BABSON

Arthur M. Blank Center
for Entrepreneurship
Babson Park, MA Phone: 781-239-4420
02457-0310 Fax: 781-239-4178
URL: http://www.babson.edu/eship

Printed: 10/07/97

ENOX Technologies

In early 1993, Voislav (Voit) Damevski and Stanley Rich, cofounders of ENOX Technologies (a mechanical engineering research firm), conferred on the future of their relationship with Burton Engine Company, one of the world's leading manufacturers of diesel engines. They had just completed a rancorous conference call with the Burton project manager over interpretations of the performance/payment thresholds in their contract. Stanley, as usual, was outspoken in his criticism:

> I can't work with those people anymore, Voit. They're unreasonable and manipulative, and it's not worth it. We ought to terminate our contract and focus on the natural gas market.

Voit was equally frustrated by the experience of dealing with Burton but less quick to conclude that ending the relationship was in the best long-term interest of ENOX. He tried to temper Stanley's outburst:

> But Stanley, there is tremendous long-term potential in the diesel market, and it may make sense to keep a hand in it. In spite of the strings it attaches, Burton has come up with a lot of money, and it's well connected to the government R&D funding pipeline. Besides, the stationary gas compressor market is finite. Eventually we'll need to find new markets.

Since 1990, ENOX Technologies, formerly PlasMachines, had been doing research for Burton on a technology that used electrical plasma to reduce nitrogen oxide in diesel exhaust emissions, a major concern due to impending change in environmental regulations. By 1993, Burton had provided ENOX more than $200,000 of its own funds and had also served as the conduit for an additional $300,000 in research money from the U.S. Department of Energy (US DOE) and state environmental organizations. Additionally, ENOX had secured Small Business Innovation Research (SBIR) grants from the U.S. Environmental Protection Agency (USEPA) to work on the plasma device. Given the high level of government and private interest in finding effective ways to reduce nitrogen oxide and the proven efficacy of this technology, continued funding for research and eventual product development seemed assured.

This case was prepared by Sam Perkins under the direction of Professor William Bygrave.
 Funding provided by the Ewing Marion Kauffman Foundation.

Soon after beginning the work for Burton, however, Voit and Rich started to investigate other applications for the underlying electronic technology they had developed to create the electrical plasma. One promising concept was to use the device as an ignition system to improve the firing of spark plugs in gasoline engines, an approach which both enhanced fuel efficiency and reduced nitrogen oxide. The ignition was well suited to the task of retrofitting older stationary engines used to run the compressors on natural gas pipelines, and by 1993, ENOX had secured several contracts to perform tests of the ignition systems on these large engines. The effort to pursue the natural gas market however, and to continue research on the exhaust technology was straining ENOX's finances, manpower and strategic focus, and the founders were struggling with the issue of balancing short and longer term market opportunities and resources.

The Founders

Voit Damevski grew up in Rochester, New York, and graduated from Syracuse University in 1985. As a youth, Voit was passionate about auto mechanics: beginning at the age of five, he spent most of his free time tinkering with engines and later, racing motorcycles. A serious accident at 21 convinced him to stop racing, but he continued the tinkering. The son of a doctor, Voit went through the motions of following in his father's footsteps by majoring in biology and planning a career in medicine. However, a month before he was due to start medical school, he decided to pursue his own vision of manifest destiny:

> It (medicine) was nothing I ever really wanted to do. Instead, I wanted to be in business. From when anyone can remember, I've always done my own thing, had my own businesses. I paid my way through school by having a painting company, importing cars, all sorts of strange jobs, and always on my own.

Voit enrolled in a local MBA program but left after one semester, disillusioned by the school's emphasis on finance. He'd wanted a program that would nurture his entrepreneurial instincts. A friend had recommended Babson College and after further investigation, Voit felt that the college's focus on entrepreneurship studies would be perfect for his needs. Voit also read, <u>Business Plans That Win Dollars</u>, by Babson professor Stanley Rich. Disdaining Stanley's advice that "cold calls get cold responses" Voit phoned him one night at 10 o'clock to praise the book and discuss his desire to get an MBA. Stanley's response was encouraging, and the call proved to be the genesis of a friendship and business partnership.

