KDM/sz

MPS/SR/Note 71-15
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HIGH VOLTAGE FAST RECHARGING PULSED

POWER SUPPLY FOR MSC KIM-COIL

K.D. Metzmacher

Contents

Distribution:

A. Susini, MSC
D. C. Fiander
D. Grier
U. Jacob
P. Pearce
G. Plass
P. H. Standley

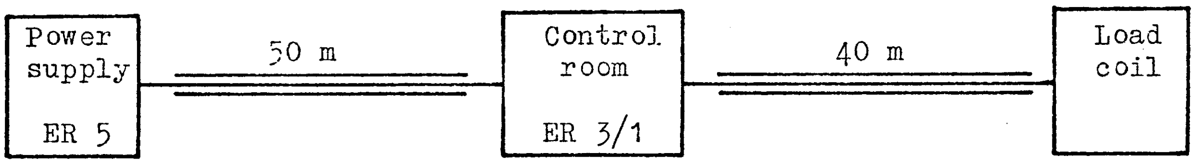
1) Requirement of MSC

Equipment is required which essentially provides a certain current in a load inductance in a certain time. The current waveform anticipated is of an underdamped sinosoidal shape. The current should rise to a value of 1000 amperes in about 0.6 μsecs in an inductance of ca. 6 μH. The damping should be such, as to limit the negative current amplitude to about 10 % of the positive current peak.

The equipment is to be operated at a nominal repetition rate of 500 Hz (max. ca. 600 Hz).

Interlock facilities, voltage and current display and pick-up points should be provided.

The space configuration in the MSC is such, that there are about 50 metres between an existing HV dc power supply (in ER 5) and the control room (ER 3/1) in which the switching and control equipment will be housed. The load inductance will be about 40 metres from the CR, such that:



2) Low voltage model, technical proposal and description of equipment

A low voltage model in the current scale of 1 : 500 was built and studied, the results of which are given in an appendix in terms of voltage and current waveform. These shapes should give a very good approximation to the real full scale circuit waveforms.

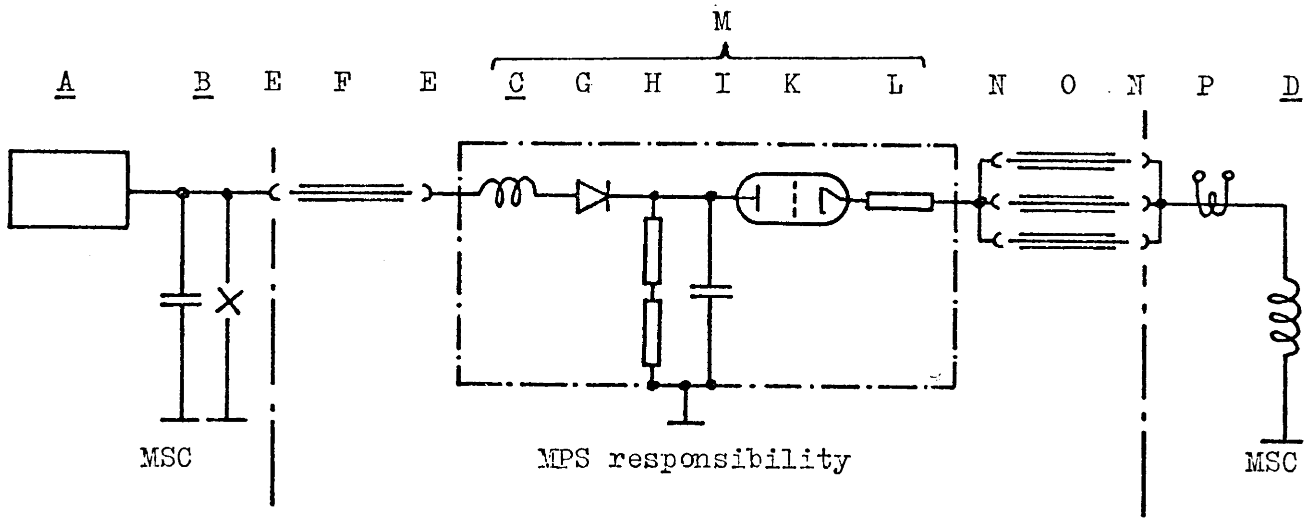
However, owing to the effect of the presence of a less than ideal switch and a transmission line in the circuit, there is a slight discrepancy in absolute terms between theoretical prediction and the scaled up practical case.

It should be noted, that (because current reflections are set up in the transmission line) the current transformer for monitoring and measuring purposes must be placed either between the transmission line and the load coil or in the coil earth return path to give the actual current in the coil.

Allowing for the above, the following technical proposal can be made:

It is proposed to make use of fast resonant charging. A capacitance, resonantly charged in a time dictated by the highest expected operating frequency, will be discharged into the load inductance through a damping resistor via a triggered thyratron.

The scheme as proposed is given in diagrammatical form below.



