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HIGHER ORDER MODE COUPLERS FOR A 500 MHz SPHERICAL SHAPE SUPERCONDUCTING CAVITY

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1. INTRODUCTION

The bunched beam of an electron storage ring shock excites the accelerating cavities to Higher Order Mode (HOM) oscillations. The phenomenon is best controlled if sufficient cavity damping is provided to let the HOM fields decay between subsequent bunch passages [1]. For copper cavities in LEP the damping by wall losses is expected to be sufficient. In superconducting (SC) cavities the wall losses are smaller by about a factor of 10^5 and adequate loaded Q's of the order 50 000 must be foreseen by coupling the HOM to external load resistors. These must then [2,3] dissipate the HOM power of about 1 kilowatt per meter (for LEP).

The required couplers must

(a) be compact to simplify the cryogenic design. At 500 MHz and lower frequencies this excludes the use of wave guide couplers [4,5] which because of their simplicity and inherent high pass characteristic are very attractive(*) at higher frequencies;

(b) cause only a minimum of additional "coupler" losses at He temperature;

(c) not impair the cavities high field properties;

(d) not couple to the fundamental mode.

(*) Desy and Wuppertal University couple fundamental and HOM by wave guides to a 9 cell 1 GHz SC cavity currently under development.

2. A PROBE COUPLER

Suppressing fundamental mode coupling, if waveguides cannot be used, requires filters for all devices which couple to the magnetic cavity field [6,7]. Electric field "probe" couplers on the other hand can be constructed simply and without a filter if used on the cavity equator, coupling especially to the TM_{011} mode, which under all longitudinal HOM has the highest coupling impendance [2,3] and hence the dominant portion of the HOM power flow (> 75%).

The probe design developed here is basically a coaxial λ/4 resonator as sketched in fig. 1(a)

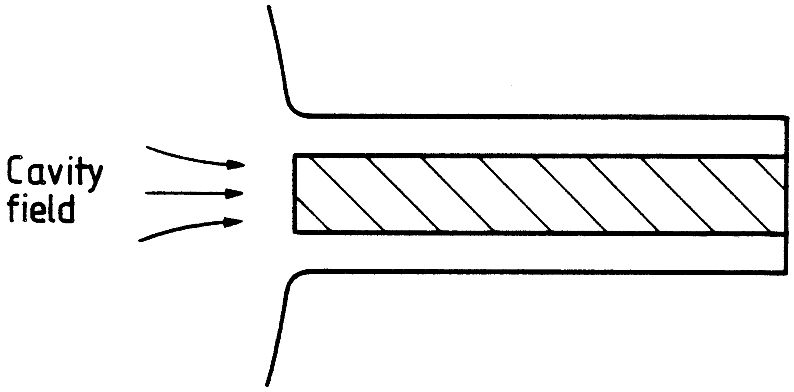

Fig. 1(a)

Its length can be reduced by capacitive loading creating at the same time a larger active area for field pick up (fig. 1(b)).

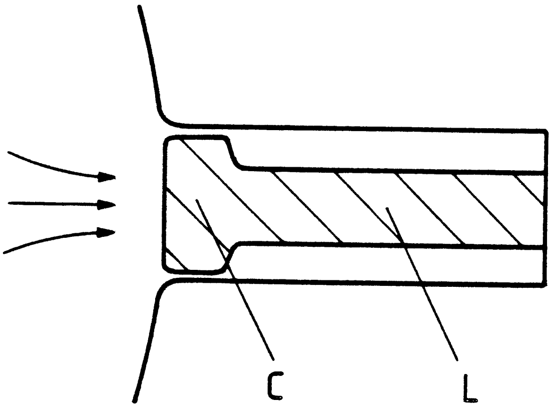

Fig. 1(b)

The end capacity C now resonates with an inductive line stub L and symbolizing the displacement current J picked up by C as a current source, we can draw the lumped element equivalent circuit of fig. 2(a)

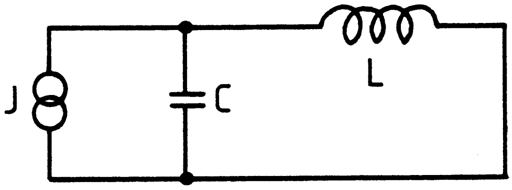

Fig. 2(a)

