



Engineering Procedure

SAEP-341

15 March 2006

Equipment Life Cycle Cost Procedure

Document Responsibility: Consulting Services Dept.

Saudi Aramco DeskTop Standards

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1 Scope

This procedure provides instructions for economically evaluating major equipment purchases with regards to their estimated total ownership cost (Life Cycle Cost) to Saudi Aramco over a fifteen (15) years period. These costs include procurement and operation cost (energy cost and quantifiable periodic maintenance) of the equipment.

This procedure details the requirements for determining Life Cycle Costs (LCC) for purchases of major equipment identified in paragraph 2. The applicable LCC analysis Spreadsheets provide a practical vehicle for performing the required calculations.

2 Applicable Equipment Types and Required LCC Data

Equipment	Required LCC Data
Power Transformers (14-SAMSS-531)	Specified rated load in kW (Lr), guaranteed no load loss in kW at rated voltage (Li), and the guaranteed load loss in kW at the oil / airself-cooled rating for 85°C winding temperature (Lc).
Form-Wound Induction Motors 250 HP and Above (17-SAMSS-502)	Motor rating (kW) and guaranteed efficiency at normal operating load of the driven equipment. <i>LCC analysis is mandatory only for motors of 746 kW (1000 HP) or larger.</i>
Brushless Synchronous Generator (17-SAMSS-510)	Motor rating (kW) and guaranteed efficiency at normal operating load of the driven equipment. <i>LCC analysis is mandatory only for motors of 746 kW (1000 HP) or larger.</i>
Form Wound Brushless Synchronous Motors (17-SAMSS-520)	Motor rating (kW) and guaranteed efficiency at normal operating load of the driven equipment. <i>LCC analysis is mandatory only for motors of 746 kW (1000 HP) or larger.</i>
Centrifugal Compressors (31-SAMSS-001)	Guaranteed brake horsepower in kW at normal operating point. <i>LCC analysis is mandatory only for compressors of 746 kW (1000 HP) driver or larger.</i>
Integrally Geared Centrifugal Compressors (31-SAMSS-006)	Guaranteed brake horsepower in kW at normal operating point. <i>LCC analysis is mandatory only for compressors of 746 kW (1000 HP) driver or larger.</i>
Centrifugal Pumps (31-SAMSS-004)	Guaranteed brake horsepower in kW at normal operating point. <i>LCC analysis is mandatory only for pumps of 746 kW (1000 HP) or larger.</i>
Boilers (32-SAMSS-021)	Guaranteed efficiency at normal operating load.
Fired Heaters (32-SAMSS-029)	Guaranteed efficiency at normal operating load.

3 Applicable Documents

3.1 Saudi Aramco Materials System Specifications

14-SAMSS-531	<i>Power Transformers</i>
17-SAMSS-502	<i>Induction Motors</i>
17-SAMSS-520	<i>Synchronous Motors</i>
17-SAMSS-510	<i>Brushless Synchronous Generator</i>
31-SAMSS-001	<i>Centrifugal Compressors</i>
31-SAMSS-004	<i>Centrifugal Pumps</i>
31-SAMSS-006	<i>Integrally Geared Centrifugal Compressor</i>
32-SAMSS-021	<i>Manufacture of Industrial Boilers</i>
32-SAMSS-029	<i>Manufacture of Fired Heaters</i>

3.2 Saudi Aramco Engineering Standards

SAES-F-001	<i>Design Criteria of Fired Heaters</i>
SAES-G-005	<i>Centrifugal Pumps</i>
SAES-K-402	<i>Centrifugal Compressors</i>
SAES-P-113	<i>Large Electrical Motors</i>
SAES-P-121	<i>Power Transformers</i>

3.3 Saudi Aramco Standards Data Sheet

8150-ENG & 8150-M-ENG	<i>Packaged Integrally Geared Centrifugal Air Compressor Data Sheet</i>
2741-ENG & 2741-M-ENG	<i>Centrifugal Pump Data Sheet for Horizontal Pumps and Vertical In-line Pumps</i>
2748-ENG & 2748-M-ENG	<i>Centrifugal Pump Data Sheet for Vertical Line Shaft Pumps</i>
Form 9550-ENG	<i>Watertube Boiler Data Sheets (herein referred to as data sheet)</i>
175-323700	<i>Manufacture of Fired Heaters</i>

3.4 Life Cycle Cost Spreadsheets

The following spreadsheets are to be used in the analysis and are available in the Forms section of the DeskTop Standards.

