EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/Lab. I/PS-EA/Spec. 74-2

TECHNICAL SPECIFICATION OF THE POWER RECTIFIERS FOR SPECTROMETERS IN THE SPS WEST EXPERIMENTAL AREA

R 31 - 031

(Power Circuitry)

The 300 GeV European Accelerator (SPS) will be equipped with two large Experimental Areas, where beams of particles (normally called secondary beams) and experiments will be installed.

This specification is concerned with the D.C. power supplies (power circuitry) to feed the spectrometers to be installed in the West Area.

(July 1974)

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I. GENERAL DESCRIPTION

1. DESCRIPTION OF THE EQUIPMENT AND WORKING CONDITIONS

The layout of experiments is frequently modified and therefore requires a highly flexible modular supply system. After careful study and experience with existing experimental areas the following system has been chosen :

a) Rectifier units, with thyristors and the necessary control equipment representing the current stabilizing elements.

b) Diode units operating in conjunction with the thyristor rectifier types as voltage boosters.

The rectifier types are arranged for possible series and parallel operation.

TABLE 1

Type	Output Voltage (V) (on load)	Nominal Current (A)	No. of phases	Rectifier Primary Voltage (V)	Rectifier Transformer Rating (kVA)	Remarks
R31	355	2500	12	380	1023	Output voltage allows for 3.5% control margin
D31	284	2500	12	380	782	

The regulation and control system is required to be compatible with the various combinations of the above supplies, to offer a high degree of precision (not normally required for industrial applications), and also to be suitable for manual or computer control with different operational modes. These conditions (especially the latter ones) give rise to a rather complex electronics system. Since it would be difficult and uneconomical for a company to develop this specialized equipment, CERN has decided to design, build and test it on its own responsibility.

CERN would like that the power supplies have basically the same mechanical design features with a certain standardisation of cubicles. These cubicles will be installed in buildings constructed by CERN.

The cubicles will be placed on a false floor (1.10 m depth). The space between this false floor and ground is used for the cabling, and will also be under air pressure. The units with forced air cooling will draw cooling air from beneath and expel it upwards. The inlet air temperature varies between a minimum of + 12°C in winter and a maximum of + 32°C in summer.

The cubicles must be able to be lifted by a fork truck (Clark) and they should also be fitted with lugs for transport by crane bridge. In the power supply buildings the cubicles will rest on a structure of metal girders adequately arranged across the buildings. It is therefore necessary that all cubicles have the same depth, namely 1500 mm.

Since units will be installed side by side, components in the cubicles have to be arranged in such a way that easy access from front and rear is assured. The R31 unit with filter is composed of two 1500 mm width cubicles to permit easier transport. It would also be possible for the R31 assembly to be composed of two units of unequal width but such that the combined width was 3000 mm.

The supplies will be connected to a three-phase 380 V cable led to the units through the interspace beneath the false floor. The mains voltage may increase to 110% of nominal : this should be considered while designing the magnetic circuit of the transformers.

The d.c. output cables leave the supply at the bottom and go to the interspace below : the connections are made by means of M16 bolts.

2. EQUIPMENT TO BE DELIVERED

Each power supply consists of a heavy current part, and a regulation and control part. The latter does not belong to the equipment to be delivered : nevertheless, the manufacturer must provide the space for an electronic crate and its supporting rails in each power supply.

The equipment to be installed in the cubicles includes, in addition to the usual elements (transformers, thyristors, etc.), a few items less commonly used. Examples are :

- d.c. current transformer of very high precision and stability,
- motor-driven polarity reversal switch,
- AMP Faston terminal strips.

3. COMPONENTS AND EXECUTION

3.1. A.C. Switchgear

The cables arriving at the supply are protected by removable circuit breakers in the sub-station.

3.2. Transformers

The transformers will all be forced air-cooled and care must be taken to ensure that the temperature of the hottest spot does not exceed $120^{o}C$ (insulation class E). The transformers must be impregnated. The windings must be made of copper. In order to adapt the voltage to the load, the rectifier units will have the possibility to connect an auto-transformer to the primary. All terminals for this should be clearly marked and it should be possible to introduce easily the necessary cables. In order to have very uniform short circuit voltages, care should be taken with the power cabling. The rectifier transformers (for R units) are special in that a double primary winding is used to reduce the coupling between the two secondary windings so that the transformer behaves as two separate transformers. This reduces the mutually induced commutation notches. Furthermore, R units are intended to operate in parallel (common gate pulse generation for master and slaves). Unit to unit tolerance should correspond to a current sharing better than 10%. It should be possible in the event of a failure to remove the transformers side-ways, after removal of the side panels.

