

NIKOLA TESLA

FATHER of ALTERNATING CURRENT

by Brian Roberts, CIBSE Heritage Group



Nikola Tesla, 1856-1943

Nicola Tesla was born in Smiljan, Lika, a borderland region of Austro-Hungary (modern day Croatia). His “father was an eloquent clergyman in the Greek Church. His mother was a woman of inherited ingenuity, and delighted not only in skilful work.....but in the construction ofmachinery required in a rural community.”

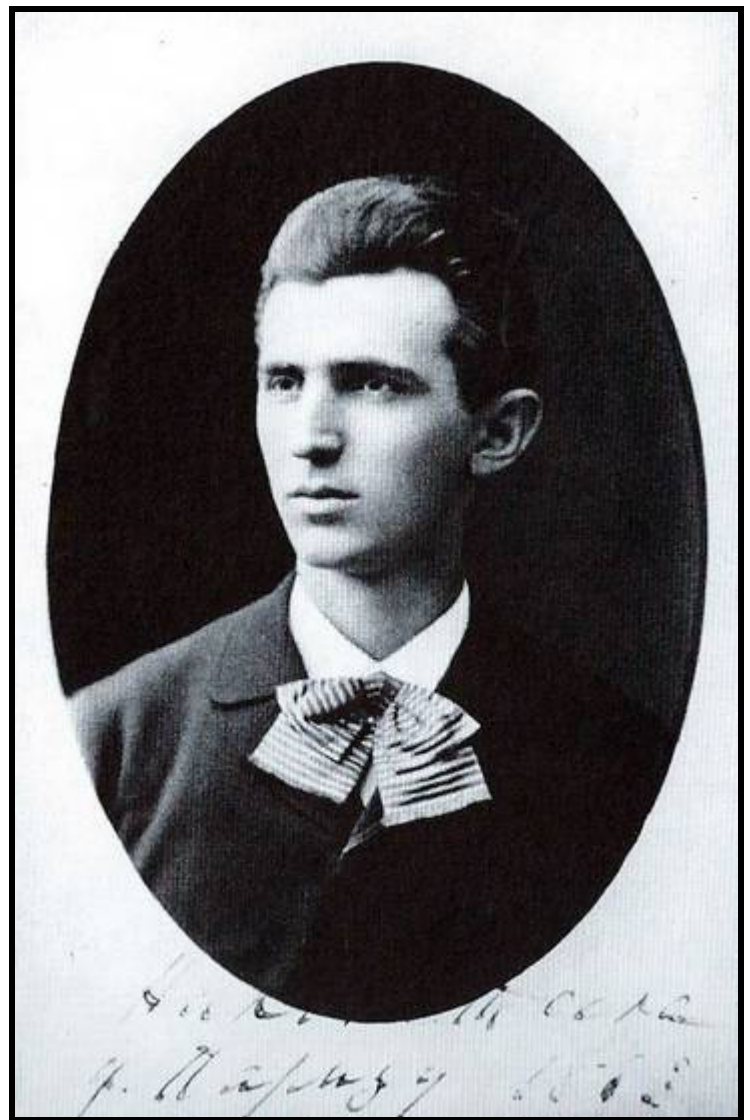
After attending state schools he continued in higher education, graduating in 1873 and devoted himself to experimentation, especially in electricity and magnetism before entering the Polytechnic at Gratz hoping to become a Professor of mathematics and physics.



From left: Milutin Tesla, Nikola's father, Milka, Angelina and Marica, Tesla's sisters



Nikola Tesla in traditional costume



Tesla in 1879 at age twenty-three



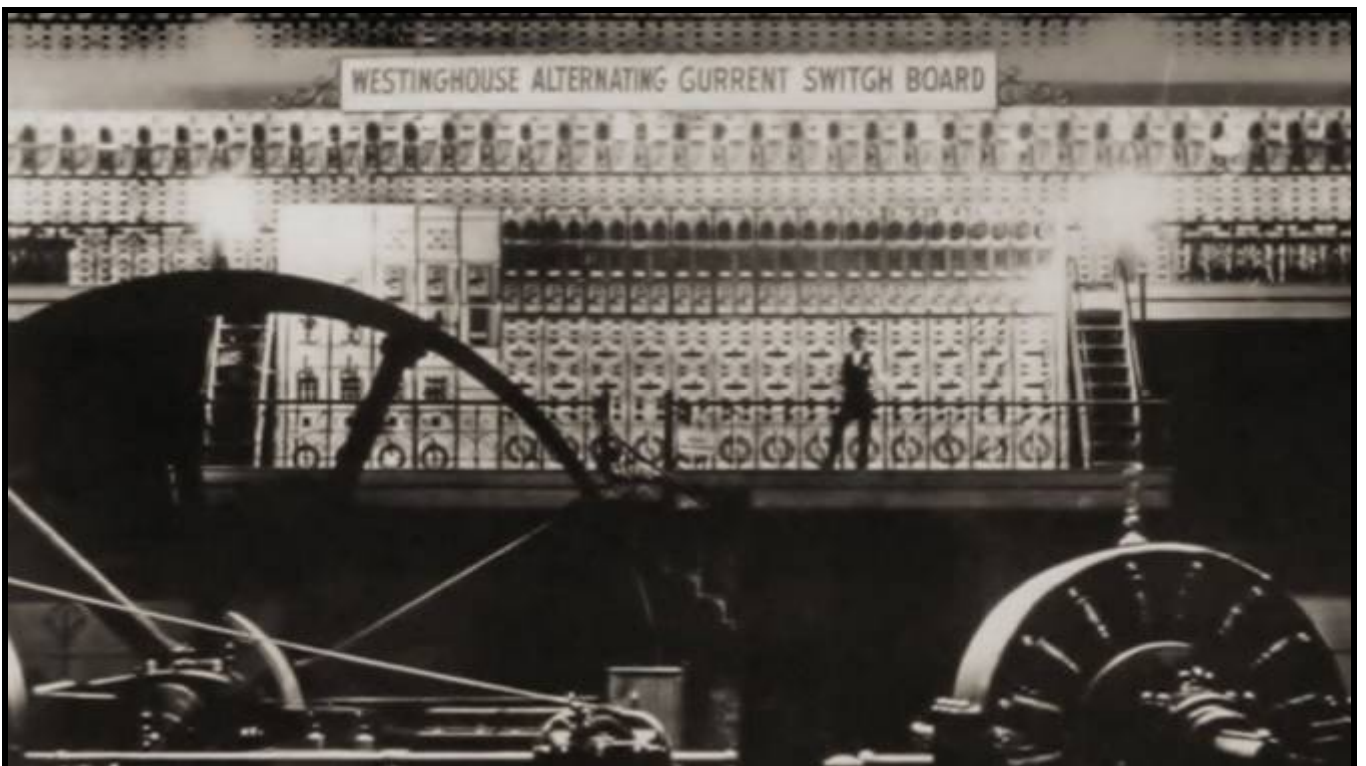
George Westinghouse, 1846-1914

Tesla gained experience in electrical engineering before emigrating to the United States in 1884 and working for Thomas Edison in New York City. Edison refused to accept new ideas and, probably because of his poor understanding of mathematics, could not fully comprehend the workings of the alternating current system. It appears that after Tesla was not given a promised bonus he resigned, which turned out to be a big mistake on Edison's part.

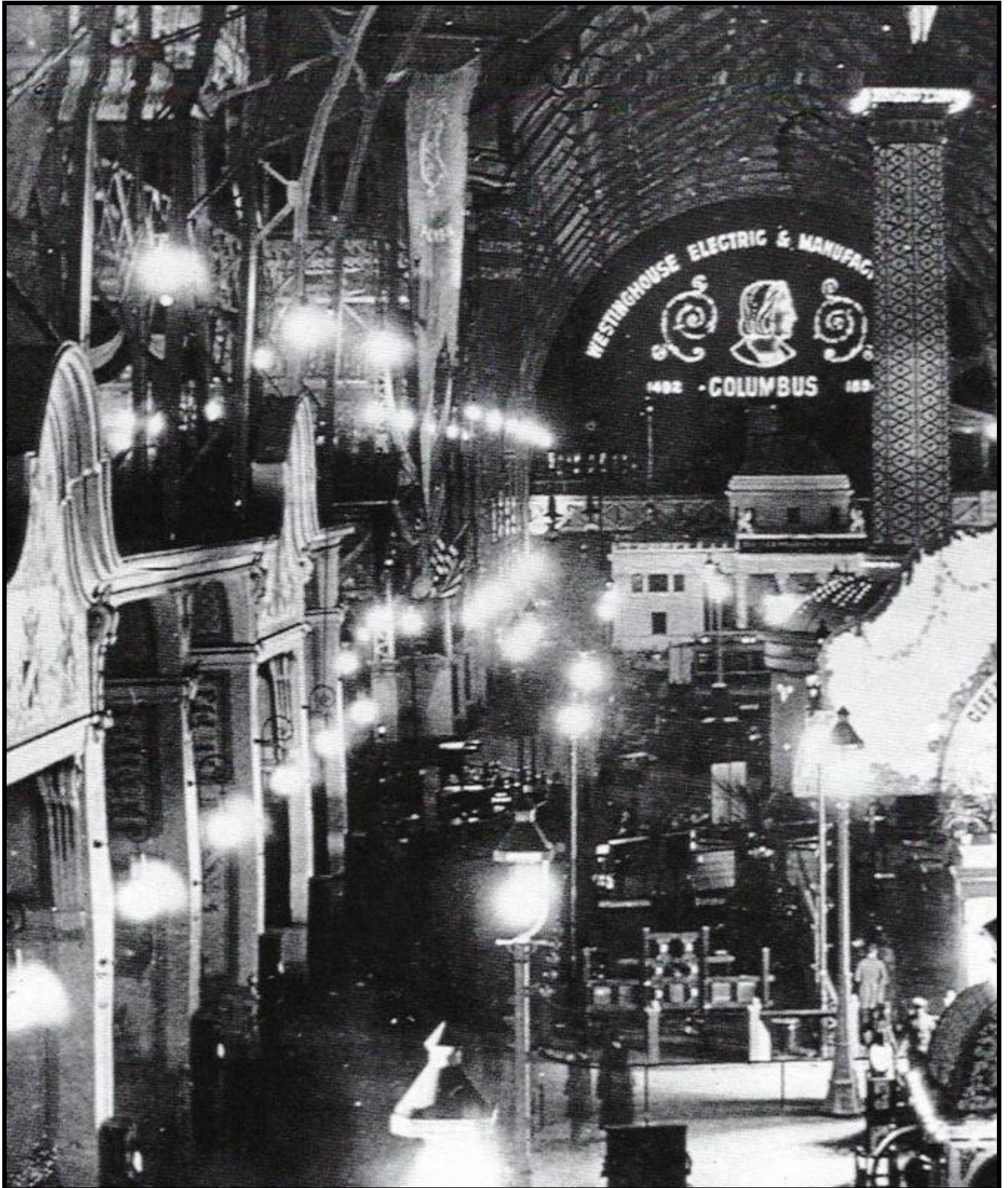
George Westinghouse, who made his fortune by inventing the railway air brake, saw the possibilities in alternating current systems and bought up Tesla's and various European patents and went into competition with Edison who waged a vitriolic campaign against AC. The battle ended in defeat for Edison since DC systems could only supply customers up to a mile from the power station while high voltage AC could be transmitted several hundred miles.



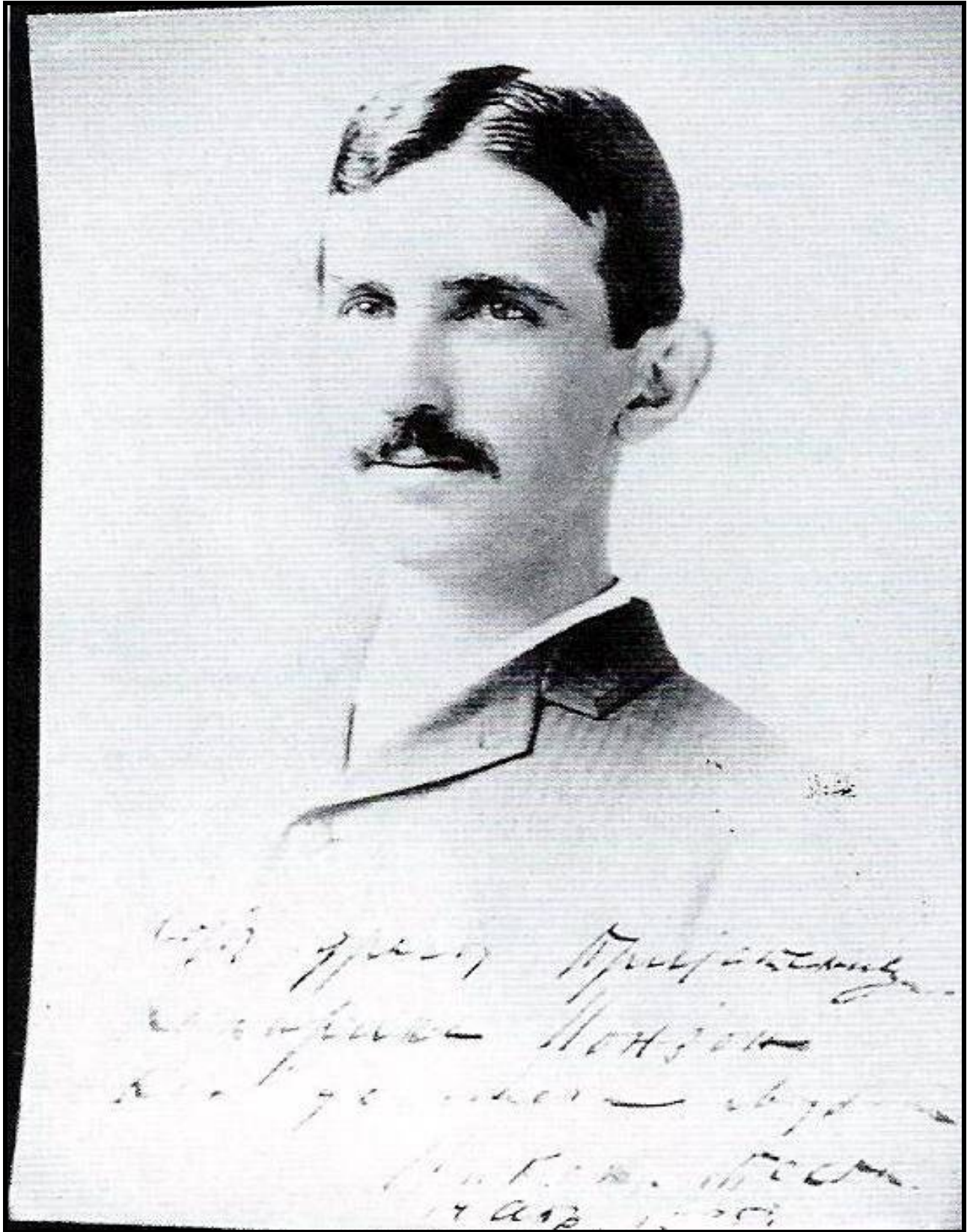
The World's Fair (Columbian Exposition) in Chicago, 1893 with lighting by Westinghouse



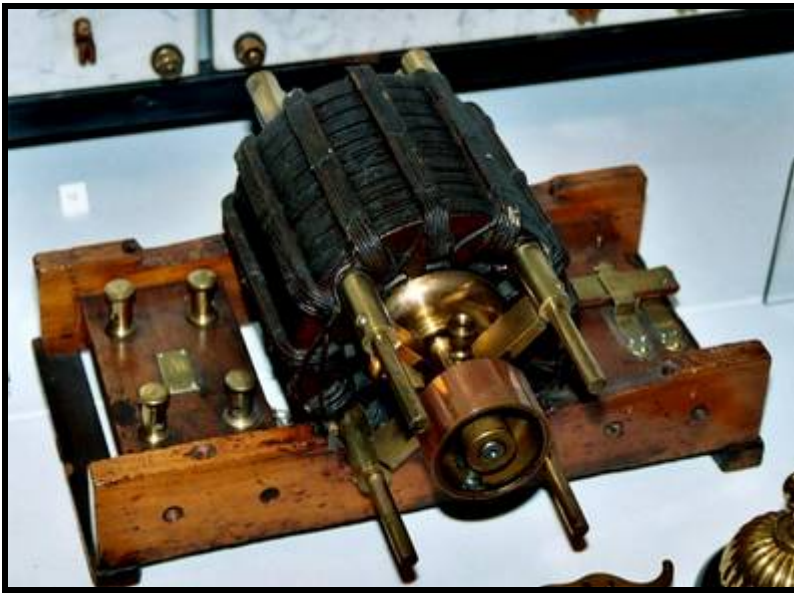
The Westinghouse Alternating Current Switchboard at the Chicago Fair



Westinghouse display at the 1893 World's Fair featuring the Tesla Polyphase System



Tesla in 1885 at age twenty-nine



Tesla Motor (British Museum)

TESLA'S AC MOTOR

SLOTTED MAGNETIC MOTOR.
No. 382,370. Patented May 1, 1888.

