Simplified Equation Status

NRC / NEI
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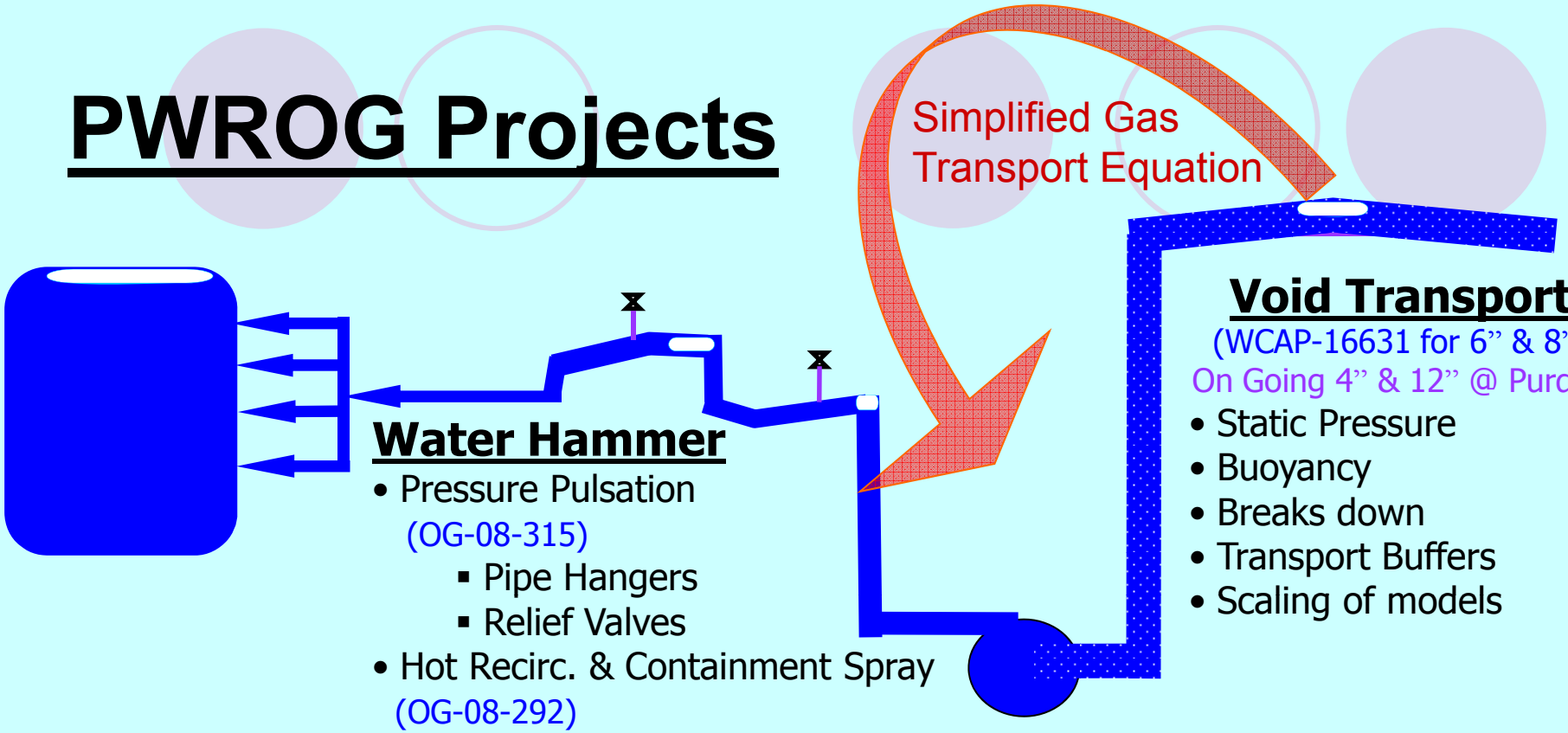
PWROG Projects



