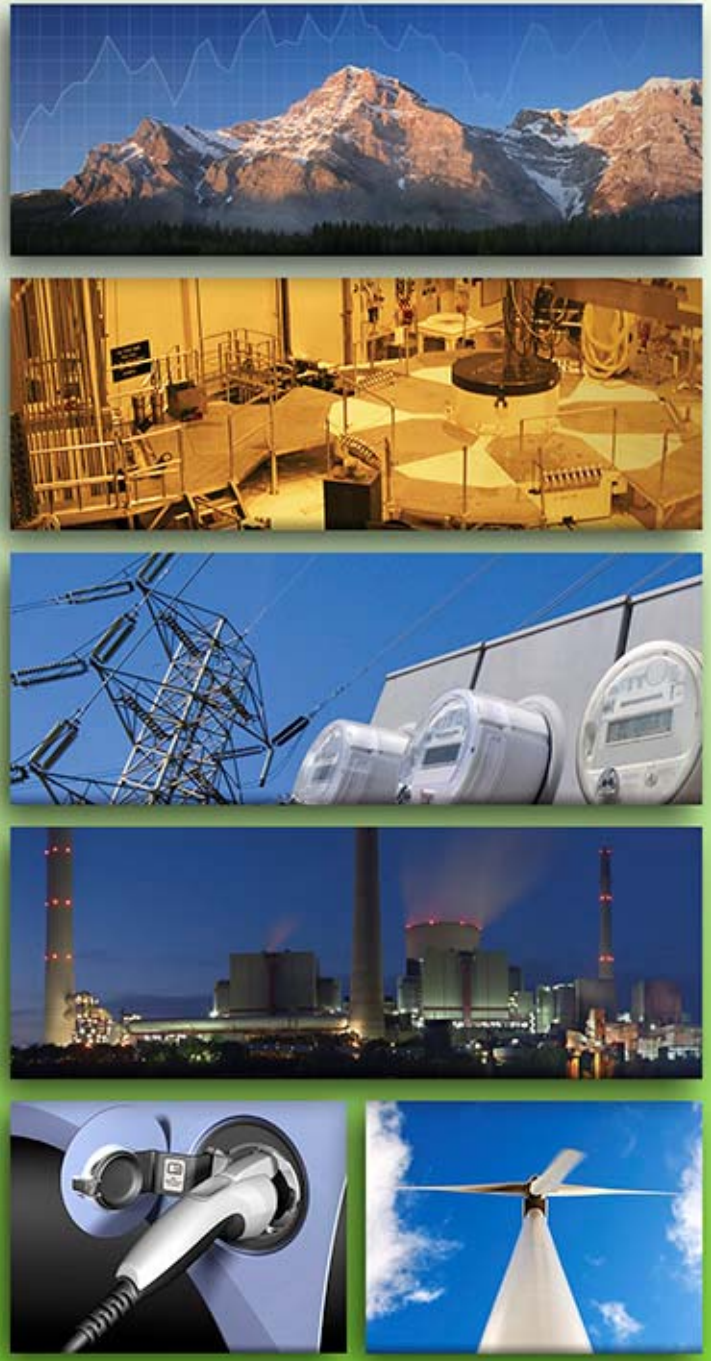

ELECTRIC POWER RESEARCH INSTITUTE

Cobalt Reduction Sourcebook

1021103

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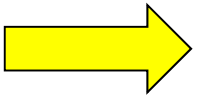
Update of Previous Guidelines (TR-103296)

- Previous Positives
  - Good background motivation (elemental cobalt issues)
  - Strong materials background
  - Incentives for cobalt reduction
  - Code requirements documented
- Areas of Improvement
  - Discussion of results
  - Expand beyond hardfacing focus to cross-discipline approach
  - Updated results with respect to materials properties
  - Expanded Discussions
    - PWRs in general
    - BWR turbines, condensers and piping
    - Chemistry/surface preconditioning
    - Industrial experience

Overview of the Sourcebook

- Divided into 7 chapters discussing
  1. Historical cobalt reduction efforts and summary of performance measures (CRE)
  2. Management responsibilities and program ownership emphasizing a team approach
  3. Material replacement strategies

     Table of material properties, valve replacement logic tree, summary of industrial sampling techniques
  4. BWR Co reduction strategies
  5. PWR Co reduction strategies

  Include **Operation** and **Shutdown** Strategies
  6. Valuation of Co reduction strategies (Tables and Flowcharts)
  7. Summary of recommendations

