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OAK RIDGE, TENNESSEE

ORNL
Central Files Number
CF-52-11-161

DATE: November 18, 1952
SUBJECT: Design Data for ISHR (Second Edition)
TO: File
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The following design data sheets are for an intermediate scale, two region, homogeneous converter for production of U^{233} .

This data is based on an overall gross power rating of 60MW.

These sheets will be supplemented and corrected as more information becomes available. It is requested that recipients of this memo examine the data with which they are concerned and report inaccuracies so corrections can be made in subsequent editions.

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DESIGN DATA FOR ISHR

* Design Basis

I Core Fluid:

* Fuel Solution

Uranium Concentration

$\text{UO}_2\text{SO}_4\text{-D}_2\text{O}$

4.8 gm/liter

* Fuel Enrichment

93.5% U^{235}

Heat Capacity of Fuel Solution at 250°C

1.15 Btu/lb °F

2.07 Btu/lb °C

Density of Fuel Solution at 250°C

0.89 gm/cm³

55.56 lb/ft³

Thermal Conductivity

0.35 Btu/hr-ft²-°F-ft

Viscosity of Fuel Solution at 250°C

0.29 lb/ft-hr

* G for D₂O Decomposition

$\frac{1.0 \text{ Molecules of D}_2}{100 \text{ ev}}$

Rate of Formation of D₂

0.0110 lb mols/sec

Rate of Formation of O₂

0.0055 lb mols/sec

Vapor Pressure of D₂O over Fuel Solution at 250°C

576 psia

Compressibility of D₂O Vapor at 250°C

0.83

D₂O Vapor Evolved with D₂ and O₂

0.0278 lb mols/sec

Heat of Recombination of D₂ and O₂

105,000 Btu/lb mol

Heat of Vaporization of D₂O at 250°C

13,300 Btu/lb mol

Gas Suspended in Fuel Solution Leaving Core

3.4% by volume

Gas Dissolved in Fuel Solution Leaving Core

$0.9 \frac{\text{cm}^3 \text{ D}_2 + 1/2 \text{ O}_2 \text{ at STP}}{\text{cm}^3 \text{ soln.}}$

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II Blanket Fluid:

* Blanket Fluid	ThO ₂ -D ₂ O Slurry
* Blanket Fluid Concentration	1000 gm Th/liter
Heat Capacity of Slurry	0.598 Btu/lb °F 1.078 Btu/lb °C
Density of Slurry at 250°C	1.65 gm/cm ³ 103 lb/ft ³
Viscosity of Slurry at 250°C	15 centipoises 36.3 lb/ft-hr
* $\bar{G}$ for D ₂ O Decomposition	$\frac{1.0 \text{ molecules of D}_2}{500 \text{ ev}}$
Rate of Formation of D ₂ in Blanket	$4.4 \times 10^{-4} \text{ lb mols/sec}$
Rate of Formation of O ₂	$2.2 \times 10^{-4} \text{ lb mols/sec}$
Heat Removed from Blanket by Slurry	8766 Btu/sec

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III Main Fuel Loop and Components:

Estimated Volume of Fuel System	3860 liters 136 ft ³
* Design Pressure	1000 psia
* Pipe Material	347 Stainless Steel
Type	Welded or Forged and Bored
Pipe Size	10 in. NPS
Required Schedule Number	80
Outside Diameter	10.750 in
Inside Diameter	9.564 in
Internal Flow Area	71.8 in ²
Wall Thickness	0.593 in
Roughness $\frac{e}{d}$	1.88×10^{-4}
Fluid Velocity	22.32 ft/sec
Friction losses at 250°C	6.7 psi/100 ft of pipe 17.4 ft of fluid/100ft of pipe 44.6 ft of pipe/velocity head
* Core Vessel Pressure Drop	2.0 velocity heads
Gas Separator Pressure Drop	2.5 velocity heads
Heat Exchanger Pressure Drop	6.0 velocity heads
Estimated Total Loop Pressure Drop	~ 13.1 velocity heads 39.3 lb/in ² 101 ft of fluid
Equivalence of Units	7.74 ft of fluid/velocity head 0.386 (lb/in ²)/ft of fluid 3.0 (lb/in ²)/velocity head
<u>Pumping Requirements:</u>	
* Number of Pumps	one
* Capacity	5000 gal/min
Type	Canned-rotor