Lumped element equivalent of probe resonator

In coupling this circuit to an external 50 Ω load as indicated in fig. 2(b)

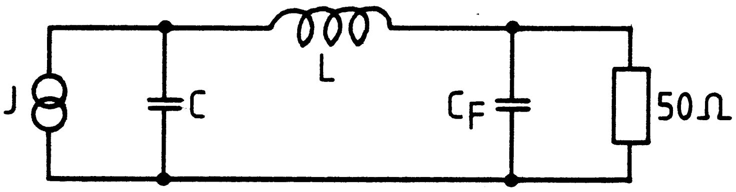

Fig. 2(b)

Probe resonator coupled to load

one arrives finally at the coaxial line circuit of fig. 3.

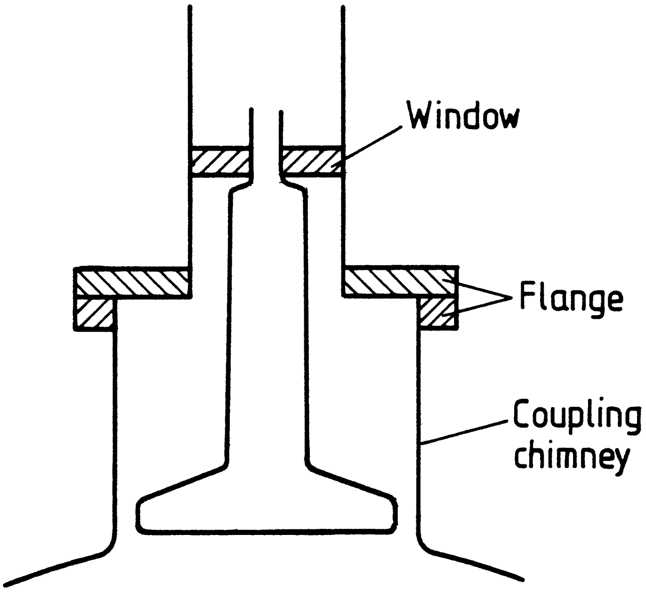

Fig. 3

Schematic out-line of probe on cavity

Here C_F has been partly absorbed into the Al_2O_3 vacuum window capacitance. All metal parts are from Nb formed by spinning or turning on a lathe and assembled by electron beam welding, only the window being brazed.

The external conductor is welded at one side to the cavity forming a coupling chimney with a Nb flange at its end which allows demounting of the probe. A flat lead ring ensures contact and vacuum tightness. The central probe conductor is hollow, and communicates by small holes with the liquid He bath which extends into the coaxial space above the vacuum window.

With the dimensions given in the technical drawing at the end of this note (fig. 4) the probe circuit resonates with a Q of 2 at 920 MHz, the TM_{011} frequency of our spherical 500 MHz cavity. Mounted with the probe's pick up surface just tangent to the original cavity boundary, measured external Q's for the TE_{111}, TM_{011}, TM_{111} and TM_{021} modes on a single cell are 55 000, 11 000, 15 000 and 70 000. The polarization direction of the dipole modes was at 32° to the probe axis. Up to now three probes of this type have been built and after careful chemical polishing tested on a single cell SC cavity up to accelerating gradients of 3.6 MV/m, the upper field limit of the test cavity used.

No additional heat losses due to the coupler were observed. The coupling to the fundamental mode was very weak but could be influenced by turning the probe. In the optimal position only some milliwatts of external power were measured at 3 MV/m acc. field which corresponds to external Q's of the order 10^{12}.

The concept of equatorial coupling requires additional loop couplers to cover all modes.

