NPA/Int. 63-28
Meyrin, 28th October 1963

POWER SUPPLIES AND MONITORING EQUIPMENT FOR PULSED MAGNETS

1. Introduction

The general principle of powering and monitoring the pulsed beam transport magnets was described by D. Neet (NPA/Int. 62-9). The greater part of the information contained therein is still valid. However, at that time no operating experience was available. In the meantime modifications and additions were made, that proved to be reliable during the 8 neutrino runs that have been done up to now. These modifications will be described here in detail and a complete and up to date set of circuit diagrams is added. Only these drawings should be used by future users for reference.

The whole setup performed extremely satisfactorily during the neutrino runs. The position of the external beam on target needed readjustment only every few hours. This could easily be made by adjusting the current in the last bending magnet. Over a period of 5 days the current in one of the bending magnets was monitored, giving a difference between highest and lowest recorded value of 2 o/oo. The pulse to pulse accuracy was ± 0.5 o/oo.

2. Power supplies

The operating principle is that of a feedback control system, in which the difference between a reference input and some function of the controlled variable is used to supply an actuating error signal to the control elements and the controlled system. The amplified error signal is applied in a manner tending to reduce this difference to zero.

The way in which the error signal depends upon the controlled variable determines the behaviour of the system under steady state conditions. The solution of the differential equations of the control system gives the transfer function and its frequency response.

Assuming a sinusoidal input signal, the Laplace transform of the transfer function can then be written as :

$$F = \frac{X_{out}}{X_{in}} = \frac{b_o + b_1 p + b_2 p^2 + \ldots..}{a_o + a_1 p + a_2 p^2 + \ldots..}$$ where p is the Laplace operator

The general types of control systems can easily be deduced from this equation

P - element : The output signal is proportional to the input signal

$$F = K = \frac{b_o}{a_o} \quad \text{(all other terms are zero)}$$

I - element The output signal equals the integral with respect to time of the input signal

$$F = \frac{K_I}{p}, \text{ where } K_I = \frac{b_o}{a_1} \quad \text{(all other terms are zero)}$$

D - element The output signal equals the derivative with respect to time of the input signal

$$F = K_D \cdot p, \text{ where } K_D = \frac{b_1}{a_o} \quad \text{(all other terms are zero)}$$

A combination PD would be

$$F = K + K_D \cdot p = K\,(1 + T_D \cdot p), \text{ where } T_D = \frac{K_D}{K}$$ is the differentiation time constant

These are only ideal cases, in reality time constants appear that give rise to delays. They present themselves e.g. in the case of a P - element as

$$F = \frac{K}{1 + T_1 \cdot p},$$ in which T_1, ... is the time constant for which the inverse transform is e^{-t/T_1}

A PD element as used in our case, then becomes

$$F = K \frac{1 + T_D \cdot p}{1 + T_1 \cdot p}$$

In the Giesenhagen supplies operation is now as follows (see PM 03). A voltage proportional to the instantaneous voltage on the capacitor bank is supplied to one of the inputs of the DC amplifier. In series with this voltage is connected part of the voltage drop in a resistor in the main charging current path, which voltage is therefore proportional to $C \frac{dV}{dt}$. A small portion of this voltage is again differentiated by C 1. A closer analysis of this circuit will show that the total input voltage can be written as

$$V_X = \frac{b_o + b_1 p + b_2 p^2}{a_o + a_1 p} V_{cap} = \frac{K + T_{D1} \cdot p + T_{D2} \cdot p^2}{1 + T_1 p} \cdot V_{cap}$$

where K is the ratio of the voltage divider across the output terminals of the power supply and T are time constants created by R_1, R_2, C_1, R and C. The other input of the amplifier is connected to a reference voltage.

As long as $/ V_X + V_{ref} / > 0$ the D.C. amplifier will show an output voltage that through the power amplifier opens the transductors that control the charging current.

Due to the arrangement of the differentiation of the input signal to the amplifier, the time constants that would otherwise delay this signal with respect to the instantaneous capacitor voltage are now properly counterbalanced, resulting in a system that is completely stable under all load conditions.

The potentiometer that controls the amount of differentiation and therefore the stability should of course be set according to the particular conditions of load and charging current. Diagrams are provided for this (PM 04). It is quite sensitive when a small load and low charging current are used, therefore the charging current should be closely observed in this case, to be certain that no oscillations or small secondary charging peaks occur.

As a rule the current should go down smoothly in about 100 msec at the end of the charging cycle. The shunt signal is available at the terminals on the door.

A second set of diagrams gives the transformer taps to be used for a certain range of output voltage. The bias current of the transductor should be changed simultaneously. To this end a connecting strip inside the supply provides terminals, marked X, X_4, X_3, X_2, X_1, which should be shorted by tags from X up to the number corresponding to the transformer tapping used.

Although relatively complicated, this principle ensures that the transductor always has the same operating point, thereby providing equal characteristics, for any output voltage.

In practice the output voltage is fixed for a certain application of the power supply, so that transformer tap and bias current are set once and for all.

All diagrams with "number of capacitors" as variable refer of course to the capacitance value with which they were measured i.e. 278 µF each. Whenever other capacitors are used they should of course be redrawn.

3. Interlocks

As it became evident that not firing or prefiring of the ignitrons did not result in overloading, but that on the other hand too frequent interruptions of the charging cycle led only to timelosses, the interlock was modified so that any ignitron failure did not switch off the power supply but only lights up an indication lamp.

4. Timing

In the former setup both kicker magnet and magnetic horn were triggered through delays of 10 msec from the T_0 pulse. As these delays had an accuracy of about 1 o/oo, the jitter of the horn pulse with respect to the kicker magnet could amount to 20 µsec on a pulse length of 200 µsec. As this was unacceptable both pulses are now taken from the same point with only an additional 100 µsec delay for the bending magnet.

A simulator was added for testing and running in the absence of P.S. machine pulses.

5. Monitoring

A monitoring panel (PM 18) allows display on one oscilloscope of :

a) Kicker magnet pulse and current in each beam transport magnet

b) Kicker magnet pulse and current in magnetic horn

c) Signal induced in the beam current transformer and signal from photo-detector after the horn.
Comparison of these two signals gives a direct check on the efficiency of the horn and the position of the beam on the target.

6. Current measuring circuit

The relay that provides the switching action (PM 16) is powered from a higher voltage to minimize the intrinsic delay.

At the input the selector switches both inner conductor and screen of the incoming cable. This prevents closed loops and multiple earthing that give rise to parasites on the current waveform.

7. Acknowledgements

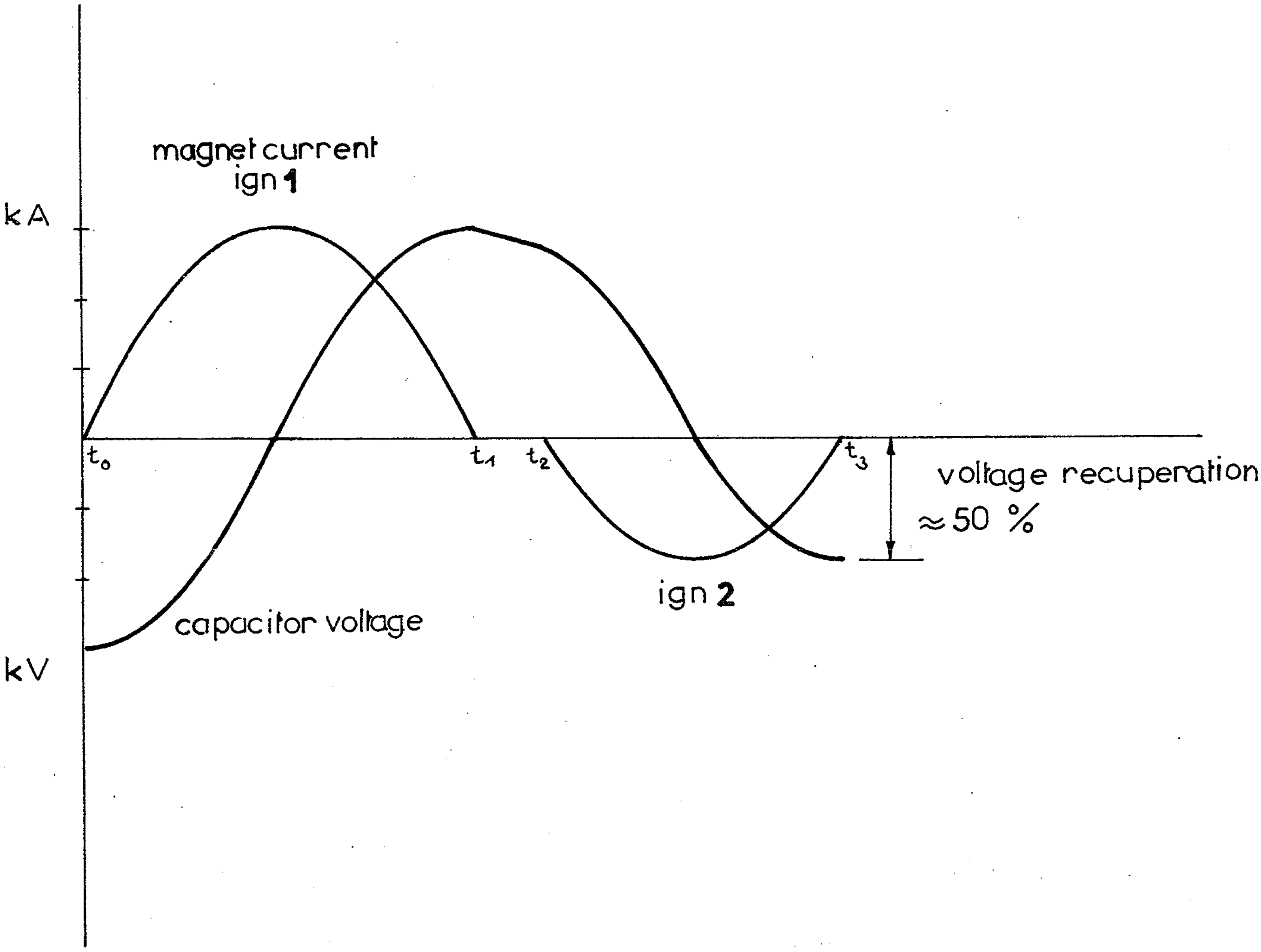
R.A. Brown and J.P. Zanasco took care of all the tests and modifications that were found to be necessary.

G. Pluym

/fv

Distribution : (open)
Scientific staff of N.P.A.

