Comparison of Stabinger and Glass Capillary Viscometer for Measuring Kinematic Viscosity of Unused Heat Transfer Fluids

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Abstract: Kinematic viscosity is an important physical property of unused heat transfer fluids. This paper uses Stabinger viscometer and glass capillary viscometer method for testing unused heat transfer fluids' kinematic viscosity and compares the results, in order to ensure the accuracy and reliability of the results. We tested the kinematic viscosity of the 85 samples. The analysis shows that Stabinger viscometer method can be applied to determine the kinematic viscosity of unused heat transfer fluids.

1. Introduction
The heat transfer fluids is a general term for organic substances used as a heat transfer medium, and includes all organic media used for indirect heat transfer purposes, such as heat transfer fluids, heat transfer oil, organic heat transfer medium, and heat medium. The maximum allowable operating temperature of the heat transfer fluids is determined according to the GB /T 23800 test. The maximum test temperature [1] under the condition where the measured heat transfer fluid's deterioration rate does not exceed 10% (mass fraction) can be divided into 280 ℃, 300 ℃, 310 ℃, 320 ℃, 330 ℃, 340 ℃, 350 ℃, 360 ℃, 370 ℃, 380 ℃, 390 ℃ and 400 ℃.

In the special equipment industry, the safe operation of boilers is closely related to people's lives [2]. Regarding organic heat carrier boilers, the TSG G0001-2012 "Boiler Safety Technical Supervision Regulations" for special equipment safety technology clearly states that "the quality of heat transfer fluid products should meet the requirements of GB 23971" heat transfer fluids "and pass the product type test. "[3] In GB 23971-2009" heat transfer fluids ", it is clearly pointed out that the method for determining the kinematic viscosity of heat transfer fluid is specified as GB / T 265" Petroleum Products Kinematic Viscosity Measurement Method and Dynamic Viscosity Calculation Method ". The latest version of this method is the 1988 version. It has been more than thirty years. The inspectors gradually found that the method takes a long time, relies on manual operation and detection, and causes greater pollution to the environment and personnel.

With the vigorous development of modern equipment technology, and ASTM D7042-10 "Determination of Dynamic Viscosity and Density of Petroleum Products and Calculation of Kinematic Viscosity Stabinger Viscometer" and NB/SH/T 0870-2013 The determination of viscosity and density and the calculation of the kinematic viscosity of the Stabinger Viscometer Law were promulgated. The Stabinger Viscometer has been gradually used for the measurement of liquid dynamic viscosity and kinematic viscosity. In the previous similar related method comparison study,
data comparison studies of base oil, lubricating oil, fuel oil and crude oil have been conducted [4], but there is no detailed comparison of the viscosity data of different types of heat transfer fluids. In this paper, the Stabinger viscometer method and the capillary viscometer method are mainly used to determine the kinematic viscosity of a large number of different types of heat transfer fluids at 40 °C and 100 °C at the highest operating temperature, and then compared the two methods.

2. The experiment

2.1. Sample
84 unused heat transfer fluids and 1 kinematic viscosity standard sample (Kenergy, USA).

2.2. instrumenttation
SVM 3000 Stabinger automatic kinematic viscosity tester produced by Anton Paar GmbH, DLX03B capillary kinematic viscosity tester produced by Dalian Lianxin Co., Ltd.

2.3. experimental method
According to NB / SH / T 0870-2013[6] "Determination of Dynamic Viscosity and Density of Petroleum Products and Calculation of Kinematic Viscosity Stabinger Viscometer" and GB / T 265-1988 "Determination of Kinetic Viscosity and Dynamic Viscosity of Petroleum Products" Two methods are used to test the samples without heat transfer fluids using the Stabinger viscometer method and the capillary viscometer method.

3. results and analysis

3.1. Choose each 10 kinds the highest working temperature (common) are 280 °C, 300 °C, 310 °C, 320 °C, 350 °C, 400 °C organic heating medium, at 40 °C, 100 °C, use manual Method and Stabinger Viscometer method (hereinafter abbreviated as SVM) to detect kinematic viscosity. For data comparison and statistical information, please refer to Table 1 to Table 6.

