Disclosures Concerning the Operation of an ELF Oscillator

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Introduction

For a scientist, Tesla was a prolific but abstruse and poetic writer. He left behind a considerable volume of technical and enigmatic descriptive writings, lectures, patents, articles and newspaper interviews. Additionally his Colorado Springs diary and his Long Island notes provide a showcase through which the wealth of his creative mind may be viewed from our present technological perspective. Such remarkable situations rarely present themselves with such prolific documentation to future generations. In reading the Colorado Springs and Long Island notes, one feels as though he has just blown away the dust of the years and opened the diaries of Columbus or DaVinci. Before him sit the thoughts and experimentations of the powerful intellect which invented for modern civilization the electrical equivalent of the wheel — the rotating magnetic field.

It would be an understatement to say that an electrical engineer can certainly empathize with the excitement described by Carter as he peered through the chink in the wall of an Egyptian tomb and saw before him the treasures of Tutankhamen. What we must ascertain, however, is whether Tesla's words, unlike Tutankahamen's trinkets, are of any practical value to the scientific community today. Certainly they do reflect how he thought and interpreted his experiments and how his physical concepts led him to make the remarkable statements published subsequent to his Colorado Springs experiments.

The fact that in addition to his Colorado Springs Diary, we also have the associated patent wrappers, special articles and later recollections, is of great importance. Any interpretation or speculation made today about his experiments must not only be internally consistent with these documents, but must also cement them together. This we take as a first requirement on speculation.

Additionally, as a second requirement, such conjecture must be made within the bounds of accepted and verifiable physical principles. Tesla was, apparently, experimenting with potentials in excess of 12 MV. Not unlike Columbus, he was sailing in uncharted seas. The possiblity of "peculiar physics" notwithstanding, out efforts have been to attempt to discuss Tesla within the framework of modern electrical theory. Whether the experimental results of Tesla were, in fact, near-field induction coupling, or perhaps Schumann resonance excitation (as we believe), or some sort of magnetospheric stimulation, or even some peculiar presently yet unknown physical phenomenon-the fact remains, a significant portion of his apparatus was constructed of wire, capacitors, spark gaps, and tuned circuits. It ought to be comprehensible in its intent and physical operation. That he got high voltage RF from his circuits is clearly understandable. It follows from a straightforward network analysis. How he obtained the incredible ELF results which he subsequently claimed, however, is the chasm to be bridged.

Issues To Be Resolved

Because of his repeated insistance on terrestrial extra low frequency resonances, it does not seem unreasonable to hypothesize that Tesls's experiments were actually carried out at this end of the electromagnetic spectrum. However, his indoor Colorado Springs apparatus clearly operated in the range of 30 KHz to 100 KHz, and the tower described in his diary was only 145 feet high. (Ref. 1) With such an electrically short tower there could be no radiation at ELF. But, on the other hand, if it was merely a waveguide or cavity resonator probe, one would expect its radiation resistance to be zero. The radiation resistance of a cavity resonator probe is zero because the resonator fields are purely relative.

It has been observed that the photographs of the Colorado Springs laboratory offer no clue as to how one might generate ELF energy. There is an even more fundamental issue to be resolved, however. The excitation of Schumann resonances by

means of a vertical probe requires a considerable current moment. The question is, "Even if Tesla successfully generated ELF voltages, how did he ever get significant ELF *currents* to flow on the vertical structure?" (Ref. 2) One could not just connect an ELF source onto the base of a 45 meter tower- the feedpoint capacitive reactance would be so large that no current would flow. Yet Tesla maintained on several occassions tht his "antenna" current was well in excess of 1000 amperes! (By the way, there is a similar issure to be resolved for the reception of power. The Thevenin equivalent of a vertical receiving antenna may have a substantial EMF. However the series capacitive reactance of vertical tower at ELF will preclude substantive power transfer in the sinusoidal steady state.)

