Vacuum, Magnet and Power Supply Group.

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Vacuum System Summary

Required vacuum:

	PB	HR
p (50 Hz)	10^{-6} Torr	
HI (10 Hz)	10^{-8} Torr	10^{-10} Torr → eg COSY Jülich, SIS/ESR GSI

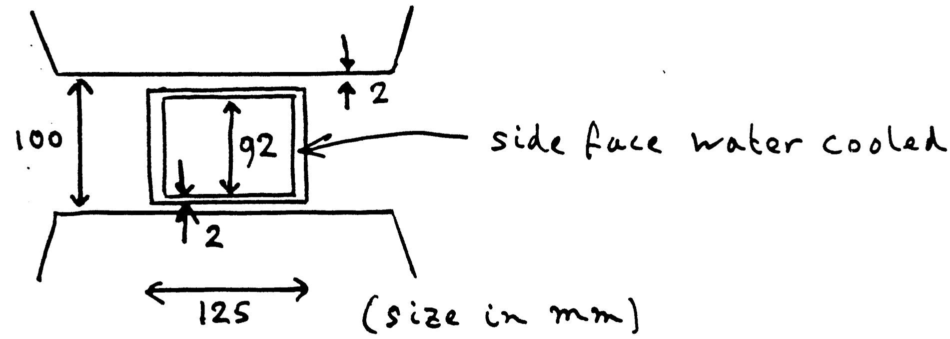
Holding Ring vacuum system:

- metal eg: stainless steel 2 mm thick (COSY)
  or: 0.3 mm thick with stiffening ribs (SIS/ESR)
- bakeable at 300 °C
- metallic seals for flanges, valves, bellows
- 8 sectors divided by slide valves
  ↳ 8 turbomolecular pumps
- other pumps — 32 ion pumps 40 l/s
  — 6 ion pumps 400 l/s
  — 40 titanium sublimation pumps 1500 l/s
- gauges 8 RGA's
  ↳ pirani, penning 10^{-10} torr ; ionisation gauge 10^{-12} torr

Pre Booster vacuum system:

- all metal or metal-ceramic
  ↳ in dipoles only!
- bellows with inside sliding fingers provide "smooth" transitions of cross sectional vac. ch. shapes (dipole → s.s. → quad)
- 8 valves for 8 sectors — 2 arcs
  — 2 Long straights
  — 4 short straights
  ↳ 8 turbomolecular groups
- pumps with sufficient capacity at spacing so as to avoid Local pressure bumps
  ↳ 36 ion pumps 40 l/s (near dipoles)
  ↳ 6 ion pumps 400 l/s (in s.s.)
- RGA's & gauges
- eddy current issue

a. Stainless Steel Dipole Chamber:



Eddy current power loss:

$$P \propto \frac{w^3 \hat{B}^2 f^2 \tau L}{\rho}$$

		SNS	PB	(HR)	
w	chamber width	230	125		mm
$\hat{B}$	max. induction	5.3	2.45	(12.8)	kG
f	frequency	50	50	(10)	Hz
τ	thickness	2	2		mm
ρ	resistivity	S.S.	S.S.		
L	length	4.4	3		m
P	power	250	4.5		kW

Comment:
- take width not larger than necessary for accomodating beam
- rectangular shape rather than elliptical
  ↳ beam loss / scraper issue
- induced sextupoles require correcting wires on vac. chamber à la AGS-booster (included in 2mm clearing with magnet pole)

b. Ceramic Dipole Chamber Option:

- walls 4 mm thick
- RF shield 3-4 mm thick

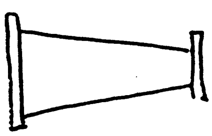
↳ aperture dipole slightly larger

Preliminary & partial Vacuum cost estimate.

