

FEATURE ARTICLE

Edison and "The Chair"

Terry S. Reynolds and Theodore Bernstein

Abstract:—Although Thomas Edison had little knowledge of the biological effects of electric currents on humans, he exerted a pivotal influence on the early history of legal electrocution, from the decision to substitute electrocution for hanging in 1888 to the actual design of an electric chair in 1892. He was able to play a pivotal role because of his status as an electrical wizard, demonstrating how largely non-technical, non-scientific factors like status can have an important impact on the way seemingly scientific and technical problems that impinge on society are resolved.

Thomas Edison was largely ignorant of human physiology and never personally conducted any extensive experimentation on the effects of electric currents on living organisms. Yet he played a pivotal role in the early history of legal electrocution on several levels at several times. He influenced the decision to adopt electricity as a mode of capital punishment and the decision to use alternating current for the process. His testimony was central in the appeal hearings that upheld the constitutionality of New York's pioneering electrocution law. And he designed an unusual electric chair used in one of the early legal electrocutions.

Edison chose to play a pivotal role in early electrocution, in spite of his lack of experience in and knowledge of the biological effects of an electric current on humans, because of real concerns over the safety of alternating current and personal bitterness towards a commercial rival. He was able to play such a role because the state officials charged with making decisions on capital punishment were so in awe of Edison that they overlooked his lack of detailed knowledge in the area. In brief, the case of Edison and the electric chair demonstrates how largely non-technical, non-scientific factors like personal bitterness and status can have as much of an impact as technical or scientific factors in the way scientific or technical problems that impinge on society are resolved.

BACKGROUND

Edison's involvement in debates over the lethality of electric currents and the use of electricity as a mode of capital punishment had its roots in the safety concerns and personal bitterness engendered by the rise of alternating current as a form of power transmission in the late 1880s. Edison, in the early part of that decade, had introduced an electric power system based on direct current transmitted at voltages no higher than around 240. Due to its low transmission voltages, direct current systems were generally safe, but could not economically reach more than a mile beyond their generators. This shortcoming, and the commercial success of electric lighting, encouraged others to seek alternative means of electric power transmission. In the mid-1880s, George Westinghouse introduced a rival power distribution system based on alternating current. Because alternating current systems can make use of transformers to step voltage levels up and down at will, the Westinghouse ac system was able to transmit power at much higher voltages than the transformer-less dc system, and step the voltages back down to safer levels for homes and offices. The primary advantage of alternating current was in copper costs, the largest capital cost item in electric power systems. The higher the transmission voltage, the

smaller the copper wire that was necessary for transmitting power. [1]

The general outlines of the controversy that ensued, the ac-dc controversy sometimes called the "battle of the systems," are well known. In November 1886 Westinghouse put the first commercial ac plant into operation in Buffalo. By late 1887 alternating current systems, due to their ability to transmit power at high voltages and thus keep copper costs low, had begun to make major inroads on the sales of the Edison direct current system. Prodded into action by its local companies, the Edison Electric Light Company responded by issuing a pamphlet in early 1888 titled *A Warning* and bound in red. This work attacked alternating current on a number of grounds, pointing out that direct current retained a number of advantages such as more efficient generators, the ability to operate electric motors, a proven record of reliability, lower cost in densely populated areas, and superior safety. For several months in early 1888 proponents of the two competing electrical systems faced off in debates over the advantages and disadvantages of their systems. [2]

In mid-1888, however, when it appeared that an ac motor might be in the wings, the proponents of direct current increasingly began to focus primarily on a single issue: the lethality of alternating current. Harold P. Brown, a self-trained electrical engineer, initiated the shift in the focus of the debate. In June 1888 he published an open letter in the *New York Post* characterizing alternating current as "damnable" and "dangerous." He contended that even at low voltages, alternating current was much more lethal than direct current and proposed, in the interest of public safety, the removal of all high voltage lines from the city. This step would have eliminated the transmission efficiency, and hence cost advantage, of alternating current. [3] Attacked by engineers associated with alternating current systems for having no data to support his charges that alternating current was more lethal than direct current, Brown appealed to Edison for support for a series of experiments to gather experimental evidence for his assertions. [4] In the fall of 1888 these experiments were to become important to New York State's implementation of a new law on capital punishment.

In the early 1880s, the State of New York had experienced several gruesome botched hangings in which prisoners were either slowly strangled to death because of insufficient slack in the hangman's rope or had their heads severed from their bodies because of too much slack. Aware of these travesties, David B. Hill, governor of New York, in 1886 appointed a commission to find a form of execution more humane than hanging. The committee was chaired by Elbridge T. Gerry, a prominent New York attorney and counsel for the Society for the Prevention of Cruelty to Animals. Included on the committee with Gerry were Dr. Alfred P. Southwick, a dentist from Buffalo, and Matthew Hale, an attorney from Albany. In 1886 and 1887 the committee made a very thorough study of the history of capital punishment with emphasis on methods historically used for inflicting the death penalty. Of the thirty-four methods

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discovered, only four were deemed worthy of serious consideration—the guillotine, the garrote, the firing squad, and the gallows. All of these, however, were considered objectionable either because they were not certain, because they mutilated the body, because they were “cruel,” or because of political factors (e.g., one reason for rejecting the guillotine was its association with revolution). The shortcomings of all previous methods of capital punishment led the commission to search for new options. Two were suggested—lethal injection and death by electricity. The first was rejected because lethal injections would have to be performed by competent physicians who, it was thought, would find it repugnant to violate their oath to preserve lives. This left electrocution. [5]

One member of the committee was already a proponent of this option. In 1881 Alfred Southwick had observed the quick, seemingly painless death of a Buffalo man who had contacted the brushes of an electric generator. Reasoning that electricity would be quicker, surer, and less painful than hanging, Southwick had carried out some crude experiments on electrocuting animals and had begun to advocate consideration of legal electrocution even before his appointment to the commission. Seeking support that would influence at least one of the other members of the committee towards his views, Southwick wrote Edison on November 8, 1887, asking his opinion of legal electrocution and information on “the necessary strength of current to produce death with certainty in all cases and under all circumstances.” Southwick also asked Edison to recommend specific equipment for electrocution and to estimate probable expense. Southwick approached Edison because of Edison’s “reputation as a scientist and especially as an electrician.” [6] Edison initially reacted negatively to this query, explaining that he opposed capital punishment.