Lastly, we mention the curious inscription in Tesla's own handwriting along the side of a now famous photograph of the Colorado Springs Laboratory,

> "Experimental Station fully developed. Activity (power delivery) one hundred thousand horsepower" (Ref. 3)

How could he possibly deliver 74.6 megawatts? The 60 Hz power mains to the laboratory were operated at 1 KV, but his Westinghkouse transformer was only rated at around 40 KVA.

In the remainder of this article, we wish to speculate on how these issues could be resolved within the bounds of consistancy with the historical documents mentioned above. The reader will have to judge whether we have successfully met the second requirement — that of conjecture based on acceptable physics.

Tesla's Descriptions of His Oscillator

Tesla described his electrical oscillator on many occasions and in may different places. It is clear that, as early as 1893, he was considering terrestrial resonances:

> "If ever we can ascertain at what period the earth's charge, when disturbed, oscillates . . . we shall know a fact possibly of the greatest importance to the welfare of the human race . . . I propose to search for the period by means of an electrical oscillator." (Ref. 4)

In the years between 1893 and 1900, he developed the coupled tuned transformer (or Tesla Coil), published the results of his extensive experiments with x-rays, contributed to the conceptual development of cosmic ray, patented a variety of circuit controllers (rotary spark gaps) and was sought out by members of the scientific and social-ite communities, both of which he continued to dazzle with his latest electrical discoveries. These were the golden years of his professional career, and they found a focal point in his experiments at Colorado Springs. It is here, where he finally was able to assemble the apparatus which, he maintained to his dying day, permitted him to ascertain terrestrial natural resonant frequencies.

In 1900, he disclosed that this apparatus could be operated in a variety of configurations to perform many different types of desired functions:

> "Thus a transformer or induction coil on new principles was evolved, which I have called 'the electrical oscillator' . . . the essential parts of which are shown in Fig. 6 (P. 188). For certain purposes a strong inductive effect is required; for others the greatest possible succ denness; for others again, an exceptionall high rate of vibration or extreme pressure while for sertain other objects immense elec trical movements are necessary . . .I have pro duced electrical movements occuring at th rate of one hundred thousand horse power. . . " (Ref. 5)

By the way, the "essential parts" shown in th photograph referred to appear to be his Westing house transformer, a rotary break, a capacitor bar and a circular fence upon which the secondary wa wound.

Perhaps the most curious of all his description of the terrestrial resonance oscillator was pu lished in 1919:

> "It is a resonant transformer with a seconda in which the parts, charged to a high pote tial, are of considerable area and arranged space along ideal enveloping surfaces of ve large radii of curvature, and at proper d tances from one another thereby insuring small electric surface density everywhere that no leak can occur even if the conductor bar. It is suitable for any frequency from few to many thousands of cycles per secon and can be used in the production of curren of tremendous volume and moderate pre sure or of smaller amperage and immen electromotive force. The maximum elect tension is merely dependent upon the cur ture of the surfaces on which the charge e ments are situated and the area of the latte
>
> Judging from my past experience, as mu as 100,000,000 volts are perfectly practical On the other hand, currents of many th sands of amperes may be obtained in the tenna . . . the Hertz-wave radiation is an tirely negligible quantity as compared v the whole energy . . . an enormous charg stored in the elevated capacity. Such a cir may then be excited with impulses of kind, even of low frequency and it will y sinusoidal and continuous oscillations those of an alternator.

> . . . it is a resonant transformer . . .accurately proportioned to fit the globe and its electrical constants and properties, by virtue of which design it becomes highly efficient and effective in wireless transmission of energy." (Ref. 6)

What we are to make of this? Based upon the available electrical output of his extra coil and the reports of spark lengths measured 100 meters away from the Colorado Springs Laboratory, we estimate that the charge stored in the elevated capacity was probably on the order of 20 millicoulombs. But how was this to be used to excite terrestrial resonances? The apparatus so furtively described in 1919 is probably a near relative of that for which he sought protection by a patent application in 1902, and which subsequently issued at the close of 1914. (Ref. 7)

