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PLC Implementation as a Flow Computer for Calculation of Saturated Steam Mass Meetings with the Linear Divided Regression Method. (Application: PT. XYZ - Kuala Tanjung)

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ABSTRACT

In supporting of production quality improvement, industry must be supported by reliable process system. Reliable measurement system also included in one system which is expected realibility. Specially for saturated steam flow measurement and calculation which is mostly done in the industry in relation to control production cost, should also be able to show accurate results. Now PLC has taken an important role in industry, beside as a control system, PLC also can be used to calculation a formula. This paper aims to use PLC as flow computer to calculate saturatedsteam density by adopting linear regression method which is divided into "n" section to increase the accuration with pressure as a input parameter. The results show a relatively small error value around 0,2% if we compare with standart linear regression method, where the value around 0,9%.
Keyword : Saturated Steam Density, Flow Computer, Linear Regression, PLC.

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1. INTRODUCTION

Currently the industrial world is very strict in terms of quality competition for a product to boost sales. In order to produce good quality products, a production process must be fully supported by a reliable process system. One component of the system is a measurement system.

Steam flow measurement is mostly done in almost every type of industry, because one of the energy sources used is heat energy from steam. Whereas for this flow measuring instrument are very many types, one of which is a type of *vortex* . In general, *the flowmeter vortex* can only display the value of the flow size in the form of a volume that is converted from the *frequency vortex* itself. To get the value of the quantity in the form of mass, a tool is needed to calculate the *density* value (mass density) which is usually called a *flow computer*.

To calculate the value of mass flow magnitude can be used the following general equation:

$$M = V \times \rho \tag{1}$$

Where :

M	: Mass flow (kG / hour)
V	: Volume flow (m^3 / hour)
ρ	: Mass meeting (kG / m^3)

The value of ρ (mass density) itself in a saturated vapor system has a linear relationship that is directly proportional to the value of the vapor pressure. The accuracy of the mass density calculation greatly affects the accuracy of the value of the mass flow, so that the small magnitude of the *error* value becomes a benchmark of the *error* value of the steam mass flow.

In this paper, we will try to offer a method of mass density calculation with a much better level of accuracy through the linear regression method approach adopted into the PLC as an alternative to the *flow computer* function that is currently widely used in industry.

2. LITERATURE RIVIEW

The use of linear regression methods has been used in many writings which aim to determine the relationship between two values or parameters. Linear regression is also widely adopted to *formulate* several problems into a form of calculation, so that they can be used to forecast or predict a value in the future.

Intan diantari et al (2015) uses linear regression to overcome excess and lack of vehicle stock at Anugrah Utama Motor. Hotanto et al (2015) uses linear regression to forecast fuel sales in the future to avoid losses due to excess stock when there is a change from high to low fuel prices. Multiple linear regression method was used by Jamner R. Lawendatu et al (2014) to analyze the income of nutmeg farmers in Sangihe Islands District - North Sulawesi. As for the prediction of electric power requirements for Lampung Province until 2030 using linear regression has been carried out by M. Syafruddin et al (2014).

In this paper, the linear system method will be implemented as a formula in the PLC program to calculate the mass meeting value in saturated vapor based on the value of the vapor pressure, so that a more accurate value can be obtained.

3. METHOD

a. Research Steps.

The steps adopted in this study can be seen in Figure 1 below. Based on the picture, collecting initial data on the relationship between mass meetings and pressure from credible sources is the first thing to do . Then with this data we divide into several segments into "n" to increase its accuracy and calculate the regression value of each segment , where in this case it is determined n = 5 . The formula of each of these ranges is then entered into the PLC program as a formula for calculating steam mass meetings . Then an evaluation of the *error* between the initial mass meeting data from the reference source and the formula mass meeting data and determine the percentage *error*.

