Corning Glass Works: The Z-Glass Project

After several highly successful years, 1977 had been difficult at Corning Glass Work's Harrisburg plant. In July 1977, the yields and productivity of the Z-Glass process began a long decline, and the entire plant organization was working overtime trying to correct the problem. Morale plummeted as yields continued to decline throughout the summer and fall. In December 1977, a team of engineers from the corporate manufacturing and engineering (M&E) staff were assigned to the plant; the group's charter was to focus on long-term process improvement while the line organization concentrated on day-to-day operations.

On the morning of March 24, 1978, Eric Davidson, leader of the M&E project team at Harrisburg, sat in his office and reflected on the group's first three months at the plant. The project had not gone well, and Davidson knew that his team members were discouraged. The technical problems they faced were difficult enough, but apparently the line organization had resisted almost everything the M&E team had attempted. In addition to conflicts over responsibility and authority, deep disagreements arose concerning the sources of the problems and how best to solve them. Cooperation was almost nonexistent, and tense relationships developed in some departments between team and line personnel. Davidson favored an immediate change in the project's direction.

Sifting through the comments and memos from his team, he recalled David Leibson, vice president of manufacturing and engineering, saying to him shortly after he accepted the Harrisburg assignment: "Eric, this is the M&E group's first major turnaround project, and the first real project of any kind in the Industrial Products Division. I picked you for this job, because you're the kind of guy who gets things done. This is a key one for our group and I think a big one for the company. In situations like this, either you win big, or you lose big. There's very little middle ground."

Corning Glass Works in the 1970s

During the late 1960s and early 1970s, Corning Glass Works was a corporation in transition. Long a leader in the development of glass and ceramic products for industrial and commercial uses, Corning had entered several consumer goods markets during the 1960s. Under the direction of Lee Waterman, president from 1962 to 1971, Corning developed a strong marketing, emphasis to accompany several new consumer products.

Although the public's perception of Corning in the 1960s was no doubt dominated by its well-known Pyrex and Ovenware cooking products and Pyroceram dinnerware, its most successful consumer product was actually TV tube casings. Utilizing an innovative glass-forming process, Corning entered the market for TV tube funnels and front plates in 1958 and so attained a strong

This case was prepared as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

market position. Throughout the mid- to late 1960s, growth in TV at Corning was rapid, and the profits at the TV Division constituted the backbone of the income statement.

During the heyday of TV, Corning's organization was decentralized. The operating divisions had considerable control over marketing and manufacturing decisions, and corporate staffs in these areas were relatively small. Only in research and development did corporate staff personnel influence the company's direction. The Technical Staffs Division was responsible for all research and development activities, well as for manufacturing engineering. New products were regarded as the lifeblood of the corporation, and the director of new product development, Harvey Blackburn, had built a creative and energetic staff. This staff developed the glass-forming process that made TV tube production possible, and the corporation looked to this group when growth in the TV Division and other consumer products began slow in the late 1960s.

Changes in TV and Corporate Reorganization

The critical year for the TV Division was 1968. Until then, sales and profits had grown rapidly and Corning had carved out a substantial share of the market. In 1968, however, RCA (a major Corning customer) opened a plant in Ohio to produce glass funnels and front plates. Several of the engineering and management personnel at the new RCA plant were former Corning employees. RCA's decision to integrate backward into glass production had a noticeable effect on the performance of Corning's TV Division. Although the business remained profitable, growth over the next three years slowed, and Corning's market share declined.

Slower growth in TV in the 1969-1972 period coincided with reduced profitability in other consumer products as costs for labor and basic materials escalated sharply. These developments resulted in weaker corporate financial performance and prompted a reevaluation of the company's basic direction.

These deliberations created a reemphasis of the technical competence of the company in new product development and a focus on process excellence and productivity. A major step in the new approach to operations and production was the establishment of M&E at the corporate level. This reorganization brought together staff specialists in processes, systems, and equipment under the direction of Leibson, who was promoted from director of manufacturing at the TV Division to a corporate vice president.

Shortly after the M&E Division was formed, Thomas MacAvoy, the general manager of the Electronics Division and the former director of Physical Research on Corning's technical staff, was named president of the company. MacAvoy was the first Corning president in recent times with a technical background; he had a Ph.D. in chemistry and a strong record in research and development. An internal staff memorandum summed up the issues facing Corning under MacAvoy:

> Our analysis of productivity growth at Corning from 1960-1970 shows that we performed no better than the average for other glass products manufacturers (2%-4% per year) and in the last two years have actually been below average. With prices on the increase, improved productivity growth is imperative. At the same time, we have to improve our ability to exploit new products. It appears that research output has, if anything, increased in the last few years (Z-Glass is a prime example), but we have to do a much better job of transferring products from the lab into production.

Manufacturing and Engineering Division

Much of the responsibility for improved productivity and the transfer of technology (either product or process) from research to production fell to the new and untried M&E Division. Because of the company's historical preference a small, relatively inactive manufacturing staff, building the

M&E group into a strong and effective organization was a considerable challenge. Remembering the early days, Leibson reflected on his approach:

> I tried to do two things in the first year: (1) attract people with very strong technical skills in the basic processes and disciplines in use at Corning; and (2) establish a working relationship with the manufacturing people in the operating divisions. I think the thing that made the difference in that first year was the solid support we got from Tom MacAvoy. It was made clear to all of the division general managers that productivity growth and cost reduction were top priorities.

