IAEA Conference on
'Opportunities and Challenges for Water Cooled Reactors in the 21st Century'

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IAEA surveillance data administration within Mat-DB

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IAEA surveillance data transfer

IAEA surveillance database was hosted at the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute in Budapest in cooperation with IAEA.

The decision to transfer the IAEA surveillance data into Mat-DB was made because of the fact that the IAEA surveillance vessel database was locally installed on a PC and has had a very limited user-interface for data entry and retrieval. The database was built up on Microsoft Access and was only used to store and administrate the data.

ODIN architecture

ODIN Web Portal on Petten Server

secure connection <-> fire-wall <-> access control <-> integrated user management

Engineering DBs

Mat-DB, Gasket-DB, Nesshy-DB

Nuclear DBs

SENUF-DB, NuCoC-DB, DARES-DB, CATT-DB, HTR-Fuel-DB, HTR-Graphite-DB

Document Management DB

DoMa

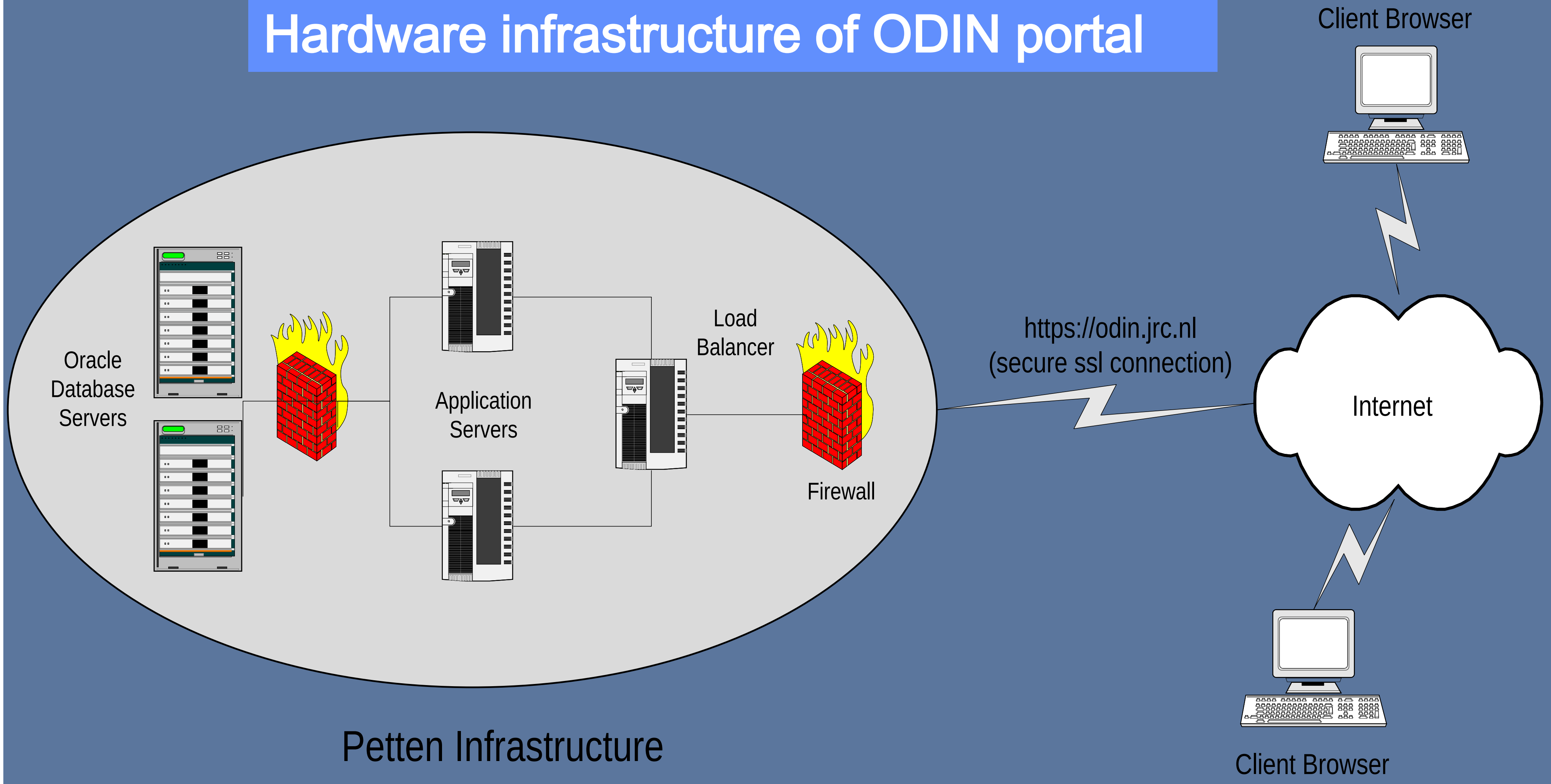
Open Interfaces to European competence sites:

Webservice between Mat-DB and FIT-IT life-time prediction at Fraunhofer IKM, Freiburg

Web-enabled Mat-DB installation at other sites – data network

Relational Database Management System (ORACLE)

Hardware infrastructure of ODIN portal



The data source responsible is administrator of materials data & related documents!

Access rights can on-line be requested from this administrator!

Mat-DB content

Mat-DB covers mechanical and thermo-physical properties data of engineering alloys at low, elevated and high temperatures for base materials and joints and includes irradiation materials testing in the field of fusion and fission, tests on thermal barrier coating for gas turbines and mechanical properties testing on a corroded specimen.

The corrosion part refers to weight gain/loss data of high temperature exposed engineering alloys, ceramics and hot isostatic pressed powder materials.