<i>LCC-001</i>	<i>Centrifugal Pumps (31-SAMSS-004) *</i>
<i>LCC-002</i>	<i>Centrifugal Pump-Motor Trains (31-SAMSS-004)</i>
<i>LCC-005</i>	<i>Centrifugal Compressors (31-SAMSS-001) *</i>
<i>LCC-006</i>	<i>Centrifugal Compressor-Motor Trains (31-SAMSS-001)</i>
<i>LCC-010</i>	<i>Integrally Geared Centrifugal Compressor-Motor Trains (31-SAMSS-006)</i>
<i>LCC-019</i>	<i>Induction Motors (17-SAMSS-502) *</i>
<i>LCC-020</i>	<i>Synchronous Motors (17-SAMSS-520) *</i>
<i>LCC-023</i>	<i>Power Transformers (14-SAMSS-531)</i>
<i>LCC-024</i>	<i>Boilers (32-SAMSS-021)</i>
<i>LCC-024A</i>	<i>Dual Fuel Boilers (32-SAMSS-021)</i>
<i>LCC-025</i>	<i>Fired Heaters (32-SAMSS-029)</i>
<i>LCC-025A</i>	<i>Dual Fuel Fired Heaters (32-SAMSS-029)</i>

* *These spreadsheets are to be used when buying stand-alone pumps, compressors, or motors. For equipment trains (i.e., motor driven pump train, etc.), the train work sheets are to be used.*

4 Instructions

4.1 SAPMT Submittal of Project Equipment Lists

Saudi Aramco Project Management Team (SAPMT) shall prepare and include the following items in the project proposal documents:

- 4.1.1 A list of the Project's equipment items that are covered by the above SAMSS.
- 4.1.2 A list of equipment items subject to LCC analysis. This list is to be included in schedule G of the contract. A copy is to be sent to Estimating Services Division (ESD/PS&CD) so that they include additional allowances in the ER estimate to cover the differential in equipment cost due to LCC analysis.
- 4.1.3 A list of equipment items with long lead-time delivery that may require expedited SAPMT bid development.
- 4.1.4 A list of the latest applicable energy costs obtained from FPD.

4.2 Equipment Requiring SAPMT Bid Development

For equipment requiring SAPMT bid development prior to contract award (long lead equipment), the following steps shall be implemented:

- 4.2.1 Upon receipt of the equipment bids, SAPMT's technical evaluation shall ensure that the bids contain the required data needed to perform LCC analysis.
- 4.2.2 SAPMT shall submit the bids technical data to CSD for review and shall highlight the technical LCC data (i.e., power, efficiency, operating factor) that will be used in the LCC analysis.
- 4.2.3 CSD shall review the technical bid data along with the LCC data elements and provide comments, if any, to SAPMT within 10 working days.
- 4.2.4 SAPMT shall perform the LCC analysis by utilizing the applicable LCC Spreadsheet (s) to determine the Life Cycle Cost for each acceptable vendor. Other quantifiable cost factors that may significantly impact the economic analysis (such as delivery dates) may be included in the LCC analysis. Inclusions of supplementary cost factors require the prior approval of the project manager and CSD's concurrence.
- 4.2.5 SAPMT shall calculate the savings (S_{LCC}) in life cycle cost according to the following equation:

$$S_{LCC} = LCC_{LIB} - LCC_{LV} \quad (1)$$

where:

LCC_{LV} is the equipment life cycle cost of the vendor with the lowest overall LCC

LCC_{LIB} is the life cycle cost of the vendor with the lowest initial bid

- 4.2.6 Purchase Order (P/O) shall be placed with the vendor having the lowest LCC (LCC_{LV}) if S_{LCC} is equal to \$25000 or 5% of the LIB whichever is higher.
- 4.2.7 After P/O placement, SAPMT shall submit a copy of the final LCC Spreadsheet(s) to Estimating Services Division (ESD/PS&CD) for archiving and to CSD for information.
- 4.2.8 If Project Management awards to a vendor, a purchase order with a potential performance liability based on the provisions of the applicable SAMSS (penalty clause), and the purchase order is to be transferred

("novated") to the successful LSTK contractor on the project, Project Management and/or Purchasing must include provisions in the Novation Agreement that specifically describe the liability being assumed by the contractor.

