# A Case Study of the Equipment Market and the Invention of the Beef Carcass Steam Pasteurization System

Tanya Roberts and Elisabete Salay

In 1995, Frigoscandia Equipment began marketing a Beef Steam Pasteurization System (BSPS), a new technology designed to kill pathogens on the exterior of beef carcasses. This case study examines the economics of the BSPS invention, using published literature and open-ended interviews of the parties involved in the invention. The survey questions follow the object approach in the Oslo Manual (OECD, 1997). (For the survey questionnaires, see Salay, Caswell, and Roberts, 2003).

The BSPS case study highlights the importance of collaboration between technology developers and users in successful food safety innovation. It also highlights the difficulty of designing and successfully marketing technologies for the control of pathogen contamination in meat. Pathogen control requires systematic control throughout the farm-to-table supply chain (Ahl, Roberts, and McDowell, 1995; Gill, 1999). While some steps in pathogen control can substitute for each other, often the controls are complementary in producing an increased probability of safe food. Even the best technology, however, can be undermined by deficiencies in control along the supply chain. The interlinked nature of the steps required to control pathogens (and prevent them from growing) means that the technological success of one particular piece of equipment may be difficult to accurately determine and market.

The BSPS equipment is the invention of Frigoscandia Equipment, though its successful adaptation to beef slaughter plants was also due to contributions from Excel, the second largest U.S. beefpacking company (a division of Cargill, Inc.) and microbiological data from collaborators at Kansas State University (KSU). The BSPS technology uses steam to kill pathogens on beef carcasses. The BSPS unit itself is contained in a stainless steel cabinet that is installed at the end of the slaughter line, just before the sides of beef (hanging from an overhead rail) enter the chiller. Within the BSPS cabinet, three procedures are performed:

- Air is blown onto the carcass to remove the film of water covering the side of beef. This permits the steam to reach and kill the surface bacterial pathogens that otherwise would be protected by the water film.
- Steam is applied to the side of the beef at a sufficient temperature and over a sufficient time period to kill the target pathogens, generally *E. coli* O157:H7, *Salmonella*, and generic *E. coli*. The industry commonly uses steam heated to 190$^{o}$ Fahrenheit (F) applied for 10-15 seconds to the sides of beef (Brodziak, 2002), though individual plants may vary temperature and time depending on the stringency of their safety requirements.
- Icy water is briefly poured over the carcass to help bring back the "bloom" (red color) to the carcass and to stop the depth of "cooking."

The 1993 *E. coli* O157:H7 outbreak from hamburgers from Jack in the Box was the key initiating event in the development of the BSPS. First, it increased consumer awareness of and demand for food safety. After this outbreak, consumers, retailers, government officials, and processors themselves began to reassess the beef industry's food safety standards. The outbreak forced companies to respond to growing customer and consumer concerns, if for no other reason than to avoid legal liability suits. Second, the outbreak accelerated efforts to modernize Federal requirements for food safety using the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) system (see box "Pathogen Reduction and Hazard Analysis and Critical Control Point Program). PR/HACCP provided food processors with more flexibility to innovate and adopt new safety technologies, such as the BSPS. In addition, the increased testing for pathogens included in PR/HACCP increased the probability that a foodborne disease outbreak would be discovered. The testing also potentially increased demand for food safety innovations such as the BSPS.

The initial assessment of the steam pasteurization technology for reducing pathogen contamination of beef was encouraging. Engineers at Frigoscandia Equipment considered the BSPS's technological risks to be low (Wilson, 2001 and 2002). Steam, the technology behind the BSPS, was well-known for its ability to kill pathogens, and early experiments in the meat and poultry industry, though mixed, were promising enough to interest Frigoscandia in the technology (table C-1). Discussions with key people in the U.S. beef industry were positive, indicating potential market demand.

Discussions with consumer activists indicated that they considered steam a safe and acceptable method for killing pathogens. Surveys of consumers have indicated that steam pasteurization is more acceptable than some other new food safety technologies such as irradiation (Fingerhut et al., 2001). However, the extent of pathogen reduction is also important to consumer evaluations of competing food safety technologies (Lusk and Hudson, forthcoming).

