SCIENTIFIC INSTRUMENT MAKING, EPISTEMOLOGY, AND THE CONFLICT BETWEEN GIFT AND COMMODITY ECONOMIES[1]

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1. INTRODUCTION

I begin with a joke Woody Allen used in his stand up comedy routines (Hyde,1979, p. 46). Toward the end of the set, Allen would pull out a beautiful pocket watch, "It's a family heirloom. My father sold it to me on his deathbed." The humor exposes the conflict which I explore in this paper. A family heirloom, which one receives from one's father on his deathbed, is a gift, not a commodity, and the moment when it is treated as a commodity it loses its gift status.

We live in a world where property is understood first and foremost in terms of commodity exchange value and all of its attendant practices and concepts. One is inclined to think of property and the commodity economies which apparently govern its flow almost as a necessary mode of human interaction. Yet there are counter-concepts—those of gifts and gift exchange—which have attracted attention from anthropologists and sociologists (Caplow, et al., 1982; Carrier, 1995; Cheal, 1988; Gregory, 1982; Lévi-Strauss, 1969; Mauss, 1990; Zelizer, 1979) and were a central concern of Friedrich Nietzsche's *Thus Spoke Zarathustra* (Nietzsche, 1982; Shapiro, 1991). Lewis Hyde presents a theory of gifts and gift exchange in his marvelous book, *The Gift: Imagination and the Erotic Life of Property* (1979). He argues that artists and their works must live in a world of gifts and gift exchange: "Works of art exist simultaneously in two 'economies,' a market economy and a gift economy. Only one of these is essential, however: a work of art can survive without the market, but where there is no gift there is no art" (p. xi). One of the reasons, Hyde argues, that art requires a gift economy is that creativity is itself a gift.

For the moment I skip the details of Hyde's argument to come directly to my main concern. Innovative scientific instrument making is a creative enterprise. For the same reasons that artistic work needs to exist in a gift economy, instrument making does too. At the same time, instrument making, research, development and production are expensive. These same instrument "gift objects" need financial support, and this usually has to come from their sale as commodities. Instrument making occurs in an open-ended process of negotiating between the demands of the marketplace and the demands of a gift economy. In what follows, I show this process at work. I focus on one site of instrument creation—the development of the first commercial grating spectrograph.

Some may be surprised from my title that I see this as an epistemological investigation. It may seem that the conflict between gift and commodity economies, as it exists in instrument making, is of sociological or perhaps economic interest. Ethical concerns might lurk here, but not epistemology. On the contrary, I think this issue is central to the epistemology of technology and science. I elaborate briefly.

Hyde argues that existence in a gift economy is necessary for the inspiration from which art flows (1979, chap. 8). So it is with knowledge as well. Gift economies are necessary for knowledge production and dissemination. Consider the fact that academics are not paid by the piece. Academic articles are written and published, but, typically, no fee is paid to their authors. The articles are intellectual gifts given in return for receiving the intellectual gifts of others. This give and take of intellectual property serves to establish and define an academic group, but more on the social functions of gift economies below.

I have argued elsewhere (Baird, 1993, 1995, 1996; Baird and Faust, 1990; Baird and Nordmann, 1994) that instruments should themselves be understood epistemologically. Instruments are elements of knowledge, different in form, but no different in epistemological significance, from scientific theories. Where theories express knowledge propositionally, instruments express knowledge in material form. A consequence of this is that instrument making, like knowledge production generally, also must exist in a gift economy.

This produces a problem. Whereas propositional knowledge is relatively inexpensive, and has been supported largely by independent wealth (initially) or teaching (more recently), instrument making is expensive. Grants may support much one-of-a-kind academic instrument development, but knowledge has to be disseminated. To disseminate material knowledge in its instrumental form, multiple instruments have to be made, and this costs money. The cost has been covered by funds from the sale of instruments as commodities. Thus, these gifts-of-material-knowledge also are commodities. It is the tension of this dual existence which I examine by case study in the paper that follows.

