Project Winterhaven

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Thomas Townsedn Brown

A PROPOSAL FOR JOINT SERVICES RESEARCH AND DEVELOPMENT CONTRACT

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PURPOSES : To engage, in general, in philanthropic enterprise and in the furtherance of the humanities - science, art and literature. To assist worthy charitable and relief organizations, educational and religious institutions. For the general advancement of science, art and literature, the promotion of scientific research, the development of art, artistic crafts, sculpture, music, musical apprecia- tion, dramatics, the ballet; for the study and dissemination of history, philosophy and languages. The construction and maintenance of labor- atory and/or other buildings and equipment, the employment of suitable personnel, the financing of scientific expeditions, tech- nical investigations and the like. The granting of awards, scholarships and endowments for meritorious effort or achieve- ment in science, art and literature. The dissemination of knowledge in science, art and literature. The doing of such acts as may be incident thereto and in furtherance of the foregoing. ^_>

BROWN, Thomas Townsend, physicist, biophysicist; born Zanesville, Ohio March 18, 1905, The Hill School, Pottstown, Pa,, Doane Academy, Granville, Ohio, California Institute of Technology, Pasadena, Calif,j Kenyon College, Gambler, Ohio, Denison University, Granville, 0hioo Special electronics research, Denison Universitys 1924-1925, Private research laboratory, Zanesville, Ohio, 1926-1930. Naval Research Laboratory, Washington, D,, C, 1930- 1933o Staff physicist, International Gravity Ex- pedition to the West Indies 1932, Physicist, Johnson Smithsonian Deep Sea Expedition 1933, Bureau of Ships, Navy Department, Officer-in-charge of Acoustic and Magnetic Minesweeping, 1940-41, Officer-in-charge, Atlantic Fleet Radar Materiel School, and Atlantic Fleet Gyrocompass School, Norfolk, Va,, Materials and Processes Engineer, Glenn L, Martin Aircraft Co,, Baltimore, Md,, Radar Consultant, Lockheed Aircraft Co, Burbank, Calif,, Consulting physicist, Pearl Harbor Navy Yard, Private research (biophysics) on radiation and plant growth. Island of Kauai,

Hawaii, The Townsend Brown Foundation Pacific Expedition, 1948-1951* Member of: American Physical Society (American Institute of Physics) since 1926, American Association for the Advancement of Science, (Fellow) American Geophysical Union of the National Academy of Science, (National Research Gouncil) Washington, DoC0 American Society of Naval Engineers, Astronomical Society of the Pacific, Patents granted: No, 300,311 (British) Method and Apparatus for Producing Force or Motion, No. 1,974,483 (UoSo) Electrostatic Motor, No, 25,417,347 (UoS,) Vibration Damper, assigned to Lockheed Aircraft Corp. No, 2,207,576 (UoS.) Electric Precipitation Method, No, (classified) (U.S.) Buoyant Cable, assigned to U, S 0 Navy,,

TABLE OF CONTENTS Purposes.

Page 1 Organization.

1.1 Proposed Organization Chart.

1.2 Historical Background.

2 Research on the Control of Gravitation.

5 Results of Research to date¡

8 Electrified disc airfoils.

9 Electrogravitational communication system.

10 Definitive Experiments:

12 Group A Field relationships. 1

2 Group B Wave propagation.

14 Group C Ponderomotive forces in solid dielectrics.

16 Group D Reactive forces in fluid dielectrics.

19 Immediate uses if experiments prove to be positive;

21 Propulsion.

21 Communications.

23 Detection of distant atomic explosions,

25 General Objectives,

26 APPENDIX

Outline of Program of Fundamental Research.

Section A The Franklin Institute of the State of Pennsylvania. Contents. Introduction. I, Library project. II, Trouton-Noble experiment. III. Low-temperature research with liquid helium cryostat.

A, Mass of electron in metals.

B, Electromagnetic equations for super-conducting state.

C, Creation of low-temperature lab, IV, Solid state phenomena.

A. Dielectric measurements.

1. Electronic polarizability.

2. Ionic polarizability.

3. Polarization due to alignment of molecules.

B. Other problems.

1. Phosphors.

C. Piezoelectric and allied phenomena.

D. Other work with crystals, V, Relationships between electrodynamics and gravitation.

Conclusions. .he Townsend Brown Foundation, Purposes of Incorporation. Z'-czas Townsend Brown, giographical sketch.PROJECT WINTERHAVEN PURPOSES : For the last several years, accumulating evidence along both theoretical and experimental lines has tended to confirm the suspicion that a fundamental interlocking relationship exists between the electrodynamic field and the gravitational field. It Is the purpose of Project WINTERHAVEN to compile and study this evidence and to perform certain critical or definitive experiments which will serve to confirm or deny the relationship,, If the results confirm the evidence it is the further purpose of Project WINTERHAVEN to examine the physical nature of the basic "electro-gravitic couple" and to foresee and develop possible long-range practical applications. The proposed experiments are to be limited at first to force measurements and wave propagation. They are to be expanded, depending upon results, to include applica- tions in propulsion or motive power, communications and remote control, with emphasis on military applications of recognized priority.

1ORGANIZATION:

It is proposed that the organization of Project WINTERHAVEN be formed by four commercial corporations engaged in applied research and four academic institutions engaged in pure research. In a program of this unusual scope and intrinsic importance, it is considered to be necessary from the start to establish a careful balance between pure and applied research and the mental qualities and attitudes found in each. It is further suggested that the attention of one-half of the organization be directed toward applications to propulsion and the other half toward applications to communication. Companies are to be selected whose current interests lie in these specific fields and whose personnel, combined facilities and hearty support can make the most effective contribution. It is proposed that a prime contractor be elected, a company not necessarily a participant in the actual re- search effort, which is experienced in the administration of government contracts and which will be recognized and approved by the Department of Defense in a proprietary award. Funds obtainable under the prime contract are then to be distributed to the eight cooperating organizations under appropriate sub-contracts.

HISTORICAL BACKGROUND :

The story of the falling apple, which led to Sir Isaac Newton's law of gravitation, is familiar to nearly everyone. It is the usual starting point in any resume about gravitation. Newton's law was the first mathematical expression of a strange and mysterious force - a force which has continued to remain a mystery for over two hundred years. During this period, few scientists have emerged to offer a solution - so great, as a matter of fact, has been the enigma. In the dusty unpublished notes of Sir Oliver Heaviside, written in the latter part of the nineteenth century, a remark- ably adequate theory of gravitation was proposed. It was the first theory, so far as is known, to link the electrodynamic field to the gravitational field. In 1905, Einstein published the Special Theory of Relativity and this was soon followed by the General Theory, describing gravitation in quite different terms but again implying a similarity and possible relationship with the electrodynamic field. Subsequently, in the Unified Field Theories, Einstein has attempted to work out the mathematical basis for such a correlation, but so far has been unable to offer any specific experiment or observation (as in the case cf Relativity} by which such a suspected relationship can be Droved, - 2 -Compelled by a deep interest in the subject, Townsend Brown (as an la-year old student at the California Institute of Technology and later at Denison University) performed crude but apparently significant experiments with electric capacitors, using plates and dielectrics of various mass. The impetus for such an investigation was provided by the academic controversy which Relativity aroused in the early twenties. Brown developed the thesis that, due to the similar or equivalent nature of the electric and gravitational fields, a reciprocal influence could be expected which, if constrained, would give rise to physical forces detectable under certain circumstances.

