

Indústria do nitrogênio

Ácido nítrico

Curso de Engenharia Química da UNESP, 2021

Disciplina de Processos da Indústria Química

Apresentado por Felipe Kreft Batista

Professor Dr Arnaldo Sarti

Sumário

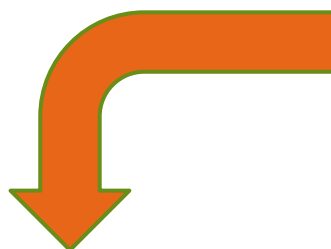
Rota química do processo

Ácido nítrico

- ▶ Histórico do processo
- ▶ Aplicação do produto
- ▶ Matéria-Prima
- ▶ Descrição do processo
- ▶ Fluxograma
- ▶ Resíduos
- ▶ Fluxograma de rotas

Química

Atenção aqui

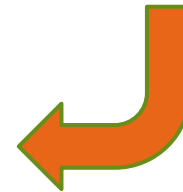


Compound, structure	Oxidation state
Nitrate, NO_3^-	+5
Nitrogen dioxide, NO_2	+4
Nitrite, NO_2^-	+3
Nitric oxide, NO	+2
Nitroxyl, HNO	+1
Nitrogen, N_2	0
Hydroxylamine, NH_2OH	-1
Ammonia, NH_3	-3

Química

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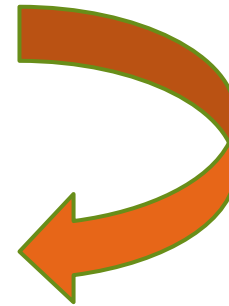
Comece aqui



Química

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Venha pra cá



Química

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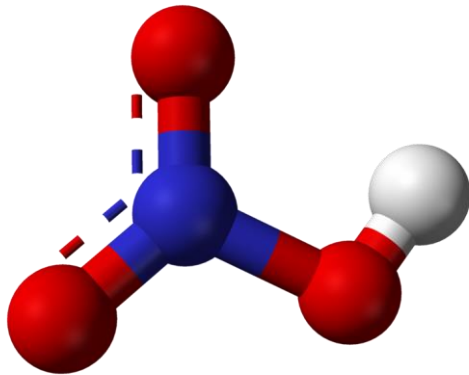
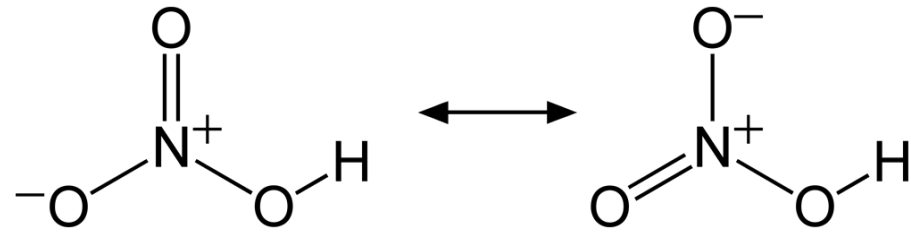


Depois pra cá

Química

Compound, structure		Oxidation state
Nitrate, NO_3^-	#3	+5
Nitrogen dioxide, NO_2		+4
Nitrite, NO_2^-		+3
Nitric oxide, NO		+2
Nitroxyl, HNO		+1
Nitrogen, N_2	#1	0
Hydroxylamine, NH_2OH		-1
Ammonia, NH_3	#2	-3

Pronto, vc sabe oq acontece com o nitrogênio!



Ácido nítrico

Histórico

- Processo de Ostwald, patente em 1902

Fig 53: Friedrich Wilhelm Ostwald 1853 - 1932



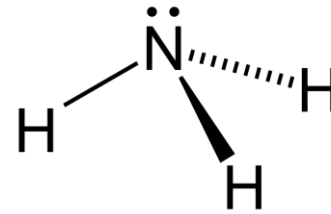
Responsável por:

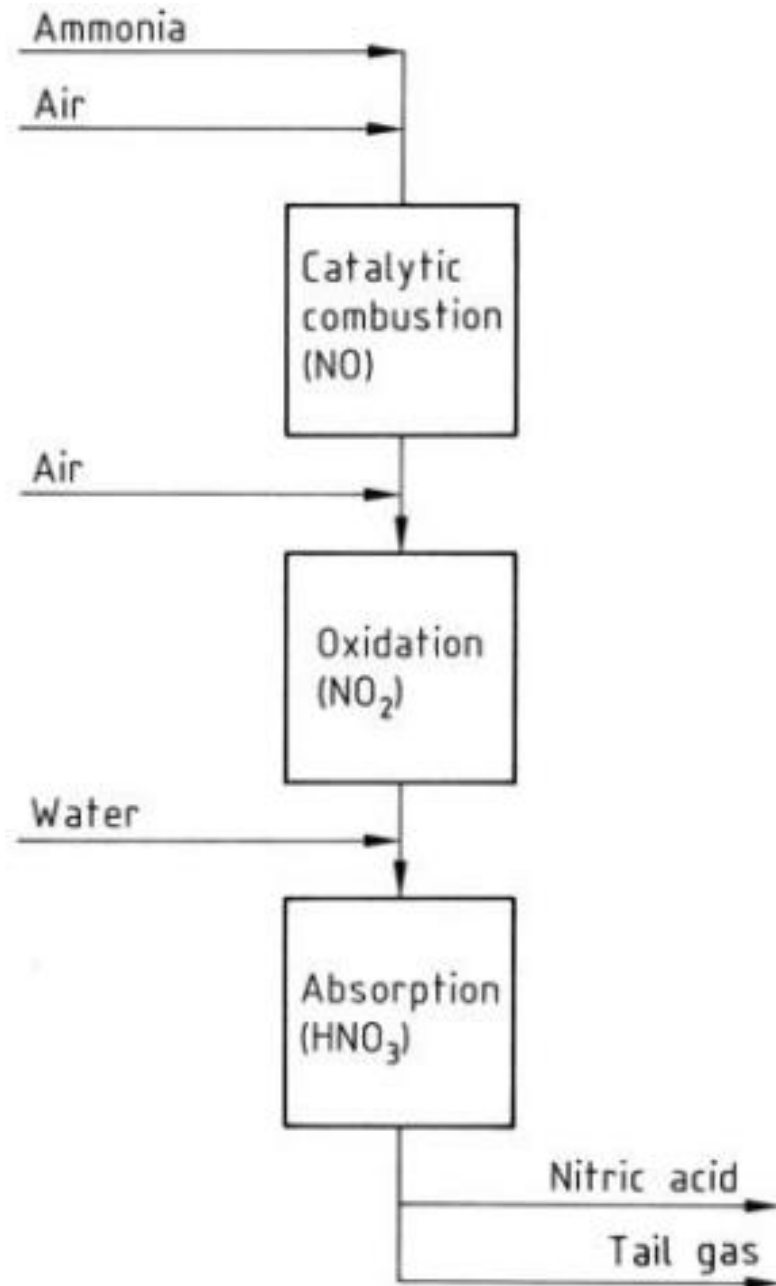
- catálise
- Cunhou o termo 'mol'
- Coeficiente de Ostwald
- Sistema de cor de Ostwald
- Lei de diluição de Ostwald
- Maturação de Ostwald
- Lei de Ostwald
- Viscosímetro de Ostwald
- Pipeta de Ostwald -Folin
- Equação de Ostwald-Freundlich
- Ciclo de Ostwald-Liesegang
- Relação de Ostwald-de Waele
- HSL e HSV → HSB

Aplicação do produto

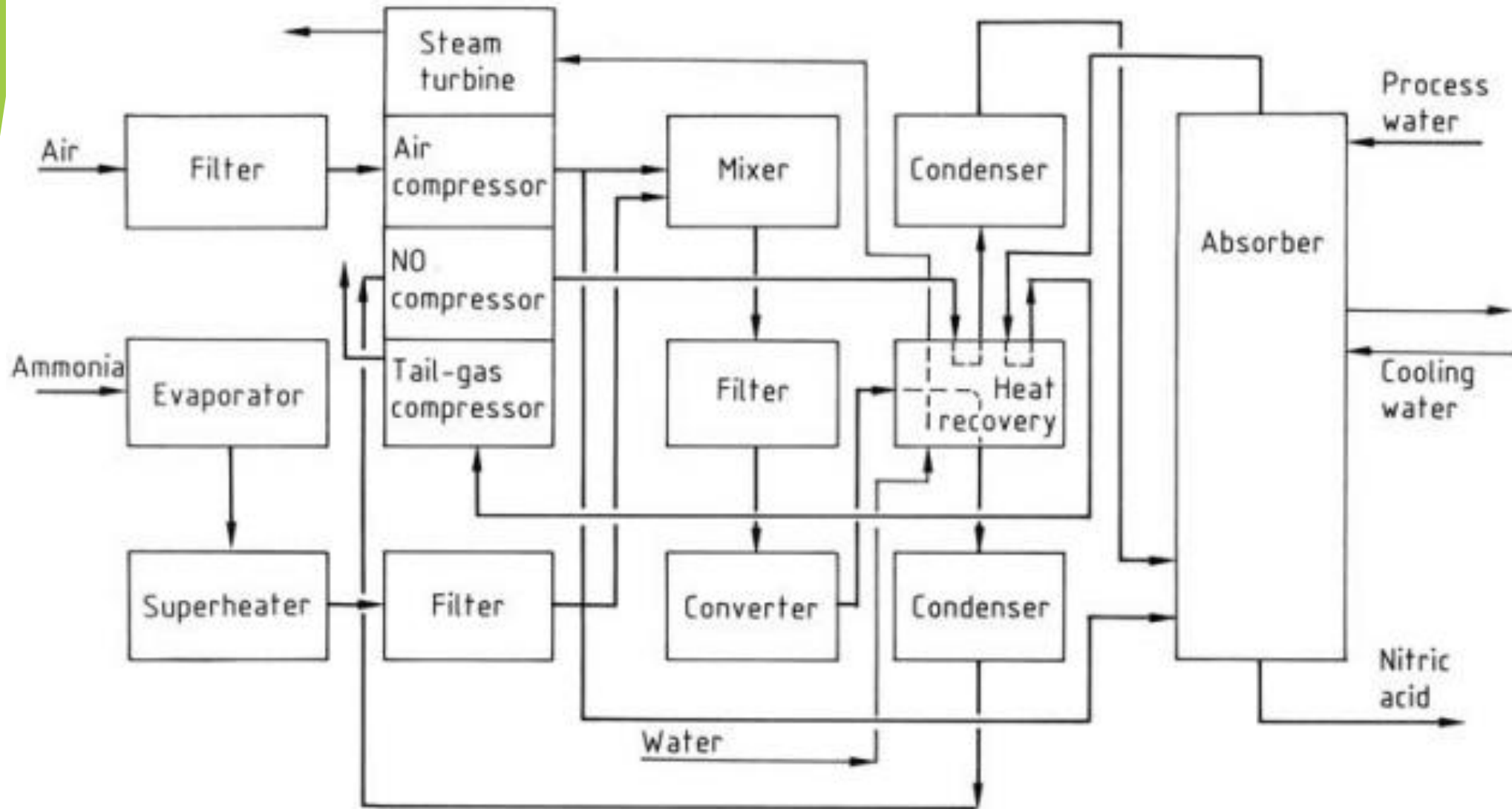
- Fertilizante na forma de nitrato
- Nitrocompostos
 - Reações orgânicas
 - Nitração
 - Nitroalcanos
 - Nitroaromáticos
 - Amidas
- Explosivo

