

Calculation Cover Sheet

TSS - Environmental Solutions
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Purpose:

Order of Magnitude Cost Estimate for Treatment of Combustion Residual Leachate at Plant Scherer (GPC) as required by 40 CFR 423.

Estimate is performed using Lang Factors, Ratios, and Proportional adjustments based on previously bid or awarded equipment of a similar nature. Estimate methodology is discussed in the following sheets.

Regulation:

The Supplemental ELG regulations (40 CFR 423) Section 423.13.(l) describe requirements for treatment of Combustion Residual /Leachate (CRL).

At Scherer, this estimate assumes Leachate to be treated under two provisions of this rule including (1) the 2024 BAT which directs Zero Liquid Discharge (ZLD), and (2) discharge of unmanaged combustion residual leachate which requires numeric Arsenic and Mercury effluent limitations.

Waste Streams Considered:

1. Zero Liquid Discharge - (1) From Existing PACash CCR Landfill Cell,
(2) From (Future) CCR Landfill Cell 3.
2. Uncontrolled CRL - From Ash Pond Bolster Sump System (Design by AECOM).

Fixed Capital Estimate (Lang Factor Method - Adjusted For Equipment Sizing)

1. Zero Liquid Discharge:
2. Uncontrolled CRL:

Total:

██████████
██████████
██████████
██████████

Process Equipment Cost Estimate

Accuracy Level: Order of Magnitude Estimate (OME)

AACE Class 5, Low: -20% to -50%, High +30% to +100%

References:

- a. Kolmetz Handbook of Process Equipment Design, KLM Technology Group
- b. Process Equipment Cost Estimating by Ratio and Proportion, PDH Center, Randall Whitesides, PE
- c. Cost Relationships in Preliminary Cost Estimation, Chemical Engineering, H.J. Lang
- d. Six-tenths Factor Aids in Approximating Costs, Chemical Engineering, Roger Williams, Jr.
- e. Data and Techniques for Preliminary Capital Cost Estimating, Chemical Engineering, K.M. Guthrie
- f. Chemical Engineering Plant Cost Indices (CEPCI)

Overview:

Fixed capital may be defined as the total cost of processing installations, buildings, auxiliary services, and engineering involved in the creation of a new plant. Capital must be allocated for direct plant expenses, such as those for raw materials, labor, and equipment.

The capital needed to supply the necessary manufacturing and plant facilities is called the fixed capital investment, while that necessary for the initial operation of the plant is termed the working capital (funds required before creating a final end product available for sale). The sum of the fixed-capital investment and the working capital is known as the total capital investment.

This Cost Estimate will include the Fixed Capital Investment based on the equipment proposed. Working Capital estimate not applicable.

Internal factors such as cost of capital, AFUDC, escalation, contingency, corporate overhead, and allocated funds are excluded and should be applied using the corporate factors in place at the time of the estimate.

(A) Ratio and Proportions Method (Fixed Capital Cost):

Lang Factor Cost Estimation Method:

A simple technique to estimate the capital cost of a chemical plant is the Lang Factor method. The Lang factor method has a tendency to produce high results. The total cost is determined by multiplying the total purchased cost for all the major items of equipment by a constant. The multipliers, depending on the type of plant are given in table 2^[10].

Table 2: Lang factor

Type of chemical plant	Lang factor, F_{Lang}
Solid processing	3.10
Solid – fluid processing	3.63
Fluid processing	4.74

The capital cost calculation is determined using Equation 1.

$$C_T = F_{Lang} \sum_{i=1}^n C_{p,i} \quad \text{Eq (1)}$$

Where,

- C_T = Capital cost of the plant
- $C_{p,i}$ = Purchased cost for the major equipment units
- n = Total number of individual units
- F_{Lang} = Lang Factor

Ref (a), (c)

(B) Adjustment for Equipment Sizing by Ratio and Proportion Estimating:

A ratio indicates the relationship between two (or more) items in quantity, amount, or size.

Proportion implies that the two (or more) items are similar, differing only in magnitude.

When preparing these preliminary estimates, equipment costs can be scaled by the Rule of Six-Tenths.

Approximate costs can be obtained if the cost of a similar item of different size or capacity is known.

The following equation expresses the rule of Six-Tenths:

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^{0.6}$$

Where C_B = the approximate cost (\$) of equipment having size S_B (cfm, Hp, ft², or whatever)

C_A = is the known cost (\$) of equipment having corresponding size S_A (same units as S_B),
and S_B/S_A is the ratio known as the *size factor*, dimensionless.

Ref (b), (d)

If a more sophisticated approach is desired, Table 1 can be used to modify the exponent used in the calculation above. Table 1 was condensed from an exhaustive tabulation provided by Guthrie in Reference (e).