These early studies and the experimental results were called to the attention of Dr, Paul Alfred Biefeld (a colleague of Albert Einstein in Germany, See appendix "Who's Who"), then professor of astronomy at Denison University and director of Swazey Observatory, Dr, Biefeld continued his interest and active support of the experiments for many years and, prior to his untimely death in 1936, subscribed by affidavit that the observed effects in his opinion did represent "an influence of the electro- static field upon the gravitational field". This strange new effect, first indicated by the results of these experiments with electric capacitors, has since been named the Biefeld-Brown effect; but due to the incompleted experiments and inconclusive results, publication has been withheld. In recent years, as additional data of a confirming nature became available, the research has been associated with government research projects of a highly classified status, and publication has been precluded, - 3 -Townsend Brown continued to conduct studies of this basic effect with particular attention to increasing the ponderomotive forces revealed in massive dielectric materials, especially, as it became apparent, In those materials with high specific inductive capacity or dielectric constant (K), Various obstacles were met and were only partly

overcome. There remained the problem of supplying the required high potentials and developing suitable dielectric materials capable of withstanding such potentials. Due largely to the limitation of the dielectric constant (K) of materials available in those days, the forces obtained in the early stages of the research were never very large. Hence the effect remained for many years in the category of a "scientific curiosity",, It appeared impossible to increase the "K" to a value sufficient to produce consistently measur- able or mechanically useful forces0 Within the last few years, however, due to the demands of radar and television instrumentation, new dielectric materials have been developed. The available values of £ have progressively increased from 6 to 100, from 6,000 to 30,000 and beyond. Dielectrics with K of 6,000 are now available commercially, increasing by a factor of one thousand the magnitude of the ponderomotive forces theoretically obtainable. This should be sufficient, if the theory holds, ifto produce mechanical forces large enough to be accurately measured and also to be useful. In short, it now appears that materials are available at last which are necessary to conduct experiments which will be conclusive in proving or disproving the hypothesis that "a gravitational field can be effectively controlled by manipulating the space- energy relationships of the ambient electrostatic field".

RESEARCH ON THE CONTROL OF GRAVITATION:

In further confirmation of the existing hypothesis, experimental demonstrations actually completed in July 1950, together with subsequent confirmations with improved materials, tend to indicate that a new motive force, useful as a prime mover, has in reality been discovered. While the first experiments with new dielectric materials of higher K indicated the presence of a noteworthy force, the tests were mainly qualitative and imperfect because of other factors, and the ultimate potential in terms of thrust still remains highly theoretical. The behavior of the new motive force nevertheless does appear to be in agreement with the hypothesis that there is an interaction between the electrical field and the gravitational field and that this interaction may be electrically controlled. Discovery of what may turn out to be the long-sought "electro-gravitic couple" should lead to the development of an entirely new form of prime mover, a form of electric motor - 5utilizing electrical and gravitational fields in combination - rather than electric and magnetic fields (as in all other forms of motors in use at the present time). It is inter- esting to note that virtually all of the electric industry today is based on the electro-magnetic inter-relationship in one form or another, dating back to the historic research of Faraday and Maxwell, These original formulations have been changed but little during the growth and development of the electrical age. It is believed by the sponsors of Project WINTERHAVEN that the technical development of the electrogravitic reaction would usher in a new age of speed and power and of revolutionary new methods of transportation and communication,) Theoretical considerations would predict that, because of the privilege of sustained acceleration, top limits of speed may be raised far beyond those of jet propulsion or rocket drive, with possibilities eventually of approaching the speed of light in "free space"0 The motor which may be forthcoming will be essentially soundless, vibrationless and heatless. As a means of propulsion in flight, its potentialities already appear to have been demonstrated in model disc-shaped airfoils, a form to which it is ideally adapted. These model airfoils develop a linear thrust like a rocket and may be headed in any direction,,The discs contain no moving parts and do not necessarily rotate while in flight,, In atmospheric air they emit a bluish-red electric coronal glow and a faint hissing sound0 Rocket-type electrogravitic reactor motors may prove to be highly efficient. Theoretically, internal resistance losses are almost negligible and speeds can be enormous. The thrust is controllable by the voltage applied, and a reversal of electric polarity may even serve as a brake (or if maintained, reverse the direction of flight)0 A tentative theory of the electrogravitic motor has been fairly well worked out and seems to be substantiated in all tests to date. However, there are certain variable factors which are not completely understood. For example, there are tidal effects apparently caused by the Sun and Moon which influence to a small extent the power developed. There are anomalous sidereal effects which seem to be related to the passage of the Earth through diffuse clouds of cosmic dust or electrified particles ejected from the Sun, There is no assurance that large-scale experiments might not reveal additional unknowns, and it is felt that only by continued research and successively more advanced steps can the ultimate development be realized.

7RESULTS OF RESEARCH TO DATE:

The Biefeld-Brown Effect was first observed in the movement of electrically-charged massive pendulums. It was subsequently observed in the movement of electrical condensers of various mass which were similarly suspended and then charged. Mechanical forces, proportional to the mass of the charged elements, were revealed which tended to move the condensers bodily, causing them to behave as if they were "falling" in the "gravitational" sense. These early results were surprising for the reason that they failed to reveal a directional effect with respect to the gravitational field of Earth, but showed only a dependence upon the mass (m) of the electrified bodies. In the years since the Biefeld-Brown Effect was first observed, other data have indicated this relative independ- ence from the field of the Earth, and now a satisfactory explanation has gradually evolved which removes the apparent paradoxo The result has been more fortunate than unfortunate - from an ultimate practical standpoint - for it has provided a theory for a gravitational drive virtually independent of the gravitational field of the Earth* Hence, it would follow that the acceleration and control of electrogravitic space- craft would be relatively unaffected upon leaving the -agravitational influence of the Earth, Several forms of electrostatically-powered motors have been designed which have seemed to indicate various degrees of gravitational characteristics. However, even the best efforts have been crude and the results compli- cated and difficult to analyze;. In general, two types of motors have been built;- those with internal dielectric and those with external dielectric. The Townsend Brown Differential Electrometer,

an automatic recording device which has been operating satisfactorily for many years, is an example of the former type. The various small models of boat motors which have been constructed are also of this type. The disc airfoils are of the second type, and these show rather surprising laboratory performance, but are extremely complex theoret- ically. Captive disc airfoils 2 feet in diameter, operating at 50 KV, have been found to develop a speed of approximately 17 feet per second in full atmospheric pressure„ The speed appears to be at least proportional to the voltage applied and probably to some as-yet unknown exponent of the voltage. -9Based on rough extrapolations from performance charts of laboratory models, the estimated speed of larger non- captive flying discs operating at 5000 KV may be 1150 miles per hour even with atmospheric resistance. It seems not unreasonable to believe that, with voltages and equipment now available, speeds in excess of lSOO miles per hour may be reached by proportionately larger discs operating at the same voltage in the upper atmosphere,