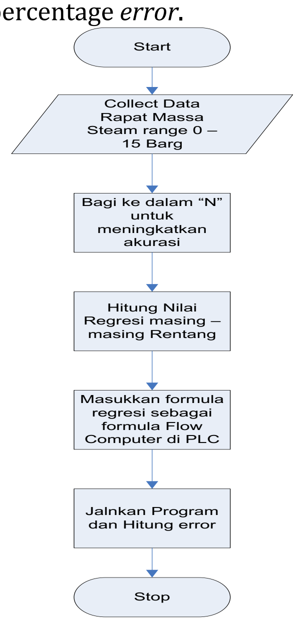

Figure 1. Research *Flow Chart*

b. Research Equipment .

In this study the equipment that will function as a *flow computer* is the Nano-Micro Versamax IC200UDR005 PLC with the following specifications.

Brand : General Electric
Series : Versamax Nano / Micro

Power : 100 ~ 240 VAC
Input : 16 DC Input
Output : 11 + 1 Output

Figure 2. Versamax Nano / Micro PLC.

a. Used Data.
The data used in this study were taken from mass density values based on the saturated vapor pressure of Spirax Sarco *database* as shown in the following table.

Tabel 1. Vapor pressure-based mass meetings

Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)
0.0	0.598	3.1	2.220	6.1	3.722	9.1	5.200	12.1	6.669
0.1	0.653	3.2	2.271	6.2	3.771	9.2	5.249	12.2	6.718
0.2	0.707	3.3	2.321	6.3	3.821	9.3	5.298	12.3	6.767
0.3	0.762	3.4	2.372	6.4	3.870	9.4	5.347	12.4	6.816
0.4	0.816	3.5	2.422	6.5	3.920	9.5	5.396	12.5	6.865
0.5	0.870	3.6	2.473	6.6	3.969	9.6	5.445	12.6	6.914
0.6	0.923	3.7	2.523	6.7	4.019	9.7	5.494	12.7	6.963
0.7	0.977	3.8	2.574	6.8	4.068	9.8	5.543	12.8	7.012
0.8	1.030	3.9	2.624	6.9	4.117	9.9	5.592	12.9	7.060
0.9	1.083	4.0	2.674	7.0	4.167	10.0	5.641	13.0	7.109
1.0	1.136	4.1	2.725	7.1	4.216	10.1	5.690	13.1	7.158
1.1	1.189	4.2	2.775	7.2	4.265	10.2	5.739	13.2	7.207
1.2	1.241	4.3	2.825	7.3	4.315	10.3	5.788	13.3	7.256
1.3	1.294	4.4	2.875	7.4	4.364	10.4	5.837	13.4	7.305
1.4	1.346	4.5	2.925	7.5	4.413	10.5	5.886	13.5	7.354
1.5	1.398	4.6	2.975	7.6	4.463	10.6	5.935	13.6	7.403
1.6	1.450	4.7	3.025	7.7	4.512	10.7	5.984	13.7	7.452
1.7	1.502	4.8	3.075	7.8	4.561	10.8	6.033	13.8	7.501
1.8	1.554	4.9	3.125	7.9	4.610	10.9	6.082	13.9	7.549
1.9	1.606	5.0	3.175	8.0	4.660	11.0	6.131	14.0	7.598

2.0	1.657	5.1	3.225	8.1	4.709	11.1	6.180	14.1	7.647
2.1	1.709	5.2	3.275	8.2	4.758	11.2	6.229	14.2	7.696
2.2	1.760	5.3	3.324	8.3	4.807	11.3	6.278	14.3	7.745
2.3	1.812	5.4	3.374	8.4	4.856	11.4	6.327	14.4	7.794
2.4	1.863	5.5	3.424	8.5	4.905	11.5	6.376	14.5	7.843
2.5	1.914	5.6	3.474	8.6	4.955	11.6	6.425	14.6	7.892
2.6	1.965	5.7	3.523	8.7	5.004	11.7	6.474	14.7	7.941
2.7	2.016	5.8	3.573	8.8	5.053	11.8	6.522	14.8	7.990
2.8	2.067	5.9	3.623	8.9	5.102	11.9	6.571	14.9	8.039
2.9	2.118	6.0	3.672	9.0	5.151	12.0	6.620	15.0	8.087
3.0	2.169								

4. RESULTS AND DISCUSSION

This section will be done f ormula the data previously obtained by using the linear regression equation to get the steam mass meeting, which had previously been carried division could be presented in the following graph.