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Pumping Requirements (continued)

Theoretical power requirement (101 ft. hd.)	112 HP
Estimated impeller efficiency	88%
Estimated motor efficiency	65%
Estimated pump efficiency	57%
Estimated power requirement	197 HP
Heat into fluid pumped	90 Btu/sec
Heat removed from motor	50 Btu/sec

Core Vessel:

* Effective Diameter	4.0 ft 122 cm
* Effective Volume	33.51 ft ³ 949 liters
* Core Pressure	1000 psia
Properties of Fuel Solution Entering Core	~ properties at 250°C
* Power Level in Core	48 mw 45,500 Btu/sec
Specific Power in Core	50.6 kw/liter
* Material	347 stainless steel
Shell Thickness	0.25 in.
* Fuel Velocity Entering Core	15 ft/sec
* Flow Rate of Fuel Solution Leaving Core	5000 gal/min 11.14 ft ³ /sec 619 lb/sec
Heat Removed from Core in Gas	1670 Btu/sec
Heat Removed from Core by Fuel Solution	43,830 Btu/sec
Temperature of Fuel Solution Entering Core	421°F 216°C
Temperature Rise of Fuel Solution in Core	61°F 34°C
* Temperature of Fuel Solution Leaving Core	482°F 250°C

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IV Main Blanket Loop and Components:

Estimated Volume of Blanket System	7549 liters 266.5 ft ³
* Design Pressure	1000 psia
* Pipe Material	347 stainless steel
Type	Welded or Forged and Bored
Pipe size	6 in. NPS
Required Schedule Number	80
Outside Diameter	6.625 in.
Inside Diameter	5.761 in.
Internal Flow Area	26.06 in ²
Wall Thickness	0.432 in.
Roughness $\frac{e}{d}$	3.12×10^{-4}
Slurry Velocity	12.3 ft/sec
Friction Losses at 250°C	7.66 psi/100 ft of pipe 10.7 ft of fluid/100 ft of pipe 22 ft of pipe/velocity head
* Blanket Vessel Pressure Drop	2.5 velocity heads
Gas Separator Pressure Drop	2.5 velocity heads
Heat Exchanger Pressure Drop	12 velocity heads
Pipe Line Pressure Drop	4.3 velocity heads
Estimated Total Loop Pressure Drop	21.3 velocity heads 36 lb/in ² 50 ft of fluid
Equivalence of Units	2.35 ft of fluid/velocity head 0.715 (lb/in ²)/ft of fluid 1.68 (lb/in ²)/velocity head
<u>Pumping Requirements:</u>	
* Number of pumps	one
* Capacity	1000 gal/min

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Pumping Requirements (continued)

Type	Canned-rotor
Theoretical power requirements (50 ft hd)	21 HP
Estimated impeller efficiency	88%
Estimated motor efficiency	65%
Estimated pump efficiency	57%
Estimated power requirements	37 HP
Heat into fluid pumped	16.9 Btu/sec
Heat removed from motor	9.27 Btu/sec

Blanket Vessel:

* Effective Diameter	8.0 ft 243.84 cm
* Effective Volume	231 ft ³ 6540 liters
* Blanket Pressure	1000 psia
* Power Level in Blanket	9.6 MW 9100 Btu/sec
Specific Power in Blanket	1.468 kw/liter
* Material	347 stainless steel
Shell Thickness	3.0 in.
* Slurry Flow Rate	1000 gal/min 2.228 ft ³ /sec 123.8 lb/sec
* Heat Removed from Blanket by Slurry	8766 Btu/sec

Gas Separator:

* Type	pipe line centrifugal
* Void Volume	0.91 ft ³ 25.75 liters
* Length of Void	4.0 ft

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Gas Separator (continued)

Diameter of Void

0.538 ft
6.46 in.

