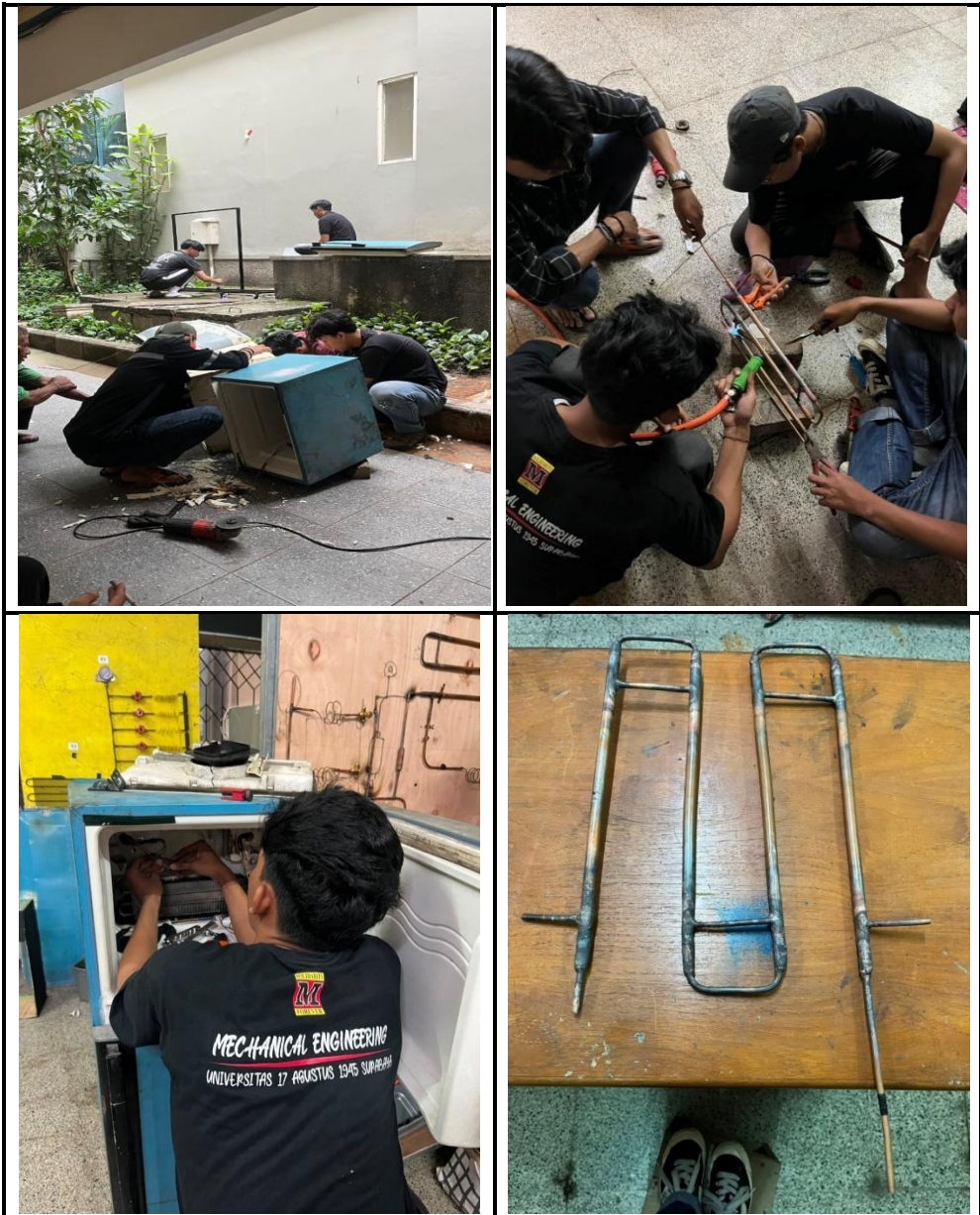
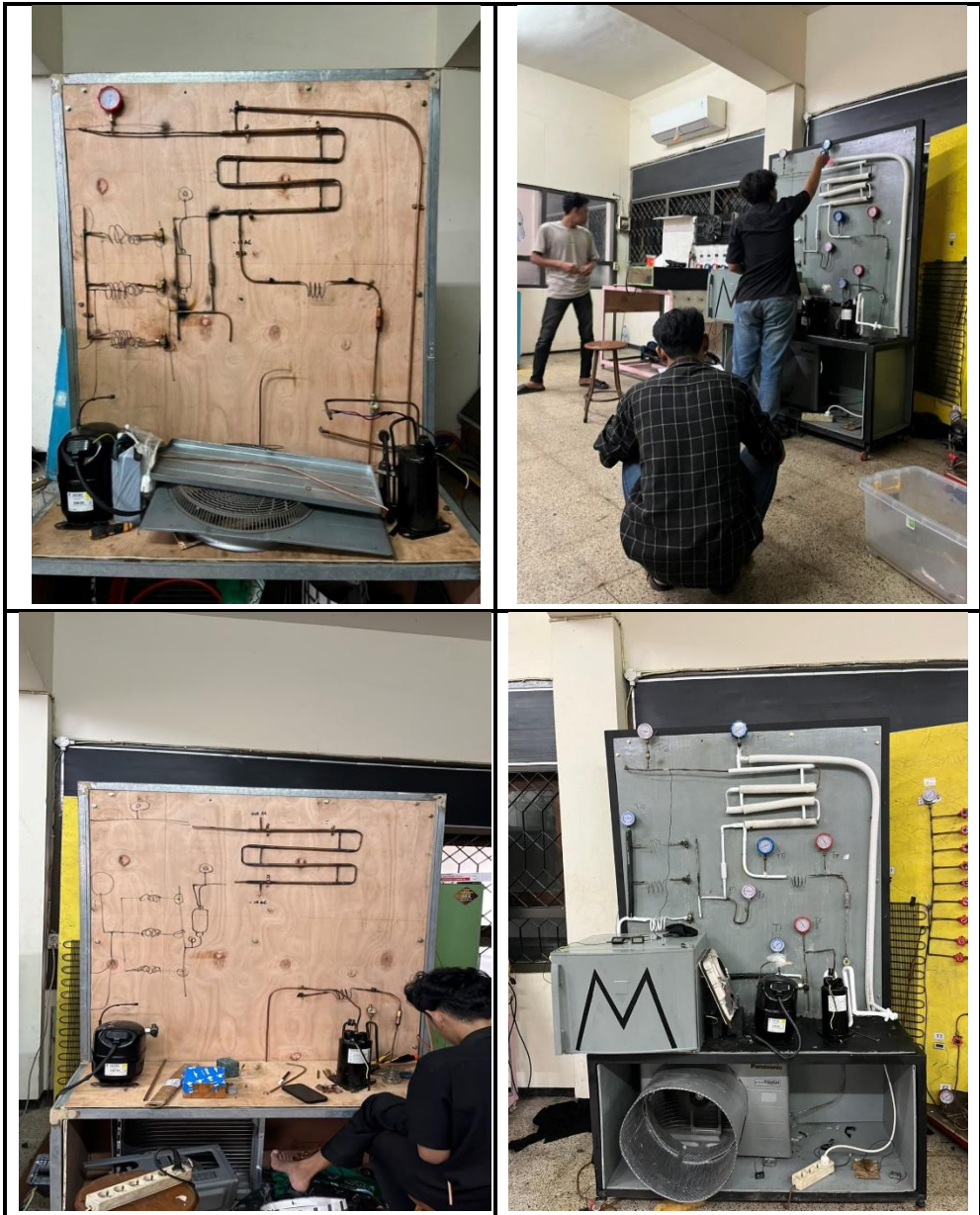
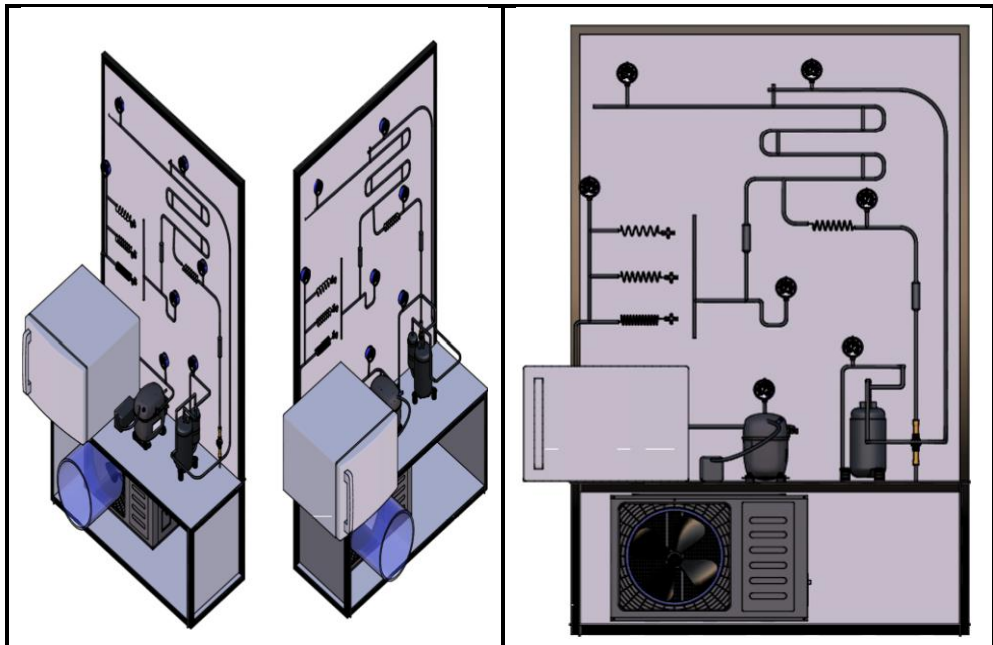