Stanley Rich was an inventor and habitual entrepreneur, who had more than 500 international patents to his name and had started a half-dozen companies. By his own admission Stanley was a "good starting pitcher"* who liked best to develop new technology and prove a marketable application that could create a business opportunity, but he had little interest in the details of building a business or running a company. As Voit described, "The everyday management, the building, sales and marketing, all of those things were functions that in Stanley's mind would just happen." He became an adjunct member of Babson's Entrepreneurial

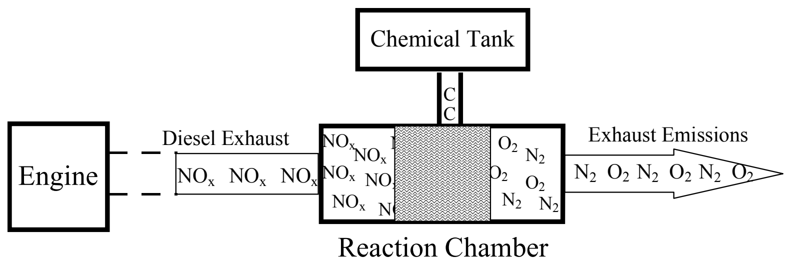
* This is an analogy to the game of baseball, which normally has nine innings. The starting pitcher rarely completes all nine innings. He usually leaves before the game is finished and is replaced by a relief pitcher (a reliever).

Studies department in 1986, but continued to consult with outside companies about technology development.

Opportunity Assessment—The Problem of Nitrogen Oxide

Volt enrolled in Babson's MBA program, and in late 1988, while Voit was finishing the program, Stanley Rich enlisted his services to help with an opportunity assessment for Burton Engine Company of a technology for reducing nitrogen oxide in diesel engine exhaust. The technology used a powdered chemical, injected into a diesel exhaust stream, that caused the nitrogen oxide to come apart and be discharged as harmless constituent elements, nitrogen and oxygen (Exhibit 1). Although the technology achieved its purpose, Stanley and Voit quickly concluded that the requirements of its use—filling up with the chemical at every fuel stop—would be too onerous to make it acceptable to most truckers. Voit recalled their research:

Exhibit 1: Exhaust After-Treatment with Chemical Additive



> Stanley picked up the phone and called six or seven truck operators and asked them how would they feel about pulling up to a gas station and not only filling up with diesel, but filling up with a powdered chemical. The first three hung up the phone on him. That was kind of an easy one to figure out.

In spite of the lack of application for that particular technology, Damevski and Rich were intrigued by the opportunity of finding a way to reduce nitrogen oxide, one of several engine emissions that were being targeted by the USEPA for reduction.* The two kicked around a lot of ideas, drawing on Stanley's formal training as an electrical engineer and Voit's informal pastime and years of experience tinkering with engines. Emerging from their verbal peregrinations came the theory of passing the exhaust through an electrical discharge of plasma, created with a radio frequency generator. The plasma would "excite" the exhaust gases in a reaction chamber, causing the unstable compounds, such as nitrogen oxide, to decompose into their components (Exhibit 2). At a meeting in January 1989, Rich ventured the idea to Burton engineers, who liked the concept, cut a check for $25,000, and said, "Here, go tinker."

---

*Nitrogen oxide (NO_x) is the collective term for nitric oxide (NO) and nitrogen dioxide (NO_2), which are formed both from natural sources (lightning and biological processes) and from anthropogenic activities (burning fossil fuels). Approximately 90 percent of the nitrogen oxides enter the atmosphere as emissions from internal comustion engines in automobile and stationary sources, which create nitric oxide (NO) at very high temperatures. NO is rapidly converted to nitrogen dioxide (NO_2), which is a major contributor to air pollution through ozone formation, smog and acid rain. In 1989, the U.S. Congress was debating the reauthorization of the 1970 Clean Air Act (CAA), and NO_x reduction was one of the issues the USEPA was pushing for. The CAA reauthroization was passed in 1990 with each state responsible for the development of implementation plans.

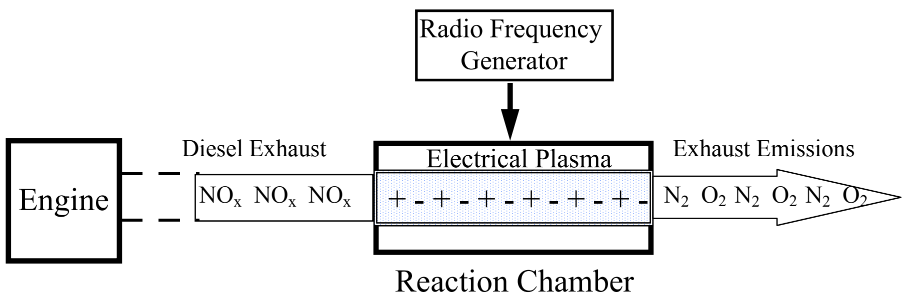
The Prototype

In August 1989, Voit and Stanley formally incorporated as PlasMachines, a name Voit loved to hate:

> That name was Stanley's wonderful creation. It was probably the worst name in history. He said we're using an electrical plasma and we're building machines—so we're PlasMachines. I said it sounds like we're in the medical instrument business. But we kept that name for quite a few years.

