

ANNEXURE-I

List of Publication

Journal Paper

- (1) Mehul Bambhania, Nikul Patel “Numerical modelling of the cavitation flow in throttle geometry”, Journal of Applied Fluid Mechanics, Vol. 16, No. 2, pp. 257-267, 2023 (SCI & Scopus) (H index-34)

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Numerical Modeling of the Cavitation Flow in Throttle Geometry

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ABSTRACT

- (2) Mehul Bambhania, Nikul Patel “Hydrodynamic Cavitation in the Fuel Injector Nozzle and its Effect on Spray Characteristics: A Review”, Journal of Heat and Mass Transfer Research, Vol. 10, pp. 1-20, 2023 (Scopus)

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Review Article

Hydrodynamic Cavitation in the Fuel Injector Nozzle and its Effect on Spray Characteristics: A Review

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ABSTRACT

The performance of internal combustion engines can be improved by optimizing fuel spray characteristics. However, high injection pressures and small nozzle diameters in modern fuel injectors result in cavitation flows inside the nozzle, making it difficult to accurately characterize vapor bubble formation and growth. In this review, we explore the influence of cavitation flow on spray formation and examine the effects of geometric and operational factors. We discuss the experimental techniques used to generate a cavitation map and the

Conference Paper

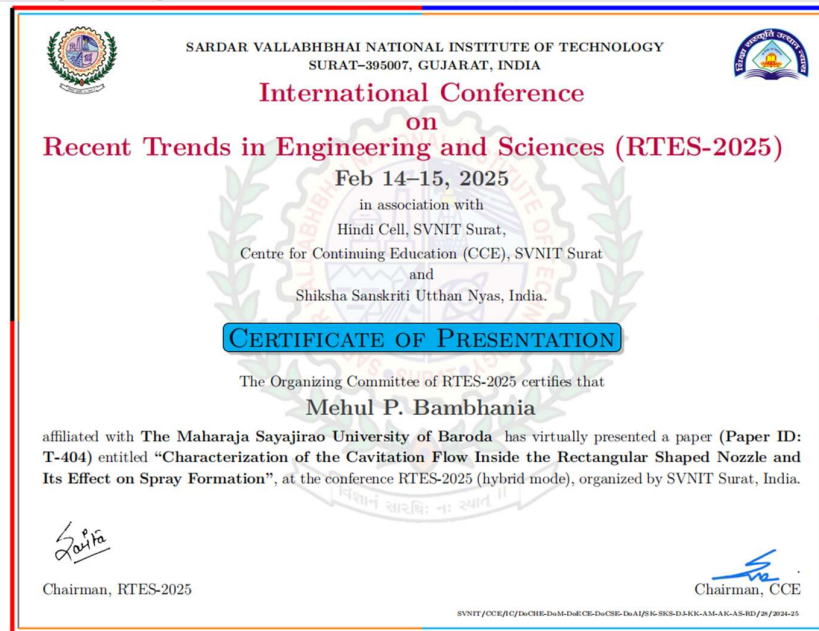
- (1) Presented paper entitled “Investigation of spray behaviour simulation to predict spray tip penetration under ultra-high injection pressure” in the International conference in Fluid, Thermal and Energy System (ICFTES’22) at NIT-Calicut on 9th June 2022.



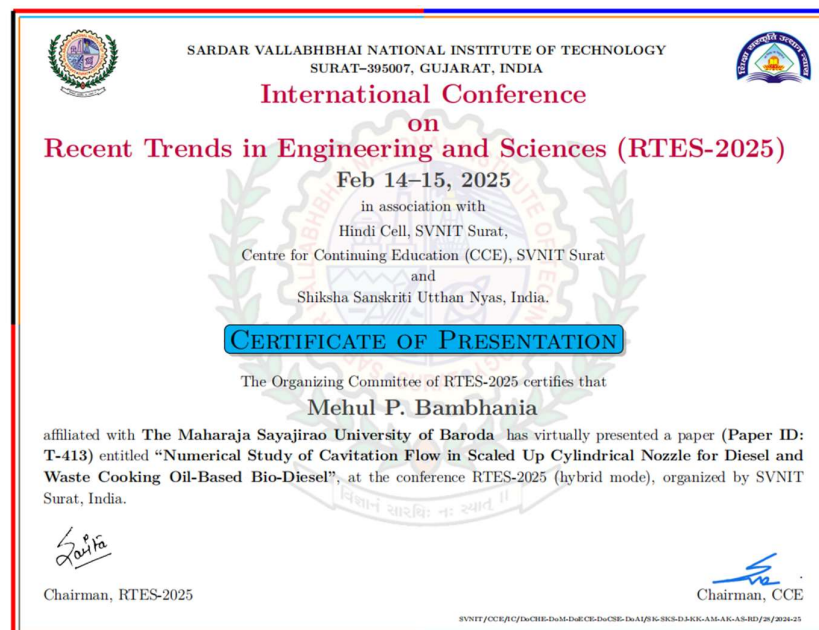
- (2) Presented paper entitled, “Experimental study for characterization of cavitation phenomenon in the optical nozzle” in International Conference on Recent Advances in (Applied) Sciences & Engineering (RAISE)12-13April,2023 organized by Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, (ISBN: 978-81-962938-1-9, pp 1-8)



- (3) Presented paper entitled “Characterization of the cavitation flow inside the rectangular shaped nozzle and its effect on Spray formation” International Conference on Recent Trends in Engineering and Sciences (RTES – 2025), SVNIT-Surat, 14-15 Feb 2025



- (4) Presented paper entitled “Numerical study of cavitation flow in scaled up cylindrical nozzle for diesel and waste cooking oil-based bio-diesel” International Conference on Recent Trends in Engineering and Sciences (RTES – 2025), SVNIT-Surat, 14-15 Feb 2025



Book Chapter

- (1) Mehul Bambhania, Nikul Patel, “Investigation of Spray Behaviour Simulation to predict spray tip penetration under ultra-high injection pressure”, Chapter 20, ISBN 978-981-99-5989-1, Lecture Notes in Mechanical Engineering, Publisher: Springer Nature-Singapore., Pages 215-227, Published on 18/01/2024, DOI: https://doi.org/10.1007/978-981-99-5990-7_20

Investigation of Spray Behaviour Simulation to Predict Spray Tip Penetration Under Ultra-High Injection Pressure



Mehul P. Bambhania and Nikul K. Patel

Abstract The spray characteristics, in particular, the spray tip penetration and atomization of the droplet are known to affect the fuel combustion in the diesel engine. Researchers have enough understanding of the diesel spray characteristics, but less frequent literature is available for biodiesel with ultra-high injection pressure. The non-evaporating spray simulation has been carried out for a single-hole fuel injector nozzle with a 0.16 mm diameter. The diesel fuel has been considered to be injected with 300 MPa injection pressure. The discrete phase model (DPM), which is based on the Lagrangian drop Eulerian fluid method, is used to simulate spray characteristics. The discrete random walk (DRW) model has taken into account the turbulent diffusion of the spray droplet. The spray tip penetration (STP) length has been calculated with the Kelvin–Helmholtz Rayleigh–Taylor (KHRT), Wave and Stochastic Secondary Droplet (SSD) spray breakup models and compared with the existing experimental data. The Wave model and experimental findings show good agreement. Three different nozzle diameters (0.16 mm, 0.25 mm and 0.3 mm) have been used to compare the L/d ratio with STP length. Finally, the spray formation with biodiesel exhibits slightly better spray penetration but suppressed atomization as compared to diesel fuel.

