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SAFETY EVALUATION OF A CONCEPTUAL FUEL RECYCLE COMPLEX

by

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ABSTRACT

A conceptual design integration study for an integrated Fuel Recycle Complex (FRC) has been completed. A safety evaluation of the radiation shielding, fire precautions, handling of nonradioactive hazardous materials, criticality hazards, operating errors, and the influence of natural phenomena on the FRC shows that all federal regulations are met or exceeded.

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INTRODUCTION

In this presentation I am going to discuss an evaluation of the potential hazards involved in an integrated Fuel Recycle Complex (FRC) assumed to be located on the Savannah River Plant site. Some of the features incorporated in its design that are intended to eliminate or mitigate these hazards will be discussed. This will not be a formal Safety Analysis with calculated probabilities, but a conceptual effort to foresee and prevent any potential for human injury (Slide 1).

FUEL RECYCLE COMPLEX DESIGN

This is an artist's conception of the integrated FRC under study, which is the product of design efforts of several groups across the country. This facility is designed to process 3000 metric tons of heavy metal per year from light water moderated reactors. The reference process is coprocessing of uranium and plutonium. No plutonium is ever available as a separate stream (Slide 2).

This analysis will consider the types of hazards shown here for each facility within the complex. The corresponding design features will then be covered (Slide 3).

Radiation Limits and Shielding

Several areas of the FRC contain source material of sufficient radiation intensity to require shielding to meet radiation exposure limits. The design basis limits shown here are within the criteria listed in the Code of Federal Regulations, 10 CFR 20. They also meet the guidelines of ERDA Manual Chapter 0524, NRC Reg. Guide 3.24, Am. National Standards for Concrete Radiation Shields and ANS-11.13/n101.6 - 1972 (Slide 4).

These are specific facility areas that require shielding to meet the exposure criteria I just pointed out on the previous slide. Rather than go into detail on each area, I would like to use the Fuel Receiving and Storage Facility as an example and explore it in some detail (Slide 5).

Fuel Receiving and Storage Facility

This is a layout of the Fuel Receiving and Storage Facility. Fuel assemblies are removed from shipping casks under water. Thirteen feet of water over fuel assemblies provides adequate radiation shielding. Mechanical and electrical stops are provided on fuel handling equipment to prevent the inadvertent raising of an assembly above a safe depth. Emergency sources of water are available to ensure that basin levels are always maintained.

Shielding is provided for water filter-deionizer systems and for heat exchangers. Sensors are used to control pool levels, and leak detectors installed behind pool liners give warning in the event of a pool leak (Slide 6).

Fire Hazards and Prevention

There are several potential fire hazards in the FRC: zirconium fines during shearing and voloxidation, the n-paraffin diluent in solvent extraction, the possible "red-oil" reaction between tri-n-butyl phosphate and nitric acid, ammonium nitrate formation in the co-coversion process, hydrogen gas used in co-conversion, MOX fabrication, UF_6 facilities, and ion exchange resins (Slide 7).

Fire detection and suppression systems are located throughout the FRC. In general, automatic wet-pipe sprinkler systems or water fog systems are used where conditions permit. In most areas where water is unacceptable, Halon® (Du Pont) 1301 systems are used (Slide 8).

Shearing and voloxidation present a special fire hazard. Zirconium and zircaloy fines are pyrophoric, especially when moist. Burning Zircaloy fines react with both water and Halon. An inert atmosphere is used where fines are generated for fire prevention. Should a fire occur, dry powdered NaCl is used as an extinguishant. Fire suppression systems are designed to remain operable during a design basis earthquake. I will define this earthquake in a few minutes.

Nonradioactive Hazardous Materials

Toxic or corrosive hazards are presented by a number of the cold feed chemicals. A partial list of nonradioactive hazardous materials is shown here. Miscellaneous chemicals used in smaller quantities include sulfuric acid, hydroxylamine nitrate, formic acid, and sulfamic acid. Normal industrial practice with additional guidance from OSHA standards NRC Regulatory Guide, and DOT Regulations is used for safe storage and handling of these chemicals (Slide 9).

For example, liquid chlorine is used to purify water for domestic uses. Chlorine cylinders are enclosed in a small building that has an air change every 3 minutes. Chlorine detectors and alarms within the enclosure warn of chlorine leaks.

Criticality Prevention

Criticality is a potential hazard in most areas of the complex. Criticality prevention, detection, and protection are required wherever fissile materials are stored or processed.