One final introductory point. Late-twentieth-century technology and science have increasingly interpenetrated each other's domains. Modern high technology is scientific in character; engineering schools teach scientific engineering. And, conversely, science is technological in character; huge teams of engineers and physicists build the instrumental foci of modern science. The increasingly popular term from science studies, "technoscience" (Latour, 1987), appropriately captures this marriage. Yet, the medium and history of science and of technology are different. These differences impact how exchanges are made in the two enterprises. The conflict between gift and commodity economies exposes just this point of tension, where the joint between science and technology may be more like a misaligned butt joint than a perfect dovetail.

2. A PERSONAL AND HISTORIOGRAPHIC POINT

The instrument I am concerned with here was developed by Baird Associates, a company founded in 1936 by my father, Walter Baird, and two other young physicists, John Sterner and Harry Kelly. This fact places my position as historian in some doubt. While I have a special interest in the history of Baird Associates, for I grew up with "BA" (as it was always referred to) and I have a special personal knowledge of Walter Baird, I do not believe I inflate the interest or importance of these developments. BA was one of several companies, and certainly not the largest, which together provided one component of sweeping cultural changes. Scientific instruments, their conception, design, manufacture, sales, and use have become central to the conduct of technology, science, and everyday life—think, for example, of the vast array of medical instruments with which health care delivery is now accomplished. These changes are a matter of historical record (Baird, 1993). BA's first spectrograph now resides at the National Museum of American History (Walsh, 1988, p. 1339).

Historical materials documenting these changes are difficult to obtain and are getting more difficult monthly. The three main competitors for the analytical grating spectrograph market during the 1930s, 40s and 50s were BA, ARL Inc., and Jarrell-Ash. (Ironically, all three now live in one corporate house—Thermo-Jarrell-Ash—and together compete primarily with foreign makers.) As part of my continuing research, I wrote ARL several years ago to see if I might have access to files and information from the company's early days. They replied that, "Due to a move by the company to new facilities approximately 2 1/2 years ago, many of the documents were lost or destroyed" (ARL, 1990). During my research at the Baird plant, I was told that just two months before I had arrived, the first BA infrared recording spectrophotometer, made in the 40s, was given back to them; they junked it. This was an historically significant instrument. My father died in 1982, before I knew that scientific instruments should be a focus of philosophical attention, and certainly before I knew to ask him about the history of his firm.

Much of what I present about BA I learned from sources that are not readily available. I have used my father's diaries, his unpublished reminiscences, papers from BA's "dead" files, copies of ancient letters, and interviews with the principles who are still alive. This information is hard to obtain, and in some cases it is becoming impossible to obtain. In short, the history of these developments is disappearing. Much of it is not available to historians. Historians have done a good job preserving a variety of materials pertaining to the dramatic theoretical developments in science this century (Kuhn, 1967). Unfortunately, not enough has been done to preserve materials pertaining to the equally dramatic instrumental developments this century. Consequently, at risk of being too close to my subject, I present here some of the history of Baird Associates.

3. GIFT ECONOMIES

Before launching into the historical details behind BA's first spectrograph, I sketch in somewhat greater detail gift economies, and, by contrast, commodity economies. Gift economies function in a wide variety of circumstances. While each has its own specificity, several generalities describe the range of gift practices. Here I mention those which are key to understanding gift economies generally and which relate specifically to my concern with instrument making.

Social Ties: The fundamental difference between gift and commodity economies can be seen in the curious subtitle of Hyde's book: "Imagination and the Erotic Life of Property." Gift economies serve to bind people together. They create and maintain social groups. All the various rules or expectations which govern gift exchange serve this end. Ralph Waldo Emerson, in his nineteenth-century essay, "Gifts," wrote, "The gift, to be true, must be the flowing of the giver unto me, correspondent to my flowing unto him" (1876, p. 163). Seen in a wider social context, gift economies establish social boundaries; one must give to the group in order to be part of the group and receive the group's gifts in return: property bonding people together—the erotic life of property.

An acid quip of physicist Henry Rowland—of whom, more below—reveals how gifts establish boundaries. Rowland, advocate of pure science and contemporary of Thomas Edison, complained that the "spark of Faraday blazes at every street corner" (quoted in Moore, 1982, pp. 160-161). Edison, in developing and adapting scientific discoveries into salable commodities from which he gained profit, raised Rowland's ire. Edison availed himself of the gifts of the scientific community, but instead of giving back to that community, he sold his inventions. Edison turned scientific gifts into commercial commodities, and thereby excluded himself from the scientific community.