Mat-DB test types

MECHANICAL PROPERTIES	Thermo-mechanical fatigue
CRACK GROWTH & FRACTURE	IRRADIATION
Creep crack growth	Irradiation creep
Cyclic creep crack growth	Swelling
Fatigue crack growth	In-pile relaxation
Fracture toughness	TENSILE
Impact	Compression
Small punch fracture	Multiaxial tensile
CREEP	Uniaxial tensile
Cyclic creep	THERMO-PHYSICAL PROPERTIES
Multiaxial creep	Density
Torsional creep	Electrical resistivity
Uniaxial creep	Emissivity
Small punch creep	Linear thermal expansion
RELAXATION	Poisson's ratio
Multiaxial relaxation	Specific heat
Uniaxial relaxation	Shear modulus
FATIGUE	Thermal conductivity
High cycle fatigue	Thermal diffusivity
Low cycle fatigue (load control)	Young's modulus
Low cycle fatigue (strain control)	CORROSION
Thermal fatigue	High temperature corrosion

Data entry and retrieval

1. metadata for detailed batch, source, test condition and specimen details are mandatory for the sake of traceability;
2. predefined thesauri for alphanumeric fields and direct input of test results from customer formatted MS EXCEL files ease the data entry process;
3. data must be validated by the source partner before they can be retrieved by authorised project partners;
4. on-line help for data entry and retrieval;
5. a query can be refined until the most suitable data pool has been selected;
6. test type specific reports are automatically generated after selecting data subsets and can individually be changed by the users;
7. predefined graphical views including numerical data presentation such as uniaxial creep curves or stress to rupture isothermals can be performed and exported as MS EXCEL objects by mouse click for further use;

Evaluation program library

1. Mat-DB features a library of evaluation programs for web-enabled assessment of uniaxial creep, fatigue, crack growth and high temperature corrosion properties;
2. evaluations can be performed after data retrieval by pressing the evaluation button or independently of Mat-DB by transferring users' data in a given format to the programs;
3. evaluation routines are integrated under Flex, a new tool built by Adobe which combines the full range of user-interaction associated with client/server systems with the robust, low-maintenance environment of a web application and makes the evaluation process much faster and much more user-interactive;
4. results can be exported to MS EXCEL for further use on the local PCs of the users;

Mat-DB related evaluation & analysis routines

Uniaxial creep

Creep relations:

Norton, Prandtl & Soderberg creep law, Monkman-Grant & Dobés-Milîcka relation

Extrapolation methods:

Larson-Miller, Manson-Haferd, Manson-Brown, Orr-Sherby-Dorn, Spera, Minimum Commitment Method

Constitutive creep equations:

Theta projection, Mc Vetty equation, Kachanov equation

Interpolation routines:

Polynomial creep curve fit, Polynomial stress dependence, Isochronous & isostrain determination

Fatigue

Ludvik law, Manson-Coffin relation, Basquin analysis, Frequency modified Manson-Coffin relation

Crack growth

ASTM compliant creep crack growth analysis, Creep crack growth plot, Fatigue crack growth analysis

HT Corrosion

Weight gain/loss analysis:

Power law, Power law-time, Parabolic Δm^2, Parabolic $t_{1/2}$, $K_{p(t)}$, Breakaway

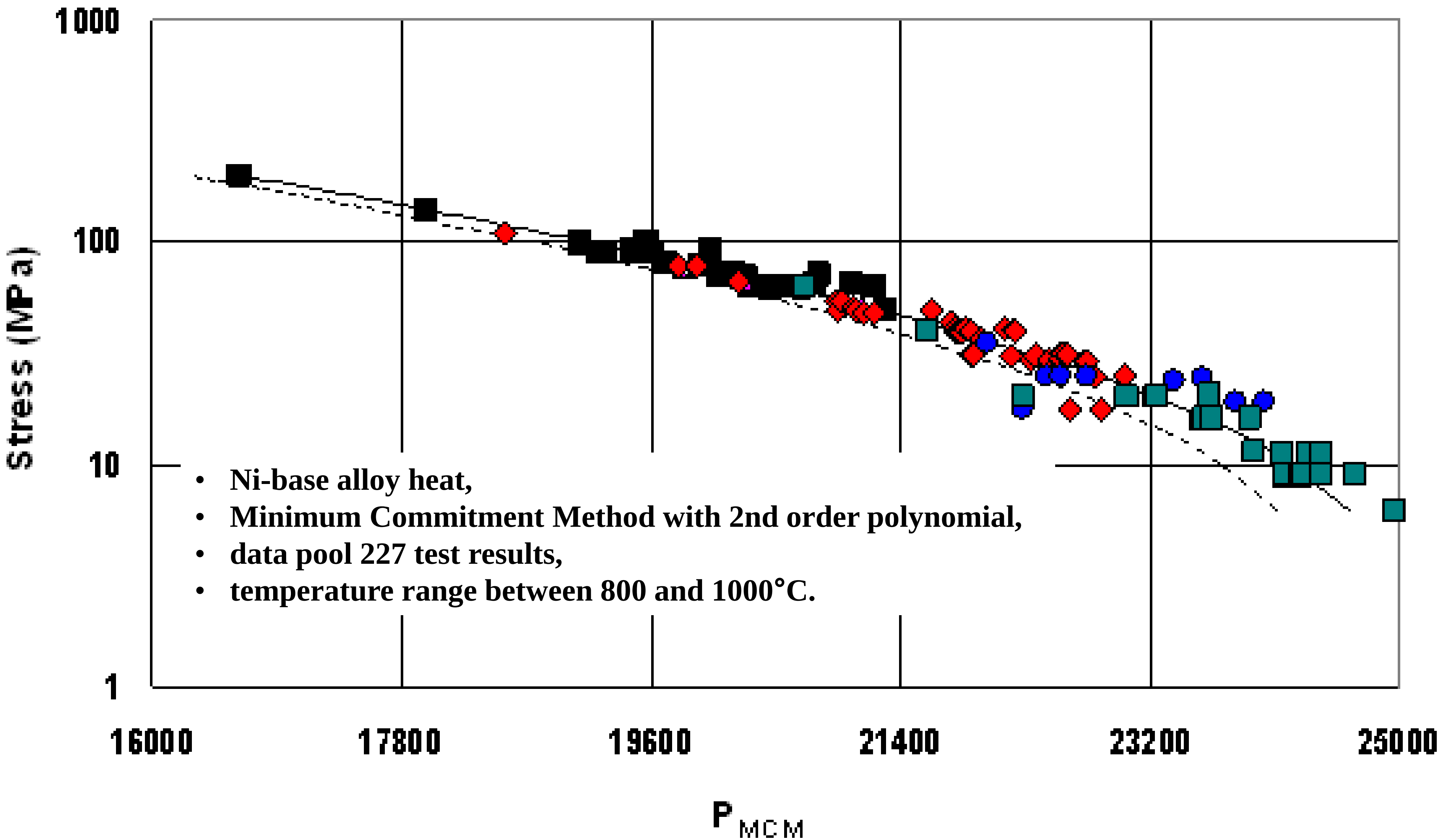
Advantages in using the Mat-DB evaluation program library:

1. fast evaluation processes help the user to get a detailed data analysis or data extrapolation useful for component design and life-time prediction;

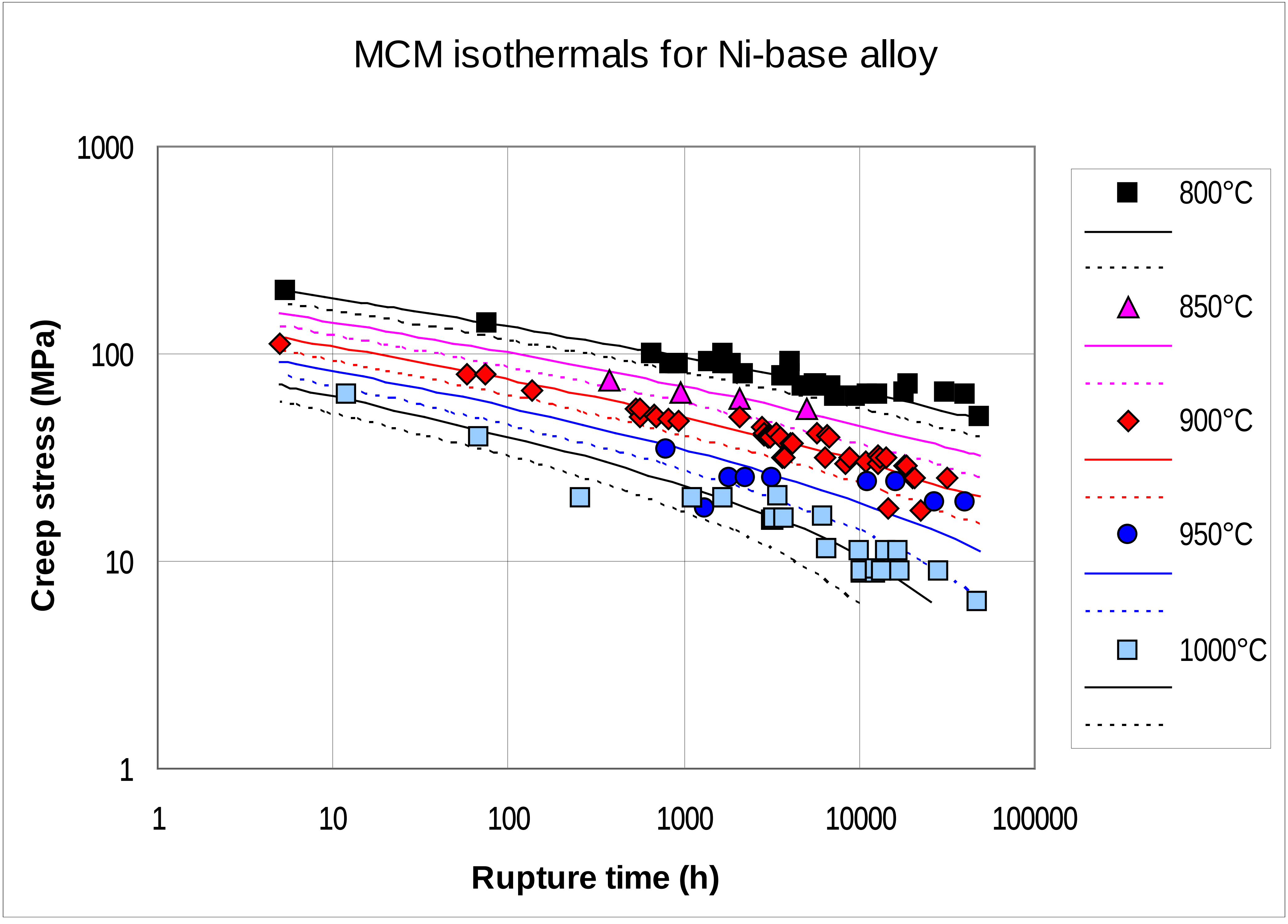
2. evaluation results are immediately available for the user; calculations are performed in a tenth of a second even for complex data sets;

3. comparisons between different extrapolation methods and calculations performed with different polynomials are done in very short time to find out which method fits the best to the selected material heat;

