

เอกสารอ้างอิง

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ภาคผนวก

ภาคผนวก ก

รายละเอียดของเครื่องมือและอุปกรณ์ประกอบการทดลอง

THE RICARDO E6/U VARIABLE COMPRESSION RATIO ENGINE
E6/U GENERAL SPECIFICATION {9}

ENGINE:

Serial No.	.. .. .	..	109/70
No. of Cylinders	.. .. .	..	1
Bore	.. .. .	..	76.2 mm
Stroke	.. .. .	..	110 mm
Capacity	.. .. .	..	507 cc
Compression Ratio (Spark Ignition)	.. .. .	..	4.5-20
Compression Ratio (C.I.)	.. .. .	..	21.40
Valves	.. .. .	..	Overhead; operated by overhead cams and finger followers.
Valve Timing	.. .. .	..	Inlet Opens 8° B.T.D.C. Inlet Closes 39° A.B.D.C. Exhaust Opens 43° B.B.D.C. Exhaust Closes 8° A.T.D.C.
Tappet Clearance (Cold)	.. .. .	..	Inlet 0.15 mm Exhaust 0.25 mm

LUBRICATION:

Type	.. .. .	..	Wet sump
Pump	.. .. .	..	Gear type, separately driven
Motor	.. .. .	..	Electric 220/250v, 50 cycle single phase.
Pressure Relief valve setting	.. .. .	..	2 bars
Filter	.. .. .	..	Tecalemit full flow
Sump capacity	.. .. .	..	9 liters
Oil Heater	.. .. .	..	0.5 kW 220 v
Cooling Control	.. .. .	..	Manually adjusted heat exchanger
Oil	.. .. .	..	Shell X-100 S.A.E. 30 or Shell Rotella 'S' SAE 30
Working temperature (normal)	.. .. .	..	60°C

IGNITION:

Type	..	..	..	..	..	..	A.E.I. Magneto S.K.H.1
Contact breaker gap	..	..	..	..	..	..	0.3 mm
Timing	..	..	..	..	..	..	Variable
Spark plug	..	..	..	..	..	..	K.L.G.R.C.5/4H
Plug gap	..	..	..	..	..	..	0.4 mm

TACHOMETER:

Make	..	..	..	..	..	..	Crompton Parkinson
Type	..	..	..	..	..	..	Electric
Speed Range	..	..	..	..	..	..	0-3 500 RPM
Drive system	Generator Belt driven from end of dynamometer shaft

DYNAMOMETER:

Make	B.K.B.
Type	Dynamo-Swinging field

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VEHICLE EMISSION CO-HC ANALYZER

Make	Iyasaka Kogyo
Type	Vehicle Emission CO-HC Analyzer
Model	..	..	..	..	..	..	EIR-2105
Detection principle	..	..	..	..	..	..	Non-dispersive infrared gas analysis
Component being detected	..	..	..	..	..	..	carbon monoxide(CO) and hydrocarbon(HC) in vehicle emission gas
Measuring range	..	..	..	..	..	..	CO-0-1.5, 0-10.0 % HC-0-500, 0-2 000 ppm
Accuracy	..	..	..	..	..	..	repeatability-within ± 2 % of full scale, Zero & Span stability-within 3 % of full scale for 3 hours.
Warm-up time	..	..	..	..	..	..	less than 30 minute
Output for recorder	..	..	..	..	..	..	DC 0-100 v
Applicable room temperature	..	..	..	..	..	..	0-40°C
Power source	..	..	..	..	..	..	AC 100 v \pm 10 v, 50/60 Hz

ภาคผนวก ข

คุณสมบัติของเชื้อเพลิง

ตาราง ข-1 เปรียบเทียบคุณสมบัติของแอลกอฮอล์และน้ำมันเชื้อเพลิง {8}

PROPERTY	METHANOL	ETHANOL	1-PROPANOL	1-BUTANOL	KEROSINE	GAS OIL
Formula	CH ₃ OH	C ₂ H ₅ OH	C ₃ H ₇ OH	C ₄ H ₉ OH	C ₁₅ H ₂₅₋₂₆	C ₁₅ H ₂₈
C/H mass ratio	3	4	4.5	4.8	6.1	6.4
RMM	32.042	46.068	60.094	74.124	181.848	208.390
Relative density(liquid) at 20°C	0.7915	0.7894	0.8036	0.8097	0.7768	0.8369
Kinematic viscosity at 20°C,cSt	0.74	1.50	3.05	3.70	2.00	5.00
Surface tension at 20 °C,mN/m	22.6	22.8	23.8	24.6	28.0	30.0
Boiling point,°C	64.8	78.4	97.3	117.4	160 to 285	180 to 300
Melting point,°C	-95.5	-117.3	-126.5	-89.8	-55.0	0 Summer 7 Winter
Vapour pressure at 37.8°C,kPa	33.0	17.7	6.7	2.4	Negligible	
Vaporization enthalpy,kJ/kg	1 089	858	670	607	250	212
Minimum ignition energy,mJ	0.3	-	1.11	-	3	4
Spontaneous ignition temperature,°C	470	426	433	367	255	245
Flammability range,% by volume of fuel	6.7 to 36	4.3 to 19	2 to 12	2.1 to 8	1 to 6	1 to 5
Calorific value						
gross,MJ/kg	22.68	29.77	33.66	36.07	46.52	45.38
net,MJ/kg	19.93	26.75	30.70	33.10	43.43	42.40
net,MJ/l	15.77	21.12	24.67	26.84	33.74	35.48
Stoich fuel/air ratio	0.155	0.111	0.097	0.090	0.068	0.069
Adiabatic stoich combustion temperature,K	2 243	2 258	2 273	2 282	2 295	2 300
Product/reactants molar ratio	1.061	1.065	1.067	1.068	1.058	1.057
Flash point(closed cup),°C	11	13	18	35	56	76

ตาราง ข-2 เปรียบเทียบคุณสมบัติของแอลกอฮอล์ทั้งตระกูล {5}

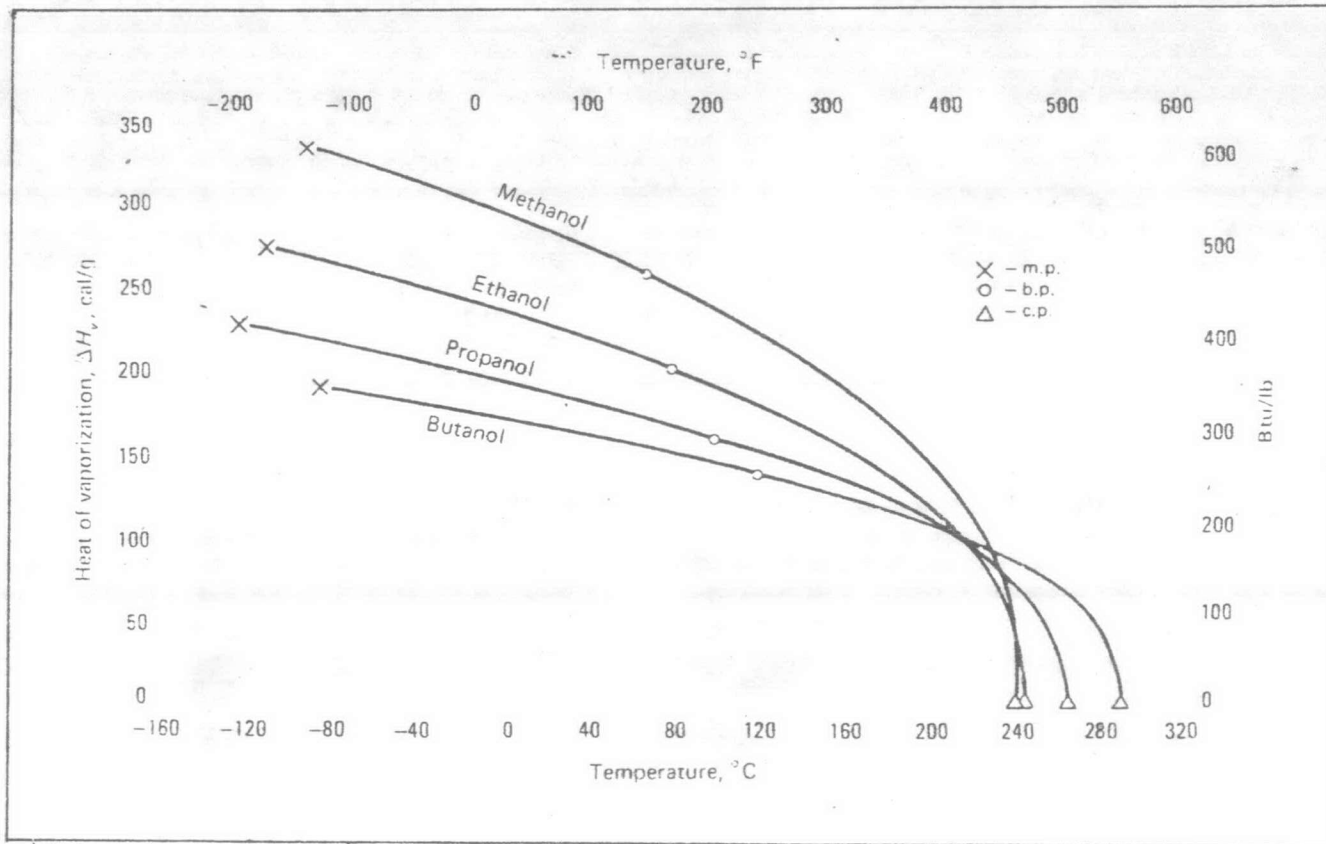
Chemical Compound	Formula	Description	Molecular Weight	Refractive Index		Melting Point (°C)	Boiling Point (°C)	Flash Point (°C)	Specific Gravity	
				T (°C)	Index				Reference to Air (°C/°C)	Ratio
Methyl Alcohol (Methanol)	CH ₃ OH	Colorless liquid	32.042	20	1.329	-97.8	64.5	12.2	20/4	0.792
Ethyl Alcohol (Ethanol)	C ₂ H ₅ OH	Colorless liquid	46.070	15	1.363	-116.	78.4	13.9	20/20	0.790
<i>n</i> -Propyl Alcohol (Propanol-1)	CH ₃ CH ₂ CH ₂ OH	Colorless liquid	60.097	20	1.385	-126.1	97.3	15.0	20/4	0.840
Isopropyl Alcohol (2-propanol)	CH ₃ CHOHCH ₃	Colorless liquid	60.097	20	1.378	-85.8	82.4	11.7	20/4	0.787
<i>n</i> -Butyl Alcohol	C ₂ H ₅ CH ₂ CH ₂ OH	Colorless liquid	74.124	25	1.397	-79.9	117.7	28.9	20/20	0.811
<i>sec</i> -Butyl Alcohol	C ₂ H ₅ CHOHCH ₃	Colorless liquid	74.124	20	1.397	-114.7	98.8	21.1	20/20	0.808
Isobutyl Alcohol	(CH ₃) ₂ CHCH ₂ OH	Colorless liquid	74.124	20	1.396	-108.	108.3	27.8	20/20	0.803
<i>tert</i> -Butyl Alcohol	(CH ₃) ₃ COH	Colorless liquid	74.124	-	1.388	25.6	82.4	11.1	25/25	0.783

