How do we design
a 60VA - non-inherently short-circuit proof safety transformer
for halogen lamps in accordance with IEC 61558, protected by a thermal cutout ?

Technical specification relevant only to design

Electrical data and diagram

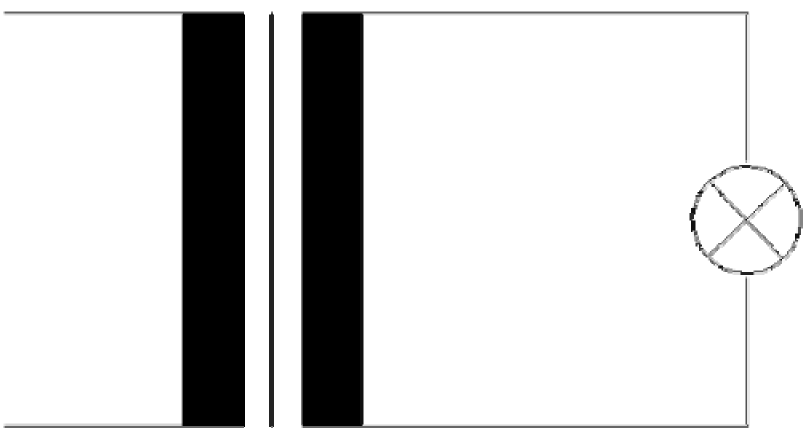
Input voltage	230V, +6%, -10%, sinusoidal
Frequency	50Hz
Nominal output voltage	12Vac
Nominal output current	5Aac

Ambient and operating conditions:

Ambient temperature	:40°C
Mode of operation	:Continuous
Test conditions	:Non-inherently short-circuit proof, protected by a thermal cutout

Specification

- Safety transformer to IEC 61558
- Insulation class E



Design criteria

IEC 6155
A non-inherently short-circuit proof transformer as per IEC 61558 is equipped with a cutout to protect against short-circuit and overload. In this case, the transformer should be equipped with a thermal cutout:
The procedure for testing is prescribed as per paragraphs 14.2, 15.3.1 and 15.3.5 as follows:

1. Firstly, the transformer as per paragraph 14.2 is loaded with nominal resistance and at 1.06 x the nominal input voltage until permanent operating temperature is achieved. In this context, the temperature of the windings must not exceed the value of θ **nominal.**
2. Next, all output windings are short-circuited. At 1.06 x the nominal input voltage, the integral thermal cutout should actuate, before the temperature reaches the level of **θ max** as per the following table.
3. Finally, the transformer is loaded at 0.95 x the value of the lowest current, which causes actuation of the thermal cutout, until attainment of continuous operating temperature. In this context, the thermal cutout should not actuate and the temperature should not exceed the value of θ **max**.

Insulation class	A	E	B	F	H
Max. winding temperature in test θ **max** (° C)	200	215	225	240	260
Max. case temperature in test (° C)	105	105	105	105	105
Max. winding temperature in nominal operation mode θ **nominal** (° C)	100	115	120	140	165
Max. case temperature in nominal operation mode (° C)	80	80	80	80	80

Insulation class
Maximal winding temperature in nominal operation mode = 115°C

Maximal winding temperature in test mode = 215°C

Insulation class E is prescribed.

Thermal cutout
The thermal cutout (temperature-operated cutout, PTC, ..) is located in the primary windings. We choose an actuation temperature of between θ **nominal a**nd **θ max.** In the case of a transformer in a mobile installation, in which context the surface temperature of the case must not exceed 80°C, the insulation class of the transformer **A** and the actuation temperature of the thermal cutout are selected lower than θ **nominal.**

Let's choose a thermal cutout actuation temperature of between θ nominal and θ max.

Sheet quality, core form and winding technology
For pricing reasons, transformers for halogen lamps are equipped with core quality 5.3W/kg and 1.5T, and 50Hz. The distinction is drawn between two basic specifications:

- With a bobbin which has a cover or is potted in the case.
- Without a bobbin, "dry" pressed, with a cover.
  In this specification, we use small cut forms with high coating thickness. Windings are enveloped in a "hose" and pressed into the winding space of the transformer. The core construction looks like that of a choke or of a welded transformer. The result is a gap which is suitable for operation with a dimmer which is envisaged for the brightness control.

Let's choose the non-annealed, cold-rolled core quality of 5.3W/kg for 1.5T, 50Hz, 0.5mm thick, sheet form EI 42/125, without holes in the corners, with pressed windings.

Impregnation
Normally, a double-chamber bobbin unit is made with a cover such that the transformer can be manufactured "dry".

Our transformer is manufactured without impregnation.

