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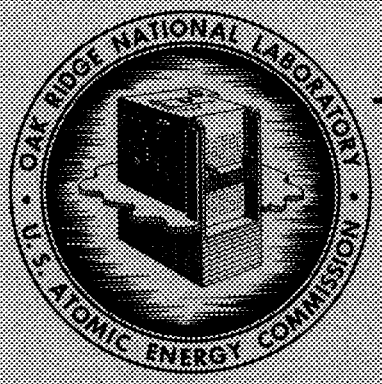
# PRELIMINARY REPORT ON BALL LIGHTNING

J. Rand McNally, Jr.

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# PRELIMINARY REPORT ON BALL LIGHTNING

J. Rand McNally, Jr.

MAY 1966

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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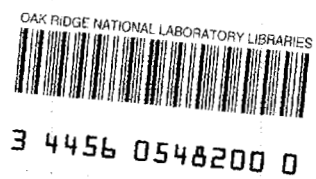

# Preliminary Report on Ball Lightning

J. Rand McNally, Jr.
Oak Ridge National Laboratory*

## ABSTRACT

This report is an extension of remarks made in a 1960 paper[1] and was prepared about December, 1960. Though out of date in several respects (e.g., the possible roles of active nitrogen and of self-binding plasma forces, etc.) and perhaps erroneous in others, the original unpublished report is still being requested by individual scientists and reference agencies. The report, with minor changes, is now (March, 1966) being placed in official documentation channels to make it more readily available to interested sources. The following abstract accompanied the oral paper: "Ball lightning is a possible stable plasma configuration and hence may merit some consideration in the field of thermonuclear research.[2] A survey of 15,923 Union Carbide Nuclear Company personnel in Oak Ridge has been made with 498 reports of unusual lightning phenomena which the observers thought may have been related to ball lightning. Some of the results of the survey will be presented."

*Research sponsored by the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

[1] Ball Lightning - A Survey, Proc. Second Annual Meeting Div. Plasma Physics, Gatlinburg, Tenn., Nov. 2-5 (1960). See Bull. Am. Phys. Soc. 6, 202 (1961).

[2] P. L. Kapitza, Proc. Acad. Sci. USSR 101, 245 (1945); V. D. Shafranov, J. Exptl. Theor. Phys. 33, 710 (1957), translated in Soviet Physics - JETP 6, 202 (1961).

# PRELIMINARY REPORT ON BALL LIGHTNING*

J. Rand McNally, Jr.
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## INTRODUCTION

The study of rare and controversial events in natural phenomena sometimes leads to new basic concepts affecting important areas of physical research. Thus, it is possible that an admixture of ideas gleaned from ball lightning observations and from the field of plasma physics may be mutually rewarding. The fact that an event is rare and that "It appears that no professional observers of the weather, such as meteorologists, have ever seen a fire-ball"[1] does not detract from the unusual character of the many literature reports, which indicate the existence of extremely unusual plasma or gas discharge properties.

"Ball lightning", as a possible stable plasma configuration, is receiving increasing emphasis in research especially in the USSR.[2] Except possibly for the controversial Cougnard deionizer[3], designed to minimize ball lightning damage to high voltage transmission line equipment, no practical application seems to have been developed.

It is entirely possible that there may be several different physical forms of "ball lightning", each exhibiting its own characteristic set of properties. The phenomena are definitely in the rare event category and reported cases are usually interpreted as one of several types of atmospheric type discharges.

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*Presented in part at the Second Annual Meeting of the Division of Plasma Physics of the American Physical Society, Gatlinburg, Tennessee, November 2-5, 1960, Paper J-15.

[1] B. F. J. Schonland, The Flight of Thunderbolts, Oxford at the Clarendon Press, p. 51 (1950).

[2] D. J. Ritchie, Missiles and Rockets, August 24, 1959.

[3] H. N. Ekvall, Electrical World, p. 85, March 11, 1957.

The air-borne, bouncing, spinning, or rolling varieties of fire-balls which either radiate and decay slowly, or disappear explosively resulting in considerable heating or damage, suggest that significant energy is stored in the fire-ball - possibly megajoules.[4,5] Carbonizing of humans by ball lightning has been reported[6] or suggested.[7]

The characteristics of the lightning bolts which apparently produce ball lightning are not known in detail. In general, however, lightning strokes may involve up to 164 coulombs, up to several kilomegavolts potential differences, and up to about 20 kilomegajoules. Most current strokes are less than $10^4$ amperes but have been reported, on rare occasions, to exceed $2 \times 10^5$ amperes.[5,8] The breakdown potential of dry air is about 30,000 volts/cm and probably less than 10,000 volts/cm for moist air.

