NAVY DEPARTMENT - OFFICE OF RESEARCH AND INVENTIONS

NAVAL RESEARCH LABORATORY
Washington, D. C.

* * * * * * * * *

ELECTRONICS-SPECIAL RESEARCH AND DEVELOPMENT DIVISION
ROCKET SONDE SECTION

10 February 1946

INTEGRATING ACCELEROMETERS USED ON THE GERMAN V-2 (A-4) MISSILE

BY

THOMAS M. MOORE

- REPORT R-2756 -

* * * * * * * *

Approved by:

E. H. KRAUSE - HEAD, ROCKET SONDE SECTION

Dr. J. M. Miller, Superintendent
Electronics-Special Research
Division

Commodore H. A. Schade
Director, Naval Research
Laboratory

Preliminary Pages	a-d
Numbered Pages	1-4
Plates	1-7
Distribution List	e

ABSTRACT

The integrating accelerometers used on the German V-2 (A-4) missile provide signal for cut-off of the rocket fuel at a predetermined velocity so that the range of the missile may be controlled. The accelerometers described are of two types: (1) the mechanical system integrates acceleration using the principle of a precessing gyro. (2) the electrolytic system integrates acceleration by means of electroplating cells.

LIST OF ILLUSTRATIONS AND FIGURES

TABLE OF CONTENTS

INTRODUCTION

One of the difficult problems in the efficient use of the V-2 Missile for bombing is in controlling its trajectory to the desired target. A fair job can be done for area bombing if the velocity and inclination of the missile can be controlled near the rocket cut-off point. The Germans expended considerable effort developing means for controlling the velocity vector of the missile, first by means of doppler apparatus and later by means of an integrating accelerometer. The doppler system was given up due to its susceptibility to jamming.

DISCUSSION

Early missiles launched against Britain were provided with a mechanically integrating accelerometer (Plate I). The gyro is mounted so as to precess at a rate determined by the acceleration of gravity for test before take-off and at a rate determined by the combined forces of gravity and acceleration of the missile after take-off. From the mechanics of a rate gyro:

$$\frac{d\theta}{dt} = K \frac{dv}{dt}$$

Integrating

$$\theta = KV$$

where

v = velocity, ft. per sec.
t = time, sec.
θ = angle through which gyro precesses
K = Constant

An integration of the acceleration then gives a measure of the velocity where K is a convenient 20 to 1 stepdown provided by the gear arrangement (Plates 1 & 2). The gyro (1) is driven by a three phase synchronous motor. The precession rate of the gyro was found to be $4\frac{1}{2}$ rpm for 1 g acceleration. Half thrust and full rocket cut-off are obtained by means of two cams, one 8° behind the other, with relays actuated when the gyro has precessed a predetermined amount. It is assumed that the numerical position of the dial for a desired range would be obtained from trajectory curves. The vernier is divided into minimum divisions representing $.1^{\circ}$ so that settings obtained are accurate to the nearest 2° precession of the gyro.

As in the above mechanism, if a gyro (1) is allowed to precess, the unsupported end will gradually fall due to bearing friction so that the precession rate is thereby lessened. In order to offset this error a small three phase motor (3) is arranged to drive the gyro about its precession axis so as to maintain the contact arm (4) within small limits. This motor therefore supplies energy sufficient to provide an effective frictionless bearing. Direction of the motor is changed by reversing two of the field leads depending on whether contact is being made in the upper or lower position. A circuit diagram for the unit is shown in Plate 2.

