RUNNING-UP OF 10 MeV PROTON LINEAR ACCELERATOR AT SWIERK

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ABSTRACT

Individual technical features of various proton linacs make their running-up processes different in some aspects. This paper describes briefly the initial period of Swierk linac operation, and discusses phenomena of multipactoring and high level breakdowns in the tank. It is understood as a fragmentary contribution to the general observations of RF discharges in linear accelerator structures.

Introduction

Swierk linear accelerator [1, 2] was designed and built by a comparatively small group and rather modest means. Great majority of machine parts and components were homemade. Such situation caused that construction took a long time and forced often to the application of materials just available. So, ten drift-tubes are fabricated from possibly good but not OFHC copper, vacuum system uses oil diffusion pumps ect. RF system has not great power reserve and does not allow for high speed field build-up.

Already during running-up period it was necessary to introduce several improvements in the machine. The troubles with multipactor and high level discharges were very persistent. The only profit was, that it gave more time for possibly careful observations of the behaviour of these discharges.

As a result of these observations the procedure mostly efficient at given conditions was found and applied to overcome the discharges.

R.F. System

The general diagram of RF system is shown in Fig.1. All generators use the same tubes - EIMAC 4W 20 000 A. Total tank RF power is supplied by three power oscillators. All of them were pre-tested on dummy-load giving more that 250 kW of peak power each, at the efficiency above 50%. The pre-exciter in operation on dummy-load gave 100 kW peak power. Checking and adjustment of the whole RF system on common load was only possible in operation on the evacuated tank.

To facilitate observations of discharges there were three viewing windows in the tank. Two of them allowed to see two power coupling loops and few drift-tubes; the third window in the form of long slit located at the beginning of the tank permitted to observe all the drift-tubes along the axis.

To check the influence of vacuum conditions on RF phenomena a spectrometer was connected to the tank volume and gave instantaneous display of residual gases spectra.

The field level in the tank was measured with five pick-up probes connected to matched detectors and slide-back voltmeter.

Tuning-in procedure of a system consisting of three power oscillators and the pre-exciter is rather laborous. It is necessary to tune-in initially the separate units and then make them to operate in parallel. In order to have good efficiency and proper frequency regulation, definite impedance must be seen at generators output. Therefore it is necessary to arrange different transformation of impedance between the tank and generators for single or parallel operation. This is accomplished by variable coupling loops and double-stub tuners in the coaxial lines. The loops can be adjusted for coupling coefficient between 0.9 and 2.5. All tuners are remotely operated from the control-room. The adjustment of pre-exciter's circuit and transmission system made its operation practically insensitive to tank conditions.

The loading of resonator by pre-exciter after the end of its 300 μsec pulse was quite low.

Resonant discharges /multipactoring/

At the beginning of every pulse the pre-exciter has to build-up the cavity field good beyond multipactoring level. The system of triggering is so arranged that anode pulse for power oscillators can be applied only when the field level in the gaps is higher than 0.25 MV/m. Typical procedure for multipactor overcoming applicable in many machines, and using low repetition rate or single shot operation, did not prove effective in the system with slow field build-up. It was tried in the early days of operation but gave after quite a long time only modest number of good pulses.

It was clear that one has to modify the secondary emission coefficient of electrode surfaces by some treatment or RF conditioning. Therefore it was proposed to sustain the discharges and use them for surface outgasing and hydro-carbons decomposition.

Initially, small c.w. generator was used for that purpose, but more efficient was the operation of pre-exciter at high repetition rate, i.e. 12.5; 25 or even 50 pps. The next step was to switch the pre-exciter on 1 msec pulse operation. Fig.2 shows tank pulses at multipactor discharges of various levels.

The observed levels lay good within the limits of theoretical prediction and were between 7 kV/m and 120 kV/m. The lowest one was most sturdy and time consuming. At this level no glowing was observable in tank volume and only small variations in tank vacuum. At higher levels the pulse picture was changing rapidly, the tank pressure increased 2 to 3 times and there was blue volume glowing in the region of drift-tubes, with local bright spots. The distribution of this glowing was all the time variable. Usually after some time of operation at such elevated level, multipactoring disappeared and normal pre-exciter field pulse was obtained. When power generators were switched on, the number of good pulses dropped again, but after longer operation this effect disappeared. Also after few days breaks, even without opening of the tank it was necessary to repeat the process of high-duty cycle pre-exciter operation to suppress multipactor discharges.

