How do we design a not short-circuit-proof 18VA - low profile safety transformer as per IEC 61558,protected by a miniature fuse in accordnce with IEC 127?

Technical specification relevant only to design

Electrical data

Input Voltage	230V, +6%,-10% sinusoidal
Frequency	50Hz
Nominal output voltage	24Vac
Nominal output current	0.75Aac

Environment and operating conditions:

Ambient temperature	70°C
Mode of operation	Continuous
Test conditions	Not short-circuit-proof, protected by miniature fuse to IEC 127

Specification

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

Design criteria

IEC 61558

A transformer which is not short-circuit-proof as per IEC 61558 is not equipped with a cutout. 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 testing is prescribed as per paragraphs 14.2 and 15.3.3:

1. Firstly the transformer is loaded as per paragraph 14.2 with the nominal resistances and with a voltage of 1.06 times the nominal input voltage until permanent operating temperature is reached. In this context, the temperature of

the windings must not exceed the value of θ **nominal**.

2. Immediately after this test, in accordance with paragraph 15.3.3, all secondaries are loaded for period T at K times the current of the fuse. Period T is the longest pre-arcing time of the fuse, caused by K times the fuse's current rating. After time T, the temperature of the windings must not exceed the value of θ **max.** The typical values for a slow-blow miniature fuse as per IEC127 are:
   T = 30 minutes
   K = 2.1
   Here, the temperature of the windings must not exceed θ **max** and that of the case must not exceed the values set out in the following table. In the case of transformers with regulation > 20%, the switch-on current is not a criterion for the choice of fuse. For that reason, it is possible to prescribe a quick-blow fuse, which would have resulted in a much shorter pre-arcing time.
3. Finally, all output windings are short-circuited. At 1.06 times the nominal input voltage, the integral thermal cut-out must actuate, before the temperature exceeds the value of θ **max** as per the following table:

Insulation class	A	E	B	F	H
Typical re-arcing time **T** in (minutes)	30	30	30	30	30
Typical factor **K**	2.1	2.1	2.1	2.1	2.1
Max. winding temperature in test θ **max** (° C)	200	215	225	240	260
Max. winding temperature in nominal operational mode θ **nominal** (° C)	100	115	120	140	165
Max. case temperature (° C)	105	105	105	105	105

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.

We select insulation class E.

Max. winding temperature in nominal operational mode	115°C
Max. winding temperature in test mode	215° C
Max. case temperature	105° C

Important note: the program will design the mean case temperature!

Ambient temperature

Normally, the transformer is operated in an environment whose temperature is between 25°C and 80°C. Very often, we encounter an ambient temperature of 40 degrees C and 70 degrees C.

In this case, the ambient temperature is stated as 70 degrees 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 high wall thicknesses and without large leakage paths, but with a larger winding space.
- On large production runs, there is no problem in inserting the core insert with regard to the question of mechanical robustness and of humming of the core plates.

Let’s design a transformer potted in a case.

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.

We have chosen a potting compound whose thermal conductivity is 0.4W/°K.

Bobbins

In this output range, recourse is had almost exclusively to a double-chamber 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.

We have selected a double-chamber bobbin from a family of bobbins with a large winding space.

Impregnation

In this topic there is the possibility of potting just the bobbin or the window of the core, or of injection under pressure. In this method, we save a quantity of potting compound for the same voltage resistance in the potted transformer, and we don't need a case.

Our transformer is potted in a case in vacuum.

Sheet quality

A flat transformer must be as flat and as small as possible. For that reason, these transformers are manufactured exclusively in UI sheet form and annealed, grain - oriented core quality with specific Fe-losses of 1.11 W/k at 1.5T and 50Hz (WV111, M6X,…).

We have selected the annealed, grain-oriented core quality of 1.11 W/kg at 1.5 T, 50 Hz, 0.35 mm thick, sheet form UI 39, without holes in the corners.

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.

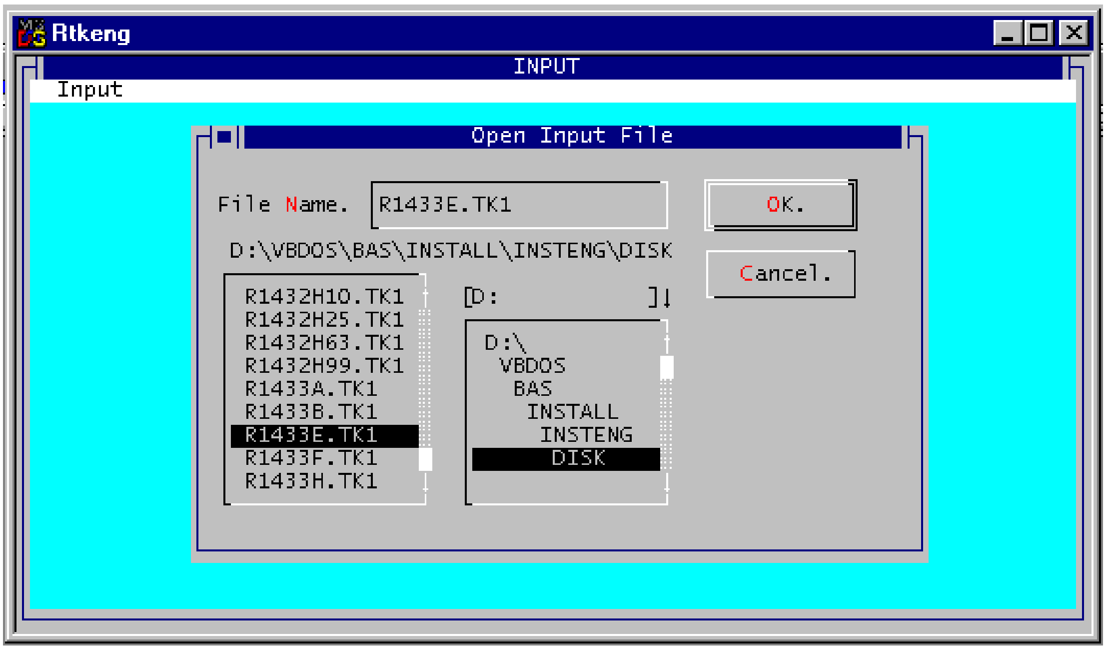
Additional tolerance for output voltage

The output voltage of a not short-circuit proof transformer is tested in the hot state at nominal primary voltage and nominal load resistance.

