CERN/TC/200 65-9
19.5.1965.

A FERRITE STEP-MAGNET FOR BUBBLE CHAMBER EXPERIMENTS

E. Chesi and G. Petrucci

Introduction

For experiments with bubble-chambers it is often convenient that the tracks of the incoming particles appear, on the different photographs, well-separated and spread evenly over a chosen field. This property, besides the obvious advantage in the clearness of the views, will simplify an eventual system of automatic track-scanning, and will also permit the use of a track labelling system.

A "sweeper-magnet", that is, a magnet deflecting the beam continuously inside the chamber, has already been constructed and used (see ref. CERN/TC/02 63-5).However, by this simple system, the distance between the tracks depends on the time distribution of the particles. To overcome this inconvenience it is necessary that the deflection power of the sweeper magnet should increase by equal steps, the timing of each step being determined by the incoming particles.

According to this idea, a 20-step ferrite core magnet has been designed and built to operate in connection with the CERN 2 metres H.B.C.(*).

General Description

In order to obtain the fast-rise steps in the deflection power, the magnet has been divided into twenty separate units. Each unit is provided with ferrite cores supplying the necessary magnetisation force; the magnetisation of the cores is inverted by means of an excitation circuit which is triggered at the desired time. The ferrite which has been used is the "Spinalor B" (manufactured by ALLEVARD UGINE) which presents a very high coercitive force (about 1800 Oe).

(*) For further informations about the characteristics and use of this kind of magnet, please see the report "A tentative design for a step-magnet" (A. Minten)

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Figure I shows the hysteresis loop of this ferrite. In spite of its high coercitive force it is possible to invert the magnetisation of the material in a time of a few microseconds (*).

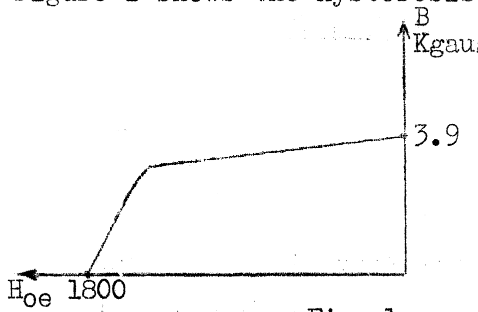


Fig. 1

The current pulse required to invert the magnetisation has to produce a field in the ferrite, as well as in the gap, considerably stronger than the field which is then maintained by the ferrite itself. Because of this fact, the field shape of a single unit presents a peak which is superimposed upon the desired step. This disadvantage has been eliminated by the use of a compensating magnetic unit i.e. another small magnet with no ferrites, the winding of which is connected in series with the windings of the ferrite units (**).

The basic circuit to generate the current pulse is given in Fig. 2. The capacitor C is charged to the voltage $-V_c$ and then discharged through ignitron No I. The current will rise following the law $i \cong V_c\sqrt{\frac{C}{L}}\ \sin wt$. For $\sin wt = 1$ ignitron No. 2 is fired. If $R \leq \frac{1}{2}\sqrt{\frac{L}{C}}$ the circuit becomes damped and there is no danger of the current reversing.

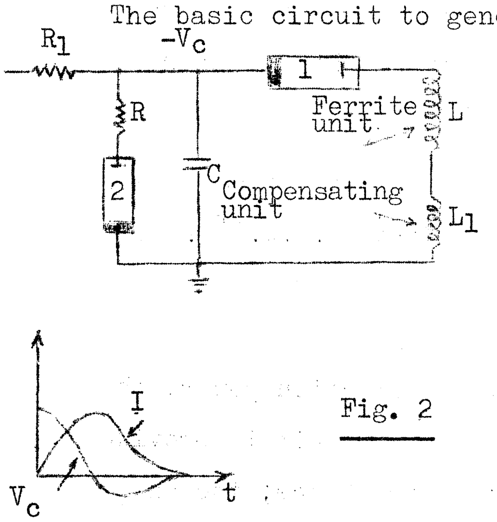
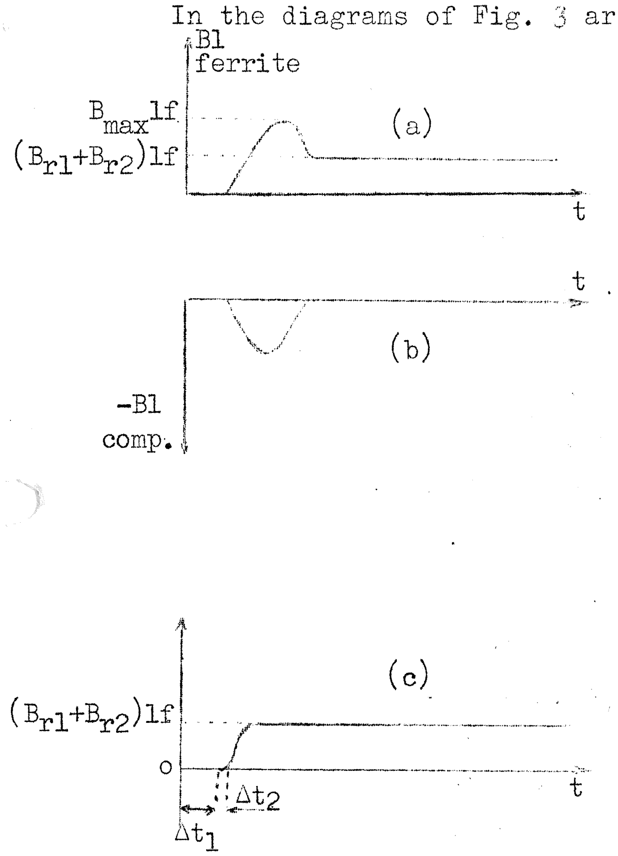


Fig. 2

(*) In practice it was not possible to detect any appreciable difference in the behaviour of this material by reducing the excitation time from 1 millisecond down to 5 microseconds.

(**) In comparison with the normal crow-bar system giving a fast-rise step followed by an exponential decrease of the field according to the excitation circuit time constant, the ferrite system presents the great advantage of being completely independent from the step length. The disadvantage is the greater energy required (about a factor 10) because, as already stated, the inversion of the magnetisation requires a higher field. Another disadvantage is that the maximum practically obtainable field step is limited by the ferrite cores to about 5000 gauss.

In the diagrams of Fig. 3 are represented :



(a) the bending strength of a ferrite unit;

(b) the bending strength of the compensating unit;

(c) the bending strength resulting from the addition of the two preceding curves.

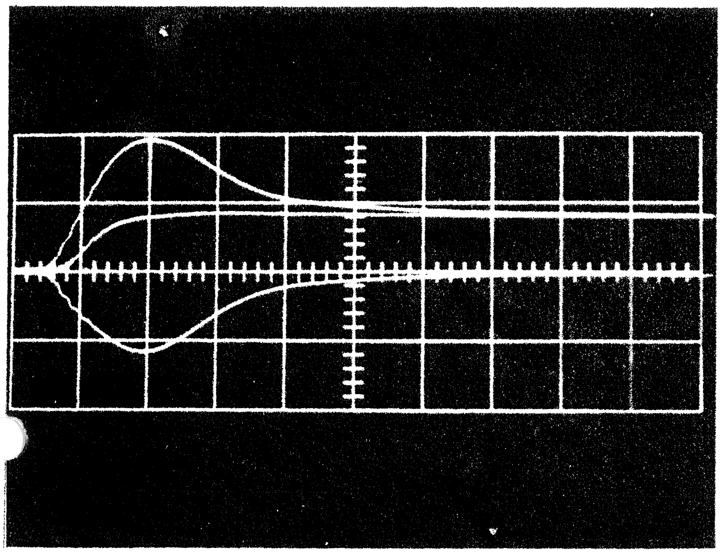
Fig. 3

On diagram C the point 0 represents the triggering time, the delay ΔT_1, is the time needed to establish the main discharge in the excitation circuit and the delay ΔT_2 is a time where the excitation current is rising but the field in the ferrite units is practically entirely balanced by the opposite field in the compensating unit.