From 1972 to 1977, engineers from the M&E Division participated in numerous projects throughout Corning involving the installation of new equipment and process changes. A typical project might require four or five M&E engineers to work with a plant organization to install an innovative conveyor system, possibly designed by the M&E Division. The installation project might last three to four months, and the M&E team would normally serve as consultants thereafter.

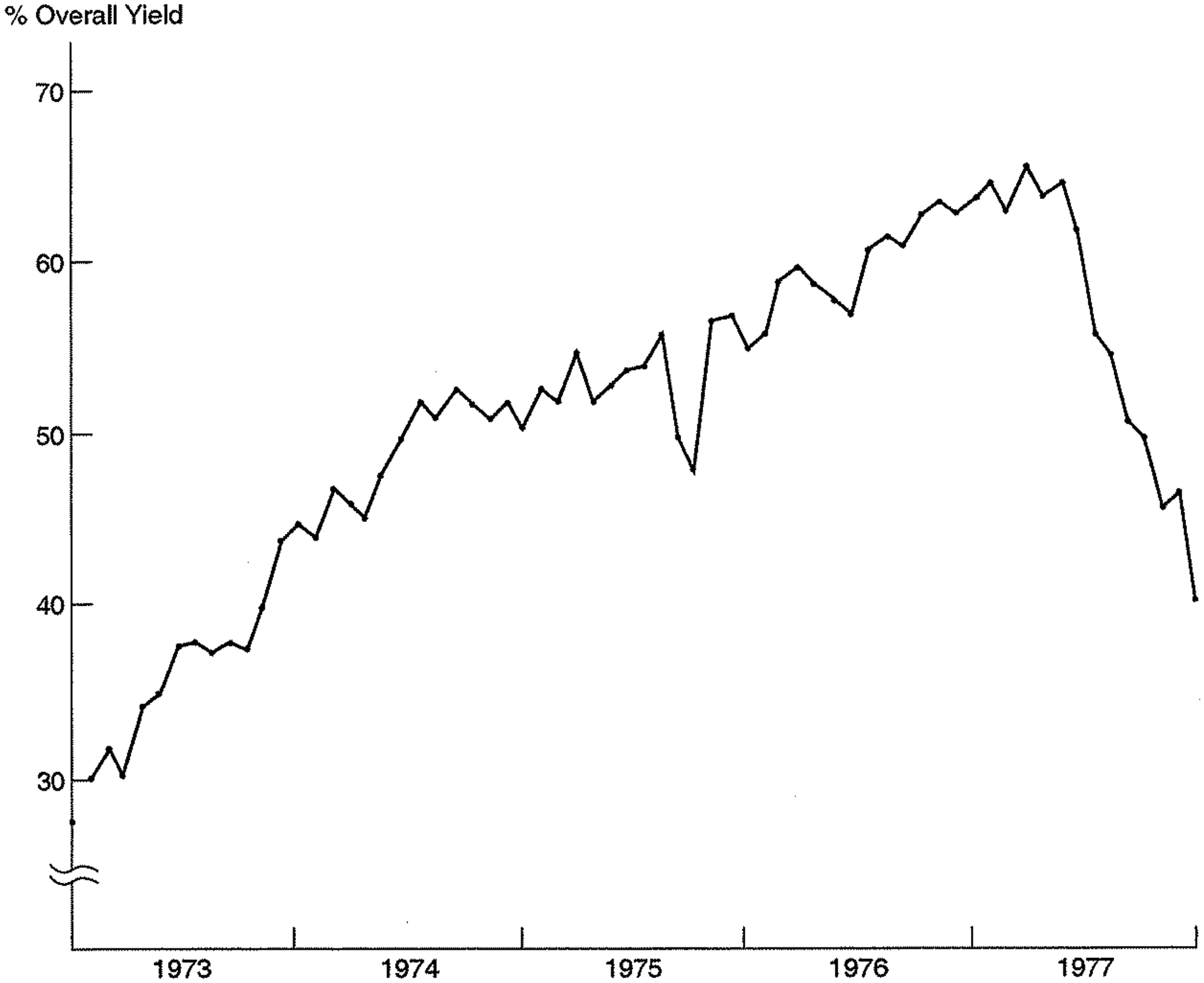
In addition to equipment projects and internal consulting, the M&E group participated in the transfer of products from R&D to production. After laboratory development and prototype testing, new products were assigned to an M&E product team that designed any new equipment required, and engineered and implemented the new process. Leibson believed that successful transfer required people who appreciated both the development process and problems of production. In many respects, M&E product teams served as mediators and translators; especially in the first few projects, their primary task was to establish credibility with the R&D group and with the manufacturing people in the operating divisions.

By 1976, M&E had conducted projects and helped to transfer new products in most of Corning's divisions, although its role in Industrial Products remained limited. The manufacturing organization in that division had been relatively strong and independent, but Leibson felt that the reputation and expertise of his staff was increasing and that opportunities for collaboration were not far off. He also felt that M&E was ready to take on a completely new responsibility—a turnaround project. Occasionally parts of a production process, even whole plants, would experience a deterioration in performance, sometimes lasting for several months, with serious competitive consequences. Leibson maintained that a concentrated application of engineering expertise could significantly shorten the turnaround time and could have a measurable impact on overall corporate productivity.

