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AMICI

Accelerator and Magnet Infrastructure for Cooperation and Innovation

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DELIVERABLE REPORT

DEFINITION OF THE POSSIBLE STRUCTURE AND CONTENT OF A DATABASE FOR MATERIALS AND COMPONENTS

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1 Introduction

The objective of deliverable D5.1 is the **'Definition of the possible structure and content of a database for materials and components'**. WP5.2 is one of the two tasks of the AMICI Work Package 5 (Industrialization) related to harmonization, and, as stated in AMICI project: "… *its main goal is to set the basis for a common knowledge, background and use among Technological Facilities and National Laboratories and industries in relation to material and components involved in accelerator and large superconducting magnets…".* The overall long-term objectives are:

(1) create a reference database for Technological Infrastructures, National Laboratories and Industry of relevant materials and components, including material properties (physical, mechanical, chemical, magnetic, electrical and thermal) in a wide temperature range;

(2) create a list of components of interests with their main properties both at cryogenic and high temperatures, and their behavior in radiation environment. In future developments, this database could be also the first step towards common models for the cost evaluation of the various parts of an accelerator and/or large superconducting magnet.

(3) identify the missing data required for further development of accelerators and superconducting magnets and propose the methods and Technological Infrastructures capable to obtain and validate the data.

The motivation for developing a database dedicated to accelerators and large superconducting magnets as well as the main requirements of such database are presented in section 2. The concept of such database, which is based on the functional breakdown structure of a complex system is shown in section 3. In section 4, the existing material databases are shortly discussed. The section 5 is devoted to the review of databases propose by other EC projects. The initial definition of the type of data and information to be included in the database is presented in section 6, followed in section 7 by the database demonstrator developed by WP5.2 working group. Finally, the proposal of a new database, a software choice, database architecture and the process for validating of selected data are described in section 8. Annex 1 show the example of detailed technical description of spoke section of ESS superconducting linac. Annex 2 presents list of available sources of data in the field of cryogenics and superconductivity.

The working group of WP5.2 adopted a three steps approach:

1. Collect an initial set of basic data and data sheets relevant to the issue of Material specifications and Components specifications. This subset should be sufficiently large, significant and agreed by experts to guide in defining the structure of the database: content, categories, key words, parameters description, etc…
2. Provide a tentative structure for the database.
3. Develop a database demonstrator that could lead to a professional database in the future.

The implementation of a professional database is well beyond the scope of the current AMICI H2020 project and could find its realization in a next step of AMICI activities.

The objectives of the work described in this report are:

1. Identify the needs of AMICI partners.
2. Review of existing material databases.
3. Review of database proposed by FuSuMaTech EC project.
4. Conceptual proposal of a database for AMICI.
5. Develop a database demonstrator.

2 Motivations for a dedicated database

We are committed to the idea that the results in the field of accelerators and SC magnets of funded research programs in academia around the world are a valuable resource and a strategic asset. This resource allows the accumulation and capitalization of knowledge and know-how. Furthermore, it will enable the European Institutes to be more efficient and agile to take on the unavoidable various new innovative technological challenges in the framework of future scientific instruments.

The development of a database dedicated to accelerators and large superconducting magnets is motivated by several facts:

1. The manufacturability, the cost, the performances including the reliability of accelerators and large superconducting magnets are determined by several parameters among which:
    - The design and engineering of the machine,
    - Material and/or component choice and specifications.
2. Data and characteristics properties of material and components, when available, are not easy to find in the literature. Some of these data are not available or are transmitted only via private communications.
3. Lack of data on materials and components suited for use and reliable operation in the specific accelerator extreme environment (e.g. radiation, cryogenic temperature…).
4. Using an easy access common database, with validated material properties, and shared between Academia Institutions, Technological Infrastructures and European industry is of great importance for and efficient development of big scientific instruments. Via such global efficient exchange of experience, Europe will be better placed for the development and construction of future large scale international projects.
5. It will allow an efficient transfer of knowledge and know-how between European Academic Institutes, Technological Infrastructures and industry.
6. The development of such database will be an added value for research and innovation.
7. In our knowledge the important NIST-USA database is no more maintained. It is then an opportunity for Europe to develop a database that will be recognized and widely used worldwide.

The main objective is therefore **to create a common reference database for materials and components used in accelerators (accelerating structures, magnets, diagnostics, ancillaries)** and start to fill it with relevant data.

3 Concept of database structure

The AMICI database to be developed, is based on the functional breakdown structure of a complex system. More precisely, as shown in Fig.1, the structure of the database is hierarchical flown-down from the particle accelerator layout to its basics elements, through the 'parts', according to their function (i.e. production or generation of particles to be accelerated, beam transport, beam bunching and transverse focusing, beam acceleration at different ranges of energy), and their 'components'. The detailed technical description of how to proceed along with some examples is presented in Annex 1.

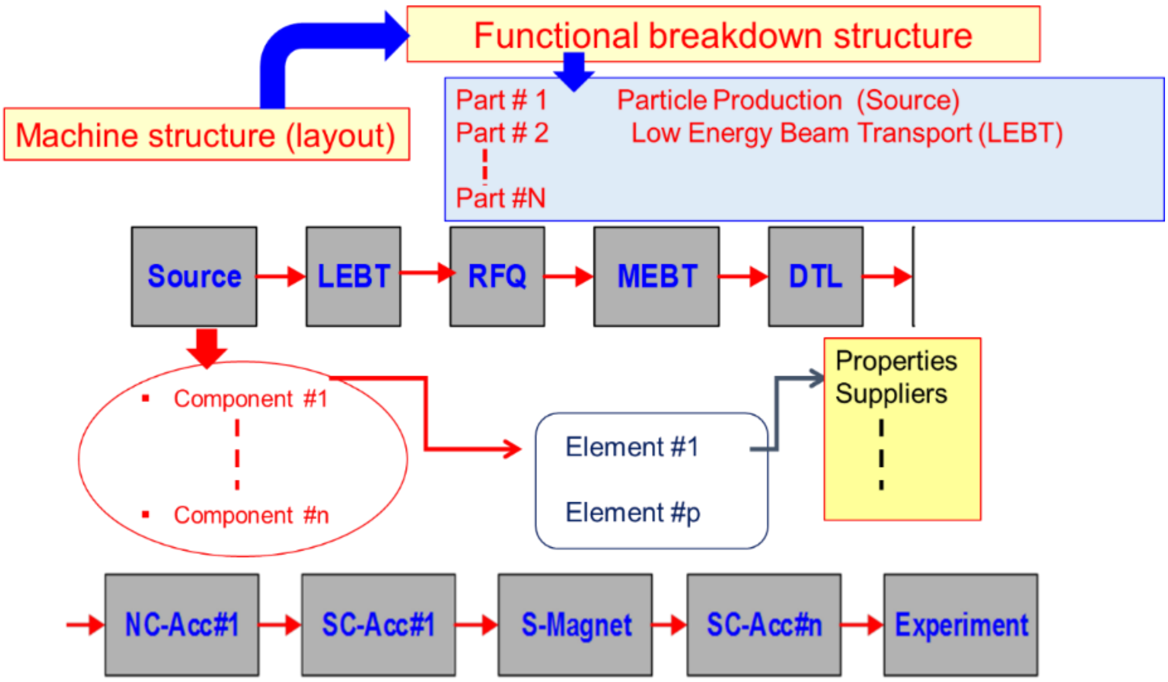


Fig. 1 Definition of an accelerator (linac type) functional breakdown structure

4 Survey of existing databases and useful sources of data

A detailed list of existing databases and data sources such as international conferences, periodical journals, books, concerning applied superconductivity including Superconducting RadioFrequency (SRF) resonators and SuperConducting magnets (SC magnets), cryogenics and low temperature applications is given in Annex 2. A first but not exhaustive list of the existing databases that could be useful for accelerators and magnets is given in Table 1. More details are available in the websites of the corresponding database.

