**Chittagong University of Engineering & Technology**

*Department of Electrical and Electronic Engineering*

# Design of a 3- $\varphi$ Distribution Transformer

**COURSE NO.** : EEE 352

**COURSE TITLE** : Electrical Machine Design.

| Submitted to | Submitted by |
|---|---|
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**REMARKS**

GROUP

7

## 1.1 Objective:

- To design a distribution transformer using the given parameter.
- Regulation on full load at 75 °C at unity power factor and at 0.8 power factor lagging.
- Efficiency at 75 °C on full load,75% load, and 50% load at unity power factor.

## 1.2 Various Design Parameter:

| | |
|---|---|
| **Rating** | **456 KVA** |
| **Phase** | **3** |
| **Frequency** | **50 Hz** |
| **Primary Voltage** | **11 KV** |
| **Secondary Voltage** | **415 V** |
| **Primary Connection** | **Delta** |
| **Secondary Connection** | **Wye** |
| **Tapping on HV** | **±2.5, ±5** |
| **Load loss** | **≤ 7 kW** |
| **% Z** | **4.50%** |
| **Max Temp. Rise** | **60 °C** |
| **Cooling** | **Oil-immersed natural cooled** |

## 1.3 Voltage per turn:

Voltage per turn, $E_t = \frac{\sqrt{\frac{KVA \times 1000}{No.of\ legs}}}{40}$

$= \frac{\sqrt{\frac{456 \times 1000}{3}}}{40}$

$= 9.7467$ volts/turn

$= 9.75$ volts/turn

## 1.4 Specific Magnetic Loading:

- Choice of core material: CRGO steel lamination of 0.35 mm thickness; mitered core construction is used; mitered at 45℃.
- Choice specific magnetic loading: $B_{max}$= 1.7 Tesla
- Choice of current density: $\delta$ =2.5 A/mm$^2$

## 1.5 Cross Section area of the core:

We know, $E_t = 4.44 \times B_m \times f \times A_i$

Where, $B_m$ = flux density; Tesla f=50 Hz

Net cross sectional area of the core is:

$A_i = \frac{E_t}{4.44 \times Bm \times f}$

$= \frac{9.75}{4.44 \times 1.7 \times 50}\ mm^2$

$= 25834.65819\ mm^2$

$= 25834.66\ mm^2$.

## 1.6 Choice of core section:

Choosing 7 step core, so the area should be nearly circular.

**In case of a 7 step core**:

$K_i$ = iron space factor = 0.88 & Stacking factor for laminations, $K_s$ =0.92

$A_i = K_i \times K_s \times \frac{\pi}{4} \times d^2$

$\rightarrow d = \sqrt{\frac{25834.66 \times 4}{0.92 \times 0.88 \times \pi}}$

$d$= 201.57 mm ≈ 202 mm

Then the area $A_i = K_i \times K_s \times \frac{\pi}{4} \times d^2$

$A_i = 0.88 \times 0.92 \times \pi \times 202^2/4$

$= 25945.56\ mm^2$

With this area, $B_m = \frac{E_t}{4.44 \times f \times Ai}$

$= \frac{9.75}{4.44 \times 50 \times 25945.56 \times 10^{-6}}$

$B_m = 1.69\ Wbm^{-2}$

## 1.7 <u>Window area(assumption)</u>:

Window space factor (kw) is taken approximately as 0.30

We know, $S = 3.33 \times A_i \times A_w \times K_w \times \delta \times B_m \times f \times 10^{-3}$

$A_w = \frac{456}{3.33 \times 25945.56 \times 0.3 \times 2.5 \times 1.69 \times 50 \times 10^{-3}}$

$= 83279.79 \approx 83280\ mm^2$

Window width , $W_w$= 166 mm

Window height = $\frac{83280}{166}$ mm $= 501.68\ mm$;we choose the height of the window 500 $mm$.

Now, Window Area = $(166 \times 500)\ mm^2 = 83000\ mm^2$.

So, the main dimension of the core and window are, d = 202 mm

D = distance between the centers of the adjacent limbs

=166+(202×0.95) = 358 mm

For seven step core largest core width is = (202×0.95) = 192 mm

Total width = (2×358) + (202×0.95) = 908 mm

Total height = 500+192+192 = 884 mm.

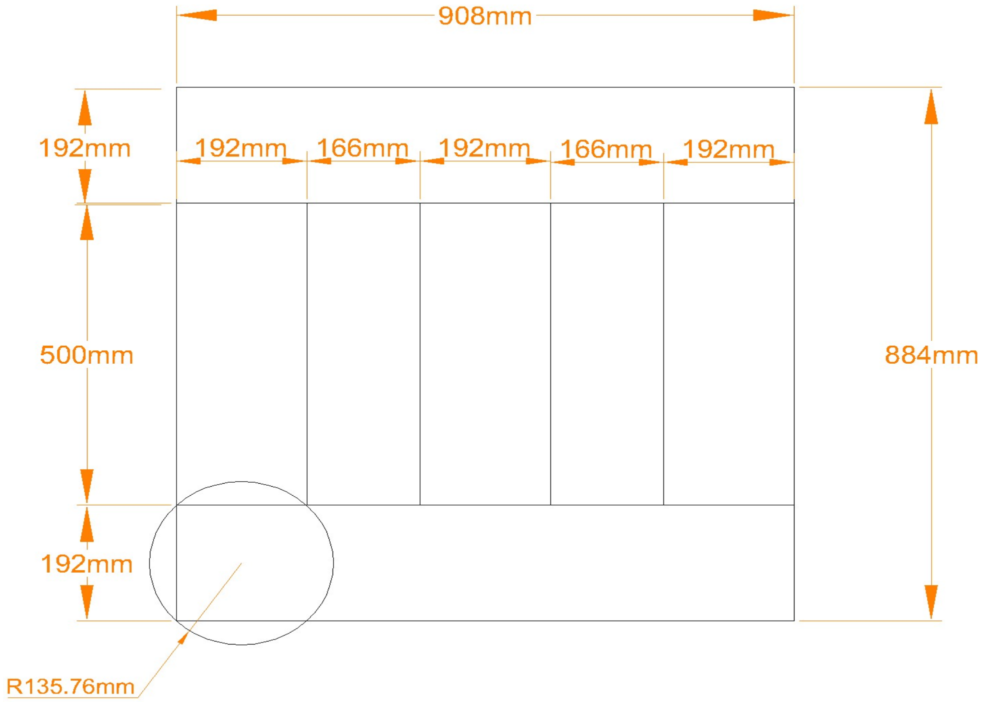


**Fig.1.** Schematic of core and assembly.

## Design of Windings

### 1.8 Number of turns in L.V. Winding (Δ-yn):

Voltage per phase = $\frac{415}{\sqrt{3}}$ =239.6 Volts

Turns per phase = 239.6/9.75 =24.57≈ 25 turns

### 1.9 Number of turns in H.V. Winding (Δ-yn):

Voltage per phase =11 kV (H.V. is delta connected)

