

HIGH PULSE AND AVERAGE POWER LOW-INDUCTION LOAD

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Abstract

A high pulse and average power low-induction load with a built-in divider is described in this report. The load has a nominal resistance of 25 Ohm and is designed to operate with a repetition rate of up to 50 Hz at the pulse duration (FWHM) of 100 ns, at the rise/fall time of 50 ns and pulse amplitude of up to 40 kV. In this mode the dissipated energy is equal to about 6.4 J per pulse and average power is equal up to 320 W. There is no heat removing from the load resistant layer during one pulse practically at such short pulse mode. Therefore the absorbing resistor should have a large heat capacity of the conducting volume. The load consists of two series resistors: a bulk ceramic resistor 1028AS250KDS is used as a main absorbing element and a low-resistance disk resistor 913WSR50K with longitudinal current running for divider. This construction provides to control the pulse shape i.e. to serve as a measuring divider. The resistors are placed in water.

This construction is installed in a cylindrical insulating tube connected to a water-cooling system. The load may be used as an absorbing load and as a circuit element in high-voltage engineering.

1 INTRODUCTION

A structure of charged particles accelerating complexes consists of various assemblies, including an injection-extraction system. Usually such system consists of kickers itself which deflect charged particles beams, high-voltage pulsers for kickers feeding, pulses transition lines from the pulsers to the kickers, loads and other elements. The peculiar properties of such system operating modes are high pulse power and high pulse energy capacity. Therefore loads (and others resistive elements of the circuits) should be suitable to operate in such modes. Thus it is necessary to note features of the resistor heat mode: during a pulse there is no an essential heat eliminates from the volume, in which the energy is dissipated, as a rule.

The accelerating complex VEPP-5 of the colliding electron-positron beams is under construction now in the Budker Institute for Nuclear Physics of Siberian Branch of Russian Academy of Science.

This project includes an injection complex consists of a forinjector–linac and a damping ring. The authors have designed generators for the storage ring kickers feeding with the following characteristics [1]:

Traveling wave voltage	up to 40 kV
Wave resistance	25 Ohm
Pulse duration (FWHM).....	100 ns
Rise/fall time	50 ns
Repetition rate.....	up to 50 Hz
Pulse power	about 64 MW
Pulse energy.....	about 6.4 J
Average power.....	about 320 W

2 POWERFUL PULSE RESISTOR TYPES

2.1 Industrial resistors

The industry delivers 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.

Russian industry delivers wire-bound resistors S5-40 also. This resistor is a bifilar winding type. However these resistors have appreciable inductance and at low values of resistance a time constant became inadmissible large – about of 100 ns and more.

2.2 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.

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 of the conduction which reaches 1-2 % per degree. The saying above demands to use of a conduction stabilization system of the electrolyte. That is significant a total cost of the load essentially. The "know-how" and use of liquid resistors it is described in [2].

2.3 "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 [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.

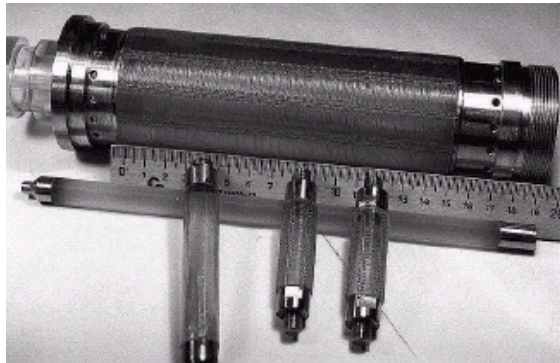


Figure 1: General view of the "zigzag" resistors

2.4 Strip-load

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 [6].

