# DESIGN OF LOAD – KLYSTRON EQUIVALENT FOR JLC

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*Abstract*

In this paper a design of a resistive load – an equivalent of a klystron for the Japan Linear Collider JLC is described. The load should operate in a pulse mode at high voltage and high averege power. Different design variants were considered. The choice in favour of ceramic bulk resistor with longitudinal conductivity was done. A caloric and hydraulic calculation was executed. A mesurements of ceramics thermal conductivity of the bulk resistor and of a single radiator produced warmth remooval were done.

Unfortunataly the last events on JLC forbad us to realys the project “in metall”. But authours houp that this design experience could be usefull for another accelerating centers. The load can find an application as a absorbing resistor in high voltage schemes.

## INTRODUCTION

Very often powerful pulse radio electronic systems could be sheared for single devices naturally. Every one of such devices could be unique and costly. That is why it could be necessary to execute a single R&D and test of such kind device when a complete set of equipment is absent. In such situations it could be tern out that to use equivalents instead of some devices will be more cost and economically justified. A similar situation arises in KEK (Japan) at a design of a new powerful pulse generator for the Japan Linear Collider supply. As usually, main parts of genetrator are a klystron and it’s feeding modulator. They plan to design the modulator by leading rate. The klystron doesn’t plan to be ready to the modulator test date. That is why a question about a possibility of a design of powerful high voltage resistor type load erises. The load should be appropriate to be used as the equivalent of the future klystron at R&D and a power test of the modulator.

## TECHNICAL CHARACTERISTICS

The load – the klystron equivalent should has the following parameters:

| | | |
|---|---|---|
| Pulse amplitude | | 510 kV |
| Current | | 280 A |
| Resistance | | 1820 Ohm |
| Flat top duration | | 1.6 usec |
| Rise/fall time | | 200 nsec |
| Repetition rate | | 100 pps |
| Space for installation: | length | 1500 mm |
| | diameter | 650 mm |
| Working medium | | transformer oil |

## POWERFUL PULSE RESISTOR TYPES

As in follows from the technical characteristics, the average dissipating power in the loads amounts of about 26 kW at the pulse energy of 257 J.

Our team has an experience in design of powerful high voltage pulse loads, and the design of the device for the said parameters is lying in our interest region.

### *Industrial Resistors*

There are some industrial companies in the world which deliver some types of resistors, approved for operation at the short pulse duration. Delivered in Russia high-frequency powerful resistors, such as MOU, are executed as a ceramic tube coating by thin conducting film. The thickness and the heat capacity correspondingly of this film are tiny. Such resistors allow dissipating a generous power in a continuous mode only. However in the pulse modes the film overheats and breakdowns may occur even during the pulse. It limits admissible modes of the pulse work at rather low level.

### *Electrolytic Resistors*

Electrolytic (fluid) resistors have a huge energy capacity. Such type resistors base on aqueous solution of salts or acids. Advantages of such resistors are: an ability to give any form to the resistor, huge energy dissipation due to a high specific heat capacity and great volume of electrolyte, restoration of the electrolyte electric strength after the casual breakdown, operatively adjustable size of resistance by replacement of the electrolyte with other conductivity, a significant time life of the resistor. More detail information about such type resistors carries [1].

There are some limitations of such resistors: a necessity of the electrolyte conditioning – a clearing of a solution of reaction products, a danger of installation pollution at emergencies of the resistor vessel and an electrolyte run-out, high temperature factor.

### *"Zigzag" Wire-Wound Resistors*

There is another type of a wire resistor – with so-called "zigzag" winding. The essence of this design, on which the copyright certificate [2], [3] is received, consists of the following. An isolating cylindrical rod is threaded. Then on the rod surface longitudinal grooves is cut on a small depth. These grooves divide the thread to some longitudinal strips with the cross slots, formed by this thread. Nichrome wire is placed in each slot in series, and fixed on each swivel. It is possible to change both nominal resistance of the resistor, and its heat capacity by choosing various rod diameters, the pitch of the thread, the amount of stripes and the wire thickness. The beginning and the end of the wire are welded to metal ends of the resistor in each strip. This construction type looks like the bifilar winding resistor [4]. However a number of limits inherent to last one are eliminated here. In figure 1 the general view of such kind resistor is shown.