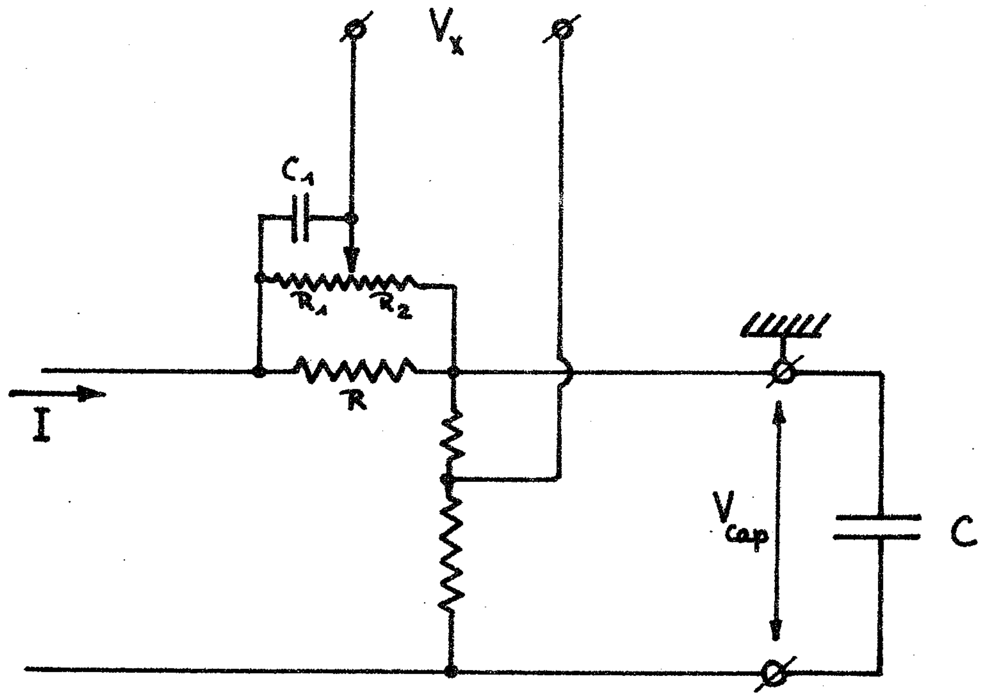
PS/4096



WAVEFORMS

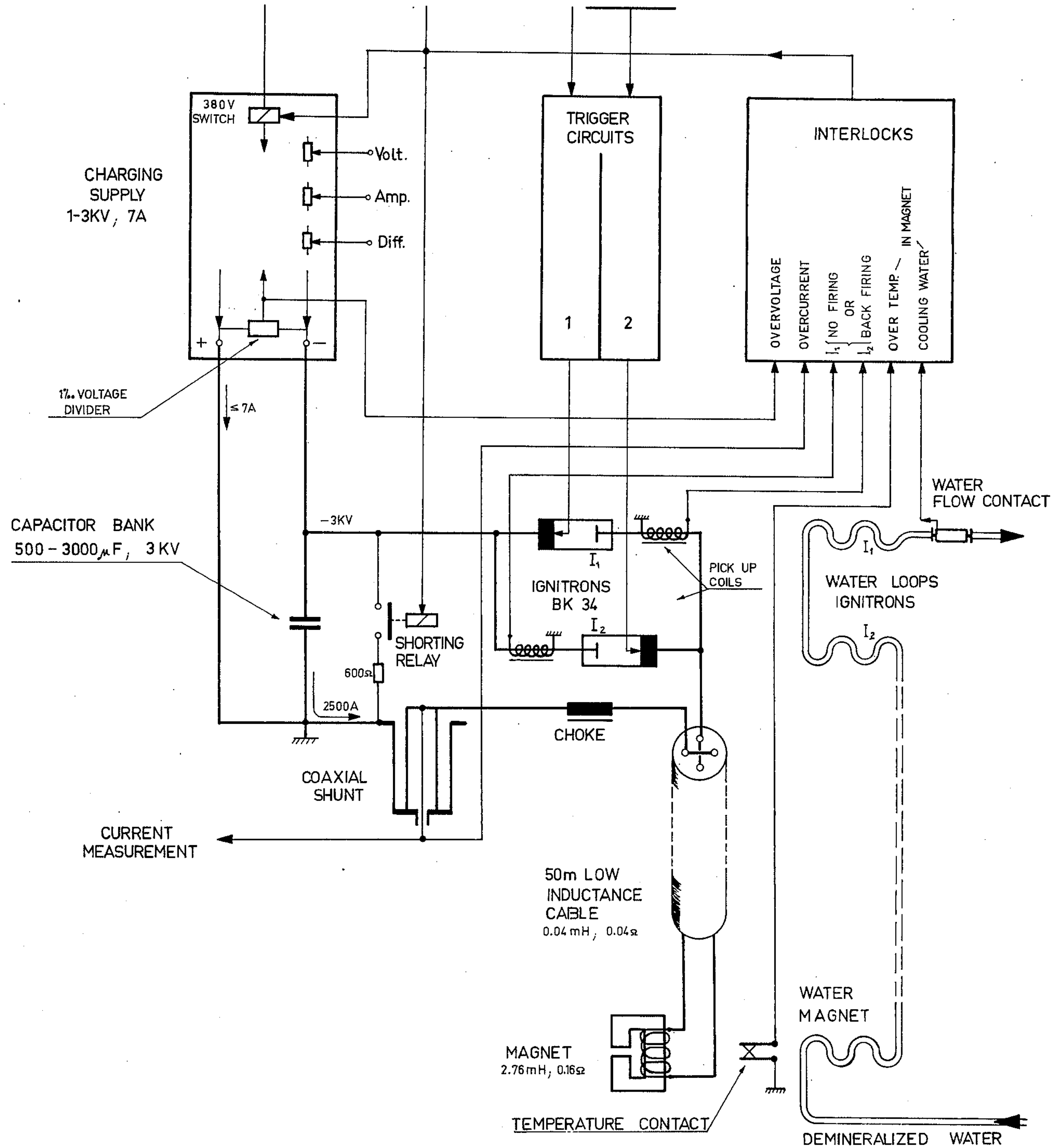
4-10-63
G.P.

SIS/R/7110



DIFFERENTIATION NETWORK

PS/4096.


CHARGING
SUPPLY
1-3KV, 7A
380V
SWITCH
Volt.
Amp.
Diff.
1‰ VOLTAGE
DIVIDER
≤ 7A
TRIGGER
CIRCUITS
1
2
INTERLOCKS
OVERVOLTAGE
OVERCURRENT
I1 NO FIRING
OR
I2 BACK FIRING
OVER TEMP.
IN MAGNET
COOLING WATER
CAPACITOR BANK
500 - 3000μF, 3 KV
-3KV
SHORTING
RELAY
600Ω
2500A
COAXIAL
SHUNT
CURRENT
MEASUREMENT
I1
IGNITRONS
BK 34
I2
PICK UP
COILS
CHOKE
50m LOW
INDUCTANCE
CABLE
0.04 mH, 0.04Ω
MAGNET
2.76 mH, 0.16Ω
TEMPERATURE CONTACT
WATER
FLOW CONTACT
WATER LOOPS
IGNITRONS
WATER
MAGNET
DEMINERALIZED WATER

CERN - NPA GENÈVE	ENGINEERING NOTES - NOTES TECHNIQUES	N° P.M. 02	PAGE
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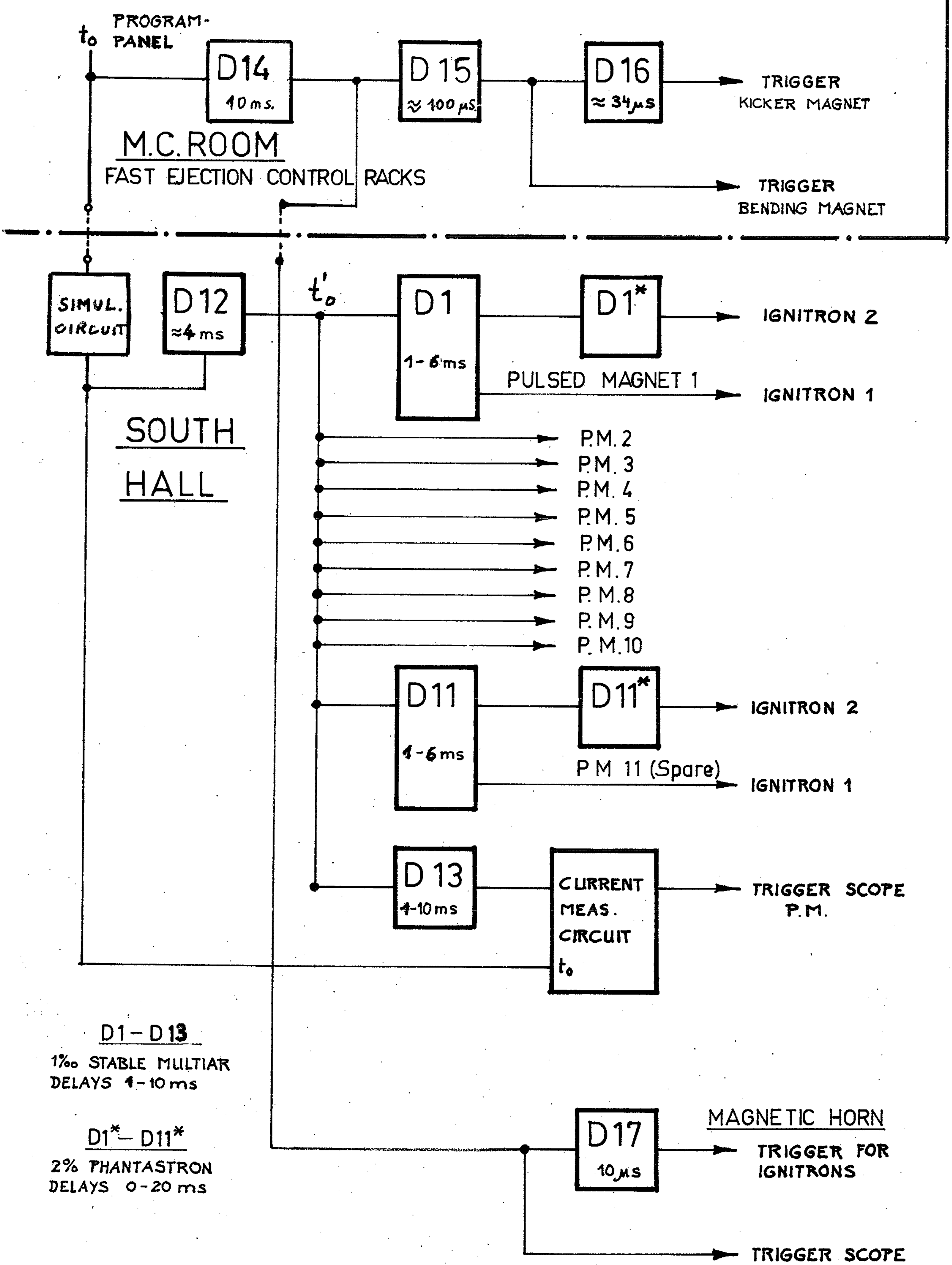
		DATE	3/10/63
		REMPL. DATE	



