

Inventing-around Edison's incandescent lamp patent: evidence of patents' role in stimulating downstream development

Ron D. Katznelson[1] and John Howells[2]

ABSTRACT

We provide an anatomy of the influence of Edison's incandescent lamp patent U.S. 223,898 on downstream development and show how subsequent inventor activity adjusts to the improved certainty provided by court decisions as to the boundaries of a patent's claims. First, we show that court decisions upholding Edison's patent generated a surge of patent filings in the incandescent lamp classes at the U.S. Patent Office. Second, by inspection of the specifications of these later patents we are able to categorize certain design-around efforts by their evasion of specific elements of the claims of Edison's '898 patent. Third, by analysis of forward citation to these patents we show that regardless of these inventions' commercial viability in the incandescent lamp market, some became important prior art for new technological fields and some laid the groundwork for the later successful substitute for Edison's carbon filament. Fourthly, we show that the recent view that Edison's patent gave the patent holder General Electric (GE) a dominant position in the incandescent lamp market is incorrect: we show that besides commercially-successful invention around the claims of this patent, data for GE's market share, number of manufacturers in the field and lamp price erosion through the period of the Edison patent's enforcement reveal GE's market position to have been stable, even weakening through the period of patent enforcement. Lastly, we derive from our account criteria against which any allegation of development block should be assessed and illustrate their utility by refuting allegations that Edison's patent blocked downstream development.

Keywords: incandescent lamp, Edison, design-around, invention-around, downstream development, patent.

Table of Contents

[1] Dr. Ron D. Katznelson is the president of Bi-Level Technologies, Encinitas, California, USA. ron@bileveltech.com. No Company resources or funding were used for this work. Dr. Katznelson used his personal time and resources for this study.
[2] Dr. John Howells is an Associate Professor at the Department of Business Administration Aarhus School of Business, Aarhus University, Aarhus, Denmark. joh@asb.dk.

1 Introduction

On November 4, 1879 Thomas A. Edison filed a patent application entitled "Electric Lamp" with the U.S. Patent Office, which was granted as U.S. Pat. No. 223,898, on January 27, 1880 (hereinafter called "the '898 patent"). This patent was one of Edison's 424 patents on electric light and power generation[3] and its significance was not readily apparent for several years. This paper presents an original analysis of the inventive activity directed at designing-around Edison's '898 incandescent lamp patent. We show that the attempt to enforce the Edison patent *stimulated* much downstream development work of varied commercial and technological significance. The originality of this study lies in the data we collect that reveals surges of patenting activity in the incandescent lamp patent classes after key events in the legal trajectory of Edison's patent; after his filing suit against an infringer in 1886 and especially after 1892 when the appeal court affirmed the 1891 decision and upheld the validity of Edison's patent. We analyze the patents that constitute the surge of patents after the 1891 court decision and find that much of the surge can be understood as a stimulated effort to design around particular elements captured in Claim 2 of Edison's patent – the then hardest claim in Edison's patent to circumvent. Furthermore, our novel forward-citation method and reading of a selection of these patents reveals that while some design-around work did not yield commercially viable alternatives to Edison's lamp, new technologies of later commercial significance were introduced to the public record, such as the Tesla coil, hermetically sealed connectors, chemical vapor deposition process, tungsten lamp filaments and phosphorescent lighting that led to today's fluorescent lamps.

We complete our analysis of the role of this patent by compiling relevant indicators of the '898 patent's holder General Electric (GE)'s control of the incandescent lamp market. The data for the number of lamp producing competitors, for lamp prices and market share, reveal this patent to have been largely ineffectual in improving GE's commercial position in the incandescent lamp market or blocking others.

Our result contradicts a widespread characterization of the Edison '898 patent as a "broad scope" patent that blocked downstream technology development, a characterization that contradicts the generally accepted rationale for the existence of the patent system: to provide an incentive for innovation and investments in new technologies.[4] The view that patents block downstream development is now a staple in the patent literature on the basis of allegations that a series of individual patents, such as the Edison '898 patent, have actually blocked development (Howells and Katznelson 2012). Therefore the allegation that the '898 patent blocked downstream development deserves a detailed analysis in its own terms. In Section 6 of this paper we provide such an analysis for specific assertions of downstream development block made by Robert Merges and Richard Nelson (Merges and Nelson 1990; Merges and Nelson 1994). We structure this section in the manner of a formal proof: first we derive from general market and economic principles a standard of proof including several criteria for determining whether development block has taken place. We then systematically apply each of these criteria to all of Merges and Nelson's allegations that there was development block downstream of the '898 patent. We use the evidence we collected and documented in Section 4 to show that there is no basis in fact for assertions that the Edison patent blocked downstream development. We conclude that if, as Merges and Nelson state, the Edison case constitutes their "best example" (Merges and Nelson 1990, 908), it is clearly ill-advised to entertain their policy recommendation that "the granting and enforcing of broad pioneer patents is dangerous social policy" (Merges and Nelson 1994, 16).

This paper is organized as follows: Section 2 discusses the literature, case law, and reviews the empirical studies regarding design around. Section 3 introduces our new empirical methods for analyzing design-around outcomes and our empirical data. Section 4 describes the legal and commercial history of the Edison patent, compiling evidence on design-around activity, the competitive environment in the incandescent lamp industry, and price decline and market share records. We have used a variety of source material for this study, with emphasis on primary sources such as patent disclosures, legal court decisions, contemporaneous trade

[3] Electric Light and Power Patents, *The Thomas Edison Papers*, Rutgers University, http://edison.rutgers.edu/elecpats.htm.

[4] We acknowledge that some unaccountably neglected business and technology historians do not view the enforcement of Edison's patent as having had such an effect. See references to the books by Bernard Carlson and Harold Passer discussed in Section 6.

publications and documents from the Thomas Edison Papers collection.[5] We discuss our finding that improved certainty of Edison's claim boundaries after the court rulings spurred design-around investments in Section 5. In Section 6 we refute the assertions that the enforcement of Edison's patent stifled downstream development by marshaling the evidence assembled in Section 4. We conclude in Section 7 that the study of Edison's patent is the study of a patent system that works as intended "to promote the progress of the useful arts."

2 Design around patents – an essential element of competition and innovation

A patent is a barrier to direct commercial entry, but not a barrier to competition and innovation in the field to which the patent pertains. Of course, improvers who wish to sell a competing product during the term of a patent must avoid the scope of the patent's claims in order to avoid infringement. Yet when it is commercially feasible, the ability to design around a patent protects improvers and permits them substantive commercial participation and leadership in the field. Their commercial design-around developments may also advance the extant patented technology by building and improving upon it. When such advancement produces patented inventions, we may use the more established term "invention around"; but in general a design-around does not *require* invention and patenting, as the prior art may suffice to achieve its object. Recognition of this function of the patent system makes it no longer possible to assert – as several authors have[6] – that a patent inevitably reduces the output of the technology it subjects to exclusive control.

The importance of the design-around function of patents has been and sometimes continues to be recognized. The National Academy of Sciences in its 1962 report on the role of patents in research acknowledged that while it may lead to duplicative research, one of its positive effects "is that new and superior products or processes are frequently developed that probably would not have been developed, at least as soon, in the absence of the need to 'invent around'" (National Research Council 1962, 14). Courts have also recognized designing-around and inventing-around activities as important innovation-inducing aspects of the patent system. The U.S. Supreme Court has noted the difference between "the intentional copyist making minor changes to lower the risk of legal action" with "the incremental innovator designing around the claims, yet seeking to capture as much as is permissible of the patented advance" (*Warner-Jenkinson Co. v. Hilton Davis Chem. Co.*, 520 U.S. 17, 36 [1997]). The Court of Appeal for the Federal Circuit has observed that "[d]esigning around patents is, in fact, one of the ways in which the patent system works to the advantage of the public in promoting progress in the useful arts, its constitutional purpose" (*Slimfold Mfg. Co. v. Kinkead Indus.*, 932 F.2d 1453, 1457 [Fed. Cir. 1991]). The court emphasized that designing around patents promotes technological progress by encouraging beneficial competition.[7]

It is not widely-recognized that public policy, regulations and the patent statute in the U.S. expressly protect and encourage designing around patents. For example, the Hatch-Waxman Act has the goal to encourage generic drug developers to design-around the existing approved drugs' pioneer patents by the statutory means of a 180-day period of marketing exclusivity for generic drug manufacturers who seek U.S. Food and Drug

[5] Throughout this paper we often refer to online resources of the Thomas Edison Papers collection by an alphanumeric string hyperlinked to particular records. The reader can use the alphanumeric reference string in the "Document ID" field in the form at http://edison.rutgers.edu/singldoc.htm to retrieve the image of the reference.

[6] For a review of literature on this topic in the context of downstream improvements see (Lemley 1997, 996).

[7] *State Indus., Inc. v. A.O. Smith Corp*, 751 F.2d 1226, 1235-36 (Fed. Cir. 1985) ("Conduct such as . . . keeping track of a competitor's products and designing new and possibly better or cheaper functional equivalents is the stuff of which competition is made and is supposed to benefit the consumer. One of the benefits of a patent system is its so called 'negative incentive' to 'design around' a competitor's products, even when they are patented, thus bringing a steady flow of innovations to the marketplace."); See also *Hilton Davis Chem. Co. v. Warner-Jenkinson Co.*, 62 F.3d 1512, 1520 (Fed. Cir. 1995) ("The ability of the public successfully to design around — to use the patent disclosure to design a product or process that does not infringe, but like the claimed invention, is an improvement over the prior art — is one of the important public benefits that justify awarding the patent owner exclusive rights to his invention."), *rev'd*, 520 U.S. 17 (1997); *In re Alappat*, 33 F.3d 1526, 1553 (Fed. Cir. 1994) ("Even after a patent has been awarded for a new, useful, and nonobvious practical application of an idea, others may learn from the underlying ideas, theories, and principles to legitimately 'design around' the patentee's useful application."); *Yarway Corp. v. Eur-Control USA, Inc.*, 775 F.2d 268, 277 (Fed. Cir. 1985).

Administration (FDA) approval for their follow-on products.[8] Designs around are thus made possible because Congress recognized – and codified through the Hatch-Waxman Act – the difference between therapeutic equivalence (bioequivalence) and claimed subject-matter equivalence under patent law.[9] Another example of an agency regulatory process that helps innovators validate specific design-around solutions to avoid infringement liability is the availability of the U.S. International Trade Commission's (ITC) advisory opinions rendered on specific designs-around in Section 337 patent infringement import investigations.[10]

U.S. jurisprudence widely protects efforts to design around extant patent claims. Courts have recognized technology standard-development-organizations' needs for full disclosure of their members' patents and pending patent applications in order to facilitate designs around patented technologies in developing industry standards;[11] have limited the availability of punitive damages to claims of willful infringement following good-faith design-around efforts, reasoning that such infringement remedies can deter designs around;[12] and held that a party alleged to have repeated infringement, when found to have attempted a new design around the patent, should not be held in contempt of court.[13]

On the other hand, not all scholars agree on the net benefits of the patent system's design-around feature. There are those who argue that competitors compelled to design around patent claims waste resources in finding non-infringing ways of achieving the same results as patented inventions, diverting resources from other productive efforts.[14] However, these authors provide no evidence that the costs of designing around patents exceed the benefits. Nor is it always clear whether the often-used term in the economic literature – "imitation" – in fact entails designing around patent *claims*. Although analytical models have been constructed to account for R&D "waste" by "imitators" who "invent around" the original patent (Kaplow 1984; Gallini 1992), neither model introduces the possibility of "imitators" who contribute valuable improvements or new innovations that would not have been otherwise introduced but for the incentives to solve a problem in a different and new way. Nor do these models address the contribution to consumer welfare from the increased competition of successful designs-around. It is a purpose of this study to fill the empirical gap in current scholarship by demonstrating an anatomy and reach of the *advantageous* outcomes of invention-around patented technology – that of Edison's incandescent lamp patent, U.S. Patent No. 223,898.

---

[8] *Drug Price Competition and Patent Term Restoration Act of 1984*, Pub. Law. No. 98-417, 98 Stat. 1585 (1984). The 180-day marketing exclusivity provision is codified in 21 U.S.C. § 355(j)(5)(B)(iv).

[9] (FTC 2002, 7) (The 180-day exclusivity period under the Hatch-Waxman Act provides an increased economic incentive for companies to challenge patent validity and to "design around" patents to find alternative, non-infringing forms of patented drugs and get to market).

[10] 19 C.F.R. § 210.79 Advisory opinions. For details on ITC design-around advisory opinions see (Blakeslee and Meservy 2007).

[11] *Qualcomm Inc. v. Broadcom Corp.* 539 F.Supp.2d 1214, 1229 (S.D.Cal. 2007) (noting that intentional concealment of IPRs deprived Standard Development Organization of opportunity to design around patented technologies in developing a standard), *aff'd* in-part 548 F.3d 1004 (Fed. Cir. 2008).

[12] *State Indus., Inc. v. A.O. Smith Corp*, 751 F.2d 1226, 1236 (Fed. Cir. 1985) (noting that "[designing around] should not be discouraged by punitive damage awards except in cases where conduct is so obnoxious as clearly to call for them"); *Westvaco Corp. v. International Paper Co.*, 991 F.2d 735, 745-6 (Fed. Cir. 1993) (Rejecting a patent holder's claim of willful infringement, finding that "Westvaco did not copy IPC's product, but instead attempted to design around IPC's product," including specific structural changes that "Westvaco's outside patent counsel deemed … as adequate to avoid infringement." Although Westvaco's design around attempt was unsuccessful and Westvaco was found to have infringed the patent, the Federal Circuit refused to award punitive damages in the face of a good-faith design around effort, noting that "[d]esigning or inventing around patents to make new inventions is encouraged." quoting *London v. Carson Pirie Scott & Co.*, 946 F.2d 1534, 1538 (Fed. Cir. 1991))

[13] *Arbek Mfg. Inc., v. Moazzam*, 55 F.3d 1567, 1570 (Fed. Cir. 1995) ("Contempt . . . is not a sword for wounding a former infringer who has made a good-faith effort to modify a previously adjudged or admitted infringing device to remain in the marketplace. Rather, the modifying party generally deserves the opportunity to litigate the infringement question at a new trial, 'particularly if expert and other testimony subject to cross-examination would be helpful or necessary,'" quoting *KSM Fastening Sys., Inc. v. H.A. Jones Co.*, 776 F.2d 1522, 1531 (Fed. Cir. 1985)).

[14] *See* (Scherer 1980, 446) (arguing that resources used in designing around patents could be put to better use); (Turner 1969, 455) (arguing that a patent forces competitors to invest resources in finding non-infringing ways of achieving the same results as the patented invention, which may in many instances divert resources from other unsolved problems); (Machlup 1958, 51) ("From an economic point of view, research is costly since it absorbs particularly scarce resources which could produce other valuable things. The production of the knowledge of how to do in a somewhat different way what we have already learned to do in a satisfactory way would hardly be given highest priority in a rational allocation of resources").

2.1 Certainty of patent claim boundaries is essential for design-around investments.

Legal scholars of patent claim interpretation have noted that absent clear notice of the conduct that will avoid infringement liability, firms are likely to eschew design-around investment and precompetitive conduct (Nard 2000, 41). It is an imperative of a well-functioning patent system that uncertainty of the metes and bounds of patent claims be minimized so as to better inform the public of the patentee's exclusive rights. To design around a patent claim, a competitor must know with some particularity and certainty where the patentee's proprietary interest begins and ends so as to allow the competitor to produce a viable non-infringing alternative.[15] It could be considerably easier for a firm to design around a patent *ex ante*, before the firm commits to a particular technological approach, but very costly *ex post*, after the design is in production. Hence, patentee-conduct that delays or evades determinations of the scope of the patent claims has been expressly condemned during the last century.[16]

Yet the courts' imperative to provide a reliable public notice of the precise boundaries of patent claims to enable informed design-around decisions is in clear tension with the opposing legal policy principle of patent claim construction, the doctrine of equivalence.[17] The importance of striking a balance between these opposing principles is illustrated by our empirical evidence in Edison's patent case: it shows that stimulated design-around investments increased as legal certainty of the patent claim boundaries improved.

2.2 Survey of empirical evidence of design-around outcomes and benefits

Chronicles of design around patents go as far back as the 18th century, to Watt's competitors in the steam-engine field.[18] Industry participants are keenly aware of the potential impact of design-around activities. When R&D managers of established public firms in various industries were asked about the limitations of

---

[15] See *McClain v. Ortmayer*, 141 U. S. 419, 424 (1891) (a patent must describe the exact scope of an invention to "secure to [the patentee] all to which he is entitled, [and] to apprise the public of what is still open to them."); *.London v. Carson Pirie Scott & Co.*, 946 F.2d 1534, 1538 (Fed. Cir. 1991) ("[C]laims must be 'particular' and 'distinct,' as required by 35 U.S.C. § 112, so that the public has fair notice of what the patentee and the Patent [Office] have agreed constitute the metes and bounds of the claimed invention. Notice permits other parties to avoid actions which infringe the patent and to design around the patent."); *TDM America, LLC v. U.S.* 85 Fed.Cl. 774, 803 (Fed. Cl. 2009) ("Furthermore, 35 U.S.C. § 112 requires a patent specification to 'conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.' This statute seeks to allow third parties to design around and avoid actions which might infringe a patent."), ruled not infringed in *TDM America, LLC v. U.S.*, 92 Fed.Cl. 761 (Fed. Cl. 2010).

[16] *Teva Pharmaceuticals USA, Inc. v. Pfizer Inc.* 405 F.3d 990, 993-994 (Fed.Cir. 2005) (Gajarsa, Dyk JJ., dissenting from the order declining rehearing *en banc*.). ("By settling with Ivax, Pfizer leveraged the Hatch-Waxman exclusivity to insulate the '699 patent from any validity challenge. Pfizer also insulated itself from any judicial determination of the metes and bounds of its '699 patent claim scope in relation to a design-around, a determination central to the proper function of our patent system…This ties up Teva's investment in its proposed generic until at least 2010, precludes it from testing a potentially weak patent, precludes it from triggering the statutory exclusivity period with a successful validity challenge, and precludes it from introducing an effective design-around, as is its right and as the patent law encourages."); *Electric Vehicle Co. v. De Dietrich Import Co.* 159 F. 492, 493 (C.C.N.Y. 1908) (noting that the Selden patent owners have hesitated to bring its validity question to actual decision: "Several such cases have been brought. … In all these suits defenses were interposed on the merits; but the testimony never has been completed, and the cases never brought to a hearing.")

[17] The Doctrine of Equivalence (DE) is an equitable doctrine applicable in patent infringement cases when the alleged infringing device does not fall within the literal words of the patent claim but performs the claimed function or uses equivalent means to that claimed in the patent. The U.S. Supreme Court addressed the tension between DE and claim construction certainty in *Festo Corp. V. Shoketsu Kinzoku Kogyo Kabushiki Co., Ltd., et al*, 535 U.S. 722, 732 (2002) ("It is true that the doctrine of equivalents renders the scope of patents less certain. It may be difficult to determine what is, or is not, an equivalent to a particular element of an invention. If competitors cannot be certain about a patent's extent, they may be deterred from engaging in legitimate manufactures outside its limits … These concerns with the doctrine of equivalents, however, are not new. Each time the Court has considered the doctrine, it has acknowledged *this uncertainty as the price of ensuring the appropriate incentives for innovation*, and it has affirmed the doctrine over dissents that urged a more certain rule.") (Emphasis added); The Federal Circuit recognized that the doctrine of equivalents represents an exception to "the requirement that the claims define the metes and bounds of the patent protection," but, it had explained, "we hearken to the wisdom of the court in *Graver Tank*, that the purpose of the rule is 'to temper unsparing logic' and thus to serve the greater interest of justice." *Texas Instruments Inc. v. United States Int'l Trade Comm.*, 805 F.2d 1558, 1572 (Fed. Cir. 1986); Federal Circuit Judge Rader stressed the importance of protecting legitimate design around efforts that rely on consistent cannons of the application of the doctrine of equivalence: *Cross Medical Products, Inc. v. Medtronic Sofamor Danek, Inc.* 480 F.3d 1335, 1346 (Fed. Cir. 2007) (Rader, J. Concurring) ("This case is a classic example of the tangentiality principle running counter to principles of public notice. Medtronic had suffered an injunction. It deliberately sought to design around the patented technology-a response that patent law encourages.").

[18] *See* (Selgin and Turner 2011, draft at 17) (describing Trevithick's invention around Watt's steam engine condenser patent in 1796 by making an engine that didn't need a condenser).

patent protection, the ability of competitors to "invent around" both process and product patents was rated higher than five on a seven-point scale of importance by 60 percent of the responding industries (Levin and others 1987).[19] Yet, there is a paucity of published empirical research on designing-around patents. Numerous works on competition and "imitation" provide empirical evidence on cases that must have involved designing around patents. However, these articles rarely make clear what the specific innovations were, whether they were patented and rarely show that imitators specifically designed around underlying patents and claims.[20] We must presume, however, that a considerable number of the cases in these studies must have involved successful design around patents.

Mansfield et al. studied 48 innovations of which 70% were patented and found that the average ratio of the imitation cost to the original innovation cost was about 0.65 and that the median increase of this specific cost ratio was 11% for patented innovations over that for non-patented innovations (Mansfield, Schwartz, and Wagner 1981). These results were in general agreement with those later found by Levin et al. (Levin and others 1987, 811). Mansfield et al. also found that about 60% of successful patented innovations were imitated within four years. In a later paper, Mansfield observed that imitations followed leaks of information concerning the detailed nature and operation of the new products or processes, which generally leaked out within about a year from product launch (Mansfield 1985).

Agarwal & Gort (Agarwal and Gort 2001) analyzed historical trends in competitive entry time following an initial innovation. They evaluated 46 products including consumer, producer, and military goods varying by capital and technological intensity. Beyond naming the product category, they have identified neither the specific products and their pioneer manufacturers nor the later-entry competitors or products. While no specific patenting information was provided, many of the innovations they list are known to have been patented. Because Agarwal & Gort found mean times to competitive entry following many of these innovations that were substantially shorter than the term of patent protection, we conclude that Agarwal & Gort captured significant patent design-around activity in their sample.

