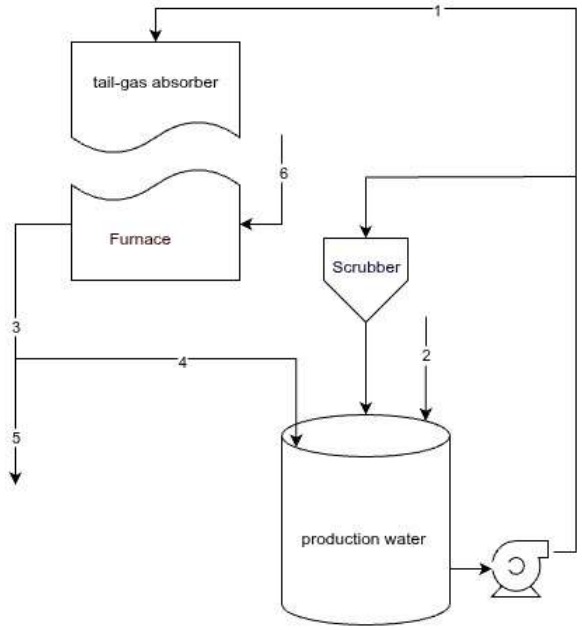
# Calculating HCl Recycle Flow

$$Furnace_{Cl2.load} := [550, 600..800]\ \frac{m^3}{hr} = \begin{bmatrix} 550 \\ 600 \\ 650 \\ 700 \\ 750 \\ 800 \end{bmatrix} \frac{m^3}{hr}$$




$$\rho_{Cl2} := 3.15\ \frac{kg}{m^3} \qquad \rho_{H2O} := 1\ \frac{tonne}{m^3}$$

$$HCl_{gas.prod} := \frac{36.5}{35.5} \cdot \rho_{Cl2} \cdot Furnace_{Cl2.load} = \begin{bmatrix} 1.7813 \\ 1.9432 \\ 2.1052 \\ 2.2671 \\ 2.429 \\ 2.591 \end{bmatrix} \frac{tonne}{hr}$$

$$HCl_{aq.3} := \frac{HCl_{gas.prod}}{0.31} = \begin{bmatrix} 5.7461 \\ 6.2685 \\ 6.7909 \\ 7.3133 \\ 7.8356 \\ 8.358 \end{bmatrix} \frac{tonne}{hr}$$

from DCS observations in comparison with Water.ideal.1

$$Leakage_{H2O.6} := 1.6\ \frac{tonne}{hr}$$

$$Water_{ideal.1} := \left| \begin{array}{l} \text{for } n \in \left[1..\text{length}\left(HCl_{gas.prod}\right)\right] \\ \quad a_n := \text{solve}\left(\dfrac{HCl_{gas.prod_n}}{HCl_{gas.prod_n} + x\ \frac{tonne}{hr}} = 0.31,\ x\right) \\ a\ \frac{tonne}{hr} \end{array} \right. = \begin{bmatrix} 3.9648 \\ 4.3253 \\ 4.6857 \\ 5.0462 \\ 5.4066 \\ 5.767 \end{bmatrix} \frac{tonne}{hr}$$

w.t% diluted acid maintained in tank because of scrubber & recycle 4. This enters tail-gas absorber

$$DiluteAcid_{real.1} := [0, 0.02..0.14] = \begin{bmatrix} 0 \\ 2 \\ 4 \\ 6 \\ 8 \\ 10 \\ 12 \\ 14 \end{bmatrix} \%$$

