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AN INFORMAL REPORT

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Ball Lightning
A Status Summary to November 1971



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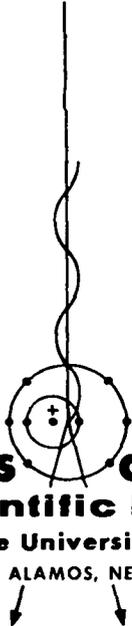
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by

J. L. Tuck



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ABSTRACT

Experiments to study Ball Lightning artificially are reported. Switch opening arcs at currents of up to 100,000 amperes from a large submarine storage battery (50-600 V) have given interesting but indecisive results. Higher voltage ~ 10 kV slowed-down condenser discharges have been similarly indecisive but with encouraging afterglows. Conjectures are made that: a) the ball lightning luminosity comes from a chemiluminescent reaction preceded by a chemionization, b) the ball lightning coherence is a consequence of a weak surface force in a cold plasma containing positive ion-negative ion dipoles. The scope of further theoretical and experimental work to elucidate these conjectures is outlined.

The lightning stroke is a well studied and understood phenomenon. For instance, the lightning current ranges from 200,000 amperes lasting for a few microseconds down to as little as 1000 amperes for a few tenths of a second. Similarly, there is much (though not complete) knowledge of the processes in the thundercloud, which produce the high voltage (~100 million volts).

When it comes to Ball Lightning (BL) the phenomenon is a mystery. There have been several statistical surveys of sightings taken from large samples - such as for example all the personnel of NASA, and the whole staff of Union Carbide. The results of such analysis are very consistent and give strong support to the reality of the phenomenon.

BL is a persistent, not very intense spherical luminosity ~30 cm diameter, mean duration 5 seconds, which can bounce on the floor, and has been seen not only in the open air, but indoors and especially, inside metal buildings and aircraft, and perhaps, artificially, from the switchgear in submarines.

There have been a few sightings of BL by physicists - notably by Niels Bohr, and as I learned at my lecture on BL at MIT in October 1970, by Victor Weisskopf, the Director of the Physics Department. Another eminent sighter was Dean Acheson who reported in his book, "In at the Creation" seeing it cross the breakfast table in a presidential aircraft. There are absolutely no reliable scientific photographs or scientific measurements of BL. Attempts have been made to get records: Elk mountain lookout in Montana was instrumented for a year by an aircraft company with a USAF contract - predictably with no result (BL is pure science at this stage - ill adapted to profit-oriented developmental type enterprise). Boruki at the Ames Laboratory (NASA) completed most of the construction part of what promised to be a well thought out and economically executed program for the automatic photography and spectroscopy of BL from a site in Arizona when the 1970 retrenchment came and support ended. Many very distinguished physicists have attempted explanations - the latest of these is Academician P.

Kapitza in the USSR. A number of experimental and theoretical papers are coming out of the USSR - two on lines rather similar to my own studies and one having an extraordinary account by a technician who 'just happened' to have 5 evacuated gas samplers with him when a BL passed overhead which he chases. He captures samples and reports five O^3/NO ratios from them. Could it be that he was monitoring a weapons test? No less than three full length books on BL have appeared since 1970 - of these two are just indiscriminating reportage and the third tries with only partial success to be a physics text. A theory of BL luminosity involving thermal excitation of sodium in hot air loaded with particles to maintain the density (M. Uman) merits serious consideration. Another very interesting theory (with some experimental support) is by D. Finkelstein (Yeshiva) and J. Powell (Brookhaven). The perennial idea of BL consisting of radioactively decaying nuclei has come up again lately, this time with positron emitters in the region of O, N. It seems to me that there are compelling reasons why nuclear reactions should not occur in lightning discharges.

The F and P theory work attributes the luminosity as due to highly metastable (forbidden) transitions between molecules of excited air. Experimentally, 1/4 second is obtained. To stretch it out to 5 seconds, F and P invoke channeling into the ball of residual electric currents after the lightning strike.

