CHERNOBYL - A RETROSPECTIVE REVIEW TWO YEARS AFTER THE ACCIDENT

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SUMMARY The world's worst nuclear disaster - the only one which caused immediate loss of life and may, possibly have a small but significant biostastical health effects over a period of some thirty to forty years - was initiated during the early morning hours of 25 April, 1986. Its cause according to remarkably frank reporting by a Soviet delegation to the International Atomic Energy Agency at a meeting in Vienna in August 1986 was criminal negligence on the part of the operating staff, the failure of the plant supervisors to make responsible emergency decisions and the neglect to report the gravity of the incident to the headquarters of the Soviet Atomic Energy Ministry for some thirty hours after commencement.

1. INTRODUCTION

The author had the privilege, through the offices of the I.A.E.A. to be the first Western nuclear scientist to visit the Chernobyl district in July 1986 to make an assessment of the cause and consequences of the accident. Since his original reports were filed much has been published in both the technical and popular press, including a number of papers by the author. In the ensuing discussion we propose to consider four major aspects of the incident -

(1) A brief summary of the possible causes of the accident, including a description of the nuclear plants of the R.B.M.K. type.

(2) The human errors and man-machine interface deficiencies which had such disastrous consequences.

(3) The resulting short term and long term consequences of the chemical explosions in the nuclear plant and their impact on the residents of surrounding districts, more distant communities and the long term effects on agriculture and human life in Eastern bloc and Western European countries.

(4) The effects of Chernobyl on the public perception of nuclear energy and the impact of the accident on the long term future of the nuclear industry, world wide.

2. CAUSES OF ACCIDENT (Ref 2)

The design of the RBMK reactor was initially attractive to the U.S.S.R. for a number of reasons. As stated in the translation of the Soviet report, these include

> ...the absence of cumbersome pressure vessels which are difficult to manufacture and limit the reactor's unit power and production base; absence of a complex and costly steam generator; the possibility of continuous refueling and a

Table 1 Physical Characteristics

of Chernobyl Unit 4

Thermal power, MW	3200
Fuel enrichment, %	2
Mass of uranium per fuel assembly, kg	114.7
Number of fuel channels	1661
Total mass of graphite moderator, kg	1.7×10^6
Core diameter, m	11.8
Core height, m	7
Circumferential graphite reflector thickness, m	1
End graphite relector thickness, m	0.5
Steam pressure in separator, MPa	6.86
Coolant average core inlet temperature, ^oC	270
Coolant average core exit temperature, ^oC	284
Coolant total flow at full power, kg/h	3.76×10^7
Flow per pump, kg/h	6.27×10^6
Average full power steam quality at core exit, %	14.5
Maximum channel steam quality at exit, %	20.1

good neutron balance; a flexible fuel cycle easily adapted to the fluctuations of the fuel market; the possibility of nuclear steam superheating; high thermal reliability and durability of coolant flow, channel failure detection, monitoring of the parameters and coolant activity in each channel and on-load replacement of leaking assemblies.

Three major shortcomings of the design are: (1) the sensitivity of the neutron field to reactivity perturbations leading to control difficulties and requiring complicated control systems, (2) a relatively small and weak containment around the core itself, and (3) a positive void coefficient of reactivity that increases as power value of 0.02 δ k/k (where δk is the change in void fraction). Because of the enhanced positive void coefficient at low power and because of control difficulties associated with lack of accurate power measurement capability at the lower levels, continuous operation of the RBMK-1000 reactors is prohibited (by the Technical Specifications) at power levels less than 700 MW(t).

For Western experts in the fields of reactor dynamics and control, it is difficult to understand why staff with responsibility for such tests have not had the opportunity to simulate them on computing apparatus. It has however been made clear by the Soviet Union - even in general publications in

Pravda - that the first nuclear plant simulators were not available in the Soviet nuclear industry until 1972. It is very unlikely that a simulator had ever been designed for the RBMK-1000.

Hence it appears that the tests described in the Appendix were a "disaster waiting to happen" as six fatal errors were perpetrated.

1. The emergency cooling system was turned off to conduct the test.
2. The reactor power output was inadvertently lowered too much, making it difficult to control.
3. All water circulation pumps were turned on, exceeding recommended flow rates.
4. The automatic signal that shuts down the reactor if the turbines stop was blocked.
5. The safety devices that shut down the reactor if steam pressure or water levels become abnormal were turned off.
6. Almost all control rods were pulled out of the core.

3. CHERNOBYL ACTIVITY RELEASE (Ref 3,4,3,5)

The destruction of the Chernobyl nuclear power station core led to the release of millions of curies of radioactive material. This should be compared to 15 curies for Three Mile Island (1 curie 3.7 x 10^{10} Becquerel) and about one million curies at Windscale in the United Kingdom in 1956. The consequences of this within the USSR were catastraphic.

1. Thirty one known deaths.
2. Two hundred and three cases of hospitalisation.
3. Over 100,000 people received elevated radiation doses.
4. Over 50,000 people were evacuated from homes which are still uninhabitable.
5. Some 2000 sq. km. of land were badly contaminated.
6. Economic distress was suffered by people within a radius of 1000 km from Chernobyl.

Sweden, in particular suffered heavy contamination causing many forms to be quarantined, food to be abandoned and remainder to be destroyed. Spikes of fallout contamination after rain caused distress in Poland, Finland and even Scotland. However it is most unlikely that the contamination of the food cycle in these countries would cause any detectable excess mortality or life shortening experiences due to cancer. With a natural cancer mortality of around 25% in most industrialised countries, the excess from Chernobyl fallout would be very small and hard to predict. However, the disaster on which probably more radioactivity was released than Hiroshima and Nagasaki combined, will be monitored closely and will provide a unique control population for studying the biostatistical response of human and animal populations to a unique event.

4. GLOBAL RESPONSE TO CHERNOBYL

Approximately twelve months after the Chernobyl accident, the nuclear industry appears to have recovered from a serious setback. Public opinion in most European countries, including Sweden, recognises that the risk-consequence phenomena associated with the nuclear fuel cycle is still considerably less than other societally accepted risks.

It is also apparent that countries with established nuclear power programmes - such as the U.S.A., Great Britain, France, Belgium, Sweden, Canada and Japan - have assessed that the Chernobyl disaster would be most unlikely to occur in nuclear power plant of Western design. There appears to be a concerted move to induce the I.A.E.A. to keep a closer watch on the operation of Soviet designed R.B.M.K. and V.V.E.R. reactors and to formulate plans for international litigation and fiscal reparation in such cases of accident.

For Soviet industry, the shutting down of its R.B.M.K. reactors and retrofitting and redesigning the equipment is a financial impossibility. It would bring to a halt much of the industrial production of European Russia. The best one can anticipate from this country is probably improved operator training and hopefully better design and multiple containment for her new nuclear power stations. (Ref 6.)

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