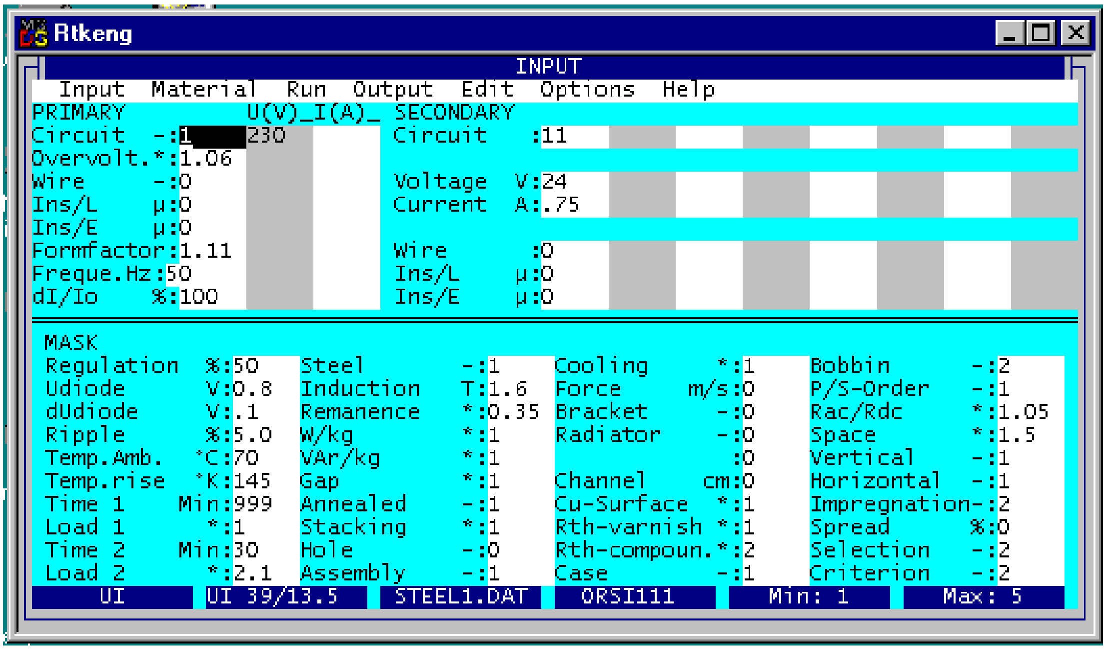
We are going to perform our design at the nominal output voltage.

Procedure for design

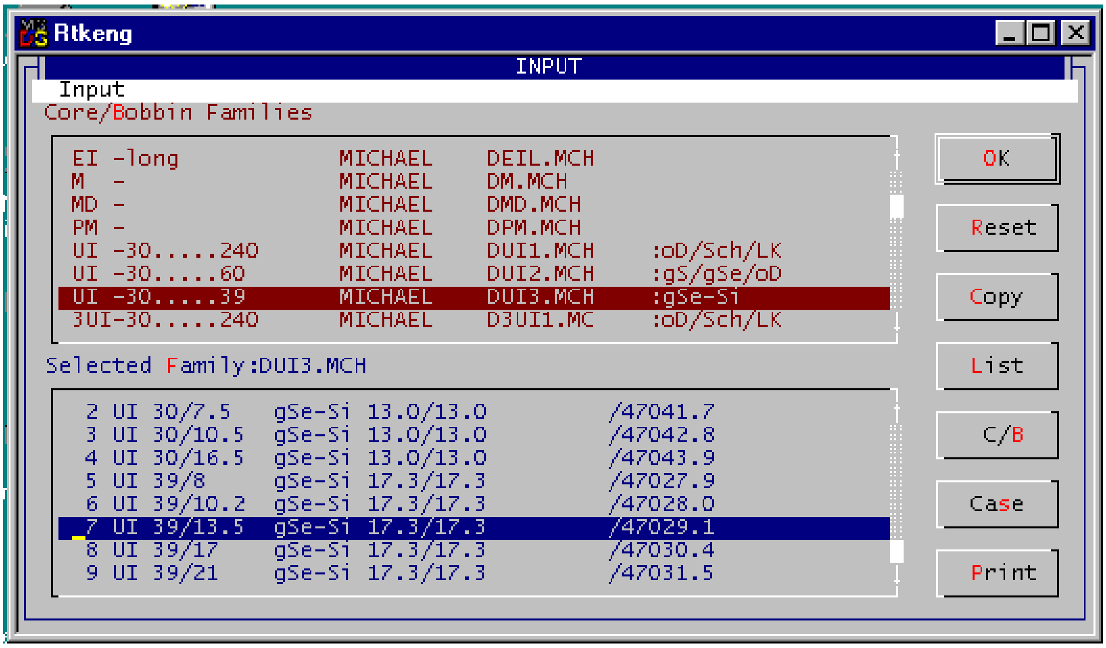
1. If you are not yet familiar with Rale design software, then please read the text: **"How do I design a small transformer?".** You should keep a copy of this text within your reach when performing design operations.
2. Start your demo program and load up input data file R1433E.TK1. This input data file has all of the most important presets for designing a not short-circuit-proof transformer of insulation class E, which has to be protected with a miniature fuse as per IEC127



