

# PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

## FACULTAD DE CIENCIAS E INGENIERÍA



PONTIFICIA  
**UNIVERSIDAD  
CATÓLICA**  
DEL PERÚ

### ESTUDIO EXPERIMENTAL DE UN MOTOR BI-COMBUSTIBLE PARA EL USO DE BIOGÁS.

#### ANEXOS

Tesis para optar el Título de Ingeniero Mecánico,  
que presenta el bachiller:

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### Anexo A: Planilla GNV

Regimen de giro	Torque	Potencia observada	pme	Consumo de Diesel	Razon de sustitución	Consumo de GNV	Presión de inyección del GNV	Temperatura del GNV	Consumo de CO2	Presión de inyección del CO2	Temperatura de CO2	Consumo de Biogás	Clase de Biogás Artificial	Consumo específico equivalente	Rendimiento efectivo	Presión atmosférica	Temperatura atmosférica	Humedad relativa	Presión Saturación	Humedad absoluta (w)	Constante de aire seco	Densidad ambiente	Velocidad del aire	Consumo de aire fresco	Consumo de aire seco	Temperatura de escape	Flujo de gases de escape	Factor de corrección	O2	CO2	NOX	CO	HC	Fr	Temperatura entrada del refrigerante	Temperatura salida del refrigerante
rpm	N.m	kW	bar	kg/h	%	kg/h	kPa	°C	kg/h	kPa	°C	kg/h	%	g/kW.h	%	kPa	°C	%	kPa	kg/kg	kJ/kg.K	kg/m3	m/s	kg/h	kg/h	°C	kg/h		g/kW.h	g/kW.h	g/kW.h	g/kW.h	g/kW.h	g/kW.h	°C	°C
1800	100	18.8	1.88	7.59	0.0	0.0	304.4	27.2	0.0	150.0	26.0	0.0	100	402.8	21.1	101.02	26	71	3.36	0.0150	0.290	1.166	20.25	213.46	210.30	189	221	0.9332	642507	171252	1.29	4.69	0.00	0.526	76.7	76.2
1800	100	18.8	1.88	6.66	12.3	1.2	283.8	27.0	0.0	150.0	26.0	1.2	100	427.4	19.8	101.02	26	71	3.36	0.0150	0.290	1.166	20.32	214.26	211.09	203	222	0.9194	639834	176708	1.05	15.18	11.65	0.559	73.8	72.7
1800	100	18.8	1.88	6.01	20.9	3.0	250.7	27.1	0.0	150.0	26.0	3.0	100	497.9	17.0	101.02	26	70	3.36	0.0148	0.290	1.166	20.38	214.91	211.78	212	224	0.8939	640638	181050	0.92	23.27	26.49	0.652	72.3	71.1
1800	100	18.8	1.88	4.39	42.1	5.5	160.0	27.2	0.0	150.0	27.0	5.5	100	564.3	15.0	101.02	27	70	3.56	0.0157	0.290	1.162	20.38	214.02	210.70	215	224	0.8619	637717	183170	0.95	32.35	45.46	0.747	71.9	70.3