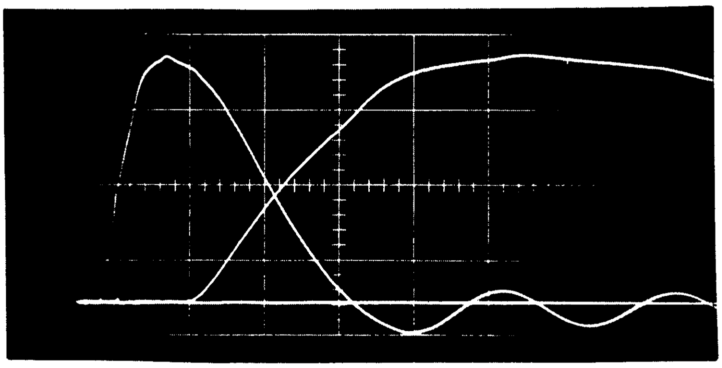
schematic diagramm of electrical equipment

A : regulated dc power supply
B : 40 μF capacitor bank with safety switch
C : charging inductance EAB 2H
D : load inductance
E : Seifert 150 kV sockets
F : 50 m Philips (x-ray) cable with plugs
G : 5 diodes UDA 10
H : voltage divider for monitoring, measuring, interlock purpose
I : capacitor bank (100 nF) LCC
K : Thyratron EEV CX 1154 plus auxiliary equipment
L : damping resistor (10 Morganite IΩ discs)
M : metalwork to house G to L plus oil cooling plant
N : Lemo sockets HT 50
O : 3 X 40 m Sterling 30 Ω cable in parallel with Lemo plugs HT 50
P : current transformer for monitoring, measuring, interlock

3) Anticipated performance

The most appropriate way of defining performance in this case is in terms of the current shape in the load coil.

A possible waveform which could be achieved is shown in the figure below.



Current in the load coil,
timebase: 1 μs/div and 200 ns/div

However, the exact shape will depend on the length of transmission cable necessary and the characteristics of the actual thyratron switch.

The power dissipation of the equipment will be in the order of 10 kW, thus a forced flow oil cooling system becomes necessary.

4) Responsibilities

It is agreed to split up the responsibilities for the manufacture of the proposed equipment between the MSC Division and the MPS/SR/FAK section in a manner that

I) the MSC Division is responsible for the provision and proper functioning of

A) a regulated dc power supply able to provide a continuous current of ca. 2 amperes at a tension of up to 14 kV, connected to

B) a high voltage capacitor bank (20 kV, 40 μF) with safety switch (crow-bar).

C) a high voltage choke EAB of 2H inductance, 3 A peak current, 1,5 A continuous current, isolation to ground 30 kV, isolation between ends 20 kV, oil insulated, dc. resistance $\leq$ 100 Ω

D) the load inductance of ca. 6 μH.

Furthermore, the MSC division is responsible for the mounting of the H.V. sockets on either end of their equipment and the accommodation of the current transformer near the load inductance, and the installation (wiring up, etc.) of the total equipment on their premises. The sockets and current transformer will be provided by MPS/SR/FAK.

In addition, the MSC Division provides the total financial commitment necessary in terms of material and labour costs for the complete equipment.

II) The MPS/SR/FAK section will be held responsible for achieving the agreed performance of the equipment in terms of current in the load inductance and of designing, ordering, manufacturing and commissioning of the rest of the required equipment (i.e. equipment items E - P).

5) Cost estimate

The cost estimate for the technical proposal for which the MPS/SR/FAK section is responsible is summarised below. A breakdown of these items can be found in an appendix.

	in 1000 SFr.	
1. Oil circuit	7.0	
2. D.C. cable	8.1	
3. Pulse cable	6.3	
4. Diodes	0.6	
5. Capacitors	3.0	
6. Current transformer	1.2	
7. Resistor	1.9	
8. Voltage Divider	0.8	
9. Tank	5.4	
10. Thyratron	11.5	
	45.8	
contingencies 5 %	2.3	48.100 SFr. total

We think that this is a realistic estimate. The total includes the price of manpower needed to prepare the equipment for final installation, but does not include wiring up of interlocks or connecting water pipes for the HE etc., which has to be carried out by MSC.