Given the positive initial assessment of the innovation, Frigoscandia Equipment funded an exploration of the technical feasibility of the project. Frigoscandia Equipment realized a substantial investment would be required to develop the equipment. Building the machinery and testing the efficacy of the procedure would require time and financial commitment. Whether the BSPS innovation would prove financially profitable would depend on how well the BSPS equipment reduced pathogens, the cost of the equipment, and the cost and benefits of alternative pathogen-control systems available to beefpacking plants. Would the domestic beef industry consider the pathogen-reduction benefits worth the purchase price of the equipment? Would the innovation succeed in global markets?

## History of BSPS Invention: Collaboration and Risk Sharing

The Swedish company, Frigoscandia Equipment, had extensive experience with inventing and marketing equipment in cold storage and food transportation (see Timeline in appendix A). By keeping foods at a very low temperature, food product quality was improved, shelf-life was extended, and food safety concerns were met. Frigoscandia's ultra-cold storage unit was being used for long-distance meat shipment by 1950. Its FLoFREEZE, a belt-type freezer tunnel, was named one of the 10 most important Swedish inventions ever by the Chalmers University of Technology in Gothenburg, Sweden. Steam pasteurization was a new food safety technology, a complementary addition to the company's product line, and a new marketing opportunity for Frigoscandia Equipment.

To reduce the technological risks and share the costs of creating the new BSPS technology, Frigoscandia Equipment contacted a business client, Excel, the second largest U.S. beefpacking company, which agreed to collaborate on the BSPS invention. Excel had the day-to-day knowledge of operating beefpacking plants where the equipment was to be used. Though the two companies jointly developed the technology and applied for the patent, Frigoscandia Equipment holds the rights to the patent on this technology because the global beef industry was the target sales market. If Excel co-held the rights to the patent, other beef companies may have been reluctant to purchase equipment, thinking they would be supporting a competitor.

As a first test of the technology's efficacy, Frigoscandia Equipment built a prototype BSPS unit.

**Table C-1—History of U.S. steam pasteurization experiments on meat and poultry**

| Year of publication | Product | Results and effectiveness against bacteria | Researcher(s) |
|---|---|---|---|
| 1972 | Hog carcass | Steam effective, significant distortion of pigskin | Carpenter |
| 1972 | Meat surfaces | Steam applied in jacketed chamber; effective | Vogel and Silliker |
| 1979 | Frozen and thawed beef | Steam applied with a nozzle 10 cm away, not effective | Anderson, Marshall, Stringer, & Naumann |
| 1985 | Chicken carcass | Steam chamber with continuous flow, mixed results, cooked appearance of skin | Davidson, D'aoust, and Awell |
| 1994 | Beef frankfurters | Steam chamber to "surface pasteurize," effective against *Listeria*—4 log reduction | Cygnarowicz-Provost, Whiting, and Craig |
| 1996 | Sheep, beef | Steam treatment is effective if meat is first air-dried | Dorsa, Cutter, Siragusa, and Koohmaraie |

Source: Data from Phebus et al., 1997.

Preliminary tests at Frigoscandia Equipment found that the BSPS prototype successfully killed the pathogen on small pieces of beef inoculated with *E. coli* O157:H7.

Next Frigoscandia Equipment and Excel decided to add academic microbiologists to the team as outside, nonbiased evaluators of the performance of the BSPS prototype. Dr. Randall Phebus at Kansas State University (KSU) was chosen to head the academic team. Frigoscandia Equipment shipped the prototype steam pasteurization system to KSU. Excel supplied six live market-weight steers. Both Frigoscandia Equipment and Excel contributed the kits and other materials required for pathogen tests of beef samples.

After slaughter at KSU, meat samples were inoculated with 5 logs of a pathogen (100,000 organisms/cm$^2$) and then treated in the BSPS prototype. All three pathogens tested, *E. coli* O157:H7, *Salmonella typhimurium*, and *Listeria monocytogenes*, were reduced by 4.65 to 5 logs at 15 seconds of steam treatment at 196-99$^o$ F (table C-2 and fig. C-1). Dr. Phebus and his team concluded that "Steam pasteurization is an effective method for reducing pathogenic bacterial populations on surfaces of freshly slaughtered beef…" (Phebus et al., 1997, p. 476).

The researchers found steam pasteurization provided numerically greater pathogen reductions than any other single treatment studied. One reason for this result is that steam vapor uniformly blankets irregularly shaped surfaces, in contrast to hot water coming from a nozzle aimed at carcasses. If there is any irregularity on the surface of the carcass, the back side of the irregularity will not receive the hot water treatment and pathogens lurking there will not be killed. Properly applied steam can reach these problem areas. BSPS is superior to chemical rinses for carcasses because it does not entail treatment of potentially toxic wastewater.

