# Reliability database for Probabilistic Safety Assessment (PSA) in support to the design of the CEA 2400 MWth Gas Fast Reactor (GFR)

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## *Contents*

## *Contents*

## *Component Failure Rate Data Base (CFRDB) definition*

A CFRDB is :

a structured database - often computerized,

which must include essential information such as

- a comprehensive list of components (e.g. *valve, pump*…),
- their main functions *(e.g. stop a flow),*
- their failure mode(s) *(on demand and running),*
- their environment (*e.g. pressure, temperature, coolant..),*
- their boundaries *(e.g. electric supply is outside)*
- their numerical values
  - failure rates ($\lambda$/hour; $\gamma$/demand)
  - Error factor (EF)

## Aim of the study

*At the CEA, a safety assessment of the GFR 2400 MWth is performed by combination between deterministic and probabilistic approaches.*

*The aim of this study is to present a CFRDB building approach based on an analogy between components and their environment with regards to the same information on similar components in existing databases.*

*At the end, this CFRDB is used into a PSA to assess the risk as accurately as possible.*

## Contents

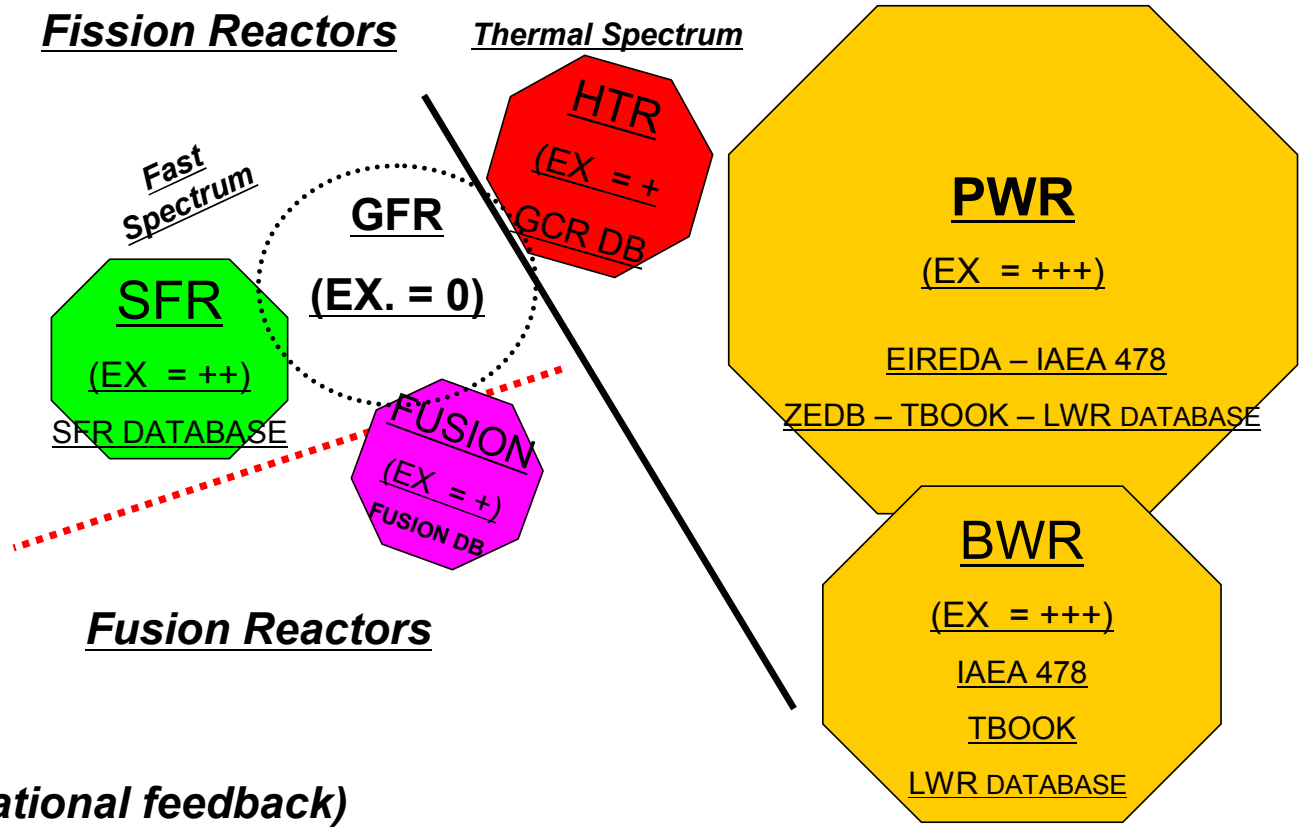
## *State of the art on existing Database*

- Representative databases have been selected from nuclear and non nuclear industry and evaluated.
- Some conclusions have been drawn for evaluation of innovative design using relevance and homogeneity criterion.
- Comment : a database could be unique (like Gas Cooled Reactor Database). In this case, all the components belonging to this CFRDB could be chosen for a safety assessment, even if the database seems obsolete.