The Z-Glass Project

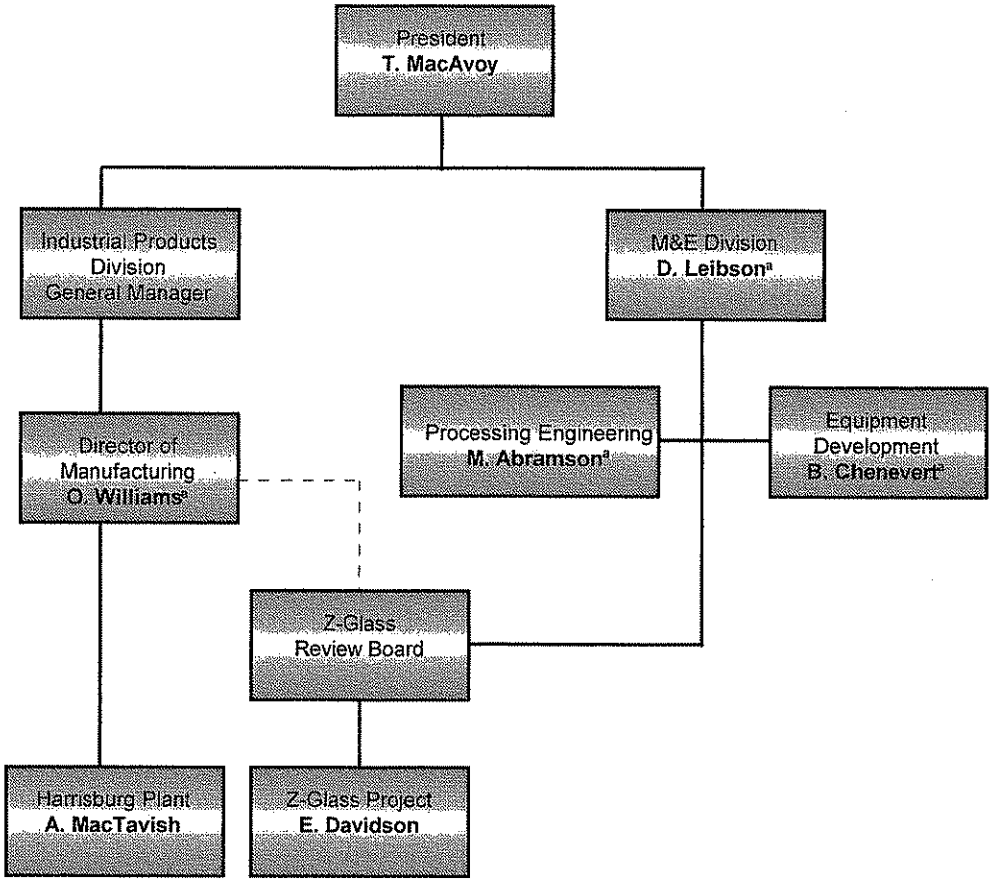
The opportunity for M&E involvement in a major turnaround effort and for collaboration with the Industrial Products Division came in late 1977. Since June of that year, yields on the Z-Glass process at the division's Harrisburg plant had declined sharply (see **Figure A**). Substantial effort by the plant organization failed to change the downward plunge in yields, and in October, Oliver Williams, director of manufacturing for Industrial Products, met with Leibson to establish an M&E project at Harrisburg.

Figure A Overall Yield, 1973-1977



Williams, a chemical engineer with an MBA from New York University, had been named director of manufacturing in November 1976, after 18 years in various engineering and operations positions at Corning. He felt that the product's importance (corporate expectations for Z-Glass were great) coupled with the seriousness of the problem warranted strong measures. Williams and Leibson agreed that an M&E project team would work in the plant under the general supervision of a review board composed of Leibson, Williams, Martin Abramson, head of process engineering in the M&E Division, and Bill Chenevert, head of M&E's equipment development group (see **Figure B** for an organization chart). The team's charter was to increase yields, define and document the process, and train the operating people (see **Exhibit 1**). A budget, the team's size, specific goals, and a timetable were to be developed in the first month of the team's operation.

Figure B Organization Chart



a. Members of review board.

Although the plant manager and his staff had not participated in the decision to bring in the M&E team, Williams and Leibson agreed that their involvement and support were essential. A decision was made to allocate all M&E charges to the Industrial Products Division to relieve the plant of the extra overhead. Moreover, M&E specialists assigned to the project would be at the plant full time.

Since this was M&E's first turnaround project, Leibson personally selected the team leader and key project engineers. He easily found people willing to work on the project. Everyone in the M&E group realized that turnarounds were the next major activity for the group and that those working on the first team would be breaking new ground. Leibson chose Eric Davidson to lead the Harrisburg project. He was 32 years old with a master's degree in mechanical engineering from Cornell and six years of experience at Corning. Davidson had completed several projects in the M&E Division, including one in France, and had also worked as an assistant plant manager. A close friend and colleague commented on Davidson's reputation: "To say that Eric is on the fast track is a bit of an understatement. He has been give one challenging assignment after another and has been very successful. The word around M&E is that if you have a tough problem you want solved, just give it to Eric and get out of the way."

Working under Leibson's direction, Davidson spent the first two weeks meeting with the plant management and selecting members of the M&E team. At the outset, he chose four specialists to work on the first phase of the project data—collection and problem definition:

Richard Grebwell 35 years old, an expert in statistical process analysis with 10 years at Corning. Although Grebwell was considered a bit eccentric by some, his characteristically brilliant use of statistical analysis was vital to the project.

Jennifer Rigby 28 years old, with a master's degree in industrial engineering from the University of Texas. She had worked in the Harrisburg plant for six months on her first assignment at Corning.

