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PEACEFUL USES OF ATOMIC ENERGY
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FOREWORD

The Fourth International Conference on the Peaceful Uses of Atomic Energy, held at Geneva from 6 to 16 September 1971 under the Presidency of Glenn T. Seaborg, was jointly sponsored by the United Nations and the International Atomic Energy Agency. The conference sessions were held at the Palais des Nations. During the same period a Governmental Scientific Exhibition on the theme "Atoms for Development" was displayed at the Palais des Expositions in Geneva.

The Proceedings are published in 15 main volumes, fourteen of which contain all the 514 papers presented at the conference. The papers are printed in English, French, Russian or Spanish, and the abstracts in all four languages; the discussions are in English. The fifteenth volume contains a Subject Index, an Author Index (including discussion contributors), a Paper Number Index, a complete Contents List of all volumes, and a List of Delegations. There are three supplementary volumes containing the discussions in French, Russian and Spanish respectively.

The conference, which attracted more than four thousand participants, observers and journalists, was planned to interest not only scientists and technologists but also public officials, economists and planners. It thus had a somewhat broader scope than the conferences of 1955, 1958 and 1964. The main topics were grouped under the following six headings: nuclear power; nuclear fuels and materials; health, safety and legal aspects; isotopes and irradiation; international and administrative aspects; and selected subjects of particular interest to developing countries.

The fourth Geneva Conference proved again to be an exceptional forum enabling those working throughout the world on the peaceful application of atomic energy to exchange the latest information on the discoveries, projects and problems of both developed and developing nations.

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AGENDA ITEM 1.5

Review of safety aspects of nuclear power plants

Revue des problèmes de sécurité dans les centrales nucléaires

Обзор вопросов безопасности на ядерных электростанциях

Problemas de seguridad en las centrales nucleares

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SOLUTIONS OF SAFETY PROBLEMS ENCOUNTERED IN THE OPERATION OF THE ITALIAN NUCLEAR POWER PLANTS

E. IANSITI
Comitato Nazionale per l'Energia Nucleare, Rome

R. LEPORE
Ente Nazionale per l'Energia Elettrica, Rome,
Italy

Abstract–Résumé–Аннотация–Resumen

SOLUTIONS OF SAFETY PROBLEMS ENCOUNTERED IN THE OPERATION OF THE ITALIAN NUCLEAR POWER PLANTS.

The operation of the Italian nuclear power plants, which are of three different types: Latina (Magnox), Garigliano (BWR), Trino Vercellese (PWR), has allowed ENEL and CNEN to gain a considerable amount of experience in the field of nuclear plant safety. The paper deals with some of the main problems encountered during operation and with the solutions adopted. In solving these problems, including the most critical ones, the main aim was to continue plant operation while maintaining the safety margin at a level comparable with the design values. The paper deals with some modifications suggested by the technological evolution which have been introduced in the plants to improve their safety standards.

EXPERIENCE ACQUISE DANS LA SOLUTION DES PROBLEMES DE SECURITE CONCERNANT LES CENTRALES NUCLEAIRES ITALIENNES.

L'exploitation des trois centrales nucléaires italiennes, de type différent: Latina (Magnox), Garigliano (à eau bouillante), Trino Vercellese (à eau sous pression), a permis au CNEN et à l'ENEL d'acquérir une expérience considérable dans le domaine de la sécurité des centrales nucléaires. Le mémoire décrit les différents problèmes qui se sont posés en cours d'exploitation, ainsi que les solutions adoptées. Tous les problèmes, y compris les plus critiques, ont été examinés et résolus de façon à permettre la poursuite de l'exploitation avec une marge de sécurité respectant les prévisions du projet. Le mémoire décrit également les modifications qui ont été apportées aux centrales, en tenant compte de l'évolution technologique, afin d'optimiser les normes de sécurité.

РЕШЕНИЕ ПРОБЛЕМ БЕЗОПАСНОСТИ НА ИТАЛЬЯНСКИХ АТОМНЫХ ЭЛЕКТРОСТАНЦИЯХ.