# Acquired CFRDB

| Acquired CFRDB | Related field | Up to date or Obsolete | Specific or Generic | Unique ? | Publication year |
|---|---|---|---|---|---|
| WASH 1400 DB | LWR | *Obsolete* | Generic | No | 1975 |
| IAEA TECDOC 478 | LWR | *Obsolete* | Generic | No | 1988 |
| ZEDB | LWR | Up to date | Specific | No | 2004 |
| T-BOOK 6 | LWR | Up to date | Specific | No | 2005 |
| EIREDA | LWR | Up to date | Specific | No | 1998 |
| LWR DATABASE (*EIDE ET AL*) | LWR | Up to date | Generic | No | 1990 |
| GCR DB *(HANNAMAN)* | HTR | Up to date | Specific | Yes | 1976 |
| SAVANNAH RIVER SITE | HWR | Up to date | Generic | No | 1993 |
| SFR DATABASE *(EIDE ET AL)* | SFR | Up to date | Specific | Yes | 1990 |
| FUSION DB *(CADWALLADER ET AL)* | FUSION | Up to date | Specific | Yes | 1990 |
| ICPP FAILURE RATE | Chemistry | Up to date | Generic | No | 1995 |
| OREDA | OFF-SHORE | Up to date | Generic | No | 2002 |
| IEEE STD 500-1984 | Electricity | Up to date | Generic | No | 1984 |
| MIL-HDBK-217F | Electronic | *Obsolete* | Generic | Yes | 1990 |

# Available operational feedback on nuclear reactors




*(EX = operational feedback)*

*FUSION: Fusion reactor. HTR: High Temperature Reactor. HWR: Heavy Water Reactor.*
*LWR: Light water Reactor. PWR: Pressurized water Reactor. SFR: Sodium Fast Reactor. GFR: Gas Fast Reactor.*

## Contents

# *Approach to build de CFRDB on innovative reactors*

## DATABASE RELEVANCE TEST

1. Function
2. Failure mode(s)
3. Environment and boundary conditions

- ***Same*** *environment* → ***identical*** *component*
- ***close*** *environment* → ***similar*** *component*
- ***nothing*** *comparable* → ***non-referenced*** *component*