For the following four months the partners worked together every day, alternating between Stanley's basement and Voit's apartment. Through Stanley's extensive network of contacts, they found and hired an electrical engineer to build the prototype electronic driver for the reactor, while Voit built the mechanical components. By November, Stanley and Voit deemed the prototype complete, but, although the contraption glowed like a neon bulb when it was turned on, they had no way to test its functionality. They reported their status to the Burton engineers, who were astonished to hear that the plasma concept had actually been turned into a physical device, and a few days later Stanley and Voit flew to the Burton test facility in Columbus, Ohio. The team hooked up the reactor to a diesel exhaust pipe, let the engine heat up and turned on the machine. The NO_X meter gauges dropped by 50 percent. They turned off the reactor, and the reading went back up. On again and down 50; off and back up. They followed that routine up, down, up down—for 10 minutes until the reactor burned out and melted down—there was nothing left of it. The Burton engineers were excited by the test results and the proof of concept.

Exhibit 2: Exhaust After-Treatment with Electrical Plasma



For Stanley, the "starting pitcher," that proof brought him to the successful completion of four or five innings, as Voit recalled:

> Stanley jumped for joy and in his mind it was done. At that point, he was ready to sell it to Burton, and it was over and done with. There was no more work. That was his mindset. I used to say he would fly at 30,000 feet when everyone else was still walking on solid ground, because he just saw so far into the future that he lost sight of the things he had to do to turn the opportunity into something that was going to be of value.

In spite of his inclination to leave the pitching mound to a middle reliever, Stanley leveraged the test results and Burton's reaction into additional financing to continue the research and development of the plasma after-treatment technology:

> This is where the genius of Stanley came in. This is where he excelled. He turned that exciting proof of concept into a $200,000 option agreement with Burton. We created the excitement there at Burton, and he turned that excitement into a lot of money fairly quickly.

That day, Burton and the partners agreed on the basic structure of a contract that would provide PlasMachines $200,000 in seed capital to conduct further research in exchange for exclusive rights for six months to negotiate a licensing deal. Burton also pledged to secure additional funding for technology development through the USDOE and other agencies. In spite of the ease of reaching the preliminary agreement, the details took nine months to work out. According to Voit, Burton started to realize that they were negotiating with only two guys, who continued to push out the timeframe of negotiations. By mid-1990, PlasMachines had nearly run through the $45,000 advance from Burton, and the start-up was close to being broke. No cash was coming in, and expenses had increased because Stanley and Voit had moved the company out their homes into office space in Natick, Massachusetts, negotiating a $700 per month lease for a 6,000 square-foot building with a bay and work area. At first, Voit was skeptical about taking on the extra cost and more space than they could use but was convinced by Stanley's optimistic view that they would eventually grow into it.

Finally, feeling that Burton was stringing them along with no incentive to conclude the deal, Voit and Stanley took their last cash and bought airplane tickets to visit Flint Diesel, a Burton competitor. They had gotten an appointment with CEO William Stark and his chief engineer, to whom they pitched their technology and its potential application and benefits. Mention of the association with Burton, however, immediately terminated Stark's interest, but Stanley and Voit nevertheless returned to Boston with their mission accomplished: they had secured Stark's business card. Voit then asked the Burton people to come to Natick to conclude negotiations, and the following day the president of a division, a lawyer, and three other people visited PlasMachines nearly vacant building. During a break in discussions, Voit directed the division president to his desk to use the phone, near to which was Stark's card was strategically placed—not too blatant, not too hidden. After the calls, the Burton people conferred for a few minutes, came back into the room, signed the agreement, and cut PlasMachines a check for $280,000 with more to follow.

The total funding package included money from three sources. The original option agreement with Burton was for $200,000 of which $45,000 had already been drawn. A research contract with the USDOE, secured by Burton, provided $160,000, one-third paid by Burton. It was a fraction of the $14 million in USDOE funds that Burton received annually. Finally, the state of California put in $280,000. With the toughest air quality standards in the United States, California funded research efforts in emissions reductions, financed by state gas taxes and overseen by the Southern California Air Quality Management District, the environmental enforcement agency. All the engine companies used these and other sources to fund research, but it was very difficult for a small firm to secure such moneys directly.

