10 MeV, 10 kW E-BEAM PROCESSING LINAC

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Abstract

A 10 MeV, 10 kW scanned E-Beam linac has been designed and built by Titan Beta and installed and operated at the Titan Scan facility in Denver, Colorado. This system is used for sterilizing medical products on a production basis and has been in operation since July 1993. It is the first in a series of E-Beam facilities for medical product sterilization. Later facilities are designed to operate at 10 MeV, 15 kW. This paper briefly describes the linac, the system, the facility and provides operating data.

Introduction

The Titan Scan system is a contract linear-accelerator-based irradiator facility which is designed to provide a safe, reliable and precise sterilization process for medical products. The facility enclosure is a concrete shielding structure with walls and roof ranging in thickness from 1 foot to 10 feet to provide the required mass for shielding the electron beam and x-ray energy produced by the accelerator equipment inside the structure.

The product delivery into and out of the shielding structure is automated and instrumented to monitor the process dose precisely and safely. The product travels in carriers by way of an automated conveyor through a labyrinth to provide product access, while completely shielding the operators and warehouse personnel from any radiation exposure.

The Modulator Room houses the power supply equipment and provides the utilities to the accelerator and conveyor in the Process Room within the shielding structure.

During operation, the Process Room and the Modulator Room are unmanned. The operator of the facility has full control of the facility from the Control Room where facility operation, safety, access, and equipment start-up and shut-down are controlled through a Programmable Logic Controller-based computer system. It was designed with component margin so as to operate 24 hours a day continuously. Safety is the main priority with redundant controls and safety links in the form of high security keying through the access door, pressure floor mats and photo-electric cells in the labyrinth to guard against inadvertent entry into the Process Room during operations. The operator must follow stringent start-up procedures and facility inspections in a prescribed sequence to allow start-up and operation of the facility.

The Titan Scan system is registered with the US Food and Drug Administration and conducts all processing activities in accord with applicable sections of the "Good Manufacturing Practices" Act (GMP's). Product delivery and shipping requires normal warehouse operating procedures. The facility incorporates product control procedures including a dosimetry laboratory which is used to check the process results and fencing which separates the facility into pre-process and post-process zones.

The process facility occupies approximately 30,000 square feet, including office facilities. This process system was constructed within a vacant, available warehouse.

System Description

The linac system was specifically designed to be part of the medical products sterilization system. The accelerator waveguide is mounted horizontally and the beam is scanned over the medical products as they are moved in front of the beam via the conveyor. A water cooled beam stop catches the beam beyond the boxes of product.

The system architecture is based on a klystron RF source and a 1.4 M standing waveguide coupled to a beam transport and scanner system. The output window is air cooled titanium.

Figure 1 shows the beamline and scanner.

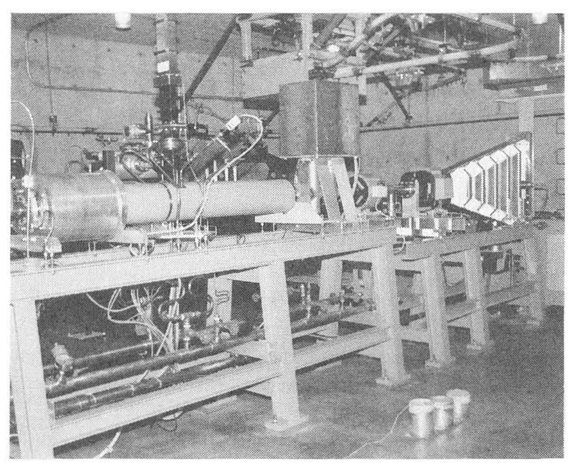

Figure 1

The beam line, accelerator and scanner, are located in the Process room with the conveyor. The modulator, klystron, local controls, and power supplies are located in the Modulator room. The linac controls, system controls, and system diagnostics are located in the Control room.

Figure 2 shows a picture of the modulator and klystron.

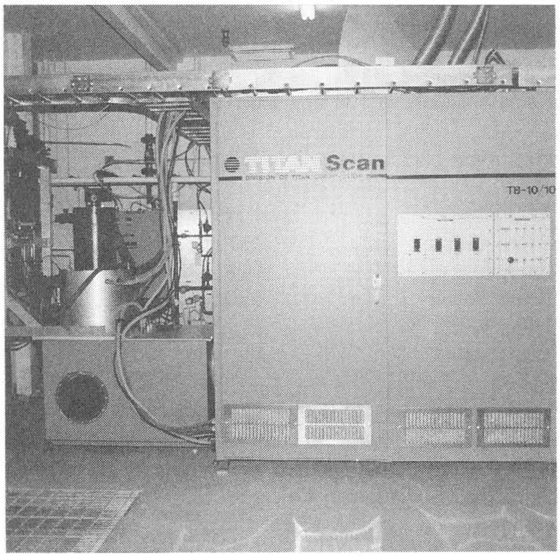

Figure 2

Figure 3 is a block diagram of the control system.

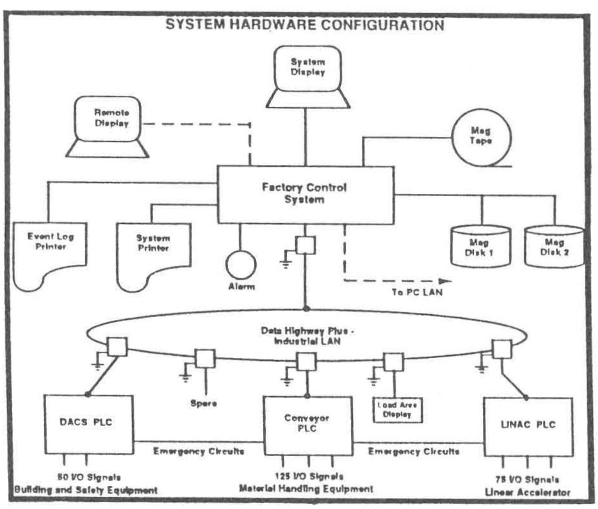

Figure 3

Figure 4 shows a picture of the loading area of the conveyor.

