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# Interfacial Tension Test of Transformer Oil

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***Abstract-****The interfacial tension (IFT) test indicates the presence of sludge in transformer insulating oil. This test measures the concentration of polar molecules in the oil and thus gives an accurate measurement of dissolved sludge in the oil. Surface tension of a new oil is high. But after a time interval, due to mechanical and electrical stress, oil becomes contaminated and deteriorated. It leads to diminished performance. To maintain the life of the transformer and to avoid breakdowns, regular testing of the transformer oil is necessary. Typically for mineral oil, new oil has a minimum reading of 40 dynes/cm and an in-service oil is good until 25 dynes/cm. It has been established that an IFT of less the .015 N/m (15 dyne/cm) shows sludge presence. An IFT of 0.015 to 0.022 N/m (15 to 22 dyne/cm) shows an uncertain condition, and an IFT value of more than 0.022 N/m (22 dyne/cm) indicates no sludging. If the IFT decrease below 0.022 N/m (with a change in the color), the oil should be tested or replaced if necessary. A lower IFT indicates the deterioration of oil as well as aging of the insulation system.*

***Keywords-Du Nouy Ring, Interfacial Tension, Polar molecules, Sludge, Surface Tension***

## I. INTRODUCTION

Transformer oil usage is growing day by day because of major expansion of electrical network in developing countries. This has resulted inincrease in demands of transformer oil.Oil is an important factor in transformer. But after a time interval, transformer oil undergoes mechanical and electrical stress. This results in chemical impurity of oil and leads todiminishedperformance. If not maintained properly, it can result in power breakdown. Hence the transformer oil must be tested at regular interval.The interfacial tension of oil is related to the purity of the oil.In this test, we measure the surface tension of the oil against that of water.The device which determines the interfacial tension is known as tensiometer. It is based on the Du Nuoy principle. This test is fast and accurate method of determining the deterioration of oil.

## II. INTERFACIAL TENSION TEST

The interfacial tension of oil insulating fluid is related to the purity of the oil.Water is polar in nature.Transformer oil is a non-polar saturated hydrocarbon. When the oil undergoes oxidative degradation, carboxylic acids are formed which are hydrophilic in nature. In this test, surface tension of the oil is measured against that of water. The value of the surface tension is lower for the deteriorated oil. Thus if the concentration of hydrophilic materials in the transformer oil is high then the interfacial tension of the oil measured against water will be low. This standard of this method is given in ASTM D971 and IS: 6104-1971. The device used to determine the IFT is known as tensiometer. It is based on the Du Nuoy principle. The oil sample is carefully floated on top of a layer of water. The force necessary to pull a platinum ring upward from below the water level through the oil is measured by using a calibrated load cell. The force is measured at the point when the ring breaks free of the water layer i.e. the interface of water and oil as it is being pulled upward through the oil layer. There are correction factors that have to be considered relating to the dimensions of the ring and the densities of the water and sample. The result is in units of dynes/cm or milliNewtons/meter (mN/m).

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## III. BLOCK DIAGRAM

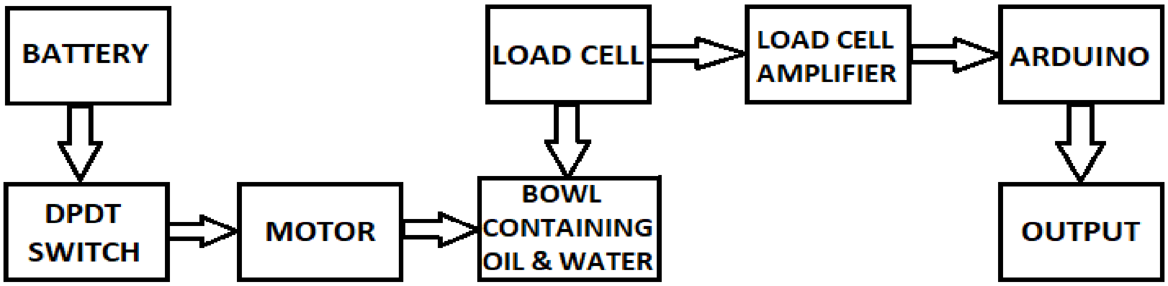


**Fig. 3 Block diagram of IFT Test**

## IV. COMPONENTS

### 4.1 Du Nuoy Ring

**Fig. 4.1 Du Nuoy Ring**

Du Nuoy ring is made up of Platinum and Iridium. It has specific dimensions. The stirrup has parallel sides of 25 mm height. The ring is packed in a protective container. It has a mean circumference of approximately 60 mm and thickness of 0.4 mm. It is dipped in the bowl containing water and oil. At the interface, it is pulled up and load cell will sense the pulling force.

### 4.2 Load Cell

**Fig. 4.2 Load Cell**

A load cell is a force sensing module. It has strain gauges mounted in precise locations on the structure. Load cells measure a specific force, and ignore other forces being applied. It is mounted on top of the kit. The electrical signal output of the load cell is very small. Hence it requires specialized amplification. Load cells measure force in one direction.

### 4.3 HX711 Load Cell Amplifier

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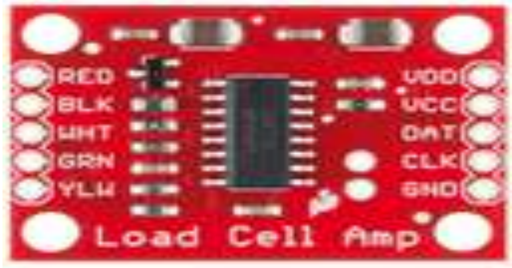


**Fig. 4.3 Load Cell Amplifier**

HX711 is a precision 24-bit analog to-digital converter (ADC). It is used in weighing scales and industrial control applications. It is directly interfaced with a load cell.HX711 Load cell amplifier is a board for HX711 IC that allows load cells to measure the weight exerted on the load cell. Load cell is connected with this amplifier. By connecting the amplifier to Arduino, changes in weight on the load cell is recorded.