Directed Energy Devices

We believe that the evolution of these ideas continued to be a central activity of Tesla's later years. It is merely our opinion, but we find it difficult to accept the senility hypothesis concerning his motivation to reach for the goals of these final years. It seems probable that the apparatus which so concerned his thoughts at this time, not only was a successive conceptual development of his prior oscillators, but any credible knowledge gained about these later structures would probably throw light on the operation of the earlier equipment — no matter how improbable his final research might have been. We believe that Tesla's surprisingly detailed 1934 analysis of Van de Graaff's (then) new machine, published in *Scientific American*, lends support to the hypothesis that he ws still technically alert and deeply engaged in high voltage research. (Ref. 8) Perhaps we are not being specific enough for the reader. The apparatus which Tesla's final disclosures concerned has come to be known as the "Death Ray". Whether there be any actual merit to such contraptions, we leave for others to speculate upon. Our interest in Tesla's thoughts on "directed energy devices" rest upon the proposition that they might shed light upon his terrestrial resonance oscillator. In 1927, Tesla said,

> "More than twenty five years ago my efforts to transmit large amounts of power through the atmosphere resulted in the invention of great promise, which has since been called the "Death Ray", . . . The underlying idea was to render the air conducting by suitable ionizeing radiations and to convey high tension currents along the path of the rays. Experiments conducted on a large scale showed that with pressures of many millions of volts virtually unlimited quantities of energy can be projected to a small distance, as a few hundred feet . . ." (Ref. 9)

From a variety of published references, spanning the years from 1934-1940, we gather that Tesla envisioned a machine which required the cooperative action of four separate entities. Again, our interest is not in the feasibility of such an apparatus, but rather in how he thought such a device was to work, and what, if any, light it might shed on his terrestrial resonance oscillator experiments. The four elements specified by Tesla are as follows:

1. "A *Method* and an *Apparatus* for producing rays and manifestations of energy in free air (eliminating the necessity of the usually required vacuum tubes)."
2. "A *Process* and an *Apparatus* for producing very great electrical force (50 MV). This is necessary to power the first mechanism."
3. "A method of intensifying and amplifying the force developed by the second mechanism."
4. "A new method for producing a tremendous repelling force."

It is, perhaps, not unremarkable that these components are quite similar to the description provided by John G. Trump, when he examined Tesla's estate. He described the "Death Ray" as

> "An *electrostatic* method of producing high voltage, capable of very great power . . . As a component of this apparatus there is an open end vacuum tube . . . A beam of high energy electrons is the . . . means by which energy is transmitted through natural media." (Ref. 10)

It should parenthetically be remarked that Tesla explicitly denied that his apparatus was a "Ray".

> ". . . this invention of mine does not contemplate the use of any so called "death rays". Rays are not applicable because they cannot be produced in requisite quantities and diminish rapidly in intensity with distance . . . My apparatus projects particles . . . (Ref. 11)

We started out discussing electrical oscillators and now find ourselves confronted with "direct energy devices". Perhaps this is not surprising when we observe that Tesla's early x-ray researches involved the use of his "single electrode x-ray tube" attached to the top of a *resonant* Tesla Coil.

The Single Electrode X-Ray Tube

Between March 11, 1896 and August 11, 1897, Tesla wrote at least 10 articles about his x-ray experiments. There is an explanation for the development of a single electrode tube in the March 11, 1896 issue of *Electrical Review*. Tesla saw that in

order to attain the most intense effects, one should use the greatest voltages available.

> "Clearly, if we put two electrodes in a bulb, or use one inside and another outside electrode, we limit the potential . . . Thus, to secure the result aimed at, *one is driven to the acceptance of a single electrode bulb,* the other terminal being as far remote as possible." (Ref. 12)

Tesla later hinted at the manner in which the tube was excited:

> ". . . in (1896) I brought out a new form of vacuum tube capable of being charged to any desired potential and operated it with effective pressures of 4,000,000 volts. (Ref. 13)

And in a 1913 newpaper interview, Tesla said:

> "As far back as 1897, I disclosed before the New York Academy of Sciences the discovery that Roentgen, or x-rays projected from certain bulbs have the property of strongly charging an electrical condenser at a distance. The energy so accumulated readily can be discharged." (Ref. 14)

We know today, of course, that x-rays are high energy photons and have neither rest mass nor charge. The question before us, however, is, "How might these single electrode tubes produce x-rays?"