3.3. Thyristors and Diodes

The thyristors and diodes to be offered in the proposed circuit are preferably double-sided cooled disc cell types. Because of the limited space in the cubicle, a two-layer arrangement with two blowers per 12-phase circuit would seem necessary. Thyristor and diode dimensioning should take this into account. Furthermore, supplies should be able to operate in parallel with an unbalance of 10%. Under these conditions, a 450 A thyristor (120^{o} conduction angle) would be necessary for the R31 and a 450 A diode for the D31 unit. The thyristor pulse transformer and associated diodes and resistors should be mounted on a card, and the assembled card should be able to withstand a 5,000 V (50 c/s) test voltage between the primary and secondary of the pulse transformer. The RC protection circuit for the thyristors and the gate current limiting resistor values are as shown in the relevant bridge drawing.

Fast acting fuses are shown (CERN circuit diagrams) situated in the lines to the bridges (1000 A r.m.s.) to protect the thyristors and diodes. If necessary, due to i^2t difficulties, they may be put in series with the thyristors and diodes.

The thyristor with its cooling fins, pulse transformer and RC network should form an integral part which will be replaced as a whole in case of failure. Power connections to the cooling fins must be tinned.

Due to the limited number of disc thyristor manufacturers, CERN has undertaken a small survey to facilitate the selection. A list of suitable types may be obtained from CERN on request.

3.4. Interconnection with CERN Electronics

The "supply electronics" comprising essentially buffer amplifiers, amplifiers, gate control, protection and control logic, is housed in a 5 unit CAMAC crate with a 5 unit socket panel which requires front access only. Some auxiliary equipment (transformers, load resistors for mimic diagram conductors, etc.), is installed in the 6-unit power control crate. The whole assembly is furnished by CERN, the supply manufacturer has only to provide the horizontal supporting rails and profiles for vertical fixation.

3.5. Auxiliary Equipment

All fans should have ball bearings which give at least two years continuous running without requiring greasing. To reduce noise, fans should have, if possible, a 4-pole winding (1450 r.p.m.). Measuring resistors (for the mimic diagram) should be close to the bus-bars.

3.6. Control Cables, Connectors and Terminal Strips

The control cables should be of flexible conductors, and the wire ends should be crimped. AMP Faston wire connections to terminal strips should be properly protected.

3.7. Mechanical Parts

The cubicles should have a robust frame suitable for crane and fork lift transport. The front and rear doors should be made out of steel sheets with suitable reinforcements. The cubicles should have easily-removable side covers (no doors). All doors should open and close easily and all units, even of different types, should have the same locks and keys. The 380 V a.c. and the d.c. output terminals, as well as the AMP terminal strip, should have plexi-glass covers. The front doors of the cubicles should have plexi-glass windows. A good quality of paintwork (to be approved by CERN) is required. All frames and doors should be earthed. Power cables must have PVC or equivalent protective covering. All input and output power terminal studs, and internal link studs must be fixed to prevent their loosening in time due to frequent connection and disconnection. All bus-bars and cables must be made of copper. All elements such as thyristors, diodes, fuses, resistors, fans, and transformer terminals should be marked according to the circuit diagram references. The system of marking must be approved by CERN.

II. DETAILED SPECIFICATION

1. SPECIFICATION FOR RECTIFIER UNIT TYPE R31 AND DIODE UNIT TYPE D31

The R31 power supplies are 12-phase rectifier sets consisting of two 3-phase bridges connected in parallel through an interphase transformer. The two bridges are fed from star/delta transformer secondary windings which are 30° phase shifted (see drawing EA-8083-4161-1).

A current balance system between the bridges uses a Hall plate in the air gap of the interphase transformer, which acts on the gate control set in such a way that the d.c. flux is minimized.

The R31 units are equipped with a motor-driven polarity reversal switch with several position-indicating contacts.

Incorporated in the R31 rectifier is a LC passive filter.

The d.c. output current is measured by a d.c. current transformer.

The transformers and the thyristor and diode bridges are forced air cooled.

The 12-phase diode rectifier type D31 is composed of two 30^{o}-phase shifted, 3-phase bridges as shown in drawing EA-8083-4167-3. It is used in series with R31 rectifiers in order to boost the voltage sufficiently for higher voltage magnets.