Due to the fact that the range of a missile will be approximately proportional to the square of the velocity at cut-off it is desirable that the integrating mechanism be as accurate as possible. Plate 6 shows an assimilated circuit arrangement for the simpler and more accurate electrolytic accelerometer developed by the Germans under the direction of Dr. Buchold. The circuit external to the components shown in Plate 3 is an assimilated one set up at the Naval Research Laboratory. An arm (1) is fitted with a copper slug which when moved within the poles of electromagnets (2) unbalances a bridge circuit. This signal is amplified, rectified and put through an erecting coil, Plate 4(1) in a permanent magnet field which maintains the arm in a neutral position. In series with this coil are two electroplating cells (3) so that the current flowing through the coil and cell units electroplate silver chloride at a rate determined by the acceleration. For an acceleration of 1 g the current was found to be about 2 milliamperes at .1 volt. By plating a predetermined period of time with the 1 g available at any launching site a quantity of silver chloride may be deposited on the anode which when removed at a rate determined by the acceleration of the missile plus gravity will provide a signal for cutting the rocket off first to half thrust and later, from the other cell, to full cut-off. The electroplating solution is sodium chloride with pure silver electrodes. One of these electrodes has been plated with silver chloride. When current is passed through the solution, metallic silver is formed at the cathode and silver chloride is produced at the anode thus causing a small voltage to be generated. It is this force of about 1 volt which is amplified and used as a signal to actuate the cut-off relay. The process can, of course, be reversed as many times as desired for test purposes.

Mr. E. J. Peobles, chemist, Naval Research Laboratory, has successfully prepared a similar cell in a straight-forward manner.

Notches provided in the release lever, Plate 3(4), allow the unit to be accurately calibrated thus insuring a linear current response to the cells.

Plate 7 shows a recording voltmeter chart of the electrolytic integrating accelerometer during the process of (a), plating silver chloride on the unplated electrode, (b) removing the silver chloride plating, (c) the voltage rise obtained when all of the silver chloride has been removed. The data shown are for an acceleration of 1 g. Temperature control for the cells consists of a thermostat, Plate 5(2) and heater elements (3) wound around the glass containers.

Power for both accelerometers is furnished by a small motor-generator set requiring 28 volts dc for the motor and providing a generator output of $42\frac{1}{2}$ volts, three phase at 481 cps (rated 500 cps).

The speed of the motor is controlled by a centrifugal governor so that the generator output frequency is held within close limits down to 20 volts input to the motor. The power input to the motor with the gyro accelerometer operating was found to be 125 watts at 28 volts.