R&D Shop

The relationship with Burton Engine promised to provide PlasMachines with funding to develop the exhaust after-treatment technology, yet Stanley and Voit quickly recognized that the R&D work was unlikely to lead to the creation of a product-based business within the next several years. Although the 1990 Clean Air Act Amendment (CAAA) set a general target for reducing nitrogen oxide by the mid-1990s, the exact timeframe, degree of reduction, regulatory mechanisms and differences in state plans remained to be worked out. California was considering a total restriction on diesel fuel, mandating that diesel engines run on natural gas by 1996, but other states were proposing less drastic measures. In response to these conditions, most engine companies were examining a range of technical options but delaying commitments until the uncertainties had been resolved. According to Voit, Burton hedged their bets by investing in several technologies for reducing nitrogen oxide, while tying up licensing options for as long as possible. Until there was a clear regulatory signal and schedule for implementation, however, the company was not compelled to move quickly from research to marketable product.

> The real hot button for Burton was to make sure that they had a window on all these unique technologies that were being developed. There was really no specified timeframe to develop a product. We realized that there wasn't going to be a market for a very long time. This wasn't the driver from Burton's standpoint, so they didn't have a defined goal.

The applicability and cost of the technology itself was a long way from what the market needed and would accept. Translating a relatively large and fragile technology into a rugged device that would attach to the end of an truck engine and survive half a million miles would be a significant challenge, accentuated by the need to price it at less than $700. In the absence of a clear and compelling regulatory mandate, Voit didn't see an application for the technology for a "long, long time. We're so far away that I didn't see a mechanism for how you get from a technology to a product."

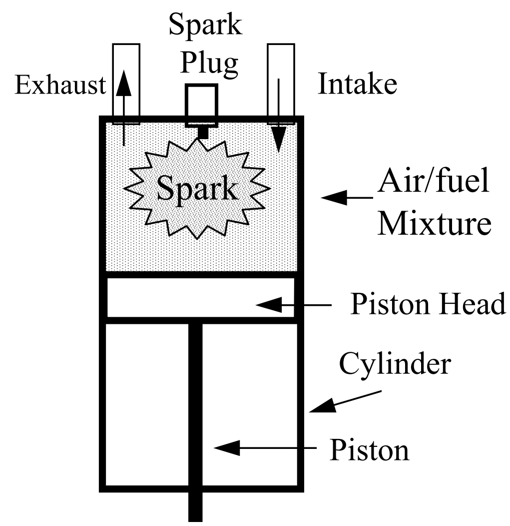
Although the immediate financing problem had been solved, Voit soon became disenchanted with the procedures and constraints of running an R&D operation that was dependent upon one customer. It was too much like a job, rather than owning a business:

> You're doing work, you're doing monthly reports, you're submitting the monthly reports. I started to get bored. R&D is great, but it's not going to lead anywhere; it's not going to make a business. You've got one customer, and you're handcuffed. That customer controls everything. What I wanted to do was create a business, and what Stanley wanted to do was create a business.

NO_X: Same Problem—Different Answer

In 1990, even as they were in the midst of negotiating with Burton and continuing the R&D work, Stanley and Voit pursued other avenues in their determination to fashion a business around their technology and the need to reduce tailpipe emissions. The route of their exploration mirrored a fundamental shift that was occurring in the environmental regulatory philosophy in the United States: preventing pollution at the source instead of treating and controlling it at the end of a process. Stanley and Voit asked the fundamental question: what could be done up front to prevent the creation of nitrogen oxide, rather than attempt to remediate nitrogen oxide in the tailpipe? Nitrogen oxide is created by the high temperatures that occur in an internal combustion gas engine when the air/fuel mixture is ignited by a spark plug (Exhibit 3). The exhaust emissions, including nitrogen oxide, are a function of the ratio of air to fuel, the temperature and the efficiency of the combustion, which, in turn, is a function of the quality and timing of the spark. A poor spark produces poor combustion and more misfires, which generate higher levels of emissions. Stanley and Voit hypothesized that the electronics they had developed to create the wave form for the plasma might also be applied to enhancing the performance of an engine's ignition system by improving the firing of the spark plug. More consistent ignition would improve the efficiency of the engine and reduce misfires, thereby reducing levels of contaminants in the exhaust emissions.

Exhibit 3: Internal Combustion Engine

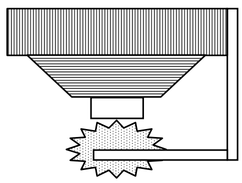


For Voit, who had a strong affinity for spark plugs, ignition coils and related electronics, the logic of the approach was clear and appealing. To augment his experience and intuitive sense of the subject, he spent much of the following six months at a library at MIT, combing through Society of Automotive Engineers (SAE) journals for information about leading edge research and applications in the field of automotive ignitions. Voit found two competing schools of thought that were developing along diametrically opposing lines. The Detroit-based approach posited that the best method of ignition was to spark the spark plug as fast as possible, concentrating the energy to maximize the precision of the timing in igniting the fuel/air mixture in the cylinder. In the other automotive capital of the world, Japan, engineers pursued the opposite path, theorizing that a long, slow release of energy to the spark plug would ensure a higher probability that the mixture would ignite, thereby maximizing the overall performance of the engine, even if the individual spark plug firings were underperforming the optimum. The PlasMachines device offered the potential to satisfy both methods of firing. It dumped a lot of energy very rapidly at the start and then sustained it for a long period of time (Exhibit 4).