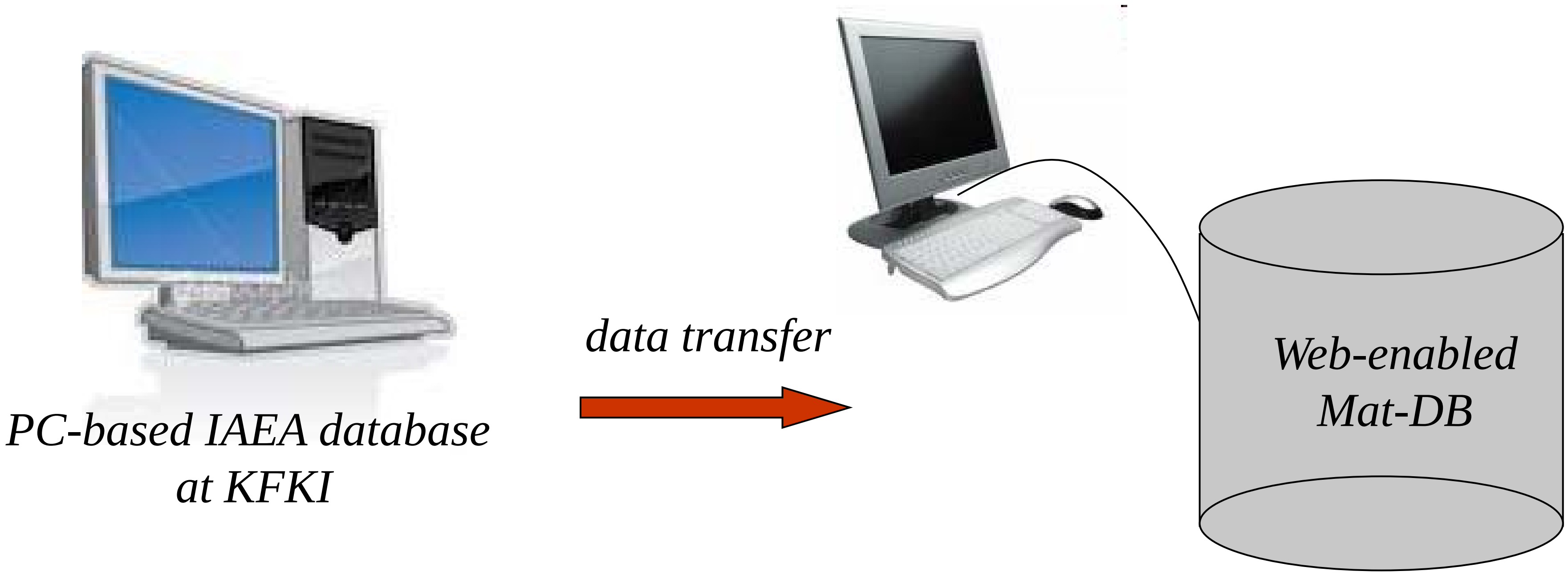
MCM parameter for Ni-base alloy



- **Ni-base alloy heat,**
- **Minimum Commitment Method with 2nd order polynomial,**
- **data pool 227 test results,**
- **temperature range between 800 and 1000°C.**


MCM isothermals for Ni-base alloy
Creep stress (MPa)
Rupture time (h)
1000
100
10
1
1
10
100
1000
10000
100000
800°C
850°C
900°C
950°C
1000°C

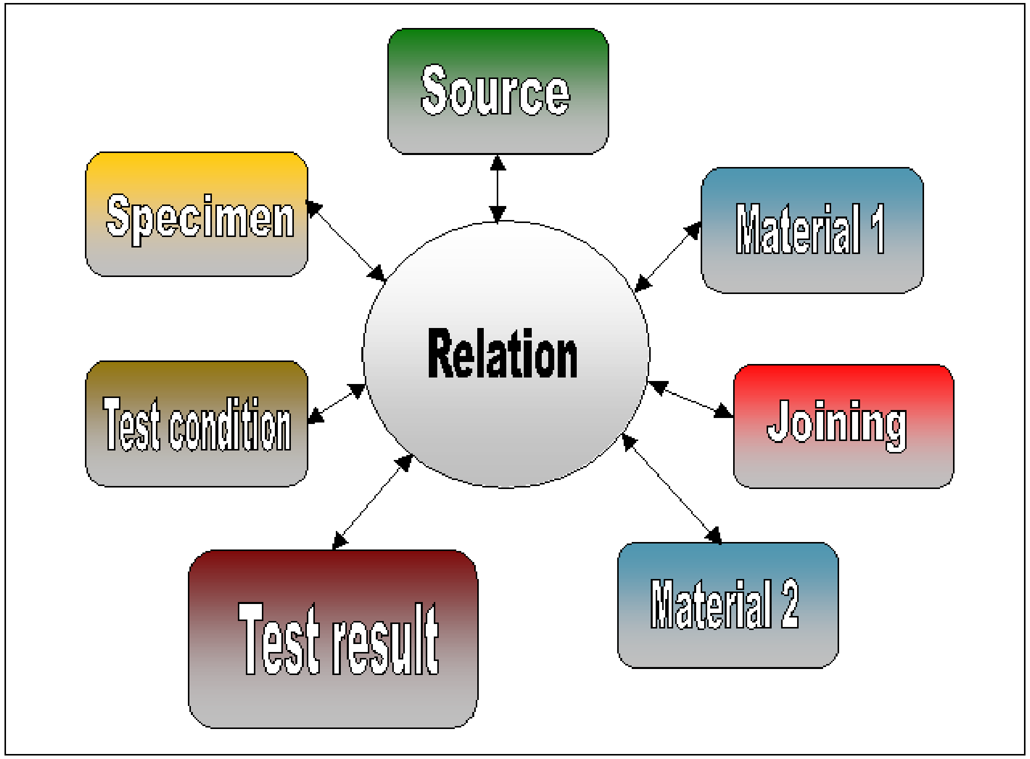
Different structures



The difficulty of the data transfer illustrates the complexity of the Mat-DB structure!