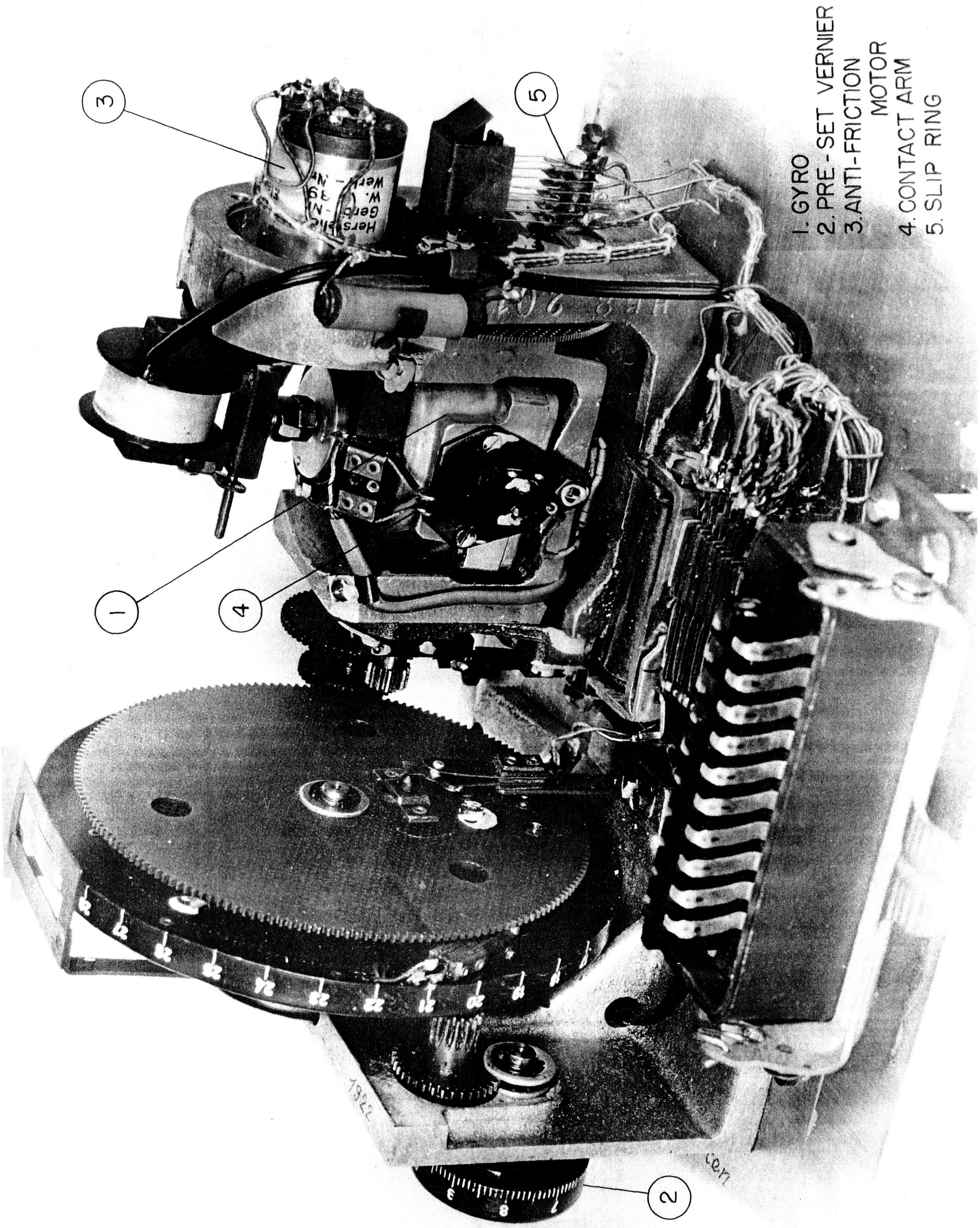
REFERENCES

1. 81-45E, U. S. Naval technical mission in Europe, L. R., of 15 June 1945 to Chief of Naval Operations from Krause, E. H.: "Guided Missiles - Report on Interrogation of Personnel Concerned with".

2. "Ballistics of German A-4(V-2) Long Range Rocket." Military Attache Report (London) No. R-2878 - 45 of 13 February 1945.

