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Fast Reactor Knowledge Preservation System: Taxonomy and Basic Requirements

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FAST REACTOR KNOWLEDGE PRESERVATION SYSTEM: TAXONOMY AND BASIC REQUIREMENTS

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FOREWORD

The IAEA has taken the initiative to coordinate efforts of Member States in the preservation of knowledge in the area of fast reactors. In the framework of this initiative, the IAEA intends to create an international database compiling information from different Member States on fast reactors through a web portal. Other activities related to this initiative are being designed to accumulate and exchange information on the fast reactor area, to facilitate access to this information by users in different countries and to assist Member States in preserving the experience gained in their countries.

The purpose of this publication is to develop a taxonomy of the Fast Reactor Knowledge Preservation System (FRKPS) that will facilitate the preservation of the world's fast reactor knowledge base, to identify basic requirements of this taxonomy on the basis of the experience gained in the fast reactor area, as well as results of previous IAEA activities on fast reactor knowledge preservation.

The need for such taxonomy arises from the fact that during the past 15 years there has been stagnation in the development of fast reactors in the industrialized countries that were involved, earlier, in intensive development of this area. All studies on fast reactors have been stopped in countries such as Germany, Italy, the United Kingdom and the United States of America and the only work being carried out is related to the decommissioning of fast reactors. Many specialists who were involved in the studies and development work in this area in these countries have already retired or are close to retirement. In countries such as France, Japan and the Russian Federation that are still actively pursuing the evolution of fast reactor technology, the situation is aggravated by the lack of young scientists and engineers moving into this branch of nuclear power.

Appreciation is expressed to all the participants who contributed to this publication. Particular thanks are due to Mahadeva Rao Koorapaty[†], India; Yu.M. Ashurko, Russian Federation, and A. Badulescu, Romania for their assistance in the compilation of this report. The IAEA officers responsible for this report were A. Stanculescu and A. Kosilov of the Department of Nuclear Energy.

[†] Deceased.

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1. INTRODUCTION

1.1. OBJECTIVES

The purpose of this publication is to develop a taxonomy of the Fast Reactor Knowledge Preservation System (FRKPS) that will facilitate the preservation of the world's fast reactor knowledge base, to identify basic requirements of this taxonomy on the basis of the experience gained in the fast reactor area, as well as results of the previous IAEA activities on fast reactor knowledge preservation. Throughout this publication the meaning of the term 'taxonomy' is in accordance with its definition given in Ref. [1]: Taxonomy — a hierarchical structure in which a body of information or knowledge is categorized, allowing an understanding of how that body of knowledge can be broken down into parts, and how its various parts relate to one another. Taxonomies are used to organize information in systems, thereby helping users to find it".

1.2. BACKGROUND

The need for such a taxonomy arises from the fact that during the past 15 years there has been stagnation in the development of fast reactors in the industrialized countries that were involved, earlier, in intensive development in this area. All studies on fast reactors have been stopped in countries such as Germany, Italy the United Kingdom and the United States of America, and the only work being carried out related to the decommissioning of fast reactors. In France, the programme on fast reactors has been considerably reduced. Many specialists who were involved in the studies and development work in this area in the above countries have already retired or are close to retirement. Besides, in countries such as France, Japan and the Russian Federation that are still actively pursuing the evolution of fast reactor technology, the situation is aggravated by the lack of young scientists and engineers moving into this branch of nuclear power.

However, the global scientific community acknowledges that fast reactors are promising and are essential for tapping the huge potential of nuclear power for contributing to the economic development of the world. A confirmation of this thesis may be seen from the development of fast reactors in Asia (China, India, Japan, Republic of Korea) as well as the revival of interest in fast reactors in the developed countries within the framework of the INPRO and Generation-IV programmes. This is the evidence that fast reactor technology will undoubtedly play an important role in the future.

In this connection, preservation of knowledge and experience gained in the fast reactor area assumes great importance in forming the basis for further improvements in designs of future fast reactors. Efforts are being made in the countries concerned to varying degrees in order to ensure the preservation of the worldwide knowledge and experience gained so far.

France has done considerable work on preservation of knowledge and experience gained in the development of sodium cooled fast reactors (RAPSODIE, PHENIX, SUPERPHENIX, EFR and experimental facilities), as well as operating experience and has established some documentary banks. The largest documentary bank, called MADONA Encyclopaedia [2, 3], includes all aspects of technology of sodium cooled fast reactors (SFR). A special database has been created on all components and systems of the Superphenix reactor [3].

In Japan, all technical documents and principal databases are stored in various topical systems of knowledge preservation on SFR and, in particular, on the JOYO research reactor [4, 5] and MONJU demonstration reactor [5]. Currently, a discussion on a general database on SFR and its development for JNC/JAERI (Japan Nuclear Cycle Development Institute/Japan Atomic Energy Research Institute) Joint Institute is under way. A special Super Archive has been created in the UK for the purpose of preservation of experience gained in the SFR area, in particular at the Prototype Fast Reactor (PFR) [6]. An electronic catalogue of documents issued on the research reactor KNK-II has been created [7]. Some work has been carried out in the Russian Federation on the preservation of knowledge on fast reactors. In particular, a database on experimental studies carried out at BFS-1 (Bolshoi Fizicheskiy Stand-1), BFS-2 (Bolshoi Fizicheskiy Stand-2) and KOBR (Koltsevoi Bystryi Reaktor) critical facilities at the IPPE (Institute for Physics and Power Engineering) has been

created [8]. A bibliographical catalogue of documents on SFR issued has been developed with IPPE participation.

The above approaches systematize the knowledge and experience on fast reactors gained at specific reactor facilities that have been designed, constructed and operated in each country. Such an approach is justified in general since preservation of practical experience and knowledge gained in design, construction and operation of specific reactors is undoubtedly an urgent task.

Preservation of knowledge gained in the SFR area has already acquired an international significance and has received a high priority within the framework of IAEA activities in this area. Several IAEA meetings have been organized on the preservation of SFR knowledge, including those held in Cadarache, France (March 2002), Idaho Falls, USA (April 2002), Daejeon, Republic of Korea (May 2003) and Obninsk, Russian Federation (February 2005). A preliminary version of the FRKPS structure was proposed at an IAEA consultants meeting in December 2004 in Vienna. This publication further develops the generalized FRKPS structure on the basis of:

— SFR experience gained in the Russian Federation;
— Suggestions and recommendations received at the IAEA meetings on this topic;
— Successful approaches implemented in the course of development of specific systems of SFR knowledge preservation in some countries such as France and Japan.

It should be noted that the structure means not only the arrangement of information in FRKPS, but also the format of its presentation.

1.3. SCOPE

The IAEA has taken the initiative to coordinate efforts of the Member States in the preservation of knowledge in the area of fast reactors. In the framework of this initiative, the IAEA intends to create an international database combining information from different Member States on fast reactors through a web portal it has established and maintained. Other activities related to this initiative are being designed to provide accumulation and exchange of information on documents issued in the fast reactor area, to facilitate access to this information by users in different countries and to assist the Member States in preserving the experience gained in their countries.

A consultants meeting was held in Vienna in December 2004 , to discuss the issues of development and maintenance of an international FRKPS. An outcome of this meeting was the recognition that the creation of the taxonomy of the FRKPS was one of the urgent tasks for this purpose and a preliminary draft was developed. Under the coordination of the IAEA, the taxonomy was further developed to its current form based on a study of the Russian experience on fast reactors. Results of this study were also reviewed by experts from the USA and the IAEA at a special meeting organized for this purpose. This publication consolidates the results of the above study and lays the foundation for the taxonomy of the international database on fast reactors, along with the next steps that will formulate the required computer software and then test the concept with a pilot programme from participating countries. Thus the report may be useful for computer specialists who will create the software for the IAEA web portal, as well as for those who wish to develop similar electronic databases on fast reactors in different countries.

1.4. STRUCTURE

This publication describes the taxonomy of FRKPS and its basic requirements. Section 2 presents the concept of the FRKPS and its structure, and formulates the main requirements to be met by this taxonomy. Section 3 describes the FRKPS taxonomy that was developed, taking into account the requirements formulated in the previous section as well as proposals put forth at the IAEA consultants meeting in Vienna. Specific features, including a generalized topical structure that is universally applicable to different stages of development of fast reactors, are also discussed as a component of the FRKPS (specific branches of root structure of the FRKPS are presented in the Annex). Section 4 describes the format of presentation of

documents to be included in the FRKPS. Section 5 is devoted to the role of key words in the developed FRKPS taxonomy and an approach to their formation. Section 6 presents some recommendations to the users on desirable opportunities in the FRKPS. Section 7 describes further work that should be carried out on the FRKPS.

2. MAIN PRINCIPLES OF THE FRKPS AND ITS TAXONOMY

For the development of an appropriate taxonomy for the FRKPS it is necessary to describe the concept of this system and then to identify the requirements and principles that should be satisfied when developing its structure.

2.1. FRKPS CONCEPT

The main elements constituting the FRKPS concept are the following:

— The purpose for which the FRKPS database is created;
— The knowledge area covered by this database;
— The approach to presentation of information, which is contained in FRKPS;
— Target users of this database.

Elaboration of each of the above elements gives rise to the proposed concept of the FRKPS described below.

The main purpose of FRKPS is to ensure preservation of SFR knowledge and experience gained in different countries in a form that facilitates effective search and use of the stored information. It is assumed that a carefully structured electronic database would not only preserve knowledge on fast reactors, but also facilitate classification of information on SFRs accumulated in different countries and exchange of this information between countries.

The knowledge area covered by this database pertains to the knowledge accumulated on SFRs, since real experience is available only on this type of fast reactor. The database should cover all aspects of reactor technology related to SFRs, as well as all options for implementation (including personnel training and lessons learned from different phases of SFR development and implementation) ever used, since this is the only way to ensure preservation of SFR technology as a whole. Nevertheless, the taxonomy of FRKPS under development should also have the flexibility for storing information on other types of fast reactor in case they are chosen for implementation in the future.

The approach to the presentation of information contained in the FRKPS database is primarily based on the fact that it should be an electronic database, since that is the only option that offers the capability for a rapid and effective search of the required information. It is obvious that classification of the wide variety of available documents and other materials on fast reactors requires a unified approach to the presentation of these documents in the database. There are two possible methods for unification of document presentation in the FRKPS.

The first method is modification of the original documents in accordance with a pre-developed and unified electronic format, including their translation into any one language chosen for FRKPS, for example English. Such an approach appears to be hardly feasible because of the enormous scope of work and, hence, considerable demands on financial and time resources. Besides, if some documents contain proprietary information this may become a significant barrier to including these documents in the common database.

The second method, which is based on concise information cards that reflect the content of the original documents, is more practical. This does not preclude storage of the original document in the FRKPS if the owner agrees. The documents would not be modified from the original language. Thus, some documents would be transferred to the FRKPS in full while others that perhaps contain proprietary information would exist in the FRKPS only with a concise description of the content on the information card. This approach requires that the

owner of the document guarantees its existence and that the information card that is prepared in a specific format indicates the location of the document. When necessary, the user of the FRKPS can contact the document owner for permission to obtain the original document.

The target users of the FRKPS will likely be specialists working in the area of fast reactors and students. Fast reactor technology embraces a wide range of disciplines. Thus, the FRKPS taxonomy must reflect this range of disciplines with multiple divisions such as neutronics, fuels and materials, thermal hydraulics, etc.

2.2. MAIN REQUIREMENTS FOR THE FRKPS TAXONOMY

Based on the above proposed concept for the FRKPS, specific requirements (criteria) to be met by the taxonomy of this information system are discussed below:

- Sufficient versatility, making it possible to cover all possible types of fast reactor in addition to SFR, and thus taking into account all possible trends of development of fast reactor technology.
- Adequate unification assuming common topical sections related to all types of fast reactor, as well as a unified format of material presentation. This should significantly facilitate the use and maintenance of the FRKPS.
- Adequate comprehensiveness to cover all aspects of fast reactor technology and all significant experience available on each specific reactor facility.
- A hierarchical nature of the structure that ensures a progressively detailed elaboration of each aspect of fast reactor technology with increasing structural level.
- An optimum range of the structure that excludes superfluous detail and hence facilitates database operation.
- Reasonable redundancy, allowing duplication of information in various sections of the system to ensure the presentation of complete information at the level of some system sections.
- Capability of developing and expanding, if necessary, thus facilitating maintenance of the system.

3. FRKPS TAXONOMY

The Vienna meeting proposed a hierarchical structure for the FRKPS taxonomy, consisting of two upper levels of the FRKPS that are represented as a two-dimensional matrix in which elements of the upper row are stages of implementation of reactor technology (1st structural level of FRKPS), and the columns under the upper row elements include topical sections corresponding to given stages of reactor technology implementation (2nd structural level of FRKPS). This matrix is shown in Fig. 1. It is proposed to divide each topical section presented in the matrix into progressively detailed subsections and connect them in such a way that each subsequent level is a more detailed presentation of the previous level. Therefore, each topical section of the upper level will have a certain branched root structure consisting of specialized topical sections.

The matrix is claimed to be versatile because its structure was developed with a hypothetical, generalized SFR power plant in mind. Moreover, this structure is applicable not only to any SFR nuclear power plant irrespective of the stage of its development, but also to any experimental fast reactor. This structure would undoubtedly be redundant with reference to some specific reactor facilities. However, this redundancy has an advantage because a given document may have information on any one of several aspects of the SFR. It should be noted that the matrix structure development is still far from complete. First, topical sections of the upper level require more development and expansion. Second, the root structure should be developed for all these sections. However, this approach to the development of FRKPS taxonomy with separation of stages and topical sections of reactor technology as shown in the matrix is considered to be highly useful. This approach, which may be called the universal stage topical hierarchical structure, (USTS), will be used in the following sections as a starting point for the development of a new FRKPS taxonomy.

Basic principles	R & D	Design, analysis, licensing	Manufacturing & construction	Fuel cycle	Operation	Decommissioning
Fast fission	Reactor physics	General system criteria	Site development	Waste management	Cold startup	Planning
Basic design and variations	Fuel and materials	Codes and standards	Components manufacturing	Transport	Low power commissioning	Experience
Safety principles and philosophy	Heat transfer and transport systems	Core design	Plant assembly		Full power operation	
	Pipe integrity	Dynamic analysis	Balance of plant		Environmental impact	
	Seismic analysis	Environmental impact	Inspection		Maintenance	
	Accident analysis	System design description	Codes & standards		Off-normal & emergency operation	
	Sodium fire	Demonstration of safety			Failed fuel detection	
	BDB events	Project cost analysis(economics)			Fuel handling	
	Control materials	Control systems				
	Shielding	Failed fuel detection				
		Shielding				

FIG. 1. Structure of the two top levels of the IAEA FRKP system proposed at the consultants meeting in Vienna.

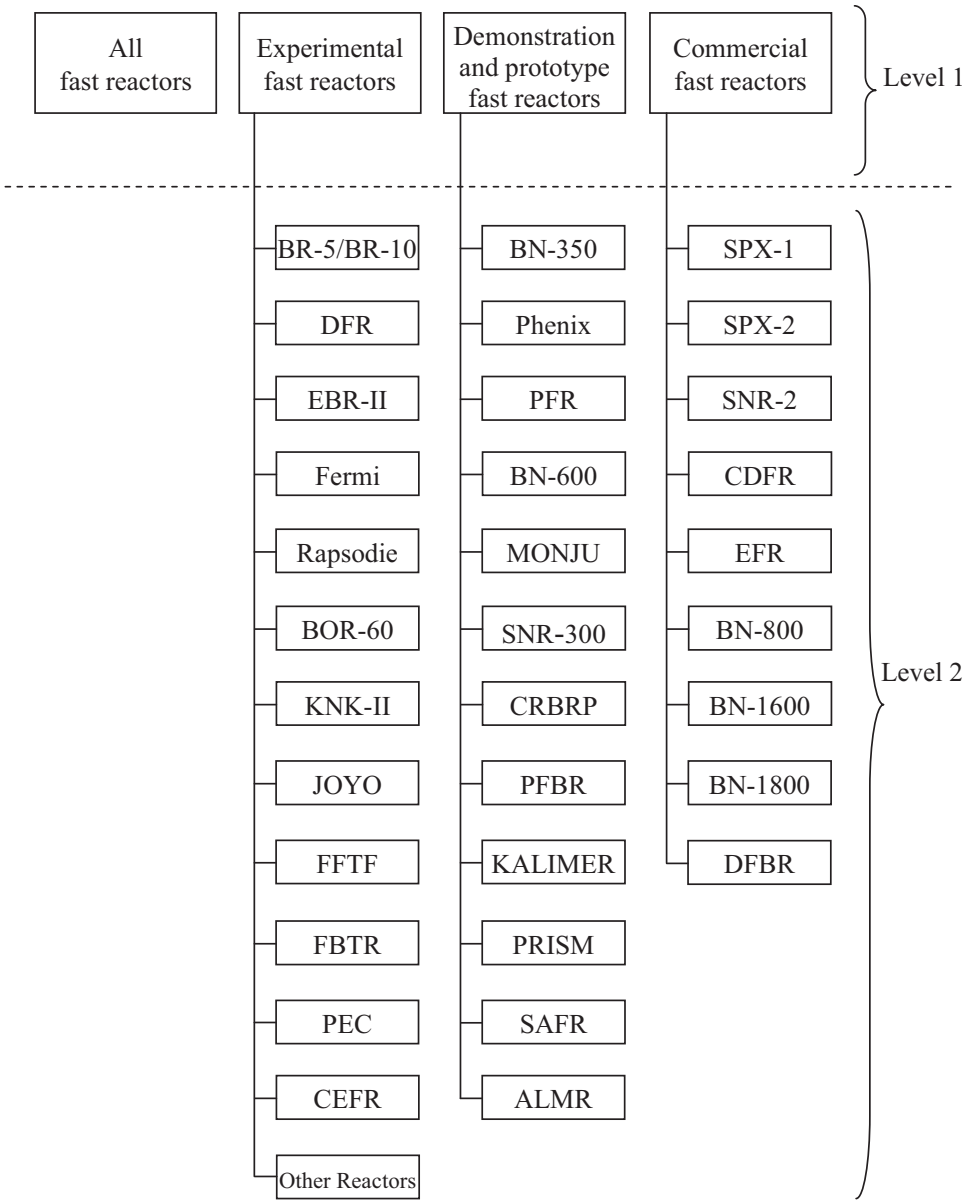

FIG. 2. First two levels of the FRKPS structure.

It was implied in the Vienna meeting that the USTS would be the structure for the entire database. However, it is now proposed that the USTS be a component of the FRKPS structure. The other component would be the structure for particular reactor facilities. This approach is taken based in anticipation that some users would search by topics or disciplines, while others may search the database by a particular reactor facility.

With this two component model as a guide the following is proposed for the FRKPS taxonomy. The first two levels of this taxonomy are shown in Fig. 2.

(1) The top level (1st level) classifies reactor facilities into the following categories:
- — Experimental FR;
- — Demonstration and prototype nuclear power plant with FR;
- — Commercial nuclear power plant with FR;
- — General section containing information on all facilities, as well as activities performed without reference to any particular reactor facility.

STAGE			1	2	3	4	5	6
	TOPIC		Basic principles	R & D	Design, analysis, licensing	Manufacturing & construction	Operation	Decommis-sioning
1	Neutronics & reactor physics		Branch 1-1	Branch 1-2	Branch 1-3	Branch 1-4*	Branch 1-5	Branch 1-6*
2	Thermal hydraulics & thermal physics		Branch 2-1	Branch 2-2	Branch 2-3	Branch 2-4	Branch 2-5	Branch 2-6
3	Material behaviour	Fuel	Branch 3-1-1	Branch 3-1-2	Branch 3-1-3	Branch 3-1-4	Branch 3-1-5	Branch 3-1-6
		Coolant	Branch 3-2-1	Branch 3-2-2	Branch 3-2-3	Branch 3-2-4	Branch 3-2-5	Branch 3-2-6
		Structural materials	Branch 3-3-1	Branch 3-3-2	Branch 3-3-3	Branch 3-3-4	Branch 3-3-5	Branch 3-3-6
		Absorber	Branch 3-4-1	Branch 3-4-2	Branch 3-4-3	Branch 3-4-4	Branch 3-4-5	Branch 3-4-6
		Other materials	Branch 3-5-1	Branch 3-5-2	Branch 3-5-3	Branch 3-5-4	Branch 3-5-5	Branch 3-5-6
4	Safety		Branch 4-1	Branch 4-2	Branch 4-3	Branch 4-4	Branch 4-5	Branch 4-6
5	Systems & equipment		Branch 5-1	Branch 5-2	Branch 5-3	Branch 5-4	Branch 5-5	Branch 5-6
6	Control & monitoring		Branch 6-1	Branch 6-2	Branch 6-3	Branch 6-4	Branch 6-5	Branch 6-6
7	Ecology & environment		Branch 7-1	Branch 7-2	Branch 7-3	Branch 7-4*	Branch 7-5	Branch 7-6
8	Codes		Branch 8-1	Branch 8-2	Branch 8-3	Branch 8-4*	Branch 8-5	Branch 8-6
9	History & other aspects		Branch 9-1	Branch 9-2	Branch 9-3	Branch 9-4	Branch 9-5	Branch 9-6

FIG. 3. The first two levels of the USTS (stage & topic matrix).

(2) The second level identifies each reactor facility (this level is absent for the general section).
(3) The third and further levels correspond to structural levels of USTS described below. These levels are repeated for the general section and each particular reactor facility.

The USTS is applied to each reactor facility, as well as the general section. Figure 3 shows the USTS component for the FRKPS. It can be viewed as an expanded version of the USTS shown in Fig. 1. Each topic at

the third level of the FRKPS taxonomy corresponding to the first level of the USTS is expanded to an additional level of detail related to reactor technology stages (the fourth level of the FRKPS taxonomy and the second level of the USTS). This breakdown is logical because a given topic can be a part of all stages. For example, the information on the topic 'Material Behaviour' can apply to all stages of reactor development. Thus, this structure would be convenient to specialists in certain disciplines and students searching the database.

The topical items shown in Fig. 3 are based on experience gained with SFRs, although the USTS will be capable of incorporating information from other reactor types.

Thus, at the first structural level of the USTS, in Fig. 3, the following basic topical sections of fast reactor (FR) technology are listed:

(1) Aspects of FR neutronics;
(2) Aspects of FR thermal hydraulics and thermal physics;
(3) Problems related to FR materials, including fuel, coolant and its technology, structural materials, absorbers and other auxiliary materials;
(4) FR safety issues, including analysis of safety characteristics, safety systems and development of standards and regulatory documents;
(5) Technological systems and components — conceptual approaches and design studies on the systems and components, their specific implementation and operation modes;
(6) FR control and monitoring issues, including those on related systems;
(7) FR ecological aspects and environmental impact;
(8) FR mathematical modelling, including calculation results, computer codes in use and their description;
(9) Economic and other aspects of FR, as well as historical documents, including memoirs, photographs, movies, etc.;

Each of the topics shown in Fig. 3 is aimed at specific objectives or target functions. The target functions for each topic are given in Table 1.

The target functions for two areas need further discussion. These areas are: (1) design studies on systems and components, (2) FR mathematical modelling. These two areas of activity are closely connected and are a necessary component of many aspects of FR technology. For instance, development of nuclear fuel requires modelling and the specified performance of the fuel depends on design studies. However, these two areas of work were specified as separate topical sections because of their specific features. In Table 1 the area entitled Technological Systems and Components includes all FR systems and components except for safety systems, which are included under Safety Issues, and control and monitoring systems, which are included under Monitoring and Control. These FR technological systems and components are separate subsections of the Technological Systems and Components section.

On the basis of the SFR development history, many of the target functions are dependent on each other and a given target function may be applicable to more than one system or component. Some examples are given below:

— A controlled chain reaction is assured by a certain configuration and condition of reactor core (neutronics and thermal hydraulics) and performance of control and safety systems (monitoring and control, and safety issues);
— Decay heat removal from the reactor in the shutdown condition depends both on thermal hydraulics and safety aspects;
— For instance, the section related to mathematical modelling contains information that was developed to contribute to the solution of problems inherent in target functions defined in other FR technology areas (justification of decisions made in various aspects of FR technology, safety justification, etc.).

The above considerations demonstrate that one document may be related to several topical sections and, hence, it should be recorded in all related FRKPS sections. Thus reasonable redundancy must be allowed in the FRKPS for placement of a document (or its reference) in the different topical sections.

The list of general topical sections given in Table 1 is complemented by a section intended for accumulation of various facts on FR development history, such as photographs, movies, memoirs, etc. This section,

TABLE 1. TARGET FUNCTION FOR EACH ASPECT OF REACTOR TECHNOLOGY

General aspect of reactor technology		Target function
Neutronics		Assurance of controlled fission chain reaction under normal operating conditions Assurance of protection of components and personnel against radiation Assurance of subcriticality under required conditions
Thermal hydraulics and thermal physics		Assurance of heat transfer and removal from the core to the tertiary circuit Assurance of required operating conditions of systems and components
Materials	Fuel	Assurance of fuel serviceability in the fuel elements
	Coolant	Assurance of required coolant technology
	Structural materials	Assurance of serviceability of various nuclear power plant elements and components
	Absorber	Assurance of serviceability of absorber element materials
	Other materials	Assurance of serviceability of building structures, auxiliary systems and services
Safety issues		Justification and assurance of safe nuclear power plant operation under abnormal operating conditions, design basis accidents (DBAs) and beyond design basis accidents (BDBAs) Development and operation of safety systems Elaboration of criteria and requirements on assurance of FR safety
Technological systems and components		Development and adoption of principal conceptual decisions on composition and arrangement of technological systems, components and elements of nuclear power plant with FR Development, design and operation of technological systems and components of nuclear power plant with FR
Monitoring and control		Assurance of monitoring and control of various parameters and characteristics of nuclear power plant and maintaining these characteristics within required range of values
Ecology		Minimization of radiological and other effect on personnel and environment Choice of nuclear power plant site, taking into account environmental impact
Mathematical modelling		Adequate modelling of FR elements and systems and processes taking place in these systems
Economic and other aspects		Comparative economic analysis of operation of nuclear power plants with FR Preservation of data on FR history — memoirs, photos and newsreel

entitled Economic and Other Aspects, could be used for additional aspects of FR technology. The provision of such a section makes it possible to ensure the preservation of a comprehensive account of all information on FR which does not fall into the other topical sections.

Subsections corresponding to some categories of materials used in FR (fuel, coolant, structural materials, absorbers and auxiliary materials) are provided in a main topical section such as Material Behaviour.

The list of topical sections shown in Fig. 3 is intended to cover all areas of reactor technology related to fast reactors. The only exceptions are issues of fuel reprocessing technology within the framework of the fuel cycle. This topic is not presented as an independent topical section in the above list, since these issues are quite specific and do not relate directly to reactor technology itself. However, some specific issues related to the fuel cycle are contained in other topical sections and these issues have been taken into account in the corresponding subsections.

In order to facilitate the use of USTS during its development, it is proposed to use abbreviated titles of the 1st level sections. These abbreviations are given in Table 2.

TABLE 2. ABBREVIATED TITLES OF THE FIRST LEVEL SECTIONS

#	Full title of topical section/subsection	Brief title of topical section/subsection used in USTS of FRKPS
1	Aspects of FR neutronics	Neutronics & reactor physics
2	Aspects of FR thermal hydraulics and thermal physics	Thermal hydraulics & thermal physics
3	Problems related to FR materials: —Fuel —Coolant and their technology —Structural materials —Absorber materials —Other auxiliary materials	Material behaviour: — Fuel — Coolant — Structural materials — Absorber materials — Auxiliary materials
4	FR safety issues	Safety
5	Technological systems and components	Systems & equipment
6	FR control and monitoring issues	Control & monitoring
7	FR ecological aspects and environmental impact	Ecology & environment
8	FR mathematical modelling	Codes
9	Economic and other aspects of FR, including documents on FR history	History & other aspects

The distribution of problems and the types of specialists needed to solve these problems will change with the stage of FR development. The specialists of various types who are involved, namely researchers, engineers, designers, operating personnel and regulatory body representatives will change with the degree of involvement depending on the stage. Such a division should be taken into account in the USTS. Therefore, the stages of fast reactor technology implementation are specified as the second level of USTS, in accordance with the list given in Fig. 1, excluding the Fuel Cycle stage. The stages of implementation are listed below:

(1) Basic Principles: Stage of development of basic principles and concept of the future nuclear power plant;
(2) R & D: Stage of R & D work for support of nuclear power plant design and design approaches used within its framework;
(3) Design, Analysis, Licensing: Stage of development of nuclear power plant design and its licensing by the regulatory body;
(4) Manufacturing & Construction: Stage of nuclear power plant construction, manufacture and installation of reactor components and systems;
(5) Operation: Stage of nuclear power plant commissioning and operation to its final shutdown;
(6) Decommissioning: Stage of development of nuclear power plant decommissioning project and its implementation.

All the stages listed above are applied to each specified nuclear power plant with its FR and components. The information from the specified nuclear power plant will thus exist in the FRKPS according to the stages shown above. The stage related to the fuel cycle mentioned in Fig. 1 is somewhat special, since it deals with a different subject, namely fresh and spent fuel and a set of systems and components intended for reprocessing or storage, depending on the fuel cycle concept adopted. Hence, the stage related to the implementation of the fuel cycle was not included in the USTS.