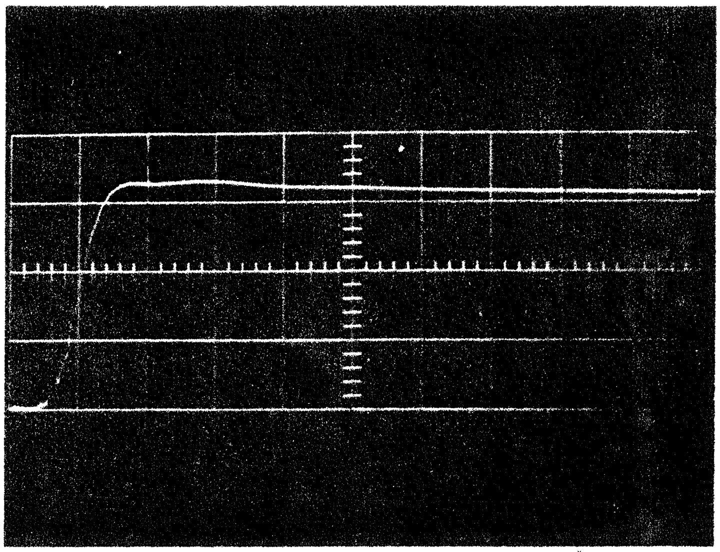
Fig. 4 shows the oscillograms obtained with a pick-up coil and an integrator; pictures 1 and 2 refer to a single unit and show clearly the effect of the compensating unit; pictures 3 and 4 illustrate the overall behaviour of the step magnet for two different step lengths (respectively about 100 μs and 10 μs per step). The minimum possible step length is given by the rise time plus the two delays ΔT_1 and ΔT_2, i.e. about 6 μsec. In the following table the most important data of the magnet are given.

Step Magnet Characteristics

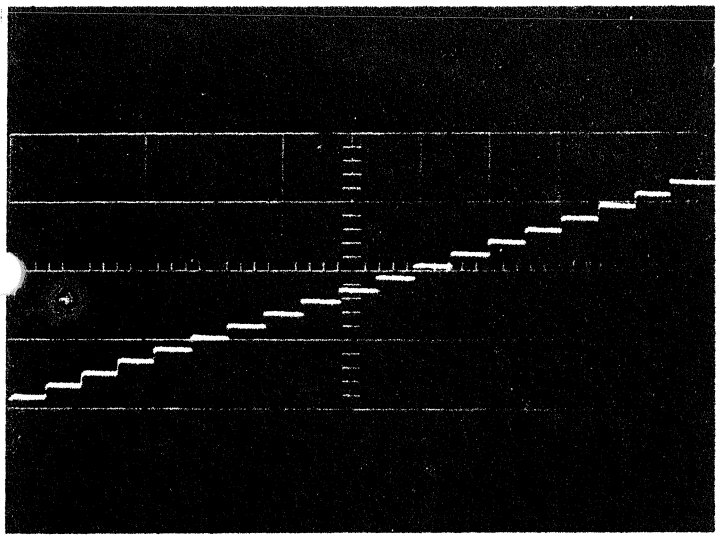
V_c	14 Kv max.
C	4.4 μF
L	~ 3.55 μH
L cable	~0.28 μH
L_1	~1.16 μH max.
Bending strength/unit	0.048 W/mt. max.
Gap	30 ÷ 40 mm.
Rise time	3.5 μs
Repetition frequency	1/2 sec.
Delay Δt (triggering circuit)	~1.2 μ sec.
Delay Δt (due to the compensating unit)	~1 μ sec.
Min. step length	~6 μ sec.



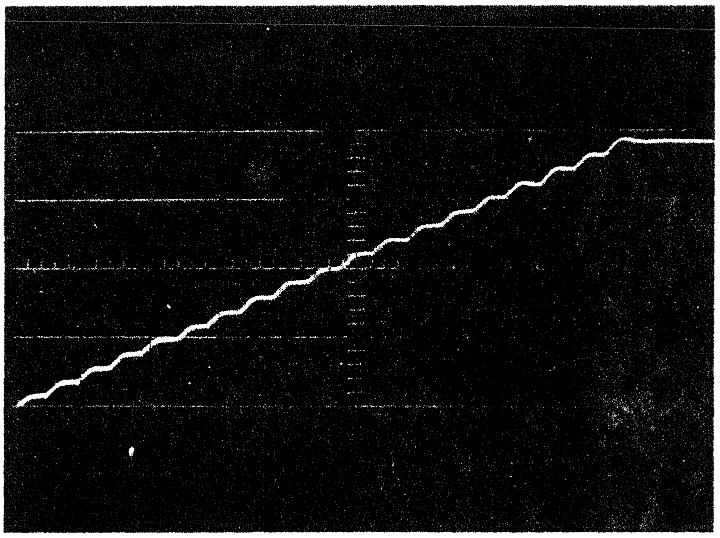
1) From the top: a) Field in the ferrite unit.
Sweep = 5 μs/cm b) Compensated field.
c) Compensating field.



2) $V_c = 12$ Kv Gap = 40 mm Sweep = 5 μs/cm
$B\ell = 0.027$ Wb/mt.



3) $V_c = 12$ Kv Gap = 40 mm Sweep = 200 μs/cm
$B\ell = 0.027$ Wb/mt × N° of steps
$RC_{integrator} \cong 75$ ms



4) $V_c = 12$ Kv Gap = 40 mm Sweep = 20 μs/cm
$B\ell = 0.027$ Wb/mt × N° of steps.

Fig. 4

Measurements

Measurements of the Bl in function of V_c have been made for different values of the gap (see graphics in Fig. 5).

The curves in Fig. 6 represent the Bl distribution in the vertical plane of the ferrite unit.

The dotted lines give the dynamic measures of Bl, obtained with a "pick-up" coil and an integrator, about 50 μs after the initial trigger pulse.

The thick lines represent the Bl measured in static conditions, by means of a flux meter. The difference between the two readings can be explained by eddy-currents circulating in some of the supporting structure of the ferrite cores.

