Gas condensation on cold surfaces, a source of multipacting discharges in the LEP2 power coupler

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1. INTRODUCTION

The LEP2 coupler feeds RF power to the four-cell 352 MHz LEP2 superconducting (sc) cavity. Starting point for its layout was a proven construction: that used on the LEP1 five-cell copper cavities. This coupler has a cylindrical window of 100 mm diameter integrated into the "doorknob" transition between a half-height waveguide and a coaxial line (of the same diameter) which in turn connects to the coupling element proper, a loop [1].

To better integrate this coupler into a cryostat two changes were made: magnetic coupling was replaced by electric (the inner conductor of the line then can stay at room temperature) and the line was extended by an "extension tube" of 53 cm length designed to minimize heat flow into the He bath (Fig. 1). It is made from two concentric thin walled stainless steel tubes mounted with a gap of 2 mm in between them which carries the cooling flow of He gas (injected with 4.5 K at the cavity side). To minimize RF dissipation the inner surface is covered with a copper layer of about three skin depths' thickness.

For LEP operation d.c. bias is used to suppress multipacting and deconditioning. However, to permit safe operation the couplers should be conditioned up to full power on the cold cavities (without d.c. bias).

2. CONDITIONING, PRECONDITIONING AND RECONDITIONING

The LEP1 coupler is conditioned **on** its copper cavity. Several multipacting bands are observed but can be conditioned away without difficulty and do not reappear during cavity operation.

The LEP2 coupler is **preconditioned at room temperature** by mounting two couplers on a special single cell copper cavity (with external Q much lower than the cavity's Q_0 so that cavity dissipation remains negligible). The whole assembly is baked out for outgassing before conditioning starts.

Preconditioning has been adopted as a method of precleaning couplers as much as possible before they are mounted on cavities with sensitive sc surfaces and — in the same context — to study the RF behaviour of copper surfaces produced by electroplating or sputtering. As these studies have shown, both deposition techniques, if properly done, may give the same room temperature performance as bulk copper, i.e. all outgassing and multipacting effects may be removed, so that the power transferred through the coupler can be cycled up and down between zero and 200 kW without any observable electronic or vacuum activity. Also, after breaking the coupler vacuum with dust filtered laboratory air and an exposure of three hours, reconditioning on the warm test stand takes only a few hours.

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3. RECONDITIONING ON THE SC CAVITY AND DECONDITIONING

However, after transfer of such couplers, which work well, on to an sc cavity, application of power is extremely laborious after cooldown. Also lower power multipacting levels are reactivated and rising the field in the coupler to the 120 kW travelling-wave equivalent takes a day or two. Even worse, lower power multipacting levels, after being passed, reappear after an excursion to higher powers (deconditioning).

The multipacting levels encountered correspond to those predicted by computer simulations [2,3] and are of the single point type with electron orbits starting and ending on the **outer** conductor of the coaxial line.

4. COOLING EXPERIMENTS

To elucidate the mechanism behind this phenomenon of enhanced multipacting in couplers subjected to He cooling on their outer conductor we equipped one of the couplers on the room temperature conditioning stand with a special experimental extension tube (copper plated version). It carries at its centre a cooling helix and in addition three e^- pickup antennas, one at the centre and the two others next to the end flanges where the temperature is not changed, whereas at the centre, by passing liquid nitrogen through the cooling helix, 70 K may be established (see Fig. 2).

We then did the following experiments.

a)
- room temperature conditioning to 160 kW
- cooling to 70 K
- reapplication of RF power

Observations: no signal of multipacting either on the warm or on the cold e^- pickups.

b)
- room temperature conditioning to 160 kW
- 3 h exposure to dust filtered laboratory air
- pumping to UHV conditions
- cooling to 70 K
- reapplication of RF power.

Observations:

There is strong multipacting at the first rise of power, but exclusively in the cold zone. Attempts to condition away the first multipacting level encountered activate a level at lower power! Several hours of conditioning only worsen the situation. It is not possible to reach 160 kW.