This breakdown of nuclear power plant development into stages follows the natural sequence of events in the implementation of any nuclear power plant with its specific design of FR or reactor plant. Of course, the major part of the work in the fast reactor area is carried out within the framework of development of a specific design. However, certain analytical and experimental studies in the area of fast reactors are carried out without application to a specific design. Such information will be placed in the section related to the R & D stage without indicating a specific facility.

The first two levels adopted in the new USTS option are also represented as a stage topic matrix in Fig. 3. The root structure, the content of which is determined by the intersection of the topic section and the stage, refers to each cell of the matrix. These root structures, hereinafter called branches, have been numbered. The number of each branch is determined by the number of the section and the number of the stage to which it refers. The branches are hierarchical multi-level structures.

Some of branches in the matrix are marked with an asterisk (*) to indicate that the branch is absent due to the fact that the topic of work was not applicable at that stage. For example, Neutronics & Reactor Physics are not necessary elements of work at the Manufacturing & Construction or Decommissioning stages. The detailed structure of branches of the stage topic matrix is presented in the Annex.

In order to avoid excessive congestion of USTS, the extent of detail of the levels of its branches and related specific topical subsections is limited. The degree of detail of each branch goes down up to the level of system-functional problems related to a specific topical section, but not up to the level of specific components and elements. An exception is made for the main reactor plant components, such as steam generators (SG), intermediate heat exchangers (IHX), main circulating pumps (MCP) etc., which are also included in USTS as separate subsections. Further detail of information up to the level of specific components and elements of systems is provided by use of key words. This approach to restriction of the number of levels in the branches and optimisation of FRKPS taxonomy makes it possible to also avoid excessive redundancy in duplicating placement of documents in different sections.

In order to ensure that the topical sections in the USTS are comprehensive, some FR components are included simultaneously in more than one topical section. For instance, the core is included in the Systems & Equipment and Neutronics & Reactor Physics sections.

General-industry components and off the shelf components and systems are not included in USTS. The proposed USTS has been developed as applied to a general nuclear power plant with an FR. Thus, this structure is sufficiently comprehensive but versatile enough to allow for further necessary extension.

4. FORMAT OF DOCUMENT PRESENTATION IN FRKPS

The method for inputing information (not the entire documents) into the FRKPS is by use of information cards (ICs). These information cards will follow a standard format. The ICs are the basic unit of the FRKPS. The advantage of this method is that it requires no translation of the original document. However, it is important that the IC gives an accurate and sufficient representation of the original document. The IC has to be comprehensive enough for the information to be correctly placed in all the pertinent sections of the FRKPS. The IC must also be comprehensive enough for the FRKPS to retrieve the information.

The format for the information included as a SQL file in English on the IC is given below:

(1) Title of the document;
(2) Type of document (appropriate classification of the documents based on their type should be provided in FRKPS, e.g. 1 — book, 2 — article, 3 — report, 4 — paper, 5 — theses, 6 — design document, 7 — code description, 8 — drawing, 9 — working material, 10 — memoirs, 11 — photographs, 12 — movies, etc. with necessary notes);
(3) Authors and institutions they represent;
(4) Issuing country/countries of the document.
(5) Title of magazine/publishing house issuing the document/meeting at which the document was presented;
(6) Year of issue;
(7) Volume of the document (number of pages);
(8) Original document language;
(9) Storage location of the hardcopy of the document (organization taking responsibility for storing the original document; name of database, if available, in which the document has been included);
(10) Set of key words (at least 10 key words for each document);

(11) Abstract of the document in the original language and in English (minimum number of characters, 1000, at least half of A4 format page, letter size 10, single spacing);
(12) Names of reactor facilities to which the document refers;
(13) Names of reactor stages related to the document;
(14) List of topical sections (directories) to which the document refers and where the reference labels should be placed;
(15) Indication of degree of accessibility of the original document;
(16) Indication of availability of an electronic version of original document;
(17) Electronic version of the original document as a separate document (if possible from the standpoint of its confidentiality level);
(18) Registration number (if available).

Each document is presented in FRKPS in 2 files (SQL file and PDF file). The necessary number of reference labels is stored in related sections (directories) of FRKPS. ICs are accessible to the user as PDF files. The name of the IC is the title of the document.

A search of related topical sections for insertion of a new IC into the FRKPS taxonomy is determined by prompting on the key words listed in the IC when compared to the key words in the different topical sections in the FRKPS. Matches of key words will determine where the new IC resides in the FRKPS.

It is necessary to provide within the framework of the FRKPS an opportunity for creation of ICs, not only for individual documents but also for some arrays of documents. These arrays of documents can be, for instance, proceedings of the topical meetings or conferences, sets of papers related to specific research, etc.

The unified IC format for documents inserted into the FRKPS should be agreed to by the Member States to provide consistency from one country to the next with regard to the volume and selection of input to the FRKPS. The unified format of IC enables its placement in the FRKPS by using a computer prompt.

5. APPROACHES TO FORMATION OF TOPICAL LISTS OF KEY WORDS

Lists of key words in the IC that are specified for each document included in the FRKPS are important components of the FRKPS taxonomy. All specific information contained in every document of the FRKPS can be divided into two parts. One part of the information (up to the level of systems and main components or global aspects of FR technology) can be described by the root structure of the FRKPS; the other part of the information (up to the level of separate elements and particular aspects of the problem) will be described by the set of key words. Thus key words allow describing detail specific information of each document, which is not reflected in the branch structure of the FRKPS.

To make the FRKPS user friendly an effort should be undertaken to systematically develop key word sets for the topical sections of the FRKPS. These key words would be used by specialists or students to query the FRKPS. The following features will be incorporated within the framework of the FRKPS:

— Formation of a thesaurus of key words (in English).
— Compatibility of the thesaurus with the INIS thesaurus to the maximum possible extent.
— A hierarchical structure of key word sets arranged in accordance with the FRKPS topical structure. For this purpose, it is proposed to form lists of key words for all levels in each topical section. The list of key words for every level should automatically contain key word arrays of lower levels of this branch.
— When a new IC to be inserted into the FRKPS has a new key word which is absent in the FRKPS key words lists, this key word will be automatically included in the list of key words of this topical section and all related higher level topical sections.

— Access to files with the lists of topical session key words would be provided to the users at any structural level for the purpose of familiarization and use in the course of a search. Of course, the users would not be able to change the key words.

The above concept of a thesaurus of key words for the FRKPS will promote its further development and improvement.

6. BASIC REQUIREMENTS FOR THE FRKPS

The proposed FRKPS taxonomy and format of document presentation are designed to provide the following opportunities to the users:

— Search of documents by going down along the chosen branch level structure;
— Multi-vector search of documents by using key words. The following attributes can be used as key words: topic, reactor facility, author, country, year, topical key words, etc;
— Making various search options by the combination of attributes:
  (a) Search of the documents containing a certain combination of attributes within the framework of one document — this means that all documents will be chosen, whose information cards contain all the specified combination of attributes (logic combination 'and' for specified attributes);
  (b) Selection of the documents containing at least one out of a certain combination of attributes in the description of the document (logic combination 'or' for specified attributes);
  (c) Combined search using a logic combination 'and/or' for specified attributes — in this case the ICs, which contain all attributes specified with logic condition 'and' and at least one out of the other attributes specified with logic condition 'or' will be chosen;
— Search of both the totality of the documents in FRKPS and some selected sections and topics;
— Sequential search (with narrowing or change of search vector), allowing for several sequential search iterations with narrowing of the list of selected documents;
— If necessary, saving of the list of the documents resulting from a search in a separate temporary file in the FRKPS;
— Direct access to the information card of any document (and the document itself if it is in the FRKPS) from the list of those selected as a result of a search;
— Access to FRKPS section from which a particular document was selected by the user;
— Consolidation of various files containing results of searches into a common file.

7. FUTURE ACTIONS ON FRKPS DEVELOPMENT

Development of the FRKPS taxonomy is only a part of the work on the creation of the FRKPS as a whole. For the development of an effective FRKPS it is necessary to perform the following additional tasks:

— Develop the concept of 'user-system' and 'contributor system' interfaces and work out the requirements to be met by the FRKPS to enable these interfaces to be effective and friendly to the users and contributors;
— Develop recommendations to the contributors regarding the use of a qualitative selection of documents whose ICs could be included in the FRKPS and on suitable measures that would ensure saving of the original documents by their owners and guarantee their availability to the authorized users;
— Develop the concept of links between the FRKPS and national databases on fast reactors;
— Develop guidance for users and contributors to the FRKPS.

Experts in the fast reactor area and IT experts should participate in the implementation of these tasks, thus providing a multi-disciplinary approach. Also, the representatives of all Member States interested in development of the FRKPS should participate in this work to provide an agreed and unified approach to the preparation of documents for inclusion in this database.

The immediate need is the development of the concept and requirements to be met by the above-mentioned interfaces. This task is required to be completed before the development of software for the FRKPS taxonomy and user system and contributor system interfaces.

It would be expedient to request the Member States to initiate actions necessary to enhance the collection and preservation of memoirs, etc. on fast reactor experience.

8. CONCLUSIONS

A multi-level Universal Stage–Topical Structure has been developed for an electronic Fast Reactor Knowledge Preservation System that covers all stages of implementation of the reactor technology and all its topical aspects.

The list of criteria to be met by the structure under development has been formulated. The proposed taxonomy has attempted to meet these criteria, which include the following:

— The developed FRKPS taxonomy is sufficiently comprehensive and versatile, as well as capable of being expanded in the future;
— The FRKPS taxonomy is developed using a hierarchy principle, i.e. progressing from general aspects of a topic to more specific aspects as the level number increases.

For convenience of the users, substructures related to particular reactor facilities have been separated from the general FRKPS taxonomy.

Format (list of attributes) of the document presentation in FRKPS has been elaborated.

Proposals on the principles of organization of the user queries into FRKPS have been developed. These proposals and FRKPS taxonomy itself are adapted to provide easy access to the system and various options of search of documents. Procedures of search and insertion of new documents into the FRKPS will be automated to the maximum extent.

Recommendations on further activities on the FRKPS development have been made.

Appendix

STRUCTURE OF BRANCHES OF STAGE-TOPICAL FRKPS MATRIX

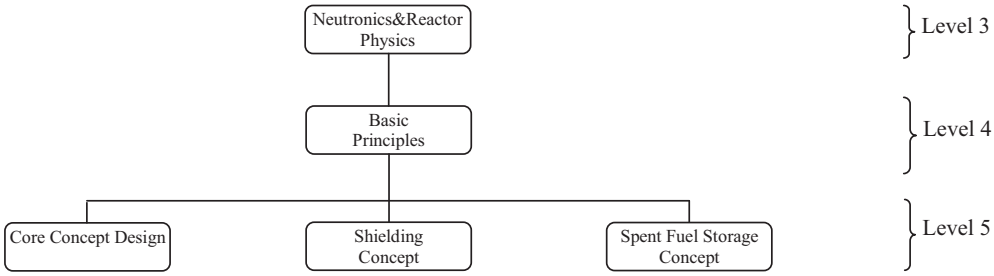

FIG. A-1. Scheme of branch 1-1.

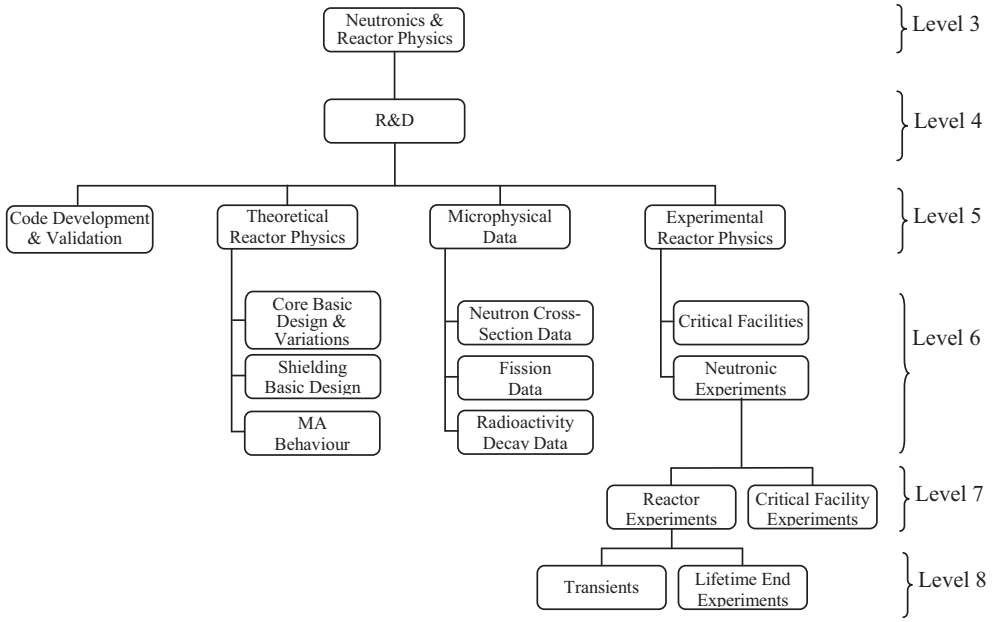

FIG. A-2. Scheme of branch 1-2.

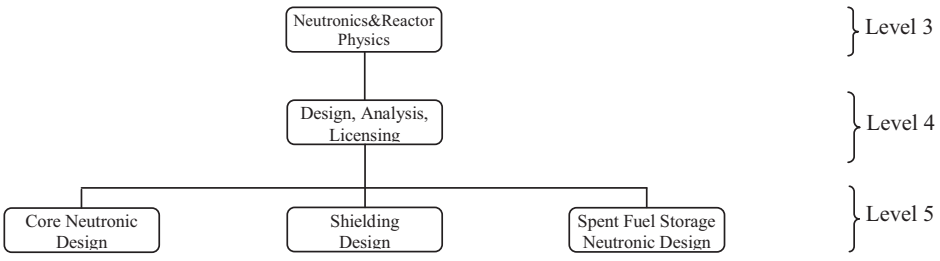

FIG. A-3. Scheme of branch 1-3.

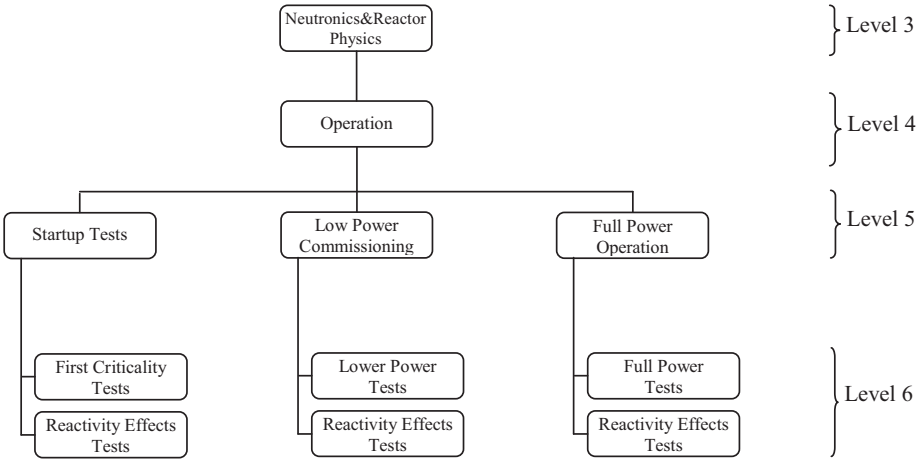

FIG. A-4. Scheme of branch 1-5.

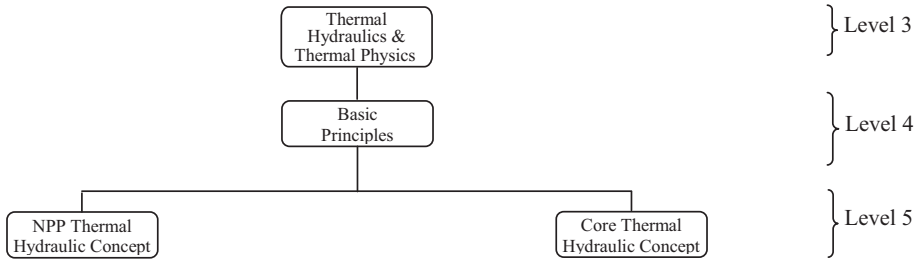

FIG. A-5. Scheme of branch 2-1.

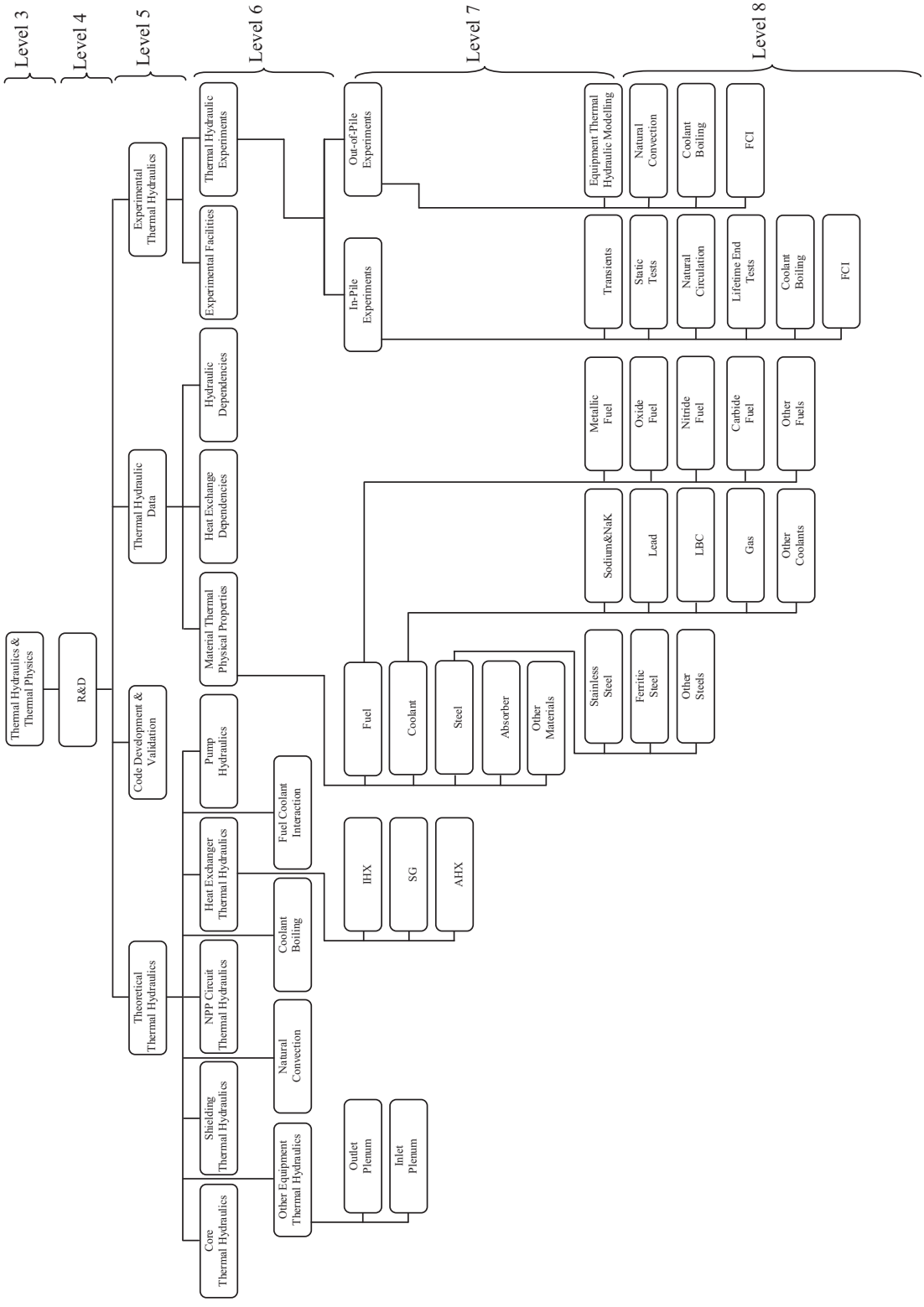

FIG. A-6. Scheme of branch 2-2.

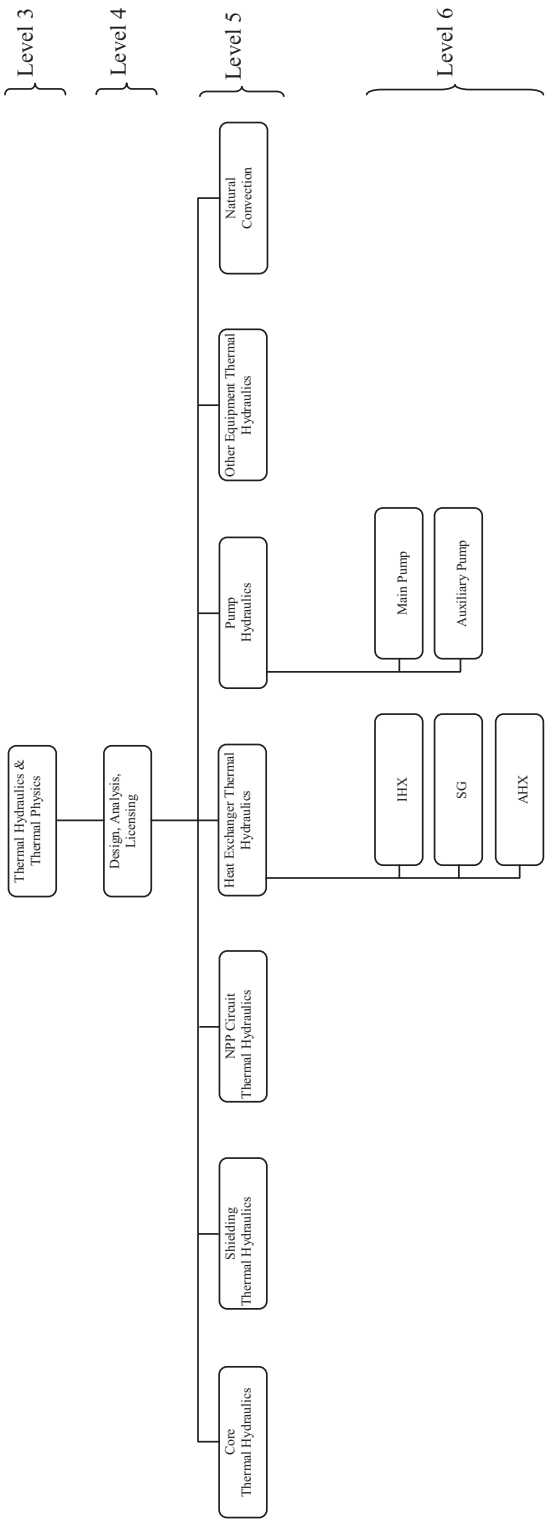

FIG. A-7. Scheme of branch 2-3.

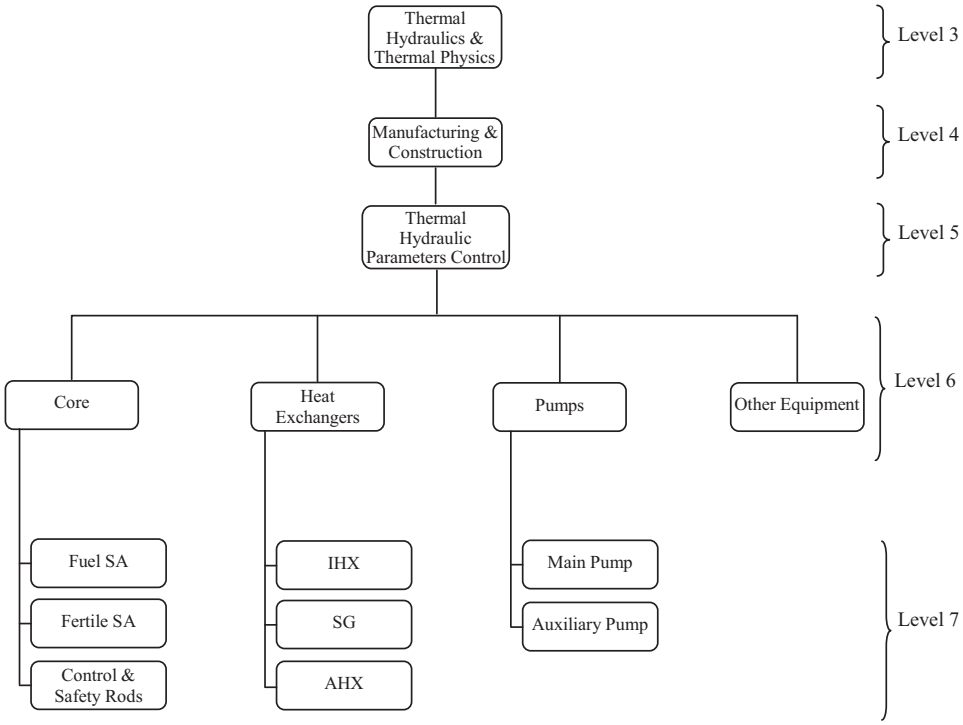

FIG. A-8. Scheme of branch 2-4.

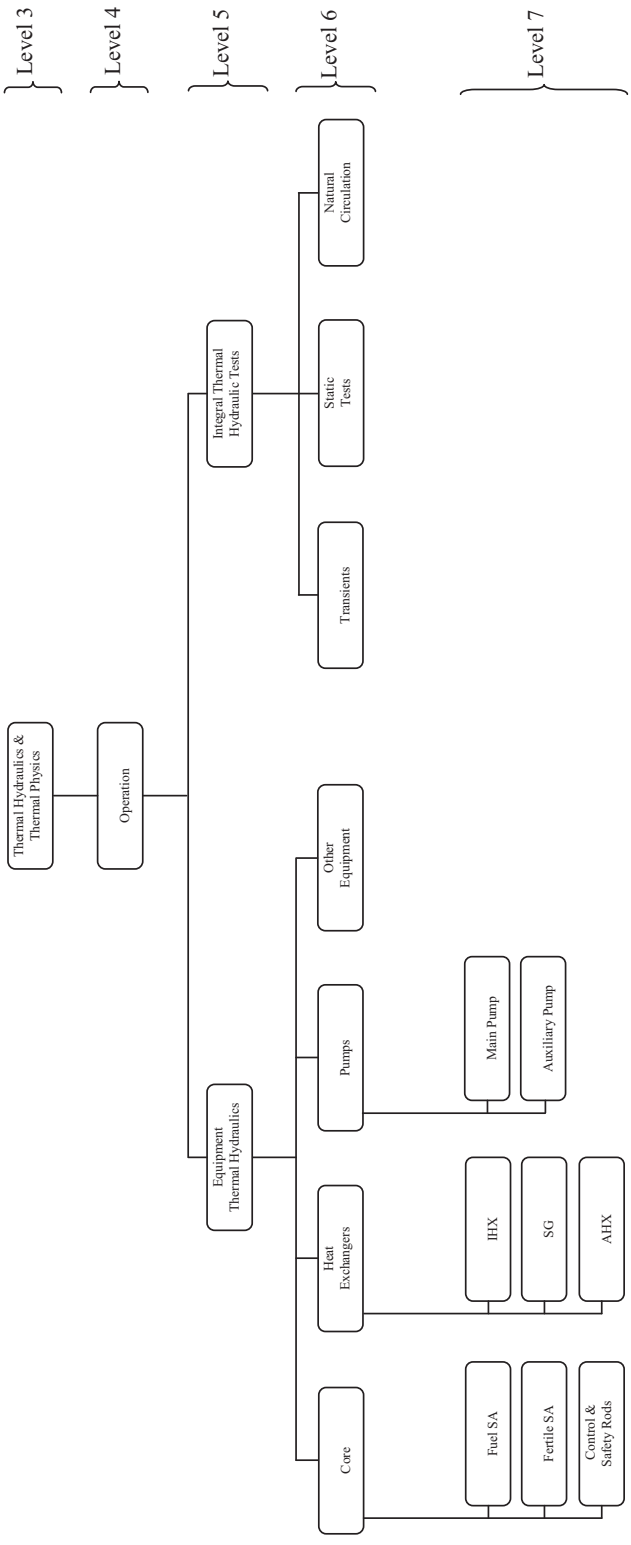

FIG. A-9. Scheme of branch 2-5.

FIG. A-10. Scheme of branch 2-6.

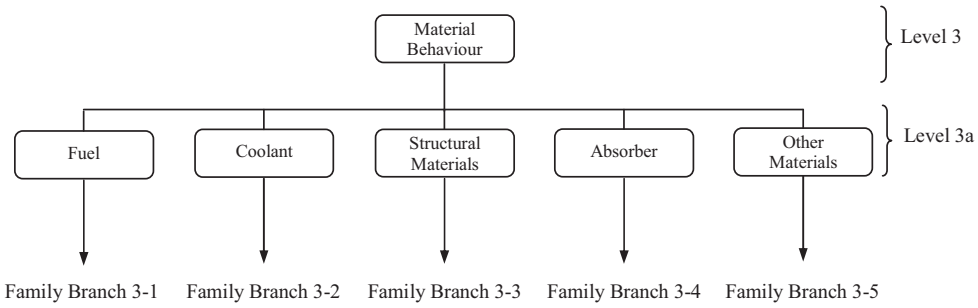

FIG. A-11. Scheme of family branch 3.