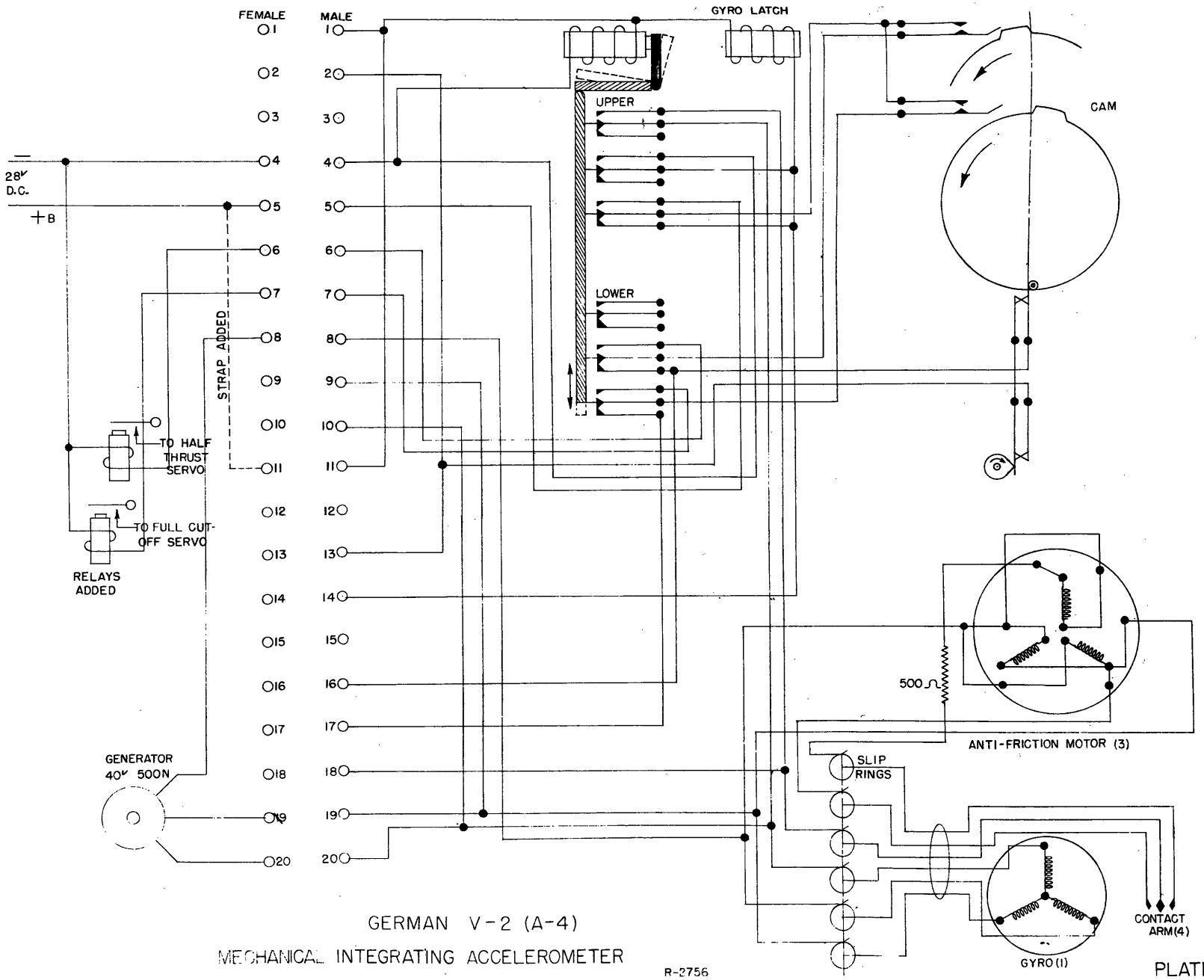
3. Lacy, R. E. and Garvey, R. J. "Electrical Equipment of German A-4(V-2) Long Range Rocket", COMNAVEU Report Serial X1505-S-45 of 3 April 1945.

4. Creighton, H. J. "Principles of Electrochemistry", Vol. I of 1935.



MECHANICAL INTEGRATING ACCELEROMETER

PLATE I



GERMAN V-2 (A-4)