During the running-up period there were two vacuum system accidents, when some oil penetrated into the tank. It was impossible then to get normal operation of RF system, and mechanical cleaning of electrode surfaces was necessary.

High field effects

Voltage breakdowns between the drift-tubes were observed for the first time, when the field reached about 0.7 of its threshold accelerating value. Visual inspection demonstrated that majority of discharges took place in the first ten gaps. It was also confirmed that for lower repetition rate higher level was achievable and the tank pressure which rose during breakdown dropped back between the pulses.

The breakdowns appeared generally at the top of the pulse and toward its end. If repetition rate was higher and the discharges repeated in succesive pulses they were shifted toward the beginning of the pulse including the front slope. It was therefore decided to arrange for equiping the timer with frequency divider and give the operator a push-button to stop trigger pulses for a desired time. It allowed to find experimentally the best distance between the pulses. It seemed also interesting to shorten the pulse length from 1000 μsec. to 350 μsec . Unfortunately this did not improve the breakdown behaviour.

During some time of operation the nature of discharges and vacuum conditions were observed and some relation measured. Few of them are demonstrated in Fig.3 and 4. Especially interesting were visual observations of pre-breakdown periods. As the input power was increasing there appeared numerous bright points at the drift-tubes surfaces. Their intensity rose and at the end the flash of breakdown occurred in one of the gaps. But, if the level reasonably below breakdown was set up and maintained for longer time the bright points slowly disappeared. This led to the use of following procedure. A field level good below breakdown was set up at low repetition rate and then repetition frequency was succesively increased as high as possible. After some time of such operation, next higher value of the field was set up at lower repetition. This method allowed for must rapid achievement of accelerating level. Once, small water leak appeared in the tank and the breakdown level immediately dropped down. The observed dependance of electric strength on water vapor pressure is shown in Fig. 5.

Conclusion

First accelerated beam was obtained at January 15 this year. Since that time further observations of the beam, RF system and transients were systematically carried out. Some modification of the system are proposed. The results will be treated in detail in separate report.

References

1. Collective work "10 MeV Proton Linear Accelerator at Swierk" Report INR No 1187/FLAP/PL
2. T.Niewodniczański "10 MeV Proton Linear Accelerator at Swierk" Paper presented to 1970 Proton Linear Conference, Batavia.

3. C.S. Taylor "Linear Accelerators, Radiofrequency problems"
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4. Z. Kozłowski "Linear Accelerator Vacuum System"
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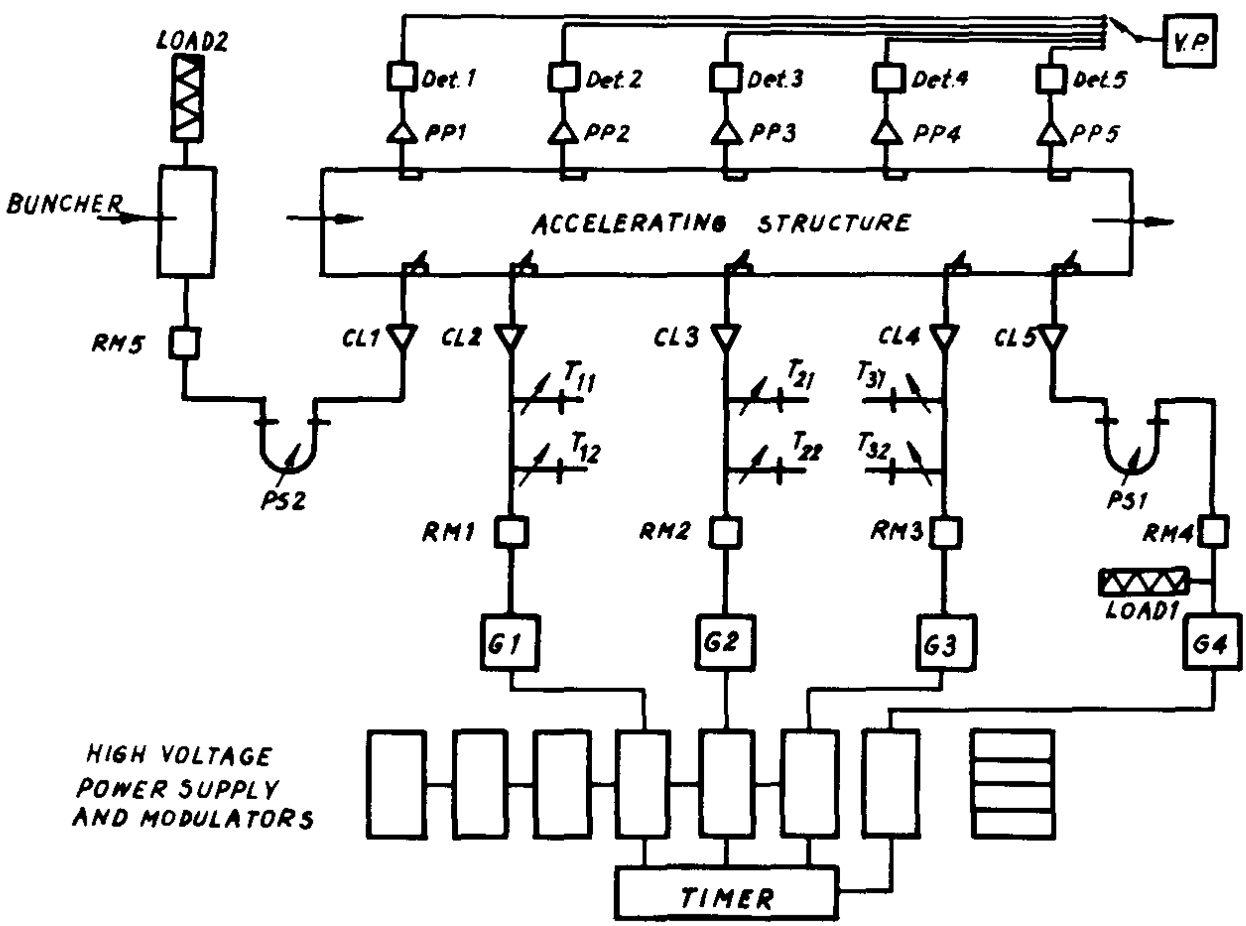

