IPM Model – Revisions to Cost and Performance for APC Technologies

Particulate Control Cost Development Methodology

FINAL

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Particulate Control Cost Development Methodology – Final

Technology Description

There are two main particulate capture unit operations employed in the utility industry:

- Electrostatic Precipitator (ESP)
- Fabric Filter (FF)

ESPs have been implemented in the utility industry since the 1960's; there have been a great number of installations in the U.S. and around the world. The ESP collects PM in a three step process: charging, collecting, and cleaning the collected ash off the electrodes. The ESP relies on fly as resistivity to charge and collect the particles. ESPs can reduce PM emissions to below 0.015 lb/MMBtu and opacity below 10% depending on the ash characteristics and particulate loading. However, it is difficult to collect fly ash when burning low sulfur coal because of high fly ash resistivity requiring large ESP. ESPs are not well suited for processes that are highly variable because the collection efficiency is sensitive to fluctuations in gas stream conditions.

Recently fabric filters (specifically pulse-jet type or PJFF) have become the preferred choice for new and retrofit utility particulate capture. PJFFs have been utilized commercially for over 25 years and are considered a mature technology. Modern PJFFs are reliable, versatile and cost effective. In a PJFF, particulate matter is collected on a fabric bag; then the particles are cleaned off the bag surfaces with a pulse of air. During cleaning, the collected particulate falls into hoppers and is removed via an ash handling system to a silo. PJFF suppliers provide guarantees as low as 0.010 lb/MMBtu depending on the application.

Co-Benefits

Due to the filter cake inherent in PJFFs, PJFF units have additional benefits that are not available in ESPs:

- Mercury removal is enhanced by a PJFF by contacting the flue gas with the unburned carbon in the fly ash;
- Collection of injected activated carbon with a PJFF can dramatically increase the mercury removal from the flue gas versus an ESP particulate collector;
- With in-duct dry sorbent injection, the SO_2 removal can be greatly increased when an PJFF is used versus an ESP for the sorbent capture; and
- Acid gases are removed when the flue gas is passed through the filter cake in a PJFF.

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Establishment of Cost Basis

The major cost driver for a baghouse is the required gross air-to-cloth (A/C) ratio. When the baghouse is installed in a retrofit situation following another collection device, such as an ESP, then an A/C of 6.0 would be appropriate if activated carbon injection is applied for mercury removal.

If the baghouse will be used as the sole particulate capture unit operation, an A/C of 4.0 should be specified. The lower A/C ratio will provide better bag life with the high inlet particulate loading expected for the single particulate capture device in the process.

Cost data from the S&L current database of projects, for several different baghouse installations, was reviewed and a relationship was developed for the capital costs of the system on a flue gas rate basis. The capital costs include:

- Duct work modifications,
- Foundations,
- Structural steel,
- ID fan modifications or new booster fans, and
- Electrical modifications.

Methodology

Inputs

Several input variables are required in order to predict the total future retrofit costs:

- Type of coal,
- Unit size,
- Unit heat rate, and
- Baghouse required size.

A retrofit factor that equates to difficulty in construction of the system must be defined.

Outputs

Total Project Costs (TPC)

A base installed cost for the baghouse is calculated (BM). The base installed cost is then increased by:

- Engineering and construction management costs at 10% of the BM cost;
- Labor adjustment for 6 x 10 hour shift premium, per diem, etc., at 5% of the BM cost; and
- Contractor profit and fees at 5% of the BM cost.

A capital, engineering, and construction cost subtotal (CECC) is established as the sum of the BM and the additional engineering and construction fees.

Additional costs and financing expenditures for the project are computed based on the CECC. Financing and additional project costs include:

- Owner's home office costs (owner's engineering, management, and procurement) at 5% of the CECC; and
- Allowance for Funds Used During Construction (AFUDC) at 6% of the CECC is added to account for AFUDC based on a complete project duration of 2 years.