Table 1: Selection of existing databases including data useful for accelerators and SC magnets

Database	Link	Description	Type
CINDAS	https://cindasdata.com/	Global Benchmark for Critically Evaluated Materials Properties Data	Industrial software
Fluid Property Packages Material Property Packages Superconductivity Analysis	http://www.htess.com/	State, transport, thermal expansion, and thermal properties of fluids and metals. Software for design and operation of SC-magnets	Industrial software
NIST	https://www.nist.gov/	Large spectrum of properties of solids and fluids including fundamental properties	Public Some parts are not free of charge for access

4.1 Description of selected existing databases

4.1.1 CINDAS (https://cindasdata.com/)

CINDAS have done a Global Benchmark for Critically Evaluated Materials Properties Data. Some of the data included in CINDAS that could be useful for accelerators and magnets:

1. Aerospace and High Performance Alloys Database (AHAD)
2. Aerospace Structural Metals Database (ASMD)
3. High Performance Alloys Database (HPAD)
4. Microelectronics Packaging Materials Database (MPMD)
5. Thermophysical Properties of Matter Database (TPMD)
6. Damage Tolerant Design Handbook (DTDH)
7. Structural Alloys Handbook (SAH)

4.1.2 NIST (https://www.nist.gov/)

NIST research generates data to work with industry, academic and government systems to advance innovation and improve the quality of life. A broad spectrum of science and technology data resources are available through a suite of services. Some of the data included in NIST database that could be useful for accelerators and magnets are:

- Chemistry WebBook
- Physical Reference Data
- Standard Reference Data
- Atomic Spectroscopy Database
- Chemistry WebBook
- Digital Library of Mathematical Functions

Some Popular Data Products included in NIST database:

- REFPROP: Reference Fluid Thermodynamic and Transport Properties FAQ
- Mass Spec: NIST/EPA/NIH Mass Spectral Library MS Data Center

- ICSD: FIZ/NIST Inorganic Crystal Structure Database ICSD-Demo.zip
- TDE: NIST ThermoDataEngine
- SESSA: NIST Simulation of Electron Spectra for Surface Analysis
- Selected NIST-Recommended Practice Guides in Material Sciences

4.1.3 High –Temperature Superconductor Critical Current

A recent paper untitled *'A Public Database of High –Temperature Superconductor Critical Current Data'*, by Stuart et al. (ASV 2016 manuscript 4MPo1C07) describes a public database dedicated to critical current of High –Temperature Superconductor.

4.2 Some other sources of data

There are many sources of valuable data for accelerators and magnets: they are detailed in Annex 2. Finally, other references and sources of data exists such as ASM HANDBOOK, books about accelerators technology, fundamental and applied superconductivity, cryogenics (general, liquid helium, cryogenic engineering, low temperature physics, RF engineering), CERN Accelerators Schools.

4.3 A database dedicated to accelerators and SC magnets

The review of existing databases clearly shows that many of these databases are very specific and are dedicated to a given application (for example aerospace engineering) and the data concerns material and component specifically developed and/or used for this application. Furthermore, many materials (for example high purity niobium for SRF cavities) and components (for example feedthrough) for accelerators and SC magnets have very precise specifications in terms of properties and even production process in order to be suited to the stringent extreme conditions (vacuum, cryogenic temperatures, radiations) and the high functional performance needed. Consequently, the component and material are often characterized by the institutes involved in accelerators and SC magnets development prior to their use because they need the data for the design and construction: note that these data are not often available in the literature. To be more efficient, save time and money, it is very important to include all these data in a dedicated database for accelerators and SC magnets.

5 Review of database proposed by FuSuMaTech EC project

The European project FuSuMaTech concerns mainly SC magnets R&D in Europe. As a large part of magnets experts from academia institutes are involved in both AMICI consortium and FuSuMatech. It was decided to have a discussion as early as possible with reference to the AMICI and FuSuMatech respective timelines. The goal of AMICI-FuSuMaTech discussion was to investigate and examine collaboration opportunities in some close topics of the two projects. A first meeting was organized at IPN Orsay in November 2017 and a report was issued. The discussion was mainly focused on the activities within AMICI and FuSuMatech that have strong similarities, namely the tasks WP5.2 (AMICI) and T4.2 (FuSuMatech), which are both dedicated to database development. It was decided to have a collaboration and a tight coordination of the above mentioned tasks in order to avoid to duplicate the work and cover better the topics of the two complementary databases (i.e. WP5.2 an T4.2). A second meeting was organized at RAL/STFC: we visited Simon CANFER (leader of FuSuMatech T4.2).

As for AMICI, the full implementation of the FuSuMaTech database was not in the scope of the H2020 project.

The objectives of the task FuSuMaTech T4.2 were:

1. Plan a comprehensive open access, web based, trusted database
2. Form a network of interested partners
3. Write a specification for a database
4. Identify existing and new materials
5. Propose a scheme for long term management
6. Liaise with the International Bureau of Weights and Measure

The work is divided into 6 subtasks:

- T4.2.1 - Determine the standard measurement data format with detailed property data points covering the full operating temperature ranges from research activities, applications and industry, by liaison with representatives from academia and industry sectors 2.
- T4.2.2 - Collect existing data, verifying its accuracy and its fit with the standard format
- T4.2.3 - Identify existing and new materials not yet measured.
- T4.2.4 - Develop a network of testing facilities, in which the different material properties can be measured.
- T4.2.5 - Propose a scheme for long time management of this data with succession.
- T4.2.6 Preparation of a proposal for the creation of a new database of Material properties at Cryogenic temperature.

6 Definition of the type of data and information to be included in the database

In the various phases (conceptual design, technical design, engineering design and development, prototyping) of a large accelerator (i.e. LHC, XFEL, ESS, DONES), the technical and scientific staff involved in the project require different kind of data and information that will be used for the design, numerical simulation, estimation of performance and costing. A non-exhaustive list of data to be included in the database is detailed in this section.

6.1 Material

- Raw material, as used to fabricate accelerator systems
  - *Niobium, Nb_3Sn, NbTi, Stainless steel,Titanium,…*
  - *Ceramics (power couplers)*
  - *Magnetic material (µmetal ,co-netic, …)*

- Material as used during processing/preparation

- *Chemical etching mixture*
- *Ultra-pure water*
- *Media for mechanical polishing*

6.2 Component

Some examples:

- Ancillaries, as used to implement accelerator systems
  - *Cables,*
  - *RF feedthrough, HV feedthrough*
  - *Screws, bolts*
  - *Gaskets*

- Sensors/Instrumentation as used in accelerator environment

It should be limited to those suited and/or specific for use in accelerators (e.g. extreme conditions in terms of vacuum, cryogenic temperature, ionizing radiation).

- *Temperature sensors*
- *Pressure sensors*
- *Piezoelectric actuators*
- *Displacement sensors*
- *Vacuum gages*

6.3 Other categories of data

Apart from material and component, other categories of data and/or information could be useful for accelerators and magnets community. A non-exhaustive list of such categories to be included in the data base:

- design and Numerical Simulation tools (Mechanical, Thermal, RF software, Multipacting and field emission).
- procedures for processing, preparation, mounting, assembling, testing.

6.4 How to include information data from industry into AMICI-DB

The minimum information and/or data to be included is:

- list of suppliers of materials, components and equipment for accelerators and magnets dedicated to scientific instruments
- brief description of the products and/or service supplied or produced.

We propose to contact industrial companies and ask them to write a short document describing their activities a link to their website: a template should be used in order to have standard information. It should be stressed that some information such as a detailed description of their know-how, and fabrication process that could be useful to academia is generally protected (Intellectual Property) for obvious reasons. A discussion with industry is needed: the aim is to define with industry the scope of the data that could be included in the database, which will be public with free access.

7 AMICI database demonstrator

We have developed and implemented a demonstrator, which illustrates the operating principle of the database.

7.1 Description of operating principle

The operating principle of AMICI database will be described and explained hereafter **with an example**. The user gives a **key word**: it is the **database input**.

For example, selecting component **SRF cryomodule (Accelerating Superconducting RadioFrequency cryomodule)** we will obtain list of main subcomponents:

1. **AMICI database** gives the **list of the main components of SRF cryomodule:**
    - SRF cavity
    - Liquid Helium (LHe) Tank
    - Cold Tuner
    - Power Coupler
    - Magnetic shields
    - Thermal Shields
    - Vacuum vessel

Next, selecting subcomponent we will obtain more details, including fabrication materials

2. **AMICI database** lists the possible fabrication materials for each of above components as illustrated in Table 2.