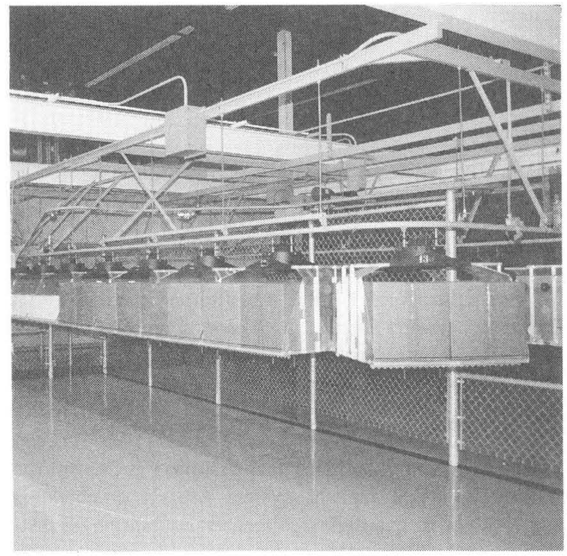

Figure 4

Subsystem Description

Beamline

The electron gun is a Pierce geometry triode design with a dispenser cathode and is operated over a range of voltages up to 25 kV and delivers up to an ampere of peak current with modest grid drive. It has a one square cm cathode and is operated with a 2 liter per second appendage ion pump.

The gun pulser is a floating deck pulser which provides the gun filament and grid bias as well as pulsing the cathode. It has an automatic filament cutback circuit which programs the filament current as a function of rep rate, otherwise backheating of the cathode from electrons turned back from the first few cavities can overheat the cathode.

A short solenoid covers the first foot of the standing waveguide to insure an acceptable beam shape and capture efficiency. With it we can obtain over 200 mA of accelerated beam current.

A magnetic shield covers the rest of the waveguide to prevent stray fields from interfering with beam position. A pair of steering coils are placed under the solenoid.

The output of the waveguide has an in-line valve and a beam current monitor prior to the scanner vacuum chamber.

RF Power

The RF power source for this system is a klystron operated at up to 5.0 MW and 25 KW at 2856 MHz. It requires 350 watts of RF drive at full peak power. We are operating it with a video pulse of 15 μsec FWHM at up to 350 pps.

An Automated Frequency Control (AFC) system utilizing waveguide reflected power phase sensing is used to maintain frequency. Although the RF driver is stable, other changing conditions can effect output without an AFC, e.g., a small temperature shift of the waveguide.

Modulator

The modulator uses a 14 section Pulse Forming Network (PFN). The operating voltage is 20 kV and the PFN impedance is 5.9 ohms. An EEV CX 2412A thyratron was chosen. End-of-line clippers protect the klystron and thyratron against voltage reversals. A 15:1 pulse transformer is utilized.
The charging power supply is Silicon Controlled Rectifier (SCR) regulated on the primary of the power transformer.

Controls

The system is remotely controlled from the Control room. The information and control system uses a graphic based interface with a distributed architecture containing industrial PLC's and a PC control system network as shown in Figure 3. The system provides real-time monitoring and control of process variables and on-line error detection and recovery.

Local controls for system adjustment along with power supplies are in a rack near the modulator. Figure 5 shows the local controls.

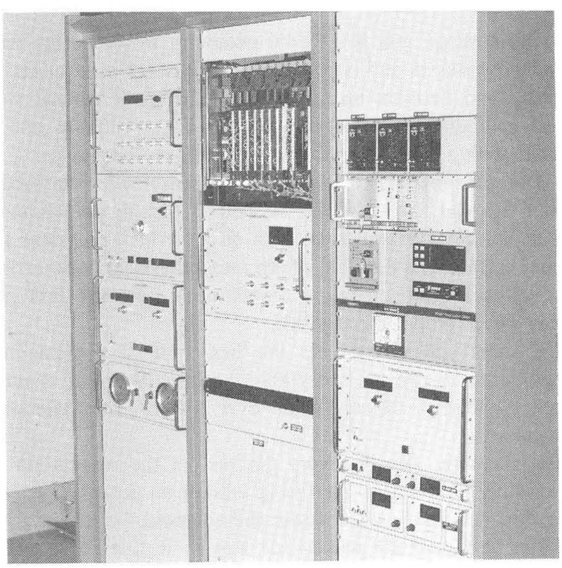

Figure 5

Material Handling System

The material handling system is a carrier based, overhead power and free system, coupled through a closing conveyor to an independent servo controlled process conveyer. The 39" long carriers are positioned with a spacing of less than one inch as they pass through the scanned beam and their speed is controlled within +0.5% of the set point. A passive mechanism provides 180° rotation of the carriers for two sided irradiation which eliminates "flipping" of the product.

Operating Data

The system was commissioned in July 1993 and has operated more than 3500 hours since then. The current operational schedule is 100 hours per week.

The operational parameters are as follows:

RF Power	4 MW
Beam Current	200 ma
Energy	10.8 MeV
Beam Power	10 kW
Pulse Width	13 μs
Rep Rate	350 pps

The system in Denver, Colorado is successfully processing product from a number of medical product manufacturers on a daily basis. New systems are presently being built for installation in Chicago, Illinois and San Diego, California.