3 – Reproduction of a COMETA paper presented in a conference

STRESA is a general-purpose database to store documents and data coming from any type of plant or experimental facility as well as from code calculations.

The arrangement is indicated in Fig. 4: the user can connect via internet to a server that will access to a database containing the data. This is the so called three tier arrangement, in which the access to the data is dedicated to the server which is detached from the real data.

The main components of the STRESA database are:

- The files on the disk
- The Access database
- The html-asp pages

The database files

For a specific choice the files which are to be stored are kept in their original format on the computer disk: ©Microsoft Word files, or ©Adobe pdf files, AVI or MPEG file for the films and so on. These files are not included in the Access database to allow a better maintenance (if new versions of the reading programs will come out, they can be easily converted). If, as an alternative, the documents were included in the Access database they were going to be embedded in the proprietary Access matrix structure, difficult to be updated: a potential data file corruption could involve all the data in the database.

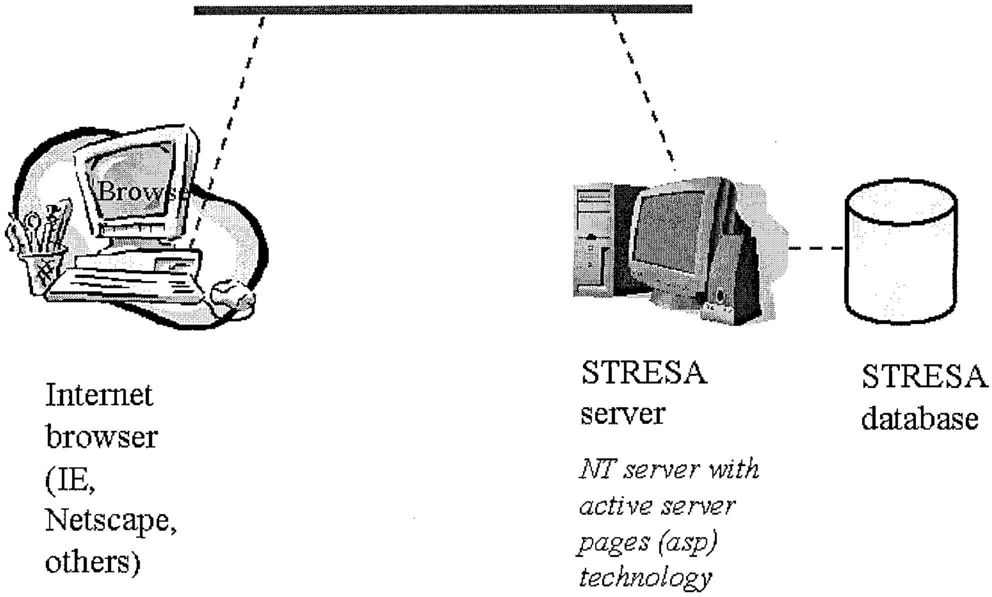

Fig. 4 - The three tier arrangement adopted for the STRESA database

The only exception to the preservation of the original format is for the data files, which are stored with a method developed at JRC called WinGraf mode (see appendix A). If the data are stored with this mode it is possible to benefit of the on-line plotting procedure, as presented in Fig. 5. The plot reported here is performed on-line, on user request, which can therefore customize it to its preferences.

If the data are not stored with this format the user can still download the data but he cannot see the plots on the screen.