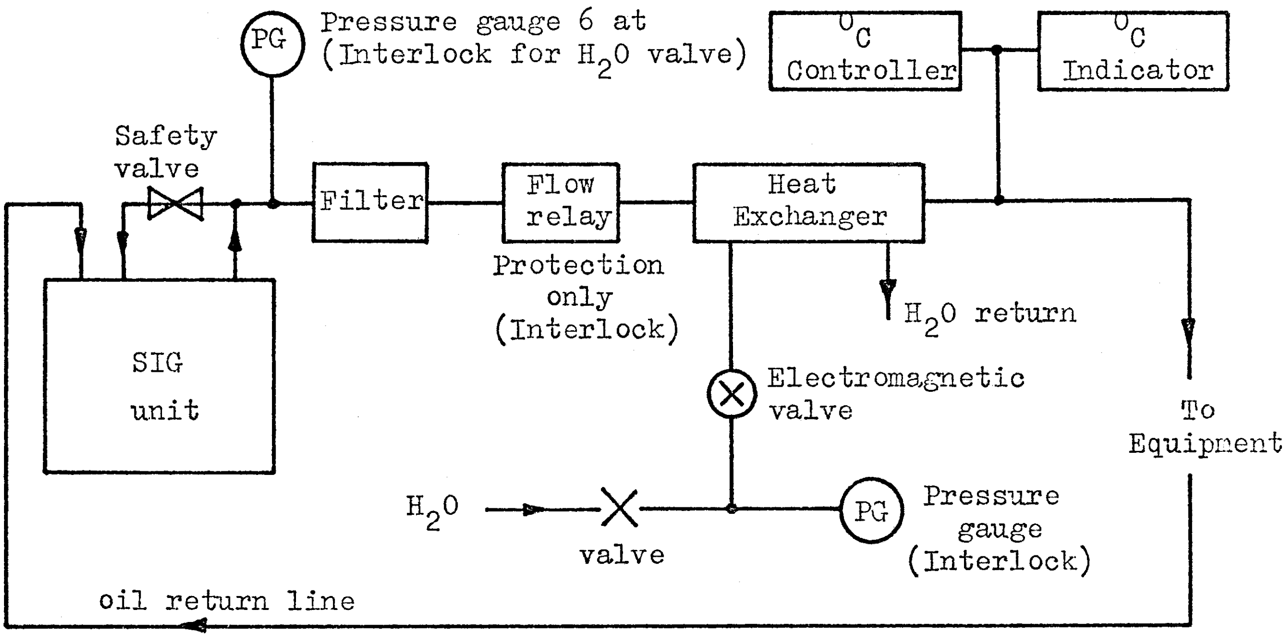
6) Authority

Before the work proper on the full scale project can commence, authority must be given to the MPS Division by the MSC Division, covering the entire costs of the project as outlined above, together with a valid job number to permit withdrawals from CERN stores and the placing of outside orders.

A P P E N D I X

Estimate for MSC Equipment

Oil circuit:



Schematic diagramm of oil circuit

	SF.	
S. valve (TIMEUS)	350	
SIG unit (SIG)	2100	
Filter (BREMSTECHNIK)	700	
Haenni press gauges (HAENNI)	300	
Flow relay (HONEYWELL)	200	
Temp. controller (ETHER)	370	
Heat exchanger (ALFO-LAVAL)	2000	
E.M. valve (STORES)	50	
Pipework (labour + material)	700	
Temp. indicator (HAENNI)	250	
	7020	Say 7000

	SF.	
D.C. cable and sockets:		
2 sockets PHILIPS	600	
50 m cable (150 kV) PHILIPS (SEIFERT)	7500	
		8100
Pulse cable and sockets:		
(120 m) 3 x 30 ohms STERLING pulse cable	3000	
6 LEMO sockets + plugs	3000	
Assembly	300	
		6300
Diodes:		
5 x UDA 10 (UNITRODE)	600	
		600
Capacitors:		
15 x 10 nF, 40 kV ??	3000	
		3000
Current transformer:		
Pearson 411	1200	
		1200
Resistor:		
* MORGANITE discs	350	
* Washers	800	
Metalwork etc.	750	
		1900
Voltage divider:		
Resistors (CERN)	220	
Capacitors (HYDRAWERKE)	150	
Mechanical	300	
Assembly	150	
		800

Tank:

	SF.	
Box	1000	
Lead throughs	150	
Silica gel + valves	100	
Temperature indicator	150	
Oil	2400	
Assembly costs	800	
Internal metalwork	800	
		5400

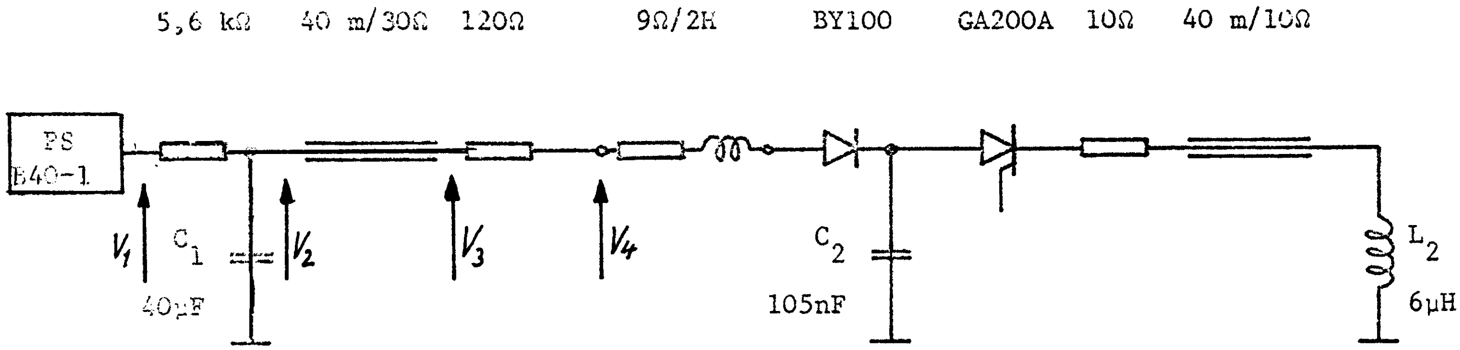
Thyratron:

Thyratron tube CX 1154 (EEV)	4000	
Isolating Tx (EAB)	250	
Heater Tx. (EAB)	70	
Res. Tx. (EAB)	50	
Grid Tx. (EAB)	30	
Trigger Tx. (CERN)	300	
Plugs & sockets (JAEGER)	70	
Filter block (CERN)	50	
Faraday cage (excl. Tx's) (CERN)	700	
Insulators (ROSENTHAL)	60	
Protective cover for Faraday cage with filter & fan	280	
Trigger pulse generator + amplifier & PS	1000	
Stabilizer (PHILIPS)	1000	
Variable delay unit	150	
Pulse generator	150	
Control rack + chassis material	350	
Preset counter	500	
Voltage /time conversion & display	2000	
Delay unit	100	
Rack wiring	400	
		11510

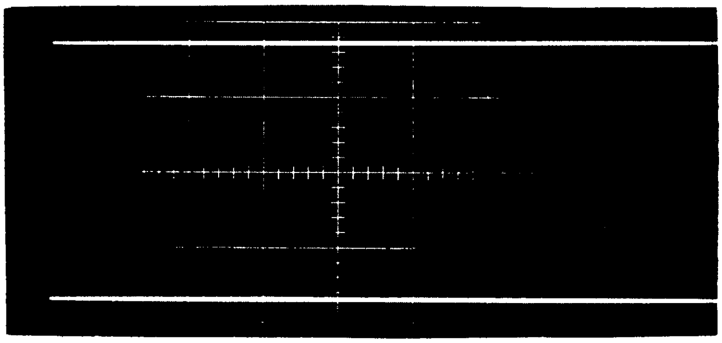
APPENDIX

Low Voltage Model

The purpose of this appendix is to illustrate the various voltage and current waveforms at different positions in the model circuit during normal operation. The waveforms are representative for the full scale circuit, the upscaling factor being ca.500 for voltages and currents alike.



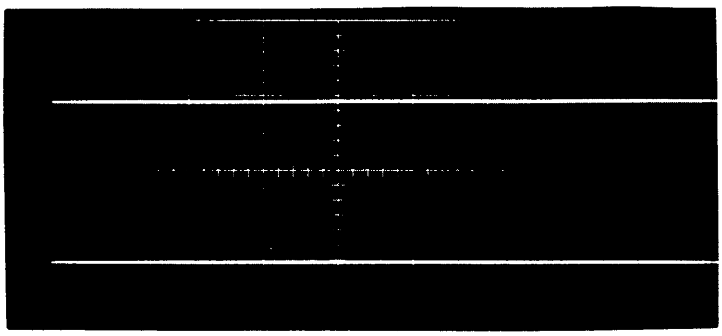
Voltages and currents in primary circuit



