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Designing non-short-circuit-proof, low profile safety transformers up to 42VA with Rale Design System, in accordance with IEC 61558, protected by miniature fuse as per IEC 127

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In the beginning…

Thirty years ago, designers performed the calculations for transformers on their pocket calculators. The designer had to pencil all the input and output fields into a form and then feed them into the calculator. Today, he can forget the pencil, but he needs to enter the figures into spread-sheet programs such as Excel and Lotus 123.

Once the first economical 8-bit computer had become available in 1978, professionals could begin to develop programs for designing transformers and inductors. This development work moved in two directions:

First, companies developed their own computer programs to meet their own specific requirements. These usually used algorithms and experience that were already available. Once an acceptable level to meet the company's needs had been reached, both in terms of technical capability and ease of use, further development ceased.

Secondly, small companies began to develop professional computer programs which are sold or leased to the manufacturers of transformers and inductors.

With the aid of continuous input from the various manufacturers, they were able to develop universal, powerful, easy-to-use tools for use throughout the industry.

Designing with the Rale Design System

The Rale Design system automatically calculates designs for transformers and inductors. Consequently, its database incorporates all the necessary materials including cores, bobbins, wires, steels, etc. in both metric and USA units. This database is totally user expandable. To use the programs, the designer needs only a basic knowledge of transformers or inductors and their operation mode. The designer does not need to use any complicated formulas, he only needs to follow two simple phases:

The user normally loads a template-input file out of the library and only fills in the input mask with the global parameters (voltage, current, temperature rise, regulation, etc.) and runs the program.
Once the program has finished the design work the user can switch to Test Mode and make manual changes to the parameters of the designed transformer (turns, wire sizes, steel, ...) and run the program in order to redesign it.

During this stage the user can also test his design, changing the input voltage, frequency, load, duty cycle, etc.

Design criteria of a non-short-circuit-proof transformer

IEC 61558

A transformer, which is not short-circuit-proof as per IEC 61558, is not equipped with any protection. However, the manufacturer is obliged to inform the user of the required safety measures by means of which the transformer must be protected in operation. In this case, the transformer should be protected by means of a miniature fuse as per IEC 127: the type and current rating of the fuse must be stated on the transformer label.

The procedure for designing and testing these transformers is set out in paragraphs **14.2** and **15.3.3**:

1. Firstly the transformer is connected to the rated supply voltage and loaded with an impedance which would give rated output current at rated output voltage and then the supply voltage is increased by 6%. Following this increase in voltage, no change is made in the circuit until the permanent-operating temperature is reached (**Ton>>Tt**). In this context, the temperature of the windings must not exceed the value of θ**nom** (see the table below).
2. Immediately after this test the transformer is loaded for a period **Ttest** corresponding to the longest pre-arcing time with the relevant "impressed" current **K*Ifnom** as specified in the **appropriate standard sheet**. After the **Ttest** period, the temperature of the windings must not exceed the θ**test** values set out in the table below.
3. Finally, one output winding is short-circuited. At 1.06 times the nominal input voltage, the I^2t-value of the fuse must actuate, before the temperature of the windings exceeds the values θ**test** set out in the table below.

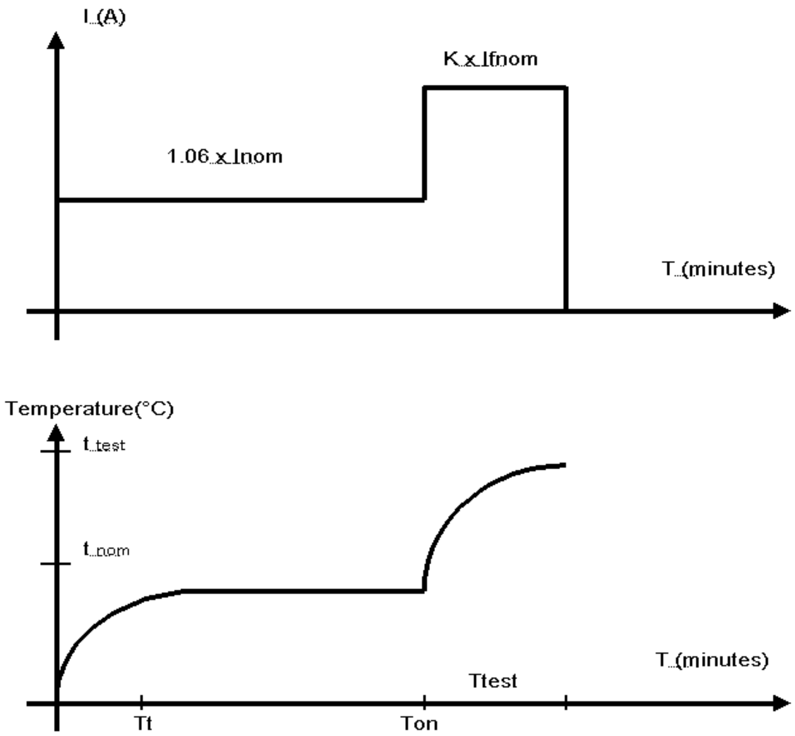


Fig. 1

Insulation class	A	E	B	F	H
Max. winding temperature in test **θtest** (° C)	200	215	225	240	260
Max. winding temperature in nominal operation **θnom** (° C)	100	115	120	140	165

IEC 127

To perform the calculations for a non-short-circuit-proof transformer, it is first necessary to select the miniature fuses.

As a rule, miniature fuses are placed on the secondary side, and if possible the nominal current for the **Ifnom** miniature fuse is selected to be approximately 6% higher than the nominal value of the **Inom** secondary current.

The table below should help us to select the type of fuse required.

Test current = K x Ifnom	1.5 x Ifnom*	2.1 x Ifnom
Pre-arcing time for quick-acting F fuse link	min. 60 minutes*	max. 30 minutes

Pre-arcing time for time-lag T fuse link	min. 60 minutes*	max. 2 minutes!
Pre-arcing time for super-time-lag TT fuse link	min. 60 minutes*	max. 30 minutes

* These values are not IEC 127 specified. They were taken from the catalogues of a number of well-known miniature fuse manufacturers!