The design basis limit for minimum subcritical margin is 0.05 in K_{eff}. This means that no operation will produce K_{eff} greater than 0.95. Here you see a list of control methods incorporated in the design. Geometrical means are used to the extent practicable. Where geometric means cannot be used, administrative means with positive instrumental controls are used. Independent and redundant controls ensure that no single undetected failure will cause loss of criticality control (Slide 10).

Let us use the Fuel Receiving and Storage Facility as an example of criticality control means. Criticality control is based on spacing of fuel elements (geometrical means). The building structure in areas where fuel is out of a cask is fully resistant to natural phenomena (earthquake and tornado). Heavy structural members support the crane rails and roof. Physical restraints prevent the cask crane from passing over the storage pools. Transfer canals and storage crane lifting limits prevent movement of a loaded basket over other loaded baskets. The pool design makes tipping of a cask, to the extent that fuel assemblies will fall out, impossible. Nuclear Incident Monitor (NIM) systems are located near potential nuclear criticality events. Two NIM's are in each fuel handling area. At least one functioning NIM unit must be in service at each location or operations will be stopped (Slide 11).

Operating Errors

The design ensures that no single undetected operating error can cause an incident having unacceptable safety consequences. A rigidly enforced system of approved procedures will be used for every operation. Procedures will provide manipulative instruction, data sheets, and control limits. Authorization for issue of a new or revised procedure is obtained at fixed levels of supervision. Operators will be trained and certified in a formal training program. The status of training and procedure compliance is routinely monitored (Slide 12).

Natural Phenomena

Structures, systems and components important to safety must withstand the effects of extreme natural phenomena without loss of essential function. For the FRC, assuming location at SRP, earthquakes and tornadoes are considered credible events, floods are not. This slide shows the earthquakes and tornadoes considered in the design. The design requirements are listed in 10 CFR 50 Appendix P and in NRC Reg. Guide 1.60 and 1.76. The effects on the design of these requirements is to require more massive walls with more reinforcement than would be otherwise required. Should the wells or pumps be lost during earthquake and fire, a large storage pond is provided for fire water and for emergency basin cooling. In the Fuel Receiving and Storage Facility, the outer walls are not tornado resistant, but the crane support structure is resistant (Slide 13).

CONCLUSION

The safety aspects of the FRC considered here were carefully studied by the whole design task force. At the Savannah River Plant, very similar processes have been operated in a safe manner for over 26 years. All pertinent Federal and industrial guides were carefully studied and incorporated. In light of this study and experience, this design will provide a fuel reprocessing complex that is not only safe, but acceptable and licensable by any appropriate federal, state or local agency.