ELECTROGRAVITATIONAL COMMUNICATION SYSTEM

(Electrogravitic induction between systems of capacitors involving propagation and reception of gravitational waves) Project started at Pearl Harbor in 1950= Theoretical background examined and preliminary demonstrations witnessed by Electronics Officer and Chief Electronics Engineer at Pearl Harbor Navy Tard, Receiver already constructed - detects cosmic noise which, according to supporting evi- dence, appears to emanate from that portion of the sky near the constellation Hercules (l6h RA, 40° N Decl,), Trans- mitter designed and now partly completed. Radiation is more penetrating than radio (has been observed to pass readily through steel shielding and more than 15 feet of concrete). 10In 1952 a short-range transmitting and receiving system was completed and demonstrated in Los Angeles. Transmission of an actual message was obtained between two rooms - a distance of approximately 35 feet. Transmission was easily obtained through what was believed to be adequate electromagnetic shielding, but this test must bear repeating under more rigorous control. See definitive experiments (Group B) hereinafter proposed» -

11 -DEFINITIVE EXPERIMENTS Group A « FIELD RELATIONSHIPS

Purpose: The tentative theory implies that the basic relation- ship between the electrodynamic field and the gravitational field is revealed "during the process of charging or dis- charging electric capacitors". Proposal: A basic experiment is proposed in which two or more large high-voltage capacitors are associated spacially with a standard geophysical gravimeter„ Careful observations are made of the gravitational anomalies induced in the region which accompany the change in electrical state0 Studies are proposed of the effects of varying total capacitance, rate- of-change of electric charge, mass of dielectric materials, specific inductive capacity (K) of such materials and whether the spacial effects are vector or scalor. These investigations shall be directed toward the derivation of a satisfactory mathematical equation including all of the above factors. 12This work is to be augmented by basic studies on variations in Earth charge (believed to be caused by natural electrogravitic induction) to be carried on by Stanford Research Institute in cooperation with the Division of Statistical Analysis of the Bureau of Standards, -

13 -Group B - WAVE PROPAGATION

Purpose : Preliminary experiments have indicated the existence of an inductive inter-action between two independent shielded capacitors. In these experiments, a discharging capacitor induces a voltage in an adjacent capacitor and the effect appears to penetrate electromagnetic shielding» Theoretically, this effect of one capacitor upon another appears to be of electrogravitic nature and constitutes evidence of a new type of wave propagation which may event- ually be utilized in a completely new method of wireless communication. Proposals It is proposed that progressively larger-scale and longer-range transmissions be conducted. Beginning with untuned systems, laboratory tests are proposed to explore the basic electrogravitic relationships between simple systems of capacitors. Then, progressing to tuned systems, and pulsed (radar) applications, large-scale out-of-door demonstrations are suggested* Such demonstrations shall be conducted between suitably protected transmitting and receiving rooms (preferably underground) which are thoroughly shielded against electromagnetic (radio) radiation. Appro- 14priâte studies of wave attenuation due to transmission through sea water and large masses of earth may then also be undertaken. This work is augmented by the basic studies on massive high-K dielectrics proposed for the University of Chicago, Calibration of receivers for natural cosmic noise or terrestrial variables is to be done at Stanford Research Institute, Menlo Park, California, -

15Group C - PONDEROMOTIVE FORCES IN SOLID DIELECTRICS

Purpose ; Investigations started in 1923 to ascertain "reasons for the movement of charged capacitors" point to the existence of a hitherto unrecognized ponderomotive force in all dielectrics under changing electric strain. This force appears to be a function of the specific inductive capacitance (K) and the density or mass (m) of the dielectric material, as well as voltage factors* Recent availability of the massive barium titanate high-K dielectrics give promise of developing these forces to the point where they may become of practical importance in specific propulsion applicationso Proposal : Beginning with a careful mathematical analysis of the Townsend Brown Differential Electrometer (an instrument developed at the University of Pennsylvania and at the Naval Research Laboratory and which has been in almost con- tinuous operation for over 20 years) ;, studies are proposed of the forces developed In mica, glass, marble, phenolics and dielectrics in general and then, in

particular, the newer - 16barium titanate ceramic dielectrics. It is proposed that laboratory scale models of both rotary and linear "motors" be constructed and subjected to exhaustive performance tests. After suitable preliminary engineering development, it is suggested that a 500 lb,, motor be constructed to propel a model ship, as a practical demonstration of one of the possibilities of the electrogravitic drive. This work is to be augmented by basic studies of the original Biefeld-Brown experiments, conducted under carefully shielded and controlled conditions in vacuum or under oil. It is proposed that these supporting studies be carried on as pure research projects at the University of Chicago, The space-couple experiments, including a repetition of the classic Trouton-Noble experiment but using high-K dielectrics, are to be performed at The Franklin Institute in Philadelphia under Dr, C, T, Chase, (For the participation of The Franklin Institute, see appendix), Low=temperature experiments (using the liquid-helium cryostat) are likewise proposed for The Franklin Institute. These studies, under the personal supervision of Dr, W, F. G. Swann, are to be so designed as to provide answers to certain questions relative to the fundamental - 17 -nature of gravitation. They are to embrace such subjects as the "Anomalous Mass of the Electron in Metals" and the "Behavior of Super-cooled Massive Dielectrics"» A special library project, housed at the Franklin Institute and supervised by Dr, Swann, is to serve as a clearing house and repository for information on the subject of field theories and gravitation. Whenever indicated, consultations on mathematical considerations, field theories and implications of Relativity are to be held with the Institute for Advance Studies at Princeton,