LAMPIRAN







Absolute pressure p [bar]	Bubble point t _b [°C]	Volume v _g [m ³ /kg]	LIQUID			Dew point t _d [°C]	Volume v _g [m ³ /kg]	VAPOUR			Latent heat h _{fg} [kJ/kg]
			Density ρ _f [kg/m ³]	Enthalpy h _f [kJ/kg]	Entropy s _f [kJ/kg·K]			Density ρ _g [kg/m ³]	Enthalpy h _g [kJ/kg]	Entropy s _g [kJ/kg·K]	
0.038	-100	0.747	1.339	36.826	0.271	-100.0	7.222	0.138	468.306	2.751	429.480
0.059	-95	0.754	1.327	46.624	0.315	-95.0	4.798	0.208	471.481	2.700	424.858
0.089	-90	0.761	1.314	54.418	0.359	-90.0	3.272	0.306	474.614	2.653	420.196
0.130	-85	0.769	1.301	62.214	0.401	-85.0	2.296	0.438	477.697	2.609	415.483
0.187	-80	0.776	1.288	70.016	0.442	-80.0	1.632	0.613	480.723	2.568	410.707
0.262	-75	0.784	1.275	77.828	0.481	-75.0	1.188	0.842	483.684	2.530	405.856
0.361	-70	0.792	1.262	85.656	0.520	-70.0	0.881	1.125	486.573	2.494	400.917
0.488	-65	0.801	1.249	93.504	0.558	-65.0	0.664	1.507	489.384	2.460	395.880
0.650	-60	0.809	1.236	101.376	0.596	-60.0	0.508	1.969	492.109	2.429	390.732
0.852	-55	0.818	1.222	109.279	0.632	-55.0	0.394	2.538	494.741	2.399	385.482
1.013	-51.66	0.824	1.213	114.564	0.656	-51.66	0.335	2.987	496.447	2.380	381.863
1.101	-50	0.828	1.208	117.218	0.668	-50.0	0.309	3.232	497.275	2.371	380.057
1.406	-45	0.837	1.194	125.198	0.704	-45.0	0.248	4.067	499.703	2.345	374.504
1.774	-40	0.847	1.180	133.226	0.738	-40.0	0.197	5.065	502.017	2.320	368.792
2.214	-35	0.858	1.166	141.307	0.772	-35.0	0.160	6.248	504.211	2.296	362.904
2.734	-30	0.869	1.151	149.448	0.806	-30.0	0.131	7.639	506.274	2.273	356.827
3.346	-25	0.880	1.136	157.656	0.839	-25.0	0.106	9.266	508.199	2.252	350.542
4.058	-20	0.892	1.121	165.940	0.872	-20.0	0.090	11.157	509.972	2.231	344.033
4.881	-15	0.905	1.105	174.306	0.904	-15.0	0.075	13.346	511.584	2.211	337.278
5.826	-10	0.918	1.089	182.765	0.937	-10.0	0.063	15.870	513.020	2.192	330.255
6.906	-5	0.933	1.072	191.326	0.968	-5.0	0.053	18.768	514.284	2.173	322.958
8.131	0	0.948	1.055	200.000	1.000	0.0	0.045	22.091	515.299	2.154	315.299
9.514	5	0.964	1.038	208.801	1.031	5.0	0.039	25.891	516.106	2.136	307.305
11.069	10	0.981	1.020	217.742	1.063	10.0	0.033	30.232	516.660	2.119	298.917
12.808	15	0.999	1.001	226.842	1.094	15.0	0.028	35.190	516.934	2.101	290.092
14.746	20	1.019	0.981	236.121	1.125	20.0	0.024	40.856	516.897	2.083	280.777
16.896	25	1.041	0.961	245.602	1.157	25.0	0.021	47.338	516.510	2.065	270.908
19.275	30	1.064	0.940	255.317	1.188	30.0	0.018	54.776	515.725	2.047	260.408
21.898	35	1.090	0.917	265.303	1.220	35.0	0.016	63.343	514.482	2.028	249.179
24.763	40	1.120	0.893	275.611	1.252	40.0	0.014	73.268	512.706	2.009	237.094
27.848	45	1.153	0.867	286.308	1.285	45.0	0.012	84.859	510.294	1.989	223.866
31.412	50	1.192	0.839	297.486	1.318	50.0	0.010	98.550	507.104	1.967	209.618
35.199	55	1.237	0.808	309.286	1.353	55.0	0.009	114.989	502.930	1.943	193.644
39.332	60	1.290	0.773	321.927	1.390	60.0	0.007	135.213	497.441	1.917	175.514
43.843	65	1.366	0.732	335.800	1.429	65.0	0.006	161.092	490.054	1.885	154.254
48.768	70	1.469	0.681	351.734	1.474	70.0	0.005	196.688	479.518	1.846	127.784
54.168	75	1.650	0.606	372.391	1.531	75.0	0.004	255.587	461.723	1.788	89.333

