ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

QUARTERLY PROGRESS REPORT NO. 1

ELECTRICAL MEANS OF PRODUCING HIGH-VELOCITY WIND

October 1951 - January 1952

By

HAROLD C. EARLY
Research Engineer

HALDON L. SMITH
Research Associate

Project M989

U. S. ARMY, ORDNANCE CORPS
CONTRACT NO. DA-20-018 ORD-11913

February 1952

QUARTERLY PROGRESS REPORT NO. 1

ELECTRICAL MEANS OF PRODUCING HIGH-VELOCITY WIND

October 1951 - January 1952

INTRODUCTION

At low gas pressures, supersonic wind can be generated by means of an electrical discharge. A University of Michigan research project, sponsored by the Army Ordnance Corps, is conducting an investigation into certain aspects of electrical wind phenomena. There are various principles which can be used as the basis for generating wind electrically. Of these, the most promising arrangement involves a d-c gaseous discharge in a transverse magnetic field at low air densities. The major part of this research program will be concerned with this type of "wind generator". The first three months of the present investigation have been devoted primarily to setting up apparatus and instrumentation to produce such discharges at substantial levels of power input.

EQUIPMENT

The experimental setup for studying low-pressure gas discharges in a magnetic field is shown in the accompanying photographs. Much of this apparatus has been assembled from various items of equipment left over from previous research projects.

Fig. 1 is a general view of the equipment which has been assembled for the present experiments. In the foreground is the electromagnet with an aluminum vacuum box placed between the pole pieces. The electromagnet is designed for intermittent operation at a low duty cycle, and, as a result, much higher field strengths are produced than could be obtained otherwise from a magnet of this relatively small size. The aluminum vacuum box was constructed for these experiments and has inside