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TYPES OF HAZARDS

- RADIATION
- FIRE
- NONRADIOACTIVE HAZARDOUS MATERIALS
- CRITICALITY
- OPERATING ERRORS
- NATURAL PHENOMENA

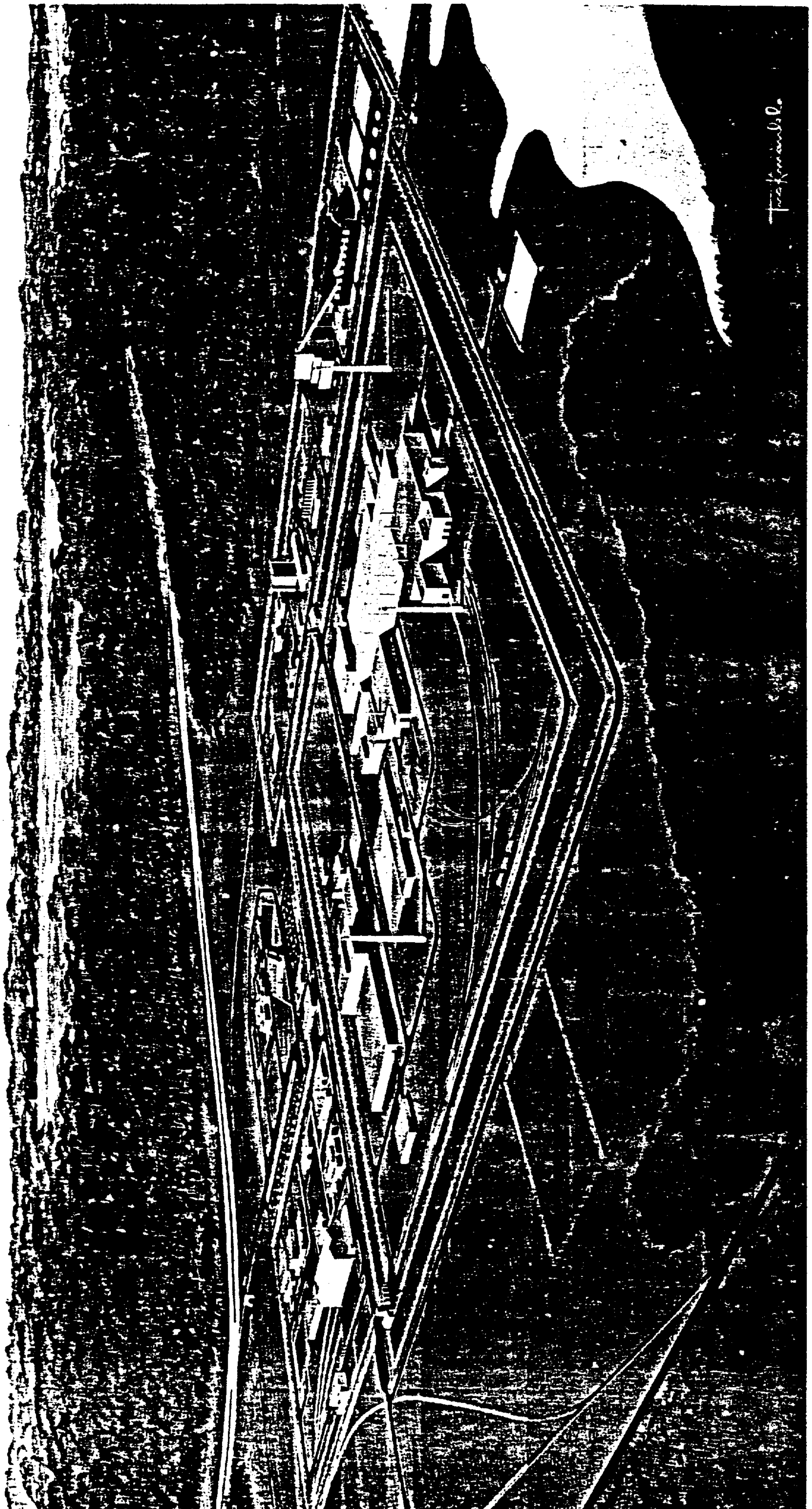
SHIELDED AREAS

- FUEL RECEIVING AND STORAGE FACILITY
- MAIN PROCESSING BUILDING
- CO-CONVERSION AND SCRAP RECOVERY
- MOX FUEL FABRICATION
- OFF-GAS TREATMENT
- SOLID WASTE PROCESSING
- INTERIM AIR COOLED STORAGE
- BURIAL GROUND

DESIGN BASIS RADIATION LIMITS

ROUTINELY OCCUPIED AREAS	0.5 mREM/Hr
INTERMITTENTLY OCCUPIED AREAS	5 mREM/Hr
TOTAL ACCUMULATED DOSE	1REM/MAN/YEAR

FUEL RECEIVING AND STORAGE FACILITY



FIRE HAZARDS

- ZIRCONIUM FINES
- n-PARAFFIN DILUENT
- "RED-OIL" REACTION
- AMMONIUM NITRATE
- HYDROGEN
- ION EXCHANGE RESINS

FIRE SUPPRESSION SYSTEMS

- o AUTOMATIC WET-PIPE SPRINKLERS
- o AUTOMATIC HALON 1301
- o HOSE REELS
- o FOG NOZZLES
- o INERT ATMOSPHERE
- o DRY NaCl