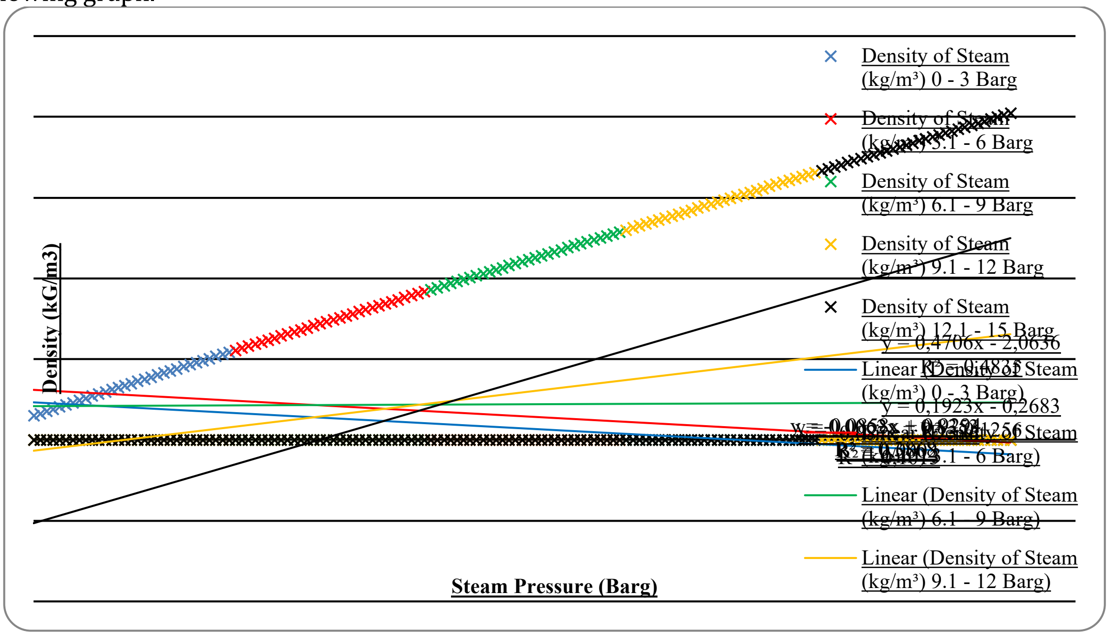

Figure 3. Graph of mass versus vapor pressure.

The graph above shows the relationship between linear mass and pressure meeting values, but in this case the lines in the graph are divided into 5 ranges of values. So there are 5 formulas for each range as follows:

$y_1 = 0{,}522\ x + 0{,}608$
$y_2 = 0{,}500\ x + 0{,}670$
$y_3 = 0{,}492\ x + 0{,}716$
$y_4 = 0{,}489\ x + 0{,}744$
$y_5 = 0{,}489\ x + 0{,}752$

The formula above is included as a formula for calculating mass meetings into the PLC. After the program starts, the calculation value will appear according to the formula above. Following are the results of the calculation of the program.

