ENCLOSURE 2

NRC MEETING

HAFNIUM

MAY 26, 1981

AGENDA

1. INTRODUCTION/PURPOSE
2. TECHNICAL DISCUSSION
   - A) OVERVIEW OF SUBSTITUTION PLAN
   - B) PRIOR EXPERIENCE
   - C) OVERVIEW OF W RCCA DESIGN
   - D) DESIGN MODS/COMPARISON WITH AgInCd
     - 312/412 PLANTS
     - XL PLANTS
   - E) MATERIALS
   - F) PHYSICS
   - G) SAFETY EVALUATION IMPACT
3. LICENSING ACTIONS
4. CONCLUSION/ACTIONS

HAFNIUM CONTROL ROD ASSEMBLY DESIGN

HAFNIUM ABSORBER MATERIAL SUBSTITUTION

OBJECTIVE: REPLACE AgInCd WITH HAFNIUM

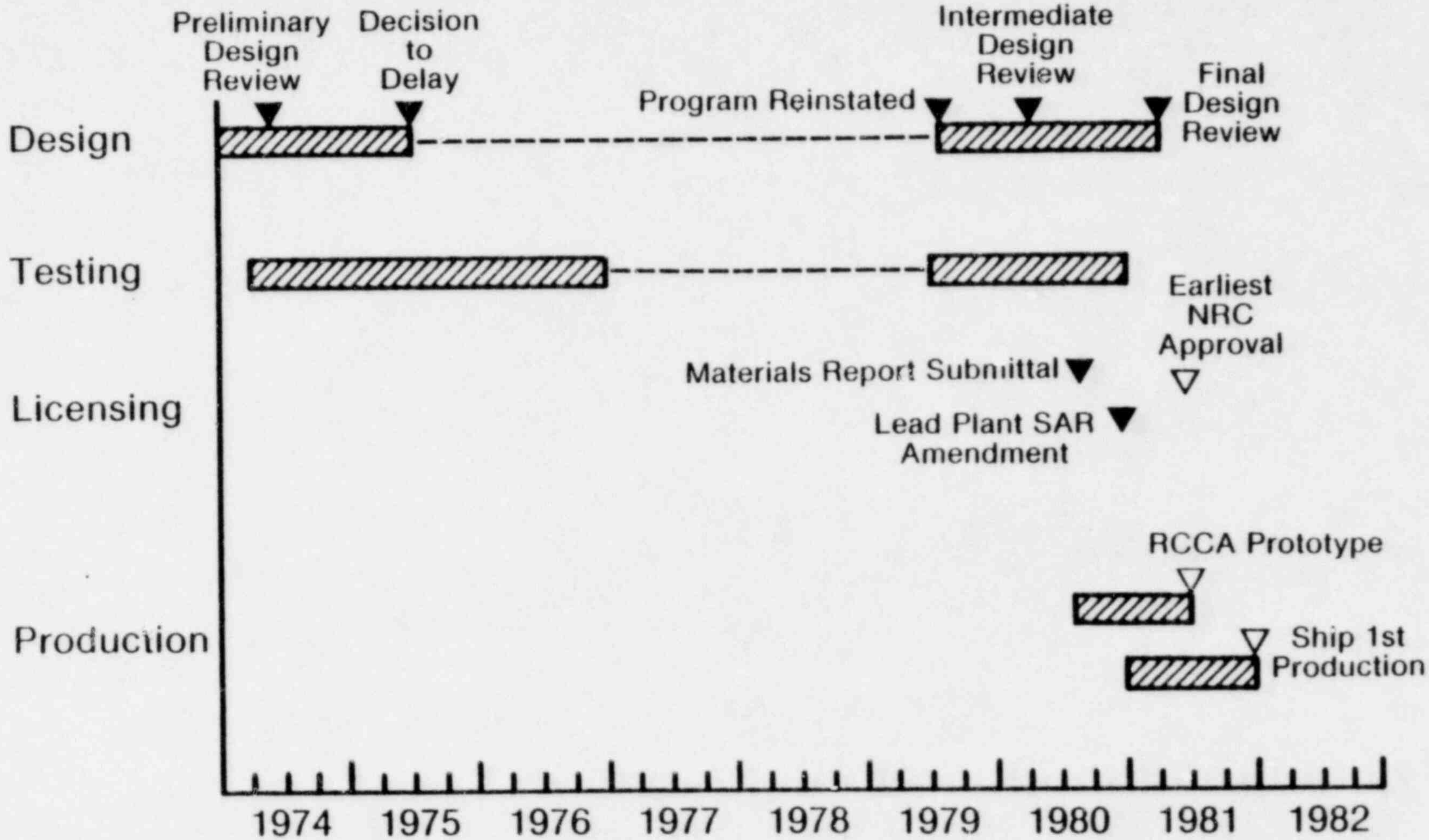
STATUS: HAFNIUM INTRODUCED IN 1980

IMPLEMENTATION: HAFNIUM SHIPMENTS START LATE 1981

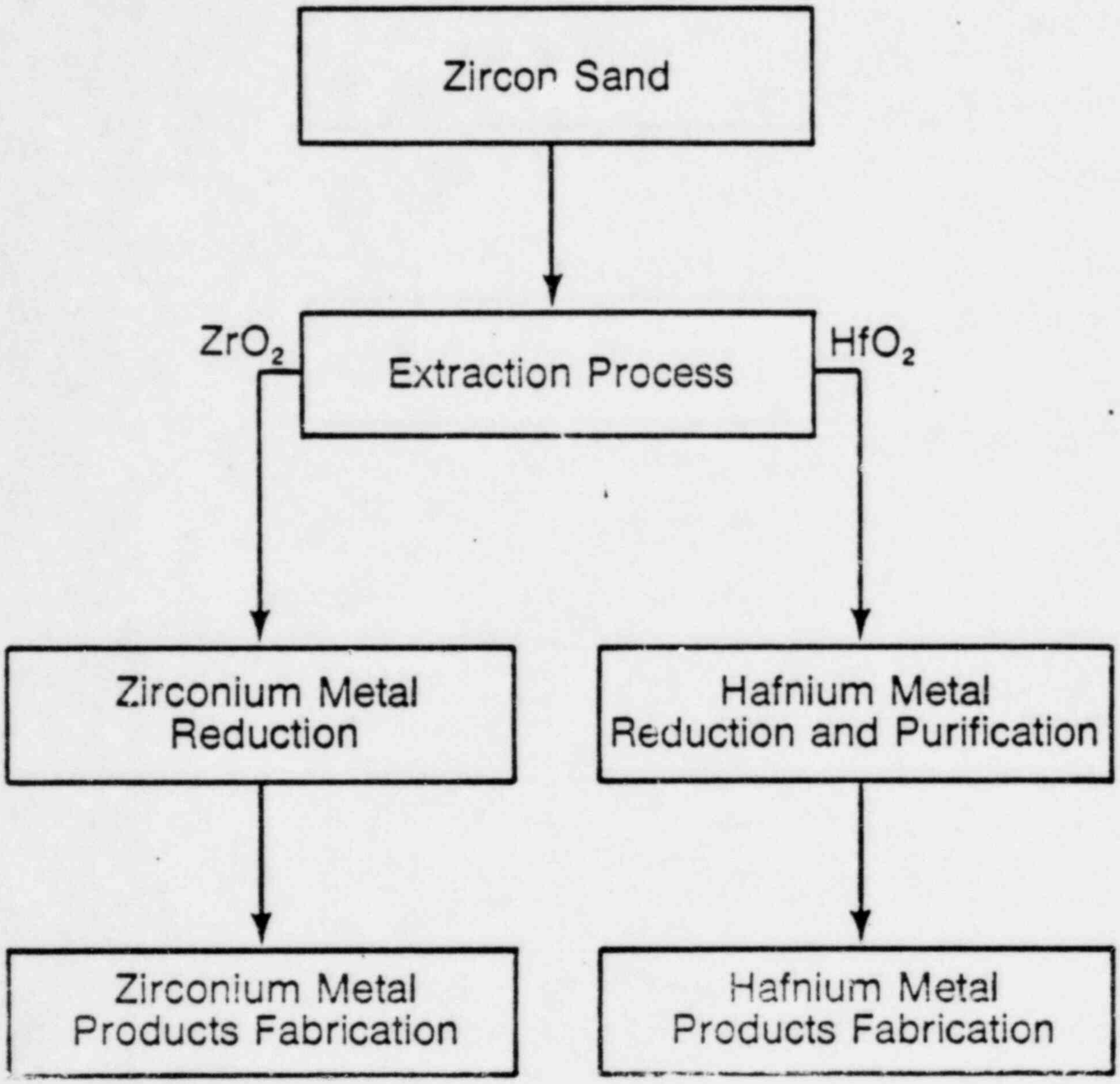
HAFNIUM APPLICABILITY

RCCA ALTERNATIVE		PLANT	DESIGN STATUS
ALL-HF	17 x 17	312/412	COMPLETE
	17 x 17	XL	PROPOSED
	16 x 16	212	COMPLETE
	15 x 15	312/412	FUTURE
	14 x 14	212	FUTURE
HF TIPS IN B_4C HYBRID	17 x 17	312/412	COMPLETE
		XL	COMPLETE