Commodity economies work against bonding. The rules and expectations which govern commodity exchange serve to define and delimit mutual responsibility and future obligation between the parties involved. Ideal commodity exchanges occur when the parties involved understand at the outset just what each gives and receives and when the interaction is to be concluded. In a sense, commodity exchanges aim to establish—ideally, mutually beneficial—conclusions of interactions. Gift exchanges aim to initiate and maintain interactions. In stark contrast to commodity exchanges, gifts cannot have a dollar-measurable value. Such a value would allow a gift recipient to close the interaction; a gift of equal value could be returned leaving neither party obligated to the other. No further interaction would be necessary. Assigned dollar values work against social bonding.

Gifts Are Personal: Gifts cannot be produced by toil alone, nor by taking some object "off the shelf." Gifts are recycled gifts. An artist cannot make art without having his or her own artistic gifts—understanding, talent, and skill bequeathed to the artist at birth and by upbringing and participation in an artistic gift economy. Objects which are gifts need something of the giver. Emerson again, "Rings and other jewels are not gifts, but apologies for gifts. The only gift is a portion of thyself. Thou must bleed for me" (1876, p. 161). An extreme sentiment, perhaps, but it does capture a distinction commonly understood between a "pro forma" and a "real" or "personal" gift.

Herein lies a central piece of the argument that creative endeavors, be they artistic or instrument making, rely on a gift economy. Edison may well have said that invention is 99% perspiration and 1% inspiration, but it would be foolish to deny that Edison was a gifted inventor. The various skills, bequeathed at birth and developed through his upbringing and his dedication to his craft were gifts which he brought to his inventive activity; inspiration—even if only 1%—remains necessary. One can see recent corporate attempts to promote "intrapreneurial" inventive activity as a way to put the necessary personal element into invention while still operating in a profit-based commodity market.

Gifts Must Move: Gift economies require a cycle of giving. The racist expression "Indian giver" has its source in this aspect of gift giving. In his 1764 history of the Massachusetts colony, Thomas Hutchinson said, "An Indian gift is a proverbial expression signifying a present for which an equivalent return is expected" (quoted in Hyde, 1979, p. 3). Hyde goes on to describe how the Massachusetts Indians may have shared a peace pipe with the Puritan settlers, leaving the pipe with the newcomers. But the Indians expected the pipe to be returned, or better, recycled and given to others as part of the socially binding cycle of giving peace making: "The Indian giver (or the original one, at any rate) understood a cardinal property of the gift: whatever we have been given is supposed to be given away again, not kept. Or if it is kept, something of similar value should move on in its stead" (Hyde, 1979, p. 4).

Here is one sense of the often quoted aphorism that a great scientist may see further only because he or she stands on the shoulders of giants. Someone who learns what science has to teach, but who does not give back to scientific culture is not a scientist. In the section, "On the Gift-Giving Virtue," of *Zarathustra*, Nietzsche wrote, "One repays a teacher badly if one always remains nothing but a pupil. And why do you not want to pluck at my wreath?" (1982, p. 190). In taking an intellectual gift one incurs a debt to contribute an intellectual gift in return—thereby to pass along or recycle the gift.

Stewardship, not ownership, is a better concept for one's relation to gifts received. For a time, one becomes the keeper of something whose value lies in its movement among those in a gift community. Accumulation, then, provides another stark contrast between gift and commodity economies. Businesses aim to accumulate capital in the form of profits. This capital can then be used in various ways at the discretion of the business managers. Gifts, on the contrary, cannot be accumulated like profits; they must be plowed back into the cycle of gift giving. Gifts received must be given away or they cease to be gifts and the recipient of the gift ceases to belong to the gift group.

Obligation: This erotic life of property is a life of bonding or ensnaring people. Here is an essential duality of gift economies. Gifts given and gifts received call up the joy of human connection, but also the suffering of obligation: bonding and ensnaring.