Robert Beck studied innovations and their subsequent design-around substitutes with data from three industries: the glass container industry, the oil refining industry, and the shoe machinery industry (Beck 1976). However, despite Beck's research into court records involving various legal proceedings containing evidence on patent licensing agreements pertaining to the cases studied, he provides no data on any patent, its claims, or any specific technological nature of "substitutes" to the original patented innovations. Yet, without showing that existing patent claims were actually designed-around, Beck leaps to a conclusion that patent rights were the actual purpose for introducing the substitutes. He then purports to have shown that patent rights systematically encourage production of substitutes for relatively profitable innovations and concludes this to be economically inefficient, without ruling out the commercial benefits of these "substitutes" in their own right. His premises and analysis were cogently criticized in a comment by Landau.[21]

Perhaps the most product-specific empirical accounts of new products designed around pioneer patents are by Joseph DiMasi and colleagues. In one study, DiMasi & Paquette identified 72 drug classes where the first-in-class (pioneer) compound was approved from 1960 to 1998 (DiMasi and Paquette 2004). They found 235 follow-on drugs for these 72 therapeutic drug classes that had been approved by the FDA through 2003. They found that the average time to competitive entry by such generic drugs has been declining steadily through the study period from about 8 years in the 1970's to less than 2 years at the end of the 1990's. While DiMasi & Paquette show the specific product names involved, they do not identify any of the pioneer patents, or whether the follow-on drug was introduced after the pioneer patent expiration or alternatively, whether the follow-on (generic) drug manufacturer entered the market with a design-around or rather based on an assertion of the pioneer patent's invalidity. There can be very little doubt, however, that a substantial

[19] In this survey, the limitation of process patents to protect against design-arounds received an average ranking of 5.49 as opposed to product patents, for which the limitation received an average ranking of 5.09 on the seven point importance scale (Levin and others 1987, Table 5).

[20] (Selgin and Turner 2011) appears as the only exception in which the specific claimed invention's boundary is discussed.

[21] See critique by Landau (Landau 1978) and Beck's reply (Beck 1978).

number of the 235 follow-on drugs involved a patent design-around, particularly in more recent years after the passage of the Hatch-Waxman Act of 1984, after which competitive entry had shorter delays. The robust design-around activity after 1984 was also manifested in more rapid market-share gains for follow-on drugs.[22]

The clinical benefits of design-around activity in pharmaceuticals are substantial. DiMasi & Paquette found that approximately one-third of all follow-on drugs have received a therapeutic priority rating from the U.S. FDA.[23] In addition, 57% of all classes they studied had at least one follow-on drug that received a priority rating. The economic benefits are no less spectacular. Another study (DiMasi 2000) found that for 20 new follow-on entrants to existing drug classes that were introduced in the U.S. from 1995 to 1999, 80% were launched at a discount to the price leader and 65% were launched at a discount to the average price for the class. The average percentage change was a 26% discount relative to the price leader and a 14% discount relative to the class average. In this study, DiMasi did not include any of the cost reduction benefits that the presence of multiple drugs in a class gives managed care through leverage in extracting rebates for drugs in the class. A Congressional Budget Office (CBO) study analyzing retail pharmacy data from 1993 and 1994 found that, for drugs that are available in both generic and brand-name versions, the average price of a generic prescription was approximately half of the average price of a brand-name prescription (Cook 1998, 28). The CBO estimated that, in 1994, the availability of generic drugs saved purchasers between $8 billion and $10 billion (Cook 1998, 31). A more recent CBO study found that in 2003 the average price of a generic drug (competing with the pioneer drug) remained half of the average price of a brand-name drug (Somers and Cook 2007, 20).

That the benefits of designing around patents in the pharmaceutical industry as discussed above are clearly measurable is also highlighted in the FTC Report on generic drug entry prior to patent expiration (FTC 2002, 9). But they are not always recognized – even by the same agency that found them. In the section "Design-Around Innovation," the FTC report on the patent system remarkably fails to mention the agency's previous measurable benefit findings and concludes that "[w]ithout a clear basis for assessing the net value of design-around activity, general conclusions are difficult" (FTC 2003, 22).

3 This study's original contribution to empirical methods of evaluating design-around outcomes

In comparison to the studies reviewed above the novelty of our approach for evaluating design-around effects is that we first establish that an actual design-around had been attempted through precise product and patent claim facts. Referring to Figure 1, we identify the original product (**A**) and its patent claims and identify with particularity the products or processes (such as **B**), designed around the original patent claims of **A**. Our present analysis is limited only to design-around efforts that were documented in subsequent patents and we use the disclosure in the patent to identify the relevant features of product **B**. We note that in general, pertinent documentation on the actual designed-around or improved products is often unavailable. It should be emphasized, however, that this analysis does not involve the claims in the patents of product **B** – only its specification.

[22] See (Grabowski 2003) (showing in Figure 2 that one year after generic drug entry, the average unit market share of generics rose from 35% in the mid '80's to 64% in the mid '90's, reaching 73% in the second year after entry).

[23] An approved drug receives an FDA therapeutic priority rating only if it provides significant or modest *gain* over existing therapy.

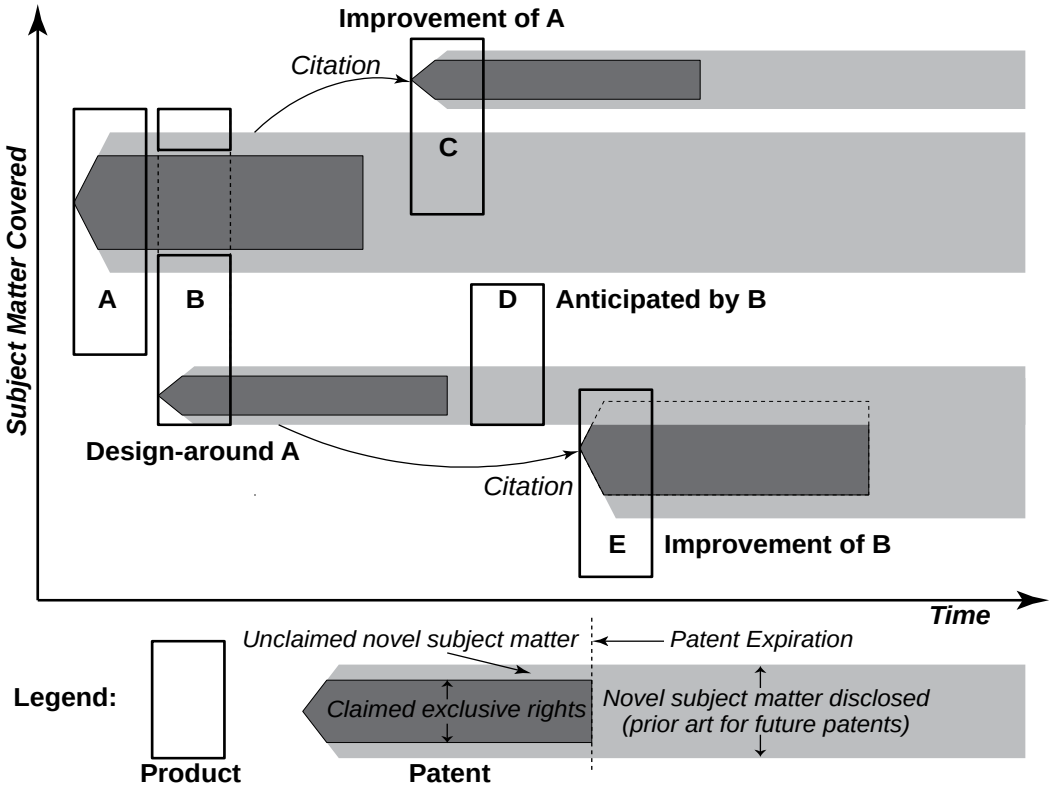

Figure 1. The patent scope and temporal relationship between an original invention (first embodied in Product **A**), a patented product **B** shown as "surrounding" the claimed subject matter of **A** (designed around **A**'s patent), and an improvement by Product **C** introduced after **A**'s patent expiration. Matter disclosed in **B**'s patent may limit future downstream claim breadth (in the case of **E**'s patent), or block issuance of patent claims altogether (as in product **D**).

Identification of products **B** as attempts at designing around **A**'s patent is by no means absolute or definitive, as it requires our informed *judgment* on:

(i) the likely interpretation given to A's patent claims by the improver when designing product B in view of the historical record and legal standards prevailing at the time;
(ii) the extent to which the design disclosed in B's patent reasonably avoids infringement of A's claims under this likely interpretation; and
(iii) evidence that the advantages of product B include an improvement on A without using A's patented techniques.

For items (i) and (iii) above we look for accounts in contemporaneous publications, court cases and in the patent disclosure of **B**. We also consider the filing date of **B**'s patent application in relation to contemporaneous relevant legal trajectory events in **A**'s patent. For item (ii), we note that the use in product **B** of unclaimed novel subject matter disclosed in **A**'s patent actually qualifies as a design-around. We therefore look to the specification in **B**'s patent and make a reasoned determination that at least one essential feature of ***each*** of **A**'s patent claims is not present in the improver's design as disclosed in **B**'s patent. Considering Edison's U.S. Patent No, 223,898 as **A**'s patent, we provide a summary of such an analysis of product **B** in Edison's case in Figure 4 and in Table 1. While some of the evidence that led us to the determinations that these entries are in fact design-around attempts is necessarily circumstantial, we believe this evidence amply supports a conclusion categorizing these as design-around attempts.

Our next step involves a novel form of citation analysis. Patent and technical paper citation analyses have been used to analyze relations between patented technologies using backward or forward citations (Hall, Jaffe, and Trajtenberg 2001). Backward citations are citations made by a patent to previously issued patents. Forward citations are citations received by a patent from subsequently issued patents. In contrast to backward citations, the number of forward citations changes over time, even beyond the patent expiration. These types of citations are shown in Figure 1 as **C**'s patent citing **A**'s patent. Some applications of patent citations in the innovation literature are: measuring patent "value" or "quality" (Harhoff and others 1999;

Trajtenberg 1990; Hagedoorn and Cloodt 2003); assessing knowledge flows and spillovers (Jaffe, Trajtenberg, and Henderson 1993; Thompson and Fox-Kean 2005); characterizing technology lifecycles (Narin, Albert, and Smith 1992); and investigating strategic behavior by firms (Podolny, Stuart, and Hannan 1996; Lanjouw and Schankerman 2001; Marco 2005). These applications impute some real probative merit to patent citations: they signal either patented technology value, or some transfer of knowledge.[24]

We introduce here a novel patent citation technique to evaluate *indirect* downstream technology impacts involving design-around efforts, as they play no less a role in downstream development than direct improvements. Once a product **B** designed around **A** is identified, we track its technological progeny downstream based on its patent(s) citations in other later patents, technical papers or legal patent proceedings. This is shown in Figure 1 as **E**'s patent citing **B**'s patent, thus indirectly and collaterally linking **E** to **A**. We call such technological lineage to the set of all downstream products or processes identified in this manner the "*collateral technology impact*" of **A**. As in traditional citation impact analysis, this term is not meant to necessarily connote causality but merely to establish a new relational indicator of subject matter in the field.

With continued reference to Figure 1, we note that downstream collateral technology impact can come in several forms. Downstream developments can exploit and build on the knowledge disclosed in **A** to design-around it and build a new technology lineage starting with **B**. Further downstream from **B**, new and superior products or processes may be developed (**D** and **E**) as improvements on **B**. In many circumstances, this lineage would not have been developed, at least as soon, in the absence of the need to 'invent around' **A**'s patent to produce product **B**.

We also note an important aspect not generally appreciated or used by economists who engage in citation analysis: a citation in a later patent often means that the claims issued in that later patent were distinguished or narrowed in prosecution so as to recite only non-obvious subject matter in view of the prior art citation. Thus, as another important collateral impact, we show that subject matter first disclosed in **B**'s patent can limit future downstream patent claim breadth (as shown in Figure 1 for the case of **E**'s patent), or even block issuance of patent claims altogether (as shown in Figure 1 for product **D**). Thus, our analysis demonstrates an inherent claim-scope *regulation* feature of the patent system not hitherto documented with empirical evidence: the prior-art limiting patent **A**'s scope, enables others to invent around it – an activity that stimulates new downstream technologies (**B**), which in turn form prior-art that limits the scope of subsequent exclusive rights of improvers (**D** and **E**). Next, we describe below our methods and data in evaluating the collateral impact of designs-around that were used to obtain our results for the Edison case, which we tabulate in Appendix B.

3.1 Data and methods

Our data was collected and processed through the five steps enumerated below.

1. We began by identifying the patent classes and subclasses for electric lamps (excluding arc lamps) and related components. We selected the patents currently classified by the U.S. Patent Office, including classes for patents covering methods, processes or instruments for making electric lamps and their components. As described in detail in Appendix A, we found a total of 392 issued U.S. patents filed between 1830 and 1899 and classified in our electric lamp classes. We ordered them by filing date and produced the cumulative temporal counts shown in Figure 3 by class category, and in Figure 4, by ownership and subject matter as further described below.

2. We analyzed Edison's '898 patent claims (listed in Figure 2), and used the contemporaneous construction given to them by the courts. In so doing, we were also informed of the claiming practices of that time.[25]

[24] *But see* (Oppenheim 2000) (reviewing the purposes and functions of citations in scientific papers and in patents and suggesting caution in interpreting patent citation data).

[25] See Sections 4 and Table 1.

With this claim construction, we noted critical claim elements that were essential for many lamps on the market at that time (see Section 4). These claim elements are listed on the leftmost column of Table 1.

3. We partitioned the 392 patents in our electric lamp classes into three subsets shown in separate plots in Figure 4 as follows:

(i) Patents labeled as "*Edison/GE*" (99 patents) are those filed by Edison or his known employees, and those expressly assigned to the Edison Company or GE.

(ii) Patents labeled as "*Other Mfrs. Design-Around*" (103 patents) disclosing lamp designs that do not use Edison's invention. These include patents disclosing designs-around which use alternatives to Edison's claimed design. Naturally, patents that are prior art to Edison's invention are included in this subset as well.

(iii) Patents labeled as "*Other Mfrs.*" (190 patents) disclosing lamp design features that may be used in lamps constructed as per Edison's invention. These include patents disclosing lamp designs that would be considered infringing at least one of Edison's claims. It also includes patents which do not disclose subject matter directed at any particular lamp construction features pertinent to Edison's invention.[26]

4. We then selected several representative patents from subset (2) above for downstream citation analysis. These representative patents described products that do not use Edison's invention and were filed in the period from the date Edison asserted his patent to the patent's expiration (1886-1894) and were selected based on one or more of the additional following criteria:

(i) The patentee, assignee or beneficiary of the patent was a known Edison/GE competitor.

(ii) Commercial information on the lamp described in the patent was available from other contemporaneous publications such as trade press or technical articles.

(iii) The product described in the patent was accused of infringing Edison's patent in litigation.

5. We further broke this group down by the claim elements of Edison's '898 patent which the product described by the patent avoids. We chose at least two patent examples for each identified claim element. The results of this selection by claim elements (22 patents) are shown in Table 1. This representative list is by no means exhaustive, as our goal was not to identify *all* design-around attempts, but to illustrate the stimulation of downstream development and the collateral technology impact of the enforcement of Edison's patent.

Having identified 22 representative patent disclosures with "design-around" features described in Table 1, we proceeded with a forward citation analysis of these patents in the following subsequent patent or legal publications:

(i) **U.S. patents**, reference section and any mention in the specification. We used the online electronic databases from LexisNexis®, U.S. Patent Office, Google Patents and FreePatentsOnline.com.

(ii) **Official gazette of the U.S. Patent Office,** for decisions on interferences and appeals to the Commissioner of Patents.

(iii) **The Federal Reporter** (Westlaw) and LexisNexis for federal court decisions.

The number of downstream citations found for each patent in our selection is shown at the second rightmost column in Table 1. For all but one patent that had no forward citation, the details of the citing patents and cases are given in Appendix B.

[26] Examples are patents disclosing methods for making filaments, methods for evacuating glass lamp globes or methods for improved sealing of lamps – none of which pertain to avoiding Edison's claims.

3.2 The limitations of our study

It is generally observed that forward citation frequency of a given patent declines with elapsed time after its issue (Hall, Jaffe, and Trajtenberg 2001; Marco 2007). We would therefore expect the largest number of forward citations of the patents in our selection to be in downstream patents issued in the late 1890's and the first few decades of the 1900's. Unfortunately, until 1947 U.S. patents were issued without the citations of the references considered by the examiner in prosecution (U.S. Patent Commissioner 1947, 169). Our only method to find only a portion of these pre-1947 citing references was through searches on the patent specification text. It is clear that we missed a substantial body of citations of our selected patents that examiners must have made before 1947. Because the USPTO online database contains citation metadata only for patents issued after 1975, finding patents issued after 1947 was best accomplished by using the **REF/** operator on FreePatentsOnline.com, which includes this field in its metadata for patents issued after 1947. Indeed, the results in Appendix B show the paucity of downstream citations in the 1890's and early 1900's, the years we would have normally expected higher forward citation frequency.

An additional inherent limitation to our method is that a subjective step is introduced in establishing the **A**-to-**E** chain in Figure 1 by finding patents of products **B** that constitute an attempt to design-around the patent of **A**. This step requires construction of **A**'s patent claims and an infringement analysis of product **B** as well as external commercial information to determine whether a design-around had been attempted. Therefore, one should not expect this method to provide an exhaustive or definitive account for all design-around attempts. Nevertheless, as we show in this Edison example, a variety of design-around activities can be identified with high certainty.

4 Edison's '898 pioneer patent – the historical and legal trajectory

Edison's '898 patent has been described as "the basic patent in the early American incandescent-lamp industry, covering the use of a carbon filament as the source of light" and is deemed to have had "a profound effect on the industry until it expired" (Merges and Nelson 1990, 885). Whereas Edison's '898 patent proved to be a fundamental incandescent lamp patent, its characterization as "covering the use of carbon filament as the source of light" (Merges and Nelson 1990, 885) is overbroad and patently wrong (pun intended) because Edison's claims were significantly narrower than that.[27] Such error appears to have been the source of much folklore about the scope of Edison's invention – the idea that Edison "invented the light bulb." The *claims* were the sole measure of the invention and the patent grant even in Edison's day.[28] In their treatise fully dedicated to broad-scope patent claims, Merges & Nelson's paper failed to quote or analyze the claims of what it concluded was a patent having broad-scope claims. The four claims in the '898 patent are shown in Figure 2, with relevant emphasis added.

[27] This was made legally clear even during an earlier federal court ruling involving Edison's rivals' patent. By clarifying that carbonized fibers of wood or other vegetable material is generally intended to mean "charcoal," the court said: "neither Sawyer and Man nor Edison can maintain any just claim to the exclusive use of charcoal generally, in any form, as an incandescing conductor in an electric lamp." *Consolidated Electric Light Co v. McKeesport Light Co.,* 40 F. 21, 25 (C.C.Pa. 1889).

[28] *Yale Lock Mfg. Co. v. Greenleaf,* 117 U.S. 554, 559 (U.S. 1886) ("The scope of letters patent must be limited to the invention covered by the claim").

(1) An electric lamp for giving light by incandescence, consisting of a *filament of carbon* of high resistance, *made as described, and secured to metallic wires, as set forth*.

(2) The combination of carbon filaments with a receiver *made entirely of glass*, and *conductors passing through the glass*, and from which receiver *the air is exhausted*, for *the purposes set forth*.

(3) A carbon filament or strip *coiled* and connected to electric conductors, so that only *a portion of the surface of such carbon conductors shall be exposed for radiating light*, as set forth.

(4) The method *herein described* of securing the *platina contact wires to the carbon filament*, and carbonizing of the whole in a closed chamber, *substantially as set forth*.

Figure 2. The claims of U.S. Patent 223,898 to Thomas A. Edison (emphasis added).

It is important to recognize that claim drafting practices developed in view of U.S. Supreme Court decisions at that time, employed the words "as described" or "as set forth" in the body of the claims in order to ensure that an overbroad claim construction by a challenger of the patent would not invalidate the claims. Thus, the words "as set forth," at the end of a claim, refer to the specification, and make it an explicitly essential part of the claim, where the claim is limited by the more specific description contained in the specification.[29] This feature of Edison's claims proved significant in sustaining their validity but also in limiting their scope.

On July 14, 1891 a U.S. district court upheld Edison's patent's validity and found that it was infringed (*Edison Elec. Light Co. v. United States Elec. Lighting Co*., 47 F. 454 [S.D.N.Y. 1891], hereinafter "*USEL*"), which decision was affirmed by the Second Circuit Court of Appeals on October 4, 1892 (*USEL*, 52 F. 300 [2d Cir.1892]. The court construed the claims based on the specification, in view of the prior art of record. This included the Starr lamp of 1845, the Roberts lamp of 1852, the Lodyguine, Konn, and other lamps which appeared between 1872 and 1876, the Bouliguine lamp of 1877, the Sawyer and Man lamp of 1878, and the Edison platinum lamp of 1879.[30] It held that Claim 2 recited a fundamental invention covering the accused lamps, namely, an incandescent lamp composed of a carbon filament, hermetically sealed in an all-glass chamber exhausted to a practically perfect vacuum, and having leading-in wires passing through the glass. The court construed Claims 1 and 4 as narrowly directed to the mode of connecting the filament to the leading wires "as set forth" in Edison's specification. The defendant was found not to infringe these latter claims, "if for no other reason, because the leading wires in its lamps are not secured to the filament according to the method of the patent; that is, by cement carbonized in situ, but by clamps such as the specification condemns" (*USEL*, 47 F. 460-461). Similarly Claim 3, limited to a "coiled" filament, was of no infringement concern because the defendant's filament was not coiled. Essentially, only Claim 2 was recognized as covering the basic invention in a manner that was the most difficult for others to avoid. After considering evidence and testimony of experts taken and prepared over several years, Judge Wallace had concluded that Edison's main invention was grounded not merely in using a carbon burner in vacuum, which was known in the art, but in using a burner consisting of an extremely thin filament of high electrical resistance that can only survive in practically perfect vacuum. Referring to those having knowledge in the art of incandescent lamps, Judge Wallace wrote:

[29] *Seymour v. Osborne*, 78 U.S. 516, 547 (1870) ("Omit the words 'substantially as described,' or 'substantially as set forth,' and the question presented would be a very different one, but inasmuch as those words, or words of equivalent import, are employed in each of the claims, the defence is without merit. Where the claim immediately follows the description of the invention it may be construed in connection with the explanations contained in the specifications, and where it contains words referring back to the specifications, it cannot properly be construed in any other way").

[30] For an extensive survey of the prior art preceding Edison's inventions see (Lamp Committee 1929).

> "Read by those having this knowledge, the radically new discovery disclosed by the specification is that a carbon filament as attenuated before carbonization as a linen or cotton thread, or a wire seven one-thousandths of an inch in diameter, and still more attenuated after carbonization, can be made, which will have extremely high resistance, and be absolutely stable when maintained in a practically perfect vacuum. It informs them of everything necessary to utilize this discovery and incorporate it into a practical lamp" (*USEL*, 47 F. 460).