Fig.1 General diagram of RF system

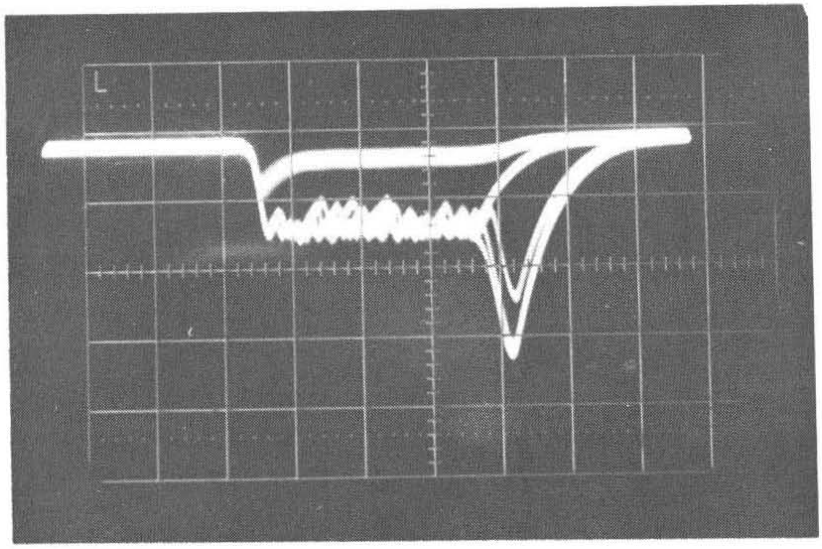

Fig.2 Multipactor pulses at various levels