Nietzsche described the gift giving virtue as the "lust to rule" (Nietzsche, 1982, p. 301; Shapiro, 1991, p. 17). As commodity economies establish status hierarchies through how much is accumulated, gift economies establish hierarchies through how much one gives. Much literature, following early anthropological work (Lévi-Strauss, 1969; Mauss, 1990) has characterized gift economies as highly oppressive because of this feature. I might speculate that one of the motivations for the increasing ubiquity of commodity economies is an attempt to flee the gift's snare. Walk into the store. Buy the can of soup and be done with it. Bypass the burden of an "I-Thou" relationship with the checker. At the same time, I might further speculate that the striking renewed emphasis on ethnic identity that one sees worldwide is a reaction to the ubiquity of commodity economies. As commodity economies increase their domain of application—escaping the gift's snare—anxiety over social-group-belongingness increases.

4. FOUNDNG A COMPANY IN GIFT/COMMODITY CONFLICT

Founding a Company: At the beginning of 1936, John Sterner and Walter Baird were working at the Watertown Arsenal in Watertown, Massachusetts.[2] (Figure 1, a photo of Walter Baird, John Sterner and Davy Low, BA's first employee from 1937, is not printed here but is available.[3]) One of the principal functions of the Army's Watertown Arsenal was the analysis of metals used in guns and ordnance. Sterner worked in the Arsenal's spectroscopy lab while Baird worked in the X-ray diffraction lab. In the process of this work it became clear to them that chemical analysis could be done more easily with instruments, such as the spectrograph and X-ray diffraction tube, than by traditional "wet" methods. But, as of 1936, these instrumental methods were restricted to a few academic and government laboratories with the expertise and funds to build the necessary instruments themselves.

On July 21, 1936, Henry Aughey of Du Pont saw a demonstration of Baird's X-ray diffraction apparatus. A month later (July 31, 1936) he wrote and asked Baird how to get a tube of his own. With this "order" from Du Pont, Baird quit work at the Watertown Arsenal to devote full time to building an X-ray tube for Du Pont. Sterner and Harry Kelly—an MIT friend of Sterner's then working at American Thermos—kept their jobs in order to provide a source of capital for the partnership.

A Letter Home: The Baird Associates (hereafter BA) budget for the last half of 1936 showed a shortfall of $1,582—this includes Kelly's and Sterner's salaries being plowed into the partnership. Baird wrote his father:

> Dear Pop- The essential purpose of the company (partnership) is to design and develop apparatus for industrial laboratories— X-ray apparatus, spectrographic etc. At the same time it is our purpose to set up a laboratory here to be used for demonstration work and for consulting. We have spent most of our time recently getting together our own laboratory and have now either finished or partly finished an X-ray tube, high vacuum and evaporation outfits and a grating spectrograph. The X-ray equipment is a salable article. So far also we have promoted a vacuum gauge which a local instrument maker is manufacturing and selling. From this we collect a royalty. Our general policy is to carry on this sort of thing—develop and try out a piece of equipment—turn it over to some established concern for production. The money we need is for the carry-over period between development and sale of an article. We have sufficient to take care of running expenses. Our credit is good. I have a

> very good chance to get the order for a grating spectrograph next month—a $1,500 job—this requires some outlay for machine work, etc., so we need the money right away. We are after $1000 and can offer 10% for a year. . . . We can assure payment. . . . Business is booming—industry is now ready for the equipment we are putting out—lack of capital only prevents us from being ready for it. . . . I state again that we need the money right now (Baird, 1937).

Baird's father's reply came two days later. He was not able to supply the needed $1,000. However, he was able to provide $50; with this and some other money in hand Baird purchased the partnership's first grating from Johns Hopkins (G. Baird, 1937). More on gratings below.

BA's Mission: BA conceived of themselves as a "think/do-tank" with the goal of producing designs and prototypes for useful analytical instruments. They were not inclined initially to go into the manufacturing and marketing of their products. This continued to be the stated purpose of the firm at least through the end of 1938 when the partners wrote a mission statement in the form of a series of questions and answers:

> 3. Q. Purpose?
> A. 1. To bridge the gap between the conception of new methods of physical measurement and their practical applications.
> 2. To build up a laboratory for the analysis and solution of special industrial physical problems. . . .
> 7. Q. What is involved in the policy of the company as stated above in the first part of the answer to Question 3?
> A. 1. Development of simple, rugged, accurate, generally usable instruments to make the measurements under consideration.
> 2. Finding a market for and constructing a limited number of these instruments.
> 3. Educating the public to the realization of the importance of the measurements involved and/or the suitability of the specific instruments for making those measurement. . . .
> 9. Q. Can this development be financed in part by orders from industrial companies and universities received prior to detailed

development?