- 4.2.9 The equipment shall be tested at the vendor facility for guaranteed efficiency if required by the applicable Saudi Aramco Materials Specification (SAMSS) and/or the Project Contract. If the equipment does not meet the specified efficiency, and cannot be corrected within the test tolerance as specified in the SAMSS, a penalty shall be imposed on the supplier as defined in the SAMSS and the Purchase order.

4.3 Equipment Not Requiring SAPMT Bid Development

For Contractor procured equipment (all non long-lead time equipment) the following steps shall be implemented:

- 4.3.1 After evaluating the vendor submittals, the Contractor shall provide the bid technical data, required commercial data per schedule G, and the **equipment site delivery date** for each vendor to SAPMT for review.
- 4.3.2 SAPMT shall review the information to determine if it contains all of the required data needed to complete the LCC analysis and shall require the Contractor to provide any missing or unacceptable data.
- 4.3.3 SAPMT shall provide a copy of the bid technical data including the LCC data elements (operating factor, efficiency at normal load point, etc.), to CSD for review.
- 4.3.4 CSD shall review the technical bid data along with the LCC data elements and provide comments to SAPMT within 10 working days.
- 4.3.5 SAPMT shall perform the LCC analysis by utilizing the applicable LCC Spreadsheet(s) to determine the Life Cycle Cost for each acceptable vendor. Other quantifiable cost factors that may significantly impact the economic analysis (such as savings due to early delivery) may be considered for inclusion in the LCC analysis. Inclusions of supplementary cost factors require the prior approval of the project manager and CSD's concurrence.
- 4.3.6 SAPMT shall calculate the savings (S_{LCC}) in life cycle cost according to the following equation:

$$S_{LCC} = LCC_{LIB} - LCC_{LV} \quad (2)$$

where:

LCC_{LV} is the equipment life cycle cost of the vendor with the lowest overall LCC

LCC_{LIB} is the life cycle cost of the vendor with the lowest initial bid

- 4.3.7 SAPMT shall direct the contractor to place the Purchase Order (P/O) with the vendor having the lowest LCC (LCC_{LV}) if S_{LCC} is equal to 105% or higher of the compensation to the LSTK Contractor (refer to paragraph 4.3.8).
- 4.3.8 If the COMPANY directs the CONTRACTOR to purchase the equipment from any manufacturer technically qualified by the CONTRACTOR other than the CONTRACTOR's proposed source of supply, the COMPANY shall compensate the CONTRACTOR for any difference between the total delivered equipment cost of CONTRACTOR's proposed source of supply and that of the COMPANY directed manufacturer.
- 4.3.9 After P/O placement, SAPMT shall provide a copy of the final LCC Spreadsheet(s) to the Estimating Services Division (ESD/PS&CD) for archiving and to CSD for information.
- 4.3.10 The equipment shall be tested at the vendor facility for guaranteed efficiency if required by the applicable Saudi Aramco Materials Specification (SAMSS) and/or the Project Contract. If the equipment does not meet the specified efficiency, and cannot be corrected within the test tolerance as specified in the SAMSS, a penalty shall be imposed on the contractor as defined in the SAMSS and the Project Contract.

4.4 All Direct Charge Purchases Requiring LCC Analysis

For Direct Charge (D/C) procurement of equipment, the following steps shall be implemented:

- 4.4.1 The Proponent Requisition Originator shall develop the Purchase Requisition (PR) or the Request for Quotation (RFQ) for the subject equipment and forward it to Purchasing for bid development. If the requested equipment requires LCC analysis as specified in the applicable SAMSS, the Requisition shall clearly indicate the required LCC data which the bidders need to provide.
- 4.4.2 Upon receipt of the PR or the RFQ, the Purchasing Buyer shall review the indicated line items and specifications to determine if any of the items require LCC analysis.