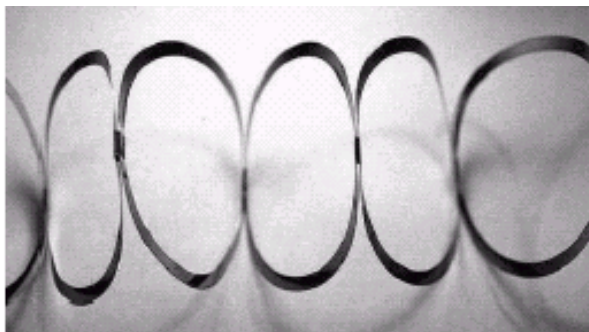


Figure 2: Axially stretched strip-load resistance element

3 BULK CERAMIC RESISTOR

The main goal of this report is the load design, based on bulk ceramic resistors. These high power solid (volumetric) non-inductive resistors are produced by Kantal. Their "bulk ceramic" construction permits to absorb huge energy throughout the resistor body uniformly. Thereby it provides avoiding failure in a thin film or wire. Production of other firm HVR is widely used in the pulse devices. We choose the Kantal (ex-CESIWID) firm goods for our experiments.

3.1 Construction

The load consists of two series resistors: a bulk ceramic resistor 1028AS250KDS 25 Ohm is used as a main absorbing element and a low-resistance disk resistor

913WSR50K 0.5 Ohm for divider with longitudinal current running. Construction has a coaxial design; an output of a measuring signal is coaxial too. In spite of not high bandpass of this system, we try to understand in this construction, how short rise time is allowable, because of similar kind resistors are planned to be used in other BINP facility – VEPP-2000, where very high bandpass is required.

3.2 Frequency characteristic

If one tries to use any thick resistive materials, a question about skin-depth appears usually. It is possible to calculate skin-depth both tube and disk resistors using geometrical sizes and specified resistance. These resistors suites for required bandpass.

3.3 Breakdown strength

As pointed above, the load has the coaxial design. Resistive element placed inside an epoxy tube and immersed directly in water. All assembly is installed in a conducting housing, which serves as a back conductor. A main insulating medium between the resistor and the housing is gas SF₆ at superfluous pressure up to 5 atm (kg/sm²). Therefore the full voltage is applied to a gas gap. It provides sufficient electric strength of all construction.

4 TESTS

4.1 Low voltage tests

In this section we describe low voltage tests. The main purpose of these tests is measuring of reflections; these reflections analyze and attempt to consider frequency characteristics of the load.

The scheme of the test stand is shown below.

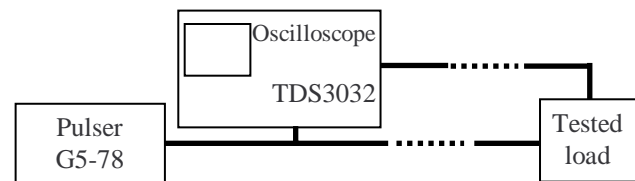


Figure 3: The scheme of the test stand.

A cable from the pulser follows through oscilloscope's Input 1 (1 MOhm) to the tested load. The cable from the oscilloscope to the tested load longer then the cable from the pulser to the oscilloscope. A testing pulse from the pulser travels to the tested load. On its way the signal pass the oscilloscope's Input 1, so we may watch this pulse. Then the signal comes to the tested load. The load absorbs the pulse, but parasitic elements reflect a part of the pulse and reflections come back to the pulser through the oscilloscope's Input 1. So we may watch the direct signal and its reflections.

This method allows watching the reflections separately from the testing pulse and measuring small reflections. An Input 2 of the oscilloscope connected to the output of the load divider.

A SPICE model of this scheme and simulated results are shown below.

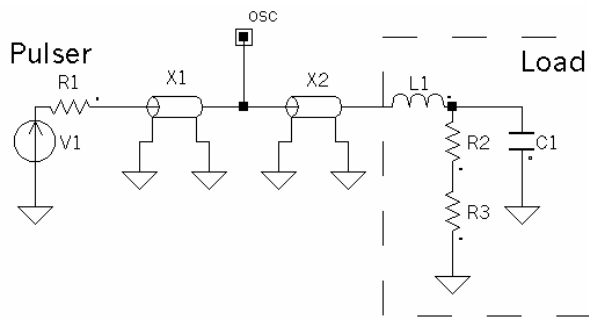


Figure 4. SPICE model of the low voltage tests.