3. Fill in your input mask as follows. If you need help, then press function key F1. For each input field, there is extensive description. In the case of this input data file, the preset ambient temperature is 40 degrees C. Correct the input values for ambient temperature and temperature rise as per the above diagram. The temperature rise employed here is 10° K lower than permitted

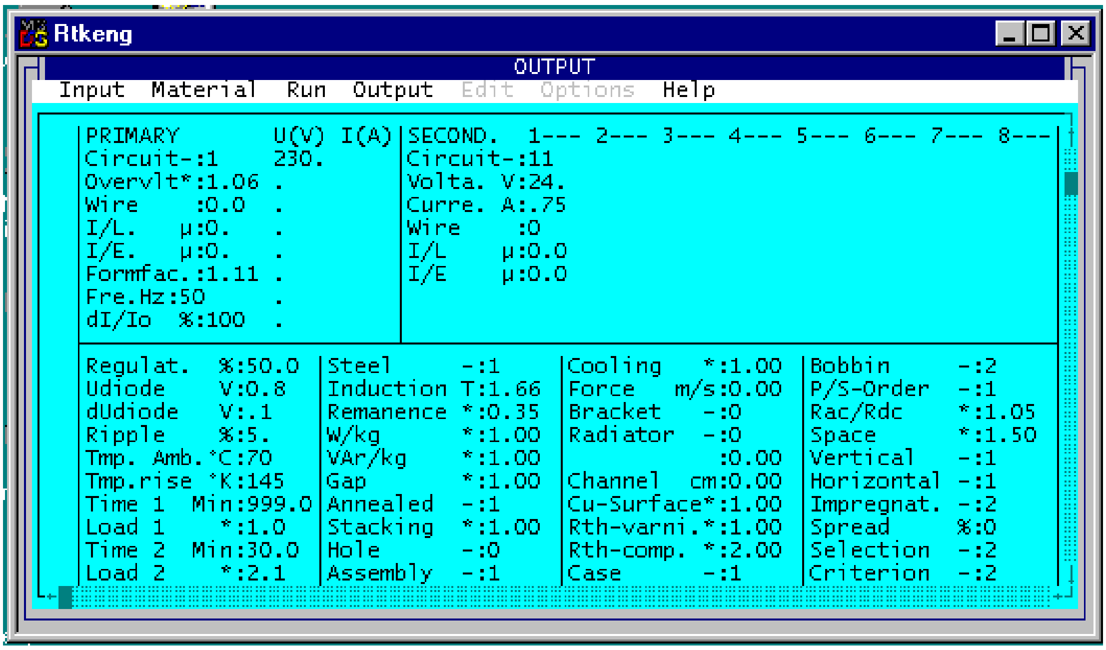


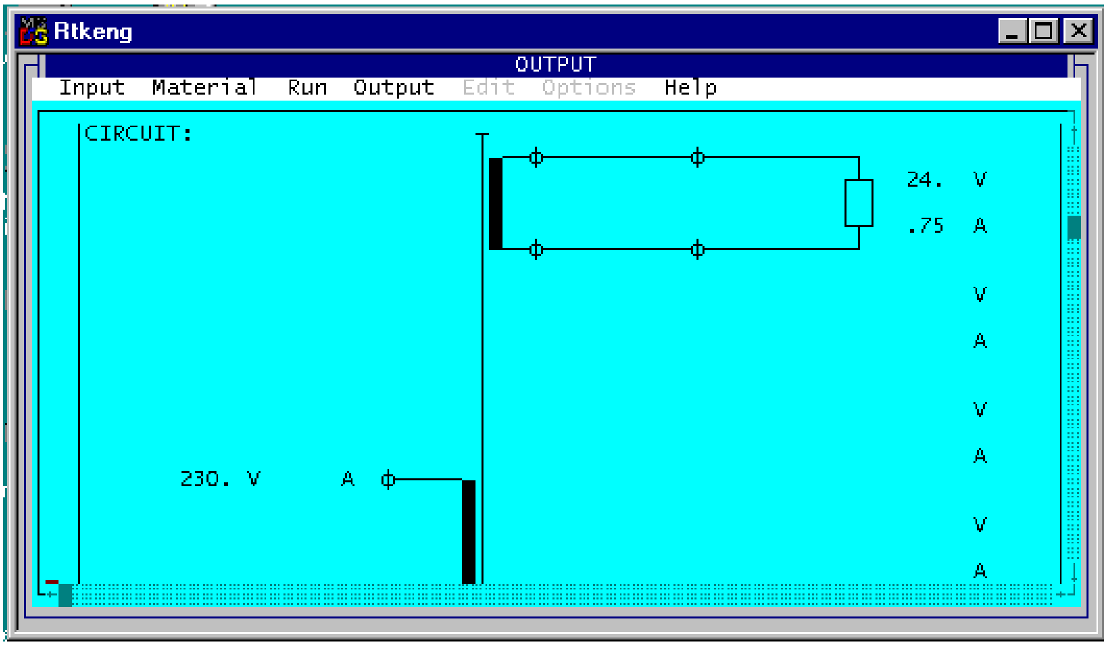
4. Select the core and bobbin with the correct case. If the dataset for the core and bobbin which you selected has no case, then you have to set up the case yourself. The core selected in the following illustration has a case in its dataset. For this reason, it is enough to mark the core UI39/13.5 and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