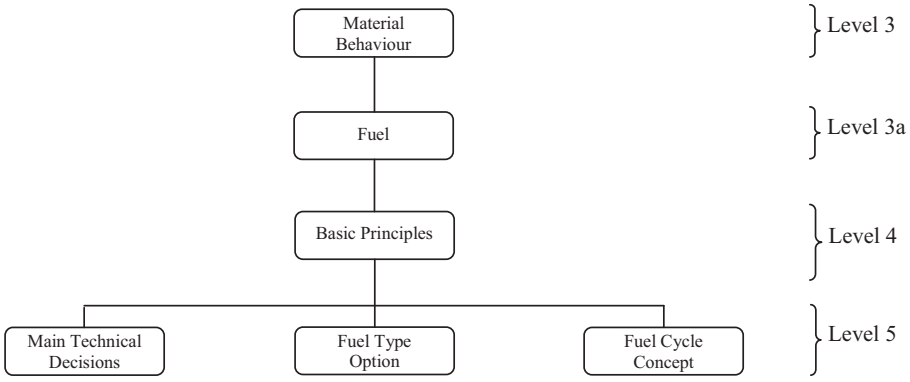

FIG. A-12. Scheme of branch 3-1-1.

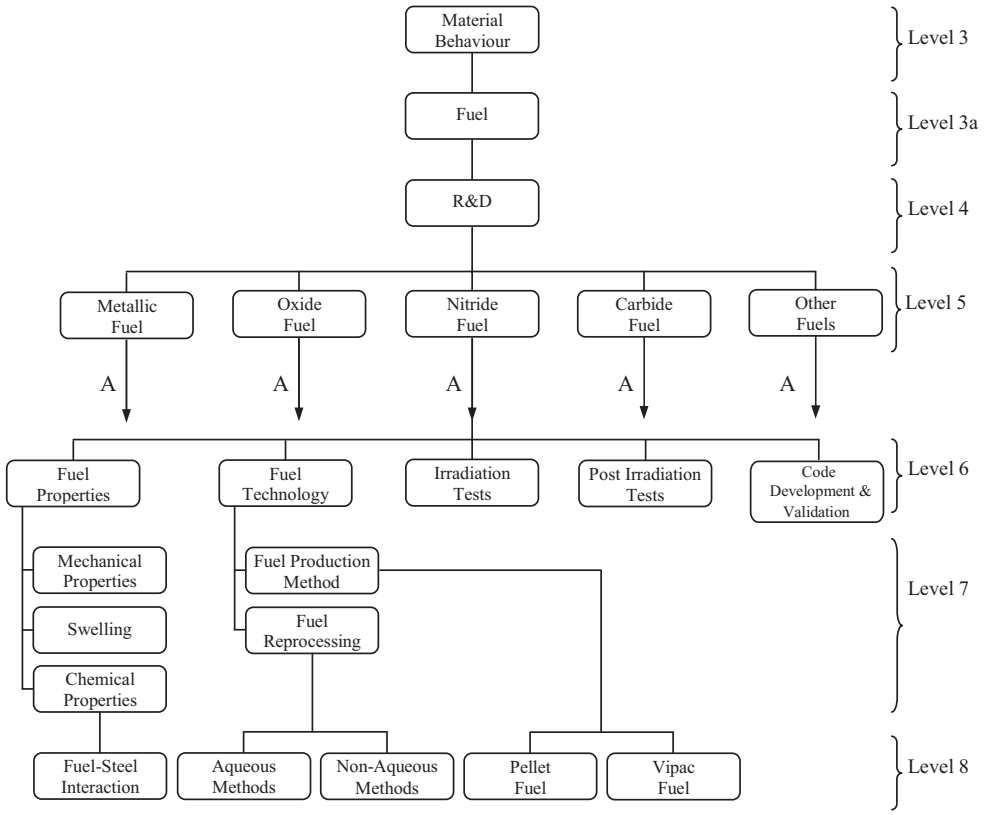

FIG. A-13. Scheme of branch 3-1-2.

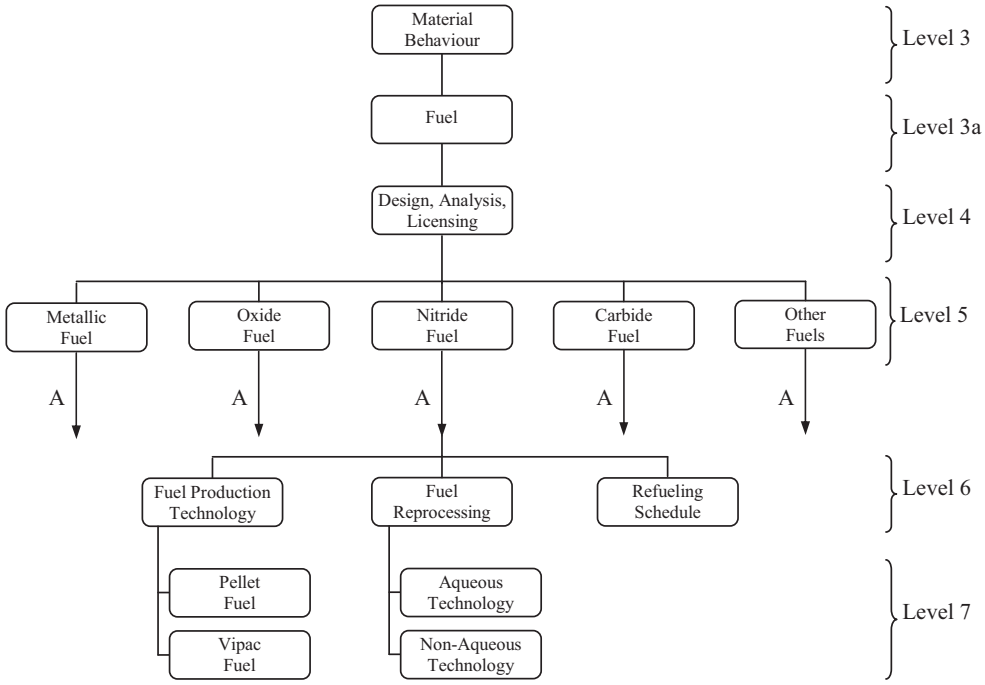

FIG. A-14. Scheme of branch 3-1-3.

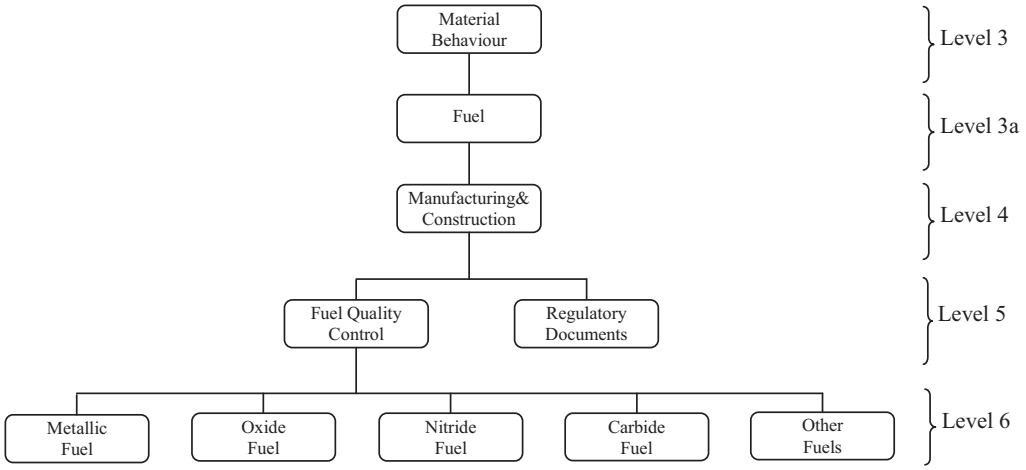

FIG. A-15. Scheme of branch 3-1-4.

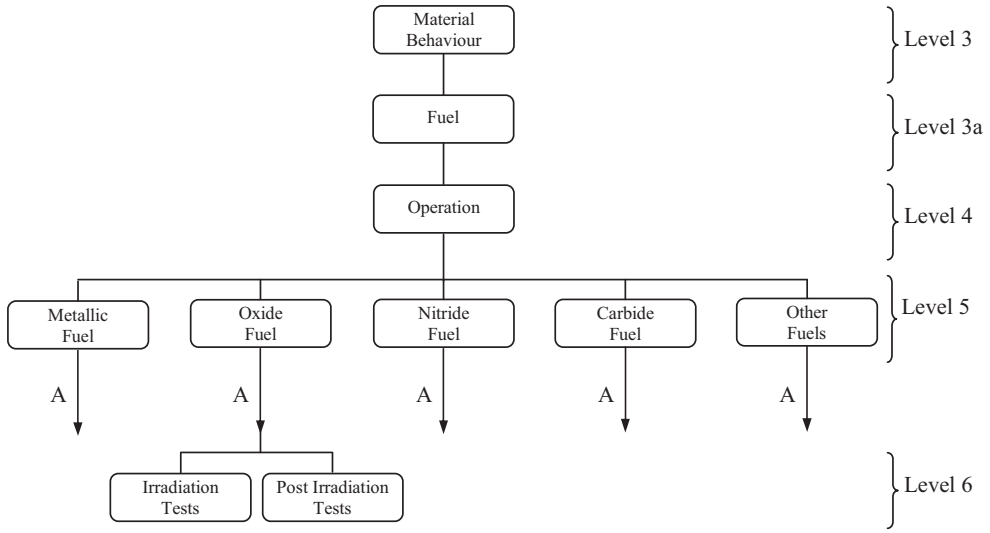

FIG. A-16. Scheme of branch 3-1-5.

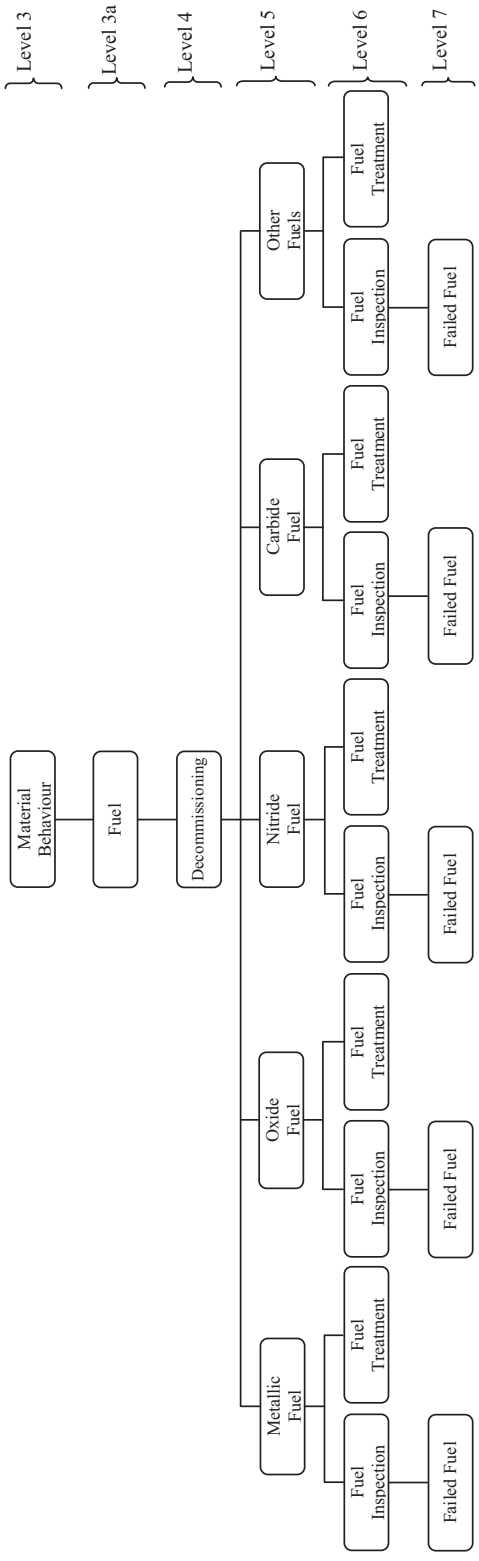

FIG. A-17. Scheme of branch 3-1-6.

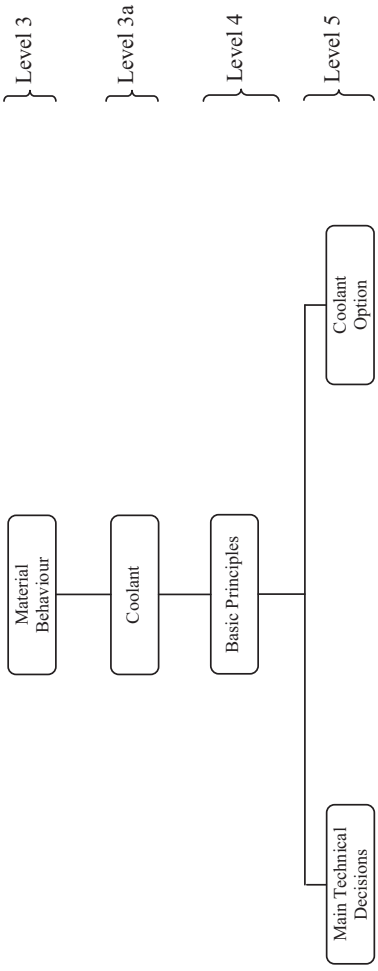

FIG. A-18. Scheme of branch 3-2-1.

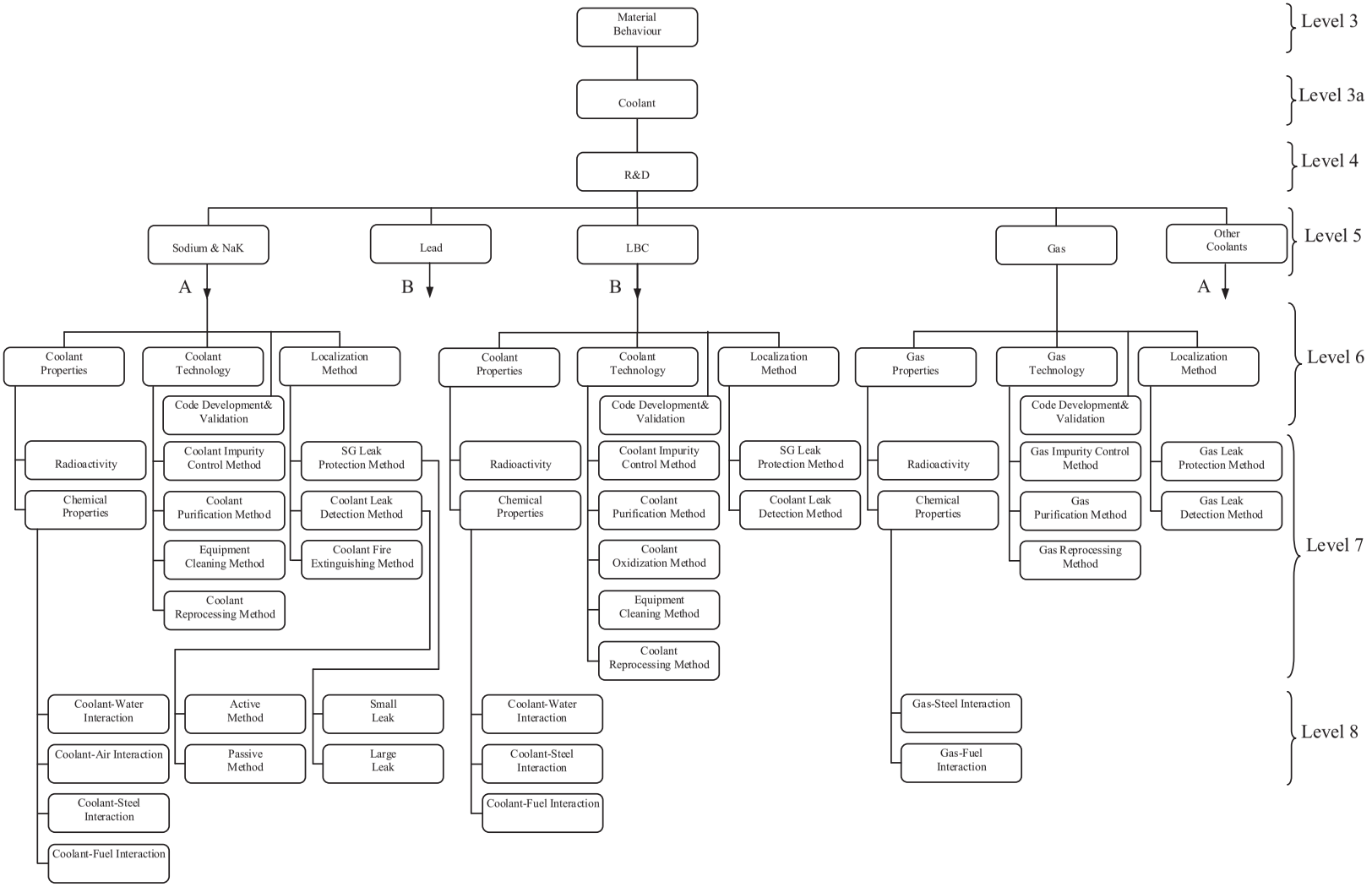

FIG. A-19. Scheme of branch 3-2-2.

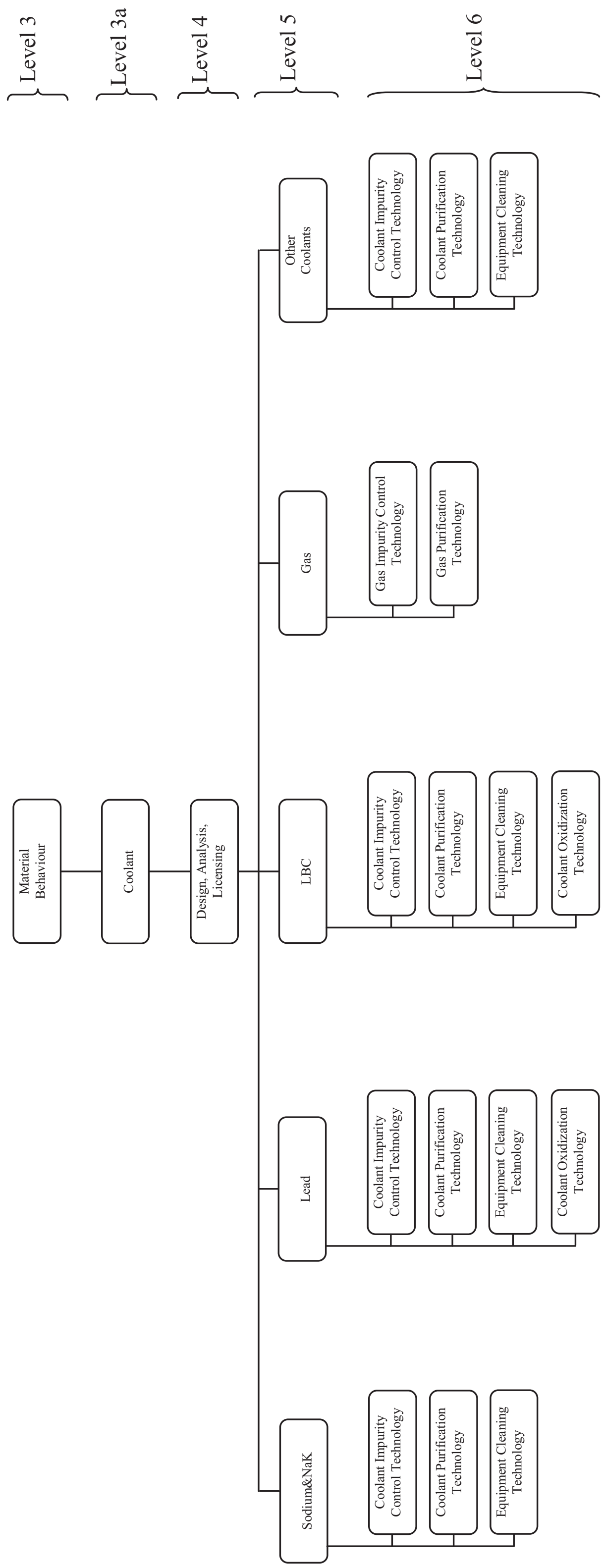

FIG. A-20. Scheme of branch 3-2-3.

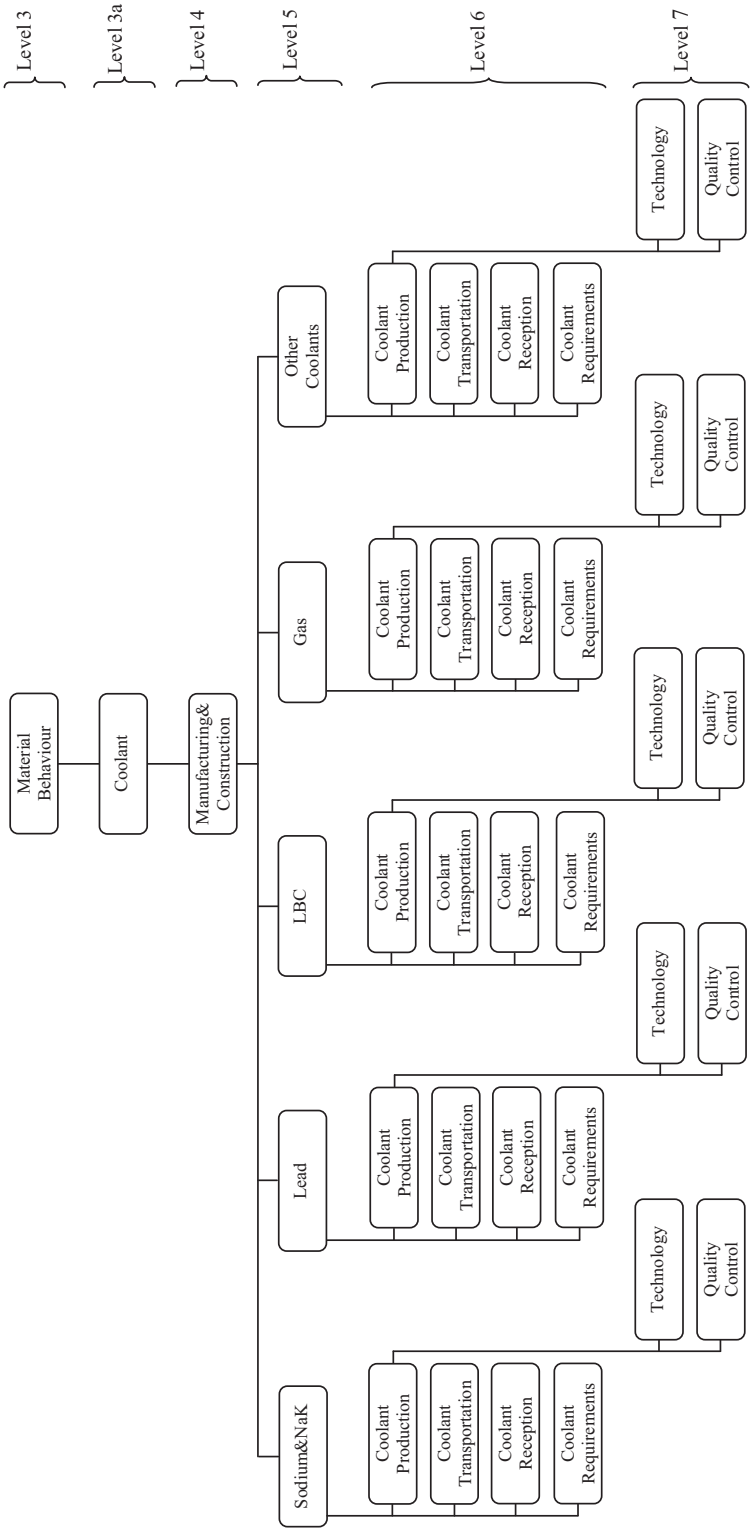

FIG. A-21. Scheme of branch 3-2-4.

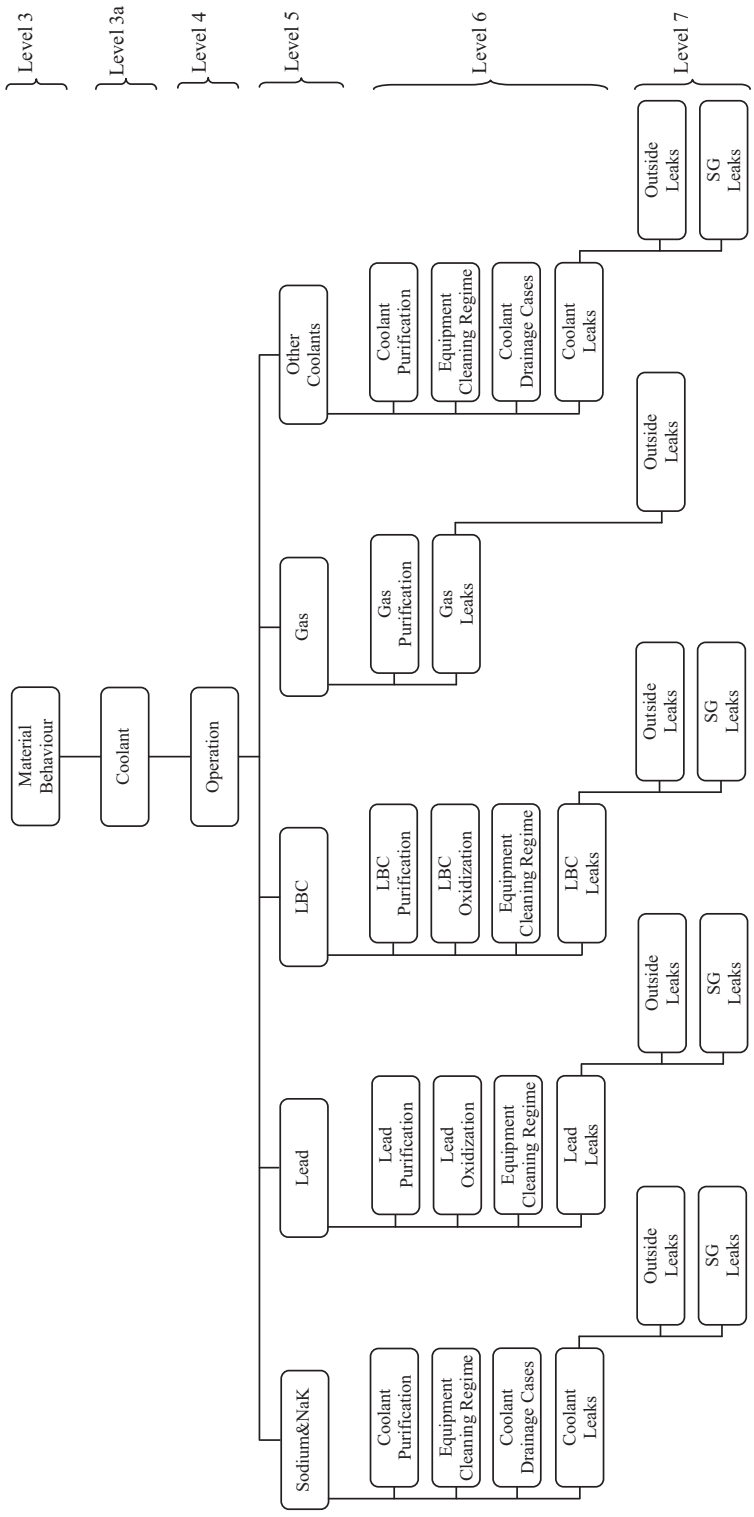

FIG. A-22. Scheme of branch 3-2-5.