Table 2: Material for fabrication of some SRF cryomodule components

Component	**Material**
Cavity	Niobium
Cavity flanges	Stainless steel or Titanium or NbTi
Liquid Helium tank	Stainless steel or Titanium
Thermal Shield	Copper or Aluminum

3. **AMICI database output**

The AMICI database record will include data in 4 formats: a text, a table, a graph and a figure. The currently identified sources of data are: other databases, referenced journal paper, book. The main challenge for such type of database would be to identify missed information and to propose measurements to fulfil the data gap. Part of such measurements would be possible with distributed network of Technological Facilities proposed by AMICI project. The required data vary for each component, but in general should covers all the properties having an impact on the functionality of the component, performance, production. Some few examples are illustrated in Table 3.

Table 3: Material properties and impacted parameters

Property	Impacted parameters
Material, Grade, Purity	Fabrication process (machining, welding,..), cost, availability
Mechanical properties	Vacuum, stress vs strain curve
Thermal properties	Cryogenic performance
Magnetic properties	SRF cavity dynamic losses
Radiation (neutrons, Xrays,..)	Reliability, lifetime, performance

A schematic workflow diagram of AMICI database is shown in Fig. 2. This example concerns SRF cryomodule: the description of this basic brick of a superconducting RF accelerator is given in Annex. It is a complex system, which consists of different critical component: SRF cavity, tuning system, main power coupler, …. The diagram illustrate how the database should operate and deliver the relevant data about the various material and critical components of the cryomodule.

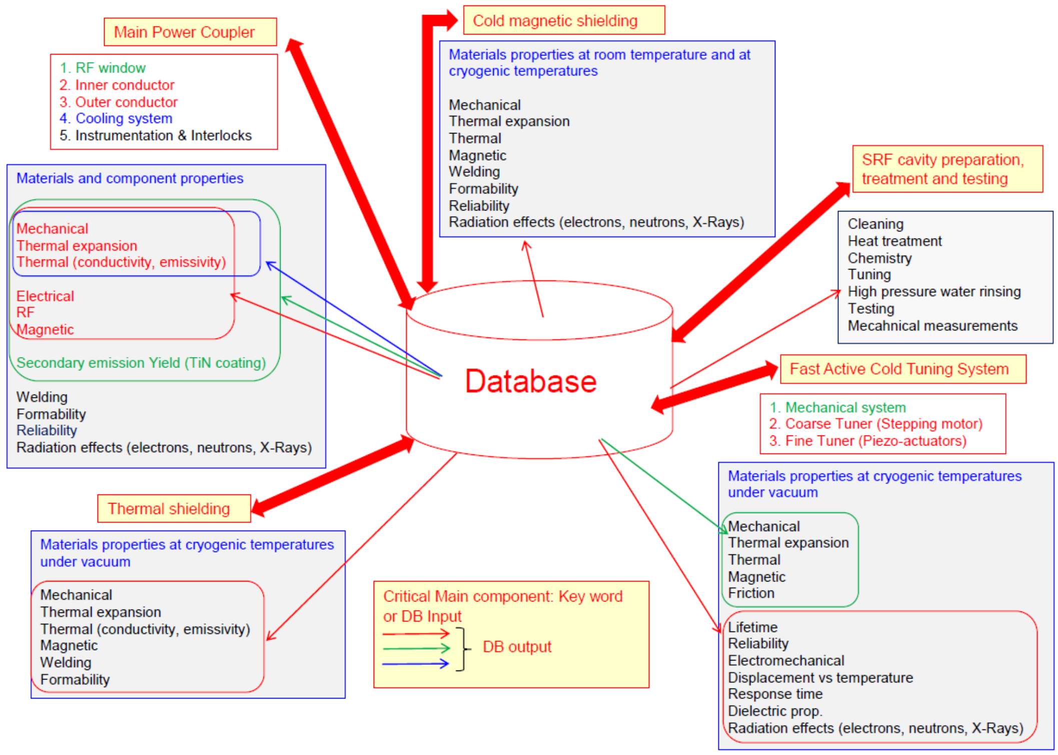


Fig. 2: Schematic workflow diagram of AMICI-DB for a SRF cryomodule

7.2 Implementation of AMICI-DB demonstrator

The data needed for the demonstrator were saved in two servers located at IPN Orsay/CNRS: these data were shared (password protected access) with IFJ-PAN in charge of demonstrator implementation using web application. The scheme of AMICI database demonstrator developed and implemented by IFJ-PAN is illustrated in Fig. 3. Two typical outputs of the demonstrator are illustrated in Fig. 4-Fig. 5. In this example, the user needs thermal data concerning Niobium (Nb), which is the material used for high performance SRF cavities fabrication. The relevant component, material and property are highlighted in burgundy color. The data of Fig. 4 show the variations of the thermal conductivity of superconducting Nb, as function of temperature at cryogenic temperature.

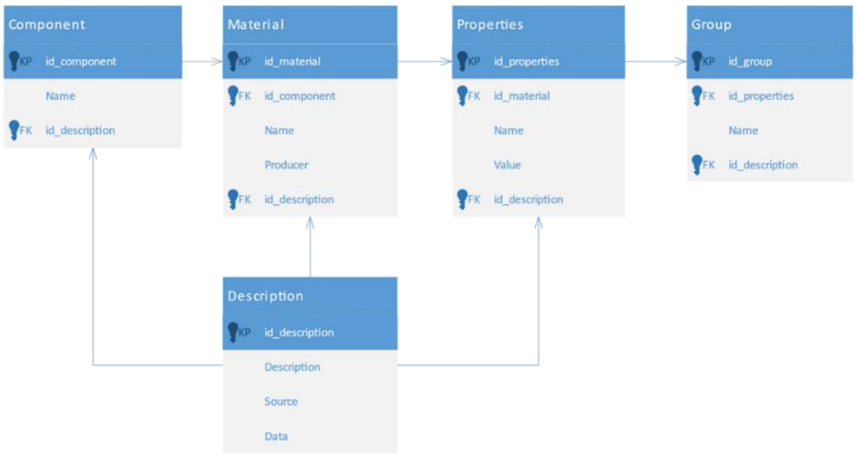


Fig. 3: Scheme of AMICI database demonstrator

More precisely, the four graphs of Fig. 4 clearly show the strong impact (i.e. large modification of the phonons peak at a temperature T~2K) of the plastic deformation of niobium on the thermal conductivity. It should be stressed bulk niobium SRF cavity are fabricated from Nb sheets using deep drawing and electron beam welding: during these two fabrication processes the material is subjected **to plastic deformation** that will **impact the performance** (i.e. thermal stability of the resonator in operation).

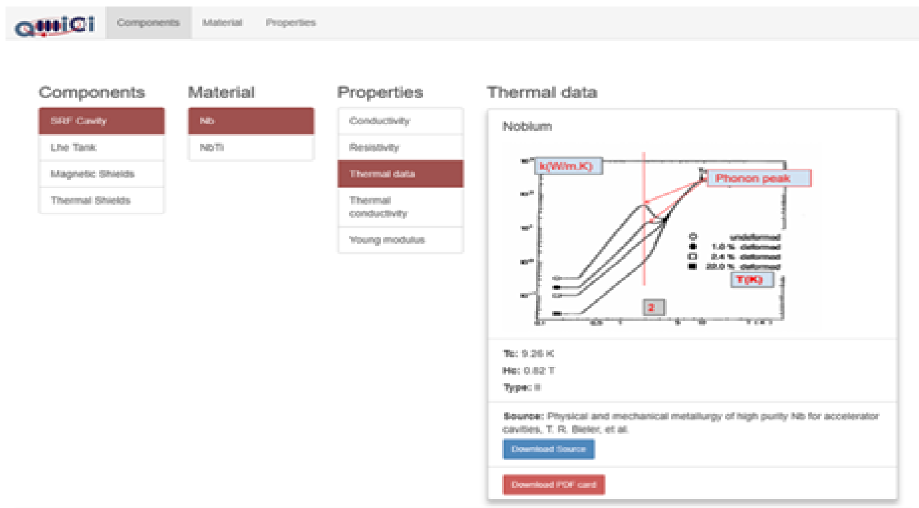


Fig. 4 Example#1 of output of the web application based demonstrators: effect of plastic deformation on thermal conductivity of niobium

The graphs of Fig. 5 show a second set of thermal conductivity data of niobium of different purities and from different suppliers: the niobium samples were tested as received or subjected to heat treatment prior to the tests. These data show large variations of thermal conductivity data depending on the material purity, the supplier and the heat treatment.