Complete information regarding units is given in CERN drawings and the accompanying part lists.

Part List and Component Specification

Part No.	Qty.	Description	Type R31	Type D31	Remarks
1	1	Removable circuit breaker (with safety interlocks)	1500	1000 A	Installed in low voltage distribution and therefore not included in the delivery
2	9	Fuses for 3-phase auxiliary circuits and transformer protection networks.	25 A		
3	1	Auxiliary mains switch (380 V)	25 A		
4		Blowers for forced air cooling 220 V, 50 Hz (4-pole motor preferably).	2 for transformer 2 for thyristors or diodes 1 for filter choke		(according to arrangement)
5	1	Rectifier transformer			
		Cooling :	forced air	forced air	
		Rating : (kVA)	1023	782	
		Primary	380 V two separated delta windings.	380 V open delta	
		(+ 10%) line voltage (- 0%)	Star/Delta as shown in drawing		
		Secondary			
		Current (I_2) (A) } Star Winding	1020	1020	Accuracy of Star/Delta ratio < 0.5%
		Phase to neutral voltage (U_2) (idle) (V) } Star Winding	167	130	
		Short circuit volt. 5% to 6% copper losses max.	12 kW	10 kW	

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
6		AC current transformers 15 VA current quantity	 1000:1 A 4	 - 	Precision class 1%
7	1	Links for Star/Delta connection of the primary windings 380 V quantity current (A)	 - 	 3 700	
8		Quantity Three-phase bridge with RC network and pulse transf. Average current for 120° conduct angle (A) Repetitive blocking and inverse voltage (V) (safety factor $\approx$ 2.5 included) (dv/dt) 50% U_{DRM} (V/µs)	2 thyristor see dwg EA 8083-4166-3 416 $\geq$ 1040 $\geq$ 100	2 diode see dwg EA 8083-4166-3 416 $\geq$ 800 -	In D31 the pulse transformer does not exist 450 A type to allow for parallel connection of units
9		Quantity Free-wheeling diodes with RC network, double-sided cooled disc cell type. Average current for 180° conduct. angle $\geq$ (A) Repetitive inverse voltage : - (A)	2 500 2000	- - -	

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
10	1	Interphase trans. current	1250 A	-	
		Equivalent 50 Hz r.m.s. voltage $2\left(\sqrt{3}/2 \sin \pi/2\ (1 + \sqrt{3}/2)\right) U_2$ (V)	2 x 70	-	
		B_{max} = 0.9 T, Air gap adjusted to magnetizing current : 50 Hz (A)	60	-	
		at nominal voltage, but $\delta/2 \geq 1$ mm to permit Hall plate introduction. Copper losses max.	2 kW	-	
11	1	DC current transformer			Delivered by CERN dimensions : 300 x 350 x 300 mm weight ≈ 70 kg
		Output voltage : (V)	10		
		At. current : (A)	2500		
		AC supply 200 V, 50 Hz			
12	4	10 A, 500 V fuses (DC measurement)	X	-	
13	1	Commutator for polarity reversal. Motor driven, 3-phase 380 V with auxiliary contacts showing the positions normal, inverted, zero (open) and between zero and normal.			Suggested manufacturer : W. Berg, Käfertalerstr. Mannheim, W. Germany
		No. of contacts per pole :	5	-	

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
14		Terminals Quantity = AC (M16 bolts) DC (M16 bolts)	 3 x 3 2 x 5	 3 x 2 2 x 5	
15		Separation links with position microswitches Quantity	 2	 -	For shorting bars if no D31 connected
16	3	Removable links for introducing a stepping transf.	 X	 -	
17	4	Circuit breakers (protection) with overload and short-circuit release. Earth protection Electronics Blower Polarity rev. switch	 0.1 ÷ 0.14A 1 ÷ 1.5 A 1.5 ÷ 2 A 0.25÷ 0.35A	 - - - -	
18		Red lamp (neon) with series res.	 1	 3	
19	1	Transformer, primary 380 V, 50 Hz secondary 220 V, 5 A single phase	 X	 -	
20	1	Contactor 20 A, 220 V, 50 Hz, coil	 X	 -	
21		Basic load resistor Quantity Resistance Power Free air dissip. to be installed under the thyristor cooling duct.	 2 330 Ω 1500 W		

