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1. Yadav C, Sahoo RR. Thermophysical properties and thermal performance evaluation of multiwalled carbon nanotube-based organic phase change materials using T-History method. International Journal of Energy Research. 2021 Oct 21.
2. Yadav C, Sahoo RR. Effect of nano-enhanced PCM on the thermal performance of a designed cylindrical thermal energy storage system. Experimental Heat Transfer. 2021 Jun 7;34(4):356-75.
3. Yadav C, Sahoo RR. Thermal analysis comparison of nano-additive PCM-based engine waste heat recovery thermal storage systems: an experimental study. Journal of Thermal Analysis and Calorimetry. 2021 Feb 25:1-8.
4. Yadav C, Sahoo RR. Thermal performance analysis of MWCNT-based capric acid PCM thermal energy storage system. Journal of Thermal Analysis and Calorimetry. 2020 Aug 28:1-2.
5. Yadav C, Sahoo RR. Experimental analysis for optimum thermal performance and thermophysical parameters of MWCNT based capric acid PCM by using T-history method. Powder Technology. 2020 Mar 15;364:392-403.
6. Yadav C, Sahoo RR. Exergy and energy comparison of organic phase change materials based thermal energy storage system integrated with engine exhaust. Journal of Energy Storage. 2019 Aug 1;24:100773.
7. Yadav C, Sahoo RR. Energetic and exergetic investigation on lauric and stearic acid phase-change material–based thermal energy storage system integrated with engine exhaust. Heat Transfer—Asian Research. 2019 May;48(3):1093-108.

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Appendix A:

Table A.1: Organic PCMs with its thermo-physical

PCM	T_m(°C)	H_f(kJ/kg)	ρ(kg/m^3)	K(W/m-K)	c_p(kJ/kg-K)	Ref.
Paraffin and Waxes						
Tetradecane	5.5–5.8	227–228	825 (s) 771 (l)	0.15 (s)	2.07 (s)	(Himran et al., 1994)
Hexadecane	16.7–18.1	236–237	835 (s) 770–776 (l)	0.15 (s)	2.11 (s)	
Octadecane	27.5–28	243–244	814–865(s) 774–780 (l)	0.15–0.36 (s) 0.15 (l)	1.9–2.14 (s) 2.3–2.66 (l)	
Eicosane	36.7	247	785 (s) 778 (l)	0.15 (s)	2.21 (s) 2.01 (l)	
Heptacosane	58.8	235	773–802	-	1.92 (s) 2.44 (l)	
Paraffin wax	32–32.1	251	830	0.514 (s) 0.224 (l)	3.26 (s) 1.92 (l)	(Agyenim et al., 2010)
Medicinal paraffin	40–44	146	830	0.5 (s) 2.3 (l)	2.2 (s) 2.1 (l)	
Commercial paraffin wax	52.1	243.5	809.5 (s) 771 (l)	0.15 (s)	2.89 (s)	
Fatty acid PCM						
Capric acid	31.5–32	152.7–162.8	1004 (s)	0.149–0.153	2.10 (s) 2.09 (l)	

			853–886 (l)			(Rozanna et al., 2005)
Lauric acid	41–44.2	177.4–211.6	1007 (s) 848–870 (l)	0.139–0.192	1.76–2.14 (s) 2.15–2.27 (l)	
Myristic acid	49–58	186.6–204.5	990 (s) 844–861 (l)	-	1.59–2.8 (s) 2.16–2.7 (l)	
Palmitic acid	55–64	163–211.8	989 (s) 845–850 (l)	0.103–0.172	2.06–2.2 (s) 1.7–2.48 (l)	
Stearic acid	55–71	186.5–210	941–965 (s) 839–848 (l)	0.097–0.172	2.07–2.83 (s) 1.9–2.38 (l)	
Sugars and sugar alcohols						
Glycerol	17.9	198.7	1260 (l)	-	-	(Hale et al., 1971)
Xylitol	92.7–94.5	232–263.3	1520	-	-	(Talja and Roos, 2001)
Erythritol	117–118	315–344	1480 (s) 1300 (l)	0.733 (s) 0.326 (l)	1.383 (s) 2.765 (l)	
Glucose	141	174	1544	-	-	(Hale et al., 1971)
d-Mannitol	165–168	294–341	1489–1520	-	-	(Kaizawa et al., 2008)
Galactitol	188–189	351.8	1470	-	-	(Kakiuchi et al.,1998)