$V_1 \cong 34$ V

10 V/div

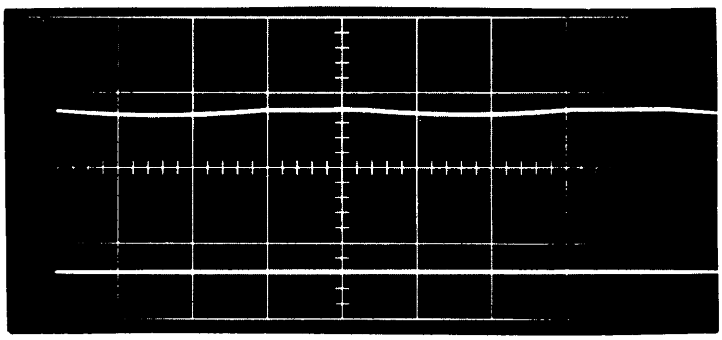
500 μs/div



V_2, $V_3 \cong 21$ V

10 V/div

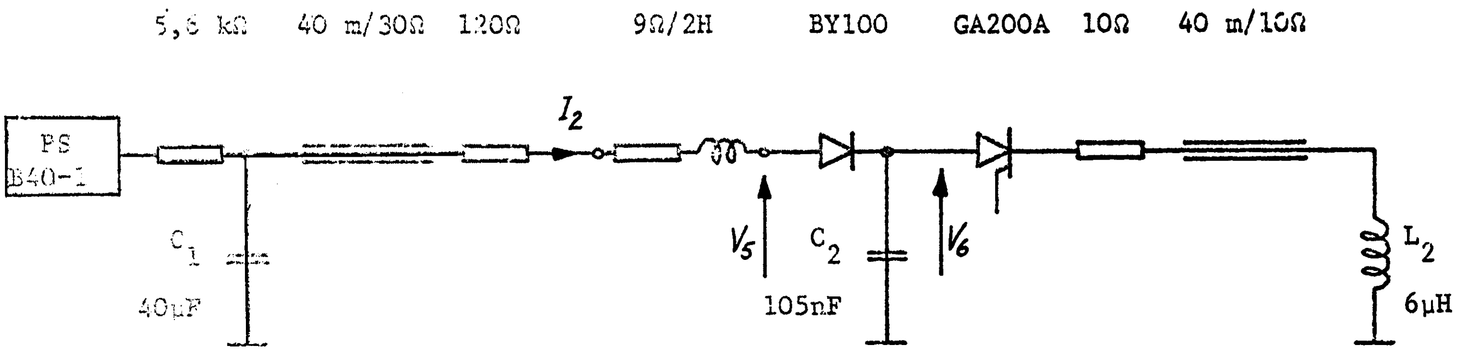
500 μs/div



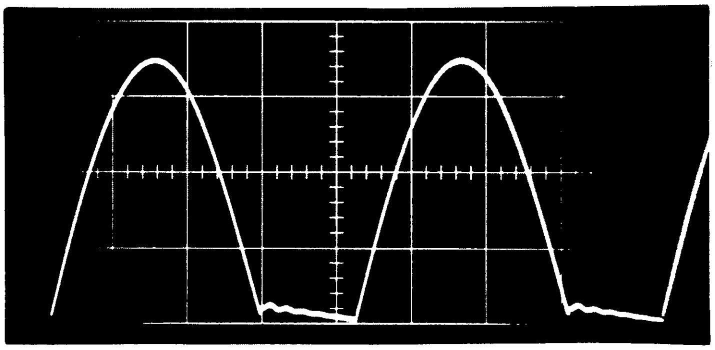
V_4

10 V/div

500 μs/div



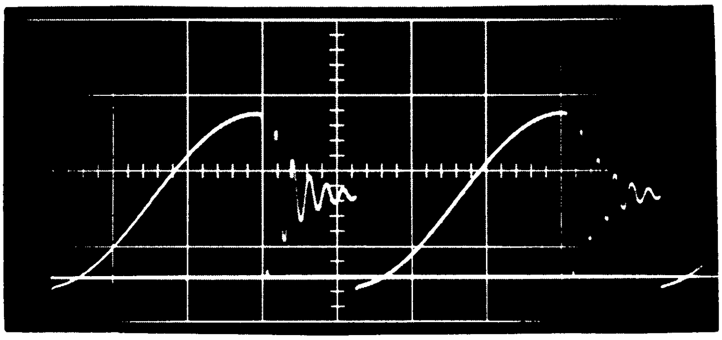
Voltages and currents in primary circuit