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Temp °C	Pressure kPa	Superheat (°C)																		Temp °C		
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90			
-100	0.038	468.306	471.821	475.341	478.860	482.408	485.982	489.532	493.121	496.779	500.398	504.012	507.688	511.398	515.118	518.874	522.658	526.471	530.314	534.180	538.068	542.015
-95	0.059	471.481	475.046	478.610	482.174	485.758	489.350	492.957	496.581	500.224	503.889	507.576	511.287	515.023	518.786	522.576	526.395	530.243	534.122	538.033	541.976	545.946
-90	0.080	474.614	478.235	481.849	485.465	489.082	492.721	496.368	500.032	503.713	507.419	511.150	514.887	518.660	522.466	526.287	530.142	534.028	537.944	541.891	545.875	549.886
-85	0.100	477.697	481.381	485.052	488.720	492.392	496.071	499.762	503.468	507.191	510.933	514.697	518.485	522.297	526.135	530.001	533.896	537.821	541.776	545.764	549.784	553.835
-80	0.127	480.723	484.478	488.212	491.938	495.663	499.390	503.132	506.884	510.652	514.438	518.245	522.075	525.929	529.809	533.716	537.652	541.618	545.614	549.643	553.704	557.797
-75	0.162	483.684	487.519	491.333	495.112	498.885	502.680	506.474	510.274	514.091	517.924	521.777	525.652	529.551	533.475	537.426	541.403	545.414	549.454	553.526	557.630	561.764
-70	0.201	486.573	490.495	494.376	498.234	502.082	505.927	509.776	513.632	517.502	521.386	525.289	529.212	533.158	537.129	541.126	545.152	549.206	553.291	557.408	561.557	565.734
-65	0.248	489.384	493.401	497.356	501.300	505.217	509.127	513.008	516.863	520.679	524.418	528.173	531.945	535.734	539.540	543.372	547.230	551.112	555.018	558.949	562.904	566.884
-60	0.302	492.198	496.290	500.286	504.302	508.234	512.175	516.121	520.030	523.916	527.773	531.605	535.415	539.205	542.974	546.771	550.592	554.436	558.303	562.194	566.109	570.049
-55	0.362	495.041	499.175	503.199	507.222	511.206	515.160	519.104	523.048	526.973	530.880	534.769	538.640	542.493	546.328	550.145	553.945	557.775	561.636	565.527	569.448	573.390
-50	1.01	497.275	501.628	505.867	510.086	514.246	518.365	522.507	526.626	530.745	534.871	538.998	543.129	547.257	551.315	555.726	559.961	564.222	568.512	572.831	577.181	581.564
-45	1.406	499.703	504.184	508.555	512.855	517.108	521.331	525.526	529.732	533.925	538.122	542.327	546.543	550.775	555.026	559.297	563.592	567.912	572.259	576.634	581.040	585.474
-40	1.774	502.017	506.634	511.124	515.552	519.884	524.200	528.491	532.769	537.041	541.312	545.589	549.875	554.114	558.491	562.826	567.183	571.565	575.972	580.408	584.870	589.364
-35	2.214	504.211	508.971	513.588	518.111	522.569	526.962	531.365	535.790	540.284	544.755	549.208	553.648	558.075	562.515	566.973	571.459	575.975	580.521	585.094	589.694	594.322
-30	2.734	506.274	511.187	515.939	520.583	525.153	529.670	534.151	538.608	543.050	547.485	551.918	556.358	560.801	565.259	569.733	574.225	578.738	583.273	587.834	592.421	597.034
-25	3.348	508.199	513.272	518.188	522.941	527.538	532.084	536.582	541.097	545.582	550.055	554.512	558.962	563.417	567.882	572.399	577.063	581.785	586.561	591.394	596.132	600.984
-20	4.058	509.972	515.218	520.265	525.177	529.982	534.732	539.431	544.089	548.722	553.339	557.947	562.552	567.160	571.775	576.400	581.040	585.697	590.373	595.071	599.793	604.544
-15	4.881	511.684	517.012	522.222	527.280	532.230	537.089	541.910	546.678	551.415	556.131	560.833	565.529	570.224	574.923	579.630	584.349	589.083	593.834	598.605	603.399	608.212
-10	5.826	513.200	518.644	524.029	529.243	534.336	539.338	544.272	549.146	554.003	558.823	563.625	568.418	573.203	577.991	582.783	587.585	592.399	597.229	602.076	606.944	611.834
-5	6.906	514.564	520.101	525.671	531.284	536.899	542.465	548.000	553.516	558.979	564.400	568.816	573.208	577.582	581.951	586.324	590.706	595.103	599.514	603.939	608.378	612.832
0	8.131	515.299	521.367	527.139	532.702	538.112	543.406	548.611	553.749	558.866	563.883	568.801	573.699	578.582	583.461	588.338	593.217	598.103	603.000	607.918	612.855	617.812
5	9.514	516.198	522.466	528.417	534.175	539.781	545.277	550.679	556.048	561.386	566.698	571.974	577.241	582.511	587.783	593.063	598.359	603.670	608.994	614.332	619.684	625.054
10	11.069	516.660	523.259	529.491	535.461	541.237	546.866	552.381	557.807	563.162	568.463	573.729	578.960	584.153	589.340	594.520	599.703	604.886	610.046	615.282	620.525	625.784
15	12.808	516.834	523.846	530.343	536.544	542.527	548.343	554.029	559.615	565.117	570.556	575.946	581.298	586.620	591.921	597.208	602.486	607.760	613.035	618.315	623.594	628.884
20	14.746	516.897	524.162	530.950	537.429	543.617	549.635	555.506	561.300	567.051	572.769	578.457	584.119	589.766	595.398	601.021	606.644	612.266	617.887	623.508	629.129	634.750
25	16.896	516.910	524.719	531.302	538.090	544.493	550.721	556.801	562.737	568.566	574.311	579.986	585.608	591.186	596.731	602.251	607.752	613.242	618.724	624.204	629.685	635.161
30	19.275	516.725	525.884	531.362	538.414	545.140	551.618	557.903	564.035	570.045	575.956	581.788	587.557	593.274	598.950	604.596	611.214	617.821	624.414	631.000	637.583	644.161
35	21.898	516.482	525.719	531.108	538.513	545.540	552.280	558.796	565.143	571.347	577.437	583.435	589.369	595.253	601.108	606.945	612.766	618.581	624.396	630.209	636.024	641.841
40	24.763	516.706	527.074	533.055	539.312	545.674	552.704	559.476	566.051	572.463	578.744	584.919	591.008	597.027	602.995	608.905	614.764	620.573	626.346	632.077	637.800	643.524
45	27.948	516.294	526.844	532.615	538.782	545.321	552.872	559.825	566.747	573.583	579.889	586.233	592.457	598.680	604.796	610.988	617.176	623.359	629.536	635.709	641.882	648.055
50	31.412	507.194	518.365	528.095	536.893	545.058	552.765	560.125	567.218	574.096	580.802	587.367	593.819	600.175	606.454	612.669	618.833	624.954	631.041	637.101	643.141	649.164
55	35.199	502.930	515.595	526.191	535.611	544.280	552.365	560.064	567.451	574.590	581.552	588.314	594.963	601.504	607.955	614.332	620.648	626.914	633.139	639.321	645.467	651.584
60	39.332	497.441	512.857	521.741	530.894	539.091	546.699	553.849	560.721	567.403	573.904	580.269	586.531	592.701	600.697	608.638	616.538	624.314	632.072	639.820	647.559	655.284
65	43.843	490.054	507.624	520.670	531.697	541.339	550.581	559.075	567.137	574.888	582.337	589.595	596.681	603.624	610.449	617.177	623.852	630.509	637.150	643.783	650.406	656.924
70	48.768	479.518	502.063	516.887	528.963	539.339	549.155	558.099	566.545	574.810	582.374	589.897	597.222	604.396	611.415	618.332	625.183	632.000	638.799	645.582	652.354	659.116
75	54.168	461.723	485.003	512.260	525.298	537.025	547.279	556.732	565.803	574.582	583.115	590.522	597.805	604.994	612.150	619.205	626.280	633.292	640.248	647.150	654.003	660.894

V = Volume in m³/kg		H = Enthalpy in kJ/kg		S = Entropy in kJ/(kg·K)		Saturation Properties in Light Blue									
		Absolute Pressure [kPa]													
Temp °C		850.0			900.0			950.0			1000.0			Temp °C	
		11.37 °C			13.34 °C			15.24 °C			17.06 °C				
		V	H	S	V	H	S	V	H	S	V	H	S		
15	0.0234	374.3	1.6134	0.0221	375.2	1.6128	0.0209	376.1	1.6122	0.0198	377.0	1.6116		15	
20	0.0240	377.7	1.6254	0.0223	378.6	1.6183								20	
25	0.0247	382.4	1.6417	0.0230	381.6	1.6348	0.0215	380.8	1.6281	0.0201	379.9	1.6215		25	
30	0.0254	387.2	1.6578	0.0237	386.4	1.6510	0.0222	385.6	1.6444	0.0208	384.8	1.6380		30	
35	0.0261	392.0	1.6736	0.0243	391.2	1.6670	0.0228	390.4	1.6605	0.0214	389.6	1.6543		35	
40	0.0267	396.8	1.6893	0.0250	396.0	1.6828	0.0234	395.3	1.6764	0.0220	394.5	1.6703		40	
45	0.0274	401.6	1.7048	0.0256	400.9	1.6984	0.0240	400.2	1.6921	0.0226	399.5	1.6861		45	
50	0.0280	406.4	1.7201	0.0263	405.7	1.7138	0.0246	405.1	1.7027	0.0232	404.5	1.7017		50	
55	0.0287	411.3	1.7353	0.0269	410.6	1.7290	0.0252	410.0	1.7230	0.0238	409.3	1.71			