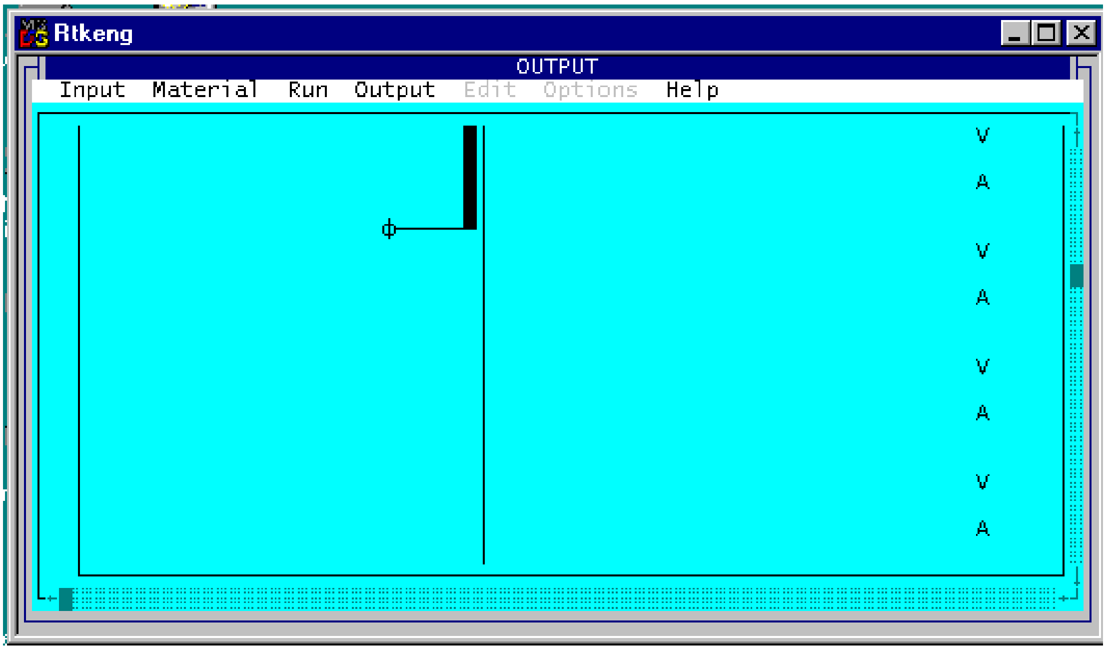


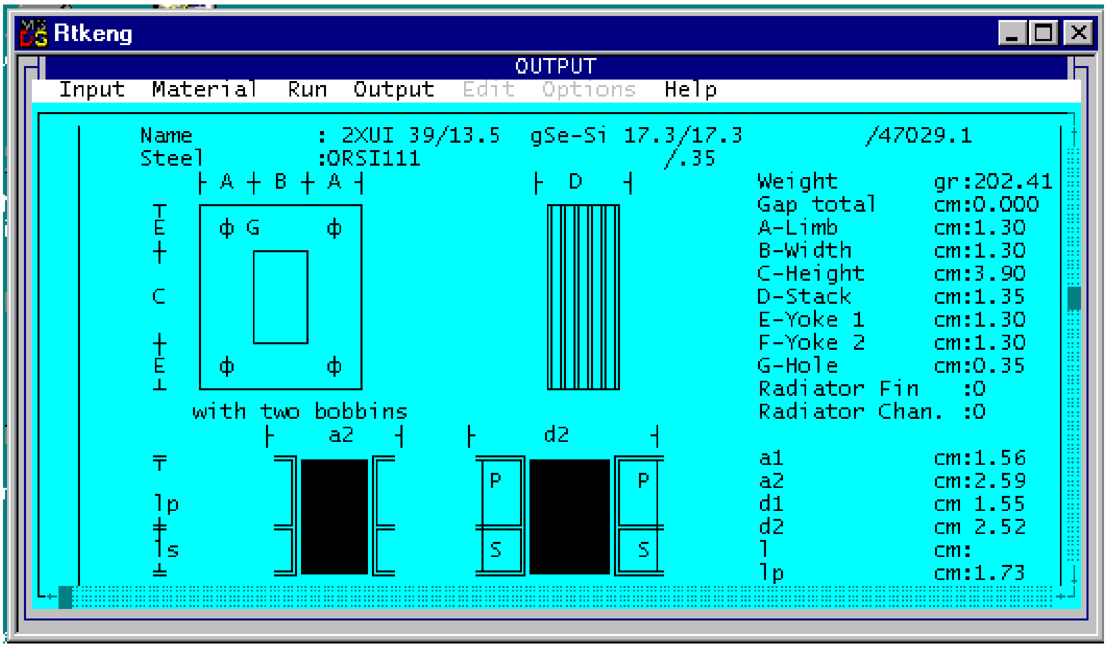
5. Click on **OK.**
6. Save your input data file. In this design example, the input data has been saved in input data file CAL0003E.TK1. This input data file was supplied together with this document. Copy it into the directory in which the RALE demo program is installed.
7. Make a connection with the Rale Design Server.
8. Load your input data file and start your design process.

