INTERNATIONAL NUCLEAR ATLANTIC CONFERENCE

INB INDÚSTRIAS NUCLEARES DO BRASIL

EVALUATION OF THE IMPACTS OF ^{234}U AND ^{235}U HEELS ON THE FORMATION OF A NEW LOT OF COMMERCIAL GRADE UF_6

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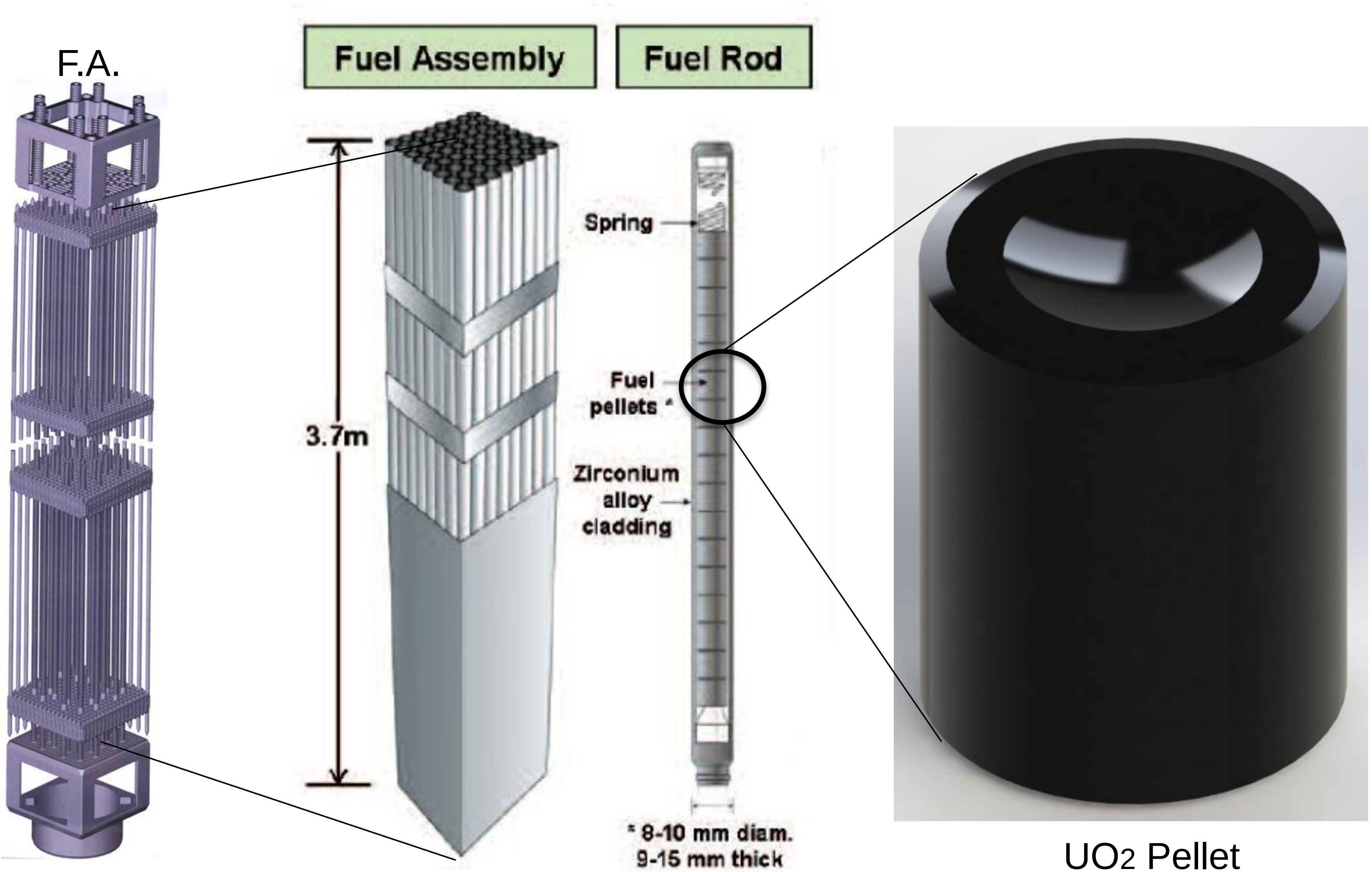
VI ENIN