As shown in the above table there are two distinct methods:

- The transformer should be protected with **each** miniature fuse type. Where the transformer has a thermal time delay of less than 10 minutes the test with **Ttest = 30 minutes and K = 2.1** is crucial. Where transformers have a thermal time delay of over 10 minutes the Ttest>=60 minutes and K =1.5 (possibly 1.6) test should be applied.
- The transformer should be protected by an inert **T** miniature fuse with low breaking capacity. Practical experience indicates that only the **Ttest = 60** minutes with K = 1.5 (possibly 1.6) criterion should be applied.

Important note:

A large number of well-known transformer manufacturers do protect their non-short-circuit proof transformers with inert T miniature fuses with low breaking capacity, designing them in test mode with **Ttest = 2 minutes and K = 2.1**. Transformers designed in this way overheat during operation at 1.5 times nominal fuse current for 60 minutes to way above the permitted temperature. **For this reason either IEC 127 needs to be expanded by adding the value that exists at 1.5 x fuse nominal current (Ifnom) , or IEC 61558 paragraph 15.3.3. should be redrafted.**

Insulation class

In these output ranges, the bobbins, the case and the potting compound are employed exclusively together with insulation categories E and B. Wire insulation and insulation foils are very often employed in insulation class F.

Ambient temperature

Normally, the transformer is operated in an environment of which the temperature is between 40°C and 70°C.

Case

For safety reasons, low-profile-constructed safety transformers are almost exclusively potted in vacuum in a case. The main advantages of a potted transformer are:

- The transformer is cooled better.
- You can use a bobbin without great wall thickness and without large leakage paths, but with a larger winding space.

Chassis

The non-short-circuit proof, low profile transformers are intended exclusively for the printed board. In order to have good thermal contact with the print, the transformer needs to be "fully" potted so that the air gap between the compound and the print is maximum 0.2 –0.5 mm.

Thermal resistance of the potting compound

The potting compound which is best from a thermal viewpoint, and also the most expensive, has a specific thermal conductivity of 0.8W/m/°K. In practice, we usually operate with a potting compound whose thermal conductivity is 0.4/W/m/°K.

Bobbins

In this output power range, recourse is made almost exclusively to a double-section bobbin. From the viewpoint of design, only the dimensions of the bobbin are important. A bobbin with increased insulation or large leakage paths has a smaller winding space and a smaller cooling surface area.

Steel

A flat transformer must be as flat and as small as possible. For that reason, these transformers are manufactured exclusively in UI sheet form without holes in the corners and annealed, grain-oriented core quality with specific Fe-losses of 1.11 W/kg at 1.5T and 50Hz (WV111, M6, etc.).

Induction

These transformers are manufactured with an induction in nominal operation of between 1.5T and 1.7T (!). No-load induction is normally above 1.8T. For that reason, we must use an annealed, grain-oriented core quality without holes in the corners.

Tolerance for output voltage

The output voltage of a not short-circuit proof transformer is tested in the hot state at nominal primary voltage and nominal load resistance and may vary by +-5% of the rated value. If 2 (typical of UI core) or more secondary coils are present, the permitted tolerance is +-10%.

Secondary coil circuitry

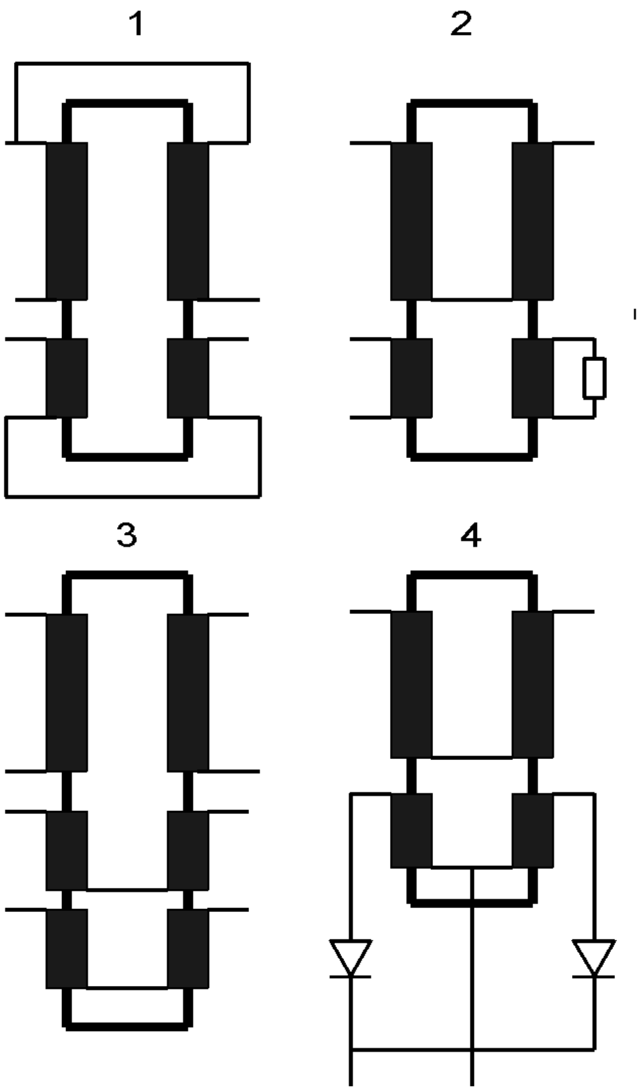


Fig. 3

The transformer usually has a primary and secondary coil on each leg. All the coil connections are accessible from the exterior and are used for serial and parallel circuits. The first picture in figure 3 shows the serial circuit. The ampere turns of the primary and secondary coils are compensated. If the transformer is used as shown in pictures 2 and 4, the ampere turns per leg are not compensated and the transformer diffuses a magnetic field that is 5-10 times greater. Picture 3 shows the design and internal wiring of the secondary coils at which the ampere turns always remain compensated.

Procedure for design

The non short-circuit-proof, low profile transformers are made by using only laminations UI30, UI39 and UI48. The decision regarding the choice of core sizes is made mainly in relation to output power, ambient temperature, and the insulation class. Thanks to this relatively small number of variants, for 10 output powers in insulation class E and ambient temperatures of 40 ° C and 70° C, it was possible to record approximately 20 input files to serve as an aid to making entries into the Rale Design Systems library.

The calculation example shown below explains the calculation procedure in brief.