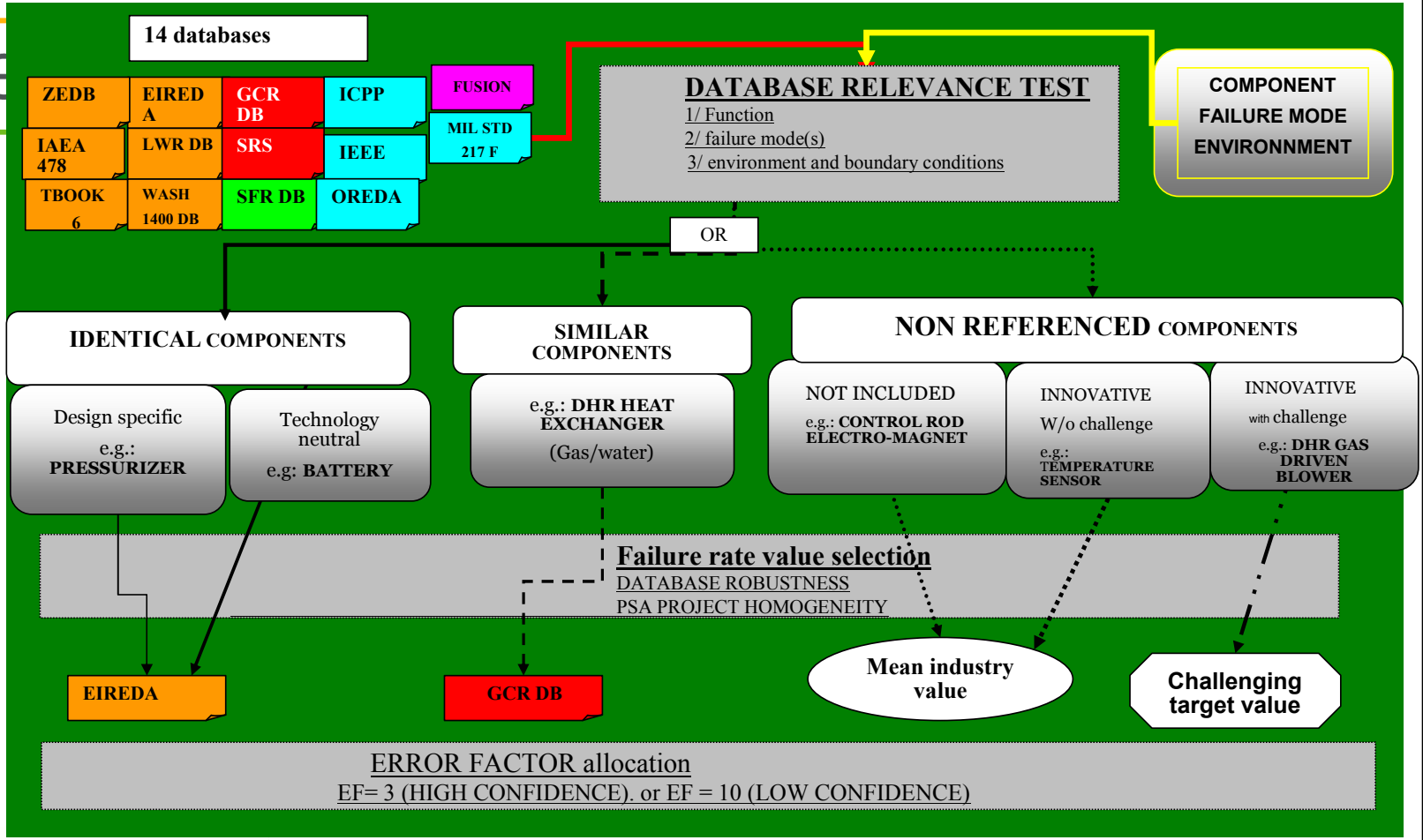
## FAILURE RATE VALUE SELECTION

1. Database robustness test
2. PSA project homogeneity

## ERROR FACTOR ALLOCATION (lognormal distribution)

1. EF = 3 (high confidence) when original value 1< EF < 5
2. EF = 10 (low confidence) when original value EF > 5 or not available

# Approach to build de CFRDB on innovative reactors

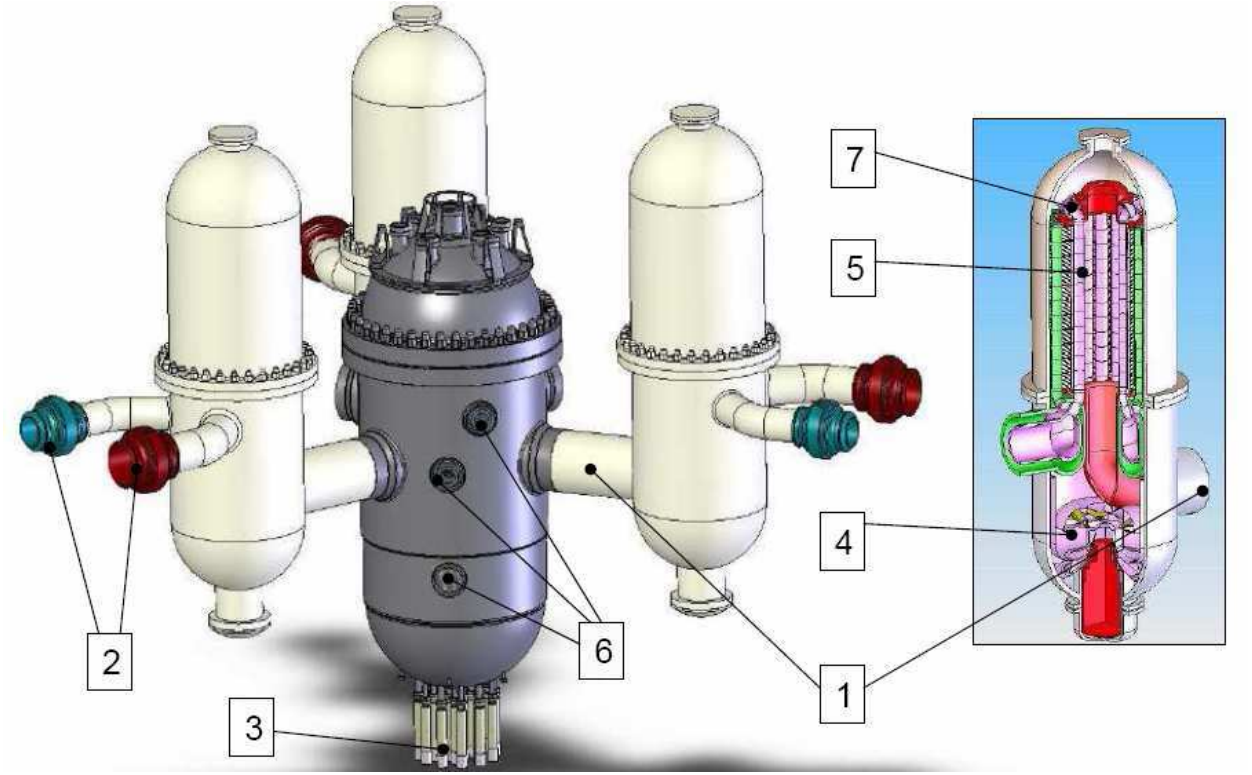


## Contents

## PSA ON FRENCH CEA 2400MWTH GFR

- Six designs have been retained in Generation IV initiative (The CEA works mainly on the Gas Fast Reactor and on the Sodium Fast Reactor).
- An appropriate Component Failure Rate Data Base (CFRDB) is needed to perform the PSA. Due to lack of available data, a CFRDB building methodology for innovative design is proposed, based on the degree of analogy of the components in existing database compared to the components for the design in progress.
- A PSA is performed with this database. Sensitivity studies are performed using a generic database instead of an unappropriate database.