Mat-DB structure

- Oriented towards international material standards and recommendations
- More than 130 tables, 1850 fields



Material entity
Chemical composition
Designation & production
Characterisation
Isotropic grain size
Duplex grain size
Directionally solidified grain size
Hardness
Microstructure
Phase
Physical constants
Thermo-mechanical heat treatment
Customer internals

IAEA surveillance data

- The IAEA Reactor Pressure Vessel Material database was founded in 1986 to collect and evaluate the data of the large coordinated research program of the Agency (CRP-3) on the effect of chemistry on irradiation embrittlement.
- 21 laboratories worldwide irradiated and tested 14 different research heats and welds.
- The obtained large number of results required to elaborate a database. Later this database has been extended to collect data from other research programs and surveillance data (*not yet in Mat-DB*).
- Since the surveillance data are sensitive information the data are open only for the database members and coded.
- Coding means that only the technical data can assessed by the members, the data source can only be named via the IAEA with the permission of the donor institutions.

Materials degradation

The understanding of the exact degradation process of different reactor pressure vessels, in-core structures, fission device materials under irradiation is fundamental as well as for the design, construction and licensing and for safe, reliable and cost-effective long-term operation of the recent and next generation nuclear reactor systems.

Irradiation embrittlement analysis

The key embrittlement mechanisms taking place during irradiation of structural materials are described as follows:

1. Direct matrix damage due to neutron bombardment can be assumed to be root square dependent on fluence for a given material and a given irradiation temperature.

2. During direct matrix damage formation, Cu together with other elements are known to lead precipitation mechanism of nano-precipitates also including matrix hardening and embrittlement. Such a mechanism is assumed to continue until saturation depending on the available amount of precipitants, Cu concentration in particular.

3. Other elements such as phosphor can segregate in grains or at grain boundaries, also in combination with matrix damage or attracted into Cu-type precipitate. Since diffusion of segregants also plays a role, this mechanism becomes rather difficult to understand in detail.

Master Curve Approach

Material embrittlement shifts the transition temperature from brittle to ductile fracture to higher temperatures and reduces the overall ductility of the materials. There are series of national codes which gives guidelines to determine the embrittlement of RPV materials. The codes are requesting tensile, impact and fracture mechanics materials testing.

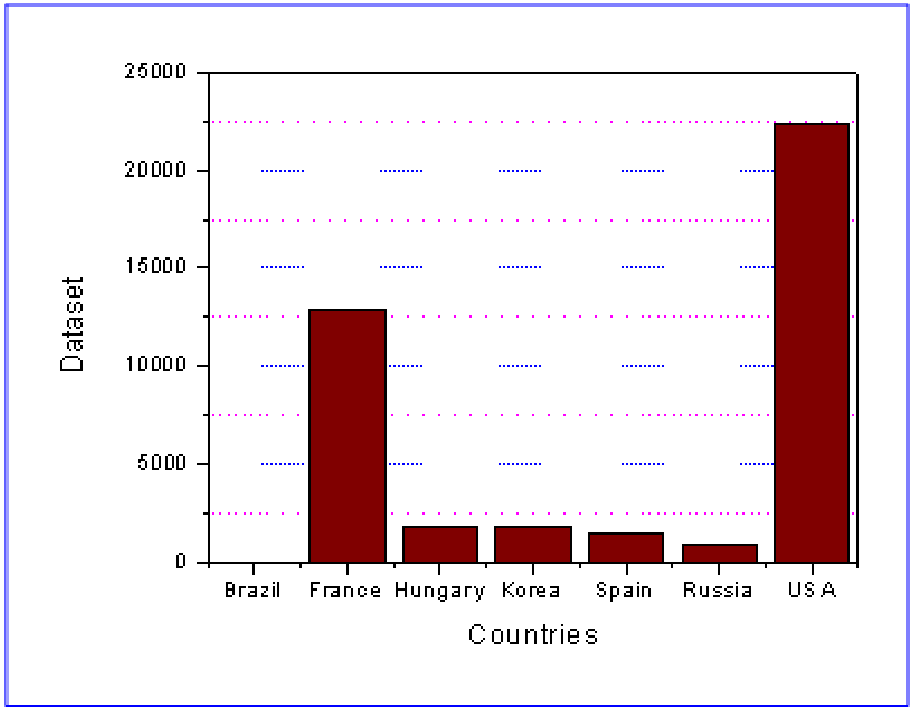
The Master Curve Approach for assessing the fracture toughness of a sampled irradiated material has been gaining acceptance throughout the world. This direct measurement approach is preferred to the indirect and correlative methods used in the past to assess irradiated RPV integrity.