> A. The Baird Associates have found that such has been the case in the majority of instruments developed to date. . . .
>
> 14. Q. What is the company's attitude toward the manufacture of instruments developed?
>
> A. We do not wish to become a manufacturing organization except where production is on a very small scale or where inadequacy of available manufacturing facilities makes such a course seem necessary and advisable.
>
> 15. Q. How then can the company make profits?
>
> A. From professional services rendered, limited manufacturing activities, and royalties on any larger scale production which might ensue (BA, 1938, pp. 1-4).

The idea of a think/do-tank aimed at creating instruments nicely distinguished the scientific or gift economy contribution from the manufacturing or commodity economy contribution in the production of instruments. Financial demands, however, continued to push these two contributions together. Contrary to their optimistic assessment here, it was difficult to finance the research and development of new instruments from "orders from industrial companies and universities received prior to detailed development."

Here is one important moral about scientific instrument making. It is not generally profitable to separate the research and development of an instrument from its manufacture. It is tempting to make such a separation because it is tempting to regard research and development as epistemically privileged; this is where new knowledge is created.

And, significantly, knowledge is a gift. Manufacture is involved with more pragmatic issues of knowledge diffusion, matters typically handled in a commodity economy. As long as research and development is not externally supported—as it is in a university environment—the issue of operating capital makes this distinction unviable. BA originally had in mind to establish an environment for something like university research where the goal would be a prototype instrument, not a published paper. Commodity economics worked against this aim. This may serve to explain Eric von Hippel's finding that most (78%) innovations in scientific instruments come from the market for the instruments (research laboratories) and not from the instrument making firms (1988).

Spectrographs, circa 1937, and the Gift Economy: In his February 8, 1936, diary entry Baird noted: "Harrison of Tech seems to have pretty conclusive evidence in which he shows that the spectrograph is a lot more handy device to use than the X-ray" (1936-40). On November 17, 1936, Sterner wrote to Kelly:

> Walter is contemplating taking the tube to Duponts and trying to sell them a camera at the same time. Also trying to get hold of a grating from Hopkins. It sounds like a good idea to me. What do you think? . . . Through the Arsenal a possibility of selling a grating has come up. Of course it is very vague, but indications point toward a very lucrative business in grating spectrographs if we can get one set up in our lab. to expt. with. I have made several good contacts regarding possible customers on that score. But we must have one built. Walter seems to feel that he can go down and come back with some sort of a grating (Sterner, 1936, p. 2).

Baird and Sterner were party to work in George Harrison's M.I.T. spectroscopy lab. This was very important, because the M.I.T. lab was pursuing advanced research in spectrographic analysis, in improving the instruments for spectrographic analysis, and in finding markets for spectrographic analysis.

Each summer, 1933 to 1942, Harrison put together a conference on spectroscopy and its applications.[4] Participants in these conferences were chosen to maximize the breadth of information concerning both applications and instruments. These conferences served to help establish the connections between physical researchers, instrument makers, and industrial chemical analysts. Harrison's Summer conferences helped to take spectrographs out of isolated academic and government laboratories and bring them to a wide array of private sector concerns where spectrographic instruments could help analytical research. In the beginning, this was all done on an academic gift economy model. Personal connections were developed through these conferences. Ideas for instruments and applications were shared. A new community was built through this give and take gifting of knowledge.

5. GRATINGS AND GIFTS

Rowland's Gift: In 1882, Henry Rowland developed a ruling engine for making gratings on concave surfaces and the theory of concave grating spectroscopes (1882; 1883). For several decades Rowland's ruling engine was the only source for high enough quality gratings to compete effectively with prisms for spectral analysis. (See Figure 2, a photo of Henry Rowland and his ruling engine.) Rowland's gratings were virtually free of the irregularities which had plagued earlier gratings. R. W. Wood succeeded Rowland as professor of physics at Hopkins. He continued Rowland's work on gratings, developing many of his own improvements in gratings (1912; 1935; 1944). And he continued turning out high quality gratings on Rowland's ruling engine.