Determined to use Edison’s reputation to support his position, Southwick persisted. A second letter from Southwick to Edison, dated December 5, 1887, argued that capital punishment had been known in all places and at all times and that the only issue in question was the mode. “Science and civilization,” he wrote, “demand some more humane method than the rope. The rope is a relic of barbarism and should be relegated to the past.” Edison’s “reputation as an electrician,” Southwick noted, would “help much with the legislature” in the crusade for a more humane form of punishment. [7]

Edison eventually acceded to both requests: to Brown’s request for laboratory assistance to demonstrate the greater lethality of alternating current in June 1888 and to Southwick’s request for support in his drive to replace hanging with legal electrocution in December 1887.

Before looking at the extent of Edison’s involvement in the parallel, but soon to be linked, debates over the lethality of alternating current and electrocution as a mode of capital punishment, let us first consider why Edison chose to enter the fray.

It would be easy to assume, as some writers have done, that Edison simply saw these issues as ways to undermine alternating current on safety grounds. [8] If alternating current were demonstrated to be more lethal than direct current, and if it were used in electrocuting criminals, consumers might fear its use in their homes and opt for safer direct current. Certainly commercial considerations contributed something to Edison’s decision to become involved with Brown’s and Southwick’s causes. But to assume that they played the primary role would be to oversimplify matters. Edison’s antipathy towards alternating current and its chief advocate, George Westinghouse, and Edison’s desire to identify ac with danger and death were based on more than simply commercial considerations.

Edison sincerely believed in the dangers of alternating current and opposed its use even before Westinghouse’s system had become

a serious threat to Edison direct current systems. For example, in an 1886 memo written to Edward Johnson, president of the Edison Electric Light Company, Edison argued that his direct current system was “infinitely better” than that of any competitor, that “nothing that anyone else could possibly do could touch us,” and that none of Westinghouse’s plans worried him “in the least.” Edison pointed to the dangers of the ac system. Noting the 2,000-volt transmission lines Westinghouse planned to use, he commented: “The first man that touches a wire in a wet place is a dead man . . . Just as certain as death, Westinghouse will kill a customer within six months after he puts in a system of any size.” Edison added:

My impression is that except in very difficult places we shouldn’t use over 1200 volts . . . We must look out for crosses and such things for if we ever kill a customer it would be a big blow to the business.

Edison already believed that alternating current was more lethal than direct current, for he noted:

1200 volts continuous current will never do greater harm than blister the flesh, and I’ll bet any amount that 1000 volts alternate current will kill certain. [9]

Thus, a sincere belief in the greater lethality of high-voltage alternating current and the threat that Edison believed this posed to the expansion of the industry to which he had given birth were the foundations for Edison’s bitter antagonism toward alternating current and Westinghouse.

These existing feelings were undoubtedly exacerbated by the inroads that the Westinghouse system made on dc systems in subsequent years and probably even more by the free use that Westinghouse and other commercial electric lighting companies made of patents that Edison believed were his.

Westinghouse, Edison believed, was particularly guilty of this, and in December 1886 Edison’s company filed almost a dozen suits against Westinghouse for patent infringements. [10]

In any case, Edison’s feelings toward Westinghouse by 1888 or 1889 had become very bitter. The extent of this bitterness can be judged by several measures besides his decisions to support Brown and Southwick. For example, in early 1889 a mutual friend, E. D. Adams, tried to bring Edison and Westinghouse together by inviting Edison to visit Westinghouse’s plant at Pittsburgh. Edison replied:

Am very well aware of his [Westinghouse’s] resources and plant, and his methods of doing business are lately such that the man has gone crazy over sudden accession of wealth or something unknown to me and is flying a kite that will land him in the mud sooner or later. [11]

Edison’s resentment of Westinghouse was so great that in 1889 he contemplated attacking the source of the Westinghouse fortune—the railroad air brake. He apparently reasoned that if Westinghouse could trespass on his field, he would trespass on Westinghouse’s. In October 1889 he requested his agents in Pittsburgh to send him all of the available literature on railroad air brakes, including copies of the type of agreement the Westinghouse Company signed with railroad companies. [12] Another indication of the depth of Edison’s resentment of Westinghouse was a plan briefly broached in 1889 to market an Edison ac system with no intention of ever really selling it. As contemplated by Edison, the Edison alternating current system would be in every possible respect identical to Westinghouse’s. The Edison Company would then criticize its own ac system as inferior to its dc system, and because the Edison system was identical to the Westinghouse system, the critique of this system would carry with it a condemnation of the Westinghouse system.

Moreover, because of the identity of the two systems, Westinghouse could not claim that the Edison Company was criticizing alternating current only for commercial advantage. [13]

Edison's willingness to have the company with which he was associated market a system with no intention of making a profit from it, the serious consideration he gave to invading Westinghouse's domain with an Edison air brake, and his remarks to Adams all suggest that Edison's feelings of ill will towards Westinghouse ran particularly deep. In such an atmosphere of personal and commercial bitterness, it is not at all surprising that Edison, despite having little knowledge of the effects of electricity on the human body, entered debates and sought to influence decisions which ideally should have required such knowledge.

EDISON AND THE DECISION FOR LEGAL ELECTROCUTION

Edison's initial foray into issues involving the lethal effects of electricity on the human body came in December 1887. After turning down Southwick's first request for information on the idea of using electric currents for execution on the grounds that he opposed capital punishment, Edison relented to Southwick's argument that capital punishment was not the issue—only the most humane form.

On December 9, 1887, Edison wrote Southwick, giving him the support he desired. Edison assured Southwick that electricity was a certain and sure method of delivering death and added:

The best appliance in this connection is, to my mind, the one which will perform its work in the shortest space of time, and inflict the least amount of suffering upon its victim. This, I believe, can be accomplished by the use of electricity, and the most suitable apparatus for the purpose is that class of dynamo-electric machinery which employs intermittent currents. The most effective of these are known as "alternating machines," manufactured principally in this country by Geo. Westinghouse . . . The passage of the current from these machines through the human body even by the slightest contacts, produces instantaneous death. [14]

Edison's approval of electrocution as a sure and reliable method for extinguishing life was crucial to the recommendation that ultimately came from the governor's committee on capital punishment. Southwick was already convinced of the viability of electrocution. Only one more person on the three man committee needed to be convinced to carry the issue, and Edison's support and reputation swung the chairman of the committee, Elbridge Gerry, over. The influence of Edison's letter on Gerry came out in hearings conducted some years later on the constitutionality of electrocution as a mode of capital punishment:

- Q. You think he [Edison] knows more about it [electricity] than anyone in the United States?
- Gerry. Yes . . .
- Q. And you think Edison somewhat of an oracle do you not?
- Gerry. Yes.
- Q. And you finally decided that where Edison spoke there was no room for doubt and you recommended the bill?
- Gerry. I certainly had no doubt after hearing his statement of it. [15]

When the commission on modes of capital punishment delivered its report to the New York legislature in January 1888 it recommended the use of legal electrocution instead of hanging for capital cases. In justifying their decision the commission noted that they had made careful inquiry "of experts in electricity." Edison was

among those quoted in support of the general recommendation, although his specific recommendation of Westinghouse-manufactured machines was deleted from the quotation. [16] The bill passed the legislature with little opposition and was signed by Governor Hill on June 4, 1888. The new law was to go into effect on January 1, 1889.