Keywords Ultra-high pressure · Diesel spray · Spray breakup model · Biodiesel spray · Discrete phase model

1 Introduction

The rapid growth in automobiles increases energy demand and carbon emissions, which leads to the risk of climate change. It is important to understand the spray characteristics of new fuel for effective power output and fulfil the new emission

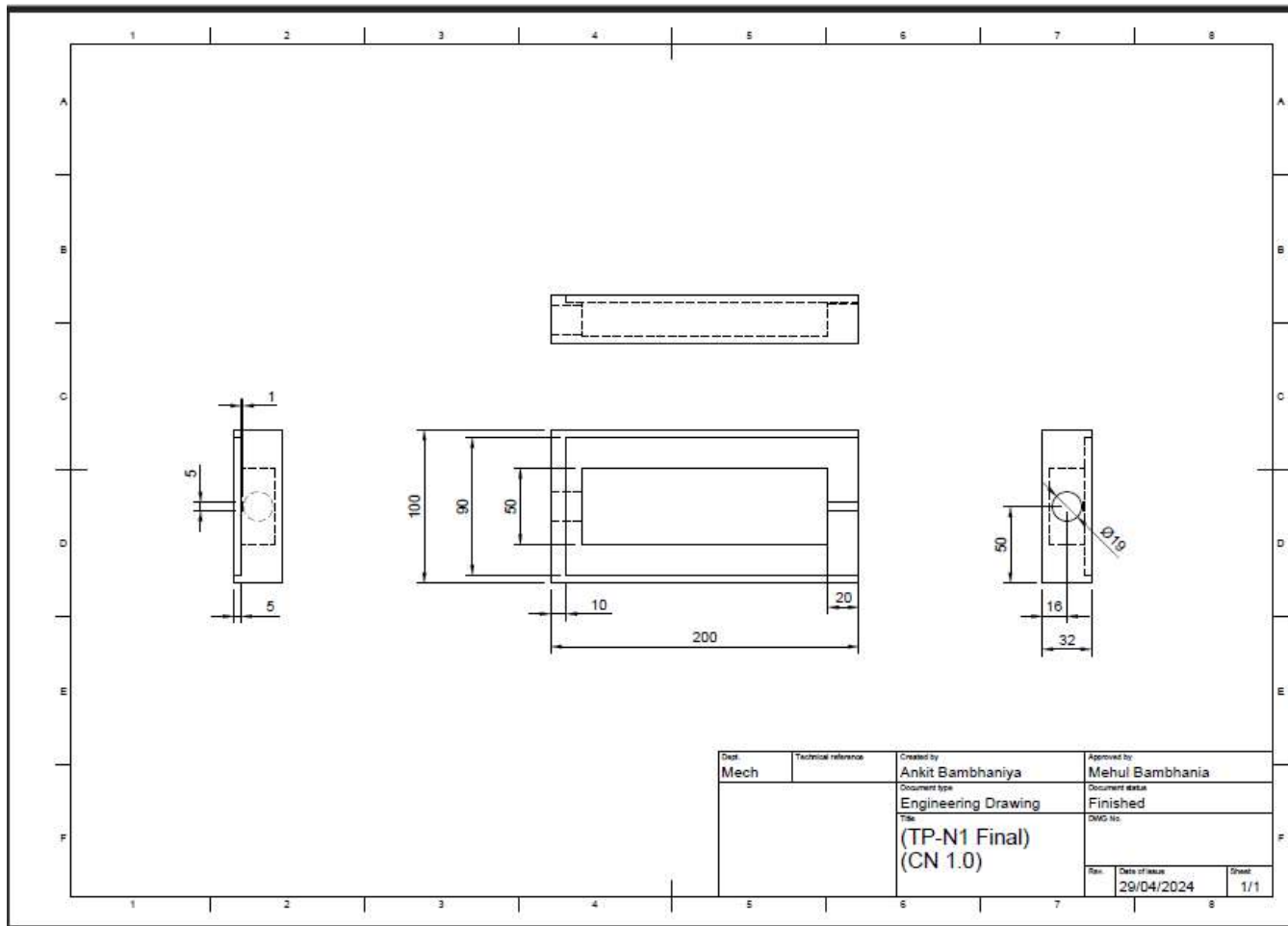
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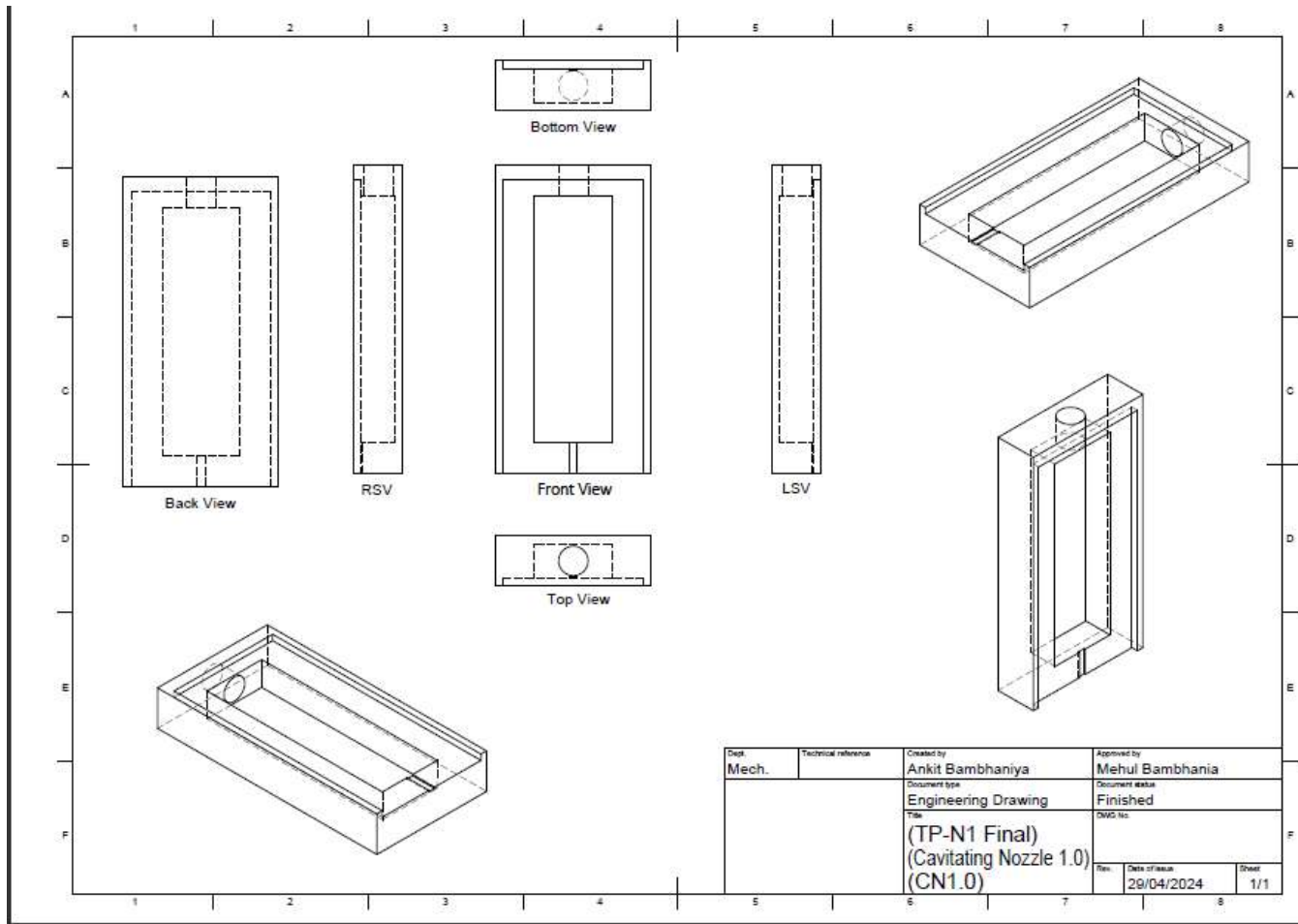
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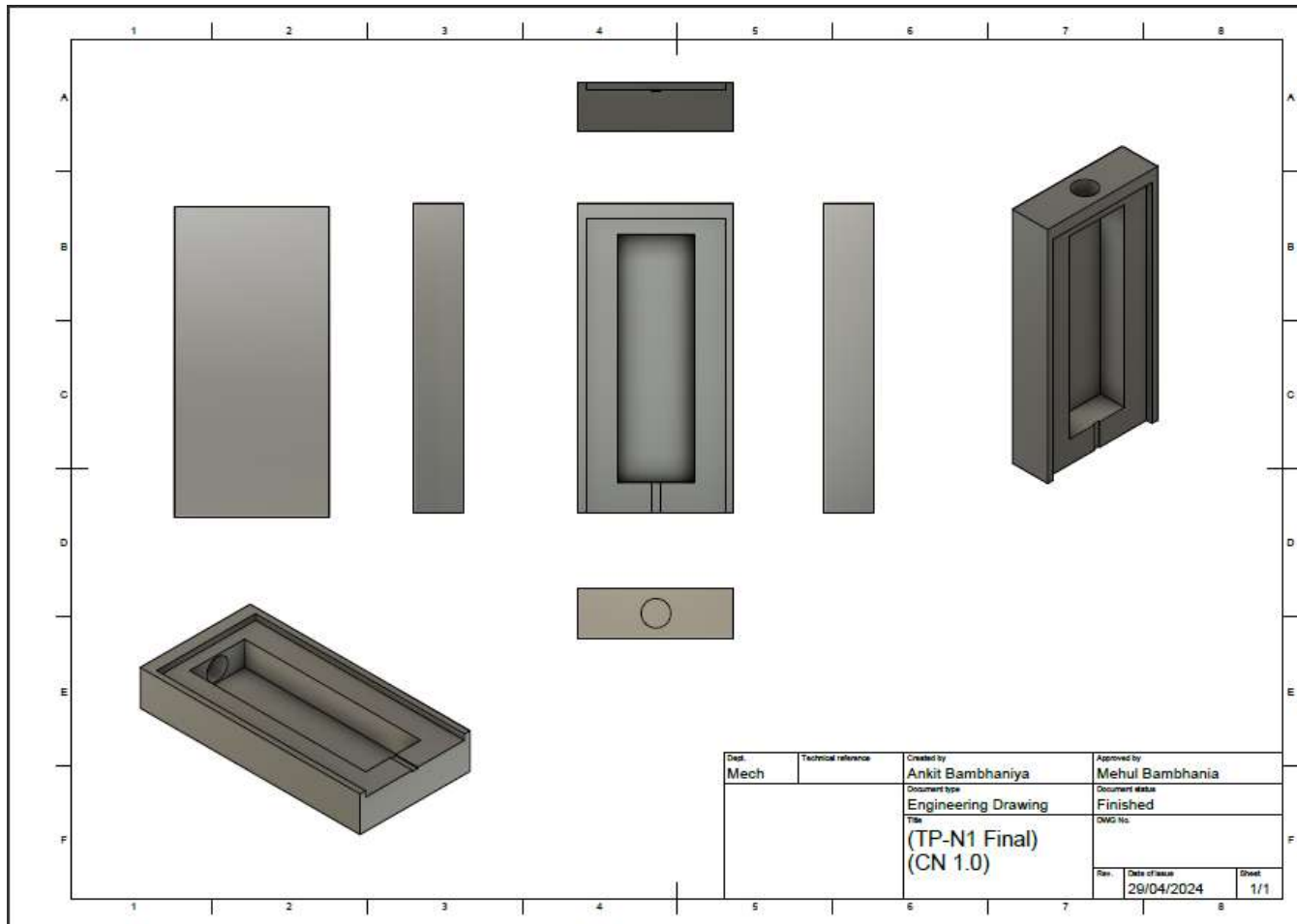
Annexure-II

