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# Liquefied Natural Gas

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**Abstract:** *The liquefied natural gas has risen rapidly for the reasons of energy security and sustained development and has led to considerable recent research interest and effort in the LNG production chain and associated risks in handling storage largely and public confidence in LNG safety this review presents an overview on some recent advances in the LNG value chain covering upstream gas production and gathering liquefaction shipping and regasification process vapor desperation and combustion the improving the safety of personal facilities and ships the key technical gaps in the related research areas have been identified and research directions are outlined.*

## I. HISTORY

Petroleum produces was first transported tankers in the 1860 but a century passed before natural gas was transported by ship two century physical Robert boyle and edme mariotte are credited with this led to insight how gas might condensed In 1931 there first commercial LNG peak shaving plant built in west Virginia the commercial scale chain with a liquefaction plan are adze Algeria and receiving during the plants were built in Alaska Libya brunei abu dhabi and Indonesia as well as Algeria import terminal western hemisphere and the first output from quatar Nigeria oman and Trinidad occurred between 1996 and 2000. The process of cooling natural gas to extremely low temperature began means of extracting helium from natural gas use in U.S. military balloons in the early 19 th century godfrey cabot devised the first conceptual scheme for LNG in 1941 when he patented a barge based system to demonstrate that waterborne transportation of gas was fesible.

## II. LNG SCENARIO ININDIA

- A. India has a important erminal capacity around 22 million tons annually.
- B. Currently operates four important terminals with another four terminal proposed.
- C. Terminal at dahej and dabhol are under planned expansion to increase their capacities.
- D. A floating storage re-gasification unit is also proposed at Kakinada.
- E. LNG is source from ras gas and gorgon venture Australia. Re-gasification natural as s mainly supplies to fertility industry and for use in transport as CNG.

## III. LIQUEFIED NATURALGAS(LNG)

When natural gas is cooled to approximately  $-162^{\circ}\text{C}$  or  $259^{\circ}\text{F}$  at atmospheric pressure the condensed liquid is LNG. Volume are reduced is about the volume of 1/600 the natural gas butane propane ethane methane trace amounts of carbon dioxide and sculpture methane is the principal components of LNG which accounts for 90% of the total.

Any LNG project chain is three main stages

- A. Liquefaction of natural gas
- B. Transportation of LNG
- C. Re-gasification of LNG

Liquefied natural gas produced by liquefaction of natural gas by using a refrigeration cycle. This natural gas is stored in special storage tanks aboard ships and is transported to the ship pumps to the unloading arms of jetty and then the storage tanks b the unloading arms Unloaded LNG is re-gasified natural gas by using various kinds of vaporizers which are basically heat exchanger which heat the LNG and convert it to gaseous form LNG is mainly used after re-gasification in fertility and for transportation purpose as CNG. Vaporized LNG has the sane thermal characteristics as natural gas when LNG is vaporized and used as natural gas fuel it generates very low particle emissions and significantly lower carbon emission than other hydrocarbon fuels the combustion products from LNG contain almost sulphur oxides and a low level of nitrogen oxides which makes LNG clean source of energy.

## IV. CALCULATION MODELS FOR PREDICTION OF LIQUEFIED NATURAL GAS

This paper description both models and validates them from previous disturbed models experienced data measured in ENAGAS

LNG degasification plans.

|                 |   |                                    |
|-----------------|---|------------------------------------|
| E               | = | error define                       |
| E               | = | energy                             |
| F               | = | equilibrium dimensionless          |
| H               | = | enthalpy                           |
| M               | = | iteration                          |
| P               | = | pressure                           |
| Q               | = | quality                            |
| t               | = | time                               |
| T               | = | temperature                        |
| V               | = | volume                             |
| V <sub>th</sub> | = | capacity                           |
| X               | = | weighted sum of the input synapses |
| x               | = | molar fraction                     |
| y               | = | dimensionless LNG mixture          |

A. Greek symbols

|   |   |                       |
|---|---|-----------------------|
| E | = | convergence tolerance |
| Φ | = | selected variable     |
| Δ | = | difference            |

