Publications:

Published Research paper

1. **Priyaranjan Jena**, Jeewan Vachan Tirkey, Reetu Raj, Lawalesh Prajapati (2024). Effect of Propane blending with Grape wood Producer gas on SI Engine performance and optimization. **Applied Thermal Engineering** 242 (2024) 122480, (ELSEVIER, SCI-IF: 6.4)
2. **Priyaranjan Jena**, Jeewan Vachan Tirkey (2023). Power and efficiency improvement of SI engine fueled with boosted producer gas-methane blends and LIVC-miller cycle strategy: Thermodynamic and optimization studies. **Energy** 289 (2024) 130068, (ELSEVIER, SCI-IF: 9.0).
3. **Priyaranjan Jena**, Reetu Raj, Jeevan Vachan Tirkey (2023). Thermodynamic performance study and RSM-based optimization of SI engine using sewage sludge producer gas blend with methane. **Energy** 273 (2023) 127179, (ELSEVIER, SCI-IF: 8.857).
4. **Priyaranjan Jena**, Jeewan Vachan Tirkey (2023). Efficiency improvement investigation through Miller cycle strategy for SI engine operating on stoichiometric producer gas and methane blends. **Thermal Science and Engineering Progress** 47 (2024) 102309, (ELSEVIER, SCI-IF: 4.56).
5. **Priyaranjan Jena**, Jeewan Vachan Tirkey, Reetu Raj, Lawalesh Prajapati (2024). Investigation on varied sewage sludge producer gas and methane blend equivalence ratios operated SI engine intact with Miller cycle strategy. **International Journal of Ambient Energy**, accepted on 09 June 2024 (Taylor and Francis-Publication SCI-IF: 2.539)
6. **Priyaranjan Jena**, Reetu Raj, Jeewan Vachan Tirkey, Ajeet Kumar (2023). Experimental analysis and optimization of CI engine Performance using Waste Plastic Oil and Diesel fuel blends. **Journal of the Energy Institute** 109 (2023) 101286 (ELSEVIER, SCI-IF: 6.47).
7. Lawalesh Kumar Prajapati, Jeewan Vachan Tirkey, Reetu Raj, **Priyaranjan Jena**, Akash Giri (2024). Performance analysis of methanol fuelled SI engine with boosted intake pressure and LIVC: A thermodynamic simulation and optimization approach. **Applied Thermal Engineering**, accepted on 03 June 2024, (ELSEVIER, SCI-IF: 6.4).
8. Lawalesh Kumar Prajapati , Jeewan Vachan Tirkey *, **Priyaranjan Jena** , Akash Giri (2024). Parametric performance evaluation of SI engine using producer gas-biogas-hydrogen blend as a fuel: A thermodynamic modeling and optimization approach. **International Journal of Hydrogen Energy** 72 (2024) 268–287 (ScienceDirect, SCI-IF:7.2)
9. Reetu Raj, Jeevan Vachan Tirkey, **Priyaranjan Jena** (2023). Gasification of Briquette, Mahua wood, and Coconut shell and application to CI engines: Comparative Performance and Optimisation Analysis. **Industrial Crops & Products**, 199(1)-2023, 116758 (ELSEVIER, SCI-IF: 6.449)
10. Reetu Raj, Jeewan Vachan Tirkey, **Priyaranjan Jena**, Lawalesh Prajapati (2024). Comparative analysis of Gasifier-CI engine performance and emissions characteristics using diesel with producer gas derived from coal– briquette-coconut shell-mahua feedstock and its blends. **Energy** (2024) 130708, (ELSEVIER, SCI-IF: 9.0). DOI: https://doi.org/10.1016/j.energy.2024.130708.

11. Deepak Kumar Singh, Reetu Raj, Jeewan Vachan Tirkey (2023), **Priyaranjan Jena**, Prakash Parthasarathy, Gordon Mckay, Tareq Al-Ansari (2023). Progress and utilization of biomass gasification for decentralized energy generation: An Outlook & Critical review. **Environmental Technology Reviews,** 12 (1): 1–36.(Taylor& Francis, SCI-IF: 3.475), https://doi.org/10.1080/21622515.2023.2242014
12. Reetu Raj, Jeewan Vachan Tirkey, Deepak Kumar Singh, **Priyaranjan Jena** (2023). Co-gasification of waste triple feed-material blends using downdraft gasifier integrated with dual fuel diesel engine: An RSM-based comparative parametric optimization. **Journal of the Energy Institute** 109 (2023) 101271 (ELSEVIER, SCI-IF: 6.47).