3. A HOM LOOP COUPLER

The HOM loop coupler used here is also a low Q resonator with the equivalent lumped element circuit of fig. 5

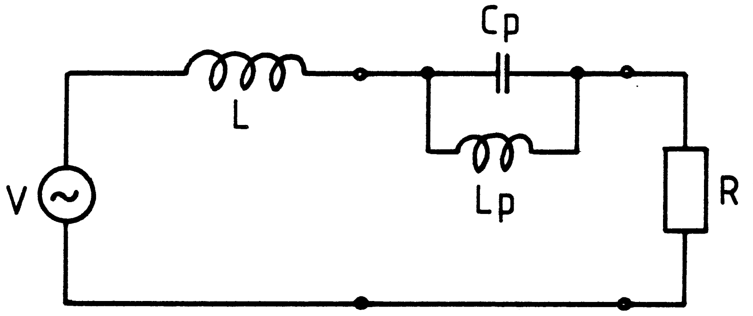

Fig. 5

Equivalent circuit of loop coupler

Here L is the self inductance of the loop and V an induced HOM voltage. R is the 50 Ω load and Lp, Cp form a notch filter tuned to the fundamental mode frequency to suppress coupling there. At higher frequencies the notch filter reactance becomes capacitive, forming with L a series resonator the eigen frequency of which is adjusted to fall onto the TM_{110} dipole mode cavity resonance. The chosen Q of the coupler resonance is again 2. The coaxial line circuit realization follows the sketch of fig. 6.

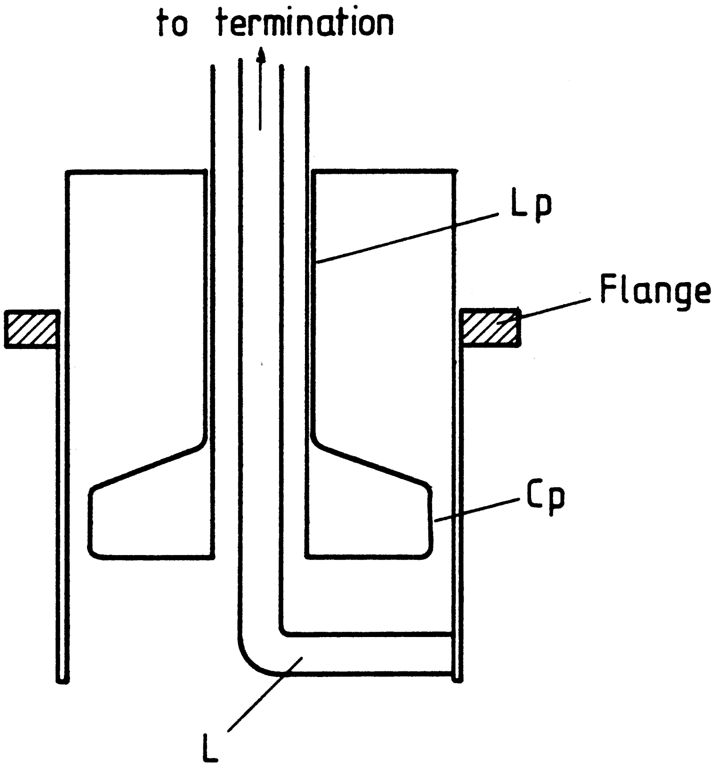

Fig. 6

Sketch of loop coupler

A capacitively loaded λ/4 resonator has been used to build the notch filter. The line leading to the termination is inside and concentric with this filter. All parts carrying RF current are made from thin walled Nb sheet in contact with liquid He.

The dimensions adopted and the flange construction are identical to that of the probe. This allows the use of the same coupling chimney dimensions for either probe - or loop coupler. Mounting dimensions (fig. 7) are in the second technical drawing at the end of this note. The obtained single cell external Q's with the coupler mounted just not protruding into the cavity are 16 000, 80 000 and 200 000 for the TM_{110}, TM_{020} and TM_{012} modes respectively again with 32° between dipole mode polarization direction and coupler axis.

The results obtained so far with both coupler types on single cell cavities are summarized in table 1, which includes all modes with significant coupling impedance up to the frequency where propagation into the beam tube sets in.

TABLE 1

Mode	Frequency	Q_0(Cu)	Q_{ex}	Remarks
TE_{111}	693	40 000	55 000	Probe at 32°
TM_{110}	737	33 000	16 000	Loop at 32°
TM_{011}	917	34 000	11 000	Probe
TM_{111}	1043	35 000	15 000	Probe at 32°
TM_{020}	1072	40 000	80 000	Loop
TM_{021}	1373	43 000	70 000	Probe
TM_{012}	1460	50 000	200 000	Loop

We have equipped each cell of the 5-cell SC cavity constructed at CERN with one such HOM coupler using loops on the end cells and probes on the three central cells.