Эксплуатация итальянских атомных электростанций трех различных типов – в Латине (магноксовый реактор), в Гарильяно (реактор с кипящей водой) и в Трино Верчелезе (реактор с водой под давлением) – позволила Национальному комитету по атомной энергии и Национальному энергетическому управлению накопить значительный опыт в области обеспечения безопасности на атомных электростанциях. В докладе изложены различные проблемы, возникшие в ходе эксплуатации, а также принятые решения. При решении этих проблем, в том числе самых актуальных, предусматривалось продолжение эксплуатации станций с соблюдением пределов безопасности на уровне, сравнимом с уровнем таких пределов, предусмотренных проектом. В докладе описаны также модификации, осуществленные на атомных электростанциях, с учетом развития технологии, с целью улучшения параметров безопасности.

SOLUCION DE PROBLEMAS DE SEGURIDAD SUSCITADOS DURANTE LA EXPLOTACION DE LAS CENTRALES NUCLEARES ITALIANAS.

La explotación de las centrales nucleares italianas - que son de tres tipos distintos: Latina (Magnox), Garigliano (de agua hirviente), Trino Vercellese (de agua a presión) – ha dado ocasión a que ENEL y CNEN adquieran una cantidad considerable de experiencia en el campo de la seguridad de las instalaciones nucleares. Este trabajo trata de algunos de los problemas principales encontrados durante la explotación y de las soluciones que se adoptaron. Al resolver estos problemas, incluso los más críticos, se ha intentado principalmente continuar la explotación de la instalación manteniendo el margen de seguridad en un nivel comparable con los valores proyectados. Este trabajo se refiere a algunas modificaciones, sugeridas por la evolución tecnológica, que se han introducido en las instalaciones a fin de mejorar sus niveles de seguridad.

1. INTRODUCTION

The operation of the Italian nuclear power stations, which are of three different types (pressurized-water, boiling-water and gas-cooled graphite-moderated), gave ENEL and CNEN the opportunity to gain a certain amount of experience of safety problems that may occur during operation.

In this paper we stress that, once a power plant has been licensed, not all the safety problems can be considered solved, since difficulties may arise which require the attention of the safety engineers, the operators, the designers and the licensing authorities.

Particular cases are summarized here which deal with phenomena such as vibration and corrosion to prove that, with due care, proper solutions can be found and the plants can be brought back into operation without decreasing the safety margins against failure. In addition, a few modifications or improvements are mentioned that were adopted in some systems to increase plant safety in the light of up-to-date safety analysis criteria.

The Italian nuclear power stations started commercial operation between January 1964 and December 1965 (Table I). The respective outputs are listed in Table II.

The paper briefly describes the difficulties and repairs at the three stations; namely: Garigliano station (BWR) – rupture of liquid-poison sparger; modifications to containment spray system; corrosion product deposition; control-rod drive housing support; ventilation system valves; Latina station (Magnox) – steel oxidation in CO_2; Trino station (PWR) – failure of internals.

2. GARIGLIANO POWER STATION

2.1. Rupture of liquid-poison sparger

2.1.1. General

During December 1965, while we were trying to plug the bottom nozzles of the pressure vessel from inside the reactor to repair the drain pipes, it was found that the liquid-poison sparger was no longer in place.

This sparger was made of two 2-in. AISI-304 stainless-steel semi-circular parts, so as to form two half rings concentric with the pressure-vessel wall. The two sections were welded to a special T-shaped piece, which was connected with the liquid-poison feeding system. Twenty-two 1/4-in. holes were arranged along the pipe generatrix for distribution of the solution within the reactor.