IS -Group D - REACTIVE FORCES IN FLUID DIELECTRICS

Purpose : Studies of boundary forces (where electrodes are in contact with fluid dielectrics) reveal the existence of a "complex" of inter-acting forces, some of which are purely electrostatic, some electromagnetic and some which could be electrogravitic. The tentative theory requires these electrogravitic forces to be present wherever a mass of dielectric material is charged and moving, and to increase in almost direct proportion to the volume of the fluid which is charged and moved. Hence it is, in a sense, the juxtaposition of the elements of the static form of capacitor described in Group C experiments, and provides what may be described as an electrokinetic propulsive system, with possible applications to high-speed aircraft and spacecraft. Proposal: It is proposed that electrically-charged circular airfoils be mathematically analyzed and improved. Starting with 2 ft. discs at 50 KV, the steps of the development should include k ft, discs at 150 KV and a final 10 ft, disc at 500 KV, Careful measurements are to be made of - 19both static and dynamic thrust. Studies are also proposed wherein the discs are adapted for vertical lift (lévitation) as well as for horizontal thrust and this feature may be incorporated in the design of the 10 ft. demonstration model. It is proposed that studies likewise be made of various methods for obtaining the required high voltages, and these studies should include the development and evaluation of the capacitor voltage multiplier and the "flame-jet" electrostatic generator (to provide up to 15 million volts). This work is to be augmented by the pure research projects, which are proposed for the University of Chicago, to answer certain questions as to relative efficiency of propulsion of discs in air at reduced pressure or in vacuum and at various voltages. -

20 -IMMEDIATE USES IF EXPERIMENTS PROVE TO BE POSITIVE:

Confirmation of the existence of the electro- gravitic couple may provide basic facts and figures which could lay the groundwork for major advances in propulsion and communication. It would initiate changes in existing concepts of the theory of Relativity and the physical nature of gravitation, and certainly provide a basis for utilizing, in a practical way, hitherto unrecognized principles. It would start a major revolution in the science of physics, with profound repercussions in astronomy, chemistry and biology. In its timeliness and provoc- ative Influence, it may become a "shot heard round the world"» Propulsion: Mankind has shown a persistent aptitude to devise means for traveling at ever-Increasing rates of speed. At a certain stage in the evolution of each device for transportation, limits have been reached beyond which he could not go. The ox-cart, the automobile, the airplane and the rocket, all have limits of speed which are basic and impossible to violate. The speed 21 -of the rocket, man's latest attempt, is limited by the velocity of the ejected gases, and this imposes upon the rocket a limitation of speed and range which man is reluctant to accept. In the coming age of space satellites and possible travel to the Moon, man will be casting envious eyes toward inter-planetary travel - travel into the depths of space where he may not even live long enough to complete his journey» It is already becoming apparent that the rocket must be superseded and speeds even further increased. The rec- ognition of this obvious fact, even to rocket engineers, serves to dampen much of their enthusiasm about the practicability of travel by rocket spaceship. Fuel is consumed in "fighting" the gravitational field of the Earth. Fuel will be required in breaking the rate of fall, if and when landings are attempted on other planets, It is quite apparent that a method of controlling grav- itation is urgently needed and that it is already long overdue. Two types of electrogravitic motors are proposed in Project WINTERHAVEN. success» Both types have a good chance of A motor weighing 500 lbs» for the propulsion of a model ship is suggested. Performance data derived from the tests of this model may be used in designing - 22larger models, which in turn would presage electro- gravitic motors for ocean liners weighing thousands of tons. Other possible applications, in due time, would include motive power for automobiles and rail- roads» The second type of electrogravitic reactor now demonstrated in disc airfoils may find its principal field of usefulness in the propulsion of spaceships in various forms. For the moment, at least, the disc form appears to have the greatest promise, largely because there is reason to believe it can be self- levitating and, therefore, made to possess the ability to move vertically (as well as horizontally) and to hover motionless, in complete control of the Earth's gravitational field. Communications : Ko person would have believed - if he had witnessed the original experiments of Prof, Hertz - that the ob-

scure phenomenon would lay the groundwork for world- wide radio communication, radar, television and the countless electromagnetic devices of this kind which today we take so much for granted. - 23 -We have had, in our lifetime, the privilege of watching the growth and approaching culmination of the radio age, let, with all its manifest advantages, the .electromagnetic wave has many limitations, and these are becoming increasingly apparent to us as over-crowded channels, annoying interference, blank-outs and shadows. We have become acutely aware of the troublesome limitations on television caused by the curvature of the earth and the shaded areas behind mountains, hills and large buildings, where satisfactory TV reception is virtually impossible. We sense that present methods are imperfect and inadequate and that somehow, in the future, an answer will be found» If the basic experiments set forth in Project WINTERHAVEN prove the controllability of the gravitational wave, a fundamentally new system of communication will become available. Theory indicates that the gravitational wave may be one of the most penetrating forms of radiant energy. Employed as a means of communication, it may solve many of the difficulties inherent In present-day radio and, at the same time, provide countless additional channels for communication. At the outset, development of the electrogravitational communication system obviously could provide a secret, almost wholly untouchable, channel for classified military communi- cations. Message transmissions could be put through without - 24breaking military radio silence, at a time when all electromagnetic transmissions are prohibited. Due to the high penetrability of the gravitational wave, communications could conceivably be maintained between submerged submarines, between submarines and shore installa- tions or between bomb-proof shelters and similar underground installations without the use of external wires. Other interesting possibilities virtually suggest themselves. Among these are the applications to undersea or underearth radar, also various remote control applications for guided missiles, where the usual antennae or dipole systems involve complications or create engineering diffi- culties because of the shielding of the metallic covering of the missiles. Detection of distant atomic explosions Due to the tremendous momentary displacement of air and the gravitational disturbance resulting therefrom, there is reason to believe that the electrogravitational receiver may be one of the few devices capable of instant long-distance detection and ranging of atomic bomb explosions. Washington, D=C, Revised: l/l/53 -

25 -GENERAL OBJECTIVES

In the foregoing project outline, specific details have been referred to for the purpose of imparting a clear and concise understanding of the type of investi- gations proposed. The general objectives of Project WINTERHAVEN embrace the entire subject of the inter- relationships between gravitation and electrodynamieso This is necessarily a long-term program. Unquestionably there are many productive avenues of exploration in this vast and comparatively open territory which cannot be foreseen. The project must adopt a policy of inviting suggestions from qualified physicists interested in attempting to solve the various problems involved. In a project of this scope and magnitude it would be a mistake to fail to recognize and investigate any phenomenon which bears even remotely upon the subject* limit It would be a mistake, for example, to the considerations to the so-called capacitor-effect, as outlined hereinbefore, when its technical antithesis, a possible inductor-effect, may provide equal opportunities. In the study of physical properties of dielectrics, low-temperature research is of especial importance, Electro- dynamic phenomena occur at low-temperatures which are com= 26pletely unknown at room temperatures. The possibilities of discovering wholly unsuspected gravitational effects below the super-conductivity threshold, at temperatures approaching absolute zero, are worthy of the costs involved» The use of the liquid helium cryostat is strongly recommend- ed as an important part of Project WINTERHAVEN. The operation of a library project such as that pro- posed for The Franklin Institute, for the accumulation of technical information and to serve as liaison with academic institutions throughout the world, is of utmost importance particularly at the beginning of the program» No responsibility can be assumed by any of the cooperating institutions to guarantee results in research. It is the express purpose of the sponsors of this project to seek the answers by organizing a cooperative program in which the best minds and all necessary laboratory facilities are brought together. It is the sincere hope that, in this way, a century of normal evolution in science, looking toward the ultimate control of gravitation for the benefit of mankind, may be compressed into 5 - 1 0 years. As with the atomic bomb project in America, money was traded to gain time. So it is with the ultimate conquest of space. It must be recognized that a concentrated study of gravitation under a government research and development contract can no longer be neglected, -