ตาราง ข-3 Specific Gravity at 60°F/60°F of Aqueous Methanol by Weight {4}

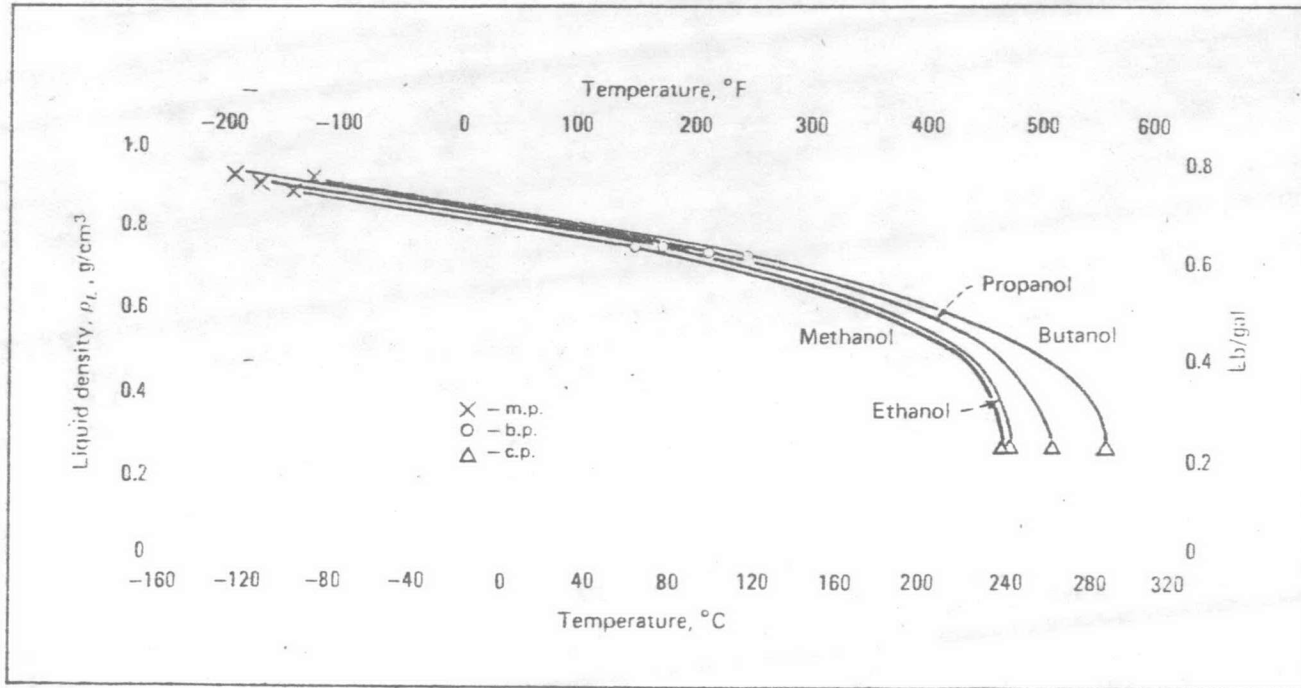
% wt	S 60°F/60°F	% wt	S 60°F/60°F	% wt	S 60°F/60°F	% wt	S 60°F/60°F
0	1.000						
1	2	26	.9602	51	.9173	76	.8610
2	62	27	.9587	52	53	77	.8585
3	45	28	72	53	33	78	60
4	27	29	57	54	13	79	35
5	12	30	42	55	.9093	80	09
6	.9895	31	28	56	72	81	.8484
7	80	32	12	57	52	82	58
8	64	33	.9496	58	31	83	32
9	49	34	80	59	09	84	06
10	33	35	62	60	.8987	85	.8380
11	19	36	47	61	65	86	53
12	04	37	29	62	43	87	26
13	.9788	38	12	63	20	88	.8300
14	74	39	.9394	64	.8897	89	.8273
15	60	40	76	65	74	90	.8245
16	46	41	58	66	51	91	.8218
17	31	42	40	67	27	92	.8191
18	17	43	22	68	04	93	.8163
19	03	44	04	69	.8778	94	.8135
20	.9688	45	.9286	70	55	95	.8107
21	74	46	68	71	33	96	.8079
22	60	47	49	72	09	97	.8051
23	46	48	30	73	.8685	98	.8022
24	32	49	11	74	60	99	.7993
25	17	50	.9192	75	.8636	100	.7965

ตาราง ข-4 Specific Gravity at 60°F/60°F of Aqueous Methanol by Volume {4}

% vol	S 60°F./60°F.	% vol	S 60°F./60°F.	% vol	S 60°F./60°F.	% vol	S 60°F./60°F.	% vol	S 60°F./60°F.
0	1.0000	20	.9741	40	.9489	60	.9148	80	.8676
1	.9985	21	.9729	41	.9474	61	.9128	81	.8647
2	.9970	22	.9718	42	.9459	62	.9108	82	.8618
3	.9956	23	.9706	43	.9444	63	.9087	83	.8588
4	.9942	24	.9694	44	.9429	64	.9066	84	.8558
5	.9928	25	.9682	45	.9414	65	.9045	85	.8528
6	.9915	26	.9670	46	.9398	66	.9023	86	.8497
7	.9901	27	.9658	47	.9382	67	.9001	87	.8465
8	.9888	28	.9646	48	.9366	68	.8979	88	.8431
9	.9875	29	.9634	49	.9349	69	.8956	89	.8397
10	.9862	30	.9622	50	.9332	70	.8933	90	.8362
11	.9850	31	.9609	51	.9315	71	.8909	91	.8327
12	.9837	32	.9597	52	.9298	72	.8884	92	.8291
13	.9825	33	.9584	53	.9281	73	.8860	93	.8254
14	.9812	34	.9571	54	.9263	74	.8835	94	.8216
15	.9800	35	.9558	55	.9244	75	.8809	95	.8177
16	.9788	36	.9544	56	.9226	76	.8784	96	.8136
17	.9777	37	.9531	57	.9207	77	.8758	97	.8094
18	.9765	38	.9517	58	.9188	78	.8731	98	.8051
19	.9753	39	.9503	59	.9168	79	.8704	99	.8008
								100	.7965



