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EARLY LOCALIZATION OF CONTAINMENT LEAKAGE DURING AN ACCIDENT.

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* DAS/SASC
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ABSTRACT :

In case of an accident in a nuclear plant, checking the containment leaktightness would be a fundamental step for the diagnosis and prognosis of the radiological consequences. Significant help in this task can be provided by softwares. For that purpose, the French Atomic Energy Commission (CEA) is developing an expert system which can provide early in the accident a classification of the possible leakage paths and help understanding the necessary corrections which have to be undertaken by the utility. This software will be used at the Emergency Technical Center of the CEA. Its basic principles are described in this paper.

* CEA/IPSN (Institute for Nuclear Safety and Protection)
** CEA/DRN (Direction for Nuclear Reactors)

EARLY LOCALIZATION OF CONTAINMENT LEAKAGE DURING AN ACCIDENT

P. PEPIN, C. CHAULIAC, M. LIBMANN, JM. MARTINEZ

In case of an accident in a nuclear plant, the last barrier to prevent fission product dispersion and radiological consequences is the containment. The good behaviour of the containment during the TMI-2 accident was the key factor for the observed low level of radioactive release into the environment. During other possible accidents, checking the containment leaktightness would be a fundamental step for accident management.

1 - PROCEDURES IMPLEMENTED ON THE NUCLEAR PLANTS TO CHECK THE CONTAINMENT BEHAVIOUR

In France, the containment performance during an accident is analyzed through the verification of the isolation of the containment penetrations and the control of the measurements of activity and dose rate.

On one hand, the procedures followed by the operators include the verification of the automatic actions (such as the closure of isolation valves following the order of containment isolation) and, if necessary, some complementary actions.

On the other hand, the safety engineer (who backs up the operating team) follows the permanent post-incident or ultimate procedure and watches over the measurements of activity and dose rate at the stack, in the reactor coolant, in the secondary side, in the sumps of the auxiliary buildings and in the containment atmosphere. The measurements are compared to thresholds and when they become significant, specific actions are undertaken to mitigate the radioactive releases (isolation of a unit, reinjection of radioactive liquid from the auxiliary buildings to the reactor building).

For instance, in the case of significant activity measured at the stack, the operating team uses a set of intervention sheets to locate the leakage. According to those sheets, the activity measurements distributed in the auxiliary buildings are examined and if one of them indicates abnormal conditions, a table showing its correspondence with the main components of the main systems helps the operators to identify the leakage position. Then, the necessary actions to isolate the unit are undertaken.

2 - METHODS USED BY THE INSTITUTE FOR PROTECTION AND NUCLEAR SAFETY (IPSN) DURING AN EMERGENCY TO ANALYZE THE CONTAINMENT BEHAVIOUR

In case of an accident in a french nuclear plant, IPSN is involved in a national emergency organization through its Emergency Technical Center (ETC). This center is entrusted with the task of providing the basic data for assessment of the accident situation and forecasting developments so that measures which could be necessary for the protection of the surrounding population may be taken in time by the authorities.

The ETC includes two units, one studying the situation within the damaged plant (plant assessment unit), the other concerned with the radiological consequences of the accident (radiological consequences unit).

Within the plant assessment unit, the emergency team uses the data transmitted by the plant computer and the Safety Panel Display System (SPDS) together with the informations collected through a phone conference network (connecting the ETC with the affected plant and the utility national emergency team).

The work of the plant assessment unit is focussed on the following points :

- the verification of the operators actions and their consistency with the procedures,

- the study of the availability of the safety systems,

- the assessment and prognosis of the physical state of the safety barriers (the fuel clad, the primary circuit and the containment) and of the safety functions (subcriticality, primary circuit water inventory, fuel heat removal, fission product containment),

- the calculation of a source term

In order to ease the work of the emergency team, IPSN has equipped its ETC with simple tools which have been developed in the frame of the SESAME program [1]. These tools consist of a set of reports, graphs, correlations and softwares (fig. 1).

