GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

FINAL REPORT

PROJECT NO. A-620

DEVELOPMENT OF AN OPTO-KINETIC STIMULATOR

By

WINSTON C. BOTELER

CONTRACT NO. N600(204)-58038

OCTOBER 1963

Performed for
U.S. NAVY SCHOOL OF AVIATION MEDICINE
DEPARTMENT OF THE NAVY
PENSACOLA, FLORIDA

TABLE OF CONTENTS

FOREWORD

This report contains a summary of the development of a visual stimulator for use in studying the response of human subjects to opto-kinetic stimulation.

The project was sponsored by the U.S. Navy School of Aviation Medicine, Pensacola, Florida, under the technical cognizance of Dr. Fred E. Guedry, Jr.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the following personnel who assisted in the development: William L. Tucker, J. J. Foust, George D. Clark, Gordon P. Kellogg. The cooperation of all the personnel of the Engineering Experiment Station who contributed to the project is also gratefully appreciated.

ABSTRACT

This report describes the design and fabrication of a device for projecting moving stripes of light onto a spherical screen. The purpose of the device is to provide an optical stimulus for use in studying the responses of human subjects to opto-kinetic stimulation. The device projects stripes on the inside of a 7 foot diameter sphere. The stripes may be rotated in either direction at speeds up to 100 revolutions per minute. Provisions are included for projecting horizontal stripes which move vertically up or down. The stripes are formed by placing specially shaped thin steel strips between a xenon arc lamp and the spherical screen.

I. INTRODUCTION

Most people have experienced opto-kinetic stimulation without being aware of it. When travelling in vehicles of various kinds, we experience the opto-kinetic stimulus to various degrees. Telephone poles going by a train window, the black expansion strips on a concrete highway, the slowly moving propeller of a single engine plane; all these produce varying degrees of stimulation to the passenger. Thus, it is possible to experience some of the reactions of angular acceleration while sitting still.

To study human reactions to opto-kinetic stimulation under laboratory conditions, it is necessary to provide a controllable stimulus to the subject. A number of opto-kinetic stimulators have been built. Most of these consist of cylinders with stripes painted either on the outside or inside. The small drums with external stripes were placed usually a foot or two in front of the subject's eyes, so that the field of view was quite small. The larger cylinders with internal stripes were generally cumbersome and capable of a very limited speed range.

Some of these objections have been overcome by using stripes of light on the inside of a spherical enclosure. Thus, the field of stripes can be rotated at high speed, if desired. The small mass of the rotating projector permits good control of the angular acceleration. The design of the projector permits variations in the number and width of the stripes by changing the metal image strips.

II. DESCRIPTION OF THE DEVICE

The opto-kinetic stimulator consists of three major components; the enclosure, the projector assembly, and the operating console.

A. Enclosure

The enclosure consists of a truncated acrylic plastic sphere of 80-7/8 inches inside diameter, mounted on a cylindrical aluminum base (Figure 1). The acrylic sphere consists of two hemispheres blown from 1/2 inch thick Plexiglas and joined at their major diameters by 1/4 turn quick disconnect fasteners. The upper hemisphere is truncated slightly on top and is covered by a 24 inch diameter flat plate which supports the projector mechanism and ventilating fan. As can be seen in Figure 1, the sphere has a short cylindrical section at the major diameter. This is due to the method of blowing the hemispheres and is not apparent when viewed from the inside.

The lower hemisphere is truncated at a diameter of 66 inches to permit the subject's feet to clear the base cylinder when seated in a Stille-Werner vestibular chair. The basic design was dictated by the physical dimensions of the Stille-Werner chair, and the height of the subject's eye level when seated in the chair. The base cylinder height is 37-11/16 inches, so that the sphere center is 62-1/8 inches above floor level. By placing the subject's eyes at the sphere center and the image projector slightly above the subject's head, the subject has a wider vertical field of vision than if the projector were at the sphere center.