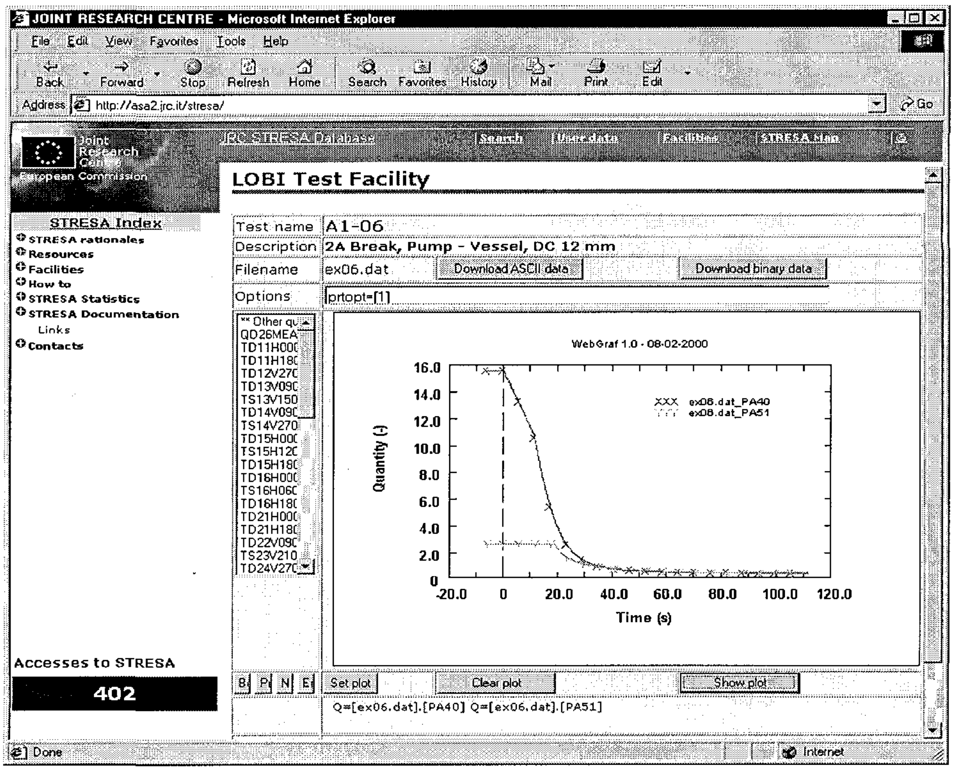

Fig. 5 – Example of plotting signals

The Access Database

A Microsoft Access Database is used to keep memory of the physical position on the disk of the electronic documents (drive and filename). The documents can therefore be accessed in hierarchical mode. An example for experimental facilities may be:

Facilities → Tests → Documents

It is thus possible to have a number of Test facilities, which have produced a number of tests. For each of these tests an arbitrary number of documents may have been stored[1].

The subdivision adopted here is arbitrary: the webmaster can decide a different one. Another example could be referred to computer codes:

Codes → Versions → Executables

Other main tables contained in the database are the list of users, the authorization tables, list of events, etc.

The html-asp files web pages

The user interface is obtained by a series of user-friendly accessible web pages which allow the retrieval of the information, the plotting of experimental data points (Fig. 5) or the visualization of films or images.

Fig. 6 shows the list of documents produced for one particular LOBI tests. If the user has enough authorization he can see the documents and/or download them. The Quick Look Report and the Experimental Data Report, scanned from the original documents, are now easily accessed on-line.

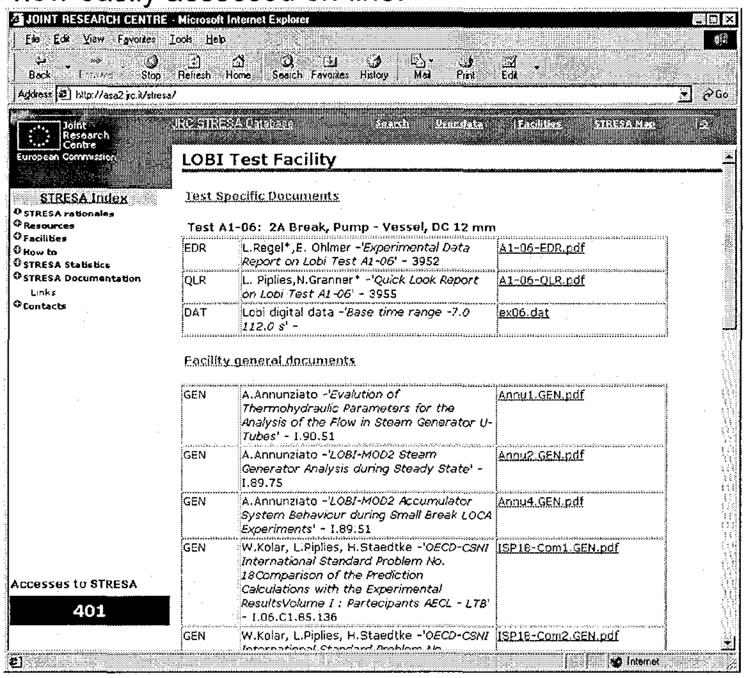

Fig. 6 – List of documentation available for a specific LOBI Test

---

[1] One document may have been produced also for more than one test, even related to different facilities.