Turns per phase = $(11 \times 1000)/9.75$ =1128.2 ≈ 1130 turns (Choosen)

Tapings of $\pm 5\%$ and $\pm 2.5\%$ are to be provided on the H.V. winding .

| Tapping | 5% | Normal | 2.5% |
|---|---|---|---|
| More | 1187 turns | 1130 turns | 1158 turns |
| Less | 1074 turns | 1130 turns | 1102 turns |

## 1.10 L.V. Winding Area($a_2$):

Current per phase = $\frac{456\times10^3}{\sqrt{3}\times415}$ = 634.38 A ≈ 635 A

Here, we choose helical cylindrical coil.

Current Density $\delta = 2.5$ A/mm$^2$ (assumed)

Area of L.V. conductor, $a_2$ =635/2.5 = 254 mm$^2$

Choosing, rectangular copper conductor from IS: 1897:1962 specs. For rectangular copper conductors for electrical machines (*Appendix*), giving area near about the required one.

## 1.11 H.V. Winding Area($a_1$):

Current per phase = $\frac{456\times10^3}{3\times11\times10^3}$ = 13.81 A ≈ 14 A. [ being delta connected.]

Area of H.V. conductor, $a_1$ =$14/2.5$ = 5.6 mm$^2$ ≈ 6 mm$^2$.

# Design & Layout of Windings

## 1.12 Design & Layout of L.V Windings:

Now for L.V winding choosing rectangular copper conductor,

Let, Cross Section = $T \times W$

$$= (5.6\ \times 11.33)[4\ conductor\ sytrips]$$

So, Forming conductor of L.V area, $a_2$ = $(5.6\ \times 11.33\ \times 4)$

$$= 254\ mm^2$$

Number of turns in L.V. = 25 turns

**Size of conductor**: 4 strips of (5.5 × 11.33) mm, cooper rectangular conductor.

Considering paper insulation of conductor = $\{(5.6 + 0.25) \times (11.33 + 0.25)\}$ $mm^2$.

Choosing 1 layer for L.V. winding; turns per layer=25/1 $= 25$.

Width of conductor (11.33+0.25) =11.58 mm is taken along the window.

With 4 conductor sides $(5.6 + 0.25) \times 4$ =23.4 mm forming conductor per layer.

For 1 layer the dimension of conductor width rise is 23.4 mm.

Height of L.V. winding in window = $(25 \times 11.58)$ =289.5 mm.

Thickness of L.V. winding = $1 \times 23.4$ = 23.4 mm.

distance between core and L.V coil = 3.5 mm.

Inside diameter of L.V. coil = $202 + (2 \times 3.5)$ = 209 mm.

Outside diameter of L.V. coil = $\{209 + (2 \times 23.4)\}$ = 255.8 mm$\cong 256\ mm$.

mean diameter of L.V. coil = (256+209)/2 = $232.5\ mm \approx 233\ mm$.

mean length of turn of L.V. coil = $\pi d = \pi \times 233 = 731.99\ mm \approx 732\ mm$.