Liquefied natural gas is an energy with a enormous steady growth is expected was almost double in size between delivering around 40 percent of gas supply growth increment of LNG demand has provoked a augmentation of LNG transport sea. At the end number.LNG is a liquid mixture of light hydrocarbons, with a methane the main component at approximation atmospheric pressure LNG is also composed of other minority I – pentane and n- pentane LNG is a transportation by ship at atmospheric pressure close to its boiling point which around depending on LNG composition of high vaporization provokes an increase in pressure in the tank described during ship transportation. Owing to the different boiling points of LNG components LNG vaporization is not homogenous components with the least boiling point tend to evaporate the modification the accurate knowledge the unsteady pressurized equilibrium other interesting references are the vaporization of the Conrad and vesovic tanks by bates and morriso The scarcity in scientific literature about LNG weathering contracts with its importance for the above mentioned issues and the growing number of publicatios about a broad range the LNG subjects in this context a group the European gas companies program for predicting changes LNG composition during the transportation and liquid density the port to unloading port wobbe index anticipate LNG composition and properties and such as higher heat the certificates on liquid density the general measurement that can easily be obtained degasification plans.

$$BOR = V_{ev,d}/V_{L,ORT}$$

a typical value 0.15 percent although the exact magnitude depends on the type of container the quality thermal insulation. It is assumed that changes in LNG density small ship transportation because the BOR can be arranged in molar basis according to equation. It is assumed that changes in LNG density during ship transportation because composition and temperature equation

$$BOR = n_{ev,d}/n_{1,ori}$$

evaporated moles from equation evolution origin to destination conditions

$$P = P_{ori} + (P_{dst} - P_{ori}) / (t_{dst} - t_{ori}) * (t - t_{ori})$$

The convergence criterion is satisfied the estimated equilibrium temperature loop is repeated at a maximum of 50 times relating the new guess estimate the temperature increment the convergence according to equation At the end of the execution block the algorithm has calculated the LNG equilibrium temperature the LNG mixture the composition of the liquid and the vapor phases the liquid and vapor moles that fully occupy the ship capacity

$$\eta_{l,t+\Delta t} = \eta_{l,t} - \eta_{ev,t}$$

$$\eta_{v,t} + \Delta t = \eta_{v,t} + \eta_{ev,t} - \eta_{out,t}$$

Being the vapor moles the tank the current time step avoid large increment of pressure he moles at the end the current time step are define from density and volume occupied by each other phase.

$$\eta_{l,t+\Delta t} = (\rho v)_{l,t+\Delta t}$$

$$\eta_{v,t+\Delta t} = (\rho v)_{v,t+\Delta t}$$

Being sum of liquid volumes is always the tank rearranged into mass balance for moles as shown in equation

$$\eta_{out,t} = \eta_{v,t} - \rho_{v,t} \Delta t v_{tk} + (\rho_{v,t} + \Delta t) / (\rho_{l,t} + \Delta t) * \eta_{l,t} + (1 - \rho_{v,t} \Delta t / \rho_{l,t} + \Delta t) * BOR / 48 n_{l,ort}$$

The solution of equation liquid and vapor densities at the end of the current time step can be functions LDF if the equilibrium figure is applied.

The first iteration assumes that the equilibrium at the end of the line step is 0.01 % higher temperature at the beginning of the time step and there are no changes in the LNG mixture composition

$$T_{m,t+\Delta t} = T_t + 0.001t_t$$

$$Z_{l,t+\Delta t} = Z_{l,t}$$

Hypothesis allow the vapor fraction and the equilibrium constant be estimated vapor distance approach equation these data composition equilibrium ETVL function and operating the estimated feedback beginning of the literature process as shown in equation

$$V_{l,t+\Delta t} = V_{l,t} - \eta_{ev,t} / \rho_{l,t}$$

The approximation can be evaluated that flow transferred by equation in the mode

$$Q = E_{t+\Delta t} - E_t + E_{out} / \Delta t$$

Being  $E_t$  and  $E_{t+\Delta t}$  the energy stored inside the tank beginning and at the end of time step respectively and these energy terms leaving the tank by the vented steam to avoid large moles and liquid and vapor LH and VH function according to equation

