APPENDIX 1

1. ENERGY EQUATIONS FOR HOT MOTORING

\[ \dot{U} = -P \dot{V} + \sum Q_j - \dot{M}_B L_B - \dot{M}_W L_W \]  
\[ U = f(T, M_B, M_W) \]  

Differentiating equation (A1.2), with respect to crank angle \( \theta \)

\[ \dot{U} = \frac{\partial U}{\partial T} \dot{T} + \frac{\partial U}{\partial M_B} \dot{M}_B + \frac{\partial U}{\partial M_W} \dot{M}_W \]  

\[ \therefore \dot{T} = \frac{\dot{U} - \frac{\partial U}{\partial M_B} \dot{M}_B - \frac{\partial U}{\partial M_W} \dot{M}_W}{\frac{\partial U}{\partial T}} \]  

Products of complete combustion per kg of fuels are evaluated as below:

\[ U_A = \sum_j C V_j, \text{ where } j \text{ represents the individual constituents such as } O_2, N_2, C_2H_5OH \& H_2O \]

\[ \therefore U = U_A \cdot T \text{ and } \frac{\partial U}{\partial T} = U_A + T \frac{\partial U_A}{\partial T} \]

Hence,

\[ \dot{T} = \frac{-P \dot{V} + \sum Q_j - \dot{M}_B L_B - \dot{M}_W L_W - \frac{\partial U}{\partial M_B} \dot{M}_B - \frac{\partial U}{\partial M_W} \dot{M}_W}{U_A + T \frac{\partial U_A}{\partial T}} \]  

2. ENERGY EQUATION FOR FIRING RUN

Products of complete combustion per kg of fuels are evaluated as below:
Ethanol

\[ C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \]

\[ 1 \text{ kg} + 2.087 \text{ kg} \quad \text{of (ethanol)} \]
\[ 1.913 \text{ kg} \quad \text{of (Oxygen)} \]
\[ 1.174 \text{ kg} \quad \text{of (H}_2\text{O)} \]

Diesel

\[ C_{12}H_{26} + 18.5 O_2 \rightarrow 12 CO_2 + 13 H_2O \]

\[ 1 \text{ kg} + 3.482 \text{ kg} \quad \text{of (Diesel)} \]
\[ 3.106 \text{ kg} \quad \text{of (CO}_2) \]
\[ 1.376 \text{ kg} \quad \text{of (H}_2\text{O)} \]

Energy equation can be written as:

\[ \dot{U} = -P\dot{V} - \sum \dot{Q}_j + \dot{Q}_D + \dot{Q}_B - \dot{D}.L_D \]  
(A1.7)

\[ U = f(T, W_E, W_D) \]  
(A1.8)

Differentiating equation (A1.8) with respect to crank angle \( \theta \),

\[ \dot{U} = \frac{\partial U}{\partial T} \dot{T} + \frac{\partial U}{\partial W_E} \dot{W}_E + \frac{\partial U}{\partial W_D} \dot{W}_D \]  
(A1.9)

\[ \dot{T} = \frac{-P\dot{V} + \dot{Q}_E + \dot{Q}_D - \sum \dot{Q}_j - \dot{D}.L_D - \frac{\partial U}{\partial W_E} \dot{W}_E - \frac{\partial U}{\partial W_D} \dot{W}_D}{\frac{\partial U}{\partial T}} \]  
(A1.10)

Let \( U = U_A \cdot T \)

Where \( U_A = \Sigma m_j C_{V,j} \), where \( j \) represents the individual constituents such as \( C_2H_5OH, C_{12}H_{26}, CO_2, H_2O, O_2 \) and \( N_2 \)

\[ \frac{\partial U}{\partial T} = U_A \cdot T + \frac{\partial U_A}{\partial T} \]
Let suffix 3 represent CO₂
4 represent H₂O
5 represent O₂
and 6 represent N₂

Now U_A can be represented as

\[ U_A = (W_{TB} - W_B) CV_B + (M_D - W_D) CV_D + (W_B D_3 + W_D D_3) CV_3 + \]
\[ (W_E E_4 + W_D D_4) CV_4 + (W_{T5} - W_E E_5 - W_D D_5) CV_5 + W_{T6} CV_6 \ldots (Al.11) \]

From equation (Al.11), the values of \( \frac{\delta U_A}{\delta T} \), \( \frac{\delta U_A}{\delta W_B} \), and \( \frac{\delta U_A}{\delta W_D} \) can be computed.

3. DETERMINATION OF CHARACTERISTIC GAS CONSTANT \( 'R' \)

\[ R = \frac{R_o}{\text{molecular weight}} \]

\[ \text{Mol. wt.} = \frac{\text{Total weight of the constituents}}{\text{Number of moles of the constituents}} \]

\[ \text{Number of moles} = \frac{\text{Weight of each constituent}}{\text{Molecular weight}} \]

\[ \therefore \text{Mol. wt.} = \frac{(W_{TB} - W_B) + (W_{TD} - W_D) + \ldots}{W_{TB} - W_B + W_{TD} - W_D + \ldots} \]

4. CALCULATION OF \( \dot{V} \)

\[ V(\theta) = V_{TDC} + \frac{\pi}{4} B^2 \cdot x(\theta) \]

where \( x(\theta) = r(1 + 1/r - \cos \theta - \sqrt{(1/r)^2 - \sin^2 \theta}) \)

\[ \dot{V} = \frac{\pi}{4} B^2 \cdot \frac{dx}{d\theta} \]

where

\[ \frac{dx}{d\theta} = r(\sin \theta + \frac{\sin \theta \cos \theta}{\sqrt{(1/r)^2 - \sin^2 \theta}}) \]