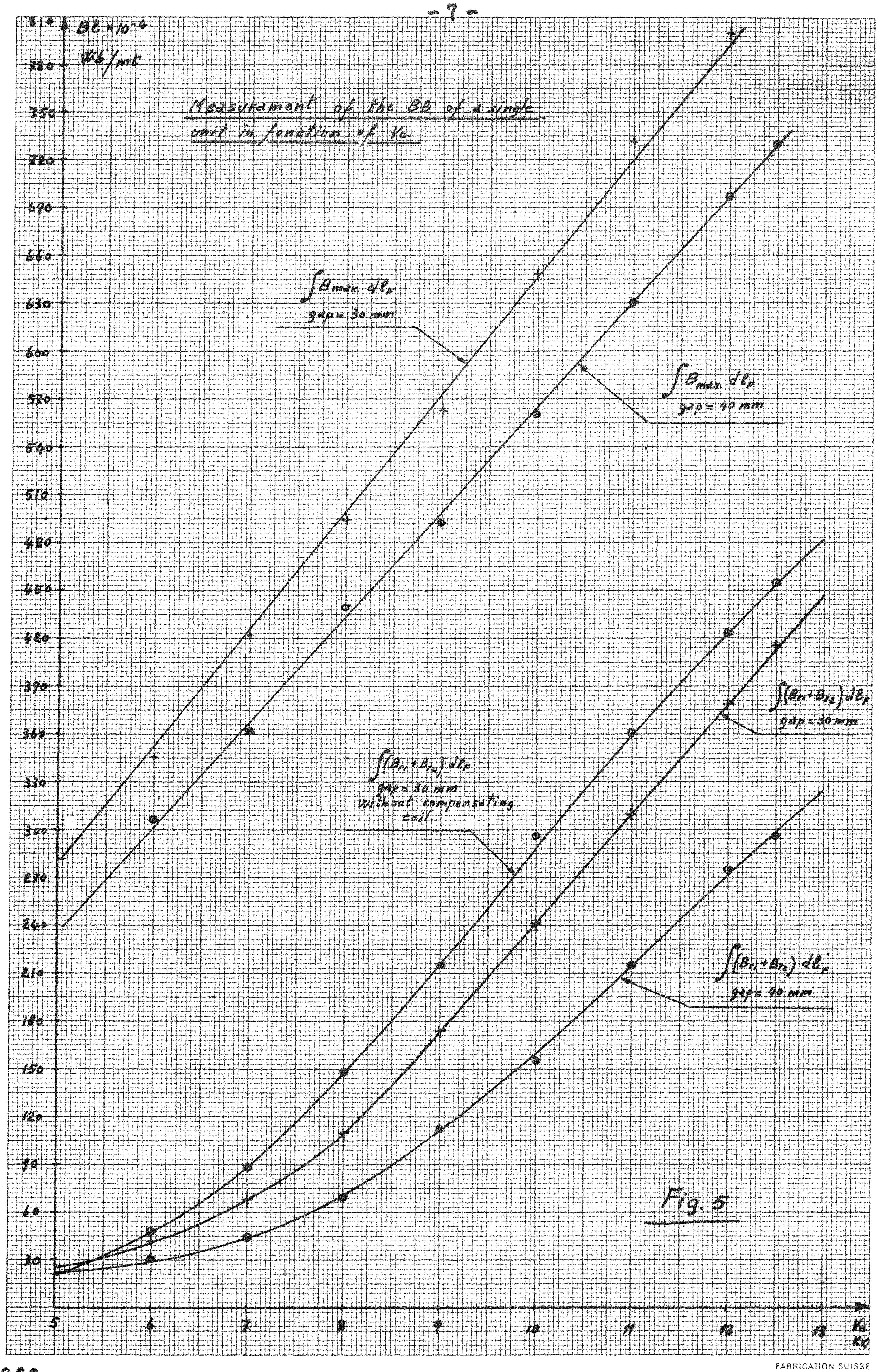


Fig. 5

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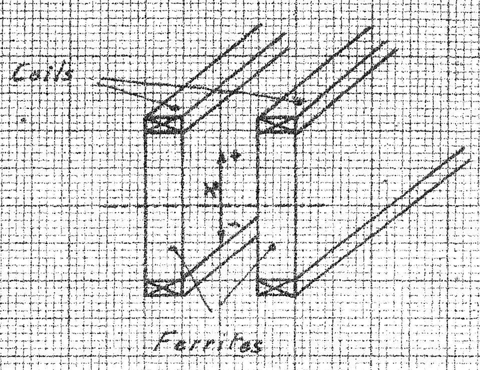
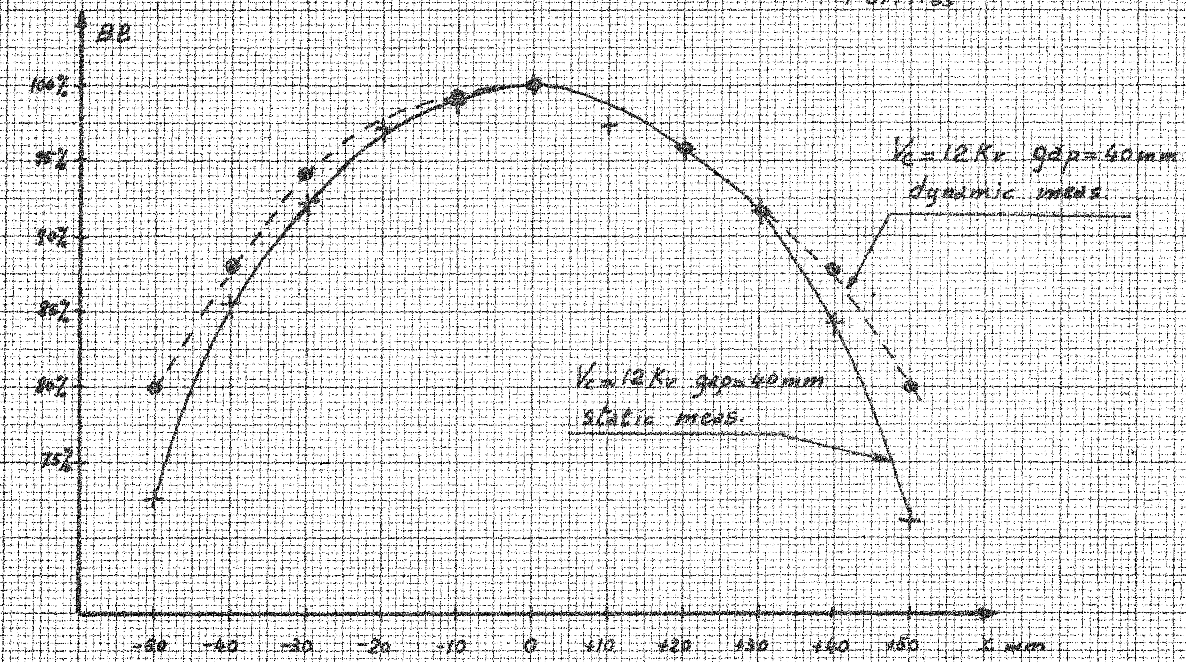
FABRICATION SUISSE

Measurements of the Bℓ distribution on the x plane





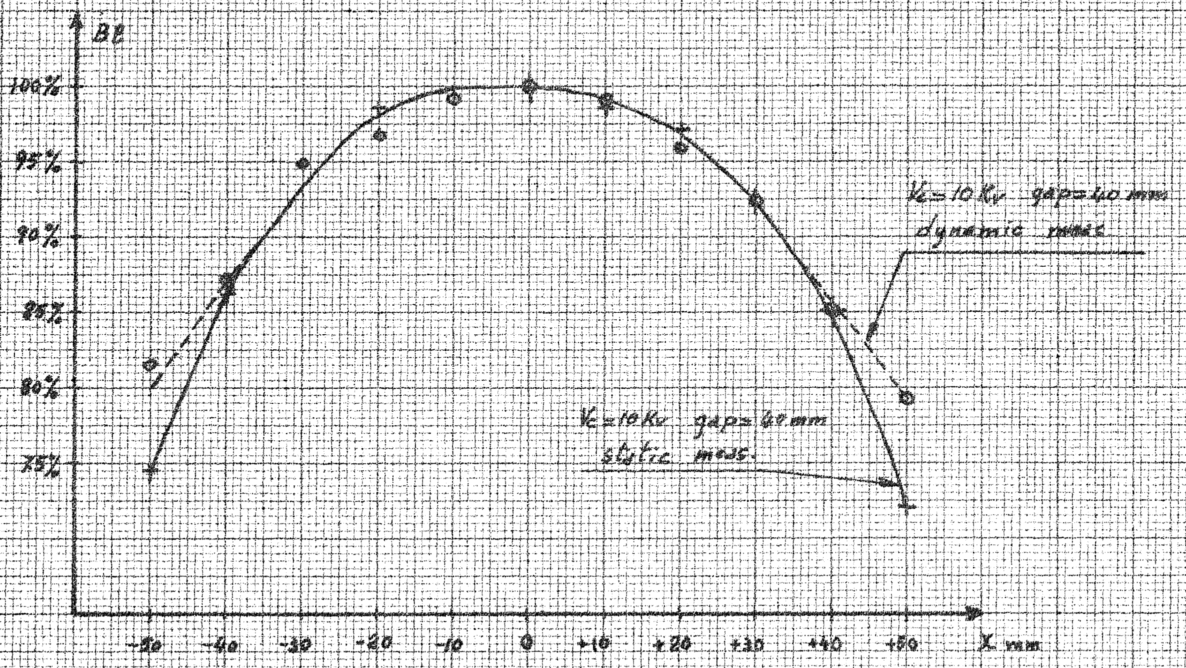


Fig. 6

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General Design

Fig. 1 illustrates the general working principle. Two scintillators counters in coincidence detect the particles and the pulses are counted by a scaler (called "fast memory") that also supplies the triggers for the units.

The detailed block diagram of the fast memory is represented in Fig. 2. The 10 KHz oscillator fills up the scaler when the available number of particles in the burst is lower than 20.

Power Supply

The maximum energy stored by the condenser bank is, for the 20 units:

$$E_c = 8600 \text{ joules.}$$

As this energy is completely dissipated at each burst, the size of the power supply will be determined by the repetition frequency. For a repetition frequancy of 1/sec, we have :

$$W = 2 \times 8600 \text{ joules} \times 1 \text{ sec} = 17 \text{ KW} \quad I_o = 1{,}21\text{A} \quad \text{Ipeak} = 7\text{A} \quad V = 15 \text{ KVolt}$$

The complete diagram of the power supply is shown in Fig. 3. A remote control has been foreseen and is also indicated in Fig. 3.

Discharging Circuit

There are 20 discharging circuits, mounted in 5 racks. Each rack therefore contains 4 circuits. Fig. 4 gives the diagram of one of them (thick lines) plus the common wiring such as : fun, safety microswitches, plugs, etc.

The connections of the excitation circuits of the units are shown in Fig. 5 (2 of the 20 units are represented). There is one compensating coil for the 20 units, with two separate winding who give opposite fields. Its gap can be continuously adjusted by a remote control between 30 and 60 mm.

To inverse the sign of the current pulse the switches A B C D are operated at each cycle.

Triggering Unit

Each ignitron is fired by a positive voltage pulse of 2,2 K_V applied to its ignitor. This pulse is supplied by the triggering unit (see diagram of Fig. 6).

The delay between the input trigger and the beginning of the main discharge in the ignitron is about 1,2 μs. The jitter in time is less than 0,1 μs.

A thermic relay allows the filaments of the thyratrons a warm-up time of about three minutes before applying the high voltage.