## PHYSICAL MODELS FOR BALL LIGHTNING

Various attempts have been made to explain the nature of ball lightning in terms of chemical dissociation and ionization phenomena.[9] Kapitza[10] opposes such hypotheses on the grounds of insufficient energy storage by this means. He also estimates the decay time to be of order 0.01 seconds for a 10 cm diameter fire-ball by comparison with the decay properties of a nuclear fire-ball. The stored energy of a fully dissociated and once

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[4] L. Tonks, Nature 187, 1013 (1960) estimates 0.36 megajoules total radiation for a particular idealized case (10 cm diameter).

[5] B. L. Goodlet, J. Inst. Elect. Eng. 81, 1 (1937) estimates 4 to 11 megajoules for an actual fire-ball the size of which was reported to be that of a large orange.

[6] M. Cerrillo (1944), translation available, R. Hines and P. A. Silberg, Advanced Development Laboratory, Raytheon Company, Wayland, Massachusetts.

[7] C. Benedicks, Arkiv. f. Geofysik 2, 1 (1951).

[8] W. W. Lewis, Protection of Transmission Systems Against Lightning, John Wiley & Sons, Inc., N. Y. (1950).

[9] See review by E. L. Hill, J. Geophys. Mag. 65, 1947 (1960).

[10] P. L. Kapitza, Proc. Acad. Sci. USSR 101, 245 (1955); Physikalische Blatter 1 (1958).

ionized cubic centimeter of air is about 160 joules.[9] This is less than the estimates of Tonks (~ 700 joules) and Goodlet (~ 16,000 joules) for energy requirements. Multiple ionization would account for additional stored energy.

There are certain basic questions to be answered: 1. Is the energy of the fire-ball fed continuously by the external atmospheric fields? 2. Does the fire-ball exist initially with this large amount of stored energy? 3. Is it possible that both of these two types of fire-balls are distinct entities? If the answer to (1.) is yes, the actual stored energy of the fire-ball would be expected to be low but the long-livedness of the system might be satisfactorily explained. If the answer to question (2.) is yes, a tremendous amount of stored energy must be confined for a long time without explosion yet, on occasion, permit rapid release of the stored energy. An analogy to the latter might be a spinning propeller which suddenly encounters an obstacle resulting in the stored energy of ordered motion being spontaneously released as heat, sound, etc.

Cerrillo[7] and more recently Kapitza[10] proposed a model in which electromagnetic energy is fed to the ball or kugelblitz from an external atmospheric source generating very intense, high frequency standing electromagnetic waves which are absorbed in the plasma. This explanation seems to describe appropriately the beaded, chain, or "rosary kugelblitz" in which energy external to the phenomenon is dissipated at the beads as a result of standing wave interference effects, although the "sausage instability" may contribute to the generation of such phenomena. Watson[11] and Tonks[4] point out that the fire-ball should lie at the electric node contrary to Kapitza's suggestion that the electromagnetic energy would be dissipated at the anti-nodes. Watson also presents arguments supporting the theory of Kapitza whereas Tonks poses several difficulties for the theory. Silberg[12] has also contributed to the standing wave theory.

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[11] W. K. R. Watson, Nature 185, 449 (1960).

[12] P. A. Silberg, Advanced Development Laboratory, Raytheon Company, Wayland, Mass.

Another possible interpretation of a ball lightning type may be that it includes a circular or ring current in equilibrium with the pressure of the external atmosphere. Shafranov[13] proposed such a theory for ring (presumably electron) current pinches in stable equilibrium configurations defined by (a) a gravitational field, (b) an external gas pressure (ball lightning), or (c) an external magnetic field. A model for a thermonuclear plasma involving an ion current ring in equilibrium in only a mirror magnetic field has also been suggested.[14] Veksler[15] has also discussed the concept of plasma rings in connection with "coherent" accelerator work. Earlier, Kolobkov[16] discussed mechanisms for producing such a rotational motion in the lightning ball by (a) kink instability of a lightning discharge or (b) near crossing of two current discharges in opposite directions. The $\overset{o}{B}_\theta$ field associated with a magnetic compression of plasma resulting from the tremendous $\overset{o}{I}$ of a lightning bolt may be another mechanism for inducing such ring currents.[17]

It is, of course, possible that generation of a fire-ball by Kapitza's model might result in a stable configuration possessing an inherently large amount of stored energy. Thus, the wavelength of the electromagnetic vibrations required by Kapitza to develop a plasma sphere of diameter d is $\lambda = 3.65\ d$ whereas the "de Broglie wavelength" associated with a ring current can be $\lambda' = 3.14\ d'$, where d' is the ring diameter.