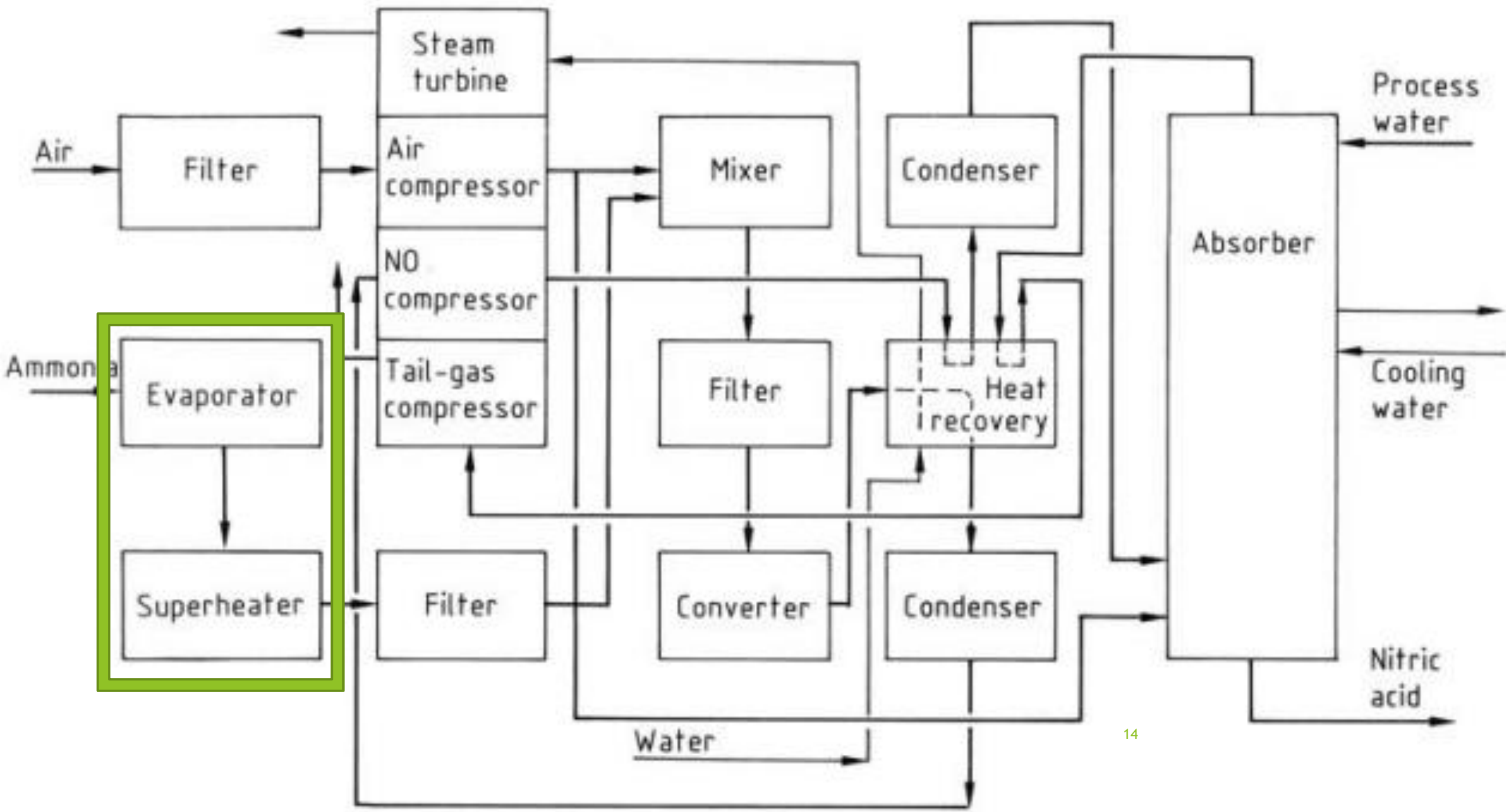
Matéria prima





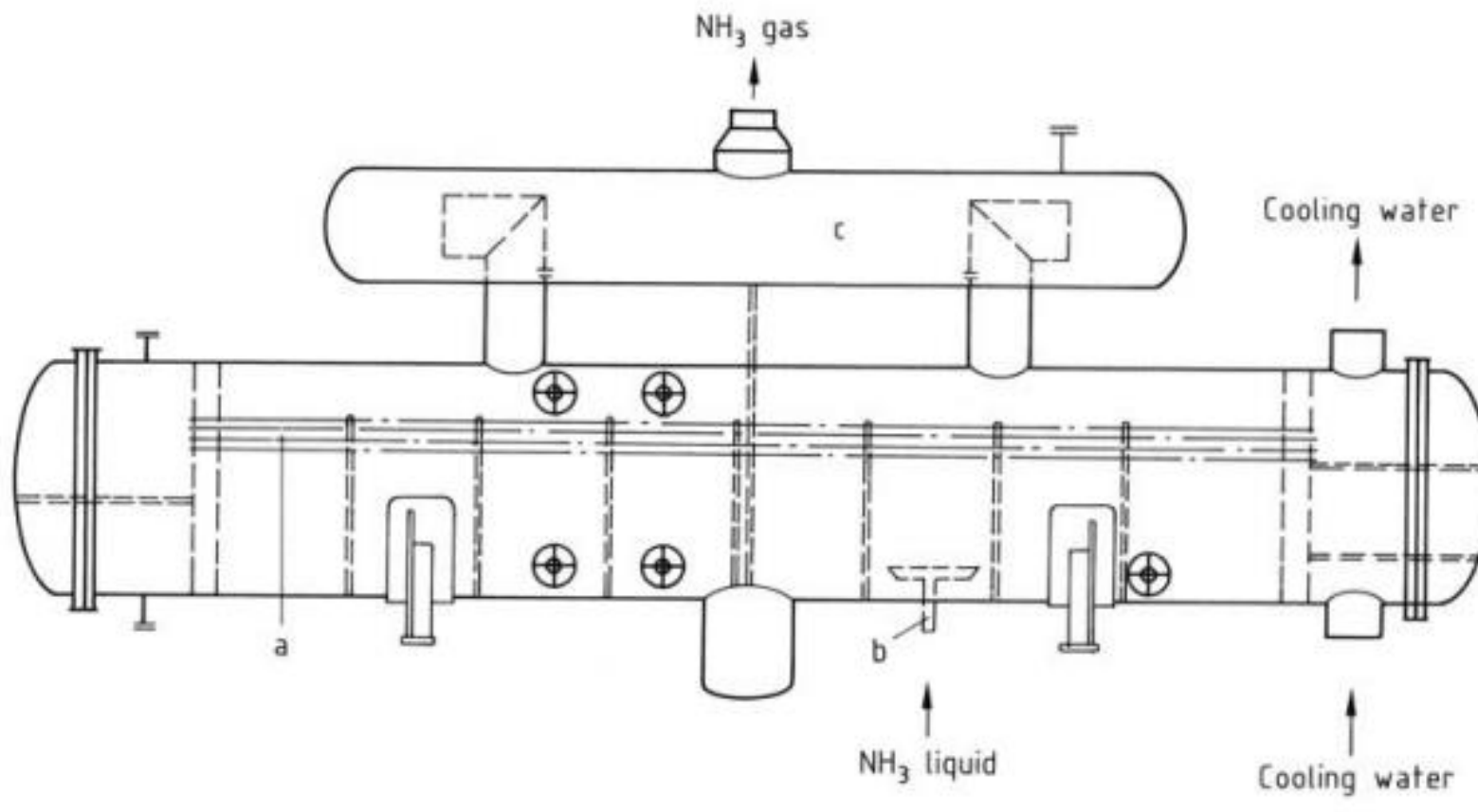
Descrição da química do processo





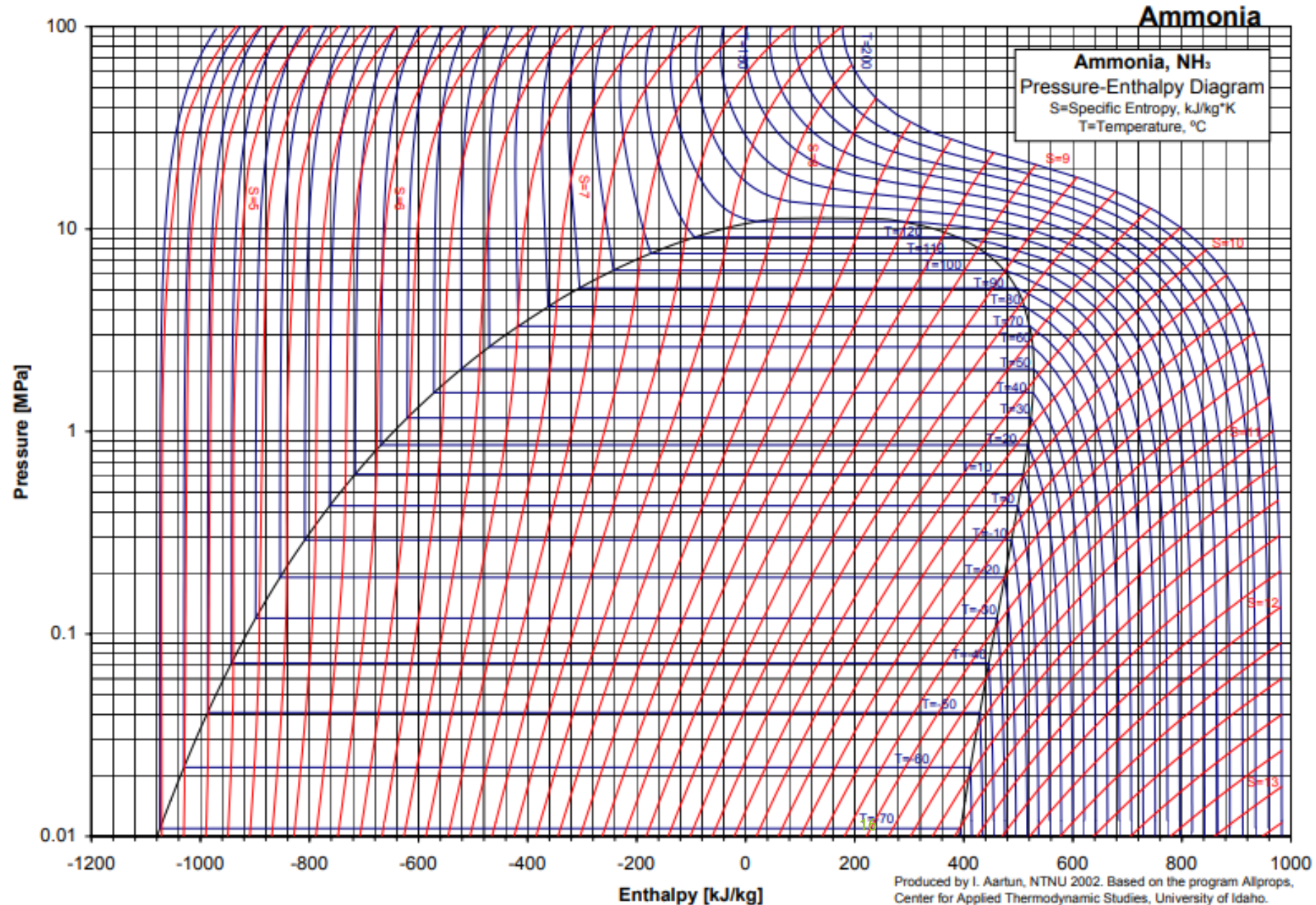
Evaporador

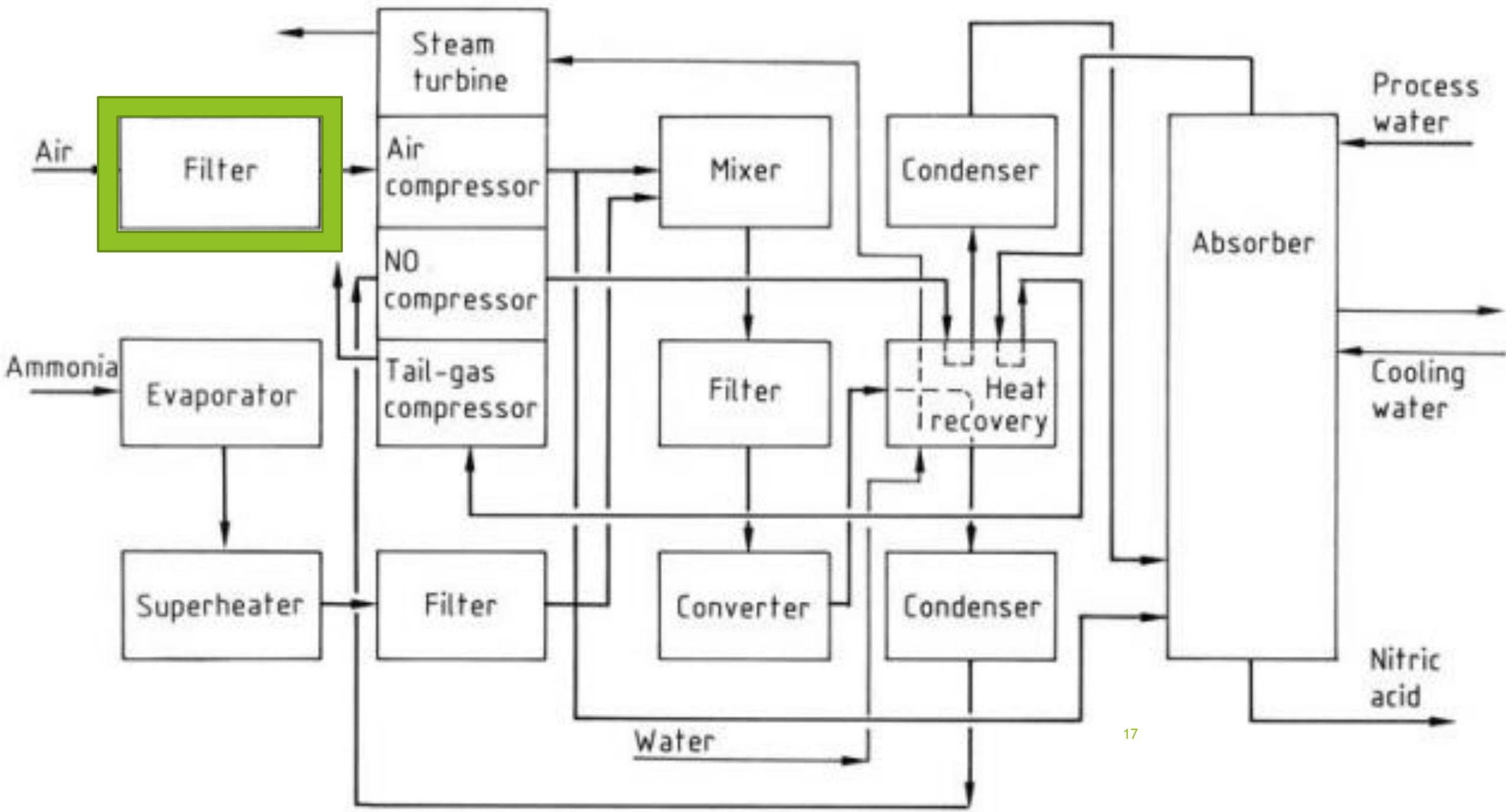
- ▶ Amônia
 - ▶ Líquido
 - ▶ Vapor
- ▶ 1 atm
 - ▶ Ebulição ($-33,4^{\circ}\text{C}$)
- ▶ Água de refrigeração
 - ▶ Aquecimento