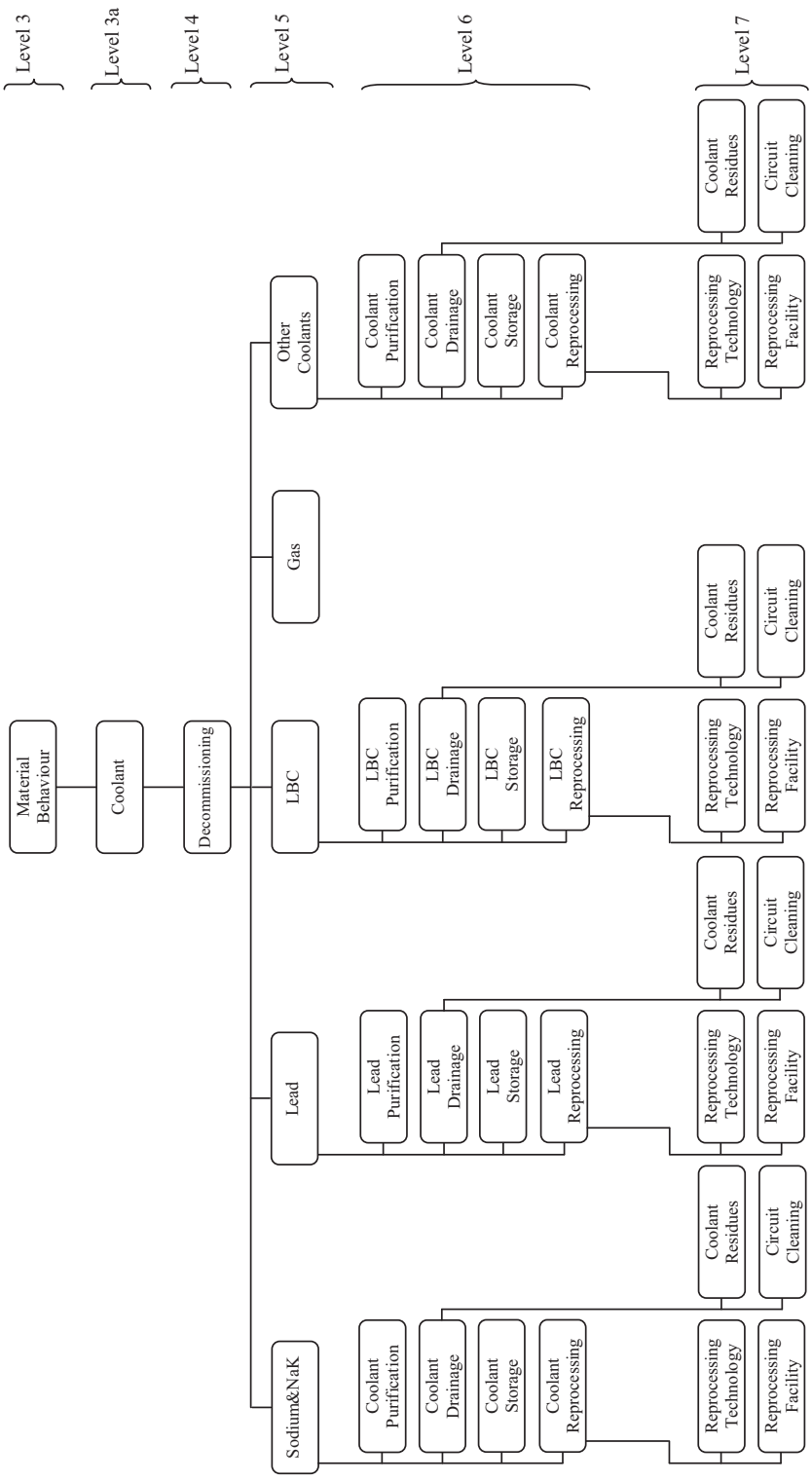

FIG. A-23. Scheme of branch 3-2-6.

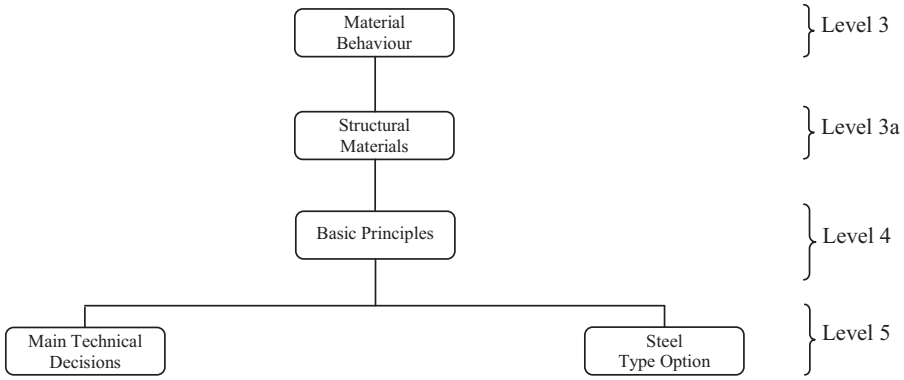

FIG. A-24. Scheme of branch 3-3-1.

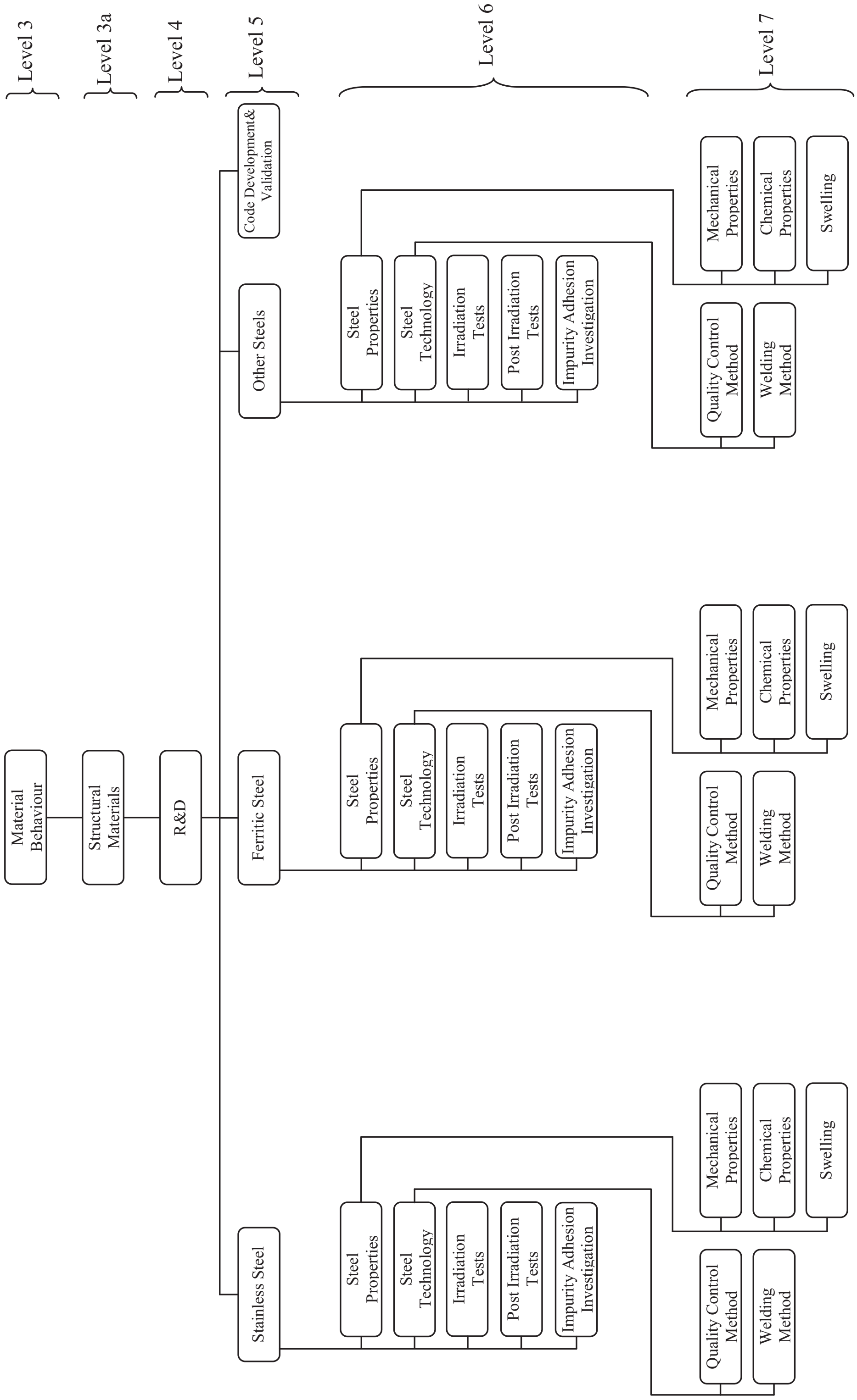

FIG. A-25. Scheme of branch 3-3-2.

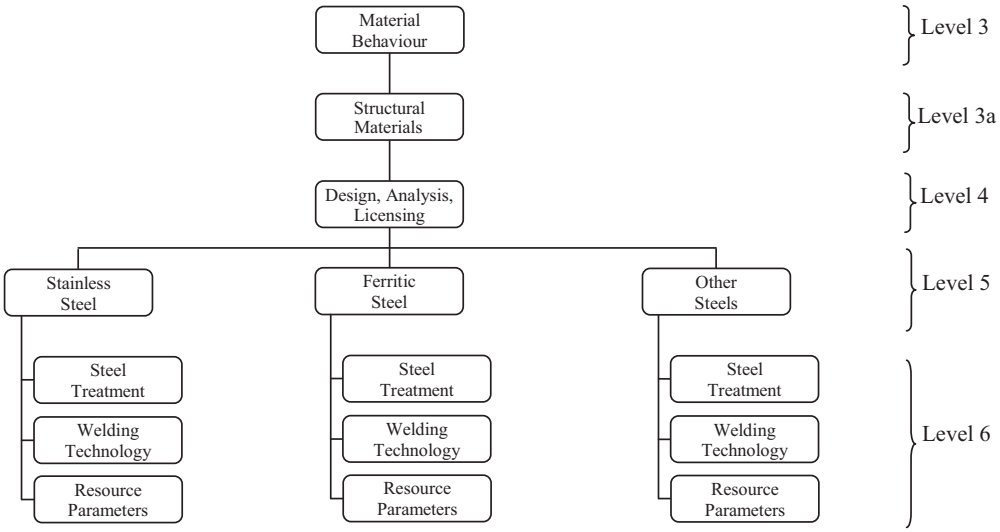

FIG. A-26. Scheme of branch 3-3-3.

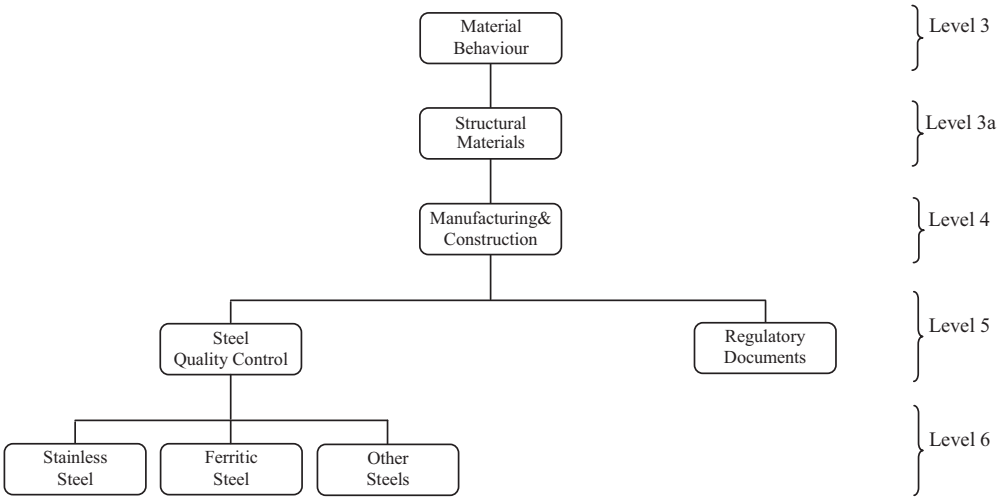

FIG. A-27. Scheme of branch 3-3-4.

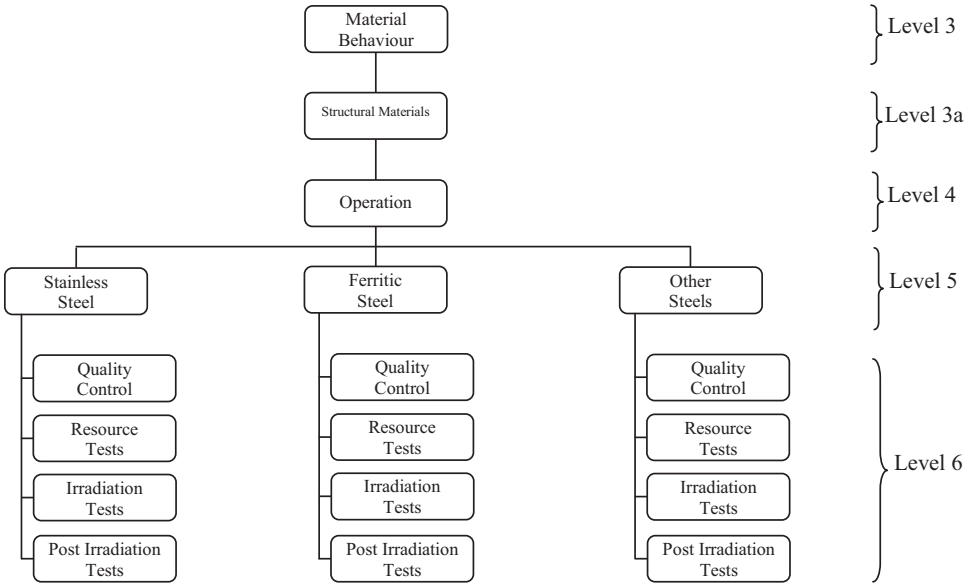

FIG. A-28. Scheme of branch 3-3-5.

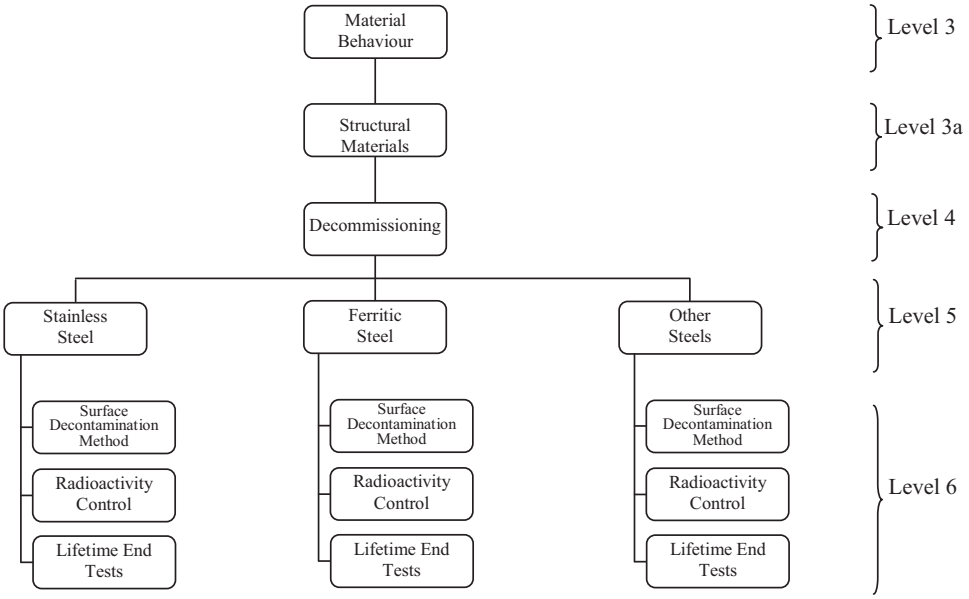

FIG. A-29. Scheme of branch 3-3-6.

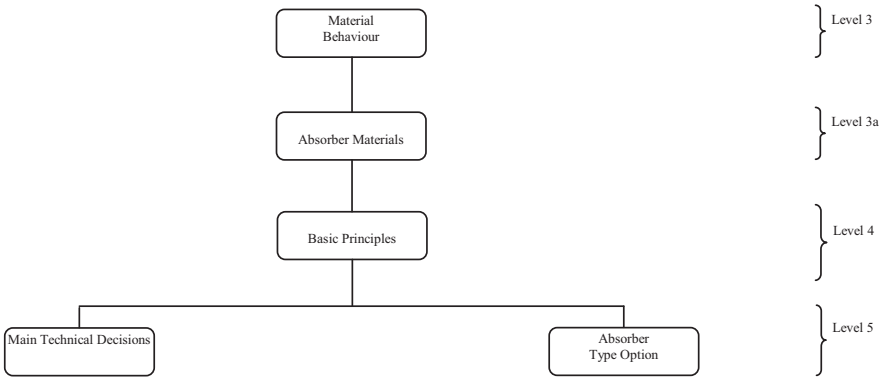

FIG. A-30. Scheme of branch 3-4-1.

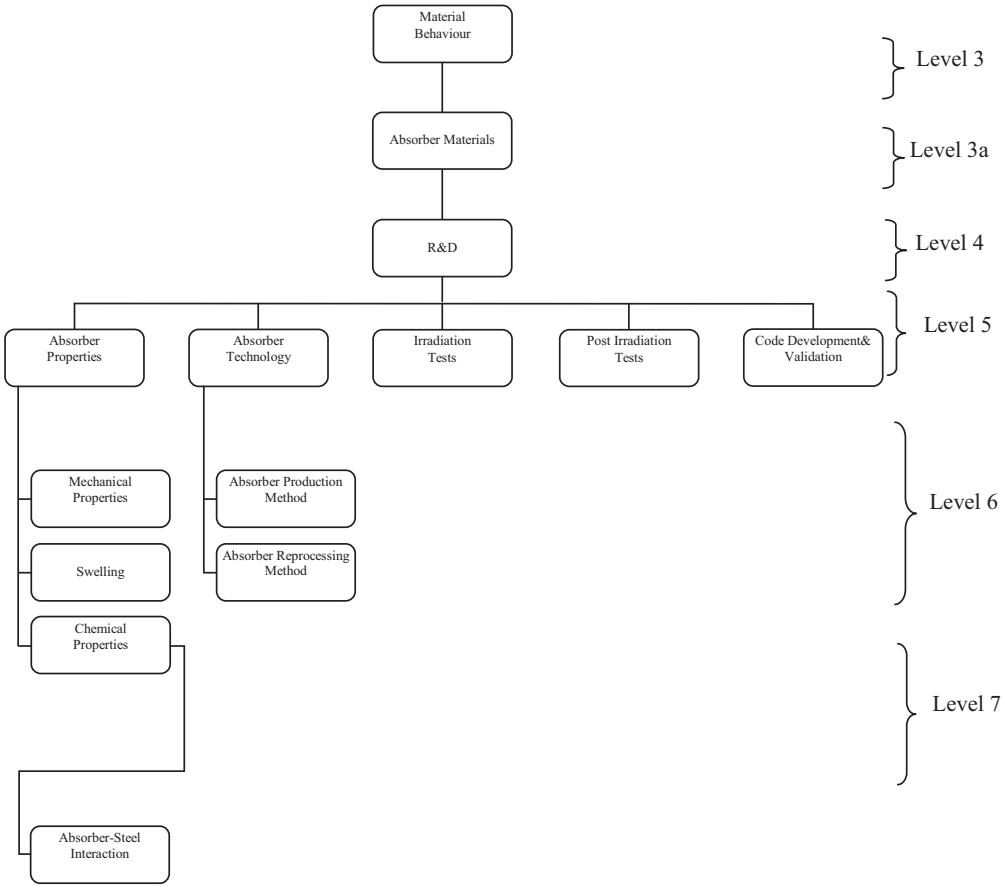

FIG. A-31. Scheme of branch 3-4-2.

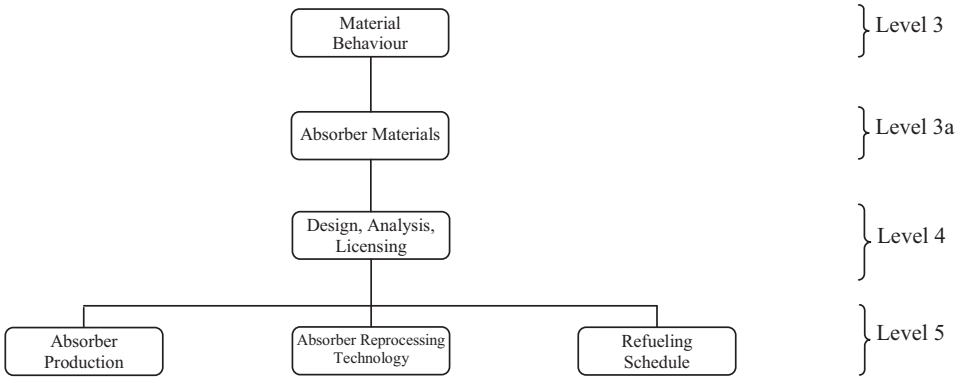

FIG. A-32. Scheme of branch 3-4-3.

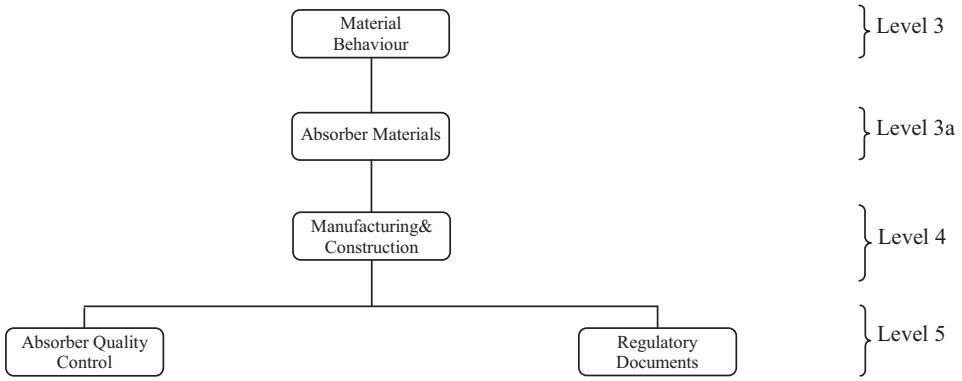

FIG. A-33. Scheme of branch 3-4-4.

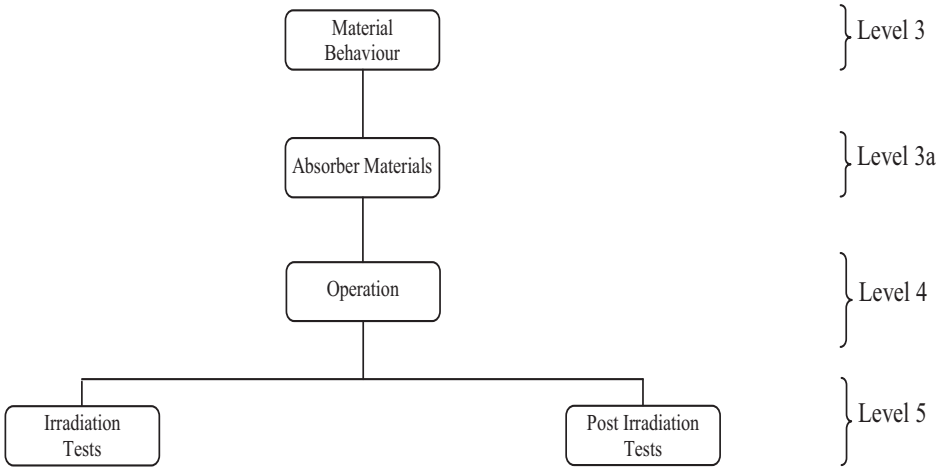

FIG. A-34. Scheme of branch 3-4-5.

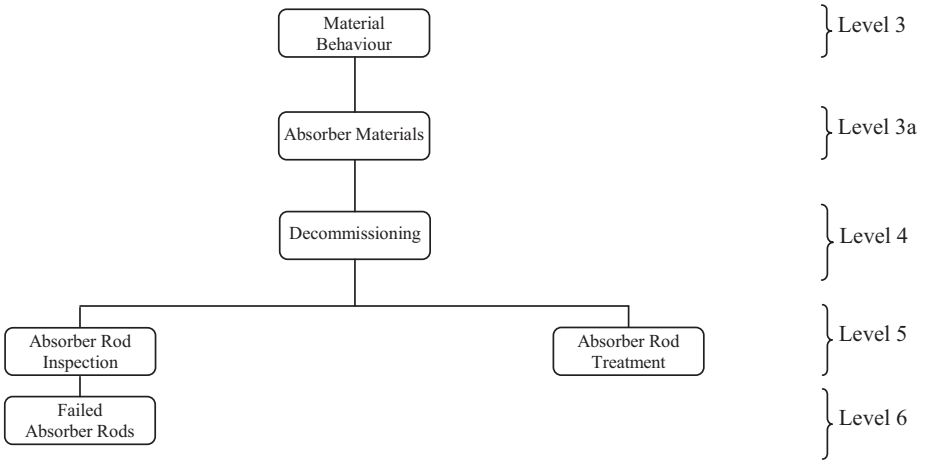

FIG. A-35. Scheme of branch 3-4-6.

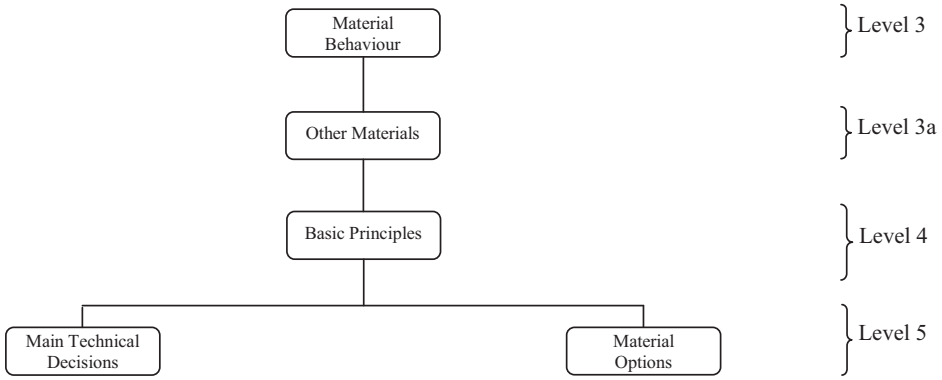

FIG. A-36. Scheme of branch 3-5-1.

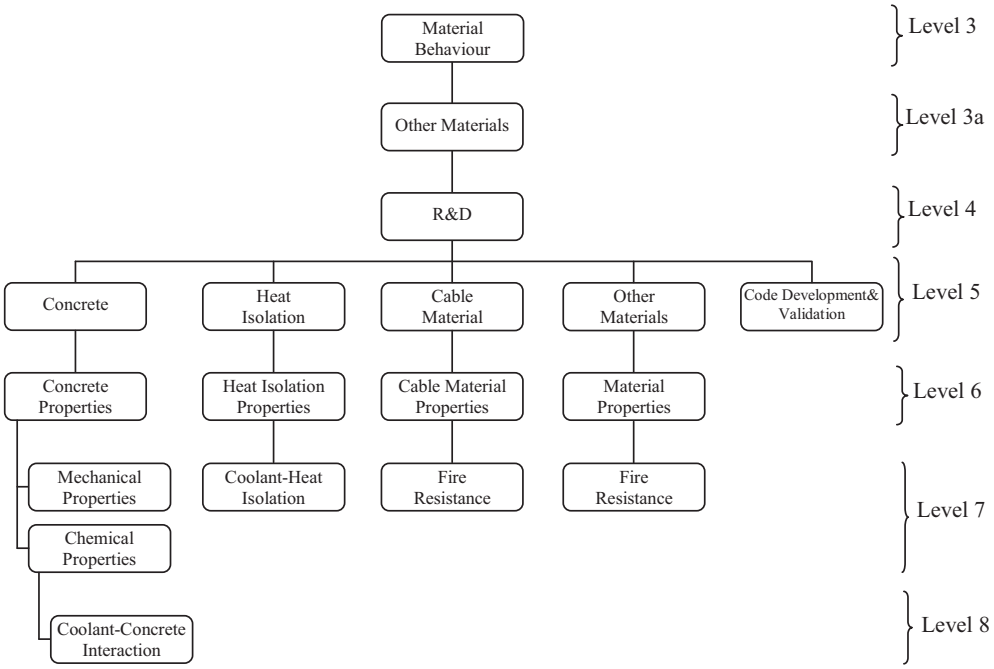

FIG. A-37. Scheme of branch 3-5-2.

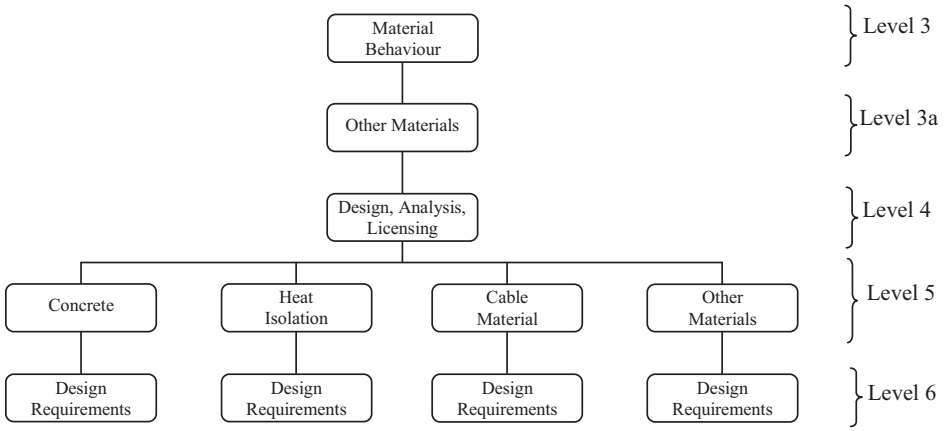

FIG. A-38. Scheme of branch 3-5-3.