รูปที่ ๗-1 Heat of Vaporization of Alcohol {7}



รูปที่ ๗-2 Liquid density of Alcohol {7}

ภาคผนวก ค

ค-1 ผลการทดลองของเครื่องยนต์เมื่อใช้เมทานอลและน้ำมันดีเซลเป็นเชื้อเพลิง

ตาราง ค-1 ผลการทดลองของเครื่องยนต์ที่ความเร็ว 1 000 รอบต่อนาที

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bnep (kg/cm ²)	Bp (kW)	B η th (%)	Bsfc (kg/kW-hr)	A/F	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _D (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	-	7.0	0.363	-	21.69	1639.65	0.810	0.455	10.64	0.798	59.72	378	240	0.265	1.5	15.391	1.638	8.844	1.646	309
2	-	7.5	0.375	-	20.40		0.868	0.488	11.05	0.768	54.40	378	235	0.260	1.6	15.900	1.757	8.244	1.551	
3	-	10.0	0.396	-	20.40		1.157	0.651	13.96	0.608	51.52	383	190	0.245	1.6	16.790	2.344	8.244	1.667	
4	-	12.5	0.471	-	21.69		1.446	0.821	14.80	0.574	46.05	388	180	0.220	1.7	19.970	2.956	8.244	1.899	
5	-	15.0	0.519	-	20.40		1.735	0.976	15.97	0.532	39.31	393	170	0.200	1.7	22.006	3.514	8.244	1.908	
6	-	17.0	0.568	-	21.69		1.967	1.128	16.86	0.504	38.19	398	170	0.200	1.8	24.083	4.061	8.244	2.153	
7	-	19.0	0.615	-	20.40		2.198	1.236	17.06	0.498	33.17	403	160	0.210	1.9	26.076	4.450	8.931	2.151	
8	-	21.0	0.641	-	20.40		2.429	1.379	18.27	0.465	31.83	408	135	0.210	2.0	27.178	4.964	8.931	2.271	
9	-	23.5	0.717	-	21.69		2.719	1.559	18.46	0.460	30.25	413	130	0.220	2.1	30.401	5.612	8.931	2.542	
10	-	25.0	0.734	-	20.40		2.892	1.643	19.00	0.447	27.79	418	120	0.220	2.3	31.122	5.915	8.931	2.518	
11	-	26.5	0.764	-	20.40		3.066	1.724	19.14	0.443	26.70	423	120	0.210	2.4	32.394	6.206	9.618	2.639	
12	-	28.0	0.797	-	19.13		3.239	1.821	19.40	0.438	24.00	433	115	0.210	2.6	33.793	6.556	9.618	2.711	
13	-	30.0	0.834	-	19.13		3.471	1.952	19.87	0.427	22.94	453	130	0.210	2.9	35.362	7.027	10.305	3.168	
14	-	31.0	0.856	-	19.13		3.586	2.017	20.01	0.424	22.35	473	145	0.200	3.2	36.294	7.261	10.305	3.632	
15	-	35.0	0.985	-	19.13		4.049	2.277	19.63	0.433	19.42	503	160	0.210	3.5	41.764	8.197	10.305	4.355	
16	-	38.0	1.126	-	19.13	1639.65	4.396	2.472	18.64	0.456	16.99	543	210	0.230	3.6	47.742	8.899	10.305	5.347	309
1	30.28	15.0	0.429	0.176	20.57	1639.65	1.735	0.976	16.19	0.620	34.00	378	375	0.400	1.7	21.697	3.514	7.557	1.604	308
2	30.56	20.0	0.489	0.204	18.00		2.314	1.301	18.89	0.533	25.97	383	350	0.390	1.9	24.799	4.684	8.244	1.518	308
3	29.89	25.0	0.566	0.228	18.00		2.892	1.626	20.51	0.488	22.67	403	320	0.385	2.1	28.542	5.834	8.931	1.924	309
4	30.07	30.0	0.620	0.252	18.02		3.471	1.952	22.44	0.447	20.67	428	330	0.380	2.4	31.310	7.027	8.244	2.464	309
5	29.93	35.0	0.714	0.288	18.02	1639.65	4.049	2.277	22.76	0.440	17.98	463	355	0.390	2.6	36.013	8.197	8.931	3.216	310
1	40.00	15.0	0.399	0.251	21.86	1639.65	1.735	0.976	16.03	0.666	33.63	378	380	0.415	1.7	21.920	3.514	7.557	1.705	308
2	40.50	20.0	0.462	0.297	18.00		2.314	1.301	18.36	0.583	23.72	383	370	0.400	1.8	25.508	4.684	8.244	1.524	308
3	40.64	25.0	0.509	0.326	18.00		2.892	1.626	20.85	0.514	21.56	403	355	0.405	2.0	28.079	5.834	8.244	1.928	309
4	39.89	30.0	0.542	0.340	18.02		3.471	1.952	23.62	0.452	20.43	423	340	0.400	2.3	29.757	7.027	8.244	2.357	309
5	40.40	35.0	0.628	0.402	18.02	1639.65	4.049	2.277	23.66	0.452	17.50	448	330	0.410	2.5	34.639	8.197	8.244	2.894	310



ตาราง ค-1 (ต่อ)

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							B_{nep} (kg/cm ²)	B_p (kW)	B_{nth} (%)	B_{sfc} (kg/kW-hr)	A/F	T_e (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q_f (kJ/hr)	Q_D (kJ/hr)	Q_w (kJ/hr)	Q_e (kJ/hr)	
1	50.03	15.0	0.358	0.339	21.86	1639.65	1.735	0.976	16.02	0.714	31.36	378	390	0.400	1.6	21.935	3.514	8.244	1.708	308
2	50.13	20.0	0.401	0.381	18.00	|	2.314	1.301	19.04	0.601	23.02	383	370	0.410	1.8	24.596	4.684	8.244	1.526	308
3	50.51	25.0	0.438	0.423	18.00	|	2.892	1.626	21.68	0.529	20.91	398	360	0.410	2.0	27.002	5.834	8.244	1.825	309
4	49.69	30.0	0.468	0.437	18.02	|	3.471	1.952	24.61	0.464	19.91	413	340	0.420	2.2	28.553	7.027	7.557	2.147	309
5	50.09	35.0	0.540	0.512	18.02	1639.65	4.049	2.277	24.76	0.462	17.13	443	340	0.430	2.3	33.100	8.197	8.244	2.790	310
1	60.34	15.0	0.307	0.442	21.86	1639.65	1.735	0.976	16.10	0.767	29.19	373	415	0.400	1.6	21.826	3.514	8.244	1.589	308
2	60.73	20.0	0.335	0.490	18.00	|	2.314	1.301	19.54	0.634	21.82	378	410	0.405	1.7	23.970	4.684	8.244	1.426	308
3	60.03	25.0	0.354	0.503	18.00	|	2.892	1.626	23.38	0.527	21.00	393	370	0.435	1.7	25.034	5.834	7.557	1.722	309
4	59.74	30.0	0.367	0.514	18.02	|	3.471	1.952	27.23	0.451	20.45	408	365	0.465	1.9	25.805	7.027	7.557	2.097	309
5	59.97	35.0	0.424	0.601	18.02	1639.65	4.049	2.277	27.36	0.450	17.58	428	350	0.480	2.2	29.956	8.197	7.557	2.463	310
1	70.67	15.0	0.240	0.547	20.57	1639.65	1.735	0.976	16.67	0.806	26.14	368	430	0.420	1.5	21.078	3.514	8.244	1.347	308
2	70.22	20.0	0.266	0.594	18.00	|	2.314	1.301	20.26	0.661	20.93	373	410	0.440	1.6	23.117	4.684	8.244	1.325	308
3	69.90	25.0	0.278	0.611	18.00	|	2.892	1.626	24.43	0.547	20.25	383	380	0.460	1.8	23.964	5.834	6.870	1.514	309
4	70.41	30.0	0.300	0.675	18.02	|	3.471	1.952	26.85	0.499	18.48	393	370	0.480	1.9	26.173	7.027	6.870	1.733	309
5	70.05	35.0	0.346	0.766	18.02	1639.65	4.049	2.277	27.38	0.483	16.21	418	375	0.500	2.1	29.937	8.197	7.557	2.258	310

ตาราง ค-2 ผลการทดลองของเครื่องยนต์ที่ความเร็ว 1 500 รอบต่อนาที

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bnep (kg/cm ²)	Bp (kW)	B _{nth} (%)	Bsfc (kg/kWh)	A/F	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _b (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	-	7.5	0.534	-	26.98	1639.65	0.868	0.732	11.64	0.730	50.52	438	185	0.305	1.8	22.642	2.635	10.992	3.988	306
2	-	10.0	0.603	-	26.98		1.157	0.976	13.74	0.618	44.74	448	185	0.290	1.9	25.567	3.514	11.679	4.312	
3	-	12.5	0.670	-	25.70		1.446	1.220	15.46	0.549	38.36	468	180	0.275	2.0	28.408	4.392	13.053	4.729	
4	-	14.5	0.742	-	28.26		1.678	1.443	16.51	0.514	38.09	483	175	0.255	2.1	31.461	5.195	13.740	5.703	
5	-	16.5	0.769	-	26.98		1.909	1.621	17.90	0.474	35.08	493	175	0.230	2.3	32.606	5.836	13.740	5.781	
6	-	18.5	0.837	-	25.70		2.140	1.805	18.31	0.464	30.70	503	170	0.235	2.4	35.489	6.498	14.427	5.834	
7	-	20.5	0.886	-	26.98		2.372	2.014	19.30	0.440	30.45	538	160	0.255	2.6	37.566	7.250	14.427	7.279	
8	-	22.5	0.930	-	26.98		2.603	2.210	20.18	0.421	29.01	563	150	0.260	2.7	39.432	7.956	15.114	8.127	
9	-	24.0	0.985	-	28.26		2.777	2.373	20.45	0.415	28.69	578	145	0.265	2.9	41.764	8.543	15.114	9.052	
10	-	27.0	1.068	-	26.98		3.124	2.635	20.95	0.405	25.26	593	130	0.290	3.2	45.283	9.486	15.801	9.193	
11	-	30.5	1.191	-	28.26		3.529	2.996	21.36	0.398	24.38	618	130	0.305	3.4	50.498	10.786	16.488	10.558	
12	-	33.0	1.255	-	28.26		3.818	3.242	21.93	0.387	22.52	643	145	0.310	3.7	53.212	11.671	16.488	11.508	
13	-	35.0	1.318	-	28.26		4.049	3.415	22.00	0.385	21.44	658	150	0.315	4.0	55.883	12.294	16.488	12.088	
14	-	38.5	1.512	-	26.98		4.454	3.757	21.10	0.402	17.84	683	145	0.320	4.6	64.109	13.525	17.175	12.623	
15	-	41.0	1.772	-	28.26		4.743	4.054	19.42	0.437	15.95	708	160	0.340	5.1	75.133	14.594	17.862	14.198	
16	-	44.0	2.022	-	28.26	1639.65	5.090	4.351	18.27	0.465	13.98	733	175	0.355	5.9	85.733	15.664	19.236	15.297	306
1	30.01	15.0	0.617	0.250	25.67	1639.65	1.735	1.473	17.03	0.589	29.61	453	410	0.420	1.9	31.143	5.303	13.740	4.299	306
2	30.58	20.0	0.701	0.292	24.83		2.314	1.978	20.03	0.502	25.01	513	390	0.430	2.1	35.542	7.121	13.740	5.937	307
3	30.29	25.0	0.757	0.311	25.67		2.892	2.456	23.09	0.435	24.04	563	370	0.420	2.2	38.295	8.842	13.053	7.755	307
4	30.11	30.0	0.897	0.365	25.62		3.471	2.927	23.26	0.431	20.30	603	350	0.400	2.5	45.307	10.537	14.427	9.080	308
5	30.75	35.0	0.972	0.408	24.34		4.049	3.415	24.91	0.404	17.64	643	340	0.410	2.9	49.344	12.294	15.114	9.969	308
6	29.81	40.0	1.186	0.476	24.32	1639.65	4.628	3.903	23.51	0.426	14.63	673	355	0.410	3.2	59.773	14.051	17.175	11.018	309
1	40.33	15.0	0.568	0.363	25.67	1639.65	1.735	1.464	16.83	0.636	27.57	448	400	0.440	1.9	31.318	5.270	14.427	4.159	306
2	39.90	20.0	0.658	0.413	24.83		2.314	1.952	19.45	0.549	23.18	508	395	0.415	2.0	36.130	7.027	14.427	5.820	307
3	40.11	25.0	0.701	0.444	24.38		2.892	2.439	22.76	0.469	21.29	543	370	0.435	2.2	38.571	8.780	13.740	6.795	307
4	40.39	30.0	0.806	0.516	24.34		3.471	2.927	23.70	0.452	18.41	588	365	0.415	2.4	44.458	10.537	14.427	8.198	308
5	39.95	35.0	0.881	0.554	24.34		4.049	3.415	25.40	0.420	16.96	633	375	0.420	2.8	48.396	12.294	15.144	9.667	308
6	39.94	40.0	1.053	0.663	24.32	1639.65	4.628	3.929	24.45	0.437	14.17	658	360	0.420	3.1	57.861	14.144	16.488	10.550	309