EDISON AND THE DECISION TO USE ALTERNATING CURRENT

The bill which the New York legislature passed authorizing the use of electrocution for capital cases did not specify the exact form in which electricity would be applied—what type of current, the voltage, duration of contact, the form of the electrodes. [17] Edison, interviewed after Hill signed the new law, was asked his opinion on what should be used. Tongue in cheek, he suggested hiring condemned criminals out as linemen to certain New York electric lighting companies, meaning those using alternating current. In a more serious vein, however, he suggested that high voltage alternating current be used and that it be applied through the arms. This was, incidentally, the most usual path of an accidental electrical shock and may have been suggested to link accidental deaths from alternating current to electrocution. Edison suggested as a possible mechanism a set of handcuffs, each cuff having a connection for an electrode, with an insulating link separating them. [18]

The problem of how to apply electricity for best results was ultimately turned over to the state's Medico-Legal Society. That society appointed a committee to study the problem and make recommendations. This committee's interest in prior work on the lethality of electric currents soon brought them into contact with Harold P. Brown, who had publicly argued the greater lethality of alternating current in an early June 1888 letter to the *New York Post*.

Brown, as previously noted, had placed himself in a vulnerable position by claiming that alternating current was more lethal than direct current without adequate experimental evidence. He had been called to task for this assertion. Determined to refute his detractors, Brown visited Edison's laboratory in West Orange, New Jersey to seek permission to use certain equipment which he could not easily obtain otherwise. Apparently persuaded of the value of Brown's work, Edison decided to provide him with encouragement as he had Southwick a few months earlier. Edison offered Brown the use of his laboratory for experiments on the comparative lethality of alternating and direct current and, in addition, assigned his chief electrician, Arthur Kennelly, to assist him. [19]

In Arthur Kennelly, Edison provided Brown with very skilled assistance. Kennelly, a telegraph engineer with a decade of self-training and experience in Britain, had immigrated to America in 1887 and secured a position as Edison's principal electrical assistant. At the time he was assigned to assisting Brown, he was just at the beginning of a long and illustrious career. Kennelly later authored or co-authored 28 books and 350 papers, made major contributions to circuit theory, predicted the existence of the ionosphere, and played a major role in standardizing international electrical units. [20]

In mid-July 1888, Kennelly and Brown began a series of experiments on the lethality of alternating and direct current in Edison's West Orange laboratories using dogs purchased locally. These experiments seemed to confirm Brown's initial assertion: alternating current was more lethal than direct current at roughly identical voltage and power levels. This work was followed up by a public demonstration and further experiments at the Columbia School of Mines in late July and early August 1888. [21] The equipment used for the Columbia experiments was provided by Edison. Kennelly, while absent from the public demonstration of the lethality of alternating current, helped Brown set up the apparatus

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and take instrument readings. [22] Moreover, correspondence from late 1888 indicates that the Edison laboratories continued aiding Brown by checking, modifying, and lending him instruments. [23] In addition, Kennelly carried out several more experiments on animals on his own and defended the conclusions reached in the earlier experiments. [24] Thus, through the loan of laboratory facilities, electrical equipment, and manpower, Edison contributed heavily to developing experimental evidence of the greater lethality of alternating current, even though he took little part in the experiments themselves and observed only "one or two" of them. [25]

Brown had been assisted in the Columbia experiments by Dr. Frederick Peterson, a member of New York's Medico-Legal Society, the group charged with responsibility for determining how best to carry out an electrocution. Peterson had apparently become aware of the area of mutual interest between the Medico-Legal Society and Brown and sought to link these interests. In the fall of 1888 Peterson was named chair of the committee appointed by the Medico-Legal Society to make specific recommendations on how to carry out electrocution. [26] Thus, the previously separate ac-dc and electrocution controversies became firmly intertwined.

Apparently at Peterson's request, Brown quickly furnished the Medico-Legal Society with details of his earlier experiments, pressing on the committee from the outset his view that alternating current was more lethal than direct current. Brown's work and his collaboration with Peterson seem to have had the desired effect. In their initial report to the Medico-Legal Society on November 15, 1888, the committee suggested that either direct or alternating current could be used, "but preferably the latter." A final decision was postponed until the December meeting. [27] Determined to get a more definite statement from the Society, Brown had F. S. Hastings, secretary and treasurer of the Edison Electric Light Company, approach Edison for the further use of his facilities to demonstrate experimentally to the committee the lethality of alternating current on large animals. Experiments of this type were felt necessary because some critics of the earlier Brown-Kennelly experiments had argued that results drawn from the application of electricity to small animals could not be applied to humans due to the latter's vastly greater body weight. Hastings considered the request "a matter of very great importance." [28] Consent was granted and on the evening of December 5, 1888, two calves and a horse, all in excellent health, were electrocuted with alternating current in Edison's laboratory. [29] Fig. 1 shows the circuit used when electrocuting a calf.

Present at the December 5 demonstration in Edison's West Orange laboratories were Gerry (the author of the electrocution bill), the members of the committee of the Medico-Legal Society, Brown, Kennelly, and Edison himself. The following day Brown wrote to Kennelly that the results of the experiments had been very satisfactory. He added that this was "especially so since Mr. Edison's talk with Mr. Gerry and the members of the committees carried great weight. Beyond a doubt," he concluded, "alternating current will be adopted for execution purposes." [30] Less than a week later the Medico-Legal Society voted unanimously to recommend the use of alternating current alone for legal electrocutions. [31] The weight of Edison's reputation had played a pivotal role in inclining the governor's committee on capital punishment towards electrocution in 1886-1887. That reputation, and the data generated by experiments carried out using equipment, instruments, and technical assistance provided by Edison, clearly contributed heavily in late 1888 to tipping the scales in favor of using alternating current for legal electrocution.