**Table C-2—Reduction in pathogens as a function of steam application time in SPS**

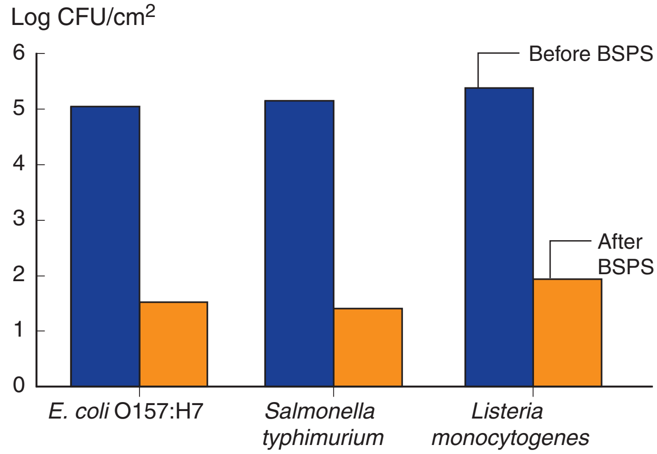
| Seconds of steam used in SPS unit | Pathogen reductions in $\log_{10}$ CFU[1] (5 logs inoculated on carcass) | | |
|---|---|---|---|
| | *E. coli* O157:H7 | *Salmonella typhimurium* | *Listeria monocytogenes* |
| 5 seconds | 3.37 | 4.54 | 4.51 |
| 10 seconds | 3.57 | 3.95 | 4.23 |
| 15 seconds | 4.65 | 5.08 | 5.01 |

[1]CFU (colony forming units) is the unit microbiologists use to count pathogens.

Source: Data from Phebus et al., 1997.

Figure C-1

**Steam pasteurization reduces mean pathogen population on beef carcasses**




Source: Data from Phebus et al., 1997.

In 1995, after the success of the prototype at KSU, Frigoscandia Equipment engineers designed, built, and installed a commercial sized BSPS unit at an Excel plant in Sterling, Colorado. This stainless steel clamshell could hold four sides of beef at a time and moved along the slaughter line (fig. C-2). It also used monitoring techniques for temperature and lot identification that Frigoscandia Equipment had developed for its food chilling and freezing equipment. After solving a number of technical issues related to the pressure, temperature, and application of the steam in the moving clamshell BSPS, Wilson (Frigoscandia Equipment), Leising (Cargill/Excel), and other Frigoscandia Equipment inventors filed a patent application on Nov. 6, 1995 (U.S. Patent, 1998).

### *Testing the Commercial-Scale Prototype*

To test the efficacy of the commercial scale-up of the BSPS prototype, Frigoscandia Equipment and Excel again invited the KSU team into the plant to conduct tests. The objective was to determine the effectiveness of the BSPS unit in reducing naturally occurring populations of indicator organisms on the surfaces of commercially slaughtered beef carcasses. Indicator microorganisms, not pathogens, were used because of the danger of introducing pathogens into a commercial facility. Over a 10-day testing period, 140 carcasses (70 cows and 70 fed cattle-steers/heifers) were tested with steam applied for 8 seconds at 195-201$^o$ F. Twenty carcasses (9 cows and 11 fed cattle) were tested with steam applied for 6 seconds. An additional 20 control carcasses (10 cows and 10 fed cattle) received no steam treatment.

Figure C-2

**Beef sides exiting the SPS clamshell unit in Sterling, Colorado**

Source: Tanya Roberts.

The KSU team found that steam treatment for 8 seconds was "very effective" in a commercial setting for reducing overall bacterial populations on beef carcass surfaces after 24 hours in the chiller (Nutsch et al., 1997, p. 491). In most cases, the enteric bacteria (some of which can be pathogens) were undetectable after pasteurization. Reductions in bacterial populations after a 6-second steam exposure time were very similar to those obtained with an 8-second exposure time. The equipment worked equally well with cows and steers/heifers, despite considerable variations in carcass size and shape.