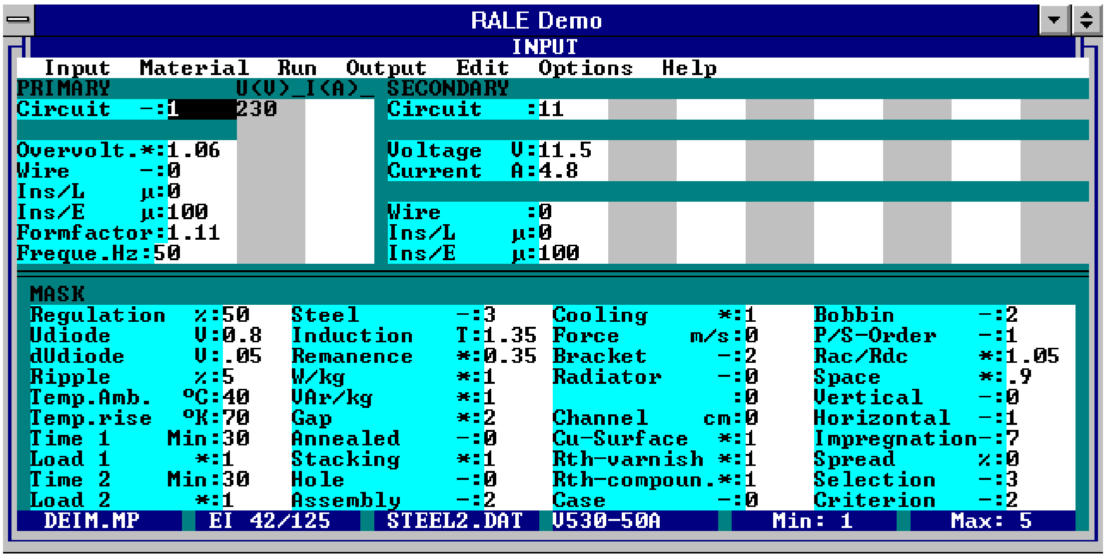
Induction
These transformers are designed with an induction of between 1.3T and 1.5T in nominal operating mode.

Nominal output voltage
Normally, the nominal output voltage of transformers for halogen lamps is 5% lower than the lamps' nominal voltage.

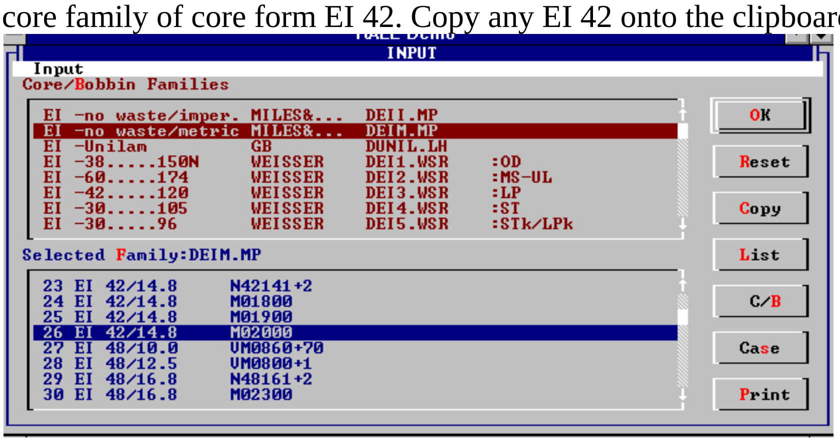
Let's calculate our design with 11.5 V nominal output voltage.

Procedure for design

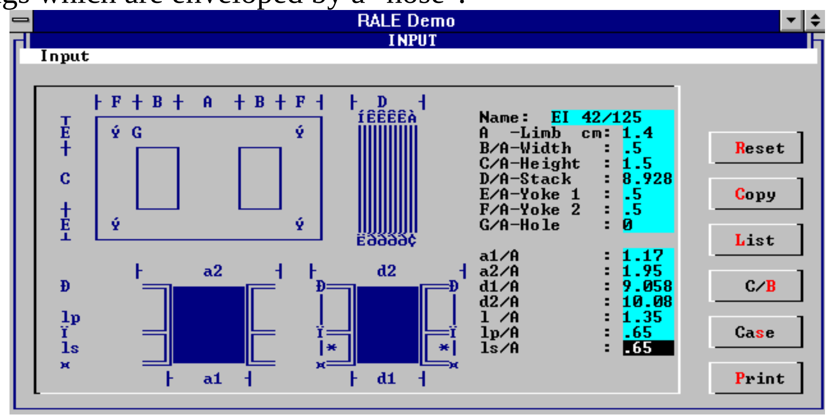
1. If you are not yet familiar with the Rale Design Software, then you should read the text: **"How do I design a small transformer?"**. You should keep a copy of this text within your reach whenever performing design operations.
2. Fill in the input mask as follows. If you need any help, press function key F1. There is extensive description for each input field.

3. 