Ferrite Magnet

The general view of the ferrite magnet is shown in Fig. 7. The magnetic circuit is composed of four iron packs, made of sheets of 0,12 mm thickness. Two of these packs are fixed, while the position of the other two can be moved in order to be able to adjust the gap between 60 and 30 mm. by steps of 10 mm.

The polar piece of a magnet is composed of two ferrite blocks (140 mm x 100 mm x 20 mm).

Fig. 8 gives the construction details of the coils. These are made of three copper turns, moulded in araldite. The two coils are connected in parallel.

The frame supporting each magnet is represented in Fig. 9, while Fig. 10 gives the complete plan of the 20 units with the switches.

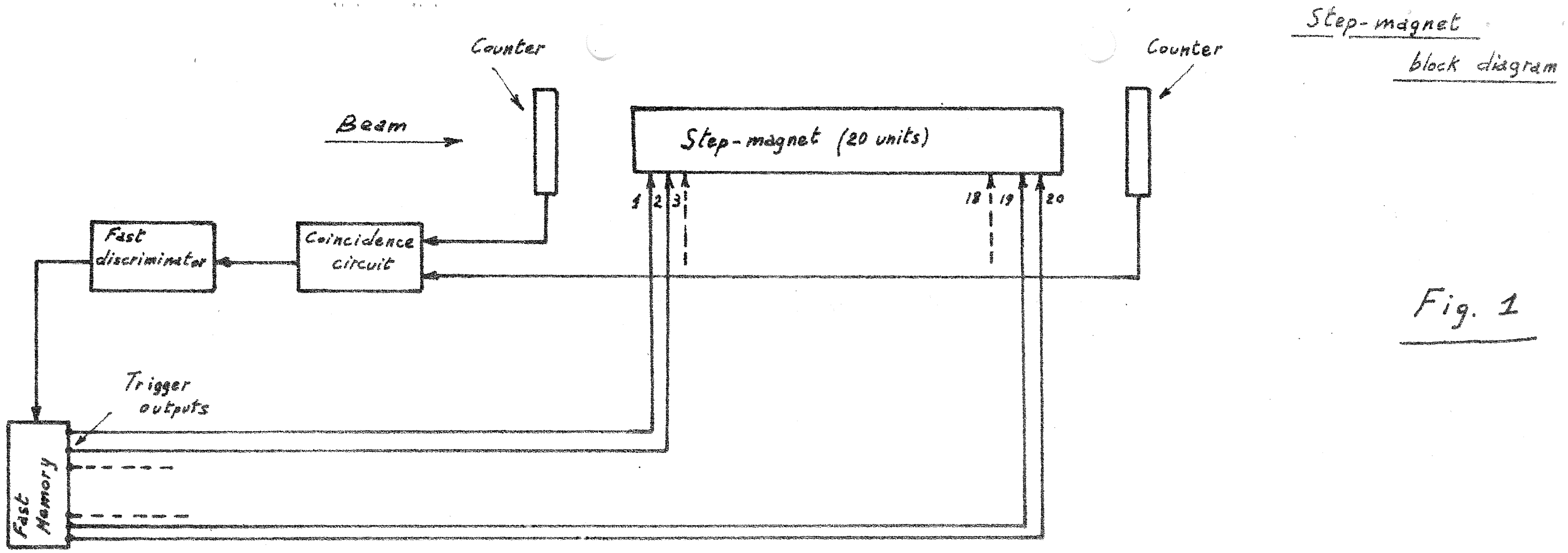

Fig. 1

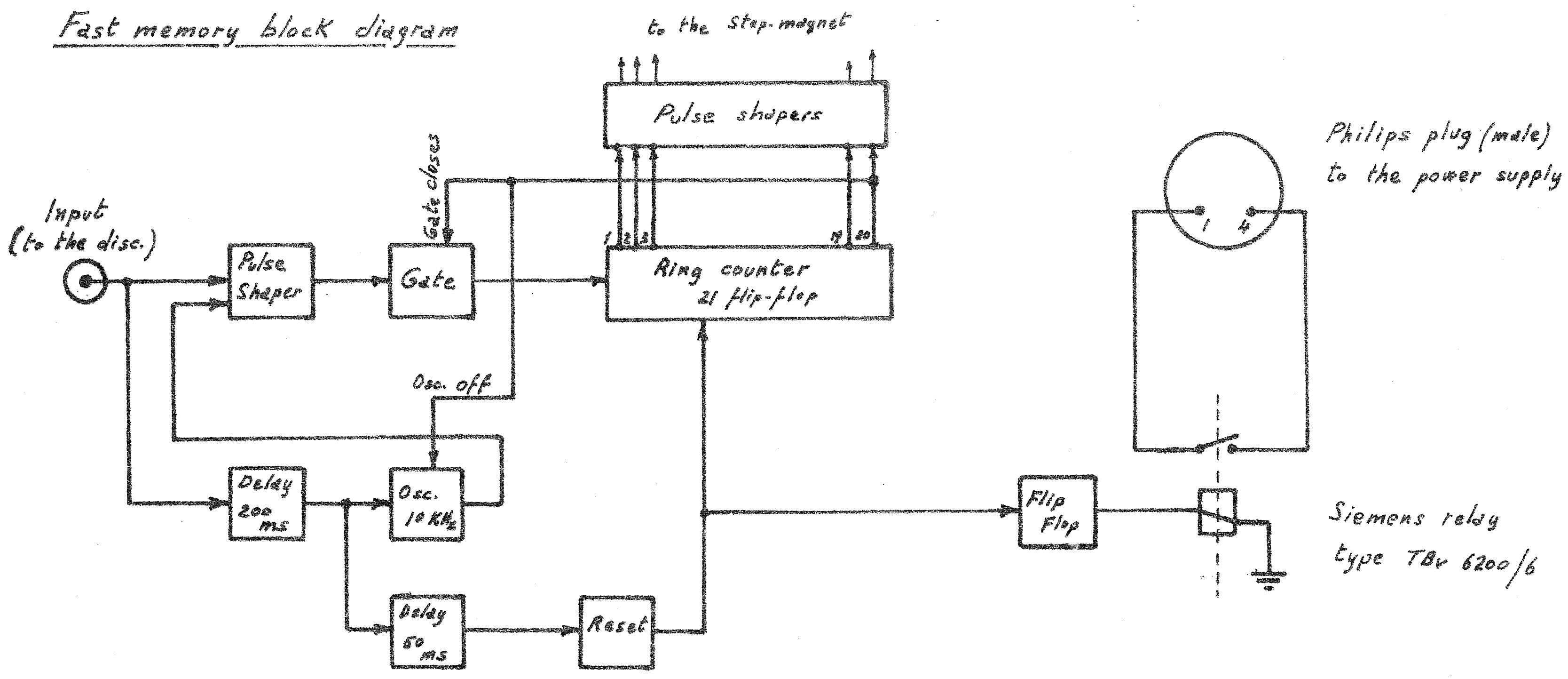

Fig. 2

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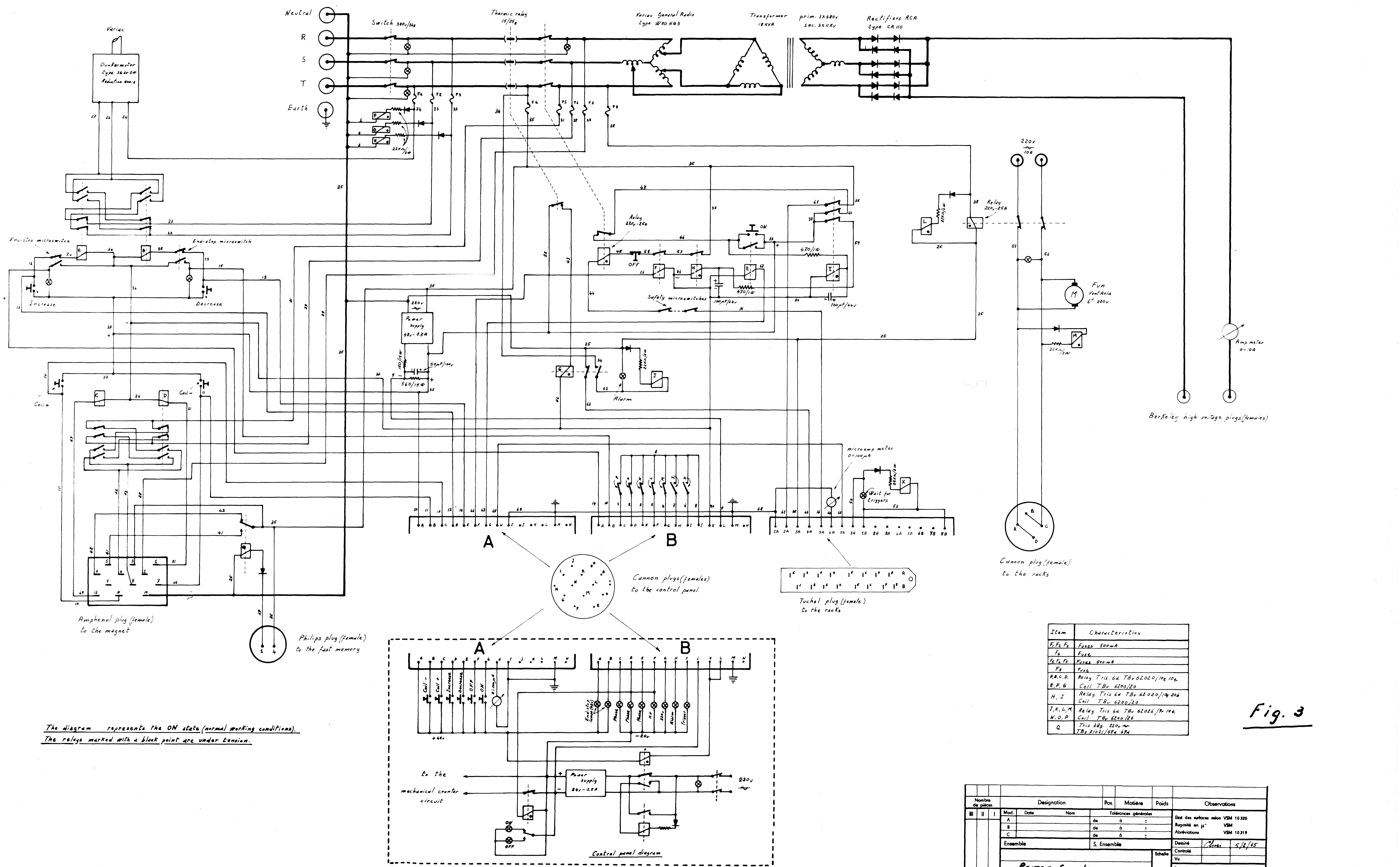

The diagram represents the ON state (normal working conditions).
The relays marked with a black point are under tension.