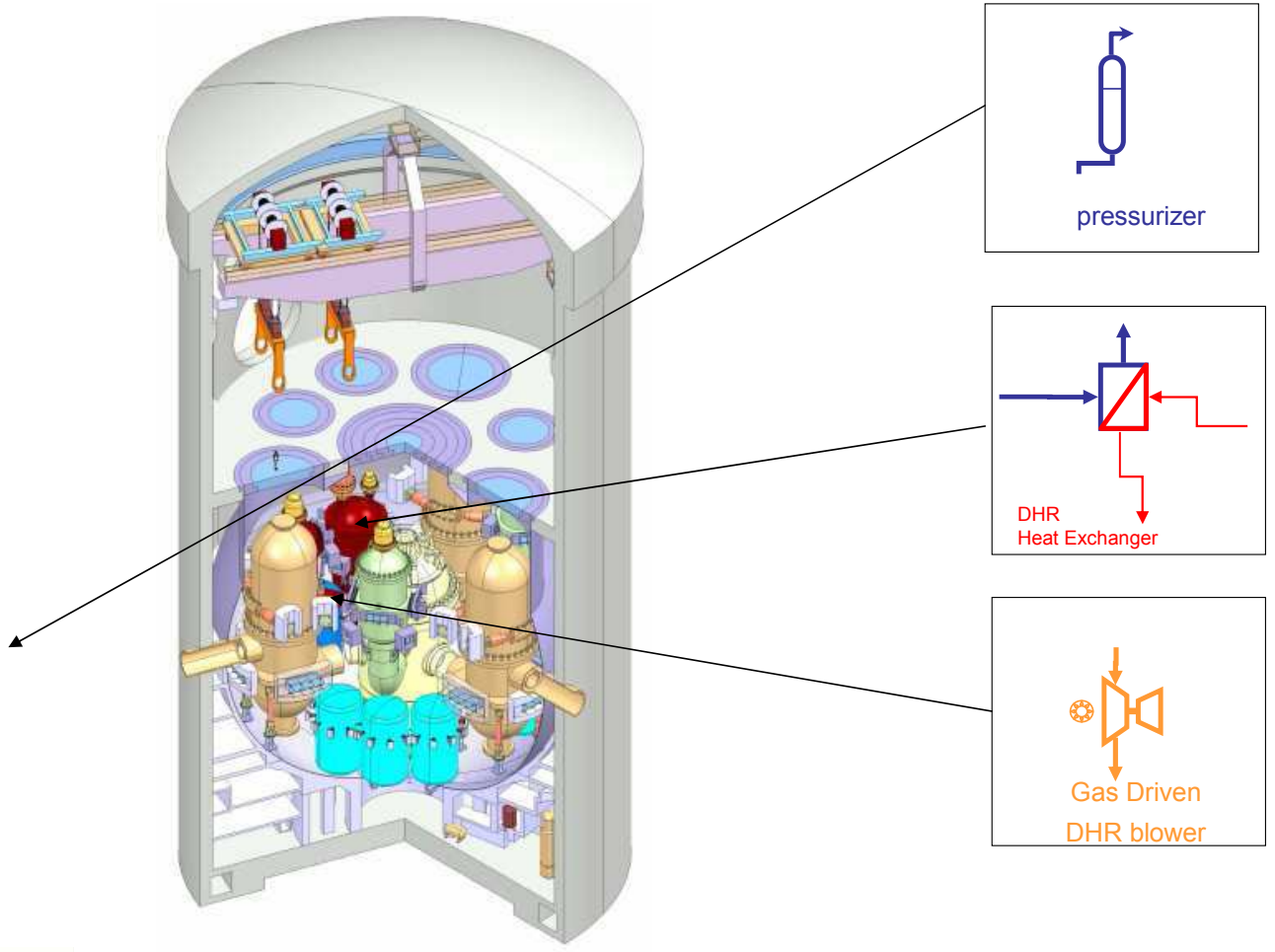
# Brief description of the GFR 2400 MWth