For the third set of tests in 1996, Frigoscandia Equipment installed a moving clamshell BSPS in a larger commercial facility, Excel's plant in Fort Morgan, Colorado. Again, KSU conducted the testing (Nutsch et al., 1998). This time, the testing team made several changes to the testing protocol to more closely approximate an actual plant operation. Samples were randomly selected from 200 carcasses from two production shifts, rather than the known carcasses in the earlier test at the Sterling plant. Steam temperature was lowered to 180$^o$ F. for either 8 or 6.5 seconds. Instead of excising a small piece of meat to test, sponges were swabbed over the carcass and the liquid was tested to see if microbes were detected. Twenty carcasses were sampled at five carcass locations to see if the steam treatment effectiveness differed at the five sites. The KSU team concluded that the BSPS moving clamshell unit was effective in reducing natural bacterial populations on freshly slaughtered beef carcasses.

Frigoscandia Equipment submitted the KSU's laboratory results on pathogen reduction to USDA. USDA regulatory approval of the BSPS process was a necessary step for commercial acceptance. The KSU data was shared with regulators, industry members, and consumer groups. In December 1995, USDA certified that Frigoscandia Equipment's BSPS moving clamshell can significantly reduce pathogens (Cargill, 1995). The BSPS is equipped with recordkeeping capabilities: carcass identification, carcass surface temperature in the steam chamber, exposure time, and deviations are automatically logged into a computer for plant monitoring and regulatory review. The monitoring features make it feasible to use the BSPS as a critical control point under FSIS PR/HACCP regulations.

In 1996, another food processing equipment innovator, Chicago-based FMC FoodTech (FMC) purchased Frigoscandia Equipment (table C-3). FMC has 100 years of experience designing and selling food-processing equipment. FMC manufactures a wide variety of "in-container" sterilization systems, such as canning and retort systems. FMC was particularly interested in Frigoscandia Equipment for its GyroCompact freezer. The purchase of Frigoscandia Equipment's freezing and chilling equipment complemented FMC's sterilization equipment. In 2001, FMC's sales were $2 billion annually, of which $150 million were Frigoscandia Equipment sales (Brodziak, 2001 and 2002). Though the BSPS technology was not an important factor in the Frigoscandia Equipment purchase, it did add another piece of food safety equipment to the FMC product line.

**Table C-3—General characteristics of Frigoscandia Equipment, 2001**

| | |
|---|---|
| Main activity | Designing, installing, and maintaining equipment and their monitoring mechanisms for the food processing industry. |
| Main products | Freezing and chilling equipment (half of world's frozen food is frozen in Frigoscandia Equipment units); steam pasteurization systems |
| Number of employees | Around 300 employees all over the world, primarily involved in sales, service, or engineering |
| Sales | Around $150 million annually, primarily in the chilling and freezing business |
| Exports | Half of sales are in USA, almost half in Europe. Sales growth areas are Latin America and East Asia |
| Parent Company: FMC FoodTech | Sales of about $2 billion annually. Headquarters in Chicago. Emphasis on solutions (R&D centers around world), food safety (innovative technologies), and service (technical support, HACCP certification) |
| Ownership | Privately owned corporation |

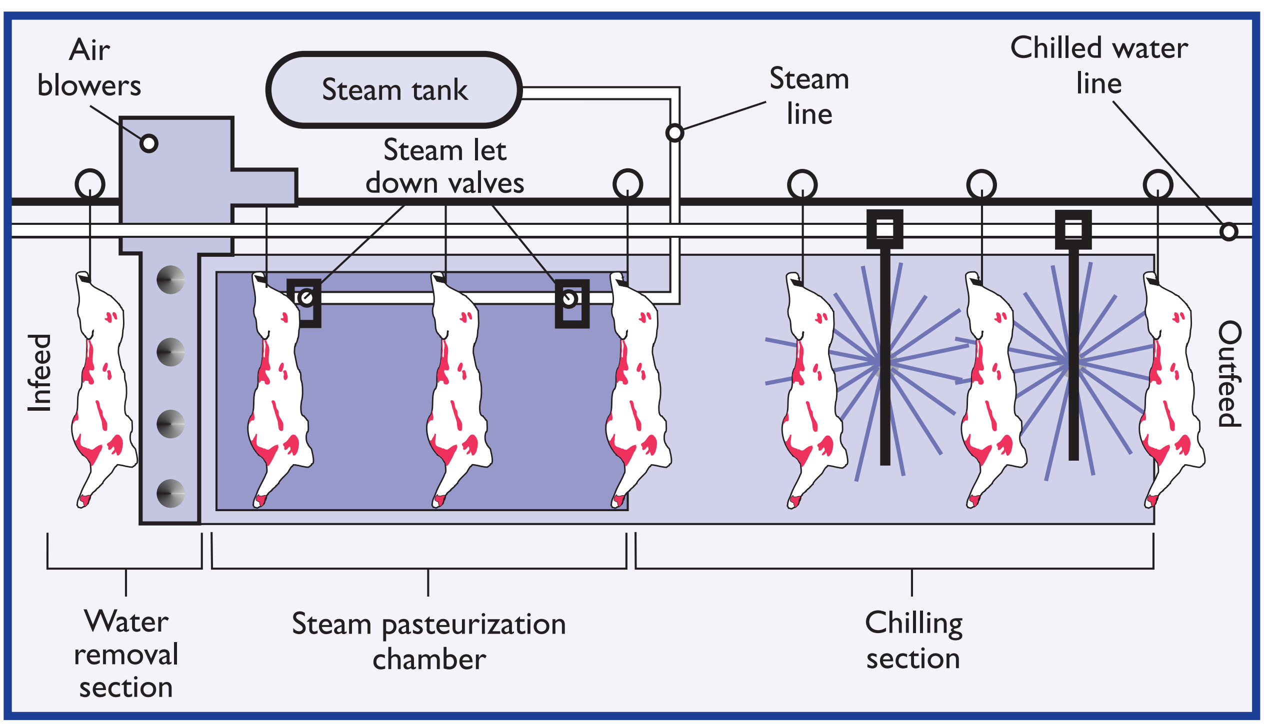
### *Development of the Static-Chamber BSPS*

