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QUANTIFYING GEOTHERMAL FLUID FLOW USING ORIFICE PLATE FLOWMETERS

Ismail BOGREKCI, Pınar DEMIRCIOGLU, Baybars DAL

Abstract: *Geothermal power plants often utilize binary or double flush systems, incorporating separators to manage the three-phase composition of geothermal fluid – steam, water, and gases. While magmeters are commonly employed for single-phase brine flow measurements due to their obstructionless nature and minimal pressure drop, issues such as lining deformation and electrode coating can lead to maintenance challenges and increased operating costs. This study explores an alternative approach by employing the differential pressure flow measurement method with an orifice plate, aiming to reduce operational, maintenance, and investment costs. To assess the effectiveness of this method, an orifice plate is designed for flow calculation, considering energy loss along the pipeline for cost analysis. Additionally, a silencer-weir box is implemented to validate observed flow results. At conditions of 65 °C, 8 bar inlet pressure, and a 120 m3/h flow rate, the pressure difference calculated with the orifice plate flowmeter is 0.073 bar. Comparative analysis indicates an annual cost of $220, showing the potential cost savings of using the orifice plate flow measurement method over other devices.*

Key words: *Geothermal, Magmeter, Orifice plate, Silencer-weir box, Pressure drop*

1. INTRODUCTION

This research focuses on geothermal resources, emphasizing their environmental benefits and the increasing interest in geothermal power plants. Geothermal fluid composition and the conditions defining it as a geothermal source are highlighted. The study addresses the growth of geothermal electricity production following the 2005 Renewable Energy Law, accounting for 1% of the country's total production. Geothermal sources, often located along fault lines, are explained, detailing their application in various sectors.

The distinction between binary cycle and flush geothermal power plant designs is outlined, emphasizing the importance of fluid flow measurements. Brine and steam flow in geothermal plants are typically measured using magnetic and vortex flow meters. The separation of fluid phases after reaching the surface, particularly in multiple well systems, incurs additional costs and space requirements.

The research aims to reduce separator and silencer weir costs, simplify reservoir management, save time in well testing, gain space in wellheads, and enable separate flow measurements for each production well. Overall, the study seeks to optimize the efficiency and cost-effectiveness of geothermal power plants.

The study explores various aspects of orifice plate flow measurement, drawing insights from multiple references. Brennan et al. [1] highlight the impact of swirl flow on orifice plates and turbine flowmeters, revealing significant errors with swirling pipelines. Reader-Harris et al. [2] propose an improved orifice plate unloading coefficient equation, while Oliveira et al. [3] conduct gas-liquid flow measurements through venturi and orifice plates.

Richard and Andrew [4] consider wet gas flow patterns, creating correlations for orifice meters to minimize liquid-induced errors. Li et al. [5] develop a wet gas flowmeter based on a double-groove orifice transducer. Manshoor et al. [6] simulate a model using a fractal flow

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corrector upstream of the orifice plate, aiming to reduce distortion. Pirouzpanah et al. [7] utilize a double-slot orifice plate and vortex flowmeter for multiphase flow measurements.

Golijanek-Jędrzejczyk et al. [8] explore the uncertainty of mass flow measurement through orifice plates, presenting analytical and Monte Carlo methods. Mubarok et al. [9] apply orifice plates for two-phase flow measurement in geothermal fluids, combining field tests and CFD analysis. Vemulapalli et al. [10] conduct a parametric analysis of orifice plates in flow measurement, emphasizing factors like thickness, diameter, and hole position. Ma et al. [11] analyze wet gas pressure drop across multi-orifice plates in a horizontal pipe, proposing correlations for different flow regimes.

Pasquini and Rosa [12] model orifice plates with a two-phase multiplier, focusing on the area contraction ratio effect. The study aims to observe the use of the differential pressure flow measuring method with orifice plates, emphasizing its potential to reduce operating, maintenance, and investment costs. The study distinguishes itself by directly focusing on practical applications, conducting field tests, and comparing orifice plate flow meters with magnetic flow meters.

2. MATERIAL AND METHOD

2.1 Magnetic Flowmeters

In geothermal applications, magnetic flowmeters, also known as magmeters, are crucial for accurately measuring the flow of electrically conductive fluids, such as hot water or steam. Operating on Faraday's law of electromagnetic induction, these devices apply a magnetic field to the fluid, generating a voltage proportional to the flow rate. Magmeters offer advantages tailored to geothermal systems, including obstructionless flow measurement, corrosion resistance for handling minerals and corrosive elements, and minimal pressure drop. Their unobtrusive design ensures efficient and reliable monitoring in geothermal fluid systems, contributing to enhanced energy efficiency and sustainability in geothermal energy extraction processes.