Evaporador

- ▶ Amônia
 - ▶ Líquido
 - ▶ Vapor
- ▶ 1 atm
 - ▶ -33,4°C

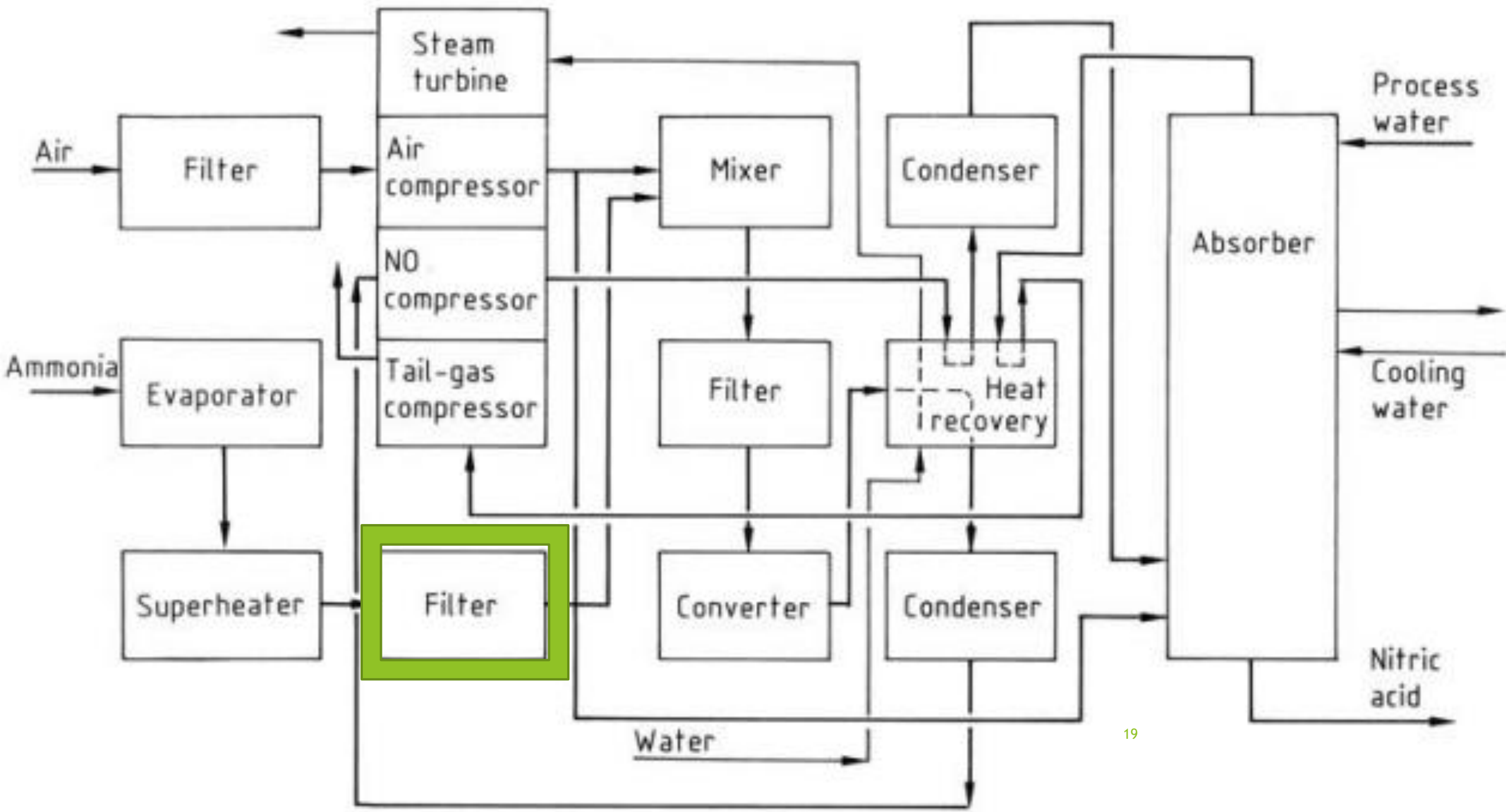




Filtro de ar

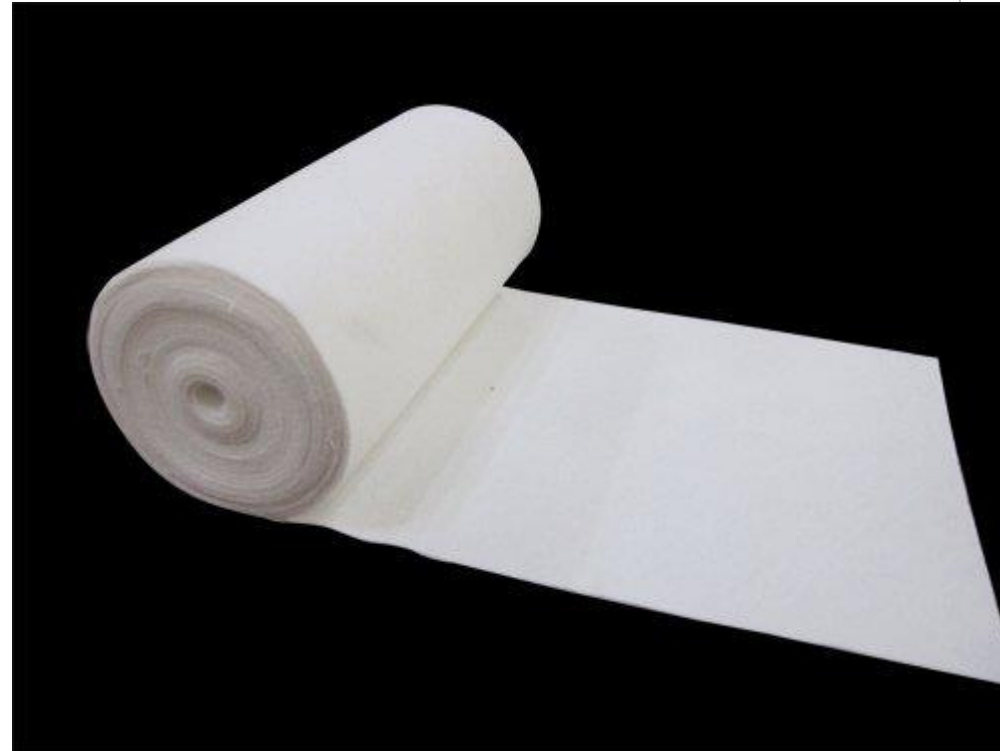
- ▶ Multiestágio
 - ▶ Fibra de vidro
 - ▶ Plástico
- ▶ Meio suporte
 - ▶ Aço inox
- ▶ Partículas > 0,5 mm
 - ▶ 99,9%

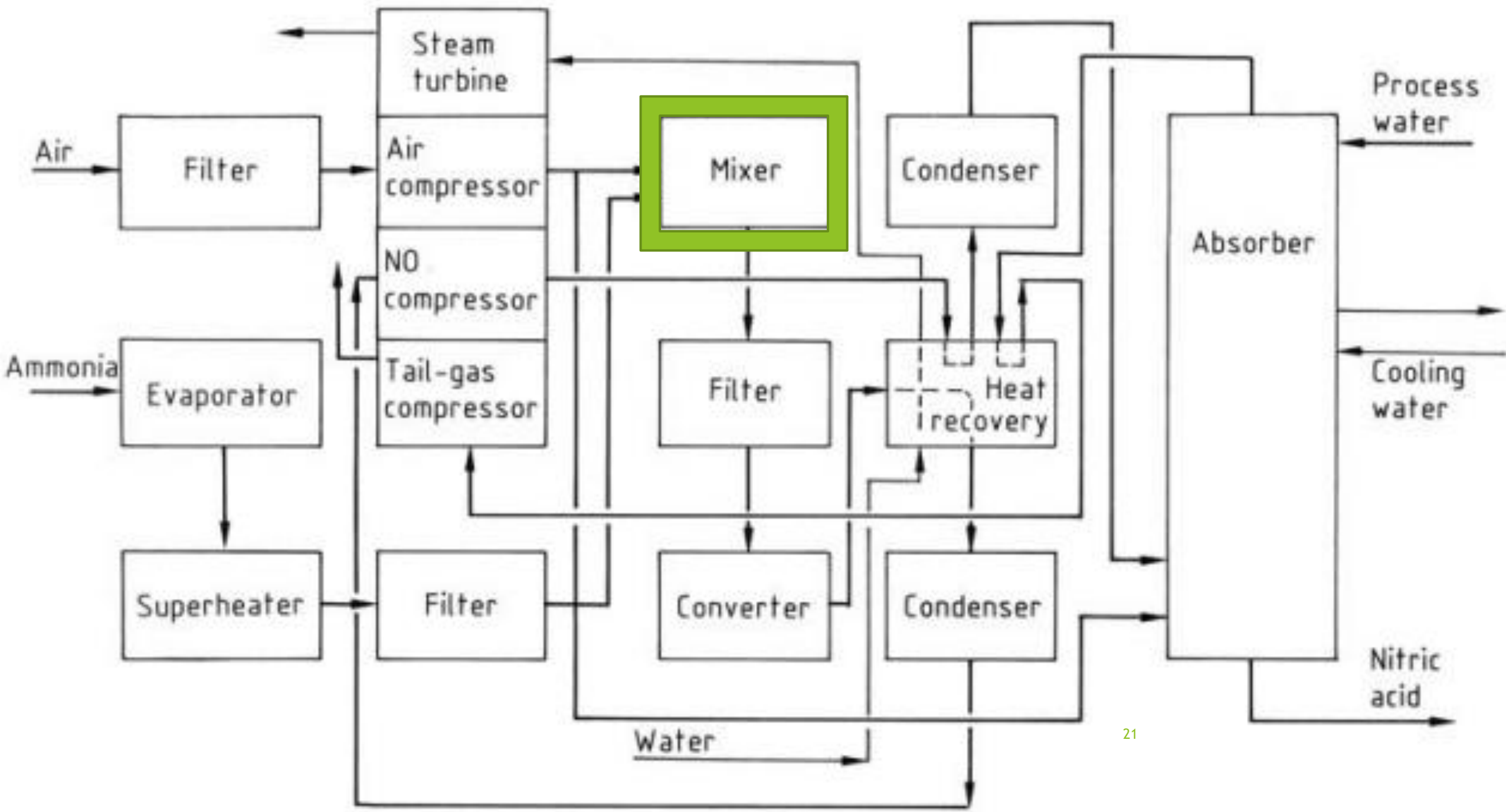




Filtro de amônia

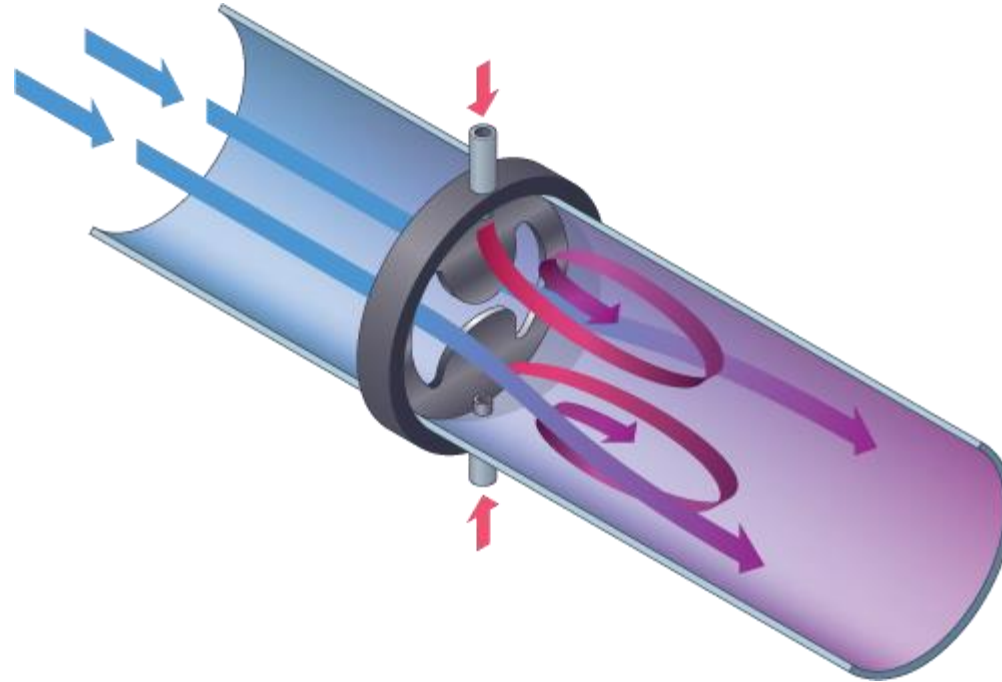
- ▶ Multiestágio
 - ▶ Teflon
 - ▶ Metais sinterizados
- ▶ Remove
 - ▶ Halogênio
 - ▶ Traços de óleo
- ▶ Partículas > 0,5 mm
 - ▶ 99,9%

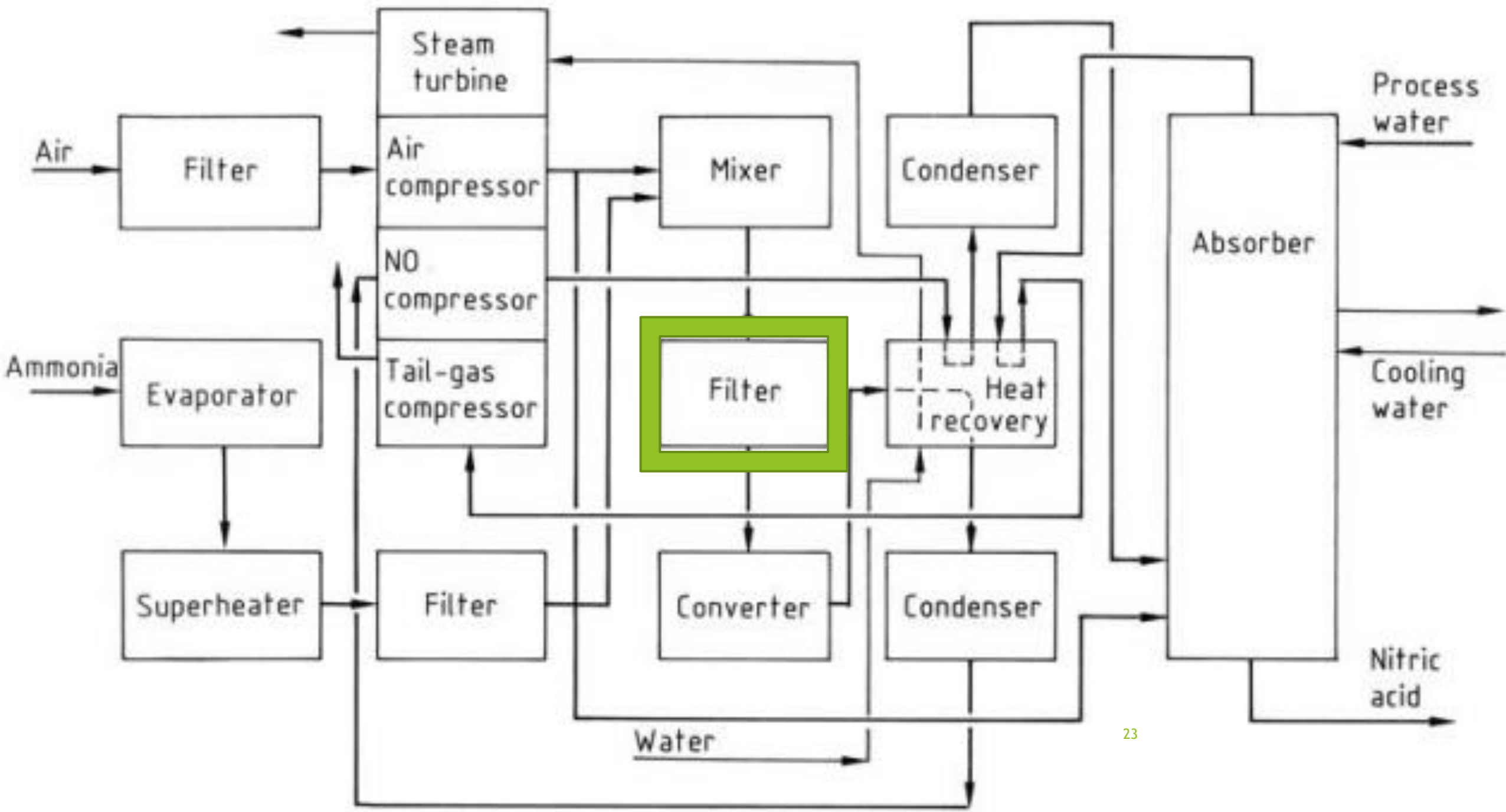




Misturador estático de gás

- ▶ Razão de mistura
 - ▶ Amônia - 1
 - ▶ Ar - 10
- ▶ FT 1
- ▶ Segurança
 - ▶ Amônia é explosiva
 - ▶ Superaquecimento localizado
- ▶ Melhor eficiência
 - ▶ conversão