There were several technological advantages to Edison's thin carbon filament of high resistance in a practical electrical illumination system over the prior art of thick carbon burners. First, the filament's ability to draw sufficiently small currents enabled networks of many lamps to be electrically connected in parallel rather than in series, making the operation of each lamp independent of the others. Second, a collateral advantage not immediately appreciated by Edison's contemporaries, was that the low current draw by Edison's high-resistance filaments placed much less critical demands on the conductive interface and contact integrity of the bond between the carbon filament and the platinum leading-in wires. The practical significance of these advantages were apparently missed by other lamp developers even years after Edison's patent issued, as they persisted in futile attempts to solve problems inherent only in thick carbon incandescent rods that draw high currents and incurred high rate of erosion.[31] A few years after Edison's patent issued, Sawyer continued to insist that the resistance of the carbon incandescent rod must be kept as low as possible and so confined his attention to short, thick carbon rods (Bright 1949, 52). These efforts were unsuccessful and Sawyer admitted that "many of the lamps failed to last more than a few hours" (Sawyer 1881, 86). In contrast, Edison's results were spectacular as his lamps had an operational life span of about 1,000 hours (Bright 1949, 134), about one hundred times longer than that of Sawyer & Man's or any other prior art lamp.

Although a thin carbon *filament* - as opposed to a carbon pencil or rod - was an essential element of Edison's invention, the word "filament" in a patent claim was not sufficiently specific to adequately distinguish Edison's invention over the prior art. A recitation of additional functional limitation was required. Claim 1 is directed at carbon filaments of "high resistance," but it includes a limitation that the filament must be "secured to metallic wires, as set forth." This latter clause rendered Claim 1 ineffective against other available methods of securing high resistance carbon filaments to the metallic wires. Fortunately for Edison, Claim 2 provided a stronger, though indirect, feature for distinctly capturing his thin, high resistance carbon filament feature. Because Edison's extremely thin and high resistance carbon filaments could only survive over a sufficiently long operating period in extreme vacuum, Edison invented the one-piece glass globe through which lead-in wires were fused and it provided the only practical solution at that time for protecting the filament by maintaining long term leak-proof extreme vacuum. Those who had employed burners of thick carbon pencils or rods prior to Edison's invention had not recognized the need for *maintaining perfect* vacuum – hitherto all lamp artisans had used exhausted *stopper* globes, or even open-air lamps. Before Edison, no one had combined a "carbon filament with a receiver made entirely of glass, and conductors passing through the glass, and from which receiver the air is exhausted" as recited in Edison's Claim 2.

Nevertheless, this seemingly broader patent claim had not conferred on Edison a scope beyond the metes and bounds defined by the essential limitations of the claim, which otherwise left considerable room for close non-infringing substitutes. Specifically, Edison's major advance of a thin, high resistance carbon filament could be freely exploited if better methods of sealing a two-piece globe could be found, or if the imperfect vacuum conditions of such a globe could be mitigated by filament renewal and lamp reuse strategy having

[31] For example, in the two-year period following Edison's patent grant, futile continued attempts to solve carbon renewal problems and challenges arising only in the usage of thick carbon pencils were evidenced by the patent applications of: Sawyer (Pat. No. 227,386) for an improved roller contact mechanism for the carbon pencil; Man (Pat. No. 227,118) for a method of preventing the occurrence of an electrical arc in the carbon pencil-to-conductor connection; Sawyer and Street (Pat. No. 241,430) for multiple carbon pencils, one of which is renewed in a bath of hydrocarbon while the other is being burned in open air; Farmer of USEL (Pat. No. 265,790) on shaping thick carbon pencils for open-air operation; Hiram Maxim (Pat. No. 252,392) for improvements in securing carbon filaments with nuts and screws to leading-in wires; Crosby and Fox (Pat. No. 248,407) for lamp burners made of large carbon sheets; Lane Fox (Pat. No. 251,774) for improved connection between the luminous bridge (burner) and the conducting-wires or terminals; Bohm (Pat. No. 250,192) for a straight carbon pencil connected by spiral conductor, maintaining mechanical tension for improved connection; and McTighe (Pat. No. 258,240) covering a built-in reservoir of hydrocarbon liquid for carbon filament renewal during lamp operation.

operational simplicity and attractive economics. As discussed below, solutions combining both of these aspects were readily introduced when Edison's patent was enforced.

Enforcement of permanent injunctions decreed under the *USEL* July 1891 judgment was pending an appeal. An account of subsequent infringing lamp sales was ordered by the court and kept, essentially as a license forced on Edison until the circuit court of appeals for the second circuit affirmed the *USEL* district court in October, 1892. Another suit was then brought in the same court against the Sawyer-Man Electric Company, and a preliminary injunction was granted and affirmed by the circuit court of appeals on December 15, 1892, which directed a modified injunction (*Edison Electric Light Co. et al. v. Sawyer-Man Electric Co.*, 53 F. 592, 599 [2nd.Cir.1892]). Infringement suits were then immediately brought against the Westinghouse Electric Company in Pennsylvania, the Perkins Electric Lamp Company and the Mather Electric Company in Connecticut, and the Beacon Vacuum Pump and Electrical Company in Massachusetts, and preliminary injunctions obtained. By February 1893, the legal and technical contours of Edison's exclusive rights had been clarified as to existing lamp designs on the market. If Edison's '898 patent had had any substantive ability to "suppress" downstream developments, it would have been during the injunction periods, lasting less than two years, until the patent's expiration on November 19, 1894. However, as we show below, numerous non-infringing lamp solutions that steered clear of one or more essential limitations of *each* of the '898 claims were successfully introduced and marketed in vigorous effective competition with the Edison lamp prior to the '898 patent's expiration.

4.1 The surge in non-infringing incandescent lamp development

We show that progress in incandescent lamp design developments in fact *accelerated* during the years of Edison's patent enforcement. Patenting activity, as exhibited by the number of patents issued in a given field, is often an objective proxy, indeed a measure, of technical development activity in that field. We explain in Section 3.1 and Appendix A that Figure 3 and Figure 4 show the cumulative patenting activity recorded in the electric lamp technology patent classes for U.S. patents filed from 1878 to 1898, inclusive. A unit step in the graphs is shown at the application filing date of each patent issued in the classes. The "ramp" rate, or the average slope in the graph over a given period, is proportional to the patenting intensity (number of patent applications in the category per unit time) during the period.

The temporal relationship of the observed patenting surges to the key legal events of Edison's patent enforcement is remarkable. By examining the patents involved during the surges we conclude that a strong causal relation existed between the legal events annotated in the figures and the significant patenting surges. We were unable to find other legal or market events that could explain these observed surges. In reference to Figure 4, several observations can be made as follows: (a) immediately after Edison obtained his patent in 1880, much of the patenting activity of other manufacturers continued to depend upon lamps of prior-art. By 1882, these were gradually displaced by patenting activity involving variations of Edison's patented technology. (b) A substantial rise in patenting activity after Edison asserted the '898 patent in U.S. Federal Circuit Court against USEL on June 11, 1886.[32] Both Edison and other manufacturers were responsible for this rise in patenting activity, but remarkably, many other manufacturers' patent applications filed at that time disclosed improvements to lamp designs that were clearly *not* aimed at avoiding Edison's claims.

[32] Edison's original complaint in the suit against USEL filed on May 2, 1885 asserted only Patents Nos. 265,311 and 251,554, the claims of which covered only lamp plugs and socket construction. (See QD0120000A). It was not until June 11, 1886 that Edison's Amended Complaint dropped the lamp plug and socket patents and asserted instead, the filament Patents Nos. 223,898, 227,229 and 265,777. (See QD012B0001).

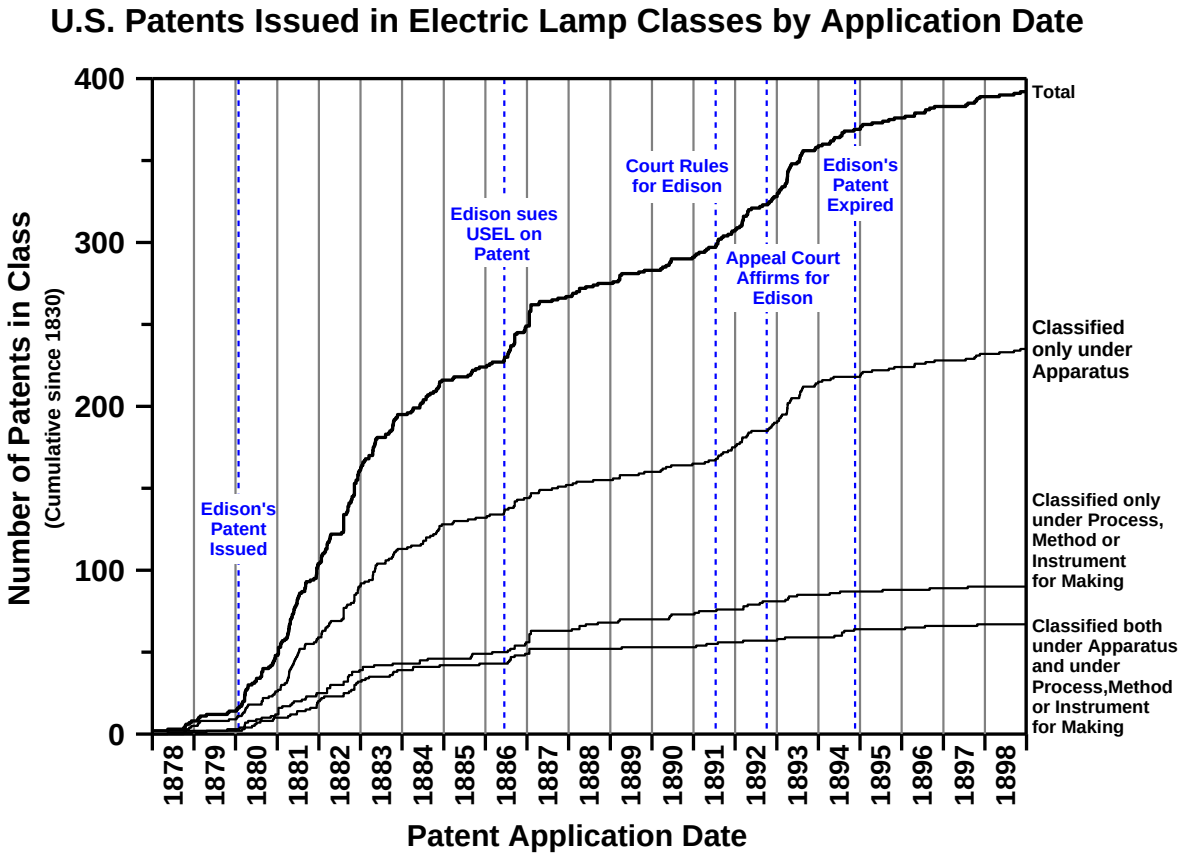

Figure 3. Patenting activity within electric lamp Classes 313 (apparatus) and 445 (process, method or instrument for making) in the relevant subclasses therein, as described in Appendix A. *Source*: USPTO online database.

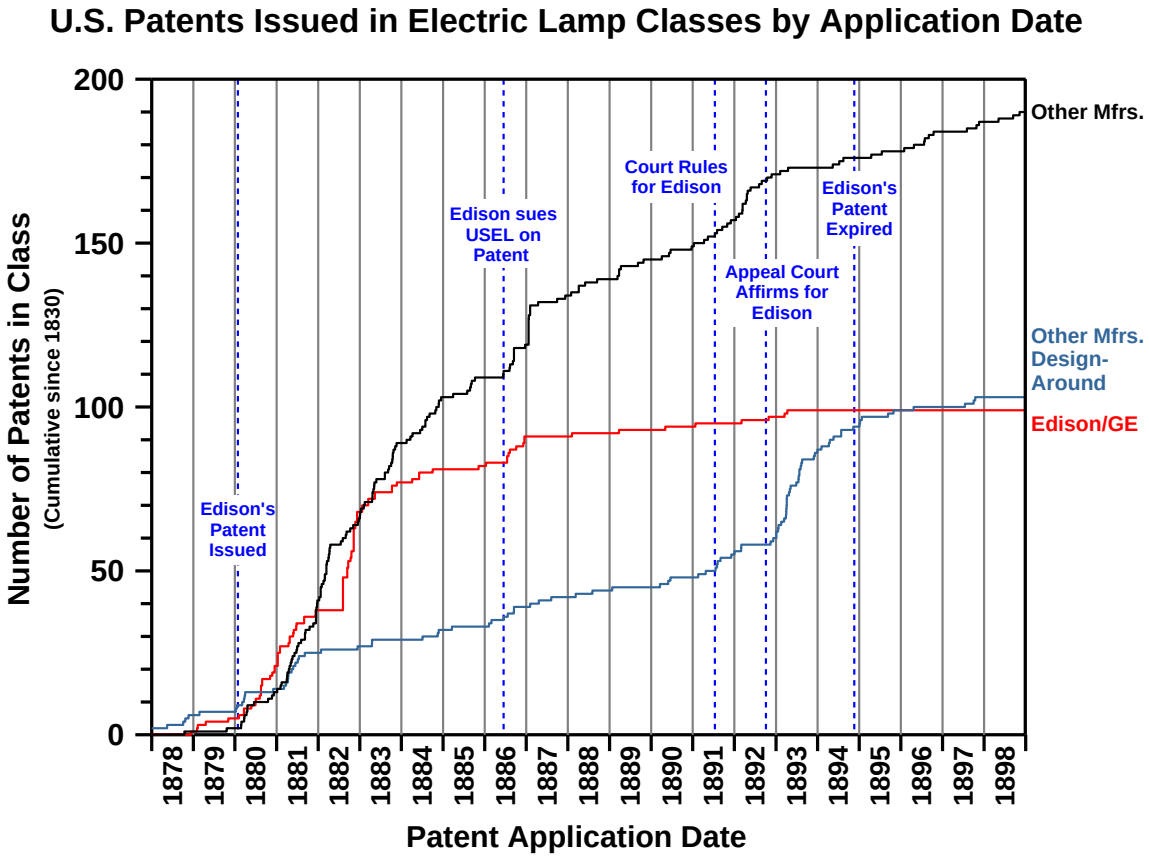

Figure 4. Patenting in electric lamp classes shown in Figure 3, broken up by ownership and design.

We note that the '898 patent was not the only patent asserted in the case and that at that time it had not yet become clear which of the Edison lamp patents would prove a fundamental test case. The amended complaint of June 1886 against USEL alleged infringement of U.S. patents Nos. 223,898, 227,229 and 265,777. However, on October 7, 1886, the Edison Electric Light Company issued a formal industry open letter from its president Edward H. Johnson (Johnson 1886) to all electric light station operators in which 8 additional Edison lamp patents and other socket patents were specifically identified as being widely infringed. The open letter also included an alleged infringement analysis of specific lamps made by USEL, Brush-Swan, Bernstein, Mather, Consolidated (Sawyer-Man) and two lamps made by Westinghouse. Indeed, we generally noted a wider variety of subject matter developed in the 1886 patenting surge. This is shown in Figure 3 where the patenting surge after 1886 involved patents for processes, methods or instruments for making lamps rather than patents for lamp apparatus proper. The surge of 1886 included patents for novel glass globe manufacturing technique, improved sealing of leading-in wires and new methods of securing carbon filaments to the platinum leading-in wires. In contrast, post-1891 developments mostly designed around the first two claims of Edison's '898 patent and were dominated by apparatus patents.

These observations with respect to Figure 3 and Figure 4 are also consistent with the notion that once Edison "had declared the patent war open," the surge of 1886 was a race to capture remaining valuable technology territory, mostly solidifying the value of Edison's invention rather than circumventing it. It appears that parties were attempting to improve their incandescent lamp patent portfolio and perhaps position themselves for the impending bargaining with each other.

The motivation for patenting activity changed following the July 14, 1891 *USEL* court decision enforcing Edison's '898 patent (*USEL*, 47 F. 454 [S.D.N.Y. 1891]). Figure 4 shows that non-infringing lamp developments accelerated following the 1891 court decision and accelerated most vigorously immediately after October 4, 1892 when the 2nd Circuit Court of Appeals affirmed the lower court decision. (*USEL*, 52 F. 300 [2d Cir. 1892]). Review of the patents filed in that period revealed that the non-infringing lamp developments were comprised of activities specializing in, and exploiting, the essential limitations of Edison's claims. These included attempts using (a) *non-carbon* filaments; (b) lamp bulbs having non-glass stopper components to avoid having a "receiver made *entirely* of glass"; (c) leading-in wires that are not "passing *through the glass*", or using no leading-in wires altogether; (d) heavy gas inside the glass bulb, such that the glass receiver is not *exhausted*.

Therefore, there can be very little doubt that the patenting surge of the post-1891 period was spurred by improvements and developments of non-infringing lamps. Indeed, new investments in developing lamp technologies that risk infringement of Edison's claims would have been unwise after the 1891 *USEL* court decision helped clarify the type of developments that would not be covered by Edison's claims. Moreover, development intensity as exhibited in Figure 3 during this period was comparable to, if not more intense than, that which ensued in the early years after Edison's invention. Franklin Pope's contemporaneous account of the surge in competing non-infringing solutions appeared in an 1893 issue of Engineering Magazine:

> "The rigid enforcement of the Edison incandescent-lamp patent by the courts, and the disinclination of the management of the General Electric Company, its present owners, to enter into any arrangement to permit the lamp to be manufactured on a royalty basis by others, has had the effect of stimulating the inventive capacity of the electricians employed by rival interests, with the result that at least two new types of lamp have been put upon the market, which apparently bid fair to be commercially successful, while it is, to say the least, extremely doubtful whether the courts will pronounce either of them to be infringements of the patent" (Pope 1893, 96).

The commercial success of non-infringing lamps actually shaped the remedies ordered by courts in patent infringement suits brought by GE, as injunctions were specifically tailored to give defendants an option to transition to the use of non-infringing lamps.[33] Such a transition was costly and was normally financed by the infringing lamp suppliers.

[33] *Edison Electric Light Co v. Mount Morris Electric Light Co*, 57 F. 642, 647 (C.C.N.Y. September 19, 1893) ("That other incandescent lamps, which are not infringements of the integral vacuum chamber carbon filament lamp of Edison would also give light, has

In the sections below we illustrate the diversity of the inventions-around and technologies that were covered in lamp patents filed after Edison's assertion of his patent in 1886. We infer from the categories shown in Figure 4 that many inventions avoided, or presumably attempted to avoid, Edison's '898 patent claims, "designing-around" the claim limitations. We also use forward citations to identify later technologies that, but for the efforts to introduce non-infringing lamp designs around Edison's ´898 patent claims, would not have been developed, or would likely have been delayed.

4.1.1 Stopper Lamps

"Stopper" lamps were the most commercially-significant design-around Edison's patent because they enabled Edison-GE rivals to retain market share through the period of enforcement of Edison's patent. Stopper lamps avoided the all-glass enclosure specified in Edison's '898 patent by having either a two-piece stem and envelope, or no stem at all (see Figure 5) (Covington 1998, 9-10). Apart from Westinghouse, companies such as Sawyer Man, Packard, and New Beacon, produced stopper lamp designs. The Sawyer-Man basic stopper lamp techniques were prior art to Edison's patent and such lamps were available on the market for several years. However, improvements in manufacturing and sealing techniques for the two-part lamp took center stage after the 1891 ruling on Edison's patent claims. Figure 5 illustrates a conceptual structure of a stopper lamp and its features that circumvent Claim 2 of the '898 Edison patent.

The major player in the non-infringing stopper lamp market was the Westinghouse Electric Corporation (Bright 1949, 90). It introduced its new stopper lamp to the market on October 6, 1892 (Westinghouse Co. 1893), two days after an appellate court had affirmed the *Edison v. USEL* district court decision. Westinghouse's then patent attorney, Charles Terry, provided an account of the company's legal non-infringement analysis, its vigorous development efforts in anticipation of the 1892 court of appeal decision and the "ingenious machines" devised at the Westinghouse Machine Company to quickly grind precision seals for stopper lamps shipped to Westinghouse's customers including the World's Fair of 1893. (Terry 1929, 68-71).

Westinghouse advertised its technical competence in stopper lamps and therefore its commercial independence from the Edison and GE interests when it won the contract to supply all electric lighting for the World's Fair Columbian Exposition that opened in Chicago in May 1893. George Westinghouse himself had been personally and closely involved in negotiating the winning bid, which under-priced GE considerably (Terry 1929, 82-84). George Westinghouse had also been directly involved in overseeing solutions for the technical challenges of improving the Sawyer-Man stopper lamp in time for the World's Fair (Skrabec 2007, 139). For example, on August 29, 1892 George Westinghouse filed a patent application for improvements in stopper lamps (U.S. Pat. No. 543,280) and on November 26, 1892 he filed for a patent on production-line vacuum pumps that he invented to speed-up exhaustion of lamp globes (U.S. Pat, No 550,359). George Westinghouse's personal involvement in these efforts signified his corporation's commitment to succeed in this non-infringement path. A measure of his company's success is the fact that for the World's Fair it manufactured "*a quarter of a million Sawyer-Man stopper lamps* for the occasion… [and] Westinghouse generated three times more electrical energy than was then being utilized in the entire city of Chicago" (Emphasis added) (Seifer 1998,119).

been repeatedly asserted; and in the Sawyer-Man Case, which was referred to on the argument and in the notice of motion, that assertion was fortified with strong affidavits." … "The motion for preliminary injunction is therefore granted; order to be settled on notice, when suggestions as to suspension for a reasonable time to adapt fixtures *to receive new* [*non-infringing*] *lamps will be entertained.* As at present advised, I am not inclined to enjoin the use of infringing lamps now in situ.") (Emphasis added).