Item	Characteristics
F_1 F_2 F_3	Fuses 500 mA
F_4	Fuse
F_5 F_6 F_7	Fuses 600 mA
F_8	Fuse
A, B, C, D, E, F, G	Relay Tris. 6d TBv 62020/10e 10e Coil TBv 6200/20
H, I	Relay Tris 6d TBv 62020/10e 20b Coil TBv 6200/20
J, K, L, M, N, O, P	Relay Tris 6d TBv 62026/9v 10e Coil TBv 6200/26
Q	Tris 38g. 220v ~ TBv 71021/69d 69d

Fig. 3

Nombre de pièces			Designation		Pos.	Matière	Poids	Observations
III	II	I	Mod. / Date / Nom	Tolérances générales				Etat des surfaces selon VSM 10 320 Rugosité en μ" VSM Abréviations VSM 10 319
			A	de à ±				
			B	de à ±				
			C	de à ±				
			Ensemble	S. Ensemble				Dessiné Chev 5/2/65
					Echelle			Controlé
								Vu
			Power Supply for 'STEP-MAGNET,					Remplace
								Remplacé par
Dossier No	Dossier No	Dossier No						Réduction

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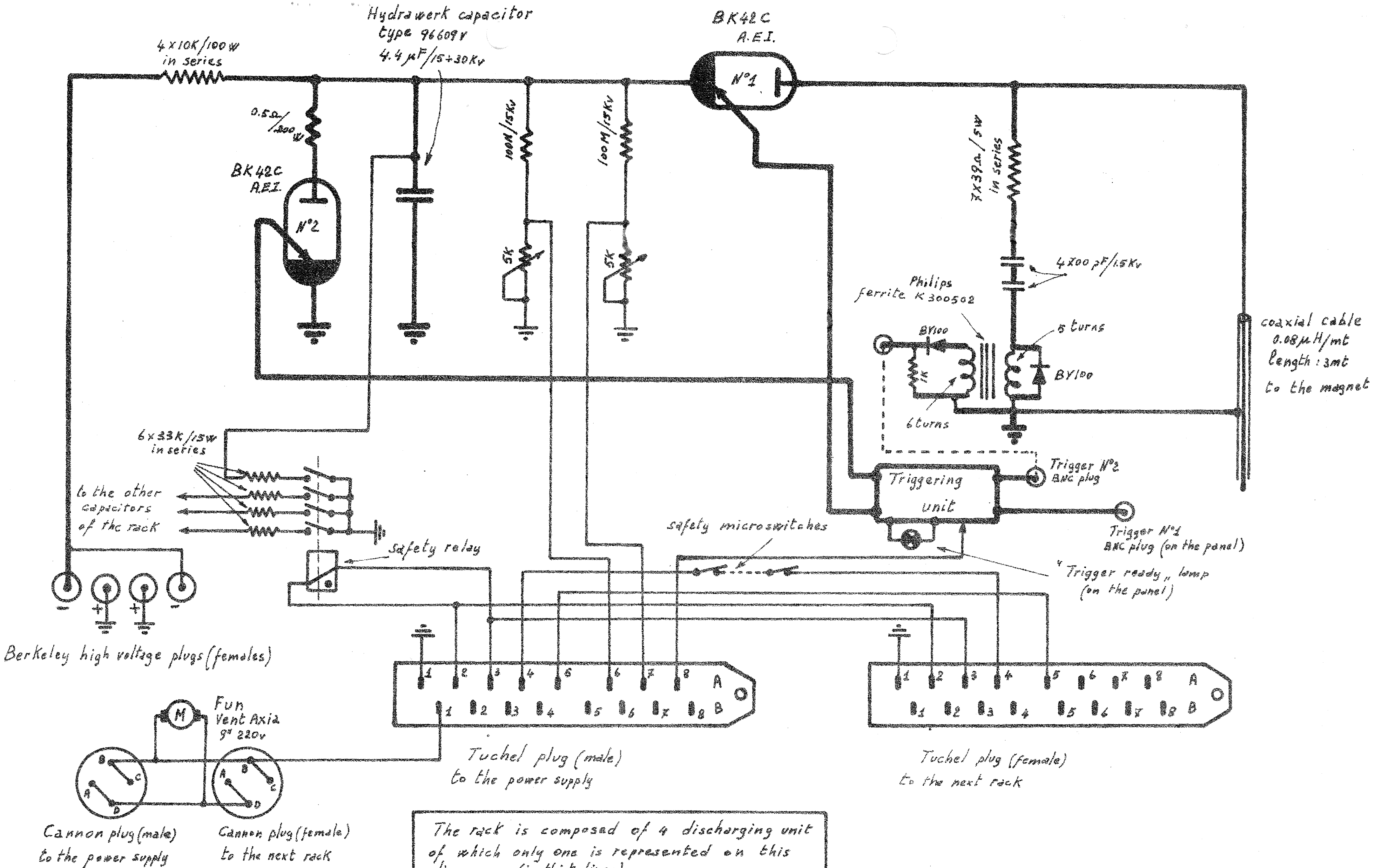

The rack is composed of 4 discharging unit of which only one is represented on this diagram (in thick lines).