Other organic PCMs						
Acetic acid	16.7	187	1050 (l)	0.18 (l)	2.04 (s) 1.96 (l)	(Hale et al., 1971)
Cyanamide	44	209	1080	-	-	
9-Heptadecanone	51	213	-	-	-	
Chloroacetic acid	56	130	1580	-	-	
Acetamide	81	241	1159(s)-998.6 (l)	-	-	
Glutaric acid	97.5	156	1429	-	-	
Urea	133–135	170–258	1340	-	-	
Acetanilide	115–119	152–222	1210	-	-	

Table A.2: Inorganic PCMs with its thermo-physical

PCM	**T_m (°C)**	**H_f (kJ/kg)**	**ρ (kg/m^3)**	**K (W/m-K)**	**c_p (kJ/kg-K)**	**Ref.**
Salt hydrates						
Calcium chloride hexahydrate	27.45–30	161.15–192	1682–1802 (s) 1496–1620 (l)	0.53–0.56 (l)	2.2 (l) 1.4 (s)	(Dincer and Rosen, 2010)
Lithium nitrate trihydrate	29.9–30.2	287–296	1550–1575 (s) 1372–1430 (l)	0.74–0.8 (s) 0.56–0.59 (l)	1.8 (s) 2.8 (l)	(Shamberger and Reid, 2012)
Sodium carbonate decahydrate	32–36	246.5–251	1440–1442 (s)	-	-	(Hasnain, 1998)
Sodium phosphate dibasic dodecahydrate	35–40	265–281	1507.1–1522 (s) 1442 (l)	0.514 (s) 0.476 (l)	1.69 (s) 1.94 (l)	
Sodium sulfate decahydrate, ‘‘Glauber’s Salt’’	31–32.4	251.1–254	1485 (s)	0.544 (s)	1.93 (s)	

Sodium thiosulfate pentahydrate	45–51.3	200–217.2	1720–1730 (s) 1660–1690 (l)	-	1.46 (s) 2.39 (l)	(Abhat, 1983)
Barium hydroxide octahydrate	78	265.7–301	2070–2180 (s) 1937 (l)	1.255 (s) 0.653–0.678(l)	1.17 (s)	
Fused/molten salt-based PCMs						
Aluminum chloride	192–192.4	272–280	2440	-	-	(Hasnain, 1998)
Lithium nitrate	250–254	360–373	2380	-	-	(Nomura et al., 2010)
Sodium nitrate	306–310	172–199	2257–2261	0.5 (s)	1.1 (s) 1.82 (l)	
Potassium nitrate	330–336	88–266	2109–2110	0.5	0.94 (s) 1.22 (l)	Michels and Pitz-Paal, 2007)
Metals based PCMs						
Gallium	29.8–30	80.12–80.3	5903–5907 (s) 6093 (l)	33.7 (s) 29.4 (l)	0.34 (s) 0.37–0.397 (l)	
60Sn 40Bi (Indalloy 281–338)	138–170	44.4	8120	30	0.18 (s) 0.213 (l)	

Indium	156.7–156.8	28.47–28.59	7310 (s) 7030 (l)	86 (s) 36.4 (l)	0.243 (s) 0.27 (l)	(Ostrý et al., 2020)
Tin	232	60.5	7280 (s) 6940 (l)	73	0.222–0.257	
Bismuth	271–271.4	53.3	9790–9800	8.1	0.12	
59Al–35Mg–6Zn	443	310	2380	-	1.63 (s) 1.46 (l)	(Kenisari, 2010)
88%Al–12%Si	576	560	2700	160	1.038 (s) 1.741 (l)	

Table A.3: Eutectics PCMs with its thermo-physical

PCM	T_m (ºC)	H_f (kJ/kg)	P (kg/m^3)	K (W/m-K)	c_p (kJ/kg-K)	Ref.
Organic-organic PCMs						
65% Carpic acid +35% lauric acid	18–19.5	140.8	-	0.143(s) 0.139(l)	1.97(s) 2.24(l)	(Rozanna et al., 2005)
77% Lauric acid +23% palmitic acid	33.0	150.6	-	-	1.77(s) 2.41(l)	(Kenisarin and Mahkamov, 2007)
75.5% Lauric acid +24.5% stearic acid	37	182.7	-	-	1.92(s) 2.10(l)	(Rozanna et al., 2005)