The KSU researchers had noted two problems with operating the moving clamshell BSPS unit at the Fort Morgan plant: 1) The steam pasteurization treatment was somewhat less effective at the neck area, perhaps because the steam inlet valves were only at the top of the moving BSPS clamshell. 2) A small percentage of carcasses were not steam treated during the two sampling days because of occasional cycle failure (Nutsch et al., 1998, p. 576). This last problem was caused by problems synchronizing the timing of the moving clamshell unit on fast line speeds—a problem that could not be readily fixed.

To address these problems, Frigoscandia Equipment decided to redesign the BSPS as a static chamber. The BSPS-Static Chamber unit (BSPS-SC) envelopes the sides of beef as they move along the overhead rail from the slaughter floor to the chiller. The static chamber performs the same three processes as the moving unit, except that with the static unit, the sides of beef travel through the enclosed chamber and sequentially receive 1) dewatering treatment, 2) steam treatment, 3) cold water shower (fig. C-3). With the BSPS-SC design, carcasses can travel through the chamber at

Figure C-3

**Beef Steam Pasteurization System — Static Chamber Unit**




Source: Frigoscandia Equipment

any chosen line speed. The doors and the overhead rail (on which the carcasses hang) have seals to maintain the positive air pressure in the chamber. In January 1998, Wilson (Frigoscandia Equipment), Leising (Excel), and other Frigoscandia Equipment inventors filed a patent application for a static chamber system that uses steam to destroy surface pathogens on meat (U.S. Patent, 1999).

The BSPS-SC has several advantages over the moving clamshell BSPS. The unit does not break down as often or require as much maintenance as the moving unit, reducing the warranty costs to Frigoscandia Equipment (Brodziak, 2002). This additional reliability is a benefit to customers as well: it facilitates use of the BSPS-SC system as a control measure in a plant's PR/HACCP system. Control measures must be reliable because the whole slaughter line must stop production if any of the critical control points in the PR/HACCP system are not functioning correctly. The BSPS-SC unit is reliable enough to use as a critical control measure.

Another benefit to beefpacking plants with the BSPS-SC was a reduction in operating costs because the steam part of the tunnel can be kept at a constant high temperature (Leising, 2002). In the moving unit, all three processes were conducted in the same chamber with the temperature fluctuating between the hot steam and the cold water wash, resulting in greater costs to bring the steam chamber up to its desired temperature.

The fourth and final invention was a change in the entrance and exit doors. Instead of two large doors, the doors were subdivided on each side into two-foot long segments, or eight doors on each end of the BSPS-SC. With this modification, the uneven-sized sides of beef enter the chamber with only the relevant doors being opened. As a result, the doors remain open less time with the static version. As a result, the vacuum seal is more easily maintained, the amount of steam needed was reduced, and the reliability of the equipment was further improved. In February 1999, Wilson (Frigoscandia Equipment), Leising (Excel), and other Frigoscandia Equipment inventors applied for a patent on the improved doors (U.S. Patent, 2000).