Dimension details of Cavitation nozzle-3 (CN 3)

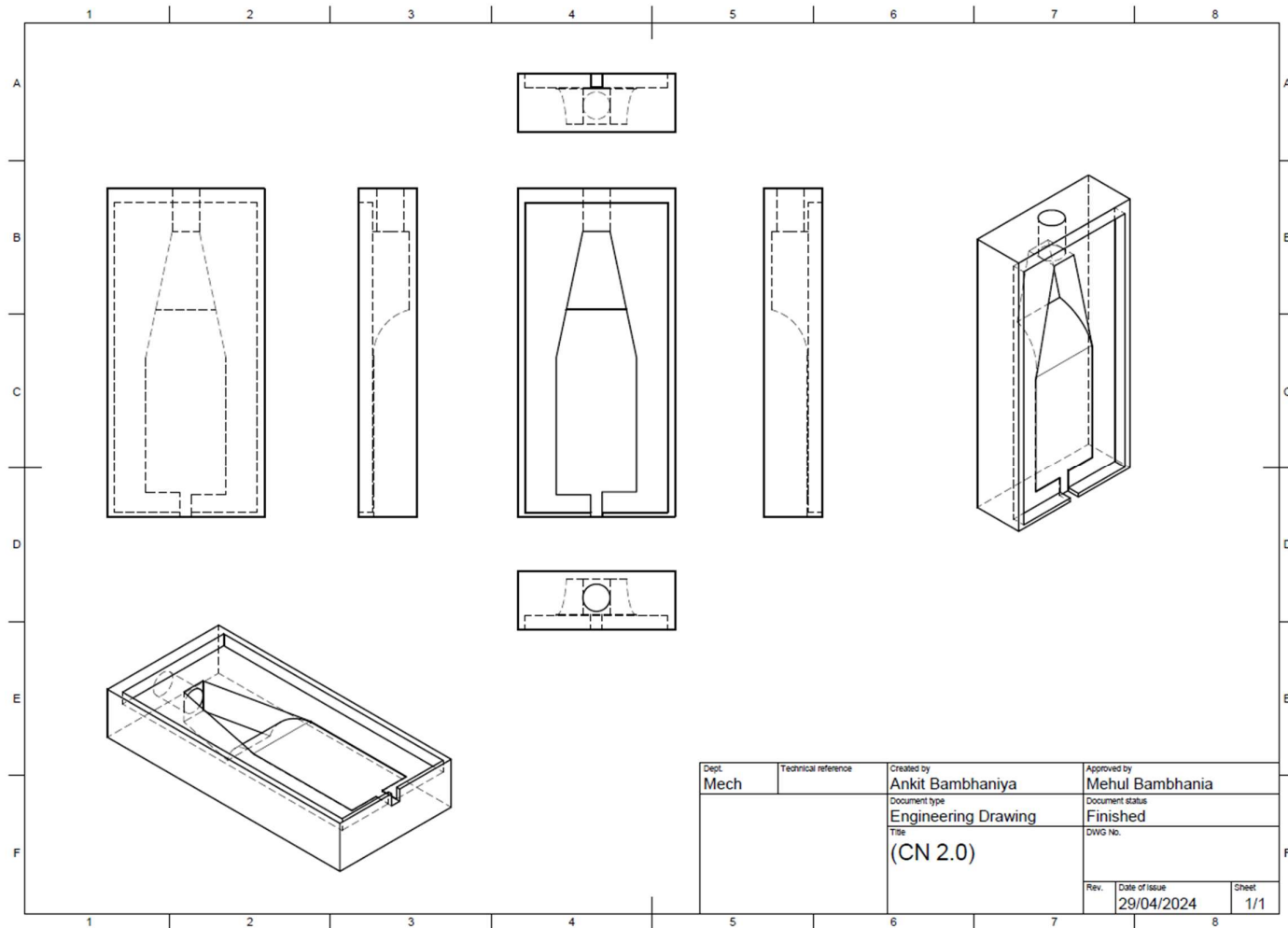




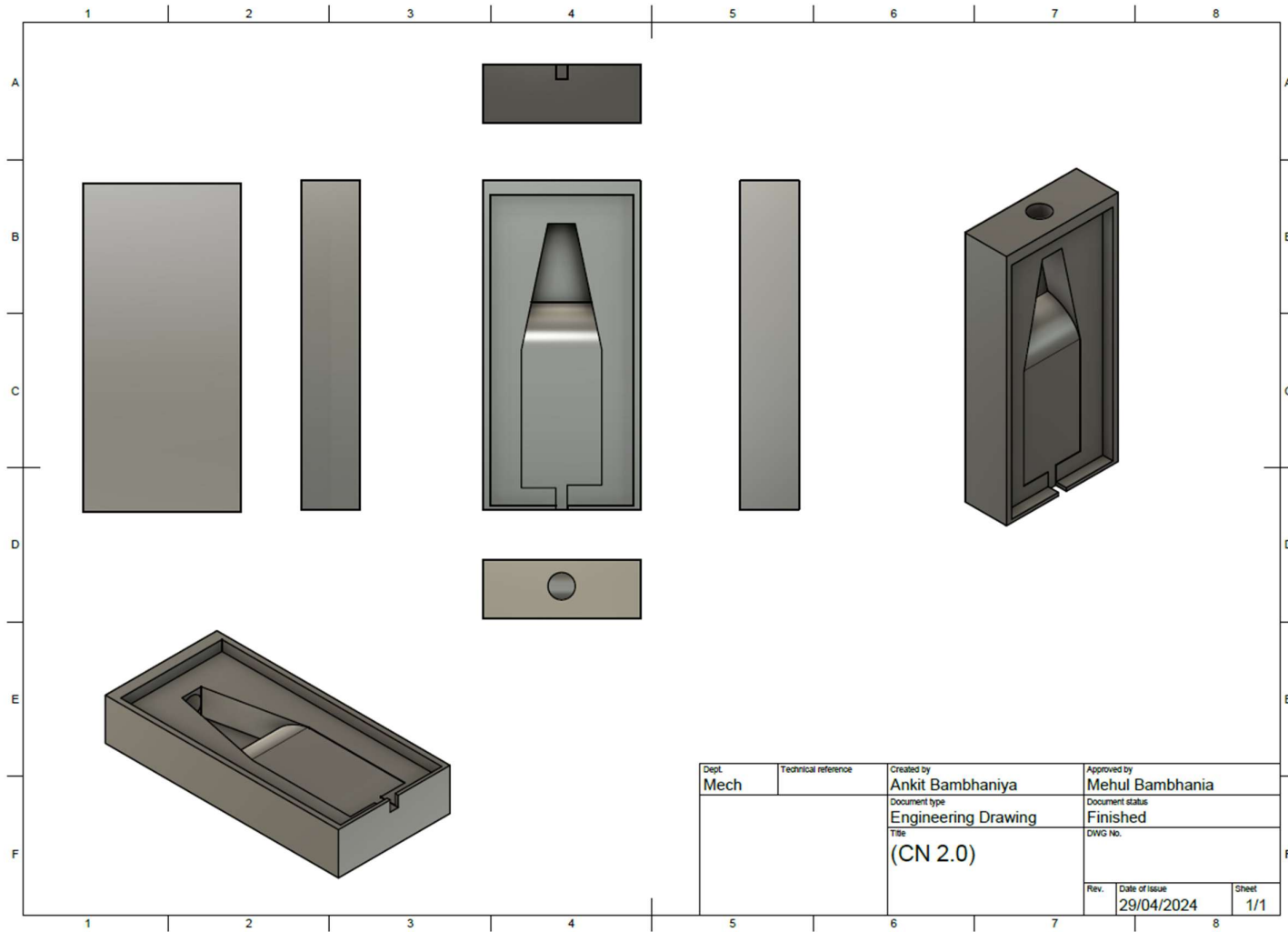
Dept.	Technical reference	Created by	Approved by
Mech.		Ankit Bambhaniya	Mehul Bambhaniya
		Document type	Document status
		Engineering Drawing	Finished
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		(Cavitating Nozzle 1.0)	
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			1/1



Dimension details of Cavitation nozzle-4 (CN 4)



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		Title (CN 2.0)	DWG No.
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Annexure-III

Experiment Data of Cavitation nozzle-3 (CN 3) for Water as Working Fluid

Sr. No.	Pressure (bar)	Cavitation Stage	LPM	Volume Flow Rate (m ³ /s)	Mass Flow Rate Actual (kg/s)	Mass Flow Rate Ideal (kg/s)	Velocity Actual (m/s)	Velocity Ideal (m/s)	Reynolds Number (Re)	Cavitation Number (CN)
1	0.5	No cavitation	3.1165	5.19E-05	0.0519417	0.055	10.388333	10	21696.603	1.8032298
2	0.6	No cavitation	3.2138	5.36E-05	0.0535633	0.0602495	10.712667	10.95445115	22373.991	1.6956947
3	0.7	No cavitation	3.3111	0.000055185	0.055185	0.0650769	11.037	11.83215957	23051.378	1.5974996
4	0.8	No cavitation	3.4084	5.68E-05	0.0568067	0.0695701	11.361333	12.64911064	23728.766	1.5075934
5	0.9	No cavitation	3.5057	5.84E-05	0.0584283	0.0737902	11.685667	13.41640786	24406.154	1.4250689
6	0.95	No cavitation	3.55435	5.92E-05	0.0592392	0.0758123	11.847833	13.78404875	24744.848	1.3863247
7	1	No cavitation	3.603	0.00006005	0.06005	0.0777817	12.01	14.14213562	25083.542	1.3491394
8	1.1	No cavitation	3.7003	6.17E-05	0.0616717	0.0815782	12.334333	14.83239697	25760.93	1.2791205
9	1.2	No cavitation	3.7976	6.33E-05	0.0632933	0.0852056	12.658667	15.49193338	26438.318	1.2144144
10	1.3	No cavitation	3.8949	0.000064915	0.064915	0.0886848	12.983	16.1245155	27115.706	1.1544968
11	1.4	No cavitation	3.9922	6.65E-05	0.0665367	0.0920326	13.307333	16.73320053	27793.094	1.0989066
12	1.5	Inception	4.0895	6.82E-05	0.0681583	0.0952628	13.631667	17.32050808	28470.482	1.0472369
13	1.6	Inception	4.1868	0.00006978	0.06978	0.098387	13.956	17.88854382	29147.87	0.9991275
14	1.7	Inception	4.2841	7.14E-05	0.0714017	0.101415	14.280333	18.43908891	29825.258	0.9542587