	Unit cost (k SF)	PB Qty	PB Total (k SF)	HR Qty	HR Total (k SF)
Turbomolecular group	20	8	160	8	160
Ion pump 40l/s t.c.u.	3	36	108	36	108
Ion pump 400l/s tcu	10	6	60	6	60
Ti subl. pump 1500l/s				40	
RGA	12	8	96	16	192
gauges	8	8	64	16	128
rack for control	10	10	100	10	100
vac. chamber	15 kSF/m	256 m	3840	256 m	3840
Leak detectors	20	3	60	3	60

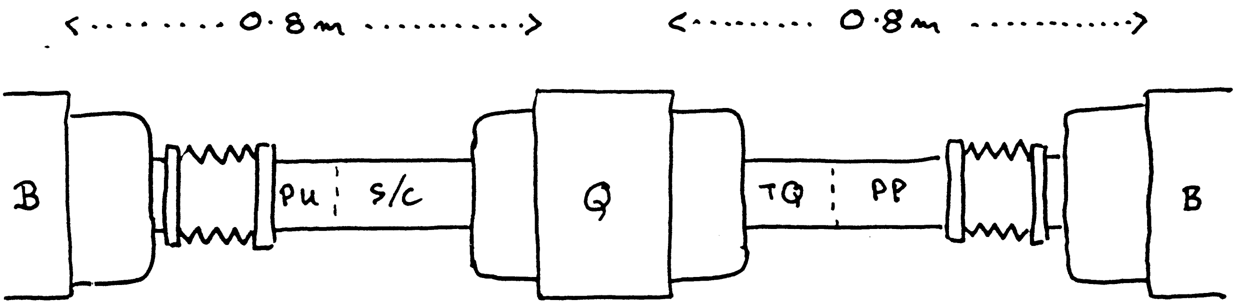
S/S Dipole Vacuum Chamber :

Eddy current power reduced for a tapered chamber :



4.5 → 2.5 kW

FODO Cell Spacings.



Coil	0.15	Coil	0.15
Bellows	0.10	T.Q	0.2
P.u	0.10	Pumping P.	0.2
Steering /c	0.30	Bellows	0.10
Coil	0.15	Coil	0.15
Total	0.8 m		0.8 m

Dipole 3.5 m → 3.0 m

$\hat{B}$ (magnetic length / ph. length = 1.05) 1.28 T

DIPOLES

$L_{magn} = 3000$ mm   gap height = 100 mm

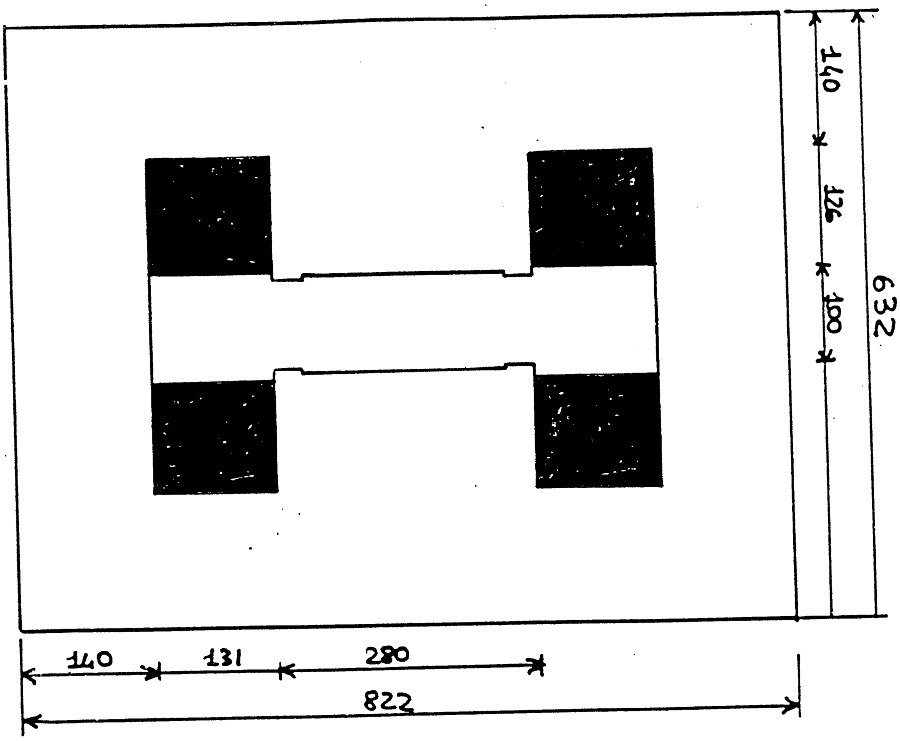
$B_{max} = 1.28$ T, $B_{min} = 0.07$ T } $f = 10$ Hz