Voit and Stanley were encouraged by the theoretical benefits of using the device for an ignition system, but they lacked a gasoline engine to test it until Voit had his parents load his 1974, 500-horsepower Firebird onto a flat bed truck and ship it to Boston. Testing the mechanism on the car proved that it worked as an ignition system but didn't offer any insights

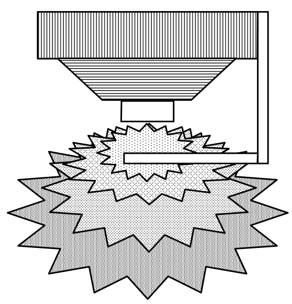
Exhibit 4:
Ignition System Comparison

Standard Ignition



Single Flame Front
One Shot at Ignition

Continuous Duration Ignition



Multiple Flame Fronts
High Ignition Probability
Consistent Combustion Timing and Stability

into its effectiveness at reducing nitrogen oxide or other contaminants, nor did it provide any measure of potential increased operating efficiency. With a moonlighting engineer to help them at night, Stanley and Voit worked on refining the design, drawing on their experience and expertise in electrical engineering and mechanics. Without a lab or equipment to test their ideas and technical refinements empirically, much of their effort relied on dialectical theorizing. As Voit described the process:

> During the day, Stanley and I would spend an enormous amount of time sitting and talking and thinking stuff through and playing what-if games. That worked very well for us. Playing these games back and forth without having a lot of equipment at our fingertips allowed us to go through the thing conceptually. Stanley was a very good electronics engineer but didn't really understand engines, He didn't understand how the system worked mechanically. So we would sit there and go back and forth. He'd say one thing, I'd say, "no it can't work that way—it's got to work this way." We did a lot of talking about what was going to be the best way to optimize the electronics for an ignition system.

Voit's initial perception of a potential market for the ignition system was the automobile racing industry, where enhanced engine performance was critical and cost considerations relatively minor. He knew the industry fairly well from his former racing days and believed its interest in experimenting with new technologies would make it a logical arena to try out the system. At the point where Voit and Stanley thought they had a functional ignition system, they shared the concept with engineers at Burton, who liked the technology even though it had no application for their own diesel engines.[*] In spite of that apparent drawback, Stanley and Voit succeeded in convincing Burton to give them an additional $20,000 to take the prototype to Southwest Research Institute[**] for a week's worth of testing on a small single-cylinder General Motors engine.

The results bettered expectations. The ignition system eliminated misfires, enabling a smoother operating engine with lower levels of emissions due to the reduction of unburned fuel in the exhaust. Further enhancing the benefits of the technology was its ability to allow an engine to operate with a leaner fuel mixture, a process known as "extending the lean limit of operation." A gasoline engine operated optimally at a ratio of 14.7 parts air to 1 part gasoline. A leaner mixture had a higher concentration of air to gas. With a conventional ignition system,

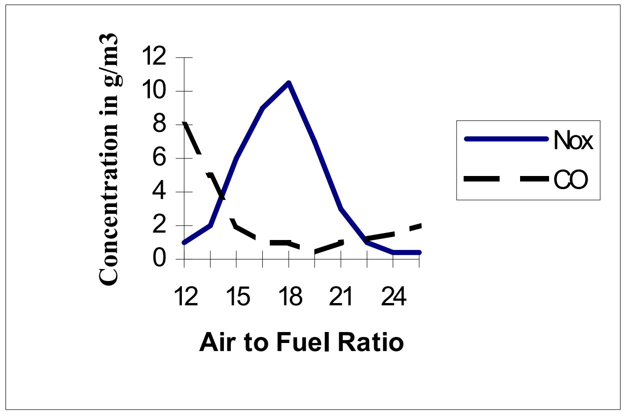
[*]In diesel engines, the pressure created in the cylinder ignites the air/fuel mixture, eliminating the need for an ignition system using spark plugs.

[**] The Southwest Research Institute is a third-party independent testing organization with a staff of 3,000 located in San Antonio, Texas. Known worldwide as the premier test organization for automobile developments, it is used by the automotive industry as an R&D center.

increasing the ratio of air to gas produced more misfiring because a leaner mixture was more difficult to ignite.