15	1.8	Inception	4.3814	7.30E-05	0.0730233	0.1043552	14.604667	18.97366596	30502.646	0.9123459
16	2	Inception	4.576	7.63E-05	0.0762667	0.11	15.253333	20	31857.421	0.8363986
17	2.1	Inception	4.6733	7.79E-05	0.0778883	0.1127165	15.577667	20.49390153	32534.809	0.8019329
18	2.2	Growth	4.7706	0.00007951	0.07951	0.115369	15.902	20.97617696	33212.197	0.7695544

19	2.3	Growth	4.8679	8.11E-05	0.0811317	0.1179619	16.226333	21.44761059	33889.585	0.739098
20	2.4	Growth	4.9652	8.28E-05	0.0827533	0.120499	16.550667	21.9089023	34566.973	0.7104146
21	2.5	Growth	5.0625	0.000084375	0.084375	0.1229837	16.875	22.36067977	35244.361	0.683369
22	2.6	Growth	5.1598	8.60E-05	0.0859967	0.1254193	17.199333	22.8035085	35921.749	0.657839
23	2.7	Growth	5.2571	8.76E-05	0.0876183	0.1278085	17.523667	23.23790008	36599.137	0.6337134
24	2.8	Growth	5.3544	0.00008924	0.08924	0.1301538	17.848	23.66431913	37276.525	0.610891
25	2.9	Growth	5.4517	9.09E-05	0.0908617	0.1324575	18.172333	24.08318916	37953.913	0.5892797
26	3	Growth	5.549	9.25E-05	0.0924833	0.1347219	18.496667	24.49489743	38631.3	0.5687952
27	3.1	Growth	5.6463	0.000094105	0.094105	0.1369489	18.821	24.8997992	39308.688	0.5493605
28	3.3	Growth	5.8409	9.73E-05	0.0973483	0.1412976	19.469667	25.69046516	40663.464	0.5133645
29	3.4	Growth	5.9382	0.00009897	0.09897	0.1434225	19.794	26.07680962	41340.852	0.4966789
30	3.8	Growth	6.3274	0.000105457	0.1054567	0.1516245	21.091333	27.5680975	44050.404	0.4374564
31	3.9	Growth	6.4247	0.000107078	0.1070783	0.1536066	21.415667	27.92848009	44727.792	0.4243065
32	4.1	Super Cavitation	6.6193	0.000110322	0.1103217	0.157496	22.064333	28.63564213	46082.568	0.3997249
33	4.3	Super Cavitation	6.8139	0.000113565	0.113565	0.1612917	22.713	29.3257566	47437.343	0.3772192
34	4.4	Super Cavitation	6.9112	0.000115187	0.1151867	0.1631564	23.037333	29.66479395	48114.731	0.3666726
35	4.5	Super Cavitation	7.0085	0.000116808	0.1168083	0.165	23.361667	30	48792.119	0.3565621
36	4.6	Super Cavitation	7.1058	0.00011843	0.11843	0.1668233	23.686	30.33150178	49469.507	0.3468641
37	4.8	Super Cavitation	7.3004	0.000121673	0.1216733	0.1704113	24.334667	30.98386677	50824.283	0.3286185
38	4.9	Super Cavitation	7.3977	0.000123295	0.123295	0.1721772	24.659	31.30495168	51501.671	0.3200309
39	5	Super Cavitation	7.495	0.000124917	0.1249167	0.1739253	24.983333	31.6227766	52179.059	0.3117756