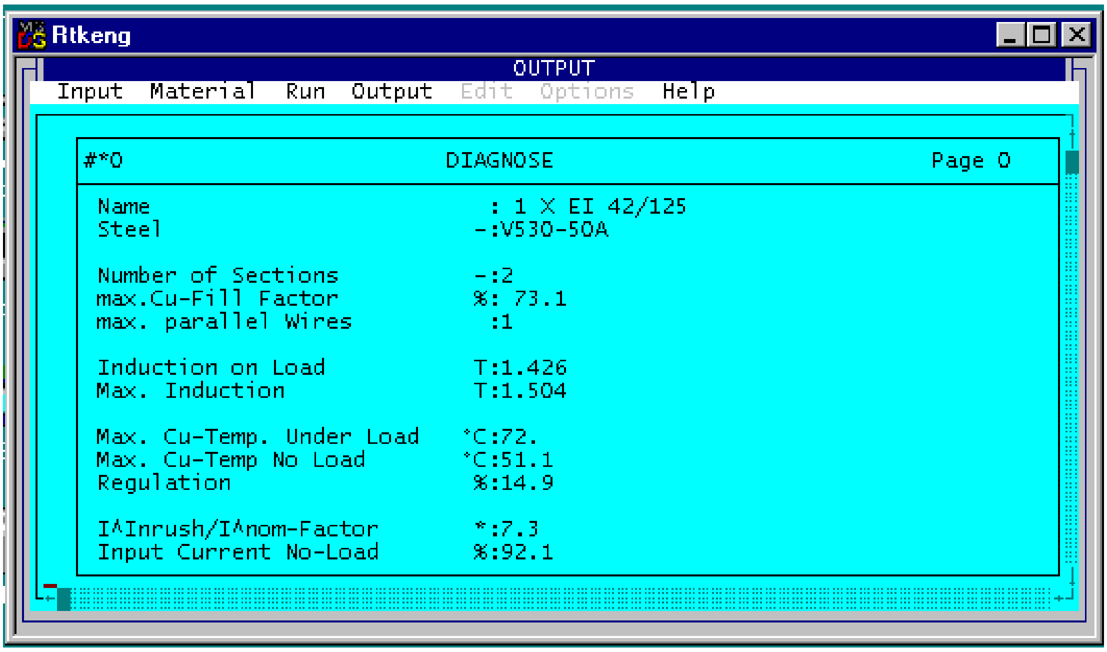
4. Select the core family of core form EI 42. Copy any EI 42 onto the clipboard.

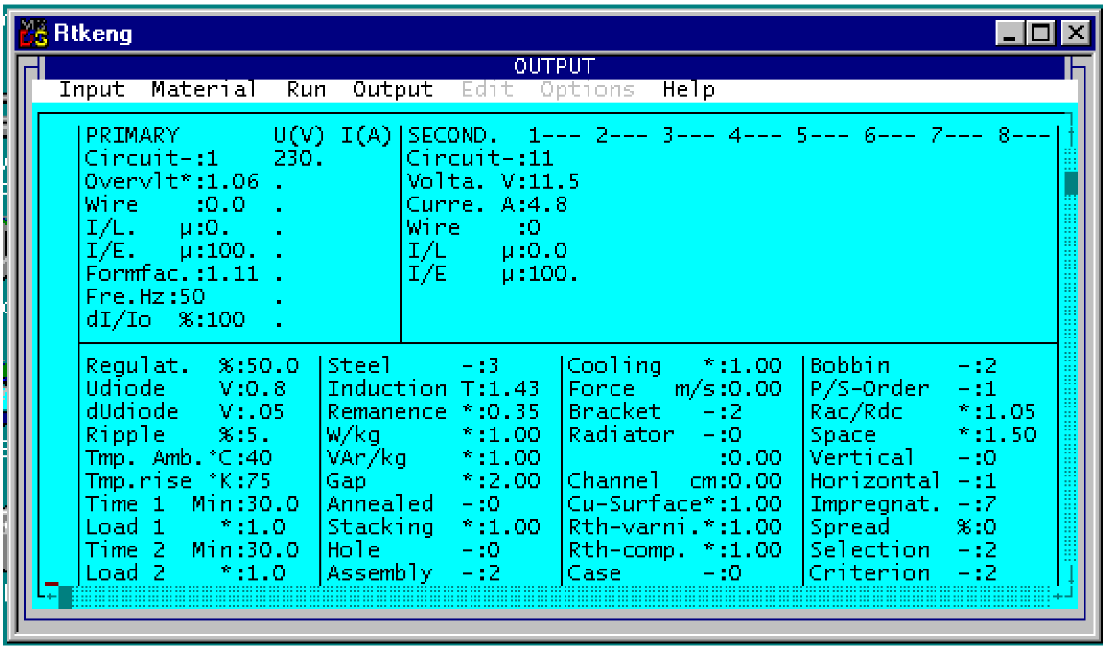
5. 

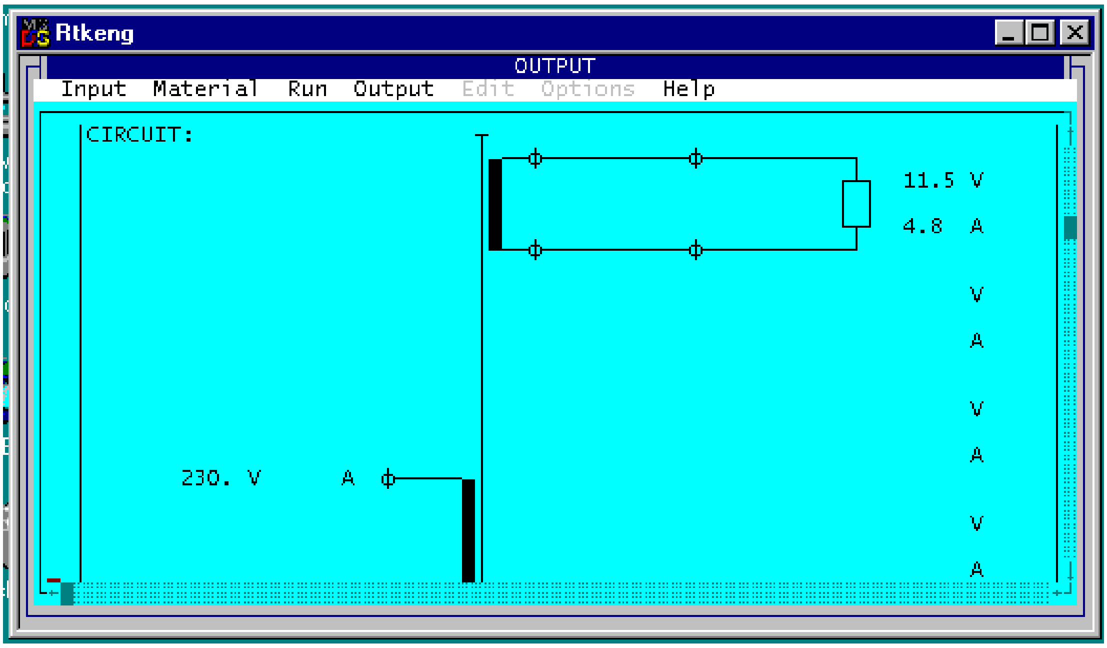
6. Change the name and the coating thickness. You also have to set up the "bobbin unit" for windings which are enveloped by a "hose".