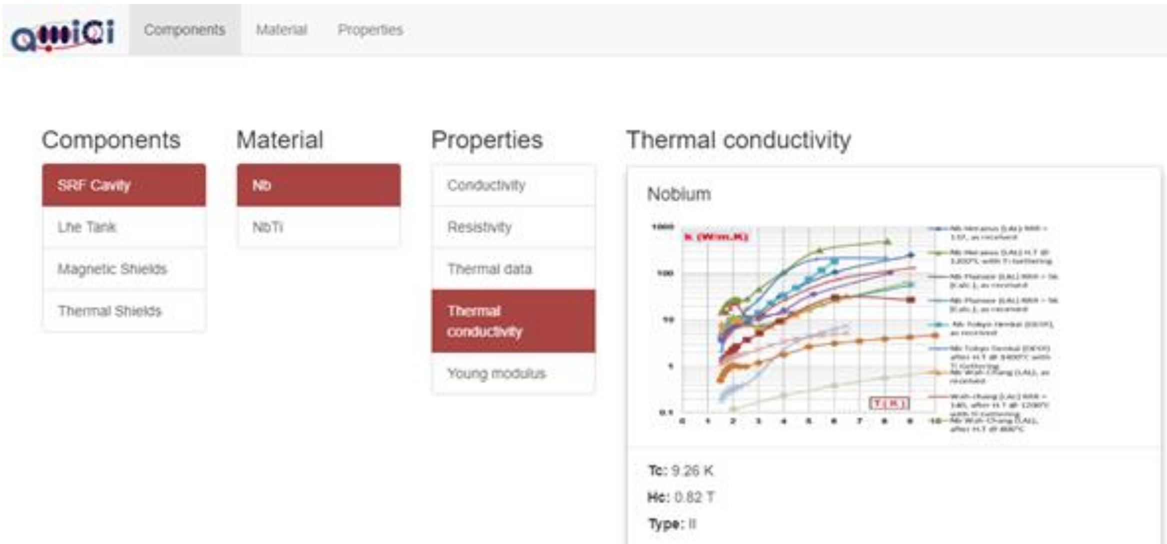


Fig. 5: Example#2 of output of the web application based demonstrators: effect of heat treatment on the thermal conductivity of niobium from various suppliers.

8 Database main requirements and proposed final solution

8.1 Main requirements

The database for accelerators and SC magnets to be developed will use as source the data of publicly available peer-reviewed publications, validated and accepted data available in Technological Infrastructures as well as old data available in existing databases. All the data to be included in the database should be validated/approved by a committee of experts. **This committee is a kind of Scientific Advisory Board of expert well recognized worldwide.** A first, but non-exhaustive list of the different fields of expertise in accelerator and magnets design, construction and operation needed for validating and approving the data to be included in the database to be developed is detailed in Annex 1.

The database should be publicly accessible and free of charge. However, a part of these data could be located if necessary in a restricted area (i.e. password protected).

The database should be managed by an institution independent from the single institutes: it is the responsibility of the consortium management to define and create this institution in charge of database management and to define its mission, the rules and conditions for accessing it. **To this aim the integrated Technological Infrastructure envisaged by AMICI looks to be an ideal candidate.**

The sustainability (i.e. the database should be kept alive) of the database as well as its maintenance should be insured by the institution in charge of the management of the database.

Obviously, it should be updated continuously by adding new data and/or link to other existing databases.

The implementation, the upgrade of the software used for the database development should be coordinated and synchronized as best as possible across the consortium involved in the project.

8.2 Choice of software for database, configuration and architecture

Several meetings with database experts from IT department of IPNO/CNRS, IFJ-PAN and Desy were organized in order to choose the best industrial software that will be used for the development and implementation of AMICI database. We have also a technical visit to Desy for a discussion with the expert who developed database concerning SRF cavities for several projects: Tesla Test Facility (TTF), FLASH and XFEL**.**

According to the database experts experience from Desy, IPNO/CNRS and IFJ PAN the ORACLE ^{TM} software seems to be suited for AMICI database.

The configuration and architecture of the information system of AMICI database could be similar to the system (Fig. 6) currently developed for XFEL/R&D cavity database. The final architecture of the system for AMICI database and its precise definition will be done prior to the implementation phase in a next project if resourced and funded.

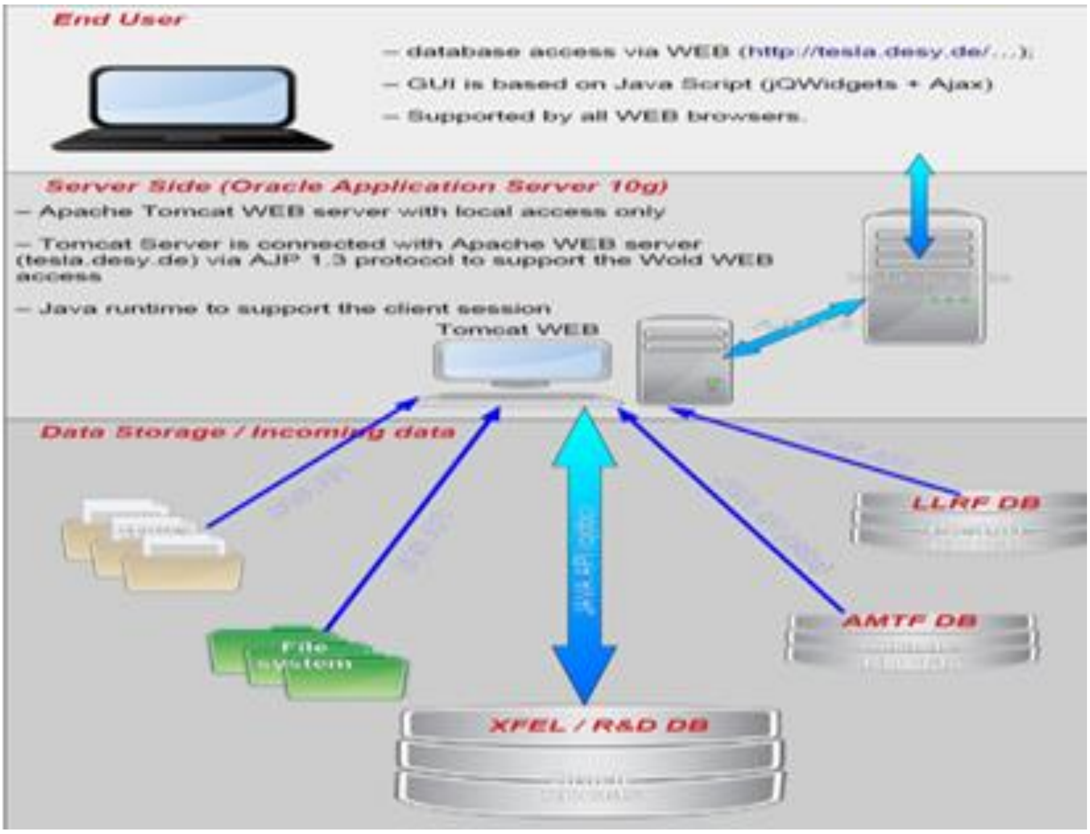


Fig. 6: Configuration of the system under development for XFEL/R&D cavity database.
(Courtesy Vladimir GUBAREV from DESY)

9 Conclusion

According to our current study, a database dedicated to our applications (accelerators and SC magnets) does not exist: the data needed are very specific to stringent the technology and the extreme operating conditions (i.e. at cryogenic temperatures or at high temperature, at vacuum or at high pressure, in radiation environment). Furthermore, the material and component specifications are very demanding (high performance at the frontier of technology in terms of performance reliability, availability, efficiency and energy saving).