Filtro pré-conversor

- ▶ Particulado
 - ▶ Exterior
 - ▶ Interior
 - ▶ Corrosão
- ▶ Mistura
 - ▶ Melhora
- ▶ Material
 - ▶ Cartuchos cerâmicos
 - ▶ Dióxido de sílcio



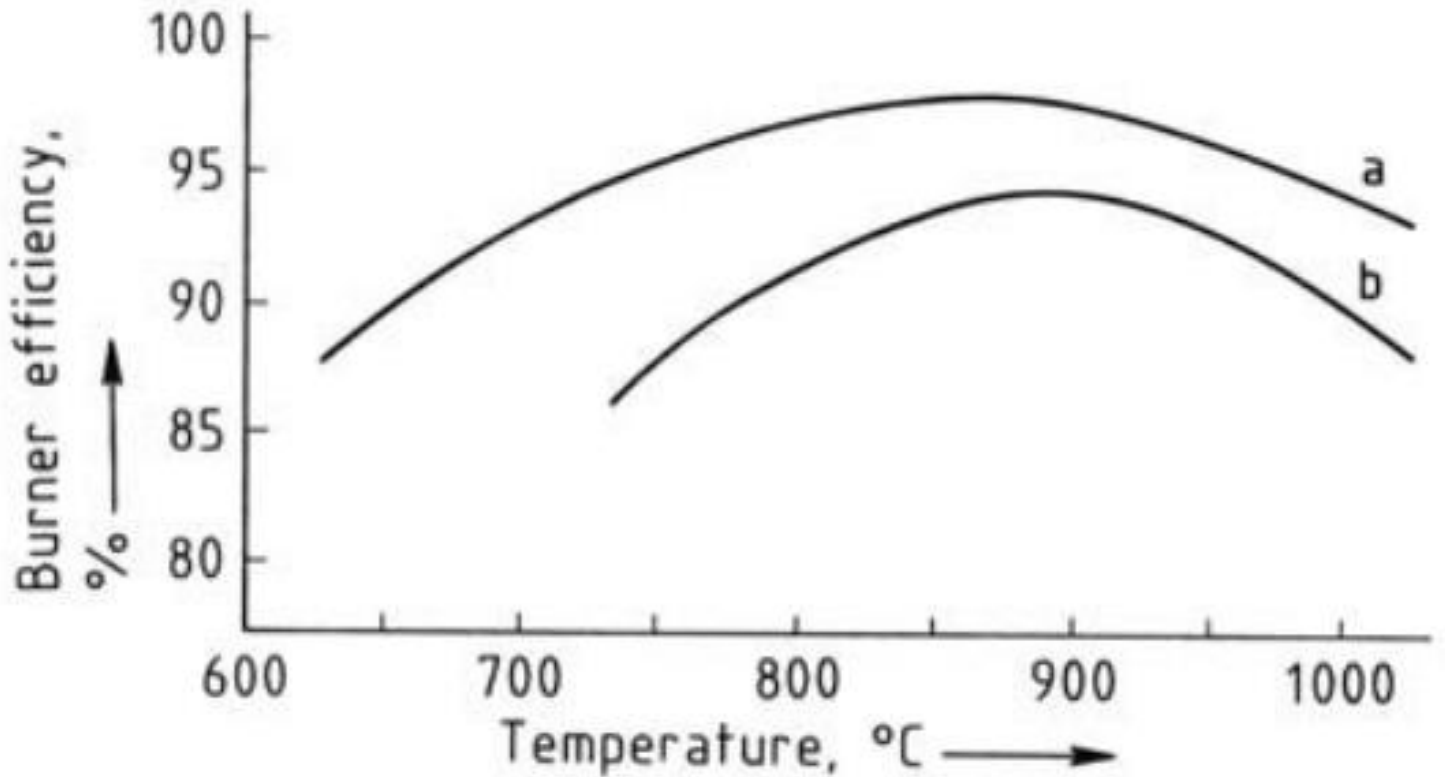
Conversor



$\Delta H = -904 \text{ kJ/mol}$ Mistura

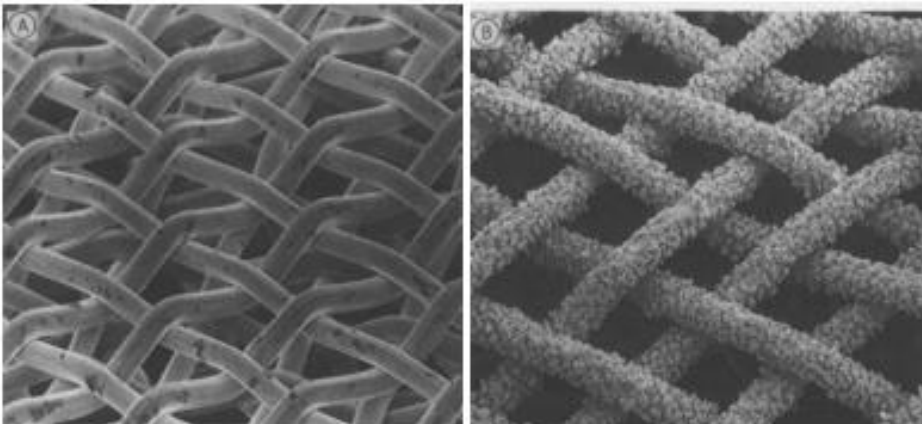
► Material

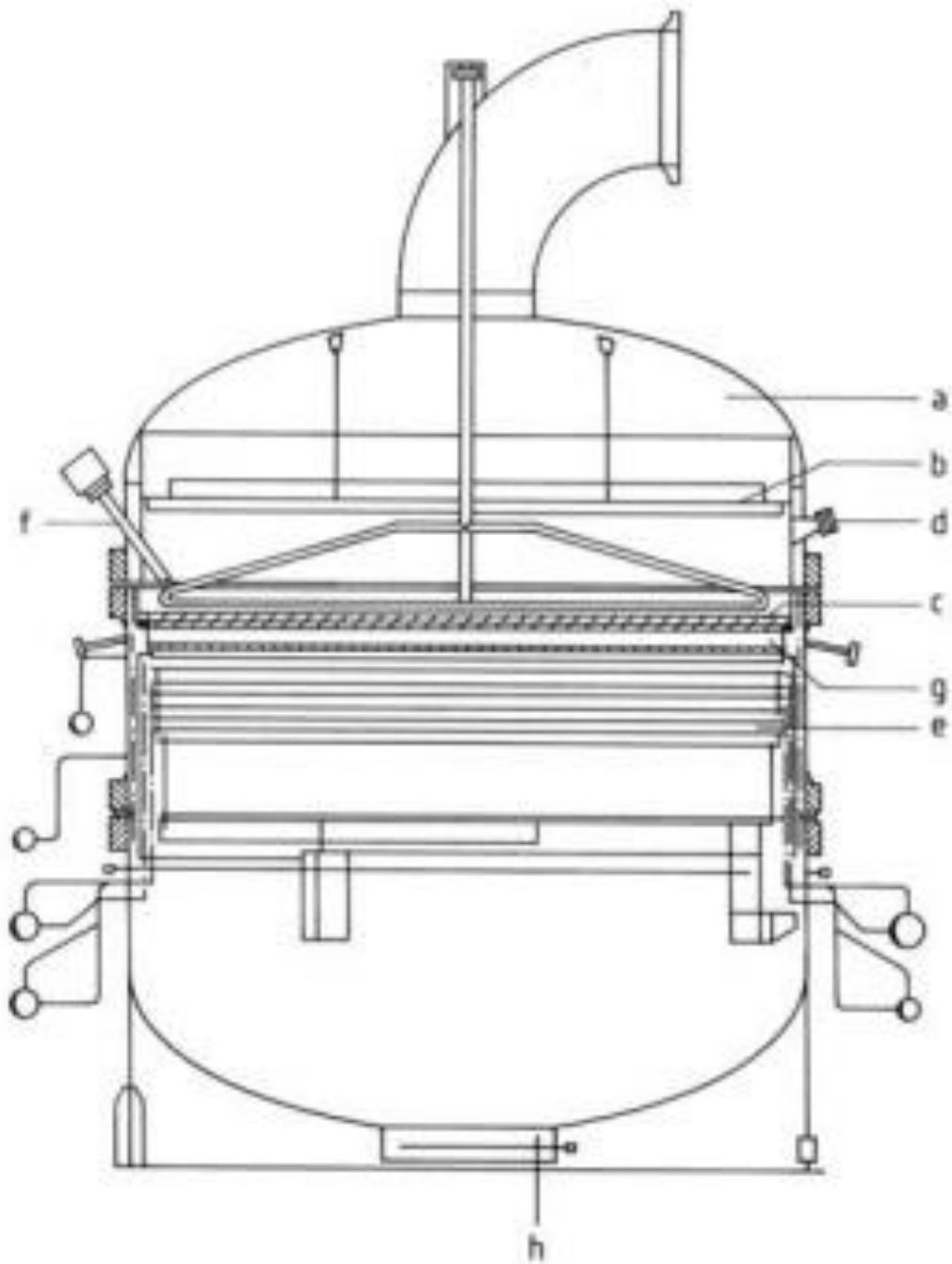
- Catalisador
 - gaze
- Caldeira integrada
 - Aproveitamento energético



