

Annex D

(informative 仅提供信息)

Dew point test 露点试验

D.1 General

A number of measuring techniques are used to determine the amount of moisture remaining in the transformer insulation. Dew point testing is a measurement of surface moisture and not the average moisture in the insulation. Dew point testing is a reliable technique to estimate moisture. The dew point temperature is the temperature at which water or dew and water vapor present in gas in the transformer tank are in equilibrium at a given gas pressure. In other words, at this temperature liquid water evaporates at the same rate at which it condenses. 有许多测量技术用于确定变压器绝缘材料中残余湿度量。露点测试是一种测量表面湿度而不是绝缘材料中平均湿度的技术。露点测试是一种可靠的估算湿度的技术。露点温度是指在给定气压下，变压器油箱中气体中水或露和水蒸气达到平衡的温度。换句话说，这个温度下液态水以与其凝结速度相等的速度蒸发。

Moisture content determined by measuring the dew point is the “average” surface moisture. It is very important to know that the average temperature of the insulation needs to be reasonably accurate to minimize the magnitude of the error produced in the conversion process. 通过测量露点确定的湿度含量是指表面平均湿度。要尽量减小在转换过程中产生的误差幅度，了解绝缘材料的平均温度是非常重要的。

D.2 Dew point test 露点试验

When to perform dew point measurement: 进行露点测量时应:

- a) Upon initial rail or truck inspection if the transformer pressure gauge indicates a loss of pressure. A dew point measurement should be taken to determine whether moisture has entered the unit. 在初次铁路或运输车辆检查时，如果变压器压力表指出压力损失。则应进行露点测量以确定水分是否已进入设备。
- b) After assembly of the transformer and prior to vacuum filling the unit, dew point should be measured to confirm that the unit is sufficiently dry. 变压器组装后和注入真空前，应测量露点以确认设备足够干燥。

D.2.1 Procedure 试验程序

Seal the unit and evacuate to 2 mm Hg for 4 h. Relieve the vacuum in the transformer tank with dry air to 3 psi and then allow it stand for 12 h so that the vapor pressure in the insulation and the gas approaches equilibrium. 将设备密封，并抽空4小时至 2 mm Hg。用干燥空气将变压器油箱中的真空度降低到 3 psi，然后静置 12 小时，使绝缘和气体中的蒸气压达到平衡。

The dew point of the gas in the tank is then measured along with the temperature of the transformer insulation and the pressure inside the tank. From these measurements the moisture remaining in the insulation is estimated using available curves. If the measurement is within the acceptable range on the dew point limit curve then proceed with vacuum filling. If the measurement is not within the acceptable range then additional processing is required to remove moisture. 然后测量油箱中气体的露点以及变压器绝缘的温度和油箱内的压力。根据这些测量结果，可以使用现有曲线估算绝缘材料中残留的水分。如果测量值在露点极限曲线上的可接受范围内，则继续进行抽真空。如果测量值不在可接受的范围内，则需要额外处理以去除水分。