## Basic Scheme

$$DiluteAcidFeed_{real.1} := \left| \begin{array}{l} \text{for } m \in \left[1..\text{length}\left(DiluteAcid_{real.1}\right)\right] \\ \quad \left| \begin{array}{l} \Sigma H2O_{feed}{}_{m} := Leakage_{H2O.6} + x \cdot \frac{\text{tonne}}{\text{hr}} \cdot \left(1 - DiluteAcid_{real.1}{}_{m}\right) \\ \text{for } n \in \left[1..\text{length}\left(HCl_{gas.prod}\right)\right] \\ \quad \left| \begin{array}{l} \Sigma HCl_{feed}{}_{n} := HCl_{gas.prod}{}_{n} + x \cdot \frac{\text{tonne}}{\text{hr}} \cdot DiluteAcid_{real.1}{}_{m} \\ a_{m\,n} := \text{solve}\left(\frac{\Sigma HCl_{feed}{}_{n}}{\Sigma HCl_{feed}{}_{n} + \Sigma H2O_{feed}{}_{m}} = 0.31,\ x\right) \end{array} \right. \end{array} \right. \\ a \cdot \frac{\text{tonne}}{\text{hr}} \end{array} \right.$$

## deNest Function

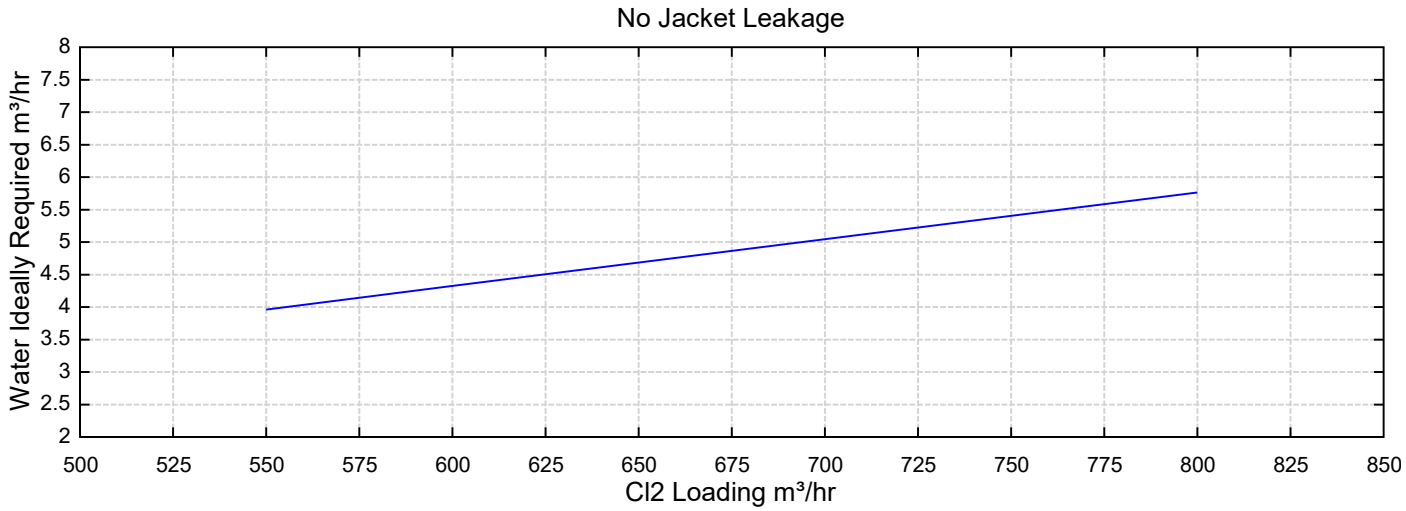
$$Table := \left| \begin{array}{l} horizontal := \text{stack}\left(\text{"Diluted Feed\% ↓ | Cl2 Load m³/h →"},\ DiluteAcid_{real.1} \cdot 100\right) \\ vertical := \text{stack}\left(Furnace_{Cl2.load}{}^{T} \cdot \frac{3600}{1} \cdot \frac{s}{m^3},\ DiluteAcidFeed_{real.1} \cdot \frac{3600}{1000} \cdot \frac{s}{kg}\right) \\ \text{augment}\left(horizontal,\ vertical\right) \end{array} \right.$$