ตาราง ค-2 (ต่อ)

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. K
							E_{mp} (kg/cm ²)	B_p (kW)	$B_{\eta th}$ (%)	B_{sfc} (kg/kW-hr)	A/F	T_e (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q_f (kJ/hr)	Q_b (kJ/hr)	Q_w (kJ/hr)	Q_e (kJ/hr)	
1	49.91	15.0	0.519	0.490	25.67	1639.65	1.735	1.464	16.59	0.689	25.47	438	450	0.460	1.8	31.771	5.270	15.114	3.867	306
2	50.00	20.0	0.586	0.554	24.83	|	2.314	1.965	19.71	0.580	21.78	488	420	0.450	2.0	35.888	7.074	15.114	5.227	307
3	50.21	25.0	0.622	0.594	25.67	|	2.892	2.439	22.98	0.499	21.11	543	410	0.430	2.1	38.211	8.780	14.427	7.157	307
4	50.47	30.0	0.704	0.678	25.62	|	3.471	2.966	24.62	0.466	18.54	583	385	0.430	2.3	43.362	10.678	15.114	8.458	308
5	50.13	35.0	0.777	0.738	24.34	|	4.049	3.415	25.80	0.444	16.07	623	370	0.445	2.6	47.653	12.294	15.801	9.374	308
6	50.00	40.0	0.913	0.863	24.32	1639.65	4.628	3.903	25.13	0.455	13.69	653	360	0.470	2.8	55.911	14.051	17.175	10.413	309
1	60.11	15.0	0.448	0.639	25.67	1639.65	1.735	1.473	16.71	0.738	23.62	433	465	0.470	1.8	31.730	5.303	15.114	3.728	306
2	59.96	20.0	0.506	0.716	24.83	|	2.314	1.965	19.80	0.622	20.34	473	440	0.465	1.9	35.724	7.074	15.114	4.792	307
3	60.79	25.0	0.514	0.754	24.38	|	2.892	2.439	23.85	0.520	19.23	518	400	0.430	2.1	36.821	8.780	14.427	6.067	307
4	60.00	30.0	0.605	0.858	24.34	|	3.471	2.966	24.98	0.493	16.64	573	405	0.440	2.2	42.752	10.678	14.427	7.768	308
5	59.54	35.0	0.652	0.907	24.34	|	4.049	3.415	26.89	0.457	15.61	588	390	0.485	2.4	45.721	12.294	15.114	8.274	308
6	60.12	40.0	0.735	1.048	24.32	1639.65	4.628	3.903	26.99	0.457	13.64	643	400	0.490	2.7	52.051	14.051	15.801	10.087	309
1	70.00	15.0	0.347	0.760	25.67	1639.65	1.735	1.464	17.65	0.760	23.06	413	480	0.490	1.7	29.860	5.270	15.114	3.126	306
2	70.59	20.0	0.392	0.890	25.67	|	2.314	1.952	20.45	0.657	20.02	448	460	0.470	1.8	34.359	7.027	15.801	4.184	307
3	69.77	25.0	0.410	0.896	24.38	|	2.892	2.456	25.09	0.532	18.67	503	390	0.435	2.0	35.241	8.842	13.740	5.618	307
4	70.19	30.0	0.464	1.032	24.34	|	3.471	2.927	26.18	0.511	16.27	553	380	0.465	2.1	40.241	10.537	14.427	7.153	308
5	69.79	35.0	0.506	1.104	24.34	|	4.049	3.415	28.29	0.471	15.12	608	410	0.510	2.3	43.457	12.294	14.427	8.922	308
6	70.16	40.0	0.562	1.250	24.32	1639.65	4.628	3.903	28.83	0.464	13.42	638	425	0.530	2.6	48.741	14.051	15.114	9.930	309

ตาราง ค-3 ผลการทดลองของเครื่องยนต์ที่ความเร็ว 2 000 รอบต่อนาที

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bmep (kg/cm ²)	Bp (kW)	B _{nth} (%)	Bsfc (kg/kW-hr)	A/F	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _b (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	-	10.0	0.773	-	38.64	1639.65	1.157	1.304	14.32	0.593	49.99	463	290	0.335	2.5	32.775	4.694	17.175	6.838	306
2	-	13.5	0.856	-	38.64		1.562	1.765	17.51	0.485	45.14	478	280	0.330	2.7	36.294	6.354	17.175	7.575	
3	-	16.5	0.972	-	37.36		1.909	2.147	18.75	0.453	38.44	498	250	0.290	2.9	41.213	7.729	17.862	8.280	
4	-	20.0	1.076	-	37.36		2.314	2.615	20.63	0.411	34.72	533	230	0.285	3.0	45.622	9.414	17.862	9.816	
5	-	22.5	1.159	-	37.36		2.603	2.927	21.44	0.396	32.23	553	210	0.280	3.2	49.142	10.537	18.549	10.751	
6	-	25.0	1.255	-	37.36		2.892	3.253	22.01	0.386	29.77	588	215	0.260	3.7	53.212	11.711	18.549	12.425	
7	-	27.5	1.345	-	37.36		3.181	3.578	22.59	0.376	27.78	608	220	0.265	3.9	57.028	12.881	18.549	13.395	
8	-	30.0	1.382	-	36.07		3.471	3.903	23.98	0.354	26.10	628	230	0.270	4.0	58.597	14.051	19.236	13.893	
9	-	32.5	1.492	-	37.36		3.760	4.228	24.06	0.353	25.04	648	220	0.280	4.2	63.261	15.221	19.236	15.387	
10	-	35.0	1.603	-	37.36		4.049	4.554	24.12	0.352	23.31	668	220	0.260	4.3	67.967	16.394	19.923	16.418	
11	-	37.0	1.688	-	36.07		4.280	4.814	24.21	0.351	21.37	693	225	0.240	4.7	71.571	17.330	20.610	17.111	
12	-	39.0	1.785	-	36.07		4.512	5.074	24.14	0.352	20.21	728	230	0.240	5.1	75.684	18.266	21.984	18.882	
13	-	40.5	1.906	-	36.07		4.685	5.269	23.47	0.362	18.92	748	235	0.235	5.5	80.814	18.968	23.358	19.941	
14	-	42.0	2.059	-	36.07		4.859	5.464	22.53	0.377	17.52	763	240	0.260	6.0	87.302	19.670	25.419	20.788	
15	-	46.0	2.411	-	36.07	1639.65	5.322	5.985	21.08	0.403	14.96	773	270	0.265	6.6	102.226	21.546	27.481	21.493	306
1	30.01	15.0	0.714	0.290	39.58	1639.65	1.735	1.952	19.49	0.514	39.42	473	490	0.510	2.4	36.053	7.027	15.114	7.554	305
2	29.98	20.0	0.801	0.325	37.03		2.314	2.602	23.16	0.433	32.89	513	420	0.445	2.7	40.440	9.367	15.114	8.814	306
3	30.81	25.0	0.924	0.389	36.94		2.892	3.220	24.70	0.408	28.13	558	390	0.420	2.9	46.930	11.592	15.114	10.912	306
4	30.19	30.0	1.068	0.437	40.74		3.471	3.903	26.02	0.386	27.07	598	360	0.410	3.1	53.993	14.051	15.801	14.051	307
5	29.57	35.0	1.225	0.486	38.12		4.049	4.554	26.60	0.376	22.28	648	375	0.415	3.3	61.626	16.394	16.488	15.775	306
6	30.14	40.0	1.408	0.574	36.85	1639.65	4.628	5.230	26.47	0.379	18.59	713	390	0.420	3.5	71.139	18.828	17.175	18.602	306
1	40.20	15.0	0.633	0.402	39.58	1639.65	1.735	1.952	20.16	0.530	38.24	463	495	0.500	2.4	34.851	7.027	15.114	7.091	305
2	39.92	20.0	0.711	0.447	37.03		2.314	2.602	23.98	0.445	31.98	508	465	0.465	2.6	39.055	9.367	14.427	8.624	306
3	40.00	25.0	0.819	0.516	39.49		2.892	3.253	26.02	0.410	29.58	548	470	0.420	2.7	45.009	11.711	15.114	11.154	306
4	41.20	30.0	0.960	0.630	39.47		3.471	3.923	26.52	0.405	24.82	583	415	0.425	3.0	53.260	14.123	15.801	12.908	307
5	40.26	35.0	1.068	0.682	36.85		4.049	4.554	27.86	0.384	21.06	638	390	0.410	3.2	58.875	16.394	16.488	14.802	306
6	39.81	40.0	1.225	0.766	36.85	1639.65	4.628	5.256	28.15	0.379	18.51	673	395	0.435	3.4	67.206	18.922	17.175	16.607	306