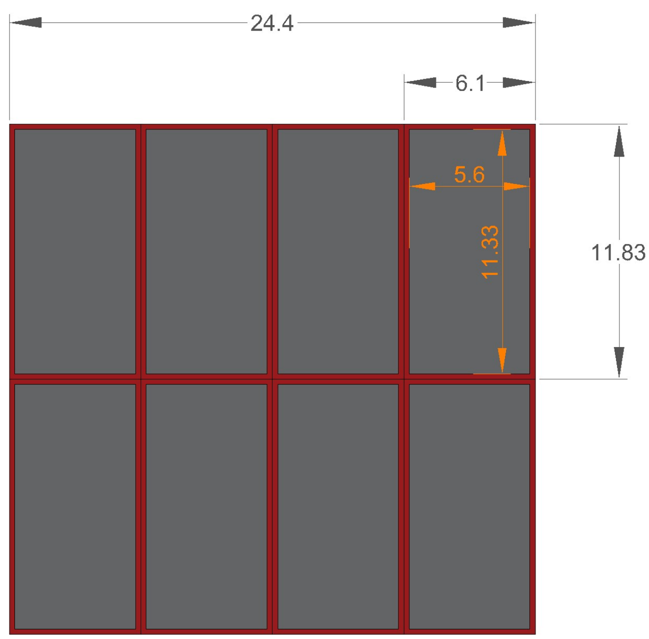


**Fig.2.** Dimension of single conductor in the layer.

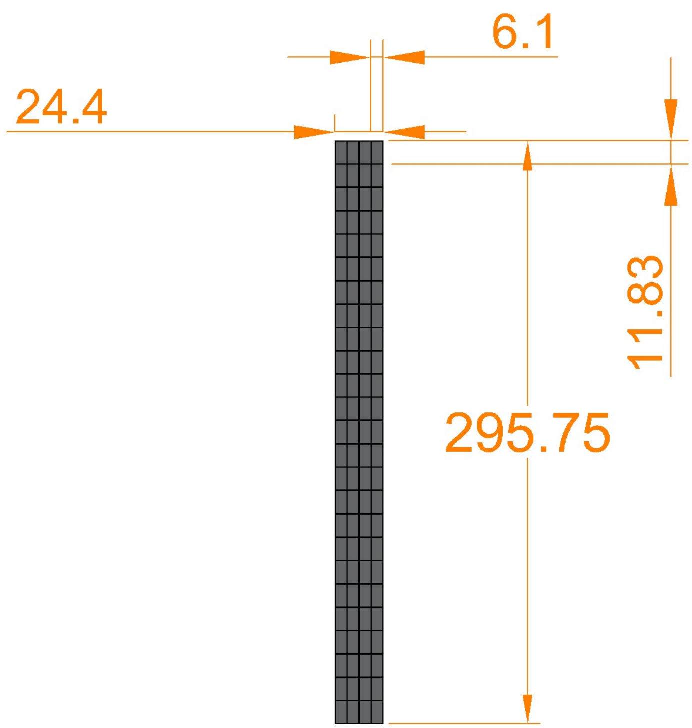


**Fig.3.** Dimension of 4 strips conductor in a single layer.

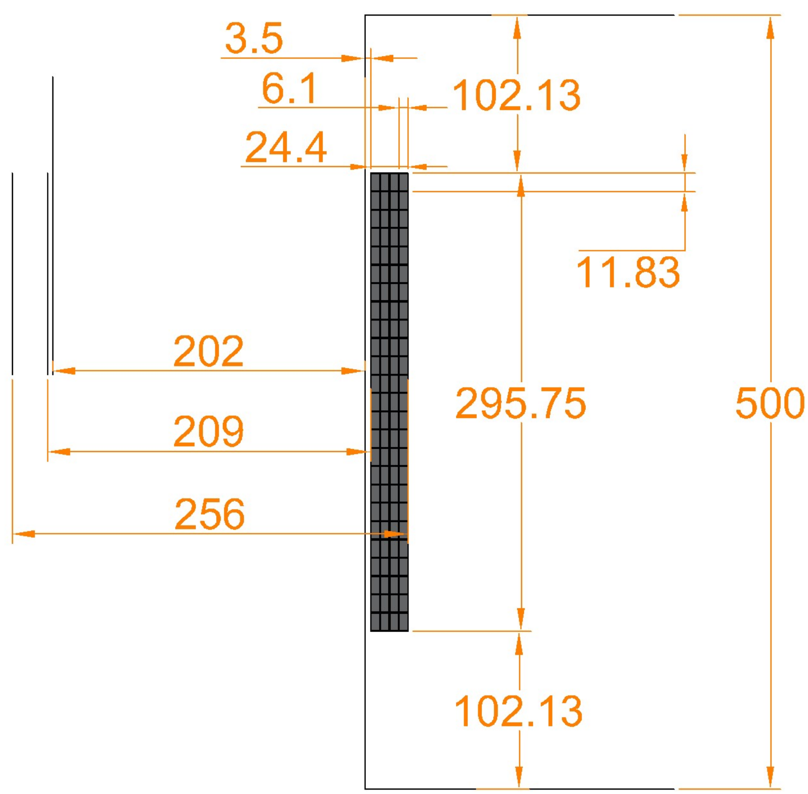


**Fig.4.** Overall layout of L.V winding.

## 1.13 Design & Layout of H.V Windings:

For H.V winding choosing round conductor, where, d= diameter of the conductor

$a_1 = \frac{\pi}{4} \times d_1^2$

$\rightarrow d_1 = \sqrt{\frac{4\times 6}{\pi}}$ = 2.76 mm.

The area is, $a_1$ = 5.98 mm$^2 \approx$ 6 mm$^2$.

So, $A_{cu}$ copper area in window = $2(a_1T_1 + a_2T_2)$

$= 2(6 \times 1187 + 254 \times 25)$

= 26944 mm$^2$.

Now, for this dimensions we get window space factor,

$\mathbf{K_w} = \frac{A_{Cu}}{A_w} = \frac{26944}{83000}$ = 0.324$\approx$ 0.32; which is near to 0.3(chosen);

The distance between L.V & and H.V winding = 12 mm.

Inside diameter of H.V. = 256 +(12 × 2) = 280 mm.

Now split H.V winding in two coils each with turns = $^{1187}/_{2}$= 594

The size of conductor is 2.76 mm.

With paper insulation on the conductor the diameter = (2.76+0.25) mm.

= 3.01 mm.

Choosing 8 layers turns per layer = 594/8 = 74 turns.

Height of winding in each H.V coil = (74 × 3.01) = 223 mm.

Thickness of each coil = $(8 \times 3.01) = 24.08\ mm \approx 24\ mm.$

Outside diameter of H.V. coil = $\{280 + (24 \times 2)\}$ = 328 mm.

Mean diameter of H.V coil = (280+24) = 304 mm.

Mean length of turn = $\pi d$ = 304× $\pi$ = 955 mm.

Height of H.V coils in window $= \{(223 \times 2) + 8\} = 454\ mm.$

The space required between coils and core on either side is taken as 23 mm.