Hafnium Control Rod Assembly Development Schedule Overview



Hafnium Production Process Outline



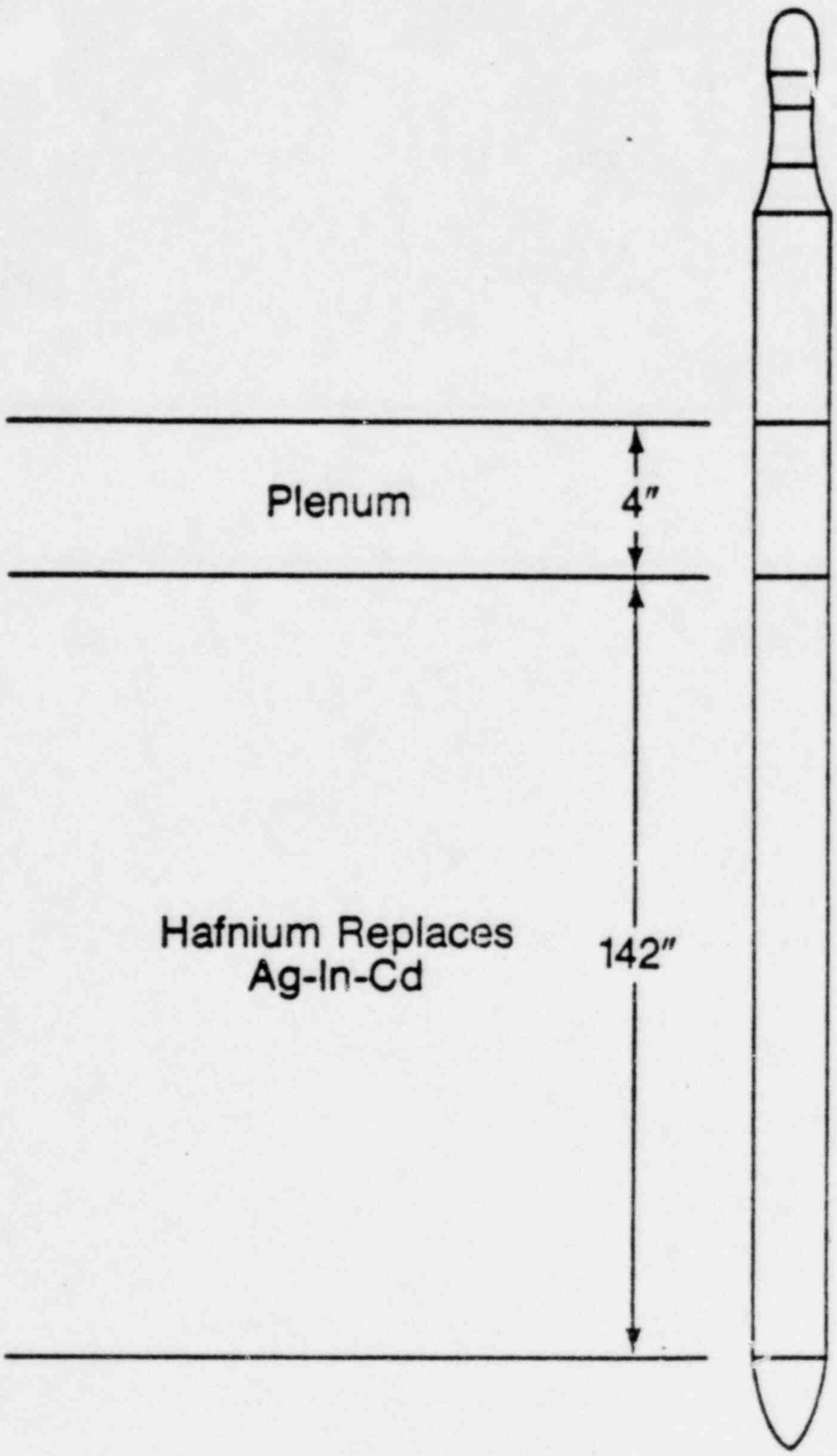
Naval Experience

Estimated Number of Reactors	Estimated Number of Reactor Years
115	1,544

Commercial Experience

