

QUALITATIVE EFFECTS OF RADIATION DAMAGE ON EQUIPMENT AND COMPONENTS AT THE R.P.I. LINAC*

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A summary of difficulties due to radiation induced damage in neutron producing targets and components is presented. Surprisingly little difficulty has been experienced considering the power levels at which the R.P.I. Linac has been operated.

The R.P.I. Linac was designed and has performed as a high powered accelerator. It was tested in excess of 50 kw of average power at 50 Mev. The shielding and facilities¹ were designed for operation with such an accelerator. The question of the selection of many small components and equipment to operate in such an environment was and still is quite difficult. Usually radiation resistant devices are either not existent or very expensive. We chose the pragmatic approach by saying, we would choose the best known device to satisfy the particular function within the usual bounds of radiation resistance², not particularly exotic items and make the replacement rather easy when failure occurs.

Overall, this approach has been satisfactory in that no serious troubles have occurred.

The most persistent trouble we have experienced has been the failure of the water jacket on the tungsten e- γ -n targets (Fig.1). This target design was based upon heat transfer considerations and not on neutron production. Unclad tungsten metal plates 2" x 2" and thicknesses varying from 1/16" to 1/4" are enclosed in a 304 stainless steel water jacket. A water flow of 25 g.p.m. is forced through the 1/16" cooling channels between the tungsten plates. Unfortunately the tungsten tends to slough off into the cooling water resulting in undesirable radioactive contamination in the event that it is spilled. Radioactivity of the cooling water was in the range of 0.01 to 0.1 μ c/ml and the isotopes of tungsten predominated.

Recently successful efforts have been made to reduce the radiological problem of the cooling water by a combination of filtering through 5 micron filters and by activated charcoal (Carbo Dur**).

The most common way this target design has failed is by "rusting" of the stainless steel. Discussions with metallurgists here and at other facilities has determined that 304 stainless steel is subject to a condition of chromium precipitation at elevated temperatures as would be expected when an electron beam of 20-30 megawatts of 5 μ sec duration is incident upon the target. It has also been pointed out by Mr. L. R. Lucas of Stanford and observed at Oak Ridge³ that carbide precipitation in the lower sensitizing temperature range can completely surround a grain boundary thus reducing its strength and corrosion resistance. To the nuclear physicist this appears as rust on the targets at the place of beam impingement and it is at this point that the failure of the water jacket occurs. The records on this are not detailed but failure seems to occur at about 300 beam impingement hours at 20 kw of average power.

Fig.2 shows four targets that failed. The one on the far left is a "lead boiler" that failed at 2-3 kw. The heat transfer in lead is relatively poor and no success at all has been achieved using it. The second target is of the design of Fig.1 and failed due to chromium precipitation in the 304 stainless steel. The third target failed due to failure of the coolant flow. The fourth target was an air cooled target of the design of Fig.1 and failed at 4 kw with 10 c.f.m. air flow.

The design of Fig.1 has been replaced by a similar version replacing the 304 stainless steel with an aluminum

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**Trade name of Permutit Company.

jacket. This target has been in operation for the last six months without any signs of failure. It should also be pointed out that a target based on the design of Fig. 1 in a stainless jacket and used on short pulses (low average power) is still operating after over 1000 hours of service. The problem is definitely a function of the energy per pulse delivered.

In general the electronics which was thought initially to be most radiation sensitive has worked better than expected. An ionization gage monitor is still operating after several years unshielded service in the Target Room. On the other hand a transistorized amplifier on the leak detector failed after a few days service in the Target Room.

The valves in the original accelerator are of the all metal hard seat type. An attempt was made to use a less expensive vacuum gate valve using viton "O" rings on the electron beam pipe. The valve began to leak after several months useage. When the valve was opened, one "O" ring was found to have lost all elasticity. It has about the same flexibility of nylon of the same dimensions.

The signal cables running from the Target Room to the Control Room have been installed for four years. They travel about 80 feet exposed to radiation in the Target Room before entering the shielding wall. After more than 6300 beam hours at an estimated average of 8 kw electron beam power these cables still measure in excess of 1000 meg ohms insulation resistance for the full length of 200 feet and will "hi-pot" to greater than 20 kv.