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[13] V. D. Shafranov, J. Exptl. Theoret. Phys. 33, 710 (1957), translation in Soviet Physics - JETP 6, 545, 1958.

[14] J. R. McNally, Jr., unpublished material (Dec., 1957); "On the Energy Dependence of the DCX Type of Sherwood Device", unpublished (Aug., 1958); "The Direct Current Experiment (DCX) and High Temperature Measurements in the Carbon Arc", paper in Optical Spectrometric Measurements of High Temperatures, University of Chicago, University of Chicago Press (1961).

[15] Private communication to J. Neufeld by V. I. Veksler during his visit to Oak Ridge National Laboratory, Nov. 16, 1959.

[16] N. V. Kolobkov, Atmospheric Electricity, p. 47-50 (1951).

[17] See, for example, V. Josephson, M. H. Dazey, and R. F. Wuerker, STL Report TR-60-0000-19258 (1960) for $\overset{o}{B}_z$ compression experiment leading to a ring current.

There appear then to be valid reasons for surveying the field of ball lightning for physical properties related to a plasma or thermonuclear system in a static or even dynamic type of equilibrium analogous to Shafranov's model.

## SURVEYS

Brand,[18] Humphreys,[19] and Rodewald[20] have collected numerous accounts of ball lightning reports and attempted to evaluate them. Brand believed 215 of 600 accounts to be detailed enough to insure a certain degree of confidence in their value. Brand's summary, available in Goodlet's article,[5] is quite excellent. Humphreys examined 280 accounts and concluded that none of these were authentic fire-balls. Rodewald discusses about 15 cases.

A preliminary survey in the form of a questionnaire was made of Oak Ridge National Laboratory monthly role personnel. A total of 110 individuals reported observations on "ball lightning" for a return of 5.6 per cent observations from a statistical sample of 1962 people. The complete survey of all Union Carbide Nuclear Company personnel in Oak Ridge resulted in a grand total of 513 reports from a statistical sample of 15,923 individuals (3.1%). The difference in these percentages is probably significant but no explanation is proposed, although it may be associated with the wider geographical background of the monthly role ORNL sample.

Table I is a copy of the questionnaire distributed in the survey. Tables II-XI list some of the results. No cross-correlations have been made. Table XII lists some of the more human interest suggestions and comments. Table XIII gives some of the actual observations.

It should be realized that the inclusion of leading, multiple choice questions offers the possibility of pyschological bias in the results obtained. However, it should also be realized that in sampling 15,923 individuals it would be quite difficult to obtain completely unbiased responses in any testing where physiological and psychological responses are involved.

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[18] W. Brand, "Der Kugelblitz", Hamburg (1923).

[19] W. J. Humphreys, Proc. Am. Phil. Soc. 76, 613 (1936).

[20] M. Rodewald, Z. Meterologie 8, 27 (1954).

A summary of the observations suggests that lightning balls (1) usually occur as the result of lightning discharge; (2) originate randomly in space although are often initially associated with wires or structures; (3) are frequently air-borne or partly air-borne; (4) move randomly in space or along conductors and oftentimes exhibit a rolling or spinning motion; (5) are usually about 10 inches in diameter; (6) are usually spherical in shape; (7) are very rarely green or violet in color but are frequently multi-colored (the white and blue-white balls are usually very hot and brilliant and often cause considerable damage); (8) have a median duration of about 3-4 seconds; (9) usually decay quite suddenly (sometimes explosively); (10) generally do not affect the vision unless of the white or blue-white category and close to the observer. In numerous cases other supporting witnesses were on hand and gave essentially the same details.

The statistics compiled agree in general with other observations reported in the literature.[5, 18-21] There is no doubt that some of them fall into the category of "St. Elmo's Fire"*, "Jacob's Ladder"**, and other type discharges involving conductors or a conductor and the atmosphere; however, there is a surprisingly large number of the individual, air-borne, free-floating type (144 instances plus 90 which were air-borne part-time) to which Kapitza's postulate of standing waves may not apply, according to Tonks.[4] No reports of beaded or rosary lightning were made.

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[21] See, also, H. Nauer, Umschau Fortschr. Wiss. u. Tech. 56, 75 (1956); J. C. Jensen, Physics 4, 372 (1933).