The height of window required = {454+46} = 500 mm

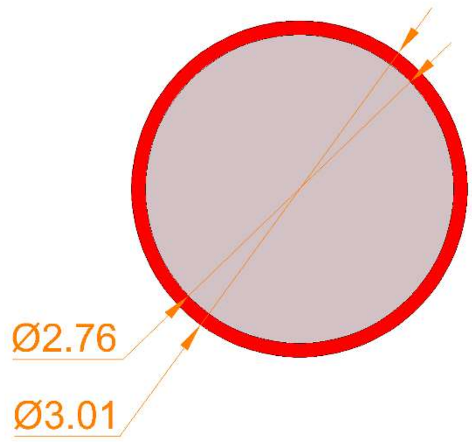


**Fig.05.** Dimension of single conductor in the layer.

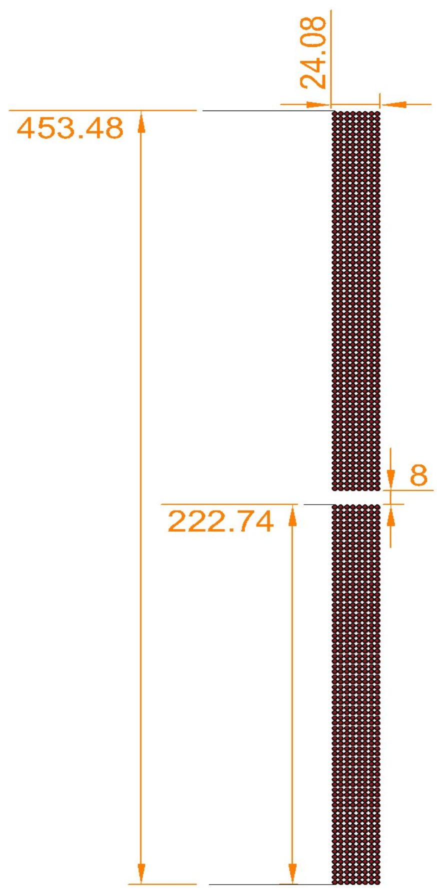


**Fig.06.** Dimension of H.V coil with 8 layer.

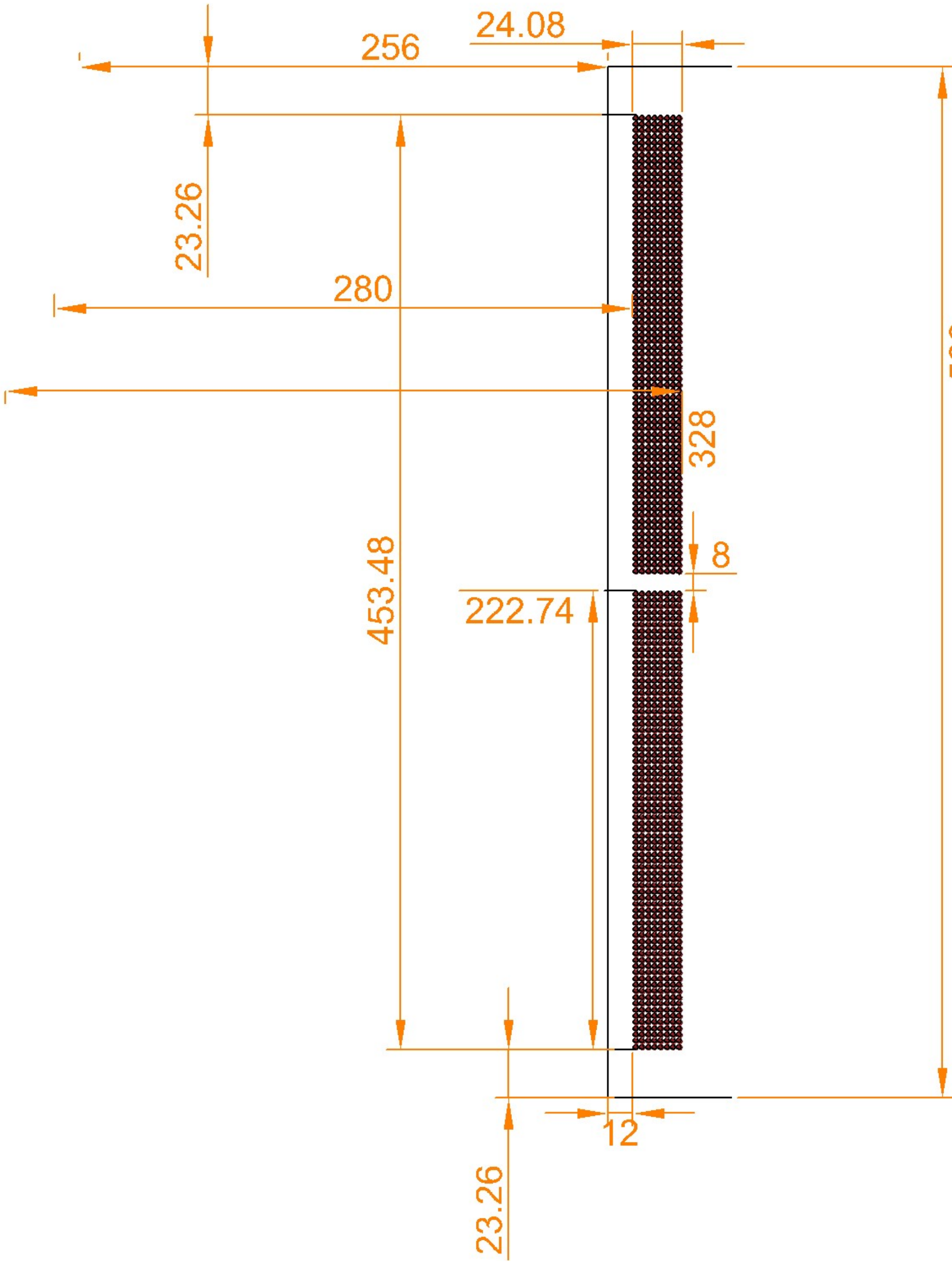


**Fig.7.** Overall layout of H.V coil.

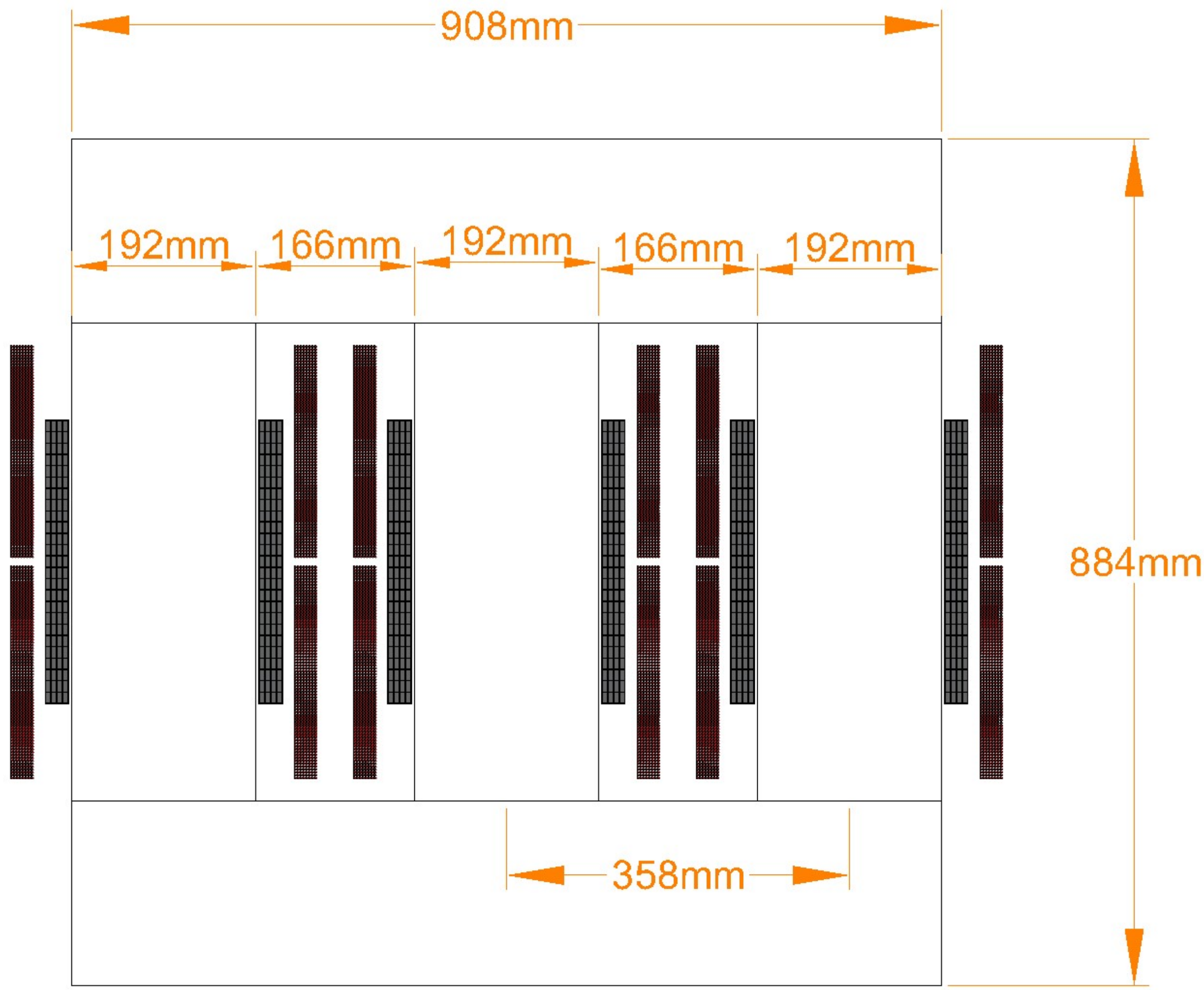


**Fig.8.** Overall Design of H.V & L.V Winding with Core.

### 1.14 **<u>Percentage of Reactance</u>:**

L.V mean length of turn = 732 mm

H.V mean length of turn = 955 mm

Average, $L_{mt}$= (732+955)/2 = 844 mm

Mean height of the coil, $h_c$ = (290+454)/2 = 372 mm

A = 12 mm, b= width of L.V coil = 23.4 mm, width of H.V coil, $b_2$ =24 mm

So, $a + \frac{b1+b2}{3}$ = (12+$\frac{23.4+24}{3}$) =27.8 mm ≈ 28 mm

AT (L.V. coil) = $635 \times 25$ =15875 AT

%X = $\frac{2\pi f \mu\, L_{mt}\,(AT)}{h_c E_T} \times (\, a + \frac{b1+b2}{3})$

= $\frac{2\pi \times 50 \times \mu \times 844 \times 10^{-3} \times 15875 \times 28 \times 10^{-3}}{372 \times 10^{-3} \times 9.75}$

= 0.04083 p.u

%X= 4.083%

### 1.15 **<u>Percentage of Resistance</u>:**

Now, $\rho_{20} = 0.01724$ ohm/mm$^2$ /m & $\alpha_{20} = 0.00393$

At 75$^0$C, $\rho 75 = \rho_{20}\{1 + \alpha_{20}(75 - 20)\}$

= $0.01724(1 + 0.00393 \times 55)$

= 0.021 ohm/mm$^2$ /m

Resistance of low voltage winding (per phase) = $\frac{0.021 \times 732 \times 25}{254 \times 1000}$

= 0.00151 ohm/phase.

Resistance of H.V. winding = $\frac{0.021 \times 955 \times 1187}{6 \times 1000}$

= 3.97 ohm per phase

Here, Ratio of Transformation = $\frac{11 \times 10^3}{239} = 46$

Now, the equivalent resistance referred to H.V side (per phase) is:

$R = 3.97 + (46)^2 \times 0.00151$

$= 7.17$ ohm

Percentage of resistance = $\frac{Equivalent\ Resistamce}{Base\ \ Resistamce} \times 100\%$