Under Revision Submitted Manuscript

13. **Priyaranjan Jena***, Jeewan Vachan Tirkey. Lean burn SI engine performance improvement using LIVC and boosted intake of methane-producer gas blends: Thermodynamics and optimization approach. **Process Integration and Optimization for Sustainability.**

International Conferences

1. **Priyaranjan Jena***, Jeewan Vachan Tirkey, Reetu Raj, Lawalesh Prajapati. Quasi-dimensional thermodynamic performance and emission modelling for dual-fuel SI engine operation using waste-based producer gas and methane. International Conference on Mechanical Engineering & Technology (ICMET-2024) March 1-3, 2024, at Mechanical Engineering Deptt, NIT, Kurukshetra, Haryana

2. **Priyaranjan Jena***, Jeewan Vachan Tirkey, Reetu Raj, Lawalesh Kumar Prajapati. Thermodynamic performance and emissions analysis of dual-fuelled SI engine using sewage waste-based producer gas and methane. International Conference on Recent Trends in Sustainable Mining and Green Energy Evolution (RTSMGEE-2024) on 27th -29th January 2023, IIT (BHU) Varanasi.

3. **Priyaranjan Jena***, Reetu Raj, Deepak Kumar Singh, Jeewan Vachan Tirkey. Mathematical simulation of SI engine performance using sewage sludge derived producer gas with methane blend. VII International Conference on Sustainable Energy and Environmental Challenges (VII SEEC) December 16-18, 2022, IIT (BHU) Varanasi.

Appendix

At the 140 MLD STP, initially the fine channels were employed using the Stainless-steel filter channels, thus representing a mechanical-based fine-screening facility. It separates the non-homogeneous contents in the fresh sewage feed. Then, mechanical strategies like initial sedimentation and centrifuge mechanism were applied, where the residual grit particles could also be separated. After dewatering, the treated sewage Sludge then undergoes further separation using sedimentation at the primary clarifiers and secondary clarifiers to act with clarifying chemicals for generating bigger, faster-settling aggregates. that ease the mechanical-based filtration through sedimentation [11]. The processing at the clarifiers is generally integrated with the aeration process. This provides sufficient duration for microbial growth inside the sludge that allows a healthy decomposition of the organic components and generate sludge.

After the treatments at clarifiers, the sludge material is treated for removal of microorganisms via chemical treatments. At the 140 MLD STP, chlorine-based treatment is considered for hygenization and the treated water is discharged into the nearby river, Varuna. The processed sludge is proceeded to activate the sludge and increase the sewage water BOD or for stabilization via anaerobic digestion. The STP facility also integrated an anaerobic digestion facility for treating the sludge. In the anaerobic method, the digestion process is mostly carried out under mesophilic conditions (30^o~42°C) [11]. Mesophilic digestion provides stability but lacks adequate hygiene. Whereas, the thermophilic fermentation (50-60°C) effectively reduces pathogens. Stabilization under thermophilic settings also shortens the digesting time. Thermophilic digestion uses more energy to heat sewage sludge and is more sensitive to slight changes in process parameters than mesophilic digestion [234]. The digestion process could be carried out through anaerobic, aerobic, or composting manners to result biogas generation and nutrients-rich residue [11]. This biogas is utilized for energy extraction for the complete STP or supply for the grid power.The other commonly used strategies for residual sludge stabilization are thermal, and lime treatments. Composting sewage sludge yields organic fertilizer [20, 235].

With the experimental experience acquired at the 140 MLD STP Dinapur and systematic information from the literature works [19], a systematic schematic representation for the widely applied sequential sewage management processes has been presented in Figure A.1. The schematic representation designates the initial dewatering and drying techniques and depicts the median practiced strategies until the final disposal of the residuals.