The liquid-poison sparger appeared to be cut off at the bracket welded to the pressure-vessel wall. The two sparger sections were lying on the bottom of the pressure vessel, broken into several fragments. It was

TABLE I. MAIN DATES FOR THE THREE POWER PLANTS

Item	Latina	Garigliano	Trino Vercellese
Beginning of construction[a]	Nov. 1958	Nov. 1959	Jul. 1961
First criticality	Dec. 1962	June 1963	Jun. 1964
First synchronization	May 1963	Jan. 1964	Oct. 1964
First power	Dec. 1963	May 1964	Dec. 1964[b] Nov. 1965[c]
Beginning of commercial operation[d]	Jan. 1964	May 1964	Dec. 1965
First general maintenance[e]	May 1965	Sep. 1965	

[a] Date on which the ground on the site was broken.
[b] 186-MW(e) turboalternator at full power.
[c] 86-MW(e) turboalternator at full power; thermal output 825 MW, corresponding to an average electric output of 252 MW(e) (equal to the maximum design thermal output for the first core). The target output of the two turboalternators is 272 MW(e)
[d] The beginning of commercial operation is taken as the moment when the plant has reached nominal power and is in a position to continue operating smoothly.
[e] General maintenance entails the shutdown of the whole station for several weeks.

TABLE II. GROSS OUTPUT AND PLANT CAPACITY FACTORS: NOMINAL POWER OF THE THREE POWER PLANTS

Year	LATINA		GARIGLIANO		TRINO VERCELLESE		TOTAL
	kWh×10⁶	utilization	kWh×10⁶	utilization	kWh×10⁶	utilization	kWh×10⁶
1963	322						322
1964	1544	83.70%	737	78.18%	122		2403
1965	1519	82.57%	967	69.00%	1025	57.80%	3511
1966	1452	78.13%	817	59.30%	1594	72.40%	3863
1967	1586	86.21%	919	65.70%	647	29.30%	3152
1968	1544	83.70%	1033	73.50%	0		2577
1969	496	27.00%	1182	84.33%	0		1678
1970	1191	64.72%	742	52.94%	1243	56.35%	3176
Total	9654		6397		4631		20 682

ascertained that all the fragments had been found and removed from the reactor by putting the pieces together as if to reform the sparger.

Several metallurgical tests were performed on a sparger fragment and on a bracket which showed a rupture near the bolt, beneath the bend, and the conclusion was reached that the liquid-poison sparger had broken in the first period of reactor operation.

2.1.2. Investigations into the damage caused by the fragments

When the rupture of the liquid-poison sparger was discovered, an investigation was carried out to establish whether the pressure vessel and its structures had been damaged as a result of the impacts of the fragments. The following items were examined: the pressure-vessel walls beneath the lower grid; the bottom of the pressure vessel; the guide-tube weldings; the control-rod guide tubes; the in-core chamber guide tubes; the lower grid and supports; the spray nozzles of the reactor emergency cooling system.

The investigation was performed with an underwater television camera designed for horizontal and vertical shots and concurrent recording on magnetic tape (AMPEX), and a borescope adjusted for horizontal and vertical observations.

The resolving power of these tools was so high that it enabled us to discover dents down to 0.3 - 0.5 mm wide.

No damage to the pressure vessel or its internal structures that would affect reactor safety was observed. The impact of the fragments on ductile material had produced dents on the curved surfaces, which are more resistant, and cuts on the sharp edges. In some areas, scratches had been caused where the rubbing and cutting action of the fragments had continued for a long time. All the damaged areas were easily identified.

2.1.3. Effects of the removal of the liquid-poison sparger on reactor operation

After the sparger removal, the only means of injecting the liquid poison into the pressure vessel was the inlet nozzle. To mix the sodium pentaborate solution with the core cooling water, there was only the turbulence of the recirculation water jet.

It might be mentioned here that the liquid-poison sparger had not been conceived as a fast, automatic backup for the normal reactor scram system, but as a device that the operator could use at his discretion after having ascertained that the reactor could not be kept sub-critical in cold conditions by any other means.