ตาราง ก-3 (ต่อ)

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANC					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bnep (kg/cm ²)	Bp (kW)	B η_{th} (%)	Bsfc (kg/kW-hr)	A/F	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _D (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	50.46	15.0	0.543	0.524	39.58	1639.65	1.735	1.952	20.10	0.547	37.09	448	510	0.490	2.3	33.467	7.027	14.427	6.400	305
2	50.00	20.0	0.612	0.579	37.03	|	2.314	2.602	24.99	0.458	31.09	498	485	0.480	2.5	37.488	9.367	13.740	8.182	306
3	49.40	25.0	0.735	0.678	38.22	|	2.892	3.253	26.21	0.434	27.05	543	435	0.450	2.6	44.677	11.711	15.114	10.595	306
4	50.14	30.0	0.827	0.787	39.47	|	3.471	3.923	27.83	0.411	24.45	573	410	0.435	2.9	50.750	14.123	15.801	12.215	307
5	50.15	35.0	0.924	0.879	36.85	|	4.049	4.576	29.06	0.394	20.44	618	420	0.440	3.1	56.696	16.474	16.488	13.857	306
6	49.65	40.0	1.046	0.976	36.85	1639.65	4.628	5.204	29.36	0.389	18.22	688	430	0.440	3.3	63.802	18.734	17.175	17.373	306
1	60.22	15.0	0.456	0.654	39.58	1639.65	1.735	1.952	21.71	0.569	35.66	443	540	0.515	2.2	32.369	7.027	13.740	6.177	305
2	59.96	20.0	0.532	0.754	37.03	|	2.314	2.602	24.92	0.494	28.79	488	470	0.500	2.4	37.584	9.367	13.740	7.755	306
3	60.81	25.0	0.630	0.925	40.77	|	2.892	3.334	26.59	0.466	26.22	513	445	0.510	2.5	45.147	12.038	14.427	9.778	306
4	60.28	30.0	0.694	0.996	39.47	|	3.471	3.903	28.51	0.433	23.36	563	450	0.485	2.8	49.276	14.051	15.114	11.938	307
5	60.00	35.0	0.773	1.096	36.85	|	4.049	4.576	30.16	0.408	19.72	598	435	0.470	2.9	54.618	16.474	15.801	12.923	306
6	60.20	40.0	0.837	1.197	36.85	1639.65	4.628	5.204	31.57	0.391	18.12	673	440	0.495	3.1	59.345	18.734	16.488	16.625	306
1	69.92	15.0	0.350	0.770	39.58	1639.65	1.735	1.952	23.28	0.574	35.34	423	560	0.540	2.1	30.186	7.027	13.053	5.254	305
2	70.25	20.0	0.412	0.919	37.03	|	2.314	2.602	26.18	0.512	27.82	473	470	0.510	2.3	35.605	9.367	13.740	7.098	306
3	70.77	25.0	0.468	1.071	39.49	|	2.892	3.253	28.43	0.473	25.66	508	450	0.520	2.5	41.188	11.711	14.427	9.266	306
4	70.50	30.0	0.534	1.207	39.47	|	3.471	3.942	30.39	0.442	22.67	538	460	0.530	2.7	46.697	14.191	14.427	10.719	307
5	70.05	35.0	0.591	1.307	36.85	|	4.049	4.576	32.23	0.415	19.42	588	460	0.540	2.8	51.107	16.474	15.114	12.468	306
6	69.95	40.0	0.649	1.397	36.85	1639.65	4.628	5.230	34.01	0.391	18.07	638	450	0.560	3.1	55.360	18.828	15.114	14.915	306

ตาราง ค-4 ผลการทดลองของเครื่องยนต์ที่ความเร็ว 2 500 รอบต่อนาที

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bnep (kg/cm ²)	Bp (kW)	B _{ηth} (%)	Bsfc (kg/kW-hr)	AVF	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _b (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	-	14.0	1.228	-	49.51	1639.65	1.619	2.277	15.74	0.539	40.32	493	250	0.305	3.4	52.067	8.197	20.610	10.344	310
2	-	16.0	1.255	-	49.51	1639.65	1.851	2.612	17.67	0.480	39.45	513	200	0.290	3.7	53.212	9.403	20.610	11.532	
3	-	18.0	1.277	-	49.51	1639.65	2.082	2.927	19.46	0.436	38.77	538	125	0.255	4.0	54.145	10.537	20.610	13.038	
4	-	22.0	1.477	-	49.50	1639.65	2.545	3.606	20.73	0.410	33.52	603	65	0.220	4.1	62.625	12.982	21.297	16.690	
5	-	28.0	1.674	-	48.24	1639.65	3.239	4.554	23.09	0.368	28.82	638	65	0.185	4.6	70.978	16.394	22.671	18.909	
6	-	30.0	1.752	-	48.24	1639.65	3.471	4.879	23.64	0.359	27.53	653	55	0.150	5.0	74.285	17.564	24.045	19.891	
7	-	33.5	1.883	-	48.24	1639.65	3.876	5.448	24.56	0.346	25.62	673	55	0.135	5.3	79.839	19.613	24.045	21.197	
8	-	36.0	1.982	-	46.97	1639.65	4.165	5.855	25.08	0.339	23.70	693	50	0.115	5.8	84.037	21.078	24.045	21.955	
9	-	40.0	2.183	-	48.24	1639.65	4.628	6.505	25.30	0.336	22.10	718	55	0.100	6.0	92.559	23.418	24.732	24.255	
10	-	42.0	2.282	-	46.97	1639.65	4.859	6.830	25.41	0.334	20.58	728	50	0.100	6.1	96.757	24.588	24.732	24.334	
11	-	43.5	2.317	-	46.97	1639.65	5.033	7.074	25.92	0.328	20.27	738	50	0.085	6.3	98.241	25.466	24.732	24.997	
12	-	45.5	2.430	-	46.97	1639.65	5.264	7.400	25.86	0.328	19.33	748	40	0.100	6.6	103.032	26.640	25.419	25.705	
13	-	47.0	2.597	-	46.97	1639.65	5.437	7.644	24.99	0.340	18.09	768	50	0.105	6.8	110.113	27.518	25.419	27.106	
14	-	48.5	2.739	-	46.97	1639.65	5.611	7.888	24.45	0.347	17.15	778	80	0.125	7.0	116.134	28.397	26.106	27.847	
15	-	50.0	3.013	-	46.97	1639.65	5.785	8.164	23.00	0.369	15.59	783	100	0.155	7.1	127.751	29.390	27.481	28.437	
1	29.88	15.0	0.866	0.357	47.44	1639.65	1.735	2.439	19.65	0.509	38.17	488	225	0.380	2.7	44.681	8.780	16.488	9.799	307
2	30.32	20.0	0.998	0.411	49.83	1639.65	2.314	3.188	22.72	0.442	35.37	538	160	0.340	2.9	50.506	11.477	16.488	13.270	308
3	29.49	25.0	1.177	0.466	47.32	1639.65	2.892	4.033	24.53	0.407	28.80	573	140	0.280	3.3	59.192	14.519	18.549	14.740	308
4	30.02	30.0	1.245	0.505	48.60	1639.65	3.471	4.879	27.95	0.359	23.77	618	125	0.235	3.8	62.853	17.564	18.549	17.934	308
5	30.73	35.0	1.369	0.574	48.46	1639.65	4.049	5.692	29.49	0.341	24.94	653	100	0.205	4.0	69.485	20.491	18.549	20.113	309
6	30.05	40.0	1.492	0.606	47.27	1639.65	4.628	6.531	31.21	0.321	22.53	683	90	0.175	4.3	75.338	23.512	17.862	21.642	308
7	29.97	45.0	1.637	0.663	47.18	1639.65	5.206	7.318	31.86	0.314	20.51	723	105	0.165	4.6	82.622	26.345	17.862	24.172	309
1	40.13	15.0	0.760	0.479	47.44	1639.65	1.735	2.439	21.02	0.508	38.29	483	255	0.395	2.4	41.770	8.780	15.114	9.518	307
2	40.98	20.0	0.893	0.589	47.27	1639.65	2.314	3.188	23.14	0.465	31.90	533	205	0.365	2.7	49.602	11.477	15.114	12.340	308
3	40.50	25.0	1.025	0.660	48.60	1639.65	2.892	4.066	25.86	0.414	28.84	563	170	0.310	3.0	56.614	14.638	17.175	14.528	308
4	39.53	30.0	1.128	0.695	47.32	1639.65	3.471	4.879	28.48	0.374	25.96	603	145	0.265	3.4	61.679	17.564	17.175	16.599	308
5	40.07	35.0	1.246	0.787	47.18	1639.65	4.049	5.692	29.91	0.357	23.21	643	120	0.240	3.6	68.515	20.491	17.175	18.979	309
6	40.00	40.0	1.372	0.863	47.27	1639.65	4.628	6.531	31.19	0.342	21.15	673	100	0.200	3.9	75.372	23.512	17.175	21.051	308
7	40.08	45.0	1.438	0.908	47.18	1639.65	5.206	7.318	33.32	0.321	20.11	713	125	0.185	4.2	79.068	26.345	17.862	23.550	309