Technical specification relevant only to design

Electrical data

Input Voltage	2 x 115, +6%,-10% sinusoidal
Frequency	50/60Hz
Nominal output voltage	2 x 12Vac
Nominal output current	2 x 0.75Aac, protected by 2 x 0.8A miniature fuse

Environment and operating conditions:

Ambient temperature	40°C
Mode of operation	Continuous
Test conditions	With non short-circuit-proof, protected by miniature fuse to IEC 127, F, T, TT, low and high breaking capacity

Specification

Safety transformer as per IEC 61558
Insulation class E
Potted in case
Core and bobbin UI 39/13.5

The above-stated parameters are stored mainly in the IEC1533E_18VAT70.TK1 input file.

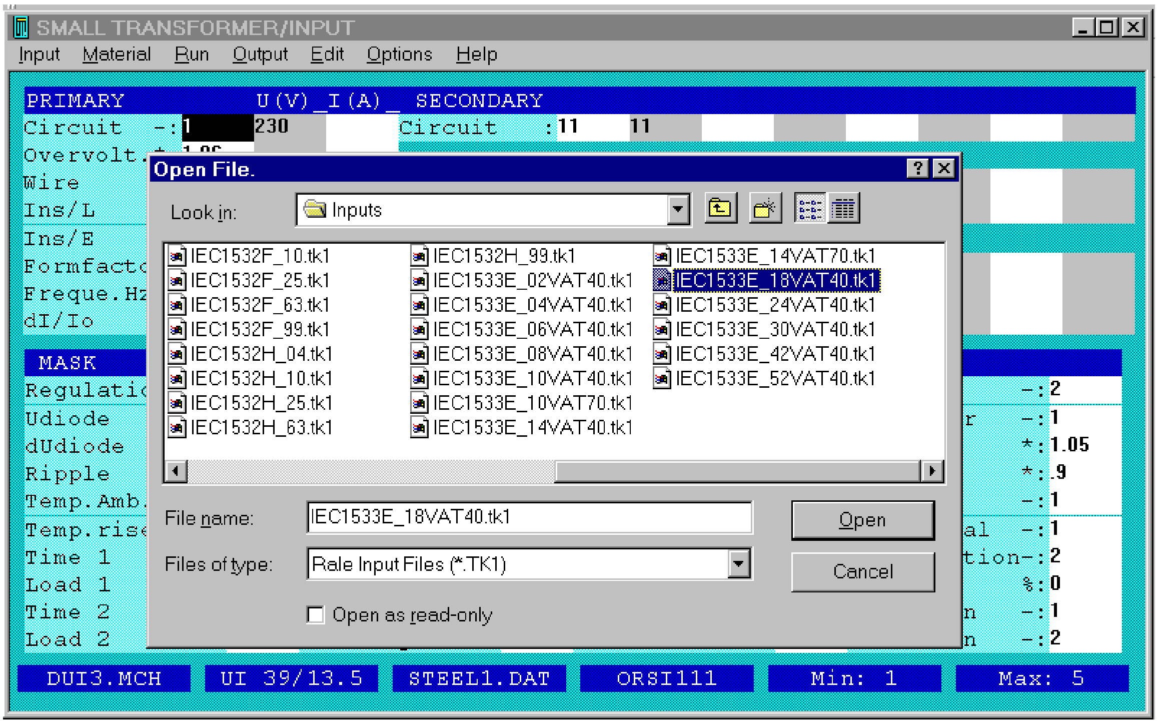


Fig. 4

After loading the input file normally you have to change the input voltage, output voltages and the output currents. If you need help, then press function key F1. For each input field, there is extensive description

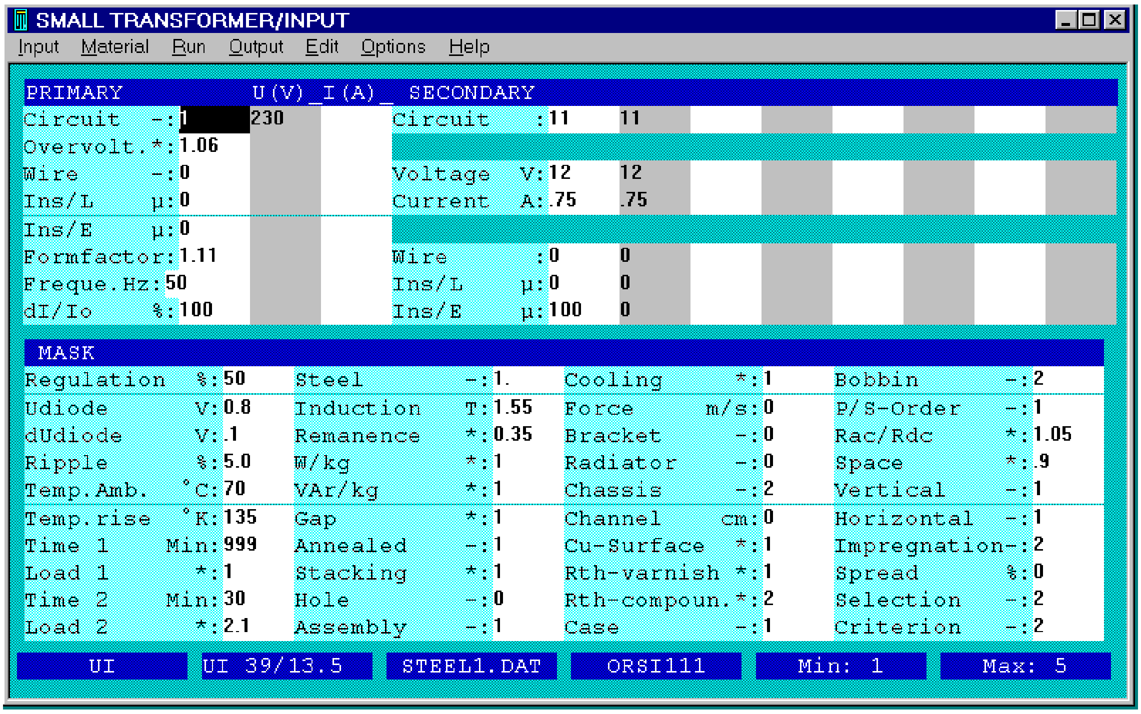


Fig. 5

This is a brief description of the input mask illustrated above:

Two secondary coils are designed for 12V, 0.75A, in warm conditions, at an input voltage of 230 V, 50 Hz.
The transformer is fed at an ambient temperature of 70 degrees C (Amb. Temp. = 70) first of all under overvoltage (overvoltage = 1.06) of 6% for a very long period (Time1 = 999 minutes) at a rated load resistance (Load1 = 1). The transformer is then loaded for 30 minutes (Time2 = 30) at 2.1 times the nominal output current (Load2 = 2.1). Once the 30 minutes have expired the transformer should reach an over-temperature of 135 degrees (K Temp. rise = 135).
The core U130/13/5 of M6 steel (Steel = 1) nested on either side has two double section bobbins (Bobbin = 2) and is potted in a case (Case = 1) with a compound of 0.4W/K/m (Rth-compound=2). The transformer is placed on a printed board (Chassis = 2).