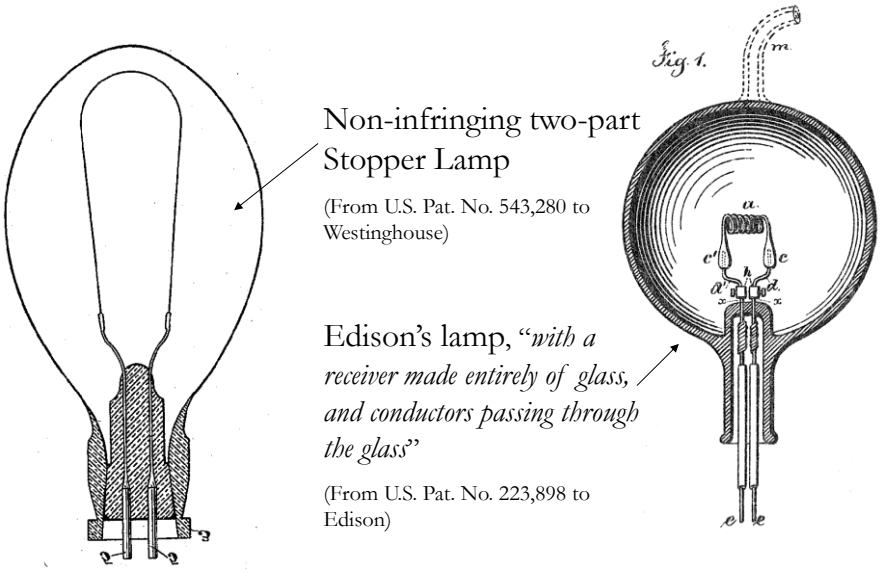

Figure 5. Comparison of Edison's all-glass globe lamp (right) and a stopper lamp (left). Edison's claim was limited to lamps with a globe made entirely of glass with conductors passing through the glass. The two-part stopper lamp did not infringe this claim because it had a stopper portion and because the conductors were not "passing through the glass."

Westinghouse's 1894 annual report following the 1893 World's Fair Columbian Exposition made clear the importance that the company attached to its control of the stopper lamp solution:

> "INCANDESCENT STOPPER LAMPS. The successful use at the World's Columbian Exposition of the stopper lamps manufactured by your company, and their large use in general lighting, have fortunately placed the company in a position to protect all of its customers from the aggressive action of the owners of the Edison patent covering the all-glass globe form of lamp. A steady advance has been made in the method of manufacture, so that your company is to-day producing a lamp which has no superior, and the use of which your officers expect to extend with great rapidity during the coming season on account of its quality and low cost of manufacture.
>
> It may be fairly stated that the peculiar methods pursued by the owners of the Edison patent in their efforts to obtain a monopoly of the sale of incandescent lamps have resulted in a disastrous failure, for the price of incandescent lamps to the public at large has been greatly reduced inconsequence of the success of your company in the production of non-infringing lamps. Your officers believe that they will be able to sell stopper lamps to the company's customers at a price not exceeding the manufacturing cost of the all-glass form, and thereby greatly promote the company's electric lighting business" (Westinghouse Co. 1894).

While the earliest versions of stopper lamps served the purpose of evading the Edison patent claims, they were not technically ideal. Some lamps suffered from lack of vacuum integrity over long operating periods due to stopper seal leaks. However, Westinghouse made significant improvements in the manufacturing processes and improved lifetime yields[34] while offering stopper lamps at a fraction of GE's price. This was economically feasible, in part through the use of lower cost leading-in wires[35] and in part through Westinghouse's lamp refurbishing strategy. The refurbishing strategy exploited the stopper lamp's advantage over the Edison lamp that it consisted of two pieces; at the end of a stopper lamp's life, the stopper could be removed and burned-out filaments could be replaced, thereby permitting reuse of the glass bulb, including the stem and connectors. This was an important cost reduction feature of the time because lamp filaments lasted

[34] For example, see U.S. Pat. No. 520,088 to Frank S. Smith of Westinghouse listed in Table 1.

[35] For effective vacuum sealing of lamp vessels made entirely of glass, the leading-in wires had to be made of expensive platinum – the only metal known at that time to have thermal expansion coefficient nearly equal to that of glass. Because non-glass stopper material could be adapted to form a satisfactory seal around iron leading-in wires, substantial cost savings were realized in stopper lamps. Frank S. Smith had earlier attempted to eliminate platinum wires even for single-piece glass lamps as described in his patent filed in 1890 (U.S. Pat. No. 471,576), in which he indicated that the cost of the platinum wires otherwise constituted 20% of the entire cost of a lamp.

no more than several hundred operating hours. Edison's single-piece glass lamp was more expensive to seal and was necessarily discarded in its entirety at the end of its filament life.[36] Edison himself recognized this disadvantage and engaged in "stopper" lamp developments of his own, resulting in his stopper lamp Patents Nos. 239,373 and 251,543. The latter patent issued nearly two years after his '898 single-piece glass patent.[37]

Historians appear to have overlooked the stopper lamp's role in a viable alternative commercial strategy to achieve competitive illumination costs through the creation of the economic niche of replaceable filament lamps. The reason for this viability is grounded in an important aspect of electrical illumination economics - the dominance of electricity costs rather than lamp costs in total cost of electrical illumination. In the early 1890's the electricity cost of powering an Edison lamp during its life was more than an order of magnitude greater than the cost of the lamp itself (Hering 1893). Furthermore, the lighting efficiency of incandescent lamps had been inversely related to their time in use. Lamps consumed more power and produced less light at the latter part of their life. The electric lighting industry had been aware of economic analysis showing that lamps should be replaced after about 400 operating hours (Hering 1893, Figures 2-3) rather than after they burned-out at 800-1200 hours of operation. Some lighting company operators had therefore adopted "best practices" along these lines because at that time, the consumer lamp industry was non-existent, and electric lamps were purchased by lighting companies who subsequently supplied them to their customers as an integral part of the lighting service.

In this backdrop, the Westinghouse new stopper lamp achieved significant electric power savings as it employed a filament treatment technology that greatly improved its filament luminance efficiency compared to Edison's untreated filaments. Westinghouse held the exclusive patent rights for the treatment process and related improvements based on the fundamental Sawyer and Man Hydrocarbon deposition process covered by U.S. Pat. Nos. 211,262 and 229,335. This technology, which was also called "flashing," had improved the filament power efficiencies by more than 30% (Pope 1894, 77-82) and enabled precise manufacturing control of the filament's electrical resistance, substantially improving operating voltage uniformity (Howell and Schroeder 1927, 79-80). These basic patents for "flashing," had earlier priority than Edison's patent and were arguably no less important in the incandescent lamp industry than Edison's patent.[38] In 1892, Westinghouse engineer Frank S. Smith[39] had developed a further improvement of the Sawyer Man flashing process (patented in U.S. Pat. No. 563,329), which provided even further efficiencies in Westinghouse's stopper lamp filaments. Generally, these treatment processes achieved their efficiency gains by facilitating higher filament temperatures during the first portion of the lamps' life. Thus, the most economical lifetimes of Westinghouse's later improved stopper lamps were shorter than Edison's lamps – around 250 operating hours (Townley 1893, 350). However, the lamp's electric power savings, partly making up for more frequent lamp replacements, coupled with the economic dominance of powering costs was an important economically mitigating combination. In January 1893, the Westinghouse Company offered rebates for unbroken, burned-out lamps, making its net price for lamp renewal only 17 cents (Westinghouse Co. 1893; Electrical Review 1893), about one third of GE's lamp price at the time. This further mitigated the disadvantage of the shorter operating life of the stopper lamp, thereby improving the stopper lamp replacement/refurbishing economic niche. Westinghouse appears to have made the stopper lamp a worthy economic rival to Edison's lamp.

---

[36] Significant commercial filament replacement business had evolved, targeting the growing installed base of Edison lamps, apparently displacing Edison lamp sales. Specialized techniques for filament replacement and lamp refurbishing were even patented (see for example U.S. Pat Nos. 363,909; 439,178; 470,471; 473,208; and 485,682). The Edison Company alleged the infringement of the '898 patent and succeeded in enjoining several lamp repair shops on the grounds that their action was not a "repair" process but a reconstruction of the Edison lamp. See *Edison Elec. Light Co. v. Davis Elec. Works* 58 F. 878, 878-9 (C.C.Mass. 1893), *aff'd* 60 F. 276 (C.A.1 1894).

[37] Edison writes in the first text column of Pat. No, 239,373: "In patents hitherto granted me are shown lamps hermetically sealed by a fusion of the glass at the union of the parts, making a permanent lamp of great durability. Sometimes, however, it may be desirable to make a lamp in which a less permanent seal is used, involving a less expensive method of sealing, and which may be taken apart readily for the substitution of a carbon or for other purposes."

[38] See Section 6.3.

[39] Smith is credited by Terry for meeting the tremendous task of manufacturing the large quantities of stopper lamps required for the World's Fair (Terry 1929, 70).

Evidence of the stopper lamp's market success comes from GE's own licensees in the field, who complained about GE's apparent complacency. GE's Michigan licensee wrote to GE in 1893 that "the new Westinghouse lamp is in use here and seems to be giving satisfaction"; and a Pennsylvania licensee wrote more bluntly: "We would like to have some positive information as to what you [GE] propose to do regarding the new Westinghouse lamp…It is of no use for you people to rest content with the conceited idea that the new lamp is of no commercial value; as it is giving very good satisfaction here, and if, as we said above, they can go ahead with it, it is going to prove a formidable rival" (Passer 1953, 161). Westinghouse continued to make substantial investments in glass and lamp factories, opening in February 1894 a new factory in Pittsburgh for mass production capacity of 10,000 stopper lamps per day (Electrical World 1894).

Another lamp vendor who was successful in supplying an independent line of development in non-infringing stopper lamps was the Beacon Vacuum Pump and Electrical Company of Massachusetts. Shortly after the Edison Electric Light Company had obtained an injunction in February 1893 against Beacon under the Edison patent (*Edison Elec. Light Co. v. Beacon Vacuum Pump & Elec. Co.*, 54 F. 678 [C.C.Mass. 1893]), Beacon introduced its non-infringing lamp, known as the New Beacon Lamp. Its lamp used a cement material for the stopper and was based on 20 patents issued in the latter half of 1893 to William E. Nickerson and Edward E. Cary. A few representative Beacon lamp patents are listed in Table 1 below. Nickerson and Carey had apparently solved several stopper sealing problems and methods of hermetically securing the leading-in wires through an impervious cement stopper. The base region was designed to reduce the heat in order to keep the cement cool. It utilized a mica shield as well as radiators. Beacon had apparently licensed the Pennsylvania Electric Engineering Co. as a second-source supplier for the stopper lamp (Covington 1998, 10). As Figure 7 shows, the New Beacon lamp had proved to be one of the low-price leaders in the market.

Stopper lamp development had also been initiated in 1891 at Western Electric Co. by Charles E. Scribner, a prolific inventor with hundreds of patents to his name. He developed various stopper lamp solutions (see U.S. Patent Nos. 563,319 and 563,321) and subsequently pioneered a new class of hermetically sealed connectors for implementing non-infringing two-part lamps. This technique is described in his U.S. Patent No. 584,750, and listed in Table 1 as having been cited by downstream patents as the pioneering prior art for hermetically sealed connectors.

Although not all two-part lamp improvements were commercially exploited, the stopper lamp fulfilled a need for alternatives to Edison's lamp. Its economic viability and utility had proven satisfactory, especially when coupled with filament refurbishing strategies. Although its use diminished after the expiration of Edison's patent in November 1894 (Terry 1929, 71), improvements in stopper lamps for replacing filaments were apparently commercially important well into 1897.[40] Westinghouse's and Beacon's considerable success in supplying new stopper lamps provides evidence that GE's enforcement of the Edison patent did not confer on it the position of being the sole producer of a product for which there were no close substitutes. Moreover, it is clear that technical advances in incandescent lamps from 1891-1894 were far from being under the control of GE.

4.1.2 Lamps with no leading-in wires passing through the glass

Within this section are described four designs-around Edison's claim on 'conductors passing through the glass' (Figure 2) that had little commercial importance in the lamp business of Edison's time, but very significant presence as prior art for later and distinct technological developments.

Non-glass stoppers, such as that in the New Beacon lamp introduced in 1893, avoided infringement of Edison's claim because the stoppers were made of cement material and the leading-in wires were not "passing through the glass." As with the single-piece glass Edison lamp, the sealing problems addressed by the designers of these lamps were by no means trivial. The hermitical seal around the wires required

[40] See U.S. Pat. No. 605,498 filed on Jul 17, 1897, describing a design for an annular lamp base structure that permits low cost filament replacement.

development of strong adhesion techniques and finding compositions with thermal expansion coefficients of the wire matching that of the surrounding stopper cement material.

Edward A. Colby used a magnetic induction transformer technique in a design-around Edison's claims that at the same time avoided the difficulty of making a satisfactory glass-to-metal seal. His AC lamps had the primary winding of a transformer on the outside of the bulb and the secondary connected to the filament on the inside. Colby's lamps may not have been commercially successful because of excessive transformer losses incurred at the low AC frequencies available at that time, but a similar principle is used in more efficient, modern high frequency induction lamps in which transformer action is used to magnetically induce a current directly in the gaseous ring. But Colby did obtain a series of patents on his technology, three of which are listed in Table 1 below. The first, U.S. Pat. No. 498,929, was cited as the pioneer prior art reference in a photoflash lamp patent filed more than 63 years later, describing a class of camera flash lamps that, in a similar manner, required no direct electrical connection for activation.[41]

It is not widely known that Nikola Tesla had invented the celebrated Tesla Coil in order to light incandescent lamps by *electromagnetic* induction. While Tesla did not explicitly indicate his motivation, he did so without direct connection of two conductors "passing through the glass" (Figure 2). Tesla's patent for the Tesla Coil – a high-frequency and high voltage generator, is in fact an electric lighting patent for which Tesla applied in 1891 and later received a grant of U.S. Patent No. 454,622. Although Tesla describes lamp embodiments in which only one conductor passes through the glass globe,[42] he states in page 3 of the '622 patent that "there need not be a direct connection [to the filament], for the carbon or other illuminating body may be rendered luminous by inductive action of the current thereon..."

As shown in Table 1 and Appendix B below, Tesla's patents resulting from his non-infringing lamp developments have been cited in modern electrodeless light bulb patents as pioneering prior art in the field. Tesla's celebrated demonstration in New York in 1891 of the first electrodeless lamp has been recognized as the seminal pioneering event in this segment of the lighting industry.[43] As Appendix B also shows, the Tesla Coil disclosure was relied upon by, and likely has limited the scope of, *at least 530 subsequent patents in wide technology areas*. It was cited as prior art in a patent infringement litigation case,[44] and even constituted prior art barring a patent in at least one patent application, which the U.S. Patent Office rejected in 1901.[45] Tesla later used his Coil in his pioneering 1897 invention of the synchronized spark plug ignition system for internal combustion engines (U.S. Pat. No. 609,250), the underlying technique of modern automobile ignition systems.

On March 2, 1892, Edward Pollard filed a patent application on a lamp without leading-in *wires* (U.S. Patent No 485,478). Instead of platinum wires, it utilized powdered silver films fused into the glass as conductors. Several manufacturers, including the Packard Company, Imperial Electric Manufacturing Company, the Buckeye Electric Company and the Boston Incandescent Lamp Company were making the lamp (Covington 1998; Covington 2006). In January 1894, the Buckeye Electric Co. introduced its version of this lamp to the market with considerable national publicity (Electrical Engineer 1894a). GE's affiliate, the Edison Electric Light Company, filed suit against the Boston Incandescent Lamp Company in a federal circuit court in Massachusetts. Edison prevailed and obtained an injunction on June 11, 1894. In its opinion, the court pointed out that Edison's claim does not recite "wires" but rather the broad term "conductors"[46]

---

[41] See item (q) in Appendix B.

[42] Even a single conductor passing through the glass is easily arguable as non-infringing, as Edison's claim recites plural *conductors* passing through the glass.

[43] (Wharmby 1993)(By creating a high frequency field in a room, Tesla demonstrated that "the mere suspension of the tubes in the room would afford the desired illumination.").

[44] *Marconi Wireless Telegraph Co. of America v. National Electric Signaling Co.* 213 F. 815 (D.C.N.Y. 1914) (Distinguishing over Tesla's prior art and finding the patent not invalid and infringed)

[45] *Ex Parte Verley*, 99 OG 1621 (Sep 11, 1901) (Patent Commissioner upholding examiner rejection, finding obviousness in view of Tesla's '622 patent), *Aff'd In re Verley*, 19 App.D.C. 597 (C.A.D.C. 1902).

[46] *Edison Elec. Light Co. v. Boston Incandescent Lamp Co.*, 62 F. 397, 398 (C.C.Mass. 1894) ("While Edison uses platinum wire, he does not limit himself to this form of conductor in his claim. The language of the claim is 'conductors passing through the glass,' and

("conductors passing through the glass", Claim 2 Figure 2). This particular attempt at non-infringement failed because the lamp was found to *literally* infringe Edison's second claim.

4.1.3 Gas-filled, or non-vacuum lamps

In this section we have again designs-around with little commercial importance in the lamp business of Edison/GE's day, but of great significance in later developments. During 1893-1894 some lamp manufacturers believed that a way to avoid infringement of the Edison patent was to turn back from the vacuum lamp to a gas-filled lamp and so attempt to evade that element of Edison's Claim 2 that specified a lamp with a receiver "from which … the air is exhausted." Another problem addressed by certain gas-filled lamps was the progressive blackening due to carbon vapors of the inner surface of the evacuated bulb. In an attempt to avoid infringement and to address the blackening of lamps, the Star Electric Lamp Company introduced the "New Sunbeam" lamp in 1893 filled with heavy gas, apparently hydrocarbon (Bright 1949, 132; Covington 2005). In 1894, the Waring Electrical Company introduced the 'Novak' lamp, which contained a low-pressure filling of bromine. The lamp was based on John Waring's patent, No. 497,038, for which he applied on January 4, 1893. The bromine-filled Waring lamps operating at low voltage were said to have improved longevity of the carbon filament and diminished blackening of the lamp's glass (Anthony 1894). However these assertions were challenged on the specific technical evidence.[47]

Waring was unable to continue production for long because Edison/GE obtained an injunction on the grounds that the lamp was made from a receiver from which, prior to filling with small amounts of bromine, *first* "the air is exhausted, for the purposes set forth" in Edison's '898 patent specification and recited in his second claim.[48] Although Waring urged that unlike Edison's lamp, his lamp did not use a vacuum, the court construed Edison's claim according to its plain language. The claim did not recite a lamp receiver exhausted to a vacuum but rather a lamp receiver "from which receiver the air is exhausted."

Although Waring's pioneering work on gas-filled lamps did not produce commercially useful results with carbon filament lamps in his day, his approach became important prior art when two decades later metal filaments were successfully introduced in an enclosed inert gas atmosphere (Bright 1949, 132). As shown in Table 1 and Appendix B below, Waring's attempt at non-infringing lamp developments, resulted in a gas-filled lamp patent which has been cited as the pioneer prior art in at least 6 patent cases relating to inert gasses and new filament materials. By using nitrogen-filled lamps in conjunction with a new construction of a tungsten filament, Irving Langmuir perfected Waring's approach, ushering-in higher efficiency tungsten lamp technology. Langmuir's key tungsten filament technology was patented on April 18, 1916 (U.S. Pat. No. 1,180,159) and the patent owner, GE, introduced it commercially as the new Mazda C lamps (Bright 1949, 318-322). GE asserted Langmuir's patent in a 1919 case,[49] in which the Waring '038 patent was used as basic prior art for gas-filling benefits. In sustaining the patent, the court distinguished Langmuir's claims over Waring's '038 prior art, necessarily preventing overbroad construction of Langmuir's claims.

A radical variant design-around within this class of non-infringing designs was the attempt by Francis M.F. Cazin to avoid altogether the clause in Edison's '898 patent Claim 2 that specified "glass receivers from which the air is exhausted". In a series of patent applications that Cazin filed immediately after the Edison injunctions took effect, he described lamps employing filaments embedded in hermetically sealed encasing structures, using solid insulators such as mica. Cazin's technology also involved coating filaments with certain oxides but apparently his designs did not yield commercial success. This was probably because the solid

---

therefore, on its face, the claim covers all kinds of material capable of carrying the electric current. If the claim had been limited to conductors of platinum wire, as the filament is limited to carbon, the case might be different.")

[47] *See* (Howell 1894, 175-176) (disputing assertions that bromine gas fillings into lamp bulbs had the 'gettering' effect of decreasing filament decomposition and bulb blackening).

[48] *Edison Elec. Light Co. v. Waring Elec. Co.*, 59 F. 358, 364 (C.C.Conn. 1894) (Finding that the Waring lamp with Bromine gas infringes Claim 2 of Edison's patent because Waring "exhausts the atmospheric air as nearly as possible" for the purposes set forth in Edison's specification and the desired Bromine gas was then admitted in small amount).

[49] *General Electric Co v. Nitro-Tungsten Lamp Co.* 261 F. 606, 610 (D.C.N.Y. 1919) (Distinguishing over Waring's '038 patent as prior art and finding the Langmuir patent valid and infringed).

insulator's direct thermal contact with the filament prevented it from reaching sufficiently high temperatures for efficient incandescence. Table 1 and Appendix B below show that his pioneering inventions fostered further efforts on his part but we have found no reference to his patents by other inventors. Unlike, for example, Waring's '098 patent, Cazin's non-infringing explorations apparently resulted in a technological "dead-end."

4.1.4 Non-carbon filament lamps

Prior to Edison's invention there had been attempts to use platinum filaments to produce a practical commercial lamp but these had all failed. In Edison's '898 patent on his commercially successful lamp design, a filament of carbon is an essential limitation in not only Claim 2, but in *all four* of the '898 patent claims (see Figure 2). The '898 patent would be decisively and legally evaded if a commercially-viable metal filament lamp could be designed.

Hirst credits Poland as the first to attempt using a non-carbon filament after Edison's success with carbon filaments (Hirst 1908). Only 10 months after Edison asserted his patent against USEL in 1886, Lawrence Poland filed in 1887 his patent application, later issued as U.S. Pat. No. 432,710, describing lamp filaments made with iridium. There can be little doubt that his lamp was designed to evade Edison's claims as it also employed a two-part stopper design. Several non-infringing attempts to use filament materials other than carbon had taken place by the early 1890s and these are listed in Table 1 and described below.

In 1888, Rudolf Langhans was working in Germany on substitutes for carbon for lamp filaments. He developed lamp filaments having cores of conductive oxides of earth metals coated with carbon, silicon, boron or a composition thereof and patented it under U.S. Pat. No. 420,881. The Thomson-Houston Electric Company brought Langhans to America in 1889 to develop this technology into a non-infringing substitute for carbon (Bright 1949, 121). Although he was ultimately commercially unsuccessful, a contemporary scholar of incandescent metal filaments opined that Langhans' experiments brought him "within a hair's-breadth of producing a lamp the efficiency of which would have been as high or higher than that of the best type of metallic filament lamps at present [1912] obtainable" (Barham 1912, 30). Nevertheless, Langhans' pioneering work in conductive metal oxides for non-infringing lamp filaments did become fundamental prior art for later developments in semiconductor devices and thin film resistors, as shown in Table 1 and Appendix B.

