SWITCH TUBE TEST SET

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Abstract
Diversified Technologies, Inc. (DTI), under contract for BAE Systems, developed a switch tube test set for the realistic testing and conditioning of high power modulator switch tubes employed in radar transmitters. The system may be configured for triode or tetrode tubes and has a nominal plate power rating of 30 kW.

I. INTRODUCTION

Diversified Technologies, Inc. (DTI) responded to an RFP from BAE Systems to supply a “Triode Test Set” capable of exercising in a laboratory environment the numerous high power vacuum tube electron devices routed through the Instrumentation Radar Support Program (IRSP) depot which BAE Systems operates for the US Government.

BAE Systems provides support to over 500 instrumentation systems at test ranges around the world, primarily for pulse modulator circuits of high power transmitters, and needed a single, reconfigurable test stand capable of supplying the typical pulse current switched through the tubes during normal operation. The ability to adequately test new or refurbish devices ensures only fully serviceable units are sent into the field. Installing and operating such tubes may lead to significant field service time, radar downtime, and possible damage to the rest of the transmitter, yet this level of testing is not typically available.

To satisfy this requirement, DTI developed and fabricated a test set system capable of supplying the electrical inputs required for the testing of multiple high power switch tubes (Fig. 1). The switch tube test set system operates under variable conditions (Table 1), and may be tuned to the particular requirements of different tubes. Table 2 (next page) describes the tubes which the pictured set may be configured to test; the testing of other tubes under load is possible for future units.

II. SWITCH TUBE TEST SET DESIGN

The test set delivers an average power of 30 kW and is capable of 50 kV and 250 A (pulsed) maximums. The test set includes a variable auto-transformer (Variac) filament supply with grid bias and grid pulse electronics suitable for the selected tubes (+/- 5 kV swing maximum). Pulse width is from .2 to 15 μs; pulse repetition frequency is from 40 to 1280 pulses per second.

The test set is comprised of standard DTI subassemblies installed in several cabinets. In addition to DTI-supplied equipment, the test set system includes space for the tube

Figure 1. Switch Tube Test Set.

to be tested and for a set of plate load resistors (“dummy load”), which may be customized to suit various test requirements. System controls are fully manual, requiring expertise on the part of the user for proper operation—automation is possible for future systems. Inherent over-current protection for the plate and grids is provided, as are interlocks for faults in the supplies or external fault signals.

III. MAJOR SYSTEM COMPONENTS

The major system components shown in Fig. 1 are:

A. The Electronics Rack

Houses the high voltage generating equipment, the variable auto-transformer (Variac), the solid-state switch control electronics, and serves as a hub for system interconnection, control, and monitoring.

B. The High Voltage Cabinet

Contains three main circuit assemblies: the plate circuit assembly, the screen grid circuit assembly, and the control grid circuit assembly. Each of these circuits contains a

Table 1. Switch Tube Test Set Specifications

Specification	Value
Max Voltage	50 kV
Max Current	250 A
Average Power	30 kW
Pulse-Width	.2 – 15 μs
PRF	40 – 1280 pulses/s

high voltage storage capacitor with bleed resistance, series resistance, solid-state switch, dump relay, and current and voltage monitoring.

C. The High Voltage Load Cabinet
Houses a set of load resistors, the filament transformer, and filament voltage and current monitoring. The voltages required to operate a tube under test are fed into this cabinet through EMI filters to minimize RFI caused by tube oscillation.

D. The Contractor Boxes
Contain the contactors to interrupt grid and screen power feeds.

E. High Voltage Elements
The high voltage cabinet (Fig. 2) contains the plate high voltage solid-state switch, snubber, grid, and screen circuits, as well as the storage capacitor. The plate high voltage circuit assembly (top portion of Fig. 2) contains the high voltage solid-state switch and inductor to limit the current rate of rise. The inductor is equipped with a freewheeling diode and resistor for energy snubbing between pulses. The switch is controlled by an inductively-coupled loop originating in the driver chassis, and the plate current is measured by a current transformer.

The grid switch circuit assembly (middle section of Fig. 2) is comprised of two solid-state switches, which modulate between the OFF and ON voltage levels. Both switches are triggered by a single inductive loop initiated in the grid switch chassis. The switch plates are reversed so that the inductive loop closes one switch and opens the other, preventing shoot-through across the two switches. The screen opening switch is inductively-coupled to the screen switch driver circuit. The screen voltage is shunted to ground, providing a path for reverse electron flow (screen emission).

Figure 2. High Voltage Cabinet. Clockwise from top left: Switch Plate; Snubber Circuit; Grid and Screen Plates; Filter Capacitor; Storage Capacitor.

Table 2. Switch Tubes Tested.

Tube (Manufacturer)	Type	Filament Voltage (V)	Filament Power (kW)	Max Plate Voltage (kV DC)	Max Plate Pulsed Current (A)
6920 (ITT)	Triode	11	3.14	35	90
5918 (Westinghouse)	Triode	11	3.14	17.5	15
LPT45H (Machlett)	Triode	6	0.36	34	65
ML7003A (Machlett)	Triode	6	0.36	45	40
LPT62 (Machlett)	Triode	6.3	0.39	65	25
ML7715 (Machlett)	Triode	6	0.36	65	25
4CW100,000E (Eimac)	Tetrode	15.5	3.33	40	110

In the event of an arc the switch defaults to the OFF bias. At the maximum over-current setting (250 A) and 50 kV, the switch will open in less than 1 μs and the fault current will peak at less than 400 A (Fig. 3).

F. Safety
The test set includes a hard-wired interlock chain which ensures that, in the event of an intentional or unintentional chain interruption, lethal voltages are disabled to contactor level and the high voltage capacitors are rapidly discharged to ground. This chain includes all the doors to the high voltage cabinet and the high voltage load cabinet. Additionally, the chain includes the emergency stop (mushroom) button and the coolant flow to the plate high voltage power supply.

G. Future Systems
While the existing system has been highly successful in the testing and conditioning of particular tubes, future users will have different requirements. The design of the switch tube test set system is highly customizable, and future systems may achieve both a larger range of operating parameters, enabling the testing and conditioning of additional tubes, and a higher degree of automation, allowing for increased ease of operation.

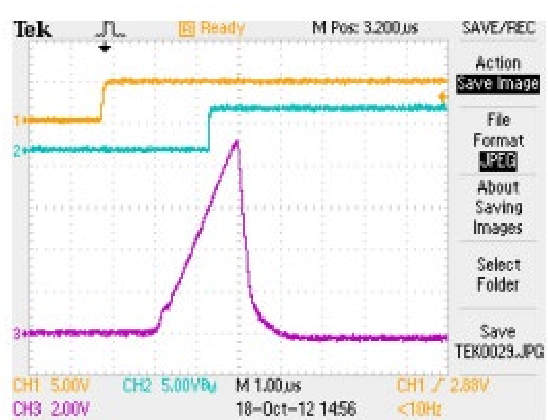

Figure 3. Simulated Arc. The fault occurs at 246 A. The switch opens in 690 ns; current peaks at 365 A.