The PlasMachines system, however, was able to achieve stable ignition of mixtures up to 22 to 1 without misfires. The leaner mixture lowered the temperature in the cylinder, which in turn reduced the formation of nitrogen oxide, whose production was directly variable with the temperature level. At a 22–1 mixture, nitrogen oxide was reduced 95 percent (Exhibit 5). In addition to the reduction in emissions, the absence of misfiring and the leaner fuel mixture both contributed to a 4 percent increase in fuel efficiency, above the threshold that automobile companies considered valuable.

Exhibit 5: Nitrogen Oxide (NO_X) Chemistry



The people at the Institute were duly impressed: "Wow that is really interesting, that's really unique technology. No one's ever seen that before" were some of the responses. As Voit recognized, however, unique technology didn't automatically translate into a marketable product on which one could build a business.

> At that point we were still dealing with the circuit board that was about 2' by 2' square and cost several thousand dollars. For an automobile ignition system, if it didn't cost about $35, no one was even going to be interested in it. So it was really neat but it was still big bucks.

Voit and Stanley had some preliminary discussions with Ford and General Motors, both of whom expressed an interest in the technology, but the difficulty of dealing with the large, bureaucratic organizations, and their non-negotiable demands, precluded continuation of the initial contacts. Even before they would agree to start serious negotiations, the big auto companies wanted all rights to any outcome of design and development. The two partners discovered that it was essentially impossible for a two-person firm to deal on anything approaching equal footing, especially where they had no patent protection. Initial patent applications had been filed but not granted and second applications had not yet been completed because Stanley and Voit were still trying to figure out exactly what it was they wanted to patent.

The technology was proven but there was no visible path to a market application. The partners saw the situation very differently:

> Stanley and I got along on everything except where business was headed. In his mind again, we had this great technology and the world ought to be beating a path right to the door. They ought to be lining up. That's really not what occurs because you are dealing with very large industries with a pervasive "not invented here" syndrome, where change doesn't come quickly because it has to be reliable and it has to be very cost effective. So you can't just walk in with this big giant thing and say "here it is, it does a better job," and expect them to say, "Okay, great." You've got a long way to go to where the technology becomes viable for application

> to building millions of automobiles a year. It's a leap of faith that's tremendous. Stanley could make the leap of faith, but I never did. I always said,
>
> " Boy, that's so far away that you've still got to find a way to make a business out of this. You have to find markets where you can sell the technology that you have today. Where are we going to sell it? How are we going to price it and who is going to buy it?" We really didn't know. This is when luck has to play a role.

From Automotive Engines to Natural Gas Compressors

In spite of confidentiality agreements with the Southwest Research Institute, word of the PlasMachine ignition system leaked out, spread around and eventually found its way to somebody associated with the natural gas pipeline industry. In early 1991, several months after the week of testing, Stanley and Voit received a phone call from an executive at Centram Natural Gas, who was interested in learning more about the technology. The natural gas industry used large stationary engines to run compressors in order to maintain a constant pressure to transport the gas through the transmission lines. The threat of more stringent environmental regulations that would lower the level of permissible emissions from the engines was forcing the natural gas companies to investigate pollution control and prevention alternatives. It offered a potential market for the ignition system that Voit was wholly unaware of:

> I had no idea what the guy was talking about. I had no idea what a stationary engine was, had never seen a natural gas transmission map and had never even thought about how natural gas gets into a house. I had no idea but I said, "Sure, no problem, let's talk."

The Centram executive flew to Boston and drove with Voit and Stanley to eastern New York state to visit one of the compressor stations. Voit wasn't prepared for what he saw: "the biggest engines in the world—gigantic".* The engines were so large because they needed to generate an tremendous amount of torque** to drive the compressors, and they operated at very low speeds—200 to 300 rotations per minute (RPM)—because they needed to be extremely reliable. The majority of gas pipeline compressor engines still working were built in the 1940s and 1950s, though some dated from the 1920s. The engines were based on old German-designed diesel ship engines, and, when properly maintained, were capable of running virtually forever. Voit described the simple engines as "like looking under the hood of a 57 Chevy; there's nothing to them." The problem with the engines was their tendency to misfire almost 25 percent of the time, due to the difficulty in getting the spark from the spark plug to ignite the mixture in a 20-inch diameter cylinder. Every misfire sent another cylinder-full of unexploded fuel into the atmosphere, and the typical engine emitted more than 200 tons of nitogen oxide per year, at the rate of 15 grams per brake horse power.

Compressor stations built after the early 1960s used smaller, more efficient turbine engines that didn't pose the same environmental problems. Because the cost of replacing the older models with the turbine type was so great, however, the gas companies were looking for ways to modify the old engines to achieve the emissions reductions that were likely to be

---

* A typical engine was the size of a two-car garage.