In a standard x-ray tube of the Coolidge type, a heated filament provides electrons which are then accelerated and strike an anode target. If an AC supply is employed, x-ray emission occurs only during the positive half cycle. However, Tesla's tube had only one electrode. We hypothesize that the tube's operation probably depended upon the quantum mechanical phenomenon of High Field Emission. One might suppose that during half of the RF high voltage cycle field emmission could possibly occur into the region of the high vacuum elongated bulb, and on the positive half cycle the cloud of electrons might be swept back into the "plain polished surface on the front side of a hemispherical aluminum electrode", with an ensuing emission of hard x-rays. This is only a hypothesis and certainly its acceptability needs to be closely examined.

There is evidence that, during the course of his New York city experiments, Tesla took to surrounding these tubes with an *insulated* shield in order to reduce corona losses. He called this "static screening". The configuration is quite similar to that discussed in the Colorado Springs notes on June 6, 1899.

> "Arrangements with single terminal tube for production of powerful rays. There being practically no limit to the power of an oscillator, it is now the problem to work out a tube so that it can stand any desired pressure . . . The best results will probably be obtained in the end by static screening of the vulnerable parts of the tube. This idea was experimented on in a number of ways . . . In each case there would be an *insulated body of capacity* so arranged that streamers cannot manifest themselves. The capacity would be such as to bring about maximum rise of e.m.f. on the free terminal." (Ref. 15)

The associated figure shown in the diary entrance indicates a (square!) container with the comments,

> "Metallic Enclosure but *insulated* so that observers can step inside." (Ref. 15)

Little more can be inferred from the diary about x-ray experiments until November 23, 1899. Finally, on January 2, 1900, Tesla states,

> ". . . my conviction is growing stronger every day that, with apparatus such as the present, wonderful results must be secured provided only that a tube is constructed capable of taking up any amount of energy. . . Many tubes have been worked here from the secondary." (Ref. 16)

In a later interview, Tesla said, concerning the Colorado Springs experiments,

> "At the time of those tests, I succeeded in producing the most powerful x-rays ever seen. I could stand at a distance of 100 feet from the x-ray apparatus and see the bones of the hand clearly with the aid of a fluoroscope screen . . . I now have apparatus designed whereby this tremendous energy of hundreds of kilowatts can be successfully transformed into x-rays" (Ref. 17)

What was he doing with these x-rays? In light of the comments by Tesla regarding charge transfer by x-rays, it does not seem unreasonable to hypothesize that a small aperture in the conducting enclosure would permit the emission of x-rays to the exterior region, causing x-ray photoionization of the atmosphere near the enclosure, these ions providing a short conducting discharge path for the charged "insulated body of capacity". It is clear from Reference 13, that Tesla was observing "coronal discharges" exterior to his single electrode tubes. This process could clearly be employed to instantaneously lower the disruptive potential of an isolated spherical capacitor, and to initiate a discharge into the air or to a nearby isolated electrode at a lower potential than the given sphere. Perhaps it is not surprising that this process has been of recent interest in x-ray and UV-laser triggered switching of high voltages. The latter being particularly interesting because capacitances charged into the megovolt range can be triggered with nano second switching delays and with sub-

nanosecond jitter.

On January 4, 1900, Tesla experimented with a ball on the top of the extra coil, ". . . very brilliant and thick sparks passing from the ball to the hood above". Tesla continued that the discharge was "highly sensitive" to, among other things, "Roentgen rays". Is it possible that Tesla was employing x-rays as a switching mechanism to statically charge his tower? The tower appears to be an "elevated insulated body of capacity". This, we hypothesize, is the x-ray charging mechanism which Tesla sought to protect in his two U.S. Patent disclosures No. 685,957 and No. 685,958.