I_2

1.665 mA/div

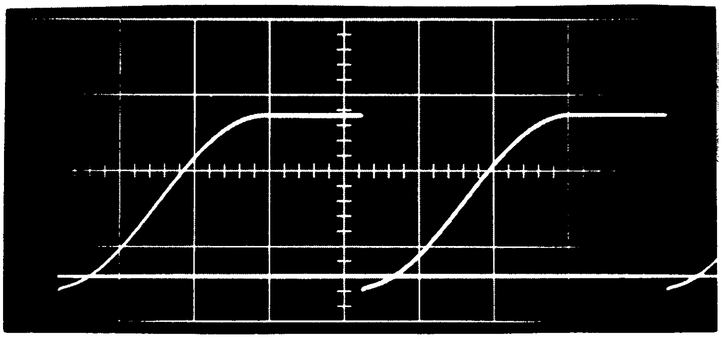
500 µs/div



$V_5 \cong 42$ V

20 V/div

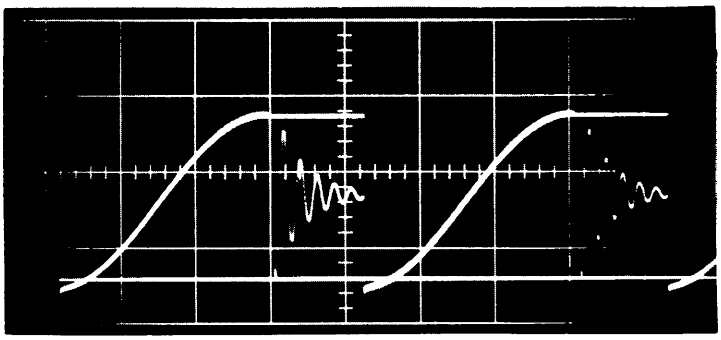
500 µs/div



$V_6 \cong 41.4$ V

20 V/div

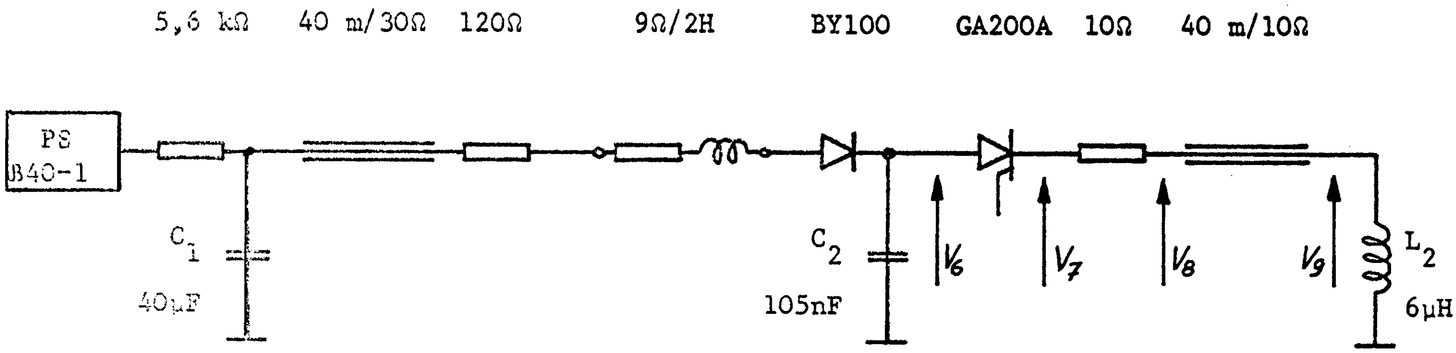
500 µs/div



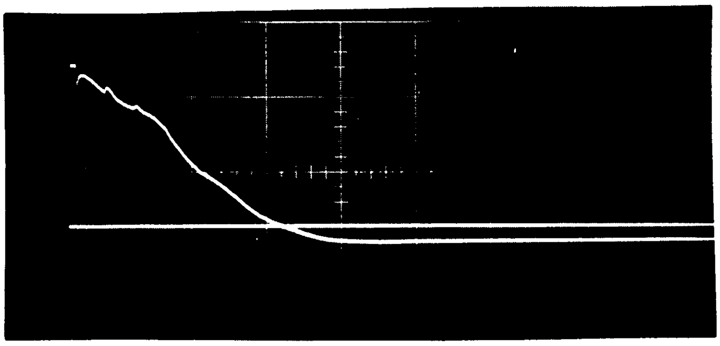
V_5, V_6

20 V/div

500 µs/div



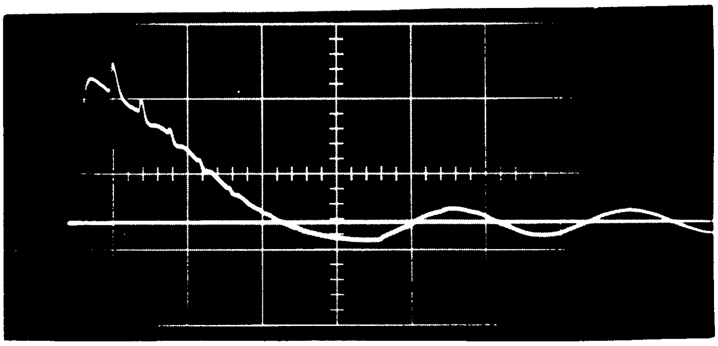
Voltages in secondary circuit just after t = 0