51% Myristic acid +49% Palmitic acid	39.8	174	-	-	-	(Peippo et al., 1991)
65.7% Myristic acid +34.3% stearic acid	44	18	-	-	-	
64.9% Palmitic acid + 35.1% stearic acid	50.4	181	-	-	-	
50% Palmitic acid +45.5% stearic acid +4.5% other fatty acids—emersol 132 Mixture	54–57	18	-	-	-	Cabeza et al.,2011)
Organic-Inorganic PCMs						
38.5% Trimethylolethane + 31.5% Water + 30% Urea	14.4	160	1170 (s) 1140 (l)	0.66 (s) 0.37 (l)	4.22 (s) 3.09 (l)	(Kenisari, 2010)
62.5% Trimethylolethane + 37% Water	29.8	218	1120 (s) 1090 (l)	0.65 (s) 0.21 (l)	2.75 (s) 3.58 (l)	
67.1% Naphthalene + 32.9% Benzoic acid	67	123.4	-	0.257–0.282 (s) 0.130–0.136 (l)	-	

Inorganic-Inorganic PCMs						
50%$NaNO_3$ + 50%KNO_3	220–222	100–100.7	1920	0.56 (s)	2.25 (s) 1.35 (l)	(Agyenim et al., 2010)
68.1%KCl + 31.9%$ZnCl_2$	235	198	2480	0.8 (s)	2.25 (s)	(Zalba B et al., 2003)
36%LiCl + 63%LiOH	262	485	1550	1.1 (s)	2.4 (s)	(Kenisari, 2010)
7.8%NaCl + 6.4%Na_2CO_3 + 85.8%NaOH	282	316	2130	-	2.51 (s)	
95.5%KNO_3+ 4.5%KCl	320	74	2100	0.5 (s)	1.21 (s)	Michels and Pitz-Paal, 2007)
41.3%KCl + 58.7%LiCl	352.7	251.5	1880	-	0.95 (s) 1.33 (l)	(Korin et al., 1998)
14%KCl + 63%$MgCl_2$ + 22.3%NaCl	385	461	2250	0.95 (l)	0.96 (s)	(Kenisari, 2010)

Table A.4: Nano-enhanced PCMs with its thermo-physical

NEPCMs	T_m (°C)	H_f (kJ/kg)	ρ (kg/m^3)	K (W/m-K)	c_p (kJ/kg-K)	Ref.
92% Palmatic acid acid-Stearic acid+8% CNTs	53.59	163	-	0.34	-	(Atinafu et al., 2018)
85% Myristic acid -Stearic acid+15% CNT	45.24	148.12	-	0.28	-	
88% Myristic acid -Stearic acid+ 12% CNT	45.16	159.53	-	0.26	-	
85% Myristic acid -Stearic acid+15% GC	49.18	153.12	-	0.27	-	
85% Myristic acid -Stearic acid+15% PC	48.65	157.35	-	0.37	-	
88% Myristic acid-Stearic acid+12% NPC	49.45	164.33	-	0.37	-	
95% Bio-based PCM+5% GnP	29.6	143.5	-	0.670	-	
95% Bio-based PCM+5% CNT	31.6	130.1	-	0.536	-	

99% Paraffin +1% Cu	60	183.9	908	0.2908(s) 0.1878(l)	2.924(s)2.390(l)	(Yu et al., 2014)
99% (Lauric acid + Stearic acid) +1% TiO_2	34.38	173.22	-	0.27	-	(Harikrishnan et al., 2014)
99% (Lauric acid + Stearic acid) +1% ZnO	34.47	173.64	-	0.29	-	
99% (Lauric acid + Stearic acid) +1% CuO	34.56	173.86	-	0.32	-	
88% (Neopentyl+ glycol) 6%Al + 6%Cu	40-43	74	1619	0.3520	1.786	(Elsayed, 2015)
88% (Neopentyl+ glycol) 6%SiO_2+ 6%Cu	40-43	76	1590	0.3298	1.792	
88% (Neopentyl+ glycol) 6%SiO_2+ 6%Al	40-43	99.4	1214	0.3296	2.297	
80% Octadecanoic acid +20%	56	181.8	963	2.635	1.849	(Zhong et al., 2013)

Graphene aerogel						
90% Octadecane + 10% Al_2O_3	26.3	212.3	850	0.14	-	Ho and Gao, 2009)

Appendix-B:

Table B.1: The past literature on the inorganic PCM based of TES system

Author/year	Inorganic PCM	Findings
(Marks, 1980)	Glauber's salt	The pure Glauber salt and the thickened mixture were unfit for long-term use as latent heat storage materials.
(Wada et al., 1984)	Sodium acetate trihydrate ($CH_3CO_2Na\ 3H_2O$)	heat storage capacity has decreased during thermal cycling.
(Kimura and Kai, 1984)	Calcium chloride hexahydrate ($CaCl_2\ 6H_2O$)	The problem of phase separation happened during the number of repeated thermal cycles. Also, $CaCl_24H_2O$ tends to settle down at the bottom of the solution.
(Dincer, 2002)	Water, Brick, Clay, Salt Hydrates, etc.	The selection of the TES systems mainly depends on the storage period required, economic viability, operating conditions.
(Shukla et al., 2008)	Erythritol	Erythritol has a very high energy density; therefore, it can be a good PCM for higher temperature thermal energy storage purposes.
(Sebaii et al., 2009)	Magnesium chloride hexahydrate ($MgCl_2.6H_2O$)	Not compatible with either aluminum or stainless steel.
(Cardenas and Leon, 2013)	Inorganic salt compositions and metallic alloys	Inorganic salt compositions and metallic alloys, as storage media in a high-temperature latent heat storage system, thermophysical properties database to facilitate the material

		selection task for high-temperature applications.
(Wei et al., 2016)	Al-Si, Al-Cu, Al-Mg, and Al-Cu-Zn alloys	By mixing Cu, Zn, and Si into an aluminum alloy help reduce the melting point of the alloy.
(Fernández et al., 2017)	Metals and metal alloy	In pure metals, subcooling will occur either with homogeneous or heterogeneous nucleation.
(Paola et al., 2020)	Glauber's salt-based PCMs	The cooling rate did not affect the initial temperature and specific heat but strongly influenced the solidification enthalpy.

Table B.2: Enhancement of thermophysical properties in NEPCM based TES system studied in the past literature

Author/year	NEPCM	Findings
(Yavari et al., 2011)	1-Octadecanol and graphene nanoparticle	4% Nanoplatelets increase 2.5 times thermal conductivity but 15.4% in latent heat.
(Jesumatty, 2012)	Paraffin and CuO	Nanoparticles by 2%, 5% and 10% in paraffin PCM thermal conductivity increased by 6%, 6.7% and 7.8% respectively.
(Shi et al., 2013)	Paraffin and graphite nanoplatelets	The thermal conductivity was increased by 0.25 to 2.7 with 10% nanoplatelets.
(Sahan and Paksoy, 2014)	Paraffin and Fe_3O_4	10% by the mass fraction of nanoparticles in PCM increased the latent heat by 20%.

(Yang et al., 2014)	Paraffin and Si_3N_4	Increased 35% thermal conductivity.
(Motahar et al., 2014)	Mesoporous silica nanoparticles in n-octadecane	Thermal conductivity increased by 5% and 6 % of 3% and 5% mass fraction of nanoparticles, respectively.
(Aziz et al., 2015)	Paraffin wax and Al_2O_3 nanoparticle	The volumetric concentration of nanoparticles of 2% would result in the highest melting rate.
(Sharma et al., 2016)	Palmitic acid and TiO_2	PCM's thermal conductivity increased by 12.7, 20.6, 46.6, and 80% for nanoparticle weight fractions of 0.5, 1.3, and 5%, respectively.
(Y.Addad et al., 2017)	Therminol 66 and CuO	By 5% nanoparticles concentration as heat transfer fluid would reduce the charging/ discharging period by 20%.
(Soroush Edadi et al., 2018)	Coconut oil and CuO	CuO in coconut does not show a significant effect in starting stage, but as time advanced, dispersion of CuO nanoparticles to coconut oil improves the melting rate in the PCM.
(Saeed et al., 2018)	Methyl palmitate, lauric acid, 2-hydroxypropyl ether cellulose and nano-graphene	At 10% of nano platelets, enhancement in:- K_s:102.2% and K_l:97.7% C_{ps}:52% and C_{pl}:64% α_s :47% and α_l :54%

Table B.3: Enhancement of thermophysical properties in TES system by applying SWCNT/MWCNT based PCM studied in the past literature