A door approximately 36 inches square in the base cylinder permits access to the sphere interior. A brushless D.C. motor driven ventilating fan on the top plate provides 100 cubic feet per minute of room air. The air inlet is on the base cylinder. Both inlet and exhaust air passages are baffled to prevent the entrance of outside light. The total weight of the enclosure is approximately 400 pounds

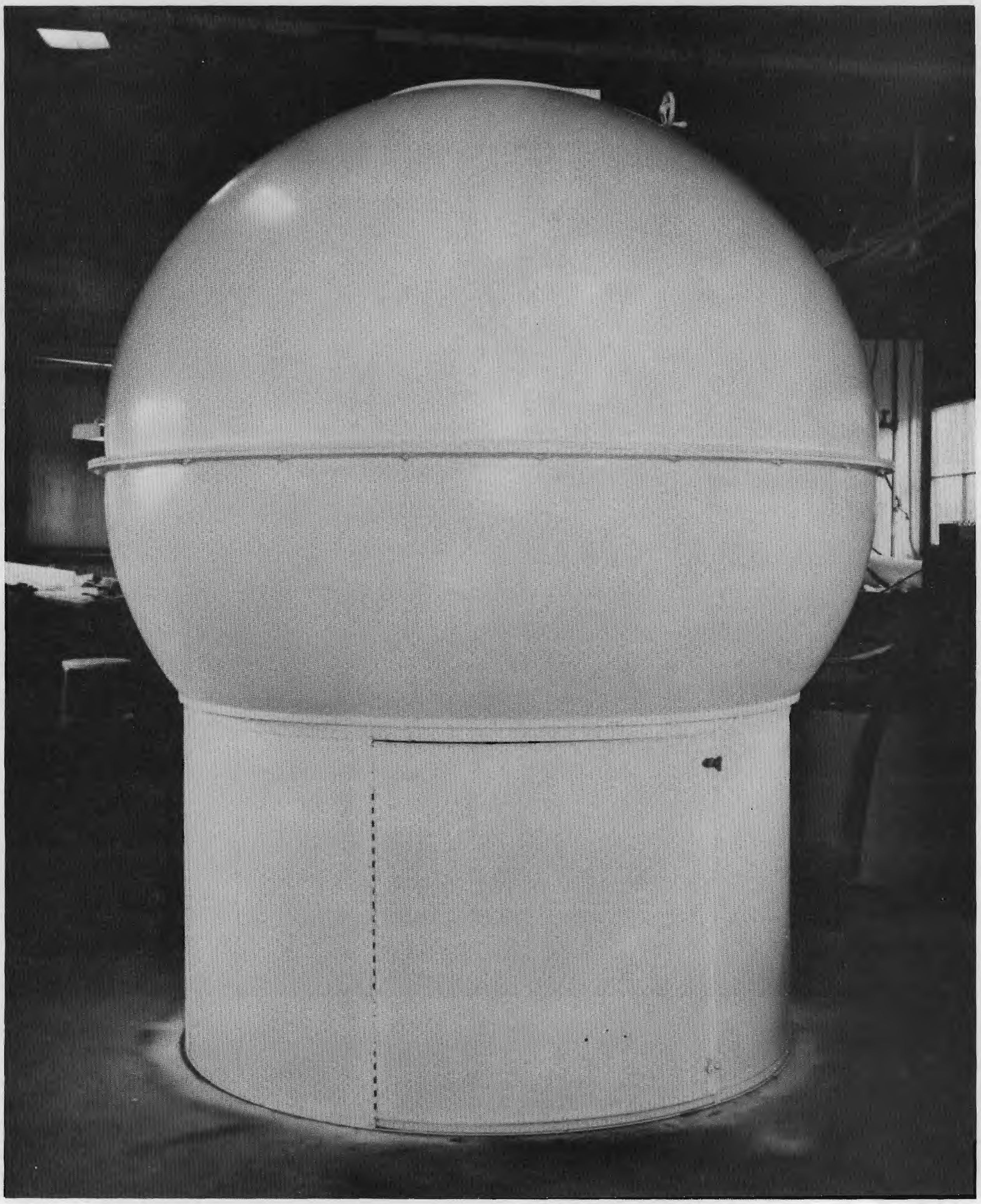

Figure 1. Optokinetic Stimulator Enclosure.

B. Projector

1. Image Projector

Details of the projector are shown in Figure 2. The projector consists of a cylinder 12 inches long and 10 inches in diameter, with slotted sides. The projector was designed originally as a slotted sphere with the lamp at the center. Because of the different beam lengths from projector to sphere at the upper and lower ends, the slits took the shape of trapezoids. Difficulties in producing these slit shapes in the sphere resulted in redesign to a cylindrical shape. The strips forming the slits in the cylindrical projector have curved edges so that the light and dark stripes projected onto the sphere are parallel from top to bottom. The strips can be inserted and removed without disturbing the rest of the assembly. The projector may be tilted up to 90 degrees from the vertical.