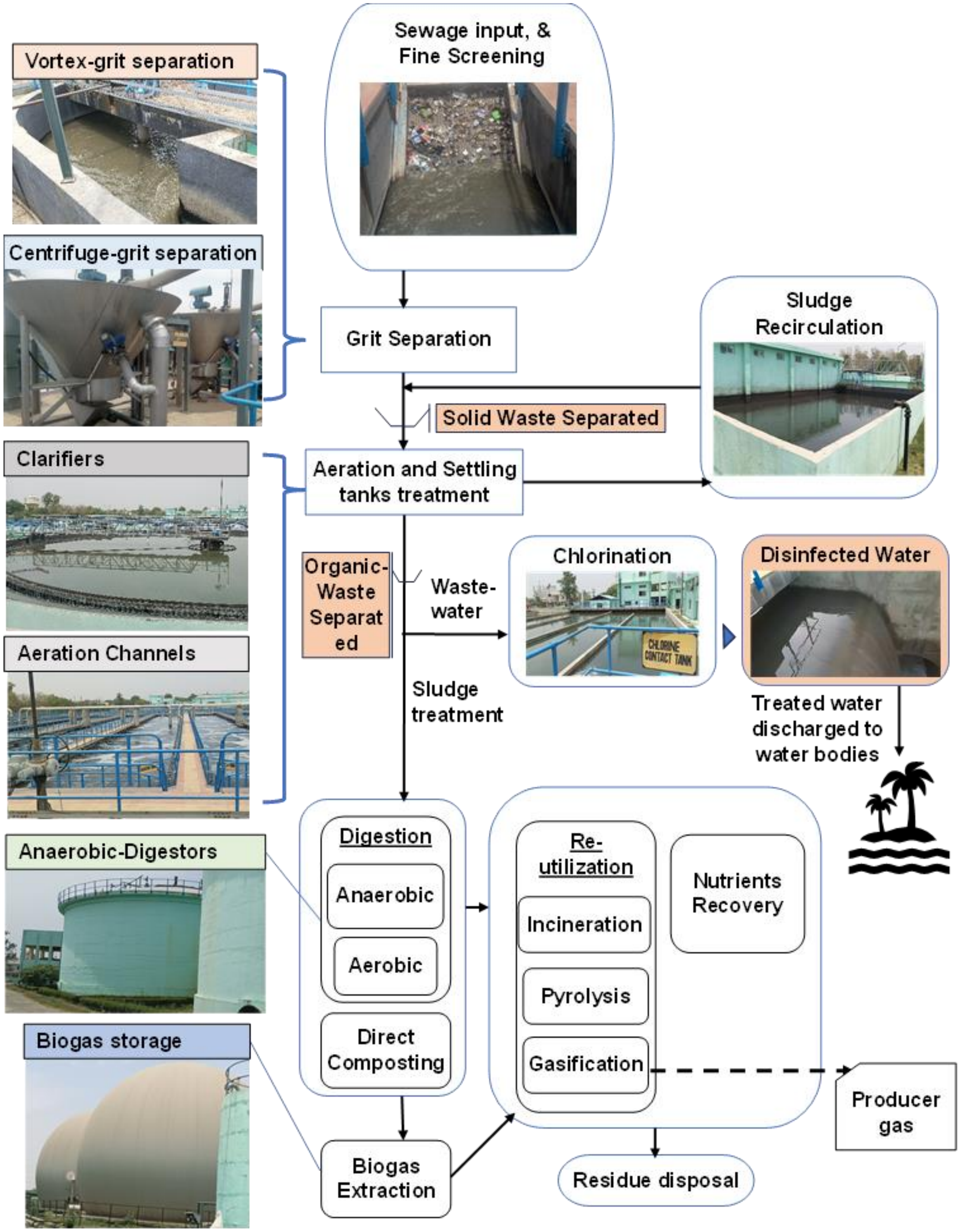

Figure A.1. Sewage management processes layout

Considering the thermodynamic analysis, the in-cylinder fuel-air charge is considered as the closed system. The first law of thermodynamics for this system could be expressed as Eqn.1, where E is the total internal energy of the charge, Q is the heat supply and W represents the net work produced.

$$\frac{dE}{d\theta}=\frac{dQ}{d\theta}-\frac{dW}{d\theta} \qquad \text{(Eqn.1)}$$

Internal Energy of the in-cylinder gases is in fractions of the burned and unburned portions. Thus, its differential could be expressed as Eqn 2.