Author/year	CNT-PCM	Findings
(Zeng et al., 2009)	MWCNT -Palmitic acid	5% of MWNTs based PA; the thermal conductivity was enhanced by 26%.
(Deqiu Zou et al., 2018)	MWCNT /Graphene-Paraffin wax	MWCNT/graphene-based PCM has 31.8%, 55.4%, and 124% higher thermal conductivity than graphene-based PCM, MWCNT based PCM, and pure PCM, respectively
(Xu et al., 2018)	CuS-MWCNTs-Paraffin wax	The thermal conductivity of CuS–MWCNTs–6 mass %/PW is higher than that of MWCNTs–4.1 mass%/PW.
(Ranjbar et al., 2020)	MWCNT- Paraffin wax, Stearic acid, and Polyethylene glycol.	At one mass% of MWCNT, the thermal conductivity of stearic acid and polyethylene glycol was enhanced by 16.83% and 16.57%, respectively.
(Dinesh et al., 2020)	MWCNT -ternary eutectic PCM (oleic acid, isopropyl palmitate, butyl stearate)	The ternary eutectic PCM with 0.10 mass % MWCNT enhances the heat transfer rate and thermal conductivity by 34.45% and 67.28%, respectively, to the pure PCM.
(Li et al., 2021)	MWCNT-Polyethylene/Paraffin wax	The thermal and electrical conductivity is improved.
(Yu et al., 2021)	SWCNT-Sodium chloride(NaCl)	It has shown a reduction in the melting point temperature and heat of fusion by 36.37%.

Table B.4: Tubes bundles arrangement based TES system studied in the past literature

Author/Year	Tubes arrangement	Findings
(Gowda et al., 1996)	Inline tube bundles	The forced convection buoyancy across the tube bundles was assisting as well as opposing the flows
(Gupta, 2005)	Staggered tube bundles	The coefficient of heat transfer increases by a decrease in the pitch to tube diameter ratio, and an increase in the number of rows in a column increases the bundle. The heat transfer coefficient was increased from bottom to top row tubes.
(Naess, 2010)	Serrated spiral fin tube bundles	The heat transfer coefficient maximum at flow areas was equal in the transversal and diagonal planes.
(Mavridou et al., 2015)	Inline tube bundles	An optimum heat transfer was obtained at the longitudinal and transverse spacing ratio to tube diameter 1.5 and 3.6, respectively.
(Tahseen et al., 2017)	Staggered tube bundles	The heat transfer rate increases with decreasing longitudinal tube diameter and strongly depends on the Reynolds number.
(Geo et al., 2019)	Inline and staggered tube	Pseudo-critical carbon dioxide cross-flow over inline and staggered tube bundles were found, with a 25% maximum difference in cooling or heating conditions.
(Wu et al., 2020)	Staggered tube-bundle	The unequally-pitch arrangement of the tube-bundle heat exchanger enhances the overall heat transfer coefficient and thermal efficiency.
(Zuao et al., 2020)	Serrated spiral fin tube bundles	The twisted serrated fin heat transfer coefficient was 1.3 and 1.2 times that of the serrated fin at 250 °C and 350 °C, respectively.

Table B.5: The past literature on the applications of the TES system

Author/year	Application	Findings
(Benli, 2011)	Glass greenhouse heating	The heating COPs of GSHP units and the overall system were obtained in the range of 2.3-3.8 and 2-3.5, respectively.
(Reddy et al., 2012)	Water heating	38mm diameter spherical capsule shows better performance compared to spherical capsules of 58 and 68mm
(Mahfuz et al., 2014)	Water heating	Water from 0.033kg/min to 0.167kg/min energy efficiency increases from 63.88 to 77.41%.
(Eduard et al., 2014)	Reduction of CO_2 emission, cold storage, and transport	Cut down the CO2 emission by 22%.
(Karthikeyan et al., 2014)	Air heating	Beyond 1W/m-K thermal conductivity for the PCM will not produce considerable heat transfer enhancement.
(Parameshwaran et al., 2014)	Air conditioning system in the building	Variable air volume-based chilled water air conditioning system and TES energy saved 38% and 42%, respectively.
(Fritsch et al., 2015)	Electricity generation	Storage costs of 10h storage for 125MW power block were below 30€/kWh
(Wilson et al., 2015)	Food and drug shipping cold storage	The thermal energy storage/release capacity was about 88-119 J/kg
(Reza et al., 2015)	Space cooling	Cost and energy saving up to 93% and 92% per day respectively.

(Santosh et al., 2016)	Cooling of electronic components	Internal fins, metallic foams, and nanoparticles are mixed with PCM to enhance the performance of heat sinks.
(Rezoie, 2017)	Residential house heating	Overall energy and exergy efficiency of the TES are 60% and 19%, respectively.