2. Projector Lamp

Illumination is provided by a 75 watt direct current xenon arc lamp mounted at the center of the projector. The lamp operates at 14 volts D.C. and produces a luminous flux of 1400 lumens. The average lamp brightness is 100,000 candles/cm^2. The lamp is extremely bright in the ultra-violet, visible, and infrared spectrum. The spectral energy distribution shows a fairly uniform distribution from wave lengths of 3,000 to 8,000 Angstrom units with peaks in the 8,000 to 9,000 Angstrom region. A minimum pulse of 3,000 volts is required to start the arc, after which the voltage drops to 14 volts, D.C.

The arc produced is 0.015 inch diameter by 0.015 inch long. This point source produces an extremely sharp shadow image of the edges of the projector slits.

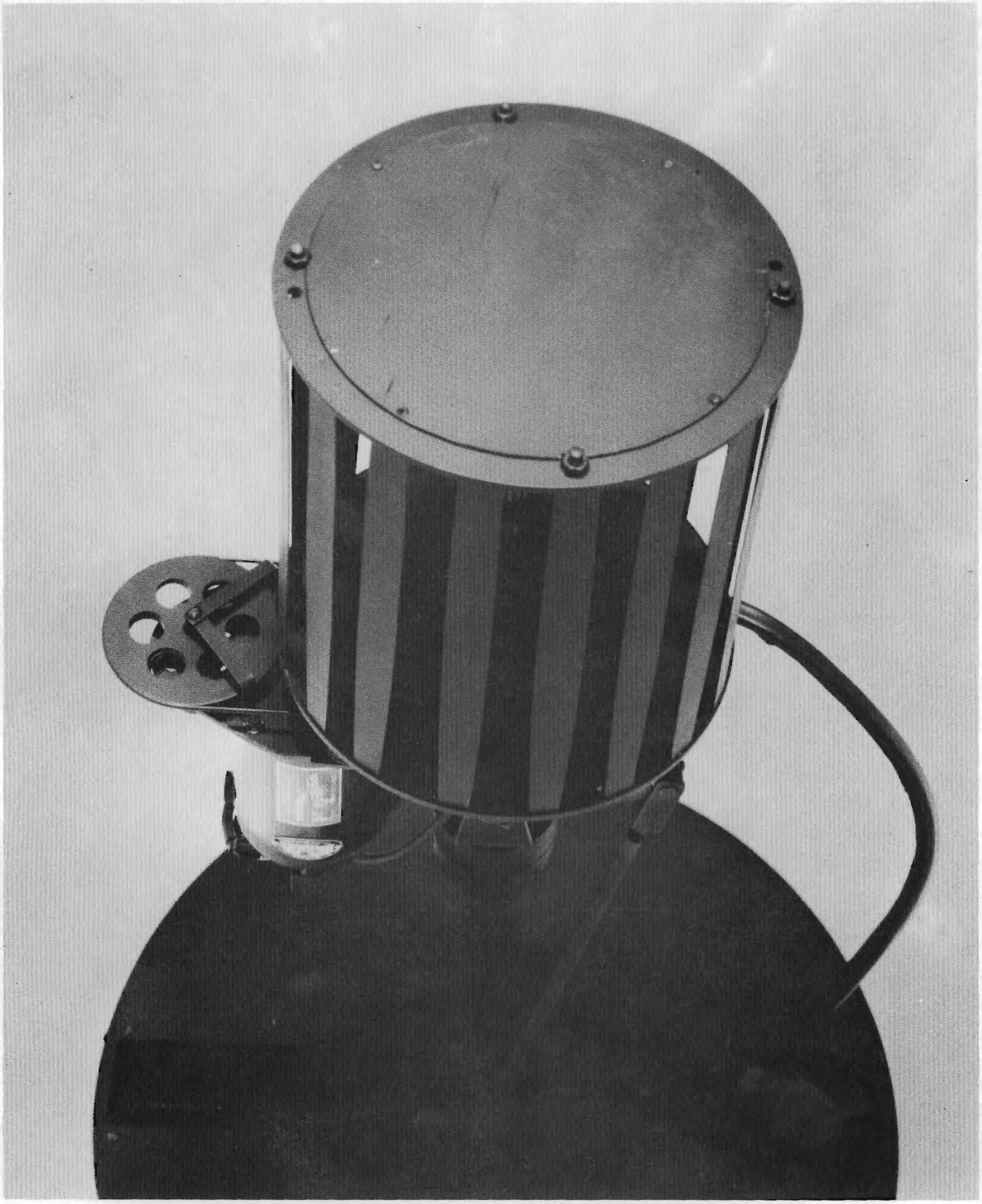

Figure 2. Projector Assembly.