$V_6 \cong 41.4$ V

20 V/div

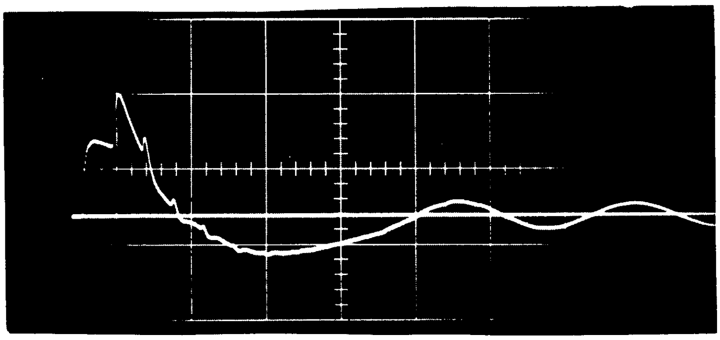
1 μs/div



V_7

20 V/div

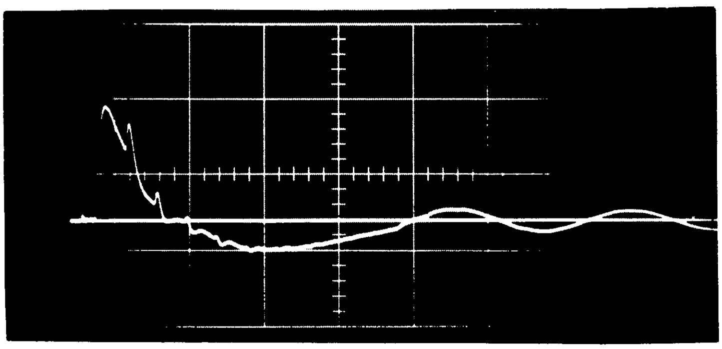
1 μs/div



V_8

20 V/div

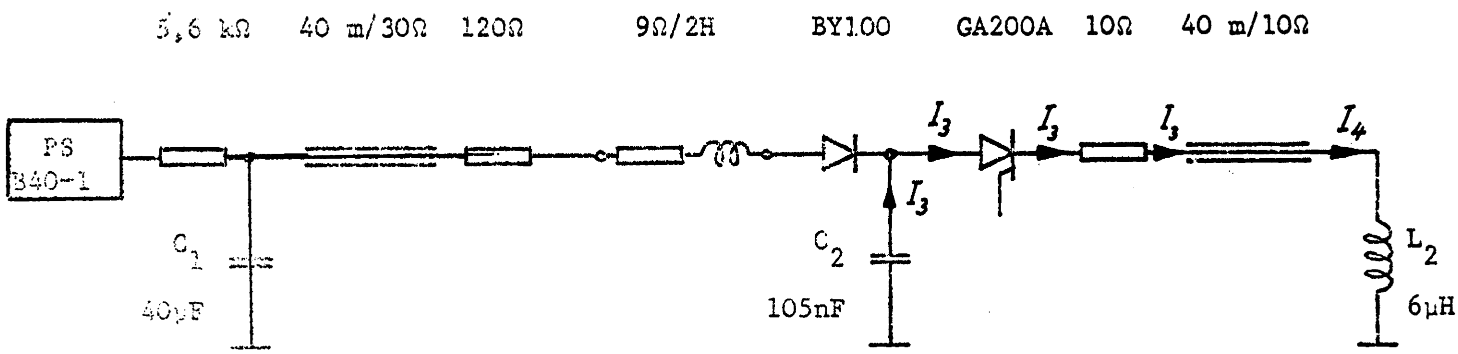
1 μs/div



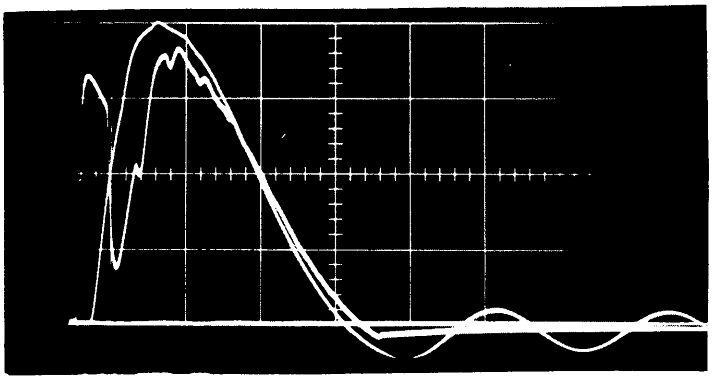
V_9

20 V/div

1 μs/div



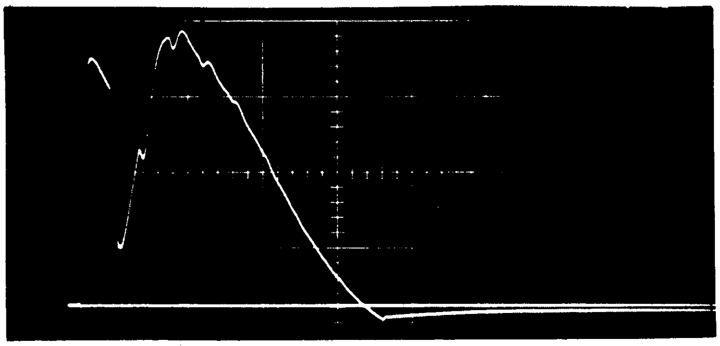
Currents in secondary circuit just after t = 0