Arthur Hopkins 40 years old, a mechanical engineer with 12 years at Corning. Hopkins had worked with Davidson on the French project and was, in Davidson's words, "a wizard with equipment."

Frank Arnoldus 37 years old, a chemist with Corning for six years. He also had worked or the French project and had earned Davidson's admiration for his ability to solve processing problems.

For the first two or three weeks, Davidson planned to use the small group to identify problems and then expand the team as specific tasks and subprojects were established. Focusing his objectives on the long term, he explained:

> I'm after increases in yields as soon as we can get them, but what I'm really shooting for is permanent improvements in the process. To do that we've got to define the process and document its operation. My whole approach is based on the idea of *receivership*: whatever solutions we come up with have to be received, or accepted, by the plant organization. And I mean really accepted; they have to *own* the changes. That's why I will be taking a team approach—each project we do will have two co-leaders, one from M&E (the transferer) and one from the plant (the receiver).
>
> After a brief period to get acquainted and develop a plan, Davidson and his M&E team began working in the plant on December 10, 1977.

Z-Glass: Product and Process

Z-Glass was Corning's code name for a multilayered, compression-molded glass product that was exceptionally strong and impact-resistant for its weight. Its durability and hardness, combined with its low weight and competitive cost, made it an attractive substitute for ceramic and plastic products used in the construction and auto industries. Introduced in 1973, Z-Glass products were an immediate success. From 1973 to 1977, production capacity grew 35% to 40% annually yet failed to meet demand (see **Exhibit 2**). Many people thought that the array of products was only the beginning of Z-Glass applications.

To Corning's knowledge, no other company in the world had yet developed the capability to make a product like Z-Glass, and if one did, presumably it would have to license the technology from Corning. In fact, much of this technology was still an art form because numerous characteristics of most Z-Glass products were not completely explainable in known glass technology: people knew what it could do and roughly why it could do it, but were still using trial-and-error methods to perfect existing products and develop new ones.

Blackburn and his staff developed Z-Glass during the early 1970s. The product was literally Blackburn's baby. He not only conceived the idea but, typical of the way Corning operated before the M&E Division was created, he and his staff solved numerous technical problems, built all the machinery and equipment needed for prototype production, and even worked in the plant during start-up. Furthermore, Blackburn had championed the product in discussions with top management. Several times when the project faltered, his reputation and skills of persuasion obtained the necessary funding. When yields began to fall in 1977, engineers at Harrisburg had consulted Blackburn when necessary; he still felt responsible for the product and knew intimately its nuances and subtleties.

The Process

Making Z-Glass products consisted of three main steps: melting, molding, and finishing which were linked and had to be carried out a fixed time sequence. The process required precise control over the composition and thicknesses of the various glass layers, as well careful timing and monitoring during the molding and finishing operations. Maintaining precision in a high-volume environment required continuous, tight controls as well as a feel for the process.

Melting The first step was the preparation of the different types of molten glass that constituted the various layers. These mixtures were prepared in separate electrically heated vats, designed and built by Corning. Each vat was carefully monitored to ensure that the ingredients of the glass were in correct proportion, evenly distributed throughout the vat, and at the appropriate temperature.

The base layer was poured continuously onto a narrow (two to three feet) moving strip. The other layers were poured on top of each other at precisely controlled intervals so that when the layered strip arrived at the molding stage, each layer of the multilayered glass sandwich was at the proper temperature and thickness for molding. Minor (and, at the beginning of process development, almost unmeasurable) deviations from the recipe could lead to major problems, often requiring ad hoc solutions using the unprogrammable skill of the operators and technicians.

Some problems were clearly identifiable with the melting operation. For example, the existence of *blisters* (tiny bubbles in one or more of the glass layers), *stones* (unmelted bits of sand), and *streaks* (imperfectly melted or mixed ingredients) were visible and obvious indicators of problems. Separation of the different layers, either after the molding or after the finishing operations, often could also be traced to improper execution during melting. But when the glass sandwich did not mold properly, there was usually some question as to which operation was at fault.

A process engineer explained the difficulty of melting control:

> The secret to avoiding problems at the melting state is maintaining its stability. Sometimes it's easy to tell when something has gone wrong there, but more often you don't find out until something goes wrong at a later stage. And usually it takes a long time to determine whether you've really solved the problem or are simply treating a symptom of a larger problem. It's tough to keep on top of what is going on in each of those melting vats because it's largely a chemical operation.

Despite the difficulty of maintaining control over the melting operation and of correcting it when problems developed, Corning had been able to achieve yields as high as 95% at this stage of the process.

Molding In contrast to melting, molding was basically a physical operation: rectangles of the soft glass sandwich were cut off the moving strip and moved onto a series of separated conveyor belts. Each slab was inserted between the jaws of a compression-molding device that contained several molds for the particular parts being produced. After the parts were stamped out, they continued down the conveyor line while the glass trim was discarded. Depending on the product mix, several conveyors might pool their contents before the parts entered the finishing stage.

Despite the apparent simplicity of this process (problems could be detected quickly and usually corrected quickly), so many different problems arose and so many different variables could be manipulated that it was generally considered to be even more difficult to control this stage than the melting stage. Typical problems included the basic dimensional specifications of the product, its edge configuration, and buckling and flattening after molding. These problems, together with machine downtime associated both with correcting problems and changing the product mix, made it difficult to achieve more than 80% efficiency (good output to rated machine capacity) during this stage.