Note that you can select the core and bobbin with the case. If the record for the core and bobbin which you selected has no case, then you have to set up the case yourself. The core selected in the following illustration has a case in its record. For this reason, it is enough to mark the core UI39/13.5 and to click on the **OK** button.

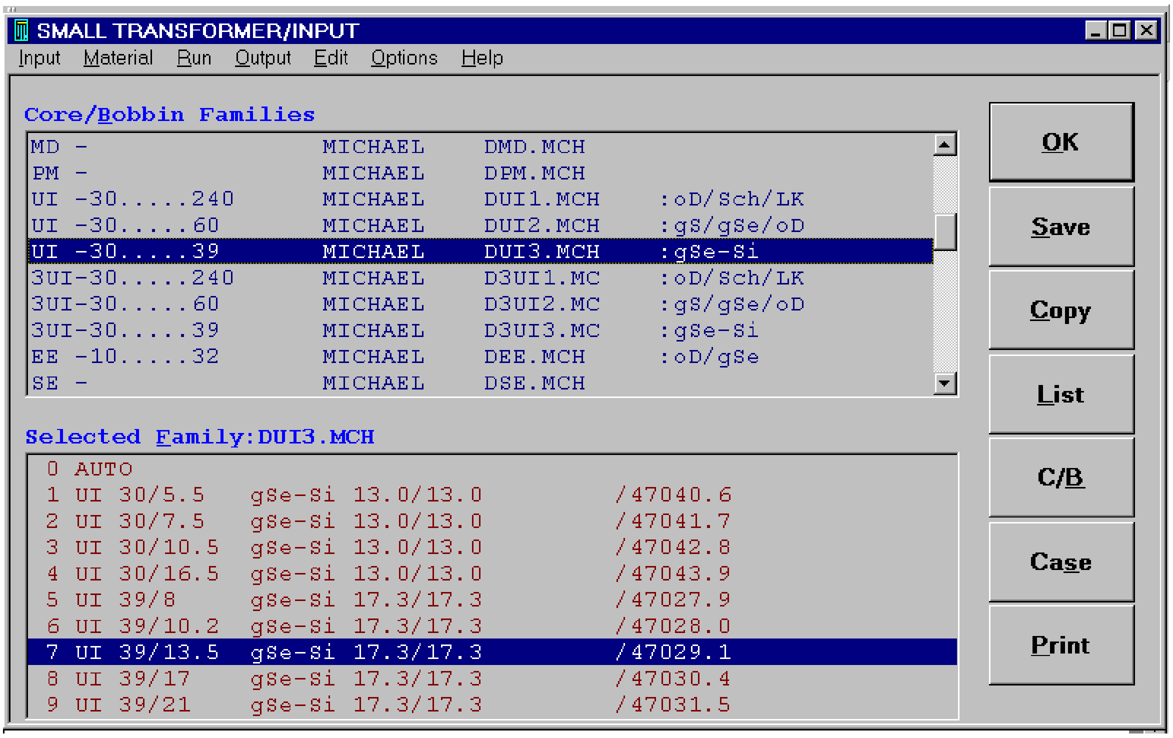


Fig. 6

After the design procedure has been completed, the following design data is available and can be printed on 3 pages.

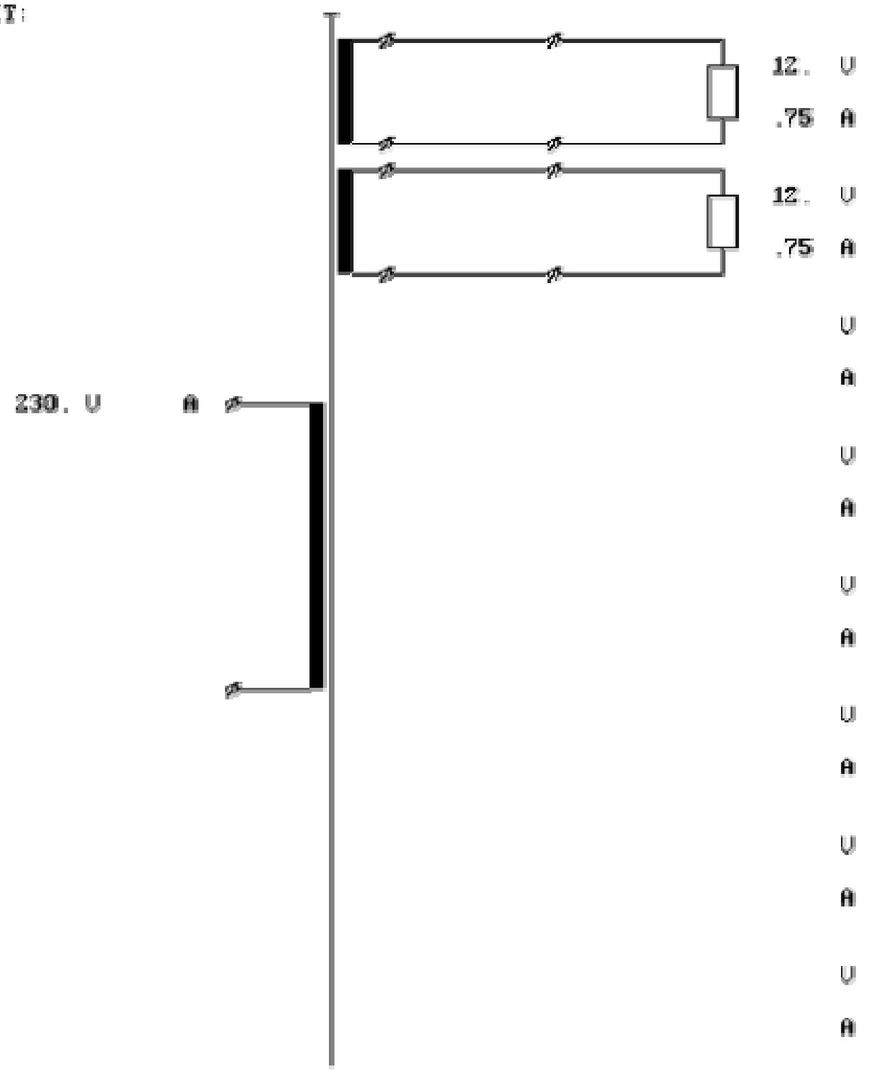
11-08-1999/20:52:59	Input and Circuit	Page 1