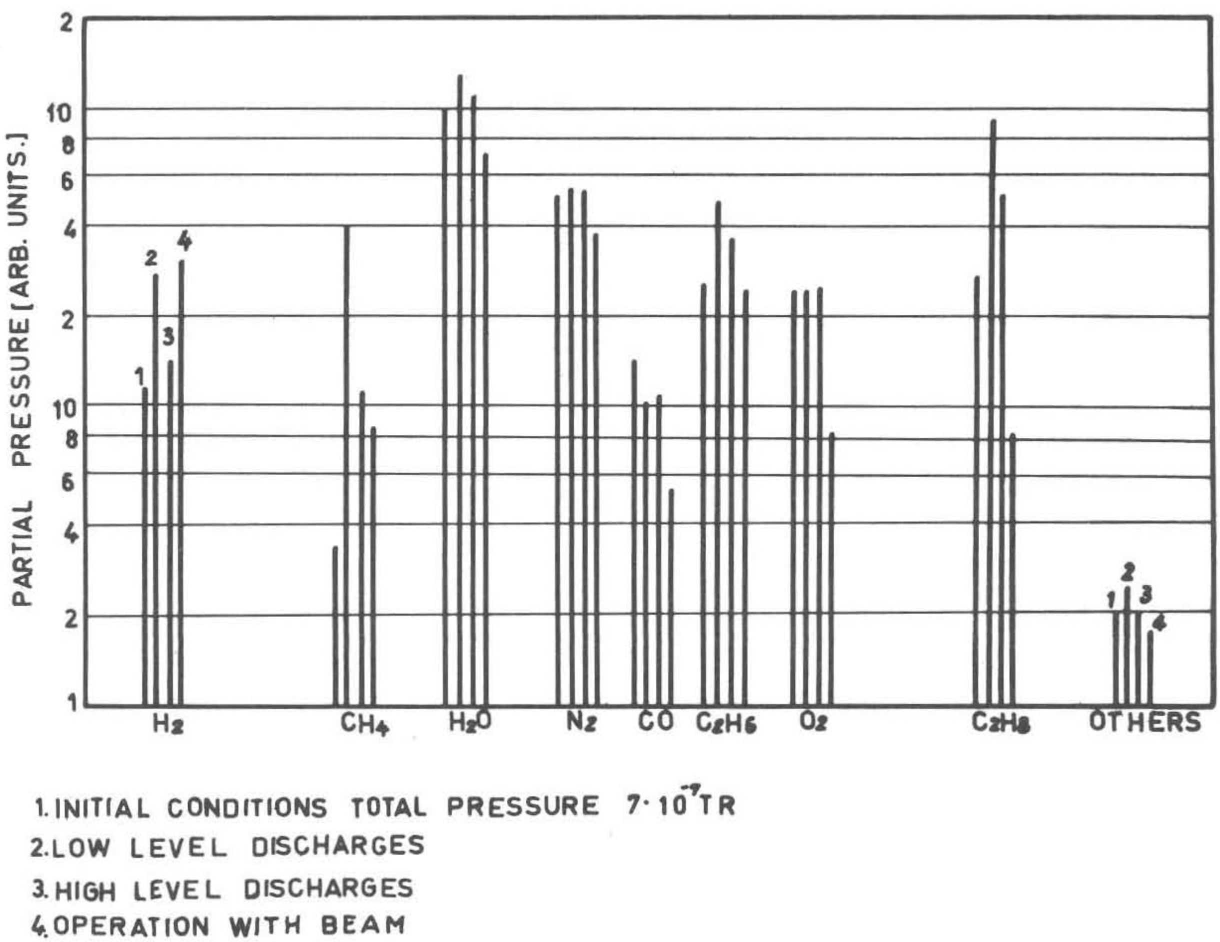

Fig.3 Residual gases spactra

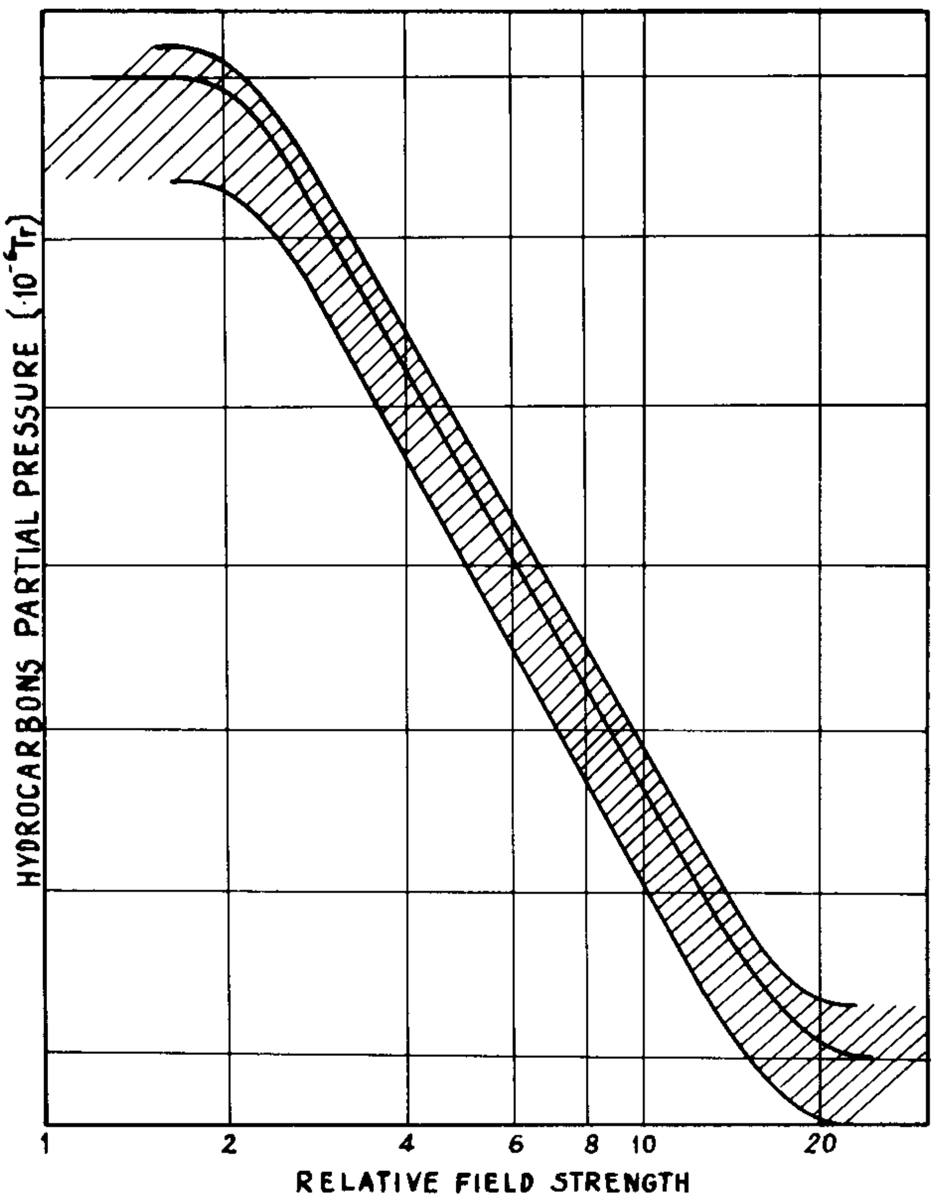