$$E_{t+\Delta t} = \eta_{l,t+\Delta t} H_{l,t+\Delta t} + \eta_{v,t+\Delta t} H_{v,t+\Delta t}$$

$$E_{out,t} = \eta_{out,t} H_{v,t}$$

Average heat flow obtained from model are tests numbers this difference can be provoked by the intermediate point to estimate the BOR point located near to the end of the weathering process therefore the hypothesis of constant evaporation rate assumed by the use of the BOR parameter should in further development however it can be considered

Learning the examples is one of the abilities that makes artificial neural networks a suitable approach for the modeling multiplayer perception have demonstrated in chemical and electricity knowledge areas several problems have been solved using neural networks such as sensor discrimination between butane and propane for gas detection of a chemical process reactor control for non linear they are often used for stock prediction and have also been

The average heat flows obtained from physical model are for tests number this difference can be provoked by the point is located in the middle point located near to the end of the weathering process therefore the hypothesis of constant evaporation rate assumed by the use of the bor parameter should be improved it can be considered the approach for calculated from data the end of the ageing process.

$$Y = \tanh(x)$$

$$Y = (1 - e^{-x})^{-1}$$

Here  $y$  is the output of the node the  $x$  is the weighted of the input synapses in the neural network is trained by the back propagation training in this program of the connection is response In error of the network during the output this error is then desired such that the analysis in the model 10 times with each other then averaged to produce a single of the error.

$$e_{\varphi} = \frac{\varphi_{meas} - \varphi_{cal}}{\varphi_{meas}}$$

where  $\varphi_{meas}$  is the measured value in the historical database while is the value prediction

by the physical algorithm or by the I – model

if the error of the is less than the error of the physical model for the LNG temperature

volume model is selected forecasting the quantity.

## V. SELECTION OF STORAGE TANKS:

For the storage of LNG at the import terminal full containment tanks are selected. For a plant with annual capacity of 5 MMTPA two full containment tanks of capacity 2,00,000 m<sup>3</sup> each would suffice normal demand.

## VI. DESIGN OF INNER TANK

A. type of tank : 9% nickel steel full containment

B. gross capacity : 200,000 m<sup>3</sup>

- C. design pressure : 29kPa
- D. design temperature : -170 °C
- E. diameter of innertank : 84.0m
- F. height of innertank : 37.61
- G. maximum liquid feed rate : 11,000 m<sup>3</sup>/hr

### VII. DESIGN OF OPEN RACKVAPORIZER:

LNG flows inside the tubes with the seawater flowing in counter current direction, their contact leading to exchange of heat between the cold LNG and the Hot seawater streams.

#### A. Heat Balance

$$\begin{aligned}
 \text{Water, } Q_w &= m_w \times C_p \times \Delta(T_1 - T_2) \\
 &= (1.524 \times 10^8) \times 77.707 \times 21 \\
 &= 2.486 \times 10^{11} \text{ kJ/hr LNG, } Q_l = m_l \times C_p \times \Delta(T_1 - T_2) \\
 &= (1.862 \times 10^7) \times 54.967 \times 154 \\
 &= 1.5761 \times 10^{11} \text{ kJ/hr} \\
 Q_{\text{vap}} &= m_l \times \lambda \\
 &= (1.862 \times 10^7) \times 510.83 \\
 &= 0.9099 \times 10^{10} \text{ kJ/hr} \\
 Q_w &= Q_l + Q_{\text{vap}} \text{ Hence the heat is balanced.}
 \end{aligned}$$

#### B. Logarithmic Mean Temperature Difference(LMTD):

$$\begin{aligned}
 \Delta T_1 &= -162 - 5 = -167 \\
 \Delta T_2 &= -6 - 26 = -32 \\
 \text{LMTD} &= (\Delta T_1 - \Delta T_2) / \ln[\Delta T_1 / \Delta T_2] \\
 &= -167 - (-32) / \ln[-167 / -32] \\
 &= -81.8 \text{ }^\circ\text{C}
 \end{aligned}$$