I think this does explain some outdoor behavior of BL, and especially its fondness for the vicinity of barbed wire fences in fields and power lines. But it begs the issue of what makes the ball coherent - how can it bounce, and furthermore, completely fails inside metal enclosures, since an external electric field would be screened out.

My own conjecture (I cannot at this stage call it a theory) is that the chemiluminescent phase of F and P, is preceded by a chemi-ionization reaction. This makes possible the extended time, without caling for an external maintaining electric field.

The next facet of my conjecture is to explain the coherence - the ball shape and ability to bounce. For six months, I sought a fluid dynamical (Hill Vortex) mechanism for BL coherence and even demonstrated some effects of this kind in the laboratory. But it had to be discarded as inadequate,

especially with respect to bouncing. I am now proposing that the very unusual plasma, consisting of cold positive and negative ions, can develop a surface tension, i.e., like a soap bubble.

This is a very novel idea, gases have never been known to exhibit surface tension. What it amounts to is almost a hitherto unobserved state of matter having partial molecular ordering in the gas phase. In liquids, this state - smectic or liquid crystal - is known. The rarity of BL, and nonoccurrence from artificial discharges of comparable strength then comes quite naturally from the difficulty of achieving the condition where the weak surface tension forces establish dominance over dispersive gas dynamic forces. The experiments on BL have been going on for about 2 years with much cooperation from N-7, financed in a small way from the charity of the \$4 million/pa (Sherwood - controlled fusion) project which I started at this laboratory. In 1969 I had a summer student to work on BL on a grant from the National Science Foundation.

I may say that the research is science for its own sake. There is no practical application in mind, though doubtless if the surface tension conjecture turns out to be correct, all sorts of consequences will follow.

The apparatus I have been using consists of: (1) a large \$2 million submarine storage battery [courtesy of Dr. J. Rowley of the Rover (Nuclear Rocket) Division]. This is used in off-duty periods to make large low-voltage discharges to attempt to produce the persistent BL-like luminosities said to be seen in old-fashioned submarines. (2) A 30 kV 75 kilojoule condenser battery in my own laboratory for study of high-voltage arcs. With the battery we have produced some enormous and interesting arcs far exceeding anything imaginable on a submarine. They leave behind yellow and red afterglows but in all except one case, nothing resembling ball lightning in duration or coherence. (Ball lightning observations tend to be biased to the yellow-orange part of the visible spectrum.) Photographs of luminous vortices exhibiting gas dynamic stabilization and prolongation of the afterglow were also obtained.

The condenser experiments have shown somewhat longer yellow afterglows, which increase as the discharge is made less turbulent. This lends support to the rarity and weak forces conjecture above.

The field of BL research is strewn with the ruins of reputations. In order to avoid that fate, I have been reluctant to publish before subjecting these ideas to criticism. Over the last two years, about 15 invited seminars and colloquia have been given at various universities, and I am now thinking of venturing on a letter to "Nature."

Future plans are as follows:

(1) Continue the condenser discharge experiments. As a one-man operation, these go with maddening slowness.

(2) The U.S. Navy has been approached to provide opportunity for observation on a submarine under way. A retired very high up Admiral is taking an interest. This would take place out of some submarine naval base - San Diego or Whale Island.

(3) It would be helpful to visit some places where BL is said to be common. One such place is

north Sweden, where the sister of one of our consultants claims to have been touched by it without harm.

(4) Filling out the above conjectures on the nature of BL mathematically will be extremely difficult. Actually analytical mathematical methods in plasma physics are being superseded these days by "computer simulation."

We have one of the foremost exponents of the technique here in this laboratory, and also one of the world's largest computers. So conditions are favorable for applying this to the BL problem.

In about a year from now at some appropriate conference, the Tokyo Lightning International Conference perhaps, a full length paper may be possible.