ตาราง ก-4 (ต่อ)

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							Bmep (kg/cm ²)	Bp (kW)	B η_{th} (%)	Bsfc (kg/kW-hr)	A/F	Te (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q _f (kJ/hr)	Q _b (kJ/hr)	Q _w (kJ/hr)	Q _e (kJ/hr)	
1	50.21	15.0	0.633	0.604	47.44	1639.65	1.735	2.439	22.59	0.507	38.35	483	285	0.415	2.0	38.877	8.780	14.427	9.518	307
2	50.13	20.0	0.785	0.746	47.27	|	2.314	3.253	24.32	0.471	30.80	533	220	0.370	2.3	48.152	11.711	15.801	12.353	308
3	49.86	25.0	0.856	0.805	47.32	|	2.892	4.066	27.97	0.409	28.49	558	185	0.335	2.8	52.338	14.638	15.801	13.862	308
4	50.31	30.0	0.942	0.902	48.60	|	3.471	4.898	30.44	0.376	26.36	593	155	0.305	3.1	57.918	17.633	15.801	16.418	308
5	49.82	35.0	1.061	0.996	48.46	|	4.049	5.715	31.73	0.360	23.56	628	135	0.280	3.4	64.837	20.574	16.488	18.564	309
6	50.38	40.0	1.141	1.096	47.27	|	4.628	6.505	33.35	0.344	21.13	663	140	0.250	3.6	70.222	23.418	16.488	20.422	308
7	50.21	45.0	1.234	1.177	47.18	1639.65	5.206	7.318	34.77	0.329	19.57	703	160	0.240	3.9	75.779	26.345	17.175	22.937	309
1	60.09	15.0	0.518	0.734	47.44	1639.65	1.735	2.439	23.99	0.513	37.89	478	365	0.460	2.0	36.592	8.780	13.740	9.201	307
2	60.00	20.0	0.627	0.888	48.55	|	2.314	3.279	26.66	0.462	32.05	523	315	0.415	2.1	44.283	11.804	14.427	12.077	308
3	59.94	25.0	0.714	1.013	48.60	|	2.892	4.098	29.23	0.421	28.14	548	260	0.365	2.4	50.463	14.753	14.427	13.637	308
4	59.81	30.0	0.795	1.122	48.60	|	3.471	4.898	31.45	0.391	25.35	583	210	0.315	2.7	56.069	17.633	15.114	15.823	308
5	60.07	35.0	0.841	1.192	47.18	|	4.049	5.692	34.48	0.357	23.52	593	185	0.290	3.0	59.415	20.491	15.801	15.961	309
6	60.00	40.0	0.928	1.312	47.27	|	4.628	6.505	35.76	0.344	21.10	653	235	0.260	3.2	65.495	23.418	15.801	19.814	308
7	59.92	45.0	0.997	1.413	47.18	1639.65	5.206	7.318	37.40	0.329	19.58	688	260	0.255	3.4	70.434	26.345	16.488	21.990	309
1	70.15	15.0	0.401	0.890	47.44	1639.65	1.735	2.439	25.27	0.529	36.75	473	425	0.495	1.8	34.740	8.780	13.053	8.963	307
2	70.88	20.0	0.480	1.104	47.27	|	2.314	3.253	27.65	0.487	29.84	513	360	0.445	1.8	42.355	11.711	13.740	11.177	308
3	69.97	25.0	0.562	1.239	49.88	|	2.892	4.147	30.77	0.458	26.28	543	315	0.390	1.9	48.522	14.929	13.740	13.670	308
4	70.09	30.0	0.630	1.397	48.60	|	3.471	4.918	32.45	0.427	23.14	578	295	0.335	2.0	54.554	17.705	14.427	15.556	308
5	70.06	35.0	0.664	1.469	47.18	|	4.049	5.692	35.68	0.391	21.19	603	290	0.305	2.2	57.431	20.491	14.427	16.600	309
6	70.23	40.0	0.715	1.601	47.27	|	4.628	6.505	37.64	0.356	20.41	648	285	0.300	2.4	62.224	23.418	15.114	16.859	308
7	70.03	45.0	0.749	1.657	47.18	1639.65	5.206	7.318	38.80	0.329	19.61	683	310	0.300	2.6	64.782	26.345	15.114	18.545	309

ตาราง ค-5 ผลการทดลองของเครื่องยนต์ที่ความเร็ว 3 000 รอบต่อนาที

RUN NO.	% meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							B_{mep} (kg/cm ²)	B_p (kW)	$B_{\eta th}$ (%)	B_{sfc} (kg/kW-hr)	A/F	T_e (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q_f (kJ/hr)	Q_b (kJ/hr)	Q_w (kJ/hr)	Q_e (kJ/hr)	
1	-	12.0	1.293	-	62.32	1639.65	1.388	2.342	15.38	0.552	48.20	583	210	0.340	4.1	54.823	8.431	20.610	19.853	309
2	-	15.0	1.506	-	62.32		1.735	2.927	16.50	0.515	41.38	593	160	0.330	4.4	63.854	10.537	21.297	20.701	
3	-	17.5	1.602	-	62.32		2.025	3.145	16.67	0.509	38.90	603	120	0.270	4.5	67.925	11.322	22.671	21.518	
4	-	20.0	1.752	-	62.32		2.314	3.916	18.98	0.447	35.57	623	100	0.240	5.0	74.285	14.098	23.358	23.157	
5	-	23.0	1.883	-	63.59		2.661	4.519	20.38	0.417	33.77	658	110	0.240	5.3	79.839	16.268	24.045	26.529	
6	-	25.5	2.008	-	62.32		2.950	4.976	21.04	0.404	31.04	673	100	0.230	5.7	85.139	17.914	25.419	27.279	
7	-	28.5	2.063	-	63.59		3.297	5.581	22.97	0.370	30.82	708	95	0.210	5.8	87.471	20.092	26.107	30.806	
8	-	32.5	2.318	-	64.87		3.760	6.406	23.46	0.362	27.99	723	100	0.180	6.3	98.283	23.062	26.107	32.823	
9	-	34.0	2.335	-	64.87		3.933	6.635	24.13	0.352	27.78	743	110	0.175	6.4	99.004	23.866	26.793	34.592	
10	-	36.0	2.412	-	63.59		4.165	7.037	24.77	0.343	26.36	763	110	0.190	6.6	102.269	25.333	26.793	35.748	
11	-	38.0	2.511	-	63.59		4.396	7.416	25.08	0.339	25.32	778	100	0.170	6.8	106.466	26.698	27.481	37.109	
12	-	40.0	2.739	-	63.59		4.628	7.806	24.20	0.351	23.22	788	85	0.170	7.0	116.134	28.102	28.168	38.126	
13	-	41.5	2.842	-	62.32		4.801	8.045	24.03	0.353	21.93	803	105	0.180	7.1	120.501	28.962	28.850	38.789	
14	-	42.5	2.975	-	62.32		4.917	8.294	23.67	0.359	20.95	813	115	0.170	7.3	126.140	29.858	30.229	39.754	
15	-	44.0	3.138	-	63.59	1639.65	5.090	8.587	23.23	0.365	20.26	828	135	0.195	7.4	133.051	30.913	32.290	42.008	
1	30.04	15.0	1.124	0.457	60.43	1639.65	1.735	2.927	18.56	0.540	38.22	573	300	0.350	3.0	56.766	10.537	17.175	18.738	307
2	30.52	20.0	1.345	0.559	48.76		2.314	3.903	20.61	0.488	25.61	603	280	0.330	3.2	68.169	14.051	19.923	17.171	307
3	29.91	25.0	1.522	0.614	48.04		2.892	4.879	22.88	0.438	22.49	638	220	0.340	3.5	76.770	17.564	20.610	19.125	308
4	29.93	30.0	1.655	0.669	46.53		3.471	5.855	25.24	0.397	20.02	688	210	0.325	3.8	83.505	21.078	21.297	21.663	309
5	30.07	35.0	1.752	0.712	47.79		4.049	6.830	27.79	0.361	19.40	728	190	0.320	4.3	88.475	24.588	20.610	24.948	308
6	30.12	40.0	2.009	0.819	46.00	1639.65	4.628	7.806	27.69	0.362	16.27	773	230	0.340	4.8	101.504	28.102	23.358	27.155	308
1	40.16	15.0	1.001	0.642	60.43	1639.65	1.735	2.937	19.14	0.559	36.78	563	310	0.400	2.9	55.237	10.573	16.488	18.004	307
2	40.40	20.0	1.235	0.792	48.76		2.314	3.903	20.62	0.519	24.06	588	285	0.385	3.1	68.149	14.051	20.610	16.283	307
3	40.00	25.0	1.421	0.896	48.39		2.892	4.879	22.49	0.475	20.88	623	245	0.380	3.3	78.108	17.564	21.297	18.385	308
4	40.00	30.0	1.506	0.950	46.53		3.471	5.858	25.46	0.419	18.95	653	265	0.345	3.7	82.788	21.078	21.297	19.547	309
5	39.83	35.0	1.569	1.018	47.79		4.049	6.830	28.32	0.379	18.47	703	305	0.360	4.1	86.814	24.588	20.610	23.361	308
6	40.67	40.0	1.772	1.149	46.00	1639.65	4.628	7.806	28.67	0.374	15.78	758	280	0.355	4.6	98.032	28.102	22.671	26.219	308