2.2 Silencer Savak Method

The Silencer Savak Method is crucial in geothermal well testing, involving controlled discharge from a production well with a silencer to minimize noise. This method allows systematic measurement of key parameters, such as well bottom pressure, temperature, and production rates, providing insights into reservoir performance. The comprehensive data obtained from Silencer Savak well tests are essential for assessing reservoir functionality, optimizing production strategies, and enhancing the overall efficiency and sustainability of geothermal energy extraction. The controlled flow and noise reduction contribute to a stable testing environment, ensuring accurate measurements for optimizing production strategies and enhancing overall efficiency and sustainability in geothermal energy extraction.

2.3 Orifice Plate

In geothermal applications, orifice plates serve as widely adopted devices for measuring fluid flow within pipelines. Comprising a simple design with a centrally drilled hole, orifice plates induce a measurable pressure drop as geothermal fluid passes through, directly correlating with the fluid's flow rate. Their appeal lies in their simplicity, cost-effectiveness, and ease of installation, making them suitable for diverse industries, including oil and gas, water treatment, and chemical processing. The versatility of orifice plates extends to measuring both single-phase and multiphase flows, proving instrumental in the accurate assessment of fluid dynamics within geothermal systems.

2.4 Method

Differential pressure transmitters operate on the principle of differential capacitance, measuring pressure differences through a tensioned metal diaphragm. This method is widely used in industrial applications for measuring properties like density, viscosity, level, and flow. In DP flow rate measurement, the transmitter is crucial for accuracy, ensuring consistent signal transmission despite changes in fluid properties or ambient conditions. Industrial output signals typically use a 4-20 mA range, often with square root extraction. Theoretical research involves verifying transmitter values using the centrifugal weir method, comparing readings obtained from different silencer weirs in the field, with a focus on orifice differential pressure and pressure transmitter display.

3. QUANTIFYING WORK USING THE SILENCER SAVAK METHOD AND EES SOFTWARE

3.1 Determining Work through Silencer Savak Method

While calculating the silencer weir, determining the weir flow constant is a crucial initial step. This requires knowledge of parameters such as weir width, weir height, water height, and weir flow mouth width. In the field, a rectangular weir is utilized. The calculation of the weir constant is presented in the equation below:

$$k = 107.1 + \frac{0.177}{h} + 14.2\left(\frac{h}{D}\right) - 27.5\left(\sqrt{\frac{(B-b)\cdot h}{D\cdot B}}\right)\cdot 2.04\cdot\sqrt{\frac{B}{D}} \tag{1}$$

In this equation:

- k is the variable being calculated based on the given parameters.
- h represents the water height.
- D is a characteristic dimension or length.
- B and b are parameters in the expression.

This equation seems to describe a relationship between k, h, D, B, and b in a specific context or field, such as fluid mechanics or hydraulics.

After determining the weir constant, the calculation of the flow rate is obtained using the following equation:

$$Q = K\cdot b\cdot h^{3/2} \tag{2}$$

where:

- Q is the flow rate,
- K is the weir constant,
- b is the width of the weir,
- h is the water height above the weir.

This formula is applied to estimate the flow rate trough a rectangular weir based on the known weir constant, width, and water height.

It was calculated to obtain flow values corresponding to water heights at the mouth of the sluice ranging from 11 meters to 18 meters. The calculations for each meter are below. Using MATLAB, the weir constant was determined by implementing the equations. The conclusion includes plot diagrams illustrating the outcomes of the calculations (Table 1).

Table 1

Overview of Silencer Savak Calculation Results [13]

h(cm)	h(m)	k	$Q(m^3/h)$
11.0	0.1100	103.66	56.275
11.5	0.1150	103.47	60.043
12.0	0.1200	103.29	63.888
12.5	0.1250	103.12	67.810
13.0	0.1300	102.95	71.805
13.5	0.1350	102.80	75.874
14.0	0.1400	102.65	80.014
14.5	0.1450	102.51	84.225
15.0	0.1500	102.38	88.505
15.5	0.1550	102.26	92.853
16.0	0.1600	102.14	97.268
16.5	0.1650	102.02	101.749
17.0	0.1700	101.91	106.295
17.5	0.1750	101.81	110.906
18.0	0.1800	101.71	115.580
18.4	0.1840	101.63	119.364