V = Volume in m ³ /kg H = Enthalpy in kJ/kg S = Entropy in kJ/(kg·K) Saturation Properties in Light Blue												
Temp [°C]	Absolute Pressure [kPa]											
	1100.0			1200.0			1300.0			1400.0		
	20.50 °C			23.71 °C			26.73 °C			29.59 °C		
	V	H	S	V	H	S	V	H	S	V	H	S
	0.0178	378.5	1.6105	0.0162	379.9	1.6093	0.0148	381.0	1.6080	0.0136	382.1	1.6067
25	0.0184	383.0	1.6257	0.0164	381.2	1.6137						25
30	0.0190	388.0	1.6422	0.0170	386.3	1.6306	0.0152	384.5	1.6193	0.0137	382.5	1.6082
35	0.0196	393.0	1.6585	0.0175	391.4	1.6473	0.0158	389.7	1.6364	0.0142	387.9	1.6257
40	0.0201	398.0	1.6746	0.0181	396.4	1.6636	0.0163	394.8	1.6530	0.0148	393.2	1.6427
45	0.0207	403.0	1.6904	0.0186	401.5	1.6797	0.0168	400.0	1.6694	0.0153	398.4	1.6594
50	0.0212	408.0	1.7061	0.0191	406.6	1.6955	0.0173	405.2	1.6855	0.0157	403.7	1.6757
55	0.0218	413.0	1.7215	0.0196	411.7	1.7112	0.0178	410.3	1.7013	0.0162	408.9	1.6918
60	0.0223	418.1	1.7367	0.0201	416.8	1.7266	0.0183	415.5	1.7169	0.0167	414.1	1.7076
65	0.0228	423.1	1.7518	0.0206	421.9	1.7418	0.0187	420.7	1.7323	0.0171	419.4	1.7232
70	0.0233	428.2	1.7668	0.0211	427.0	1.7569	0.0192	425.8	1.7476	0.0176	424.6	1.7386
75	0.0238	433.3	1.7816	0.0216	432.2	1.7718	0.0196	431.1	1.7626	0.0180	429.9	1.7539
80	0.0243	438.5	1.7962	0.0220	437.4	1.7866	0.0201	436.3	1.7775	0.0184	435.2	1.7689
85	0.0248	443.6	1.8108	0.0225	442.6	1.8012	0.0205	441.5	1.7923	0.0188	440.4	1.7838
90	0.0253	448.8	1.8252	0.0230	447.8	1.8157	0.0210	446.8	1.8069	0.0193	445.7	1.7985
95	0.0258	454.1	1.8395	0.0234	453.1	1.8301	0.0214	452.1	1.8214	0.0197	451.1	1.8130
100	0.0263	459.3	1.8536	0.0239	458.4	1.8444	0.0218	457.4	1.8357	0.0201	456.4	1.8275
105	0.0268	464.6	1.8677	0.0243	463.7	1.8585	0.0222	462.7	1.8499	0.0205	461.8	1.8418
110	0.0272	469.9	1.8816	0.0248	469.0	1.8725	0.0227	468.1	1.8640	0.0209	467.2	1.8560
115	0.0277	475.2	1.8955	0.0252	474.4	1.8865	0.0231	473.5	1.8780	0.0212	472.6	1.8700
120	0.0282	480.6	1.9092	0.0256	479.8	1.9003	0.0235	478.9	1.8919	0.0216	478.1	1.8840
125	0.0286	486.0	1.9229	0.0261	485.2	1.9140	0.0239	484.4	1.9057	0.0220	483.5	1.8978
130	0.0291	491.4	1.9364	0.0265	490.6	1.9276	0.0243	489.9	1.9193	0.0224	489.0	1.9116
135	0.0295	496.9	1.9499	0.0269	496.1	1.9411	0.0247	495.4	1.9329	0.0228	494.6	1.9252
140	0.0300	502.4	1.9633	0.0273	501.6	1.9545	0.0251	500.9	1.9464	0.0231	500.1	1.9387
145	0.0305	507.9	1.9766	0.0278	507.2	1.9679	0.0255	506.5	1.9598	0.0235	505.7	1.9522
150	0.0309	513.5	1.9898	0.0282	512.8	1.9811	0.0259	512.0	1.9731	0.0239	511.3	1.9655
155	0.0313	519.1	2.0029	0.0286	518.4	1.9943	0.0262	517.7	1.9863	0.0242	517.0	1.9788
160	0.0318	524.7	2.0159	0.0290	524.0	2.0074	0.0266	523.3	1.9994	0.0246	522.6	1.9919
165	0.0322	530.3	2.0289	0.0294	529.7	2.0204	0.0270	529.0	2.0124	0.0250	528.3	2.0050
170	0.0327	536.0	2.0418	0.0298	535.3	2.0333	0.0274	534.7	2.0254	0.0253	534.1	2.0180
175	0.0331	541.7	2.0546	0.0302	541.1	2.0461	0.0278	540.4	2.0382	0.0257	539.8	2.0309
180							0.0282	546.2	2.0510	0.0260	545.6	2.0437

