Title	Experimental study on the viscosity of water and steam at high pressures and temperatures
Sub Title	
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Publisher	慶応義塾大学藤原記念工学部
Publication year	1967
Jtitle	Proceedings of the Fujihara Memorial Faculty of Engineering Keio University (慶応義塾大学藤原記念工学部研究報告). Vol.20, No.81 (1967.) ,p.207(31)- 208(32)
JaLC DOI	
Abstract	
Notes	Summaries of Doctor and Master Theses
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00200081-0031

Experimental Study on the Viscosity of Water and Steam at High Pressures and Temperatures

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1. Introduction.

During the past 50 years there has been an increasing demand for a more accurate determination of the properties of water substances. The paucity of experimental data at combined conditions of high pressures and temperatures is stressed. At our thermal engineering laboratory, there have been obtained considerable amount of results about thermodynamic properties of steam. Then we began to study on the transport properties of water substance. At first, we planned the measurement of the viscosity of water and steam in the pressure range up to 1000 ata and in the temperature range up to about 900°C

2. Experimental apparatus.

The experimental apparatus based on the transpiration of fluid through a capillary tube was designed. And two kinds of capillaries were prepared for this apparatus. One is made of Jena glass and the other of platinum. Each of them has about $0.25 \sim 0.37$ mm in bore and about 300 mm in length. Main parts of the experimental apparatus is consisted of the following five parts.

1) A glass or platinum capillary enclosed in high-temperature steel vessel placed in an electric furnace.
2) The measurement system for the rate of flow through the capillary.
3) The measurement system for the differential pressure through the capillary.
4) The system for temperature measurement.
5) The system for pressure measurement.

3. Capillary method

The simplest arrangement from the theoretical point of view is laminar flow pattern through a straight circular tube, socalled Poiseuille flow. This type of flow seems to be inherently stable, and the principal solution, apart from correction, is elementary. Poiseuille viscometers have shown themselves to be eminently successful in work with gases and can be regarded at present, as the most reliable viscometer under a wide range of experimental conditions.

It is easy to derive for a fully developed parabolic velocity profile, the volumetric rate of flow of the incompressible fluid.

Q is given by

$$Q = \frac{\pi r^4}{8\eta l} \cdot \Delta P \tag{1}$$

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where ΔP is the differential pressure across the tube over a length l, and r is radius.

Hence the viscosity η can be calculated if Q and ΔP are measured. The dimension l and r enter into the capillary constant. But two kinds of correction are necessary to modify eq. (1).

First the liquid entering the capillary is accelerated at the expense of the measured pressure drop. The amount of this conversion of static pressure to kinetic energy may be expressed as a part of the measured pressure drop by the addition of a term $m\rho Q^2/\pi^2 r^4$, in which m is a coefficient whose magnitude depends in part upon the flow pattern at the entrance of the tube. The second correction is that the resistance in converging and diverging streamlines at the ends of the tube is proportional to the radius and may be expressed as the length of the tube $(l+nr)$, in which n is a constant.

Then the equation for the flow through the tube is usually expressed as follows

$$\eta=\frac{\pi r^4\Delta P}{8Q(l+nr)}-\frac{8\pi(l+nr)}{m\rho Q} \tag{2}$$

4. Results.

After the calibration of the capillary, about 40 experimental points were obtained, 16 of which were obtained using the glass capillary. The measurements of compressed water using the glass capillary at the temperature near 100°C and in pressure range 100 to 500 ata are shown within the tolerance of the skeleton table by ICPS. Except two measured points which are considered not successfully measured, standard deviation of those 14 points is ± 0.8 %. By using platinum capillary, we examined the apparatus' condition at the temperature 400°C and in the pressure range 100 to 500 ata. But the results are unsatisfactory because of irregular behaviour of some apparatus. And now we are promoting the improvement of the apparatus, in order to expect the successful work.