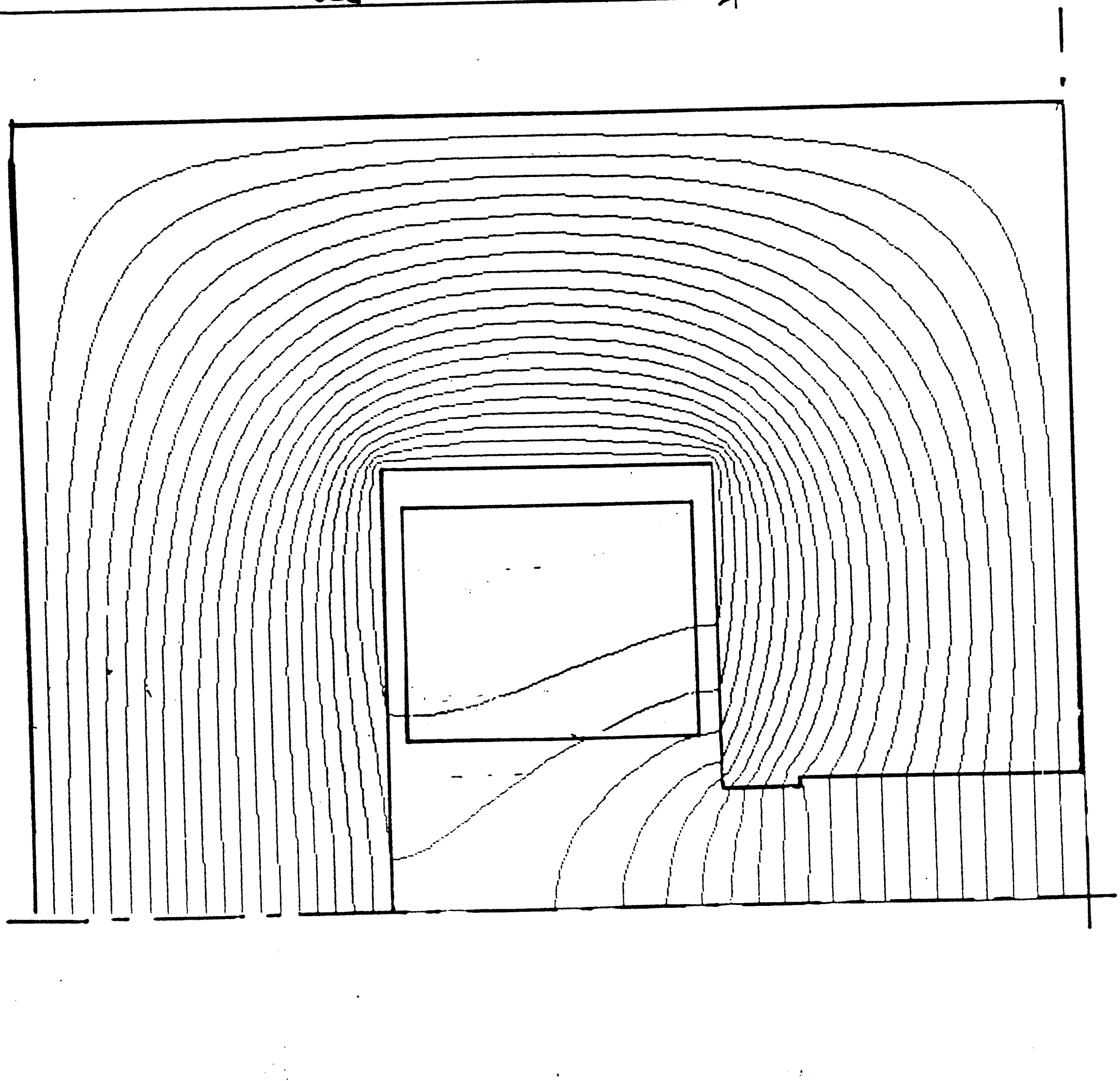
$B_{max} = 0.37$ T, $B_{min} = 0.13$ T } $f = 50$ Hz