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
22		Protection resistors 2 x 270 kΩ (1,5 W) in parallel to be attached at the measured point. Quantity	18		Preferable moulded epoxy resin with 2 angle pieces at the end and AMP spade at the centre
23	1	Power control crate type	U7506	-	Delivered by CERN
24		Terminal strip. Fast-on 6.3 mm (quadruple lugs) Quantity for : TSA TSB TSC TSD Total	15 15 35 70 115	20 20	Suggested manufacturer : Entrelec, Lyon, France TSE is installed in the power crate delivered by CERN
25	2	Thermal contacts (normally closed). 2.5 kV isolation mounting surface/contact For thyristors/diodes > 95°C For rect. trans. > 112°C	 X X	 X X	
26	1	Delay circuit for zero voltage release (≈ 100 ms)	-	X	
27	1	Emergency off button	X	X	

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
28	1	Relay with delay make ($\overset{\sim}{<}$ 1 s) input 220 V ac	-	X	
29	1	Resistor 220 Ω, 100 W with adjustable tap	-	X	
30	1	Commutator 6 A, 2-pole	-	X	
31	6	Fuses for thyristors (diodes) 300 V with auxiliary contact normally closed	1000 A	1000 A	(2 fuses in parallel). Fuses must protect the thyristors. If it is not possible with fuses in the lines then fuses in series with each thyristor (12) should be foreseen
32		Flexible jumpers to interconnect the D31 unit to the R31 unit	-	2 x 1250A 1 x 2500A	
33	1	Filter choke	200 µH (2500 A)	-	Maximum losses = 2 kW
34	1	Metal paper condenser bank (850 V)	C_1 = 0.5 mF	-	The residual a.c. voltage (600 Hz) after the filter is about 30 V (r.m.s.).
35	1	Metal paper condenser bank (850 V)	C_2 = 2.5 mF	-	
36	1	Damping resistor 0,58 Ω	X	-	Free air dissipation = 5 kW

Part List and Component Specification

Part No.	Qty.	Description	Type		Remarks
			R31	D31	
37	2	RC protection circuit across transformer Secondary	R_1 ≒ 3.3 Ω (10 W) R_2 ≒ 82 kΩ (10 W) C_1 ≒ 25 µF (850 V) F_1 = 25 A (500 V)	- - - -	Auxiliary diode bridge D1 $V_{rrm} \geq$ 1100 V $I_{FAV} \geq$ 20 A F_1 included in Part No. 2
38	1	Filter protection fuse	200 A 1000 V	-	Filter inrush current ≒ 1000 A (τ ≒ 1 ms)

3. MECHANICAL ARRANGEMENTS

The suggested arrangements are shown in CERN drawings. The R31 supply assembly must be contained in a volume of 3000 × 1500 × 2300 mm with access by doors from front to rear. (This is made up of two units of preferably 1500 mm width - see General Description -).

Power interconnections between the two parts of R31 need not be flexible since the two parts will be bolted together on site. The control cables should not be "interfaced" by a terminal strip but should pass between units and be coiled up inside one unit for transport.

The D31 supply will be housed in a 1500 × 1500 × 2300mm cubicle. Connection between the R31 units and the D31 unit will be as shown in drawing EA-8083-4061-1).

The cubicle should be covered on the top by a grid.

The lower parts of the transformers are enclosed in an air-tight box, which is put under over-pressure by a fan. The air forced through the ventilation slits of the transformer windings provide a very efficient cooling. The front and rear panels of the air-tight box should be easily removable for cleaning purposes. Convection cooled, high temperature insulated transformers will not be accepted.

III. TESTS

(Values for the various tests to be found in the component specification).

1. TESTS TO BE CARRIED OUT IN THE FACTORY

CERN requires the following tests to be carried out in the factory :

a) Transformer and interphase transformer tests (separately)

- Isolation : 3 kV, 50 c/s for one minute between all windings and between each winding and the core.

- In rectifier and diode units : the ratio of the voltages of the transformer secondary windings should be accurately measured (star/delta).
- The short-circuit voltage on all phases should be measured and short-circuit voltages between the secondary windings.
- The iron and copper losses should be measured.
- The copper temperature (hot spots) should be measured after a 3 hours run at full current.

b) Cubicle tests

- CERN will supply the power control crate and the cable terminal strip/socket panel for each rectifier unit and one set of the necessary electronics. A representative from CERN will supervise the tests as follows :
  - Cable check
  - System test at low current
  - Test of the power circuitry at full load current including a "temperature run" of several hours for the first units of each type, and one hour for the following units.