INDIAN POINT UNIT 1	CORE A HAD A FULL COMPLEMENT
YANKEE ROWE	FULL CORE COMPLEMENT FOR 3 YEARS. TWO CRUCIFORM CONTROL RODS IN CORE SINCE 1972
SHIPPINGPORT	FULL CORE COMPLEMENT

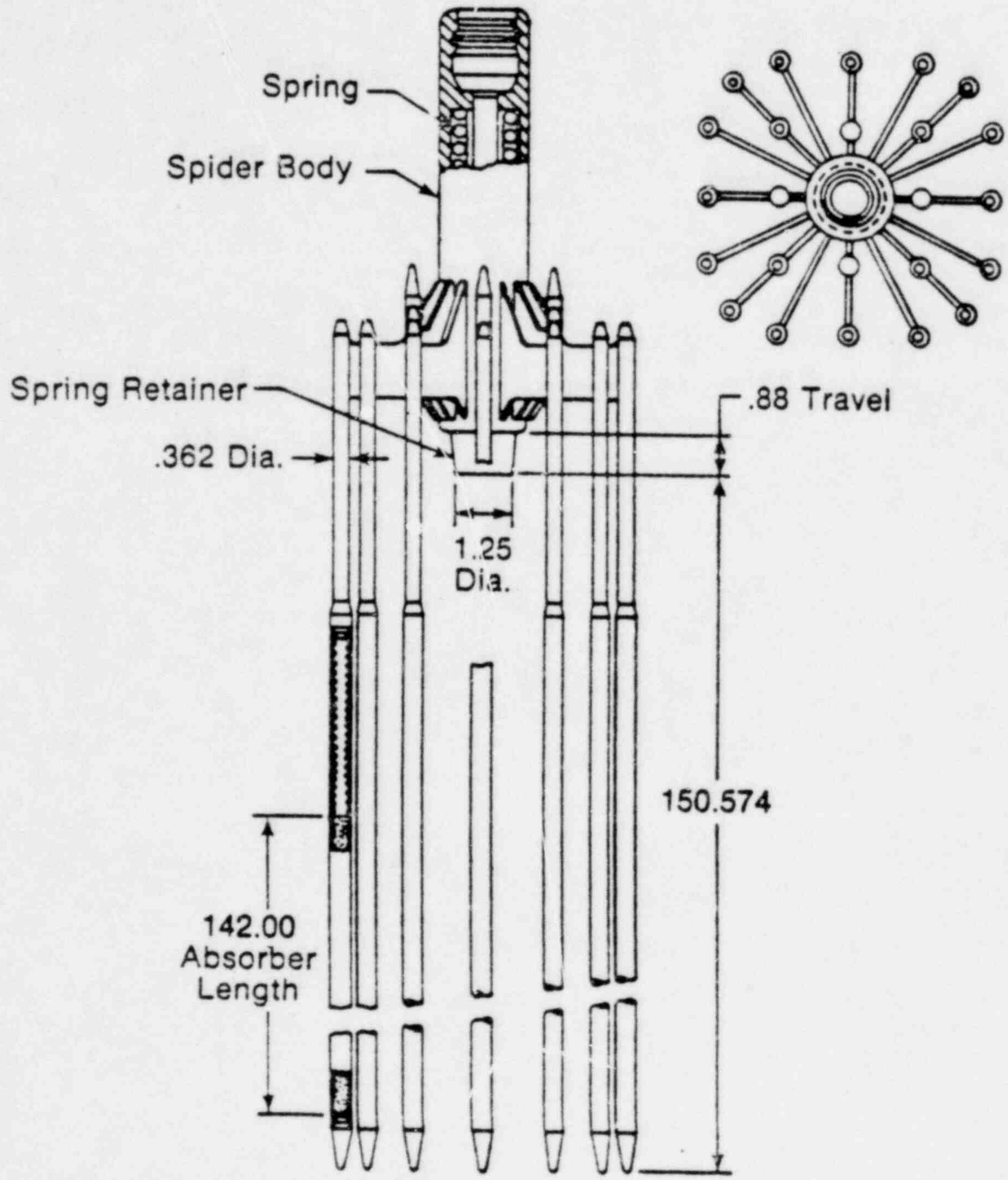
Hafnium RCCA Rodlet Design For 212, 312, 412 Plants