Using Table 1 size exponents transforms the previously presented formula into,

$$C_B = C_A \left(\frac{S_B}{S_A} \right)^N$$

Where the symbols are identical to those already described and N is the *size exponent*, dimensionless, from Table 1:

Ref (b), (e)

PROCESS EQUIPMENT SIZE EXPONENT (N) - TABLE 1		
EQUIPMENT NAME	UNIT	SIZE EXPONENT (N)
Agitator, propeller	Hp	0.50
Agitator, turbine	Hp	0.30
Air compressor, single stage	cfm	0.67
Air compressor, multiple stage	cfm	0.75
Air dryer	cfm	0.56
Boiler, industrial, all sizes	lb/hr	0.50
Boiler, package	lb/hr	0.72
Centrifuge, horizontal basket	dia (inches)	1.72
Centrifuge, solid bowl	dia (inches)	1.00
Conveyor, belt	feet	0.65
Conveyor, bucket	feet	0.77
Conveyor, screw	feet	0.76
Conveyor, vibrating	feet	0.87
Crystallizer, growth	ton/day	0.65
Crystallizer, forced circulation	ton/day	0.55
Crystallizer, batch	gallons	0.70

Ref (b), (e)

PROCESS EQUIPMENT SIZE EXPONENT (N) - TABLE 1		
EQUIPMENT NAME	UNIT	SIZE EXPONENT (N)
Dryer, drum and rotatory	sq. ft.	0.45
Dust collector, cyclone	cfm	0.80
Dust collector, cloth filter	cfm	0.68
Dust collector, predipitator	cfm	0.75
Evaporator, forced circulation	sq. ft.	0.70
Evaporator, vertical and horizontal tube	sq. ft.	0.53
Fan	Hp	0.66
Filter, plate and press	sq. ft.	0.58
Filter, pressure leaf	sq. ft.	0.55
Heat exchanger, fixed tube	sq. ft.	0.62
Heat exchanger, U-tube	sq. ft.	0.53
Mill, ball and roller	ton/hr	0.65
Mill, hammer	ton/hr	0.85
Pump, centrifugal carbon steel	Hp	0.67
Pump, centrifugal stainless steel	Hp	0.70
Tanks and vessels, pressure, carbon steel	gallons	0.60
Tanks and vessels, horizontal, carbon steel	gallons	0.50
Tanks and vessels, stainless steel	gallons	0.68

(C) Adjustment of Estimate Based on Historical Cost Indices

Cost Indices are useful when basing the estimated costs of a project on other than current prices.

Choice of the Cost Index to apply is at the discretion of the estimating engineer.

Several indices may include:

- Consumer Price Index (CPI),
- Engineering News Record (ENR),
- Chemical Engineering Plant Cost Index (CEPCI),
- Marshall and Swift Equipment Cost Index (M&S)

Cost indexes are numerical values that reflect historical change in engineering costs. The cost index numbers are dimensionless, and reflect relative price change in either individual cost items such labor, material, utilities; or groups of costs such consumer prices, producer prices. Indexes can be used to update historical costs with the basic ratio relationship as follows^[6].

$$C_2 = C_1 \left(\frac{I_2}{I_1} \right) \quad \text{Eq (2)}$$

where,

C_1 = Estimated cost at previous time

C_2 = Cost at expected time

I_1 = Index value at expected time

I_2 = Index value at previous time

Ref (a), (f)

(D) Total Capital Cost Estimate (Adjusted for Size)(Adjusted for Inflation)

The Fixed Capital Cost, adjusted for system size and inflation is a multiplication of the factors discussed in the preceding paragraphs.

$$CT = F_{Lang} \sum_{i=1}^n Cp,i * \left(\frac{Sb}{Sa}\right)^N * \left(\frac{I2}{I1}\right)$$

Calculation Summary (ZLD Portion)

Reference Plant Description

Process Estimate is for equipment and treatment as required by the Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (40CFR Part 423). One portion of this treatment system requires Zero Liquid Discharge for Combustion Residual Leachate while a second portion requires treatment for Arsenic and Mercury removal for a waste stream classified as uncontrolled leachate.

For the Zero Liquid Discharge Stream, the Reference Plant is a Thermal Evaporator/Crystallizer Unit (Mechanical Vapor Recompression) proposed for treatment of Softened Reverse Osmosis Brine produced from the FGD Process at Plant Scherer. Thermal Energy is supplied by Electric Heaters and Mechanical Components since no waste heat or natural gas is available at the site. The Process includes both liquid evaporation and solids handling steps which lend to the use of the mid-range Lang Factor for Total Installed Costs. Select vendors offer modularized and prepackaged units that may afford some cost reductions (i.e. smaller Lang Factor 1.7 Reported) (to be addressed by more detailed project estimates).