When the recirculating pumps are in operation, the water turbulence at the core inlet ensures that the sodium pentaborate mixes with the water flowing into the core. If the reactor is at power in natural circulating conditions, there will still be water turbulence from the strong water flow in this condition, as demonstrated in the startup tests.

2.1.4. Conclusions

On the basis of our findings, we reached the conclusion that the rupture of the liquid-poison sparger and the long period that the fragments had remained on the bottom of the pressure vessel had in no way affected safety conditions. The plant was therefore brought into operation again, but it was decided during the refuelling shutdown that other inspections should be made in the reactor pressure vessel.

Two inspections have been carried out to date and no deterioration of the situation has been observed. The main purpose of the inspections was to check all the internal components that had been affected by the rupture of the liquid-poison sparger ring, together with some other areas, in such a way that all the internal components would receive a general inspection over a period of three to four years.

2.2. Modifications to the containment spray system

2.2.1. General

To improve the characteristics of the containment system, some modifications were made to the internal spray system of the containment. The original system distributed and atomized the water to decrease the overpressure resulting from a reactor primary system rupture. The new system, which sprays a solution of sodium thiosulphate, also removes the iodine released in the containment sphere.

2.2.2. Modifications

The following modifications were made (Fig. 1): addition of a tank for the preparation, dosage and storage of the sodium thiosulphate solution; installation of two metering pumps; modification of the number, design and layout of the sparging nozzles.

The new nozzles have the following characteristics. The nozzle worth is 7/16 in. to avoid accidental clogging; the water is not atomized through centrifugation but through impact of the water stream against a conveniently serrated baffle, and, as a result, the drop distribution is improved over the entire volume instead of being in the form of the conical distribution made by the supply nozzles.

The design of the baffle ensures that, when a drop detaches, it is not greater than 1 mm in diameter. The high speed of the drops in the atmosphere guarantees their further break-up, so that the average size of no more than 0.7 mm assumed by the calculation is quite conservative. The nozzles and the related pipes have been arranged in such a way that they are protected against missiles in the event of an accident.

2.2.3. Periodical tests

During plant operation, the following test program is carried out on a routine basis: analysis of the thiosulphate solution; control of the performance of the motor-operated valve; pump performance; cleaning of the piping.

During the plant shutdown, the filter on the inlet line inside the containment is visually inspected and the pressure drop between the regulation valve and the nozzles is measured to ensure that the pipes are not clogged.

2.3. Prevention of corrosion product deposition

At the Garigliano station, the condensate is purified by mixed beds and returned to the main steam drum and secondary steam generators by way of two LP and two HP feedwater heaters. Water purity in the primary steam is maintained by the clean-up demineralizer, which processes 40 tons/h of primary water.