40	5.1	Super Cavitation	7.32125	0.000122021	0.1220208	0.1756559	24.404167	31.93743885	50969.437	0.3267495
41	5.4	Hydraulic Flip	6.8	0.000113333	0.1133333	0.1807484	22.666667	32.86335345	47340.574	0.378763
42	5.5	Hydraulic Flip	6.9	0.000115	0.115	0.1824144	23	33.1662479	48036.759	0.3678639
43	5.6	Hydraulic Flip	7	0.000116667	0.1166667	0.1840652	23.333333	33.46640106	48732.943	0.3574286
44	5.8	Hydraulic Flip	7.2	0.00012	0.12	0.1873233	24	34.05877273	50125.313	0.3378472
45	6	Hydraulic Flip	7.4	0.000123333	0.1233333	0.1905256	24.666667	34.64101615	51517.683	0.319832
46	7.6	Hydraulic Flip	9	0.00015	0.15	0.2144295	30	38.98717738	62656.642	0.2162222
47	7.9	Hydraulic Flip	9.3	0.000155	0.155	0.2186207	31	39.74921383	64745.196	0.2024974

Experiment Data of Cavitation nozzle-3 (CN 3) for Diesel as Working Fluid

Sr. No.	Pressure (bar)	Cavitation Stage	LPM	Volume Flow Rate (m ³ /s)	Mass Flow Rate Actual (kg/s)	Mass Flow Rate Ideal (kg/s)	Velocity Actual (m/s)	Velocity Ideal (m/s)	Reynolds Number(Re)	Cavitation Number(CN)
1	0.5	No Cavitation	3.02	5.03E-05	0.0503333	0.0501074	10.066667	10.976426	9179.667472	2.3611837
2	0.6	No Cavitation	3.146	5.24E-05	0.0524333	0.0548899	10.486667	12.02407224	9562.660221	2.1758363
3	0.7	No Cavitation	3.272	5.45E-05	0.0545333	0.0592879	10.906667	12.98748239	9945.65297	2.0114863
4	0.8	No Cavitation	3.398	5.66E-05	0.0566333	0.0633814	11.326667	13.88420269	10328.64572	1.8650776
5	0.9	No Cavitation	3.524	5.87E-05	0.0587333	0.0672261	11.746667	14.72642081	10711.63847	1.7340909
6	0.95	No Cavitation	3.587	5.98E-05	0.0597833	0.0690683	11.956667	15.12995911	10903.13484	1.6737127
7	1	No Cavitation	3.65	6.08E-05	0.0608333	0.0708625	12.166667	15.52301051	11094.63122	1.6164338
8	1.1	No Cavitation	3.776	6.29E-05	0.0629333	0.0743213	12.586667	16.28067078	11477.62397	1.5103573
9	1.2	No Cavitation	3.902	6.50E-05	0.0650333	0.077626	13.006667	17.00460604	11860.61671	1.4143899
10	1.3	No Cavitation	4.028	6.71E-05	0.0671333	0.0807957	13.426667	17.69895511	12243.60946	1.3272867
11	1.4	No Cavitation	4.154	6.92E-05	0.0692333	0.0838457	13.846667	18.36707374	12626.60221	1.2479888
12	1.5	No Cavitation	4.28	7.13E-05	0.0713333	0.0867885	14.266667	19.01172752	13009.59496	1.1755906
13	1.6	No Cavitation	4.406	7.34E-05	0.0734333	0.0896348	14.686667	19.63522775	13392.58771	1.1093145
14	1.7	No Cavitation	4.532	7.55E-05	0.0755333	0.0923935	15.106667	20.2395295	13775.58046	1.048489
15	1.8	No Cavitation	4.658	7.76E-05	0.0776333	0.0950721	15.526667	20.82630404	14158.57321	0.9925324
16	2	Inception	4.91	8.18E-05	0.0818333	0.1002148	16.366667	21.952852	14924.55871	0.8932657
17	2.1	Inception	5.036	8.39E-05	0.0839333	0.1026896	16.786667	22.49497936	15307.55145	0.8491262
18	2.2	Inception	5.162	8.60E-05	0.0860333	0.1051061	17.206667	23.02434542	15690.5442	0.8081792
19	2.3	Inception	5.288	8.81E-05	0.0881333	0.1074684	17.626667	23.54181105	16073.53695	0.7701242
20	2.4	Inception	5.414	9.02E-05	0.0902333	0.1097798	18.046667	24.04814448	16456.5297	0.7346951

21	2.5	Inception	5.54	9.23E-05	0.0923333	0.1120435	18.466667	24.54403468	16839.52245	0.7016558
22	2.6	Inception	5.666	9.44E-05	0.0944333	0.1142624	18.886667	25.03010236	17222.5152	0.6707961
23	2.7	Inception	5.792	9.65E-05	0.0965333	0.116439	19.306667	25.50690906	17605.50795	0.6419283
24	2.8	Growth	5.918	9.86E-05	0.0986333	0.1185757	19.726667	25.97496478	17988.5007	0.6148848
25	2.9	Growth	6.044	0.0001007	0.1007333	0.1206746	20.146667	26.43473436	18371.49344	0.5895149
26	3	Growth	6.17	0.0001028	0.1028333	0.1227375	20.566667	26.8866429	18754.48619	0.5656833
27	3.1	Growth	6.10125	0.0001017	0.1016875	0.1247664	20.3375	27.33108033	18545.51198	0.5785035
28	3.3	Growth	5.96375	9.94E-05	0.0993958	0.1287282	19.879167	28.19894897	18127.56354	0.605487
29	3.4	Growth	5.895	9.83E-05	0.09825	0.1306641	19.65	28.62301711	17918.58932	0.6196922
30	3.8	Growth	5.62	9.37E-05	0.0936667	0.1381365	18.733333	30.25991822	17082.69245	0.681822
31	3.9	Super Cavitation	5.825	9.71E-05	0.0970833	0.1399423	19.416667	30.65548949	17705.81557	0.6346756
32	4.1	Super Cavitation	6.235	0.0001039	0.1039167	0.1434857	20.783333	31.43170067	18952.06182	0.5539502
33	4.3	Super Cavitation	6.645	0.0001108	0.11075	0.1469437	22.15	32.18919972	20198.30806	0.4877011
34	4.4	Super Cavitation	6.85	0.0001142	0.1141667	0.1486425	22.833333	32.56134155	20821.43119	0.458947
35	4.5	Super Cavitation	7.055	0.0001176	0.1175833	0.1503222	23.516667	32.929278	21444.55431	0.4326629
36	4.6	Super cavitation	7.26	0.000121	0.121	0.1519832	24.2	33.29314847	22067.67743	0.4085737
37	4.8	Super Cavitation	7.67	0.0001278	0.1278333	0.1552521	25.566667	34.00921208	23313.92368	0.3660606
38	4.9	Super Cavitation	7.875	0.0001313	0.13125	0.1568609	26.25	34.36164856	23937.0468	0.3472502
39	5	Super Cavitation	8.08	0.0001347	0.1346667	0.1584535	26.933333	34.71050673	24560.16993	0.3298534
40	5.1	Super Cavitation	8.285	0.0001381	0.1380833	0.1600302	27.616667	35.05589341	25183.29305	0.3137319

41	5.4	Super Cavitation	8.9	0.0001483	0.1483333	0.1646697	29.666667	36.07221672	27052.66242	0.2718715
42	5.5	Super Cavitation	9.105	0.0001518	0.15175	0.1661874	30.35	36.40468658	27675.78554	0.2597669
43	5.6	Hydraulic Flip	9.31	0.0001552	0.1551667	0.1676914	31.033333	36.73414747	28298.90866	0.248453
44	5.8	Hydraulic Flip	9.72	0.000162	0.162	0.1706596	32.4	37.38435985	29545.15491	0.2279351
45	6	Hydraulic Flip	10.13	0.0001688	0.1688333	0.1735771	33.766667	38.02345503	30791.40116	0.2098576
46	7.6	Hydraulic Flip	13.41	0.0002235	0.2235	0.1953545	44.7	42.79398674	40761.37113	0.1197529
47	7.9	Hydraulic Flip	14.025	0.0002338	0.23375	0.1991729	46.75	43.63043041	42630.7405	0.1094808