The X-Ray Patents

In March of 1901, Tesla filed two patent applications concerning x-ray devices. One was for a "Method" and one was for an "Apparatus" for the "Utilization of Radiant Energy". They describe in considerable detail a remarkable technique for switching high voltages and for charging and discharging and "elevated insulated body of capacitance".

Consider, for example, an isolated sphere. Such a body may be charged to a certain electrical potential with respect to a zero potential reference, taken as infinitely distant. In such a system the spherical conductor may be charged to a certain potential before the electric field intensity gives rise to a force great enough for the surrounding air to break down and "disruptively" discharge the sphere. Tesla found by experiment that the disruptive potential, in volts, for a sphere at sea level could be approximately calculated as 7,540,000 R, where R is the radius of the sphere in meters. Tesla, in fact, reported that he kept a variety of spheres around to use both as capacitors and in order to estimate the voltages used in his experiments.

A practical form of high voltage capacitor may be constructed by elevating an insulated spherical conductor above the surface of the earth. It is an elementary problem in electromagnetics to calculate the field and capacitance of such a charged system. In this configuration the "capacitor" effectively has "true ground" as one terminal, and the conducting spherical ball itself forms the second "armature" or terminal of the distibuted capacitor. This form of capacitor may be charged up by bodily conveying charge of one sign to the elevated sphere. Alternatively, it may be discharged simply by bringing the grounded conductor close enough to the sphere for arcing to occur.

Bearing this in mind, Tesla's x-ray patents take on a meaningful interpretation.

> "It is well known that certain radiations such as . . . Roentgen rays . . . possess the property of . . . discharging conductors . . . They ionize or render conducting the atmosphere through which they are propagated . . . (they) may at any rate discharge an electrified conductor . . . by carrying off bodily its charge . . . When rays of the above kind are permitted to fall upon an insulated conducted body connected to one of the terminals of a condenser . . . a current flows into the condenser . . . an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge . . . taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressure without leaking and may leave no perceptible electrification when discharging instantaneously . . . the above precautions should be more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser . . . A simple way of supplying . . . electricity is to connect . . . to an insulated conductor supported at some height in the atmosphere . . . I usually connect the second terminal of the condenser to ground . . . in order to utilize . . . the energy accumulated in the condenser, I furthermore connect to the terminals of the same . . . another instrument or device for alternately closing and opening the circuit . . . If the device . . . be of such character that it will operate to close the circuit . . . when the potential in the condenser has reached a certain magnitude, the accumulated charge will pass through the circuit . . . The controller may consist of two fixed electrodes separated by a minute air gap . . . which breaks down more or less suddenly when a definite difference of potential is reached at the terminals of the condenser and returns to its original state upon the passage of the discharge." (Ref. 18)

Tesla then describes the manner of excitation of his single electrode x-ray tube:

> " . . . the source of radiant energy is a special form of Roentgen tube divised by me, having but one terminal K, generally of aluminum, in the form of a half sphere, with a plain polished surface on the front side from which the streams are thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently high electromotive force." (Ref. 18)

Tesla continues, describing the operation of the apparatus:

> "The . . . discharge circuit connected to the

terminals . . . of the condenser includes in this case . . . a circuit controller comprising a fixed terminal or break . . . and a movable terminal . . . in the shape of a wheel, with conducting and insulating segments, which may be rotated at an arbitrary speed by any suitable means . . . When the tube . . . is excited . . . streams of matter . . . convey a positive charge to . . . the condenser terminal . . . This results as before explained in an accumulation of electrical energy in the condenser, which goes on as long as the circuit is (opened). Whenever the circuit is closed owing to the rotation of the (wheel) the stored energy is discharged . . . The source may be any form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderantly of one sign. If ordinary symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the (condenser) plate only during those periods when they are productive of the desired result." (Ref. 18)

What we make of this is that Tesla is describing a technique to take the high voltage RF output of the secondary and use it to charge up an "elevated insulated body of capacitance" — in essence, an open air switch or diode rectifier. After charging the capacitor, at RF rates, he subsequently discharges the capacitor, at relatively low pulse repetition frequencies (PRF's), for example at perhaps 6 or 8 discharges per second-or any other that he might desire. The companion patent is also interesting. (Ref. 19)

It is also somewhat revealing that Tesla said in his Van de Graaf article in 1934 that,

> "My wireless tower on Long Island erected in 1902, carried a sphere which had a diameter of 67.5 feet . . . It was to be charged to 30,000,000 volts by a simple device for supplying *static* electricity and power." (Ref. 8)

After analyzing the Van de Graaf machine he concedes that it produces large static voltages but concludes that its *power* performance is trifling — the rate of charge delivery to spherical electrode being on the order of a few tens of milliamperes.