- 4.4.3 Upon receipt of bids, the Buyer shall request the Proponent Requisition Originator to perform the technical evaluation.
- 4.4.4 The Buyer shall obtain the latest applicable energy costs from FPD for use in the LCC analysis.
- 4.4.5 The Buyer shall perform the LCC analysis by utilizing the applicable LCC Spreadsheet(s) to determine the Life Cycle Cost for all technically and commercially acceptable vendors.
- 4.4.6 The buyer shall calculate the savings (S_{LCC}) in life cycle cost according to the following equation:

$$S_{LCC} = LCC_{LIB} - LCC_{LV} \quad (3)$$

where:

LCC_{LV} is the equipment life cycle cost of the vendor with the lowest overall LCC cost

LCC_{LIB} is the life cycle cost of the vendor with the lowest initial bid

- 4.4.7 Purchase Order (P/O) placement shall be with the vendor having the lowest LCC (LCC_{LV}) if S_{LCC} is equal to \$25000 or 5% of the LIB whichever is higher.
- 4.4.8 If the equipment cost for the selected equipment is higher than the PR's authorized limit, the Requisition Originator (Proponent) shall initiate a Change Requisition to authorize these additional funds.
- 4.4.9 After P/O placement, Buyer shall submit a copy of the final LCC Spreadsheet to Estimating Services Division (ESD/PS&CD) for archiving and a copy to CSD for information.
- 4.4.10 The equipment shall be tested at the vendor facility for guaranteed efficiency if required by the applicable Saudi Aramco Materials Specification (SAMSS) and/or the Project Contract. If the equipment does not meet the guaranteed efficiency, and cannot be corrected within the test tolerances allowed, a penalty shall be imposed upon the supplier in accordance with the terms and conditions specified in the applicable Purchase Order.

Revision Summary

15 March 2006

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.

Appendix A – Calculation Methods for Life Cycle Cost Analysis

This section is included in this SAEP for clarification purpose only. The logic is already included in the Life Cycle Cost Spreadsheets.

A.1 Centrifugal Pumps and Centrifugal Compressors

Unless otherwise approved by the Coordinator, Rotating Equipment Division, Consulting Services Department, the Life Cycle Cost (LCC) of the centrifugal pumps and centrifugal compressors is determined from the following formula:

$$LCC = IC + OC \quad (4)$$

where:

IC = Initial Cost, \$ (Purchase order cost of all equipment being bought)

OC = Present value of Operating power Cost, \$, for operating period of 15 years

= $P * EF * \text{No. of units being bought}$

P = Equipment Power in kW, at normal flow rate for actual fluid.

EF = Evaluation Factor (\$/kW) will be shown on the data sheet and/or in the quotation request

= $5.85 * EC * AH$

EC = Energy Cost in \$/kWhr

AH = Annual operating Hours

= $OF * 8760$

OF = Operating Factor

= Number of Operating Units divided by the number of units being bought.

A.2 Electrical Motor Driven Centrifugal Pump, Electrical Motor Driven Centrifugal Compressor and Electrical Motor Driven Integrally Geared Compressor Trains

Unless otherwise approved by the Coordinator, Rotating Equipment Division, Consulting Services Department, the Life Cycle Cost (LCC) of the electrical motor driven trains is determined from the following formula:

$$LCC = IC + OC \quad (5)$$

where:

- IC = Initial Cost, \$ (Purchase order cost of all trains being bought)
- OC = Present value of Operating power Cost, \$, for operating period of 15 years

$$= P / (E_m * E_g) * EF * \text{No. of trains being bought}$$
- P = Driven equipment Power in kW, at normal flow rate for actual fluid.
- E_m = Motor Efficiency at normal operating load (decimal)
- E_g = Gear Efficiency at normal operating load (decimal). If there is no gear, E_g = 1
- EF = Evaluation Factor (\$/kW) will be shown on the data sheet and/or in the quotation request

$$= 5.85 * EC * AH$$
- EC = Energy Cost in \$/kWhr
- AH = Annual operating Hours

$$= OF * 8760$$
- OF = Operating Factor

$$= \text{Number of Operating trains divided by the number of trains being bought.}$$

A.3 Electrical Motors

Unless otherwise approved by the Coordinator, Electrical Systems Mechanical Division, Consulting Services Department, the Life Cycle Cost (LCC) of the electrical motors is determined from the following formula:

$$LCC = IC + OC \quad (6)$$

where:

- IC = Initial Cost, \$ (Purchase order cost of all motors being bought)
- OC = Present value of Operating power Cost, \$, for operating period of 15 years

$$= RP * EF * \text{No. of motors being bought}$$
- RP = Required Power in kW

$$= P / E_m$$
- P = Motor load in kW, at normal operating conditions.