MINISTÉRIO DE MINAS E ENERGIA

PÁTRIA AMADA BRASIL GOVERNO FEDERAL

From Fuel Assembly to UO_2 Pellet



UO_2 Pellet

From Pellet to UF_6

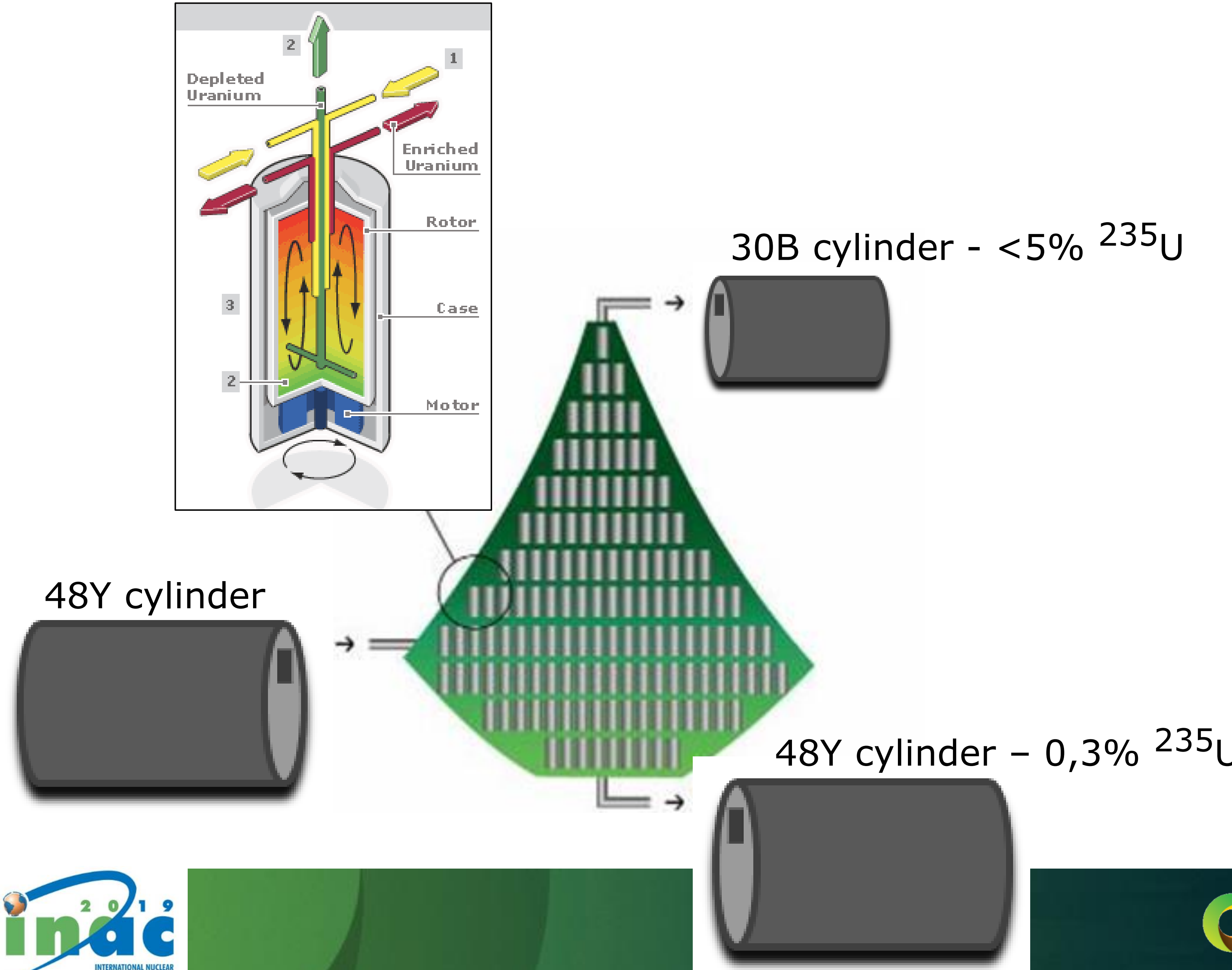
UO_2 Powder

Pellet

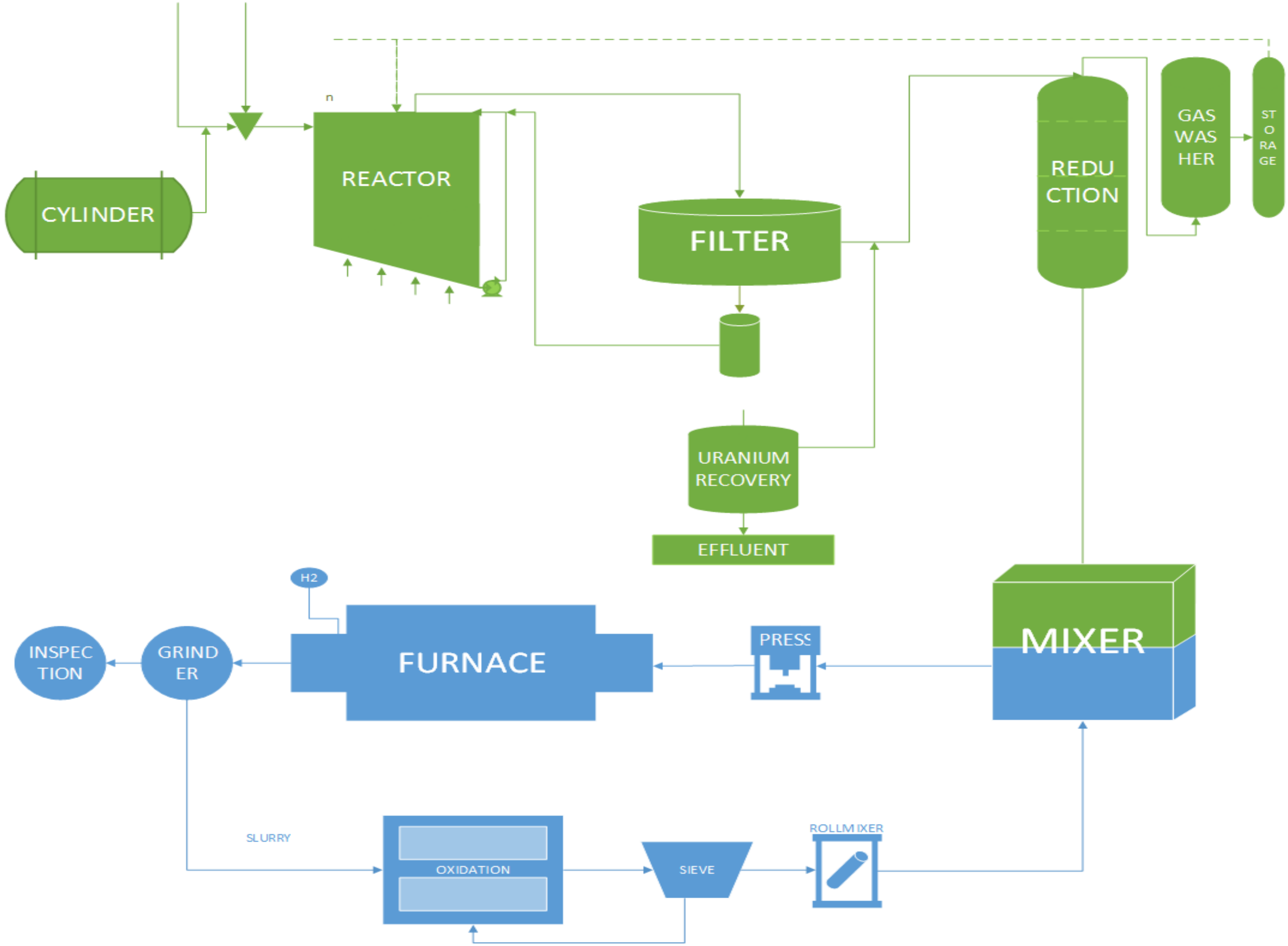
AUC Filter

30B Cylinder

Uranium Enrichment



New Lot of UF_6: Production of AUC



After AUC: Handling the Cylinder with Heel

After extraction of UF_6, the cylinder may contain 11 Kg of UF_6 called *Heel*.