1800	100	18.8	1.88	3.88	48.8	7.2	22.3	27.5	0.0	150.0	27.0	7.2	100	641.0	13.2	101.02	27	69.5	3.56	0.0156	0.290	1.162	20.44	214.67	211.36	219	226	0.8357	638317	188091	0.95	34.87	55.69	0.848	70.9	69.7
1800	80	15.1	1.50	7.03	0.0	0.0	304.5	28.0	0.0	150.0	28.0	0.0	100	466.1	18.2	101.02	28	67	3.78	0.0160	0.290	1.158	20.11	210.44	207.13	213	217	0.9372	517473	125925	1.51	6.35	0.00	0.495	70.9	69.9
1800	80	15.1	1.50	6.33	9.9	1.1	283.3	28.1	0.0	150.0	28.0	1.1	100	504.3	16.8	101.02	28	67	3.78	0.0160	0.290	1.158	20.14	210.76	207.45	215	218	0.9229	513984	130306	1.24	18.06	14.87	0.537	70.9	69.8
1800	80	15.1	1.50	5.27	25.0	2.9	251.6	28.1	0.0	150.0	28.5	2.9	100	567.6	14.9	101.02	28.5	66.5	3.89	0.0163	0.290	1.156	20.20	211.05	207.65	215	219	0.8999	511377	134869	1.09	27.80	34.95	0.607	70.7	69.6
1800	80	15.1	1.50	3.93	44.1	5.4	162.5	28.6	0.0	150.0	29.0	5.4	100	666.2	12.7	101.02	29	65	4.00	0.0164	0.290	1.154	20.05	209.09	205.71	214	218	0.8648	508490	135026	1.15	38.08	60.17	0.723	70.1	69.1
1800	80	15.1	1.50	3.30	53.0	7.2	22.5	28.8	0.0	150.0	29.0	7.2	100	761.9	11.1	101.02	29	64.5	4.00	0.0163	0.290	1.154	20.30	211.68	208.28	214	222	0.8386	513613	140046	1.12	40.94	74.65	0.819	69.9	68.8
1800	60	11.3	1.13	6.37	0.0	0.0	304.3	29.2	0.0	150.0	29.0	0.0	100	563.6	15.0	101.02	29	64	4.00	0.0162	0.290	1.154	19.84	206.98	203.69	202	213	0.9421	391631	84696	1.80	8.04	0.00	0.456	69.8	68.7
1800	60	11.3	1.13	5.42	15.0	1.1	284.0	29.1	0.0	150.0	29.5	1.1	100	592.4	14.3	101.02	29.5	63	4.12	0.0164	0.290	1.152	19.81	206.31	202.98	200	213	0.9294	406591	86903	1.45	22.71	21.65	0.484	69.4	68.4
1800	60	11.3	1.13	4.32	32.3	2.9	248.9	29.0	0.0	150.0	28.0	2.9	100	672.3	12.6	101.02	28	64	3.78	0.0152	0.290	1.158	19.50	204.24	201.17	173	211	0.9054	385727	85611	1.52	36.11	52.43	0.557	75.1	74.8
1800	60	11.3	1.13	3.34	47.6	5.3	159.8	29.0	0.0	150.0	29.0	5.3	100	827.2	10.3	101.02	29	64	4.00	0.0162	0.290	1.154	19.51	203.51	200.27	185	212	0.8682	383877	88292	1.49	46.44	88.82	0.692	75.8	74.8
1800	60	11.3	1.13	2.84	55.4	7.2	22.7	29.2	0.0	150.0	29.0	7.2	100	972.1	8.7	101.02	29	64	4.00	0.0162	0.290	1.154	19.51	203.51	200.27	189	214	0.8370	384204	90557	1.42	48.20	106.28	0.815	73.4	72.5