For the study of the containment behaviour, the softwares are the following ones :

- the SINBAD software which provides some help to quantify the containment leakage rate and its evolution versus pressure,

- the ALADIN software which studies the availability of the elementary systems (and, in particular, some systems playing a part in the containment of fission products),

- the PERSAN software which calculates the fission product deposition inside the containment and the fission product release outside the containment,

- the ALIBABA software which helps the emergency team to find the containment leakage path and to understand the corrective actions being undertaken by the operators. The following paragraphs focus on this software.

3 - THE METHOD PROPOSED IN THE ALIBABA SYSTEM

The measurements used by ALIBABA in order to find the leakage path are roughly the same as those used by the operators and the safety engineer in the plant (fig. 2)

The indications about the isolation of the containment penetrations are transmitted to the ETC through the SPDS or the plant computer. Most of the measurements of activity are transmitted by fax or through the phone conference network.

<u>The first step</u> of the method consists in checking the validity of the measurements. They are invalid in case of failure of their electrical sources (information coming from the SPDS or the plant computer) or of the measurement device itself (information transmitted by the operators through the phone conference network). The measurements of activity located in the ventilation systems are also considered as invalid if the ventilation is out of run.

In a second step, the method looks for the leakage path according to an "upstream" and a "downstream" approach.

The upstream approach draws up the list of the elementary systems corresponding to the penetrations where an isolation fault is observed.

In the downstream approach, the activity measurements are taken into account in order to go backward towards the components, the rooms, the elementary systems and the penetrations related to the leakage.

The comparison between those two approaches allows a classification of the penetrations :

- the "red" ones are those corresponding to a containment isolation fault,

- the "orange" ones are those connected to pipes in the vicinity of which activity is detected,

- the "yellow" ones are those connected (through the pipes of the elementary systems) to the rooms where significant activity is suspected (activity measurement performed in the ventilation system).

The following complementary rules are used :

- only one colour can be attributed to a penetration, with a decreasing priority from red to yellow (a penetration which is both red and orange will be considered as red, etc ...),

- for the penetrations of the same colour, a priority order is taken into account. It is based upon the other colour which could have been attributed to the penetration, and the type of fluid usually present in the pipe (gas, hot liquid, cold liquid ...).

In a third step, a comparison with the diagnosis of the operators and an analysis of their actions is undertaken. Within the ALIBABA method, some simplified diagrams of the elementary systems associated to the main containment penetrations are provided. Those diagrams show the penetrations, the main components of the elementary systems, the rooms in which they are located, the ventilation systems of the rooms with their activity measurements, and finally the valves which should be closed.

A quick look at the diagrams corresponding to the faulty penetrations allows a fast understanding of the situation and of the corrections which have to be started. So they help the emergency team to better follow and discuss the diagnosis and the actions of the operators.

The method may end with a fourth step, which provides some additional information in some conditions. In that step, an activity balance throughout the plant is performed.

The activity rate at the stack is compared to the sum of the upstream activity rates measured in the ventilation systems of the auxiliary buildings. The measurement uncertainties are taken into account and, if any significant discrepancy between the two terms is observed, a warning is issued : either a leakage path between the containment and the auxiliary buildings has not been identified (for instance because there is no activity measurement along this path), or some activity is released directly from the buildings to the atmosphere and the stack is bypassed.

4 - APPLICATION OF THE METHOD : THE ALIBABA SOFTWARE

4.1 - Choice of a computer assisted method

At first, the ALIBABA method was presented in a report including the selection and description of the measurements and of their electrical sources, the tables of correspondence between the activity measurements and the containment penetrations, and the simplified diagrams of the elementary systems.

However it appeared that the manual use of this documentation was rather uneasy and that some computer help could be useful. So it was decided to launch the study of an expert system entitled ALIBABA and using the data gathered during the development of the method as its knowledge basis.