Table 1. Freon™ 404A Saturation Properties—Temperature Table

Temp [°C]	Pressure [kPa]		Volume [m³/kg]		Density [kg/m³]		Enthalpy [kJ/kg]			Entropy [kJ/(kg·K)]		Temp [°C]
	Liquid v_f	Vapor v_g	Liquid v_f	Vapor v_g	Liquid ρ_f	Vapor ρ_g	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	
-100	3.0	2.7	0.0007	5.3706	1436.6	0.186	75.6	229.6	305.2	0.4409	1.7728	-100
-99	3.3	3.0	0.0007	4.9310	1435.2	0.203	76.7	229.2	305.8	0.4472	1.7685	-99
-98	3.6	3.3	0.0007	4.5310	1433.7	0.221	77.8	228.7	306.5	0.4534	1.7644	-98
-97	3.9	3.6	0.0007	4.1701	1432.1	0.240	78.9	228.2	307.1	0.4596	1.7604	-97
-96	4.3	3.9	0.0007	3.8432	1430.4	0.260	80.0	227.7	307.7	0.4658	1.7565	-96
-95	4.6	4.3	0.0007	3.5448	1428.6	0.282	81.1	227.3	308.3	0.4719	1.7527	-95
-94	5.1	4.6	0.0007	3.2733	1427.0	0.306	82.1	226.8	308.9	0.4781	1.7489	-94
-93	5.5	5.1	0.0007	3.0257	1425.2	0.331	83.2	226.3	309.6	0.4842	1.7452	-93
-92	5.9	5.5	0.0007	2.7996	1423.3	0.357	84.4	225.8	310.2	0.4903	1.7417	-92
-91	6.4	6.0	0.0007	2.5934	1421.4	0.386	85.5	225.4	310.8	0.4963	1.7382	-91
-90	7.0	6.5	0.0007	2.4044	1419.5	0.416	86.6	224.9	311.4	0.5024	1.7347	-90
-89	7.5	7.0	0.0007	2.2301	1417.5	0.448	87.7	224.4	312.1	0.5084	1.7314	-89
-88	8.1	7.6	0.0007	2.0738	1415.4	0.482	88.8	223.9	312.7	0.5145	1.7281	-88
-87	8.6	8.2	0.0007	1.9286	1413.3	0.518	89.9	223.4	313.3	0.5205	1.7250	-87
-86	9.5	8.8	0.0007	1.7953	1411.2	0.557	91.0	222.9	314.0	0.5264	1.7219	-86
-85	10.2	9.5	0.0007	1.6728	1409.0	0.598	92.1	222.5	314.6	0.5324	1.7188	-85
-84	11.0	10.3	0.0007	1.5598	1406.8	0.641	93.3	222.0	315.2	0.5383	1.7159	-84
-83	11.8	11.1	0.0007	1.4560	1404.5	0.687	94.4	221.5	315.9	0.5443	1.7130	-83
-82	12.7	11.9	0.0007	1.3602	1402.2	0.735	95.5	221.0	316.5	0.5502	1.7101	-82
-81	13.6	12.8	0.0007	1.2718	1399.8	0.786	96.6	220.5	317.1	0.5561	1.7074	-81
-80	14.6	13.7	0.0007	1.1902	1397.4	0.840	97.8	220.0	317.8	0.5620	1.7047	-80
-79	15.7	14.7	0.0007	1.1147	1395.0	0.897	98.9	219.5	318.4	0.5678	1.7021	-79
-78	16.8	15.8	0.0007	1.0448	1392.6	0.957	100.0	219.0	319.1	0.5737	1.6995	-78
-77	17.9	16.9	0.0007	0.9801	1390.1	1.020	101.2	218.5	319.7	0.5795	1.6970	-77
-76	19.2	18.1	0.0007	0.9201	1387.6	1.087	102.3	218.0	320.4	0.5853	1.6945	-76
-75	20.5	19.3	0.0007	0.8645	1385.0	1.157	103.5	217.5	321.0	0.5911	1.6922	-75
-74	21.9	20.7	0.0007	0.8128	1382.4	1.230	104.6	217.0	321.6	0.5969	1.6898	-74
-73	23.3	22.1	0.0007	0.7648	1379.8	1.308	105.8	216.5	322.3	0.6027	1.6876	-73
-72	24.8	23.5	0.0007	0.7201	1377.2	1.389	106.9	216.0	322.9	0.6084	1.6854	-72
-71	26.5	25.1	0.0007	0.6785	1374.5	1.474	108.1	215.5	323.6	0.6142	1.6832	-71
-70	28.2	26.7	0.0007	0.6398	1371.9	1.563	109.3	215.0	324.2	0.6199	1.6811	-70
-69	29.9	28.4	0.0007	0.6036	1369.1	1.657	110.4	214.5	324.9	0.6256	1.6790	-69
-68	31.8	30.2	0.0007	0.5700	1366.4	1.755	111.6	214.0	325.5	0.6313	1.6770	-68
-67	33.8	32.1	0.0007	0.5385	1363.6	1.857	112.8	213.4	326.2	0.6370	1.6751	-67
-66	35.8	34.1	0.0007	0.5091	1360.9	1.964	113.9	212.9	326.8	0.6427	1.6732	-66
-65	38.0	36.2	0.0007	0.4816	1358.1	2.076	115.1	212.4	327.5	0.6483	1.6713	-65
-64	40.3	38.4	0.0007	0.4559	1355.2	2.193	116.3	211.9	328.2	0.6540	1.6695	-64
-63	42.7	40.7	0.0007	0.4319	1352.4	2.316	117.5	211.3	328.8	0.6596	1.6678	-63
-62	45.2	43.1	0.0007	0.4093	1349.6	2.443	118.7	210.8	329.5	0.6652	1.6661	-62
-61	47.8	45.7	0.0007	0.3881	1346.7	2.577	119.8	210.3	330.1	0.6708	1.6644	-61
-60	50.5	48.3	0.0007	0.3683	1343.8	2.715	121.0	209.7	330.8	0.6764	1.6628	-60
-59	53.3	51.1	0.0007	0.3497	1340.9	2.860	122.2	209.2	331.4	0.6820	1.6612	-59
-58	56.3	54.0	0.0007	0.3321	1337.9	3.011	123.4	208.6	332.1	0.6876	1.6596	-58
-57	59.4	57.0	0.0007	0.3157	1335.0	3.168	124.6	208.1	332.7	0.6931	1.6581	-57
-56	62.7	60.2	0.0008	0.3002	1332.1	3.331	125.8	207.5	333.4	0.6987	1.6567	-56
-55	66.1	63.4	0.0008	0.2856	1329.1	3.501	127.1	207.0	334.0	0.7042	1.6552	-55
-54	69.6	66.9	0.0008	0.2719	1326.1	3.678	128.3	206.4	334.7	0.7098	1.6539	-54
-53	73.3	70.5	0.0008	0.2590	1323.1	3.861	129.5	205.9	335.3	0.7153	1.6525	-53
-52	77.1	74.2	0.0008	0.2468	1320.1	4.052	130.7	205.3	336.0	0.7208	1.6512	-52
-51	81.1	78.1	0.0008	0.2353	1317.1	4.250	131.9	204.7	336.7	0.7263	1.6499	-51
-50	85.2	82.1	0.0008	0.2244	1314.1	4.456	133.1	204.2	337.3	0.7318	1.6487	-50
-49	89.5	86.4	0.0008	0.2142	1311.0	4.670	134.4	203.6	338.0	0.7373	1.6475	-49
-48	94.0	90.7	0.0008	0.2045	1308.0	4.891	135.6	203.0	338.6	0.7427	1.6463	-48
-47	98.7	95.3	0.0008	0.1953	1304.9	5.121	136.8	202.4	339.3	0.7482	1.6451	-47
-46	103.5	100.0	0.0008	0.1866	1301.8	5.359	138.1	201.8	339.9	0.7537	1.6440	-46
-45	108.6	104.9	0.0008	0.1784	1298.8	5.605	139.3	201.2	340.6	0.7591	1.6430	-45
-44	113.8	110.1	0.0008	0.1706	1295.7	5.861	140.6	200.6	341.2	0.7645	1.6419	-44
-43	119.2	115.4	0.0008	0.1633	1292.6	6.125	141.8	200.0	341.9	0.7700	1.6408	-43
-42	124.8	120.9	0.0008	0.1563	1289.5	6.399	143.1	199.4	342.5	0.7754	1.6399	-42
-41	130.6	126.6	0.0008	0.1496	1286.4	6.682	144.3	198.8	343.2	0.7808	1.6389	-41

Table 1. Freon™ 404A Saturation Properties—Temperature Table (continued)