$Table =$

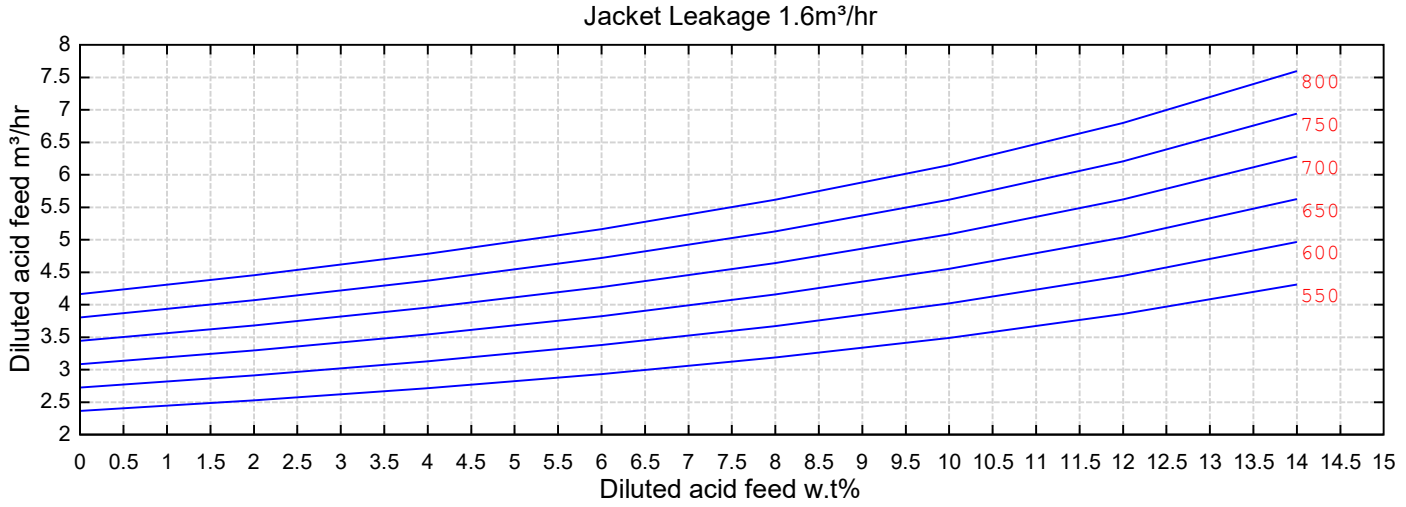
| "Diluted Feed% ↓ \| Cl2 Load m³/h →" | 550 | 600 | 650 | 700 | 750 | 800 |
|---|---|---|---|---|---|---|
| 0 | 2.36 | 2.73 | 3.09 | 3.45 | 3.81 | 4.17 |
| 2 | 2.53 | 2.91 | 3.3 | 3.68 | 4.07 | 4.45 |
| 4 | 2.72 | 3.13 | 3.54 | 3.96 | 4.37 | 4.78 |
| 6 | 2.93 | 3.38 | 3.83 | 4.27 | 4.72 | 5.17 |
| 8 | 3.19 | 3.67 | 4.16 | 4.64 | 5.13 | 5.62 |
| 10 | 3.49 | 4.02 | 4.56 | 5.09 | 5.62 | 6.15 |
| 12 | 3.86 | 4.45 | 5.03 | 5.62 | 6.21 | 6.8 |
| 14 | 4.31 | 4.97 | 5.63 | 6.28 | 6.94 | 7.6 |