Objectives of Cobalt Reduction Sourcebook (1021103)

- Define dominant sources of elemental cobalt in BWRs and PWRs
- Assess key radiation field mitigation technologies and their expected effectiveness
- Provide a generalized cobalt reduction strategy and identify program owners

Generalized Valuation Strategy

1. Tabulated lists of
   - Available Co reduction methods
   - Expected time to observe benefits
   - Approximate costs
2. A series of flowcharts for implementing a Co reduction strategy for BWR and PWR plants

PWR Co Reduction Summary Table (excerpts*)

Technology/ Strategy	Benefits	Concerns	Expected Time Required Before Dose Rate Reduction	Approximate Cost
Elemental Cobalt Sources				
Improved valve maintenance monitoring with XRF	Reduce Stellite particles to core	None	2-3 cycles for core fuel replacement needed before expected reduction in RW ^{60}Co concentrations. Best case ^{60}Co decay curve after core replacement.	~$80K plus training and maintenance
Activity Removal Methods				
Local system chemical decontamination	High decontamination factors on piping	Waste and critical path.	Immediate reduction of dose rates.	~ $1 million, depends on system
In-vessel vacuuming	Removes particulate activity	Filters must be handled and stored	Immediate reduction of local particulate radiation fields.	~$50K
Out-of-Core Surface Incorporation Prevention				
Zinc injection	Proven results, large experience base	Fuel concerns for high duty cores	^{60}Co decay curve due to no new cobalt incorporation into oxide films. Faster decay curves possible if other gamma emitters are also mitigated.	~$300K/unit if no fuel exams or fuel cleaning required
Electropolishing	Significantly lower dose rates, reduced contamination levels	Must be performed with replacement components	Immediate results with newly installed equipment, contamination rates are 50% or greater slower.	~$10K with small components, more for SG Channel heads

*Full table evaluates 14 PWR technologies and strategies

BWR Co Reduction Summary Table (excerpts*)