Finishing The finishing operation consisted heat treating the molded objects, then applying one of several possible coatings. Heat treating stabilized the internal tensions generated by the molding operation and appeared to improve the lamination between the various layers of the glass sandwich. Since it required a precise sequence of temperatures and their duration, this operation occurred as the objects passed on conveyor belts through long ovens. Cracks or lay separation occurred infrequently, sometimes caused by the heat-treating operation.

The application of coatings, however, was more of a job-shop operation and could be done off-line. There were numerous coatings that could be applied, from the practical (improving the reflective, insulating, or electrical conducting properties of the surface) to the ornamental. Sometimes, decals were also applied, either in place of or in addition to a coating. The selection of coatings was steadily increasing, and one process engineer characterized the operation as "a continual bother: lots of new processes and equipment, lots of short runs but a necessity to maintain high speeds." The seldom-attained target yield was 95%.

The unique characteristics of the three stages made overall control and fine-tuning of the total process quite difficult. The backgrounds and skills of the hot-end workers varied considerably from those at the cold end, and involved entirely separate branches of engineering. When problems arose, many went undetected for some time, and often appeared only during destructive testing of parts after they had completed the process. Then it was often difficult to isolate which part of the process was at fault, because there appeared to be a high degree interrelation among them. And, finally, once a problem and its cause were identified, it sometimes took a long period of trial-and-error fiddling until people could be convinced that it was indeed corrected.

The Harrisburg Plant

The decision to put Z-Glass into the Harrisburg plant had been based on its availability. Built in 1958 and long devoted to the production of headlights and other auto products, the plant had operated at excess capacity for several years in the late 1960s. In 1972, headlight production was consolidated in the Farwell, Ohio, plant while Harrisburg was set up for Z-Glass production. Several of the production foremen and manufacturing staff members were transferred to Farwell and replaced by individuals who had been involved in Z-Glass prototype production. (**Table A** contains a profit and loss statement for the Harrisburg plant in 1975 and 1976.)

Table A Harrisburg Plant—Profit and Loss Statement, 1976-1977 ($ thousands)

	1976	1977
Sales[a]	$26,653.3	$40,565.0
Direct expenses		
Materials	9,947.2	16,214.2
Labor	3,714.3	6,194.7
Gross profit	12,991.8	18,156.1
Manufacturing overhead		
Fixed[b]	6,582.6	11,106.9
Variable[c]	1,429.3	2,114.4
Plant administrative expenses	1,784.5	2,715.2
Plant profit	3,195.4	2,219.6

[a]Capacity utilization (on a normal sales basis) was 92% in 1976 and 84% in 1977.
[b]Includes depreciation, insurance, taxes, maintenance, utilities, and supervision.
[c]Includes fringe benefits, indirect labor, tools, and supplies.

The Harrisburg plant manager was Andrew MacTavish, a 54-year-old Scotsman. He came to the United States shortly after World War II and began working at Corning as a helper on a shipping crew at the old main plant. Over the years, MacTavish had worked his way up through various supervisory positions to production superintendent and finally to plant manager. He was a large man with a ruddy complexion and a booming voice. Although his temper was notorious, most people who had worked with him felt that some of his tirades were more than a little calculated. Whatever people's perceptions of his personality might be, there was no question who was in charge at Harrisburg.

In mid-1977, MacTavish had been at Harrisburg for six years. From the beginning he had developed a reputation as a champion of little people, as he called them. He wore what the workers wore, and spent two to three hours each day on the factory floor talking with foremen, supervisors, and production workers. If he had a philosophy of plant operations, it was to keep management as close to the people as possible and to rely on the experience, judgment, and skill of his workers in solving problems.

The Harrisburg plant was organized along department lines, with a production superintendent responsible for three general foremen who managed the melting, forming, and finishing departments. Ron Lewis, production superintendent, had come to the plant in 1975 after eight years at Corning. He was quietly efficient and had a good rapport with the foremen and supervisors. Besides Lewis, three other managers reported to MacTavish: Al Midgely, director of maintenance and engineering, Arnie Haggstrom, director of production planning and inventory control, and Royce Ferguson, head of personnel.

By June 1977, the management group at Harrisburg plant had worked together for two years and had established what MacTavish thought was a solid organization. He commented to a visitor in May 1977:

> I've seen a lot of plant organizations in my time, but this one has worked better than any of them. When we sit down in staff meetings every morning, everyone is on top of their situation, and we've learned to get to the heart of our problems quickly. With the different personalities around here, you'd think it would be a dog fight, but these people really work together.

Of all the managers on his staff, MacTavish worked most closely with Midgely. Midgely, 46 years old, came to the plant with MacTavish, had a B.S. in mechanical engineering, and was regarded as a genius when it came to equipment. "He can build or fix anything," MacTavish claimed. Midgely was devoted to MacTavish: "Ten years ago, Andy MacTavish saved my life. I had some family problems after I lost my job at Bausch and Lomb, but Andy gave me a chance and helped me pick up the pieces. Everything I have I owe to him." Several people in the Harrisburg plant gratefully acknowledged MacTavish's willingness to help his people.

M&E Project at Harrisburg

Davidson's top priority in the first two weeks of the project was to define the problem. Overall yields had declined, but no one had analyzed available information to identify the major causes. The M&E group believed that the plant organization had spent its time on fire fighting during the past six months, with little overall direction. Grebwell analyzed the historical data collected by the production control department. Other team members spent this time familiarizing themselves with the process, meeting with their counterparts in the plant organization, and meeting together to compare notes and develop hypotheses about what was going on.