Plotting curves for various furnace Cl2 loading

$$\left| \begin{array}{l} \text{for } n \in \left[1..\text{cols}\left(DiluteAcidFeed_{real.1}\right)\right] \\ \quad \left| \begin{array}{l} y_{n} := \text{col}\left(DiluteAcidFeed_{real.1} \cdot \frac{3600}{1000} \cdot \frac{s}{kg},\ n\right) \\ plot_{n} := \text{augment}\left(DiluteAcid_{real.1} \cdot 100,\ y_{n}\right) \\ label_{n} := \text{augment}\left(14,\ y_{n}{}_{8},\ \text{var2str}\left(Furnace_{Cl2.load}{}_{n} \cdot 3600 \cdot \frac{s}{m^3}\right),\ 8\right) \end{array} \right. \end{array} \right.$$




$$\left\{\text{augment}\left(\text{Furnace}_{\text{Cl2.load}}\cdot\frac{3600}{1}\ \frac{\text{s}}{\text{m}^3},\ \text{Water}_{\text{ideal.1}}\cdot\frac{3600}{1000}\ \frac{\text{s}}{\text{kg}}\right)\right.$$




$$\left\{\begin{matrix}\text{plot}\\ \text{deNest}\left(\text{label}\right)\end{matrix}\right.$$

**Balance around production water tank**

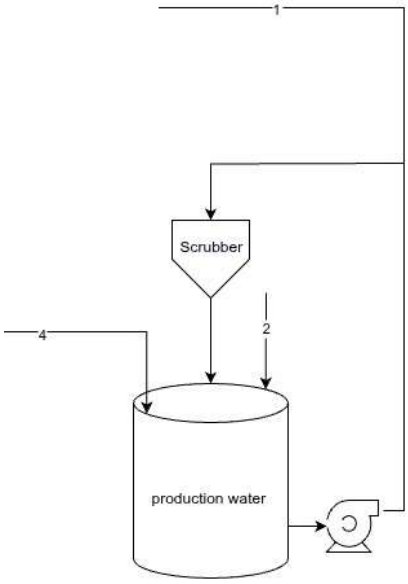
$$DiluteAcid_{Feedvol.1} := [3..7]\ \frac{\text{tonne}}{\text{hr}} = \begin{bmatrix}3\\4\\5\\6\\7\end{bmatrix}\ \frac{\text{tonne}}{\text{hr}}$$

$$DiluteAcid_{FeedConc.1} := [0.02, 0.04..0.10] = \begin{bmatrix}2\\4\\6\\8\\10\end{bmatrix}\ \%$$

$$PureWater_{Feedvol.2} := a\ \frac{\text{tonne}}{\text{hr}}$$

$$Acid_{Feedvol.4} := b\ \frac{\text{tonne}}{\text{hr}}$$

$$Acid_{FeedConc.4} := 0.31$$



## Basic Scheme

$$var := \left| \begin{array}{l} \text{for } m \in \left[1..\text{length}\left(DiluteAcid_{Feedvol.1}\right)\right] \\ \quad \left| \begin{array}{l} \text{for } n \in \left[1..\text{length}\left(DiluteAcid_{FeedConc.1}\right)\right] \\ \quad \left| \begin{array}{l} WB_{m\,n} := Acid_{Feedvol.4} \cdot \left(1 - Acid_{FeedConc.4}\right) + PureWater_{Feedvol.2} - DiluteAcid_{Feedvol.1\,m} \cdot \left(1 - DiluteAcid_{FeedConc.1\,n}\right) \\ AB_{m\,n} := Acid_{Feedvol.4} \cdot Acid_{FeedConc.4} - DiluteAcid_{Feedvol.1\,m} \cdot DiluteAcid_{FeedConc.1\,n} \\ \begin{bmatrix} j_{m\,n} \\ k_{m\,n} \end{bmatrix} := \text{roots}\left(\begin{bmatrix} WB_{m\,n} \\ AB_{m\,n} \end{bmatrix}, \begin{bmatrix} a \\ b \end{bmatrix}\right) \end{array} \right. \end{array} \right. \\ \begin{bmatrix} j \\ k \end{bmatrix} \end{array} \right.$$