27 -A P P E N D I X P A R T ONE FUNDAMENTAL RESEARCHA P P E N D I X PROGRAM OF FUNDAMENTAL RESEARCH

Section A,

The Franklin Institute of the State of Pennsylvania, ai Library project, b) Liaison with other academic institutions, (c) General considerations of field theories and gravitation, (d) Repetition of Trouton-Noble experiment with high-K dielectrics, (e) Low temperature research of electrodynamic phenomena using liquid helium cryostat. Section B. Stanford Research Institute» Repetition of Fernando Sanford experiments. Studies of variation in electrical potential of the Earth* IS (c) Studies of electrogravitic induction, (d) Development of a short-period gravimeter for capacitor tests, (e) Cooperation with Lear, Inc. in studies of field relation- ships and gravimetric analysis. Section Co Division of Statistical Analysis, National Bureau of Standards, Analysis of differential electrometer records,, IT » capacitor mid-point variations, " " Sanford variations. :d)

Correlations with solar, lunar and sidereal time other snatural variables» • a Section D 0 University of Chicago» (a) Repetition of basic pendulum experiment (Biefeld-Brown effectj in oil and other dielectric fluids, and in vacuum, b) Tests of ponderomotive forces in capacitors. c) Quantitative effects Of K, m and other factors» d) Studies of high=K"massive dielectrics and relation to forces developed, (e) Consideration of inductor=effect in relation to condenser- effect. (f) Thrust measurements of electrified disc airfoils in air at reduced pressures, and in vacuum»

23S E C T I O N A THE FRANKLIN INSTITUTE of the STATE OF PENNSYLVANIATHE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA PHILADELPHIA 3 - PENNSYLVANIA FOUNDED FEBRUARY 5, iSZÍ LABORATORIES FOR RESEARCH AND DEVELOPMENT HENRY B. ALLEN Director December 10, 1952 Kr. T. Townsend. Brown The Townsend Brown Foundation I4I0 Bowen Building Washington 5, Ü. C. Jear Mr. Brown: We enclose herewith the proposals for work under your Foundation, made out i n accordance with our discussions 01 November 13. As you w i l l s e e , we have high-lighted the p o s s i b i l i t i e s inherent in low temperature work involving the use of a c r y o s t a t . However, we have included the Trouton-Noble experiment and, of course, the general plan for t h e o r e t i c a l work looking towards an analysis of the' s i t u a t i o n with regard t o the relationship between g r a v i t a t i o n and electrodynamics. We s h a l l , of course, hold ourselves ready for any further discussions of these matters which may seem desirable as a preliminary to the f i n a l statement of a definite program. I t was a great pleasure to have the opportunity t o confer with you on these m a t t e r s . Dr. Swann told me t h a t he l i k e d very much your approach to the problems, 3Jld we a l l hope t h a t we may have the pleasure of serving the Foundation to the end of accomplishing some r e a l l y good fundamental work for science. With kindest regards, I am Very Nicol H. Sm.i1 Executive Director Encl.

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA INFORMAL PROPOSAL AND BUDGET ESTIMATE FOR RESEARCH IN PURE SCIENCE PREPARED FOR THE TOWNSEND BROWN FOUNDATION

CONTENTS :

Material submitted includes:

1, A proposal for initial support of library work, conferences, and travel, to facilitate cooperation with The Townsend Brown Foundation in Pure Science Studies In the fields of Electromagnetism and Grav- itation,

2, A research proposal and budget estimate for a repetition under improved conditions of the classic Trouton-Noble experiment,

3, A discussion of two fundamental experiments aimed at improving our knowledge of the behavior of electrons in solids. Included is information and cost estimates on the Collins Helium Cryostat, which would be essential In performing these experiments,

4» A discussion of further work in Pure and Applied Science directed toward improving our knowledge of the Solid State, and particularly our knowledge of high K dielectrics, Such studies would widen the frontiers of Physical Science and would - be facilitated by the use of low temperatures A-las provided by liquid helium, 5» A short statement on ways to approach a better under- standing of gravitation, electromagnetism, and relationships between the two subjects. INTRODUCTION: In two visits and various correspondence, Mr, T. Townsend Brown has indicated his interest and that of The Townsend Brown Foundation in certain aspects of Pure Science. Interest has also been expressed in the possibility of supporting research work in these Laboratories, with scientific discovery and publication the principal objective» The attached proposal discusses in turn the various items of interest which have been under consideration by Mr, Brown and members of the research staff of these Laboratories» A-2I, Proposal for preliminary grant to support exploration of the fields of interest to Mr. Brown and the Foundation. It is requested that The Townsend Brown Foundation grant to The Franklin Institute Laboratories for Research and Development the sum of $5000, for the following purposes:

A, To support exploratory work, including literature surveys and conferences, on the subjects of gravi- tation and electromagnetism,

B» To establish a working arrangement with the Foundation so that ideas of mutual interest may be effectively pursued.

C. To support the expense of further discussions so that additional interests of the Foundation may be explored and studied. Expenditures under this grant would consist of salaries and overhead, and travel expenses. Personnel involved would be chosen from the 250 staff members of the Laboratories, their supervisors, or Senior Staff Advisors, according to the field under discussion and the special interests and training of the individual.

A-3II. Proposal and Budget Estimate for Repetition of the Trouton-Noble Experiment.

The Townsend Brown Foundation has expressed particular interest in the Trouton-Noble experiment, and has a desire to see the experiment repeated under improved conditions. The Trouton-Noble experiment concerns itself with an electromagnetic