PRIMARY	U(V)	I(A)
Circuit-:1	230.	
Overvlt*:1.06	.	
Wire :0.0	.	
I/L. µ:0.	.	
I/E. µ:0.	.	
Formfac.:1.11	.	
Fre.Hz:50	.	
dI/Io %:100	.	

SECOND.	1---	2---	3---	4---	5---	6---	7---	8---
Circuit-	:11	11						
Volta. V	:12.	12.						
Curre. A	:.75	.75						
Wire	:0	0						
I/L µ	:0.0	0.0						
I/E µ	:100.	0.0						

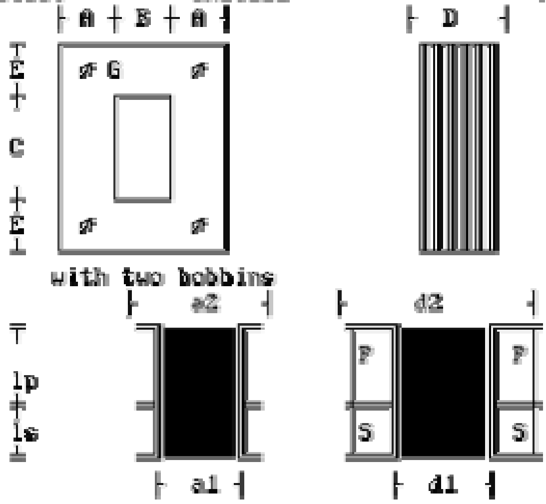
Regulat. %:50.0	Steel -:1	Cooling *:1.00	Bobbin -:2
Udiode V:0.8	Induction T:1.57	Force m/s:0.00	P/S-Order -:1
dUdiode V:.1	Remanence *:0.35	Bracket -:0	Rac/Rdc *:1.05
Ripple %:5.	W/kg *:1.00	Radiator -:0	Space *:0.90
Tmp. Amb.°C:70	VAr/kg *:1.00	Chassis -:2.00	Vertical -:0
Tmp.rise °K:135	Gap *:1.00	Channel cm:0.00	Horizontal -:1
Time 1 Min:999.0	Annealed -:1	Cu-Surface*:1.00	Impregnat. -:2
Load 1 *:1.0	Stacking *:1.00	Rth-varnl.*:1.00	Spread %:0
Time 2 Min:30.0	Hole -:0	Rth-comp. *:2.00	Selection -:2
Load 2 *:2.1	Assembly -:1	Case -:1	Criterion -:2

CIRCUIT:



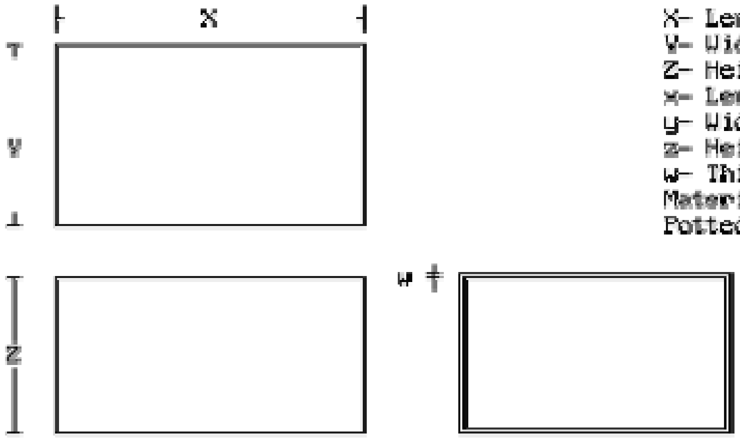
11-08-1999/20:52:59 CORE / BOBBIN / STEEL / CASE   Page 2

Name : 2XUI 39/13.5 gSe-Si 17.3/17.3 /47029.1
Steel :ORSI111 /.35



Weight gr:202.41
Gap total cm:0.000
A-Limb cm:1.30
B-Width cm:1.30
C-Height cm:3.90
D-Stack cm:1.35
E-Yoke 1 cm:1.30
F-Yoke 2 cm:0.00
G-Hole cm:0
Radiator Fin :0
Radiator Chan. :0

a1 cm:1.56
a2 cm:2.59
d1 cm 1.55
d2 cm 2.52
l cm:
lp cm:1.73
ls cm:1.73



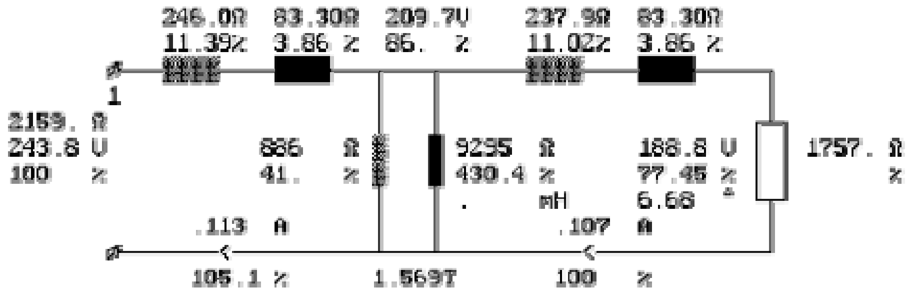
X- Length 1 cm:5.50
Y- Width 1 cm:6.55
Z- Height 1 cm:2.76
x- Length 2 cm:0.00
y- Width 2 cm:0.00
z- Height 2 cm:0.00
w- Thickness cm:0.10
Material :
Potted :

	Typ	Turns	T	WG	UG	Par	W/ø mm	H/ø mm	T/L	L	I/L µ	I/E µ	Weight gr	RWH %
1	1	3550.	0	50.0	50.0	1	.18	.18	81	21.98	.	.	59.377	78.
2														
3														
4														
5														
6														
7														
8														
1	11	238.0	0	69.0	69.0	1	.5	.5	30	3.98	.	100	28.163	40.
2	11	238.0	0	69.0	69.0	1	.5	.5	30	3.98	.	.	33.343	38.
3														
4														
5														
6														
7														
8														
TOTAL													120.8	78.