$$\begin{bmatrix} PureWater_{Feedvol.2} \\ Acid_{Feedvol.4} \end{bmatrix} := \begin{bmatrix} var_1 \dfrac{\text{tonne}}{\text{hr}} \\ var_2 \dfrac{\text{tonne}}{\text{hr}} \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} 2.806 & 2.613 & 2.419 & 2.226 & 2.032 \\ 3.742 & 3.484 & 3.226 & 2.968 & 2.71 \\ 4.677 & 4.355 & 4.032 & 3.71 & 3.387 \\ 5.613 & 5.226 & 4.839 & 4.452 & 4.065 \\ 6.548 & 6.097 & 5.645 & 5.194 & 4.742 \end{bmatrix} \\ \begin{bmatrix} 0.194 & 0.387 & 0.581 & 0.774 & 0.968 \\ 0.258 & 0.516 & 0.774 & 1.032 & 1.29 \\ 0.323 & 0.645 & 0.968 & 1.29 & 1.613 \\ 0.387 & 0.774 & 1.161 & 1.548 & 1.935 \\ 0.452 & 0.903 & 1.355 & 1.806 & 2.258 \end{bmatrix} \end{bmatrix} \dfrac{\text{tonne}}{\text{hr}}$$

$$RecycleAcid_{31\%} := \left| \begin{array}{l} horizontal := \text{augment}\left("\text{Feed flow tonne/hr} \downarrow \ | \ \text{Feed HCl\%} \rightarrow", DiluteAcid_{FeedConc.1}^{\ T} \cdot 100\right) \\ vertical := \text{augment}\left(DiluteAcid_{Feedvol.1} \dfrac{\text{hr}}{\text{tonne}}, Acid_{Feedvol.4} \dfrac{\text{hr}}{\text{tonne}}\right) \\ \text{stack}\left(horizontal, vertical\right) \end{array} \right.$$

$$PureWater_{Feed} := \left| \begin{array}{l} horizontal := \text{augment}\left("\text{Feed flow tonne/hr} \downarrow \ | \ \text{Feed HCl\%} \rightarrow", DiluteAcid_{FeedConc.1}^{\ T} \cdot 100\right) \\ vertical := \text{augment}\left(DiluteAcid_{Feedvol.1} \dfrac{\text{hr}}{\text{tonne}}, PureWater_{Feedvol.2} \dfrac{\text{hr}}{\text{tonne}}\right) \\ \text{stack}\left(horizontal, vertical\right) \end{array} \right.$$

$$RecycleAcid_{31\%} = \begin{bmatrix} \text{"Feed flow tonne/hr} \downarrow \ | \ \text{Feed HCl\%} \rightarrow" & 2 & 4 & 6 & 8 & 10 \\ 3 & 0.194 & 0.387 & 0.581 & 0.774 & 0.968 \\ 4 & 0.258 & 0.516 & 0.774 & 1.032 & 1.29 \\ 5 & 0.323 & 0.645 & 0.968 & 1.29 & 1.613 \\ 6 & 0.387 & 0.774 & 1.161 & 1.548 & 1.935 \\ 7 & 0.452 & 0.903 & 1.355 & 1.806 & 2.258 \end{bmatrix}$$

$$PureWater_{Feed} = \begin{bmatrix} \text{"Feed flow tonne/hr} \downarrow \ | \ \text{Feed HCl\%} \rightarrow" & 2 & 4 & 6 & 8 & 10 \\ 3 & 2.806 & 2.613 & 2.419 & 2.226 & 2.032 \\ 4 & 3.742 & 3.484 & 3.226 & 2.968 & 2.71 \\ 5 & 4.677 & 4.355 & 4.032 & 3.71 & 3.387 \\ 6 & 5.613 & 5.226 & 4.839 & 4.452 & 4.065 \\ 7 & 6.548 & 6.097 & 5.645 & 5.194 & 4.742 \end{bmatrix}$$