In the context of strong competition worldwide, such database is really needed and will help European institutes and industry to significantly contribute and to play a leading role in future European and international projects. We have defined the possible structure and content of a database for materials and components for accelerators and magnets dedicated to scientific instruments.

The concept of the proposed database is based on a functional breakdown structure of a complex system. We described in details (Annex 1) of how to proceed through an example, namely the spoke section of the superconducting linac of ESS (European Spallation Source) under construction.

We have surveyed the existing databases that include data, which could be useful for accelerators and large magnets. We have also defined the criteria to guarantee the validity and reliability of the data to be included in the database.

We have collected and organized an initial set of basic data and data sheets relevant to the issue of Material and components specifications.

We should insure the maintenance of the database over time and continuously update it in terms of its functionality and the data included.

We have proposed a list of experts in Europe to which the team developing the database should refer for: (1) defining the key words (database input), (2) describing the critical component of the various parts of the accelerator and/or large magnet, (3) defining the relevant properties useful for design, construction and operation of these complex systems.

An initial database demonstrator base on web application was developed.

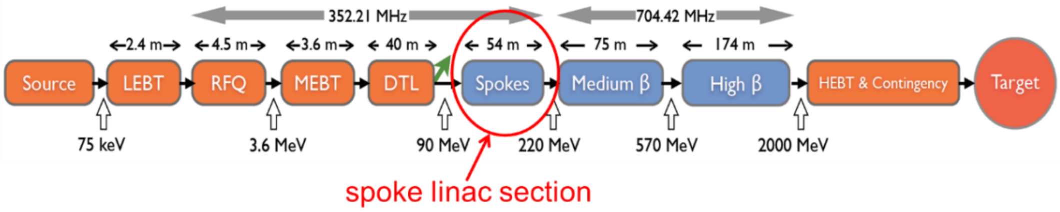
A possible architecture of the information system, based on ORACLE ™ software, for the database development and implementation was described. We have now sufficient material for the implementation of the database.

As a first step, it is necessary to have the database demonstrator tested by possible end-users to check that it corresponds to their expectations and, if necessary, adjust it following their recommendations.

Annex 1

1. ESS linac as example of how to proceed

In this section we will give the detailed process of how to proceed through an example: the challenging superconducting proton linac of European Spallation Source (ESS) under construction. The layout of ESS linac is illustrated in Fig. 1.



Section	Cavity β	Total number of Modules	Cavity frequency	# Cavity per module	# Cavity per section	Cryomodule length	Section length
Spoke	0.50	14	352 MHz	2	28	~ 2.9 m	58.5 m
Medium-beta	0.67	15	704 MHz	4	60	~ 6.7 m	113.9 m
High-beta	0.92	30	704 MHz	4	120	~ 6.7 m	227.9 m
Total		59			208		~ 400 m

Fig. 1 Layout of ESS linac

The layout of Fig. 1 shows clearly the different parts of the linac according to their respective functions as illustrated in Table 1.

Table 1: main parts of the ESS linac according to their function

Part #	Name	Description	Main Function
1	Source	Protons source	Particle production
2	LEBT	Low Energy Beam Transport	Beam transport
3	RFQ	RadioFrequency Quadrupole	Beam bunching, acceleration and transverse Focusing
4	MEBT	Medium Energy Beam Transport	Beam transport
5	DTL	Drift Tube Linac	Beam acceleration
6	Spoke	Spoke superconducting section	Beam acceleration from 90 MeV to 220 MeV
7	Medium β	Medium β superconducting section	Beam acceleration from 220 MeV to 570 MeV
8	High β	High β superconducting section	Beam acceleration from 570 MeV to 2000 MeV

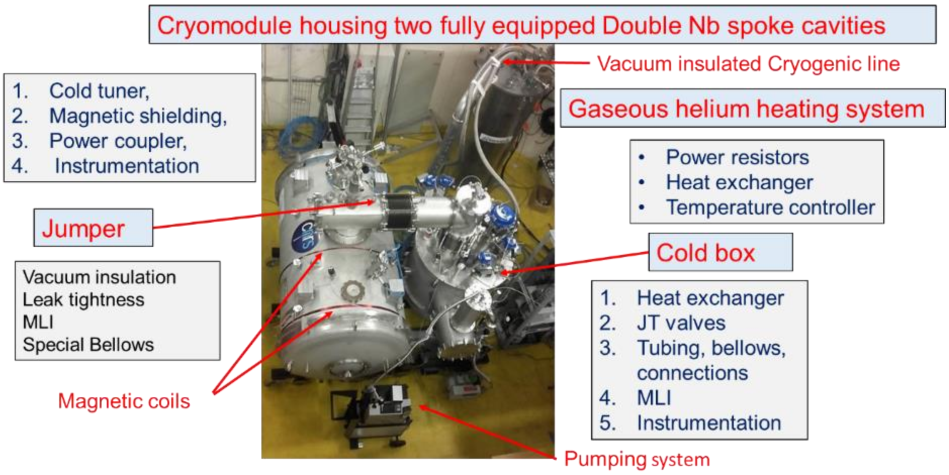


Fig. 2 Main components of a cryomodule with its cold box

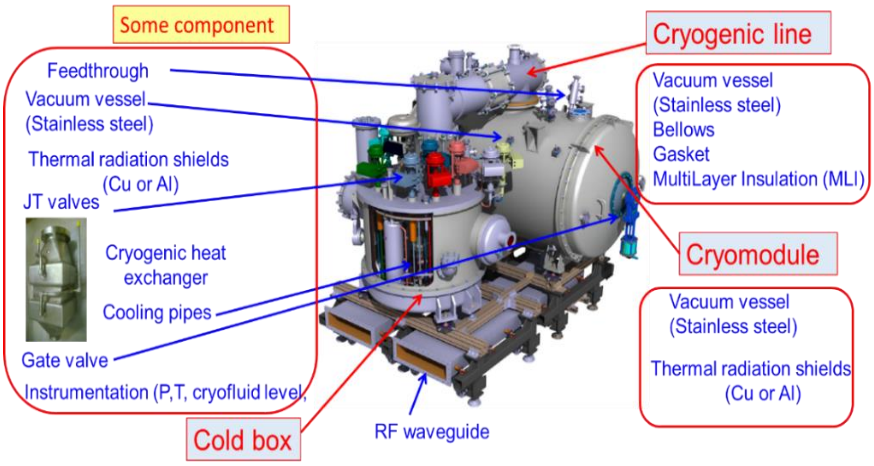
Now we will focus on the spoke linac section for a more detailed description. This spoke linac consists of a chain of 14 CryoModules (CM) with their respective cold boxes connecting the CM to the cryogenic main distribution line via a jumper.

The main components (Fig. 2) of a cryomodule with the cold box are:

- the stainless steel vacuum vessel,
- two Double-Spoke superconducting resonators housed in the vacuum vessel,
- the cold tuning system,
- the RF power coupler,
- the magnetic shielding,
- the thermal radiation shields,
- the instrumentation.

These main components include various element and/or critical parts impacting directly the performance and or the functionality of the cryomodule: some of them are illustrated in Fig. 3.