One problem surfaced immediately: the relative inexperience of the department supervisors. As MacTavish explained to them, four of the six supervisors had been in the plant less than nine months. The people they replaced had been with the Z-Glass process since its prototype days. MacTavish felt that part of the explanation for the decline in yields was the departure of experts. He expressed confidence in the new people and indicated that they were rapidly becoming quite knowledgeable.

Grebwell's preliminary statistical work (see **Exhibit 3**) pointed to the molding department as the primary source of defects, with melting the second major source. The team identified four areas for immediate attention: overall downtime, trim settings, glass adhesion, and layer separation. As Grebwell's work proceeded, other projects in other departments were identified, and staff members were added to the team. By mid-January, it was evident that the overall project would have to encompass activities throughout the plant. It was decided that the only way to measure performance equitably was to use overall yield improvement. A timetable for improved yields was established and approved by the review board in late January 1978.

Davidson commented on the first six weeks of the project:

> Our initial reception in the plant was lukewarm. People were a little wary of us at first, but we did establish a pretty good relationship with Ron Lewis and some of the people in the production control group. I was confident that, with time, we could work together with MacTavish and people in other departments, but I wasn't as confident that the problems themselves could be solved. My objective was to obtain long-term improvements by defining and documenting the process, but when I arrived I found an inadequate data base and a process more complex than anyone had imagined.

Davidson encountered resistance to the very idea of process documentation. The view of MacTavish and others in the plant was aptly summarized by Blackburn, who appeared in Harrisburg off and on throughout the first three months of the M&E project. On one such visit, he took Davidson into a conference room to converse:

> **Blackburn** [after drawing on the blackboard]: Do you know what this is? This is a corral and inside the corral is a bucking bronco. Now what do you suppose this is?
>
> **Davidson** It looks like a cowboy with a book in his hand.
>
> **Blackburn** That's right, sonny, it's a green-horn cowboy trying to learn how to ride a bucking bronco by reading a book. And that's just what you are trying to do with a

> your talk about documentation. And you'll end right where that greenhorn is going to end up—flat on your face.

Conflict Emerges

Following the review board's acceptance of the proposed timetable, Davidson intended to create subproject teams, with an M&E specialist and a plant representative as co-leaders. Despite Blackburn's lecture, Davidson pressed ahead with plans for process definition and documentation. A key element of the program was the development of instrumentation to collect information on the critical operating variables (glass temperature, machine speeds, timing and so forth). Beginning in early January, Arnoldus had spent three weeks quietly observing the process, asking questions of the operators, and working on the development of instruments. He had decided to debug and confirm the systems on one production line (there we five separate lines in the plant) before transferring the instruments to other lines.

The instrumentation project was scheduled to begin on February 1, with the installation of sensors to monitor glass temperature in the molding process. No plant representative for the project had been designated by that time, however, and Davidson postponed the installation. A series of meetings between Davidson and MacTavish followed, but not until two days before the next review board meeting, on February 23, were plant representatives for each subproject chosen. Even then, things did not go smoothly. Arnoldus described his experience:

> I didn't want to impose the instrumentation program on the people; I wanted them to understand that it was a tool to help them do their jobs better. But I had a terrible time getting Hank Gordel (the co-leader of the project team) to even talk to me. He claimed he was swamped with other things. The thing of it is, he *was* busy. The plant engineering group had several projects of their own going, and those people were working 15 hours a day. But I knew there was more to it than that when I started hearing people refer to the M&E team as *spies*. After a while, people stopped talking to me and even avoided me in elevators and the cafeteria.

The other subprojects suffered a similar fate. The only team to make any progress was the group working on materials control. Ron Lewis thought the program was a good one and supported it; he had appointed one of his better supervisors to be co-leader. In the other areas of the plant, however, little was accomplished. Attempts to deal informally (lunch, drinks after work) with people in the plant organization failed, and Davidson's meetings with MacTavish and his requests for support were fruitless. Indeed, MacTavish viewed the M&E team as part of the problem. He forcefully expressed himself in a meeting with Davidson in late March 1978:

> I've said right from the beginning that this yield problem is basically a people problem. My experienced production people were promoted out from under me, and it has taken a few months for the new people to get up to speed. But this kind of thing is not going to happen again. I've been working on a supervisor backup training program that will give me some bench strength.
>
> I'm not saying we don't have problems. I know there are problems with the process but the way to solve them is to get good people and give them some room. What this process needs now is some stability. Last year two new products were introduced, and this year I've got you and you engineers out there with your experiments and your projects, fiddling around with my equipment and bothering my people.
>
> And then there's Blackburn. He blows here with some crazy idea and goes right out there on the floor, and gets the operators to let him try out his latest scheme.

The best thing for this plant right now would be for all of you to just get out and let us get this place turned around.