	f=10 Hz	f=50 Hz	f=10 Hz	f=50 Hz	
resistance/magnet	2.70		4.05		mΩ
inductance/magnet	3.20		5.06		mH
I_{min}	356	642	286	513	A
I_{max}	6487	1867	5209	1493	A
$\dot{I}_{max}$	192.5		154		kA/s
RI_{max}	17.5	5	21	6	V
$L\dot{I}_{max}$	616		779		V
total voltage $\hat{V}$	633.5	621	800	785	V
$\hat{V} \cdot I_{max}$	4.1	1.2	4.2	1.2	MW
peak stored energy	67.3	5,6	68.6	5,6	kJ
ohmic losses at max current	113.1	9.4	110	9.0	kW
	M = 16		**M = 20**		

pole width = 280 mm

max. induction in the core ≳ 1.6 T


140
126
100
632
140
131
280
822



QUADRUPOLES

	$M_{QF}=4$		$M_{QD}=4$		$M_{QF}=22$		$M_{QD}=21$	
L [mH]	0.32		0.32		9.7		8.8	
R [mΩ]	0.92		0.92		28		254	
I_{max} [A]	4470	1275	4270	1218	813	232	813	232
I_{min} [A]	240	440	229	420	44	80	44	80
$\dot{I}_{max}$ [kA/s]	132		126		24		24	
RI_{max} [V]	4	1.2	3.9	1.1	23	6.5	20.6	5.8
$L\dot{I}_{max}$ [V]	42		40		233		211	
total voltage $\hat{V}$ [V]	46	43	44	41	256	21.0	232	214
$\hat{V} I_{max}$ [kW]	206	55	188	50	[illegible]	56	189	50
ohmic losses at I_{max} [kW]	18.4	1.5	16.8	1.4	15.5	1.5	16.8	1.4
peak stored energy [kJ]	3.2	0.26	2.9	0.24	3.2	0.26	6.5	0.70
	f = 10 Hz	f = 50 Hz	f = 10 Hz	f = 50 Hz	f = 10 Hz	f = 50 Hz	f = 10 Hz	f = 50 Hz

QF:

G_{max} = 9.0 T/m, G_{min} = 0.43 T/m } f = 10 Hz

G_{max} = 2.5[illegible] T/m, G_{min} = 0.[illegible] T/m } f = 50 Hz

QD

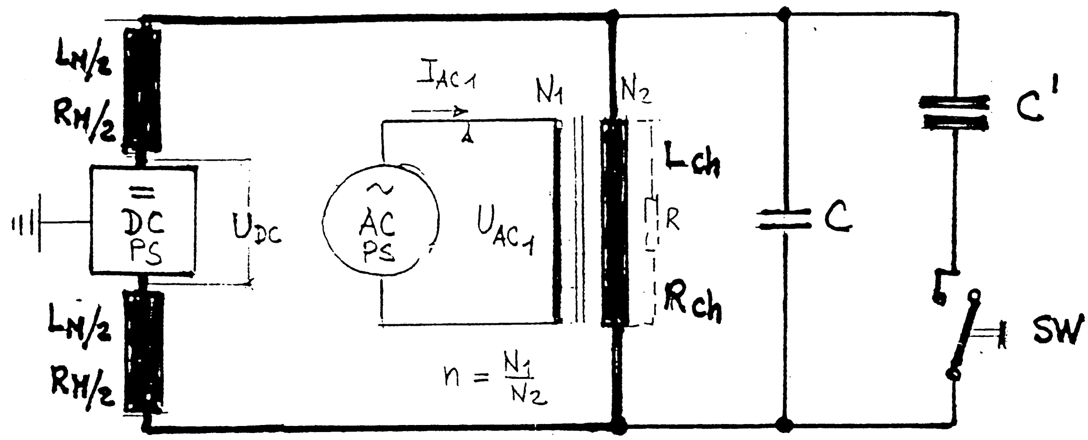
G_{max} = 8.6 T/m, G_{min} = 0.47 T/m } f = 10 Hz