DISCHARGING CIRCUIT

Fig. 4

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Magnet diagram

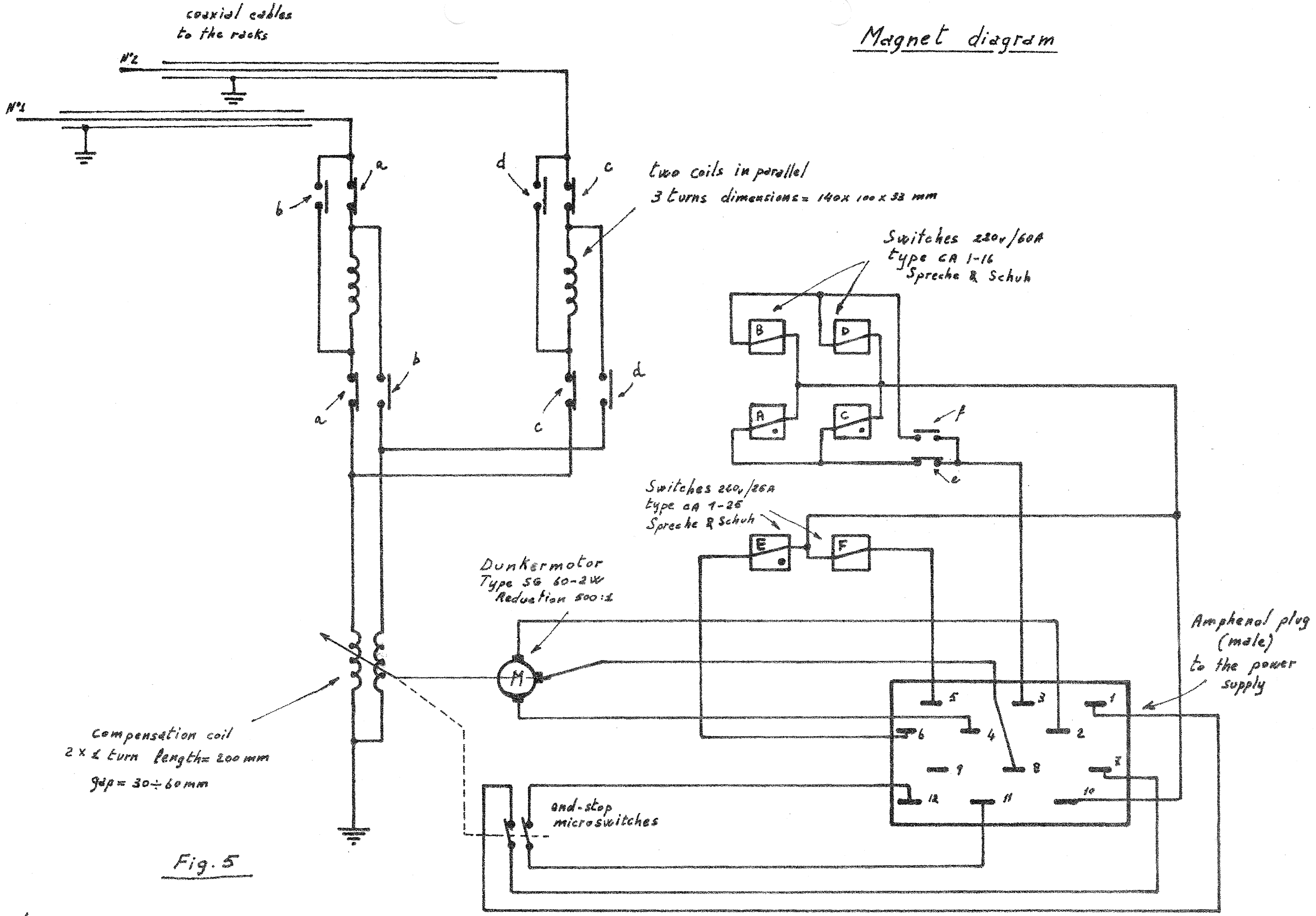

Fig. 5

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All resistors are ½ W unless otherwise specified.
The triggering unit is composed of two separate channels of which only one is represented here. The power supplies are common to both.

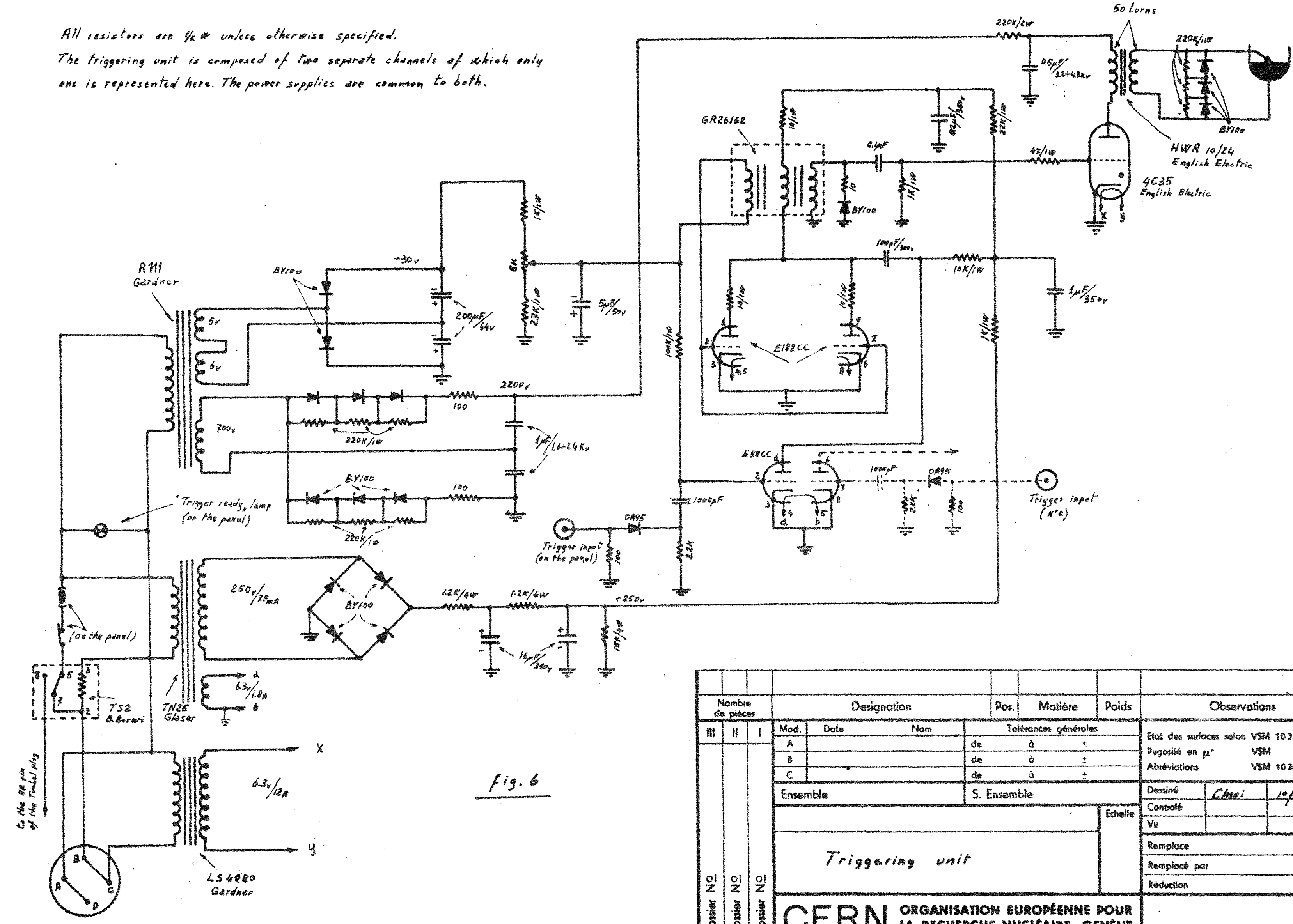

fig. 6

Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I	Mod. / Date / Nom		Tolérances générales		Etat des surfaces selon VSM 10 320; Rugosité en µ" VSM; Abréviations VSM 10 319
			A		de à ±		
			B		de à ±		
			C		de à ±		
			Ensemble		S. Ensemble	Echelle	Dessiné Chaci 10/2/65
							Contrôlé
							Vu
			Triggering unit				Remplace
							Remplacé par
							Réduction
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE				