A. Lang Factor Estimate Method (ZLD Portion)

Notes / Comments

Chemical Plant Type	Lang Factor F - Lang
Solids Process	3.10
Solid-Liquid Process	3.63
Liquid Process	4.74

Lang Factor - Selected

F- Lang

3.63

Total Equipment Cost (Reference Plant)

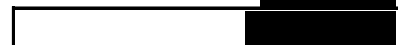
Cp,i

\$

Capital Cost (Reference Plant)

CT

\$



Solid - Liquid Process

4-Vendor Average Cost

B. Adjustment for Equipment Sizing By Ratio and Proportions Method

Capital Cost (Reference Plant)	Ca	\$		
Reference Plant Size (GPM, HP, cfm, etc.)	Sa	GPM	45	
Proposed Plant Size (GPM, HP, cfm, etc.)	Sb	GPM	30	PacAsh + Future Cell 3 (CRL)
Sizing Exponent (0.6 or Table I1)	N	-	0.55	Table (1) - FC Crystallizer
Capital Cost (Proposed Plant)	Cb	\$		

C. Adjustment Based on Historical Cost Indices Method

Capital Cost (Current Time)	C1	\$		
Cost Index Value (Current Time)	I1	Value	607.5	CEPCI - 2019, Future 2024
Current Year	Y1	Year	2019	
Cost Index Value (Proposed Time)	I2	Value	800.3	CEPCI - 2024, Future 2029
Proposed Year	Y2	Year	2024	
Effective Annual Inflation Rate	i	%	5.67%	Historical 2019 - 2024, applied Forward 2024-2029
Capital Cost (Proposed Time)	C2	\$		2029 Completion Date

D. Total Capital Cost Estimate (Adjusted For Size)(Adjusted for Inflation)

Capital Cost (Proposed Plant)	
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Calculation Summary (Uncontrolled CRL Portion)

Reference Plant Description

Process Estimate is for equipment and treatment as required by the Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (40CFR Part 423). One portion of this treatment system requires Zero Liquid Discharge for Combustion Residual Leachate while a second portion requires treatment for Arsenic and Mercury removal for a waste stream classified as uncontrolled leachate.

For the Uncontrolled Leachate portion, physical/chemical processes and adsorptive treatment processes are available to meet Arsenic and Mercury removal rates specified in the ELG Rule. During Ash Pond Closure, this CRL is returned to the Ash Pond to be treated by the temporary Wastewater Treatment System currently installed. This portion of the estimate would apply to installation of a new treatment system, if desired, that allows a smaller flowrate - once the ash pond dewatering system is no longer required.

The Reference Plant is based on Adsorption Treatment Vessels (Qty = 4) operated in series. First set captures mercury and the second set captures arsenic. The permeate from this system will be sent to discharge or reuse. The media, once saturated with the arsenic and mercury captured, will be discarded to landfill and replaced with fresh media. The adsorptive technology was selected due to high modularity and standardization of the design (which allows significant future reduction of the Lang Factor for Total Installed Cost estimation).

A. Lang Factor Estimate Method (Uncontrolled CRL Portion)

Notes / Comments

Chemical Plant Type	Lang Factor F - Lang
Solids Process	3.10
Solid-Liquid Process	3.63
Liquid Process	4.74

Lang Factor - Selected	F- Lang		4.74	Liquid Process (Modular)
Total Equipment Cost (Reference Plant)	Cp,i	\$		
Capital Cost (Reference Plant)	CT	\$		

B. Adjustment for Equipment Sizing By Ratio and Proportions Method

Capital Cost (Reference Plant)	Ca	\$		
Reference Plant Size (GPM, HP, cfm, etc.)	Sa	GPM	50	
Proposed Plant Size (GPM, HP, cfm, etc.)	Sb	GPM	170	Ash Pond Bolster Sumps
Sizing Exponent (0.6 or Table I1)	N	-	0.6	Table (1) - Tanks and Pressure Vessels
Capital Cost (Proposed Plant)	Cb	\$		

C. Adjustment Based on Historical Cost Indices Method

Capital Cost (Current Time)	C1	\$		
Cost Index Value (Current Time)	I1	Value	607.5	CEPCI - 2019, Future 2024
Current Year	Y1	Year	2019	
Cost Index Value (Proposed Time)	I2	Value	800.3	CEPCI - 2024, Future 2029
Proposed Year	Y2	Year	2024	
Effective Annual Inflation Rate	i	%	5.67%	
Capital Cost (Proposed Time)	C2	\$		2029 Completion Date

D. Total Capital Cost Estimate (Adjusted For Size)(Adjusted for Inflation)

Capital Cost (Proposed Plant)	
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