Holt & Coy. Eng. and Mach. A. Thompson
in Phila. Pa. at the
P. & O. Bldg. of the
ATTORNEYS.

doesn't turn (stator). Usually both parts are electromagnets, so that their north and south poles can be reversed simply by changing the direction of current running through them. If pole changes are properly timed, the rotor chases around trying to bring itself into alignment with successive stator poles but never catching up. The rotor's own momentum keeps it in the chase, seeking each "next" pole; otherwise it might just twitch back and forth as nearby poles reversed.

Motors before Tesla operated on direct current, and their limitations in commerce and industry had already become troublesome. Because the supply current travels in one direction only, it must be mechanically switched to run first one way and then the other through a motor's pole projections—in DC motors devices called "commutators" do this.

In Tesla's AC motors, by contrast, the field's poles are always in play, moving in steady, invisible arcs around the stator faces. Mechanical contacts, too, can be done away with by using induction to build and reverse the rotor fields. And AC devices operate, of course, without need of converting their source of power.

Tesla didn't merely make AC theoretically feasible, he created a completely operational technology. He patented over a score of designs: motors to overcome high resistance on starting, to run with variable loads, at constant speeds or at variable speeds—anything that might reasonably be asked of electrical engineering. This motor and related AC technology launched modern electrical industry and, essentially, the twentieth-century way of life.

CURVES SHOWING CYCLE OF OPERATIONS

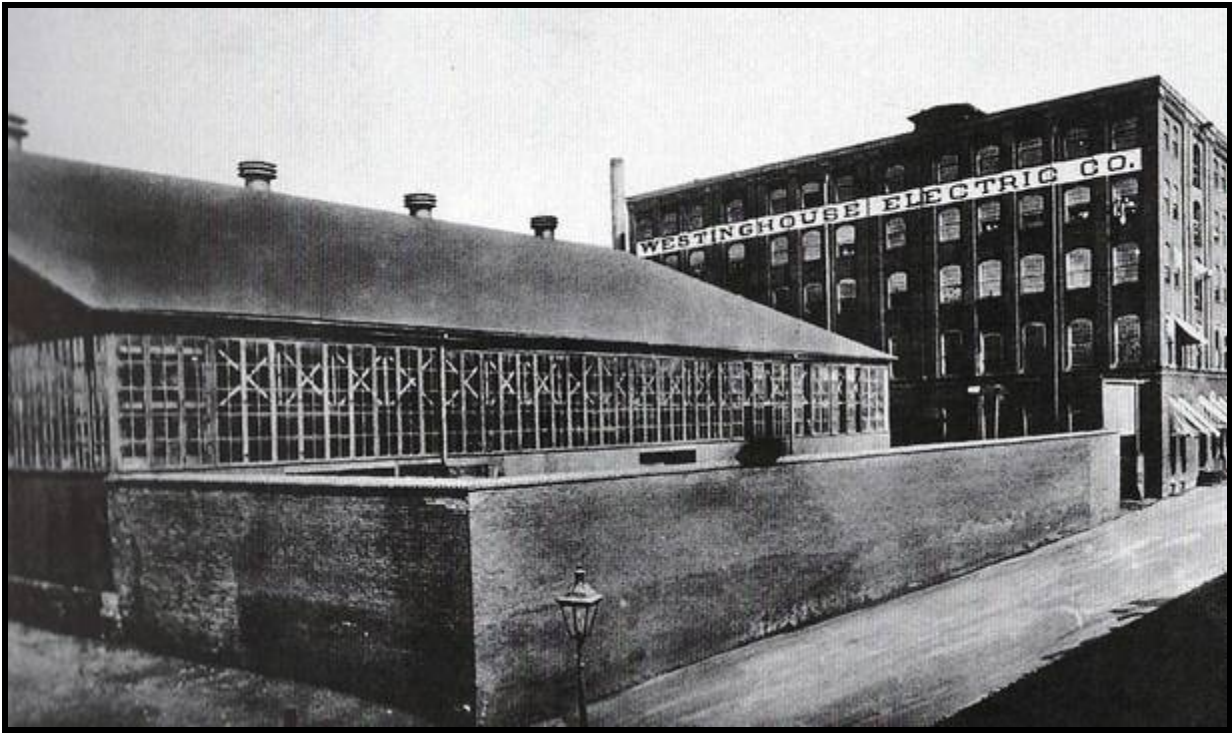
"Phase" difference of 90° between current maximums.

MOTOR SCHEMATICS SHOWING MAGNETIC FIELD ROTATION

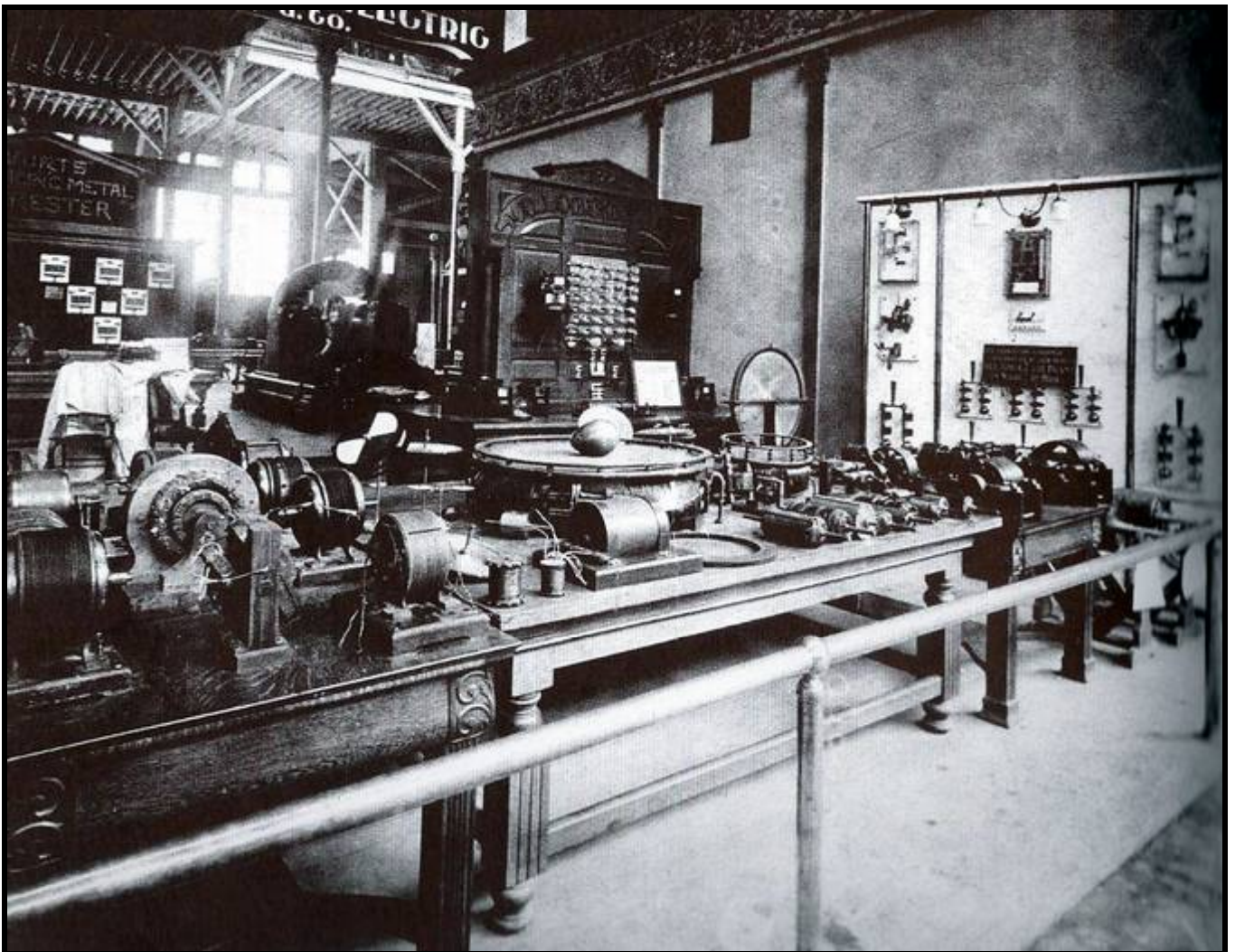
Tesla's most famous invention, the AC motor, has been called a technological advance equivalent to the wheel. The analogy is justified by the immense impact the two discoveries had on subsequent technological development. Unlike the wheel, however, the most important moving part of Tesla's AC motor was something invisible and insubstantial: a magnetic field.

All electrical motors, AC and DC, operate on the same basic principle: a magnetized part that turns (rotor) aligns itself with another magnetized part that

Tesla's AC Motor (from Cheney & Uth)



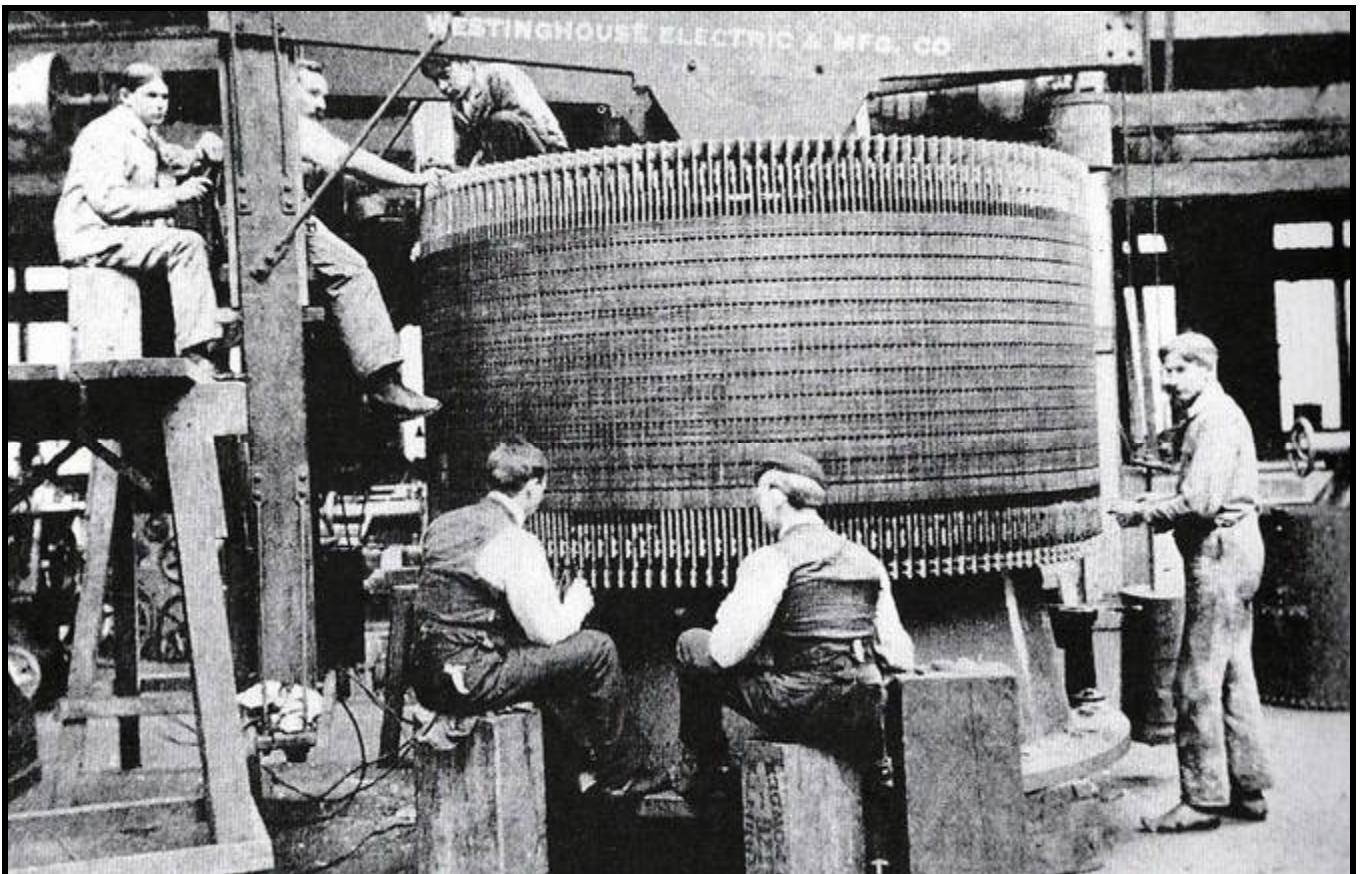
First factory of the Westinghouse Electric Company in Pittsburgh



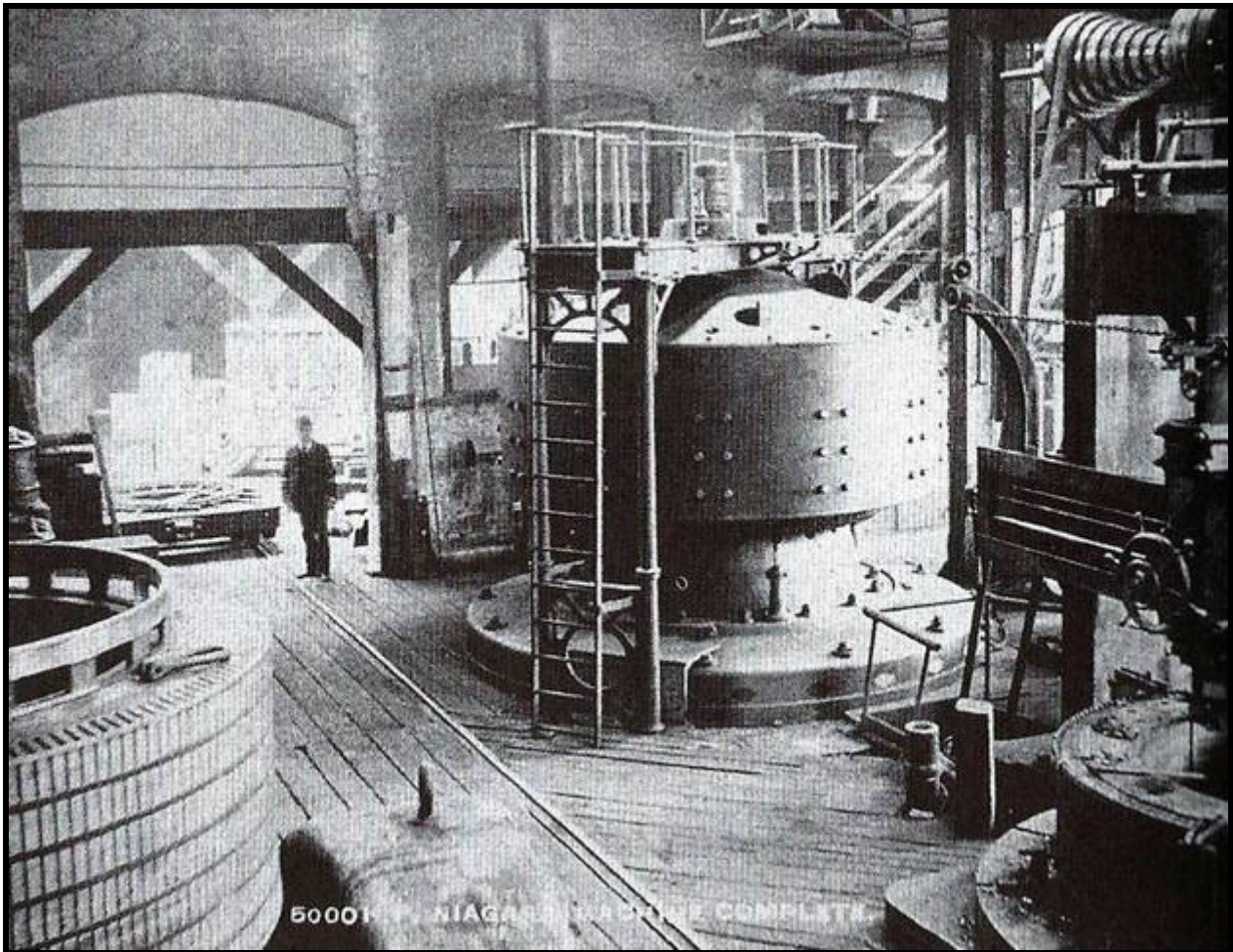
Tesla's demonstration test bench with his Egg of Columbia which stood on end when the table on which it sat was magnetically excited by AC