The disadvantage of such design is a big effort.

This construction was considered as one of the candidates to be used as a base for the equivalent design.

But the requirement of rather high resistance demands to use too thin wire. This could carry some additional technological problems and influence for the resistor life time.

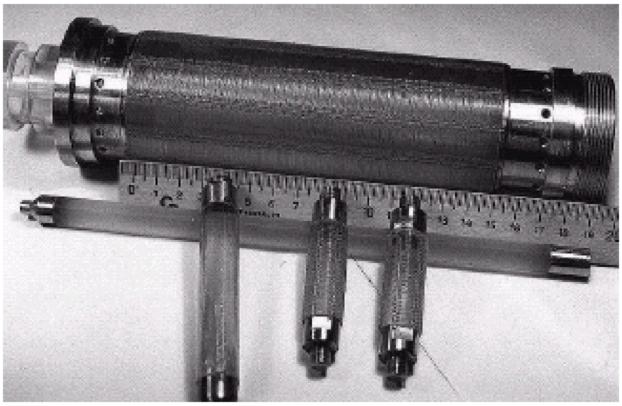

Figure 1: General view of the "zigzag" resistors

### *Strip-Line Cylindrical Bifilar Resistor*

The load based on the resistive element having a strip-line cylindrical bifilar design [5] is described below. The resistive element is executed from metal rings. Each ring is connected with the previous one and the following one in two diametrically opposite points. As a result two parallel sections of the resistor are formed. In figure 2 the resistance element is shown stretched in an axial direction for presentation. It is possible to connect the rings in more points. Such type load was described more detailed in [4], [6].

We haven't stopped our choice on such type resistor, because of the same reason as for the "zigzag" resistors.

Figure 2: Axially stretched strip-line cylindrical bifilar resistance element

## BULK CERAMIC RESISTOR

The main purpose of this message – the description of development of powerful high-voltage pulse load on the basis of bulk ceramic resistors.

Our command already has experience of use of resistors of such type (manufacturer Kantal) [6], therefore we have tried to develop a new design on this basis. During development it was necessary for us to find out, as far as a washer-shape resistors are high-voltage, how it is possible to remove heat from the resistor, what thermal loadings are allowable inside a resistive washer, what behavior of resistors in transformer oil, what real factor of a voltage overload can arise on resistors in real construction.

### *Construction*

We have found out an ability of the resistor to carry high voltage from the manufacturer. As appeared, this ability is a function of a conductivity of ceramics and of pulse duration, and at nominal values of tens Ohm one resistor of one inch longitudinal length can sustain the voltage up to 15 kV.

In our design warm from ceramics is removed by a massive copper radiators placed in transformer oil. A mode of current of oil - laminar, a necessary heat rejection is provided at the small charge of the heat-carrier and at small oil pressure difference on the resistor.

Unexpectedness was that fact, that in oil the resistor nominal changes. The nature of this phenomenon lays in manufacturing techniques of such resistors – in a sintering. The supplier has specified the top limit of the change of the resistance value - the increase at 18 %. This change has single character and takes place within two weeks after an immersing of the resistor in oil.

With distribution of heat inside ceramics of the resistor there were the biggest complexities.

In our case the maximal average power which can dissipate one resistor, is limited to as much as possible allowable temperature in a body of the resistor. As the manufacturer has declared, the maximal allowable body temperature of the resistor should not exceed 230 °C. Being set by this temperature, it is possible to define temperature of a surface of end faces of the resistor, setting, thus, boundary conditions for the further calculations.

The factor of heat conductivity specified by the manufacturer has demanded experimental check. By our calculations it is appeared, that at such heat conductivity it is impossible to provide a heat removing from the resistor body at nominal dissipating power without of ceramics heat over the allowable limit. Therefore the special stand has been collected and thermal tests were done.

For this purpose has been taken the washer-shape resistor, it was located with one end on a thermostatically controlled surface. A lateral and other end surfaces were thermo insulating, and through the resistor the electric current was passed. Knowing the dissipating in the resistor power, the area of a washer and its height, and measuring a temperature difference between end faces, we have calculated the factor of heat conductivity of ceramics which in some times exceeded declared last one by the manufacturer. We have notified the representative of the firm-manufacturer about our measurements.