$$E=m_m e_m+m_p e_p \Rightarrow \frac{dE}{d\theta}=m_m\frac{de_m}{d\theta}+e_m\frac{dm_m}{d\theta}+m_p\frac{de_p}{d\theta}+e_p\frac{dm_p}{d\theta} \qquad \text{(Eqn.2)}$$

By using the conservation of mass, Eqn.3 is formulated.

$$\frac{dm}{d\theta}=\frac{dm_m}{d\theta}+\frac{dm_p}{d\theta}=0\Rightarrow\frac{dm_m}{d\theta}=-\frac{dm_p}{d\theta} \qquad \text{(Eqn.3)}$$

Using Eqn.3, the Eqn.2 could be re-written as Eqn.4.

$$\frac{dE}{d\theta}=\left(e_p-e_m\right)\frac{dm_p}{d\theta}+m_m\frac{de_m}{d\theta}+m_p\frac{de_p}{d\theta} \qquad \underline{\text{(Eqn.4)}}$$

The entity describing the mass fraction burned rate profile is dm_p/dt [65]. This is dependent on the flame speed and is calculated from the burned zone geometry. It is expressed in terms of the density of unburnt charge (ρ_m), flame propagation speed (turbulant, u_t) and the flame front area (F_s), as in Eqn. 5.

$$\frac{dm_p}{dt}=\rho_m.u_t.F_s \qquad \text{(Eqn.5)}$$

As the in-cylinder gaseous charge is assumed as the ideal gas, the differential of its specific volume with respect to the crank-angle variation would be as Eqn.6.

$$P\upsilon = RT \Rightarrow \upsilon = \frac{RT}{P} \Rightarrow \frac{d\upsilon}{d\theta} = \frac{R}{P}\frac{dT}{d\theta} - \frac{RT}{P^2}\frac{dP}{d\theta} = \upsilon\left(\frac{1}{T}\frac{dT}{d\theta} - \frac{1}{P}\frac{dP}{d\theta}\right) \qquad \text{(Eqn.6)}$$

Also as, $e = c_V T$, the first law can be extended for the unburned mixture as Eqn.7.

$$\frac{dE_m}{d\theta} = \frac{dQ_m}{d\theta} - \frac{dW_m}{d\theta} \Rightarrow \frac{de_m}{d\theta} = \frac{1}{m_m}\frac{dQ_m}{d\theta} - P\frac{d\upsilon_m}{d\theta}$$

$$\Rightarrow c_{V,m}\frac{dT_m}{d\theta} = \frac{1}{m_m}\frac{dQ_m}{d\theta} - P\upsilon_m\left(\frac{1}{T_m}\frac{dT_m}{d\theta} - \frac{1}{P}\frac{dP}{d\theta}\right) \qquad \text{(Eqn.7)}$$

Eqn.6 is further used to find the temperature profile differential for unburned charge respective to crank angle variation (Eqn.8) as $\frac{P\upsilon_m}{T_m} = R_m$ and $c_{V,m} + R_m = c_{P,m}$

$$\frac{dT_m}{d\theta}\left(c_{V,m} + \frac{P\upsilon_m}{T_m}\right) = \frac{1}{m_m}\frac{dQ_m}{d\theta} + \upsilon_m\frac{dP}{d\theta} \Rightarrow \frac{dT_m}{d\theta} = \frac{1}{c_{P,m}.m_m}\frac{dQ_m}{d\theta} + \frac{\upsilon_m}{c_{P,m}}\frac{dP}{d\theta} \qquad \text{(Eqn.8)}$$

The in-cylinder volume, V is a function of the crank angle, θ and as the two-zone quasi-dimensional modelling is adopted in this study, the V is assumed to be subdivided by the flame front into two zones (a zone with the unburned fuel-air mixture (V_m), another with the burned products (V_p)) [46]. Thus, V= V_m + V_p, and their crank ange derivative is presented as per Eqn 9. The two zones behave with an ideal gas nature (of $PV=mRT$), which results in derivation of Eqn. 10 and 11, respectively for the unburned mixture and burned products zones.