Westinghouse also resorted to hiring a promising outsider to pursue this non-infringing filament development path. Alexander De Lodyguine was hired by Westinghouse to work on coating platinum with other metals for use in incandescent lamp filaments (Bright 1949, 120). On January 4, 1893 he filed a patent application that later issued as U.S. Pat. No. 575,002, covering a process for coating platinum wires with rhodium, iridium, ruthenium, osmium, chromium, molybdenum and tungsten. We found from our examination of the incandescent lamp patent category that *this appears to be the first time that tungsten was suggested as a candidate for inclusion in lamp filaments*. De Lodyguine filed a further patent application on April 10, 1894, later issued as U.S. Pat. No. 575,668 in which he detailed a process for constructing filament metal "fillet" with coatings composed of molybdenum and tungsten, the metals that he had found best adapted for use in his new manufacturing process. The eight downstream references to De Lodyguine's patents in Appendix B show that his pioneering work on metal filaments including tungsten, laid the foundation for the major advances in tungsten incandescent lamps as well as methods for making composite conductors and metallic joints. As further evidence of their fundamental nature, De Lodyguine's patents were the key prior art considered in GE's patent infringement suits that asserted its basic tungsten lamp patents.[50]

Original contributions to the non-infringing filament development path also came from within Edison/GE's research organization: Jonas W. Aylsworth was a chemist serving as Edison's chief chemical experimenter

[50] *General Electric Co. v. Laco-Philips Co.* 233 F. 96, 103 (C.A.2 1916) (Asserting the Just & Hanaman tungsten lamp patent 1,018,502); *General Electric Co. v. P.R. Mallory & Co.* 298 F. 579, 583 (C.A.2 1924) April 07, 1924) (Asserting the tungsten patents of Just & Hanaman – 1,018,502, and of Langmuir – 1,180,159).

from 1887; he had his own chemical laboratory and often worked independently (Israel 1998, 272, 314). As Edison's development team became part of the General Electric engineering organization, Aylsworth became the chemist in charge of the carbonizing department of the GE factory at Harrison New Jersey. In 1894 he independently pioneered a Chemical Vapor Deposition (CVD) process for coating filament cores with the metals niobium, tantalum, molybdenum, titanium or zirconium. On July 27, 1894 he filed applications for patents covering this process, which patents issued as U.S. Pat. Nos. 553,296 and 553,328. Aylsworth describes the use of carbon or platinum as cores for the deposition process, permitting in the latter case the construction of non-carbon metallic filament. Based on engineering society records, Aylsworth subsequently formed a startup named Aylsworth & Jackson Incandescent Filament Manufacturers in Orange New Jersey. His partner, Francis E. Jackson, had previously been in charge of the lamp-testing department of the GE factory at Harrison New Jersey. In late 1896 Aylsworth & Jackson joined the Incandescent Lamp Manufacturers Association as one of the 10 independent members of this association formed by GE (Stevens 1912, 595). Although Aylsworth's attempts to manufacture niobium filaments (Electrical Engineer 1896) using his CVD process had apparently met with no commercial success, at least 17 downstream references cite his patents as pioneer prior art (see Table 1 and Appendix B). Aylsworth's non-infringing filament developments laid foundations in a new field of metal CVD, in which he has been recognized as a pioneer (Jones and Hitchman 2007, 2).

Within this category of non-infringing filament designs-around, mention must also be made of a design-around that ingeniously sought to dispense with the filament altogether. In late 1894 Daniel McFarlan Moore invented a phosphorescent electric lamp, the forerunner of modern fluorescent lamps (Bright 1949, 221; Hammond and Pound 1941, 262). His series of patents on phosphorescent lamps and related regulators were filed shortly after the Edison patent expired in November 1894 (U.S. Pat. Nos. 548,130; 548,131; 548,132; 548,133 and 548,574; 548,575; 548,576) and for this reason we omit them from Table 1 and Appendix B. However, Moore had been working on his inventions during a period in which many researchers had been looking for alternatives and improvements to Edison's lamp and Moore also started a company in an attempt to commercialize his lamp. There is little doubt that these were in part efforts to "design around" Edison's claims that led to the conception of a whole new branch in the illumination industry – fluorescent lamps.

Edison's '898 Claim Elements	Non-infringing Improvement or Attempt to Design-Around Edison's Claim	Sponsor, assignee or user of the improvement	Inventor(s)	U.S. Patent No.	Filing Date (in 18YY)	Number of downstream patents citing or relying on this patent (See Appendix B)
Carbon Filaments (all claims)	Developed non-Carbon filaments by pioneering Chemical Vapor Deposition (CVD) to deposit the metals Niobium, Tantalum, Molybdenum, Titanium or Zirconium.	Aylsworth & Jackson Incandescent Filament Manufacturers	Jonas W, Aylsworth	553,296	27-Jul-94	16
				553,328	27-Jul-94	1
	Developed non-Carbon filaments made from metal deposits of Molybdenum, Tungsten, Rhodium, Iridium, Ruthenium, Osmium and Chromium	Westinghouse Electric Corp.	Alexander De Lodyguine	575,002	4-Jan-93	4
				575,668	10-Apr-94	4
	Developed filaments having cores of conductive oxides of earth metals coated with either Carbon, Silicon, Boron or a composition thereof	Thomson-Houston Electric Co.	Rudolf Langhans	420,881	5-Apr-88	4
… with a receiver made *entirely of glass*, (Claim 2)	Novel hermetically sealed connector for a two-part lamp	Western Electric Co.	Charles E. Scribner	584,750	24-Apr-93	4
	Improved stopper and conductor seal for a two-part lamp	Westinghouse Electric Corp.	Frank S. Smith	520,088	28-Jun-93	
… and *conductors passing through the glass* … (Claim 2)	Developed lamp stem with improved cement seal and support for leading-in wires not passing through the glass	Beacon Vacuum Pump and Electrical Co.	William E. Nickerson	500,670	1-Apr-93	1
				501,531	6-Apr-93	1
				503,671	17-Jul-93	1
				507,558	5-Aug-93	1
			Edward E. Cary	500,053	7-Apr-93	1
	No wires passing through the glass. Powdered silver fused in glass serve as electrical conductors to power the filament	Buckeye Electric Co.	Edward Pollard	485,478	2-Mar-92	5
	No wires passing through the glass. Secondary closed-coil filament powered from a primary coil by magnetic induction		Edward A. Colby	498,929	15-Feb-93	1
				499,097	15-Feb-93	2
				558,634	21-May-94	1
	Invented the celebrated Tesla Coil generator to light incandescent lamps by electromagnetic induction, without connection of two "conductors passing through the glass."	Westinghouse Electric Corp.	Nikola Tesla	454,622	25-Apr-91	13
						519
				514,170	2-Jan-92	1
… from which receiver *the air is exhausted*, for the *purposes set forth* (Claim 2)	Avoiding vacuum in the glass receiver by employing a low-pressure filling of Bromine. Heavy gases such as Bromine reduce bulb blackening.	Waring Electric Co.	John Waring	497,038	4-Jan-93	6
	Developed filament hermetic encasing structures using solid insulators such as mica. No glass receivers "from which the air is exhausted" were used.		Francis M. F. Cazin	523,460	7-Dec-92	7
				523,461	24-Jul-93	7
				566,285	24-Jul-93	7
Total number of patents in survey				**22**		**607**

Table 1 Sample of inventions discussed in the text that both designed-around Edison's patent and fostered significant downstream inventions. See Appendix B for an expanded version of this table, listing patents and adjudications that cite these 22 patents.

4.2 The crowding field of electric incandescent lamp manufacturers

The subdivisions of the previous section illustrate the technical diversity of development paths initiated by the sometimes commercially successful efforts to design-around Edison's '898 patent. One might expect the commercially successful designs-around the '898 patent to limit the market control attainable by the enforcement of the '898 patent and so in this and the following sections we assess other forms of commercial evidence that bear on this question.

Figure 6 shows that the number of active firms in the field of incandescent lamps *almost doubled during the period of this patent's enforcement* and therefore more vigorous competition in the field took place *after* Edison's patent was upheld by the courts. We suggest that this rise occurred when it did because the economic incentive to market new and non-infringing lamps existed only after GE began enforcing Edison's patent.

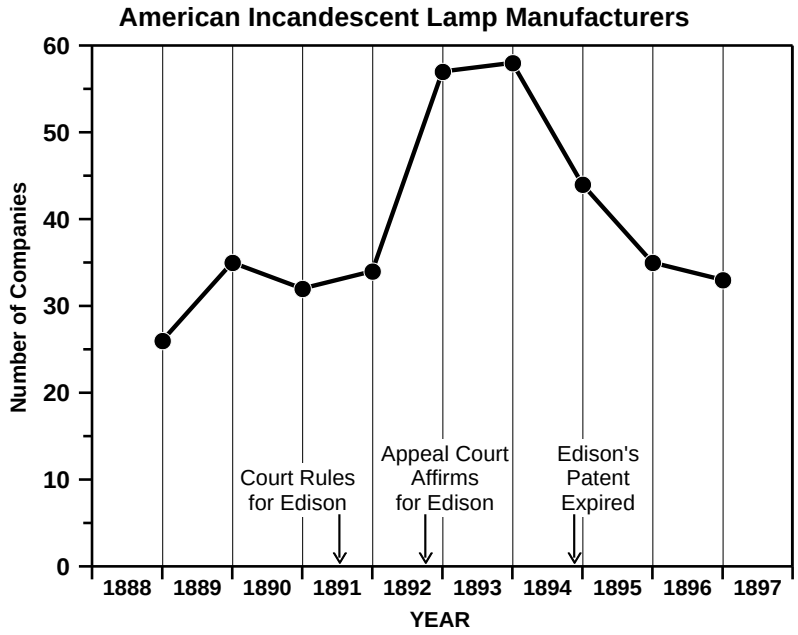

Figure 6 The number of active incandescent lamp manufacturers in America by year. *Source*: (Bright 1949, Table XI at 92).

4.3 The price decline of incandescent lamps

Figure 7 shows sales prices for incandescent lamps from 1881 to 1905. The Edison/GE prices are shown in solid staircase line, depicting the complete set of annual price data disclosed by Henry Schroeder (Schroeder 1911, 428-9). Schroeder was GE's sales engineering executive (Covington 2003) and his data is independently corroborated for specific dates by other entries in the figure, including a source in the Edison Papers from April 1889. The important December 1893 GE price reduction to 32½ cents is also corroborated precisely by trade articles published weeks later (Electrical Engineer 1893c; Electrical Engineer 1893a).

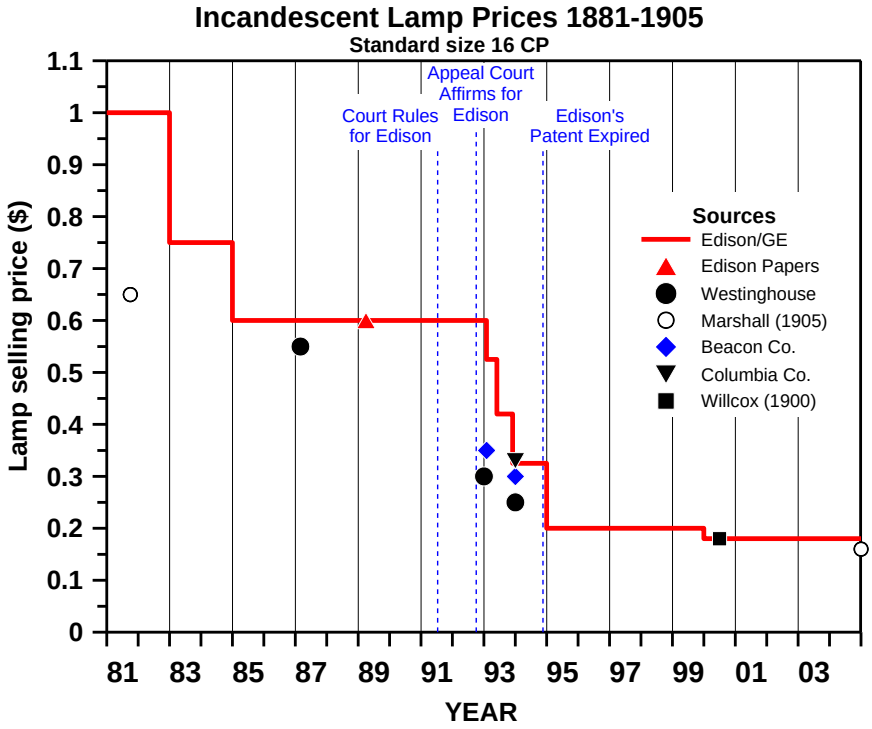

Figure 7. Selling prices of standard 16-candle incandescent lamps between 1881 and 1905. The sources for the data in order appearing in the legend are: "Edison/GE": (Schroeder 1911, 428-9), "Edison Papers": 1889 at D8939ABB1; "Westinghouse": 1887 at D8732AAL, 1893: (Electrical Review 1893), 1894: (Electrical Engineer 1893b); "Marshall (1905)": (Marshall 1905, 21); "Beacon Co.": 1893: (Beacon Co. 1893), 1894: (Electrical Engineer 1894c); "Columbia Co.": 1894: (Electrical Engineer 1894b); "Wilcox (1900)": (Willcox 1900, 293).

As the figure shows, GE cut its lamp prices three times in 1893, the year for which Bright had reported only a single price of 50 cents from unknown vendor(s). The first GE price cut that year (to 52½ cents) was made in February, only a couple of months after Westinghouse introduced its non-infringing stopper lamp in full force as a response to Edison's injunction ruling of October 1892. Also shown are the price reductions of non-infringing lamps from Westinghouse and the Beacon Company, undercutting GE's prices by as much as 50%. The remarkable aspect of this 14-year long price trajectory is that *the most precipitous price declines took place during the enforcement of the Edison patent*. The sequence of events during this period suggests that GE was responding to, rather than leading, these price moves.

4.4 A stable Edison/General Electric's incandescent lamp market share

As noted earlier, Edison and his successor GE had refused to license competitors. Had Edison's patent constituted a barrier around which rival incandescent lamp manufacturers could not have traversed, their lamp sales market share would have declined precipitously after GE began enforcing the patent. We found evidence, presented in Figure 8 that shows that no dramatic decline had occurred.

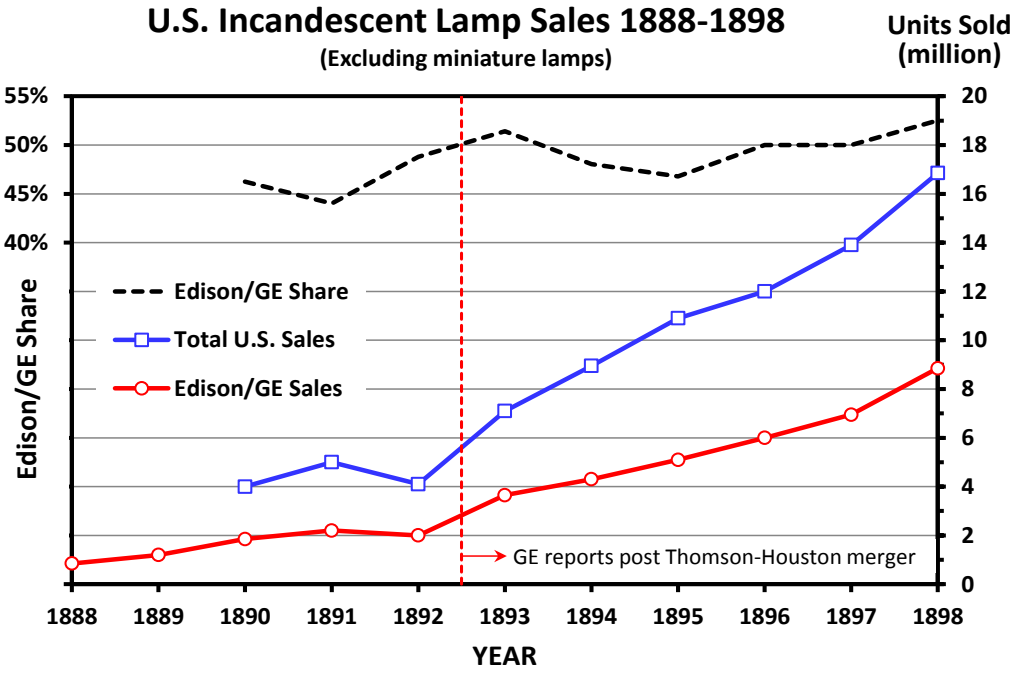

Figure 8. Total U.S. Incandescent lamp sales and the market share of the Edison and General Electric Company. The market share percentage graph for Edison/GE corresponds to the left coordinate axis. Note that the transition from 1892 to 1893 in Edison/GE reported data includes for the first time the sales of the Thomson–Houston company, which merged with the Edison Company to form GE in 1892. *Sources*: Edison/GE sales: (Schroeder 1917, Fig. 2); Total U.S. sales: (Liston 1918, Fig. 84).

Figure 8 shows the U.S. incandescent lamp unit sales from 1888 to 1898, including Edison/GE's share. Note that while there was a decline in sales in 1892, the decline was across the board, including in Edison/GE's sales, consistent with the substantial decline in general building infrastructure expenditures in 1892 that preceded the financial panic of 1893.[51] Note also that the slight increase of Edison/GE's share to about 52% in 1893 was due to the inclusion of Thompson-Houston sales in the GE figures for the first time. Moreover, it is remarkable that GE's share in 1894 (through most of which Edison's patent was in force) declined appreciably, perhaps due to the aggressive underpricing of its competitors' non-infringing lamps (see Figure 7). The data in Figure 8 is also consistent with Bright's statement that in 1896 "the lamp division of General Electric itself handled about half the domestic lamp business" (Bright 1949, 104) and with Passer's 50% estimate of GE's share at that time (Passer 1953, 162).

5 Improved certainty of Edison's claim boundaries spurred design-around investments

The evidence presented in subsections of Section 4 confirms the general proposition advanced in Section 2.1: we have found substantial evidence that much design-around activity was given impetus once legal certainty as to the value and precise boundaries of Edison's patent claims had been established by the 1886 filing of suit against USEL and the court judgments of 1891 and 1892. If we return to the interpretation of the patenting activity plot in Figure 4 designated as "Other Mfrs. Design-Around" and assume that this plot is indicative of investments in design-around solutions,

[51] See (Whitten 2010) (Building construction declined irregularly since April 1892, which transmitted to the rest of the economy, "dampening general activity through restricted investment opportunities and curtailed demand for construction materials." A similar "uneven downward drift in business activity after spring 1892 was evident from a composite index of cotton takings (cotton turned into yarn, cloth, etc.) and raw silk consumption, rubber imports, tin and tin plate imports, pig iron manufactures, bituminous and anthracite coal production, crude oil output, railroad freight ton mileage, and foreign trade volume.").

we make two important observations. First, an increase in design-around investments is readily seen during the final stages of litigation and after the district court decision in July 1891. Second, an onset of a much larger investment in design-around occurred immediately after the decision at the appeals court in October 1892. Importantly, a mere pronouncement by the lower court of its claim interpretation and ruling had not been nearly as effective in fostering design-around investments as the appellate decision affirming it. This plot shows that *the design-around investment rate following an appellate affirmance decision was about three times that which took place in connection with the lower court decision.*

This observation is consistent with other investment decision events that followed the October 1892 decision to affirm. Westinghouse decided to introduce its new stopper lamp to the market only after it was certain of the legal status of Edison's claims – on October 6, 1892,[52] two days after an appellate court had affirmed the *Edison v. USEL* district court decision. These facts show that substantial legal certainty is a prerequisite for making substantial investments in design-around.

6 Did Edison's patent block downstream technology development?

Several authors have characterized Edison's incandescent lamp patent as a broad scope patent that blocked downstream technology development. Leading the group are Robert Merges and Richard Nelson (Merges and Nelson 1990; Merges and Nelson 1994), whose evidence and inferences we discuss in more detail below. Carrier gives Edison's patent case as an example of patents that "would limit post-patent innovation" (Carrier 2002, 830) and Leibovitz describes Edison's actions as translating "his development lead into a lasting competitive advantage, which he uses as he pleases to maintain high prices and block others from entering the market" (Leibovitz 2002, 2253). But Merges and Nelson's work is particularly important for two reasons: its claims to provide illustrative empirical evidence in six fundamental technologies for their thesis that "the granting of broad patents in many cases has stifled technical advance" (Merges and Nelson 1990, 877) – claims that have earned their thesis a celebrated position as "a staple in the scholarly literature on patent law."[53] Secondly, Merges and Nelson (hereinafter M&N for brevity) present the Edison patent case as an example of a pioneer patent that the U.S. Patent Office and the federal courts gave excessively broad claim construction, which M&N argued "included [judicial] finding that after-developed technology was equivalent to that specified in the claims" (Merges and Nelson 1990, 857 note 81). They argued that "the broad Edison patent slowed down progress in the incandescent lighting field" and that "broad patents [such as Edison's] do have a significant impact on the development of a technology and hence on industry structure, and this should be reflected in those doctrines that collectively determine patent scope" (Merges and Nelson 1990, 887).

M&N's thesis is essentially a form of an "anti-commons" theory, highlighting a purported tragic outcome of broad patents' exclusive power causing underuse of the invention and hence the stalled development of a technology. Their thesis has gained widespread traction in the patent law literature (Howells and Katznelson 2012) for it appears to contradict the widely-accepted rationale for the existence of patent law: to provide an incentive for innovation, for investment in, and development of, new inventions. M&N's thesis has so far gone unchallenged: at the time of writing, an inspection of titles and abstracts and selected papers from over 325 ISI citations to their 1990 and the 1994 articles did not show any citing paper to have critically re-examined the empirical basis for their conclusions. M&N's paper's singular contribution is widely understood; Jaffe recognizes the 1990 paper as the "only paper that I know of that presents evidence on how patent scope affects innovation" (Jaffe 2000, 547). In short, it is evident that M&N's thesis continues to influence the

[52] *See* Westinghouse's open letter to users of incandescent lamps in (Electric Light 1892).

[53] Indiana University Maurer School of Law Conference, *Patent Scope Revisited: Merges & Nelson's "On the Complex Economics of Patent Scope," 20 Years After.* (September 23-24, 2010) ("Taking Kitch's work as their model, Merges & Nelson crafted their own new answers to the question of how patent scope decisions affect technological development. They concluded that the law should strive to preserve competition for improvements, even at the expense of eroding incentives for pioneer firms to some extent."). At www.law.indiana.edu/front/special/2010_patent/index.shtml.

policy debate over what is, and what should be, the role of patents in contemporary technological change. In another paper we refute with *evidence* M&N's underlying findings and thesis in *all five* of the empirical examples they cite (Howells and Katznelson 2012). Here, only the evidence that M&N cite for the downstream blocking effect of the Edison patent is considered in detail.