Lord Kelvin (centre) visited Westinghouse in 1897 and recognised the advantages of AC



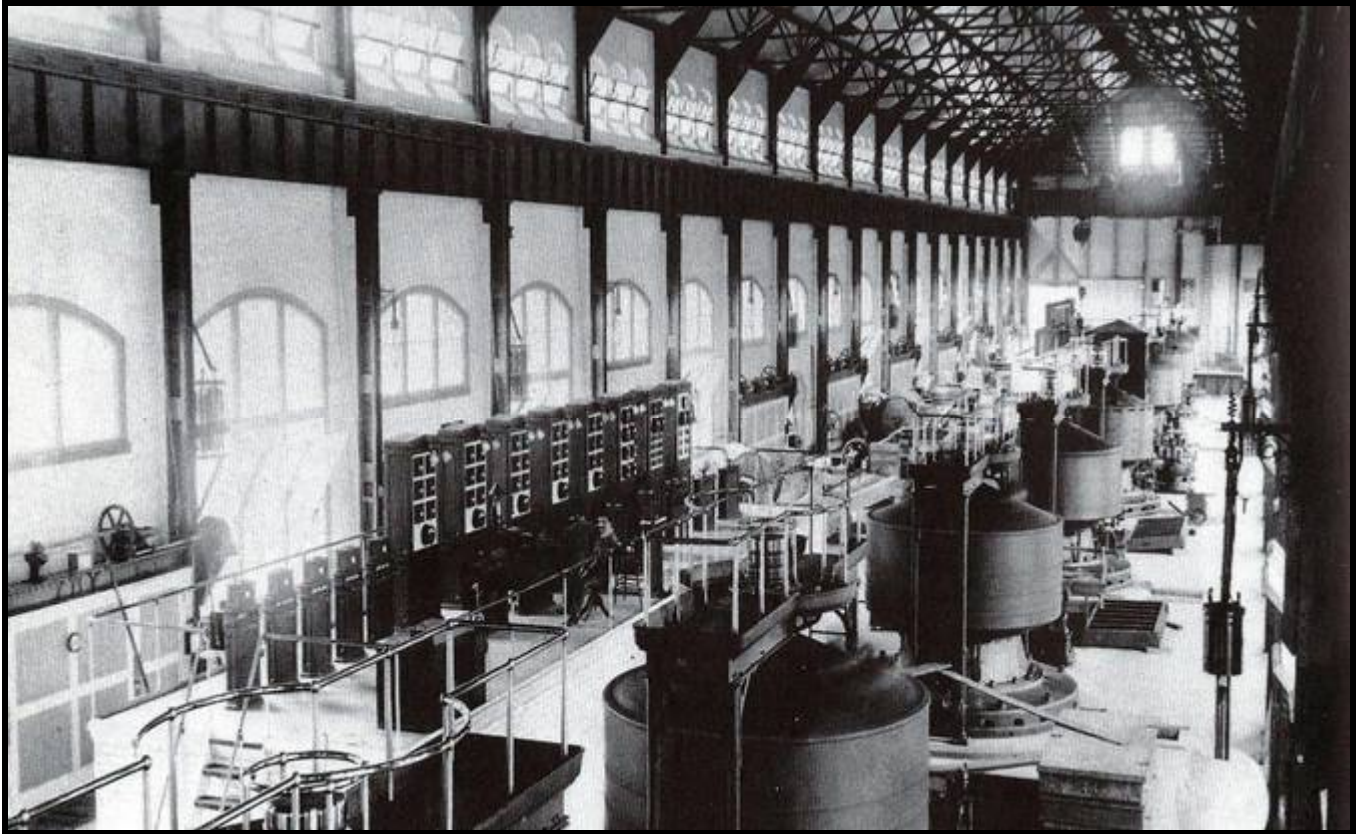
Niagara generator under construction at Westinghouse in Pittsburgh, 1894



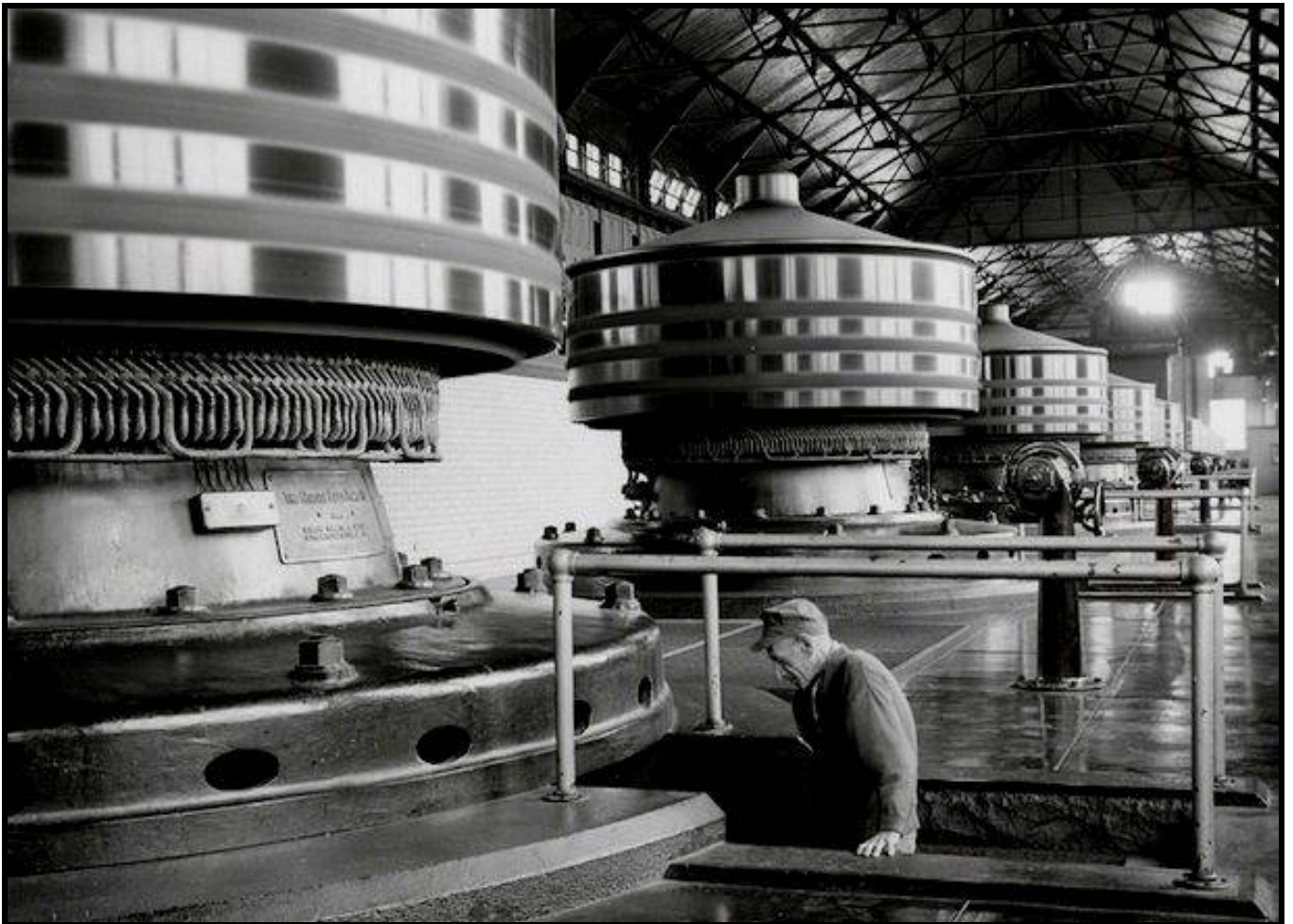
The first Niagara generator at the Falls Power Station, 1895



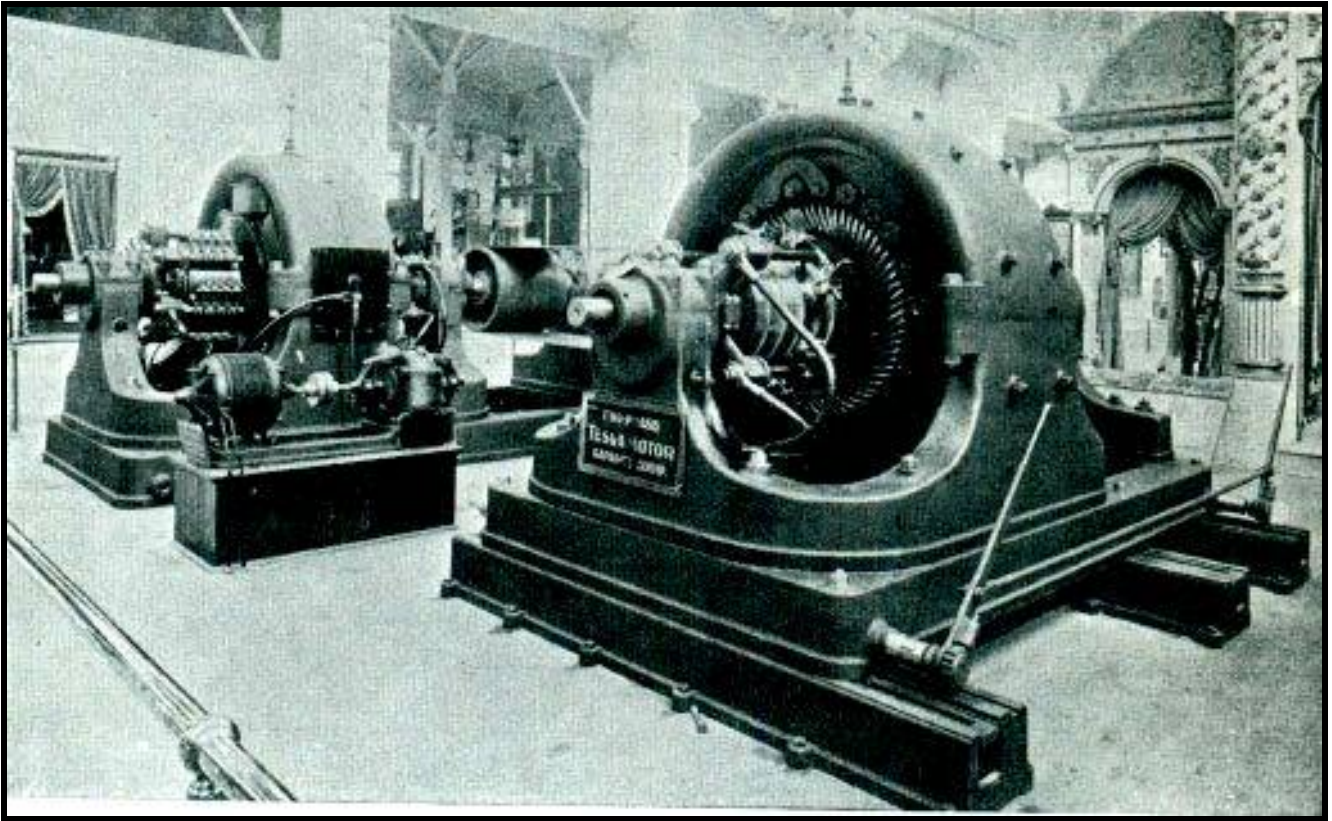
The first three Niagara Falls generators went on line on 16th November, 1896



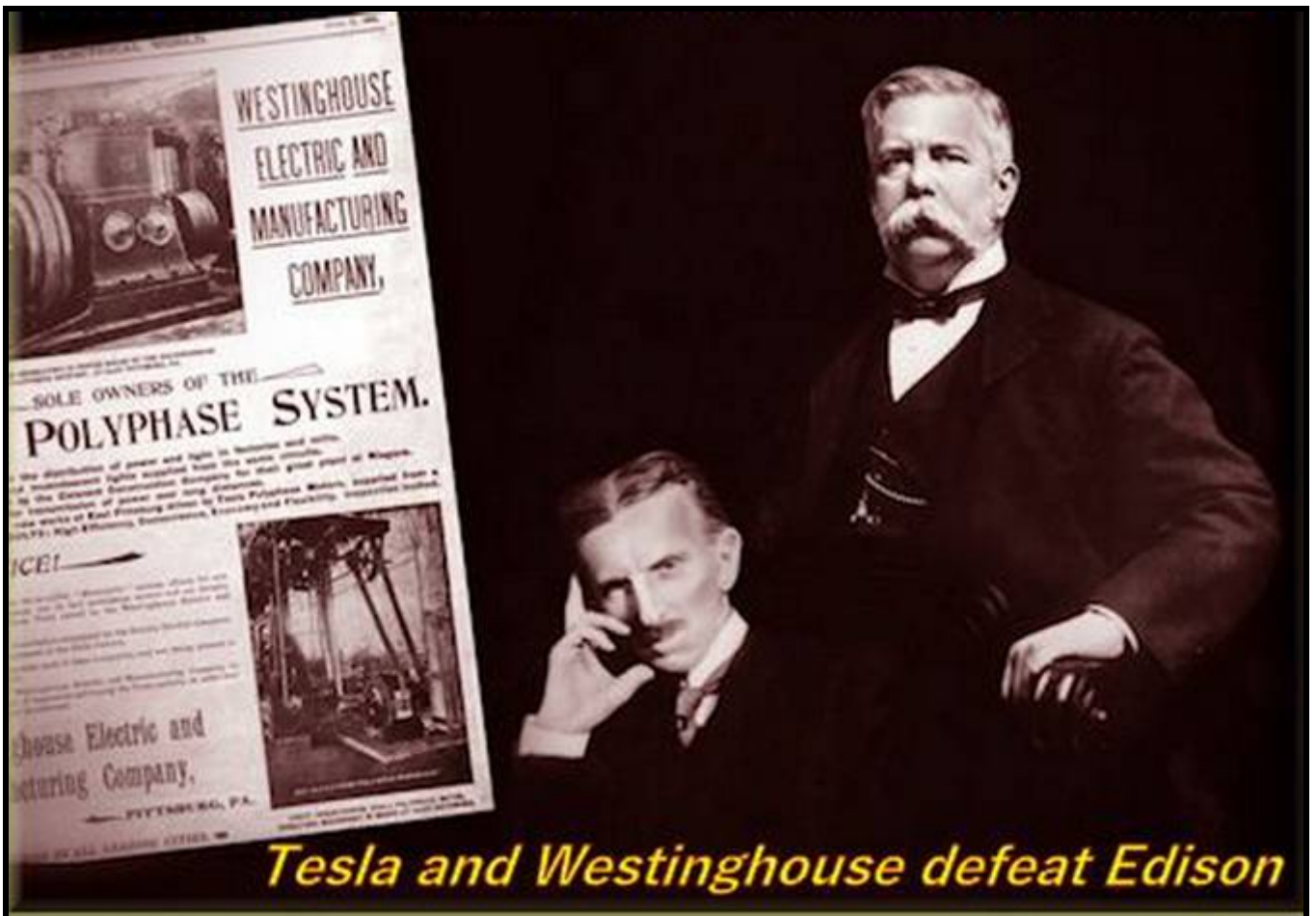
The Edward Dean Adams Power Station at Niagara Falls with ten 5000 horsepower Tesla-Westinghouse AC generators



Niagara Falls Power Station which transmitted AC at 22 kV to Buffalo some 22 miles away and later to New York a distance of over 300 miles