Temp [°C]	Pressure [kPa]		Volume [m³/kg]		Density [kg/m³]		Enthalpy [kJ/kg]			Entropy [kJ/(kg·K)]		Temp [°C]
	Liquid p_f	Vapor p_g	Liquid v_f	Vapor v_g	Liquid ρ_f	Vapor ρ_g	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	
-40	136.7	132.5	0.0008	0.1434	1283.2	6.975	145.8	198.2	343.8	0.7862	1.6380	-40
-39	142.9	138.6	0.0008	0.1374	1280.1	7.278	146.9	197.6	344.5	0.7908	1.6371	-39
-38	149.4	144.9	0.0008	0.1317	1277.0	7.592	148.1	197.0	345.1	0.7950	1.6362	-38
-37	156.1	151.5	0.0008	0.1263	1273.8	7.916	149.4	196.3	345.8	0.8004	1.6353	-37
-36	163.0	158.3	0.0008	0.1212	1270.7	8.250	150.7	195.7	346.4	0.8077	1.6345	-36
-35	170.1	165.3	0.0008	0.1163	1267.5	8.595	152.4	194.8	347.0	0.8150	1.6337	-35
-34	177.5	172.6	0.0008	0.1117	1264.4	8.951	153.7	194.0	347.7	0.8203	1.6330	-34
-33	185.2	180.1	0.0008	0.1073	1261.2	9.319	155.0	193.4	348.3	0.8256	1.6322	-33
-32	193.0	187.8	0.0008	0.1031	1258.0	9.698	156.3	192.7	349.0	0.8309	1.6315	-32
-31	201.2	195.8	0.0008	0.0991	1254.9	10.090	157.5	192.1	349.6	0.8362	1.6308	-31
-30	209.5	204.1	0.0008	0.0953	1251.7	10.492	158.9	191.3	350.3	0.8410	1.6301	-30
-29	218.2	212.5	0.0008	0.0917	1248.5	10.906	161.2	189.7	350.9	0.8512	1.6295	-29
-28	227.0	221.3	0.0008	0.0882	1245.3	11.332	162.5	189.1	351.5	0.8563	1.6289	-28
-27	236.2	230.3	0.0008	0.0849	1242.2	11.772	163.7	188.4	352.2	0.8615	1.6283	-27
-26	245.7	239.7	0.0008	0.0818	1239.0	12.225	165.0	187.8	352.8	0.8667	1.6277	-26
-25	255.4	249.3	0.0008	0.0788	1235.8	12.692	166.3	187.1	353.4	0.8718	1.6271	-25
-24	265.4	259.2	0.0008	0.0759	1232.5	13.174	167.6	186.5	354.0	0.8769	1.6265	-24
-23	275.8	269.4	0.0008	0.0732	1229.3	13.669	168.9	185.8	354.7	0.8821	1.6260	-23
-22	286.4	279.9	0.0008	0.0705	1226.1	14.180	170.2	185.1	355.3	0.8872	1.6255	-22
-21	297.4	290.7	0.0008	0.0680	1222.8	14.705	171.5	184.4	355.9	0.8924	1.6250	-21
-20	308.7	301.8	0.0008	0.0656	1219.6	15.246	172.8	183.8	356.5	0.8975	1.6245	-20
-19	320.3	313.3	0.0008	0.0633	1216.3	15.803	174.1	183.1	357.1	0.9026	1.6240	-19
-18	332.2	325.1	0.0008	0.0611	1213.1	16.376	175.4	182.4	357.8	0.9078	1.6235	-18
-17	344.5	337.2	0.0008	0.0589	1209.8	16.966	176.7	181.7	358.4	0.9129	1.6231	-17
-16	357.1	349.7	0.0008	0.0569	1206.5	17.572	178.0	180.9	359.0	0.9180	1.6226	-16
-15	370.1	362.5	0.0008	0.0550	1203.2	18.196	179.4	180.2	359.6	0.9231	1.6222	-15
-14	383.4	375.7	0.0008	0.0531	1199.8	18.838	180.7	179.5	360.2	0.9282	1.6218	-14
-13	397.1	389.2	0.0008	0.0513	1196.5	19.498	182.1	178.7	360.8	0.9334	1.6214	-13
-12	411.1	403.1	0.0008	0.0496	1193.2	20.177	183.4	178.0	361.4	0.9385	1.6210	-12
-11	425.6	417.4	0.0008	0.0479	1189.8	20.875	184.7	177.2	362.0	0.9436	1.6206	-11
-10	440.4	432.1	0.0008	0.0463	1186.4	21.593	186.1	176.5	362.6	0.9487	1.6202	-10
-9	455.6	447.2	0.0008	0.0448	1183.0	22.331	187.5	175.7	363.2	0.9538	1.6198	-9
-8	471.2	462.6	0.0008	0.0433	1179.6	23.089	188.8	174.9	363.8	0.9589	1.6195	-8
-7	487.2	478.5	0.0008	0.0419	1176.1	23.868	190.2	174.1	364.3	0.9641	1.6191	-7
-6	503.6	494.7	0.0008	0.0405	1172.7	24.669	191.6	173.3	364.9	0.9692	1.6188	-6
-5	520.5	511.4	0.0008	0.0392	1169.2	25.492	193.0	172.5	365.5	0.9743	1.6184	-5
-4	537.7	528.5	0.0008	0.0380	1165.7	26.338	194.4	171.7	366.1	0.9794	1.6181	-4
-3	555.4	546.1	0.0008	0.0368	1162.2	27.207	195.8	170.9	366.6	0.9846	1.6178	-3
-2	573.5	564.1	0.0008	0.0356	1158.6	28.100	197.2	170.0	367.2	0.9897	1.6175	-2
-1	592.1	582.5	0.0008	0.0345	1155.1	29.018	198.6	169.2	367.7	0.9948	1.6171	-1
0	611.1	601.3	0.0008	0.0334	1151.5	29.960	200.0	168.3	368.3	1.0000	1.6168	0
1	630.6	620.7	0.0008	0.0323	1147.8	30.928	201.4	167.4	368.9	1.0051	1.6165	1
2	650.6	640.5	0.0008	0.0313	1144.2	31.923	202.9	166.5	369.4	1.0102	1.6162	2
3	671.0	660.7	0.0008	0.0304	1140.5	32.944	204.3	165.7	369.9	1.0154	1.6159	3
4	691.9	681.5	0.0008	0.0294	1136.8	33.994	205.7	164.7	370.5	1.0205	1.6156	4
5	713.3	702.7	0.0008	0.0285	1133.0	35.072	207.2	163.8	371.0	1.0257	1.6153	5
6	735.1	724.5	0.0008	0.0276	1129.2	36.179	208.6	162.9	371.5	1.0308	1.6150	6
7	757.5	746.7	0.0008	0.0268	1125.4	37.316	210.1	162.0	372.1	1.0360	1.6147	7
8	780.4	769.5	0.0008	0.0260	1121.6	38.485	211.6	161.0	372.6	1.0412	1.6144	8
9	803.8	792.7	0.0008	0.0252	1117.7	39.685	213.1	160.0	373.1	1.0464	1.6141	9
10	827.8	816.5	0.0008	0.0244	1113.7	40.917	214.5	159.1	373.6	1.0515	1.6138	10
11	852.2	840.8	0.0008	0.0237	1109.8	42.184	216.0	158.1	374.1	1.0567	1.6135	11
12	877.2	865.7	0.0008	0.0230	1105.7	43.485	217.5	157.0	374.6	1.0619	1.6132	12
13	902.8	891.1	0.0008	0.0223	1101.7	44.821	219.1	156.0	375.1	1.0671	1.6129	13
14	928.9	917.1	0.0008	0.0216	1097.5	46.194	220.6	155.0	375.6	1.0723	1.6126	14
15	955.6	943.8	0.0008	0.0210	1093.4	47.605	222.1	153.9	376.0	1.0776	1.6123	15
16	982.9	970.7	0.0008	0.0204	1089.1	49.055	223.6	152.9	376.5	1.0828	1.6120	16
17	1010.6	998.4	0.0008	0.0198	1084.9	50.545	225.2	151.8	377.0	1.0880	1.6116	17
18	1039.0	1026.7	0.0008	0.0192	1080.5	52.076	226.7	150.7	377.4	1.0933	1.6113	18
19	1068.1	1055.6	0.0008	0.0186	1076.1	53.650	228.3	149.6	377.9	1.0985	1.6110	19

Table 1. Freon™ 404A Saturation Properties—Temperature Table (continued)