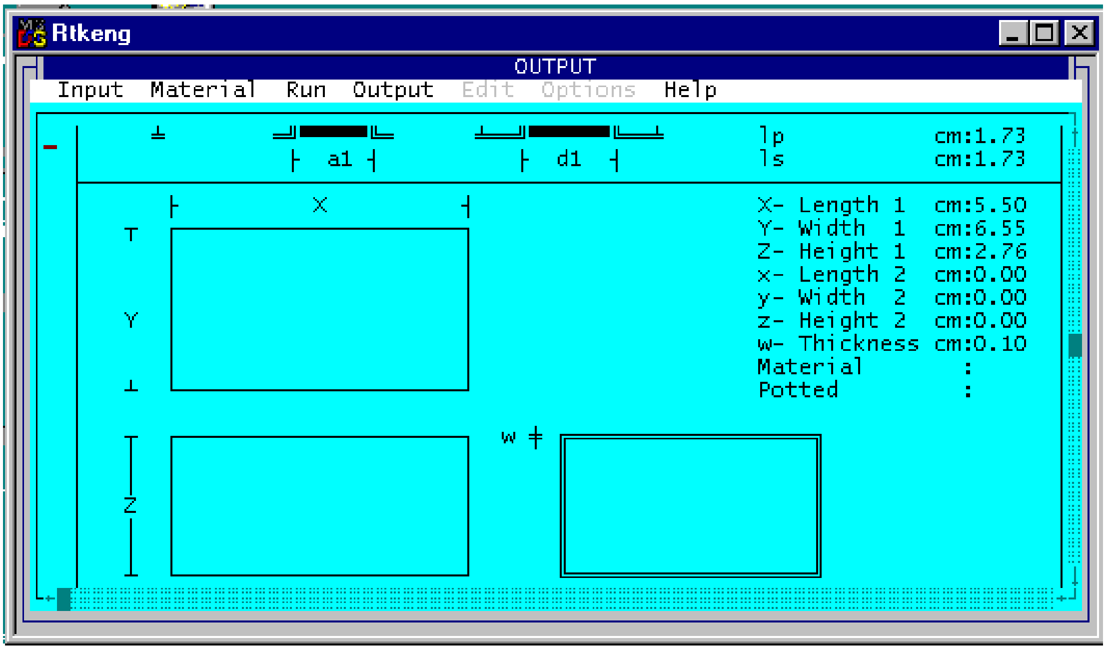
After the design procedure has been completed, the following design data is available and can be printed on 3 pages.

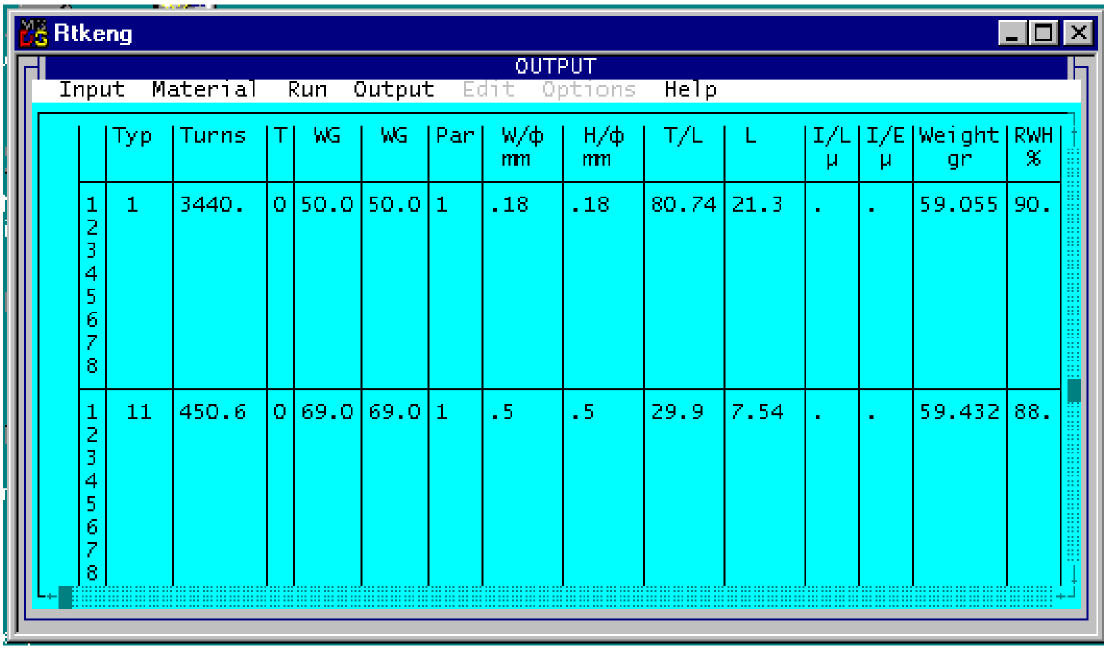



Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
CIRCUIT:
24. V
.75 A
V
A
V
A
230. V A
V
A