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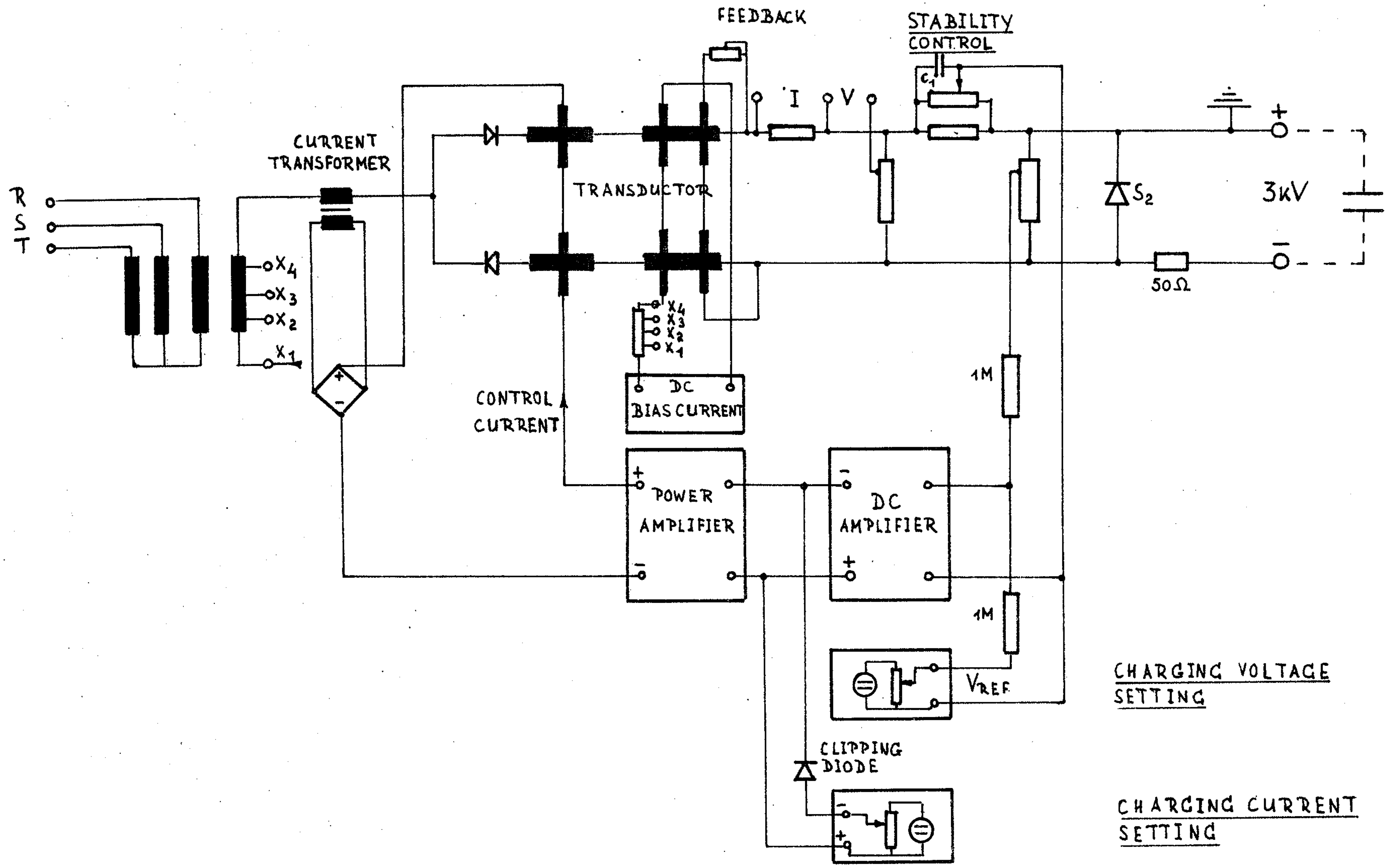
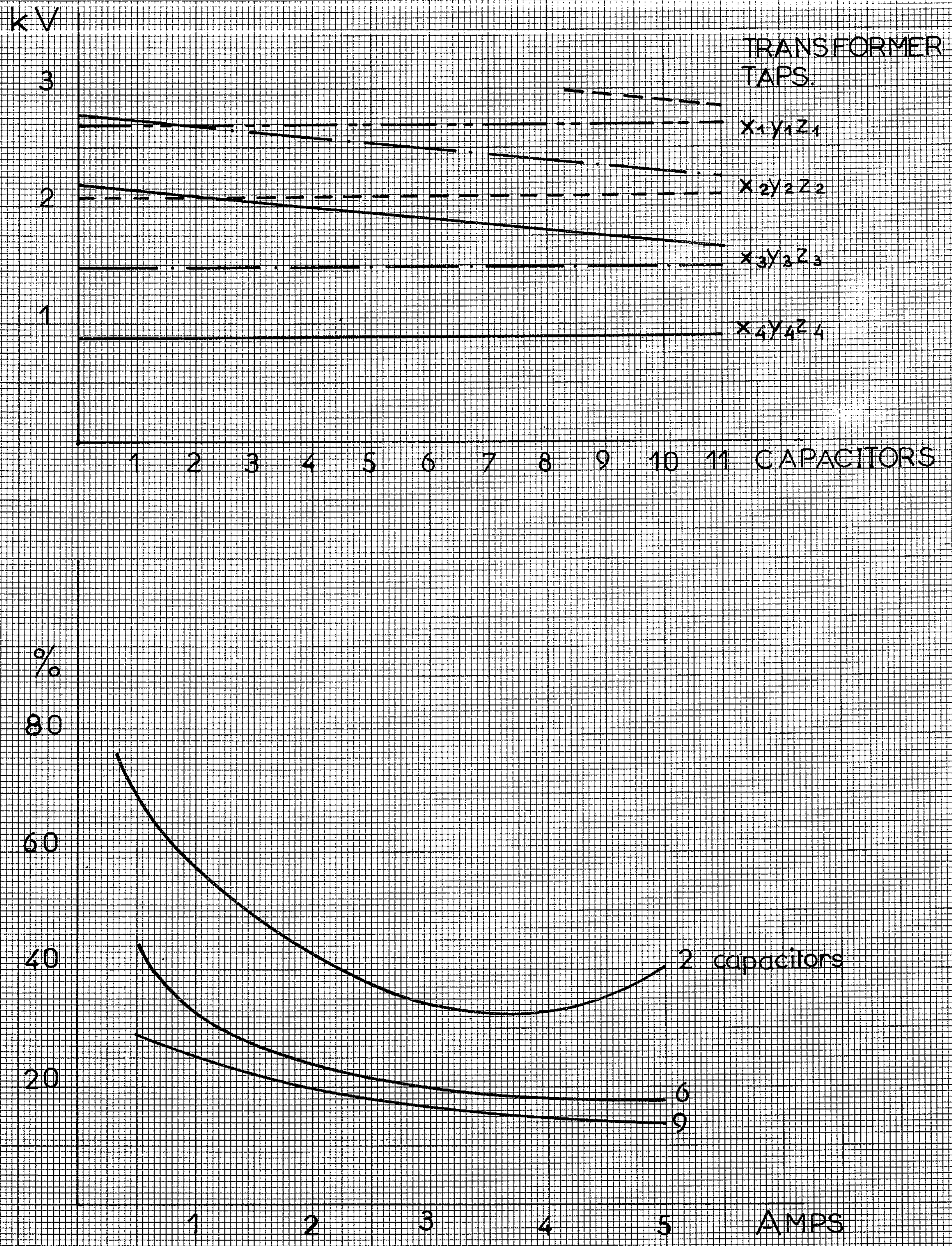


PM 03

3-10-63 G.P.

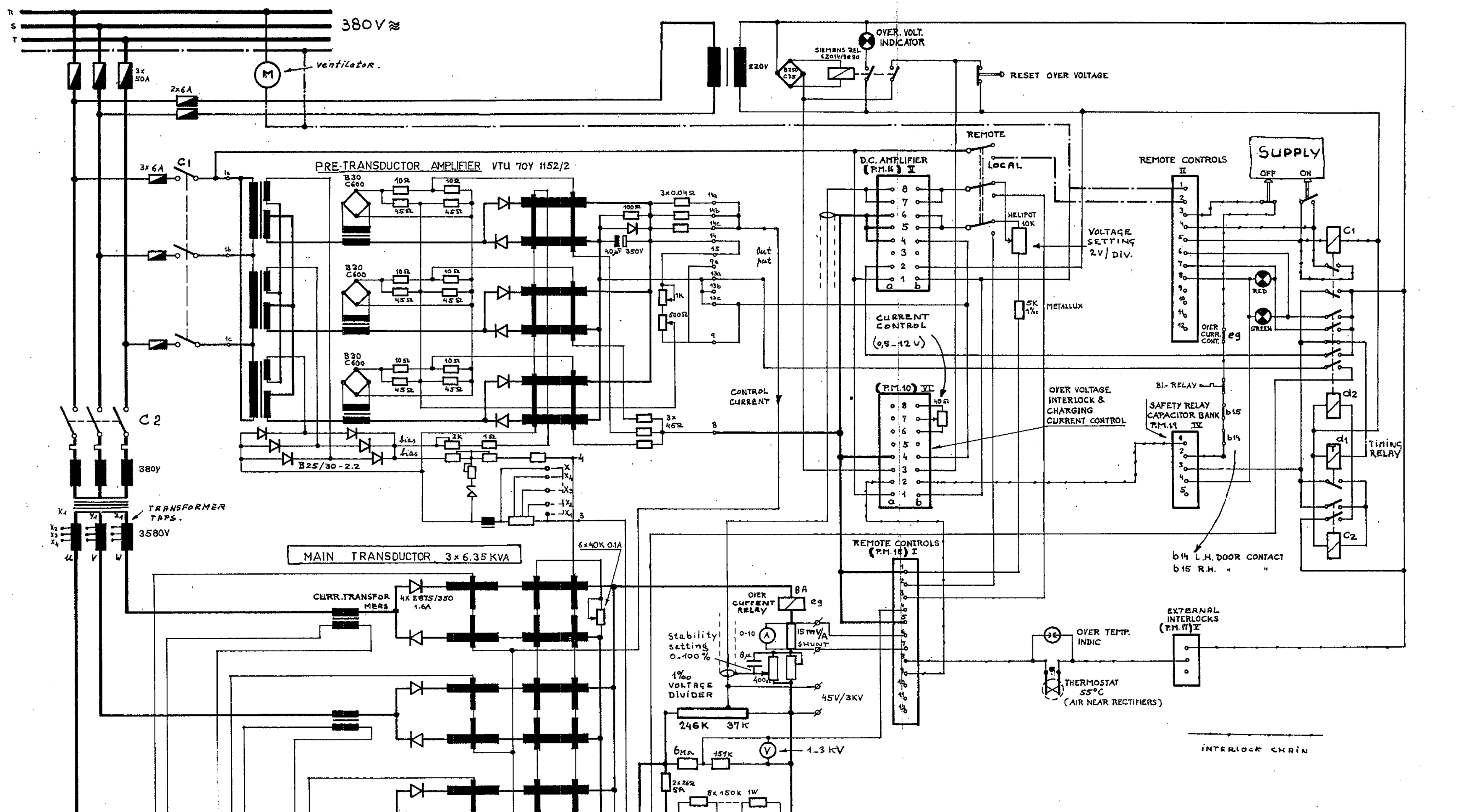
SIS/R/7105



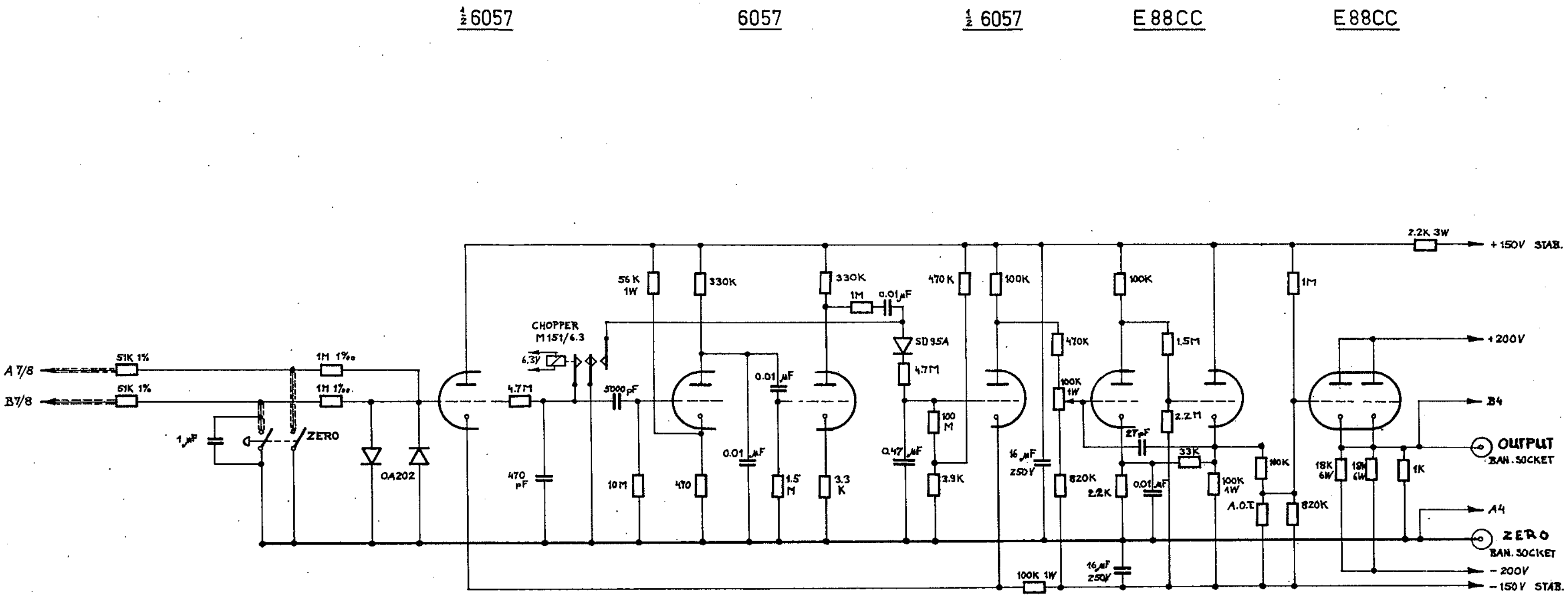
PM 04.