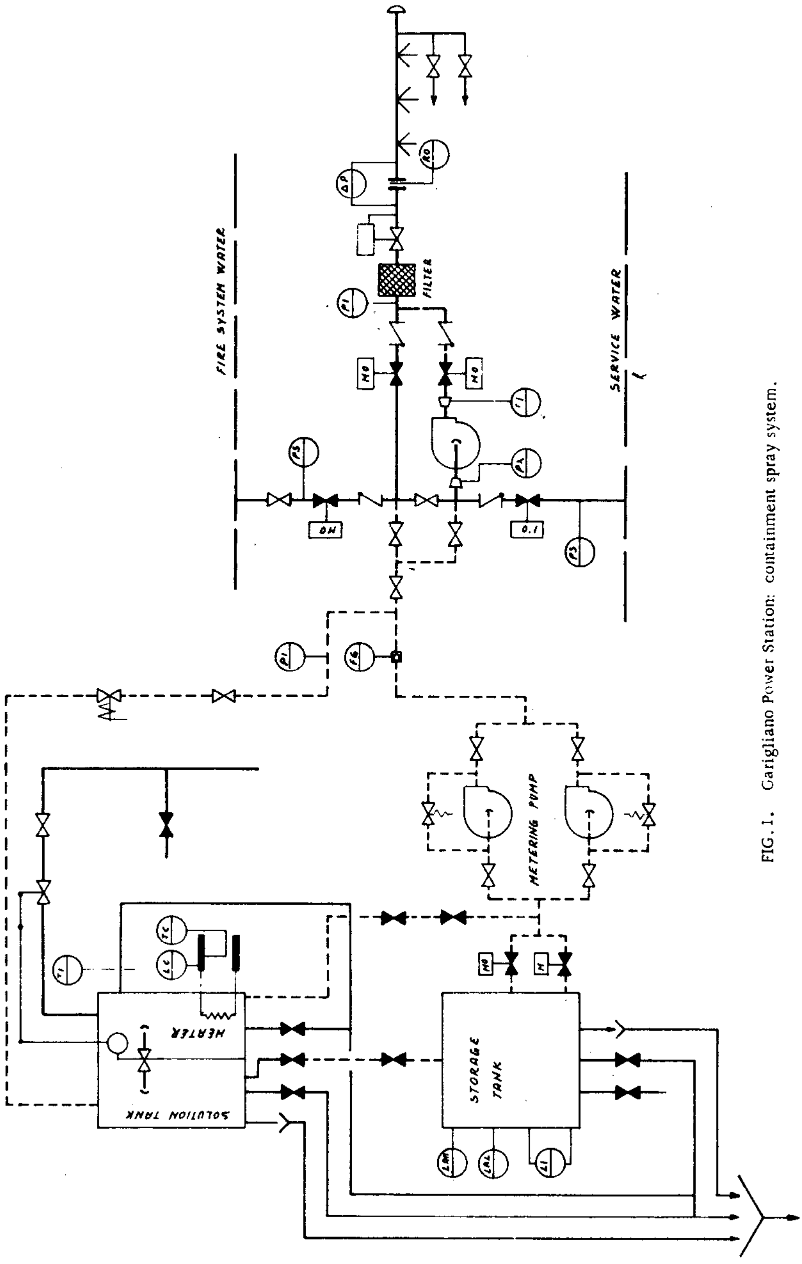

FIG. 1. Garigliano Power Station: containment spray system.

During the first (1A) and second (1B) fuel cycles, large amounts of crud were deposited at the fuel assembly inlets, causing an increased core pressure drop and entailing stricter operating limitations. At the end of both cycles, these deposits had to be removed mechanically. The deposits on the bottom tie-plate, which were responsible for the abnormal increase in core Δp, consisted of a thick layer of porous black material.

Chemical and structural analyses indicated the following composition:

Copper	60%	in the form of CuO and 6 $CuO \cdot Cu_2O$
Iron	24%	in the form of $NiO \cdot Fe_2O_3$
Nickel	16%	in the form of $NiO \cdot Fe_2O_3$ and NiO

After measures had been taken to minimize CuO pick-up from the Cu-Ni alloy FW heaters, no appreciable increase in the core Δp was observed during Cycle IC (August 1967 to June 1968) and no fuel cleaning was necessary.

During the June 1968 shutdown, the FW heaters were replaced with AISI 304 L units, which definitely solved the problem of crud deposit at the fuel inlet.

2.4. Installation of support for the control-rod drive housings

The control-rod drive housings are welded to the bottom of the pressure vessel. In the very unlikely event of a failure in one of the welds, the pipe could be ejected from the pressure vessel, dragging out the control rod. The step of positive reactivity resulting from rod ejection causes a power excursion, which could result in undesirable values of fuel enthalpy.

In compliance with the criteria adopted for BWR's designed after the Garigliano plant, we decided to install a supporting structure beneath the pressure vessel. This structure limits the stroke of the control-rod drive housing and would also limit a power excursion.

The structure components (joists, tie-rods, springs, nuts, screws and pillars) were designed to resist, with a certain margin, rupture of the most critical control-rod housing (Figs 2 and 3).

The support was also analysed in regard to earthquake effects.