3.2 Transferring Silencer Savak Calculations to EES Program

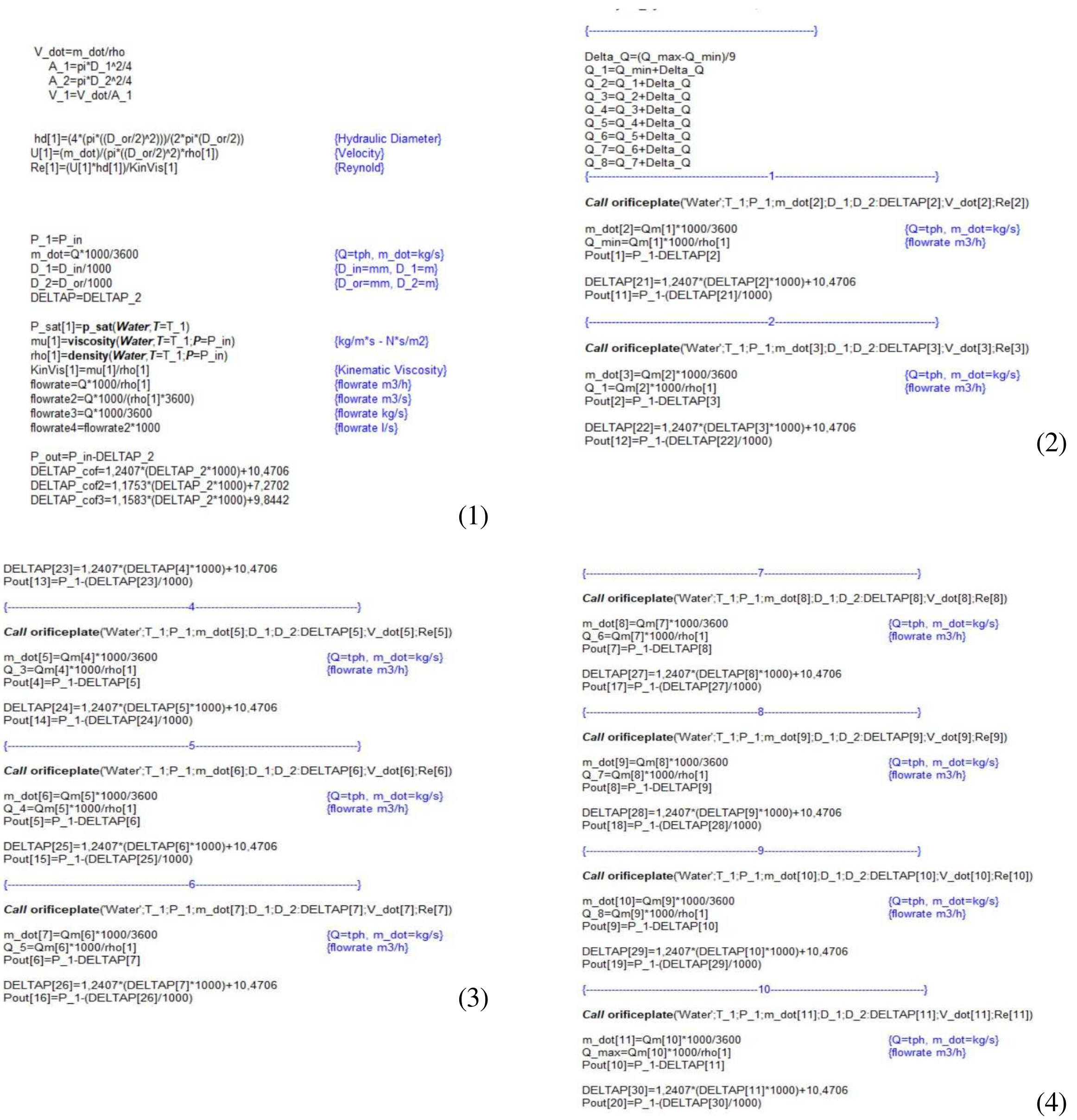
In this section, calculations are detailed, conducted in EES program. Designed for engineering applications, the EES streamlines the transfer and analysis of data, featuring a sample diagram window. The determination of values such as orifice pressure difference and efficiency are facilitated, aligning with results from field studies. The primary aim of this programming is to expedite the computation of annual cost values and showcase the operational and repair advantages of the orifice plate flowmeter over other flow meters.

An example within the EES program covers the computation of various physical properties, including the saturation pressure of water, dynamic viscosity, and density, depending on specific conditions. The EES program's orificeplate procedure is employed to assess the pressure drop across a standard orifice plate for steady, incompressible, horizontal flow.

The EES calculations (Figures 1 and 2) incorporate field values, ranging from 30 m³/h to 300 m³/h, at a temperature of 65°C, an inlet pressure of 8 bar, and flow rates at minimum and maximum intervals. The orifice plate flowmeter is positioned in a pipe with an inner diameter of 387.34 mm.

The calling sequence for this function is: **Call orifice plate (Fluid$, T_1, P_1, m_dot, D_1, D_2: DELTAP, V_dot, Re)**. Here's a breakdown of the parameters:

- **Fluid$**: A string variable or constant containing the name of any fluid in the EES database.
- **T_1**: Temperature, provided in the same units as configured in the EES Unit System.
- **P_1**: Pressure, supplied in the same units as configured in the EES Unit System dialog.
- **m_dot**: Mass flow rate, in kg/s.
- **D_1**: Inlet diameter, in meters.
- **D_2**: Orifice diameter, in meters.
- **DELTAP**: Pressure drop across the orifice, in the same units as configured in the EES Unit System dialog.
- **V_dot**: Volumetric flow rate, in m^3/s.
- **Re**: Reynolds number.