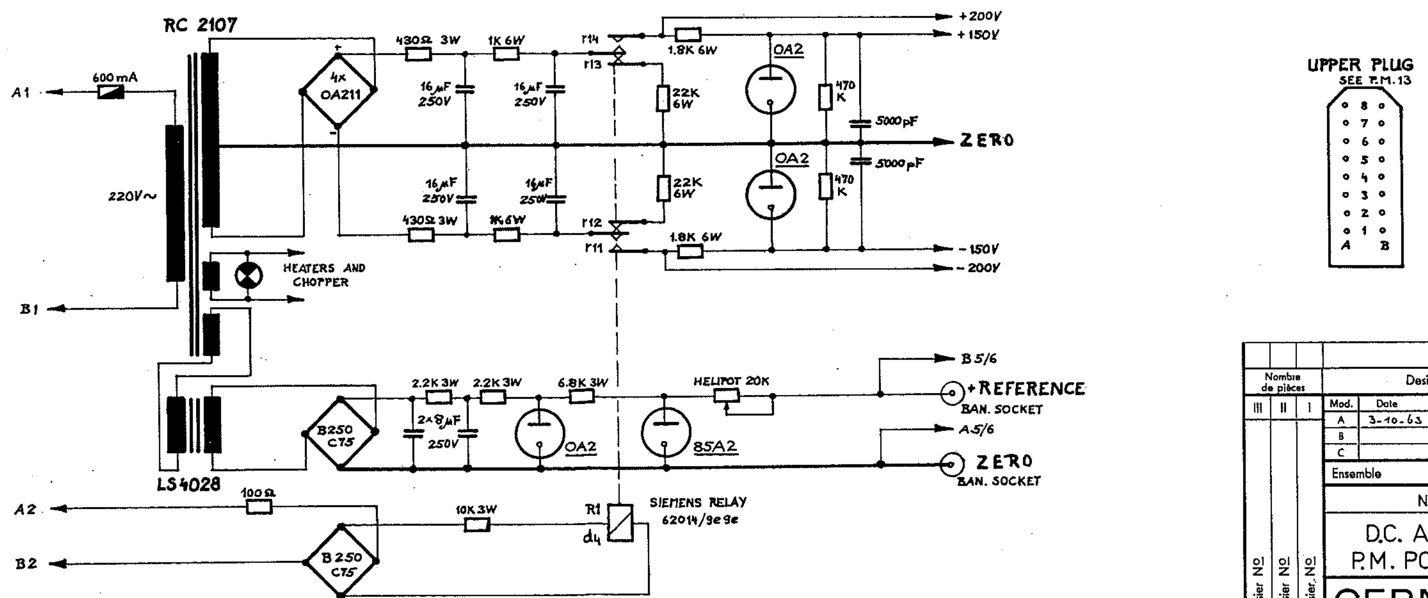
4-10-63
G.P.

SIS/R/7108



Nombre de pièces			Designation			Pos.	Matière	Poids	Observations
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A	2.10.63	PLuyM	de	±		Rugosité en μ" VSM
			B			de	±		Abréviations VSM 10319
			C			de	±		Dessiné 8.62
			Ensemble			S. Ensemble			Contrôlé
Dossier No	Dossier No	Dossier No	NEUTRINO BEAM					Echelle	Vu
			CHARGING SUPPLIES "GIESENHAGEN"						Remplace / Remplacé par / Réduction
			CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						P.M. 05

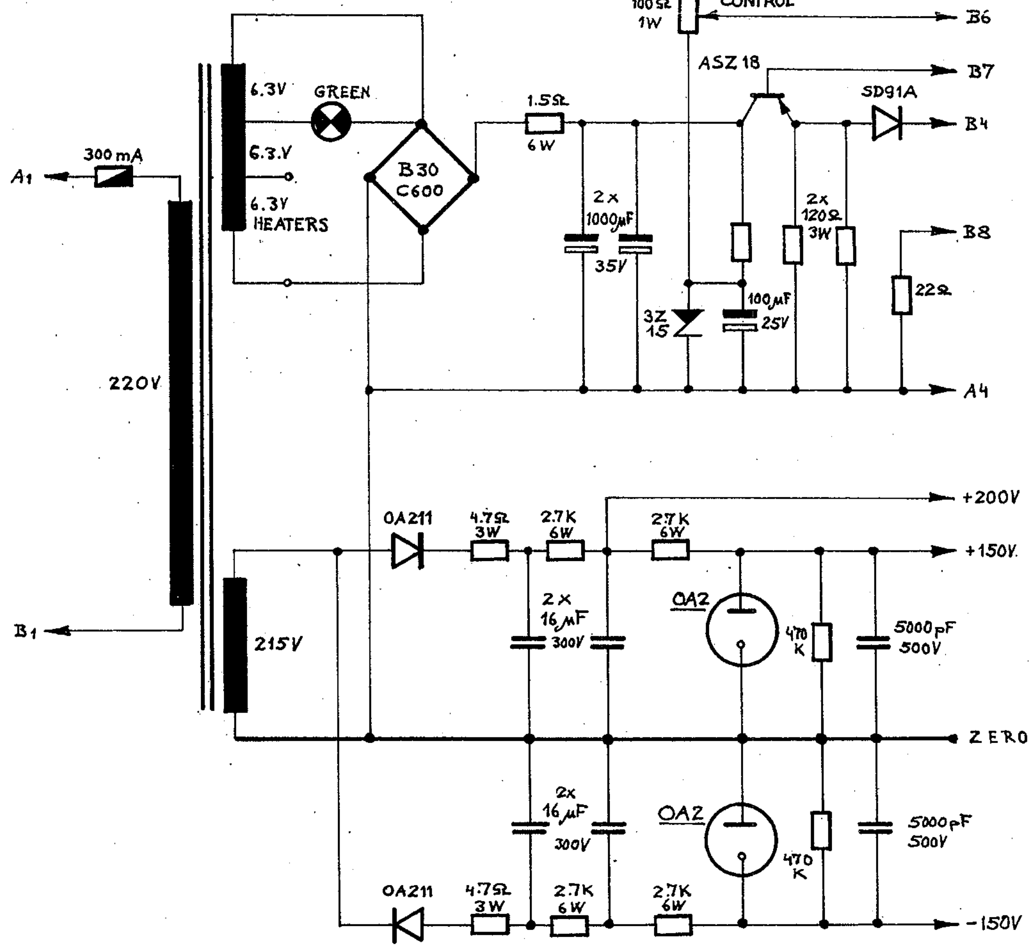




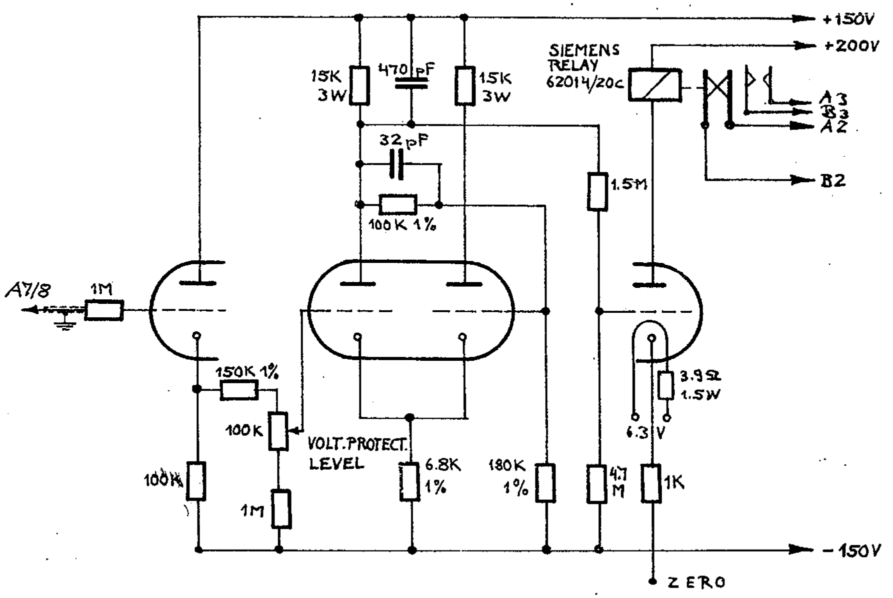
Nombre de pièces			Designation			Pos.	Matière	Poids	Observations	
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320	
			A	3-10-63	PLUYM	de	à	±	Rugosité en µ'	VSM
			B			de	à	±	Abréviations	VSM 10319
			C			de	à	±		
			Ensemble			S. Ensemble			Dessiné	7.8.62 S. [illegible]
			NEUTRINO BEAM					Echelle	Contrôlé	
			D.C. AMPLIFIER FOR P.M. POWER SUPPLY TYPE 3						Vu	
									Remplace	
									Remplacé par	
									Réduction	
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						P.M.06	

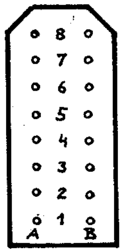
SIS/R/7120

SUB CHASSIS I
POWER SUPPLIES



SUB CHASSIS II
OVER VOLTAGE INTERLOCK

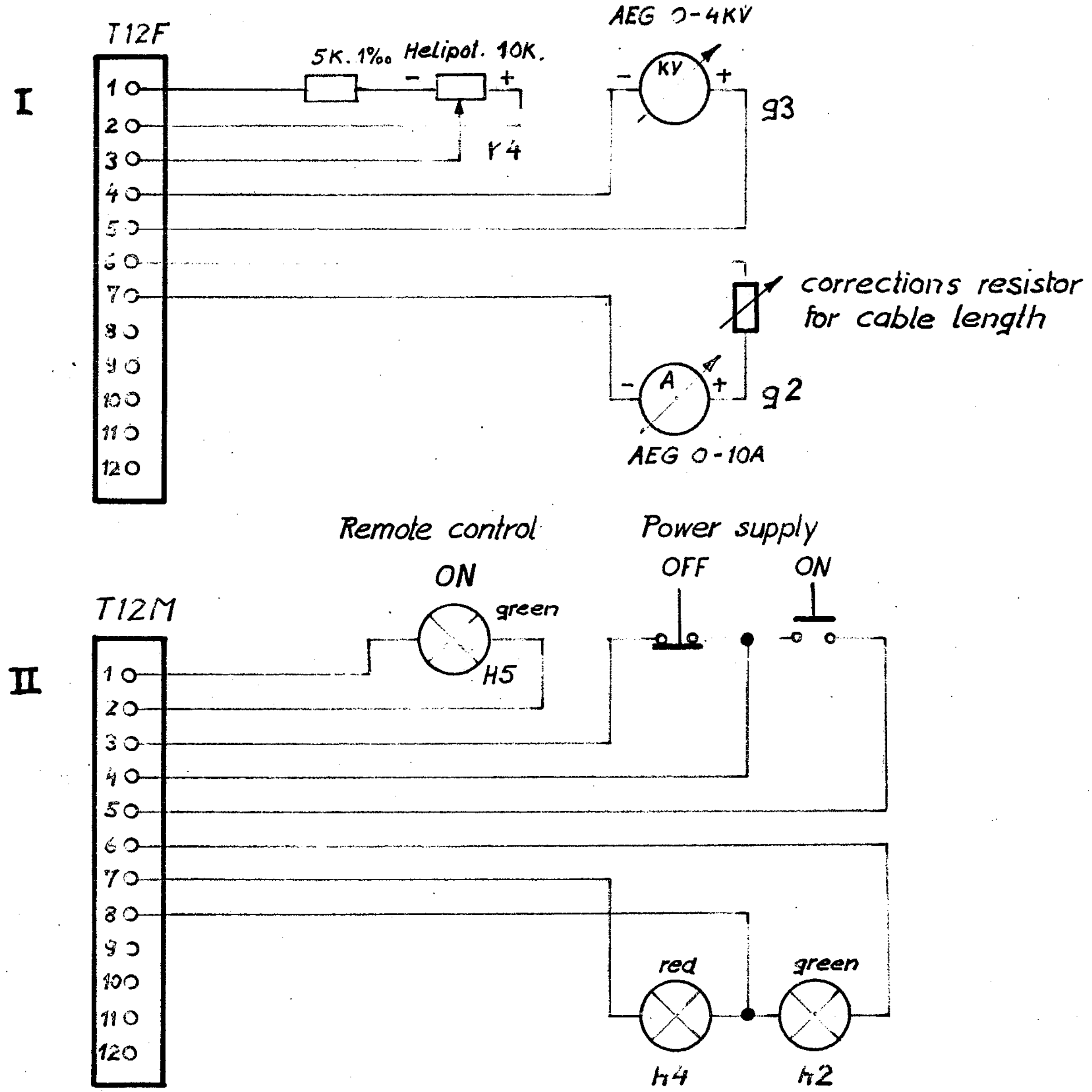




LOWER PLUG
FROM REAR
SEE P.M. 13

Nombre de pièces			Designation	Pos.	Matière	Poids	TO WORK IN CONJUNCTION WITH P.M.15
III	II	I	Mod. / Date / Nom	Tolérances générales			Observations
			A / 4-10-63 / PLUYM	de à ±			Etat des surfaces selon VSM 10320
			B	de à ±			Rugosité en μ'' VSM
			C	de à ±			Abréviations VSM 10319
			Ensemble	S. Ensemble			Dessiné 9.8.62 S. Zeller
			NEUTRINO BEAM	Echelle			Controlé
			OVER VOLTAGE INTERLOCK & CHARGING CURRENT CONTROL				Vu
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE				Remplace / Remplacé par / Réduction
							P.M. 07