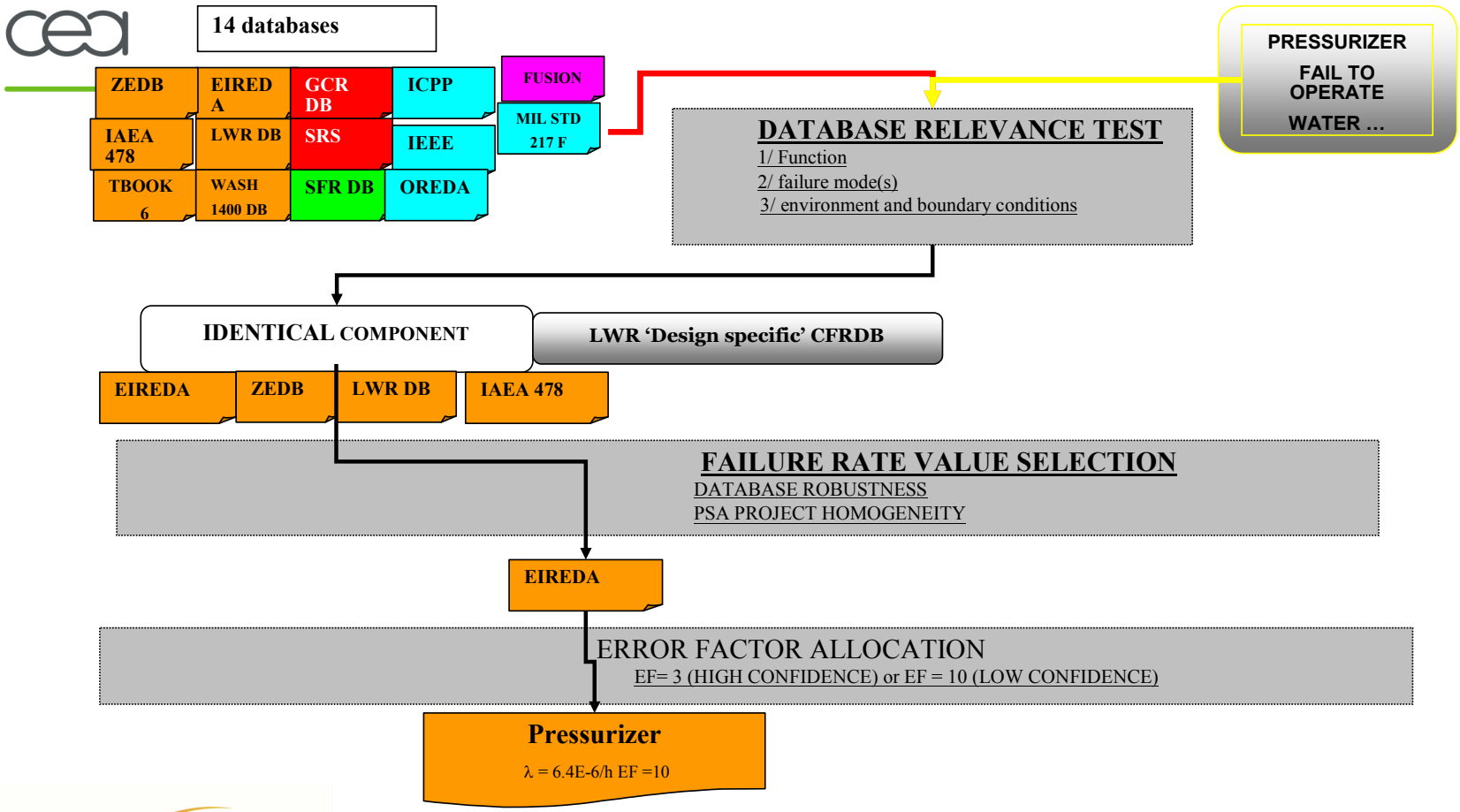

**1. Primary cross-duct. 2. Secondary pipes with isolating valves. 3. Control Rod Drive Mechanisms. 4. Primary blower and associated motor. 5. Compact Heat Exchanger modules**

**6. Pipe connections for DHRemoval systems. 7. Primary isolation valve To accommodate the high gas temperature, a crossduct**