Temp [°C]	Pressure [kPa]		Volume [m³/kg]		Density [kg/m³]		Enthalpy [kJ/kg]			Entropy [kJ/(kg·K)]		Temp [°C]
	Liquid p	Vapor p	Liquid v	Vapor v	Liquid 1/v	Vapor 1/v	Liquid H	Latent H	Vapor H	Liquid S	Vapor S	
20	1097.7	1085.1	0.0009	0.0181	1071.7	55.267	229.9	148.4	378.3	1.1038	1.6106	20
21	1127.9	1115.2	0.0009	0.0176	1067.2	56.930	231.5	147.3	378.7	1.1091	1.6103	21
22	1158.7	1145.9	0.0009	0.0171	1062.6	58.640	233.0	146.1	379.2	1.1144	1.6099	22
23	1190.2	1177.2	0.0009	0.0166	1057.9	60.398	234.6	144.9	379.6	1.1197	1.6095	23
24	1222.3	1209.2	0.0009	0.0161	1053.2	62.206	236.3	143.7	380.0	1.1250	1.6091	24
25	1255.0	1241.8	0.0010	0.0156	1048.4	64.066	237.9	142.5	380.4	1.1304	1.6087	25
26	1288.4	1275.1	0.0010	0.0152	1043.5	65.980	239.5	141.3	380.8	1.1357	1.6083	26
27	1322.5	1309.1	0.0010	0.0147	1038.5	67.949	241.2	140.0	381.1	1.1411	1.6079	27
28	1357.2	1343.7	0.0010	0.0143	1033.5	69.975	242.8	138.7	381.5	1.1465	1.6075	28
29	1392.6	1379.0	0.0010	0.0139	1028.3	72.062	244.5	137.4	381.9	1.1519	1.6070	29
30	1428.7	1415.0	0.0010	0.0135	1023.1	74.210	246.2	136.1	382.2	1.1574	1.6065	30
31	1465.4	1451.7	0.0010	0.0131	1017.8	76.422	247.9	134.7	382.6	1.1628	1.6060	31
32	1502.9	1489.1	0.0010	0.0127	1012.3	78.702	249.6	133.3	382.9	1.1683	1.6055	32
33	1541.1	1527.2	0.0010	0.0123	1006.8	81.050	251.3	131.9	383.2	1.1738	1.6050	33
34	1580.0	1566.0	0.0010	0.0120	1001.1	83.472	253.0	130.5	383.5	1.1793	1.6044	34
35	1619.7	1605.6	0.0010	0.0116	995.4	85.968	254.8	129.0	383.8	1.1848	1.6038	35
36	1660.1	1645.9	0.0010	0.0113	989.5	88.543	256.5	127.5	384.1	1.1904	1.6032	36
37	1701.2	1687.0	0.0010	0.0110	983.5	91.201	258.3	126.0	384.3	1.1960	1.6026	37
38	1743.1	1728.8	0.0010	0.0106	977.4	93.944	260.1	124.5	384.6	1.2016	1.6019	38
39	1785.8	1771.4	0.0010	0.0103	971.1	96.777	261.9	122.9	384.8	1.2073	1.6012	39
40	1829.2	1814.8	0.0010	0.0100	964.7	99.704	263.8	121.3	385.0	1.2130	1.6005	40
41	1873.4	1859.0	0.0010	0.0097	958.2	102.730	265.6	119.6	385.2	1.2187	1.5998	41
42	1918.4	1904.0	0.0011	0.0094	951.5	105.860	267.5	117.9	385.4	1.2245	1.5990	42
43	1964.2	1949.8	0.0011	0.0092	944.6	109.098	269.4	116.2	385.6	1.2303	1.5981	43
44	2010.8	1996.4	0.0011	0.0089	937.6	112.452	271.3	114.4	385.7	1.2362	1.5973	44
45	2058.3	2043.9	0.0011	0.0086	930.4	115.926	273.2	112.6	385.8	1.2421	1.5964	45
46	2106.6	2092.2	0.0011	0.0084	923.0	119.529	275.1	110.8	385.9	1.2480	1.5954	46
47	2155.7	2141.3	0.0011	0.0081	915.5	123.267	277.1	108.9	386.0	1.2540	1.5944	47
48	2205.6	2191.3	0.0011	0.0079	907.7	127.150	279.1	107.0	386.1	1.2600	1.5933	48
49	2256.5	2242.2	0.0011	0.0076	899.7	131.185	281.1	105.0	386.1	1.2662	1.5922	49
50	2308.2	2294.0	0.0011	0.0074	891.5	135.384	283.2	102.9	386.1	1.2723	1.5910	50
51	2360.7	2346.6	0.0011	0.0072	883.0	139.757	285.3	100.8	386.1	1.2786	1.5897	51
52	2414.2	2400.2	0.0011	0.0069	874.3	144.317	287.4	98.6	386.0	1.2849	1.5884	52
53	2468.6	2454.6	0.0012	0.0067	865.3	149.078	289.6	96.4	385.9	1.2913	1.5870	53
54	2523.8	2510.0	0.0012	0.0065	856.0	154.056	291.7	94.1	385.8	1.2977	1.5855	54
55	2580.0	2566.4	0.0012	0.0063	846.4	159.270	294.0	91.7	385.7	1.3043	1.5839	55
56	2637.1	2623.7	0.0012	0.0061	836.5	164.738	296.2	89.2	385.5	1.3110	1.5822	56
57	2695.2	2681.9	0.0012	0.0059	826.2	170.496	298.5	86.7	385.2	1.3178	1.5804	57
58	2754.2	2741.1	0.0012	0.0057	815.6	176.541	300.9	84.0	384.9	1.3247	1.5785	58
59	2814.2	2801.4	0.0012	0.0055	804.5	182.935	303.3	81.2	384.6	1.3317	1.5764	59
60	2875.1	2862.6	0.0013	0.0053	792.9	189.706	305.8	78.3	384.2	1.3389	1.5742	60
61	2937.0	2924.8	0.0013	0.0051	780.9	196.901	308.4	75.3	383.7	1.3463	1.5718	61
62	2999.9	2988.0	0.0013	0.0049	768.3	204.575	311.0	72.1	383.1	1.3539	1.5692	62
63	3063.8	3052.3	0.0013	0.0047	755.0	212.799	313.7	68.8	382.5	1.3617	1.5664	63
64	3128.7	3117.6	0.0013	0.0045	741.0	221.659	316.5	65.2	381.8	1.3697	1.5633	64
65	3194.6	3184.0	0.0014	0.0043	726.2	231.271	319.5	61.5	380.9	1.3781	1.5599	65

Temp. $T, ^\circ\text{C}$	Density $\rho, \text{kg/m}^3$	Specific Heat $C_p, \text{J/kg}\cdot\text{K}$	Thermal Conductivity $k, \text{W/m}\cdot\text{K}$	Thermal Diffusivity $\alpha, \text{m}^2/\text{s}$	Dynamic Viscosity $\mu, \text{kg/m}\cdot\text{s}$	Kinematic Viscosity $\nu, \text{m}^2/\text{s}$	Prandtl Number Pr
-150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
-100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
-50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
-40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
-30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
-20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
-10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041

Handwritten notes and diagrams:

Diagram 1: A schematic of a counter-flow heat exchanger. It shows two horizontal tubes. The top tube is labeled "Con In" at the left and "Con Out" at the right. The bottom tube is labeled "Evap In" at the right and "Evap Out" at the left. Arrows indicate the flow direction: from left to right in the top tube and from right to left in the bottom tube. A temperature difference ΔT_1 is indicated at the left end, and ΔT_2 is indicated at the right end.

Diagram 2: A cross-sectional view of a tube. It shows an inner tube with diameter d_i and an outer tube with diameter d_o . The annular space between them is labeled ΔT .

Equations:

$$A_r = T_{\text{hot in}} - T_{\text{hot out}}$$

$$\Delta T = T_{\text{hot in}} - T_{\text{cold in}}$$

- Diketahui:
- * Fluida Panas Refrigeran R-404
 - Suhu masuk $T_{h,in} = 59,5^\circ\text{C}$ (Super heated)
 - Suhu keluar $T_{h,out} = 36^\circ\text{C}$ (cair jenuh)
 - * Fluida Dingin Refrigeran R-32
 - Suhu masuk $T_{c,in} = 10,3^\circ\text{C}$ (campuran)
 - Suhu keluar $T_{c,out} = 13,3^\circ\text{C}$ (Uap Panas)
 - ~~kecepatan massa~~ $\dot{m} = 132,651 \text{ kg/s}$ (effec refrigerasi) $\rightarrow Q = \dot{m} \times R_p = 0,028 \text{ kg/s} \times 132 = 3,71 \text{ kW} = 3710 \text{ W}$
 - Laju aliran massa $\dot{m} = 0,028 \text{ kg/s}$
 - * Properti termo Refrigeran R-404 (Panas)
 - Suhu rata-rata = $(59,5 + 36) / 2 = 47,75^\circ\text{C}$ (Suhu Jenuh) 48°C (tabel)
 - $\rho_f = 907,7 \text{ kg/m}^3$
 - $\rho_g = 127,150 \text{ kg/m}^3$
 - $h_f = 279,1 \text{ kJ/kg}$
 - $h_g = 386,1 \text{ kJ/kg}$
 - $h_{fg} = 107,0 \text{ kJ/kg}$
 - $\mu_f = 0,000106 \text{ kg/m.s}$
 - $k_f = 0,0718 \text{ W/m.K}$
 - $C_{p,f} = 1,60 \text{ kJ/kg.K}$
 - * Properti termo Refrigeran R-32 (Dingin)
 - Suhu rata-rata = $(10,3 + 13,3) / 2 = 12^\circ\text{C}$ (suhu uap jenuh)
 - $\rho_f = 1012 \text{ kg/m}^3$
 - $\rho_g = 58 \text{ kg/m}^3$
 - $C_{p,f} = 1638 \text{ kJ/kg.K}$
 - $\mu_f = 0,000136 \text{ kg/m.s}$
 - $k_f = 0,113 \text{ W/m.K}$
 - * Pipa dalam (R404) : $1/4 \text{ inch} = 0,635 \text{ cm} = 0,00635 \text{ m}$ (D_i)
 - * Pipa luar (R32) : $1/2 \text{ inch} = 1,27 \text{ cm} = 0,0127 \text{ m}$ (D_o)
 - * Material pipa tembaga : $k_{wall} = 400 \text{ W/m.K}$
 - * Susunan aliran : counter flow