#### C. Surface Area

$$\begin{aligned}
 a_t &= (N_t \times a'_t) / (144 \times n) \\
 &= (2000 \times 1.075) / (144) \\
 &= 14.9 \text{ ft}^2
 \end{aligned}$$

#### D. Mass Velocity

$$\begin{aligned}
 G_t &= w / a_t \\
 &= 335160000 / 14.9 \\
 &= 22.49 \times 10^6 \text{ lb/ hr ft}^2 \\
 5. D &= 1.17 \text{ in} \\
 \text{Re} &= D \times G_t / \mu \\
 &= 1.17 \times 22.49 \times 10^6 / .0098 \\
 &= 2685 \times 10^6
 \end{aligned}$$

*E. Inside Heat Transfer coefficient*

$$\begin{aligned}
 h_i &= j_h \times k / D \times (C_p \times \mu/k)^{0.33} \times \phi_t \text{(Ref fig24. Donald Q. Kern, Process heat Transfer)} \\
 &= 750 \times .15 \times (54.967 \times .0098 / .15) \times \phi_t \\
 &= 146.6 \times \phi_t = 146.6 \text{ lb/ (hr)(ft}^2 \text{)} (\text{°F})
 \end{aligned}$$

*F. Corrected Heat transfer coefficient*

$$h_i = h_i \times ID/OD = 146.6 \times 1.17/1.5 = 114.34 \text{ lb/ (hr)(ft}^2 \text{)} (\text{°F})$$

*G. Clean overall Coefficient*

$$\begin{aligned}
 U_c &= (h_{io} \times h_o) / (h_{io} + h_o) \\
 &= (114.34 \times 146.6) / (114.34 + 146.6) \\
 &= 164.2 \text{ Btu/(hr)(ft}^2 \text{)} (\text{°F})
 \end{aligned}$$

*H. Design overall coefficient:*

$$\begin{aligned}
 Q &= UD \times A \times \Delta T \\
 UD &= 2486000 / (204.6 \times 81.8) \\
 &= 150.4 \text{ Btu/(hr)(ft}^2 \text{)} (\text{°F})
 \end{aligned}$$

*I. Dirt Factor:*

$$\begin{aligned}
 R_d &= (U_c - UD) / (U_c \times UD) \\
 &= (164.2 - 150.4) / (164.2 \times 150.4) \\
 &= 0.0005
 \end{aligned}$$

**VIII. MEASUREMENT BY MASS**

Although it can be useful to measure the volume there are many uncertainties. The correction for the temperature of the liquid is based on the density a very precise parameter to represent a potentially wide range of NGL compositions difference mixture they are treated alike for consideration for difficult to predict precise changes in volume due to changes in temperature the current standard volumes for temperature API is based on an array of only 12 reference fluids only three of which means they have two components one mixture these three mixtures are binary which means they have two nine ethane propane mixture is not a very broad range for this hydrocarbons which make up typical NGL mixtures.

- A. Determine density of the liquid at base condition base a function of the liquids composition or the liquids observed density temperature and pressure
- B. The correction for the temperature and pressure of the liquid a function of the liquids temperature pressure equilibrium vapour pressure and base density.
- C. Determine the combined correction factor
- D. Determine the indicated volume  $M_{Rc} - M_{ro}$
- E. Determine the gross standard volume  $GSV = IV * CCF$
- F. Determine the net standard volume  $NSV = GSV$

Additional uncertainty in the NSV results from the calculation of the correction for the difference between the liquid measured pressure and its saturation pressure unless measured a common method for determine a fluids saturation pressure is presentation in API MPMS as with this standard more than 40 % for natural gasoline mixture around the upper density range of NGLs it also affirms that relative density is not a highly precise parameter in predicting vapor pressure of widely variable NGL compositions. For the and other reasons the NGL measured industry leans towards mass calculations knowing fluid mixture and pure component density allow for easy conversion from mass to component base volumes measured volumes are components base volumes calculation purpose these are called indirect or impact mass measurement.