Various ways of removal of heat by liquid thermo carrier are possible, but distinction is appeared only in character of a liquid movement - laminar or turbulent. First of all, it would be desirable to leave as the cooling liquid transformer oil since the problem of a cooling volumes sharing (of a load vessel and a klystron tank) in this case disappears. Even if each volume have single cooling contour, a possible liquid blowing from one volume to another will not put damage to the device as a whole.

On the strength of the set dimensions, the resistors high-voltage durability and nominal, the necessary quantity of resistors has been chosen. The load consists from 45 in series connected washer-shape resistors. The general view of load is shown in Figure 3.

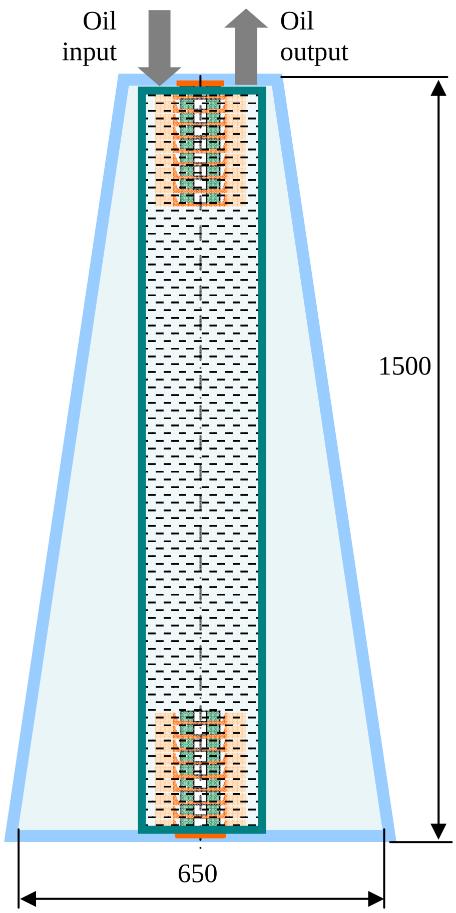


Figure 3: General view of the load

In the chosen design for removal from the load of rated power of 26 kW it is necessary to pass through the load cooling contour transformer oil with the charge of 20 l/minutes. In this case loss the oil pressure drop on the load will amount 0.1 atm.

### *Model of Transient Processes and Limitations*

One of features of operating of the describing above load is its pulse mode. With the purpose of check of the load suitability for the pulse mode operation at the set pulse shape transient processes modeling under the equivalent scheme was made. Oscillograms of pulses on all scheme elements are received.

Except for main resistive elements in it both cross-section capacities on a shielding housing and longitudinal capacities between elements are taken into account. An influence of parasitic inductances is insignificant here. Knowing the geometrical sizes or setting them compulsorily, it is possible to control parasitic parameters such a way that the chosen decision satisfied to the technical project. A model for transient analysis is shown in Figure 4.

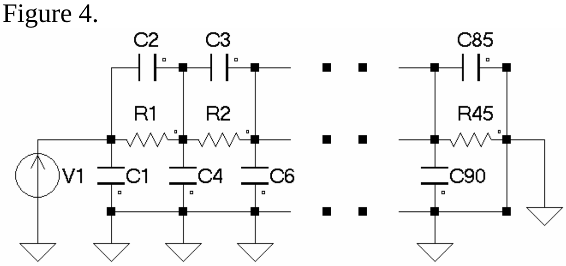


Figure 4: A model for transient analysis

As one would expect the results of modeling have shown, that the biggest voltage overload arise on the first load elements from the high-voltage end. To the bottom elements the pulse comes without distortions already.

## CONCLUSION

The design of the powerful high-voltage pulse load on the voltage of 510 kV for use as the equivalent of the klystron at adjustment and test of modulators is offered. Necessary calculations and thermal tests of one cell are executed.

The load can find an application as an element of powerful high-voltage pulse schemes also. The results of the work can be useful to other developers of the powerful high-voltage equipment.

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