ตาราง ก-5 (ต่อ)

RUN NO.	x meth.	LOAD W (N)	\dot{m}_f (kg/hr)	\dot{m}_m (kg/hr)	\dot{m}_a (kg/hr)	\dot{m}_w (kg/hr)	PERFORMANCE					EXHAUST				ENERGY BALANCE				Amb. temp. (K)
							B_{rep} (kg/cm ²)	B_p (kW)	$B_{\eta th}$ (%)	B_{sfc} (kg/kW-hr)	A/F	T_e (K)	HC (ppm)	CO (%)	SMOKE (Bosch no.)	Q_f (kJ/hr)	Q_b (kJ/hr)	Q_w (kJ/hr)	Q_e (kJ/hr)	
1	49.86	15.0	0.866	0.814	60.43	1639.65	1.735	2.927	19.90	0.574	35.97	558	340	0.430	2.6	52.941	10.537	16.488	17.647	307
2	50.18	20.0	1.076	1.025	47.39	|	2.314	3.916	21.34	0.537	22.56	583	290	0.395	2.8	66.051	14.098	21.297	15.558	307
3	50.60	25.0	1.196	1.158	48.39	|	2.892	4.879	23.80	0.482	20.57	618	260	0.370	3.1	73.789	17.564	21.984	18.075	308
4	50.00	30.0	1.245	1.177	46.53	|	3.471	5.874	27.73	0.412	19.21	668	260	0.365	3.5	76.246	21.146	20.610	20.456	309
5	50.67	35.0	1.333	1.295	47.79	|	4.049	6.830	29.87	0.385	18.18	703	270	0.360	3.8	82.329	24.588	19.923	23.380	308
6	49.75	40.0	1.522	1.425	46.02	1639.65	4.628	7.806	30.24	0.378	15.62	753	280	0.365	4.5	92.933	28.102	22.671	25.930	308
1	60.45	15.0	0.704	1.018	60.43	1639.65	1.735	2.927	21.02	0.588	35.09	543	390	0.435	2.6	50.138	10.537	15.114	16.545	307
2	59.93	20.0	0.876	1.239	47.39	|	2.314	3.903	22.72	0.542	22.41	573	340	0.400	2.9	61.836	14.501	20.610	14.959	307
3	59.92	25.0	0.998	1.412	48.04	|	2.892	4.879	24.93	0.494	19.93	588	320	0.395	2.9	70.456	17.564	20.610	16.118	308
4	59.41	30.0	1.061	1.469	46.53	|	3.471	5.855	28.38	0.432	18.39	633	300	0.380	3.0	74.264	21.078	20.610	18.343	309
5	60.01	35.0	1.124	1.601	47.79	|	4.049	6.853	31.01	0.398	17.54	688	290	0.375	3.4	79.566	24.671	20.610	22.459	308
6	60.40	40.0	1.235	1.781	46.02	1639.65	4.628	7.806	31.98	0.386	15.26	733	285	0.405	4.1	87.859	28.102	21.297	24.654	308
1	70.02	15.0	0.543	1.168	60.43	1639.65	1.735	2.937	22.84	0.583	35.32	533	440	0.410	2.4	46.301	10.573	14.427	15.799	307
2	70.54	20.0	0.674	1.526	48.76	|	2.314	3.929	23.97	0.560	22.16	553	380	0.420	2.7	58.991	14.144	19.236	14.166	307
3	69.45	25.0	0.789	1.696	48.04	|	2.892	4.887	26.16	0.508	19.33	583	340	0.415	2.8	67.255	17.593	19.929	15.826	308
4	69.73	30.0	0.828	1.803	46.53	|	3.471	5.874	29.77	0.448	17.69	613	330	0.400	3.1	71.041	21.146	20.610	17.157	309
5	69.12	35.0	0.901	1.907	47.79	|	4.049	6.830	32.26	0.411	17.02	663	315	0.390	3.4	76.209	24.588	20.610	20.872	308
6	70.67	40.0	0.947	2.159	46.02	1639.65	4.628	7.806	33.78	0.398	14.81	713	320	0.415	3.8	83.182	28.102	20.610	23.418	308

ค-2 ตัวอย่างการคำนวณ

ข้อมูลที่ใช้

Engine speed (N)	2 500	RPM
Brake load (W)	46	N
Time for 50 ml of diesel oil (t_f)	115	s
Time for 50 ml of methanol (t_m)	120	s
Pressure drop across inlet air orifice (H)	37	mm
Exhaust gas temperature (T_e)	693	K
Water inlet temperature ($T_{c_{in}}$)	363.5	K
Water outlet temperature ($T_{c_{out}}$)	367	K
Air inlet temperature (T_a)	303	K
Ambient pressure (P_o)	760	mm Hg
Heating value of diesel oil (q_f)	42 400	kJ/kg
Heating value of methanol (q_m)	19 900	kJ/kg
Density of diesel oil (ρ_f)	836.9	kg/m ³
Density of methanol (ρ_m)	791.5	kg/m ³

Fuel flow rate:

$$\begin{aligned}
 \text{Diesel oil, } \dot{m}_f &= \frac{50 \text{ (ml)}}{115 \text{ (s)}} \times \frac{836.9 \text{ (kg/m}^3\text{)}}{10^6 \text{ (ml/m}^3\text{)}} \\
 &= 3.638 \times 10^{-4} \text{ kg/s} \\
 &= 1.310 \text{ kg/hr} \\
 \text{Methanol, } \dot{m}_m &= \frac{50 \text{ (ml)}}{120 \text{ (s)}} \times \frac{791.5 \text{ (kg/m}^3\text{)}}{10^6 \text{ (ml/m}^3\text{)}} \\
 &= 3.298 \times 10^{-4} \text{ kg/s} \\
 &= 1.187 \text{ kg/hr}
 \end{aligned}$$

Air flow rate:

$$\begin{aligned}
 \dot{m}_a &= 2.23 \times H \times (0.5) \text{ m}^3/\text{hr} \\
 &= 2.23 \times 37 \times 0.5
 \end{aligned}$$

$$\begin{aligned}
 &= 41.255 \quad \text{m}^3/\text{hr} \\
 \rho_{\text{air}} &= 1.2928 \times \frac{273}{\text{Amb. temp. (K)}} \times \frac{760}{P_0} \quad \text{kg/m}^3 \\
 (\text{at NTP, } \rho_{\text{air}} &= 1.2928 \quad \text{kg/m}^3) \\
 \rho_{\text{air}} &= 1.2928 \times \frac{273}{303} \times \frac{760}{760} \quad \text{kg/m}^3 \\
 &= 1.1648 \quad \text{kg/m}^3 \\
 \dot{m}_a &= 41.255 (\text{m}^3/\text{hr}) \times 1.1648 (\text{kg/m}^3) \\
 &= 48.054 \quad \text{kg/hr}
 \end{aligned}$$

Air-fuel ratio:

$$\begin{aligned}
 A/F &= \frac{\dot{m}_a}{\dot{m}_f + \dot{m}_m} = \frac{48.054}{1.310 + 1.187} \\
 &= 19.24
 \end{aligned}$$

Cooling water flow rate:

$$\begin{aligned}
 \dot{m}_w &= 1687.2 \quad \text{l/hr} \\
 (\text{at } 80^\circ\text{C, } \rho_{\text{water}} &= 0.97182 \quad \text{kg/l}) \\
 \dot{m}_w &= 1687.2 (\text{l/hr}) \times 0.97182 (\text{kg/l}) \\
 &= 1639.65 \quad \text{kg/hr}
 \end{aligned}$$

Brake mean effective pressure:

$$\begin{aligned}
 \text{Bmep} &= W \times 0.11569 \quad \text{kg/cm}^2 \\
 &= 46 \times 0.11569 \\
 &= 5.322 \quad \text{kg/cm}^2
 \end{aligned}$$

Brake power:

$$\begin{aligned}
 \text{Bp} &= \frac{W \times N}{15372.27} \quad \text{kW} \\
 &= \frac{46 \times 2500}{15372.27} \\
 &= 7.481 \quad \text{kW}
 \end{aligned}$$

Brake specific fuel consumption:

$$\begin{aligned}
 \text{Bsfc} &= \frac{\dot{m}_f + \dot{m}_m}{B_p} \quad \text{kg/kW-hr} \\
 &= \frac{1.310 + 1.187}{7.481} \\
 &= 0.333\ 778\ 9 \quad \text{kg/kW-hr} \\
 &= 333.779 \quad \text{g/kW-hr}
 \end{aligned}$$

