Test Instructions

HM150.01 Pipe Friction Apparatus

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Test Instructions
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Unit description

The **HM150.01** unit is used to examine pipe friction losses in laminar and turbulent flow.

The pipe section used is a brass pipe with an inside diameter of 3 mm and a length of 400 mm.

The pressure losses are measured in laminar flow with a water manometer. The static pressure difference is indicated.

In turbulent flow the pressure difference is measured with a mercury-filled U-tube manometer.

A level tank is provided to generate the laminar flow. It ensures a constant water inflow pressure on the pipe section at a constant water level.

The level tank is not used to generate turbulent flow. The water is fed directly from the water main into the pipe section.

The flow rate is set by means of needle valves at each end of the pipe.

The water is supplied either from the **HM150** fluid technics base module or from the laboratory main.

An enclosed water circuit can be established with the **HM150**.
The unit basically comprises:

1. Demonstration board
2. U-Tube manometer
3. Discharge needle valve
4. Pressure tapping at the end of the pipe
5. Pressure tapping at the beginning of the pipe
6. Pipe section
7. Inlet needle valves
8. Hose connection
9. Ball cock
10. Overflow
11. Water tank
12. Water manometer
2 Preparing the experiment

- Set up the experiment on the HM150 so that the discharge directs the water into the sewer.
- Connect a hose between the HM150 and the unit.
- Open the HM150 discharge.

3 Experiments

Pressure lost of laminar flow is to be compared with turbulent flow.

3.1 Laminar flow

- Connect the water manometer to the two pressure measuring nipples.
- Open the needle valve at the discharge fully.
- Switch the HM150 pump on and adjust the ball-cock so that a constant water level is created at the overflow.
- Close the needle valve at the discharge until a constant pressure difference of 2 cm is established on the water manometer. This corresponds to the fall $h_v$.

- Determining the volume flow.

- Increase the flow in increments ($h_v$ increases) and repeat the volume flow measurements.

It also needs to be investigated whether the flow is laminar or turbulent. The switch from laminar to turbulent flow form occurs when:

$$Re_{kr} \approx 2300$$

$Re_{kr}$ means laminar flow

$$Re_{turb.} \geq 2300$$ means turbulent flow

The Reynolds number is calculated from

$$Re = \frac{w \cdot d}{\nu}$$

where

- $d$ = inside diameter of the pipe section [m]
- $w$ = flow rate [m/s]
- $\nu$ = viscosity of the medium [m$^2$/s]

$$Fall \ h_v = h_1 - h_2$$

$h_1$: static pressure at the entrance to the pipe.
The volume flow \( V \) is best measured with a measuring vessel and a stopwatch.

\[
V = \frac{V}{T}
\]

The flow rate is produced from:

\[
w = \frac{V}{A}
\]

\( V \)= volume flow  
\( A \)= cross-sectional area of the pipe

where  \( A = \frac{\pi \cdot d^2}{4} \) and \( d = 3 \text{ mm} \).

The fall \( h_v \) is set with the drain valve. From the fall the pipe coefficient of friction is calculated \( \lambda \) as:

\[
\lambda = \frac{2 \cdot h_v \cdot d}{\rho_{H_2O} \cdot l \cdot w^2}
\]

where \( l = 400 \text{ mm} \) pipe section, the value for \( h_v \) has to be inserted in Pa

The theoretical pipe coefficient of friction \( \lambda_{th} \) is to be compared with the measured value. For laminar flow:

\[
\lambda_{th} = \frac{64}{Re}
\]
3.2 Measured values for laminar flow

The following measured values were produced for laminar flow. While performing the experiment, ensure that the water level in the tank remains constant.

Measured values:

<table>
<thead>
<tr>
<th>h_v</th>
<th>t</th>
<th>V</th>
<th>V</th>
<th>w</th>
<th>Re</th>
<th>λ</th>
<th>λ_{th} (calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>195</td>
<td>0.2</td>
<td>0.00102</td>
<td>0.144</td>
<td>403</td>
<td>0.141</td>
<td>0.158</td>
</tr>
<tr>
<td>3</td>
<td>138</td>
<td>0.2</td>
<td>0.00145</td>
<td>0.205</td>
<td>574</td>
<td>0.105</td>
<td>0.114</td>
</tr>
<tr>
<td>4</td>
<td>105</td>
<td>0.2</td>
<td>0.00190</td>
<td>0.265</td>
<td>754</td>
<td>0.081</td>
<td>0.085</td>
</tr>
<tr>
<td>5</td>
<td>78</td>
<td>0.2</td>
<td>0.00256</td>
<td>0.362</td>
<td>1014</td>
<td>0.056</td>
<td>0.063</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>0.2</td>
<td>0.00277</td>
<td>0.391</td>
<td>1096</td>
<td>0.057</td>
<td>0.058</td>
</tr>
<tr>
<td>8</td>
<td>58</td>
<td>0.2</td>
<td>0.00344</td>
<td>0.486</td>
<td>1362</td>
<td>0.050</td>
<td>0.047</td>
</tr>
<tr>
<td>15</td>
<td>77</td>
<td>0.4</td>
<td>0.00519</td>
<td>0.734</td>
<td>2060</td>
<td>0.040</td>
<td>0.031</td>
</tr>
</tbody>
</table>
In this experiment the level tank is not used. For turbulent flow a higher flow rate is required. The water is therefore fed directly from the HM150 or from the main into the pipe section. Proceed as follows:

- Close the ball-cock fully.

- Connect the Mercury U-tube manometer to the two pressure measuring nipples.
- Open the needle valve at the discharge fully.
- Switch the HM150 pump on.
- Close the needle valve at the discharge until a constant pressure difference of 20 mbar is established on the U-tube manometer. This corresponds to a fall $h_v$ of 15 mm. ($1 \text{ mm Mercury Column} = 1.33322 \text{ mbar}$)

- Determining the volume flow.
- Increase the flow in increments ($h_v$ increases) and repeat the volume flow measurements.

$$Fall \ h_v = h_1 - h_2$$

$h_1$: static pressure at the entrance to the pipe section.
$h_2$: static pressure at the outlet from the pipe section.

The calculations are made in the same way as for the laminar flow.

According to Blasius, however, the theoretical pipe coefficient of friction $\lambda_{th}$ for turbulent flow is calculated as follows:

$$\lambda_{th} = \frac{0.3164}{\sqrt[4]{Re}}$$
3.4 Measured values for turbulent flow

The following measured values were produced for turbulent flow.

Measured values:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>67,42</td>
<td>0,40</td>
<td>0,0059</td>
<td>0,838</td>
<td>2349</td>
<td>0,0420</td>
<td>0,0454</td>
</tr>
<tr>
<td>30</td>
<td>5791</td>
<td>0,40</td>
<td>0,0069</td>
<td>0,976</td>
<td>2736</td>
<td>0,0460</td>
<td>0,0437</td>
</tr>
<tr>
<td>40</td>
<td>46,09</td>
<td>0,40</td>
<td>0,0086</td>
<td>1,22</td>
<td>3420</td>
<td>0,0390</td>
<td>0,0413</td>
</tr>
<tr>
<td>60</td>
<td>3545</td>
<td>0,40</td>
<td>0,0112</td>
<td>1,59</td>
<td>4458</td>
<td>0,0348</td>
<td>0,0387</td>
</tr>
<tr>
<td>80</td>
<td>32,79</td>
<td>0,40</td>
<td>0,0121</td>
<td>1,724</td>
<td>4834</td>
<td>0,0395</td>
<td>0,0379</td>
</tr>
<tr>
<td>100</td>
<td>27,91</td>
<td>0,40</td>
<td>0,0143</td>
<td>2,027</td>
<td>5683</td>
<td>0,0357</td>
<td>0,0364</td>
</tr>
<tr>
<td>120</td>
<td>25,48</td>
<td>0,40</td>
<td>0,0157</td>
<td>2,22</td>
<td>6224</td>
<td>0,0358</td>
<td>0,0356</td>
</tr>
<tr>
<td>140</td>
<td>22,47</td>
<td>0,40</td>
<td>0,0178</td>
<td>2,52</td>
<td>7066</td>
<td>0,0324</td>
<td>0,0345</td>
</tr>
<tr>
<td>160</td>
<td>21,26</td>
<td>0,40</td>
<td>0,0188</td>
<td>2,66</td>
<td>7957</td>
<td>0,0330</td>
<td>0,0335</td>
</tr>
<tr>
<td>200</td>
<td>19,31</td>
<td>0,40</td>
<td>0,0207</td>
<td>2,93</td>
<td>8214</td>
<td>0,0342</td>
<td>0,0332</td>
</tr>
</tbody>
</table>
Graph of measured values

Coefficient of pipe friction vs. Reynolds number:

- \( \lambda \) measured
- \( \lambda_{th} \) theoretical

Laminar to Turbulent transition at Reynolds number range of 1000 to 7000.