SIS/R/7117



Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I					

Mod.	Date	Nom	Tolérances générales		
A	4-10-63	PLUYM	de	à	±
B			de	à	±
C			de	à	±

Etat des surfaces selon VSM 10320
Rugosité en μ VSM
Abréviations VSM 10319

Ensemble
S. Ensemble

Dessiné	29-6-62.	G.I.
Controlé		
Vu		

NEUTRINO BEAM

REMOTE CONTROL UNIT FOR P.M. POWER SUPPLY

Echelle

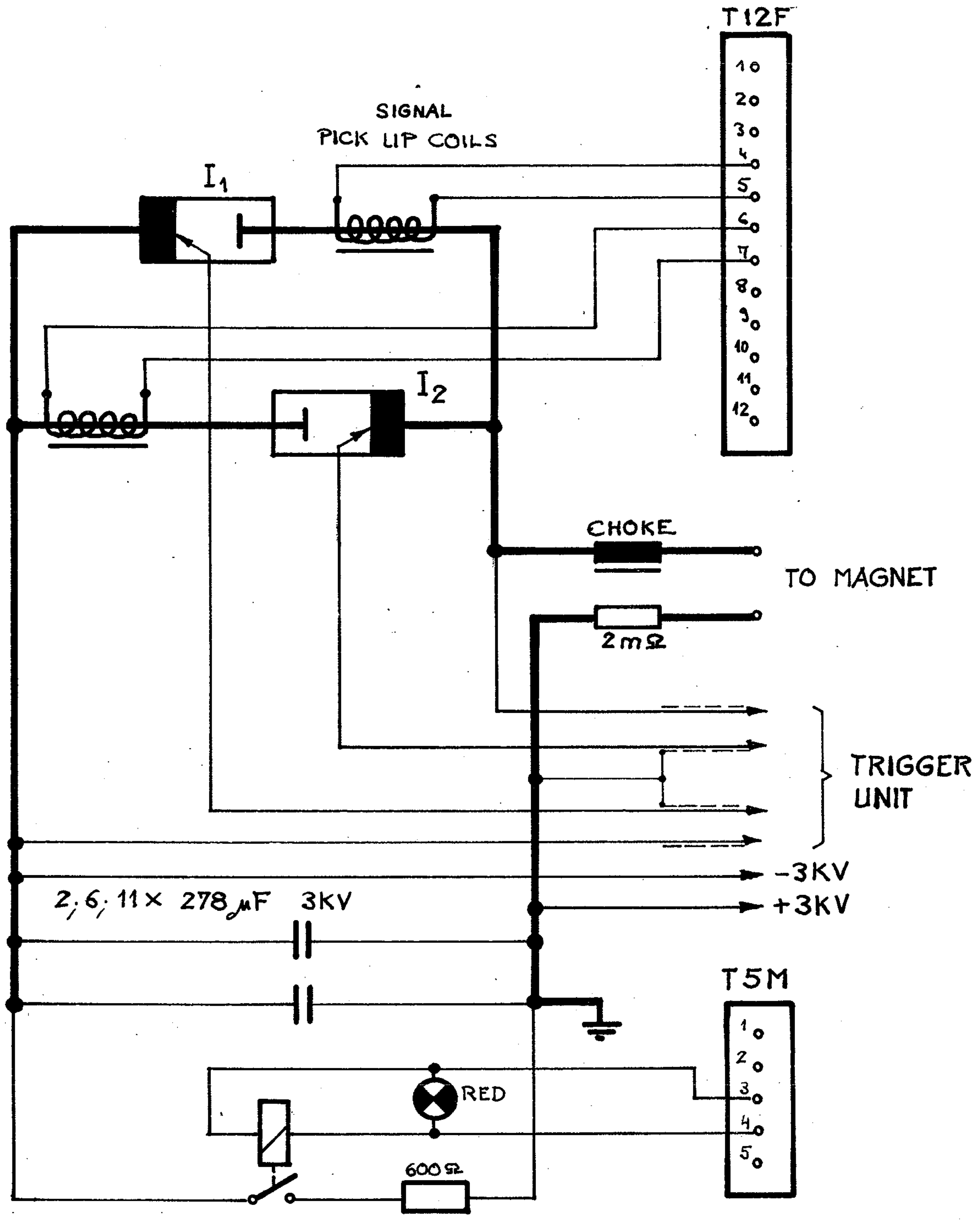
Remplace
Remplacé par
Réduction

Dossier No
Dossier No
Dossier No

CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE

P.M.08

IS/R/7109



Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I					

Mod.	Date	Nom	Tolérances générales		
A	4-10-63	PLUY M	de	à	±
B			de	à	±
C			de	à	±

Etat des surfaces selon VSM 10320
Rugosité en μ VSM
Abréviations VSM 10319

Ensemble | S. Ensemble

Dessiné	27.8.62	S. [signature]
Controlé		
Vu		

NEUTRINO BEAM

CONNECTIONS TO CAPACITOR BANK

Echelle

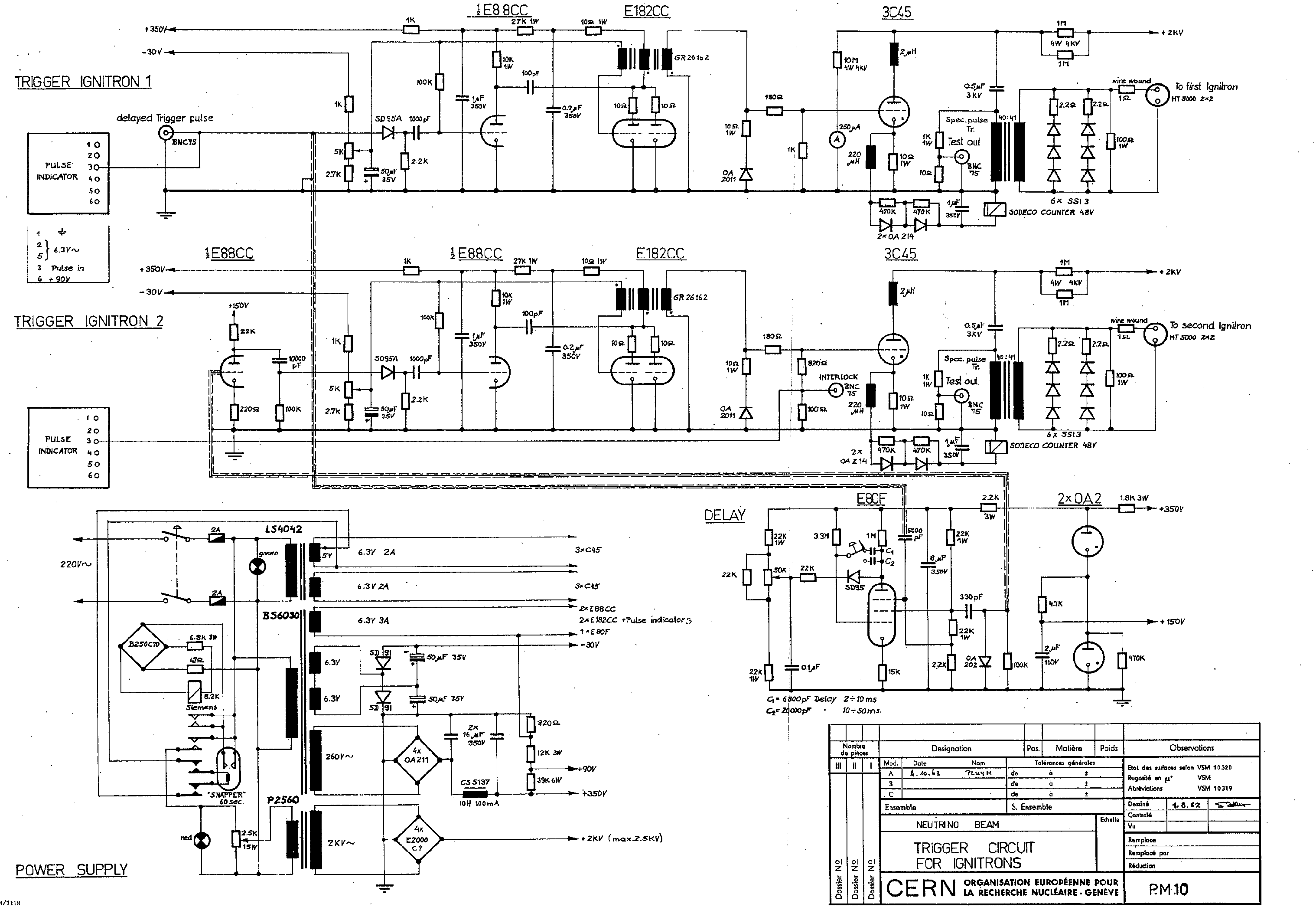
Remplace
Remplacé par
Réduction

Dossier No Dossier No Dossier No

SIS/R/7106

CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE

P.M.09



Nombre de pièces	Designation	Pos.	Matière	Poids	Observations
Mod. A — Date 4.10.63 — Nom 7LU4M	Tolérances générales				Etat des surfaces selon VSM 10320; Rugosité en μ VSM; Abréviations VSM 10319
Ensemble	S. Ensemble				Dessiné 1.8.62