Experiment Data of Cavitation nozzle-5 (CN 5) for Water as Working Fluid

Sr. No.	Pressure (bar)	Cavitation Stage	LPM	Volume Flow Rate (m3/s)	Mass Flow Rate Actual (kg/s)	Mass Flow Rate Ideal (kg/s)	Velocity Actual (m/s)	Velocity Ideal (m/s)	Reynolds Number (Re)	Cavitation Number (CN)
1	0.5	No Cavitation	3.11	5.18E-05	0.051833333	0.0589049	10.5594	10	33080.827	1.745277
2	0.6	No Cavitation	3.222	0.0000537	0.0537	0.064527	10.9396742	10.954451	34272.162	1.6260506
3	0.7	No Cavitation	3.334	5.56E-05	0.055566667	0.0696972	11.3199484	11.83216	35463.497	1.5186369
4	0.8	No Cavitation	3.446	5.74E-05	0.057433333	0.0745094	11.7002226	12.649111	36654.833	1.4215253
5	0.9	No Cavitation	3.558	0.0000593	0.0593	0.0790292	12.0804968	13.416408	37846.168	1.3334393
6	0.95	No Cavitation	3.614	6.02E-05	0.060233333	0.0811947	12.2706339	13.784049	38441.836	1.2924354
7	1	No Cavitation	3.67	6.12E-05	0.061166667	0.0833041	12.460771	14.142136	39037.503	1.2532941
8	1.1	No Cavitation	3.782	6.30E-05	0.063033333	0.08737	12.8410452	14.832397	40228.838	1.1801632
9	1.2	No Cavitation	3.894	0.0000649	0.0649	0.091255	13.2213194	15.491933	41420.174	1.1132514
10	1.3	No Cavitation	4.006	6.68E-05	0.066766667	0.0949812	13.6015936	16.124515	42611.509	1.0518728
11	1.4	No Cavitation	4.118	6.86E-05	0.068633333	0.0985667	13.9818679	16.733201	43802.844	0.995434
12	1.5	No Cavitation	4.23	0.0000705	0.0705	0.1020262	14.3621421	17.320508	44994.179	0.9434185
13	1.6	No Cavitation	4.342	7.24E-05	0.072366667	0.1053722	14.7424163	17.888544	46185.515	0.8953761
14	1.7	Inception	4.454	7.42E-05	0.074233333	0.1086152	15.1226905	18.439089	47376.85	0.8509121
15	1.8	Inception	4.566	0.0000761	0.0761	0.1117641	15.5029647	18.973666	48568.185	0.8096798
16	2	Inception	4.79	7.98E-05	0.079833333	0.1178097	16.2635131	20	50950.856	0.7357226
17	2.1	Inception	4.902	0.0000817	0.0817	0.120719	16.6437873	20.493902	52142.191	0.7024874
18	2.2	Inception	5.014	8.36E-05	0.083566667	0.1235599	17.0240615	20.976177	53333.526	0.6714543
19	2.3	Growth	5.126	8.54E-05	0.085433333	0.1263369	17.4043358	21.447611	54524.861	0.6424331
20	2.4	Growth	5.238	0.0000873	0.0873	0.1290541	17.78461	21.908902	55716.197	0.6152536

21	2.5	Growth	5.35	8.92E-05	0.089166667	0.1317153	18.1648842	22.36068	56907.532	0.5897631
22	2.6	Super Cavitation	5.462	9.10E-05	0.091033333	0.1343238	18.5451584	22.803509	58098.867	0.5658245
23	2.7	Super Cavitation	5.574	0.0000929	0.0929	0.1368825	18.9254326	23.2379	59290.202	0.5433144
24	2.8	Super Cavitation	5.686	9.48E-05	0.094766667	0.1393943	19.3057068	23.664319	60481.538	0.5221213
25	2.9	Super Cavitation	5.798	9.66E-05	0.096633333	0.1418617	19.685981	24.083189	61672.873	0.5021445
26	3	Super Cavitation	5.91	0.0000985	0.0985	0.1442869	20.0662552	24.494897	62864.208	0.4832926
27	3.1	Super Cavitation	6.022	0.0001004	0.100366667	0.1466719	20.4465294	24.899799	64055.543	0.4654828
28	3.3	Super Cavitation	6.246	0.0001041	0.1041	0.1513293	21.2070779	25.690465	66438.214	0.4326943
29	3.4	Super Cavitation	6.358	0.000106	0.105966667	0.1536051	21.5873521	26.07681	67629.549	0.4175842
30	3.8	Super Cavitation	6.806	0.0001134	0.113433333	0.1623895	23.1084489	27.568098	72394.89	0.3644192
31	3.9	Super Cavitation	6.741346154	0.0001124	0.112355769	0.1645123	22.8889294	27.92848	71707.172	0.3714427
32	4.1	Super Cavitation	6.612038462	0.0001102	0.110200641	0.1686779	22.4498902	28.635642	70331.736	0.386113
33	4.3	Super Cavitation	6.482730769	0.000108	0.108045513	0.172743	22.0108511	29.325757	68956.301	0.4016698
34	4.4	Super Cavitation	6.418076923	0.000107	0.106967949	0.1747401	21.7913316	29.664794	68268.583	0.4098032
35	4.5	Super Cavitation	6.353423077	0.0001059	0.105890385	0.1767146	21.571812	30	67580.865	0.4181861
36	4.6	Super Cavitation	6.288769231	0.0001048	0.104812821	0.1786673	21.3522925	30.331502	66893.147	0.4268289
37	4.8	Super Cavitation	6.159461538	0.0001027	0.102657692	0.18251	20.9132533	30.983867	65517.711	0.4449381
38	4.9	Super Cavitation	6.094807692	0.0001016	0.101580128	0.1844014	20.6937338	31.304952	64829.993	0.454428

39	5	Super Cavitation	6.030153846	0.0001005	0.100502564	0.1862735	20.4742142	31.622777	64142.275	0.4642248
40	5.1	Hydraulic Flip	5.9655	9.94E-05	0.099425	0.188127	20.2546947	31.937439	63454.557	0.4743418
41	5.4	Hydraulic Flip	6.147	0.0001025	0.10245	0.1935811	20.8709426	32.863353	65385.159	0.446744
42	5.5	Hydraulic Flip	6.2075	0.0001035	0.103458333	0.1953653	21.0763586	33.166248	66028.692	0.4380782
43	5.6	Hydraulic Flip	6.268	0.0001045	0.104466667	0.1971334	21.2817746	33.466401	66672.226	0.4296622
44	5.8	Hydraulic Flip	6.389	0.0001065	0.106483333	0.2006227	21.6926065	34.058773	67959.294	0.4135417
45	6	Hydraulic Flip	6.51	0.0001085	0.1085	0.2040524	22.1034385	34.641016	69246.361	0.3983118
46	7.6	Hydraulic Flip	7.478	0.0001246	0.124633333	0.2296534	25.3900942	38.987177	79542.902	0.301866
47	7.9	Hydraulic Flip	7.6595	0.0001277	0.127658333	0.2341422	26.0063421	39.749214	81473.503	0.2877294