# Brief description of the GFR 2400 MWth (cont'd)



# Reliability database relevance, appropriateness and selection for use in a PSA



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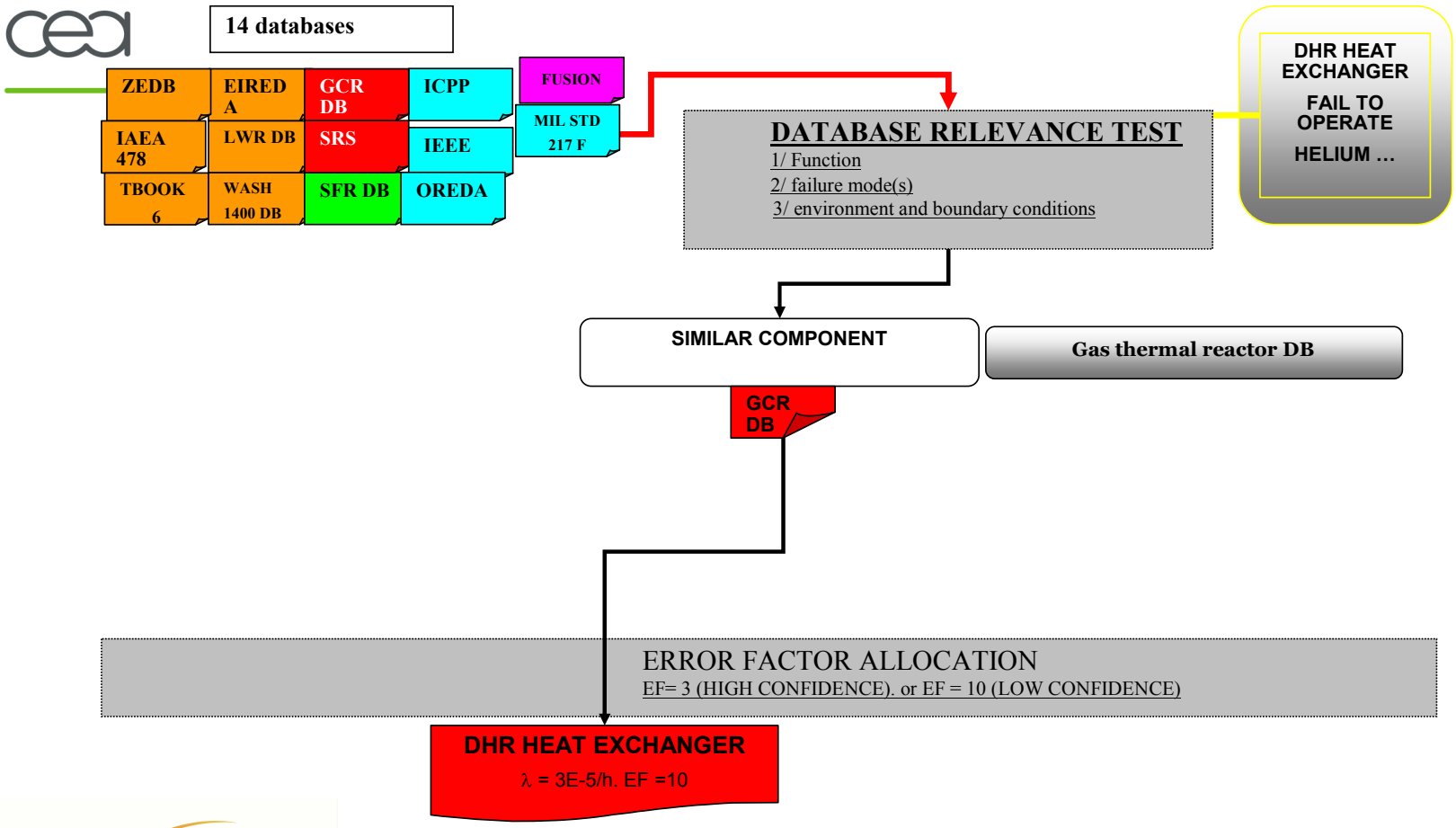