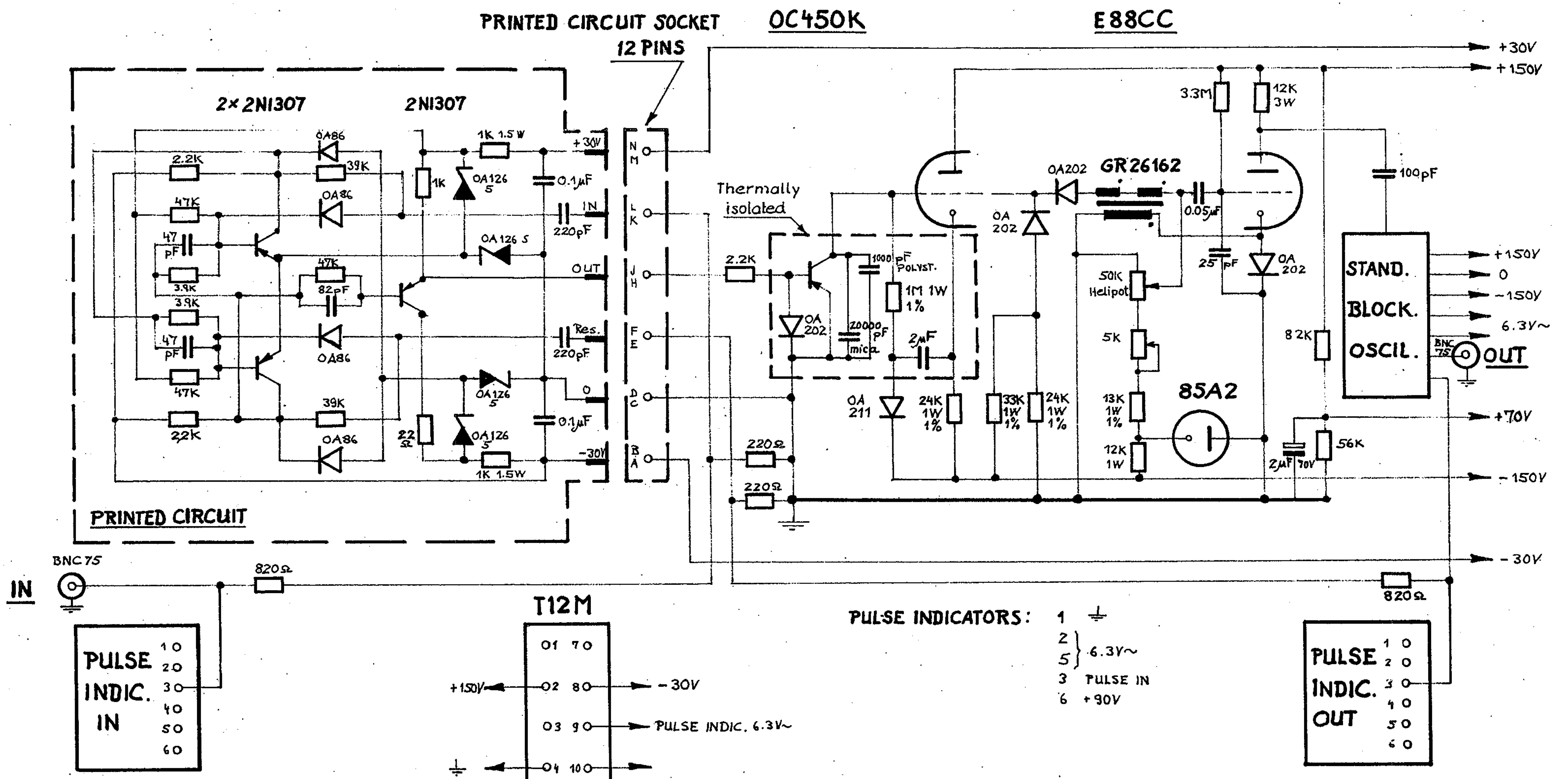
NEUTRINO BEAM

TRIGGER CIRCUIT FOR IGNITRONS

CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE

P.M.10

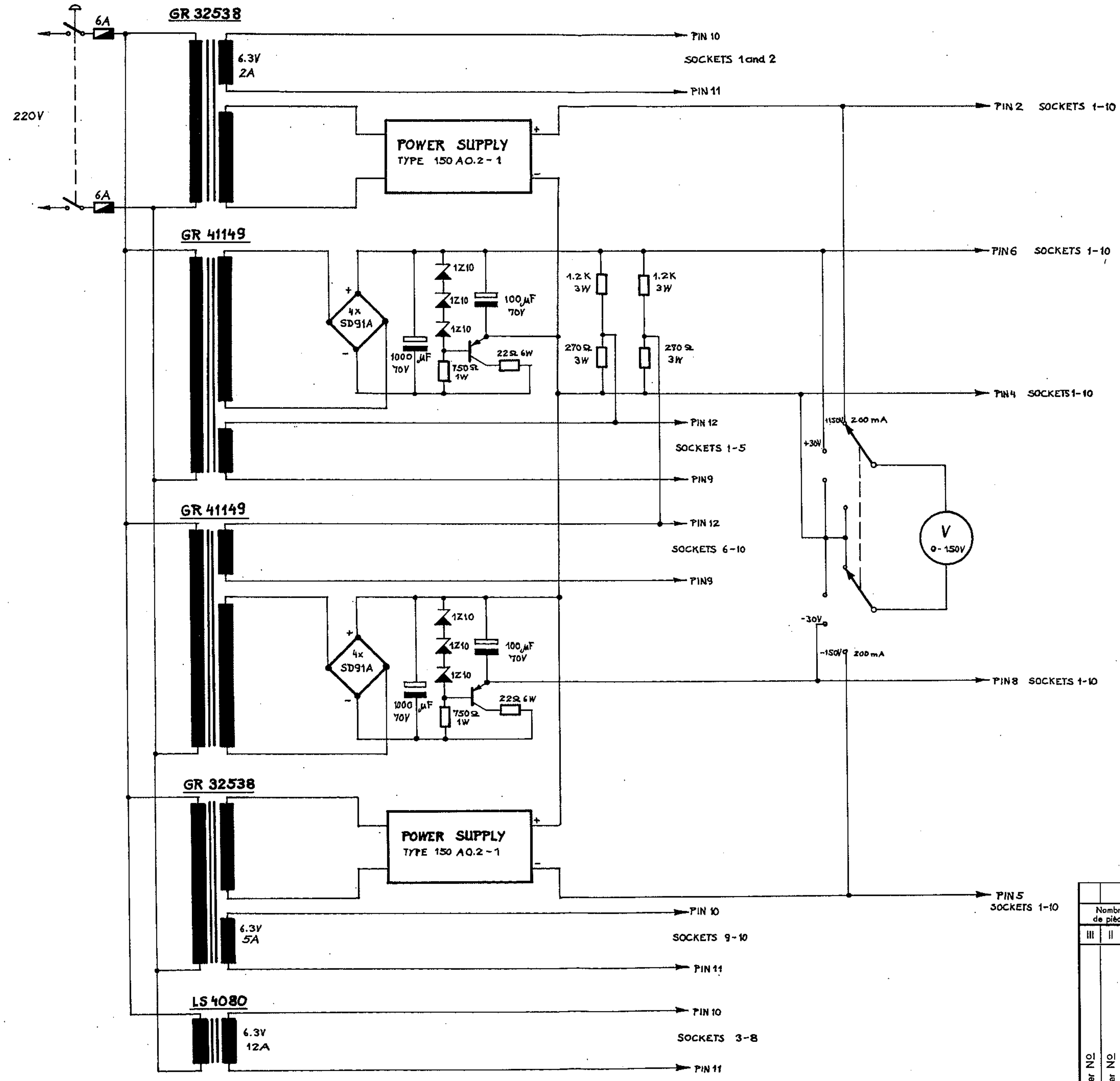
SIS/R/7118



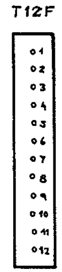
2"VARIABLE DELAY" CIRCUITS IN ONE "3UNITS" STANDARD RACK

Nombre de pièces			Designation			Pos.	Matière	Poids	Observations	
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon	VSM 10320
			A	4-10-63	PLUYM	de	à	±	Rugosité en μ	VSM
			B			de	à	±	Abréviations	VSM 10319
			C			de	à	±	Dessiné	2.8.62 S. [illegible]
			Ensemble			S. Ensemble			Controlé	
			NEUTRINO BEAM				Echelle		Vu	
Dossier No	Dossier No	Dossier No	VARIABLE DELAY 1 ÷ 10 ms						Remplace	
									Remplacé par	
									Réduction	
			CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						PM11	

SIS/R/7116

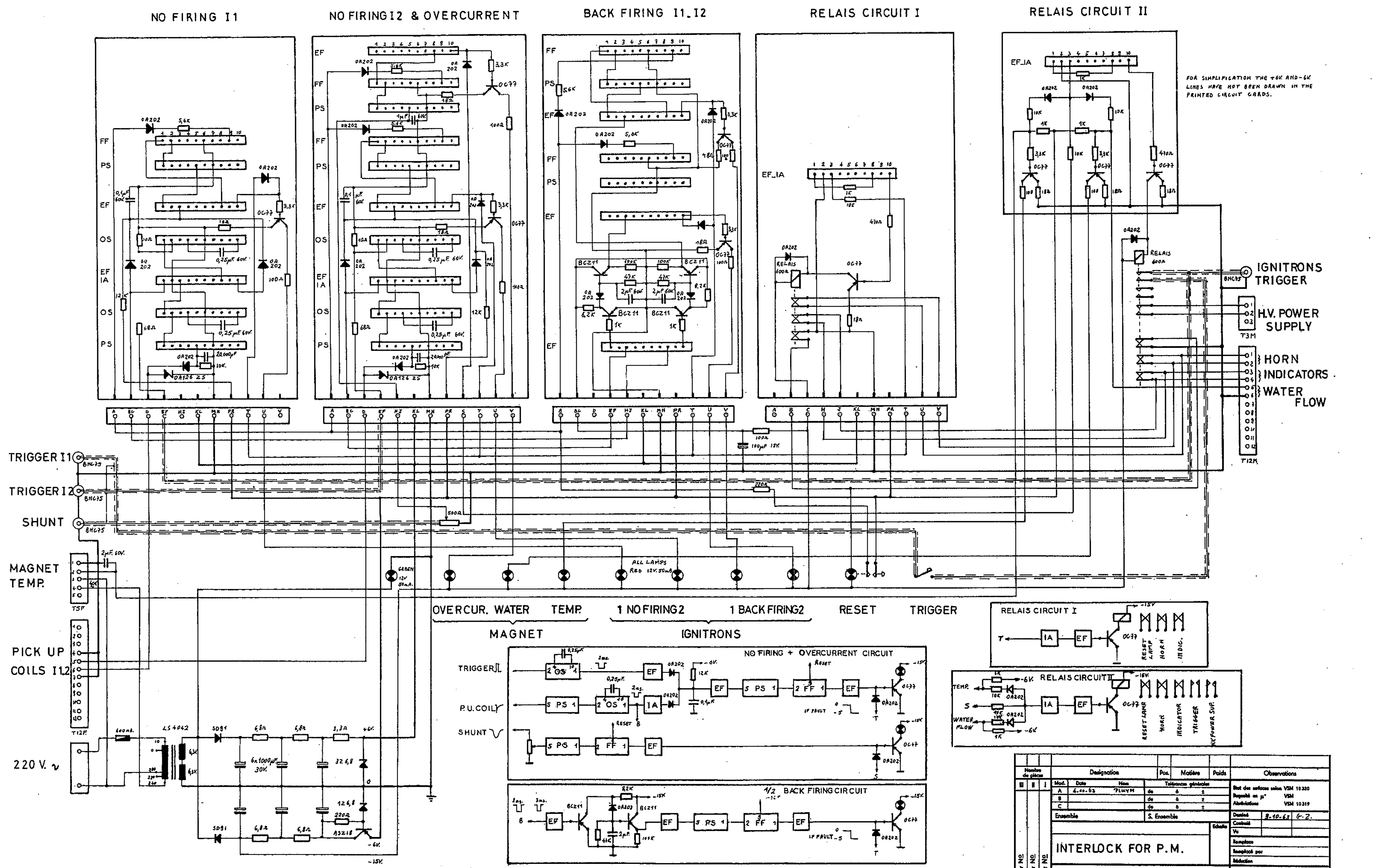


OUTPUT CONNECTIONS:
10 × T12F CONNECTED AS INDICATED IN DRAWING



Nombre de pièces			Designation			Pos.	Matière	Poids	Observations
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A	4.10.63	PLUYM	de à ±			Rugosité en μ VSM
			B			de à ±			Abréviations VSM 10319
			C			de à ±			
			Ensemble			S. Ensemble			Dessiné 13.8.62
			NEUTRINO BEAM				Echelle		Controlé
			POWER SUPPLY FOR DELAY CIRCUIT 1÷ 10ms						Vu / Remplace / Remplacé par / Réduction
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						P.M.12