* Named after St. Erasmus (died A.D. 303?) who under the persecution of Diocletian was tortured, rolled in pitch and set afire. He remained unhurt, was reimprisoned to be starved to death but was reportedly freed by an angel. The blue glowing lights (corona discharge) sometimes seen at mastheads before and after storms were thought by the Neapolitan seamen to be signs of their patron's protection and were called St. Elmo's fire (Erasmus through the years became Eramus, Ermus, Ermo, and finally Elmo). St. Elmo's fire is characterized as a high voltage, low current discharge. Also, sometimes called "Peter's fire" after Blessed Peter Gonzalez of Portugal.

** In the Old Testament, Jacob is reported to have seen a band of angels ascending to heaven upon a glowing ladder. A low voltage, high current electrical arc between two almost parallel wires gives a discharge which is magnetically blown along the wires - hence the name Jacob's Ladder.

The fact that 62 observations of doughnut or ring configurations and 50 observations of surface type of glow distributions were reported suggests the possibility of an excited ring or surface. It is possible that psychological factors inherent in the question may have led observers to make such reports on the glow distribution ("Was it a surface, volume, doughnut, or ring type of glow?"). It is also possible that multi-coloring of the ball (see Table VIII) due to internal temperature variations may account for such a glow distribution. Although no question was asked specifically on the internal motion of the lightning ball, 46 individuals reported a rolling, spinning, or tumbling type of motion suggesting rotational plasma or mass flow and the possibility of an internal ring current. Many cases reported in the literature ascribe a rotational property to the ball. A ball lightning observation reported by L. B. Loeb to Humphreys[19] included the statement, "It has been my impression in thinking of it that the so-called ball was internally in rapid rotation of some sort or there was a vortex which gave it its shape".

TABLE I. QUESTIONNAIRE ON "BALL LIGHTNING"

"Ball Lightning" has been considered by numerous capable scientists as having objective reality and several physical models have been proposed to explain the phenomenon. In view of its possible interpretation as a stable plasma configuration and hence importance in the thermonuclear field the following questionnaire is submitted. Please fill out and return to the Thermonuclear Experimental Division. Any additional comments, references, or listing of observers you make will be appreciated.

1. Have you ever seen "ball lightning"? Yes_____ No_____
2. Did it occur only after a lightning flash? Yes_____ No_____
3. Approximately how long did it persist? _____
4. Did it decay slowly or suddenly? _____
5. What size or range of sizes was the ball? _____
6. Was it a surface, volume, doughnut, or ring type of glow? _____
7. Did the size of the ball change? _____
   (a) quickly _____
   (b) gradually _____

8. Did any unusual sounds accompany the phenomena or its disappearance? Yes_____ No_____

9. Did it cause any unusual disturbance or leave any aftereffects? Yes_____ No_____

   (a) objects scorched? Yes_____ No_____

   (b) objects melted? Yes_____ No_____

   (c) magnetic objects disturbed? Yes_____ No_____

   (d) non-metallic objects disturbed? Yes_____ No_____

   (e) electrostatic effects? Yes_____ No_____

   (f) photographic film (x-ray) effects? Yes_____ No_____

   (g) activation effects? Yes_____ No_____

   (h) sunburn? Yes_____ No_____

   (i) odor? Yes_____ No_____

   (j) other? _____

10. Did you notice any point type discharges? Yes_____ No_____

11. Did it move randomly in space, follow conductors, remain in general contact with surfaces, or was it air-borne part of the time? _____

12. What color and color changes were noted? _____

13. Did you notice any heat or heating effects? Yes_____ No_____

14. Did you have any special visual effects during or after the event? Yes_____ No_____

15. Comments, suggestions, etc:

_____

_____

_____

_____

_____

_____

Thermonuclear Experimental Division
Building 9201-2
Room 335

TABLE II. OBSERVATIONS ON CONDITIONS ASSOCIATED WITH ORIGIN OF BALL LIGHTNING

| | |
|---|---|
| Unreported or Uncertain | 69 |
| Following Lightning Discharge | 376 |
| Not Following Lightning Discharge | 65 |
| Clear Sky | 3 |
| TOTAL | 513 |

TABLE III. OBSERVATIONS ON POINT OF ORIGIN

| | |
|---|---|
| Unreported or Uncertain | 350 |
| Metallic Structures | 42 |
| Electrical Lines | 41 |
| Non-metallic Structures | 33 |
| Occurred in Air | 26 |
| Telephone Lines | 21 |
| TOTAL | 513 |