We recognize that other business and technology historians do not view the enforcement of Edison's patent as having had such an effect, but their work has been ignored in the legal journal publications that propagate the downstream block thesis. Bernard Carlson writes that the formation of GE cannot be attributed to the patent situation in the industry at that time and that "even though the court had found in favor of Edison in the incandescent-lamp case, both Westinghouse and Thomson-Houston had found ways to work around the Edison patent" (Carlson 1991, 299). The historian Harold Passer, who described the adjudication of Edison's patent in 1891 and 1892, understood that the existence of Westinghouse's non-infringing lamp and of new market entrants during the period of the patent's enforcement meant that "the influence of the patent was small" on the growth of the industry (Passer 1953, 154-155).

Instead of Carlson's and Passer's evidence and conclusions on the influence of the '898 patent, M&N's thesis relies throughout its exposition of the Edison patent example on the history by Arthur Bright of the electric lamp industry (Bright 1949). We acknowledge that Bright has been recognized as a key source of historical *data* on the electric light industry. Unfortunately, as we show below, Bright's book often draws contradictory, unsupported, and at times absurd *conclusions* that are not supported by its data. Moreover, some of the data in Bright's book is lacking or unreliable. The potent combination of selective use of Bright's data and citation of his book's unsupported conclusions contribute to M&N's revisionist account of the Edison patent history with counterfactual "findings" on all the topics of Section 4: downstream developments, competition, lamp prices and market share.

6.1 A standard for determining whether patent-induced, downstream development block has occurred

There is a fundamental issue at stake here: what is the standard of evidence required to support the allegation that the enforcement of a particular patent has blocked related downstream technology development? Its importance is such that we set out here the standard of evidence to be applied to assertions that blocking occurred and that technical advance has been 'stifled.' From the outset, it is important to distinguish the type of evidence that clearly *does not* establish proof of such claims. The mere existence of a patent dispute *per se* establishes nothing of the kind. Equally unavailing is evidence that an alleged infringer may have spent substantial resources over a protracted period in defending the patent infringement suit, or that the case received widespread publicity. Similarly, evidence that infringing products which were not otherwise an advance[54] over the extant patented technology were barred from use does not meet the 'proof of downstream technology blocking' standard – it only shows that the patent system worked as intended to exclude unlicensed infringers from exploiting the invention. Furthermore, the issuance of a court injunction "with accounting" that does not take actual effect during the pendency of an appeal does not normally block an alleged infringer from using the accused improvements because a temporary license sanctioned by the court effectively authorizes such continued operation. In addition, evidence that stifling of development may have occurred due to activity involving anti-competitive combination or trust formations does not meet the patent blocking standard *per se*. One must not confuse evidence of market power abuse (perhaps even misuse of patent licensing practices) that have little to do with the specific scope or exclusion power of the patent in question, with evidence of its downstream technology

[54] Determinations of whether a given product accused of infringement constitutes an advance is not merely subjective because courts are often required to arrive at such findings of fact based on the evidence and the expert testimony.

blocking. We now turn to two standards that we believe are most applicable in determining whether patent blocking of downstream development occurred.

6.1.1 Whether commercial activity evidence supports a conclusion of blocking

An allegation of blocked development should as a minimum be supported by evidence from the relevant legal, economic and commercial variables, ostensibly controlled by 'blocking patents', such as production data, market share data, price trends, patenting activities of related downstream technologies, patent licensing and the number of market participants. M&N's paper suggest some of these correlates by juxtaposing what it calls "pluralistic rivalrous system versus one in which technical advance is under the control of one or a few organizations" (Merges and Nelson 1990, 879). If the patent holder had not licensed others under the patent, evidence of *at least one* of the following types must exist as a minimum threshold required to support a conclusion that technical downstream advance had been suppressed or retarded by enforcement of the patent:

1) Evidence that the patent covered a product for which there were no close commercially feasible non-infringing substitutes. If such close substitutes were available, the patent clearly cannot have blocked developments in the field to which it pertained.

2) Evidence that the patent owner comprised the entire industry to which the patent pertained, at least during the successful enforcement of the patent. If other firms had lawfully participated in such industry, their developments could not have been blocked, by definition.

3) Evidence that the patent owner was a 'price maker' and had considerable control over the price because through the patent exclusion power it could control the quantity supplied, and had the ability to fix the price of the product in the market.

4) Evidence that technical advance in areas to which the patent pertained were under the control of the patent owner. If technical advances in the field were introduced by other firms in the industry, their developments were not blocked, by definition.

6.1.2 Whether the facts in alleged blocking cases lend themselves hypothetically to remedies purported to alleviate such blocking

M&N's thesis advances the policy recommendation that the patent office and the courts should "exercise discretion" and grant narrower claims or adopt the Reverse Doctrine of Equivalents in the courts to reduce patent scope in its alleged cases of broad scope patent blocking. Elsewhere, one of us (Katznelson 2012) shows that if that policy recommendation should make sense, the evidence in M&N's cases should have fact-patterns that are amenable to the application of these doctrines. This legal inquiry is beyond the scope of this paper but the result is that these purported patent scope-reduction doctrines could not have been applicable to the fact-patterns in any of the cases in M&N's papers including the Edison patent case (Katznelson 2012).

6.2 Commercial activity evidence in the Edison case shows that no downstream development block occurred

We now apply the standard identified in Section 6.1.1 above, showing that none of the four criteria support a conclusion that technical downstream advance had been suppressed or retarded by the enforcement of Edison's patent.

6.2.1 Close commercially feasible non-infringing substitutes were available

We observe that Edison's patent covered a technology *for which there were close, commercially feasible and non-infringing substitutes*. The evidence clearly shows that the design-around Edison's claims resulted

in the commercial success of the non-infringing stopper lamp described in Section 4.1.1 and other lamps with no leading-in wires passing through the glass, as described in Section 4.1.2. Competitors sold incandescent lamps in vigorous competition with Edison/GE as Figure 7 shows, and were able to retain a substantial market share doing so, as Figure 8 shows. It is clear that close commercially viable and successful non-infringing substitutes to the Edison lamp were available on the market.

6.2.2 The patent owner did not comprise the entire industry to which the patent pertained

While the Edison patent holder, GE, did not license other manufacturers, it did not comprise the entire industry to which the patent pertained: several competing firms including Westinghouse, Beacon and Columbia sold non-infringing lamps in vigorous competition with GE during its successful enforcement of the Edison patent as shown in Figure 7 and Figure 8. M&N's contention, citing Bright's text, that after the 1891 court ruling upholding Edison's patent, competition "suddenly became impossible" is clearly wrong. Their paper also states that "entry into the industry slowed from 26 new firms in 1892 to 8 in 1894, the last year of the patent's life" (Merges and Nelson 1990, 885 citing Bright 1949, at 89, 91, 92, Table XI). M&N's paper adopts here an idiosyncratic measure of competition – the number of firms *entering* the field in a given period rather than the number of *existing* firms *actively competing* in the field during the period. In contradiction to their paper's conclusion that competition ceased, Section 4.2 and Figure 6 show that the number of lamp manufacturers active in the market during that period rose to unprecedented levels. Thus, evidence shows that competition only *increased* during the enforcement of Edison's patent.

M&N's paper also suggest a substantial increase in GE's market share as a third indicator for the alleged "blocking" nature of Edison's patent. The paper states that after the court ruling upholding Edison's patent and GE's subsequent enforcement actions, "the company's market share grew from 40 to 75 percent," citing Bright's unsupported statement at page 91 that the Edison lamp gained a market share "from a little less than half to around three-fourths of all lamps sold." (Merges and Nelson 1990, 885 citing Bright 1949, at 91). Bright provides no market data or any evidence and it is unclear how M&N concluded that Bright's initial GE share figure of "a little less than half" means 40% rather than 49%. In any event, we show in Section 4.4 and in Figure 8 evidence that Edison/GE's market share in lamp sales during the patent enforcement period had not increased beyond 52% – an increase mostly owing to the absorption of Thomson-Houston into GE – and that it had rather *declined* during the latter part of the patent's enforcement period.

In view of Bright's book's statement on page 104 that in 1896 "the lamp division of General Electric itself handled *about half* the domestic lamp business," it appears extremely implausible that GE could have nearly doubled its lamp market share temporarily over two years, as M&N's paper contends, only to cede much of it back by 1896. Given that electric lighting was generally sold as a total system in this period, we are able to make an independent check on these assertions of dramatic market share shifts. Local illuminating companies purchased plants from one or the other of the manufacturing companies, with the electrical equipment (including lamps and related sockets) made by one manufacturing company (*Edison Electric Light Co. et al. v. Sawyer-Man Electric Co.*, 53 F. 592, 595 [2nd.Cir.1892]). Rival manufacturers patented their unique proprietary lamp plugs and the distinct proprietary sockets installed in these plants were incompatible among rival lamp suppliers. This ensured an exclusive continuous supply of one type of lamp to each plant contracting with that lamp's supplier. Because lamps had an operating life of only several hundred hours, lamp sales were directed at replacements and expansion of these plants with only a minority going to new plants. Annual market share of lamp *sales* necessarily closely tracked the installed base share and could not have changed radically. For GE to have captured 75% of the lamp market, it would have had to (a) dominate all *new* plant sales in 1893-94 and (b) undergo a wholesale replacement of the *installed base of lamp sockets, converting them to GE sockets*. Evidently, a complete replacement of sockets in customer

premises was costly, troublesome and not a viable economic solution in situations requiring a change of lamp type (Willcox 1900, 295).[55]

Accepting M&N's and Bright's assertion of a temporary GE market-share surge scenario would necessarily require one to believe that GE, or its customers, had invested in wholesale replacement of over a million lamp sockets *only to replace them again* after the Edison patent expired, when GE's market share ostensibly declined back to 50% in 1896. This is simply an incredible scenario and our evidence in Figure 8 clearly confirms that no such dramatic market share jump and decline occurred; M&N's assertions of dramatic changes in GE's market share are not only operationally implausible, but are simply not supported by the facts.

6.2.3 The patent owner was not a 'price maker'

Incandescent lamp price evidence discussed in Section 4.3 and shown in Figure 7 strongly suggests that GE, the Edison patent owner, was not a 'price maker' and that once non-infringing lamps were introduced to the market immediately after GE had succeeded in enforcing the Edison patent, GE had very little control over the market price of lamps during the remaining life of the patent. Nevertheless, as an indicator for the alleged reduction of competition due to the "blocking" nature of Edison's patent, M&N's paper adopts Bright's unsupported conclusion that after the 1891 court ruling upholding Edison's patent, "the steady downward trend of lamp prices slowed until the patent expired" (Merges and Nelson 1990, 886 citing Bright 1949, at 93). Even if "slowing" in price decline had occurred, neither Bright's book nor M&N's paper explain how a rational economic inference of *suppressed* competition in the supply of a given good can be made as long as prices for that good decline. If, as alleged, GE had the capacity to block lamp sales of others, why would GE reduce *its own* price even a little?

Furthermore, Bright's lamp price survey method appears extremely unreliable,[56] shifting between unspecified vendors in different years and conspicuously lacking the most important information for supporting his conclusion – lamp prices set by Edison/GE, the alleged "price maker." Unlike Bright and M&N, we have obtained the record of GE prices and that of its competitors and have identified all our sources. The evidence in Figure 7 shows that *the most precipitous price declines took place during the enforcement of the Edison patent*. The timing of GE price reductions appears to have tracked their competitors' new non-infringing product launches and/or lower price announcements.[57] In any event, GE's market behavior can hardly be descriptive of an "organizational complacency" as M&N's paper asserts (Merges and Nelson 1990, 887 at note 202). In conclusion, the evidence shows that GE was not the 'price maker' and that lamp price declines were most dramatic during the period of enforcement of the Edison patent, contrary to the M&N paper's assertions.

---

[55] While the use of lamp adapters for incompatible sockets was more practical, it required vendors' cooperation because sockets and mating lamp structures were patented by their respective manufacturers. Such cooperation only took place between Thomson Houston and Edison upon their merger into GE when some Thomson-Houston sockets received an Edison-to-Thomson Houston socket adapter (Willcox 1900, 294). *See* the adapter developed by GE as described in U.S. Pat. No. 480,988 filed in May, 1892.

[56] In a discussion on page 93 of his book, Bright based his price information "largely on advertisements and articles in various electrical journal during the period" without identifying any of the sources. His numerical estimates appearing on this page are riddled with year-to-year inconsistencies and factual contradictions as to what the numbers mean. For example, in one sentence on page 93 he calls these numbers "averages" while providing no information on how the "averages" were weighted or calculated in each year. In another sentence on the same page he provides these numbers as "ranges" of prices, clearly deviating from the notion of reporting them as "averages." Importantly, when reporting on the 1893 (apparently "average") price of 50 cents, he hastens to add that Westinghouse's list price was only 30 cents that year. We were unable to find any source that would support a finding of a 50 cent price *averaged* over prices in 1893, let alone an increase over the average price of 1892, which Bright asserts.

[57] Another factor that might have contributed to some price declines is the effects of the 1893 financial panic (Bright 1949, 97).

6.2.4 The patent owner did not control technical advances in areas to which the patent pertained

As shown in Section 4.1, technical advances in areas to which Edison's patent pertained were clearly not under the control of the patent owner, GE. Yet, M&N's paper states that "the validation of Edison's broad patent slowed the pace of improvements considerably." (Merges and Nelson 1990, 886). The paper selectively uses the following text from Bright (Bright 1949, 138-9) while omitting a key sentence on non-infringing development activity (omitted sentence underlined below):

> "The lengthy and expensive patent struggle in the lamp industry from 1885 to 1894 was a serious damper on progress in lamp design, *although process improvement continued*. The Edison interests concentrated on eliminating competition rather than outstripping it. Although the patent monopoly *stimulated some competitors to develop non infringing lamps*, their efforts did not lead to significant results. After 1894, when it was no longer protected by a basic lamp patent, General Electric devoted more attention to lamp improvement to maintain its market superiority" (Merges and Nelson 1990, 887) (Footnotes omitted, emphasis added and restored text underlined).

Note that the first sentence in Bright's original statement above is self-contradicting: if Edison's patent had been a broad-scope blocking patent that had placed a "serious damper on progress in lamp design", how could it have permitted "continued process improvement" of presumably infringing lamps? In any event, neither Bright's book nor M&N's paper provided actual evidence of a "serious damper in lamp design" and evidence to the contrary has been readily available – see our extensive treatment in Section 4.1. Moreover, Bright's unsupported assertion that competitors' non-infringing lamp developments "did not lead to significant results" is an understatement in spectacular contradiction with the evidence we present in Section 4.1 – and bizarrely also in contradiction to Bright's own data elsewhere in his book.[58]

M&N's paper concludes that "the broad Edison patent slowed down progress in the incandescent lighting field" (Merges and Nelson 1990, 887); their 1994 paper further claims:

> General Electric … obtained a series of injunctions and shut down a number of competitors. From that time, until the patent lapsed, G.E. did control the 'prospect'. According to Bright (1949), who looked into the history in considerable depth, over that period filament development and lamp development more generally *virtually stagnated*. G.E., protected by the patent, basically sat on its monopoly position, as contrasted with developing its 'prospect' in an orderly way. Only when the patent was close to lapsing did G.E. step up its efforts in lamp technology. Shortly after, of course, technical advance in the field became competitive again (Merges and Nelson 1994, 15) (emphasis added).

The examination of the facts presented in Section 4 of this paper shows that for every constituent claim in the above quotation, the *exact opposite had actually occurred*. First, the patenting surge in the areas of "filament development and lamp development more generally" shown in Figure 3 clearly demonstrates that while patent filings in the relevant patent classes *increased* to 72 during the 41 months of Edison's patent enforcement between July 14, 1891 and November 19, 1894, patent filings *decreased* to only 20 patents in the period of equal span (41 months) following the patent's expiration. Second, although not showing all of GE's patenting activities in the general area of incandescent lamps, Figure 4 shows that immediately after the appeals court affirmance, GE had increased its own incandescent lamp development activity as evidenced by the fact that the number of incandescent lamp patent applications that GE filed in the class during the year immediately following the affirmance was double that filed in the previous year or in any one of the five

[58] *See* (Bright 1949): at 90: "A few other companies remained in production [after Edison's successful patent enforcements] or reopened their plants by redesigning their lamps and claiming that the newer types did not infringe the Edison patent. Although the courts issued new injunctions against some of the redesigned lamps, a few were sufficiently different to be able to remain on the market. In addition, many new companies were formed after 1892 to produce "non-infringing" lamps." … "By far the most important of the non-infringers was the Westinghouse Electric & Manufacturing Company." Also describing Westinghouse's non-infringing stopper lamp used in the World's Fair of 1993; at 119-120: "In the United States [the interest in metallic filament] in large part represented attempts by competitors to get around the basic Edison patent;" at 120: Lawrence Poland's iridium-filament lamp; at 132: non-infringing efforts of the Star Electric Lamp Co. with its new hydro-carbon gas "Sunbeam" lamp and the Waring Electric Company with its bromine gas "Novak" lamp.

preceding years. This evidence shows that while GE was not "controlling the prospect," it actively "developed the prospect" of its own inventions.

Finally and contrary to M&N's paper's assertion, Figure 3 shows that the expiration of Edison's patent did not usher-in more vigorous incandescent lamp developments. Ironically, it was not the expiration of Edison's patent that caused GE to step up its efforts in lamp technology shortly prior to its expiration. Rather, the expiration of a *different* patent - that for filament "flashing" owned by GE's *rival* – enabled GE to implement its most significant advance of that time. This was the adoption of the by-then public domain "flashing" technology, previous to which GE had been forced to use old inferior filament treatment methods until the expiration of the "flashing" patent in 1893 (Howell and Schroeder 1927, 80). According to Bright, GE then adopted this filament treatment process at the Harrison Lamp Works to "catch up with competitors who had previously been using the process" (Bright 1949, 122, 96; see also Howell and Schroeder 1927, 79-80).[59] The significance and value of this filament treatment technology is further explained in Section 4.1.1. This evidence and all other evidence presented in Section 4 clearly show that GE was far from "sitting on its monopoly position" or being complacent.

Substantial downstream developments by firms other than GE were undertaken and new collateral technology areas were pioneered by others (see a few examples in Table 1). Clearly, no evidence of any type enumerated in Section 6.1.1 above as indicative of downstream development block exists in the Edison case and the notion that GE's control of the Edison incandescent lamp patent 'held back' developments is simply not supported by the historical facts.

6.3 Was Edison's incandescent lamp patent a 'blocking patent' in Great Britain?

M&N's paper contends not only that Edison's US patent blocked downstream development, but also that Edison's British counterpart filament patent slowed incandescent lamp developments in Great Britain. M&N assert that the market power of the Edison-Swan Co. ("Ediswan Co.") derived from its patent position and that it was used to deter downstream development:

> "This [slowing pace of improvements owing to the validation of Edison's broad patent] was especially true in Great Britain, where the Edison Company's patent position was even more commanding, due to its control of a basic patent on a process for producing carbon filaments. A series of court victories over its largest competitors gave the British "Ediswan" company "a practical monopoly of incandescent-lamp production." (Merges and Nelson 1990, 885 citing Bright 1949, 108). … In England, filament improvement was almost entirely halted during the period of Edison patent monopoly from 1886 to 1893" (Merges and Nelson 1990, 885 citing Bright 1949, 138).

On the same page that M&N's paper cites, Bright's book reveals a different cause for retarded development activity in the British lighting industry – the British Electric Lighting Act of 1882:

> "All the electric-lamp companies had had a difficult time from 1882 to 1888 under the Electric Lighting Act. Of the pioneers the only important survivors were the Ediswan, Brush, and Woodhouse & Rawson companies, and they all had found it hard to remain solvent. After amendment of the Act in 1888, *the entire industry grew much more rapidly. New lamp producers entered the business, and the market expanded"* (Bright 1949, 108) (Emphasis added).

Bright's book also provides data that shows that in the few years after the amendment of the Electric Lighting Act, the number of incandescent lamp manufacturers in Great Britain grew from 11 in 1889 to 14 in 1891 (Bright 1949, 487). These data clearly contradict the notion that the Ediswan Co. had a monopoly by means of its patent position. M&N's paper here cites Bright's contentions, rather than Bright's actual data that contradict his own contentions.

[59] Indeed, some of GE's increased patenting activities at that time were improvements in contacts for filaments that were made by the newly adopted "flashing" method of hydrocarbon deposition (Pat. No. 500,849 filed October 28, 1892).

Indeed, the "Ediswan" company may have acquired a very strong market position relative to other firms, but M&N's paper does not consider the highly likely possibility that this had been a peculiar result of the British regulatory regime. It was the Electric Lighting Act of 1882 in Great Britain that had made it nearly impossible for the many newly established British electric light companies to obtain finance, given that Act's limitation of their franchise to a mere 21 years (Hughes 1962). Many electric-light companies and in particular central station-based companies collapsed and were liquidated (Bright 1949, p. 107). But the 1882 Act did *not* regulate isolated plants (eg. on industrial sites) that had no need for legal access to public rights-of-way. Electric light companies, such as Ediswan, that were diversified and able to build and operate *isolated* plants,[60] were better able to survive the stifling regulatory regime of the 1882 Act. They did so by shedding contracts to build central station lighting systems.[61] There is a good case here that the Ediswan Company's ability to survive the 1882 Act gave it an advantageous market power throughout and particularly after that Act was amended in 1888. One is reminded of our objective standards discussed in Section 6.1 that evidence of market power is not evidence of *patent* blocking development.

M&N's paper's contention that the patent position of the Ediswan Co. blocked downstream filament development in Great Britain is not supported by any analysis of the claims in Edison's British patent. In this regard, it is important to note that the legal action brought by the Ediswan Company against Woodhouse and Rawson in 1884 asserted three British patents, only one of which was Edison's.[62] Moreover, later that year, the Ediswan Company brought a second action against Woodhouse and Rawson,[63] on this occasion alleging infringement of the Sawyer & Man patent GB4847/1878 on the carbon filament "flashing" process, Ediswan having acquired the patent in 1883.