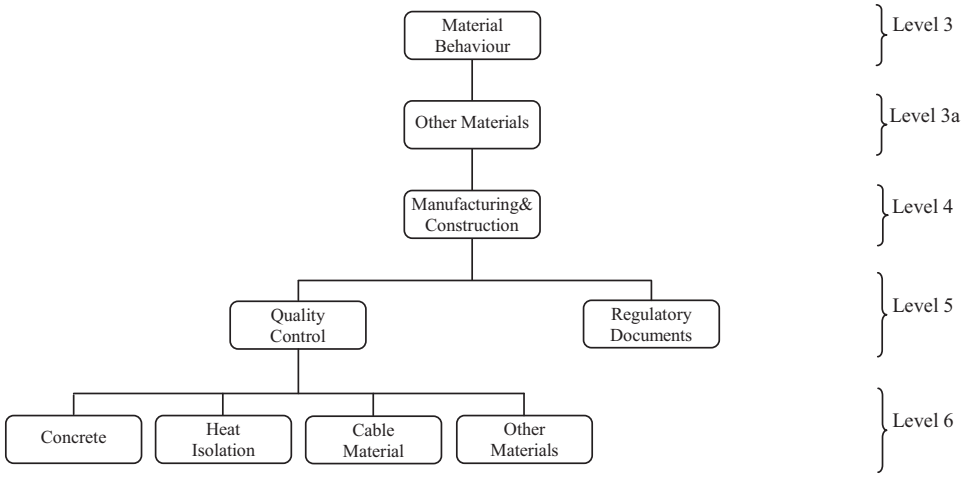

FIG. A-39. Scheme of branch 3-5-4.

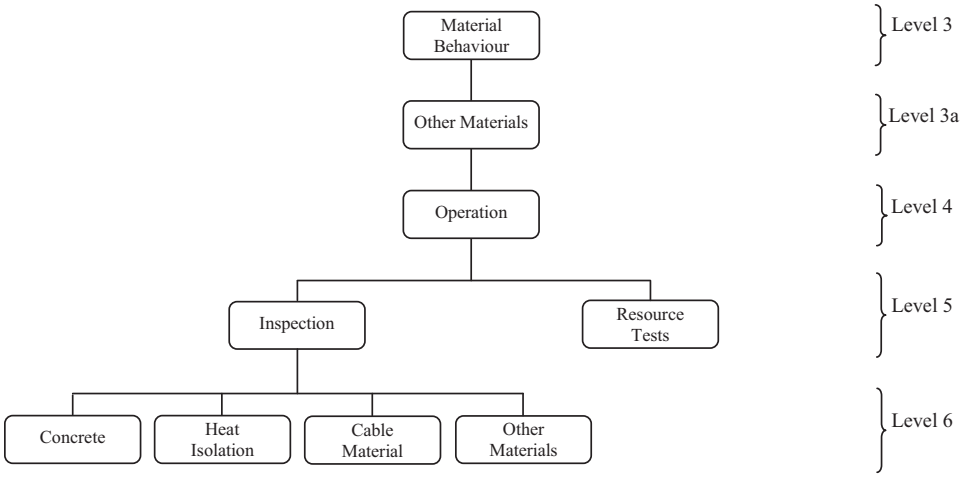

FIG. A-40. Scheme of branch 3-5-5.

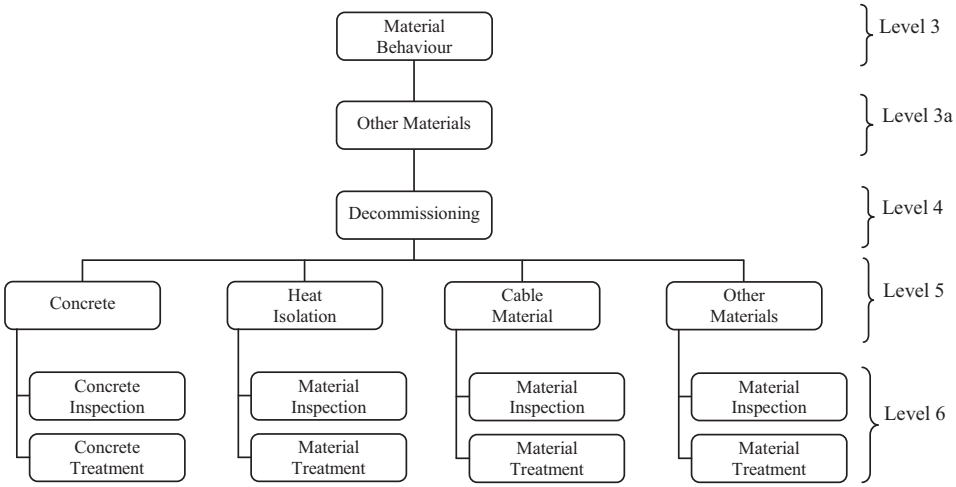

FIG. A-41. Scheme of branch 3-5-6.

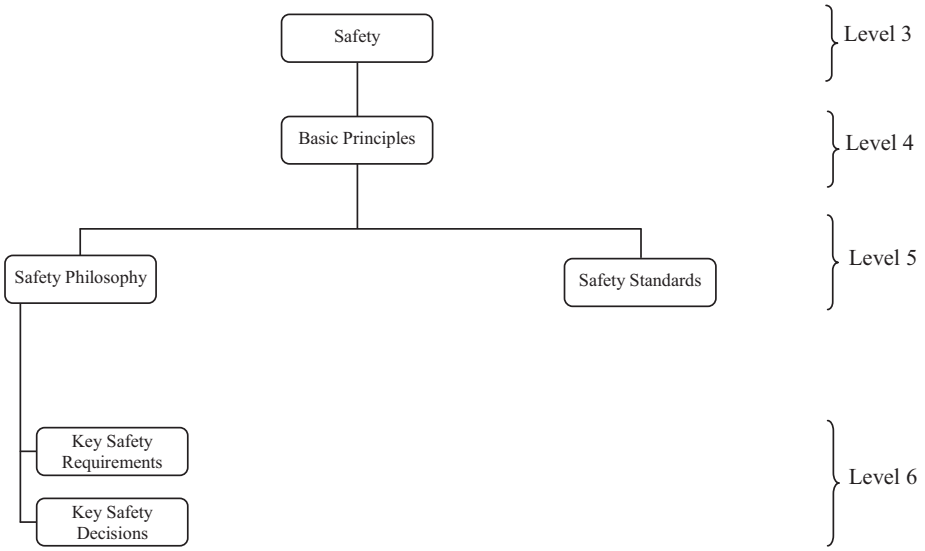

FIG. A-42. Scheme of branch 4-1.

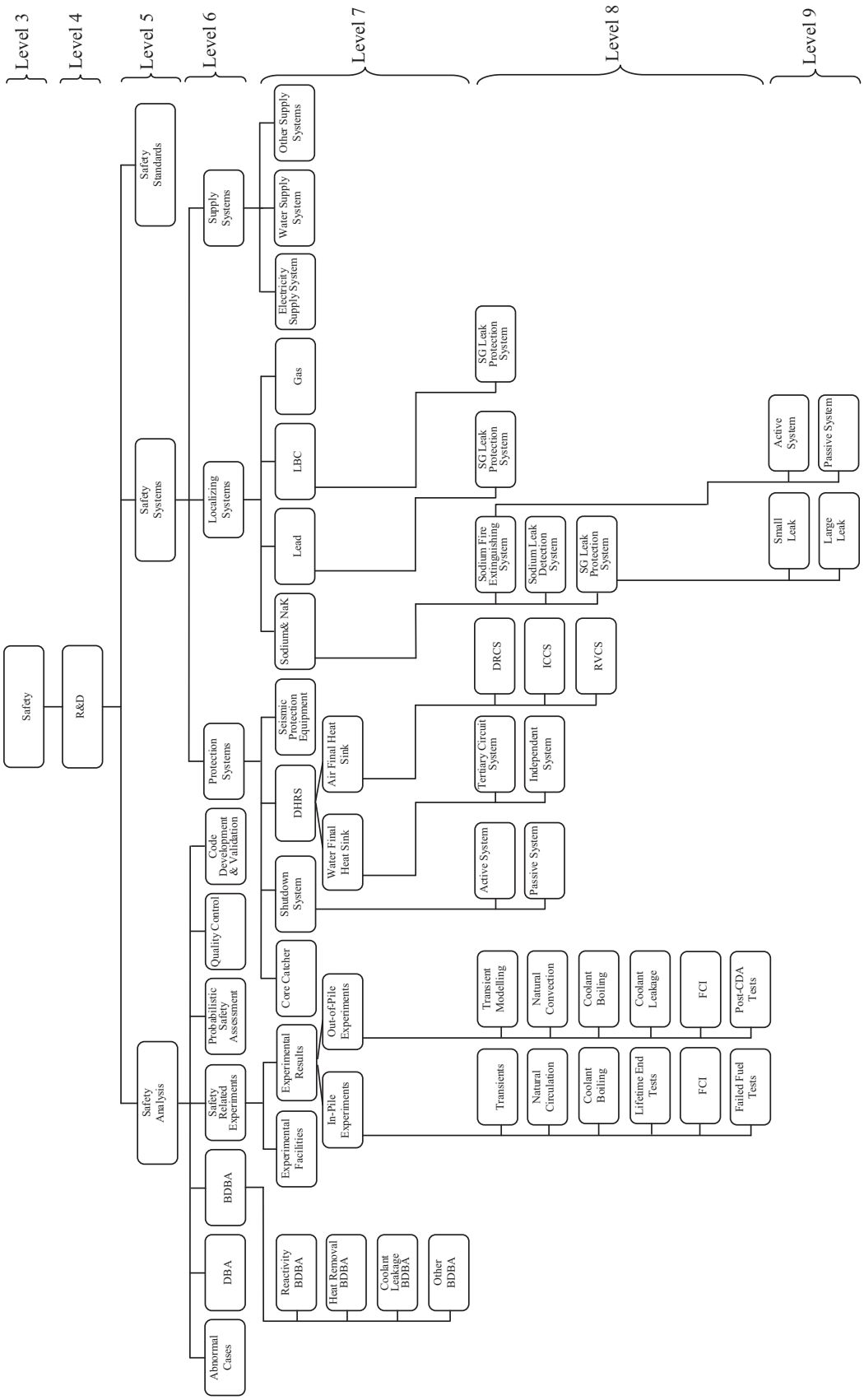

FIG. A-43. Scheme of branch 4-2.

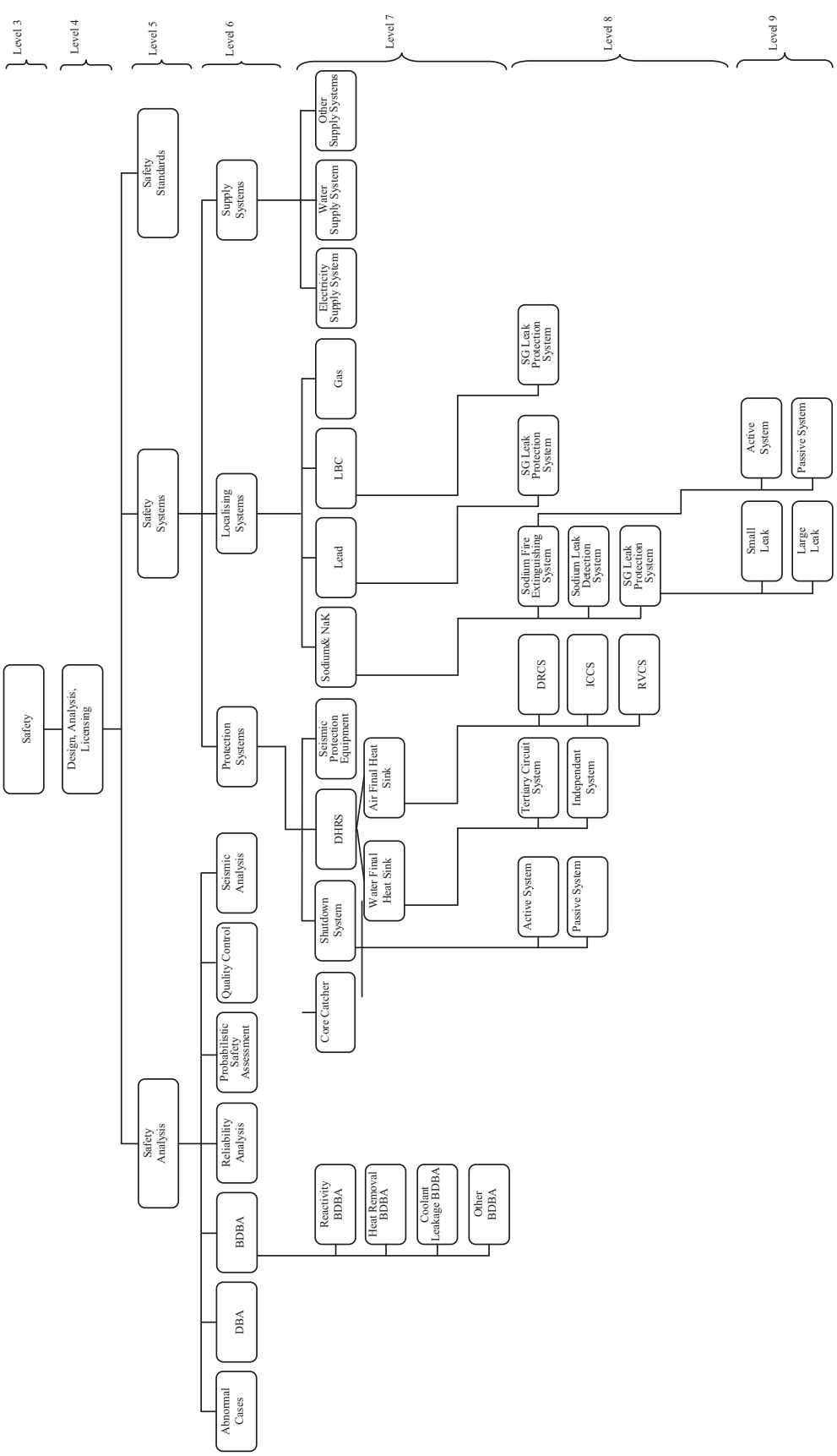

FIG. A-44. Scheme of branch 4-3.

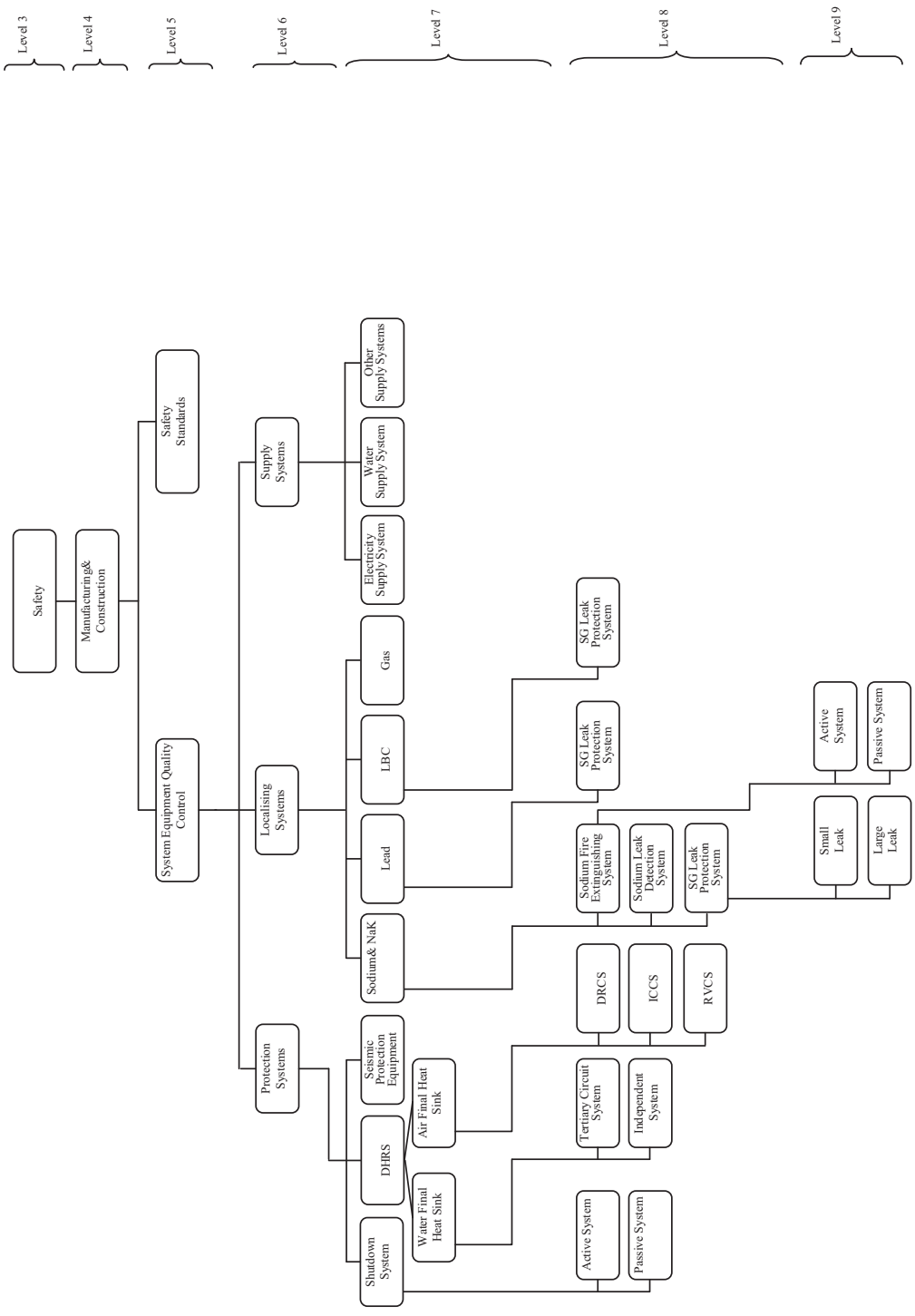

FIG. A-45. Scheme of branch 4-4.

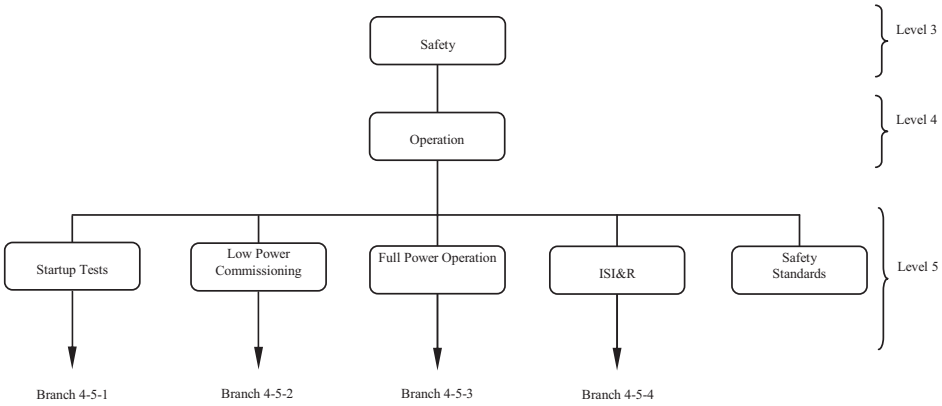

FIG. A-46. Scheme of branch 4-5.

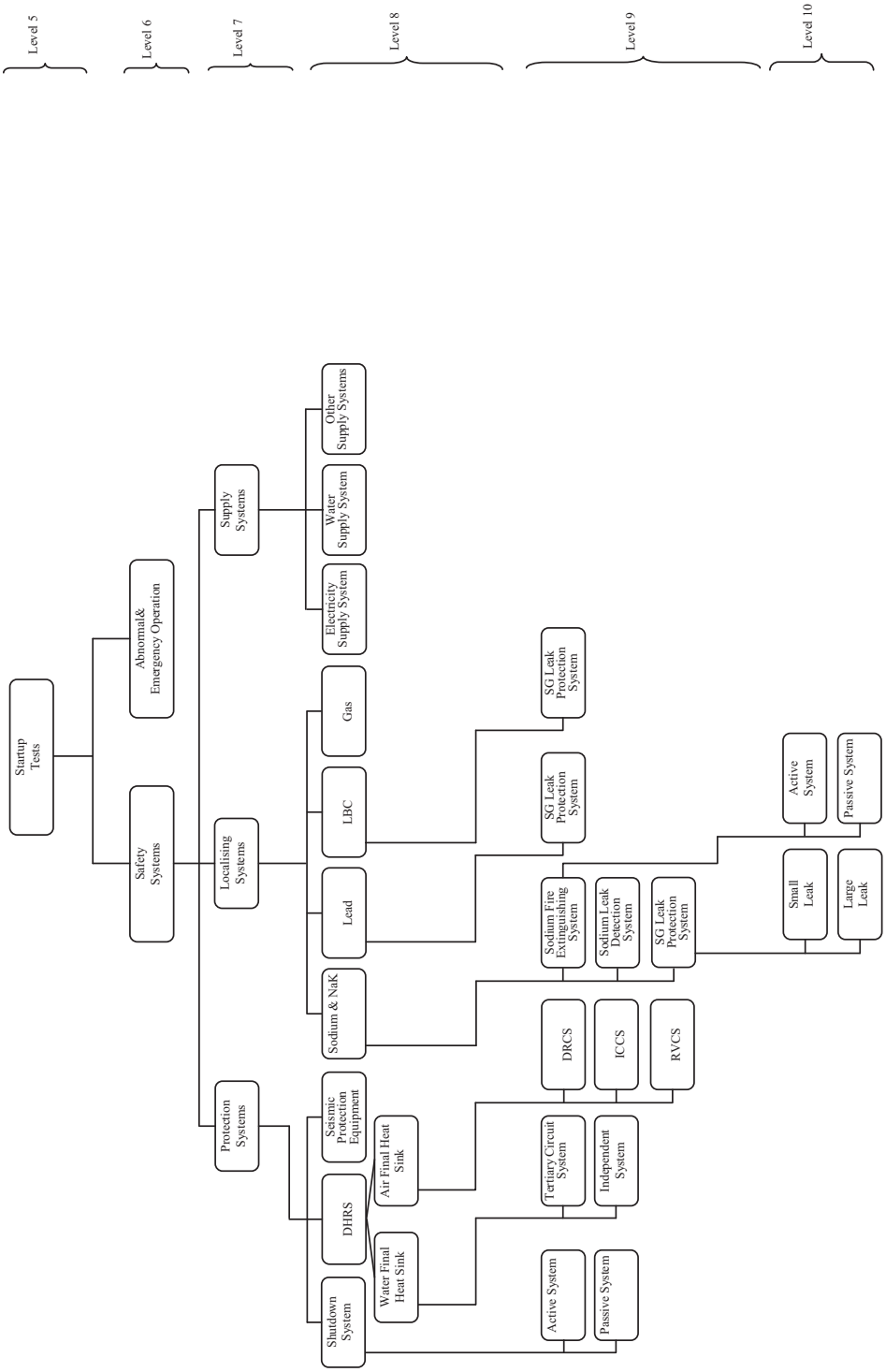

FIG. A-47. Scheme of branch 4-5-1.

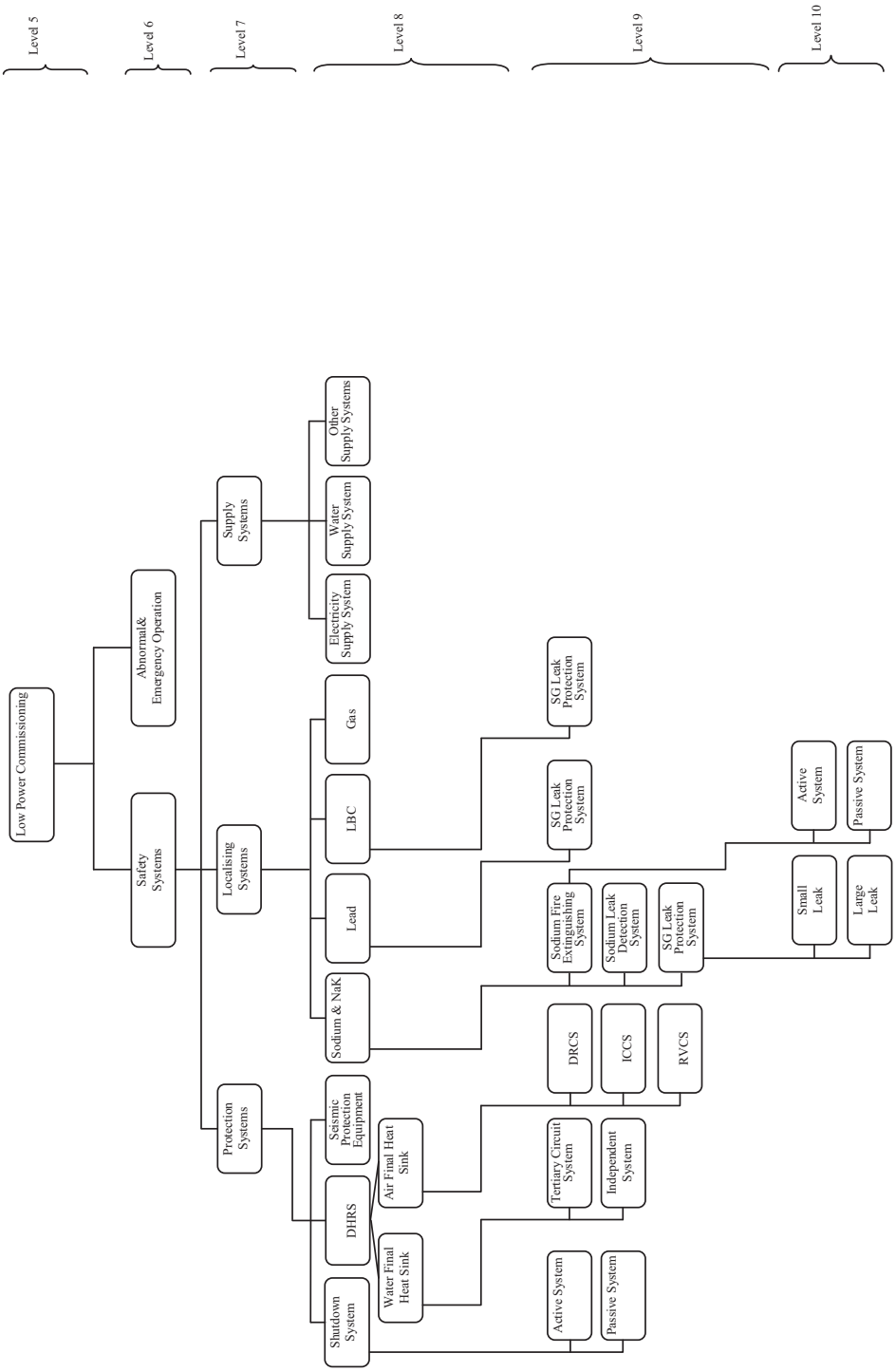

FIG. A-48. Scheme of branch 4-5-2.

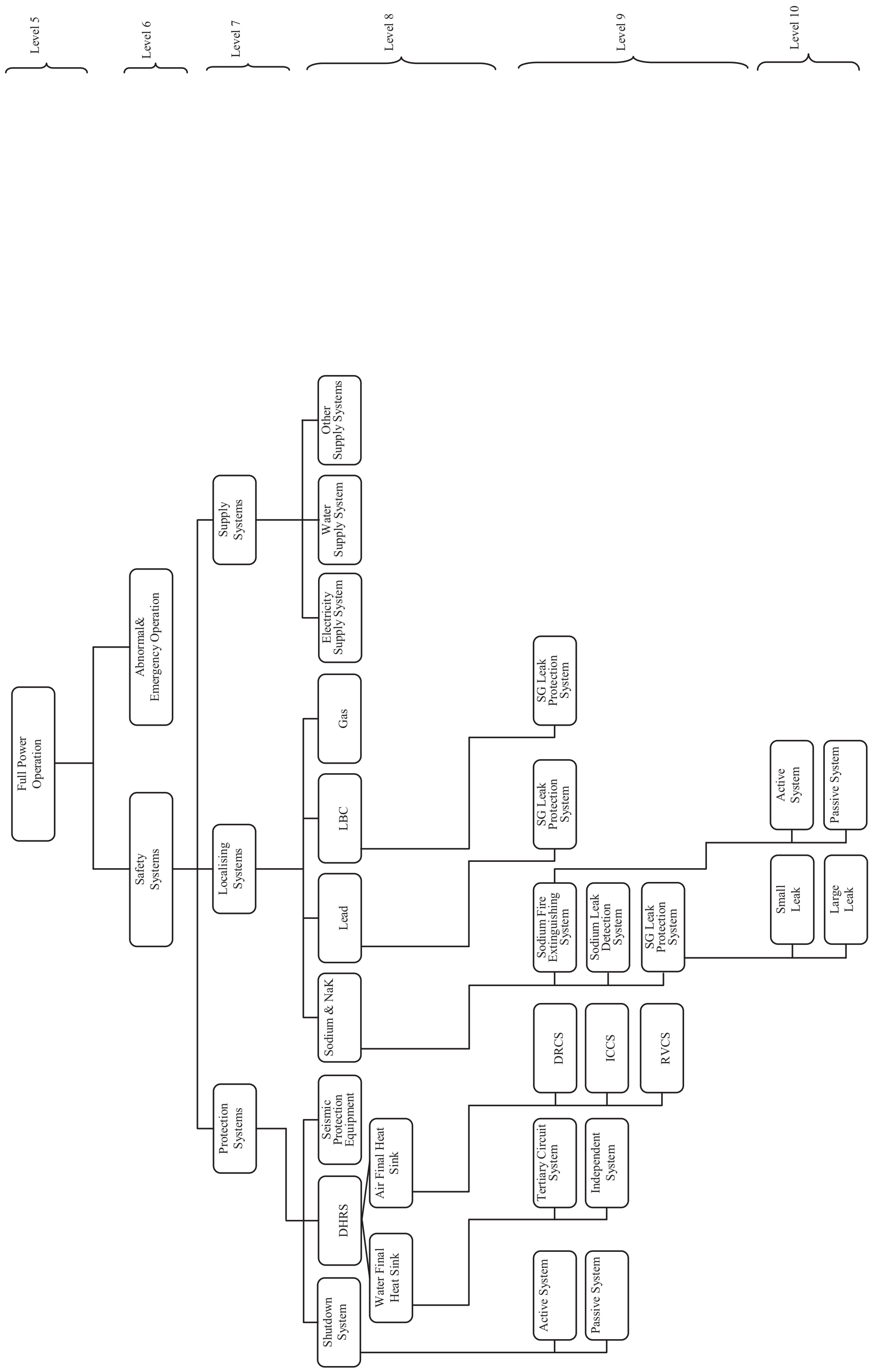

FIG. A-49. Scheme of branch 4-5-3.