Fig. 3 Some components of a cryomodule with its cold box



2. The properties needed for design, fabrication and operation of SRF cryomodule

2.1 Examples of relevant properties and impacted parameters

Some of the relevant properties, in correlation with the impacted parameters, are illustrated in Fig. 4. In this example, the keyword or database input is ‘Accelerating SRF Cryomodule’ or SRF CM. Then we access to a typical 3D drawing of the SRF CM describing the different component in terms of their function (in blue): gate valve, thermal radiation shields, … The outputs of the database are: 1) the table correlating the material physical properties to the impacted parameter, 2) the relevant data in various format (table, graph, journal paper reference, link to a website of another database). Note that the construction of this table as well as the data to be included in the database should be validated/approved by a committee of experts (please refer to next section of the current report). **<u>This committee is a kind of Scientific Advisory Board of expert well recognized worldwide.</u>**

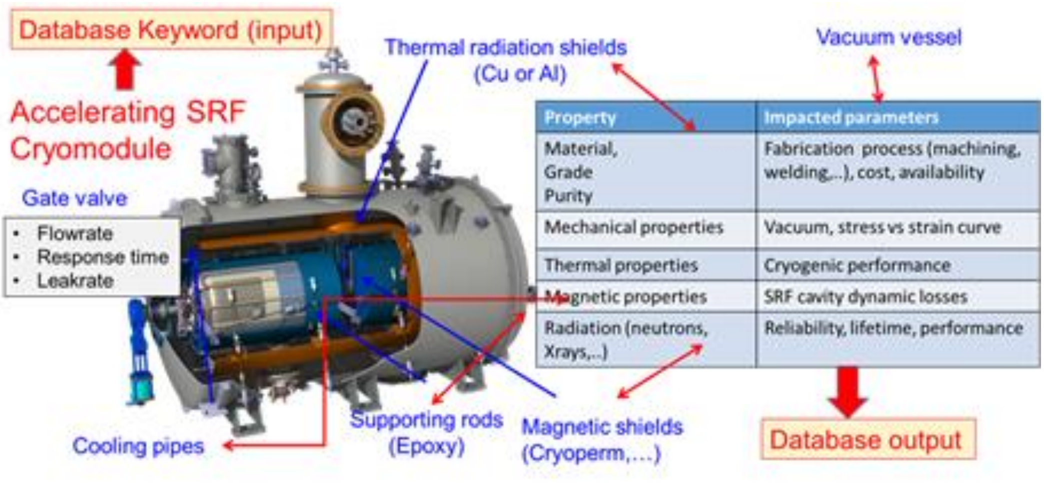


Fig. 4 Relevant physical properties in correlation with the function of some component of a SRF cryomodule

2.2 Examples of critical components of a SRF cryomodule and relevant data

- *<u>RF power coupler</u>*

The main function of the RF power coupler (Fig. 5) is the efficient transfer, in matched condition, of the RF power from the source through the waveguide network to the particle beam.

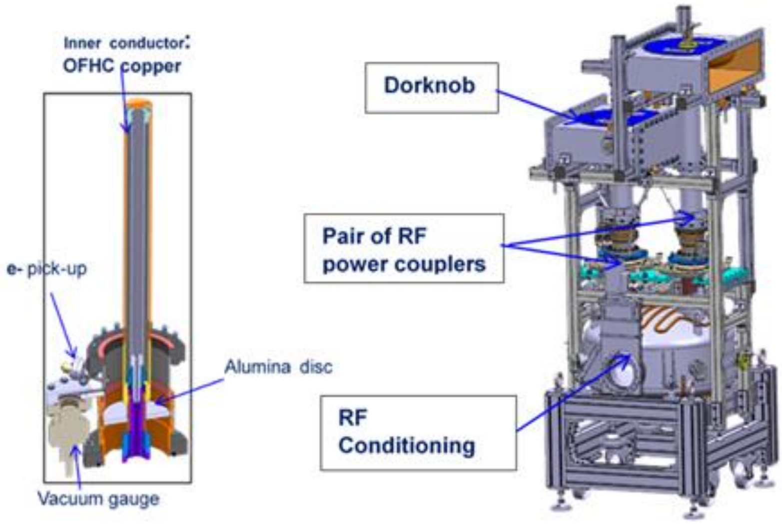


Fig. 5 Typical 3D drawing of a RF power coupler (left) and test stand for RF conditioning (right).

This complex device operates in stringent conditions:

a) Handle and transmit a high RF power (10 kW-500 kW) through a ceramic window,

b) It is a thermal interface between warm (T = 300 K) and cold parts (T = 2–4.2 K) of the cryomodule

c) It is a RF transparent vacuum barrier between atmospheric pressure in the wave guide operating at room temperature and ultrahigh vacuum (<10^{-8} mbar) in the SRF cavity at T= 2 K.

In some applications, the reliability of the RF power coupler could be very demanding: for example, in the case of the ADS (Accelerator Driven System) SRF based linac MYRRHA, less than five beam trips in excess of 1 s duration per year are tolerated.

The data relevant to RF coupler design, engineering, fabrication, conditioning and operation should include:

1. The physical properties impacting the performance (electrical, mechanical and thermal properties of materials, secondary emission coefficient, …)
2. Information about referenced industrial know how (i.e. past successful experience) in the following items: a) High RF power (Klystrons, IOT, ...), b) High power RF components (WG, loads, ...), c) Alumina window, d) Vacuum brazing, e) Surface treatment (Copper plating of inner and outer conductors, TiN coating of Alumina window), f) Mechanical fabrication and assembly, g) Instrumentation (vacuum, light, electron activity, …).

- *Cold tuning system*

The main function of Fast Active Cold Tuning System (FACTS) for SRF cavities is to match the cavity resonant frequency to RF source frequency. The FACTS allows high performance operation of the linac: 1) improved beam quality in terms of phase and energy stability, 2) Increased acceleration efficiency resulting in the reduction of operating cost and energy saving. A FACTS is a complex mechanical system (Fig. 6) including two complementary parts: 1) a coarse tuning mechanism, 2) a fine tuning mechanism having the following functions:

1. ***Slow and coarse tuner***

   Slow and long range (~2mm, 500 kHz) resonant frequency adjustment during cool down from room temperature (T~300 K) to liquid helium temperature (T=2 K). It is actuated with a stepping motor and a planetary gear box.

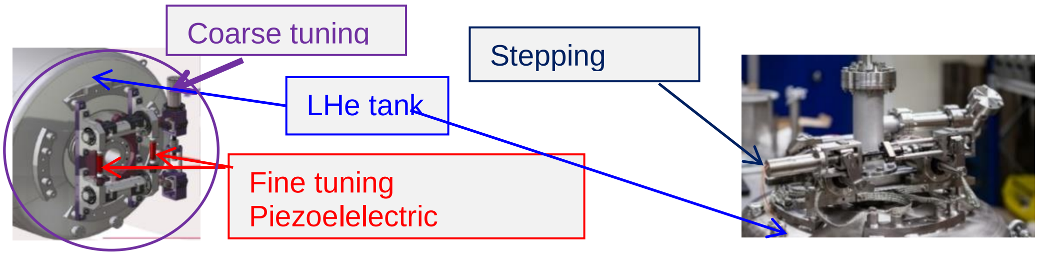


Fig 6. Fast Active Cold Tuning System developed by IPNO for ESS spoke linac section

2. ***Fast and fine tuner***

   Fast active dynamic compensation of short range (~4µm, 1kHz) Lorentz detuning during cavity operation. It is actuated with a piezoelectric element.

3. Fields of expertise of the scientific board

A first, but non-exhaustive list of the different fields of expertise in accelerator and magnets design, construction and operation needed for validating and approving the data to be included in the database to be developed is detailed below:

- Particle sources (electrons, positrons, ions).
- Beam transport.
- Beam diagnostics.
- Vacuum and surface preparation.
- Cryogenics.
- RFQ.
- SRF cavities, Power couplers, HOM couplers, Cold Tuning Systems, Magnetic shielding, horizontal cryostats, Cold boxes, cryogenic instrumentation.
- LLRF, timing.
- High power RF sources and distribution.
- Normal conducting cavities.
- Beam dynamics.
- Beam dump.
- Interaction region.
- Superconducting magnets (dipoles, quadrupoles, correction magnets), magnet protection system, current leads, magnet cooling, pressurized superfluid helium.
- Power sources for magnets.

4. Part of database dedicated to magnets

The European project FuSuMaTech concerns mainly superconducting magnets R&D in Europe. As a large part of magnets experts from academia institutes are involved in both AMICI consortium and FuSuMatech, it was decided to have a discussion as early as possible with reference to the AMICI and FuSuMatech respective timelines.

