of a nuclear power programme. This particularly entails the availability of qualified manpower.

IAEA provides assistance in the assessment of the basic infrastructures, i.e. planning and decision-making capabilities, organizational structures, electric grid size and structure, qualified manpower, industrial support, and financing. This also includes the assessment of the ability to absorb technology transfer, and in drawing up development plans, building as far as possible on a country's experience with nuclear techniques and research reactors. In manpower development, the entire range of TC activities is offered, namely, country-specific projects, large-scale UNDP projects, training courses, missions, and workshops. Many elements of this package of assistance overlap and are co-ordinated with those provided in developing a plan for the nuclear power programme.

The Agency's role in nuclear power project feasibility studies (including financial feasibility) is limited to giving advice on organization of the study, defining its contents, and reviewing its execution and results. Co-operation with the World Bank and the United Nations Industrial Development Organization (UNIDO) is offered whenever possible.

● ***Determining a policy and strategy for national participation.*** National participation is an integral part of the nuclear power programme. The scope and level of national participation will vary according to the specific conditions prevailing within each country and will depend on national policies and infrastructures, investment capability, adequate market factors, such as costs of national products, financing, quality standards, technology know-how, nuclear safety, and availability of raw material.

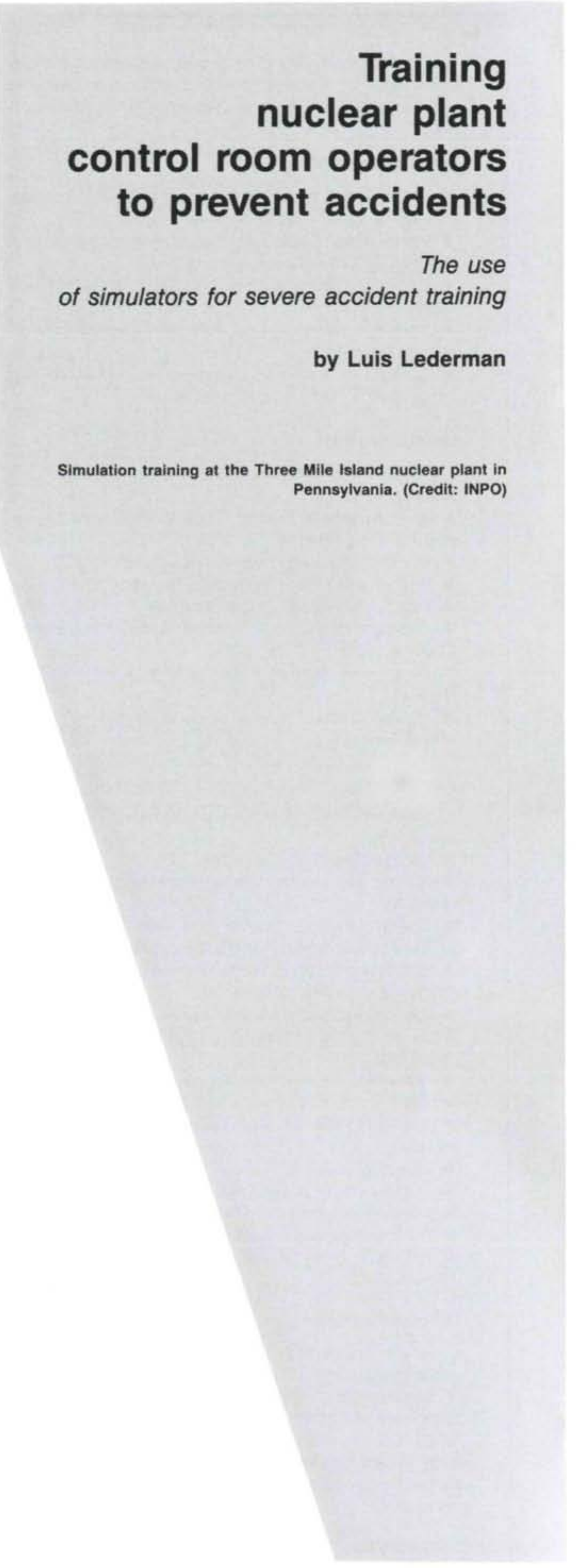
The IAEA's role is mainly to assist in devising a national participation study. It includes an industrial survey to find out those national industries whose production meet or might meet the quality standards of nuclear technology.