$= \frac{7.17}{\frac{11 \times 10^3}{14}} \times 100\%$

$= 0.91\%$

Here, %X =4.083 and %R = 0.91

## 1.16 Percentage of Impedance:

So, Percentage Impedance %Z = $\sqrt{(4.083)^2 + (0.91)^2}$

= 4.18% Which is within the permissible limit.

## 1.17 Weight of Iron in Core &Yoke Assembly:

From main dimension the volume of the core and yoke is given by;

$= Ai \times \{(908 \times 2) + (500 \times 3)\}$

$= 86035476.96 \ \approx 86035477 \ mm^3$

Weight of Iron = $7.85 \times 1000$ $Kg/m^3$

Weight of core & yoke = $\frac{86035477 \times 7.85}{1000 \times 1000}$ = 675.378 ≈ 676 Kg.

Core loss at $B_{max}$= 1.69 $Wbm^{-2}$ is 1.5 watts/Kg

Core loss in transformer = $1.5 \times 676$ = 1014 watts.

## 1.18 Magnetizing Volt Amperes:

For $B_{max}$ = 1.69 $Wbm^{-2}$, VA/Kg from the curve is 13 VA/Kg.

Magnetizing volt amperes = (676×13) = 8788 A.

## 1.19 Weight of L.V Winding:

We know density of copper = 8.89 gm/cm$^3$

Number of turns = 25, $a_2$ = 254 mm$^2$ & Mean length of turn= 732 mm.

Weight of L.V winding (per limb) = $\frac{8.89 \times 254 \times 732 \times 25}{10^6}$

= 41.322 Kg.

## 1.20 Weight of the h.v. winding (per limb):

Number of turns = 1187, normal = 1130, $a_1$= 6 mm$^2$ & Mean length of turn = 955 mm.

Weight of 2 coils(one limb) = $\frac{8.89 \times 6 \times 955 \times 1187}{10^6}$ = 60.465 Kg.(for all turns.)

For normal turn, the weight of coils(one limb) = $\frac{8.89 \times 6 \times 955 \times 1130}{10^6}$ = 57.56 Kg.

## 1.21 Total weight of copper in transformer:

We can write, 3(L.V+H.V) =3(41.32+57.56) =296.64 kg.

## 1.22 Copper loss and load loss at 75$^0$ C:

H.V current per phase = 14 A

Copper losses for 3 phases = $(3 \times 14^2 \times 7.17)$= 4216 W

Let, stray load loss for about 7%,

Then load loss at 75$^0$C = $(4216 \times 1.07)$ = 4511 Watts.

Iron loss = 1014 watts.