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V_dot=m_dot/rho
   A_1=pi*D_1^2/4
   A_2=pi*D_2^2/4
   V_1=V_dot/A_1


 hd[1]=(4*(pi*((D_or/2)^2)))/(2*pi*(D_or/2))           {Hydraulic Diameter}
U[1]=(m_dot)/(pi*((D_or/2)^2)*rho[1])                  {Velocity}
Re[1]=(U[1]*hd[1])/KinVis[1]                           {Reynold}


P_1=P_in
m_dot=Q*1000/3600                                      {Q=tph, m_dot=kg/s}
D_1=D_in/1000                                          {D_in=mm, D_1=m}
D_2=D_or/1000                                          {D_or=mm, D_2=m}
DELTAP=DELTAP_2

P_sat[1]=p_sat(Water;T=T_1)
mu[1]=viscosity(Water;T=T_1;P=P_in)                    {kg/m*s - N*s/m2}
rho[1]=density(Water;T=T_1;P=P_in)
KinVis[1]=mu[1]/rho[1]                                 {Kinematic Viscosity}
flowrate=Q*1000/rho[1]                                 {flowrate m3/h}
flowrate2=Q*1000/(rho[1]*3600)                         {flowrate m3/s}
flowrate3=Q*1000/3600                                  {flowrate kg/s}
flowrate4=flowrate2*1000                               {flowrate l/s}

P_out=P_in-DELTAP_2
DELTAP_cof=1,2407*(DELTAP_2*1000)+10,4706
DELTAP_cof2=1,1753*(DELTAP_2*1000)+7,2702
DELTAP_cof3=1,1583*(DELTAP_2*1000)+9,8442
```

(1)

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{-------------------------------------------------------}

Delta_Q=(Q_max-Q_min)/9
Q_1=Q_min+Delta_Q
Q_2=Q_1+Delta_Q
Q_3=Q_2+Delta_Q
Q_4=Q_3+Delta_Q
Q_5=Q_4+Delta_Q
Q_6=Q_5+Delta_Q
Q_7=Q_6+Delta_Q
Q_8=Q_7+Delta_Q
{----------------------------------------1----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[2];D_1;D_2:DELTAP[2];V_dot[2];Re[2])

m_dot[2]=Qm[1]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_min=Qm[1]*1000/rho[1]                                {flowrate m3/h}
Pout[1]=P_1-DELTAP[2]

DELTAP[21]=1,2407*(DELTAP[2]*1000)+10,4706
Pout[11]=P_1-(DELTAP[21]/1000)

{----------------------------------------2----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[3];D_1;D_2:DELTAP[3];V_dot[3];Re[3])

m_dot[3]=Qm[2]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_1=Qm[2]*1000/rho[1]                                  {flowrate m3/h}
Pout[2]=P_1-DELTAP[3]

DELTAP[22]=1,2407*(DELTAP[3]*1000)+10,4706
Pout[12]=P_1-(DELTAP[22]/1000)
```

(2)

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DELTAP[23]=1,2407*(DELTAP[4]*1000)+10,4706
Pout[13]=P_1-(DELTAP[23]/1000)

{----------------------------------------4----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[5];D_1;D_2:DELTAP[5];V_dot[5];Re[5])

m_dot[5]=Qm[4]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_3=Qm[4]*1000/rho[1]                                  {flowrate m3/h}
Pout[4]=P_1-DELTAP[5]

DELTAP[24]=1,2407*(DELTAP[5]*1000)+10,4706
Pout[14]=P_1-(DELTAP[24]/1000)

{----------------------------------------5----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[6];D_1;D_2:DELTAP[6];V_dot[6];Re[6])

m_dot[6]=Qm[5]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_4=Qm[5]*1000/rho[1]                                  {flowrate m3/h}
Pout[5]=P_1-DELTAP[6]

DELTAP[25]=1,2407*(DELTAP[6]*1000)+10,4706
Pout[15]=P_1-(DELTAP[25]/1000)

{----------------------------------------6----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[7];D_1;D_2:DELTAP[7];V_dot[7];Re[7])

m_dot[7]=Qm[6]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_5=Qm[6]*1000/rho[1]                                  {flowrate m3/h}
Pout[6]=P_1-DELTAP[7]

DELTAP[26]=1,2407*(DELTAP[7]*1000)+10,4706
Pout[16]=P_1-(DELTAP[26]/1000)
```

(3)

```
{----------------------------------------7----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[8];D_1;D_2:DELTAP[8];V_dot[8];Re[8])

m_dot[8]=Qm[7]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_6=Qm[7]*1000/rho[1]                                  {flowrate m3/h}
Pout[7]=P_1-DELTAP[8]

DELTAP[27]=1,2407*(DELTAP[8]*1000)+10,4706
Pout[17]=P_1-(DELTAP[27]/1000)

{----------------------------------------8----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[9];D_1;D_2:DELTAP[9];V_dot[9];Re[9])

m_dot[9]=Qm[8]*1000/3600                               {Q=tph, m_dot=kg/s}
Q_7=Qm[8]*1000/rho[1]                                  {flowrate m3/h}
Pout[8]=P_1-DELTAP[9]

DELTAP[28]=1,2407*(DELTAP[9]*1000)+10,4706
Pout[18]=P_1-(DELTAP[28]/1000)