A large Tesla Motor

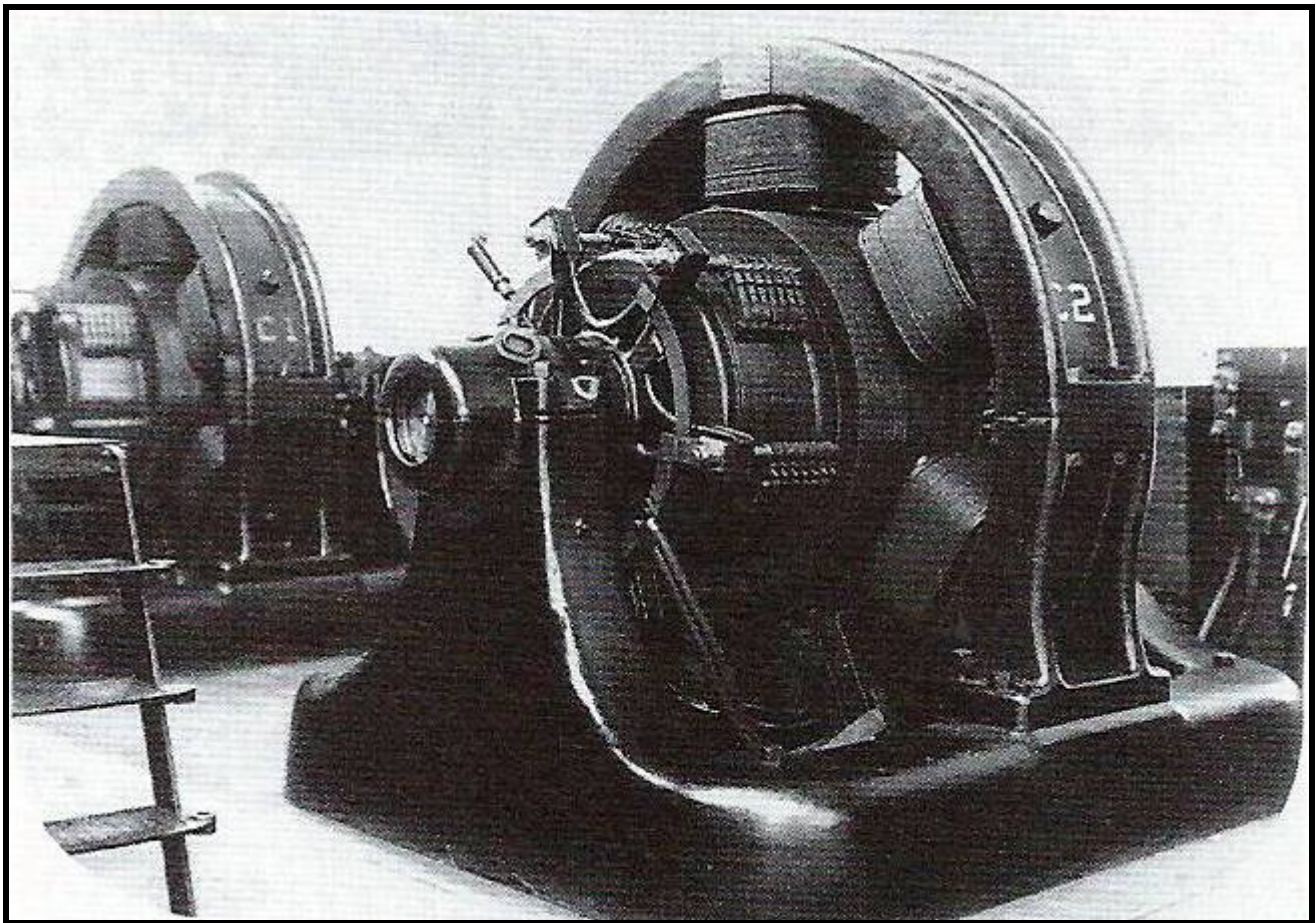


Tesla and Westinghouse defeat Edison

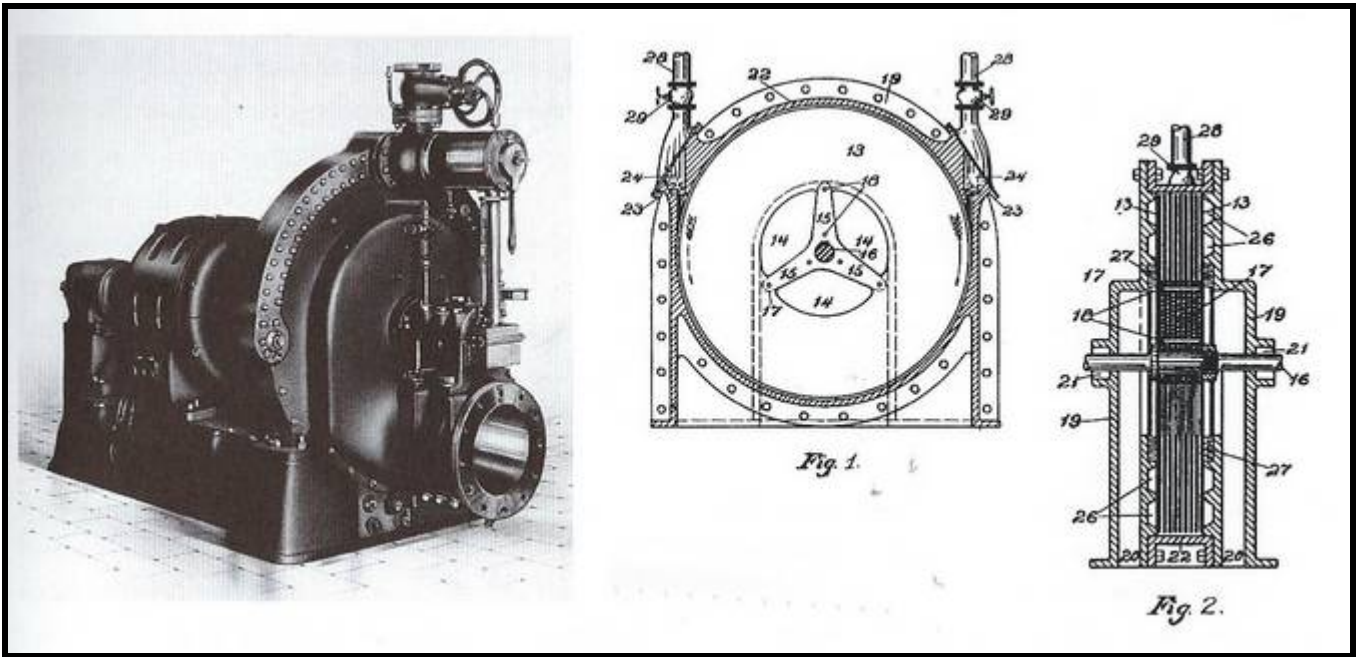
The end of the "Battle of the Currents" (AC versus DC)



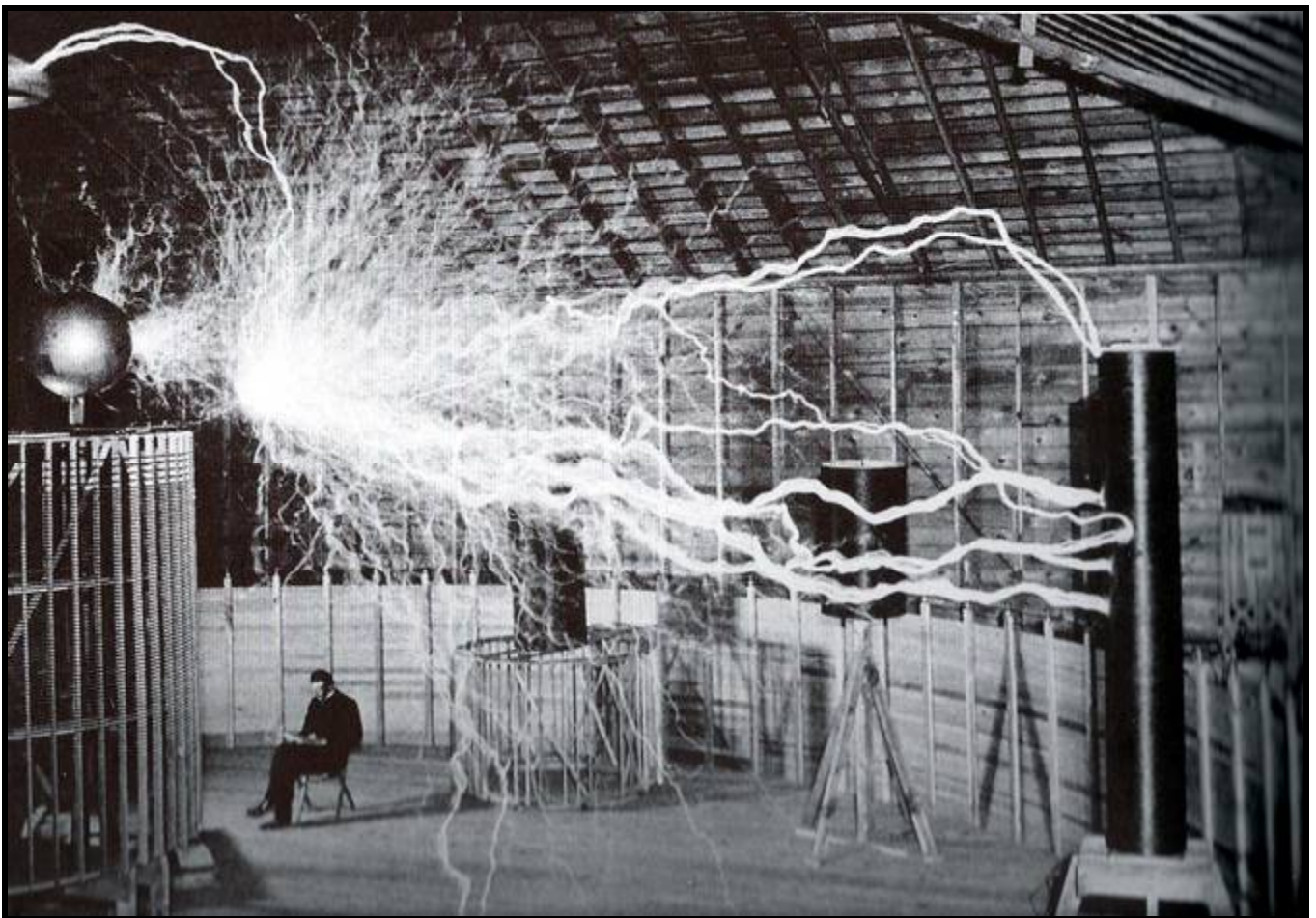
A notice similar to that earlier produced by Edison relating to DC lighting



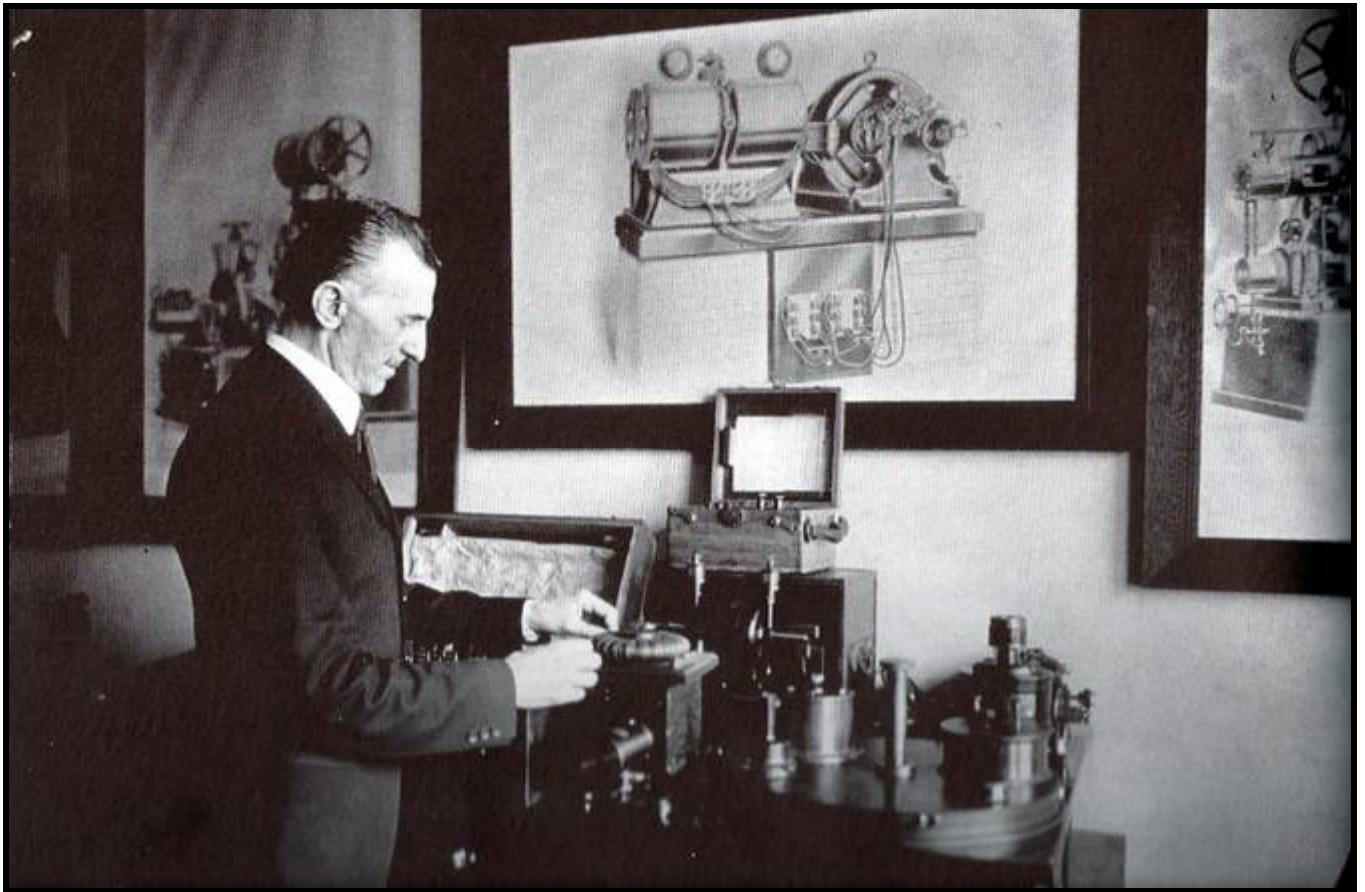
Another view of a large Tesla AC motor



The Tesla Turbine or "Turbo Pump"



Tesla experimenting with a million volts of man-made lightning



Tesla demonstrating electrical apparatus in 1916



The Tesla Electric Light and Manufacturing Company Stock Certificate

TESLA'S EXPERIMENTS WITH ALTERNATING HIGH VOLTAGE CURRENTS

While in Europe alternating currents with frequencies not exceeding 100 per second were still being studied eagerly for practical applications, reports were received from America in 1891 that most surprising experiments were being carried out there with alternating currents of 15,000 cycles. The initiator of these studies was a Hungarian employed with the Westinghouse Company—Nicola Tesla. With remarkable talent he has conducted experiments and research in a hitherto almost unexplored field: that of alternating currents of extremely high voltage and frequency. He gave an account of his work before the American Institution of Electrical Engineers in New York in a lecture which has since become famous. It made an indelible impression upon the audience, both on account of the brilliant experiments and the completely new vistas it has opened. His work places Tesla among the greatest of our present-day scientists and inventors such as Edison, Graham Bell and Thomson.

