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FRAMATOME ANP, INC.

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NRC Meeting

BAW-10243

Statistical Fuel Assembly Hold Down Methodology

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Statistical Hold Down (SHD)

Fuel Assembly Hold Down System

Fuel Assembly Hold Down Methods

SHD Methodology

Variables in Fuel Assembly Hold Down

SHD Calculational Model

SHD Propagation Models

SHD Monte Carlo Propagation

SHD Protection

SHD Illustrational Results

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Fuel Assembly Hold Down System

- Typical Spring System
- Net Hold Down Force is
  - Assembly Weight
  - Less Assembly Buoyancy
  - Less Hydraulic Forces
  - Plus Hold Down Spring Force
- Consequences of
  - Negative Hold Down Force
  - Excessive Hold Down Force

Fuel Assembly Hold Down Methods

- Traditional (Very Conservative Adjustment)
  - Compounded – Worst Case Uncertainties
  - Strongly Underestimates Hold Down Force
  - Possible Addition of Unnecessary Force
- Statistical Treatment (Realistic Adjustment)
  - Nominal Calculation
  - Statistical Combination of Uncertainties
  - Nominal Adjusted by Statistical Uncertainties

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SHD Methodology

- Identify Independent Variables
- Develop Calculational Model
- Quantify Uncertainties and Distributions
- Propagate Uncertainties
  - Monte Carlo Propagation
  - Establishes Realistic Overall Uncertainty
- Establish Tolerance Limit for Protection

Variables in Fuel Assembly Hold Down

- Mechanical – Affect the Downward Spring Force
  - Hold Down Spring
  - Fuel Assembly Length
  - Core Plate Separation
- Hydraulic – Affect the Upward Coolant Force
  - Coolant Mass Flow (Pumps, Coolant Density)
  - Fuel Assembly Hydraulic Resistance
  - Core Flow Distribution

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SHD Calculational Model

Net Fuel Assembly Hold Down Force =

(Spring Depression)(Spring Constant)

+ Dry Weight of the Fuel Assembly

- Fuel Assembly Buoyancy

- Hydraulic Resistance of the Fuel Assembly

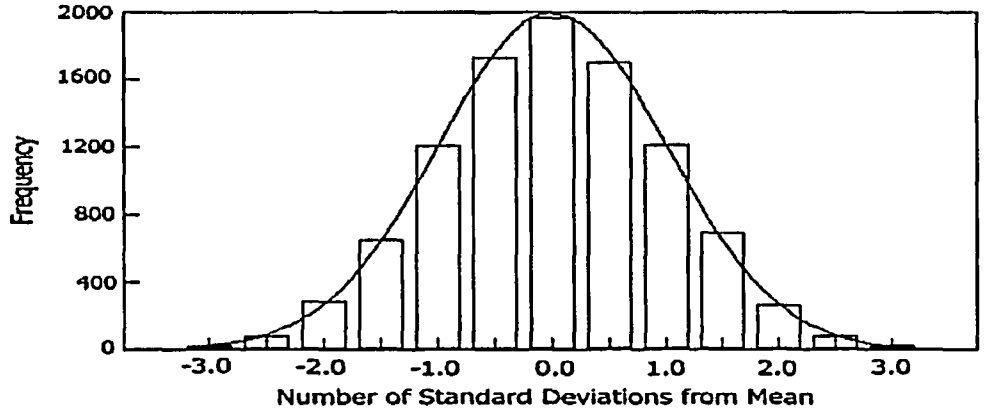
$$NHD = (SD)(SC) + (DW) - (VOL)(DEN) - [\,LDP\,(BP2)\,]$$

NHD: Net hold down force, lbf
SC: Spring constant, lbf/in
VOL: Displacement of the assembly, ft3
LDP: Hydraulic lift pressure drop, lbf/in2
SD: Spring depression, in
DW: Dry weight of the assembly, lbm
DEN: Average density of the water, lbm/ft3
BP: Fuel assembly bundle pitch, in