Acknowledgements

I thank all my colleagues, especially P. Bernard and H. Piel for their readiness to discuss possible coupling approaches with me helping to define a realizable concept. The rapid design, fabrication and testing of couplers was a group effort and relied also strongly on the competence and skill of the SB workshops for spinning, brazing, electron beam welding and surface treatments which I gratefully acknowledge.

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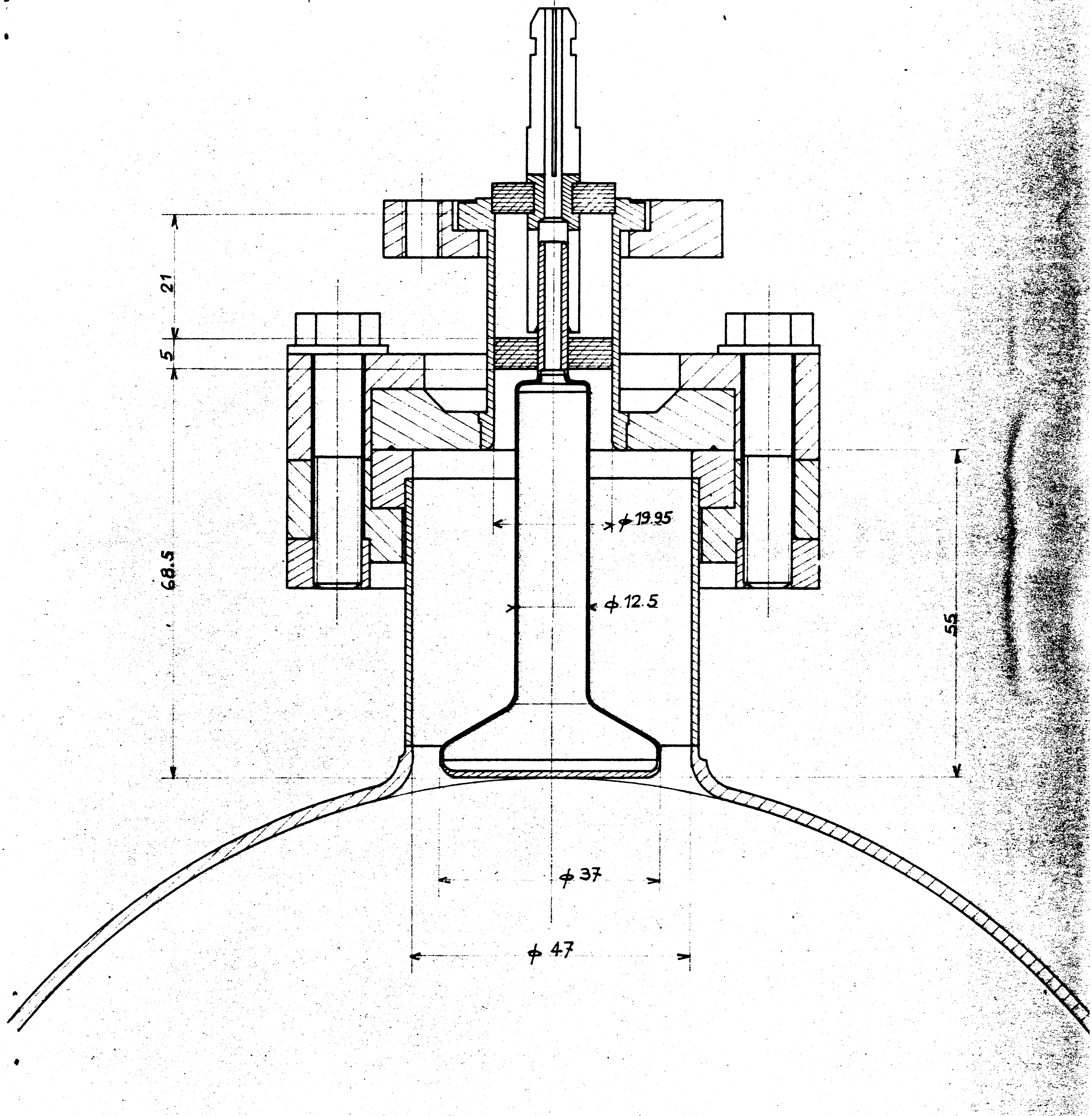