Brake thermal efficiency:

$$\begin{aligned}
 \eta_{\text{th}} &= \frac{B_p}{\dot{m}_f q_f + \dot{m}_m q_m} \times 100 \\
 &= \frac{7.481 \text{ (kJ/s)} \times 3\ 600 \text{ (s)} \times 100}{1 \text{ (hr)} \{ 1.310 \text{ (kg/hr)} \times 42\ 400 \text{ (kJ/kg)} + 1.187 \text{ (kg/hr)} \times 19\ 900 \text{ (kJ/kg)} \}} \\
 &= 34.02
 \end{aligned}$$

Energy balance:

$$\begin{aligned}
 \text{Energy input, } Q_f &= \dot{m}_f q_f + \dot{m}_m q_m \\
 &= 1.310 \text{ (kg/hr)} \times 42\ 400 \text{ (kJ/kg)} + 1.187 \text{ (kg/hr)} \times 19\ 900 \text{ (kJ/kg)} \\
 &= 79\ 165.3 \quad \text{kJ/hr}
 \end{aligned}$$

Energy equivalent to brake power,

$$\begin{aligned}
 Q_b &= B_p \times 3\ 600 \quad \text{kJ/hr} \\
 &= 7.481 \times 3\ 600 \\
 &= 26\ 931.6 \quad \text{kJ/hr} \\
 \eta_{\text{th}} &= \frac{26\ 931.6}{79\ 165.3} \times 100 \\
 &= 34.02
 \end{aligned}$$

Energy reject to cooling water,

$$\begin{aligned}
 Q_w &= \dot{m}_w c_{pw} (T_{c_{\text{out}}} - T_{c_{\text{in}}}) \quad \text{kJ/hr} \\
 &= 1\ 639.65 \text{ (kg/hr)} \times 4.19 \text{ (kJ/kg-K)} \times (367 - 363.5) \text{ (K)} \\
 &= 24\ 045.47 \quad \text{kJ/hr} \\
 (c_{pw} &= 4.19 \text{ kJ/kg-K})
 \end{aligned}$$

$$Q_w = \frac{24\,045.47}{79\,165.3} \times 100$$

$$= 30.37$$

Energy reject to exhaust,

$$Q_e = (\dot{m}_a + \dot{m}_f + \dot{m}_m) c_{pe} (T_e - T_a) \quad \text{kJ/hr}$$

$$c_{pe} = 0.988 + 0.23 \times 10^{-3} (T_e) + 0.050 \times 10^{-6} (T_e)^2 \quad \text{kJ/kg-K}$$

$$= 0.988 + 0.23 \times 10^{-3} (693) + 0.550 \times 10^{-6} (693)^2$$

$$= 1.1714 \quad \text{kJ/kg-K}$$

$$Q_e = (48.054 + 1.310 + 1.187) \text{ kg/hr} \times 1.1714 \text{ (kJ/kg-K)} \times (693 - 303) \text{ (K)}$$

$$= 22\,094.02 \quad \text{kJ/hr}$$

หรือ

$$Q_e = \frac{22\,094.02}{79\,165.3} \times 100$$

$$= 29.17$$

Energy reject by radiation, friction, etc.,

$$Q_r = Q_f - Q_b - Q_w - Q_e$$

$$= 79\,165.3 - 26\,931.6 - 24\,045.47 - 22\,094.02$$

$$= 6\,094.21$$

$$Q_r = \frac{6\,094.21}{79\,165.3} \times 100$$

$$= 7.70$$

ภาคผนวก ง

ตาราง ง-1 แสดงการเปรียบเทียบการใช้เชื้อเพลิงที่ภาระสูงสุดของเครื่องยนต์

ความเร็ว RPM	100 % Diesel	30 % meth.	40 % meth.	50 % meth.	60 % meth.	70 % meth.	100 % Diesel	30 % meth.	40 % meth.	50 % meth.	60 % meth.	70 % meth.
	อัตราการสิ้นเปลืองเชื้อเพลิง, kg/kW-hr						อัตราการสิ้นเปลืองเชื้อเพลิง, liter/kW-hr					
1 000	0.456	0.440	0.452	0.462	0.450	0.483	0.544	0.534	0.553	0.567	0.556	0.606
1 500	0.465	0.426	0.437	0.455	0.457	0.464	0.555	0.517	0.533	0.559	0.564	0.577
2 000	0.403	0.379	0.379	0.389	0.391	0.391	0.481	0.460	0.463	0.477	0.483	0.486
2 500	0.369	0.314	0.321	0.329	0.329	0.329	0.441	0.382	0.392	0.405	0.407	0.408
3 000	0.365	0.362	0.374	0.378	0.386	0.398	0.437	0.440	0.457	0.464	0.477	0.494
	อัตราการสิ้นเปลืองเชื้อเพลิง, MJ/kW-hr						อัตราการสิ้นเปลืองเชื้อเพลิง, บาท/kW-hr					
1 000	19.31	15.81	15.21	14.53	13.15	13.14	4.02	5.17	5.78	6.35	6.64	7.72
1 500	19.70	15.31	14.72	14.32	13.33	12.48	4.10	4.99	5.56	6.25	6.75	7.34
2 000	17.08	13.60	12.78	12.25	11.40	10.58	3.55	4.56	4.82	5.33	5.78	6.16
2 500	15.65	11.29	10.80	10.35	9.62	8.85	3.26	3.69	4.09	4.54	4.86	5.19
3 000	15.49	13.00	12.55	11.90	11.25	10.65	3.23	4.26	4.79	5.18	5.72	6.31
	ผลต่างค่าเชื้อเพลิง, บาท/kW-hr						ค่าเชื้อเพลิงสูงขึ้น, %					
1 000	-	1.15	1.76	2.33	2.62	3.70	-	28.61	43.78	57.96	65.17	92.04
1 500	-	0.89	1.46	2.15	2.65	3.24	-	21.71	35.61	52.44	64.63	79.02
2 000	-	1.01	1.27	1.78	2.23	2.61	-	28.45	35.77	50.14	62.82	73.52
2 500	-	0.43	0.83	1.28	1.60	1.93	-	13.19	25.46	39.26	49.08	59.20
3 000	-	1.03	1.56	1.95	2.49	3.08	-	31.89	48.30	60.37	77.09	95.36

1 kg ของน้ำมันดีเซลมีปริมาตร 1.195 ลิตร ราคาดีเซลละ 7.39 บาท (สิงหาคม 2524 กรุงเทพมหานคร)

1 kg ของเมธานอลมีปริมาตร 1.263 ลิตร ราคาดีเซลละ 15.00 บาท (สิงหาคม 2524 กรุงเทพมหานคร)

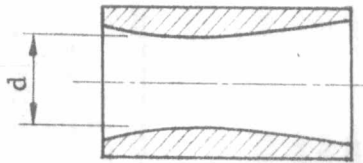
ภาคผนวก จ

การหาขนาดคอคคอตของคาร์บูเรเตอร์

คาร์บูเรเตอร์ที่ใช้ประกอบการทดลอง จำเป็นที่จะต้องมีขนาดที่เหมาะสม โดยเฉพาะอย่างยิ่งส่วนที่เป็นคอคคอต (throat) ซึ่งเป็นส่วนที่บังคับให้อากาศเข้ามาน้อย สำหรับเครื่องยนต์สูบเดียว จะคำนวณขนาดคอคคอตได้จาก [3] หน้า 95 ดังสมการ

$$d = 0.82 \sqrt{vN} \quad (\text{จ-1})$$

เมื่อ d = เส้นผ่านศูนย์กลางของคอคคอต, มม
 v = ปริมาตรบรรจุของแต่ละสูบ, ซีซี
 N = ความเร็วของเครื่องยนต์, $\frac{1\ 000 \text{ รอบ}}{\text{นาที}}$



รูปที่ จ-1 ภาพแสดงบริเวณคอคคอตของคาร์บูเรเตอร์

สำหรับเครื่องยนต์ที่ทดลอง RICARDO E6/U

ความเร็วสูงสุดที่ใช้ 3 500 รอบต่อนาที

ปริมาตรบรรจุของแต่ละสูบ 507 ซีซี

$$\begin{aligned} d &= 0.82 \sqrt{507 \times \frac{3\ 500}{1\ 000}} \\ &= 34.54 \text{ มม} \end{aligned}$$

ขนาดที่ได้จะเป็นไปตามทฤษฎี ซึ่งในการใช้งานจะต้องมีขนาดเล็กลง คือ

$$\begin{aligned} \text{ขนาดเส้นผ่านศูนย์กลางใช้งานของคอคคอต} &= 0.8d \text{ มม} \quad (\text{จ-2}) \\ &= 27.63 \text{ มม} \end{aligned}$$

ซึ่งจากการใช้คาร์บูเรเตอร์ที่มีอยู่ขนาดคอคคอต 26.00 มม นับว่าใกล้เคียงกับการคำนวณ

ประวัติ

ชื่อ นายสมศักดิ์ สินประเสริฐ

เกิด วันที่ 27 มิถุนายน 2497

วุฒิการศึกษา วิศวกรรมศาสตรบัณฑิต สาขาวิศวกรรมเครื่องกล

จาก สถาบันเทคโนโลยีพระจอมเกล้า วิทยาเขตพระนครเหนือ

ปีการศึกษา 2520

การทำงาน อาจารย์ระดับ 3 ภาควิชาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์
สถาบันเทคโนโลยีพระจอมเกล้า วิทยาเขตพระนครเหนือ