Surveillance data

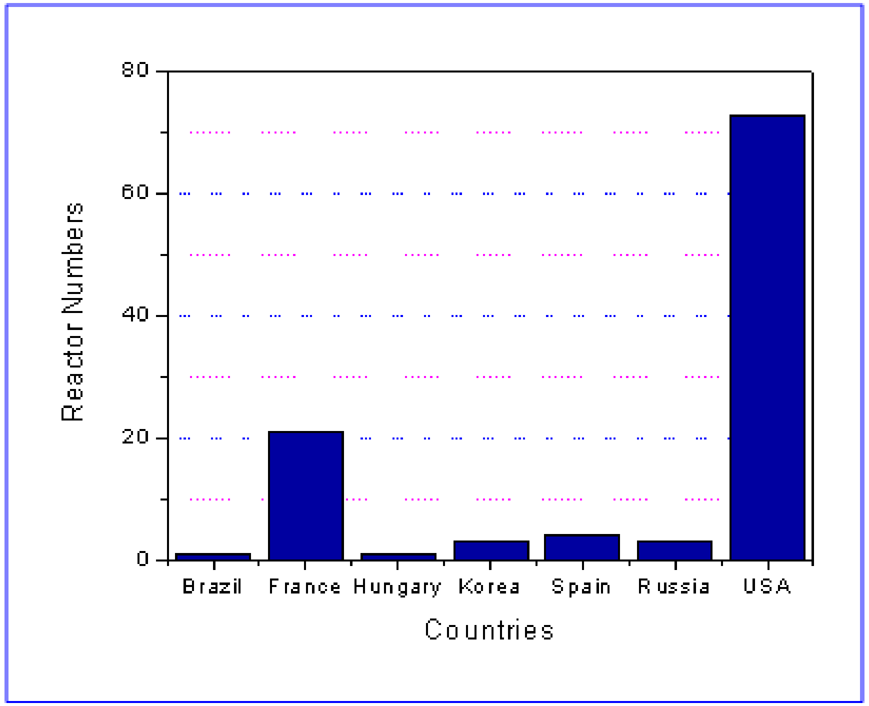
- Surveillance datasets are the base of the evaluation process for reliability, safety and lifetime of operating units.
- From them Charpy transition temperature, Master curve, flow curve and other aged material characteristic trend curves can be analysed by using built-in database routines, or by data export to the favorite mathematical software package of the user.
- Materials testing is very expensive. Data on aged materials are even more valuable since the ageing process (e.g. thermal, fatigue, corrosion, irradiation etc.) are also very costly and time consuming. Using surveillance data obtained on trepans cut from shut-down units after long operation, surveillance data and laboratory data can be compared and flux as well as the synergetic effect of different ageing mechanisms can also be evaluated.
- Storing surveillance data in a materials database is a general task of Knowledge Management.

IAEA surveillance reactor pressure vessel data

The IAEA surveillance data pools which have transferred to Mat-DB contain in total 41523 experimentally measured impact, tensile and fracture toughness data sets from nuclear power plants in Brazil, France, Hungary, Korea, Spain, Russia and USA.