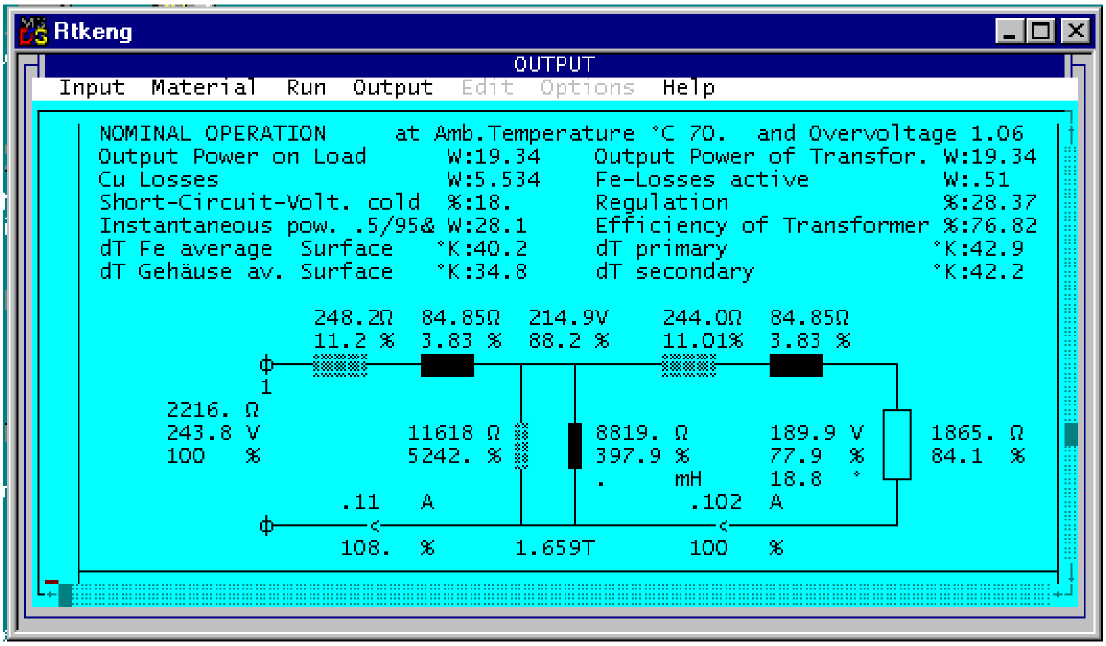

Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
V
A
V
A
V
A
V
A

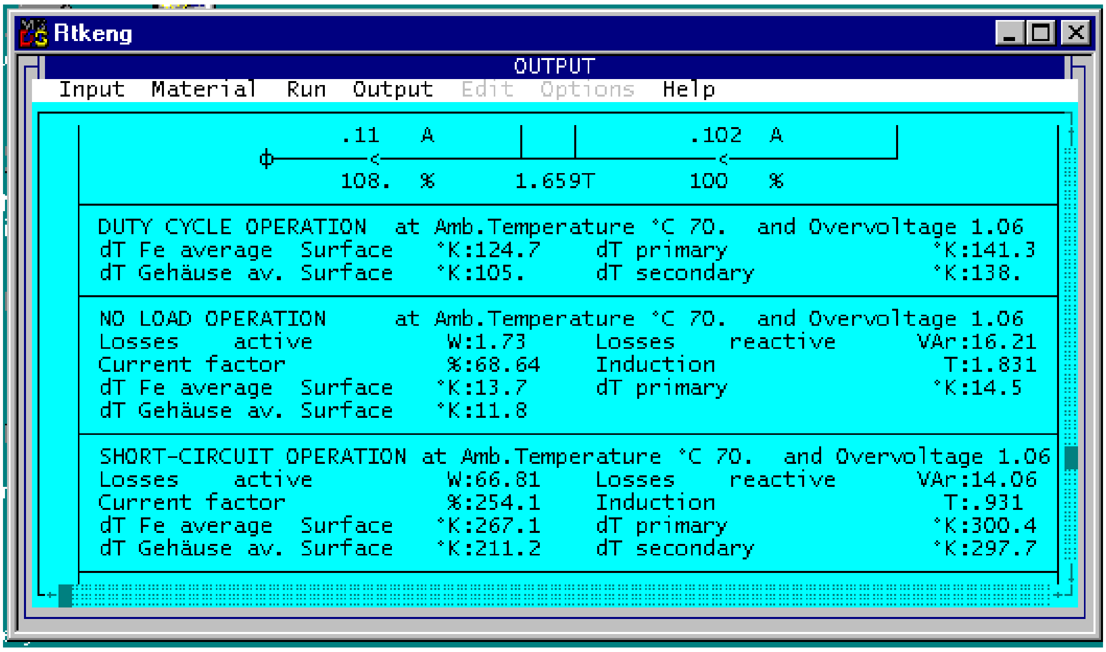

Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
Name : 2XUI 39/13.5 gSe-Si 17.3/17.3 /47029.1
Steel :ORSI111 /.35
A B A
D
E
C
E
G
with two bobbins
a2
d2
lp
ls
P
S
Weight gr:202.41
Gap total cm:0.000
A-Limb cm:1.30
B-Width cm:1.30
C-Height cm:3.90
D-Stack cm:1.35
E-Yoke 1 cm:1.30
F-Yoke 2 cm:1.30
G-Hole cm:0.35
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