Table 2. Calculation of mass meetings with an interval formula divided by 5

Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)
0.0	0.608	3.1	2.220	6.1	3.717	9.1	5.194	12.1	6.669
0.1	0.660	3.2	2.270	6.2	3.766	9.2	5.243	12.2	6.718
0.2	0.712	3.3	2.320	6.3	3.816	9.3	5.292	12.3	6.767
0.3	0.765	3.4	2.370	6.4	3.865	9.4	5.341	12.4	6.816
0.4	0.817	3.5	2.420	6.5	3.914	9.5	5.390	12.5	6.865
0.5	0.869	3.6	2.470	6.6	3.963	9.6	5.438	12.6	6.913
0.6	0.921	3.7	2.520	6.7	4.012	9.7	5.487	12.7	6.962
0.7	0.973	3.8	2.570	6.8	4.062	9.8	5.536	12.8	7.011
0.8	1.026	3.9	2.620	6.9	4.111	9.9	5.585	12.9	7.060
0.9	1.078	4.0	2.670	7.0	4.160	10.0	5.634	13.0	7.109
1.0	1.130	4.1	2.720	7.1	4.209	10.1	5.683	13.1	7.158
1.1	1.182	4.2	2.770	7.2	4.258	10.2	5.732	13.2	7.207
1.2	1.234	4.3	2.820	7.3	4.308	10.3	5.781	13.3	7.256
1.3	1.287	4.4	2.870	7.4	4.357	10.4	5.830	13.4	7.305
1.4	1.339	4.5	2.920	7.5	4.406	10.5	5.879	13.5	7.354
1.5	1.391	4.6	2.970	7.6	4.455	10.6	5.927	13.6	7.402
1.6	1.443	4.7	3.020	7.7	4.504	10.7	5.976	13.7	7.451
1.7	1.495	4.8	3.070	7.8	4.554	10.8	6.025	13.8	7.500
1.8	1.548	4.9	3.120	7.9	4.603	10.9	6.074	13.9	7.549
1.9	1.600	5.0	3.170	8.0	4.652	11.0	6.123	14.0	7.598
2.0	1.652	5.1	3.220	8.1	4.701	11.1	6.172	14.1	7.647
2.1	1.704	5.2	3.270	8.2	4.750	11.2	6.221	14.2	7.696
2.2	1.756	5.3	3.320	8.3	4.800	11.3	6.270	14.3	7.745
2.3	1.809	5.4	3.370	8.4	4.849	11.4	6.319	14.4	7.794
2.4	1.861	5.5	3.420	8.5	4.898	11.5	6.368	14.5	7.843
2.5	1.913	5.6	3.470	8.6	4.947	11.6	6.416	14.6	7.891
2.6	1.965	5.7	3.520	8.7	4.996	11.7	6.465	14.7	7.940
2.7	2.017	5.8	3.570	8.8	5.046	11.8	6.514	14.8	7.989
2.8	2.070	5.9	3.620	8.9	5.095	11.9	6.563	14.9	8.038
2.9	2.122	6.0	3.670	9.0	5.144	12.0	6.612	15.0	8.087
3.0	2.174								

To see accuracy needs to be calculated relative error values as shown in the following table, where the average percentage *error* value of the overall value is 0.2%.

Table 3. Calculation of mass meeting *errors* with a formula of 5 values.