TABLE IV. OBSERVATIONS ON ENVIRONMENTAL CONDITIONS

| | |
|---|---|
| Unreported or Uncertain | 55 |
| Air Borne | 144 |
| Attached to Conductors | 114 |
| General Contact with Non-Conductors | 111 |
| Air Borne Part Time | 89 |
| TOTAL | 513 |

TABLE V. OBSERVATIONS ON TYPE OF MOTION

| | |
|---|---|
| Unreported or Uncertain | 237 |
| Along Conductors | 103 |
| Floating, Bouncing, Random Motion | 68 |
| Tumbling, Spinning or Rolling Motion | 46 |
| Approximate Straight Line Motion | 31 |
| Stationary | 14 |
| Along Surface | 7 |
| Jumped from Conductor to Conductor | 7 |
| TOTAL | 513 |

TABLE VI. ESTIMATED SIZE OF LIGHTNING BALLS

| | |
|---|---|
| Unreported or Uncertain | 67 |
| Less Than One Inch | 3 |
| One-Two Inch | 18 |
| Three-Four Inch | 52 |
| Five-Eight Inch | 114 |
| Nine-Sixteen Inch | 129 |
| Seventeen to Thirty-Two Inch | 73 |
| Thirty-Three to Sixty-Four Inch | 37 |
| Greater Than Sixty-Four Inch | 20 |
| TOTAL | 513 |

TABLE VII. REPORTED GLOW DISTRIBUTION IN LIGHTNING BALLS

| | |
|---|---|
| Unreported or Uncertain | 79 |
| Uniform or Volume | 313 |
| Ring or Doughnut | 62 |
| Surface | 50 |
| Miscellaneous Shapes | 9 |
| TOTAL | 513 |

TABLE VIII. REPORTED COLOR* OF LIGHTNING BALLS

| | |
|---|---|
| Unreported or Uncertain | 202 |
| Red | 38 |
| Orange | 32 |
| Yellow | 23 |
| Green | 3 |
| Blue | 26 |
| Violet | 2 |
| White | 22 |
| Blue-White | 27 |
| Red-Orange | 23 |
| Yellow-White | 16 |
| Orange-Yellow | 14 |
| Miscellaneous Two-Color Combinations | 57 |
| Miscellaneous Three-Color Combinations | 28 |
| TOTAL | 513 |

*Possible color-blindness of subjects not known

TABLE IX. ESTIMATED DURATION OF LIGHTNING BALLS

| | |
|---|---|
| Unreported or Uncertain | 68 |
| Less Than One Second | 33 |
| One to Two Seconds | 133 |
| Three to Four Seconds | 136 |
| Five to Eight Seconds | 44 |
| Nine to Sixteen Seconds | 43 |
| Seventeen to Thirty-Two Seconds | 23 |
| Thirty-Three to Sixty-Four Seconds | 16 |
| Sixty-Five to One Hundred Twenty-Eight Seconds | 7 |
| Greater Than One Hundred Twenty-Eight Seconds | 10 |
| TOTAL | 513 |

TABLE X. TYPE OF DECAY OF LIGHTNING BALLS

| | |
|---|---|
| Unreported or Uncertain | 92 |
| Slowly | 112 |
| Suddenly | 309 |
| TOTAL | 513 |

TABLE XI. REPORTED VISUAL AFTEREFFECTS

| | |
|---|---|
| Unreported or Uncertain | 97 |
| After Image, Blurred Vision, etc. | 110 |
| No Effects | 306 |
| TOTAL | 513 |

TABLE XII. SELECTED HUMAN INTEREST COMMENTS AND SUGGESTIONS

1. "Physicists are notoriously unreliable observers".
2. "I have heard of this phenomenon from a highly unreliable source".
3. "Somebody must have better things to do with their time".
4. "Try 'White Lightning'".
5. "Try flying saucers".
6. "I don't look at lightning".
7. "I couldn't swear to any of the above answers, so I won't attempt to answer them".

8. "I will endeavor to be more observant".
9. "My salary doesn't pay for a scientific scope".
10. "You are really leaving no stone unturned".
11. "I've never seen flying saucers either".
12. "A man I once worked for many years ago described an orange ball of fire he had seen ..... The man was poorly educated".
13. "Lightning struck tree several hundred feet away, ball flashed across and into open end garage, followed wall at ground level, probably faded as it left garage when I did".
14. "I ducked".
15. "It was pretty".
16. "Don't want to see any more".
17. "Let God handle this".