11-08-1999/20:52:59 General Data Seite 3

NOMINAL OPERATION at Temperature °C 106.8 and Overvoltage 1.06

Output Power on Load	W:20.28	Output Power of Transfor.	W:20.28
Cu Losses	W:5.68	Fe-Losses active	W:.47
Short-Circuit-Volt. cold	%:18.31	Regulation	%:29.12
Instantaneous pow. .5/950	W:22.9	Efficiency of Transformer	%:76.16
dT Fe average Surface	°K:35.3	dT primary	°K:37.
dT Gehäuse av. Surface	°K:29.7	dT secondary	°K:36.6



DUTY CYCLE OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06

dT Fe average Surface	°K:121.7	dT primary	°K:132.
dT Gehäuse av. Surface	°K:97.9	dT secondary	°K:130.1

NO LOAD OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06

Losses active	W:1.11	Losses reactive	VAr:11.34
Current factor	%:41.42	Induction	T:1.769
dT Fe average Surface	°K:7.7	dT primary	°K:7.8
dT Gehäuse av. Surface	°K:6.5		

SHORT-CIRCUIT OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06

Losses active	W:136.1	Losses reactive	VAr:63.51
Current factor cold	%:546.	Induction	T:.894
dT Fe average Surface	°K:248.8	dT primary	°K:269.1
dT Case aver. Surface	°K:189.	dT secondary	°K:267.1

PRIMARY (Tap:1)	1----	2----	3----	4----	5----	6----	7----	8-----
Voltage Input/Output V	:243.8							
Out. Voltage no load V	:							
Current Input/Output A	:0.113							
Current in segment A	:0.113							
Icc-Current cold A	:0.62							
Io -Current A	:0.047							
Inrush Current peak ^A	:1.64							
Inrush Current rms A	:0.69							
Cu-Losses W	:3.1							
Resistance cold Ω	:183.0							
Reactance Ω	:83.30							
Eddy-Current Factor	:1.							

SECONDARY	1----	2----	3----	4----	5----	6----	7----	8-----
Output Voltage V	:12.6	12.5						
Output Current A	:0.8	0.802						
Out. Voltage no load V	:16.	16.						
Sec. Voltage V	:12.8	12.5						
Sec. Current A	:0.8	0.802						
Sec. Voltage cold V	:13.5	13.2						
Sec. Load Ω	:16.	15.6						
Icc cold A	:4.9	4.27						
Cu-Losses warm W	:1.254	1.492						
Resistance cold Ω	:1.457	1.726						
Reactance Ω	:.7497	.7481						
Eddy-Current Factor	:1.	1.						
Capacitor mF	:.	.						

This is followed by a check of the calculated data.

- Firstly, we check the maximum winding temperature in nominal operating mode = ambient temperature + dTprim in nominal operating mode = 70+37 =107 < 115°C
- The maximum winding temperature in the test mode is:
  ambient temperature + dT primary = 70 + 132 = 202<215°C
- The mean case temperature in the test mode is:
  Ambient temperature + dT case in test operation = 70 + 97.9 = 169.9>105°C
  This means that this transformer has to be installed in a unit such that it cannot be touched during operation.

Test Mode

In test mode the transformer can be checked in the same way as on a test rig, and if necessary be altered manually.

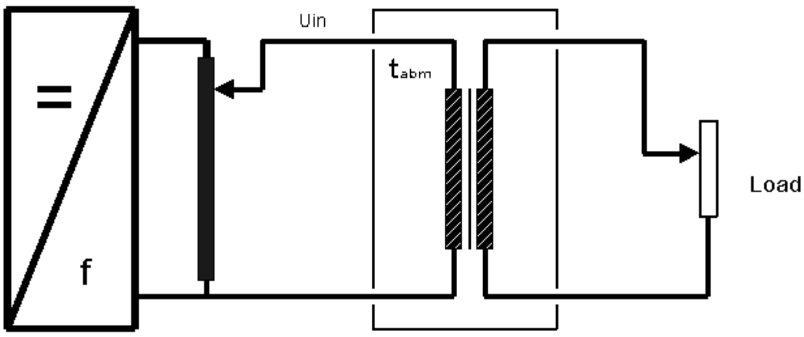
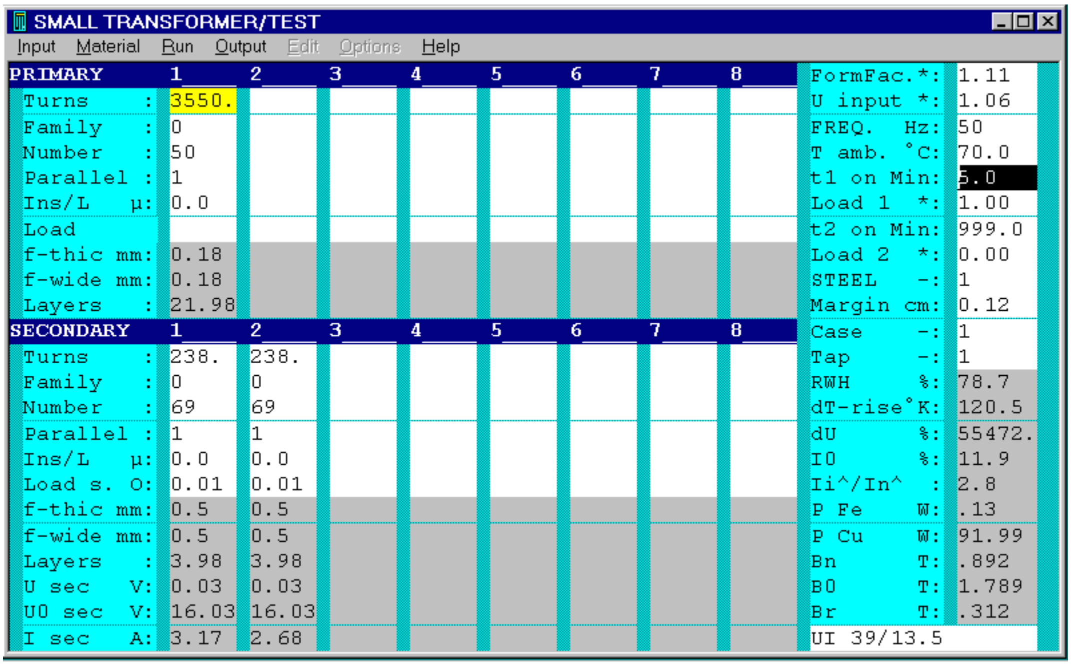