Pressure (bar gauge)	Density of Steam (kg/m³)	Pressure (bar gauge)	Density of Steam (kg/m³)	Pressure (bar gauge)	Density of Steam (kg/m³)	Pressure (bar gauge)	Density of Steam (kg/m³)	Pressure (bar gauge)	Density of Steam (kg/m³)
0.0	1.8%	3.1	0.0%	6.1	0.1%	9.1	0.1%	12.1	0.0%
0.1	1.2%	3.2	0.0%	6.2	0.1%	9.2	0.1%	12.2	0.0%
0.2	0.7%	3.3	0.1%	6.3	0.1%	9.3	0.1%	12.3	0.0%
0.3	0.4%	3.4	0.1%	6.4	0.1%	9.4	0.1%	12.4	0.0%
0.4	0.1%	3.5	0.1%	6.5	0.1%	9.5	0.1%	12.5	0.0%
0.5	0.1%	3.6	0.1%	6.6	0.2%	9.6	0.1%	12.6	0.0%
0.6	0.2%	3.7	0.1%	6.7	0.2%	9.7	0.1%	12.7	0.0%
0.7	0.3%	3.8	0.1%	6.8	0.2%	9.8	0.1%	12.8	0.0%
0.8	0.4%	3.9	0.2%	6.9	0.2%	9.9	0.1%	12.9	0.0%
0.9	0.5%	4.0	0.2%	7.0	0.2%	10.0	0.1%	13.0	0.0%
1.0	0.5%	4.1	0.2%	7.1	0.2%	10.1	0.1%	13.1	0.0%
1.1	0.5%	4.2	0.2%	7.2	0.2%	10.2	0.1%	13.2	0.0%
1.2	0.5%	4.3	0.2%	7.3	0.2%	10.3	0.1%	13.3	0.0%
1.3	0.5%	4.4	0.2%	7.4	0.2%	10.4	0.1%	13.4	0.0%
1.4	0.5%	4.5	0.2%	7.5	0.2%	10.5	0.1%	13.5	0.0%
1.5	0.5%	4.6	0.2%	7.6	0.2%	10.6	0.1%	13.6	0.0%
1.6	0.5%	4.7	0.2%	7.7	0.2%	10.7	0.1%	13.7	0.0%
1.7	0.4%	4.8	0.2%	7.8	0.2%	10.8	0.1%	13.8	0.0%
1.8	0.4%	4.9	0.2%	7.9	0.2%	10.9	0.1%	13.9	0.0%
1.9	0.4%	5.0	0.2%	8.0	0.2%	11.0	0.1%	14.0	0.0%
2.0	0.3%	5.1	0.1%	8.1	0.2%	11.1	0.1%	14.1	0.0%
2.1	0.3%	5.2	0.1%	8.2	0.2%	11.2	0.1%	14.2	0.0%
2.2	0.2%	5.3	0.1%	8.3	0.2%	11.3	0.1%	14.3	0.0%
2.3	0.2%	5.4	0.1%	8.4	0.2%	11.4	0.1%	14.4	0.0%
2.4	0.1%	5.5	0.1%	8.5	0.2%	11.5	0.1%	14.5	0.0%
2.5	0.1%	5.6	0.1%	8.6	0.1%	11.6	0.1%	14.6	0.0%
2.6	0.0%	5.7	0.1%	8.7	0.1%	11.7	0.1%	14.7	0.0%
2.7	0.1%	5.8	0.1%	8.8	0.1%	11.8	0.1%	14.8	0.0%
2.8	0.1%	5.9	0.1%	8.9	0.1%	11.9	0.1%	14.9	0.0%
2.9	0.2%	6.0	0.1%	9.0	0.1%	12.0	0.1%	15.0	0.0%
3.0	0.2%								

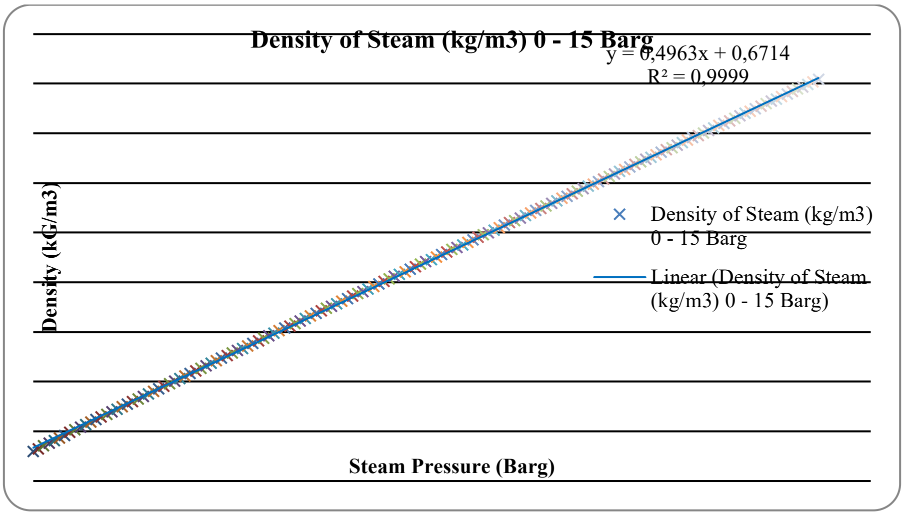

Figure 4. Graph of mass density vs. vapor pressure regression without being divided into n.