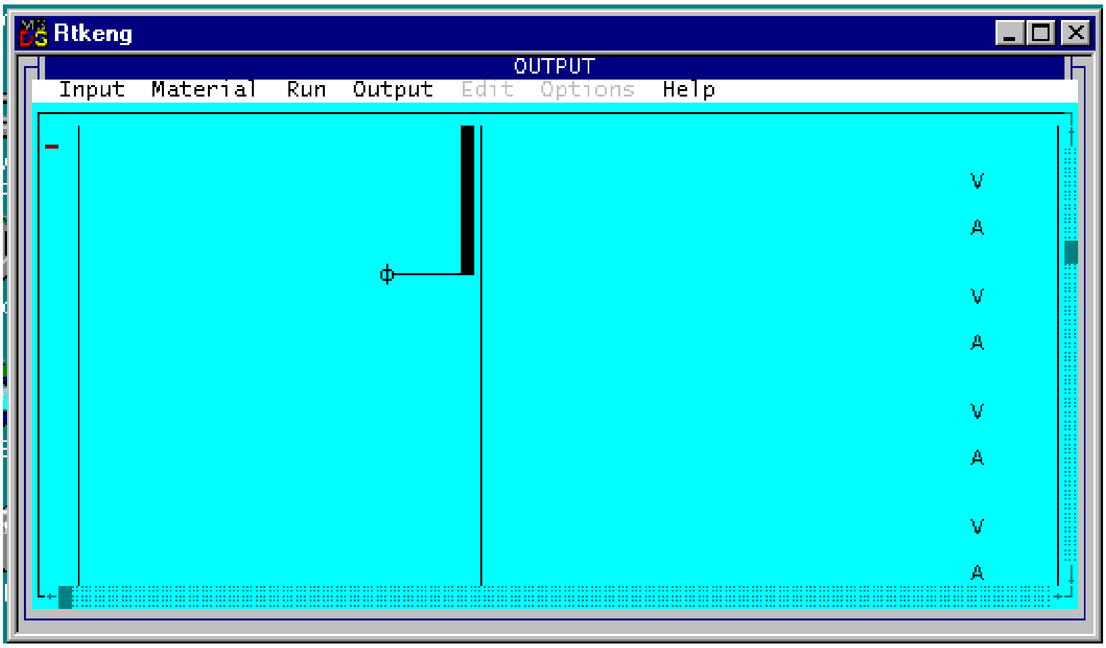
7. 

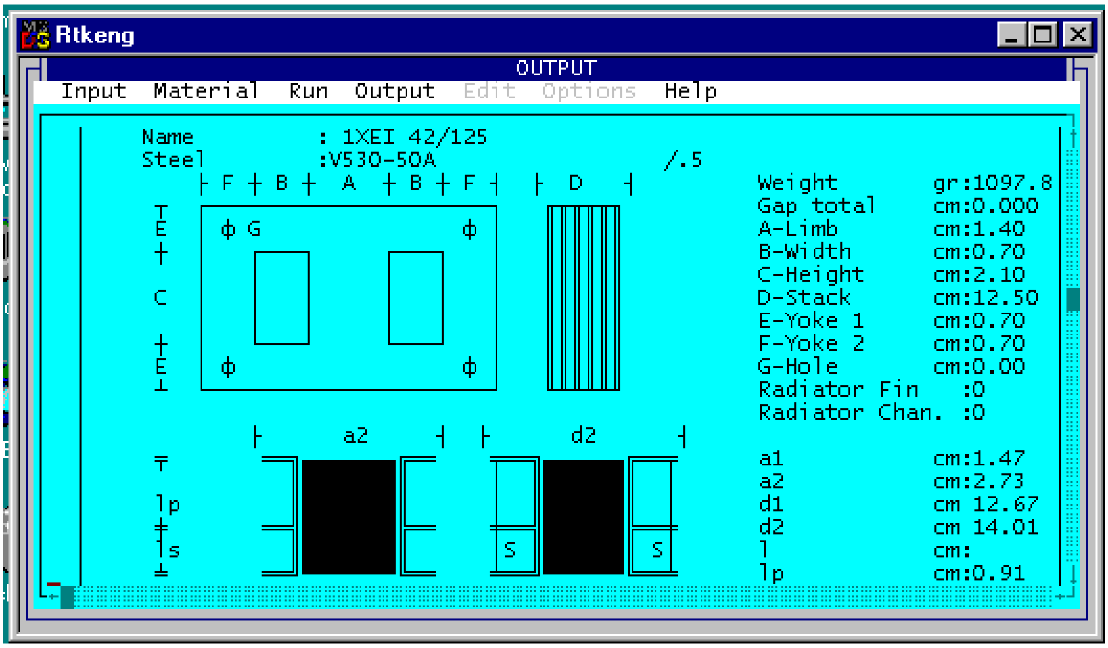
8. Click on **OK**.
9. Save your input data file. In this design example, the input data has been saved in input data file **CAL0004E.TK1**. This input data file was supplied together with this document. Copy it into the directory where the RALE Demo program is installed.
10. Make a connection with your Rale design server.
11. Load up your input data file and start designing.
12. After completion of your design work, the following design data is available, that can be printed on three pages:

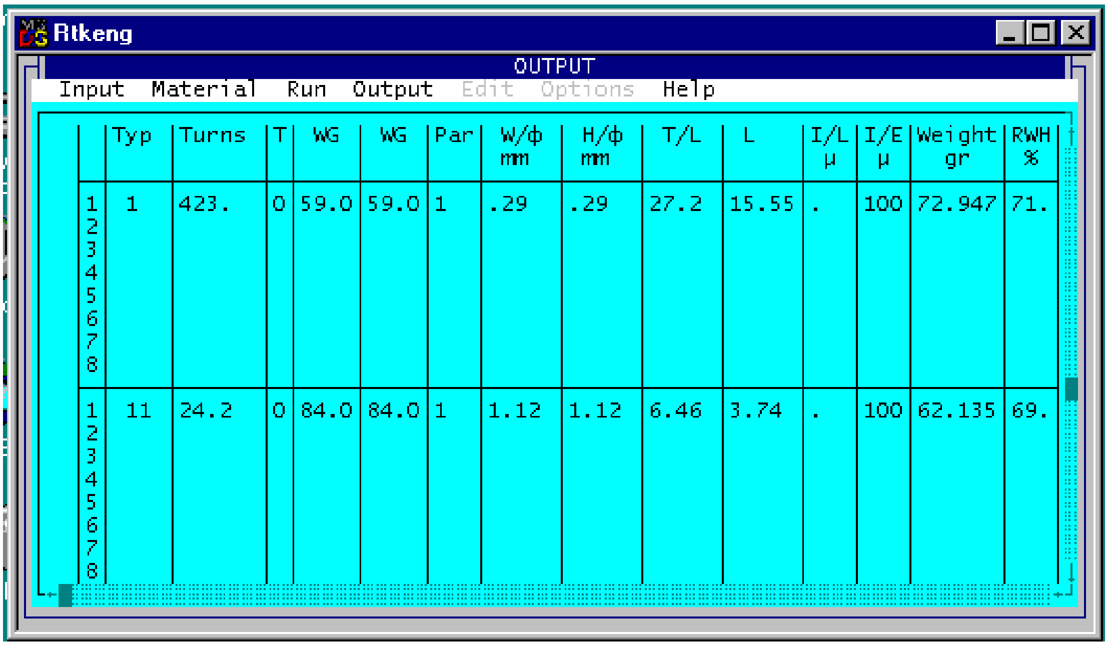
13. 
Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
#*0 DIAGNOSE Page 0
Name : 1 X EI 42/125
Steel -:V530-50A
Number of Sections -:2
max.Cu-Fill Factor %: 73.1
max. parallel Wires :1
Induction on Load T:1.426
Max. Induction T:1.504
Max. Cu-Temp. Under Load °C:72.
Max. Cu-Temp No Load °C:51.1
Regulation %:14.9
I^Inrush/I^nom-Factor *:7.3
Input Current No-Load %:92.1


Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
PRIMARY U(V) I(A)
Circuit-:1 230.
Overvlt*:1.06 .
Wire :0.0 .
I/L. µ:0. .
I/E. µ:100. .
Formfac.:1.11 .
Fre.Hz:50 .
dI/Io %:100 .
SECOND. 1--- 2--- 3--- 4--- 5--- 6--- 7--- 8---
Circuit-:11
Volta. V:11.5
Curre. A:4.8
Wire :0
I/L µ:0.0
I/E µ:100.
Regulat. %:50.0
Udiode V:0.8
dUdiode V:.05
Ripple %:5.
Tmp. Amb.°C:40
Tmp.rise °K:75
Time 1 Min:30.0
Load 1 *:1.0
Time 2 Min:30.0
Load 2 *:1.0
Steel -:3
Induction T:1.43
Remanence *:0.35
W/kg *:1.00
VAr/kg *:1.00
Gap *:2.00
Annealed -:0
Stacking *:1.00
Hole -:0
Assembly -:2
Cooling *:1.00
Force m/s:0.00
Bracket -:2
Radiator -:0
:0.00
Channel cm:0.00
Cu-Surface*:1.00
Rth-varni.*:1.00
Rth-comp. *:1.00
Case -:0
Bobbin -:2
P/S-Order -:1
Rac/Rdc *:1.05
Space *:1.50
Vertical -:0
Horizontal -:1
Impregnat. -:7
Spread %:0
Selection -:2
Criterion -:2

