



# NUCLEAR POWER PLANT SAFETY AND MECHANICAL INTEGRITY

DESIGN AND OPERABILITY OF MECHANICAL SYSTEMS,  
EQUIPMENT AND SUPPORTING STRUCTURES

GEORGE ANTAKI  
RAMIZ GILADA



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**NUCLEAR POWER  
PLANT SAFETY  
AND MECHANICAL  
INTEGRITY**



## BIOGRAPHY

Mr Antaki has nearly 40 years of experience in nuclear power and process engineering. He is a Fellow of the American Society of Mechanical Engineers (ASME). He is the Chairman of ASME III Working Group Piping Design and ASME B31.1 Mechanical Design Committee, and a member of the ASME Operation and Maintenance Subgroup. Mr Antaki was an engineer and a group manager at Westinghouse, and is currently Chief Engineer, Becht Nuclear Services. Mr Antaki resides in Aiken, South Carolina.

Mr Gilada has nearly 35 years of experience in nuclear mechanical and civil projects. He is a member of ASME III Working Group Piping Design, the Working Group Flaw Evaluation, and the ASME Operation and Maintenance Subgroup. He is the Principal Consultant Engineer at the Comanche Peak Nuclear Power Plant, Texas, with responsibilities in the field of civil and structural mechanics, and also in piping and suspended systems engineering. Mr Gilada resides in Cleburne, Texas.



# PREFACE

This is a book about issues and tasks faced by engineers in nuclear power plants, with a focus on the safe and reliable operation of mechanical systems and equipment, and their supporting structures. The issues and challenges described in this book vary from the most complex subjects, such as replacing steam generators or tackling complex material damage mechanisms, down to the simpler tasks like maintenance, cleaning, and painting that, while simpler, call for logical and technically sound solutions.

This book is a compilation from our personal experiences that span many decades. Our sole purpose is to aid a new generation of engineers navigate through the vast amount of information in this field, and to emphasize the importance, in our business, of approaching every day's challenges with the same degree of rigor and thoroughness to achieve safe and reliable plant operation.

We have tried to describe the thought process followed in defining the issues at hand, and solving them using knowledge from codes, standards, regulations, past experience, and the basic principles of mechanical, materials, and structural engineering. This knowledge converges into a field, best described as Safety and Mechanical Integrity, which we chose for the title. It is the field of engineering in which we face challenges to plant equipment and plant operation (whether human induced, or caused by operational transients, ageing and obsolescence, or natural phenomena hazards) and have to make important operability and run-or-repair decisions.

**George Antaki**  
Becht Engineering Co.

**Ramiz Gilada**  
CPNPP





# ACKNOWLEDGMENTS

The opportunity to work in nuclear power plants and to support their safe operation has provided us many opportunities to contribute and also to constantly learn the art of engineering. We are thankful for the support provided to us by plant management in permitting us to share some of this experience for the benefit of others in the industry.

We are honored to be part of Code committees in the field of nuclear power, and thank our colleagues, our friends of so many years on Code committees, for the constant give-and-take that takes place in translating everyday knowledge into codes and standards, and eventually into books like this one.

At times, with the day-to-day emergencies, we thought we may not make our deadlines, but thanks to the excellent support and insights of Chelsea Johnston and Poulouse Joseph of Elsevier, we persevered. Finally, we would like to acknowledge the support we have received from our families during the two year journey to produce this book.



# ACRONYMS AND DESCRIPTION

<b>ACI</b>	American Concrete Institute
<b>ACRS</b>	Advisory Committee on Reactor Safeguards
<b>AEC</b>	Atomic Energy Commission
<b>AFW</b>	Auxiliary feedwater
<b>AG</b>	Code on Nuclear Air and Gas Treatment
<b>AHU</b>	Air Handling Unit
<b>AISC</b>	American Institute of Steel Construction
<b>AISI</b>	American Iron and Steel Institute
<b>ANS</b>	American Nuclear Society
<b>ASCE</b>	American Society of Civil Engineers
<b>ASME</b>	American Society of Mechanical Engineers
<b>ASME O&amp;M</b>	Operation and Maintenance of Nuclear Power Plant
<b>ASTM</b>	ASTM International
<b>AWS</b>	American Welding Society
<b>AWWA</b>	American Waterworks Association
<b>BDBE</b>	Beyond-Design Basis Event (and BDB Earthquake)
<b>BEZ</b>	Break Exclusion Zone
<b>BL</b>	NRC Bulletin
<b>BTP</b>	Branch technical position
<b>BWR</b>	Boiling water reactor
<b>B&amp;PV</b>	Boiler and Pressure Vessel
<b>CC</b>	Code Case
<b>CEA-CEN</b>	Commissariat a l'Energie Atomique Centre d'Etudes Nucleaires
<b>CFD</b>	Computational fluid dynamics
<b>CFR</b>	Code of Federal Regulations
<b>CGD</b>	Commercial Grade Dedication
<b>CP</b>	Construction permit
<b>CR</b>	Contractor report
<b>CRDM</b>	Control rod drive mechanism
<b>CS</b>	Core support and Containment spray
<b>DMW</b>	Dissimilar metal welds
<b>EPRI</b>	Electric Power Research Institute
<b>EQ</b>	Environmental qualification and Equipment qualification
<b>ERDA</b>	Energy Research and Development Administration
<b>ET</b>	Eddy current testing
<b>FA</b>	Functionality assessment
<b>FAC</b>	Flow-accelerated corrosion
<b>FEA</b>	Finite element analysis
<b>FEMA</b>	Federal Emergency Management Agency
<b>FIV</b>	Flow-induced vibration
<b>FLEX</b>	Diverse and flexible coping strategies