Water Hammer

- Pressure Pulsation
  (OG-08-315)
  - Pipe Hangers
  - Relief Valves
- Hot Recirc. & Containment Spray
  (OG-08-292)

Void Transport

(WCAP-16631 for 6" & 8")
On Going 4" & 12" @ Purdue

- Static Pressure
- Buoyancy
- Breaks down
- Transport Buffers
- Scaling of models

Non-Condensable Gas into the Reactor Vessel

(OG-08-293)

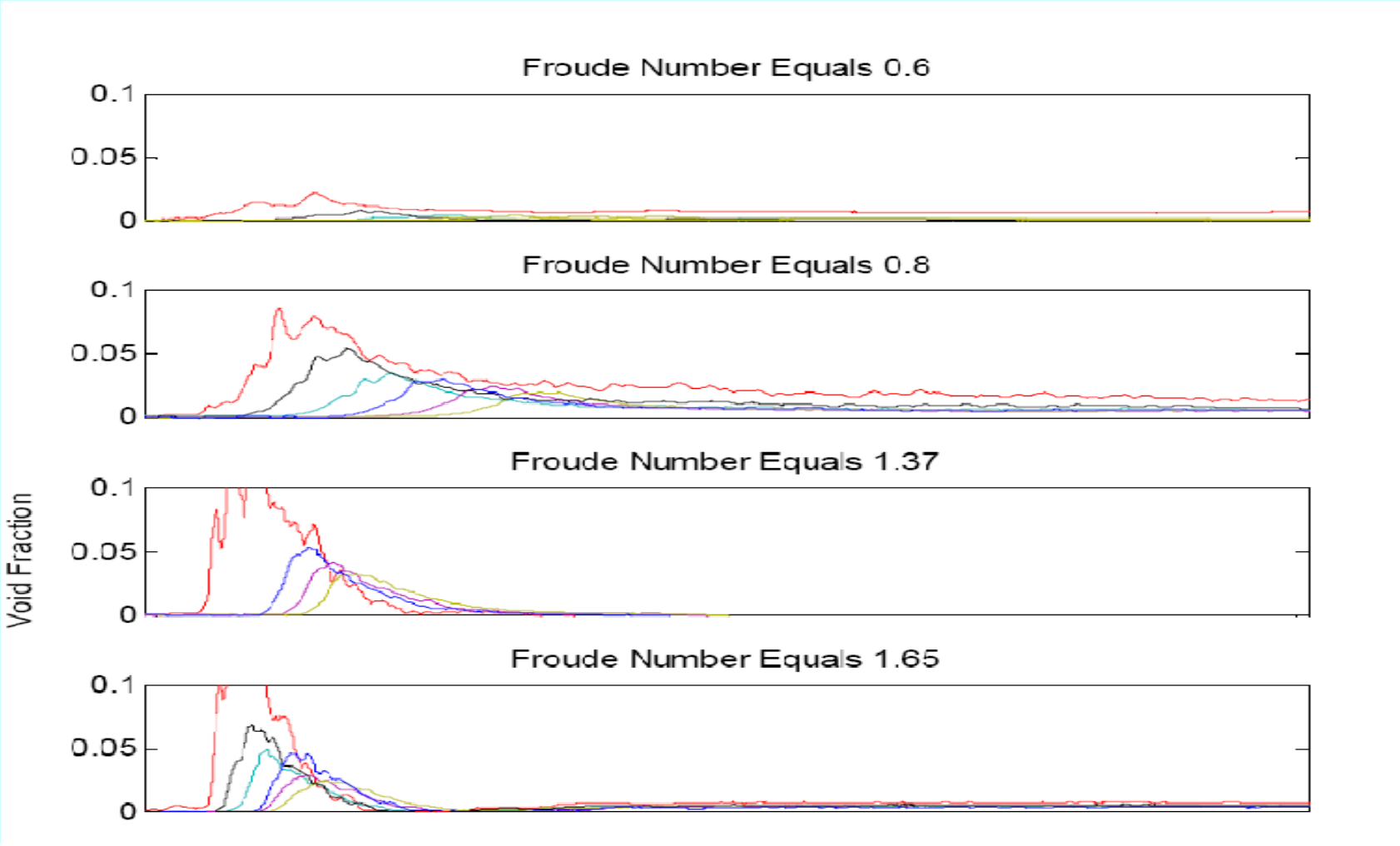
- ECCS Delay
- LOCA & Non-LOCA Qualitative Evaluation