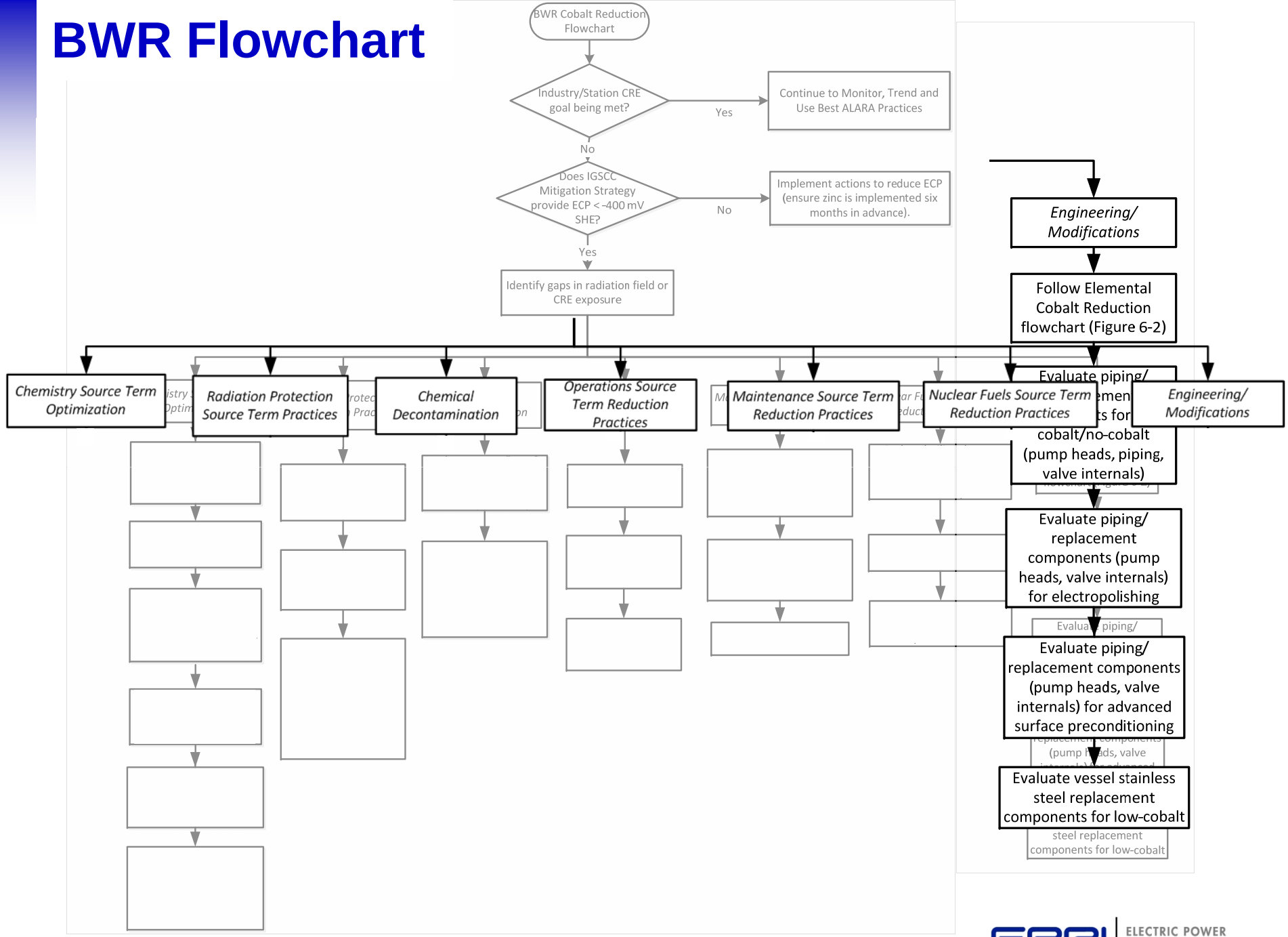
Technology/ Strategy	Benefits	Concerns	Expected Time Required Before Dose Rate Reduction	Approximate Cost
Elemental Cobalt Sources				
OEM Blades	Reduce In-vessel elemental cobalt and Co-60 sources	Cost, disposal, outage critical path	Reactor Water Co-60 concentrations should decrease quickly, Cobalt-60 decay curve expected in best case	$200k per CRB (an estimate from a plant in 2010; includes disposal)
Activity Removal Methods				
Submersible Treatment Equipment	Remove soluble activated corrosion products	Accessibility, vessel dose rates	Immediate impact in local dose rates during refueling.	~$50,000 (plant estimate, includes vessel and other hardware)
Out-of-Core Surface Incorporation Prevention				
HWC-M; NMCA-HWC; OLNC-HWC	Required for IGSCC mitigation. Need to achieve low ECP, < -400 mV SHE for minimal Co-60 incorporation into corrosion films.	DZO at least 6 months before reducing conditions are established . ^{16}N issues with HWC-M; Soluble Co-60 increases following NM applications. NM must be reapplied. HWC must be initiated with NM technology	Immediate impact in maintaining current levels (or dropping along cobalt-60 decay curve) when combined with zinc.	$1-2 million for first OLNC (includes skid purchase). Annual noble metal purchase/license fee afterwards (~$300,000). HWC-M hydrogen annual H_2 cost $500,000 to $1 million.
Electropolishing/ Pre-oxidation/ Stabilized Chrome	Reduced Co-60 incorporation into corrosion films	None significant	Immediate impact, new equipment will contaminate to radiation fields 50% or less than similar untreated equipment.	<$10,000 for small components