torque operating on a charged con- denser which moves with uniform velocity in the direction inclined to the normal to its surface. According to the theory of relativity, compensating effects, in this case having to do with the effect of motion on elastic proper- ties of materials, arise to defeat what would otherwise be the rotation produced by the torque aforesaid. In the days before universal acceptance of the theory of relativity, there was reason to believe that measurements of the rotation of such a condenser as the above, when supported by some suspension, would serve to determine the velocity of the earth's motion through space. If, for a moment, we put ourselves in the mind of one who does not accept the theory of relativity in its entirety or wishes to test its validity further, the A-4torque described above and possible rotation resulting from it become matters of experimental interest. A situation of great interest centers around the effect of the dielectric materials in the condenser in deter- mining the torque. Now it appears that the original calculation of the aforesaid torque is completely erroneous; and it appears that if the torque had been calculated correctly, invoking the same fundamental principles as were invoked in the earlier calculations, it would have been found to depend only upon the potential difference between the plates of the condenser and to be independent of the dielectric constant. However, a more refined analysis of the situation, which does not simply average the properties of the polarized molecules into a representa- tion in terms of a dielectric constant, reveals that there may be a contribution to the torque which depends on the nature of the molecular dipoles, and in a manner which is not expressible in terms of the dielectric coefficient. The above conclusions have been reached by E. H. Kennard and W. F. G. Swann independently by differ- ent processes of mathematical analysis. - They would have rendered the Trouton-Noble experiment one of consider- able interest to a person who had any doubts about the theory of relativity, and the interest would be enhanced A-5by the bearing of the nature of the dielectric material upon the outcome of the experiment. The present proposal for this experiment is sub- mitted because of Mr, Brown1s expressed interest in its bearing on dielectric characteristics. We feel, however, that there are better ways of investigating dielectric phenomena, some of which are discussed below. In con- nection with studies of the relationship between gravita- tion and electromagnetism, again there are more effective procedures; this question is discussed at greater length in a future section of this proposal. Even though we would not have initiated a recommend- ation for a repetition of this experiment at this time, it could be performed if desired by the Foundation. A grant of $15,000 for research, overhead, and materials and supplies, would cover the performance of this experi- ment over the period of a year.

A-6III. Discussion of two fundamental physical experiments, and proposal and budget estimate for the Collins Helium Cryostat, necessary for the performance of these experiments,

A, Experiment having to do with the observation of momentum in a ring of conducting material carrying a current at the instant when the material is carried from the super-conducting to the non- superconducting state. Briefly, the above experiment envisages a metal ring in which a current of electricity has been produced by the creation of a magnetic field passing through the ring when all is at a temperature such that the super- conducting state prevails. Under such conditions, the current will continue practically indefinitely. If we now raise the temperature, the super-conductiv- ity will disappear at a certain critical temperature, and the angular momentum of the electric current will be shared with the ordinary material of the ring in such a way as to give an angular rotation to the latter. The ring is, of course, to be envisaged as supported by a suspension and the angular rotation observed will depend upon the stiffness of this suspension. An interesting feature of the experiment lies in the fact that the sensitivity is A-7greatest when the cross-section of the wire of the ring is smallest. The limiting conditions which de- termine the ultimate sensitivity are based upon the requirement that when the energy of the current is dissipated and passes through the super-conducting state, the heat evolved shall not be sufficient to burn up the apparatus. The fundamental theoretical interest of the experi- ment lies in the fact that the angular rotation obtained depends upon the electronic mass, and theoretical con- siderations have been presented to support the belief that this electronic mass may be different for the electrons in a metal than for the electrons in a free state. The aforesaid theoretical considerations bearing on the electronic mass are the work of physicists at other institutions and we believe that most authorities on quantum theory are of the opinion that the effective mass of the electron in a metal is the same as that for an electron in a free state. However, even those who support this view are in favor of performing the experi- ment because of the complexity of the theoretical con- siderations involved. We may say that the concept of this kind of experi- ment goes back to the time of Maxwell. Some 45 years ago, A-8Dr» Swann became interested in the possibilities of an experiment of this kind, but that was before the days when we knew of super-conductivity, and the potentialities of the experiment under such conditions did not seem promising. When Dr, Imre Patai came to The Bartol Foundation of The Franklin Institute, he brought with him an interest in this experiment and it was one of the experiments which we had planned to perform if he had lived. Tentative arrangements for securing liquid helium were discussed with the U. S. Bureau of Standards, Dr, Patai had worked out the theory of the experiment in elementary form and Dr. Swann made a calculation of it based on more general considerations and traced the consequences of the calcula- tion as regards defining the conditions of limiting sensitivity, etc., as cited above. The most fundamental requirement is, of course, a means of producing liquid helium, and this implies a cryostat. If a cryostat were obtained, moreover, the potentialities of an enormous amount of other work in solid state physics would be provided for. In this respect, an experiment of this kind has an advantage over such an experiment as a repetition of the Trouton-Noble experiment. In the repetition of the Trouton-Noble experiment, the usefulness of the apparatus vanishes A-9when the observations are completed. In an experiment involving a cryostat, however, the completion of the immediate undertaking leaves an organization of equip- ment and procedure which is available for a large amount of very valuable scientific work of other kinds. The cryostat itself would involve a room, probably some 20 feet square, and would cost about $24,000. It would

require about 1-1/2 men to operate it. Information on the cryostat is attached. It is probable that the experiment in question could be carried out and the cryostat eould be operated by calling upon the services of one full-time physicist and two technicians. It should be possible to complete the experiment in one year. Personnel, and expenses other than that for the cryostat, would be supplied by the Institute. It may be remarked that if we are able to act quickly in the matter of a cryostat, we have the possibility of securing a man thoroughly skilled in the operation of the equipment. Intimately related to the foregoing experiment is another which will now be described. A-10

B. An experiment to test the electromagnetic equations for the super-conducting state. Among the many interesting phenomena which occur at low temperatures, super-conductivity has long held the attention of experimentalist and theoretician alike since its discovery by H. Kammerlingh Onnes in 1911. With the discovery of the Meissner effect in 1933, the basic experimental behavior necessary for the development of an electrodynamic theory of super-conductivity has been established. F. and H. London, in 1935, developed a set of equations which describe the macroscopic electrodynamic behavior of super-conductors in a satisfactory fashion. These equations have not been tested in a quantitative manner at the present time. One experiment which would shed considerable light on the correctness of these equations has been suggested by F. London. This experiment involves a study of the magnetic properties of a rotating sphere. The theory of this experiment is worked out in complete detail by F. London. We shall give below a physical description of the nature of this experiment. Consider a sphere of radius R. If we start with the sphere at rest below its super-conducting transition temperature and bring it into motion with uniform angular A-llvelocity c*> , then by considering the super-conducting electrons as perfectly free it can be deduced that the sphere should become magnetized upon rotation. The reason for this is as follows: When the sphere is initially set into motion the electrons, being perfectly free from interaction with the crystal lattice, will not move with the sphere, and a current Is set up due to their relative motion. This changing current in turn induces an electric field within the sphere which acts on the electrons in such a manner as to accelerate them in the direction of rotation of the sphere. The final result is that when the sphere has reached a constant angular velocity the super-conducting electrons everywhere move with the sphere except for a narrow layer at the surface, where they lag behind slightly to produce a small current. This result was predicted on the basis of a free electron theory before the develop- ment of the theory of F. and H, London» The London theory predicts the same result for the rotating sphere, except that it makes an additional pre- diction, F, London states that the rotating sphere will have a magnetic moment independent of the prehistory of the sphere. In particular, if a rotating sphere is cooled below its transition temperature while rotating, the sphere will acquire the same magnetic moment as it A-12would upon starting from rest below its transition temperature and being brought to the same angular velocity. On the basis of a free electron theory of super-conductivity, it is difficult to understand how a sphere which is already rotating will suddenly acquire a magnetic moment upon being cooled below its transition temperature. In this case, the electrons move with the sphere above the transition temperature due to their finite interaction with the lattice (finite resistance). That they should suddenly lag behind to produce a mag- netic moment on cooling below the transition temperature seems surprising. The magnetic moment predicted for the rotating sphere is small, but should be measurable with sufficiently careful experimental technique. This experiment would constitute a fundamental method of testing the basic assumptions of the London theory.