Pump Interim Gas Ingestion Tolerance Criteria (V-EC-1866)

- Steady State & Transient Void Limits
- Types of Pumps
- Peak / Average Void Fraction
- Momentary TDH Degradation
- NPSHR vs. NPSHA

Gas Transport vs. Flow Rate

Observation: Higher flow results in higher void fraction (over a shorter duration) being transported



Bounding Condition

1. **Met Most Stringent Void Acceptance Criteria :**
   - Highest Flowrate
   - Supported by Conservative Tested Void Condition

2. **PIRT To Minimize The Initial Void Volume**
   - Conservatively Limit to 5% (i.e., 11% test)

3. **Minimize The Risk To Pump Operability**

1. **Likely Be Implementable at the Plant**

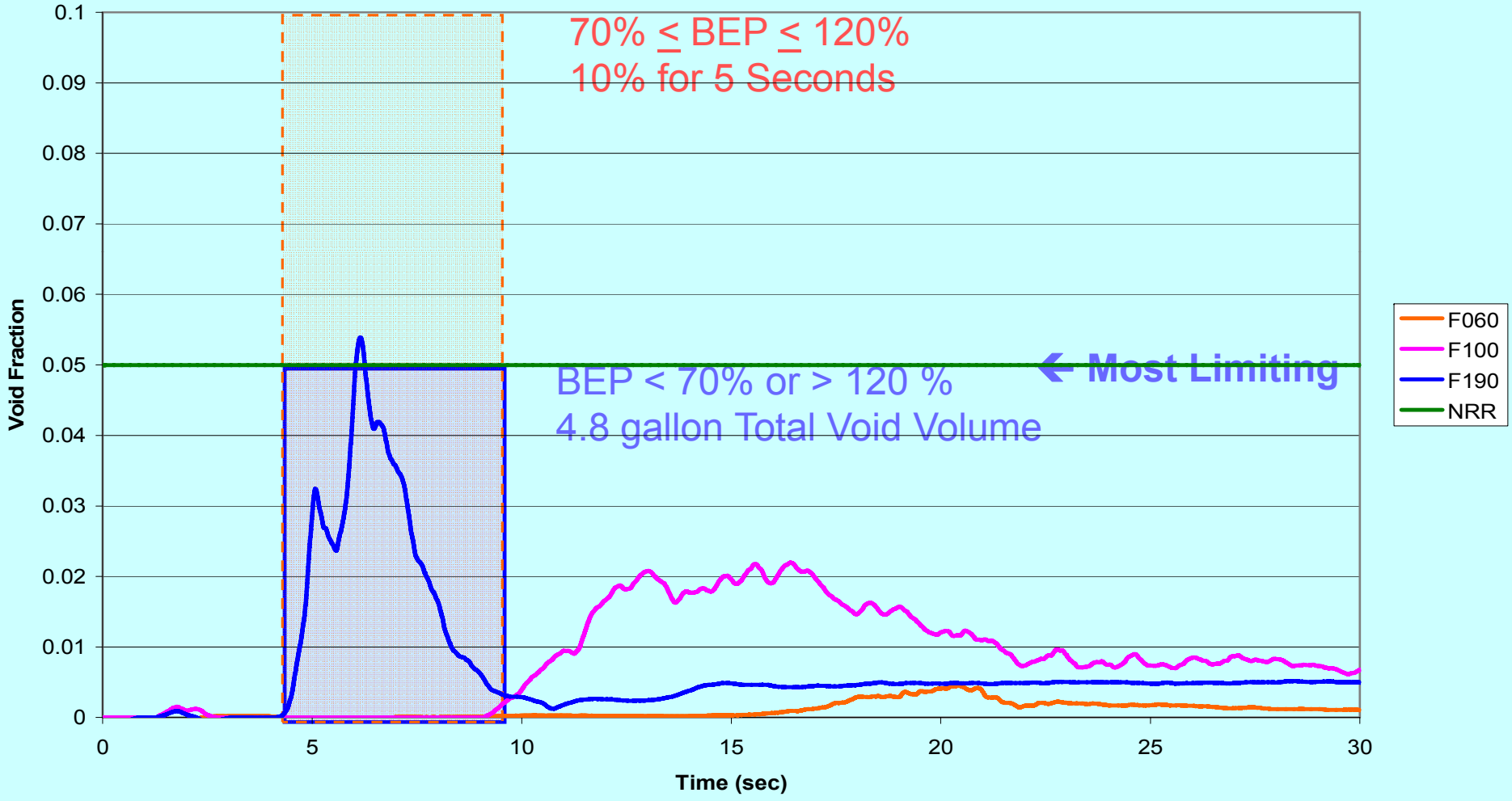
Simplified Equation vs. APC Criteria

	$\%\frac{Q}{Q_{BEP}}$	BWR Typical Pumps	PWR Typical Pumps		
			Single Stage (WDF)	Multi-Stage Stiff Shaft (CA)	Multi-Stage Flexible Shaft (RLIJ, JHF)
Steady State Operation > 20 seconds	40%-120%	2%	2%	2%	2%
Steady State Operation > 20 seconds (see Note)	< 40% or > 120%	1%	1%	1%	1%
Transient Operation ≤ 5 seconds	70%-120%	10%			10%
Transient Operation ≤ 5 seconds (see Note)	< 70% or > 120%	5%			5%
Transient Operation ≤ 20 seconds	70%-120%		5%	20%	
Transient Operation ≤ 20 seconds (see Note)	< 70% or > 120%		5%	5%	

Note: Further review by the respective Owner's Groups may determine that criteria for pump operation below 70% BEP may not be required, as the conditions are bounded by the set of criteria for the 70%-120% BEP range.