4.2 - Choice of the software environment

A CEA product, entitled SPIRAL, was chosen as the software environment to realize the expert system. Written in C language for both efficiency and portability purposes, SPIRAL is already used in many applications (e.g., design and implementation of simulation systems, complex industrial process control and model based diagnosis).

SPIRAL is a combination of powerful and efficient Artificial Intelligence techniques. In addition to a PROLOG-like formalism, it enables Object Representation (e.g., classes, simple inheritance, daemons).

Backward Inference rules basic scheme, Forward Chaining, Truth Maintenance facilities together with Graph Modelization and Search procedures have been implemented. These features may be directly adressed through usual PROLOG clauses.

4.3 - The ALIBABA software formalism

The ALIBABA method, as presented in chapter 3, requires the organization and modelization of numerous objects of different kinds (e. g. valves, sensors, ventilation systems). Object representation is now well specified to deal with these problems : each component of the ALIBABA system is represented by an instance, depending on the kind of the component.

Furthermore, in order to carry out the automatic search of the leakage paths and the presentation of the possible corrections, the ALIBABA software requires a topological modelization of the installation : a "functionnal topological modelization" (related mainly to the upstream approach) and a "spatial topological modelization" (related mainly to the downstream approach).

The functionnal topological modelization describes and defines the sequence of the components along the different branches of an elementary system. It consists in nodes corresponding to the different components and edges describing their relations with neighbouring components. According to this description, the different circuits are seen as graphs.

The spatial topological modelization describes the relations between the ventilated rooms, the associated activity measurements and the components.

4.4 - Use of the ALIBABA software

The ALIBABA expert system is implemented on a work station. An object oriented interface to windowing systems (fig. 3) allows an efficient and easy acquisition of the data transmitted by the affected plant.

The software proceeds according to the four previously defined steps. After studying the validity of the measurements, it proposes a list of leakage paths with the coloured classification of the penetrations. Then, the emergency team can compare this list with the informations provided by the operators and follow the corrective actions being undertaken, by displaying the simplified diagrams of the elementary systems on the screen of the work station (fig. 4). Finally, the expert system may provide some additional comments based upon the activity balance throughout the plant.

CONCLUSION

The ALIBABA expert system is still under development. The feasibility study lasted six months and was achieved at the end of 89. The realization of the mockup for 900 MWe plants started in the early 90 and will be completed at the beginning of 91.

The use of ALIBABA at the Emergency Technical Center of the IPSN will ease the work of the emergency teams for the study of containment performance :

- it will provide an extensive documentation about the topology of the elementary systems inside the auxiliary buildings (place of the components, relations with the activity measurements and the ventilations ...),

- it will help in finding the containment leakage paths and understanding the operator actions.

Finally, it must be stressed that, during an emergency, the sooner the activity measurements in the auxiliary buildings will be analyzed with computer help, the earlier the diagnosis will be formulated. This organization will result in earlier and easier corrective actions and therefore in lesser consequences.

[1] - C. CHAULIAC, D. MANESSE, B. CRABOL, J. NEY
Goals, organization and means of the french IPSN emergency technical centre
ENC'90 - ENS/ANS - Foratom Conference - Paper 24/23.09
Eurexpo, Lyon (France), 1990 September 23-28