* Axial Fluid Velocity

4.48 ft/sec

Inside Diameter

11.50 in.

Shell Size

12 in. NPS x .625 in. wall
(12.750 in. O.D.)

Heat Exchanger:

* Type

Two pass, horizontal, shell
and tube, with slurry in tubes
and water and steam in shell

* Slurry Inlet Temperature

250°C
482°F

Slurry Exit Temperature

214°C
418°F

* Steam Pressure at Exit of Exchanger

215 psia

* Steam Temperature (saturated)

388°F

Flow of Slurry

1000 gal/min

Heat Removed from Slurry

8783 Btu/sec

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V Nuclear Data:

Core:

* Core Diameter	4 ft.
* Fuel Solution	UO ₂ SO ₄ -D ₂ O
* Uranium Enrichment	93.5% U ²³⁵
* Void Volume	3%
Uranium Concentration	4.785 gm U/liter 5.462 gm U/kg D ₂ O
τ at 250°C **	208.7 cm ²
L ² at 250°C **	238.3 cm ²
Diffusion Constant at 250°C ** Fast	1.714 cm
Slow	1.286 cm
Resonance escape probability, p	1.000
Fast fission effect, ϵ	1.000
Thermal Utilization, $f = \sum a(U) / \sum a(\text{Total})$	0.9936
Fission neutrons per absorption in U, η	2.1189
Infinite Multiplication Constant	2.1053
Thermal Neutron Cross Sections ** at 250°C	
Σ_f	0.004543 cm ⁻¹
Σ_a (including Σ_f)	0.005395 cm ⁻¹
Σ_s	0.34801 cm ⁻¹
Thermal Neutron Flux at 48,000 kw	
ϕ_{av}	3.763 x 10 ¹⁴ n/cm ² sec
ϕ_{max}	9.039 x 10 ¹⁴ n/cm ² sec
Fast Neutron Flux at 48,000 kw	
ϕ_{av}	3.825 x 10 ¹⁴ n/cm ² sec
ϕ_{max}	8.798 x 10 ¹⁴ n/cm ² sec

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** Taking into account the 3% voids

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Blanket:

* Thickness		2 ft
* Material		ThO ₂ -D ₂ O Slurry
* Thorium Concentration		1000 gm Th/liter
* U ²³³ Concentration		zero
τ at 250°C		186.8 cm ²
L ² at 250°C		
Diffusion Constant at 250°C	Fast	1.429 cm
	Slow	1.152 cm
Thermal Neutron Cross Sections	Σ_a	0.013526 cm ⁻¹
	Σ_s	0.37012 cm ⁻¹
Fast (resonance) Neutron Cross Section		
	Σ_R	0.004819 cm ⁻¹
Thermal Neutron Flux	ϕ_{av}	1.2404 x 10 ¹³ n/cm ² sec
	ϕ_{max}	1.0883 x 10 ¹⁴ n/cm ² sec
Fast Neutron Flux		
	ϕ_{av}	1.3023 x 10 ¹³ n/cm ² sec
	ϕ_{max}	1.4754 x 10 ¹⁴ n/cm ² sec

Neutron Balance:

Absorptions in Core	U ²³⁵	1.00000
	U ²³⁸	0.00029
	S	0.00082
	D ₂ O	0.00653
Absorptions in Blanket	Th (Resonance)	0.20892
	Th (Thermal)	0.58171
Absorptions in Shell		0.30711

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Neutron Balance (continued)

Losses Due to Leakage	Fast	0.00726
	Slow	<u>0.00867</u>
		2.12131

Conversion Ratio

$$\frac{\text{Atoms U}^{233} \text{ Produced}}{\text{Atoms U}^{235} \text{ Consumed}} = 0.79063$$

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