Experiment Data of Cavitation nozzle-5 (CN 5) for Diesel as Working Fluid

Sr. No.	Pressure (bar)	Cavitation Stage	LPM	Volume Flow Rate (m ³ /s)	Mass Flow Rate Actual (kg/s)	Mass Flow Rate Ideal (kg/s)	Velocity Actual (m/s)	Velocity Ideal (m/s)	Reynolds Number (Re)	Cavitation Number (CN)
1	0.5	No Cavitation	3.385	5.64E-05	0.0564167	0.0536649	11.493109	10.976426	15720.634	1.811449
2	0.6	No Cavitation	3.52	5.87E-05	0.0586667	0.0587869	11.951475	12.024072	16347.601	1.6751671
3	0.7	No Cavitation	3.655	6.09E-05	0.0609167	0.0634971	12.409841	12.987482	16974.569	1.5537054
4	0.8	No Cavitation	3.79	6.32E-05	0.0631667	0.0678813	12.868208	13.884203	17601.537	1.4449906
5	0.9	No Cavitation	3.925	6.54E-05	0.0654167	0.071999	13.326574	14.726421	18228.504	1.3472994
6	0.95	No Cavitation	3.9925	6.65E-05	0.0665417	0.0739719	13.555757	15.129959	18541.988	1.3021278
7	1	No Cavitation	4.06	6.77E-05	0.0676667	0.0758936	13.78494	15.523011	18855.472	1.2591903
8	1.1	No Cavitation	4.195	6.99E-05	0.0699167	0.0795979	14.243306	16.280671	19482.44	1.17945
9	1.2	No Cavitation	4.33	7.22E-05	0.0721667	0.0831373	14.701673	17.004606	20109.407	1.1070511
10	1.3	No Cavitation	4.465	7.44E-05	0.0744167	0.086532	15.160039	17.698955	20736.375	1.0411194
11	1.4	No Cavitation	4.6	7.67E-05	0.0766667	0.0897985	15.618405	18.367074	21363.342	0.9809069
12	1.5	No Cavitation	4.735	7.89E-05	0.0789167	0.0929503	16.076771	19.011728	21990.31	0.9257708
13	1.6	No Cavitation	4.87	8.12E-05	0.0811667	0.0959987	16.535138	19.635228	22617.278	0.8751561
14	1.7	No Cavitation	5.005	8.34E-05	0.0834167	0.0989532	16.993504	20.239529	23244.245	0.8285816
15	1.8	Inception	5.14	8.57E-05	0.0856667	0.101822	17.45187	20.826304	23871.213	0.7856285
16	2	Inception	5.41	9.02E-05	0.0901667	0.1073298	18.368602	21.952852	25125.148	0.7091677
17	2.1	Inception	5.545	9.24E-05	0.0924167	0.1099803	18.826969	22.494979	25752.116	0.6750569
18	2.2	Inception	5.68	9.47E-05	0.0946667	0.1125684	19.285335	23.024345	26379.084	0.6433492
19	2.3	Inception	5.815	9.69E-05	0.0969167	0.1150984	19.743701	23.541811	27006.051	0.6138242
20	2.4	Growth	5.95	9.92E-05	0.0991667	0.1175739	20.202067	24.048144	27633.019	0.586286

21	2.5	Growth	6.085	0.0001014	0.1014167	0.1199983	20.660434	24.544035	28259.987	0.5605602
22	2.6	Growth	6.22	0.0001037	0.1036667	0.1223748	21.1188	25.030102	28886.954	0.5364913
23	2.7	Growth	6.355	0.0001059	0.1059167	0.1247059	21.577166	25.506909	29513.922	0.5139399
24	2.8	Growth	6.49	0.0001082	0.1081667	0.1269943	22.035532	25.974965	30140.89	0.4927811
25	2.9	Super Cavitation	6.625	0.0001104	0.1104167	0.1292422	22.493899	26.434734	30767.857	0.4729026
26	3	Super Cavitation	6.76	0.0001127	0.1126667	0.1314516	22.952265	26.886643	31394.825	0.4542031
27	3.1	Super Cavitation	6.895	0.0001149	0.1149167	0.1336245	23.410631	27.33108	32021.793	0.4365911
28	3.3	Super Cavitation	7.165	0.0001194	0.1194167	0.1378676	24.327364	28.198949	33275.728	0.4043068
29	3.4	Super Cavitation	7.3	0.0001217	0.1216667	0.1399409	24.78573	28.623017	33902.696	0.3894913
30	3.8	Super Cavitation	7.84	0.0001307	0.1306667	0.1479439	26.619195	30.259918	36410.566	0.3376847
31	3.9	Super Cavitation	7.66666667	0.0001278	0.1277778	0.1498779	26.030675	30.655489	35605.571	0.3531265
32	4.1	Super Cavitation	7.32	0.000122	0.122	0.1536728	24.853636	31.431701	33995.58	0.3873658
33	4.3	Super Cavitation	6.973333333	0.0001162	0.1162222	0.1573763	23.676597	32.1892	32385.589	0.4268375
34	4.4	Super Cavitation	6.8	0.0001133	0.1133333	0.1591958	23.088077	32.561342	31580.593	0.4488752
35	4.5	Super Cavitation	6.9	0.000115	0.115	0.1609947	23.427608	32.929278	32045.014	0.4359586
36	4.6	Super Cavitation	7	0.0001167	0.1166667	0.1627737	23.767138	33.293148	32509.434	0.4235916
37	4.8	Super Cavitation	7.2	0.00012	0.12	0.1662746	24.446199	34.009212	33438.275	0.4003856
38	4.9	Super Cavitation	7.3	0.0001217	0.1216667	0.1679977	24.78573	34.361649	33902.696	0.3894913
39	5	Super Cavitation	7.4	0.0001233	0.1233333	0.1697033	25.12526	34.710507	34367.116	0.3790356

40	5.1	Super Cavitation	7.5	0.000125	0.125	0.1713919	25.464791	35.055893	34831.537	0.3689954
41	5.4	Super Cavitation	7.8	0.00013	0.13	0.1763608	26.483383	36.072217	36224.798	0.341157
42	5.5	Hydraulic Flip	7.9	0.0001317	0.1316667	0.1779863	26.822913	36.404687	36689.219	0.3325747
43	5.6	Hydraulic Flip	8	0.0001333	0.1333333	0.1795971	27.162444	36.734147	37153.639	0.3243123
44	5.8	Hydraulic Flip	8.2	0.0001367	0.1366667	0.182776	27.841505	37.38436	38082.48	0.3086852
45	6	Hydraulic Flip	8.4	0.00014	0.14	0.1859006	28.520566	38.023455	39011.321	0.2941609
46	7.6	Hydraulic Flip	10	0.0001667	0.1666667	0.2092242	33.953055	42.793987	46442.049	0.2075599
47	7.9	Hydraulic Flip	10.3	0.0001717	0.1716667	0.2133137	34.971646	43.63043	47835.31	0.1956451

Experiment Data of Cavitation nozzle-5 (CN 5) for Bio-Diesel as Working Fluid

Sr. No.	Pressure (bar)	Cavitation Stage	LPM	Volume Flow Rate (m ³ /s)	Mass Flow Rate Actual (kg/s)	Mass Flow Rate Ideal (kg/s)	Velocity Actual (m/s)	Velocity Ideal (m/s)	Reynolds Number (Re)	Cavitation Number (CN)
1	0.5	No Cavitation	3.33	0.0000555	0.0555	0.0548448	11.306367	10.740277	6981.118	1.810155
2	0.6	No Cavitation	3.488	5.81E-05	0.0581333	0.0600795	11.842825	11.765384	7312.3542	1.6498759
3	0.7	No Cavitation	3.646	6.08E-05	0.0607667	0.0648933	12.379284	12.708068	7643.5905	1.509979
4	0.8	No Cavitation	3.804	0.0000634	0.0634	0.0693738	12.915742	13.585496	7974.8267	1.3871493
5	0.9	No Cavitation	3.962	6.60E-05	0.0660333	0.0735821	13.4522	14.409594	8306.0629	1.2787195
6	0.95	No Cavitation	4.041	6.74E-05	0.06735	0.0755984	13.720429	14.804451	8471.681	1.2292112
7	1	No Cavitation	4.12	6.87E-05	0.0686667	0.0775623	13.988658	15.189046	8637.2992	1.1825235
8	1.1	No Cavitation	4.278	0.0000713	0.0713	0.081348	14.525117	15.930406	8968.5354	1.0967879
9	1.2	No Cavitation	4.436	7.39E-05	0.0739333	0.0849652	15.061575	16.638766	9299.7716	1.0200493
10	1.3	No Cavitation	4.594	7.66E-05	0.0765667	0.0884346	15.598033	17.318177	9631.0079	0.9510914
11	1.4	No Cavitation	4.752	0.0000792	0.0792	0.0917729	16.134492	17.971922	9962.2441	0.8888968
12	1.5	No Cavitation	4.91	8.18E-05	0.0818333	0.094994	16.67095	18.602706	10293.48	0.8326093
13	1.6	No Cavitation	5.068	8.45E-05	0.0844667	0.0981094	17.207408	19.212792	10624.717	0.7815037
14	1.7	No Cavitation	5.226	0.0000871	0.0871	0.1011289	17.743866	19.804093	10955.953	0.7349629
15	1.8	No Cavitation	5.384	8.97E-05	0.0897333	0.1040607	18.280325	20.378244	11287.189	0.6924591
16	2	No Cavitation	5.7	0.000095	0.095	0.1096896	19.353241	21.480555	11949.661	0.6178094
17	2.1	No Cavitation	5.858	9.76E-05	0.0976333	0.1123984	19.889699	22.011019	12280.898	0.5849321
18	2.2	Inception	6.016	0.0001003	0.1002667	0.1150435	20.426158	22.528996	12612.134	0.5546111
19	2.3	Inception	6.174	0.0001029	0.1029	0.117629	20.962616	23.035329	12943.37	0.526588
20	2.4	Inception	6.332	0.0001055	0.1055333	0.120159	21.499074	23.530769	13274.606	0.5006364