TABLE XIII. SELECTED COMMENTS ON BALL LIGHTNING REPORTS

Observation No. 2

"(a) This incident happened several years ago. The opinion of several at the time was that lightning discharged to one conductor of a 154 KV transmission line and followed it to a power substation less than 1/4 mile away. Choke coils and lightning arrestors with horn gaps at substation did not check the discharge to any appreciable extent; however, ground cables from arrestors were slightly burned. The damage consisted of broken insulators and melted copper conductors on low tension bus and complete burnout of 3 - 2000 KVA transformers.

(b) Several people saw this incident. We were all approximately 250 ft. from point at substation where extensive damage was done.

(c) The noise along with this was very deafening and was similar to noise of large spark gap with great frequency.

(d) The interval of time of the damage to substation was very short and during this brief interval there were many discharges from low tension bus to structure, and from transformer cases to structure - all insulators on low tension bus were shattered, as well as both low tension and high tension bushings of all three 2000 KVA transformers.

(e) We were never able to tell if the 'ball' or 'discharge' of lightning did all the damage to the substation, or if it was the primary cause in starting the 'shorting' between low tension bus, structure and transformer cases.

(f) The mystery of the incident was that this 'ball' or 'discharge' passed through or over 154 KV oil switch on the line entering substation, and it was not damaged in the least. Neither did it open, as would normally happen in case of a 'surge'.

(g) This thing was kicked around for some time and many debates followed. I never did learn anything that was definitely established or documented.

(h) One thing did stand out - there was terrific heat from the 'ball' or 'discharge' - the surface of the transmission line was deeply pitted on top - however the materials (porcelain, steel and copper) of low tension bus and its insulators with supporting steel structure were in part completely melted as if from a crucible - this same melting occurred on tops of transformers cases and with portions of both LT and HT bushings."

Observation No. 3

"This was noted during an intense electrical storm. Lightning struck a telephone line and the ball was discharged from the phone. It appeared to be a sphere about 4 to 6 inches in diameter which 'floated' by a screen door when it disappeared. I was a child at the time and was not interested in detailed observation but was merely frightened."

Observation No. 8

"Twice, on different occasions, a tumble weed type of movement was seen along a fence, along railroad tracks. These observations were made in mid-afternoon just before a local twister, no rain, where we were. Seemed to explode and vanish."

Observation No. 10

"The summer of 1927 I was working with a state highway surveying party. One afternoon we were having an electrical storm. No rain at the time. One of the boys was holding a level rod (a level rod is wooden, about 13' long and on the bottom and top it has a brass cap) in the center of a black top road. The lightning seemed to strike the top of the rod, it appeared to be a ball, then spinning it left rod and struck road about 50' away, rolled down road about 100' and disappeared as tho it was exhausted."

Observation No. 12

"The ball appeared on a 5500 volt transmission line approximately 20 ft. from a pole. The ball persisted and slowly moved along the wire to the insulator which then exploded."

Observation No. 16

"About 1926, during a summer thunderstorm centered 1/2 to one mile away, I was watching frequent cloud-to-ground lightning discharges. I saw a white ball 'float' to the ground, following a vertical path. To my recollection it was not preceded or accompanied by an ordinary lightning stroke. I estimate approximately one second from its appearance at the base of the cloud until it disappeared behind a hill into a uninhabited swamp and woods area. The ball did not change in size or appearance during my observation; its path was somewhat wider than that of an ordinary lightning stroke. Some luminosity of the trail persisted for a fraction of a second behind the ball. There were no unusual sounds and I have no information on after effects. So far as I know, I was the only observer."

Observation No. 17

"About 1939, during a local electrical storm, I observed a ball of fire following the upper (ground) wire of a high-tension line a little less than a half mile away. This ball was immediately preceded by a stroke of lightning which I presume hit the high-tension line. The ball lasted for two or three seconds; I'm sorry I don't remember its disappearance, but I think it was sudden. The ball appeared to be one or two feet in diameter, was reddish in color, did not seem to change size, and was spherical in shape. It followed the conductor as though it were rolling on top of it for perhaps 100 yards. I cannot say with certainty whether it was accompanied with unusual sounds or visual effects. The electrical transmission line was knocked out but I do not know for sure of any other disturbances or after effects. I believe that some of our neighbors also saw this phenomenon."

Observation No. 20

"About 30 years ago I saw a firey ball descend from the sky and strike a fence of barbed wire attached to wooden posts. The ball traveled along the top of the top strand of wire for some minutes, then disappeared. A strange rustling sound accompanied this appearance. In the beginning, the

ball appeared larger than at the end. The size of the ball I should place at less than 4" and I don't believe it was much larger than 18" in diameter. I examined the fence within minutes after the ball had disappeared and found the tops of the posts warm and very slightly scorched. That is, only the loose portion of the surface was scorched."