Therefore, total loss= (4511+1014) =5525 watts. [which is less than 7 KW]

## 1.23 Calculation of Performance:

**Efficiency on full load at unity p.f;**

Output = $456\times10^3$ Watts

Efficiency = $\frac{456\times10^3}{456\times10^3+5}\times 100\%$

= 98.80%

**Efficiency on 3/4$^{th}$ full load at unity p.f**;

Core loss=1014 watts

Load loss on 3/4$^{th}$ load = $4511\times\left(\frac{3}{4}\right)^2$ = 2537 watt

Total loss= (2537+1014) = 3551 Watts

Efficiency at 3/4$^{th}$ load = $\frac{456\times10^3\times0.75}{456\times10^3\times0.75+3551}\times 100\%$

= 98.97%

**Efficiency on ½ of full load at unity p.f;**

Core loss = 1014 Watts, load loss on ½ load = $4511\times\left(\frac{1}{2}\right)^2$ = 1128 Watt

Total loss = (1128+1014) = 2142 Watts

Efficiency at ½ of full load = $\frac{456\times10^3\times0.5}{456\times10^3\times0.5+214}\times 100$ = 99.06%.

## 1.24 Voltage Regulation:

**Regulation on full load at unity power factor:**

%R = 0.91%, %X= 4.083%

Now, $(V+IR)^2+(IX)^2 = E^2$

$(1+0.0091)^2 + (0.04083)^2 = E^2$

E = 1.0099

Regulation = (1.0099-1) p.u.= 0.99%.

**Regulation on full load at 0.8 pf lagging:**

= [IR cos$\varphi$ + IX sin$\varphi$] %

= [0.091$\times$ 0.8 + 4.083 $\times$ 0.6] %

= 3.18%.

## 1.25 Core loss Current:

Core loss = 1014 watts

Core loss current, $I_c = \frac{1014}{3\times11\times10^3}$ = 0.031 A.

## 1.26 Magnetizing Current:

Magnetizing VA = 8788 VA

Magnetizing Current,$I_m = \frac{8788}{3\times11\times10^3}$ = 0.27A.

## 1.27 No-load Current:

No load current per phase, $I_0 = \sqrt{(0.27)2 + (0.031)2}$ = 0.271 A.

Current per phase = 14 A

No load current = (0.27/14)$\times$100% = 1.93% of full load current.

## 1.28 Design of tank:

Outside diameter of H.V coil is 328 mm

The distance between adjacent coils and adjacent limbs = $\{166 - 2\left(\frac{328}{2} - \frac{192}{2}\right)\}$

$= 30\ mm.$

Clearance at each end = $70\ mm.$

Thus, the length of the tank = $(328 \times 3 + 30 \times 2 + 70 \times 2)$ = 1184 mm.

Breadth of the tank = $328 + (60 \times 2)$ = 448 mm; Chosen 450 mm.

Height = 884 + 100 mm for base + 250 mm oil level above oil level

+350 mm for leads.

= 1234 mm up to oil level + 350 mm for leads

= 1584 mm.

Inside dimensions of the tank of the transformer is = (length × breadth × height)

$= (1184 \times 450 \times 1584)$
$= 843955200 \text{ mm}^3$.

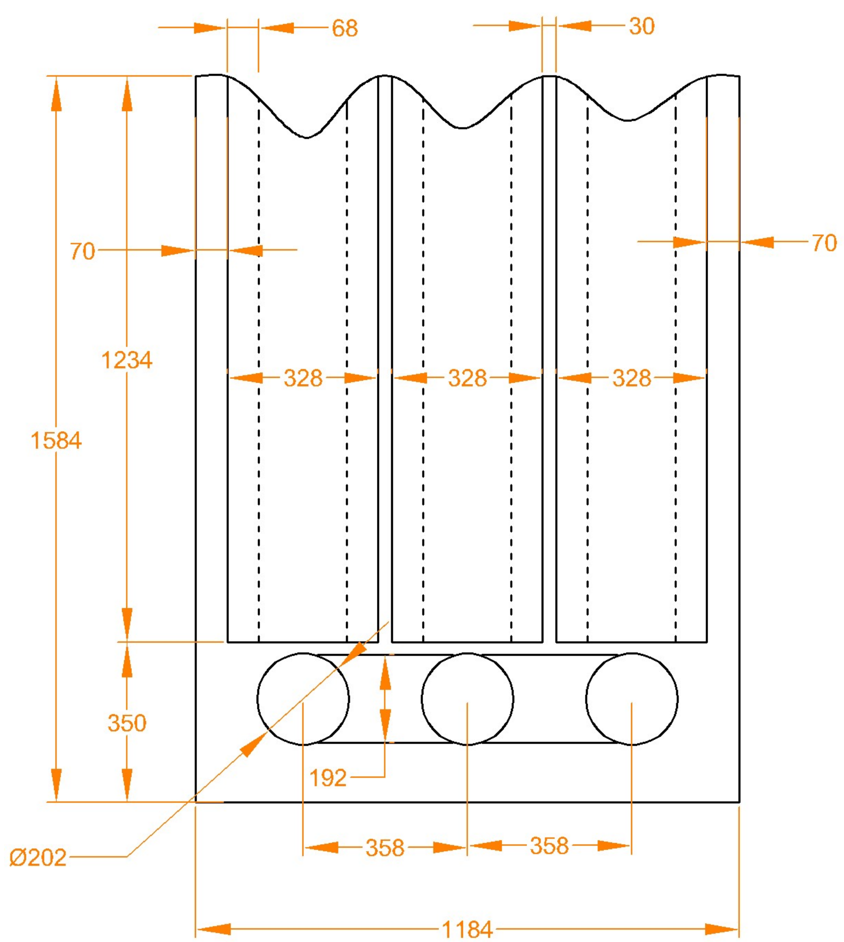


**Fig.9.** Dimension of Tank.

## 1.29 **Temperature Rise**:

Now, for dissipation of heat only 4 surfaces of the tank are taken into consideration. The top and bottom are not considered.

Surface of tank =$\left(\frac{1584}{1000} \times \frac{450}{1000}\right) \times 2$ =1.4256 $mm^2$ ≈ 1.43$mm^2$

$= \left(\frac{1584}{1000} \times \frac{1184}{1000}\right) \times 2$ = 3.75 $mm^2$

Total dissipating surface area, $S_t$ = (1.43 +3.75 ) = 5.18 $mm^2$

Full load to be dissipated = 5525 watts

Now, it will dissipate 12.5 $S_t$ W/$^0$C temperature due to convection (6.5W) & radiation 6W = $\frac{5525}{12.5 \times 5.18}$ = 85.3$^0$C

Now, to maintain the temperature of transformer walls limited to 45$^0$C (to limit temperature rise of oil below 60$^0$C)

In that case, the surface of the tank for cooling has to be increased either by radiations or tubes attached to the tank.