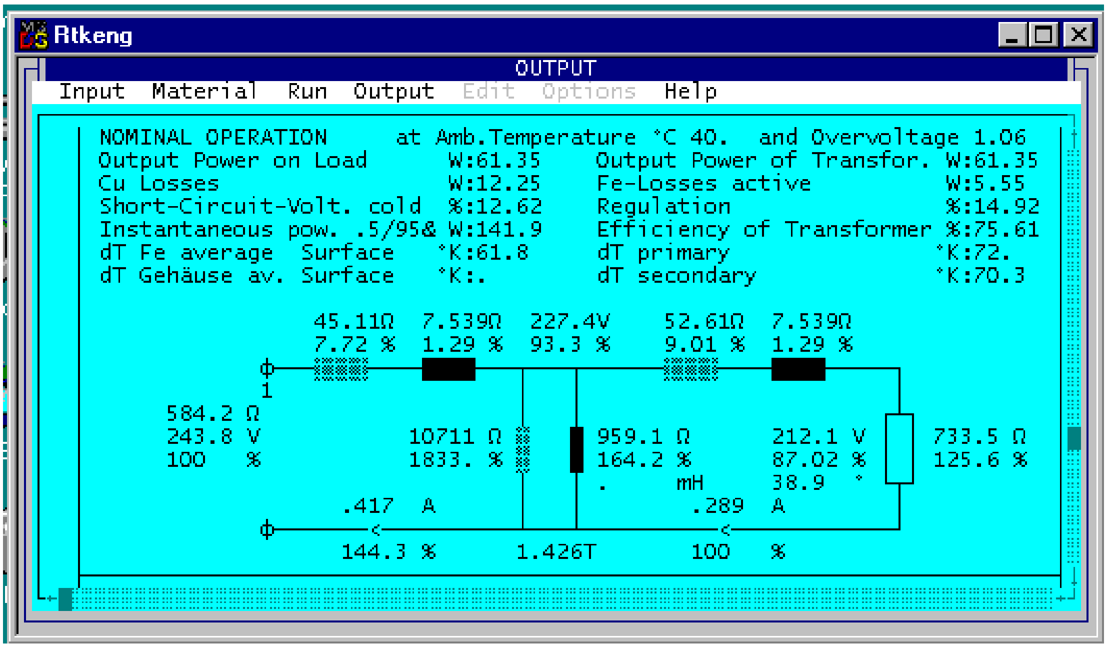

Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
CIRCUIT:
11.5 V
4.8 A
V
A
V
A
230. V A
V
A