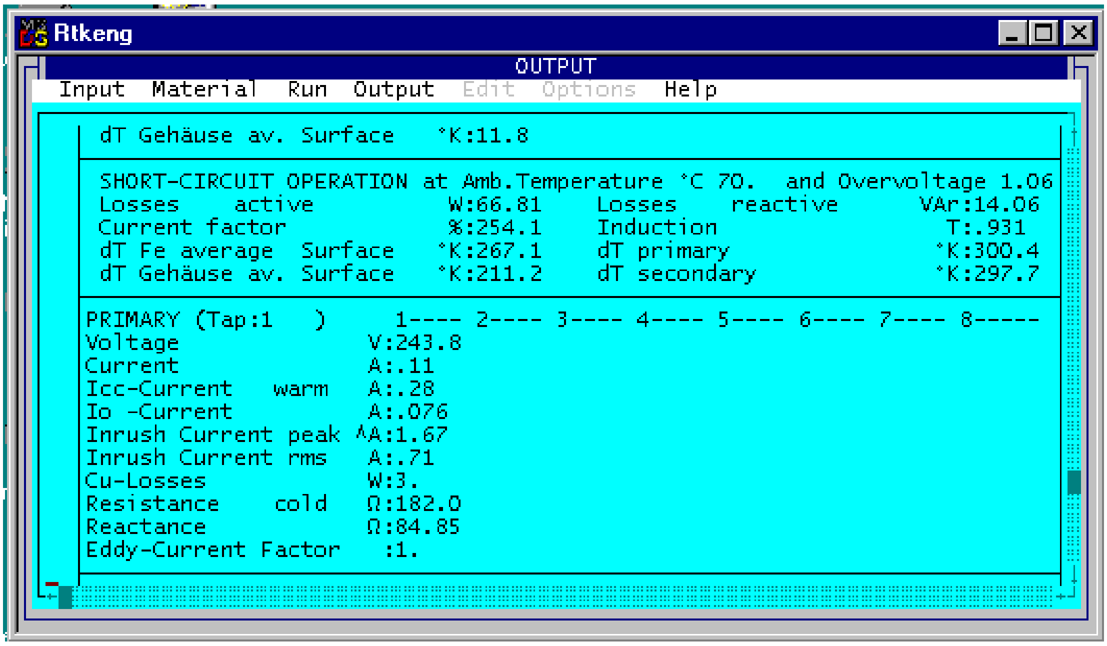

Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
a1
d1
lp cm:1.73
ls cm:1.73
X
Y
Z
w
X- Length 1 cm:5.50
Y- Width 1 cm:6.55
Z- Height 1 cm:2.76
x- Length 2 cm:0.00
y- Width 2 cm:0.00
z- Height 2 cm:0.00
w- Thickness cm:0.10
Material :
Potted :

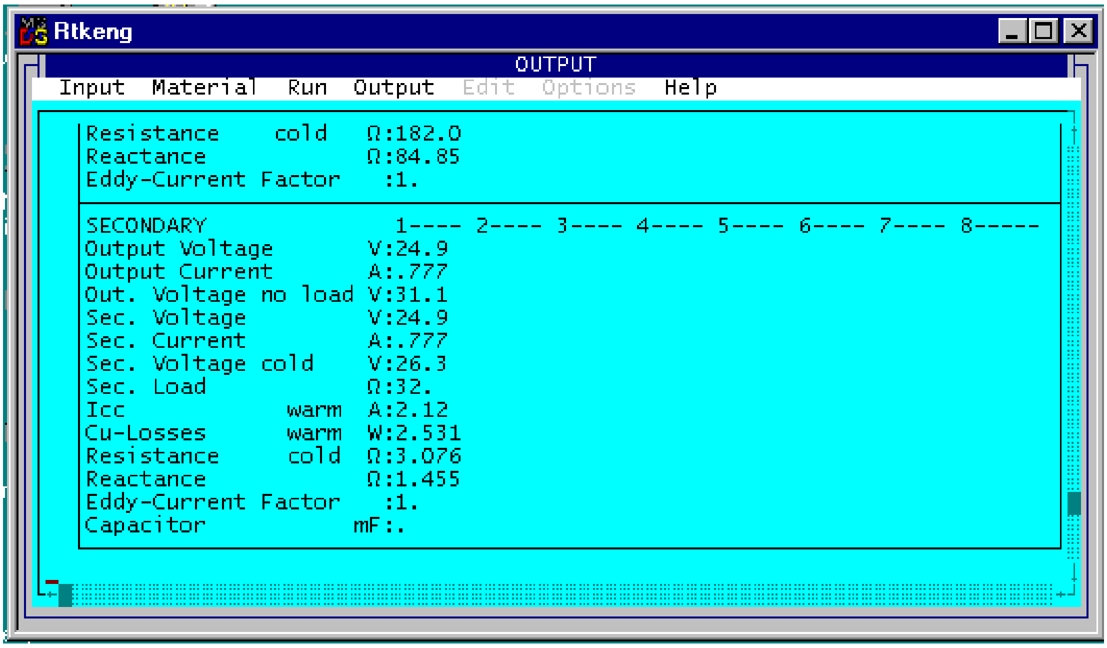


	Typ	Turns	T	WG	WG	Par	W/ϕ mm	H/ϕ mm	T/L	L	I/L μ	I/E μ	Weight gr	RWH %
1 2 3 4 5 6 7 8	1	3440.	0	50.0	50.0	1	.18	.18	80.74	21.3	.	.	59.055	90.
1 2 3 4 5 6 7 8	11	450.6	0	69.0	69.0	1	.5	.5	29.9	7.54	.	.	59.432	88.




Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
.11 A
.102 A
108. %
1.659T
100 %
DUTY CYCLE OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06
dT Fe average Surface °K:124.7 dT primary °K:141.3
dT Gehäuse av. Surface °K:105. dT secondary °K:138.
NO LOAD OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06
Losses active W:1.73 Losses reactive VAr:16.21
Current factor %:68.64 Induction T:1.831
dT Fe average Surface °K:13.7 dT primary °K:14.5
dT Gehäuse av. Surface °K:11.8
SHORT-CIRCUIT OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06
Losses active W:66.81 Losses reactive VAr:14.06
Current factor %:254.1 Induction T:.931
dT Fe average Surface °K:267.1 dT primary °K:300.4
dT Gehäuse av. Surface °K:211.2 dT secondary °K:297.7


Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
dT Gehäuse av. Surface °K:11.8
SHORT-CIRCUIT OPERATION at Amb.Temperature °C 70. and Overvoltage 1.06
Losses active W:66.81 Losses reactive VAr:14.06
Current factor %:254.1 Induction T:.931
dT Fe average Surface °K:267.1 dT primary °K:300.4
dT Gehäuse av. Surface °K:211.2 dT secondary °K:297.7
PRIMARY (Tap:1) 1---- 2---- 3---- 4---- 5---- 6---- 7---- 8-----
Voltage V:243.8
Current A:.11
Icc-Current warm A:.28
Io -Current A:.076
Inrush Current peak ^A:1.67
Inrush Current rms A:.71
Cu-Losses W:3.
Resistance cold Ω:182.0
Reactance Ω:84.85
Eddy-Current Factor :1.