Edison's role in using legal electrocution to discredit alternating current and Westinghouse did not end in 1888. Edison, through his association with Harold Brown, was also to play an important

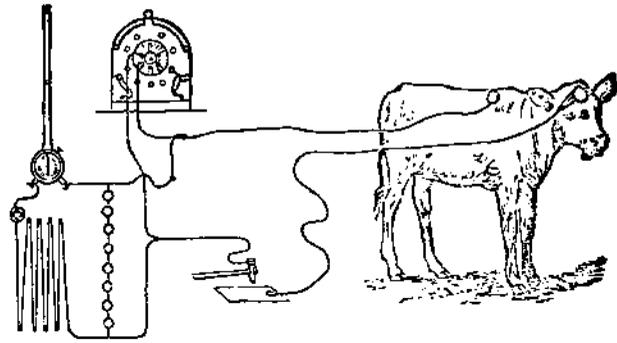


Fig. 1. Electrical circuit used in 1888 by H. P. Brown in experiments to demonstrate the lethality of alternating current by electrocuting a calf. From Brown, *Comparative Danger*. See reference [19].

role in supplying the New York prisons with the alternating current equipment necessary for implementing the electrocution law.

On March 1, 1889, with the technical details for electrocution worked out by the Medico-Legal Society, Governor Hill of New York signed a bill authorizing the superintendent of prisons, Austin Lathrop, to secure the necessary apparatus for electrocution. Lathrop contacted Brown, probably because of his visibility in the controversy over the lethality of alternating current, and asked him if he would secure the necessary apparatus for the three state prisons and design a mode of applying the current to the condemned. Brown turned down the request to design the electric chair, but he did accept the offer to secure the apparatus. [32]

The task of designing the first electric chair fell to two physicians, Dr. Carlos MacDonald and Dr. A. D. Rockwell. Rockwell had extensive prior experience in electrotherapeutics. Lathrop, probably at the request of MacDonald and Rockwell, asked that additional experiments be carried out with alternating current before an apparatus was actually designed, probably to work out details of electrode placement. Once again, Edison contributed. Brown, working with MacDonald and Rockwell, first turned to Hastings of the Edison Electric Light Company for help in securing equipment for these experiments. Hastings was anxious to use Westinghouse equipment for electrocutions to enhance the image that alternating current was dangerous, but found himself unable to "buy, borrow, or steal a Westinghouse dynamo." He thus asked Edison for permission to use his facilities for the requested tests of electrode placement. [33] These tests were conducted in mid-March of 1889 by Brown, with the assistance of MacDonald, Rockwell, and Edward Tatum of the University of Pennsylvania. [34]

Brown secured the contract to provide the generating equipment to the New York prisons. This contract provided for payment only after the equipment had been installed and was in good working order. [35] Brown was not wealthy enough to purchase the Westinghouse alternators and auxiliary equipment, and Westinghouse, who was attempting to prevent the use of his equipment for electrocution, was not willing to sell machines to Brown at all, much less on credit. This made subterfuge necessary. Apparently through the intervention of the Thomson-Houston Company and the Edison General Electric Company, or both, since negotiations were already under way for a merger of the companies, three used Westinghouse generators were located and an agreement concluded for their sale. The necessary funds were then provided Brown. [36]

Edison's role in the transactions that provided Westinghouse generators to the New York prisons is not clear. Some correspondence seems to indicate that Edison was consulted on how to help Brown secure Westinghouse machines for the prison. The

New York Sun, for example, published a letter from Brown to Edison in which Brown discussed several of his plans for discrediting Westinghouse and alternating current, including his intention of using Westinghouse equipment for the first legal electrocution. Brown estimated that he could carry off these projects for \$5,000, but informed Edison that he was having some trouble convincing the officials of the Edison Electric Light Company to provide these funds:

In view of the approaching consolidation [with Thomson-Houston], the people of 16 Broad Street [Edison] do not feel like undertaking the matter unless you approve of it. A word from you will carry it through, without it the chance will be lost. Is it not worthwhile to say the word? [37]

This letter was dated March 27, 1889. By early April the "word" had apparently been given. On May 7, 1889, Brown closed the deal with the New York prison system, [38] and on May 13 wrote Edison observing: "Thanks to your note to Mr. Johnson [Edward H. Johnson, the president of the Edison Electric Light Company] I have been able to arrange the matter satisfactorily." [39]

EDISON AND THE CONSTITUTIONALITY OF ELECTROCUTION

New York's electrocution law was to go into effect on January 1, 1889. The first criminal subject to the new law was William Kemmler. Kemmler in 1889 was a 28 year old huckster living in Buffalo, where he made his livelihood as a fruit peddler. Under the name of John Hort, Kemmler was living with Matilda "Tillie" Ziegler and her five-year old daughter, Ella. Kemmler's life in Buffalo was apparently spent in an alcoholic daze, as he was drunk from three to five times a week. Tillie was often in the same condition. A contemporary newspaper account described the pair by saying that both were "dissolute, ignorant and ugly." [40]

On the morning of Friday, March 29, 1889, Kemmler had a prolonged argument with Tillie over her relationship with John "Yellow" Debella, a roomer in the Hort household and an employee of Kemmler's. In a fit of drunken rage Kemmler beat Tillie to death with the blunt end of a hatchet and then retired to a nearby saloon, where police, alerted by the neighbors, found him. Kemmler was indicted for first degree murder the next day. His trial began in early May and lasted four days. On May 10, 1889, Kemmler was found guilty in spite of his defense based on "alcoholic insanity," and on May 14 the judge passed sentence with the words required by New York's new electrocution law:

The sentence of the Court is that, within the week commencing on Monday the 24th day of June, one thousand eight hundred and eighty-nine, and within the walls of Auburn State Prison . . . the defendant suffer the punishment of death, to be inflicted by the application of electricity as provided by the Code of Criminal Procedure of the State of New York. [41]

Kemmler's attorney appealed the sentence, basing the appeal on the argument that electrocution was a cruel and unusual punishment, and hence prohibited by the New York Constitution. Justice Charles C. Dwight of the state supreme court ordered a stay of execution until the constitutional question was resolved. Hearings began in New York on July 8, 1889. The referee at the hearings was attorney Tracy C. Becker of Buffalo. William Poste, Deputy Attorney General, represented the State of New York. Kemmler's original attorney assisted in the appeal, but the defense was led by Bourke Cockran, one of the country's most prominent legal orators. Why Cockran became interested in the case is not certain. Since it was obvious that Kemmler could never have afforded