By the late 1930s, the most serious problem holding back the production of grating spectrographs was the availability of gratings. A 1968 review of the development of spectrograph design tells us, "Between the world wars a good grating could only be obtained by personal contact between the head of a research group and the few possible sources of supply, and such a grating was a highly prized possession" (Learner, 1968, p. 540). Gratings were exchanged as intellectual gifts.

Joining the Grating Gift Community: Baird, having just completed his Ph.D. at Hopkins, knew the people responsible for producing the gratings. Still, obtaining gratings for use in a commercial venture was not like making an order from Edmund Scientific. R. W. Wood was particular about the people to whom he would sell gratings. During a trip to Hopkins to try and get some gratings from Wood, Baird wrote Sterner as follows:

> Wood showed me correspondence from Bausch & Lomb. They have written for a price on 25 plane gratings (per year) which they intend to use in a Littrow mounting for chemical analysis. They demand ghost free gratings with little scattered light. They seem to know little about chemical analysis, and the lens necessary introduces the same dispersion troubles now dogging the prism model. R.W. snorts at the above order—says that B&L wants to make 80% on their instruments and he doesn't like it (1936).

The BA spectrograph, designed for a concave grating, not a plane grating, held greater promise of being capable of quantitative spectrographic analysis. The instrument would be enclosed in a light-tight cabinet of transportable size: 11 feet by 2 feet square; previously grating spectrographs had required an entire light-tight room. Confining the optical elements to a small cabinet had the additional benefit of making precise control of the temperature simpler. It would be a genuine contribution to science. Finally, Wood trusted Baird's intentions: BA was not in it for the money but to contribute to science. (See Figure 3, a photo of delivery of a 3-meter spectrograph from the late 1930s.)

These negotiations display all of the features of a gift economy. BA—to be more precise, Baird, Sterner, and Kelly—had the qualifications to be members of the scientific gift community; their aim was to give something back to science: a transportable spectrograph suitable for quantitative analysis. Baird approached Wood on a personal level; he knew him from his graduate study at Hopkins. Wood could trust that profit was not BA's primary motive, that they did not aim to become a major instrument manufacturing firm.

The Wisdom of Solomon: In 1939, BA traded one of their spectrographs to Hopkins. On delivery, there was a disagreement over the number of gratings BA was to receive in return for their instrument. (See Figure 4, a photo of R. W. Wood.) Baird wrote Sterner :

> R.W. has not been tamed as yet, but am beating on him. Dieke is on my side but the practical politics need careful handling. The sad part is that since RW's retirement, his salary comes partially from the grating department, so this barter is cash out of his pocket (1939).
>
> In 1975, Baird remembered the trade as follows:
>
> I had a big argument with one R. W. Wood about whether I got three gratings or four gratings. I wanted the gratings, and I gave him the 1-meter spectrograph. However, when we got right down into the final nitty gritty argument, it turns out that he said you get three, and I said I want four. We both understood that you can't cut a grating in half, so I ended up with three (1975).

My father told this story on many occasions and I know that when he spoke of cutting a grating in half he referred to the biblical story where King Solomon determined which of two women was the mother of a baby. When the king threatened to cut the baby in half the true mother relinquished her claim in order to save her child's life. In the 1930s, gratings, like babies, were gifts. The grating in question was Wood's to give or not; it was not a commodity whose price could be set by "fair negotiations." BA did not get the fourth grating.

Gratings are Personal: While Wood was officially in charge of the ruling engines, Wilbur Perry was the technician who ruled the gratings and kept the ruling engines in proper running order. Baird was on good terms with Perry. At one point, he writes that he "managed to save [for Baird] one of the 30,000 line gratings so Wood didn't find it" (Perry, undated).