MECHANICAL INTEGRATING ACCELEROMETER

R-2756

PLATE 2

ELECTROLYTIC INTEGRATING ACCELEROMETER

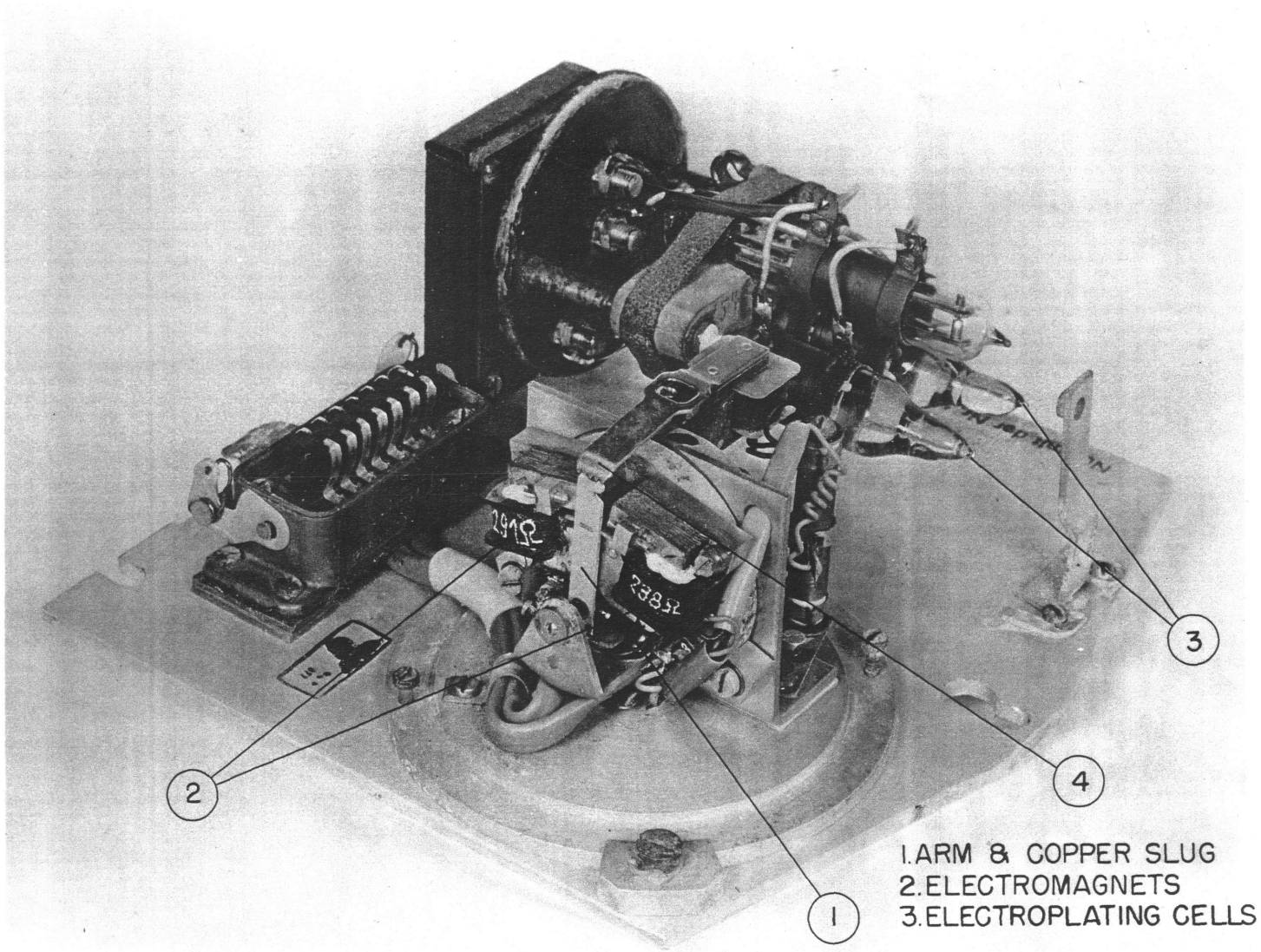
