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## **DEGREE OF POLYMERIZATION OF CELLULOSE** **ASTM D 4243**

Cellulose is used throughout transformers in the form of insulating papers and boards. Cellulose is a polymeric material of cellobiose,  $-\text{[C}_{12}\text{H}_{14}\text{O}_4(\text{OH})_6\text{]}_n-$ , where  $n$  is in the range of 300 to 700 units. Cellobiose itself is made up of two glucose units,  $\text{C}_6\text{H}_7\text{O}(\text{OH})_5$ . In a sample of cellulose there is a variety of different size molecules of the polymeric material. There are a number of methods available to determine the average molecular weight of such samples. The method described herein uses the determination of the intrinsic viscosity,  $[\eta]$ , and the value obtained is referred to as the average viscometric degree of polymerization,  $\_Pv$ . In order to measure the viscosity of a cellulose sample it must first be dissolved in a suitable solvent system. Such a solvent system that works well for dissolving cellulose is a cupriethylene-diamine solution.

### Procedure:

The entire details for determining the average viscometric degree of polymerization are given in the ASTM D 4243 method and are only briefly mentioned here. A sample of the cellulose is degreased with hexane in a Soxhlet extractor, dried, and conditioned in a controlled humidity environment. A weighed sample of the cellulose is then dissolved in the cupriethylene-diamine solution by tumbling it in a sealed flask with glass balls. The dynamic viscosity of the resulting solution is determined and by comparing it with the viscosity of the cupriethylene-diamine solvent, one can calculate the intrinsic viscosity and the average viscometric degree of polymerization.

### Significance:

The average viscometric degree of polymerization represents the average number of glucose units in the cellulose polymer and these values can range from 800 to 1600 units with the most probable value being about 1200. As the paper undergoes aging these polymer chains degrade into smaller units or if the paper is subjected to a severe fault such as overheating or arcing the polymers will also be degraded. As shorter length chains are formed this lowers the average degree of polymerization. Thus this method allows one to assess the condition of the cellulose insulation within the unit. Since these values do represent averages, when evaluating a sample of cellulose it should be compared to a fresh sample of the same origin. Fresh Kraft paper will have a  $\_Pv$  around 1100 to 1200. After factory drying tests this value will drop to 800 to 1000 and then decreases exponentially with time. A tentative value of about 150 is used to indicate the end of the useful life of the cellulose. For partial rewinding of failed coils, a minimum value of 250 has been used.

It should be pointed out that this test requires a sample of paper, which means that the unit must be taken out of service to be sampled. Furthermore it is an intrusive test that destroys the sample being tested and decreases the amount of the material left in the unit, which might be deleterious to the unit. Methods that sample the oil and look for degradation products of the paper, such as furanic type compounds, are under development at the present time.