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L. DiPaolo, G. Baldacchini and V. Montelatici : EFFECT OF A STATIC MAGNETIC FIELD ON A SUPERCONDUCTING MILLIMETER CAVITY RESONATOR. -

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L. Di Paolo(x), G. Baldacchini(o) and V. Montelatici: EFFECT OF A STATIC MAGNETIC FIELD ON A SUPERCONDUCTING MILLIMETER CAVITY RESONATOR. - Relation presented at "LII Congresso Società Italiana di Fisica, Trieste 1966".

INTRODUCTION. -

Recently measurements on the radio frequency absorbtion of superconducting materials have been performed. These researches had the aim of producing high Q resonators for use as particle accelerators(1, 2).

The effect of a static magnetic field on a superconducting resonator is of great importance in the construction of some types of accelerators.

For instance a microtron with a straight section has the R. F. accelerating cavity inside the fringing field of a static magnet. This field, if sufficiently strong, increases the surface impedance of the superconductor, consequently the figure of merit, Q_o, decreases towards the value it has when the metal is in the normal state.

The aim of this work is to investigate the way in which Q_o is affected by a static magnetic field at different temperatures.

(x) - Thesis, University of Rome.

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Q_o AS A FUNCTION OF A STATIC MAGNETIC FIELD. -

The Q_o is related to the absorption of microwave radiation by:

$$Q_o = \frac{\pi Z_o}{R_s} f(1, m, n)$$

with $R_s = R_n A(\omega) f(t) + R_o$ given by the Pippard relation(3) with

$$f(t) = \frac{t^4 (1 - t^2)}{(1 - t^4)^2}$$

and where $t = T/T_c$ is the reduced temperature, R_n is the real part of the surface impedance of the metal above the transition temperature T_c giving the loss of microwave field, $A(\omega)$ is a costant which depends on the frequency and on the surface finish; R_o is the residual resistance at 0°K, which depends on trapped flux in the metal impurities, and in lattice defects(4); $Z_o = 377\,\Omega$ and $f(1, m, n)$ is a geometrical factor, it depends on the mode of oscillation and on the diameter and lenght.

Since a resonant mode TE_{011} was selected with the ratio diameter/lenght = 2.25 we have $\pi Z_o f(1, m, n) = 640$ at the frequency of 25 Gcs. The Q_o measurements are performed dinamically at a rate of 50 c/s by comparing the power reflected from the cavity with that incident on it at resonance, near resonance and at two selected points half way along the resonance curve. Frequency markers for calibration of the oscilloscope trace were obtained by modulating at a few megacycles the klystron repeller, and observing sideband power from the cavity. In this way one has the frequency interval between the two selected points on the cavity resonance curve.

From these power reflection coefficients the Q_L (loaded) and Q_o (unloaded) were computed. The power incident on the cavity was a few milliwatts.

The coupling between the feeding guide and the cavity was continuosly variable by a stub inserted near the iris coupling of the cavity.

Figure 1 shows a drawing of the cavity with the device used to insert the variable stub. The upper flange is adapted for a glass dewar in which the liquid helium-4 is pumped to obtain a minimum temperature of about 0.85°K; the cavity and the feeding guide were evacuated inside. The helium bath was stabilized in temperature with and electronic thermoregulator to better than 10^{-3}°K. The "1958 He^4 scale of temperature" was used for the conversion from pressure to tem