Fig. 1 shows the LOBI facility flow chart, while Fig. 7 shows the collapsed liquid level in one particular LOBI test at the time when the loop seal is cleared. This type of films is very useful when analysing complex experimental sequences in which the water masses are moving within the test facility. X-y plots are less intuitive and difficult to analyze.

As an additional example, Fig. 8 shows a film obtained in the FARO facility which illustrates the initial molten UO_2 jet just before entering the water. This type of film has been very useful in assessing the real form of the jet and excluding previous hypotheses on the molten jet dispersal (jet pre-fragmentation in the gas space was assumed in some models).

Entrance in the Database and authorizations

As a new user register in the database, he receives a password via e_mail which allows to enter and see the list of documents produced. He cannot get any file, unless the database responsible has not assigned a document as free available (level 0). In order to access a specific document the user can make a request via e_mail specifying which document he wants to access.

The responsible of data release, clearly indicated on each page, can give authorization to that user allowing him to get: (a) one particular document, (b) all the documents of a particular test or (c) all the documents of a particular test facility.

Once the user get this authorization, that normally does not take more than a couple of minutes of working time, he is enabled to download the requested data.

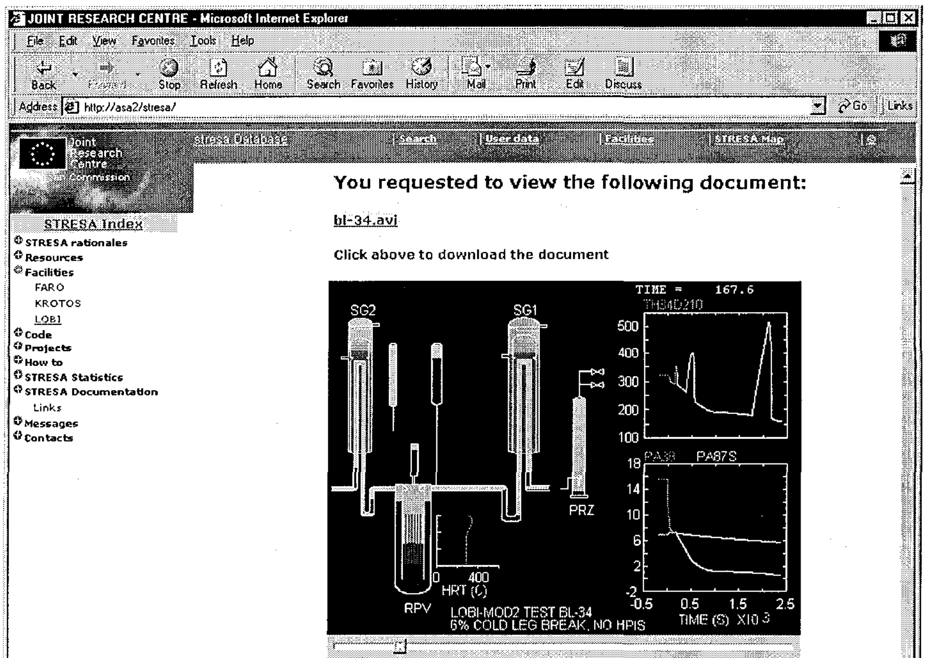

Fig. 7 – Display of measured collapsed levels in the LOBI facility during Test BL-34. It is possible to identify the time of loop seal clearing which determines a temporary core rewetting.