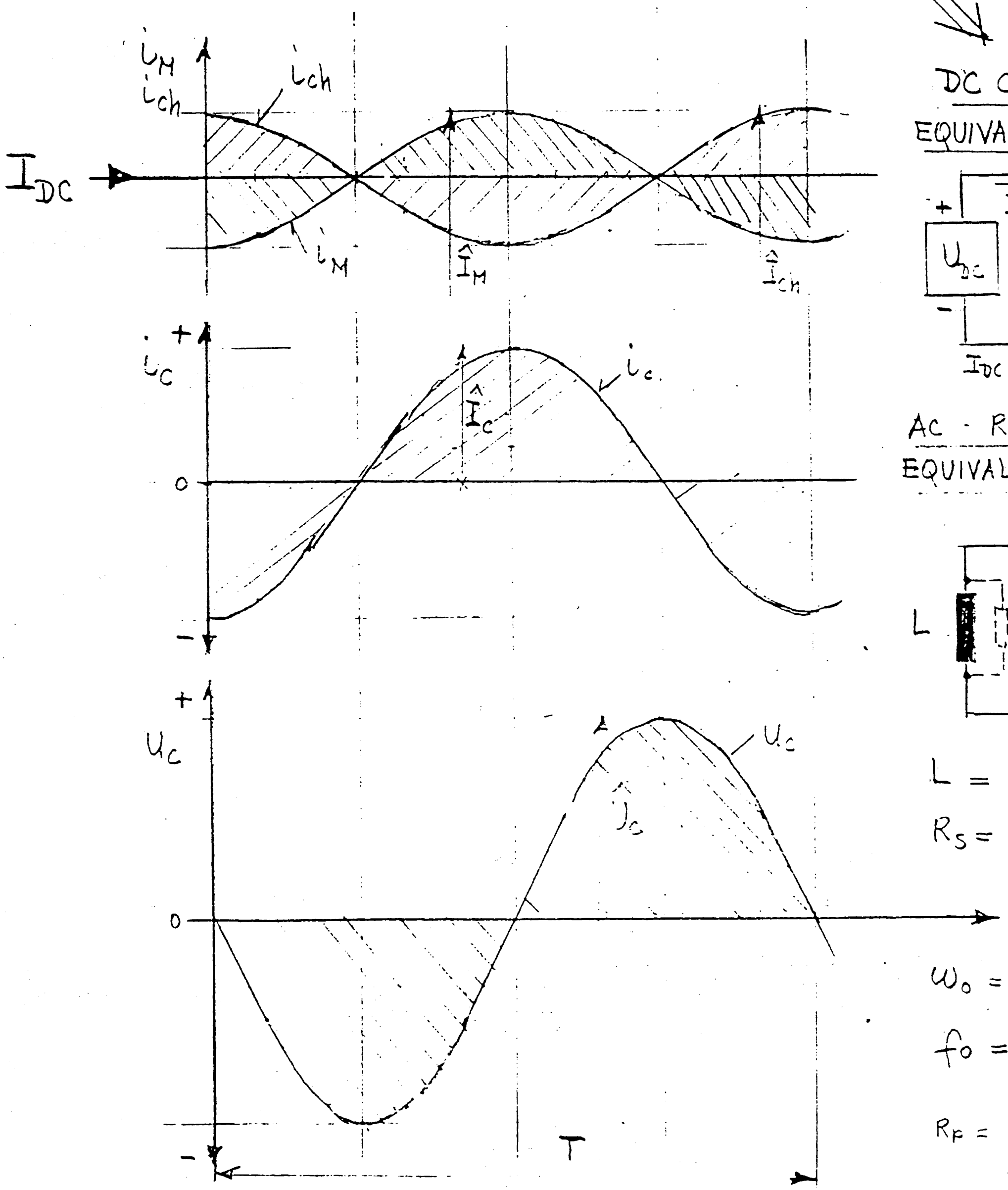
G_{max} = 2.47 T/m, G_{min} = 0.85 T/m } f = 50 Hz