When the news of Tesla's experiments reached Europe, he was approached by the most prominent scientific circles in Britain and France who invited him to repeat his

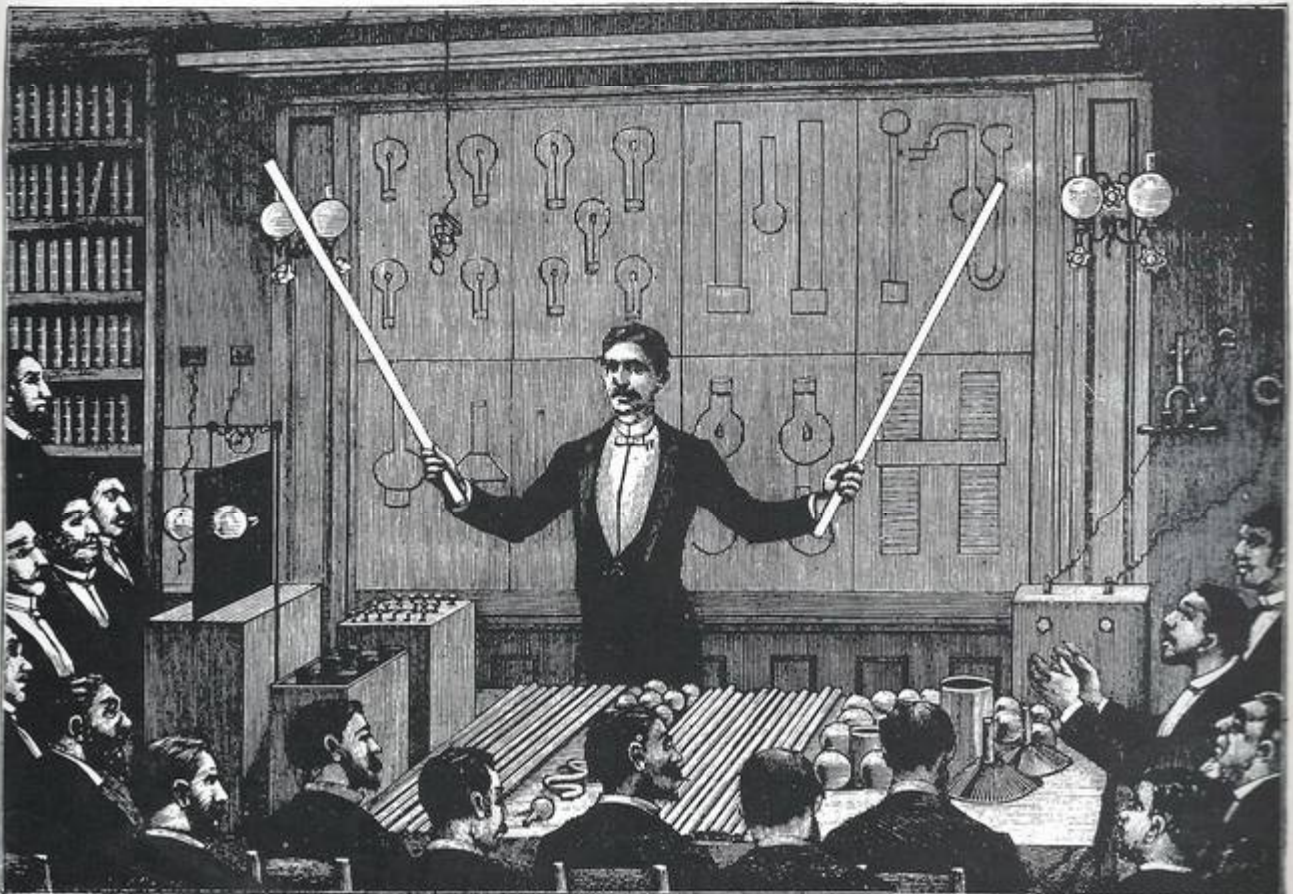
experiments in those countries. These lectures were attended by large and enthusiastic audiences which included men of great authority in the fields of the theoretical and applied sciences. After three hours of lecturing to an enthralled and fascinated audience, Tesla was compelled to admit that he had discussed only part of his research work.

Tesla uses two different types of equipment for generating his alternating high-frequency currents. One is a dynamo with 384 wire coils and an equal number of field magnets rotating at 50 revolutions per minute, thus producing an alternating current of $50 \times 384 = 19,200$ cycles per second. Tesla also uses a special type of transformer. Its primary coil has only a few windings and is connected in series with a spark-gap, a condenser and the secondary winding of a Ruhmkorff-type induction-coil. With the second combination, tensions of *half a million volts* and scores of thousands of cycles per second can be generated, producing most impressive discharge phenomena in the open air and in glass tubes filled with rarefied air.

In the air, these currents engender electrical fireworks of unprecedented splendour

which assume the weirdest shapes, forming luminous fans and plumes of gossamer-like texture. Amazingly enough, these ultra-high voltages are in no way dangerous, thanks to their high frequency. In Berlin, Tesla placed himself between two of his assistants who were almost 15 feet apart, each of them touched one pole of the high-voltage transformer, and when Tesla reached out to them with his two arms, wavy bundles of violet-coloured electric fire shot forth from his fingertips, spreading out to one assistant's hand and to the other's forehead. This to the great dismay of some of the spectators, until they noticed that the experiment was harmless and painless!

One of Tesla's most striking experiments was his demonstration with the 3-foot-long Geissler tubes. For that purpose, two metal bars, 10 feet in length, attached to the floor and ceiling, were connected to the poles of his high-voltage transformer. When Tesla moved two Geissler tubes into the field between the two bars, they became luminous over their entire length without being connected either to the metal bars or to the transformer. In the words of one reporter: "Tesla stood there



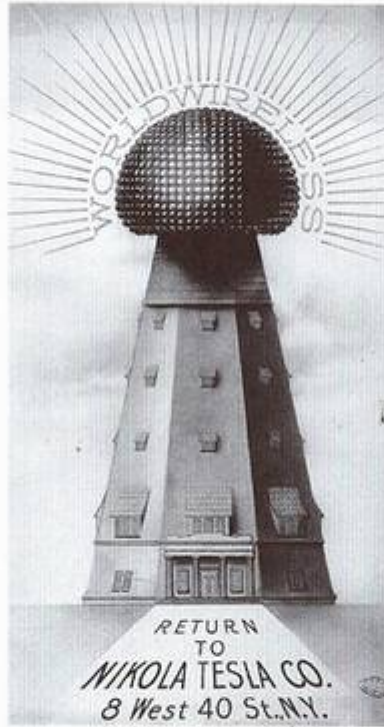
"Tesla stood there like the archangel, brandishing the flaming sword!" [1893]

Extract from the French magazine La Nature of 1894

THE WORLD SYSTEM

Tesla's "World System" was an astonishingly accurate prediction of the electronic world we live in today, but in 1906 it could scarcely be believed. His promotional brochure stated that the system would possess the following features:

- (1) The interconnection of the existing telegraph exchanges or offices all over the world;
- (2) The establishment of a secret and noninterferable government telegraph service;
- (3) The interconnection of all the present telephone exchanges or offices on the globe;
- (4) The universal distribution of general news, by telegraph or telephone, in connection with the press;
- (5) The establishment of intelligence transmission for exclusive private use;
- (6) The interconnection and operation of all stock tickers of the world;
- (7) The establishment of a "World System" of musical distribution, etc.;



Promotional illustration for Tesla's
"World System"

- (8) The universal registration of time by cheap clocks indicating the hour with astronomical precision and requiring no attention whatever;
- (9) The world transmission of typed or handwritten characters, letters, checks, etc.;
- (10) The establishment of a universal marine service enabling the navigators of all ships to steer perfectly without compass, to determine the exact location, hour, and speed to prevent collisions and disasters, etc.;
- (11) The inauguration of a system of world printing on land and sea;
- (12) The world reproduction of photographic pictures and all kinds of drawings or records.

"Besides these I referred to," Tesla added, "other and incomparably more important applications of my discoveries will be disclosed at some future date" (Tesla 1919e).

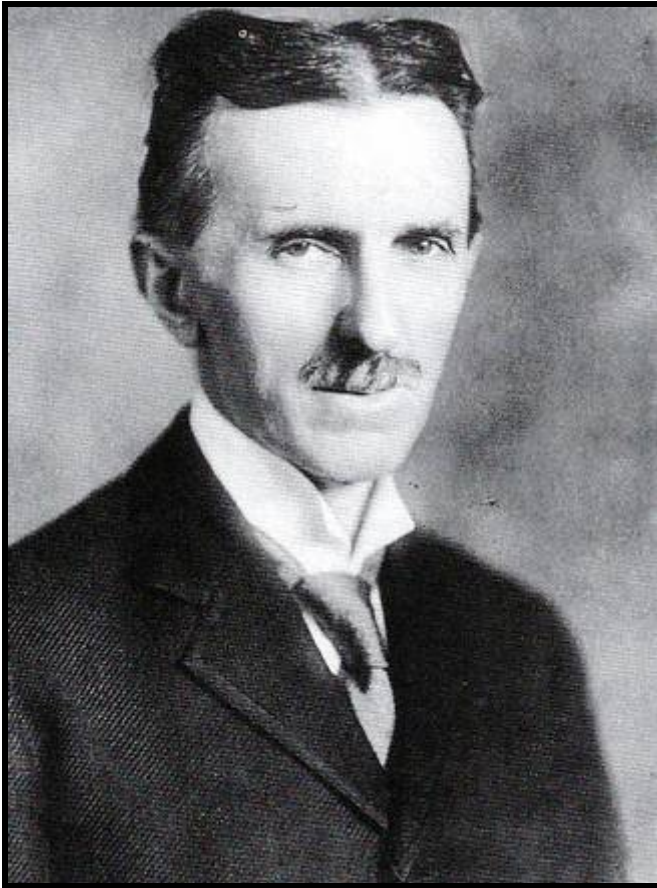
Tesla's World System (from Cheney & Uth)

TESLA'S LEGACY

This is described in the words of his biographer, Robert Lomas, in his book of 1999:

"Everybody knows that Thomas Edison devised electric light, that Guglielmo Marconi thought up radio and George Westinghouse built the world's first hydro-electric power station. Everyone knows the *facts*, but they are wrong.

One man alone dreamt up these things: Nikola Tesla, a Serbian-American scientist, who also invented *inter alia* the fluorescent light, seismology and a worldwide data communication network which prefigured the internet. He is without doubt this century's greatest unsung scientific hero."



Nikola Tesla in 1930 at age sixty-four



Tesla's coffin in the Cathedral of St John the Divine, New York City, 12th January 1943

APPENDIX: SOME EARLY TESLA PATENTS

(No Model.)

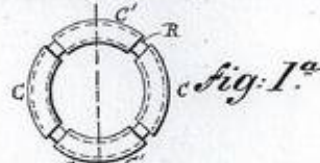
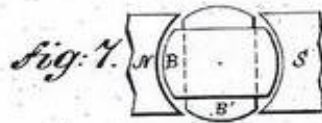
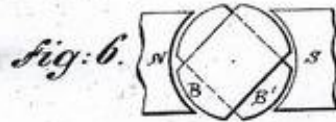
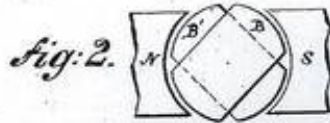
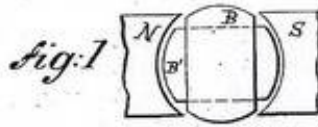
4 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,968.

Patented May 1, 1888.



WITNESSES:

Frank E. Hartley
Frank B. Murphy

INVENTOR:

Nikola Tesla,
BY
Duncan, Curtis & Sage
ATTORNEYS.

(No Model.)

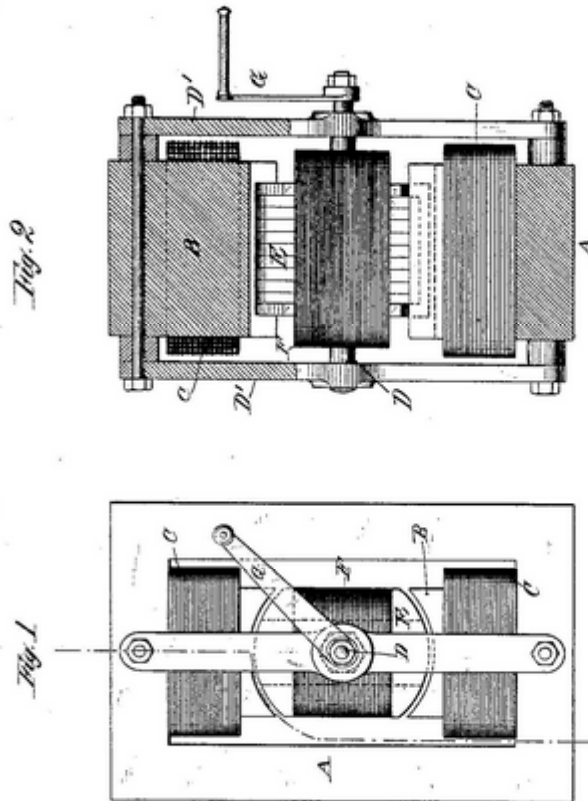
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N. TESLA.

REGULATOR FOR ALTERNATE CURRENT MOTORS.

No. 390,820.

Patented Oct. 9, 1888.



WITNESSES:

Saxziel Nessler.
Robt. F. Gaylord.

INVENTOR.

Nikola Tesla.
BY
Duncan, Curtis & Page.
ATTORNEYS.

(No Model.)

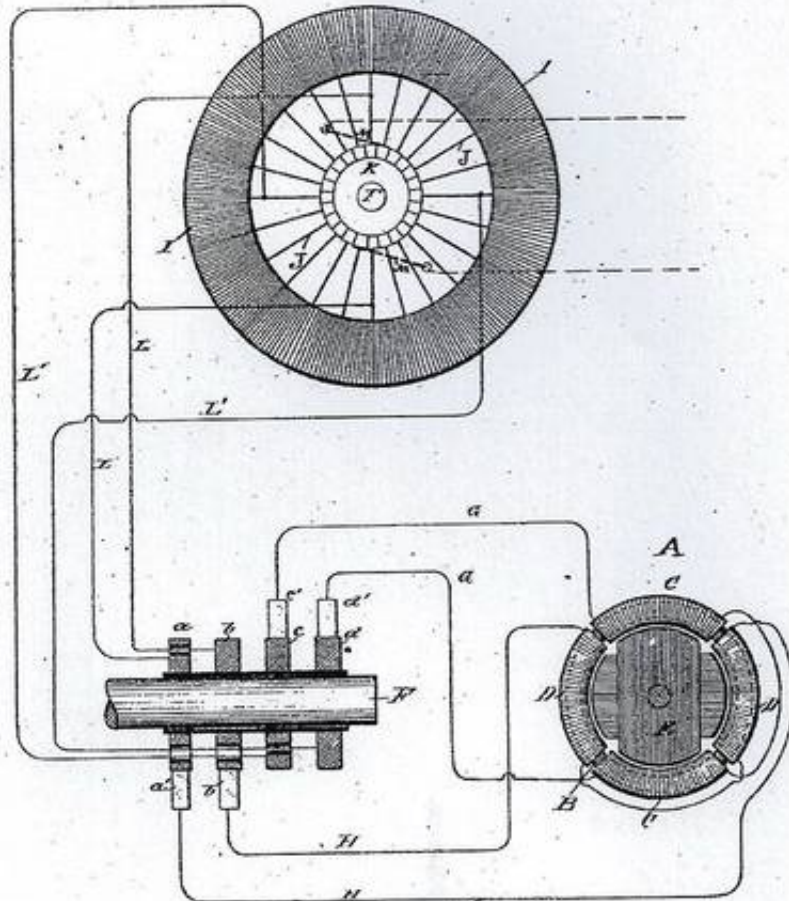
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N. TESLA.
DYNAMO ELECTRIC MACHINE.

No. 390,414.

Patented Oct. 2, 1888.

Fig. 1



WITNESSES:

Raphael Netter
Franklin Harvey

INVENTOR

Nikola Tesla

BY

Duncan, Curtis & Bag
ATTORNEYS.