## The Innovating Collaborators Appropriated a Variety of Benefits

The three collaborators for the BSPS-SC invention, Frigoscandia Equipment, Excel, and KSU, contributed in different ways to the development of the technology—and benefited differently. Frigoscandia Equipment, through Craig Wilson, initiated the innovation and contributed technical and administrative expertise. The costs to Frigoscandia Equipment of designing, building, and testing the BSPS prototype and the moving clamshell BSPS unit was $1.2 million spread over 3 years, mid-1994 to mid-1997 (Brodziak, 2001 and 2002). These costs were in-house labor and other variable costs, including contracting costs to the machine shop that produced the parts for the prototypes. The BSPS-SC modification took Frigoscandia Equipment 9 months and $100,000 to design and build. Frigoscandia Equipment's total investment was $1.3 million for the BSPS-SC innovation.

The two largest U.S. beefpacking companies, Excel and IBP, bought the equipment for all of their slaughterplants. Frigoscandia Equipment earned a small profit on the BSPS-SC equipment sales and the installation (Brodziak, 2001 and 2002). From 1996-2001, Frigoscandia Equipment sold 28 BSPS-SC units: 20 large and 8 smaller units. Smaller units were sold at approximately $250,000 each, depending on site-specific requirements.

Excel's contribution included paying for the beef used in the testing and all plant operation costs during the testing at the Excel's Sterling and Fort Morgan plants. Excel also invested a considerable amount of resources in adjustments and adaptations to the unit, including engineering maintenance. Excel recouped some of these expenses because it was not charged for the first moving clamshell BSPS unit and adjustments were made in the purchase price of other BSPS units to compensate for Excel's investment. Excel also benefited by taking advantage of its "first right of refusal" and being the first U.S. company to install the BSPS and BSPS-SC in all its packing plants (Cargill, 1997). This gave them a "first mover" advantage (Porter, 1998), namely, an enhanced reputation as a leader in food safety research and development that led to an increase in beef sales and contracts.

KSU was brought into the development team to conduct a wide variety of microbiologial tests on pathogens and indicator organisms using four different pieces of equipment, using different testing procedures, and using different combinations of steam temperature/time in the BSPS units. KSU contributed the time of two Ph.D. students and one professor to the project. Most of the testing equipment was purchased by Frigoscandia

Equipment and Excel, including about $40,000 to $50,000 worth of testing kits and other supplies.

All three collaborators boosted their food safety reputation through their involvement in the innovation. Frigoscandia Equipment strengthened its position in the food safety equipment industry. Excel became known as a food safety leader and gained market share in the beefpacking business (Leising, 2002). KSU became known for its expertise in microbial food safety (Leising, 2002). Two KSU students earned doctorates doing microbiological research on the BSPS technology. KSU now grants distance-learning degrees in Food Science and this program has been recognized for its quality by the Institute of Food Technologists (Phebus, 2002).

## The BSPS-SC: Three Years to Technological Innovation and Market Acceptance

A review of the history of the BSPS-SC technology reveals that numerous factors led to the successful development and commercialization of the technology, including outbreaks and recalls, patent protection, technical expertise, industry contacts, and government regulations. The 1993 *E. coli* O157:H7 outbreak supplied the initial push for the innovation, driving Frigoscandia Equipment and Excel to pursue the technology (Cargill, 1997). In August 1997, another outbreak of *E. coli* O157:H7 in hamburger occurred, and the Hudson Foods Company recalled 25 million pounds of contaminated beef, closed the plant for cleaning, and finally sold the plant because sales contracts were canceled. This outbreak convinced IBP, the largest U.S. beefpacking company, to purchase the BSPS equipment for all its slaughterhouses.

Patents played a critical role in protecting the appropriability of the innovation. To keep competitors from copying the design of the BSPS-SC, four patents were issued to Frigoscandia Equipment. The first patent, on the prototype tested at KSU, was a concept patent and was filed early in the innovation process, 1994, to act as a place-holder for patent protection for more developed designs (Wilson and Leising, 1994). The BSPS-SC invention was protected by three more patents on the more complex and complete designs: moving clamshell unit, static chamber model, and static chamber with improved entrance and exit doors (U.S. Patent, 1998, 1999, 2000).