### 4.4 Arduino Uno


**Fig. 4.4 Arduino Uno**

Arduino Uno board is a microcontroller which has 14 digital input/output pins in which 6 can be used as PWM outputs, an ICSP header, 6 analog inputs, a power jack, a reset button and a USB connection. It contains all the required support needed for microcontroller. To get started, it is simply connected to a computer with a USB cable. Load Cell and HX711 load cell amplifier are connected to it as input.

### 4.5 DC Motor

**Fig. 4.5 Motor**

Geared DC motor is used to move the sample oil platform upward and downward. Diameter of shaft is 6mm. It is used to connect gears or wheels. These gears are arranged with the Rack and pinion gear. Here motor with speed of 3.5 rpm is used. Motor is supplied with battery of 12V DC. Torque provided by this motor is 5kgcm.

## V. PROCEDURE

- Take a sample of oil, at least 25 mL, in accordance with standard method of ASTM and IS.

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- Take a fresh sample of distilled water (50 to 75 mL)for interfacial tension measurements.
- Distilled water should be covered, capped, or sealed. Atmospheric dust and vapour can easily contaminate water, as can the growth ofbacteria.
- Introduce distilled water at a temperature of 25°Cinto a clean sample container to a depth of 10 to 15 mm. Placeit on the platform so that the ring comes down inthe centre of the container and is not close to any wall.
- Make sure no foam is present at the water surface. If foam is visible,discard the water. Foam indicates that the water is contaminatedor that the vessel is not clean.
- Clean the ring and hook it to the load cell.
- Raise the platform until the ring is immersed to adepth not to exceed 6 mm into the water.
- Slowly lower the platform. As the film of liquid adheringto the ring approaches the breaking point, proceed slowly withadjustments. Rupture the surface by lowering the bowl.
- Record the reading when rupture occurs. Surface tension is calculated using the value 0.997 g/cm3 for (D-d), the difference in density between water and air. A value of 25-45 mN/m must be obtained. If low values are found, clean and rinse the sample container thoroughly and obtain a fresh sample of water froma different source of supply. If low surface tension values are still obtained, check calibration of the load cell and examine the ring to ensure the plane of the ring is parallel to the water surface.
- Carefully layer the oil on the surface of the water (with the ring submerged) until a depth of at least 10 mm is reached. One such procedure is to pipette the oil onto the surface slowly so that minimum mixing occurs and so that oil does not touchthe surface of the submerged ring. Make sure that the oil is not so deep as to cover the ring cross bar.
- Allow the oil-water interface to age for 30s after the last of the oil has been layered onto the water.
- Lower the platform and record the value at rupture. Time this part of the measurement so that, as nearly as possible, 30 s are required to draw the ring through the interface. Proceed very slowly as the breaking point is approached, since the break is usually sluggish (due to viscosity of the oil). Complete the entire operation, from the time of pouring the oil onto the water until the interface ruptures, in about 60s.
- Calibrate the load cell against known weights and adjust its zero point according to the procedure of its manufacturer.
- Make certain that all portions of the ring are in the same horizontal plane

## VI. CALCULATION

Calculate the Surface tension of the sample by means of the following equation;

$$\gamma = \frac{F}{4\pi R}\left({}^{mN}/_{m}\right) \quad (1)$$

Where, $\gamma = \text{surface tension}$

R= Centre diameter of the ring

$$F = ma\left({}^{kg.m}/_{s^2}\right) \quad (2)$$

Where, F=force acting on the ring

m=mass in kg

a= acceleration due to gravity=9.80665 $\left({}^{m}/_{s^2}\right)$

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Calculate the Correction factor by following equation;

$$C = 0.7250 + \sqrt{\frac{1.452\gamma}{i^2(D-d)} + 0.04534 - \frac{1.679}{R/r}} \quad (3)$$

Where, i =circumference of ring, mm,

D=density of water at 25°C, g/mL,

d = density of test specimen at 25°C, g/mL,

R = radius of ring, mm,

r= radius of wire of ring, mm.

Now, we calculate the interfacial tension by following equation;

Interfacial tension =$\gamma \times C$ (mN/m)

## VII. RESULT

**Table no.**
**7 Practical Result**

| Type of Oil | Minimum IFT Value (in dynes/cm) |
|---|---|
| New Oil | 35 |
| Used for System KV < 69 KV | 24 |
| 70 KV - 288 KV | 26 |
| > 288 KV | 30 |
| For C.B. - New Oil | 40 |
| - In Use | 25 |
| Limit for Oil-Reclamation | 20 |

## VIII. CONCLUSION

Transformer oil usage is expected to grow in near future because of a major expansion of electric network and upgradation of transformers in developing countries. Hence demands of transformer oil will also increase. To manage and extend transformer life, purity of oil must be maintained. If not maintained, it can lead to breakdown of transformer. To avoid harsh breakdowns, regular testing of the transformer oil is must. Our project i.e. Interfacial Tension Test of transformer oil measures the tension at the interface between two liquids (oil and water). This test senses the presence of oil decay products and soluble contaminants in the liquid. Reduced value of interfacial tension shows the sludge content in oil. By testing the oil at scheduled time, we can repair or replace the transformer before a failure occurs.

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