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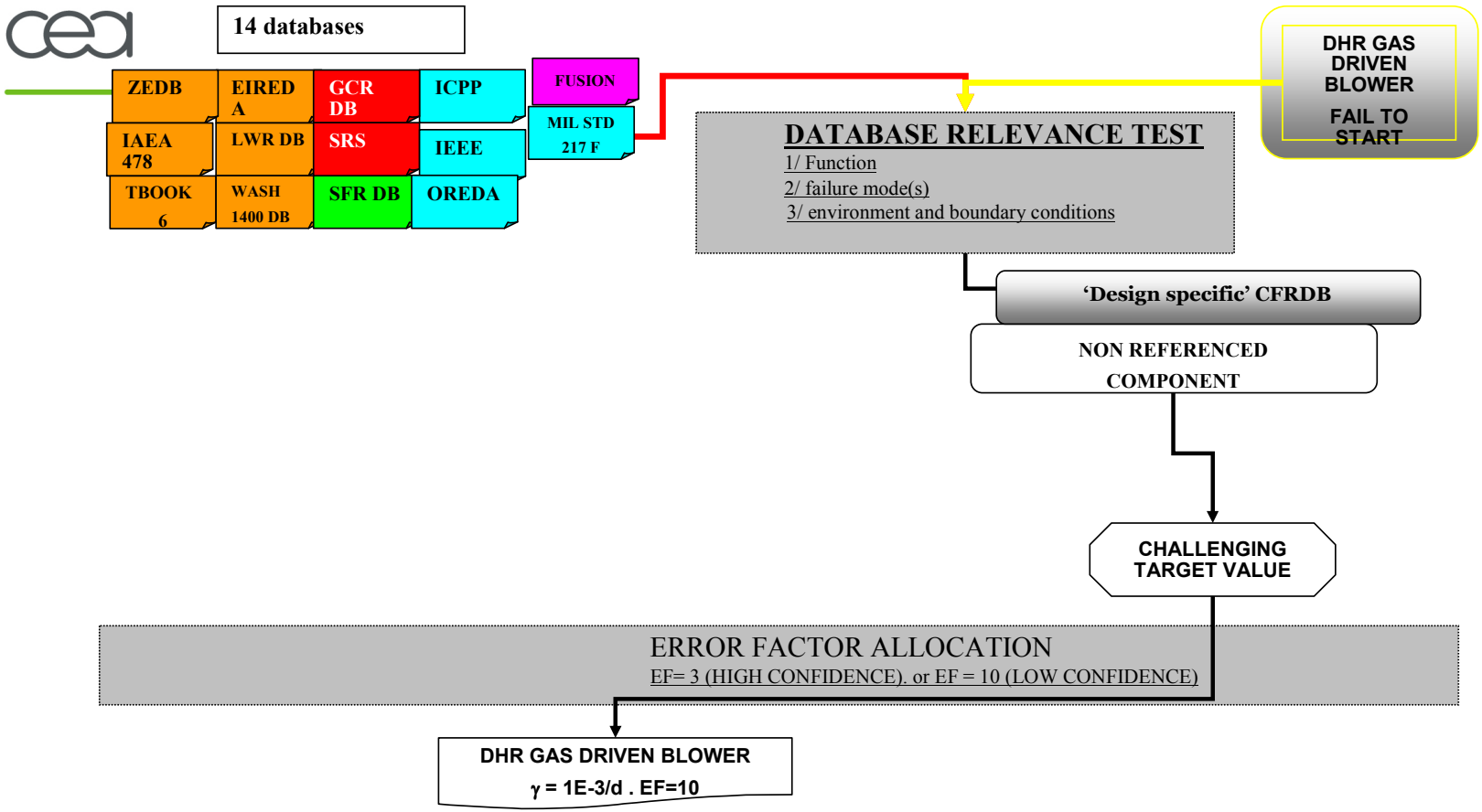
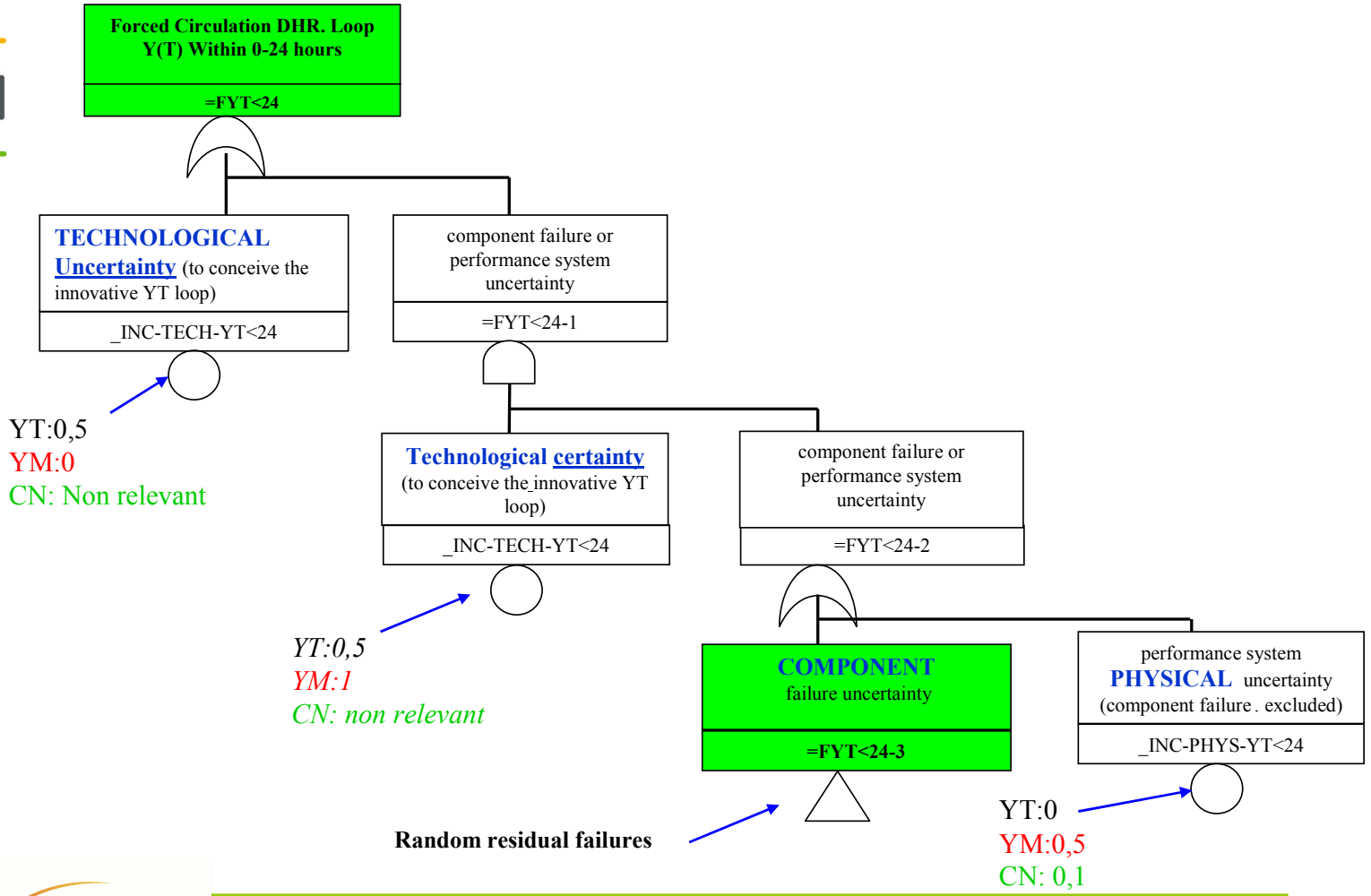