Cockran's fees, the general feeling was that Cockran had been retained by George Westinghouse or one of his associates in a last-ditch attempt to prevent the use of alternating current in legal electrocution. [42]

Edison's role in the early stages of the hearings was minimal. The spotlight was on Brown, who was clearly a key witness for the state. But in preparation for his questioning Edison had Kennelly write Brown advising him that the only possible objection that could be raised to legal electrocution was mutilation of the body, which could be avoided by the use of liquid electrodes. [43]

The tack taken by Kemmler's attorney, Cockran, in the hearings was to demonstrate that electricity was not a painless or certain means of producing death. He produced witnesses who had been struck by lightning or received high-voltage electrical shocks and survived or people who knew of such occurrences. Other experts were called in to argue that the standard means of measuring resistance, the Wheatstone bridge, was inapplicable to the human body and that it was, therefore, impossible to determine the magnitude of the current that could pass through the human body. [44]

After several days, Cockran had so managed to confuse the issue that the state, apparently at Brown's suggestion, decided to ask Edison to appear at the hearings. Brown wrote to Samuel Insull, Edison's private secretary, requesting Edison's appearance. Brown noted that the Westinghouse people had raised technical objections which "Edison could dispose of by a word." [45] Edison not only agreed, but he invited the principals in the hearing to his laboratories for a practical demonstration of the use of the Wheatstone bridge and the lethality of alternating currents. [46]

Edison was called to the stand on July 23, 1889. He testified that he was convinced that death by electrocution would be instantaneous and that alternating current was the best way to administer it. One thousand volts alternating current, he asserted, would "in every case" produce instant, painless death. He also outlined a means of electrocution using liquid electrodes which he felt could apply electric current to the body without burning the skin. [47]

Cockran seems to have recognized that Edison's testimony, because of Edison's reputation, was crucial to the state's attempt to uphold its electrocution law. He thus attempted to undermine Edison's credibility in the area of bioelectricity. His questioning along these lines clearly disclosed the extent of Edison's ignorance of the effects of electrical currents on living organisms. Cockran, for example, asked Edison about the mechanical effects which would be produced by the application of a powerful alternating current to human muscles. Edison confessed that he did not know very much "about that part of it." [48] Cockran later asked Edison if he understood anything about anatomy. Edison replied: "No, sir." Cockran continued: "You do not claim to understand anything about the structure of the human body?" Edison answered: "No, sir; only generally." Cockran then asked Edison if he knew whether blood or muscular tissue was the better conductor of electricity. Edison replied that he thought blood was a better conductor, but that he would have to experiment to be absolutely certain. [49] "Do you know anything about the conductivity of the brain?" Cockran continued. Edison responded: "No, sir." [50]

At another point in the hearings Cockran probed the basis of Edison's belief that electrocution was a certain and painless way of producing death. Edison replied that he had gotten the idea "from reading accounts of the death of a great many people" and seeing experiments in the laboratory. When asked whether the experiments made by Brown and Kennelly were among those he had seen, Edison admitted that he had observed "only one or two"

of them. [51] The Edison laboratory notebooks indicate no other extensive set of experiments in the area, so it is clear on what a weak base Edison stood. When asked whether he had personally ever made experiments on the resistance of the human body to electrical currents, Edison testified that measurements had been made in his presence on a large number of employees and assistants. [52] But under further questioning from Cockran he revealed that these experiments had been carried out only two days earlier, specifically to prepare Edison for testimony and had not been repeated on the same individual to verify repeatability of results. [53]

In brief, Edison's testimony at the hearings indicated that he had no extensive experience in or special knowledge of the application of electricity to living organisms. He had carried out no extended set of experiments on living subjects, had observed only "one or two" of the Brown-Kennelly experiments, and had seriously begun the study of the resistance of the human body to electric currents only two days before he was called to the stand. He knew little of human anatomy and confessed ignorance in key areas such as the electrical conductivity of the brain, muscle tissue, and blood.

Exactly what effect Edison's testimony had on the referee and on the judge who reviewed the testimony in the Kemmler appeal cannot be determined. In view of the confusing and conflicting testimony presented by the array of electrical experts and physicians, Edison's reputation probably overrode Cockran's exposure of his ignorance of the effects of electricity on living organisms. Certainly some newspapers regarded his testimony as critical. The *Albany Journal*, for example, noted: "The Kemmler case at last has an expert that knows something concerning electricity. Mr. Edison is probably the best informed man in America, if not in the world, regarding electrical currents and their destructive powers." [54] Another paper declared: "If Edison is any authority upon the subject of electricity and it is difficult to think of a better, it would seem that there will be no doubt as to the efficacy of electricity as a death-dealing agency." [55] And the *New York Times*, commenting over a year later, noted: "It was largely due probably to such testimony from such experts [referring to Edison's testimony] that the law was upheld finally in the courts." [56] Kemmler's appeal was denied on October 9, 1889. Subsequent appeals also failed, and Kemmler was electrocuted on August 6, 1890.

THE EDISON CHAIR

Physicians with some acquaintance with the medical effects of electricity, notably A. D. Rockwell, designed the electric chair which was to be used in the Kemmler execution. Instead of using the hand-to-hand liquid electrodes recommended by Edison to Brown and by Edison in the appeal hearings, they adopted head-and-spine metallic electrodes, both covered with sponges and enclosed in rubber cups.

The first legal execution, that of Kemmler, was plagued with problems. The first passage of current lasted seventeen seconds. As physicians were examining Kemmler after the first jolt, they suddenly observed spasmodic movements of the chest. Chaos ensued. On the chance that Kemmler had not been killed by the initial application of the current, it was hurriedly, and after some difficulties, applied again. This time the contact lasted for 72 seconds, and was turned off only after a burning smell (presumed to be Kemmler's flesh) was noted by observers. [57]

The confusion surrounding Kemmler's execution, the movement of his chest after the first application of the current, and the burning after the second application caused a number of newspapers to condemn the whole process. Westinghouse, not unpredictably, declared: "I do not care to talk about it. It has been a brutal affair. They could have done better with an axe." [58]

Edison remained convinced, however, that electrocution was a valid means of capital punishment. But he took the opportunity to promote his suggested mode of electrocution and to poke fun, as was his wont, at theoreticians. He commented on the problems with the Kemmler execution:

The fault rests upon the doctors. They acted upon theory, and knowing the base of the skull to be the nerve center of the human system, they determined to reach it as directly as possible. Theoretically they were right, but practically they were wrong, as experience has demonstrated. [59]