If total surface area is considered x times the tank surface area,

We get, $5.18 \times x(8.8+\frac{3.7}{x}) \times 45 = 5525$

→x = 2.27.

Thus, additional area to be provided = 5.18 × 1.27 = 6.5786 $m^2$ ≈ 6.58 $m^2$

As 1234 mm is height up to oil level, Height of tube is taken as 1184 mm.

Surface of 1 tube of mm diameter= $\pi \times 50 \times 1184 \times 10^{-6}$ = 0.1859 $m^2$≈ 0.19 $m^2$

Number of tubes required = $^{6.58}/_{0.19}$= 34.62≈34 tubes

## 1.30 **Volume and weight of Coil**:

Volume of tank up to oil level = $\left(\frac{1184}{1000} \times \frac{450}{1000} \times \frac{1234}{1000}\right)$ =0.657 $m^3$ ≈ 0.66 $m^3$

Volume of transformer core and copper =$\left(\frac{676}{7.85 \times 1000} + \frac{296.64}{8.89 \times 1000}\right)$

= 0.12 $m^3$

Volume of oil = (0.66-0.12) $m^3 = 0.54\ m^3$

Oil required in transformer = $(0.54 \times 1000)$ = 540 liters

Weight of Oil required in transformer = $(540 \times 0.89)$ = 480.6 Kg.

## 1.31 Volume &Weight of Tank:

If the thickness of tank wall is taken as 5 mm

Weight of tank = 0.005× $\{(\frac{1184}{1000} \times \frac{1584}{1000} \times 2 + \frac{1184}{1000} \times \frac{450}{1000} \times 2 + \frac{1584}{1000} \times \frac{450}{1000} \times 2) \times 1000 \times 7.85\}$