The manufacturer should undertake to supply the following, for the above testing :

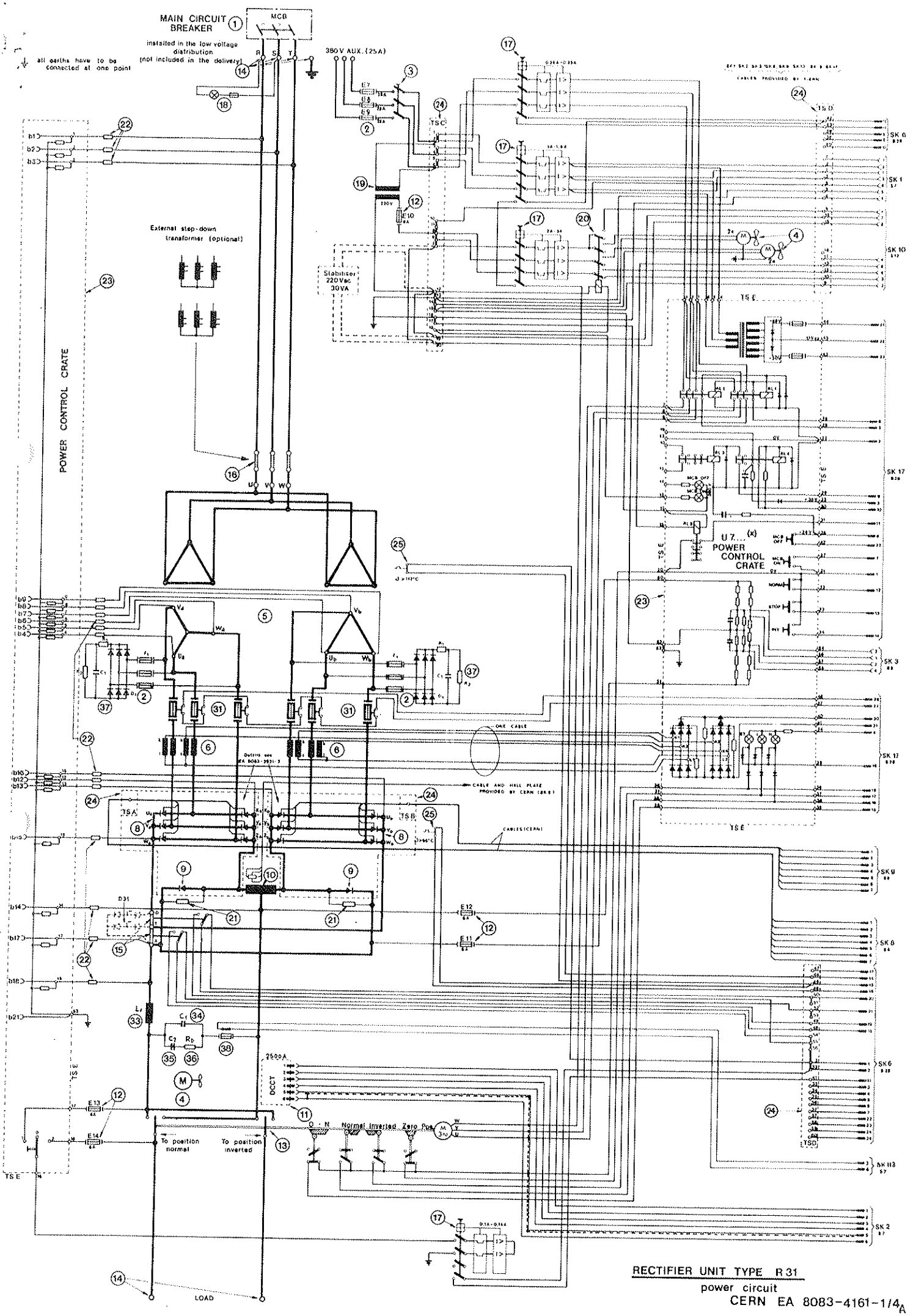
- Differential oscilloscope
- Voltmeters and Ammeters
- A load (approx. 50 V, 2500 A, with a time constant of approx. 10 ms)
  (A pure resistance of 20 mΩ in series with a filter choke (0,2 mH) gives a time constant of 10 ms)
- A stepping transformer to adapt mains capability for full current test
- A three-phase roller transformer in order to perform initial tests at low voltage and current.

The manufacturer should also during these tests delegate to the CERN representative a competent person to effect any changes due to defects and generally to assist with the testing.