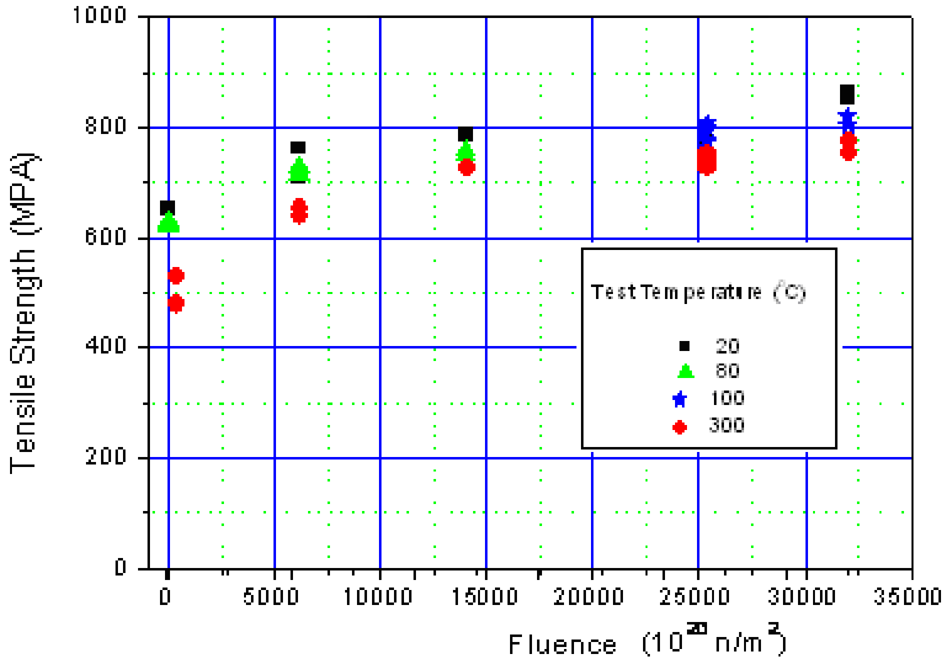


Surveillance data coming from different member states

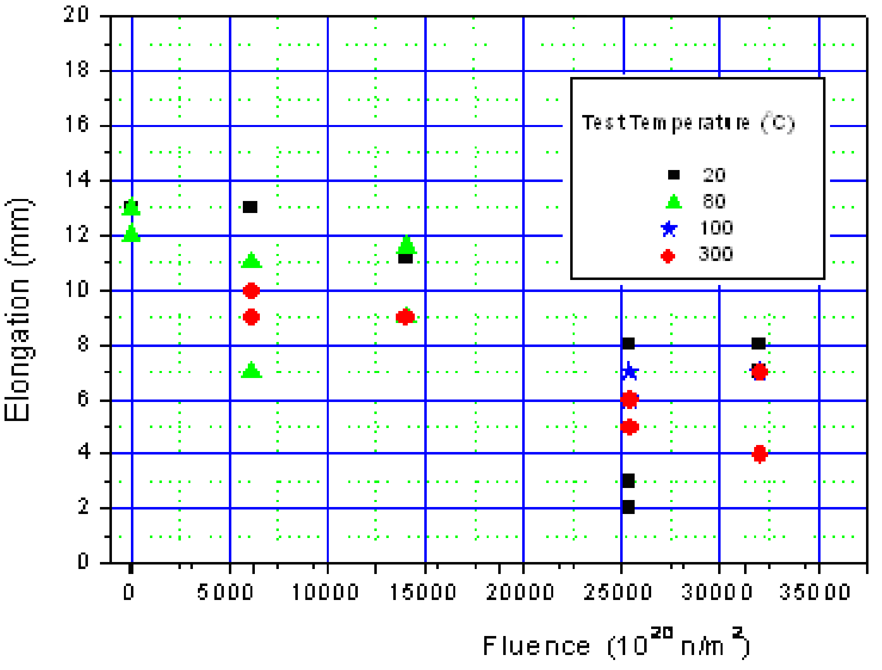


Member state reactors providing surveillance data

15H2MFA base material

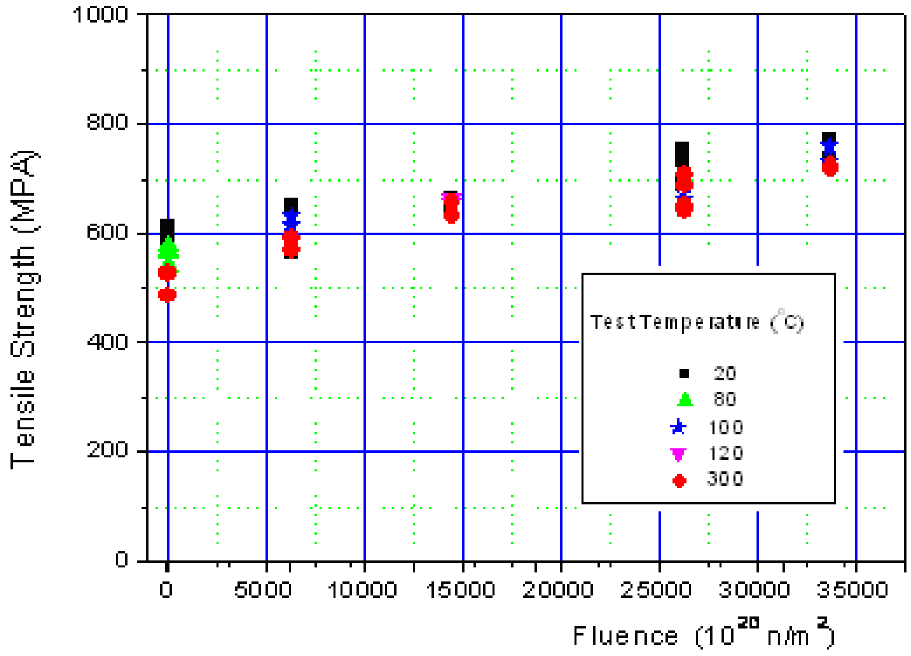


Tensile strength versus fluence

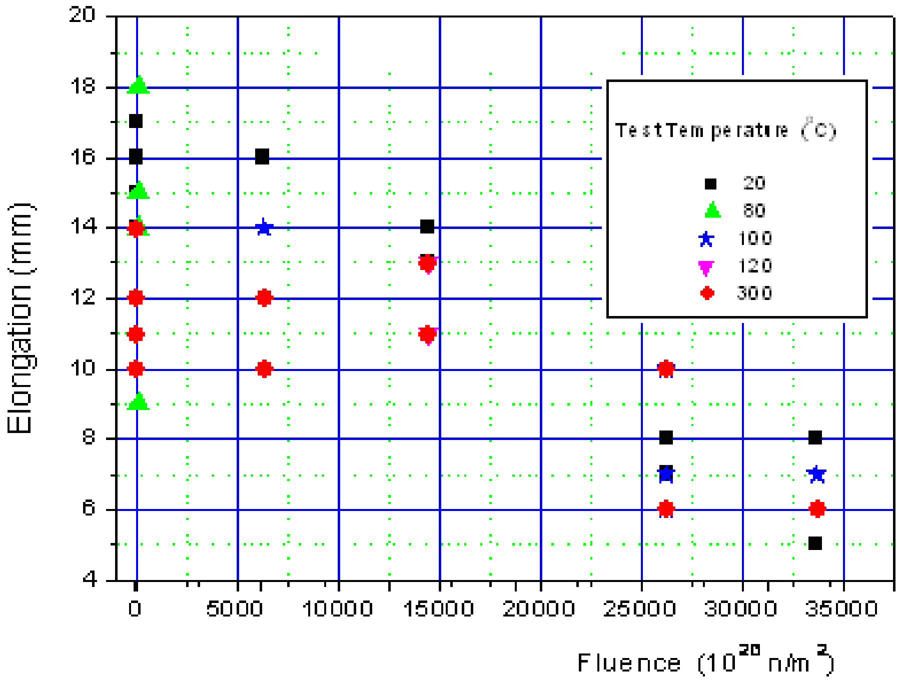


Tensile elongation versus fluence

SVZ-10HMFT weld material

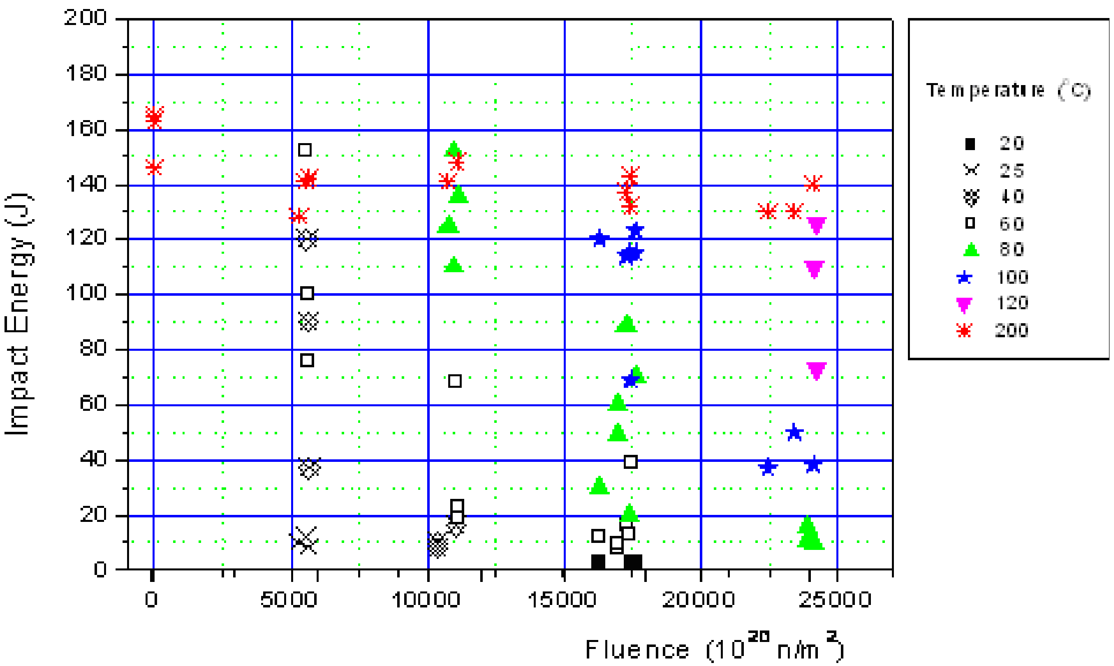


Tensile strength versus fluence

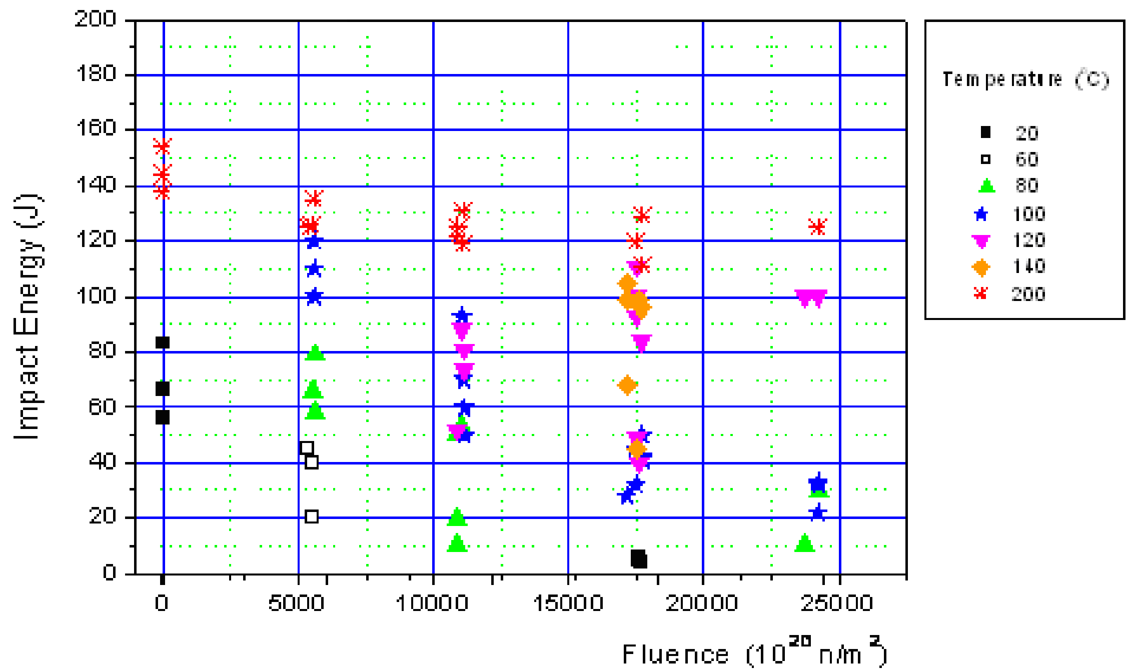


Tensile elongation versus fluence

15H2MFA base material



SVZ-10HMFT weld material



Charpy-V impact energy versus fluence

Advantages in using Mat-DB (1)

- The IAEA surveillance data are stored on the secure Mat-DB server in confidential pools. Data access rights can be granted by the data owners of the IAEA member states.
- They can be shared with each other and retrieved on-line together with public R&D data in fast manner world-wide wherever Internet access is available.
- The data can be analysed graphically and numerically and processed for further use on the local PCs of the users.
- The surveillance data are important for design, construction and licensing. They can also be used to re-calculate the actual life-time after incidents which can cause increases of primary or secondary stresses in the reactor vessel wall.
- Surveillance data in combination with recent R&D data would also provide better information about embrittlement healing after annealing procedures for existing reactors.

Advantages in using Mat-DB (2)

- Data entry of new surveillance data can remotely be done by the members themselves. The data entry process is easy and straight forward; test results together with curve information can be uploaded directly from the local PCs.