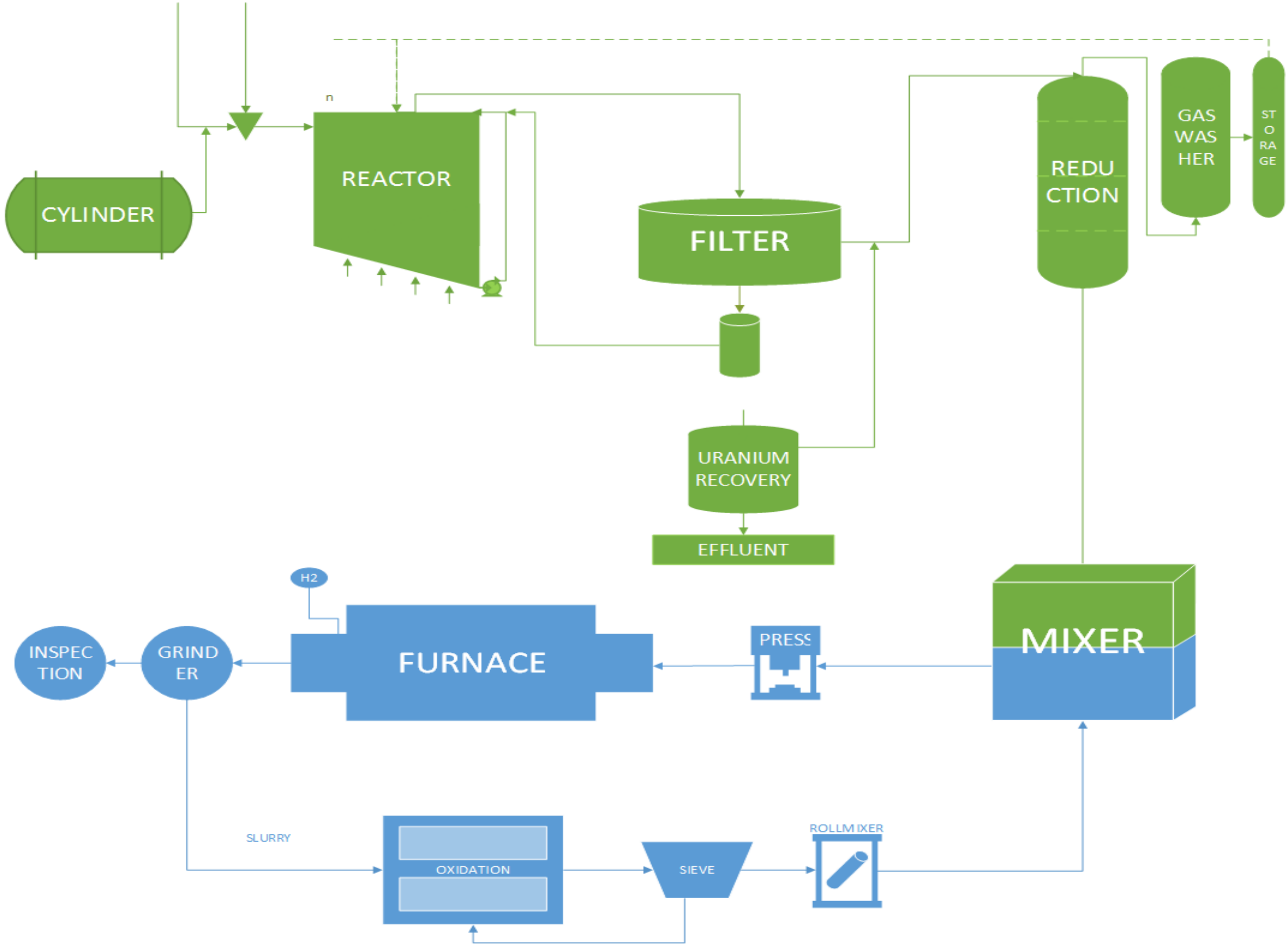
This contains Th and Pa (high emissors), so they must be disposed at an opened area for 6 months until complete decay to ^{234}U according to:

After this period, the options are:

- Reextraction of UF_6
- Washing/Inspection
- Refill with UF_6 for New Lot

$$^{238}_{92}\mathrm{U} \xrightarrow[4.468\times10^{9}\ \mathrm{y}]{\alpha} {}^{234}_{90}\mathrm{Th} \xrightarrow[24.1\ \mathrm{d}]{\beta^-} {}^{234\mathrm{m}}_{91}\mathrm{Pa} \left\{ \begin{array}{l} \xrightarrow[1{,}17\ \mathrm{min}]{0.16\%} {}^{234}_{91}\mathrm{Pa} \xrightarrow[6{,}7\ \mathrm{h}]{\beta^-} \\ \xrightarrow[1{,}17\ \mathrm{min}]{99.84\%\ \beta^-} \end{array} \right\} {}^{234}_{92}\mathrm{U}$$

New Lot of UF_6: Production of AUC



Formation of a New Lot of UF_6

CYLINDER CONDITION

- New Cylinder
- Cleansed Cylinder
- Cylinder containing *heel*

UF6 PROCESS

- Formation of Lot from Isotopic Separation *(IS)*
- Formation of Lot From Mass Transference *(MT)*

a. Mass Transference of UF_6 from donor cylinder to new one
b. Mass Transference of UF_6 from donor cylinder to clean one
c. Mass Transference of UF_6 from donor cylinder to a cylinder containing *heel*
d. Mass Transference of UF_6 from donor cylinder to a cylinder containing mass greater than *heel*

- Formation of Lot from Isotopic Recomposition Process *(IR)*

The Study of the Influence of the ^{234}U *Heel* on the lot

$$^{238}_{92}\mathrm{U} \xrightarrow[4.468\times10^{9}\ \mathrm{y}]{\alpha} {}^{234}_{90}\mathrm{Th} \xrightarrow[24.1\ \mathrm{d}]{\beta^-} {}^{234\mathrm{m}}_{91}\mathrm{Pa} \left\{ \begin{array}{c} \xrightarrow[1{,}17\ \mathrm{min}]{0.16\%} {}^{234}_{91}\mathrm{Pa} \xrightarrow[6{,}7\ \mathrm{h}]{\beta^-} \\ \xrightarrow[1{,}17\ \mathrm{min}]{99.84\%\ \beta^-} \end{array} \right\} {}^{234}_{92}\mathrm{U}$$

$$N_n(t) = \sum_{i=1}^{n}\left[N_i(0)\times\left(\prod_{j=i}^{n-1}\lambda_j\right)\times\left(\sum_{j=i}^{n}\left(\frac{e^{-\lambda_j t}}{\prod_{p=i,p\neq j}^{n}(\lambda_p-\lambda_j)}\right)\right)\right]$$

$$N_D(t) = N_D(t_0)\cdot e^{-\lambda_D\cdot\Delta t} + \lambda_C\cdot N_C(t_0)\cdot\left(\frac{e^{-\lambda_C\cdot\Delta t}}{\lambda_D-\lambda_C}+\frac{e^{-\lambda_D\cdot\Delta t}}{\lambda_C-\lambda_D}\right) + \lambda_B\cdot\lambda_C\cdot N_B(t_0)\cdot\left(\frac{e^{-\lambda_B\cdot\Delta t}}{(\lambda_C-\lambda_B)\cdot(\lambda_D-\lambda_B)}+\frac{e^{-\lambda_C\cdot\Delta t}}{(\lambda_B-\lambda_C)\cdot(\lambda_D-\lambda_C)}+\frac{e^{-\lambda_D\cdot\Delta t}}{(\lambda_B-\lambda_D)\cdot(\lambda_C-\lambda_D)}\right)+$$
$$+\lambda_A\cdot\lambda_B\cdot\lambda_C\cdot N_A(t_0)\cdot\left(\frac{e^{-\lambda_A\cdot\Delta t}}{(\lambda_B-\lambda_A)\cdot(\lambda_C-\lambda_A)\cdot(\lambda_D-\lambda_A)}+\frac{e^{-\lambda_B\cdot\Delta t}}{(\lambda_A-\lambda_B)\cdot(\lambda_C-\lambda_B)\cdot(\lambda_D-\lambda_B)}+\frac{e^{-\lambda_C\cdot\Delta t}}{(\lambda_A-\lambda_C)\cdot(\lambda_B-\lambda_C)\cdot(\lambda_D-\lambda_C)}+\frac{e^{-\lambda_D\cdot\Delta t}}{(\lambda_A-\lambda_D)\cdot(\lambda_B-\lambda_D)\cdot(\lambda_C-\lambda_D)}\right)$$