Throughout the 30s and 40s, Perry did his best to provide BA with good gratings when they were needed. Some of his postcards to BA:

> [1939] Dear Walter, I trust you have received the grating which was sent from here Aug 1st. This grating seemed to be a good looking one. . . .
>
> [1941a] Dear Walter, I am working on your two gratings now and should finish one by the 19th. . . . I plan to rule a 3 meter for you every time that the machine is free to keep a supply on hand.
>
> [Later in 1941b] Dear Walter, . . . There was no mistake about ruling it with 30,000 instead of 15,000 because I needed a surface to locate my aluminum film troubles. Treat it well.
>
> [1945] Dear Walter, . . . The order from Baird Associates for 18 gratings nearly floored R. W., because he very promptly brought it down to me and informed me at the time that it should keep me busy for some time to come.

Through this contact, BA could depend on a reliable supply of what were the best gratings in the world.

6. FROM GIVING TO SELLING

Giving to a New Community: The partners rushed to get the first spectrograph finished so that it could be displayed at the 1937 MIT Spectroscopy Conference, July 19-22, 1937 (BA, 1950, p. 2). The instrument was not sold until 1940—see below. But it did induce the U.S. Bureau of Mines to order an instrument of their own. The instrument was built by BA, and delivered, after many delays, in April 1938. BA's profit over the direct costs of its manufacture was $1,260. But there were many indirect costs associated with setting up a laboratory and manufacturing facility (BA, 1937; Sterner, 1938a; 1938b; Walsh, 1988, p. 1338). (See Figure 5, a photo of a BA advertising photo collage for the 3-meter spectrograph.) While sold at a loss, the sale nonetheless was important. This spectrograph helped to demonstrate the advantages of gratings over prisms. On the basis of 18 months experience with the BA spectrograph, Morris Slavin, of the Bureau of Mines, argued in favor of grating spectrographs at the 1939 MIT Summer conference (1940). Thus, while BA did not profit financially, BA did profit in gift terms. Through its gift of a good grating spectrograph to the developing community of instrumental analysts, BA helped establish this way of doing analysis.

From Giving to Selling: Through the remainder of the 1930s, BA sold seven more grating spectrographs. While sales started slowly, they picked up in the 1940s. Fifty-four spectrographs were sold through the rest of the 1940s, and the line continued in production well into the 1960s. The price dropped in 1938 and 1939, from $2,610 to about $2,175, but thereafter rose steadily. By 1940, the price for a three-meter spectrograph had risen to $3,700 (Baird Corporation, undated). BA's financial officer during the 1950s wrote:

> When the instrument was housed in a wooden case and employed an open (dangerous) electrode stand, the margin was reasonably good, but ever since it was all enclosed in steel costs have been too high to show a net profit (Chamberlain, 1958, p. 12).

Given the nature of the market, BA could not expect a large volume of sales. Unfortunately a small number of sales drives up the proportion of indirect—research—costs which each instrument has to share. Small numbers drive down profitability. Once several instruments had been placed in use, however, BA did make some money on accessories and supplies for these instruments.

With the advent of World War II, BA volume picked up substantially, as the following table shows. The numbers are *not* in millions of dollars:

Year	Total Net Sales	Gross Profit (Loss	Earnings Before Taxes
1936	230	34	(41)
1937	726	(1,084)	(1,460)
1938	6,036	204	(592)
1939	10,126	2,740	749
1940	27,486	3,593	2,200
1941	49,129	16,930	11,600
1942	128,889	32,278	23,038
1943	203,498	47,956	29,469
1944	140,922	50,850	43,332
1945	387,558	45,472	30,301
1946	353,645	72,103	32,603

(Covers 8 months; Untitled, 1953.)

While there was growth prior to 1942, after 1942 business nearly tripled. A 1948 Fortune magazine article featuring BA put it this way:

> Spectrochemistry, old in principle, was used only in advanced-research laboratories until about ten years ago. Researchers, who often built their own instruments, were seldom interested in devising routine methods for analyzing standard chemical substances. And the chemists who ran the industrial control laboratories were cool toward academic techniques that obtained answers by measuring the wave length of invisible ultraviolet and infrared light.
>
> When the war came along many control laboratories were caught flat-footed. Time-consuming methods of nineteenth-century chemistry finally had to be dropped in favor of spectrochemistry (1948, p. 133).