Edison argued that the contact should have been through the hands since electricity traveled much more freely through fluids than through bone. Bone, he declared, was "one of the poorest conductors." By making contact at the skull "the doctors invited a degree of failure." Contact "could not have been made in a less desirable place." He again recommended the use of liquid electrodes with hand-to-hand contact, the path of the current being directed across the chest. [60]

The reaction of prison authorities to the criticism following the Kemmler electrocution was to exclude representatives of the press from subsequent executions. Undeterred, they executed four more men on July 7, 1891, and another on December 7, 1891. In these electrocutions the head-spine electrode system used at the Kemmler execution was abandoned and replaced by a system in which one electrode covered the forehead and temples, while a second larger one was applied to one calf. Because the press was excluded from these five executions, the exact details are unknown. The official autopsies seem to indicate that things went off much better than in the Kemmler case. The only matter detracting from the executions seems to have been some burning or bruising in the area around the head electrode, apparently due to the high resistance contact formed between electrode and skin in that area or, perhaps, due to the high resistance of the skull. [61]



Fig. 2. Executioner E. F. Davis at the controls during the four electrocutions at Sing Sing Prison on July 7, 1891. From *Police Gazette*, July 25, 1891.

Edison was not closely connected with any of these executions, but was apparently kept informed. A letter in the Edison archives dated August 5, 1891, apparently referring to Joseph Wood, the first of many black victims of the electric chair, suggests that the blistering which occurred on the victim's face was due to the high resistance of the "darkey's skull." [62] Fig. 2 shows E. F. Davis, the executioner at all New York electrocutions from Kemmler's in 1890 to 1914, operating the controls at Wood's execution.

Continued criticism from the press over their exclusion from post-Kemmler executions and doubts prompted by the exclusion about the efficacy of the new method of capital punishment led prison authorities to open the seventh legal electrocution to observers from the press.

Not only did prison officials elect to open executions to officials from the press for the seventh electrocution on February 8, 1892, but the chair selected for electrocution, unlike the previous six, was equipped to deliver current to the victim in the manner which Edison had been recommending since 1889. Current was to be directed through the chest by immersing the victim's hands in a liquid solution to which electrodes were attached. Edison believed that the body's resistance to current flow was significantly less across the chest than from head to spine or head to calf, and he believed that liquid electrodes would lower the resistance between electrode and skin, preventing the scorching or blistering of body tissues.

Exactly why prison officials decided to use Edison's system at this juncture is unclear. Undoubtedly the desire to make a good impression on the press was one factor. Elimination of the scorching and discoloration of the facial areas caused by the electrode contacts in the early electrocutions would certainly contribute to a good impression, and Edison considered this to be one of the primary advantages of his system. Even more important, once again, was probably the weight of Edison's prestige and reputation. He had condemned the head-spine and head-calf systems designed by men of inferior reputation, so there was likely a steady pressure on prison officials and their consultants to give Edison's system a try, especially in view of the scorching and blistering problems they faced. *Electrical World*, for example, commented in an editorial after the Kemmler execution that the electrode contacts used seemed to be as ineffectual as Edison had suggested they would be and concluded that Edison's critique of the whole subject seemed to them "a remarkably fair one." [63] And a Connecticut paper suggested that prison officials should switch to Edison's system, commenting:

Mr. Edison probably knows as much about this subject as any man, and it may obviate the sufferings of the victim and a repetition of the scenes of horror in the Kemmler case. [64]

It was apparently due to this pressure that experiments were carried out in November 1890 at Sing Sing using horses. The press noted at this time that the electrodes to be used on the next victim for the chair had not yet been determined, but that Edison's suggestion was being considered. [65]

The Edison electric chair was used in the 1892 execution of Charles E. MacElvaine, who had murdered a storekeeper during a robbery on August 21, 1889. MacElvaine was seated in the chair with his hands strapped into small buckets of salt water as shown in Fig. 3. The normal head and calf electrodes were also fastened to MacElvaine as a backup system should Edison's system fail. Kennelly, from Edison's lab, was present as a witness. A charge of 1,600 volts was first applied through Edison's hand electrodes for fifty seconds as the current rose from 2 to 3.1 amperes. When



Fig. 3. The Edison electric chair with its hand electrode configuration used for the electrocution of Charles MacElvaine, February 8, 1892. From MacDonald, "Infliction of the Death Penalty." See reference [57].

the current was turned off MacElvaine was unconscious, but when physicians began to examine the body, he began to make wheezing, coughing, and gasping sounds. A second charge, this time of 1,500 volts, was quickly applied through the backup head-calf electrodes for 36 seconds. During this second application the current was 7 amperes and death was considered certain. [66]

Commentators generally judged after the MacElvaine execution that Edison's system had failed and the liquid, hand electrode system was never used again. Edison had expected hand-to-hand resistance to be lower than head-to-calf. It was not. Measurements of voltage and current taken during the execution indicated that hand-to-hand resistance was twice as high as with the normal electrode configuration. [67] The reason for the major error in judgment is not difficult to identify. Edison was simply not qualified to design apparatus in this field, as several physicians who had specialized in medical electricity emphasized or insinuated after the MacElvaine experiment. Because of Edison's immense reputation they were polite in their criticism. Professor L. H. Laudy of Columbia, for instance, declared:

Edison probably reasoned all right from his standpoint as an electrician, but all wrong from the standpoint of a physician. [68]

And Dr. Carlos MacDonald, referring to Edison's criticism of the early electrocutions, declared:

However logical this criticism may be from the standpoint of an electrician, it is not sustained by our knowledge of electrotherapeutics and of the physical properties of live bone. [69]

Following the execution of MacElvaine, W. J. Jenks, an engineer, was asked to comment on the technical aspects of the electrocution. Jenks argued that the Edison hand-to-hand electrode configuration provided a higher resistance path than the head-to-calf electrode configuration, accounting for its failure. But he suggested that if larger liquid electrodes had been used, resistance be-

tween electrodes would have been only 65 percent of the head-to-calf electrode system. [70] This proposed improved liquid, hand-to-hand electrode system was never tried.

Edison responded to the MacElvaine execution by denying that his system had been a failure. He argued that it had, after all, produced instant unconsciousness and probably death, even if not as readily as the head-to-calf system. He concluded that if the head method of application was found more satisfactory, there was no reason for changing to the hand contact. The former, he declared, was more scientific, the latter more practical. [71] Kennelly was more honest. He admitted that while the hand-to-hand method was the simple and practical method to perform electrocutions, the head method was "the true way for rapid and complete nerve destruction. I give that point to the doctors." [72] The doctors, indeed, had the point. All subsequent electrocutions used head-to-calf electrodes.