Technical expertise and personal contacts also played critical roles in the development of the innovation. Frigoscandia Equipment had a 50-year history in making chilling and freezing equipment for the beef industry. The BSPS-SC used pieces of the monitoring equipment from these chillers and freezers in building the monitoring equipment for the BSPS. Craig Wilson, director of special projects for the U.S. office of Frigoscandia Equipment, played the pivotal role in conceptualizing the invention, building the prototype, and designing the commercial scale-up. His professional and personal relationship with Dr. Leising helped forge the links in the agreement between Frigoscandia Equipment and Excel that led to the risk-sharing and knowledge-sharing and culminated in the successful BSPS innovation. KSU played a critical role in testing different BSPS models at a variety of time/temperature combinations. These data from an academic and independent source were critical for USDA approval and important for the beef industry to understand the relationships among pathogen reduction levels, steam temperature, and the duration of steam application.

U.S. government certification in 1995 that BSPS significantly reduces pathogens lessened the uncertainty facing industry purchasers regarding the efficacy of the technology and opened the door for use of the BSPS as a critical control point in PR/HACCP (Cargill, 1995; USDA, 2002). In addition, a number of government guidelines have explicitly endorsed the use of the technology. For example, in 2000, USDA's Agricultural Marketing Service specified that suppliers of beef trim and ground bison to Agency-administered purchasing programs, such as the school lunch program, must include an anti-microbial intervention as a critical control point (CCP) in the establishment's HACCP plan. "The CCP must be one of the following processes: steam pasteurization; an organic acid rinse; or 180º F hot water wash" (USDA, 2000).

The BSPS-SC innovation has enjoyed great market success in the United States. Excel, the second-largest U.S. beefpacking company, installed the technology in all seven of its beefpacking plants by June 1997. IBP, Inc., the largest beefpacking company, installed BSPS-SC equipment in all its beef slaughterhouses. (In 2001, IBP was purchased by Tyson Foods, Inc., and Tyson became the world's largest marketer of beef, pork, and chicken.) Costco requires all of its beef suppliers to use the Frigoscandia Equipment BSPS-SC in the slaughterhouse.

The positive market response is also reflected in a beef-product recall insurance policy available through the American Meat Institute, the meat industry's largest trade association. This recall insurance, which is sold by MacDougall Risk Management, offers the possibility of reduced rates and higher likelihood of coverage for plants that have installed the BSPS-SC (MacDougall, 2002). Other insurance programs covering product quality or safety are also sensitive to baseline plant risks and safety investments.

Despite the major marketing accomplishments in the United States, the BSPS-SC technology has yet to become standard practice in the beef industry outside of North America. One explanation for this result could lie in the difficulty of successfully integrating even the most reliable technology into a plant's pathogen control system (Bisaillon et al., 1997; Powell et al., 2001). Part of the skill in using any new pathogen-reduction technology is integrating it in the whole production system. For example, the effectiveness of the BSPS-SC, may be compromised if the carcasses are not chilled fast enough or are improperly spaced. Improper spacing of carcasses allows touching in the chiller and results in compromising both the temperature reduction and the rate of drying, creating conditions where pathogens can multiply (Phebus, 2002).

Pathogen control is difficult, and the food industry has a history of using multiple-hurdles to control foodborne pathogens, especially since pathogens can recover from a "kill-step" and grow back (unlike chemical or material contaminates) (Morris, 1999). Key factors in pathogen control in a beef slaughter plant include whether pathogens enter the plant on the hides and in the gastrointestinal tract of incoming cattle, whether hide removal or evisceration contaminate the carcass after killing, whether steam pasteurization and other kill steps are effectively administered, and proper spacing and temperature reduction in the chiller. The combination of all these events determines the probability of pathogen-free status for carcasses as they enter the fabrication room (Roberts, Malcolm, and Narrod, 1999; USDA, 2001; Sofos et al., 1999; Roberts, Narrod, Malcolm, and Modarres, 2001).

The benefits of any pathogen-reduction system are also difficult to measure on an ongoing basis, since constant monitoring and microbial testing are required. There is great variability in the pathogen load that the individual cattle bring into the plant, there is variability among workers and their practices, and different firms may use different steam times and temperatures. Pathogen testing is required to assure the BSPS-SC is as effective "as planned." The benefits of the BSPS-SC technology can also be reduced if the appropriate level of control is not maintained at all subsequent key processing stages in the plant. Because the efficacy of the technology is judged within the context of a plant's whole safety system, the dependability of the technology could vary greatly from plant to plant, depending on the characteristics of each plant's safety system. This fact complicates the task of developing and marketing food safety technologies—and the task of proving and maintaining their efficacy on a daily basis.