* Hitung laju aliran Massa ($\dot{m}_h$) R uou

$$\Delta h = h_{in} - h_{out} = 386 - 279 = 107 \text{ W/kg}$$

$$\dot{m}_h = \frac{Q}{\Delta h} = \frac{3710 \text{ W}}{107 \text{ W/kg}} = 34.67 \text{ kg/s} = 0.03467 \text{ kg/s}$$

* Hitung LMTD

$$\Delta T_1 = T_{h,in} - T_{c,out} = 59.5 - 13.3 = 46.2^\circ \text{C}$$

$$\Delta T_2 = T_{h,out} - T_{c,in} = 36 - 10.3 = 25.7^\circ \text{C}$$

$$\Delta T_{lm} = \frac{46.2^\circ \text{C} - 25.7^\circ \text{C}}{\ln(46.2/25.7)} = 35.3^\circ \text{C} = 308.45 \text{ K}$$

* Hitung kecepatan Aliran dan bilangan Reynold

* sisi R uou (pipa dalam)

1. Luas penampang

$$A = \frac{\pi D_i^2}{4} = \frac{\pi (0.00635)^2}{4} = 3.167 \times 10^{-5} \text{ m}^2$$

2. Kecepatan massa

$$G_h = \frac{\dot{m}_h}{A} = \frac{0.03467 \text{ kg/s}}{3.167 \times 10^{-5} \text{ m}^2} = 1.093 \text{ kg/m}^2 \cdot \text{s}$$

3. Bilangan Reynold (fase cair)

$$Re = \frac{G_h D_i}{\mu_f} = \frac{1.093 \text{ kg/m}^2 \cdot \text{s} \cdot 0.00635 \text{ m}}{0.0006 \text{ kg/m} \cdot \text{s}} = 1154.75 \text{ (turbulen > 4000)}$$

* sisi R32 (pipa dalam)

1. Luas penampang

$$A_{ann} = \frac{\pi}{4} (D_{ci}^2 - D_o^2) = \frac{\pi}{4} (0.0127^2 - 0.00635^2) = 9.495 \times 10^{-5} \text{ m}^2$$

2. Diameter hidraulik

$$D_h = D_{ci} - D_o = 0.0127 - 0.00635 = 0.00635 \text{ m}$$

3. Kecepatan massa

$$G_c = \frac{\dot{m}_c}{A_{ann}} = \frac{0.028 \text{ kg/s}}{9.495 \times 10^{-5} \text{ m}^2} = 294.86 \text{ kg/m}^2 \cdot \text{s}$$

4. Bilangan Reynold

$$Re = \frac{G_c D_h}{\mu_f} = \frac{294.86 \text{ kg/m}^2 \cdot \text{s} \cdot 0.00635 \text{ m}}{0.000136 \text{ kg/m} \cdot \text{s}} = 13767 \text{ (turbulen)}$$

* Koefisien konveksi

A) R 404 (kondensasi) didalam pipa menggunakan Dittus-Boelter
($n = 0,3$)

1.) Hitung bilangan Prandtl ($n = 0,3$)

$$Pr_F = \frac{\mu_F \cdot C_{p,F}}{k_F} = \frac{0,00106 \text{ kg/m.s} \cdot 1,60 \text{ W/kg}^\circ\text{K}}{0,0718} = 0,00236$$

$$Pr_F^{0,3} = 0,00236^{0,3} = 0,0324$$

2) Hitung $Re^{0,8}$

$$Re^{0,8} = 6547^{0,8} = 1129,36$$

3) Hitung Bilangan Nusselt dengan Dittus-Boelter ($n = 0,43$)

$$\begin{aligned} Nu &= 0,023 \times Re^{0,8} \times Pr_F^{0,3} \\ &= 0,023 \times 1129,36 \times 0,324 \\ &= 8,41 \end{aligned}$$

4) Hitung koefisien konveksi

$$h_{f0} = \frac{Nu \cdot k_F}{D_i} = \frac{8,41 \cdot 0,0718}{0,00535 \text{ m}} = 112,86 \text{ W/m}^2\text{K}$$

~~B) R 32 (evaporasi) di dalam pipa menggunakan Dittus-Boelter ($n = 0,4$) dengan properti cair~~

5) Faktor dua fase untuk kondensasi ($f = 2,5$)

$$h_i = f \times h_{f0} = 2,5 \times 112,86 = 282,15 \text{ W/m}^2\text{K}$$

B) R 32 (evaporasi) di dalam pipa menggunakan Dittus-Boelter ($n = 0,4$)

1.) Hitung bilangan Prandtl ($n = 0,4$)

$$Pr_F = \frac{0,00136 \text{ kg/m.s} \cdot 1638 \text{ W/kg}^\circ\text{K}}{0,113 \text{ W/m}^\circ\text{K}} = 1,97$$

$$Pr_F^{0,4} = 1,97^{0,4} = 1,311$$

2.) Hitung $Re^{0,8}$

$$Re^{0,8} = 13767^{0,8} = 2046,78$$

3) Hitung Bilangan Nusselt dengan Dittus-Boelter ($n = 0,4$)

$$\begin{aligned} Nu &= 0,023 \times 2046,78 \times 1,311 \\ &= 61,71 \end{aligned}$$

4) Hitung koefisien konveksi

$$h_{f0} = \frac{Nu \cdot k_F}{D_h} = \frac{61,71 \cdot 0,113}{0,00635} = 1098,14 \text{ W/m}^2\text{K}$$

5) factor dua fase untuk evaporasi ($F = 3$)

$$h_o = 1098,14 \times 3 = 3294,42 \text{ W/m}^2\text{K}$$

- Hitung koefisien ~~permutasi~~ ~~teori~~ perpindahan panas menyeluruh (U_o)

$$\begin{aligned} \frac{1}{U_o} &= \frac{1}{h_o} + \frac{D_o \ln(D_o/D_i)}{2k_{\text{wall}}} + \frac{D_o}{h_i D_i} \\ &= \frac{1}{3294,42 \text{ W/m}^2\text{K}} + \frac{0,00635 \text{ m} \ln(0,00635/0,00535 \text{ m})}{2(400 \text{ W/m}^2\text{K})} + \frac{0,00635 \text{ m}}{282,15 \text{ W/m}^2\text{K} \cdot 0,00535 \text{ m}} \\ &= 0,000303 + 0,00420 \quad (\text{tahanan konduksi diabaikan sangat kecil}) \end{aligned}$$

$$\frac{1}{U_o} = 0,00450$$

$$U_o = \frac{1}{0,00450} = 221,74 \text{ W/m}^2\text{K}$$

* Hitung luas permukaan ~~pipa~~ yang diperlukan

$$A_o = \frac{Q}{U_o \Delta T_{lm}} = \frac{370 \text{ W}}{221,74 \text{ W/m}^2\text{K} \cdot 308,45 \text{ K}} = \cancel{0,4923} 0,0542 \text{ m}^2$$

* Hitung panjang pipa

$$L = \frac{A_o}{\pi D_o} = \frac{\cancel{0,4923 \text{ m}^2}}{\pi \cdot 0,00635 \text{ m}} = \frac{0,0542 \text{ m}^2}{3,14 \times 0,00635} = 2,71 \text{ m}$$