A = ^{238}U,
B = ^{234}Th,
C = ^{234m}Pa,
D = ^{234}U

Calculating the ^{234}U in *Heel*

UF_6	2277	[kg]
Uranium Mass (approximate)	1539.56	[kg]
^{235}U	4.238	[wt%]
^{234}U	8900	[μg/g^{235}U]
^{238}U	95.724	[wt%]

	^{235}U	**^{238}U**	**^{234}Th**	**^{234m}Pa**	**^{234}Pa**	**^{234}U**
Initial Mass [kg]*	65.250	1473.735	0.000	0.000	0.000	0.580
Molar Mass [g/mol]	235	238	234	234	234	234
Half-Life [years]	7.04E+08	4.47E+09	0.065753	2.22603E-06	0.000765	2.45E+05
Decay Constant [s^{-1}]	3.12E-17	4.92E-18	3.33E-07	9.87E-03	2.87E-05	8.99E-14

Period / Type	UF_6 [Kg]	U [Kg]	^{238}U [Kg]	^{235}U [Kg]	^{234}U [Kg]
Day 0-180	2277	1539.5625	1473.5488	65.4314	0.582338791
Day 180-360	11	7.4375	7.1186	0.3161	0.002813234
Day 360	11	7.4375	7.1186	0.3161	0.002813252

For example, 1989 kg of UF_6 (for rounding purposes) at 4.25%wt ^{235}U and containing an initial ^{234}U content of 8900 ppm were added to the existing 11 kg of UF_6 in *heel*. So: ^{234}U Mass increase in the *heel* = 17.67 μg ^{234}U

Impacts of ^{234}U from Heel in the New Lot

Increase in the ^{234}U content on the new lot

Injected UF_6 Mass [Kg]	4.25 [%wt ^{235}U]	2.6 [%wt ^{235}U]	0.85 [%wt ^{235}U]
	^{234}U [ppm]		
2000	0.000306	0.000554	0.001868
1900	0.000322	0.0005[illegible]	[illegible]
1800	0.00034	0.0006[illegible]	[illegible]
1700	0.000359	0.0006[illegible]	[illegible]
1600	0.000382	0.0006[illegible]	[illegible]
1500	0.000407	0.0007[illegible]	[illegible]
1400	0.000436	0.0007[illegible]	[illegible]
1300	0.000469	0.0008[illegible]	[illegible]
1200	0.000508	0.000919	0.003102
1100	0.000553	0.001002	0.003381
1000	0.000608	0.0011[illegible]	[illegible]
900	0.000675	0.0012[illegible]	[illegible]
800	0.000758	0.0013[illegible]	[illegible]
700	0.000865	0.0015[illegible]	[illegible]
600	0.001006	0.001822	0.006148
500	0.001203	0.002179	0.007351
400	0.001496	0.002709	0.00914
300	0.001977	0.00358	0.012079
200	0.002914	0.005276	0.017804
100	0.005539	0.01003	0.033843

Final ^{234}U Content on the new lot

Injected UF_6 Mass [Kg]	4.25 [%wt ^{235}U]	2.6 [%wt ^{235}U]	0.85 [%wt ^{235}U]
	^{234}U [ppm]		
2000	8900.0003	8900.0006	8900.0019
[illegible]	[illegible]900.0003	8900.0006	8900.002
[illegible]	[illegible]900.0003	8900.0006	8900.0021
[illegible]	[illegible]900.0004	8900.0007	8900.0022
[illegible]	[illegible]900.0004	8900.0007	8900.0023
[illegible]	[illegible]900.0004	8900.0007	8900.0025
[illegible]	[illegible]900.0004	8900.0008	8900.0027
[illegible]	[illegible]900.0005	8900.0008	8900.0029
1200	8900.0005	8900.0009	8900.0031
1100	8900.0006	8900.0010	8900.0034
[illegible]	[illegible]900.0006	8900.0011	8900.0037
[illegible]	[illegible]900.0007	8900.0012	8900.0041
[illegible]	[illegible]900.0008	8900.0014	8900.0046
[illegible]	[illegible]900.0009	8900.0016	8900.0053
600	8900.001	8900.0018	8900.0061
500	8900.0012	8900.0022	8900.0074
400	8900.0015	8900.0027	8900.0091
300	8900.002	8900.0036	8900.0121
200	8900.0029	8900.0053	8900.0178
100	8900.0055	8900.0100	8900.0338