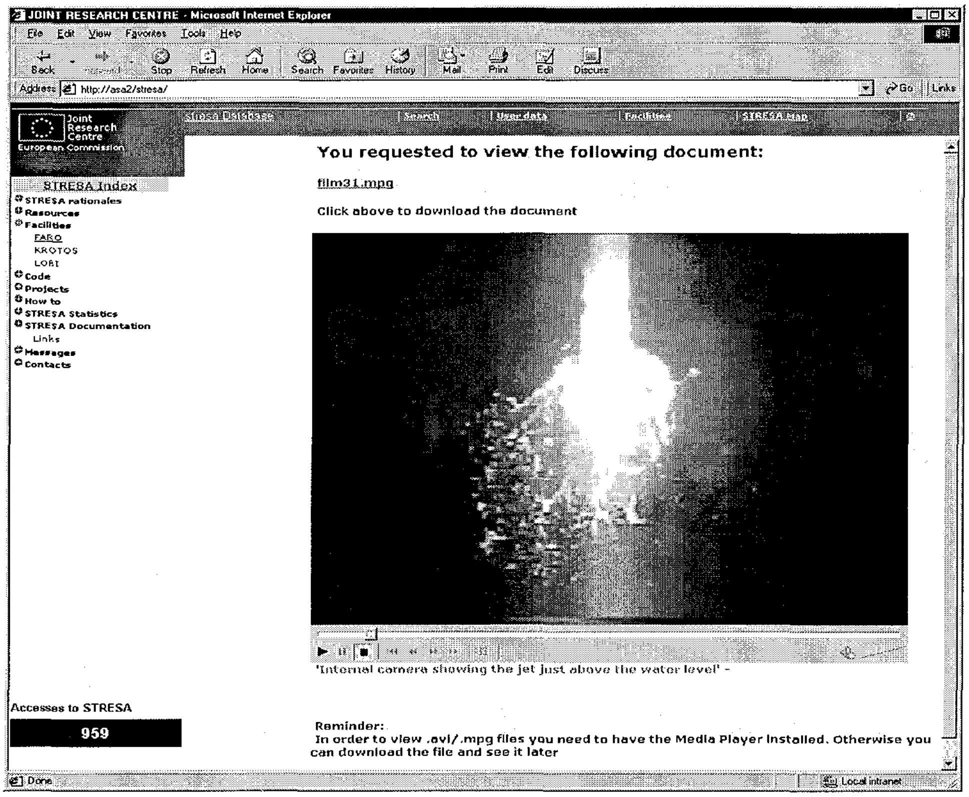

Fig. 8 – A film performed during a FARO test which shows the initial portion of a molten UO_2 jet at about 3000 K just before entering the water pool

STRESA database networks

A major characteristic of the STRESA database is that it can also be configured as a **network** database with a number of **local databases**. From the central database, it is possible to make connection with other local STRESA_like databases thus forming network of databases, which increases the potential and the power of this type of storing system.

As the user is registered in the initial database, so called "portal", he gets a list of facilities or codes or whatever is present in the portal itself or in another connected database. If the facility is located in an external database in the Internet network (say STRESA_x), during the link, the user is recognized by the STRESA_x database and is allowed to enter. However, when he enters, if not specifically authorized by the responsible of the STRESA_x database he will only be allowed to view the list of documents produced for that particular facility.

The relevant point is the fact that the authorization to download data is given by the responsible of the STRESA_x database and not by the portal responsible.

Another important point is the fact that the responsible of the STRESA_x database has to permit the portal users to reach his database. If, for any reason, the conditions for the access are missing, it is sufficient to remove that portal from the list of allowed portals to prevent this occurrence.

As a final remark, it is possible to conceive more than one network based on the same or different databases, either thematic or of any other purpose. As an example, the JRC STRESA contains LOBI, FARO, KROTOS and COMETA documents. The LOBI can be part of a thermohydraulic network and FARO and KROTOS could be part of a FCI network.

Example of networks

This type of arrangement is the basis of an activity, financed by the European Commission FP5, named CERTA, which has the objective to create a network of European thermal hydraulic test facilities databases. The network arrangement will be organized with a central entry web-page (http://asa2.jrc.it/certa) from which it will be possible to access the various databases distributed across the Internet network, including BETHSY, FIXII, LOBI, PACTEL, PANDA, PIPER-ONE, PKL, PMK, SPES, UPTF.

An agreement is under way with OECD-NEA to adopt STRESA as database structure for the Computer Code Validation Matrix (CCVM) which has been defined and stored in the NEA headquarters in Paris.