The goal of AMICI-FuSuMaTech discussion is to investigate and examine collaboration opportunities in some close topics of the two projects. A first meeting was organized at IPN Orsay in November 2017 and a report was issued. The discussion was mainly focused on the activities within AMICI and FuSuMatech that have strong similarities, namely the tasks WP5.2 (AMICI) and T4.2 (FuSuMatech), which are both dedicated to database development.

It was decided to have a collaboration and a tight coordination of the above mentioned tasks in order to avoid to duplicate the work and cover better the topics of the two complementary databases (i.e. AMICI WP5.2 and FuSuMaTech T4.2).

A second meeting was organized at RAL/STFC: we visited Simon CANFER (leader of FuSuMatech T4.2). Note that the implementation of FuSuMatech database is not part of T4.2 and not currently resourced via STFC. This situation is similar to that of AMICI database implementation.

4.1 Brief description of FuSuMaTech T4.2

The objectives of the task T4.2 are:

1. Plan a comprehensive open access, web based, trusted database
2. Form a network of interested partners
3. Write a specification for a database
4. Identify existing and new materials
5. Propose a scheme for long term management
6. Liaise with the International Bureau of Weights and Measures

The task T4.2 includes 6 subtasks:

- T4.2.1 - Determine the standard measurement data format with detailed property data points covering the full operating temperature ranges from research activities, applications and industry, by liaison with representatives from academia and industry sectors 2.
- T4.2.2 - Collect existing data, verifying its accuracy and its fit with the standard format
- T4.2.3 - Identify existing and new materials not yet measured.
- T4.2.4 - Develop a network of testing facilities, in which the different material properties can be measured.
- T4.2.5 - Propose a scheme for long time management of this data with succession

- T4.2.6 Preparation of a proposal for the creation of a new database of Material properties at Cryogenic temperature

4.2 Superconducting magnets

SuperConducting magnets (SC magnets) are used for various applications such as particle accelerators, High Energy Physics (HEP) detectors and other scientific instruments (e.g. fusion, MRI, medical instrumentation): some examples are illustrated in Fig. 7.

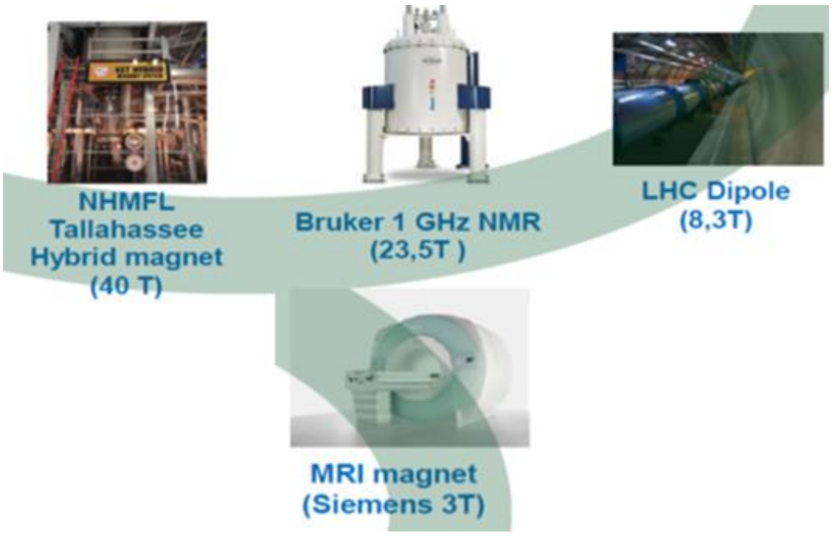


Fig. 7 Some examples of application of SC-magnets

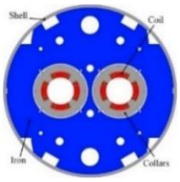
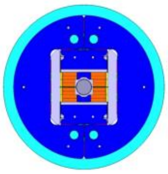
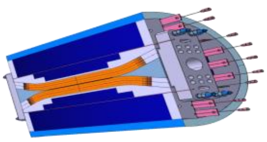
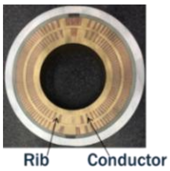
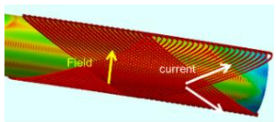
The SCmagnets could be classified according to their function in the machine. The non-exhaustive typology (according to their function) is illustrated in Table 2.

Table 2: Typology of SC magnets for accelerators, detectors and other scientific instruments.

Accelerator magnets (LHC, HL-LHC, FCC)	
Main magnets	Correction magnets
Dipoles	sextupoles
Quadripoles	octupoles
	decapoles
Insertion zone magnets	
Detector magnets	
Solenoid (CMS)	
Toroid (ATLAS)	
Other applications	
Fusion	
tokamak (ITER, JT60-SA)	
stellerator (W7X)	
Medical applications (Iseult)	
Space applications	

A second criteria is used for SC magnets description (Table 3): it is based on their type (e.g. Cos Theta, Block, …). It should be stressed the function of magnets determines: 1) the electromechanical design, 2) mechanical configuration of the magnet structure, 3) the type of cable that to be used for the fabrication of the coil, 4) the cooling mode of the magnet/cable in close relation with the type of cable and the performance to be achieved.

Table 3: Some examples of type of SC magnets according to their functions

Type	Type of magnet Example	Sketched drawing	Cable
Cos Theta	Quadrupole Q4		
Block	FRESCA2		
Canded Cos Theta	LBNL		

Various SC materials, wires, tapes, conductor type (Fig. 8) and configuration (thermal stabilization, cooling, …) could be used depending on the application, performance needed and other criteria such as cost, ...

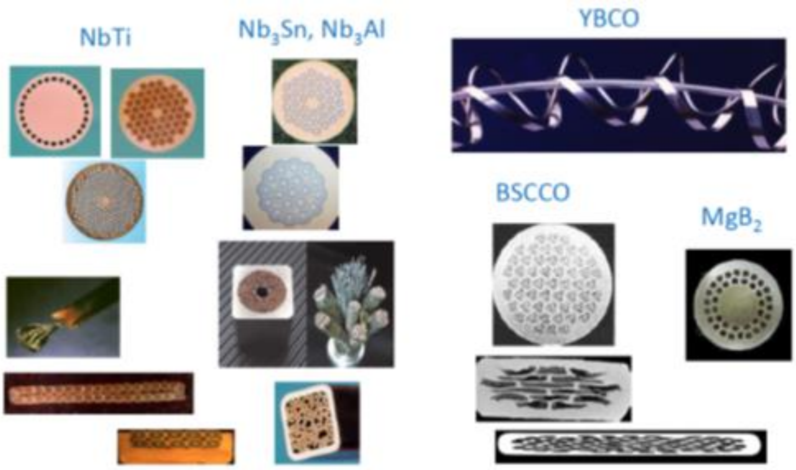


Fig. 8 SC materials for superconducting magnets (Courtesy. Lionel Quettier)

Similarly, to a SRF cryomodule, information and data concerning SC magnet could be retrieved following the workflow diagram of Fig. 9. More precisely, the **input to database** is the key word **'function of the magnet'**, while the **properties of a critical component in relationship with a characteristic parameter** are the **output of database**.

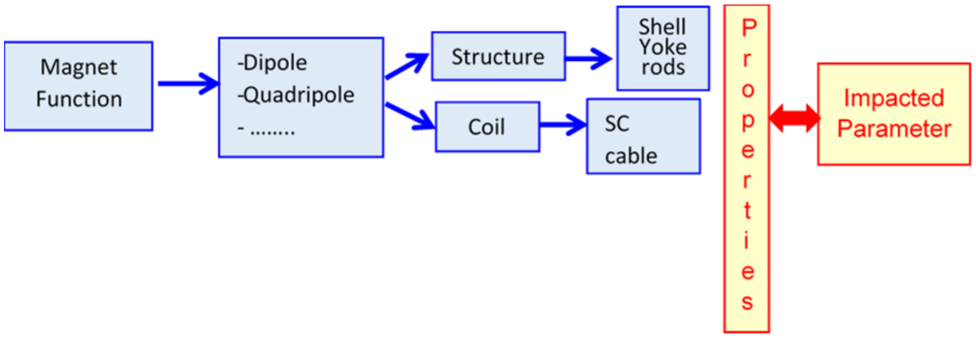


Fig. 9 Schematic workflow flow diagram for SC magnets

For SC magnets we will proceed as for top-down as for accelerators. The process will be as follow:

1. ***Data base input***
- Description of the cryomodule housing superconducting magnet and ancillaries
- Definition of the Critical component of magnet and SC-magnet cryomodule.
- Main component of type of cable for the SCmagnet coils in relation to specific application
2. ***Data base output***
- Relevant properties in correlation with the impacted SC magnet parameters (performance reliability, manufacturing issues, ….)