ASTM C996

For ^{235}U < 5%wt

^{234}U < 11.000 ppm

Therefore,

Impact of 234U: Null!

Evaluation of the Influence of ^{235}U *heel* in the Processes of the Enrichment Facility

PROCESS OF GENERATION OF UF_6 TO BE INJECTED IN THE CYLINDER CONTAINING *HEEL*	**CONDITION OF THE *HEEL* INSIDE CYLINDER TYPE 30B (TO RECEIVE UF_6 FROM THE PROCESSES)**		
	CYLINDER TYPE 30B TO FILL CONTAINING *HEEL* NO CERTIFICATED (UF_6 WITH %wt ^{235}U UNKNOWN)	CYLINDER TYPE 30B TO FILL CONTAINING *HEEL* WITH CERTIFICATION (UF_6 WITH %wt ^{235}U KNOWN)	
		HEEL: 0,3 ~ 4,3 %wt ^{235}U (±0,05%wt ^{235}U)	*HEEL* WITH ^{235}U CONTENT ON NOMINAL VALUE (CLIENT REQUEST)
	IS THE CERTIFICATION REQUIRED FOR THE NEW LOT?		
IS	I. YES	I. YES	I. YES
MT	I. YES	I. MAYBE	I. NO
IR	I. YES	I. MAYBE	I. MAYBE

Applied Example

MASS TO BE TRANSFERED		$\%wt\ ^{235}U$ FINAL PRODUCT					
UF_6 [Kg] 4.25 [$\%wt\ ^{235}U$]	U [g]	***Heel 5*** [$\%wt\ ^{235}U$]	***Heel 4*** [$\%wt\ ^{235}U$]	***Heel 3*** [$\%wt\ ^{235}U$]	***Heel 2*** [$\%wt\ ^{235}U$]	***Heel 1*** [$\%wt\ ^{235}U$]	***Heel 0,3*** [$\%wt\ ^{235}U$]
2000	1352272.				38%	4.232%	4.228%
1900	1284659.				37%	4.231%	4.227%
1800	1217045.				36%	4.230%	4.226%
1700	1149431.				36%	4.229%	4.225%
1600	1081818.				35%	4.228%	4.223%
1500	1014204.				34%	4.226%	4.221%
1400	946590.				32%	4.225%	4.219%
1300	878977.				31%	4.223%	4.217%
1200	811363.6	4.257%	4.248%	4.239%	4.230%	4.220%	4.214%
1100	743750.0	4.257%	4.248%	4.238%	4.228%	4.218%	4.211%
1000	676136.				26%	4.215%	4.207%
900	608522.				23%	4.211%	4.202%
800	540909.				19%	4.206%	4.196%
700	473295.				15%	4.200%	4.189%
600	405681.				09%	4.191%	4.179%
500	338068.				02%	4.180%	4.165%
400	270454.				90%	4.163%	4.144%
300	202840.				70%	4.135%	4.110%
200	135227.3	4.289%	4.237%	4.185%	4.133%	4.081%	4.044%
100	67613.6	4.324%	4.225%	4.126%	4.027%	3.928%	3.859%

INB SPECIFICATION

For UF_6 4.25%wt ^{235}U

Tolerance: 4.20 – 4.30%wt ^{235}U

Therefore

^{235}U of Heel affects the lot!

Conclusion

The effects of ^{234}U and ^{235}U *heels* were evaluated for the production of a new lot of commercial grade UF_6

The Heel with any concentration of ^{234}U does not cause significant effect on the UF_6 lot for any values regarding the specification

The UF_6 *heel* may impact significantly the ^{235}U concentration on the final product and therefore must be controlled in order to remain on the specification limits.

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Thank You

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