** Torque is the tendency of a force to produce rotation around an axis.

mandated in the implementation of the Clean Air Act.*** Prior to the development of the PlasMachines ignition system, the primary alternative available to gas companies was a major rebuild of the engines, including new cylinders, new cylinder liners, new connecting rods, turbo chargers, and manifolds. The modification would create a smaller pre-ignition chamber in which a rich fuel mixture would be ignited by the spark plug, and this explosion would ignite a leaner fuel mixture in the main combustion chamber. Fewer misfires and lower combustion temperatures would reduce nitrogen oxide emissions. Centram had a proposal from the engine manufacturer to rebuild and modify 65 engines at a cost of $1.2 million each.

Given the simplicity of the forty-year-old engine, Voit considered the ease of hooking up a PlasMachine ignition system to be a "slam dunk." For $40,000 upfront, Voit and Stanley agreed to build a prototype system for Centram. They took their one circuit board that had been tested at the Southwestern Institute and found an engineering firm in Waltham, Massachusetts, to make six copies (one for each cylinder of the engine) for $27,000. Within three months the system was ready for testing, which Voit performed on a home-made engine simulator—a piece of metal with six evenly spaced magnets that spun around to simulate the timing mechanism for the six spark plugs. In mid-1991, they installed the prototype on a Centram engine and ran it continuously for 2,500 hours without mishap. Simply by eliminating the misfires the system reduced nitrogen oxide emissions by 67 percent.

At that point in early 1992, Voit and Stanley realized they had found the niche market where their technology was currently applicable and cost effective. Although the market wasn't growing, it had many favorable characteristics. There were a known quantity of engines, (approximately 10,000 in the United States and an equal number worldwide), relatively few variations in engine type and only a handful of potential customers, all of whom had the same regulatory mandate. Price wasn't an issue because the only alternative was so much more expensive. The technology didn't require miniaturization, as would have been necessary for the automotive market. The challenges involved the introduction of new technology into a staid industry and the development of credibility for a small start-up among large corporations. The walls of Voit's office started to fill up with natural gas transmissions maps of the United States, showing 600,000 miles of pipelines.

Looking for a customer closer to home, Voit and Stanley approached Dunbar Natural Gas in late 1992. Dunbar had 13 engines in New England, which they had budgeted $16.7 million to overhaul. They were eager to explore less costly alternatives. Pulling a figure out of thin air, Voit proposed installing the PlasMachines ignition systems for $150,000 per engine, and after several months of negotiation, they eventually secured a $100,000 payment up front to test the system on an engine in Rhode Island. Voit spent most of the summer of 1993 working around the clock, commuting between the Natick office, where he spent days, and the Rhode Island plant, where he and four engineers from Dunbar performed the testing at night. To produce as lean a mixture as possible, they modified the air intake, rented eighteen 500 horsepower compressors and plumbed them all together to blow air into the huge engine. The results were

*** The target levels were dependent upon the geographic location of the compressor station but were likely to be in the range of less than 1 gram per brake horse power.

positive: they were able to reduce nitrogen oxide to a level 60 percent lower than the state requirements and equal to California code, the lowest in the country. After two months of testing, Voit had completed a comprehensive map of the engine's operations, emissions levels, fuel efficiency, and costs, creating documentation that Dunbar could use to negotiate optimal targets and timetables with state regulators.

From Regional to National Markets

Dunbar showed the test results to its parent company, Hallet Western, which was intrigued by the technology and decided to assume control of the project. Voit and Stanley flew down to Houston to discuss a contract and soon discovered the inbred nature of the natural gas industry and "how business is done in Houston":

> The culture is very conservative. It's an old-boy network like I've never encountered in my life. It's based in Houston; it's bred in Houston. You've got to be cut from Texas A&M in order to survive. I've gotten down to too many meetings where I've been pegged as a Yankee from Boston who supports Ted Kennedy. It is unreal. It's relentless. Bring your cowboy boots. You can go in and give them the best pitch in the world on why fundamentally and economically it makes sense, and they may turn around and give the business to their friend that they have been doing business with for 20 on a handshake deal because that's the way it's done.

Voit proposed to run tests with the ignition system on each of the four types of engines that Hallet used for a total price of $400,000. The Houston executives responded with the suggestion that the $400,000 be coupled with a firm price on future product to be installed after the testing was completed. Voit realized that dealing with these senior people was very different than what he was used to, "We didn't know what it would cost us. I had no clue. We didn't have a product."

At that point, PlasMachines had five employees, only two of whom were being paid cash. In addition to Voit, who was involved both in technology development and efforts to raise capital, George Arnos headed up the sales effort, and Ray Caldwell, whom Stanley had brought in from the automotive industry, was president. Both received most of their compensation in the form of stock options. Two salaried engineers were also employed full-time. Stanley's own involvement had become significantly limited by 1993, due to declining health.