Design Objective

- Replace AgInCd with Hafnium
- Minimize changes to already proven design

Standard RCCA Configuration



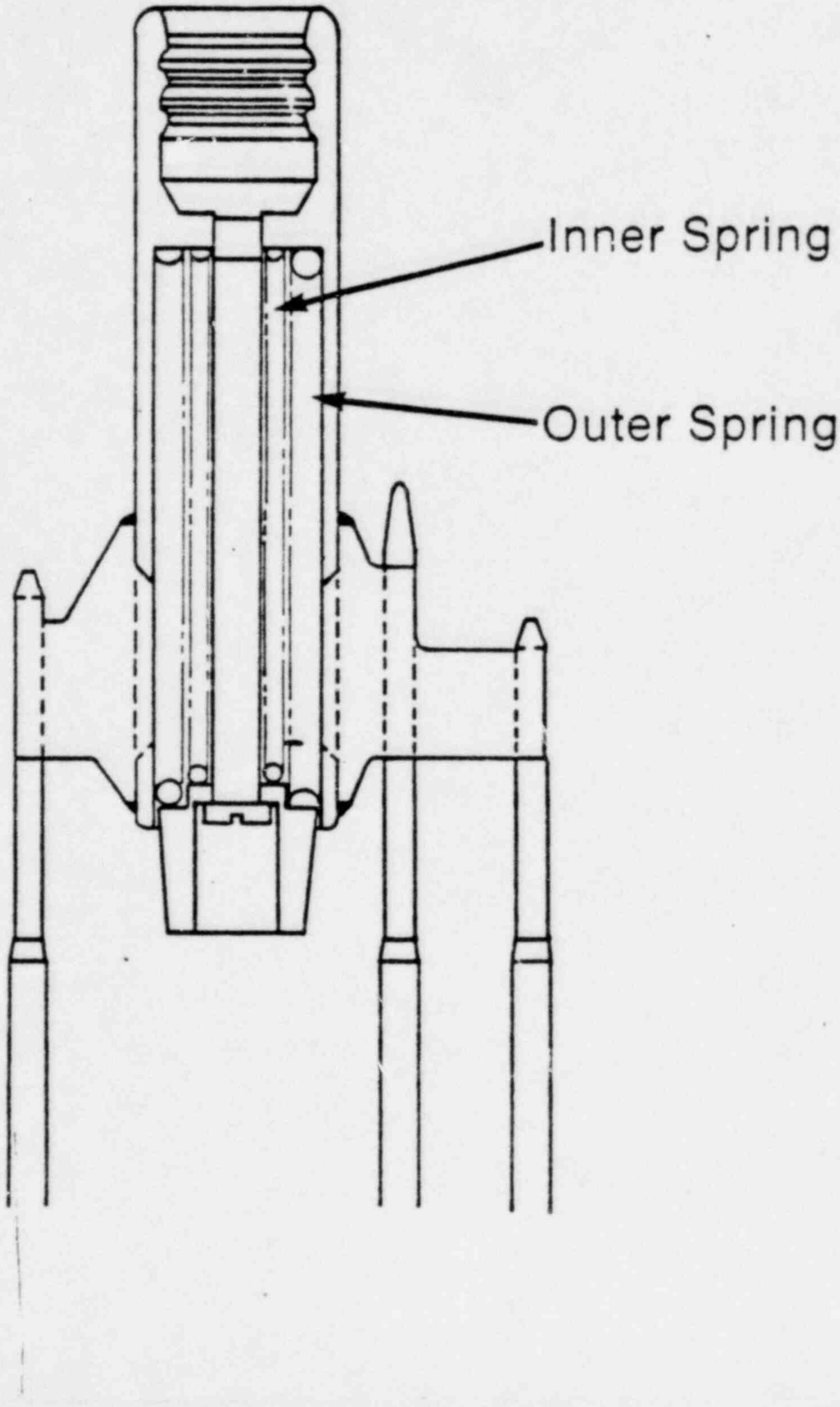
Cladded Absorber Concept Preferred Over Uncladded