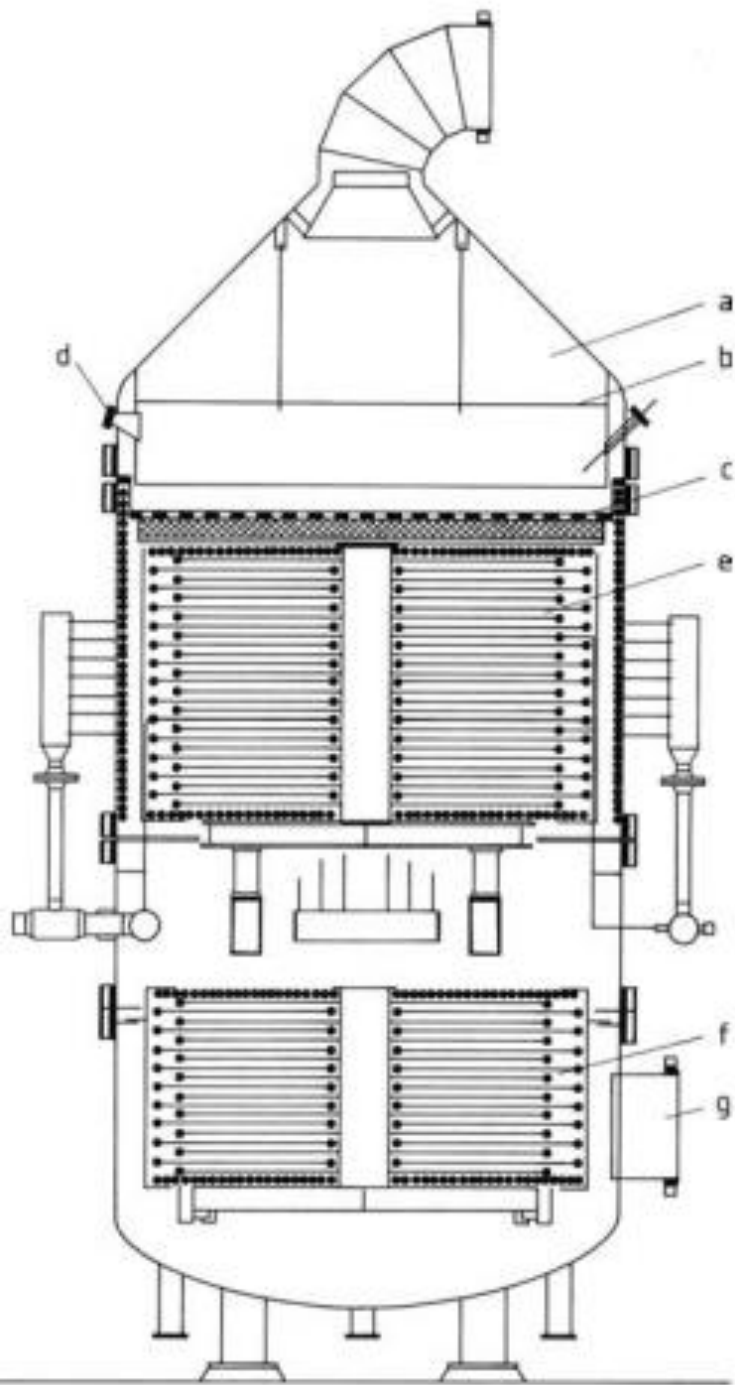
► a = 1 bar

► b = 4 bar

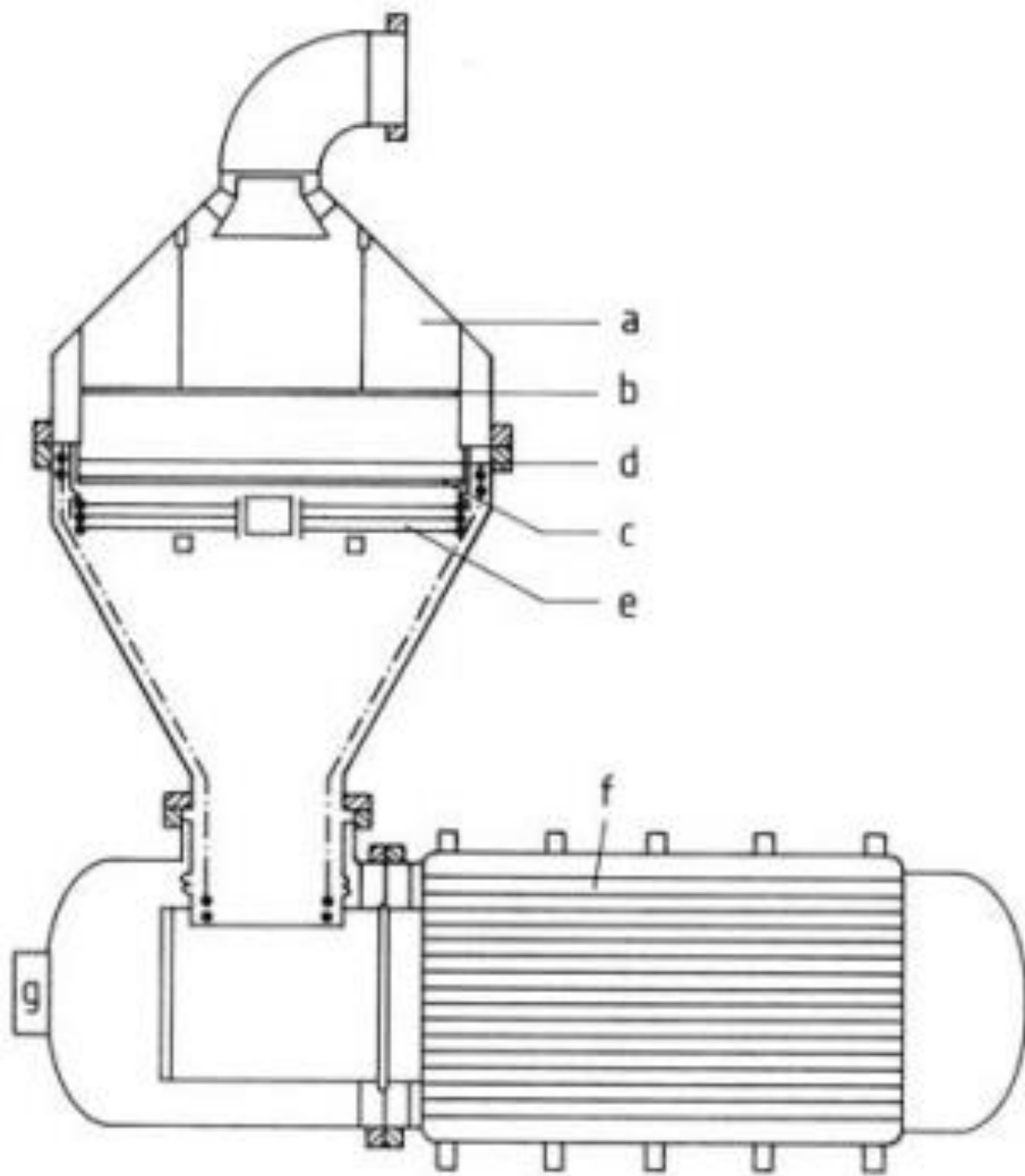




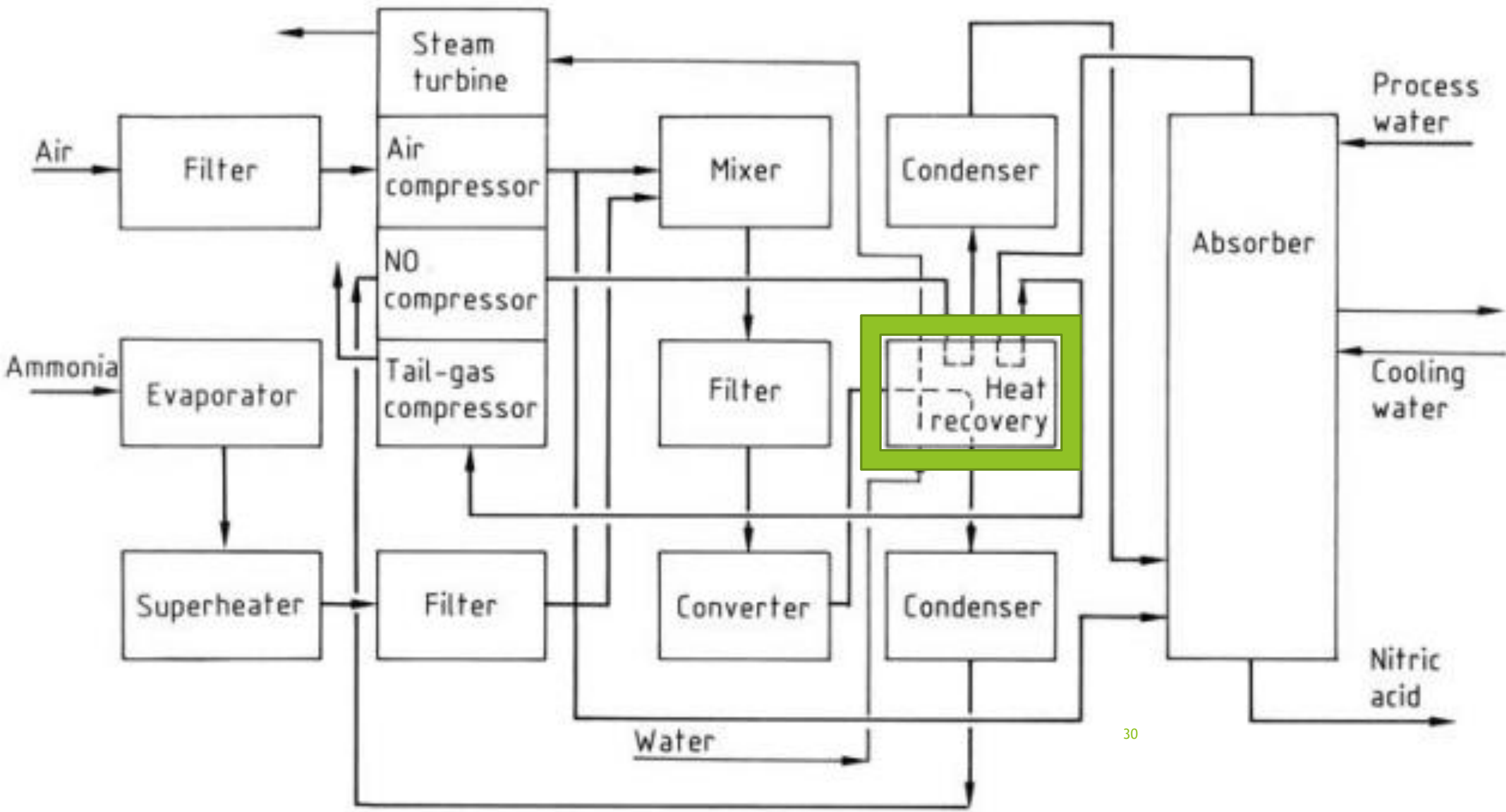
Reator de oxidacao catalitica de amonia com sistema de recuperacao de calor I - Lentjes



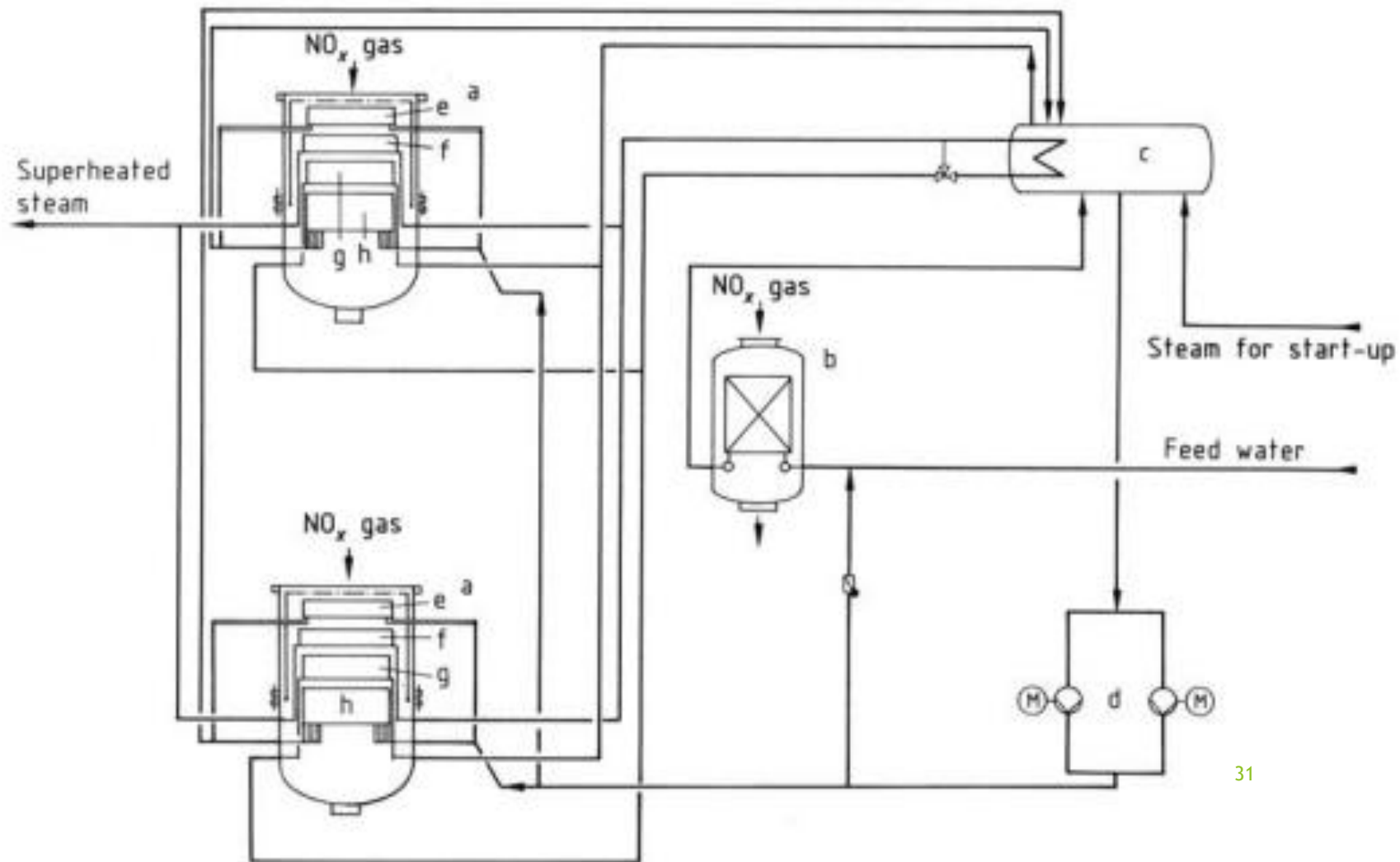
reator de oxidacao catalitica de amonia com
recuperacao integrada de calor

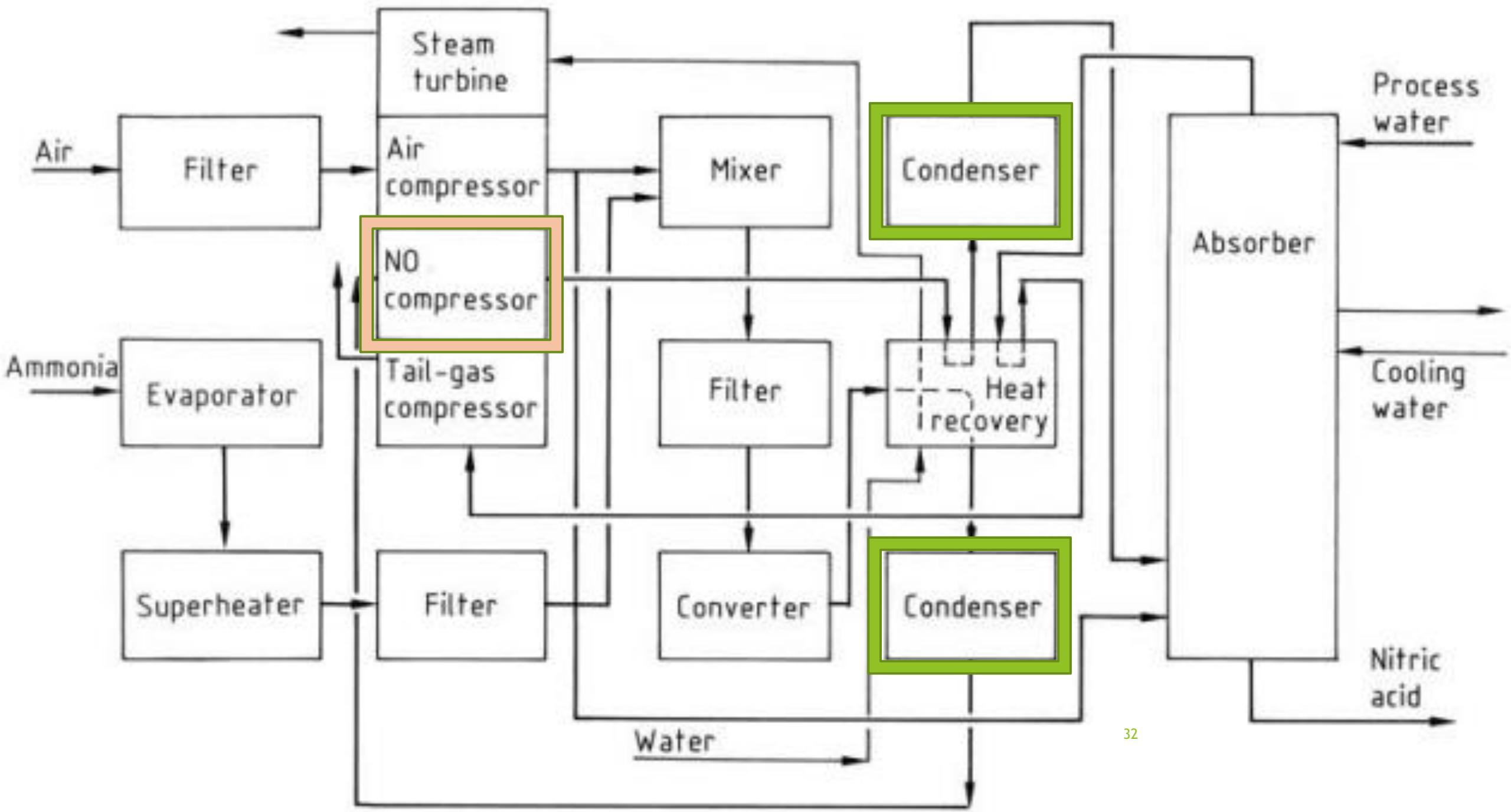


reator de oxidacao catalitica de
amonia com recuperacao
integrada de calor com caldeira

