EVALUATION OF ACCIDENT INITIATED BY REACTIVITY INSERTION IN PWR

By

Hala Kamal Girgis Selim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
In
ENGINEERING PHYSICS

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Title of Thesis:

Evaluation of Accident Initiated by Reactivity Insertion in PWR

Key Words: Reactor Safety; Neutronic/Thermal-Hydraulic Coupling; Rod Ejection Accident; (Th-Pu)O2; UO2/MOX

Summary:
Reactivity Initiated Accident (RIA) induced by control rod ejection is a design basis accident for Pressurized Water Reactors and the regulatory authority requires that the accident should be analyzed for nuclear reactors. The safety performance of The Westinghouse GenIII$^+$ reactor AP1000 is investigated at steady state and during RIA using different fuels. In the study, two alternative core loading patterns is proposed in which 30% of the UO2 fuel assemblies is replaced with (U-Pu)O2 fuel in one of the patterns and (Th-Pu)O2 fuel in the other. The steady state analysis illustrate that UO2/MOX and UO2/(Th-Pu)O2 core loading patterns can be utilized as the safety criteria mentioned in Design Control Document are met. RIA analysis show that no fuel failure occurs under transient. The overall performance of UO2/MOX and UO2/(Th-Pu)O2 core loading patterns have proved to be similar to that of UO2 core loading. The safety limits are not violated for the control rod ejection accident which points the safety of AP1000 in the case of the transient.

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To the Spirit of My Mother

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LIST OF ABBREVIATION

AP1000	Advanced Passive 1000 - Westinghouse pressurized water reactor
PWR	Pressurized Water Reactor
RIA	Reactivity Initiated Accident
QUARK	QUAndry based Reactor Kinetics (coupled neutronic/thermal-hydraulic code)
WIMS	Winfrith Improved Multigroup Scheme (lattice cell code)
DCD	Design Control Document
DNBR	Departure from Nucleate Boiling Ratio
LWR	Light Water Reactor
NPP	Nuclear Power Plant
GEN	Generation
TMI	Three Miles Island
NRC	Nuclear Regulatory Commission
DBA	Design Basis Accident
DEC	Design Extensions Condition
DID	Defence-In-Depth
AOO	Anticipated Operational Occurrence
PIE	Postulated Initiating Event
LOCA	Loss Of Coolant Accident
SCRAM	Safety Control Rods Activation Mechanism
ATWS	Anticipated Transients Without SCRAM
PSA	Probabilistic Safety Assessment
IAEA	International Atomic Energy Authority

INES	International Nuclear Event Scale
CPS	Core Protection System
BWR	Boiling Water Reactor
RBMK	High Power Channel-type Reactor - Russian boiling water reactor
HELIOS	Lattice physics code
REMARK	Neutron kinetic code
THEATRe	Thermal hydraulic code
CITATION	Nuclear Reactor Core Analysis Code
VVER	Water-Water Energetic Reactor - Russian pressurized water reactor
COBRA	Thermal hydraulic code
REA	Rod Ejection Accident
FSAR	Final safety Analysis Report
HZP	Hot Zero Power
BOC	Begin Of Cycle
RIL	Rod Insertion Limit
ARI	All Rods Inserted
CASMO	lattice physics code
SIMULATE	Transient Analysis Code
HFP	Hot Full Power
FALCON	Fuel Performance Code
PCMI	Pellet-Clad Mechanical Interface
EOC	End Of Cycle
DECART	Core Analysis Code
PARCS	Reactor Kinetics Code
MSBR	Molten Salt Breeder Reactor

ORNL	Oak Ridge National Laboratory
RDA	Rod Drop Accident
HPLWR	High Performance Light Water Reactor
KIKO3D-ATHLET	Coupled Neutronic/Thermal Hydraulic Code
RELAP-MOD	Thermal hydraulic code
TRILLO	Nuclear Power Station in Spain
WGPu	Weapons-Grade Plutonium
RGPu	Reactor-Grade Plutonium
ATHLET-QUABOX/CUBBOX	Coupled Neutronic/Thermal Hydraulic Code
MCNP	Neutronic calculations Code
SDM	Shut Down Margins
MTC	Moderator Temperature Coefficient
FTC	Fuel Temperature Coefficient
ROX	Plutonium Rock-Like Oxide
PYREX	Burnable Absorber (borosilicate glass)
IFBA	Integral Fuel Burnable Absorbers
RCCA	Rod Cluster Control Assemblies
Ag-In-Cd	Silver-Indium-Cadmium
MSHIM	Mechanical Shim
SS	Stainless Steel
BA	Burnable Absorber
CR	Control Rod
BOL	Begin Of Life