3.2. A total of 25 heat transfer fluids (including standard solution, American Kenergy) with a maximum use temperature of (special) 330 °C, 340 °C, and 380 °C are selected. The manual method and the Stabinger viscometer method are used at 40 °C and 100 °C Detect kinematic viscosity. The comparison and statistics of the data are shown in Table 7 (in recent years, there are no samples with the highest use temperature of 360 °C, 370 °C, and 390 °C, and there are few samples with the highest use temperature of 380 °C).

Table 1 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 280 °C (unit: mm² / s)

| number | Manual Method (40°C) | SVM (40°C) | RSD(%) | Manual Method (100°C) | SVM (100°C) | RSD(%) |
|--------|----------------------|-----------|--------|-----------------------|------------|--------|
| 280-1  | 29.18                | 29.18     | <0.01  | 5.031                 | 5.030      | 0.01   |
| 280-2  | 22.10                | 22.07     | 0.10   | 3.992                 | 3.994      | 0.04   |
| 280-3  | 21.58                | 21.77     | 0.62   | 3.981                 | 3.971      | 0.18   |
| 280-4  | 23.13                | 23.01     | 0.37   | 4.296                 | 4.284      | 0.20   |
| 280-5  | 37.88                | 37.98     | 0.19   | 5.973                 | 5.972      | 0.01   |
| 280-6  | 38.58                | 38.74     | 0.29   | 5.481                 | 5.478      | 0.04   |
| 280-7  | 4.083                | 4.082     | 0.02   | 1.379                 | 1.386      | 0.36   |
| 280-8  | 4.381                | 4.382     | 0.02   | 1.459                 | 1.463      | 0.19   |
| 280-9  | 32.86                | 32.64     | 0.48   | 5.310                 | 5.327      | 0.23   |
| 280-10 | 22.70                | 22.74     | 0.12   | 4.110                 | 4.109      | 0.02   |
Table 2 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 300 ℃ (unit: mm² / s)

| number | Manual Method (40℃) | SVM (40℃) | RSD(%) | Manual Method (100℃) | SVM (100℃) | RSD(%) |
|--------|---------------------|-----------|--------|-----------------------|------------|--------|
| 300-1  | 15.06               | 15.13     | 0.33   | 3.312                 | 3.313      | <0.01  |
| 300-2  | 23.04               | 22.96     | 0.25   | 4.560                 | 4.534      | 0.41   |
| 300-3  | 17.65               | 17.51     | 0.56   | 3.521                 | 3.522      | 0.02   |
| 300-4  | 10.16               | 10.17     | 0.07   | 2.180                 | 2.178      | 0.06   |
| 300-5  | 31.87               | 31.86     | 0.02   | 5.386                 | 5.395      | 0.12   |
| 300-6  | 29.34               | 29.46     | 0.29   | 4.294                 | 4.299      | 0.08   |
| 300-7  | 32.14               | 32.14     | <0.01  | 5.404                 | 5.423      | 0.25   |
| 300-8  | 20.14               | 20.11     | 0.11   | 3.820                 | 3.816      | 0.07   |
| 300-9  | 27.14               | 27.10     | 0.10   | 4.144                 | 4.153      | 0.15   |
| 300-10 | 28.09               | 27.88     | 0.53   | 4.204                 | 4.203      | 0.02   |