C. Matters concerning the creation of a low temperature laboratory. It is to be supposed that the cryostat, if secured, would become the property of The Franklin Institute Laboratories for Research and Development. It seems appropriate, however, to recommend that the low tempera- ture laboratory be given some designation which would A-13serve to perpetuate the organization concerned in donating the equipment. Thus, if the cryostat should be provided by The Townsend Brown Foundation, it would seem appropriate that the laboratory be called the "Townsend Brown Laboratory for Low Temperature Research". Such a procedure would provide the means for credit- ing the Foundation with respect to all publications which would subsequently emanate from the Laboratory. It may be remarked that continual financial support of the operation of the Laboratory by the Foundation would prob- ably not be necessary; for once the Laboratory became established, there would be very little difficulty in obtaining Government and possibly other support on a high level of allotment for the purposes of carrying on the work of the Laboratory. In a following section we have outlined some of the types of problems which might be expected to be carried on by a low temperature laboratory of the above kind. We also include a Bibliography of work which has already been published in the field of Low Temperature Research, A-14>e*t¿c Extreme low temperature research such as the following is being carried out in the many university and industrial laboratories equipped with ADL Collins Helium Cryostats. M e a s u r e m e n t of the mechanical p r o p e r t i e s of m e t a l s . Study of the superconductivity of solids. Investigation of the n a t u r e of n u c l e a r forces. M a g n e t i c susceptibility m e a s u r e m e n t s o n p a r a m a g n e t i c salts. Second sound measurements in liquid h e l i u m . Experiments on the p a r a m a g n e t i c resonance a b s o r p t i o n of solids. Study of phosphors a n d semiconductors for detection of infrared radiation. Investigation of the p r o p e r t i e s of liquid H e 3 . M e a s u r e m e n t of the r a t e of transfer of t h e H e I I film o v e r v a r i o u s surfaces. I n t e r p r e t a t i o n of the optical a b s o r p t i o n of solids. Study of electronic c o m m u n i c a t i o n s a n d c o n t r o l processes. The development of the ADL Collins Helium Cryostat as a reliable means for the quantity production of liquid helium has brought an entire field of research, previously carried on in only a few laboratories, into the range of every-day investigation and use. Phenomena which have been known to occur in the neighborhood of Absolute Zero, and those which have recently been discovered, had not been exploited for useful purposes simply because of the excessive effort required to obtain these low temperatures. The general effect of extreme low temperature is the production of ordered states of atoms and electrons.

Study of matter in an ordered state bas revealed variations in behavior which at higher temperatures were masked by thermal motion. These phenomena have made low tempera- ture one of the most fascinating and fertile frontiers of current physical research, with practical development now only a question of time and research. Low-temperature physics is a technique which will make itself felt in all fields of pure and applied physics and engineering when the variety of uses to which it may be put is more fully realized.

90.1IV, Research in solid state phenomena with special relation to dielectrics of high' specific inductive capacity.

It is our understanding that researches on substances with high values of K are of considerable interest to The Townsend Brown Foundation, and we have no hesitation in concurring in the importance of such researches. It would seem that further investigation of the properties of substances of high K should be made in the realms of breakdown resistance, ferro-electrets, hysteresis, and allied phenomena. Special interest attaches'also to the characteristics of electrets as such and to the conditions necessary to secure high activity of such electrets over long periods of time. In all of the foregoing work, low temperature re- searches involving the cryostat would.be of fundamental importance; for although the dielectrics are not usually used at low temperatures, many of the characteristics which determine their behavior at ordinary temperatures can be examined more readily by experiments performed at low temperatures. In view of the Foundations interest in dielectric phenomena, we shall discuss this field first. A-15A, Proposal for a program on dielectric measurements at low temperatures, A survey of the literature on low temperature phenomena shows a large amount of work which has been carried out on the properties of paramagnetic salts, whereas the properties of dielectric materials have hardly been investigated at all. The reasons for this (f difference in emphasis are easily understood. At liquid i. helium temperatures, the system of magnetic moments in most of the common paramagnetic salts is still in a thermally disordered state so that its magnetic properties are still varying with temperature in an interesting fashion. In addition, since the technique of adiabatic demagnetization of a paramagnetic salt is the sole means, at the present time, of producing temperatures well below 1 K, it is only natural that a great amount of effort has been spent in the elucidation of the properties of these materials. Most normal dielectric materials show a negligible variation of their dielectric properties with temperature, especially in the liquid helium region. This may be seen by looking at the main sources of polarization in a dielectric, namely: A-16 \

1, The electronic polarizability, which arises from the fact that the outer electrons of an atom can be displaced with respect to the nucleus by an external electric field thereby creating a dipole moment. This is a property of the particular atom under consideration and is independent of temperature,

2, The ionic polarizability, arising from the displacement of positive ions with respect to negative ions in an ionic crystal. In most materials, this type of polarizability varies only very slowly with temperature, leading to a slight variation of dielectric constant with temperature. That this is not always the case is the reason for the present proposal,

3, Polarization due to the alignment of molecules with permanent dipole moments. In solids, where the molecule is not free to rotate, this effect is absent. In recent years, a number of ferroelectric compounds have been discovered which are practically completely analogous in their dielectric behavior to ferromagnetic materials. Thus, they show a Curie temperature, above which the dielectric constant follows a Curie-Weiss law and below which they exhibit spontaneous electrical polari- zation and hysteresis properties. Barium titanate (BaTiO-J A-17is the most well known of these compounds. Most of these compounds have Curie temperatures which are fairly high. Two compounds are known which have very low Curie temperatures. These are Potassium Tantalate (KTaO^) and Lithium Thallium Tartrate (LiTlC^H^Oè.I^O) , with Curie temperatures at 13»2°K and 10°K respectively. The existence of these very low Curie temperatures has created an additional interest in the study of dielectrics at the low temperatures obtainable with a Collins Helium cryostat. In addition to the intrinsic value of a program on the properties of dielectrics at low temperatures, it is conceivable that it might be possible to provide another means of producing temperatures lower than 1°K other than adiabatic demagnetization. If one had a ferroelectrici material with a Curie temperature well below 1°K, then! I by the adiabatic, reversible depolarization of the material, it should be possible to produce a cooling effect (electro-caloric effect). Since the equipment involved in this process is somewhat simpler than in the corres- ponding magnetic case, it would be of considerable interest to investigate its feasibility. This method is not applicable below the Curie temperature since the presence of hysteresis and spontaneous polarization intro- duces irreversible heating effects upon applying or removing an external electric field. A-18The Curie temperature of BaTiO-j can be decreased by reducing the lattice parameter either by the addition of strontium or by application of external pressure. Presumably, this technique can be used to decrease the Curie Temperature of KTa03 or LiTlC/^Oo^O, An understanding of the factors which influence the Curie temperature and of the range of Curie temperatures in different crystals is important for the development of a basic theory of ferroelectricity. In summary, it appears that a program on the properties of dielectrics at low temperatures can con- tribute substantially to our understanding of solids. We propose to carry on such a program at The Franklin Institute. The starting point for this program should logically be an investigation of KTaC^ and LiTlC^H^Oé-HgO as well as structurally similar crystals and their solid solutions with each other. A-19Bp Certain additional problems in which the cryostat can be of service. Work concerned with Phosphors The Bartol Foundation of The Franklin Institute has been concerned for some time in the investigation of phosphors, with particular relation to our studies leading to the enhancement of particle counter techniques. The properties of