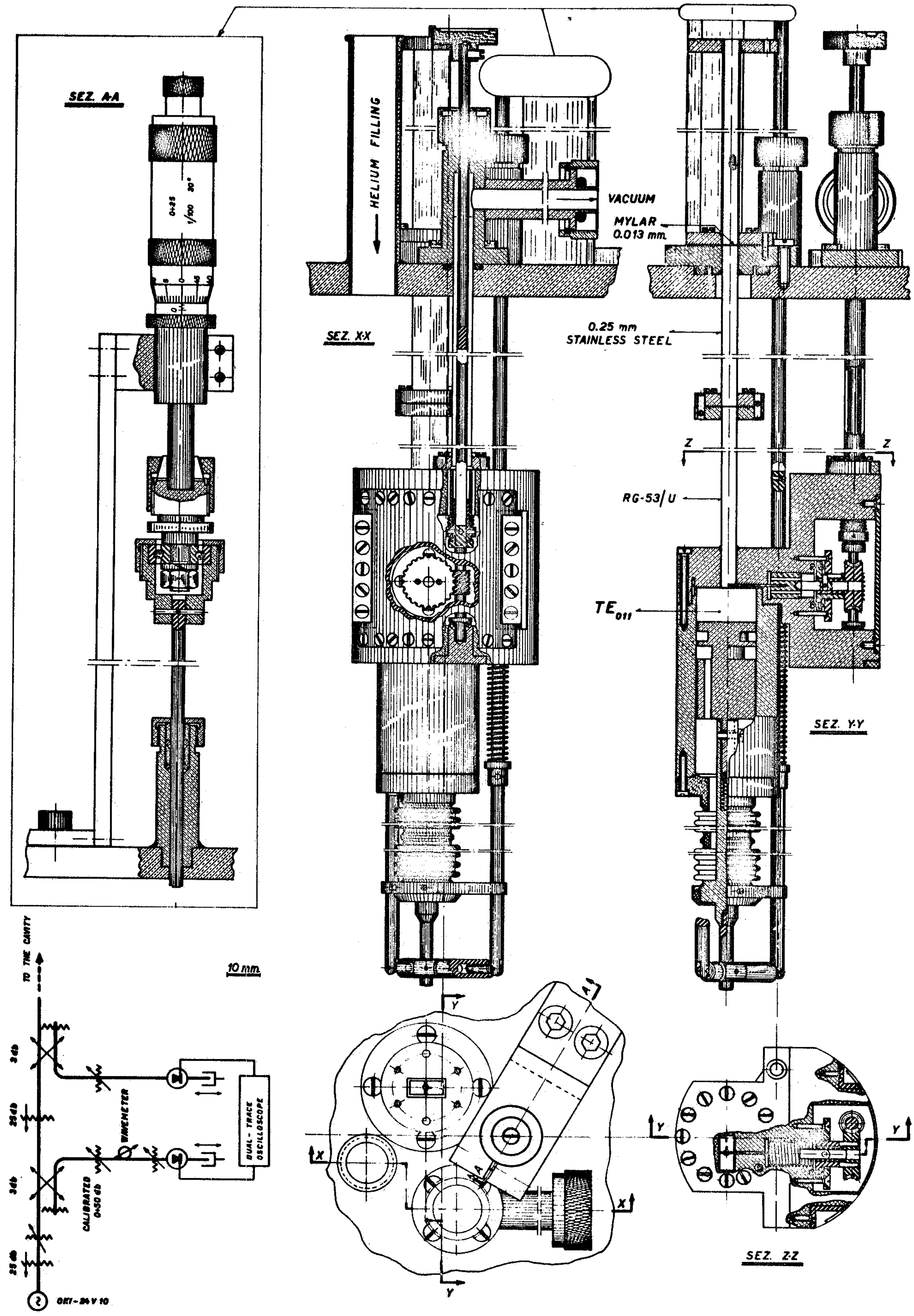

FIG. 1 - Drawing of the cavity with drivers of tunable iris and piston.

perature. A mylar sheet 0.005 inches in thickness was used to separate the two sections of the guide.

The Q_o measurements were performed in two distinct periods to find some deterioration due to temperature-cycles and exposition to the atmosphere.

The copper cavity (the inner surface was made to high accuracy by extruding the cylinder over a steel sphere) had a thick layer of electrodeposited tin which had a nominal purity of 98%. With the cavity under vacuum was measured the Q_o in the temperature range from 4°K down to .9°K.

Through the relation (1) was obtained R_S as a function of T, the curve showed the typical trend of the real part of the surface impedence, at 1°K $R_S = 1.2 \times 10^{-3}$

After some months, the cavity was exposed to the atmosphere, the Q_o decreased in the whole interval of temperature giving a value about 40% less, Fig. 3 shows the behaviour of the two Q_o values.

The Q_o dependence on static magnetic field was investigated in this second period.

Figure 2 gives Q_o as a function of H(gauss) at various temperatures; the static magnetic field was parallel to the cavity axis, and the errors in the Q_o measurements are not greater than 10%.

From the curves one note that the Q_o value begins to decrease for a magnetic field H   .22 H^{x}, where H^{x} is the field at which the superconductivity was destroyed completly in the cavity. No difference was noted in the normal state of the cavity and its Q_o at the field H^{x}.

The curve of the critical field H_C, due to Pippard and Shoenberg, as a function of the temperature is showed in the figure 2 (on the top).

The lower experimental points rappresent the values of the magnetic field at which the Q_o begings to decrease, while the upper points are the values of H^{x}.

Although the metal used in not a pure one, the measurements give some information. Naturally an high pure metal gives a factor about 10^2 higher in the Q_o.

One can extimate the maximum permitted power incident on the cavity without affecting Q_o.

The volume V of the cavity being fixed, the mean radio frequency field H cannot reach a value higher the static one at which the Q_o decreases.