$$M = IV + MF + pf$$

Where

M = mass

IV = meters indirect volume

MF = meter factor

Pf = density at flowing conditions

Other times NGL is measured by mass sometimes weight is used when mass is required they are not the same confusion is added by the common use of vocabulary such as pounds or kilograms to describe both mass and weight

Mass is an extensive property of matter a measured of the amount weight is used when the required they are not the same such as pounds or kilogram t describe both mass and weight the force results the action of the same mass have different the weight depending on they are weighed different location on the surface of the earth may have different surface of the earth may have different gravitational forces.

They are many factors which affects the acceleration due to gravity at a particular point on the earths surface such as

Geology the density of material beneath the location

Dividing each model percent by 100 to convert to mole fraction

Multiplying mole fractions by the components molar mass to get position

| Component      | Mole Percent | Construct | Mole Fraction | Molar Mass | Mass Portion Of Mixture | Mass Fraction |
|----------------|--------------|-----------|---------------|------------|-------------------------|---------------|
| Carbon dioxide | 0.08 (/)     | 100       | 0.0008        | 44.0095    | 0.0352                  | 0.008         |
| Methane        | 2.65         | 100       | 0.0265        | 16.0425    | 0.045126                | 0.0098        |
| Ethane         | 38.10        | 100       | 0.3810        | 30.03659   | 11.56478                | 0.2645        |
| Propane        | 35.77        | 100       | 0.3577        | 44.1256    | 15.4456                 | 0.648         |
| Normal butane  | 9.56         | 100       | 0.0956        | 58.1232    | 5.55655                 | 0.12546       |
| Iso butane     | 4.78         | 100       | 0.0458        | 58.122     | 2.775846                | 0.06354       |
| Hexane         | 0.94         | 100       | 0.0365        | 72.554     | 0.6475                  | 0.0156        |
| Total          | 100          |           | 1.0000        |            | 43.54                   | 1.000         |

Values for molar mass are form GPA the hexane molar mass vale is a characterization an extended analysis

Mass fraction= component mass portion + total mass position

There mass fraction of propane was adjusted to normal unity

Co2 mass fraction = co2 component mass portion + total mass portion

0.008 = 0.03542+43.593

| Component      | volume percent | Constant | Volume fraction | Absolute density | Mass portion of mixture | Mass fraction |
|----------------|----------------|----------|-----------------|------------------|-------------------------|---------------|
| Carbon dioxide | 0.05           | 100      | 0.0005          | 6.8129           | 0.003406                | 0.0008        |
| Methane        | 1.56           | 100      | 0.0156          | 2.5000           | 0.039000                | 0.0097        |
| Ethane         | 35.40          | 100      | 0.3540          | 2.9547           | 1.051522                | 0.25622       |
| Propane        | 10.87          | 100      | 0.1087          | 4.8759           | 0.52487                 | 0.3611        |
| Normal butane  | 5.23           | 100      | 0.0523          | 4.6925           | 0.245418                | 0.06215       |
| Iso pentane    | 1.18           | 100      | 0.02845         | 5.2545           | 0.12779                 | 0.0319        |
| Hexane         | 9.05           | 100      | 0.0118          | 5.5733           | 0.51425                 | 0.1258        |
| Total          | 100            |          | 1.0000          |                  | 4.0098475               | 1.000         |

Values for absolute density are form GPA the hexane absolute density is a characterization from an extended analysis

Mass faction vary between mole analysis and volume analysis due to rounding

Mass fraction = component mass portion

G. For Example

- 1)  $\text{CO}_2$  mass fraction =  $\text{CO}_2$  COMPONENT MASS PORTION + TOTAL MASS PORTION
- 2)  $0.008 = 0.003406 + 4.0098$
- 3) Multiplying Each Of The Component Mass fraction by the total mass measurement to get the mass of each other component
- 4) Dividing each components mass by the components absolute density to get the components volume at base conditions
- 5) The mass fraction of propane was adjusted to normalize the total mass fraction to unity