Table 3 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 310 ℃ (unit: mm² / s)

| number | Manual Method (40℃) | SVM (40℃) | RSD(%) | Manual Method (100℃) | SVM (100℃) | RSD(%) |
|--------|---------------------|-----------|--------|-----------------------|------------|--------|
| 310-1  | 39.13               | 39.46     | 0.59   | 5.397                 | 5.364      | 0.44   |
| 310-2  | 31.74               | 31.74     | <0.01  | 5.401                 | 5.363      | 0.50   |
| 310-3  | 30.96               | 30.95     | 0.02   | 5.409                 | 5.412      | 0.04   |
| 310-4  | 27.14               | 27.16     | 0.05   | 5.111                 | 5.109      | 0.03   |
| 310-5  | 28.16               | 28.16     | <0.01  | 5.063                 | 5.078      | 0.21   |
| 310-6  | 11.36               | 11.36     | <0.01  | 2.322                 | 2.324      | 0.06   |
| 310-7  | 10.36               | 10.44     | 0.54   | 2.244                 | 2.238      | 0.19   |
| 310-8  | 29.49               | 29.46     | 0.07   | 3.978                 | 3.962      | 0.29   |
| 310-9  | 11.78               | 11.77     | 0.06   | 2.340                 | 2.348      | 0.24   |
| 310-10 | 11.28               | 11.28     | <0.01  | 2.550                 | 2.548      | 0.06   |

Table 4 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 320 ℃ (unit: mm² / s)

| number | Manual Method (40℃) | SVM (40℃) | RSD(%) | Manual Method (100℃) | SVM (100℃) | RSD(%) |
|--------|---------------------|-----------|--------|-----------------------|------------|--------|
| 320-1  | 18.36               | 18.35     | 0.04   | 3.590                 | 3.608      | 0.35   |
| 320-2  | 9.140               | 9.140     | <0.01  | 2.114                 | 2.127      | 0.43   |
| 320-3  | 10.16               | 10.22     | 0.42   | 2.418                 | 2.420      | 0.06   |
| 320-4  | 29.33               | 29.46     | 0.31   | 5.331                 | 5.338      | 0.09   |
| 320-5  | 11.23               | 11.24     | 0.06   | 2.380                 | 2.379      | 0.03   |
| 320-6  | 26.39               | 26.36     | 0.08   | 4.659                 | 4.661      | 0.03   |
| 320-7  | 25.54               | 25.54     | <0.01  | 4.552                 | 4.550      | 0.03   |
| 320-8  | 9.810               | 9.820     | 0.07   | 2.363                 | 2.358      | 0.15   |
| 320-9  | 27.19               | 27.12     | 0.18   | 4.120                 | 4.118      | 0.03   |
| 320-10 | 5.240               | 5.230     | 0.14   | 1.587                 | 1.580      | 0.31   |
Table 5 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 350 °C (unit: mm² / s)

| number | Manual Method (40°C) | SVM (40°C) | RSD(%) | Manual Method (100°C) | SVM (100°C) | RSD(%) |
|--------|----------------------|------------|--------|-----------------------|------------|--------|
| 350-1  | 28.63                | 28.72      | 0.22   | 3.757                 | 3.760      | 0.06   |
| 350-2  | 15.02                | 15.01      | 0.05   | 2.913                 | 2.921      | 0.19   |
| 350-3  | 12.76                | 12.86      | 0.55   | 2.807                 | 2.796      | 0.28   |
| 350-4  | 28.54                | 28.64      | 0.25   | 3.786                 | 3.780      | 0.11   |
| 350-5  | 13.59                | 13.64      | 0.26   | 2.773                 | 2.771      | 0.05   |
| 350-6  | 26.27                | 26.30      | 0.08   | 3.770                 | 3.766      | 0.08   |
| 350-7  | 28.90                | 29.12      | 0.54   | 3.884                 | 3.902      | 0.33   |
| 350-8  | 15.85                | 15.71      | 0.63   | 3.212                 | 3.208      | 0.09   |
| 350-9  | 30.52                | 30.50      | 0.05   | 4.107                 | 4.096      | 0.19   |
| 350-10 | 28.25                | 28.26      | 0.03   | 3.784                 | 3.790      | 0.11   |