SHD Propagation Models

Normal Distribution

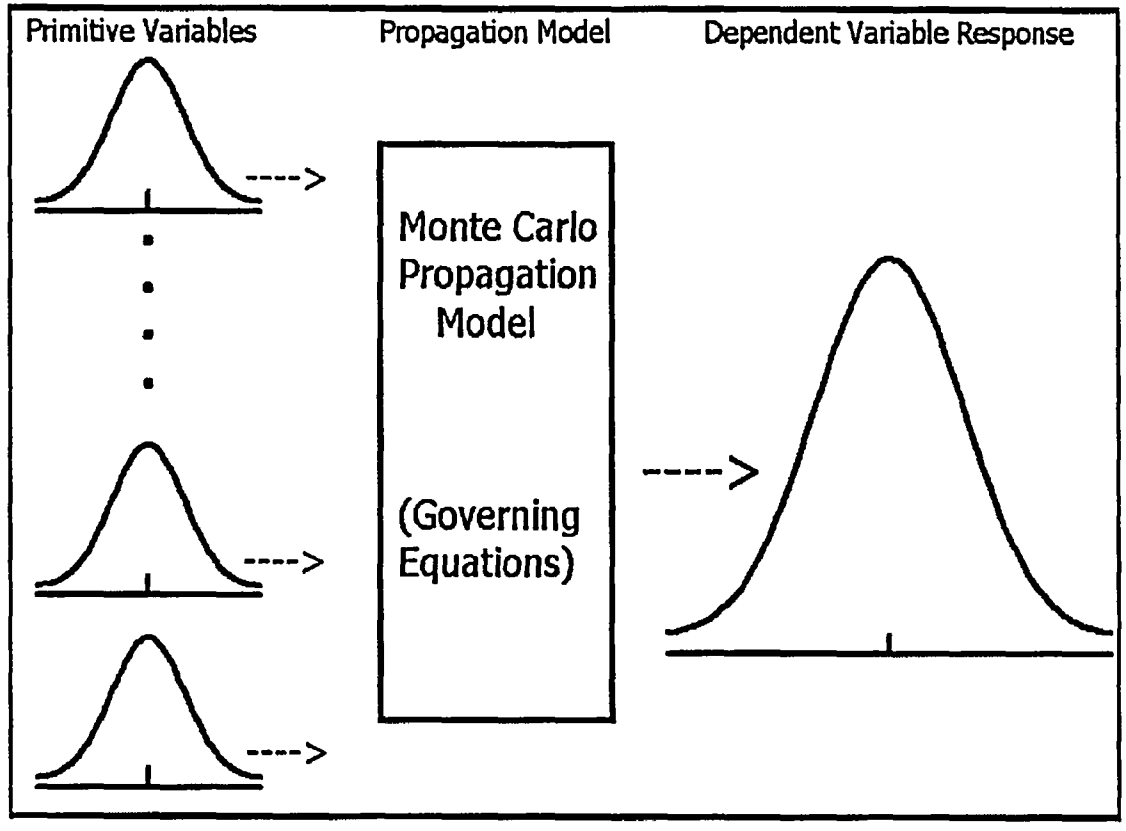
$$N[0,1] = \sum_{i=1}^{12} [RND_i] - 6$$



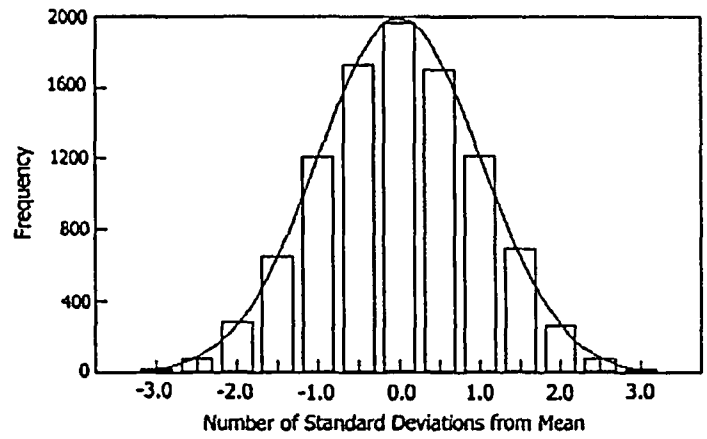
Uniform Distribution

$$U[-1,1] = 2(RND) - 1$$

SHD Monte-Carlo Propagation



SHD Protection



DATA FILE	: ML6.DAT	# OF DATA	: 10000
MAX VALUE	: 0.422874D+03	MIN VALUE	: -.101294D+03
RANGE	: 0.524168D+03	MEDIAN	: 0.182676D+03
MEAN	: 0.182131D+03	STD DEV	: 0.686690D+02
SKEWEDNESS	: -.323581D-01	KURTOSIS	: 0.190057D-01
UPPER D'	: 0.282672D+06	LOWER D'	: 0.281496D+06
DPRIME VAL	: 0.281929D+06	ACCEPT NORMALITY AT 5% LEVEL	

$$SHD = NHD - 1.67\sigma$$

SHD Illustrational Results

Plant A (Type 1 Fuel with Coil Springs)

Full Core 4th Pump Startup @ EOL
NHD = [ ], SHD = [ ] (THD =[ ])

Full Core Full Power @ EOL
NHD = [ ], SHD = [ ] (THD =[ ])

Plant B (Type 2 Fuel with Leaf Springs)

Allowable 4th Pump Startup Temperature @ EOL
With SHD 4PSUT = [ ], Without SHD 4PSUT = [ ]

Full Core Full Power @ EOL
NHD = [ ], SHD = [ ] (THD = [ ])