1800	40	7.5	0.75	5.59	0.0	0.0	304.4	29.0	0.0	150.0	28.0	0.0	100	741.2	11.4	101.02	28	67	3.78	0.0160	0.290	1.158	19.22	201.17	198.00	163	207	0.9478	261895	48170	2.41	12.58	12.17	0.411	70.8	70.1
1800	40	7.5	0.75	4.53	19.0	1.0	284.6	28.9	0.0	150.0	28.5	1.0	100	755.9	11.2	101.02	28.5	67	3.89	0.0165	0.290	1.156	19.19	200.46	197.22	167	206	0.9376	259879	48621	2.28	33.22	63.31	0.423	72.8	72.3
1800	40	7.5	0.75	3.83	31.4	2.8	251.1	28.9	0.0	150.0	28.0	2.8	100	926.3	9.2	101.02	28	66.5	3.78	0.0159	0.290	1.158	19.09	199.82	196.70	169	206	0.9101	259290	49648	2.24	50.89	111.01	0.524	74.8	74.1
1800	40	7.5	0.75	3.03	45.7	5.3	160.0	28.9	0.0	150.0	28.0	5.3	100	1198.9	7.1	101.02	28	67	3.78	0.0160	0.290	1.158	19.33	202.35	199.17	174	211	0.8705	261605	52893	2.14	65.35	171.49	0.673	74.7	74.0
1800	40	7.5	0.75	2.57	54.0	7.2	22.7	29.0	0.0	150.0	28.0	7.2	100	1419.1	6.0	101.02	28	67	3.78	0.0160	0.290	1.158	19.40	203.02	199.83	179	213	0.8395	263220	54056	2.06	67.70	201.77	0.796	73.4	72.5
1800	20	3.8	0.38	4.87	0.0	0.0	303.6	29.4	0.0	150.0	28.0	0.0	100	1292.5	6.6	101.02	28	67	3.78	0.0160	0.290	1.158	19.06	199.47	196.33	168	204	0.9541	133654	20645	4.85	21.91	29.91	0.362	72.4	71.7
1800	20	3.8	0.38	4.14	15.1	1.7	284.6	29.3	0.0	150.0	28.0	1.7	100	1610.4	5.3	101.02	28	67	3.78	0.0160	0.290	1.158	19.02	199.12	195.99	162	205	0.9278	133212	21326	4.34	60.04	135.51	0.455	72	71.3
1800	20	3.8	0.38	3.51	28.0	2.7	251.6	29.2	0.0	150.0	28.0	2.7	100	1757.4	4.8	101.02	28	67	3.78	0.0160	0.290	1.158	19.06	199.47	196.33	161	206	0.9136	132616	22180	4.14	91.86	239.97	0.498	71.5	70.7
1800	20	3.8	0.38	2.50	48.7	5.2	160.7	29.3	0.0	150.0	28.0	5.2	100	2231.9	3.8	101.02	28	66.5	3.78	0.0159	0.290	1.158	19.12	200.16	197.03	163	208	0.8757	132429	23586	3.87	118.92	368.57	0.634	71.3	70.5
1800	20	3.8	0.38	2.30	52.8	7.2	22.5	29.0	0.0	150.0	28.0	7.2	100	2790.4	3.0	101.02	28	66	3.78	0.0157	0.290	1.158	19.15	200.50	197.40	138	210	0.8386	132072	25100	3.38	122.11	380.97	0.792	72.9	73