Other European institutions (e.g. ENEA-I and FZK-D) are also adopting the STRESA structure which offers great advantages in terms of data and documentation management, storage and retrieval as well as networking potentials.

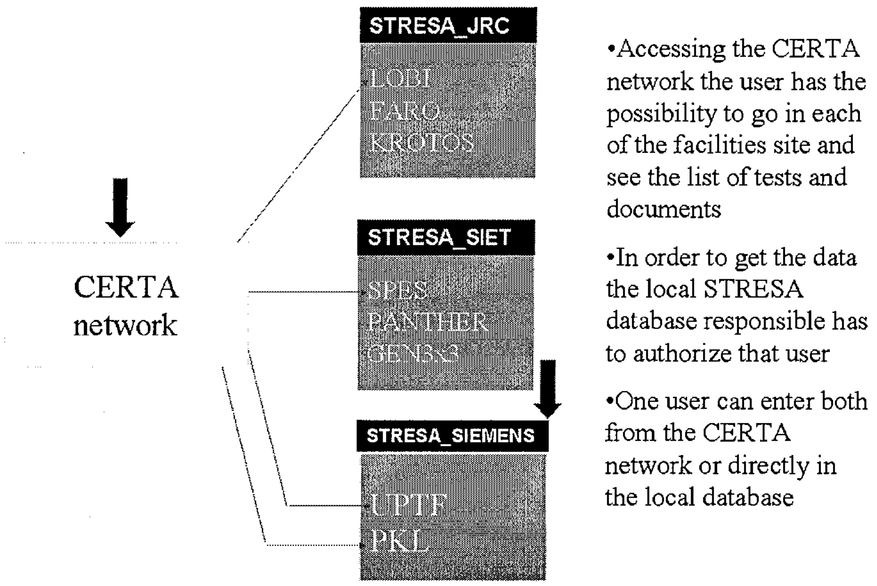

Fig. 9 – Example of network arrangement of the STRESA platform

Conclusions

A new web-based informatic structure has been developed at JRC Ispra in order to store and disseminate documents and data from the in-house experimental programs (LOBI, FARO and KROTOS) and codes (COMETA). The STRESA system is however flexible enough to be used also for purposes different from the one originally designed for.

The structure and the characteristics of the database allow any user via a simple Internet browser to access the whole documentation produced for these programs.

The access to the documents can be restricted and specific authorization may be required to retrieve the data.

It is possible to built networks of STRESA systems based on thematic subjects which have the advantage to perform easy search and retrieval of the information preserving the property right of the data owners.

References

[1] C. Addabbo and A. Annunziato: Contribution of the LOBI Project to LWR Safety Research; Nuclear Safety, Vol. 34, No. 2, April-June 1993.

[2] D. Magallon and H. Hohmann: Experimental Investigation of 150 kg Scale Corium Melt Jet Quenching in Water; Nuclear Engineering and Design 177 (1997) 321-337.

[3] I. Huhtiniemi, H. Hohmann and D. Magallon: FCI Experiments in the Corium-Water Systems; Nuclear Engineering and Design 177 (1997) 339-349.

[4] A. Annunziato and C. Addabbo: COMETA User's Manual; European Commission Report S.P.I. 98.130, October 1998.

[5] A. Annunziato and C. Addabbo: STRESA – a web-based Informatic Platform for Storage of Reactor Safety Analysis Data : European Commission S.P.I. 00.103, 2000.

[6] H. Casper: Report from the Contract Partner of the LOBI A-Programme; Proceedings of the LOBI Seminar, EUR Report 14174 EN, 1992.

[7] M. Reocreux: Activities of the LOBI B-Working Group in the Community B-Programme; Proceedings of the LOBI Seminar, EUR Report 14174 EN, 1992.

APPENDIX A – Description of the WinGraf data mode

The WinGraf data mode has been developed at JRC Ispra during the LOBI and FARO projects and has been extensively used to store and analyse data frome these facilities.

The WinGraf database system is composed of one main file containing all the data in a compressed space-optimized way. Once the user strictly follows these programs for writing their own interface, it is then possible to use this mode with whichever source of data.

The data base is composed of a series of blocks, one for each quantity written. The time base of each quantity <u>must</u> appear before the quantity itself.