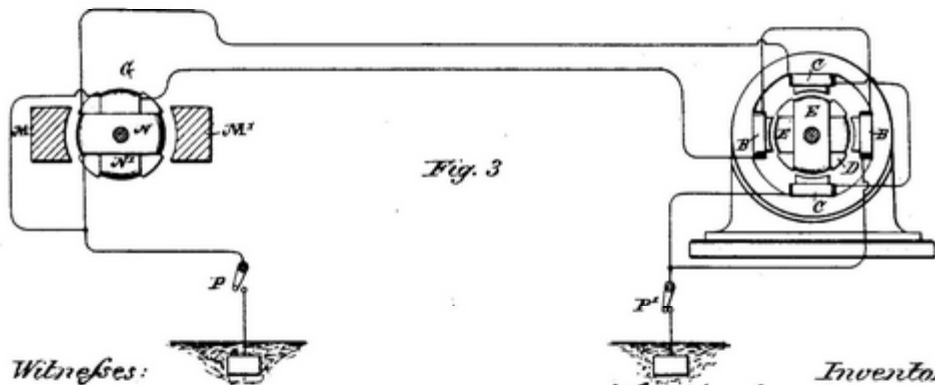
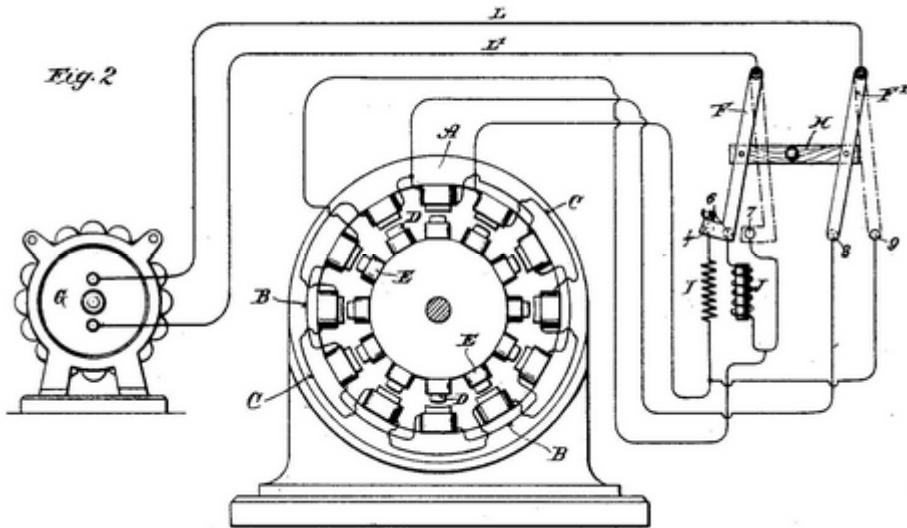
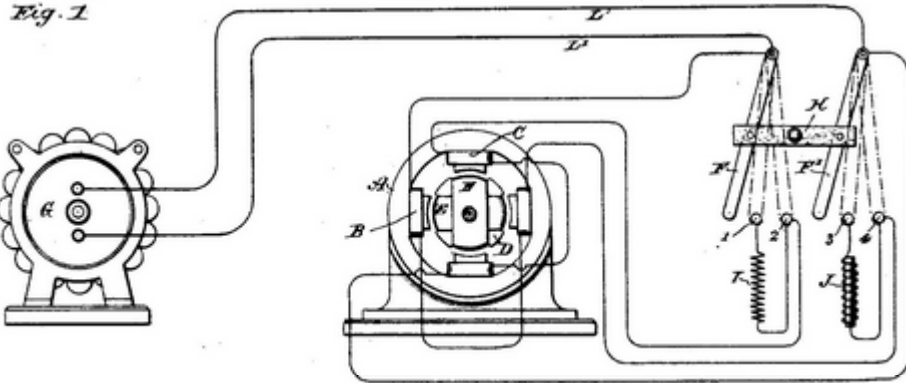
(No Model.)

N. TESLA.

METHOD OF OPERATING ELECTRO MAGNETIC MOTORS.

No. 401,520.

Patented Apr. 16, 1889.



Witnesses:
Rajzar Vetter
Cyril Hopkinson

Inventor,
Nikola Tesla
by
Duncan, Curtis & Page
Attorneys.

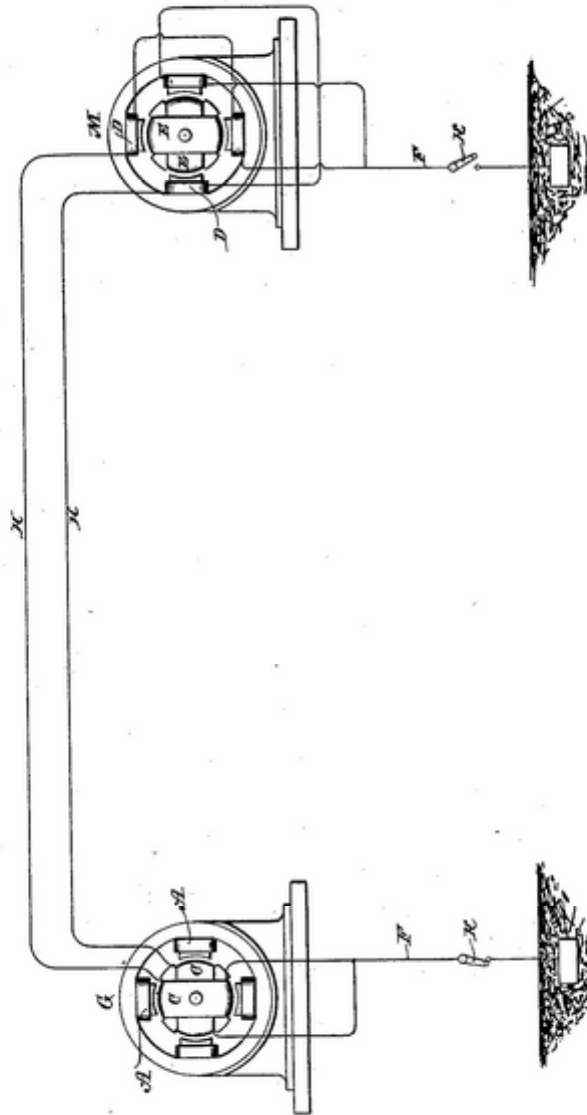
(No Model.)

N. TESLA.

METHOD OF ELECTRICAL POWER TRANSMISSION.

No. 405,859.

Patented June 25, 1889.



Witnesses:
Raphael Nixon
Robt. F. Gaylord

Inventor
Nikola Tesla
By
Duncan, Curtis & Page.
Attorney.

(No Model.)

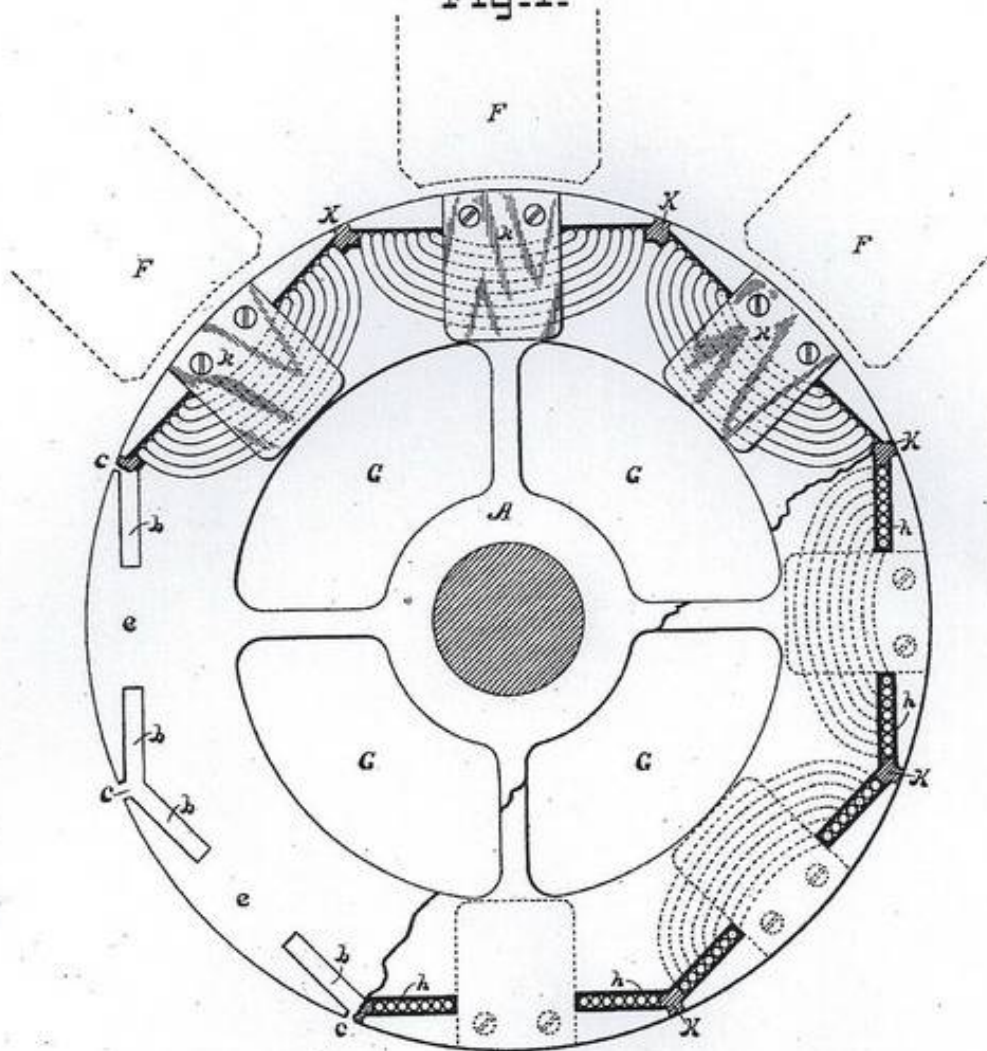
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A. SCHMID & N. TESLA.
ARMATURE FOR ELECTRIC MACHINES.

No. 417,794.

Patented Dec. 24, 1889.

Fig-1.



WITNESSES:

George Brown, Jr.
Wm. Smith.

INVENTORS

Albert Schmid,
Nikola Tesla.
Charles A. Terry
Att'y.

(No Model.)

N. TESLA.

ALTERNATING CURRENT ELECTRO MAGNETIC MOTOR.

No. 433,700.

Patented Aug. 5, 1890.

Fig. 1

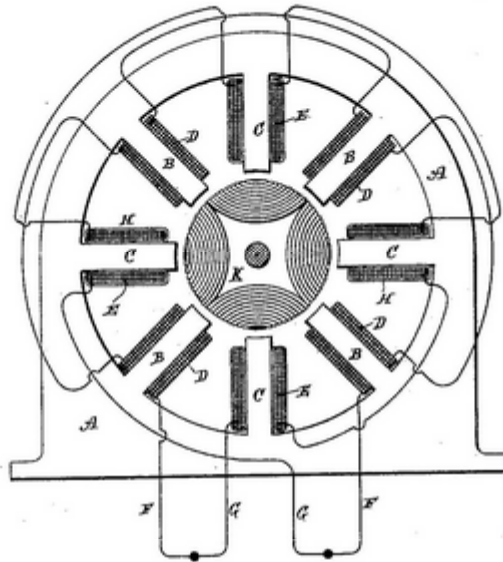
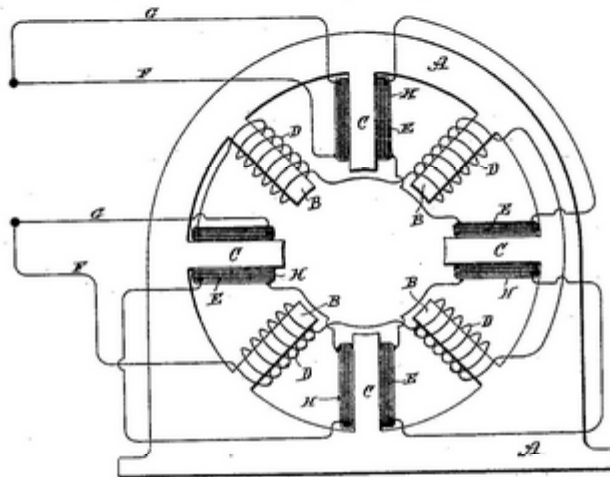


Fig. 2



Witnesses:

Raphael Netto
Ernest Hopkinson

Inventor

Nikola Tesla
by
Duncan, Curtis & Sage
Attorneys.

(No Model.)

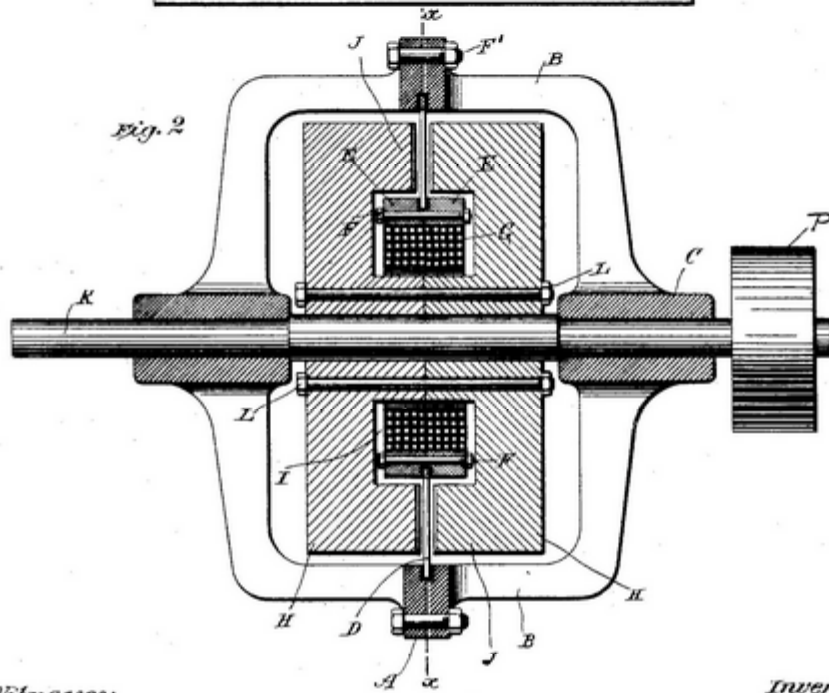
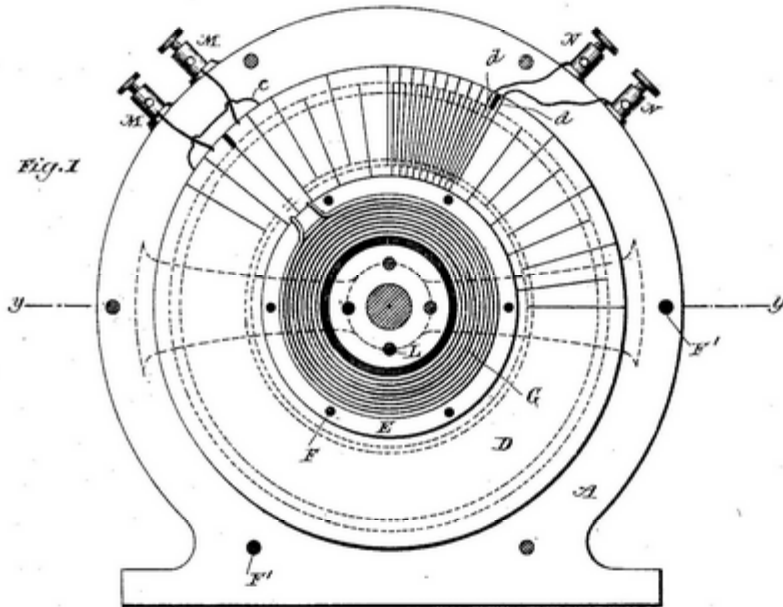
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N. TESLA.

ALTERNATING ELECTRIC CURRENT GENERATOR.

No. 447,921.

Patented Mar. 10, 1891.



Witnesses:
Ernest Hopkinson
Frank B. Murphy.

Inventor
Nikola Tesla
by
Duncan & Page
Attorneys.

(No Model.)

N. TESLA.
ELECTRIC INCANDESCENT LAMP.

No. 455,069.

Patented June 30, 1891.

Fig. 1

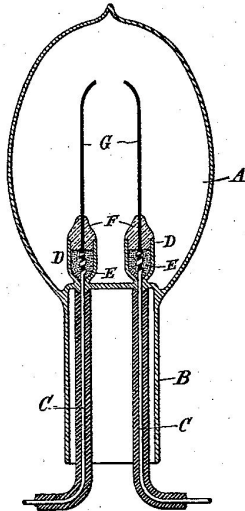
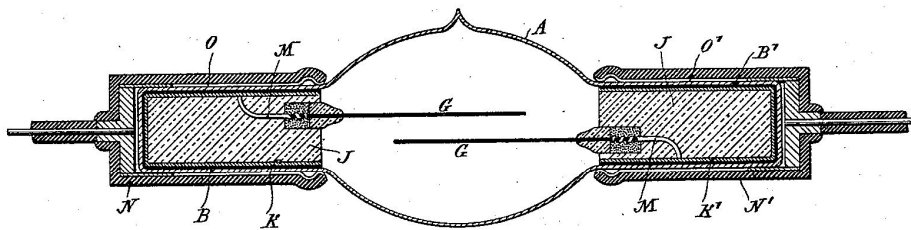


Fig. 2



Witnesses:
Raphael Neter
Frank B. Murphy.