{----------------------------------------9----------------------------------------}

Call orificeplate('Water';T_1;P_1;m_dot[10];D_1;D_2:DELTAP[10];V_dot[10];Re[10])

m_dot[10]=Qm[9]*1000/3600                              {Q=tph, m_dot=kg/s}
Q_8=Qm[9]*1000/rho[1]                                  {flowrate m3/h}
Pout[9]=P_1-DELTAP[10]

DELTAP[29]=1,2407*(DELTAP[10]*1000)+10,4706
Pout[19]=P_1-(DELTAP[29]/1000)

{----------------------------------------10----------------------------------------}

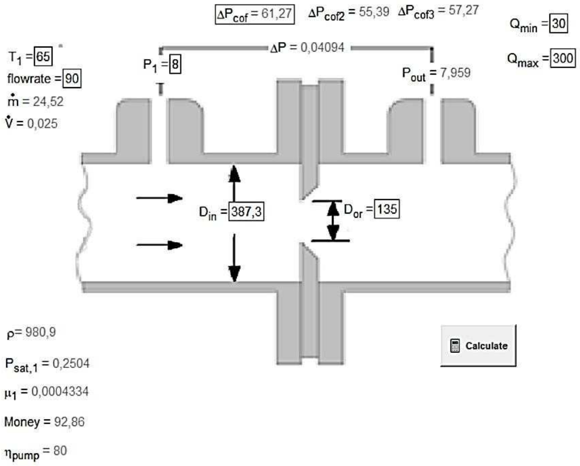
Call orificeplate('Water';T_1;P_1;m_dot[11];D_1;D_2:DELTAP[11];V_dot[11];Re[11])

m_dot[11]=Qm[10]*1000/3600                             {Q=tph, m_dot=kg/s}
Q_max=Qm[10]*1000/rho[1]                               {flowrate m3/h}
Pout[10]=P_1-DELTAP[11]