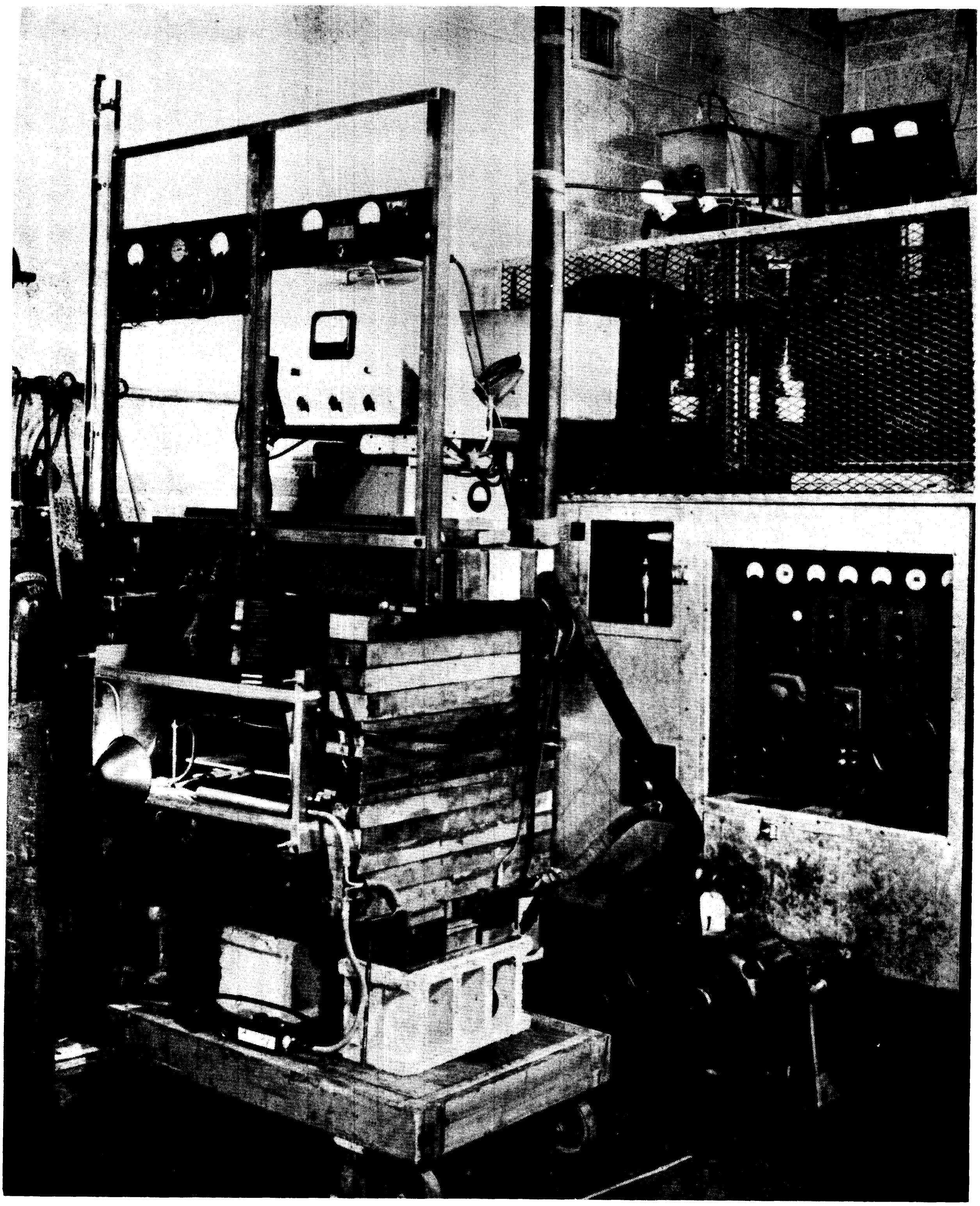

Fig. 1

dimensions of 9 inches by 24 inches by 28 inches. The entire front end is covered with a removable thick glass window through which the discharge phenomenon may be observed. On the rack above the electromagnet are mounted the alphatron and thermocouple vacuum gages and the booster-pump controls. At the extreme left is a cylinder of dry nitrogen which may be bled into the system to achieve any desired pressure. In the background to the right may be seen the two high-voltage rectifier power supplies. The lower unit is a converted RA-38 variac-controlled power supply which will deliver currents up to 1 ampere at voltages up to 15,000 volts. The upper unit consists of a "pole" type distribution transformer and four type 869B mercury-vapor rectifier tubes which can produce 10 amperes of current at 2,000 volts.

Fig. 2 is a rear view of the magnet and vacuum chamber, and shows the vacuum pumps and the magnet power supplies. The vacuum system consists of a Kinney type CVD 556 forepump used in conjunction with a Distillation Products Inc. type MB 100 vapor booster pump. These pumps provide usable working pressures of less than 1 micron of Hg and very high pumping speeds. This high speed is very desirable, since it permits an equilibrium pressure to be maintained, even when nitrogen is bled into the system at a fairly rapid rate. Such a continual exchange of gas helps to keep the chamber free from contamination and assures reproducible results. The magnet power is supplied from two war-surplus "turret trainer" 28-volt d-c power supplies, seen in the background of Fig. 2. They can supply up to 300 amperes of current, which produces a field of 4500 gauss across a 7-inch air gap.

This equipment, which has been assembled for the present tests, is believed to be large enough and sufficiently versatile to provide a variety of experimental information and design data, and to assist in developing measurement and instrumentation techniques. It is expected that this information will be adequate to enable the performance of a larger unit to be predicted with reasonable accuracy.

EXPERIMENTATION

Preliminary experiments with the equipment described above are being carried on currently. Fig. 3 is a photograph taken through the glass window of the discharge at a pressure of about 30 microns of Hg.

The central post is a copper cathode with iron rings to decrease sputtering; the anode consists of a ring of copper tubing. Both electrodes