The total project cost is based on a multiple lump sum contract approach. Should a turnkey engineering procurement construction (EPC) contract be executed, the total project cost would be 10 to 15% higher than what is currently estimated.

Escalation is not included in the estimate. The total project cost (TPC) is the sum of the CECC and the additional costs and financing expenditures.

Fixed O&M (FOM)
The fixed operating and maintenance (O&M) cost is a function of the additional operations staff (FOMO), maintenance labor and materials (FOMM), and administrative labor (FOMA) associated with the baghouse installation. The FOM is the sum of the FOMO, FOMM, and FOMA.

The following factors and assumptions underlie calculations of the FOM:

- All of the FOM costs were tabulated on a per kilowatt-year (kW-yr) basis.
- In general, 0 additional operators are required for a baghouse.
- The fixed maintenance materials and labor is a direct function of the process capital cost (BM).
- The administrative labor is a function of the FOMO and FOMM.

Variable O&M (VOM)
Variable O&M is a function of:

- Bag and cage replacement.

The following factors and assumptions underlie calculations of the VOM:

- All of the VOM costs were tabulated on a per megawatt-hour (MWh) basis.
- Bag and cage replacement every 3 and 9 years respectively for unit operations with 6.0 A/C.
- Bag and cage replacement every 5 and 10 years respectively for unit operations with 4.0 A/C.

Input options are provided for the user to adjust the variable O&M costs per unit. Average default values are included in the base estimate. The variable O&M costs per unit options are:

- Bag and cage costs in $/item.

The variables that contribute to the overall VOM are:

VOMB = Variable O&M costs for bags and cage replacement

The total VOM is the VOMB. The additional auxiliary power requirement is reported as a percentage of the total gross power of the unit.

Table 1 contains an example of the complete capital and O&M cost estimate worksheet for a baghouse installation.

Table 1. Example Complete Cost Estimate for a 4.0 A/C Baghouse Installation (Costs are all based on 2009 dollars)

Variable	Designation	Units	Value	Calculation
Unit Size (Gross)	A	(MW)	500	<--- User Input
Retrofit Factor	B		1	<--- User Input (An "average" retrofit has a factor = 1.0)
Gross Heat Rate	C	(Btu/kWh)	9500	<--- User Input
Type of Coal	D		Bituminous	<--- User Input
Baghouse Air-to-Cloth Ratio	E		4.0 A/C Ratio	<--- User Input
Heat Input	F	(Btu/hr)	4.75E+09	= A*C*1000
Flue Gas Rate	G	(acfm)	2,068,502	Downstream of an air preheater For Bituminous Coal = A*C*0.435 For PRB Coal = A*C*0.400 For Lignite Coal = A*C*0.362
Aux Power	**H**	**(%)**	**0.60**	0.6 default value **Should be used for model input.**
Aux Power Cost	J	($/kWh)	0.06	
Bag Cost	K	($/bag)	80	
Cage Cost	L	($/cage)	30	
Operating Labor Rate	M	($/hr)	60	Labor cost including all benefits

Capital Cost Calculation	Example		Comments
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty			
BM ($) = if(E = 6.0 Air-to-Cloth then 422, E = 4.0 Air-to-Cloth then 476)*B*G^0.81	$	62,128,000	Base module for an additional baghouse including: ID or booster fans, piping, ductwork, etc…
BM ($/KW) =		124	Base module cost per kW
Total Project Cost			
A1 = 10% of BM	$	6,213,000	Engineering and Construction Management costs
A2 = 5% of BM	$	3,106,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 5% of BM	$	3,106,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3	**$**	**74,553,000**	Capital, engineering and construction cost subtotal
CECC ($/kW) =		**149**	Capital, engineering and construction cost subtotal per kW
B1 = 5% of CECC	$	3,728,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
B2 = 6% of CECC + B1	$	4,697,000	AFUDC for baghouse: 6% for a 2 year engineering and construction cycle
TPC ($) = CECC + B1 + B2 + C1 + C2	**$**	**82,978,000**	Total project cost
TPC ($/kW) =		**166**	Total project cost per kW
Fixed O&M Cost			
FOMO ($/kW yr) = (0 additional operators)*2080*M/(A*1000)	$	-	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = BM*0.005/(B*A*1000)	$	0.62	Fixed O&M additional maintenance material and labor costs
FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM)	$	0.01	Fixed O&M additional administrative labor costs
FOM ($/kW yr) = FOMO + FOMM + FOMA	**$**	**0.63**	Total Fixed O&M costs
Variable O&M Cost			
VOMB ($/MWh) = if(E = 6.0 Air-to-Cloth then 0.004, E = 4.0 Air-to-Cloth then 0.005)*(K/3+L/9)	$	0.15	Variable O&M costs for bags and cages.
VOM ($/MWh) = VOMB	**$**	**0.15**	