- One for one absorber material change
- Retain proven features of design:
  - S. St structure and joints
  - Wear interfaces
- Manufacturing flexibility (same parts)
- Facilitate licensing

312/412 17 X 17 RCCA
Design Features

	All Ag	All Hf
Absorber O.D. (inch)	.341	.341
Absorber Length: (inch) Ag or Hf	142	142
Clad I.D. (inch)	.344	.344
Clad O.D. (inch)	.381	.381
Clad Material	304 S.S.	304 S.S.
Rodlet Spring Material	302 S.S.	302 S.S.
Spider Springs	Single	Double Nested

Nested Spider Spring



312/412 17 X 17 RCCA Designs
Performance Comparison

	All Ag	All Hf
RCCA Wt. (lbs.)	149	180
Drive Rod Wt. (lbs.)	136	136
Overall Wt. (lbs.)	285	316
Calculated N-1		
Rod Worth (%$\Delta\rho$)		
STD Fuel	5.71	5.76
OFA Fuel	6.15	6.20

Key Differences

Key Differences from AgInCd Design	Result
Greater Weight	• Change rodlet spring (shipping) • Use nested spider spring • Use appropriate drive shaf* coupling • Faster drop time
Reactivity Worth/Depletion	• Better than AgInCd
Lower Coef. Therm. Exp.	• Larger hot clearances
Lower Thermal Conductivity	• Higher absorber temperature (melting temp. higher also)
Cause of Potential Absorber Dimensional Change	• Hf volume change due to hydriding: AgInCd Volume change due to irradiation Both within same design limits
Greater Stiffness	• No measurable change in wear performance
Corrosion Resistance	• Better than AgInCd

Conclusion: Design margin is unchanged or improved

Design Verification/Testing

Item	Verification
• Reactivity Worth	• Computer Codes • 1974 Critical Experiment
• Drop Time	• Previous D-Loop Tests (with less weight)
• Scram Loads	• Analytical Models Based on D-Loop and Bench Test Data
• CRDM Stepping Loads, Drive Line Wear, Vibration	• Previous D&M-Loop Tests at Comparable Conditions • Loads within Original Design Basis
• Coupling/Joints	• Fatigue Tests at Representative Loads
• Rodlet Integrity	• Previous Tests and Operating Experience • Cladded Hf Autoclave Tests

PROPOSED XL HAFNIUM RCCA

KEY DIFFERENCES

	XL	312/412
Absorber Length (in.)	158.87	142.00
R C C A Wt. (lbs)	200	180
Overall Wt (lbs)	340	316
Spider Spring Travel (in)	1.05	0.88
Rodlet Spring	Preload Adjusted For Wt.	