such phosphors are determined very largely by the presence of impurities in a manner which is rather well understood, but which calls for much further investigation. Fundamental to the behavior of such phosphors is the postulated existence of certain energy levels, generally referred to as "traps", to which electrons may be raised by way of a conduction band by suitable external stimulation, and from which they may depart, again through the conduction band, with the emission of light - frequently ultraviolet light. The temperature plays a very important role in the theory of such emission and absorption of energy, and it is of great interest to investigate the behavior of these phosphors over as wide a range of temperatures as possible. A-20The particular interest of very low temperature measurements lies in the possible existence of traps very near (in energy) to the conduction band. If such traps exist, the light emission at low tempera- ture would be drastically different from what it would be in their absence, both in amount and as regards time variation. Moreover, the study of light emission at these temperatures should lead to knowledge of the depths of the traps below the energy of the conduction band,

C. Piezoelectric and allied phenomena. It is, of course, natural to include piezoelectric phenomena as part of basic research relating to any wide program concerned with dielectric material. Requirements for the types of researches above suggested can vary over very wide limits depending upon the amount of work undertaken. As a rule, the apparatus involved is relatively inexpensive. Some of it is even of the old electroscope and tin can type, 'Valuable work could be done by one physicist and a technician working continually and supported by a very modest budget» It would be possible to carry on a larger program with corresponding enhancement of the numbers of personnel. A-21We can readily visualize k or 5 independent fields of research going on at the same time and involving per- haps 4 or 5 physicists, with an equal number of tech- nicians. Do Other work having to do with crystals. While the cathode group of the Bartol Research Foundation has been concerned largely with the proper- ties of semi-conductors, the interest has lain rather in the direction of high temperatures than low tempera- tures. Nevertheless, this work does ramify into a realm dealing with the fundamental properties of the crystalline structures which are concerned. Low tempera- ture measurements have primary bearing upon optical phenomena concerned with these structures. For example, optical absorption studies of thorium oxide have been made, and show a bell-shaped absorption curve at 4000 S, followed by a complete cut-off at 3700 A. For wave lengths longer than that corresponding to the maximum of the absorption bell, a monotomic decrease of absorption takes place. There are reasons for believing that at low temperatures the width of the bell will decrease, and that further structure will appear which will be of interest regarding conduction theory. A-22The aforesaid narrowing of an absorption maximum at low temperatures is well known in the case of F centers in alkali halides, and has been used by Seitz as evidence that the F band in KBr is due to one kind of lattice effect only. Moreover, from the width and height of the band, the number of absorption centers can be computed. As the band narrows, the maximum shifts to shorter wave lengths. The theoretical implications of this phenomenon have not yet been worked out. A shift to shorter wave lengths is found also for the fundamental absorption band, as well as for absorp- tion due to color centers. This shift is presumably to be associated with thermal perturbation of the levels of the valance electrons. In general, it can be said that, when phenomena involving very shallow traps are involved, low tempera- tures are required for the phenomena to appear. At higher temperatures the electrons do not remain in the traps for an appreciable time. These characteristics are, of course, in harmony with those already discussed in connection with phosphors. In the case of oxygen-rich thorium oxide, a reddening is produced by irradiation with light of 4000 A, This color is stable at 300°K and bleaches rapidly at 500°, It is possible that, at low temperatures, additional forms of radiation coloring will appear, such coloring being thermally destroyed at room temperature.

V, Researches seeking to discover a relationship between electrodynamics and gravitation. It is our understanding that The Townsend Brown Foundation is greatly interested in such a project as would be defined by the above heading. It is to be remarked that the problem of relating gravitation to electrodynamics and the quantum theory is one which has taxed the ingenuity of some of the best mathematical brains for the last 30 years. As yet no very complete satisfactory resolution of the matter has been found. However, we are not completely in the dark with regard to it0 Thus, the so-called "red-shift" produced by gravitation, and even the deviation of light by stars, are phenomena which are concerned with the relationship between gravitation and electrodynamics. The magnitudes of these phenomena, however, are so small that even the red shift, for example, which is measured in a gravitational field some 50 times that of the earth at its surface, or in a gravitational potential some 2500 times that of the earth at its surface, is a quantity so small as to tax the ingenuity of our most refined experimentalists. No one can deny the possibility that there may arise a Newton who so revolutionizes all of our previous thoughts on gravity, electrodynamics and quantum theory as to render the story of the interrelation of these fields one of consistency and satisfaction. No one can deny that that interrelationship would have very profound significance. Even if it does, however, it would seem likely that smallness of magnitude of the interrelationships, as pertaining to any terrestrial experiments, would continue to exist and that any practical bearing which the inter- relationships might have upon us would lie in their effects in some large-scale cosmological situation which they control and which, in turn, control our origin and existence. We believe that there is much yet to be done in the correlation of our understanding of these matters and we believe that the work is worthy of effort. We are in- clined to think, however, that it is rather of the long- range type.

For the foregoing reasons, we believe that something may be achieved by what Mr, Townsend Brown has called the "library project" which, as its first step, attempts to write a report summarizing the status of the whole problem, and suggesting avenue for its extension. It would seem natural to suggest that the Foundation should sponsor two types of investigation, one

of the experimental character on other matters, and along the lines of the examples already quoted, and the other of the long-range theoretical type, looking towards an elucidation of some of the fundamental problems involved, as aforesaid. CONCLUSION: The Franklin Institute Laboratories for Research and Development welcome this opportunity for closer cooperation with Mr, Brown and The Townsend Brown Foundation, In case the Foundation desires to support a repetition of the Trouton-Noble experiment, this work could proceed at once, and occupy the time necessary to acquire a cryostat and' set the equipment in operation. Work on the two basic experiments outlined above would then proceed at our expense, with due credit to the Foundation for making this important work possible. A-26

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