The quantities name must be univoque. If one name is repeated the first one is considered. The names of the quantities are 40 characters long as maximum.

Block 1 – (Time_Base_num_1)
Block 2 – (Quantity 1 whose time base is Time_Base_num_1)
Block 3 – (Quantity 2 whose time base is Time_Base_num_1)
…
Block k – (Quantity k-1 whose time base is Time_Base_num_1)
Block k+1 – (Time_Base_num_2)
Block k+2 – (Quantity k whose time base is Time_Base_num_2)
…

Each block is composed of:

First Line
Second Line
Third Line
Data Block

First Line
The first line is an ASCII line of length 82 contains the following informations:

Position	*Length*	*Name*	*Meaning*
1	40	Desc	Descriptor name (max 40 charatcters)
50	13	Vmin	Minimum value of descriptor (e12.6,1x)
65	13	Vmax	Maximum value of descriptor (e12.6,1x)
42	6	-	'WgD2.0'
80	1	itipo	One of these: 1 – time base, 2 – normal quantity, 3 – 'real' mode quantity
81	2	-	CR+LF: char(13)+char(10)

Second Line
The second line is an ASCII line of length 82 contains the following informations:

Position	Length	Name	Meaning
1	9	Np	Number of points (I4)
60	10	Units	Units – 10 characters (optional)
81	2	-	CR+LF: char(13)+char(10)

Third Line

Position	Length	Name	Meaning
1	40	TDesc	Time descriptor name (max 40 characters)
81	2	-	CR+LF: char(13)+char(10)

Here is an example of the three lines of a data base file mode 2:

```
TW.05.115.0370.150_dapb                    WgD2.1  -0.043967     0.019541        2
75000                                                      sec
TIME0
```

The Data Block can be of two types (compact or real) depending on the *itipo* flag:

Itipo=1 means time vector quantity is imposed real mode
Itipo=2 means normal quantity is imposed compact mode
Itipo=3 means 'real' quantity is imposed real mode

The block is composed of a quantity of lines whose number depends on the number of points of the descriptor Np with the following relation:

Nlines=(int((Np-1)/1000)+1)*1000/NPL

Where NPL=40 for compact mode and NPL=20 for real mode. NPL is the number of points per line. As an example if the number of points is 1800, and the compact mode (mode=' ') is selected the number of lines is:

Nlines=(int((1800-1)/1000)+1) * 1000/ 40 = 50

The Nlines lines contain the single data points.

Each line contains NPL data points:

1	*2*	*3*	...	*NPL*	*81-82*
V(1)	V(2)	V(3)	...	V(NP)	CR+LF
V(NPL+1)	V(NPL+2)	V(NPL+3)	...	V(NPL*2)	CR+LF
...					CR+LF
V(NPL*(NLINES-1)+1)	V(NPL*(NLINES-1)+2)	V(NPL*(NLINES-1)+3)	...	V(NPL*(NLINES))	CR+LF

Each data point is composed of 2 (compact mode) or 4 (real mode) bytes. If y(k) is the k-th value to be written, the 2 or 4 bytes are calculated as follows:

<u>Compact mode</u>

$M = (Y - ymin) / (ymax - ymin)* 255^2$

n2 = Int(M / 255)
n1 = M - n2 * 255

Byte-1: char(n1)
Byte-2: char(n2)

<u>Real mode</u>

$M = (Y - ymin) / (ymax - ymin)* 255^4$

$n4 = Int(M / 255^3)$

$n3 = Int((M - n4 * 255^3) / 255^2)$
$n2 = Int((M - n4 * 255^3 - n3 * 255^2) / 255)$
$n1 = Int(M - n4 * 255^3 - n3 * 255^2 - n2 * 255)$

Byte-1: char(n1)
Byte-2: char(n2)
Byte-3: char(n3)
Byte-4: char(n4)

A number of sample programs exist in FORTRAN, VISUAL-BASIC or C languages which allow to write or to read very easily this type of mode. The reasons for adopting the described system are: the possibility to index the file and easily retrieve the quantities, the very small space occupation and the relatively much higher resolution in terms of minimum appreciable quantity respect to other methods.