- Mat-DB data entry interface request mandatory information which is important for the evaluation process. The database also owns thesauri for many alphanumeric fields and specimen types. They can be selected from boxes and help to standardize the data content.
- Fracture mechanics data, if available, can be added to the existing data pools.
- Data entry and administration assistance are provided by JRC-IE.
- The maintenance of Mat-DB is guaranteed by the JRC-IE. Upgrades, e.g. new test types or evaluation routines, and updates are permanently executed.
- The Master Curve Approach is for instance under implementation in the Mat-DB evaluation program library.

Conclusion

- To store the IAEA surveillance reactor vessel materials data in Mat-DB is not only an issue of knowledge preservation, it is also very useful for design, construction and licensing process of new reactors and for fast embrittlement analysis to actualise the life-time prediction.
- To build up own database tools with extended user-guidance demands very cost-intensive investments. JRC-IE as neutral European institution offers the use of the database free-of-charge to IAEA members and guarantees security and data confidentiality.
- Other big projects such as the former German High Temperature Reactor project and European R&D projects for Generation IV rector systems such as the HTR related ones HTR-M and RAPHAEL and the cross-cutting project GETMAT have been using Mat-DB for central data storage and administration.

Register in the ODIN portal

https://odin.jrc.ec.europa.eu/

to have immediate access to all public data within the various databases!