FIG. 7

In Fig 8 the transformer designed as shown above is tested in short-circuit operation.


SMALL TRANSFORMER/TEST
Input Material Run Output Edit Options Help

PRIMARY	1	2	3	4	5	6	7	8
Turns :	3550.							
Family :	0							
Number :	50							
Parallel :	1							
Ins/L µ:	0.0							
Load								
f-thic mm:	0.18							
f-wide mm:	0.18							
Layers :	21.98							
SECONDARY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Turns :	238.	238.						
Family :	0	0						
Number :	69	69						
Parallel :	1	1						
Ins/L µ:	0.0	0.0						
Load s. O:	0.01	0.01						
f-thic mm:	0.5	0.5						
f-wide mm:	0.5	0.5						
Layers :	3.98	3.98						
U sec V:	0.03	0.03						
U0 sec V:	16.03	16.03						
I sec A:	3.17	2.68						

FormFac.*:	1.11
U input *:	1.06
FREQ. Hz:	50
T amb. °C:	70.0
t1 on Min:	5.0
Load 1 *:	1.00
t2 on Min:	999.0
Load 2 *:	0.00
STEEL -:	1
Margin cm:	0.12
Case -:	1
Tap -:	1
RWH %:	78.7
dT-rise°K:	120.5
dU %:	55472.
I0 %:	11.9
Ii^/In^ :	2.8
P Fe W:	.13
P Cu W:	91.99
Bn T:	.892
B0 T:	1.789
Br T:	.312
UI 39/13.5	

FIG. 8

In test mode, we still have to simulate a time-limited short-circuit until the maximum permitted short-circuit temperature is reached. The correspondingly calculated short-circuit current and time have to be compared with the pre-arcing data for the fuse, in order to ascertain whether the fuse will switch off the current circuit before the maximum permitted temperature is reached. As an aid the short-circuit temperature rise has been calculated in the form of operating time up to 2 minutes and is illustrated in Fig. 9. Here it is possible to determine that the pre-arcing time of the fuse at 3.3A must be less than 7.5 minutes.

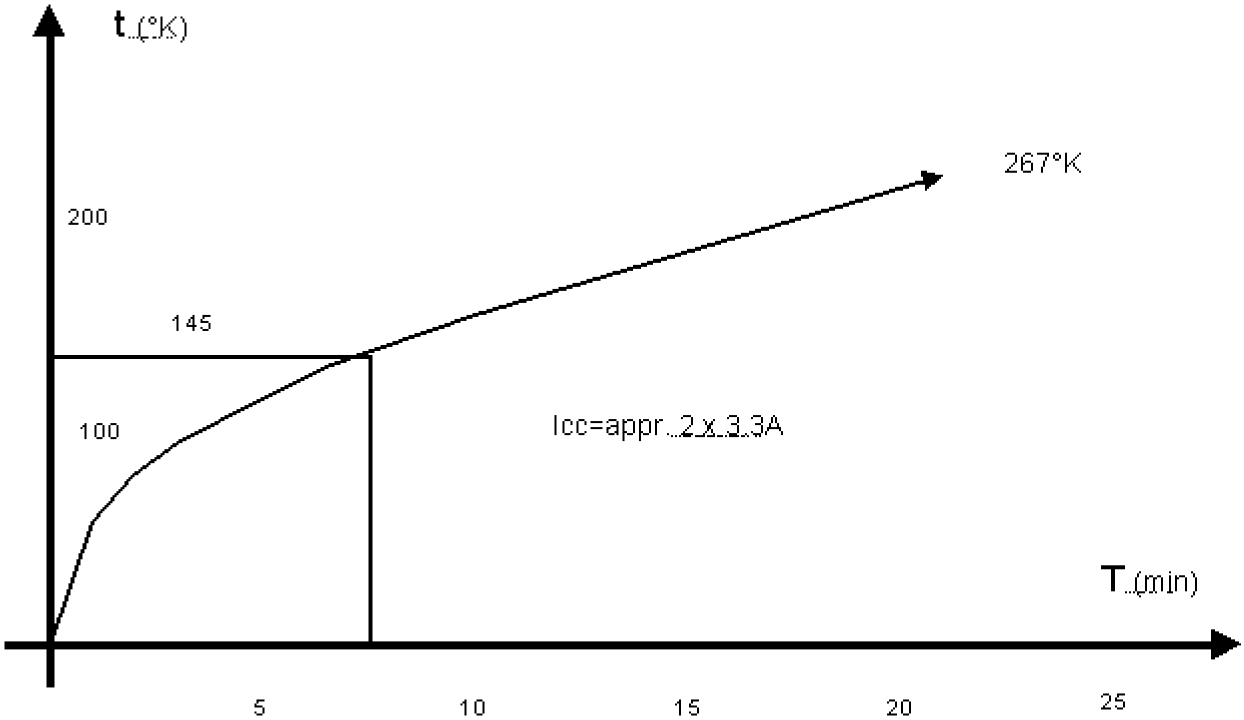


FIG.9

How should a transformer with an inert miniature fuse with low breaking capacity be tested?