> "As far back as 1899, I made experiments with 18,000,000 volts and in some tests I was able to pass a current of 1100 amperes through the air. With my transformers a potential difference of 30,000,000 volts, or more, could easily be obtained and in the present state of the technical arts a tube or other device capable of taking up very great energy might be manufactured." (Ref. 8)

By the way, diary schematic diagrams notwithstanding, it is evident that neither the elevated tower at Colorado Springs nor the 67.5 foot diameter sphere on the tower at Wardencylffe were electrically connected to the extra coil when in operation. This is also borne out by the Long Island notes of May 29, 1901, where Tesla shows an elevated insulated body of capacitance being charged through space from a ball on the top of an extra coil. The spacing between these elements is shown to be a controllable distance — perhaps this was the purpose for the steam elevated shaft at the center of the Wardenclyffe tower. The geometry is not unlike that shown in Figure 5 of Reference 20. It is well known that drawn out electrical discharges will effect rectification much as a point to plane discharge. However, the process is usually considered too inefficient.

An ELF Generator

Whatever the rectification mechanism might have been one might hypothesize an ELF generator which employs the charging mechanism just discussed. Such a charging technique could have been used to electrostatically charge the tower with "small" pulses of charge occurring on the positive half cycles of the RF coil oscillations. This would build up the static charge of the tower to some large Q at a very high DC voltage. (When discussing the upper hood configuration on Nov. 28, 1899, Tesla said,

> "This arrangement permitted the charging of the pole easily up to a million volts." (Ref. 21)

If Tesla were to discharge the condenser at a much slower frequency, the discharge current could be extremely large, being limited only by his ground bed resistance. This hypothesis is consistent with a public statement made by Tesla in 1934 in *Scientific American;*

> " . . . Under proper conditions, it is possible to discharge spheres in a time interval incomparably shorter than consumed in charging them, and so *amplify* enormously the intensity of the action." (Ref. 8)

That is to say, the rate of flow of energy during the charging cycle might be at 75 kilojoules per second over 1 sec., but the rate of flow of energy during the discharge cycle could be at a rate of 75 Megajoules per second over a time interval of 1 millisecond. In both cases the average power is 75KW, but the peak power during the discharge activity would be about 100,000 HP.

As early as 1893, in the Franklin Institute lecture, Tesla described an electrostatic pulse generator which was repetitively charged with a small amount of energy per charge, at a high pulse repetition rate, and then rapidly discharged but at a

low pulse repetition rate.

This would make possible extremely large peak powers on the discharge cycle. In his speech, Tesla is describing the situation where a large condenser has been charged up to its disruptive potential by a small machine supplying static charge:

> "When the condensers are charged to a certain potential, air gives way and a disruptive discharge occurs. There is then a sudden rush of current and generally a large portion of accumulated electrical energy spends itself. The condensers are thereupon quickly charged and the same process is repeated in rapid succession . . . It is evident that if the *rate* at which the *energy* is dissipated by the discharge is very much greater than the *rate of supply* to the condensers, the sudden rushes will be comparatively few, with long time intervals between. This always occurs when a condenser of considerable capacity is charged by means of a comparatively small machine." (Ref. 22)

Several paragraphs later, Tesla continues the description with a hydromechanical oscillator analogy:

> " . . . Imagine a tank with a wide opening at the bottom, which is kept closed by spring pressure, but so that it snaps off *suddenly* when the liquid in the tank has reached a certain height. Let the fluid be supplied to the tank by means of a pipe feeding *at a certain rate.* When the critical height of the liquid is reached, the spring gives way and the bottom of the tank drops out. Instantly the liquid falls through the wide opening, and the spring, reasserting itself, closes the bottom again. The tank is now filled, and after a certain time interval, the same process is repeated." (Ref. 23)

Thus it appears that Tesla had conceived of a technique for obtaining large discharge currents with controlled pulse repetition frequencies. The vertical discharge current would produce a vertical current of moment Id*l*. This signal, we hypothesize, could be controlled at an appropriate pulse repetition frequency for Schumann Cavity excitation. The controller, as described in Tesla's patents quoted above could either be "operated by a given rise of potential in the condenser" (Effectively an ELF relaxation oscillator) or "by the rotation of the wheel" (break device).

In spite of the fact that our hypothetical ELF generator has some merit for satisfying the internal consistency hypothesis which we stated earlier as a ground rule, its acceptability must be measured against the second requirement of sound physics Tesla said that he got over 1000 amperes in his "antenna". Schumann's solution is in the sinusoidal steady state and even 1000 amperes in a 45 meter tower would seem to make possible relatively weak global field strengths. We have taken up this issue in another research document now in preparation for publication.

(Interestingly, however, if one looks at this hypothetical ELF generator as a fundamental form of the "switched capacitor" devices now of such great interest, the switched charge $\Delta Q = C \Delta V$. Over a period which is much larger than the switching period T_s, the charge may be assumed to be quasicontinuous so that an equivalent current flow is equal to ΔQ divided by T^s. The equivalent resistor is T^sdivided by C. (Ref. 24) The application of the theory, however requires careful attention in Tesla's case if damped waves are assumed at the RF output of the extra coil.)

We observe that if our hypothesis is correct,then it is not remarkable that Tesla would have said,

> "Such a circuit may then be excited with impulses of any kind, even low frequency and it (the magnifying transmitter) will yield sinusoidal and continuous oscillations like those of any alternator." (Ref. 6)

If our conjecture has any substance in fact, then the tuned circuit of his magnifying transmitter was the whole earth-ionosphere cavity resonator!

Corona Effects

There is one other observation to make about his "Magnifying Transmitter" and that is that its upper regions were engulfed in a coronal glow. In Colorado Springs and at Wardenclyffe he employed hoods to reduce corona. At Wardenclyffe, he had apparently planned to employ inverted hemispherical bowls to cover the spherical ball with. In 1921, he said that "the underlying principal" and the "practical significance" of his 1914 patent (Ref. 7) was a technique "for confining the highest tensive flow to the conductors". He stated that the idea was to construct a conductor.

> "... so that its outer surface has itself a large radius of curvature, or is composed of separate parts which, irrespective of their own curvature, are arranged in proximity to one another and on an ideal enveloping symmetrical surface of large radius. These parts may be in the shape of shells, hoods, discs, cylinders or strands . . ." (Ref. 25)

We take it that the role of all the hemispherical shells in the 1914 patent was perhaps to physically bring about a more uniform distribution of charge over the sphere than could have been gotten with a lower portion missing because of the supports. If this be so, then they apparently would function in a distributed manner much like resistive dividers in a power supply capacitor chain, more or less caus-

ing a uniform charge distribution over the effective area of the sphere, and raising its disruptive potential to the maximum possible value. This would mean that a given size ball on a support could be charged to a greater maximum voltage.

Speaking of corona, we should also point out another curious feature of the Colorado Springs experiments.

From the patent wrappers associated with U.S. Patent #645,576, it is apparent that Tesla included a remarkable description of a rather extensive corona sphere surrounding his "elevated and insulated" antenna terminal, sometime before November 25, 1899. (See Ref. 26).