In July 1888, the Ediswan Company had been successful in its patent infringement lawsuit against Holland, but its success was owing to the Sawyer & Man "flashing" patent, as the High Court held Edison's patent invalid.[64] In February 1889, the High Court decision was subsequently reversed by the Court of Appeals with respect to Edison's patent.[65]

As this legal patent enforcement trajectory of the Ediswan Company shows, the Edison patent hardly commanded a "flagship" role in Ediswan's patent portfolio and enforcement campaign because the Ediswan Company had other strong claims that independently captured practical incandescent lamp implementations. Indeed, contemporaneous accounts analyzing the incandescent lamp patent situation in Great Britain did not even identify the Edison patent but identified other patents as essential. In anticipation of patent expiration in the field of incandescent lamps, the editor of the British magazine *The Electrical Engineer* wrote in 1892:

> "Unless we are in error, the method of flashing so extensively used in the preparation of incandescent lamp filaments will become public property during this November. It was in November 1878, that Cheesbrough took out the patent for Sawyer. This was the patent round which no infringers could get. Many attempts were

[60] As of April 1883, excluding the Holborn Viaduct central station in London, there were 28 complete Edison isolated plants of about 7,500 lamps in operation or in process of installation in Great Britain. See *Bulletin of the Edison Electric Light Company*, No. 17 (April 6, 1883), at 20-21, (CB017).

[61] Not merely abandoning the pioneer Holborn Viaduct station in London, the Ediswan Company on October 20, 1884, informed the Board of Trade that none of the provisional orders granted the company under the Act of 1882 enabling the company to erect central station systems in London would be carried out. (Hughes 1962, 34).

[62] *Edison & Swan United Electric Light Co. v. Woodhouse & Rawson*, RPC 167 (1886) (Asserting Patents GB4576/1879 to Edison, GB18/1880 to Swan and GB4193/1881 to Gimingham).

[63] *Edison and Swan United Electric Light Co. v Woodhouse & Rawson* (Second Action), RPC 183 (1886) (Holding Patent GB4847/1878 to Sawyer & Man valid and infringed), *aff'd* RPC 99 (1887).

[64] *Edison& Swan Electric Light Co. v. Holland*, RPC 459 (1888) (Holding Patent GB4847/1878 to Sawyer & Man valid and infringed and holding Patent GB4576/1879 to Edison invalid); See (Electrical Engineer (London) 1888; Electrical Engineer 1888).

[65] *Edison& Swan Electric Light Co. v. Holland*, RPC 243 (1889) (Reversing the High Court and holding Patent GB4576/1879 to Edison valid and infringed by lamps produced by the Anglo-American Brush Corp.); See (Electrical Review 1889).

> made to prepare suitable filaments without flashing, but it may be taken for granted that all such attempts failed. … Sawyer's or Cheesbrough's flashing patent is numbered 4,847 of 1878 hence the patent lapses this year and as above stated, in November. Many people fancy that they have discovered some kind of filament outside the patents of [the Ediswan Co.], and that with the end of the Sawyer patent process, they will be able to start manufacture. In our opinion there can be no real competition with the [Ediswan] combination *till the lapse of patent No 250 of 1880* [to Swan], that is, till the beginning of the year 1894, say about eighteen months from this date" (Electrical Engineer (London) 1892) (Emphasis added).

Thus, under this contemporaneous account and all other data, M&N's thesis that "the validation of Edison's broad patent slowed the pace of improvements considerably" and that "[t]his was especially true in Great Britain" has no basis in fact.

7 Conclusion - The study of Edison's patent is the study of the patent system at work

In this paper we present an original analysis of the extent and variety of designs-around Edison's U.S. 223,898 patent and we compile supporting commercial data that shows that the related, widespread belief that this patent was used by GE to block downstream technology development in the incandescent lamp field was entirely mistaken. Our analysis of the legal trajectory of Edison's '898 patent revealed that key legal events altered inventive behavior of others as certainty of the value and boundaries of Edison's patent claims was established. When Edison filed suit in 1886 there was a surge of patenting activity on inventions related to the Edison lamp technology which we interpreted as actors in the field seeking to capture key improvements to enhance their bargaining position prior to the forthcoming adjudication of the patent. The surge of invention after the 1891 and especially the 1892 affirmance of the 1891 judgment were of a different character: these patented designs were mostly efforts to design-around the four constituent features of Edison's patent claims. Some of these designs-around, such as Westinghouse's stopper lamps, provided commercially-viable and legal means to remain in the incandescent lamp field unaffected by GE's enforcement of the '898 patent. Other designs were exploited commercially and then in litigation with Edison's patent, tested with precision the enforceable boundary of the claims of the '898 patent and with varying success: Waring's low pressure bromine-filled lamps were found infringing; the Beacon Company would eventually establish a non-infringing commercially-viable path using conductors passing through a cement-glass seal.

Other designs-around were not exploited commercially for the contemporary incandescent lamp market, such as the Tesla Coil. Regardless of immediate *commercial* significance, we found several designs-around to be *technologically* significant by our compilation of forward citations to the relevant patents. Whereas the Tesla Coil had no commercial significance in the incandescent lamp market of Edison's day, it became a valuable technology for many diverse later inventions. And in Lodyguine's 1893 patent on a method of coating platinum filaments with earth metals we believe we have found the first proposal to use tungsten as a filament material; a line of research with obvious great future commercial value for the nascent incandescent lamp market.

In conclusion, it is a certainty that when the courts upheld the validity of Edison's patent they provided the clarity as to the bounds of Edison's claims that stimulated investments in new prospects and a burst of inventive activity directed at evading Claim 2 of that patent – the claim that presented the most difficult barrier to competitors. These barriers, however, were not insurmountable. In observing designs-around Edison's claims in the *patents* of others, we observed the patent system working on multiple levels: it also rewards inventors with exclusive rights for pioneering solutions that steer clear of rights previously awarded to others.

Successful invention around is generally acknowledged to be a legal means of evading a patent's claims and thereby remaining in business or forging new ways of doing business. Nevertheless a

number of authors led by Merges and Nelson have portrayed GE's use of Edison's patent as a prime instance of a 'broad-scope' patent that blocked downstream development and suppressed competition in the incandescent lamp field. If, as M&N's paper states, the Edison case constitutes their "best example" (Merges and Nelson 1990, 908), it is clearly ill-advised to entertain their thesis that "the granting and enforcing of broad pioneer patents is dangerous social policy. It can, and has, hurt in a number of ways" (Merges and Nelson 1994, 16). Although GE refused to license the patent, our analysis of the surge in designs-around suggests that this strengthened the incentive to design around the patent. Nevertheless, we made a further analysis of commercial indicators of the degree of GE's control of the incandescent lamp market during the enforcement period of the Edison patent from 1891 to 1894. All our indicators show that in this period, GE did not gain increased market control; GE's market share did not increase; the number of firms in the incandescent lamp field rose; and GE made its steepest price reductions to its lamps. This greatly contributed to consumer welfare.

The conclusion is clear; the Edison patent did not aid GE in its attempt to increase its market control during the patent's enforcement period, but this effort *was* successful in stimulating inventive efforts to design around the patent claims. Finally, in this anatomy of the downstream influence of Edison's patent, we see the public disclosure function of the patent system at work through our citation analysis which showed that many disclosed design-around efforts proved significant building blocks and prior art for later, novel technological fields. Thus, we have seen in this study the patent system at work - it works as intended "to promote the progress of useful arts."

Acknowledgements

The authors wish to thank Professor Paul Israel, Director of the Thomas A. Edison Papers Project at Rutgers University, for his guidance on the available historical records and to Mr. Steven Chadwell of the Search and Advisory Service in the British Patent Office for providing copies of 19th century British patents discussed in this paper. Thanks are also due to the participants of the July 2010 Arts and Humanities Research Council Conference on Managing Knowledge in the Techno-Sciences, 1850-2000, at the University of Leeds for constructive comments on an earlier version of this paper.

References

Agarwal, Rajshree and Michael Gort. 2001. "First-Mover Advantage and the Speed of Competitive Entry, 1887-1986." *Journal of Law and Economics* 44 (1): 161-177 (Apr.).

Anthony, William A. 1894. "On the Effect of Heavy Gases in the Chamber of an Incandescent Lamp." *Transactions of the American Institute of Electrical Engineers* 11: 133-180 (March 1894).

Barham, George Basil. 1912. *The Development of the Incandescent Electric Lamp*. London: Scott, Greenwood & Son.

Beacon Co. 1893. "The New Beacon Incandescent Lamp – 35 Cent Price Advertisement by the Beacon Vacuum Pump & Electrical Co." *Proceedings of the National Electric Light Association, 16th Convention*: 434 (February 28, 1893).

Beck, Roger L. 1976. "Patents, Property Rights, and Social Welfare: Search for a Restricted Optimum." *Southern Economic Journal* 43 (2): 1045-1055 (Oct.).

——— 1978. "Patents and Over-Investment in Process Inventions: Reply." *Southern Economic Journal* 45 (1): 289-292 (Jul.).

Blakeslee, Merritt R. and Christopher V. Meservy. 2007. "Seeking Adjudication of a Design-Around in Section 337 Patent Infringement Investigations: Procedural Context and Strategic Considerations." *AIPLA Quarterly Journal* 35: 385-414.

Bright, Arthur Aaron. 1949. *The Electric-Lamp Industry: Technological Change and Economic Development from 1800 to 1947*. New York: Macmillan Co.

Carlson, W. Bernard. 1991. *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900*. Cambridge: Cambridge University Press.

Carrier, Michael A. 2002. "Unraveling the Patent-Antitrust Paradox." *University of Pennsylvania Law Review* 150 (3): 761-854 (Jan.).

Cook, Anna. 1998. *How Increased Competition from Generic Drugs has Affected Prices and Returns in the Pharmaceutical Industry*. A CBO Study. Washington, D.C.: U. S. Congressional Budget Office.

Covington, Edward J. 1998. *The Electric Incandescent Lamp, 1880-1925*. Highland Heights, Ohio: E.J. Covington.

——— 2003. "Henry Schroeder." http://home.frognet.net/~ejcov/schroeder.html.

——— 2005. "The 'New Sunbeam' or 'Acorn' Lamp." http://home.frognet.net/~ejcov/kammer2.html.

——— 2006. "The Lamp of Edward Pollard." http://home.frognet.net/~ejcov/pollard.html.

DiMasi, J. A. 2000. *Price Trends for Prescription Pharmaceuticals: 1995–1999, a Background Report Prepared for the Department of Health and Human Services.*

DiMasi, J. A. and C. Paquette. 2004. "The Economics of Follow-on Drug Research and Development - Trends in Entry Rates and the Timing of Development." *PharmacoEconomics* 22: 1-14.

Electric Light. 1892. "Electric Lamps." *Electric Light* (October 6, 1892).

Electrical Engineer. 1888. "The Edison Lamp Patent Adjudged Invalid in England." *The Electrical Engineer* 7: 370-372 (August 1888).

——— 1893a. "Incandescent Lamp Economics." *The Electrical Engineer* 16: 511 (December 13, 1893).

——— 1893b. "New Low Voltage Lamps of the Westinghouse Company." *The Electrical Engineer* 16: 547-548 (December 27, 1893).

——— 1893c. "Reduction in the Price of Edison Lamps." *The Electrical Engineer* 16: 497 (December 6, 1893).

——— 1894a. "The Buckeye Lamp without Leading-in Wires." *The Electrical Engineer* 17 (298): 55-56 (January 17, 1894).

——— 1894b. "New Price List of the Columbia Incandescent Lamp Company." *The Electrical Engineer* 17: 40 (January 10, 1894).

——— 1894c. "Price of Beacon Lamps Reduced." *The Electrical Engineer* 17: 40 (January 10, 1894).

——— 1896. "Niobium Filament Lamp." *The Electrical Engineer* 17: 169 (February 14, 1896).

Electrical Engineer (London). 1888. "Edison and Swan United Electric Light Company Limited v. Holland and Others." *The Electrical Engineer (London)* 11: 61 (July 20, 1888).

——— 1892. "Flashing." *The Electrical Engineer (London)* 14: 332-333 (September 30, 1892).

Electrical Review. 1889. "Incandescent Lamp Patents." *The Electrical Review* 24: 212-216 (February 22, 1889).

——— 1893. "The New Westinghouse Lamp and Electric Lighting in America." *The Electrical Review* 32: 113-114 (February 3, 1893).

Electrical World. 1894. "Pittsburgh Notes." *The Electrical World* 23 (7): 226 (February 17, 1894).

FTC. 2002. *Generic Drug Entry Prior to Patent Expiration*. Washington, D.C.: U.S. Federal Trade Commission.

——— 2003. *To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy*. Ch. 2(III)(B)(1). Washington, D.C.: U.S. Federal Trade Commission.

Gallini, Nancy T. 1992. "Patent Policy and Costly Imitation." *The Rand Journal of Economics* 23 (1): 52-63 (Spring).

Grabowski, Henry G. 2003. "Patents and New Product Development in the Pharmaceutical and Biotechnology Industries." *Proceedings, Federal Reserve Bank of Dallas* (September): 87-104.

Hagedoorn, J. and M. Cloodt. 2003. "Measuring Innovative Performance: Is there an Advantage in using Multiple Indicators?" *Research Policy* 32 (8): 1365-1379.

Hall, B. H., A. B. Jaffe, and M. Trajtenberg. 2001. "The NBER Patent Citations Data File : Lessons, Insights and Methodological Tools." *NBER Working Paper no. W8498*.

Hammond, John Winthrop and Arthur Pound. 1941. *Men and Volts; the Story of General Electric*. Philadelphia, New York etc.: J.B. Lippincott Company.

Harhoff, Dietmar, Francis Narin, F. M. Scherer, and Katrin Vopel. 1999. "Citation Frequency and the Value of Patented Inventions." *The Review of Economics and Statistics* 81 (3): pp. 511-515

Hering, Carl. 1893. "The most Economical Age of Incandescent Lamps." *Transactions of the American Institute of Electrical Engineers* X: 63-84.

Hirst, H. 1908. "Recent Progress in Tungsten Metallic Filament Lamps." *Journal of the Institution of Electrical Engineers* 41 (192): 636-661.

Howell, John White. 1894. "On the Effect of Heavy Gases in the Chamber of an Incandescent Lamp - Discussion." *Transactions of the American Institute of Electrical Engineers* 11: 155-161 (March 1894).

Howell, John White and Henry Schroeder. 1927. *History of the Incandescent Lamp*. Schenectady, N.Y.: Maqua Co.

Howells, John and Ron D. Katznelson. 2012. "The Myth of Downstream Development Suppression by Patents: Merges and Nelson's Evidence Reconsidered." *To Appear*. Working paper available at http://bit.ly/Myth-of-patent-blocking

Hughes, Thomas Parke. 1962. "British Electrical Industry Lag: 1882-1888." *Technology and Culture* 3 (1): 27-44 (Winter).

Israel, Paul. 1998. *Edison : A Life of Invention*. New York: John Wiley.

Jaffe, Adam B. 2000. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process." *Research Policy* 29 (4-5): 531-557 (4).

Jaffe, Adam B., Manuel Trajtenberg, and Rebecca Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *The Quarterly Journal of Economics* 108 (3): 577-598 (Aug.).

Johnson, Edward H. 1886. *the Edison Electric Light: The Legal and Commercial Status*. New York: Edison Electric Light Co. Also Published in *the Electrician and Electrical Engineer*, 5: 468-473, (December 1886).

Jones, A. C. and M. L. Hitchman. 2007. *Chemical Vapour Deposition : Precursors and Processes,* Royal Society Of Chemistry.

Kaplow, Louis. 1984. "The Patent-Antitrust Intersection: A Reappraisal." *Harvard Law Review* 97 (8): 1813-1892 (Jun.).

Katznelson, Ron D. 2012. "Did Edison's Incandescent Lamp Patent Block Downstream Technology Development?" *To Appear*.

Lamp Committee. 1929. *The Development of the Incandescent Electric Lamp Up to 1879*. New York: Association of Edison Illuminating Companies.

Landau, Daniel L. 1978. "Patents and Over-Investment in Process Inventions? Comment." *Southern Economic Journal* 45 (1): 285-288 (Jul.).

Lanjouw, J. O. and M. Schankerman. 2001. "Characteristics of Patent Litigation: A Window on Competition." *RAND Journal of Economics* 32 (1): 129-151.

Leibovitz, John S. 2002. "Inventing a Nonexclusive Patent System." *The Yale Law Journal* 111 (8): 2251-2287 (Jun.).

Lemley, Mark A. 1997. "The Economics of Improvement in Intellectual Property Law." *Texas Law Review* 75: 989-1084.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, Sidney G. Winter, Richard Gilbert, and Zvi Griliches. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* 1987 (3, Special Issue On Microeconomics): 783-831.

Liston, John. 1918. "Some Developments in the Electrical Industry during 1917." *General Electric Review* 21 (1): 4-52 (January 1918).

Machlup, Fritz. 1958. *An Economic Review of the Patent System*. Study of the Subcommittee on Patents, Trade-Marks, and Copyrights of the Committee on the Judiciary, United States Senate, Study. Vol. 15. Washington: U.S. Govt. Print. Off.

Mansfield, Edwin. 1985. "How Rapidly does New Industrial Technology Leak Out?" *The Journal of Industrial Economics* 34 (2): pp. 217-223 (Dec.).

Mansfield, Edwin, Mark Schwartz, and Samuel Wagner. 1981. "Imitation Costs and Patents: An Empirical Study." *The Economic Journal* 91 (364): pp. 907-918 (Dec.).

Marco, A. C. 2005. "The Option Value of Patent Litigation: Theory and Evidence." *Review of Financial Economics* 14 (3-4): 323-351.

——— 2007. "The Dynamics of Patent Citations." *Economics Letters* 94 (2): 290-296.

Marshall, J. T. 1905. "The Development of the Manufacture of the Edison Incandescent Electric Lamp, 1881–1905." *Journal of the Franklin Institute* 160 (1): 21-49.

Merges, Robert P. and Richard R. Nelson. 1990. "On the Complex Economics of Patent Scope." *Columbia Law Review* 90 (4): 839-916 (May).

——— 1994. "On Limiting Or Encouraging Rivalry in Technical Progress: The Effect of Patent Scope Decisions." *Journal of Economic Behavior & Organization* 25 (1): 1-24.

Nard, Craig A. 2000. "A Theory of Claim Interpretation." *Harvard Journal of Law & Technology* 14 (1): 1-82.

Narin, F., M. B. Albert, and V. M. Smith. 1992. "Technology Indicators in Strategic Planning." *Science and Public Policy* 19: 369-381.

National Research Council. 1962. *The Role of Patents in Research, Part I*. National Research Council. Publication. Vol. 980A-B. Washington D.C.: National Academy of Sciences, National Research Council.

Oppenheim, Charles. 2000. "Do Patent Citations Count?" In *the Web of Knowledge: A Festschrift in Honor of Eugene Garfield*, edited by Blaise Cronin and Helen Barsky-Atkins, 405-432. Medford, NJ: American Society for Information Science & Technology.

Passer, Harold C. 1953. *The Electrical Manufacturers, 1875-1900; a Study in Competition, Entrepreneurship, Technical Change, and Economic Growth*. Studies in Entrepreneurial History. Cambridge, Mass.: Harvard University Press.

Podolny, J. M., T. E. Stuart, and M. T. Hannan. 1996. "Networks, Knowledge, and Niches: Competition in the Worldwide Semiconductor Industry, 1984-1991." *American Journal of Sociology* 102 (3): 659-689.

Pope, Franklin L. 1893. "Electricity." *Engineering Magazine* 6 (1): 92-96 (October 1893).

——— 1894. *Evolution of the Electric Incandescent Lamp*. 2d ed. New York, N.Y: Boschen & Wefer.

Sawyer, William Edward. 1881. *Electric Lighting by Incandescence, and its Application to Interior Illumination. A Practical Treatise*. New York: D. Van Nostrand.

Scherer, F. M. 1980. *Industrial Market Structure and Economic Performance*. 2d ed. Chicago: Rand McNally College Pub. Co.

Schroeder, Henry. 1911. "History of Incandescent Lamp Manufacture." *General Electric Review* 14 (9): 426-444 (September 1911).

——— 1917. "Lamp Sales of the Edison Lamp Works during 1916." *General Electric Review* 20 (1): 335-336 (January 1917).

Seifer, Marc J. 1998. *Wizard : The Life and Times of Nikola Tesla : Biography of a Genius*. New York: Citadel Press.

Selgin, George and John Turner. 2011. "Weak Patents, Or, the Myth of Watt's Innovation-Blocking Monopoly, Exploded." *Journal of Law and Economics* 54: forthcoming. http://ssrn.com/abstract=1589712.

Skrabec, Quentin R. 2007. *George Westinghouse : Gentle Genius*. New York: Algora Pub.

Somers, Julie and Anna Cook. 2007. *Prescription Drug Pricing in the Private Sector*. A CBO Study. Washington, D.C.: U.S. Conggressional Budget Office.

Stevens, W. S. 1912. "A Group of Trusts and Combinations." *The Quarterly Journal of Economics* 26 (4): 593-643 (Aug.). http://www.jstor.org/stable/1883799.

Terry, Charles A. 1929. *The Early History of the Westinghouse Electric & Manufacturing Company; an Extension Course*. East Pittsburgh, Pa.: Educational Dept., Westinghouse Electric & Manufacturing Co.

Thompson, Peter and Melanie Fox-Kean. 2005. "Patent Citations and the Geography of Knowledge Spillovers: A Reassessment." *The American Economic Review* 95 (1): 450-460 (Mar.).

Townley, Calvert. 1893. "The Incandescent Lamp from a Commercial Standpoint." *Proceedings of the National Electric Light Association, 16th Convention*: 337-351 (February 28, 1893).

Trajtenberg, Manuel. 1990. "A Penny for Your Quotes: Patent Citations and the Value of Innovations." *The Rand Journal of Economics* 21 (1): 172-187 (Spring).

Turner, D. F. 1969. "Patent System and Competitive Policy." *New York University Law Review* 44 (3): 450-476.

U.S. Patent Commissioner. 1899. *Report of the Commissioner of Patents to the Secretary of the Interior for the Fiscal Year Ended June 30, 1899*. Washington, D.C.: Government printing office.

——— 1947. *Annual Report of the Commissioner of Patents to the Secretary of Commerce for the Fiscal Year Ended 1947*. Washington, D.C.: Government printing office.

Westinghouse Co. 1893. "To Users of Incandescent Lamps." *The Electrical World* 21: xvii (January 7, 1893).

——— 1894. "Westinghouse Electric and Manufacturing Company 1894 Annual Report," Reprinted in: *The Electrical Engineer* 17 (315): 438 (May 16, 1894).

Wharmby, D. O. 1993. "Electrodeless Lamps for Lighting: A Review." *IEE Proceedings-A* 140 (6): 465-473 (November 1993).

Whitten, David O. 2010. "The Depression of 1893." In *EH.Net Encyclopedia*. http://eh.net/encyclopedia/article/whitten.panic.1893 ed.: Economic History Association.

Willcox, Francis W. 1900. "Incandescent Lamps." *Journal of the Franklin Institute* 149 (4): 282-298.