Dipole Magnet Losses L = 3.5 m

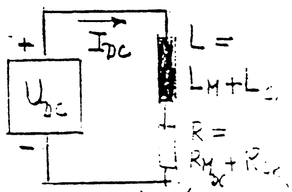
	10	50	Hz
frequency	10	50	Hz
$\hat{I}$	5560	1600	A
I_{DC}	2933	1075	A
$\hat{I}_{AC}$	2628	525	A
R_{DC} (16 turns)	3.07	3.07	mΩ
L (/dipole)	3.73	3.73	mH
$P_{FE} = P_{hyst} + P_{ec}$	900	2200	W
$P_{R\,DC} = R\,I_{DC}^2$	26.4	3.5	kW
$P_{R\,AC} = R\,I_{AC\,rms}^2$	10.6	0.4	kW
$P_{R\,ec}$ = (windings)	0.206	0.206	kW
$P_{R\,ec}$ = (vac. ch)	4.85	4.43	kW
P_{total} (/dipole)	42.85	10.736	kW
P_{total} (36 dipoles)	1.5425	0.3865	MW
P_{total} (DC)	0.9504	0.126	MW
P_{total} (AC)	0.592	0.260	MW
$Z_m = \sqrt{R^2+\omega^2L^2}$	0.23	1.77	Ω
$U_{AC} = Z_m\,\hat{I}/\sqrt{2}$ (rms)	0.436	0.435	kV
U_{AC} (36 dipoles) (rms)	15.7	15.7	kV
$\hat{U}_{AC}$	22.2	22.1	kV
$U_{DC} = R_m\,I_{DC}$ (total)	0.324	0.119	kV