> "... a conductor or terminal, to which impulses such as those here considered are supplied, but which is otherwise insulated in space and is remote from any conducting bodies, is surrounded by a luminous, flame-like brush or discharge, often covering many hundreds or even as much as several thousands of square feet of surface ... This influence is not confined to that portion of the atmosphere which is discernible by the eye as luminous and which, as has been the case in some instances actually observed, may fill the space within a spherical or cylindrical envelope of a diameter of sixty feet or more, but reaches out to far remote regions, the insulating qualities of the air being, as I have ascertained, still sensibly impaired at a distance of many hundred times that through which the luminous discharge projects from the terminal, and in all probability, much further.... I have noticed that this region of decidedly noticeable influence continuously enlarges as time goes on ... in some instances the area covered by the flame-discharge mentioned, was enlarged more than six-fold by an augmentation of the electrical pressure amounting scarcely to more than 50%." (Ref. 27)

Tesla apparently observed a corona sphere in excess of sixty feet in diamter. The space charge distribution apparently was due to the extremely high static or DC voltage on the elevated electrode. We conjecture that both its mode of production and its use were as outlined above.

The Tesla Tower

During the mid 1930's, Tesla's work on a defense weapon apparently went so far as to be actually considered for construction. From files at the Tesla Museum, it is apparent that Tesla had several "artist conceptions" made of a building with a tower in the form of a cylinder 16.5 feet in diameter, 115 feet tall. The structure was capped at the top by a 10 meter diameter sphere (covered with hemispherical shells as in the 1914 patent). The sketches were prepared by one Titus De Bobula of New York City. There is also correspondence with the Alcoa Aluminum Company between July 29 to September 24 of 1935, concerning fabrication, the last letter in essence saying that Alcoa was ready to start as soon as Tesla advanced the funds.

Whether the project would have been another disaster or not, we have no idea. Since we have already gone this far out on a limb of speculation, permit us to conjecture what Tesla might have had in mind. We listed the four components that Tesla maintained were essential. With the first, one might associate the *Method* (Patent #685,958) and *Apparatus* (#685,957) for producing x-rays and providing rectification. With the second, one might associate the *Process* (#645,576) and the *Apparatus* (#649,621) for producing high voltage RF — i.e. the Tesla Coil patents. Certainly Tesla powered his x-ray tubes from the top of Tesla Coils.

These four components are mentioned in at least four references during 1934 — a time when he was thinking and writing about the Van de Graaff machine. Perhaps it is not surprising to find the same language as appears above in component three also appearing in Reference 8.

> "... under proper conditions, it is possible to discharge spheres in a time interval incomparably shorter than consumed in charging them and so *amplify* enormously the intensity of the action." (Ref. 8)

Certainly, as pointed out above, this would be consistent with the second item.

To guess what the fourth component is would be shooting in the dark. However, let us go even further out on the limb and suggest that Tesla was perhaps employing a technique to rapidly lower the disruptive potential of a *statically* charged elevated electrode. As is evidenced by the diary entrance of June 6, 1899, Tesla had already experimented along these lines. For example, suppose that one had a charged, insulated spherical shell in static equilibrium, and then rapidly punctured the shell with a very slender highly conducting track or path. (Or equivalently, introduced a charge of like sign immediately external to the sphere.) The question to be answered is, "Would a 32 foot diameter sphere charged to 50 MV produce sufficient repelling force for the contemplated weapon?" This question can probably be answered, but we have not yet performed the calculation. The answer might be no.

Final Comments

We have gone well beyond the bounds of propriety in our speculations. However, we believe that considerable light may have been thrown upon the

intent and operation of Tesla's terrestrial resonance oscillator. If we have been able to provoke the reader to probe more deeply into Tesla's research, then we feel that we have attained some degree of success.

Lastly, no matter what the results or scientific merit of our research, whether every speculation be false or perfectly true — we all must never lose touch with the central fact that Tesla was a man whose creative intellect was set free to soar.

Truly he touched the Holy Fire — and the world community is better off because of this good and decent and noble gentleman, whom we honor at this Centennial Symposium.

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[2]I am indebted to Professor Vojin Popovic of Belgrade University for asking this insightful question.

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[7]"Apparatus for Transmitting Electrical Energy", Nikola Tesla, U.S. Patent #1,119,732. Application filed January 18, 1902; Patented, December 1, 1914.

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