This type of experiment was subsequently repeated by exposing the coupler to dry N_2 gas and to an air-like gas of N_2, O_2 mixture (passed through an antimoisture filter) instead of the laboratory air.

In both cases multipacting at the cold zone, although weaker, intensified under conditioning, so that 160 kW could not be reached. However, after removal of the liquid

N_2 flow, processing of multipacting levels immediately started to progress and a clean coupler state could be reached after about one hour.

5. *IN SITU* BAKE-OUT OF THE CERAMIC WINDOWS

The absorption of gas on a cleaned (by ion discharge) surface may increase its secondary electron emission by factors of 2 and higher, and water adsorption is especially effective [4].

It is also a known fact that exposing materials to strong RF fields causes desorption of gas even outside active multipacting bands.

Therefore we suspected that application of RF power after gas exposure liberates gas which, after readsorption in the cooled zone, increases there the secondary emission creating the conditions for multipacting.

In following up the suspicion that the window area of the coupler might be the principal reservoir of adsorbed gas after breaking the vacuum, we tried in two further exposure experiments with moisture filtered N_2 and laboratory air to find out whether **baking** the window at 200°C for 24 hours after re-establishing the vacuum would improve the situation. The remaining coupler parts were **not** baked out.

The results are fully in support of the supposition. After cooling no multipacting level below 120 kW was reactivated and the strong tendency to deconditioning had disappeared.

Since this bake-out procedure was very successful on the liquid nitrogen test bench we repeated it on a real sc test cavity. This cavity is equipped with a standard fixed input coupler and a mobile output coupler, permitting operation of the input coupler at loads between full reflection and match. During mounting on the cavity in the clean room, these couplers were exposed to air for several hours. Prior to the cooling down of the cavity the ceramic windows (titanium-coated) were *in situ* baked out at 200°C for 24 hours. This procedure is relatively simple to perform since the ceramic window part of the coupler protrudes from the cryostat and is therefore easily accessible.

As a result of this procedure, conditioning to more than 8 MV/m was possible within four hours at full reflection and within 13 hours under matched conditions. Previous tests without bake-out of the windows needed several days of conditioning to reach these values.

Finally, this cavity was exposed to air again for about 24 hours, followed by the bake-out procedure and this time by the cooling down of the cavity only (and not cooling of the coupler extensions). Conditioning was done by keeping the extensions uncooled. Pulse power with about 10% duty cycle was used during this operation to avoid overheating. By applying this method the conditioning time could be further reduced by about a factor of 2.

6. CONCLUSION

In transferring a coupler construction from normal to sc cavities, gas adsorption in the warm-cold transition zone of the coupler is harmful. The main source of gas appears to be the warm ceramic window after exposure to air during the mounting operations.

The adsorbed gas enhances the secondary emission of electrons leading to strong multipacting which is extremely difficult to condition away. (An explanation could be that, in addition to the continuing desorption of gas from the window due to RF heating, molecules desorbed by the impinging electrons return to the same cold surface area which acts as a cryopump.)

Considerable improvement was obtained by *in situ* bake-out of the window (24 hours, 200°C) before cooldown of the cavity. Of course even better results could be expected by *in situ* bake-out of the complete cavity-coupler system, in the present design not possible because of the use of heat-sensitive superinsulation.