<b>FMEA</b>	Failure mode and effects analysis
<b>FSAR</b>	Final safety analysis report
<b>GDC</b>	General design criteria
<b>GIP</b>	Generic implementation procedure
<b>GL</b>	NRC Generic Letter
<b>GMRS</b>	Ground motion response spectra
<b>GPM</b>	Gallons per minute
<b>HE</b>	High Energy
<b>HVAC</b>	Heating, ventilation and air conditioning
<b>IAEA</b>	International Atomic Energy Agency
<b>ID</b>	Inside diameter
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>IER</b>	Industry Event Report
<b>IN</b>	NRC Information Notice
<b>INPO</b>	Institute of Nuclear Power Operations
<b>IOE</b>	Industry operating experience
<b>ISI</b>	Inservice inspection
<b>IST</b>	Inservice testing, ISTB (pumps), ISTC (valves), ISTD (snubbers)
<b>LBB</b>	Leak before break
<b>LER</b>	Licensee Event Report
<b>LOCA</b>	Loss of coolant accident
<b>MC</b>	Metal containment
<b>ME</b>	Moderate energy
<b>MEB</b>	Mechanical engineering branch
<b>MR</b>	Maintenance rule
<b>MRP</b>	Material Reliability Program (EPR1)
<b>MSIV</b>	Main steam isolation valve
<b>MSS-SP</b>	Manufacturers Standardization Society — Standard Practices
<b>MT</b>	Magnetic testing
<b>NDE</b>	Nondestructive examination
<b>NDT</b>	Nondestructive testing
<b>NEI</b>	Nuclear Energy Institute
<b>NEMA</b>	National Electrical Manufacturers Association
<b>NQA</b>	Nuclear Quality Assurance
<b>NRC</b>	Nuclear Regulatory Commission
<b>NUREG</b>	NRC Regulatory Guidance
<b>OBE</b>	Operating basis earthquake
<b>OD</b>	Operability determination
<b>OD</b>	Outside diameter
<b>OSHA</b>	Occupational Safety and Health Administration
<b>O&amp;M</b>	Operation and Maintenance
<b>PCC</b>	Post-Construction Code
<b>PRA</b>	Probabilistic risk assessment

<b>PRHA</b>	Pipe rupture hazards analysis
<b>PT</b>	Penetrant testing
<b>PTS</b>	Pressurized thermal shock
<b>PVRC</b>	Pressure Vessel Research Council
<b>PWR</b>	Pressurized water reactor (and pipe whip restraint)
<b>PWSCC</b>	Primary water stress corrosion cracking
<b>P&amp;ID</b>	Piping and instrumentation diagram
<b>QA</b>	Quality assurance
<b>QC</b>	Quality control
<b>QME</b>	Qualification of Active Mechanical Equipment
<b>RAHA</b>	Radial Arm and Hoist Assembly
<b>RCS</b>	Reactor coolant system
<b>RG</b>	Regulatory guide
<b>RHR</b>	Residual heat removal
<b>RT</b>	Radiographic testing
<b>SAM</b>	Seismic anchor motion
<b>SAR</b>	Safety analysis report
<b>SCC</b>	Stress corrosion cracking
<b>SG</b>	Steam generator
<b>SMA</b>	Seismic margins assessment
<b>SMACNA</b>	Sheet Metal & Air Conditioning Contractors' National Association
<b>SPRA</b>	Seismic Probabilistic Risk Assessment
<b>SQUG</b>	Seismic Qualification Utilities Group
<b>SRP</b>	Standard review plan
<b>SS</b>	Stainless steel
<b>SSC</b>	Structure, system and component
<b>SSE</b>	Safe shutdown earthquake
<b>TIG</b>	Tungsten inert gas (welding)
<b>TS</b>	Technical specification
<b>UT</b>	Ultrasonic testing
<b>VT</b>	Visual testing
<b>ZOI</b>	Zone of influence

### **Section III**

<b>NCA</b>	ASME Section III Subsection General Requirements for Division 1 (Piping & Components) and Division 2 (Concrete Containments)
<b>NB</b>	ASME III Subsection for Class 1 Components
<b>NC</b>	ASME III Subsection for Class 2 Components
<b>ND</b>	ASME III Subsection for Class 3 Components
<b>NE</b>	ASME III Subsection for Class MC Components
<b>NF</b>	ASME III Subsection for Pipe Supports

**Section XI**

<b>IWA</b>	ASME XI General Requirements
<b>IWB</b>	ASME XI Requirements for Class 1 Components of Light-Water Cooled Plants
<b>IWC</b>	ASME XI Requirements for Class 2 Components of Light-Water Cooled Plants
<b>IWD</b>	ASME XI Requirements for Class 3 Components of Light-Water Cooled Plants

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