ONE CELL SINGLE RESONANCE CIRCUIT



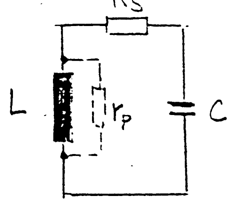


DC CURRENT EQUIVALENT CIRCUIT



$I_{DC} = U_{DC}/R$

AC - RESONANCE EQUIVALENT CIRCUIT



$L = L_M // L_{ch}$

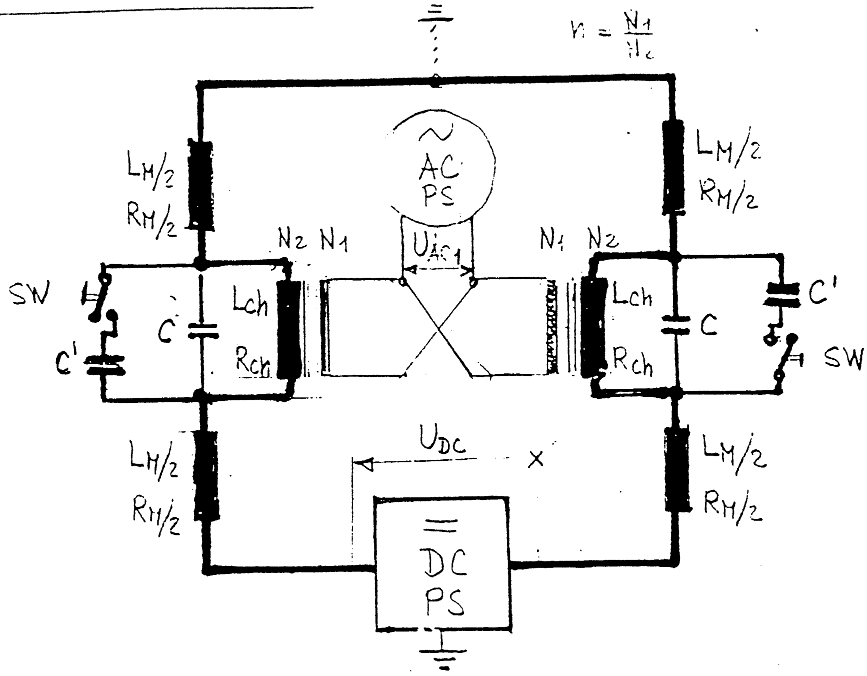
$R_S = R_{M_{AC}} // R_{ch_{AC}}$

$\omega_0 = 1/\sqrt{L.C}$

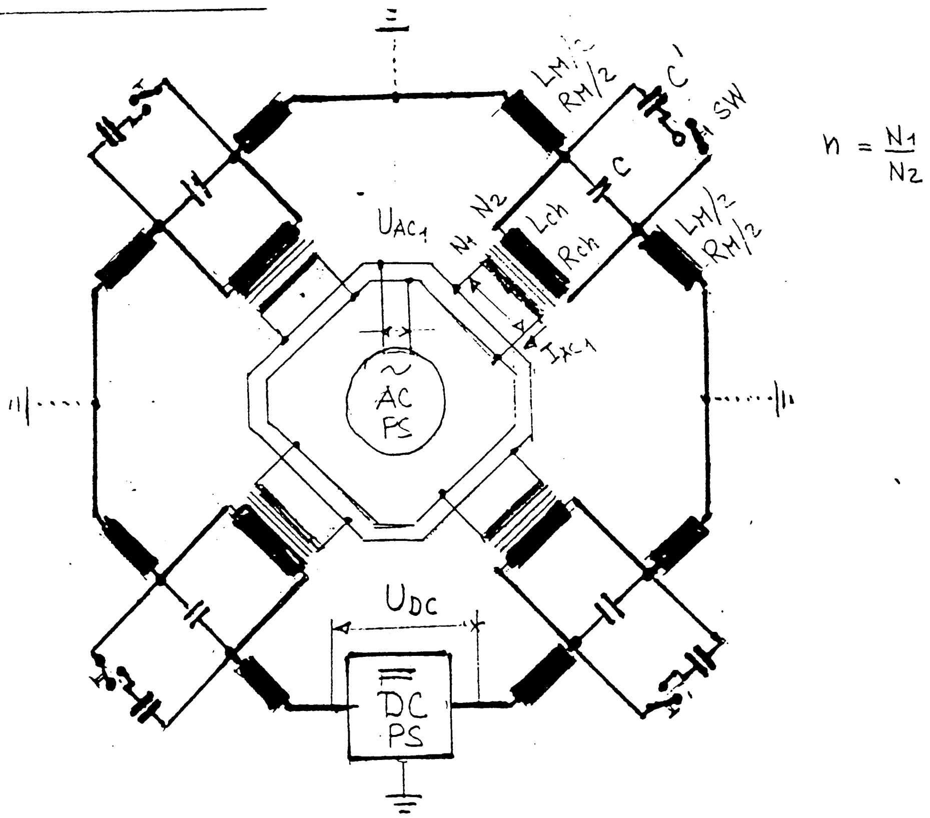
$f_0 = \frac{\omega_0}{2\pi}$

R_P = Resistance corresponding to the Vacum chamber Losses

2 CELL CIRCUIT

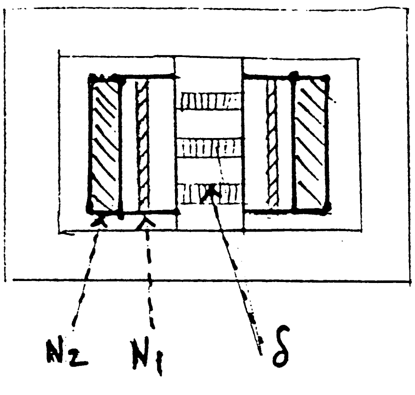


4 CELL CIRCUIT

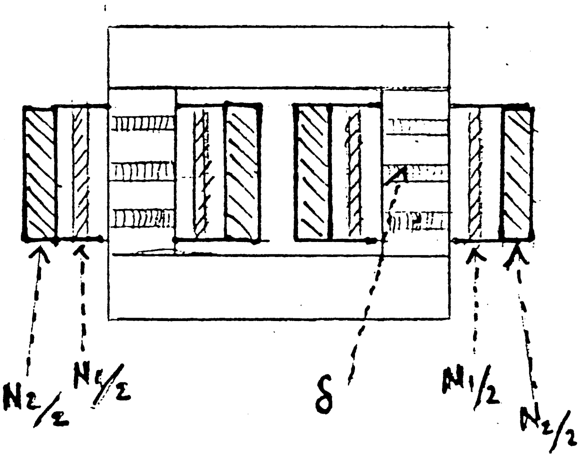


TRANSFORMER CHOKE L_{ch}

SHELL TYPE



CORE TYPE



$$n = \frac{N_1}{N_2} = \frac{1}{4} \text{ to } \frac{1}{6}$$

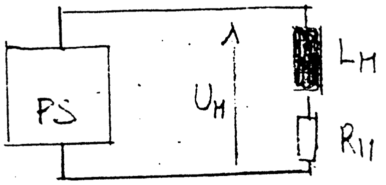
Choke has to pass $[I_{DC} + I_{AC}]$

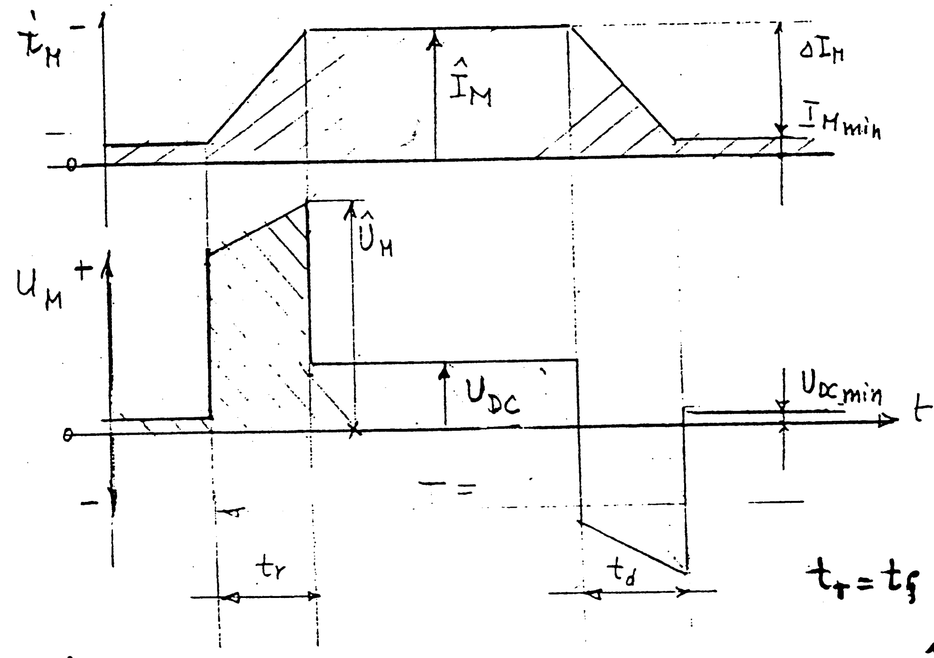
$$L_{ch} (\hat{I}) \geq 0.9 \, L_{ch} (\check{I})$$

A.C. Power Supply (50 Hz / 10 Hz)

1. Alternator (1 or 2 ?)
2. Solid state semiconductor supply.