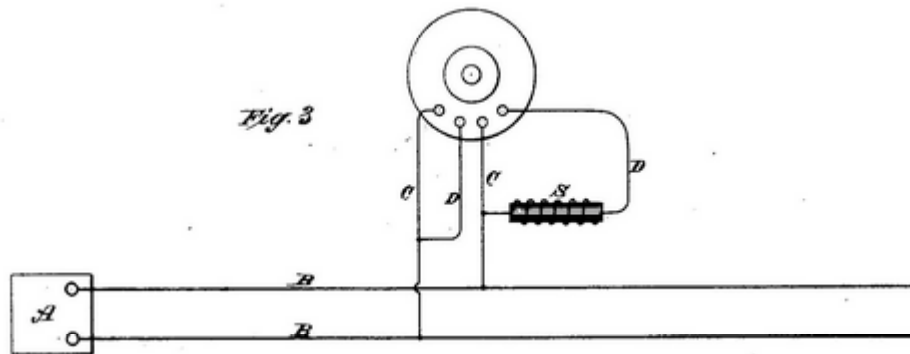
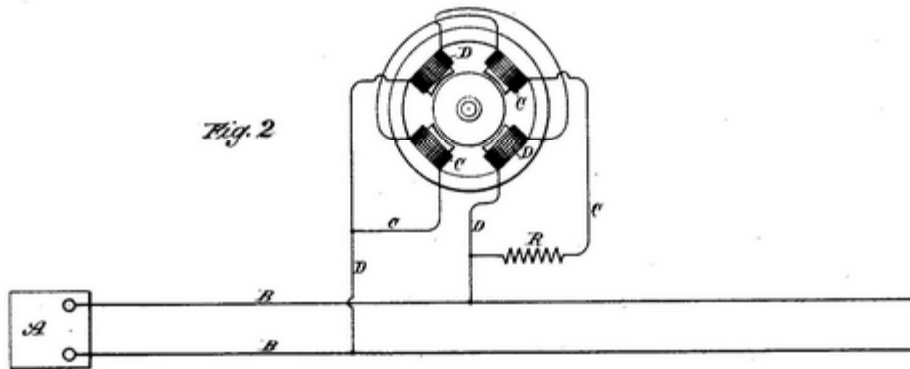
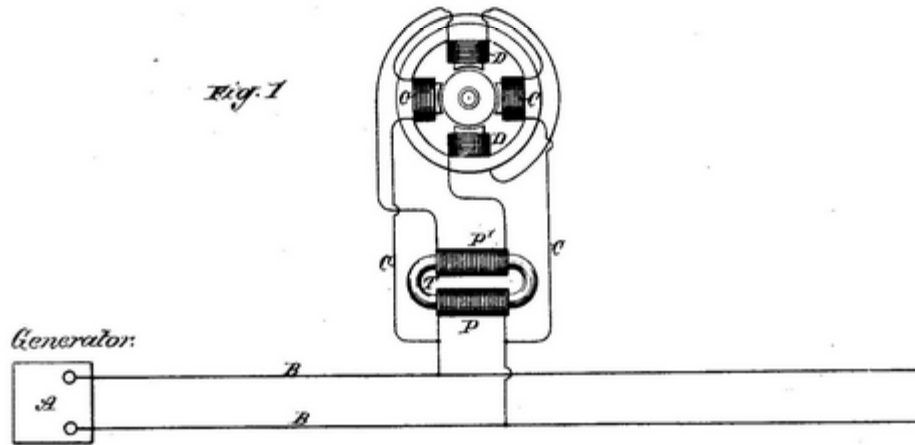
Inventor
Nikola Tesla
by
Duncan & Page
Attorneys.

(No Model.)

N. TESLA.
ELECTRICAL TRANSMISSION OF POWER.

No. 511,559.

Patented Dec. 26, 1893.



WITNESSES:
Raphael Netter
Ernest Hopkinson

INVENTOR
Nikola Tesla
BY
Duncan, Curtis & Page
ATTORNEYS.

(No Model.)

N. TESLA.
ALTERNATING MOTOR.

No. 555.190.

Patented Feb. 25, 1896.

Fig. 1

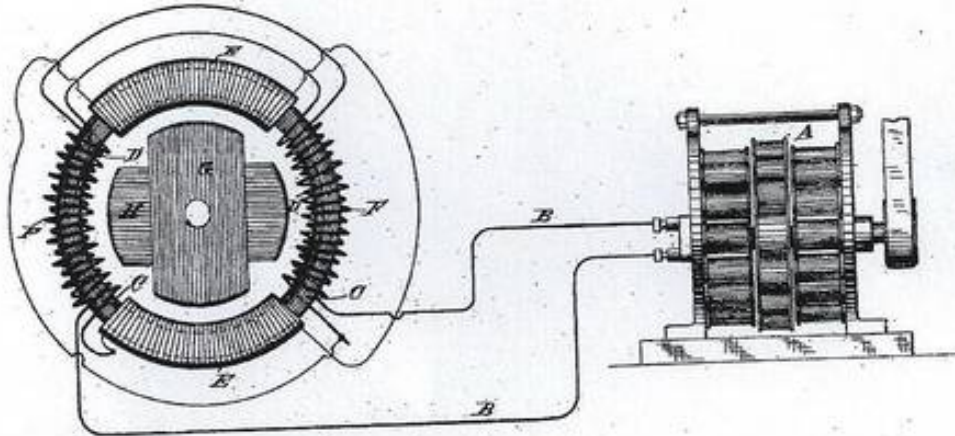
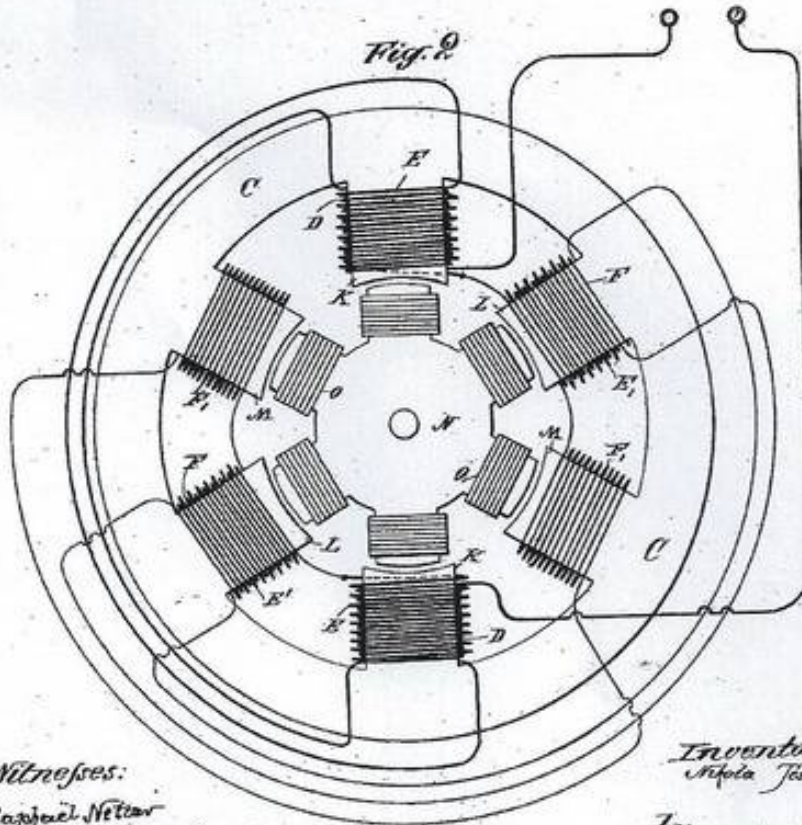


Fig. 2



Witnesses:
Raphael Netzer
Robert F. Gaylord

Inventor
Nikola Tesla
by
Duncan, Curtis & Sage
Attorneys.

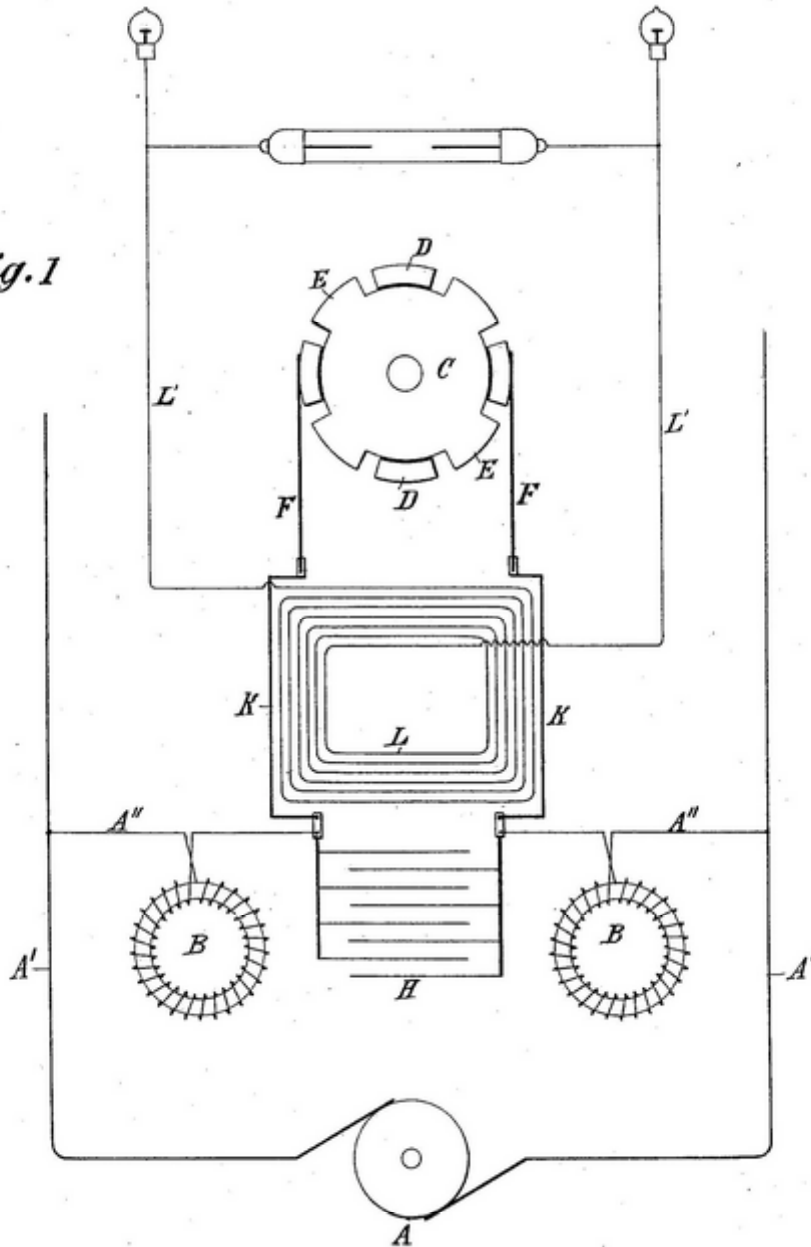
N. TESLA.

APPARATUS FOR PRODUCING ELECTRIC CURRENTS OF HIGH
FREQUENCY AND POTENTIAL.

No. 568,176

Patented Sept. 22, 1896.

Fig. 1



Witnesses:
Raphael Ketter
Dwight W. Cropper

Nikola Tesla, Inventor
by Messrs. Curtis & Page.
Atty's.

BIOGRAPHY

1893 *The Inventions, Researches & Writings of Nikola Tesla*, T C Martin: Barnes & Noble (2014 reprint)

----- *N Tesla*, US Patent Office Records

1894 *Tesla's Experiments with Alternating High Voltage Currents*, p.232, La Nature

1919 *My Inventions: The Autobiography of Nikola Tesla*, Nikola Tesla (2011 reprint)

1973 *Victorian Inventions*, Leonard de Vries, (from the Dutch), *Electricity*, pp. 86-105, John Murray, London

1999 *The Man who invented the 20th Century: Forgotten Genius of Electricity, Nicola Tesla*, Robert Lomas (2013 reprint)

2001 *Tesla: Master of Lightning*, Margaret Cheney & Robert Uth, MetroBooks, USA

2007 *Tesla: Master of Lightning*, DVD, PBS (Public Broadcasting Service), America
May be available only in Region 1, NTSC format

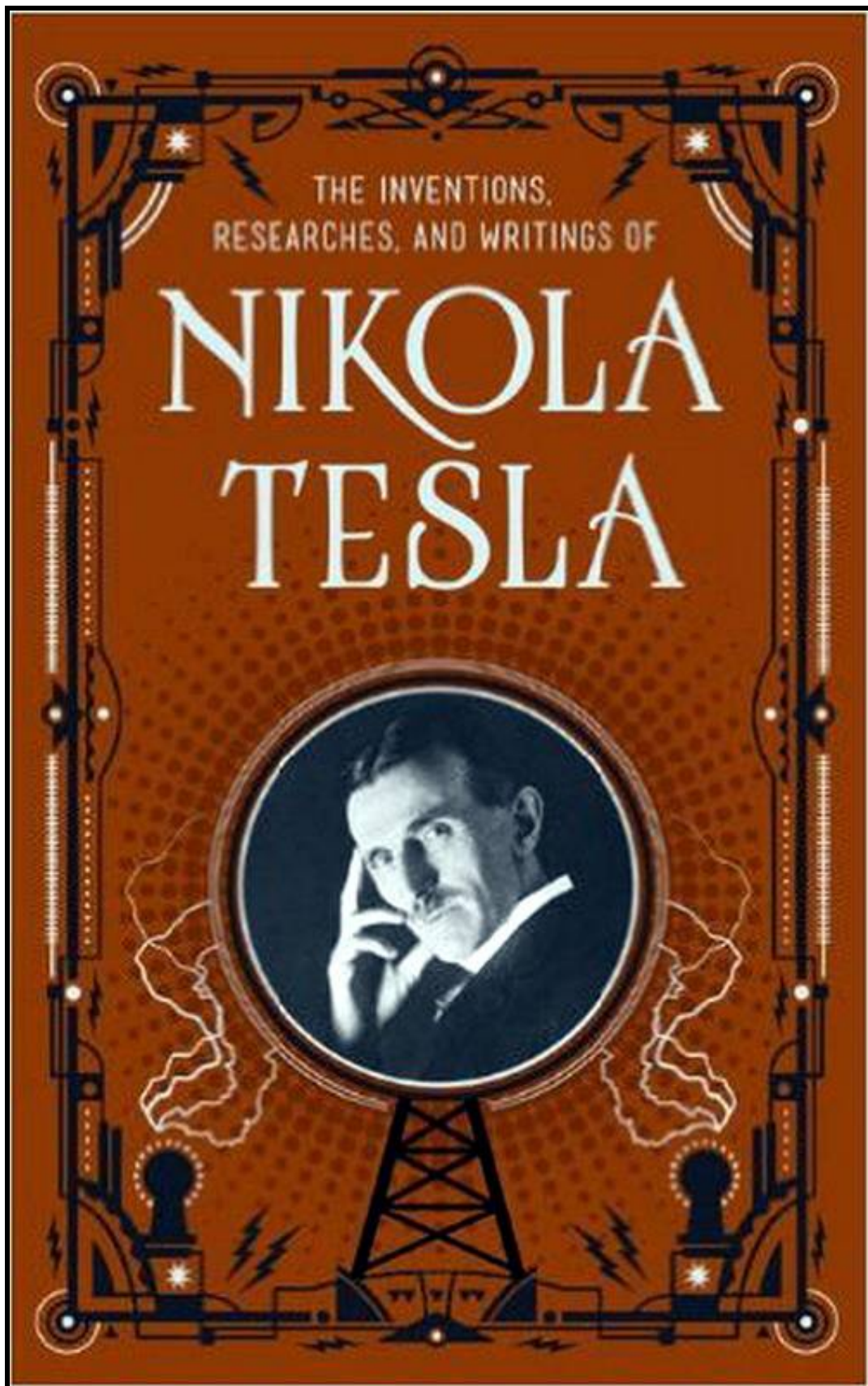
<https://en.wikipedia.org/wiki/Nicola-Tesla>