2. PROVISIONAL ACCEPTANCE TESTS

After completion of successful factory tests, units shall be delivered to CERN site where provisional acceptance tests will be carried out by CERN personnel. These tests will include :

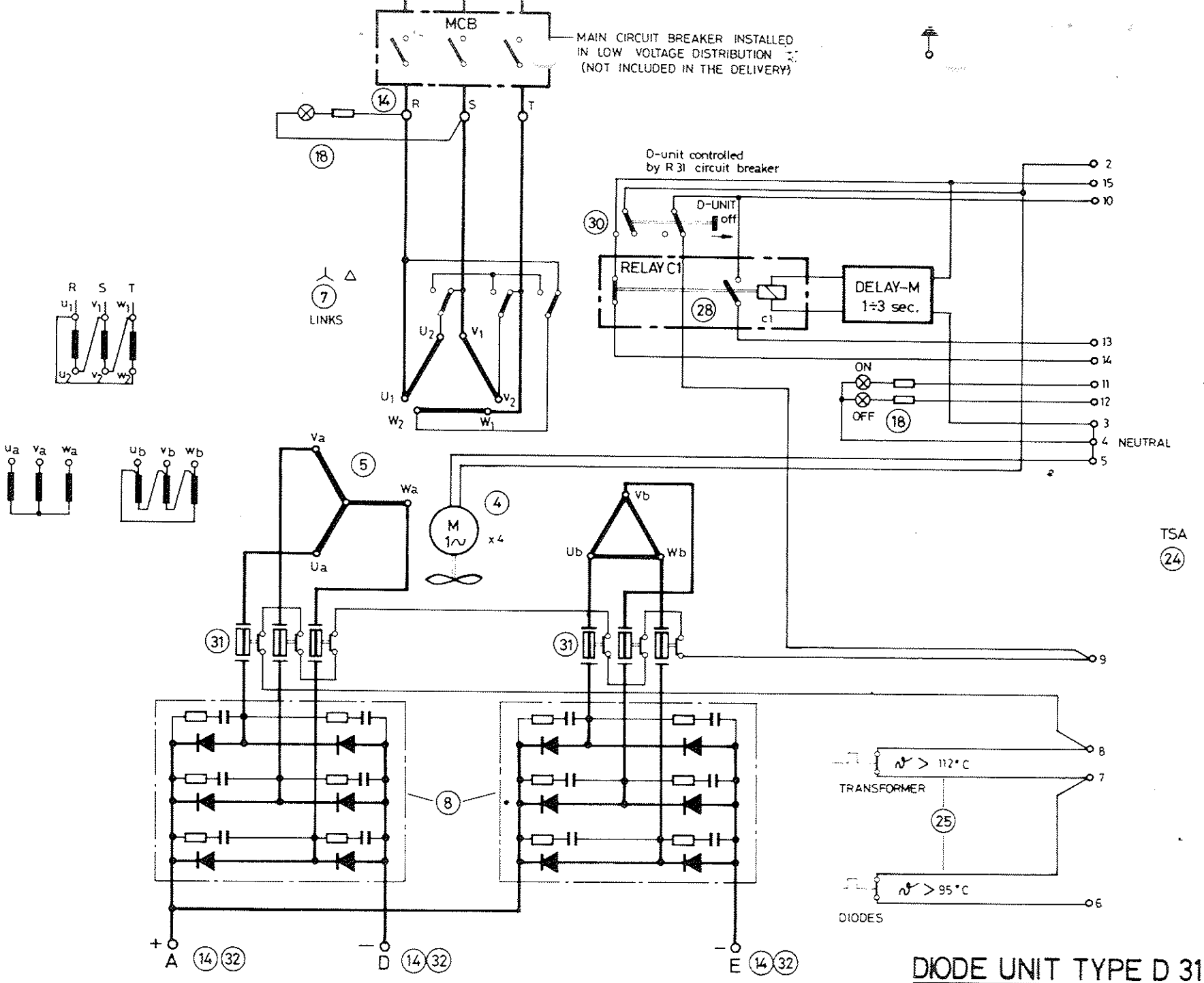
- Mechanical inspection
- A 24-hour run at nominal ratings using the supply electronics. This test will be carried out within six months of delivery.