*Full table evaluates 17 BWR technologies and strategies

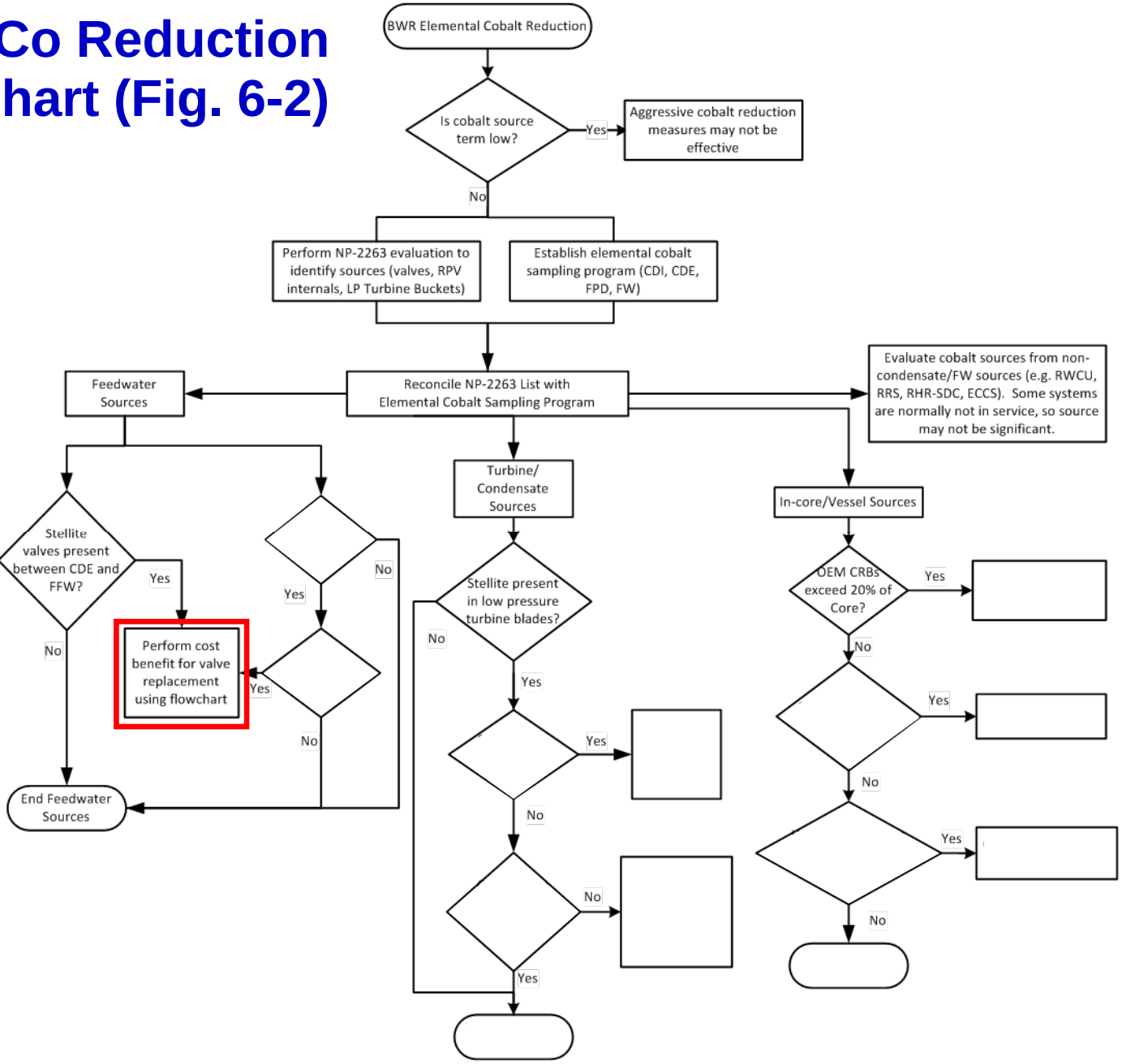
Optimizing Effectiveness and Managing Expectations

- First consider station specific source term reduction/radiation issues
  - Historical BRAC/SRMP vs. Outage CRE changes
- Before implementation – characterize overall cobalt source term
  - Elemental transport to core
  - Activated transport to out-of-core surfaces
- Elemental cobalt reduction requires a long time for benefit realization
- After Co Reduction Program Implementation
  - Full core change out may be required for optimized reductions