Key Material Differences

	Hf	AgInCd
Coefficient of Thermal Expansion (IN/IN/°F)	3.3×10^{-6}	12.5×10^{-6}
Thermal Conductivity (Watts/CM/°C)	0.213 at 620°F	.902 at 600°F
Density (GM/CC)	13.36	10.17
Modulus of Elasticity (PSI)	13.8×10^{6} at 700°F	9.7×10^{6} at 600°F
Melting Point (°C)	2,222	800
Strength (PSI, 0.2 YS)	> 30,000	~ 7,000
Resistance to Corrosion (MG/DM^2 IN 200 Days)	< 10	> 200
Dimensional Stability	Susceptible to Hydriding	Susceptible to Irradiation Swelling

Ⓦ NFD and Naval Specification Chemistry Comparison

	Naval Spec	Ⓦ NFD Spec	Remarks
Interstitial (PPM, MAX) (O, N, H)	525	1,510	Difference Affects Weldability and Formability
Iron (PPM)	200-500	750	Negligible Impact
Total Metallic (PPM, MAX) Other than Zr	1,530	2,000	Negligible Impact
Zr (% MAX)	4.5	4.5	Same
Hf (% MIN)	95.3	95.3	Same

MATERIALS TESTS AND OPERATING EXPERIENCE

OTHER THAN NFD

- NAVAL REACTORS EXPERIENCE
- SHIPPINGPORT
- ATR
- ETR
- OPERATING EXPERIENCE IN PWR'S

NFD TESTING

- CLADDED HAFNIUM AUTOCLAVE TEST
- STAINLESS STEEL-HAFNIUM CHEMICAL COMPATIBILITY

PHYSICS CONSIDERATIONS

CONTROL ROD WOPTH

HAFNIUM AND AG-IN-CD HAVE NEARLY IDENTICAL ROD WORTHS AT OPERATING CONDITIONS BY DESIGN.

CRITICAL EXPERIMENT DATA AND ANALYTICAL ESTIMATES INDICATE WORTH EQUIVALENCE AT OPERATING CONDITIONS.

METHODOLOGY EMPLOYED TO GENERATE HF GROUP CONSTANTS AND HF ROD WORTHS IS DESCRIBED IN WCAP-9217(P), 9218 (NP) "RESULTS OF CONTROL ROD WORTH PROGRAM".

HF METHODOLOGY IS IDENTICAL TO AG-IN-CD METHODOLOGY.

PHYSICS CONSIDERATIONS

CRITICAL EXPERIMENT DATA

SOURCE	HAFNIUM COLD WORTH RELATIVE TO AG-IN-CD
BNWL CRITICALS (1974)	2.2% LESS
ANDERSON AND THEILACKER, NEUTRON ABSORBER MATERIALS FOR REACTOR CONTROL	~1.0% LESS
VALENTINE (BETTIS)	~2.5% LESS (SOME DIFFERENCE IN ROD GEOMETRIES)
HARTLEY AND BAYARD (BETTIS)	1.2% LESS

NOTE:

1) ABOVE COMPARISONS WERE MADE AT COLD TEMPERATURES (~68°F)

2) DIFFERENCES BETWEEN HF AND AG-IN-CD HZP ROD WORTHS WILL BE SMALLER THAN INDICATED ABOVE DUE TO THE HARDER NEUTRON SPECTRUM AT OPERATING TEMPERATURES.

3) BETTIS PERSONNEL INDICATE THAT HF IS WORTH SLIGHTLY MORE THAN AG-IN-CD AT OPERATING TEMPERATURES.

