Dynamic Simulation Tools for Isotopic Separation System Modelling and Design

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Motivation

Cryogenic distillation is a key process for tritium processing in fusion: it is necessary for isotopic separation but is prone to hold high tritium inventories.

Process simulation can be a useful tool for real-time tritium monitoring and the design of new fusion systems. Employing a commercial simulator such as Aspen HYSYS can be of interest to new agents in the industry and will be used in this work.

Inputs

The input data used the modeling in this research are:

- The design of TSTA experimental columns [1].
- Hydrogen thermodynamic data [2].

	H2 (nH2)	HD	HT	D2 (nD2)	DT	T2 (nT2)
M (g/mol)	2.01588	3.02204	4.02399	4.02820	5.03015	6.03210
α	-0.219	-0.18	-0.12	-0.15	-0.13	-0.14
T_b (K)	20.397	22.14	22.906	23.6651	24.372	25.04
T_c (K)	33.19	35.91	37.13	38.35	39.42	40.22
P_c (kPa)	1313	1484	1570	1650	1770	1850

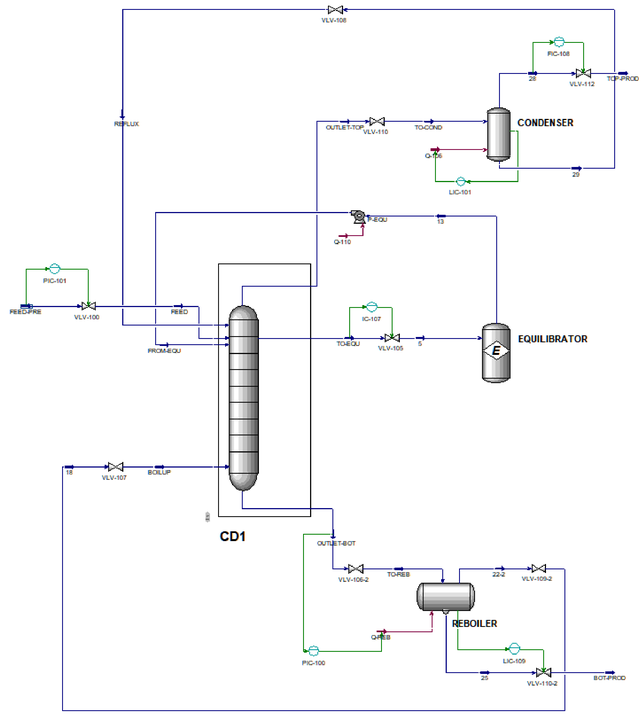
- The thermodynamic model parameters in [3] for the Peng Robinson Twu-alpha equation at cryogenic conditions.

	L	M	N
H_2	0.7189	2.5411	10.2000
HD	0.1009	1.0204	1.9102
HT	0.6820	1.2469	0.2000
D_2	1.2584	6.1846	0.0759
DT	0.9783	1.6726	0.2000
T_2	1.0943	1.6009	0.2000

- Dynamic experimental data in [4].

Development

A cryogenic column model of 81 stages + condenser and reboiler has been constructed by matching the design of the first column at TSTA.



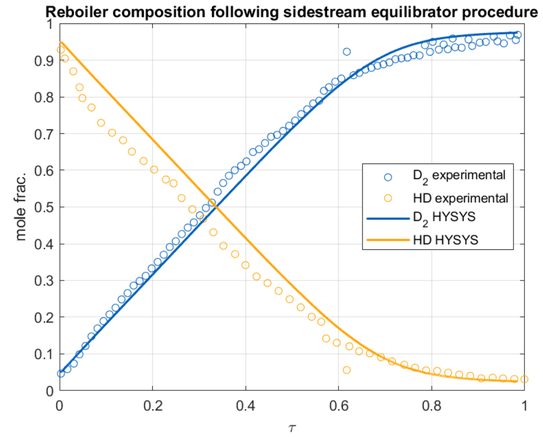
Aspen HYSYS flowsheet of the cryogenic distillation column

The model fits the distillation purities:

	FEED		TOP PRODUCT		BOTTOMS PRODUCT	
	Sherman	**HYSYS**	**Sherman**	**HYSYS**	**Sherman**	**HYSYS**
H_2	0.00014	0.00014	0.00053	0.00052	0.0	0.0
HD	0.01000	0.01001	0.04100	0.03721	4.70E-09	2.90E-09
HT	0.00930	0.00931	0.03600	0.03462	0.0000017	0.0000008
D_2	0.24800	0.24814	0.91800	0.88396	0.01700	0.01466
DT	0.48300	0.48327	0.00470	0.04370	0.64900	0.64469
T_2	0.24900	0.24914	6.0E-7	6.6E-6	0.33500	0.34065

Results

The model is used to simulate the transition from single column operation to sidestream recycle through an equilibrator. The column is filled with a 2:1 mixture of H:D and the sidestream starts operating to recycle a flow of 33.2 % of the value of the feed. The results match the experimental data



Conclusions

- A dynamic model of an isotopic hydrogen distillation column has been built in Aspen HYSYS, verifying Twu-alpha thermodynamic parameters for cryogenics.
- The suitability of a commercial process simulator for tritium processing is verified.

References

[1] R. H. Sherman, “Cryogenic hydrogen isotope distillation for the fusion fuel cycle,” United States, 1985.

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[3] J. Noh, A. M. Fulgueras, L. J. Sebastian, H. G. Lee, D. S. Kim, and J. Cho, “Estimation of thermodynamic properties of hydrogen isotopes and modeling of hydrogen isotope systems using Aspen Plus simulator,” *J. Ind. Eng. Chem.*, vol. 46, pp. 1–8, Feb. 2017.

[4] R. H. Sherman *et al.*, “Application of sidestream recycle to the separation of hydrogen isotopes by cryogenic distillation,” *Proc. - Symp. Fusion Eng.*, vol. 1, pp. 77–79, 1993.