I am convinced we can do it. In fact, we've already been doing it. You've seen the data for the last 12 weeks. Yields have been increasing steadily, and we're now above the average for last year. While you people have been making plans and writing memos, we've been solving the problem. [Data from the preliminary yield report are presented in **Figure C** and **Table B.**]

Figure C Yields and Downtime, 1976-1978

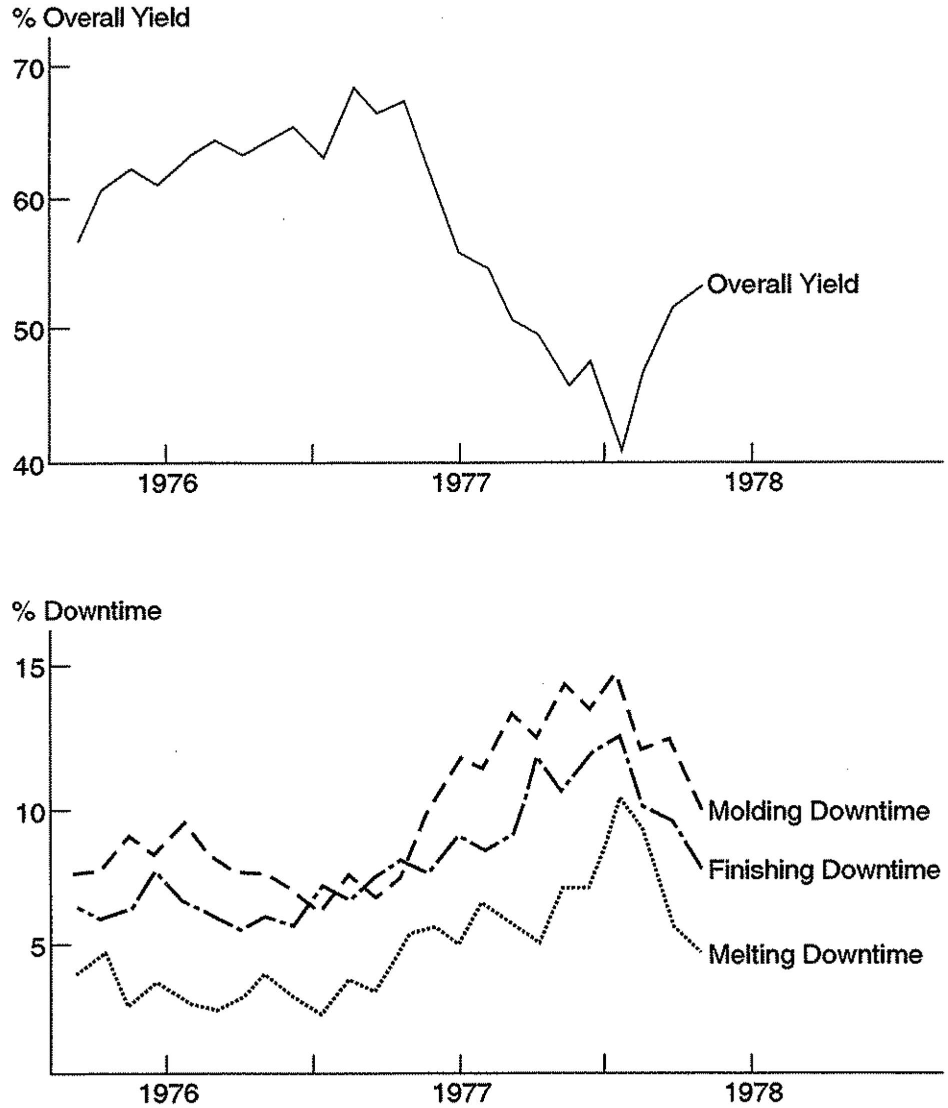


Table B Harrisburg Plant—Summary of Yields, Period 3, 1978

	Product Lines					
Department	**Z1**	**Z4**	**Z10**	**Z35**	**Z12**	**Total**
Melting	74.6	69.3	76.6	77.9	70.9	-
Molding	79.7	71.3	83.5	83.8	72.4	-
Finishing	85.8	83.7	88.7	87.6	84.9	-
Overall	51.0	41.4	56.7	57.2	43.6	53.4

Resolving the Crisis

Davidson sat at his desk in the Harrisburg plant on March 24, 1978, and reviewed the events of the last three months. He realized that he also had been guilty of excessive fire fighting, and had not taken the time to step back from the situation and plot out a course of action. The situation demanded careful thought.

He was genuinely puzzled by the recent improvement in yield performance; since the M&E team had done very little beyond data analysis, the improvement must have come from elsewhere. All his training and experience supported the concept of definition and documentation, but he had never encountered such complex process. Perhaps MacTavish was right, but he just couldn't bring himself to believe that.

Several options came to mind as he thought of ways to resolve the crisis; none of them were appealing. He could go to Leibson and Williams and ask, perhaps demand, that MacTavish be replaced with someone more supportive. He could continue to try to build alliances with supporters in the plant (there were a few such people) and get a foothold in the organization. Or he could develop a new approach to the problem (perhaps new people) and attempt to win over MacTavish. Davidson knew that his handling of this situation could have important consequences for the M&E Division, for the company, and for the careers of several people, his included.

Exhibit 1 Memorandum on Team Charter

To: Harrisburg Project Team
From: E. Davidson
Date: November 24, 1977
Re: Team Charter

The charter of the project team is yield improvement as top priority, definition and documentation of the process, and operator training. Enclosed is a copy of the proposed Process Definition and Documentation Program; it will serve as the framework for process diagnosis and control. Its main elements are as follows:

Priority	
1	Define best known *operating setpoint* for each major variable.
2	Establish auditing system to track variables daily with built-in feedback loop.
3	Develop and implement *process troubleshooting* guides.
4	Write and implement *Operating Procedures*
5	*Train* operating personnel in procedure usage.
6	*Audit* operating procedures on random frequency.
7	Write and implement *Machine Specification* Procedures.

Your comments on the program are encouraged.