DELTAP[30]=1,2407*(DELTAP[11]*1000)+10,4706
Pout[20]=P_1-(DELTAP[30]/1000)
```

(4)

Fig. 1. EES equation windows



$\Delta P_{cof} = 61,27$ $\Delta P_{cof2} = 55,39$ $\Delta P_{cof3} = 57,27$

$Q_{min} = 30$

$Q_{max} = 300$

$T_1 = 65$

flowrate = 90

$\dot{m} = 24,52$

$\dot{V} = 0,025$

$P_1 = 8$

$\Delta P = 0,04094$

$P_{out} = 7,959$

$D_{in} = 387,3$

$D_{or} = 135$

$\rho = 980,9$

$P_{sat,1} = 0,2504$

$\mu_1 = 0,0004334$

Money = 92,86

$\eta_{pump} = 80$

Fig. 2. EES Visuals: Diagram Window

4. RESULTS AND DISCUSSION

This study focuses on the evaluation of measurement instruments employed in well tests within geothermal fields, specifically examining the performance of magnetic flow meters using the silencer weir method and flow meters equipped with orifice plates. The primary objective is to establish a thorough comparison between these two methodologies by employing a combination of theoretical calculations and practical fieldwork validation.

To assess the precision and reliability of orifice plate flowmeters, a comprehensive weir study was undertaken both in the field and through Excel. The resulting dataset includes parameters like flow rate, orifice differential pressure, and pressure differences based on water height. These findings serve as a reference for evaluating the performance of orifice plate flowmeters in well tests (Table 2). Figure 3 reveals differential pressure vs. flow rate. This relationship is key in understanding the performance characteristics of the system under consideration.

The subsequent phase of the study involves similar assessments for magnetic flow meters utilizing the silencer weir method. This encompasses both theoretical calculations and real-world field experiments, aiming to validate the accuracy and reliability of magnetic flow meters in geothermal environments. The integration of tools ensures an exploration of the instrumentation's capabilities, contributing to well testing in geothermal applications.

Table 2

Flow Rate, Orifice Differential Pressure, and Calculated Pressure Differences According to Water Height [13]

net height (cm)	Flow Rate (m^3/h)	Orifice Differential Pressure	Calculated Differential Pressure
11.00	56.270	337.60	245.00
11.10	57.020	335.31	251.00
11.05	56.650	336.52	248.00
11.40	59.280	373.07	272.00
11.50	60.000	381.03	278.00
11.55	60.424	382.83	282.00
12.10	64.666	433.87	324.00
12.10	64.666	426.46	324.00
12.00	63.888	418.88	316.00
12.80	70.198	492.51	381.00
12.80	70.198	489.35	381.00
12.70	69.399	487.90	373.00
13.30	74.238	555.47	427.00
14.70	85.929	731.42	572.00
14.70	85.929	730.80	572.00
15.10	89.369	802.94	619.00
15.70	94.611	914.13	693.00
16.10	98.159	941.51	746.00
16.10	98.159	943.25	746.00
16.50	101.749	1005.70	802.00
16.90	105.381	1073.00	860.00

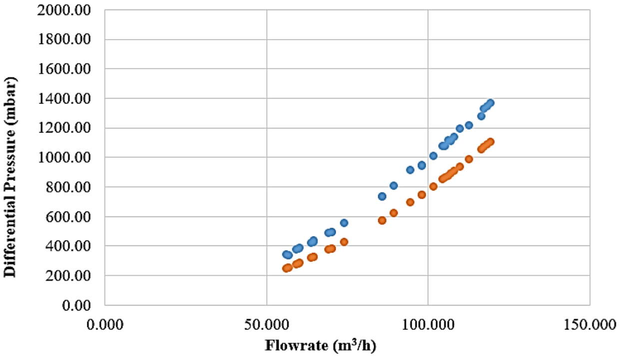


Fig. 3. Differential Pressure-Flow Rate Relationship [13]

The integration of MATLAB extended beyond weir constant calculation, where the program's GUI design capabilities played a vital role. Utilizing the graphical user interface (GUI) feature inherent in MATLAB, an intuitive and user-friendly program interface was developed. The intricacies of weir constant computation were seamlessly translated into a visually accessible platform, enhancing the overall user experience. For transparency and reproducibility, the codes responsible for the weir constant calculation in the MATLAB program have been meticulously documented and are provided in the Appendix. This inclusion ensures that fellow researchers and practitioners can replicate and validate the methodology employed in the study. Subsequent to the weir constant determination, the obtained 'k' values were employed in flow calculations within the MATLAB program. This dynamic integration facilitated the automatic computation of flow rates based on the established weir constant. To visually represent these calculations, a plot diagram was generated, illustrating the relationship between flow rates and the corresponding water level heights. The GUI program interface (Figures 4 and 5) not only served as a conduit for computational processes but also offered a streamlined visual representation of the intricate calculations. Users could interact with the program effortlessly, inputting parameters and obtaining real-time results. The graphical output, complemented by detailed numerical data, provided a comprehensive overview of the impact of weir constants on flow rate calculations.

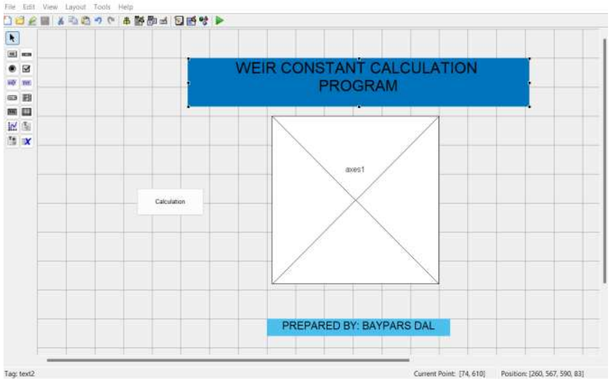


Fig. 4. MATLAB GUI: User Interface for Orifice Plate Flowmeter Analysis Program

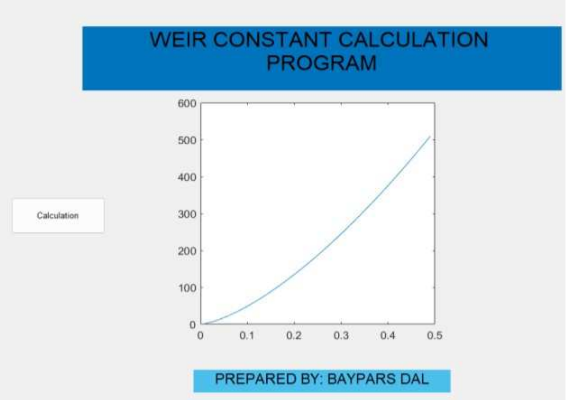


Fig. 5. MATLAB GUI Results: Weir Constant Calculation in Orifice Plate Flowmeter Analysis