Anexo B: Planilla GNV + CO<sub>2</sub>

Régimen de giro		Torque	Potencia observada	pne	Consumo de Diesel	Razón de sustitución	Consumo de GNV	Presión de inyección del GNV	Temperatura del GNV	Consumo de CO2	Presión de inyección del CO2	Temperatura de CO2	Consumo de Biogás 80%	Clase de Biogás Artificial	Consumo específico equivalente	Rendimiento efectivo	Presión atmosférica	Temperatura atmosférica	Humedad relativa	Presión Saturación	Humedad absoluta (w)	Constante de aire humedo	Densidad ambiente	Velocidad del aire	Consumo de aire fresco	Consumo de aire seco	Temperatura de escape	Flujo de gases de escape	Factor de corrección	O2	CO2	NOX	CO	HC	Fr	Temperatura entrada del refrigerante	Temperatura salida del refrigerante
rpm	N.m	kW	bar	kg/h	%	kg/h	kPa	°C	kg/h	kPa	°C	kg/h	%	g/kW.h	%	kPa	°C	%	kPa	kg/kg	kJ/kg.K	kg/m3	m/s	kg/h	kg/h	°C	kg/h	g/kW.h	g/kW.h	g/kW.h	g/kW.h	g/kW.h	g/kW.h	°C	°C		
1800	100	18.8	1.88	7.62	0.0	0.0	205.6	27.9	0.0	0.0	27.0	0.0	0.0	404.5	21.0	101.02	27	70	3.56	0.0157	0.290	1.162	20.30	213.16	209.86	197	221	0.9328	640077	172296	1.27	4.73	0.00	0.530	74.7	75	
1800	100	18.8	1.88	6.63	13.1	1.5	277.7	29.8	0.5	150.0	28.5	1.9	75.4	440.3	19.3	101.02	28.5	67	3.89	0.0165	0.290	1.156	20.32	212.27	208.83	210	221	0.9144	636057	175665	1.00	14.86	16.03	0.582	72.8	71.9	
1800	100	18.8	1.88	5.92	22.4	2.7	250.2	29.7	1.0	150.0	29.0	3.7	74.7	478.0	17.7	101.02	29	67	4.00	0.0170	0.290	1.153	20.31	211.75	208.22	218	221	0.8975	633365	178994	0.92	21.81	29.67	0.636	72.8	71.8	
1800	100	18.8	1.88	4.51	40.8	5.2	158.2	29.9	2.5	150.0	29.0	7.7	74.9	554.9	15.3	101.02	29	67	4.00	0.0170	0.290	1.153	20.26	211.27	207.75	219	224	0.8636	637428	182423	0.93	30.70	49.15	0.745	72.7	71.7	
1800	100	18.8	1.88	3.99	47.7	7.1	21.7	30.0	7.2	150.0	29.5	14.3	74.9	640.5	13.2	101.02	29.5	66	4.12	0.0172	0.290	1.151	20.24	210.60	207.04	219	229	0.8332	647090	190676	0.85	33.41	60.44	0.865	72.2	71.2	
1800	80	15.1	1.50	6.97	0.0	0.0	303.6	30.5	0.0	0.0	29.5	0.0	0.0	462.5	18.3	101.02	29.5	66	4.12	0.0172	0.290	1.151	20.04	208.52	204.99	209	215	0.9371	519925	119583	1.44	5.50	0.00	0.496	71.9	70.9	
1800	80	15.1	1.50	6.09	12.7	1.2	281.8	30.3	0.4	150.0	29.5	1.6	74.4	492.2	17.2	101.02	29.5	66	4.12	0.0172	0.290	1.151	19.99	208.03	204.52	207	216	0.9230	514535	124243	1.14	16.89	20.89	0.531	71.9	70.9	
1800	80	15.1	1.50	5.39	22.7	2.8	250.9	30.3	1.0	150.0	30.0	3.8	74.1	565.1	15.0	101.02	30	65.5	4.24	0.0176	0.290	1.149	19.99	207.68	204.09	209	217	0.8996	513677	127520	1.02	25.52	39.82	0.614	71.6	70.6	
1800	80	15.1	1.50	4.36	37.5	5.2	159.0	30.3	2.5	150.0	30.0	7.7	74.9	683.4	12.4	101.02	30	65.5	4.24	0.0176	0.290	1.149	19.93	207.03	203.45	208	219	0.8622	515430	131501	1.08	35.59	66.29	0.749	71.1	70.1	
1800	80	15.1	1.50	3.79	45.7	7.1	21.8	30.4	7.2	150.0	30.0	14.3	74.9	787.5	10.8	101.02	30	65.5	4.24	0.0176	0.290	1.149	19.88	206.54	202.98	207	225	0.8317	522243	139197	0.99	38.12	81.65	0.868	71	70	
