ISSUE STATEMENT

Worldwide, a number of boiling water reactor plants (primarily BWR/4 and /5 designs) are experiencing jet pump degradation associated with flow induced vibration. The primary causes for jet pump degradation from flow-induced vibration are thought to be turbulent flow through the jet pumps, slip joint leakage flow instability, and pressure pulsations from pump vane passing. Jet pump degradation is generally characterized by wedge and rod wear, but one plant recently experienced substantial cracking in a jet pump riser extending 240 degrees around the circumference. The rate and severity of observed jet pump degradation is increasing. Further, the power uprates being pursued by many plants can lead to increased flow-induced vibration loads on the jet pump assembly.

DRIVERS

There are a number of factors that drive the need for timely resolution of the jet pump flow induced vibration issue, including:

Asset Management

Asset management is the primary driver associated with the management of jet pump flow-induced vibration. Jet pump degradation has become one of the most costly BWR material issues, with industry costs currently exceeding $20 million. Several plants have experienced wedge and rod wear even after installing clamps, auxiliary wedges or labyrinth seals. In 2008, a BWR/5 plant experienced a significant fatigue crack in a jet pump riser that resulted in several months of downtime and required a temporary repair. Currently, the plant is only allowed to operate for a single cycle at reduced power.

Anticipated Growth in the Extent and Severity of Degradation

As more plants pursue power uprates, the potential for more widespread and severe jet pump degradation increases. Power uprates result in higher back-pressure on the jet pumps, which can exacerbate jet pump degradation if mitigation techniques are not available and implemented.

Safety Impact

The integrity of the jet pump assembly is of paramount importance to safe plant operations. The jet pump ensures reflooding to at least 2/3 core height in the event of a concurrent recirculation pipe break, and for some BWRs, the jet pump assembly provides a flow path for low-pressure injection.

Potential for Regulatory Action

Although the Nuclear Regulatory Commission (NRC) has not taken action to-date in response to observed jet pump degradation, increased regulatory scrutiny is possible if such degradation is not addressed by industry, particularly if another significant jet pump fatigue crack is identified.

RESULTS IMPLEMENTATION

Improved jet pump inspection guidance (BWRVIP-41R3 and NRC approved BWRVIP-41R3-A) and repair guidance (BWRVIP-51R1 and NRC approved BWRVIP-51R1-A) will be developed applying lessons learned during the test program as well as insights from the jet pump degradation and operational history review. Nuclear plant owners will implement the revised jet pump inspection and repair guidance in accordance with NEI-08 implementation guidelines.

Results of BWRVIP testing to investigate jet pump phenomena will allow utilities to assess their relative susceptibility to jet pump degradation based on jet pump design and plant operating conditions. The results will also provide the basis for defining a "demonstration test protocol" to assess the effectiveness of proposed flow-induced vibration mitigation solutions.

Demonstration test results will be provided to BWRVIP utilities by each participating vendor and can be used to inform decisions on potential implementation of one or more jet pump mitigation solutions.

PROJECT PLAN

The jet pump degradation management research program includes compilation of plant data on jet pump degradation, plant operation and repair histories to understand relationships between plant operation, configuration and degradation, sub-scale testing to study the slip joint leakage flow instability phenomenon, and full-scale testing of prototypical jet pump assemblies to assess the effectiveness of vendor-proposed flow-induced vibration mitigation solutions. In addition, lessons learned from testing will be factored into revisions to jet pump inspection and repair guidelines.

Accomplishments to date include compilation and publication of jet pump degradation and operational history information, sub-scale testing at 1/5th and 1/2 scale to better understand the slip joint instability phenomena, testing using a full scale mock-up of a typical slip joint configuration to assess the relationship between slip joint flow and differential pressure, and fabrication of a full-scale test facility that includes a BWR/5 jet pump assembly.. Tests completed to date have reproduced the BWR/5 SJLF instability phenomenon and highlighted the need for on-line measurement of the slip joint gap and well as remote control of the alignment between the mixer and diffuser to provide repeatable test results. Other tests have shown that the full scale, full-flow test facility meets all flow, pressure, and temperature requirements; has defined the relationship between slip joint ΔP and M-Ratio; assessed the effect of recirculation pump vane passing frequency on system resonances; and has demonstrated the effects of variation in operating parameters such as set screw gaps, mixer-diffuser concentricity alignment, water temperature, and drive flow.

In addition, two vendor proprietary conceptual designs for improved lateral support of the jet pump mixer/diffuser have been developed and are documented in BWRVIP-207 and -210. These designs hold promise to significantly reduce the potential for flow-induced vibration (FIV) damage to jet pump components.

The facility has been used to develop a worst case "demonstration test protocol" for use in evaluating vendor-developed flow-induced vibration mitigation solutions. The test facility is now available for use to participating vendors at their cost to assess the effectiveness of their solutions in mitigating BWR/5 jet pump flow-induced vibration loading.

The full scale test facility may undergo modifications to allow full flow testing of a BWR/4 full scale jet pump assembly up to 600 psia and 320 ºF. This work is currently unfunded.