PHYSICS CONSIDERATIONS

CONTROL ROD WORTH CALCULATIONS

TYPICAL CALCULATED ROD WORTHS FOR A 4-LOOP, 12 FT CORE, HZP, EOL, EQUILIBRIUM CYCLE, STANDARD 17X17 FUEL

	ROD WORTH (%Δρ)	
	N	N-1
AG-IN-CD	6.95	5.70
HAFNIUM	7.00	5.74

N-1 ROD WORTH IS USED TO CALCULATE SHUTDOWN MARGIN

HF N-1 ROD WORTHS WILL BE REDUCED BY 10% FOR SHUTDOWN MARGIN CALCULATIONS

HAFNIUM AND AG-IN-CD WILL ALSO HAVE NEARLY IDENTICAL WORTHS IN 14 FT CORES AND OPTIMIZED FUEL CORES

PHYSICS CONSIDERATIONS

GROUP CONSTANTS AND SPECTRUM EFFECTS

COMPARISON OF HF AND AG-IN-CD GROUP CONSTANTS

CONSTANT	RATIO (HF/AG-IN-CD)
D^1	1.03
Σ_A^1	1.16
Σ_R	0.92
D^2	1.22
Σ_A^2	0.72

INCREASED RESONANCE ABSORPTION IN HF COMPENSATES FOR DECREASED THERMAL ABSORPTION

INCREASE IN $\emptyset_1/\emptyset_2$ WITH INCREASE IN TEMPERATURE RESULTS IN HF WORTH INCREASE RELATIVE TO AG-IN-CD
(TYPICAL VALUES: $\emptyset_1/\emptyset_2$ COLD = 4.6, $\emptyset_1/\emptyset_2$ HOT = 5.8)

CORE AVERAGE $\emptyset_1/\emptyset_2$ IS NEGLIGIBLY CHANGED DUE TO PRESENCE OF HF:

	$\emptyset_1/\emptyset_2$ (HZP, ARI)
HAFNIUM	6.14
AG-IN-CD	6.18

NO IMPACT ON CORE KINETICS

LIFETIME CONSIDERATIONS

CONTROL ROD DEPLETION IS NORMALLY NOT A PROBLEM SINCE PLANTS ARE USUALLY OPERATED WITH ARO

HAFNIUM DEPLETES SLOWER THAN AG-IN-CD OVER A LARGE FLUENCE PANGE DUE TO:

1) TRANSMUTATION OF HF ISOTOPES
2) QUICK BURNUP OF CD-113 IN AG-IN-CD

EVEN WITH DAILY LOAD FOLLOW, WORTH DEPLETION IS NOT A PROBLEM SINCE < 10% OF CONTROL RODS SEE SIGNIFICANT FLUENCE

SAFETY EVALUATION IMPACT

- REACTIVITY WORTH
  - NO REACTIVITY WORTH PENALTY (ESSENTIALLY SAME WORTH)
  - NO SIGNIFICANT EFFECT ON SAR-TYPE ACCIDENTS
- RCCA DROP TIME
  - HAFNIUM RCCA HEAVIER THAN AG-IN-CD
  - FASTER DROP TIME BENEFICIAL TO ALL SAR-TYPE ACCIDENTS

CONCLUSIONS: SAFETY REQUIREMENTS ARE MET EQUAL TO OR BETTER THAN AG-IN-CD

LICENSING ACTIONS

- PRIOR AND CURRENT HAFNIUM APPROVALS
- MATERIALS TOPICAL (WCAP-9179) APPENDIX SUBMITTED OCTOBER, 1980
- COMANCHE PEAK FSAR AMENDMENT 14 SUBMITTED JANUARY, 1981
- SNUPPS FSAR REVISION 2 SUBMITTED FEBRUARY, 1981
- OTHER SPECIFIC PLANT FSAR AMENDMENTS IN PROGRESS
- COMANCHE PEAK AND SNUPPS SERS IN PREPARATION

CONCLUSIONS

BASED UPON THE MATERIAL, MECHANICAL, NUCLEAR, AND SAFETY EVALUATIONS PRESENTED, IT CAN BE CONCLUDED THAT THE DIRECT SUBSTITUTION OF HAFNIUM FOR AG-IN-CD INTO THE PRESENT WESTINGHOUSE RCCA DESIGNS SATISFIES ALL PERTINENT PERFORMANCE AND SAFETY REQUIREMENTS AS DOCUMENTED IN REGULATORY GUIDE 1.70 AND THE STANDARD REVIEW PLANS.

MEETING SUMMARY DISTRIBUTION

Docket File
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