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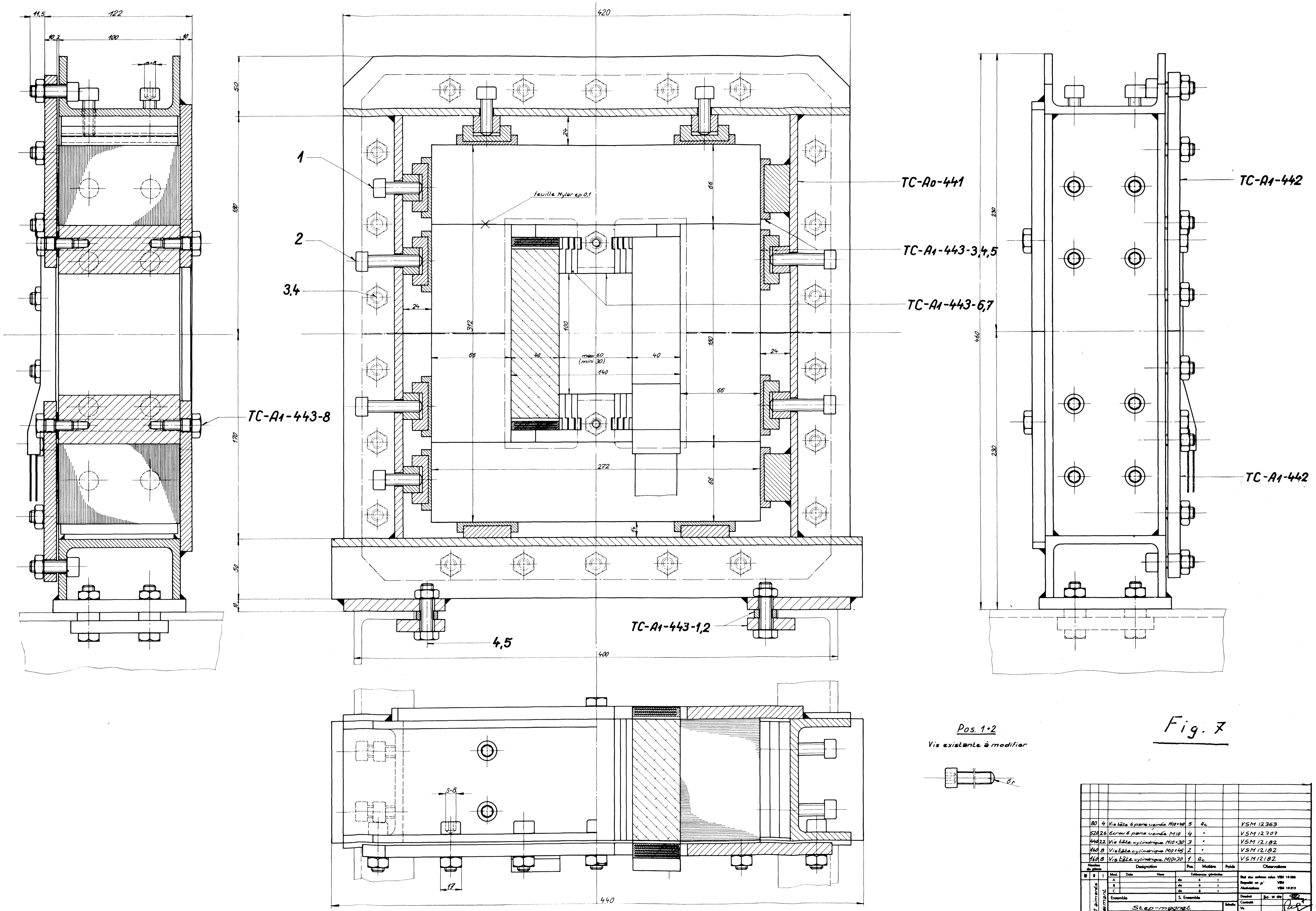

Fig. 7

Nombre de pièces III	II	I	Designation	Pos.	Matière	Poids	Observations
	80	4	Vis tête 6 pans usinée M10×40	5	Ac		VSM 12363
	520	26	Ecrou 6 pans usinée M10	4	"		VSM 12707
	440	22	Vis tête cylindrique M10×30	3	"		VSM 12182
	160	8	Vis tête cylindrique M10×45	2	"		VSM 12182
	160	8	Vis tête cylindrique M10×30	1	Ac		VSM 12182

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

Etat des surfaces selon VSM 10 380
Rugosité en μ' VSM
Abréviations VSM 10 319

Ensemble | S. Ensemble

Dessiné 30 · VI · 64

Contrôlé

Vu

Remplace

Remplacé par

Réduction

Dossier No
Dossier No pr 20 aimants
Dossier No pr 1 aimant

Step-magnet

Ensemble 1

Echelle 1:1

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TC-A0-444

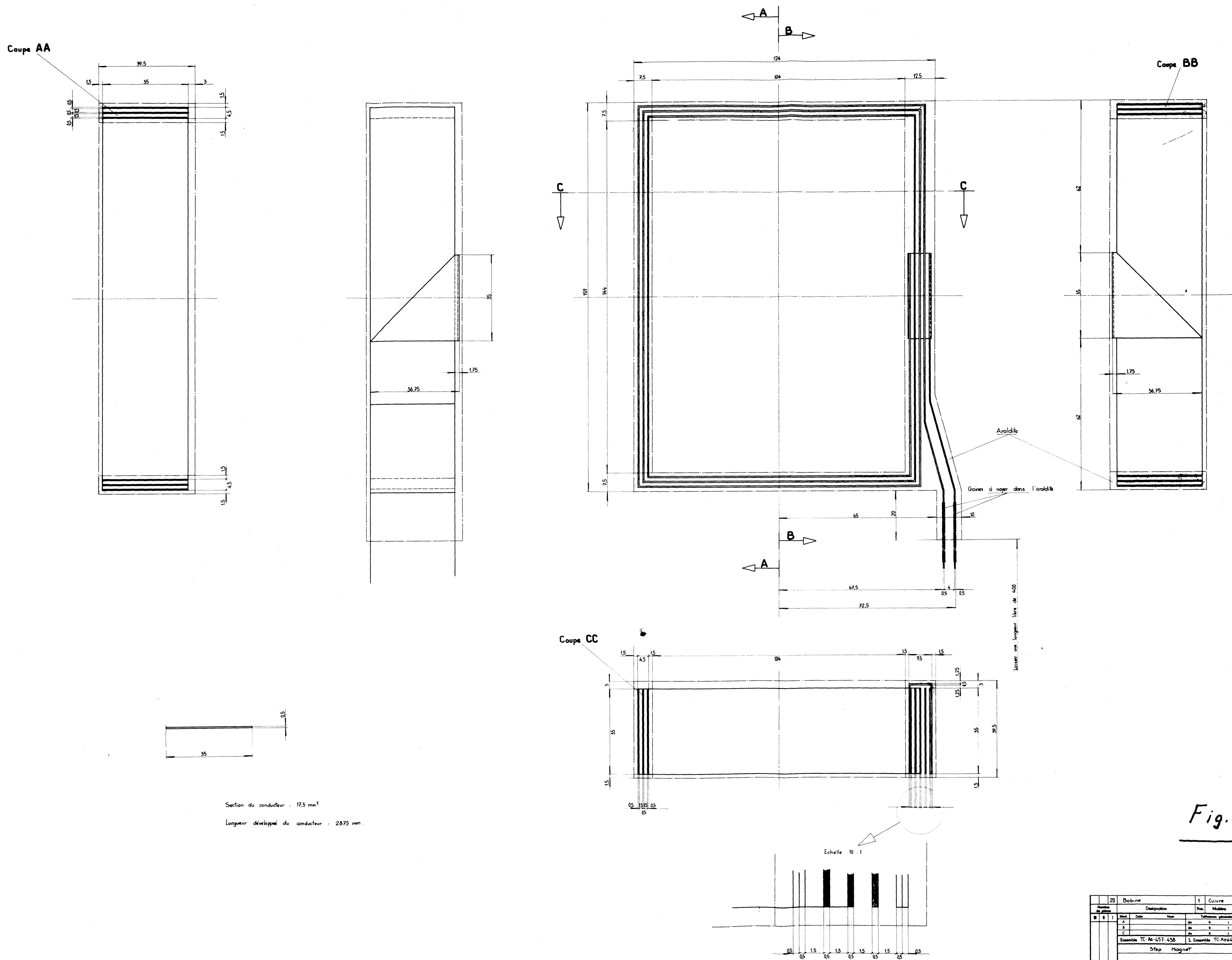

Fig. 8

		20	Bobine	1	Cuivre		Isolation à l'araldite
Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I	Mod. / Date / Nom		Tolérances générales		Etat des surfaces selon VSM 10 320
			A		de à ±		Rugosité en µ VSM
			B		de à ±		Abréviations VSM 10 319
			C		de à ±		
			Ensemble TC-A0-457-458		S. Ensemble TC-A0444 458		Dessiné 6.7.64
			Step Magnet			Echelle	Contrôlé
							Vu
Dossier No	Dossier No	Dossier No	Bobine type II			2:1	Remplace
							Remplacé par
							Réduction
			CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE				TC-A0-454