SIS/R/7122



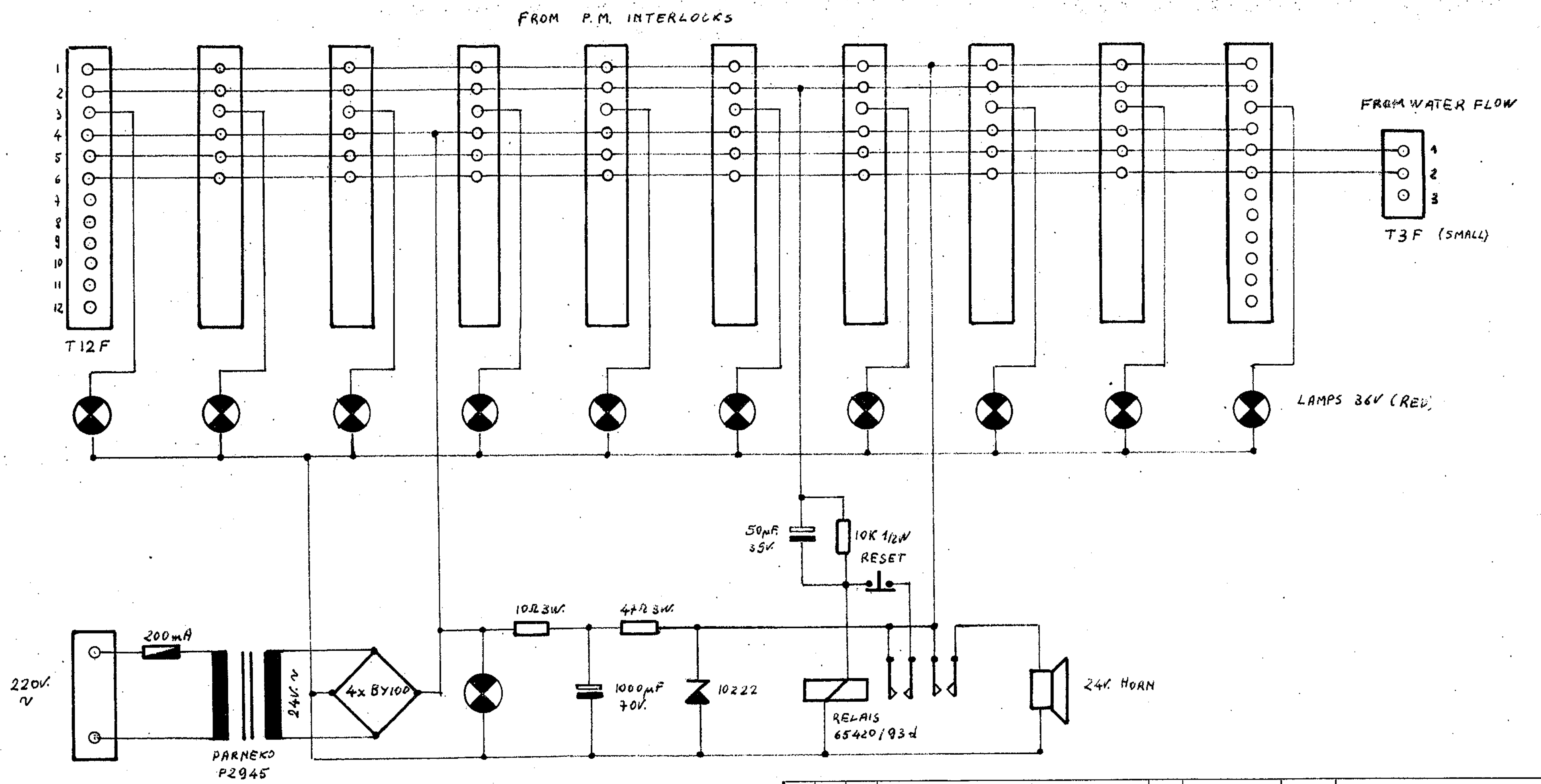
Nombre de pièces	Désignation	Pos.	Matière	Poids	Observations
Mod. A	Date 6-10-63				
Ensemble	S. Ensemble				Dessiné 8-10-63

INTERLOCK FOR P.M.

CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE

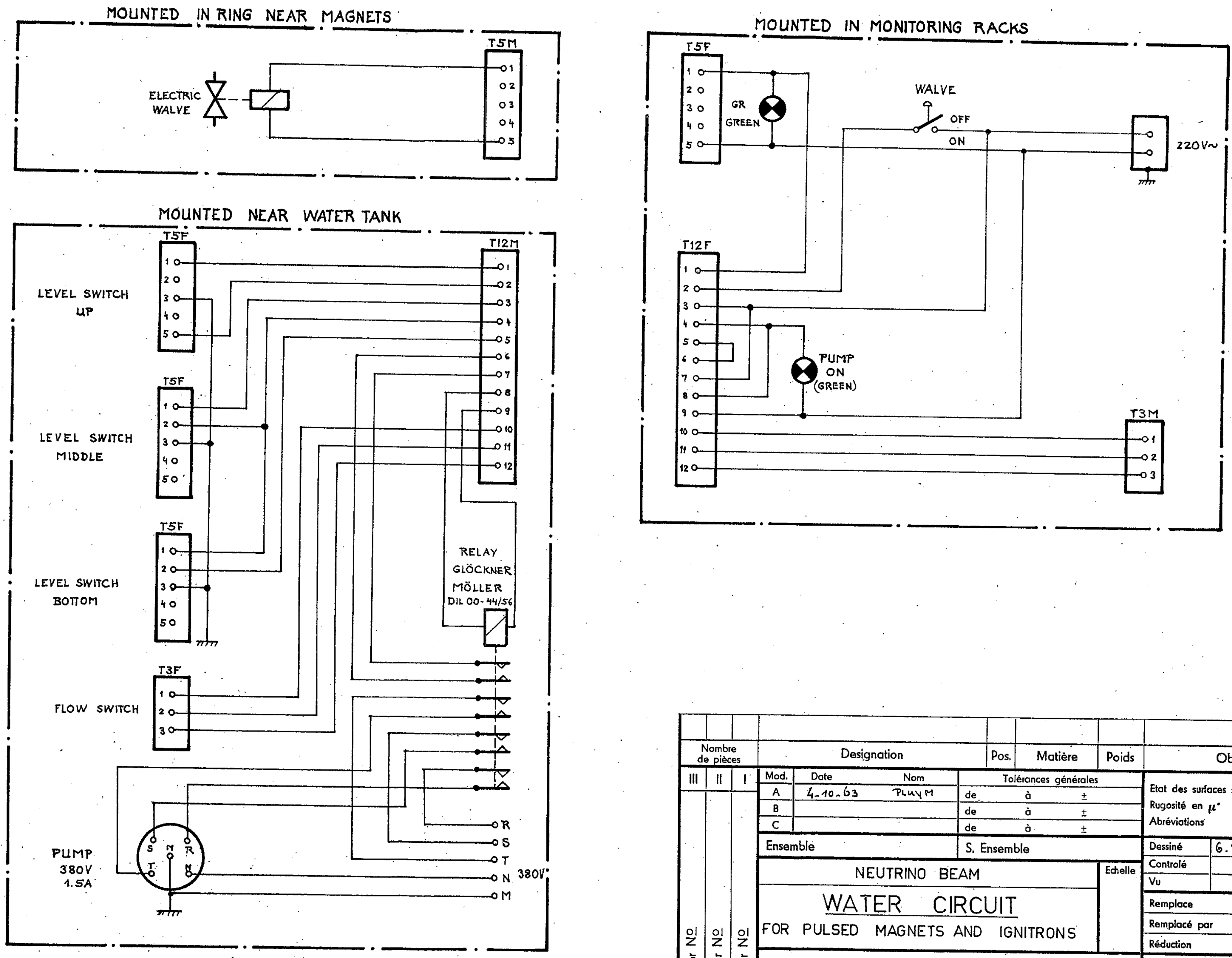
P.M.13

SIS/R/7119



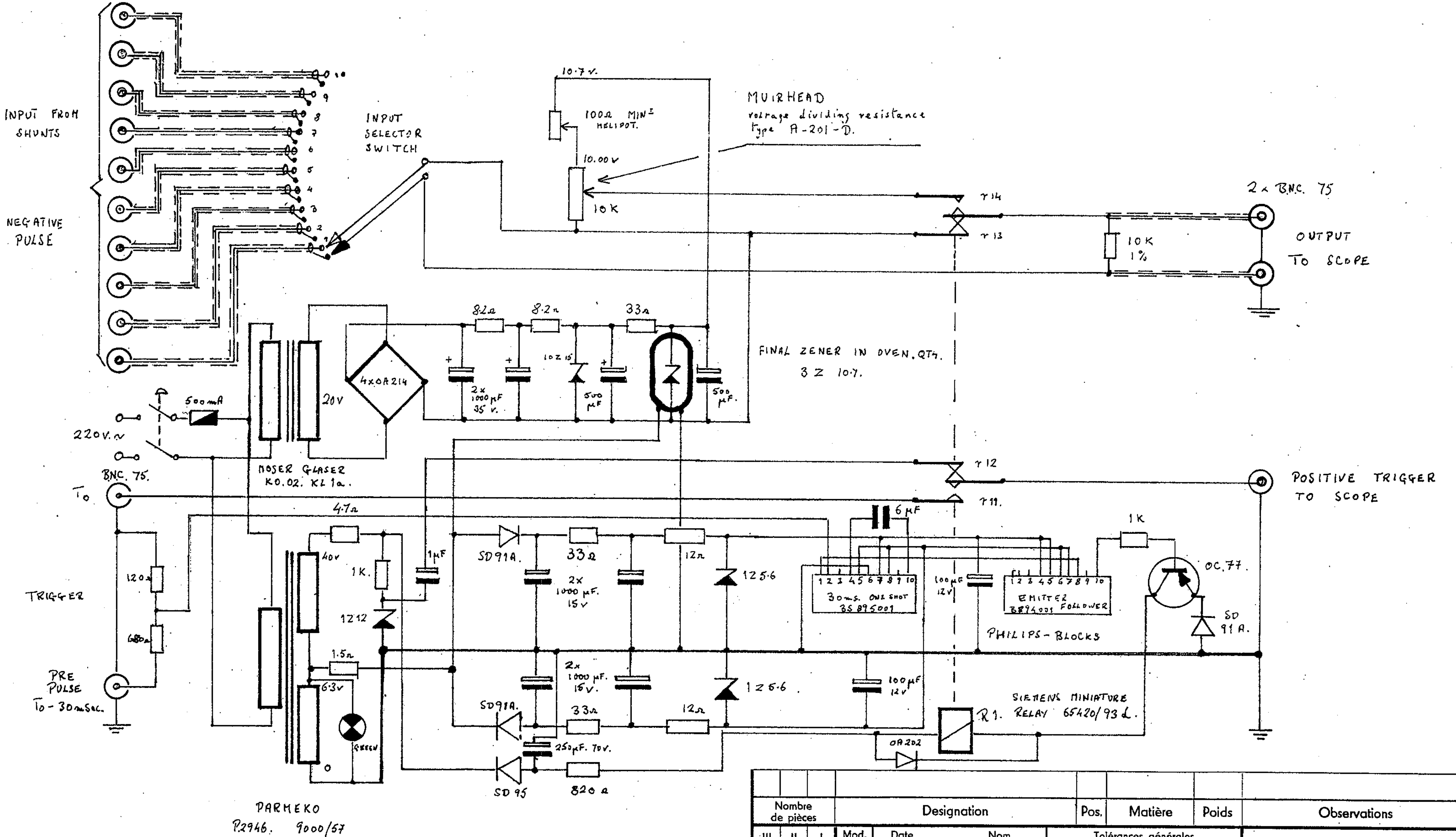
Nombre de pièces			Designation			Pos.	Matière	Poids	Observations
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A	4-10-63	PLUYM	de à ±			Rugosité en μ VSM
			B			de à ±			Abréviations VSM 10319
			C			de à ±			
			Ensemble			S. Ensemble			Dessiné 4-10-63 G.Z.
						Echelle			Controlé
									Vu
Dossier No	Dossier No	Dossier No	INTERLOCK INDICATORS						Remplace
									Remplacé par
									Réduction
			CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						P. M. 14