It has been found that ordinary rubber hose with cotton cloth reinforcement does not badly harden until about six months usage if kept more than three feet away from a moderately shielded target. On the other hand, nylon fittings have been found to crumble after only a few months in this radiation environment.

Most of this article has been devoted to the point that with care radiation damage can be lived with. Fig. 3 shows the complete failure of a 2' x 10' wooden beam which was part of a

chopper blast shield located several inches from the electron beam drift pipe and approximately three feet from the $e^- \gamma$ -n target. The break is at beam height; the wood has lost all strength and exhibits many of the characteristics of dry rot.

References

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3. Long, E. L. and Michelson, C., "Some Observations of Intergranular Corrosion of Irradiated Type 304 Stainless Steel", ORNL-3684, November 1964.

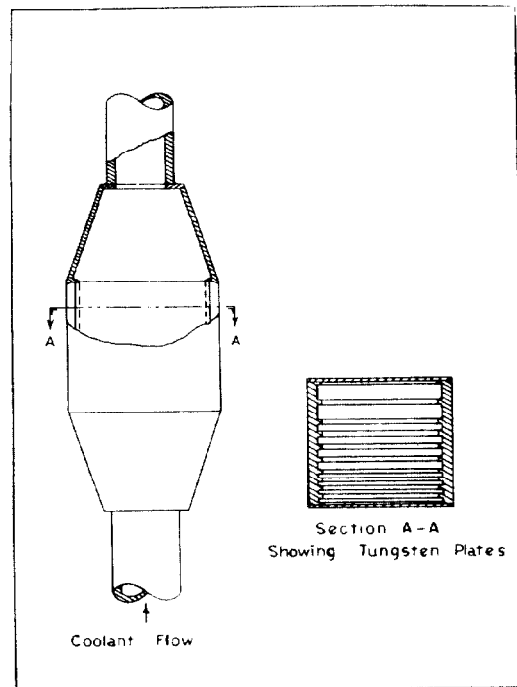


Fig. 1. Cross Section of the R.P.I. LINAC Water-Cooled Standard Tungsten Target.

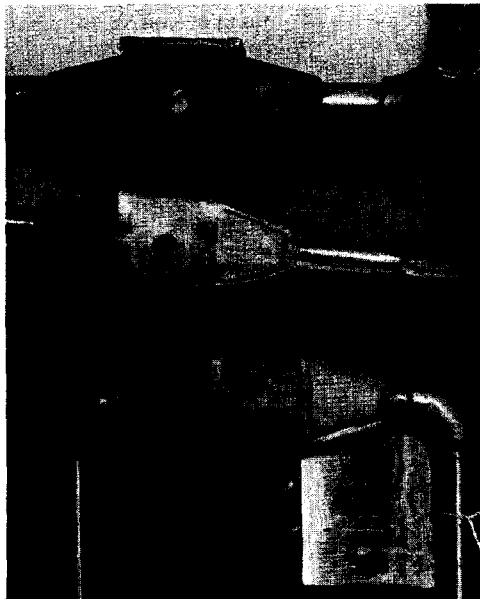


Fig. 2. Four Electron Beam Targets that Failed. (See Text)

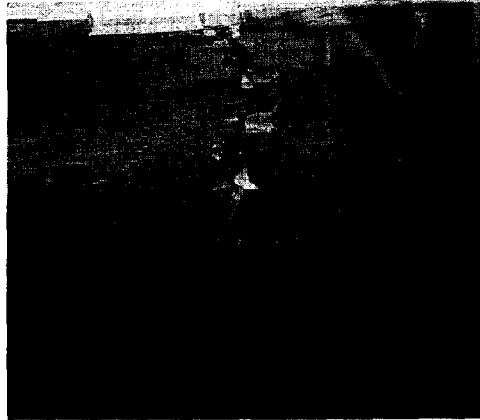


Fig. 3. Wooden Beam that Failed from Radiation Damage.