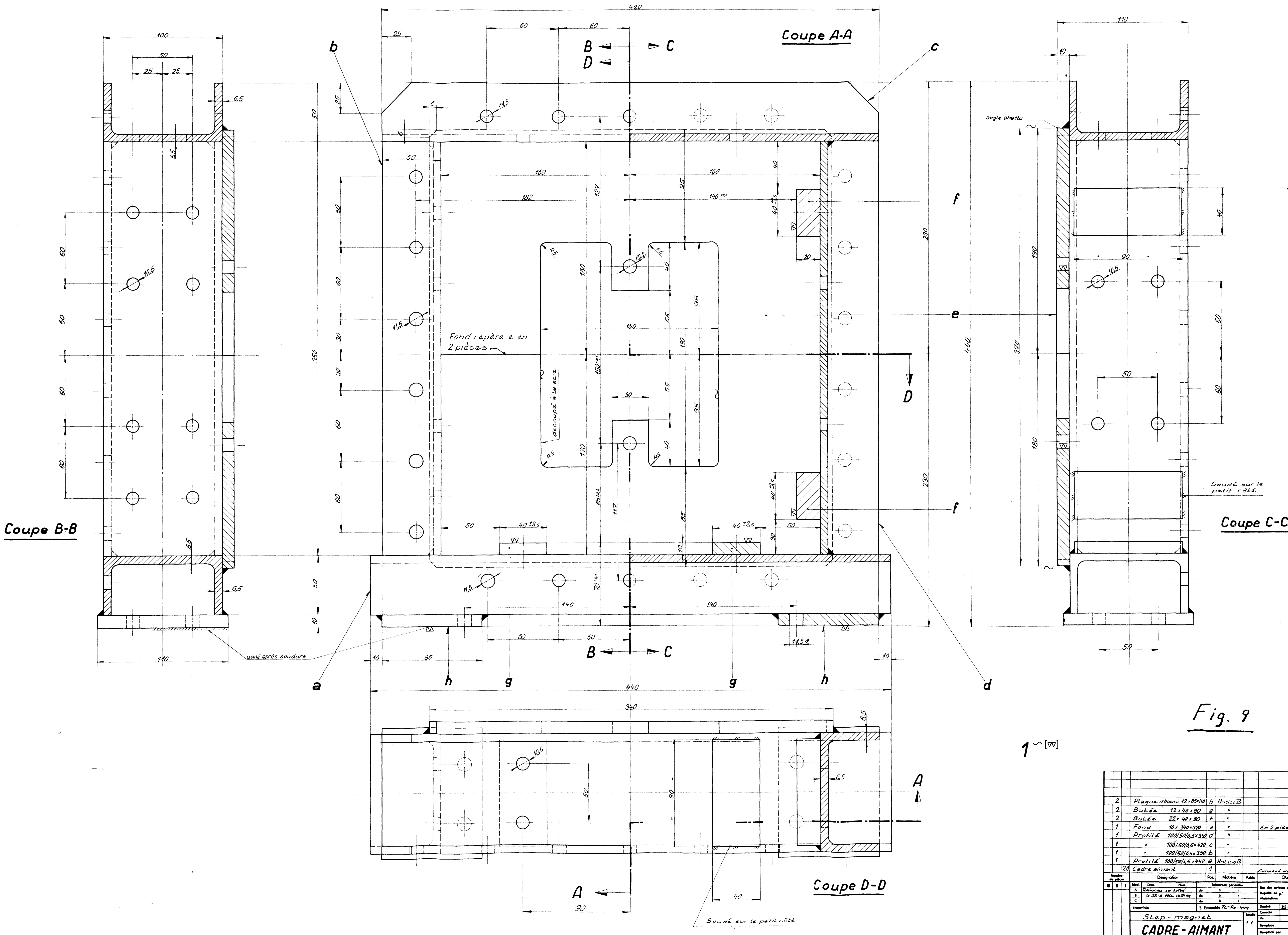

Fig. 9

Nombre de pièces III	II	I	Désignation	Pos.	Matière	Poids	Observations
	2		Plaque d'appui 12×85×110	h	Antico B		
	2		Butée 12×40×90	g	"		
	2		Butée 22×40×90	f	"		
	1		Fond 10×340×370	e	"		En 2 pièces
	1		Profilé 100/50/6,5×350	d	"		
	1		" 100/50/6,5×420	c	"		
	1		" 100/50/6,5×350	b	"		
	1		Profilé 100/50/6,5×440	a	Antico B		
		20	Cadre aimant	1			Composé de a-h soudés

Mod.	Date	Nom	Tolérances générales
A	Tolérances sur butée		de à ±
B	le 28.8.1964	Volkening	de à ±
C			de à ±

Etat des surfaces selon VSM 10 330
Rugosité en µ" VSM
Abréviations VSM 10 319

Ensemble
S. Ensemble TC-A0-444

Dessiné 22.VI.64
Contrôlé
Vu
Remplace
Remplacé par
Réduction

Step-magnet
CADRE-AIMANT
Echelle 1:1

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TC-A0-441 A

Dossier No
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Dossier No

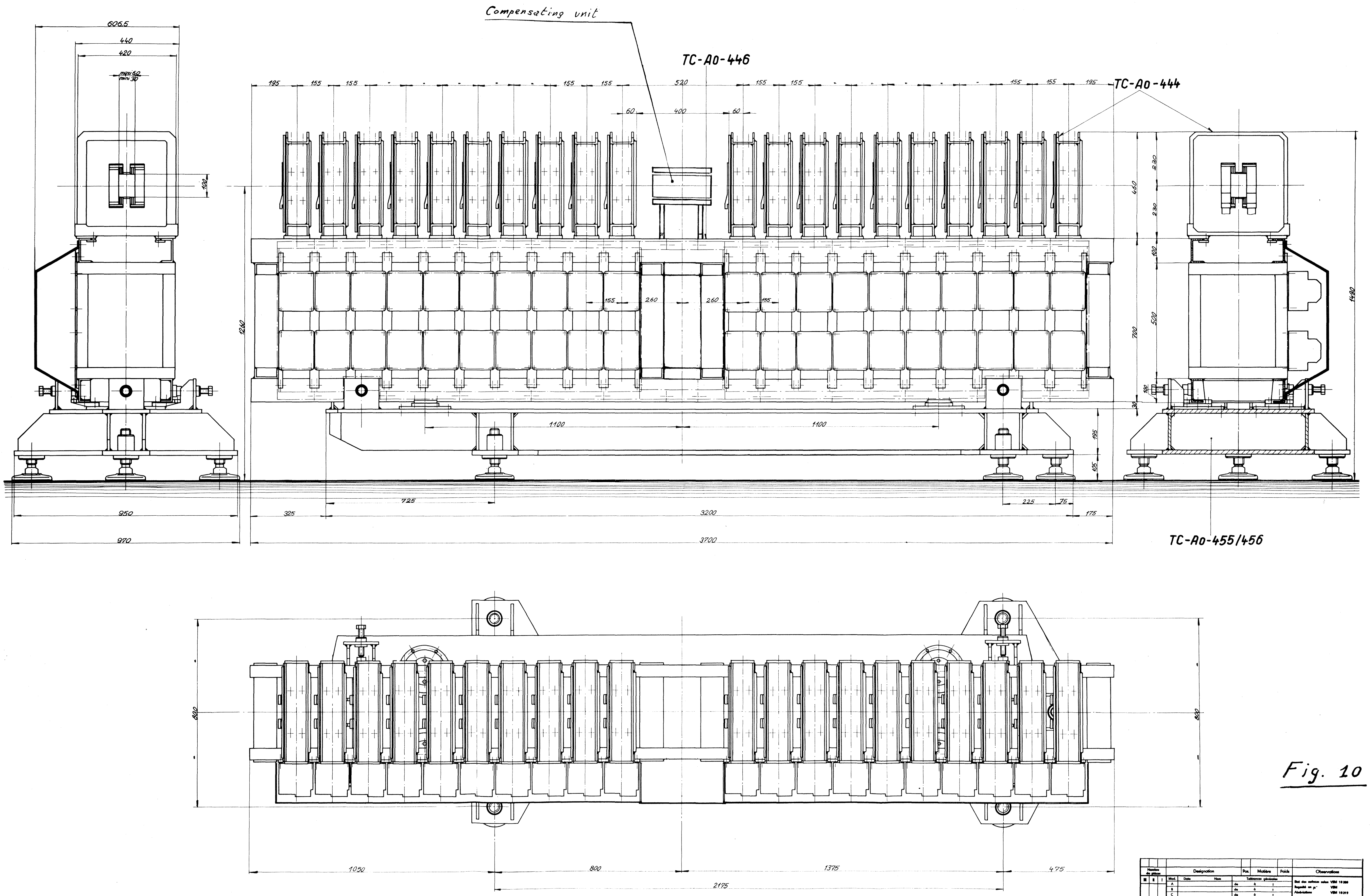

Fig. 10

Nombre de pièces			Designation		Pos.	Matière	Poids	Observations
III	II	I	Mod. Date Nom	Tolérances générales				Etat des surfaces selon VSM 10 230
			A	de à ±				Rugosité en μ VSM
			B	de à ±				Abréviations VSM 10 319
			C	de à ±				
			Ensemble TC-Ao-458	S. Ensemble				Dessiné 9.VII.64
			Step-magnet		Echelle 1:5			Contrôlé
			Ensemble avec verins					Vu
								Remplace
								Remplacé par
								Réduction
Dossier No	Dossier No	Dossier No	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE					TC-Ao-457