- Em = Motor vendor's Guaranteed Efficiency at normal operating load (decimal)
- EF = Evaluation Factor (\$/kW) will be shown on the data sheet and/or in the quotation request
= $5.85 * EC * AH$
- EC = Energy Cost in \$/kWhr
- AH = Annual operating Hours
= $OF * 8760$
- OF = Operating Factor
= Number of Operating motors divided by the number of motors being bought.

A.4 Life Cycle Cost Evaluation for Boilers and Fired Heaters

Unless otherwise approved by the Coordinator, Mechanical & Civil Engineering Division, Consulting Services Department, the Life Cycle Cost (LCC) of the boilers and fired heaters is determined from the following formula:

Single Fuel Services:

$$LCC = IC + OC \quad (7)$$

where:

- IC = Initial Cost, \$ (Purchase order cost of all units being bought)
- OC = Present value of Operating power Cost, \$, for operating period of 15 years
= $CF * EF * \text{No. of units being bought}$
- CF = Consumed Fuel (Heat Release) in MMBTU/hr
= L / EFF
- L = Unit load (Duty) at normal condition (MMBTU/hr) provided in the data sheet by the buyer.
- EFF = Unit Efficiency (decimal) at normal condition provided by vendor.
- EF = Evaluation Factor (\$-hr / MMBTU) will be shown on the data sheet and/or in the quotation request
= $5.85 * EC * AH$
- EC = Energy Cost in \$/MMBTU
- AH = Annual operating Hours
-

$$= OF * 8760$$

OF = Operating Factor

= Number of Operating units divided by the number of units being bought. OF = 1 for process heaters since there is no standby process heaters.

Dual Fuel Services:

$$LCC = IC + OC_x + OC_y \quad (8)$$

where:

IC = Initial Cost, \$ (Purchase order cost of all units being bought)

OC_x = Present value of Operating power Cost, \$, for operating period of 15 years

$$= CF_x * EF_x * \text{No. of units being bought}$$

OC_y = Present value of Operating power Cost, \$, for operating period of 15 years

$$= CF_y * EF_y * \text{No. of units being bought}$$

CF_x = Consumed Fuel (Heat Release) in MMBTU/hr

$$= L_x / EFF$$

CF_y = Consumed Fuel (Heat Release) in MMBTU/hr

$$= L_y / EFF$$

EF_x = Evaluation Factor for fuel type x (\$-hr / MMBTU) will be shown on the data sheet and/or in the quotation request

$$= 5.85 * EC_x * T_x / AH$$

EF_y = Evaluation Factor for fuel type y (\$-hr / MMBTU) will be shown on the data sheet and/or in the quotation request

$$= 5.85 * EC_y * T_y / AH$$

L = Unit load (Duty) at normal condition (MMBTU/hr) provided in the data sheet by the buyer.

EFF = Unit Efficiency (decimal) at normal condition provided by vendor.

EC = Energy Cost in \$/MMBTU

AH = Annual operating Hours

$$= OF * 8760$$

OF = Operating Factor

= Number of Operating units divided by the number of units being bought. OF = 1 for process heaters since there is no standby process heaters

Note: x & y are the types of fuel that will be provided in the data sheets by buyer.

A.5 Power Transformers

Unless otherwise approved by the Coordinator, Electrical Systems Mechanical Division, Consulting Services Department, the Life Cycle Cost (LCC) of the power transformers is determined from the following formula:

$$LCC = IC + (\text{No. of transformers being bought} * (A * Li + B * Lc)) \quad (9)$$

where:

IC = Initial Cost, \$ (Purchase order cost of all transformers being bought)

$A * Li$ = Present value of no-load loss cost in \$, for operating period of 15 years

$B * Lc$ = Present value of load loss cost in \$, for operating period of 15 years

A = No Load Loss Constant, \$/kW
= $5.85 * E1 * T1$

E1 = Energy Cost, \$/kWhr

T1 = Annual operating Hours, 8760 hr

Li = Manufacturer guaranteed no-load loss, kW

B = Load Loss Constant, \$/kW
= $0.49 * A$

Lc = Manufacturer guaranteed load loss, kW

Commentary Note:

The constant 5.85 is a present value factor based the formula $PV = \frac{1 - (1+i)^{-n}}{i}$, where i is the discount rate (15%) expressed as a decimal number and n is the life of the motor (15 years).