Fig. 1

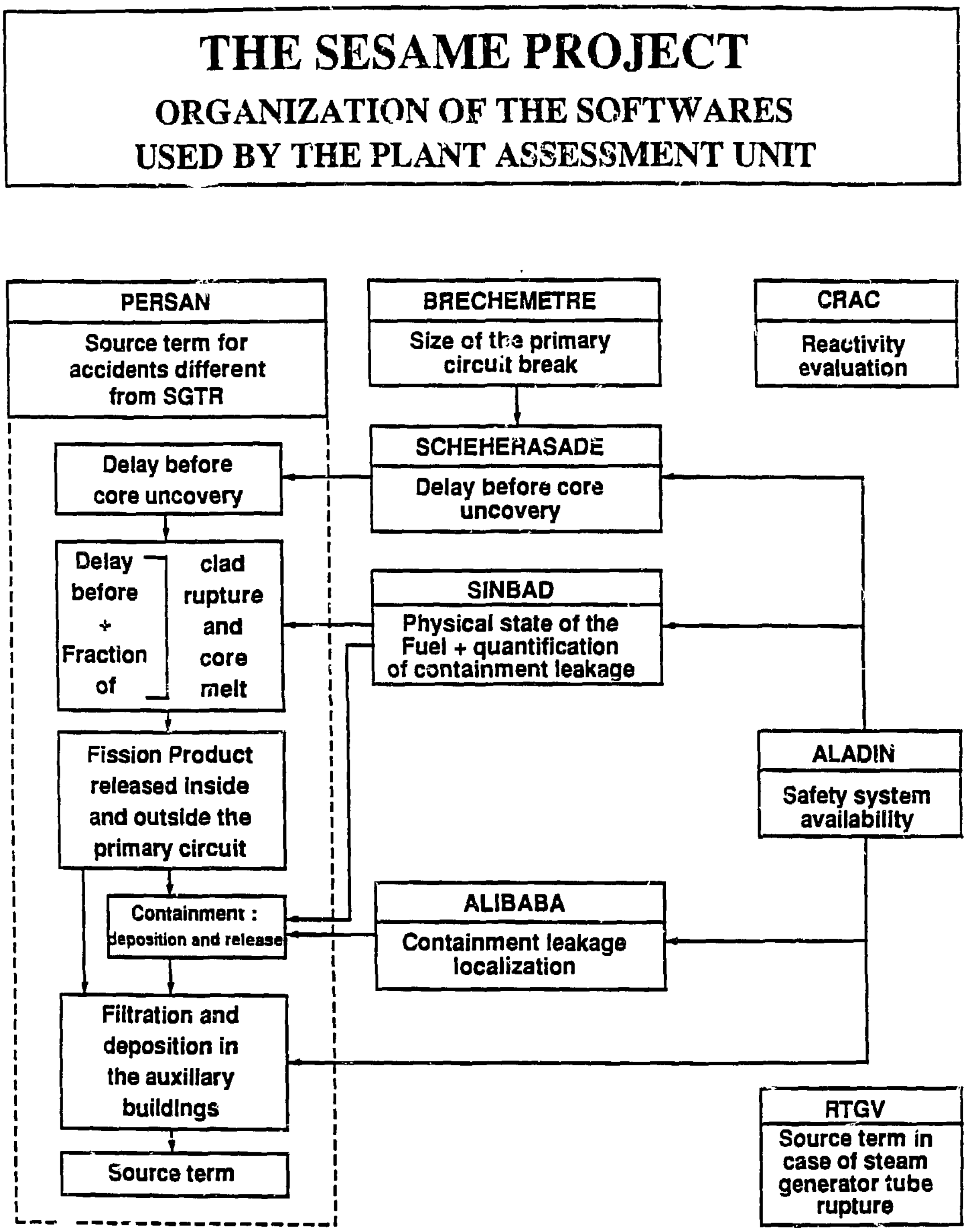