The SC- magnets database part should include among other data/information: 1) Magnet design and computation software (CAD, electromagnetic, mechanical/structural and thermal calculation), 2) Tooling used for production of prototypes, 3) SC magnets cables fabrication process, 4) Description of the qualification tests of SC cables (i.e. mechanical, thermal, electrical properties at cryogenic temperatures), 5) Cryogenic cooling scheme and modes, 6) Instrumentation, magnet protection and quench management system, 7) safety and cryogenic hazard issues.

Annex 2

Available sources of data in the field of cryogenics and superconductivity:

They are mainly Conference Proceedings, Journals and Periodicals and Books

I. Conference Proceedings

Cryogenic Engineering Conference / International Cryogenic Materials Conference

Proceedings from CEC/ICMC are collected in Advances in Cryogenic Engineering, Volumes 1 – 63, published at various times by Plenum Press, AIP Press, Springer and IOP. The conference is held biennially (odd years) in North America.

A list of proceedings from 2011 to present is available on the CEC/ICMC website. Direct links to the most recent volumes are provided below. These volumes are completely open access, and you are free to download, copy or distribute to anyone. You are also free to share these links to any and all, and they will have free access to the full set of articles.

Proceedings from the 2015 CEC/ICMC

— 2015 Cryogenic Engineering Conference

— 2015 International Cryogenic Materials Conference

Proceedings from the 2017 CEC/ICMC

— 2017 Cryogenic Engineering Conference

— 2017 International Cryogenic Materials Conference

The CEC/ICMC conferences have gone bookless, though attendees through 2015 had the option to purchase a printed copy when registering. A few copies are available through Centennial Conferences.

International Cryogenic Engineering Conference and International Cryogenic Materials Conference

ICEC/ICMC is held biennially (even years) in Europe or Asia. Proceedings from the 26th ICEC/ICMC (2016) are available in open access from IOP Science.

Applied Superconductivity Conference

The biennial ASC (even years) is held in North America and focuses on all aspects of applied superconductivity. IEEE Xplore publishes the conference proceedings as the ***IEEE Transactions on Applied Superconductivity***, and provides online, though not open, access to volumes published from 1991 onward. One must be a member to access the papers. Printed copies are available direct from IEEE.

Magnet Technology Conference

This biennial conference (odd years) is dedicated to all aspects of Magnet Technology, with a significant focus on superconducting magnets. The conference proceedings are published in a special volume of the IEEE Transactions on Applied Superconductivity. The most recent conference website is accessible here.

International Cryocooler Conference

The biennial ICC (even years) covers all aspects of cryocooler research and applications. Proceedings from past conferences are available on the ICC webiste, where registration is currently open for ICC20.

Space Cryogenics Workshop, a Division of CSA

This is a biennial workshop (odd years) dedicated to the use of cryogenics in space exploration and research. Selected papers may be found in the journal Cryogenics. Proceedings from the 2009 Space Cryogenics Workshop, Sidney Yuan, ed., are available in print for purchase from CSA.

Superconducting Radiofrequency Workshop

This is a biennial conference (odd years) on all aspects of RF superconductivity. The conference proceedings are published on the Joint Accelerator Conferences website.

II. Journal and periodicals

- Cold Facts is currently published six times a year by the Cryogenic Society of America. Issues starting at Vol. 2, #1, March 1985, are archived as PDFs in CSA's member section and select back issues are available from CSA for $35.
- Cryogenics is a monthly refereed journal published by Elsevier Science. It covers all aspects of cryogenic engineering and science.—Journal of Low Temperature Physics is a biweekly international medium for the publication of original papers and review articles on fundamental theoretical and experimental research developments in all areas of cryogenics and low temperature physics.—Low Temperature Physics is published monthly by the American Institute of Physics (AIP) and reports on experimental and theoretical studies.
- Journal of Applied Physics is an international journal that reports significant new experimental and theoretical results of applied physics research. It is published by AIP.—Journal of the Cryogenics and Superconductivity Society of Japan. Teion Kogaku is published by JCSJ.
- Physics Today is the flagship publication of the AIP, informing readers about science and its place in the world with authoritative features, news stories, analysis and fresh perspectives on technological advances and ground-breaking research.
- Journal of Heat Transfer is published monthly by the American Society of Mechanical

Engineers, disseminating information of permanent interest in the areas of heat and mass transfer. Contributions may consist of results from fundamental research that apply to thermal energy or mass transfer in all fields of mechanical engineering and related disciplines. Also, archival results of research that focuses on the evaluation of thermophysical properties associated with heat and mass transfer, as well as on the theory of heat and mass transfer, are published. The ***Journal of Heat Transfer*** is complementary to the ***Journal of Thermal Science and Engineering Applications***, which focuses on applications.
- Superconductor Week is a semi-monthly newsletter providing global coverage of the technology and commercialization of low- and high-temperature superconductors and cryogenics for large- and small-scale applications. It offers readers a combination of original reporting, exclusive interviews and expert analysis designed to provide valuable insight and mission-critical information on the industry. Klaus Neumann serves as executive editor.
- Superconductivity News Forum (SNF, Global Edition) is published quarterly by the European Society for Applied Superconductivity and the IEEE Council on Superconductivity. All issues are accessible on the front page.
- Low Temperature News is published by the British Cryogenics Council. John Vandore, john@vandore.com, serves as editor.
- Gasworld serves the international industrial gas industry. Contact Rob Cockerill, global managing editor, rob.cockerill@gasworld.com. Gasworld has acquired both the ***Specialty Gas Report*** and ***Cryogas International***, which became part of the Gasworld US edition in 2013.

III. Books

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Design and Design Manuals

— R.Barron, Industrial Noise Control and Acoustics, CRC, 2005. This book describes useful procedures in the design of industrial noise abatement systems and equipment to reduce the generation and transmission of noise and to comply with OSHA, EPA and other standards. Cryogenic engineers can apply the information to design for noise reduction from compressors, pumps, fans and other equipment used in gas liquefaction systems. Contains case studies and example problems illustrating the principles discussed in each chapter.
—Eden Cryogenics, Cryogenic Design Guide, Contact Eden Cryogenics directly to obtain a copy. Eden's Design Guide covers a variety of cryogenic equipment, engineering, design and manufacturing methods. It is split into two sections: 1) Cryogenic Systems (Understanding the Basics) and 2) Cryogenic Component Selection. Section 1 defines and discusses cryogenic cooling systems, cryogenic refrigeration and liquefaction systems, cryostats, cryogenic dewars and vessels and vacuum insulated piping. Section 2 provides assistance in the selection of cryogenic components which include cryogenic valves, filters and couplings.
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—DOE, symmetry magazine, symmetry is an online magazine about particle physics and its connections to other aspects of life and science, from interdisciplinary collaborations to policy to culture. A joint publication of Fermi National Accelerator Laboratory and SLAC National Accelerator Laboratory, symmetry receives funding through the US Department of Energy.
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IV. Websites and Databases

—Cryogenic Society of America
—CSA Space Cryogenics Workshop
—CSA Cryogenic Treatment Database
—NIST Cryogenic Technology Resources
—The Cryogenics Society of Europe
—The British Cryogenics Council
—The Cryogenics and Superconductivity Society of Japan
—IEEE Council on Superconductivity
—The Compressed Gas Association
—The Refrigeration and Cryogenics Association of Romania
—The Society for Cryobiology
—The Indian Cryogenics Council
—The International Society of Cryosurgery