Observation No. 23

"Bounced three times, then rolled about 100 ft. down center of street. Orange flame color was constant."

Observation No. 42

"Ball seemed to roll in a forward direction. Velocity seemed slow relative to rate of rotation. Ball also seemed to parallel ground about 30 ft. above it."

Observation No. 45

"This occurred after a lightning strike from a power pole. The ball seemed to move down the pole, across a street, over a man and into a wooded area. The man was dazed, sunburned, but otherwise unhurt."

Observation No. 46

"The above occurred once in Iowa, later in western Nebraska. Both involved the old 'crank type' country telephone. During electrical storms my father taught my seven brothers and me to always aim the phone mouthpiece toward the ceiling to minimize the chances of our being struck by a, quote, 'lightning ball'. At the time I was both too frightened and too small to observe any scientific aspects of the phenomenon, however, I recall seeing the red ball flash from phone to ceiling similar to a Roman candle discharge, except of much shorter duration."

Observation No. 49

"Date was late summer 1939 or 40, place Palestine, Ill. There was a thunderstorm in progress. I do not recall definitely whether it was raining before the event, but I believe it had not yet started raining. Later it rained rather hard. My memory is that it was simply 'working up to it' with thunder and lightning. My little sister had gone into a bedroom to use the phone when I heard her cry out and call my name. I ran into the room in time to see a 'ball of fire' settling to the floor much as an air filled balloon would. It struck the floor and rebounded slightly, again, about like a balloon. There was a rotary motion of the object. It rolled

and bounced (damped bounce like a light ball) across the floor to the leg of an iron bed. There was a blue flash, a rather loud spark discharge sound, a little vapor or smoke visible, and the thing was gone. I seem to recall that the white enamel on the bed leg was burned a little, but nothing dramatic. I might say that the sphere seemed to deflect on hitting the floor, that is, made a flat contact spot. The phone stood on a stand near the other end of the bed, and I seem to recall some malfunction of the phone, the particulars of which I forget. My sister told me that she called out when she saw the thing descending rapidly outside the window, and that it came down and through the steel wire screen (!) and bounced on the window sill. I might state that I find myself in the very unscientific shape of depending totally on my memory - I did not write a thing down at the time!"

Observation No. 57

(a) "I have seen what Midwest farmers refer to as a 'ball of lightning' on two different occasions. In each instance the ball was traveling at a high rate of speed along a power line. The ball had a very distinct blue cast, because of the viewing distance, I could not obtain a good estimate of its size. It, however, appeared to maintain a stable configuration during the short time in which I viewed it. In each case a severe electrical storm was occuring in the immediate area. The ball did not leave the power line on which I first observed it not withstanding the fact that other lines were nearby. It moved along the line and out of sight very rapidly. So far as I know, no damage to the line resulted."

(b) "On a third occasion I witnessed what may have been a simple lightning strike or may have been such a ball. I was working underneath a car with an extension light hung nearby during a severe electrical storm. I heard a crack suggestive of a lightning stroke and within a second or two witnessed a blue discharge from the extension light which raced from one point to another of the underside of the car. This discharge lasted for several seconds during which time I experienced at least one major shock. The final grounding point of the discharge was unseen."

Observation No. 61

"This is probably a marginal case. It occurred at the time lightning apparently struck (or very near) our house. The outdoor antenna wire was

shredded but not melted. Where the antenna entered the room the window sill was torn loose. The 'ball' appeared to originate at the window, float to the center of the room very rapidly, and just go out. Kerosene lamps in the room were extinguished and there was a strong odor of 'brimstone'."

Observation No. 63

"I am enclosing a sketch* of a phenomenon which I observed as a child; although perhaps it is not 'Ball Lightning', there may be some relationship. Do with it as you wish. I regret I cannot give more details. I was perhaps 10 or 12 years old at the time, very interested in watching lightning. I only remember this because it impressed me as being unusual (1) it occurred during a rather violent thunderstorm; (2) the 'Fire Ball' appeared as an explosion, and was instantaneous; (3) the color was the same as that of the spark; (4) a loud crash followed the discharge - perhaps 1 sec. later; (5) 30 seconds or more later, as I was still gawking in that direction, there was a repeat performance, almost identical to the first; (6) to the best of my knowledge, I know of no conductor in that area that could have been hit. I know of no damage to anything. The barn was not struck. I recall no further observation, as I was distracted at this point by the maid, who was now crouched in a corner, praying fervently!"