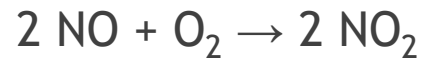


Recuperação de calor



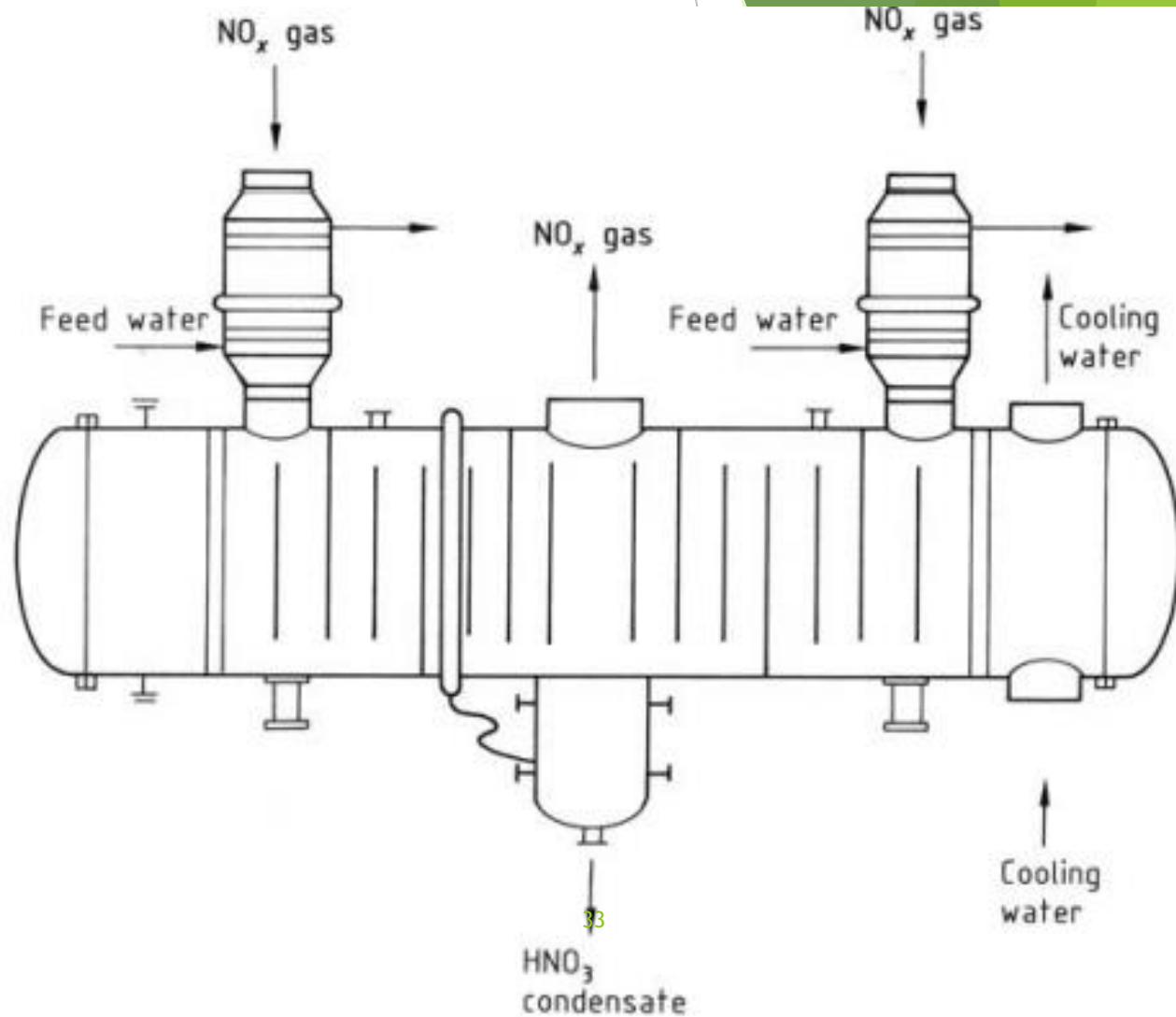


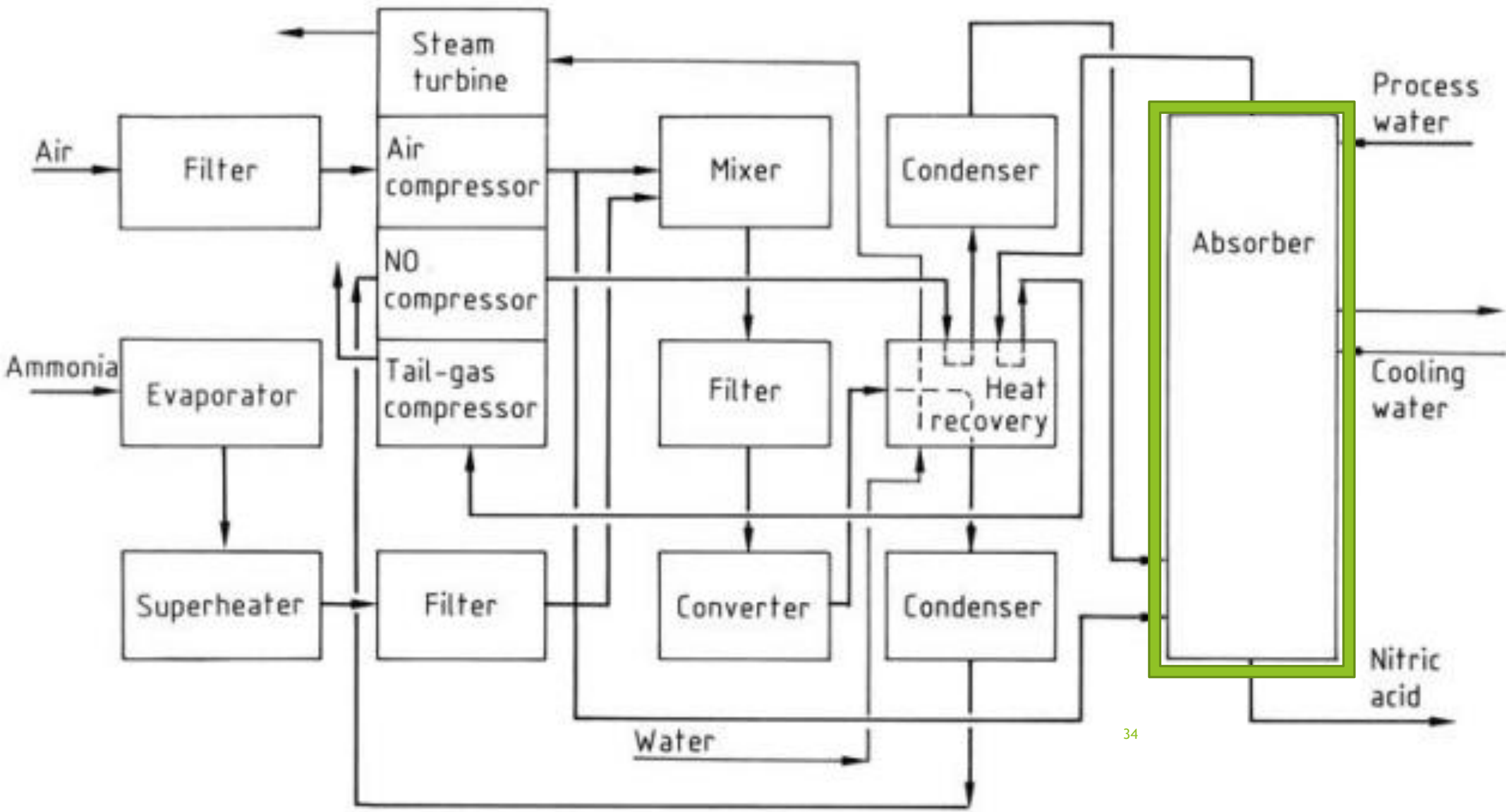
Condensador - resfriador



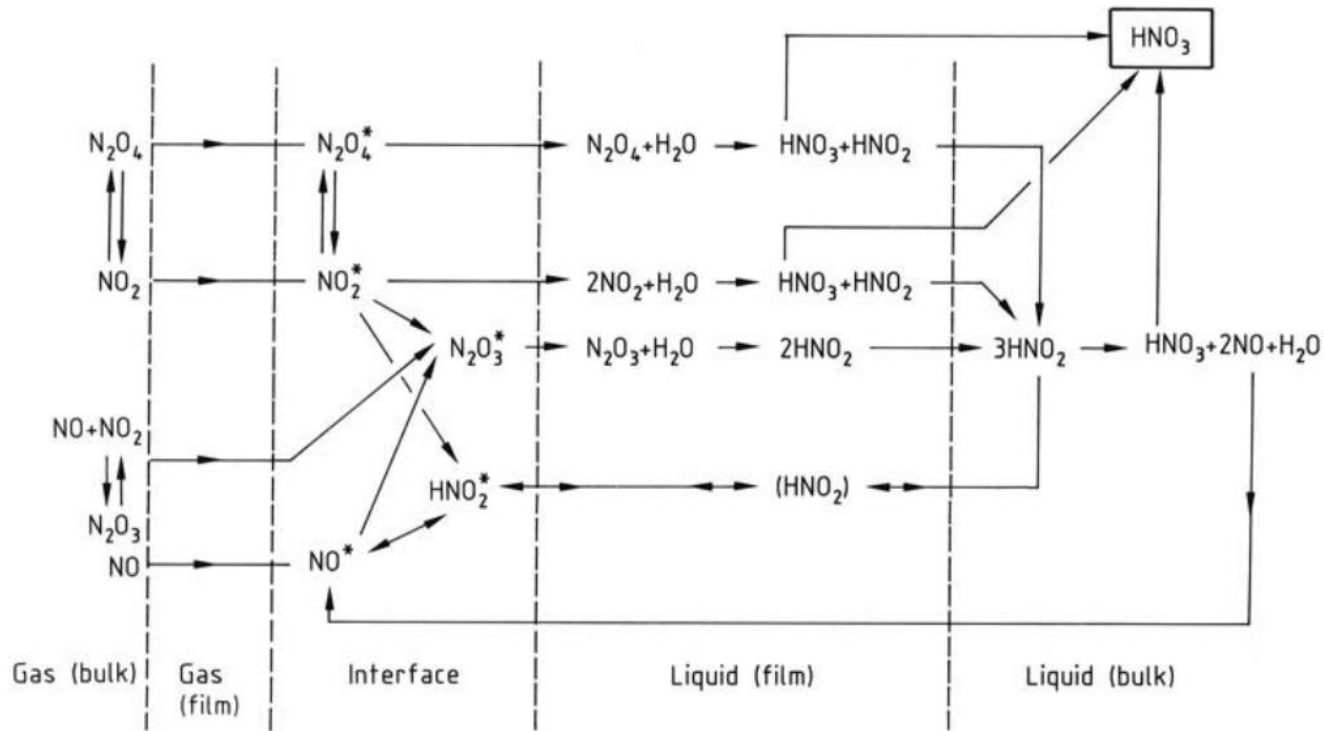
$$\Delta H = -1127 \text{ kJ/mol}$$

Desenho térmico
difícil

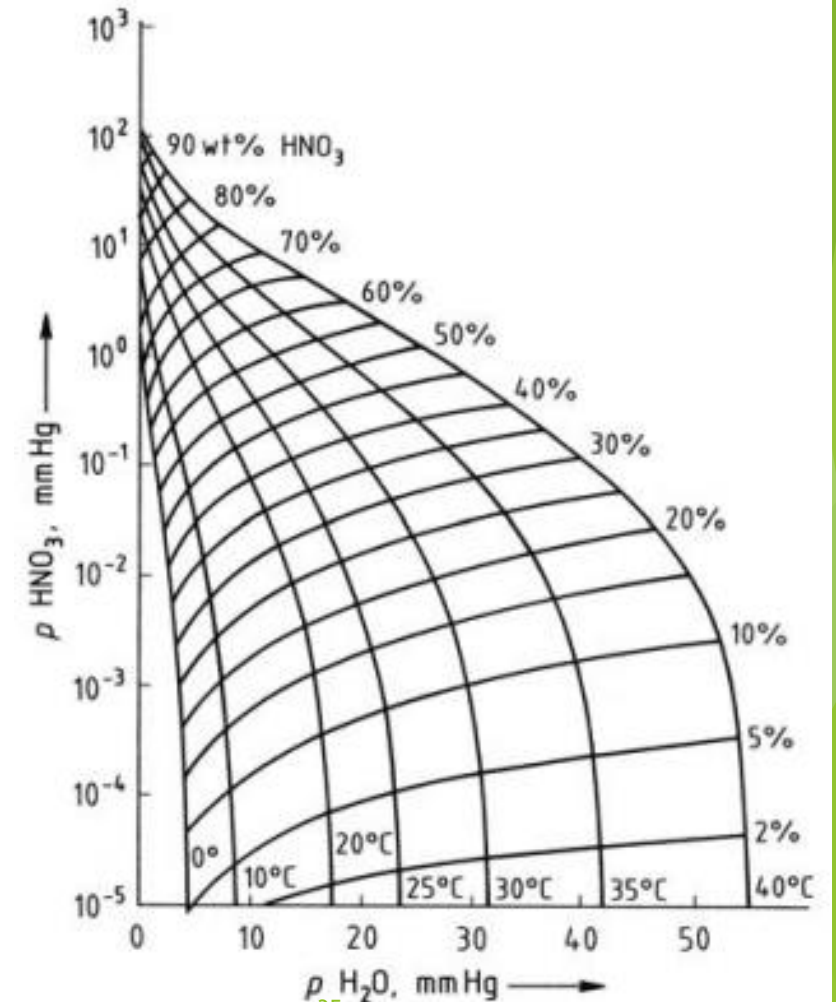




Torre de absorção



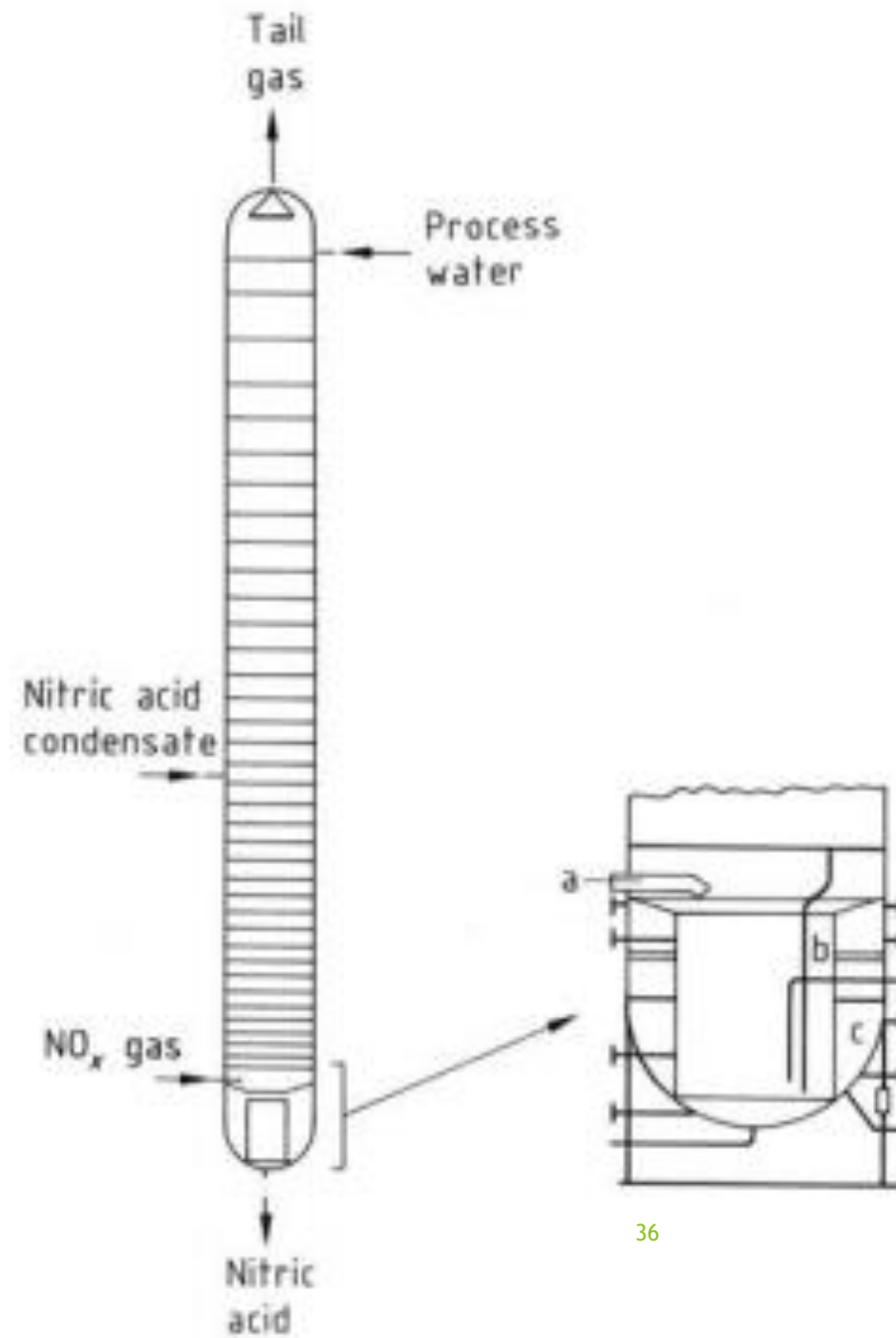
- Modelo de absorção não estequiométrico de nitrogênio em água