Industry Deregulation

Until 1993, evolving state regulations had been the principal driver behind gas companies' interest in the PlasMachines ignition systems, which enabled the companies to meet increasingly stringent emissions standards. Other benefits of the device, such as increased fuel efficiency and reduced maintenance were largely irrelevant to the gas companies. As participants in a regulated utility, they simply passed along incremental costs to consumers in a rate increase. Whether the engine fuel cost $100,000 or $125,000 annually didn't matter to their financial bottom line. This situation changed in 1993 when the natural gas industry was deregulated the Federal Energy Regulatory Commission (FERC) in a document entitled FERC Order 636. Instead of owning the gas they shipped, pipeline companies became solely transportation companies, and they were suddenly forced into a competitive environment where controlling costs became very important.

Having customers who had spent a long period as a regulated industry and then suddenly transitioned to deregulation had several significant implications for PlasMachines, which in 1993 changed its name to ENOX Technologies. The primary driver—emissions reduction—took a back seat to the efficiency benefits. While the environmental advantages remained important, ultimately they were a less compelling justification for many companies than saving money. Most businesses waited until the last moment before complying with a regulatory mandate, and as the pendulum of environmental compliance seemed to start a reverse swing in the mid-1990s with the arrival of the GOP-controlled Congress, the threat of tougher emissions levels lost its edge. According to Voit: "Our customers that were lining up (for emissions reduction reasons) now had sort of slacked off." Soon after deregulation, ENOX started to sell their technology on the basis of economic value:

> We were quantifying the savings and selling on cost savings in fuel and the decreased amount of hours that people needed to spend. The interval between servicing the engines had increased. The availability of the engine, the number of hours it was available on a given month or in given operating season had dramatically improved. All of those had a dollar cost associated with them.

One of the challenges, however, in calculating and illustrating the economic gains was the lack of accurate cost information on which to base the savings. As part of a regulated utility, the gas companies had no incentives to manage costs and thus no need to capture or understand them on a level that would be useful for evaluating operations. While a company might know the total fuel cost for all transmission plants in the country, it typically had no ability to track the costs of operating a specific engine at a particular pumping station. Part of ENOX's job became educating their customers about the need to understand their costs in order to realize how significant the potential savings could be if the engines were made to operate more efficiently.

The long period of regulation followed by sudden deregulation had another profound implication for ENOX and its ability to respond to the needs of the market. Because regulation stifled innovation and technological sophistication, ENOX encountered only minor competition from the gas companies internally to enhance engine efficiency and automate. As one example, Voit explained:

> Their idea of automation is to install an alarm to signal low oil pressure instead of a red blinking light. There's no examination of why the oil pressure is low, or why the engine's misfiring or why the fuel rate went down or why the emissions are higher. For us it's pretty much virgin territory.

With deregulation, however, came the need to cut costs, and many companies, who didn't understand their operating costs, cut where it was easiest, operations and maintenance personnel. The combination of lack of internal technical sophistication and loss of experienced mechanics provided ENOX with a two-pronged advantages. After several years of intimate work enhancing the efficiency of different types of engines, ignition systems, and fuel mixtures, ENOX had more expertise with these systems than anyone else in the country.

Relationship with Burton Engine Company

Throughout the period of developing its expertise with natural gas transmission engines, ENOX continued its work with Burton Engine on the electric plasma device for reducing nitrogen oxides in exhaust emissions. In 1993, Stanley Rich received a patent on various components of the after-treatment technology. Concerns about the relationship with Burton and the value of continuing the research mounted in proportion to the growing promise of the gas pipeline market. The personalities of the people involved and the different cultures of the organizations inhibited their ability to collaborate effectively. Stanley was particularly outspoken and tended to grate against the more reserved, corporate types who inhabited the Burton bureaucracy. The absence of personal affinity between the parties was exacerbated by the conditions Burton attached to their contracts. As ENOX started to generate more cash flow without strings from several different customers, the Burton deals looked increasingly less attractive. Moreover the technology remained a long way from being applicable. By Voit's calculations, it would have taken an order of magnitude improvement in efficiency for the device to be cost effective, because many of the components of the automotive electrical system—alternator, battery, wires—would have needed to be upgraded to generate the electrical charge to create the plasma. That increase would have required a substantial investment.

Nevertheless there continued to be significant interest in the technology due to the size of the potential market, and there promised to be continued research funding available. Voit debated the issue:

> It was R&D. It was paying some overhead, and there was a large potential market down the road. But it was also really taking away a lot of the focus in the company.

Preparation Question

1. Outline a five-year strategic plan for ENOX. Your plan must consider the resources that would be needed to implement your plan. How could ENOX obtain these resources?