Simplified Equation vs. DSS & APC

Figure 6
6 inch 5% initial void fraction RIMP2 **(11% initial void & Fr=1.9)**



Methodology Consideration

1. **ß Ratio = Q_{gas} / $Q_{mixture}$**
   - Voids Must Mix With Water Results in A Much Lower Void Fraction To The Pump

2. **Different Transport for 4”, 6” & 8” and 12”**
   - Due to void size to Pipe X-Section Ratio
   - Void Formation Anomalies
   - Limited to Actual Pump Flow Ranges

Treatment of the Simplified Equation

1. Suction Headers With Takeoffs
   - Use Simplified Equation to calculate allowable void volume for each individual pump suction
   - Apply the smallest of the allowable void volume to the common suction header
2. Allowable Void Volume < 1/4 Of The Downstream Vertical Pipe Volume
3. Allowable void accounts for static pressure change between high point and pump suction
   - Elevation change must be $\geq$ 10 feet

Advantages of the Simplified Equation

1. Simplified Equation is Conservative
   - Limits The Allowable Void Volume
   - Not Likely To Gas Bind The Pump
   - Provides Reasonable Basis for Pump “Operability”
   - Reasonable Engineering Judgment
   - Enveloped by DSS / APC Void Criteria
   - Supported by the Purdue Test Data

2. Simple Method To Determine Allowable Void Volume At Any Pump – All Safety Related Pumps

Status

- Purdue Test Report Issued by July 31
- Simplified Report Issued by August 16, 2010
- Future Work May Relax Void Limit on Common Suction Header