Table 3 presents the results obtained through MATLAB analysis, while Figure 6 illustrates the relationship between Flow Rate (Q) and Water Height (h) with a plot diagram. These MATLAB-derived results and Figure 6 offer a depiction between flow rate and water height, providing valuable insights into the behavior of the system being studied.

Table 3

MATLAB Results [13]

h	k	Q
0.11	103.6623	56.27466
0.115	103.469	60.04266
0.12	103.287	63.88816
0.125	103.1152	67.80954
0.13	102.9529	71.80529
0.135	102.7991	75.87398
0.14	102.6532	80.01431
0.145	102.5147	84.225
0.15	102.3829	88.5049
0.155	102.2575	92.8529
0.16	102.1379	97.26794
0.165	102.0238	101.749
0.17	101.9149	106.2953
0.175	101.8108	110.9057
0.18	101.7113	115.5795
0.185	101.6161	120.3159
0.19	101.525	125.1142
0.195	101.4378	129.9735
0.2	101.3543	134.8932
0.205	101.2742	139.8726
0.21	101.1975	144.9111
0.215	101.124	150.0081
0.22	101.0534	155.163
0.225	100.9858	160.3752
0.23	100.921	165.6442
0.235	100.8589	170.9696
0.24	100.7993	176.3507
0.245	100.7421	181.7871
0.25	100.6873	187.2785
0.255	100.6348	192.8242
0.26	100.5845	198.424
0.265	100.5363	204.0773
0.27	100.4902	209.7839
0.275	100.446	215.5434
0.28	100.4037	221.3553
0.285	100.3633	227.2193
0.29	100.3247	233.1351
0.295	100.2878	239.1024
0.3	100.2525	245.1208

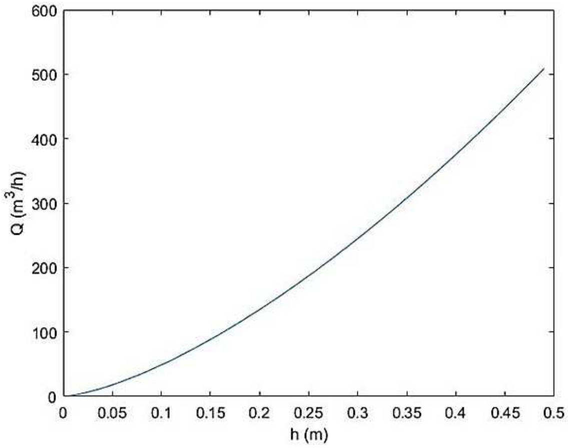


Fig. 6. Flow Rate (Q) vs. Water Height (h): Plot Diagram [13]

This study explores the challenges associated with magnetic flowmeters in the field of flow measurement, highlighting issues such as breakdown susceptibility and potential explosions, leading to substantial financial implications. Orifice plate flowmeters are presented as a viable alternative, particularly in European power plants, due to their ease of maintenance and cost-effectiveness. Focused on geothermal power plants in Turkey, the research conducts a comparative analysis between orifice plate and magnetic flowmeters, considering crucial parameters like inlet pressure, temperature, flow rate, and costs. The study reveals that implementing an orifice plate flowmeter proves economically advantageous, costing $220 annually. By underscoring the advantages of orifice plate flowmeters, especially in maintenance and cost efficiency, the research suggests their potential to address challenges associated with magnetic flowmeters and influence flowmeter selection in various industrial applications (Table 4). Additionally, the study conducts a comparative analysis between field measurements and numerical simulations, specifically assessing the feasibility of employing orifice plate flowmeters as substitutes for magnetic flow meters in reinjection wells. The comparison, detailed in a comprehensive table, serves as a critical step in evaluating the practicality and efficiency of transitioning to orifice plate flowmeters for enhanced operational and economic considerations in geothermal applications.

Table 4

Flow Rate, Differential Pressure, and Cost [13]

Flowrate (m^3/h)	ΔP	Money
30	0.004535	$3.43
60	0.01818	$27.49
90	0.04094	$92.86
120	0.07282	$220.20
150	0.1138	$430.20
180	0.1639	$743.60
210	0.2232	$1181.00
240	0.2915	$1763.00
270	0.369	$2511.00
300	0.4556	$3444.00

An analysis of orifice plate flowmeters in a reinjection well revealed a non-linear correlation between flow rate and differential pressure. The graph (Figure 7) depicted an exponential rise in pressure differences as flow rates increased, emphasizing the importance of understanding these dynamics in the context of the well. This observation highlights the intricate relationship between flow characteristics and pressure variations in the studied orifice plate flowmeter system.

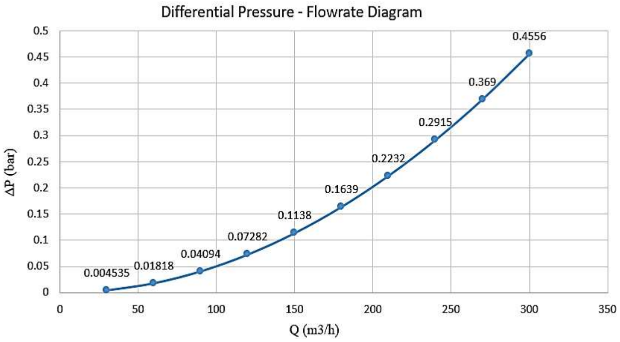


Fig. 7. Differential Pressure - Flowrate Diagram [13]

After conducting calculations, a cost graph was generated to depict the relationship between flow rates and their associated pressure differences in orifice plate flowmeters. The graph illustrates pressure differences corresponding to flow rates ranging from 30 to 300. Additionally, the energy cost incurred due to these pressure differences is quantified and presented on the graph, highlighting the amount of energy lost in the process. The cost graph (Figure 8) encapsulate the study results, offering valuable insights into the economic implications associated with different flow rates in the utilization of orifice plate flowmeters. This representation enhances our understanding of the system's cost dynamics, providing valuable information for decision-making in the practical application of orifice plate flowmeters.

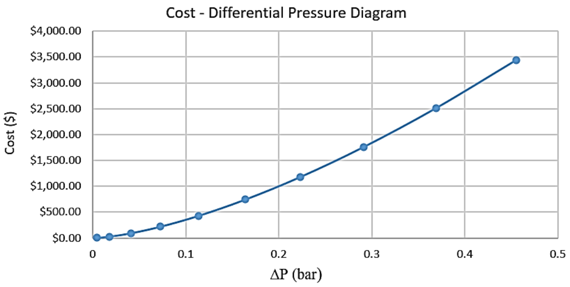


Fig. 8. Differential Pressure - Flowrate Diagram [13]

5. CONCLUSION