3. Projector Drive Motor and Tachometer

The projector is driven by a 1/12 horsepower, 1725 rpm D.C. shunt wound motor which is controlled by a solid state controller. The motor is coupled to the projector with a 17:1 two stage "O" ring drive reducer. The projector speed may be varied from about 2 rpm to 100 rpm in either direction.

A Servo-Tek D.C. tachometer with an output of 7 volts/1000 rpm is "O" ring coupled at a 1:1 ratio with the rotating projector.

C. Operating Console

The exterior of the operating console is shown in Figure 3. Meters are provided for lamp voltage, lamp current, and projector speed. The left hand side of the panel contains the lamp controls. Full scale movement of the intensity control changes the operating current about 16%. There is very little apparent difference in the intensity, therefore, the lamp has been operated satisfactorily at the lowest intensity setting.

The right hand side of the console contains the motor operating controls. The armature voltage is varied by means of an adjustable autotransformer in series with a silicon bridge rectifier. The field voltage is constant and is obtained with a silicon bridge rectifier.

The transistor commutated ventilating fan is powered by a separate rectifier circuit and is started with the main power switch.

The motor, lamp, and tachometer circuits are connected from the console to the stimulator with individual coaxial cables.

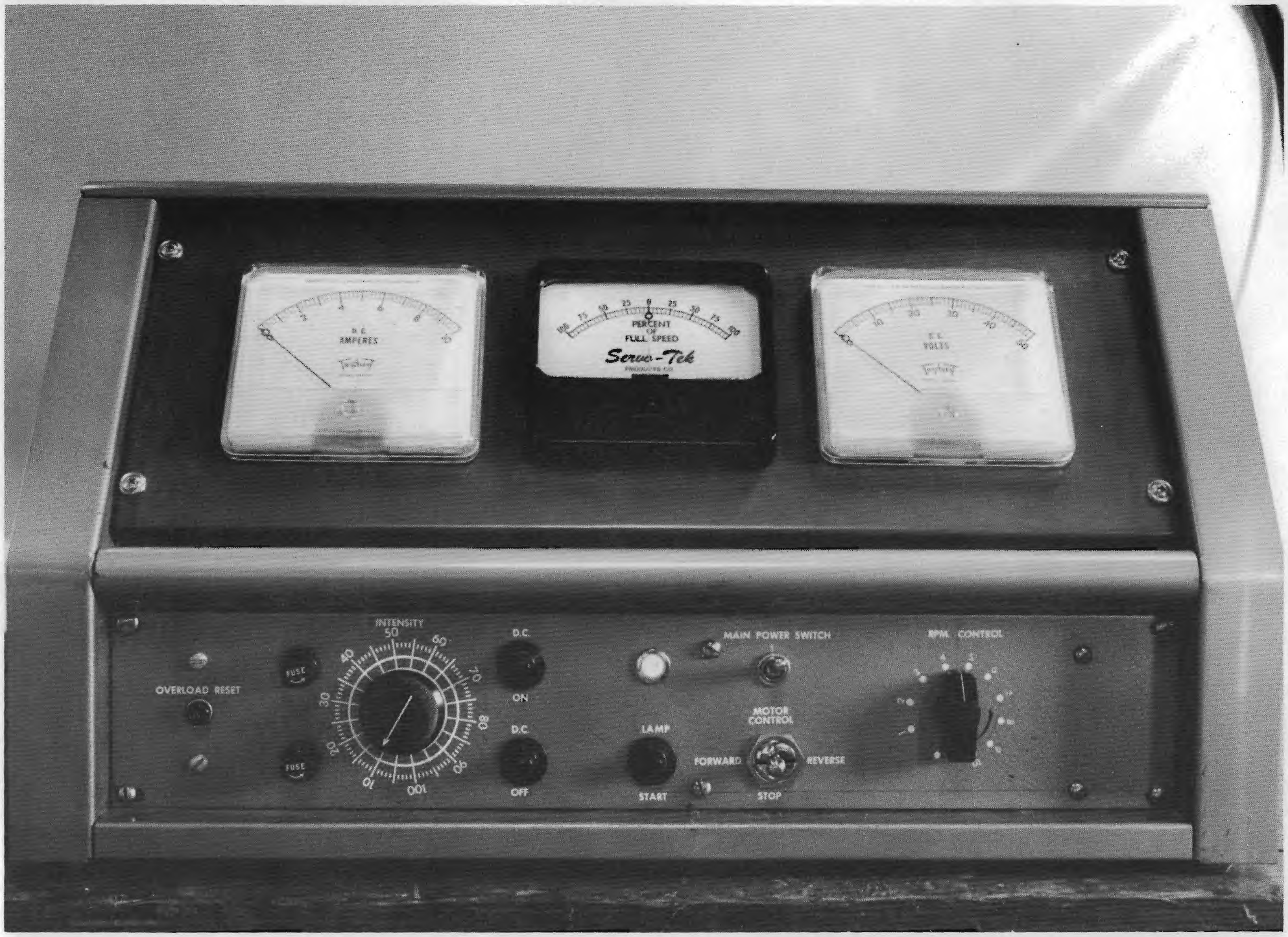

Figure 3. Operating Console.