21	2.5	Inception	6.49	0.0001082	0.1081667	0.1226368	22.035532	24.01599	13605.843	0.476557
22	2.6	Growth	6.648	0.0001108	0.1108	0.1250654	22.571991	24.491601	13937.079	0.4541739
23	2.7	Growth	6.806	0.0001134	0.1134333	0.1274479	23.108449	24.958149	14268.315	0.4333316
24	2.8	Growth	6.964	0.0001161	0.1160667	0.1297865	23.644907	25.416135	14599.551	0.4138917
25	2.9	Growth	7.122	0.0001187	0.1187	0.1320838	24.181365	25.866013	14930.788	0.3957312
26	3	Growth	7.28	0.0001213	0.1213333	0.1343418	24.717824	26.308199	15262.024	0.3787403
27	3.1	Super Cavitation	7.438	0.000124	0.1239667	0.1365625	25.254282	26.743075	15593.26	0.3628205
28	3.3	Super Cavitation	7.344888889	0.0001224	0.1224148	0.1408989	24.938141	27.592272	15398.059	0.3720778
29	3.4	Super Cavitation	7.298333333	0.0001216	0.1216389	0.1430178	24.780071	28.007217	15300.458	0.3768399
30	3.8	Super Cavitation	7.112111111	0.0001185	0.1185352	0.1511967	24.14779	29.608901	14910.056	0.3968324
31	3.9	Super Cavitation	7.065555556	0.0001178	0.1177593	0.1531733	23.989719	29.995962	14812.456	0.4020792
32	4.1	Super Cavitation	6.972444444	0.0001162	0.1162074	0.1570517	23.673579	30.755474	14617.255	0.4128897
33	4.3	Super Cavitation	6.879333333	0.0001147	0.1146556	0.1608366	23.357438	31.496676	14422.053	0.4241422
34	4.4	Super Cavitation	6.832777778	0.0001139	0.1138796	0.162696	23.199368	31.860812	14324.453	0.4299418
35	4.5	Super Cavitation	6.786222222	0.0001131	0.1131037	0.1645345	23.041297	32.220832	14226.852	0.4358611
36	4.6	Super Cavitation	6.739666667	0.0001123	0.1123278	0.1663526	22.883227	32.576874	14129.252	0.4419034
37	4.8	Super Cavitation	6.646555556	0.0001108	0.1107759	0.1699305	22.567086	33.277532	13934.051	0.4543714
38	4.9	Super Cavitation	6.6	0.00011	0.11	0.1716915	22.409016	33.622387	13836.45	0.4608041
39	5	Hydraulic Flip	6.8	0.0001133	0.1133333	0.1734346	23.088077	33.963739	14255.736	0.4340966

40	5.1	Hydraulic Flip	7	0.0001167	0.1166667	0.1751603	23.767138	34.301695	14675.023	0.4096455
41	5.4	Hydraulic Flip	7.6	0.0001267	0.1266667	0.1802385	25.804321	35.296153	15932.882	0.3475178
42	5.5	Hydraulic Flip	7.8	0.00013	0.13	0.1818997	26.483383	35.62147	16352.168	0.3299248
43	5.6	Hydraulic Flip	8	0.0001333	0.1333333	0.1835459	27.162444	35.943843	16771.455	0.3136348
44	5.8	Hydraulic Flip	8.4	0.00014	0.14	0.1867947	28.520566	36.580067	17610.027	0.284476
45	6	Hydraulic Flip	8.8	0.0001467	0.1466667	0.189988	29.878688	37.205412	18448.6	0.2592023
46	7.6	Hydraulic Flip	12	0.0002	0.2	0.2138245	40.743665	41.87331	25157.182	0.1393932
47	7.9	Hydraulic Flip	12.6	0.00021	0.21	0.2180039	42.780849	42.691758	26415.041	0.1264338

Annexure-IV

Bio-Diesel (WCO) Laboratory Test Report



ACCURA TEST
LABORATORIES
Quality With Service

Date :- 03.04.2024

TEST REPORT NO : ATL/AHM/ 0425/2024-25

TEST REPORT

This is to certify that ACCURA TEST LABORATORIES, Ahmedabad carried out analysis of the sample of WASTE COOKING OIL METHYL ESTER submitted by M/s. THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARIDA(FOTE), Vadodara.

CLIENT NAME : M/s. THE MAHARAJA SAYAJIRAO
UNIVERSITY OF BARIDA(FOTE),
ADDRESS : MSU(FOTE) Vadoadara, Gujarat, India

SAMPLE RECEIVED ON : 31.03.2024
SAMPLE DATE : Not Mention
COMMODITY (AS DECLARED PARTY) : Waste cooking oil methyl ester (Batch no 2)
QUANTITY OF SAMPLES : 500ml per Sample
SAMPLE CONDITION/DESCRIPTION : Sample in plastic bottles
SEAL NO : Unseal

Our Findings are :

Parameters/Mark	Units	Batch no 2	Test method
Flash Point	°C	136	IS 1448 (P-21) 1992 Ra2012
Kinematic Viscosity @40°C	Cst	4.53	IS 1448 (P-25) 1976 Ra 2002
Density @15°C	Gm/ml	0.8663	IS 1448 (P-16) 1990 Ra 2002
Gross Calorific Value	Kcal/Kg	8630	IS 1448 (P-6) 1984 Ra 2002

Remark : Sample not drawn by us, submitted by the Party.

For Accura test laboratories

(Authorized Signatory)

Note :

1. Quantity of the sample received was exhausted during our analysis
2. The results are related to the sample/s tested only
3. Content of this report are meant for your guidance & should not used for Advertisement, evidence or Litigation.
4. This test report shall not be reproduced except in full, without the written approval of Accura test laboratories

ISO 9001 : 2015



ACCURA TEST
LABORATORIES
Quality With Service

Date :- 03.04.2024

TEST REPORT NO : ATL/AHM/ 0426/2024-25

TEST REPORT

This is to certify that ACCURA TEST LABORATORIES , Ahmedabad carried out analysis of the sample of WASTE COOKING OIL METHYL ESTER submitted by M/s. THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARIDA(FOTE), Vadodara.

CLIENT NAME : M/s. THE MAHARAJA SAYAJIRAO
UNIVERSITY OF BARIDA(FOTE),
ADDRESS : MSU(FOTE) Vadoadara, Gujarat, India

SAMPLE RECEIVED ON : 31.03.2024
SAMPLE DATE : Not Mention
COMMODITY (AS DECLARED PARTY) : Waste cooking oil methyl ester (Batch no 3)
QUANTITY OF SAMPLES : 500ml per Sample
SAMPLE CONDITION/DESCRIPTION : Sample in plastic bottles
SEAL NO : Unseal

Our Findings are :

Parameters/Mark	Units	Batch no 3	Test method
Flash Point	°C	182	IS 1448 (P-21) 1992 Ra2012
Kinematic Viscosity @40°C	Cst	4.06	IS 1448 (P-25) 1976 Ra 2002
Density @15°C	Gm/ml	0.8669	IS 1448 (P-16) 1990 Ra 2002
Gross Calorific Value	Kcal/Kg	8445	IS 1448 (P-6) 1984 Ra 2002

Remark : Sample not drawn by us, submitted by the Party.

For Accura test laboratories ,

(Authorized Signatory)


Note :

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Annexure-V

ANTI-PLAGIARISM REPORT

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