● ***Financial planning for nuclear power projects.*** Financing of nuclear power projects involves complex issues which need to be fully understood by all parties involved. The IAEA promotes information exchange between buyers, suppliers, financing organizations, and export credit insurers to achieve a better understanding of the special requirements, complexities, and possibilities of nuclear power financing in developing countries. It also assists, in conjunction with the World Bank, in strengthening and supporting local government and utility capabilities for financial planning in the electric power sector to help improve availability of financing for nuclear power.

Training nuclear plant control room operators to prevent accidents

The use of simulators for severe accident training

by Luis Lederman



Simulation training at the Three Mile Island nuclear plant in Pennsylvania. (Credit: INPO)

The use of simulators to train operators is common in the nuclear industry and in other highly developed technologies. In recent years, results of probabilistic safety assessments (PSA) and nuclear power plant operational experience have highlighted a number of scenarios which require further operator training.

Scenarios which can lead to severe accidents generally combine human errors, common cause failures, random component failures, and various types of systems interactions and are essentially "beyond design basis". By their very nature, they are rare events and operator response in those situations is difficult to predict. Under such circumstances, it is appealing to use simulators to train operators to prevent or cope with severe accidents; therefore, various approaches are being investigated.

In a recent meeting convened by the IAEA in Vienna, the experience with simulators for training for emergency conditions was reviewed.*

To be adapted for simulation, possible scenarios must be considered in the framework of the intended application. For example, to establish stress situations for the operating team, short-term considerations have to be made with respect to scenario duration. Training of emergency teams which have to intervene during accidents and the verification of procedures or stategies are also major objectives for simulation of accident scenarios which demand specific considerations.

The limitations of full-scope simulators are noticeable, particularly for long-term scenarios. Boundary conditions have been treated to date in a restrictive manner. Initial conditions are limited to full power operation. This assumption excludes from consideration situations involving possible lower availability of safety-related systems and distraction of operating crew due to the performance of additional tasks. Such situations are typical of sub-critical and other low-power levels and should be taken into consideration. On the other hand, because accuracy of computer simulations decreases as a function of core degradation, severe accident scenarios are terminated at phases where manual interactions cannot control the progression of core damage.

For training purposes, the main characteristic of a scenario is to recreate the situation in the control room. Three distinct phases are suggested to develop a scenario:

- Disturbances are introduced gradually with increasing severity to motivate and integrate the operator in the scenario;
- Additional failures or disturbances are introduced to create as much stress as possible for the operator;
- The scenario is prolonged to enable the occurrence of specific difficulties which may appear in the long term; complementary information can be given to members of technical support teams to allow them to participate and to make decisions.

Reviews of the functional requirements for full-scope simulators used in training operators for severe accidents have identified limitations of present simulator models. These include:

- Existing mathematical models (neutronic, thermohydraulic, control, and logic) are not validated for a wide range of transients leading to severe accident conditions;
- Real time simulation programmes, many of which are written in specific machine language to increase the efficiency of execution and therefore are difficult or even impossible to be modified.

Particular areas which require new simulation models or upgrading include two-phase flow, containment response, emergency core cooling system (ECCS), core thermohydraulic and neutronics, and fuel behaviour. For the modelling of core thermohydraulics, two distinct periods are identified. The first period, pre-core damage, can be treated generally by loss-of-coolant accident (LOCA) models. In the second period, simulation is substantially more difficult. This is particularly true if the core heat-up proceeds at a fast rate and the scenario assumes partial or full ECCS failure. Detailed modelling is also needed for phenomena that during actual accident conditions can give conflicting readings in different core quadrants.

Results of PSAs indicate that many of the dominant core damage accident sequences originate from transients involving the plant's secondary side. Therefore, two-phase flow modelling for the balance of the plant is required.

During a severe accident, containment parameters such as temperature, pressure, humidity, and radioactivity are monitored in the control room. The operator must be able to recognize these parameters and take appropriate action. Containment models should include phenomena of steam and water moving between compartments, and action of safety devices like sprays and vents to trace the location of hydrogen.

Due to the complexity of the physical phenomena associated with severe accidents, mathematical models can easily produce unrealistic conditionts. In these cases, instructors must be made aware of the situation, preferably by the software.

It is generally agreed that modelling beyond the design basis should be approached with extreme care in simulator training. Furthermore, care should be taken to avoid inappropriate over-emphasis on particular accident scenarios which can make the operator predisposed to a particular diagnosis and subsequent course of action.

* *Experience with simulator training for emergency conditions*, IAEA-TECDOC-443, Vienna, 1987.

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