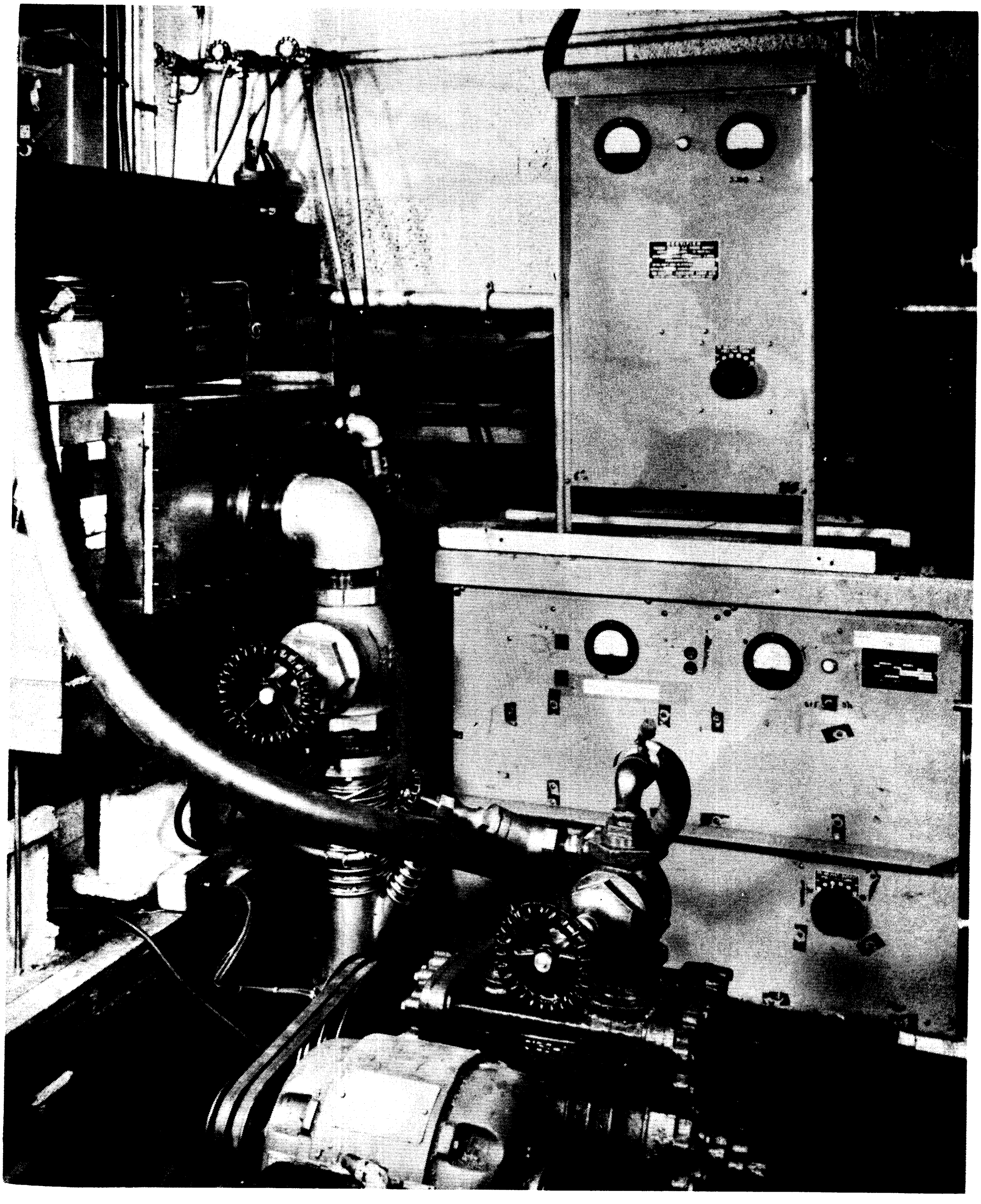

Fig. 2

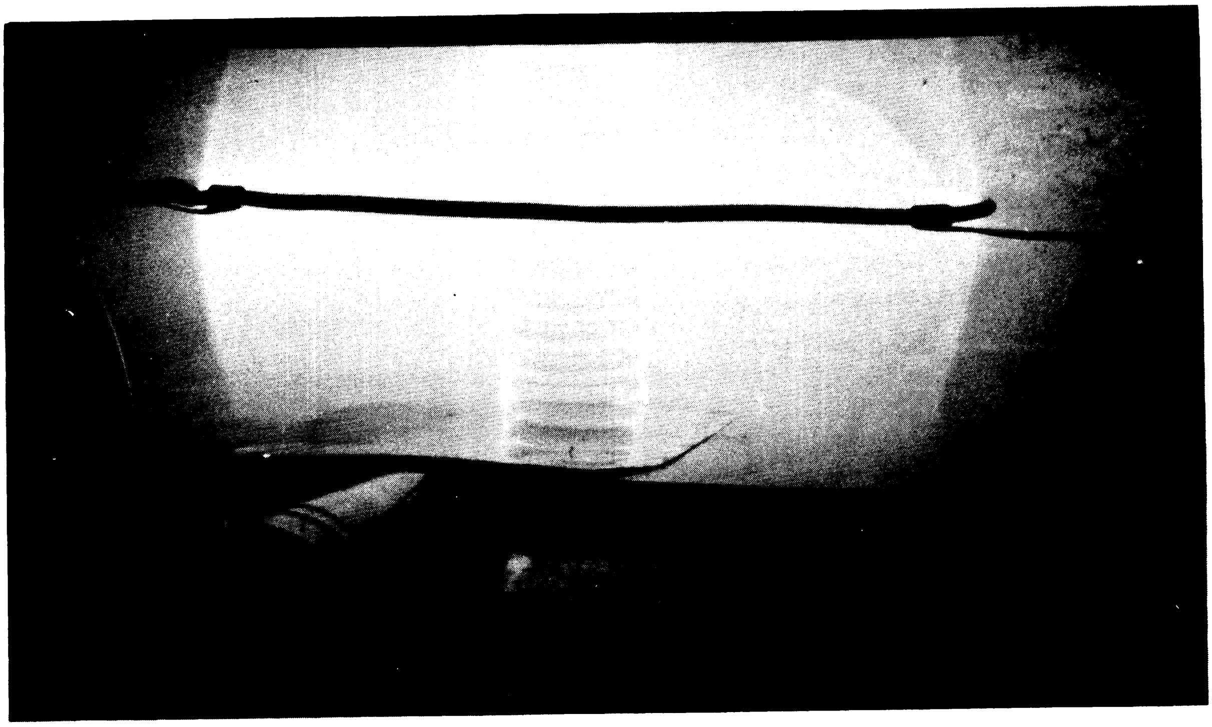

Fig. 3

are water-cooled. In order to determine the general behavior of this type of discharge, volt-ampere characteristics have been plotted for a wide range of gas pressures using the electrode geometry mentioned.

MEASURING WIND VELOCITY AT LOW AIR DENSITIES

Since conventional wind-tunnel techniques are not applicable at air densities corresponding to pressures less than several millimeters of Hg, the performance of the electrical-discharge type of wind generator cannot be properly evaluated until a more accurate method has been developed for determining wind velocity. In connection with a previous investigation of an ionic wind tunnel, a variety of principles for velocity measurement were investigated but no completely satisfactory method was found.

One method of velocity measurement which has been investigated utilizes the phenomenon of nitrogen after glow. It appears reasonable that, if some region in a rotating mass of gas can be "tagged", the rate of rotation could be determined by stroboscopic methods. Nitrogen afterglow might provide such a means.

Recent tests in a bell jar indicate that afterglow, of significant intensity, can be produced at pressures as low as 20 microns by using high current pulses between tungsten electrodes. However, when the same electrical means of exciting the afterglow was tried in connection with the wind generator, the afterglow was too weak to be useful. It is presumed that the decrease in the afterglow under these conditions may be related to the higher gas temperature, or to contamination from the copper electrodes. A trip was made to Langley Field, Virginia, to discuss these experiments with T. W. Williams and J. M. Benson, who have had considerable experience with flow-visualization techniques utilizing nitrogen afterglow. Their work, however, involved higher gas pressures, and was concerned with density variations which did not relate directly to the problems of the present experiment.