Fig. 4

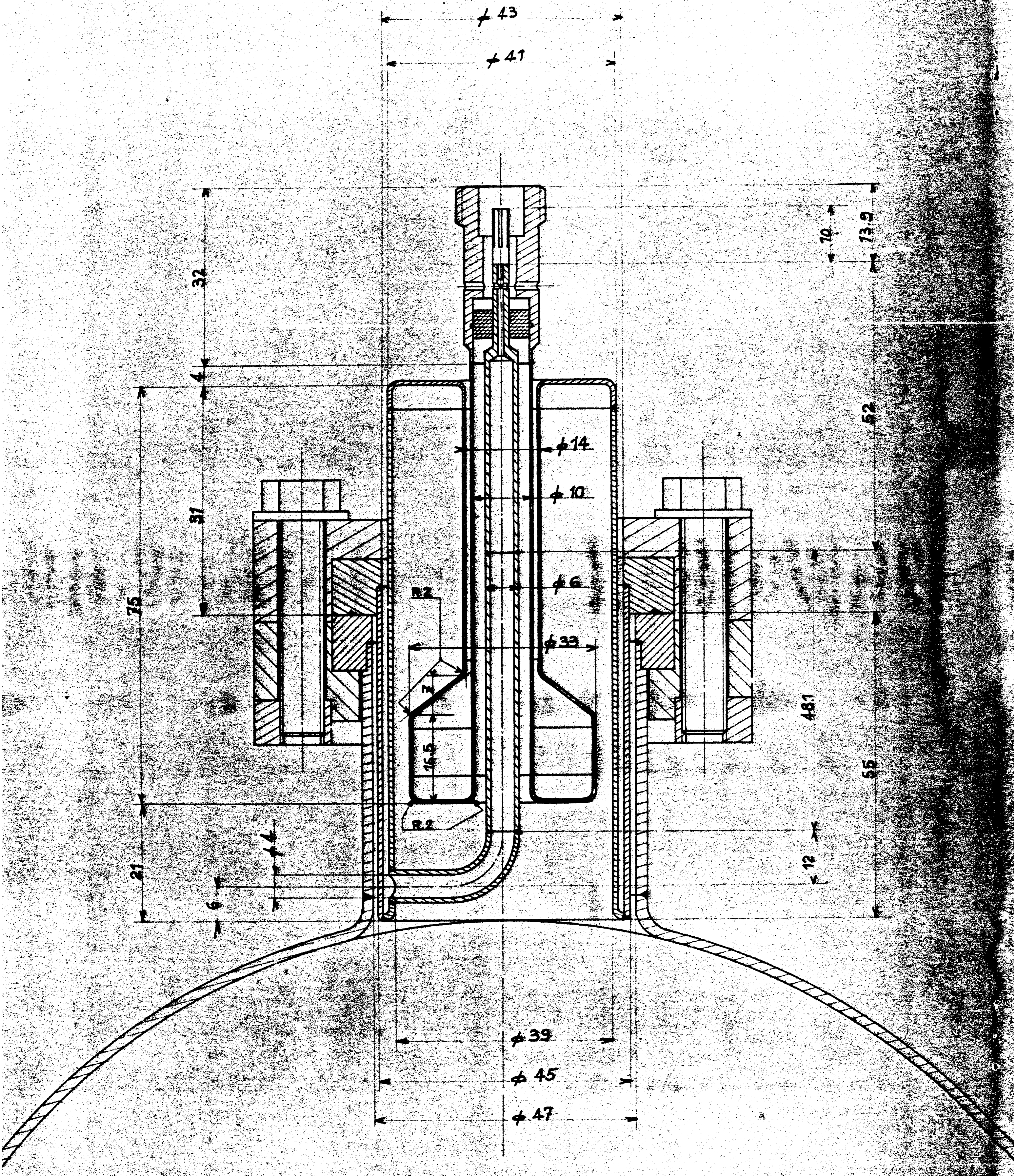
ϕ 43
ϕ 41
32
10
13,9
4
52
ϕ 14
ϕ 10
31
75
ϕ 6
R.2
ϕ 33
7
16,5
481
55
R.2
ϕ 4
21
12
6
ϕ 39
ϕ 45
ϕ 47

Fig. 7