This study seeks to elucidate the cost-effectiveness and operational simplicity associated with the implementation of orifice plate flowmeters for the measurement of geothermal fluids in Turkey. Geothermal power plants in the region draw their fluids from medium and high enthalpy geothermal reservoirs, necessitating the utilization of diverse flowmeter devices to accurately gauge fluid properties. Commonly employed devices encompass magnetic flow meters, silencer weir methods, dp transmitters, and orifice plate flow meters.

Throughout the field study, various silencer weirs were deployed to facilitate a comparative analysis of measurements obtained through orifice plate flowmeters. The magnetic flowmeter orifice was identified as yielding the most precise measurements. Concurrently, a Graphical User Interface (GUI) window was constructed in MATLAB, integrating calculations for water height, weir mouth width, and weir constant. The outcomes of these calculations closely aligned with the findings derived from the field study.

Utilizing the operational principles of orifice plate flowmeters, calculations were conducted using the Engineering Equation Solver (EES) program. A comparative evaluation against Excel-based calculations revealed minimal margins of error, affirming the consistent and closely aligned results obtained through orifice plate flowmeters.

In a system characterized by a temperature of 65 °C, an inlet pressure of 8 bar, and a flow rate of 120 m3/h, orifice plate flowmeter computations produced a pressure difference of 0.073 bar. The saturated pressure registered at 0.25 bar, with an outlet pressure of 7.93 bar. The resultant annual cost of $220 underscored the pronounced cost-effectiveness of orifice plate flowmeters versus other devices.

This study imparts valuable insights poised to guide the assimilation and progression of orifice plate flowmeters within geothermal fields and wells in Turkey. Their cost-effectiveness and ease of maintenance position them as credible alternatives to the prohibitively expensive and non-repairable flowmeter devices currently prevalent, thereby exerting a discernible influence on the trajectory of flowmeter technology in the geothermal sector. Future research directions could involve exploring advancements in orifice plate flowmeter technology, such as improved materials and designs, and investigating their applicability in broader geothermal contexts or other fluid measurement scenarios. Additionally, the study suggests exploring potential synergies with emerging technologies, such as incorporating Internet of Things (IoT) capabilities for real-time monitoring and data analysis. These avenues of inquiry would contribute to further enhancing the efficiency and versatility of orifice plate flowmeters in geothermal applications.

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Cuantificarea Fluxului De Fluid Geotermal Utilizând Debitmetre Cu Plăci De Orificiu

Centralele geotermale folosesc adesea sisteme binare sau cu două etape, incorporând separatoare pentru a gestiona compoziția trifazică a fluidului geotermal - abur, apă și gaze. În timp ce magmetrele sunt adesea folosite pentru măsurarea fluxului de lichid într-o singură fază datorită caracteristicilor lor fără obstacole și a scăderii minime a presiunii, probleme precum deformarea căptușelii și acoperirea electrozilor pot duce la provocări de întreținere și la creșterea costurilor operaționale. Această studie explorează o abordare alternativă prin utilizarea metodei de măsurare a fluxului cu presiune diferențială folosind o placă de orificiu, având ca scop reducerea costurilor operaționale, de întreținere și investiții. Pentru a evalua eficacitatea acestei metode, se proiectează o placă de orificiu pentru calculul fluxului, luând în considerare pierderile de energie de-a lungul conductei pentru analiza costurilor. În plus, se implementează o cutie silencer-weir pentru a valida rezultatele observate ale fluxului. La condiții de 65 °C, 8 bar presiune de intrare și un debit de 120 m3/h, diferența de presiune calculată cu ajutorul debitmetrului cu placă de orificiu este de 0,073 bar. Analiza comparativă indică un cost anual de 220 de dolari, demonstrând potențiale economii de costuri în utilizarea metodei de măsurare a fluxului cu placă de orificiu față de alte dispozitive.

Ismail BOGREKCI, Professor, Aydin Adnan Menderes University (ADU), Mechanical Engineering Department, ibogrekci@adu.edu.tr, 09010 Aydin, TURKEY.

Pınar DEMIRCIOGLU, Prof. Dr. techn., Aydin Adnan Menderes University (ADU), Mechanical Engineering Department, pinar.demircioglu@adu.edu.tr, 09010 Aydin, TURKEY; Visiting Professor, Technical University of Munich (TUM), Mechanical Engineering, pinar.demircioglu@tum.de, 85748 Garching, GERMANY.

Baybars DAL, Ph.D. Student, Lecturer, Aydin Adnan Menderes University, Mechanical Engineering, Aydin, TURKEY