Another method of velocity measurement which has been investigated analytically and shows promise involves a differential pressure measurement. The type of wind generator currently being studied consists of a radial electrical discharge between concentric electrodes in an axial magnetic field, generating wind that revolves in the annular space between the two electrodes. Centrifugal force on this revolving mass of gas causes the static pressure at the periphery to be greater than the static pressure at the center. It can be shown that velocity of the gas can be calculated from a knowledge of this differential pressure and the density of the gas. Work is currently in progress on such an experiment.

TANGENTIAL CURRENT MEASUREMENT

The type of discharge involved in the present experiments is very interesting from the standpoint of **basic** physics. A number of experimental measurements are planned which will provide information as to the fundamental mechanisms involved in a gas discharge in a transverse magnetic field.

One experiment which is believed to be of particular importance is a measurement of the current which is flowing in a direction perpendicular to the electric field. In the present case the electric field is radial and the transverse current flows in a tangent or circular direction. This tangential current has a very important effect on all the phenomena associated with the discharge. Because of the magnetic field, the tangential current produces a net radial force on the gas which alters the distribution of static pressure throughout the volume. It is hoped that this radial force can be employed to counteract the centrifugal force due to the rotation of the gas and thus greatly reduce the viscous drag which now limits the wind velocity which can be attained.

A number of methods of measuring this tangential current have been considered and investigated theoretically. The most promising method of measurement involves applying a step function to the discharge current and an observation of the induced voltage in a split anode ring. Equipment is now under construction which will be used in connection with an experiment of this type.

PERSONNEL

At the present time the following people are employed on the project:

Haldon Smith, Research Associate	7/8 time
Harold Early, Research Engineer	1/2 time
William G. Dow, Professor, Elec. Eng. Dept.	Consultant
Vance Burns, Technician	approximately 2/3 time
Edmund Kayser, Machinist	approximately 1/3 time