While the MacElvaine failure ended Edison's role in the history of legal electrocution, it did not put a serious dent in his stature as a folk hero. His admirers quickly forgot the error, even if they noticed it in the first place. [73]

CONCLUSIONS

Edison had an important, and sometimes decisive, role at four points in the early history of legal electrocution:

1. In late 1887, when the decision was made to substitute electricity for the hangman's rope.
2. In 1888, when the decision was made to use alternating current in the electric chair.
3. In 1889, when Kemmler's appeal was rejected.
4. In 1892, when the Edison hand-to-hand liquid electrode system was used for the seventh legal electrocution.

In brief, probably more than any other single man, Edison influenced the early evolution of electrocution as a mode of capital punishment. Yet, as Cockran's cross-examination of Edison at the Kemmler appeal hearing indicated, Edison possessed little knowledge of medical electricity.

In view of his lack of qualifications in the area, it may seem somewhat strange that Edison played such an important role in the early history of legal electrocution. The key to this paradox is Edison's reputation. By the late 1880s Edison was practically a folk hero. His past successes in telegraphy, telephony, and especially his development of a commercial incandescent lighting system had made him in the eyes of the lay public "the greatest electrician of the age," and the general assumption of this public was that Edison's acknowledged abilities in one area of electrical technology made him an expert in all areas. They failed to understand that Edison's successful work in developing multiplex telegraphs, variable-resistance telephones, high-resistance incandescent filaments, and three-wire power transmission networks did not guarantee that he was similarly knowledgeable in bioelectricity, or that he was qualified to detail the way electricity could be applied in a lethal manner to the human body.

Time and again during the early history of legal electrocution, Edison's reputation tipped the scales. Southwick in 1887 appealed to him because of his "reputation as an electrician" and assured him that his opinion would "carry great weight with the legislature." Edison's reputation convinced Gerry that electrocution was a workable method of capital punishment. Edison's reputation made more of an impression than did the revelations of his bioelectrical ignorance. And finally, the pressure of Edison's prestige seems to have been critical in persuading prison officials to try liquid, hand-to-hand electrodes in 1892. Reputation rather than expert knowledge was very clearly responsible for the remark-

able role Edison played in the early history of legal electrocution.

It should be emphasized that Edison was not alone in his ignorance of bioelectricity. The entire field was of relatively recent origin, and a number of the other "expert" witnesses called to the stand at the Kemmler appeal hearings exhibited similar ignorance. But the impression a witness leaves on the judge, jury, or press is often more important than professional competence, and lack of technical knowledge has never been a barrier to someone wishing to take the stand when technology impinges on the public domain. Certainly Edison recognized that he knew little of bioelectricity and knew of the near awe with which his opinions were regarded by an admiring public. Seemingly these considerations should have imposed on Edison the responsibility for withholding opinions in areas where his knowledge was weak and inadequate. But neither Edison, nor a number of other "experts," did so. In some cases it was probably strong personal feelings about capital punishment that prompted testimony despite lack of reliable knowledge. In Edison's case the decision to testify seems to have been due to the bitterness that he felt towards George Westinghouse and high-voltage alternating current, a bitterness generated by both commercial rivalry and the fear that unsafe electrical systems would hinder the diffusion of electric power generally.

POSTSCRIPT

One of the hopes of the advocates of legal electrocution in the late nineteenth century was that autopsies of electrocuted criminals would yield valuable information on the effects of electricity on the human body and that this information might prove useful in treating victims of electrical accidents. These hopes proved false. In legal electrocutions very high voltages with high current levels are used and the current flows from head to calf. Electrical accidents involving this very peculiar set of circumstances are extremely rare, so studies of the victims of legal electrocution lent little aid to the victims of common electrical accidents. Nor did these studies increase understanding of the nature of electrical action on the human body. Experiments on laboratory animals eventually led to the discovery of how electricity kills.

Today we know that the usual cause of death in electrical shock is cardiac arrest produced by currents passing through the heart. Very high currents, such as those used in legal electrocutions, can also produce death due to damage to the nervous system. Indeed, one of the advantages of the head-to-calf electrodes may lie in the fact that it kills two ways—by inducing cardiac arrest and simultaneously destroying the central nervous system. Unfortunately, some recent studies also suggest that electrocution is neither as instantaneous nor as painless as Edison, Brown, Southwick, and others believed in the late nineteenth century. But subsequent research has also indicated that Edison and his associates were, after all, right about one thing: alternating current is more lethal than direct current. It requires three times more direct current than 60 Hz alternating current to produce cardiac arrest. [74]

ACKNOWLEDGMENTS: The authors wish to express their gratitude to the College of Engineering of the University of Wisconsin for providing funds for travel involved in research for this paper. They also wish to acknowledge the assistance they received from the archivists at the Edison National Historic Site, West Orange, New Jersey, in particular, the help of Leah Burt.