3. DC PS – charging choke – PFN – Th. switch – res. choke
   (make-up pulse during cycle)

PRE-HOLDING RING POWER SUPPLY (for 36 Dipole Magnets)





$t_r = t_f = 0.2$ s

$\hat{I}_M = 5560$ A $\quad I_{M\,min} = 240$ A $\quad \Delta I = \hat{I}_M - I_{M\,min} = 5320$ A

$$\frac{di}{dt} = \frac{(\hat{I}_M - I_{M\,min})}{t_r} = \frac{\Delta I}{t_r} = \frac{5330}{0.2} = 26600 \text{ A/s}$$

$R_{M(tot)} = 110.5$ mΩ $\qquad \tau_M = \frac{L_M}{R_M} = 1.214$ s

$L_{M(tot)} = 134.2$ mH

$U_{DC} = R_M \cdot I_M = 0.1105 \cdot 5560 = 614$ V

$U_{DC\,min} = R_M \cdot I_{M\,min} = 0.1105 \cdot 240 = 27$ V

$\hat{U}_M = R_M \cdot \hat{I}_M + L\frac{di}{dt} = 614 + 0.1342 \cdot 26600 = 4184$ V

$\hat{P}_M = \hat{I}_M \cdot \hat{U}_M = 5560 * 4184 = \underline{33.261}$ MW

$P_{M_{DC}} = R_M \cdot \hat{I}_M^2 = \underline{3.4159}$ MW

Extend t_r and t_f ?

Is $\hat{I}_M$ required to be $\underline{5560 \text{ A}}$?