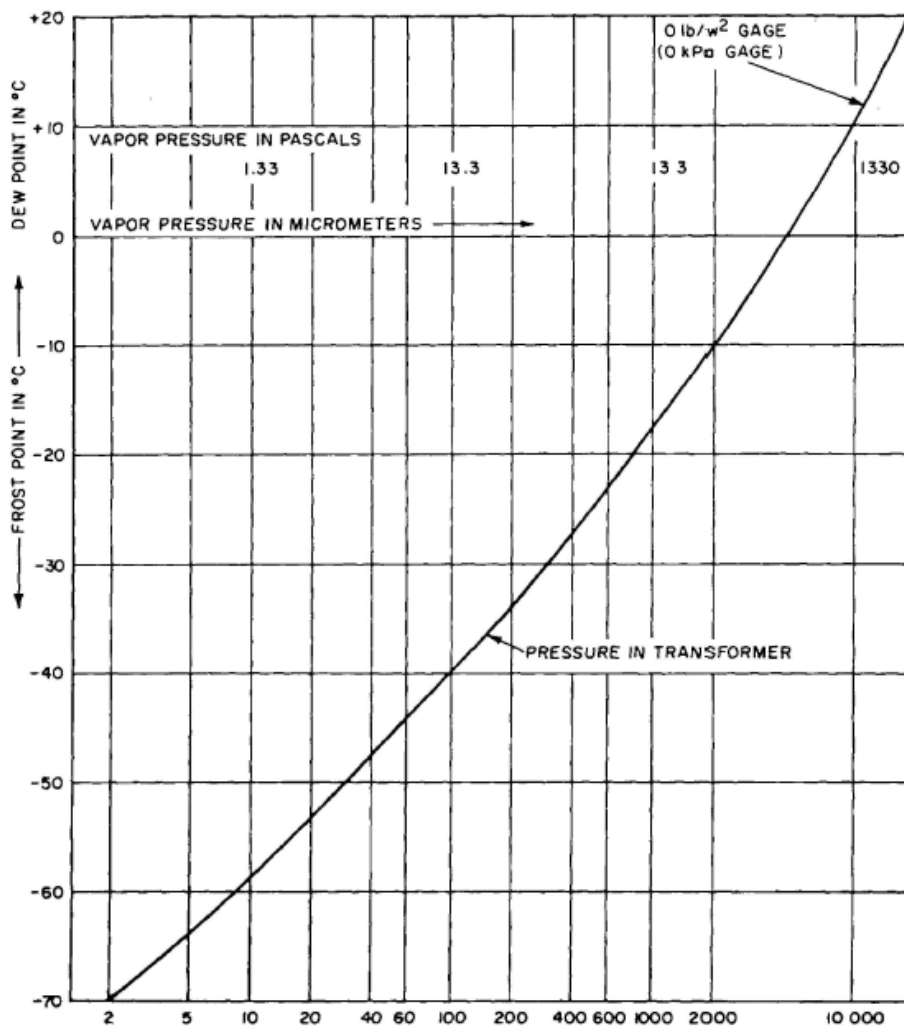
D.2.2 Example 举例

The following example clarifies the procedure: 以下例子阐述了该过程:

Measured dew point 测量露点 = -45°C
Insulation temperature 绝缘温度 = 20°C
Pressure in tank 油箱内压力 = 2.0 psig (13.8 kPa)
Atmospheric pressure 空气压力 = 14.7 psi (101.325 kPa)

On Figure D.1, read the vapor pressure corresponding to a dew point of -45°C as $60\text{ }\mu\text{m}$ (8 Pa). Correct this vapor pressure for the overpressure in the tank of 2.0 psig (13.8 kPa) as follows: 在图 D.1 中, 读出对应于 -45°C 露点的蒸汽压为 $60\text{ }\mu\text{m}$ (8 Pa)。针对 2.0 psig (13.8 kPa) 的油箱内过压修正此蒸汽压, 如下所示:

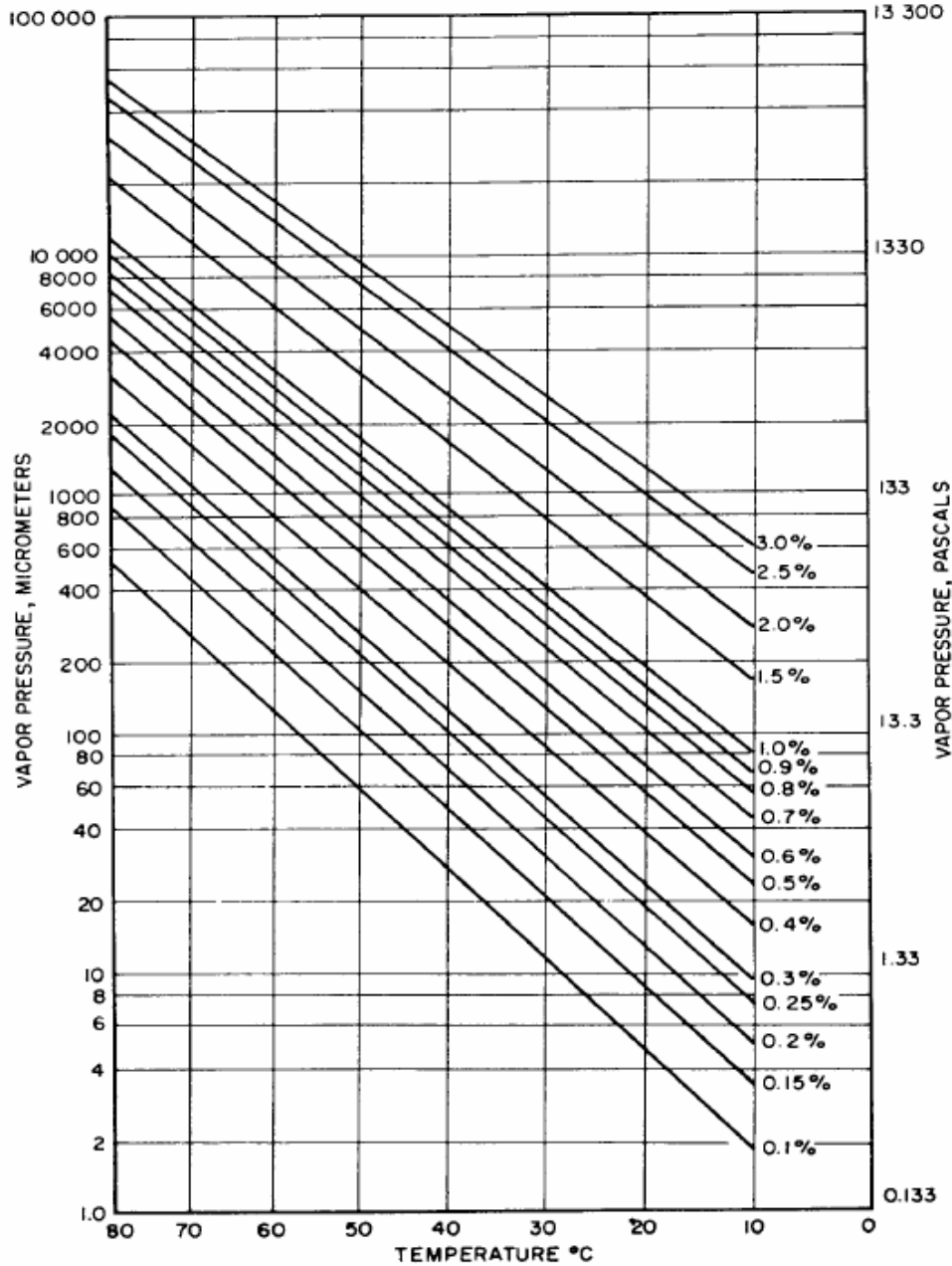
$$[(14.7 + 2.0) \times 60] / 14.7 = 68\text{ }\mu\text{m} \text{ or } [(101.325 + 13.8) \times 8] / 101.325 = 9.1\text{ Pa}$$



Source 来自: IEEE Std C57.93.

Figure D.1—Conversion from dew point or frost point to vapor pressure
图 D.1——露点或霜点到蒸汽压的转换

Now using the moisture equilibrium chart, Figure D.2, find the intersection of 20°C insulation temperature and $68\text{ }\mu\text{m}$ (9.1 Pa) of vapor pressure. Read the moisture content of approximately 0.6% from the diagonal lines labeled in percent moisture content. 现在使用水分平衡图, 图 D.2, 找到 20°C 绝缘温度和 $68\text{ }\mu\text{m}$ (9.1 Pa) 蒸汽压的交点。从标有水分含量百分比的对角线上读取大约 0.6% 的水分含量。



Source: IEEE Std C57.93.

NOTE—This chart was prepared using information from a Piper Chart (see Piper [B65]), which was extrapolated and interpolated from published data on cotton paper. Piper gave a multiplication factor of 1.7 to use for Kraft paper (non-thermally upgraded). This chart incorporates the 1.7 factor, and the values obtained need to be corrected. It should be noted that equilibrium moisture content of cellulose is dependent on whether equilibrium is approached by absorption or desorption, since there is a hysteresis effect. 请注意：本图表是使用Piper图表（参见Piper [B65]）中的信息编制的，该图表是根据棉纸的已发布数据进行外推和内插得出的。Piper为Kraft纸（非热升级）提供了一个乘法系数为1.7。本图表包含了这个1.7的系数，并且得到的数值需要进行修正。值得注意的是，因为存在滞后效应，纤维材料的平衡湿度取决于是否通过吸湿或脱湿来接近平衡。

Figure D.2—Moisture equilibrium chart (with moisture content in percent of dry weight of insulation) 图 D.2——水分平衡图（水分含量占绝缘干重的百分比）