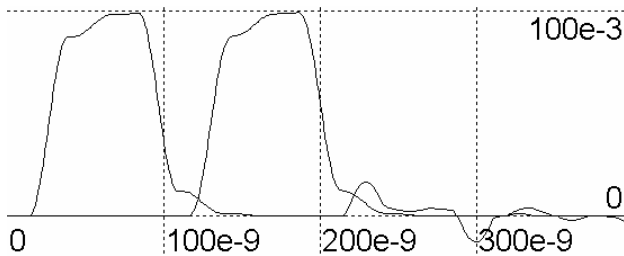


Figure 5. Simulated results of the low voltage tests.

Next picture shows an experimental result. The first pulse is the pulse, which travel from pulser through the Input 1 of the oscilloscope to the load. Small pulses after 250 ns and 300 ns of a first pulse's front are reflections from the load. The second pulse is the pulse from built-in divider.

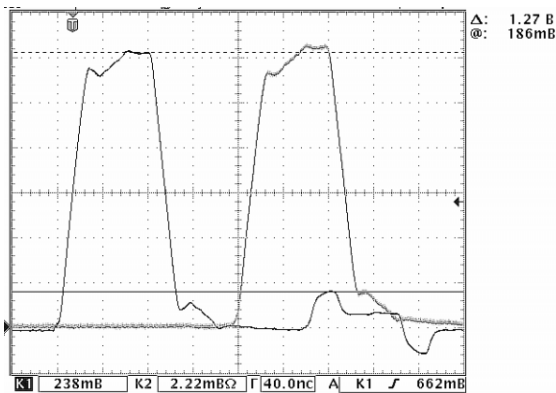


Figure 6. Experimental results of the low voltage tests.

As we can see on this picture, at this risetime (20 ns) the reflections are equal to about 10 %. A signal shape from the divider shows very good agreement with a first signal shape.

High voltage tests

We connect the load to a high voltage generator directly for this test. Picture 7 shows pulses from the divider at 18 kV and 33 kV voltages correspondently. Output voltage ratio is equal 991.

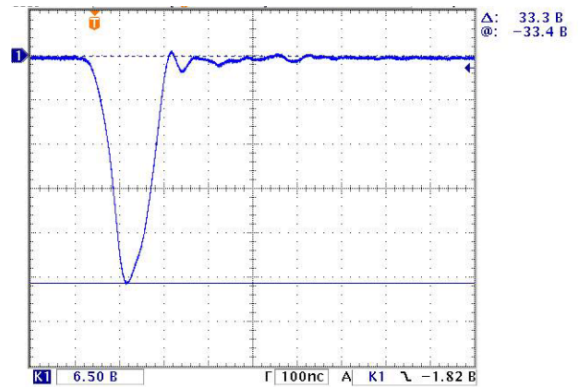
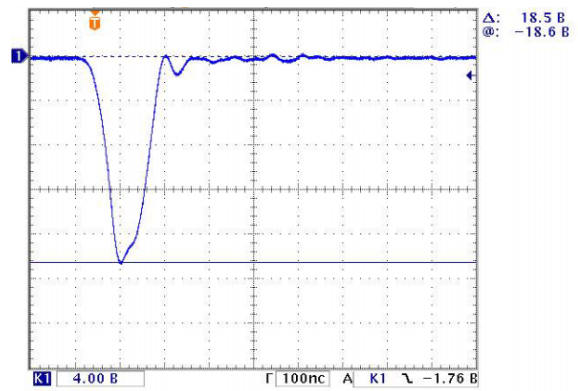


Figure 7. Experimental results of the high voltage tests.

These tests confirm that the load satisfies completely to the complex VEPP-5 requirements.

5 ACKNOWLEDGEMENTS

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