Appendix A – Electric lamp patent classifications

Edison's patent No. 223,898 is classified by the U.S. Patent Office in primary Class 313 for lamp apparatus. Within Class 313, the subclasses covering incandescent and discharge lamp apparatus are shown below. Class 445 covers processes, methods or instruments of making lamps or related components. The subclasses within Class 445 that relate to making lamps are also shown below.

Incandescent lamp apparatus or components thereof:

Class 313: Electric lamp and discharge devices

Subclasses included in search:

/271-279 With support and/or spacing structure for electrode – For filament
/315 Incandescent lamps
/316 Incandescent lamps – Plural filaments or glowers
/317 With envelope
/333 Electrode and shield structures – Filament or wire shield or electrode
/341-345 Electrode and shield structures – Filament or resistance heated electrodes[66]
/548 Incandescent lamp gettering
/557 Incandescent lamp type
/569 With gas or vapor – Having a particular total or partial pressure – Incandescent lamp
/578 -- With gas or vapor – Incandescent filament lamp
/233 Involving particular degree of vacuum

USPTO database search string for this class category:

```
(CCL/313/548 OR CCL/313/557 OR CCL/313/569 OR CCL/313/578 OR CCL/313/233 OR CCL/313/27? OR CCL/313/315 OR CCL/313/316 OR CCL/313/317 OR CCL/313/333 OR CCL/313/34?)
```

Process, method or instrument for making incandescent lamps or components thereof:

Class 445: Electric lamp or space discharge component or device manufacturing

Subclasses included in search:

/6 Process – With start up, flashing or aging
/20 Process – Generating gas or vapor within an envelope, or coating by vapor, gas, mist or smoke within the envelope – Filament heating
/27 Process – With assembly or disassembly - Incandescent lamp making
/32 Process – With assembly or disassembly - Including electrode or getter mounting - Incandescent filament mounting
/38-43 Process – With assembly or disassembly - Including evacuating, degasifying or gas, vapor, liquid or meltable or sublimable solid introduction
/48 Process – Electrode making – Incandescent filament making
/53-57 Process – Including evacuating, degasifying or getter or fluent material introduction
/58 Process – With coating, e.g., providing protective coating on sensitive area
/60-73 Apparatus

USPTO database search string for this class category:

```
(CCL/445/20 OR CCL/445/27 OR CCL/445/32 OR CCL/445/38 OR CCL/445/39 OR CCL/445/40 OR CCL/445/41 OR CCL/445/42 OR CCL/445/43 OR CCL/445/48 OR CCL/445/53 OR CCL/445/54 OR CCL/445/55 OR CCL/445/56 OR CCL/445/57 OR CCL/445/58 OR CCL/445/6$ OR CCL/445/7?)
```

After further analysis of the classification system,[67] we determined that these were the only two class categories pertinent to our study of specific lamps and related components, to which our search was limited. Although the subclasses we selected did not contain all the electric lamp patents filed during our period of interest, for the most part, patents in other classes involving lamps are not directed towards lamps or related components per se. Other such classes include: Class 314 (electric lamp and discharge devices: consumable electrodes) which mostly contains arc lamps; Class 315 (electric

[66] Replaced by "34?" for search efficiency because of equivalence in the 1830-1900 period.
[67] See USPTO's patent classification web page at http://www.uspto.gov/web/patents/classification/index.htm.

lamp and discharge devices: systems) which contains systems incorporating lamps circuits, cutout devices, generators and the like; Class 362 (illumination) which contains lamps within illumination devices; and Class 439, (electrical connectors) which contains combination of an electric lamp and electrical connector structure.

Under each of these two class categories listed above, we show the USPTO online patent database[68] search strings we used to limit the search results. Of course, patents classified in multiple subclasses were found but were counted only once.

Our interest was to cover all incandescent lamp related patents filed up to, and including 1898. We discovered that all patents classified in our class-categories were filed later than 1830 and therefore we began our absolute cumulative count shown in the vertical axis in Figure 3 from 1830. Because none of the patent databases to which we have had access contained sufficiently reliable data or retrieval fields for the filing dates of U.S. patents from the 19th century,[69] we began by selecting patents based on their issue dates, which are reliably available for this period on the USPTO online database. We then manually entered the filing date of each patent in our lamp patent database that met the criteria - classified within our class categories and filed on or before December 31, 1898.

In order to save exhaustive inspection of every patent issued after 1898 to see whether it was filed during our period of interest, we had to set an issue-date upper search limit beyond which we should not expect to find any patents meeting our filing date criteria. By investigating typical pendencies of samples of patents in our class categories issued in 1899-1901, we found that those were typically less than 6 months with only a few exceptions having pendencies up to 1 year. We verified that this short pendency was indeed the general case during the turn of the century by checking the patent pendency statistics published at that time by the U.S. Patent Commissioner and noted a remarkable small relative application backlog and a very short delay. The number of applications awaiting action on the part of the Office on July 1, 1899 was 2,989 out of 40,320 applications received that year; every first Office Action was issued within one month from date of filing, and every turnaround action on applicants' amendment was sent back within fifteen days of receipt by the Office (U.S. Patent Commissioner 1899, 3-5). On this basis we limited our search to patents issued no later than January 1st 1900.

Each of the composite search strings for the two class categories were used with the **AND** Boolean operator to find sets of patents that belong to both class categories and also on both sides of the **ANDNOT** Boolean operator to find sets of patents that belong to one set and not the other. The sets were further limited by issue date with the "**AND ISD/01/01/1830->01/01/1900**" operator.

Of all the "hits" found, 24 patents involving gas lamps, electric arc lamps, illuminated displays, or lamp sockets/holders were excluded because they were apparently misclassified or clearly not involving any pertinent incandescent lamp subject matter. 392 other patents met our criteria and were included in the analysis. Of these, 235 were classified only under "Apparatus" categories, 90 were classified only under "Process, method or instrument for making" categories; and 67 were

[68] USPTO online database available at http://patft.uspto.gov/netahtml/PTO/search-adv.htm. In composite search strings longer than the limit, we found the alternative online database at www.freepatentsonline.com which employs the same query syntax, to accommodate longer strings while having superior response time.

[69] Both the Lexis-Nexis and Google databases have OCR-based filing date information but much of it is corrupted or missing for U.S. patents from the 19th century.

classified both under "Apparatus" and under "Process, method or instrument for making." These three groups are shown in Figure 3 by their cumulative number according to filing date.

Appendix B – Downstream patents citing designs-around Edison's patent

The following three pages contain tables of 21 design-around patents listed in Table 1 that have forward citations. The tables contain a tally of all citations in downstream patents and legal cases that cite the design-around patent even if the patent at issue in the legal case had not included such citation. These provide a measure of the downstream collateral impact of Edison's '898 patent.

Edison's Claim Elements	Non-infringing Improvement or Attempt to Design-	Sponsor, Assignee or	Inventor(s)	U.S. Patent Number	Filing Date (in 18YY)	Downstream U.S. patents citing or relying on the improvement patent (including citations during adjudications)					
						U.S. Patent No. Or Publication Number	Filing Date	Title	Inventor(s)	Assignee	Adjudication note
Carbon Filaments (all claims)	Filaments by pioneering Chemical Vapor Deposition (CVD) to deposit the metals Niobium, Tantalum, Molybdenum, Titanium or Zirconium.	Aylsworth & Jackson Incandescent Filament Manufacturers	Jonas Walter Aylsworth	553,296	27-Jul-94	2,537,255	20-Mar-1946	Light-Sensitive Electric Device	Walter H. Brattain	Bell Telephone Laboratories	
						2,604,395	19-Nov-1945	Method of Producing Metallic Bodies	Bruce W. Gonser & Edward E. Slowter	Fansteel Metalurgical Corp.	
						2,756,166	27-Jan-1951	Vacuum Metallizing And Apparatus Therefor	Paul Alexander et al.	Continental Can Co.	
						2,822,301	3-Jun-1952	Vacuum Metallizing And Apparatus Therefor	Paul Alexander et al.	Continental Can Co.	
						2,873,108	23-Jul-1947	Apparatus for High Purity Metal Tecovery	Theodore T, Magel		
						2,873,184	25-Mar-1947	Thermal Decomposition of Uranium Compounds	Theodore T, Magel		
						2,873,185	23-Jul-1947	Deposition of Metal on Nonmetal Filament	Theodore T, Magel		
						2,978,358	28-Mar-1958	Method of Obtaining Uniform Coatings on Graphite	Ivor E. Campbell		
						2,990,293	13-Jan-1956	Method of Impregnating and Rust-Proofing Metal Articles	Henry A. Toulmin	Commonwealth Engineering Co.	
						3,020,148	5-Apr-1960	Production of Refractory metals	Wilmer A. Jenkins & Howard W. Jacobson	E.I du Pont	
						3,055,088	22-Sep-1958	Composite Metal Body for High Temperature Use	John J. Cox, Jr.	E.I du Pont	
						3,065,532	22-Apr-1958	Method Of Making Metallic Joints	Herbert B. Sachse	Keystone Carbon Co.	
						3,069,765	12-Dec-1956	Method Of Bonding And/Or Coating Metals	Clyde S. Simpelaar	Modine Mfg. Co.	
						3,089,949	28-Nov-1958	Arc Welding method and Article	Howard C. Ludwig	Westinghouse Electric Corp.	
						3,248,612	23-Jul-1962	Capacitor Electrode and method	Donald G. Rogers	Sprague Electric Co.	
						3,268,362	26-May-1961	Deposition of Crystalline Niobium Stannide	Joseph J. Hanak & John L. Cooper	Radio Corporation of America	
				553,328	27-Jul-94	2,640,798	27-Feb-1951	Method of Bonding	Nicholas Langer		
	Filaments of Molybdenum, Tungsten, Rhodium, Iridium, Ruthenium, Osmium, Chromium	Westinghouse Electric Corp.	Alexander De Lodyguine	575,002	4-Jan-93	872,936	19-Jan-1905	Tungsten Electric Incandescent Lamp	John Allen Heany		
						1,082,933	19-Jun-1912	Tungsten And Method Of Making The Same For Use As Filaments Of Incandescent Electric Lamps And For Other Purposes	William D. Coolidge	General Electric	
						4,525,379	6-Jan-1984	Method Of Manufacturing An Electrode For A High-Pressure Gas Discharge Lamp And Electrode For Such A Lamp	Horst Hubner	U.S. Philips Corp.	
						1,018,502	6-Jul-1905	Incandescent Bodies For Electric Lamps	Alexander Just & Franz Hanaman	General Electric	(a)
				575,668	10-Apr-94	1,010,866	23-Sep-1908	Process Of Making Composite Conductors	William D. Coolidge	General Electric	
						3,069,765	12-Dec-1956	Method Of Bonding And/Or Coating Metals	Clyde S. Simpelaar	Modine Mfg. Co.	
						3,065,532	22-Apr-1958	Method Of Making Metallic Joints	Herbert B. Sachse	Keystone Carbon Co.	
	Filament cores of conductive oxides of earth metals coated with either Carbon, Silicon, Boron or a composition	Thomson-Houston Electric Co.	Rudolf Langhans	420,881	5-Apr-88	2,547,406	8-May-1947	Method and Means for Controlling the Resistance of Oxidic Semiconductors	Francis J. Morin	Bell Telephone Labs., Inc.	
						2,594,921	23-May-1949	Fire or Temperature Rise Detecting Appliance	Arnold Hansard Douglas	Wilkinson Sword Co.	
						3,005,764	24-May-1948	Neutronic Reactor Structure	Farrington Daniels	The United States	
						3,242,006	3-Oct-1961	Tantalum Nitride Film Resistor	Dieter Gerstenberg	Bell Telephone Labs., Inc.	

Notes: (a) De Lodyguine patents were cited as prior art in: *General Electric Co. v. Laco-Philips Co. 2* 33 F. 96, 103 (C.A.2 1916); *General Electric Co. v. P.R. Mallory & Co.* 298 F. 579, 583 (C.A.2 1924)

Edison's Claim 2 Elements	Non-infringing Improvement or Attempt to Design-Around Edison's Claim	Sponsor, Assignee or user	Inventor(s)	U.S. Patent Number	Filing Date (in 18YY)	Downstream U.S. patents citing or relying on the improvement patent (including citations during adjudications)					
						U.S. Patent No. Or Publication Number	Filing Date	Title	Inventor(s)	Assignee	Adjudication note
a receiver made *entirely of glass*	Novel hermetically sealed connector for a two-part lamp	Western Electric Co.	Charles E. Scribner	584,750	24-Apr-93	2,688,737	13-Jan-1950	Hermetically sealed connector	Nick Oskerka Jr.	American Phenolic Corp.	
						3,055,465	3-Apr-1957	Metal-to-ceramic joint and method of forming	Hans Pulfrich	Telefunken GMBH	
						4,383,175	30-Sep-1980	Encapsulated scintillation detector	Ival L. Toepke	Bicron Corp.	
						5,548,116	1-Mar-1994	Long life oil well logging assembly	Kiril A. Pandelisev	Optoscint, Inc.	
… and *conductors passing through the glass* …	Developed lamp stem with improved cement seal and support for leading-in wires not passing through the glass	Beacon Vacuum Pump and Electrical Co,	William E. Nickerson	500,670		4,353,623	11-Jun-1980		Hermann F. L. Maier	U.S. Philips Corp.	
				501,531	6-Apr-93	3,069,583	30-Oct-1959	Electric Lamp	Samuel Swasey et al.	Sylvania Electric Products, Inc.	
				503,671	17-Jul-93	4,353,623	11-Jun-1980	Leadthrough for Electric Conductors	Hermann F. L. Maier	U.S. Philips Corp.	
				507,558	5-Aug-93	3,997,809	16-May-1975	Decorative lamp having an integral base and envelope	Robert J. Kyp		
			Edward E. Cary	500,053	7-Apr-93	2,826,710	28-Jul-1953	Reflector type lamp	Willis L. Lipscomb		
	No wires passing through the glass. Powdered silver fused in glass is the conductor powering the	Buckeye Electric Co.	Edward Pollard	485,478	2-Mar-92	2,569,848	31-May-1950	Electron Tube Seal Structure	William W Eitel & Martin E. Wolfe	Eitel-McCullough, Inc.	
						3,047,409	3-Feb-1955	Methods for Combining Metals and Compositions Containing Metals With Glass and Materials Produced	Games Slayter et al.	Owens-Corning Fiberglass Corp.	
						2,842,696	6-Oct-1955	Color Cathode Ray Image Reproducing Tube and Method	Erwin P. Fischer-Colbrie	General Electric	
						2,964,881	25-Oct-1956	Method of Making a Conductive Vitreous Seal	Johannes Cornelis Janssen	North American Philips Co.	
						2,950,414	Apr 1, 1959	Storage Tube	Richard D. Ketchpel	Hughes Aircraft Co.	
	No wires passing through the glass. Closed-coil filament powered by magnetic induction		Edward A. Colby	498,929	15-Feb-93	2,913,892	6-Aug-1956	Photoflash Lamp	William H. Fritz et al.	Union Carbide Corp.	
				499,097	15-Feb-93	5,309,541	16-Apr-1993	Flexible light conduit	Graham W. Flint	Laser Power Corp.	
						2,859,368	20-Oct-1951	Heat Lamp	Orrick H. Biggs & Stuart D. Davis	Sylvania Electric Products, Inc.	
				558,634	21-May-94	2,785,265	5-Dec-1952	Inductor	Winfield W. Salisbury	Zenith Radio Corp.	
	Invented the celebrated "Tesla Coil" generator to light incandescent vacuum lamps by electromagnetic induction, without direct connection of two ***conductors*** passing through the glass.	Westinghouse Electric Corp.	Nikola Tesla	454,622	25-Apr-91	568,176	22-Apr-1896	Apparatus for Producing Electric Currents of High Frequency and Potential	Nikola Tesla		
						568,177	17-Jun-1896	Apparatus for Producing Ozone	Nikola Tesla		
						514,170	2-Jan-1892	Incandescent Electric Light	Nikola Tesla		
						514,167	2-Jan-1892	Electrical Conductor	Nikola Tesla		
						514,168	2-Aug-1893	Means for Generating Electric Currents	Nikola Tesla		
						2,534,532	14-Jul-1945	High-Voltage Rectifier	Otto H. Schade	Radio Corporation of America	
						4,563,617	10-Jan-1983	Flat Panel Television/Display	Allen S. Davidson		
						5,506,596	26-Sep-1994	Reduced tension modular neon sign system	David Pacholok	Everbrite, Inc	
						6,104,107	11-Jan-1995	Method and apparatus for single line electrical transmission	Stanislav & Konstantin Avramenko	Uniline Ltd.	
						6,476,565	11-Apr-2001	Remote powered electrodeless light bulb	Michael Charles Kaminski		
						20050201715	14-Feb-2005	System, method, and computer program product for magneto-optic device display	Sutherland C. Ellwood Jr.	Panorama FLAT Ltd.	
						App. 653,809	2-Oct-1897	Electrical Machine	Albert Verley		(b)
						763,772	10-Nov-1900	Improvements in Apparatus for Wireless Telegraphy	Guglielmo Marconi	Marconi Wireless Telegraph Co.	(c)
						NexisLexis® found 519 U.S. patents with any of the terms "Tesla oscillating coil(s)", "Tesla coil(s)", "Tesla high-frequency coil(s)" or "coil! of the Tesla type"					
				514,170	2-Jan-92	4,563,617	10-Jan-1983	Flat Panel Television/Display	Allen S. Davidson		

Notes: (b) *Ex Parte Verley*, 99 OG 1621 (Sep 11, 1901) (U.S. Patent Commissioner affirming examiner rejection in view of Tesla's prior art), aff'd *In re Verley*, 19 App.D.C. 597 (C.A.D.C. 1902) (denying patent to Verley).

(c) *Marconi Wireless Telegraph Co. of America v. National Electric Signaling Co*. 213 F. 815 (D.C.N.Y. 1914) (Distinguishing over Tesla's prior art and finding the patent not invalid and infringed)

Edison's Claim 2 Elements	Non-infringing Improvement or Attempt to Design-Around Edison's Claim	Sponsor, Assignee or user	Inventor(s)	U.S. Patent Number	Filing Date (in 18YY)	Downstream U.S. patents citing or relying on the improvement patent (including citations during adjudications)					
						U.S. Patent No. Or Publication	Filing Date	Title	Inventor(s)	Assignee	Adjudication note
… from which receiver ***the air is exhausted***, for the ***purposes set forth***.	Avoiding vacuum in the glass receiver by employing a low-pressure filling of Bromine. Heavy gases such as Bromine reduce bulb blackening.	Waring Electric Co.	John Waring	497,038	4-Jan-93	1,180,159	19-Apr-1913	Incandescent Electric Lamp	Irving Langmuir	General Electric Corp.	(d)
						2,799,804	21-Oct-1952	Radar transmi receive Switch	Manfred A. Biondi	Westinghouse Electric Corp.	
						3,022,439	11-Mar-1960	Electric Lamps	Dexter P. Cooper, Jr.	Polaroid Corp.	
						3,470,410	16-Jan-1967	Bromine Regenerative Cycle Incandescent Lamps With Protective Overwind Coils On Coiled Filament Legs	Glenn F. Patsch	General Electric Corp.	
						3,475,649	18-Sep-1967	Tungsten Incandescent Lamps With Iodine Halides	Naoyoshi Nameda et al.	Tokyo Shibaura Electric Co.	
						3,538,373	3-Jan-1968	Electric Incandescent Lamp Containing A Reactive Carrier Gas Which Comprises Hydrogen And Bromine	P.C. Van der Linden & R.A.J. Maria Meijer	North American Philips Co.	
	Developed filament hermetic encasing structures using solid insulators such as mica. No glass receivers "from which the air is exhausted" were used		Francis M. F. Cazin	523,460	7-Dec-92	835,938	Feb 2, 1899	Electric Incandescent Lamp	Francis M. F. Cazin		
						844,778	Jul 27, 1899	Luminant In Electric Incandescent Lamps	Francis M. F. Cazin		
						877,172	21-Sep-1904	Method of Producing Filaments for Electric Incandescent Lamps and the Product of Such method	Francis M. F. Cazin		
						877,408	17-Mar-1904	Manufacture Of Electbic Incandescent Lamps	Francis M. F. Cazin		
						879,083	30-Nov-1903	Electric-Incandescent-Lamp Luminant and the Process of Manufacturing It	Francis M. F. Cazin		
						879,084	31-May-1904	Manufacture Of Filaments in Electbic Incandescent Lamps, Process and Product	Francis M. F. Cazin		
						879,085	2-Jun-1904	Filament In Electric Incandescent Lamps And Its Manufacture	Francis M. F. Cazin		
				523,461	24-Jul-93	835,938	2-Feb-1899	Electric Incandescent Lamp	Francis M. F. Cazin		
						844,778	27-Jul-1899	Luminant In Electric Incandescent Lamps	Francis M. F. Cazin		
						877,172	21-Sep-1904	Method of Producing Filaments for Electric Incandescent Lamps and the Product of Such method	Francis M. F. Cazin		
						877,408	17-Mar-1904	Manufacture Of Electbic Incandescent Lamps	Francis M. F. Cazin		
						879,083	30-Nov-1903	Electric-Incandescent-Lamp Luminant and the Process of Manufacturing It	Francis M. F. Cazin		
						879,084	31-May-1904	Manufacture Of Filaments in Electbic Incandescent Lamps, Process and Product	Francis M. F. Cazin		
						879,085	2-Jun-1904	Filament In Electric Incandescent Lamps And Its Manufacture	Francis M. F. Cazin		
				566,285	24-Jul-93	835,938	2-Feb-1899	Electric Incandescent Lamp	Francis M. F. Cazin		
						844,778	27-Jul-1899	Luminant In Electric Incandescent Lamps	Francis M. F. Cazin		
						877,172	21-Sep-1904	Method of Producing Filaments for Electric Incandescent Lamps and the Product of Such method	Francis M. F. Cazin		
						877,408	17-Mar-1904	Manufacture Of Electbic Incandescent Lamps	Francis M. F. Cazin		
						879,083	30-Nov-1903	Electric-Incandescent-Lamp Luminant and the Process of Manufacturing It	Francis M. F. Cazin		
						879,084	31-May-1904	Manufacture Of Filaments in Electbic Incandescent Lamps, Process and Product	Francis M. F. Cazin		
						879,085	2-Jun-1904	Filament In Electric Incandescent Lamps And Its Manufacture	Francis M. F. Cazin		

Notes: (d) *General Electric Co v. Nitro-Tungsten Lamp Co.* 261 F. 606 (D.C.N.Y. 1919) (Distinguishing over Waring's prior art and finding the patent valid and infringed).