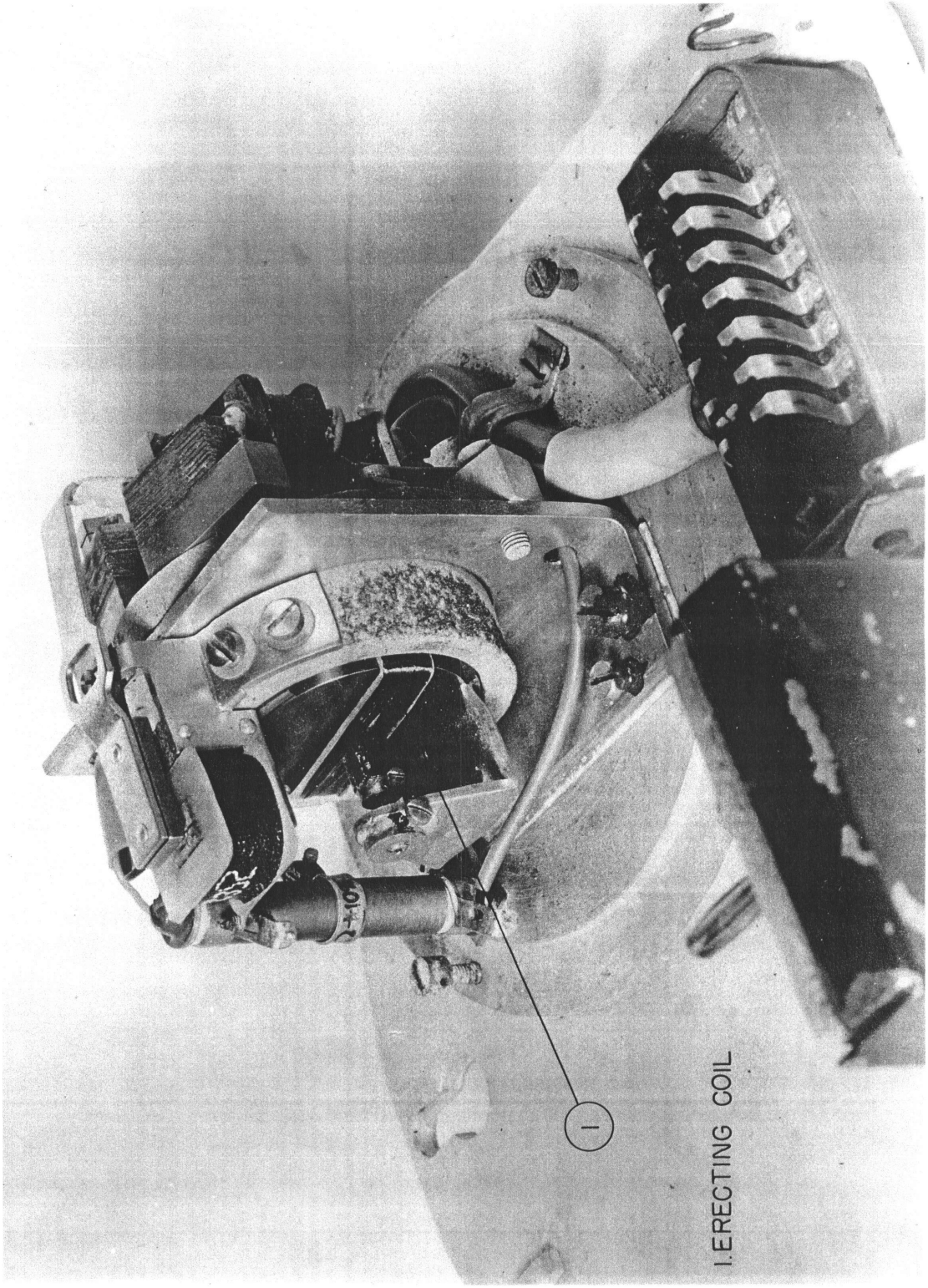
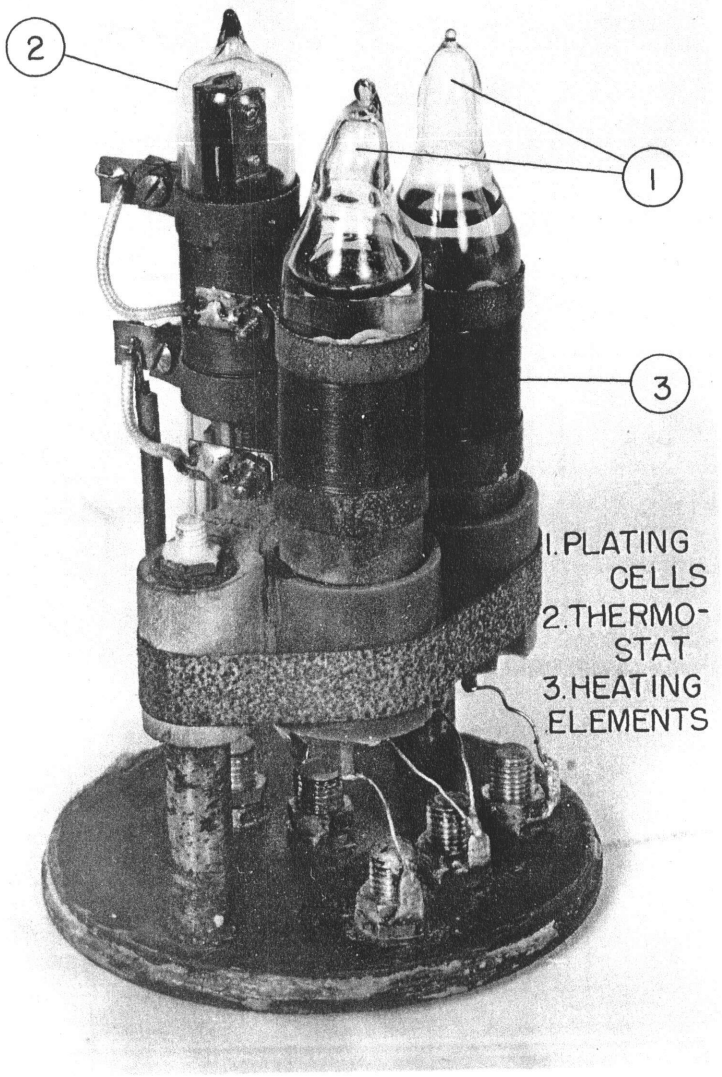