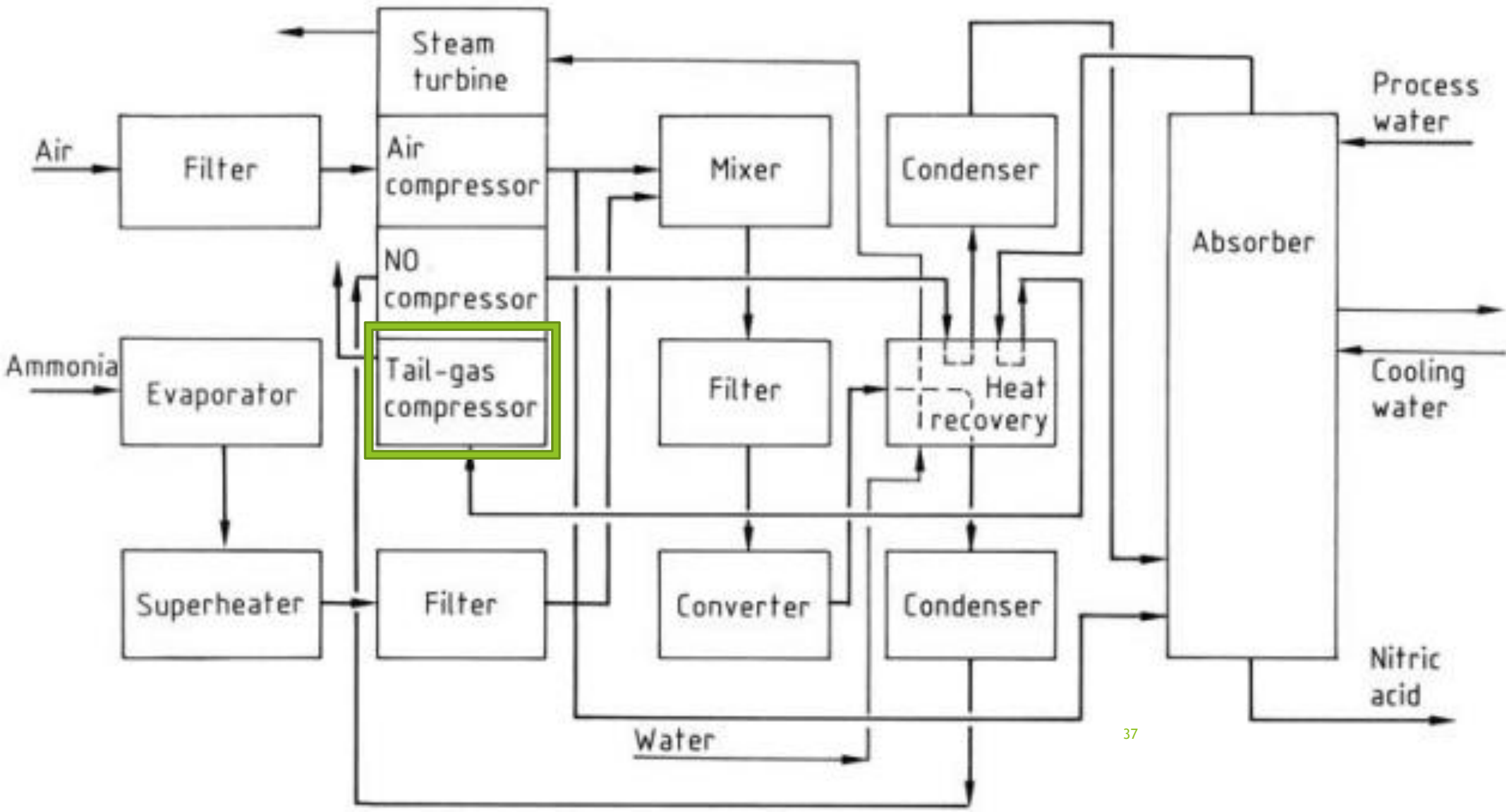


- Pressões parciais

Torre de absorção

► FT 3





Tratamento de NO_x

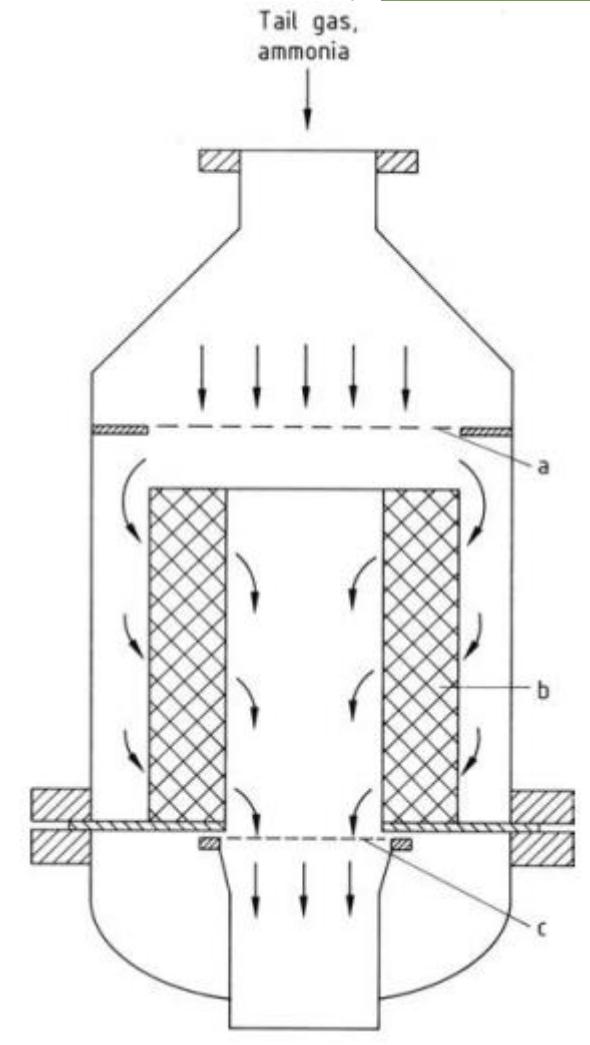
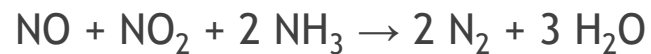
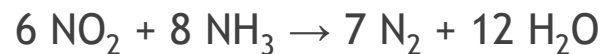
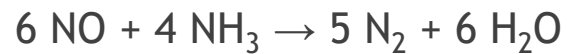
- Conversão catalítica não seletiva