Fig.4 Influence of hydrocarbons pressure on breakdown lebel

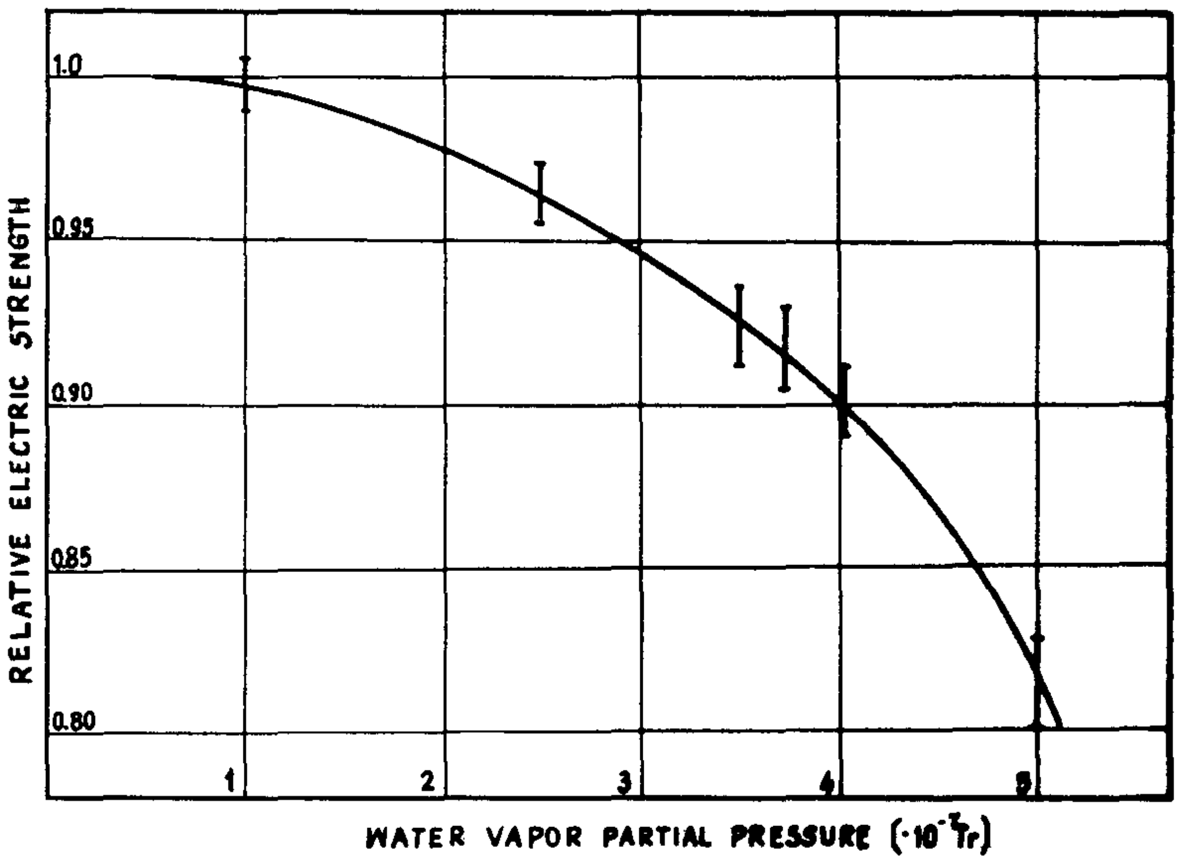

Fig.5 Influence of water vapor