From the graph above, the regression formula can be determined without the following range of values :

$$y = 0,496\,x + 0,671$$

By formulating the above equation into the PLC program, the mass meeting values are as follows:

Table 4. Calculations of mass meetings without ranges are divided into n

Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)
0.0	0.671	3.1	2.209	6.1	3.697	9.1	5.185	12.1	6.673
0.1	0.721	3.2	2.258	6.2	3.746	9.2	5.234	12.2	6.722
0.2	0.770	3.3	2.308	6.3	3.796	9.3	5.284	12.3	6.772
0.3	0.820	3.4	2.357	6.4	3.845	9.4	5.333	12.4	6.821
0.4	0.869	3.5	2.407	6.5	3.895	9.5	5.383	12.5	6.871
0.5	0.919	3.6	2.457	6.6	3.945	9.6	5.433	12.6	6.921
0.6	0.969	3.7	2.506	6.7	3.994	9.7	5.482	12.7	6.970
0.7	1.018	3.8	2.556	6.8	4.044	9.8	5.532	12.8	7.020
0.8	1.068	3.9	2.605	6.9	4.093	9.9	5.581	12.9	7.069
0.9	1.117	4.0	2.655	7.0	4.143	10.0	5.631	13.0	7.119
1.0	1.167	4.1	2.705	7.1	4.193	10.1	5.681	13.1	7.169
1.1	1.217	4.2	2.754	7.2	4.242	10.2	5.730	13.2	7.218
1.2	1.266	4.3	2.804	7.3	4.292	10.3	5.780	13.3	7.268
1.3	1.316	4.4	2.853	7.4	4.341	10.4	5.829	13.4	7.317
1.4	1.365	4.5	2.903	7.5	4.391	10.5	5.879	13.5	7.367
1.5	1.415	4.6	2.953	7.6	4.441	10.6	5.929	13.6	7.417
1.6	1.465	4.7	3.002	7.7	4.490	10.7	5.978	13.7	7.466
1.7	1.514	4.8	3.052	7.8	4.540	10.8	6.028	13.8	7.516

1.8	1.564	4.9	3.101	7.9	4.589	10.9	6.077	13.9	7.565
1.9	1.613	5.0	3.151	8.0	4.639	11.0	6.127	14.0	7.615
2.0	1.663	5.1	3.201	8.1	4.689	11.1	6.177	14.1	7.665
2.1	1.713	5.2	3.250	8.2	4.738	11.2	6.226	14.2	7.714
2.2	1.762	5.3	3.300	8.3	4.788	11.3	6.276	14.3	7.764
2.3	1.812	5.4	3.349	8.4	4.837	11.4	6.325	14.4	7.813
2.4	1.861	5.5	3.399	8.5	4.887	11.5	6.375	14.5	7.863
2.5	1.911	5.6	3.449	8.6	4.937	11.6	6.425	14.6	7.913
2.6	1.961	5.7	3.498	8.7	4.986	11.7	6.474	14.7	7.962
2.7	2.010	5.8	3.548	8.8	5.036	11.8	6.524	14.8	8.012
2.8	2.060	5.9	3.597	8.9	5.085	11.9	6.573	14.9	8.061
2.9	2.109	6.0	3.647	9.0	5.135	12.0	6.623	15.0	8.111
3.0	2.159								

With a percentage *error* of 0.9% as shown in the following table :