= 245 Kg

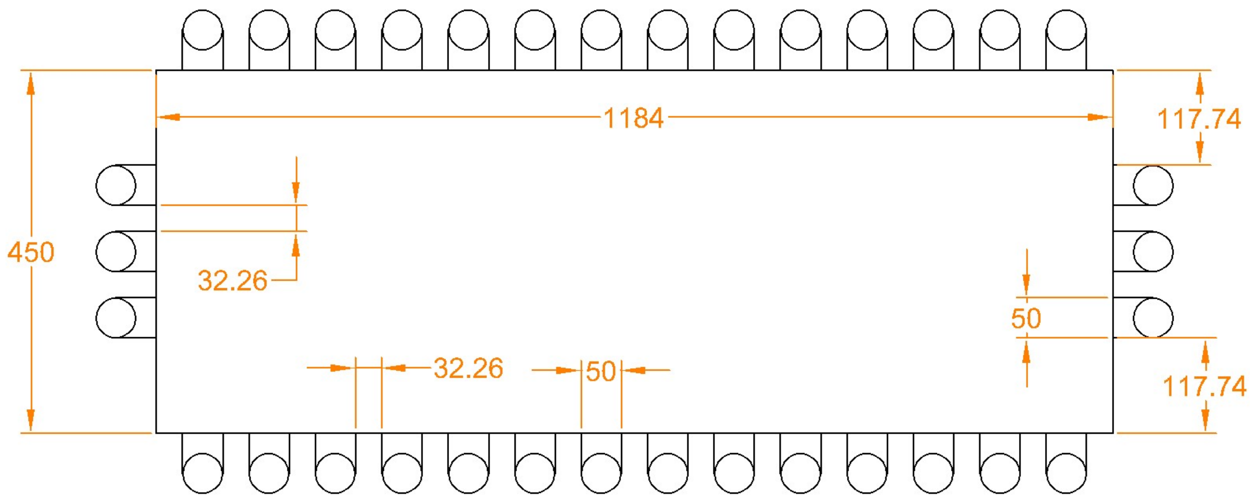


**Fig.10.** Top view of Transformer with tube.

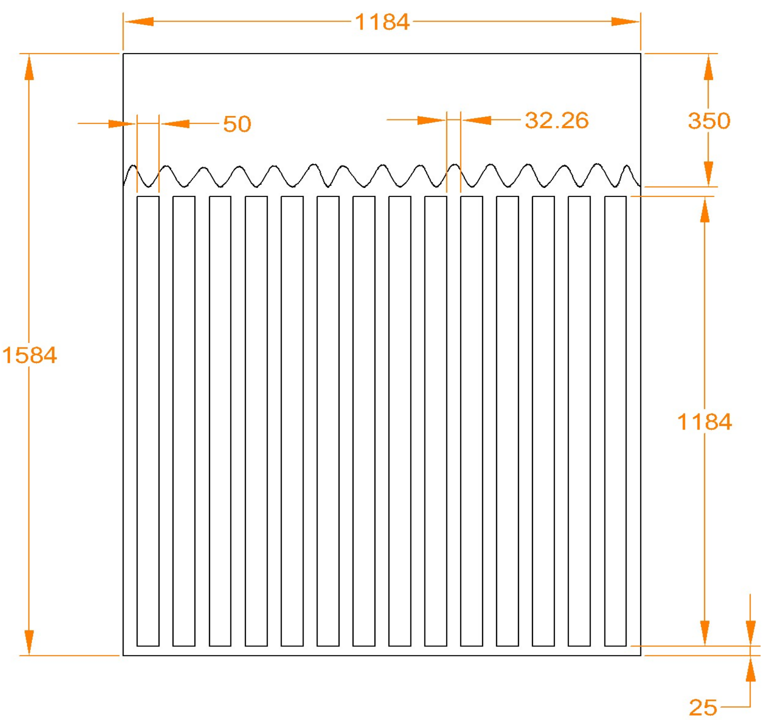


**Fig.11.** Side view of Transformer with tube (length).

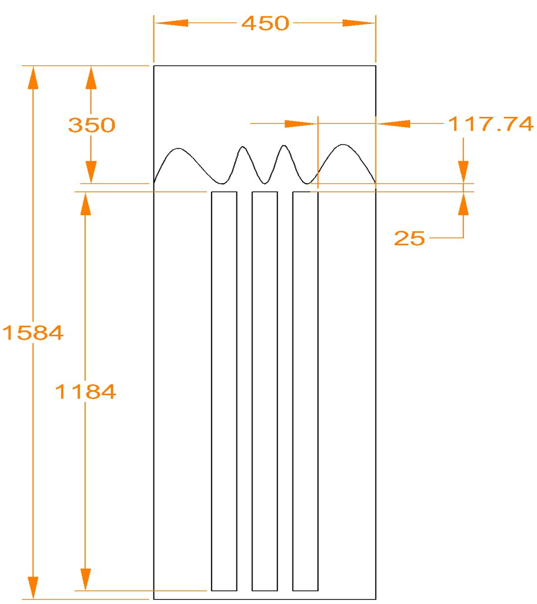


**Fig.12.** Side view of transformer with radiator (breadth).

## 1.32 Volume and weight of oil in tubes:

40 tubes each with 50 mm diameter & 1.184 m length

Volume = $\frac{\pi}{4} \times (\frac{50}{1000})^2 \times 1.184 \times 40$ = 0.093 m$^3$

Volume of oil in tubes = $(0.093 \times 1000)$ = 93 liters

Weight of oil in tube = $(93 \times 0.89\ )$= 82.77 Kg.

Weight of tubes = $\pi Dl \times 0.005 \times 40 \times 7.85 \times 1000$

$= \pi \times 50 \times 10^{-3} \times 1.184 \times 0.005 \times 40 \times 7.85 \times 1000$

= 292 Kg.

## 1.33 Total Weight of Transformer:

| | |
|---|---|
| Weight of core & yoke assembly | 676 kg |
| Weight of copper in windings | 296.64 kg |
| Weight of tank | 245 kg |
| Weight of tubes | 292 kg |
| Weight of oil in tank | 480.6 kg |
| Weight of oil in tubes | 82.77 kg |
| **Total Weight** | 2073.01 kg |

## 1.34 Summary:

***Specifications:***

Transformer designed as per IS : 1897:1962 ;

| | |
|---|---|
| kVA | 456 kVA |
| H.V. volts | 11kV |
| L.V. volts(No load) | 415 V |
| Phase | 3 |
| Connection | Delta/star |
| Vector group | DY11 |
| Percentage impedance | 4.5% |
| H.V. tapping | ±2.5% and ±5% |
| Temperature rise over oil less than | 60 ºC |
| Type of cooling | Self-Oil Cooled |
| Load loss less than | 7 KW |

***Core and yoke:***

**Material:** CRGO (cold rolled grain oriented) steel laminations 0.35 mm thick; mitered core construction 45° cut. Voltage per turn, 9.75 volts; Flux density $B_{max}$=1.69 Wb/m$^2$; Net area of cross-section of core = 25834.66 m$^2$; circumscribing circle diameter = 202 mm.

**Size of core, yoke, and frame:** Yoke made of the same section as the core. Distance between centers of adjacent limbs= 358 mm: width of the window= 166 mm; the height of window= 500 mm; overall height of frame = 884 mm; overall width of core frame = 908 mm. Weight Of core & yoke assembly 676 kg. Core loss at $B_{max}$ =1.69 wb/m$^2$,1.5 watts/kg. Magnetizing VA/kg = 13 VA/kg.

| Windings | L.V. | H.V. |
| --- | --- | --- |
| Type of winding | Helical | Dick |
| Current density | 2.5 A/mm$^2$ | 2.5 A/mm$^2$ |
| Cross-sectional area of conductor | 254 mm$^2$ | 6 mm$^2$ |
| Conductor: Copper | 4 strips of 5.5×11.33 mm | Diameter 2.76 mm |
| Number of Layers per limb | 1 | 8 discs |
| Number of turns | 25 | 1130 Normal 1187 max tapping |
| Number of turns per layer | 25 | 74 |
| Height of winding in window | 289.5 mm | 454 mm |
| Thickness of coil | 23.4 mm | 24 mm |
| Inside diameter of coil | 209 mm | 280 mm |
| Outside diameter of coil | 256 mm | 328 mm |
| Mean length of turn | 732 mm | 955 mm |
| Resistance at 75 ºC | 0.00151 ohms | 3.97ohms |
| Weight of copper for winding per limp | 41.322 kg | 57.56 kg |
| Total Weight of Copper | 296.64 kg | |

***<u>Insulation</u>:***

**Insulation between core and l.v. winding**: pressboard paper
**Insulation for conductors**: paper
**Insulation between layers :** Crape paper
**Insulation between l.v. and h.v. windings :** bakelized paper cylinder; Laminated pressed wood sticks for spacers for cooling.
**Class A insulation for ON-type transformers.**

***Tapping:***

The tapping H.V winding**;**

| **Tapping** | **5%** | **Normal** | **2.5%** |
|---|---|---|---|
| **More** | **1187 turns** | **1130 turns** | **1158 turns** |
| **Less** | **1074 turns** | | **1102 turns** |

***Tank:***

Temperature rise of oil 85.3 $^{0}$C. Inside dimensions of tank: length 1184 mm; breadth 450 mm; height 1584 mm Tubes 34, each of 50 mm diameter; 1184 mm long.

| | |
|---|---|
| Oil in transformer tank | 540 liters |
| Oil in Tubes | 93 liters |
| Weight of oil in tank | 480.6 kg |
| Weight of oil in tubes | 82.77 kg |
| Weight of tank | 245 Kg |
| Weight of tubes | 292 Kg |
| weight of complete transformer | 2073.01 kg |

***Performance:***

| | |
|---|---|
| Percentage resistance | 0.91 % |
| Percentage reactance | 4.083% |
| Percentage impedance | 4.18% |
| Iron loss | 1014 watts |
| Copper and stray load loss, i.e. load loss at 75º C | 4511 watts |
| Total loss on full load | 5525 watts |
| Efficiency on full load at unity power factor | 98.80% |
| Efficiency on 3/4 th full load at unity power factor | 98.97% |
| Efficiency on 1/2 full load at unity power factor | 99.06% |
| Regulation on full load at unity power factor | 0.99% |
| Regulation on full load at 0.8 power factor lagging | 3.18% |
| Core loss current per phase | 0.031 A |
| Magnetizing current per phase | 0.27 A |
| No load current per phase | 0.271 A |