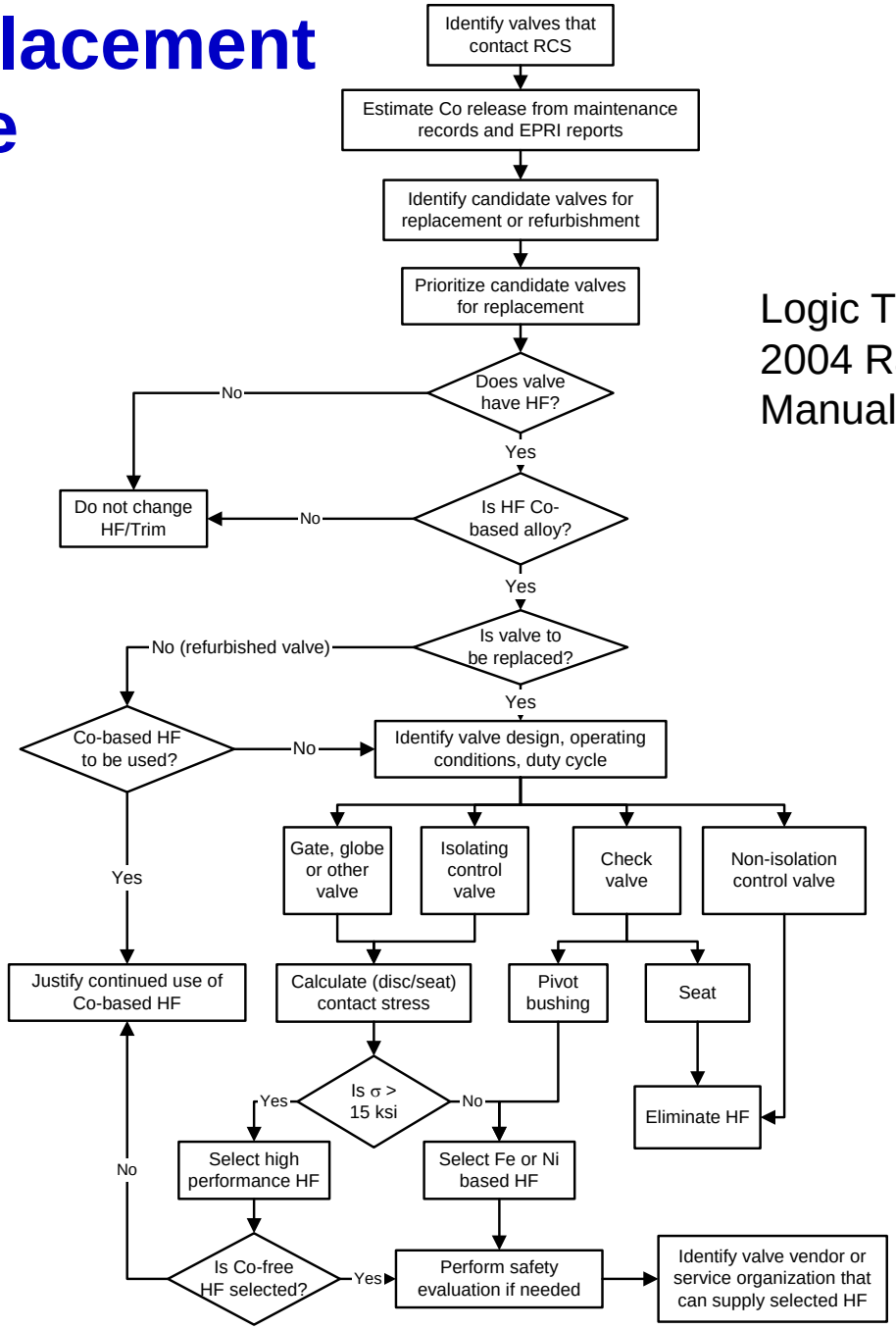
BWR Flowchart



BWR Co Reduction Flowchart (Fig. 6-2)



Valve Replacement Logic Tree



Logic Tree carry over from 2004 Radiation Field Control Manual (1003390)

Industrial Experience

Plant*	Technology/ Strategy	Dose Rate Reduction Benefit	Time Required to Observe Benefit	Comments
BWR Dose Rate Reductions				
Plant A	OEM CRB replacement; LPT Stellite® Replacement	From 270- 470 mR/hr to 70 mR/hr	About 2-4 years, (complete core replacement needed).	Chemical Decontamination and LTNC performed at same 2004 outage as Stellite Reduction.
Plant B	DZO Implementation	BRAC at time of implementation (2/98) about 400 mR/hr. BRAC in 2008 about 110 mR/hr	About 10 years	HWC initiated in 1999, Moderate HWC in 2007. No chemical decontamination performed.
PWR Dose Rate Reductions				
Plant C	Zinc injection two cycles before replacement, electropolished steam generator channel heads, constant pH, low core duty	Very low radiation fields	Immediate impact on channel heads, approximate Co-60 decay curve (50% every 5 years)	
Plant D	Electropolished steam generator channel heads, recent zinc injection.	Very low radiation fields for channel heads.	Immediate channel head dose rate reduction.	

*Full table contains actual plant references and 13 cases.

Key Aspects of the Cobalt Reduction Sourcebook (1021103)

- Generalized valuation strategies for BWR and PWR
  - Tables including key technologies, benefits, concerns, estimated time before observable results, and cost
  - Flowcharts explaining steps to implementation
- Includes actual industrial experience
- Focuses on cross-discipline cobalt reduction program

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