I_3, I_4

537 mA/div

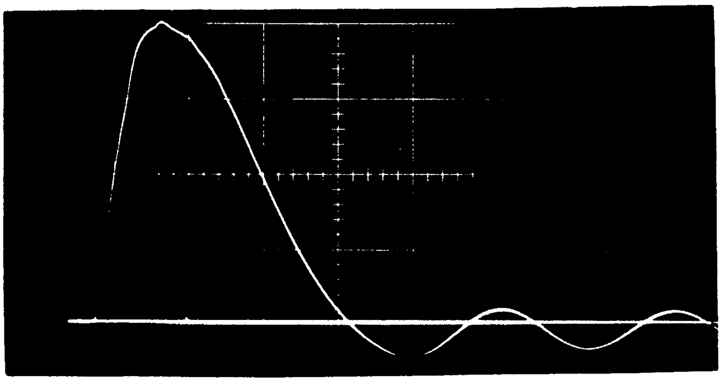
1 μs/div



I_3

537 mA/div

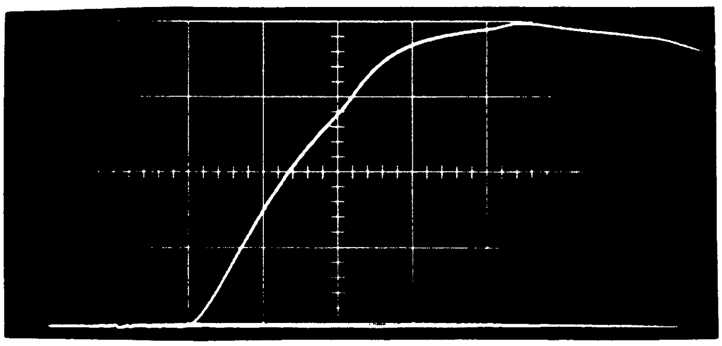
1 μs/div



I_4

537 mA/div

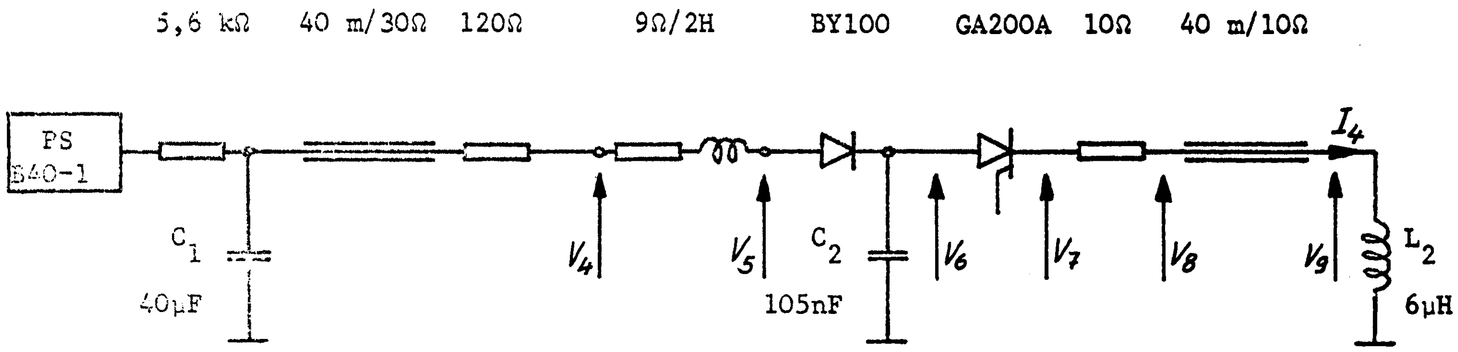
1 μs/div



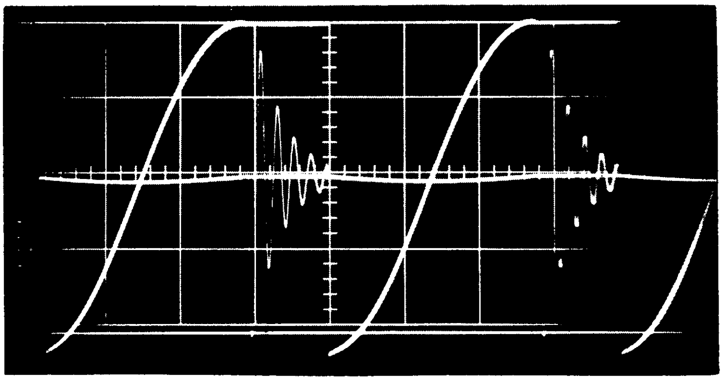
I_4

537 mA/div

200 ns/div



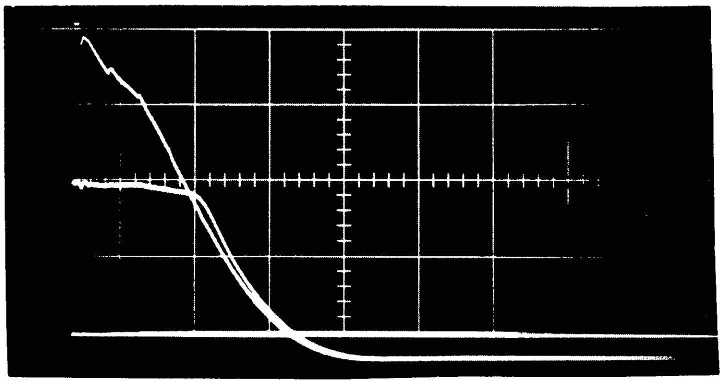
Superposed voltage and current photographs



V_4, V_5, V_6

10 V/div

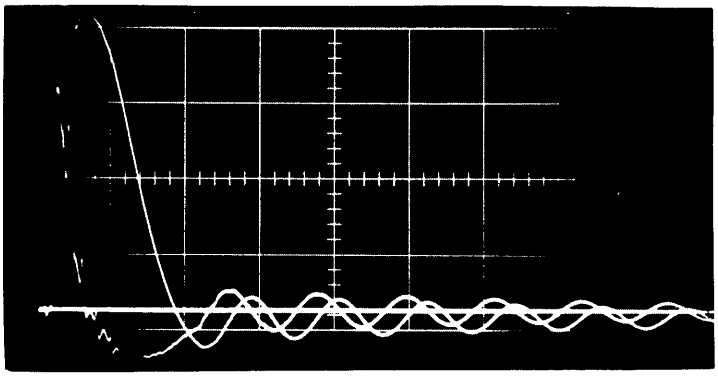
500 μs/div



V_5, V_6

10 V/div

1 μs/div

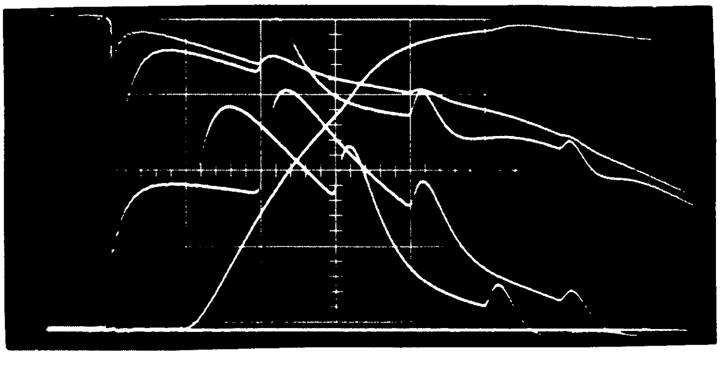


V_9, I_4

10 V/div

537 mA/div

2 μs/div



V_6, V_7, V_8, V_9, I_4

10 V/div

537 mA/div

200 ns/div