III. OPERATION AND MAINTENANCE

A. Lamp

The lamp circuit is energized by pressing the "D.C. On" button. The lamp is started by pressing the "Lamp Start" button, which impresses a high RF voltage in series with the lamp and the power supply. This RF signal has a peak value of approximately 15,000 volts. This is by passed around the power supply and is fed across the lamp producing ionization of the xenon gas. A current then flows from the D.C. power supply, causing an arc to develop between the electrodes. The lamp once lighted is a constant current device operating at about 7.5 amperes and 14 volts.

CAUTION: The PEK X-75 lamp contains xenon gas under several atmospheres pressure even when not in operation.

The lamp should be handled only while wearing safety glasses. Never handle the quartz bulb of the lamp. Spent lamps should be disposed of by wrapping in heavy fabric and smashing.

Because of the ultra-violet radiation and the high operating pressure of the X-75 lamp, the subject or operator should not enter the stimulator enclosure while the lamp is on. For maximum safety, the subject should be seated before the lamp is turned on. The X-75 xenon arc lamp closely approximates natural sunlight in spectral distribution with only 62% of the sun's brightness. Consequently, subjects should experience no discomfort in viewing the reflected light on the shell. The inner surface of the spherical screen is painted with ultra-violet absorbing paint which reduces considerably the reflected ultra-violet light.

B. Projector and Motor Drive

The motor contains sealed bearings and should require no maintenance other than an occasional inspection of the commutator and brushes. The operating and maintenance instructions for the "Ratiotrol" variable speed drive are detailed in the manual for that equipment. All rectifiers are mounted on heat sinks in the console. Wiring diagrams for the motor control and tachometer filter network are shown on Drawing No. A-620-401A.

IV. RESULTS

A number of subjects viewed the moving stripe display at various speeds. All reported apparent counter rotation of the sphere and themselves, after several minutes viewing. The subjects were seated on a stool directly under the projector and some had difficulty staying on the stool after a short viewing period. On most subjects tested, the maximum stimulation occurred at projector speeds between 10 and 15 rpm, or about 4 to 6 stripes per second. The projector had 26 slits, so that with equal dark and light stripes, the stripes were about 7 degrees wide, or about 5 inches on the viewing screen. Some subjects reported the ability to see sharp stripes at speeds up to 13 stripes per second.

The xenon arc lamp has a tip-off on the quartz envelope in the plane of the arc which produces a shadow on the screen. This will be behind the subject when the chair is stationary. However, when the chair is rotated this will provide a positional reference cue. Since the equipment was completed, the PEK Laboratories has introduced a mercury arc lamp of the same dimensions as the PEK X-75 xenon arc lamp, which has no tip-off in the plane of the arc. This lamp appears to have a uniform 360° radial light distribution, and can be substituted without changes in the power supply or mounting brackets.

The shadow due to the lower lamp lead can be eliminated if suitable slip rings can be secured to carry the lamp starting pulse.

Considerable difficulty was encountered in the wiring and checkout of the stimulator. Unfortunately, the actual magnitude of the 15,000 volt lamp starting pulse was not determined properly until after the unit was fabricated and operated. Arcing was encountered at the lamp bracket, in the wiring harness, and in the console.

A humid period near the end of the testing program disclosed additional arc-overs. Each arc-over to the chassis produced considerable damage among the solid state components in other circuits.

The problem was solved by using point-to-point wiring with coaxial conductors from the lamp power supply to the lamp. The choke was potted in epoxy resin.

A filter network was added to the tachometer because of pick-up noise generated by the switching diodes in the projector drive motor.

A separate transformer was added for the lamp power to eliminate damage to other components due to the lamp starting pulse.

The stimulator was installed in the Vestibular Laboratory at the U.S. Navy School of Aviation Medicine, Pensacola, Florida.

Respectfully submitted:

Winston C. Boteler
Project Director

APPENDIX I

LIST OF DRAWINGS

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