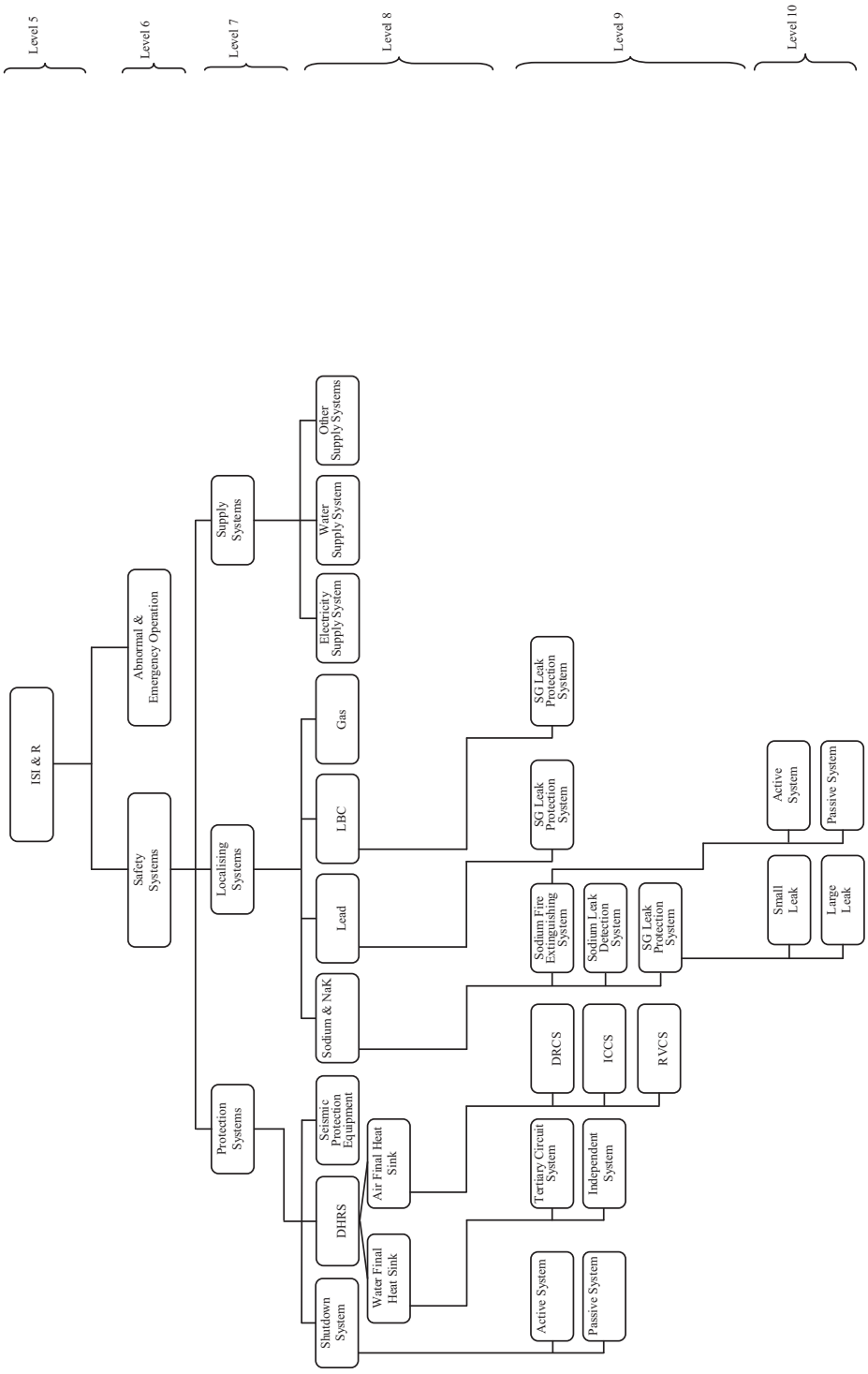

FIG. A-50. Scheme of branch 4-5-4.

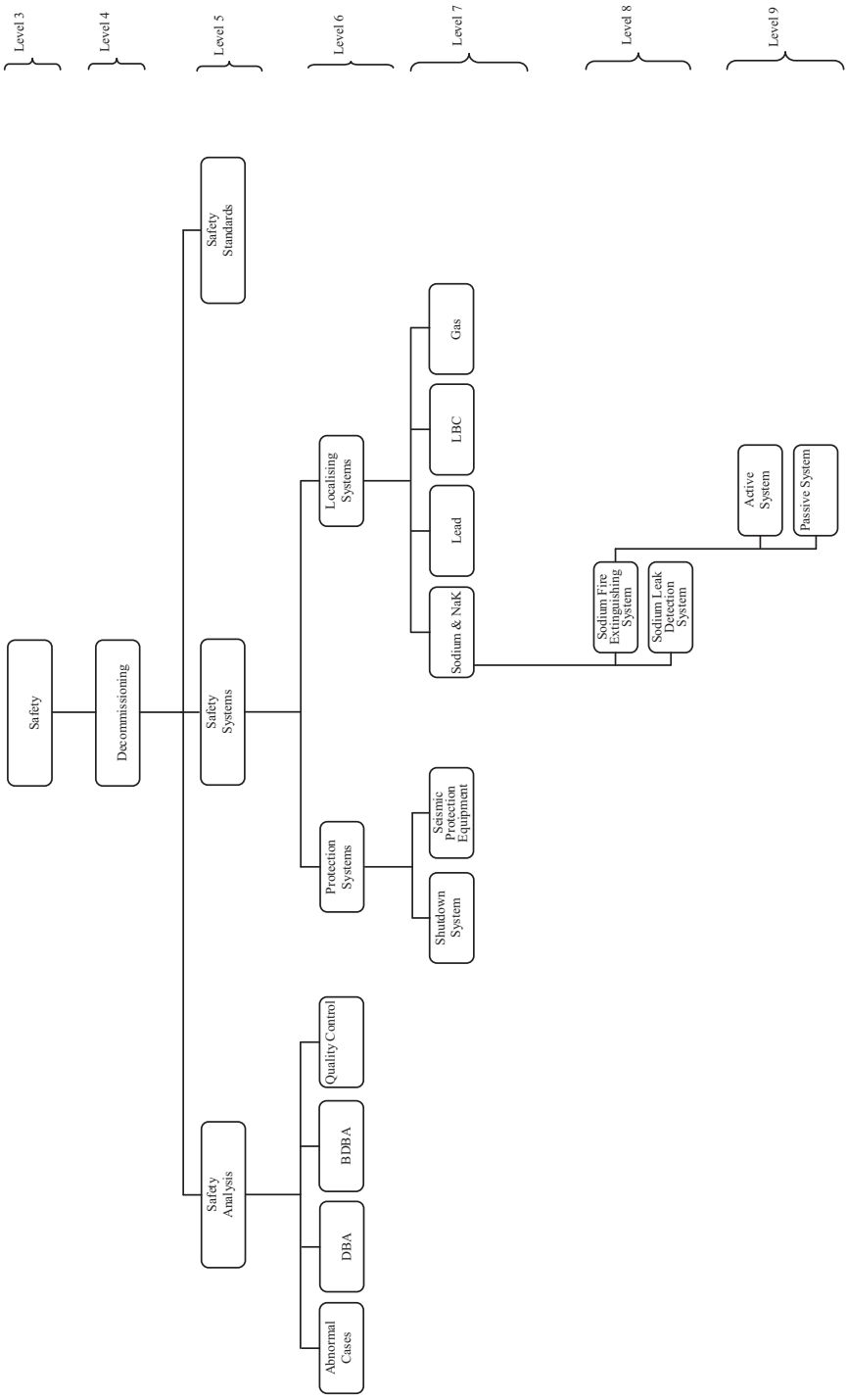

FIG. A-51. Scheme of branch 4-6.

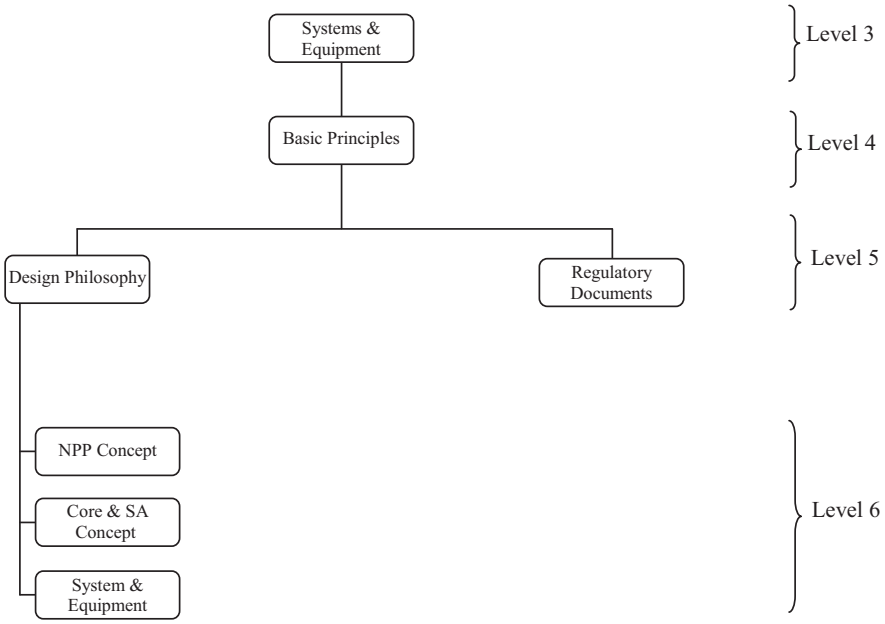

FIG. A-52. Scheme of branch 5-1.

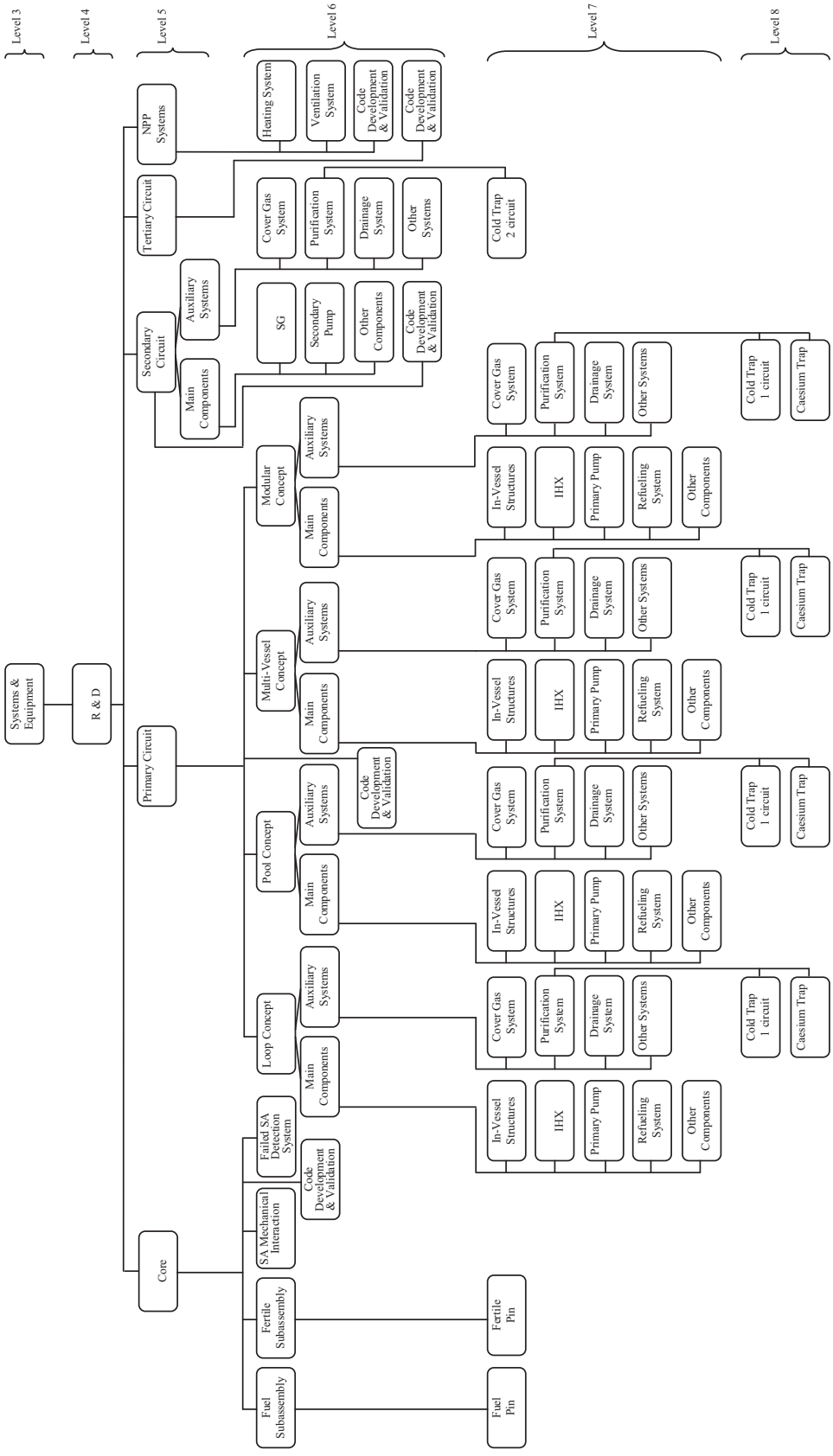

FIG. A-53. Scheme of branch 5-2.

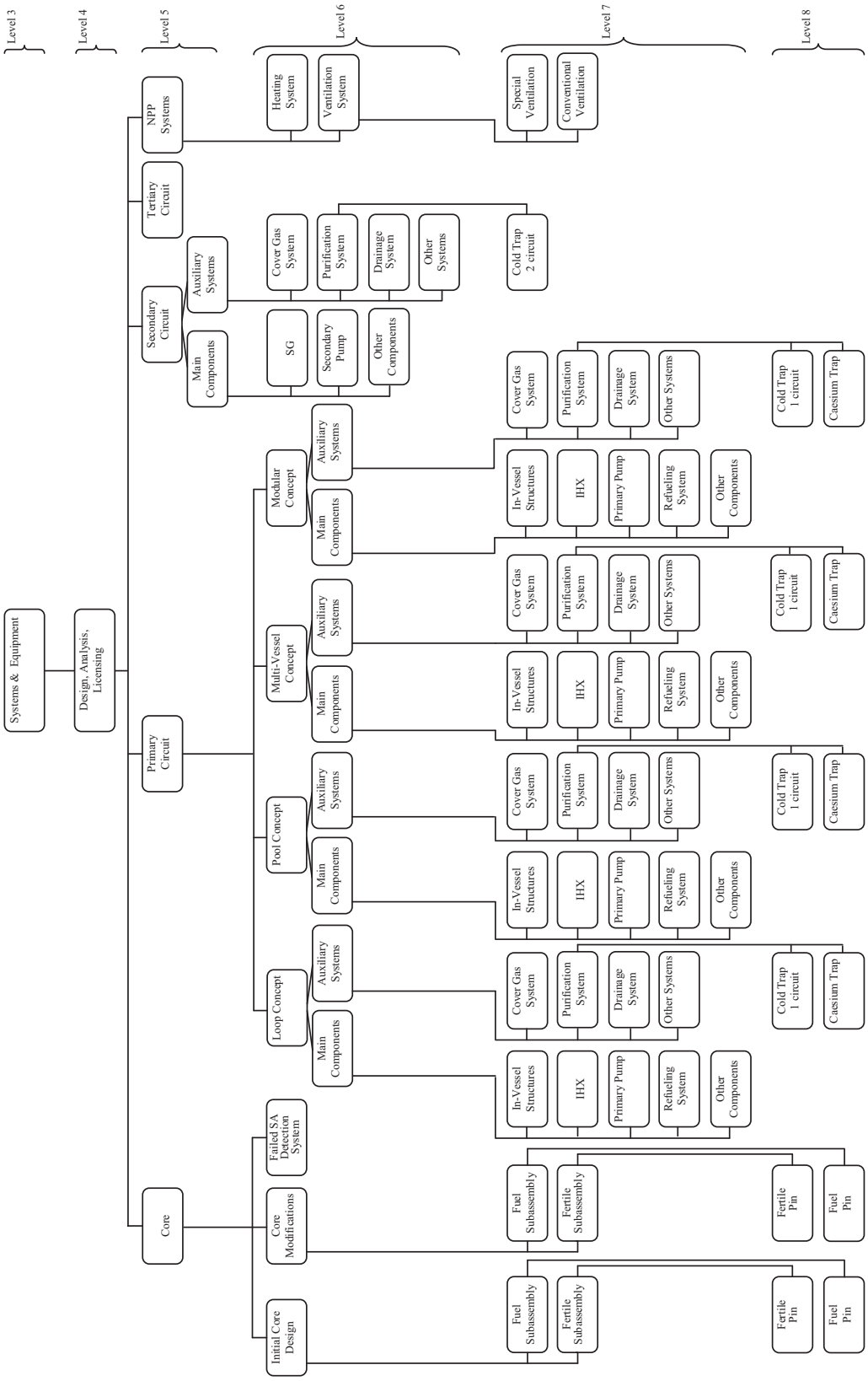

FIG. A-54. Scheme of branch 5-3.

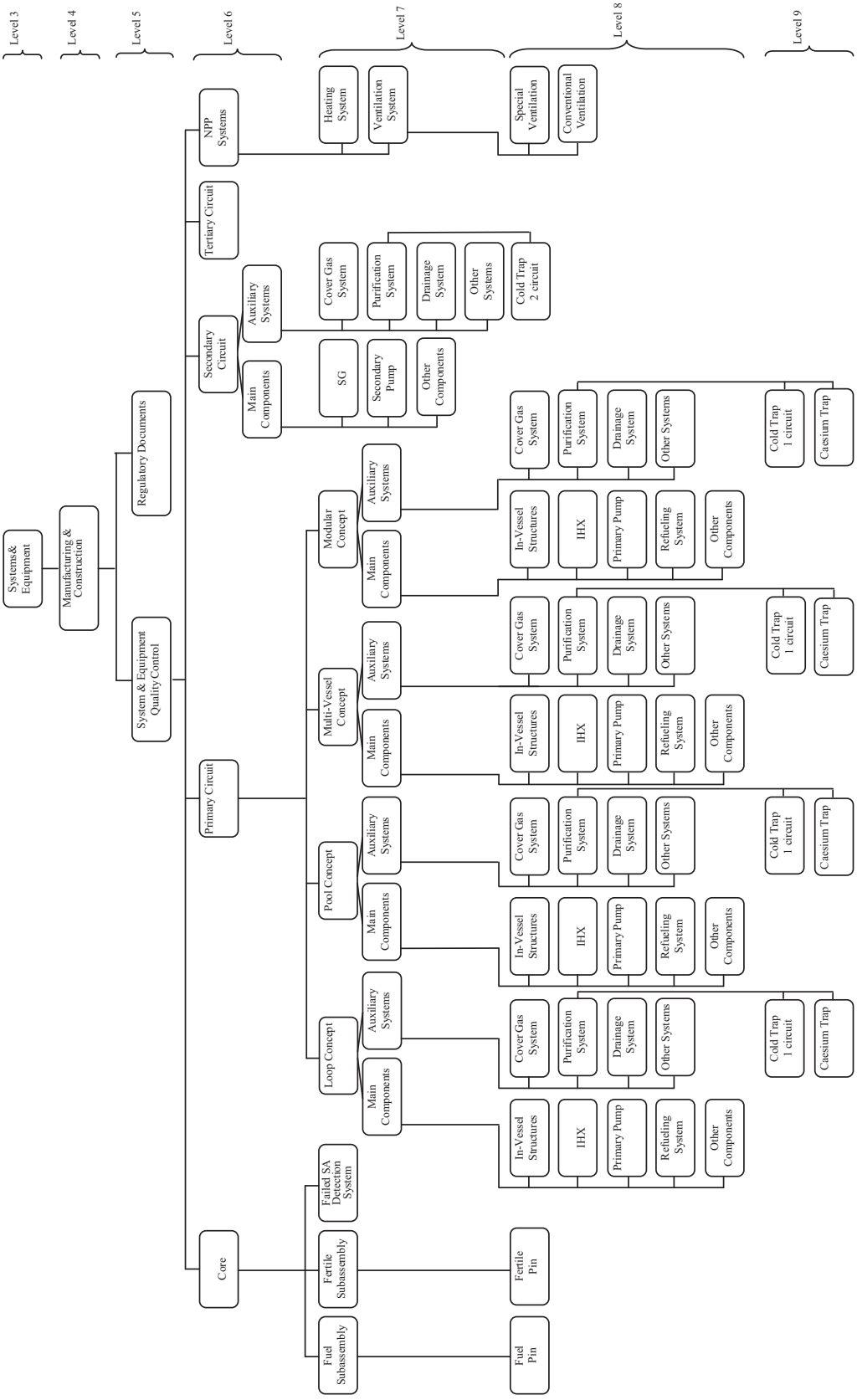

FIG. A-55. Scheme of branch 5-4.

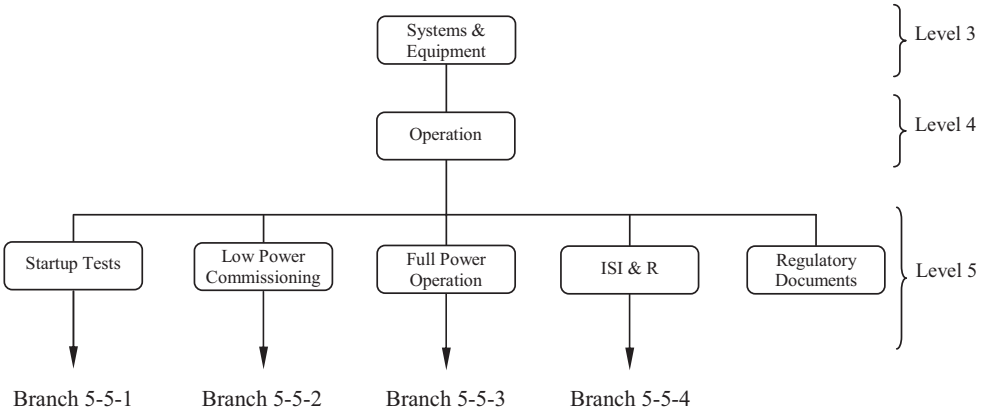

FIG. A-56. Scheme of branch 5-5.

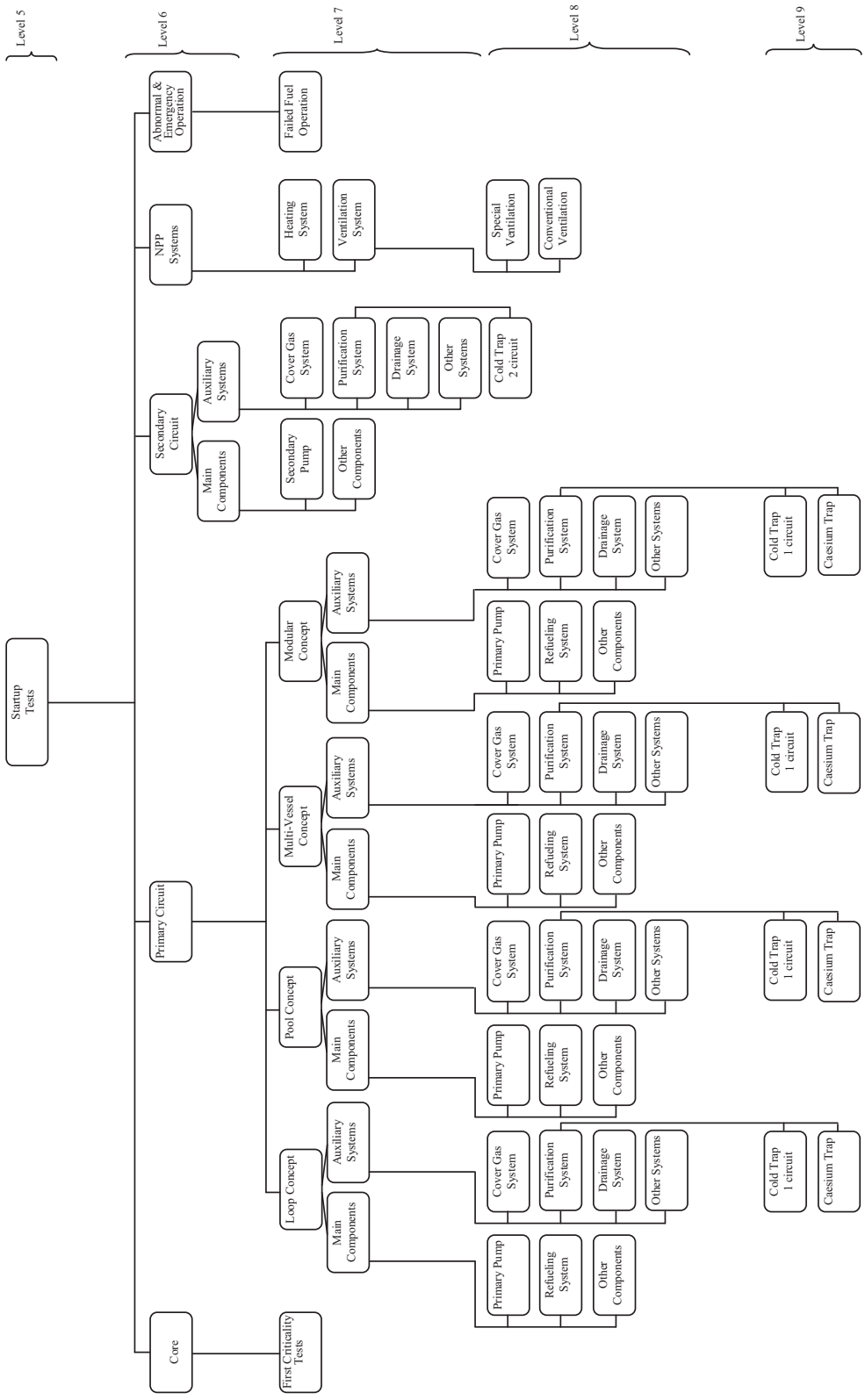

FIG. A-57. Scheme of branch 5-5-1.

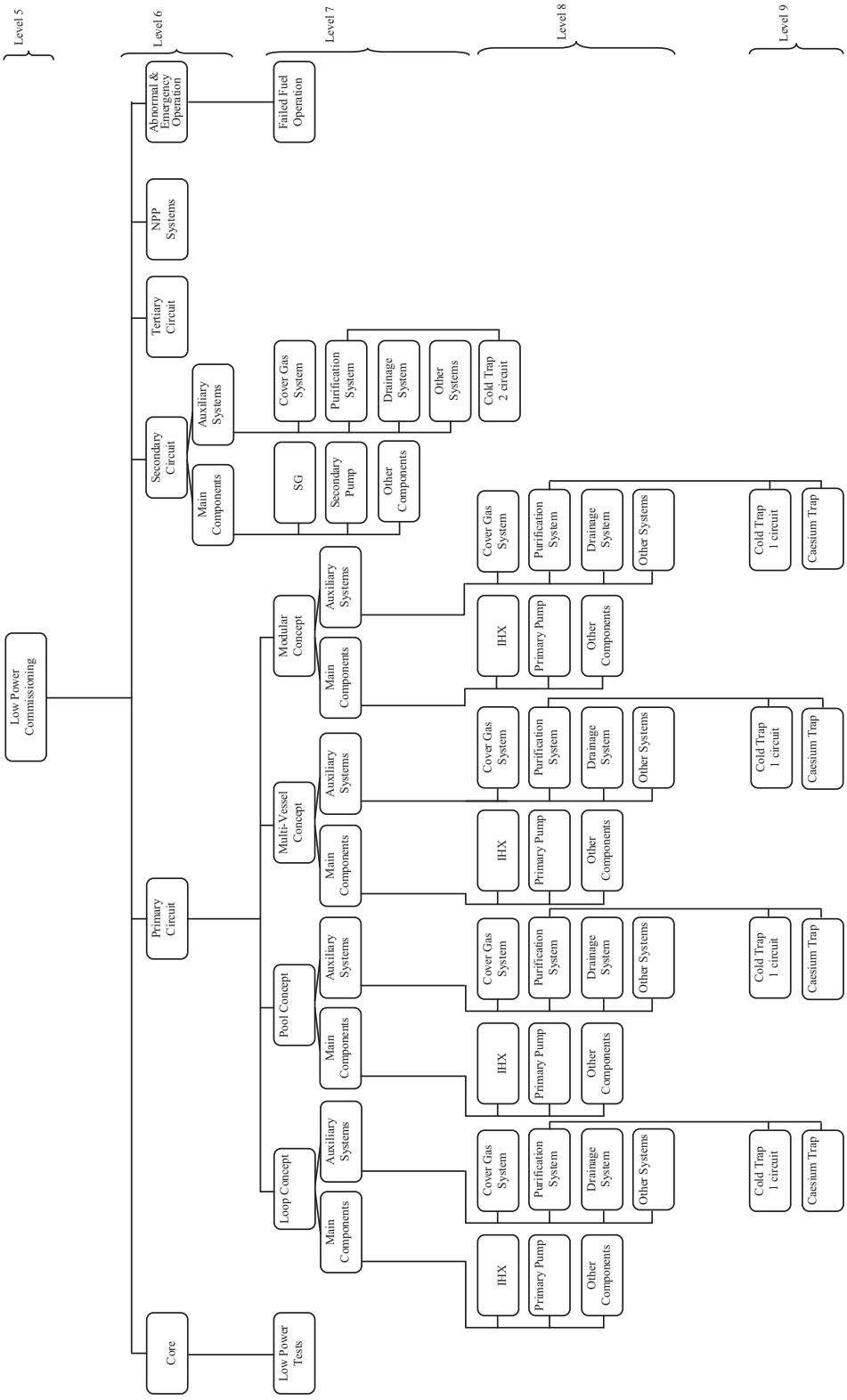

FIG. A-58. Scheme of branch 5-5-2.