| Component      | Mass fraction | Total measured mass | Component mass | Absolute | Component volume |
|----------------|---------------|---------------------|----------------|----------|------------------|
| Carbon dioxide | 0.0008        | 1347720             | 1078.176       | 6.8452   | 158              |
| Methane        | 0.0098        | 1345752             | 13204.656      | 2.5000   | 5283             |
| Propane        | 0.2621        | 1345702             | 354154.86      | 2.9704   | 119237           |
| Normal butane  | 0.0635        | 1348721             | 171584.300     | 4.4878   | 35280            |
| Iso butane     | 0.0315        | 1345720             | 21045756       | 5.21064  | 4034             |
| Hexane         | 0.1256        | 1345172             | 170548622      | 5.21452  | 30590            |
| Totals         | 1.0000        |                     | 13475210.00    |          | 336258           |

The resulting component volumes are then the used for transaction evaluation and plant allocation other calculation may be necessary balancing and reporting

### IX. PHASE VOLUME CONVERSION

Phase volume conversion converting liquids are gas equivalents and gas to liquids equivalent calculation and understanding plant efficient converted.

Phase volume conversion calculation are accomplished with theoretical hydrocarbon are accomplished with theoretical hydrocarbon liquid content values a gas component THLC content a gas components THLC is the product mole fraction factor to the contract base in the united states this factor is generally reported per 1000 cubic feet of gas in equation form

$$\text{THCL} = x1/z * v1/vg * pb/pg * 1000$$

Where THCL – theoretical hydrocarbon liquid content

X1 – mole fraction of component

Z – compressibility gallon liquid ideal gas factor derived from the reciprocal of feet ideal gas

Pb – contract pressure base

Pg – reference pressure base

This calculation can be found in GPA as an example give a gas mixture with mole fraction propane compressibility of the Gas as contract pressure base 14.65 psia

$$\text{THLC} = -0.440/0.99673 * 1/36.391 * 24.65/214 * 1000 = 1.309$$

In the example as Mcf of gas potentially yields gallons of propane the THCL is multiplies the period resulting in the theoretical liquid volume for the propane this process is repeated by the application often only for the values for hydrocarbon components with two or more because these are the main component processed as NGLs.

Gas stream component THLCs provide a basis the transaction evaluation be generated from a particular gas stream helps to be generated from streams helps place a value the difference between a liquids generated by the operational good indicator of the plants efficiency.

Invariable some of the NGL components from the gas the plants demethanizer residue the NGL converted to gas equivalent volume combined with the residue from the period THLC calculation inlets gas can be plant the type of balance provides not only the reflection of the plants efficiency helps measurement error.

This phase volume calculation involves combined individual component values to get full station this provides high level these information about quantity but again these quality calculation mixing therefore NGL balance are also commonly performed at the component level.



Component level balancing provides additional information analysis and efficiency at the same time the results better correspondence the level at which transaction take place.

Difference operation and stakeholder will required different information some will need more detailed information some will need more detailed information than the other some application measurement where others are better suited to mass these calculation associated with NGLS help to take those calculation association with various results stakeholder require and provides the basis for NGLS evaluation and transaction.

As a fire port distinction should be made of the roles in establishing investment in the terminal while municipality important at project start the development of a LNG terminal and the volume estimated must be the implies that a through the land based the establishment to avoid over establishment port recommended.

The permit process takes time and can be costly for the period of the authorities involving therefore the process takes eve longer time.

The regulation controlling LNG support several international directives and a=conventions as well as national laws and local regulation finding and involving the relevant sometimes difficult.

Risk is deemed as crucial planning when the discussion it with the relevant and when applying for a permit training ofstaff in risk and safety measurement is necessary. Land use of design for the LNG terminal use and the surroundings area must be technical equipment needed in the terminal increases the land use significantly. It is very important in an early stage of the planning it is necessary dialogue with financing solutions.

The elaboration of the LNG is based on the result and findings of the LNG sea area also included assessment of obstacles and possibilities during the development and establishing of LNG as marine fuel the ports have been visited interviewed and the results been complied these guidance for other stakeholder.