1800	60	11.3	1.13	6.23	0.0	0.0	303.1	30.9	0.0	0.0	30.0	0.0	0.0	551.3	15.4	101.02	30	65	4.24	0.0174	0.290	1.149	19.65	204.10	200.60	199	210	0.9425	389894	80643	1.74	7.26	0.00	0.453	70.8	69.8	
1800	60	11.3	1.13	5.58	10.6	1.9	279.3	30.7	0.6	150.0	30.0	2.5	74.3	679.1	12.5	101.02	30	65	4.24	0.0174	0.290	1.149	19.58	203.44	199.96	200	211	0.9131	388446	83717	1.37	20.81	28.97	0.564	70.2	69.2	
1800	60	11.3	1.13	4.65	25.5	3.6	251.3	30.7	1.2	150.0	30.0	4.8	75.1	770.7	11.0	101.02	30	65	4.24	0.0174	0.290	1.149	19.47	202.29	198.82	196	212	0.8880	387493	85019	1.41	32.03	55.15	0.647	69.9	69	
1800	60	11.3	1.13	3.47	44.3	5.9	159.6	30.6	2.8	150.0	30.0	8.7	74.9	899.1	9.4	101.02	30	65	4.24	0.0174	0.290	1.149	19.42	201.79	198.33	195	214	0.8542	387149	89044	1.33	43.16	93.38	0.760	69.5	68.9	
1800	60	11.3	1.13	3.13	49.8	7.1	21.7	30.7	7.2	150.0	30.0	14.3	75.0	993.9	8.5	101.02	30	65	4.24	0.0174	0.290	1.149	19.38	201.29	197.84	197	219	0.8330	391301	94239	1.21	46.37	112.65	0.843	69.3	68.3	
1800	40	7.5	0.75	5.55	0.0	0.0	303.7	31.3	0.0	0.0	30.0	0.0	0.0	736.6	11.5	101.02	30	65	4.24	0.0174	0.290	1.149	19.34	200.96	197.51	188	207	0.9480	263140	46867	2.33	10.59	0.00	0.410	69.1	68.1	
1800	40	7.5	0.75	4.52	18.7	1.8	280.6	31.0	0.6	150.0	30.0	2.5	74.2	876.6	9.7	101.02	30	64.5	4.24	0.0173	0.290	1.149	19.26	200.13	196.72	176	207	0.9218	262026	48408	2.08	28.61	44.05	0.494	68.5	67.6	
1800	40	7.5	0.75	3.87	30.3	3.6	251.3	30.9	1.2	150.0	30.0	4.8	75.0	1048.8	8.1	101.02	30	64	4.24	0.0172	0.290	1.149	19.18	199.30	195.93	174	208	0.8942	261382	49862	2.03	45.01	90.19	0.596	68.1	67.2	
1800	40	7.5	0.75	3.24	41.6	5.9	158.9	30.8	2.8	150.0	30.0	8.7	75.0	1321.6	6.4	101.02	30	64	4.24	0.0172	0.290	1.149	19.15	198.96	195.60	156	211	0.8539	259365	54863	1.68	58.72	140.89	0.755	67.8	67	
1800	40	7.5	0.75	2.53	54.5	7.1	22.1	28.9	7.3	150.0	32.0	14.4	74.4	1410.4	6.0	101.02	32	56	4.75	0.0168	0.290	1.142	19.21	198.32	195.04	172	215	0.8364	261768	58098	1.66	62.45	176.79	0.810	70.3	69.7	
1800	20	3.8	0.38	5.24	0.0	0.0	302.9	29.6	0.0	0.0	32.5	0.0	0.0	1391.2	6.1	101.02	32.5	56	4.89	0.0173	0.290	1.140	19.01	195.94	192.60	164	201	0.9496	130680	20933	4.41	18.18	0.00	0.397	68.9	68.2	
1800	20	3.8	0.38	4.22	19.5	1.3	280.4	29.5	0.4	150.0	33.0	1.7	76.2	1508.9	5.6	101.02	33	56	5.03	0.0178	0.290	1.138	19.02	195.58	192.15	158	201	0.9337	129959	21647	3.86	51.63	72.99	0.434	68.4	67.6	
1800	20	3.8	0.38	3.51	33.1	2.8	251.6	29.6	1.0	150.0	33.0	3.8	74.2	1769.5	4.8	101.02	33	56	5.03	0.0178	0.290	1.138	19.00	195.41	191.99	159	203	0.9109	129602	22619	3.64	81.61	169.96	0.513	68.2	67.4	
1800	20	3.8	0.38	2.48	52.6	5.3	160.2	29.9	2.5	150.0	33.5	7.8	75.1	2266.5	3.7	101.02	33.5	56	5.17	0.0183	0.290	1.135	18.97	194.71	191.20	163	205	0.8695	129439	24110	3.29	106.47	293.55	0.663	68.1	67.4	
1800	20	3.8	0.38	2.28	56.5	7.2	7.2	30.1	7.1	150.0	33.5	14.2	74.9	2761.5	3.1	101.02	33.5	56	5.17	0.0183	0.290	1.135	18.92	194.20	190.70	165	211	0.8347	131777	25736	3.06	112.38	365.02	0.812	67.8	67.1	