- Pt, V₂O₅, Óxido de Ferro, Titânio

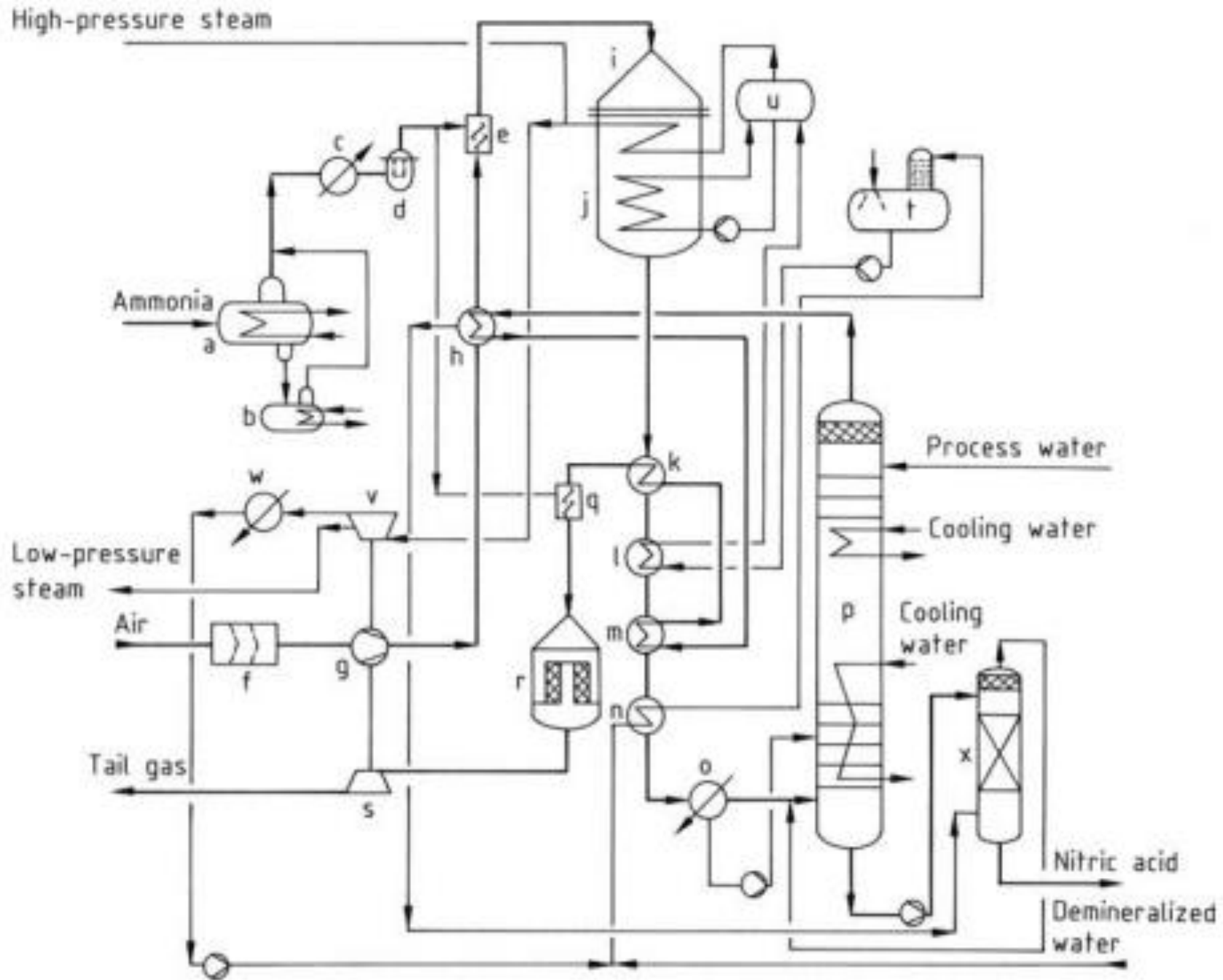


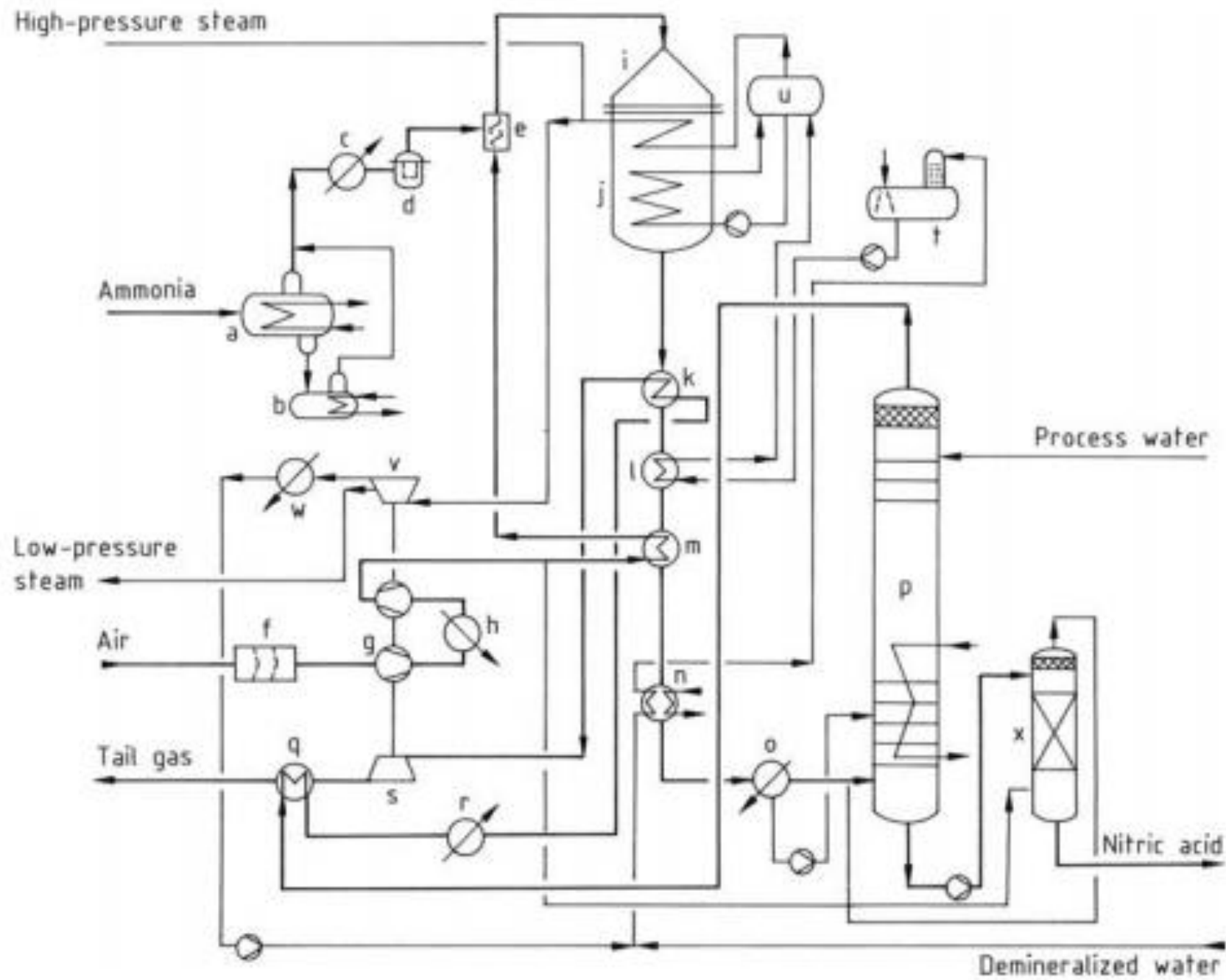
- Conversão catalítica seletiva

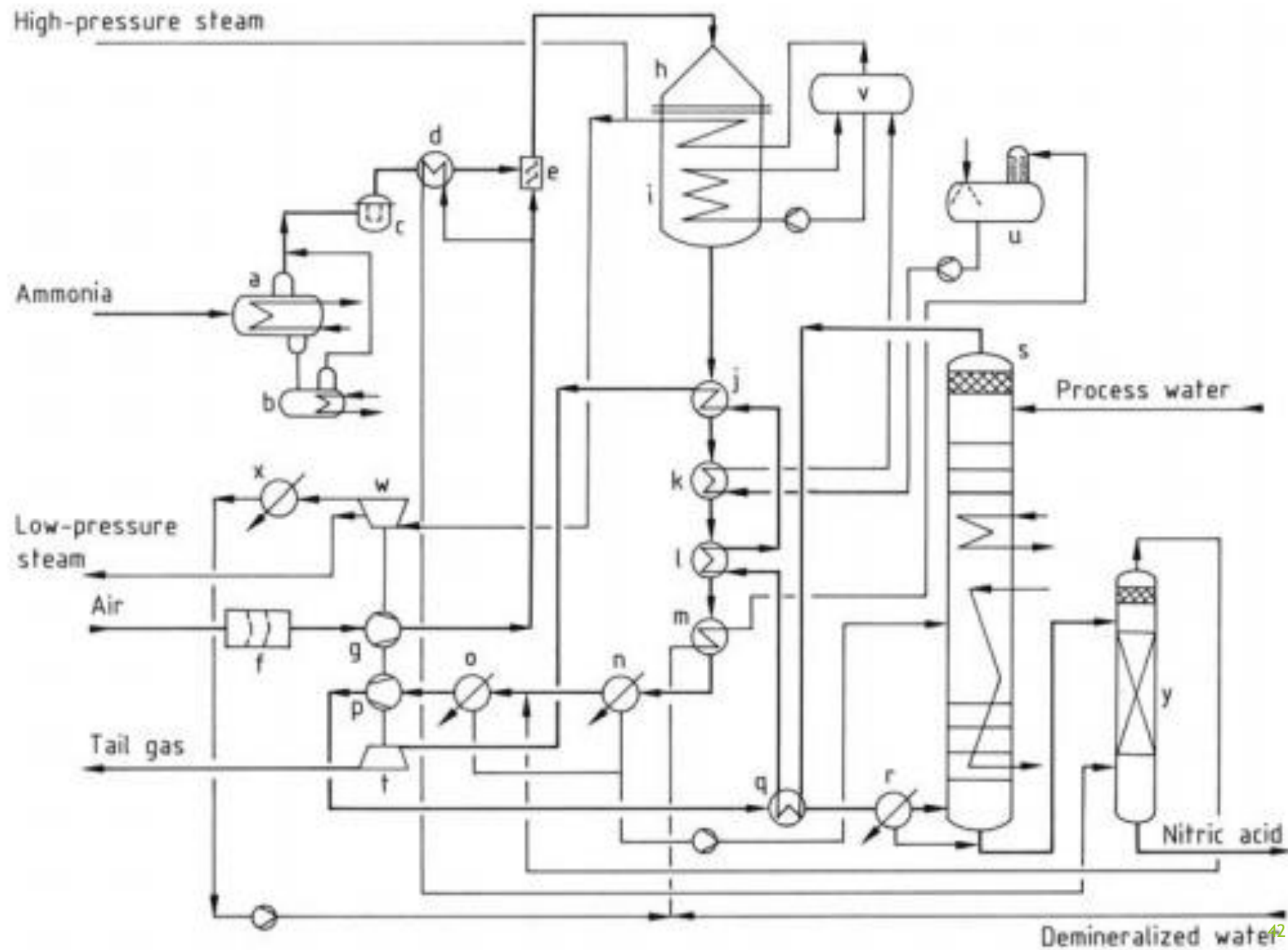
- Usa amônia



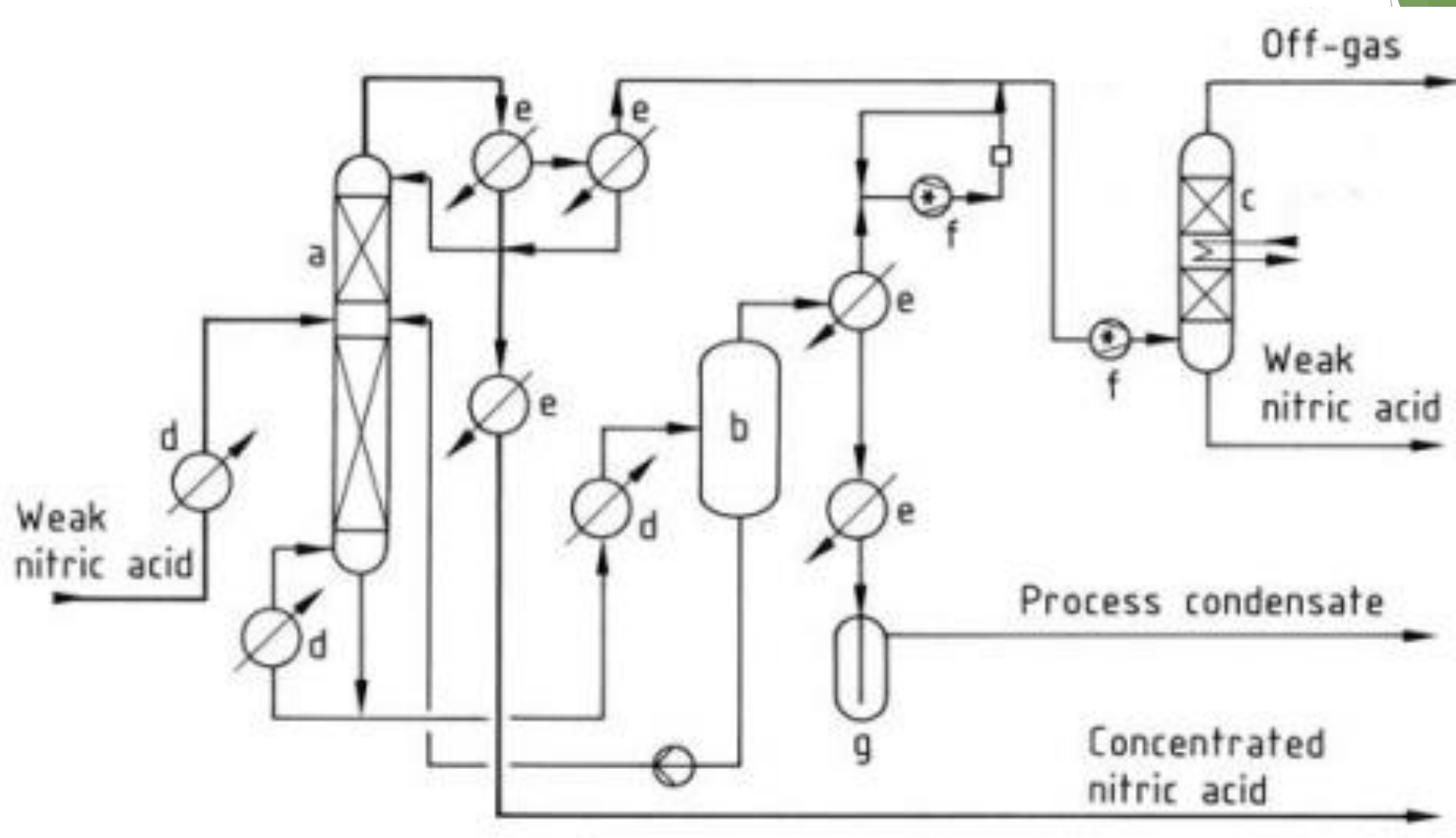
Fluxograma de rotas tecnológicas

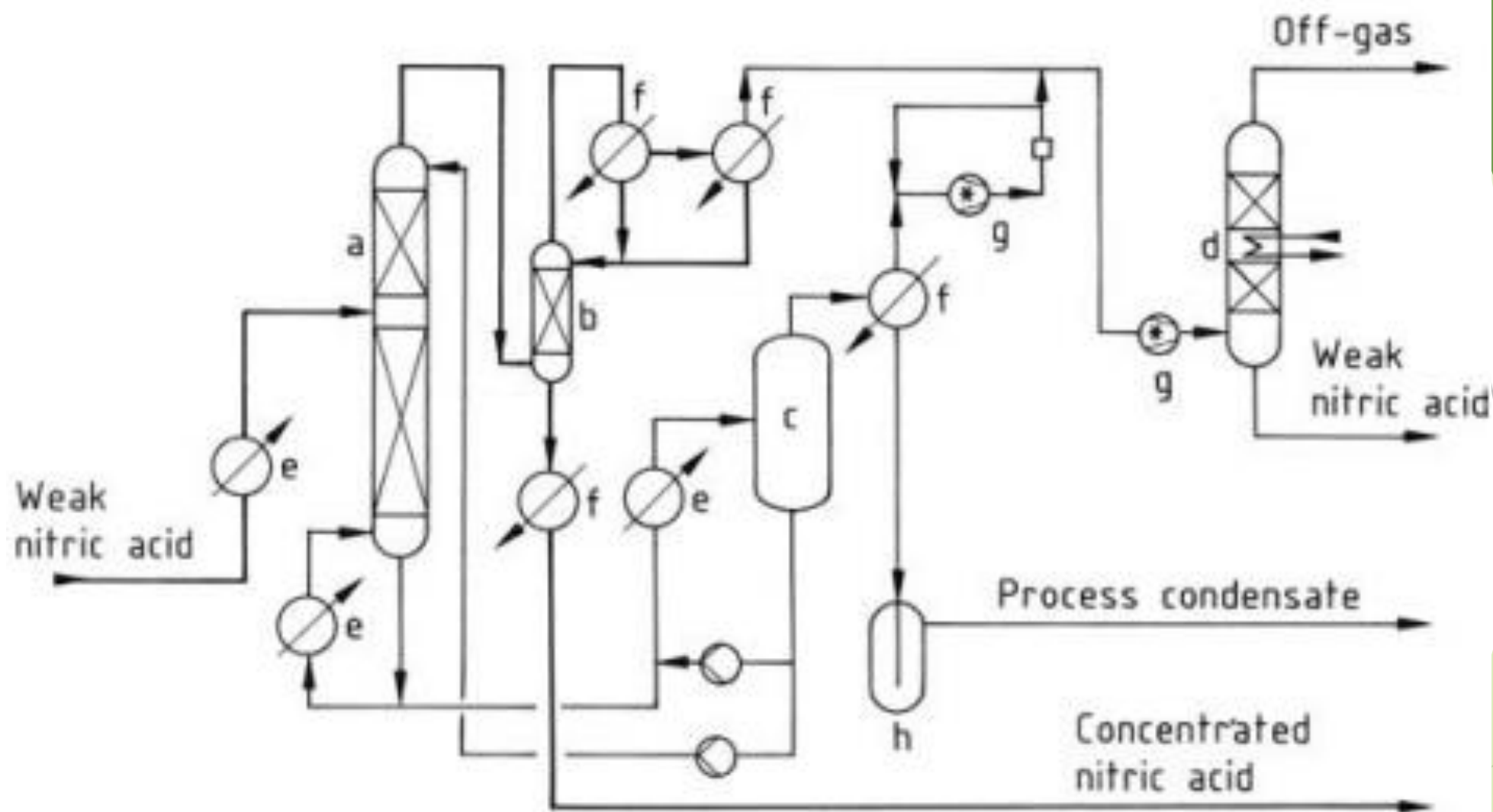






- Processo de duas pressões pressão (queimador e absorvedor)





Referências

- ▶ [1] ANDREW, S. P. S. Ammonia, Nitric Acid, Ammonium Nitrate and Urea. In: THOMPSON, R. Industrial Inorganic Chemicals: Production and uses. Cambridge: The Royal Society of Chemistry, 1995. Cap. 6, p. 149-173.
- ▶ [2] APPL, M. **Ammonia Principles and Industrial Practice**. New York: Wiley-VCH, 1999. Disponível em: <https://scihub.hkvisa.net/10.1002/9783527613885>
- ▶ [3] APPL, M. Ammonia, 1. Introduction. In: _____ **Ullmann's Encyclopedia of Industrial Inorganic Chemistry**. Dannstadt-Schauernheim: Wiley VCH, v. v.24, 2012a.
- ▶ [4] APPL, M. Ammonia, 2. Production Processes. In: _____ **Ullmann's Encyclopedia of Industrial Inorganic Chemistry**. Dannstadt-Schauernheim: Wiley VCH, v. v.24, 2012b
- ▶ [5] HAUSSINGER, P.; LOHMULLER, R.; WATSON, A. M. Hydrogen. In: _____ **Ullmann's Encyclopedia of Industrial Inorganic Chemistry**. [S.l.]: Wiley-VCH, 2007.
- ▶ [6] PATTABATHULA, V.; RICHARDSON, J. Introduction to Ammonia Production. **American Institute of Chemical Engineers**, Setembro 2016. Disponível em: <<https://www.aiche.org/resources/publications/cep/2016/september/introduction-ammonia-production>>. Acesso em: 27 maio 2021.
- ▶ [7] APPL, M. Ammonia, 3. Production Plants. In: _____ **Ullmann's Encyclopedia of Industrial Inorganic Chemistry**. Dannstadt-Schauernheim: Wiley VCH, v. v.24, 2012c

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- ▶ [7] PATTABATHULA, V.; WILLIAMS, G. One Hundred Years of Ammonia Production - A recap of significant contributions to feeding the world. **Annual Safety in Ammonia Plants and Related Facilities Symposium**, Frankfurt, 54, 2013
- ▶ [8] REIMERT, R. et al. Gas Production, 2. Processes. In: _____ **Ullmann's Encyclopedia of Industrial Chemistry**. [S.l.]: Willey-VCH, v. 16, 2012.
- ▶ [9] THIEMANN, M.; SCHEIBLER, ; WIEGAND, K. W. Nitric Acid, Nitrous Acid, and Nitrogen Oxides. In: _____ **Ullmann's Encyclopedia of Industrial Chemistry**. [S.l.]: Willey VCH, v. 24, 2012