RISKS

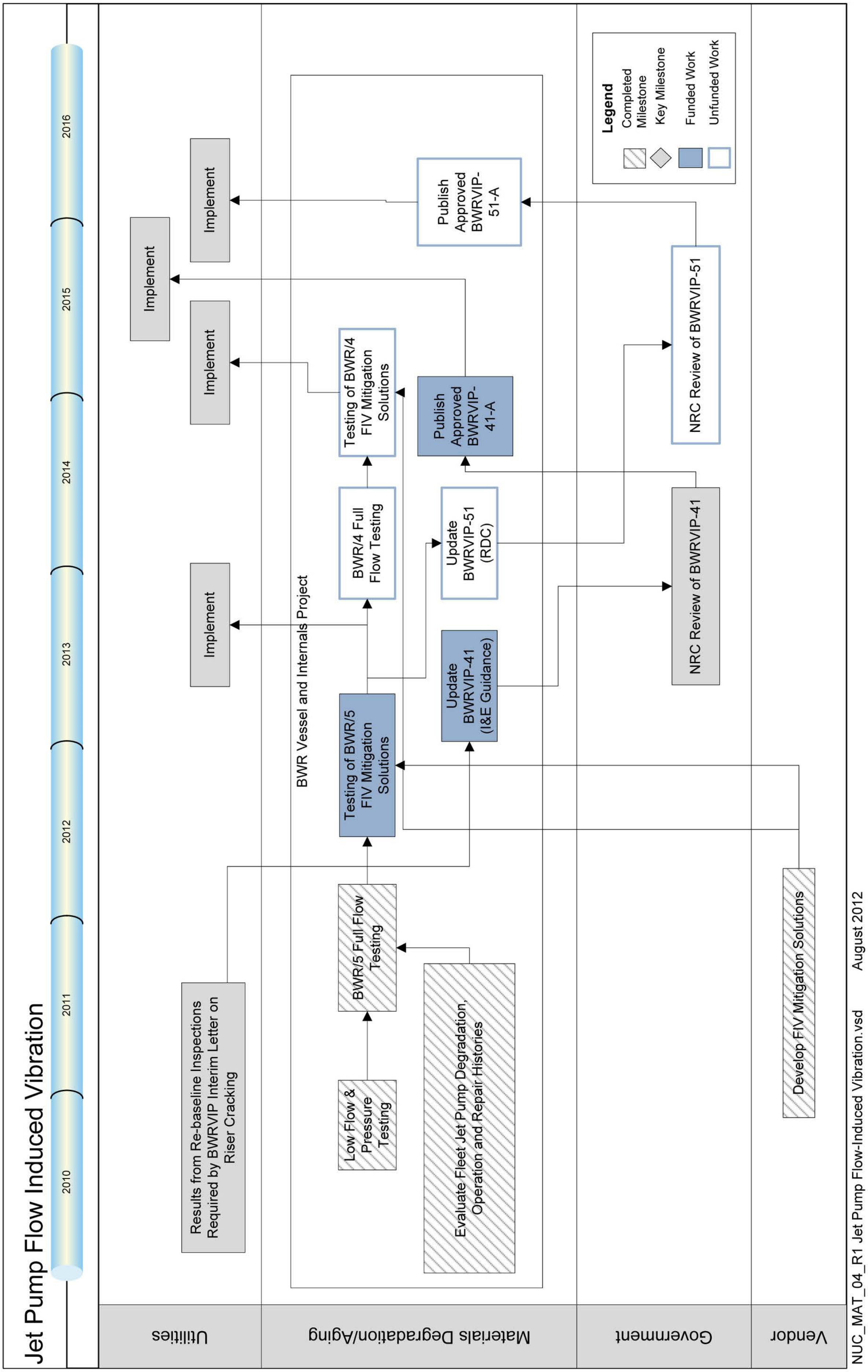
The program is thought to have a sound technical basis; however, there is potential risk in the following areas:

- Testing will be conducted at non-prototypical temperature (320 vs 532 ºF) and pressure (600 vs 1000 psia) conditions. The difference in pressure is not considered significant. Temperature, however, affects the kinematic viscosity which influences the onset of the slip joint instability phenomenon. Since the kinematic viscosity at 320 ºF is very close to that at 532 ºF, this effect is considered small and manageable.
- Only one of the 12 jet pump designs in the fleet is currently funded for testing (Typical BWR/5 251" design). The BWR/4 251" jet pump design has also experienced degradation, but is currently not funded for testing.
- To obtain repeatable results, extreme care must be taken to ensure consistent slip joint concentricity between tests. The test facility will include a specialized system for remote measurement and control of slip joint concentricity.
- The effectiveness of FIV mitigation solutions to be tested is not assured.

RECORD OF REVISION

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

REVISION	DESCRIPTION OF CHANGE
0	**Original Issue:** August 2011 **Roadmap Owner:** Randy Stark
1	**Revision Issued:** August 2012 **Roadmap Owner:** Randy Stark **Changes:** Updates to "Project Plan" that include project progress and accomplishments since original issue. Updates to Project Risks based on project progress over the last year. Editorial changes throughout the document.
1	**Revision Issued:** December 2012 **Roadmap Owner:** Andy McGehee


Jet Pump Flow Induced Vibration
2010
2011
2012
2013
2014
2015
2016
Utilities
Materials Degradation/Aging
Government
Vendor
Results from Re-baseline Inspections Required by BWRVIP Interim Letter on Riser Cracking
Implement
Implement
Implement
Implement
Implement
BWR Vessel and Internals Project
Low Flow & Pressure Testing
BWR/5 Full Flow Testing
Testing of BWR/5 FIV Mitigation Solutions
BWR/4 Full Flow Testing
Testing of BWR/4 FIV Mitigation Solutions
Evaluate Fleet Jet Pump Degradation, Operation and Repair Histories
Update BWRVIP-41 (I&E Guidance)
Update BWRVIP-51 (RDC)
Publish Approved BWRVIP-41-A
Publish Approved BWRVIP-51-A
NRC Review of BWRVIP-41
NRC Review of BWRVIP-51
Develop FIV Mitigation Solutions
Legend
Completed Milestone
Key Milestone
Funded Work
Unfunded Work
NUC_MAT_04_R1 Jet Pump Flow-Induced Vibration.vsd
August 2012