Observation No. 64

"I was standing on shore of circular pond of about 1/4 mile radius. Lightning hit center of pond, ball developed, traveled 10 or 15 ft. above water for approximately 100 yd., hit water, bounced up with air again, hit a hundred yards further on and suddenly disappeared while again in mid air. My age and that of several other witnesses was approximately 14 years."

Observation No. 69

"Ball seen rolling if you will on electric line conductor in air for 3 - 200 ft. spans and exploded at corner."

Observation No. 78

"During a storm, the oven door on the stove was knocked open and the ball lightning rolled out."

*Lightning spark shown terminating in a fire ball about 10 to 20 ft. above an old barn which was located about 1000 ft. from observer.

Observation No. 86

"Occurred during heavy thunderstorm; accompanied lightning strike just outside home; entered through open door in rolling motion and proceeded in a direct line toward shell casing (4" diameter shell casing)."

Observation No. 111

"Red with white tumbling light inside."

Observation No. 113

"A bolt of lightning hit a tree, splitting it partway down. The ball came off from the tree, traveling horizontally in a straight line. It stopped about 20 yards from the tree, seemed to spin or vibrate, and exploded with a bang."

Observation No. 129

"I was looking out of a window during a thunderstorm. Lightning struck a large oak tree about center and split off a limb. I noticed that the lightning continued down the trunk and seemed to roll away from the tree on the ground for a distance of about 15 to 20 ft. becoming larger from start to finish. I was approximately 75 to 100 yards from all this."

Observation No. 169

"I saw the ball lightning while feeding cattle on a farm in middle Tennessee in 1946. A bolt of lightning struck an electric fence or close to the electric fence about 600 ft. from the end of the fence where I was standing. After the strike, 3 balls of fire shot in rapid succession from the end of the fence and traveled about 200 ft. in the air (in a straight line) and hit the ground. The only noise I heard was the thunder and 3 'bangs' when the balls of fire left the fence. The pasture had a dehydrated appearance where the balls hit the earth. I was unable to tell where or what the initial bolt of lightning had struck."

Observation No. 184

"The lightning struck a country telephone line, traveled approximately 1/4 mile following the line to where it was disconnected at the house, rolled off the end of the line, hit approximately 12' out into the yard and bursted like a giant sparkler. Note: The pole at the point where the line was disconnected was split and the insulator bursted."

Observation No. 294

"This ball was seen a number of times by members of the family. It was always in the same room and same part of room about 2 ft. from ceiling."

Observation No. 332

"I was standing at a window during an electrical storm and observed this 'ball of fire' strike a utility pole. Upon contact with the pole there was an unusual illuminating effect upon the surrounding area. The ball of fire dissipated much as a Fourth-of-July 'sparkler' does. Evidently, it did not affect the transformer on the pole, as no repairs were made."

Observation No. 336

"Effect was viewed once from a distance of about 150 ft. away from the ball, visual effects from the initial flash obscured the effect for about 2 seconds. Ball seemed to originate about 6 ft. away from the 'ground to air' stroke."

Observation No. 368

"Lightning struck a metal well pump located on a porch to a residence, several 'balls' traveled on the surface of the floor the entire length of the porch, perhaps 30 feet, then vanished leaving no signs in its wake."

Observation No. 377

"What I saw happened many years ago and I do not remember the details too well. Lightning struck an electric power line transformer during a very severe electrical storm after darkness. When the lightning struck there was a noise like a crack of a gun. Balls of fire began pouring from the transformer and fell to the ground one after another. They appeared to be reddish orange in color and about 2 feet in diameter. I did not make any observations of the area in which this occurred after the storm."

Observation No. 403

"I saw this ball lightning at the age of 12 one afternoon on way home from school. We had a wind electrical storm combination which blew tree limbs down across power lines along the highway, over in lot about 100 yds. from the road. This pond intercepted the ball of lightning which went thru air in straight line to the pond. Upon hitting the water it sounded as if putting a red hot piece of iron into the water."

Observation No. 466

"I personally have observed this type lightning only once many years ago. It was entirely air-borne, resembled a Fourth of July fire work and was interconnected by lightning flashes. The thunder was especially violent, the first ball was blue, which exploded into several blue balls which traveled randomly and decayed in flashes of red light."

Observation No. 487

"Tumbled across floor, like pinwheel, ball appeared to be revolving, threw some sparks."

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