The series of tests that Frigoscandia Equipment and Excel funded prior to marketing the BSPS was necessary to gain U.S. regulatory acceptance and market acceptance by the two largest U.S. beefpacking companies. Nevertheless, even this level of testing has so far been unable to convince European companies to purchase the BSPS-SC. In addition, the technology has not been adopted by other slaughter industries: to date no U.S. hog slaughter companies have purchased the BSPS-SC system for pork carcasses. Future market penetration of the BSPS-SC technology, both domestically and internationally, hinges on the proven dependability of the technology and its role in the process control systems of the future.

## Appendix A: Time Line for Beef Steam Pasteurization System Innovation

**1979:** Frigoscandia Equipment, now established in the United States, begins working with the U.S. meat industry on freezing.

**Jan. 1993:** A foodborne disease outbreak in the Western States is associated with *E. coli* O157:H7 in hamburgers from Jack in the Box.

**Late 1993/early 1994:** Craig Wilson, in charge of special projects at Frigoscandia Equipment (Bellevue, WA) discusses with other Frigoscandia engineers how to prevent such outbreaks. Steam pasteurization of beef carcasses is suggested as a technically viable option. Wilson calls his professional friend Jerry Leising, Excel Vice President and Director of Research and Development, who offers to collaborate in inventing and testing equipment to use steam to pasteurize the surface of beef carcasses.

**Early 1994:** Frigoscandia designs and builds a small prototype to assure that *E. coli* O157:H7 on beef can be killed with steam. Informal talks with meat and poultry companies reveal that beef companies are the most interested in steam pasteurization equipment.

**Nov. 7, 1994:** Wilson (Frigoscandia Equipment) and Leising (Excel) apply for a patent, "Method and apparatus for steam pasteurization of meats," U.S. Pat. Appl. 08/335,437. Frigoscandia Equipment is the assignee on the patent.

**1994:** Kansas State University (KSU) is included as part of the development team. Frigoscandia's prototype moves to KSU and tests begin on beef carcasses.

**1995:** Larger moving clamshell BSPS unit pieces are manufactured by subcontractors and assembled/installed by Frigoscandia engineers in an Excel plant in Sterling, Colorado.

**Nov. 6, 1995:** Patent application is filed by Wilson (Frigoscandia Equipment) Leising (Excel) and other Frigoscandia inventors for a larger moving clamshell BSPS unit. Frigoscandia Equipment is the assignee on the patent.

**Dec. 1995:** USDA approves the BSPS process for killing pathogens on the surface of beef carcasses.

**1996:** FMC FoodTech, a Chicago-based firm with 100 years of experience in food technology, buys Frigoscandia Equipment.

**June 1, 1997:** Excel announces that Frigoscandia's BSPS has been installed in all its North American beef plants.

**Aug. 1997:** FSIS requests the recall of ground beef for contamination with *E. coli* O157:H7 at Hudson Foods. The recall is very large, because contaminated meat from one day is mixed in with the next day's production.

**Aug. 1997:** IBP, Inc. executive asks Wilson to meet with IBP executives. IBP decides to purchase the BSPS-SC for all its beef slaughter plants.

**Sep. 1997:** USDA turns over approval of meat and poultry equipment to NSF International, a private certification body.

**Jan. 23, 1998:** Patent application is filed by Wilson (Frigoscandia Equipment), Leising (Excel) and other Frigoscandia inventors for a static chamber system that uses steam to destroy surface pathogens on meat. Frigoscandia Equipment is the assignee on the patent.

**Oct. 1998:** Wilson leaves Frigoscandia Equipment and becomes Costco's assistant Vice President for food safety and technology in Issaquah, Washington.

**Feb. 26, 1999:** Patent application is filed by Wilson (Frigoscandia Equipment), Leising (Excel) and other Frigoscandia inventors for apparatus for steam pasteurization of food. The unique element is the improved entrance and exit door structures to the static chamber. Eight doors, each 2 feet tall on each side, move when touched by the side of beef, and the vacuum seal is better maintained in the system. Frigoscandia Equipment is the assignee on the patent.

**2002:** Costco and other buyers stipulate that beef supplies must come from a plant using the Frigoscandia Equipment's BSPS-SC system at an appropriate time and temperature (Wilson, 11/4/02).