pressure on breakdown level

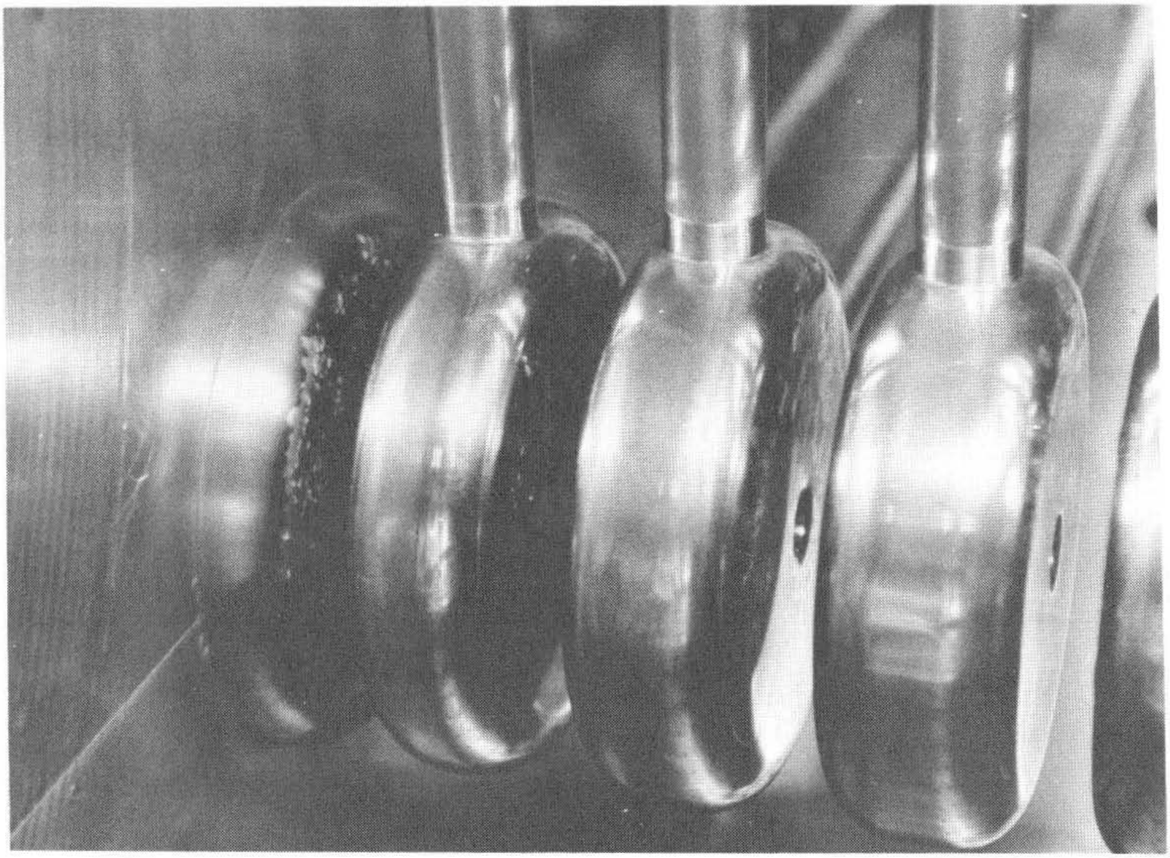

Fig. 6 View of first few drift-tubes with breakdown spots.