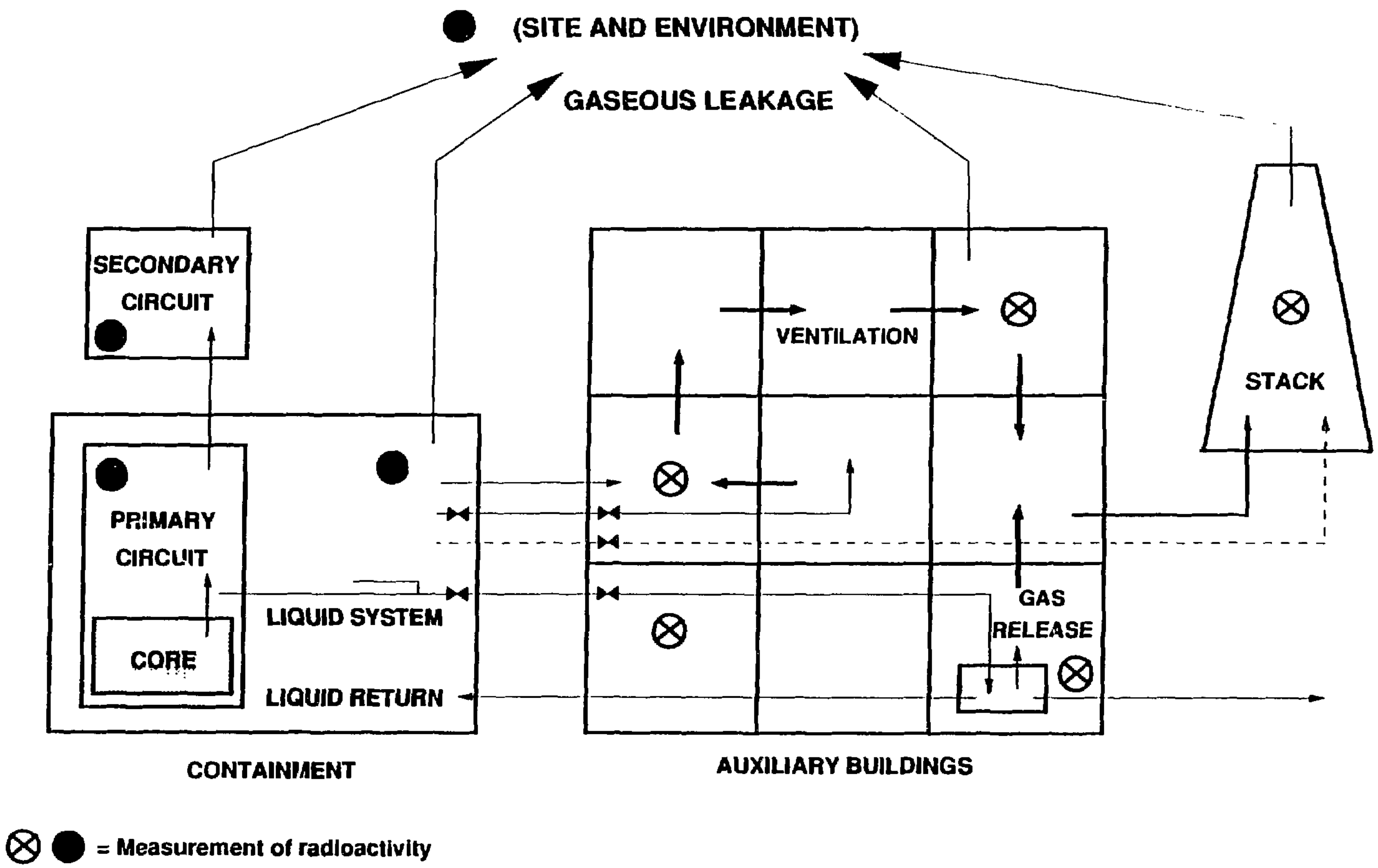