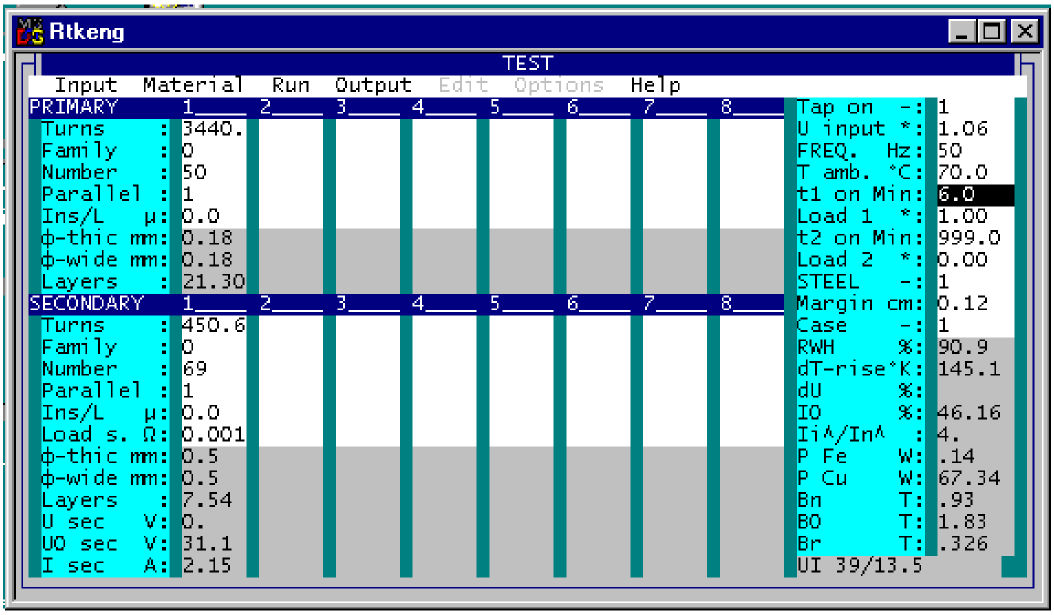
9. This is followed by checking of the calculated data.

- Firstly, we check the maximum winding temperature in nominal operating mode=ambient temperature + dTprim in nominal operating mode = 70+42.9 =112.9 < 115°C
- The maximum winding temperature in ED mode is:
  ambient temperature + dTprim in short-circuit = 70 + 141 = 211<215°C
- The mean case temperature in ED mode is:
  Ambient temperature + dT case in tesoperation = 70 + 105 = 175.0>105°C
  This means that this transformer has to be installed in a unit such that it cannot be contacted during operation.
- Now we'll check the winding data and the filling factor.

10. If the design data is not satisfactory, then we have two ways in which we can implement the desired correction:

- We can go back to the input mask (function key F2), correct the input data and re-design the transformer, or

  We can go back to the test program (function key F5), modify the designed transformer manually and convert the transformer by that means.



11. In the test program, 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.
12. This simulation is performed as follows:

- The loading resistance is subjected to the value of **Lad s. = 0.001Ω** (practically short-circuited).
- Time **T1 on i**s increased in increments until overtemperature **dT** has reached the maximum permitted value of 145°K. In this instance it is attained after 5 minutes.
- Load **Load 1 = 1** => operation at loading resistance of 0.001Ω .
- Time **T2 on = 999** minutes.
- Load **Load 2 = 0** => no-load mode

This means that from a very long (T2 in=999 minutes) no-load period (load2 = 0) we simulate a short-circuit (Load1=1 = short-circuit resistance) during period 1.
We now read the following:

- I short-circuit = I sec = 2.15A
- Duration of short-circuit = T1 on = 6 minutes

After completion of the design work, we can print out the design data on-line or store it on the local PC and print it off-line. The output data file from this design example CAL0003E.TK2 is supplied together with this document. Copy it into the directory in which your Rale Demo Programm is installed.

Tips&Tricks

The transformer is too full

This case frequently arises if you select your own core. Let us say that we wish to use this core for 40VA output, for example.

- Increase the overtemperature to the permitted level.
- Increase the induction. Ensure that the idling temperature does not exceed the value permitted for the insulation class.

The transformer is relatively empty

This case frequently arises if you select your own core. Let us say that we wish to use this core for 10VA output, for example.

- Select a smaller core or
- Reduce the temperature rise or
- Reduce the induction.

The bobbin unit chambers are filled asymmetrically, e.g. 70%:90%.

Manually change the wire thicknesses in the test program:

- Select the next larger wire thickness in the chamber which is less full.
- Select the next smaller wire thickness in the chamber which is fuller.
- Correct the number of windings of the secondary in order to arrive at the desired output voltage.

Nominal operating data

This transformer was designed for 6% overvoltage. In order to arrive at the nominal data for this transformer design, test the designed transformer at the nominal input voltage in the test program (**Uin = 1**).

The temperature in nominal operating mode is too high

- Reduce the overtemperature and increase the induction.
- Set a better core quality..
- Increase the cooling surface area. Select a larger case. The case colour should be dark.

The no-load current is too high

The no-load is not a criterion for design. The no-load temperature must not exceed the permitted limit.

Nominal output current

The secondary nominal currents with a secondary-side located fuse are selected in the same way as the fuse nominal currents. In the event of a discrepancy, the K factor must be converted as follows:

Kactual = Kfuse * I nominal fuse / I nominal secondary

Statement of supply voltage and output voltages

In the case of a UI transformer, both the primary and the secondary are wound in two sections or on two legs. For that reason, we write the following information on the label of this transformer:

Input voltage	2 x 115V, 50Hz/60Hz
Output voltage	2 x 12V

Fuse’s nominal current

The nominal current of the fuse according to IEC and UL for the same fuse will differ by a factor of approx 0.7. The nominal current of the fuse as per standard UL will blow the fuse. At the fuse’s nominal current as per IEC, the fuse can be used without blowing.

InominalIEC / InominalUL = 0.7

Home