PLATE 3



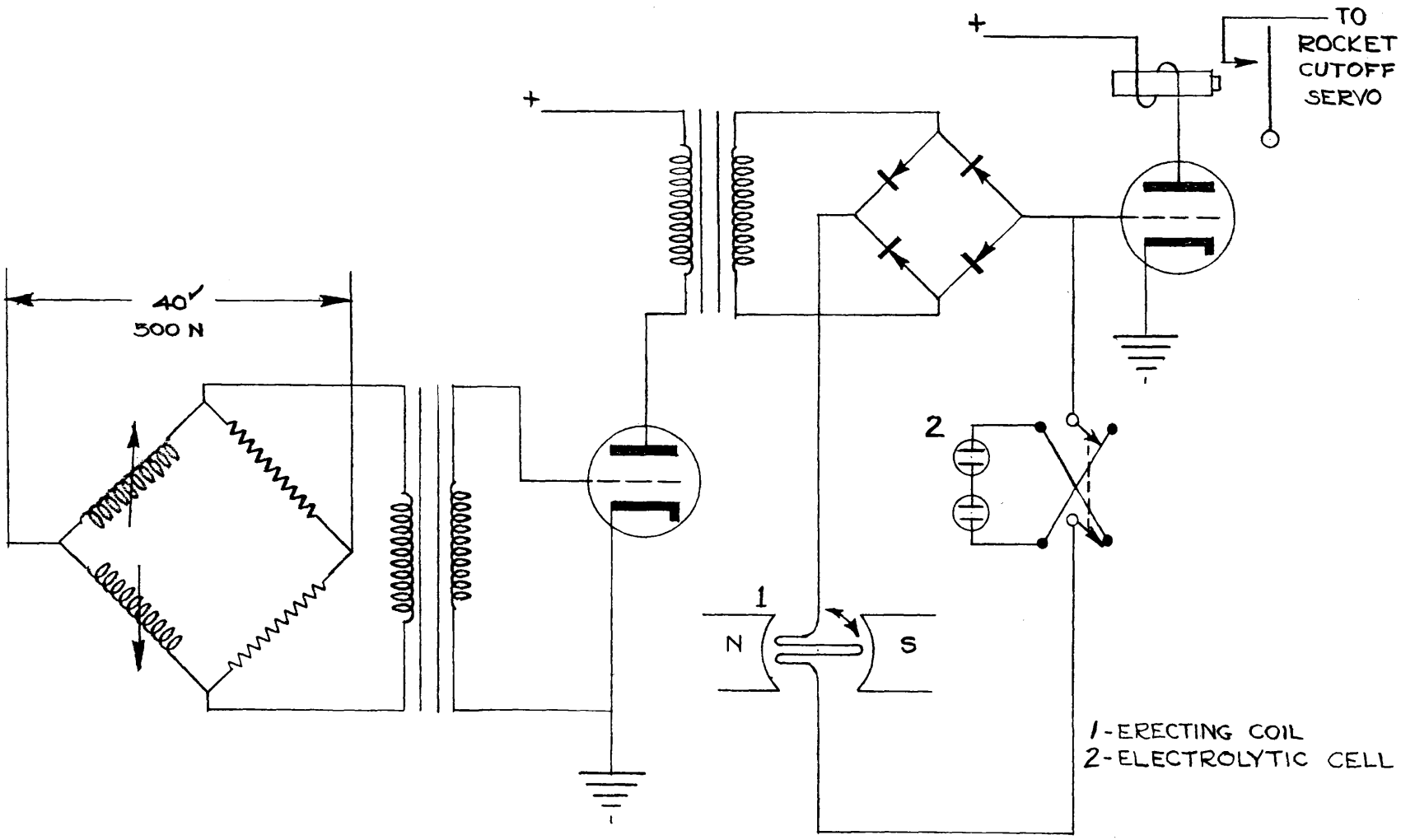
ELECTROLYTIC INTEGRATING ACCELEROMETER

PLATE 4



ELECTROLYTIC INTEGRATING ACCELEROMETER
PLATING CELLS & THERMOSTAT

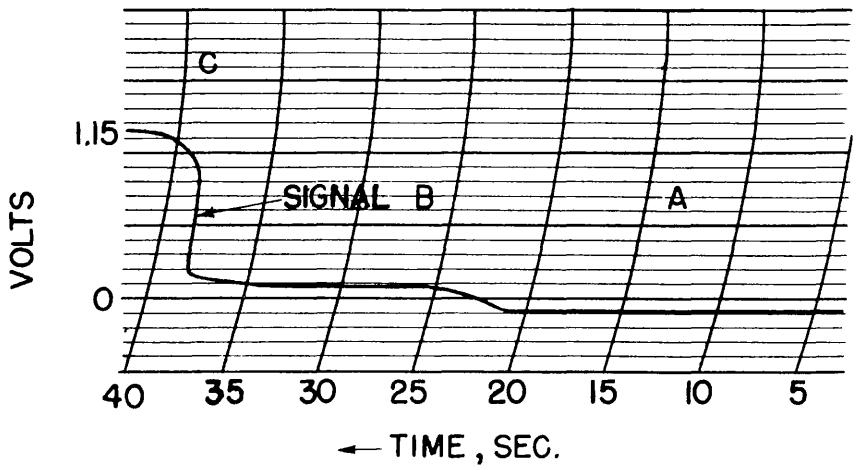
PLATE 5



GERMAN V-2 (A-4)
ELECTROLYTIC INTEGRATING ACCELEROMETER

R-2756

PLATE 6



A-PLATE SILVER CHLORIDE
B-DE PLATE SILVER CHLORIDE
C-VOLTAGE RISE (SIGNAL)

VOLTAGE RISE OBTAINED FROM PLATING CELL

V-2 (A-4)

ELECTROLYTIC INTEGRATING ACCELEROMETER

Distribution:

BuAer R & E Division

BuAer Code Aer-E-18

BuOrd Re4f

CNO Op-6

ORI