THE SESAME PROJECT
ORGANIZATION OF THE SOFTWARES
USED BY THE PLANT ASSESSMENT UNIT
PERSAN
Source term for accidents different from SGTR
Delay before core uncovery
Delay before + Fraction of
clad rupture and core melt
Fission Product released inside and outside the primary circuit
Containment : deposition and release
Filtration and deposition in the auxiliary buildings
Source term
BRECHEMETRE
Size of the primary circuit break
SCHEHERASADE
Delay before core uncovery
SINBAD
Physical state of the Fuel + quantification of containment leakage
ALIBABA
Containment leakage localization
CRAC
Reactivity evaluation
ALADIN
Safety system availability
RTGV
Source term in case of steam generator tube rupture

FIG. 2 - **FP RELEASE PATH : THE ALIBABA SYSTEM**



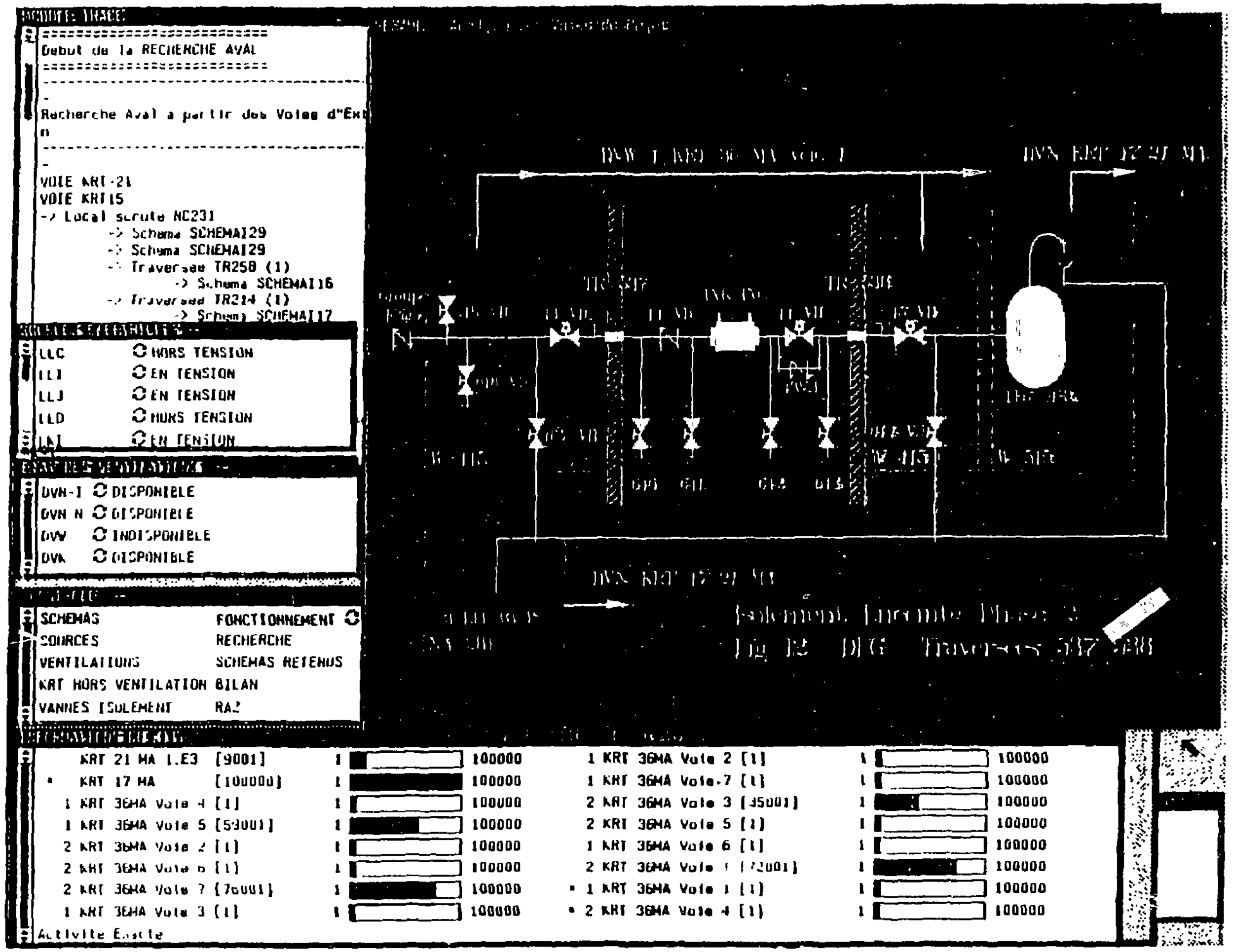


FIG. 3 - USER INTERFACE WITH THE

ALIBABA EXPERT SYSTEM

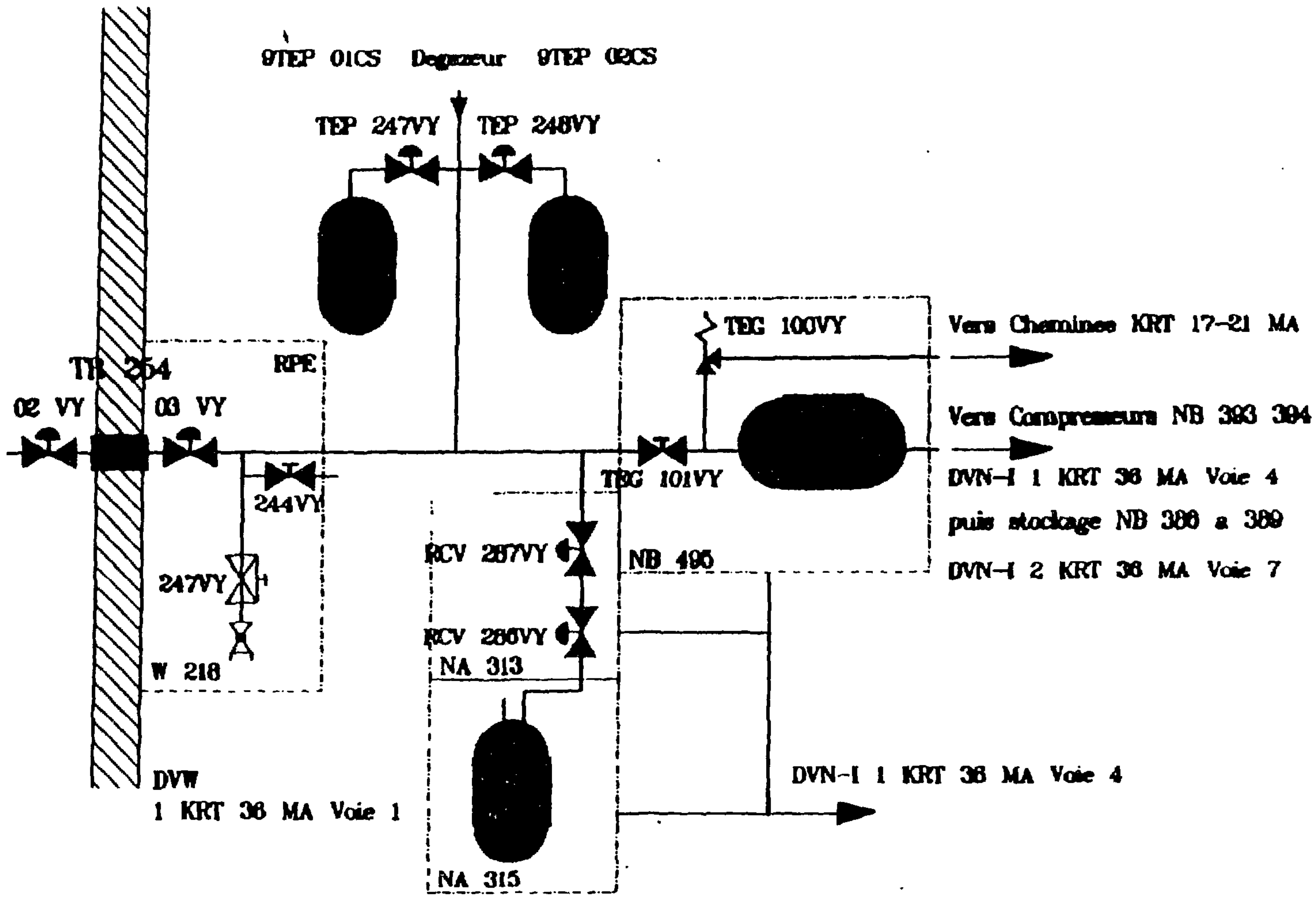


FIG. 4 - SIMPLIFIED DIAGRAM OF AN ELEMENTARY SYSTEM