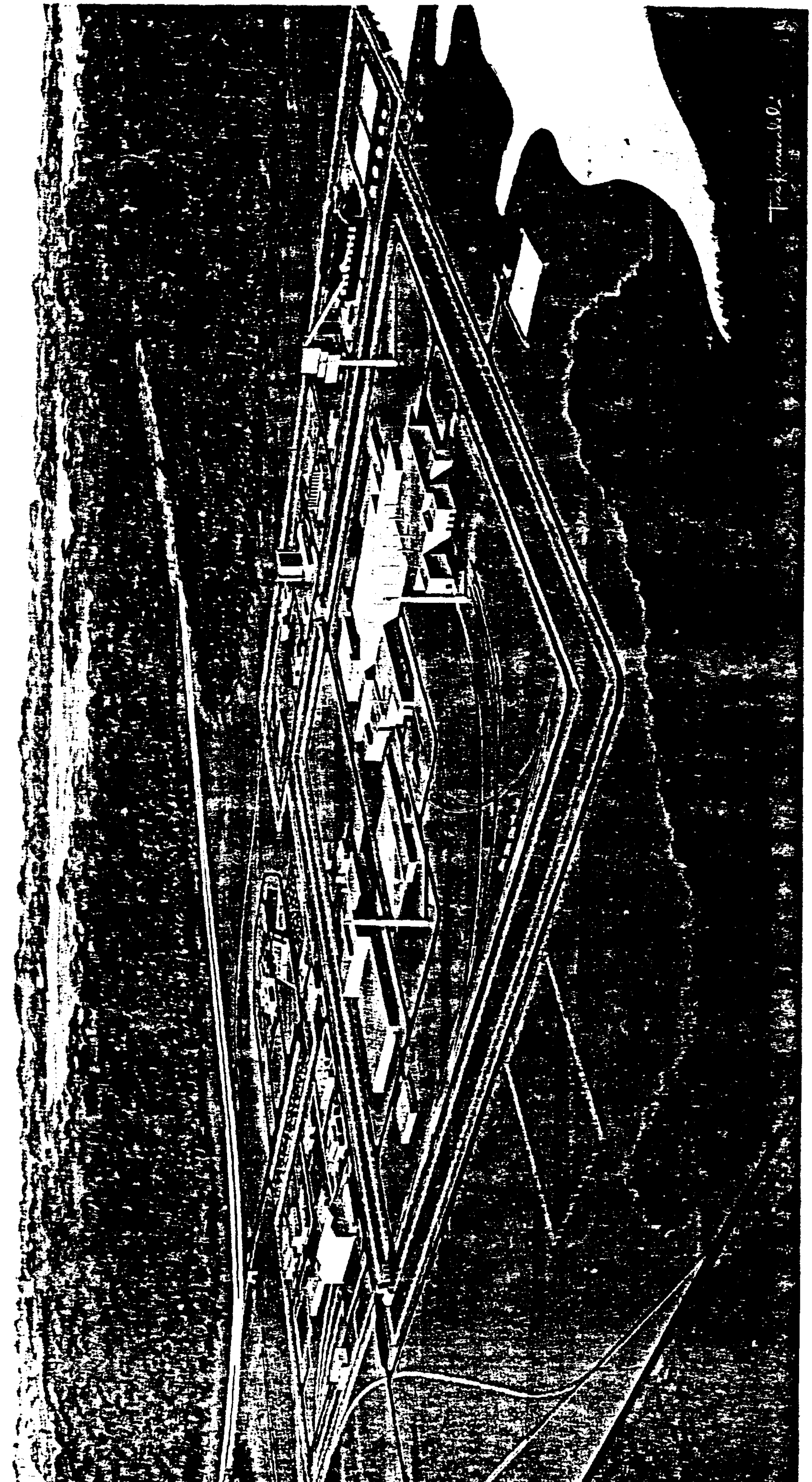
NONRADIOACTIVE HAZARDOUS MATERIALS

- CHLORINE
- HYDROFLUORIC ACID
- FLUORINE
- AMMONIA
- NITRIC ACID
- SODIUM HYDROXIDE
- HYDROGEN
- SULFURIC ACID
- MISC.

CRITICALITY PREVENTION

FACILITY	MEANS
FUEL RECEIPT & STORAGE	FIXED SPACING
SHEARING & VOLOXIDATION	BATCH SIZE MATERIAL BALANCE NO HYDROGENEOUS MATERIALS
DISSOLVERS	CONCENTRATION BATCH SIZE SOLUBLE POISONS
SOLVENT EXTRACTION	CONCENTRATION SCRUB RATE & ACIDITY
Pu/U CONC. & STORAGE	GEOMETRY
CO-CONVERSION	GEOMETRY CONCENTRATION
MOX	GEOMETRY ADMINISTRATIVE

FUEL RECEIVING AND STORAGE FACILITY



OPERATING ERROR PREVENTION

- NO SINGLE ERROR CAUSES INCIDENT
- TRAINED PERSONNEL ONLY
- RIGID PROCEDURAL CONTROL

NATURAL PHENOMENA

o EARTHQUAKE (OPERATING BASIS)	0.13 g
o EARTHQUAKE (SAFE SHUTDOWN)	0.2 g
o TORNADO	
MAX VORTEX VELOCITY	230 mph
MAX TRANSLATIONAL VELOCITY	50 mph
MAX PRESSURE CHANGE	1.5 psig/3 sec