$$V = \frac{\pi}{4}D^2 a_c\left[\left(1-\cos\theta\right) + \frac{L}{a_c} - \sqrt{\frac{L^2}{a_c^2} - \sin^2\theta}\,\right] \quad ;\ V= V_m + V_p$$

$$\frac{\partial V}{\partial\theta} = \frac{\partial V_m}{\partial\theta} + \frac{\partial V_p}{\partial\theta} = 0 \qquad \text{(Eqn.9)}$$

$$\frac{\partial V_m}{\partial \theta}=\frac{R_mT_m}{P}\frac{dm_m}{d\theta}+\frac{m_mR_m}{P}\frac{dT_m}{d\theta}-\frac{m_mR_mT_m}{P^2}\frac{dP}{d\theta}=\frac{V_m}{m_m}\left(-\frac{\partial m_p}{\partial \theta}\right)+\frac{R_mm_m}{P}\frac{\partial T_m}{\partial \theta}-\frac{V_m}{P}\frac{\partial P}{\partial \theta}$$

(Eqn.10)

$$\frac{\partial V_p}{\partial \theta}=\frac{R_pT_p}{P}\frac{dm_p}{d\theta}+\frac{m_pR_p}{P}\frac{dT_p}{d\theta}-\frac{m_pR_pT_p}{P^2}\frac{dP}{d\theta}=\frac{V_p}{m_p}\left(\frac{\partial m_p}{\partial \theta}\right)+\frac{R_pm_p}{P}\frac{\partial T_p}{\partial \theta}-\frac{V_p}{P}\frac{\partial P}{\partial \theta} \qquad \text{(Eqn.11)}$$

Substituting Eqn. 10 and 11 in Eqn.9 results in Eqn. 12.

$$\frac{\partial V}{\partial \theta}=\frac{\partial m_B}{\partial \theta}\left(\frac{V_p}{m_p}-\frac{V_m}{m_m}\right)+\frac{R_mm_m}{P}\frac{\partial T_m}{\partial \theta}+\frac{R_pm_p}{P}\frac{\partial T_p}{\partial \theta}-\frac{V}{P}\frac{\partial P}{\partial \theta} \qquad \text{(Eqn.12)}$$

Now, by substituting Eqn. 8 in Eqn.12, the differential for T_P is obtained as Eqn.13.

$$\frac{dT_p}{d\theta}=\frac{P}{m_pR_p}\left[\frac{dV}{d\theta}-\left(\frac{V_p}{m_p}-\frac{V_m}{m_m}\right)\frac{dm_p}{d\theta}-\frac{m_mR_m}{P}\frac{dT_m}{d\theta}+\frac{V}{P}\frac{dP}{d\theta}\right]$$

$$\Rightarrow\frac{dT_p}{d\theta}=\frac{P}{m_pR_p}\left[\frac{dV}{d\theta}-\left(\frac{R_pT_p}{P}-\frac{R_mT_m}{P}\right)\frac{dm_p}{d\theta}-\frac{m_mR_m}{P}\left(\frac{1}{c_{p,m}m_m}\frac{dQ_m}{d\theta}+\frac{\upsilon_m}{c_{p,m}}\frac{dP}{d\theta}\right)+\frac{V}{P}\frac{dP}{d\theta}\right]$$

$$\Rightarrow\frac{dT_p}{d\theta}=\frac{P}{m_pR_p}\left[\frac{dV}{d\theta}-\left(\frac{R_pT_p}{P}-\frac{R_mT_m}{P}\right)\frac{dm_p}{d\theta}-\frac{R_m}{c_{p,m}P}\frac{dQ_m}{d\theta}-\frac{R_mV_m}{c_{p,m}P}\frac{dP}{d\theta}+\frac{V}{P}\frac{dP}{d\theta}\right] \qquad \text{(Eqn.13)}$$

Coupling Eqn.4 with the first law of thermodynamics (Eqn.1), and substituting Eqn. 8 and 13, results in Eqn.14.