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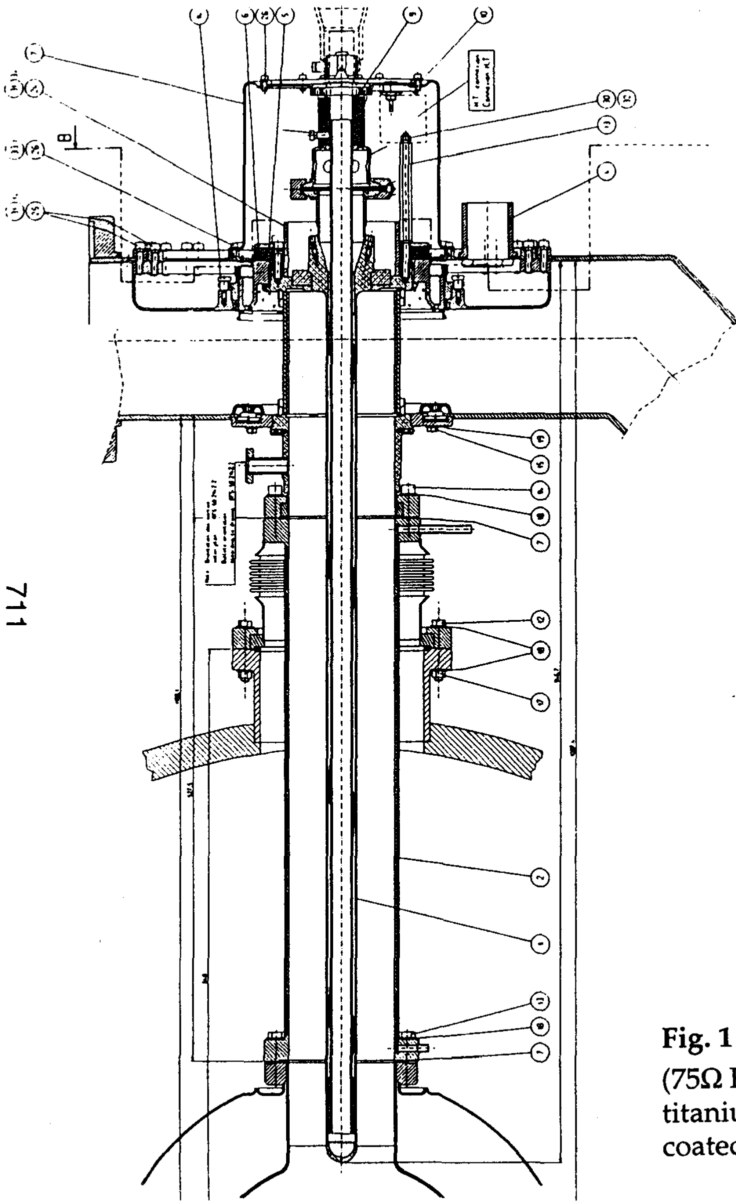

Fig. 1 LEP2 Main Coupler
(75Ω Fixed Coupler, 2.5 kV d.c. bias, titanium-coated ceramic window, copper-coated stainless-steel extensions)

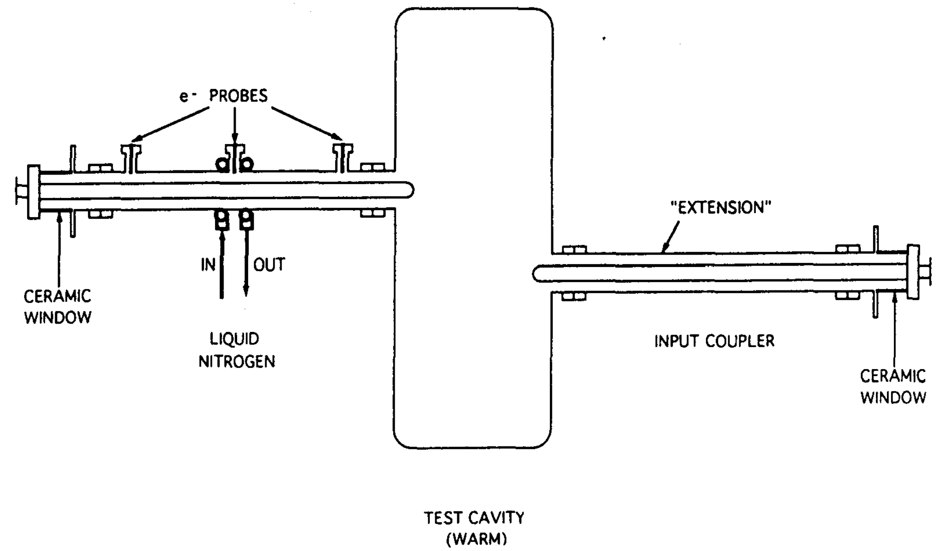

Fig. 2 Liquid Nitrogen Test Bench