Table 5. Calculation of mass density *errors* without value ranges

Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)	Pressure (bar gauge)	Density of Steam (kg/m^3)
0.0	12.3%	3.1	0.5%	6.1	0.7%	9.1	0.3%	12.1	0.1%
0.1	10.4%	3.2	0.5%	6.2	0.7%	9.2	0.3%	12.2	0.1%
0.2	8.9%	3.3	0.6%	6.3	0.7%	9.3	0.3%	12.3	0.1%
0.3	7.6%	3.4	0.6%	6.4	0.6%	9.4	0.3%	12.4	0.1%
0.4	6.6%	3.5	0.6%	6.5	0.6%	9.5	0.2%	12.5	0.1%
0.5	5.7%	3.6	0.7%	6.6	0.6%	9.6	0.2%	12.6	0.1%
0.6	4.9%	3.7	0.7%	6.7	0.6%	9.7	0.2%	12.7	0.1%
0.7	4.3%	3.8	0.7%	6.8	0.6%	9.8	0.2%	12.8	0.1%
0.8	3.7%	3.9	0.7%	6.9	0.6%	9.9	0.2%	12.9	0.1%
0.9	3.2%	4.0	0.7%	7.0	0.6%	10.0	0.2%	13.0	0.1%
1.0	2.7%	4.1	0.7%	7.1	0.6%	10.1	0.2%	13.1	0.1%
1.1	2.4%	4.2	0.7%	7.2	0.5%	10.2	0.2%	13.2	0.2%
1.2	2.0%	4.3	0.7%	7.3	0.5%	10.3	0.1%	13.3	0.2%
1.3	1.7%	4.4	0.8%	7.4	0.5%	10.4	0.1%	13.4	0.2%
1.4	1.4%	4.5	0.8%	7.5	0.5%	10.5	0.1%	13.5	0.2%
1.5	1.2%	4.6	0.8%	7.6	0.5%	10.6	0.1%	13.6	0.2%
1.6	1.0%	4.7	0.8%	7.7	0.5%	10.7	0.1%	13.7	0.2%
1.7	0.8%	4.8	0.8%	7.8	0.5%	10.8	0.1%	13.8	0.2%
1.8	0.6%	4.9	0.8%	7.9	0.5%	10.9	0.1%	13.9	0.2%
1.9	0.5%	5.0	0.8%	8.0	0.4%	11.0	0.1%	14.0	0.2%
2.0	0.3%	5.1	0.7%	8.1	0.4%	11.1	0.1%	14.1	0.2%
2.1	0.2%	5.2	0.7%	8.2	0.4%	11.2	0.0%	14.2	0.2%
2.2	0.1%	5.3	0.7%	8.3	0.4%	11.3	0.0%	14.3	0.2%
2.3	0.0%	5.4	0.7%	8.4	0.4%	11.4	0.0%	14.4	0.2%

2.4	0.1%	5.5	0.7%	8.5	0.4%	11.5	0.0%	14.5	0.3%
2.5	0.2%	5.6	0.7%	8.6	0.4%	11.6	0.0%	14.6	0.3%
2.6	0.2%	5.7	0.7%	8.7	0.3%	11.7	0.0%	14.7	0.3%
2.7	0.3%	5.8	0.7%	8.8	0.3%	11.8	0.0%	14.8	0.3%
2.8	0.4%	5.9	0.7%	8.9	0.3%	11.9	0.0%	14.9	0.3%
2.9	0.4%	6.0	0.7%	9.0	0.3%	12.0	0.0%	15.0	0.3%
3.0	0.5%								

5. CONCLUSION

The mass density calculation method of saturated steam with PLC applications using a linear regression approach can be used as an alternative *flow computer* that is widely used today with the best accuracy of about 0.2% in this study. The saturated vapor mass density calculation method which is divided into 5 ranges of values has a better *error* value which is an average of 0.2% compared to those not divided into a range of values that have an average *error* of 0.9%. The use of PLC is good enough to do computational flow according to the formula programmed into PLC memory..

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