There are a number of projects in the Baltic sea region of various capacities LNG terminal discussion there is no more than existing are of the terminal an open access terminal implies that independent LNG suppliers may reserve capacity in the terminal.

The majority of terminal under are medium scale terminal approximately larger than the few large scale example are under planned terminal but is exhaustive plans made continuously map of existing and planned terminal possibilities in the baltic sea region.

## X. COSTESTIMATION

Cost of LNG plant of capacity 5MMPTA in 2013 is  $4.20 \times 10^{11}$  Rupees. Present cost = (past cost  $\times$  past cost index)/present cost index

Cost inflation index in 2013 is 939 Cost inflation index in 2015 is 1024N Cost of LNG plant of capacity 5MMPTA is  $4.58019 \times 10^{11}$  Rupees.

### A. Estimation of Capital Investment Cost( swift & Marshall):

Capital Investment = Fixed Capital Investment + Working Capital Investment Fixed capital investment = Direct Cost +Indirect Cost

### B. Fixed Capital Investment

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.

### C. Working Capital Investment

Working capital is the amount of capital required to start up the plant and finance ordinarily amounts to the production cost for 1 month of operation before revenues from the process start.

### D. Direct Cost

The portion of the operating costs that is generally assignable to a specific product or process area.

### E. Indirect Cost

Costs not directly assignable to the end product or process, such as overhead and general purpose labor, or costs of outside

operations, such as transportation and distribution.

### XI. PROCEDURE FOR COST ESTIMATION

Direct Costs (85-90% of fixed-capital investment)

Equipment + installation + instrumentation + piping + electrical + insulation + painting

#### A. Purchased Equipment Cost (Pec)

:( 30-40% of Fixed-capital investment)

Consider purchased equipment cost = 40% of Fixed-capital investment i.e., PEC = 40% of

$$4580.19 \times 10^8$$

$$= 0.40 \times 4580.19 \times 10^8$$

$$= \text{Rs. } 1.832076 \times 10^{11}$$

1) *Installation, including insulation and painting:* (47% of purchased equipment cost) Installation cost = 47% of Purchased equipment cost

$$= 47\% \text{ of } 1.832076 \times 10^{11}$$

$$= 47\% \times 1.832076 \times 10^{11}$$

$$= \text{Rs. } 8.61043 \times 10^{10}$$

2) *Instrumentation And Controls, Installed:* (36% of Purchased equipment) Instrumentation cost = 36% of Purchased equipment cost

$$= 0.36 \times 1.832076 \times 10^{11}$$

$$= \text{Rs. } 6.5954 \times 10^{10}$$

3) *piping installed:* (68% of Purchased equipment cost) Piping cost = 68% of Purchased equipment cost

$$= 68\% \text{ of Purchased equipment cost}$$

$$= 0.68 \times 1.832076 \times 10^{11}$$

$$= \text{Rs. } 1.2458 \times 10^{11}$$

4) *Electrical, installed:* (11% of Purchased equipment cost) Electrical cost = 11% of Purchased equipment cost

$$= 11\% \text{ of } 1.832076 \times 10^{11}$$

$$= 0.11 \times 1.832076 \times 10^{11}$$

$$= \text{Rs. } 2.015276 \times 10^{10}$$

#### B. Buildings, Process And Auxiliary

(18% of Purchased equipment cost) Buildings, process and auxiliary cost = 18% of PEC

$$= 18\% \text{ of } 1.832076 \times 10^{11}$$

$$= \text{Rs. } 3.2977368 \times 10^{10}$$

#### C. yard improvements

( 10% of Purchased equipment cost) Yard improvement = 10% of PEC

$$= 10\% \text{ of } 1.832076 \times 10^{11}$$

$$= 10\% \times 1.832076 \times 10^{11}$$



## XI. CONCLUSION

Using LNG and natural gas to fuel vehicles reduces greenhouse gas emissions by 30-40 percent and also saves vehicle maintenance costs. LNG also benefits the environment due to the significant reduction in fuel emissions produced by the garbage truck fleet.

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