Exhibit 2 Harrisburg Plant—Sales by Product Line, 1973-1978 (numbers in thousands)

	Z1		Z4[a]		Z10		Z35		Z12[b]		Total	
	Pieces	$	Pieces	$	Pieces	$	Pieces	$	Pieces	$	Pieces	$
1973	-	-	-	-	119	$2,220.1	495	$5,217.8	-	-	614	$7,437.9
1974	-	-	-	-	232	4,315.2	549	6,313.5	-	-	781	10,628.7
1975	384	$5,161.5	-	-	239	4,983.2	552	6,513.6	-	-	1,175	16,658.3
1976	784	11,514.2	45	$552.3	268	5,831.9	591	7,541.7	82	$1,213.2	1,770	26,653.3
1977	803	12,005.0	407	5,372.4	264	6,087.6	671	8,689.5	534	8,410.5	2,679	40,565.0
1978[c]	171	2,565.1	35	493.5	145	1,957.5	250	2,975.2	61	988.3	662	8,979.6

[a]Introduced in early 1975.

[b]Introduced in late 1976.

[c]Data for 1978 cover reporting periods 1-3 (i.e., first 12 weeks of 1978). Note that, because of seasonal factors, it is not possible to arrive at an accurate indication of annual output of a particular product by multiplying the 1978 (1-3) results by 13/3.

Exhibit 3 Grebwell's Memorandum of Preliminary Statistics

To: M&E Project Team
From: R. Grebwell
Re: Yield Report for December 1977

Below are data on yields in period 13 (provided by the production control department) along with notes based on preliminary observations. Rejects are based on 100% inspection. Note that selecting a reason for rejection is based on the concept of "principal cause"; if more than one defect is present, the inspector must designate one as the primary reason for rejection.

Harrisburg Plant—Yield Report Period 13, 1977

I. Melting	**Good Output as a % of Scheduled Capacity[a]**					
	Z1	**Z4**	**Z10**	**Z35**	**Z12**	**Downtime[b] as a % of Total Scheduled Time**
Glass	70.4	65.4	72.3	73.5	66.9	-
Equipment downtime	-	-	-	-	-	10.3

II. Molding and Finishing	**% Rejected by Product, Reason and Department[c]**					
	Z1	**Z4**	**Z10**	**Z35**	**Z12**	**Downtime[b] as a % of Total Scheduled Time**
A. Molding						
Trim[d]	6.4	12.8	4.1	3.4	10.2	-
Structural	3.7	6.2	1.7	2.8	5.7	-
Adhesion	4.5	8.3	2.5	3.1	8.5	-
Downtime	-	-	-	-	24.4	15.2
B. Finishing						
Cracks	0.8	4.2	0.3	1.2	3.6	
Separation	2.6	3.8	1.5	2.2	4.4	
Coatings	1.9	2.4	0.6	1.7	2.1	
Downtime						12.6

Exhibit 3 (continued)

III. Summary[e]	Good Output as a % of Scheduled Capacity					
	Z1	Z4	Z10	Z35	Z12	Total
Melting	70.4	65.4	72.3	73.5	66.9	-
Molding	72.4	61.6	77.8	76.9	64.1	-
Finishing	82.8	78.3	85.3	82.9	78.6	-
Overall	42.2	31.5	48.0	46.9	33.7	40.7

[a]This is overall yield and includes the effects of glass defects as well as downtime.

[b]No data are available on equipment downtime by product; the overall figure is applied to each product.

[c]The data are presented by department. They indicate the percentage of department output rejected and the principal reason for rejection. Total overall process yield (good output as a % of rated capacity) depends on both product defects and downtime.

[d]The reasons for rejection breakdown is as follows:

Molding

Trim: This is basically two things—dimensions and edge configuration. It looks to me like the biggest problem is with the edges. The most common cause of defects in the runs I have watched is that the settings drifts out of line. Apparently this depends on where the settings are established, how they are adjusted and the quality of the glass.

Structural: Pieces are rejected if they buckle or if the surface has indentations. This one is a real mystery—it could be a problem with the equipment (not right specs) or the operating procedures. Without some testing it's hard to tell. One possibility we need to check is whether the temperature of the incoming glass is a factor.

Adhesion: If compression ratios are too low or if the glass temperature is not "just right" or the glass has stones, then the glass adheres to the surface of the molds. The operators check the ratios, but the ideal range is marked on the gauges with little bits of tape, and I suspect the margin of error is pretty large.

Finishing

Cracks: Pieces sometimes develop cracks after heat treating. The principal suspect is consistency of temperature and flame zone. It is very hard to tell whether this is due to poor initial settings or changes in flames once the process starts. Inconsistencies in the material may be another source of cracks.

Layer Separation: Layer separation seems to be caused by same factors as cracks.

Coatings: This is almost entirely a problem of operator error—handling damage, poor settings on equipment, inattention to equipment going out of spec, and so forth.

[e]There are four steps to calculating overall yield:

1. For a given product in a given department, add up reject rates by reason and subtract from 1;
2. Then multiply by (1 - % downtime) to get department yield for that product (e.g., molding yield for Z12 = (1 -.244) (1 - .152) = .641);
3. Multiply department yields to get overall yield by product (e.g., yield for Z12 = .669 x .641 x .786 = .337);

To get overall yield, take a weighted average of product yields, with share in total output (on a total pieces basis) as weights; in period 13 these weights were Z1 = .3, Z4 = .15, Z10 = .10, Z35 = .25, and Z12 = .2.