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- [3] *New York Evening Post*, June 5, 1888. This letter is reprinted in *Electrical Engineering* 7: 360-61, 1888 and *Electrical World* 12: 40, 1888.
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- [6] A. P. Southwick to Edison, November 8, 1887, Edison Archives, Edison National Historic Site, West Orange, N.J.
- [7] A. P. Southwick to Edison, December 5, 1887, Edison Archives. We were unable to locate Edison's reply to Southwick's November 8 letter, but the substance of that reply can be determined from the December 5 Southwick letter.
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- [20] On Kennelly see Charles Susskind, "Arthur Edwin Kennelly," *Dictionary of Scientific Biography*, New York: Charles Scribner's Sons, 1973, 7: 288-89; Vannevar Bush, "Arthur Edwin Kennelly," *National Academy of Sciences, Biographical Memoirs* 22: 83-119, 1943; and Chester L. Dawes, "Arthur Edwin Kennelly," *Dictionary of American Biography*, New York: Charles Scribner's Sons, 1958, 22: 357-59.
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- [24] The experiments are cited in Brown, *Comparative Danger*, p. 19, and can be found in the Edison Laboratory Notebooks in the Edison Archives. For Kennelly's defense of the earlier experiments see Kennelly to the Editor, *The World*, August 20, 1888, and Kennelly to the Editor, *Electrical Review*, September 7, 1888, Edison Archives. Kennelly's interest in the physiological effects of electricity was long lived. In 1910 he published a paper on the physiological effects of high frequencies as generated by the Alexanderson high-frequency alternator, "The Physiological Tolerance of AC Strengths up to Frequencies of 100,000 Cycles per Second," *Electrical World* 56: 154-156, 1910. Our thanks to James Brittain for calling this reference to our attention.
- [25] "I only saw one or two." Thomas A. Edison testimony, *Electrocution Hearing*, 2: 637.
- [26] On the merging of Brown's interest in comparative lethality and the Medico-Legal Society's interests in implementing the electrocution legislation see Harold P. Brown testimony, *Electrocution Hearing*, 1: 24; Brown, *Comparative Danger*, p. 15.
- [27] *New York World*, November 15, 1888; "A Report on Execution by Electricity," *Electrical World*, 12: 275-76, 1888; "Execution by Electricity," *Telegraphic Journal and Electrical Review*, 23: 610, 1888.
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- [30] Brown to Kennelly, December 6, 1888, Edison Archives.
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- [32] Brown, "The New Instrument of Execution," *North American Review*, 149: 586-87, 1889. Brown was apparently brought into the deal by Carlos MacDonald of the state asylum for insane criminals. MacDonald appears to have suggested to Brown that he present a proposal for providing the apparatus for electrocution to the state, along with an estimate of costs, at a meeting of the superintendents of the state prisons and the wardens of Sing Sing, Dannemora, and Auburn that was convened for the purpose of deciding on the proper instruments for carrying out electrocutions (MacDonald to Brown, March 19, 1889, *Sun Letters* [see reference 36 below]). See also Charles F. Durston testimony, *Electrocution Hearing*, 2:1011-15.
- [33] Hastings to Edison, March 8, 1889, Edison Archives.
- [34] "Death Current Experiments by New York State Authorities," *Electrical World*, 13: 176, 1889; *New York Star*, March 18, 1889.
- [35] Brown to Edison, March 27, 1889, Edison Archives; Charles F. Durston testimony, *Electrocution Hearing*, 2: 1011-15.
- [36] The details of Brown's dealings are outlined in the *New York Sun*, August 25, 1889. The *Sun* printed forty-five letters focusing on Brown's involvement in the legal electrocution controversy and his relationship with the Edison Electric Light Company and Thomson-Houston to discredit Westinghouse under the guise of an disinterested, objective electrical expert. The *Sun* letters were apparently stolen from Brown's desk, for Brown reported the theft of letters a few days later (*New York Times*, September 5, 1889) and charged that the letters printed in the *Sun* were edited to leave a negative impression and in some cases had even been altered. The *Sun* letters, however, seem to be generally authentic, for the ones whose duplicates can be found in the Edison Archives are essentially

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- [39] Brown to Edison, May 13, 1889, Edison Archives.
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- [41] The Kemmler crime and trial are covered by the *Buffalo Evening News*, March 30, April 1, May 7, May 8, May 9, May 10, and May 14, 1889.
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- [43] Kennelly to Brown, June 29, 1889, Edison Archives.
- [44] See *Electrocution Hearing*, v. 1. Cockran attempted to make Brown look foolish. There is a defense of Brown's testimony by Charles T. Heinrich, "Electrocution," *Scientific American Supplement*, no. 710, August 10, 1889, pp. 11341-42. Heinrich noted that witnesses ("experts") hired by the defense were attempting to confuse power and voltage in their testimony.
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- [52] *Ibid.*, pp. 624-25. For additional information about these experiments see *Electrocution Hearing*, 2: xxvi-xxvii (People's Exhibit B); the Edison Laboratory Notebooks for July 19, 1889; and A. E. Kennelly, "The Law of Probability of Error as Applied to the Observed Electrical Resistance of the Human Body," *Electrical World*, 14: 73-74, 1889.
- [53] Thomas A. Edison testimony, *Electrocution Hearing*, 2: 637-38; Arthur E. Kennelly testimony, *ibid.*, p. 714.
- [54] *Albany Journal*, July 24, 1889.
- [55] *Wilkes-Barre News Dealer*, July 25, 1889.
- [56] *New York Times*, August 7, 1890.
- [57] There are a number of reports on the Kemmler execution. See for example the *New York Times*, August 7, 1890; Carlos F. MacDonald, "The Infliction of the Death Penalty by Means of Electricity: Being a Report of Seven Cases," *New York Medical Journal*, 55: 505-9, 1892; and "The Execution of Kemmler by Electricity," *Electrical World*, 16: 99-100, 1890.
- [58] *New York Times*, August 7, 1890.
- [59] "Mr. Edison on the Kemmler Execution," *Electrical World* 16: 105, 1890.
- [60] *Ibid.*
- [61] MacDonald, "Infliction of the Death Penalty," pp. 508-09, 535-42.
- [62] Undecipherable name (perhaps Fred or Ned Cablins or Collins or Cablin) to Edison, August 5, 1891, Edison Archives.
- [63] *Electrical World*, 16: 97, 1890. The editorial appeared in the August 16, 1890 issue.
- [64] *Ansonia Sentinel* (Connecticut), November 3, 1890.
- [65] *New York Star*, November 28, 1890.
- [66] *New York Times*, February 9, 1892; *New York Recorder*, February 9, 1892.
- [67] Arthur Kennelly, "Physiological Observations at the McIlvaine [sic] Electrocution," *Electrical Engineer*, 13: 157-8, 1892.
- [68] *New York Times*, February 9, 1892.
- [69] MacDonald, "Infliction of the Death Penalty," p. 507.
- [70] W. J. Jenks, "Electrical Execution," *New York Medical Journal*, 55: 542-44, 1892.
- [71] *Newark Call*, February 14, 1892.
- [72] Letter from Kennelly to W. J. Jenks, March 14, 1892, quoted in Jenks, "Electrical Execution," p. 543.
- [73] That memories were short where Edison's failures were involved is clear from the reaction of several eastern newspapers to a botched electrocution in 1893. Two different papers in reacting to the incident described Edison as an opponent of legal electrocution who had warned of possible failures in the electrical system (*Jersey City Journal*, August 2, 1893; *New York Recorder*, July 29 and August 3, 1893).
- [74] For recent studies of the effects of electricity on living organisms, see Theodore Bernstein, "Effects of Electricity and Lightning on Man and Animals," *Journal of Forensic Sciences*, 18: 3-11, 1973; G. G. Knickerbocker, "Fibrillating parameters of direct and alternating (20 Hz) currents separately and in combination—an experimental study," *IEEE Transactions on Communications*, COM-21: 1015-1017, 1973. For the argument that electrocution may not be as instantaneous and painless a form of death as once thought see Harold Hillman, "An Unnatural Way to Die," *New Scientist*, October 27, 1983, p. 278.

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