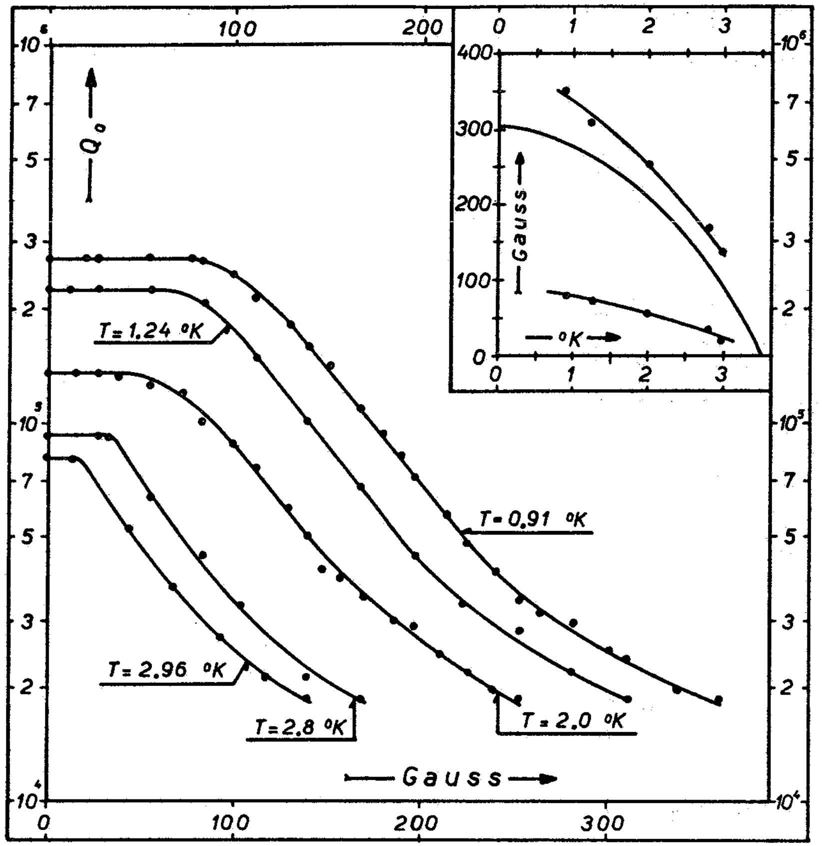

FIG. 2 - Behaviour of Q_O as function of magnetic field at various temperatures (on right corner), D. C. critical field vs temperature.

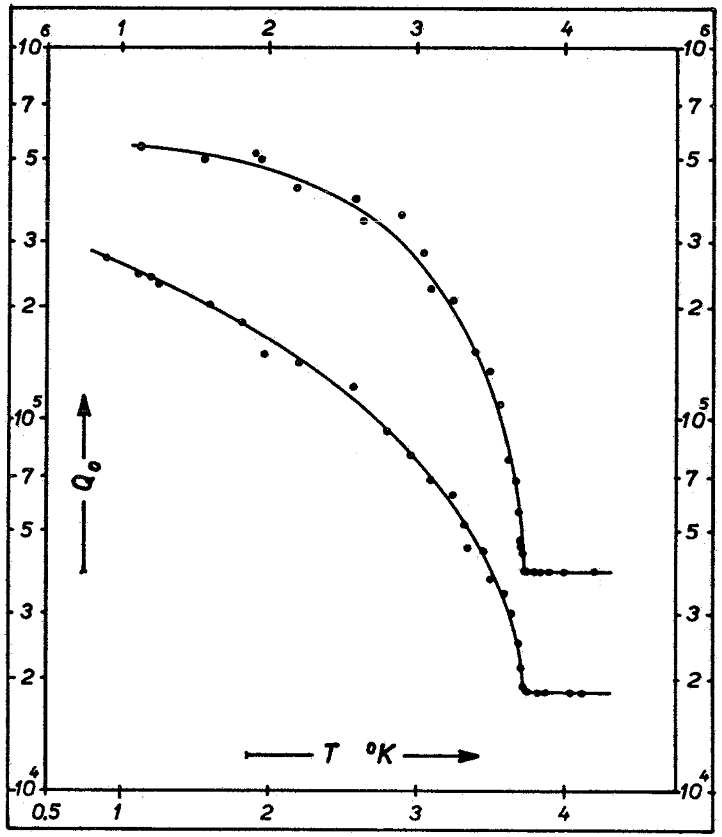

FIG. 3 - Behaviour of Q_O as function of temperature, lower curve after exposition to atmosphere.

From the definition of Q_o one obtains:

$$P(\text{watt}) \simeq \frac{1}{4Q_o} \frac{f_o(c/s)\ 10^{-7}\ H^2\ (\text{gauss}^2)\ V\ (\text{cm}^3)}{|1 - \Gamma|^2}$$

where f_o is the resonance frequency, $|\Gamma^2|$ the power reflection coefficent at resonance. In our case, at T = .91°K, for H = 80 gauss P = = 44 watt with $\Gamma = o$.

One can infer that for superconductors with high critical field and transition temperature, such as Pb, Nb, the Q_o remains costant for higher field. Consequently one can rise the incident power on the cavity.

ACKNOWLEDGMENTS. -

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