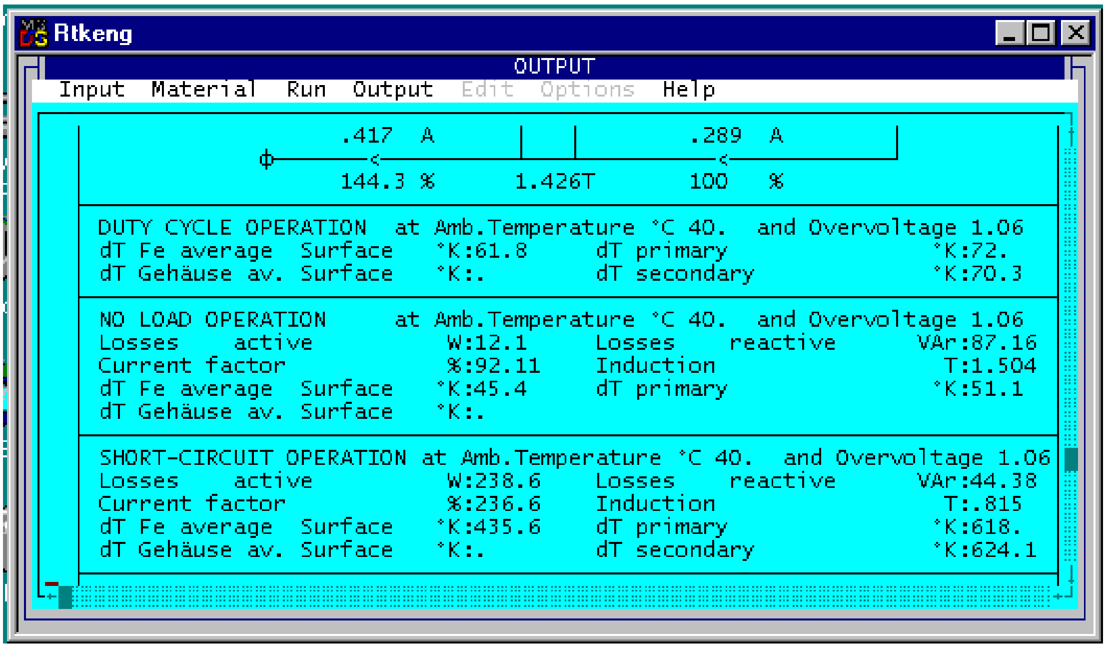

Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
V
A
V
A
V
A
V
A

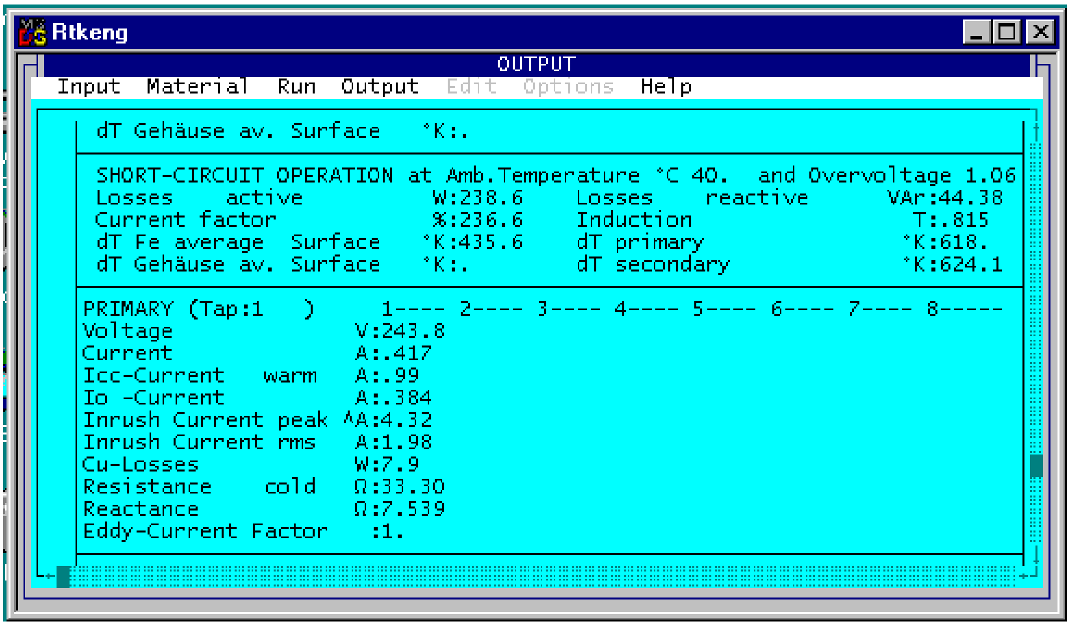


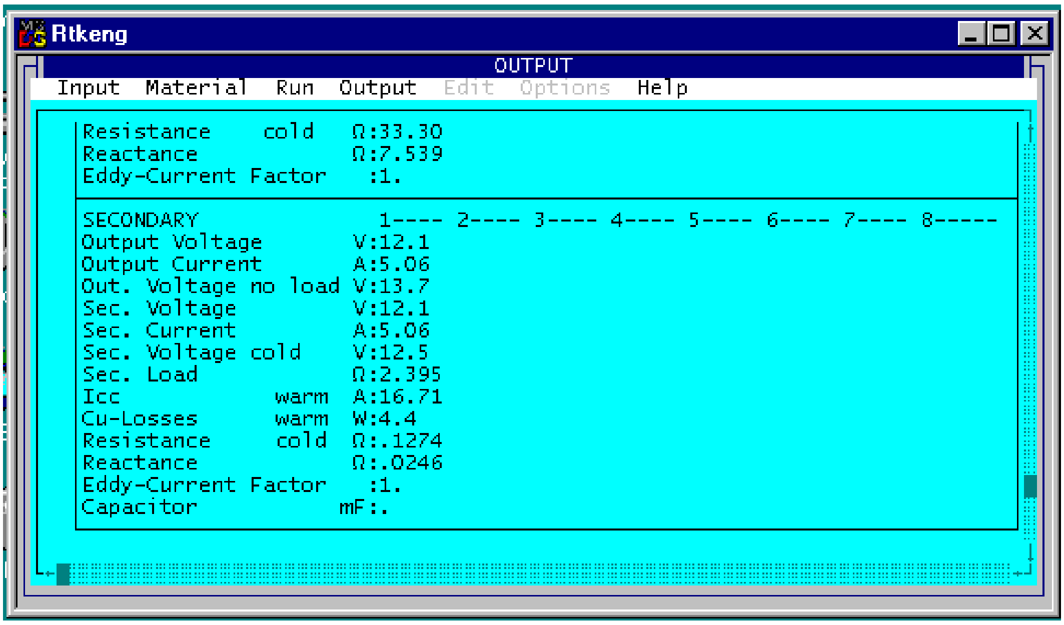


	Typ	Turns	T	WG	WG	Par	W/ϕ mm	H/ϕ mm	T/L	L	I/L µ	I/E µ	Weight gr	RWH %
1 2 3 4 5 6 7 8	1	423.	0	59.0	59.0	1	.29	.29	27.2	15.55	.	100	72.947	71.
1 2 3 4 5 6 7 8	11	24.2	0	84.0	84.0	1	1.12	1.12	6.46	3.74	.	100	62.135	69.


Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
NOMINAL OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06
Output Power on Load W:61.35 Output Power of Transfor. W:61.35
Cu Losses W:12.25 Fe-Losses active W:5.55
Short-Circuit-Volt. cold %:12.62 Regulation %:14.92
Instantaneous pow. .5/95& W:141.9 Efficiency of Transformer %:75.61
dT Fe average Surface °K:61.8 dT primary °K:72.
dT Gehäuse av. Surface °K:. dT secondary °K:70.3
45.11Ω 7.72 %
7.539Ω 1.29 %
227.4V 93.3 %
52.61Ω 9.01 %
7.539Ω 1.29 %
1
584.2 Ω 243.8 V 100 %
10711 Ω 1833. %
959.1 Ω 164.2 % . mH
212.1 V 87.02 % 38.9 °
733.5 Ω 125.6 %
.417 A
.289 A
144.3 %
1.426T
100 %


Rtkeng
OUTPUT
Input Material Run Output Edit Options Help
.417 A
.289 A
144.3 %
1.426T
100 %
DUTY CYCLE OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06
dT Fe average Surface °K:61.8 dT primary °K:72.
dT Gehäuse av. Surface °K:. dT secondary °K:70.3
NO LOAD OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06
Losses active W:12.1 Losses reactive VAr:87.16
Current factor %:92.11 Induction T:1.504
dT Fe average Surface °K:45.4 dT primary °K:51.1
dT Gehäuse av. Surface °K:.
SHORT-CIRCUIT OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06
Losses active W:238.6 Losses reactive VAr:44.38
Current factor %:236.6 Induction T:.815
dT Fe average Surface °K:435.6 dT primary °K:618.
dT Gehäuse av. Surface °K:. dT secondary °K:624.1



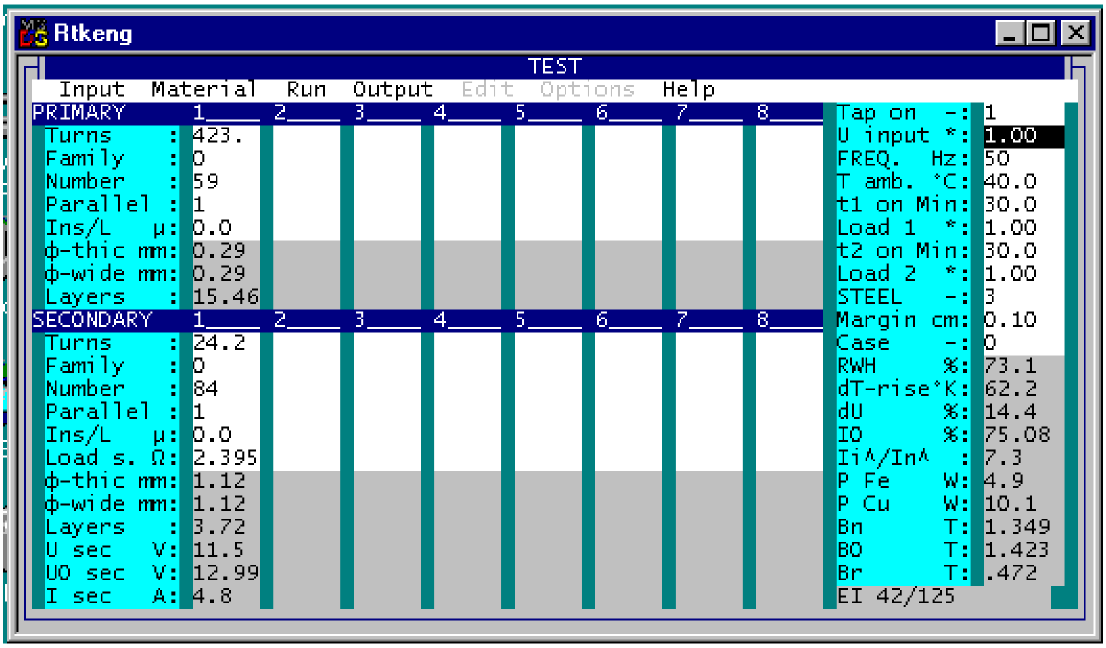


14. This is followed by monitoring of the design data.

- We start by checking the max winding temperature in nominal operation mode = ambient temperature + dTprim in nominal operation mode= 40+72 =112 < 115°C
- Next, we check the winding data and the filling factor (73%<100%).

1. If the design data is not satisfactory, then there are two ways to 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 access the test program (function key F5), manually modify the transformer design and re-design the transformer by that means. Here are results at the nominal input voltage:



1. After completing our design work, we can print out the design data on-line, or save it on the local PC and print it out off-line. The output data file from this design example CAL0004E.TK2 is supplied together with this document. Copy it into the directory in which the Rale demo program is installed.

Tips & Tricks

The transformer is too full

This is often the case if we select our own core. Suppose we want to use the core for 100VA, for example.

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

The transformer is relatively empty

This is often the case if we select our own core. Suppose we want to use the core for 100VA, f or 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 thickness in the test program:

- Select the next higher wire thickness in the chamber which is less full.
- Select the next lower wire thickness in the chamber, which is more full.
- 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% over-voltage. In order to arrive at the nominal data for this transformer design, test the designed transformer with the nominal input voltage in the test program. (**Uin = 1**).

Temperature in nominal operation mode is too high

- Reduce the temperature rise and increase the induction.
- Set a better core quality.
- Increase the cooling surface area. Choose a larger case. The color of the case should be dark.

Is the idling current too high?
The idling current is not a criterion for design. The idling temperature must not exceed the permitted limit.

The combined fuse
In the event of poor thermal connection between the thermal cutout and the protected winding, a further fine fuse is employed to prevent short-circuit. With this combined fuse, the thermal cutout provides protection against overload and the fine fuse provides protection against short-circuit.

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