Table 2. Example Complete Cost Estimate for a 6.0 A/C Baghouse Installation (Costs are all based on 2009 dollars)

Variable	Designation	Units	Value	Calculation
Unit Size (Gross)	A	(MW)	500	<--- User Input
Retrofit Factor	B		1	<--- User Input (An "average" retrofit has a factor = 1.0)
Gross Heat Rate	C	(Btu/kWh)	9500	<--- User Input
Type of Coal	D		Bituminous	<--- User Input
Baghouse Air-to-Cloth Ratio	E		6.0 A/C Ratio	<--- User Input
Heat Input	F	(Btu/hr)	4.75E+09	= A*C*1000
Flue Gas Rate	G	(acfm)	2,068,502	Downstream of an air preheater For Bituminous Coal = A*C*0.435 For PRB Coal = A*C*0.400 For Lignite Coal = A*C*0.362
Aux Power	**H**	**(%)**	**0.60**	0.6 default value **Should be used for model input.**
Aux Power Cost	J	($/kWh)	0.06	
Bag Cost	K	($/bag)	80	
Cage Cost	L	($/cage)	30	
Operating Labor Rate	M	($/hr)	60	Labor cost including all benefits

Capital Cost Calculation		Example	Comments
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty			
BM ($) =	if(E = 6.0 Air-to-Cloth then 422, E = 4.0 Air-to-Cloth then 476)*B*G^0.81	$ 55,080,000	Base module for an additional baghouse including: ID or booster fans, piping, ductwork, etc…
BM ($/KW) =		110	Base module cost per kW
Total Project Cost			
A1 = 10% of BM		$ 5,508,000	Engineering and Construction Management costs
A2 = 5% of BM		$ 2,754,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 5% of BM		$ 2,754,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3		**$ 66,096,000**	Capital, engineering and construction cost subtotal
CECC ($/kW) =		**132**	Capital, engineering and construction cost subtotal per kW
B1 = 5% of CECC		$ 3,305,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
B2 = 6% of CECC + B1		$ 4,164,000	AFUDC for baghouse: 6% for a 2 year engineering and construction cycle
TPC ($) = CECC + B1 + B2 + C1 + C2		**$ 73,565,000**	Total project cost
TPC ($/kW) =		**147**	Total project cost per kW
Fixed O&M Cost			
FOMO ($/kW yr) = (0 additional operators)*2080*M/(A*1000)		$ -	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = BM*0.005/(B*A*1000)		$ 0.55	Fixed O&M additional maintenance material and labor costs
FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM)		$ 0.01	Fixed O&M additional administrative labor costs
FOM ($/kW yr) = FOMO + FOMM + FOMA		**$ 0.56**	Total Fixed O&M costs
Variable O&M Cost			
VOMB ($/MWh) = if(E = 6.0 Air-to-Cloth then 0.004, E = 4.0 Air-to-Cloth then 0.005)*(K/3+L/9)		$ 0.12	Variable O&M costs for bags and cages.
VOM ($/MWh) = VOMB		**$ 0.12**	