RECTIFIER UNIT TYPE R 31

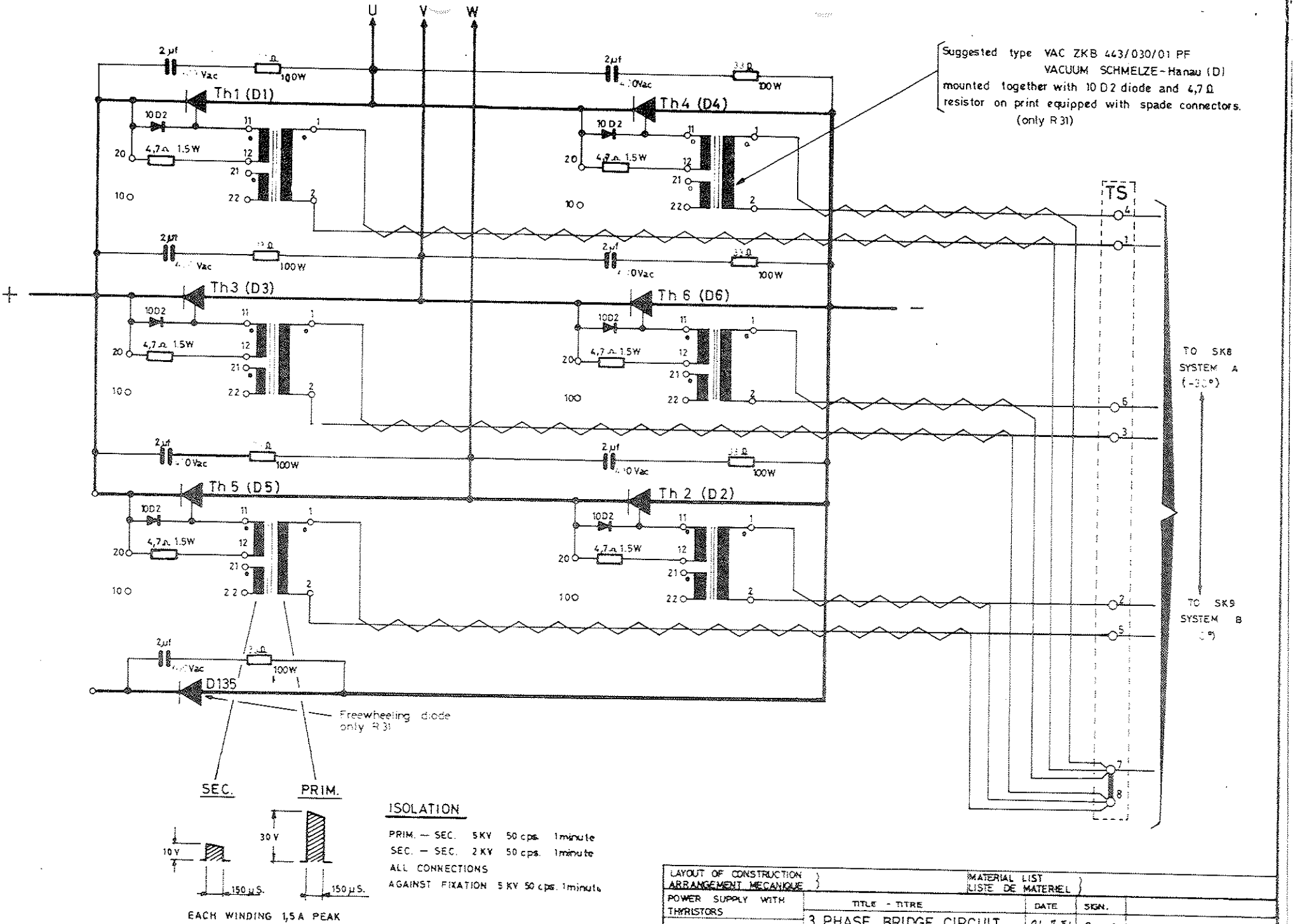
power circuit

CERN EA 8083-4161-1/4$_A$



DIODE UNIT TYPE D 31 POWER CIRCUIT

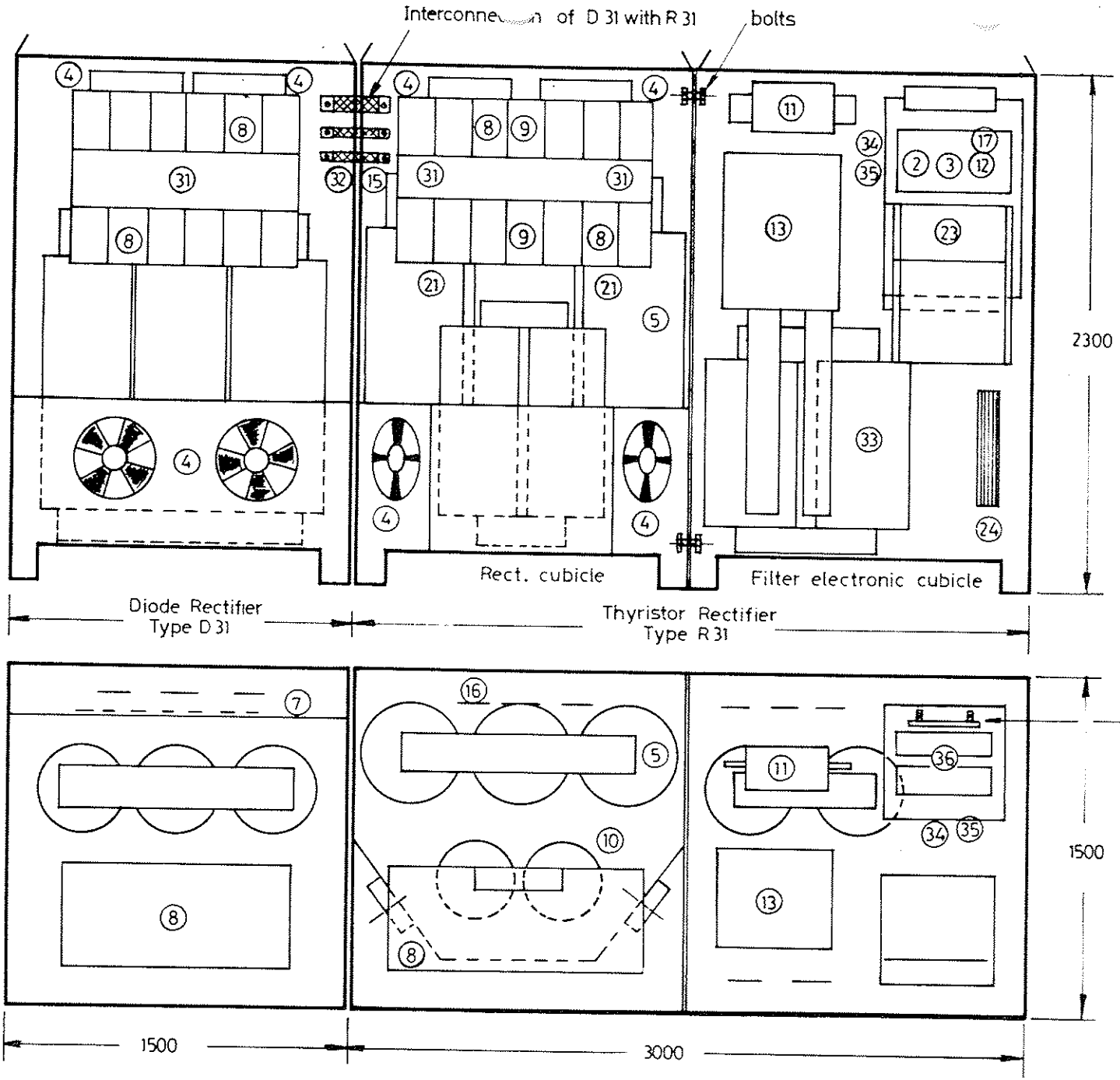
CERN EA 8083-4167 - 3/4



ISOLATION

PRIM. — SEC. 5 KV 50 cps. 1 minute
SEC. — SEC. 2 KV 50 cps. 1 minute
ALL CONNECTIONS
AGAINST FIXATION 5 KV 50 cps. 1 minute

LAYOUT OF CONSTRUCTION ARRANGEMENT MECANIQUE		MATERIAL LIST LISTE DE MATERIEL		
POWER SUPPLY WITH THYRISTORS	TITLE - TITRE	DATE	SIGN.	
CERN - EA	3 PHASE BRIDGE CIRCUIT FOR R 31 AND D 31 RECT.	24-7-64	PIZOT	8083 - 4166 - 3/4



Type R 31 consist of two 1500 x 1500 x 2300 mm cubicles (to facilate transport and simplify frame work) bolted together after installation

Doors: Front and rear
750 mm wide

Facility to extend C-bank externally (cable connections)

THYRISTOR UNIT TYPE R 31
AND DIODE UNIT TYPE D 31
mechanical layout
CERN EA 8083-4168-4

25-7-74 PIZOT R.