# Generical uncertainty Fault tree: Decay Heat Removal failure



## *2 FAILURE RATE DATABASES ARE MAINLY USED*

1. **GCR DB**, for the components of the primary circuit
2. **EIREDA**, for the components of the secondary and tertiary circuits

For some specific data not provided by the previous database:

→ **LWR DB** (for some valves and tanks)

→ **T-BOOK 6** (for data related to the control rods failure to insert)

If no suitable data has been found, « mean industry » failure rate values have been used (for some captors, transmitters and the control rods electromagnets):

→ $\gamma$ (per demand) = **$10^{-3}$/d** - $\lambda$ (under operation) = **$10^{-6}$/h.**

# Selected GFR component reliability numerical values for use in PSA

| Component lists | component selected numerical values | | | | |
|---|---|---|---|---|---|
| | fail to run $\lambda$ (/h) | Error Factor | fail to start $\gamma$ (/d) | Error Factor | Ref. |
| Primary DHR circulator | 1.00E-04 | 10 | 3.00E-04 | 10 | GCR DB |
| Primary DHR heat exchanger | 3.00E-05 | 10 | - | | GCR DB |
| Primary and DHR isolation valve | - | | 1.00E-03 | 10 | GCR DB |
| Nitrogen or helium tank | 1.00E-08 | 10 | - | | GCR DB |
| DHR gas driven blower ([2]) | 1.00E-04 | 10 | 1.00E-03 | 10 | GCR DB / - (1)(2) |
| Pressurizer | 6.40E-07 | 10 | 2.00E-05 | 10 | EIREDA |
| Electronic 2 out of 3 voting device | 1.20E-06 | 10 | - | | EIREDA |
| Battery | 1.20E-06 | 3 | 4.00E-05 | 3 | EIREDA |
| Tertiary circulation pump | 1.00E-05 | 3 | 1.00E-05 | 3 | EIREDA |
| Tertiary or secondary isolation valve | 4.20E-06 | 3 | 1.10E-04 | 3 | EIREDA |
| Temperature sensor | 1.00E-06 | 10 | - | | - (1) |
| Control rod Electro-magnet | - | - | 1.00E-03 | 10 | - (1) |
| Optical cross link signal/trip breakers | 1.00E-07 | 10 | - | | [T-BOOK] |
| Control rod | - | | 2.70E-04 | 3 | [LWR DB] |

(1) No CFRDB was found relevant. Target values are allocated.
(2) For the same component, with 2 failure modes, the values can be selected from different databases.

## Contents

# Conclusions (1/2)

An original and generic approach for elaborating reliability data is presented here. It is based on an analogy between innovative plant components and acquired CFRDB dedicated to existing components and systems:

- On one hand, this approach allows directly to use numerical values from existing CFRDB for **identical components**,
- on the other hand, it enables more accurate values, for the **similar components** to be selected.
- Regarding **not referenced** components :
  - For **innovative components**, due to the lack of data, challenging target values were allocated. The potential impact of the approach is to underline the boundary of the innovative components and to focus on them.
  - For **components without any innovation degree** but not included in existing reliability database, mean industry values were allocated.

# Conclusions (2/2)

This approach has been applied to build a CFRDB in support to the CEA 2400 MWth GFR design.

- Furthermore, the Gas thermal reactor unique failure rata database [GCR DB] was used for ‘‘similar’’ components
- while French PWR database [EIREDA] was used for “identical” components.

The resulting GFR database we built is still under evolution because the relevant information could be subject to modifications.

A PSA is expected as a support to the design of another Generation IV innovative design, the CEA Sodium Fast Reactor.

- A large reactor operating feedback exists. A reliability database has to be built to reach this aim.
- We foresee that the context would be significantly different but the approach presented here will be applied in the same generical way.

# Do you have any questions ?