Table 6 The kinematic viscosity data of the unused heat transfer fluids for the maximum permitted bulk temperature 400 °C (unit: mm² / s)

| number | Manual Method (40°C) | SVM (40°C) | RSD(%) | Manual Method (100°C) | SVM (100°C) | RSD(%) |
|--------|----------------------|------------|--------|-----------------------|------------|--------|
| 400-1  | 2.524                | 2.523      | 0.03   | 1.003                 | 1.008      | 0.35   |
| 400-2  | 2.522                | 2.520      | 0.06   | 1.004                 | 1.006      | 0.14   |
| 400-3  | 2.509                | 2.520      | 0.31   | 1.010                 | 1.008      | 0.14   |
| 400-4  | 2.521                | 2.524      | 0.08   | 1.012                 | 1.009      | 0.21   |
| 400-5  | 2.520                | 2.522      | 0.06   | 1.011                 | 1.010      | 0.07   |
| 400-6  | 2.538                | 2.532      | 0.17   | 1.058                 | 1.054      | 0.27   |
| 400-7  | 2.537                | 2.533      | 0.11   | 1.023                 | 1.020      | 0.21   |
| 400-8  | 2.514                | 2.520      | 0.17   | 1.009                 | 1.011      | 0.14   |
| 400-9  | 2.531                | 2.534      | 0.08   | 1.010                 | 1.010      | <0.01  |
| 400-10 | 2.521                | 2.528      | 0.20   | 1.003                 | 1.006      | 0.21   |

Table 7 The kinematic viscosity data of the unused heat transfer fluids for special maximum permitted bulk temperature (unit: mm² / s)

| number | Manual Method (40°C) | SVM (40°C) | RSD(%) | Manual Method (100°C) | SVM (100°C) | RSD(%) |
|--------|----------------------|------------|--------|-----------------------|------------|--------|
| 330-1  | 16.44                | 16.28      | 0.69   | 3.143                 | 3.148      | 0.11   |
| 330-2  | 5.460                | 5.461      | 0.01   | 1.602                 | 1.604      | 0.09   |
| 330-3  | 16.65                | 16.66      | 0.04   | 3.204                 | 3.200      | 0.09   |
| 330-4  | 15.62                | 15.62      | <0.01  | 3.110                 | 3.113      | 0.07   |
| 330-5  | 3.040                | 3.050      | 0.23   | 1.194                 | 1.198      | 0.24   |
| 330-6  | 30.48                | 30.67      | 0.44   | 4.080                 | 4.074      | 0.10   |
| 330-7  | 31.95                | 31.90      | 0.11   | 4.000                 | 4.003      | 0.05   |
| 330-8  | 14.88                | 14.92      | 0.19   | 3.044                 | 3.052      | 0.19   |
| 330-9  | 2.520                | 2.520      | <0.01  | 1.083                 | 1.080      | 0.20   |
### 3.3 RSD
Relative standard deviation (RSD, %) is used to analyze the precision of test results in inspection and testing work. RSD is usually required to be within 5% in routine analysis; in the Chinese Pharmacopoeia, the RSD for sample content determination is strictly required to be within 2%.

According to Table 1 to Table 7, the RSD results of the two kinematic viscosity detection methods show that the precision of the two methods is extremely high, and 95.0% of the RSDs are below 0.5%.

### 4. Conclusion
As can be seen from the large amount of data above, compared with the GB / T 265-1988 [5] capillary manual determination of kinematic viscosity method, the Stabinger viscometer method has higher precision and no significant difference in data; At the same time, whether it is a single injection or an automatic sample tray, the detection efficiency of the Stabinger viscometer method is much higher than the manual determination of kinematic viscosity method; and in the cleaning process after detection, the Stabinger viscometer method can be automatically cleaned. Compared with the manual determination of kinematic viscosity method, it avoids the contact and volatilization of a large amount of organic solvents, and to a large extent avoids human damage and environmental pollution.

A total of 85 heat transfer fluids samples were tested in this project, with a total of 340 kinematic viscosity data. The sample type covers most of the unused heat transfer fluids samples with different maximum operating temperatures on the market. It can provide supplements and amendments to the relevant standards for organic heat carriers such as GB 23971 "Organic Heat Carrier " and GB / T 24747 "Technical Conditions for Safety of Organic Heat Carrier " in the preparation (revision) of kinematic viscosity detection methods, providing important and solid data support and technical support.

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