To clarify this matter the transformer calculated above using K=1.5 / Ttest = 60 Minutes and K=2.1 / Ttest = 2 Minutes was operated in test mode. The results are shown in the table below:

Test mode	Temperature rise °K
K=1.5, Ttest=60 minutes	75
K=2.1, Ttest = 2 minutes	53

It can be clearly seen that the transformer that was designed in accordance with test mode K=2.1 / Ttest=2 Minutes, and in operation under test mode K=1.5/Ttest = 60 minutes, will exceed the over-temperature by a factor of some 1.5.

Technical specification common for all designs

All non-short-circuit proof transformers in the table below were calculated under the same conditions:

Input voltage : 230Vac +6%,-10%
Frequency : 50/60Hz

Steel : Grain oriented M6, annealed
Laminations : UI, alternated stacking
Bobbin : Double section
Insulation class : E

Ambient temperature : 70°C for class E
Case : Potted, compound 0.4 W/m/°K
Chassis : Printed board on black-wood-plate
Protection : Miniature fuse as per IEC 127 (K=2.1, Ttest=30 minutes)

Regulation : max. 50%
Build : max. 95%, with wire-insulation grad 1

The parameters of the designs are core size, output power, max. regulation in the nominal operation (max. 50%) or the temperature rise (max. 145°K) in the test operation.

Core Stack	UI30 5.5**	UI30 7.5	UI30 10.5	UI30 16.5	UI39 10.2	UI39 13.5	UI39 17.0	UI39 21.0	UI48 17.0
Power	2	4	6	9	14	18	24	30	42
Input voltages Turns Diameter	230 10422 0.075	230 7500 0.90	230 5500 0.1	230 3660 0.125	230 4486 0.16	230 3486 0.18	230 2700 0.212	230 2260 0.224	230 2196 0.28
Output voltages (V)	2 x 5 0.2 – 328 0.30	2 x 5 0.40 0.40 246 0.355	2 x 5 0.6 0.63 170 0.425	2x 5 0.9 1.0 98 0.56	2 x 5 1.4 1.4 130 0.67	2 x 5 1.8 2.0 96 0.75	2 x 5 2.4 2.5 67 0.90	2 x 5 3.0 3.15 55 1.06	2 x 5 4.2 4 53 1.25

Output current of **one** secondary (A)	2 x 6 0.166 – 392 0.29	2 x 6 0.33 0.40 296 0.335	2 x 6 0.5 0.5 206 0.375	2 x 6 0.75 0.80 120 0.50	2 x 6 1.16 1.25 156 0.60	2 x 6 1.5 1.6 116 0.67	2 x 6 2.0 2.0 80 0.85	2 x 6 2.5 2.5 66 0.90	2 x 6 3.5 4.0 64 1.18
Fuse (A)	2 x 8 0.125 – 524 0.236	2 x 8 0.25 0.25 370 0.29	2 x 8 0.375 0.40 260 0.335	2 x 8 0.57 0.63 160 0.425	2 x 8 0.875 1.0 196 0.56	2 x 8 1.13 1.25 152 0.60	2 x 8 1.50 1.60 108 0.75	2 x 8 1.875 2.0 87 0.85	2 x 8 2.33 2.5 86 0.95
Turns of **one** secondary	2 x 9 .111 - 590 0.224	2 x 9 0.222 0.25 430 0.265	2 x 9 0.33 .40 295 0.335	2 x 9 0.50 0.50 178 0.40	2 x 9 0.777 0.80 222 0.53	2 x 9 1.00 1.00 172 0.53	2 x 9 1.33 1.5 120 0.71	2 x 9 1.66 1.6 98 0.75	2 x 9 2.33 2.50 96 0.95
Diameter (mm)	2 x 12 0.083 – 770 0.19	2 x 12 0.166 0.16 566 0.224	2 x 12 0.25 0.25 390 0.28	2 x 12 0.375 0.40 240 0.355	2 x 12 0.583 0.63 298 0.45	2 x 12 0.75 0.80 230 0.50	2 x 12 1.0 1.0 160 0.60	2 x 12 1.25 1.25 132 0.67	2 x 12 1.75 1.60 128 0.80
	2 x 15 .066 – 960 0.17	2 x 15 0.133 0.16 740 0.20	2 x 15 0.2 0.2 500 0.236	2 x 15 0.3 0.315 296 0.315	2 x 15 0.466 0.5 370 0.40	2 x 15 0.6 0.63 288 0.45	2 x 15 0.80 0.80 200 0.53	2 x 15 1.0 1.0 166 0.60	2 x 15 1.40 1.60 157 0.71
	2 x 18 0.055 – 1160	2 x 18 0.11 .125 850	2 x 18 0.166 0.16 590	2 x 18 0.25 0.25 360	2 x 18 0.388 0.40 430	2 x 18 0.5 0.5 344	2 x 18 0.666 0.63 239	2 x 18 0.833 0.80 198	2 x 18 1.166 1.25 190

	0.16	0.19	0.224	0.29	0.375	0.40	0.50	0.53	0.67
Regulation %	<45	<50	<45	<26	<30	<30	<20	<18	<17
No-load losses (W)	<0.6	<1.1	<1.0	<0.95	<0.9	<1.0	<1.3	<1.4	<1.7
Cu-losses (W)	<1.0	<2.2	<2.7	<2.5	<5.0	<5.0	<4.5	<5.0	<6.0
Max. nominal temperature at 243V (°C)	<83	<100	<110	<100	<110	<110	<110	<110	<110
Max. temperature in the test (°C)	<160*	<210	<210	<200	<210	<210	<210	<210	<210
Efficiency %	>65	>63	>66	>74	>74	>75	>79	>82	>84
Size (mm): L W H	53 44 17.6	53 44 19.6	53 44 22.6	53 44 28.6	67.8 57 24.4	67.8 57 27.6	67.8 57 31.4	67.8 57 35.8	83.5 70 39
Cu-Weight (gr)	<45	<46	<49	<60	<115	<125	<140	<150	<228
Fe-Weight (gr)	50	67	93	148	154	204	255	315	385

Comments:
At the same value of the transformer rated output current and the nominal fuse current the output voltage of the transformer was designed to be 5% lower.

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** This transformer is **inherently short-circuit proof** with the max. temperature of 160°C in the short-circuit operation at the input voltage 243V.

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