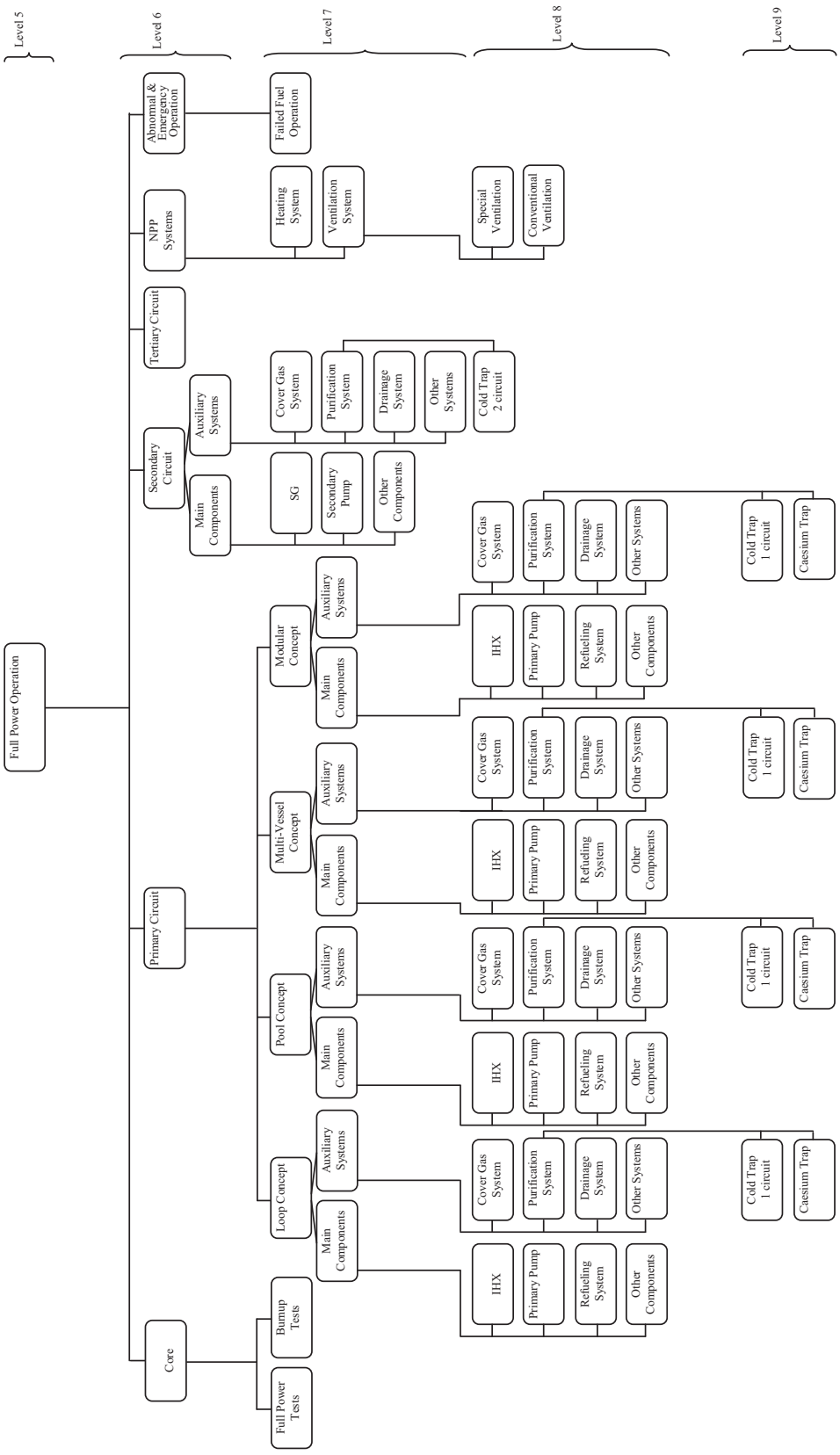

FIG. A-59. Scheme of branch 5-5-3.

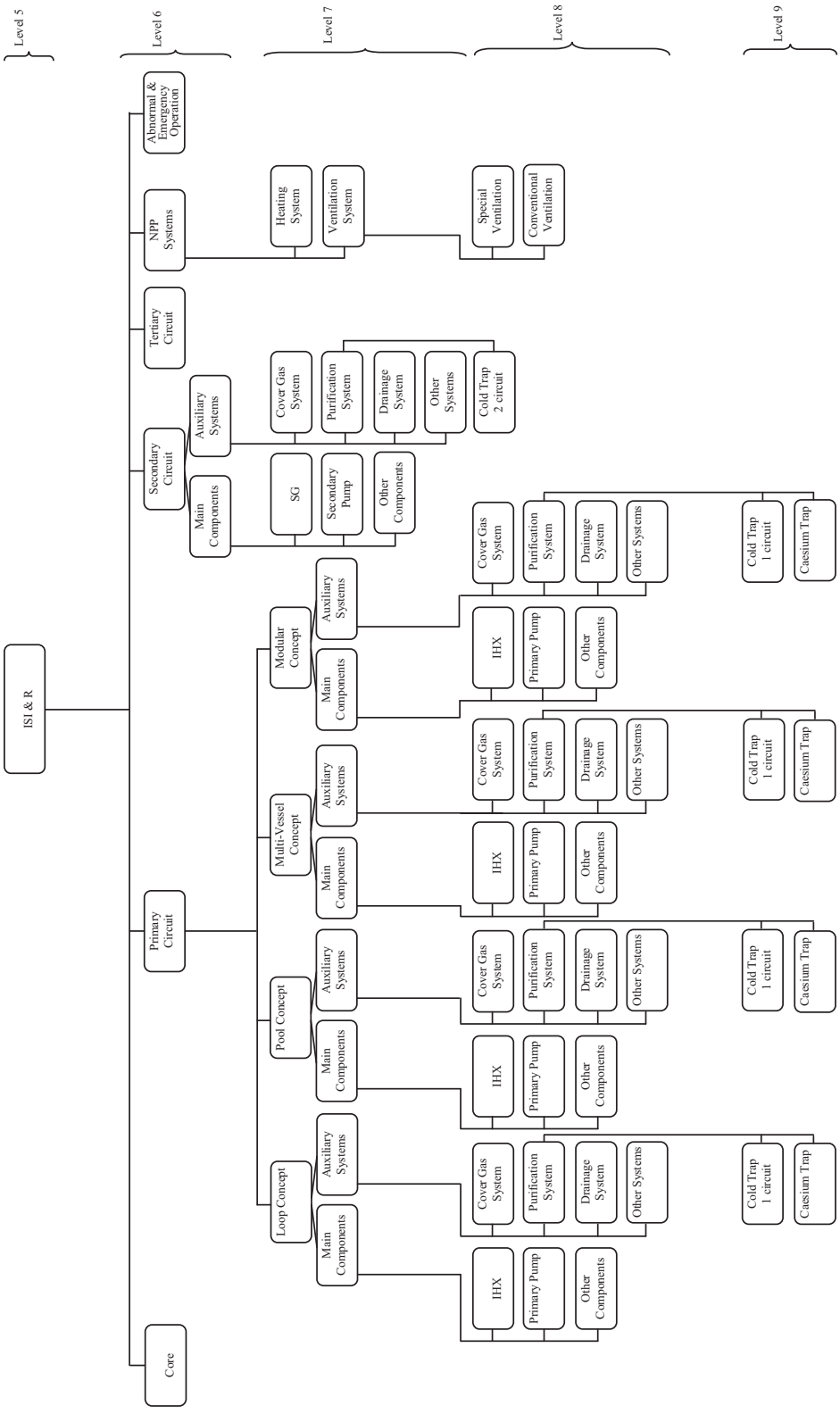

FIG. A-60. Scheme of branch 5-5-4.

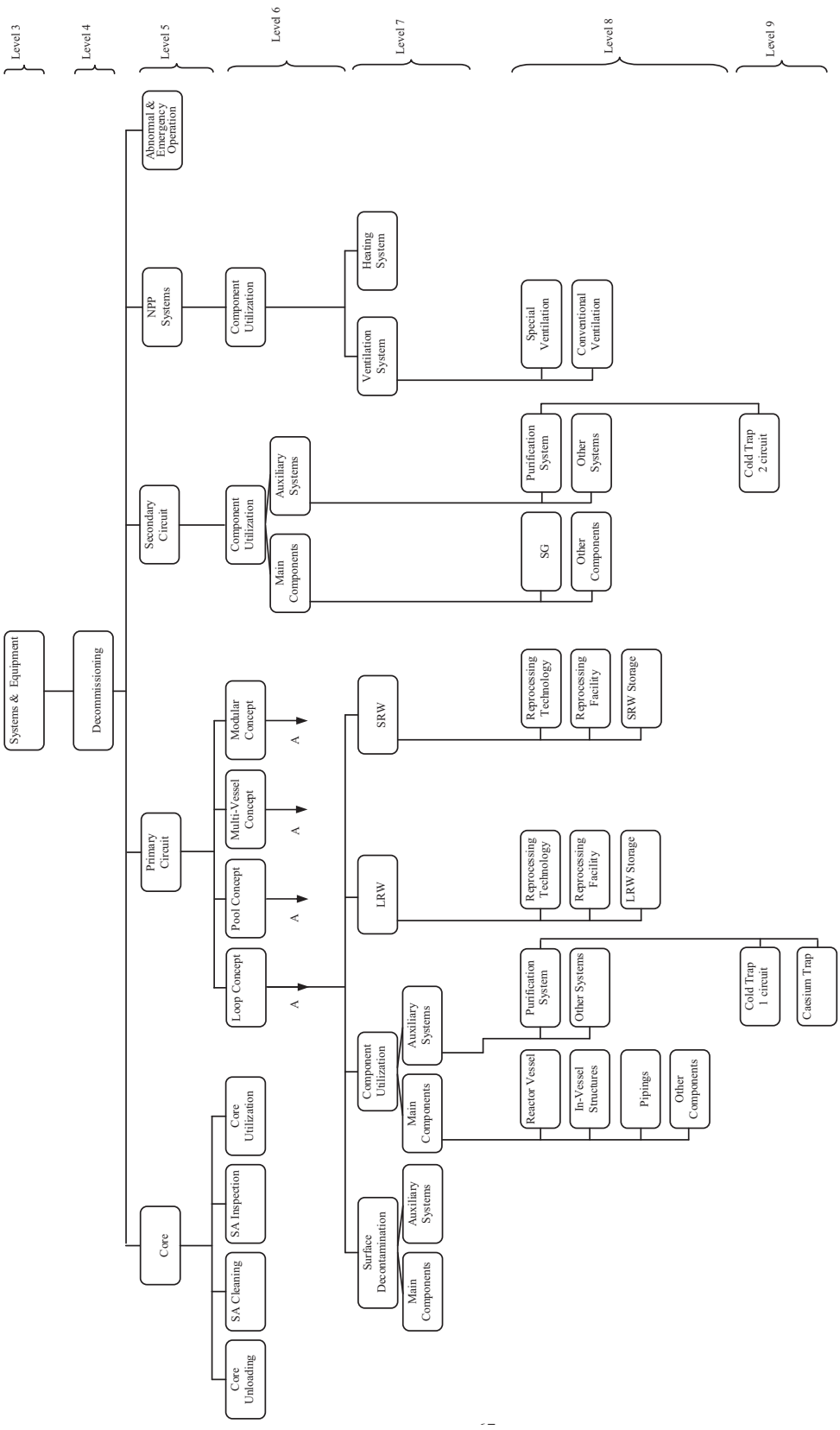

FIG. A-61. Scheme of branch 5-6.

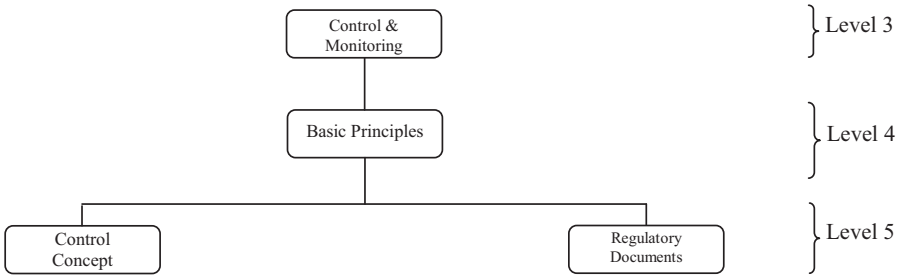

FIG. A-62. Scheme of branch 6-1.

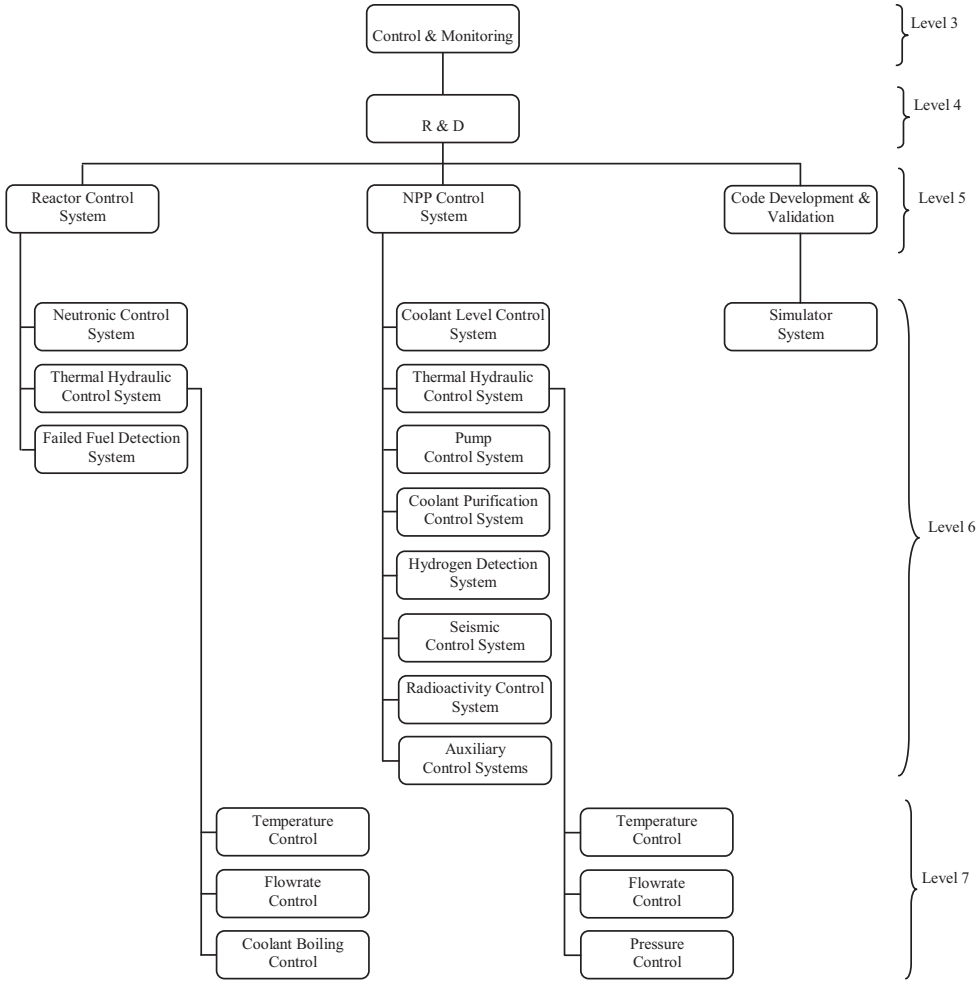

FIG. A-63. Scheme of branch 6-2.

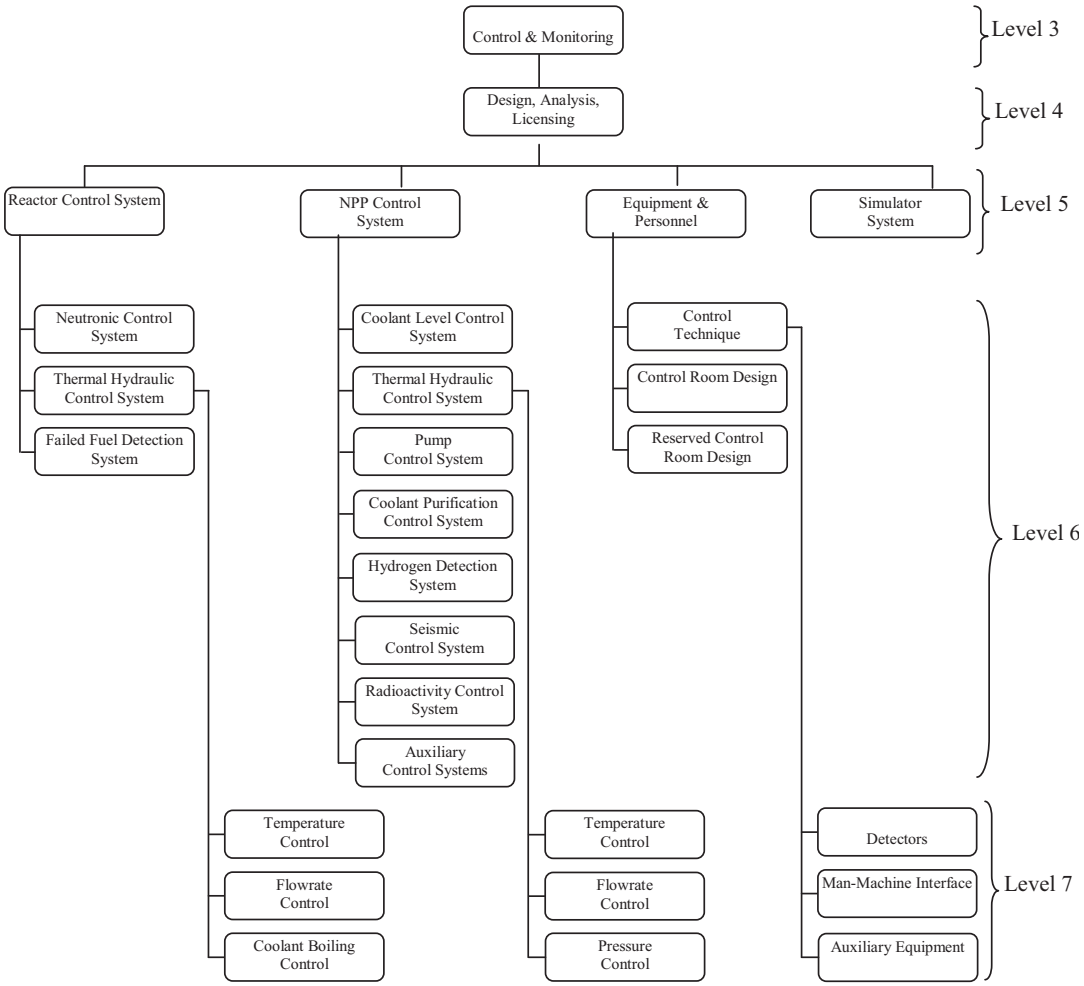

FIG. A-64. Scheme of branch 6-3.

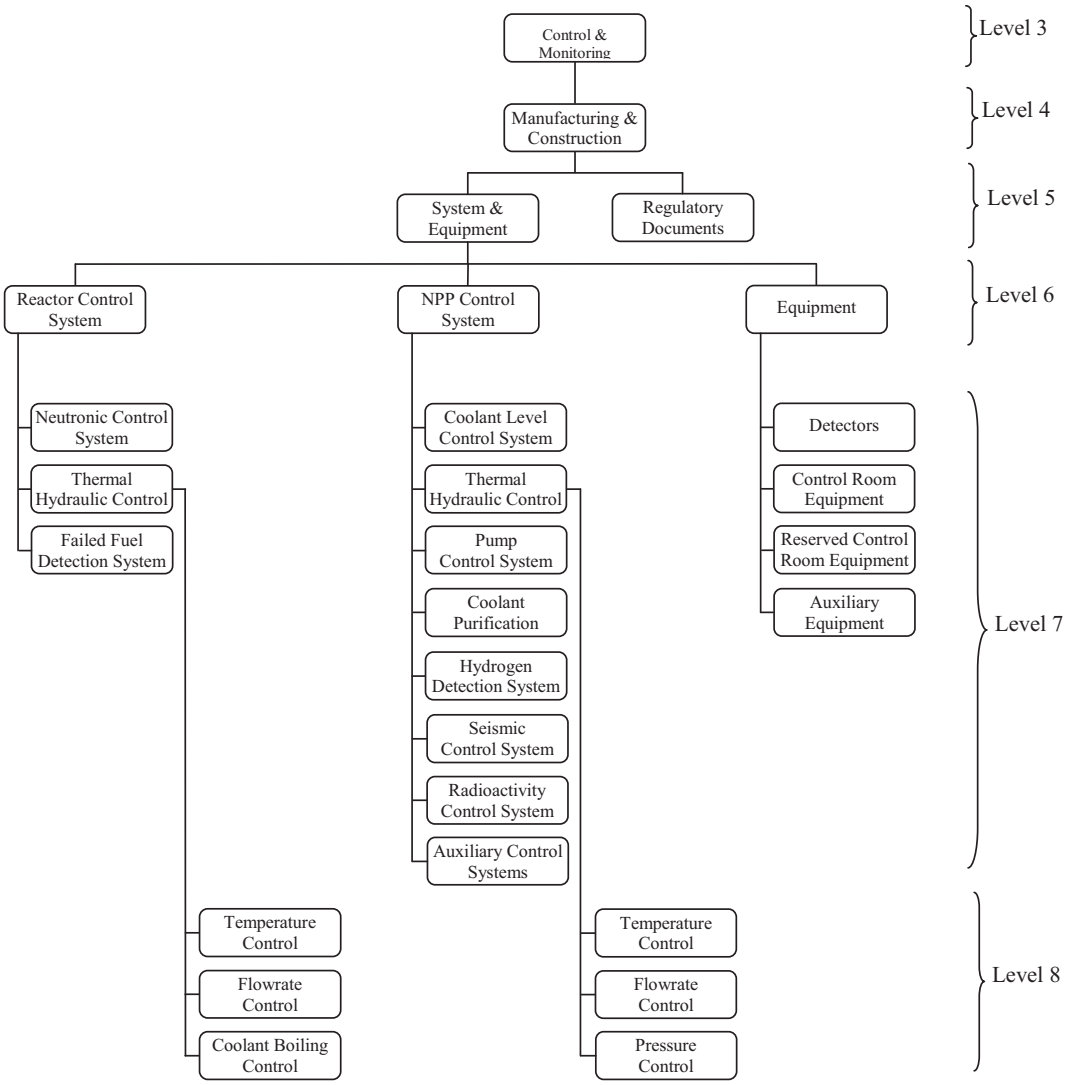

FIG. A-65. Scheme of branch 6-4.

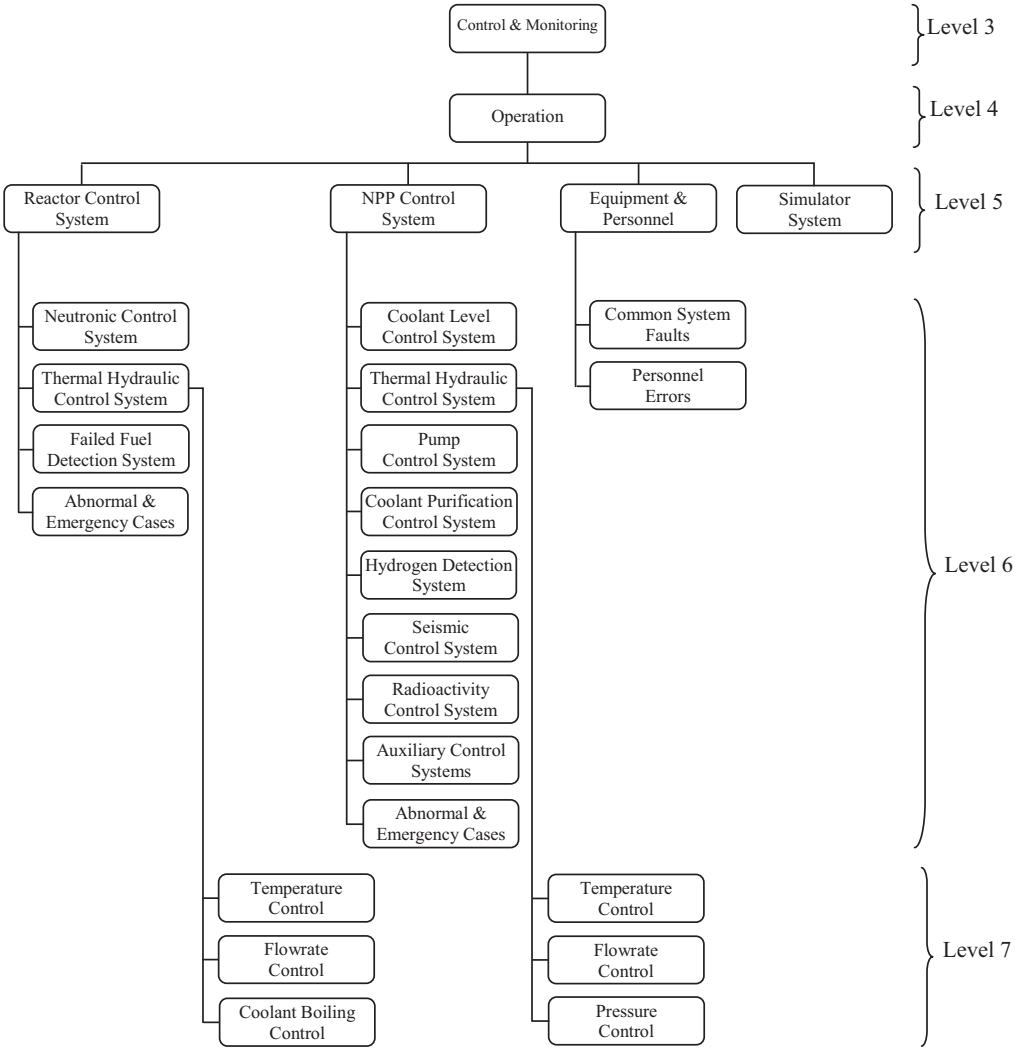

FIG. A-66. Scheme of branch 6-5.

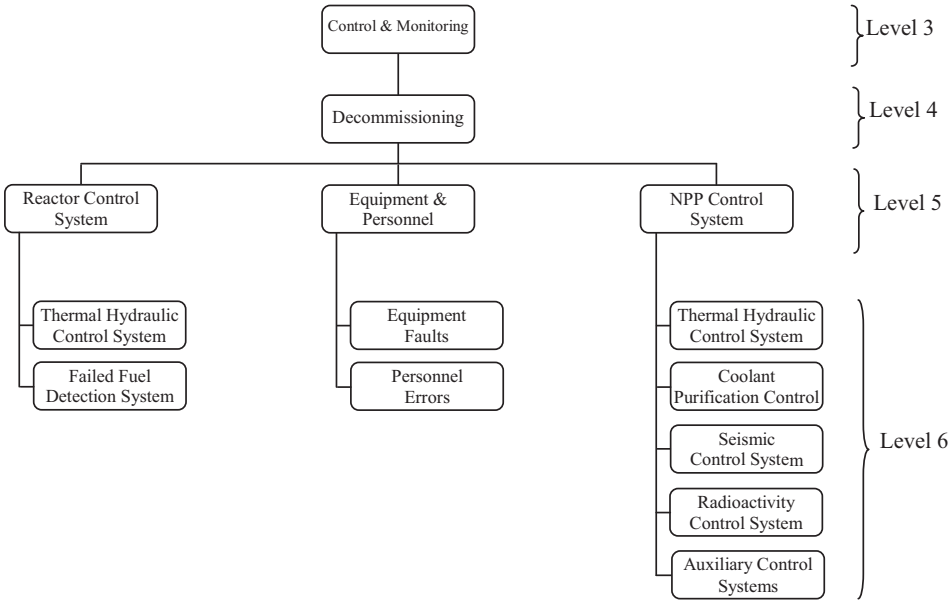

FIG. A-67. Scheme of branch 6-6.