2.5. Ventilation system valves

To ensure compliance with the limitation on the daily containment leakage rate (0.1%), provision was made to maintain a water head on the fast closure isolation valves of the ventilating system.

For this purpose, a 25-mm pipe was branched off the containment spray system and connected to each of the two ventilating ducts within the container. If an accident occurs, the spray system operating initially on water will keep the containment pressure down and create a water seal on the ventilating valves.

The ventilating ducts are filled with water in ten minutes.

The thiosulphate is injected into the spray system 15 minutes after the accident, when the iodine release becomes significant. In order to avoid overloading on the ventilating ducts, an overflow has been installed to keep the water level constant at 10 cm over the ventilating ducts. The ventilating duct sections to be flooded have been designed for a pressure of 27 atm abs. and are clamped on both sides of containment penetrations.

The additional stresses on the ducts caused by flooding are not important. The total stress is below the resistance limits of the material.

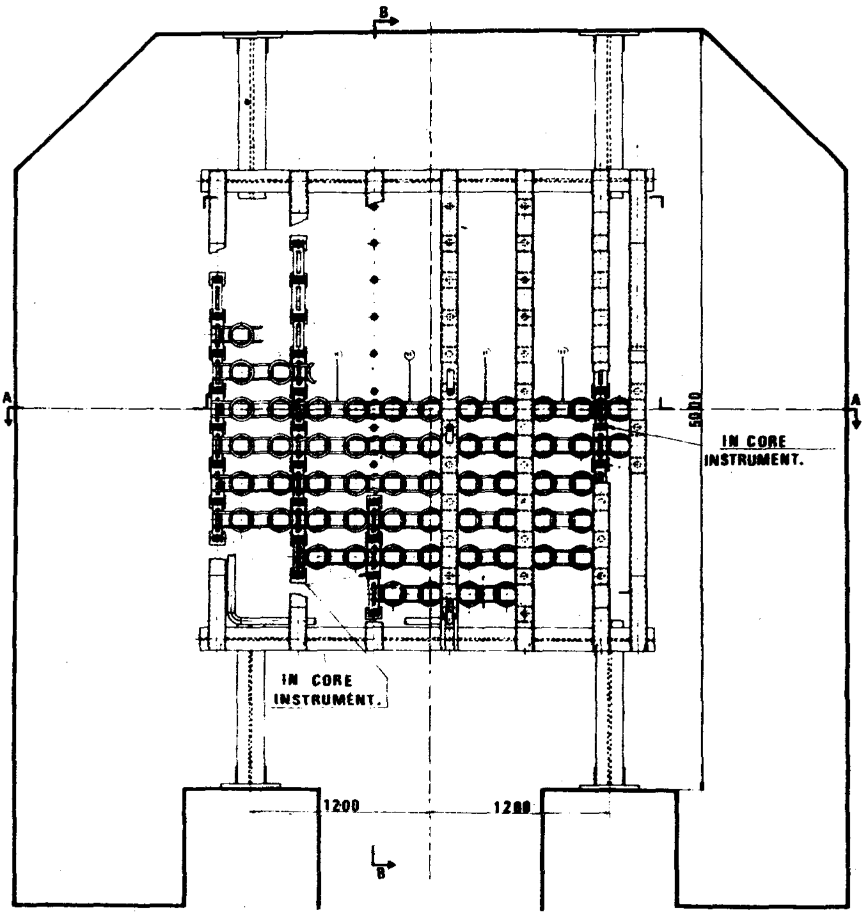

FIG. 2. Garigliano Power Station: support structure of control rod drive housing – plan view.

3. LATINA POWER STATION

On March 17 1969, after some BSD system pipes had been damaged, a television inspection was made of the charge pan and showed that some of the gas thermocouple clips had been dislodged and were missing. An extensive inspection program was immediately started on the reactor high-temperature areas and the steam generators. At the end of the inspection program, there was an overall picture of the abnormal conditions, which enabled a repair program to be worked out.