<https://en.wikipedia.org/wiki/Alternating-current>

See also www.pbs.org/tesla

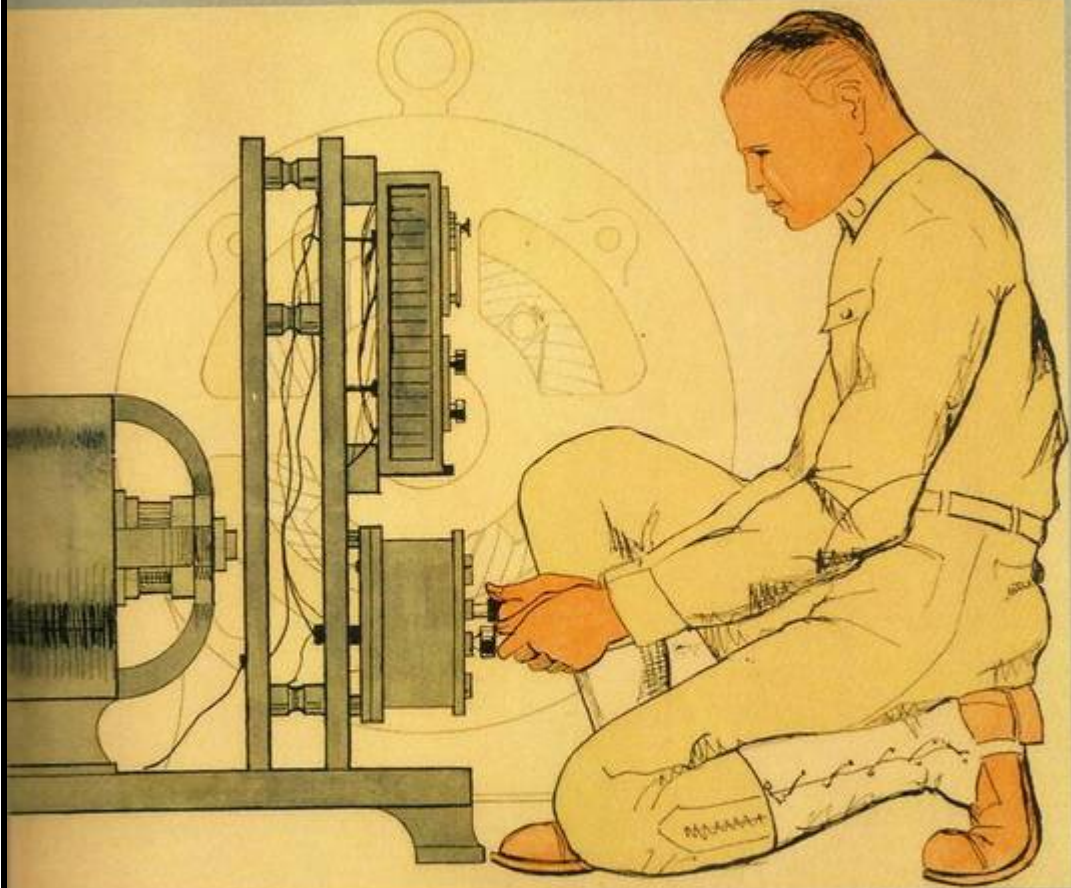
A complete listing of Tesla's US Patents with Drawings is available on the internet

POSTSCRIPT & FURTHER READING & VIEWING



1893

NIKOLA TESLA



MY INVENTIONS

The Autobiography of Nikola Tesla

1919

ASHRAE Journal

HEATING, REFRIGERATING AND AIR-CONDITIONING OCTOBER/1982

EXCLUSIVE REPORT:
ASHRAE Standards
100 Series:
Energy Conservation For
Existing Buildings



Joseph Henry



Joseph Henry's electro-magnetic motor, 1831. Henry and Faraday discovered that a changing magnetic field generates an electromotive force that in turn produces current flow.

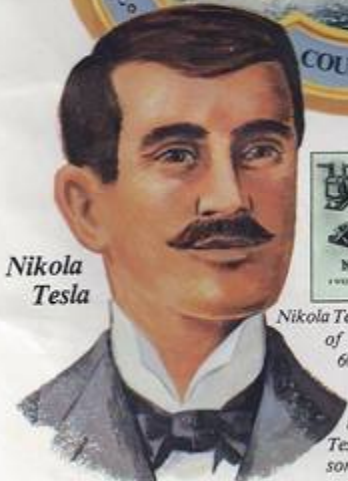


In 1821, Michael Faraday demonstrated that if a current is flowing in a wire, placed as shown in a permanent magnet, there will be a force on that wire. The force F is perpendicular to the directions of both the magnetic field B and the current element IdL .



Michael Faraday

Electricity: A Prime Mover of Industry



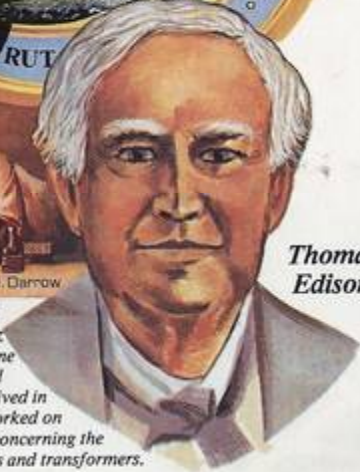
Nikola Tesla



Nikola Tesla pioneered the development of ac generators and established 60 Hz as the standard frequency in America after the Niagara Falls hydro-electric plant was built. The letterhead above, of Tesla's business stationery recalls some of his important inventions.



Thomas Alva Edison and Charles Proteus Steinmetz examining the damage done to insulators by "artificial lightning." Steinmetz arrived in New York in 1890 and worked on the theoretical problems concerning the design of streetcar motors and transformers.



Thomas Edison

ASHRAE Research 1982-83

THE MAN WHO INVENTED THE TWENTIETH CENTURY

Nikola Tesla, Forgotten
Genius of Electricity

'Intriguing... puts today's hype wars into perspective'

GUARDIAN

ROBERT
LOMAS



1999

TESLA

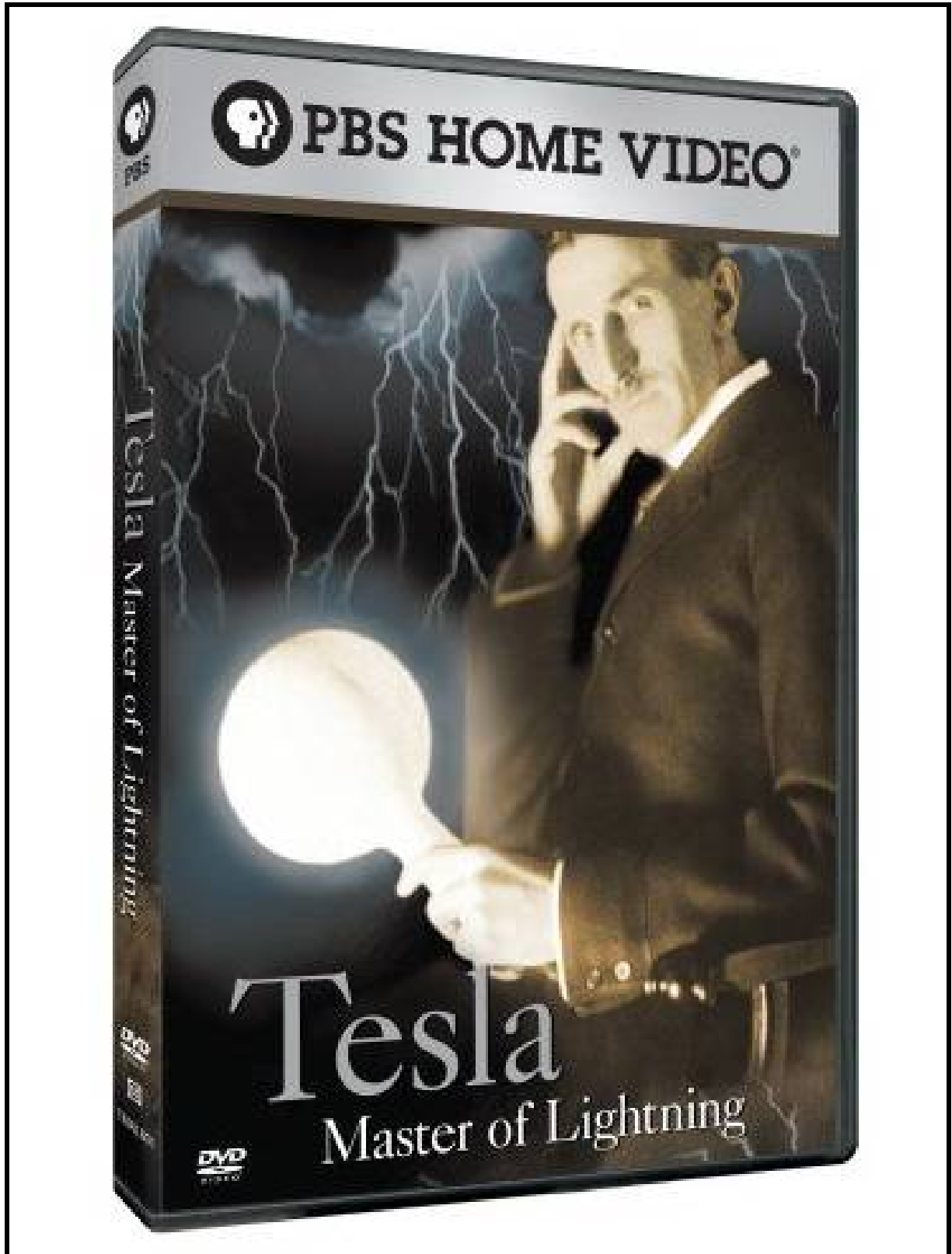
MASTER OF LIGHTNING



Clayton
CHENEY
1978

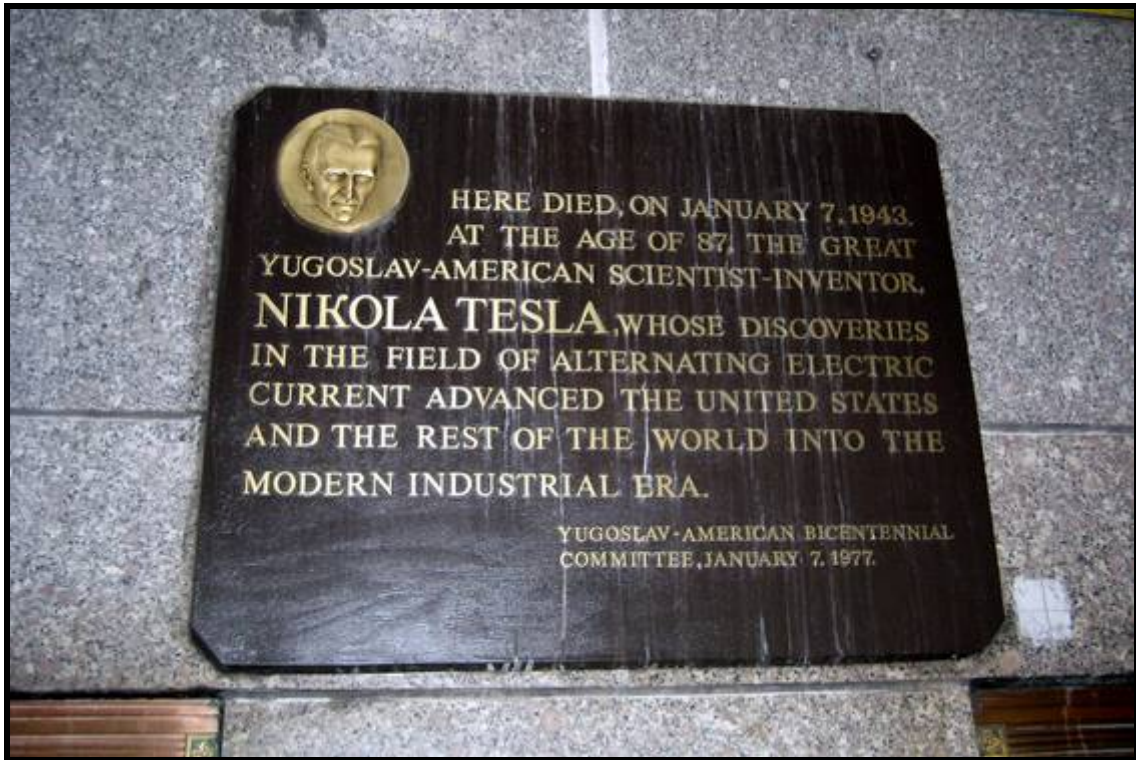
MARGARET CHENEY
& ROBERT UTH

2001

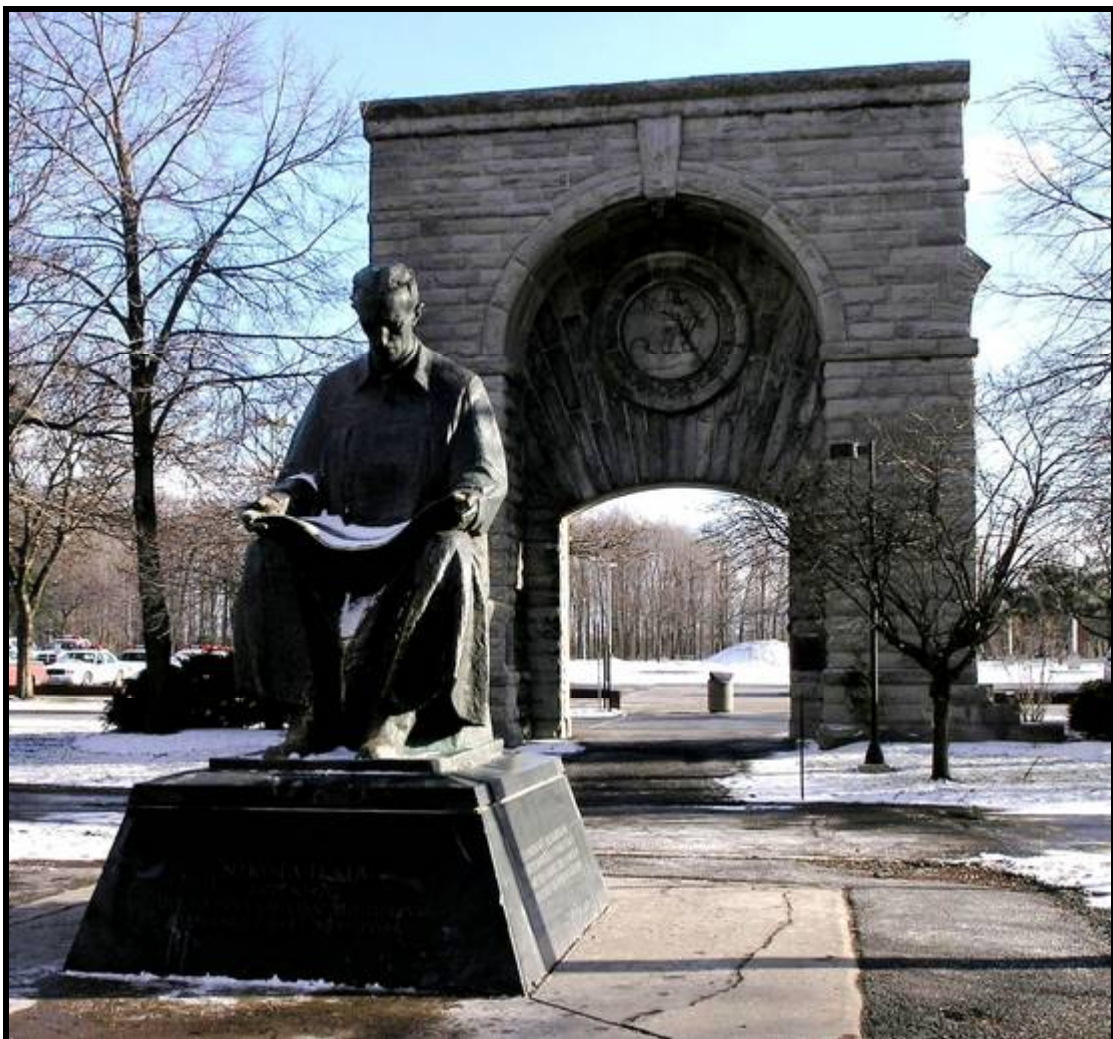


2007

EPILOGUE



New York Memorial Tablet to Nikola Tesla



Nikola Tesla statue at Goat Island, Niagara Falls



Monument at Niagara Falls to Nikola Tesla, standing on top of his AC motor

The SI derived unit the tesla (symbol T) is the standard unit of magnetic flux density.