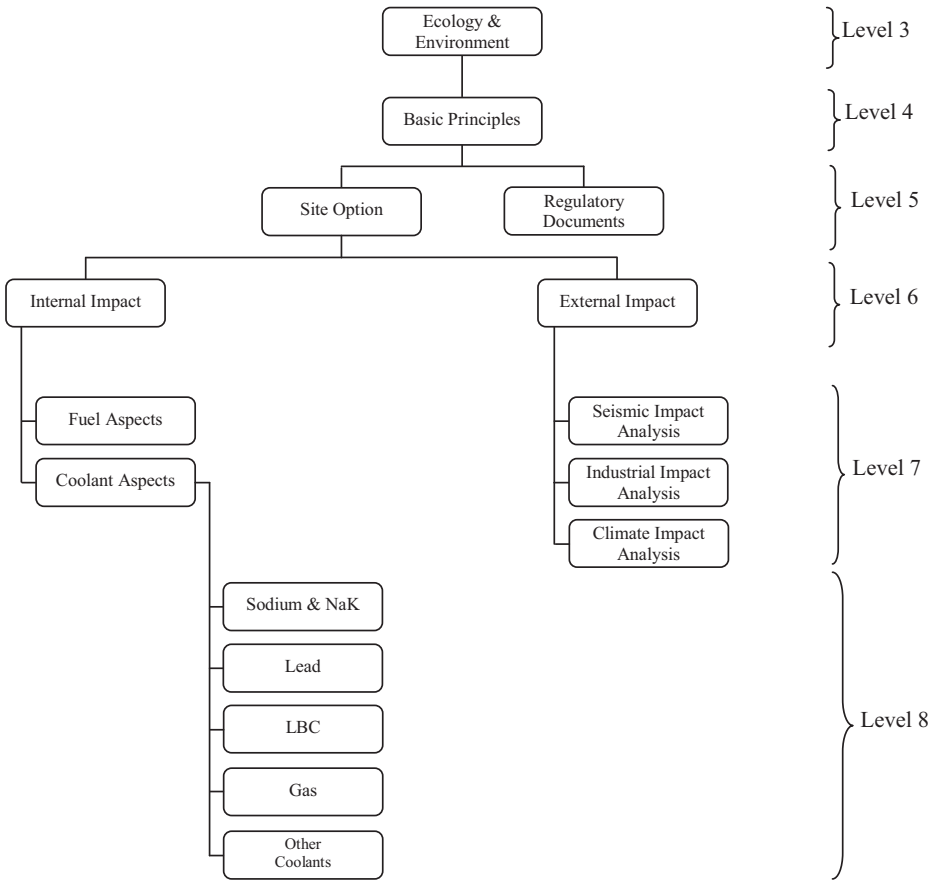

FIG. A-68. Scheme of branch 7-1.

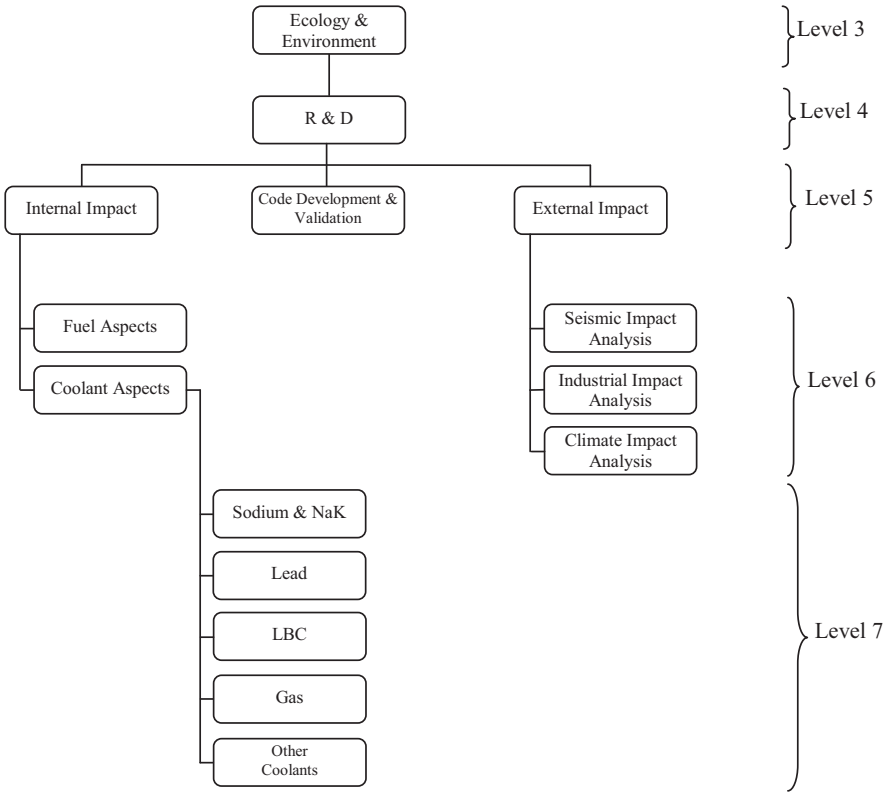

FIG. A-69. Scheme of branch 7-2.

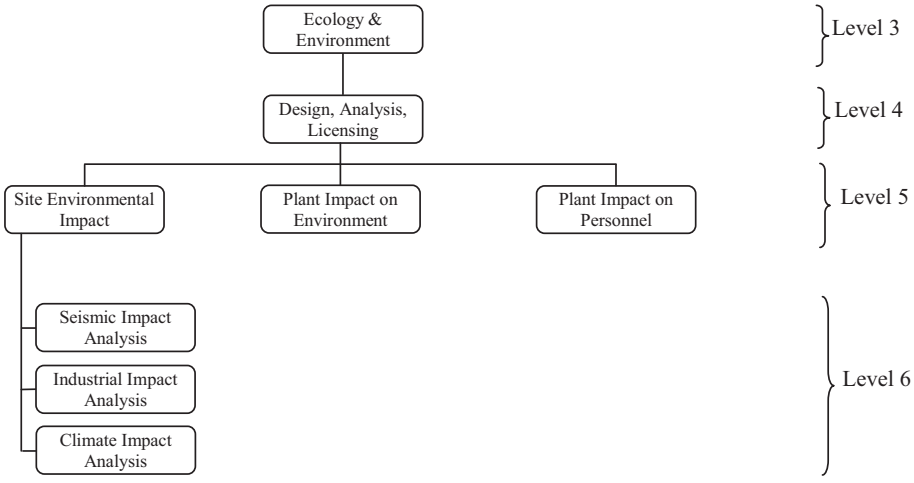

FIG. A-70. Scheme of branch 7-3.

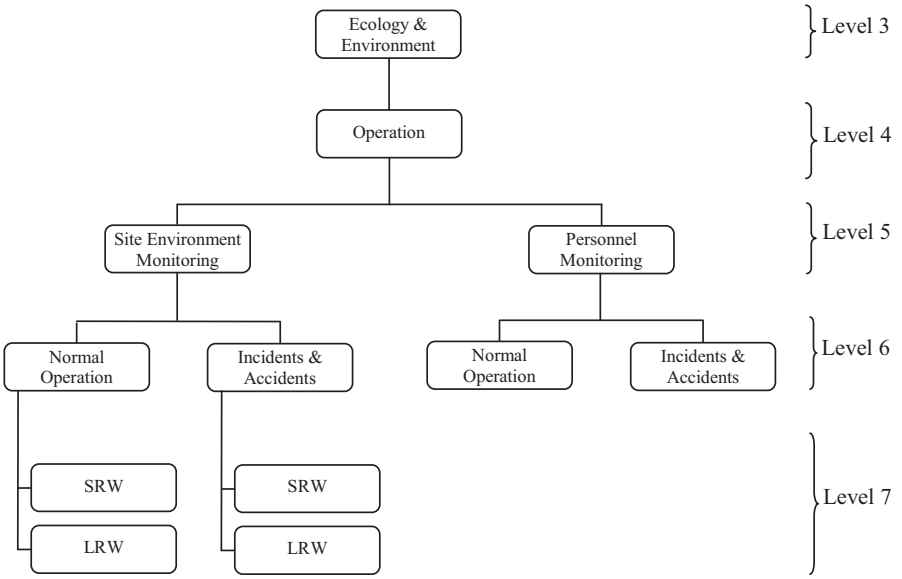

FIG. A-71. Scheme of branch 7-5.

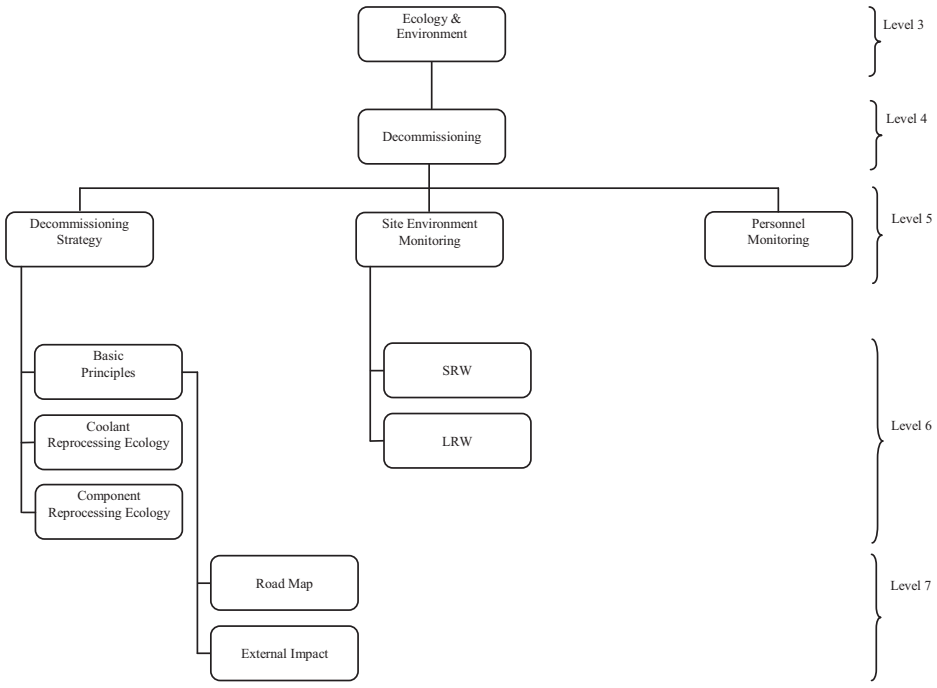

FIG. A-72. Scheme of branch 7-6.

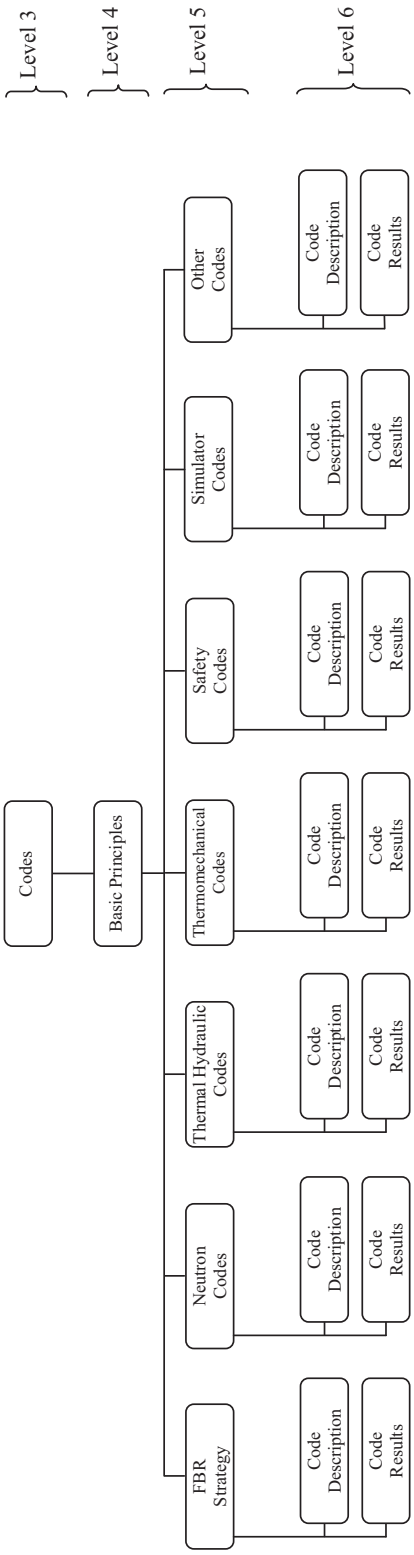

FIG. A-73. Scheme of branch 8-1.

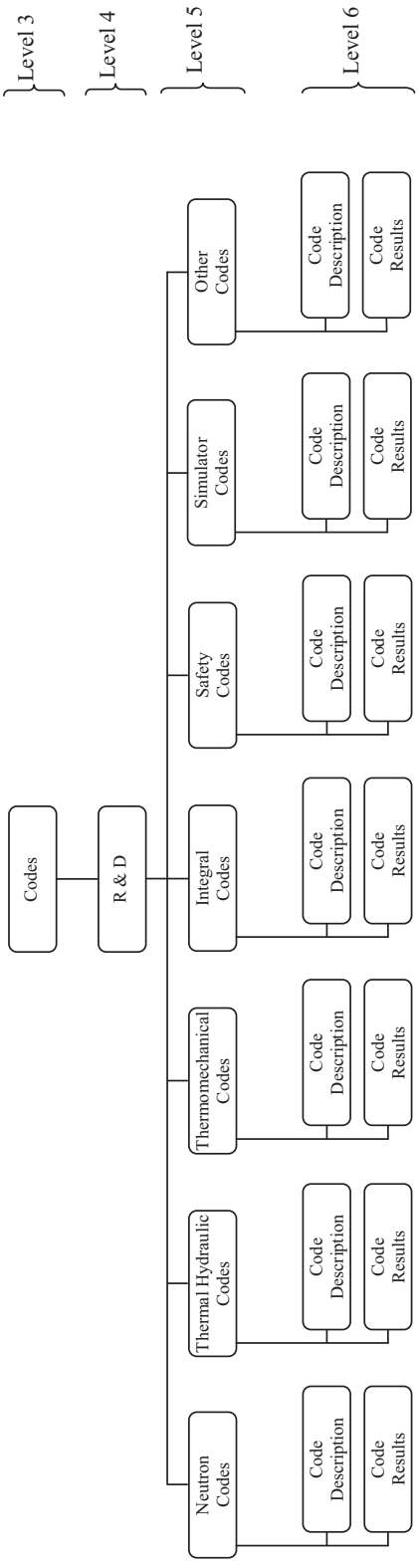

FIG. A-74. Scheme of branch 8-2.

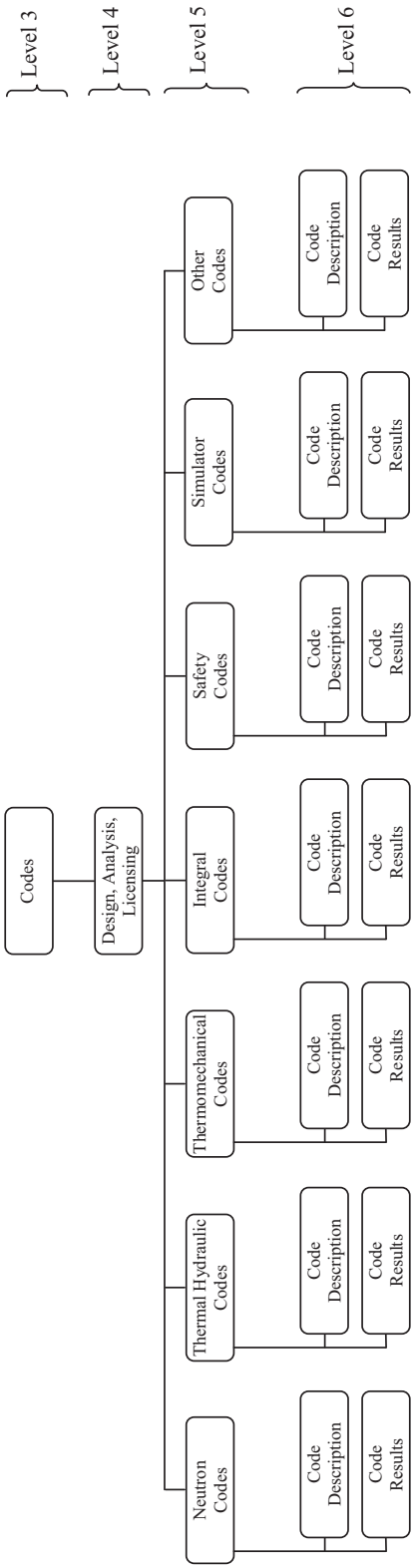

FIG. A-75. Scheme of branch 8-3.

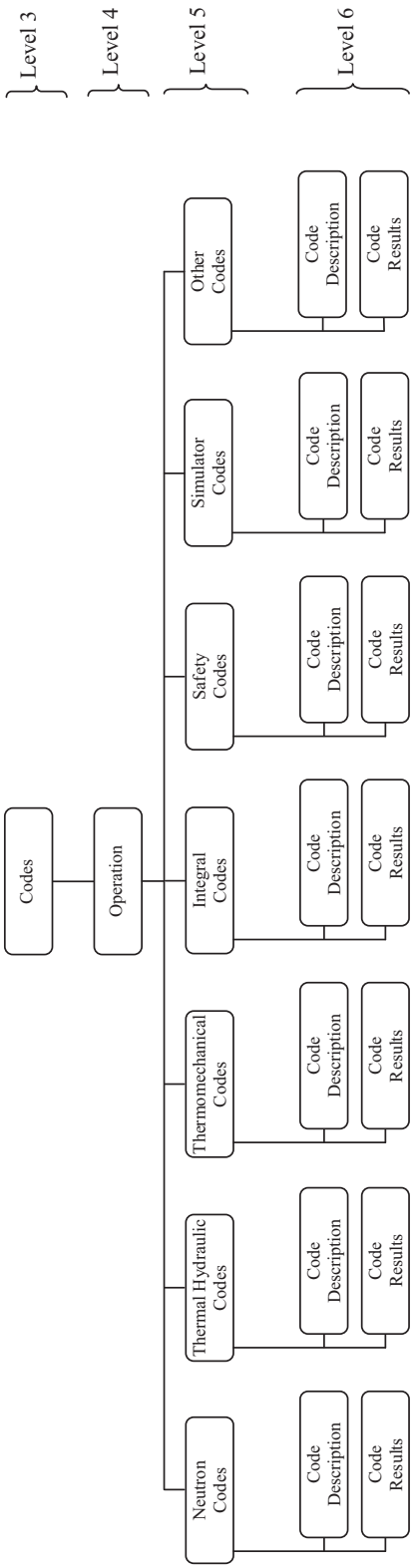

FIG. A-76. Scheme of branch 8-5.

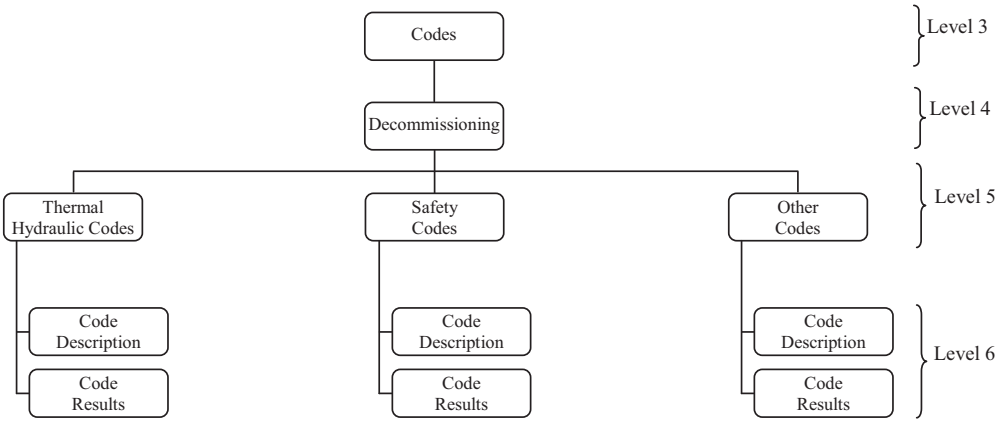

FIG. A-77. Scheme of branch 8-6.

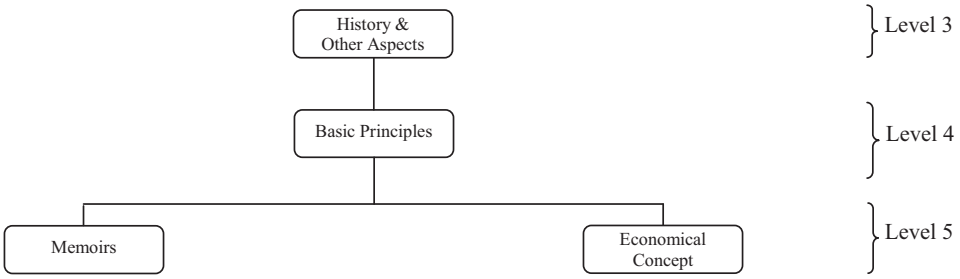

FIG. A-78. Scheme of branch 9-1.

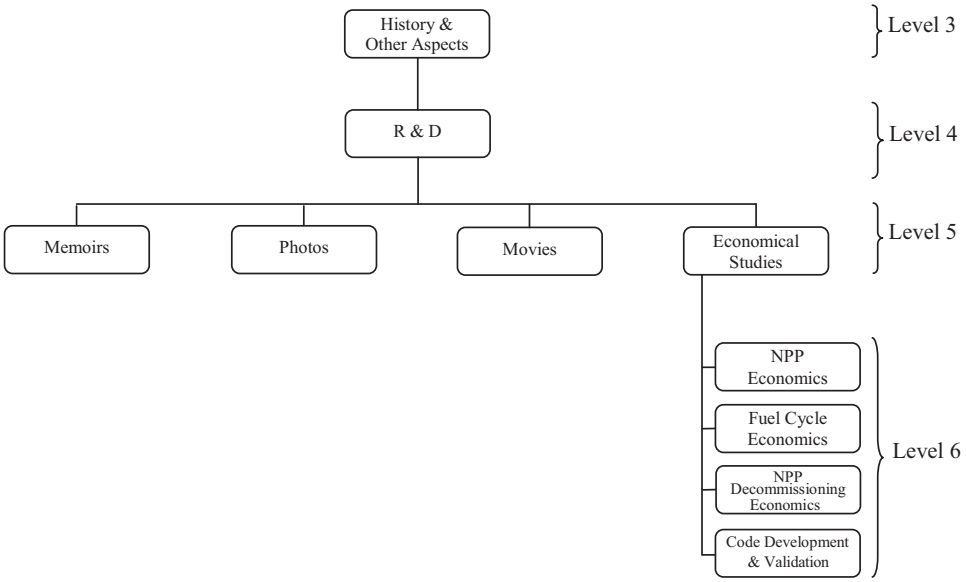

FIG. A-79. Scheme of branch 9-2.

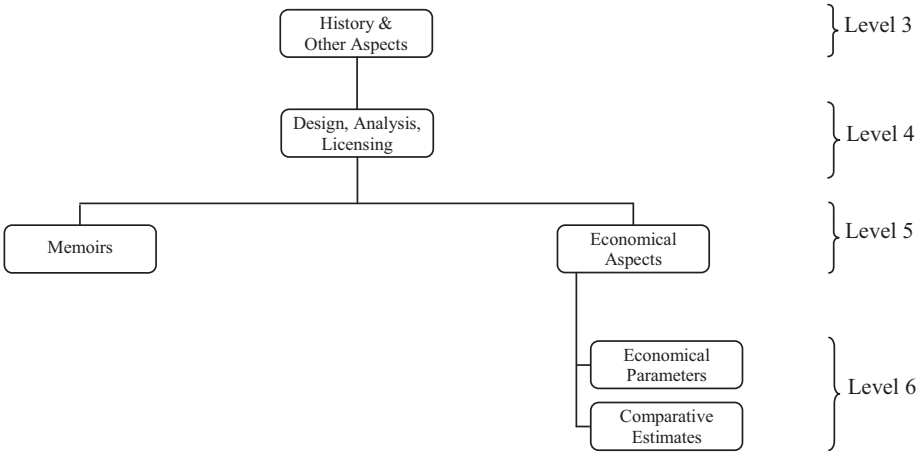

FIG. A-80. Scheme of branch 9-3.

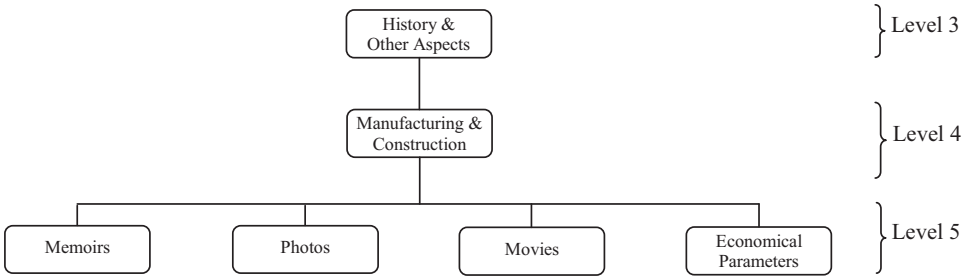

FIG. A-81. Scheme of branch 9-4.

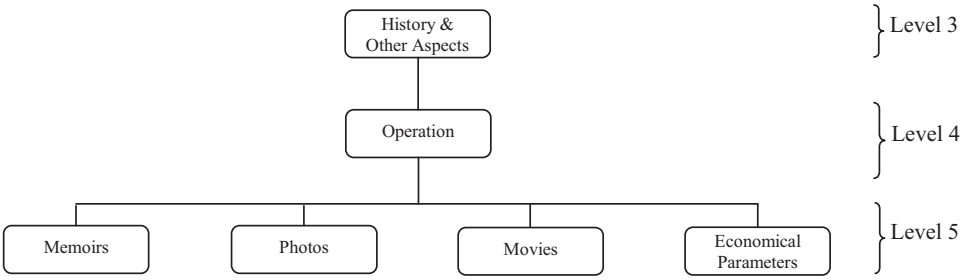

FIG. A-82. Scheme of branch 9-5.

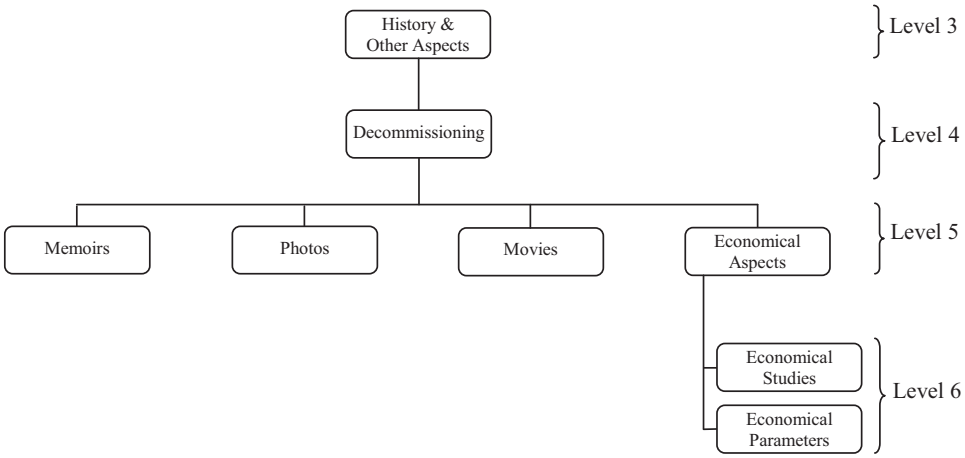

FIG. A-83. Scheme of branch 9-6.

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ABBREVIATIONS

AHX	Air heat exchanger
BDBA	Beyond design basis accident
CDA	Core disruption accident
DBA	Design basis accident
DHRS	Decay heat removal system
DRCS	Direct reactor cooling system
FBR	Fast breeder reactor
FC	Fuel cycle
FCI	Fuel–coolant interaction
FR	Fast reactor
FRKPS	Fast reactor knowledge preservation system
IC	Information card
ICCS	Intermediate circuit cooling system
IHX	Intermediate heat-exchanger
INIS	International nuclear information system
ISI & R	In-service inspection & repair
LBC	Lead–bismuth coolant
LRW	Liquid radioactive wastes
MA	Minor actinide
MCP	Main circulating pump
RVCS	Reactor vessel cooling system
SA	Subassembly
SFR	Sodium cooled fast reactor
SG	Steam generator
SRW	Solid radioactive wastes
USTS	Universal stage topic structure

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