The demand for rapid analyses, particularly of metals such as those used at the Watertown Arsenal, brought industry to spectrochemical methods and the instruments required to do them. The capital to finance this move from "nineteenth-century" wet techniques, to instrumental techniques came from the government as part of the financing of the war. Once the war was over a new tradition in chemical analysis had been established, a tradition which depended on expensive instrumentation supplied by companies such as BA.

World War II marks another more local transition. By the late 1940s the BA spectrograph was a commodity, and an expensive one at that—by 1953 the unit sold for $12,500.

A Gift Becomes a Commodity: The very first spectrograph BA built, the one which had been on display at the 1937 MIT Conference, was sold in 1940 to New England Spectrochemical, to raise capital for the firm.[5] (See Figure 6, a drawing of Specky.) Writing in his diary in 1940, Baird lamented the sale:

> Our first spectrograph now has a new home. I am not too well pleased with its new owners for I am sure they will not treat Specky with the proper degree of affection. I could hardly expect them to. To me that instrument represents nearly a week's work without sleep. It also represents the feeling that went into this business something which money cannot buy. We sold it because we need money and Specky represented most of our capital. We also sold it knowing we could replace it with a more perfect instrument. It was Specky's imperfections which endeared "her" to us for I know every inch, every screw. We may build many an instrument but that one has a soul where all the others have only bodies (1936-1940, January 20, 1940).

Specky was BA's gift to instrumental analysis, the direct result of intimate familiarity with the theoretical principles and mechanical and optical guts which allowed its users to perform new feats of measurement. Understanding Specky provided an appreciation for what some of nature's possibilities are. At the same time Specky represented capital which was much needed to keep BA financially alive. It existed in a curious tension between being a gift and a commodity.

While BA survived, it did not thrive financially. Still it did thrive in the academic gift economy. During the 1940s and 1950s BA was known primarily as a research group. First-rate scientists were attracted to BA because they could maintain membership in the academic gift economy. Baird reflected on the company's record in 1975:

> [C]ertain things could have been done better. They could have been done with more of an idea with respect to money. But here was a period that was absolutely exciting in terms of. . . producing new and interesting stuff. . . . I guess the difference, looking backwards, is that I was much more interested in science and the improvement of science and what science could do than I was interested in making money. Now that may sound kind of peculiar but, nevertheless, I think if you go back over all these years and look at all of our annual reports, you will find that somehow each year we ended with a little bit of plus and a hell of a lot of excitement. The trick was to promote this excitement while making sure that each year ended up "with a little bit of plus."

7. CONCLUSION

I close with three brief morals which I take from this history:

1. Creative work needs a gift economy. It is in the nature of the creative impulse to give to—and to take from—the creative community. This is a consequence of the fact that creative people stand on shoulders. Gifts received prompt gifts given.

2. Creative work—instrument making, in any case—is capital intensive and, consequently, must also exist in a commodity economy. The "little bit of plus" is necessary.

3. These two demands exist in tension. There is no simple rule for specifying how much to give versus how much to charge. This is a matter that is negotiated case by case, weaving a path between economic ruin and creative alienation.[6]

NOTES

1. I would like to acknowledge one important source for this paper. While researching at the BA plant I happened to meet a man name W. L. Hyde who worked at BA for several years in the 1940s. After leaving BA, he pursued an interesting career traversing industry, the academy, and academic administration. I spoke with him about my research and he suggested that the conflict between gift and exchange economies should be an important part of what I have to say. He recommended his son's book, *The Gift*. And so, what I offer here is a gift, partially in return for the gifts from Dr. Hyde, his son, and my father.

2. More detail on the early history of Baird Associates can be found in Baird, 1991.

3. Figures are not available in the electronic version of this paper. However, text and figures can be found on my home page:

http://www.cla.sc.edu/PHIL/faculty/baird/baird1.html.

4. Proceedings for the 5th, 6th and 7th Summer conferences (1937, 1938, 1939) were published by John Wiley (Harrison, 1938; 1939; 1940) and proceedings for the 8th, 9th, and 10th conferences (1940, 1941, and 1942) were published in several issues of the *Journal of the Optical Society of America* (volumes 31, 32, and 33).

5. This is the instrument which is now at the Smithsonian's Museum of History and Technology.

6. All ephemera are in the personal possession of the author.

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