SIS/R/7112



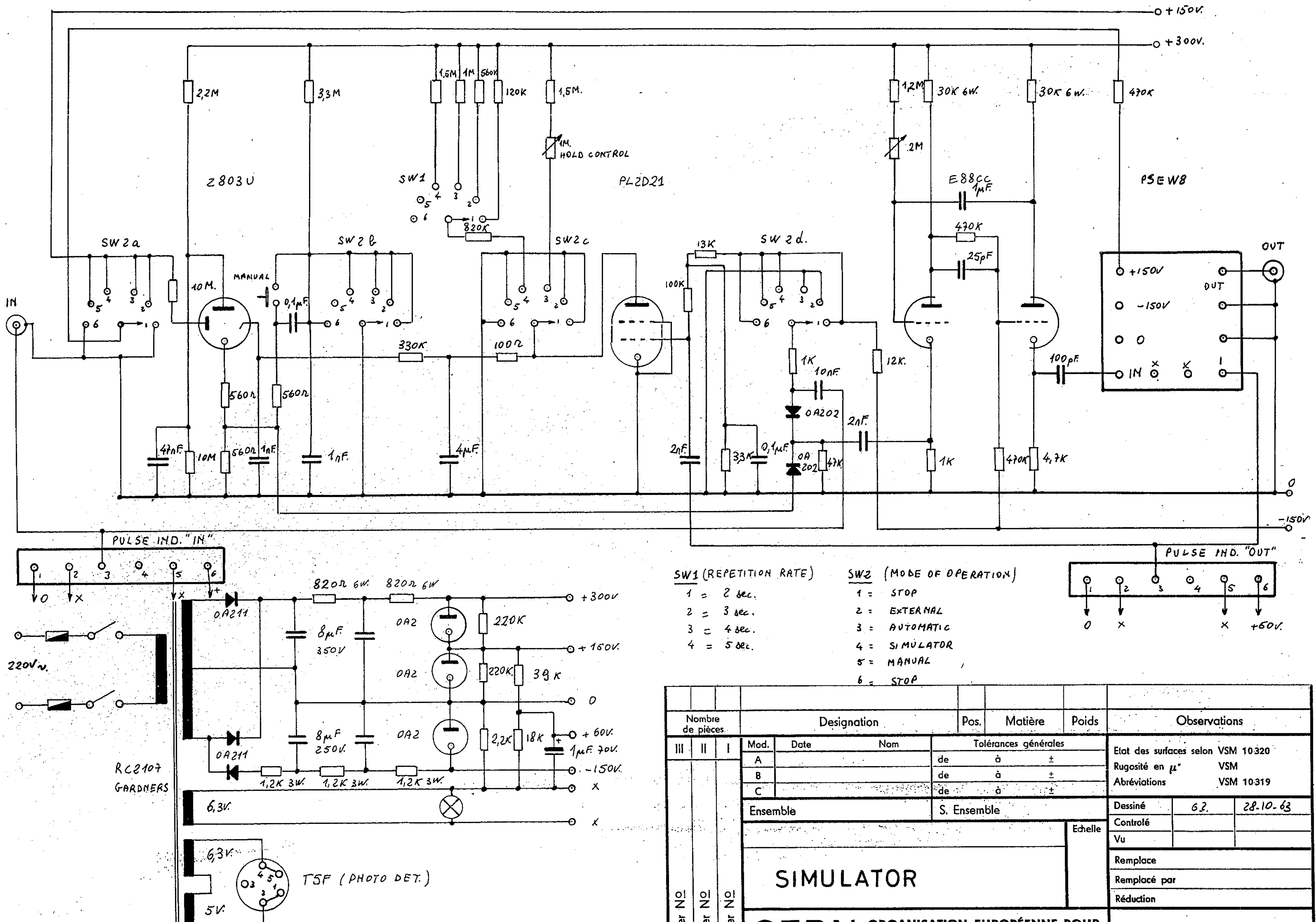
Nombre de pièces			Designation			Pos.	Matière	Poids	Observations
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A	4-10-63	PLUYM	de	à	±	Rugosité en μ VSM
			B			de	à	±	Abréviations VSM 10319
			C			de	à	±	
			Ensemble			S. Ensemble			Dessiné 6.9.62
Dossier No	Dossier No	Dossier No	NEUTRINO BEAM					Echelle	Controlé
			WATER CIRCUIT						Vu
			FOR PULSED MAGNETS AND IGNITRONS						Remplace
									Remplacé par
									Réduction
			CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						P. M.15

SIS/R/7113



Nombre de pièces			Designation			Pos.	Matière	Poids	Observations
III	II	I	Mod.	Date	Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A			de à ±			Rugosité en μ VSM
			B			de à ±			Abréviations VSM 10319
			C			de à ±			
			Ensemble			S. Ensemble			Dessiné 8.10.63 R. Tronc
			NEUTRINO BEAM				Echelle		Controlé
			CURRENT MEASURING CIRCUIT						Vu
									Remplace
									Remplacé par
									Réduction
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE						PM 16

SIS/R/7115



SIS/R/7248

Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I					

Mod.	Date	Nom	Tolérances générales		
A			de	à	±
B			de	à	±
C			de	à	±

Etat des surfaces selon VSM 10320
Rugosité en μ" VSM
Abréviations VSM 10319

Ensemble	S. Ensemble

Dessiné	62.	28-10-63
Controlé		
Vu		

Echelle

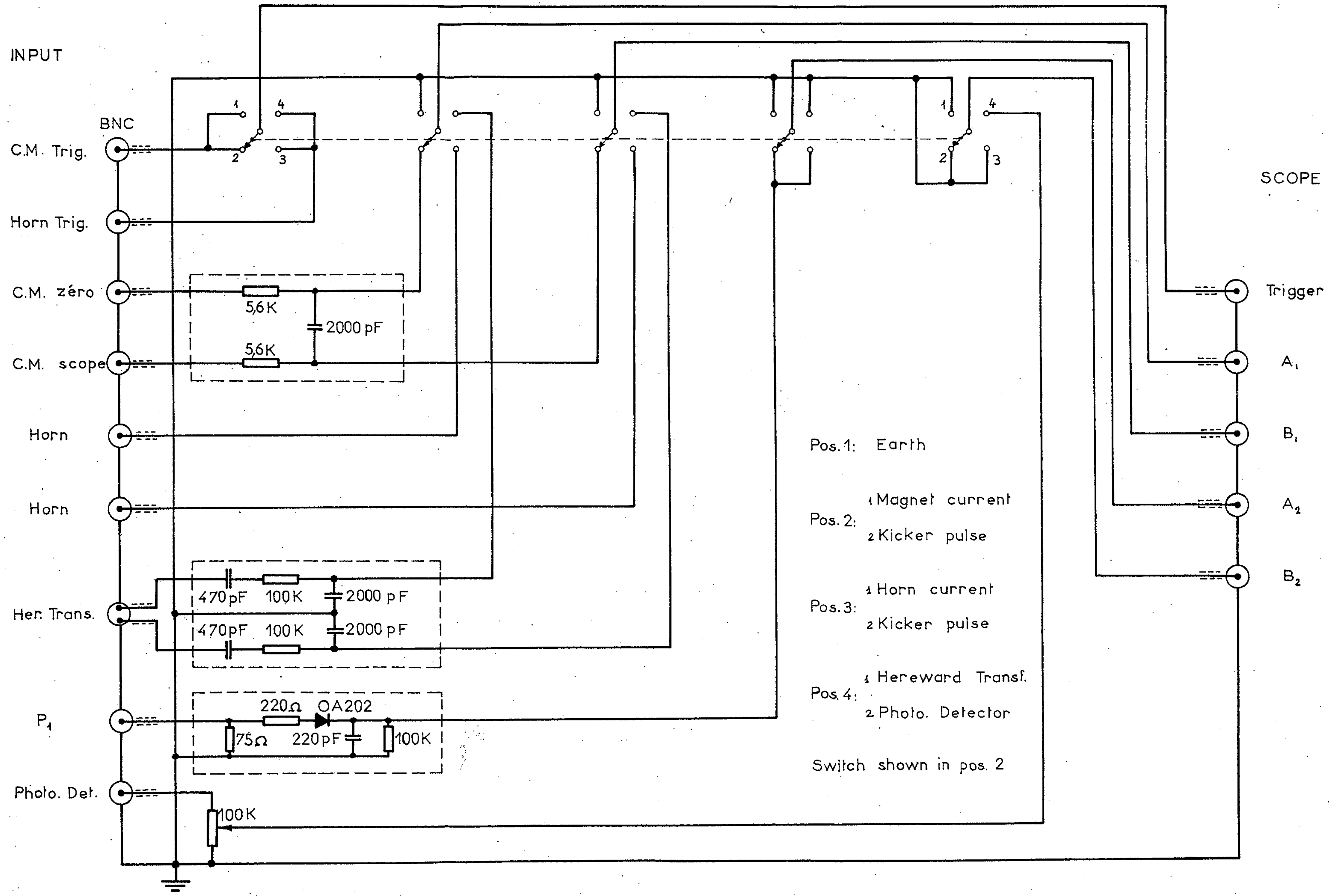
Remplace
Remplacé par
Réduction

Dossier No | Dossier No | Dossier No

SIMULATOR

CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE

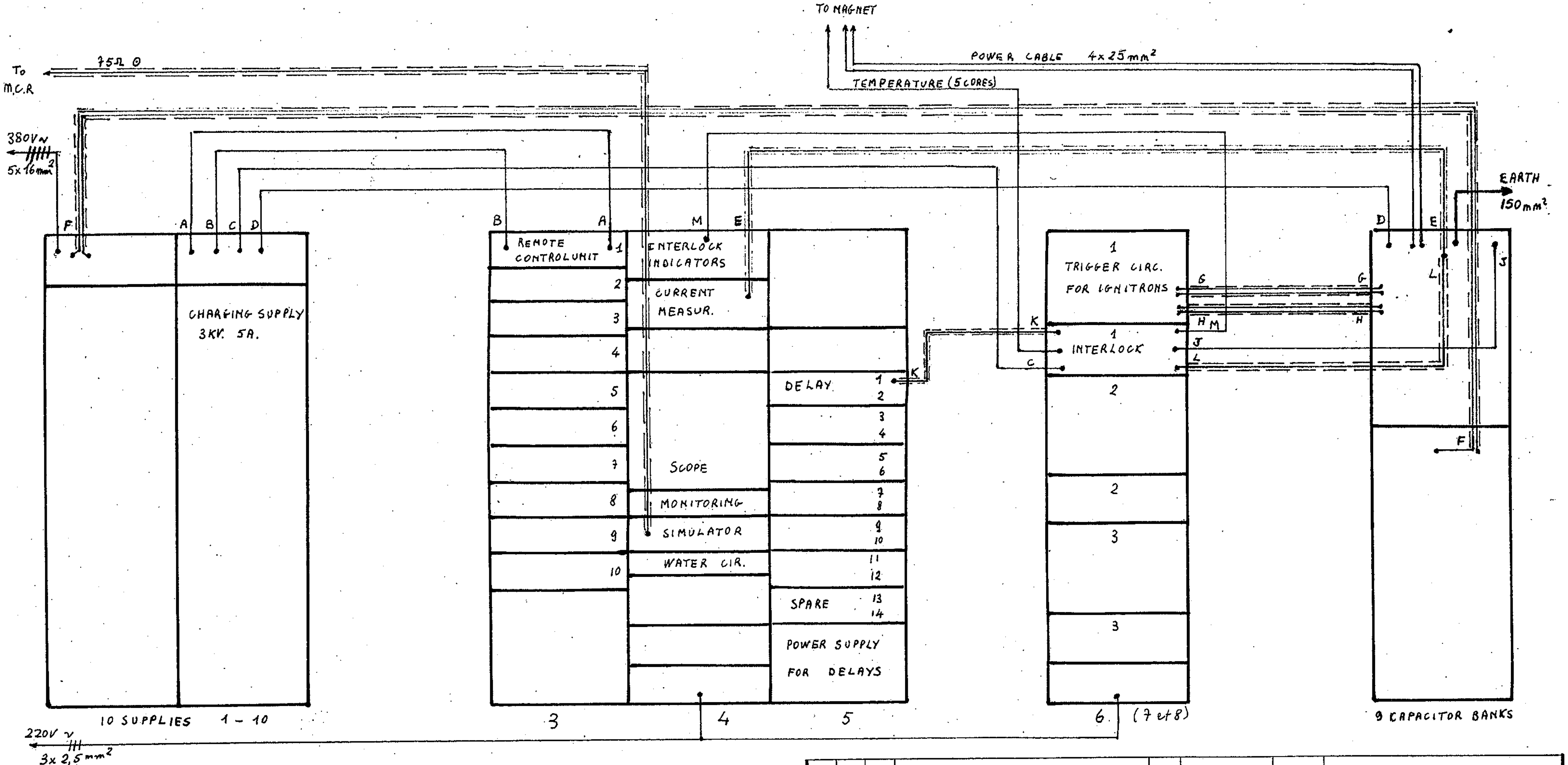
PM 17



SCOPE MONITORING

P.M. 18

SIS/R/7111



A et B	REMOTE CONTROL	12 CORES
C	POWER SUPPLY INTERL.	3 CORES
D	CAPAC. BANK INTERL.	5 CORES
E	SHUNT SIGNAL	75Ω ⊙
F	H.V. CABLE	Special
G et H	TRIGGER IGNITRONS	100Ω
J	P.U. COILS	12 CORES
K	TIMING SIGNAL	75Ω ⊙
L	OVERCURRENT SIGNAL	75Ω ⊙
M	INTERLOCK INDICATORS	12 CORES

Nombre de pièces	Designation	Pos.	Matière	Poids	Observations
III / II / I	Mod. A, B, C — Date — Nom		Tolérances générales: de à ±		Etat des surfaces selon VSM 10320; Rugosité en μ" VSM; Abréviations VSM 10319
	Ensemble	S. Ensemble			Dessiné 4.10.63 G2.; Controlé; Vu
	CABLE PLAN		Echelle		Remplace; Remplacé par; Réduction
Dossier No / Dossier No / Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE				P.M. 19

SIS/R/7134