$$\left(e_p-e_m\right)\frac{dm_p}{d\theta}+m_m\frac{de_m}{d\theta}+m_p\frac{de_p}{d\theta}=\frac{dQ}{d\theta}-\frac{dW}{d\theta}$$

$$\Rightarrow\left(e_p-e_m\right)\frac{dm_p}{d\theta}+m_mc_{v,m}\frac{dT_m}{d\theta}+m_pc_{v,p}\frac{dT_p}{d\theta}-\frac{dQ}{d\theta}+P\frac{dV}{d\theta}=0$$

$$\Rightarrow\left(e_p-e_m\right)\frac{dm_p}{d\theta}+m_m c_{v,m}\left(\frac{1}{c_{P,m}m_m}\frac{dQ_m}{d\theta}+\frac{V_m}{m_m.c_{P,m}}\frac{dP}{d\theta}\right)+$$

$$m_p c_{v,p}\left\{\frac{P}{m_pR_p}\left[\frac{dV}{d\theta}-\left(\frac{R_pT_p}{P}-\frac{R_mT_m}{P}\right)\frac{dm_p}{d\theta}-\frac{R_m}{c_{p,m}P}\frac{dQ_m}{d\theta}-\frac{R_mV_m}{c_{p,m}P}\frac{dP}{d\theta}+\frac{V}{P}\frac{dP}{d\theta}\right]\right\}-\frac{dQ}{d\theta}+P\frac{dV}{d\theta}=0$$

$$\Rightarrow\left(e_p-e_m\right)\frac{dm_p}{d\theta}+\frac{c_{v,m}}{c_{P,m}}\frac{dQ_m}{d\theta}+\frac{c_{v,m}V_m}{c_{P,m}}\frac{dP}{d\theta}+$$

$$\frac{c_{v,p}.P}{R_p}\left[\frac{dV}{d\theta}-\left(\frac{R_pT_p}{P}-\frac{R_mT_m}{P}\right)\frac{dm_p}{d\theta}-\frac{R_m}{c_{p,m}P}\frac{dQ_m}{d\theta}-\frac{R_mV_m}{c_{p,m}P}\frac{dP}{d\theta}+\frac{V}{P}\frac{dP}{d\theta}\right]-\frac{dQ}{d\theta}+P\frac{dV}{d\theta}=0$$

$$\Rightarrow\left(e_p-e_m\right)\frac{dm_p}{d\theta}+\frac{c_{v,m}}{c_{P,m}}\frac{dQ_m}{d\theta}+\frac{c_{v,m}V_m}{c_{P,m}}\frac{dP}{d\theta}+\frac{c_{v,p}.P}{R_p}.\frac{dV}{d\theta}-\left(\frac{R_pT_p}{P}-\frac{R_mT_m}{P}\right)\frac{c_{v,p}.P}{R_p}\frac{dm_p}{d\theta}-$$

$$\frac{c_{v,p}}{R_p}\frac{R_m}{c_{p,m}}\frac{dQ_m}{d\theta}-\frac{c_{v,p}}{R_p}\frac{R_mV_m}{c_{p,m}}\frac{dP}{d\theta}+\frac{c_{v,p}V}{R_p}\frac{dP}{d\theta}-\frac{dQ}{d\theta}+P\frac{dV}{d\theta}=0$$

$$\Rightarrow\left[\left(e_p-e_m\right)-c_{v,p}\left(T_p-\frac{R_mT_m}{R_p}\right)\right]\frac{dm_p}{d\theta}+\left(\frac{c_{v,m}}{c_{P,m}}-\frac{c_{v,p}R_m}{R_pc_{p,m}}\right)\frac{dQ_m}{d\theta}+$$

$$\left(\frac{c_{v,m}V_m}{c_{P,m}}-\frac{c_{v,p}}{R_p}\frac{R_mV_m}{c_{p,m}}+\frac{c_{v,p}V}{R_p}\right)\frac{dP}{d\theta}-\frac{dQ}{d\theta}+\left(1+\frac{c_{v,p}}{R_p}\right)P\frac{dV}{d\theta}=0$$

$$-\frac{dP}{d\theta}=\frac{\left\{\left(1+\frac{c_{v,p}}{R_p}\right)P\frac{dV}{d\theta}+\left(\frac{c_{v,m}}{c_{P,m}}-\frac{c_{v,p}R_m}{R_pc_{p,m}}\right)\frac{dQ_m}{d\theta}+\left[\left(e_p-e_m\right)-c_{v,p}\left(T_p-\frac{R_mT_m}{R_p}\right)\right]\frac{dm_p}{d\theta}-\frac{dQ}{d\theta}\right\}}{\left(\frac{c_{v,m}V_m}{c_{P,m}}-\frac{c_{v,p}}{R_p}\frac{R_mV_m}{c_{p,m}}+\frac{c_{v,p}V}{R_p}\right)}$$

(Eqn.14)

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